J8.8 ASSESSING ACCURACY OF THE BLUESKY SMOKE MODELING FRAMEWORK DURING WILDFIRE EVENTS

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1. OBJECTIVE

Case study analyses of the BlueSky smoke modeling framework help identify the input values or modeling components that require improvement. BlueSky is a smoke modeling forecasting system that combines burn information with models of consumption, emissions, meteorology, and dispersion to yield a prediction of surface concentrations of particulate matter of diameter less than 2.5 micrometers (PM2.5) and of diameter less than 10 micrometers (PM10) from wildland fire. For additional information regarding the BlueSky smoke modeling framework, see O'Neill et al (2003) in this issue (J8.7). In this work BlueSky has been applied to several wildfires to provide a thorough analysis of system performance. Case studies include the Bitterroot Wildfire Complex of 2000 in Montana and Idaho and the Hayman Fire of 2002 in Colorado. Deficiencies discovered in individual model components during the course of these case studies will be fixed and improvements will be incorporated into the real-time BlueSky smoke modeling system.

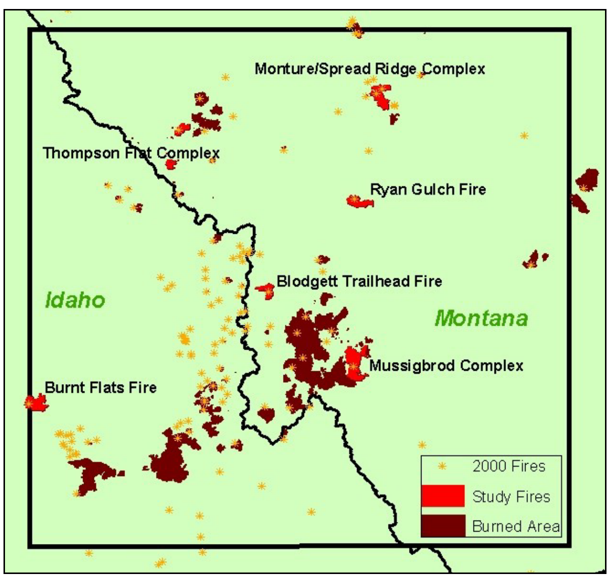

Figure 1. This map shows the location and extent of the Bitterroot wildfires within the 312-km by 312-km case study domain.

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2. THE 2000 BITTERROOT WILDFIRES IN MONTANA AND IDAHO

A drought over the West intensified over the spring and early summer of 2000 when a persistent upper-level ridge parked over the Northern Rockies sent fuel moistures plummeting. Monsoonal moisture from the south caused thunderstorms that produced "dry lightning," which triggered wildfires across the Intermountain West. Many of these fires persisted from June to October and joined with others to become huge wildfire complexes. Approximately 250 of these wildfire complexes burned in the Rocky Mountains of Idaho and Montana, centering on the Bitterroot mountain range on the border of the two states. Figure 1 displays a map of many of the fires simulated by BlueSky within the case study domain.

Figure 2. An image from the MODIS satellite taken 24 August 2000 at 1840 UTC (1240 LT). It clearly shows wildfire smoke pooling in Montana's north-south aligned Bitterroot Valley, located just left of center in the upper portion of the image. (NOAA)

High concentrations of PM2.5 and other particulates affected thousands in the region, with the counties of Ravalli (population 37,000) and Missoula (population 96,000 including the city of Missoula) bearing the brunt of the smoke, particularly throughout the month of August. Figure 2 shows a MODIS satellite image depicting smoke collecting in the Bitterroot Valley just south of Missoula. TEOM (Tapered Element Oscillating Microbalance) instruments measured PM2.5 concentrations exceeding 100 μg/m^3 at Hamilton, just south of Missoula in the Bitterroot Valley, throughout the

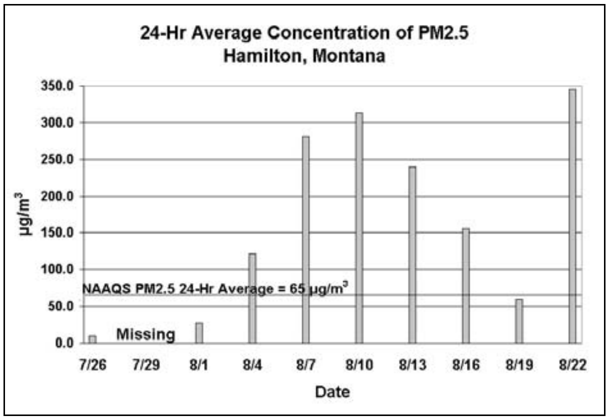

Figure 3. Twenty-four hour average PM2.5 concentrations were collected every three days at the Rivalli County Courthouse in Hamilton. During much of August, PM2.5 concentrations exceeded NAAQS. (Montana/Idaho Airshed Group.)

