Emissions Inventory Preparation in Support of High-Resolution CMAQ Modelling Applications

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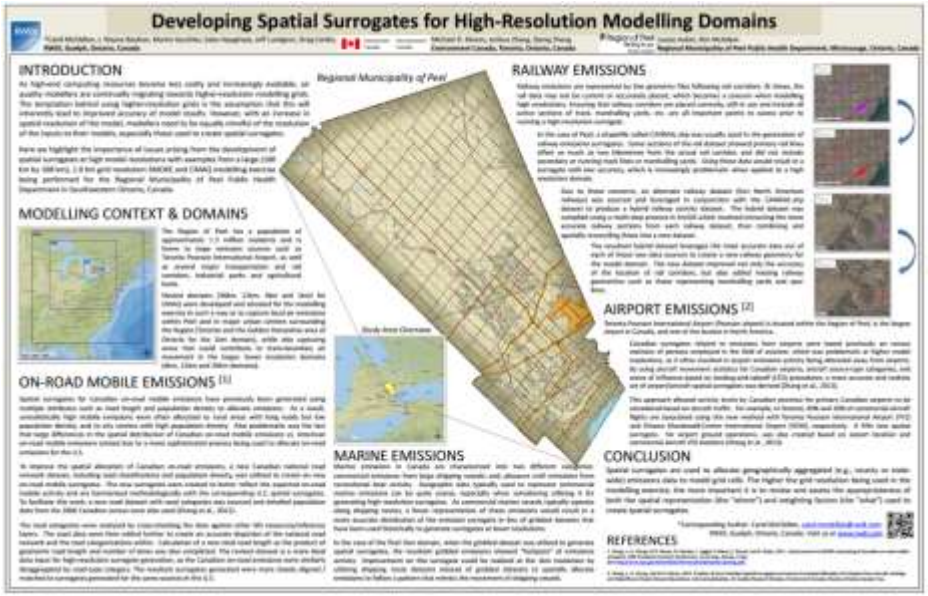
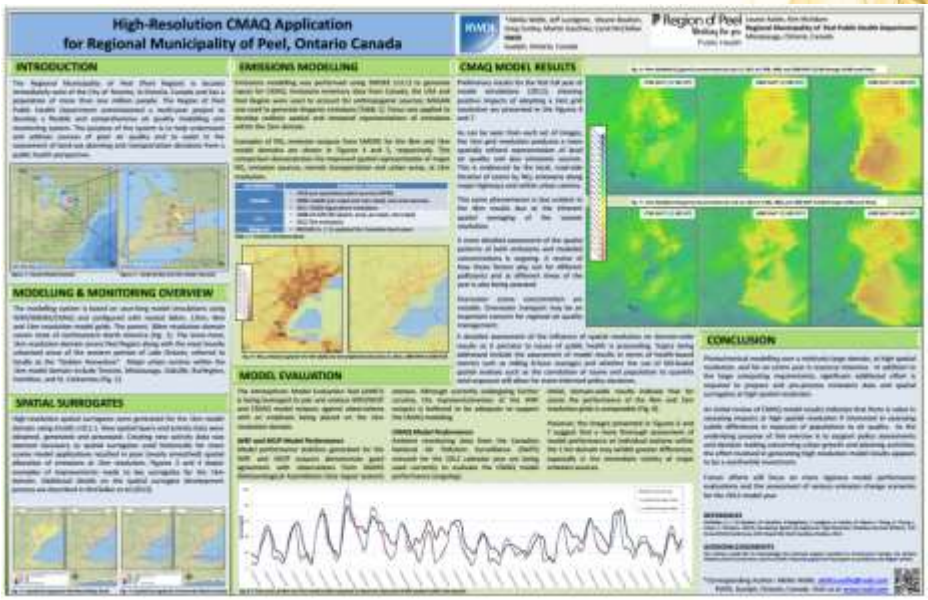
Other References

McClellan, C., J. W. Boulton, M. Gauthier, S. Hajaghassi, J. Lundgren, G. Conley, M. Moran, J. Zhang, Q. Zheng, L. Aubin, K. McAdam, (2013), ***Developing Spatial Surrogates for High-Resolution Modeling Domains*** (Poster), 12th Annual CMAS Conference, UNC Chapel Hill, North Carolina, October, 2013.

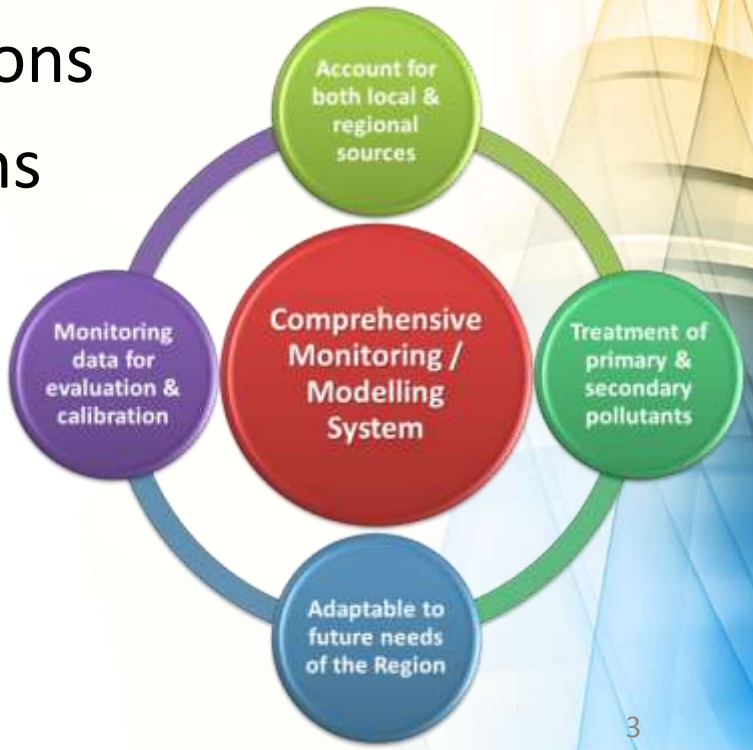




Lundgren, J., J. W. Boulton, G. Conley, M. Gauthier, A. Wolfe, C. McClellan, Z. Adelman, M. Omary, L. Aubin, K. McAdam, (2014), ***High Resolution CMAQ Application for the Regional Municipal of Peel***, Ontario, Canada, (*Poster)*, 13th Annual CMAS Conference, UNC Chapel Hill, North Carolina, October, 2014.

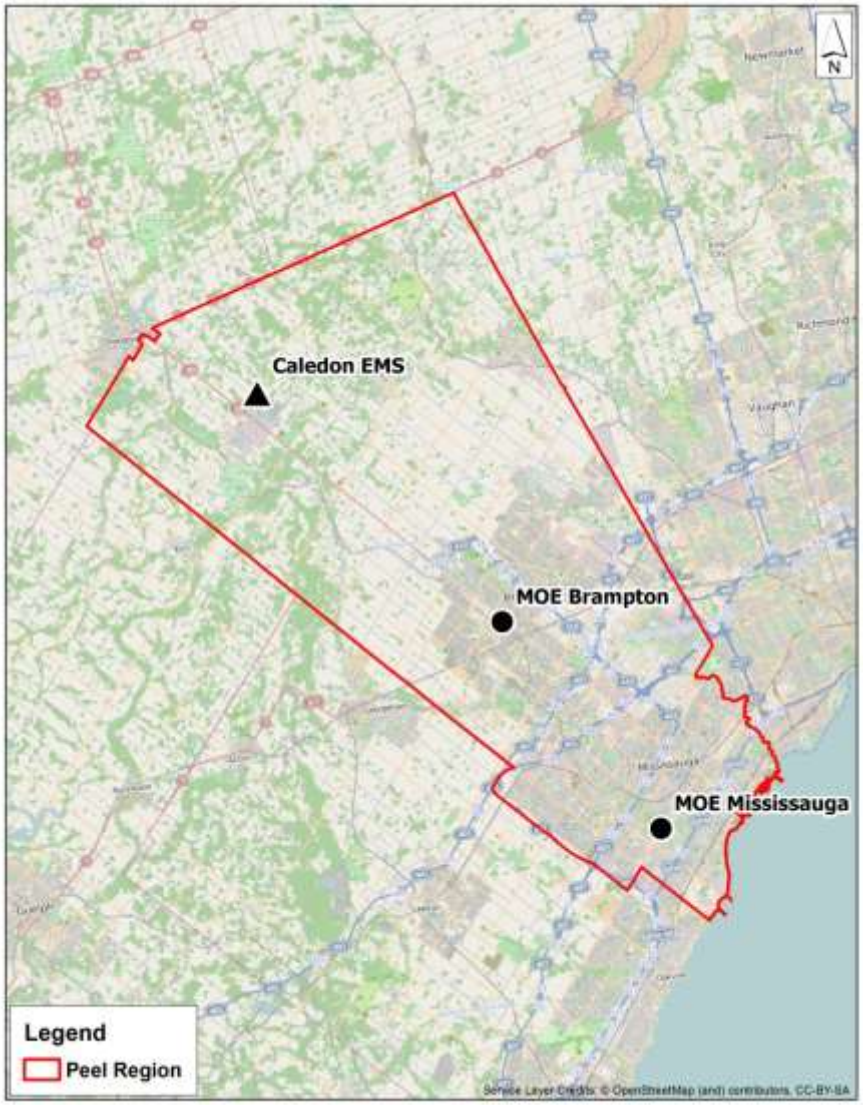
Region of Peel Modelling & Monitoring System

