Fire Consortia for Advanced Modeling of Meteorology and Smoke - FCAMMS

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Abstract

USDA Forest Service Research and Development is leading a national effort to develop cooperative centers (Fire Consortia for Advanced Modeling of Meteorology and Smoke / FCAMMS) for high-resolution mesoscale meteorology modeling. FCAMMS are addressing problems in fire and smoke management by providing regional simulations of weather and weather-dependent phenomena including fire danger, fire behavior, and smoke distributions. Weather elements such as wind speed and direction, temperature, precipitation, and humidity as well as smoke, fire, and fire-weather indices (e.g., ventilation, Haines, Fosberg , US National Fire Danger Rating System, and Canadian Fire Danger Rating indices, etc.) are generated on grids with 12 km spacing (many areas at 4 km spacing) for the entire continental USA. While maintaining a regional focus by providing local priority products, each Consortium also produces nationally relevant simulations. These simulations represent hourly changes in each element, starting from observed conditions and predicting up to 48 hours into the future. These model simulations are used for trials in fire-weather assessments, fire danger, fire behavior, and smoke management as well as for research and development into improved fire and smoke intelligence.

FCAMMS grew from the recognition that cooperation was needed to address fire weather and smoke problems. The Northwest Regional Modeling Consortium, a leading example of the value of cooperation, arose with Forest Service participation in 1995 and provided the prototype for the other Consortia. A consortium approach was selected for many reasons, but the complexity and costs of obtaining input data for simulations and the complexity of the models themselves were strong motivating factors. Although initially funded as a research activity (expanding ideas pioneered by the work in the Pacific Northwest) under the USDA Forest Service component of the National Fire Plan, FCAMMS have been designed to build broad partnerships among the fire weather, fire research, and air quality regulatory communities while ultimately transferring better technologies to user communities. They have also provided much-needed boosts for Forest Service fire research capacity and advanced computational technologies. The paper will provide an overview of the five (5) FCAMMS currently in operation. Each provides interim research products to cooperators, partners, and others interested in high-resolution meteorological fire intelligence. Each consortium will implement new products that can be evaluated immediately, and they will each carry forward longer-term development and research products refined for utility, special regional needs, and reliability

Introduction: **A** critical research component of the National Fire Plan calls for the development, improvement, and validation of models for fire-weather, fire danger, fire behavior prediction, fire hazard rating, and smoke management in wildfires and prescribed fires. Responding in September 2000, the USDA Forest Service's Deputy Chief for Research and Development issued an internal request for research proposals for the regional collaborative efforts identified above.

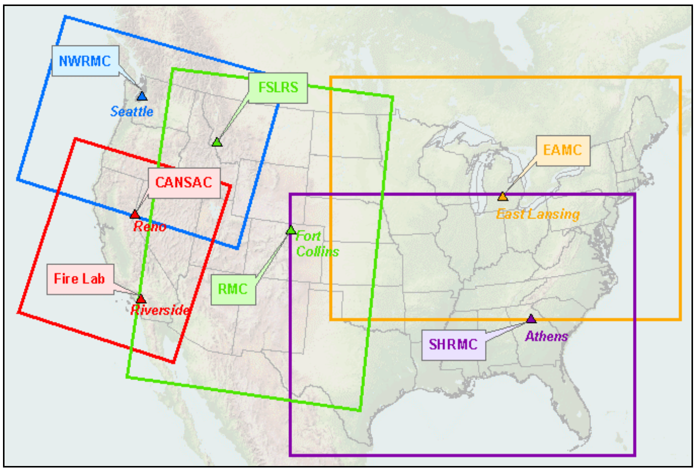

Figure 1. Locations of the five Fire Consortia for Advanced Modeling of Meteorology and Smoke (FCAMMS) established under the United States of America National Fire Plan and the 36 KM geographic domains covered by the individual consortia.

