

The BlueSky Western Canada Wildfire Smoke Forecasting System

Background

Forest fire smoke can result in high concentrations of particulate matter and other gases up to a thousand kilometres or more from the fire. Of primary concern is the public exposure to wood smoke, given that it is comprised of particulate matter smaller than 2.5 microns (PM_{2.5}) which can be inhaled deep into the lungs, and can damage our health (World Health Organization, 2005). In addition, the mixture of pollutants in wood smoke can include known health-damaging compounds (Naeher et al., 2007). For more information, see: www.bcairquality.ca/health/.

At the National Workshop on Smoke Forecasting in Edmonton (Workshop, 2007) a need was identified for an operational smoke forecasting system (SFS) in Canada. Such a system would be an extremely useful tool for weather forecasters, health authorities, researchers, regulatory agencies, all levels of government and the public. For example, it would provide weather forecasters with information to respond to public and media interest about smoke (related to nuisance, tourism, immediate safety, etc.). It would inform health authorities about present and forecast exposure to smoke in order to warn the public about risks from poor air quality, especially individuals who need to take action to minimize exposure. In addition, it would provide health researchers with information on smoke-exposed populations. Finally, burn managers and regulatory approval agencies for prescribed burns would have a tool to support decision-making on the smoke implications of burns.

Discussions following the Edmonton Workshop lead to the concept of a pilot project that would apply the U.S. Forest Service BlueSky system to British Columbia and Alberta. BlueSky is a framework developed by the U.S. Forest Service AirFire Team (Larkin et al. 2008). It consists of data and models of fuel consumption, emissions, fire, weather, and smoke dispersion all linked into a single system. Hourly forecasts for up to two days are generated for ground-level concentrations of PM_{2.5} from wildfires, prescribed burns, and agricultural fire. The output is available from the web and is visualized in the form of colours and animations over a region. The U.S. BlueSky is applied to several domain areas that cover the rest of the continental U.S. (www.getbluesky.org)

Building on an existing system rather than creating a new one has many advantages including: applying technology that is already tested and in operational use, using a common system to determine the impacts of smoke from fires across the border and outside North America, and the ability of the BlueSky framework (which is comprised of modules) to swap in Canadian components such as emissions data and meteorological forecast model output.

The following provides a description of the origins and components of the 2010 Pilot Project, and outlines the enhancements made for the 2011 version of the system.

The Process Involved in Developing the Pilot Project

A multi-agency steering group was created in 2008 to provide overall direction to the project. The group represents an informal partnership between provincial agencies in British Columbia and Alberta (B.C. Ministry of Forests, Lands and Natural Resource Operations, B.C. Ministry of Environment, Alberta Environment, Alberta Sustainable Resource Development), the University of British Columbia (Department of Earth and Ocean Sciences, School of Occupational Health), U.S. Forest Service (AirFire Team), Environment Canada (both Pacific/Yukon and Prairie/Northern Regions), and Natural Resources Canada (both

Pacific and Northern Forestry Research Centres). Partner agencies contributed funds to the pilot, as well as in-kind services and direction to the overall project design.

Western Canada BlueSky Pilot System: Conceptual Approach for B.C. and Alberta

The conceptual outline of the system is provided in Figure 1. Each component is discussed in the following sections.

