Environment and Climate Change Canada / Environnement et Changement climatique Canada

Multi-Year (2013-2016) Performance Evaluation of FireWork Wildfire PM Forecasts for North America

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Abstract

Adverse effects of wildfires on human health, visibility, and the environment are of great concern to Canadians during the wildfire season from April to October. In order to provide more accurate guidance on wildfire impacts on air quality and visibility, Environment and Climate Change Canada (ECCC) has been running an experimental air quality forecast system with near-real-time wildfire emissions at the Canadian Meteorological Center Operations division since 2013. Initially, only 3 summertime months (June, July and August) were covered by FireWork forecasts, but since 2016, when this system became operational at ECCC, the FireWork air quality forecast system has been run over the seven-months period from April 1 to October 31.

Modelling wildfire emissions and dispersion and forecasting time series of concentrations of air pollutants are essential in monitoring air quality and assessing wildfire impacts. Over the past four years, the performance of the FireWork system was regularly evaluated and analysed at ECCC. In this poster we show multi-year results for different statistics such as RMSE, correlation, and MB and some categorical scores. Some conclusions about FireWork's performance analysis and potential improvements are also shown.

1. Introduction

- Biomass burning (BB), from both natural process (e.g. wildfire) or anthropogenic activities (e.g. controlled prescribed fires or burns), can emit significant amounts of pollutants that can adversely impact local and regional air quality (AQ), public health and climate.
- Emissions from BB includes primary pollutants such as carbon monoxide (CO), particulate matter (PM), and ammonia (NH3), as well as ozone (O3) precursors such as nitrogen oxides
- In addition to their multiple impacts, wildfires have been identified as major natural hazard with a strong effect on the economy and the environment in the summertime in Canada. Therefore, it is essential to explore their potential health impacts.
- Modelling wildfire emissions and dispersion and forecasting time series of concentrations of air pollutants is essential in monitoring air quality and assessing wildfire impacts.
- Sections 2 shows the methodology and modelling setup used in the FireWork AQ modelling system

Objective

- This work aims to validate the performance of the FireWork forecast system over the past four years (2013-2016), and
- Intent to help all Canadians, and especially people involved in preventing air pollution–related health impacts, to understand the differences between particles (PM2.5) from wildfires and those from urban sources in terms of potential impacts on exposed populations and the required response.

2. Methodology and Set-Up

FireWork Modelling System :

