Evaluate Wildfire Emissions in the Canadian GEM-MACH Air Quality Forecast System

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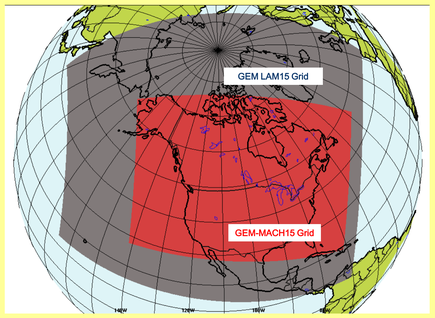
Abstract: An emissions framework for wildfire was recently developed for Environment Canada's real-time GEM-MACH air quality forecast system. The framework incorporates modules from the US Forest Service's BlueSky framework for fire events in the US, and from the Canadian Forest Service's CWFIS (Canadian Wild Fire Information System) for fire events across Canada. Hourly fire emissions are incorporated into GEM-MACH model as major point sources and parameterized with online meteorology. The system was applied to simulate a historical fire event in summer 2010 in British Columbia, Canada.

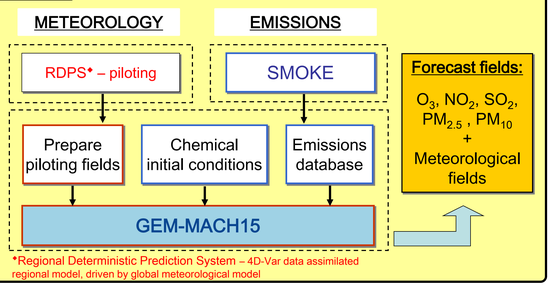
1. GEM-MACH15 - Canada Operational Air Quality Forecast Model

Model Configuration	
Projection	Limited Area Model (LAM) over North America on rotated lat.-lon.
Grids	348 x 465 at 15 x15-km grid
Vertical Coordinate	58 Hybrid Levels
Model Top	0.1 hPa (~60 km)
Time Step	450 s for meteorology 900 s for chemistry
Emissions	Canada 2006, US 2012, Mexico 1999, BEIS v3.09 / BELD3
Execution Time	34 minutes for 48-h forecast on 384 CPUs
Aerosol	Two bin aerosol size for 2.5 and 10 µm; 9 chemical components

Online Meteorology-Chemistry model:
- Twice per day forecast (00Z /12Z)
- 48-hour forecasts of O_3, $PM_{2.5}$ and NO_2
- Inputs for Air Quality Health Index (AQHI)

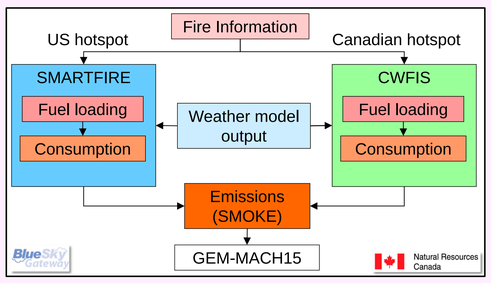


Emissions:
- Current operational system does not include intermittent emissions.
- Anthropogenic emissions are diurnal, day-of-the week by month.
- Plume-rise for major point source is calculated at runtime.
- Biogenic emissions are calculated online with forecast meteorology.



2. Fire Emissions Processing

Wildfire occurs frequently in Canada especially between April – October. Over the past decade (2001-11), approximately 1.9 million hectares of forest burn annually. Emissions from fire are a major intermittent source missing in the current model setup.
New modelling framework with the BlueSky (US Forest Service - http://www.airfire.org/bluesky) is being implemented to address this:



Fire Information:
- Fire hotspot in Canada is retrieved daily from the Canadian Wildland Fire Information System – http://cwfis.cfs.nrcan.gc.ca
- Fire hotspot information in US is retrieved daily from the BlueSky Gateway - http://www.getbluesky.org

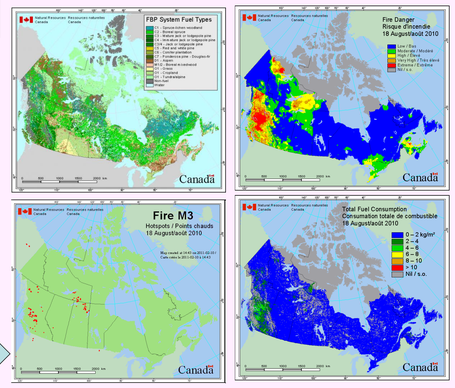
Canadian Wildland Fire Information System

The system is operated by Canadian Forest Service, Natural Resources Canada. It provides 4x daily update of forest fire information across Canada during fire season.