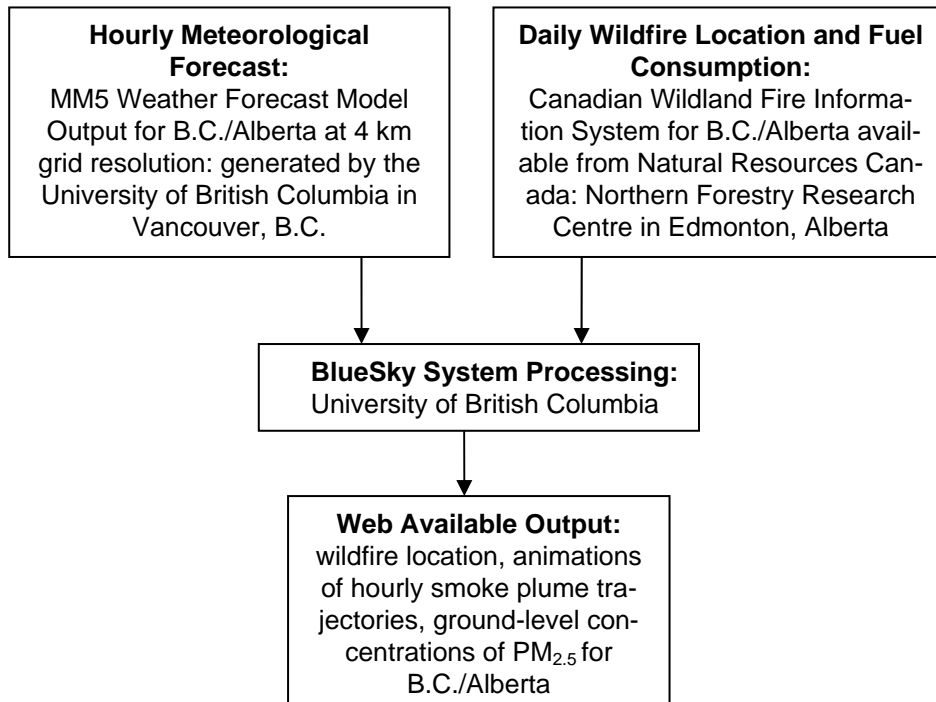


Figure 1. Conceptual Outline of 2010 B.C./Alberta Smoke Forecasting Pilot System

Meteorological Fields

The BlueSky system requires weather forecast model output that consists of hourly meteorology forecast for two-days in advance, at sufficient spatial resolution in order to resolve the effects of the rugged terrain which dominates B.C. and portions of Alberta. The Department of Earth and Ocean Sciences at the University of British Columbia (UBC) in Vancouver runs three different weather forecast models with two different sets of initialization data. From this output, real-time, ensemble weather forecasts are produced (see <http://weather.eos.ubc.ca/wxfcst/>). One of the forecast models is MM5 (Dudhia, 1993). Given that the BlueSky system is able to process MM5 output, the UBC generated MM5 output was used for the B.C./Alberta pilot. Some modifications were made to this implementation of MM5 which included extending the original 4 km grid resolution domain to cover all of B.C. and Alberta.

Wildfire Location and Emissions

One of the challenges facing the pilot project was the need to supply real-time wildfire location and fuel consumption estimates to the system. In particular Canadian forest fuel related information can be different than those in the United States. Thus emission estimates require assumptions and processing of Canadian data into the required parameters for ingestion into the U.S.-based BlueSky system.

To develop a Canadian version of this component of the system, Sonoma Technologies Inc was contracted to work with scientists at the Canadian Northern Forestry Centre to develop a module that would use information from the Canadian Wildland Fire Information System (CWIFS). Sonoma Technologies Inc. is the contractor that provides technical support to the U.S. BlueSky SFS.

The CWIFS includes the Fire Monitoring, Mapping, and Modelling (FireM3) system and National Forest Inventory data (<http://cwfis.cfs.nrcan.gc.ca/>). FireM3 uses MODIS satellite-based hotspot detection along with perimeter polygons and other algorithms to estimate fire size. National Forest Inventory data is used along with the Fire Prediction Behaviour (FPB) Model in order to produce fuel consumption estimates suitable for the dispersion part of the BlueSky system (http://cwfis.cfs.nrcan.gc.ca/en_CA/background/summary/fbp). In addition, a data link was established so that location and fuel consumption could be accessed real-time via the web from the Canadian Northern Forestry Research Centre in Edmonton, Alberta.

Running BlueSky at the University of British Columbia

The original concept of the pilot involved transferring the emissions and meteorological model output to the U.S. Forest Service server running BlueSky for the Pacific North-West region in Seattle, Washington. However the huge volume of meteorological model output generated at UBC in Vancouver made transfer to the server in Seattle impractical. Through the generosity of the U.S. Forest Service, a computer loaded with the BlueSky framework was loaned to UBC, thus avoiding the data transfer bottleneck issue and allowing a local running of the system. U.S. Forest Service staff modified the system for application to B.C./Alberta, and configured the system to read and process these Canadian generated inputs.

Although these modifications moved the system toward a “Canada- ready” version, further coordinate system adjustments were required. In 2009, through partnership contributions Sonoma Technologies Inc. made these changes, linked the meteorological forecast model output and the wildfire source information within the system framework, installed and tested the software on the BlueSky computer at UBC, and provided training to technical support staff.

From Pilot Testing to an Operational Smoke Forecasting System

In late 2009, the Western Canada BlueSky SFS was successfully tested and stress-tested by running simulations for August 2009, a period of extreme fire activity in B.C. In addition, Sonoma Technologies Inc. conducted a qualitative performance evaluation of the system by comparing forecast output to actual plume locations (as derived by satellite imagery and aerosol optical depth estimates) for select periods within this simulation month. These stress-tests and qualitative performance evaluations provided confidence in the system’s ability to process volumes of data correctly, and to produce reasonable estimates of plume impacted areas.

