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Evaluation of the BlueSky Smoke Forecasting System and Its Utility for Public Health Protection in BC

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Smoke from forest fires is a major contributor to extreme events of particulate matter (PM) air pollution in North America, and fire smoke exposure has been associated with respiratory and cardiovascular effects. Current tools to assess smoke exposure in Canada include PM measurements from regulatory air monitoring networks, and products generated from satellite data. For example, the Hazard Mapping System (HMS) (http://www.osdpd.noaa.gov/ml/land/hms.html) implemented by NOAA provides a semi-quantitative estimate of PM from smoke plumes detected by multiple remote sensing platforms. These tools, however, have their own limitations. While forest fire smoke can impact large populations, the available monitoring networks may not provide adequate coverage for estimation of health impacts, and the instruments may fail during smoke events with extremely high concentrations. On the other hand, detections from HMS can cover very large areas, but they represent the smoke in the total column of the atmosphere, which can be different from the ground-level conditions of most concern. A system that could supplement real-time regulatory monitoring and remote sensing data would be a valuable tool for public health, especially if it could predict ground-level concentrations in advance.

The Western Canada BlueSky Smoke Forecasting System (BlueSky) (http://www.bcairquality.ca/bluesky/) is a modeling framework that provides hourly forecasts of ground-level PM2.5 concentrations from wildfire smoke up to 60 hours in advance. Its domain has been expanded from Western Canada eastward to Ontario since its official launch in 2010 [Province of British Columbia, 2011]. This system has been in development since 2008, based on an existing framework created by the U.S. Forest Service AirFire Team. Meteorological forecasts from MM5 are combined with fire locations as well as consumption and emissions information from the Canadian Wildland Fire Information System, and are input to the HYSPLIT model to compute smoke dispersion. The output is an estimate of ground-level PM2.5 concentrations every 4 km^2 in British Columbia and Alberta, and every 12 km^2 throughout the rest of the model domain. So far, there has not been any quantitative and systematic evaluation of the system performance (although qualitative assessments have taken place). Our research aims to fill this gap and to assess the utility of BlueSky for public health protection. We focused our analysis on the 2010 fire season which included several large smoke episodes in British Columbia.

Forecast Evaluation

Our project addresses two questions. First, how do predictions from BlueSky compare with smoke measurements? Specifically, how do the PM2.5 estimates compare with measurements from the regulatory monitoring network, and how do the predicted plume shapes compare with those observed by satellite? Second, is there an association between BlueSky-generated PM2.5 predictions and measures of respiratory health in smoke-impacted communities? If so, this would support the use of BlueSky predictions to inform decision making for mitigating public health impacts from wildfire smoke.

For the first question, we conducted statistical analyses to assess both the spatial and temporal relationships between daily average BlueSky predictions and ground-level PM2.5 measurements from the regulatory monitoring network. For the spatial analysis, model forecasts were compared with observed values from all ambient air quality monitoring stations at a fixed time. For the temporal analysis, we compared the time series of model predictions and ambient air quality measurements at fixed locations. In addition, agreement between the location and size of smoke plumes predicted by BlueSky and observed from HMS was examined using a spatial statistic called the figure of merit in space (FMS), calculated as the intersection of the two plume types (areas covered by both) divided by their union (areas covered by one or the other or both, Figure 1, next page).

