Abstract

In the province of Québec, where Montréal is located, NO_x emissions from on-road sources account for more than 50% of the total anthropogenic emissions. NO_x is a major SMOG precursor. Consequently, in order to improve air quality modeling at local scale, a "bottom-up" approach was developed to refine the mobile emissions estimates of the Greater Montréal area. Emission rates were produced and applied to activity data. An emission model (MOBILE6.2C) was used to generate emission rates while a Travel Demand Model (EMME/2) was used to produce vehicle flow on the Greater Montréal road network. Both models were linked by means of a user friendly interface called GRID. Vehicle fleet, fuel and climatic characteristics were taken into account. The whole procedure provided air quality modelers, for a 2001 early August week long smog event, with hourly mobile emissions distributed on a fine grid (HC, CO, NO_x, CO_2, SO_2, NH_3, $PM_{2.5}$ and PM_{10} emissions on 1 km^2 cells). This "bottom-up" approach led to a redistribution of mobile emissions (decrease in the suburbs, increase on the Montréal Island) and to a global variation of NO_x (-35%), $PM_{2.5}$ (-55%) and CO (+15%) estimations in comparison with the 2000 Criteria Air Contaminants "top-down" estimates. As a result, greater correspondence between air quality modeling outputs (AURAMS) and monitored O_3 and $PM_{2.5}$ levels was obtained near or downwind of Montréal for a studied smog episode. The bias dropped from 3.1 to 1.7 ppb for the prediction of the daily maximum ozone concentrations, while the correlation coefficient rose from 0.24 to 0.36.

Improving the Mobile Emissions Inventory for Air Quality Modeling in the Montréal Area, Canada.

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Objective

To produce fine scale estimates of on-road emissions in major urban areas of Canada for air quality modeling applications such as:

- Improving day to day air quality forecasts
- Estimating benefits of emissions control scenarios
- Providing tools for the planning of road infrastructures
- Contributing to estimate population exposure to air pollutants caused by urban traffic
- Allowing the use of the models at higher spatial resolution

Partners

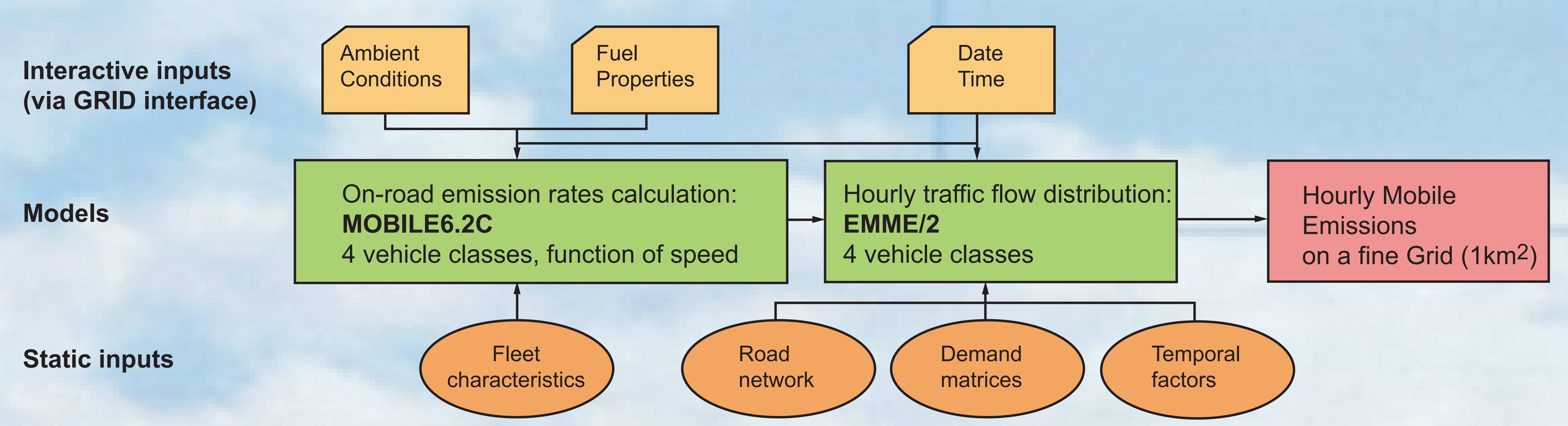
The Centre for Research on Transportation (University of Montréal) carried out this project and built the processing system.