In response to this request scientists within the atmospheric research program of the USDA Forest Service developed a research and product development strategy built around the concept of regional modeling consortia. Scientists at five USDA Forest Service research stations were funded to develop five regional Fire Consortia for the Advanced Modeling of Meteorology and Smoke (FCAMMS), as shown in Figure 1. Each regional Consortium is a multi-agency coalition of researchers, fire managers, air-quality managers, and natural resource managers at the federal, state, and local levels.

The Consortia mission is to:

- Increase understanding of fire-weather, fire danger, fire behavior, and the transport, diffusion and impact of smoke from fire;
- Develop and implement new technologies related to regional fire-weather and air-quality;
- Enhance our ability to use fire for land management purposes, and;
- Improve tools for fire fighters by better predicting the dangers of wildfire.

In order to deliver this mission, the FCAMMS are developing and maintaining contemporary computational and data processing resources for US fire fighting and smoke management use. The computer requirements needed to simulate high-resolution meteorology include very large data processing and storage capacities, high-speed calculation capabilities, broadband communications facilities and web-based, map-based graphical displays. In general, these capabilities are being provided through the use of clusters of multiple PC processors operating under LINUX systems, utilizing large RAID disk array data stores and relying on the World Wide Web for communication. To a large extent these represent new and different ways for Forest Service to do business. FCAMMS have also led to significant improvements in the internal capacity of the USDA Forest Service Research and Development hiring scientists and technicians with modern computer and atmospheric sciences skills.

Consortium Approach: FCAMMS are developing as consortia for a number of reasons. First, contemporary atmospheric sciences require partnerships and sharing of resources. The wide array of skills required in the FCAMMS mission as well as the very high cost of facilities and tools suggest a partnership approach. Second, the USDA Forest Service can not maintain a competitive position doing the sorts of research "on its own" because of its limited number of research meteorologists. Third, there are others available for partnerships that represent expertise and capabilities well beyond any that the Forest Service might ever hope to develop or maintain.

For example, simply generating the information required to simulate high-resolution, real-time meteorology requires:

- access to data generated by global-scale weather forecast models run by sister federal agencies, international institutions, universities, the US military and others;
- a capability to ingest these model data and simulate timely, higher-resolution, realistic regional meteorology;
- a capability to understand, analyze, and compare with ground based and satellite observations, critique, verify, and improve these regional meteorological simulations, and;
- a capability to ingest fire activity data and use it with the meteorological simulations to estimate smoke emissions, transport, transformation, dispersion and removal.

Land managers are not likely to do this alone because they often lack needed access to satellite observations and forecast model data. The required skills, communications capacities and research capabilities are well beyond US federal land manager norms. Meanwhile others, especially universities and other US government agencies including the military, National Aeronautics and Space Administration (NASA), National Oceanic and Atmospheric Administration (NOAA) and the Environmental Protection Administration (EPA), are on the cutting-edge of developing the technologies and capabilities required. Finally, the expense and complexity of this job is well beyond the capability of land management budgets. Hense, the consortium approach, taking advantage of expertise in other agencies and universities is the only approach that makes sense.

The FCAMMS have established and continue to seek a wide variety of research and technology transfer partnerships with numerous federal, state, and local agencies and private organizations (see Table 1). The ideal FCAMMS is structured around a small 'inner core' group of scientists and technicians who run high-resolution meteorological simulation models, such as MM5 and similar ancillary models and who make results available to others (scientists). A relatively larger group of specialists who take data from the 'inner ring' and combine it with other data, other types of model simulations, observational data to produce information and information based products for agencies (information suppliers). In the ideal case, the largest component ('outermost ring') of the FCAMMS is populated by individuals and agencies that use the information (users). Ideally, the users will provide feedback, guidance, funding, and help in identifying problems for scientists and information providers.

Table 1. FCAMMS current members and partners with model run information.

