Southern Smoke Issues

In This Issue

Feature Article

Superfog – Unraveling the Smoke/Fog-on-the-Highway Problem

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On 9 January 2008, four people died in a 70 car pileup on Interstate 4 in central Florida. The accidents were caused by visibility reductions in dense smoke/fog associated with a nearby wildfire. The Florida event was similar to past smoke/fog incidents in many respects. The accidents occurred late at night from 4:00 – 7:00 AM - just before sunrise. There was natural fog in the area but not enough to seriously restrict visibility. The smoke/fog was unusually dense restricting visibility to a few feet. Accounts of "couldn't see my shoes" "couldn't see my hand in front of my face" were typical of accounts given by other victims.

Fog that reduces visibility to less then 3 meters (10 feet) – roughly the line-of-sight distance over the hood of a vehicle from a motorist to the road is defined as "superfog" which is something that most of us have never experienced and we have no framework for understanding those who have. Several victims of the Florida fog described it as a "black wall." In driving at night, one sees objects ahead by light reflected from headlights. In dense fog, the same objects are obscured by light reflected from fog droplets. Now imagine a fog so dense one cannot see any light reflected from his headlights. That is superfog.

From the Editor

Welcome to the first issue of the Southern Smoke Issues newsletter. I hope that this newsletter will provide a much needed communication pathway from research to the smoke management community and that this communication will be two way. While researchers need to do a better job of keeping the field informed of new developments, the field needs to let research know about important issues that are currently neglected by research efforts. This feedback can be used to hopefully solve some of the simple, low hanging fruit problems while also providing future direction for research efforts and build the partnerships critical to solving the more complex problems. To that end please submit any smoke/ air quality issues, needs, comments, questions, upcoming training/meetings for inclusion in upcoming newsletters to sgoodrick@fs.fed.us.

Thanks
Scott Goodrick
Editor, Southern Smoke Issues

Where and how superfog forms has been the subject of research at the USFS Center for Forest Disturbance Science at Athens GA for the past 15 years. The prevailing theory was that particulate matter (convective condensation nuclei (CCN)) in smoke causes superfog. CCN particles compete for available moisture in the air resulting in numerous small fog droplets. Many small droplets scatter light more efficiently than fewer large droplets hence reduced visibility.

However, there were problems with the CCN theory. Natural fog seldom reaches liquid water contents (LWC) high enough to form superfog even in the presence of wood smoke. Furthermore, observations of smoke rising into natural fog showed no real effect. Therefore, the CCN theory may explain smoke-enhanced fog but an additional factor is needed for the formation of superfog – smoke moisture.

Water is a product of combustion. For 3 tons of fuel consumed per acre, the chemistry of combustion yields 1.5 tons of water. That means half of what we call smoke is really water. Add in water evaporated from preheated fuels that are consumed, water evaporated from the ground and water evaporated from fuels not consumed. If the water equivalent released from these sources is just 0.01 inch then the water

Figure1. Aerial view of a prescribed burn in central Georgia show bright spots suspected of being superfog.

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Meetings

Bluesky Smoke Modeling Framework Stakeholder's Meeting, Boise ID May 20-22, 2008 - http://www.airfire.org/bluesky/meeting.html

17th International Emission Inventory Conference - "Inventory Evolution - Portal to Improved Air Quality" Portland, Oregon, June 2 - 5, 2008 - http://www.epa.gov/ttn/chief/conference/ei17/index.html

Training

RX410 will be taught the week of June 16-20, 2008 near Russellville, AR. The class filled very quickly and there were more people nominated than could possibly be accommodated. The class of 30 people is pretty diverse with students from Arkansas, Oklahoma, Kentucky, Virginia, Alabama, North Carolina, Louisiana, Florida, South Carolina, Georgia and Arizona. While most of the participants are US Forest Service, the National Parks, US Fish & Wildlife, Department of Defense, and TNC are represented.

released per acre is 1.1 tons. Add in 1.1 tons of water for each additional 0.01 inch of water equivalent released.

