HIGH RESOLUTION CMAQ APPLICATION FOR THE REGIONAL MUNICIPALITY OF PEEL, ONTARIO, CANADA

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1. INTRODUCTION

The Regional Municipality of Peel (Peel Region) has a population of more than one million people and is adjacent to the City of Toronto, in the province of Ontario, Canada.

The Region of Peel Public Health Department commissioned a multi-year project to develop a flexible and comprehensive air quality modelling and monitoring system. The purpose is to provide data to hhelp understand and address sources of poor air quality and to assist in the assessment of land-use planning and transportation decisions.

2. MODELLING AND MONITORING OVERVIEW

A passive monitoring program was implemented to complement existing monitoring programs in the region, support the evaluation of model performance and inform potential areas of interest for future modelling scenarios. Results from the monitoring program are under review and hence not described here.

The modelling system is based on year-long model simulations using WRF/SMOKE/CMAQ. The system is configured with nested 36km, 12km, 4km and 1km resolution model grids. The parent 36km resolution domain covers most of northeastern North America.

The inner-most 1km-resolution domain covers Peel Region along with the heavily urbanized areas along the western portion of Lake Ontario, referred to locally as the “Golden Horseshoe”. Major urban centres within the 1km model domain include Toronto, Mississauga, Oakville, Burlington, Hamilton, and St. Catharines (Figure 1).

Hourly meteorological inputs were generated for the complete 2012 year using WRF v.3.4.1.

Emissions processing was performed using SMOKE v.3.1. Regional emissions inventories for the US and Canada are described in Table 1. High resolution spatial surrogates were developed to more effectively and accurately allocate emissions within the innermost model domain. Plume rise calculations for point sources were processed by CMAQ.

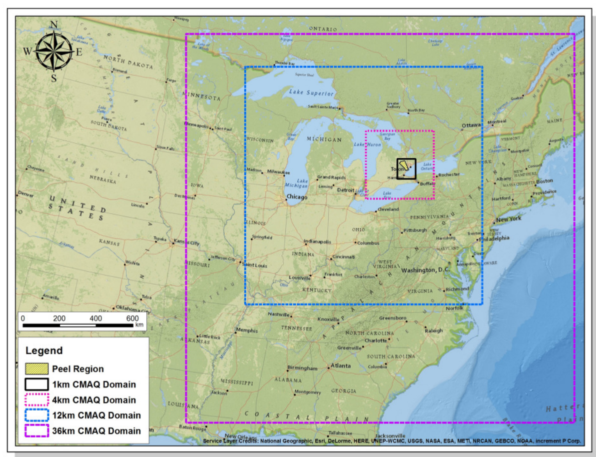

Fig. 1. Extent of nested CMAQ modelling domains being used for the Peel Region modelling system.

Jurisdiction	Emissions Inventories
Canada	• 2010 pre-speciated point sources (NPRI) • 2006 mobile (on-road and non-road), and area sources • 2011 NAESI Agriculture emissions
U.S.	• 2008 US EPA NEI (point, area, on-road, non-road) • 2012 fire emissions
Biogenic	• Megan (v. 2.1) updated for Canadian land cover

Table 1. Emissions Inventory inputs.

3. SPATIAL SURROGATES

High-resolution spatial surrogates were generated for the 1km model domain using ArcGIS v10.2.1. New activity layers and data were sourced and further developed or created. Collecting and creating new activity data was deemed necessary as data used historically for more coarse model resolution applications resulted in poor (overly smoothed) spatial allocation of emissions at the 1km domain resolution. Figures 2 and 3 depict examples of improvements made to key surrogates for the 1km domain within the Peel modelling system. Additional details on the spatial surrogate development process are described in McClellan *et al.* (2013).

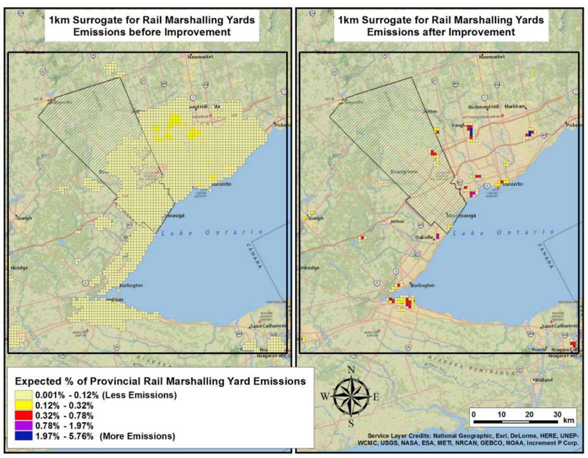

Fig. 2. Comparison of surrogates used to represent emissions from rail marshaling yards before and after improvements completed using GIS techniques.

