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The Southern High-Resolution Modeling Consortium - A Source for Research and Operational Collaboration

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1. INTRODUCTION

The Southern High-Resolution Modeling Consortium (SHRMC) is one of five regional Fire Consortia for Advanced Modeling of Meteorology and Smoke (FCAMMS) consortia established as part of the National Fire Plan. FCAMMS involves research and development activities collaborating across all land management agencies, NOAA, NASA, and Universities. These activities will support fire fighters by developing and disseminating high-resolution fire weather, fire danger, fire behavior, and smoke management products. FCAMMS products will merge the latest science in weather forecasting and satellite observations with existing models and fire science to increase accuracy of information used by fire weather forecasters and fire intelligence officers to control wildfires more quickly and manage all fires more efficiently.

2. THE SOUTHERN HIGH-RESOLUTION MODELING CONSORTIUM

2.a. SHRMC background

In 2000, a smoke management project called the Technically Advanced Smoke Estimation Tools (TASET) produced a structured analysis of smoke management modeling and recommended specific developments for advancing the state of the science in the field of fire weather and smoke management (Fox and Riebau, 2000). An outcome of TASET was the recognition that spatially and temporally high-resolution weather prediction data was critical to the success of any operational smoke estimation program. Because of the enormous computing requirements and local contingencies involved with high-resolution weather data, it was recommended that the Country be divided into regions with modeling centers supporting each region. The modeling centers would be patterned after the operational high-resolution modeling consortium in the Pacific Northwest (Ferguson, 1998).

Including the Pacific Northwest Consortium, there are currently five FCAMMS centers. Figure 1 shows the locations of the centers and the areas of the Country served by 12 km modeling domains from each center. SHRMC, located at the University of Georgia at Athens, is planned to provide smoke and fire weather information to the thirteen southern states that comprise the USFS Region 8. The domain includes the states roughly south of the Ohio River and Texas eastward.

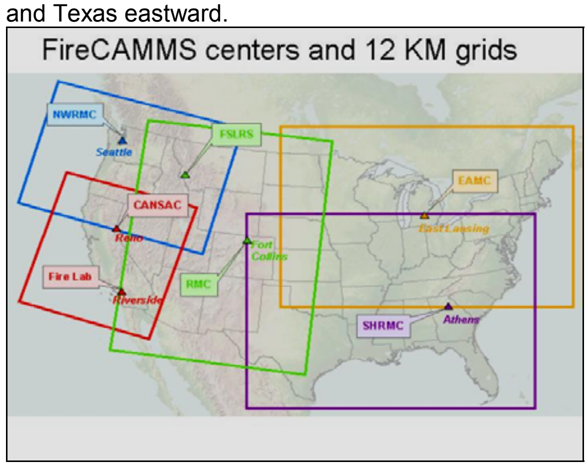

Figure 1. Areas of 12 km grids and locations of the five FCAMMS centers.

2.b. SHRMC physical facilities

SHRMC is constructed around four basic principles. First, the models required for high-resolution weather prediction are complex. They require extensive data sets for initialization, consume computer resources and generate huge data sets (~5 gigabytes) that must be subjected to post-processing before products can be made available to users. Second, the information, skills, and costs needed to operate these models are greater than any single agency can afford. Manpower needs range from computer hardware technicians, to software specialists, to technology transfer specialists, to basic researchers who validate model parameterizations, to applied researchers who develop products from model outputs. Third, shared funding reduces single party costs. An enterprise such as SHRMC will be able to produce fire and smoke related weather products on a 24/7 basis over the long haul with stable funding from diverse sources. And fourth, the

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products developed via SHRMC must be tailored to user need.

Figure 2 shows a conceptual model of how SHRMC works. An inner ring consists of a small group of scientists who run the high-resolution numerical weather prediction model (currently MM5) and ancillary models. They provide the results in formats useful for others. The middle ring consists of a larger group of scientists who take the data from the inner ring and combine it with other information to produce products for agencies. The outer ring consists of agencies that are a part of SHRMC who provide funding and problems for the inner and middle rings.

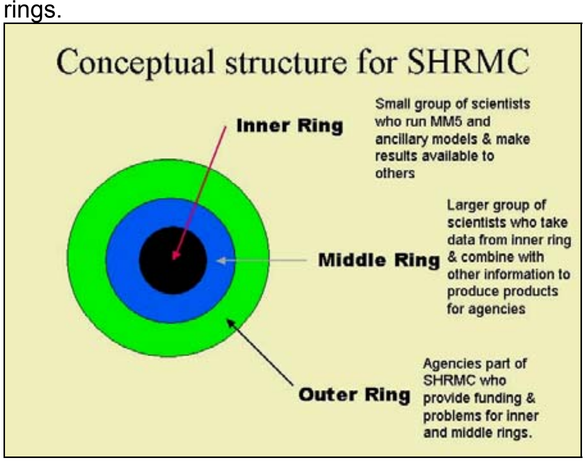

Figure 2. Conceptual structure for SHRMC.

