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Recent Improvements to the Representation of Anthropogenic Emissions in the Canadian Operational Air Quality Forecast Model (GEM-MACH)

Mike Moran¹, Qiong Zheng¹, Junhua Zhang¹, Radenko Pavlovic²,
Sylvain Ménard², and Mourad Sassi²

¹Air Quality Research Division, Environment Canada, Toronto, Ontario, Canada

²Air Quality Modelling Applications Section, Environment Canada, Montreal, Quebec, Canada

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The Challenge: The preparation of emissions inputs for AQ models is not known to be a glamorous or exciting task



The Reward: The “quality” of emissions inputs has a direct impact on AQ model performance

Talk Outline

- Canadian context
- How to improve emissions inputs
- Some examples of improvements
- Ongoing and future work



Canadian AQ Forecasting System (1)

- Primary messaging tool is the Air Quality Health Index (AQHI)
- Main target is urban areas > 100,000 population
- GEM-MACH AQ / Wx on-line forecast model provides guidance on AQHI component values (**NO₂**, **O₃**, **PM_{2.5}**) and meteorological fields out to 48 h (as described yesterday by Sylvie Gravel)
- Forecast domain covers most of North America

Canadian AQ Forecasting System (2)

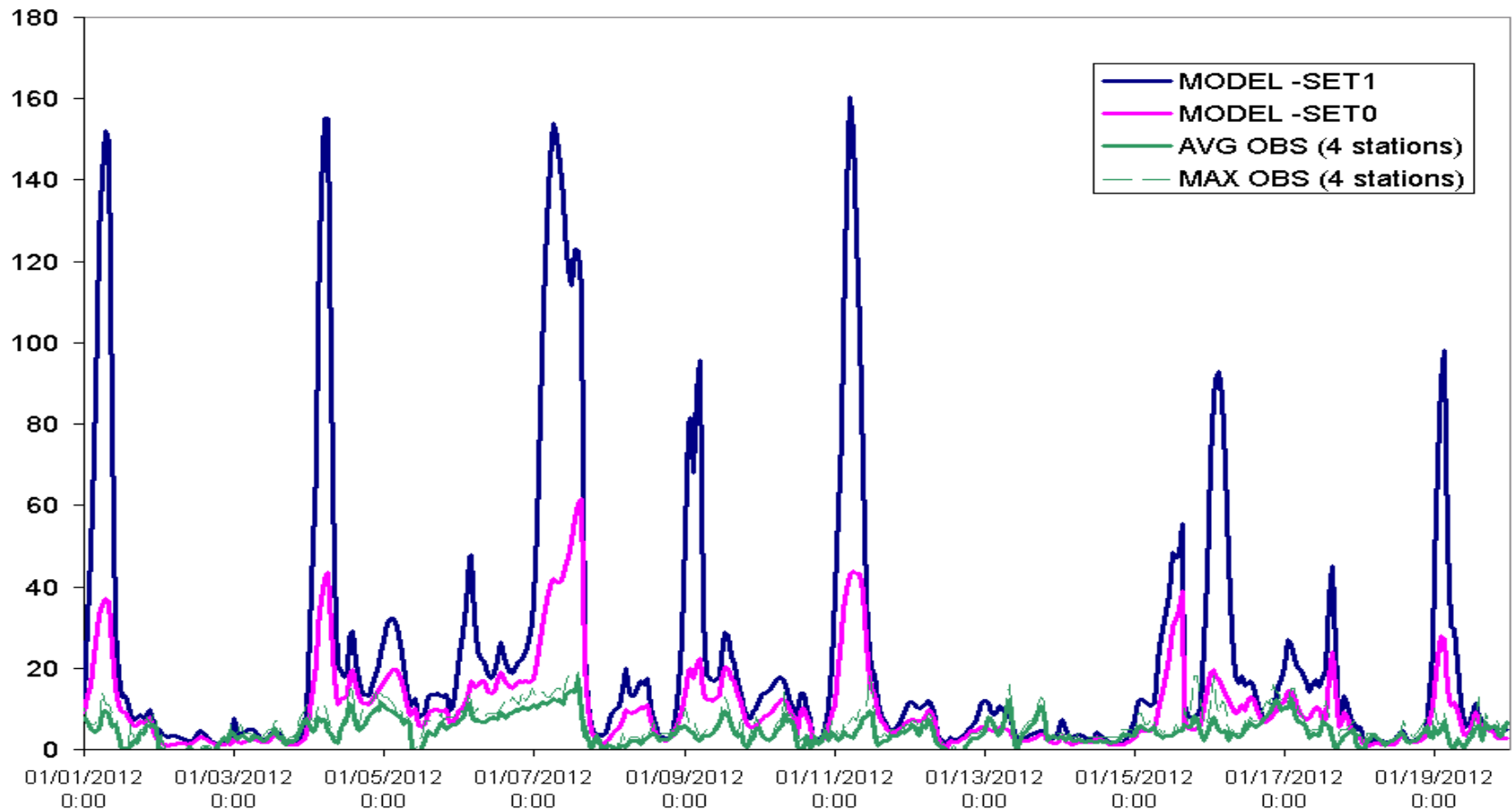
- Recently reduced grid spacing from 15 to 10 km
- Have plan to introduce higher-resolution urban nested domains; prototype will be a nested domain centred on Toronto with 2.5-km grid spacing
- ➔ Need continental-scale emissions fields at 10 km and regional emissions fields at 2.5 km
- Have had problems with $\text{PM}_{2.5}$ and NO_2 overpredictions in urban areas, especially in winter

