



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

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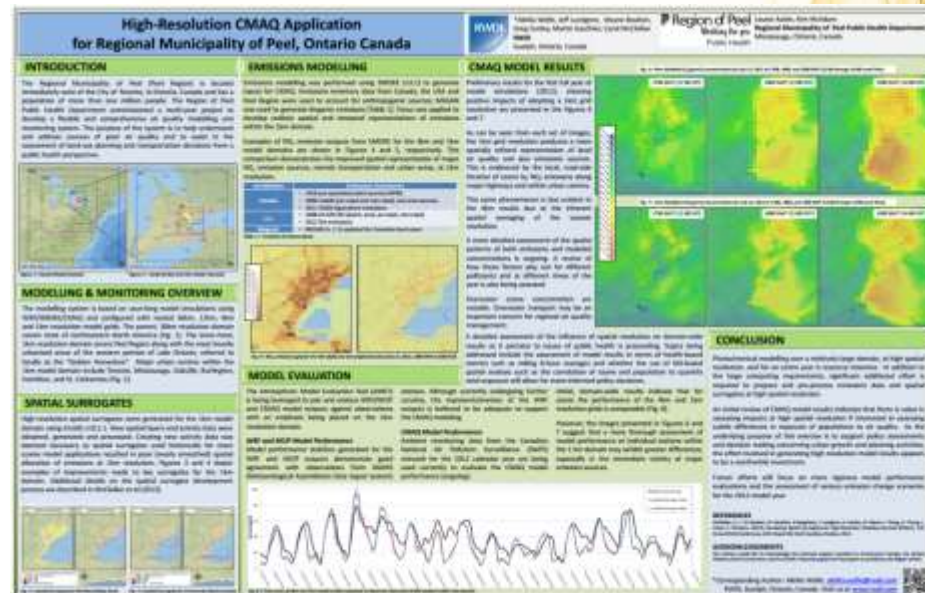
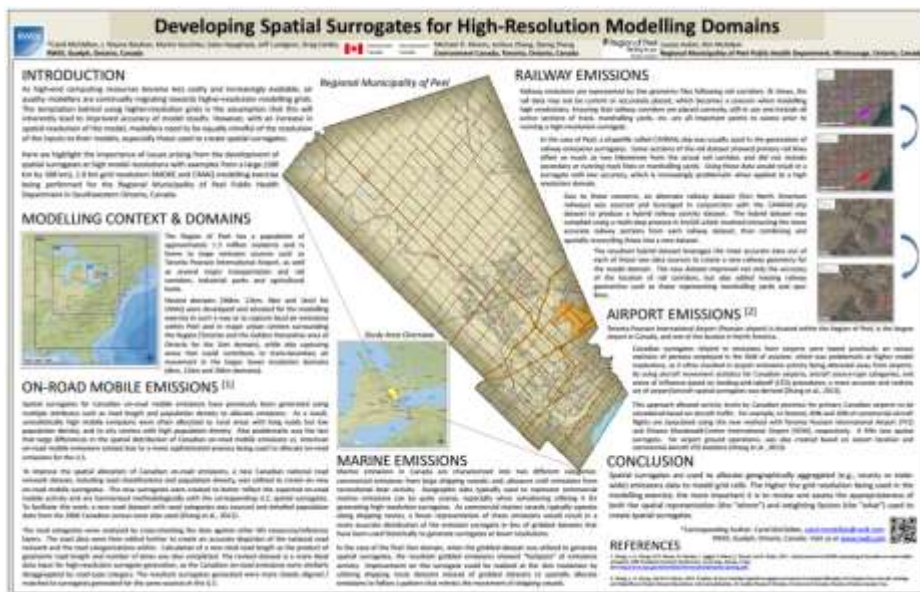
Mike Moran, Junhua Zhang, Qiong Zheng
Environment Canada, Air Quality Research Division

Zac Adelman, Mohamed Omary
University of North Carolina, Institute for the Environment

Louise Aubin, Kim McAdam
Regional Municipality of Peel Public Health Department

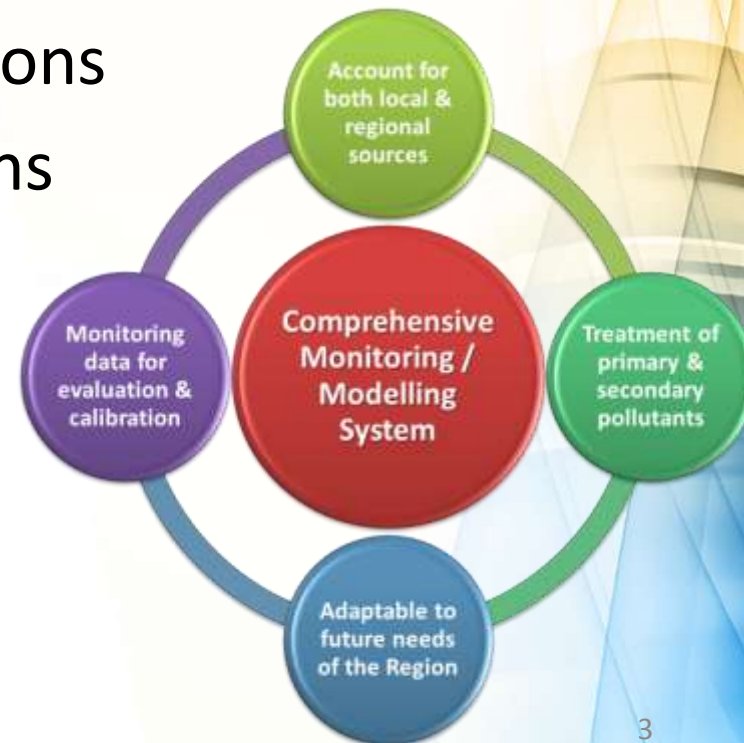
Other Sources of Information

McClellan, C., J. W. Boulton, M. Gauthier, S. Hajaghasi, 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.

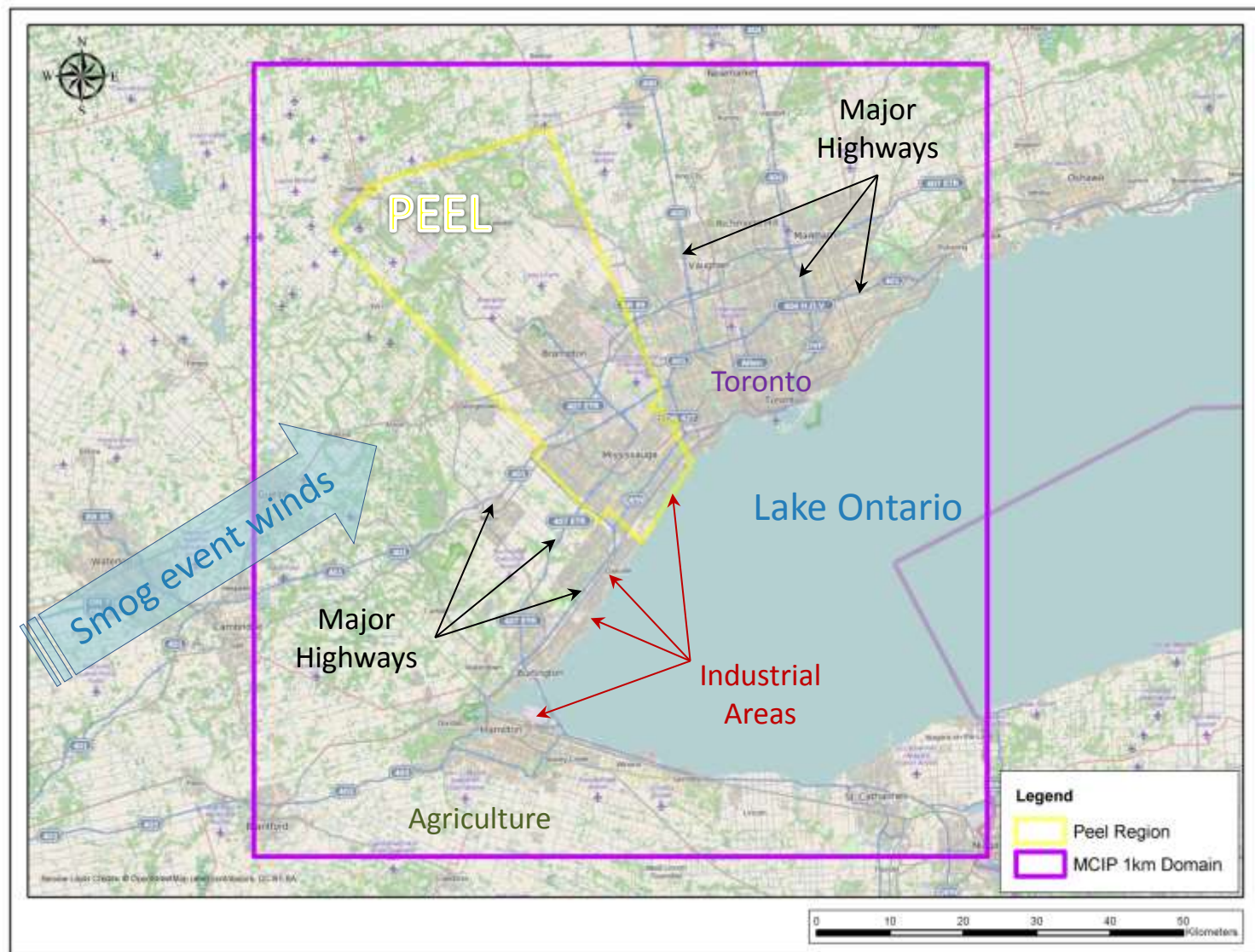


Lundgren, J., J. W. Boulton, G. Conley, M. Gauthier, A. Wolfe, C. McClellan, Z. Adelman, M. Omary, L. Aubin, K. McAdam, (2014), **High Resolution CMAQ Application for the Regional Municipal of Peel**, Ontario, Canada, (Poster), 13th Annual CMAS Conference, UNC Chapel Hill, North Carolina, October, 2014.