Consistent with Figure 2, SHRMC is structured around a Board of Directors and an Advisory Board. The Board of Directors consists of the core group of scientists who make the decisions necessary to perform the duties required for the inner ring. The Advisory Board consists of representatives from the various agencies that participate in SHRMC. They promote SHRMC, provide funding and problems to solve, and give general oversight to the Directors so that problems of interest to the user community remain central to the objectives of SHRMC. The Directors make the decisions necessary to carry out the requests of the Advisors.

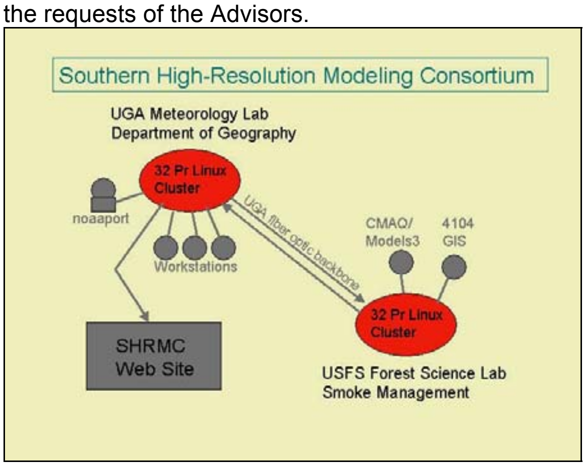

Figure 3. Layout of the computer facilities for SHRMC

SHRMC requires considerable computer power to carry out its mission. The computing system is structured around two 32 processor cluster computers (Figure 3). Each computer is rated at 20 gflop. The first computer is located at the University of Georgia Department of Geography. It became operational in August 2002. It is connected to a four-channel NOAA-Port system that is the gateway for observed and modeled weather data. This computer is linked to a cluster of workstations that manage the SHRMC web page and provide connects for researchers to access model outputs. It is designated as the technology transfer/operational computer. The meteorological model MM5 has been operational since January 2003.

The second 32 processor cluster computer, located at the USFS Southern Station Forest Sciences Laboratory also on the UGA campus is devoted to research and development of new models. The two cluster computers are linked through the UGA fiberoptic backbone. A group of workstations are linked with the research computer to provide Forest Service scientists direct access to model outputs. The research computer is expected to be completed later this fall (2003).

2.c. SHRMC Research Priorities

SHRMC plans to include a diverse group of partners whose common need is for products derived from high-resolution numerical weather models. There are several research areas SHRMC can support. Among these are fire and smoke.

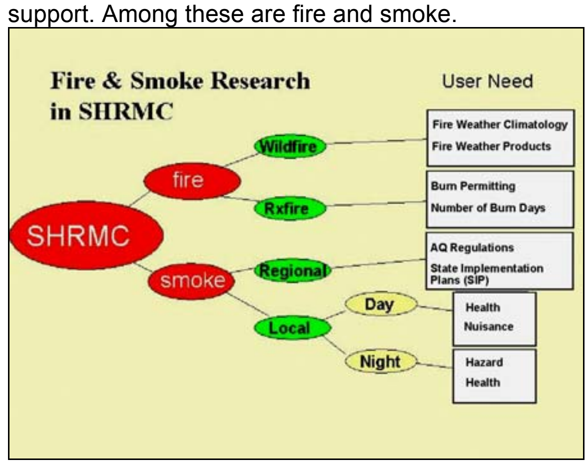

Figure 4. Fire and smoke research priorities in SHRMC.

Figure 4 shows the scope of fire and smoke research in SHRMC. Wildfire and prescribed fire are separate categories because the user need differs. Fire weather products critical for wildfire management are less important for prescribed fire than identifying conditions for burn permitting and accurately defining and extending the number of burn days. Smoke products also vary from the regional to the local scales. On the regional scale, modeling of air quality measured in terms of PM2.5 particulate matter and air chemistry is needed to assist users in meeting air quality regulations and defining State Implementation Plans. On the local scale, smoke modeling focuses on helping users address problems of nuisance smoke over local sensitive targets and hazards to transportation caused by smoke-related visibility reductions.

2.d. SHRMC Products

Products developed via SHRMC fall into four classes.

Class 1. Basic meteorological variables fall into Class 1. These include wind speed and direction, temperature, relative humidity, and geopotential height at various levels within the MM5 model domain. Derived variables such as stability, divergence, vorticity, cloud water, and precipitation also fall into the basic variable class.

Class 2. Class 2 products include simple indices derived as smoke or fire weather products. Examples include Ventilation Index, Lavdas Dispersion Index, Mixing Height, Transport Wind, Haines Index, and the Fosberg Fire Weather Index.