Given the right weather conditions, smoke can be dry or smoke can be wet. Figure 1 shows smoke from a prescribed burn in central Georgia. Note the bright white areas in the plumes near the ground (arrows). What if smoke moisture initially flashed into superfog. Then, as it mixed with dry ambient air, the superfog evaporated as the plume of smoke continued rising. This concept of plume moisture flashing into fog and subsequently evaporating can be seen happening in the plume of fog rising from the power plant cooling towers in the distance. To test the idea that smoke moisture contributes to superfog, post-prescribed burn smoke temperature and relative humidity data were collected for a total of 27 smoldering "smokes" at four sites between March 2002 and March 2003 (Figure 2). A "smoke" is defined as a tiny plume of smoke less than 30 cm across rising above a patch of smoldering fuel. Note how the smoke thins and disperses as it moves away from the source.

Figure 2. Sampling temperature and relative humidity of smoke from smoldering logs in the wake of a prescribed burn in central Georgia.

The smoke data were instrumental in three studies of the formation and behavior of superfog. The first study looked at bulk properties of smoke moisture. Smoke moisture has no impact on ambient moisture during the daytime. However, at night, under light winds and conditions of entrapment of smoke near the ground, smoke moisture can add to existing fog and/or raise relative humidity to 100%

Paper of Interest

Air Quality impacts from prescribed forest fires under different management practices

By Di Tian, Yuhang Wang, Michelle Bergin, Yongtao Hu, Yongqiang Liu and Armistead Russell

Forest fires are essential and natural processes to maintain forest health. However, inadvertent fires can also cause ecosystem damage and property loss, and threaten human health and safety. In order to minimize such adverse impacts, as part of current forest management practices, forest fires are intentionally planned and ignited. Such fires are usually referred to as prescribed fires, and are inherently anthropogenic sources. This study indicated that air quality impacts from prescribed forest fires changed with different forest management practices. For example, burning during different seasons can have different air quality impacts due to different meteorological conditions and photochemical characteristics. Such impacts change with pollutants concerned, distance of fires and concerned regions, and wind directions. In addition, burning frequency is another important factor. If prescribed fires are less frequent, biofuel burnt in each fire is more, leading to larger emissions and air quality impacts per fire. However, the long-term regional impacts on air quality are reduced since the annual burned area is reduced. It has great implication for attaining annual and

at locations were fog would otherwise not have formed.

The second study looked at the potential for individual smokes to form superfog. None of the smokes were saturated (RH=100%) when the measurements were taken. Smokes were cooled via a simple radiation model for from 1-5 seconds and then mixed with ambient air. The mixing of equal masses of warm, moist smoke with cool, moist ambient air is called non-gradient mixing. It is possible to mix two air masses of different temperature with neither air mass being saturated and get a mixed air mass that is saturated or supersaturated with excess liquid water content (LWC) available to form fog. The model calculated fog LWC up to 17 times greater than the LWC of dense natural fog and capable of producing superfog.

Figure 3. Superfog rising above smoldering forest litter on 21 March

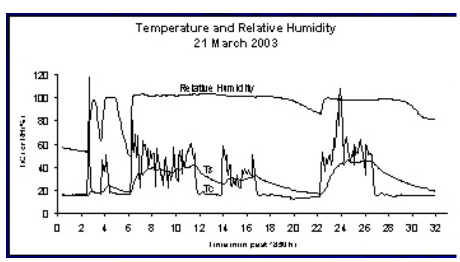

Figure 4. The temperature and relative humidity traces for the superfog event on 21 March 2003. Relative humidity hovers at 100% as shown. Curves labeled Ts and Tc give different response temperature measurements and show when the probe was in

Smoke data for the first two studies came from smoldering stumps and logs on the forest floor. Data for the third study came from a burning pile of forest litter. The third study was unique because the measurements were taken in actual superfog. Differences between smoke plumes can be seen in Figures 2 and 3. Figure 2 shows a typical smoke observed from smoldering logs. The smoke is transparent and disperses as it moves away from the source. Furthermore, Paper of Interest - continuied

24-hr PM2.5 NAAQS. This study also showed significant emissions and air quality impacts from smoldering, along with exacerbated air quality impacts per unit emissions. Understanding air quality impacts from prescribed fires under different forest management practices is becoming critical to non-attainment designation, control strategy development, and effective air quality and ecosystem management. http://pubs.acs.org/cgi-bin/asap.cgi/esthag/asap/pdf/es0711213.pdf

Smoke plume effects air quality.

the smoke has a bluish tint gained from scatter of blue light by fine scale particulate matter. Figure 3 shows the dense gray plume of superfog rising above the litter. The cloud is only about 12 inches (30 cm) deep. The cloud is totally opaque all the way to the edges. Temperature and relative humidity traces (Figure 4) show the jump in relative humidity to 100% each time the probe was placed in the smoke.