Given these encouraging results, the next step involved the development of a method to display the output files (smoke-impacted areas and the corresponding PM_{2.5} concentrations every hour up to 2 days into the future) via a public website. This method involves transferring the output files daily from UBC and posting them on the British Columbia air quality website maintained by the Ministry of Environment (www.bcairquality.ca). The displays are available in JPEG and KMZ formats. The JPEG format is the most versatile as it does not require any specialized software to display the results. The KMZ format requires Google Earth to run, but viewing smoke forecast animations is enhanced by the additional Google Earth functionality in terms of data layers, viewing areas, location labels, etc. The

web page graphics and Google Earth rendition of one hour of the forecast concentrations for the 2011 enhanced version of the system are shown in Figures 1 and 2 respectively.

The system went live and forecasts were reliably produced and made publically available every morning via the website during the summer of 2010. During August (a period of intense wildfire activity in B.C.), the smoke forecasting website received over 60,000 hits, confirming the high interest and need for this tool.

Caveats and System Needs Based on the Experience from the 2010 Wildfire Season

Given the research nature of this work, the results are considered experimental. A review of the forecasts from last season has provided insights on the system and indicates areas in need of improvements. These are listed here:

- There is more certainty in forecast plume impact zones that depict relative measures of impact, rather than absolute $PM_{2.5}$ concentrations.
- Cloud cover or thick smoke will obscure hotspot detection – updated fire activity data collected by different agencies should be incorporated.
- More evaluation of the performance of the system is required.
- Include smoke from wildfires outside the domain. For example smoke from wildfires in the northern U.S. Border States or the NWT can impact B.C. and Alberta.
- Currently the system includes around 12 hours of smoke from the previous day – this should be extended to include smoke from the previous 24-48 hours.
- Include source persistence, where fire emissions follow a realistic time variation through the entire forecast period.
- Expand the forecast domain to include portions of the Yukon, NWT, the border U.S. states, Saskatchewan and Manitoba.
- Obtain a new computer to ensure future stability of the project, and to speed up processing times.
- Correct the unrealistic bull's eye concentration patterns that appear and disappear at distances far from the source.

System Enhancements: Ready for the 2011 Wildfire Fire Season for All of Western Canada

With further support and contributions from the B.C. Ministry of Environment, Alberta Environment, National Research Council and the B.C. Clean Air Research Fund (CLEAR), some of the needs identified above have lead to the following enhancements:

- All of Western Canada, north-western Ontario, the southern portions of the Yukon, NWT and Nunavut, and the U.S. border States are now included in the smoke forecast. This required a nested-grid version of the meteorological model (4 km grid resolution for B.C. and Alberta, 12 km for the other areas)
- A faster computer was acquired and is running the enhanced system at UBC.
- Wildfires and corresponding smoke from the U.S. border States are included in the forecasts.
- Source persistence is enabled – where the emissions follow a realistic diurnal cycle through the forecast period.
- Further qualitative and quantitative evaluations of the performance of the system using satellite and ground-based air quality measurements.

With respect to performance, the enhanced system was stress-tested and evaluated for case periods of extreme wildfire activity during 2010. The results indicate that the system is able to handle large data volume situations and produce results that show the source, meteorology, transport, dispersion and output display are linked properly together and are

producing results consistent with each of their respective functions. Finally, qualitative comparisons indicate that although system may miss predicting the smaller geographic scale details of the smoke patterns, the forecasts show a general consistency with the large scale, observed smoke patterns as recorded by satellite imagery. As indicated above, qualitative and quantitative evaluations will continue.

Summary

The Western Canada SFS is based on the existing U.S. Forest Service, BlueSky framework and benefits a wide variety of stakeholders impacted by smoke from wildfires. Over the past few years, Canadian components of the system have been developed to the point where the Western Canada BlueSky SFS is into its second year of operation. A multi-agency workgroup, representing a wide variety of expertise, was established to shepherd the pilot project, and has been a critical to its success. The experience of the 2010 fire season indicates that the interest and need for this information is high. It also points to the need for further improvements – some of which will be implemented for the 2011 fire season.

Due to the need for further testing and development, the forecasts are considered experimental. In addition, the system is subject to many uncertainties associated with any model that forecasts all the complex processes involved. However, the development team expects with further evaluation, enhancements and experience with this system, it will become an indispensable tool used to inform both the public and decision makers.

