Smoke Forecasts from Wildland Fires for Canada

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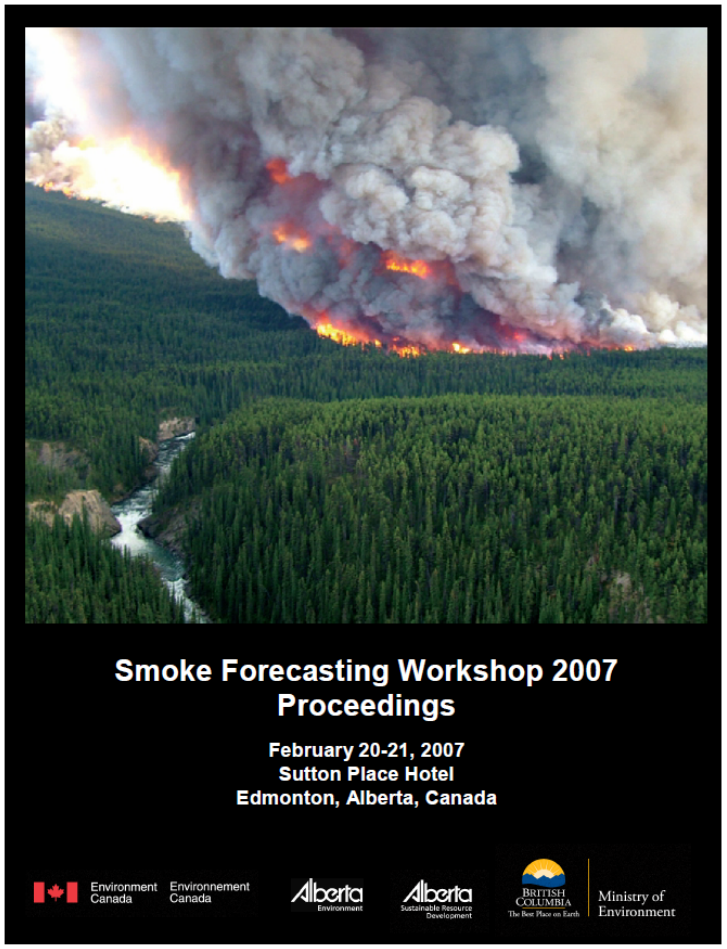
Introduction

Every year Canada typically experiences 8,000 forest fires resulting in dozens of evacuations of communities due to smoke.

Health alerts impacting the lives of millions of Canadians are issued each summer indicating the negative health effects of smoke exposure.

Industries and tourism are also affected by smoke.

