Presented at the 13th Annual CMAS Conference, Chapel Hill, NC, October 27-29, 2014

DEVELOPMENT OF TRANSPORTATION AIR EMISSIONS IN CANADIAN CITIES

Nick Walters*, Xin Qiu, Hamish Hains, and Fuquan Yang
Novus Environmental, Guelph, ON, Canada

1. INTRODUCTION

Urban transportation emissions can impact significantly on local and regional air quality. A common approach to account for roadway emissions for modelling purposes is to apply road network spatial allocations with regional transportation total emissions. Emission processing models, such as U.S. EPA's SMOKE, can then be used to obtain gridded, hourly, speciated emissions. Tools are available to help generate these emissions including the U.S. EPA's Spatial Surrogate Tool or Environment Canada's new Spatial Emissions Distribution Information System (SEDIS).

Transportation emissions for Alberta's Capital Region were required as an input to the regional air quality model CMAQ. Comparison of two available data sources was done to select the most accurate emissions to characterize transportation inputs in the region.

2. TRANSPORTATION EMISSIONS SOURCES

Two data sources were available for transportation emissions in the region; standard distribution of Environment Canada province-wide emission totals using a spatial surrogate, and city specific emissions calculated by the City of Edmonton.

2.1 CanVec Road Network and Smoke Surrogate Tool

The U.S. EPA Spatial Surrogate Tool can be used to generate inputs for emission models such as SMOKE. For transportation emissions, a regional total is distributed using a road network shapefile, with road types, lengths, and densities determining the portion of the regional emissions that will be distributed to each modelling grid cell. To accurately generate transportation emissions however an up-to-date road network is required.

CanVec is a digital cartographic reference product produced by Natural Resources Canada (NRCan). It provides quality topographic information in vector format from the best available data sources in Canada and complies with international geomatics standards. Along with topography, shapefiles are available detailing industrial and commercial areas, energy, and transportation among many others.

The recently updated CanVec road network is much more complete than previously available sources used for generating spatial surrogates. A comparison of the road networks in Alberta's Capital Region from 2006 to 2010 is shown in

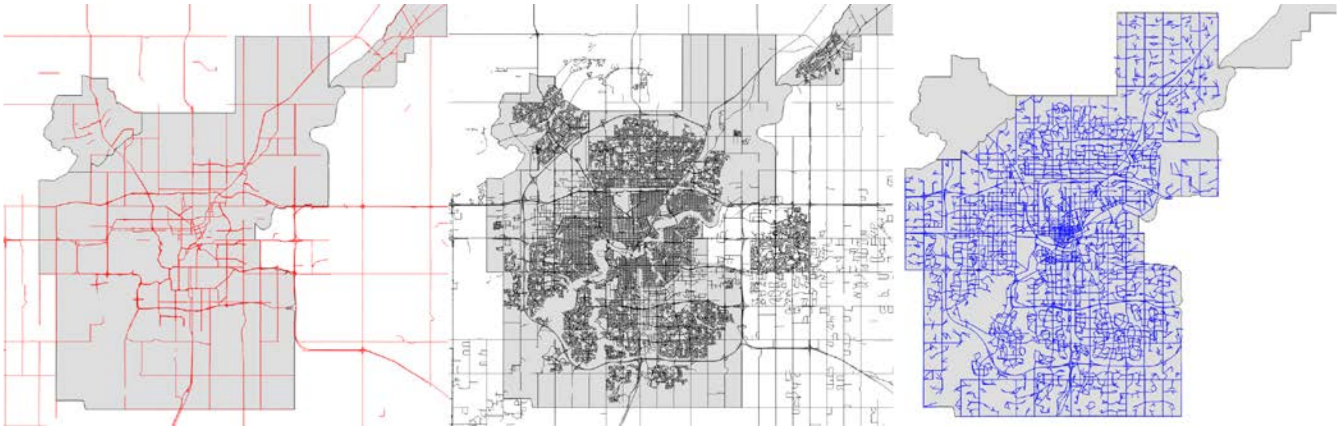

Figure 1: CanVec 2006 road network (left), CanVec 2010 road network (center), and CALMOB6 link based road network (right).

