# SYMPOSIUM PROCEEDINGS

# The Marriott Inn & Conference Center University of Maryland University College October 21-24, 2013

Mirko D'Andrea

**Brandon Frederick** 

Presented by



International Association of Wildland Fire

Wikimedia

Commons

**INTERNATIONAL** 

In conjunction with

National Wildfire Coordinating Group Smoke Committee & Joint Fire Science Program



## INTRODUCTION TO THE PROCEEDINGS OF THE INTERNATIONAL SMOKE SYMPOSIUM

The International Smoke Symposium was held in Hyattsville, Maryland at the University of Maryland University College, USA, October 21-24, 2013. The objective of this symposium was to bring together air quality, fire, and smoke specialists from the research community, non-governmental organizations (NGOs), local/state/federal government agencies, tribes, and private practitioners and organizations to discuss the state-of-the-science and state-of-the-applied-science for smoke management and addressing the air quality impacts of wildland fire smoke.

This objective was certainly met at this symposium. We had participants from several different organizations; organizations that don't typically attend conferences about Wildland Fire such as the American Lung Association, NOAA and the EPA. It was our intention to bring these groups together and we were able to do that successfully.

Another objective was to broaden our audience by providing the Symposium to a virtual audience. This turned out to be quite successful and we received great feedback from those who participated remotely. In addition, all of the presentations are still available online for those who were unable to attend.

It is our intention to have another Smoke Symposium in the future and hope to continue this very important dialogue.

The symposium included three workshops that preceded the conference on Monday, October 21st. The conference opened on the morning of October 22nd and included eight plenary speakers, one hundred and three oral presentations and thirty four poster presenters. Attendance was lower than anticipated due to the government shut down the weeks prior, however 125 were present in person and 50+ attended virtually; the evaluations of the conference were very positive.

Session topics included: Fire emission inventories and remote sensing; Fire and smoke modeling; Social aspects of smoke and public perception and messaging; Smoke/fire under a changing climate; Experiences of managing smoke (what works, what doesn't); Addressing impacts of wildfires to both the public and fire personnel; and What is the future in smoke research?

Special Sessions included: Reducing Smoke through Wood Energy: The Role of USDA; Fire's Impacts on Ozone and PM - Data Results and Tools for Analysis; Transportation Corridor Safety; Smoke and People: Bringing Clarity to Beliefs, Attitudes; Revising "Wildfire Smoke: A Guide for Public Health Officials"; and Influencing Factors; and State of Fire Behavior Models and their Application to Ecosystem and Smoke Management Issues.

**જા જા** જા

## CONFERENCE PRESENTED BY:



## IN CONJUNCTION WITH:



**SPONSORS:** 







AIR SCIENCES INC. DENVER + PORTLAND

# THE CONFERENCE ORGANIZERS GRATEFULLY ACKNOWLEDGE THE SUPPORT OF THE FOLLOWING ORGANIZATIONS AND INDIVIDUALS WHO HAVE CONTRIBUTED TO THIS EVENT:

#### **Sponsors**

National Aeronautics and Space Administration (NASA) United States Forest Service National Wildfire Coordinating Group (NWCG) Joint Fire Science Program (JFSP) Coalition of Prescribed Fire Councils Air Sciences, Inc.

#### **PARTNERS**

Department of Defense Montana Prescribed Fire Services, Inc. National Institute of Aerospace National Institute of Standards and Technology National Park Service Nine Points South Technical Pty. Ltd. Oregon State University, College of Forestry Scion, Rural Fire Research Team U.S. Environmental Protection Agency

## A SPECIAL THANK YOU TO THE CONFERENCE PLANNING COMMITTEE WHO WORKED HARD TO PULL TOGETHER A VERY SUCCESSFUL EVENT:

#### **STEERING COMMITTEE**

Pete Lahm (Conference Chair), USDA Forest Service, National Wildfire Coordinating Group, Smoke Committee Chuck Bushey, IAWF Mark Fitch, National Park Service John A. Hall, Ph.D., Department of Defense, Resource Conservation and Climate Change, Strategic Environmental Research and Development Program / Environmental Security Technology Certification Program SERDP/ESTCP Susan O'Neill, Ph.D., USDA Forest Service, Pacific Northwest Research Station AirFire

Pacific Northwest Research Station, AirFire Team

Allen R. Riebau, PhD., Nine Points South Technical Pty. Ltd.; USDA Forest Service Research and Development (retired); National Program Leader for Atmospheric Science/Chief Atmospheric Scientist

#### Mikel Robinson, IAWF

**Erika N. Sasser, Ph.D.,** Division Office of Air Quality Planning & Standards, Office of Air and Radiation, U.S. Environmental Protection Agency

**Amber Jeanine Soja, Ph.D.,** National Institute of Aerospace (NIA), Resident at: NASA Langley Research Center, Climate Science and Chemistry and Dynamics Branches

#### **PROGRAM COMMITTEE**

**Tom Zimmerman** (Program Chair) International Association of Wildland Fire Nelson Bryner, US Department of Commerce, National Institute of Standards and Technology, Fire Research Division Gary M. Curcio, Retired NCFS Fire Environment Branch Head; Co-founder of IPA Fire Environment Specialists, LLC Rick Gillam, U.S. Environmental Protection Agency Region 4 Pete Lahm, USDA Forest Service, National Wildfire Coordinating Group, Smoke Committee Narasimhan K. ('Sim') Larkin, Ph.D. U.S. Forest Service Pacific Northwest Research Station AirFire Team Pacific Wildland Fire Sciences Laboratory Jessica L. McCarty, Ph.D., Michigan Tech Research Institute (MTRI) Christine S. Olsen, Ph.D., College of Forestry, **Oregon State University** Ana G. Rappold, Ph.D., US Environmental **Protection Agency** Mikel Robinson, IAWF Tara Strand, PhD, Rural Fire Research Team, Scion, NZ Crown Research Institute

The findings and conclusions of each article in this publication are those of the individual author(s) and do not necessarily represent the views of the International Association of Wildland Fire. All articles were received in digital format and were edited for uniform type and style; each author is responsible for the accuracy and content of his or her own paper.

#### CITATION

Wade DD (Ed), Robinson ML (Comp) (2015) 'Proceedings of International Smoke Symposium', 21-24 October 2013, Hyattsville, NC. (Electronic) (International Association of Wildland Fire: Missoula, MT)

ళ Edited by Dale Wade ళ

র্জ Compiled by Mikel Robinson র্জ

রু Cover design by Shauna Murphy রু

## **TABLE OF CONTENTS**

#### ORAL PRESENTATIONS

Managing for fire and smoke in a changing climate: is it a moving or a fixed target? Gary L Achtemeier, USDA Forest Service, Center for Forest Disturbance Science and Ned Nikolov, BUSDA Forest Service, Wildland Fire RDNA, Rocky Mountain Research Station4 1
Wildland firefighter smoke exposure George Broyles, US Forest Service and Joe Domitrovich, US Forest Service 
Mapping prescribed burns and wildfires from Twitter with natural language processing and information retrieval techniques
K Arthur Endsley, Michigan Tech Research Institute (MTRI) and Jessica L McCarty, Michigan Tech Research Institute (MTRI)
Status of the Wildland Fire Emissions Information System: A NASA tool for fire-derived carbon and trace gas emissions estimation   Nancy HF French, Michigan Tech Research Institute, Michigan Technological University, Donald McKenzie, Pacific Wildland Fire Sciences Lab, U.S. Forest Service PNW Research Station , Michael Billmire, Michigan Tech Research Institute, Michigan Technological University, Roger D Ottmar, Pacific Wildland Fire Sciences Lab, U.S. Forest Service PNW Research Station , Susan Prichard, University of Washington, Jessica L McCarty, Michigan Tech Research Institute, Michigan Technological University, and K Arthur Endsle, Michigan Tech Research Institute, Michigan Technological University   Michigan Technological University, and K Arthur Endsle, Michigan Tech Research Institute, Michigan Technological University   30
Lung Toxicity of Pocosin Wildfire-Derived Particulate Matter: Implications for Toxicity Screening
n Lung Tissue Slices
Yong Ho Kim, Curriculum in Toxicology, University of North Carolina, Mary Daniels, National Health and Environmental Effects Research Laboratory, U.S. Environmental Protection Agency, Elizabeth Boykin, National Health and Environmental Effects Research Laboratory, U.S.

Elizabeth Boykin, National Health and Environmental Effects Research Laboratory, U.S. Environmental Protection Agency, Q. Todd Krantz, National Health and Environmental Effects Research Laboratory, U.S. Environmental Protection Agency, Eugene A. Gibbs-Flournoy, Curriculum in Toxicology, University of North Carolina, John McGee, National Health and Environmental Effects Research Laboratory, U.S. Environmental Protection Agency, Michael Hays, National Risk Management Research Laboratory, U.S. Environmental Protection Agency, Janice A. Dye, National Health and Environmental Effects Research Laboratory, U.S. Environmental Protection Agency and M. Ian Gilmour, National Health and Environmental Effects Research Laboratory, U.S. Environmental Protection Agency

#### Producing emission estimates from cropland burning in the contiguous United States for the 2011 National Emissions Inventory: Lessons learned from a remote sensing-based approach

Jessica L. McCarty, Michigan Tech Research Institute (MTRI), George A. Pouliot, Atmospheric Modeling and Analysis Division, National Exposure Research Laboratory Environmental Protection Agency, Mary E. Miller, Michigan Tech Research Institute (MTRI), Amber J. Soja, Institute of Aerospace (NIA), NASA Langley Research Center and Tesh Rao, Emissions Inventory & Analysis Group, Office of Air Quality Planning & Standards Environmental Protection Agency

# The Joint Fire Science Program smoke line of work and smoke science plan: history, implementation, and progress

AR Riebau, Nine Points South Technical Pty. Ltd., DG Fox, Nine Points South Technical Pty. Ltd C Huber, Nine Points South Technical Pty. Ltd

#### Smoke monitoring and dispersion modeling at the Palmerton Superfund Site

John Hom, USDA Forest Service, Northern Research Station, Thomas Whitlow, Cornell University, Dept. of Horticulture, Michael Kiefer, Michigan State University, Dept. of Geography, Dan Kunkle, Leigh High Gap Nature Center, Warren Heilman, USDA Forest Service, Northern Research Station, Sharon Zhong, Michigan State University, Dept. of Geography, Matthew Patterson, USDA Forest Service, Northern Research Station A Xindi Bian, USDA Forest Service, Northern Research Station

#### Alaska wildfire observations and near real-time emission modeling with WRF-Chem

#### Spatio-temporal estimation of gaseous and particle emissions from a major Australian wildfire

Nicholas C Surawski, CSIRO Ecosystem Sciences and CSIRO Sustainable Agriculture Flagship, Andrew L Sullivan, CSIRO Ecosystem Sciences and CSIRO Sustainable Agriculture Flagship, Stephen H Roxburgh, CSIRO Ecosystem Sciences and CSIRO Sustainable Agriculture Flagship and Carl (Mick) P Meyer, CSIRO Marine and Atmospheric Research

#### Recent emissions research in southwestern shrub and grassland fuels

David R Weise, USDA Forest Service, PSW Research Station, Wayne Miller, University of California – Riverside, Bourns College of Engineering, David R Cocker III, University of California – Riverside, Bourns College of Engineering, Heejung Jung, University of California – Riverside, Bourns College of Engineering, Seyedehsan Hosseini, University of California – Riverside, Bourns College of Engineering, Marko Princevac, University of California – Riverside, Bourns College of Engineering, Marko Princevac, University of California – Riverside, Bourns College of Engineering, Robert J Yokelson, The University of Montana, Department of Chemistry and Biochemistry, Ian Burling, The University of Montana, Department of Chemistry and Biochemistry, Sheryl Akagi, The University of Montana, Department of Chemistry and Biochemistry, Shawn Urbanski, USDA Forest Service, RM Research Station, WeiMin Hao, USDA Forest Service, RM Research Station

## Detecting and quantifying rangeland burning using remotely sensed burned area and active fire data A Case Study of Western Minnesota

Jessica L. McCarty, Michigan Tech Research Institute (MTRI), Steve Shumacher, BU.S. Fish and Wildlife Service, Amber J. Soja, CInstitute of Aerospace (NIA), NASA Langley Research Center, David M. Banach, Michigan Tech Research Institute (MTRI)

## Modeling Carbon Emissions from the 2002 Biscuit Fire Using FARSITE for Applications for Future Fire Emissions

Jessica L. McCarty, Michigan Tech Research Institute (MTRI), David M. Banach, Michigan Tech Research Institute (MTRI)

#### SPECIAL SESSION PRESENTATIONS

#### State of fire behavior models and their application to ecosystem and smoke management issues

Susan J Prichard, University of Washington, School of Environmental and Forest Sciences, Roger D Ottmar, Pacific Wildland Fire Sciences Laboratory, US Forest Service Pacific Northwest Research Station, John A Hal, US Department of Defense, SERDP/ESTCP, Allen R Riebau, Nine Points South Technical Pty. Ltd, NK (Sim) Larkin, Pacific Wildland Fire Sciences Laboratory, US Forest Service Pacific Northwest Research Station, Timothy J Brown, Desert Research Institute, Mark A Finney, Missoula Fire Sciences Laboratory, US Forest Service Rocky Mountain Research Station, W Ruddy Mell, Pacific Wildland Fire Sciences Laboratory, US Forest Service Pacific Northwest Research Station, Craig B Clements, Department of Meteorology, San Jose State University, J Kevin Hiers. HUS Department of Defense, Air Force and Matt B Dickinson, US Forest Service Northern Research Station

#### **MISCELLANEOUS**

#### **Program Schedule & Abstracts**

#### Managing for Fire and Smoke in a Changing Climate: Is it a Moving or a Fixed Target?

Gary L. Achtemeier<sup>A C</sup> Ned Nikolov<sup>B</sup>

<sup>A</sup>USDA Forest Service, Center for Forest Disturbance Science, 320 Green Street, Athens, GA, USA <sup>B</sup>USDA Forest Service, Wildland Fire RDNA, Rocky Mountain Research Station, Fort Collins, CO, USA <sup>C</sup>Corresponding author. Email: garyacht@gmail.com

**Abstract:** Most of climate change is understood in terms of global-scale warming caused by carbon dioxide released from anthropogenic combustion of fossil fuels. Climate models predict slow but steady warming over the next five to ten decades. Developing fire and smoke management strategies under conditions of continuous climate change may be difficult as weather continually adjusts to changing climate. Thus long-term climate change by  $CO_2$  warming may present a "moving target" for decision-making by land managers. On the other hand, "climate surge" events followed by long periods with little to no change can produce initial large changes in weather that afterward remain relatively unchanged. Conceptually, it is easier to develop land management strategies to adapt to these "fixed target" conditions. Evidence is presented to support an argument that most of recent climate warming in the northern hemisphere is the outcome of a natural "climate surge." There have been no significant global temperature changes over the past 14 years. Thus land management strategies can be based on current climate – a new normal.

*Brief Summary*: Intrusions of warm anomalous Atlantic sea water into the Arctic Ocean may explain ice melt and regional warming of atmospheric temperatures there thus creating a "climate surge."

#### Introduction

During the two decades from 1980-2000, average global temperatures rose at a rate of approximately 0.2 °C per decade (IPCC, 2007). Climate change directly impacts natural resources through changes in temperature and precipitation. Ecosystem response to climate change can be varied and complex as members of highly integrated systems respond in different ways. Increased temperatures and greater frequency of severe drought may convert dense, productive forests into savannahs. Latitudinal shifts in forest and grassland habitats may change fire regimes and therefore sources of smoke and associated impacts on air quality in populated areas. Climate change has already likely altered fire regimes, insect outbreaks, and tree mortality in the U.S. interior west and southwest (Ryan *et al.*, 2008).

Strategic planners for natural resources need to know "What next?" Will climate change (global cooling) return temperatures to pre-1980 levels? Will climate change continue at rates observed

in the 1990's (global warming)? Or will climate change cease over an interim period and global temperatures level off at current conditions?

Climate models predict that warming will continue at roughly the same rate as during the decade of the 1990's thus raising global temperatures by 1.5 °C to 3.5 °C by the end of the century (IPCC, 2007). Continuous climate change presents the strategic planner with a "moving target." The climate one hundred years from now will be different from the climate fifty years from now. The climate fifty years from now will be different from the climate twenty years from now. The climate twenty years from now will be different from the climate twenty years from now.

However, average global temperatures have not risen significantly for the past fourteen years – since 1998. This raises the question as to whether the bulk of warming during the 1990's and cessation of warming during the 2000's can be explained by some natural "climate surge" – a rapid increase in global temperature follow by a long period with little or no change. If the latter occurred, then conceptually, it is easier to develop land management strategies to adapt to these "fixed target" conditions.

We assembled existing climate data to determine whether strategic planners face a "moving target" – climate change as predicted by many climate models – or a "fixed target" – a climate surge (which has already occurred) followed by a long period with little or no change in average global temperatures.

#### **Climate Data**

Climate data used for this study were assembled from the following sources. Surface Temperature: UK Met Office Hadley Center - Climate Research Unit (HadCRU3): http://www.metoffice.gov.uk/hadobs/hadcrut3/diagnostics/global/nh+sh/ NOAA National Climate Data Center (NCDC): http://www.ncdc.noaa.gov/cmb-faq/anomalies.php NASA Goddard Institute for Space Studies (GISS):

http://data.giss.nasa.gov/gistemp/graphs/

Satellite-derived Lower-Troposphere Temperature:

University of Alabama at Huntsville (UAH): http://vortex.nsstc.uah.edu/data/msu/t2lt/uahncdc.lt Remote Sensing Systems Inc. (RSS): http://www.remss.com/data/msu/monthly\_time\_series/

Atmospheric CO2 Concentration:

NOAA ESRL Global Monitoring Division (NOAA): http://www.esrl.noaa.gov/gmd/ccgg/trends/global.html Scripps Institution of Oceanography (SIO) Monitoring Network: http://cdiac.ornl.gov/trends/co2/sio-keel.html Ice Cover: National Snow and Ice Data Center (NSIDC) University of Illinois at Urbana Champaign (UIUC) http://arctic.atmos.uiuc.edu/cryosphere/timeseries.south.anom.1979-2008

#### Results

Figure 1 shows plots of annual global temperature and carbon dioxide for the period 1880-2010. Temperatures cooled from 1880 through 1910 then warmed from 1910 through 1943. A general cooling trend occurred from 1943 through 1975 but cooling did not approach levels seen in 1910. Warming commenced after 1975 followed by accelerated warming from 1993 through 2002 thus giving to the overall record the so-called "hockey stick" profile. Figure 1 also shows carbon dioxide trending upward from 1880 through 1960 then trending sharply upward thereafter.

Figure 2 shows global surface temperature past year 2000 as a function of  $CO_2$  scenario (IPCC, 2001). Depending on sensitivity to  $CO_2$  warming, all models predict warming ranging from 1.0 °C to 5.8 °C over the next century.

Figure 3 shows the 100-year climate change past year 2000 for North America according to A1B scenario and 21 models [North America/USA Climate Projections: 2007 IPCC (AR4) Report]. Note that the greatest annual warming is projected for polar regions.

Figure 4 shows the global temperature record averaged over latitude strips for the period 1980-2012. A small cooling trend (-0.05 °C per decade) is found south of 60 deg south latitude in the region of Antarctica (Figure 4a). A small warming trend of 0.08 °C per decade (Figure 4b) is shown for the southern hemisphere extratropics (30-60 deg south latitude). A similar pattern is shown for the tropics (Figure 4c). Figure 4d shows the upward trend in the northern hemisphere extratropics (30-60 deg north latitude) of 0.26 °C per decade. Finally, Figure 4e shows a strong warming trend of 0.45 °C per decade in the north polar region.

The predictions of Figure 2 are not confirmed by the HadCRUT4 data for the period 1997-2011 (Figure 5) which show no significant warming during the past fourteen years. The Berkeley Earth Surface Temperature Project (BEST) results (Figure 6) confirm the findings shown in Figure 5. In addition, Figure 7 shows the mean annual temperature and mean annual atmospheric carbon dioxide for the period 1980 through 2012. Temperature trends are shown by piecewise regression. Figure 7 shows that the strong global warming observed during the 1990's is not found after 2002.

#### Discussion

The climate model predictions shown in Figure 2 and Figure 3 appear to be supported by the global temperature record averaged over latitude strips as shown in Figure 4. The greatest warming has occurred in the Arctic regions as predicted. These results confirm the greenhouse model and suggest strategic planners face a climatic "moving target" when engaging in natural

resource planning. However, the climate data shown in Figures 5, 6 and 7 suggest strategic planners face a climatic "fixed target" – a climate "surge" followed by little or no change.

In re-examining temperatures averaged by latitude bands, it is apparent that the bulk of temperature increases that contribute to global warming have occurred in the northern hemisphere. Furthermore, given that warming in the Arctic has been almost twice as large as warming in the northern mid-latitudes, and, given the continentality of the northern hemisphere, atmospheric transport between the Arctic and mid-latitudes may account for the bulk of warming there. Therefore, global warming over the past thirty years appears to be mostly a northern hemisphere event, and, within the northern hemisphere, the warming appears to be driven by events in the arctic.

The rise in temperatures over the Arctic is confirmed by sea ice anomaly data for the period 1979-2012 (Figure 8). Beginning ca 1990, sea ice extent declined by four percent below sea ice coverage in the 1980's. After 2004, sea ice extent fell by an additional six percent. Ice melt sets up a nonlinear feedback loop. Ice melt allows absorption of solar radiation which warms sea water which warms the atmosphere which melts more ice, etc. Conceptually the loop of water warming air warming water can continue unabated until all Arctic ice has melted unless some mechanism halts the cycle.

The primary question then is "what started the sea ice melt in 1990?" Here strategic planners for natural resources face a "chicken or egg" question. Had the atmosphere been warmed sufficiently by greenhouse gases in the 1980's to trigger the initial melt – an outcome of the "moving target?" Or did an anomalous warming of the sea water trigger the initial melt allowing for the feedback loop the warmed the atmosphere – an outcome of the "fixed target?" In other words, does the source of the warming reside in the atmosphere or in the ocean?

Polyakov et al. (2011) document transport of warm water anomalies into the mid-layers (150-900 m depth) of the Arctic Ocean from the Atlantic Ocean. Figure 9 (their Figure 1) estimates pathways of Atlantic Water (AW) into the Arctic Ocean. In the early 1990's, a pulse of warm water with a temperature anomaly of 1.0 °C entered the Arctic Ocean. This warm water pulse finally reached the Canada Basin during the 2000's. A second pulse of warmer AW water (1.2 °C) entered the Arctic Ocean during the mid-2000's and by 2009 had passed through the Eurasian Basin.

Analyses of the heat budget of the AW layer by Polyakov et al. supports an argument that part of the heat from the pulses of warm AW water has been transported upward through gradients of salinity by not completely understood mechanisms to warm Arctic sea ice from below. The sea ice extent data (Figure 8) support this argument. Sea ice extent remained relatively constant though the 1980's then began declining beginning around 1990 as the first warm pulse entered the Arctic Ocean. Reduced sea ice extent continued through the early 2000's when the second and warmer AW pulse entered and was followed by greater sea ice extent reduction after 2003.

Melting of sea ice changes the albedo over large areas of the Arctic Ocean. Increased heat storage during the Arctic summer delays refreezing by several weeks in the fall. The resulting

thinner ice sheet melts earlier during the late spring. The outcome is increased length of the Arctic summer and decreased strengths of cold air masses transported into the mid-latitudes during the warm season.

However, the Arctic sea ice melt mechanism cannot continue indefinitely. Arctic sea ice extent will decline to a minimum beyond which climate impacts will diminish and warming will halt – the "climate surge." There are already indications this has already occurred. The piecewise regression of mean global temperatures (Figure 7) shows that mean global temperatures peaked in 2002 and have leveled off or fallen slightly during the past decade.

#### Conclusions

We have argued that intrusions of warm Atlantic water flowing into the Arctic Ocean have melted Arctic sea ice from below. The outcome was/is reduced albedo, higher heat storage in the Arctic Ocean, increased length of the Arctic summer, and reduced strengths of cold air masses transported into mid-latitudes during the warm season. Thus this natural phenomenon set up a "climate surge" during the decade of the 1990's characterized by anomalous warming of temperatures over the Arctic as sea ice extent declined. The warmed air was transported into the northern mid-latitudes raising mean annual temperatures there but to a lesser extent than had the warming in the Arctic. Barring even warmer pulses of AW water, the natural heating mechanism may have peaked and begun tapering off. Arctic sea ice extent has recovered somewhat from the record reduction in 2006. The rapid warming observed during the 1900's has ceased and temperatures have not warmed for more than a decade.

The outcome of warming of Arctic sea water by a natural phenomenon should be welcome news to strategic planners for global natural resources. As it takes approximately twenty years for AW pulses to circulate through the Arctic Ocean, there remain ten years for the second AW pulse to complete its circuit.

Therefore, for the strategic planner, persistence may be the best forecast. Since 2002, global temperature anomalies (which are dominated by the Arctic warming event) have leveled off. Therefore strategic planning can be based on current climate – the new normal – which presents a "fixed" target – at least for the next decade.

#### References

IPCC, 2001. Climate Change 2001: Synthesis Report (AR3). A Contribution of Working Groups I, II, III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Watson, R.T.. and the Core Writing Team (eds)]. Cambridge University Press, Chambridge, United Kingdom, and New York, NY, USA, 398 pp.

IPCC, 2007. Climate Change 2007: Synthesis Report (AR4). Contribution of Working Groups I, II, III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing team, Pachauri, R.K. and Reising, A. (eds)]. IPCC, Geneva, Switzerland, 104 pp.

Polyakov I, Vladimir AA, Ashik IM, Bacon S, Beszczynska-Moller A, Carmack EC, Dmitrenko IA, Fortier L, Gascard J, Hansen E, Holemann J-C, Ivanov VV, Kikuchi T, Kirillov S, Lenn, Y-D, McLaughlin FA, Piechura J, Repina I, Timokhov LA, Walczowski W, Woodgate R, 2011: Fate of early 2000s Arctic warm water pulse. Bulletin of the American Meteorological Society, 561-566.

Ryan MG, Archer SR, Birdsey RA, Dahm CN, Heath LS, Hicke JA, Hollinger DY, Huxman TE, Okin GS, Oren R, Randerson JT, Schlesinger WH (2008) Land resources. In: Backlund P, Janetos A, Schimel D, Hatfield J, Boote K, Fay P, Hahn L, Izaurralde C, Kimball BA, Mader T, Morgan J, Ort D, Polley W, Thomson A, Wolfe D, Ryan MG, Archer SR, Birdsey RA, Dahm CN, Heath LS, Hicke JA, Hollinger DY, Huxman TE, Okin GS, Oren R, Randerson JT, Schlesinger WH, Lettenmaier D, Major D, Poff L, Running S, Hansen L, Inouye D, Kelly BP, Meyerson L, Peterson B, Shaw R (eds) The effects of climate change on agriculture, land resources, water resources, and biodiversity. A Report by the U.S. Climate Change Science Program and the Subcommittee on Global Change Research, Washington, DC, USA, pp 75–120.

#### **Figure Captions**

Figure 1. Annual temperature and carbon dioxide profiles for the period 1880-2010.

Figure 2. Global surface temperature past year 2000 as a function of CO<sub>2</sub> scenario [2001 IPCC (TAR) Report].

Figure 3. 100-year climate change past year 2000 according to A1B scenario & 21 models [North America/USA Climate Projections: 2007 IPCC (AR4) Report].

Figure 4. Plots of average temperature around latitude bands for a) south polar, b) southern hemisphere extratropics, c) tropics, d) northern hemisphere extratropics, and e) north polar.

Figure 5. HadCRUT4 data since 1997.

Figure 6. BEST data since 2001. The second last point should be disregarded as it is due to anomalous station sampling. [Berkeley Earth Surface Temperature Project (BEST)]

Figure 7. Mean annual temperature and mean annual atmospheric carbon dioxide for the period 1980 through 2012. Temperature trends are shown by piecewise regression.

Figure 8. Sea ice anomalies for the period 1979-2012 for northern hemisphere.

Figure 9. From Polyakov et al. (2011): Circulation of the intermediate Atlantic water of the Arctic Ocean shown by red and pink arrows. Refer to the original paper for details.



Figure 1. Annual temperature and carbon dioxide profiles for the period 1880-2010.



Figure 2. Global surface temperature past year 2000 as a function of CO<sub>2</sub> scenario [2001 IPCC (TAR) Report].



Figure 3. 100-year climate change past year 2000 according to A1B scenario & 21 models [North America/USA Climate Projections: 2007 IPCC (AR4) Report].

#### Proceedings of the International Smoke Symposium October 21-24, 2013, Hyattsville, Maryland, USA Published by the International Association of Wildland Fire, Missoula, Montana, USA



Figure 4. Plots of average temperature around latitude bands for a) south polar, b) southern hemisphere extratropics, c) tropics, d) northern hemisphere extratropics, and e) north polar.

Proceedings of the International Smoke Symposium October 21-24, 2013, Hyattsville, Maryland, USA Published by the International Association of Wildland Fire, Missoula, Montana, USA



Figure 5. HadCRUT4 data since 1997.



Figure 6. BEST data since 2001. The second last point should be disregarded as it is due to anomalous station sampling. [Berkeley Earth Surface Temperature Project (BEST)]



Figure 7. Mean annual temperature and mean annual atmospheric carbon dioxide for the period 1980 through 2012. Temperature trends are shown by piecewise regression.



Figure 8. Sea ice anomalies for the period 1979-2012 for northern hemisphere.



Figure 9. From Polyakov et al. (2011): Circulation of the intermediate Atlantic water of the Arctic Ocean shown by red and pink arrows. Refer to the original paper for details.

#### Wildland Firefighter Smoke Exposure

George Broyles<sup>AB</sup> Joe Domitrovich<sup>A</sup>

<sup>A</sup>US Forest Service, 3833 S. Development Ave. Boise, ID 83705 <sup>A</sup>US Forest Service, 5785 Highway 10 W. Missoula MT. 59808, <u>jdomitrovich@fs.fed.us</u> <sup>B</sup>Corresponding author. Email: <u>gbroyles@fs.fed.us</u>

Additional Keywords: Carbon Monoxide, crystalline silica, wildland fire, prescribed fire carboxyhemoglobin

#### Introduction

Wildland firefighters are subject to exposure from a variety of inhalation irritants. From a health and safety perspective some of the most important are carbon monoxide, respirable particulate matter, polycyclic aromatic hydrocarbons, benzene, and aldehydes such as formaldehyde and acrolein.

Some compounds in wildland fire smoke are known or suspected carcinogens. Irritants in this smoke have the potential to cause short- and long-term health hazards to wildland firefighters in the normal course of their duties (Reinhardt, 1991; Reinhardt & Ottmar, 1997, 2004). Health effects may include short-term conditions such as headaches, fatigue, nausea, and respiratory distress while long-term health effects may include an increased risk of cardio-vascular disease.

There have been numerous studies done to assess wildland firefighter exposure over the past 25 years. Previous National Wildfire Coordinating Group (NWCG) sponsored smoke exposure studies indicate that employees were overexposed to CO approximately 5 percent of the time at wildfires and 10 percent of the time at prescribed fires (Reinhardt et al. 2000). National Institute of Occupational Safety and Health (NIOSH) studies indicates a concern for both wildland firefighters and incident support personnel at fire camps. However, there has not been a study that encompasses the wide geographic area where wildland firefighters work, nor has a single study covered sufficient numbers of firefighters that would allow the Forest Service to accurately determine exposures for the various duties, environments, and other variables associated with wildland firefighting.

For these reasons more expansive and definitive exposure measurements are needed to account for the full range of exposures across all geographic areas where wildland fires occur. A common thread throughout many of the earlier studies made it clear that a larger more comprehensive assessment was required. For example, Reh and Deitchman (1992) state their small sample size made it impossible to make broad-based generalizations about firefighter exposure.

Despite the exposure research that has been done sufficient information to accurately understand the magnitude of exposures and the variables associated with unsafe levels of exposure was still

lacking. As stated by Reisen et al. in 2009; Exposure to potentially harmful levels of contaminants in wildland smoke may be one of the least understood risks of wildland firefighting.

This assessment was designed to quantify exposure; its magnitude, when, where and perhaps why it occurs. By identifying the conditions and activities that lead to unsafe exposure, firefighters and fire managers can be better prepared to reduce these exposures.

#### What

The US Forest Service began this project in 2009 measuring exposure to CO on firefighters engaged in fire suppression activities.

In 2010 the project was expanded to include

- Assessment of respirable particulate matter and crystalline silica (SiO<sub>2</sub>)
- Assessment of incident personnel at ICPs and spike camps
- Initial attack fire assessment

#### **Data Collection Summary**

Data were collected;

- In 11 of the 13 National Fire Danger Rating System (NFDRS) fuel models
- In 17 States
- On initial attack, prescribed, large project fires and prescribed natural fires
- On over 30 different job tasks
- During high exposure events (CO values typically not measured in previous research)

Data Hours/Sample Size

- Over 7,500 hours of CO measurements on firefighters
- Over 1,550 hours of CO measurements at ICPs and spike camps
- 179 PM4 and SiO<sub>2</sub> firefighter samples
- 78 PM4 and SiO<sub>2</sub> samples at ICPs and/or spike camps

#### <u>How</u>

During the course of the project exposures were measured on handcrews, engine crews, dozer operators, fireline overhead personnel and at incident command posts and spike camps.

Carbon monoxide, respirable particulate matter (PM4) and SiO<sub>2</sub> were measured in the breathing zone of firefighters. Area samples were taken at incident base camps.

Carboxyhemoglobin readings were taken preshift, midshift, and postshift.

**Work Activity**. Direct observation of firefighters by trained assessment personnel was used to determine if operational tasks are associated with exposure. Job activities recorded included

fireline construction, hiking, mopup, holding, and briefing. Minute-by-minute observations were recorded for later analysis. By remaining with the crew throughout the entire shift, accuracy of the data and accounting for any factors that may influence exposure levels was ensured. Additional variables recorded for analysis included: wind speed/direction, relative humidity, temperature barometric pressure, fire behavior, and fuel model.

Twenty-four measurements were taken to provide exposure measurements for the incident camp personnel.

CO data were collected on a minute-by-minute basis to allow for the determination of numerous occupational exposure metrics: time weighted averages (TWA) and/or maximums for 24 hour, shift-time, fireline-time, 8 hour, 1, 5, and 15 minutes etc.

#### **Data Analysis Assumptions**

- Exposures were calculated by fire type: wildland, initial attack, prescribed, and prescribed natural fire
  - to determine the exposure characteristics associated with each fire management regime.
  - to account for differences in shift averages impacted by the amount of time firefighters were actually engaged in fire suppression.
- Shift TWAs included all the time firefighters were in paid status.
- One-minute average CO concentration was used for analysis.
- OSHA PEL formula (29 CFR 1910.1000 table Z-3) was used to calculate total particulate exposure.
- A rolling 8-hour exposure was calculated. In cases where the firefighter was on the line for more than 8 hours, the highest continuous 8-hour exposure is used.

#### Findings

The estimated amount of time that CO exposure exceeds the OSHA 8-hour TWA (50 ppm) is 5.6% on project fires and 3.5% on prescribed fires (2009 - 2011). These percentages could be as high as 10.7% and 12% respectively.

The estimated amount of time that CO exposure exceeds the NIOSH 8-hour REL (35 ppm) is 13% on project fires and 14% on prescribed fires (2009 – 2011).

Operational tasks related to the highest exposures that are statistically significant are: mop-up, holding, direct handline and dozer operators (open cabs).

Data analysis is ongoing. Future analysis will be done to determine significant variables of interest, exposures by fuel model and geographic region. CO/PM correlations will be determined.

Exposure to wildland smoke even at low to moderate levels may present a safety and health hazard to wildland firefighters. Smoke exposure hazards should be included in all levels of wildland firefighting training.

#### **Literature Citation**

Bytnerowicz, A., Arbaugh, M., Riebau, A., & Andersen, C. (Eds.). (2009). Wildland Fires and Air Pollution, Developments In Environmental Science 8. Oxford, UK: Elsevier.

Reinhardt, T. (1991). Monitoring firefighter exposure to air toxins at prescribed burns of forest and range biomass. Research Paper PNW-RP-441, October.

Reinhardt, T, & Ottmar, R. (1997). Smoke exposure among wildland firefighters: A review and discussion of current literature. General Technical Report, PNW-GTR-373, February.

Reinhardt T., Ottmar R., Hanneman A., 2000 Smoke exposure among firefighters at prescribed burns in the Pacific Northwest. Res. Pap. PNW-RP-526. Portland, OF: U.S. Department of Agriculture, forest Service, Pacific Northwest Research Station 45 p.

Reinhardt, R., & Ottmar, R. (2004). Baseline measurements of smoke exposure among wildland firefighters. *Journal of Occupational and Environmental Hygiene*, *1*, 593-606.

Reisen, F., & Brown, S. (2009). Australian firefighters' exposure to air toxics during bushfire burns of autumn 2005 and 2006. *Environment International*, *35*, 342-352.

Ward, D. (1998). E. smoke from wildland fires. USDA Forest Service, October, p. 70-84.

# Mapping prescribed burns and wildfires from Twitter with natural language processing and information retrieval techniques

K. Arthur Endsley<sup>A</sup> Jessica L. McCarty<sup>A</sup>

<sup>A</sup>Michigan Tech Research Institute (MTRI), 3600 Green Court, Suite 100, Ann Arbor, MI, kaendsle@mtu.edu and jmccarty@mtu.edu

#### Abstract:

New media are increasingly used to capture ambient geographic information in multiple contexts, from mapping the evolution of the Tahrir Square protests in Egypt to predicting influenza outbreaks. The social media platform Twitter is popular for these applications; it boasts over 500 million messages ("tweets") generated every day from as many total users at an average rate of 5,700 messages per second. In the United States, Twitter is used to communicate prescribed agricultural or other burning and the emergence, response to, and containment of wildfires. A prototype for operational prescribed and wildland fire detections from social media, specifically Twitter, was created using natural language processing and information retrieval techniques. The intent is to identify and locate prescribed burns and wildland fires in the contiguous United States often missed by satellite detections with the hope of providing relevant, spatio-temporal fire data for emission estimates, inventories and burned area mapping efforts. The authors present their methodology and an evaluation of its performance in collecting relevant tweets, extracting metrics such as area burned and geo-locating the fire events using the GeoNames geographic gazette. Compared to two operational satellite fire products, this data mining effort mapped fires potentially unknown to the satellite record.

Additional Keywords: social media, text mining, geocoding, prescribed fire, wildland fire, geospatial techniques

#### Introduction

The automated extraction of volunteered and ambient geospatial information from social media has proven to be useful in a variety of contexts, from mapping the evolution of the 2011 Tahrir Square protests in Egypt (Stefanidis *et al.* 2013) to predicting influenza outbreaks (Lampos *et al.* 2010). There is already a significant body of work showcasing the use of Twitter for disaster alerting, mitigation, and response (e.g. MacEachren *et al.* 2011; USGS 2012) where information extracted from the social media platform often performs equal to or better than conventional techniques (Petrovic *et al.* 2013). In fact, according to Sakaki *et al.* (2010), the operational earthquake alerting system in Japan provides alerts faster than the national Meteorological Agency. In the domain of prescribed burns and wildland fires, however, Twitter has previously been used only for qualitative assessments and case studies (e.g. Vieweg *et al.* 2010), such as a single fire in France (Longueville *et al.* 2009).

Twitter's popularity for such applications can likely be attributed to its volume of users and frequency of use: 200 million active users, 60% of those on mobile devices, sending over 500

million tweets every day (Moore 2013; Twitter 2013*a*). Twitter is used by a number of federal, state and local officials in the United States as well as by motivated individuals in a number of countries world-wide (e.g. Australia and New Zealand, as seen during the 2013 New South Wales fires) to report prescribed burns in advance (sometimes as part of a reporting obligation) or to communicate emergence, response to, and containment of wildfires. These reports, like all Twitter messages (or "tweets"), are limited to 140 characters of unstructured text.

A prototype framework was developed to collect messages from Twitter potentially describing wildfire or prescribed burn activity data, to extract from them information such as the type of fire and acreage burned, and to map the location of the fires in near-real time. The goal of this research was to assess the predictive power of information extracted from new media, specifically Twitter, for gleaning useful occurrence information for environmental and natural hazard applications. Specifically, the aim was to identify and locate known wildland and prescribed fire events in the contiguous United States (CONUS) often missed by satellite detections, thus providing relevant spatio-temporal fire data for emission estimates, ongoing burned area mapping efforts, and natural hazard management.

#### **Materials and Methods**

#### Natural Language Processing

The general approach employed in this study requires the use of natural language processing (NLP), information retrieval (IR), and data mining techniques. The specific steps involved are, in this order: (1) To collect potential tweets of interest from the Twitter network; (2) Detect and remove duplicate tweets (or "retweets"); (3) Determine the area burned, if possible; (4) Classify the fire incident as either a prescribed burn or wildfire; and (5) Locate the fire described in the tweet with real world coordinates. Basic NLP techniques such as *tokenizing* (breaking text up into individual signifiers, usually words), *removing stopwords* (removing common and largely meaningless words like "if, and, or, but") and parts-of-speech *tagging* are applied at almost every step of the process to facilitate computation (Russell 2011).

Tweets concerning potential fire activity were collected using the Twitter Search application programming interface (API), which allows access to millions of tweets going back approximately one week in time (Twitter 2012). While no estimate of average daily fire-related tweet volume is currently available, it is likely to be a small fraction of the approximately 5,700 tweets generated every second. In defining "fire-related" we distinguish between (1) relevant, well-formed tweets that provide actionable information about prescribed burn(s) or wildland fire(s) and (2) everything else. Specifically, this research distinguishes between tweets such as, "Enjoying a camp fire tonight; I love the smell of wood smoke!" (not well-formed or relevant) and, "Prescribed fire today: 50 acres at Sebastian Tree Farm, near #Micco Road and US1" (both well-formed and relevant). Also of interest to this research is the avoidance of tweets such as, "I see smoke outside! I wonder what's #burning?" which is relevant, but not well-formed.

Search terms submitted to the Twitter Search API were chosen by the authors such that the bulk of tweets returned were almost exclusively well-formed and relevant (after Vieweg *et al.* 2010). The terms are case-insensitive and may be partially contained by the words of the tweet (e.g. a

search for "fire" also returns "FIRE" and "wildfire"). The chosen query also contained words that are known to be associated with those fire-related tweets that are most likely to convey information about the location and size of the fire, such as state abbreviations and the following terms with their common abbreviations: *road*, *highway*, *county*, *acre*.

Given that, in this study, the tweets returned typically contain the search terms "acre" or "acres," the acreage burned is extracted from the tweet text using basic regular expressions. The date and time of the fire are taken from the tweet's metadata, assuming that the date and time of authorship is sufficiently proximate to the date and time of the fire incident. This assumption is borne out by the authors' experience reading fire-related tweets.

Fire type classification is assumed to be relatively straightforward. The classification rests solely on a tweet's inclusion of certain tokens (i.e. words) thought to be singularly representative of prescribed burns. This approach proceeds from the assumption that the majority of wildfire communication on Twitter is about wildfires and that less common communications about prescribed burns include one or more of a finite set of tokens that are exclusively associated with prescribed burns (e.g. "prescribed" and "#RxFire")

#### Retweet Detection

For the purposes of this study, only unique reports describing wildfires or prescribed burns are of interest. The intent is to avoid documenting the same fire twice or more in order to produce accurate estimates of bulk acreage burned and to reduce the overall number of tweets that need to be processed. Therefore, once a tweet sufficiently describing a fire is captured, the aim is to filter out all later tweets describing the same fire. These might even be exact or near duplicates of an earlier tweet. We have observed that these so-called "retweets" have no reliably definitive signifiers in the text or their metadata to distinguish them from original compositions. A common convention of using the letters "RT" to signify a retweet is not universally adopted. The approach used in this study is to determine the similarity, or distance, between two tweets as if they were arbitrary points in some feature space. If the tweets fall within a certain distance of one another, then one or the other must be a retweet.

An efficient means of comparing the text of any two tweets is provided by an implementation of locality-sensitive hashing (LSH) called minhashing (Moulton 2012; Jaffer 2013), which is also used by Twitter Inc. themselves for search engine optimization (Twitter 2011). In a minhashing procedure, we compare sets of hashes made from the inclusive n-tuples (or n-grams) of the ordered words in the tweet text—sets like "50, acres, burned" (a 3-gram or trigram) are mapped to a new text string or hash using a special, one-way mathematical relationship allowing for quick comparisons. If the tweets were authored by two different Twitter users, the younger (more recent) tweet is marked as a retweet.

#### Geocoding

This research aims to locate prescribed burns and wildland fires associated with relevant and well-formed tweets collected through the Twitter Search API. Some tweets are explicitly geotagged, meaning they are given geographic coordinates by their authors, usually from embedded global positioning system (GPS) measurements appended to the metadata by a mobile

device. However, in practice, these account for less than 1% of all tweets (Cheng *et al.* 2010, Lee *et al.* 2011). Therefore, the majority of tweets must be geocoded. Geocoding is generally defined as an attempt to determine the real-world coordinates of an entity (e.g. a building, a topographic feature, a person) from unstructured or loosely-structured data. The classic example of geocoding is transforming postal addresses into latitude and longitude coordinates. Similarly, geocoding in this application is concerned with assigning geographic coordinates to a tweet based on its textual content, specifically, the tweet text and some metadata from the user profile (after Leetaru *et al.* 2013). The approach used in this study is a synthesis of named-entity recognition (NER) and gazetteering with clustering used to resolve ambiguous cases. NER is an NLP technique that chunks adjacent words into meanings (such as "location" or "person") based on their parts-of-speech. Here, NER is used to identify words or groups of words with potential geographic significance—so-called toponyms, or words that might be successfully mapped to a place through gazetteering.

Gazetteering is the process of using a geographical lookup table (gazette) to associate place names with their coordinates. Each toponym is searched for in the geographic gazette. The geographic gazette used in this study is the GeoNames collection (GeoNames.org), which contains over 2.1 million geographic entities in the United States and U.S. territories. If more than one match is found per tweet (i.e., if more than one term in the tweet is found in the gazette) and if those matches are not duplicates of the same gazette entry, then the tweet has ambiguous geographic coordinates. Only one set of coordinates can be assigned to the tweet, so clustering is used to pick a centroid of geographic locations based on all of the retrieved locations.

Two types of clustering were tested in this study, k-means clustering (with k=2) and a proprietary clustering scheme termed "pair-wise clustering" which seeks to minimize the distance first between gazette entries that have the same toponym (e.g. the city of Riverside, California and Riverside County in California) and then to minimize the distance between each toponym centroid, arriving at a final centroid which is assigned as the tweet's coordinates. The developed algorithm searches for two clusters in k-means clustering (k=2) as it assumes that it is retrieving two types of entries from the gazette: those that describe the true location of the fire and those that describe faraway places with similar names (e.g. Riverside, California versus Riverside, Iowa). In k-means clustering, the centroid of the "tightest" cluster is assigned as the geographic coordinates of the tweet where "tightest" is determined as the minimum total distance between cluster members.

#### Results

#### Twitter Data Mining Prototype

A total of 13,241 tweets were collected starting July 4, 2012 and continuing until June 11, 2013 ( Figure 1) when the version of the Twitter Search API being used at the time was deprecated (Twitter 2013b) and tweets could no longer be collected. The collection thus spans 342 days with an average rate of 38 tweets per day and represents the contributions of 6,351 unique users. A performance evaluation of the methods described in the preceding section was performed over this dataset using human evaluators, which are justifiably the "gold standard" in tweet text interpretation. Evaluators used in this project were all research professionals familiar with both the geospatial and fire sciences. In each evaluation, the results of the algorithm were compared to that of one human evaluator (in some cases, out of a group) over a random sample of tweets that had been identified as non-retweets—that is, each performance evaluation is an assessment in light of the retweet detection algorithm having been applied.

Assessment of the retweet detection algorithm involved a manual classification of 120 tweets from a simple random sample of all tweets, all of which were classified by the algorithm. The evaluator considered as a retweet any tweet for which there could be found an earlier tweet of sufficient similarity. The "sufficient similarity" criterion is, of course, based on the human evaluator's own intuitive assessment. The human classifier's results were compared to the retweet detection algorithm. The algorithm achieved an overall accuracy of 72% with a recall, or true positive rate, of 82%. The majority of the error is commission error. Almost half of the truly independent tweets were mistakenly classified as retweets by the algorithm. The naïve approach to the problem of retweet detection is predicated solely upon the presence of the "RT" token in the tweet text. A comparison of this approach was made to the naïve approach. While the naïve approach's omission error indicates that some retweets lack the "RT" token, the overall accuracy of the naïve approach exceeded 83%.



Figure 1: Many notable fire events, as well as data holidays due to active development, can be seen in the time series histogram above which displays the total number of tweets each day over the period of study. Tweet volumes are higher in the early summer months.

One consequence of the query submitted to the Search API is that recovered tweets were tailored for the extraction of acreage burned. Thus, it is unsurprising that the overall accuracy of the method in correctly extracting acreage burned exceeded 99% in this study. We found that fewer than 1% of the tweets were classified as prescribed burns by our methodology. There were too few prescribed burns in the entire Twitter collection analyzed in this study, as verified by human

evaluators, to provide a representative sample. Of the wildland fires described by tweets in this study, over 96% were correctly classified as wildfire.

To implement the detection of prescribed burns and wildfires from Twitter in near-real time, almost all of the delay between a fire's occurrence and its accurate mapping should be confined to the time required to author tweet describing it. To that end, we benchmarked the system's performance in processing 100 tweets at a stretch, which were randomly shuffled before each iteration, to measure the speed of our processing framework and to allow us to estimate the rate at which we can process tweets. On an Intel Core i7 CPU at 3.0 GHz, 100 tweets could be all but geocoded in 2.9 seconds. With geocoding, the time required jumps to 8.1 minutes for 100 tweets, which should hardly be surprising, as this step requires multiple database lookups (in the geographic gazette) per tweet. However, as the highest throughput of fire-related tweets to date seen in this study has been 600 tweets per day (less than 1 tweet every 2 minutes, on average), this performance meets and exceeds current requirements for near-real time mining of fire-related Twitter messages.

#### Geocoding Performance

Assessment of the geocoding algorithm performance again involved a human evaluator who, in this case, rather than making a discrete classification, manually attempted to determine the location of 60 tweets randomly sampled from those located successfully (if not accurately) by the algorithm, excluding those explicitly geotagged. Of the original 60, the human evaluator was able to determine the unambiguous location of the fires in 32 tweets. The evaluator employed any information in the tweet and on the web to learn where the fire referred to was located. This includes sources of information not used by the algorithm, such as web pages linked in the tweet. The intended effect is to compare the algorithm to the best geocoder available: human intuition applied to the largest library of spatial information available (the internet).

For each of the 32 tweets in the sample, the Vincenty distance (Vincenty 1975) between the actual and geocoded locations were calculated and compared to one of 32 random locations within exactly the same geographic extent allowed by the geocoder. Two clustering schemes were also compared, resulting in three assessments: a random geocoding, geocoding using the defined algorithm with k-means clustering (k=2), and geocoding using the defined algorithm with pair-wise clustering. The results are displayed as a flipped cumulative frequency plot in Figure 2.



Figure 2: The geocoding performance of the algorithm developed in this study is compared to that of a random geocoding for two different clustering schemes. Though both clustering schemes perform better than random, the proprietary clustering scheme, pairwise clustering, performs significantly better than k-means.

While the geocoder obviously performs better than chance with either clustering scheme, there is significant room for improvement. With pair-wise clustering, the best clustering in terms of geocoding performance, less than 10% of the geocoded tweets in the sample were geocoded to within 8 km of the actual location of the fire. This distance is a significant threshold as it represents the approximate instantaneous field-of-view (IFOV) of the Moderate Resolution Imaging Spectroradiometer (MODIS) sensor at swath's edge (in the 1 km resolution data), which ranges from approximately 4.83 km to 9.71 km (Yang and Di 2004). The 1 km MODIS Active Fire Product is used by the U.S. Forest Service for early warning fire mapping (http://activefiremaps.fs.fed.us/) and in the NASA Earth Observing System Data and Information System (EOSDIS; https://earthdata.nasa.gov/data/near-real-time-data/firms/active-fire-data). Roughly 15% of the sample were geocoded to within 22 km of the true location and 22% to within 100 km.

The geocoded results were further compared to the satellite record: the positional accuracy of our geocoding against the MODIS Active Fire Product (Giglio *et al.* 2003) and the accuracy of our burned area estimates against the MODIS Burned Area (MCD45A1) Collection 5.1 product (Roy *et al.* 2008). In terms of positional accuracy, only about 4% of the geocoded tweets were located within 8 km of the corresponding fire's location in the MODIS Active Fire record. Approximately 33% of the geocoded tweets in our collection correspond with the coincident

MODIS-based burned area estimates. This implies that the remaining collection, equal to 1,697 tweets from July 2012 to June 2013, may contain references to fires potentially unknown and currently missed in the satellite record.

#### Comparison with Official Fire Activity and Burned Area

As estimates of burned area were also extracted from the Tweet text describing a fire, this study included a comparison with official burned area statistics from the National Interagency Fire Center (NIFC), which provides metrics on both wildfires and prescribed burns. According to the NIFC, approximately 4.09 million acres of wildfire burned between January 1 and October 15, 2013 (NIFC 2013). Over the same period, we estimate approximately 17 million wildfire acres burned; a 315% percent surplus in burned area, but nonetheless on the order of magnitude expected. As only a limited record of this study is available so far and the NIFC reporting is aggregated by year, direct comparisons over arbitrary ranges of time are not possible. This study did collect data during the bulk of the fire season in North America for 2012, from July 4 to December 31 of that year. The NIFC estimate for wildfire acres burned is 9.3 million, compared to our estimate of 7.6 million. The NIFC does provide "to date" estimates, which allow for partial-year comparison with the continuous record currently produced by this study.

Prescribed burn acreage estimates were also compared to both the NIFC estimates and to the National Association of State Forester's and the Coalition of Prescribed Fire Council's 2012 National Prescribed Fire Use Survey Report (Melvin 2012). According to the latter report, 20.2 million acres of prescribed burning from forestry and agriculture took place in 2012 while the NIFC estimates burning from federal agencies that same year accounted for 1.9 million acres. The approach described in this study, which yielded only 114 tweets thought to describe prescribed burns, can account for only about 15,000 acres from July 4 to December 31, 2012. It is difficult to determine whether prescribed fires are not often being discussed on Twitter or if the collection of tweets in this study were not sufficiently representative of prescribed fire communication on Twitter.

#### **Conclusions and Discussion**

This study describes a prototype framework for mapping prescribed burn and wildfire events based on Twitter messages in near-real time. The results can be explored in their spatio-temporal context online through an interactive web map (

Figure 3) developed by the authors (http://spatial.mtri.org/fireminer/). The software architecture is based entirely on open-source software in the Python programming language and on established information retrieval and natural language processing techniques including named entity-recognition and gazetteering.



Figure 3: The screenshot above displays the website where the tweets collected and geocoded during this study can be found, in addition to an ongoing, near-real time stream of tweets that are continuously analyzed.

The retrieval of fire-related tweets demonstrated high precision, as did the differentiation between retweets and non-retweets, such that very few irrelevant, misleading or redundant fire incident reports were admitted. The query submitted to the Search API was sufficiently and arbitrarily constrained such that virtually all of the tweets collected are well-formed and relevant to wildfires or prescribed burns, though this has not yet been quantified. The more interesting question that needs to be addressed, rather than measuring and incrementally boosting the performance of the methodology employed here, is: How can we distinguish between fire-related and non-fire related tweets in near-real time from a large, random sample of tweets?

Figure 4 shows the word cloud produced by analyzing the most common non-trivial words in the collection of tweets from this study. Future improvements to the Twitter Search API query might better integrate key terms based on their prominence in a word cloud visualization. Additionally, future data mining activities aimed at differentiating types of wildland and prescribed fire (forestry vs. agriculture as outlined in the National Prescribed Fire Survey) would benefit from word cloud visualizations to determine best key terms and/or terms causing false detections. Further improvements could be made to any social media-based data mining prototype through outreach efforts to educate current fire and land managers, scientific community, citizen

scientists, and the general public to safely share their observations of prescribed and wildland fires on social media with the appropriate key terms to identify location, burned area, and fire type. This type of outreach could further enhance the value of social media data mining for fire managers seeking to monitor wildfire outbreaks, conditions, and post-fire regrowth from crowd-sourced information.



Figure 4: A word cloud based on the tweets collected provides a view of the common terms used in fire-related tweets and can be helpful for designing new or improved queries to the Twitter Search API.

While the geocoding performance, in particular, needs to be significantly improved before implementation in operational fire event detection and reporting, the geocoding error can be attributed almost entirely to failures in disambiguation between common toponyms (Leetaru et al. 2013). Multiple solutions to this problem are now known but perhaps the most appropriate and effective for this application would be to construct a custom geographic gazette. Starting with the GeoNames.org database, for instance, future work might benefit from filtering out entities that do not meet certain criteria (e.g. population, feature type, urban versus rural index). Alternatively, ambiguous results could be ranked by these criteria, which allows for either fuzzy or discrete matching. In addition, this study did not consider other contextual information available such as the location and biography from the author's Twitter profile. Leetaru *et al.* (2013) describe both custom gazette generation and these disambiguation approaches, comparing the effect on accuracy in choosing between geocoding on tweet text, the profile biography, and the author's stated location. They found that the majority of accurate gazette matches came from the stated location in the author's Twitter profile. While this location would be too coarse for mapping fires, it could be used to disambiguate results from full-text retrievals based on the tweet text and/or biography text.

Future applied research related to this project should focus on improving disambiguation in the geocoding and on the selection and evaluation of machine learning algorithms for discriminating between fire-related and non-fire related tweets. Significant gains in these areas would allow for

an operational wildfire and prescribed burn detection system that operates in near-real time on large volumes of tweets, such as those delivered by the real-time Twitter Streaming APIs. Such a system would complement the satellite remote sensing record, particularly concerning small fires (< 200 acres) and prescribed burns that are not captured by existing emission inventories. Current attempts at more comprehensive emission inventories, like SmartFire 2 (Raffuse *et al.* 2011), can be labor and time intensive to incorporate ground reports from state and federal agencies (i.e., ICS-209 reports). This study illustrates that social media can be used to inform and possibly expand current fire emission inventories to create a comprehensive emissions inventory that includes fires from the satellite records, state and federal reports, and verified data from social media.

#### Acknowledgments

This research was made possible through internal research and development funding at the Michigan Tech Research Institute (MTRI). The authors would like thank research interns David Banach, Scott Hawkins, and James Whitehead for their assistance as human evaluators.

#### References

- Cheng Z, Caverlee J, Lee K (2010) You are where you tweet: A content-based approach to geolocating Twitter users. *Proceedings of the 19th ACM International Conference on Information and Knowledge Management*. Toronto, Canada.
- Giglio L, Descloitres J, Justice CO, Kaufman Y (2003) An enhanced contextual fire detection algorithm for MODIS. *Remote Sensing of Environment* **87**, 273-282. doi: 10.1016/S0034-4257(03)00184-6.
- Jaffer, S (2013) Finding similar items using minhashing. Available at http://www.toao.com/posts/finding-similar-items-key-store-minhashing.html October 19, 2013. [Verified 9 January 2014]
- Lampos V, Bie T, Cristianini N (2010) Flu detector Tracking epidemics on Twitter. Machine Learning and Knowledge Discovery in Databases 6323, 599–602. doi:10.1007/978-3-642-15939-8\_42
- Lee CH, Yang HC, Chien TF, Wen WS (2011) A novel approach for event detection by mining spatio-temporal information on microblogs. 2011 International Conference on Advances in Social Networks Analysis and Mining, 254–259. doi:10.1109/ASONAM.2011.74
- Leetaru K, Wang S, Cao G, Padmanabhan A, Shook E (2013) Mapping the global Twitter heartbeat: The geography of Twitter. *First Monday* **18**. doi:10.5210/fm.v18i5.4366
- Longueville BD, Smith RS, Luraschi G (2009) "OMG, from here I can see the flames!": A use case of mining Location Based Social Networks to acquire spatio-temporal data on forest fires. *Proceedings of the 2009 International Workshop on Location Based Social Networks*. Seattle, Washington, U.S.A.: Association for Computing Machinery.
- MacEachren AM, Robinson AC, Jaiswal A, Pezanowski S, Savelyev A, Blanford J, Mitra P (2011) Geo-twitter analytics: Applications in crisis management. *Proceedings*, 25th International Cartographic Conference. Available at http://nzdis.org/projects/projects/berlin/repository/ravisions/61/entry/trunk/MastersDe

http://nzdis.org/projects/projects/berlin/repository/revisions/61/entry/trunk/MastersDocs/ Papers/Filer\_Papers/MacEachren\_ICC\_2011.pdf [Verified 9 January 2014]

- Melvin M (2012) 2012 National Prescribed Fire Use Survey Report. Available at http://www.stateforesters.org/sites/default/files/publicationdocuments/2012\_National\_Prescribed\_Fire\_Survey.pdf [Verified 9 January 2014]
- Moore H (2013, September 13) Twitter heads for stock market debut by filing for IPO. *The Guardian*. New York, NY, U.S.A. Available at http://www.theguardian.com/technology/2013/sep/12/twitter-ipo-stock-market-launch [Verified 9 January 2014]
- Moulton R (2012) Simple simhashing: Clustering in linear time. *Ryan Moulton's Articles*. Available at http://moultano.wordpress.com/article/simple-simhashing-3kbzhsxyg4467-6/ [Verified 9 January 2014]
- NIFC (2013) National Interagency Fire Center: Statistics. Available at: http://www.nifc.gov/fireInfo/fireInfo\_statistics.html [Verified 9 January 2014]
- Petrovic S, Osborne M, McCreadie R, Macdonald C, Ounis I, Shrimpton L (2013) Can Twitter replace Newswire for breaking news? Proceedings of the International AAAI Conference on Weblogs and Social Media (ICWSM). Association for the Advancement of Artificial Intelligence. Available at http://homepages.inf.ed.ac.uk/miles/papers/short-breaking.pdf [Verified 9 January 2014]
- Raffuse SM, Larkin NK, Pryden DA, TM Dedecko (2011) New Methods for Modeling and Monitoring Wildfires Using Multiple Data Sources: SmartFire v2. AGU Fall Meeting Abstracts - 2011. Available at http://adsabs.harvard.edu/abs/2011AGUFMNH53A1717R [Verified 10 January 2014]
- Roy DP, Boschetti L, Justice CO, J Ju (2008) The Collection 5 MODIS Burned Area Product -Global Evaluation by Comparison with the MODIS Active Fire Product. *Remote Sensing* of Environment 112, 3690-3707. doi:10.1016/j.rse.2008.05.013.
- Russell MA (2011) Chapter 8: Blogs et al..: Natural Language Processing (and Beyond). In Mining the Social Web: Analyzing Data from Facebook, Twitter, LinkedIn, and Other Social Media Sites. (O'Reilly Media, Inc.)
- Stefanidis A, Crooks A, Radzikowski J (2013) Harvesting ambient geospatial information from social media feeds. GeoJournal, **78**, 319–338. Available at
  - http://link.springer.com/article/10.1007/s10708-011-9438-2 [Verified 9 January 2014]
- Twitter (2011) The engineering behind Twitter's new search experience. (I. Twitter, Ed.) *Engineering Blog.* Twitter. Available at https://blog.twitter.com/2011/engineeringbehind-twitter's-new-search-experience [Verified 9 January 2014]
- Twitter (2012) Using the Twitter Search API. (I. Twitter, Ed.) *Developers*. Available at http://dev.twitter.com/docs/using-search [Verified 9 January 2014]
- Twitter (2013a) New Tweets per second record, and how! (I. Twitter, Ed.)*Twitter Engineering Blog.* Available at https://blog.twitter.com/2013/new-tweets-per-second-record-and-how [Verified 9 January 2014]
- Twitter (2013b) Calendar of API changes. (I. Twitter, Ed.) *Developers*. Retrieved from https://dev.twitter.com/calendar [Verified 9 January 2014]
- USGS (2012) U.S. Geological Survey: Twitter Earthquake Detector (TED). Available at http://recovery.doi.gov/press/us-geological-survey-twitter-earthquake-detector-ted/ [Verified 9 January 2014]
- Vieweg S, Hughes A, Starbird K, Palen L (2010) Microblogging during two natural hazards events: what twitter may contribute to situational awareness. *ACM (Ed.), CHI 2010:*
*Crisis Informatics* pp. 1079–1088. Atlanta, GA, U.S.A.: ACM. Available at http://dl.acm.org/citation.cfm?id=1753486 [Verified 9 January 2014]

- Vincenty T (1975) Direct and Inverse Solutions of Geodesics on the ellipsoid with Application of Nested Equations. *Survey Review* **22**, 88-93.
- Yang W, Di L (2004) An accurate and automated approach to georectification of HDF-EOS swath data. *Photogrammetric Engineering & Remote Sensing* **70**, 397-404.