The system includes landuse databases, hotspot detection by remote sensing, forecast meteorology and fire behavior predictions.

The system produces fire and fuel consumption parameters necessary for fire emission estimates.

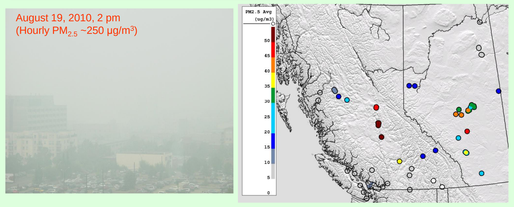
Examples of CWFIS outputs for August 18 2010:

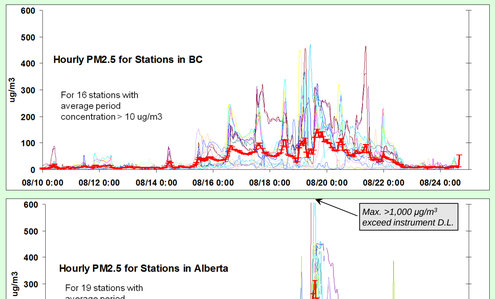


3. Case Study for August 2010 Fire in British Columbia, Canada

This is the largest forest fire of the past decade for BC. Wildfire consumed ~330,000 ha. in the province. On Aug. 18, ~100,000 ha. were consumed within 24-hrs. Emissions from fire were transported over long distances (500 km to 1,000 km) and impacted cities in central Alberta. GEM-MACH15 was setup to hindcast the event (Aug. 10-24 2010) and results are compared with operational forecasts and measurements.

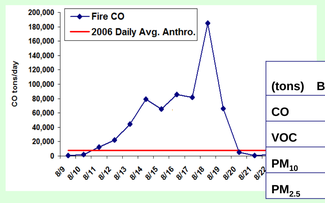
Air Quality Observations:





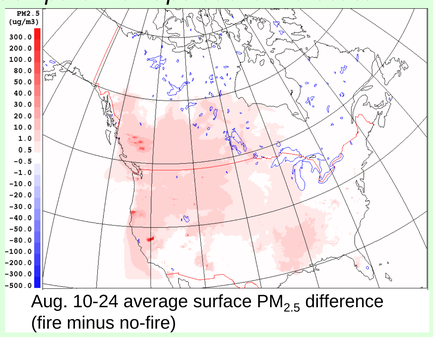
Model Results:

Emissions



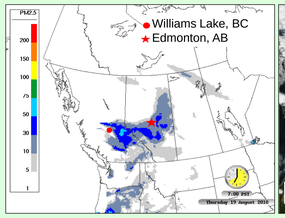
(tons)	BC+AB Fire	BC+AB Anthropogenic
CO	654,122	126,541
VOC	155,514	33,415
PM_{10}	70,337	41,552
$PM_{2.5}$	59,608	9,032

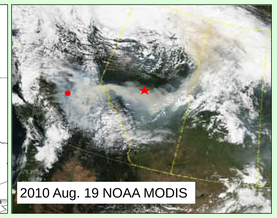
Compare with Operational Forecast:

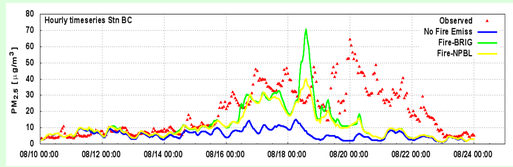


Aug. 10-24 average surface $PM_{2.5}$ difference (fire minus no-fire)