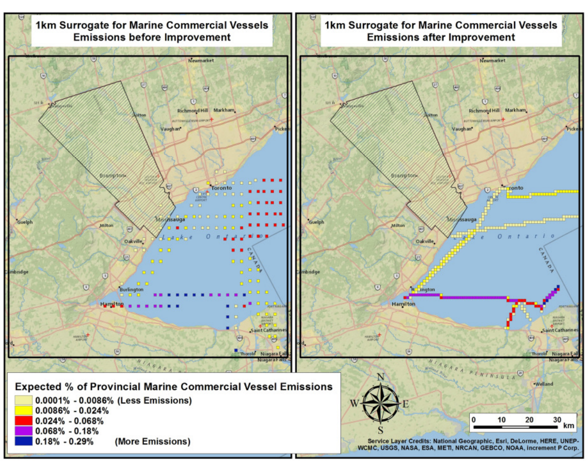

Fig. 3. Comparison of surrogate used to represent emissions from marine commercial vessels before and after improvements completed using GIS techniques.

4. EMISSIONS MODELLING

Emissions modelling were performed using SMOKE to generate the emission inputs for CMAQ. The SMOKE modelling process incorporated emissions inventory data from Canada, the USA and Peel Region to account for anthropogenic sources and MEGAN outputs for biogenic sources. Specific focus was applied to develop realistic spatial and temporal representations of emissions within the 1km domain.

Examples of the processed NOx emissions output from SMOKE for the 1km and 4 km model runs are shown in Figures 4 and 5, respectively (the 4km results are cropped to the 1 km domain extents). This comparison demonstrates the improved spatial representation of major NOx emission sources, namely transportation and urban areas at 1 km resolution.

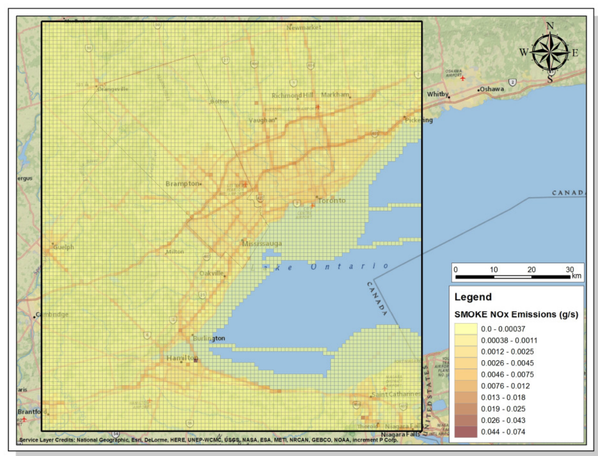

Fig. 4. NOx emissions (g/s) from SMOKE for the 1km domain for July 13, 2012, 1800 GMT (13:00 EST).

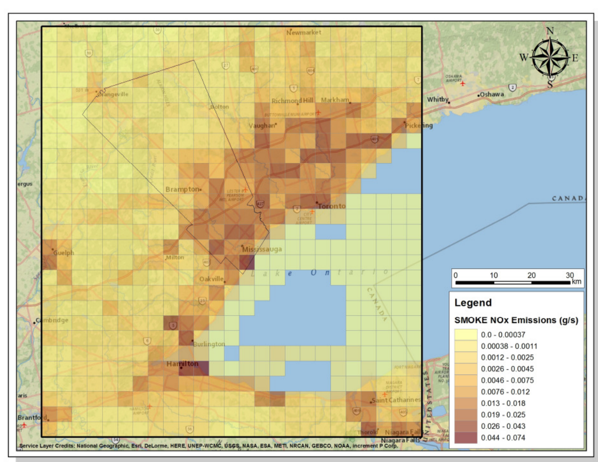

Fig. 5. NOx emissions (g/s) from SMOKE for the 4km model domain, cropped to the 1km domain extents, for July 13, 2012 1800 GMT (13:00 EST).