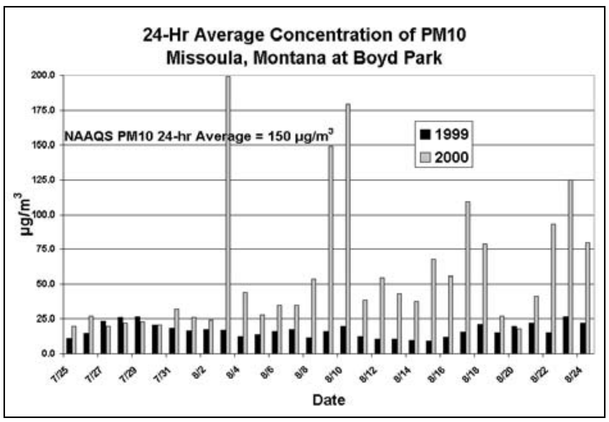

Figure 4. Twenty-four hour average PM10 concentrations collected at Boyd Park in Missoula, Montana. The NAAQS for PM10 were exceeded in Missoula for three days during the first two weeks in August. Data from 1999 were included to reference background levels. (Montana/Idaho Airshed Group)

month of August (Figure 3). Missoula also exceeded NAAQS standards for PM10 (Figure 4).

BlueSky is being applied to simulate the wildfire season in the Bitteroot Mountains of Montana and Idaho for the period of 25 July to 24 August 2000 to test its ability to predict not only the timing and location of smoke impacts, but the surface concentrations of PM2.5 and PM10. In addition, the case study will demonstrate BlueSky's ability to track hundreds of fires simultaneously.

The two primary inputs necessary for BlueSky are meteorology, either from surface or upper-air observations, or gridded output from the MM5 model (Grell et al., 1994), and fire information. A nested 36-km, 12-km, and 4-km MM5 run was completed for the study area during the period that fires were most active. Both the 12-km MM5 data and the 4-km MM5 data were then downscaled to 1 km using the CALMET diagnostic wind model (Scire et al., 2000a). CALMET downscales the MM5 wind field to finer resolutions taking into account high-resolution terrain and landuse information from USGS (1-km) and generates the meteorological fields necessary for input into the CALPUFF dispersion model (Scire et al., 2000b). Figure 1 shows the 1-km resolution domain of 312 by 312 grid cells centered over the Bitterroot Mountain range of Montana and Idaho.

BlueSky requires burn information such as fire date and time, fire location, acres burned, fuel loadings by size class, and fuel moisture. Two sources were used to compile this information: a 1-km gridded analysis of fuel loadings compiled by Hardy et al. (1998) and the wildfire daily situation reports from the USDA Forest Service. Situation reports document daily fire perimeter size, fire center location in latitude and longitude, the name of the fire, and less frequently, other information such as fuel moisture. Situation reports contained documentation on 245 fires active within the case study domain during the period from 25 July to 24 August 2000. This fire information is then input into the EPM/CONSUME model v1.02 (Peterson and Sandberg, 1984) to give emission rates of both PM2.5 and PM10.

Because EPM v. 1.02 was designed for determining smoke emissions from prescribed fire and detailed fire behavior information was unavailable for all fires, an algorithm was developed to facilitate use of EPM with wildfire. First, differences in fire perimeter size from day to day served as a base amount for each day. Fifty percent of one day's base acres were "burned" on that day, and the other 50% were "burned" on ten succeeding days in 5% increments. This calculation was done on each day's assigned acreages for the entire month-long period. In addition, we parsed each day's assigned acreages into four periods with 10% of the daily acreage burning at 0300 local time (LT), 20% at 0900 LT, 50% at 1500 LT, and 20% at 2100 LT.

Finally, the emission rates from each fire were processed into area sources for input into the CALPUFF dispersion model along with the meteorological fields from CALMET, to yield a 1-km gridded field of PM2.5 concentrations.

The first goal of the Bitterroot case study was to optimize the meteorology. The study relied on two first-order ASOS stations—Missoula and Helena, Montana—for verifying wind speed and direction, as well as temperature. Although the RAWS (Remote Automatic Weather Stations) network of the Forest Service was more extensive and would have provided a much better breadth of terrain for testing modeled data, RAWS sites within the domain suffered from poor documentation of both anemometer height (many were situated below canopy at varying heights above ground) and location (stations are sometimes moved).