FCAMMS	Members and Partners	Frequency	Run Time	Model Domain Grid Spacing
Eastern Area Modeling Consortium (EAMC) East Lansing, Michigan http://www.ncrs.fs.fed.us/emac	USDA Forest Service, North Central Research Station, Northeastern Research Station, USDA Forest Service Region 9 Aviation and Fire Management and Air Resources Management Program, Northeastern Area State & Private Forestry, Eastern Area Geographic Coordination Center, North Carolina State University, University of Utah, Jackson State University, University of Wisconsin, NOAA Air Resources Laboratory	Twice-daily	48hr	36km, 12km, 4km (1 Km planned over New Jersey)
Northwest Regional Modeling Consortium (NWRMC) Seattle, Washington http://www.atmos.washington.edu/pnw_environ/	National Weather Service, University of Washington, Washington State University, USDA Forest Service Pacific Northwest research Station, Port of Seattle, United States Navy, U.S. Environmental Protection Agency, Washington State Department of Ecology, Puget Sound Clean Air Agency, Washington State Department of Natural Resources, Washington State Department of Transportation, Seattle City Light	Twice-daily	72hr 48hr	36km, 12km, 4km
Southern High Resolution Modeling Consortium (SHRMC) Athens, Georgia http://shrmc.ggy.uga.edu/	University of Georgia, Georgia Forestry Commission, USDA Forest Service Region 8, USDA Forest Service Southern Research Station, National Weather Service	4 times - daily	48hr	36km, 12km
California and Nevada Smoke and Air Consortium (CANSAC) Reno, Nevada and Riverside, California http://www.fs.fed.us/fcamms	Desert Research Institute, University of Nevada, University of California – Santa Barbara, University of California – San Diego, Maui High Performance Computer Center, Naval Postgraduate School, Scripps Institute, USDA Forest Service Pacific Southwest Research Station	Twice-daily Twice-daily Twice-daily	48hr 48hr 48hr	36,12,6,4,2 km 108,36,12k 27,9,3,1km
Rocky Mountain Modeling Consortium (RMC) Fort Collins, Colorado http://www.fs.fed.us/rmc/	USDA Forest Service Air Resources Program, NOAA Forecast Systems Laboratory, Rocky Mountain Area Geographic Coordinating Center, Southwest Area Geographic Coordinating Center, USDA Forest Service Rocky Mountain Station	4 times - daily	24hr	12km, 4km (as of Mar 2003)

Within the wildfire community this idealized structure is already pretty well implemented. Forest Service Research and Development has initiated the FCAMMS and is providing funding support for the inner core of scientists and technicians, mostly Forest Service employees and university scientists and students. The information suppliers in this case are the fire program's National Interagency Coordination Center (NIFC) and predictive services capability delivered through the Geographic Area Coordination Centers (GACCS). Finally, the fire management community as a whole represents the final set of users for these products. Unfortunately, roles for both information providers and users, including state air quality regulators are not well identified for applications in air quality and smoke management.

Each Consortium conducts basic and applied research on new fire-weather and fire-climate index development, seasonal fire severity, small-scale fire-atmosphere interaction dynamics, smoke emissions, transport and diffusion, and coupled fire-atmosphere modeling. In support of these research goals, each regional consortium produces daily, regional predictive simulations of weather, fire-weather, and transport/diffusion variables using a common set of modeling tools (e.g. the MM5 mesoscale meteorological model, Grell et al. 1994) over the domains as shown in Figure 1. Individual consortium web sites make this information available to the user community on a daily basis. Users are provided a variety of map products and analyses depicting the current and 24-48 hour atmospheric conditions relevant for fire-weather, fire behavior, and smoke transport and diffusion. All the consortia are committed to improving their products work by feedback from their user communities and field verification studies. Table 1 also provides a summary of the FCAMMS simulations and websites.