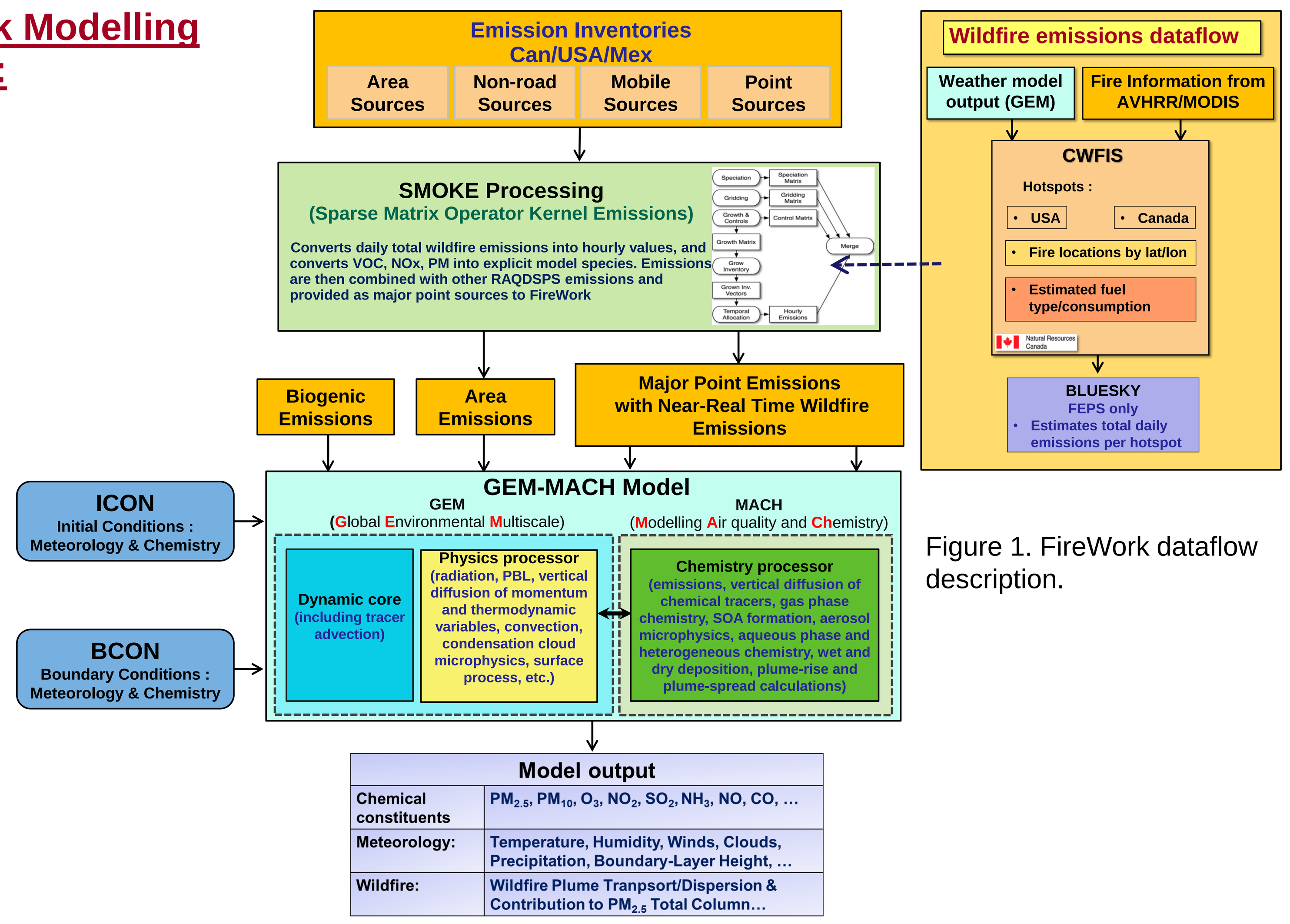

Figure 1. FireWork dataflow description.

FireWork Grid

Figure 2. FireWork domain boundaries before (red) and after (green) a major upgrade to ECCC's operational AQ systems on 7 September 2016.

FireWork has the same configuration as the Regional Air Quality Deterministic Prediction System (RAQDPS). The only difference is the inclusion of near-real time wildfire emissions.

- Run twice daily (initiated at 00 UTC and 12 UTC) for 48 hours
- Available at approximately the same time as the operational RAQDPS model

Grid configuration	Limited Area Model over North America (LAM)
Grid projection	Rotated Latitude-Longitude
Model horizontal spacing	10 km
Vertical coordinate	80 Hybrid Levels up to 0.1 hPa (~60 km)
Model time step	300 s for meteorology; 900 s for chemistry
Model output	Meteorology & Chemistry (gases and particles)
On-line chemistry processes	Representation of gas and aerosol chemistry, including: •Gas-Phase Chemistry: ADOM-II (42 species, 114 reactions) •Aerosol representation: 2 size bins (0 -2.5 um, 2.5 – 10 um); 8 chemical species (SO_4, NO_3, NH_4, EC, pOC, sOC, crustal material, sea salt) •Aerosol dynamics/microphysics •Aqueous & Inorganic heterogeneous chemistry •Secondary organic aerosol chemistry •Cloud processing (aerosol activation, aqueous-phase chemistry, wet removal of gas and aerosols) •Dry deposition for aerosol particles and gases. •One-way coupling (meteorology affects chemistry)

- VAQUM, an AQ forecast performance evaluation toolkit, was used to compute various statistics to enable a comprehensive evaluation of FireWork's forecasting performance (Gilbert et al., 2010)