Further analysis of the smoke moisture data and data on smoke particle sizes and number of particles released in combustion as reported in the literature led to the creation of a superfog model. The model showed that the mixing of warm, moist smoke with cool, moist ambient can produce superfog reducing visibility to as low as 10 cm (4 inches). Because there is so much LWC converted from vapor to liquid, the latent heat of condensation adds to the heat from smoldering combustion to lift the superfog above the ground. Then, depending on the amount of fog LWC and the relative humidity of the ambient air, several fates await the superfog. For smaller LWC and unsaturated ambient air, mixing quickly evaporates superfog leaving a rising plume of smoke. For larger LWC and unsaturated ambient air, mixing evaporates some of the superfog until fog temperature has cooled to below ambient temperature. Then the colder superfog settles to the ground and persists under its self-created temperature inversion. For larger LWC and saturated ambient air, mixing evaporates some of the superfog but fog temperature remains slightly above ambient temperature. The weight of the suspended liquid water drags the plume to the ground. Once on

Figure 5. Part of the 70-vehicle pileup on Interstate 4 in central Florida on the morning of 9 January 2008.

the ground, superfog tends to persist until after sunrise when it is dispersed by solar heating.

Now let’s return to the Interstate 4 disaster. Thanks to the local news media Figure 5 shows wrecked vehicles strewn along the 6-lane expressway. Smoke from still-smoldering tractor trailers can be seen at the far right of the image. Figure 6 shows the same scene several hours earlier. The expressway, the cars, the tractor trailers cannot be seen. Note the trees extending above the superfog. It is estimated that the depth of the superfog was approximately 20 feet. Yet nothing can be seen.

What does this study tell us about driving conditions and motorist behavior? Some newspaper accounts of the disaster carried statements by officials implying that motorists were irresponsible and were driving too fast for road conditions. However, the reaction time for a motorist driving at 60 mph to go 50 feet (a generous estimate) from unlimited visibility to zero visibility (black wall) in superfog is little more than half a second. Motorists had insufficient reaction time and they never saw what they hit. Other media published guidelines for driving in dense fog. For driving in superfog, these guidelines are meaningless. There is only one guideline for driving in superfog: Do not drive.

Dense smoke from a brush fire and fog caused a multi-vehicle pileup on Wednesday, closing Interstate 4 near Lakeland, Fla.

Southern Smoke Issues

Ariel view of fire line at Eglin.

Smoke plume from Eglin presribed burn.

Eglin Incident Members.

Collaborative Research in the Core Fire Sciences: Prescribed Fire Combustion-Atmospheric Dynamics Research Experiments (Rx-CADRE)

by
Joseph J. O'Brien

21st Century wildfires are increasing in frequency, intensity and complexity. These trends seem likely to continue in the face of climate change, shifting land use patterns, and an increasingly urbanized landscape. Application of prescribed fires that could reduce wildfires is also becoming more and more challenging. Fire science must rise to these challenges in a timely manner, but there is a need for greater collaboration and the pooling of talent and resources. Kevin Hiers, Research Associate, of the Joseph W. Jones Ecological Research Center initiated an experimental test of collaboration potential by organizing RxCADRE, the Prescribed Fire Combustion-Atmospheric Dynamics Research Experiments. Kevin organized teams of fire experts with a wide range of fire monitoring expertise and equipment from across the US and Canada in order to instrument prescribed burns at Eglin Air Force Base and the Jones Center. Concurrent workshops were held that brought fire and fire effects modelers into the mix, and created the linkage between data generation and data use for fire and fire effects model validation and development. Specifically, the goals were to 1) compare *in situ* and remote sensed heat environments of prescribed burns, 2) document coupled atmospheric interactions, 3) produce validation datasets for coupled fire-atmospheric dynamic models, and 4) relate fire behavior to first order fire effects. To fully instrument fires, data was collected on pre-burn fuel loads, post burn consumption, ambient weather, *in situ* convective dynamics, plume dynamics, radiant heat release (both from *in-situ* and remote sensors), *in-situ* fire behavior, and select fire effects. The experiment was organized under the tenets of the Incident Command System and included