FCAMMS products:

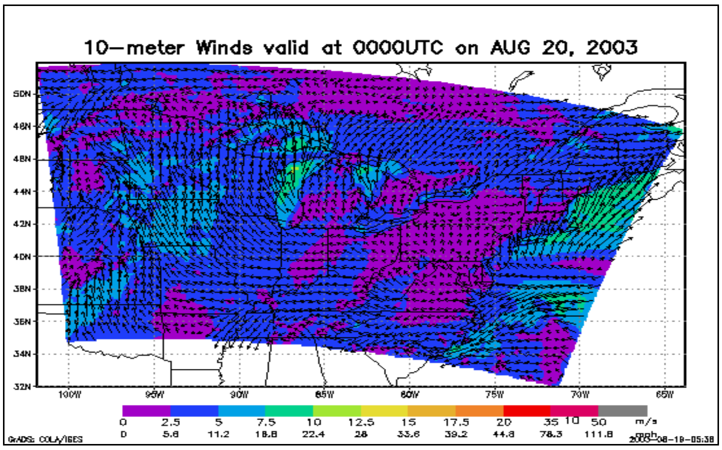

Figure 2. EMAC map of 10-meter Wind (meters/sec) at 12km resolution initialized at 0000 August 19, 2003, 24 hours after model initialization.

High-resolution weather variables

All of the consortia provide a range of weather products simulated using the MM5 model on grid resolutions of 36 km and better. Figure 2, from the Eastern Area Modeling Consortium, illustrates a 24-hour forecast of the surface wind vector for the 12 km grid for the eastern US. Figure 3, from the Southern High Resolution Modeling Consortium, illustrates a 48 hour forecast providing intelligence about possible future wind and moisture conditions.

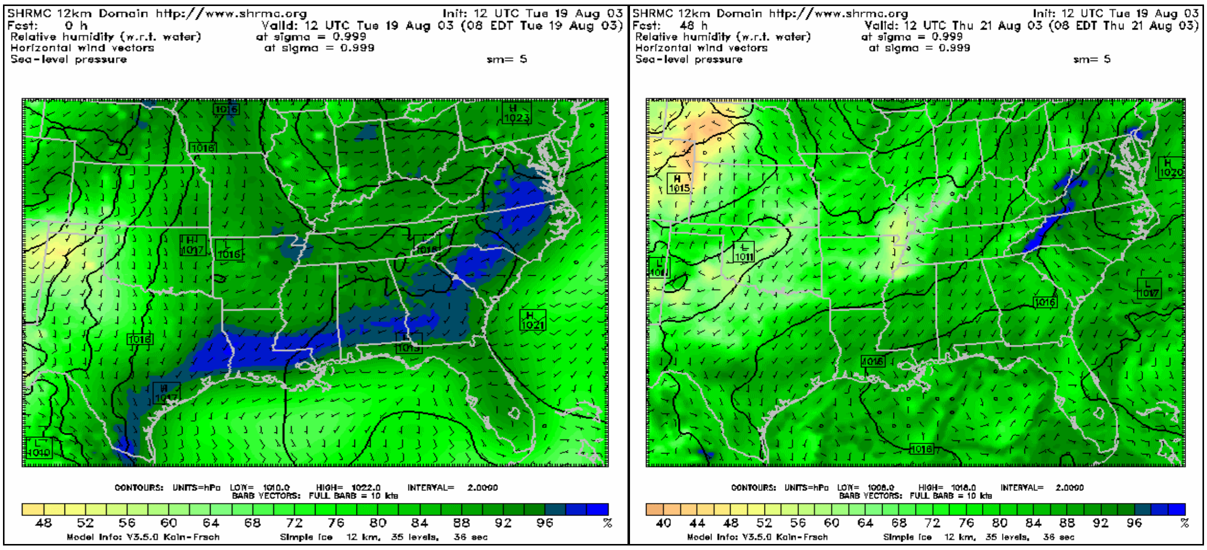

Figure 3. Illustration of a forecast from the 12 km resolution MM5 simulation by the Southern High Resolution Modeling Center (SHRMC) of surface relative humidity, wind vectors, and surface pressure initiated at 00z, August 19 and at 08:00 on August 21.

