DEVELOPING SPATIAL SURROGATES FOR HIGH-RESOLUTION MODELLING DOMAINS

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1. INTRODUCTION

As high-end computing resources become less costly and increasingly available, air quality modelers are continually migrating towards higher-resolution modelling grids. The temptation behind using higher-resolution grids is the assumption that this will inherently lead to improved accuracy of model results. However, with an increase in spatial resolution of the model, modelers need to be equally mindful of the resolution of the inputs to their models, especially those used to create spatial surrogates.

In this paper we highlight the importance of issues arising from the development of spatial surrogates at high model resolutions with examples from a large (100 km by 108 km), 1.0 km grid resolution SMOKE and CMAQ modelling exercise being performed for the Regional Municipality of Peel Public Health Department in Southwestern Ontario, Canada.

2. MODELLING OVERVIEW

The Region of Peel (hereafter, Peel) is a regional municipality located in southern Ontario, Canada, located directly west of the City of Toronto on Lake Ontario in the Greater Toronto Area (GTA) (See **Fig. 1**). Peel has a population of approximately 1.3 million residents and is located close to the Canada / United States border. It is home to large emission sources such as Toronto Pearson International airport, as well as several major transportation and rail corridors, industrial parks and agricultural lands.

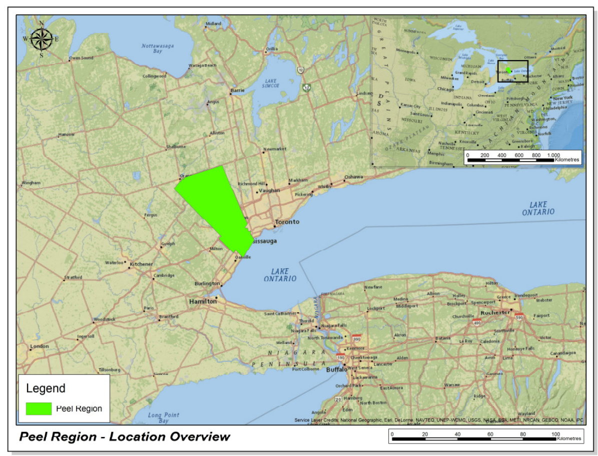

Fig. 1. Peel Region – Location Overview.

In 2011, the Regional Municipality of Peel Public Health Department embarked on the construction of an air quality modelling system that could be used to study the impacts of potential emissions from various land use planning scenarios to guide policy decisions relating to public health and the Region's growth and sustainability programs.

Nested domains (36km, 12km, 4km and 1km) for CMAQ were developed and situated for the modelling exercise in such a way as to capture local air emissions within and in major urban centers surrounding Peel (Toronto and the Golden Horseshoe area of Ontario for the 1km domain), while also capturing areas that could contribute to trans-boundary air movement in the larger, lower resolution domains (4km, 12km and 36km domains) (See **Fig. 2**).

As part of the spatial surrogate processing exercise, some surrogates were identified as problematic when attempting to employ the same data and processes as used for lower resolutions in the development of surrogates for the higher

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resolution 1km domain. Special attention to the data and processing of spatial surrogates at 1km was necessary to ensure that the surrogates would result in the modeling system producing local air quality results that were representative in terms of both location and magnitude. Additionally, improvements of the surrogate calculation processes were identified for future modelling years. A sample of different approaches for dealing with calculating more accurate surrogates for high resolution modelling is detailed in the following section.