Evaluation of Emissions Fields

AQ model performance evaluation (SIC stations)

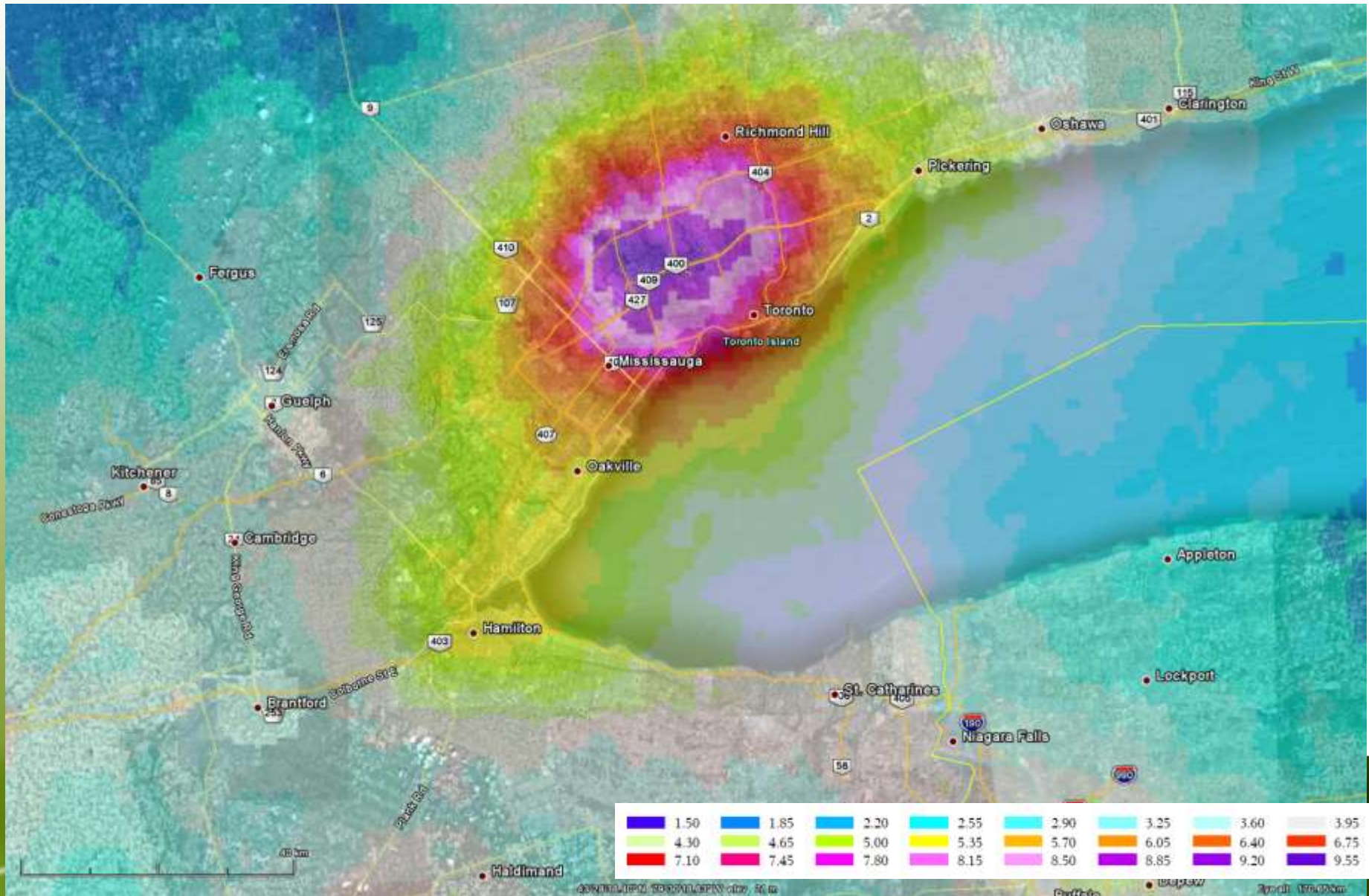
- Other indirect measurements: satellite data, field studies, mobile monitors
- Detailed subdomain analysis of emissions processing and identification of key sectors
- Methodology comparison across jurisdictions
- Direct examination of emissions magnitudes, particularly for wintertime