**Corresponding author:* Nick Walters, Novus Environmental, Research Park Centre, 150 Research Lane, Suite 105, Guelph, ON, N1G 4T2; phone: 226.706.8080 ext. 223; e-mail: nickw@novusenv.com

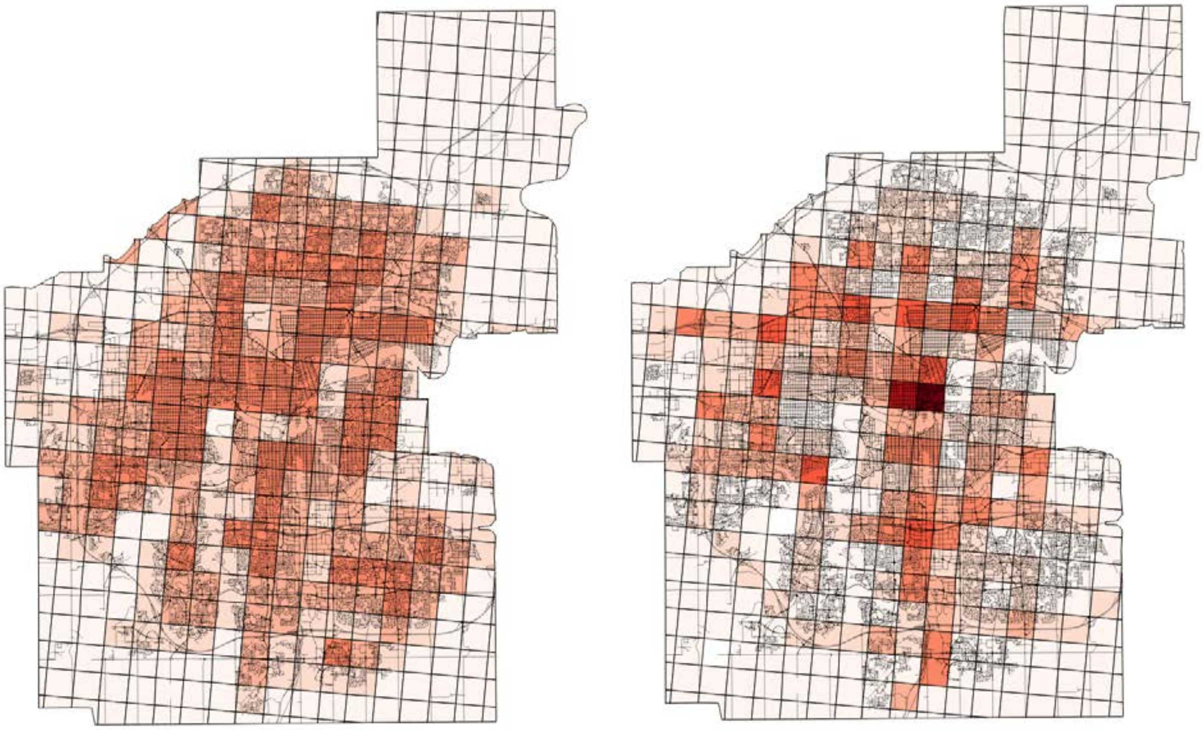

Figure 2: NOx emissions distribution from Canvec with SMOKE surrogate (left) and CALMOB6 emissions model (right)

Figure 1. The CanVec road network update is province wide, ensuring that provincial total emissions are still appropriately distributed for the entire study area.

2.2 City of Edmonton CALMOB6

The City of Edmonton uses a fuel economy and emissions model based on the U.S. EPA's MOBILE6 to calculate emissions within the city boundary. The model uses the output of urban travel forecasting models based on city specific traffic counts to provide emissions tailored exclusively for the area.

The output of the CALMOB6 emissions model is a set of link-based emissions that allocates emissions from smaller streets on to larger links. The CALMOB6 road network is also shown in **Figure 1** for comparison to the updated CanVec road network.

Since the model was developed for the City of Edmonton only, emissions from the model are not available outside of the city limits. This means that if CALMOB6 data is selected for use inside Edmonton the remainder of the region/study area would still need to use the CanVec spatial surrogate.