# Status of the Wildland Fire Emissions Information System: A NASA tool for fire-derived carbon and trace gas emissions estimation

Nancy HF French<sup>A</sup> Donald McKenzie<sup>B</sup> Michael Billmire<sup>A</sup> Roger D Ottmar<sup>B</sup> Susan Prichard<sup>C</sup> Jessica L McCarty<sup>A</sup> K Arthur Endsley<sup>A</sup>

<sup>A</sup>Michigan Tech Research Institute, Michigan Technological University, Ann Arbor, MI, USA nhfrench@mtu.edu <sup>B</sup>Pacific Wildland Fire Sciences Lab, U.S. Forest Service PNW Research Station, Seattle, Washington, USA <sup>C</sup>University of Washington, Seattle, WA, USA

#### Abstract:

The Wildland Fire Emissions Information System (WFEIS) was developed under NASA Carbon Cycle Science and Applications programs to provide a consistent approach to estimating emissions at continental to sub-continental scales (see http://wfeis.mtri.org). We present an overview of the WFEIS system, including the web system and data used for emissions estimates for the US. Plans for system development, preparations underway for transitioning to an operational environment, and ideas for extending WFEIS to other regions are also presented. Additional Keywords: Fire emissions, Alaska, CONUS, web-enabled API

## Introduction

In this presentation we reviewed a recently developed system for modeling regional-scale fire emissions within the U.S. called the Wildland Fire Emissions Information System (WFEIS). The system uses tools developed for land and fire management to make spatial estimates of firederived carbon and traces gas emissions. WFEIS can be used to calculate emissions across multiple fires revealing within-burn variability based on fuels and fire timing. Daily estimates can be derived and are reported by fuel type. Emissions data at these spatial and temporal scales have not been previously available and can provide detailed information for a variety of disciplines including fire science, smoke management, emissions inventories, and carbon cycle science. The presentation present an overview of the WFEIS system, including the web system and data used for emissions estimates for the US. Plans for system development, preparations underway for transitioning to an operational environment, and ideas for extending WFEIS to other regions are also presented.

## Structure and functionality of WFEIS

WFEIS is a web-based tool that provides users a simple user interface for computing wildland fire emissions across North America at landscape to regional scales (1-km spatial resolution). WFEIS provides access to fire perimeter maps along with corresponding fuel loading data layers

#### Proceedings of the International Smoke Symposium October 21-24, 2013, Hyattsville, Maryland, USA

Published by the International Association of Wildland Fire, Missoula, Montana, USA



and fuel consumption models to compute wildland fire fuel consumption and fire emissions for specified locations and date ranges (Figure 1). The system taps into tools developed by the US Forest Service to describe fuels, fuel loading (Fuel Characteristic Classification System (FCCS); McKenzie et al. 2012; Ottmar et al. 2007), and fuel consumption (Consume; Ottmar et al. 2009). For implementation in the US, the system integrates information from USGS and NASA on fire location and timing, USDA NASS on cropland type, and NOAA to derive fire weather. Using a data base of FCCS fuelbeds, fuel consumption and fire emissions are calculated with Consume 4.1, an open-source model in the Python programming language, to derive temporally and geospatially-specific estimates of emissions sources from wildland and cropland burning. Although total carbon emissions is the focus for development, the Consume model allows for estimation of many smoke constituents, including criteria air pollutants defined by the USEPA. The system currently allows for calculation of emissions from fires within the United States (excluding Hawaii and territories) from 1982 to 2010.

WFEIS is built from open-source software following international standards facilitating extended system development. The web interface includes a GUI calculator which builds URL-based queries using a RESTful software architecture to implement a web-based Application Programming Interface (API). The system is under active development to increase computational speed and efficiency, to improve the input data sets used in the calculations, provide a measure of uncertainty in the estimates, and to enhance the web interface with additional filter options to serve user needs.

The WFEIS website allows for two approaches for making fuel consumption and emissions estimates. First, there is an Emissions Calculator webpage that provides a graphical user interface for constructing queries (Figure 2). Second, the WFEIS website responds to queries submitted via properly encoded URL requests (i.e. it implements a RESTful Web API). Examples of valid WFEIS URLs, accessed via the emissions calculator within the KML and text report output formats, can be modified by users and resubmitted to the WFEIS system.

#### **Emissions results from WFEIS**

Output data on consumption and emissions can be requested in several formats from WFEIS. In addition to a text report, tabular results are available as CSV or CMAQ-compatible formats, and multiple vector and raster formats of mapped fire emissions are available, including ArcGIS Shapefile, Google KML, GeoTIFF, and NetCDF. The system provides a framework for estimating regional fire emissions anywhere that data are available. Limited application of the



Figure 2: Emissions calculator web page. Clicking on the "Emissions Calculator" button from the home page (Figure 1) leads to the calculator page, where various extents and options can be selected. The "Run WFEIS" button generates data based on user selections, displaying the results in the chosen format in a new internet browser tab.

WFEIS concept in Mexico and Canada has been facilitated by collaborations with Mexican and Canadian experts. WFEIS has potential to be ported to other places around the world to provide emissions estimation capability at moderate spatial scales, which has value for country-scale emissions inventories and regional-scale air quality assessment.

**Emissions estimates from WFEIS** are consistent with comparable model results (French et al. 2011). Annual emissions across the US vary based on the amount of fire and where the fire occurs (Table 1). Results of regional assessments of fire emissions for the US shows large variability in emission, which is driven by where fire occurs and the type of vegetation fuels burning (Table 2). This type of assessment can be made for regional assessments with WFIES. The system is available for additional exploration of emissions for the US at the web site: http://wfeis.mtri.org.

Year	Burned (kn	l area 1 <sup>2</sup> )	Total cons (Tg	umption	Total (Tg	CO <sub>2</sub> g)
	CONUS	AK	CONUS	AK	CONUS	AK
2001	8,182	438	16.38	9.07	13.79	7.18
2002	13,744	8,518	51.98	126.09	44.19	99.91
2003	18,450	2,322	55.62	24.00	50.37	19.08
2004	10,223	26,407	16.34	363.23	15.53	288.19
2005	17,918	19,507	23.17	292.00	21.24	231.38
2006	26,903	1,087	59.66	9.61	51.03	7.68
2007	29,637	2,445	82.83	23.93	71.86	19.03
2008	17,524	402	50.38	5.19	42.45	4.11
2009	15,944	11,359	24.25	163.11	22.22	129.37
2010	12,414	4,313	14.93	48.43	12.09	38.50

Table 1: Annual burned area, consumption, and emissions results from WFEIS for CONUS 2005 and Alaska 2007, large fire years in each region.

Table 2: Compiled data from WFEIS on burned area, consumption, and emissions for 2003 by Level 1 ecoregion (Commission for Environmental Cooperation 1997).

Ecoregion Number	CONUS Ecoregion	Burned area (km <sup>2</sup> )	Total fuel consumption (Tg)	Total CO <sub>2</sub> (Tg)
3.0	Alaska Taiga	2,322	24.00	19.08
9.0	Great Plains	5,236	9.14	7.55
6.0	Northwestern Forested Mountains	4,086	30.83	24.81
11.0	Mediterranean California	3,123	7.81	11.31
8.0	Eastern Temperate Forests	2,736	3.28	2.72
15.0	<b>Tropical Wet Forests</b>	1,052	0.03	0.03
10.0	North American Deserts	965	0.42	0.51
13.0	Temperate Sierras	723	1.62	1.45
12.0	Southern Semi-Arid Highlands	380	0.57	0.49
5.0	Northern Forests	94	1.63	1.28
7.0	Marine West Coast Forest	56	0.29	0.23

#### References

- French, N. H. F., and Coauthors, 2011: Model comparisons for estimating carbon emissions from North American wildland fire. *J. Geophys. Res.*, **116**, G00K05.
- McKenzie, D., N. H. F. French, and R. D. Ottmar, 2012: National database for calculating fuel available to wildfires. *EOS*, **93**, 57-58.
- Ottmar, R. D., S. J. Prichard, and G. A. Anderson, 2009: Consume 3.0 Users Guide. Pacific Wildland Fire Sciences Laboratory, USDA Forest Service.
- Ottmar, R. D., D. V. Sandberg, C. L. Riccardi, and S. J. Prichard, 2007: An overview of the Fuel Characteristic Classification System (FCCS) quantifying, classifying, and creating fuelbeds for resource planning. *Can. J. For. Res.*, **37**, 1-11.

# Lung Toxicity of Pocosin Wildfire-Derived Particulate Matter: Implications for Toxicity Screening in Lung Tissue Slices

Yong Ho Kim<sup>1</sup> Mary Daniels<sup>2</sup> Elizabeth Boykin<sup>2</sup> Q. Todd Krantz<sup>2</sup> Eugene A. Gibbs-Flournoy<sup>1</sup> John McGee<sup>2</sup> Michael Hays<sup>3</sup> Janice A. Dye<sup>2</sup> M. Ian Gilmour<sup>2</sup>

<sup>1</sup>Curriculum in Toxicology, University of North Carolina, Chapel Hill, NC, USA, kim.yongho@epa.gov, gibbs-flournoy.eugene@epa.gov,

<sup>2</sup>National Health and Environmental Effects Research Laboratory, U.S. Environmental Protection Agency, Research Triangle Park, NC, USA, <u>daniels.mary@epa.gov</u>, <u>boykin.elizabeth@epa.gov</u>, <u>krantz.todd@epa.gov</u>, <u>mcgee.john@epa.gov</u>, <u>dye.janice@epa.gov</u>, gilmour.ian@epa.gov,

<sup>3</sup>National Risk Management Research Laboratory, U.S. Environmental Protection Agency, Research Triangle Park, NC, USA, <u>hays.michael@epa.gov</u>

## Abstract:

Inhalation of particulate matter (PM) generated from wildfires can cause acute lung injury, and pulmonary and systemic inflammation, however the chemical constituent(s) responsible for these effects vary according to the fuel, combustion conditions, and exposure concentration. Sizefractionated PM samples were collected downwind from a peat-bog wildfire in Eastern North Carolina in 2008. ENCF-1 was collected during  $\frac{6}{26}\frac{2008}{-7}\frac{-7}{11}\frac{2008}{2008}$  when the fire was still smoldering, while ENCF-4 was collected during  $\frac{8}{8}/2008 - \frac{8}{19}/2008$  after the fire had been controlled but not extinguished. Samples were extracted in methanol, analyzed for chemical constituents and adjusted to 10 mg/ml in water. The size-fractionated PM (ultrafine, <0.2 µm; fine, 0.2-2.5  $\mu$ m; coarse, 2.5-10  $\mu$ m) were instilled into mice at 100  $\mu$ g/50  $\mu$ l saline or cultured with lung tissue slices at 11 µg per lung slice (8 mm diameter). At 24 h post-exposure, biomarkers of lung injury and inflammation were assessed in lung lavage fluid from mice, and conditioned medium from the lung slices. Results showed that both ENCF-1 and -4 coarse PM had relatively greater endotoxin content than the fine and ultrafine PM, and other ambient PM samples previously analyzed. Moreover, only the coarse PM significantly increased neutrophils, protein and biomarkers of inflammation (e.g., interleukin-6 (IL-6)) in the lung lavage fluid, and similar pro-inflammatory (e.g., IL-6) effects were also observed from the lung tissue slice model, indicating that cell functionality and intercellular interaction in lung slices closely mimicked the in vivo tissue environment. This study suggests that exposure to wildfire coarse PM causes substantial toxicity in the lung in association with endotoxin content, and that the lung tissue slice assay can replace the *in vivo* instillation model for PM toxicity screening. (This abstract does not represent U.S. EPA policy).

Additional Keywords: [Wildfire, Particulate matter, Endotoxin, Lung tissue slices, Cytokines]

# Producing emission estimates from cropland burning in the contiguous United States for the 2011 National Emissions Inventory: Lessons learned from a remote sensing-based approach

Jessica L. McCarty<sup>A</sup> George A. Pouliot<sup>B</sup> Mary E. Miller<sup>A</sup> Amber J. Soja<sup>C</sup> Tesh Rao<sup>D</sup>

<sup>A</sup>Michigan Tech Research Institute (MTRI), 3600 Green Court, Suite 100, Ann Arbor, MI, jmccarty@mtu.edu and memiller@mtu.edu

<sup>B</sup>Atmospheric Modeling and Analysis Division, National Exposure Research Laboratory Environmental Protection Agency, Research Triangle Park, NC, pouliot.george@epa.gov <sup>C</sup>Institute of Aerospace (NIA), NASA Langley Research Center, Hampton, VA, amber.j.soja@nasa.gov

<sup>D</sup>Emissions Inventory & Analysis Group, Office of Air Quality Planning & Standards Environmental Protection Agency, Research Triangle Park, NC, rao.venkatesh@epa.gov **Abstract:** 

Prescribed fires in agricultural landscapes generally produce smaller burned areas than wildland fires but are important contributors to emissions impacting air quality and human health. The purpose of this research was to refine a regionally-tuned cropland burned area product by utilizing higher spatial resolution crop type data from the USDA NASS Cropland Data Layer and burned area training data from field work and very high resolution commercial satellite data to improve the U.S. Environmental Protection Agency's 2011 National Emissions Inventory. The final deliverable to the EPA included a detailed database of 25 different atmospheric emissions at the county level, emission distributions by crop type and seasonality, and GIS data. The resulting emission estimations were shared with all 48 states in the contiguous U.S., with detailed error estimations for Wyoming and Indiana. This work also provided opportunities in discovering the different needs of federal and state partners, including the various geospatial abilities and platforms across the many users and how to incorporate expert knowledge into quantitative remote sensing estimations of emissions.

Additional Keywords: Cropland, prescribed fires, remote sensing, emissions, air quality

#### The Joint Fire Science Program Smoke Line of Work and Smoke Science Plan: History, Implementation, and Progress

#### A.R. Riebau<sup>1</sup> D.G. Fox<sup>1</sup> C. Huber<sup>1</sup>

<sup>1</sup>Nine Points South Technical Pty. Ltd., PO Box 2419, Clarkson, Western Australia 6030, Australia

## Introduction

From its inception in 2000 the Joint Fire Science Program (JFSP) has funded research in smoke. Over the years the breadth and complexity of JFSP smoke science has greatly increased and has had significant implications for many areas of fire management. Acknowledging the depth of the smoke science legacy, the implications of on-going research, and planned levels of future funding, in 2009 JFSP developed a Smoke Science Plan (SSP). This action was intended to insure the line of work would remain responsive to management needs while producing focused science that was broadly complimentary to other areas of JFSP research. This plan was devised through personal interviews and an extensive web-based needs investigation between scientists and managers using on-line questionnaires. It is structured under four themes, which are considered complementary investigative areas needed to further both smoke science and management practice. The themes are: 1) Emissions Inventory Research, 2) Smoke and Fire Model Validation, 3) Smoke and Populations, and, 4) Climate Change and Smoke. The objective of the *Emissions Inventory Theme* is to develop the missing science and knowledge needed for improving national wildland fire emissions inventories. Funded projects are characterizing organic aerosol emissions and their impacts on regional particulate and ozone pollution and evaluating the quality of inventory tools in current use. Future work will define best practices for developing future inventories and inventory systems. The objective of the Model Validation Theme is to develop the scientific scope, techniques and partnerships needed to objectively validate smoke and fire models using field data. Funded projects are developing methodologies to archive, organize, present and apply field data for model validation, and initiating comprehensive validation dataset collection. Future work will advance an interagency agenda for smoke model validation. The objective of the Populations and Smoke Theme is to quantify the impact of wildland fire smoke on populations and fire fighters, elucidate the mechanisms of public smoke acceptance in light of needs for balance between ecosystem health and acceptable smoke exposure risk. Funded projects are also considering potential impacts of megafire smoke on large urban centers. Future work will assess smoke health risks and provide science to improve public smoke warning systems. The objective of the *Climate Change Theme* is to understand implications of wildland fire smoke to and from climate change using UN IPCC scenarios as guidelines.

The Smoke Science Plan has been implemented for approximately three years. As can be seen in Table 1, some 13 projects have been completed and 16 more are currently underway. Rather than trying to describe progress here, we refer the interested reader to the Joint Fire Science's

website (firescience.gov). A query to the JFSP database on research results in Smoke Management will yield something on the order of 100 results in about 21 completed projects, although many of these are from projects established before the Smoke Science Plan. As a complement to the SSP, JFSP is implementing a formal *Smoke Communications Plan*, a new activity designed to insure that SSP products are more effectively delivered to users nationwide. The communication plan includes a variety of efforts to disseminate smoke line of work results to potentially interested parties. The Communications plan calls for the development of a brief synopsis of each completed project. This synopsis addresses the following questions: Why is this work important? What did we learn? Listing of management implications. These are then disseminated widely through a web broadcast to a large list of interested parties. This is then followed up with a webinar so interested people can learn more of the details directly from the project authors.

The Smoke Science Plan has been designed to achieve its goals by the end of 2015. Each of the four themes has identified specific final theme products. The Emissions Inventory theme final products are a comprehensive suite of peer-reviewed best science smoke inventory methods that are ready to be used in an inter-agency effort to improve the wildland fire component of state and national emissions inventories. The Model Validation theme final product is a best-science *methodology* that provides a consistent framework for evaluating smoke model performance, with the appropriate science agency partnerships developed that will foster additional data collection efforts to support a broader array of test cases for model validation. The Smoke and Populations theme final product is a *best science research warning system* for public smoke risk that can be tested for eventual adoption into air quality/pollution episode forecasts by EPA and NOAA. The Smoke and Climate Change theme final products are best science synthesis *document(s)* that outlines air quality changes precipitated by fire regimes resulting from climate change and an assessment of how emissions from changing fire regimes will in turn influence climate change. In addition, all of the modelling input and output files used in analyses will be available for additional research (for example: evaluating the air quality impacts of various prescribed fire management policies under changing climate). Over the coming year we will be evaluating our progress under the Smoke Science Plan and in light of this progress, evaluating the potential for completing the final products and, if necessary, revising or recommending continuation of selected aspects of the Plan.

 Table 1. JFSP funded projects organized by SSP theme. This table lists both completed and active projects. More information is available on the JFSP website.

 https://www.firescience.gov/index.cfm

Theme: Model Validation	
<b>Completed Projects</b>	Active Projects

Validation of Fuel Consumption Models for Smoke Management Planning in the Eastern Regions of the US	Data Set for Fuels, Fire Behavior, Smoke and Fire Effects Model Development and Evaluation (Rx Cadre)
Evaluation of Smoke Models and Sensitivity Analysis for Determining their Emission Related Uncertainties	Fire and Smoke Model Validation Workshop
Evaluation and Improvement of Smoke Plume Rise Modeling	
Airborne and Lidar Experiments for the Validation of Smoke Transport Models	
Creation of a Smoke and Emissions Model Intercomparison Project (SEMIP) and Evaluation of Current Models	
Sensitivity Analysis of Air Quality to Meteorological Changes in Fire Simulations	
Development of Modeling Tools for Predicting Smoke Dispersion from Low- Intensity Fires	
Sub-Canopy Transport and Dispersion of Smoke: A Unique Observation Dataset and Model Evaluation	
Superfog Formation: Laboratory Experiments and Model Development	

# **Theme: Emissions Inventory**

<b>Completed Projects</b>	Active Projects
Experimental Determination of Secondary Organic Aerosol Production from Biomass Combustion	Influence of Fuel Moisture and Density on Black Carbon Formation During Combustion of Boreal Peat Fuels
Deterministic and Empirical Assessment of Smoke Contribution to Ozone	Critical Assessment of Wildland Fire Emissions Inventories: Methodology, Uncertainty, Effectiveness
	Assessment of Prescribed Fire Emissions and Inventories
	Particulate Matter Deterministic and Empirical Tagging and Assessment of Impacts on Levels

#### Theme: Climate Change and Smoke **Completed Projects Active Projects** Measuring the Optical Properties and Climate Identification of Necessary Conditions for Impacts of Aerosol from Wild and Prescribed Arctic Transport of Smoke from US Fires Fires in the US Smoke Consequences of IPCC's Scenarios Modeling Study of the Contribution of Fire **Projected Climate and Ecosystems** Emissions on Black Carbon Concentrations and Changes in the US - Review Paper **Deposition Rates** Assessing the Impacts on Smoke, Fire and Air Quality Due to Changes in Climate, Fuel Loads, and Wildfire Activity over the SE United States Estimating the Effects of Changing Climate on Fires and Consequences for US Air Quality Using a Set of Global and Regional Climate Models

# **Theme: Smoke and Populations**

Completed Projects	Active Projects
	Public Perceptions of Smoke: contrasting tolerance amongst WUI and urban communities in the Interior West and the SE US
	Examining the Influence of Communication Programs and Partnerships on Perceptions of Smoke Management
	Impacts of Mega-Fires on Large US Urban Area Air Quality Under Changing Climate and Fuels
	Future Mega-Fires and Smoke Impacts
	Wildland Fire Smoke Health Effects on Wildland Firefighters and the Public
	Visual Range and Particulate Matter Data Analysis and Literature Review

# Smoke monitoring and dispersion modeling at the Palmerton Superfund Site

John Hom<sup>A</sup> Thomas Whitlow<sup>B</sup> Michael Kiefer<sup>C</sup> Dan Kunkle<sup>D</sup> Warren Heilman<sup>E</sup> Sharon Zhong<sup>C</sup> Matthew Patterson<sup>A</sup> Xindi Bian<sup>E</sup>

<sup>A</sup> USDA Forest Service, Northern Research Station, 11 Campus Blvd, Newtown Square, PA 19073, jhom@fs.fed.us, mmpatterson@fs.fed.us
 <sup>B</sup>Cornell University, Dept. of Horticulture, 23 Plant Science, Ithaca, NY, 14850, thw2@cornell.edu
 <sup>C</sup>Michigan State University, Dept. of Geography, 116 Geography Building, East Lansing, MI 48824, mtkiefer@msu.edu, zhongs@msu.edu
 <sup>D</sup>Leigh High Gap Nature Center, 8844 Paint Mill Rd, Slatington, PA 18080, danlgnc@ptd.net
 <sup>E</sup>USDA Forest Service, Northern Research Station, Stephen S. Nisbet Bldg., 1407 S. Harrison Road, Room 220. East Lansing, MI 48823, wheilman@fs.fed.us, xbian@fs.fed.us

# Abstract:

This smoke monitoring and modeling study at the Palmerton Superfund Site estimates the amount of heavy metals released and predict smoke transport with prescribed burning. The Lehigh Gap Nature Center (LGNC) is located on the Palmerton Superfund site in Pennsylvania, which was contaminated with heavy metals from long term zinc smelting, resulting in loss of vegetation cover. The barren mountainsides were remediated by the Nature Center by planting prairie grasses on the site. The prairie grasses have stabilized the soil, do not take up the heavy metals, but are now considered a fire hazard. To effectively manage the prairie grasses, the LGNC in cooperation with the U.S. Environmental Protection Agency and the USDA Forest Service, are testing prescribed fire as a management tool to reduce the fire hazard and eliminate unwanted woody trees and shrubs which take up and mobilize the heavy metals in the soil. Results from this test burn includes monitoring the prescribed burn for contaminates and particulate emissions, meteorological variables, and fuel consumption. A coupled meteorological and atmospheric dispersion modeling system, ARPS-FLEXPART, is used to predict the local meteorological and air-quality impacts of the grassland prescribed burn and smoke dispersal to the surrounding wildland urban interface.

Additional Keywords: [heavy metals, prescribed burn, smoke transport modeling, Palmerton Superfund site]

## Alaska wildfire observations and near real-time emission modeling with WRF-Chem

M. Stuefer<sup>1</sup>, C. Waigl<sup>1</sup>, C K Kim<sup>2</sup>

 Geophysical Institute, University of Alaska, Fairbanks, 903 Koyukuk Dr. 99775 AK, USA, Phone: (907) 474 6477, E-mail: stuefer@gi.alaska.edu
 Department of Atmospheric Sciences, University of Arizona, Tucson, AZ

## Abstract:

Biomass burn emissions from Alaska wildfires have been predicted with the Weather Research and Forecast Model with inline Chemistry (WRF-Chem) in operational mode during recent fire seasons. Timely information of data characterizing the fire source is crucial for the model runs to accurately predict the smoke dispersion in near real time. Our WRF-Chem model preprocessing system includes options for different fire source data from satellite remote sensing and from local fire agencies. Radiative measurements and emission data from fires in interior Alaska are used to refine model parameterization and source data. The injection heights and vertical distribution of fire emissions strongly depend on fuel characteristics and the state of a fire. We conducted aerial observations using a thermal infrared camera and an optical particle spectrometer. The flight data are important to improve satellite derived fire detection products and to evaluate the modeled fire plumes. Examples of observed in-situ particle concentrations showed partly good coincidence with the model.

Additional Keywords: Alaska wildfires, biomass burn emissions, WRF-Chem, smoke modeling, air quality prediction, airborne measurements

## Introduction

Operational prediction centers typically use decoupled models to predict air quality and weather due to the low computational costs. With the fast increase in computing power, integrated modeling systems become more attractive enabling us to better understand and simulate feedback processes between pollutants in the atmosphere and the weather itself. We use the WRF-Chem model, which accounts for a fully consistent treatment of pollutants with the meteorological fields (Grell et al., 2005). All transport is calculated on the identical model grid structure with identical time increments, and a suite of physical and chemical parameterization schemes account for improved processing and understanding of the feedback between air quality and weather. A biomass burn emissions and a sub-grid scale plume rise model (Freitas et al., 2007) has been coupled with WRF-Chem originally within Version 3.1 in 2007. Grell and others (2011) have shown the modeled impact of emissions from extreme Alaska wildfires on the weather in terms of changed radiative fluxes and precipitable water in the polluted atmosphere.

In recent years, we successfully used the WRF-Chem model to operationally predict wildfire particulate matter (PM2.5 and PM10), black carbon and organic carbon concentrations downwind from Alaska wildfires (http://smoke.arsc.edu/). The system ingests wildfire locations and sizes detected by satellite remote sensing as model source data. We also receive fire information from the Alaska Interagency Coordination Center, which manages Alaska wildfires

and coordinates suppression efforts. The fire source data are automatically mapped into the modeling domain. Emission rates are calculated in a bottom-up approach, and depend on combustion factors, the amount of aboveground biomass, emission factors, and emissions are directly proportional to the fire size. We compared fields of airborne fire pollutants with satellite imagery, and used particulate measurements from state and National Park observational sites to confirm an overall good model performance. However, main operational uncertainties have been associated with the fire data.

#### **Fire Source Data**

Active fire detection from satellite remote sensing offers the most practical and consistent technique to initialize smoke emissions injection locations over a geographically extended domain (tens of thousands of km2) in near-real time. Active fire products from the Moderate Resolution Imaging Spectroradiometer (MODIS) sensors on the Terra (MOD14) and Aqua (MYD14) polar-orbiting satellite platforms are available as daily datasets including location, size and detection time of thermally anomalous MODIS pixels (Justice et al., 2002).

In an effort to improve the MODIS fire source, we further characterize the active fire component. The thermal anomaly is modeled via a two-channel approach, following Matson and Dozier (1981). We have found a significant volume of errors of omission MOD14 and MYD14 products for the boreal forest wildfires in particular in the areas of lower-intensity residual burn. Therefore, we use MODIS calibrated at-sensor radiances. Dozier's retrieval yields more accurate active fire areas and temperatures with non-saturated radiance data.

We also work on implementation the more modern Visible Infrared Imaging Radiometer Suite (VIIRS) sensor aboard the Suomi/NPP platform. VIIRS data include several thermal infrared bands and a specialized mid-infrared (4  $\mu$ m) band designed for the detection of high-temperature signals. Among its advantages are a higher spatial resolution and less severe pixel size variation (from 0.78 by 0.74 km at nadir to approximately 1.6 by 1.6 km at the swath edge of its moderate resolution bands) when compared to MODIS (from 1 by 1 km to 4.8 km in along-scan direction by 2 km along-track). Both MODIS and, since 2013, VIIRS data are downlinked and processed at the University of Alaska by the Geographic Information Network of Alaska (GINA). The locally available products include calibrated radiances (MODIS L2B, VIIRS SDS) and the MOD14 and MYD14 thermal anomalies products. Barring clouds, at least 8 suitable MODIS scenes as well as two or three VIIRS scenes are available daily at the sub-arctic latitudes of interior Alaska.

## **Aerial Observations of Fires and Emissions**

We conducted flights with a single engine Piper PA12 bush-plane type aircraft with a GRIMM Model 1.129 Sky OPC Aerosol Spectrometer (http://www.grimm-aerosol.com ) installed. The spectrometer nozzle was attached to the wing strut of the plane in some distance from the slipstream of the aircraft propeller (Fig .1). In addition a broadband thermal infrared camera (FLIR A655sc) was mounted inside the fuselage for assessing fire intensity. The camera optics were pointed vertically downward through a dedicated window at the bottom of the aircraft

fuselage. The FLIR camera fire temperature and area measurements have been used in case studies comparing the remote sensing fire products outlined above. Figure 2 gives an example of aerosol spectrometer measurements to a wildfire in proximity to Fairbanks, Alaska. We approached the fire at the top of the plume at 10,000 feet, and spiraled within the plume to few hundred feet above the fire. The PM10 measurements compared well with the magnitudes of concentrations along the flight-path.

Our observational flights will be continued during future fire seasons in Interior Alaska. Further measurements of particle concentrations are needed to better understand wildfire emissions and plume dynamics. Improved fire detection and characterization with new VIIRS fire products and MODIS thermal anomaly data will support fire management and also account for better prediction of the associated polluted air. We plan to use WRF-Chem operationally during the upcoming Alaska fire seasons.

#### Acknowledgements

We gratefully acknowledge support from the Alaska Department of Natural Resources, the Arctic Region Supercomputing Center of the University of Alaska Fairbanks, and the US Air Force. Support was received from the NASA Earth System Science (ESS) Fellowship Program.

## References

Freitas SR, Longo KM, Chatfield R, Latham D, Silva Dias MAF, Andreae MO, Prins E, Santos JC, Gielow R, and Carvalho Jr. JA (2007). Including the sub-grid scale plume rise of vegetation fires in low resolution atmospheric transport models. *Atmospheric Chemistry and Physics* 7, 3385–3398.

Grell GA, Peckham SE, Schmitz R, McKeen SA, Frost G, Skamarock WC, and Eder B (2005). Fully Coupled "online" Chemistry Within the WRF Model. *Atmospheric Environment 39*, 6957–6975.

Grell G, Freitas S, Stuefer M, and Fast J (2011). Inclusion of biomass burning in WRF-Chem: impact of wildfires on weather forecasts. *Atmos. Chem. Phys* 11, 5289–5303.

Justice CO, Giglio L, Korontzi S, Owens J, Morisette JT, Roy D, Descloitres J, Alleaume S, Petitcolin F, Kaufman Y (2002). The MODIS fire products. *Remote Sensing of Environment*, 83(1-2), 244–262. doi:10.1016/S0034-4257(02)00076-7

Matson M, Dozier J (1981). Identification of subresolution high temperature sources using a thermal IR sensor. *Photogrammetric Engineering and Remote Sensing*, 47(9), 1311–1318.

## Figures:



Figure 1: Aerial observations of wildfires with a Piper aircraft (right top insert). The large picture was taken on top of the Dry Crekk Fire plume near Fairbanks, Alaska. The left inserts show CO2 measurement data (top) and a FLIR camera thermal infrared image (bottom).



Figure 2: Particulate matter (PM10) emitted from the Dry Creek fire near Fairbanks, Alaska, in 2012. Left are observed PM10 concentrations derived from a GRIMM spectrometer, right are the WRF-Chem modeled concentrations. The red dot indicates Fairbanks International Airport.

# Spatio-temporal estimation of gaseous and particle emissions from a major Australian wildfire

Nicholas C. Surawski<sup>A</sup> Andrew L. Sullivan<sup>A</sup> Stephen H. Roxburgh<sup>A</sup> Carl (Mick) P. Meyer<sup>B</sup>

<sup>A</sup>CSIRO Ecosystem Sciences and CSIRO Sustainable Agriculture Flagship, Clunies Ross St, Acton, ACT 2601, Australia, <u>Nicholas.Surawski@csiro.au</u> <u>Andrew.Sullivan@csiro.au</u>, <u>Stephen.Roxburgh@csiro.au</u> <sup>B</sup>CSIRO Marine and Atmospheric Research, 107-121 Station St, Aspendale, VIC 3195, Australia Carl.Meyer@csiro.au

#### Abstract:

This study investigates the spatio-temporal evolution of greenhouse gas and particle emissions from a devastating Australian wildfire (the 2009 Kilmore East fire); which set new extremes in terms of fire weather, loss of life, and damage to assets and infrastructure [*Cruz et al.*, 2012]. Emissions estimates were derived using the Seiler and Crutzen method [*Seiler and Crutzen*, 1980], using information from laboratory-based measurements of fire emissions, state agency and remotely sensed data, estimates determined from the literature and expert judgement to enable this calculation technique to be applied in a spatio-temporal manner. The results show that approximately 63 % of total greenhouse gas equivalent emissions from the Kilmore East fire were derived from coarse woody fuels, 22 % were from surface fuels, 7 % from bark, 5 % from elevated fuels, whilst only 2% of total emissions were derived from crown fuels. Approximately 76 % of total greenhouse gas emissions for the Kilmore East fire were from black carbon (BC) about 6 % from methane and about 2 % from N<sub>2</sub>O. The emissions estimates from the current study are compared with other sources and reasons for discrepancy in these estimates are identified.

Additional Keywords: Wildfire, greenhouse gas emissions, particle emissions

#### Introduction

The estimation of gaseous and particulate emissions from wildfire is often based on broad assumptions about the area burnt, fuel consumed, and also emission factors. Rarely is it possible to have detailed information on the various eco-physical parameters which enable a more process-driven emissions estimate to be derived. There is, therefore, a need for the accounting of wildfire emissions to consider more carefully the various eco-physical factors that influence the components that go into the final emissions calculation.

Due to the unique magnitude of the Kilmore East fire in terms of fire weather, fire behaviour and loss to life, property and infrastructure it is a reasonably well studied fire [*Cruz et al.*, 2012; *Cruz et al.*, 2010; *Paton-Walsh et al.*, 2012; *Teague et al.*, 2010], making it a suitable fire event to use as a case study to estimate emissions. In particular, there is sufficient data available to attempt a bottom-up estimate of emissions using the ubiquitously employed Crutzen and Seiler [1980]

technique. It is intended that the results from this study are a useful input for air quality and climate models that consider fire as a disturbance.

## Methods

A variety of data sources were used to apply the Seiler and Crutzen technique in a spatiotemporal manner. A fire severity layer was developed by *Cruz et al.* [2012] based on pre-fire and early and late post-fire Landsat Thematic Mapper (TM 5) images. This satellite imagery enabled a patchiness correction to be applied to the fire scar and enabled the identification of previously burnt grassland. Fuel loads were obtained by state agency data (Victorian Department of Sustainability and Environment) which predicted fuel loads based on the time since the last fire. Two different methods were applied to estimate combustion and emission factors. The first method used expert judgement values for combustion factors (in the absence of published data) and the second method used combustion factors for surface fuels based on laboratory experiments conducted in a combustion wind tunnel facility. Literature values for emissions factors derived from *Andreae and Merlet* [2001] and *Akagi et al.* [2011] for temperate forest were used initially and a revised estimate of emissions factors from laboratory tests performed on surface fuels were also used. Emissions mapping was performed in ArcGIS v10.0 with some further post-processing work done in Mathworks Matlab.

A critical part of this emissions case study was to perform an expert judgement exercise to map the areas within the fires scar that burnt as either a heading, flanking or backing fire. Mapping the fire type with respect to time enabled spatial application of the laboratory derived emissions factors which explored the role of fire type on emissions.

## Results

Figure 1 shows a schematic of fire behaviour for the Kilmore East fire which is useful for understanding the results presented in this article. The fire was apparently ignited by arcing from a broken power line situated in the north-west corner of the map shown in Figure 1 [*Teague et al.*, 2010]. The fire was initially fanned by very strong north-westerly winds (with wind gusts up to 90 km/h) which created a very long and narrow heading fire to develop (shown by the yellow-red isochrones in Figure 1). The arrival of a cold front at about 6 PM shifted the prevailing wind direction to the south-west which turned a long flanking fire into a large heading fire.

Figure 2 shows the cumulative burnt area and fuel consumed for the Kilmore East fire. From both graphs a sigmoidal relationship between burnt and fuel consumed with respect to time can be observed. This pattern is consistent with the fire behaviour isochrones shown in Figure 1 where most of the burnt area and fuel consumed occurred after a wind change associated with the passage of a cold front. After completion of the tenth burning period (at midnight on the 7<sup>th</sup> February 2009) approximately 100 000 hectares (ha) of land was burnt with about 7 000 hectares of the total burnt area consisting of previously burnt grassland from prescribed burning operations. Based on a fire behavior expert judgement exercise, about 33 % of total burnt area is from heading fires, 63 % from flanking fire, 8 % from high intensity flanking fire and only 4 % from backing fire. About 63 % of total fuel consumed was from coarse woody material (> 6 mm in diameter); about 22 % of total fuel consumption was from surface fuels, about 7 % from bark consumption, about 5 % from elevated fuel consumption and about 2 % from crown fuels.



Figure 1: A schematic of fire behaviour for the 2009 Kilmore East fire.





Figure 2 shows cumulative greenhouse gas equivalent emissions for  $CO_2$ ,  $CH_4$ ,  $N_2O$  and BC. Note that all of the emissions with greenhouse forcing have been multiplied by the relevant global warming potential to get greenhouse gas (i.e.  $CO_2$ ) equivalent emissions. Once again a sigmoidal pattern can be observed with respect to time for greenhouse emissions, as was the case for burnt area and fuel consumed. As was the case for fuel consumed, about 63 % of total greenhouse gas equivalent emissions were derived from coarse woody material, about 22 % from surface fuels, 7 % from bark, 5 % from elevated fuels and only 2 % from crown fuels.  $CO_2$  emissions constitute 76 % of total greenhouse gas equivalent emissions, 15 % is from BC, 6 % from methane and only 2 % from  $N_2O$ .

As described in the methods section of this article, emissions estimates were derived based on expert judgement values for combustion factors and fire behaviour, but laboratory based

estimates were also made on combustion and emission factors. Consequently, this enables a comparison to be made between emissions estimates derived from the literature (and with expert judgement) to those obtained from laboratory based work. A comparison of emissions estimates was not possible for BC as the use of Teflon filters during experimental work prevented an accurate BC measurement to be made. There is excellent agreement between surface fuel consumed and  $CO_2/CH_4$  emissions for both of these techniques; however, N<sub>2</sub>O emissions are not in good agreement. Surface fuel consumed and CO<sub>2</sub> emissions have best fit slopes of 0.989 and 0.999 respectively so both methods are in excellent agreement for these two quantities. Methane emissions are higher than those derived from the literature method by about 6 %, which is due to the slightly higher emissions factors ( $\leq 0.53$  %) compared to those derived from the literature (0.39 %). As for the disagreement between both methods for N<sub>2</sub>O emissions, the laboratory derived emissions factors are lower by a factor of four compared with those published in temperate forest by Akagi et al. [2011]. This discrepancy is due to the lower nitrogen-to-carbon ratios for eucalyptus vegetation in Australia compared with temperate forest globally and due to the reasonably tight modified combustion efficiency range achieved during experiments (77-93 %) which does not fully capture emissions from smouldering combustion.



**Figure 3:** Cumulative greenhouse gas equivalent emissions for CO<sub>2</sub> (top left panel), CH<sub>4</sub> (top right panel), N<sub>2</sub>O (bottom left panel) and BC (bottom right panel).

Emissions maps were prepared for the Kilmore East fire and are shown in Figure 5. Emissions of all greenhouse species are dominated by those occurring in wet sclerophyll forest (dominated by *E. Regnans*) which are, globally, the world's most carbon dense forests that been quantified [*Keith et al.*, 2009]. A significant emissions contribution also emanates from mixed dry-wet sclerophyll stands dominated by *E. obliqua* and *E. globulus*. Previously burnt grassland occupying about 7 000 ha is shown as white in Figure 5. Also, it can be observed from Figure 5 that distinct "banding" occurs in the emissions estimates in the larger burn periods. This is due to the parameterisation of combustion factors and emission factors with respect to fire type (e.g. heading, backing and flanking) which formed part of the expert judgement exercise.



**Figure 4:** Comparison of surface fuel consumed and CO<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O emissions between literature (and expert judgement derived values) and those obtained experimentally. Solid black lines show the best linear fit (with intercepts forced to zero) and dashed black lines show the curve for exact agreement. Best fit slopes are 0.989 for surface fuels (top left panel), 0.999 for CO<sub>2</sub> (top right panel), 1.059 for CH<sub>4</sub> (bottom left panel), 0.222 for N<sub>2</sub>O (bottom right panel).

Proceedings of the International Smoke Symposium October 21-24, 2013, Hyattsville, Maryland, USA Published by the International Association of Wildland Fire, Missoula, Montana, USA



Figure 5: Emissions maps (t/ha) for CO<sub>2</sub>, CH<sub>4</sub>, BC and N<sub>2</sub>O for the Kilmore East fire.

#### Comparison of emissions estimates with other results

Recently, emissions estimates were quantified by *Paton-Walsh et al.* [2012] for the Kilmore East fire using a combination of new (or existing) top-down and bottom-up methods. Paton-Walsh estimated emissions from the Kilmore East fire using the Fire Inventory from NCAR version 1 (FINNv1) [*Wiedinmyer et al.*, 2011] and also compared their top-down estimates with GFED v3.1 [*van der Werf et al.*, 2010]. Paton-Walsh et al. also estimated emissions using a correlation

between aerosol optical depth and fire emissions; however, this comparison is not shown as estimates for  $CO_2$ ,  $CH_4$  and BC were not available for this technique.

All emissions estimates (in addition to those derived in this study) are shown in Table 2 and are scaled to an equivalent burnt area (i.e. 100 000 ha) to enable comparisons to be made. Over the month of February 2009 around 450 000 ha of land was burnt and around 100 000 ha was burnt on the 7<sup>th</sup> February. However, GFEDv3.1 only estimates 267 200 ha of burnt area (for February) and FINNv1 estimates 141 200 ha of burnt area.

Numerically, the three emissions estimates are in good agreement although the estimates from FINNv1 are significantly (31-47 %) lower than those from GFEDv3.1. The current estimates are in best agreement with GFEDv3.1 for  $CO_2$  and BC whilst better agreement is achieved with FINNv1 for  $CH_4$ . In terms of finding reasons for these discrepancies, since the emissions estimates in Table 2 are scaled to the same burnt area, any differences are due to variations in the combustion and emission factors used and also fuel load since all techniques use the bottom-up Seiler and Crutzen method to estimate emissions. The emissions factors in GFEDv3.1 are based on *Andreae and Merlet* [2001], whilst FINNv1 uses *Akagi et al.* [2011] in addition to Andreae and Merlet. Emissions factors for greenhouse species has not changed drastically between Andreae and Merlet and its revision (i.e. Akagi et al.), hence differences in emissions factors are not driving the observed discrepancies.

Although further work needs to be completed, the parameterisation of combustion factors differs markedly between FINNv1 and GFEDv3.1 which suggests a potential source of discrepancy. FINNv1 parameterises combustion factors based on a relationship with tree cover. For coarse woody fuels (which dominate the fuel load in this study) the combustion factor is 0.3 with greater than 60 % tree cover, whilst no woody fuel consumption is assumed to occur for tree cover less than 40 %. Conversely, the mean combustion factor for woody fuel in GFEDv3.1 is 50%. Based on unpublished observations by the authors, the combustion factor used in GFEDv3.1 is in better agreement with that observed in Australian temperate forest and consequently gives emissions estimates in better agreement with those observed in the current study. Hence, the combustion factor is a likely source of discrepancy and underscores the need to improve estimates of this parameter globally [*Bond et al.*, 2013].

Table 2: Comparison of emissions estimates for the Kilmore East fire scaled to an equivalen	t
burnt area.	

	<b>Emissions</b> (Gigagrams)			
Compound	Current study	FINNv1	GFEDv3.1	
CO <sub>2</sub>	7370	5130	6740	
CH <sub>4</sub>	17.6	15.6	20.6	
BC	2.5	1.6	2.4	

# Conclusions

Emissions of key greenhouse species have been estimated for a major Australian wildfire in a spatio-temporal manner. Fuel consumed and emissions are driven strongly by the combustion of coarse woody fuels. Emissions from this fire event are dominated by those from  $CO_2$ . For surface fuels,  $CO_2/CH_4$  emissions agree very well based on a comparison between literature derived and laboratory derived emission factors, although considerable disagreement is observed for N<sub>2</sub>O. Surface fuel consumption agrees very well between the expert judgement and laboratory derived combustion factors. Comparison of greenhouse emissions were made with other data sources and it was found that the parameterisation of combustion factors played a critical role in the relative agreement between different methods. It is worth noting that sufficient data to undertake a fully bottom-up emissions estimate is generally not possible and top-down emissions estimates (i.e. from remote sensing) can be subject to considerable error. Altogether, this suggests a continued need for scientists working in either (or both) disciplines to work together to better quantify the varied impacts of wildland fire. **References:** 

Akagi, S. K., R. J. Yokelson, C. Wiedinmyer, M. J. Alvarado, J. S. Reid, T. Karl, J. D. Crounse, and P. O. Wennberg (2011), Emission factors for open and domestic biomass burning for use in atmospheric models, *Atmospheric Chemistry and Physics*, *11*(9), 4039-4072.

Andreae, M. O., and P. Merlet (2001), Emission of trace gases and aerosols from biomass burning, *Global Biogeochemical Cycles*, *15*(4), 955-966.

Bond, T. C., et al. (2013), Bounding the role of black carbon in the climate system: A scientific assessment, *Journal of Geophysical Research-Atmospheres*, *118*(11), 5380-5552.

Cruz, M. G., A. L. Sullivan, J. S. Gould, N. C. Sims, A. J. Bannister, J. J. Hollis, and R. J. Hurley (2012), Anatomy of a catastrophic wildfire: the Black Saturday Kilmore East fire in Victoria, Australia, *Forest Ecology and Management*, 284, 269-285.

Cruz, M. G., A. Sullivan, R. Hurley, N. Sims, J. Gould, G. Mattingley, T. Wells, and J. Hollis (2010), The Kilmore East fire: progression and behaviour, 1-79 pp, CSIRO, Canberra, ACT, Australia.

Keith, H., B. G. Mackey, and D. B. Lindenmayer (2009), Re-evaluation of forest biomass carbon stocks and lessons from the world's most carbon-dense forests, *Proceedings of the National Academy of Sciences of the United States of America*, *106*(28), 11635-11640.

Paton-Walsh, C., L. K. Emmons, and C. Wiedinmyer (2012), Australia's Black Saturday fires - comparison of techniques for estimating emissions from vegetation fires, *Atmospheric Environment*, *60*, 262-270.

Seiler, W., and P. J. Crutzen (1980), ESTIMATES OF GROSS AND NET FLUXES OF CARBON BETWEEN THE BIOSPHERE AND THE ATMOSPHERE FROM BIOMASS BURNING, *Climatic Change*, 2(3), 207-247.

Teague, B., R. McLeod, and S. Pascoe (2010), 2009 Victorian Bushfires Royal Commission. Final Report Summary.*Rep.*, 1-42 pp, State of Victoria, Melbourne.

van der Werf, G. R., J. T. Randerson, L. Giglio, G. J. Collatz, M. Mu, P. S. Kasibhatla, D. C. Morton, R. S. DeFries, Y. Jin, and T. T. van Leeuwen (2010), Global fire emissions and the contribution of deforestation, savanna, forest, agricultural, and peat fires (1997-2009), *Atmospheric Chemistry and Physics*, *10*(23), 11707-11735.

Wiedinmyer, C., S. K. Akagi, R. J. Yokelson, L. K. Emmons, J. A. Al-Saadi, J. J. Orlando, and A. J. Soja (2011), The Fire INventory from NCAR (FINN): a high resolution global model to estimate the emissions from open burning, *Geoscientific Model Development*, *4*(3), 625-641.

#### **Recent emissions research in southwestern shrub and grassland fuels**

David R. Weise<sup>A</sup> Wayne Miller, David R. Cocker, III, Heejung Jung, Seyedehsan Hosseini, Marko Princevac<sup>B</sup> Robert J. Yokelson, Ian Burling, Sheryl Akagi<sup>C</sup> Shawn Urbanski, WeiMin Hao<sup>D</sup>

<sup>A</sup>USDA Forest Service, PSW Research Station, 4955 Canyon Crest Dr., Riverside, CA 92507, dweise@fs.fed.us
 <sup>B</sup>University of California – Riverside, Bourns College of Engineering, 900 University Ave., Riverside, CA 92521, <u>wayne.miller@ucr.edu</u>
 <sup>C</sup>The University of Montana, Department of Chemistry and Biochemistry, Missoula, MT 59812, bob.yokelson@mso.umt.edu
 <sup>D</sup>USDA Forest Service, RM Research Station, 5775 W US Highway 10, Missoula, MT 59808-

9361, surbanski@fs.fed.us

#### Abstract:

While it is currently challenging to use prescribed burning in chaparral and other southwestern shrub fuel types due to many constraints, any such activities require smoke management planning. Information on fuels and emissions from chaparral were limited and based on older sampling systems. The DoD SERDP program funded a project to measure fuels and smoke emissions in the laboratory and field. In February 2009, 49 dry, compact fuel beds from six chaparral fuel types, two Emory oak fuel types, and masticated mesquite were burned at the Missoula Fire Sciences Lab and smoke emissions were sampled. Emission factors for CO, CO<sub>2</sub>, NO<sub>x</sub>, PM, and for many previously unmeasured gaseous and particulate emissions were derived. Emission factors of some compounds differed between fuel types (Burling et al. 2010; Hosseini et al. 2010, 2013). Several other research groups performed measurements on the laboratory fires as well (Roberts et al. 2010, 2011; Veres et al. 2010; Warneke et al. 2011). We also successfully measured fuels and sampled emissions from the ground and an aircraft on two prescribed burns in chaparral and one in Emory oak woodland (Burling et al. 2011; Johnson et al. 2013). Smoke emissions were measured on three additional chaparral fires including one in which we followed the plume nearly 32 km downwind from an airborne platform. Concentrations of many compounds increased in the plume as the smoke aged and chemical reactions continued (Akagi et al. 2012). While the laboratory and field fuel beds were markedly different in terms of moisture content and bulk density, many of the laboratory-derived emission factors correlated well with field-derived emission factors (Miller 2013; Yokelson et al. 2013). The aircraft data were then compared to smoke transport-dispersion predictions using the current air quality tools (CMAO, BlueSky, and SMARTFIRE). While it was not possible to perform statistical comparison given the sample size, of the three air quality tools examined, BlueSky produced predictions which compared favorably with observed data (Miller 2013). Emission factors derived in this study and in a companion study (RC-1649, Johnson et al. 2013) as well as emission factors previously published in a variety of refereed and gray literature have been

compiled into the Wildland Fire Emission Factors Database which is available from the Forest Service National Data Archive (Lincoln et al. 2013).

**Acknowledgement:** The financial support provided by the Department of Defense SERDP projects RC-1648 and RC-1649 and the logistical support provided by Ft. Huachuca, Ft. Hunter-Liggett, and Vandenberg AFB to conduct the prescribed burns are appreciated.

## References

Akagi SK, Craven JS, Taylor JW, McMeeking GR, Yokelson RJ, Burling IR, Urbanski SP, Wold CE, Seinfeld JH, Coe H, Alvarado MJ, Weise DR (2012) Evolution of trace gases and particles emitted by a chaparral fire in California. *Atmospheric Chemistry and Physics* **12**, 1397-1421.

Burling IR, Yokelson RJ, Akagi SK, Urbanski SP, Wold CE, Griffith DWT, Johnson TJ, Reardon J, Weise DR (2011) Airborne and ground-based measurements of the trace gases and particles emitted by prescribed fires in the United States. *Atmospheric Chemistry and Physics* **11**, 12197-12216.

Burling IR, Yokelson RJ, Griffith DWT, Johnson TJ, Veres P, Roberts JM, Warneke C, Urbanski SP, Reardon J, Weise DR, Hao WM, de Gouw J (2010) Laboratory measurements of trace gas emissions from biomass burning of fuel types from the southeastern and southwestern United States. *Atmospheric Chemistry and Physics* **10**, 11115-11130.

Chang-Graham AL, Profeta LTM, Johnson TJ, Yokelson RJ, Laskin A, Laskin J (2011) Case study of water-soluble metal containing organic constituents of biomass burning aerosol. *Environmental Science and Technology* **45**(**4**), 1257-1263.

Hosseini S, Qi L, Cocker D, Weise D, Miller A, Shrivastava M, Miller JW, Mahalingam S, Princevac M, Jung H (2010) Particle size distributions from laboratory-scale biomass fires using fast response instruments. *Atmospheric Chemistry and Physics* **10**, 8065-8076.

Hosseini S, Urbanski S, Dixit P, Li Q, Burling I, Yokelson R, Johnson T, Sharivastava M, Jung H, Weise DR, Miller W, Cocker D. (2013) Laboratory characterization of PM emissions from combustion of wildland biomass fuels. *Journal of Geophysical Research – Atmospheres* **118**(17), 9914-9929.

Johnson TJ, Sams RL, Profeta LTM, Akagi SK, Burling IR, Yokelson RJ, Williams SD (2013) Quantitative IR spectrum and vibrational assignments for glycolaldehyde vapor: glycolaldehyde measurements in biomass burning plumes. *The Journal of Physical Chemistry A* **117(20)**, 4096-4107.

Johnson TJ; Yokelson RJ; Akagi SK; Burling IR; Weise DR; Urbanski SP; Stockwell CE; Lincoln EN; Profeta LTM; Mendoza A; Schneider MDW; Sams RL; Williams SD; Wold CE; Griffith DWT; Cameron M; Gilman JB; Warneke C; Roberts JM; Veres P; Kuster WC; de Gouw J. 'Final Report for SERDP Project RC-1649: Advanced Chemical Measurements of Smoke

from DoD-prescribed Burns.' 295 p. http://

Lincoln E; Hao W; Weise DR; Johnson TJ (2013) 'Wildland Fire Emission Factor Database.' USDA Forest Service National Research Data Archive, http://

Miller, W (2013) 'New tools for estimating and managing local/regional air quality impacts of prescribed burns.' College of Engineering, Center for Environmental Research and Technology

(CE-CERT) University of California, Riverside Final Report SERDP Project RC-1648. (Riverside, CA). http://

Roberts, JM, Veres P, Warneke C, Neuman JA, Washenfelder RA, Brown SS, de Gouw J (2010). Measurement of HONO, HNCO, and other inorganic acids by negative-ion proton-transfer chemical-ionization mass spectrometry (NI-PT-CIMS): application to biomass burning emissions. *Atmospheric Measurement Techniques* **3**(**4**), 981-990.

Roberts JM, Veres PR, Cochran AK, Warneke C, Burling IR, Yokelson RJ, Lerner B, Gilman JB, Kuster WC, Fall R, de Gouw J (2011) Isocyanic acid in the atmosphere and its possible link to smoke-related health effects. *Proceedings of the National Academy of Science* **108(22)**, 8966-8971.

Warneke C, Roberts JM, Veres P, Gilman J, Kuster WC, Burling I, Yokelson R, de Gouw JA (2011) VOC identification and inter-comparison from laboratory biomass burning using PTR-MS and PIT-MS. *International Journal of Mass Spectrometry* **303**, 6-14.

Veres P, Roberts JM, Burling IR, Warneke C, de Gouw J, Yokelson RJ (2010). Measurements of gas-phase inorganic and organic acids from biomass fires by negative-ion proton-transfer chemical-ionization mass spectrometry. *Journal of Geophysical Research* **115(D23)**, D23302. Yokelson RJ, Burling IR, Gilman JB, Warneke C, Stockwell CE, de Gouw J, Akagi SK, Urbanski SP, Veres P, Roberts JM, Kuster WC, Reardon J, Griffith DWT, Johnson TJ, Hosseini S, Miller JW, Cocker DR III, Jung H, Weise DR (2013) Coupling field and laboratory measurements to estimate the emission factors of identified and unidentified trace gases for prescribed fires. *Atmospheric Chemistry and Physics* **13**, 89-116.

# Detecting and Quantifying Rangeland Burning Using Remotely Sensed Burned Area and Active Fire Data: A Case Study of Western Minnesota

Jessica L. McCarty<sup>A</sup> Steve Shumacher<sup>B</sup> Amber J. Soja<sup>C</sup> David M. Banach<sup>A</sup>

<sup>A</sup>Michigan Tech Research Institute (MTRI), 3600 Green Court, Suite 100, Ann Arbor, MI, jmccarty@mtu.edu and dmbanach@mtu.edu
 <sup>B</sup>U.S. Fish and Wildlife Service, Detroit Lakes WMD, 26624 N. Tower Road, Detroit Lakes, MN 56501, Steve\_Shumacher@fws.gov
 <sup>C</sup>Institute of Aerospace (NIA), NASA Langley Research Center, Hampton, VA, amber.j.soja@nasa.gov

## Abstract:

Rangeland burning in the Great Plains of the contiguous United States is often a component of land management for preserving and/or promoting native vegetation, expanding and improving wildlife habitat, improving foragability for livestock and wildlife, and controlling invasive species. This study focused on a rangeland area of western Minnesota actively managed with prescribed burning by the U.S. Fish and Wildlife Service (USFWS) for wildlife habitat, native grasses, and reduction of fire danger in peatlands. The objective of this analysis was to determine if coarse resolution global satellite-based burned area and active fire products as well as moderate resolution satellite burn scar data could be used to detect and quantify these numerous but small scale management burns being conducted in a short time period. Satellite-based fire data and products could then potentially be used to monitor small-scale prescribed events, as well as prove to be important inputs into ecological, landscape, and atmospheric emission models, including managing the impact of smoke from rangeland and peatland fires on local populations and fire response units.

Additional Keywords: Rangeland, prescribed fires, remote sensing, fieldwork, Minnesota, peatlands

## Introduction

Prescribed burning is a common practice throughout the contiguous United States. The National Association of State Forester's and the Coalition of Prescribed Fire Council's 2012 National Prescribed Fire Use Survey Report estimated a total of 20.2 million acres of prescribed burning from forestry and agriculture took place in 2012 (Melvin 2012). This analysis focused on a rangelands of western Minnesota actively managed with prescribed burning by the U.S. Fish and Wildlife Service (USFWS) for wildlife habitat, native grasses, and reduction of fire danger in peatlands – which has strong negative impacts on local air quality. Land use in this region ranges from established, mechanized cropland areas to wooded peatlands to the native and recovering prairies and rangelands targeted in this analysis. Because of the heterogeneous land use, prescribed and wildland fire are both a concern. The area of study covers five counties of

Minnesota; Becker, Clay, Mahnomen, Norman, and Polk (approximately 6,000 miles<sup>2</sup> /15,539 km<sup>2</sup>; Figure 1). Wildland fires in and/or prescribed fires spreading to the peatland areas is possible and these wildland fires were included in this analysis.



**Figure 1.** The study area in western Minnesota where prescribed burning was conducted by the U.S. Fish & Wildlife Service.

The objective of this analysis was to determine if coarse resolution global satellite-based burned area and active fire products as well as moderate resolution satellite burn scar data could be used to detect and quantify these numerous but small scale management burns being conducted in a short time period. Satellite-based fire data and products could then potentially be used to monitor small-scale prescribed events, as well as prove to be important inputs into ecological, landscape, and atmospheric emission models, including managing the impact of smoke from rangeland and peatland fires on local populations and fire response units.