- Estimate air quality where no monitors exist
- Assess relative contributions from emission sources
- Shape and influence health-based policy / regulations
- Develop informed public education and messaging
- Prioritize emission reduction options
- Assist in making planning decisions from a public health perspective



Region of Peel

Region of Peel Modelling & Monitoring System

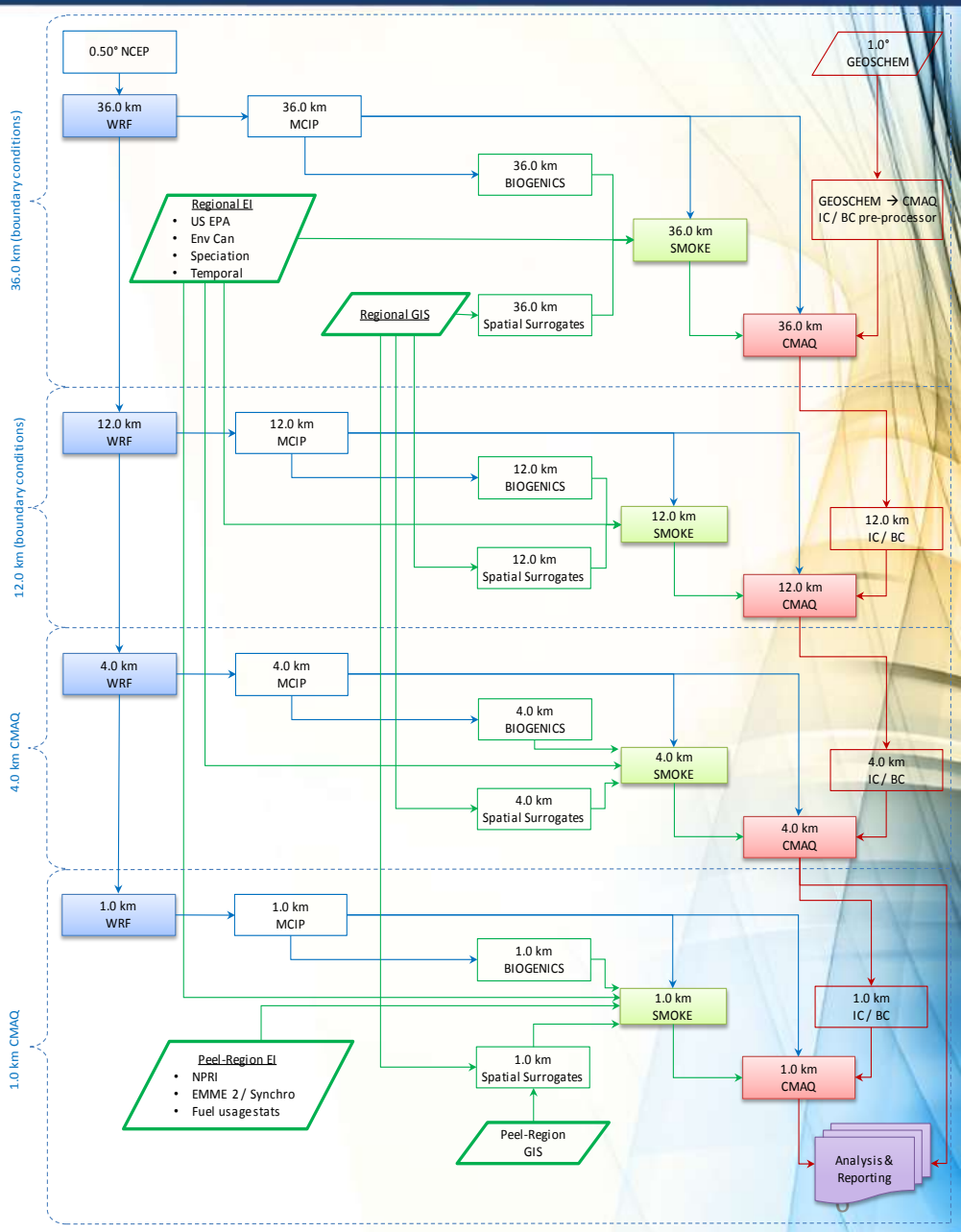


Region of Peel Modelling & Monitoring System

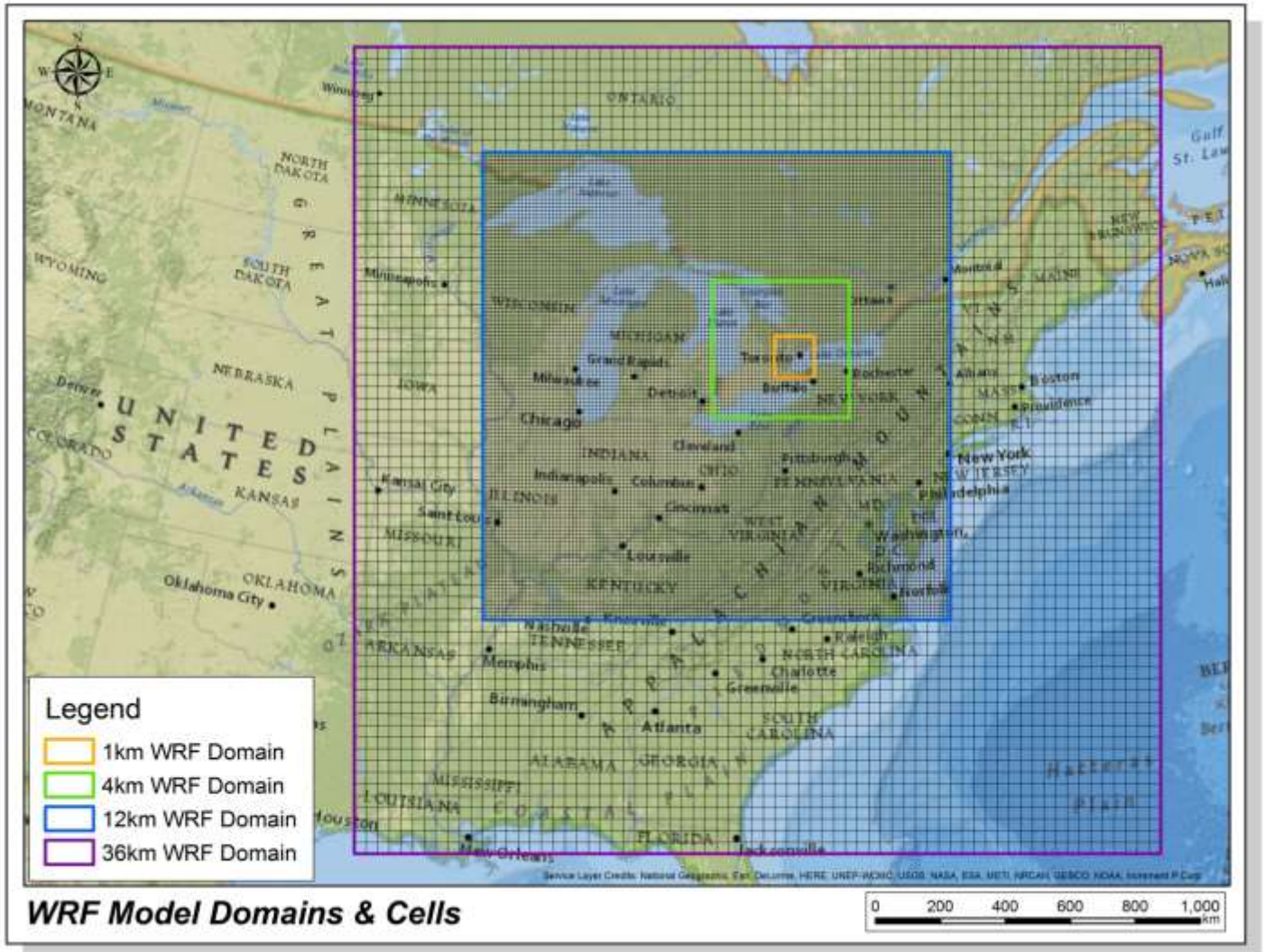
Model Configuration:

- WRF (Ver. 3.4.1)
- MCIP (Ver. 4.1
- SMOKE (Ver. 3.1)
- MEGAN (Ver. 2.1)
- CMAQ (Ver. 5.0)

CMAQ (v. 5.0) MODEL CONFIGURATION	
Horizontal Advection	Yamartino
Vertical Advection	Per WRF outputs
Horizontal Diffusion	Multiscale
Vertical Diffusion	ACM2
Gas Chemistry Mechanism	CB05 (without Chlorine)
Gas Chemistry Solver	Euler Backward Iterative (EBI)
Aerosol Mechanism	CMAQ 6th generation model (aero6)
Clouds/Aqueous Chemistry	Cloud ACM AE6
Plume in Grid	none