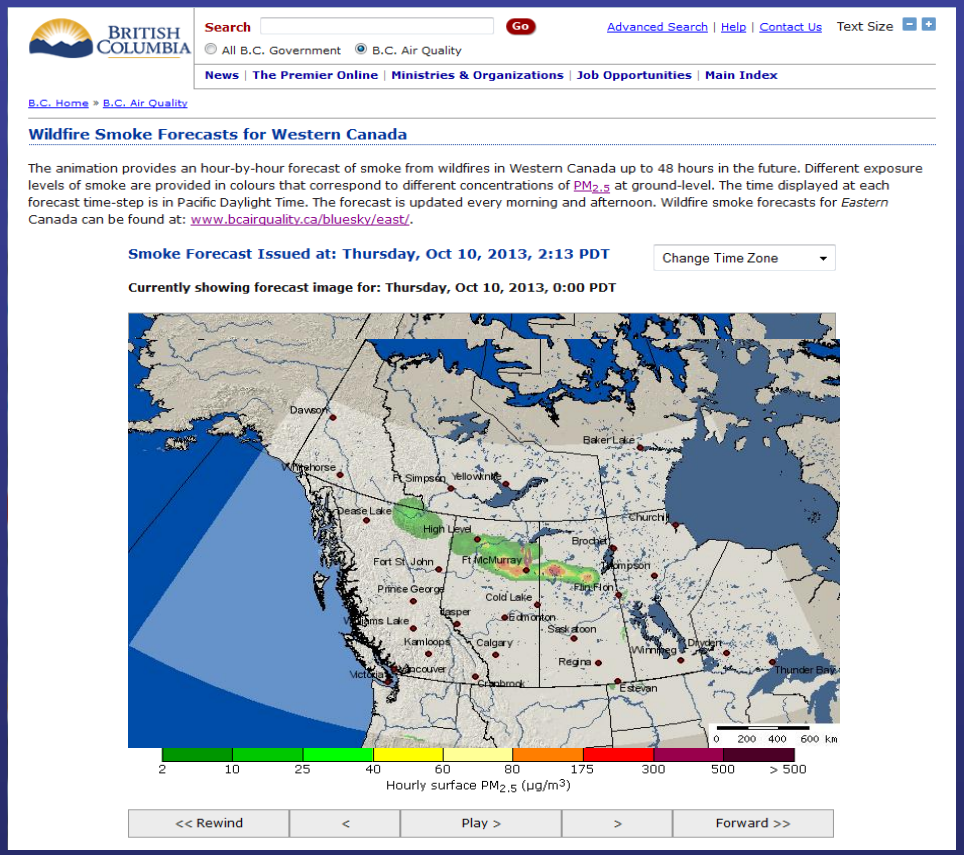
Initial Meeting, 2007



In 2007 a workshop was held in Edmonton, which included provincial and federal agencies in charge of resource management, public health, and environment.

This lead to an initial strategy of testing the BlueSky system in Canada.

BlueSky Canada



A prototype system was emplaced at the University of British Columbia (UBC) and smoke forecasts for British Columbia and Alberta were initiated in August, 2010.

BlueSky for Eastern Canada created: began producing smoke forecasts in August, 2013

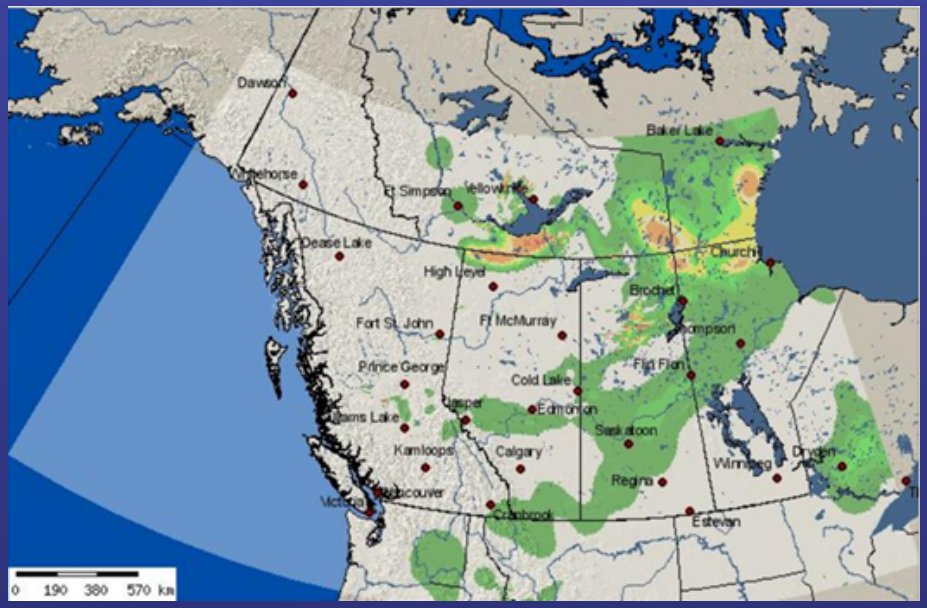
www.bcairquality.ca/bluesky/west/
www.bcairquality.ca/bluesky/east/