## **Material and Methods**

#### Fieldwork and ground truth data

Between 15 and 25 October 2012, fieldwork was conducted in western Minnesota and eastern North Dakota. Fire Information for Resource Management System (FIRMS; earthdata.nasa.gov/data/near-real-time-data/firms) data was acquired daily to determine the

locations of fires detected by the Moderate Resolution Imaging Spectroradiometer (MODIS) sensors (Figure 2). The 1 km MODIS active fire data can detect fires as small 100 m<sup>2</sup> (Giglio *et al.* 2003), which is approximately 10 times smaller than the average USFWS rangeland fire perimeter polygons used in this study. The 30 USFWS fire perimeter polygons collected on-site at the time of the prescribed burning were considered to be the ground truth data in this analysis. The resulting polygon shapefile datasets include the date of the burn and burn type, indicated as RX for prescribed and WF for wildfire. The fire perimeter shapefiles were divided into the management years of 2011 and 2012 but the time of day of the burns was not recorded in the metadata. MODIS Active Fire points were buffered to a diameter of 1 km and any USFWS fire perimeter that fell within or touched the boundary of the 1 km buffer during the same day of burning was considered an accurate satellite fire detection of the USFWS fire.



**Figure 2.** MODIS Active Fire locations detected during October 2012 fieldwork (top) and the sites visited during fieldwork (bottom).

Data collected included locational, vegetation, land use, agriculture/cropland, and burn/ecosystem classification information (Figure 4). Locational data included the state, county, and latitude and longitude, which were acquired using a Trimble GPS unit. Cropland and land use data included the USDA NASS Cropland Data Layer (CDL;

http://www.nass.usda.gov/research/Cropland/sarsfaqs2.html) value, combustion completeness percentage, and soil class and type. The burn/ecosystem classification includes information pertaining to if any burn/scar was visible or if the burned area had been recently disturbed. Ecosystem descriptions included the type (bog, fen, marsh, etc.) dominant species, and lesser species. In some instances, a MODIS Active Fire detection was deemed to be a false detection due to either lacking evidence of a burn or recent disturbance to the site (i.e., tilling, irrigation).

#### Remote Sensing Analysis

This analysis used a combination of satellite-based fire and land cover products as well as GIS soils data and field data, including the burn perimeters collected by the USFWS during the prescribed burning events. While the majority of fires utilized in this study were prescribed, 5 of the 30 fires during 2011 and 2012 monitored by the USFWS were wildfires.

The MODIS Burned Area product (MCD45A1) detects burned areas by considering spectral, temporal, and vegetation structural changes (Figure 3) (Roy *et al.* 2007; Roy *et al.* 2008). The spatial resolution of 500 m, equivalent to 25 ha, is sufficient enough for mapping agricultural burning (McCarty *et al.* 2008; 2009; 2012). The daily temporal resolution of this dataset is also ideal for temporal matching of a spatially contiguous USFWS burn scar within  $\pm$  8 days.



**Figure 3.** MODIS Burned Area Product MCD45A1 version 5 product for Becker County, Minnesota for April 2012.

Evaluating the sensitivity of a cropland-specific fire product to rangeland burning within a mixed cropland-rangeland landscape analysis was conducted by combining the 8-day MODIS differenced Normalized Burn Ratio (dNBR) with spatial and temporal data for prescribed fires conducted throughout western Minnesota (Figure 4). The NBR was calculated from each pre-processed composite, and then burned areas were identified through differencing of the NBR (dNBR) between pre- and post-burn images. This product was developed by McCarty for use in calculating cropland burning emissions (McCarty *et al.* 2008) and is currently used by the EPA in the National Emissions Inventory.



Figure 4. MODIS Cropland dNBR product for Becker and Clay counties for November 2011.

Burn scars were digitized from uncorrected 30 m Landsat Enhanced Thematic Mapper Plus (ETM+) composites of bands 7, 4, and 2, representing the shortwave infrared, middle infrared, and green wavelengths of the electromagnetic spectrum, respectively (Figure 5). Landsat ETM+ data was available for 2012 and prescribed burned area polygons were digitized.



**Figure 5.** Example of Landsat 7 ETM+ burn scar. Date of prescribed fire: 3 April 2012 and date of image: 12 April 2013.

Finally, soils and fuels data were acquired from the Soil Survey Geographic Database (SSURGO; http://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm) and US Forest Service Fuels Characteristic Classification System (FCCS; http://www.fs.fed.us/pnw/fera/fccs/), which provides soil and fuel information that can be displayed as tables or maps. The unique soil and fuel type identifier or combination of two equally dominant identifiers that comprised the majority of each USFWS fire perimeter were extracted from these datasets.

## Results

After the analysis of the remote sensing data as compared to ground truth and USFWS data, it was determined that the remote sensing products were not spatiotemporally similar to the reported prescribed and wildland fires. Both the MODIS active and burned area products only detected 30 out of 71 fires between the years 2011 and 2012 (Figure 6 and Table 1). This equates to approximately 9,820 acres out of approximately 14,100 acres burned (Table 2).



**Figure 6.** The 2011 and 2012 USFWS fire perimeters; the lighter colors indicate known prescribed and wildland fires detected by the satellite fire products and the darker colors indicate fires not detected by the satellite fire products.

Year	Number of USFWS fires detected by MODIS products	Total number of USFWS Prescribed and Wildfires	Percent Difference
2011	9	29	-69.0 %
2012	21	42	-50.0 %
TOTAL	30	71	-57.7%

**Table 1.** Comparison of the amount of satellite detected (MODIS active fire and burned area) versus USFWS prescribed and wildland fire boundaries.

Year	Area of USFWS fires detected by MODIS products (acres)	Total area of USFWS Prescribed and Wildfires (acres)	Percent Difference
2011	3,865	6,052	-36.1%
2012	5,955	8,369	-28.8%
TOTAL	9,820	14,421	-31.9%

**Table 2.** Comparison of the total areas of satellite detected (MODIS active fire and burned area)

 versus USFWS prescribed and wildland fire boundaries.

A majority of prescribed burn perimeters monitored by the USFWS that were detected by satellite fire products were in herbaceous wetlands, grassland herbaceous, and woody wetlands as classified in the CDL. However, burn perimeters that occurred in forested areas and in croplands (soy, corn, sugarbeets, and spring wheat) were not detected by the MODIS fire products, including the McCarty cropland burned area product or the Landsat burn scar products. It is also possible that the fires occurred in the presence of canopy and therefore a significant change in surface reflectance was not detectable. Likewise, cropland fires can be difficult to detect if soils are disturbed (i.e., plowed/tilled, planted, winter cover applied).

This analysis did not find any shared soil types between the 2011 and 2012 prescribed burned areas that were also detected by the satellite products. In addition, the analysis of the FCCS fuel values showed that the prescribed burn perimeters monitored by the USFWS that were detected by satellite fire products were nearly equally attributed to wetland, grassland, forest, and agriculture fuel types.

## Conclusions

This study is one of the first to characterize rangeland burning in a complex landscape like western Minnesota. Current operational and scientific MODIS fire products mapping active fires and burned areas only detected approximately 42% of all the USFWS and fieldwork-derived fire perimeters did account for approximately of 70% of total ground truthed burned area estimations. Prescribed burning is a common practice throughout rangeland ecosystems but current satellite products may not have adequate spatial and/or temporal resolution to accurately detect and map burned areas. Future research should focus on improving satellite-based prescribed burning products for both active fire detections and burned area as prescribed burning accounts for over 20 million acres of burning annually outside of rangeland ecosystems (Melvin 2012).

## Acknowledgments

The findings and conclusions in this article are those of the author(s) and do not necessarily represent the views of the U.S. Fish and Wildlife Service. This work was funded via NASA Applications contract # NNX12AQ90G; PI Amber Soja. The authors would like thank former MTRI research interns Erik J. Boren, Meghan M. Sheehan, and Justin Carter for their input and analysis related to this project.
#### References

- Giglio L, Descloitres J, Justice CO, Kaufman YJ (2003) An Enhanced Contextual Fire Detection Algorithm for MODIS. *Remote Sensing of Environment* **87**, 273-282.
- McCarty JL, Pouliot G, Raffuse SM, Ruminski M, Szyksman JJ, Soja AJ (2012) Using satellite data to quantify cropland burning and related emissions in the contiguous United States: Lessons learned. EPA's 20th International Emission Inventory Conference in Tampa, Florida, 13-16 August 2012. Available at http://www.epa.gov/ttnchie1/conference/ei20/session2/jmccarty.pdf [Verified 10 January 2014]
- McCarty JL, Korontzi S, Justice C, Loboda T (2009) The spatial and temporal distribution of crop residue burning in the contiguous United States. *Science of the Total Environment* **407**, 5701-5712.
- McCarty JL, Loboda T, Trigg S (2008) A hybrid remote sensing approach to quantifying crop residue burning in the United States. *Applied Engineering in Agriculture* **24**, 515–27.
- Melvin M (2012) 2012 National Prescribed Fire Use Survey Report. Available at http://www.stateforesters.org/sites/default/files/publicationdocuments/2012 National Prescribed Fire Survey.pdf [Verified 9 January 2014]
- Roy DP, Boschetti L, Justice CO, Ju J (2008) The collection 5 MODIS burned area product

   Global evaluation by comparison with MODIS active fire product. *Remote Sensing of Environment* 112, 2690-3707.
- Roy DP, Boschetti L, Justice CO (2007) The global MODIS burned area product. 4<sup>th</sup> International Wildland Fire Conference, May 13-17, Seville, Spain.

## Modeling Carbon Emissions from the 2002 Biscuit Fire Using FARSITE for Applications for Future Fire Emissions

Jessica L. McCarty<sup>A</sup> David M. Banach<sup>A</sup>

<sup>A</sup>Michigan Tech Research Institute (MTRI), 3600 Green Court, Suite 100, Ann Arbor, MI, jmccarty@mtu.edu and dmbanach@mtu.edu

### Abstract:

In July 2002, lighting strikes ignited five separate fires within the Siskiyou National Forest in southern Oregon. These fires merged in early August to form the Biscuit Fire Complex, one of the largest (approximately 499,000 acres or 200,000 hectares) and costliest wildfires in Oregon's recorded history. FARSITE, a fire area simulator used by the US Forest Service and National Parks Service, spatially and temporally simulates fire behavior based on terrain, fuel, and weather inputs. The Biscuit Fire was modeled within FARSITE to verify that the program could replicate the growth, behavior, and emissions of this well quantified fire. Using a GIS developed model of the Siskiyou National Forest region, the simulation successfully modeled the growth of the Biscuit fire between 13 July and 31 August, corresponding to dates when the wildfires started to just days before declared contained. The carbon emissions of the modeled fire were then calculated using ArcWFEIS (an ArcGIS version of the Wildland Fire Emissions Information System: www.wfeis.mtri.org) and Python-CONSUME, two models developed by the Michigan Tech Research Institute. With this successful validation of carbon emissions from a historic fire, FARSITE will be used to model the impacts of climate change on emissions from future lighting-ignited wildfires.

Additional Keywords: Biscuit fire, FARSITE, fire growth, fire emissions, modeling, GIS, remote sensing

#### Introduction

During the summer of 2002, the Siskiyou National Forest in southern Oregon was experiencing an unusually dry summer season with record heat (USDA Forest Service 2002). On the afternoon of 13 July, a storm event passed through the region and ignited five separate fires; Biscuit Number 1, Carter, Biscuit Number 2, Florence, and the Sourdough Fire (Figure 1). As the fires continued to burn, they eventually merged on 5 August forming the Biscuit Fire Complex. Upon being declared contained, over 500,000 acres (200,000 hectares) of land had burned, making the Biscuit Fire one of Oregon's largest and costliest fires to date (Campbell *et al.* 2007).



**Figure 1.** The Biscuit Fire perimeter and approximate locations of the five lightning strikes. The incidences associated with each strike: 1 - Biscuit 1; 2 - Carter; 3 - Biscuit 2; 4 - Florence; and 5 - Sourdough.

The objective of this study was to determine if FARSITE could accurately predict the growth over time and space of a multi-ignition wildland fire as well as the burned area of a wildland fire given known environmental, climatic, and fire duration statistics. The Biscuit Fire Complex was chosen as it is a well know, studied, and quantified fire (Azuma *et al.* 2004; Raymond and Peterson 2005; Donato *et al.* 2006; Campbell *et al.* 2007; French *et al.* 2011).

## **Material and Methods**

FARSITE (Fire Area Simulator; www.firemodels.org/index.php/national-systems/farsite), a fire area simulator used by the US Forest Service (USFS) and National Parks Service (NPS), spatially and temporally simulates fire behavior based on terrain, fuel, and weather inputs. Developed by Finney (1997), the model is intended to aid in past, active (i.e., current), and potential (i.e., future) fire analyses. This model requires 5 co-registered and identical spatiotemporal resolution GIS raster files of fuels, canopy, topography/elevation, slope, and aspect. Weather conditions - wind speed, wind direction, cloud cover, relative humidity, and temperature - are also required climatic variables (Finney 1997; Finney and Andrews 1999). The objective of this study was to determine if FARSITE could accurately predict the growth over time and space of a multi-ignition wildland fire as well as the burned area of a wildland fire given known environmental, climatic, and fire duration statistics. Given the modeled burned area, carbon emissions were calculated using the Seiler and Crutzen (1980) method for comparison with published carbon emissions from French et al. (2011). Calculated within the Wildland Fire Emissions Information System (WFEIS; wfeis.mtri.org/) model, French et al. (2011) utilized remote sensing estimates of burned area derived from the Moderate Resolution Imaging Spectroradiometer (MODIS) and Landsat Thematic Mapper (TM) and Enhanced Thematic Mapper Plus (ETM+).

The five co-registered and spatiotemporal resolution GIS files, along with data pertaining to model parameters, environmental, and fuel conditions, were imported into FARSITE. Four of

the five fires from the Biscuit Complex were ignited - minus the Carter fire, which was shortlived (13 July – 16 July) and eventually re-burned by the merging of the other four fires within the larger fire complex. This model consisted of burn dates ranging between 13 July 2002 and 31 August 2002, corresponding to the dates when the wildfires started to just days before it was declared contained. FARSITE produced a daily fire progression shapefile which was then processed through ArcWFEIS, an ArcGIS version of WFEIS, calculating the area burned per fuel per day (Figure 2). The burned area of each fuel layer for the entire 50 days modeled were then imported into Python-Consume, a USFS emissions program updated by the Michigan Tech Research Institute (MTRI). Emissions for the atmospheric species of PM, PM<sub>10</sub>, PM<sub>25</sub>, CO, CO<sub>2</sub>, CH<sub>4</sub>, and non-methane hydrocarbons (NMHC) from the Biscuit Fire were calculated in Python-Consume (http://code.google.com/p/python-consume/). For this initial analysis, vegetative carbon emissions were estimated from the predicted CO<sub>2</sub> emissions.



**Figure 2.** FARSITE daily fire progression for 13 July - 31 August 2002; the two epicenters of the concentric circles represent the northern and southern lightning events with a merging of the modeled fire spread on 12 August (as opposed to 7 August 2002 from incident reports).

#### Results

According to the FARSITE model, the fires merged on 12 August 2002, which is five days later than reported. The WFEIS fire progression dataset merged the fires on 7 August 2002, temporally matching real-time incident reports. While the FARSITE modeled fire burned slightly slower than reported, the fire was successfully spatially modeled. FARSITE predicted a total burned area for the Biscuit Complex to be 197,744 ha. These results were then compared to an existing global fire burned area product from MODIS (MCD64A1; Giglio *et al.* 2010) and the Global Fire Emissions Database version 3 (GFEDv3; van der Werf *et al.* 2010). Compared to the reported values from two Landsat-derived burned area datasets (199,500 ha and 200,444 ha, respectively), the MODIS MCD64A1 Burned Area (169,916 ha), and GFEDv3 (167,351 ha), the FARSITE-modeled burned area was on average 7% greater (Table 1). The U.S. Congressional report on the Biscuit Fire states the official burned area to be approximately 500,000 acres or 202,342 ha (GAO 2004). The official burned area is 1.4% greater than the FARSITE predicted burned area and 10% higher than the average burned area calculated from remote sensing-based data sets.

		a	% Difference
Model	Burned Area	Carbon Emission	C emissions vs.
1100001	(ha)	(Tg C)	FARSITE C
			emissions
FARSITE	197,744	11.74	-
	Original FCCS	Fuels Map	
FOFEM 5.7			
Very dry	199,500	8.97	- 24%
Dry	199,500	8.26	- 30%
Moderate	199,500	6.93	- 41%
CONSUME 3.0			
Very dry	199,500	10.62	- 10%
Dry	199,500	9.93	- 15%
Moderate	199,500	8.37	- 29%
WFEIS	200,444	13.65	+ 16%
	Revised FCCS	Fuels Map	
FOFEM 5.7			
Very dry	199,500	3.92	- 67%
Dry	199,500	3.67	- 69%
Moderate	199,500	3.16	- 73%
CONSUME 3.0			
Very dry	199,500	3.44	- 71%
Dry	199,500	3.26	- 72%
Moderate	199,500	2.63	- 78%
WFEIS			
Landsat burned area	200,444	6.20	- 47%
"Daily Progression" modeled fire			
spread	200,444	6.13	- 48%
MODIS MCD64A1 burned area	169,916	5.22	- 56%
CanFIRE	200,444	3.92	- 67%
FBP System	200,444	3.38	- 71%
GFEDv3	167,351	3.63	- 69%

**Table 1.** Comparison of burned area and carbon emissions from published modeled results in French et al. (2011) and this study's FARSITE results; models include First Order Fire Effects Model (FOFEM; http://www.fs.fed.us/ccrc/tools/fofem.shtml), CONSUME (http://www.fs.fed.us/pnw/fera/research/smoke/consume/index.shtml), and the Fuel Characteristics Classification System (FCCS; http://www.fs.fed.us/ccrc/tools/fccs.shtml).

CO<sub>2</sub> emissions from the FARSITE modeled Biscuit Fire (predicted area of 197,744 ha) were calculated to be 2.35e+07 tonnes, which equates to 11.74 Tg C (carbon from biomass). This total was compared to French *et al.* (2011) published emission value of 13.65 Tg C, which modeled the Biscuit Fire within WFEIS. The percent difference of carbon emissions between the two models was valued at 16.0%. A difference in burned area of 2,700 ha is one of the attributing factors in the varying results between models. In addition, when compared to the additional models that used the original FCCS fuels (FOFEM, CONSUME, and WFEIS), FARSITE emissions were on average 19% greater than the published values (Table 1).

#### Conclusions

This study is a novel use of FARSITE and has reexamined the strengths and weaknesses of using this modeling program to aid in the analysis of past fires, specifically the spatio-temporal analysis of fire growth. The results of this analysis are unique due to the incorporation of additional software programs such as ArcWFEIS and Python-Consume for the calculation of

carbon emissions, and the use of results from a second fire modeling program, WFEIS, to validate not only the quantitative results from FARSITE but also to compare the spatial and temporal accuracies of the models. Although the percent difference of carbon emissions between FARSITE and WFEIS was valued at 16%, the percentage can be considered minimal due to the spatial size and ecological and topographic complexity of the region.

With this successful validation of carbon emissions from a historic fire, FARSITE has proven to be an appropriate model for predicting the impacts of climate change on emissions from future lighting ignited wildfires. FARSITE will be applied to other fire regimes (prescribed fire) and other ecosystems (grasslands, croplands, peatlands) for current and predicted future fires under climate change scenarios.

#### Acknowledgments

This publication was made possible by USEPA grant 83518901. Its contents are solely the responsibility of the grantee and do not necessarily represent the official views of the USEPA. Further, USEPA does not endorse the purchase of any commercial products or services mentioned in the publication.

#### References

- Azuma DL, Donnegan J, Gedney D (2004) Southwest Oregon Biscuit Fire: An Analysis of Forest Resources and Fire Severity. USDA Forest Service Research Paper PNW-RP-560. Available at http://soda.sou.edu/awdata/040804z1.pdf [Verified 10 January 2014]
- Campbell J, Donato D, Azuma D, Law B (2007) Pyrogenic carbon emission from a large wildfire in Oregon, United States, *Journal of Geophysical Research* **112**, G04014, doi:10.1029/2007JG000451.
- Donato DC, Fontaine JB, Campbell JL, Robinson WD, Kauffman WD, Law BE (2006) Postwildfire logging hinders regeneration and increases fire risk, *Science* **311(5759**), 352. doi: 10.1126/science.1122855.
- Finney MA (1997) FARSITE Fire Area Simulator Users Guide and Technical Documentation. 160 pp. Available at http://www.fs.fed.us/fire/planning/nist/farsit3xug.pdf [Verified 10 January 2014]
- Finney MA, Andrews PL (1999) FARSITE A Program for Fire Growth Simulation. *Fire Management Notes* **59**(2), 13-15.
- French NHF, de Groot WJ, Jenkins LK, Rogers BM, Alvarado E, Amiro B, de Jong B, Goetz S, Hoy E, Hyer E, Keane R, Law BE, McKenzie D, McNulty SG, Ottmar R, Pèrez-Salicrup DR, Randerson J, Robertson KM, Turetsky M (2011) Model comparisons for estimating carbon emissions from North American wildland fire. *Journal of Geophysical Research* **116**, G00K05, 21 pp.
- GAO (2004) Biscuit Fire Analysis of Fire Response, Resource Availability, and Personnel Certification Standards. U.S. Congressional Report GAO-04-426, 41 pp.
- Giglio L, Randerson JT, van der Werf GR, Kasibhatla PS, Collatz GJ, Morton DC, DeFries RS (2010) Assessing variability and long-term trends in burned area by merging multiple satellite fire products, *Biogeosciences* **7**, 1171-1186. doi: 10.5194/bg-7-1171-2010.

- Raymond C, Peterson DL (2005) How did prefire treatments affect the Biscuit Fire? *Fire Management Today* **65(2)**, 18-22. Available at http://www.firescience.gov/projects/03-2-3-09/project/03-2-3-09\_03\_2\_3\_09\_Deliverable\_03.pdf [Verified 10 January 2014]
- Seiler W, Crutzen PJ (1980) Estimates of gross and net fluxes of carbon between the biosphere and the atmosphere from biomass burning. *Climatic Change* **2**(**3**), 207-247.
- USDA Forest Service (2002) Biscuit Fire 2002 Chronology. Accessed December 2012. 58 pp. Available at http://coyoteaerospace.com/firepape/final\_ch.pdf [Verified 10 January 2014]
- van der Werf GR, Randerson JT, Giglio L, Collatz GJ, Mu M, Kasibhatla PS, Morton DC, DeFries RS, Jin Y, van Leeuwen TT (2010) Global fire emissions and the contribution of deforestation, savanna, forest, agricultural, and peat fires (1997-2009), *Atmospheric Chemistry and* Physics **10**, 11707-11735. doi: 10.5194/acp-10-11707-2010.

## State of Fire Behavior Models and their Application to Ecosystem and Smoke Management Issues

Susan J. Prichard<sup>1</sup> Roger D. Ottmar<sup>2</sup> John A. Hall<sup>3</sup> Allen R. Riebau<sup>4</sup> N.K. (Sim) Larkin<sup>2</sup> Timothy J, Brown<sup>5</sup> Mark A. Finney<sup>6</sup> W. Ruddy Mell<sup>2</sup> Craig B. Clements<sup>7</sup> J. Kevin Hiers<sup>8</sup> Matt B. Dickinson<sup>9</sup>

<sup>1</sup> University of Washington, School of Environmental and Forest Sciences, Seattle, WA 98195-2100. <u>sprich@uw.edu</u>

<sup>2</sup> Pacific Wildland Fire Sciences Laboratory, US Forest Service Pacific Northwest Research Station, Seattle

<sup>3</sup> US Department of Defense, SERDP/ESTCP, Alexandria, VA

<sup>4</sup> Nine Points South Technical Pty. Ltd., Western Australia

<sup>5</sup> Desert Research Institute, 2215 Raggio Parkway, Reno, NV

<sup>6</sup> Missoula Fire Sciences Laboratory, US Forest Service Rocky Mountain Research Station, Missoula, MT

<sup>7</sup> Department of Meteorology, San Jose State University, San Jose, CA

<sup>8</sup> US Department of Defense, Air Force

<sup>9</sup> US Forest Service Northern Research Station, Delaware, OH

#### Introduction

This special session was organized by the Department of Defense (DoD) Strategic Environmental Research and Development Program (SERDP) and Environmental Security Technology Certification Program (ESTCP) in conjunction with the Joint Fire Science Program (JFSP) and Core Fire Science Caucus. With over 30 million acres of land throughout the United States, the DoD manages a wide diversity of ecosystems and important habitat for many threatened and endangered species. Of the 5 million acres of DoD forestland, over half are southern pine forests that are generally maintained by frequent prescribed burns. In fire-adapted ecosystems such as southern pine and western pine forests, the DoD uses fire as an important ecological restoration and forest management tool and conducts prescribed burns on an average of 400,000 acres annually. To support DoD's continued use of fire in ecosystem-based management, SERDP and its sister demonstration program ESTCP have funded efforts to characterize wildland fire emissions to meet air quality requirements, understand how fire interacts with invasive non-native species such as cheatgrass (*Bromus techtorum*) in the western United States, and demonstrate and validate fire behavior models. To provide direction to its future research and demonstration efforts, SERDP/ESTCP is developing a fire science plan. The fire science plan has five focus areas that support DoD needs and offer areas of potential collaboration with other agencies to advance fire science: (1) fire behavior, (2) ecological effects of fire, (3) carbon accounting, (4) emissions characterization, and (5) fire plume dispersion.

Smoke emissions from wildland fires are highly dependent on accurate estimates of area burned, pre-burn fuel loading, and fuel consumption. For this reason, better understanding of wildland fire behavior is fundamental to improving estimates of fuel consumption and pollutant emissions. To assess the status of fire behavior modeling and priorities for model development as it pertains to smoke and ecosystem-based forest management, SERDP and its partners organized a special session entitled "State of Fire Behavior Models and their Application to Ecosystem and Smoke Management Issues" as part of the International Smoke Symposium on October 24, 2013 in College Park, Maryland (http://www.iawfonline.org/2013SmokeSymposium).

Presenters were invited to provide a status update and summary of research needs in the following areas: fuel characterization, smoke dispersion modeling, smoke validation, next-generation fire behavior modeling, fire-atmosphere interactions, ecosystem management, and fire effects. Research and funding directions for the SERDP/ESTCP and JFSP were also presented. The following sections provide a brief synopsis of each presentation and synthesize information into a status of fire behavior modeling, research applications, and recommendation for future research directions.

## 1) John A. Hall, Overview of funding sources SERDP/ESTCP and JFSP and their research / demonstration priorities.

Although the Department of Defense (DoD) is not generally viewed as a traditional land management agency, it is responsible for 30 million acres, 5 million of which are forestland. A large fraction of managed forestland is in southeastern pine, which requires frequent understory burning to maintain low surface fire hazard and open understories. The DoD underburns 400,000 acres of southern pine with prescribed fire on an annual basis and manages over 20% of existing, manageable longleaf pine ecosystems. Some of the management challenges the DoD faces regarding wildland fire include:

- Management of fire-prone ecosystems. These include fire-adapted communities such as ponderosa pine (*Pinus ponderosa*) in the western United States and long-needled pine forests (e.g., longleaf pine, *P. palustris*, and loblolly pine, *P. taeda*) in the southeastern United States. Frequent prescribed burning of forest understories is applied to reduce fuels and potential fire hazard but is also essential for mission support, which requires open-canopied forests and open forest understories, and ecosystem-based management purposes using the principles of ecological forestry. Vegetation management decisions are driven by mission support and stewardship and are not revenue driven.
- 2) Prescribed fire is an integral component of silviculture and ecological forestry in fire-adapted ecosystems, but like other agencies, the DoD is challenged to maintain the use of prescribed

burning programs under increasingly restrict smoke management and air quality requirements. Because smoke emissions are highly correlated with area burned and fire severity, a key research and development priority is to better understand how fire behavior relates to smoke management.

- 3) Carbon accounting in forest management and prescribed fire programs (including tradeoffs such as prescribed burning versus wildfire scenarios) is an emerging concern and will likely be a management priority in the near future.
- 4) Model validation. Given that understanding and predicting potential fire behavior is critical to predicting wildfire emissions, validation of existing fire behavior models is a big priority.

The five Core Fire Science Research Areas for the SERDP/ESTCP include fire behavior, ecological effects of fire, carbon accounting, emissions characterization and fire plume dispersion.

- 1) Fire behavior. Better characterization of wildland fire behavior is critical to understanding fire effects, wildland fire emissions and tradeoffs in carbon management. Research priorities include modeling fire spread, understanding interactions between fine-scale meteorology, topography, and plume dynamics.
- 2) Ecological effects of fire. Important topics include restoring and maintaining ecosystems with prescribed fire and characterizing fire regimes, including those altered by non-native, invasive species (e.g. cheatgrass). Single-species management such as the restoration of red-cockaded woodpeckers (*Picoides borealis*) has played an important role in the past, but the long-term goal will be for forest health and ecosystem-based management.
- **3) Carbon accounting.** Life-cycle carbon accounting is seen as an emerging topic and likely a future priority for DoD land management. Research priorities include carbon accounting in forest management and under prescribed and wildland fire scenarios. Tradeoffs with other ecosystem services (e.g., mission support, biodiversity) also need to be examined.
- 4) Emissions characterization. Because fire is an important land management tool, particularly in southern pine forests, emissions characterization will continue to be a research priority. Research priorities include fuel characterization and consumption studies, quantifying emissions under different fuel types, fuel loads, and distinguishing emissions from flaming vs. smoldering combustion phases of fire.
- 5) **Fire plume dispersion.** Research to better understand the local and regional effects of plume dispersion from prescribed and unplanned wildland fires.

Following this special session, presentations will be summarized and used to help identify research gaps and model validation needs. The SERDP/ESTCP fire science strategy will be finalized and used to coordinate with other agencies to avoid duplication of efforts as well as leverage resources for funding initiatives. The fire science strategy will be shared with the JFSP to coordinate investment and implementation strategies and then implemented through SERDP Statements of Need and ESTCP topics. An important final step is to effectively communicate findings to end users, which include both DoD resource managers and air quality personnel.

In conclusion, main research areas of interest to DoD include: 1) emissions characterization that quantify the effects of prescribed burning on air quality and help maintain the use of fire as a management tool, 2) quantify and manage carbon in open-canopy forests that also maintain other ecosystem services on DoD lands, 3) advance ecological forestry as a standard practice for DoD, and 4) achieve appropriate standardization and validation of tools and models that facilitate consistent application and technology transfer to end users.

### 2) Allen R. Riebau, JFSP alignment with SERDP/ESTCP

Al Riebau provided a brief review on JFSP's process for identifying key research questions and directions, including potential areas of collaboration with SERDP and ESTCP. JFSP has a deep alignment and natural partnership with SERDP and ESTCP programmatic goals. Through round tables, science plans and exchange networks, JFSP is continually identifying and prioritizing key research questions in order to fund critical aspects of fire science research. Research funding is awarded through a competitive process, and findings are disseminated through regional consortia (http://www.firescience.gov/JFSP\_consortia.cfm), publications and social media.

Currently, the main JFSP lines of work include fuels treatment, smoke management and model integration (IFT-DSS). Some of the critical management needs identified for JFSP funding priorities include spot-weather forecasts, threatened and endangered species, fire effects on water and cultural resources. New science initiatives include fire social sciences, fire ecology and remeasurement opportunities. Specific to smoke, researchers didn't have the technological advances for field measurement, data assimilation and analyses that we now have to address questions regarding smoke management and wildland fire emissions. With the advent of social media and increased use of webinars, options for communicating results have also expanded.

The JFSP Smoke Science Plan (2010) identified four research themes including 1) smoke emissions inventory research, 2) fire and smoke model validation, 3) smoke and populations, and 4) climate change and smoke. Each research theme outlines yearly priorities over a five-year plan to achieve thematic objectives. Next steps for JSFP's smoke management research directions include fuel consumption projects and large, integrated science assessments. JFSP is interested in bigger science areas (e.g., climate change, regional assessments) than what has been addressed before and opportunities to leverage funding to support them through shared funding directions with SERDP/ESTCP and other funding and research partners.

## **3.** Roger D. Ottmar. State of fuel characterization and consumption for wildland fire planning

The objective of this presentation was to identify strategic areas in fuel and fuel consumption research required for future investment in fire science modeling. The presentation covered: 1) a review of why fuel characterization and consumption measures are important, what the current state of the science is, and what needed investments are required as we move forward, 2) how new tools such as terrestrial and remotely sensed LiDAR and SAR will provide the fuel and fuel consumption characterization for future fire modeling, and 3) a description of the recent RxCADRE project, an integrated research effort that uses a stepwise, hierarchical data collection process to efficiently acquire research knowledge across several disciplines.

Wildland fuels are extremely variable across ecosystems and are a critical component of fire behavior and effects modeling. They are both spatially and temporally variable, and adequate characterization often requires multiple sets of measurements to account for seasonal changes in the fuelbed, (e.g., leaf on and leaf off conditions in eastern hardwood forests), vegetation and fuel succession, and human and natural disturbance events such as insects, disease, wind throw, mechanical fuel treatments, prescribed burns and unplanned wildland fires.

Fuel characterization is a key component of all fire models that support decision support systems across many disciplines including smoke management, fire and fuels management, carbon accounting, wildlife habitat management, and climate change assessments. The appropriate characterization of the fuelbed is especially important for modeling of smoke from wildland fire and predicting air quality impacts. In particular, fuel loading and consumption represent the two largest errors in emission characterization and production estimates.

Wildland fuels can be characterized by traditional measurement methods such as line intercept (Brown 1974) and clip plots. There are also biometric equations, photo series, pile loading, photo load (Sikkink et al. 2009) and now ground- and aerial-based LiDAR (Seielstad et al. 2011) techniques that can be used to characterize fuels that can reduce workloads but often at the expense of accuracy. As fire models become more sophisticated (e.g., physics-based models such as WFDS and FIRETEC), they will require improved characterization of the physical properties and spatial distribution of the fuels. There will be an increasing need for three-dimensional, high-resolution fuels and reliance on terrestrial and remote sensing. These remote sensing techniques have an advantage in that data can be collected without disturbing fuels, traditionally a challenge in pre- and post-burn fuel sampling. Broad-scale mapping of fuel loads are constrained by a data type mismatch between satellite images, which generally capture canopy characteristics (e.g., vegetation type and cover) and surface fuel loads important for fuel consumption estimates. Options to validate and rectify fuel mapping datasets are limited.

There are several key research and development needs to better improve our ability to characterize fuels:

- Improved methods to characterize all fuelbed components (e.g., organic soils, tree cones),
- Characterization of new fuels and vegetation assemblages (e.g., masticated fuels, homes and landscapes within the wildland-urban interface, and invasive species assemblages),
- Improved high-resolution and three-dimensional fuel measurements required for next-generation fire behavior models (e.g., LiDAR, Synthetic Aperture Radar, SAR),
- Measurement of fine-scale bulk density surface area-to-volume ratios, and spatial location of fuel particles within wildland fuelbeds,
- Validation and testing of current and future measurement techniques,
- Creation of a central data repository of fuel characteristics and consumption studies to assist with validation and testing, and
- Improved methods for mapping and spatial positioning of both surface and canopy fuels.

Current fuel consumption models have had minimal validation to date and contain data gaps (e.g., Northeast hardwoods in Consume). Investments are needed to develop a consistent, robust evaluation data set to evaluate and refine consumption algorithms in Consume (Prichard et al. 2007), FOFEM (Reinhardt et al. 1997, Reinhardt 2003) and the Canadian Fire Effects Model (CanFIRE, de Groot et al 2007). Consumption models need to be developed for fuelbed types and components not addressed in current models, including masticated fuels, tree crowns and WUI homes and landscapes. Further work is also needed to estimate consumption by flaming, smoldering, and long-term (residual) smoldering combustion and to better represent the role of fuel moisture in predicting fuel consumption. Finally, fuel consumption can now be estimated by next-generation fire behavior models, and additional inputs and validation will be necessary for broader application of these models.

Recent advances in LiDAR and SAR have greatly improved fuel characterization by representing fuelbed structure at fine (i.e., submeter) resolution and across forest stands (>1000 ha) (Seielstad et al. 2011). However, more work is needed to calibrate remotely-sensed images to on-the-ground field measurements. Future work with LiDAR- or SAR-based fuel characterization will require an integrated approach with fuel and fire behavior modelers to apply remote sensing sampling techniques to heterogeneous fuel complexes, perform sensitivity analyses, and address important scaling issues such a scaling small burn units to landscapes. The recent RxCadre experiment is an example of a successful, integrated approach between modelers and sensors and has made use of LiDAR-based fuel characterization and ground-based field sampling.

In conclusion, several major research needs for fuel and fuel consumption characterization include: 1) refine field data sampling methods including LiDAR for fire model inputs, 2) improve fuelbed maps and validation techniques, 3) collect systematic measurements of fuel consumption by fuelbed component (e.g., shrubs, herbaceous fuels, woody fuels by size class, litter and duff) and combustion phase, 4) move toward physics-based fuel consumption modeling, 5) improve fuel moisture modeling, and 6) promote integrated research approaches with direct communication with modelers.

## 4. Narasimham (Sim) K. Larkin, State of smoke dispersion modeling for wildland fire planning

A basic definition of smoke modeling is that it uses fire information and weather predictions to estimate smoke impacts. Currently, there are wide range of smoke prediction tools and models including simple spreadsheet tools, stand-alone models or software applications, web tools, daily forecasts, custom models and coupled fire-atmospheric models. With all of the available models, a common question for smoke modelers and managers alike is, "How well do smoke models work?" The published literature on smoke model evaluation ranges from anywhere from poor to very well. It may be more useful to reframe the question into, "How well do models work for specific applications?" Predictive models are generally used on a daily or routine basis and tend to have low accuracy. In contrast, retrospective or custom models for a specific project generally offer the most accurate predictions but are not suitable for daily or routine applications.

Consideration of tradeoffs is important when evaluating smoke models. More complex modeling efforts require intensive inputs and a need for training and expertise to interpret outputs. Simpler models are generally accessible to a broader user base and require few input variables, allowing for routine use and repeatable results that are readily interpreted by users. Model assessments generally involve pairwise comparisons between predictions and measured data without consideration of model utility. For smoke modeling, an example shortcoming of this approach is that a complex smoke dispersion model may be highly accurate but results may not be in time to be useful. To increase the timeliness and accessibility of predictive models, there is generally a tradeoff between model accuracy and model utility. Ideally, we would try to apply what we do best in complex modeling to make improvements in predictive models will require substantial advances in technology, automation, better input data, and training for informed interpretation of model results.

Typical errors in smoke modeling can include initiation error (e.g., estimated inputs), problems of interpretation, and model approximation errors. Initialization issues affect the areas in smoke modeling that we wish would affect us the least – daily or routine smoke forecasting. Compared to weather forecasters with a high resolution of weather stations throughout the country, smoke modelers have ten to one hundred times fewer monitoring stations. Unfortunately, smoke has much smaller decorrelation scales than weather variables (e.g. temperature), so the lack of air quality monitoring stations can result in substantial initiation errors in daily smoke forecasts. Problems of interpretation in smoke forecasts can become even more acute because they are not generally interpreted by trained specialists.

The recently completed Smoke and Emissions Model Intercomparison Project (SEMIP, JFSP project 08-1-6-10; Larkin *in review*) evaluated model uncertainty across interrelated steps to smoke dispersion modeling including fire shape and area, fuel loadings, total consumption, rate of consumption, speciated emissions, vertical plume profile, and dispersion/trajectories. The SEMIP project found model uncertainty to be dependent on the type of smoke modeling application. For single-event emissions, fuel loading inputs and availability of appropriate emissions factors are the major sources of error. In contrast, plume rise and timing are the most important predictors of smoke dispersion from single-events. For regional emissions inventories, fire information (e.g., fire area and location) and fuel load inputs are the most important sources of error whereas regional air quality is most dependent on fire information and predicted plume rise.

Current models offer reasonable predictions of plume shape and overall regional impact levels of smoke pollution. Some of the issues that smoke modelers still face are to 1) refine near-field, near-drainage predictions, 2) improve meteorology including boundary layers, grid scale and terrain effects (e.g., drainage flows), and 3) provide better initialization of model inputs including improved fuel characterization, fuel moistures, fire growth, fire growth estimation and plume rise.

Several refinements are needed for process models with known inadequacies including plume rise modeling, timing, fire growth, and plume chemistry. In particular, additional model

development and testing is needed to improve current plume rise models. Most plume rise models still rely on a simple representation plume rise from smoke stacks and tend to overpredict smoke from large fires and underpredict smoke from small fires.

Another important component of improving smoke prediction is to facilitate and promote interpretation of model results. One of the key differences between smoke and weather forecasting is that weather forecasters interact more with model outputs whereas smoke forecasting is much more reliant on model outputs. Future model development should facilitate interpretation of outputs for model users.

In conclusion, recent technological advances will allow for significantly better smoke forecasting systems with improvements in fire growth modeling for area burned and diurnal timing, coupled dynamic plume rise modeling for better injection, and improved understanding of plume chemistry. We have the capability in the next few years to incorporate fire growth modeling to create the next generation of smoke models. A key challenge will be to collect validation data in order to support development of these next-generation models. Although there is clearly room for improvement, current models do benefit decision makers. At regional scales, models add confirmation and quantification of expert's judgment. At local scales (e.g., smoke management planning), less experienced users are obtaining better estimates than they could generate on their own.

#### 4. Timothy J. Brown - Results from the JFSP Smoke Model Validation Workshop

A smoke validation workshop, funded by JFSP (13-S-01-01), was held in September 2013 at the Desert Research Institute (Reno, NV) to support the validation of fire behavior and emissions models. The objectives of the workshop were to 1) formalize the research elements and strategies needed to advance smoke modeling and 2) design and plan a field campaign that can significantly advance our understanding of smoke and improve current modeling systems.

Participants represented a diverse set of disciplines and organizations including the U.S. Forest Service, the Canadian Forest Service, NASA, EPA, JFSP, and universities. Focus areas were formed to organize discussions into five topic areas including 1) Fire Behavior Modeling and Measurements, 2) Multi-scale Emissions and Smoke Measurements, 3) Air Chemistry and Smoke Modeling, 4) Fuels Consumption and Measurements, and 5) Smoke Management and Agency Overviews.

Phase I of the validation study will involve a preliminary model evaluation (proposed years 1-1.5) and will concentrate on how to validate next-generation, coupled fire-atmospheric fire behavior models including the Weather Research and Forecasting model (WRF-Fire; Mandel et al. 2011), ForeFire (Balbi et al. 2009, Filippi et al. 2011), FIRETEC (Linn et al. 2002), and the Wildland Urban Interface Fire Dynamics Simulator (WFDS; Mell et al. 2007). Results from the validation studies will also be available to improve operational models including FARSITE (Finney 1998), FSPro (Fire Spread Probability), Promethius (Tymstra et al. 2009) as well as models within integrated applications such as the BlueSky Modeling Framework (http://www.airfire.org/bluesky), Wildland Fire Emissions Inventory System (WFEIS; http://wfeis.mtri.org), Integrated Fuel Treatment Decision Support System (IFT-DSS; http://www.firescience.gov/JFSP\_ifftdss), and Congestion Mitigation and Air Quality Improvement program (CMAQ; http://www.fhwa.dot.gov/environment/air\_quality/cmaq). Primary topics for model evaluation will include fire growth, fuel consumption and plume structure prediction.

Phase 2 will create a study design and execute a field sampling campaign (proposed years 2-5). Interagency and international partners will be contacted and encouraged to participate. Workshop participants recommended a case study approach in one to two locations involving three to four large burns. Preference will be made to multi-day, very large events with heavy pre-burn fuel loads and high-severity fire. Rapid response to a wildfire event would be ideal but difficult to coordinate; one to two high-severity prescribed fires are more realistic. A key challenge will be to coordinate instrumentation with the timing of the fire event.

Phase 3 will involve model evaluation, including a synthesis of validation results, presentation of findings and implementation for operations (proposed years 3-6). Model performance, including computational time and requirements and sensitivity to input errors, will be evaluated. Iterative testing will be employed to allow modification of inputs and refinement of outputs based on validation datasets. Validation metrics will include fire growth, fire behavior, fuel consumption, pollutant emissions, plume structure, downwind plume location, plume chemistry, and ground smoke impacts.

Project deliverables will include validation datasets (i.e. collected observations, along with metadata and sampling descriptions available for download), documents (i.e., final report, published papers on validation dataset and a wide range of model evaluations, and a report providing guidance on future model refinements) and a code repository to disseminate improved code for the various models.

## 5. Mark A. Finney - Operation fire modeling and research directions

This presentation reviewed operational fire modeling and what the limitations within current models portend for fire research. With the large number of predictive models available, modeling isn't a limiting factor in advancing models but rather understanding the underlying phenomena.

On average, over 80,000 wildland fire incidents occur in the United States per year and burn 4-10 million acres of land. Approximately 3% of all fires are responsible for 95% of the annual area burned by US wildfires. Wildland firefighting operations are provided by federal, state, county and city firefighters. Federal land management agencies are required to report wildland fire incidents and response strategies using the Wildland Fire Decision Support System (WFDSS; Tabor et al. 2013). The WFDSS contains geospatial vegetation and fuels data (LANDFIRE and regional), fire locations and history from MODIS data (http://modis.gsfc.nasa.gov/), National Weather Service data, point and zone fire weather forecasts, geospatial values data including housing and infrastructure, WindNinja (http://www.firelab.org/research-projects/physical-fire/145-windninja) to compute wild fields for fire behavior modeling, and operational fire behavior models. There are four main operational fire modeling methods in WFDSS including: 1) Short- and nearterm fire spread modeling for one fire using a single, static weather scenario using FARSITE (Finney 1998) and Minimum Travel Time methods (Finney 2002), 2) FlamMap (Finney 2006) to evaluate many fires across landscapes using a single, static weather scenario, 3) FS Pro (Finney et al. 2011) to evaluate multiple weather scenarios for a single fire, and 4) FSim/general risk burn probability modeling (Finney et al. 2011) to evaluate many weather scenarios over multiple fires.

The authors analyzed recent WFDSS usage and found that only 3.4 % of all fires on federal land had any analysis conducted with operational fire behavior models. One of the likely reasons for the low percentage of modeled runs is that most fires are immediately suppressed. Of the modeled federal fires, basic runs using FlamMap or Behave (Andrews 1986, Andrews and Chase 1989) were conducted on 4% of fires, short-term (1-3 day) models using Minimum Travel Time accounted for 24% of fires, near-term (1-7 day) FARSITE runs accounted for 37% of fires, and 7-30 day ensemble predictions using FSPro accounted for 35% of fires.

One of the most important benefits to fire operations is that they facilitate wildland fire training and understanding of the basic principles of fire behavior. For example, Rothermel's (1972) surface fire spread model is still in use within operational fire models because it provides reasonable results, is generalizable and flexible for wildland fire planning and operations, useful in training on basic fire behavior, and practical as it uses meaningful fuels and weather inputs.

An important characteristic of all operational fire modeling is that uncertainty dominates all inputs and observations. Therefore, efforts to validate and improve upon inputs have questionable value. Agreement between observations and model results can arise for non-unique combinations of inputs just by luck. A summary of how wind speed and fuel moisture affect measured rate of spread (Sullivan 2013) provides an illustration of the broad range of relationships found from past empirical studies or assumed functions. This illustrates how poorly the processes of fire spread are understood. Uncertainties in fire behavior modeling underscore the need for fundamental research to understand how fires spread and constraints to fire spread (e.g. fuels, wind, moisture, live and dead biomass).

The Missoula Fire Laboratory is doing basic fire research to instruct next-generation fire modeling. Some of their recent work has been on radiative heating and convective cooling of fine fuel particles and studies of boundary layer and buoyancy dynamics. For example, convection is required for ignition, but given their heat and buoyancy, how can flames maintain contact with fuel? Recent experiments have demonstrated how buoyancy dynamics involve intermittent pushes of the flame into the fuelbed, which facilitates flame contact. In another set of experiments, they have observed flame towers at fine spatial scales in the laboratory and across landscape burns. These are likely caused by Görtler Vortices (Jeschke and Beer 2001) where buoyancy dynamics result in upward and downward convergence zones and create flame towers and troughs. This phenomenon has also been observed across large landscapes, including Australian bush fires and Alaska boreal crown fires (Swearingen and Blackwelder 1987, Coen et al. 2004). Buoyancy dynamics are extremely periodic and can be represented by calculated frequencies and scaling constants (e.g., the Strouhal-Froude scaling number). Most models

assume a constant rate of heat transfer to fuels, but these observations suggest that heat transfer is anything but constant.

In conclusion, basic research on fire behavior in the laboratory with field validation is essential to improve fire behavior modeling. Operational and, in fact, all fire spread models are limited by our current understanding of fire spread and depend mostly on assumptions of how fire spread occurs. Research on fire spread in the laboratory with field confirmation is essential for advancing both modeling and understanding of how fires spread.

### 6. W. Ruddy Mell – Future of coupled fire-atmospheric modeling

Fire and wind interact at multiple scales, and coupled fire-atmospheric models attempt to resolve these interactions. For example, wind can be mediated by terrain, vegetation, changes in weather and fire. Fire can also influence wind through fire-front acceleration and terrain interaction (e.g., fire running up drainages), mass fires in which fire-generated winds dominate the ambient winds, and buoyancy-induced flow (e.g., plume rise due to fire-induced buoyancy).

Conventional models cannot model these processes directly and, when attempted, represent them through empirical relationships or rules based on observation. Because they simulate fundamental processes, physics-based models have broader applicability whereas empirically-based models are bounded by the limits of the original observations (e.g., Rothermel's 1972 spread model). Physics-based models can span a wide range of spatial scales because they capture the driving fundamental processes that are present at all scales. Comprehensive physics-based models explicitly model the processes of the thermal degradation of vegetation, gas phase combustion and char oxidation, smoke generation and transport, terrain influence on the ambient wind, and the interaction of the fire and surrounding atmosphere through buoyancy induced turbulent mixing. Fundamental to this is the simulation of convective and radiative heat transfer.

Coupled fire-atmospheric models apply to a broad set of disciplines and management applications including smoke generation and transport, firefighter safety, and fire effects (Mell et al. 2010b). More specifically, fire management problems that require fire-atmospheric coupled models include fire through raised fuels, fuel treatment effectiveness, unsteady fire behavior, fire in the wildland urban interface, smoke generation and transport, firefighter safety, and fire effects and structure ignition.

It is not possible, with current computers and numerical approaches, to directly simulate all the physical processes with complete spatial resolution. A computer simulation that directly captures the first order chemical reactions of combustion requires grid cells approximately 1 mm on a side. Similarly, fire starts with ignition, which can occur at scales on the order of a millimeter. Australian grassland fires in 5 m/s winds have head fire depths of 10 m and plume rise occurs at much greater spatial scales (10's of km or greater). Ideally, a physics-based model of wildland fire would span all these scales and capture the relevant physical processes with equal physical fidelity, but computing limitations prevent this. For example, if we assume, based on our existing physics-based model, approximately 1 kB of computer memory is required for each 1 mm grid

cell then a 1-m<sup>3</sup> domain requires 1 TB of memory, and a 10-m<sup>3</sup> domain requires a prohibitively large 1000 TB of memory.

The art of modeling is to determine which processes are relevant to the problem at hand and do the best job at retaining the appropriate physics. As a result, coupled fire-atmospheric models must approximate the governing equations. For example, NIST's work on faster than real time smoke transport modeling from burning oil spills on water (ALOFT; http://www.fire.nist.gov/aloft) used a fine grid resolution with simplified two-dimensional equations of motion to capture plume rise and buoyancy induced mixing. Once the plume reached its stabilization height the calculation was passed onto a coarser-grid three-dimensional dispersion model for more efficient computing of long range smoke transport.

The Wildland Urban Interface Fire Dynamics Simulator (WFDS) modeling suite is able to simulate wildland and wildland-urban interface fire processes from laboratory) to landscape scales using a comprehensive physics-based approach (Mell et al. 2007, 2010a). This physics-based component of the WFDS suite is called WFDS-PB. In addition, the WFDS suite contains a simpler approach, with varying levels of physics, for simulating the propagation of the fire front. This component of the model suite is using a level set method to propagate the fire line and is called WFDS-LS. Four examples of WFDS are presented along with their computation times for simulating fire spread within a 2-km<sup>2</sup> WUI area, assuming for simplicity that 0.5-m tall Australian grassland fuels covers the entire domain. These examples are given to provide insight into the trade-offs in computational time and the amount of physics retained. In each case, the ambient wind speed is 14 m/s (representative of Santa Ana winds in southern California) and flows from the northwest to the southeast. While it is not the only implementation choice, the WFDS-LS model examples below use the same elliptical fire front spread assumptions found in FARSITE (Bova and Mell, 2014).

Example 1: The WFDS-LS was run with a 20-m horizontal x 3-m vertical grid was 75 times faster than real time (simulating 150 s required 2 s of CPU time on one core). The wind field was assumed to have a constant speed of 14 m/s throughout the domain and was unaffected by the terrain. This is the same assumption used in FARSITE.

Example 2: WFDS-LS model was run with the same grid resolution as in Example 1, however for this case a terrain shaped wind field was computed a-priori using WFDS-PB and used in the WFDS-LS fire front propagation model. The wind simulation added 8 minutes to the computation time (overall the computation was 3 times slower than real time). This implementation is similar in approach to using the simple wind model WindNinja (Forthofer and Butler, 2014) to provide terrain shaped winds to FARSITE (Finney 2004).

Example 3: WFDS-LS was run to propagate the fire front while coupled to the wind computation portion of WFDS-PB to obtain the local wind. The local wind field was influenced by the terrain and heat flux into the atmosphere at the fire front location. This run took 1 hour 20 minutes (32 times slower than real time). This approach of coupling a wind simulation to a simple fire front propagation model is used in the atmospheric weighted models WRF-Fire and ForeFire.

Example 4: WFDS-PB was run to simulate the fire spread at a 2-m resolution. Computations were 500 times slower than real time and required 128 core processors and a 30-hour run time. This simulation is the only one that provides heat flux and mass consumption information that would pertain to fire effects.

Due to computational requirements of comprehensive physic-based models, a range of fireatmospheric models will continue to be needed for wildland fire management. Physics-based models are useful as research tools but also have proven capability for application and are needed to support the development and testing of simpler tools. Major needs include advances in computational efficiency and more supporting measurements for sub-model parameterization and validation. Measurements are needed at both laboratory and field scales. Laboratory-scale measurements, due to their measurable uncertainty, can be used to develop and assess submodels with a comprehensive physics-based approach (e.g., role of moisture, live versus dead fuels, char oxidation, smoke production). Field-scale measurements are needed to test the ability of models tested and developed at laboratory scales to "scale-up" to field scenarios. Also, it is not feasible to test the range of relevant parameter values in the laboratory, especially for large fires, high winds, and complex fuels. Suites of models are needed with physics-based models to inform solutions within faster operational models.

For model validation, experimentalists and modelers need to work together in order to ensure that the relevant measurements are taken and the actual experimental procedure and configuration is modeled. It will be important to characterize model limitations over a range of relevant scales and scenarios. Specific needs for laboratory studies include 1) momentum drag in vegetation, 2) radiant absorption by vegetation, 3) thermal degradation of vegetation types including live and dead vegetation, 4) heat release rates by vegetation type, and 5) experiments that enable laboratory-to-field extrapolation (e.g., fireline acceleration).

Needs for field measurements include: 1) time evolution and dimension for the entire fire line perimeter and its depth, 2) measured heat flux, 3) smoke plume concentration, rise and height, 4) vegetation size class distribution and mass in pre- and post-fire conditions, 5) wind including near-ground and far field around experimental burn plots and influences of terrain and vegetation on wind, 6) firebrand production and deposition, and 7) experiments on fuel break effectiveness.

## 7. Craig B. Clements, State of Fire-Atmosphere Interactions Research: smoke and fire behavior modeling

Fire-atmosphere interactions (FAI) are defined as the interactions between presently-burning fuels and the atmosphere in addition to interactions between fuels that will eventually burn in a given fire and the atmosphere (Potter 2012a). The duration of FAI is considered to be as long as fire-induced perturbations are greater than ambient variability. In other words, FAI is the coupling of the fire and the atmosphere and feedback mechanisms between the two. Potter (2012a and b) provided a review of historic FAI research and summarized five research goals in FAI research and provided recommendations for future research directions. FAI information gaps can be organized into five main categories including 1) atmosphere vertical structure and

the role of stability on fire spread, 2) vertical wind profiles, 3) plume dynamics, 4) wind and firefront dynamics, and 5) micrometeorology and turbulence.

- Temperature profiles and atmospheric stability. To gain a better understanding of temperature structure of plumes and effects on fire behavior, some of the key research areas include the rate of entrainment in a rising plume, the degree to which energy is released by a fire and how that translates into kinetic energy of the updraft, and how stability profiles influence updrafts including the relative influence of horizontal convergence, divergence and fire intensity.
- 2) Research on vertical wind profiles is needed to inform fire behavior and atmospheric modeling. In particular, information is needed on boundary layer mixing of winds aloft down to the surface including vertical shear and the development of fire whirls. Preliminary research on vertical wind shear profiles was conducted by Byram (1954). A recent numerical model of differing wind shear profiles and fire behavior impacts was published by Konchanski et al. (2013). Research on wind profiles is rooted in basic meteorology and requires further understanding of how boundary layer mixing of winds aloft down to the surface influence fire behavior (e.g., development of fire whirls).
- 3) Plume dynamics are not well understood including inflows (lateral surface, rear surface, descending rear) as well as accelerating updraft (Potter 2012a, b). Key research questions include a) what factors influence the origin of inflow (e.g., standard measurements of sensible heat flux), and b) how would incorporation of descending inflow affect fire spread?
- 4) Wind and fire-front dynamics. One of the key questions is what is the most pertinent measure of wind speed (i.e., surface, mid-flame and upper level) in predicting rate of fire spread? Empirical studies have shown a weak correlation between spread rate and wind speed (Cheney et al. 1993, Potter 2012a,b). High resolution wind profiles are still missing in validation datasets.
- 5) Micrometeorology and turbulence. There are few measurements on the effects of fireinduced turbulence on fire spread, but Taylor et al (1973) suggests that variability of fireinduced winds plays a role. Sun et al. (2009) also suggest that boundary layer turbulence is an important factor in fire spread. Key research questions include:
  - What role does ambient turbulence have on fire spread and smoke, dispersion and fire-front properties?
  - How does fire intensity affect turbulence structures?
  - A better understanding of fire front properties and sensible heat flux is also needed.

Technological developments have allowed for a wide range of new measurements to be made in FAI studies. In-situ meteorological measurements are one of the most important aspects of new field studies such as FireFlux and Fire Flux II (Filippi et al. 2013, Konchanski et al. 2013), sub-canopy (Strand et al. 2013) and the 2012 RxCadre experiments (http://www.firelab.org/research-projects/physical-fire/205-rxcadre). Measured data can be used to 1) quantify FAIs and their role on fire behavior, 2) evaluate coupled-fire model simulations and 3) determine the impact of meteorology on fire behavior, emissions and smoke transport. For example, the Fire Weather Research Laboratory (San Jose State University, CA) has a mobile atmospheric profiling station (CSU-MAPS) that includes a Halo-scanning Doppler LiDAR (Charland and Clements 2013),

radiometric microwave temperature/relative humidity profiler, Vaisala MW31 Radiosonde System, and a surface weather station.

Micrometeorology of the fire-front passage (FFP) can now be quantified by measuring surface wind reversal, peaks in turbulence via sensible heat flux, and atmospheric pressure minimum values. The relative strength of each variable determines fire-atmospheric coupling. An example experiment is FireFlux II (Jan 30, 2013) which characterized turbulence spectra using wind directions, vertical velocity and temperature profiles during pre-, during, and post-periods of the fire-front passage. Spectra were calculated every 30 minutes, which allowed characterization of normalized (ambient) turbulence spectra (Seto et al. 2013) during and post fire-front passage. The study detected an increase in velocity spectra at higher frequencies due to shedding of small-scale eddies from fire front. RxCadre compared vertical and horizontal velocity turbulence spectra in RxCadre and FIreFlux2. Turbulence spectra were very similar between the two studies, and even low intensity fires (e.g., in RxCadre fires) have increased turbulent energy at high frequencies.

Microwave radiometer T/RH measurements have shown promising results. In one example, a start of a cold/dry front was detected by a drop of relative humidity just before a burn unit was successfully ignited. Scanning Doppler wind LiDAR has also been successfully used to characterize plume development using a 1.5-µm laser. However, better resolution is needed for three-dimensional characterization and would require at least dual Doppler measurements to fully characterize plume structure. Fire whirl observations have also been made.

In summary, reliable observations are needed to test theories and validate FAI models at microto mesoscales. In-situ monitoring is now possible with available technologies and offers promising advances in observations to inform fire behavior modeling. Some key measurement needs include 1) dual or tri-Doppler LiDAR measurement strategies for plume dynamics and wind field monitoring (e.g., real time, three-dimensional wind profiles), 2) coupled LiDAR with in-situ towers to generate composite wind and turbulence field analyses, and 3) fire behavior measurements at high temporal and spatial resolution simultaneous with FAI measurements.

## 8. J. Kevin Hiers, Application of Fire Behavior Models to Ecosystem Management

Forest managers are faced with managing ecosystems under a future with no analogues. Climate change and invasive species including pests and diseases have altered vegetation dynamics, creating novel ecosystems and disturbance regimes. A critical challenge for managers is to change a fundamental approach to ecosystem management. Ecological managers generally work under an adaptive management strategy, using past experience to guide future decisions and strategies. Although variability is inherent in fire management, prescriptions around mean historic conditions are meaningless under a no-analogue future. For example, managing for a specific structure (e.g., historic fuel loads or stand densities) may not ensure a viable future for some ecosystems (e.g., long leaf pine ecosystems). Similarly, fire and fuels managers have generally characterized historic fire regimes and used historic conditions as restoration targets. However, we can expect more wildland fires to occur out of perceived or historic norms.

Variability is inherent in fire management, and under a changing climate, predictions around mean conditions will be meaningless. Future fire management must be able to capture relevant or anticipated variability with physics-based models of fire behavior. Forest fire research has traditionally had two very separate disciplines of physical sciences (combustion, heat) and ecological sciences (foresters, ecologists, fire effects). Fuels are the connection between the two formerly disparate disciplines.

Because we can no longer use the past to anticipate the future, ecological models need to couple physics-based fire models with vegetation change. Empirical models will not work for a no-analog future. More specifically, to capture fine- to- large-scale variation relevant to fire effects, process-based ecosystem models need to be coupled with mechanistic ecosystem disturbance models including physics-based fire behavior predictions that simulate both fine- and coarse-scale fire dynamics. Next-generation models should be useful to identify thresholds of ecological response (i.e., tipping points) through simulations under ranges of potential climatic and vegetation change scenarios.