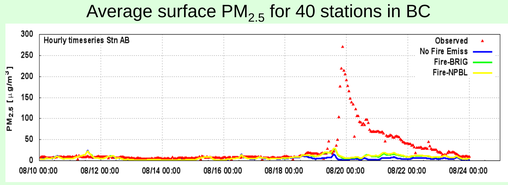
Compare with Measurements:







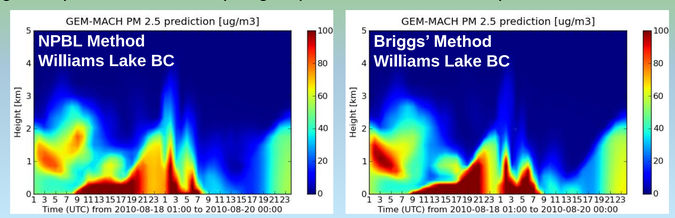
Average surface $PM_{2.5}$ for 40 stations in BC



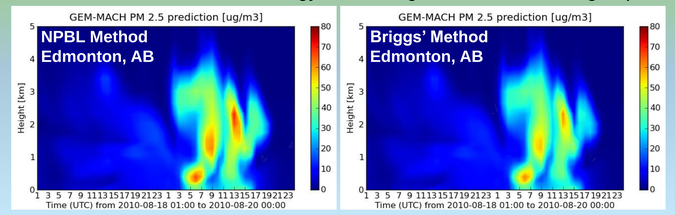
Average surface $PM_{2.5}$ for 25 stations in Alberta

4. Plume-rise Algorithms

Two plume-rise parameterizations were applied to investigate impacts of vertical plume distribution on $PM_{2.5}$ transport and surface concentrations. A simple normalized PBL (NPBL) distribution is compared with the default Briggs' plumerise. The NPBL method distributes hourly emissions evenly from surface to the time-varying PBL profile at fire hotspot grid points. See also comparisons with observations in section above. A new, energy-based algorithm is also being implemented.



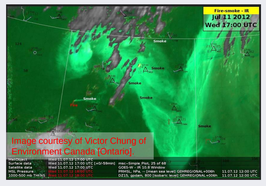
Vertical $PM_{2.5}$ time profile for Williams Lake, BC (near source)



Vertical $PM_{2.5}$ time profile for Edmonton, AB (~500 km from source)

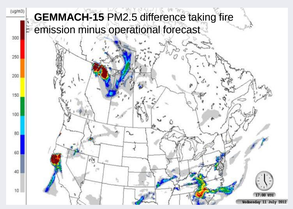
5. Ongoing Work

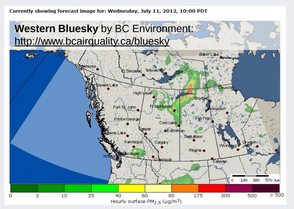
A test system was setup to run alongside the current operational forecast for summer 2012. Preliminary analysis showed system underestimates quantitative $PM_{2.5}$, but captures spatial distribution. Figures below compare results with Western Bluesky system and satellite measurements for a fire event in Alberta.

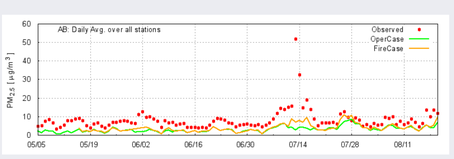


Left: Satellite composite image for a fire event in Alberta.

Right: Corresponding $PM_{2.5}$ concentration contours from GEM-MACH15 and Western Bluesky.







Average PM2.5 forecast for ~27 stations in Alberta with and without fire emissions.

6. Conclusions

A new approach to include real-time fire emissions information into Canadian GEM-MACH15 air quality forecast system was developed. The approach uses the BlueSky framework to incorporate fire ignition information from CWFIS (Canada) and SMARTFIRE (USA). A case study demonstrated:
-Wildfires produce significant amount of emissions; which result in large $PM_{2.5}$ loadings across the model domain.
-Include wildfire emissions showed improvements in surface $PM_{2.5}$ forecasts especially near the source areas.
-$PM_{2.5}$ concentrations show sensitivity to plume-rise parameters mostly near the source of emissions.

Canada