Acknowledgements

The contributions of many individuals and agencies have made this project a success. E. Meyer (B.C. Ministry of Forests, Lands and Natural Resource Operations), G. Okrainetz, C. Jenkins, L. Huang, W. Mohns (B.C. Ministry of Environment), R. Stull, G. Hicks, M. Brauer (University of British Columbia), A. Pankratz, B. Wiens, R. Vingarzan, (Environment Canada), L. Cheng, D. Lyder (Alberta Environment), D. Schroeder, C. Tymstra (Alberta Sustainable Resource Development), S. Taylor, K. Anderson (Natural Resources Canada), S. Larkin, R. Solomon (U.S. Forest Service AirFire Team), S. Raffuse, K. Craig (Sonoma Technologies Inc).

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Figure 2. Web page for the BlueSky Wildfire Smoke Forecast for Western Canada (www.bcairquality.ca/bluesky)

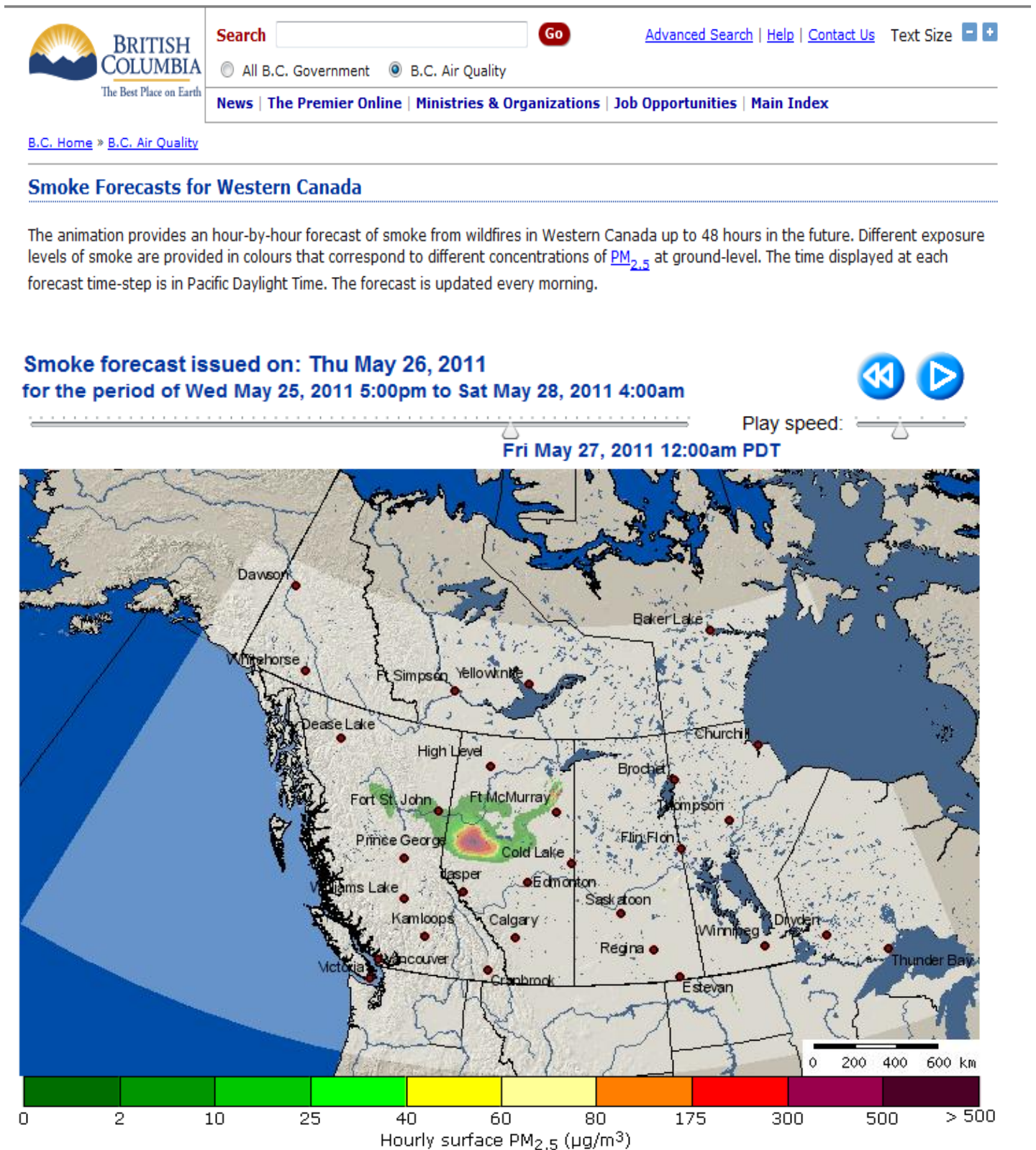


Figure 3. Google Earth Output (Animations of Hourly PM_{2.5} Concentrations)