There are several challenges to process-based ecosystem modeling. 1) Carbon dynamics operate on a range of intersecting scales and are difficult to quantify and track, 2) Ecosystem modelers encounter scaling issues (e.g., from the scale of a leaf to forest stands to landscapes) that are difficult to reconcile, 3) Co-limitations of resources (N, P, water, light) complicate ecological responses and are difficult to model; and 4) Currently, disturbance regimes are generally represented by other models and are not well integrated into process-based ecosystem models.

A range of process-based ecosystem models exist, but it is challenging for managers to select which models to use based on represented scales, data requirements, species representation and how disturbance regimes are incorporated. Future models need to articulate limits to model application (domains of inference) and identify uncertainty at operational and planning scales. For this, we need long-term datasets to monitor and validate predictions. To assist managers in model selection, inter-model comparisons using common datasets will be important. Linking ecosystem process-based models with mechanistic disturbance models will be critical for managers under a changing climate.

# 9. Matthew J. Dickinson - Trends and Major Gaps in Fire Effects Research and Development

Advances in fire behavior science will facilitate advances in fire effects science as fire behavior predictions and fire effects models become more physically realistic. This trend will have most immediate consequences for what are termed first-order fire effects, effects that happen as a direct result of flame and plume behavior. I will illustrate the benefits arising from increasingly mechanistic fire models with recent examples from the literature. As well, I will provide an assessment of trends and gaps in fire effects science from recent reviews that take a broader view of fire effects science by including second-order effects, tools for fuel treatment and prescribed fire planning, and risk-based wildfire management.

Fire behavior models are increasingly mechanistic. With the advent of gridded coupled fireatmosphere models, fire behavior predictions respond realistically to variability in fuels, vegetation structure and meteorological conditions (see Mell, this report). With these new capabilities, we can study spatially-explicit boundary conditions for fire effects. A growing number of fire effects studies are using fire-atmosphere models to examine variation in fuel/vegetation structure and to quantify boundary conditions and provide inputs to fire effects models. For example:

- Bova et al. (2011) used WFDS to evaluate boundary conditions for gas mixing into cavities used by fauna. The two critical variables are gas temperature and carbon monoxide, representing the most significant ways animals can be harmed by fire in a cavity. Applications can be extended to unsheltered fauna such as bats (Dickinson et al. 2010).
- 2) The stem heating model FireStem was just updated to model boundary conditions of uneven stem heating (Chatziefstratiou 2013). Work is in progress by Bova et al. to validate the use of the coupled fire-atmosphere model WFDS (see Mell, this report) as a means of generating stem heat flux inputs to FireStem (now called FireStem 2D).
- 3) Hoffman, Battaglia and Ziegler (in prep) are using WFDS to evaluate the effects of canopy fuel treatments on canopy turbulence and fire spread. The study demonstrated a high variability in turbulence and nonlinear effects on rate of spread.
- 4) Michaletz et al. (2013) used the WFDS model (see Mell, this report) to generate boundary conditions for a white-spruce cone heating model. Results suggested that this non-serotinous species could often regenerate effectively after crown fires because viable seeds in cones survived heating.

One may ask how practical it is to use complicated physics-based models in fuel treatment and prescribed fire planning and fire management applications. Mechanistic, physics-based models take longer to run, often at speeds slower than real time. A solution to this problem lies in the definition and use of functional relationships or look-up tables developed from the output of computationally-intensive models such as WFDS and FireSTem2D. These lookup tables can then provide inputs required by fire effects models.

Current operational fire behavior models, mostly based on the Rothermel (1972) model, unlike more mechanistic fire models, do not generally provide the boundary conditions needed by new fire effects models. Consequently, a key research need is to develop the means by which boundary conditions that link fire behavior with effects can be obtained. As an example, Bova and Dickinson (2008) demonstrated how basic fire behavior information, like rate of spread, fire intensity, and flame dimensions, variables that can be derived from Rothermel-based models, could be used to generate radiation and conduction boundary conditions for thermocouple probes heated in fires. This approach could be adapted to provide boundary conditions for predicting soil and tree heating in fires.

Fire effects science is becoming increasingly mechanistic, leading to improved predictive capabilities and understanding. Process-based fire effects science has and will benefit from advances in physics-based fire science. Fire science and fire effects science will both benefit from improvements in both fire measurement science (i.e., fire metrology) and predictive

infrastructure (i.e., the availability of model input variables such as fire weather, fuel moisture, and fuel and stand structure at appropriate spatial and temporal scales). Improvements in first-order fire effects science will result in improved prediction of second-order (longer-term) fire effects and those improvements will result in improved predictions of fire behavior and, in turn, first-order fire effects. Fire effects science supports development of risk-based decision-support systems for fuels and fire management.

### **Conclusions – key research/demonstration gaps**

The following are key research and demonstration gaps synthesized from the special session on *State of Fire Behavior Models and their Application to Ecosystem and Smoke Management Issues* that may be of relevance to SERDP/ESTCP or of interest to the Department of Defense:

#### Fuel characterization and consumption

- Improved characterization and mapping of fuels is needed that accounts for all fuelbed components from canopy to surface fuels. To address this, evaluation of new, spatially explicit fuel measuring protocols and tools (e.g., LiDAR and SAR) is needed with field sampling verification. Development of a central data repository for fuel datasets would also benefit fuel consumption and fire behavior modeling efforts.
- Improve post-fire consumption estimates, accounting for all fuelbed components and combustion phases (i.e., flaming versus smoldering) over a variety of fuel moisture and other environmental conditions. Integrated approaches using field and laboratory sampling, remotely sensed data, and physics-based models that resolve fuel combustion would be particularly useful.

#### Smoke and plume dispersion modeling

- Develop and improve smoke and plume dispersion models. We need to address 1) better utility, accuracy, and timeliness of model inputs and outputs, 2) smoke dispersion, 3) meteorology, 4) fuel characteristics, 5) improved initialization process modeling, and 6) improved interpretation capabilities.
- Develop next-generation smoke models. This will require field experiment partnerships and validation criteria and focus on heavy fuels. Experimentalists and modelers need to work together to inform validation studies, new measurements, and model refinement. Additional topics include: 1) combustion models that account for fuel moisture, 2) mechanics that drive fire brands (generation, transport, and ignition).

#### Fire behavior modeling

• Improve model validation, testing, and identification of uncertainties of physics-based fire behavior and effects models. Specifically, we need to improve our understanding of why fires spread or don't spread, including relationships between fire spread and wind speed and moisture conditions. This will require laboratory work and field confirmation. Issues of scaling from laboratory to field observations are complex. Fire behavior models need to be tested across multiple scales, and it will be important to characterize model limitations across a range of relevant scales and scenarios. Common datasets are needed to allow cross-model comparisons at different scales. To ensure consistency, synthetic datasets may be useful.

Standards for comprehensive validation datasets are needed to inform future field campaigns and/or the development of synthetic datasets.

#### Fire-atmosphere interactions

• Improve our understanding of fire-atmosphere interactions including 1) vertical temperature and wind profiles, 2) plume dynamics, 3) wind and fire front dynamics, and 4) micrometeorology including turbulence. Develop new uses of LiDAR including dual or tri-Doppler LiDAR measurement strategies for plume dynamics and wind field monitoring. Coupled LiDAR with in-situ towers can be used to generate composite wind and turbulence field analyses.

### Climatic change and ecosystem modeling

- Evaluate plausible future climate change scenarios and no analog, novel, and disappearing climates and their implications for fire and ecosystem-based management. To anticipate a range of outcomes and possible threshold effects under climatic change scenarios, ecosystem process models will need to directly incorporate disturbance models. Coupled physics-based fire behavior models will need to be merged with ecological effects process models. Some of the challenges will be to: 1) articulate model domain of inference, 2) explicitly characterize uncertainties, 3) validate models with long-term data sets, and 4) conduct inter-comparisons among different models against common data sets.
- Large, integrated science assessments are needed for climate change, regional assessments, and model validation and will require coordination to leverage funding to support them through shared funding and research projects.

#### Fire effects science

- Fire effects science is becoming increasingly mechanistic, leading to improved predictive capabilities and understanding. Process-based fire effects science has and will continue to benefit from advances in physics-based fire science. Fire behavior and fire effects disciplines will both benefit from improvements in fire measurements and predictive infrastructure (i.e., the availability of model input variables such as fire weather, fuel moisture, and fuel and stand structure at appropriate spatial and temporal scales).
- Studies are needed to parameterize fire effects models with next-generation, physics-based fire behavior models including boundary conditions and realistic fire behavior in structurally heterogeneous fuels, changes in forest structure from surface and canopy fuel treatments, and changes in meteorological conditions. Improvements in first-order fire effects science will result in improved prediction of second-order (longer-term) fire effects and those improvements will result in improved predictions of fire behavior and, in turn, first-order fire effects.

#### **References:**

Andrews P. L. 1986. BEHAVE: fire behavior prediction and fuel modeling system - BURN subsystem, part 1. General Technical Report INT-194. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 133 pp.

- Andrews P. L. and Chase C. H. 1989. BEHAVE: fire behavior prediction and fuel modeling system - BURN subsystem, part 2. General Technical Report INT-260. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 96 pp.
- Balbi J.H., Morandini F., Silvani X., Filippi J.B., and Rinieri R. 2009. A physical model for wildland fires. Combustion and Flame 15: 2217–2230.
- Bova A. and Dickinson M. 2008. Beyond "fire temperatures:" calibrating thermocouple probes and modeling their response to surface fires in hardwood fuels. Canadian Journal of Forest Research 38:1008-1020.
- Bova, A.S., Bohrer, G., Dickinson, M.B. 2011. A model of gas mixing into single-entrance tree cavities during wildland fires. Canadian Journal of Forest Research. 40: 1659-1670.
- Bova A. and Mell W.E. 2014 A comparison of level set and marker methods for fire spread simulation. In review International Journal of Wildland Fire
- Brown J.K. 1974. Handbook for inventorying downed woody material. INT-GTR-16. USDA Forest Service Intermountain Forest & Range Experiment Station. Ogden, UT. 24 pp.
- Byram G.M. 1954. Atmospheric conditions related to blowup fires. Paper 35. Asheville, NC: USDA Forest Service, Southeastern Forest Experiment Station.
- Charland, A. M. and Clements, C.B. 2013. Kinematic structure of a wildland fire plume observed by Doppler lidar. Journal of Geophysical Research-Atmospheres. 118: 3200-3212.
- Chatziefstratiou E.K., Bohrer G., Bova A.S., Subramanian R., Frasson R.P., Scherzer A., Butler B.W. and Dickinson M.B. 2013. FireStem2D a two-dimensional heat transfer model for simulating tree stem injury in fires. PLos ONE 8: e70110.
- Cheney N.P., Gould J.S., Catchpole W.R. 1993. The influence of fuel, weather and fire shape variables on fire-spread in grasslands. International Journal of Wildland Fire 3: 31–44.
- Coen J., Mahalingam J. and Daily J. 2004. Infrared Imagery of Crown-Fire Dynamics during FROSTFIRE. Journal of Applied Meteorology 43:1241-1259.
- de Groot W.J., Landry R., Kurz W., Anderson K.R., Englefield P., Fraser R.H., Hall R.J., Banfield E., Raymond D.A., Decker V., Lynham T.J. and Pritchard J. 2007. Estimating direct carbon emissions from Canadian wildland fires. International Journal of Wildland Fire 16: 593-606.
- Dickinson, M. B., Norris, J., Bova, A. S., Kremens, R. L., Young, V., Lacki, M. J. 2010. Effects of wildland fire smoke on a tree-roosting bat: integrating a plume model, field measurements, and mammalian dose–response relationships. Canadian Journal of Forest Research, 40:2187–2203.
- Filippi J.B., Bosseur F., Pialat X., Santoni P-A., Strada S. and Mari C. 2011. Simulation of coupled fire/atmosphere interaction with the MesoNH-ForeFire Models. Journal of Combustion Article ID 540390. 13 pp.
- Filippi J.B., X. Pialat and C.B. Clements. 2013. Assessment of FOREFIRE/MESONH for wildland fire/atmosphere coupled simulation of the FireFlux experiment. Proceedings of the Combustion Institute 34:2633-2640.
- Finney M. A. 1998. FARSITE: Fire Area Simulator-model development and evaluation. RMRS-RP-4. US Department of Agriculture, Forest Service, Rocky Mountain Research Station. Ogden, UT. 44 pp.
- Finney M. A. 2002. Fire growth using minimum travel time methods. Canadian Journal of Forest Research 32:1420-1424.

- Finney M. A. 2006. An overview of FlamMap fire modeling capabilities. In: Fuels management—how to measure success: conference proceedings. 2006 March 28-30; Portland, Oregon. Proceedings RMRS-P-41. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station: 213-220. 13 pp.
- Finney M.A. 2004. FARSITE: Fire area simulator-model development and evaluation. USDA Forest Service Rocky Mountain Research Station Research Paper RMRS-RP-4. Fort Collins, CO.
- Finney M.A., Grenfell I.C., McHugh C.W., Seli R.C., Trethewey D., Stratton R.D. and Brittain S. 2011. A method for ensemble wildland fire simulation. Environmental Modeling & Assessment 16:153-167.
- Forthofer J., Butler B. 2014 http://www.firelab.org/research-projects/physical-fire/145-windninja
- Jeschke, P, and Beer, H. 2001. Longitudinal vortices in a laminar natural convection boundary layer flow on an inclined flat plate and their influence on heat transfer. Journal of Fluid Mechanics 432:313-339.
- Larkin N.K., Stand T.T., Drury S.A., Raffuse S.M., Solomon R.C., O'Neill S.M., Huang S., and Wheeler, N. In review. Phase 1 of the Smoke and Emissions Model Intercomparison Project (SEMIP): Test Cases, Methods, and Analysis Results. U.S. Forest Service Pacific Northwest Research Station General Technical Report.
- Linn R. R., Reisner J., Colman J. and Winterkamp, J. 2002. Studying wildfire using FIRETEC. International Journal of Wildland Fire 11:1-14.
- Mandel J., Beezley J.D. and Kochanski A.K. 2011. Coupled atmosphere-wildland fire modeling with WRF-Fire version 3.3, Geoscientific Model Development Discussions (GMDD) 4: 497-545.
- Mell W., Jenkins M.A., Gould J. and Cheney P. 2007. A physics-based approach to modelling grassland fires. International Journal of Wildland Fire 16:1-22.
- Mell W.E., Maranghides A., McDermott R. and Manzello S. 2010a. Numerical simulation and experiments of burning Douglas fir trees. Combustion and Flame 156:2023-2041.
- Mell W.E., McDermott R.J. and Forney G.P. 2010b. Wildland fire behavior modeling: perspectives, new approaches and applications. Proceedings of 3rd Fire Behavior and Fuels Conference (October 25-29 in Spokane, WA). International Association of Wildland Fire, Birmingham, AL.
- Michaletz, S.T., E.A. Johnson, W.E. Mell, and D.F. Greene. 2013. Timing of fire relative to seed development may enable non-serotinous species to recolonize from the aerial seed banks of fire-killed trees. Biogeosciences 10:5061-5078.
- Potter B.E. 2012a. Atmospheric interactions with wildland fire behaviour I. Basic surface interactions, vertical profiles and synoptic structures. International Journal of Wildland Fire 21:779–801.
- Potter, B.E. 2012b. Atmospheric interactions with wildland fire behaviour II. Plume and vortex dynamics. International Journal of Wildland Fire 21:802–817.
- Prichard S.J., Ottmar R.D., and Anderson G.K. 2007. CONSUME user's guide and scientific documentation [online]

http://www.fs.fed.us/pnw/fera/research/smoke/consume/consume30\_users\_guide.pdf [accessed August 8, 2013]

- Reinhardt E. 2003. Using FOFEM 5.0 to estimate tree mortality, fuel consumption, smoke production and soil heating from wildland fire. Presentation at the 2nd International Wildland Fire Ecology and Fire Management Congress, 16-20 November 2003, Orlando, FL. 6 pp.
- Reinhardt E.D., Keane R.E., and Brown J.K. 1997. First order fire effects model: FOFEM. GTR-INT-344. USDA Forest Service Rocky Mountain Research Station, Ogden, UT. 65 pp.
- Rothermel R.C. 1972. A mathematical model for predicting fire spread in wildland fuels. INT-RP-115. Ogden, UT: U.S. Department of Agriculture, Intermountain Forest and Range Experiment Station. 40 pp.
- Seielstad C., Stonesifer C., Rowell E. and Queen L. 2011. Deriving fuel mass by size class in Douglas-fir (*Pseudotuga menziesii*) using terrestrial laser scanning. Remote Sensing 3: 1691-1709.
- Seto D., Clements C.B. and Heilman W.E. 2013. Turbulence spectra measured during fire front passage. Agricultural and Forest Meteorology 169:195–210.
- Strand T., Rorig M., Yedinak K., Seto D., Allwin E., Garci F.A. O'Keef P.O., Checans V.C., Mickler R., Clements C. and Lamb B. 2013. Subcanopy transport and dispersion of smoke. Final Report to the Joint Fire Science Program. Project 09-1-04-2. 63 pp.
- Sullivan A.L. 2013. Wildland surface fire spread modelling, 1990–present 2: Empirical and quasi-empirical models. International Journal of Wildland Fire 18:369-386.
- Sun R., Krueger S. K., Jenkins M. A., Zulauf M. A. and Charney J. J. 2009. The importance of fire-atmosphere coupling and boundary layer turbulence to wildfire spread, International Journal of Wildland Fire 18:50–60.
- Swearingen J. D. and Blackwelder R. F. 1987. The growth and breakdown of streamwise vortices in the presence of a wall. Journal of Fluid Mechanics 182:255–290.
- Taylor R.J., Evans S.J., King N.K., Stephens E.T., Packham D.R. and Vines R.G. 1973. Convective activity above a large-scale bushfire. Journal of Applied Meteorology 12:1144– 1150.
- Tymstra C., Bryce R.W., Wotton B.M. and Armitage O.B. 2009. Development and structure of Prometheus: the Canadian wildland fire growth simulation Model. Inf. Rep. NOR-X-417. Natural Resources Canada, Canadian Forest Service, Northern Forestry Center, Edmonton, AB.

	l Tr	INTERNATIONAL SMOKE	SYMPOSIUM		
		October 21-24, 20	)13		
	Presen II	ted by International Associat	ion of Wildland Fire		
	PROGR	AM SCHEDULE (As of	October 16, 2013)		
		Monday, October 2	21. 2013		
		WORKSHOPS (Room 2	110/2111)		
8:30 am		Workshop Reg	istration Opens		
9:30 - 11:30 am	WORKS	HOP 1: Development and Deploy	yment of Superfog Analysis Mod	tel – SAM	
11:30 - 12:45 pm		Lunch (or	n your own)		
12:45 - 3:45 pm	WORKS	HOP 2: BlueSky Framework and Instructors: Miriam Rorig,	I BlueSky-enabled Tools: Latest Susan O'Neill, Sim Larkin	Updates	
4:00 - 6:00 pm	Workshop 3: NASA ARSET	: What We Can and Cannot Do L Instructor: Ric	Jsing Remote Sensing Products hard Kleidman	for Air Quality Applications	
4:00 - 8:00 pm		Exhibitor Move In (C	Chesapeake Salon B/C)		
5:00 - 8:00 pm		Conference Registration De	<b>sk Open</b> (Chesapeake Foyer)		
		Tuesday, October	22, 2013		
7:30 - 8:30 am		Continental Breakfast	(Chesapeake Salon B/C)		
7:30 am		Registration	Desk Opens		
8:15 - 8:20 am		Opening Remarks and Welc	ting (Chesapeake - Salon A)		
8:30 - 9:00 am	Dan Bailey, President, International Association of Wildland Fire				
9:00 - 9:45 am	<b>KEYNOTE ADDRESS</b> Robert Bonnie, USDA, Under Secretary of Agriculture for Natural Resources and the Environment				
9:45 - 10:15 am	Networking Break with Exhibitors (Chesapeake Salon B/C)				
		CONCURRE	NT SESSIONS		
	Room 2110/2111	Room 2112	Room 2115	Chesapeake - Salon A	
	Wildland Fire and Air Quality Response Moderator: Alan Goodwin	Fire Emissions and Air Quality Modeling Moderator: Sean Baffuse	Smoke and Climate Change Moderator: Doug Fox	Fuels and Fire Emissions Moderator: Amber Soja	
10:15 - 10:20 am	Intro	Intro			
10:20 - 10:40 am	1. America Still Burning Alexander Maranghides	4. Recent Emissions Research in Southwestern Shrub and Grassland Fuels David Weise	7. Climate, Carbon, Emissions: The Evolving Scope and Importance of Smoke Science <i>William Sommers</i>	10. Assessment of Emission Gas and Health Hazard for Combustion of Surface Fuelbeds in Korean Forests Donghyun Kim	
10:40 - 11:00 am	2. A New State Protocol to Protect Public Health From Severe Wildfire Smoke Impacts in Oregon Brian Finneran	5. Exploiting Visualization for Better Understanding of Wildland Fire Behavior <i>Glenn Forney</i>	8. Projecting the Impacts of Climate Change on Annual Areas Burned Over the Southeastern U.S. Kevin Talgo	<b>11.</b> The Potential Air Quality Impacts of Fires: Isocyanic acid HNCO James Roberts	
11:00 - 11:20 am	3. Wildland Fire Management Policy and Air Quality in the Southern Sierra Nevada: Using the Lion Fire as a Case Study for a Multi-year Perspective on PM2.5 Impacts and Fire Policy <i>Don Schweizer</i>	6. Smoke Monitoring and Dispersion Modeling at the Palmerton Superfund Site <i>John Hom</i>	9. Managing for Fire and Smoke in a Changing Climate: Is it a Moving or a Fixed Target? <i>Gary Achtemeier</i>	12. Investigating the Behaviour of Hourly PM2.5 Emissions During Prescribed Burns in a South-Eastern Forest <i>Luke Naeher</i>	
11:20 - 11:30 am	Q&A	Q&A	Q&A	Q&A	
11:30 - 12:30 pm		Poster Session (Ch	esapeake Salon B/C)		
ഗ	P1. Wildfires: Exposure Assessment and Related Health Impacts Youssouf Hassani	P6. Use of Wildfire Smoke Forecasting Model to Mitigate Burden on a Population's Health and Wellbeing Ana Rappold	P11. Predicting Future Mega-fire Locations and Impacts Narasimhan Larkin	P16. The National Wildfire Coordinating Group Smoke Committee (SmoC) <i>Pete Lahm</i>	
i č		94			

Poster Presentation	<ul> <li>P2. 2012 National Prescribed Fire Use Survey Mark Melvin</li> <li>P3. Estimating Emissions for the 2008 Evans Road Fire in North Carolina George Pouliot</li> <li>P4. The Evolution of a Successful NASA Satellite Science to Air Quality</li> <li>Applications: From Science to Inception to Realization. The United States National Fire Emissions Inventory</li> </ul>	<ul> <li>P7. FRAMES Emissions and Smoke Portal: Tools for Smoke Management Education <i>Josh Hyde</i></li> <li>P8. An Evaulation of the Western Canadian BlueSky Forecasting System for 2012 <i>David Lyder</i></li> <li>P9. Soot Flame Measurement and Characterization <i>Paul Anderson</i></li> </ul>	<ul> <li>P12. Linking Visual Range, PM2.5 Concentrations and Air Quality Health Impact Indices for Wildfires Susan O'Neill</li> <li>P13. Air Quality and the Wildland Fire Management Research Development and Application Program Morgan Pence</li> <li>P14. Quantification of Methane Source Locations and Emissions Kuldeep Prasad</li> </ul>	<ul> <li>P17. When Ecosystem</li> <li>Management Causes Urban Air</li> <li>Quality Problems: Tallgrass,</li> <li>Prescribed Fire, and Smoke</li> <li><i>Carolyn Blocksome</i></li> <li>P18. Lung Toxicity of Pocosin</li> <li>Wildfire-Derived Particulate</li> <li>Matter: Implications for Toxicity</li> <li>Screening in Lung Tissue Slices</li> <li><i>Yong Ho Kim</i></li> </ul>	
	P5. New Technologies and Nighttime Aerial Firefighting Operations, Nitrofirex Project Adian Pena (Virtual Only)	P10. Exceptional Events Impact on Utah Air Quality from 2012 Wildfire Season, a Regulatory Perspective ( <i>Virtual Only</i> ) <i>Joel Karmazyn</i>	P15. Assessing the Exposure Risk of Regional Population to Smoke from Fires (Virtual Only) Mick Meyer		
12:30 - 1:30 pm		LUNCH (Chesap	beake Salon B/C)		
1:30 - 2:15 pm	PLENARY SESSION Satellite Monitoring of Fires and International Coordination Christopher Justice, PhD, Chair of the Department of Geographical Sciences, University of Maryland				
2:15 - 3:00 pm	PLENARY SESSION Wildfire in the Western United States in the Mid-21st Century and Consequences for Air Quality: Results From an Ensemble of Climate Model Projections Loretta J. Mickley, PhD. Senior Research Fellow, School of Engineering & Applied Sciences Harvard University				
3:00 - 3:30 pm		Networking Break with Exhib	itors (Chesapeake Salon B/C)		
		CONCURREN	NT SESSIONS		
	Room 2110/2111 Wildland Fire and Air Quality Response Moderator: Mark Fitch	Room 2112 Fire Emissions and Air Quality Modeling Moderator: Cindy Huber	Room 2115 Fuels and Fire Emissions Moderator: Evan Ellicot	D. Chesapeake - Salon A Special Session:Reducing Smoke through Wood Energy: The Role of USDA Moderator: Dave Atkins	
3:30 - 3:35 pm	Intro	Intro	Intro	Intro	
3:35 - 3:55 pm	13. Wildland Urban Interface Exposure Scale Alexander Maranghides	17.Monitoring and Modeling Local Smoke Dispersion during Low-Intensity Prescribed Fires <i>Warren Heilman</i>	21. Status and Future Plans for the Wildland Fire Emissions Information System: A NASA Tool for Fire-derived Carbon and Trace Gas Emissions Estimation Nancy French	25. The USDA Wood to Energy Initiative Patrick Holmes	
3:55 - 4:15 pm	14 .Basic Smoke Management Practices Pete Lahm	18. The 2013 BlueSky Canada Wildfire Smoke Forecasting System Kerry Anderson	22. Impact of Polyethylene Plastic on Smoke Emissions from Debris Piles David Weise	26. The Forest Service's Role in Wood Energy Dave Atkins	
4:15 - 4:35 pm	15. Do We Always Need Dispersion Models? Empirical Airshed Capacity Values for Prescribed and Wildland Fire in the Sierra Nevada, California Leland Tarnay	<b>19.</b> NOAA's Operational Prediction of Wildfire Smoke Dispersion <i>Ivanka Stajner</i>	23. Comprehensive Emission Measurements from Prescribed Burning in Florida: Field and Laboratory, Aerial and Ground <i>Brian Gullett</i>	27. Rural Development's Role in Wood Energy <i>Todd Campbell</i>	

4:35 - 4:55 pm	16. Establishing a National Standard Methodology for Operational Mixing Height Determination <i>Tim Brown</i>	20. Developm Wildfire Forec David I	ent of a Boreal asting System <i>Lavoue</i>	24. Super-Dense Smoke: A Cause for Dangerous Smoke Exposure? Gary Achtemeier	28. Wood Stove Innovations and Smoke Management John Ackerly
4:55 - 5:05 pm	Q&A	Qa	&A	Q&A	Q&A
5:05 - 7:00 pm		Soci	al Reception (Cl	hesapeake Salon B/C)	
6:45 - 8:00 pm	Haunted Stroll - University of	Maryland ( <i>Fundra</i> famili	aiser - Donations ies of the fallen Y	will go to the National Fallen Firef ′arnell Hill Firefighters)	ighter Foundation to benefit the
		Wednesda	y, Octobe	r 23, 2013	
7:30 - 8:30 am	Continental Breakfast (Chesapeake Salon B/C)				
8:00 am			Registration	Desk Opens	
8:15 - 8:20 am		Moderator a	and Facilitor Mee	ting (Chesapeake - Salon A)	
8:30 - 8:45 am	Tom Zimmerman, Bo	Velcome Back and a contract of Directors, I	nd Daily Annour	ncements (Chesapeake - Salon A poiation of Wildland Fire and Symp	4) posium Program Chair
8:45 - 9:30 am	PLENARY SESSION Smoke Consequences of New Wildfire Regimes Driven by Climate Change Uma Shankar, Senior Research Scientist, Institute for the Environment-University of North Carolina				
9:30 - 10:00 am		Networking E	Break with Exhib	hitors (Chesapeake Salon B/C)	
			CONCURREN	NT SESSIONS	
	Room 2110/2111			Room 2115	D. Chesapeake - Salon A
	Smoke and Climate Change Moderator: Brian Stocks		Special Session: Fire's Impacts on Ozone and PM - Data Results and Tools for Analysis Moderator: Mark Fitch		Special Session: Transportation Corridor Safety Moderator: Gary Curcio
10:00 - 10:05 am	Intro			Intro	Intro
10:05 - 10:25 am	<b>29.</b> Wildland Fire Emissions, Carbon and Climate: A Special-Issue Synthesis Project <i>Colin Hardy</i>		<b>33.</b> FETS Fire Inventories – Methodology and Results for Assessment of Smoke's Impact on Ozone and PM <i>Matthew Mavko</i>		<b>37.</b> Highway Safety during Smoke/Fog Incidents Kelly Hildreth
10:25 - 10:45 am	<b>30</b> . In the Line of Fire: Physiological Responses of Plants to Smoke <i>Vicky Aerts</i>		34. Photochem Contribution t	ical Modeling to Assess Smoke's o Ozone and Particulate Matter <i>Ralph Morris</i>	<b>38.</b> Historical Perspectives of Forestry Smoke and Highway Visibility Issues in the South James T. Paul
10:45 - 11:05 am	<ul><li>31. Future Trends in Large Fire and Smoke in the United States under Changing Climate Yong Liu</li></ul>		35. JFSP Smo	ke Science Projects: DEASCO3 and PMDETAIL <i>Matthew Mavko</i>	39. National Weather Service Smoke Management Decision Support Tools in the Carolinas and Georgia John Tomko
11:05 - 11:25 am	<b>32.</b> The Untold Story of Pyrocumulonimbus II <i>Michael Fromm</i>		<b>36.</b> DEAS Charles (	CO3: Meeting the Needs of User Groups <i>Tom) Moore/Dave Randall</i>	40. Development and Usage of a New Forecast Tool to Improve Super-fog Forecasts Josh Weiss
11:25 - 11:35 am	Q&A			Q&A	Q&A
11:35 - 12:35 pm		Pos	ter Session (Ch	esapeake Salon B/C)	
	P19. A New IGAC/iLEAPS/WMO Initiative on Biomass Burning (Virtual Only) Mick Meyer	P23. Case Stu Weather Condit for 2002 Bi Southwes Susan	idy: Analysis of ions and Smoke scuit Fire in st Oregon <i>O'Neill</i>	<b>P27.</b> Ground Zero Daily Smoke Production Values for NC Coastal Plain Organic Soil Fire –Pains Bay May/June 2011 <i>Gary Curcio</i>	<b>P31.</b> Examination of PM2.5 Composition of Samples Impacted by Wildfires <i>Tracy Dombek</i>
ntations	P20. Modeling Carbon Emissions from the 2002 Biscuit Fire Using FARSITE for Applications for Future Fire Emissions David Banach	P24. An Emp Estimate Dai Smoke Exposu Geographic Are Data S <i>Angel</i>	irical Model to ly Forest Fire re over a Large a Using Multiple ources a Yao	<b>P28</b> . Landsat Based Fire- inducted Forest Cover Loss Mapping in European Russia <i>Alexander Krylov</i>	<b>P32.</b> The BlueSky Modeling Framework and SmartFire Fire Information System: Recent updates and current status <i>Sim Larkin</i>

ter Presei	P21. The Use of Instantaneous Satellite AOD to Constrain Biomass Burning Aerosol Emissions in the GOCART Model - Method Refinement <i>Mariya Petrenko</i>	<b>P25</b> . UAV Operations and Wildland Data Collection <i>Alexander Maranghides</i>	P29. Facilitating Knowledge Exchange About Wildland Fire Science <i>Christine Olsen</i>	<b>P33.</b> A Literature Review to Identify the Population Health Outcomes Most Affected by Forest Fire Smoke <i>Kathryn Morrison</i>	
Post	P22. Updating the Air Quality Index Method to Caution the Public when Air Quality Changes Rapidly Susan Lyon Stone	<b>P26.</b> Great Plains Fire Science Exchange <i>Carolyn Blocksome</i>	P30. Detecting and Quantifying Rangeland Burning Using Remotely Sensed Burned Area and Active Fire Data: A Case Study of Western Minnesota Jessica McCarty	<b>P34</b> . Integrated and Integral Forest Fire Management - Operation Roraima 2013, Brazil Jose Carlos Mendes de Morais (Virtual Only)	
12:35 - 1:35 pm		LUNCH (Chesap	peake Salon B/C)		
		Transition to Che	esapeake Salon A		
1:35 - 2:20 pm	Wayne E. Cascio, M.	PLENARY Smoke and Human Health: Me D, FACC, FAHA, Director, Enviror	SESSION edical Science and Responses Inmental Public Health Division, NH	IEERL/ORD/US EPA	
2:20 - 2:50 pm	PLENARY SESSION The Joint Fire Science Program Smoke Line of Work and Smoke Science Plan: History, Implementation, and Progress Allen R. Riebau, PhD. Joint Fire Science Program Smoke Science Plan Coordination Team, Nine Points South Technical Pty. Ltd., Western Australia				
2:50 - 3:15 pm		Networking Break with Exhib	hitors (Chesapeake Salon B/C)		
	Boom 2110/2111	CONCURREN	NT SESSIONS	D Chasanaaka Salan A	
	Smoke and Populations - Health Moderator: Chuck Bushey	Fire Activity and Emission Inventory Moderator: Nancy French	Fire Emissions and Air Quality Modeling Moderator: Karen Wood	Special Session: Transportation Corridor Safety Moderator: Gary Curcio	
3:15 - 3:20 pm	Intro	Intro	Intro	Intro	
3:20 - 3:40 pm	<b>41.</b> Surveillance to Support Mitigation of the Public Health Impacts Associated with Forest Fire Smoke Sarah Henderson	46. Mapping prescribed burns and wildfires on Twitter with data mining and information retrieval techniques <i>K. Arthur Endsley</i>	<b>52.</b> Comparison of BlueSky Framework Configurations During Autumn Wildfire Season in the Pacific Northwest, USA <i>Miriam Rorig</i>	58. A Superfog Index Based on Historical Data <i>Gary L. Achtemeier</i>	
3:40 - 4:00 pm	<b>42.</b> Health Outcomes Associated with Smoke Exposure in Albuquerque, New Mexico during the 2011 Wallow Fire <i>Heidi Krapfl</i>	<b>47.</b> Daily Burned Area in Northern Eurasia from 2002 to 2010 and its Contribution on Arctic Black Carbon <i>Wei Min Hao</i>	<b>53</b> .BlueSky Playground: A Web- Based Smoke Modeling Decision Support Tool <i>Sean Raffuse</i>	<b>59.</b> A Framework for an Operational Superfog Forecast Index <i>Josh Weiss</i>	
4:00 - 4:20 pm	<b>43</b> . Characterization of Wildland Firefighter Exposure to Carbon Monoxide and PM2.5 Using Real- Time Aerosol Monitors <i>Luke Naeher</i>	48. Top-down Smoke Aerosol Emissions Estimation from Satellite Fire Radiative Power Measurements <i>Charles Ichoku</i>	<b>54.</b> Modeling Smoke for Incident Support <i>Miriam Rorig</i>	60. Development of a New Superfog Screening Tool through Theoretical, Experimental and Numerical Investigation <i>Christian Bartolome</i>	

4:40 - 5:00 pm	<b>45.</b> Evaluation of the BlueSky Wildfire Smoke Forecasting System as a Tool for Public Health Protection <i>Angela Yao</i>	50. Quantifying the Potential for High-Altitude Smoke Injection using the Standard MODIS Fire Products and Sub-Pixel-Based Methods David Peterson	56. Overview of an Intensive 2013 Field Study Measuring Crop Residue Burning Emissions Robert Elleman	62. Application of Operational Tools by Air Resource Advisors for Smoke Related Transportation Corridor Safety <i>Gary M. Curcio</i>		
5:00 - 5:20 pm		<b>51.</b> Development of Operational Global Biomass Burning Emission Product Using Fire Radiative Energy Derived From MODIS and Geostationary Satellites <i>Xiaoyang Zhang</i>	<b>57.</b> Alaska Wildfire Observations and Emission Modeling with WRF-Chem <i>Martin Stuefer</i>	<b>63</b> . Federal Highway Administration: Management Response for Poor Visibility <i>Kimberly Vasconez</i>		
5:20 - 5:30 pm	Q&A	Q&A	Q&A	Panel Discussion - What Next?		
5:30 - 7:00 pm	This "hands-on" evening sess	DEASCO 3 ion provides the opportunity for S support from the develop	Happy Hour ymposium attendees to use the we pers and the project team.	ebsite and tools with in-person		
7:00 - 9:00 pm	Inte Facili	Evening eractive "Smoke Challenges, Sm tated by Claudia Standish, Vice-(	<u>Session</u> noke Solutions" Networking Ses Chair Smoke Managers' Sub-Comi	<b>sion</b> mittee		
		Thursday, October 2	24, 2013			
7:30 - 8:30 am		Continental Breakfast (	Chesapeake Salon B/C)			
8:00 am		Registration	Desk Opens			
8:15 - 8:20 am	Moderator and Facilitor Meeting (Chesapeake Salon A)					
8:30 - 8:45 am	Welcome Back and Daily Announcements (Chesapeake Salon A)           Pete Lahm, US Forest Service and Symposium Chair					
8:45 - 9:30 am	<b>Collaborative A</b> Mark Melvin, Conservation Ma	PLENARY Approach: "Smoke Management nagement/Education Technician J Coalition of Presc	<b>' SESSION</b> and Balancing the Role of Fire i loseph W. Jones Ecological Resea ribed Fire Councils	in Ecosystems" arch Center and Chair, National		
9:30 - 9:50 am	Networking Break with Exhibitors (Chesapeake Salon B/C)					
	CONCURRENT SESSIONS					
	Room 2110/2111	Room 2112	Room 2115	Chesapeake - Salon A		
	Wildland Fire and Air Quality Response Moderator: Susan O'Neill	Special Session: Smoke and People: Bringing Clarity to Beliefs, Attitudes, and Influencing Factors Moderator: Christine Olsen	Special Session: Towards a Brown Carbon Emissions Model and Inventory for Climate and Environmental Toxicity Impacts Assessment Moderator: Brooke Hemming	Special Session: State of Fire Behavior Models and their Application to Ecosystem and Smoke Management Issues Moderators: Roger Ottmar/ Kevin Hiers		
9:50 - 9:55 am	Intro	Intro 69 Engaging Students and	Intro	Intro 79 Overview of Euroding		
9:55 - 10:15 am	of the Air Quality Index at Changing Public Behavior Susan Lyon Stone	Managers through Video Modules: Development of a Short Course about Public Perceptions of Smoke Jarod Blades	the Ambient Atmosphere and Lab <i>Christopher Cappa</i>	Sources SERDP/ESTCP and JFSP and their research/demonstration priorities John Hall		
10:15 - 10:35 am	65. Examining the Validity of Using Observed Visual Range to Estimate Mass Concentration <i>William Malm</i>	<b>70.</b> Public and Agency Perceptions about Smoke: Interview and Survey Results from Four States <i>Christine Olsen</i>	<b>76</b> . The Chemical Composition of Aerosols from Wildland Fires: Current State of the Science and Possible New Directions <i>Michael Hays</i>	80. State of Fuel Characterization and Consumption for Wildland Fire Planning Roger Ottmar		
10:35 - 10:55 am	66. Whither the Wind? Developing an Air Stagnation Climatology for the United States Joseph Charney	71. Smoke and People: The Implications of Beliefs, Attitudes, and Perceived Risk for Communication <i>Eric Toman</i>	77. The Burning of Biomass Generates Humic-like Substances Which Can Impact Human Health Via Iron Complexation Andrew Ghio	81. State of Smoke Dispersion Modeling for Wildland Fire Planning <i>Sim Larkin</i>		

10:55 - 11:15 am	<b>67.</b> Ground Zero Daily Smoke Production Values for NC Coastal Plain Organic Soil Fire – Pains Bay May / June 2011 <i>Gary Curcio</i>	72. Public Tolerance of Smoke from Wildland Fire: Comparative Results from Surveys in Nine US States Jarod Blades	<b>78.</b> Fire-derived Brown Carbon Impacts and Inventories: A Research and Development Framework Brooke L. Hemming	82. Results from the JFSP Smoke Model Validation Workshop <i>Tim Brown</i>
11:15-1135 am	68. Quantifying and Incorporating the Cost of Smoke into Strategic Fire Planning <i>Doug Rideout</i>	73. Longitudinal Panel Results: How the 2012 Fire Season Impacted Public Perceptions in Northern California Stacey Frederick	Q&A	83. Operational Fire Modeling and Critical Research Questions <i>Mark Finney</i>
11:35 - 11:55 am	Q&A	74. Future Directions and Next Steps Troy Hall and Eric Toman		Discussion and Q&A
11:55 - 12:15 pm		Panel, audience and small group discussions		
12:15 - 1:15 pm		LUNCH (Chesap	peake Salon B/C)	L
1:15 - 2:00 pm		PLENARY Fire Smoke and Human Health: Janice E. Nolen, Assistant Vi American Lur	SESSION How We Share What We Know ce President, National Policy, ng Association	
2:00 - 2:10 pm		Transition to Cor	current Sessions	
	Room 2110/2111	Room 2112	Room 2115	Chesapeake - Salon A
	Fuels and Fire Emissions Moderator: Sim Larkin	Fire Activity and Emission Inventory Moderator: Charles Ichoku	Special Session: Revising "Wildfire Smoke: A Guide for Public Health Officials" Moderator: Susan Stone	Special Session: State of Fire Behavior Models and their Application to Ecosystem and Smoke Management Issues Moderators: Roger Ottmar/ Kevin Hiers
2:10 - 2:15 pm	Intro	Intro	Intro	Intro
2:15 - 2:35 pm	84. The Contribution of Fuel Loading Uncertainty to the Variability among Wildland Fire Smoke Emission Inventories Shawn Urbanski	89. Trend and Uncertainties of Wildland Fire Emissions in Georgia Di Tian	<b>94</b> . Overview of New Health Information <i>Ana Rappold</i>	<b>100.</b> Future of Coupled Fire- Atmospheric Modeling <i>Ruddy Mell</i>
2:35 - 2:55 pm	85. Spatio-temporal Estimation of Gaseous and Particle Emissions from a Major Australian Wildfire <i>Nicholas Surawski</i>	<b>90.</b> Fire Regimes in Russia: Impacts on Environment, Ecosystems and Society <i>Anatoly Shvidenko</i>	<b>95</b> . Overview of New Air Quality Index Information <i>Susan Lyon Stone</i>	<b>101</b> . State of Fire-Atmosphere Interactions Research for Smoke and Fire Behavior Modeling <i>Craig Clements</i>
2:55 - 3:15 pm	86. Smoke Wmissions from Lowland Eucalyptus Forests: Implications for Carbon Accounting Malcolm Possell	<b>91.</b> The Wildland Fire Portion of the 2011 National Emissions Inventory Sean Raffuse	<b>96</b> . Communicating with Public Health Agencies <i>Scott Damon</i>	<b>102.</b> Fire and Smoke Modeling to Meet Ecosystem Management Objectives <i>Kevin Hiers</i>
3:15 - 3:35 pm		Networking Break with Exhib	itors (Chesapeake Salon B/C)	
3:35 - 3:55 pm	87. Exploring Uncertainty in Fire Radiative Energy-based Emission Estimates <i>Evan Ellicott</i>	92. Producing Emission Estimates from Cropland Burning in the Contiguous United States for the 2011 National Emissions Inventory: Lessons learned from a Remote Sensing-based Approach Jessica McCarty	97. Interagency Wildland Fire Air Quality Response Efforts <i>Pete Lahm</i>	103. Research and Model Validation Gaps for Understanding Fire Effects <i>Matthew Dickenson</i>
3:55 - 4:15 pm	88 Smoldering Smoke as a Source of Terpenes, Hemi- terpenes and OVOCs <i>Tim Johnson</i>	93. A Short-term Predictor of Satellite-observed Fire Activity in the North American Boreal Forest: Toward Improving the Prediction of Smoke Emissions David Peterson	<b>98.</b> Adaptations of the Guide: New Mexico Tools and Next Steps <i>Heidi Krapfl</i>	Discussion and Q&A

4:15 - 4:35 pm			<b>99</b> . State of Idaho Use of the Wildfire Guide in 2012 <i>Mary Anderson</i>		
4:35 - 4:40 pm	Q&A	Q&A	Q&A		
4:40 - 4:45 pm		Transition to Closing Sessi	on (Chesapeake Salon A)		
4:45 - 5:00 pm	Closing Presentation				
5:00 pm	Conference Adjournment				
### TUESDAY, OCTOBER 22

#### **KEYNOTE ADDRESS**

**Presenter:** Robert Bonnie, USDA, Under Secretary of Agriculture for Natural Resources and the Environment

#### TUESDAY, OCTOBER 22

#### **SATELLITE MONITORING OF FIRES AND INTERNATIONAL COORDINATION**

**Presenter:** Christopher Justice, PhD, Chair of the Department of Geographical Sciences, University of Maryland **Co-author:** Krishna Vadrevu, Department of Geographical Sciences, University of Maryland College Park

Fires occur throughout the world, wherever there is enough dry fuel and weather conditions to carry the fire. These include wildfires and land use fires. In some regions of the World with little or no human population, or where there are no fire management capabilities, wild fires are allowed to burn across the landscape. In other regions, development and the high pressure for land often means that people live in fire-prone ecosystems. Extreme weather events in such regions can result in catastrophic fires, resulting in loss of life and property and efforts to manage or fight wildfires come at great expense. In a gradually warming world, we can expect modification of current fire regimes. Fires associated with land use practices such as crop residue burning or land-clearing are found in many parts of the World and are by comparison easier to manage, although not without its own challenges. Policies can be put in place to reduce or ban burning, but need to be enforced. Fires produce emissions which impact atmospheric composition and airquality, and for an exposed population, persistent smoke can have serious health impacts. Emission products injected into the atmosphere travel long distances powered by atmospheric circulation patterns. In extreme cases, trans-boundary transport of smoke gains international attention and efforts are made to develop international policy solutions.

Satellite observations can give us a global perspective of the extent of fire on the planet, highlighting where fires occur in time and space. They can also be used to show the distribution of smoke associated with fires. Starting with the NOAA AVHRR polar-orbiting system, in the early 1980's, daily satellite observations have been used to develop global maps of fire distribution. These were subsequently improved by the two NASA MODIS instruments, with sensors specifically designed for fire monitoring, together providing global observations four times per day. Operational geostationary satellites provide a higher temporal frequency fire record with regional observations every 30 minutes. Algorithms have been developed for extracting active fire and post-fire, burned area and smoke aerosol information from satellite observations. The science of providing consistent fire products from satellite assets are now providing information on fires and aerosols for both global change research and applications of societal benefit. Data systems have been developed to deliver both near real-time consistent long-term records of these

products in different formats to meet the needs of diverse user communities. The international GOFC-GOLD Program has been established to provide a forum for sharing new developments in this science and to advocate for continuity and advances in satellite fire observations. The presentation will highlight aspects and prospects of satellite fire monitoring science and applications. Sample case studies on fire mapping and monitoring will also be showcased including pollution episodes captured by the satellites. An overview of the GOFC fire program and its activities will be presented.

#### TUESDAY, OCTOBER 22

# WILDFIRE IN THE WESTERN UNITED STATES IN THE MID-21ST CENTURY AND CONSEQUENCES FOR AIR QUALITY: RESULTS FROM AN ENSEMBLE OF CLIMATE MODEL PROJECTIONS

**Presenter:** Loretta J. Mickley, PhD, Senior Research Fellow School of Engineering & Applied Sciences Harvard University

Wildfire emissions can adversely affect air quality locally and downwind. In North America, wildfire activity is strongly related to weather conditions, such as temperature and humidity. Observations show an increasing trend in the area burned by fires in the western United States, suggesting that climate change may have already enhanced wildfire activity in this region. In this study, we estimate future wildfire activity over the West during the mid-21st century (2046-2065), based on results from an ensemble of climate models. We develop fire prediction models by regressing meteorological variables from the current and previous years together with fire indexes onto observed regional area burned. The regressions explain 25%-60% of the variance in observed annual area burned during 1980-2004, depending on the ecoregion. In a second approach, we parameterize daily area burned with temperature, precipitation, and relative humidity. For California, we also include the impact of Santa Ana wind and other geographical factors on wildfires. The parameterization approach explains 50% of the variance in observed area burned over forest ecoregions and as much as 64% of the variance in southwestern California. By applying the meteorological fields from 15 climate models to these fire prediction models, we quantify the robustness of our wildfire projections at mid-century. We then use a chemical transport model to assess the impact of changing wildfire activity on air quality.

In the regression approach, our results show increases of ~20-120% in area burned in the Western United States by the 2050s; the parameterization yields increases of ~60-170%. For the month of August alone, area burned nearly quadruples in the Rocky Mountains. The parameterization also predicts a lengthening of the fire season by about three weeks in the warmer and drier climate at mid-century. We find that these increases in wildfire activity enhance summertime surface concentrations of organic carbon aerosol over the western United States by ~50-70% at midcentury, relative to the present day. Concentrations of black carbon aerosol increase by ~25%. The pollution is most enhanced during extreme episodes: above the 84th percentile of concentrations in the Rocky Mountains, organic carbon aerosol nearly doubles and black carbon aerosol increases by ~50%. Visibility during these episodes decreases from 130 km to 100 km. Our use of an

As of 10/16/2013

ensemble of climate models allows us to predict trends in future fire activity with greater confidence than previously, and to diagnose the consequences of these trends for air quality across the western United States.

#### WEDNESDAY, OCTOBER 23

#### SMOKE CONSEQUENCES OF NEW WILDFIRE REGIMES DRIVEN BY CLIMATE CHANGE

**Presenter:** Uma Shankar, Senior Research Scientist, Institute for the Environment-University of North Carolina

**Co-authors:** Donald McKenzie, Uma Shankar, Robert E. Keane, Warren E. Heilman, E. Natasha Stavros, Douglas G. Fox, and Allen C. Riebau

Smoke from wildfires has adverse biological and social consequences, and various lines of evidence suggest that wildfire smoke episodes in the future may be more intense and widespread, demanding that methods be developed to address its effects on people, ecosystems, and the atmosphere. We review the essential ingredients of a modeling system for projecting smoke consequences in a rapidly warming climate that is expected to bring about significant changes in wildfire regimes. We present relevant details of each component of the system, offer suggestions for the elements of a modeling agenda, and give some general guidelines for making choices among potential components, and assessing their uncertainties. This overview is intended for a prospective audience of researchers who are expected to be already fluent in building some or many of these components. Thus our guidelines neither prescribe nor advocate particular models or software; our intent, instead, is to highlight fruitful ways of thinking about the task as a whole and about its components, while providing substantial, if not exhaustive, documentation from the primary literature as reference. This synthesis provides a guide to the complexities of smoke modeling under climate change, and a research agenda for developing a modeling system that is equal to the task while being feasible with current resources.

#### WEDNESDAY, OCTOBER 23

#### **SMOKE AND HUMAN HEALTH: MEDICAL SCIENCE AND RESPONSES**

**Presenter:** Wayne E. Cascio, MD, FACC, FAHA, Director, Environmental Public Health Division, NHEERL/ORD/US EPA

#### WEDNESDAY, OCTOBER 23

# THE JOINT FIRE SCIENCE PROGRAM SMOKE LINE OF WORK AND SMOKE SCIENCE PLAN: HISTORY, IMPLEMENTATION, AND PROGRESS

**Presenter:** Allen R. Riebau, PhD. Joint Fire Science Program Smoke Science Plan Coordination Team, Nine Points South Technical Pty. Ltd., Western Australia

From its inception in 2000 the Joint Fire Science Program (JFSP) has funded research in smoke. Over the years the breadth and complexity of JFSP smoke science has greatly increased and has had significant implications for many areas of fire management. Acknowledging that the depth of the smoke science legacy created, the implications of on-

going research, and the planned levels of future funding created a need in the smoke line of work for the next evolutionary step in its management, IFSP in 2009 developed a Smoke Science Plan (SSP). This action was purposed to insure the line of work was more responsive to management needs and produced more focused science that was yet more broadly complimentary to other focus areas of IFSP research. This plan was devised through personal interviews and an extensive web-based needs investigation between scientists and managers using on-line questionnaires. It is structured under four themes, which are conceptualised as complementary investigative areas which will further both smoke science and management practice. The themes are: 1) Emissions Inventory Research, 2) Smoke and Fire Model Validation, 3) Smoke and Populations, and, 4) Climate Change and Smoke. The objective of the Emissions Inventory Theme is to develop the missing science and knowledge needed for improving national wildland fire emissions inventories. Funded projects are characterizing organic aerosol emissions and their impacts on regional particulate and ozone pollution and evaluating the quality of inventory tools in current use. Future work will define best practices for developing future inventories and inventory systems. The objective of the Model Validation Theme is to develop the scientific scope, techniques and partnerships needed to objectively validate smoke and fire models using field data. Funded projects are developing methodologies to archive, organize, present and apply field data for model validation, and initiating comprehensive validation dataset collection. Future work will advance an interagency agenda for smoke model validation. The objective of the Populations and Smoke Theme is to quantify the impact of wildland fire smoke on populations and fire fighters, elucidate the mechanisms of public smoke acceptance in light of needs for balance between ecosystem health and acceptable smoke exposure risk. Funded projects are also considering potential impacts of megafire smoke on large urban centers. Future work will assess smoke health risks and provide science to improve public smoke warning systems. The objective of the Climate Change Theme is to understand implications of wildland fire smoke to and from climate change using UN IPCC scenarios as guidelines. Now that the Smoke Science Plan has been implemented for approximately three years, what progress has resulted under each theme? Has there been complementary progress between the theme research? In this paper we will discuss these questions, outline how the process of Joint Fire Science Program solicitations influences the progress of its sponsored smoke science, elaborate the measures of progress we see appropriate for the smoke line of work, and clarify objectively the state of smoke science investments we have made. Finally, we will begin a preliminary discussion of what science needs or 'gaps' we see as needful for the Joint Fire Science Program to address after the current Smoke Science Plan expires in 2016. As a necessary complement to the SSP the JFSP has now begun implementing a formal Smoke Communications Plan, a newly designed activity which will insure that SSP products are more effectively delivered to users nationwide though the JFSP network of technology transfer consortia.

#### THURSDAY, OCTOBER 24

# **COLLABORATIVE APPROACH: SMOKE MANAGEMENT AND BALANCING THE ROLE OF FIRE IN ECOSYSTEMS**

**Presenter:** Mark Melvin, Conservation Management/Education Technician Joseph W. Jones Ecological Research Center and Chair, National Coalition of Prescribed Fire Councils

For millennia, anthropogenic knowledge of fire was passed from generation to generation. Humans sought ways to live with fire harmoniously, and to efficiently create environments that were safe and more habitable and productive. In the United States, these ancient linkages between man and knowledge of domestic fire began to erode as our country became industrialized; and after five generations, today this linkage is nearly severed. Renewing this human and fire link is essential to restore and maintain ecosystem health, and more importantly, to provide public health and safety.

Twenty-first century prescribed fire managers face increasingly complex challenges that limit or potentially threaten the use of fire. Never before in history have land managers found these challenges broader in scope. Modern day prescribed fire managers must consider a complex web of policy, legal statutes, and liability, as well as public safety, health, and acceptance. Perhaps the greatest change over the last century is the land manager's need to plan and execute prescribed fire in a socially acceptable manner. But, collectively these challenges are greater than any one land owner, group, agency, or state can address alone.

The degree of difficulty of implementing an individual burn is often defined by location and complexity, but coordination is the key to success. The most successful prescribed fire programs, no matter their location or level of difficulty, are the result of effective partnerships. Across the country local, state, and regional groups are emerging, leveraging unity and vision, and accomplishing common goals. These groups are identifying barriers to fire implementation and developing pathways to success. Most importantly, they are restoring and/or preserving the modern day land manager's ability to use prescribed fire for resource benefit. The challenges are many, but if prescribed fire is to remain a viable resource management tool into the future, it will require the combined problem-solving efforts of the entire fire community and increased public acceptance.

#### THURSDAY, OCTOBER 24

#### FIRE SMOKE AND HUMAN HEALTH: HOW WE SHARE WHAT WE KNOW

**Presenter:** Janice E. Nolen, Assistant Vice President, National Policy, American Lung Association

### 1. America Still Burning

Author(s): Maranghides Alexander, NIST William Mell, USFS

**Abstract:** In 1973 America Burning articulated the statistics of the devastating costs associated with building fires. The National Commission on Fire Prevention and Control (NCFPC) and its staff published the report on May 4, 1973. Included in the report was the NCFPC's recommendation to establish a permanent U.S. Fire Administration "to provide a national focus for the Nation's fire problem, and to promote a comprehensive program with adequate funding to reduce life and property loss from fire. Through a series of federal initiatives and investments in academia, after 40 years of research, fire protection engineering has in large part address the building fire problem in the US.

The national Wildland and WUI fire problems in the US, however, have been rapidly increasing in the last five 5 decades. Documented WUI structural losses averaged 3000 per year between 2000 and 2010, and appear to be increasing. In 2011, over 2000 homes were destroyed in Texas and in between 2012 and 2013, within a twelve month period over 1000 were destroyed in Colorado alone.

The fundamental problem facing the WUI fire problem is the complete disconnect between the built environment and the fire and ember exposures experienced during real WUI fires. This complete uncoupling between test methods, building codes/standards and best practices and the actual exposures resulted in the unsuccessful transfer of this complex technical problem to the homeowner. This is in complete contrast to how the "inside" fire problem has been solved for building fires.

This paper will outline the technical gap between current tools and the specific needs of building codes and standards. Additionally the paper will highlight the need to bridge that gap though research in laboratory, field fire testing, post fire reconstructions and fire modeling.

**Bio**: Alexander Maranghides is responsible for the NIST WUI Fire Exposure Data Collection and Modeling research effort. He is the co-inventor, with Dr. William Mell (USFS) of the WUI Exposure Scale. Mr. Maranghides is Fire Protection Engineer with 20 years experience in intermediate and large scale testing and Widland Urban Interface fire research

# 2. A New State Protocol to Protect Public Health From Severe Wildfire Smoke Impacts in Oregon

Author(s): Brian Finneran, Oregon Dept of Environmental Quality

**Abstract:** Following Oregon's severe 2012 wildfire season, a state task force of air quality, health, and safety representatives developed the Oregon Wildfire Response Protocol for Severe Smoke Episodes. This protocol provides guidance to state, federal, and local officials, organizations and other partners in Oregon when there are major smoke impacts from wildfire. It highlights roles and responsibilities for providing air monitoring, wildfire smoke forecasting, and public/media communication, and includes health effects information and recommended public health actions based on the level and duration of smoke exposure. Presentation will describe protocol development, how well the protocol worked when put to the test by major wildfires this year, and possible application to other states.

**Bio**: Brian Finneran is Senior Air Quality Specialist with the Oregon Department of Environmental Quality. He has worked for the agency for 32 years, and is the state smoke management coordinator, overseeing all forestry and agricultural prescribed burning programs, and coordinating agency response to major wildfires, to ensure air quality and public health are protected. He is also the state regional haze coordinator, responsible for protecting visibility in federal Class I areas, and developed Oregon's first regional haze plan in 2010. Brian lives in Portland OR, married with two children, avid cyclist and photographer. Education: Humboldt State University, University of Oregon. 118- Oral Presentation

# 3. Wildland Fire Management Policy and Air Quality in the Southern Sierra Nevada: Using the Lion Fire as a Case Study for a Multi-year Perspective on PM2.5 Impacts and Fire Policy

Author(s): Schweizer, Don

**Abstract:** Wildland fire is an important component to forest ecological health in the Sierra Nevada, which is located adjacent to the California Central Valley - one of the most polluted airsheds in the world. Historic fire suppression has led to a backlog of fuels, limited the ecological benefits of fire, and reduced short-term smoke impacts. Smoke impacts can be expected to increase as fire size and intensity increase and the fuel backlog is consumed whether through reintroduction of fire or through stand replacing fire. The Lion Fire, a primarily low intensity 8,370 hectare fire that was extensively monitored for PM2.5, is used to quantify impacts to air quality. Long-term PM2.5 monitoring sites were used to assess impacts to air quality and subsequently quantify annual air quality impacts from a fire that is near the historic normal fire size and intensity for this area. Ground level PM2.5 impacts were not found to reach the populated Central Valley. Localized impacts were generally moderate and were below annual federal air quality standards for PM2.5. The localized impacts to air quality measured during this fire can inform fire managers and policy in an area with severe anthropogenic air pollution and where frequent widespread fire is both beneficial and inevitable. The more extensive air quality impacts documented with large high intensity fire may be averted by embracing the use of fire to prevent unwanted high intensity burns. A widespread increase in the use of fire for ecological benefit may provide

the resiliency needed in Sierra Nevada forests as well as be the most beneficial to public health through the reduction of single dose exposure to smoke and limiting impacts spatially.

**Bio**: Don Schweizer is a researcher with UC Merced studying smoke impacts from wildland fire. He is involved in air pollution research and smoke monitoring throughout the Sierra Nevada mountains of California and has worked as an Air Resource Specialist with the U.S. Forest Service and the National Park Service..

#### 4. Recent Emissions Research in Southwestern Shrub and Grassland Fuels

#### Author(s):

David Weise, USDA Forest Service Seyedehsan Hosseini, UC Riverside Sheryl Akagi, University of Montana Robert Yokelson, University Montana Marko Princevac, UC Riverside Wayne Miller, UC Riverside Heejung Jung, UC Riverside David R. Cocker, III, UC Riverside Shawn Urbanski, USDA Forest Service Ian Burling

**Abstract:** While it is currently challenging to use prescribed burning in chaparral and other southwestern shrub fuel types due to many constraints, any such activities require smoke management planning. Information on fuels and emissions from chaparral were limited and based on older sampling systems. The DoD SERDP program funded a project to measure fuels and smoke emissions in the laboratory and field. These data were then compared to smoke transport predictions using the current air quality tools (CMAQ, BlueSky, and SMARTFIRE. A collaborative laboratory experiment produced new emission factors for many previously unmeasured gaseous and particulate emissions. We successfully measured fuels and sampled emissions from the ground and an aircraft on two prescribed burns in chaparral and one in Emory oak woodland. Smoke emissions were measured on three additional chaparral fires including one in which we followed the plume nearly 20 miles downwind from an airborne platform. Of the three air quality tools, BlueSky produced predictions which compared favorably with observed data. This presentation will present highlights of this complete, complex, multi-partner project which has produced numerous results to date.

