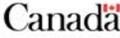



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ECCC Modelling and Network Analysis of the Oil Sands

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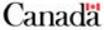
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2. Environmental Monitoring and Science Division, AEP

Oil Sands Symposium, November 22, 2016

Outline

- An introduction to the **G**lobal **E**nvironmental **M**ultiscale-**M**odelling **A**ir-quality and **C**hemistry (GEM-MACH) model
 - Version 1.5.1 (used up to September of 2016).
 - Version 2.0 (used after September 2016).
- Updates and improvements to the model and modelling work in 2016/17
 - Organic Aerosol Processes
 - Mercury
 - PAHs
 - Very high resolution tests (1km)
- Next Steps
- Plans for the next 5 years

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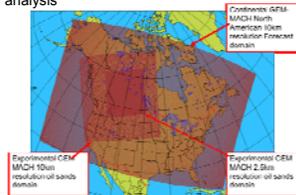
GEM-MACH: EC's AQ Model

- First described in Moran et al (2010).
- Comparison of **v1.5.1** against 2006 and 2010 observations for North America and other peer models in *Atmospheric Environment* special issue on the Air Quality Model Evaluation International Initiative, Phase 2 (AQMEII-2); Makar et al, 2015 (a,b).
- **V2.0 of GEM-MACH is now in use in Canada's operational air-quality forecast – and for oil sands simulations carried out by ECCC.**
- GEM-MACH is an on-line chemical transport model which includes:
 - chemistry and meteorology combined in a single model (on-line)
 - Gas-phase chemistry (42 species)
 - Aqueous phase chemistry and scavenging
 - Inorganic and organic particle formation
 - 2-or-12-aerosol size fraction representation
 - 8 aerosol species (sulphate, ammonium, nitrate, primary organic carbon, secondary organic carbon, elemental carbon, crustal material, sea-salt)
 - Option for feedbacks between weather and air pollution in 12 bin mode, inclusion of PAHs, Hg, etc.



GEM-MACH Description (Old setup: version 1.5.1)

- 2-bin version (i.e., 2 aerosol size fractions):
 - Ongoing experimental forecasts
 - In continuous operation since October of 2012
 - Used in support of the assessment of ecosystem and human health impacts
 - 2006/2010 emissions (v1.5.1)
- 12-bin version (i.e., 12 aerosol size fractions):
 - Comparisons with field intensive observations
 - Used for detailed chemical process analysis
 - Short-term scenarios
 - 2010/2013 emissions (v1.5.1)



Tests of GEM-MACH version 2 compared to version 1.5.1

- We tried a parallel run, evaluating both v2 (new) and v1.5.1 (old) model versions, using WBEA data for August and September of 2013

The new version of GEM-MACH significantly outperformed the old version

- At right: model with the better score has been highlighted in green.
- Similar improvements for the 12 bin version of the model

Stats	SO ₂ (ppbv)		NO (ppbv)		NO ₂ (ppbv)		O ₃ (ppbv)		PM _{2.5} (µg·m ⁻³)	
	GMv2	GMv1	GMv2	GMv1	GMv2	GMv1	GMv2	GMv1	GMv2	GMv1
Num. of obs.	7140		4890		4880		3301		5137	
RMSE of predictions (PAC2)	0.25	0.16	0.10	0.11	0.35	0.29	0.78	0.69	0.33	0.29
Mean Bias	0.57	1.67	0.42	0.54	0.00	1.12	-0.25	8.28	-2.02	-3.86
Mean Gross Err	1.65	2.55	0.79	1.44	3.01	4.77	7.46	0.03	4.12	4.5
Norm. Mean Bias	0.58	1.65	0.12	0.25	0.12	0.31	-0.01	0.45	-0.36	-0.65
Norm. Mean Gross Err	1.65	2.52	1.50	1.76	1.05	1.32	0.40	0.54	0.71	0.77
Root Mean Sq Error	4.63	7.15	10.90	17.10	6.91	9.76	19.00	4.40	5.94	6.26
Corr. Coeff.	0.30	0.29	0.14	0.11	0.32	0.26	0.55	0.45	0.38	0.34
Coef. of efficiency	-0.14	-0.83	-0.03	0.27	-0.12	0.41	0.15	-0.14	-0.25	-0.35
Index of Agreement	0.44	0.09	0.48	0.37	0.44	0.30	0.58	0.43	0.40	0.33

