J8.7 **THE BLUESKY SMOKE MODELING FRAMEWORK**

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1. INTRODUCTION

BlueSky is a real-time smoke forecasting system that predicts surface smoke concentrations from prescribed fire, wildfire, and agricultural burn activities. Developed by the USDA Forest Service, with funding from the National Fire Plan, and in cooperation with the US Environmental Protection Agency (EPA), it is a tool used by fire managers to aid in burn/no-burn decisions. The BlueSky prototype is currently being evaluated by over 30 members of a modeling consortium, which includes managers, regulators, and scientists from 4 states (Oregon, Washington, Montana and Idaho), 3 tribes, the EPA and all federal land agencies in the Pacific Northwest. It is being used to help coordinate burning activities across land ownerships and to help plan activities to minimize impacts.

A tool such as BlueSky is of critical importance because competition for airshed is increasing. A history of fire suppression has left many forests ripe for catastrophic wildfires. Prescribed fire is a means of reducing the wildfire risk and for re-establishing the natural eco-system. Furthermore, wheat stubble burning and grassland burning are part of the typical practices of many farming communities. Many of these burning activities occur at rural/urban interfaces and can impact sensitive populations such as asthmatics and the elderly. Thus a tool such as BlueSky, by providing daily predictions of where smoke plumes will occur and indicating concentration levels, is extremely useful to burn managers in a variety of agencies making burn/no-burn decisions. Furthermore, by combining prescribed burning smoke with smoke from agricultural burning and wildfires, cumulative impacts from all burning activities can be addressed.

2. THE BLUESKY FRAMEWORK

Currently operational in the Pacific Northwest, BlueSky is a success story of what inter-agency collaboration can accomplish. BlueSky provides daily predictions of where smoke plumes will occur and also provides relative areal impact information by predicting PM2.5 concentrations. Figure 1 shows the five major components comprise the BlueSky modeling framework: Fire Characteristics, Meteorology, Emissions Estimation, Smoke Dispersion, and Web-Display of all the output products.

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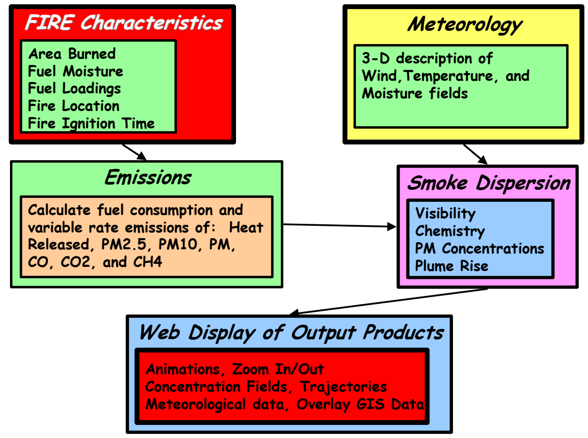

Figure 1. Components of the BlueSky system.

The fire characteristics and meteorology components are the two primary inputs to BlueSky. Fire characteristics include fire location, acres burned, date and time of ignition, ignition duration, and fuel loading and moisture information. These data are typically provided by a burn reporting system. In the Pacific Northwest BlueSky is integrated with two burn reporting systems, the Fuel Analysis, Smoke Tracking, Report Access Computer System (FASTRACS) and the Montana Idaho Airshed Group's burn reporting system known as "RAZU."

FASTRACS is used by federal land managers in the states of Oregon and Washington, while RAZU is used in Montana and Idaho by federal, state, and private land managers. Efforts are also underway to integrate BlueSky with the burn reporting systems in the states of Oregon and Washington. Nightly, BlueSky downloads predicted burn information from these burn reporting systems. FASTRACS provides virtually every piece of fire characteristic information necessary for BlueSky, while the Montana/Idaho system contains only date, acres burned, location (in township, range, section, "TRS"), and ownership. Thus, the BlueSky framework has been developed to obtain other necessary data by other means. Hardy et al. (1998) developed a 1-km resolution mapping of fuel loadings for the western US, and this mapping is used in BlueSky when fuel loadings are not provided by the burn reporting systems. A program to convert from TRS to latitude/longitude is also available, and logic was developed to use reasonable values of ignition duration based upon burn type.