Modeled data from grid cells encompassing the Helena and Missoula sites were compared with observational data for two periods: an unstable weather period of thunderstorm activity (10 Aug – 12 Aug) and a quieter more stable weather period dominated by a high-pressure system (21 Aug – 23 Aug). Comparisons of model performance were also made of nighttime observations against daytime observations, 4-km MM5 against 12-km MM5, and different parameter

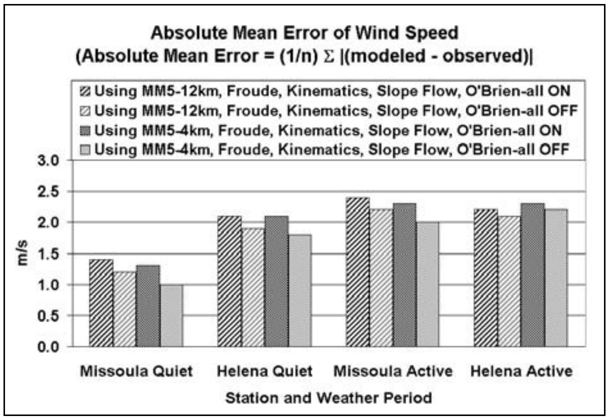

Figure 5. Absolute Mean Error of Wind Speed calculated from CALMET (modeled) observations at both Missoula, Montana and Helena, Montana during both a period of quiet weather (21-23 August 2003) dominated by high pressure and a period of active weather (10-12 August 2003) dominated by thunderstorms.

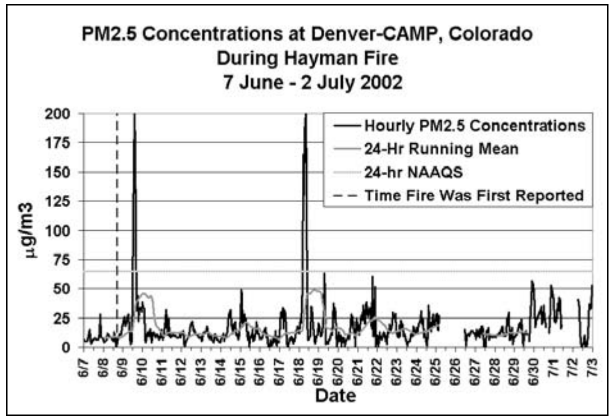

Figure 6. PM2.5 concentrations at Downtown Denver (CAMP station) recorded two smoke events with values as high as 200 µg/m^3 (9 June and 18 June). The 24-hr running mean did not, however, exceed NAAQS. (Department of Environmental Quality, Colorado)

configurations of the CALMET model. We investigated model configurations with combinations of four CALMET parameters that are designed for special use in complex terrain: O'Brien Smoothing, Slope-Flow, Kinematics, and Froude Adjustment options. Model performance was judged by accuracy of three meteorological measurements—wind speed, wind direction, and temperature—and runtime speeds.

Tests showed that using these parameters did not improve model performance of wind direction. According to absolute mean error on wind speeds, however, CALMET runs employing these parameters actually performed poorer than runs not using these parameters (Figure 5).

Use of two of these parameters—O'Brien Smoothing and Kinematics—while not enhancing meteorological fields, greatly increased runtimes. Using both Slope-Flow Adjustment and Froude Adjustment parameters in the model did not increase runtimes. Modeled PM2.5 concentrations will be compared against ground-level observations of particle concentrations and TEOMS for validation. Satellite images such as Figure 2 and digital photographs will supplement objective verification in the study. Results are expected to show BlueSky modeled surface concentrations are an order of magnitude less than measured surface concentrations.

3. THE 2002 HAYMAN WILDFIRE IN COLORADO

The Hayman Fire burned over 55,000 hectares from 8 June and 2 July 2002, becoming the largest fire in Colorado recorded history. Starting just west of the Front Range of the Rockies, the fire consumed forests as close as 50 km from downtown Denver. Smoke from the Hayman Wildfire particularly afflicted the Denver metropolitan area (population 2,500,000) with episodes of high particulate concentrations and visibility impairment during both the afternoon of 9 June and the morning of 18 June. During these two events a downtown TEOM recorded measurements as high as 200 µg/m^3 (Figure 6). Because of its proximity to a major city, the fire gained national media attention. The Hayman Fire in Colorado offers a chance to test the BlueSky modeling framework on a high-profile wildfire that affected millions of people.