Observed and Predicted Toronto PM_{2.5} (ug/m³) Time Series (1-19 Jan. 2012)

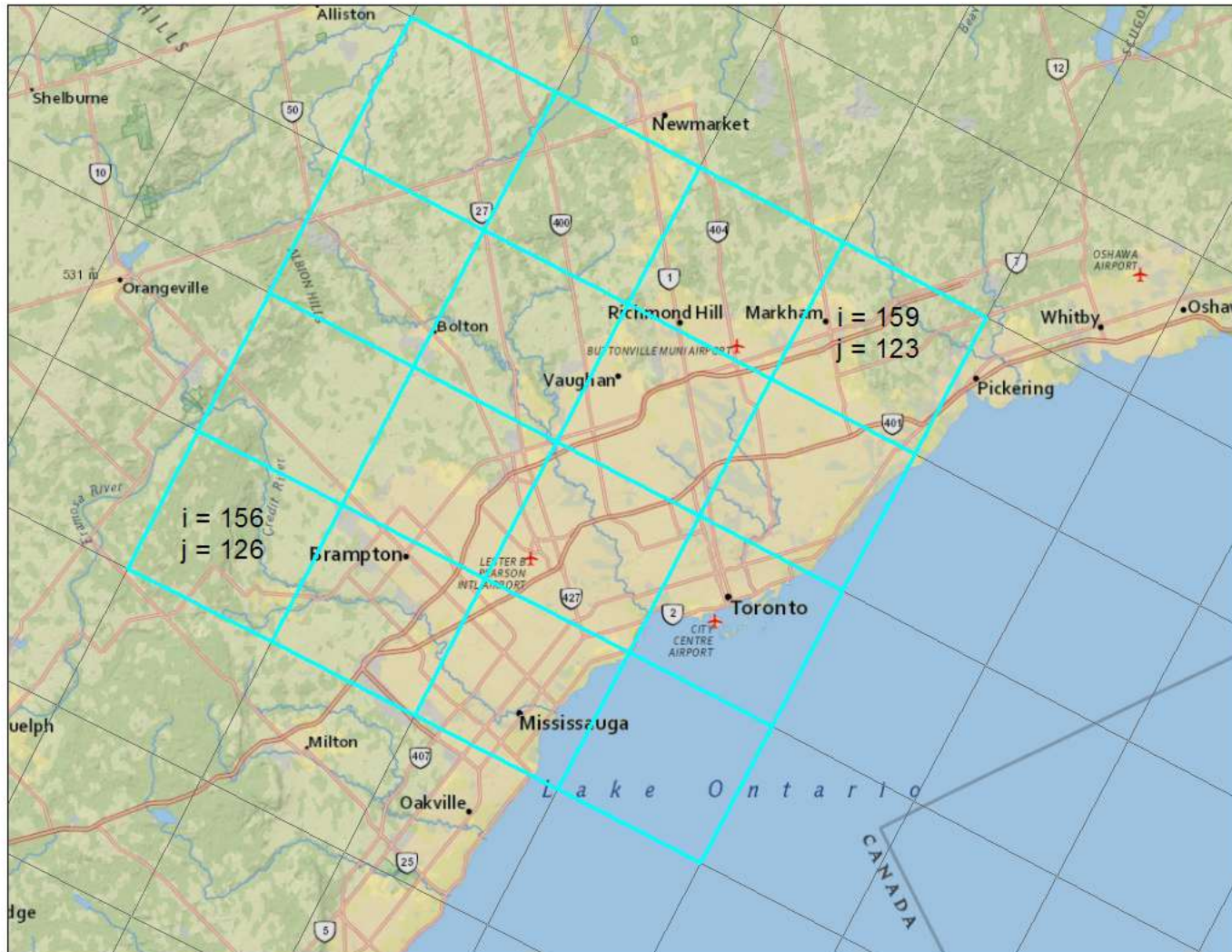


Stations considered: 60410, 60421, 60430 et 60424

2005-2010 OMI NO₂ Vertical Column Density over Toronto (courtesy of Chris McLinden, Environment Canada, Dec. '11)