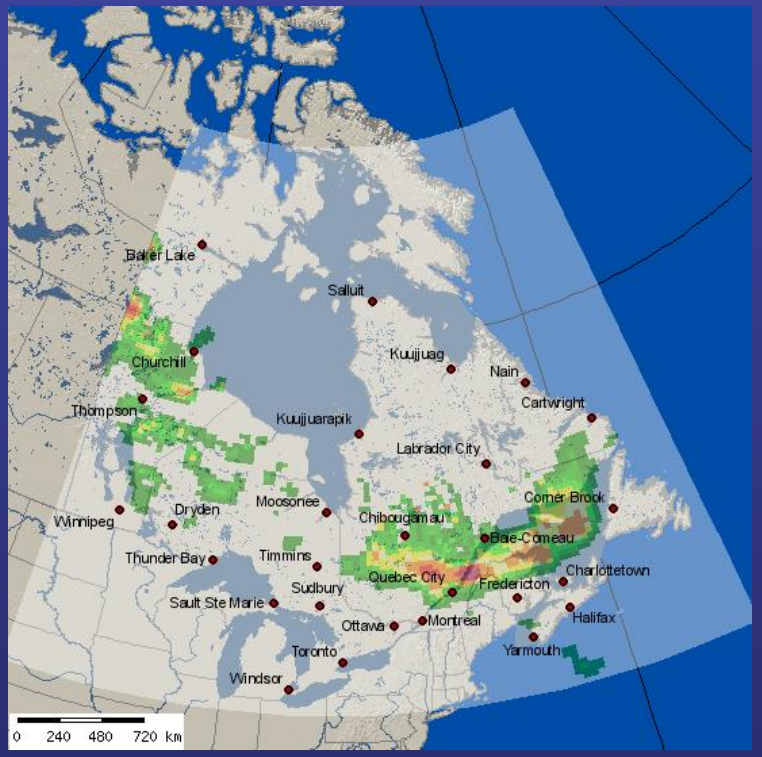
BlueSky Canada

In 2013, funding from the Canadian Safety and Security Program (CSSP) provided an opportunity to develop a national system.

The intended output will be the creation of national smoke forecast products and tools useful for providing information to the public.