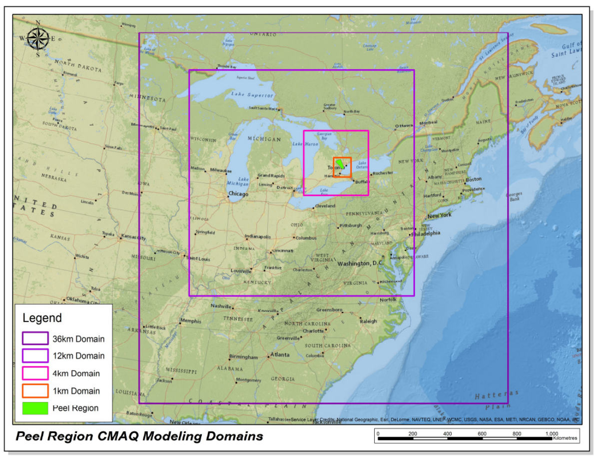

Fig. 2. Peel Region CMAQ Modelling Domains.

3. EMISSIONS SURROGATES

Typical methods and datasets used to generate surrogates for modelling are not always applicable in cases where modelling at a higher resolution is being implemented. Issues arise when data that are too coarse, too generalized, improperly or not precisely projected/transformed and/or no longer appropriate are utilized without due care, especially at higher resolutions (Kim, 2009).

The following sections detail some surrogate allocations that were determined to be problematic for high resolution applications in the Peel study. A general overview of the specific problems and improvements made to the input data, methods and/or workflows employed when generating spatial surrogates are discussed.

3.1 On-Road Mobile Emissions

Spatial surrogates for Canadian on-road mobile emissions have previously been generated using multiple attributes such as road length and population density to allocate emissions. As a result, unrealistically high mobile emissions were often allocated to rural areas with long roads but low population density, and to city centers with high population density. Also problematic was the fact that large differences in the spatial distribution of Canadian on-road mobile emissions vs. American on-road mobile emissions existed due to a more sophisticated process being used to allocate on-road emissions for the U.S.

To improve the spatial allocation of Canadian on-road emissions, a new Canadian national road network dataset, including road classifications and population density, was utilized to create six new on-road mobile surrogates that better reflect the expected activity and are harmonized methodologically with the corresponding U.S. spatial surrogates. To facilitate this work, a new road dataset was sourced that included comparable road categories as found in U.S. road datasets (Zhang et al., 2012). Road locations are accurate to within a few meters. Detailed population data from the 2006 Canadian census were also used.

The road categories in this dataset were analyzed by cross-checking the data against other GIS resources/reference layers and were then edited further to create an accurate depiction of the national road network and the road categorizations within and to calculate a new total road length as the product of geometric road length and number of lanes.

The revised dataset was then used in an updated surrogate generation workflow, and the resultant surrogates were more closely aligned / matched to surrogates generated for the same sources in the U.S. Because the full road network was separated into road-type categories, the Canadian on-road emissions were similarly disaggregated by road-type category, which provides a more ideal data input for high-resolution surrogate generation.

3.2 Airport Emissions

Toronto Pearson International Airport (Pearson airport), is located within the Region of Peel and is the largest airport in Canada, and the eleventh busiest in North America based on total movement counts in 2012 (ACI-NA, 2012). As such, Peel is host to a considerably large amount of airport activity and associated emissions.

Canadian surrogates related to emissions from airports were previously based on census statistics of persons employed in the field of aviation, which was problematic at higher model resolutions, as it often resulted in airport emissions activity being allocated away from airports. By using aircraft movement statistics for 211 primary Canadian airports for 2006, four aircraft source-type categories, and zones of influence that were based on tightly prescribed aircraft landing-and-takeoff (LTO) procedures, a more accurate and realistic set of airport/aircraft spatial surrogates was derived (Zhang et al., 2013). This approach allowed activity levels by Canadian province for primary Canadian airports to be considered based on aircraft traffic. For example, in Ontario, 49% and 10% of commercial aircraft flights are associated using this new method with Toronto Pearson International Airport (YYZ) and Ottawa Macdonald-Cartier International Airport (YOW) respectively. In the previous approach, the relative distribution of aircraft emissions between airports was based on a more indirect surrogate, namely the geographic distribution of the aviation-industry work force. A fifth new spatial surrogate, for airport ground operations, was also created based on airport location and commercial aircraft LTO statistics (Zhang et al., 2013).

