Developing a near real-time regional system for modeling air quality impacts of prescribed fire emissions – linking state fire activity information with regional scale air quality models

Scott Goodrick, Gary Achtemeier, Yongqiang Liu
Center for Forest Disturbance Science, US Forest Service, Forestry Science Laboratory
320 Green St Athens GA 30602

Jim Brenner
Florida Division of Forestry
3125 Conner Blvd. Tallahassee, FL 32399

ABSTRACT

Emissions from wildland fires are becoming of increasing importance with recent changes to air quality regulations regarding PM2.5 concentrations and regional haze. Wildfire reporting is fairly well handled, especially when compared with the reporting of prescribed fire activities. Information on prescribed fire emissions ranges from good to nonexistent. With states developing/implementing Smoke Management Plans, the status of prescribed fire emissions information will begin to improve; however differences between states on the information captured in their prescribed fire reporting systems will likely lead to some difficulties in working with the data. The Southern High Resolution Modeling Consortium, as a potential user of this data, has begun work on a flexible database system designed to bring data from the various states together in a consistent format for use by the air quality community. The basic operations of the modeling system and fire activity database will be demonstrated using prescribed fire activity data from the state of Florida.

INTRODUCTION

In 1998, the Environmental Protection Agency (EPA) issued the Interim Air Quality Policy on Wildland and Prescribed Fire to protect public health and welfare by taking steps toward mitigating the air quality problems associated with smoke. As part of this policy the EPA urged states to develop and implement some form of smoke management program (SMP). The goals of an SMP are to mitigate the nuisance and public safety hazards (to roads and airports) posed by smoke from wildland fires and to prevent the deterioration of air quality (violations of the National Ambient Air Quality Standards – NAAQS and visibility reduction in Class I Federal areas). While land managers had become accustomed to implementing smoke management practices to minimize the threat of local smoke hazards and nuisance, taking a more regional view of smoke management to address air quality issues is a major departure from previous practices and requires the development of new tools.

The starting point for any discussion of fire emissions needs to begin with fire activity data which provides the most basic description of the source, what is burning where and when. For wildfires, a national reporting system (ICS-209) is in place that captures significant wildfire activity on a daily basis. In this system a significant wildfire is defined as 1) a fire of 100 acres or

more in timber, or 2) a fire of 300 acres or more in grass/brush or 3) a Type 1 or 2 Incident Management team is dispatched to the fire. While the ICS-209 system does not capture all wildfires, it does capture the majority of large fires.

Tracking prescribed fire activity is a very different story as there is currently no universally accepted system to capture this information. While the various federal land management agencies have different systems for tracking prescribed fire accomplishments, state and private prescribed fire activities are not captured in any centralized system and the information captured varies widely by state. The inconsistent nature of prescribed fire reporting data make the development of a fire emissions inventory quite problematic as the fire activity data is key to describing the fire as a pollutant source.

The Florida Fire Management Information System (FMIS) provides a statewide reporting system for both wildfires and prescribed fires (Brenner and Goodrick, 2005). FMIS is a key component of the State of Florida's Smoke Management Program (SMP) as well as being central to the day to day activities of the Florida Division of Forestry. This paper examines the potential for linking FMIS to an air quality forecasting system to estimate the impact of prescribed burning on regional air quality on a near real-time basis. The next section will provide a basic description of FMIS and how it fits into the State of Florida's SMP and how this system is being linked to the Southern Smoke Simulation System (4S), a system for assessing the air quality impacts of smoke from wildland fires. Results will be presented from a set of simulations conducted for March 2007 and discussion will focus on how this system can eventually add information to Florida's SMP and how other states can get make use of the 4S system in their SMPs.

SYSTEM DESCRIPTION

The Florida Fire Management Information System (FMIS) is a tightly integrated set of applications that handle the data input, processing and reporting needs of work undertaken by the Florida Division of Forestry (DOF), including: open burning authorizations (prescribed fire), wildfire and other incident response, as well as law enforcement actions taken by DOF personnel (Brenner and Goodrick, 2005). By integrating these functions into a single system and storing the data in a single relational database, the DOF has eliminated duplicate data entry and reduced paperwork, while at the same time increasing both the quantity and quality of information being recorded and reported. Every incident, regardless of type is recorded by the application as they occur, providing unprecedented access to wildland fire information at the local and statewide levels in near real time.

FMIS accomplishes a key component of any SMP, tracking prescribed fire activity, but also supplies an additional component, smoke screening. The planning process for any prescribed burn should incorporate smoke screening as an integral component as smoke from prescribed fires has caused serious accidents resulting in fatalities and significant property damage; resulting in rather poor public relations for prescribed fire. FMIS implements a baseline level of smoke screening for every prescribed burn conducted within the state to help minimize threats to life and property.