**Bio**: David R. Weise, Research Forester, USDA Forest Service has been involved in prescribed fire research in the southeastern and southwestern U.S. since 1980. His current research interests focus on the mechanisms of lower intensity fire behavior in live fuels such as chaparral, sagebrush, and gallberry. This experimental and modeling work has documented

shortcomings of existing fire spread models and indicated the importance of convective heat transfer for successful fire spread in these fuel types. Recent work has also focussed on developing improved smoke emissions information for chaparral fuel types.

### 5. Exploiting Visualization for Better Understanding of Wildland Fire Behavior

Author(s): Glenn Forney, NIST William Mell, U.S. Forest Service

**Abstract:** Fire models are used to study fire behavior in wildland environments. Visualization is a technique used to obtain insight from these models by converting numbers into pictures. This allows one to more easily gain a better understanding of the underlying fire phenomena (a picture is worth a thousand words). This talk gives an overview of some of the visualization techniques that the software tool Smokeview uses for examining outdoor fires.

WFDS (Wildland-urban interface Fire Dynamics Simulator), a variant of the fire model FDS, is a computational fluid dynamics (CFD) model of fire-driven fluid. The fundamental purpose of any mathematical model, a fire model such as WFDS in particular, is to gain insight into the underlying phenomena. Visualization then aids in gaining this insight. There is no one best method for visualizing data. Each technique highlights a different aspect of the data. This data takes many forms. Some data is static, whereas other data evolves with time. Smokeview displays fire dynamics data allowing quantitative assessment to be performed using visualization techniques such as animated tracer particles that follow the flow, animated shaded 2D and 3D contours that display flow quantities and animated flow vectors that display flow quantities and direction. Smokeview also visualizes smoke realistically by converting soot density to smoke opacity, displaying smoke as it would actually appear. Each of these visualization techniques highlights different aspects of the underlying flow phenomena.

**Bio**: Glenn Forney is a computer scientist at the Engineering Laboratory of NIST. He received a bachelor of science degree in mathematics from Salisbury State College and a master of science and a doctorate in mathematics from Clemson University. He joined the National Institute of Standards and Technology in 1986 and has since worked on developing tools that provide a better understanding of fire phenomena, most notably Smokeview, a software tool for visualizing fire simulation data.

#### 6. Smoke Monitoring and Dispersion Modeling at the Palmerton Superfund Site

Author(s): John Hom, USDA Forest Service Mike Kiefer, Michigan State Univ. Warren Heilman, USDA Forest Service Michael Gallagher, USDA Forest Service Dan Kunkle, Lehigh Gap Nature Center Matthew Patterson, USDA Forest Service Tom Whitlow, Cornell University

Abstract: This smoke monitoring and modeling study at the Palmerton Superfund Site will estimate the amount of heavy metals released and predict smoke transport with prescribed burning. The Lehigh Gap Nature Center (LGNC) is located on the Palmerton Superfund site in Pennsylvania, which was contaminated with heavy metals from long term zinc smelting, resulting in loss of vegetation cover. The barren mountainsides were remediated by the Nature Center by planting prairie grasses on the site. The prairie grasses have stabilized the soil, do not take up the heavy metals, but are now considered a fire hazard. To effectively manage the prairie grasses, the LGNC in cooperation with the U.S. Environmental Protection Agency (EPA) and the USFS, are testing prescribed fire as a management tool at this site to reduce the fire hazard and eliminate unwanted woody trees and shrubs which take up and mobilize the heavy metals in the soil. Results presented from this test burn include monitoring the prescribed burn for contaminates and particulate emissions, meteorological variables, and fuel consumption. A coupled meteorological and atmospheric dispersion modeling system, ARPS-FLEXPART, is used to predict the local meteorological and air-quality impacts of the grassland prescribed burn and smoke dispersal to the surrounding wildland urban interface.

**Bio**: I am an interdisciplinary scientist with the USDA Forest Service, Northern Research Station. Currently I am working on validation of smoke dispersion models from low intensity fires, using tree ring analysis to predict adaptability to climate change, as well as research in the interaction of climate, fire and invasive insects.

**7. Climate, Carbon, Emissions: The Evolving Scope and Importance of Smoke Science Author(s):** *William Sommers, George Mason University* 

**Abstract:** Science advancement derives from our ability to observe, our need to understand what we observe and our desire to forecast future events based on our observations and understanding.

Fire has been a principal agent of carbon movement between terrestrial ecosystems, the atmosphere and other carbon reservoirs for over 420 million years of Earth history, appearing in fossil charcoal records soon after the arrival of vascular plants. Emissions from wildland fire observed in charcoal records vary over geologic time and human history, informing our understanding of fire-climate and fire-human interactions. In recent decades, our understanding of global fire processes has been enhanced by satellite based observations of fire and smoke. Paleo-fire charcoal and remote sensing observations of smoke, while at opposite ends of the time continuum, have both received heightened attention because they contribute to our understanding of how fire and climate change function.

Until recently, smoke science has mainly focused on observing and understanding how smoke is emitted and transported in regard to air quality, transportation and human health concerns. While these traditional smoke science pursuits remain important, future expansion of smoke science will trend towards observations that enhance quantification of fire emissions in regard to carbon transport and climate processes. Examples of recent and planned research activities that illustrate this trend to new observational approaches for studying climate, carbon and emissions will be discussed. In addition to providing new insights into fire processes and emissions, these activities are helping to shape the future direction of smoke science. The enhanced observations and understanding gained from these activities will be needed to forecast future mega smoke events associated with climate driven shifts in fire regimes that are increasingly impacting large populations both within and across national boundaries. They are also integral to forecasting future climate feedback mechanisms associated with accelerated carbon cycling by fire. Traditional smoke scientists and their clients will have opportunities but also face challenges as funding resources shift and smoke science grows in scope and importance. Suggestions are offered for fostering continuing contributions to this rapidly evolving field of science.

**Bio**: Dr. Sommers has been involved with fire research for over 40 years and is currently a Research Professor affiliated with the EastFIRE Laboratory, Environmental Science and Technology Center (ESTC), College of Science, George Mason University (GMU), Fairfax, Virginia, USA. Prior to joining Mason, Dr. Sommers was affiliated with Forest Service Research from 1973 until his retirement as Director of Forest Fire Research in 2000. Dr. Sommers has served as Chair of the National Wildfire Coordinating Group (NWCG), as Vice-President and Board of Directors member of the International Association of Wildland Fire (IAWF), and the International Association of Boreal Forest Research (IBFRA). During his career Dr. Sommers has been involved with in the formation of the IAWF, the Joint Fire Science Program (JFSP), the Wildland Urban Interface (WUI) and the U.S. Global Change Research Program initiatives. Dr. Sommers recently served as the lead author of a JFSP report entitled: Synthesis of Knowledge: Fire History and Climate Change. Education: PhD (1972): State University of New York, Albany, NY.

SM (1967): Massachusetts Institute of Technology, Cambridge, MA BS (1965): City College of New York, New York, NY

# 8. Projecting the Impacts of Climate Change on Annual Areas Burned Over the Southeastern U.S.

**Author(s):** Kevin Talgo, University of North Carolina at Chapel Hill - Institute for the Environment

Uma Shankar, University of North Carolina at Chapel Hill - Institute for the Environment Aijun Xiu, University of North Carolina at Chapel Hill - Institute for the Environment Jeffrey Prestemon, USDA Forest Service

Dongmei Yang, University of North Carolina at Chapel Hill - Institute for the Environment

Abstract: Under the Forest and Rangeland Renewable Resources Planning Act (RPA) of 1974, the Forest Service and other federal agencies, along with researchers from many universities, are required to generate national RPA Assessment reports on a ten-year cycle. These reports include descriptions of the current conditions of the US forest and rangeland, identify the main drivers of changes in these resources, and provide projections of resource conditions in the next 50 years. In support of this goal, analyses were conducted to project the impacts of climate change on annual areas burned (AAB) using global climate simulation data corresponding to the latest projection time frame, 2010-2060. The criteria for the emissions scenario and climate model selection in the RPA Assessment framework are that they be globally consistent, scientifically credible, and well documented. Statistically downscaled data for fire weather parameters at 8 arc-minute resolution were obtained from a suite of three models for three scenarios available in the Parameterelevation Regressions on Independent Slopes model (PRISM) system archive for the retrospective period 1940-2006 and simulations from global climate models for 2010-2060. These were remapped to a modeling domain over the Southeastern U.S. on a columnrow grid and used to develop statistical models that project AAB in contemporary and future periods. Statistical models, derived from theory, recognize not only the changes in driving climate variables but also those in biophysical, socioeconomic, and land use variables that have been shown to explain wildfire historical variations in time and space. Statistical models are applied, using projected AAB climate and projections of the additional wildfire drivers to yield corresponding wildfire projections across the spatial domain, 2010 to 2060. For this report, wildfire projections are summarized by ecological region and state.

# 9. Managing for Fire and Smoke in a Changing Climate: Is it a Moving or a Fixed Target?

### **Author(s):** Gary L. Achtemeier, USDA Forest Service Ned Nikolov, USDA Forest Service

**Abstract:** Most of climate change is understood in terms of global-scale warming caused by carbon dioxide released from anthropogenic combustion of fossil fuels. Climate models predict slow but steady warming over the next five to ten decades. Developing fire and smoke management strategies under conditions of continuous climate change may be difficult as weather continually adjusts to changing climate. Thus long-term climate change by CO2 warming may present a "moving target" for decision-making by land managers. On the other hand, "climate surge" events followed by long periods with little to no change can produce initial large changes in weather that afterward remain relatively unchanged. Conceptually, it is easier to develop land management strategies to adapt to these "fixed target" conditions. Evidence is presented to support an argument that most of recent climate warming in the northern hemisphere is the outcome of a natural "climate surge" rather than from slow long-term human-caused CO2 warming. There have been no

significant global temperature changes over the past 14 years. Thus land management strategies can be based on current climate – a new normal.

**Bio**: Gary L. Achtemeier is senior meteorologist with the USDA Forest Service Southern Research Station Institute for Forest Disturbance Science located at Athens, Georgia, USA. His research interests include smoke plume rise and dispersion from prescribed burns (Daysmoke), smoke transport along the ground at night over complex terrain (PB-Piedmont), smoke/fog and roadway visibility (superfog), and rule-based fire spread and plume updraft core modeling (Rabbit Rules).

# **10.** Assessment of Emission Gas and Health Hazard for Combustion of Surface Fuelbeds in Korean Forests

### Author(s): Donghyun Kim, IIASA and KFRI

**Abstract:** This study sought to identify the composition of emission gases and measured their concentration from combustion of surface fuelbeds in Korean forests. As a result, it was found that there were 14 kinds of the emitted gases such as Carbon monoxide, Carbon dioxide, Acetic acid, Butyl acetate, Ethylene, Methane, Methanol, Nitrogen dioxide, Nitrogen monoxide, Ammonia, Hydrogen fluoride, Sulfur dioxide and Hydrogen bromide. The overall concentration of combustion gas emitted from fuelbeds of Pinus densiflora was about 4.5 times higher than Quercus variabilis. Particularly, it was found that concentration of carbon monoxide exceeded the upper limit of their time-weighted average (TWA, ppm). The average concentration of carbon monoxide and carbon dioxide measured 94.43 ppm and 810.37 ppm in Pinus densiflora. Carbon dioxide and Carbon monoxide from fuelbeds combustion of Pinus densiflora were emitted 2.77 g and 0.29 g per gram of fuelbeds in the combustion process. These two gas types account for higher than 99% of overall gas emission due to combustion of surface fuelbeds.

**Bio**: I joined IIASA's Ecosystems Services and Management (ESM) Program in October 2012, as a research scholar financed by the Korean Forest Research Institute (KFRI) in cooperation with the International Union of Forest Research Organizations (IUFRO). My research carried out with ESM is contributing to the development of a fire weather index at national/regional level and Study on Carbon flux and emission from forest fire.

I has been working at KFRI, South Korea since 2003, where he has focused on developing solutions for forest fire protection and management.

I received his PhD in forest fire and disaster management from the Kyoto University in Kyoto, Japan, in 2009. My PhD work focused on developing a prediction model for the spread of fire, based on numerical analysis.

# **11. The Potential Air Quality Impacts of Fires: Isocyanic acid HNCO**

Author(s): James Roberts, National Oceanic and Atmospheric Administration

Solomon Bililign, North Carolina A&T State University Paul J. Young, Lancaster University, UK Ian R. Burling, Department of Chemistry, University of Montana Marc N. Fiddler, North Carolina A&T State University Robert J. Yokelson, Department of Chemistry, University of Montana Carsten Warneke, NOAA/University of Colorado Trevor C. VandenBoer, Memorial University, New Foundland, CAN Patrick Veres, NOAA/University of Colorado Joost de Gouw, NOAA/University of Colorado Mary C. Barth, National Center for Atmospheric Research

**Abstract:** Recent improvements in measurement techniques have led to a more complete picture of the chemistry of fire emissions. This increase in understanding presents the possibility of identifying and predicting the effects of specific compounds on human health. Isocyanic acid, HNCO, is one such compound that is present in flaming stage combustion of biomass fires, and that has recognized biochemical pathways related to known smoke-related health effects. The measurement of HNCO in laboratory and ambient fires will be described. The atmospheric chemistry of HNCO will be summarized and results of several global numerical modeling studies will be presented. Strategies for assessing the impact of HNCO from domestic or wild fires will be explored.

**Bio**: Dr. Roberts is a Research Chemist in the Chemical Sciences Division of the NOAA Earth System Research Laboratory in Boulder, Colorado. Dr. Roberts has 35 years of experience inthe conduct of laboratory and field studies of atmospheric chemistry.

# **12. Investigating the Behaviour of Hourly PM2.5 Emissions During Prescribed Burns in a South-Eastern Forest**

Author(s): Naeher, Luke, The University of Georgia, College of Public Health, Department of Environmental Health Science, Athens, GA, USA
J.L. Pearce, The University of Georgia, College of Public Health, Department of Environmental Health Science, Athens, GA, USA
S. Rathbun, The University of Georgia, College of Public Health, Department of Biostatistics, Athens, GA, USA
G. Achtemeier, United States Department of Agriculture, Forest Service, Athens, GA, USA

**Abstract:** An air quality monitoring campaign was conducted from 2003-2007 during the months of December through April in which real-time monitoring of particulate matter ≤ 2.5 m (PM2.5) was conducted on 52 prescribed burns. In effort to explain the variation associated with monitored emissions we present a generalized additive model where the logarithm of hourly PM2.5 concentrations are modeled as the sum of linear and non-linear functions of meteorological conditions, burn characteristics, space, and time. Our fitted model explains 52 % of the hourly variation in PM2.5. Concentrations are significantly

influenced by distance from burn perimeter, hour of ignition, type of ignition, time elapsed since ignition, temperature, wind shifts, intensity of the burn, wind speed, duration of the burn, and regional background PM2.5 concentrations. Moreover, upper air parameters for boundary layer height and wind speed, as well as the status of the burn (active or extinguished), were found to be insignificant.

**Bio**: Luke P. Naeher is an Associate Professor in the Department of Environmental Health Science at The University of Georgia's College of Public Health. Dr. Naeher's research focus is exposure assessment and environmental epidemiology with a particular focus on health effects related to air pollution. Dr. Naeher has current research projects on exposures related to woodsmoke in Peru (pregnant women) and the southeastern US (forest firefighters). Dr. Naeher teaches undergraduate and graduate classes in environmental science, environmental health science, and air pollution at UGA, and is currently the major professor for several MS, PhD, and DrPH graduate students.

#### 13. Wildland Urban Interface Exposure Scale

Author(s): Alexander Maranghides, NIST William Mell, USFS

**Abstract:** One of the fundamental issues driving the destruction of homes at the interface is the very limited coupling between building codes and standards and potential fire and ember exposure. The limited exposure information currently available does not address the full range of realistic WUI exposures and offers little context for the design of ignition resistant landscapes and buildings. While the principles of ignition and fire spread at the WUI have been known, actual exposure quantification has been very limited. The resulting gap between exposure and structure ignition has therefore resulted in a lack of tested and implementable hazard mitigation solutions. As an example, there is currently little quantifiable information that links the ember generation from wildland fuels to building assemblies testing.

A WUI fire and ember exposure scale (WUI-scale) nee d s to be created to help consistently q uantify the expected s everity of WUI fire events based on measures, or scales, of expected ember and fire exposure. O nce established, these technically based e m ber and fire e x posures for the WUI can form the technical foundation for the development of a set of performance based building codes ai m ed at providing a level of structure ign i tion protection commensurate with the expected fire and/or e m ber exposure.

The concept is based on quantifying expected fire and e m ber exposure throughout an existing WUI community. The proposed WUI-scale can be used to explicitly identify WUI areas that have a fire problem, as opposed to areas that meet housing density or wildland vegetation requirements as is frequently done. The scale can therefore be used to provide the boundaries where specific land use and/or building construction regulations would apply. Finally, the exposure scale can be used for both new and exi s ting WUI communities.

**Bio**: Alexander Maranghides is the co-inventor, with William (Ruddy) Mell, of the WUI hazard Scale. Mr. Maranghides is a Fire Protection Engineer with 20 years experience in intermendate and large scale fire testing, and the wildland urban interface.

#### 14. Basic Smoke Management Practices

Author(s): Peter W. Lahm, USDA Forest Service Susan O'Neill, USDA Forest Service Doug Whisenhunt, USDA Natural Resources Conservation Service Greg Johnson, USDA Natural Resources Conservation Service

Abstract: Smoke from prescribed burning is not like many other air pollution sources. Direct controls cannot be put on it as might be applied to a point source, such as a power plant smoke stack, but rather a variety of environmental factors must be taken into account to manage both the burn and the smoke from the burn. Basic Smoke Management Practices (BSMPs) outlined in this presentation offer a suite of options that a fire manager can utilize to reduce the impacts of their smoke. Six BSMPs will be profiled: evaluate smoke dispersion conditions, monitor effects on air quality, record keeping (smoke journal), communication, emission reduction techniques, and airshed sharing. These BSMPs have applicability depending on the type of burn, fuels to be burned and level of effort needed to address air quality concerns. Not all BSMPs are applicable to all situations, therefore fire managers are urged to investigate the information available and applicable to their area and needs. Furthermore, these six BSMPs are only a subset of possible BSMPs and others can be adopted. The Exceptional Event Rule (EER – Federal Register /vol. 72 no. 55 /March 22, 2007) also includes a discussion regarding employing BSMPs on a prescribed burn, and how such burns may qualify under the EER if smoke from the burn contributes to an air quality exceedance at a monitor. BSMP's are utilized by the individual fire manager and may be an expectation of a state-wide smoke management program or employed to maintain the social acceptability of using prescribed fire and managing air quality impacts of smoke. This talk will profile possible basic smoke management practices, how BSMPs can form a foundation for a Smoke Management Program, history and usage in regulations, and policy implications.

**Bio**: Pete Lahm is the Air Resource Specialist for the USDA Forest Service, Fire and Aviation Management, in Washington, DC. Starting in 2004, Pete has led the Forest Service's smoke management efforts developing technical approaches and policies related to smoke impacts. Since 2009 he has chaired the National Wildfire Coordinating Group's Smoke Committee. Prior to 2004, Pete managed the Arizona Interagency Air Resource and Smoke Management Program. He chaired the Western Regional Air Partnership's Fire Emissions Joint Forum from 1996-2004. Pete holds a Master's of Environmental Management from Duke University.

# **15.** Do We Always Need Dispersion Models? Empirical Airshed Capacity Values for Prescribed and Wildland Fire in the Sierra Nevada, California

### Author(s): Leland Tarnay, Yosemite National Park

**Abstract:** Effective smoke management (i.e, minimizing air quality impacts in smoke sensitive areas) for prescribed and wildland fire, requires matching smoke emissions to dispersion, so that the capacity of the airshed to disperse smoke on a given day is not exceeded by the amount of smoke emitted. Dispersion modeling aside, are there any rules of thumb for airshed capacity that work? How well? Even with new tools becoming available every day to aid fire managers in predicting dispersion, estimating emissions, and monitoring where their smoke goes, success often involves is as much art as science, and plenty of local knowledge. Variability in fuels across the area burned, topography, dispersion, fire behavior, plume loft, and even timing of emissions all can alter impacts dramatically, at both the local and regional scale. Under both good and poor dispersion regimes, this work looks for consistencies in the relationship between emissions and air quality impacts using data gleaned from air monitors deployed for both prescribed and wildland fire from 2010-2012 in the central and southern Sierra Nevada of California.

**Bio**: Leland Tarnay is the Air Resources Specialist at Yosemite National Park. He has a B.S. degree from UC Davis in Biological Sciences from University of California (1995), Davis and a Ph.D. in Environmental Sciences from University of Nevada, Reno (2001). He has worked on nitrogen deposition and pollutant sources in the Lake Tahoe Basin, as Air Resources Specialist for the NPS Washington DC region, and since 2005 has focused on impacts of fire on air quality, carbon stocks, and greenhouse gas budgets in Yosemite and other areas of the Sierra Nevada.

# 16. Establishing a National Standard Methodology for Operational Mixing Height Determination

**Author(s):** Timothy Brown, Desert Research Institute Gary Curcio, IPA Fire Environment Specialist, LLC Matthew G. Fearon, Desert Research Institute

**Abstract:** Since its development in the late 1960s, the Holzworth method has remained a popular forecasting tool for estimating dispersion potential, or more commonly referenced as the mixed layer height. Many additional studies followed Holzworth's work that emphasized similar techniques with slight nuances. Despite these more recent studies, the Holzworth method is still widely used, perhaps due to its pragmatic nature and intuitive design. The National Weather Service continues to the use this method in a slightly modified form to issue routine forecasts of mixed layer height. Forecasts of mixed layer height are prepared for fire and smoke management such as prescribed burning, though

smoke concentration and dispersion from wildfire is becoming increasingly important as related to public health.

The nature of the Holzworth method and other mixed-layer determination techniques (e.g., Stull method) are principally based on the static stability structure of the atmosphere. Through similar mechanics, these methodologies provide a reasonable estimate of the convective mixed layer for a dry or moist (unsaturated) atmosphere, Holzworth and Stull, respectively. However, their exclusion of the dynamic stability (e.g., wind shear) can lead to significant underestimation of the mixed-layer height. In the context of the operational forecasting, this study re-examines these static stability techniques and compares computed heights (from radiosondes) to those derived from satellite-based lidar (from CALIPSO aerosol depth). Estimates are also examined against planetary boundary layer values from model-derived turbulent kinetic energy (TKE) – the mean kinetic energy per unit mass associated with eddies in the turbulent flow, and a combined representation of static and dynamic stability. This presentation will describe these comparisons, and discuss a recommendation for a national standard methodology for operational mixing height determination.

**Bio**: Director of the Western Regional Climate Center, and established and directs the Program for Climate, Ecosystem and Fire Applications (CEFA) at the Desert Research Institute in Reno, Nevada.

# **17. Monitoring and Modeling Local Smoke Dispersion during Low-Intensity Prescribed Fires**

Author(s): Warren Heilman, USDA Forest Service Michael T. Kiefer, Michigan State University Michael R. Gallagher, USDA Forest Service Matthew Patterson, USDA Forest Service Yongqiang Liu, USDA Forest Service Christie Stegall, USDA Forest Service Nicholas S. Skowronski, USDA Forest Service Kenneth L. Clark, USDA Forest Service John L. Hom, USDA Forest Service Warren E. Heilman, USDA Forest Service Xindi Bian, USDA Forest Service Shiyuan Zhong, Michigan State University Joseph J. Charney, USDA Forest Service

**Abstract:** Smoke from low-intensity prescribed fires used for fuels management can have an adverse effect on local air quality and lead to human health and safety concerns, particularly in wildland-urban-interface areas. Local smoke behavior during low-intensity prescribed fires is a complex process, particularly in forested environments where forest overstory vegetation adds further complexity to fire-fuel-atmosphere interactions that govern local smoke dispersion. The planning and tactical management of low-intensity prescribed fires in forested environments may be enhanced with meteorological and smoke modeling systems that adequately account for the effects of forest overstory vegetation on fire-fuel-atmosphere interactions and the local transport of fire emissions. Through a recently completed Interagency Joint Fire Science Program (JFSP) study (Project 09-1-04-1) involving meteorological and air-quality monitoring and modeling of lowintensity prescribed fires in the New Jersey Pine Barrens, we now have additional insight into how forest overstory vegetation can affect local smoke dispersion. Also, a new version of the Advanced Regional Prediction System (ARPS) capable of simulating turbulent flows inside forest vegetation layers (ARPS-CANOPY) was developed as part of the study. When coupled with an appropriate particle dispersion model, ARPS-CANOPY could potentially be used to predict local air-quality impacts of low-intensity prescribed fires in forested environments. This presentation provides a summary of some of the key meteorological/air-quality observational and ARPS-CANOPY-based modeling results from JFSP Project 09-1-04-1.

**Bio**: Dr. Warren E. Heilman is a Research Meteorologist with the USDA Forest Service -Northern Research Station in East Lansing, MI. He received a B.S. degree in physics from South Dakota State University, and M.S and Ph.D. degrees in meteorology from Iowa State University. His current research is focused on monitoring and modeling small-scale fire-fuelatmosphere interactions and their impacts on fire behavior and smoke dispersion.

# 18. The 2013 BlueSky Canada Wildfire Smoke Forecasting System

Author(s): Kerry Anderson, Canadian Forest Service Narasimhan K. Larkin, U.S. Forest Service Roland Schigas, Department of Earth, Ocean & Atmospheric Sciences, University of British Columbia Steve Sakiyama, BC Ministry of Environment Sean Raffuse, Sonoma Technology, Inc Roland Stull, Department of Earth, Ocean & Atmospheric Sciences, University of British Columbia Al Pankratz, Environment Canada David Lyder, Alberta Department of Environment and Sustainable Resource Development Jed Cochrane, Parks Canada

**Abstract:** In 2007, an inter-agency partnership began the development of a system to forecast the spread of smoke from wildfires in Western Canada based on the US Forest Service BlueSky framework. In 2010 the Western Canada BlueSky system became a reality and smoke forecasts were produced throughout the wildfire season. The system is currently run at the University of British Columbia and couples information on wildfire hot spots observed by satellite, forest fuel loads compiled by the Northern Forestry Research

Center, algorithms to predict smoke emissions and plume rise, weather forecast data produced by a high-resolution numerical weather model (WRF3) and smoke dispersion modeling using HYSPLIT. The forecasts are available through a British Columbia government website ( http://www.bcairquality.ca/bluesky/west/ ) where animations of hourly wildfire smoke in the form of PM2.5 ground level concentrations out to 48 hours into the future can be viewed

The current system, BlueSky Canada, provides smoke forecasts for all of Canada south of the Arctic Ocean. Forecasts are produced twice a day in order to use the latest hotspot detection information. Tests indicate the system is able to handle thousands of fires and properly process the fire information, transport and dispersion in concert with the weather forecasts. Space-time paired comparisons to PM2.5 monitoring data show errors in the details of the magnitude and timing of events, although qualitative comparisons between the forecast smoke patterns and actual impacted areas using MODIS images indicate reasonable agreement in situations involving extensive smoke from large fire complexes.

The system was developed through the collaborative efforts of the following partners: British Columbia Ministry of Environment, British Columbia Ministry Ministry of Forests, Lands and Natural Resource Operations, Alberta Department of Environment and Sustainable Resource Development, Manitoba Health, Ontario Ministry of Natural Resources, Natural Resources Canada, Environment Canada, University of British Columbia and the United States Forest Service. In addition to the above partners, this work is supported by the Canadian Safety and Security Program (CSSP-2012-CP-1182) which is managed by Defence Research and Development Canada's Centre for Security Science.

**Bio**: Kerry Anderson is a fire research scientist with the Canadian Forest Service. Dr. Anderson is actively involved in research to predict smoke forecasting, fire weather and fire behaviour. Through this research, Anderson has and continues to develop models to assist fire management agencies in daily operational planning by predicting the potential impact of fires on the landscape. These models provide a means to determine effective fire suppression response strategies to mitigate the threat. In turn, the goals are to help protect the public, communities, and forests; promote the health of the forest ecosystem; and minimize fire suppression expenditures.

# 19. NOAA's operational prediction of wildfire smoke dispersion

Author(s): Ivanka Stajner, NOAA/NWS Perry Shafran, NOAA/NWS and I.M. Systems Group Jeff McQueen, NOAA/NWS Jianping Huang, NOAA/NWS and I.M. Systems Group Roland Draxler, NOAA/ARL Shobha Kondragunta, NOAA/NESDIS **Abstract:** NOAA provides operational predictions of wildfire smoke dispersion nationwide. These predictions are produced beyond midnight of the following day at 12km resolution at hourly time intervals. Smoke predictions are distributed with other air quality predictions in numerical format and in graphical format at http://airquality.weather.gov/ . Smoke predictions combine NOAA National Centers for Environmental Prediction (NCEP) operational Nonhydrostatic Mesoscale Model on Arakawa B-grid (NMMB) weather predictions with the Hybrid Single Particle Lagrangian Integrated Trajectory (HYSPLIT) dispersion model to provide standalone predictions of wildfire smoke. Smoke sources are based on NOAA/NESDIS analysis of satellite imagery for detection of smoke source locations that is combined with US Forest Service's BlueSky framework to estimate smoke emissions. Routine verification of smoke and dust predictions relies on satellite retrievals of smoke column integrals, which have been developed for this application.

Recent system updates include use of the NMMB weather model, which was implemented at NCEP in October of 2011. Updates for HYSPLIT model planned to be implemented in July 2013 include higher maximum smoke plume rise (up to 1.25 times the planetary boundary layer depth) and decreased wet removal of particles. Examples of predictions and verification for recent wildfires will be shown.

**Bio**: Dr. Ivanka Stajner is the Manager for the National Air Quality Forecast Capability at NOAA's National Weather Service in Silver Spring, Maryland. Prior to her work on air quality prediction at NOAA and Noblis, she was a scientist at SAIC leading data assimilation efforts that combine satellite observations with global atmospheric models at NASA's Goddard Space Flight Center to study ozone. She earned Ph.D. and M.S. degrees from the University of Illinois in Urbana-Champaign, and a B.S. degree from the University of Zagreb in Croatia. She is an Associate Editor for the Journal of Geophysical Research-Atmospheres.

# 20. Development of a Boreal Wildfire Forecasting System

#### Author(s): David Lavoue, DL Modeling & Research

**Abstract:** Forest fires are frequently the main cause of poor air quality in the Canadian northern communities, commonly resulting in health-related evacuations. Long-range transport of wildfire smoke plumes to Canadian urban areas may also result in episodes of deteriorated air quality.

I have been developing a boreal wildfire forecasting system which integrates various numerical models to predict air pollutant emissions and smoke plume dispersion at 48 hours from wildfire dynamics. The following details the different models composing the wildfire forecasting system.

The forecast procedure starts from the daily active wildfire polygons determined with the cluster analysis of fire hotspots detected by MODIS and AVHRR instruments and the fire

activity reported on the ground. Hotspots are partitioned with a k-means clustering algorithm. Hierarchical agglomerative clustering is used to refine initial cluster centers and outliers are removed to optimize algorithm performance.

The Canadian Fire Weather Index (FWI) and Fire Behavior Prediction (FBP) Systems are used to generate fire weather and fire behavior parameters across Canada. Components of the FWI System are calculated from surface meteorological conditions in the 15 km uniform domain of the Canadian Global Environmental Multiscale (GEM) model. Fire behavior components are assessed with the FBP System from the FWI System components, weather conditions, fuel types, and elevation data.

Fire emissions are dynamically predicted by combining the Canadian fire growth model Prometheus with a combustion phase-dependent emission scheme, which includes numerous chemical compounds, including greenhouse gases, carbon monoxide, nitrogen oxides, volatile organic compounds, and aerosols (e.g., black carbon).

The fire front spread is calculated with an elliptical wavelet propagation technique driven by GEM weather. Vectorized fire fronts and area burned polygons are generated for time steps ≤ 1 hour at a horizontal resolution of a few hundred meters which can be exported to various GIS and geobrowsers.

Fire plume rise heights and profiles are calculated with plume rise models and empirical algorithms from fire power and atmospheric stability estimates. Subsequently, the dispersion model HYSPLIT is run to predict the meso-scale and long-range transport and dispersion of smoke.

**Bio**: David Lavoue has over ten years of experience in research and studies in atmospheric sciences. He runs numerical models to study atmospheric transport of pollution and to assess its impact on air quality and climate. As a consultant for Environment Canada, his role was to inform scientists and managers of the role of forest fires in climate and air quality applications, including transport of particulate matter into the Arctic. He performed various modelling output analysis using ambient air measurement datasets, meteorological observations, and climate records.

# 21. Status and Future Plans for the Wildland Fire Emissions Information System: A NASA Tool for Fire-derived Carbon and Trace Gas Emissions Estimation

Author(s): Nancy French, Michigan Tech Reseach Institute Michael Billmire, Michigan Tech Reseach Institute Jessica L McCarty, Michigan Tech Reseach Institute Susan Prichard, University of Washington Roger D Ottmar, USDA Forest Service K Arthur Endsley, Michigan Tech Reseach Institute

#### Donald McKenzie, USDA Forest Service

**Abstract:** The Wildland Fire Emissions Information System (WFEIS) was developed under NASA Carbon Cycle Science and Applications programs to provide a consistent approach to estimating emissions at continental to sub-continental scales (see http://wfeis.mtri.org). We present an overview of the WFEIS system, including the web system functionality and data used for emissions estimates for the US. Plans for system development, strategies for transitioning to an operational environment, and ideas for extending WFEIS to other regions are also presented.

The system taps into tools developed by the US Forest Service to describe fuels, fuel loading (Fuel Characteristic Classification System (FCCS)), and fuel consumption (Consume). For implementation in the US, the system integrates information from USGS and NASA on fire location and timing, USDA NASS on cropland type, and NOAA to derive fire weather. Using a data base of FCCS fuelbeds, fuel consumption and fire emissions are calculated with Consume 4.1, an open-source model in the Python programming language, to derive temporally and geospatially-specific estimates of emissions sources from wildland and cropland burning. Although total carbon emissions is the focus for development, the Consume model allows for estimation of many smoke constituents, including criteria air pollutants defined by the USEPA. In addition to tabular results, WFEIS produces multiple vector and raster formats of mapped fire emissions. The system provides a framework for estimating regional fire emissions anywhere that data are available. Limited application of the WFEIS concept in Mexico and Canada has been facilitated by collaborations with Mexican and Canadian experts. Implementation of the approach in other parts of the world is feasible wherever mapped fuels are available or can be generated.

WFEIS is built from open-source software following international standards facilitating extended system development. The web interface includes a GUI calculator which builds URL-based queries using a RESTful software architecture to implement a web-based Application Programming Interface (API). The system is under active development to increase computational speed and efficiency, to improve the input data sets used in the calculations, provide a measure of uncertainty in the estimates, and to enhance the web interface with additional filter options to serve user needs.

**Bio**: Dr. French has been working on applications of remote sensing to ecology and vegetation studies for over 20 years. Dr. French's research has focused on wildfires and their effect on the structure and function of the terrestrial ecosystem and the implications of fire to carbon cycling. Dr. French has led projects investigating the impact of wildfire on respiratory health and characterizing fire in tundra ecosystems. Dr. French serves on the Editorial Board and as an Assistant Editor for the International Journal of Wildland Fire and is a member of the North American Carbon Program Science Steering Group.

#### 22. Impact of Polyethylene Plastic on Smoke Emissions from Debris Piles

Author(s): David Weise, USDA Forest Service Seyedehsan Hosseini, UC Riverside Heejung Jung, UC Riverside David R. Cocker, III, UC Riverside Manishkumar Shrivastava, Pacific Northwest National Laboratory Qi Li, UC Riverside Michael McCorison, USDA Forest Service

Abstract: Shrubs and small diameter trees exist in the understories of many western forests. They are important from an ecological perspective; however, this vegetation also presents a potential hazard as "ladder fuels" or as a heat source to damage the overstory during prescribed burns. Cutting and piling of this material to burn under safe conditions is a common silvicultural practice. To improve ignition success of the piled debris, polyethylene plastic is often used to cover a portion of the pile. While burning of piled forest debris is an acceptable practice in southern California from an air quality perspective, inclusion of plastic in the piles changes these debris piles to rubbish piles which should not be burned. With support from the four National Forests in southern California, we conducted a laboratory experiment to determine if the presence of polyethylene plastic in a pile of burning wood changed the smoke emissions. Debris piles in southern California include wood and foliage from common forest trees such as sugar and ponderosa pines, white fir, incense cedar, and California black oak and shrubs such as ceanothus and manzanita in addition to forest floor material and dirt. Manzanita wood was used to represent the debris pile in order to control the effects of fuel bed composition. The mass of polyethylene plastic incorporated into the pile was 0, 0.25 and 2.5% of the wood mass-a range representative of field conditions. Measured emissions included NOx, CO, CO2, SO2, polycyclic and light hydrocarbons, carbonyls, particulate matter (5 to 560 nm), elemental and organic carbon. The presence of polyethylene did not alter the emissions composition from this experiment.

**Bio**: David R. Weise is a Research Forester with 32 years experience in prescribed fire research in the southwestern and southeastern Unite States. His current research focus is on fire behavior in live fuels including smoke emissions.

### 23. Comprehensive Emission Measurements from Prescribed Burning in Florida: Field and Laboratory, Aerial and Ground

**Author(s):** Brian Gullett, U.S. Environmental Protection Agency Johanna Aurell, University of Dayton Research Institute Amara Holder, U.S. Environmental Protection Agency

**Abstract:** Johanna Aurell1, Amara Holder2, Brian Gullett2 1University of Dayton Research Institute University of Dayton Dayton, OH 45469 20ffice of Research and Development U.S. Environmental Protection Agency Research Triangle Park, NC 27711

Simultaneous aerial- and ground-based emission sampling was conducted during prescribed burns at Eglin Air Force Base in November 2012 on a short grass/shrub field and a pine forest. Cumulative emission samples for volatile organic compounds, elemental carbon, organic carbon, chlorinated dioxins and furans, and PM2.5 and continuous samples for black carbon, particle size, and CO2 were taken. Aerial instruments were lofted using a 5 m diameter, helium-filled aerostat that was maneuvered with two remotely-controlled tethers mounted on all-terrain vehicles. A parallel set of instruments on the ground made simultaneous measurements, allowing for a comparison of ground level versus elevated measurements. Ground instruments were supplemented by additional measurements of polycyclic aromatic hydrocarbons and particle aerosol absorption and light scattering. Raw biomass was also gathered on site and tested in a laboratory combustion facility using the same array of instruments. This work compares emissions derived from aerial and ground sampling as well as field and laboratory results.

**Bio**: Dr. Brian Gullett is a Senior Research Scientist with the U.S. EPA's Office of Research and Development in Research Triangle Park, NC. He has published over 125 journal articles in the fields of dioxin formation, air toxics measurements, and open area sampling of forest burns, agricultural burns, at-sea oil burns, waste burns, and military ordance burning and detonations. His team has developed an aerostat-lofted instrument system for emission sampling and is working on sensor development and multicopter unmanned aerials systems.

#### 24. Super-Dense Smoke: A Cause for Dangerous Smoke Exposure?

**Author(s):** Gary Achtemeier, USDA Forest Service Luke P. Naeher, University of Georgia John L. Pearce, Emory University

**Abstract:** PM2.5 smoke concentration data were collected from networks of 5-18 gravimetric samplers during 55 prescribed burns conducted at the Savannah River Forest near Aiken SC from 2003-2007. One burn on 28 March 2006 produced extreme 22-hr

averaged concentrations of 600-900 micrograms per cubic meter out to 1.6 km (1.0 mile) from the burn perimeter. Two real-time monitors found maximum concentrations approaching 6000 micrograms per cubic meter after midnight with concentrations above 3000 micrograms per cubic meter continuously from 11PM to 6AM on 29 March. We ran PB-Piedmont to simulate local winds over the burn area. Winds went calm for five hours after sunset then slowly transported smoke over the samplers. None of the gravimetric samplers were located in drainages. PB-Piedmont signaled the presence of natural fog and conditions were favorable for superfog. We offer that the enormous concentrations (dangerous exposure levels) were an outcome of build-up of emissions from smoldering during a prolonged period of calm over the 1100 acre block burned. Thus for planning purposes, land managers face the prospect of no wind during the following night as a reason for not burning.

**Bio**: Bio: Gary L. Achtemeier is senior meteorologist with the USDA Forest Service Southern Research Station Institute for Forest Disturbance Science located at Athens, Georgia, USA. His research interests include smoke plume rise and dispersion from prescribed burns (Daysmoke), smoke transport along the ground at night over complex terrain (PB-Piedmont), smoke/fog and roadway visibility (superfog), and rule-based fire spread and plume updraft core modeling (Rabbit Rules).

### SPECIAL SESSION: Reducing Smoke through Wood Energy: The Role of USDA

The USDA Wood Energy Initiative is working to reduce smoke by creating cleaner, more efficient wood energy systems. This work helps implement the Secretary's vision of building a forest restoration economy. Decades of fire suppression have resulted in dense forests and increasing fire risk across millions of acres of forests. These forests require restoration, achieved through both prescribed fire and mechanical treatments. Costs of mechanical hazardous fuels treatments can be reduced when there is demand for the material created by those treatments. Increasing the use of wood energy increases this demand. This policy-based approach to wildfire reduction and smoke management has many co-benefits, including renewable energy and rural job creation. Through the Wood to Energy Initiative, USDA technical and financial assistance programs have been realigned to better leverage one another, particularly those in the Forest Service and Rural Development. Through these actions and others, USDA is working to reduce smoke and increase renewable energy.

# 25. The USDA Wood to Energy Initiative

#### Author: Patrick Holmes, Natural Resources and Environment, USDA

**Abstract**: The western wildfire season is 78 days longer now than twenty years ago. Ten states have experienced record-breaking fires over the past ten years. Larger and more severe wildfires have resulted in unprecedented costs borne by the public and private sectors for firefighting and suppression as well as the rehabilitation and replacement of

lost and damaged infrastructure and property. USDA can work with partners to mitigate these risks at comparatively modest upfront costs through preventative forest restoration activities such as thinning to remove hazardous fuels. We can further advance these efforts by pursuing forest biomass energy facilities that provide baseload, renewable heat and electricity, and can meaningfully reduce the costs of restoration.

USDA's Wood to Energy Initiative, a focused partnership between five different agencies has been working to increase the demand for wood since 2010. The purpose of the initiative was to create synergy between the various programs that already existed, particularly within USDA's Rural Development and Natural Resources and Environment that were not well coordinated. We use federal funds in the form of small grants, loans and guaranteed loans to leverage private investment. In FY 2012 between the five agencies over \$1 billion of investment in potential projects were supported, leveraging substantial private funds. Less than 4% of those funds were in the form of grants.

Increasingly we are working with our private partners to support wood energy. USDA is signing a Memorandum of Understanding with four wood energy trade associations: the Alliance for Green Heat, the Biomass Power Association, the Biomass Thermal Energy Council, and the Pellet Fuels institute. These associations have members that represent a broad range of stakeholder interests. Doing this work collaboratively with these trade associations will help us be more effective. We look forward to partnering with them on this work.

**Bio:** Patrick Holmes is the Special Assistant to the Under Secretary for Natural Resources and Environment at USDA.

#### 26. The Forest Service's Role in Wood Energy

#### Author: Dave Atkins, USDA Forest Service

**Abstract**: Facilitating the adoption wood energy systems is an important aspect of our work to restore the nation's forests. Decades of fire prevention and suppression efforts, historic logging practices, and limitations on active forest management across the U.S. have resulted in overstocked forest stands. These dense conditions impact forests' resilience to climate change, insects, diseases, and other stressors, creating ideal conditions for future catastrophic fires and smoke.

Converting residues from forest management to wood energy will enable forest managers and communities to replace fossil fuels and create local jobs while expanding America's renewable energy portfolio. Markets for thermal and electric applications of forest biomass are perhaps our best opportunity for reducing the costs of restoration. In California, recent legislation requiring 50MW of forest biomass energy from high-fire risk areas will result in 30,000 acres per year of hazardous fuels treatments across federal, state and private lands. Expanding this policy or similar models to other states could measurably impact the pace of restoration while decreasing smoke.

Another example of work the Forest Service is doing to reduce smoke is through wood stove change out programs. The Forest Service has partnered with the Missoula County Health Department to carry out a wood stove change out program in Seeley Lake, Montana. This community has had problems with smoke pollution. 60 wood stoves were replaced through last winter, which has already had an impact on air quality. This year only four days of poor air quality were reported during the months of November and December, compared with an average of 15 to 20 days of poor air quality in past years. The community hopes to replace at least 154 wood stoves by the time the project ends this December.

This and other work that the Forest Service carries out through its Woody Biomass Utilization Grants, its support of Statewide Wood Energy Teams, and other technical and financial assistance for wood energy helps to reduce wildfire risk, reduce inefficient wood burning, and improve smoke management.

**Bio:** Dave Atkins is the National Woody Biomass Program Manager at the USDA Forest Service in Washington, D.C.

### 27. Rural Development's Role in Wood Energy

#### Author: Todd Campbell, USDA Rural Development

**Abtract:** Rural Development has long been a supporter of economic development and renewable energy in rural communities. Through the USDA Wood to Energy Initiative, Rural Development's programs have been leveraged with Forest Service and other programs to increasingly support wood energy. In FY12, about \$950,000 in grants and \$1.3 million in loan guarantees went to wood energy projects through the Rural Energy for America Program. The Rural Utilities Service provided almost \$264 million in loan guarantees to wood electricity projects. Rural Development funding for wood energy projects also comes through the 9005 Advanced Biofuels Payment programs, which provided about \$277,000 to pellet producers in FY12.

Several of the projects funded through Rural Development have direct implications for smoke management and wildfire reduction. One of the projects funded by the Rural Utilities Service was a loan guarantee for an 11.5MW wood energy power plant in Gypsum, Colorado. The project received a \$40 million loan guarantee from Rural Development's Rural Utilities Service. It will provide electricity to Holy Cross Rural Electric Cooperative. The feedstock from this facility comes in part from a \$8.66 million ten year stewardship contract to remove hazardous material from the White River National Forest. This facility is estimated to use 70,000 dry tons per year, equal to about 100,000 to 120,000 green tons. If this material was not used in the biomass facility, it would be piled and burned, creating substantially more emissions.

Through leveraging its programs with other USDA programs and private financing, Rural Development supports wood energy projects and reduces smoke.

Bio: Todd Campbell is the Acting Chief of Staff for USDA Rural Development.

### 28. Wood Stove Innovations and Smoke Management

#### Author: John Ackerly, Alliance for Green Heat

**Abstract**: As the price of heating oil has increased in the US, more residents are returning to wood heat. Most existing wood stoves date from before the EPA implemented emissions certification requirements for these devices. In addition, even those wood stoves that meet EPA's requirements often produce unacceptably high levels of smoke in neighborhoods once in use. This is due to several factors including fuel quality, operator habits and basic technology design. Improved designs that improve combustion performance, and reduce operational variability are needed.

The Alliance for Green Heat, the US Forest Service, NYSERDA, Popular Mechanics Magazine and others are hosting a Wood Stove Design Challenge to address these needs through a competition for manufacturers, innovators, and university teams to drastically reduce smoke from residential stoves.

Since 1990 stoves technology has not seen much innovation. Communities facing serious smoke issues in the West have undertaken wood stove change out programs to reduce or eliminate pre-1990, uncertified stoves and replace them with post 1990 EPA certified models. But some evidence suggest that the reduction of smoke from these change-outs is not as much as it should have been, and that more innovative stove technology is needed to produce necessary levels of smoke reduction.

The Wood Stove Design Challenge will showcase next generation stove designs that may achieve far greater smoke reduction than existing EPA certified designs and help change out programs achieve great smoke reduction. The Wood Stove Design Challenge seeks designs that remove the operator from the equation, and reduce the emissions impact of using unseasoned wood.

In addition, the impact of smoke caused by a household heating with wood will be explored compared to the impact of a neighbor heating with wood. How porous are homes and how can families protect themselves from neighbors who produce too much smoke? How effective are property setback regulations that are common for certain wood heating devices in the northeast?

Bio: John Ackerly is the Founder and President of the Alliance for Green Heat.

#### 29. Wildland Fire Emissions, Carbon and Climate: A Special-Issue Synthesis Project

#### Author(s): Colin Hardy, USDA FS-RMRS

Abstract: We have developed and are publishing a synthesis and discussion of published information on greenhouse gas (GHG) and black carbon (BC) aerosol emissions from wildland fires, within the overall context terrestrial ecosystem processes and biomass burning. This special-issue project focuses on a national-level review of what is known about GHG and BC emissions from wildland fires across all biomes in the United States. The demand for this review is an outcome from the increasingly recognized importance of wildland fire in the movement of terrestrial carbon in both emissions to the atmosphere and sequestration in ecosystems. Knowledge of the various processes and mechanisms that govern wildland fire dynamics and emissions is necessary to accurately assess the current and potential future role of wildland fire in global climate and carbon cycles, particularly in forest-dominated biomes. This special issue begins with a summary and science overview of wildland fire emissions, carbon and climate and introduces eight accompanying articles. The accompanying articles begin with consideration of fire and terrestrial carbon cycle processes and conclude with how emissions resulting from those processes interact with climate. We link those starting and endpoints with six articles that sequentially focus on: fire activity and burned area (how much area is burned and how the released energy is distributed); wildland fuels (what is burned); consumption (how fuel is burned and how much is burned); emission factors (how we figure out what is emitted with respect to the mass of fuel consumed); emissions (how we determine emission rates, species and total emissions); and atmospheric processes (what happens once the emissions enter the atmosphere). In sum, this series of articles provides a wildland fire and emissions knowledge chain linking carbon cycling to climate, set in a forest ecology and management context.

**Bio**: Colin Hardy is the Program Manager for the USDA Forest Service's Fire, Fuel, and Smoke Science Program, Rocky Mountain Research Station, located at the Missoula Fire Sciences Laboratory in Missoula, Montana, USA. His research organization is the largest unit in the country dedicated to wildland fire, and the laboratory comprises the most comprehensive and largest suite of combustion and wind tunnel facilities in the world. Dr. Hardy is a native of Missoula, and is a second-generation fire scientist. He holds a Bachelor's degree in Resource Conservation from the University of Montana, a Master's of Forest Resource Management from the University of Washington, and a Ph.D. in Forestry from the University of Montana. His d octoral work focused on thermal infrared remote sensing of wildland fires, with substantial work characterizing and mapping geo-thermal features in Yellowstone National Park. He has published over 85 papers relating to wildland fire, smoke emissions, fire regimes, and fire remote sensing.

#### 30. In the Line of Fire: Physiological Responses of Plants to Smoke

**Author(s):** Vicky Aerts, University of Sydney Paul Struik, Wagenigen University Tina Bell, University of Sydney

**Abstract:** Current predictions on global climate change suggest that forest fires and associated production of smoke will inevitably increase. In the last decade, smoke has caused substantial financial losses for the agricultural industry, in particular for the wine industry due to smoke-tainted wine. Although the effect of smoke on human physiology has been studied extensively, research about the effect of smoke on plant physiology is lacking.

This paper focuses on the effect of smoke from combusting Eucalyptus saligna leaf litter on strawberry and sunflower plants. The research question being addressed was "Can smoke affect leaf gas-exchange of agricultural crops?".To study this question, whole plants were placed in a sealed, transparent chamber and exposed to varying concentrations of smoke for different periods of time. Smoke of different CO and CO2 concentrations was created by burning a known weight of leaf litter and leaves were exposed for 5, 10 or 15 minutes. Before and after exposure of plants to smoke, rates of photosynthesis and transpiration were measured. Carbon dioxide concentration (ppm) was measured continuously in the chamber while plants were exposed to smoke. Gas samples were also taken from the chamber for analysis of CO2 and CO. This study found that while smoke reduced gas exchange of leaves, resulting in lower rates of photosynthesis and respiration, the effects depended on the concentration of smoke, the exposure time and the anatomy of the exposed leaves. Plant recovery after exposure to smoke also depended on these variables. These results will be used to model effects of smoke on photosynthesis and to scale up from individual plants to whole crops and landscape.

These findings are of importance for land managers and other stakeholders involved in prescribed burns adjacent to agricultural lands. Such information can contribute to fire management plans and can guide preventive measures for exposure to smoke of agricultural crops.

**Bio**: I am originally from the Netherlands where I obtained my Bachelor and Master's degree in Forest and Nature Conservation at Wageningen University. During my Masters, I had the opportunity to take fire courses in Sweden and to do my internship in Australia. After my graduation, I started working for Saint Gobain Distribution the Netherlands where I implemented timber certification management systems. In October 2010, I started my PhD at the University of Sydney with support from the Bushfire Cooperative Research Centre. My topic is: "The effects of smoke from bushfires and prescribed burns on native and agricultural plant physiology".

# **31.** Future Trends in Large Fire and Smoke in the United States under Changing Climate

Author(s): Yong Liu, USDA Forest Service Jia Yang, Auburn University Bo Tao, Auburn University John Stanturf, USDA Forest Service Hanqin Tian, Auburn University Scott Goodrick, USDA Forest Service

**Abstract:** Wildfires have been projected to increase in the United Stated this century in response to the projected climate change. This study focuses on future trends in large fires, which account for a small number of total fires but contribute substantially to smoke and the air quality impact. Present and future fire potential indices are calculated using dynamical downscaling of regional climate change. The probabilities of large fire occurrence and spreading are estimated using a comprehensive approach of data analysis, algorithm development, and numerical modeling. Fuel and fire properties are simulated and projected using a dynamic global vegetation model. Smoke transport and the air quality impacts are simulated using a smoke trajectory model. The results indicate increasing trends in large fires and the smoke impacts under the changing climate.

**Bio**: Yongqiang Liu is a Research Meteorologist and Team Leader of the Atmospheric Science Team, Center for Forest Disturbance Science, USDA Forest Service. His research is focused on climate-forest ecosystem interactions, which is aimed at understanding forest disturbances (wildfire, land cover change, forest water stress, etc.), their interactions with climate variability and climate change, and the environmental consequences. The research is expected to help strategy development and implementation to reduce forest vulnerability to forest disturbances and their adverse environmental impacts.

#### 32. The Untold Story of Pyrocumulonimbus II

#### Author(s): Michael Fromm, NRL

**Abstract:** Wildfire is becoming the focus of increasing attention with heightened concerns related to climate change, global warming, and safety in the urban-wildland interface. One aspect of wildfire behavior- pyrocumulonimbus firestorm dynamics and atmospheric impact-has a curious history of theory and observation. These "pyroCb" are fire-started or –augmented thunderstorms that in their most extreme manifestation inject huge abundances of smoke and other biomass burning emissions into the lower stratosphere. The observed hemispheric spread of smoke and other biomass burning emissions could have important climate consequences. However, direct attribution of the stratospheric pollution from pyroCb only occurred in the last decade. Such an extreme injection by

thunderstorms was previously judged to be unlikely because the extratopical tropopause is considered to be a strong barrier to convection.

Some "mystery layer" events-puzzling stratospheric aerosol layer observations- and layers reported as volcanic aerosol can now be explained in terms of pyroCb as the "smoking gun." PyroCb events occur with surprising frequency, and they are likely a relevant aspect of several historic wildfires. We survey the Canada/USA fire season of 2002 and identify 17 pyroCbs, some of which are associated with newsworthy fires such as Hayman, Rodeo/Chediski, and Biscuit fires. In addition, we document the northern hemisphere fire season of 2013 and explore in detail the numerous pyroCb events in Russia, Canada, and the USA. By 1 July 2013, more than 25 pyroCbs have erupted, created dangerous conditions on the ground and injecting smoke into the stratosphere.

**Bio**: Dr. Fromm is a meteorologist with 30 years experience in research and data analysis. His area of focus is in atmospheric aerosols and clouds in the troposphere and stratosphere. He is founder/moderator of an email discussion group on the subject of pyroconvectio . He is lead author of 15 refereed journal articles. He participated in NASA's ARCTAS (Arctic Research of the Composition of the Troposphere from Aircraft and Satellites) measurement campaign in boreal summer 2008 studying pollutant transport into the Arctic.

# SPECIAL SESSION: Fire's Impacts on Ozone and PM - Data Results and Tools for Analysis

An interconnected series of talks from the "Deterministic and Empirical Assessment of Smoke's Contribution to Ozone (DEASCO3)" and "Prescribed and other Fire Emissions: Particulate Matter Deterministic & Empirical Tagging & Assessment of Impacts on Levels (PMDETAIL)" studies, both supported by the Joint Fire Sciences Program.

# 33. FETS Fire Inventories – Methodology and Results for Assessment of Smoke's Impact on Ozone and PM

#### Author(s): Matthew E. Mavko, Air Sciences Inc

**Abstract:** The background, technical work, and applications for the Fire Emissions Tracking System (FETS) and Deterministic and Empirical Assessment of Smoke's Contribution to Ozone (DEASCO<sub>3</sub>) inventory will be summarized. Integration of other systems and data sets into the FETS (Monitored Trends in Burn Severity perimeter and severity data, National Oceanic and Atmospheric Administration Hazard Mapping System fire detections and precipitation grids, Michigan Technical Research Institute crop data layer, Fuel Characteristic Classification System fuelbed layers, California State Fire burn reports) will be highlighted. The details of the DEASCO<sub>3</sub> fire emissions inventory methodology from activity inputs through the time, space, and chemical characterizations of fire emissions for photochemical grid modeling will be presented. **Bio:** Mr. Matthew Mavko is a Senior Air Quality Scientist and data management specialist at Air Sciences Inc. in Portland Oregon. Mr. Mavko specializes in spatial data management and analysis for environmental projects. Specific applications include developing tools and web applications for environmental databases; design and development of a web-based tracking system for fire activity in the western United States; design and development of permitting, tracking, and management systems for Tribal and State fire programs; and development of a GIS-based predictive model of nitrogen dioxide for urban neighborhoods.

# 34. Photochemical Modeling to Assess Smoke's Contribution to Ozone and Particulate Matter

### Author(s): Ralph E. Morris, ENVIRON

**Abstract:** This presentation will include details about the extensive photochemical modeling performed in DEASCO<sub>3</sub> to assess smoke's contribution to ozone and particulate matter for unplanned (wildfire) and planned (prescribed and agricultural fire, separately) fire types, and how elevated ozone episodes were determined through monitoring data analysis. Actual emissions for all other sources were also included in the modeling using state-of-the-art, retrospective regulatory methods employed for air quality planning under the Clean Air Act. The source apportionment techniques utilized are widely applied for all source categories, and the DEASCO<sub>3</sub> fire modeling robustly tests the method for fire. The explanatory power of the model results were used to supply data for the tools for ongoing decision support. Methods and results will be reported for 2002 and 2008 study periods across the contiguous U.S. region, including a revised plume rise treatment and model performance to assess fire contributions to ozone.

**Bio:** Mr. Ralph Morris is a Managing Principal as ENVIRON's Novato California office where he directs air quality model development and application studies. He has over 30 years' experience in air quality modeling and has been involved in ozone, PM2.5 and regional haze State Implementation Plans (SIPs), air quality impacts of oil and gas and other developments under NEPA and assessments of regional and international transport on air quality.

# 35. JFSP Smoke Science Projects: DEASCO3 and PMDETAIL

#### Author(s): Matthew E. Mavko, Air Sciences Inc

**Abstract:** The Joint Fire Sciences Program has funded two leveraged projects under their Smoke Science Plan: the Deterministic and Empirical Assessment of Smoke's Contribution to Ozone (DEASCO<sub>3</sub>) and the Particulate Matter Deterministic and Empirical Assessment of Impacts on Levels (PMDETAIL), to assist fire and smoke managers in analyzing the contributions of smoke to elevated ozone and particulate matter episodes. The DEASCO<sub>3</sub> project was completed in the summer of 2013, and the PMDETAIL project builds on DEASCO<sub>3</sub>, extending the analysis over a longer retrospective analysis period of 10+ years to address PM impacts. The projects' collaborator teams, organizational approaches, website architecture, tool development, and documentation will be presented. The DEASCO<sub>3</sub> project's Most Impacted Areas map will also be presented, and plans for the cornerstone products from PMDETAIL will be reviewed.

# 36. DEASCO<sub>3</sub>: Meeting the Needs of User Groups

#### Author(s): Charles T. (Tom) Moore and Dave Randall

**Abstract:** Better connecting the fire and smoke management community to the air quality management community of state air agencies and EPA is a desired outcome of the DEASCO<sub>3</sub> project. We will present the perspective of users, not developers, derived from land manager collaboration in the DEASCO<sub>3</sub> analysis and tool designs, and from beta testing by fire, smoke, and air quality managers. The user groups and their relationships to the DEASCO<sub>3</sub> website design will also be presented. Decision support capabilities in this "shared workspace" between fire, smoke, and air quality managers will be presented in terms of lessons learned from case studies – the DEASCO<sub>3</sub> results for the contribution of fire to elevated ozone provides surprising results. Examples of fire planning uses by land managers, analysis of Exceptional Events, and State Implementation Plan preparation will be presented.

**Bio:** Mr. Tom Moore is the Western Regional Air Partnership (WRAP) Air Quality Program Manager and works for the Western States Air Resources Council (WESTAR). He has overseen numerous regional air pollution studies and analysis projects, and held management positions in state and local government. He also coordinated WRAP program activities for the Western Governors' Association for more than a decade. Before WRAP, he managed air quality monitoring and analysis activities for the Arizona Department of Environmental Quality, leading the development and implementation of health and visibility monitoring networks throughout Arizona. He has also served on national advisory groups for air quality health standards and regional haze.

**Bio:** Mr. Dave Randall is a Principal and project manager at Air Sciences Inc. in Golden, CO. He has worked with the Western Regional Air Partnership for over 10 years on several projects addressing emissions due to fire on wildlands and agricultural lands. Mr. Randall's expertise includes determining best-methods practices for refining fire activity and emission rates (including speciation of particulate and organics emissions from fire) and for incorporating plume rise and diurnal distribution of fire emissions into near- and far-field photochemical grid modeling.