Smoke Management Tools

Simple Smoke Screening Tool - http://shrmc.ggy.uga.edu/maps/screen.html

The Southern Smoke Management Guide made use of a simple graphical smoke screening system. This system relied upon a simple protractor and paper maps in marking out a smoke impact zone. The Simple Smoke Screening Tool is a web enabled version that overlays the smoke protractor on Google Maps (output can also be displayed in Google Earth). The information required includes location (latitude/longitude in decimal degrees) size of burn, type of fuels, ignition method and wind direction. The acreage value is used to set the width of the screening grid and is also used with the fuel type and ignition method to determine the screening distance. This tool is still in development so please send any comments/suggestions to sgoodrick@fs.fed.us

air operations and the novel addition of a research branch. A total of five fires were lit from March 1- 6 using a variety of ignition techniques including aerial mass ignition, burning a total of 4500 acres. Collaborators from CFDS included Joe O'Brien, Scott Goodrick, and Gary Achtemeier. O'Brien shared some novel measurement techniques for capturing *in situ* fire behavior using an infrared thermal camera operated on a mobile platform positioned adjacent to and above the flames. This technique provides a safe, stable platform and allows the capturing of images with reduced distortion. Both macro- and microscale smoke plume validation measurements were collected for the CFDS smoke team. The Discovery Channel Canada and Georgia Public Broadcasting collected interviews and footage for their respective Daily Planet and Georgia Outdoors programs. The experiment was a complete success, both in terms of the data collected, the collaborations initiated, and the perfect safety record. In addition, the prescribed burns met the operation goals of the land managers. Kevin Hiers: "We showed that prescribed fires can be conducted at a large scale and in a timely manner to meet research objectives here in the Southeast. This provides an ideal climate for collaborative wildland fire research." Indeed, the researchers were unanimous in their appreciation of the skill of southern prescribed fire managers. The data will be pooled and there are plans for several multi-author peer reviewed publications.

Participants:
Kevin Hiers, project organizer
Roger Ottmar, project co-organizer, fuel loading and consumption
Matt Dickinson, remote sensing fire environment, fire effects
Bret Butler, *in situ* fire environment
Craig Clements, micrometeorology
Bob Kremens, remote sensing fire environment, plume observations
Bob Vihnanek, fuel loading and consumption
Dan Jimenez, *in situ* fire environment
Joe O'Brien, *in situ* fire behavior and fire effects
Scott Goodrick, fire modeling and fire weather
Janice Cohen, *in situ* fire-weather environment
Sean Michaletz, Graduat student with Matt D.
Alister Smith, Fire effects remote sensing

Joe O'Brien in bucket truck to observe smoke plume.

Andy Hudak, Fire effects remote sensing
Warren Heilman, USFS wind profiling
David Frankman, Graduate student with Bret B.

Incident staff:
Kevin Hiers, IC
Dave Brownlie, Plans, USFWS
Matt Snider, Operations, TNC
Mark Melvin, Burn Boss, Jones Research Center
Shan Cammack, Logistics, Georgia DNR
Kevin McIntryre, Liaison Jones Research Center
Doc Watson, Pilot
Neal Edmondson, Georgia Forestry Commission

Special Guests (March 4-6):
Rod Linn, LANL
Ruddy Mell, NIST
Phil Cunningham, FSU
Mike Hilbruner, USFS

Smoke plume from prescribed fire.