BlueSky Canada

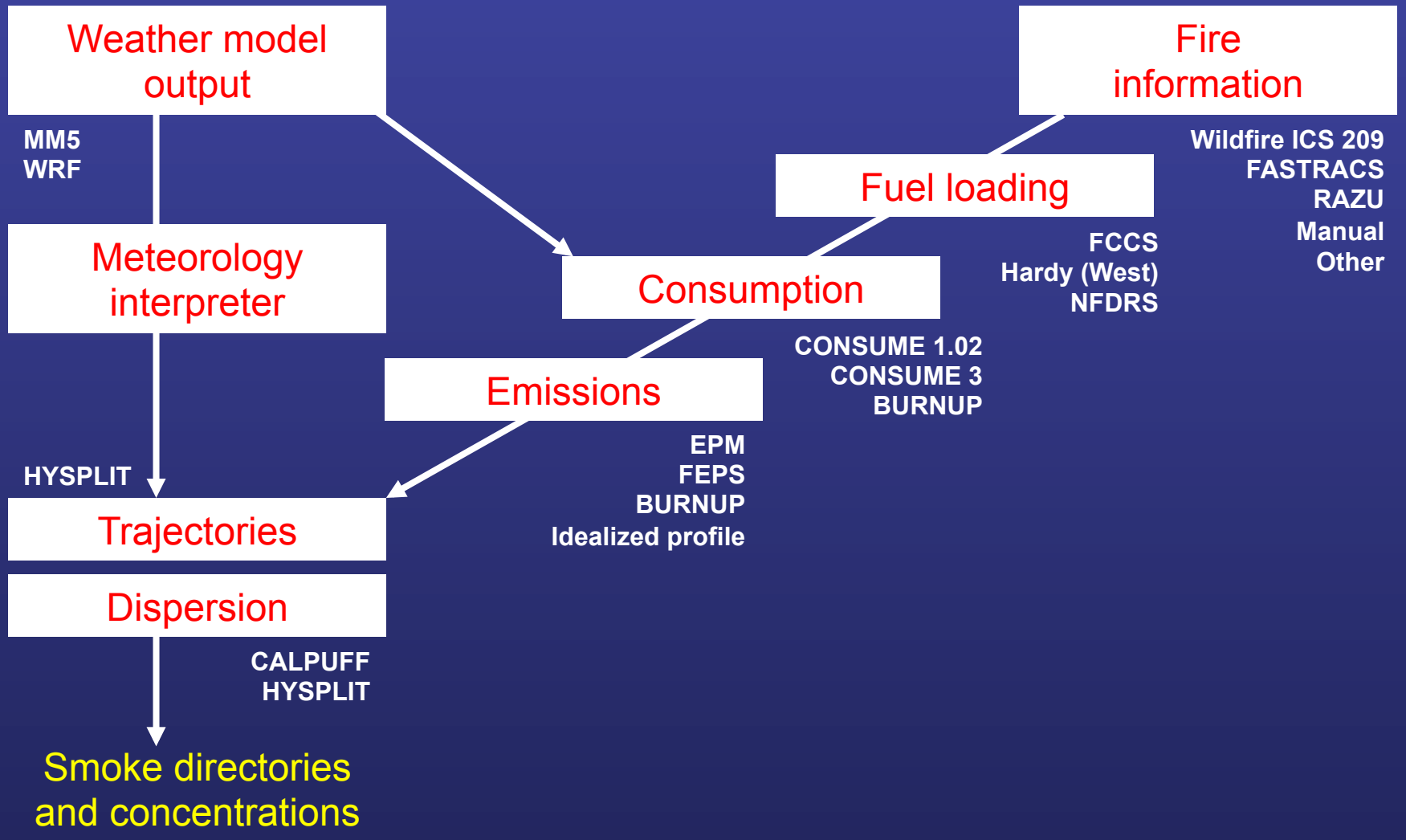




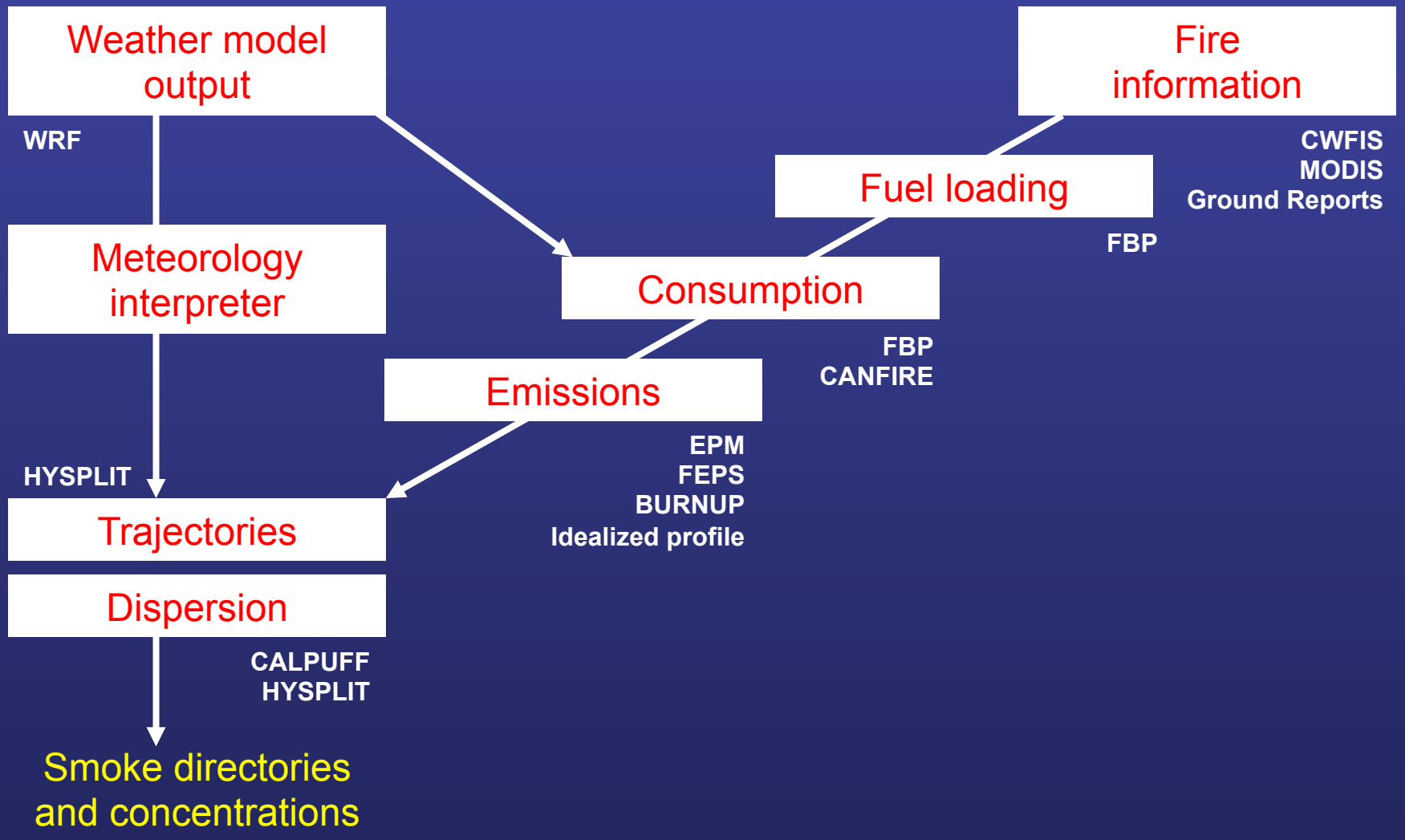
BlueSky Canada uses the WRF model run twice daily in a nested fashion.