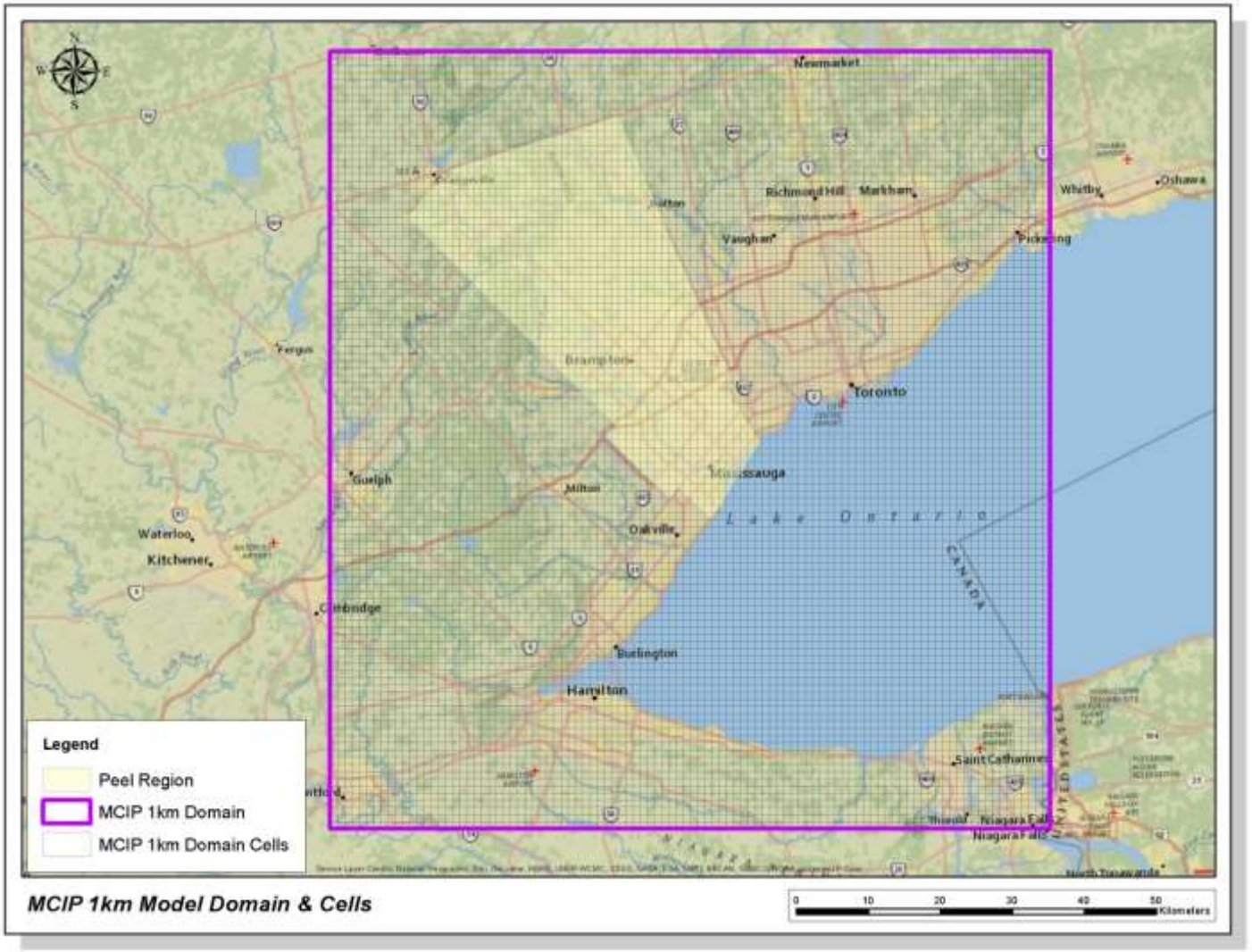


Air Quality Model Domains



WRF Model Domains & Cells

Innermost (1.0 km) Domain



MCIP 1km Model Domain & Cells

Emissions Inventory Sources Used

CANADA

- 2010 pre-speciated major point sources (NPRI)
- 2006 area and mobile (on-road and non-road)
- 2011 National Agri-Environmental Standards Initiative (NH_3)

US

- 2008 US EPA for point, area, on-road and non-road
- 2012 fire emissions

Biogenic

- MEGAN (Version 2.1)

Annual Emissions (tonnes) in 1.0 km Domain

SOURCE CATEGORY	CO	NO_X	VOC	NH_3	SO_2	PM_{10}	$PM_{2.5}$
TRANSPORTATION							
Air Transportation	8,746	4,226	2,081	3	342	0	149
Rail Transportation	853	5,546	146	5	250	0	177
Marine Transportation	9,492	1,460	2,898	2	715	0	232
OnRoad Urban mobile	302,282	48,008	29,388	3,290	245	1,433	10,883
OnRoad Rural mobile	68,926	16,058	6,716	752	56	453	308
Unpaved Roads	9,473	43	2,101	1	1	0	3,886
INDUSTRY							
Metals, Mining and Mineral Production	18,982	838	52	1	58	0	3,448
Utilities	245	826	16	10	111	0	26
Forestry and Wood Products	187	61	1,787	0	56	0	7
Manufacturing and Assembly	0	0	32,226	0	0	0	0
Printing and Related Industries	0	0	9,224	0	0	0	0
Industrial use of off-road engines (e.g., forklifts, heavy equipmen	24,685	11,829	1,533	2	537	0	212
Industrial Point Sources	19,440	16,816	7	1,219	18,765	3,419	2,497
Primary industry	0	0	38,852	0	0	0	0
ANTHROPOGENIC & MISC							
Waste Management	2,085	142	2,180	27	413	0	302
Commercial Fuel Combustion	211,677	9,312	7,316	72	3,719	0	901
Construction Activities	10,606	7,482	1,125	6	390	0	673
Gasoline Stations and Petroleum Wholesales	0	0	4,497	0	0	0	269
Population, Urban and Rural Dwellings	50,805	7,351	2,423	213	1,451	0	2,090
Residential Wood Combustion	71,493	1,033	15,285	93	148	0	10,791
Farms / Agriculture	5,780	9,056	2,743	1,243	413	0	1,224
Other / Miscellaneous	0	0	58	0	0	0	81
Total without fugitive dust	**815,756**	**140,086**	**162,656**	**6,938**	**27,669**	**5,306**	**38,158**
Fugitive Dust (including agricultural, construction and road dust)	0	0	0	0	0	77,937	14,585
Total including fugitive dust	***815,756***	***140,086***	***162,656***	***6,938***	***27,669***	***83,243***	***52,742***

