Biomass: Burning, Decomposition

Considerations for Biomass Burning in Wildlands and Agriculture

Allen R. Riebau
National Program Leader for Atmospheric Science, USDA Forest Service
RPC-4th WFWAR, P.O. Box 96090, Washington, DC 20090 USA

Abstract

The need for managing smoke resulting from wildfire and other forms of biomass burning is increasing. Management of smoke is a steadily maturing activity in the United States which has been built upon a foundation of many years of needs assessment. This maturation is driven by both a desire on the part of wildland fire managers to do the right thing and the increasing likelihood of regulatory attention. Regulatory interest in biomass emissions is driven by regional haze regulations and the possibility of new national ambient air quality standards (NAAQS) for particulate matter, with standards for particles smaller than 2.5 microns (PM2.5) and between 2.5 and 10 microns (PM10-2.5) as prime examples. Five years ago an assessment of tools needed to support technical smoke management was completed under the US Joint Fire Science Program. Recommendations included new research and development initiatives for tools in three categories. These categories were wildland fire 1) strategic and tactical planning, 2) operations, and 3) post-fire evaluation. This paper reviews what has been accomplished during the last five years, and in so doing, identification is made of some continuing research needs and remaining challenges. The application of what we have learned about wildland fire emissions and management of smoke has both implication and utility for agriculture. In conclusion, this paper will discuss how biomass burning for agriculture may both converge and diverge from forestry and rangeland applications, with some practical suggestions made for next steps.

Global Scale Analysis of the Atmospheric Impact of Fire Emissions

Prasad Kasibhatla[1], Quanlin Li[1], James Randerson[2], Guido van der Werf[3], Louis Giglio[4], and Jim Collatz[5]
[1]Nicholas School of the Environment and Earth Sciences, Duke University, Durham, NC, USA;
[2]University of California, Department of Earth System Science, Irvine, California, USA;
[3]Vrije Universiteit, Department of Hydrology and Geo-Environmental Sciences, Faculty of Earth and Life Sciences, Amsterdam, The Netherlands;
[4]Science Systems and Applications, Inc., National Aeronautics and Space Administration, Goddard Space Flight Center, Greenbelt, Maryland, USA;
[5]National Aeronautics and Space Administration, Goddard Space Flight Center, Greenbelt, Maryland, USA.

Abstract

Biomass fires associated with human activities such as forest and savanna burning for agricultural and other purposes, burning of agricultural residues, and domestic burning of biofuels, represent a significant source of chemically and radiatively important trace gases and aerosols to the atmosphere. Over the last two decades, there has been considerable progress in quantifying the spatiotemporal distribution of fire emissions, and in understanding their impact on atmospheric chemical composition. In this paper, we review our current knowledge in this area, focusing in particular on recent large-scale fire emission estimates derived using multiple satellite products in a modeling framework involving biogeochemical and atmospheric chemistry models. One focus of our analysis will be on assessing the consistency of the satellite-derived fire emissions with independent estimates in regions where agricultural open field burning occurs. A second focus of analysis will be on delineating the potential impact of emissions from large-scale fires on air quality in various agroecological zones.

An Air Quality Impacts Planning Tool

Narasimhan Larkin, Robert Solomon, Susan O'Neill, and Sue Ferguson
U.S. Forest Service AirFIRE Team, Pacific Wildland Fire Sciences Laboratory, 400 N. 34th Street, Seattle, WA 98103 USA

Introduction

Newly revised clean air standards and new regional haze rules are prompting emitters and regulators (states, tribes, and county or local air agencies) to develop more accurate accounting of emissions and impacts. At the same time, there is an increasing use of fire in forested landscapes to help reduce hazardous fuel buildup and maintain and restore healthy ecosystems. The result is that in many parts of the country, agriculture and forest activities are directly competing for the same air space.

There are few tools that allow forest and agricultural land managers to understand the likely air quality impacts, or even regions impacted, by their controlled burning practices. Ferguson (2001) recently compiled a summary of tools available for managing smoke from wildland fire and found that most tools are too simple to be realistic or too complicated to be employed regularly. The result is inconsistent assessment of smoke impacts, inconsistent or unreasonable regulation, and little if any information on alternative scenarios that could allow burning to continue with reduced impact.