Meteorology is obtained from the mesoscale meteorological model (MM5, Grell et al., 1994) run operationally by the University of Washington's Department of Atmospheric Sciences (Mass et al., 2003). The MM5 domain also defines the BlueSky domain (figure 2). Currently BlueSky utilizes the 12-km MM5 domain that extends from British Columbia, Canada, to Northern California, and from the Pacific Ocean to east of the Rocky Mountains in Montana. In the near future a 4-km domain will encompass much of this same area and then BlueSky will operate on a 4-km domain resolution. A consortium of federal, state, and private interests support the MM5 forecast system (Mass et al., 2003 and Ferguson et al., 2003).

Fire characteristics are processed through the Emission Production Model (EPMv1.02, Sandberg and Peterson, 1984) to give emission estimates of particulates ($PM_{2.5}$, PM_{10}, and total PM), carbon compounds (CO, CO_2, CH_4, NMHC), and heat generated. The emission estimates from EPM along with meteorology from MM5 are processed for the CALPUFF Gaussian dispersion model (Scire et al. 2000) and the HYSPLIT trajectory model (Draxler et al., 1997).

CALPUFF is a puff dispersion model that simulates point, volume or area sources, assuming that plume dispersion occurs in a Gaussian pattern. CALPUFF also estimates plume rise and accounts for density differences between the plume and the ambient air. A pre-processing program, EPM2BAEM, converts the emissions from EPM into an area emission source suitable for input into CALPUFF. It calculates flame height (Cetegen et al.,1982) using the heat-release estimates from EPM and vertical velocity of the smoke plume, assuming conservation of buoyancy flux proportional to heat-release rate.

Twelve-hour trajectories are computed using the HYSPLIT model from each of the burn locations and at evenly spaced ("default") intervals across the domain. These default trajectories are used to give an indication of where smoke from a fire would go if a burn were ignited near the location of the default trajectory. This is useful for the case where a land manager did not get their burn information into the BlueSky forecast. The trajectories and concentration fields yield subtly different pieces of information. BlueSky displays surface concentrations, while the corresponding trajectories can rise and fall in the atmosphere. Also trajectories at a given time are a product of the current and future meteorology (currently a 12 hr period) while concentration fields at a given time are a product of dispersion from a fire ignition time to the current display time. Thus, often the trajectories and concentration fields displayed in BlueSky appear not to agree. Having two such pieces of information located together in time and space is yielding insights into how to model and forecast smoke concentrations from fire on a regional scale.

3. BLUESKYRAINS

The BlueSky concentration fields and trajectories are displayed on the website in the Rapid Access INformation System (RAINS); a Geographical Information System (GIS) application developed by the US EPA. By integrating BlueSky with RAINS, the user can zoom in on areas of interest, step through time, and overlay GIS data layers such as sensitive receptors (e.g., schools, hospitals), geo-political boundaries, meteorology from the MM5 forecast, observational data, and topography. Figure 2 depicts PM2.5 concentrations from 131 planned burns in the Pacific Northwest on May 12, 2003 overlain with GIS layers of, PM10 non-attainment areas, Class I Wilderness areas, Washington State air quality monitors, and gray shaded topographical relief. A user can also use the "identify" button at the bottom of the screen to query the database to obtain the PM2.5 concentration of a particular grid cell or data regarding any other GIS layer. Thus land managers can use BlueSkyRAINS to obtain quantitative information regarding predicted smoke impacts from burning activities.

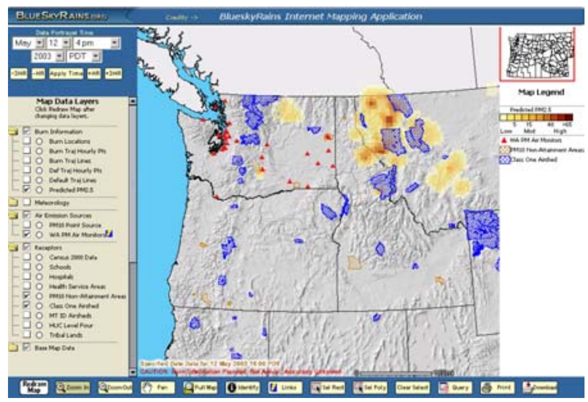

Figure 2. Surface PM2.5 concentrations forecast by the BlueSky smoke prediction system from 131 planned burns for May 12, 2003 displayed in the Rapid Access Information System (RAINS) and overlain with GIS layers of PM10 non-attainment areas, Class I Wilderness areas, Washington State air quality monitoring locations, and gray-shaded topography.