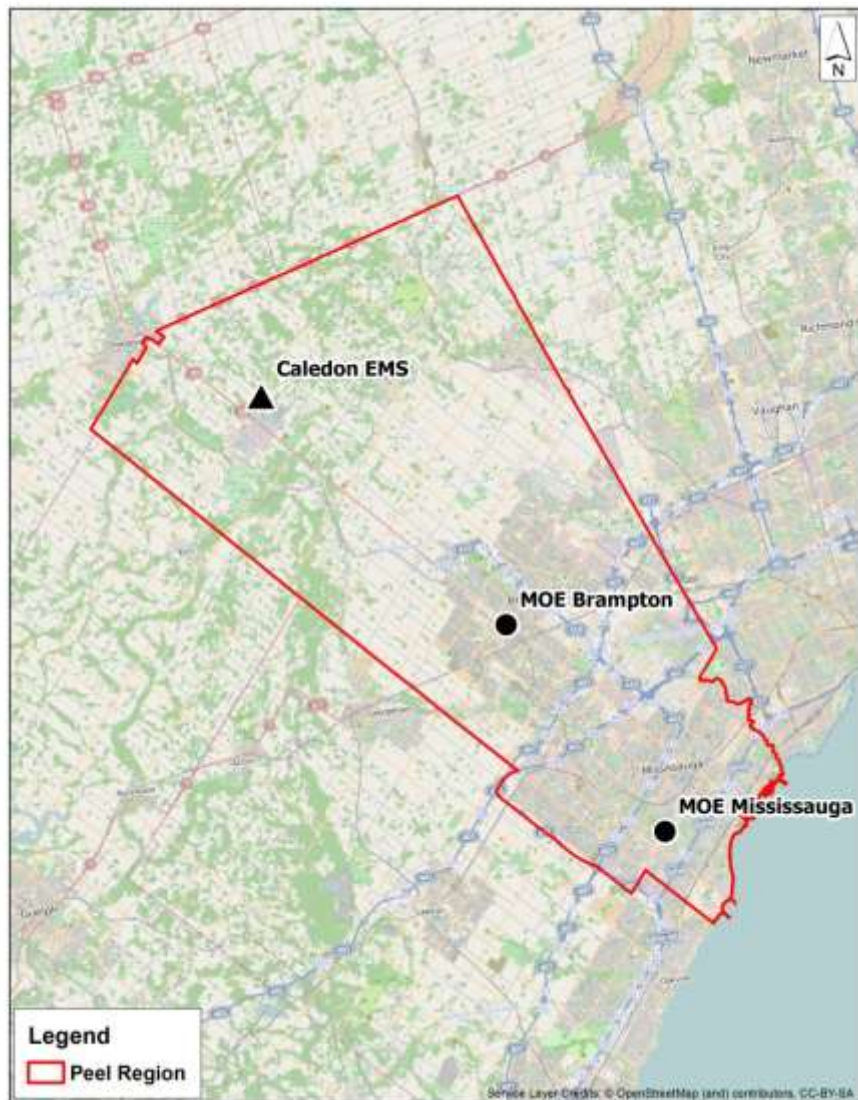
- Estimate air quality where no monitors (all year)
- Assess contributions from emission sources (all year)
- Shape & influence health-based policy / regulations
- Support informed public education and messaging
- Prioritize emission reduction options
- Assist in making planning decisions from a public health perspective



Region of Peel



Region of Peel Modelling & Monitoring System



RWDI Caledon Passive Station: NH_3 , NO_2 , NO_x , SO_2 , O_3

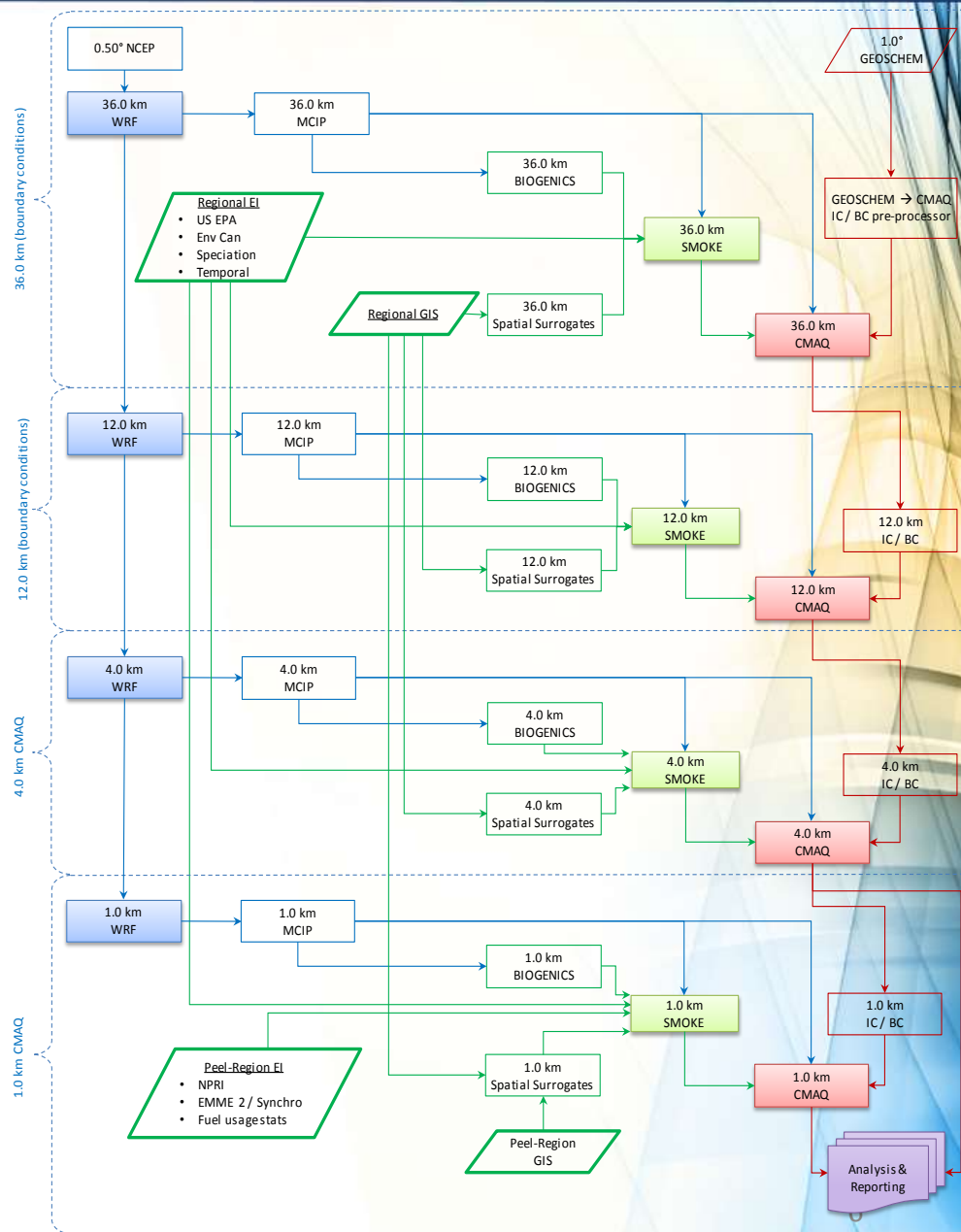


Model Configuration:

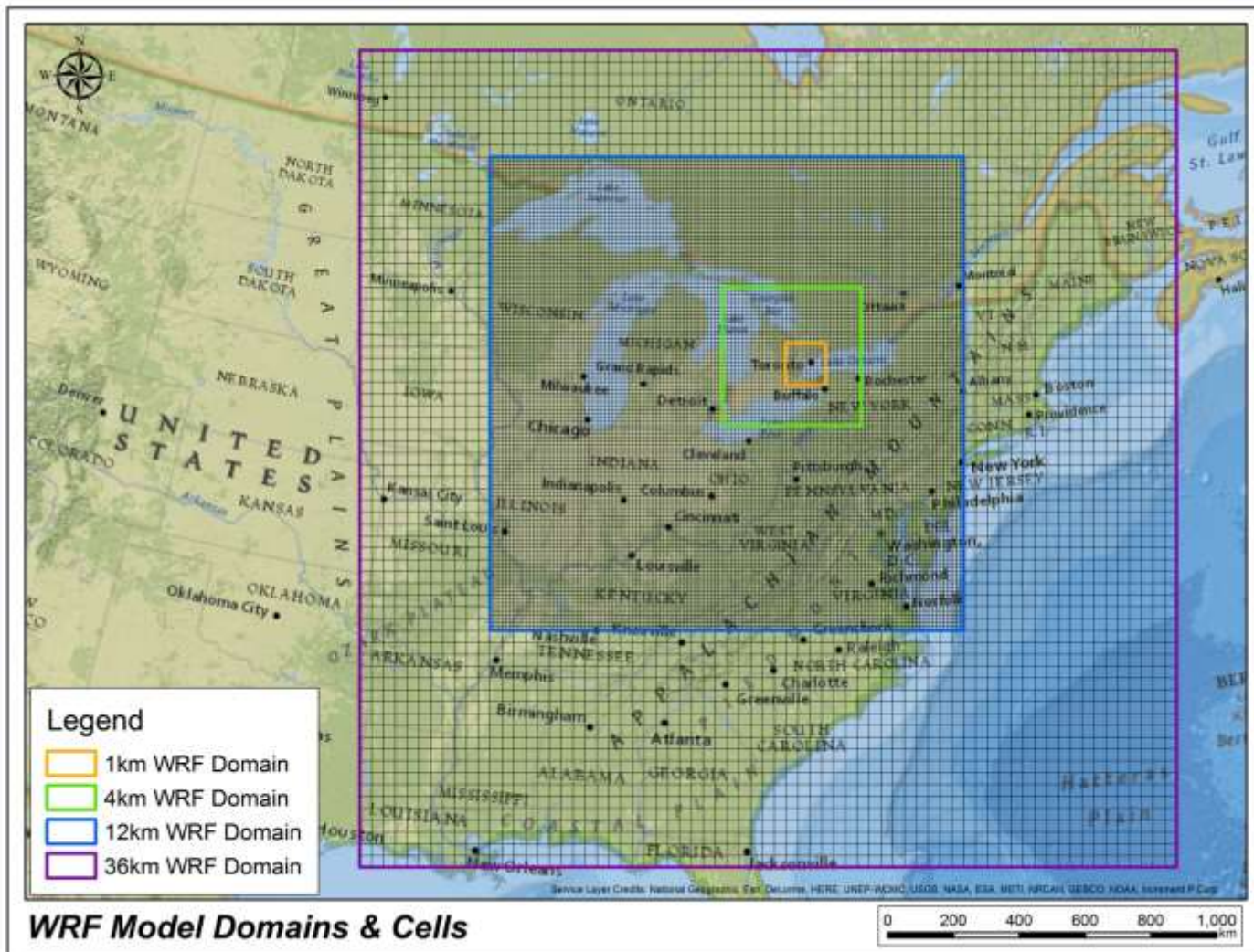
- WRF (Ver. 3.4.1)
- MCIP (Ver. 4.1)
- SMOKE (Ver. 3.1)
- MEGAN (Ver. 2.1)
- CMAQ (Ver. 5.0)

CMAQ (v. 5.0) MODEL CONFIGURATION

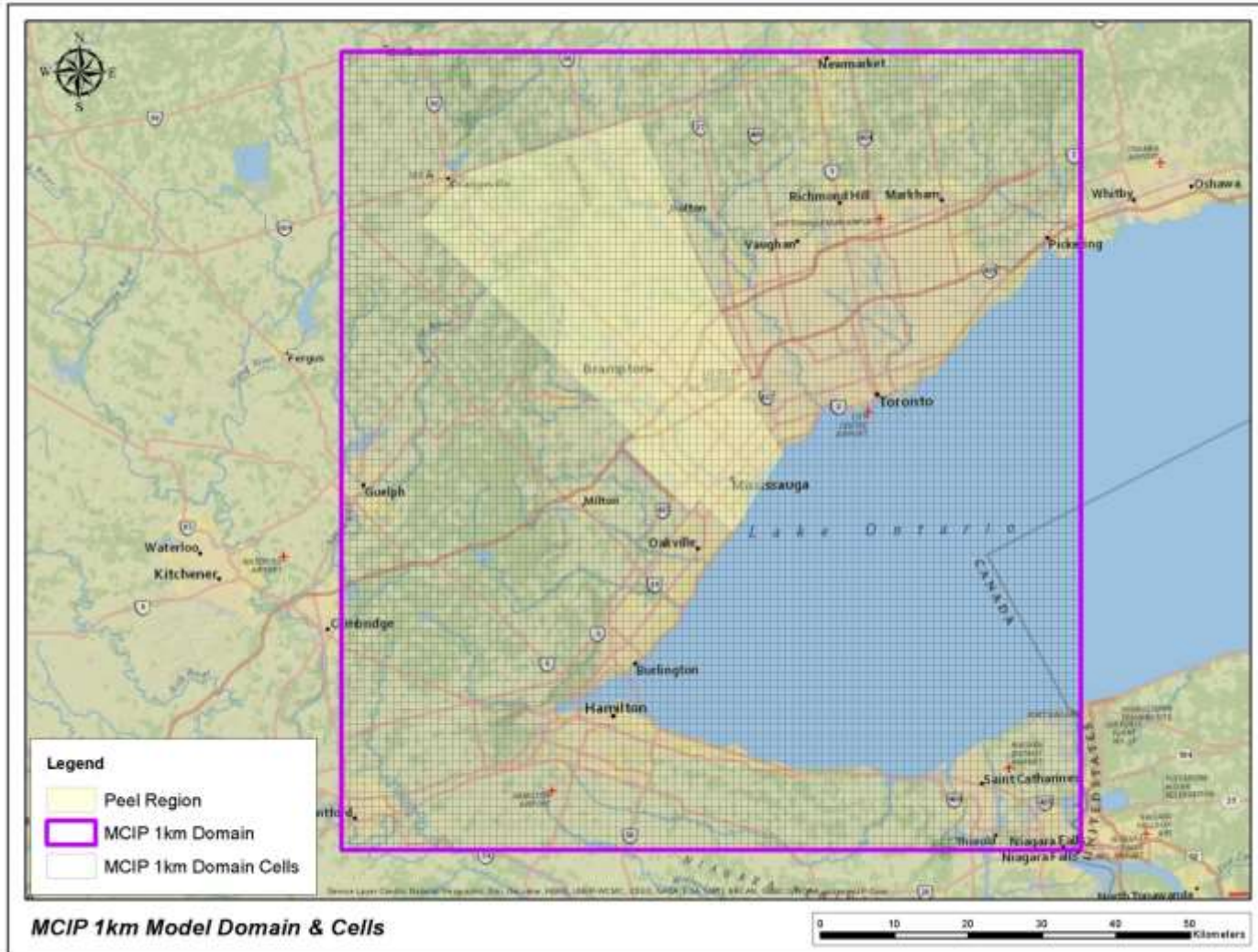
Horizontal Advection	Yamartino
Vertical Advection	Per WRF outputs
Horizontal Diffusion	Multiscale
Vertical Diffusion	ACM2
Gas Chemistry Mechanism	CB05 (without Chlorine)
Gas Chemistry Solver	Euler Backward Iterative (EBI)
Aerosol Mechanism	CMAQ 6 th generation model (aero6)
Clouds/Aqueous Chemistry	Cloud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



Air Quality Model Domains (36/12/4/1)



Innermost (1.0 km) Domain



CANADA

- 2010 pre-specified major point sources (NPRI)
- 2006 area and mobile (on-road and non-road)
- 2011 National Agri-Environmental Standards Initiative (NH₃)

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 equipment)	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

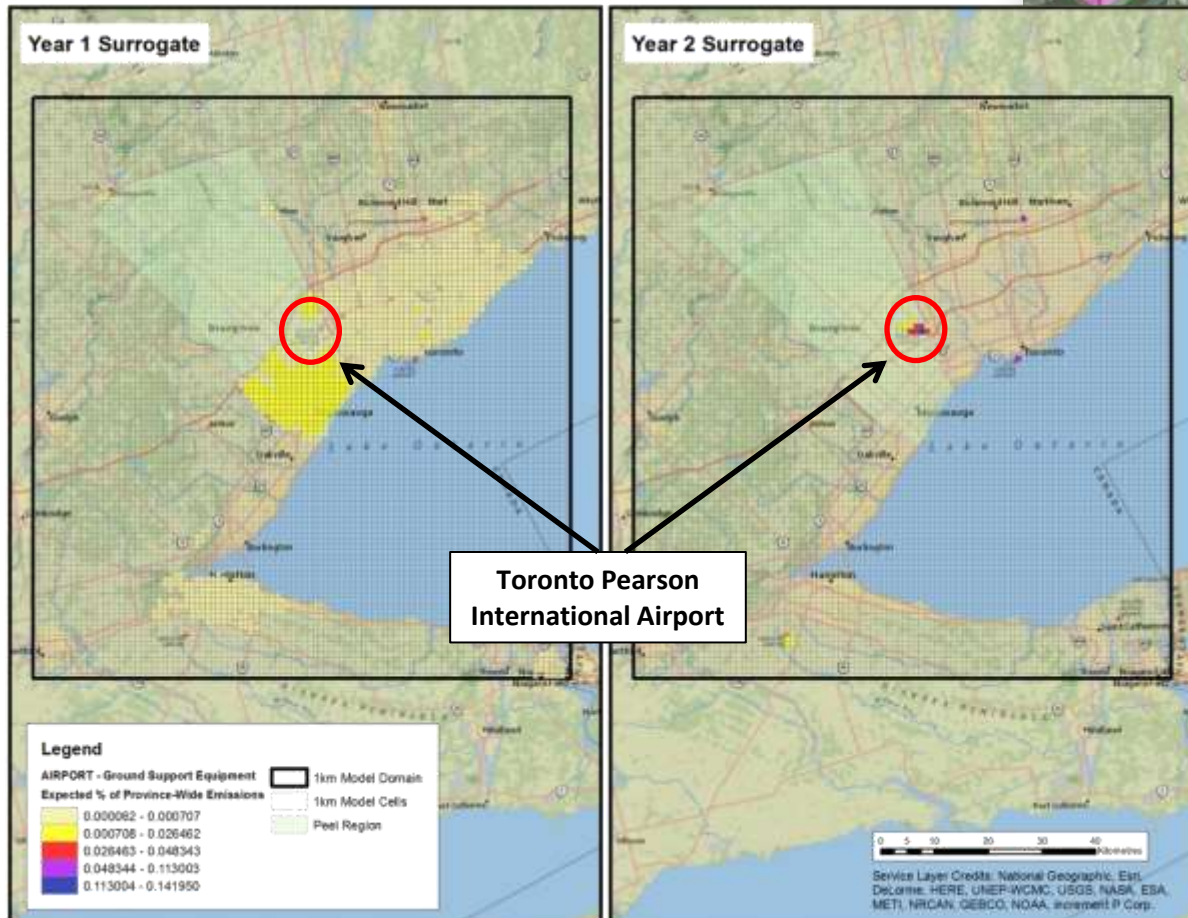
Missing / generic
stack parameters
much more
important...