Analysis of GEM-MACH15 Emissions for 4x4 Toronto Subdomain



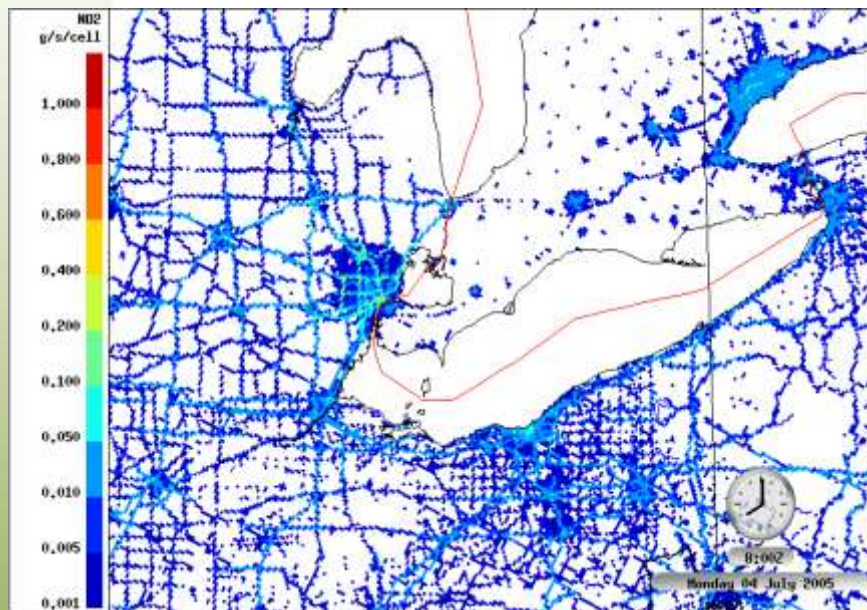
Top 10 NOx Surface Source Sectors in Toronto GEM-MACH15 4x4 Subdomain for SET1 Emissions (total 83,675) from SMKREPORT

Source	SCC	Primary Surrogate	SCC Description	NOx [tons/year]	NOx percent (%)
oarea	2000000000	106	Other industries	4,790	5.7
oarea	2104006000	101	Stationary Source Fuel Combustion;Residential;Natural Gas;Total: All Combustor Types	4,722	5.6
onroad	2230070230	200	Mobile Sources;Highway Vehicles - Diesel;All HDDV including Buses (use subdivisions -071 thru -075 if possible);Urban Interstate: Total	3,682	4.4
oarea	2103006000	921	Stationary Source Fuel Combustion;Commercial/Institutional;Natural Gas;Total: Boilers and IC Engines	3,481	4.2
onroad	2230070250	200	Mobile Sources;Highway Vehicles - Diesel;All HDDV including Buses (use subdivisions -071 thru -075 if possible);Urban Other Freeways and Expressways: Total	3,254	3.9
onroad	2230070290	200	Mobile Sources;Highway Vehicles - Diesel;All HDDV including Buses (use subdivisions -071 thru -075 if possible);Urban Minor Arterial: Total	2,993	3.6
onroad	2230070110	202	Mobile Sources;Highway Vehicles - Diesel;All HDDV including Buses (use subdivisions -071 thru -075 if possible);Rural Interstate: Total	2,939	3.5
onroad	2230070270	200	Mobile Sources;Highway Vehicles - Diesel;All HDDV including Buses (use subdivisions -071 thru -075 if possible);Urban Other Principal Arterial: Total	2,755	3.3
offroad	2270005015	111	Mobile Sources;Off-highway Vehicle Diesel;Agricultural Equipment;Agricultural Tractors	2,745	3.3
offroad	2267003020	106	Mobile Sources;LPG;Industrial Equipment;Forklifts	2,650	3.2

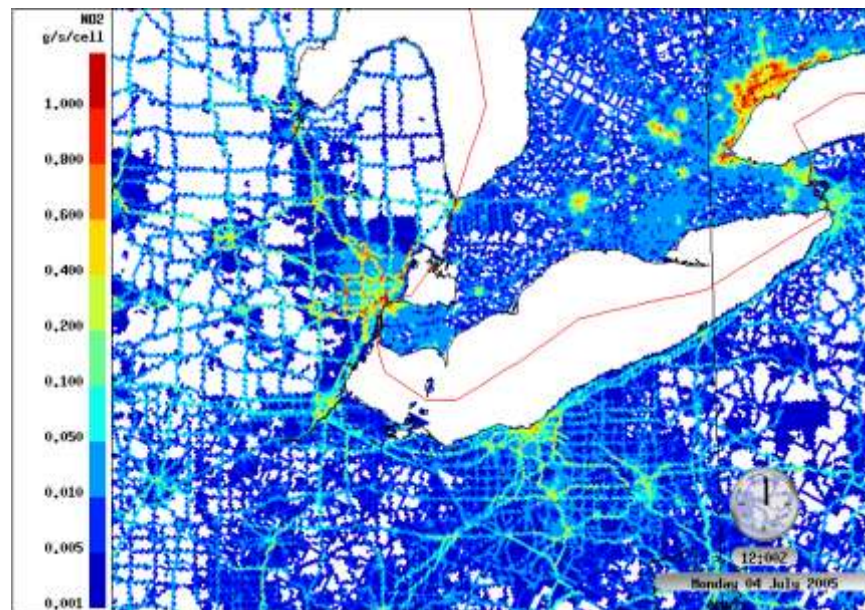
Comparison of Canadian and U.S. On-Road NO₂ Emissions