For 2014, the system was run down to a 4 km resolution for Western Canada and 36 km for Eastern Canada.

BlueSky Modeling Framework

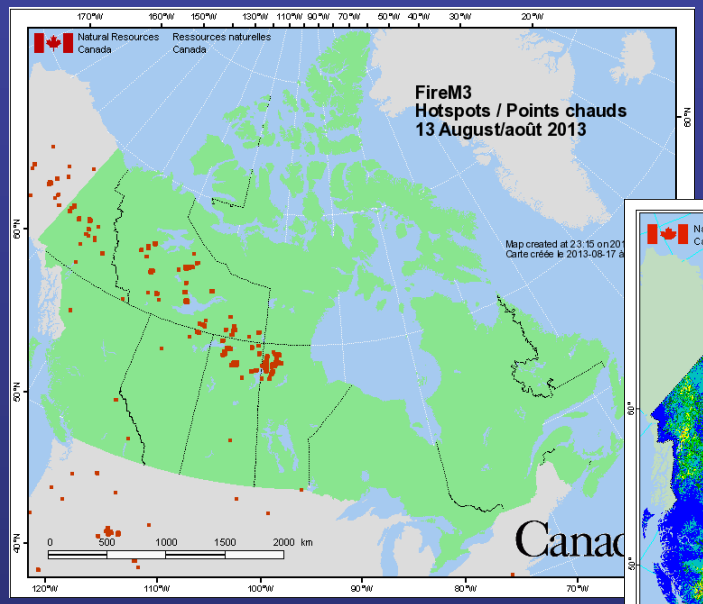


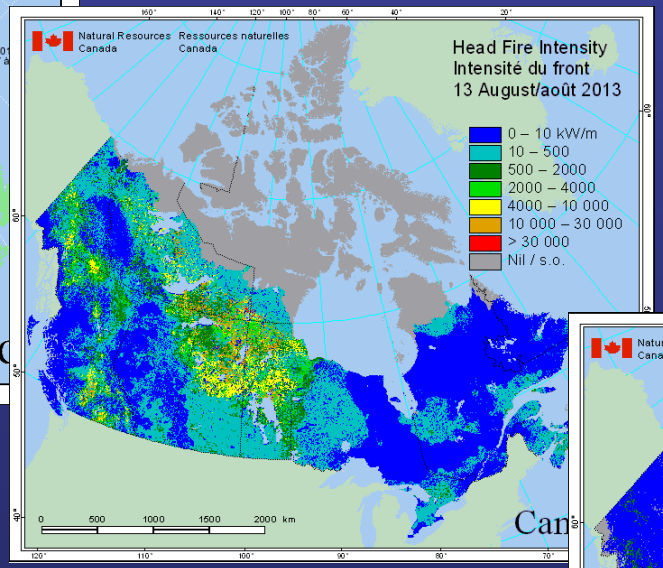
BlueSky Canada

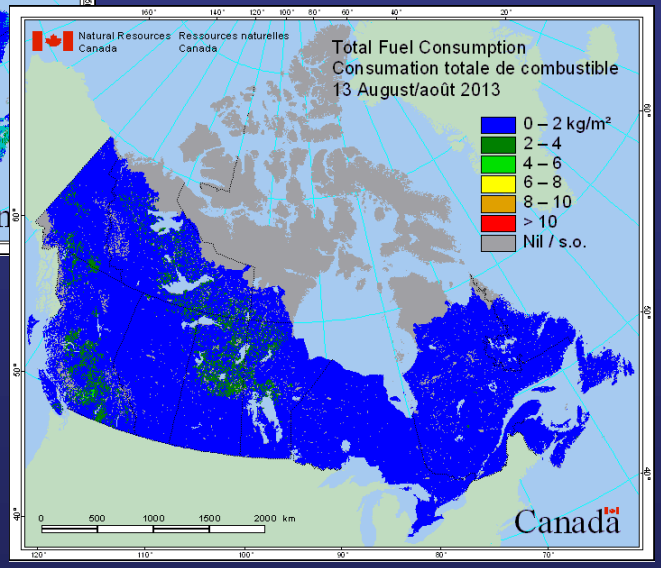


BlueSky Canada

MODIS and NOAA/AVHRR hotspot information is passed onto BlueSky Canada twice daily.