3. MODEL COMPARISON

Emissions provided by CALMOB6 are calibrated to traffic data from the City of Edmonton and provide improved accuracy when compared to emissions from the Spatial Surrogate Tool. A comparison of emissions within the city limits was done to establish possible differences between the methods and facilitate selection of a transportation emission model for use in SMOKE. Emissions during a typical January weekday are provided for both models in **Table 1** as a worst-case scenario for the city.

Table 1: Typical weekday total emissions

Model	NO_x [t/d]	$PM_{2.5}$ [t/d]	SO_2 [t/d]	CO [t/d]
Canvec	11.34	0.35	0.25	140.16
CALMOB6	7.63	0.16	0.06	148.69

As shown, the CALMOB6 model generally results in lower total emissions for the City of Edmonton when compared to the spatial surrogate. However, the spatial distribution of these emissions differs, as the spatial surrogate is distributing emission based solely on road type and density, not on actual traffic counts. Emissions by grid cell, based on a 1.33 km modelling grid, were plotted against the road network to investigate the spatial distribution of each method. A comparison of the results is provided in **Figure 2** for daily NO_x emissions for January in the city.

While the CALMOB6 emission totals are lower, they are very well distributed throughout the city, with emission hot spots along major truck routes, highways, and through the downtown core. The spatial surrogate on the other hand shows some of the larger emission hot spots in residential areas throughout the city. This can be attributed to a higher road density in these areas skewing the distribution of the province-wide emissions.

By incorporating actual traffic data into the model, CALMOB6 is able to characterize transportation emissions in the city with better spatial accuracy than the SMOKE spatial surrogate. For regional air quality CMAQ modelling, the CALMOB6 emissions were selected for the city.

4. INTEGRATING CALMOB6 EMISSIONS

While CALMOB6 emissions were selected for the City of Edmonton, the Spatial Surrogate was still required to be used for the remainder of the province/study area. Integrating these two transportation emission sources presented a unique challenge. Poor transitions between sources could result in boundary effects in the model with unexpected impacts along the city edges.

4.1 Grid Matching

The SMOKE grid imposed on the study area did not match the City of Edmonton boundary, resulting in grid cells that were only partially covered by the CALMOB6 links. Analysis of the road network along the city boundary determined if the CALMOB6 links were sufficient to cover the grid cell, or if the cell would need to be handled completely by the spatial surrogate. No grid cells were split between both source methods. A section of the city boundary is shown in **Figure 3** where CALMOB6 links were discarded in favour of emissions from the provincial spatial surrogate exclusively.

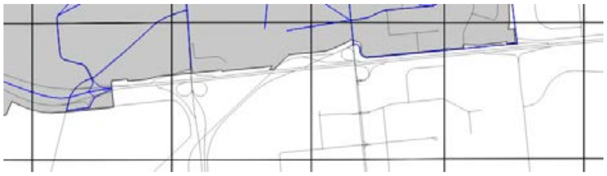

Figure 3: Discarded CALMOB6 emission links along the Yellowhead Highway

4.2 Temporal Profiles

While it was shown that the CALMOB6 data provides a better spatial distribution than the Spatial Surrogate, the temporal distribution is very coarse, focusing on typical rush hour periods and daily totals. To eliminate edge effects when blending emission profiles a better temporal distribution needed to be developed for use with the CALMOB6 emission totals.

4.2.1 Diurnal Patterns

Temporal profiles for emissions within the City of Edmonton were developed as two separate classes: heavy and light vehicles. The CALMOB6 model uses 21 vehicles classes which were divided into these 2 categories based on vehicle type and relative spatial distribution of each class.

Traffic counts provided by the city were used to generate a representative profile for light-duty vehicles during both weekday and weekend periods. Plots of the resulting light duty vehicle diurnal profiles are included in **Figure 4** for both weekdays and weekends.