Yellow dots depict
major sources with
inadequate or
missing stack
parameters.



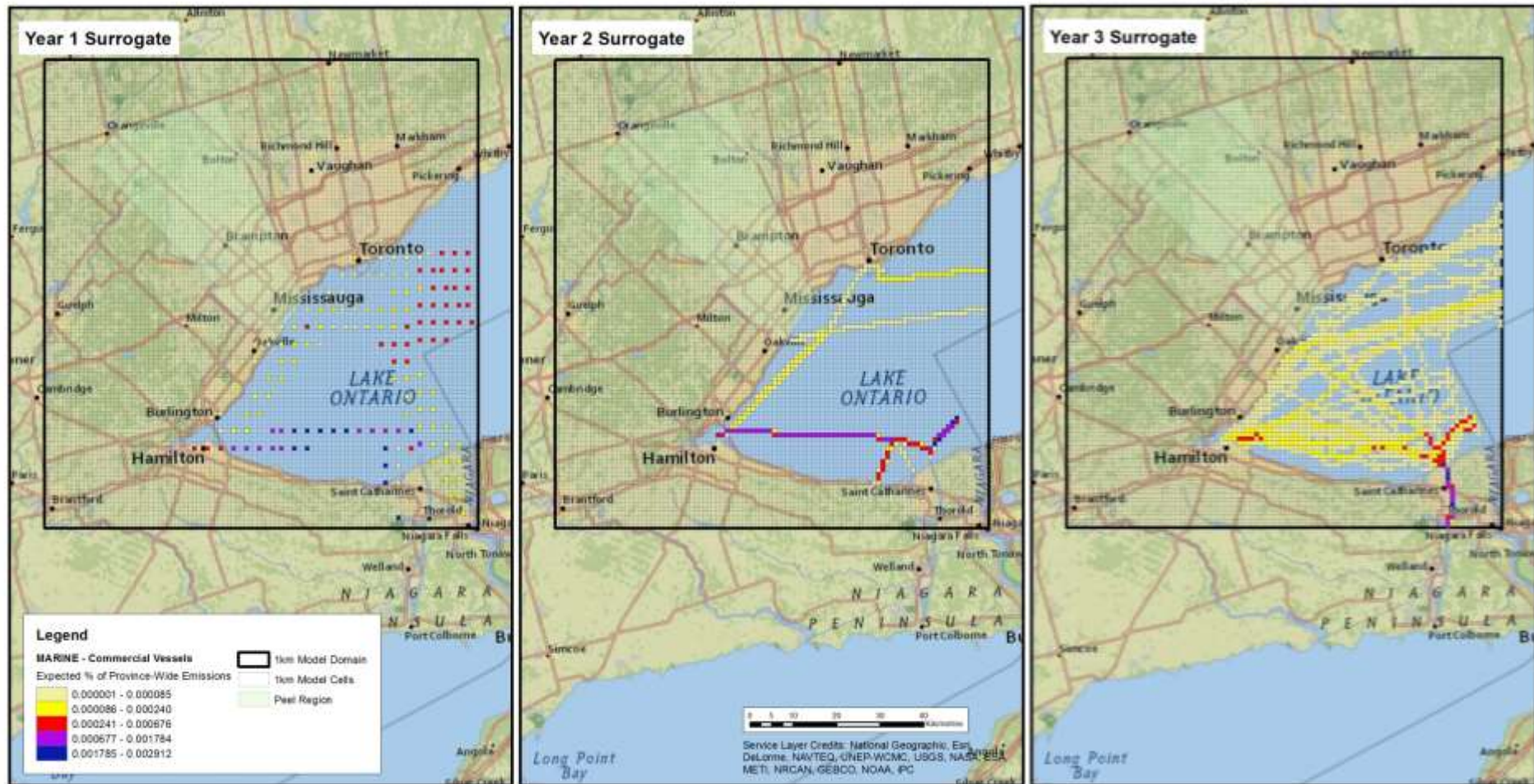
Spatial Allocations - Airport GSE

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



Make friends with
your GIS people –
you'll need them!!!

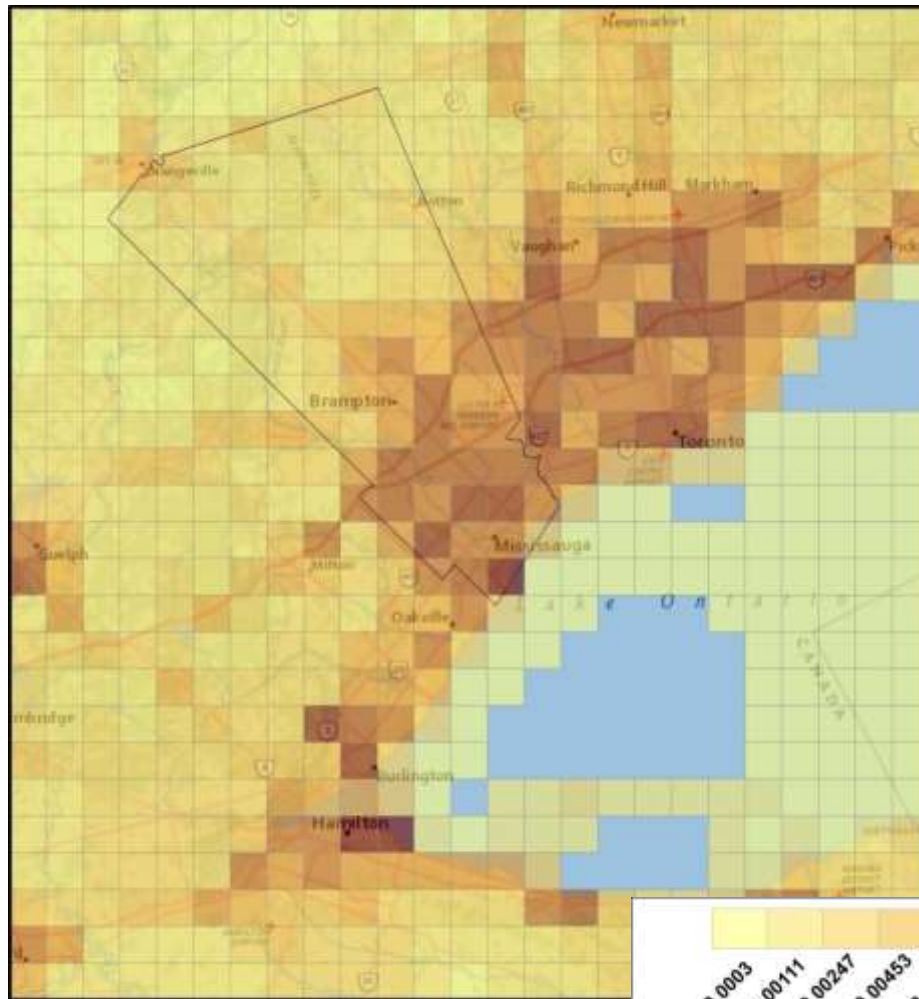
Emissions inventories are never 'done'...



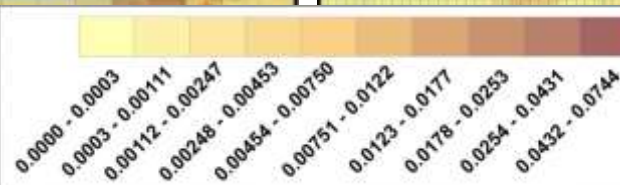
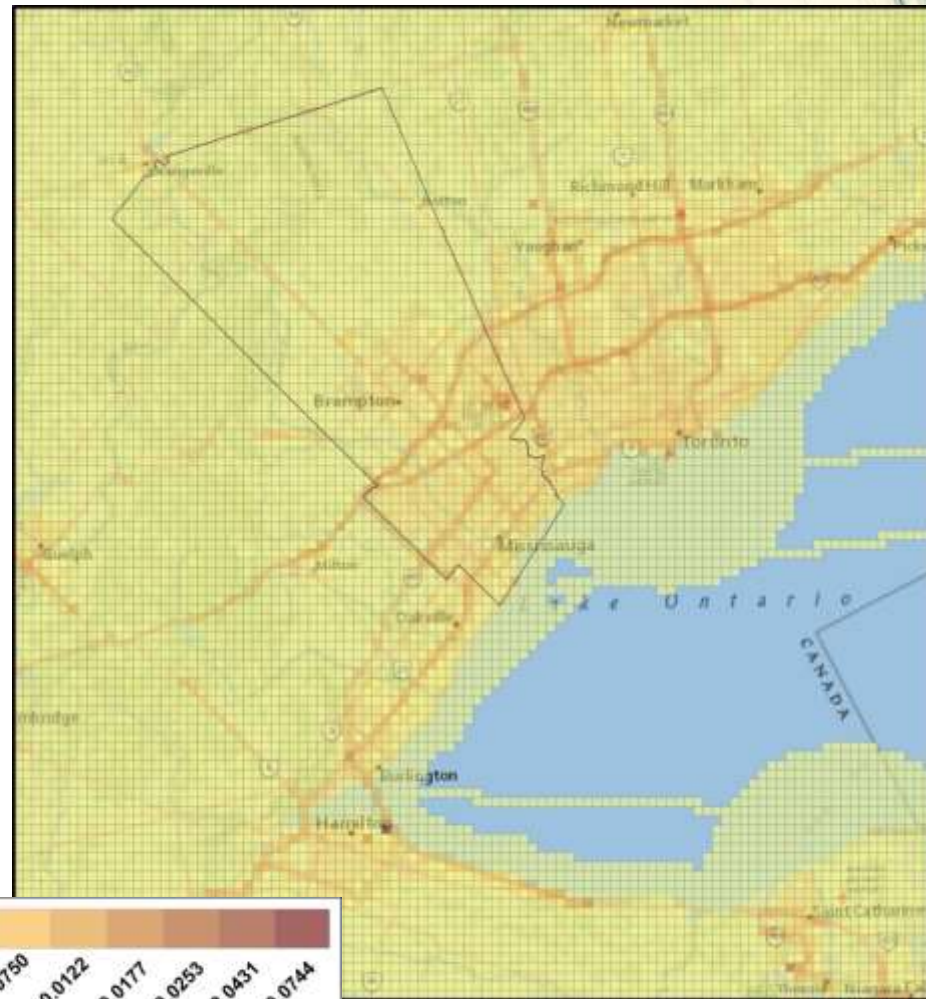
NO_x Emissions (g/s) Over 1.0 km Domain