Notes: emissions of gasses from soils and vegetation (Biogenics) not included

UNIQUE CHALLENGES WHEN MODELLING AT HIGH SPATIAL RESOLUTION

AKA – the Devil is in the details…

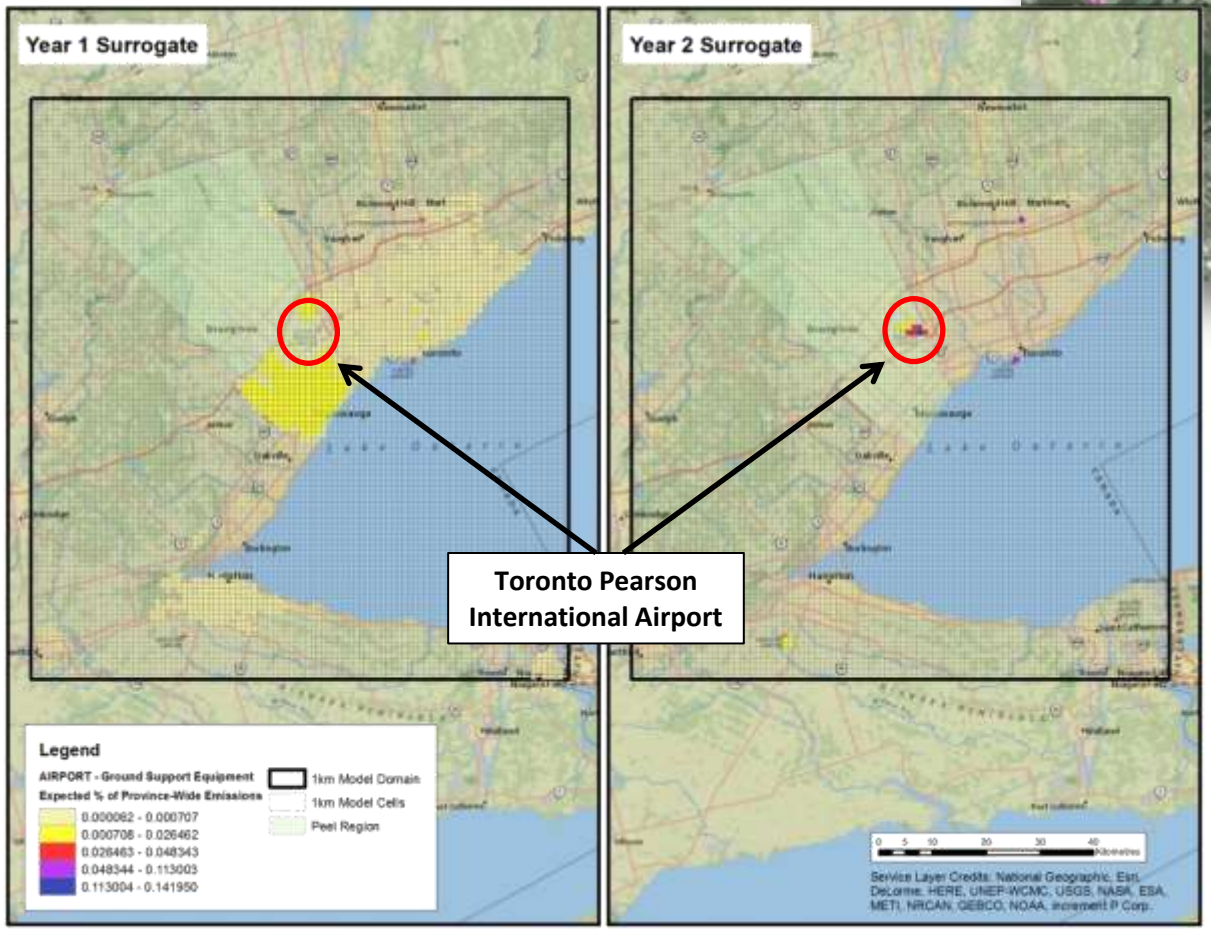
Missing Stack Parameters

Missing / generic stack parameters much more important…

Yellow dots depict major sources with inadequate stack parameters.

Spatial Allocations – Airport GSE

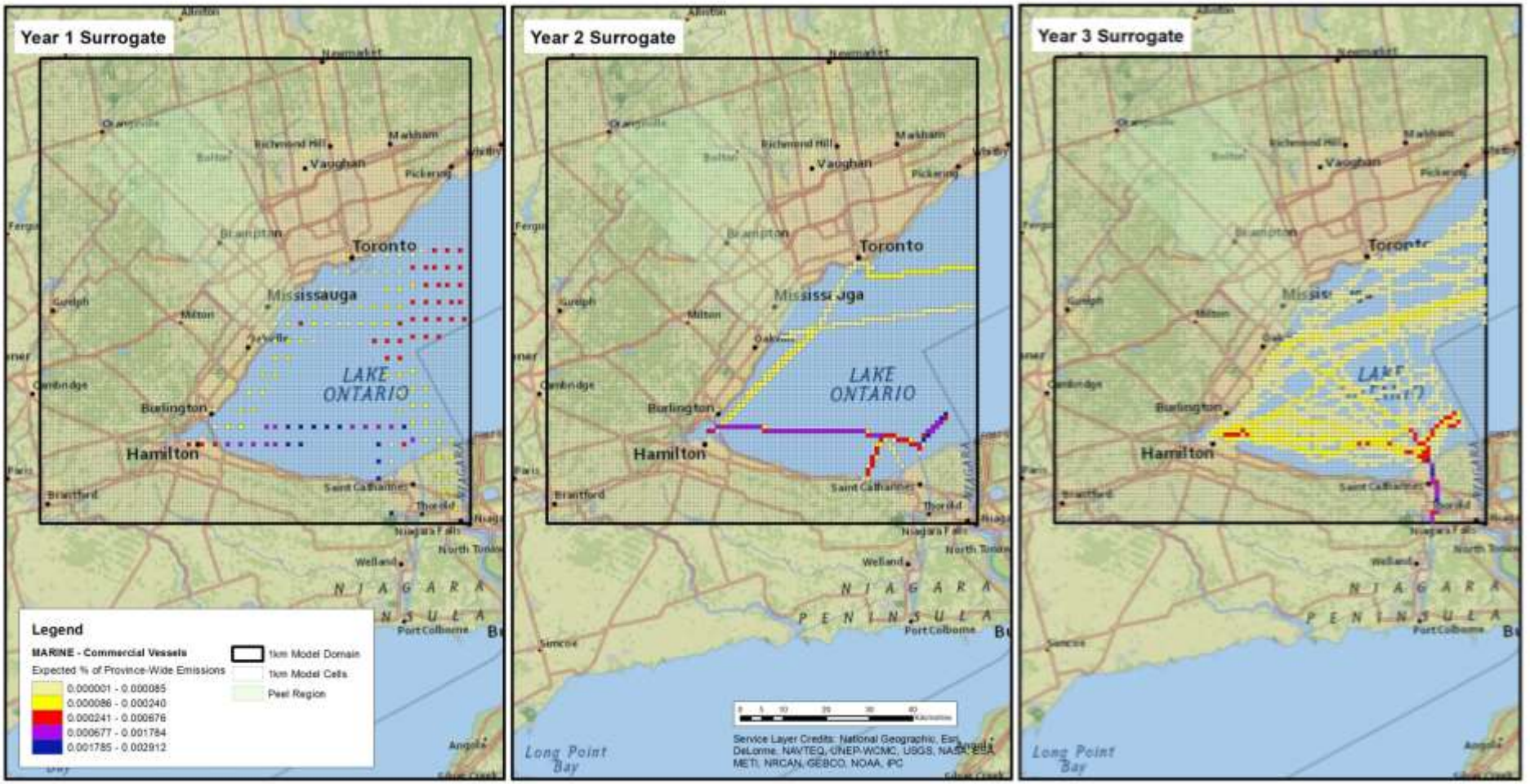
Heads-up digitizing, buffering, and other GIS techniques…



Make friends with your GIS team!!!

Spatial Allocations - Commercial Marine

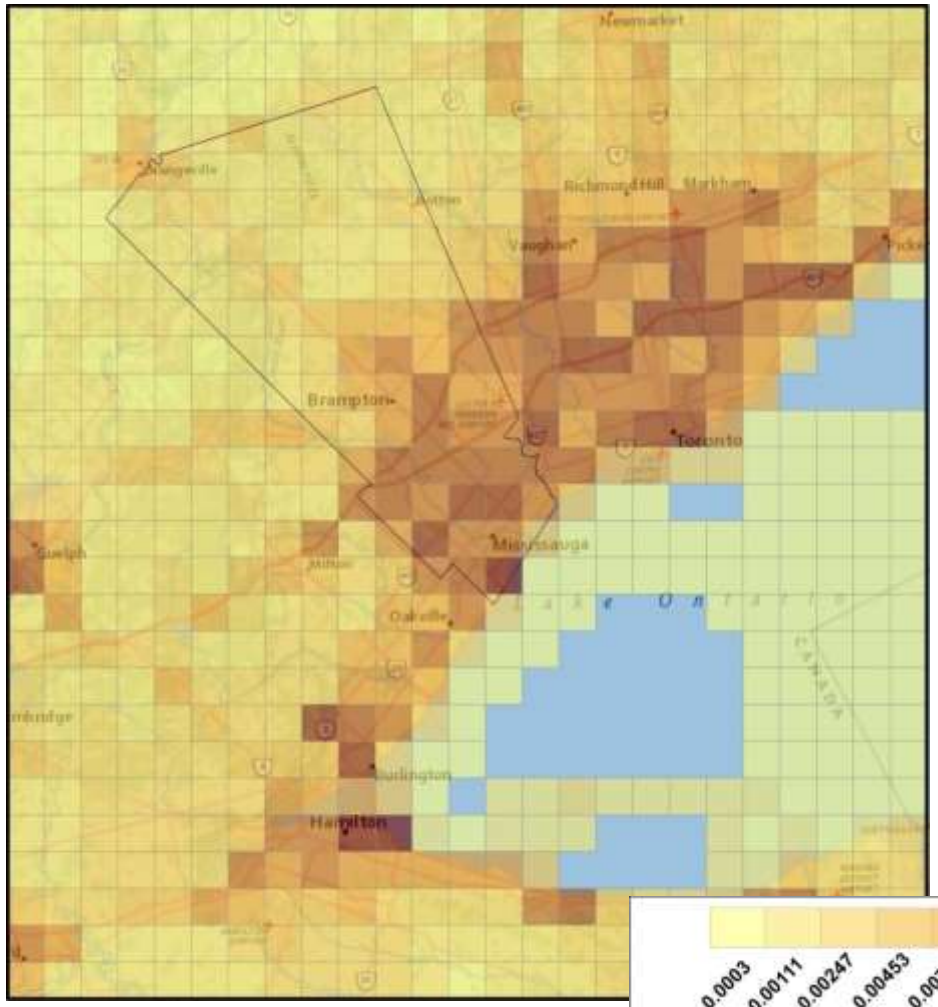
Continual improvement…



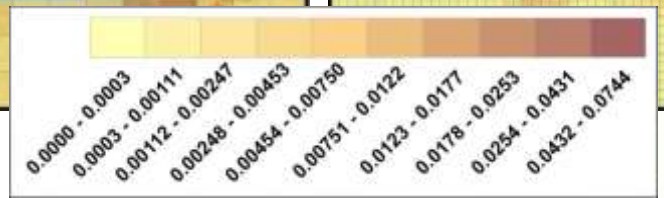
NOx Emissions (g/s) Over 1.0 km Domain

July 13, 2012, 1800 GMT (13:00 EST)