MM5 data for Colorado were not available for BlueSky; therefore, surface weather observations were input directly into the CALMET model to generate a wind field. Situation reports supplied fuels information. EPM was run similarly to the Bitterroot case study. The Denver-CAMP TEOM station served as the only validation point.

Initial comparisons between predicted and actual concentrations show that BlueSky reasonably captured the timing of the smoke impacts on the city as shown in Figure 7 and the visible satellite image at the same time in Figure 8. MODIS satellite images and NOAA visible satellite loops as well as a sequence of digital images of Downtown Denver further validate this. However, the predicted PM2.5 concentrations were significantly lower than the measured data. This may either indicate lack of accurate fuels data, fire behavior information, weather data, model deficiencies, or any combination of these. Berg et al (2003) documents another case study testing BlueSky's performance at simulating a single major wildfire, the 2001 Rex Creek Fire in Washington state.

Had BlueSky's real-time domain included Colorado in the summer of 2002 and wildfire information, authorities might have been able to use its predictions to warn residents of possible smoke impacts to health and visibility. Given BlueSky's accessibility online (BlueSkyRains.org), the encouraging results from the Hayman case study suggest that one day its user-base may broaden to include the general public.

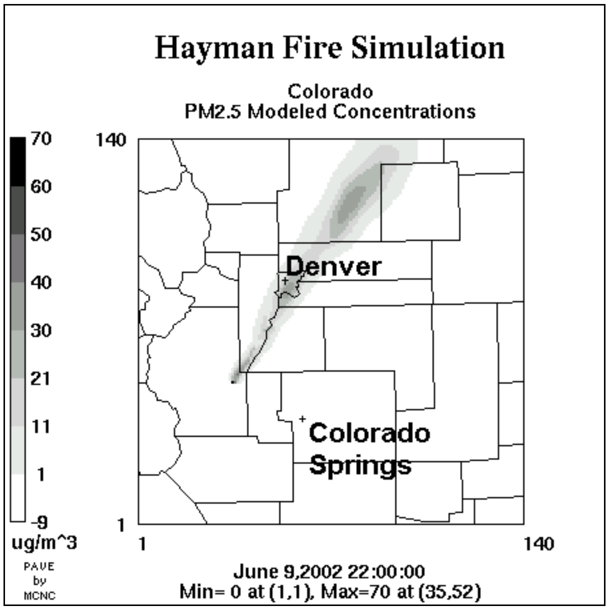

Figure 7. Predicted PM2.5 concentrations from the Hayman Fire for 9 June 2002 at 2200 UTC (1600 LT).

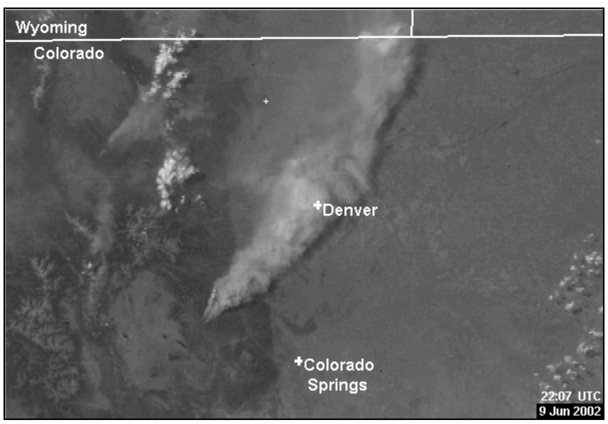

Figure 8. GOES-11 visible satellite image for 9 June 2002 at 2207 UTC (1607 LT) showing the smoke plume from the Hayman Fire affecting metropolitan Denver.

4. CONCLUSION

While this work is in preliminary stages, we have discovered reasonable performance from meteorological components of the BlueSky system and reasonable performance in timing and location of dispersing plumes. Much work needs to be done, however, to improve the magnitude of surface concentrations that are predicted.

A prototype of BlueSky has been running in the northwestern U.S. since the summer of 2002. Smoke managers from a multitude of agencies, including federal, state, local, and tribal authorities, are using BlueSky to coordinate prescribed fire activities, to better manage air resources, and to minimize impacts to communities as well as the environment. Incident command teams are relying on it to help inform local residents of potential smoke problems and to anticipate containment strategies. More recently, local air regulatory agencies and citizens have started using BlueSky's predictions to mitigate health risks. Therefore, understanding its skill and improving its accuracy is vitally important and underscores the need for case studies such as these.

5. REFERENCES

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