FMIS provides a smoke screening component for all burn authorizations to assess potential visibility hazards resulting from the smoke from prescribed burns. The primary component of the smoke screening system is the trajectory component of HySplit (HYbrid Single-Particle Lagrangian Integrated Trajectory) first described by Draxler (1992) which has been used successfully in studies of volcanic ash plumes (Heffter and Stunder, 1993) and forest fires (Sapkota et al 2005). Trajectories are created every hour starting at 3 levels above the burn site: surface, half of the mixed layer depth and at the top of the mixed layer. Along each trajectory the perpendicular spreading of the plume is determined using a gaussian distribution following the methodology of VSmoke (Lavdas, 1996) with initial emissions calculated using CONSUME (Ottmar et al., 1993). A polygon representing the 300 $\mu g\ m^{-3}$ ground level concentration of PM2.5 is constructed and returned to FMIS for intersection with layers containing smoke sensitive features. The choice of a PM2.5 concentration of 300 $\mu g\ m^{-3}$ was chosen to provide some level of buffer around a concentration associated with visibility reductions of approximately three quarters of a mile, 500 $\mu g\ m^{-3}$ (Therriault and Smith, 2001). While FMIS does provide a baseline screening tool, its focus is on hazards due to reduced visibility. There are other aspects of smoke screening that are left to the land manager (screening for health and/or air quality concerns).

The Southern High Resolution Modeling Consortium has been developing the Southern Smoke Simulation System (4S) in an attempt to provide the land manager with a tool that allows him to assess the potential air quality impacts of a prescribed burn. 4S is a framework derived from BlueSky (Ferguson, 2001; Ferguson et al., 2001) that links a series of models together to address concerns regarding smoke transport. The primary components in this framework are:

- MM5 is used to provide forecast weather information to support air quality forecasts out to 72 hours.
- Maps of fuel type to aid in determining available fuel. Currently using NFDRS national fuels map as well as a high resolution fuels map for Florida developed as part of their wildland fire risk assessment (Brenner, ????).
- CONSUME (v3.0) for estimating fuel consumption during the burn.
- EPM (Sanberg and Petersun, 1984) for translating the total fuel consumed into an hourly emissions profile for the burn.
- CMAQ-Daysmoke (Liu et al, 2007) for modeling emissions transport and chemical reactions. Daysmoke (Achtemeier, 2007) is used to initialize the vertical distribution of fire emissions within CMAQ.

On a daily basis prescribed fire activity data is collected from FMIS and is used to produce a forecast of PM2.5 and ozone impacts. The fire activity data consists of the location, size, start time and planned ignition technique of the prescribed burn. Ignition technique is a critical component in describing a prescribed fire as an ignition source as the manipulation of fire intensity has a strong impact on the combustion efficiency and resultant emissions.

SAMPLE FORECAST

On March 8, 2007, DOF authorized 288 prescribed fires covering a total of 28,405 acres (note that this does not include any burning vegetation piles from land clearing operations). The estimated total fuel consumed by these fires is 36,722 tons which works out to an average of around 1.3 tons per acre. The total PM2.5 emissions from these fires are estimated at 807,888 lbs

(1,777,354 kg). An example forecast of surface PM2.5 concentration associated with these burns is provided in Figure 1. The majority of the burning is located in the panhandle and prevailing winds were from the east. Peak one hour average smoke concentrations were just over 40 $\mu g\ m^{-3}$ which occurred just west of Tallahassee and persisted for several hours. While the smoke concentrations alone would only rate a moderate classification on the Air Quality Index (AQI), adding other pollutant sources would raise this level considerably. One aspect of these CMAQ-based forecasts that is still being evaluated is the influence of the model grid size. Currently the model grid size is 12km which may be too coarse to properly represent the fire plumes by spreading their impact over an overly large area.

INTEGRATION ACROSS THE SOUTH

As currently implemented, 4S is providing a starting point for examining regional scale smoke impacts on air quality; however to truly get at the regional problem a critical component is missing, regional fire activity data. In the southeastern United States prescribed fire is used to treat 6-8 million acres (2-3 million ha) of forest and agricultural lands each year (Wade et al., 2000). While the state of Florida represents a significant fraction of this activity, comparable fire activity information from all of the southern states is required to fully evaluate the problem. Most of the states lack a fire activity tracking system such as FMIS and implementing such a system will likely require a substantial investment by each state as well as a potential revamping of business practices.

The Southern High Resolution Modeling Consortium, as a party interested in regional fire activity data is currently developing a database system similar to the prescribed fire tracking component of FMIS that could be used by other states to track their prescribed fire activities. In an effort to minimize changes in forestry agency daily business, this system is designed to shift the data entry burden to the user rather than a dispatch officer. The system is designed to provide the user with tools to assist in the preparation of burn prescriptions following a flexible template.