#### **SPECIAL SESSION:** Transportation Corridor Safety

At times wildland smoke has reduced visibility on our roadways. This serious hazard has been associated with multiple car pile-ups that have resulted in physical injury, property damage and fatalities. Smoke or smoke that induces fog formation when occurring with vehicle traffic is a combination that requires attention in order to reduce the risk of lethal outcomes. In the year 2000, the National Fire Plan established five regional Fire Consortia for Advanced Modeling of Meteorology and Smoke (FCAMMS). These five centers were designed as working collaborative partnerships. One mission was to develop products to increase understanding of fire weather, fire danger, fire behavior, and the transport, diffusion and impact of smoke from wildland fire. Real time products are continually being developed to support decision making. This special session reviews meteorological conditions when wildland smoke can affect transportation corridor safety, developing operational smoke management tools to assess wildland smoke impacts, and how this information can assist planning and timely implement mitigation measures. The workshop's objective is to provide the necessary information for incident management teams, first responders and responsible agencies (i.e. Department of Transportation, Highway Patrol, Emergency Management, etc.) whereby the risk caused by reduced visibility can be minimized by timely mitigation measures implemented before expected reduced visibility actually occurs.

### 37. Highway Safety during Smoke/Fog Incidents

#### Author: Lt. Colonel Kelly Hildreth, Florida Highway Patrol

Abstract: At approximately 4:00 AM on Sunday, January 29, 2012, a series of multiplevehicle collisions occurred within a localized area of smoke-induced low visibility on Interstate 75 (I-75). This area, covering to mile on I-75, in what is known as the Paynes Prairie area, south of Gainesville, Florida. Collisions occurred in both the northbound and southbound travel lanes of I-75. The collision sequence began when lead vehicles entered dense smoke and slowed to a near stop or actually stopped in the travel lanes, and consequently were struck by other motorists. As subsequent vehicles entered the dense smoke, some drivers slowed their vehicles drastically while others did not. Additional collisions occurred as vehicles drove into the smoke and wreckage area at varying speeds. Ultimately, 6 crashes occurred involving 24 vehicles and resulted in 11 fatalities and 46 known and reported injuries. Following the crashes, FHP enhanced its guidelines, policies, and procedures to better respond to smoke/fog incidents in the future. FHP refined communications procedures both internally and with partner agencies (Florida Fire Service (FFS) and Florida Department of Transportation (FDOT)) to establish ongoing dialog and process improvement projects for smoke/fog incidents. Additionally FHP augmented methods for gathering information from relevant entities such as the National Weather Service and FFS. Finally, FHP worked with partner agencies to establish a public awareness campaign to educate drivers on the dangers of driving in smoke/fog conditions.
**BIO**: Lieutenant Colonel Hildreth began her career with the Florida Highway Patrol in 1995. She has served various roles throughout the agency including Chief Recruitment Officer, Director of Professional Compliance, and Emergency Operations Coordinator. Currently she serves as the Patrol's Deputy Director overseeing Patrol Operations, which encompasses 12 troops throughout the state of Florida. Following the January 29, 2012, multiple-vehicle collision in a localized area of smoke-induced low visibility on Interstate 75 near Gainesville, Florida, she and FHP personnel worked to enhance guidelines, policies and procedures to mitigate any future such events from occurring on Florida Highways. The team developed a three-pronged approach includes internals staffing and monitoring protocols; partnerships with weather, fire, and transportation professional; and educating drivers to alter behavior during smoke/fog situations.

# 38. Historical Perspectives of Forestry Smoke and Highway Visibility Issues in the South

#### Author: James T. Paul, retire USFS Fire Research

**Abstract:** The commonality of weather variables and highway incidents in the South will be discussed. The paper "Use of General Weather and Dispersion Index to Minimize the Impact of Smoke on Highway Visibility" (Paul, Lavdas and Wells) will be compared with more recent research. Finally, some physical and management issues that need attention will be discussed.

# 39. National Weather Service Smoke Management Decision Support Tools in the Carolinas and Georgia

#### Author(s): John Tomko, NWS Greer, SC, Gary M. Curcio, IPAFES La Grange, NC Gary Achtemeier, SHRMC Athens, GA

**Abstract:** Over the last few years, several decision support tools have been developed or enhanced by the National Weather Service for smoke management in the Carolinas and Georgia. The land management customers of the National Weather Service face growing challenges in balancing smoke management with prescribed burning goals. To meet these challenges, National Weather Service offices have partnered with local land managers to add smoke management parameters to existing forecasts, incorporated forecast products developed in other parts of the country, and developed entirely new forecast products for the local smoke management community. The product improvements were achieved with only modest changes to existing forecast products, as most of the needed data were already being produced, in some cases for as long as a decade. Software that leveraged this data was obtained from National Weather Service offices in other parts of the Southeast, and modified for both the local geographic area and the needs of the customers. This has allowed land management customers to focus on more precise windows of opportunity for burning. It therefore has provided valuable intelligence on smoke dispersion and possible impacts to nearby transportation corridors. Several parameters have overlapping usefulness in the fields of fire weather, aviation forecasting, and hazardous material release forecasts.

#### 40. Development and Usage of a New Forecast Tool to Improve Super-fog Forecasts

**Author(s):** Josh Weiss NWS Wilmington, NC Gary M. Curcio, IPAFES La Grange, NC Gary Achtemeier, SHRMC Athens, GA

**Abstract:** In the past decade smoke management tools have been developed to increase the ability to anticipate dense smoke near smoldering burns. These include the atmospheric dispersion index (ADI), low visibility occurrence risk index (LVORI), and the point fire weather matrix (PFW). Still, dense smoke events have caused significant public impact in the form of traffic accidents, which on average kill or injure tens of people every year in the United States. The cause of many of these accidents is not just dense smoke, but Super-fog, a combination of smoke and fog which reduces visibility to 1 meter or less. Although Super-fog poses a significant threat to public safety, it remains a somewhat poorly forecasted and understood phenomenon.

The National Weather Service (NWS) in Wilmington, NC has developed a tool in the Graphical Forecast Editor (GFE) to provide forecasters an easy method to diagnose Superfog potential. The tool creates a binary mask which highlights regions where favorable parameters from the Super-fog matrix combine to produce conditions conducive to Superfog. This mask heightens the awareness of forecasters on duty to Super-fog potential near an ongoing fire, who will then delve further into the threat, and alert the local Fire Behavior Analyst (FBAN) or Air Resource Advisor (ARA) working the fire to the Super-fog danger. This tool proved beneficial during the "Dad" fire of June, 2012 which burned more than North Carolina. Using this tool, the 21,000 acres in the Croatan National Forest of National Weather Service forecasters at the neighboring Morehead City, NC forecast office alerted foresters to possible Super-fog potential. This was accomplished the night before as visibilities were expected to become extremely reduced in the vicinity of the fire. This tool can help decrease the possibility of missed dense smoke or Super-fog events when weather conditions approach critical thresholds. It therefore, facilitates timely awareness but, most importantly, enhances responding personnel and public safety.

### 41. Surveillance to Support Mitigation of the Public Health Impacts Associated with Forest Fire Smoke

**Author(s):** Sarah Henderson, BC Centre for Disease Control Angela Yao, BC Centre for Disease Control Catherine Elliott, BC Centre for Disease Control

#### Abstract:

BACKGROUND: During the extreme fire season of 2010 health authorities in British Columbia (BC), Canada used ad-hoc surveillance methods to track the public health impacts of fire smoke, including daily phone calls to emergency departments and pharmacies. In 2012, the BC Centre for Disease Control (BCCDC) initiated the BC Asthma Medication Surveillance (BCAMS) system to support public health protection during smoke episodes.

METHODS: Salbutamol sulfate is a pharmaceutical preparation used to relieve acute symptoms of obstructive lung diseases, such as asthma. Daily counts of salbutamol dispensations are received from the BC PharmaNet database, and aggregated for each of the 89 local health areas in the province. Counts from 2003 to the current date are run through an outbreak alerting algorithm developed by the BCCDC, and patterns that are unusual when compared historic trends are flagged for review by provincial medical health officers. Reports are summarized in easily interpreted maps and charts that include information on fine particulate matter (PM2.5) to provide environmental context.

RESULTS: The 2012 fire season was mild in BC, but smoke transported from Siberia resulted in several days of degraded air quality across the province. The BCAMS system successfully detected population increases in salbutamol dispensations during this period, confirming that the BC population can be affected by smoke from distant fires. Based on evaluation by medical health officers and surveillance experts following the 2012 fire season, BCAMS was extensively updated for 2013. The upcoming fire season is expected to be more severe, and BCAMS will provide more support to field personnel by integrating information on salbutamol dispensations with PM2.5 measurements where they are available, PM2.5 estimates where measurements are not available, and PM2.5 forecasts from the Western BlueSky Canada framework.

CONCLUSIONS: The BCAMS system was piloted in the summer of 2012, and it will undergo annual evaluation and improvement until the summer of 2016. Future upgrades will include daily data on respiratory physician visits, and will allow for distribution of reports in near-real-time. With support from Health Canada the R code for BCAMS is freely available from the BCCDC, accompanied by sample data and a user guide.

**Bio**: Dr. Sarah Henderson is a Senior Scientist with Environmental Health Services at the British Columbia Centre for Disease Control and an Assistant Professor at the University of British Columbia School of Population and Public Health. She has expertise in a wide range of environmental exposures and their public health implications, but smoke is one of her favorite topics because of the unique challenges it poses environmentally, geographically, politically, and medically. Over the past decade Sarah has worked on multiple research projects related to assessment of forest fire smoke exposure and its health impacts in Canada, Australia, and around the world.

# 42. Health Outcomes Associated with Smoke Exposure in Albuquerque, New Mexico during the 2011 Wallow Fire

Author(s): Heidi Krapfl, NM Dept. of Health Barbara Toth, NM Dept. of Health Brian Woods, NM Dept. of Health Adam Resnick, NM Dept. of Health

**Abstract:** The 2011 wildfire season in the southwest was record breaking, with over 1 million acres burned in both Arizona and New Mexico. Smoke from the Wallow fire in Arizona reached Albuquerque, over 150 miles away, where there were many days over the first two weeks of June when air quality was not in the "Good" range, according to the Environmental Protection Agency's (EPA) Air Quality Index for particulate matter of size 2.5 microns and smaller (PM 2.5).

In order to assess potential health impacts from smoke exposure from several wildfires, daily emergency department (ED) visits for 2011 were collected by the New Mexico Department of Health's (NMDOH) Epidemiology and Response Division. These visits were restricted to the locations that were exposed to wildfire smoke and grouped by respiratory and cardiovascular diagnoses. Air quality monitoring data for PM2.5 were provided by the United States Forest Service, which compiled data from various sources. Twenty four-hour average PM2.5 levels were calculated using hourly data and these levels were used to create a single exposure for each geographic area.

Poisson regression was used to calculate ED rates, standard errors and 95% confidence intervals with the pre-fire period as the referent time. Although different areas experienced high levels of PM2.5 exposure from different fires, a combination of factors resulted in the analysis being restricted to the Albuquerque area.

For all ages, there was an increased risk of respiratory ED visits in the Albuquerque area for conditions such as asthma (8%) during the acute exposure period compared to the pre-wildfire period. However, t he population of 65+ was especially at risk for ED visits. There was a significantly increased risk of ED visits among the 65+ population for asthma (73%, P<0.05) and for diseases of the veins, lymphatic and circulatory system (56%, p=0.05).

Continuing to provide health messages to the populations potentially most affected by wildfire smoke is imperative. When air quality does not require evacuation but is still poor and temperatures are high, cooling centers should be available for those residents who do not have access to air conditioners.

**Bio**: Heidi Krapfl is the bureau chief of the Environmental Health Epidemiology Bureau with the New Mexico Department of Health. She has served in this position since 2008. Before that

she was an environmental epidemiologist with the bureau from 2006 to 2008. Ms. Krapfl holds a Master's of Science in environmental health, with a concentration in epidemiology.

### 43. Characterization of Wildland Firefighter Exposure to Carbon Monoxide and PM2.5 Using Real-Time Aerosol Monitors

#### Author(s): Luke Naeher, University of Georgia

Daniel B. Hall, The University of Georgia, Franklin College of Arts and Sciences, Department of Statistics Olorunfemi Adetona, University of Georgia, College of Public Health, Environmental Health Science

#### Abstract:

Background: Previous exposure studies have mostly characterized PM2.5 exposure among wildland firefighters using time integrated exposures averaged over the duration of the firefighter workshift or work at the fireline. Exposure to PM2.5 in this study is characterized in real time and the data are used to explore whether PM2.5 and CO are correlated in real time, investigate the contributions of peak exposures to the overall exposure, and determine the effect of job task on exposure.

Methods: 60 individual person-day real time CO and 37 PM2.5 samples were collected from 15 firefighters over 10 burn days at the fireline while they worked at prescribed burns. Time activity diaries were used to collect information regarding the job tasks of the firefighters. Questionnaires were administered post-shift to identify possible confounding exposures that the firefighters may have experienced while working at the burns.

Results: Peak exposures contributed substantially to the overall exposures of the firefighters. The percentage of time at the fireline with exposure above 3 mg/m3 ranged between 2.6% and 40%, and accounted for 24% to 82% of the exposure. Plots of concurrently measured real time CO and PM2.5 indicated that exposure to both pollutants correlated well over shorter temporal resolutions. Exposures to both CO and PM2.5 differed by task (p<0.01). Persons who were "holding" had the highest exposures to both pollutants, and had the most exposure incidences exceeding the recommended excursion short term exposure limits.

Conclusions: We characterized exposure to PM2.5 in real time and obtained results that could be useful for managing wildland firefighter exposure to woodsmoke. Peak exposures over a relatively small amount of time contributed substantially to overall exposures. Variation of 109 concurrently measured CO and PM2.5 closely mirrored each other across periods of very small temporal resolution.

# **Bio**: Luke P. Naeher is an Associate Professor in the Department of Environmental Health Science at The University of Georgia's College of Public Health. Dr. Naeher's research focus is

exposure assessment and environmental epidemiology with a particular focus on health effects related to air pollution. Dr. Naeher has current research projects on exposures related to woodsmoke in Peru (pregnant women) and the southeastern US (forest firefighters). Dr. Naeher teaches undergraduate and graduate classes in environmental science, environmental health science, and air pollution at UGA, and is currently the major professor for several MS, PhD, and DrPH graduate students.

#### 44. Wildland Firefighter Smoke Exposure

**Author(s):** George Broyles, USFS Joe Domitrovich, USFS

**Abstract:** Wildland firefighters work in a dynamic environment and are exposed to a variety of hazards. Exposure to harmful constituents in wildland smoke underlies virtually every aspect of risk management and must be addressed effectively in order to assure other risk management decisions are sound. Wildland smoke may be one of the least understood risks of wildland firefighting (Reisen et al., 2009). Health effects include short-term conditions such as headaches, fatigue, nausea, and respiratory distress while long-term health effects may include an increased risk of cardio-vascular disease.

Carbon monoxide, particulate matter (PM4) and crystalline silica (SiO2) were measured in the breathing zone of firefighters. Carbon monoxide was measured every minute and PM4 and SiO2 were collected at 1.05 ml/L and averaged over the work shift. Direct observation of firefighters was used to determine if operational tasks could be connected with exposure. Data was collected on wildland and prescribed fires in 17 states representing 11 of the 13 NFDRS fuel models during a four year period. Measurements were also taken at incident base camps (ICPs). Exposure to CO was calculated for: 24 hr., shift, fireline, max 8 hr., max 5 min., and max 1 min.

During the four-year study, 7,517 hours of CO measurements on firefighters and 1,554 hours of CO measurements at ICPs and spike camps were taken. There were a total of 179 PM4 and SiO2 firefighter samples and 78 samples at ICPs and/or spike camps. The operational tasks of mop-up, holding and handline were related to highest exposures. The estimated amount of time that CO exposure exceeds the OSHA 8-hour TWA is 5.6% on project fires and 3.5% on prescribed fires. These percentages could be as high as 10.7% and 12% respectively.

Based on this study there has been no appreciable reduction in firefighter exposure since the levels identified in the 1990's by Reinhardt and Ottmar and in some instances unsafe exposures as identified by OSHA are more frequent and severe than previous research has identified. This data will assist firefighters and fire managers to be better prepared to reduce exposures. **Bio**: George Broyles is a Fire and Fuels Project Leader for the USFS National Technology and Development Program. He has worked for the USFS for 25 years in fire management and timber management. He completed his Masters in Natural Resources at the University of Utah, Logan and his Bachelors in Sociology and Political Science at Black Hills State University, South Dakota. His recent projects in support of wildland firefighter safety include the wildland firefighter smoke exposure project and the hydrogen sulfide monitoring project. He is a member of the NWCG Risk Management Committee Smoke Exposure Task Group.

Joe Domitrovich is an exercise physiologist at the Missoula Technology and Development Center and wildland firefighter. He has been a Hotshot and worked on Type II IA crews. He completed his Ph.D. and Masters in exercise physiology at the University of Montana, Missoula and his Bachelors at Cal Poly San Luis Obispo in California. He has been conducting health and safety studies on wildland firefighters for close to a decade. His work with MTDC includes hydration, nutrition, health effects of smoke, heat related illnesses, fatigue and fitness. He is an advisor to the NWCG Risk Management Committee and a member of NFPA 1984; Wildland Firefighter Respiratory Protection.

### 45. Evaluation of the BlueSky Wildfire Smoke Forecasting System as a Tool for Public Health Protection

### Author(s): Angela Yao, BC Centre for Disease Control

#### Michael Brauer, University of British Columbia

Sarah B Henderson, BC Centre for Disease Control, University of British Columbia Abstract: Background: Wildfire smoke is a major contributor to extreme air pollution events in many regions and exposure has been associated with cardiopulmonary health impacts. With more severe and frequent smoke events expected in the future with continued climate change, we need enhanced tools to support public health protection. The BlueSky Western Canada Wildfire Smoke Forecasting System (BlueSky) predicts PM2.5 (particulate matter <2.5 micrometer in diameter) from wildfire smoke up to 60 hours in advance. This prospective information can be useful for public health responses if it reflects observed conditions. Since there is no "gold standard" measurement of wildfire smoke, we developed a novel approach to assess the performance of the BlueSky forecasts. Objectives: To evaluate the utility of BlueSky for public health protection by 1) comparing its forecasts with observations and 2) assessing their associations with population-level indicators of respiratory health in British Columbia, Canada. Methods: We compared the BlueSky PM2.5 forecasts with PM2.5 measurements from air quality monitors, and we compared BlueSky smoke plume forecasts with plume tracings from remote sensing data (HMS). Two health outcome indicators, daily counts of asthma-related medication dispensations and outpatient physician visits for asthma, were aggregated for each geographic local health area (LHA). We assigned daily continuous measures of PM2.5 and binary measures of smoke plume presence, either forecasted or observed, to each LHA. We employed Poisson regression to estimate the association between these exposure measures and the two health indicators. Results: We found modest agreement between forecasts and

observations, which was improved during intense fire periods. A 30μg/m3 increase in BlueSky PM2.5 was associated with 8% and 5% increases in asthma-related medication dispensations and physician visits, respectively. BlueSky plume coverage was associated with 5% and 6% increases in the two health indicators. The effects were similar to those associated with observed PM2.5 and HMS smoke plumes, and point estimates were higher for the most smoky areas. Conclusions: BlueSky forecasts showed modest agreement with retrospective measures of smoke, and were predictive of respiratory health indicators, suggesting they can provide useful information for public health protection.

**Bio**: Angela Yao is an environmental health scientist at the British Columbia Centre for Disease Control. She received her BSc in Environmental Science in China and her MSc in environmental health at the University of British Columbia, Vancouver, Canada. Her research interest is in air quality and population health, especially on forest fire smoke exposure. Here, she is presenting the major parts of her master thesis.

### 46. Mapping prescribed burns and wildfires on Twitter with data mining and information retrieval techniques

#### **Author(s):** K. Arthur Endsley, Michigan Tech Research Institute Jessica L. McCarty, Michigan Tech Research Institute

Abstract: Data mining techniques applied to social media have proven useful for capturing ambient geographic information in a variety of contexts, from mapping the evolution of the Tahrir Square protests in Egypt to predicting influenza outbreaks. The social media platform Twitter is often used for such applications because of its widespread adoption, frequency, and message volume: over 500 million messages (Â"tweetsÂ") generated every day from as many total users at an average rate of 5,700 messages per second. There is significant prior work in using Twitter for disaster alerting, mitigation, and response but much of it consists of merely qualitative assessments; fire-related work has been limited to case studies of single fires. In the United States, Twitter has been used by a number of federal, state and local officials as well as motivated individuals to report prescribed burns (sometimes as part of a reporting obligation) or to communicate the emergence, response to, and containment of wildfires. The authors have developed a framework for capturing these fire incident reports from Twitter using natural language processing and information retrieval techniques. The goal of this research was to assess of the predictive power of data mining, applied to the Twitter platform, and potentially any source of short, unstructured text messaging, for the automated mapping and identification of prescribed and wildland fires in real time. In addition, we aim to identify and locate known fires in the contiguous United States (CONUS) often missed by satellite detections, with the hope of providing relevant, spatio-temporal fire data for emission estimates and inventories as well as burned area mapping efforts. The authors present their methodology and an evaluation of its performance in collecting relevant tweets, extracting metrics such as area burned, and geo-locating the fire events using the GeoNames geographic gazette. A comparison to the

satellite record (e.g. MODIS Active Fire) is also provided. The final outputs are available in real-time as a Google Maps-like interactive web map and in geospatial data products such as KML.

**Bio**: K. Arthur Endsley is a Research Scientist at the Michigan Tech Research Institute in Ann Arbor, MI, where he develops geospatial software to address a variety of remote sensing and earth observation applications. He is primarily interested in geospatial analysis and visualization, machine learning, information retrieval, and image analysis for environmental monitoring and mitigation applications. Mr. Endsley has extensive experience in Python and JavaScript application development, object-oriented programming, and geospatial database management. He is an active proponent of sustainable permaculture and open-source software development using web standards and open protocols for improving access to and accessibility of multi-sensor, multidisciplinary data.

### 47. Daily Burned Area in Northern Eurasia from 2002 to 2010 and its Contribution on Arctic Black Carbon

Author(s): Wei Min Hao, US Forest Service Alex Petkov, US Forest Service Rachel Corley, US Forest Service Shawn Urbanski, US Forest Service Bryce Nordgren, US Forest Service

**Abstract:** Biomass fires in Northern Eurasia are a significant source of atmospheric black carbon that could be deposited on Arctic ice and contribute to accelerated ice melting. However, atmospheric conditions are favorable for the transport of high latitude smoke plumes to Arctic only during a certain time of year. It is therefore necessary to develop daily burned areas and fire emissions of black carbon at a high spatial resolution in Northern Eurasia in order to evaluate quantitatively the contribution of different fire types to black carbon deposition in the Arctic. We have developed daily burned areas at a 500m resolution from 2002 to 2012 over a region of 30°N – 80°N and 10°W–170°W. The burned areas are derived from a burn scar mapping algorithm that employs the MODIS thermal anomalies product MOD14, surface reflectance of MODIS spectral bands 1–7, and the MODIS land cover/land cover change product MOD12. The algorithm for mapping burned area has been validated by comparison with Landsat derived burn scars (Hao et al., 2012). The study domain is divided into seven geographic regions: Russia, Europe (Eastern, Western, Northern and Southern), Eastern Asia, and Central and Western Asia. For each geographic region, burned areas are further categorized by the land cover types (forest, shrubland, grassland, and savannas). The trends and temporal variability (monthly, annual, inter-annual) of burned areas in each land cover type for each geographic region are analyzed. We will present the results of the study and discuss the significance of different source regions and fire types to black carbon deposition in the Arctic and the implications for accelerated ice melting.

**Bio**: Dr. Wei Min Hao is a senior scientist at US Forest Service, Rocky Mountain Research Station. He was a contributor to the Intergovernmental Panel on Climate Change, the corecipient of the 2007 Nobel Peace Prize. He leads an interdisciplinary team to study the impacts of fires on air quality, atmospheric chemistry, and climate at regional and global scales. He also studies the impact of future climate on vegetation, fire, and air quality. Dr. Hao received a Ph.D. degree from Harvard University, two M.S. degrees from MIT, and a B.S. degree from Fu Jen Catholic University in Taiwan.

#### 48. Top-down Smoke Aerosol Emissions Estimation from Satellite Fire Radiative Power Measurements

#### Author(s): Charles Ichoku, NASA Goddard Space Flight Center Luke Ellison, Science Systems & Applications, Inc

**Abstract:** Biomass burning occurs seasonally in most vegetated parts of the world, consuming large amounts of biomass fuel, generating intense heat energy, and emitting corresponding amounts of smoke plumes that comprise different species of aerosols and trace gases. Accurate estimates of these emissions are required as model inputs to evaluate and forecast smoke plume transport and impacts on air quality, human health, clouds, weather, radiation, and climate. Emissions estimates have long been based on bottom-up approaches that are not only complex, but also fraught with compounding uncertainties. Fortunately, a series of recent studies have revealed that both the rate of biomass consumption and the rate of emission of aerosol particulate matter (PM) by open biomass burning are directly proportional to the fire radiative power (FRP) or rate of release of fire radiative energy (FRE) that is measurable from satellite. This direct relationship enables the determination of coefficients of emission (Ce), which can be used to convert FRP or FRE to smoke aerosol emissions in the same manner as emission factors (EFs) are used to convert burned biomass to emissions. We have leveraged this relationship to generate a global gridded Ce for smoke aerosol or total particulate matter (TPM) emissions using measurements of FRP and aerosol optical depth (AOD) from the Moderate-resolution Imaging Spectro-radiometer (MODIS) sensors onboard the Terra and Aqua satellites. The first version of this new fire energetics and emissions research (FEER.v1) Ce product has now been made available to the community and can be obtained from http://feer.gsfc.nasa.gov/. In this presentation, we will discuss the characteristics of this Ce product, including its uncertainties, strengths and limitations. We will also demonstrate the simplicity and utility of using the gridded Ce product and satellite measurements of FRP to derive emissions, and present some comparisons of these emission products against those of other emissions inventories.

**Bio**: Dr. Charles Ichoku is a Research Physical Scientist at the Climate & Radiation Laboratory of NASA Goddard Space Flight Center, Greenbelt, MD. His activities include the quantitative evaluation and utilization of satellite retrievals of land-surface and atmospheric products,

particularly fires and aerosols, for important environmental research and applications. He led the team that conducted an independent pre-launch evaluation of the MODIS fire detection algorithm that has been delivering spectacular fire products to the world, and has since proceeded to lead the development of cutting-edge smoke emission products from satellite measurements of fire radiative power.

### 49. Inferring Smoke Plume Optical Properties and Ageing Effects from Near Simultaneous Ground and Satellite Remote Sensing Data

Author(s): Tadas Nikonovas, PhD student

**Abstract:** Smoke radiative forcing is highly uncertain as plumes contain both scattering and absorbing carbonaceous particles, the proportions of which depend on the emission source, combustion phase and smoke plume age. Currently available satellite sensors do not measure aerosol absorption directly, therefore complementary observational data or modelling efforts are needed for quantitative estimation. Aerosol optical properties and absorption spectra retrieved from ground-based sun-sky radiometer (AERONET) data and case studies indicate particularly large variability for Boreal forest wildfire emissions. Current uncertainty in sign and magnitude of the radiative forcing stresses the need for smoke plume source and age resolved analysis methods. The aim of this research is to enable automatic characterisation of a large number of plumes to establish a database of age and source resolved near-simultaneous ground and satellite observations. This is critically needed for 1) establishing the ageing effects on smoke optical properties and size distributions in relation to plume sources, 2) exploring the potential of satellite-based absorption retrieval, 3) parameterising aerosol models used by satellite retrieval algorithms, and ultimately, constraining smoke radiative forcing and total atmospheric emission. The study links AERONET measurements with multiple independent satellite based aerosol and active fire observations (CALIPSO, MISR, MODIS, AATSR) using air parcel trajectories modelled by the HYSPLIT model. Datasets from multiple sources are integrated in space-time analysis to allow the determination of smoke source and age at time of observation.

**Bio**: Degree in phisical geography. Msc Geographic Information and Climate Change. Currently PhD student at Swansea University, geography department, Earth Observation Group

# 50. Quantifying the Potential for High-Altitude Smoke Injection using the Standard MODIS Fire Products and Sub-Pixel-Based Methods

**Author(s):** David Peterson, National Research Council, Monterey, CA Jun Wang, Department of Earth and Atmospheric Sciences, University of Nebraska, Lincoln, NE

Edward Hyer, Marine Meteorology Division, Naval Research Laboratory, Monterey, CA

Abstract: All smoke emission inventories and chemical transport models require an estimation of the initial smoke injection height. Several methods currently exist for identifying and characterizing plume altitude from satellite, but these methods are difficult to automate and require post-fire images. Therefore, a method to predict high-altitude injection based on fire observations and modeled meteorology would be very useful for a range of research and operational modeling applications. This study examines smoke plume height data from the Multi-angle Imaging SpectroRadiometer (MISR) and fire observations from the MODerate Resolution Imaging Spectroradiometer (MODIS) in the North American boreal forest during the active fire seasons of 2004 and 2005. Results show that increasing values of fire radiative power (FRP) systematically correspond to higher altitude smoke plumes, and an increased probability of injection above the boundary layer. High FRP events comprise less than 10% of the total smoke plumes examined in this study, and less than 18% of the injections above the boundary layer, but nearly 60% of the injections above a fixed altitude of 2.5 km AGL. In addition, this study explores the potential benefits from a fire size and temperature-based calculation of MODIS fire radiative power (FRPf). While based on the heritage of earlier bi-spectral retrievals of sub-pixel fire area and temperature, the current investigation incorporates a radiative transfer model to remove solar effects and account for atmospheric effects as a function of Earth-satellite geometry at 3.96 and 11 µm. Smoke plume height comparisons with FRPf are similar to the standard FRP, but FRPf contains additional fire area information, which is also strongly related to plume height. The flux of FRPf over the retrieved fire area can also be calculated to produce an estimate of smoke plume thermal buoyancy, but its utility is limited to large clusters of fire pixels. FRPf flux may also be helpful for characterizing the meteorological effects on fire activity. An optimal method for predicting high-altitude smoke injection would use the combination of climatology, standard MODIS FRP, and FRPf flux data. The relative importance of those indicators is shown to depend on the characteristics of a given fire event.

**Bio**: Dr. David Peterson is a National Research Council Postdoc at the Naval Research Laboratory in Monterey, California. David has experience in meteorology and satellite remote sensing. He is currently working on combining satellite observations of fire activity and numerical weather prediction to improve the prediction of smoke emissions.

#### 51. Development of Operational Global Biomass Burning Emission Product Using Fire Radiative Energy Derived From MODIS and Geostationary Satellites

Author(s): Xiaoyang Zhang, ESSIC-University of Maryland at NOAA/NESDIS/STAR, College Park, Maryland Shobha Kondragunta, NOAA/NESDIS/STAR, College Park, Maryland Moraes da Silva, NASA Goddard Space Flight Center, Greenbelt, MD Sarah Lu, IMSG at NOAA/NWS/NCEP, College Park, Maryland Hyuncheol Kim, NOAA Air Resources Laboratory, College Park, Maryland Abstract: Biomass burning releases a significant amount of trace gases and aerosol emissions into the atmosphere and affects climate change, carbon cycle, and air quality. Near-real time estimates of biomass burning emissions are particularly important for air quality monitoring and forecasting. However, estimating biomass burning emissions is complex and challenging, which results in large uncertainties among various emission products. We present here a blended global biomass burning emission product by combining Global Biomass Burning Emissions Product (GBBEP-Geo) and Quick Fire Emissions Data (QFED). The GBBEP-Geo is produced in near-real time using diurnal Fire Radiative Power (FRP) that is simulated from instantaneous FRP at an interval of 15-30 minutes retrieved from a network of multiple geostationary satellites. The network consists of two Geostationary Operation Environmental Satellites (GOES) which are operated by the National Oceanic and Atmospheric Administration(NOAA), the Meteosat Second Generation satellites (MET-09) operated by the European Organization for the Exploitation of Meteorological Satellites (EUMETSAT), and the Multi-functional Transport Satellite (MTSAT) operated by the Japan Meteorological Agency (JMA). Although GBBEP-Geo provides emission estimates with high temporal frequency, it lacks spatial coverage in high latitudes and most regions of the Middle East, India and boreal Asia. In contrast, QFED is a near-real-time biomass burning emission system from the NASA Global Modeling and Assimilation Office. It produces daily biomass burning emissions using MODIS fire count and FRP products from both Aqua and Terra satellites. Cloud effects on FRP observations are reduced using the proportion of cloud cover. The OFED emissions are further calibrated with MODIS Aerosol Optical Depth (AOD). QFED dataset offers a complete global coverage, but the fires are only detected four times a day (tow times for Agua and Terra, separately). To produce an improved global product of biomass burning emission in near-real time, we combine GBBEP-Geo and OFED after they are both calibrated using MODIS AOD. For global aerosol forecasting and assimilation using Global Forecast System (GFS) based on NOAA Environmental Modeling System (NEMS), the blended biomass burning emissions are further calibrated at various ecosystems by comparing MODIS AOD with modeled AOD. The latter is produced after the blended biomass burning emissions are ingested in the NEMS GFS Aerosol Component (NGAC) system. The primary results of the blended global biomass burning emissions in 2011-2012 will be presented. Further, the improvement of AOD forecasting in the global aerosol forecast model will be introduced.

**Bio**: Xiaoyang Zhang received the Ph.D. degree in physical geography from King's College London, London, UK, in 1999. He was a Research Associate and Research Assistant Professor at the Department of Geography, Boston University, from 1999-2005. As a Senior Research Scientist from April 2005-May 2012 at Earth Resources Technology Inc and an Associate Research Scientist at the Cooperative Institute for Climate and Satellites (CICS) at the University of Maryland from June 2012, he has been working at NOAA/NESDIS/STAR through a contractor/visiting scientist. His research interests include satellite remote sensing of vegetation properties and biomass burning emissions.

### 52. Comparison of BlueSky Framework Configurations During Autumn Wildfire Season in the Pacific Northwest, USA

Author(s): Miriam Rorig, USDA Forest Service Marlin E. Martinez, Universidad del Turabo, Gurabo, Puerto Rico Susan O'Neill, USDA Forest Service Joan Mauel Colon, Indiana University, Purdue, IN

**Abstract:** The BlueSky Smoke Modeling Framework is a system used to predict PM 2.5 concentrations from wildland fire. BlueSky is comprised of several individual models (fuels, consumption, emissions, dispersion, etc.), and was developed to be modular, such that different models could be used in any step of the pathway. BlueSky was also developed to be run in an automated fashion, with all data scheduled to be downloaded so the modeling framework can be run overnight. At the peak of wildfire season, with numerous fires burning throughout the U.S., sometimes computing resources are not sufficient to complete the simulation in a timely fashion. Because of this, BlueSky is typically configured to use models and settings that allow efficient run times.

During September and October 2012, we had a unique opportunity to do multiple BlueSky runs with different model configurations for several large fires that were generating significant smoke impacts in Washington and Idaho. In addition to the automated CONUS BlueSky runs, the AirFire Team added several custom, Pacific Northwest regional runs to help local and state health and air quality agencies anticipate smoke effects and communicate them to the public. We used different BlueSky configurations, which allowed us to compare different BlueSky outputs for these Pacific Northwest fires. Statistics on maximum and average PM2.5 concentrations, number of grid cells exceeding threshold values, and other metrics for comparison will be presented.

**Bio**: Miriam Rorig has been a meteorologist with the Pacific Northwest Research Station since 1994, with research focusing on fire weather meteorology and smoke dispersion modeling. She has been instrumental in the development and evaluation of the BlueSky Smoke Modeling Framework, and is actively involved in teaching smoke dispersion modeling and working collaboratively with land managers to use tools developed for smoke management by the AirFire Team.

#### 53. BlueSky Playground: A Web-Based Smoke Modeling Decision Support Tool

Author(s): Sean Raffuse, Sonoma Technology, Inc. Anthony Cavallaro, Sonoma Technology, Inc. Robert Solomon, Desert Research Institute ShihMing Huang, Sonoma Technology, Inc. Narasimhan K. Larkin, USFS AirFire **Abstract:** Fire exclusion across the United States is a major contributor to wide-scale changes in forest structure, alterations in species composition, and accumulation of forest floor material. Fuels treatments, including prescribed fires and pile burns, have become increasingly important as fire seasons continue to worsen in severity. In addition, standards for particulate pollution continue to tighten, requiring land managers who approve or conduct prescribed fires to manage smoke production carefully to minimize smoke impacts in sensitive areas.

BlueSky Playground is an interactive, web-based tool for estimating smoke emissions and resulting downwind smoke concentrations from wildfires, prescribed fires, and pile burns. It connects to fuel loading, fuel consumption, fire emissions, and smoke dispersion models using the BlueSky Framework, providing access to powerful modeling tools in an easy'to-use interface. BlueSky Playground is part of the Wildland Fire Decision Support System Air Quality suite (WFDSS-AQ) and has been revamped recently to provide more useful tools and an updated interface for both wildfire smoke modeling and prescribed burn planning, including access to regional high-resolution forecast meteorology in some areas. The resulting system both provides better user control over parameters affecting fire emissions, and allows for more dispersion modeling options.

**Bio**: Sean coordinates STI's research and development at the intersection of wildland fires and air quality. He develops tools and techniques for evaluating how smoke impacts the environment and how those impacts can be reduced. Outside of professional life, he enjoys music, games, sports, cooking, and his family.

#### 54. Modeling Smoke for Incident Support

Author(s): Miriam Rorig, USDA Forest Service Narasimhan K. Larkin, USDA Forest Service Robert Solomon, Desert Research Institute, Reno, NV Susan O'Neill, USDA Forest Service Pete Lahm, USDA Forest Service, F&AM

**Abstract:** Numerous large wildfire complexes burned throughout the western United States during the summers of 2011, 2012, and 2013, including historically large fires in many areas. These and other fires caused significant smoke impacts, including evacuations, increases in hospital visits, disruptions to travel and commerce, and other societal and environmental impacts. To assist incidents and regions with understanding smoke, custom smoke modeling and smoke assessments, and new smoke oriented incident support roles (the Air Resource Advisor) were developed. This work built off of efforts undertaken over the past several years, but has become more formalized starting with the 2011 Southwest fires in Arizona and New Mexico. We describe the smoke modeling efforts, new tools, and new analyses and understandings that have been generated by this close collaboration and partnership between U.S. Forest Service Research and the Incident and Area commands, on-the-ground operational firefighting teams and other state and local agencies working to mitigate the smoke impacts from the fire and relay information to the public.

**Bio**: Miriam Rorig has been a meteorologist with the Pacific Northwest Research Station since 1994, with research focusing on fire weather meteorology and smoke dispersion modeling. She has been instrumental in the development and evaluation of the BlueSky Smoke Modeling Framework, and is actively involved in teaching smoke dispersion modeling and working collaboratively with land managers to use tools developed for smoke management by the AirFire Team.

#### 55. Analysis of Modeled Smoke Concentrations to Variations in Inputs, Modeling Components and Dispersion Model Parameters - Considerations for Retrospective Analyses and Real-time Smoke Prediction Applications

Author(s): Susan O'Neill, USDA Forest Service Robert Solomon, USDA Forest Service Tara Strand, Scion Research, New Zealand Miriam Rorig, USDA Forest Service Narasimhan K. Larkin, USDA Forest Service

**Abstract:** The prediction of near-surface and aloft smoke concentrations from fires is sensitive to variations in fuel loadings, fuel consumption, emission factors, plume rise, the timing of emissions through the day, meteorology, and dispersion model parameterizations. This analysis explores these sensitivities in terms of near-surface smoke concentrations and is unique because in particular it explores the sensitivity of how model domain resolution and dispersion model parameters further adjust/change the smoke concentrations produced from the emissions modeling pathway. In the Summer of 2013 the BlueSky Smoke Modeling Framework was updated to include the latest version of the HYSPLIT dispersion model (version 4.9) and to operate in a particle mode, where many particles are released to simulate smoke plume dispersion rather than in puff mode where puffs were released to simulate smoke plumes. The horizontal grid resolution, vertical sampling location, and other particle parameters can have dramatic effects on results and runtimes. These factors are examined using the Summer 2013 daily BlueSky predictions and a retrospective case study analysis of a prescribed burn in Washington State. This analysis is critical to understanding uncertainties in simulated near-surface smoke concentrations which are used to inform wildland fire operations and air quality agencies in times of regional scale smoke impacts.

**Bio**: Susan O'Neill is a Research Air Quality Engineer with the USDA Forest Service Pacific Northwest Research Station, AirFire Team, and has a Ph.D. from the Laboratory for Atmospheric Research at Washington State University.She is an original developer of the BlueSky smoke modeling framework and research interests extend to all aspects of modeling fire emissions, smoke dispersion and transport, and smoke plume chemistry.

### 56. Overview of an Intensive 2013 Field Study Measuring Crop Residue Burning Emissions

#### Author: Robert Elleman

**Abstract:** In August 2013, a team from the Environmental Protection Agency, two US Forest Service laboratories, US Department of Agriculture Agricultural Research Service, Washington State University, University of Idaho, and several partner smoke management agencies met over a nine day period to study smoke from agricultural fires in the Pacific Northwest. The ultimate goal of the project is to help smoke management agencies predict the amount of smoke from agricultural burns and also to inform emission inventories of North American agricultural smoke. The crops of interest are Kentucky Bluegrass and wheat – the former for being notoriously smoky and the latter for being a very commonly burned crop in the Northwest and around the world. One week of sampling was split between the Nez Perce Reservation in Northern Idaho and near Walla Walla, Washington. To accomplish our goal, we characterized the pre-burned field and measured the ground, near-ground, and downwind smoke density and chemical composition. Fuel loading measurements were taken for representative fields, and fuel moisture measurements were obtained for every field immediately before ignition. A network of E-BAM ground samplers captured ground level smoke concentrations around the edges of the burn. Other groundbased instruments targeted gaseous species and particulate mass, composition, light scattering, and light absorption. For the near-ground measurements an aerostat, or instrumented tethered balloon, vertically sampled gaseous and particulate emissions immediately downwind of the fires. The US Forest Service instrumented light airplane sampled the plumes downwind and complemented the plume density and height measurements from the US Forest Service lidar. What makes this study unique is the full picture we got from these fires: from knowledge of the pre-burned material, to ground, near-ground, airborne, and remotely-sensed measurements of the plume. Such a comprehensive sampling strategy of agricultural smoke is rare.

This presentation will explain the study design, the measurements, and the plan for data analysis and smoke forecast model improvements.

**Bio:** Robert Elleman is a meteorologist with the U.S. Environmental Protection Agency in Seattle, WA. He helps develop and improve technical tools that air quality agencies in the Pacific Northwest and Alaska use in their efforts to manage smoke and other air pollutants. He has a Ph.D. in Atmospheric Sciences from the University of Washington.

#### 57. Alaska wildfire observations and emission modeling with WRF-Chem

#### Author(s): Martin Stuefer, University of Alaska Fairbanks

Saulo Freitas, Center for Weather Forecasting and Climate Studies, INPE, Cachoeira Paulista, Brazil

Georg Grell, Earth Systems Research Laboratory of the National Oceanic and Atmospheric Administration (NOAA)

#### Chris Waigl, University of Alaska Fairbanks

**Abstract:** A biomass burn emission model and a fire plume rise algorithm have been coupled with WRF/Chem and used in a semi-operational mode during the recent Alaska fire seasons. Timely information of data characterizing the fire source and state is crucial for the model runs to accurately predict the smoke dispersion in near real time. We report on our (a) model setup with options to use different fire source data from satellite remote sensing and from local fire agencies, (b) model sensitivities and (c) our ongoing airborne fire and fire emission measurements. The injection heights and vertical distribution of fire emissions strongly depend on fuel characteristics and the state of a fire. We flew over selected fires in Interior Alaska and use a thermal infrared camera and an optical particle spectrometer to derive observational data near the source for model evaluation. WRF-Chem predicts the direct impact of fire emissions on people in the surrounding environment. The model further allows investigating the impact of emissions on weather by considering the direct and indirect effects of smoke aerosol, and calculating the radiative transfer through the polluted atmosphere. Our WRF-Chem studies of the extreme fire events in 2004 revealed significant modifications of the tropospheric temperature profiles and clouds in areas with high concentrations of emissions.

**Bio**: MARTIN STUEFER Geophysical Institute, University of Alaska Fairbanks, Fairbanks. Alaska. 99775 USA Email: stuefer@gi.alaska.edu Positions: Research Assistant Professor, Geophysical Institute, UAF Related Publications: •G. Grell, S. Freitas, M. Stuefer, J. Fast, 2011: Inclusion of Biomass Burning in WRF-Chem: Impact of Wildfires on Weather Forecasts. Journal of Atmos. Chem. Phys., 11, 5289–5303, 2011. •M. Stuefer, Freitas, S. R., Grell, G., Webley, P., Peckham, S., McKeen, S. A., and Egan, S. D., 2013: Inclusion of ash and SO2 emissions from volcanic eruptions in WRF-Chem: development and some applications, Geosci. Model Dev., 6, 457-468, doi:10.5194/gmd-6-457-2013, 2013.

#### SPECIAL SESSION: Transportation Corridor Safety (continued)

#### 58. A Superfog Index Based on Historical Data

**Author:** Gary L. Achtemeier USDA Forest Service Center for Forest Disturbance Science Athens, GA

**Abstract:** A superfog screening model was used to predict superfog lasting for at least one hour for seventeen combinations of fuel temperature and relative humidity linked with ambient weather. Results were normalized to a 10-point scale with zero being no fog and ten being superfog for all sixteen fuel conditions. The superfog index (SFI) shows a strong dependency on low ambient temperature such that fog chances decline with warmer night-time lows. The SFI was applied to proximity ambient weather data for the 09 Jan 2009 I-4 and 29 Jan 2012 I-75 disasters in Florida. The SFI was high in all cases suggesting potential for superfog. Superfog plus extenuating circumstances led to the I-4 and I-75 disasters.

#### 59. A Framework for an Operational Superfog Forecast Index

**Author(s):** Josh Weiss NWS Wilmington, NC Gary M. Curcio, IPAFES La Grange, NC Gary Achtemeier, Center for Forest Disturbance Science Athens, GA

**Abstract:** The National Weather Service, the U.S. Forest Service, and land managers have collaborated to develop an operational superfog forecast index. Superfog is a very dense fog that is generated when heat, moisture, and particulate matter from smoke plumes from smoldering combustion mix with cool, humid ambient air masses. These conditions are best met during the coolest periods late at night or early morning. Superfog reduces visibility to less than 3 m (10 ft.). This is sufficient to cause total obscuration for drivers of motor vehicles when superfog crosses roadways.

The superfog screening model developed by the Forest Service is being interfaced with the NWS Advanced Weather Interactive Processing System (AWIPS) Graphical Forecast Editor. The screening model predicts superfog lasting for at least one hour for sixteen combinations of smoldering fuel plume temperature and relative humidity measured in superfog linked with ambient temperature and relative humidity. The output is a superfog forecast tool based on NWS hourly forecast temperature and dewpoint. This will allow NWS to forecast superfog probability out to 60-hrs in the vicinity of any smoldering fires using numerical weather model data. Examples of how the collaborative prediction system works for both point and area fire weather forecasts will be shown.

### 60. Development of a New Superfog Screening Tool through Theoretical, Experimental and Numerical Investigation

Author(s): Christian Bartolome, University of California, Riverside Marko Princevac, University of California, Riverside David Weise, US Forest Service Pacific Southwest Station Akula Venkatram, University of California, Riverside Gary Achtemeier, US Forest Service Southern Research

Abstract: Major car pile ups, such as ones in Florida on the Interstate Highways 4 and 75 in 2008 and 2012, have resulted from the formation of a superfog. Superfog is dense smoke cloud that reduces visibility to less than 3 meters. Here we will present theoretical, numerical and laboratory modeling efforts that have been conducted to explain the origins of superfog. Thermodynamics of water vapor, droplet size distribution, liquid water content, extinctions coefficients and boundary layer development were explored. Laboratory measurements of smoldering smoke and smoke boundary layer growth have been conducted for various environmental and fuel conditions. In these experiments the favorable conditions for the superfog formation were determined to be: fog droplet sizes less than 1 2m, minimum cloud condensation nuclei concentrations of 105 per ccm, liquid

water content greater than 2 g kg-1, ambient temperature less than 40oF, ambient humidity greater than 80%, fuel moisture contents greater than 40% by mass, and wind velocities less than 1 m s-1 (2.2 mph). Based on these results the superfog Analysis Model (SAM) has been developed to aid land managers to quickly assess situations as favorable or unfavorable to the formation of superfog. SAM has been validated by laboratory experiments and has been successful in predicting previous superfog events. The theoretical formulations, experiments and the SAM development and features will be presented.

#### 61. Bringing PB-Piedmont to Users: Web Implementation of a Surface Drift Smoke Model

Author(s): Timothy J. Brown Research Professor Desert Research Institute Thomas M. Jackman Interim Senior Director of CAVCAM Desert Research Institute Gary Achtemeier Research Meteorologist USDA Forest Service Scott Goodrick Project Leader/Supervisory Research Meteorologist USDA Forest Service

**Abstract**: Smoke from both prescribed fires and wildfires can, under certain meteorological conditions, become entrapped within shallow layers of air near the ground at night and get carried to unexpected destinations as a combination of weather systems push air through interlocking ridge-valley terrain typical of the Piedmont of the southern U.S. Entrapped smoke confined within valleys is often slow to disperse. When moist conditions are present, hygroscopic particles within smoke may initiate or augment fog formation. With or without fog, smoke transported across roadways can create visibility hazards. Planned Burn (PB)-Piedmont is a fine scale, time-dependent, smoke-tracking model designed to run on a PC computer as an easy-to-use aid for land managers. PB-Piedmont gives high-resolution in space and time predictions of smoke movement within shallow layers at the ground over terrain typical of that of the Piedmont. PB-Piedmont applies only for weather conditions when smoke entrapment is most likely to occur at night during clear skies and light winds.

This project is a collaborative effort between the Desert Research Institute (DRI) program for Climate, Ecosystem and Fire Applications (CEFA), USFS Southern Research Station (SRS) and USFS Region 8 (the southern region where this product will be first tested and utilized). This presentation will describe the model background web implementation of the model for operational decision-support and planning.

#### 62. Application of Operational Tools by Air Resource Advisors for Smoke Related Transportation Corridor Safety

#### Author: Gary M. Curcio, IPAFES La Grange, NC

**Abstract:** Wildland smoke's ground level movement and associated particulate matter can create safety hazards for transportation corridors. When smoke concentrations are high or

persist as nuisance smoke, environmental conditions need to be evaluated, smoke concentrations monitored and smoke plume drift modeled. In June 2012, heavy persistent smoke was being released into the air due to the Dad Fire in eastern North Carolina. The Fire Weather Point Matrix (PFW), Super-fog Smart Tool and HYSPLIT atmospheric dispersion model were used to assess the daily threat to transportation corridor safety. These tools provided intelligence to the Incident Management Team's Air Resource Advisors (ARA). As early as June 22nd, a Superfog event was projected for June 24th 2012. Situational awareness was constantly maintained and permitted the implementation of timely mitigation measures. An Interagency Smoke Mitigation Plan was used. The appropriate agencies and public were notified. The predicted fog event reduced roadway visibility to 500 ft.

#### 63. Federal Highway Administration Perspective Concerning Poor Highway Visibility

#### Author: Kimberly Vasconez, FHA

Abstract: Listening to traffic reports and watching the evening news serve as daily reminders of the number of traffic incidents that occur on the Nation's roadways. For public safety responders and support teams removing vehicles from the highways, the risk of injury or death is constant. Add to this, the complication of weather-related factors, such as fog and smoke that reduce visibility, and responders and motorists face even higher odds that they will be struck while on the roadway. In 2012 alone, more than 250 public safety professionals— including police officers, firefighters, emergency medical services providers, and tow operators—lost their lives in the line of duty, with an estimated 13 percent of those occurring during incident response. Moreover, incidents cost billions each year in congestion-related costs and impacts on local economies. Since the 1990s, the Federal Highway Administration (FHWA) has worked with its State and local partners to define and develop a new public safety discipline focused on safely and quickly clearing incidents from highways and roadways. Today, FHWA systematically coordinates a national program to support the safe and expedient clearance of incidents. Will explore national efforts to enhance and professionalize traffic incident management (TIM) as a public safety discipline. The attendees will discover how FHWA is providing national leadership in establishing programs, guidance, and education to help State and local authorities improve the safety and effectiveness of responses to incidents on the Nation's roadways. The impact of smoke on traffic incident operations, debris clearance, and evacuations through the impacted area will be explored."

**Bio:** Kimberly C. Vásconez serves as the Traffic Incident & Events Management Team Leader with the Federal Highway Administration's Office of Operations. Her team develops National policy, guidance and tools for Traffic Incident Management (TIM), Traffic Planning for Special Events, Incident Operations at Traffic Management Centers, and Evacuation Planning. Ms. Vásconez has 28 years of disaster management experience from USDOT, DHS/FEMA, and USAID. Her career highlights include developing the TIM program, the National Urban Search and Rescue and Disaster Logistics programs; serving on the Homeland Security National Operations Center team; and working most major incidents from 1991 to 2004. As FEMA's Senior Disaster Logistics Official, she orchestrated FEMA's logistics mobilization for the 9/11/2001 Pentagon and World Trade Center responses and served as the Logistics Section Chief in Oklahoma City while supporting US&R operations. Ms. Vásconez worked for the USAID's Office of U.S. Foreign Disaster Assistance, where she traveled throughout Latin America, the Caribbean, Africa, Asia, and Europe aiding countries in their disaster planning and exercises. She was a Latin American specialist and developed the International US&R capability and the Disaster Assistance Response Teams. She served on a DART sent to Panamá 1991, where she worked in a displaced persons camp. She began her Federal career with the Department of the Navy. She has received commendations for her work from USDOT, FEMA, USAID, U.S. Army Corps of Engineers, the National Association of Search and Rescue, Hampton Roads, Virginia, and the State of California. She holds a Master of Public and International Affairs from the University of Pittsburgh and a BA in Journalism from Indiana University of Pennsylvania."

#### Special Session Transportation Corridor Safety Panel Discussion A panel discussion including presenters and session participants will explore "What Next"?

Fire weather intelligence can be made available by the NWS. The Consortia and NOAA are providing dispersion tools as to the where and when wildland smoke can be expected. With these developments, what is next? What can be done and what needs to be done through the interagency community (Natural Resource, National Weather Service, DOT, Law Enforcement, Emergency Management Agencies, etc.) to facilitate application of an ever increasing knowledge base that can play an integral part in minimizing roadway fatalities contributed to wildland smoke? This brief panel discussion will be a prelude to Wednesday's evening and more encompassing Interactive Smoke Challenges, Smoke Solutions Networking Session.

#### 64. Evaluating the Effectiveness of the Air Quality Index at Changing Public Behavior

Author(s): Susan Stone, US EPA Brooks Depro, Research Triangle Institute Kristin Isaacs, US EPA Carol Mansfield, Research Triangle Institute Stephen Graham, US EPA

**Abstract:** Air pollutants, especially particulate matter which is the main component of smoke, have been associated with cardiovascular morbidity, including hospital or ED visits for heart failure, cardiac dysrhythmia, myocardial infarction and stroke, as well as mortality. These cardiovascular effects occur primarily in older adults. EPA's Air Quality Index (AQI) is the nationally uniform U.S. index for informing the public about daily air quality and associated health risks if any. The AQI is forecast daily and also available in

real-time air quality reports that include information about at-risk populations, potential health risks and exposure reduction measures. Information about the AQI, and related tools for healthcare providers and educators can be found on the AIRNow Website (http://www.airnow.gov). Many approaches have been used to evaluate the effectiveness of the AQI in reducing people's exposure to air pollution and morbidity effects. Several approaches will be presented, including: public awareness surveys; health surveys (e.g., the Behavioral Risk Factor Surveillance Survey); population measures of exposure reduction; an activity diary study of behavior changes in asthmatic children; and epidemiological studies of asthma-related health measures. Results from the National-Scale Activity Survey (N-SAS) will be presented, the first activity diary study to evaluate behavior changes in older adults in response to AQI advisories. This Web-panel study recruited 1600 adults in 9 urban areas; data collected includes initial activity screening, activity diaries and a followup survey of awareness of the AOI and behavior changes. It addressed the question "What is the likelihood our respondents will change their behavior in response to the AQI?" Our results show that older adults are more likely to take exposure reduction measures. These results provide a plausible explanation for the results of recent fire studies that show lower effects estimates in people age 65 and great than younger adults.

**Bio**: Susan Stone is a Senior Environmental Health Scientist at the EPA. She is leader of the team reviewing the ozone national ambient air quality standards and Air Quality Index team leader, has coauthored many of EPA's public information documents about the health effects air pollution, and has given presentations across the U.S. and internationally. Ms Stone was co-lead for the National Scale Activity Survey (N-SAS), and is one of the authors of two studies of the health impacts of smoke from a fire in Eastern North Carolina. Ms Stone has an M.S. from the School of Public Health at UNC.

#### 65. Examining the Validity of Using Observed Visual Range to Estimate Mass Concentration

#### Author(s): William Malm, Colorado State University Bret Schichtel, National Park Service

**Abstract:** Several state air quality agencies have developed policies to issue Air Quality Index (AQI) warnings based on low values of visual range (VR). AQI warnings are based on particulate mass (PM) concentrations resulting from fire smoke, often of short time duration. Because monitoring data are not available in all places where an AQI warning might potentially be given, states have used human-observed visual conditions (i.e., sighting distant targets to determine VR) to estimate ambient PM concentrations. The underlying relationship between VR and assumed PM is Vr \* PM = CNST for all ambient conditions and for all parts of the United States. The validity of this procedure is highly dependent on background levels of hygroscopic aerosols in conjunction with ambient humidity levels. For instance, it is not uncommon in the eastern United States to have an ambient aerosol that contains in excess of 70 µg /m3 of water mass. The uncertainty in determining mass using this procedure is also dependent on the accuracy with which a visual estimate can be made and on the inherent variability of the background and smoke aerosol mass extinction efficiency. This analysis examines the validity of the Vr \* PM = CNST relationship, assesses the uncertainty in the constant value based on known physical and optical characteristics of an aerosol, assesses the effect of uncertainties in estimating VR, examines how this relationship may change as a function of national annual average background conditions and as function of season and location within the continental United States, and makes recommendations for the form of the Vr-PM relationship and how to use this equation under varied background and locational differences.

**Bio**: Dr. William C. Malm is a senior research scientist/scholar at Colorado State University's Cooperative Institute for Research in the Atmosphere (CIRA) and a retired research physicist for the National Park Service Air Resources Division where he was program coordinator for the visibility/particulate research and monitoring program.

Dr. Malm's expertise is in the area of visibility and related topics. He pioneered studies of visibility perception that elicit human responses, in terms of both psychophysical and value assessment, to changes in scenic quality as a function of aerosol optical properties.

# 66. Whither the Wind? Developing an Air Stagnation Climatology for the United States

Author(s): Joseph J Charney, US Forest Service Alan F Srock, Michigan State University

**Abstract:** Air stagnation events can greatly impact fire behavior and planning. Stagnant air can cause major complications for fires primarily because of diminished smoke ventilation, which in turn limits visibility and may negatively affect safety and public health. Warnings for air stagnation can halt a prescribed burn for an extended period of time, even if stagnation does not occur. Currently, there is no widely accepted definition of air stagnation, as the criteria for the frequency and duration of dangerous stagnation events vary greatly around the country. We wanted to build a climatology of air stagnation events that would be consistent everywhere, and could thus help fire managers when making burn decisions.

To build the climatology, we decided to start with a long-term surface weather dataset, since air stagnation at the surface would affect smoke dispersion most directly. We collected 30 years of hourly surface observations from weather stations around the United States, and extracted the winds from each station for the entire period. After perusing the data, we selected thresholds for a stagnation event as a maximum wind speed of 6 kt for at least 24 hours. For individual stations, we will show frequency distributions based on each event's duration, month of occurrence, and first and last hour below threshold speed. Then, to expand spatial coverage beyond that available from surface observation sites alone, we

will present distributions calculated from higher-resolution gridded surface analyses. Comparisons between surface observations and gridded datasets will help us determine confidence for stagnation occurrences in regions where the distribution of surface stations is sparse.

**Bio**: I am a research meteorologist with the US Forest Service Northern Research Station. My research concerns the application of meteorological observations, simulations, analyses, and theories to research projects that improve our understanding how the overlying atmosphere can affect the evolution of a wildland fire and the resultant smoke.

#### <mark>67. Ground Zero Daily Smoke Production Values for NC Coastal Plain Organic Soil</mark> Fire – Pains Bay May / June 2011 Author(s): Gary Curcio

#### 68. Quantifying and Incorporating the Cost of Smoke into Strategic Fire Planning

Author(s): Douglas Rideout, Colorado State Univesity Jeff Manley, National Park Service David Rossi, Colorado State University

**Abstract:** Smoke emissions from wildland fires and prescribed burns are a growing concern for wildland fire managers as they often severely restrict the ability to implement fuels treatments and can constrain the management of unplanned ignitions. While some extent of emissions are unavoidable, strategic planning can addresses their frequency, timing and location to reduce their impacts. Estimating the cost of smoke and incorporating it into landscape level fire planning can reduce the burden on wildland fire officials confronted with a potentially frustratingly complex set of choices and constraints. Currently, no systems are available for strategically incorporating the cost of smoke in fire planning at the landscape level. We engineered the STARFire spatial planning system to address this void by estimating the value of fire and fuels management at the landscape level and by estimating and including the cost of smoke. By working with locally defined emission standards and translating them into an emission unit cost, we were able to internalize the cost of smoke into fire management decision-making. This has the potential to aid the fire planner in formulating and analyzing trade-offs to be proactive in managing current versus future emissions. This is especially important for unplanned events where fire managers have restricted decision space. In economic terms, we adapted STARFire to estimate and internalize the negative externality of emissions at the landscape level to manage emissions and generate a more efficient fuels treatment plan that incorporates the social costs of smoke. In a case study at Sequoia and Kings Canyon National Parks, we used emission standards to estimate a Pigouvian "tax rate" (per unit of emissions). The rate was incorporated into the STARFire spatial planning system to enhance the ability of managers to mitigate the smoke impacts of unplanned ignitions and fuels treatments.