Currently, there is no way of rapidly assessing impacts from new sources or of understanding the cumulative impact from multiple sources. This is particularly critical for temporary sources such as planned agricultural burns and prescribed fire treatments. Because there is no way of rapidly assessing the impacts from these sources, there is no easy way to experiment with alternatives in location or timing of a source that could help mitigate impact. Thus agriculture and forest managers and air regulators cannot game play and negotiate to help maintain air quality.

To fill this need, we are creating a new web-based tool for helping to anticipate air quality impacts from point sources, which we have called the Air Quality Impacts Planning Tool (AQUIPT, http://www.airfire.org/aquipt). By combining the power of air quality dispersion models with historical weather information over a long period of time, AQUIPT allows users to determine likely emissions impacts beyond the 5 day forecast limit of dynamical weather models.

While it cannot answer what the impacts will be in the future, say this September, by utilizing 30 years of historical data, AQUIPT shows probabilistically what the impacts would have been based on the previous 30 Septembers. In this way, AQUIPT attempts to fill a needed gap in a suite of tools available to agricultural, forest, and air regulator users.

Methodology

AQUIPT has been developed from the BlueSky smoke modeling framework (O'Neill et al., 2005), although significant alterations have been made to BlueSky for this purpose. While the BlueSky framework was originally designed for use with short term weather forecasts, AQUIPT relies on a longer term (30 year) database of hourly historical weather.

Via a website, users submit requests for analysis of a point source of interest. The user can specify the type of point source: wildfire, prescribed burn, agricultural burn, factory, dairy farm, among others. The user can choose from default parameters for the source, or supply known information. The user can supply a particular period of interest (for example specific calendar months).

After submission of the request, the model is run on a cluster computer. In order to generate the requested results, multiple model runs are performed and statistically aggregated. The emissions source is run for a 3 day period starting every day of the selected time period over the past 30 years. For example, if the user requested information for September impacts, 30 days*30 years = 900 3-day model runs are performed.

Statistical aggregates of the output are collected and mapped. The user is then notified that the results are available via email, and they can view and download the maps on the website.

Historical weather information is needed as hourly three dimensional gridded fields at 36-km horizontal resolution for the full 30 year time period. This requires a very large (multi-TB) database. This database is created by downscaling historical climate observations using a mesoscale meteorological model. Global climate model renanalysis products have been created that incorporate historical observations and therefore represent a "best-guess" at the state of the atmosphere; we utilize the National Center for Environmental Prediction/National Center for Atmospheric Research reanalysis product for the period 1970-2000. We are also investigating using the European Center for Medium Range Forecasting (ECMWF) reanalysis product. These products need to be downscaled for our purposes. Downscaling is done with the NCAR/Penn State MM5 mesoscale model in a nested mode down to a 36-km grid over the contiguous 48 states. During downscaling four dimensional data assimilation (FDDA) is utilized to nudge the model with observations. The meteorological data is run through the CALMET model for use by the CALPUFF dispersion model.

Emissions are generated utilizing standard profiles for various types of point sources. For wildland fires, emissions are calculated from regional fuel loadings and the CONSUME/EPM emissions model. Other types of sources have proscribed emissions profiles and speciation that is scaled by the user specified size of the source.

Dispersion/transport is done by the CALPUFF dispersion model. CALPUFF is a standard puff type model. Output from the dispersion model is aggregated utilizing specialized code and then statistical maps are generated by the FERRET visualization tool.

Status and Summary

The AQUIPT project is currently in its second year of development. A prototype tool is functional for testing purposes.

The largest portion of work has been the development of the historical climate database. As we require full 3-dimensional fields for the dispersion/transport modeling, this database must be generated by downscaling from global climate model reanalysis products. We are currently utilizing the National Center for Atmospheric Research (NCAR)/National Center for Environmental Protection (NCEP) reanalysis product, but we are also investigating switching to the European Center for Medium Range Weather Forecasting (ECMWF) reanalysis product. Ten years of downscaled data are available via the prototype, but the historical downscaled data are being recomputed and extended based on observation/model output comparisons.