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

4.0 km Gridded Emissions

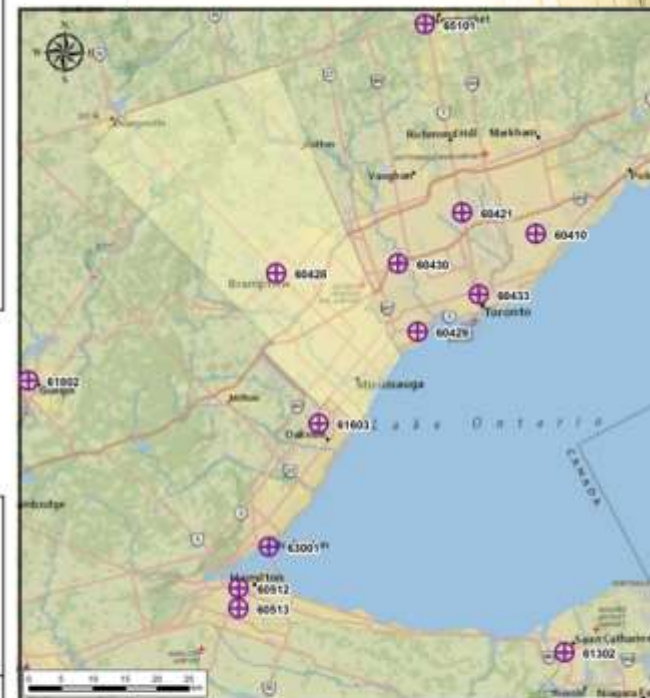
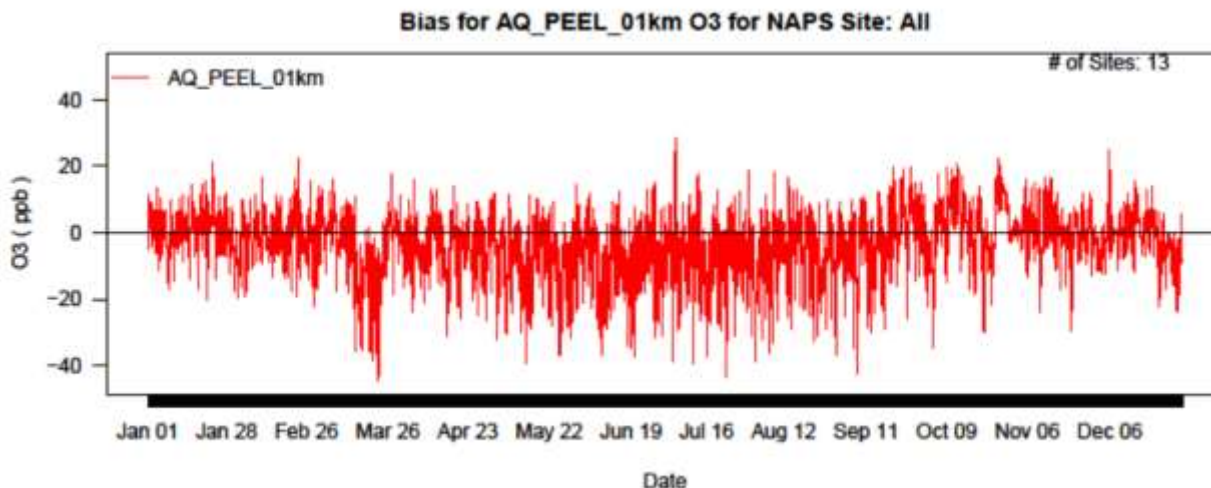
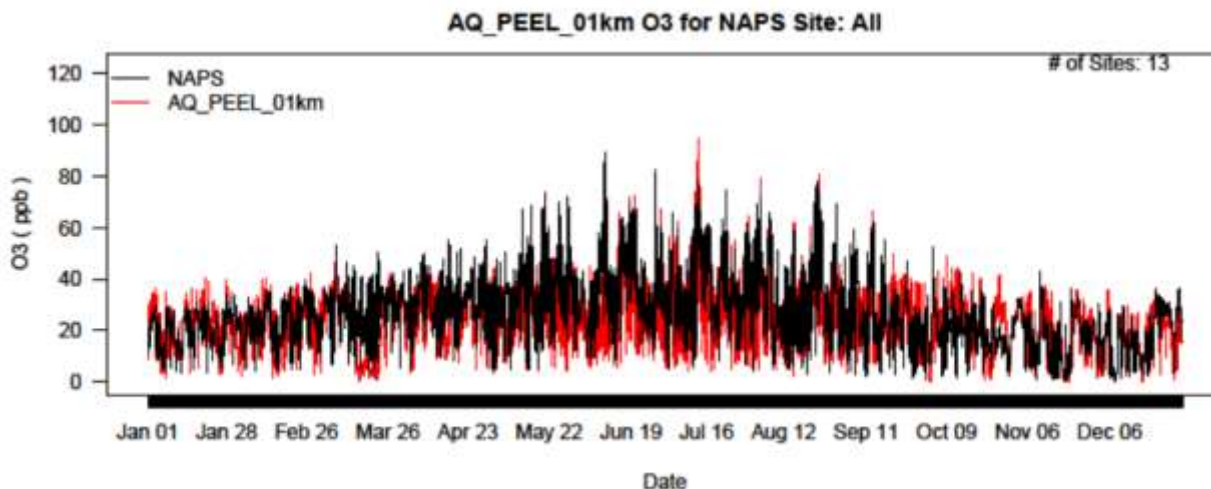


1.0 km Gridded Emissions

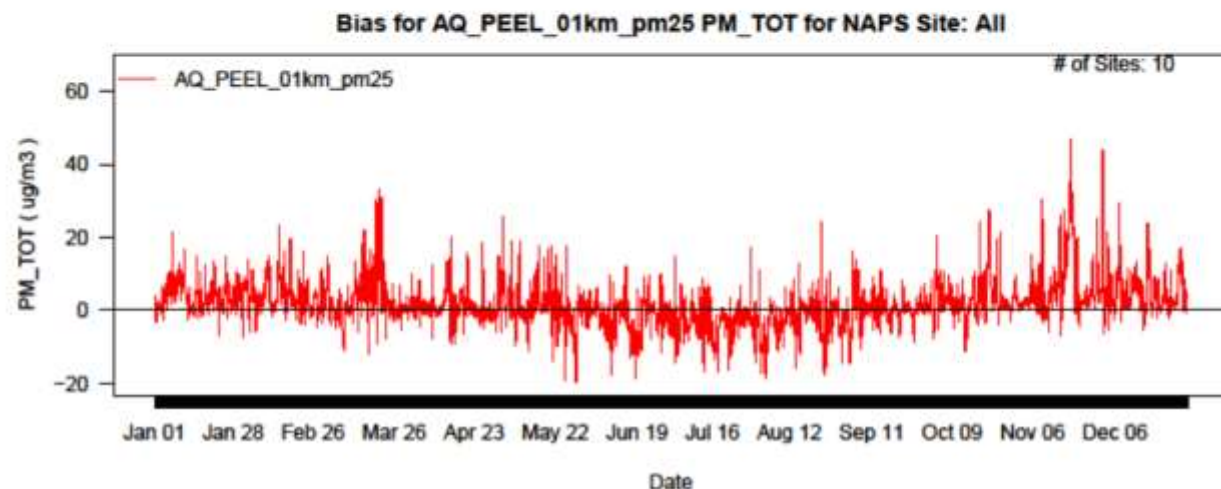
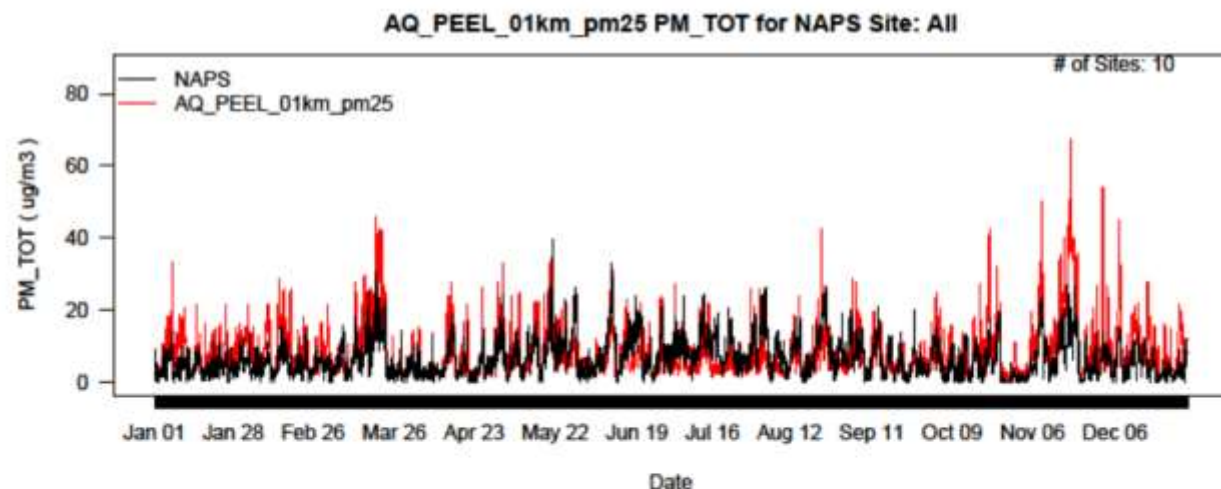