High-resolution fire indices

Figure 4 from the Northwest Regional Modeling Consortium MM5 simulations, illustrates the change over time in the pattern of the forecasted Haines Index. The Haines Index is a simple measure of the chance that an existing fire will become a dangerous, erratic fire. It reflects atmospheric stability and moisture in a layer of the atmosphere roughly 1 to 5 km above the surface. High values indicate higher risk of dangerous fire behavior (Haines, 1988). Figure 5, from the Rocky Mountain Modeling Consortium's southwestern window, illustrates the forecast changes on a 4 km resolution of the Fosberg Fire Weather Index. The Fosberg Index is a measure that reflects expected flame length and fuel drying based on wind speed, temperature and humidity. High values indicate high flame lengths and rapid drying (Fosberg, 1978). Figure 6 illustrates the California Fire Weather index, a variant of the Fosberg Fire Weather Index. This index results from combining wind, temperature and humidity information as used by the National Fire Danger Rating Program (NFDR; Deeming, et.al. 1977). In essence, the CFWI suggests where it will be hot, dry and windy, hense increasing the likelihood of fires. The color-coding goes from low values in green toward higher values in red. Figure 6 illustrates a 7-day forecast done by the CANSC at the USDA FS Riverside Fire Laboratory and University of California at San Diego, Scripps Institute of Oceanography's Experimental Climate Prediction Center**.** The figure illustrates the value of longer range, higher-grid resolution model information for fire fighters.

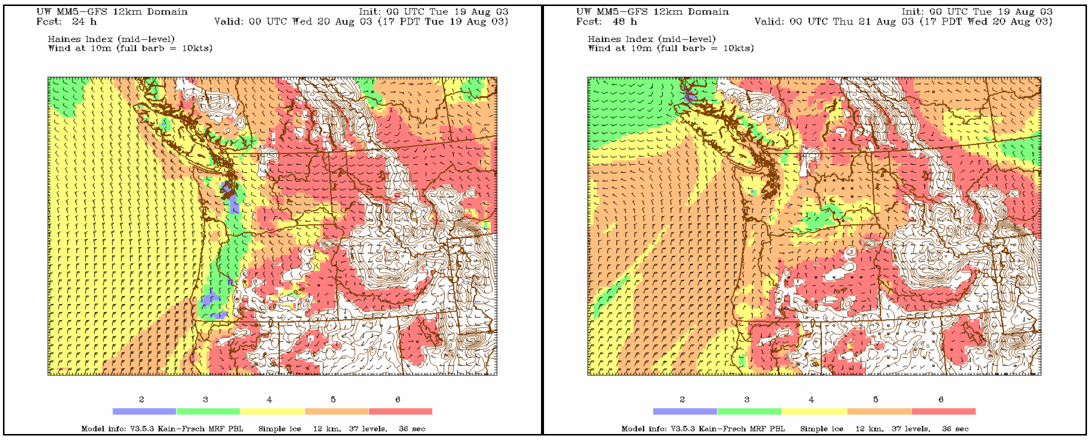

Figure 4. Illustration of the forecast Haines index, initialized at 00z 19 August, 24 hours into the forecast and the same after 48 hours based on a 12 km resolution MM5 simulation from the Northwest Regional Modeling Consortium (NWRMC).