Back end programs to run the system are fully functional and statistical collection and graphing of the output is automated. We are currently communicating with a variety of users to determine the best output formats/statistics to use. Examples of output statistics include: percent time impacted, percent time impacted above a threshold concentration, maximum concentration at location during the entire selected time period, average concentration.

Several point source types are available, including wildfire, prescribed burn, and constant emissions source. Additional source profiles need to be collected but are easily added to the system in order to make it more versatile and customized.

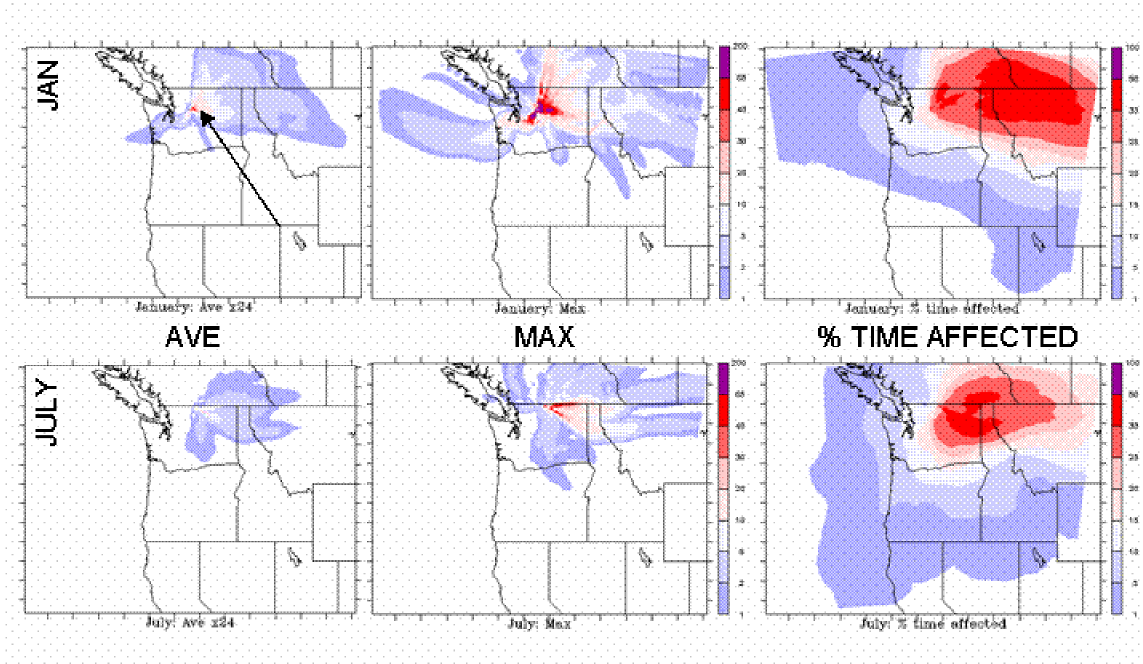
Examination of output results show significant inter-annual variability in dispersion patterns from the same source. Statistically significant trends have not been identified at this point, partially due to the limited time period (10 years) currently available. We are currently investigating whether dispersion patterns can be statistically associated with know inter-annual climate variability patterns such as the El Nino Southern Oscillation.

References

Ferguson, S.A. 2001. Smoke Dispersion Prediction Systems. In 2001 Smoke Management Guide. C.C. Hardy, R.D. Ottmar, J.L. Peterson, J.E. Core, and P. Seamon, editors. National Wildfire Coordinating Group, Fire Use Working Team. National Interagency Fire Center, ATTN: Great Basin Cache Supply Office, 3833 S. Development Avenue, Boise, Idaho 83705. NFES 1279. 163-178.

O'Neill, S., J. Hoadley, S. Ferguson, R. Solomon, J. Peterson, N. Larkin, R. Peterson, R. Wilson, and D. Mahany (2005). "Applications of the BlueSkyRAINS smoke modeling system." *Journal of the Air and Waste Management Association*, (in press).