CCTM (CMAQ) MODEL PERFORMANCE 2012 BASE YEAR SIMULATION

Annual O₃ (ppb) modelled vs observed (domain-wide)



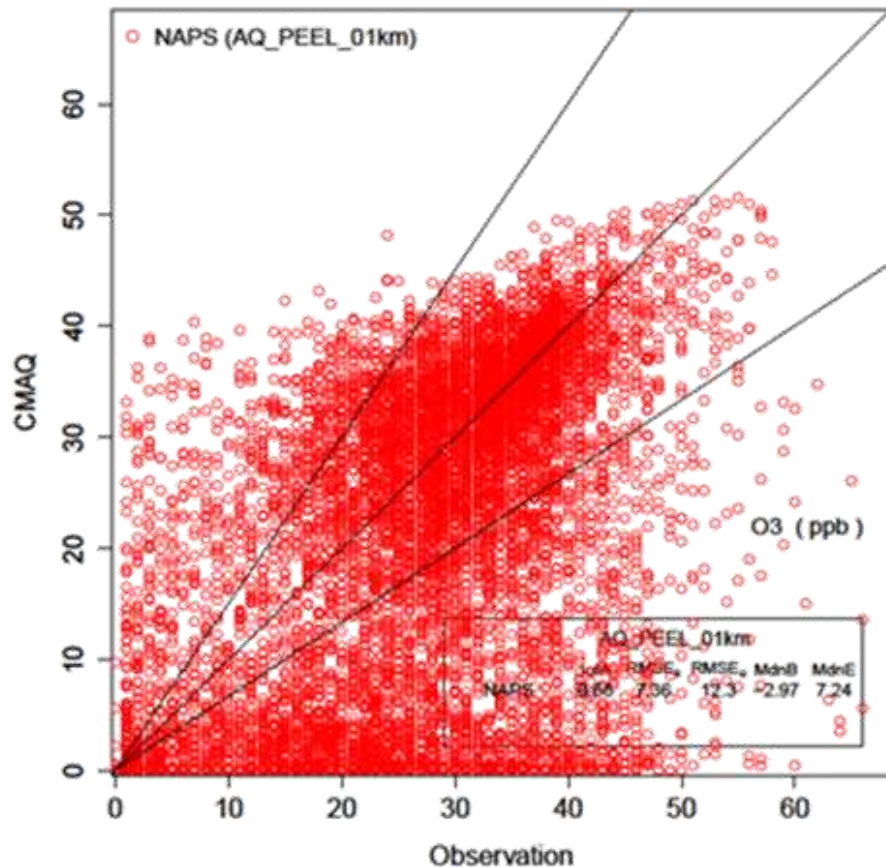
Annual PM_{2.5} ($\mu\text{g}\cdot\text{m}^{-3}$) modelled vs observed (domain-wide)



Domain-wide modelled vs observed O₃ (ppb)

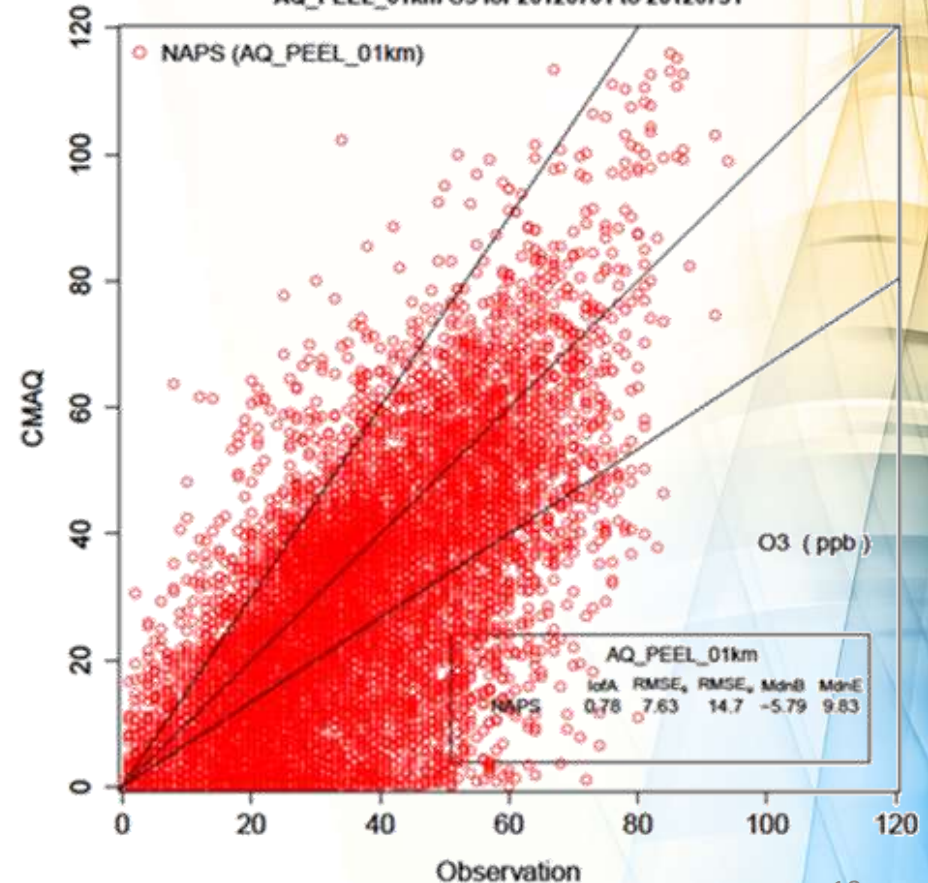
March

AQ_PEEL_01km O3 for 20120301 to 20120331



July

AQ_PEEL_01km O3 for 20120701 to 20120731

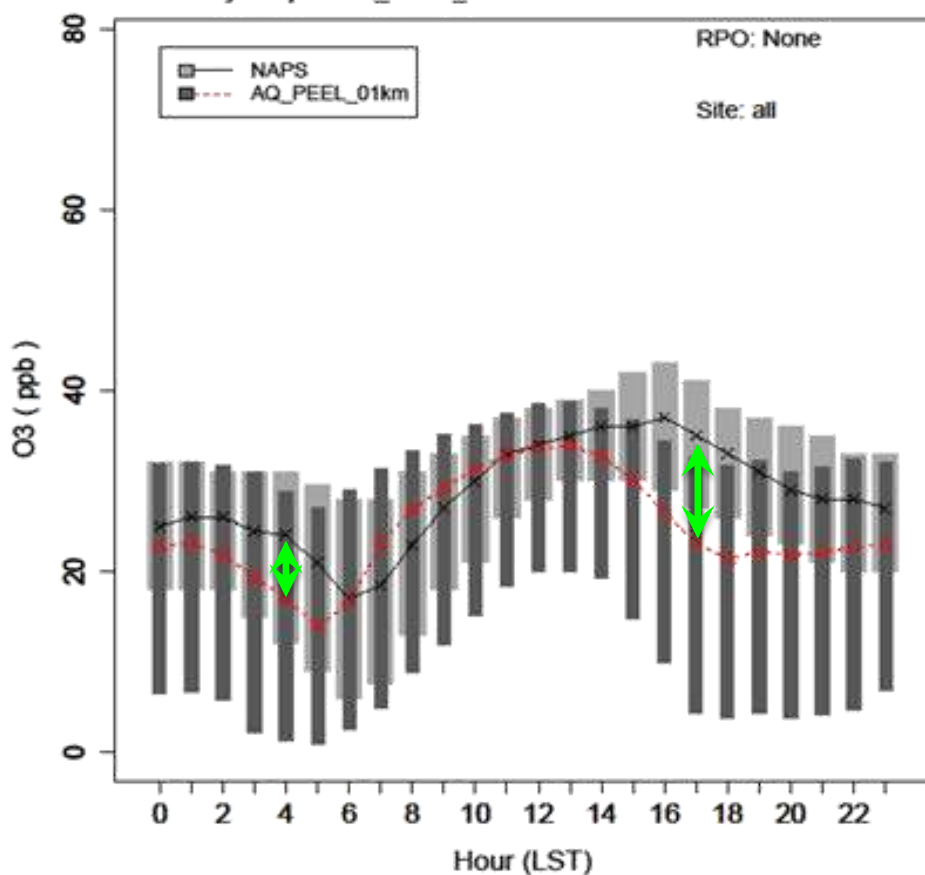


Domain-wide modelled vs observed O₃ (ppb)