(from Zhang et al., 2010, 19th International Emission Inventory Conference)

NO₂ Emissions, 4:00 a.m. Local Time (8Z)

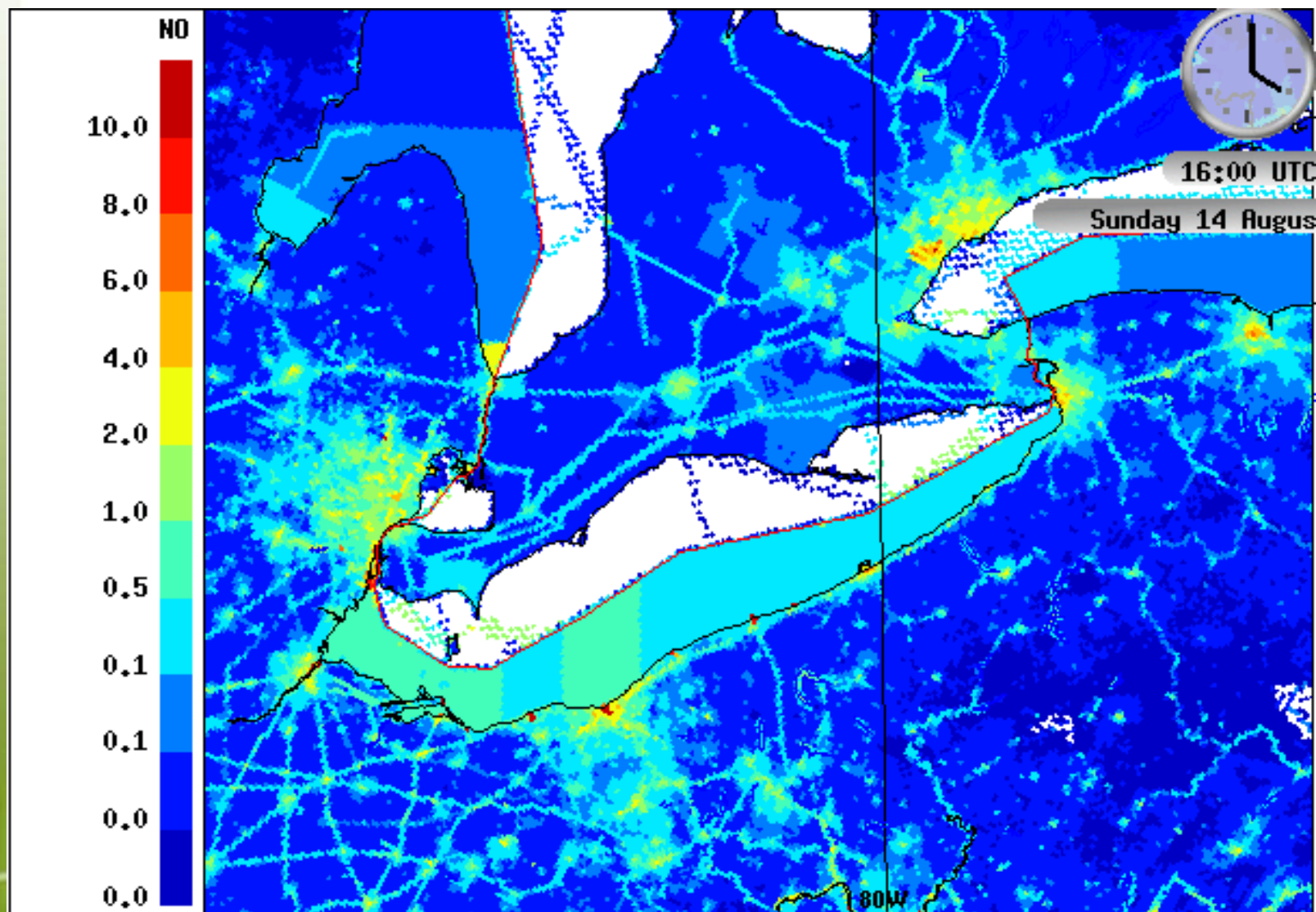


NO₂ Emissions, 8:00 a.m. Local Time (12Z)



- (1) High-resolution (2.5km) emissions processing for the 2007 BAQS-Met study (Makar et al, ACP 10, 11151-11173, 2010) identified differences between Canadian and US mobile emissions
- (2) Locations of the major highways in the US are obvious, but major Canadian highways cannot be distinguished from smaller roads
- (3) The Canadian on-road emissions appear to be overweighted to city centres (compare Detroit and Toronto) and also to smaller roads
- (4) Canadian emissions are significantly smaller than the U.S. emissions a few hours before dawn, e.g., 4 a.m. local time