Figure 1. Sample of statistically aggregated output for PM2.5 impacts from a wildland fire. In this example a fire (location indicated by arrow) was run every day during multiple years of Januarys and Julys. Differences between the dispersion patterns in January and July are seen. Average, maximum, and % time affected (concentration > 0) are shown.



Modeling Air Quality Effects of Prescribed Burn in Georgia with CMAQ-Daysmoke

Yongqiang Liu, Gary Achtemeier, and Scott Goodrick
USDA Forest Service/Forest Sciences Laboratory
320 Green St., Athens, Georgia

Abstract

Prescribed burn of forest and other ecosystems is extensively used in the Southeast as a management tool for reducing accumulation of understory debris and maintaining ecosystem health(Wade et al. 2000) . Emissions from prescribed burn are an important source of air pollutants in the Southeast, a region with some of the highest levels of PM and ozone in the nation (Zheng et al. 2002). To evaluate the air quality effects of prescribed forest burn in this region, a modeling tool has been constructed at the USDA Forest Service Southern High-Resolution Modeling Consortium 4S (Achtemeier et al. 2003), which simulates smoke transport and dispersion and the related chemical and physical processes using the Community Multiscale Air Quality (CMAQ) model (Byun and Ching 1999). A unique feature with this modeling tool is the coupling of Daysmoke, a dynamical model to simulate movement and deposition of smoke particles, to provide smoke plume rise (Achtemeier 1998). In Daysmoke, the plume is assumed to be a succession of rising turrets. Detrainment occurs when stochastic plume turbulence places particles beyond plume boundaries. Eddies are two-dimensional and oriented normal to the axis of the mean layer flow. Particles passing a "wall" seven miles downwind from a burning are counted for each hour during the burning period. CMAQ-Daysmoke will assist fire and air quality managers and policy makers in meeting air quality regulations and defining implementation plans. This study illustrates the capacity and sensitivity with CMAQ-Daysmoke through modeling prescribed burn in Georgia on March 6, 2002.

Two burns occurred in Central Georgia with the areas of 856 acres and 420 acres, respectively. Emissions were estimated with the emission models. The simulation domain has 100X100 grid points with a resolution of 12km and 21 layers. The CMAQ vertical component of the grid had 21 layers. The inputs in the Sparse Matrix Operator Kernel Emissions Modeling System (SMOKE) (Houyoux et al. 2002), a model to process emission data and provide initial and boundary chemical conditions for CMAQ modeling, include $PM_{2.5}$, PM_{10}, SO_2, CO, NOx, NH_3, and VOC. The first five compounds were obtained from burning emission data. The two other compounds were specified based on the values in the 1999 EPA National Emissions Inventory. The Carbon Bond-IV (CB-IV) chemical mechanism was used to simulate gas-phase chemistry in CMAQ. Meteorology was simulated with MM5 using the Kain-Fritsch (1993) convective parameterization, the Medium Range Forecast boundary layer scheme(Hong and Pan 1996), the simple ice microphysics scheme and a 5-layer soil model for the land surface scheme. The MM5 outputs were processed through the Meteorology-Chemistry Interface Processor (MCIP) v2.2 for use of SMOKE and CMAQ.

The simulated plume rise is about 0.2 km at 1000 and 1100 LST (Fig.1). Then it rapidly increases to about 1.4 km and remains near this height throughout the afternoon. Most smoke particles are distributed in the upper portion of the smoke plume. The largest $PM_{2.5}$ concentration of over 10 micrograms m^{-3} is found at the grid where the burns are located. The smoke particles are transported northeastward by the prevailing winds (Fig.2). It is found that the specification of smoke plume rise and vertical profile is one of the major uncertainties in modeling the air quality effects of prescribed burn with CMAQ-Daysmoke. Sensitivity experiments are conducted to understand the uncertainties.

References

Achtemeier, G.L., 1998: Predicting dispersion and deposition of ash from burning cane. *Sugar Cane*, 1, 17-22.