4.0 km Gridded Emissions



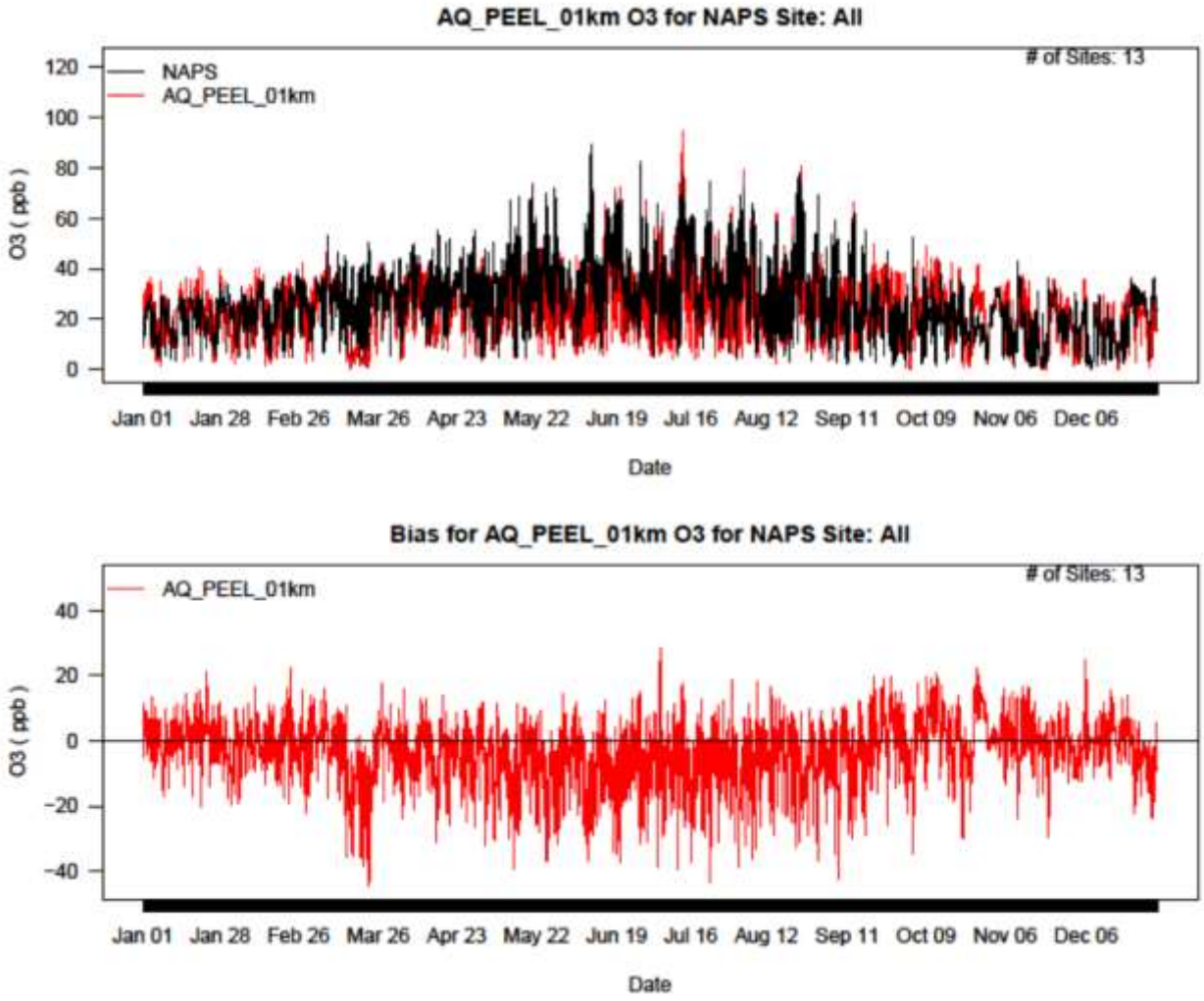
1.0 km Gridded Emissions



CCTM (CMAQ) MODEL PERFORMANCE

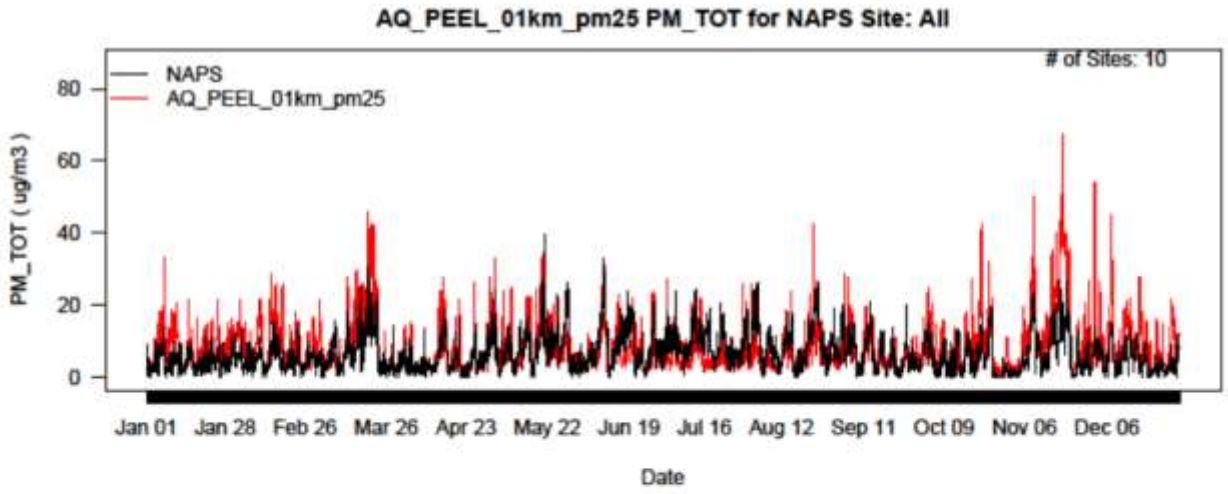
DRAFT Results - Ozone

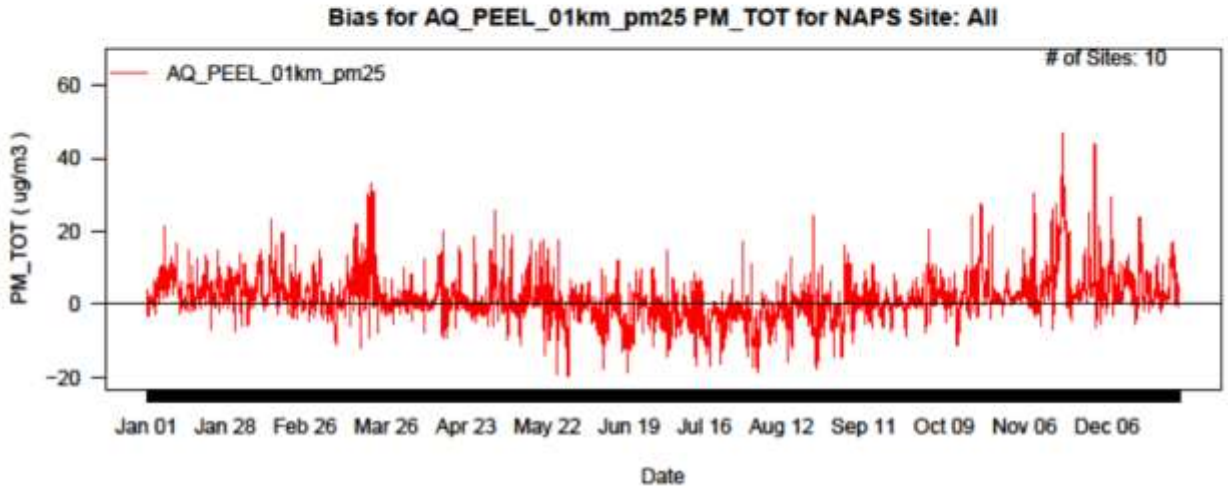
Annual O_3 (ppb) modelled vs observed (domain-wide)



DRAFT Results – $PM_{2.5}$

Annual $PM_{2.5}$ ($\mu g \cdot m^{-3}$) modelled vs observed (domain-wide)