Example: Cross-border Disagreement of NO Emissions over Water Due to Different U.S. and Canadian Spatial Surrogates (2.5-km Grid)



Possible Approaches to Improve Input Emissions and Emissions Processing

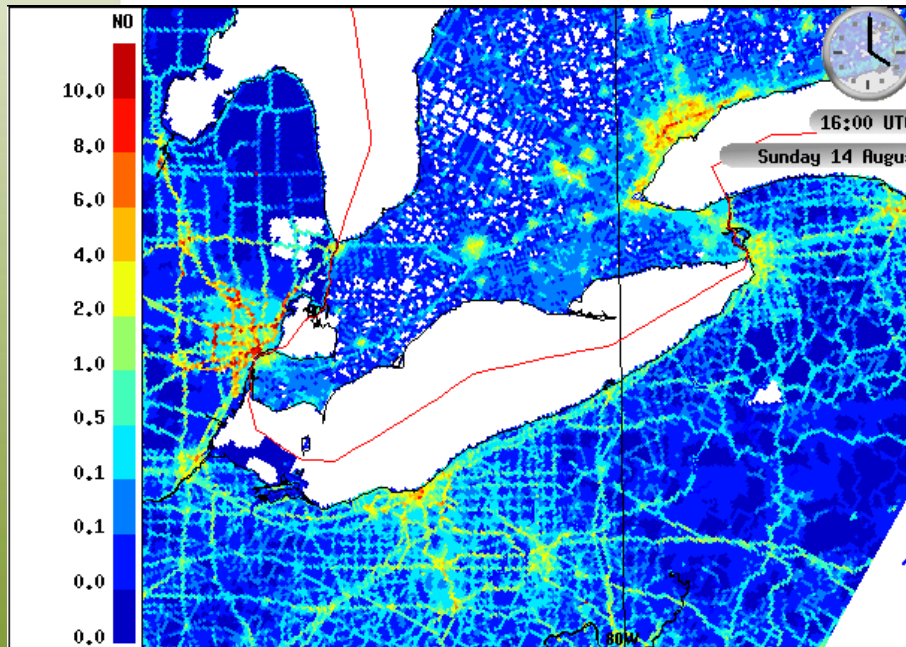
- Use of projected inventories and/or facility closure info
- Feedback to inventory developers
- Improved / new spatial & temporal surrogates and chemical speciation profiles
- Use of alternate emissions and activity data sets (e.g., link-based emissions, LTO statistics, household surveys, ...)
- Focus on problematic source sectors (e.g., residential wood combustion, prescribed burning, road dust, construction, agriculture, ...)
- Scale dependence of spatial surrogates
- Meteorological modulation (e.g., T, V, PCP, snow cover)

Recent Improvements to Input Emissions and Emissions Processing for GEM-MACH

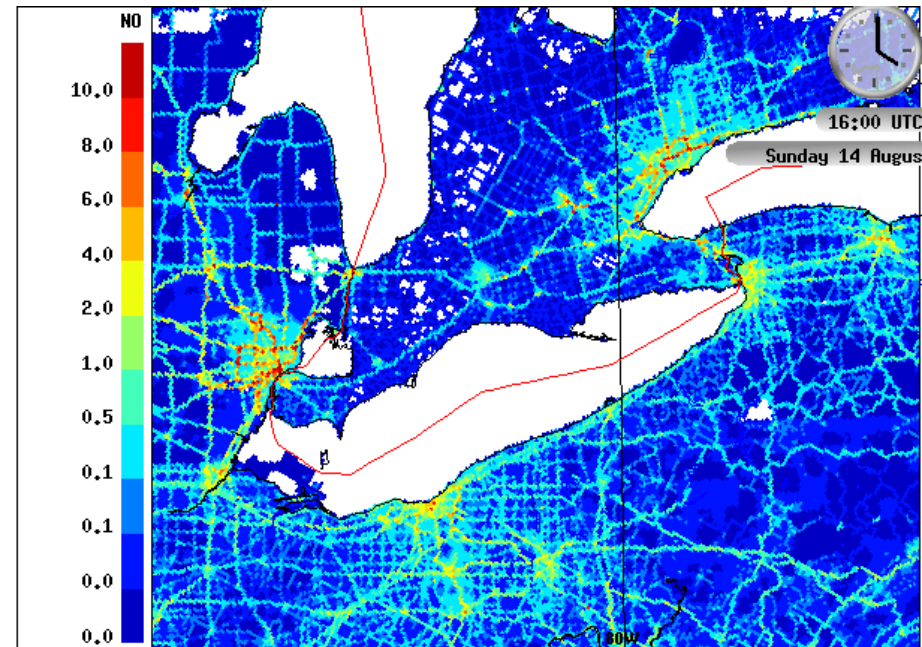
Use of U.S. 2012 projected emissions inventory and Canadian facility closure information