**Bio**: Dr. Rideout is Director of the WESTFIRE Research Center at Colorado State University and Professor of forest economics. His research focuses on the economics and management of wild and prescribed fires. Increasing awareness of critical issues in fire management have the Center focused on topics such as: the wildland urban interface, strategic analysis and budgeting of fire programs and fuels management and initial attack systems. The Center has played a central role in the construction and implementation of the new fire planning systems including FPA and STARFire.

# SPECIAL SESSION: Smoke and People: Bringing Clarity to Beliefs, Attitudes, and Influencing Factors

This session presents the results from multiple Joint Fire Science Program-funded research projects aimed at addressing the need to understand public perceptions and tolerance of smoke from various sources in multiple areas of the United States. Collaborators from Oregon State University, The Ohio State University, and the University of Idaho have approached this topic from multiple theoretical and methodological perspectives, yet have found surprisingly consistent results across regions. However, spatial and contextual factors are important for management consideration. During this session, key results and products will be shared, followed by a participatory panel session that will explore ways to apply and evaluate any proposed solutions.

#### 69. Engaging Students and Managers through Video Modules: Development of a Short Course about Public Perceptions of Smoke

#### Author: Jarod Blades

Abstract: Engaging students and managers through video modules: Development of a short course about public perceptions of smoke Part of special session: Smoke and People: Bringing clarity to beliefs, attitudes, and influencing factors Authors: Troy E. Hall, Jarod Blades, and Hillary Loomis (University of Idaho) An important output of Joint Fire Science Program research on public perceptions of smoke from wildland fire has been the development of a series of video modules that can be integrated into existing college courses and National Wildland Fire Training. The four 10-minute modules were produced by the University of Idaho in conjunction with studies funded by the Joint Fire Science Program to better understand the public's attitudes and tolerance of smoke from wildland fire. Our goal for this short course was to share the current state of knowledge, including the results of surveys conducted in nine states across the US, regarding the public's perception of smoke from wildland fire, and to help fire professionals effectively communicate with the public. The four modules were designed to be used either independently or as a complete series. Module 1 explores why understanding public perception is important. This module defines key terms used throughout the series and discusses why public perception is important for fire managers to understand. Module 2 explores how public values, beliefs, attitudes, and risk assessment influence their perception and tolerance of wildland fire and smoke. Module 3 addresses how specific

individual (e.g., health status) and community characteristics (e.g., rural vs. urban) shape perception and smoke tolerance, and Module 4 focuses on the public's trust in land management agencies and discusses best practices for public communication. Each module ends with a summary of the module topics and discusses how the material could be used for better communication between fire managers and the public. A set of discussion questions is also provided, which are designed to promote classroom discussion about how the topics relate to personal experiences with smoke management and how they could be applied. During this session we will present short segments of these modules to provide the opportunity for conference participant feedback and suggestions about how to improve the modules.

**Bio:** Jarod Blades, PhD candidate, University of Idaho, Department of Conservation Social Sciences. Jarod Blades has more than a decade of natural and social science experience in the public and private sectors. His dissertation research examines psychological factors underpinning public attitudes toward land management and tolerance of smoke, as well as the use of different social survey methods to understand smoke tolerance. He also serves as a social scientist with a team exploring effective communication of climate science to stakeholders.

# 70. Public and agency perceptions about smoke: Interview and survey results from four states

#### Author: Christine Shaw Olsen

**Abstract:** Smoke is a growing concern for communities as well as land and air quality managers. It affects air quality across landscapes much larger than the originating fire and can have significant negative impacts on nearby and distant communities. In early 2013, the U.S. Environmental Protection Agency (EPA) lowered ambient air quality standards for particulate matter which will likely result in more communities struggling to meet EPA limits as a result of smoke. At the same time, wildfires seem to grow in number and size every year, producing major smoke impacts on some communities, and underscoring the need to reduce fuels on unburned landscapes to reduce the risk of future fire events. Managers and landowners wishing to use fire as a tool for fuel reduction (i.e., prescribed fire, pile burns) could face significant barriers, both because of air quality standards and because of public concern for smoke impacts. Accordingly, it is important to understand public beliefs regarding smoke, especially focusing on what factors may influence acceptance of smoke emissions.

In this presentation we present findings from the first two stages of a three-stage project funded by the Joint Fire Science Program and the Western Wildland Environmental Threat Assessment Center (WWETAC). Phase one included interviews conducted in 2011 in southcentral Oregon, northwest Montana, northern California and central-coast of South Carolina among forest and fire managers, air quality regulators, and some community group members. This presentation will focus on the major challenges identified by interview participants regarding smoke management, and communication strategies that were identified as useful for overcoming these challenges. Phase two of this project included a public mail survey conducted in 2012 in the same four locations. This presentation will provide an overview of survey results as well as focused information on factors that may influence tolerance for smoke. Each origin of smoke emissions is treated separately to help define the different opinions associated with different types of fires. Results will be discussed cumulatively across all sites.

**Bio:** Christine Shaw Olsen, Ph.D., is a Research Social Scientist and Instructor in the Department of Forest Ecosystems & Society at Oregon State University in Corvallis, Oregon. Dr. Olsen is co-investigator of the Northwest Fire Science Consortium and conducts research on citizen-agency interactions, public opinions about fire and fuel reduction activities, and communication about forestry and fire. Her most recent projects examine public perceptions of smoke from prescribed fire, citizen-agency trust, and coupled human-natural systems in fire-prone landscapes. Dr. Olsen teaches classes about forest management for multiple resource values, managing in the wildland-urban interface, sustainable resource management, and social science methods.

# 71. Smoke and People: The Implications of Beliefs, Attitudes, and Perceived Risk for Communication

#### Author: Eric Toman

**Abstract:** Wildland fires have increased in extent and severity in recent years. At the same time, the number of people living in harm's way has increased dramatically. This has not only resulted in more people and private property potentially at risk from future fire events, but also an increased population who may critically evaluate and be affected by fuels reduction efforts. In the United States, citizen acceptance of fuels treatments, including the use of prescribed fire, is relatively strong and has proven fairly stable. However, responses also indicate some concerns with these treatments, including potential negative impacts of smoke emissions from prescribed fire use. Given the nature of smoke, emissions from treatments have the potential to effect citizens far beyond the treated area. While concerns about smoke are often cited by fire managers and residents as a potential limiting factor in developing successful fuels programs, little prior research has examined public beliefs and attitudes about smoke emissions or smoke management approaches. The research presented here is part of a larger effort to address this gap.

In spring 2012, a research team from The Ohio State University and Oregon State University used a modified Dillman approach to implement a general population survey in four locations (California, Montana, Oregon, and South Carolina). The included questions targeted several factors regarding citizen beliefs, attitudes, and perceived risks of smoke emissions as well as their prior experiences with fire, fuels treatments, and implementing agencies. In this presentation, we draw on the Risk Information Seeking and Processing model (RISP), which describes key variables that influence individual behaviors to seek information and make decisions regarding perceived hazards, to explore existing conceptualizations of smoke. This analysis will provide particular insight into the factors that influence participant decisions to seek additional information regarding smoke emissions and management. We will discuss the implications of these findings for communication efforts regarding smoke emissions and management.

**Bio:** Eric Toman is an Assistant Professor in the School of Environment and Natural Resources (SENR) at The Ohio State University. Using theory and methods from sociology and socialpsychology, Dr. Toman's research examines human adaption to changing environmental conditions. He has conducted research on the human dimensions of wildland fire and fuels management for over 10 years including projects at the state and national level. Prior to joining SENR, he completed a fellowship in the Climate Program Office of the National Oceanic and Atmospheric Administration in Washington, D.C. He received his Ph.D. in Forest Resources from Oregon State University in 2005.

### 72. Public Tolerance of Smoke from Wildland Fire: Comparative Results from Surveys in Nine US States

#### Author: Jarod Blades

Abstract: Public Tolerance of Smoke from Wildland Fire: Comparative Results from Surveys in Nine US States Part of special session: Smoke and People: Bringing clarity to beliefs, attitudes, and influencing factors Authors: Troy E. Hall, Jarod Blades, Christine Olsen, Eric Toman, Stacey Frederick Smoke from wildland fires is a serious land management consideration because it can affect public health, impede road and air traffic, damage property, inhibit forest management activities, decrease recreation and tourism, and trigger EPA determinations of poor air quality. Public impacts from smoke from wildland fires are increasing in the US Northern Rockies and the South due to increases in wildfire activity, the use of prescribed fire and management-ignited fire, and population growth in the wildland urban-interface (WUI). A paucity of literature specific to public perceptions of smoke from wildland fires exists. This presentation compares two studies that were funded by the Joint Fire Science Program to address this need. The University of Idaho study focused on two regions of the United States – the Northern Rockies (Idaho and Montana) and South-Central US (Texas and Louisiana). The Ohio State-Oregon State University study focused on Montana, Oregon, California, and South Carolina. Questionnaire items related to tolerance of smoke, beliefs about prescribed fire, risk perception, trust, and knowledge were shared between the two studies to allow for comparison across regions and communities. The two studies have found surprisingly consistent results across regions. Citizens recognize that smoke impacts from fire are likely, especially those associated with scenic impairment, loss of recreation/tourism opportunities, and health, though tolerance of smoke (particularly from wildfire or fires

ignited for forest health purposes) is quite high. High levels of tolerance are associated with strong agreement that smoke impacts are an unavoidable side-effect of promoting forest health and human safety in the WUI. There were surprisingly few substantive differences between the findings of the two studies across states or urban/rural divides. Overall, findings from these studies suggest that the public is quite tolerant of smoke from wildland and prescribed fires. These findings provide insights into improving communication between managers and the public.

**Bio:** Jarod Blades, PhD candidate, University of Idaho, Department of Conservation Social Sciences. Jarod Blades has more than a decade of natural and social science experience in the public and private sectors. His dissertation research examines psychological factors underpinning public attitudes toward land management and tolerance of smoke, as well as the use of different social survey methods to understand smoke tolerance. He also serves as a social scientist with a team exploring effective communication of climate science to stakeholders.

# 73. Longitudinal panel results: How the 2012 fire season impacted public perceptions in Northern California

#### Author: Stacey Frederick

**Abstract:** Smoke and reduced air quality as a result of fires (including wildfire and prescribed) is a major concern for people across the country and in many parts of the world. This concern can inhibit the ability of forest managers to use fire as a management tool in the prevention of catastrophic wildfires and maintaining ecosystem function. While limited research has been done into the public perceptions of smoke, even less has looked at the changes in these perceptions overtime. Opinions and perceptions are in a constant state of change as new influences emerge. In order to measure these changes, a longitudinal panel study was employed to survey residents in Northern California near the Shasta-Trinity National Forest. As a panel study implies, surveys were sent to the same individuals in 2012 and 2013 using the same survey format and questions. This presentation will discuss the potential influences including the socially significant fires that occurred between the two survey dates. Significant changes discussed will include public relations to forest agencies, smoke acceptance and experiences, smoke risk perceptions, and communication experiences among others. Suggestions for incorporating these results into management plans will also be discussed

**Bio:** Stacey Frederick is a second year M.S. student in the College of Forestry at Oregon State University. Her interests lie in the human interactions and components associated with natural resources issues. Previous and current research experience explore these human dimensions as they relate to wildland and managed fires with a special emphasis on issues of smoke.

### 74. Future Directions and Next Steps

Author(s): Troy Hall and Eric Toman

#### SPECIAL SESSION: Towards a Brown Carbon Emissions Model and Inventory for Climate and Environmental Toxicity Impacts Assessment

Abundant evidence of the existence of a light-absorbing component of organic particles emitted by biomass combustion now exists in the scientific literature. The light absorbing properties of this material, commonly called "brown" carbon (BrC), make it a matter of interest to the climate and atmospheric chemistry community. Climate modeling calculations in combination with remote sensing observations suggest that, depending on the location, BrC can play a meaningful role in regional-scale biomass burning-induced positive climate forcing. This warming impact adds to existing concerns about the air quality effects of present and future wildfire. However, further consideration of the chemistry of light-absorbing organic compounds points up the relevance of these materials to human health and ecosystems toxicity. Molecular structures with the functional groups necessary for light absorption in the UV/visible range, such as certain nitro-PAHs, are commonly found among those compounds known to be toxic. Furthermore, while organic compounds of the right structure and composition can absorb light and add to the toxicity of solid fuel combustion particles, the addition of transition metals ubiquitous in biomass materials and entrained from soil during landscape fires may be amplifying these effects. Lignin, a primary biomass structural material, pyrolyses in a fire to form derivatives (HULIS) that very successfully bind iron and other transition metals to form electochemically-active complexes that are able to absorb solar radiation in the UV/visible portion of the solar spectrum. In biological systems, these materials strip iron from essential biochemical structures inducing respiratory effects associated with smoke inhalation.

Capturing and projecting the climate and health effects of brown carbon from wildland fires, especially in the context of a warming climate, depends on our ability to estimate its emissions. The fire sciences community continually strives to advance our capability for anticipating fire and its characteristics. What is needed are improvements in our ability to use these fire characteristics, along with our knowledge of chemical kinetics and biomass fuel composition, to produce a more complete description of the organic pollutants emitted. This session explores some of the questions that must be considered in an effort to inventory current and model future BrC emissions, and the particular impacts this information can be used to quantify.

#### 75. Observing Brown Carbon in the Ambient Atmosphere and Lab

**Author:** Christopher D. Cappa, Ph.D., Department of Civil and Environmental Engineering, University of California, Davis **Abstract:** Although there is much evidence that light absorbing "brown carbon" (BrC) exists in the atmosphere, the properties and impacts of BrC are only beginning to be understood. What primarily distinguishes BrC from black carbon (BC) is that absorption by BrC increases strongly towards short wavelengths. Further, whereas BC is derived entirely from primary emissions, BrC can be either primary or formed from secondary processes. Ambient measurements of BrC are beginning to give a picture of a substance whose properties can vary substantially from location to location, driven by differences in both sources and atmospheric processing. Consequently, the impacts of BrC will vary by location and in time. This presentation will discuss some of these observations of BrC, both from ambient measurements and laboratory experiments, as well as some of the measurement tools available to identify and characterize BrC.

**Bio:** Prof. Cappa is a professor at the University of California, Davis in the department of Civil and Environmental Engineering. He received his B.S. in Chemistry with a minor in Environmental Science from Hope College in Holland, MI in 2000 and his PhD in physical chemistry from the University of California, Berkeley, in 2005, after which he was a postdoc at the National Oceanic and Atmospheric Administration in Boulder, CO. He started on the faculty at UC Davis as an Assistant Professor in 2007, and was promoted to Associate Professor in 2012. His work encompasses both laboratory and field measurements in pursuit of improving our understanding of the chemical, physical and optical properties of atmospheric aerosols.

### 76. The Chemical Composition of Aerosols from Wildland Fires: Current State of the Science and Possible New Directions

**Author(s):** Michael D. Hays, US EPA, Office of Research and Development, National Risk Management Research Laboratory

Amara Holder, US EPA, Office of Research and Development, National Risk Management Research Laboratory Brian Gullett, US EPA, Office of Research and Development, National Risk Management Research Laboratory Chris Geron, US EPA, Office of Research and Development, National Risk Management Research Laboratory Brooke Hemming, US EPA, Office of Research and Development, National Center for Environmental Assessment

**Abstract:** Wildland fire emits a substantial quantity of aerosol to the atmosphere. These aerosols typically comprise a complex mixture of organic matter and refractory elemental or black carbon with a relatively minor contribution of inorganic matter from soils and plant micronutrients. Identification of individual chemical components in aerosols emitted from wildfire is important to understanding public health effects, climate change, and supports the dispersion, apportionment, and air quality models most relevant to regulatory

policy. And while current analytical chemistry technology is offering unprecedented information about aerosol composition, a large fraction of organic aerosol released during wildland fires often remains unidentified. This presentation aims to examine the current state of the science with regard to molecular level identification of organic aerosol particles emitted from biomass burning with a focus on wildland fires. Not only will we examine the novel hyphenated chromatography-mass spectrometry tools being used to measure grouptype chemistry and the individual molecular constituents in wildland fire aerosols, but we will also propose the use of additional analytical-chemical technology that may assist in further unraveling unidentified aerosol matter from this globally important aerosol source.

**Bio:** Michael D. Hays is a Physical Scientist at the US EPA Office of Research and Development, National Risk Management Laboratory, Air Pollution Prevention and Control Division, (APPCD), Emissions Characterization and Prevention Branch (ECPB). Dr. Hays received his B.S. degree in Chemistry and Ph.D. in Analytical Chemistry/Environmental Studies from the University of Massachusetts Lowell. He was also awarded a postdoctoral fellowship at Case Western Reserve University in Cleveland, Ohio, where he synthesized adsorbent materials for control of sulfur and carbon dioxide emissions. Since joining the EPA, the primary research interest of Dr. Hays is the chemical characterization of fine particulate matter (PM2.5) from combustion emissions sources, including heavy-duty diesel engines, aircraft turbine engines, residential wood combustion, wildland fire, and various industrial stacks. Dr. Hays has also focused on the development of analytical methods for the physical and chemical characterization of PM2.5. His analytical-chemical research interests include thermal desorption and extraction, and the application of hyphenated chromatography-mass spectroscopy techniques.

#### 77. The Burning of Biomass Generates Humic-like Substances Which Can Impact Human Health Via Iron Complexation

#### Author(s): Andrew J. Ghio, M.D., US Environmental Protection Agency

**Abstract:** The biological effect of particle exposure can be associated with a disruption in cell iron homeostasis. We have demonstrated that an initiating event in oxidative stress and biological effect after mineral oxide particle (i.e. silica) exposure is a sequestration of cell iron by the particle. Organic compounds can similarly complex sources of host cell iron to disrupt the homeostasis of this metal. Humic-like substances (HULIS) are heterogeneous, amorphous, organic materials (ubiquitous on earth) which, as a result of a variety of acidic functional groups, complex metal cations to facilitate their mobilization, transport, and deposition in soils, sediments, waters, and coals. Wood smoke particles (WSP) formed during incomplete oxidation of biomass contain HULIS ( $8.2 \pm 6\%$ ). The HULIS content of WSP significantly exceeded that quantified in combustion products of coal and diesel which were much greater than that from oil. The sample of HULIS tested in our study had a rich brown color, consistent with the "brown carbon" seen in filter samples taken from smoldering biomass plumes. We quantified the total acidity and carboxylates

present in the HULIS extracted from WSP, and determined that the material had a substantial capacity for complexing metals. Cells exposed to this material showed an increase in free cell iron, i.e. iron was removed from its biologically necessary sites in the cell such as in the mitochonria or other critical cellular organelles. By pre-treating the respiratory epithelial cells, that were the subject of this study, with iron and then exposing them to WSP, all endpoints of biological effect/toxicity diminished including oxidant generation, transcription factor activation, and pro-inflammatory mediator release. From this, we conclude that the biological response following exposure to WSP is associated with complexation of biochemically-essential host cell iron by HULIS included in the particle. Therefore, an initiating event in the response of cells, tissues, and living systems to wood smoke is a complexation of requisite host iron by HULIS included in the particle. This suggests that wood smoke-drived HULIS (brown carbon) is a toxic material that should be accounted for in inventories used to assessing the human health effects of landscape fire.

**BIO:** Andrew Ghio is a medical officer with the Clinical Research Branch of the US Environmental Protection Agency. Areas of interest include lung injury following exposures to particles and fibers, wood smoke, air pollution, ozone, and asbestos. Recent manuscripts have focused on a potential mechanistic basis for toxicity of particles through their impact on iron equilibrium in the cell.

# 78. Fire-derived Brown Carbon Impacts and Inventories: A Research and Development Framework

**Author:** Brooke L. Hemming, Ph.D., Environmental Media Assessment Group, National Center for Environmental Assessment, US EPA Office of Research and Development

**Abstract:** Landscape fire emissions are a complex mix of photochemically- and radiativelyactive pollutants. Much is known about the health and climate impacts of the primary and secondary air pollutants found in fire plumes: NOx, SOx and VOCs. Conversely, the composition and impacts of the organic carbon-containing (OC) particles, especially the light-absorbing "brown carbon (BrC)" component, produced by fire are still poorly understood. Laboratory, ground and satellite studies indicate that OC particles can have a variable effect in forcing climate that might be explained by the presence of BrC compounds that are emitted as a function of fire stage. Polycyclic aromatic hydrocarbons (PAHs) are known to be present in fire particles, though are poorly quantified. Compounds arising from the pyrolysis of lignin, a primary element of biomass, have also been found in OC particles. New toxicology studies suggest that these lignin-derived monomers and polymers form complexes with biologically critical iron leading to pulmonary and systemic inflammation.

Understanding these landscape fire impacts requires an evaluation of the sources of color (light absorption) and the potential for cytotoxic complex formation by organic particulate matter. This evaluation should be followed by the construction of emissions models for these materials that can account for climate-relevant changes in ecosystems and

meteorological variables, allowing for present and future impacts assessment. Existing chemical characterization data from biomass combustion may not yet be adequate for this purpose. However, study results from related fields (biofuels engineering, combustion kinetics and others) can provide insight into how to set upper and lower bounds on the formation and emissions of brown carbon. A systematic synthesis of these insights, combined with those from landscape fuel studies, and the expertise of fire managers can constrain emissions estimates.

Strategic landscape fire management, especially under warming climate conditions, will require a careful balancing of considerations for ecosystems welfare, climate and human health protection. The purpose of this presentation is to outline a research strategy that will address the uncertainties concerning the formation and emission of brown carbon compounds and associated metallocomplexes towards the goal of producing emissions models needed for present and future fire management.

Disclaimer: The views expressed in this abstract are those of the author and do not necessarily represent the views or policies of the U.S. Environmental Protection Agency.

**BIO:** Brooke L. Hemming, Ph.D. is an assessment scientist in the US EPA National Center for Environmental Assessment (NCEA). She specializes in climate science and atmospheric aerosol chemistry, and has a particular interest in the chemistry of biomass burning emissions. Brooke is a primary co-author of high profile science assessments on climate and air quality, climate and black carbon, and the criteria air pollutants (PM, ozone and lead). She studied and did research in bioinorganic chemistry at UC Berkeley as an undergraduate, received her Ph.D. in Physical Chemistry from Stanford and completed post-doctoral studies at the California Institute of Technology. Brooke joined NCEA, in 2002, following a two year American Association for the Advancement of Science fellowship in EPA's Office of International Affairs.

#### SPECIAL SESSION: State of Fire Behavior Models and their Application to Ecosystem and Smoke Management Issues 79 - 83 (coming soon)

#### 79. Fire Science Needs for the Department of Defense

#### Author: John Hall

**Abstract:** Fire plays a vital role in the ecology of fire-adapted ecosystems and, due mostly to the introduction of non-native invasive species, in non-fire-adapted ecosystems as well. The Department of Defense (DoD) manages both types of ecosystems. In forest ecosystems, use of prescribed fire is an integral part of the silvicultural prescription toolbox associated with ecological forestry. To support DoD's continued use of fire as a management tool, the Strategic Environmental and Research Development Program (SERDP) and Environmental Security Technology Certification Program (ESTCP) fund efforts to address both

characterizing emissions associated with fire to meet air quality requirements and understanding how fire acts as a disturbance process that resets ecological communities of management concern to DoD. Emerging needs include carbon accounting in fire-adapted ecosystems and trade-offs with other ecosystem services, a more fundamental understanding of how fire behavior affects ecosystem and smoke management issues, and fire behavior and other model validations. To assist in providing direction to its research and demonstration efforts, in coordination with the rest of the fire science community, SERDP/ESTCP is developing a fire science plan. The conceptual model that provide a strategic basis for this plan is organized around five focal areas of research/demonstration that support DoD needs and provide avenues for collaboration with other agencies interested in advancing fire science: (1) fire behavior, (2) ecological effects of fire, (3) carbon accounting, (4) emissions characterization, and (5) fire plume dispersion.

**Bio:** Dr. John Hall manages the Resource Conservation and Climate Change program area for the Department of Defense's (DoD) Strategic Environmental and Research Development Program (SERDP) and Environmental Security Technology Certification Program (ESTCP). Both programs address fire-related research and demonstration issues of concern to DoD resource managers. Dr. Hall's graduate degrees are from Washington State University.

#### 80. State of Science of Fuel Characterization Before and After Wildland Fire

#### Author(s):

Roger Ottmar, U.S. Forest Service, Pacific Northwest Research Station, Pacific Wildland Fire Sciences Laboratory, Seattle, WA, USA Carl Seielstad, University of Montana, Missoula, MT, USA Clint Wright, U.S. Forest Service, Pacific Northwest Research Station, Pacific Wildland Fire Sciences Laboratory, Seattle, WA, USA

**Abstract:** This presentation is part of a special session entitled "State of Fire Behavior Models and Their Application to Ecosystem and Smoke Management issues". Wildland fuelbeds are composed of fuel particles derived from live and dead plant parts. The physical and chemical characteristics, amount, arrangement, continuity, and condition of those particles, in addition to topography and weather influence how much, and which parts, of a fuelbed will combust and consume during wildland fires. During the past 40 years, great strides have been made toward characterizing fuels before and after wildland fire to support fire models that predict fire behavior, fuel consumption, fire effects, and smoke production. This has led to the development and improvement of protocols and tools to characterize fuels such as the planar intercept inventory method, fuel type-specific allometric equations, natural and activity fuel photo series, Fire Effects Monitoring and Inventory System (FIREMON), Fuel Loading Models (FLM), Fuel Characteristic Classification System (FCCS), and aerial and terrestrial LiDAR. As the need for fuels data increases in complexity, however, these protocols and tools will soon prove to be inadequate, requiring new and innovative approaches to better capture the structural and
chemical complexity, and spatial diversity of pre- and post-fire fuel. For example, The Wildland–urban Interface Fire Dynamics Simulator (WFDS) requires explicit surface areato-volume ratio and bulk density properties of each fuelbed layer. These variables are difficult to measure in the field with current inventory methodologies but new approaches using terrestrial LiDAR and three dimensional fuel modeling show promise for addressing this need. In addition, a variety of important fuelbed types and categories are poorly characterized with current systems and protocols, including wetlands, invasive species, masticated fuels, tree and shrub crowns, rotten logs, and below ground biomass. This presentation will begin by reviewing the past and present state of characterizing fuels and important knowledge gaps, and conclude with a discussion of innovative ways to close these gaps as we move forward in building a solid science foundation for improved understanding and prediction of fire behavior, fire effects, and smoke production from wildland fire.

**Bio**: Roger Ottmar is a Research Forester, with the Fire and Environmental Research Applications Team, Pacific Wildland Fire Sciences Laboratory, Seattle, Washington. Roger leads efforts to develop: 1) a natural fuels photo series; 2) Consume, a model to predict fuel consumption and emission; and 3) the Fuel Characteristic Classification System to build and characterize fuelbeds for the United States and the world. He consults on the assessment of wildland firefighter exposure to smoke and leads the RxCADRE project, individual researchers and research teams from across the United States that collaboratively collect data to evaluate fire models.

## 81. State of Smoke Dispersion Modeling for Wildland Fire Planning

#### Authors:

Narasimhan K. Larkin, Susan O'Neill, Sean Raffuse, Miriam Rorig, Robert Solomon, Tara Strand, Tim Brown, Roger Ottmar, Pete Lahm

**Abstract:** Increasingly, managers are utilizing smoke information in decisions involving wildland fire, ranging from planning prescribed burns, to helping evaluate options in incident response. How well can smoke information meet the needs of wildland fire managers? What are the most critical needs for advancing our ability to better model smoke dispersion? We examine the current state of smoke dispersion modeling, including what is being asked of the models and how well they are able to provide this information. The range of available smoke forecasts, smoke dispersion tools, and decision support systems are presented. Results from test cases are presented as well as feedback from those using current systems. The best successes and most critical failings of current smoke dispersion systems evaluated from the context of both technical accuracy and the ability to support on the ground decisions.

### 82. Results from the JFSP Smoke Model Validation Workshop

**Author:** Timothy Brown, Desert Research Institute Craig Clements, San Jose State University Sim Larkin, USDA Forest Service

**Abstract:** As part of the Joint Fire Science Smoke Science (JFSP) Plan, a workshop has been organized for late summer 2013 to address one of the plan's themes of smoke model validation. This workshop is purposed to develop a consensus approach to undertake smoke model validation through field measurements. It builds upon needs described in the JFSP Smoke Science Plan in the JFSP Models and Measurements Workshop, and lessons learned from the Rx Cadre field experiments. While smoke is a component of the Rx Cadre experiments, it is not sufficiently addressed to substantially advance smoke modeling and prediction, or to create an authoritative smoke measurement and modeling database. To do this, a select group of smoke, fuels and fire behavior scientists have been invited into a workshop forum to both formalize the research elements and strategies needed to advance smoke modeling, and to design and plan a field campaign that can significantly advance our understanding of smoke. This presentation will discuss the workshop, and plans for a field campaign aimed at improving smoke modeling and prediction.

**Bio:** Tim Brown is the director of the Western Regional Climate Center, and the Program for Climate, Ecosystem and Fire Applications (CEFA) at the Desert Research Institute in Reno, Nevada.

83. Operational Fire Modeling and Critical Research Questions

#### Author:

Mark Finney, USFS, Missoula Fire Sciences Laboratory Jack Cohen, USFS, Missoula Fire Sciences Laboratory

**Abstract:** The rapidly expanding demand for operational fire modeling systems ranges from individual fire forecasts (single predictions) to continental scale risk analyses (ensemble simulations). The systems now employed are used in planning, operational support, and new research. All of these systems depend on having a common core set of fire behavior models that have simple computational demands, are robust to the unknowns and uncertainties of the fire and the environment, are responsive to the practical set of inputs available, and offer understanding of fire behavior to the user (not just another black box model). Although the limitations of the current core fire behavior models are well understood, the pathways to worthwhile replacements are not. Partly, this is because the requirements for fire models have never been identified. As argued here, however, the main reasons for no clear pathwavs to replacement are the absence of a confirmed theory of fire spread. In other words, we don't know how fires spread and modeling directions have created confusion rather than knowledge. Without such knowledge, the cost and rationale for replacing current models cannot be justified based on how adequately the physics of fire spread is represented (because it is not known and has been erroneously assumed). Recent laboratory experiments and field observations are presented that suggest an important new reason why the question of how fire spreads has

remained unanswered. It suggests several critical measurements from field-scale burns that must be obtained.

**Bio:** Mark Finney is a research forester with the Missoula Fire Sciences Laboratory. His research focuses on fire behavior fundamentals and operational fire modeling, and a few other odds and ends, such as trying to ignite forest fires with rifle bullets.

## 84. The Contribution of Fuel Loading Uncertainty to the Variability among Wildland Fire Smoke Emission Inventories

### Author(s):

Shawn Urbanski, US Forest Service, RMRS Wei Min Hao, US Forest Service, RMRS Matt Reeves, US Forest Service, RMRS Robin Silverstein, US Forest Service, RMRS

Abstract: Biomass burning (BB) emission inventories (EI) provide critical input for atmospheric chemical transport models used to understand the impact of biomass fires on air quality, atmospheric composition, and climate. While significant progress has been achieved recently in the development of regional and global BB EI, agreement among different emission inventories is often poor. Fuel loading is generally considered the greatest uncertainty in modeling emissions from wildland fires in the US. We present a high resolution (x = 500 m, t = 1 day) BB EI based on newly developed fuel loading models for forests and rangelands of the coterminous US. Fuel loading for forests is taken from a new forest fuel classification Fuel Type Groups (FTGs; Keane et al., 2013) which was developed from a large set of USFS Forest Inventory and Analysis surface fuel estimates (n > 14.000). Rangeland fuel loading is estimated with a Normalized Differenced Vegetation Index (NDVI) based biomass product developed using a large set of field data from the USDA Soil Survey Geographic (SSURGO) database, NDVI from the MODIS sensor on the Terra satellite, and landscape attributes (Reeves, 2013). The NDVI based rangeland biomass product accounts for the inter-annual variability in fine fuel loading which can exceed the decadal mean loading by more than 100%. The new fuel loading models are coupled with burned area maps from several BB EI models (Wild Fire Emission Inventory, Global Fire Emissions Database, Fire Inventory from NCAR, and the US EPA National Emission Inventory) to evaluate the contribution of fuel loading to the differences among the inventories' estimates of fuel consumption and smoke emissions. The new forest and rangeland fuel loading models are also implemented in the Wild Fire Emission Inventory model to assess the contribution of uncertainties in fuel loading to uncertainty in the estimates of fuel consumption and pollutant emissions at multiple spatial and temporal scales.

**Bio**: Shawn Urbanski is a research physical scientist with the US Forest Service. His research includes emissions quantification and field experiments for the validation of smoke emission and transport models. The emission quantification research involves laboratory and field experiments to characterize the composition of emissions from

prescribed burning and wildfires and the development improved wildland fire emission inventories. The model validation research involves airborne measurements of plume rise, chemical composition, and dispersion of smoke from wildfires and prescribed burns. The field measurements provide datasets to quantitatively evaluate emission estimates, plume rise models and high-resolution smoke dispersion forecasting models.

## 85. Spatio-temporal Estimation of Gaseous and Particle Emissions from a Major Australian Wildfire

Author(s): Nicholas Surawksi, CSIRO Ecosystem Sciences Stephen Roxburgh, CSIRO Ecosystem Sciences Carl (Mick) Meyer, CSIRO Marine and Atmospheric Research Andrew Sullivan, CSIRO Ecosystem Sciences

**Abstract:** The estimation of gaseous and particulate emissions from wildfire is often based on broad assumptions about the area burnt, fuel consumed, and also emission factors. Rarely is it possible to have detailed information on the various eco-physical parameters which enable a more process-driven emissions estimate to be derived. There is, therefore, a need for the accounting of wildfire emissions to consider more carefully the various ecophysical factors that influence the components that go into the final emissions calculation.

This study investigates the spatio-temporal evolution of greenhouse gas and particle emissions from a devastating Australian wildfire (the 2009 Kilmore East fire); which set new extremes in terms of fire weather, loss of life, and damage to assets and infrastructure. Emissions estimates were derived using the Seiler and Crutzen method [ Seiler and Crutzen , 1980 ], using information from laboratory-based measurements of fire emissions, state agency and remotely sensed data, estimates determined from the literature and expert judgement to enable this calculation technique to be applied spatially.

Emissions were dominated by those occurring after a major wind change which transformed the flank of the fire into a large head fire. The results show that greenhouse gas equivalent emissions were dominated by those from burning coarse woody material (about 60% of total). Combustion of surface fuels contributed about 27% of greenhouse gas equivalent emissions; whereas, fine bark fuel contributed 7%, fine elevated fuel contributed 5%, whilst crown fuel contributed only 2% to the emissions total. Furthermore, approximately 88% of the total gaseous emissions emanated from CO2, whilst the contribution from CH4 and N2O were 7% and 5% respectively. As for particulate emissions, PM10 emissions contributed almost half (~ 46%) of the equivalent emissions (including both gas and particle phase emissions) once its much higher (~ 590) global warming potential was taken into account. Overall, the results from this study shed significant light on the sources of emissions from landscape wildfire which could be used for more refined reporting in international inventories.

Seiler, W., and P. J. Crutzen (1980), Climatic Change, 2(3), 207-247.

**Bio**: Dr Nicholas Surawski is an OCE post-doctoral fellow employed by the CSIRO in Canberra, Australia. His research focuses on the impacts of fire on carbon cycling in Australia's southern forests. Prior to joining the CSIRO in 2012, Dr Surawski completed a PhD in vehicle emissions from the Queensland University of Technology. He also holds degrees in Environmental Science and Mathematics.

### 86. Smoke Emissions from Lowland Eucalyptus Forests: Implications for Carbon Accounting

**Author(s):** Malcolm Possell, University of Sydne87 Tina Bell, University of Sydney Meaghan Jenkins, University of Sydn Tina Bell, University of Sydney Tina Bell, University of Sydney

Abstract: Within Australia, annual carbon emissions from fires are estimated to be greater than those from the burning of fossil fuels. The calculation of these estimates is based upon measurements of area burned, fuel loadings, combustion completeness and emission factors. These data come from a combination of satellite, field studies and literature sources. Of the 23 major vegetation groups within Australia, published emission factors exist for only three of these groups: savanna grassland, savanna woodland and Eucalyptus forests in the Sydney region. In this study, we made laboratory measurements of emission factors of carbon dioxide, carbon monoxide and a number of volatile organic compounds, from various fuel fractions collected from a lowland Eucalyptus forest in south-east Australia. We compare these emission factors to the ones used in Australia's National Greenhouse Gas Inventory calculations and from other literature sources. We find that the proportion of carbon lost to the atmosphere from Eucalyptus lowland forest sites, because of fire, is similar to other vegetation types but the composition of the carbon loss is different. Using field measurements of fuel loading and carbon content before and after hazard reduction burns, we made estimations of total carbon emissions from sites within Eucalyptus lowland forests using the emission factors measured in this study. We compare these results against those made using the default values in Australia's National Greenhouse Gas Inventory calculations. In the majority of the Eucalyptus lowland forest sites studied, the Australian National Inventory Report default values result in significantly greater calculations of total carbon emissions than those using the measured values for these forests. This study highlights the need for a wider range of vegetation classes within Australia to be studied especially with regard to fuel loadings and emission factors. This would improve the certainty around fire emission estimates for carbon accounting and when assessing the impacts of smoke on air quality.

## **Bio**: Dr Malcolm Possell is a Teaching and Research Fellow in Biosphere-Atmosphere Interactions in the Faculty of Agriculture and Environment at the University of Sydney, Australia. He is currently a researcher in the Bushfire Co-operative Research Centre

investigating the emission of greenhouse gases from fires and their environmental effects. His broad areas of research are biosphere-atmosphere interactions, trace gas analysis and the effects of trace gases, including those from biomass burning, on atmospheric chemistry.

### 87. Exploring uncertainty in fire radiative energy-based emission estimates

Author(s): Evan Ellicott, University of Maryland Luke Ellison, SSAI / NASA GSFC Wilfrid Schroeder, University of Maryland Charles Ichoku, NASA GSFC

Abstract: Biomass consumption and smoke emissions were estimated for a prescribed fire implemented in Henry Coe state park, California, on October 18th, 2011. A combination of nearly coincident ground, airborne, and spaceborne data retrievals were used to estimate fuel consumption, emission factors, fire radiative power (FRP), and gas and aerosol emissions. In addition, we gathered biomass consumption and emission factors from various literature sources to use and compare with the empirical estimates. Pre- and postfire in situ fuel load and consumption estimates were collected at two- 2 hectare blocks consisting of a primarily grass fuel located next to ground fire sampling instruments. The fire energetics samples were taken during the active phase of the fire using three dual-band ground radiometers which were tied to overpasses by the Autonomous Modular Sensor-Wildfire (AMS) multi-spectral airborne sensor; the latter serving as the primary bridge between ground and spaceborne fire retrievals. There was strong agreement (<1% error) between peak fire radiant heat flux data derived from near-coincident in situ and airborne measurements. Agreement between airborne and spaceborne FRP data improved significantly after correction for omission errors and atmospheric attenuation, resulting in as low as 5% difference between Aqua/MODIS and AMS. Fire radiative energy (FRE) estimates from the field radiometers were used with in situ fuel consumption measurements to yield an energy-to-mass factor (0.261 kg MJ-1kg) which was then applied to the entire fire affected area using the fire radiative energy estimated (14.5e+06 MJ) from airborne and spaceborne retrievals of fire radiative power (FRP). This in turn yielded a total fuel consumption estimate of 3.8e+06 kg. Initial fire emissions estimates were calculated using three separate methods based on the FRE data derived from the integrated airborne and spaceborne FRP retrievals. The results ranged from a difference of 15% to nearly a factor of 3, demonstrating the uncertainty in using various approaches and sources of data to calculate fire emissions. Further investigation led to the creation of an error budget to account sources of bias including additional components such as differences in FRE estimates and energy-to-mass consumption factors.

**Bio**: I am interested in the application of remotely sensed data to investigate the interactive and dynamic nature of landscape ecology and interactions with humans. Incorporating spatial analysis tools along with in situ measurements I am particularly interested in

quantifying biomass burning emissions and severity. I also seek to understand how patterns of wildfire and land use may vary with climate change and anthropogenic influence.

### 88. Smoldering Smoke as a Source of Terpenes, Hemi-terpenes and OVOCs

Author(s): Timothy J. Johnson, Pacific Northwest National Laboratory Sonia M. Kreidenweis, Colorado State University Hugh Coe, Univesity of Manchester Gavin R. McMeeking, Colorado State University Shawn Urbanski, US Forest Service James Reardon, US Forest Service David R. Weise, US Forest Service Albert Mendoza, Pacific Northwest National Laboratory Robert J. Yokelson, University of Montana Ian R. Burling, University of Montana Sheryl Akagi, University of Montana Tim Johnson, Scientist

Abstract: We have recently completed a 5-year study characterizing smoke emissions from smoldering and flaming combustion during prescribed burns on U.S. Department of Defense (DoD) bases in the Southeast, including 2010 burns during the wet season at Camp Lejeune, North Carolina and 2011 burns during the dry season at Fort Jackson near Columbia, South Carolina. While fire has long played a role in the longleaf pine ecosystem, there are still some pine stands in the southeastern United States where fire has been suppressed, while others are burned regularly to meet DoD training objectives as well sustain ecosystems. The Lejeune burns occurred during the wet season on lowland sites in frequently burned stands, while the Jackson burns were lit on Carolina sandhill sites in stands that had not seen fire in several decades and had recently experienced drought conditions. Despite the different fuel and weather conditions, we found that fires in both locations were a source of terpenes such as limonene and pinene, hemi-terpenes such as isoprene, as well as their oxidation products including formaldehyde, glyoxal and glycolaldehyde. Such organic species were generated by the smoldering combustion, which can be identified by higher CO to CO2 ratios. Refractory black carbon (BC) emissions measured from aircraft displayed the opposite relationship, and were generally higher for fires with stronger contributions from flaming combustion. Emission measurements for BC, as well as for the gases measured by infrared spectroscopy and other techniques will be discussed.

**Bio**: Tim Johnson is a research chemist at Pacific Northwest National Laboratory specializing in infrared, Raman and other spectrosocpies, including to gas-phase measurements.

89. Trend and Uncertainties of Wildland Fire Emissions in Georgia

Author(s): Di Tian, Georgia Environmental Protection Division Chao Luo, Georgia Institute of Technology Yuhang Wang, Georgia Institute of Technology Tao Zeng, Georgia Environmental Protection Division James Boylan, Georgia Environmental Protection Division

**Abstract:** Fires burn more than a million acres of wildland per year in Georgia, emitting large amounts of pollutants such as particulate matter, nitrogen oxide (NOx), volatile organic compounds (VOC), and carbon monoxide (CO). In 2011, wildland fires in Georgia emit 132,866 tons of PM2.5 (50% of total anthropogenic PM2.5 emissions). Unlike in the western U.S., most wildland fires in Georgia are prescribed fires which are ignited intentionally for ecosystem health. Better understanding of the air quality impacts from wildland fires is greatly desired with the implementation of the more stringent 2008 ozone and the 2012 PM2.5 National Ambient Air Quality Standard.

In this work, trend of wildland fire emissions in Georgia is analyzed by comparing 5 wildland fire inventories: VISTAS 2002, Georgia 2005, SEMAP 2007, Georgia 2008 and Georgia 2011. Trend of burning records kept by Georgia Forestry Commission is also analyzed. The burned area for prescribed fires in Georgia has steadily increased through the years, and wildfires vary greatly between years. This work also investigated uncertainties in current wildland fire emissions inventories by comparing the wildland fire inventories developed using detailed ground fire records and the Satellite Mapping Automated Reanalysis Tool for Fire Incident Reconciliation (SMARTFIRE) inventory developed by U.S. Forest Service using both ground records and satellite data. SMARTFIRE data tend to overestimate fire activities in fall and underestimate fire activities in spring. The cause of the over- and underestimation is investigated here by comparing detailed burning data with Hazardous Mapping System (HMS) data which dominate SMARTFIRE inventory in the southeast. The uncertainties in the fuel consumption and emission factors are also discussed. In addition, the trend of wildland fire emissions is compared with source apportionment results from Positive Matrix Factorization (PMF). The findings in this work can facilitate closer interdisciplinary cooperation between federal/state/local air quality and forest managers, as well as research communities in order to better understand emissions from prescribed fires, the major wildland fire type in the southeast, and their air quality impacts.

**Bio**: Dr. Tian earned her Ph.D. in Environmental Engineering at Georgia Institute of Technology in 2006, and has been working in Georgia Environmental Protection Division since then. Her expertise includes emissions inventory development, air quality modeling, and control strategy development. Her work has been used to inform air quality policy decisions for the state of Georgia and other states in the southeast. She has large interests in air quality impacts from biomass burning. She has authored three peer-reviewed journal publications and been working on several other research projects funded by U.S. EPA STAR program and NASA in this area.

### 90. Fire Regimes in Russia: Impacts on Environment, Ecosystems and Society

Author(s): Anatoly Shvidenko, IIASA Dmitry Schepaschenko, IIASA

**Abstract:** We present a regional overview of the recent (1998-2011) fire regimes in Russia and their impacts on environment, ecosystems and society. The burnt area is estimated and georeferenced based on AVHRR data and compared with other remote sensing long period series (GFED3, SPOT Vegetation). Distribution by fire type and intensity is defined based on long period empirical models (Shvidenko et al. 2011). An Integrated Land Information System (Schepaschenko et al. 2011) was used for the quantitative characteristic of land cover, ecosystems and amount of fuel. The average amount of fuel consumed by fire was estimated at 121 28 Tg C year-1 with large interannual variability. We present the regional estimates of fire emissions (gas composition, particles).

We show that mega (catastrophic-) fires become an inherent feature of current fire regimes. During the last twenty years, catastrophic fire situation occurred in different regions of Russia, basically in its Asian part, with the frequency about 10 years. They result in substantial ecosystems degradation; impoverishment of biodiversity, particularly at zonal ecotones; generate a specific condition of the atmosphere and seasonal whether over huge territories; provide large economic and infrastructure damage; and substantially impact life conditions of population and health of people. Taking into account expected climate change and following dramatic acceleration of fire regimes in these territories, there is an urgent need of development of an effective system of fire protection in Russia.

**Bio**: Professor Shvidenko's main fields of interest are forest inventory, monitoring, mathematical modeling, global change, and boreal forests. He has authored and coauthored over 340 scientific publications. He served as lead author and coordinating lead author in the Third Millennium Ecosystem Assessment and in the IPCC Assessments. He has taken part in a number of important international global change activities and initiatives as member of steering committees and councils (Global Terrestrial Observing System, Terrestrial Carbon Observation Panel, FAO Forest Resource Assessment, International Boreal Forest Research Association, etc.).

#### 91. The Wildland Fire Portion of the 2011 National Emissions Inventory

Author(s): Sean Raffuse, Sonoma Technology, Inc. ShihMing Huang, Sonoma Technology, Inc. Narasimhan K. Larkin, USFS AirFire **Abstract:** As air quality standards have tightened, smoke from wildland fires has faced greater scrutiny from the air quality management community. This led to a need to improve the quality and accuracy of wildland fire emissions inventories. Previous work has demonstrated that estimates of wildland fire emissions vary greatly depending on the methods employed. Further, there has been a lack of fire activity information for prescribed burns and small fires, which both occur at a much higher frequency than larger fire events, but are largely unaccounted for or ill represented in national data sets.

For the wildland fire portion of the EPA's 2011 default National Emissions Inventory (NEI), we solicited and received data from state forestry, federal land management, and regional air quality agencies. In all, 38 national and state fire occurrence data sets were included. State specific data were available for 21 states. The inventory was developed using the SmartFire2-BlueSky system. We present a tour of this inventory, including methods and results, with a particular focus on how additional local data changed the results, issues that remain, and suggestions for future inventory efforts.

**Bio**: Sean Raffuse is an Atmospheric Scientist at STI and a member of the BlueSky and SmartFire research teams. His work focuses on developing methods and tools for improving fire and smoke modeling.

## 92. Producing emission estimates from cropland burning in the contiguous United States for the 2011 National Emissions Inventory: Lessons learned from a remote sensing-based approach

Author(s): Jessica McCarty, Michigan Tech Research Institute Tesh Rao, Office of Air Quality Planning & Standards, Environmental Protection Agency Mary Ellen Miller, Michigan Tech Research Institute George Pouliot, Atmospheric Modeling and Analysis Division, National Exposure Research Laboratory, Environmental Protection Agency Amber J. Soja, National Institute of Aerospace and NASA LaRC

**Abstract:** Prescribed fires in agricultural landscapes generally produce smaller burned areas than wildland fires but are important contributors to emissions impacting air quality and human health. Currently, there are a variety of available satellite-based estimates of crop residue burning, including the NOAA/NESDIS Hazard Mapping System (HMS) the Satellite Mapping Automated Reanalysis Tool for Fire Incident Reconciliation (SMARTFIRE 2), the Moderate Resolution Imaging Spectroradiometer (MODIS) Official Burned Area Product (MCD45A1)), the MODIS Direct Broadcast Burned Area Product (MCD64A1) the MODIS Active Fire Product (MCD14ML), and a regionally-tuned 8-day cropland differenced Normalized Burn Ratio product for the contiguous U.S. The purpose of this NASA-funded research was to refine the regionally-tuned product utilizing higher spatial resolution crop type data from the USDA NASS Cropland Data Layer and burned area training data from field work and high resolution commercial satellite data to improve the U.S. Environmental Protection Agency 's National Emissions Inventory. The final delivered to the EPA included a detailed database of 25 different atmospheric emissions at the county level, emission distributions by crop type and seasonality, and GIS data. The resulting emission estimations were shared with all 48 states in the contiguous U.S., with detailed error estimations for Florida, Wyoming, and Indiana. This work also provided opportunities in discovering the different needs of federal and state partners, including the various geosptial abilities and platforms across the many users and how to incorporate expert knowledge into quantitative remote sensing estimations of emissions.

**Bio**: Dr. Jessica L. McCarty is a Research Scientist at the Michigan Tech Research Institute in Ann Arbor, MI. She received her Ph.D. in Geography from the University of Maryland in 2009. Dr. McCarty is interested in applying remote sensing and geospatial technologies and modeling to wildland and prescribed fire, fire-related atmospheric emissions, and land cover/land use change and mapping. She is interested in crowd-sourced, social media, and citizen science to improve environmental analyses. Dr. McCarty has participated in and led NASA-, USDA-, and EPA-funded projects in the U.S., Canada, and Russia, and has completed fieldwork in these countries.

## 93. A Short-term Predictor of Satellite-observed Fire Activity in the North American Boreal Forest: Toward Improving the Prediction of Smoke Emissions

**Author(s):** David Peterson, National Research Council, Monterey, CA Edward Hyer, Marine Meteorology Division, Naval Research Laboratory, Monterey, CA Jun Wang, Department of Earth and Atmospheric Sciences, University of Nebraska, Lincoln, NE

**Abstract:** In order to meet the emerging need for better estimates of smoke emissions in air quality (AQ) forecast models, a statistical model, based on numerical weather prediction (NWP), is developed to predict the following day's satellite observations of fire activity in the North American boreal forest during the fire season (24-hour forecast). In conjunction with the six components of the Canadian Forest Fire Danger Rating System and other NWP outputs, fire data from the MODerate Resolution Imaging Spectroradiometer (MODIS) and the Geostationary Operational Environmental Satellites (GOES) are used to examine the meteorological separability between the largest fire growth and decay events. with a focus on central Alaska during the large fire season of 2004. This combined information is analyzed in three steps including a maximum likelihood classification, multiple regression, and empirical correction, from which the meteorological effects on fire growth and decay are statistically established to construct the fire prediction model. Both MODIS and GOES fire observations show that the NWP-based fire prediction model is an improvement over the forecast of persistence commonly used in AQ forecasting systems. Results from an independent test (2005 fire season) show that the RMSE of predicted MODIS fire observations is reduced by 5.2% compared with persistence. Improvements are strongest (RMSE reduction of 11.4%) for cases with observed decay or extinction of fires.

Similar results are obtained from additional independent tests using the 2004 and 2005 GOES fire observations. This study uniquely demonstrates the value and importance of combining NWP data and satellite fire observations to predict biomass-burning emissions, which is a critical step toward producing a global short-term fire prediction model and improving operational forecasts of smoke transport at large spatial scales.

**Bio**: Dr. David Peterson is a National Research Council Postdoc at the Naval Research Laboratory in Monterey, California. David has experience in meteorology and satellite remote sensing. He is currently working on combining satellite observations of fire activity and numerical weather prediction to improve the prediction of smoke emissions.

## SPECIAl SESSION: Revising "Wildfire Smoke: A Guide for Public Health Officials"

Since 2001, the document "Wildfire Smoke: A Guide for Public Health Officials" has been an essential resource for federal, state and local agencies in making public health decisions during smoke events. Three federal agencies, the Environmental Protection Agency (EPA), the Centers for Disease Control and Prevention (CDC) and the Forest Service (USFS) plan to revise the document for the 2014 fire season. This session is designed to present an overview of the initial plans for revising the document, and solicit feedback from stakeholders about revisions that would be most useful. The session would include a panel of 5-6 speakers, as described below, who would speak for 10 minutes each. Then to ensure adequate time for feedback, 30-45 minutes would be allowed for discussion.

#### 94. Overview of New Health Information

#### Author: Ana Rappold, EPA

This talk will include a general overview of new studies pertaining to the health effects of wood smoke exposure, reducing exposure using commonly available respirators and room air cleaners and related health topics that would be included in the updated guide.

**Bio:** Ana G. Rappold is an environmental statistician whose research is focused on the health effects of air pollutants. Ana has been researching health effects associated with 2008 and 2011 fires in peat bogs of NC.

## 95. Overview of New Air Quality Index Information

#### Author: Susan Lyon Stone, EPA

This talk will include new information on the effectiveness of the Air Quality Index (AQI) in changing public behavior, including results from EPA's National-Scale Activity Survey (N-SAS), a diary study of behavioral changes in adults age 35 and older. It will also cover what is known about the effectiveness of the AQI in reducing asthma outcomes, such as

emergency department visits. EPA's new approach for providing hourly AQI values for PM2.5 advisories, the "NowCast," will be discussed.

**Bio:** Susan Lyon Stone, Senior Environmental Health Scientist, stone.susan@epa.gov, US EPA Susan Stone is a Senior Environmental Health Scientist at the EPA. She is leader of the team reviewing the ozone national ambient air quality standards and Air Quality Index team leader, has coauthored many of EPA's public information documents about the health effects air pollution, and has given presentations across the U.S. and internationally. Ms Stone was co-lead for the National Scale Activity Survey (N-SAS), and is one of the authors of two studies of the health impacts of smoke from a fire in Eastern North Carolina. Ms Stone has an M.S. from the School of Public Health at UNC

## 96. Communicating with Public Health Agencies

## Author: Scott Damon, CDC

Public communication related to emergency, unplanned, or "wildfire" biomass burning is best understood as a function of the audience for that communication. Two enduring communication models, the Health Belief Model and the Stages of Change or Transtheoretical Model, are instructive in analyzing and preparing differing communication response strategies for communities with varying degrees of experience in responding to unplanned biomass burning smoke events. This talk will focus on practical public health communication related to wildfires; specifically, we will discuss approaches taken to communicate with public health agencies and the public to help identify information that is useful as well as optimal approaches to disseminate the information.

**Bio:** Scott Damon is the Lead Health Communication Specialist for the Air Pollution and Respiratory Health Branch at the Centers for Disease Control and Prevention (CDC). In this role, he develops and oversees CDC's communication on asthma and respiratory health issues. Scott received a Master of Arts in International Affairs (MAIA) from Ohio University and a Certificate of Public Health (CPH) from the John Hopkins University. In addition, Scott is a Returned Peace Corps Volunteer (RPCV).

## 97. Interagency Wildland Fire Air Quality Response Efforts

## Author: Pete Lahm, USDA-FS

An overview of interagency efforts to address the air quality impacts of wildland fires that are widespread, long duration and have substantial effects to public health and fire personnel. The importance of consistent and reliable public information regarding public health impacts is critical and the updated guide can help facilitate these responses by Air Resource Advisors and others in the air quality responses to wildland fires. **Bio**: Pete Lahm is the Air Resource Specialist for the USDA Forest Service, Fire and Aviation Management, in Washington, DC. Starting in 2004, Pete has led the Forest Service's smoke management efforts developing technical approaches and policies related to smoke impacts. Since 2009 he has chaired the National Wildfire Coordinating Group's Smoke Committee. Prior to 2004, Pete managed the Arizona Interagency Air Resource and Smoke Management Program. He chaired the Western Regional Air Partnership's Fire Emissions Joint Forum from 1996-2004. Pete holds a Master's of Environmental Management from Duke University.

## 98. Adaptations of the Guide: New Mexico Tools and Next Steps

## Author: Heidi Krapfl, NM DOH

The New Mexico Department of Health's Environmental Health Epidemiology Bureau, in collaboration with input from the Environment Department's Air Quality Bureau, has worked to adapt materials from the wildfire guide since about 2011. This has included a general fact sheet about smoke and health effects, a fact sheet about selecting the right mask for smoky conditions, a table providing recommendations for public health officials and communities, and guidance about gauging particulate matter concentrated based on visibility. Each document will be described briefly and a summary of questions and feedback that have arisen from the public. This, in turn will be used to address the larger question of what changes might be needed for the guide.

**Bio:** Heidi Krapfl is the bureau chief of the Environmental Health Epidemiology Bureau with the New Mexico Department of Health. She has served in this position since 2008. Before that she was an environmental epidemiologist with the bureau from 2006 to 2008. Ms. Krapfl holds an Master's of Science in environmental health, with a concentration in epidemiology.

## 99. State of Idaho Use of the Wildfire Guide in 2012

## Author: Mary Anderson, ID DEQ

This talk will describe how the State of Idaho used the wildfire guide during the 2012 wildfire season. It will highlight challenges faced and how Idaho responded during one of its worst wildfire seasons for smoke impacts in recent history.

**Bio:** Mary Anderson is the Smoke Management Program Coordinator for Idaho DEQ. She is responsibility for managing the crop residue burning and prescribed burning programs, as well as, coordinating DEQ's response to wildfire smoke.

**SPECIAL SESSION:** State of Fire Behavior Models and their Application to Ecosystem and Smoke Management Issues (continued)

## 100. Future of Coupled Fire-Atmospheric Modeling

### Author:

*Ruddy Mell,* US Forest Service *Rod Linn* 

**Abstract:** The spatial scales at which combustion and heat transfer occur in a wildland fire are significantly smaller than the spatial scales characterizing smoke rise and transport over a landscape. This scale separation makes it computationally expensive to simulate fire behavior and smoke transport with equal fidelity. As a result, operational models that focus on wildland fire behavior or smoke transport simplify, in different ways, the fire-atmosphere coupling. The coupling of the fire and atmosphere physics is relevant to a number of fire problem areas including fire fighter safety, fire effects, fire behavior in complex fuels and terrain, accelerating fire fronts, smoke generation, and smoke plume rise and transport. Thus, there is a need to improve the modeling of fire-atmosphere processes over a range of model applications. These improvements will come with a computational cost, which must be balanced against the increased model capability. This presentation will give an overview of potential advances in fire-atmosphere modeling given the increasing availability of affordable multiprocessor computing platforms. Also, advances in computer model capability need to be supported, when possible, by commensurate measurements. These measurements needs will also be discussed.

**Bio:** Ruddy Mell is a combustion engineer with the U.S. Forest Service who has been involved with computer modeling of wildland fires and wildland-urban interface (WUI) fires for the past 10 years. Prior to entering the field of wildland fire he worked in the areas of modeling turbulent combustion, microgravity combustion, and structure fires at the U.S. National Institute of Standards and Technology (NIST). His model development work occurs in close collaboration with experimentalists and modelers at the U.S. Forest Service, NIST, and academia. His current focus is on the development and testing of the wildland-urban interface fire dynamics simulator suite (WFDS). The objective of these models, and results from field and laboratory work, is to provide better tools for wildland and WUI fire researchers and guidelines for WUI homeowners, communities, and fire officials for risk assessment and mitigation.

## **101**. State of Fire-Atmosphere Interactions Research for Smoke and Fire Behavior Modeling

## Author(s):

Craig Clements, San Jose State University Scott Goodrick, USFS **Abstract:** Fire-atmosphere interactions are driven by the state of the fuels, ambient meteorology, and terrain. These interations often lead to complex circulations in and around the fire front that can impact its behavior and intensity and resulting smoke emissions and dispersion. While in the past decade, there has been a major research thrust in smoke emissions modeling and measuremens, there have been few studies aimed at better understanding fire-atmosphere interactions and their relation to smoke emissions. New observational remote-sensing technologies including scanning Doppler lidar and radar have been used to quantify the complex circulations in and around wildland fires. In addition to remote sensing, in situ eddy-covariance measurements have been used to quantify the turbulence characteristics of different fire regimes and investigate the validity of Monin–Obukhov simularity theory for use in smoke dispersion models. This presentation will present the current state of knowledge of fire-atmosphere interactions and future needs including measurement technologies and design of future field campaigns for disperison model development.

*Bio:* Associate Professor of Meteorology, Director of Fire Weather Reserach Laboratory at San Jose State University

## 102. Fire and Smoke Modeling to Meet Ecosystem Management Objectives

### Author: J. Kevin Hiers

Abstract: Managed fire regimes are now critical to meet all conservation objectives in fireadapted ecosystems nationwide. Due to climate change, the introduction of non-native invasive species, altered fuel beds, the restoration and maintenance of these fire-dependent ecosystems and protected species contained therein faces nearly insurmountable uncertainty. The Department of Defense (DoD) is heavily invested in fire ecosystems of the desert southwest, southeastern US, and Alaska. In forest ecosystems, use of prescribed fire is an integral part of managed fire regimes, but the experience of managers, which is so important to risk management, will become less relevant given uncertainties. Trial and error approaches to management will not be a reasonable strategy to increasing uncertainty as smoke impacts and prescribed fire escapes are increasingly subject to litigation. In support of ecosystem management, modeling must become more mechanistic in it prediction and integrate prediction across multiple scales and ecological processes. No longer are empirical approaches satisfactory to meet the challenges of a no-analogue future. To meet the needs of future managers, process based models of ecological response to disturbance must be integrated with physics-based models of fire behavior to predict ecosystem feedbacks. Models of fire behavior and smoke management should more explicitly identify their domain of inference to managers. Related, models should clearly articulate unknowns and uncertainties for managers at both operational and planning timescales. Thresholds of ecological response to management must be identified in model predictions, and monitored for in the field through long-term.