3.3 Marine Emissions

Marine emissions in Canada are characterized into two different categories: commercial emissions from large shipping vessels; and, pleasure craft emissions from recreational boat activity. Geographic data typically used to represent commercial marine emissions can be quite coarse, especially when considering utilizing it for generating high resolution surrogates. As commercial marine vessels typically operate along shipping routes, a linear representation of these emissions would result in a more accurate distribution of the emission surrogate in lieu of gridded datasets that have been used historically to generate surrogates at lower resolutions.

In the case of the Peel 1km domain, when the gridded dataset was utilized to generate spatial surrogates, the resultant gridded emissions showed “hotspots” of emissions activity.

Improvement on this surrogate could be realized at the 1km resolution by utilizing shipping route datasets instead of gridded datasets. This would help to spatially allocate emissions to follow a pattern that mimics the movement of shipping vessels more evenly and accurately throughout the domain grid.

3.4 Railway Emissions

Railway emissions are represented by line geometry files following rail corridors. At times, the rail data may not be current or accurately placed, which becomes a concern when modelling high resolutions. Ensuring that railway corridors are placed correctly, still in use and include all active sections of track and yards are all important points to assess prior to running a high-resolution surrogate.

In the case of Peel, a shapefile called CANRAIL.shp was historically used in the generation of railway emissions surrogates. Some sections of the rail dataset showed primary lines offset as much as two km from the actual rail corridor, and did not include secondary or running track lines or marshaling yards (See **Fig. 3**). Using data such as this would result in a surrogate with low accuracy, which is increasingly problematic when applied to a high resolution domain.

Fig. 3. CANRAIL.shp Dataset – Offset Example.

Due to these concerns, an alternate railway dataset (Esri North American railways) was sourced and leveraged in conjunction with the CANRAIL.shp dataset to produce a hybrid railway activity dataset.

The hybrid dataset was compiled using a multi-step process in ArcGIS which extracted the more accurate railway data from each railway dataset, then merged/combined and aligned them back together. After the dataset was combined, quality assurance checks were performed by comparing the new alignment to imagery across the model domains. Some manual adjustments and corrections were performed to rectify some hanging ends and remove abandoned sections of track (See **Fig. 4** for example).

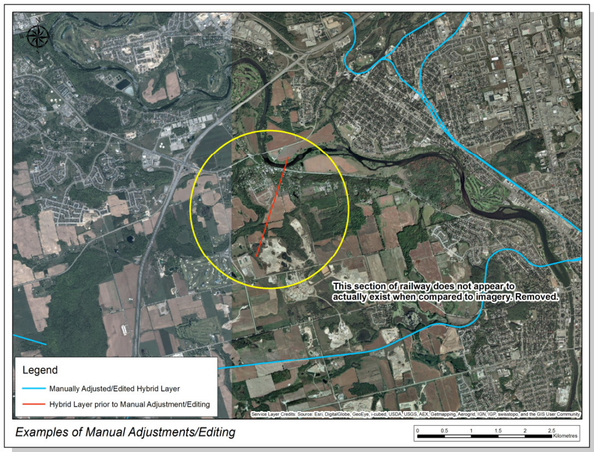

Fig. 4. Example of Manual Adjustments/Editing.

The resultant hybrid dataset leverages the most accurate data out of each of those two data sources to create a new railway geometry for the model domain. The new dataset improved not only the accuracy of the location of rail corridors, but also added missing railway geometries such as those representing marshaling yards and spur lines.

4. CONCLUSION

Spatial surrogates are used to allocate geographically aggregated (e.g., county or state-wide) emissions data to model grid cells. The higher the grid resolution being used in the modelling exercise, the more important it is to review and assess the appropriateness of both the spatial representation (the "where") and weighting factors (the "what") used to create spatial surrogates.

5. REFERENCES

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