5. CMAQ MODEL RESULTS

Results for the first full year of model simulations showing both the positive and negative impacts of adopting a 1km grid resolution are presented, demonstrating the complexity involved in a modeling exercise of this scope and magnitude.

The results for the 4km grid resolution are also presented to provide a side-by-side comparison of how the 1km results differ from the 4km to facilitate an understanding of the benefits and dis-benefits of applying WRF/SMOKE/CMAQ at high spatial resolutions.

Figures 6 through 11 are displayed as side-by-side panels covering a three-hour progression (time series) of CMAQ model results for ground level ozone (O_3) from July 13, 2012 1700 GMT (12:00 EST) through 1900 GMT (14:00 EST), inclusive.

Images on the left are from the 1km resolution CMAQ results; images on the right are from the 4km resolution domain but trimmed to the 1 km domain extent to facilitate a more direct comparison. The same colour legend and scale is used in all figures.

As can be seen from each set of images, the 1km grid resolution produces a more spatially refined representation of local air quality and also emissions sources. This is evidenced by the local, road-side titration of ozone by NOx emissions along major highways and within urban centres. This same phenomenon is less evident in the 4km results due to the inherent spatial averaging of the coarser resolution.

A more detailed assessment of the spatial patterns of both emissions and modeled concentrations is ongoing. A review of how these factors play out for different pollutants and at different times of the year is also being assessed.

6. MODEL PERFORMANCE

The Atmospheric Model Evaluation Tool (AMET) is being leveraged to pair and analyze the results of both WRF/MCIP and CMAQ model outputs to measured values collected by in situ monitoring programs.

6.1 WRF and MCIP Model Performance

Model performance statistics generated for the WRF and MCIP outputs demonstrate good agreement with observations from MADIS stations. Although there are some slight seasonal biases that are undergoing further examination, the representativeness of the meteorological model outputs is believed to be adequate to support the air quality modeling without having a major impact on the CMAQ model performance. As a result, no further discussion of the meteorological model performance is presented.

6.1 CMAQ Model Performance

Ambient monitoring data from the Canadian National Air Pollution Surveillance (NAPS) network and U.S. AQS, for the 2012 calendar year, are being used to evaluate the CMAQ model performance. This work had just begun at the time of writing and hence only preliminary results for ozone for the month of July are presented. Further evaluations for other periods and pollutants are ongoing.

Time series of hourly O_3 concentrations (in ppbV) for July 10th to 25th, 2012 for the 1km and 4km resolution domains are presented in Figures 12 and 13, respectively. These time series are for the respective domain-wide observed averages, not any one specific station.

Figure 12 demonstrates that for the 1km domain, the model captures the peaks and troughs well with modest overestimates of daytime peaks and slight underestimates at night. Specific signatures in the times series such as higher overnight levels on July14th, 22nd,23rd and 26th are also captured well, as are the subtle steps observed in evening ozone levels.

Figure 13 demonstrates similar results but for the entire 4km domain (note – missing observations for July 16th manifest as a “straight-line” anomaly in the graph). The model performance is very similar or slightly better than for the 1km results.

Arguably, these simple time series might suggest that the model performance is the same or better at the 4km resolution as the line of modelled values is generally a tighter fit with the observed values.

However, our previous review of modeled spatial patterns over the 1km domain indicate that model evaluations must take into account not just domain-wide statistics but also the location and timing.

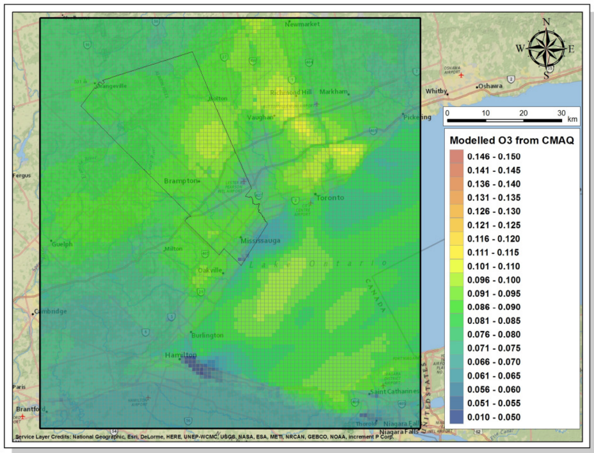

Fig. 6. 1km modelled O_3 (ppmV) concentrations for July 13, 2012 1700 GMT (12:00 EST).