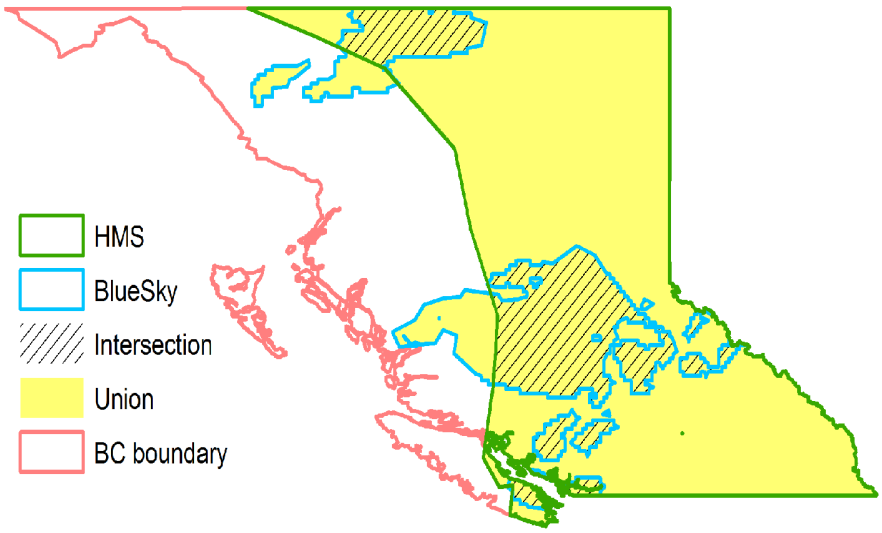

Figure 1. Diagram illustrating the calculation of the Figure of Merit in Space (FMS). AHMS = area of HMS plume and ABlueSky = area of BlueSky plume. AHMS ∩ ABlueSky is the intersection of the plume areas of HMS and BlueSky (area in hatching), and AHMS ∪ ABlueSky is the union of the two plume areas (area in yellow).

For the second question, Poisson regression was performed between BlueSky predicted PM2.5 concentrations and (1) counts of prescriptions dispensed to relieve symptoms of obstructive lung diseases, and (2) counts of outpatient physician visits for respiratory diseases. These two measures can serve as indicators of population sensitivity to wildfire smoke exposure.

Preliminary results suggest reasonable but inconsistent agreement between BlueSky and both PM2.5 measurements and plumes observed by remote sensing. The correlation coefficients for different days and locations ranged from -0.39 to 0.93. Generally, good agreement tended to occur during the middle of a fire smoke event (Figure 2) and at locations that were heavily and constantly impacted

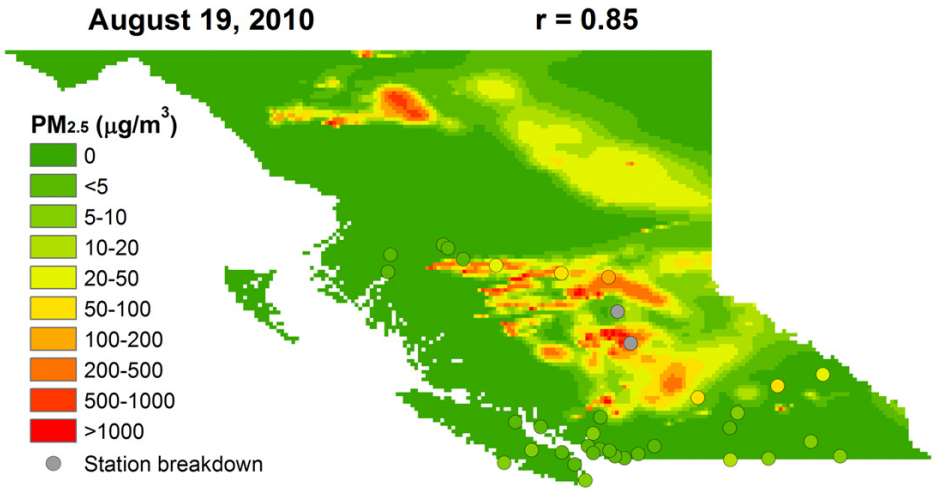

Figure 2. An example of good agreement between BlueSky predictions and monitoring network measurements from August 19, 2010. The background color represents PM2.5 concentrations predicted by BlueSky and the color of the circles represents PM2.5 concentrations measured by air quality monitoring stations. The scale of the color is the same for both predictions and measurements. The grey circles indicate monitoring stations that malfunctioned due to high PM concentrations.

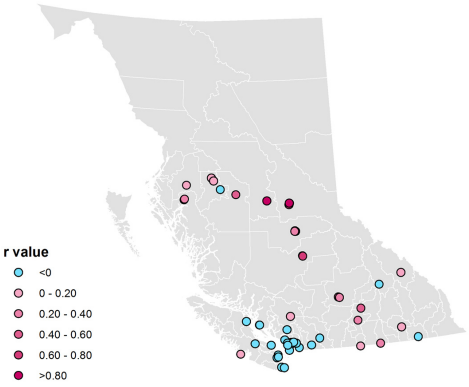

Figure 3. Correlation (r) computed from time-series data between BlueSky predictions and PM2.5 measurements from the regulatory monitoring network in British Columbia. High r values are observed at locations in the interior of the province, which was heavily impacted by smoke in 2010.

by fire smoke (Figure 3). For the comparison between BlueSky and HMS plumes, high FMS scores were observed in the middle of the fire smoke events (Figure 4). Overall, the size of the BlueSky predicted smoke plumes tended to be smaller than those observed by HMS.