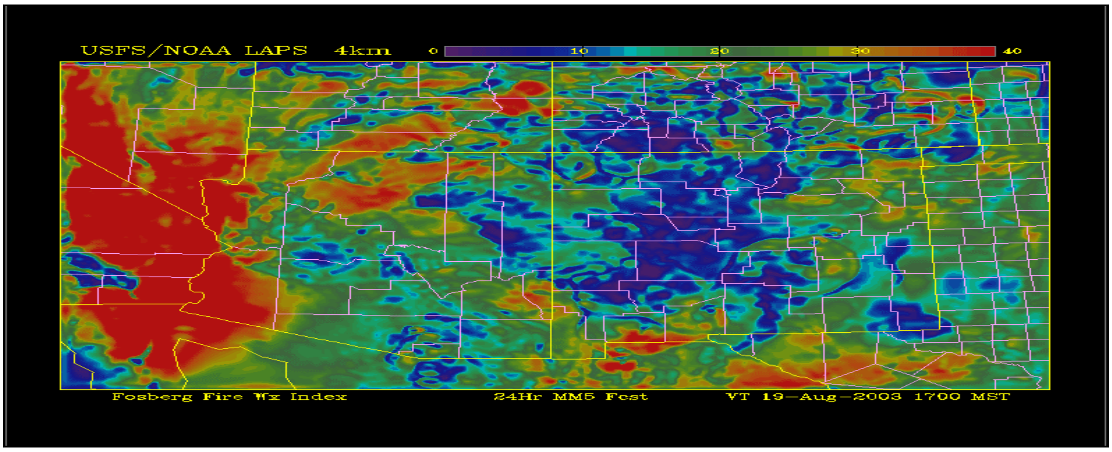

Figure 5. Illustration of Fosberg Fire Weather Index (red highest value) predicted from the Rocky Mountain Modeling Center's 4 km MM5 simulation over Arizona and New Mexico.

Fire Danger Rating Products

An evolving, more complex application than the various indicies uses data from a variety of sources to derive several parameters of the U.S. National Fire Danger Rating System. Each day local meteorological observations collected by the Remote Automated Weather Stations (RAWS) network are used to calculate the Keetch-Byram Drought Index and moisture indexes of the 100-hour (about 2.5 cm to 8 cm in diameter) and 1000-hour (about 8 cm to 20 cm in diameter) dead woody fuels. These data are spatially interpolated to 1-km and then re-projected to match the MM5 grid.

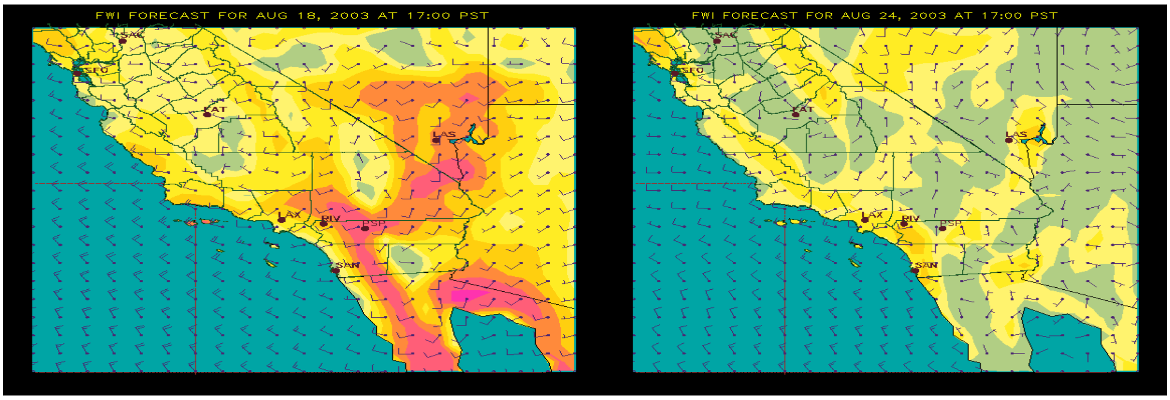

Figure 6. California Fire Weather Index (red as highest index value), produced by the California Smoke and Air Consortium in collaboration with Scripts Institute. The forecast is for 7days, illustrated as a 24-hour forecast at 17:00 August 18 and 168 hour forecast at 17:00 for August 24.