3. Results

The Canadian WildFire Season

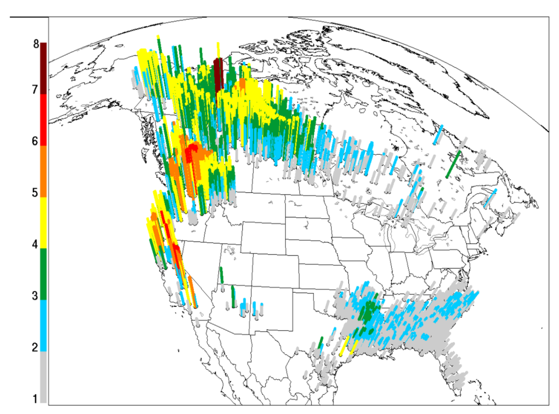

Figure3. Example of Total Fuel Consumption (TFC) per hotspot (kg m^{-2}) for the period 2 June – 31 August 2015 ; provided by CWFIS (TFC > 1.0 kg m^{-2})

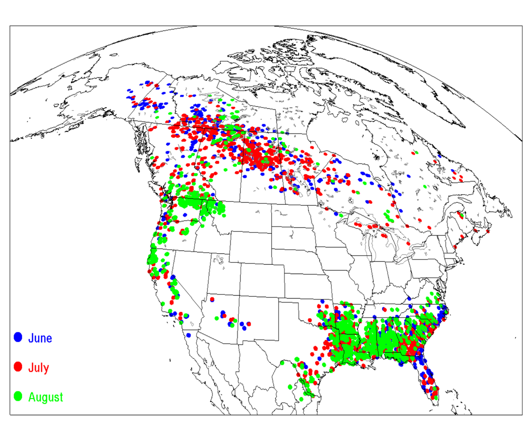

Figure 4. Example of months (JJA 2015) in which detected wildfire started (TFC > 1.0 kg m^{-2})