Class 3. The power of SHRMC lies in the ability to provide critical high-resolution weather data to complex fire, smoke, and air chemistry models. Class 3 products include those developed from coupled fire-atmosphere models, air chemistry models such as CMAQ, regional scale modeling systems such as BlueskyRAINS, and local smoke models such as PB-Piedmont or PB-Coastal Plain.

Class 4. Class 4 products link short-term and long-term climate with wildfire, prescribed fire, and smoke management. Climatic effects of wildland fires include climatic influences on fire and the impacts of burning on climate. Spatial and temporal variability of fire activities, long-lead seasonal wildlfire prediction, measurements of fuel properties (type, loading, moisture) from the field and remote sensing, and emission calculation and analysis are among the outcomes planned for SHRMC.

Figure 5 shows an example of the use of high-resolution modeling for the simulation of a wildfire smoke plume (Cunningham, et al., 2003). The model used was the Weather Research and Forecast (WRF) model. The inset shows the simulated behavior of a plume under select wind conditions. The simulated plume splits into counter-rotating plumes separated by a mid-region with little smoke. This seems to be an unrealistic result except that the photograph on the right confirms that the phenomenon of plume splitting actually occurs. Models such as WRF will help SHRMC scientists better understand weather conditions that produce erratic plume behavior.

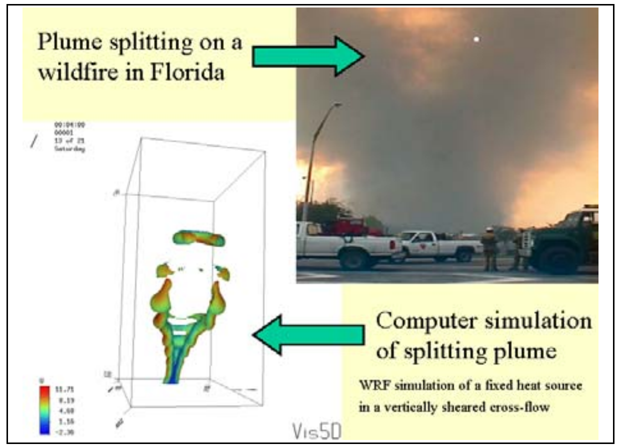

Figure 5. An example of the WRF model simulation of a splitting smoke plume associated with a wildfire in Florida.

PB-Piedmont is a time-dependent high-resolution wind/smoke model designed to assist land managers in determining where residual smoke trapped near the ground goes at night over complex terrain such as that of the Piedmont of the South and East United States (Achtemeier, 2001). Figure 6 shows a “post-burn” analysis of residual smoke from a 402 acre burn conducted in western Georgia on 20 October 1986. At 0630 LST 21 October, a motorist at A encountered zero visibility in smoke/fog. Nearly simultaneously, there was a personal injury accident at B. There was no information on the presence or absence of smoke at C. Black lines identify roadways.

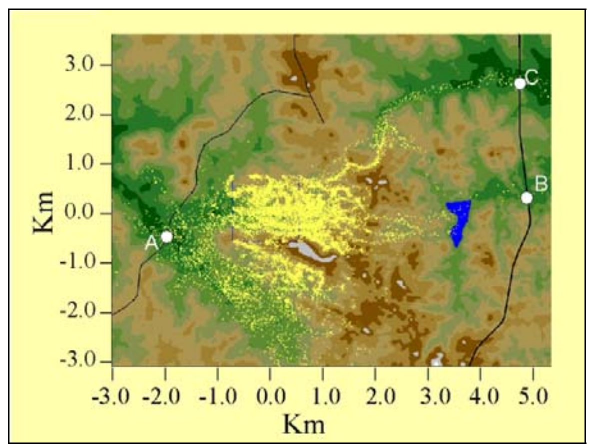

Figure 6. PB-Piedmont simulation of smoke at night from a 402 acre burn in western Georgia on 0630 LST 21 October 1986.

Figure 7 diagrams the Southern Smoke Simulation System (Project 4S) planned as a protocol to assess regional air quality from weather, fuels, and burn data supplied for prescribed burns. One of the challenges for Project 4S is determining where in the atmosphere smoke from prescribed burns is carried. This information is required for properly locating the altitude for calculating air chemistry in CMAQ. An aid