Smoke Management Tools			
Tool Name	Description	Status	Contact
CONSUME	Software application designed to convert inputs of fuel characteristics, lighting patterns, fuel conditions, and meteorological attributes into estimates of fuel consumption and emissions by combustion phase. http://www.fs.fed.us/pnw/fera/research/smoke/consume/index.shtml	V3.0	Roger Ottmar (rottmar@fs.fed.us)
FEPS	Fire Emission Production Simulator (FEPS) is a user-friendly computer program designed to help managers estimate and mitigate the rates of heat, particles, and carbon gas emissions from controlled burns. FEPS can be used for most forest, shrub and grassland types in North America and the world. Total burn consumption values are distributed over the life of the burn to generate hourly emission and release information. http://www.fs.fed.us/pnw/fera/feps/index.shtml	V1.1	Ellen Eberhardt (eeberhardt@fs.fed.us)
Vsmoke-GIS	VSMOKE and VSMOKE-GIS smoke dispersion models are classified as Gaussian dispersion models and predicts downwind PM2.5 (fine particle) concentrations, and provide visibility estimates. The user of VSMOKE-GIS can enter up to 10 fine particle concentrations to evaluate, or choose the 5 fine particle concentration that relate to the Environmental Protection Agency's 1-hour air quality index (AQI) for particulate matter. Hourly emissions and heat release rates estimates from FEPS are utilized by VSMOKE and VSMOKE-GIS. http://webcam.srs.fs.fed.us/vsmoke/	V2.1.1	Bill Jackson (bjackson02@fs.fed.us)
BlueSky	BlueSky is a modeling framework designed to predict cumulative impacts of smoke from forest, agriculatural, and range fires across the landscape. By utilizing predictions from a weather forecast model and fire information, BlueSky can create forecasts of ground concentrations of smoke. BlueSky output products are being created by regional Fire Consortium for the Advanced Modeling of Meteorology and Smoke (FCAMMS), and the National Weather Service uses BlueSky based smoke emissions in their smoke forecast product. http://www.airfire.org/bluesky/ and http://www.fcamms.org/ BlueSky proved itself to be an informative and useful tool during the Georgia/Florida wildfires last year. SHRMC is working to implement BlueSky for use by all land managers in the southeast for prescribed fires as well as wildfires. We are currently working with the Airfire team of the Forest service's Pacific Northwest Research Station to implement the latest version of BlueSky and hope to have this available in the near future. Information on BlueSky in the southeast can be found at: http://shrmc.ggy.uga.edu/smoke/bsky/index.html	Research	General BlueSky Sim Larkin (larkin@fs.fed.us) BlueSky SouthEast Scott Goodrick (sgoodrick@fs.fed.us)

Smoke Management Tools			
Tool Name	Description	Status	Contact
PB-Piedmont	terrain of ridges and valleys typical of the Piedmont of the southeastern United States. The model inputs elevation data from the USGS national 30 m DEM data base. Weather data and weather data from either FCAMMS-MM5 (prediction) or hourly NWS surface data (monitoring). PB-Piedmont maps smoke along with terrain in a GIS display that comes with the model. Roads and locations of key target may also be added to the display.	Research	Gary Achtemeier (gachtemeier@fs.fed.us)
Southern Smoke Simulation System	Southern Smoke Simulation System (SHRMC-4S) is a regional smoke and air quality framework developed at the Southern High-Resolution Modeling Consortium (SHRMC). It provides fire and land managers with the information on concentrations and spatial patterns and temporal variations of smoke pollutants (PM, ozone etc.) from wildland fires. SHRMC-4S consists of a burn data system, models to calculate fire emissions, Daysmoke for plume rise calculation, CMAQ for chemical modeling, and MM5 for meteorological modeling. Applications of SHRMC-4S have been fucosed on simulatting prescribed burns in the South. Efforts are underway to predict the air quality effects of prescribed burn. The prediction will be displayed using Google-Earch and availble at SHRMC website.	Research	Yong Liu (yliu@fs.fed.us)
CalSmoke	A user interface to compile the necessary information needed to operate the CALPUFF atmospheric dispersion model when planning future prescribed fires in Region 8 of the USDA Forest Service. Preprocessed meterological files have been prepared for 3 years, and a software tool will allow the user to identify days that meet specified meteorological parameters at the proposed burn location. ArcGIS is being utilized to develop the inputs need for the modeling receptors and defining the burn units. The GIS information about the burn units and hourly emissions and heat release rates estimates from FEPS are utilized to build the area source emissions file needed by CALPUFF. CALPUFF results include PM2.5, CO, and CH4 concentration estimates, and visibility estimates. CALPUFF results can be viewed in ArcGIS.	V1.0 (alpha)	Bill Jackson (bjackson02@fs.fed.us)
Simple Smoke Screening Tool	A simple web-based screening tool derived from the 1976 Southern Forestry Smoke Management Guidebook. http://shrmc.ggy.uga.edu/maps/screen.html	Research	Scott Goodrick (sgoodrick@fs.fed.us)

Smoke Management Tools

Tool Name	Description	Status	Contact
RS Smoke Detection	MODIS technique is used to detect smoke from wildfires in the EastFIRE Laboratory of George Mason University, which is a collabrator of FS SRS through coop agreement. Real time or near real-time images of smoke from the 2007 southern Georgia wildfires and other products can be downloaded from http://eastfire.gmu.edu/temp/eastfirewatch/index.htm	Research	John Qu (jqu@cos.gmu.edu)

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