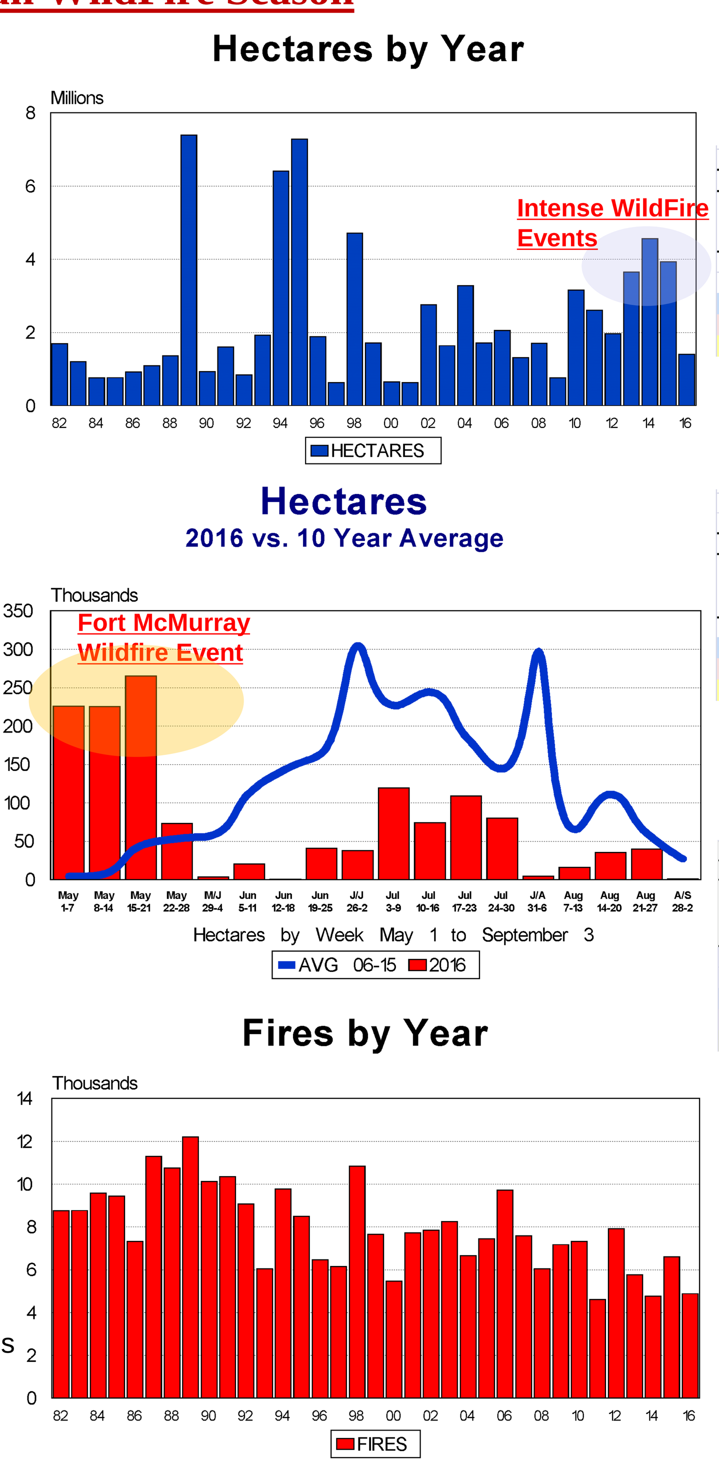

Figure 5. Top: Total hectares burned by year in Canada since 1982. Middle: Comparisons 2016 burned hectares versus 10-year average (2006-2015). Bottom: Number of wildfires detected by year in Canada. (Source: Canadian Interagency Forest Fire Centre, http://www.ciffc.ca)

PM2.5 Objective Scores

Summer 2013

Objective Scores (based on hourly forecasts)

BOOTSRAPPING		Canada		W Canada		E Canada	
Pollutant	Statistic	OPS	with Forest Fires	OPS	with Forest Fires	OPS	with Forest Fires
$PM_{2.5}$	MB	-0.06	0.71	-1.29	-0.52	0.96	1.74
	R	0.35	0.40	0.13	0.25	0.34	0.39
	URMSE	10.10	10.00	7.08	7.13	11.96	11.79

Legend
OPS G-M better
G-M with Forest Fires better
Statisticlly not significant

Summer 2014

Objective Scores (based on hourly forecasts)

BOOTSRAPPING		Canada		W Canada		E Canada	
BOOTSRAPPING		Canada		W Canada		E Canada	
Polluant	Statistic	OPS	FireWork	OPS	FireWork	OPS	FireWork
$PM_{2.5}$	MB	-2.32	-0.27	-6.52	-2.72	1.08	1.72
	R	0.13	0.36	**0.03**	**0.41**	0.38	0.40
	URMSE	13.90	13.04	15.99	15.04	10.82	10.75

Legend
OPS G-M better
G-M with Forest Fires better
Statisticlly not significant

Summer 2015

Objective Scores (based on hourly forecasts)

BOOTSRAPPING		Canada		Ouest du Canada		Est du Canada	
Polluant	Statistique	OPS	FireWork	OPS	FireWork	OPS	FireWork
$PM_{2.5}$	MB	-2.38	-0.69	-5.14	-2.02	-0.10	0.40
	R	0.12	0.47	**0.09**	**0.49**	0.35	0.41
	URMSE	14.36	14.25	18.72	18.83	8.71	8.66

Legend
OPS G-M better
G-M with Forest Fires better
Statisticlly not significant

Summer 2016

Objective Scores (based on hourly forecasts)

BOOTSRAPPING		Canada		W Canada		E Canada	
Polluant	Statistic	OPS	Firework	OPS	Firework	OPS	Firework
$PM_{2.5}$	MB	-1.44	-1.24	-1.75	-1.20	-1.17	-1.27
	R	0.22	0.24	0.11	0.19	0.34	0.34
	RMSE	7.16	8.95	8.02	11.36	6.33	6.21