Tests of GEM-MACHv2 compared to v1.5.1

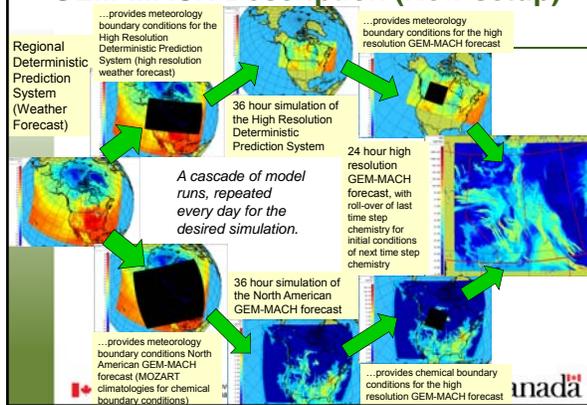
- The improvement in model performance was sufficiently high that we decided to:
 - Switch the ongoing experimental forecast to the new model version (completed September 2016)
 - Carry out a repeat run of August 2013 through July 2014 (runs underway, will complete January 2016).
 - Acid deposition impacts to be re-estimated using new model version

GEM-MACH Description (New setup)

- Both 2 and 12-bin oil sands simulations are now making use of GEM-MACH version 2
 - Improved algorithms for advection and surface fluxes
 - Links with the most recent version of the weather forecast model (GEM)
- New emissions for 2013
 - Canadian non oil sands area source emissions for 2013 (AEPI), and NPRI major point sources for 2013.
 - CEMA 2010 inventory and spatial allocations still used for the Athabasca oil sands region
 - Alberta Environment and Parks Continuous Emissions Monitoring data obtained and converted for model use for August and September 2013 retrospective simulations

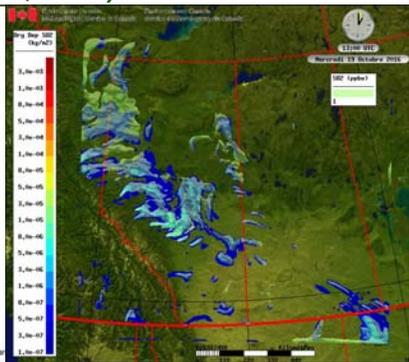


GEM-MACH Description (New setup)



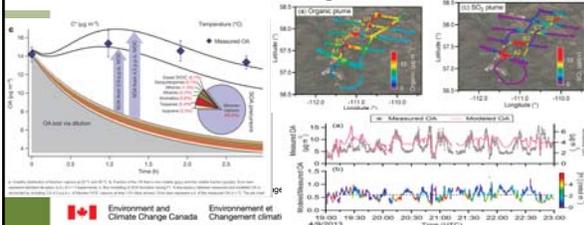
A recent forecast for SO₂ (October 19, 2016)

- Transparent clouds: model-predicted SO₂ concentrations above 1 ppbv.
- Surface contours: SO₂ dry deposition to the surface of the earth, in (kg m⁻²).



Organic aerosol process modelling: Craig Stroud

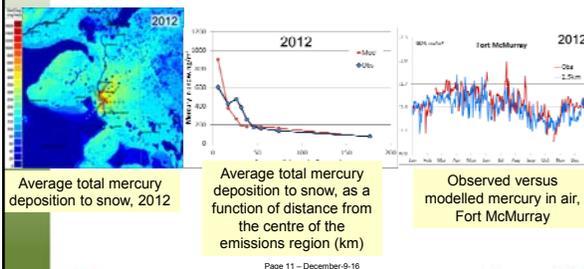
- Air quality modelling was used to test ideas for how organic aerosol formation takes place at the oil sands – Ligio et al *Nature* paper.
- Air quality modelling is being used to examine the extent to which having acidic aerosols at the oil sands might influence organic aerosol formation.