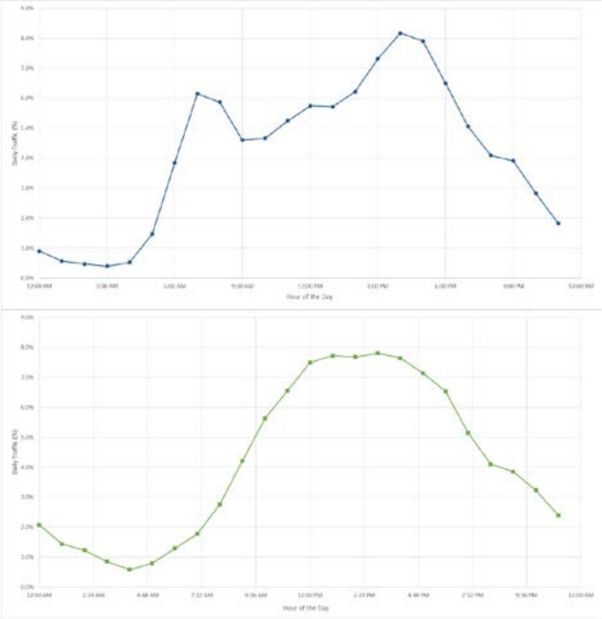

Figure 4: Weekday (top) and weekend (bottom) diurnal traffic profiles.

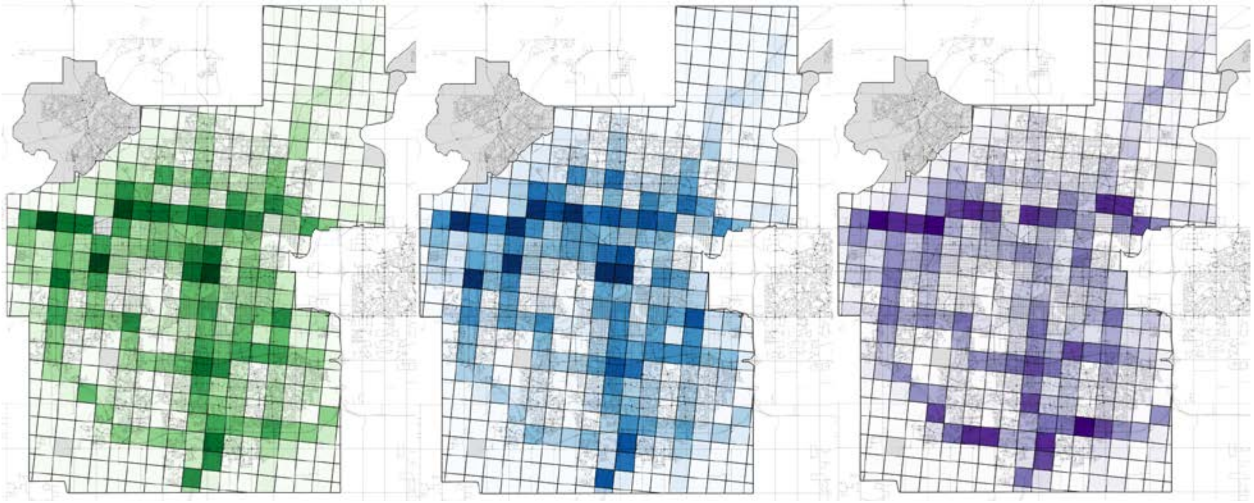

Figure 5: HDV emissions distribution for NOx (green), PM2.5 (blue), and SO2 (purple)

Traffic counts provided inside the city were not representative of heavy-duty traffic and a separate profile was required. Using results from The City of Edmonton's External Truck/Commodity Survey conducted previously a heavy-duty traffic profile was generated. Without weekend data included in the survey it was assumed that the weekend pattern would not change in terms of hourly profile, only total daily traffic volumes as discussed in section 4.2.2.

4.2.2 Weekly Patterns

Weekly traffic patterns for light-duty vehicles were extracted from the traffic counts provided by the city. It should be noted that some counts were for areas adjacent to a major shopping centre and showed increased traffic during weekend periods. Since this was not representative of the entire city these counts were removed from the overall profile before generating the weekly pattern.

Heavy duty traffic variations were not available as a weekly pattern from any of the data sources available so the U.S. EPA standard heavy duty weekly traffic distribution was applied. The weekly profiles used for both light and heavy duty traffic are summarized in **Table 2**.

Table 2: Weekly traffic profiles summary

Day of the Week	% of Average Weekday Traffic	
	Light Duty Profile	**Heavy Duty Profile**
Weekday	100%	100%
Saturday	89.4%	93.8%
Sunday	72.8%	31.3%

5. GENERATED SPATIAL SURROGATES

Once the emission totals were calculated and the temporal profiles developed for all scenarios, new spatial surrogates needed to be produced to integrate the emissions with SMOKE. This needed to be done for each of the vehicle classes to properly distribute emissions by standard classification code (SCC).