Legend
OPS G-M better
G-M with Forest Fires better
Statistically not significant

Significant improvements for PM2.5 statistics with FireWork

Difference: FW - OPS

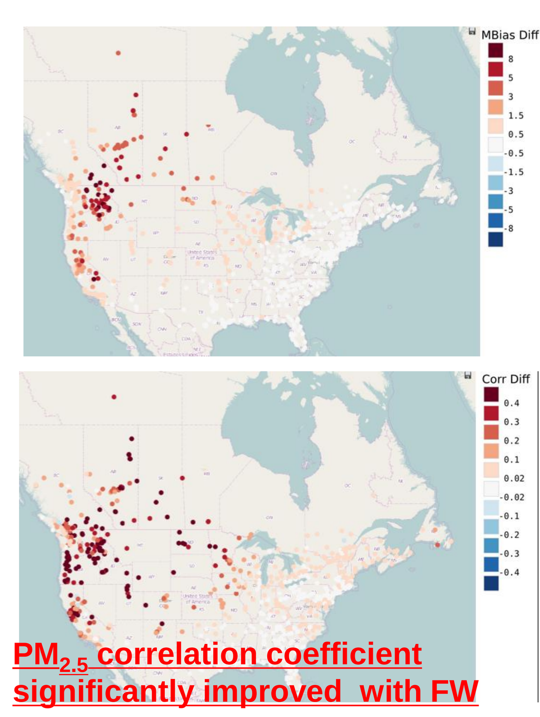

Figure 6. $PM_{2.5}$ mean Bias (top) and correlation (bottom) for Summer 2015 for individual measurement stations. .

Forecasted wildfire emissions contribution to average summertime PM2.5 concentrations

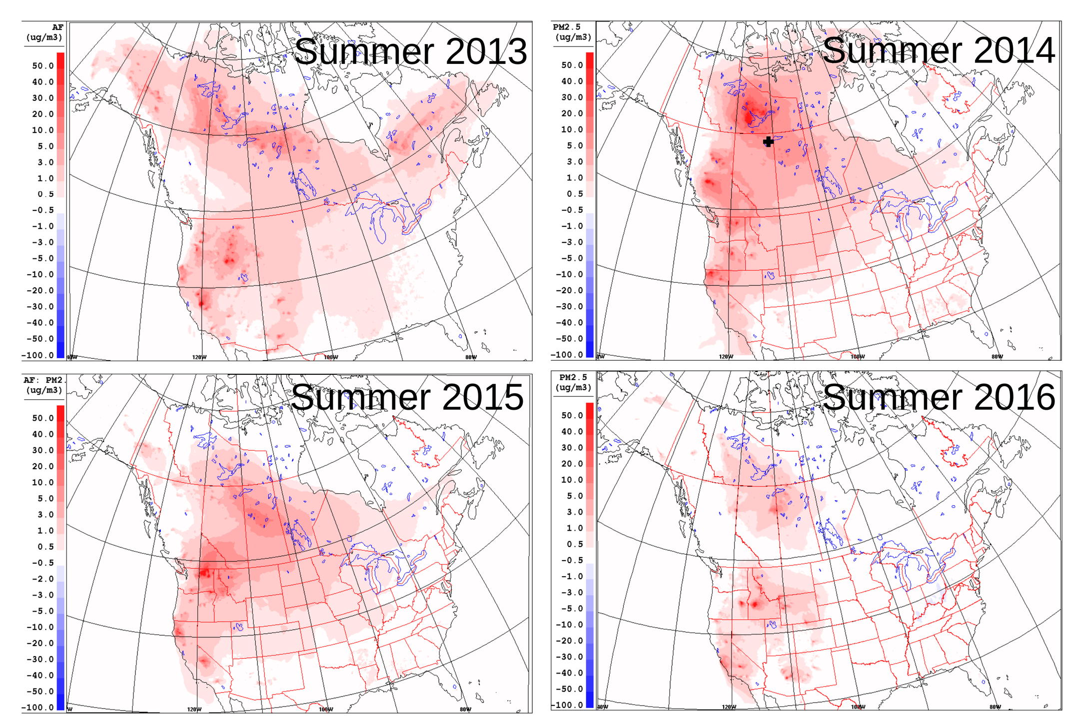

Figure 7. Average wildfire emission contribution to forecasted surface $PM_{2.5}$ (ug/m^3) concentrations. Top Left: Summer 2013, Top Right: Summer 2014, Bottom Left: Summer 2015 and Bottom Rght: Summer 2016.