Achtemeier, G,S. Goodrich, Y.-Q. Liu, 2003: The Southern High Resolution Modeling Consortium-A source for research and operational collaboration. *Proceedings of the 2nd Int'l Wildland Fire Ecology and Fire Management Congress.* Amer. Meteor. Soc. Nov. 16-20, 2003, Orlando, FA.

Byun, D.W. and J. Ching, 1999, *Science algorithms of the EPA Model-3 community multiscale air quality (CMAQ) modeling system*, Research Triangle Park (NC): EPA/600/R-99/030, National Exposure Research Laboratory.

Hong, S.-Y., and H.-L. Pan, 1996: Nonlocal boundary layer vertical diffusion in a medium-range forecast model. Mon. Wea. Rev., 124, 2322-2339.

Houyoux, M., J. Vukovich, C. Seppanen, and J.E. Brandmeyer, 2002: SMOKE User Manual, MCNC Environmental Modeling Center.

Kain, J.S., and J.M. Fritsch, 1993: Convective parameterization for mesoscale models: The Kain-Fritsch scheme. The representation of cumulus convection in numerical models, K. A. Emanuel and D. J. Raymond, Eds., Amer. Meteor. Soc., 246 pp.

Wade, D.D.; Brock, B.L.; Brose, PH. and others, 2000. Fire in eastern ecosystems. In: Brown, J.K.; Smith, J.K., eds. Wildlandfire in ecosystems: effects of fire on flora. Gen. Tech. Rep. RMRS-42. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station: 53-96. Chapter 4. Vol. 2.

Zheng, M., Cass, G.R., Schauer, J.J., Edgerton, E.S., Source Apportionment of PM2.5 in the Southeastern United States Using Solvent-Extractable Organic Compounds as Tracers. *Environ. Sci. Technol., 36,* 2361-2371, 2002.