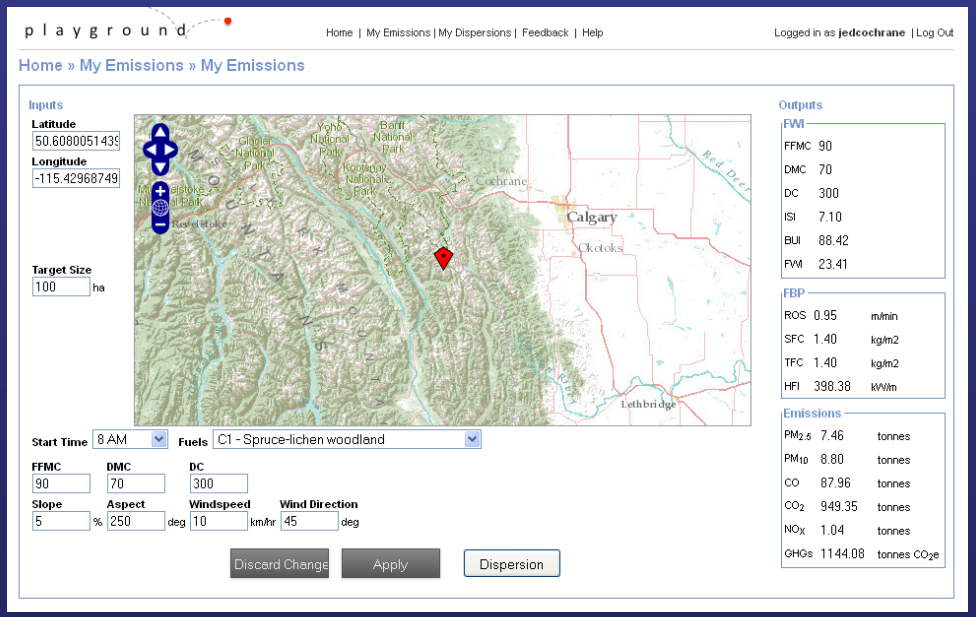




Fire weather, fuel consumption and smoke emissions are calculated by the Canadian Wildland Fire Information System (CWFIS).

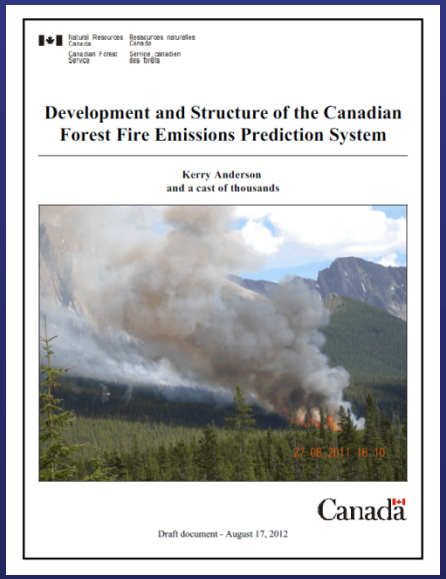
BlueSky Canada Playground

BlueSky - Canada Playground is an interactive smoke forecast tool used by fire management agencies to predict possible smoke emissions and dispersion from prescribed fire operations.



Canadian Forest Fire Emissions Prediction System

The Canadian Forest Fire Emissions Prediction System (CFFEPS) will be a new module compatible with the Canadian Forest Fire Danger Rating System used to predict smoke plume dynamics and emissions.