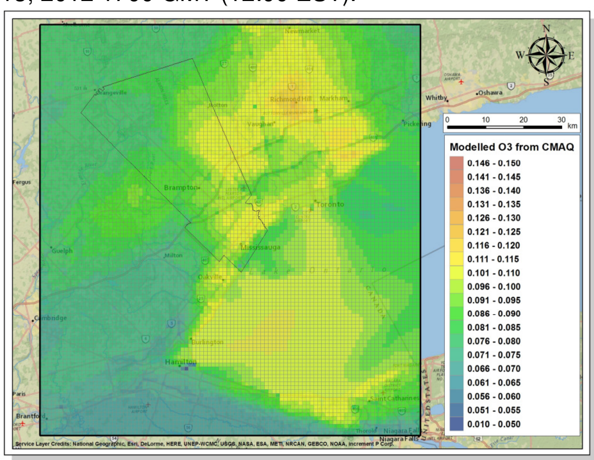

Fig. 7. 1km modelled O_3 (ppmV) concentrations for July 13, 2012 1800 GMT (13:00 EST).

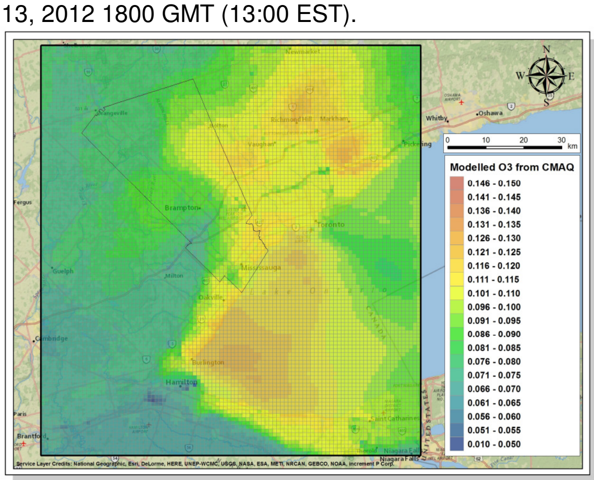

Fig. 8. 1km modelled O_3 (ppmV) concentrations for July 13, 2012 1900 GMT (14:00 EST).

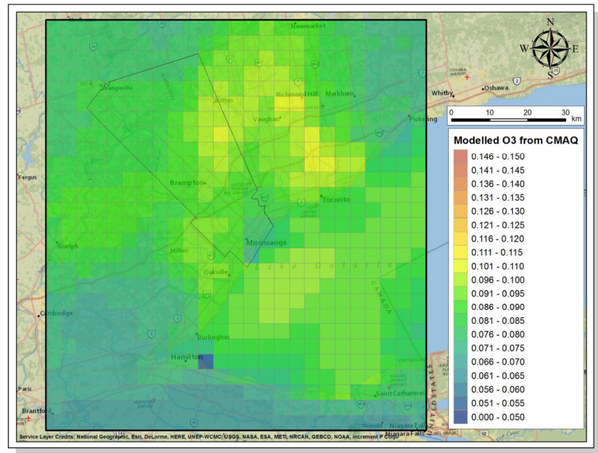

Fig. 9. 4km modelled O_3 (ppmV) concentrations for July 13, 2012 1700 GMT (12:00 EST).

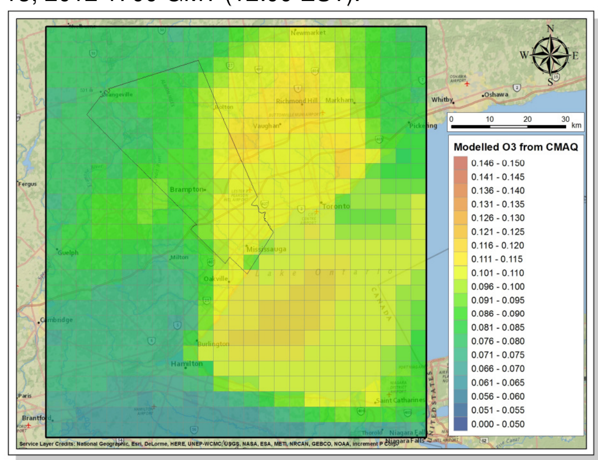

Fig. 10. 4km modelled O_3 (ppmV) concentrations for July 13, 2012 1800 GMT (13:00 EST).