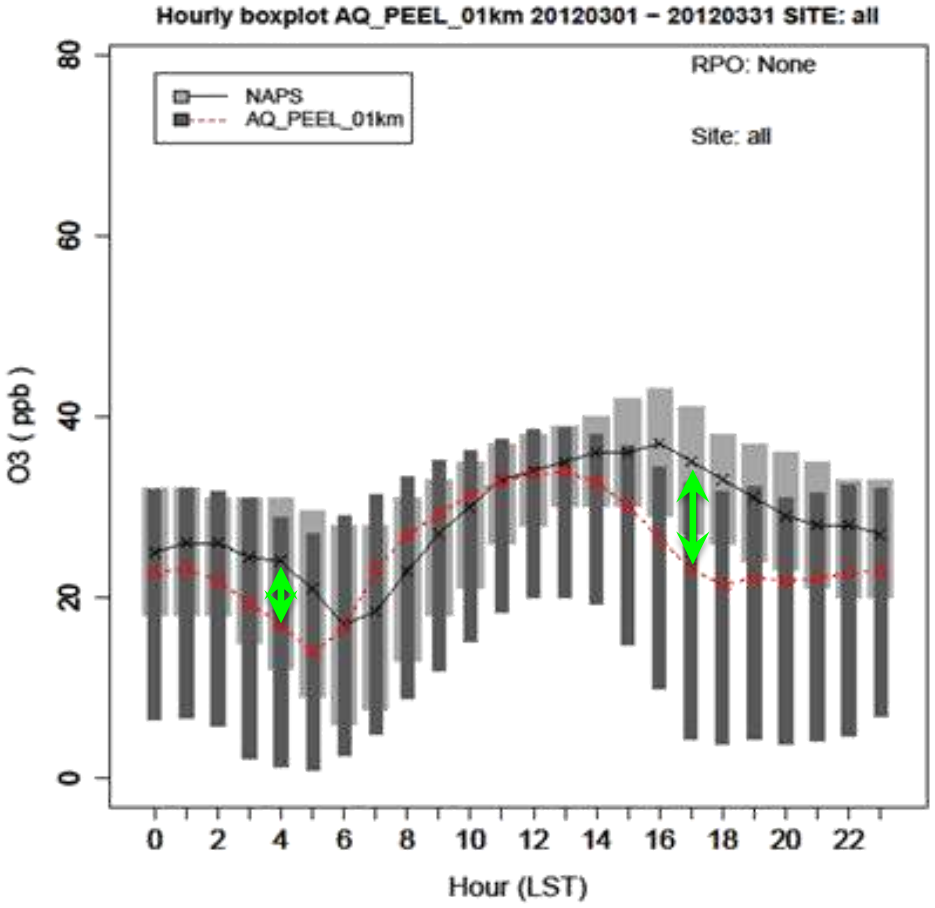




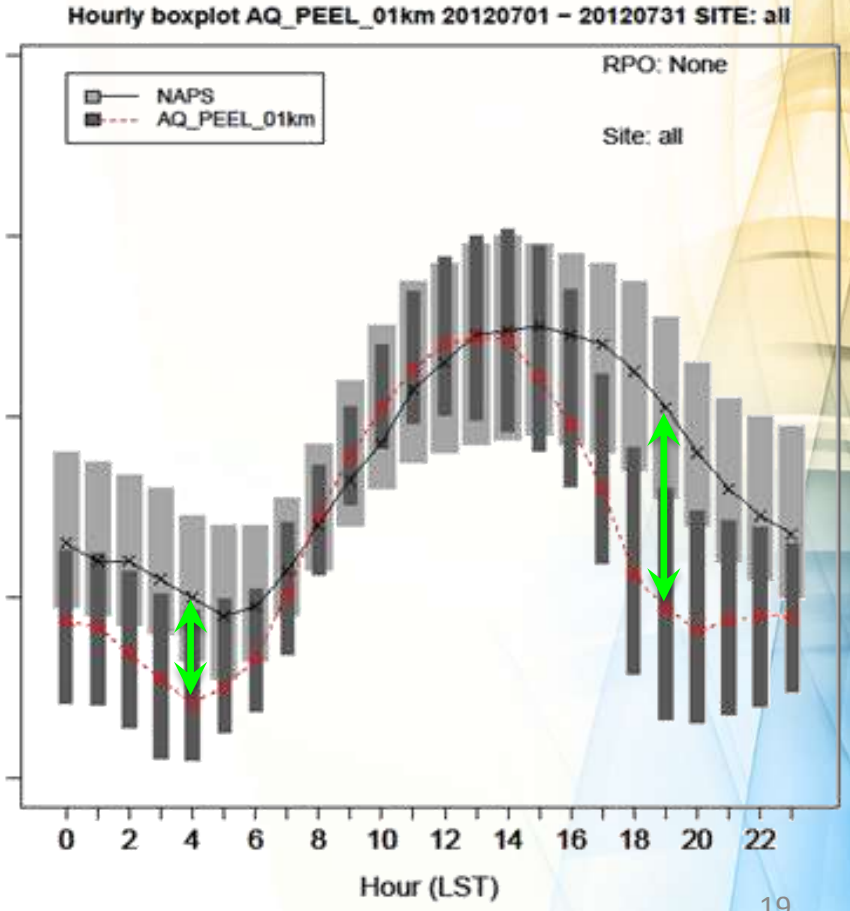
DRAFT Predicted & Measured Ozone

Domain-wide modelled vs observed O_3 (ppb)

March



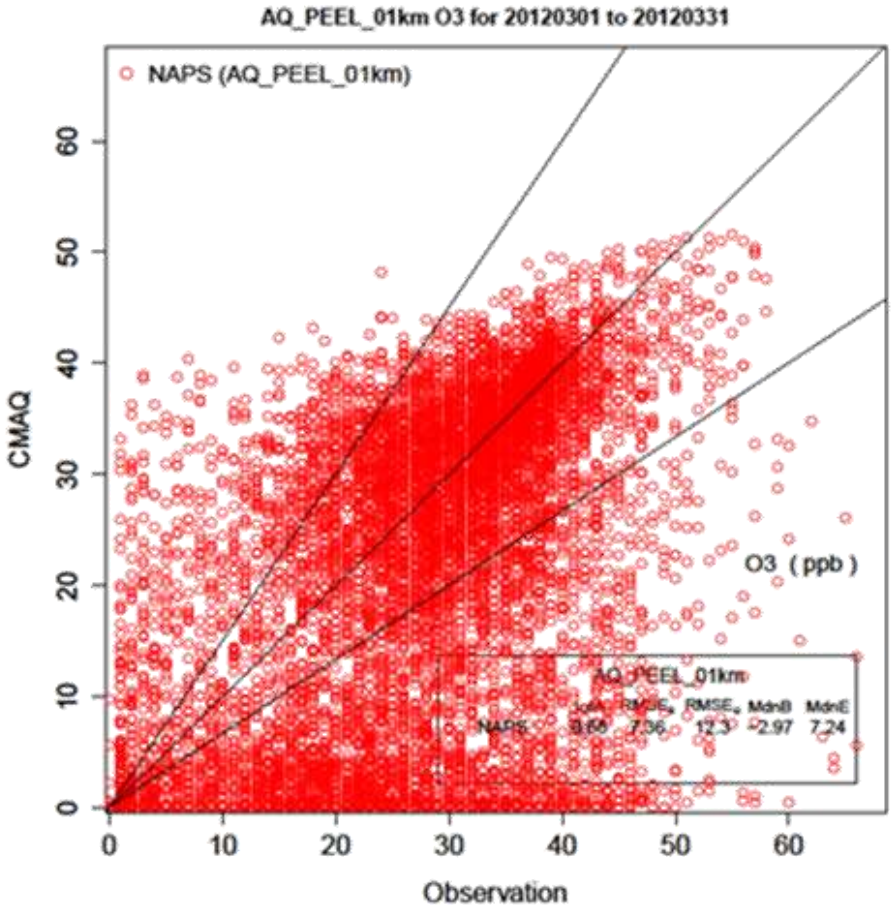
July



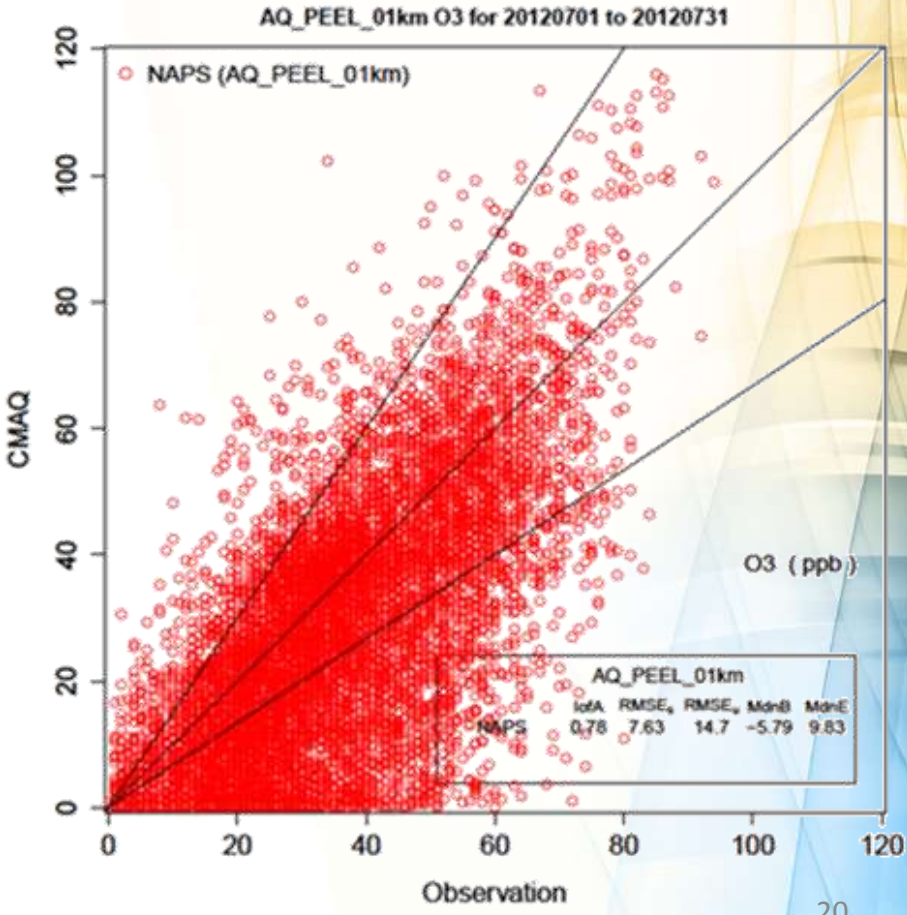
DRAFT Predicted & Measured Ozone

Domain-wide modelled vs observed O_3 (ppb)