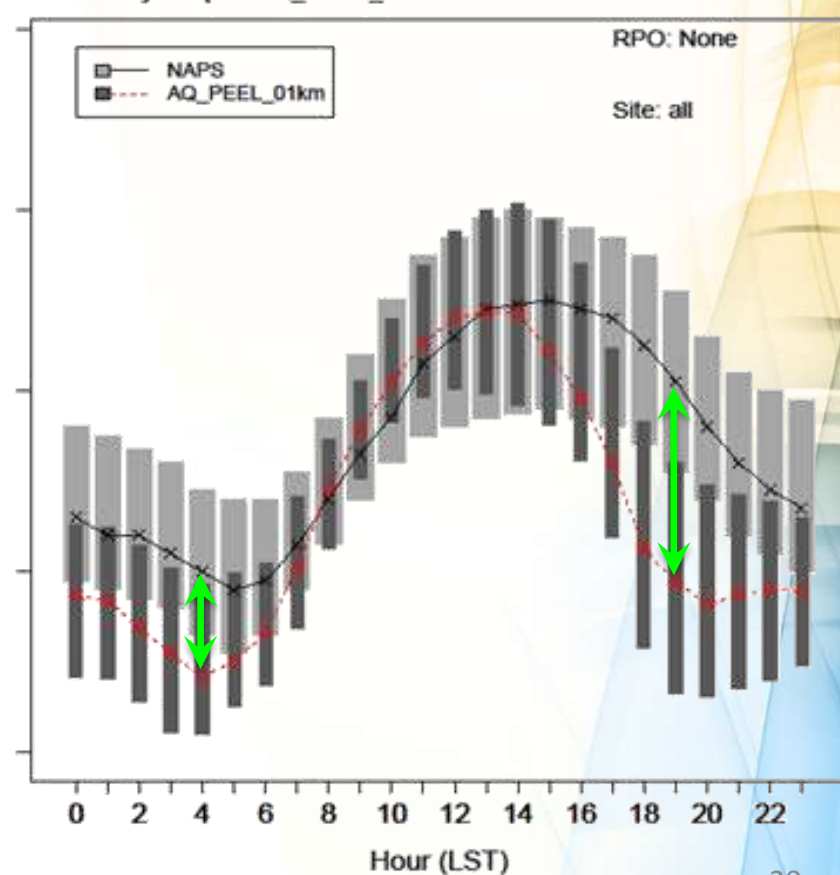
March

July

Hourly boxplot AQ_PEEL_01km 20120301 – 20120331 SITE: all



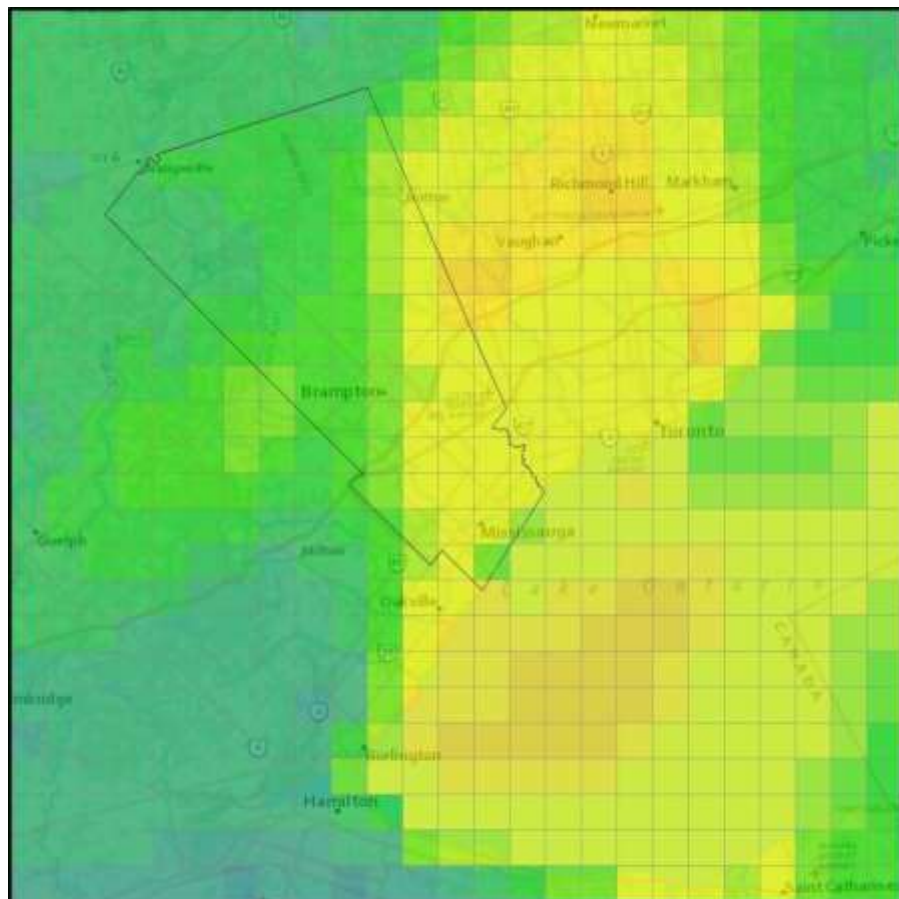
Hourly boxplot AQ_PEEL_01km 20120701 – 20120731 SITE: all



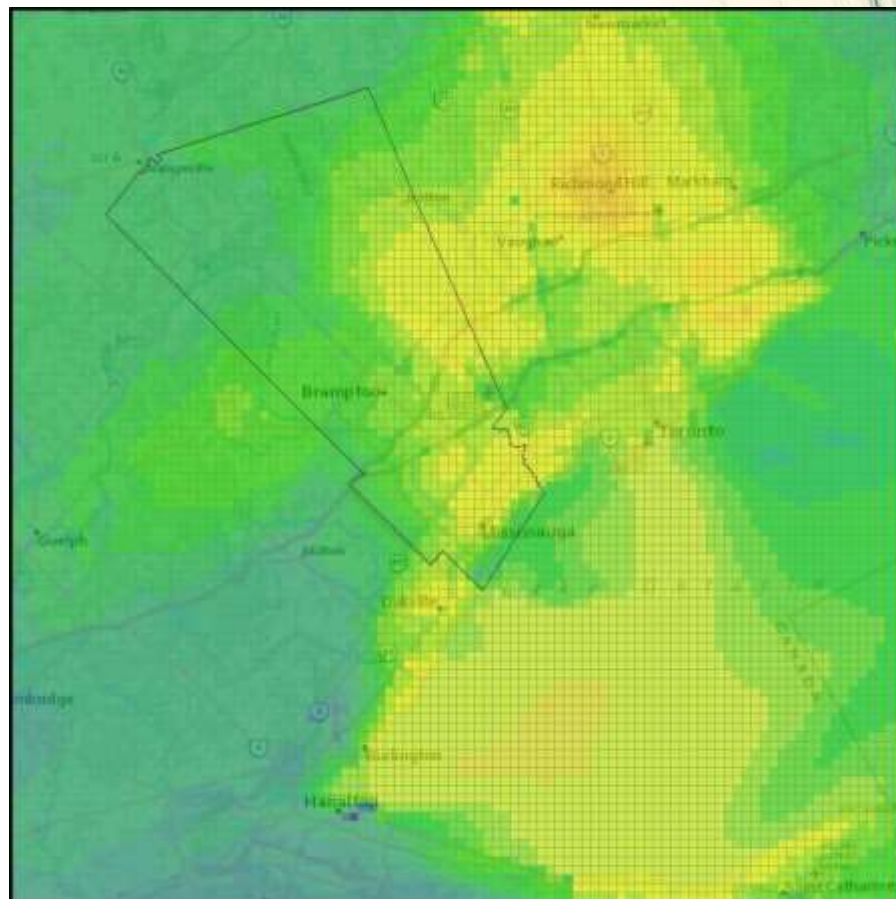
DRAFT Modelled O_3 (ppmV) over 1.0 km Domain