Relative greenness maps are derived weekly from Normalized Difference Vegetation Index (NDVI; Burgan and Hartford, 1993) data observed by AVHRR satellites and provided by the EROS Data Center (EDC), U.S. Geological Survey. These maps are developed weekly with 1.1-kilometer spatial resolution and can be projected to the MM5 grid, and used to estimate live fuel moisture. Each hour, fine fuel moistures (1-hour, < about 1 cm, and 10-hour, about 1 cm to 2.5 cm) are derived from MM5 predictions of wind, relative humidity, air temperature, and estimated cloudiness. Wind values, temperature and relative humidity can each be interpolated from the model predicted surface layer. Cloudiness is derived from moisture conditions in the upper atmosphere. The map projections of observed values and predicted values from MM5 are combined to predict hourly values of the NFDR, Energy Release Component (ERC), Spread Component (SC), Burning Index (BI), and Ignition Component (IC). An example of how this scheme functioned during the 2000 wildfire season (Figure 7) in Idaho and Montana is provided by the NWRMC.

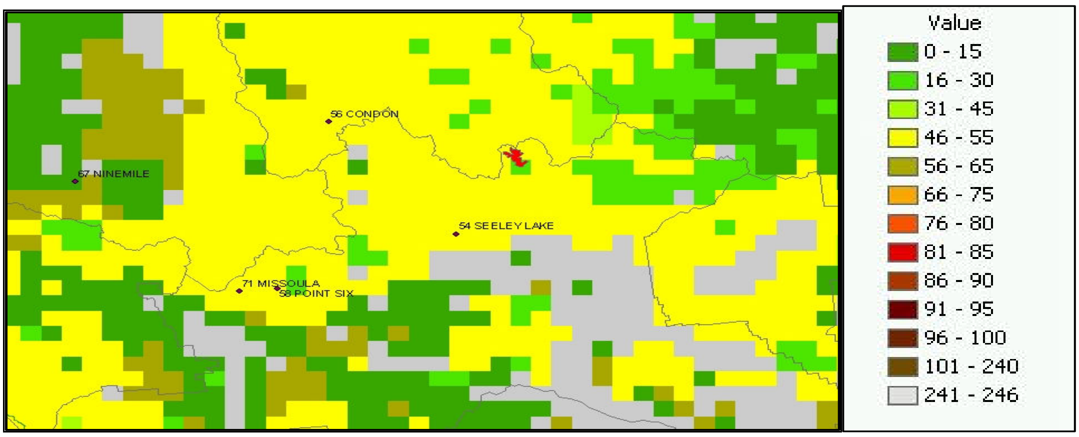

Figure 7. Energy Release Component of the U.S. National Fire Danger Rating System, predicted 12 hours in advance from the MM5 meteorological model at 4-km spatial resolution during the Monture/Spread Ridge fire complex in western Montana for 27 July 2000.