Figure 5 shows plots of respiratory reliever dispensation counts for the Cariboo-Chilcotin local health area of British Columbia, a region that was heavily impacted by forest fire smoke plumes in 2010. The figure also includes PM2.5 concentrations predicted by BlueSky and measured by an ambient air quality monitoring station in the area. Peaks of dispensation counts coincide with peaks of predicted and measured PM2.5. The same association was also observed in other smoke impacted areas, and between BlueSky predictions and counts of physician visits for respiratory diseases. We are currently assessing these associations with more sophisticated statistical analysis to provide a quantitative measure of the strength of the relationship. In addition, we are currently monitoring the 2012 fire season activity, and will incorporate additional fire event data into our analyses.

Acknowledgements

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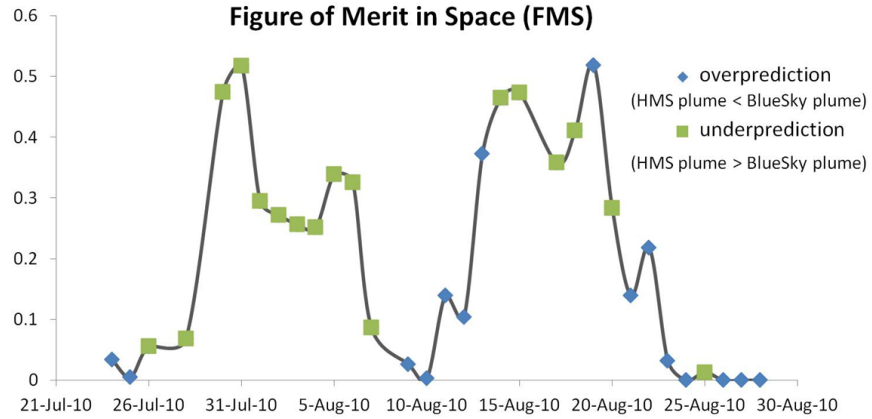

Figure 4. Figure of Merit in Space (FMS) scores comparing plumes predicted by BlueSky with plumes observed by HMS. The FMS is calculated as the intersection divided by the union of the predicted and observed plumes (Figure 1).

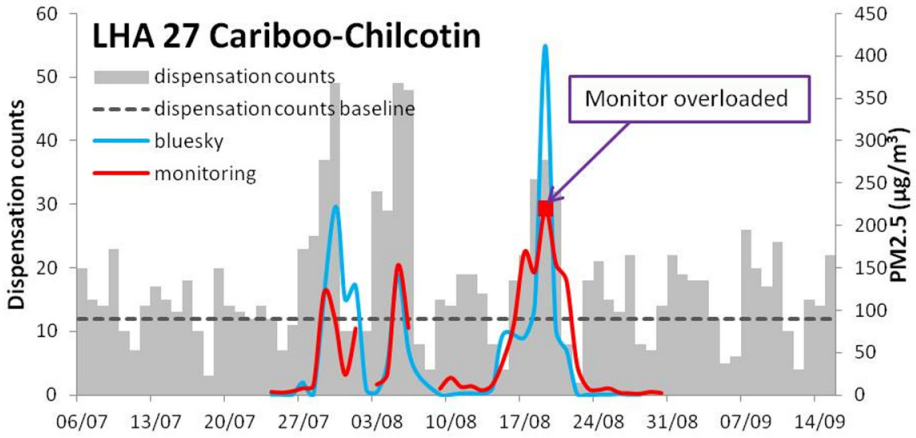

Figure 5. Gray bars indicate the daily counts of dispensations for respiratory reliever medications (low days are weekends and holidays). The broken black line indicates the average daily counts in July, August and September from 2003 through 2010. The blue and red lines indicate the PM2.5 concentrations predicted by BlueSky and measured by the monitoring stations, respectively. On August 19th, the monitoring instrument was overloaded by the intense smoke, resulting in unreliable records.

References

1. Province of British Columbia (2011) Smoke Forecasts for Western Canada. Retrieved April 6, 2012 http://www.bcairquality.ca/bluesky/