- New Canadian spatial surrogates for on-road mobile, pleasure craft, Oil Sands, mining, & construction sources
- Updates to some Canadian temporal profiles
- New library of PM speciation profiles and addition of some VOC speciation profiles
- Land-use-dependent transportable fraction used to scale near-source fugitive dust emissions

Example: Changes To Spatial Allocation Of Canadian On-road Mobile Emissions– Improved Representation Of Road Type, One Spatial Surrogate Replaced By Set Of 6 Surrogates

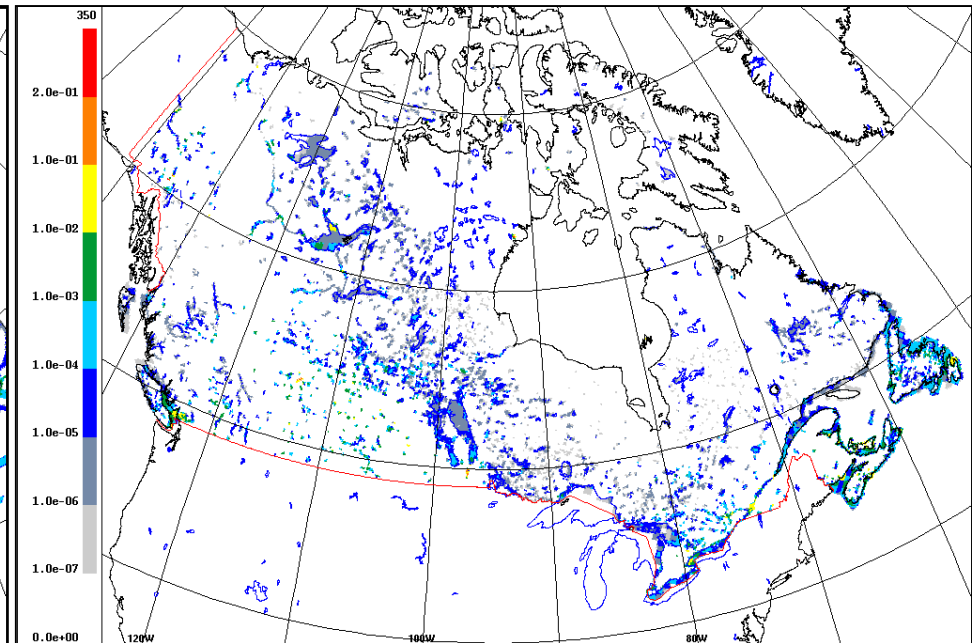
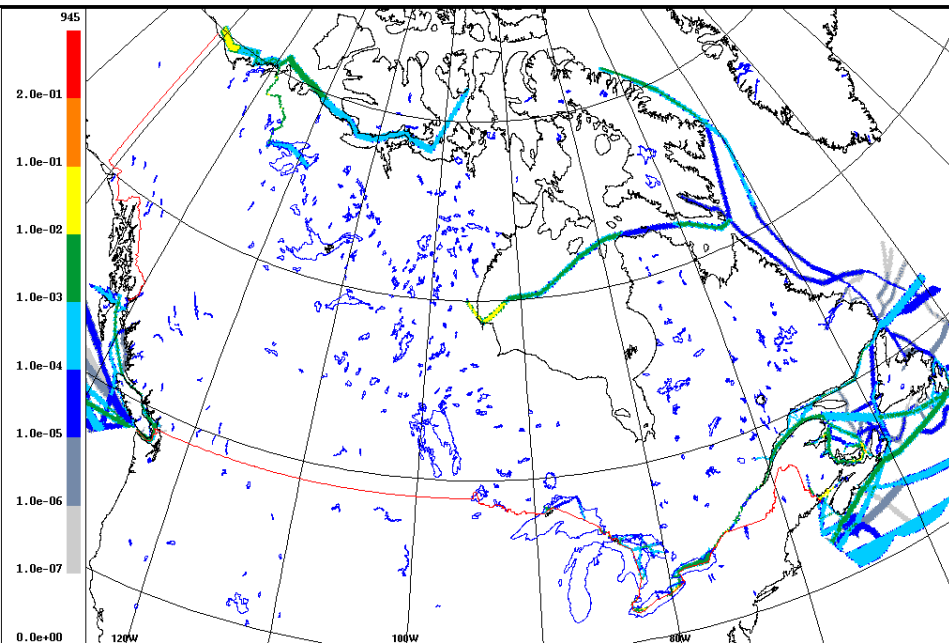


Old



New

Example: New Spatial Surrogate for Canadian Pleasure-Craft Marine Emissions Based on Proximity of Water Bodies to Roads & Population