March



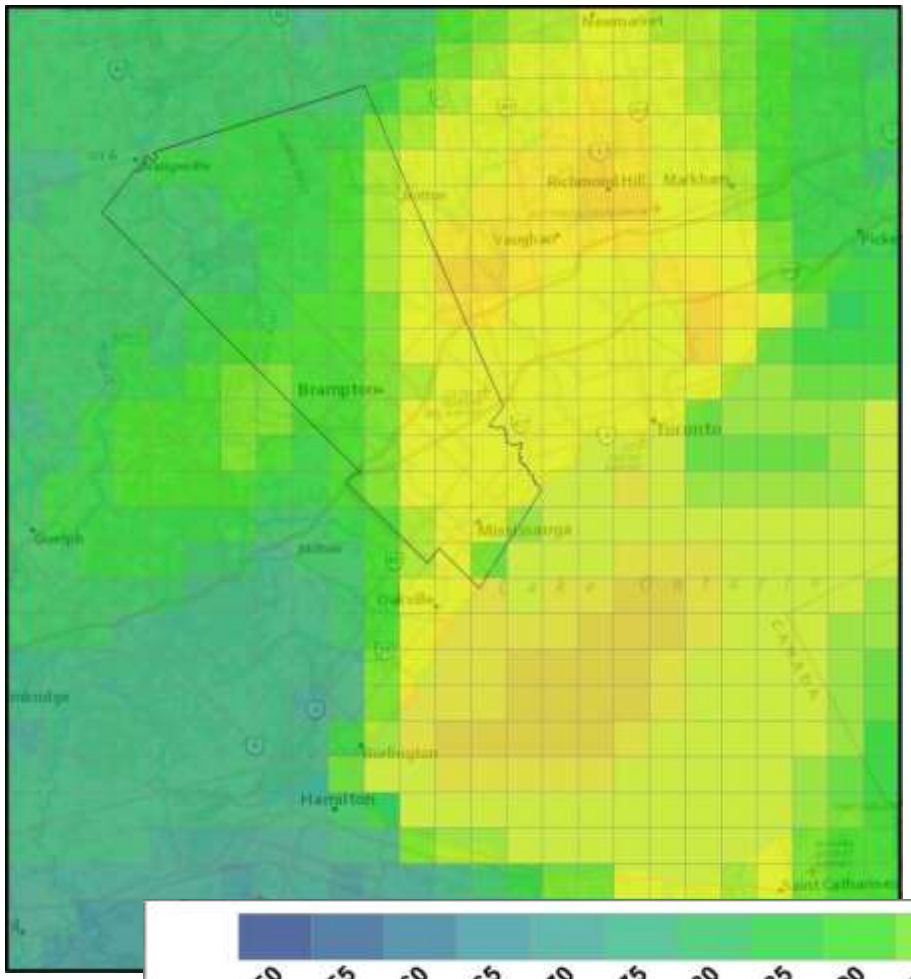
July



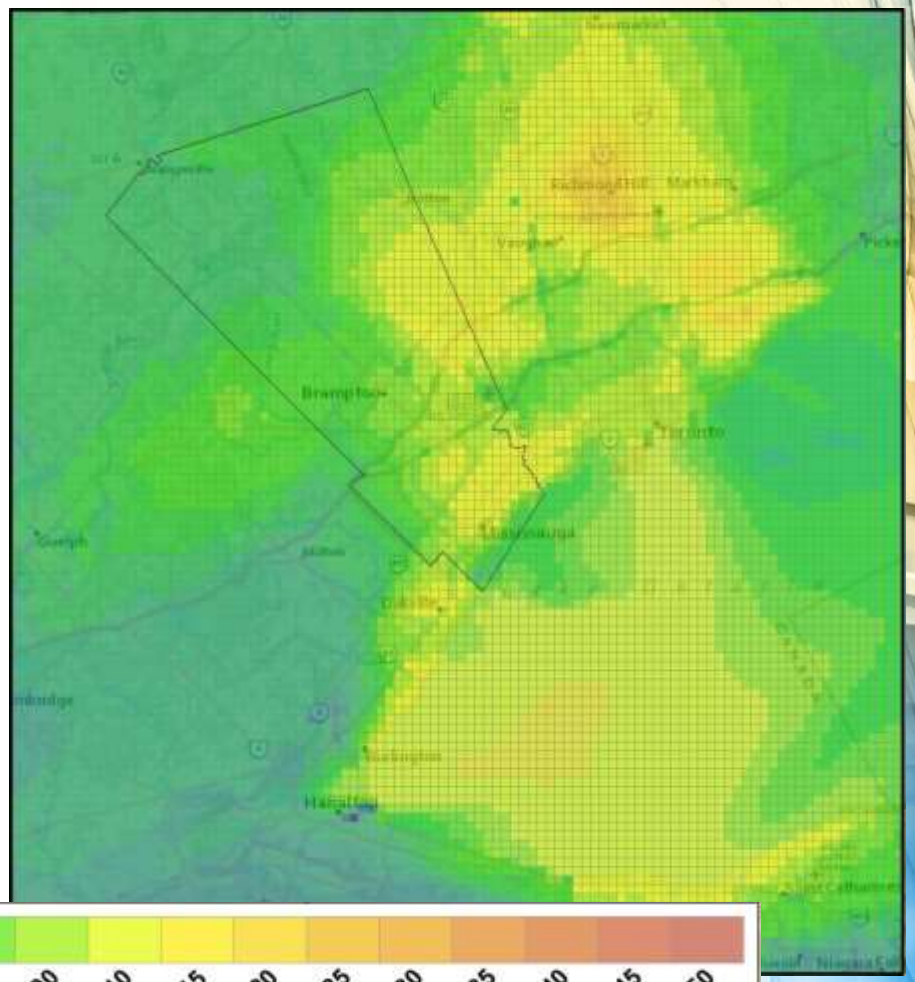
DRAFT Modelled O_3 (ppmV) over 1.0 km Domain

July 13, 2012, 1800 GMT (13:00 EST)