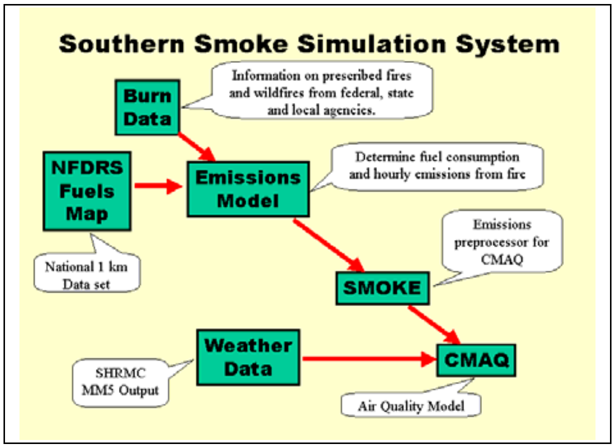

Figure 7. A schematic of the Southern Smoke Simulation System showing the data and models required to convert information from prescribed burns into predictions of regional air quality.

for properly locating and distributing smoke from prescribed burns is an experimental model DAYSMOKE (Figure 8), designed to simulate smoke distribution as it varies during the history of a prescribed burn.

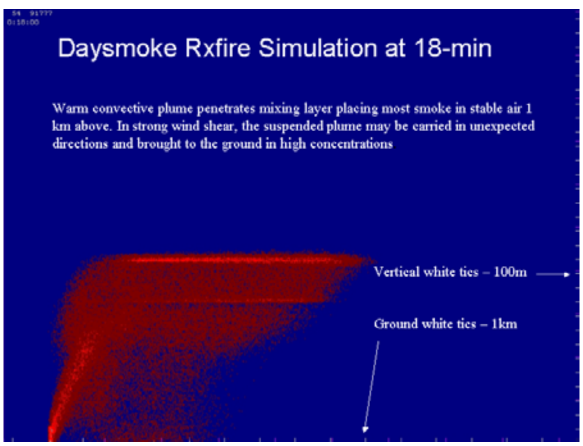

Figure 8. A simulation of vertical smoke distribution from an experimental prescribed burn plume model - DAYSMOKE.

DAYSMOKE is a turret growth model adapted from a model for smoke and ash plumes from sugar cane fires (Achtemeier, 1998). It is designed to simulate smoke rise and distribution in a veering/shearing wind field with variable stability. The model generates a cloud of particles to represent smoke. Each particle is assigned a fall speed typical of that for smoke. DAYSMOKE can distribute smoke within the "ventilation layer" and/or entrap smoke in the stable atmosphere above the mixed layer.

Satellite remote sensing has shown promise as a technique for detecting wildfires. By measuring changes in surface vegetation, satellites can also detect areas burned from prescribed fires. Information of the size of areas burned can assist in calculations of emissions for input into regional air quality models. However, many southern prescribed fires are too small to be measured by satellite. The significance of a large number of small burns to the overall emissions inventory is critical for the accuracy of air quality modeling in the South.

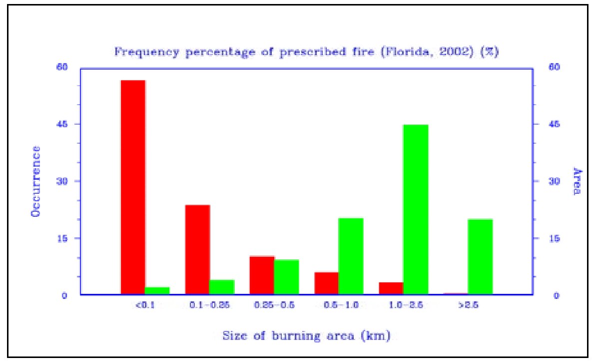

Figure 9. Percentages of the number of burns (red) and size of the burns (green) for various size categories for prescribed burns in Florida during 2002.

Figure 9 shows the percentage frequency of prescribed burns in Florida during 2002 along with the percentage frequency of the size of the area burned. The size of the area burned is defined as the side of a square of area equal to the area of the burn. This figure illustrates that a small number of fires (about 20 percent) with the size larger than 250 m account for about 95 percent of the total area burned. The minimum spatial resolution for MODIS is 250 m. Therefore, if the area burned can be equated to emissions, and other factors such as crown cover are negligible, about 95 percent of the total smoke emissions may be detectable by MODIS.

3. DISCUSSION

The Southern High-Resolution Modeling Consortium (SHRMC) is planned as a mechanism to provide smoke and fire weather products that are designed for use by Southern land managers. As part of the national Fire Consortia for Advanced Modeling of Meteorology and Smoke (FCAMMS), SHRMC shares products with other consortia. This includes products such as BlueskyRAINS, developed by the Pacific Northwest Consortium in association with EPA.

The power of SHRMC lies in its ability to provide high-resolution weather data for complex fire, smoke, and air chemistry models. This allows scientists to gain understanding of complex processes involving fire and smoke. New knowledge can be translated into answers to the questions land managers are asking today and will ask tomorrow.

4. ACKNOWLEDGMENTS

The support of Ken Forbus and Tim Giddens in computer construction and software implementation is critical to the success of SHRMC.

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