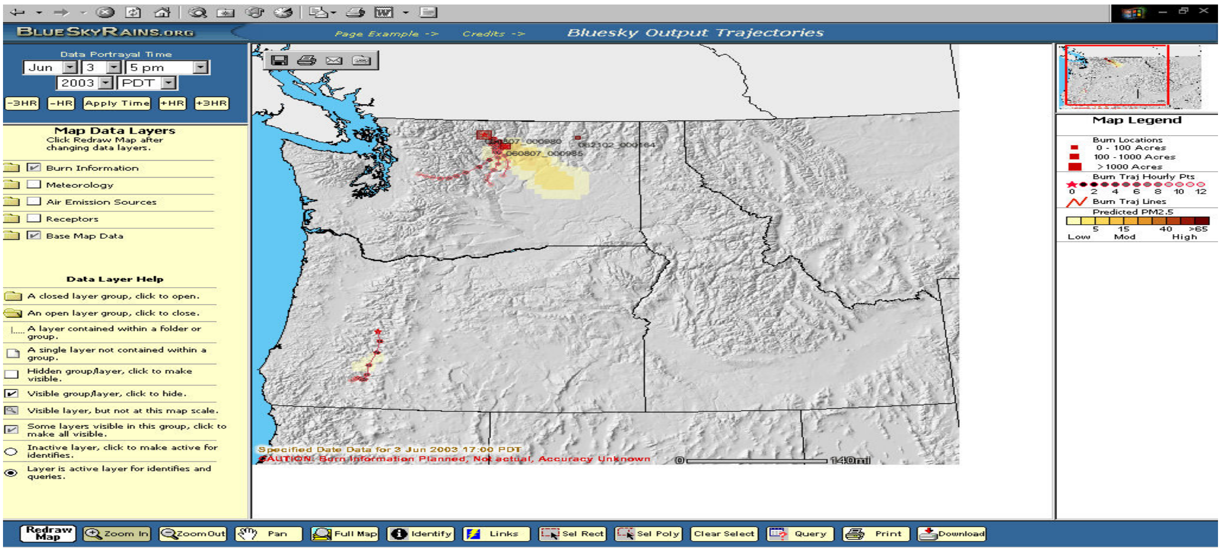

Figure 8. Wildfire smoke trajectories and concentrations as illustrated by the BlueSky/RAINS (NWRMC) system for prescribed fire activity on June3, 2003.

Smoke Dispersion Products

A major justification for the FCAMMS is to provide intelligence for managing smoke from forest burning. Smoke management has strategic planning, tactical planning and operational aspects to it. For the purpose of strategic planning applications are needed that can consider regional scale impacts on issues such as the contribution to regional haze and ozone. For tactical planning, there is a need for a permitting tool; one that allows some indication of where smoke is likely to go once a fire is ignited. For the operational application, there is a need for real-time forecasts of smoke impacts from individual and groups of potential and actual fires. Although the FCAMMS will eventually address all of these applications the operational application is currently the best developed using the BlueSky modeling framework. The BlueSky smoke-modelling framework is a flexible framework for obtaining smoke impacts by combining fire location information, forest fuels, outputs from MM5 meteorological simulations and air quality dispersion models (e.g., the CALPUFF) to illustrate where smoke will go and how much of it will get there. The NWRMC is cooperating with the US EPA to prototype the BlueSky/RAINS program. BlueSky/RAINS links the BlueSky smoke modeling framework with the Rapid Access INformation System (RAINS) based web serving technology. RAINS utilizes the ArcIMS / geographic information system (GIS) to allow for data overlays from a variety of geographical data. BlueSky/RAINS is currently being tested in the US Pacific Northwest. Figure 8 illustrates some of the capability of the BlueSky/RAINS system to provide information about the likely trajectories and ground level concentration impacts from prescribed fire activity. The GIS provides great flexibility displaying the results.

Conclusions and Next Steps: Continuing issues associated with the FCAMMS include solidifying each consortium, including its participants (through formal agreements), funding and projects. FCAMMS must also be provided a national overlay to the regional activities of each consortium. Each consortium has grown naturally based on the interests and capabilities of the scientists and managers involved in its development. While this spirit will continue, there remains a need for nationally common products.

The BlueSky framework represents a significant step forward in dealing with smoke emissions, and the FCAMMS plan to implement it in each consortium. However, there are challenges in doing this. One is a concern for how to provide data on fire locations and fire emissions for the system nationally (Battye and Battye, 2002; Sestak, et. al., 2002). Secondly, there is a need to add additional dispersion modeling capabilities to the BlueSky framework, to broaden its applicability for strategic planning. For example, applications, such as Clean Air Act required state implementation plans (SIP), require a specialized inventory of fire data including the date, duration, and location of all major wild and planned fires along with an accurate estimate of emissions and plume rise from such fires. SIPs also require hourly estimates of emissions for a "typical" year, detailed chemical characterization of the emissions for the purpose of driving regional air chemistry models and an ability to "game" the emissions for future years. "Gaming" might include tradeoffs between prescribed and wildfire, as well as alternative locations for fire and the potential for drought and major fire activity. Tactical planning might require more accurate, precise and detailed information about the location and nature of the planned burning. Operational activities will need real-time information, not simply what is planned but what has actually been ignited, for which ground-observations, aircraft over-flight information, and remote sensing will need to be intelligently combined with mesoscale meteorology and dispersion model simulations.

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