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

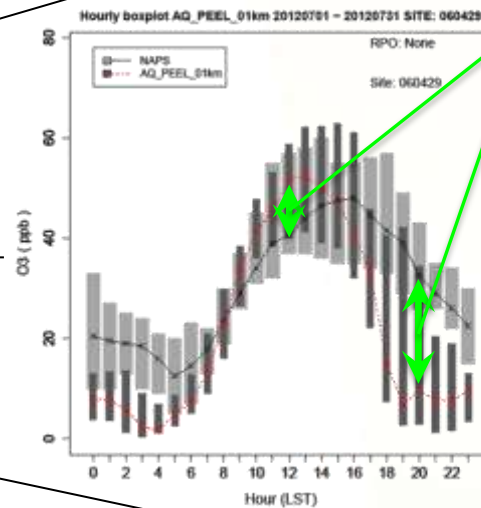
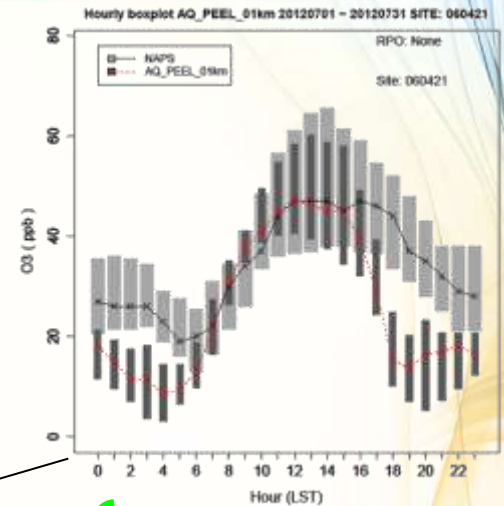
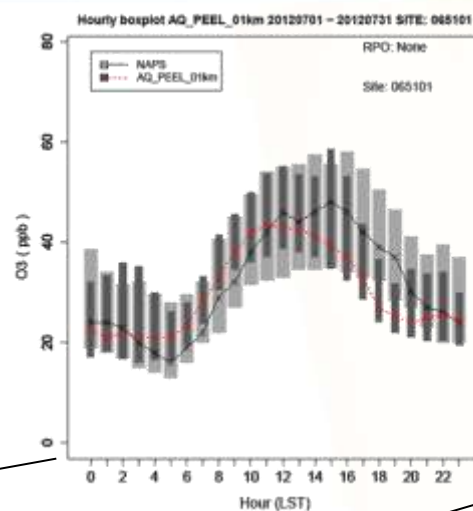
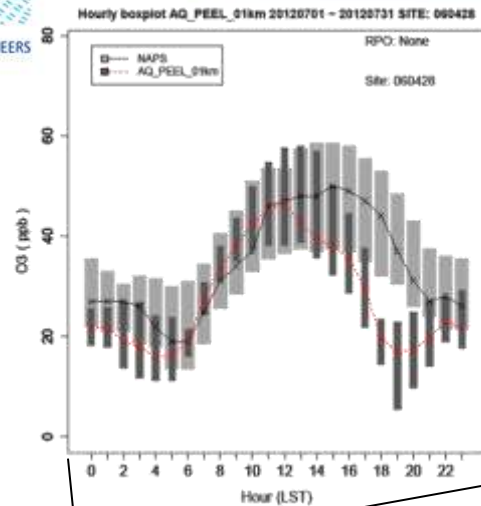
4.0 km Gridded Concentration



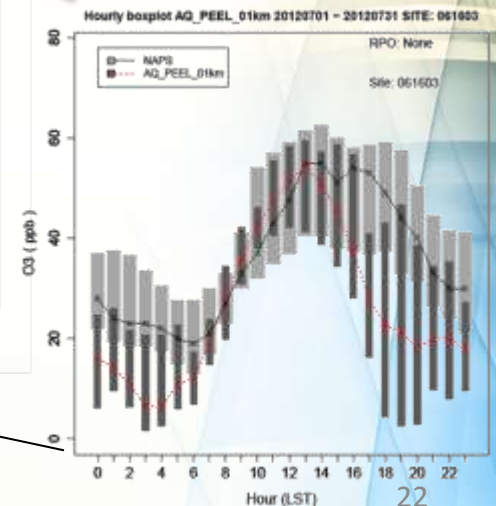
1.0 km Gridded Concentration



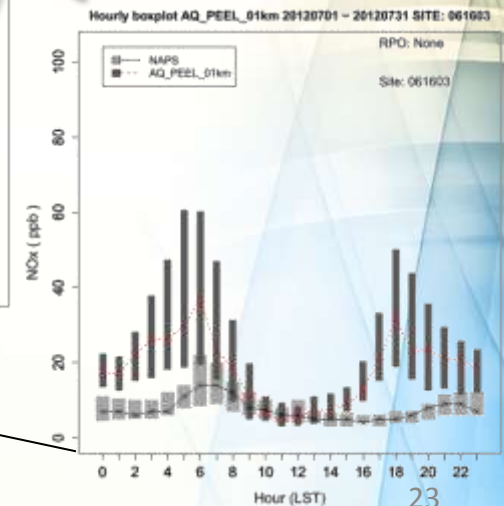
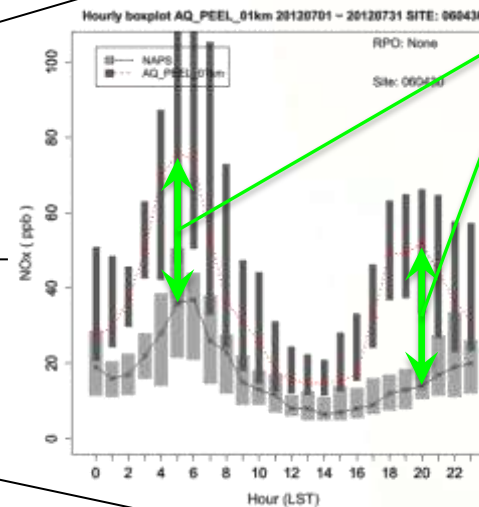
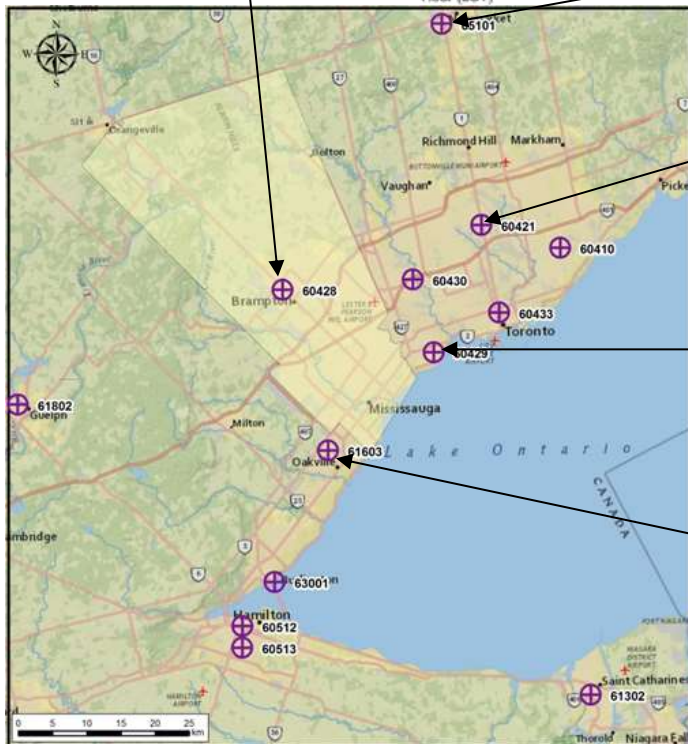
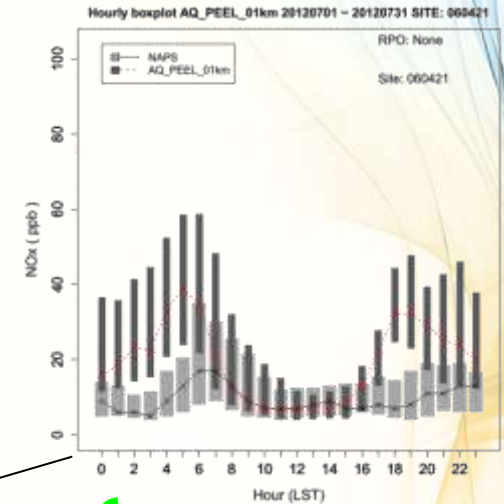
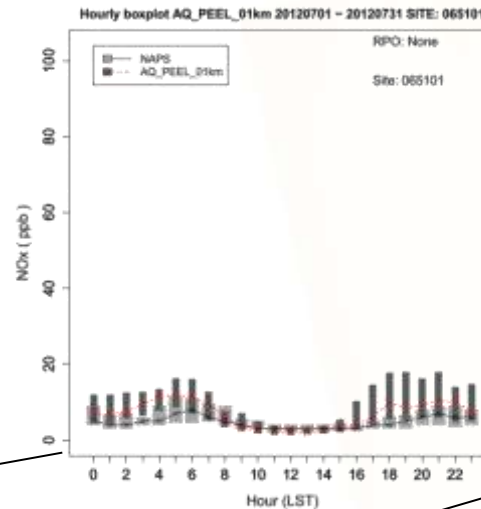
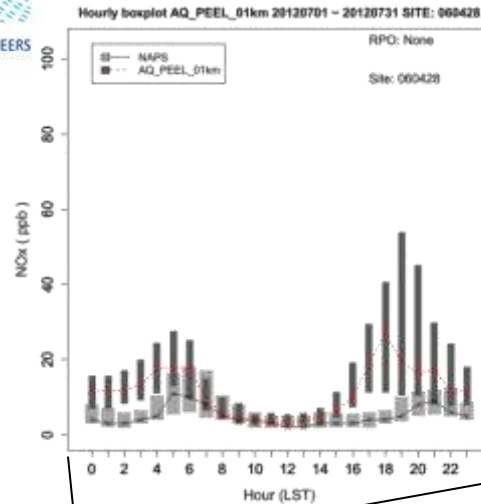
DRAFT Results for O₃ (July)



Spatial ?
Temporal ?
Emissions ?
Meteorology ?



DRAFT Results for NO_x (July)



Spatial ?
Temporal ?
Emissions ?
Meteorology ?

- Model performance 'good' for both ozone and PM_{2.5}
- High resolution evident in results (O₃ near highways)
- High resolution highlights model performance 'challenges' (EI, spatial, temporal, meteorology)
- Much to investigate and likely improvements to be made (so what else is new?)
- New 2010 EI for Canada improves O₃ performance (e.g., near highways)
- Emission updates and emission change scenarios currently underway

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



***Thank you for
your time.***

Questions?

***Funding provided by: Regional Municipality of Peel
Public Health Department***