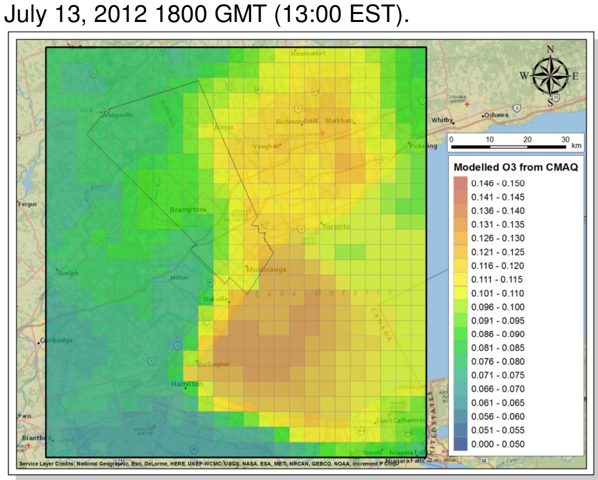

Fig. 11. 4km modelled O_3 (ppmV) concentrations for July 13, 2012 1900 GMT (14:00 EST).

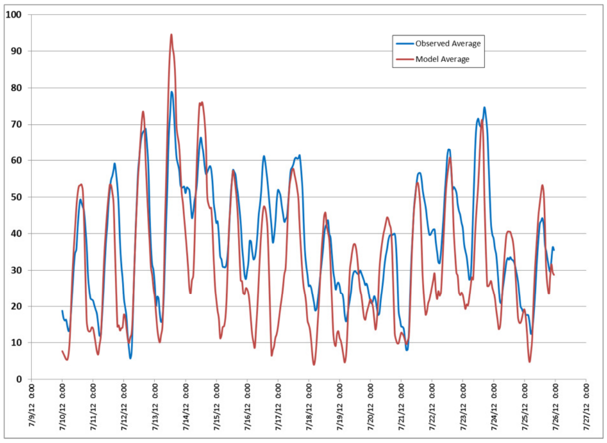

Fig. 12. Time series generated in AMET comparing NAPS air quality monitoring program recorded O_3 values in ppb to CMAQ modelled values for the 1km model domain.

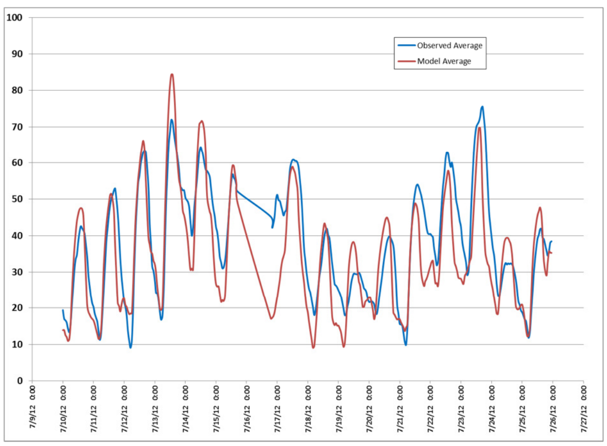

Fig. 13. Time series generated in AMET comparing NAPS air quality monitoring program recorded O_3 values in ppb to CMAQ modelled values for the 4km model domain.

7. CONCLUSIONS

Photochemical modelling over a relatively large domain, at high spatial resolution, and for an entire year is highly resource intensive. In addition to the large computing requirements, significant additional effort is required to prepare and pre-process emissions data and spatial surrogates. Without this effort the full advantage of modelling at high resolution would not be recognized (i.e., spatial data used to create surrogates at 4km or coarser resolutions may not be adequate for preparing surrogates at 1 km resolution).

An initial review of the CMAQ results indicates that there is value in assessing impacts at high spatial resolution if interested in knowing some of the subtle differences in exposure of populations to air quality. As the underlying purpose of this exercise is to support policy assessments and decision making concerning urban growth and planning activities, the effort involved in generating high resolution model results appears to be a worthwhile investment.

Future efforts will focus on more rigorous model performance evaluations and the assessment of various emission change scenarios designed to assess potential air quality health management strategies and to inform policy and development within Peel Region.

7. 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.

8. ACKNOWLEDGEMENTS

The authors would like to acknowledge the technical support provided by Environment Canada, the Ontario Ministry of the Environment, and the US EPA. Financial support for this project is provided by the Region of Peel.