Old

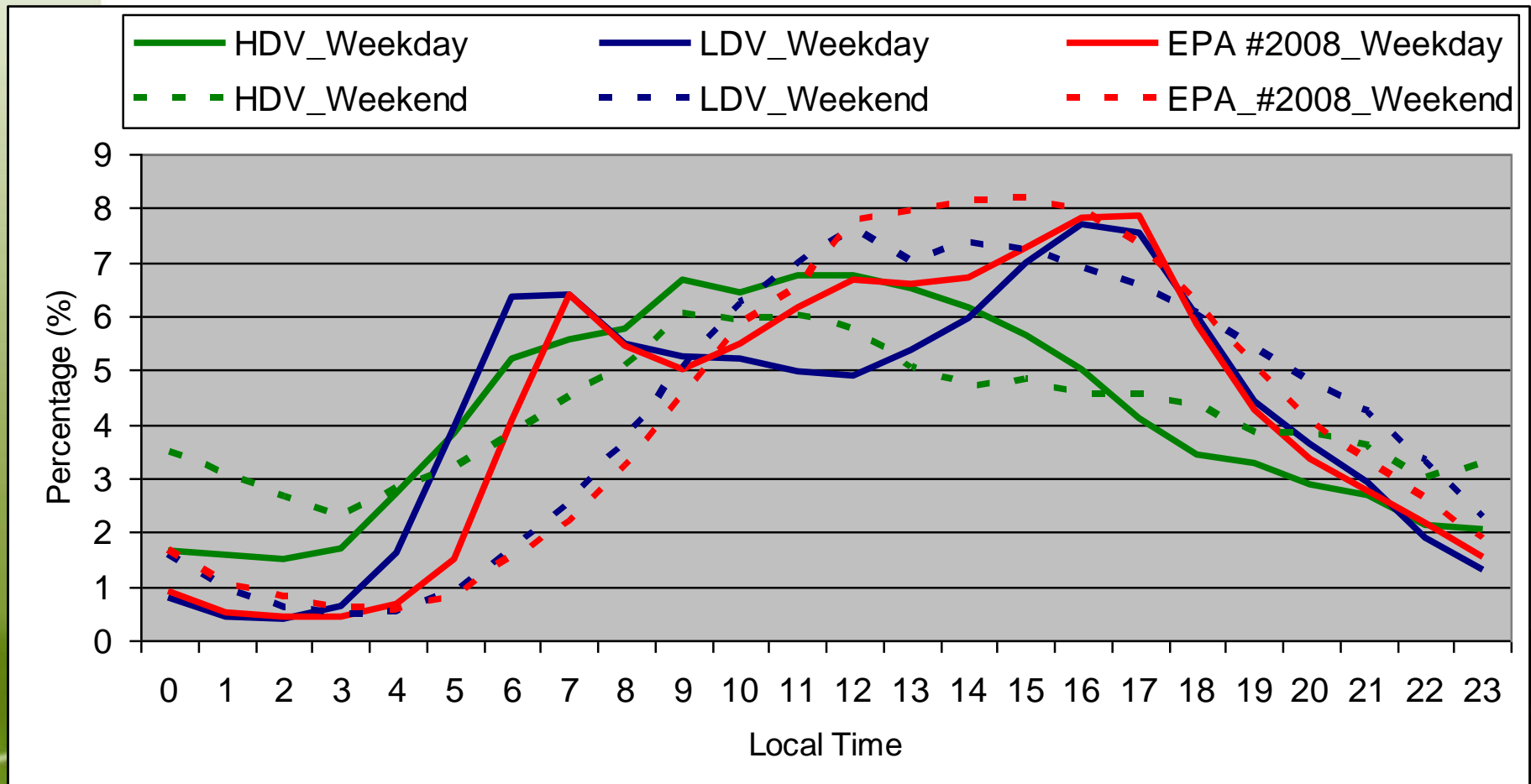
(Still used for commercial marine vessels)

New



Example: New Diurnal Temporal Profiles for Heavy-Duty Vehicles

New diurnal profiles derived from FEVER traffic count vs. those used by the U.S. EPA: profile #2008 -- urban freeway



Ongoing and Future Work

- Use newer Canadian and Mexican emissions inventories
- Investigate greater use of Canadian emissions reported at subprovincial level (e.g, by census division)
- Continue work on Canadian spatial surrogates, including new surrogates for residential wood combustion, local traffic, road dust, & aircraft landings / takeoffs (LTOs)
- Complete implementation of meteorological modulation of fugitive dust emissions in GEM-MACH
- Develop or modify spatial surrogates to have scale dependence on grid spacing for high-resolution grids

Scale Dependence of Spatial Surrogates

Issue: the use of some common surrogates such as population or dwelling density becomes less appropriate in urban cores for many source types such as local traffic or lawnmowers that have other constraints such as road geometry or the presence of lawns



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Thank you for your attention