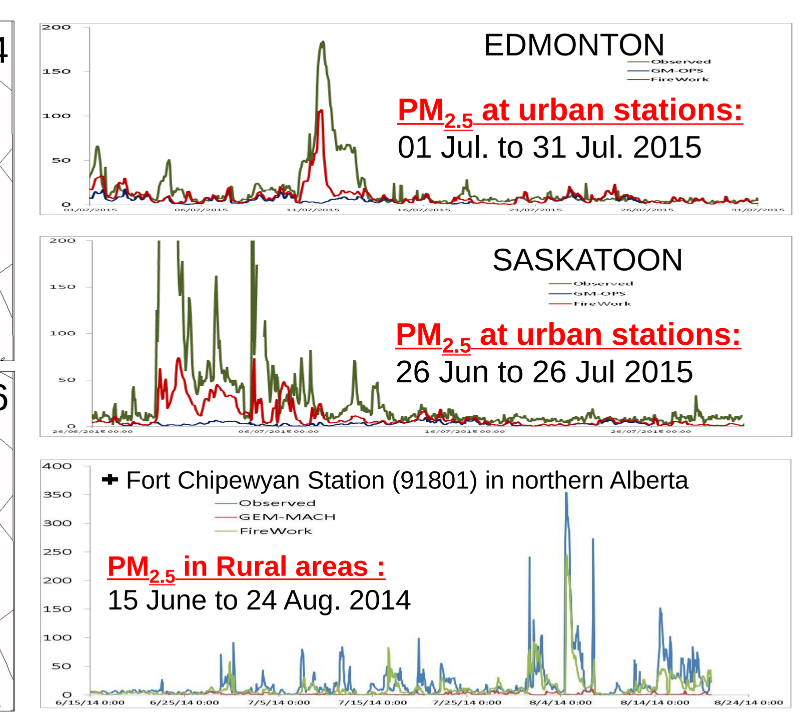

Figure 8. Forecasted (Operational and Firework) and observed $PM_{2.5}$ concentrations (ug/m^3) at selected Urban (Top and Middle) and Rural stations (Bottom) in western Canada.