4. BLUESKY AND WILDFIRES

BlueSky, though designed to aid land managers in making their prescribed fire burn decisions, is also being applied to model wildfires. This was first attempted in August/September of 2002 when the managers monitoring the Quartz Complex wildfire in the Pasayten wilderness of Washington State became concerned about smoke impacts across the Canadian border and in small towns in nearby drainages. The land managers provided fuel load estimates for BlueSky, and BlueSky was run simulating a 500 acre per day fire spread. In this effort it was demonstrated that BlueSky could be applied to wildfires with a minimum of burn information (acres/day, location). This wildfire simulation capability was employed regularly during the 2003 wildfire season. The situation ("SIT") reports that summarize regional wildfire activity are monitored daily and these data are input into the daily BlueSky forecast. The smoke modeling consortium that supports the BlueSky development (see section VI for more details regarding the consortiums) is also running twice daily forecasts for the Rocky Mountain Consortium's (RMC) 4-km Southwest domain that covers the states of Arizona and New Mexico to support their wildfire concerns. Figure 3 shows the 4-km Southwest domain and surface PM2.5 concentrations from 6 wildfires occurring July 24, 2003 in Arizona and New Mexico. Results are displayed using a javascript animator, and the gif images were generated from scripts driving the Package for Analysis and Visualization of Environmental data (PAVE).

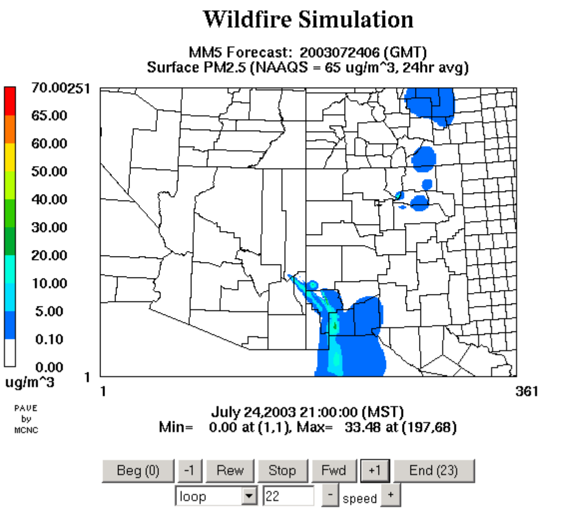

Figure 3. Surface PM2.5 concentrations predicted by BlueSky running for the Rocky Mountain Consortium's 4-km southwest domain. The surface PM2.5 concentrations are from 6 wildfires occurring in the states of Arizona and New Mexico on July 24, 2003.

5. BLUESKY AND AGRICULTURAL BURNING (CLEARSKY)

BlueSky will be integrated with the ClearSky (www.AIRPACT.wsu.edu/ClearSky/index.html) agricultural burning smoke prediction system developed by the Laboratory for Atmospheric Research at Washington State University under contract to the State of Idaho. The ClearSky project is an experimental application of the CALPUFF plume dispersion model, employed in a forecast system to support local smoke managers in Northern Idaho's Kootanai and Benewah counties. ClearSky allows these managers to generate field-burning scenarios and review the resulting CALPUFF simulation results through the project website prior to making burn decisions. The ClearSky system was operated on a daily basis during the August through September 2002 burn season. It is now being expanded to include all of Washington State and to incorporate the Washington State Department of Ecology's real-time observations as part of a real-time verification system for agricultural smoke. Figure 4 shows the expanded 4 km resolution ClearSky domain with PM2.5 concentrations from planned field burning activities in Northern Idaho.