Each grid cell was assigned a percentage of the total emissions from each pollutant by vehicle class. While there are slight variations from pollutant to pollutant in terms of emission distribution, it was found that the overall profile for heavy and light duty vehicles remained fairly consistent. As shown in **Figure 5**, the distribution of heavy duty emissions is approximately equal across pollutants.

To generate the final surrogates the emission distribution for NO_x, $PM_{2.5}$, and SO_2 were averaged together. **Figure 6** shows the final spatial surrogates for light-duty vehicles along with the heavy-duty vehicle surrogate. These surrogates effectively communicate the patterns produced by the CALMOB6 emissions, with heavy-duty contributions coming largely from the highways and the downtown core, while light duty emissions are well distributed, especially in residential areas.

6. CONCLUSIONS

Estimating transportation emissions using region specific data provides a more accurate estimation of the spatial distribution of emissions. By developing temporal profiles based on city

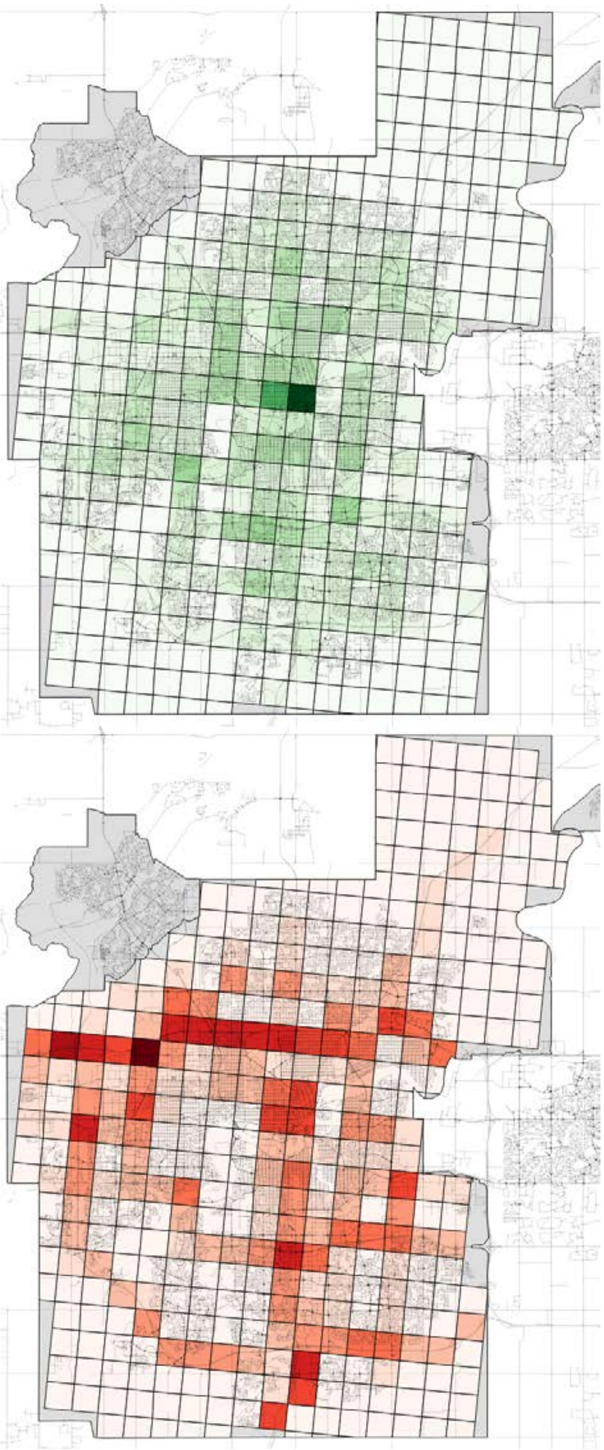

Figure 6: Light-duty (top) and heavy-duty (bottom) spatial surrogates

specific traffic counts, emissions can be well characterized for input to regional air quality models.

Updated spatial surrogates can be developed using this information and integrated into SMOKE modelling. Further testing to compare the final impact of the two models is required to evaluate the relative impact to regional air quality from each of the models.