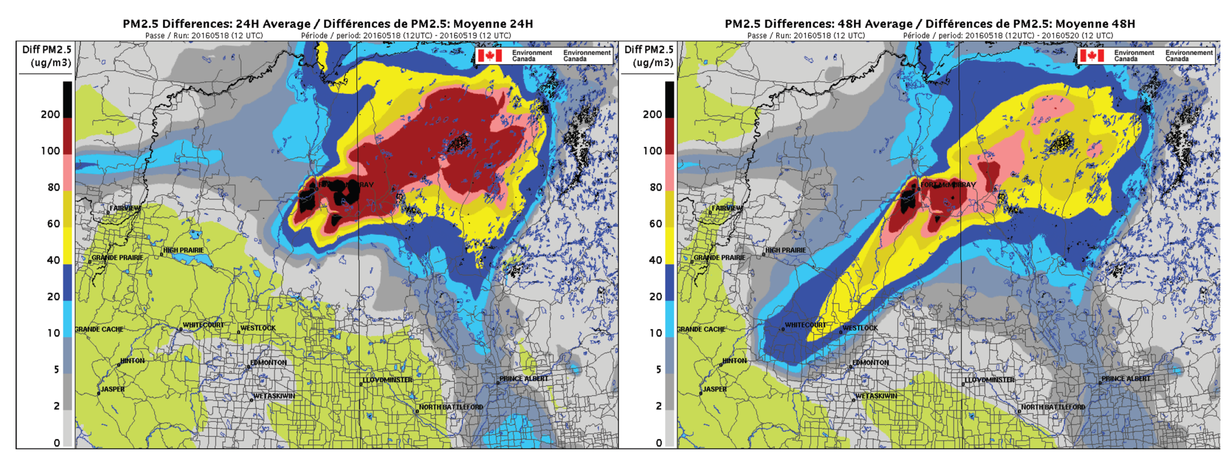

Figure 9. Contribution of forecasted wildfire emissions to surface $PM_{2.5}$ concentrations (µg/m^3) over a 24-hour period (left) and a 48-hour period (right) during the 18th May 2016 Fort McMurray wildfire event in northern Alberta (12 UTC run).

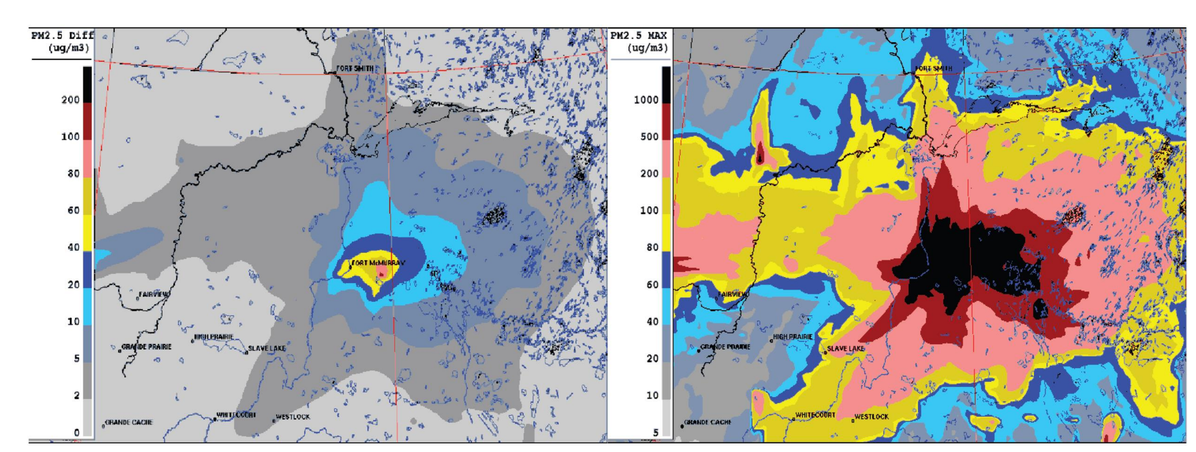

Figure 10. Contribution of forecasted wildfire emissions to mean monthly $PM_{2.5}$ concentrations (µg/m^3) at the surface (left) and to maximum hourly $PM_{2.5}$ concentrations (right) for May 2016 in northern Alberta.

4. Conclusions

Since 2013, an online-coupled meteorology-chemistry wildfire model system, FireWork, has been deployed by the Canadian Meteorological Centre Operations division to deliver real-time air quality forecasts over North America during the Canadian wildfire season. Forecasted $PM_{2.5}$ concentrations during the wildfire season for the 2013-2016 period showed FireWork to be a very useful tool in forecasting PM2.5 concentrations. In Canada, PM2.5 trends are strongly driven by wildfire-generated pollution. $PM_{2.5}$ from wildfires have an impact on health, not only locally, but also in areas hundreds of kilometres away from the wildfire sources. For example, in May 2016 during the Fort McMurray fire event, the average forecasted wildfire contributions to total forecasted $PM_{2.5}$ concentrations were above 50 µg/m^3 for the area close to Fort McMurray. For maximum hourly $PM_{2.5}$ concentration, the area close to Fort McMurray and a few hundred kilometers downwind of the city had forecasted maximum concentrations above 500 µg/m^3 and the most heavily affected area had forecasted values above 10,000 µg/m^3.