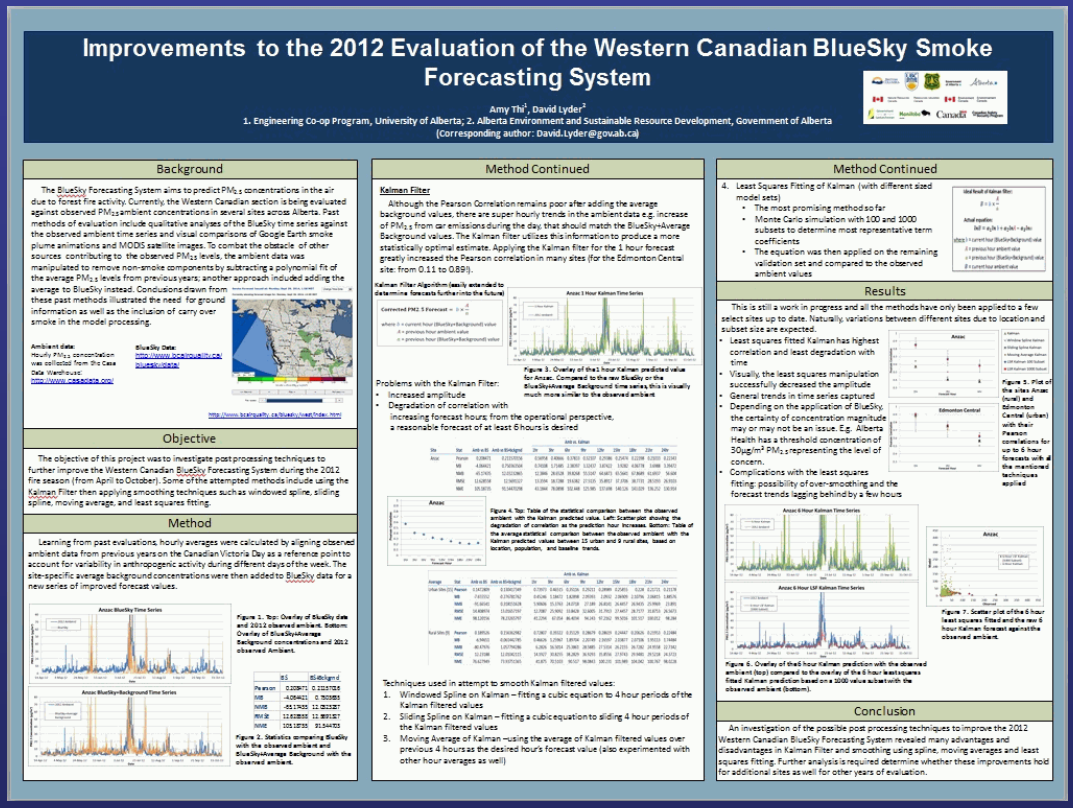


National Forum/Workshop

National Forum/ Workshop will be a scientific exchange with users to be held in conjunction with the Wildland Fire Canada 2014 conference, Halifax, NS, leading to a national standing forum on smoke and air quality.

Evaluation

Efforts are being made to evaluate the performance of the BlueSky system in Western Canada:



Improvements to the 2012 Evaluation of the Western Canadian BlueSky Smoke Forecasting System

Amy Thi[1], David Lyder[2]
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Background

The BlueSky Forecasting System aims to predict $PM_{2.5}$ concentrations in the air due to forest fire activity. Currently, the Western Canadian section is being evaluated against observed $PM_{2.5}$ ambient concentrations in several sites across Alberta. Past methods of evaluation include qualitative analyses of the BlueSky time series against the observed ambient time series and visual comparisons of Google Earth smoke plume animations and MODIS satellite images. To combat the obstacle of other sources contributing to the observed $PM_{2.5}$ levels, the ambient data was manipulated to remove non-smoke components by subtracting a polynomial fit of the average $PM_{2.5}$ levels from previous years; another approach included adding the average to BlueSky instead. Conclusions drawn from these past methods illustrated the need for ground information as well as the inclusion of carry over smoke in the model processing.

Ambient data: Hourly $PM_{2.5}$ concentration was collected from the Data Warehouse: http://www.casadata.org/

BlueSky Data: http://www.pyrocb.ca/blueskydata/

Objective

The objective of this project was to investigate post processing techniques to further improve the Western Canadian BlueSky Forecasting System during the 2012 fire season (from April to October). Some of the attempted methods include using the Kalman Filter then applying smoothing techniques such as windowed spline, sliding spline, moving average, and least squares fitting.