## 103. Research and Model Validation Gaps for Understanding Fire Effects

#### Authors:

Matthew Dickinson, Northern Research Station Joseph J. O'Brien, Southern Research Station, US Forest Service Anthony Bova, US Forest Service & Colorado State University

**Abstract:** Advances in coupled fire-atmosphere modeling not only have important implications for fire behavior and smoke transport modeling, but also for predicting the effects of wildland fires. Fire effects of interest include the relatively direct effects of fires on soils, vegetation, and fauna. In turn, these direct effects influence longer-term, more contingent processes such as soil erosion, maintenance of diversity, fuel response, habitat change, and hydrological effects. Fires occur in fuels and environmental conditions that are often legacies of past disturbances including past fires, fuel treatments, hurricanes, mortality from insects and disease, and invasions by novel species and coupled fire atmosphere-models must be sufficiently flexible to respond to varying conditions created by these disturbances. Coupled fire-atmosphere models have only recently been used to understand fire effects, but the results are promising and new areas of application continually emerge. In this talk, we will illustrate the application of coupled fire-atmosphere models to fire effects prediction, including effects on trees and fauna. We will also explore new areas of application in which coupled models are likely to give results quite different from fire models currently in operation. Finally, challenges in using computationally intensive models for effects prediction will be discussed along with gaps in capabilities.

**Bio:** Matt Dickinson and Joe O'Brien are Research Ecologists with the Northern and Southern Research Stations, respectively, and Tony Bova is a physicist working on coupled fireatmosphere dynamics with the US Forest Service and Colorado State University. Matt and Joe work together on the RxCADRE project, focusing on ground and airborne monitoring of fire behavior and effects. Joe also works on the role of disturbance in the maintenance of biodiversity in plant communities and tree physiology. Matt and Tony collaborate on modeling the processes that govern fire effects such as tree and faunal injury and mortality.

## P1. Wildfires: Exposure Assessment and Related Health Impacts

### Author(s):

Youssouf Hassanil, Epidemiology fo Allergic and Respiratory Disease Inserm U707 Saint Antoine Hospital Paris Annesi-Maesano Isabella, Inserm U707 Banerjee Soutrick, Inserm U707 Liousse Catherine, Laboratory for aerology Toulouse Roblou Laurent, Laboratory for aerology Toulouse

**Abstract:** The United Nation ISDR estimates that between 3 to 4 million square kilometers are damaged annually by fire, 18,000 square kilometers of which are located in Europe, according to GFED3 (Global Fire emission Database version 3). The Mediterranean region is one of the most affected regions by fires in Europe. Approximately 500,000 hectares on average are burned annually by 50,000 fires in the countries of southern Europe bordering the Mediterranean Sea. Wildfires, or biomass burning, cause serious damage in ecosystems and are potentially harmful to population health. Several studies have established the relationship between one of the major components of wildfire, particulate matters [particles with diameter less than 10 micrometers (PM10) and less than 2.5 micrometers (PM2.5)] and health outcomes such as respiratory diseases, visits to hospital emergency rooms and hospital admissions. The associations between wildfire emissions and mortality or other diseases were less investigated. A major difficulty related to the assessment of the impact of wildfire emissions derives from the complexity of wildfire exposure assessments. In order to evaluate health effects of wildfire emissions in Europe, this review documents several methods used to assess smoke exposure in the literature. These methods include satellite data, chemical transport models, and personal exposure monitoring. Moreover, air pollution sources from urban areas can provide the same components emitted by wildfires. A case study concerning a wildfire that occurred in Marseille, France, July 22nd, 2010 is also discussed.

**Bio:** Youssouf Hassani : PhD student, Epidemiology of Allergic and Respiratory Diseases team (EPAR), National Institute of Medical Research (INSERM U707) Faculty of Medecine Saint Antoine Paris. Pierre Louis School of Public Health (ED393) Paris and School for Public Health (EHESP) Rennes. Msc in epidemiology Pierre and Marie Curie University Paris 6. MEng in biotechnology High School of engineering Marseille.

## P2. 2012 National Prescribed Fire Use Survey

## Author(s):

Mark Melvin, Joseph W. Jones Ecological research Center

**Abstract:** In the United States, annual wildfire activity has been tracked for decades. These data are necessary for securing resources, instituting fire-fighter training standards,

monitoring trends, providing public safety measures, and guiding national policy needed to manage wildfire. Much less is known about prescribed fire activities, but the needs are similar. How much and where prescribed fire occurs year-to-year, and to what degree it meets resource needs is poorly understood. A national evaluation that specifically focuses on the scale at which prescribed fire occurs, what programs support prescribed fire, and identifies factors that limit prescribed fire use is nonexistent. These are all relevant questions necessary to make informed policy and programmatic decisions. To aid in gaining a better understanding of prescribed fire use, the National Association of State Foresters and the Coalition of Prescribed Fire Councils collaborated in early 2012 to conduct a national prescribed fire use survey of all state agencies responsible for prescribed fire activities.

**Bio**: Mark Melvin is employed at the Joseph W. Jones Ecological Research Center at Ichauway, located in Newton, Georgia. Mark has over 20 years of private land management experience in the south and approximately 100,000 acres of prescribed fire experience. At Ichauway, he works with conservation management and education staff to promote the appropriate use of prescribed fire. Some of his outreach efforts include; prescribed fire short courses that provide "hands-on" experience, participation with numerous university courses for undergraduate and graduate programs, private landowner outreach, and partners with many natural resource management agencies.38: Poster Presentation

## P3. Estimating Emissions for the 2008 Evans Road Fire in North Carolina

## Author(s):

Pouliot, George, US EPA Ana Rappold, US EPA

**Abstract:** The Evans Road Fire in 2008 was started from a series of lightning strikes on June 1, 2008. When the fire was contained by the end of August, it had burned nearly 41,000 acres. This fire also burned a depth of two to three feet deep into organic soil, smoldering for many days. Smoke from the fire was observed as far west at the Raleigh Durham area and air quality was severely degraded by the fire. This fire was unique in that the majority of the emissions came from the below ground smoldering of peat. We will summarize our method for estimating emissions from this fire using field estimates of the carbon above and below the ground. In addition, we will compare our revised emission estimates with those obtained from the National Emissions Inventory. Finally, we will show some chemical transport modeling simulations of the fire using CMAQ version 5.

The research descirbed in this abstract does not necessarily reflect the views and the policies of the US EPA.

*Bio:* George Pouliot is a Physical Scentist at the Emissions and Model Evaluation Branch, Atmospheric Modeling and Analysis Division NERL/ORD/ US EPA. Areas of research include

estimating emissions sources such as biomass burning, biogenic, and dust that are dependent on meteorology for use in regional air quality modeling applications. He received his Ph.D. in Atmospheric Science from North Carolina State University in 2000.

Ana G. Rappold, Statistician, Environmental Public Health Division, NHEERL/ORD/US EPA

P4. The Evolution of a Successful NASA Satellite Science to Air Quality Applications: From Science to Inception to Realization. The United States National Fire Emissions Inventory

Author: Amber Soja

### P5. New Technologies and Nighttime Aerial Firefighting Operations, Nitrofirex Project

#### Author(s):

Adrian Peña Cervanties, Nitrofirex Luis M. Bordallo, Nitrofirex Alexander Burwitz, Nitrofirex

#### **Abstract: INTRODUCTION**

The maturity of the technologies for the guidance and control of UASs allows proposing innovative operational options such as the ability to spray (a liquid) or spread (a powder) a significant amount of an agent of any sort at a pre-established point in the atmosphere.

This is the case of NITROFIREX, an innovative project that integrates available technologies from the defense industry to achieve this operational capability. Of all possible applications the forest-fire fighting is where NITROFIREX places its highest priority. This is because of the ecological damage these fires bring forth, the cause social alarm they generate and the human and economic losses that take place whilst fighting them.

NITROFIREX at last offers the long awaited nighttime firefighting capability and also allows direct support to the ground crews in their relentless fight against forest fires.

#### THE NITROFIREX CONCEPT

The ability to transport large amount of payload in the minimum time to the area of operations is performed by heavy transport aircraft (Launcher Aircraft L A) designed to do this at the most efficient economical way.

What NITROFIREX does is to transport this payload from the transport aircraft to the programmed release point.

This is achieved by using unmanned Autonomous Gliders Containers, AGCs that are released through the rear ramp of the LAs. The AGCs fly autonomously to the programmed release point in the source of the fire realizing their contents with utmost precision and then returning to base for reuse.

Once the AGG drops the extinguishing agent it performs its escape maneuver using its remaining speed and big weight loss to attain as much altitude as possible.

Upon reaching the highest point it returns to its base of operations, empty now, so as to be reused as soon as possible.

Because of all that has been mentioned the NITROFIREX project raises the application of modern technology in the aviation sector with the goal to improve the operative and economical efficiency and above all to offer nighttime operation, which is the main shortcoming of current aerial means.

## Bio: Adrian Peña Cervantes.

Mr. Adrian Peña has an extensive background in avionics, telemetry, automation and control design. During the last 8 years has participated internationally in UAS projects from Mexico involving the development of Light UAS platforms as well RPV and small unmanned airships. His experience in the unmanned aerial systems ranges from UAS legal framework, Payload-sensors applications, GNC (Guidance, Navigation and Control) design to GCS (Ground Control Station) design and Data Link connectivity. He is passionate about the opportunities to grow the Unmanned Aerial Systems market in Mexico and internationally and has participated actively in UAS R&D programs in Latin America as well joint-venture UAS civilian programs with companies in Europe. An active member of AUVSI and the International Airship Association since 2005 has attended many training programs and conferences in South Korea, Japan, Latin America and Europe. Military career includes 3 years serving as aviation specialist in avionics and Radio communications with the Mexican Naval Aviation Maintenance Center. Here he worked on avionics, navigation systems and electro-optics. Since early 2012 he is providing professional services for NITROFIREX to support their Latin American expansion and night aerial fight fighting concept as a regional delegate.

## P6. Use of Wildfire Smoke Forecasting Model to Mitigate Burden on a Population's Health and Wellbeing

## Author(s):

Ana Rappold, US EPA\39 David Diaz-Sanchez, US EPA Devlin Robert, US EPA Fann Neal, US EPA Wayne Cascio, Environmental Public Health Division, ORD/US EPA **Abstract**: Wildland fires activities are a major source of fine particular matter and other airborne pollutants associated with adverse health outcomes. Although a number of wildfire smoke forecasting methods are available, there is currently no systematic program aimed to mitigate the public health burden in affected communities. In a recent study of health effects from a major peat fire in North Carolina we estimated statistically significant increases in relative risk of Emergency Department visits for asthma, COPD, pneumonia and acute bronchitis, congestive heart failure, as well as symptoms involving respiratory system and other chest pain symptoms. In the current work we evaluate the feasibility of smoke forecasts to mitigate health care utilization and societal cost attributed to this fire. We obtained daily estimates and forecast predictions of smoke-related fine particular matter from NOAA's smoke forecasting system. We use forecast predictions of smokerelated fine particulate matter to determine spatial regions likely to be impacted under a daily forecast. We then impute cause-specific emergency department visits in these areas from the model and estimate the association with the smoke exposure. By imputing the daily visit counts from the model we simulate an intervention scenario corresponding to the susceptible population taking measures of exposure reduction by relying on smoke forecasts. A reduction from 50% to 0% excess risk (per 100 g/m3 PM2.5) at lag 0 was shown for asthma related visits. In addition to reduction in relative risk we quantify the cost of ED visits attributed to the smoke exposure, estimate cost of hospital admission resulting from ED visits, long term effects, chronic and acute cardio-respiratory illnesses, loss of productivity, and opportunity cost of lost wages. The results of the study suggest that it may be possible to reduce the health burden utilizing the tools and resources already available in general community.

The results of the study suggest that it may be possible to reduce the health burden utilizing the tools and resources already available in general community.

**Bio**: Ana G. Rappold is an environmental statistician whose research is focused on the health effects of air pollutants. Ana hs been reaserching health effects associated with 2008 and 2011 fires in peat bogs of NC.

## P7. FRAMES Emissions and Smoke Portal: Tools for Smoke Management Education

## Author(s):

Josh Hyde, University of Idaho Eva Strand, University of Idaho Alistair Smith, University of Idaho Pete Lahm, USDA Forest Service Lynn Wells, University of Idaho Mark Fitch, U.S. National Park Service **Abstract**: Smoke and air quality are important aspects of wildland fire management. Great efforts are expended to minimize potential impacts from prescribed fires and address impacts from wildfires. To provide information to help managers address smoke and air quality the University of Idaho and National Wildfire Coordinating Group's Smoke Committee (NWCG SmoC), and Fire Research and Management Exchange System (FRAMES) coordinate to offer the Emissions and Smoke Portal (www.FRAMES.gov/smoke). The Emissions and Smoke Portal contains a diverse mix of tools to help address educational needs of fire personnel as well as data needs of researchers.

The Emissions and Smoke portal contains educational resources including the Smoke Management and Air Quality for Land Managers online resource, the interactive Smokepedia glossary, two case studies, and a library of recorded presentations from content experts explaining smoke policy and management approaches. Managers and researchers interested in the social sciences will benefit from the section focused on Public Perceptions and Tolerance of Smoke from Wildland Fires, which is an ongoing area of research aimed at investigating the publics' views and concerns regarding smoke generated by fire. Other offerings include lists of external links and documents organized by topics such as federal regulations, smoke and air quality management and monitoring aids. A search and browse section provides targeted access to data, documents, programs, projects, tools and web pages documented in the FRAMES Resource Cataloging System. Additional efforts by SmoC and the University of Idaho

to provide smoke management guidance include work to deliver an updated version of the Smoke Management Guide for Prescribed and Wildland Fire, smoke training assessments, and the development of short video training modules to address smoke exposure, transportation safety, and modeling.

**Bio**: Josh Hyde works as an instructional & research associate and smoke program coordinator with the University of Idaho. He works with the NWCG Smoke Committee and Fire Research and Management Exchange System (FRAMES) to produce smoke and air quality outreach and training materials. Josh also works with the National Interagency Fuels Technology Transfer (NIFTT) to review online geospatial tools to represent fuels and develop training materials.

## P8. An Evaulation of the Western Canadian BlueSky Forecasting System for 2012

## Author(s):

David A. Lyder, Government of Alberta Valerie Ho, University of Alberta

**Abstract**: A BlueSky framework has been employed in Western Canada and the Northern United States since 2010 to model the dispersion of smoke from wild fires. This is a collaborative effort amongst several Western Canadian provincial and federal government agencies, the University of British Columbia and the United States Forest Service. The system is hosted by the University of British Columbia. The system has been running since its initial release in 2010 but the findings presented hhere summarize the performance of the system for April to October, 2012.

In general there is qualitative agreement between satellite imagery of the wild fire smoke and modelled wild fire smoke (PM2.5). However, a detailed comparison of the time series of modelled wild fire smoke to ambient data in Alberta highlighted some of the strengths and limitations in the modelling system. In particular we noted: 1. the need for ground reports to supplement satellite derived data regarding wild fire sources as Western Canada was heavily covered by clouds until July of that year; 2. The need for carry over smoke to be carried over from forecast to forecast; and 3. The loss of precision in the system when predicting relatively low ambient level concentrations, which may be attributed to incorrect source profiling or plume modelling (plume too thin).

A quantitative evaluation of the BlueSky time series relative to ambient data considered ways to correct for the sparse nature of BlueSky data relative to ambient. An initial evaluation based on correcting the ambient to remove non-wild fire smoke using an average ambient time series was undertaken. Various treatments of this data, e.g., only comparing the ambient when BlueSky produced a value, produced a modest Pearson correlation between 0.32 – 0.34. Additional analysis comparing the sum of the average ambient background with the BlueSky data showed a low correlation (0.05). However, a Kalman filter approach, modifying the predicted BlueSky plus ambient based on the ratio of past BlueSky plus background ambient to ambient showed considerable improvement. A correlation of about 0.9 was seen for one hour forecasts, while a six hour forecast had a correlation of 0.72.

**Bio:** David Lyder is an Air Emissions Engineer with the Air Policy Group of Alberta Environment and Sustainable Resource Development. He has been with the department since 2008. He has been evaluating the Western Canadian BlueSky system since its debut in 2010. His interests are in pattern recognition of naturally occurring systems.

## **P9. Soot Flame Measurement and Characterization**

## Author(s):

Paul Anderson, University of Maryland Peter Sunderland, University of Maryland Haiqing Guo, University of Maryland

**Abstract:** Soot is an important component of smoke, contributing to respiratory illness, accelerated firespread and global warming. Unfortunately, expressions that predict soot formation and oxidation in flames contain large uncertainties. In this study, a ternary flame system was developed, separating the soot formation and soot oxidation zones. A column

of soot, generated by an acetylene/air coflowing laminar diffusion flame on an 11.1 mm burner, was passed through a ring burner supporting a hydrogen diffusion flame. The hot region of the hydrogen flame produced a soot flame. The soot flame was axisymmetric and steady for more than 60 mm in height, providing a region in which soot oxidation could be observed in the absence of hydrocarbons. Soot flame temperatures between 1200-1350 K were found using soot emission ratio pyrometry at 450, 650, and 900 nm, followed by deconvolution. Soot volume fractions varied between 0-95 ppm and were measured using laser extinction at 680 nm followed by deconvolution. Axial flame velocities were measured between 1.2-2.6 m/s by tracking a 2 ms interruption to the soot column with high speed imaging at 420 frames/s. Velocities increased with height due to buoyancy. Soot primary particle diameter was determined by transmission electron microscopy analysis of thermophoretically obtained soot samples. Mean primary particle diameter ranged between 28.6-43.5 nm. A continuous decrease in soot flux was observed in the axial direction, indicating soot oxidation. Soot oxidation rates were found to be between 0-0.8 g/m 2 -s. Oxidation rates initially increased with height above burner, peaking at a height of 20 mm. Above this point, oxidations rates decreased with height.

**Bio**: Paul Anderson is a PhD student in Mechanical Engineering at the University of Maryland, College Park.

## P10. Exceptional Events Impact on Utah Air Quality from 2012 Wildfire Season, a Regulatory Perspective

## Author(s): Karmazyn, Joel

**Abstract:** The 2012 western wildfire season was one of the worst due to excessive hot and dry conditions across western states. In Utah alone, there were 1,534 wildfires that burned 415,266 acres (National Interagency Fire Center) at a cost of over \$50 million dollars (Utah Division of Forestry, Fire and State Lands). Wildfire smoke was visible in portions of the metropolitan area of the state known as the Wasatch Front starting in June and became heavy in August through September. Health advisories across western states became a daily event, as were violations of the National Ambient Air Quality Standards for PM2.5 and Ozone. This paper will address the regulatory impact upon Utah due to these naturally occurring exceptional events, particularly focusing on PM2.5 and Utah's air quality documentation submitted to EPA for exclusion of violations due to these natural events. A case study will be presented of a PM2.5 violation due to wildfire smoke that occurred during the summer 2012. We will present the type of qualitative and quantitative data available to us for filing exceptional events documentation and identify data gaps that are often viewed by EPA as impediments to documentation concurrence by EPA.

Bio: Joel Karmazyn is an air quality planner with the Utah Division of Air Quality.

## P11. Predicting Future Mega-fire Locations and Impacts

#### Author(s):

Narasimhan Larkin, U.S. Forest Service Brian Stocks, B.J. Stocks Wildfire Investigations Ltd. E. Ashley Steel, U.S. Forest Service E. Natasha Stavros, University of Washington Harry Podschwit, University of Washington Donald McKenzie, U.S. Forest Service Renaud Barbero, University of Idaho John Abatzoglou, University of Idaho

**Abstract:** While there is not yet a consensus on exactly what constitutes a mega-fire, there is a growing awareness in the wildland fire community that recent wildland fires in many regions of the world are having escalating and increasingly severe impacts on human lifestyles and health. High-profile fires in quickly-expanding wildland urban interface areas around the world are frequently exhibiting increasingly severe impacts. For example, over the past few years, severe fires in the western United States have resulted in significant societal impacts in many communities, including record setting losses of homes, infrastructure, and trajecally loss of life.

We use statistical relationships between past megafire occurrence in the United States and climate indices to look at the probabilities of future megafire events. Trends and variability in future megafire likelihood is shown across an ensemble of future climate conditions including RCP 4.5 and 8.5 scenarios. Predictions are done at a variety of spatial scales and using a variety of statistical tools. These occurrence probabilities are then used in conjunction with knowledge of atmospheric transport patterns to project smoke impact probabilities across the United States.

Bio: Sim Larkin leads the U.S. Forest Service AirFire Team, and has developed numerous tools for managers to model emissions and smoke from wildland fire including creating the BlueSky modeling framework.

## P12: Linking Visual Range, PM2.5 Concentrations and Air Quality Health Impact Indices for Wildfires

#### Author(s):

Susan O'Neill, USDA Forest Service Mike Broughton, US Fish & WIldlife Service Mark J. Fitch, National Park Service Peter W. Lahm, USDA Forest Service

**Abstract:** Many states are investigating or already implementing a methodology developed in the arid intermountain west where concentrations of particulate matter with

aerodynamic diameter less than or equal to 2.5 micrometers (PM2.5) are estimated from an observed visual range (VR) measurement. The PM2.5 concentration estimate is then linked to the EPA public health warning scale called the air quality index (AQI) to inform the public about potential health impacts from smoke from wildfire. This methodology is used in situations where monitoring data are not available and there is a need to inform the public about potential health consequences from regional-scale smoke episodes. Important caveats are: 1) the method only applies when relative humidity (RH) < 65%, and 2) the atmosphere must be predominantly impacted by smoke (i.e. low concentrations of PM2.5 from other anthropogenic sources). In this work, the Interagency Monitoring of PROtected Visual Environments (IMPROVE) light extinction equation was applied to investigate the correlation of VR and PM2.5 as an atmosphere becomes more smoky. This was done for various parts of the country where background anthropogenic concentrations can be more significant than in the arid inter-mountain west and where RH can typically exceed 65%. Results show that for regions where RH > 70% and non-negligible background anthropogenic concentrations exist, this VR/PM2.5/AQI methodology developed in the arid inter-mountain west may not apply. A national health-based air quality standard does not exist for short-term PM2.5 impacts, but the Environmental Protection Agency (EPA) has included this VR/PM2.5/AQI methodology in its Wildfire Smoke, A Guide for Public Health Officials and Canada has also developed a multi-pollutant (PM2.5, ozone, NO2) 3-hr based air quality health index (AQHI). The various state, EPA and international approaches to informing the public about potential health impacts from wildfire smoke will be presented along with the technical analysis of PM2.5 and VR based on the IMPROVE light extinction equation.

**Bio:** Susan O'Neill is a Research Air Quality Engineer with the USDA Forest Service Pacific Northwest Research Station, AirFire Team, and has a Ph.D. from the Laboratory for Atmospheric Research at Washington State University. She is an original developer of the BlueSky smoke modeling framework and research interests extend to all aspects of modeling fire emissions, smoke dispersion and transport, and smoke plume chemistry.

## P13. Air Quality and the Wildland Fire Management Research Development and Application Program

## Author(s):

Morgan Pence, USDA Forest Service Brooke Hemming, US Environmental Protection Agency

**Abstract:** The Wildland Fire Management Research Development & Application (WFM RD&A) program is a highly effective organization providing exemplary fire science integration and wildland fire management support to management agencies and personnel through proactive and timely response in collaboration with partners. The RD&A Program sponsors and guides the development and application of wildland fire scientific knowledge;

decision support tools; and provides science application services to the interagency wildland fire community. It serves as a primary point of contact for communication between fire scientists and wildland fire field managers working as an advisor to program administrators at local, regional, and national levels. WFM RD&A focus areas include: wildland fire decision support, documentation, planning and implementation; decision analysis support for fire decision making; development of science-based analysis tools and training; weather information to support wildland & prescribed fire and air resource management.

**Bio**: Morgan Pence, Forest Service employee, works for the Wildland Fire Management Research Development and Application program as a Fire Application Specialist. <u>www.wfmrda.nwcg.gov</u>.

## P14. Quantification of Methane Source Locations and Emissions

#### Author(s): Kuldeep Prasad, NIST

Abstract: Quantification of Methane Source Locations and Emissions

Kuldeep Prasad(1), Brian Lamb(2), Maria Obiminda Cambaliza(3), Tegan Lavoie(3), Olivia E Salmon(3), Paul Shepson(3), Thomas Lauvaux(4), Ken Davis(4), and James R. Whetstone(1)

- (1) National Institute of Standards and Technology, Gaithersburg, MD.
- (2) Department of Civil Engineering, Washington State University, Pullman, Washington.
- (3) Department of Chemistry, Purdue University, West Lafayette, IN.
- (4) Department of Meteorology, The Pennsylvania State University, University Park, PA.

**Abstract:** The problem of identifying, attributing, and quantifying methane emissions from urban sources such as landfills, waste-water treatment facilities and natural gas distribution systems is an actively debated topic. This interest is fueled, in part, by recent measurements indicating that urban emissions are a significant source of methane (CH4, a potent greenhouse gas) and in fact may be substantially higher than current inventory estimates. As a result developing methods for locating and quantifying emissions from urban methane sources is of great interest to industries such as landfill owners, and governmental agencies.

In an attempt to identify major methane source locations and emissions in the city of Indianapolis, systematic measurements of CH4 concentrations and meteorology data were made at street level using multiple vehicles equipped with cavity ring-down spectrometers. A number of discrete sources were detected at methane molar ratios in excess of 15 times background levels. The street level data is analyzed with plume inversion models including Weather Research and Forecasting (WRF) software, Fire Dynamics Simulator (FDS) and backward Lagrangian Simulations (bLS) to identify source location and emission rates. The methodology for analyzing the street level data and our estimates of CH4 emissions from various sources in the city of Indianapolis will be presented.

## **Bio**: Kuldeep Prasad is a Research Engineer in the Fire Research Division at the National Institute of Standards and Technology.

## P15. Assessing the Exposure Risk of Regional Population to Smoke from Fires Author(s):

Mick Meyer, CSIRO Marine & Atmospheric Research Melita Keywood, CSIRO Marine & Atmospheric Research Martin Cope, CSIRO Marine & Atmospheric Research Sunhee Lee, CSIRO Marine & Atmospheric Research Fabienne Reisen, CSIRO Marine & Atmospheric Research

**Abstract:** The potential health impacts from smoke are well known. Protracted exposure of rural and urban populations, particularly the more susceptible groups including the elderly, people with impaired cardiovascular function and allergies, extends the risk from bushfires to the entire population and, in some cases, due to the number of people exposed, may constitute the greatest risk to health. The cost of these impacts can be substantial. Consequently smoke management is now a major issue for fire agencies. The exposure risks vary widely with the class and location of the fire events, and range from extensive fumigation of SE Australian populations from fires that persist for weeks to localised impacts from small fires.

The Fire & Impact Risk Evaluation-Decision Support Tool (FIRE DST) project has been developing techniques for assessing the risks and impacts through a series of case studies. The key issue to emerge is not the total emission of smoke, but the extent to which the emissions mix back to the surface layer, and the persistence of the smoke in the air shed. Of the three wildfire events investigated, the alpine fires of 2003 and 2006 impacted most of Victoria, including Melbourne for protracted periods, contrasting with the extreme Kilmore fire of 2009 (VIC), which, in comparison, was short-lived with limited smoke impacts. The mechanisms of smoke emission and dispersion observed in these events has some similarities to processes observed in the regeneration burning, where injection height and boundary layer ventilation rate determine the surface concentration and duration. The key features of these case studies that lead to their contrasting outcomes form the subject of this presentation.

**Bio**: Dr C.P. (Mick) Meyer is a senior atmospheric research scientist with a specific interest on measurement, accounting and verification of trace gas and aerosol emissions from biogenic sources, particularly biomass burning. He developed the methodologies currently used for the National Greenhouse Inventory for non-CO2 emissions from the biosphere, and the emissions of dioxins from open burning in Australia used for reporting Australia's emissions of POPs

under the Stockholm Convention. He was a lead author of the 2006 IPCC Guidelines for Greenhouse Gas Inventories.

## P16. The National Wildfire Coordinating Group Smoke Committee (SmoC)

## Author(s):

Peter W. Lahm, USDA Forest Service Susan M. O'Neill, USDA Forest Service Mike Broughton, US Fish and Wildlife Service

Abstract: The National Wildfire Coordinating Group's (NWCG) Smoke Committee (SmoC) provides interagency leadership, coordination and integration of air resource and wildland fire management objectives. Air quality is critical to human health and welfare and fire is an important disturbance process in many wildland ecosystems. The SmoC strives to support successful management and utilization of wildland fire while appropriately addressing smoke impacts, for public and fire personnel health, welfare and safety. Members are from the Bureau of Land Management, Fish & Wildlife Service, National Park Service, Bureau of Indian Affairs, US Forest Service, and the National Association of State Foresters (eastern and western representatives), as well as the Natural Resources Conservation Service, the National Association of Clean Air Agencies (NACAA), The Nature Conservancy (TNC), and Department of Defense (DoD). Other subject matter experts and stakeholders contribute as needed. SmoC has three subcommittees; the Technical Smoke Topics Subcommittee, the Training Subcommittee and the Smoke Managers Subcommittee. SmoC also operates several task teams such as the Smoke Management Guide Revision, the HYSPLIT Trajectories in Spot Weather Forecasts (in cooperation with NOAA), and the Retrospective Emission Inventory Task Teams. SmoC has partnered with the University of Idaho and Fire Research and Management Exchange System (FRAMES) developing a website (www.frames.gov/smoke), which has interactive training on "Smoke Management and Air Quality for Land Managers" that reflects the latest in air quality regulations, and an online Workshop & ndash; "Effective Communication for Smoke Management in a Changing Air Quality Environment". Other projects include an assessment of smoke training in NWCG courses and task books. An assessment of the proliferation of smoke training in key wildfire incident management positions was conducted and is the basis for broad recommendations for air quality training of the wildland fire community currently being developed. SmoC supports these activities as well as the deployment of Air Resource Advisors and smoke exposure and smoke monitoring via the development of cache of instruments. More information about SmoC can be obtained at www.mvfirecommunity.net "Air Quality and Fire Issues."

**Bio:** Pete Lahm is the Air Resource Specialist for the USDA Forest Service, Fire and Aviation Management, in Washington, DC. Starting in 2004, Pete has led the Forest Service's smoke management efforts developing technical approaches and policies related to smoke impacts. Since 2009 he has chaired the National Wildfire Coordinating Group's Smoke Committee. Prior to 2004, Pete managed the Arizona Interagency Air Resource and Smoke Management Program. He chaired the Western Regional Air Partnership's Fire Emissions Joint Forum from 1996-2004. Pete holds a Master's of Environmental Management from Duke University.

## P17. When Ecosystem Management Causes Urban Air Quality Problems: Tallgrass, Prescribed Fire, and Smoke

## Author(s):

Carolyn Blocksome, Kansas State University Doug Watson, Kansas Department of Health and Environment Tom Gross, Kansas Department of Health and Environment

**Abstract:** Fire has been used by humans to manage the Great Plains rangelands of Central North America for an estimated 10,000 years. The 2,500,000 acres burned each year by private landowners in April in the Flint Hills region of Kansas and Oklahoma have contributed to high ozone readings downwind. Prescribed burning is essential for maintaining these prairies as grasslands. The need to continue to use fire for ecosystem management must be balanced with the need for clean air. The Kansas Flint Hills Smoke Management Plan was collaboratively developed to acknowledge the two needs and to provide a solution for reducing the impact on ozone readings. Implementation of the plan began in Spring 2011. Full evaluation of the plan's effectiveness has been delayed due to drought conditions and a corresponding reduction in reduction in acres burned.

**Bio:** Dr. Carol Blocksome is a faculty member in the Department of Agronomy at Kansas State University. Dr. Blocksome received her bachelors and doctoral degrees from Kansas State University and her master's degree from Fort Hays State University in range management. Her interests focus on environmental and ecological issues related to range management. For the past several years, she has worked on water quality and prescribed burning as they relate to range management and grassland ecology. She was active in the multi-agency groups that wrote and promoted the Kansas Flint Hills Smoke Management Plans.

## P18. Lung Toxicity of Pocosin Wildfire-Derived Particulate Matter: Implications for Toxicity Screening in Lung Tissue Slices

## Author(s):

Yong Ho Kim, U.S. EPA Janice Dye, U.S. EPA John McGee, U.S. EPA Michael Hays, U.S. EPA Q.Todd Krantz, U.S. EPA Eugene Gibbs-Flournoy, U.S. EPA Mary Daniels, U.S. EPA Elizabeth Boykin, U.S. EPA **Abstract:** Inhalation of particulate matter (PM) generated from wildfires can cause acute lung injury, and pulmonary and systemic inflammation, however the chemical constituent(s) responsible for these effects vary according to the fuel, combustion conditions, and exposure concentration. Size– fractionated PM samples were collected downwind from a peat-bog wildfire in Eastern North Carolina in 2008. ENCF-1 was collected during 6/26/2008 & ndash; 7/11/2008 when the fire was still smoldering. while ENCF-4 was collected during 8/8/2008 – 8/19/2008 after the fire had been controlled but not extinguished. Samples were extracted in methanol, analyzed for chemical constituents and adjusted to 10 mg/ml in water. The size-fractionated PM (ultrafine, <0.2 m; fine, 0.2-2.5 m; coarse, 2.5-10 m) were instilled into mice at 100 g/50 l saline or cultured with lung tissue slices at 11 g per lung slice (8 mm diameter). At 24 h post-exposure, biomarkers of lung injury and inflammation were assessed in lung lavage fluid from mice, and conditioned medium from the lung slices. Results showed that both ENCF-1 and -4 coarse PM had relatively greater endotoxin content than the fine and ultrafine PM, and other ambient PM samples previously analyzed. Moreover, only the coarse PM significantly increased neutrophils, protein and biomarkers of inflammation (e.g., interleukin-6 (IL-6)) in the lung lavage fluid, and similar pro-inflammatory (e.g., IL-6) effects were also observed in the lung tissue slice model, indicating that cell functionality and intercellular interaction in lung slices closely mimicked the in vivo tissue environment. This study suggests that exposure to wildfire coarse PM causes substantial toxicity in the lung in association with endotoxin content, and that the lung tissue slice assay can replace the in vivo instillation model for PM toxicity screening. (This abstract does not represent U.S. EPA policy).

**Bio:** Yong Ho Kim is a postdoctoral fellow in the U.S. Environmental Protection Agency (EPA). He received a PhD degree in 2008 from the Department of Chemical Engineering at the University of Southern California (USC) and then moved to the Department of Medicine at USC to study how inhaled particles interact with the lung cells in the laboratory of Edward D. Crandall (Department Chair) as a postdoctoral research associate. In 2013, he joined the laboratory of M. Ian Gilmour (Branch Chief) at U.S. EPA and currently is working on ambient particle toxicity screening and development of ex vivo lung model.

# P19. A New IGAC/iLEAPS/WMO Initiative on Biomass Burning Author(s):

Mick Meyer, CSIRO Australia Melita Keywood, CSIRO Australia Johannes Kaiser, ECWMF

**Abstract**: Biomass burning changes the land surface and emits large quantities of trace gases and aerosol to the atmosphere that influence atmospheric chemistry, radiative processes and cloud formation. In addition, there is large uncertainty on how climate change and global change will impact the frequency, intensity, duration, and location of

biomass burning in the short- and long-term, making their emissions a large source of uncertainty in future atmospheric composition. Therefore biomass burning and its emissions need to be observed and modeled accurately to understand the composition of the atmosphere and how it changes at different temporal and spatial scales. Significant gaps remain in our understanding of the contribution of deforestation and savanna, forest, agricultural waste, and peat fires to emissions. Under the International Global Biosphere Project-International Global Atmospheric Chemistry (IGBP-IGAC) umbrella a series of international and interdisciplinary research campaigns on biomass burning in tropical, subtropical and boreal biomes conducted during the 1990s formed the basis of our understanding of role of emissions from fires on global atmospheric chemistry. However, the large-scale international and global collaborative effort has been replaced by numerous smaller-scale projects and campaigns in recent times. Therefore IGAC, iLEAPS (integrated Land Ecosystem - Atmosphere Process Study), and WMO (World Meteorological Organisation) have created a new joint initiative on biomass burning. The aim of the Interdisciplinary Biomass Burning Initiative (IBBI) is to coordinate and facilitate research on all aspects of biomass burning in order to better quantify the impact of biomass burning (including feedbacks) on the Earth System. IBBI is in its infant stage and input from the community is invited. More information is available at http://www.mpic.de/projekte/ibbi.html

## P20. Modeling Carbon Emissions from the 2002 Biscuit Fire Using FARSITE for Applications for Future Fire Emissions

## Author(s):

David Banach, Michigan Tech Research Institute Jessica McCarty, Michigan Tech Research Institute David Banach, Michigan Tech Research Institute

**Abstract:** In July 2002, lighting strikes ignited five separate fires within the Siskiyou National Forest in southern Oregon. These fires merged in early August to form the Biscuit Fire Complex, one of the largest (approximately 499,000 acres or 200,000 hectares) and costliest wildfires in Oregon's recorded history. FARSITE, a fire area simulator used by the US Forest Service and National Parks Service, spatially and temporally simulates fire behavior based on terrain, fuel, and weather inputs. The Biscuit Fire was modeled within FARSITE to verify that the program could replicate the growth, behavior, and emissions of this well known, quantified, and studied fire. Using a GIS developed model of the Siskiyou National Forest region, the simulation successfully modeled the growth of the Biscuit fire between 13 July and 31 August, corresponding to the dates when the wildfires started to just days before it was declared contained. The carbon emissions of the modeled fire were then calculated by processing the results through ArcWFEIS (an ArcGIS version of the Wildland Fire Emissions Information System: www.wfeis.mtri.org) and Python-CONSUME,

two models developed by the Michigan Tech Research Institute. The total amount of FARSITE modeled carbon emission from the Biscuit Fire was compared to a previously published value from French et al. (2011): 11.74 Tg C versus 13.65 Tg C, respectively. With this successful validation of carbon emissions from a historic fire, FARSITE will be used to model the impacts of climate change on emissions from future lighting ignited wildfires.

**Bio:** David Banach is a Research Intern with the Environmental Science Lab at Michigan Tech Research Institute, located in Ann Arbor, Michigan. By incorporating his knowledge of GIS and remote sensing, David has contributed to research that includes modeling of historic and future wildfires, the analysis of cropland and rangeland burning and emissions - including fieldwork in North Dakota and Minnesota, and validation of satellite fire products. Additional research expertise and interests include the Great Lakes, transportation, and wetlands.

## P21. The Use of Instantaneous Satellite AOD to Constrain Biomass Burning Aerosol Emissions in the GOCART Model - Method Refinement

## Author(s):

Mariya Petrenko, ORAU / NASA GSFC Mian Chin, NASA Goddard Space Flight Center Ralph Kahn, NASA Goddard Space Flight Center

**Abstract:** Aerosol models rely heavily on external emission inventories to simulate location and strength of biomass burning (BB) sources. These inventories, however, use different methods and assumptions to estimate aerosol emissions, and consequently their estimates differ, often by a factor of up to 8 globally and even more regionally. We have previously introduced a method of using snapshots of MODIS-measured aerosol optical depth (AOD) to constrain BB emissions in the GOCART model (Petrenko et al., 2012). The work presented here builds up on the developed method and aims to address some of the previously discussed method limitations, such as limited number of test cases, biases in satellite AOD retrievals, and effects of model configurations on retrieved AOD. We then plan to apply the refined quantitative relationship between BB aerosol emissions and simulated model AOD to correct the emission estimates to be used as input to GOCART. We expect this method for correcting BB aerosol emissions to be useful to aerosol modelers, as well as discussion of regional emission biases to be of use to the developers of emission inventories.

**Bio:** Mariya M. Petrenko is a NASA Post-Doctoral Fellow at NASA Goddard Space Flight Center in Greenbelt, MD. She received her B.S. in Environmental Science from the National University of "Kiev-Mohyla Academy" in Kiev, Ukraine, M.S. in Atmospheric Sciences from the University of Wyoming in Laramie, WY, and Ph.D. in Atmospheric Sciences from Purdue University in West Lafayette, IN. The areas of her research interest include in-situ measurements and remote sensing of aerosol properties, and application of these observations to better understand and improve simulations of biomass burning aerosol emissions in the aerosol models.

## P22. Updating the Air Quality Index Method to Caution the Public when Air Quality Changes Rapidly

## Author(s):

Susan Stone, US EPA Phil Dickerson, US EPA Michelle Wayland, US EPA Adam Reff, US EPA Neil Frank, US EPA Alison Davis, US EPA John White, US EPA David Mintz, US EPA Lewis Weinstock, US EPA

Abstract: A key feature of the AirNow.gov website is a "Current AQI" map for ozone and PM2.5. To generate this map, along with a map that shows only PM2.5, the AirNow program has to convert the latest hourly monitored readings to the 24-hour Air Quality Index. This is accomplished with the "Nowcast" -- a combination of monitor data and air quality projections to show current air quality in the 24-hour AQI form. The Nowcast method AirNow has used since 2003 was designed to estimate the midpoint of a 24-hour average. That method served us well for a number of years and has helped increase public awareness of PM2.5 and health. However, in the past two years, a number of stakeholders have expressed concern that the current method does not respond quickly when air quality changes rapidly. For example, PM2.5 air quality that worsens rapidly can be in the "very unhealthy" range for several hours before the Nowcast catches up – meaning we are not cautioning people when their health is potentially at risk. The reverse also can be true. In February of 2013, EPA began a review of the Nowcast and, after analyzing millions of data points, developed a new, more responsive method. The new method represents a short-term average when air quality is changing rapidly and a longer-term average when air quality is stable. Because this new method responds to rapidly changing air quality, it cautions people in time for them to reduce their 24-hour exposures. When the new method is implemented in the summer of 2013, the AirNow maps will more closely reflect rapidly changing fine particle conditions, such as those we see during wildfires.

**Bio:** Susan Stone is a Senior Environmental Health Scientist at the EPA. She is leader of the team reviewing the ozone national ambient air quality standards and Air Quality Index team leader, has coauthored many of EPA's public information documents about the health effects air pollution, and has given presentations across the U.S. and internationally. Ms Stone was co-lead for the National Scale Activity Survey (N-SAS), and is one of the authors of two studies

of the health impacts of smoke from a fire in Eastern North Carolina. Ms Stone has an M.S. from the School of Public Health at UNC.

## P23. Case Study: Analysis of Weather Conditions and Smoke for 2002 Biscuit Fire in Southwest Oregon

## Author(s):

Susan O'Neill, USDA Forest Service Marlin E. Martinez, Universidad del Turabo, Gurabo, PR Brian Potter, USDA Forest Service

Abstract: A series of lightning storms ignited five fires in the Siskiyou Mountains in Southwest Oregon starting on July 13, 2002. Within days the fires joined together. The fire burned for two months across almost half a million acres of wildland and communities. Estimated cost to control and suppress the fire amounted to \$150 million and a work force of more than 7,000 people constructed over 400 miles of fireline in order to control and suppress the fire. An analysis of the weather conditions and the smoke emissions from the Biscuit Fire was performed in a two-phase case study research. First, a meteorological reconstruction of the weather observed during the fire event was accomplished. This analysis took into consideration available synoptic analyses, mesoscale meteorological data, and on-site meteorological observations during the fire. Second, a re-creation analysis of the smoke behavior, emissions and effects was performed through the use of the BlueSky Smoke Modeling Framework and the Hybrid Single-Particle Lagrangian Integrated Trajectory (HYSPLIT) dispersion model. The first phase analysis included collecting detailed information regarding the fire location, fire progression, and growth, enabling the creation of three different ignition pattern scenarios. The detailed fire progression analysis was used as input to BlueSky, to investigate how greater detailed fire ignition and progression information impacts smoke concentrations near-surface and aloft. This analysis is intended to clarify the variability and uncertainty in emissions impacts resulting from uncertainty in input variables and model assumptions. Results will aid managers on the planning of strategies to protect health, life and properties.

**Bio**: Susan O'Neill is a Research Air Quality Engineer with the USDA Forest Service Pacific Northwest Research Station, AirFire Team, and has a Ph.D. from the Laboratory for Atmospheric Research at Washington State University. She is an original developer of the BlueSky smoke modeling framework and research interests extend to all aspects of modeling fire emissions, smoke dispersion and transport, and smoke plume chemistry.
## P24. An Empirical Model to Estimate Daily Forest Fire Smoke Exposure over a Large Geographic Area Using Multiple Data Sources

## Author(s):

Angela Yao, BC Centre for Disease Control

## Abstract

Background: Public health authorities are aware of the population health risks posed by forest fire smoke (FFS), and they are seeking effective tools to support decision making for risk mitigation. The British Columbia Asthma Medication Surveillance product was developed to accommodate this need. It highlights the public health impacts of FFS by combining information on fine particulate matter (PM2.5) measurements with daily counts of respiratory outcome indicators. However, the use of PM2.5 measurements to assess smoke exposure has been a limitation for the product because more than 50% of the local health areas are not covered by the monitoring network. The primary objective for this study was to generate smoke-related PM2.5 estimates for these uncovered areas.

Methods: Data used to build the model included: 1) remotely sensed aerosol optical depth; 2) remotely sensed fire radiative power, 3) smoke plume tracings from the hazard mapping system; 4) the venting index; and 5) PM2.5 measurements on the previous day. These potentially predictive variables were entered into a multiple linear regression model for current day PM2.5 measurements at up to 85 stations. Data from days with high levels of smoke between 2003 and 2012 were used to train the model, and data on days with high, moderate, and low smoke were used to test the model.

Results: The final model explained 71% of the variance in PM2.5 concentrations. Estimates were generated for all populated areas of the province with a spatial resolution of 5 km. Comparison between model estimates and monitor observations suggested good agreement on days of different smoke levels, with overall correlations from 0.57 to 0.84 and normalized root mean square errors of less than 102%. The results from leave-one-out analyses on high smoke days indicated the best model performance during intense fire seasons.

Conclusions: Our model performs well compared with other available empirical and physical models, which have a maximum correlation of 0.60 in the literature. Its simplicity allows easy application in time constrained public health surveillance activities. With its sufficient coverage and fine spatial resolution, it can also be useful for epidemiologic studies on FFS.

**Bio:** Angela Yao is an environmental health scientist at the British Columbia Centre for Disease Control. She received her BSc in Environmental Science in China and her MSc in environmental health at the University of British Columbia, Vancouver, Canada. Her research interest is in air quality and population health, especially on forest fire smoke exposure.

# P25. UAV Operations and Wildland Data Collection Author(s):

Alexander Maranghides, NIST Mike Hennig, Colorado State University Gene Robinson, RP Flight System

**Abstract:** Unmanned Aerial Vehicles (UAVs) are being evaluated for field data collection in wildfire, prescribed fire and post widland urban interface fire environments. This poster will highlight the necessary steps to safely operate UAVs in these different environments. Logisitcal, operational and instrumentation issues will also be highlighted.

A Certificate of Authorization (COA) was obtained and renewed from the Federal Aviation Administration. The COA has enabled NIST to conduct acceptance testing of the ARRA purchased UAVs. The UAVs were successfully flown at the Winn Ranch, in Wimberley, Texas. Proficiency testing to meet FAA requirements has been maintained and is scheduled throughout the upcoming year.

Characterization of the UAV instrumentation capabilities has begun and will continue into 2014. UAVs have been upgraded to enhance field data collection both in terms of IR signature and data communication. UAVs are essential for collecting critical prescribed fire behavior information. Participation in prescribed burns will typically occur during the winter/spring months. Participation during future post fire field deployments will occur during the summer/fall months.

Standard Operating Procedures (SOPs) are driven by the FAA COA requirements and the training and SOPs provided by the vendor. The FAA is mandating all air operations, while all ground activities are specified by the UAV manufacturer and accepted by FAA.

**Bio:** Alexander Maranghides is a Fire Protection Engineer with 20 year of fire research experience. He oversees the NIST WUI FIre Exposure Data Collection and Modeling research effort. His fields of expertise are intermadiat eand large scale fire testing and the wildland urban interface.

## P26. Great Plains Fire Science Exchange

## Author(s):

Carolyn Blocksome, Kansas State University Sherry Leis, Missouri State University

**Abstract:** Fire is an essential component of the grassland ecosystems of the Great Plains region of North America. The Great Plains Fire Science Exchange is a Joint Fire Science

Consortium that covers the shortgrass, mid-grass, and western tallgrass region of the central United States. The purpose of the consortium is to connect scientific research with on-the-ground management by promoting knowledge and skills transfer through workshops, meetings, webinars, literature reviews and fact sheets, website and Facebook, newsletters, and other outreach methods. The Exchange also conducts needs assessments to identify research needs that would answer questions managers have about applying fire to obtain specific management goals. Other regional issues are addressed by the Exchange, such as smoke, grassland fuel management and fire techniques.

**Bio**: Dr. Carol Blocksome is a faculty member in the Department of Agronomy at Kansas State University. Dr. Blocksome received her bachelors and doctoral degrees from Kansas State University in production agronomy and range management, and her master's degree from Fort Hays State University. Her interests focus on environmental and ecological issues related to range management. For the past several years, she has worked on water quality and prescribed burning as they relate to range management and grassland ecology. She was active in the multi-agency groups that wrote and promoted the Kansas Flint Hills Smoke Management Plans.

## P27. Ground Zero Daily Smoke Production Values for NC Coastal Plain Organic Soil Fire –Pains Bay May/June 2011 Author(s): Gary Curcio

## P28. Landsat based fire-inducted forest cover loss mapping in European Russia

## Author(s):

Krylov, Alexander, University of Maryland Matthew C. Hansen, University of Maryland Svetlana Turubanova, University of Maryland Peter Potapov, University of Maryland Jessica L. McCarty, Michigan Tech Research Institute Alexandra Tyukavina, University of Maryland

**Abstract:** Wildfires play an important role in the ecosystem dynamics of European Russia. A number of MODIS-based burned area products for Russia were created in recent years (Bartalev et al. 2008, Loupian et al. 2011, Giglio et al. 2009). However, drivers and consequences of forest fires in European Russia are challenging to characterize using coarse spatial resolution products. Specifically, these burned area products not discriminate of forest and agriculture fires within areas of fine-scale forest/cropland mosaics or in the regions with extensive agricultural land abandonment and recent afforestation. The use of 30m spatial resolution Landsat-based products allows for the detection of forest areas damaged or destroyed by fires more accurately, especially on the boundaries between forests and agricultural lands.

Annual Landsat image composites, similar to those of Potapov et al. (2012), were used to generate percent tree cover estimates and to calculate annual growing season NDVI. These time-series data were used to assign year of disturbance. Fire-induced loss was separated from other stand-replacement dynamics using 1 km Moderate Resolution Imaging Spectroradiometer (MODIS) active fire hotspots.

Preliminary analysis indicated that the majority of forests were burned during large, catastrophic fire events in dry years (e.g. 2002 and 2010). Fires mostly affected pine-dominated forests on sandy soils. Timing of these fire events (July-September) is different from the period of active agricultural burning (April-May). Forest fires were typically located within large forested landscapes away from active agriculture regions. Therefore cropland fires are presumably not the major driver of forest fire initiation. Agriculture fires can contribute to the degradation of forests along the borders with croplands; however, this process is difficult to quantify at the regional scale using Landsat data. Future research will focus on non-stand replacement fire assessment (including the fires spread from agriculture burning) using Landsat and MODIS data fusion.

**Bio:** Alexander Krylov graduated from Moscow State University of Forest in 2005, in 2006-2012 worked in the Russian Center of Forest Health, now he is Faculty Research Assistant at the Department of Geographical Sciences, University of Maryland. Areas of Interest: Remote sensing of forest health, fires, windfalls, bark beetle.

## P29. Facilitating Knowledge Exchange About Wildland Fire Science

## Author(s):

Christine S Olsen, Oregon State University

**Abstract**: The Joint Fire Science Program's (JFSP) Knowledge Exchange Consortia Network is actively working to accelerate the awareness, understanding, and adoption of wildland fire science information by federal, tribal, state, local and private stakeholders within ecologically similar regions. Our network of 14 regional consortia provides timely, accurate, and regionally relevant science-based information to assist with fire management challenges . Regional activities, through which we engage fire managers, scientists and private landowners, include online newsletters & announcements, social media, regionallyfocused web-based clearinghouses of relevant science, field trips & demonstration sites, workshops & conferences, webinars & online training, and syntheses & fact sheets. This poster provides an introduction to and map of the regional consortia.

**Bio:** Christine Shaw Olsen, Ph.D., is a Research Social Scientist in the Department of Forest Ecosystems & Society at Oregon State University in Corvallis, Oregon. Dr. Olsen is co-

investigator of the Northwest Fire Science Consortium and conducts research on citizenagency interactions, public opinions about fire and fuel reduction activities, and communication and education about forestry and fire. Her current projects examine public perceptions of smoke from prescribed fire, citizen-agency trust, and coupled human-natural systems in fire-prone landscapes. Dr. Olsen teaches classes about forest management for multiple resource values, managing in the wildland-urban interface, sustainable resource management, and social science methods.

## P30. Detecting and Quantifying Rangeland Burning Using Remotely Sensed Burned Area and Active Fire Data: A Case Study of Western Minnesota

## Author(s):

Jessica McCarty, Michigan Tech Research Institute Erik J. Boren, Michigan Tech Research Institute Steve Schumacher, U.S. Fish and Wildlife Service, Detroit Lakes WMD Meghan M. Sheehan, Michigan Tech Research Institute David M. Banach, Michigan Tech Research Institute

**Abstract:** Rangeland burning in the Great Plains of the contiguous United States is often a component of land management for preserving and/or promoting native vegetation, expanding and improving wildlife habitat, improving foragability for livestock and wildlife, and controlling invasive species. This analysis focused on a rangeland area of western Minnesota actively managed with prescribed burning by the U.S. Fish and Wildlife Service (USFWS) for wildlife habitat, native grasses, and reduction of fire danger in peatlands. The objective of this analysis was to determine if coarse resolution global satellite-based burned area and active fire products as well as moderate resolution satellite burn scar data could be used to detect and quantify these numerous but small scale management burns being conducted in a short time period. Satellite-based fire data and products could then potentially be used to monitor small-scale prescribed events, as well as prove to be important inputs into ecological, landscape, and atmospheric emission models, including managing the impact of smoke from rangeland and peatland fires on local populations and fire response units.

**Bio:** Dr. Jessica L. McCarty is a Research Scientist at the Michigan Tech Research Institute in Ann Arbor, MI. She received her Ph.D. in Geography from the University of Maryland in 2009. Dr. McCarty is interested in applying remote sensing and geospatial technologies and modeling to wildland and prescribed fire, fire-related atmospheric emissions, and land cover/land use change and mapping. She is interested in crowd-sourced, social media, and citizen science to improve environmental analyses. Dr. McCarty has participated in and led NASA-, USDA-, and EPA-funded projects in the U.S., Canada, and Russia, and has completed fieldwork in these countries.

## P31. Examination of PM2.5 Composition of Samples Impacted by Wildfires

## Author(s):

Tracy Dombek, RTI Jessie Deal, RTI James Rourke, RTI David Hardison, RTI Steven Walters, NC Dept of Environmental Quality Eva Hardison, RTI Prakash Doraiswamy, RTI RTI International, Research Triangle Park, NC

++ Currently with Division of Air Quality, NC Department of Environmental and Natural Resources, Raleigh, NC

Abstract: Wildfires are an issue of increasing concern under changing climatic conditions. The increased frequency and intensity of wildfires in recent years, particularly in the Western US, have received considerable attention. Over the past decade or so, wildfires have destroyed a large area of forests (e.g., ranging from 137,000 acres burned by the Haymen fire in Colorado in 2002 to the 6.2 million acres destroyed by the Alaskan wildfires in 2004 and to the 1.1 million acres burned by the Lightning Siege fires in California in 2008). In this study, we leverage data from the EPA PM2.5 Chemical Speciation Network (CSN) and the National Park Service IMPROVE network to analyze aerosol composition of samples impacted by wildfires. We focus on sites in the Western US as we examine data from current and recent events for comparison to our earlier work examining composition at sites impacted by the 2003 California wildfires. We plan to present data from the 2011 and 2012 fires in the Western US, wildfires in Alaska in early 2013, and recent wildfires during 2013. We also plan to analyze recently collected samples for levoglucosan, a key tracer of biomass burning. We will analyze the dominance of levoglucosan in relation to soluble potassium as well as other elements at the different sites and their variability. We will also compare the smoke-impacted aerosol composition from the 2003 data to that in recent years to examine trends in elements and other species.

**Bio:** Ms. Tracy Dombek is currently a Research Chemist at RTI, where she performs chemical analyses in support of air quality programs and is working to assume the Laboratory Supervisor role in the ion analysis laboratory. She has extensive knowledge of ion analysis of ambient samples for anions and cations. Before joining RTI, she was a quality assurance chemist with the Illinois State Water Survey where she successfully led a group with diverse educational backgrounds and ensured that all applicable QA protocols are followed to produce data of highest quality measures as part of the National Atmospheric Deposition Program [NADP]).

## P32. The BlueSky Modeling Framework and SmartFire Fire Information System: Recent updates and current status

## Author(s):

Narasimhan K. Larkin, USDA Forest Service Tara Strand, Scion Research, New Zealand Robert Solomon, Desert Research Institute, Reno, NV Miriam Rorig, USDA Forest Service Sean M Raffuse, Sonoma Technology, Inc, Petaluma, CA

## Susan M. O'Neill, USDA Forest Service

**Abstract:** The BlueSky and SmartFire modeling frameworks have been developed to facilitate fire emissions calculations, emissions inventory development, and smoke and air quality impact modeling. SmartFire provides a platform for collecting disparate fire information reporting sources including both satellite and ground reports, associating fire information across sources, and reconciling the information into a unified data stream by utilizing the underlying uncertainties of each input source. BlueSky allows for fuel loading, fire consumption, emissions, plume rise, and smoke dispersion modeling. Together, SmartFire and BlueSky have been used in creating the wildland component of the EPA National Emissions Inventory, daily smoke model predictions for the U.S. and Canada, and development of customizable tools for wildland fire planning and incident response. We present the current status, including recent updates, of both the SmartFire and BlueSky frameworks here.

**Bio:** Dr. Larkin conducts research in applied climatology and fire emissions and air quality, with emphasis on the application of data analysis, statistical methods and scientific visualization. His primary research topics include analysis of wildland fire-climate and fire-air quality relationships and applications product development for wildland fire management planning, decision-making and policy. Dr. Larkin is the original designer of the BlueSky Modeling Framework used around the world for real-time and retrospective smoke modeling, and the creator of the SmartFire2 system used by the U.S. EPA and other agencies for fire activity and emissions inventory development.

#### P33. A Literature Review to Identify the Population Health Outcomes Most Affected by Forest Fire Smoke

#### Author(s):

Kathryn Morrison, McGill University Sarah Henderson, British Columbia Centre for Disease Control David Buckeridge, McGill University

**Abstract:** Forest fire smoke exposure has been consistently associated with acute respiratory health outcomes and inconsistently associated with other acute and long-term health effects. Primarily, smoke from wildfires affects human health through exposure to small particulate matter that can penetrate deep into the lungs. Given that wildfires are increasing in frequency and intensity due to climate change, their health effects are of increasing public health interest. Currently there are no guidelines for the surveillance of health outcomes associated with forest fire smoke, or for evaluation of interventions to prevent or reduce exposure. Additionally, it is not clear which measures of exposure and/or health impact are best suited for the surveillance and forecasting of the population effects. To address this knowledge gap, we are conducting a literature review to identify

the population health outcomes most affected by forest fire smoke. This review will guide the development of a surveillance and forecasting infrastructure in British Columbia, Canada, to support appropriate emergency response during smoke episodes. Potential measures of smoke exposure include direct and indirect (e.g., via remote sensing and modeling) levels of particulate matter, and potential measures of population health include a range of healthcare utilization data, from dispensed asthma medications to ambulance callouts for respiratory health outcomes. A better understanding of the utility of these measures is the first step towards the development of an analytical framework for realtime surveillance and forecasting of health outcomes associated with exposure to forestfire smoke across large areas and heterogeneous populations.

**Bio**: Kathryn Morrison is a PhD student in epidemiology at McGill University. She has a background in geographic information science and is interested in the surveillance of infectious and non-infectious disease and methods for modeling spatial and temporal variation of disease in populations.

## P34. Forest Fire Management - Operation Roraima 2013, Brazil Author(s):

Jose Carlos Mendes de Morais

**Abstract:** In 1998, the indiscriminate use of fire to manage agricultural and forest areas in favourable weather conditions in the state of Roraima resulted in one of the largest forest fires in the modern era, which was immensely aggravated by the lack of preparation of public institutions that are responsible for fire prevention and protection.

This event, however, left important lessons and prompted the establishment of new forest fire fighting and prevention policies across Brazil.

Fifteen years later, Operation Roraima Green 2013 adopted a new fire prevention and fighting model based on concepts, methods and routines of "Integrated and integral forest fire management ".

Joint coordination was established to constitute the Integrated Multi-Agency Operational Coordination Centre (Centro Integrado Multi Ag ncias de Coordena o Operacional) - CIMAN Federal - with a situation room to monitor high fire-risk forest areas, namely protected federal, state and municipal zones, public forests and forest areas of national interest. Greater emphasis was placed on the detection of hotspots by means of remote sensing, warning and quick initial attack on behalf of response bodies, in accordance with priorities established by all the involved entities and institutions.

A Unified Command Unit was constituted to establish priorities for forest fire fighting and prevention activities based on the doctrine of the Incidents Command System - SCI.

Key challenges of integral management were:

- 1 Forecasting risk situations;
- 2 Fire prevention actions and control of intentional forest burning;
- 3 Fire fighting preparation;
- 4 Forest fire fighting;
- 5 Civil and criminal accountability of offenders;
- 6- Recovery and reconstitution of affected areas.

The Centre also promoted intense flow of information on implemented actions, which allowed perfect integration between the involved institutions.

**Bio**: Degree in Environmental Management from the Scientific Institute of Higher Education and Research (Instituto Cientifico de Ensino Superior e Pesquisa). Technician and permanent staff member of the Brazilian Institute of Environment and Natural Renewable Resources (Instituto Brasileiro de Meio Ambiente e dos Recursos Naturais Renov veis - IBAMA). Professional experience in the area of Ecology, with emphasis on Environment, in the key practice areas of nature conservation, forest fire fighting and prevention, and specialized and technical inspection.