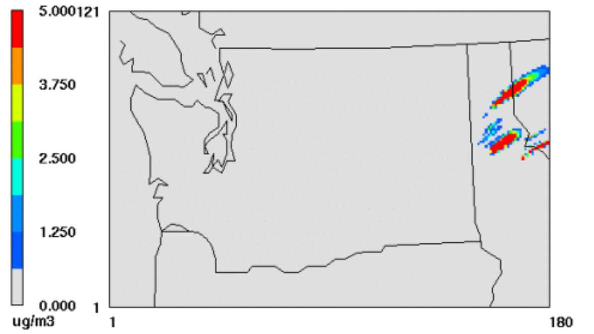

Figure 4. The ClearSky agriculture burn forecast system 4 km domain depicting PM2.5 concentrations from planned field burning activities in Northern Idaho.

6. THE BLUESKY DEVELOPMENT COMMUNITY AND FCAMMS

The BlueSky smoke-modeling framework is a community development project that was born out of a multi-agency smoke modeling meeting in July 2000. Agencies represented by the community of members include the USDA Forest Service Regions 1 and 6, Fire Vision Enterprise, Rocky Mountain Research Station, and the Pacific Northwest Research Station; the Bureau of Land Management, in Washington, Oregon, and Montana; the States of Oregon, Washington, Montana, and Idaho; the Environmental Protection Agency; Pend Oreille, Okanogan, and Quinault Tribes; Fish and Wildlife Service; National Park Service; and several Universities. Members include managers and scientists who meet at least annually, with subcommittees meeting more often to review, discuss, and help direct the development of BlueSky functions and attributes.

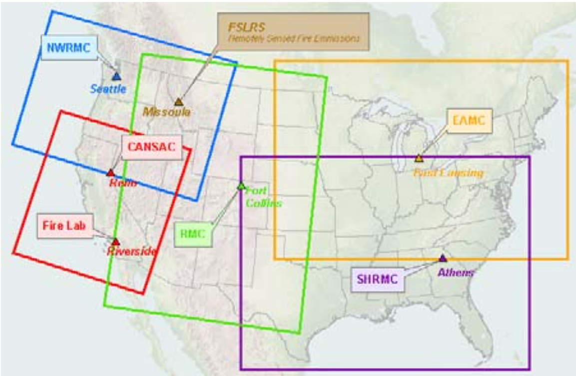

Figure 5. The five Fire Consortia for the Advanced Modeling of Meteorology and Smoke (FCAMMS) domains in which the BlueSky system will be implemented. Each square represents the MM5 forecast domain of the particular consortium.

The BlueSky project is also a member of the Fire Consortia for Advanced Modeling of Meteorology and Smoke (FCAMMS). Multi-agency consortia in all regions of the contiguous US have been modeled after BlueSky's consortium and are embarking on similar modeling and user-support projects. Results from this BlueSky project in the Pacific Northwest will become part of the BlueSky package that is being implemented in other regions. Figure 5 shows the five different FCAMMS regions, where each region is defined by its MM5 forecast system domain.

7. BLUESKY – SUMMARY AND FUTURE DEVELOPMENT

BlueSky is a framework linking together existing systems and models to provide a forecast of surface PM2.5 concentrations from prescribed fire, wildfire, and agricultural burn activities. A success story in the US Pacific Northwest, the system has been operational since July of 2002 with the RAINS GIS capabilities online only since March of 2003. Initial functionality has been achieved but many areas require additional development.

Currently the PM2.5 concentration predictions made by BlueSky are not evaluated, therefore they can serve only as an indication of relative smoke impacts on communities and ecosystems. Evaluation is necessary if land managers are to use this tool to avoid exceeding the National Ambient Air Quality Standards (NAAQS). Air quality monitoring systems are being integrated into BlueSky to provide a real-time evaluation system by summer 2004. In addition, initial results from several case studies are underway (e.g. Adkins et al., 2003 and Berg et al., 2003) suggesting that while timing and location are reasonably accurate, the magnitude of predicted surface concentrations needs improvement.

Development is also underway to incorporate the BURNUP (Reinhardt et al., 1997) emissions model, do a sensitivity analysis, and add additional chemical species to eventually predict the formation of secondary aerosols and ozone downwind of fires. Research is also necessary to evaluate different plume rise algorithms and improve the simulation of fire behavior.

Having tools such as BlueSky in use by land managers is unprecedented. Furthermore, given the extensibility of the BlueSky system, this capability will transfer to other regions across the US.

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