Method

Learning from past evaluations, hourly averages were calculated by aligning observed ambient data from previous years on the Canadian Victoria Day as a reference point to account for variability in anthropogenic activity during different days of the week. The site-specific average background concentrations were then added to BlueSky data for a new series of improved forecast values.

Figure 1. Top: Overlay of BlueSky data and 2012 observed ambient. Bottom: Overlay of BlueSky+Average Background concentrations and 2012 observed Ambient.

Figure 2. Statistics comparing BlueSky with the observed ambient and BlueSky+Average Background with the observed ambient.

Method Continued

Kalman Filter

Although the Pearson Correlation remains poor after adding the average background values, there are super hourly trends in the ambient data e.g. increase of $PM_{2.5}$ from car emissions during the day, that should match the BlueSky+Average Background values. The Kalman Filter utilizes this information to produce a more statistically optimal estimate. Applying the Kalman filter for the 1 hour forecast greatly increased the Pearson correlation in many sites (for the Edmonton Central site: from 0.11 to 0.89!).

Kalman Filter Algorithm (easily extended to determine forecasts further into the future)

Figure 3. Overlay of the1 hour Kalman predicted value for Anzac. Compared to the raw BlueSky or the BlueSky+Average Background time series, this is visually much more similar to the observed ambient

Problems with the Kalman Filter:

- Increased amplitude
- Degradation of correlation with increasing forecast hours: from the operational perspective, a reasonable forecast of at least 6 hours is desired

Figure 4. Top: Table of the statistical comparison between the observed ambient with the Kalman predicted value. Left: Scatter plot showing the degradation of correlation as the prediction hour increases. Bottom: Table of the average statistical comparison between the observed ambient with the Kalman predicted values between 11 urban and 9 rural sites, based on location, population, and baseline trends.

Techniques used in attempt to smooth Kalman filtered values:

1. Windowed Spline on Kalman – fitting a cubic equation to 4 hour periods of the Kalman filtered values
2. Sliding Spline on Kalman – fitting a cubic equation to sliding 4 hour periods of the Kalman filtered values
3. Moving Average of Kalman –using the average of Kalman filtered values over previous 4 hours as the desired hour's forecast value (also experimented with other hour averages as well)

Method Continued

4. Least Squares Fitting of Kalman (with different sized model sets)
   - The most promising method so far
   - Monte Carlo simulation with 100 and 1000 subsets to determine most representative term coefficients
   - The equation was then applied on the remaining validation set and compared to the observed ambient values

Results

This is still a work in progress and all the methods have only been applied to a few select sites up to date. Naturally, variations between different sites due to location and subset size are expected.

- Least squares fitted Kalman has highest correlation and least degradation with time
- Visually, the least squares manipulation successfully decreased the amplitude
- General trends in time series captured
- Depending on the application of BlueSky, the certainty of concentration magnitude may or may not be an issue. E.g. Alberta Health has a threshold concentration of 30μg/m³ $PM_{2.5}$ representing the level of concern
- Complications with the least squares fitting: possibility of over-smoothing and the forecast trends lagging behind by a few hours

Figure 5. Plot of the sites Anzac (rural) and Edmonton Central (urban) with their Pearson correlations for up to 6 hour forecasts with all the mentioned techniques applied

Figure 6. Overlay of the6 hour Kalman prediction with the observed ambient (top) compared to the overlay of the 6 hour least squares fitted Kalman prediction based on a 1000 value subset with the observed ambient (bottom).

Figure 7. Scatter plot of the 6 hour least squares fitted and the raw 6 hour Kalman forecast against the observed ambient.

Conclusion

An investigation of the possible post processing techniques to improve the 2012 Western Canadian BlueSky Forecasting System revealed many advantages and disadvantages in Kalman Filter and smoothing using spline, moving averages and least squares fitting. Further analysis is required determine whether these improvements hold for additional sites as well for other years of evaluation.

Improvements to the 2012 Evaluation of the Western Canadian BlueSky SmokeForecasting System

by Amy Thi, David Lyder (Alberta Environment)

Team

The project team consists of experts from:

- *BC Ministry of Environment*
- *Environment Canada*
- *Natural Resources Canada*
- *Parks Canada*
- *University of British Columbia*

Collectively, this team has over 120 years of experience in atmospheric, air quality and fire sciences.

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