The user's prescription then moves through a set of stages: planned, active, executed and evaluated. The planned stage is simply the creation of the prescription. Users may have any number of prescriptions in the system and when conditions look good for a prescription can be moved to the active stage. When active, the planned burn is then included in any forecasts produced by 4S allowing the user as well as air quality agencies to monitor potential smoke issues arising from multiple burns. On the planned day of the burn the fire transitions to the execute stage and is considered part of the state's prescribed fire activity data for that day. The final stage is an evaluation stage that allows a user to document the accomplishments of his burn, such as the actual number of blackened acres. This information is used to adjust that state fire activity numbers to provide for a more accurate emission inventory. Remote sensing is another avenue being pursued as a means of capturing fire activity data.

SUMMARY

We have described initial steps toward an operational air quality forecasting system for assessing the potential impacts of wildland fires. The system integrates fire activity information from the Florida Fire Management Information System into a smoke modeling framework to provide estimates of air quality impacts such as surface PM2.5 and ozone concentrations. The system is highly dependent upon the fire activity data which must include location, size, time and

ignition method of the fire to adequately describe the emission source. An open and flexible database architecture is being developed to try and capture this data from other states (currently North Carolina is exploring this database option).

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KEYWORDS
Smoke, wildland fire, prescribed fire, emissions, modeling

FIGURES

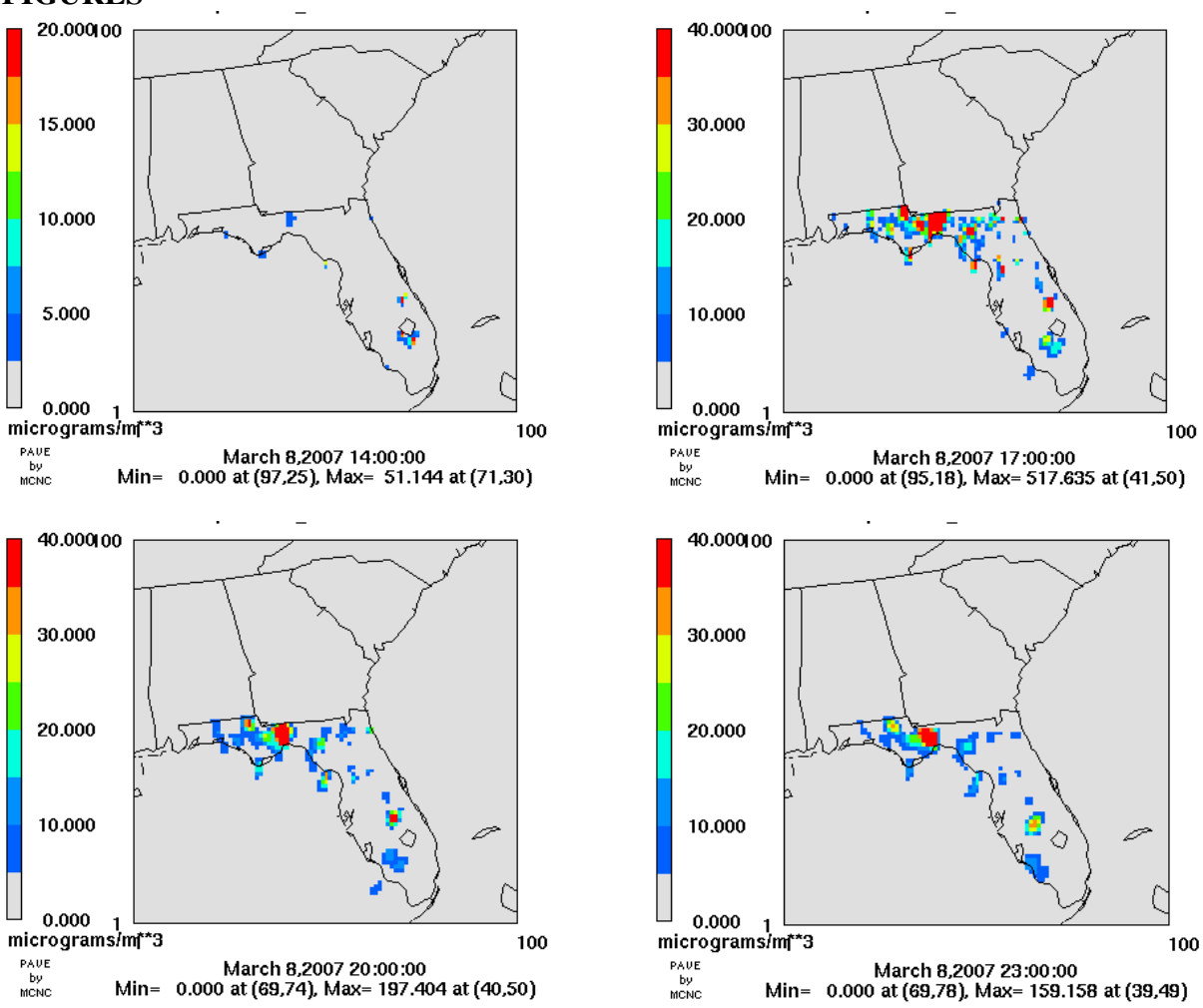

Figure 1: Surface one hour average PM2.5 concentration forecast produced by Southern Smoke Simulation System