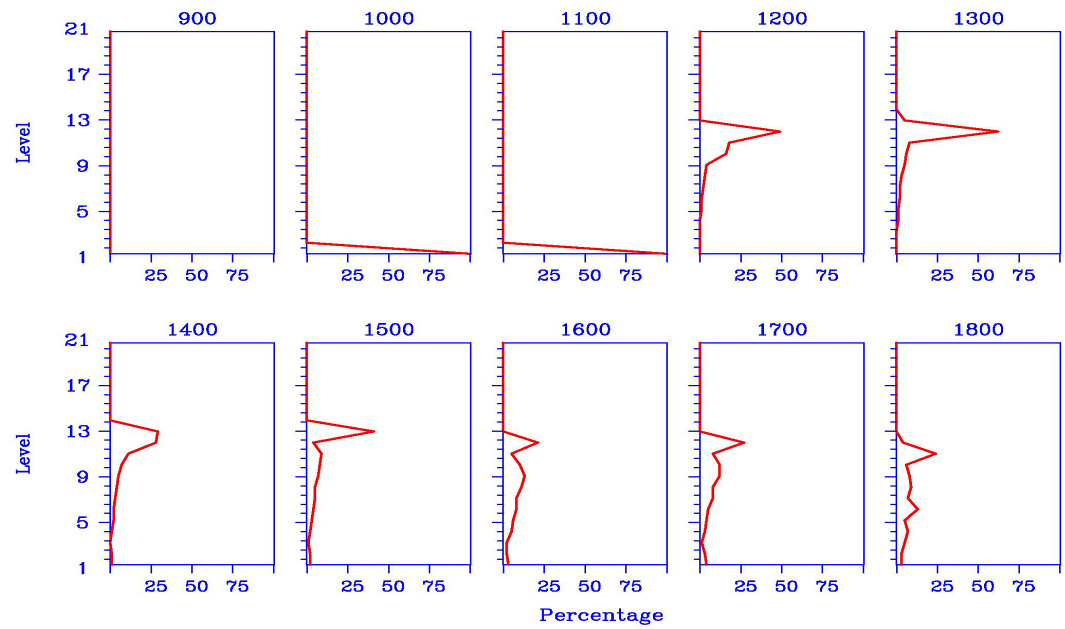


Figure. 1 Vertical distributions of smoke particles estimated using Daysmoke

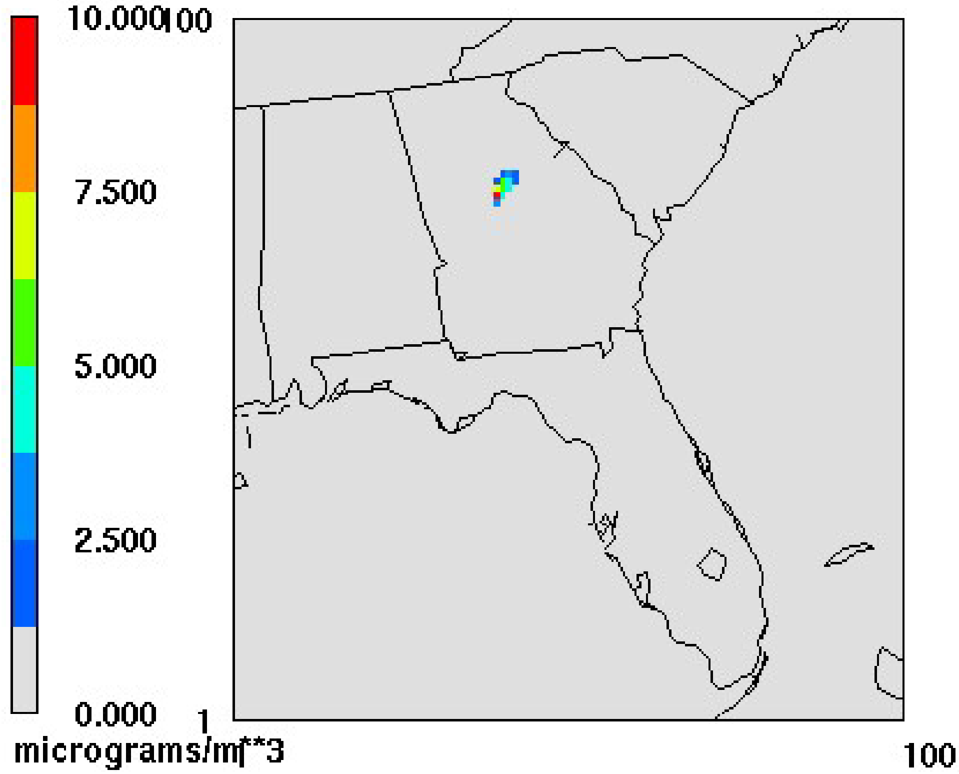


Figure. 2 Ground $PM_{2.5}$ concentration at 1400 LST

Remotely Sensed Measurements of Air Quality Emissions from Agricultural Biomass Burning in the Contiguous United States

Stefania Korontzi, Jessica McCarty, and Chris Justice
Department of Geography, 4321 Hartwick Road, Suite 209, University of Maryland, College Park, MD 20740 USA

Abstract

On an annual basis, approximately 12% of all fires detected by the Moderate Resolution Imaging Spectroradiometer (MODIS) in the contiguous United States occur in croplands. These fires have received little attention in the scientific literature, yet they impact local and regional air quality. This project will analyze the seasonal and interannual variability of air quality emissions from crop residue burning in the contiguous United States for the years 2004 through 2007. Satellite measures of crop types and burned area will be combined with crop-type specific emission factors for atmospheric species, included in the 1990 Clean Air Act, to quantify air quality emissions. These estimates will support the improvement of the EPA's National Emissions Inventory (NEI) by estimating spatially and temporally explicit emissions. Reported national emissions will be compared with the new estimates to identify areas of discrepancy and evaluate uncertainty in the findings. Additionally, MODIS AOT (aerosol optical thickness) and Aerosol Robotic Network (AERONET) data will be used to characterize the contribution of cropland burning to aerosol optical thickness and air quality and assess the accuracy of the land-based air quality emissions estimates. Preliminary analyses for a case study of agricultural burning along the Mississippi Delta area of Arkansas and surrounding areas in Tennessee and Mississippi will be presented.