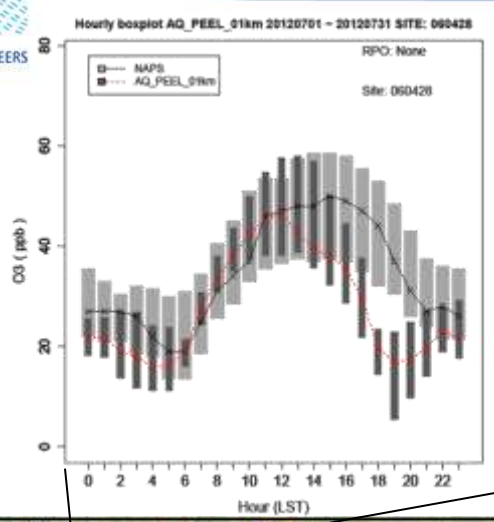
4.0 km Gridded Concentration

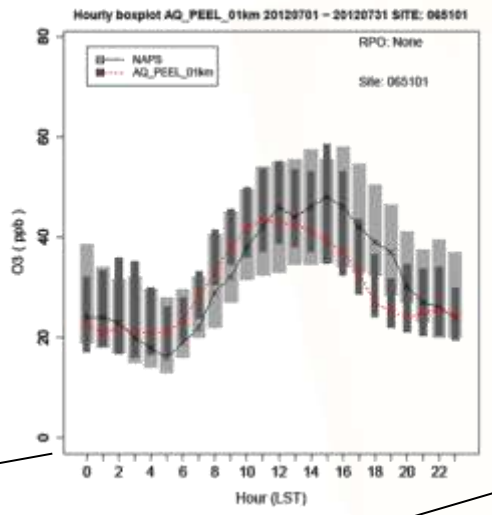


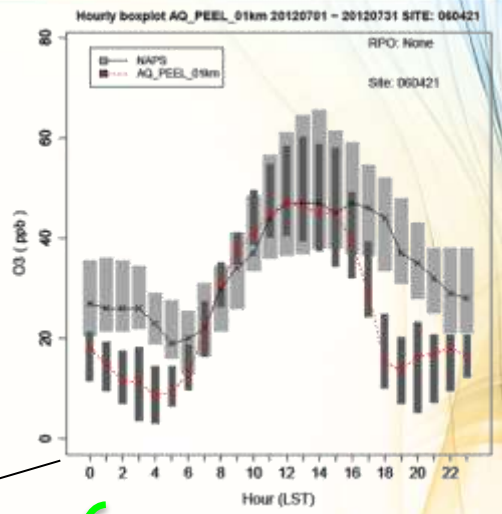
1.0 km Gridded Concentration

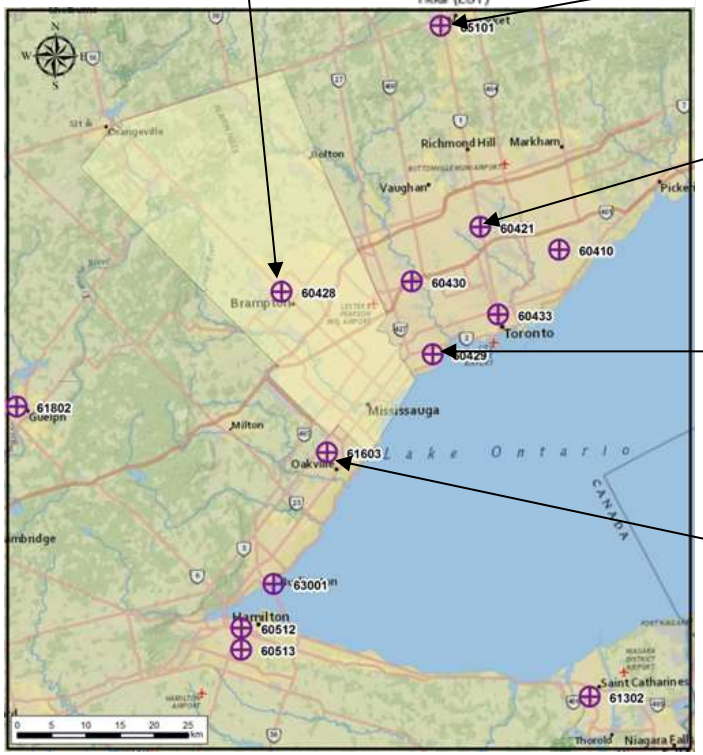


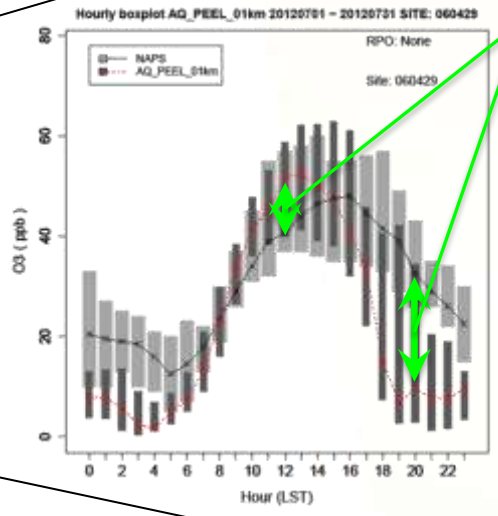
DRAFT Temporal Profiles for O_3 (July)



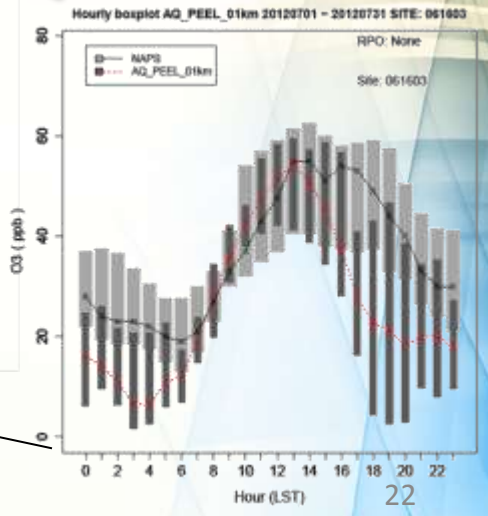




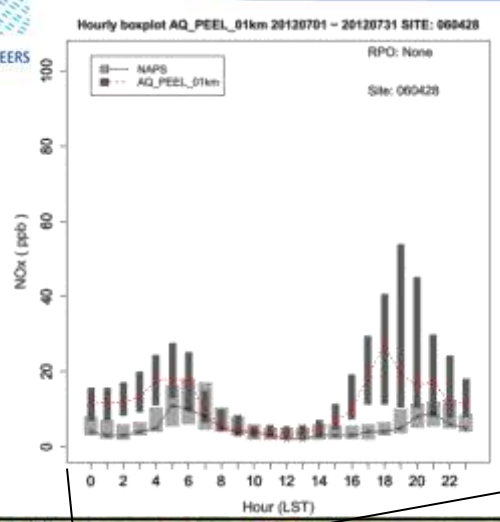


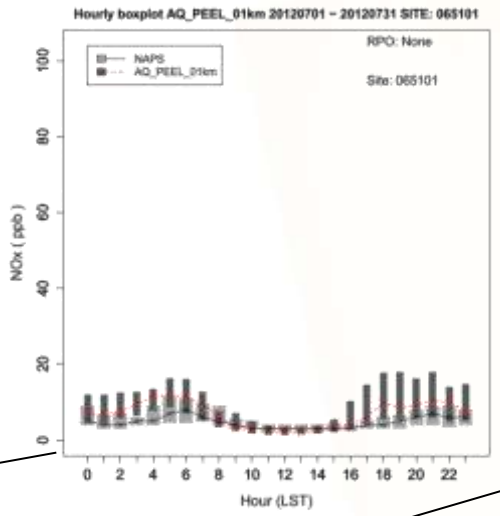


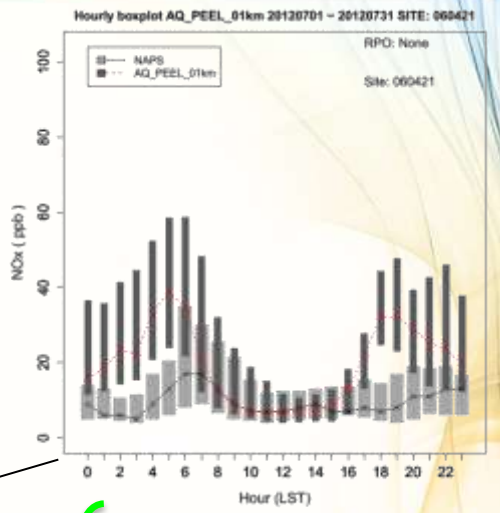
Spatial ?
Temporal ?
Emissions ?
Meteorology ?

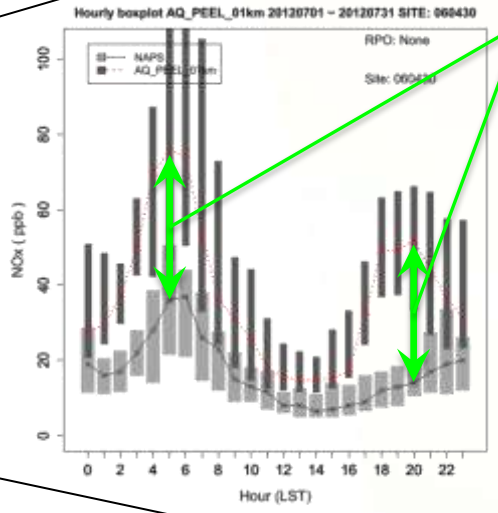


DRAFT Temporal Profiles for NO_X (July)

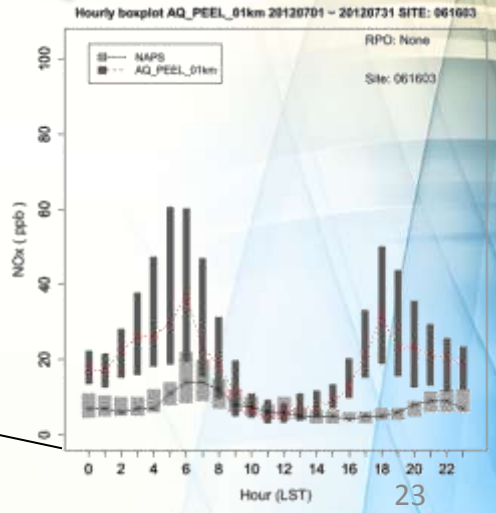








Spatial ?
Temporal ?
Emissions ?
Meteorology ?



Initial Observations

- Model performance quite good for ozone and $PM_{2.5}$
- High resolution notable in results (O_3 near highways)
- Higher resolution highlights model performance issues (EI, spatial, temporal, meteorology, etc.)
- Much to investigate and improvements to be made - so what else is new?
- New 2010 EI for Canada improves performance (especially near highways due to on-road vehicle emission decreases)
- Emission change scenarios underway

Take Home Messages

- Raw spatial surrogate activity data suitable at 12 and 4 km resolutions likely not be suitable at 1.0 km
- Plumes cross multiple cells quickly even at modest winds, making meteorology, chemistry, and timing of emissions more important at high resolution
- Stack parameters and source locations more important at high resolution
- Challenges capturing meteorological phenomena (inversions, nocturnal boundary layer, land-sea breeze) still exist at high resolution

RWDI

CONSULTING ENGINEERS & SCIENTISTS

Thank you for your time.

Questions?

Funding provided by: Regional Municipality of Peel
Public Health Department