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GEM-MACH-Hg Simulations for the oil sands: Ashu Dastoor

- A version of GEM-MACH with mercury chemistry has been used to simulate 4 years of chemistry and deposition (2012 shown is below)



Average total mercury deposition to snow, 2012

Average total mercury deposition to snow, as a function of distance from the centre of the emissions region (km)

Observed versus modelled mercury in air, Fort McMurray

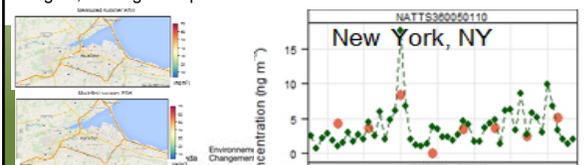
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GEM-MACH-PAH: Planned Oil Sands Simulations

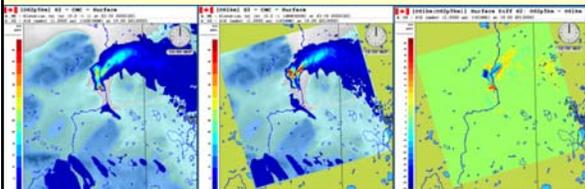
- Benzene and polycyclic aromatic hydrocarbons (PAHs) are **carcinogenic**, **mutagenic**, and **teratogenic** compounds that are ubiquitous in the atmospheric environment
- 7 semi-volatile gas & particle-phase PAHs and gas-phase benzene have been added to GEM-MACH, and modelled at 2.5-km resolution for a domain encompassing the Great Lakes
- Comparisons to observations and reruns with improved emissions are underway – this version of GEM-MACH will be ported to the oil sands region, starting this April.



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GEM-MACH: 2.5km versus 1km resolution

- Tests of a 1km version of GEM-MACH are underway at Carleton University (Matthew Russell and Amir Hakami).
- Evaluation of 1km results against aircraft observations will start in December 2016.



2.5km resolution SO₂ 1km resolution SO₂ Difference (2.5km - 1km)

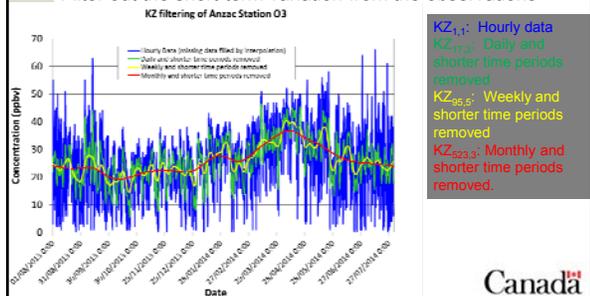
The higher resolution simulations are capable of resolving higher concentration plumes – evaluation against aircraft observations are starting soon.

ECCC Network Analysis under JOSM

- The ECCC part of this project has four stages, and is expected to take two fiscal years (April 1 2016 – March 31, 2018) to complete
- The work has four stages
 - (1) Numerical testing of the time filtering and clustering methodology
 - (2) Application of the methodology to AEP monitoring network data
 - a. What can the methodology tell us about the network? Are some stations odd/different? Are some stations measurements very similar to others (potentially redundant)?
 - b. Quantification of station similarities and differences ← Where we are now.
 - (3) Application of the methodology to GEM-MACH output at monitoring network locations
 - (4) Application of the methodology to GEM-MACH gridded output
- Successful completion of each stage is a precursor to going on to the next stage.

Network Analysis: Time Filtering of Alberta Environment and Parks Data

- An example using AEP data (station 1225: Anzac): O₃
- Filter out the short-term variation from the observations



GEM-MACH Oil Sands Modelling: Next 5 years

1. New Estimates of Acid Deposition using GEM-MACH version2
2. Improved Forecast system for spring/summer 2018 monitoring intensive.
 - a) Better organic aerosol formation incorporated in model.
 - b) Nesting down from global (gas chemistry) down to 1km resolution in oil sands region.
 - c) Updates to emissions (Continuous Emissions Monitoring, aircraft observation based estimates, and other data)
3. GEM-MACH-PAH: estimates of PAH emissions and concentrations in the oil sands area.
4. GEM-MACH process updates (organic aerosols, cloud processing, completion of GEM-MACH-Hg work under JOSM)
5. Forest fires! ECCC is working on a *high resolution forest fire simulation capability* using the new v2 JOSM setup.

**Thank-you for your
interest!**

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