All data related to the road network and origin destination matrices, as well as the traffic management system, were provided by **Transports Quebec.**

Methodology

Generating bottom-up estimates for on-road emissions

The GRID procedure is a bottom-up approach. The first part of this procedure aims at obtaining emission rates. It creates input files for the MOBILE6.2C software (the Canadian version of MOBILE6.2), extracts the emission rates from the output files from that software and integrates those rates in the EMME/2-format functions. The goal of the second part is to produce traffic flow on the network and to estimate pollution on a fine grid. It determines the number and speed of vehicles on the road network, links the emission rates to those numbers and quantifies existing pollution in the cells of a fine grid. This part uses the EMME/2 software.



Ambient Conditions | Fuel Properties | Date Time

Interactive inputs are set and both emission rates and traffic flow models are launched through GRID's interface

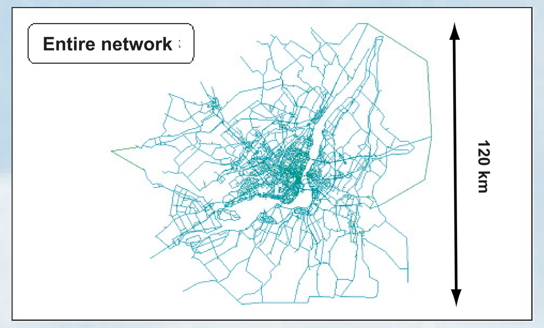
MOBILE6.2C

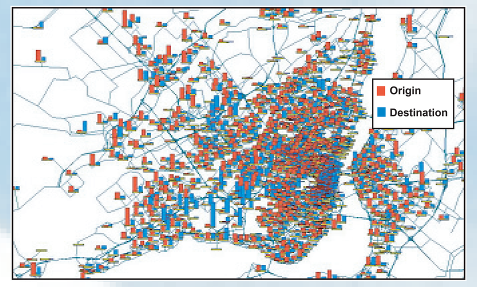
Emissions are calculated according to vehicle class (LDV, LDT, HDT, Buses), age, speed, VKT and emission processes

Sources	Pollutant	Process
Parked vehicles (on centroids)	VOC	Start
		Hot soak
		Resting
		Diurnal
	CO, NO_x	Start
Vehicles in movement (on links)	VOC	Running
		Run loss
		Crankcase
	CO, NO_x, CO_2, SO_2, NH_3, SO_4	Running
	$PM_{2.5}$	Running, break & tire wear

Road network

The road network is divided in highways and arterials



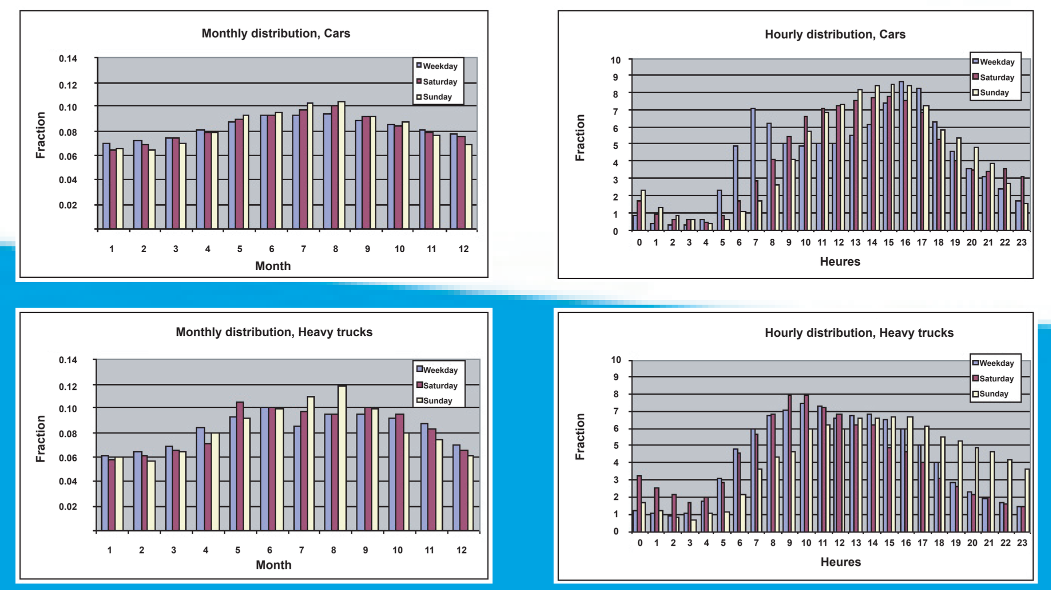


Demand matrices

Detailed origin-destination matrices were obtained for a typical Fall weekday (1998). This day counts five matrices for each of the following vehicle class LDV, LDT and HDT

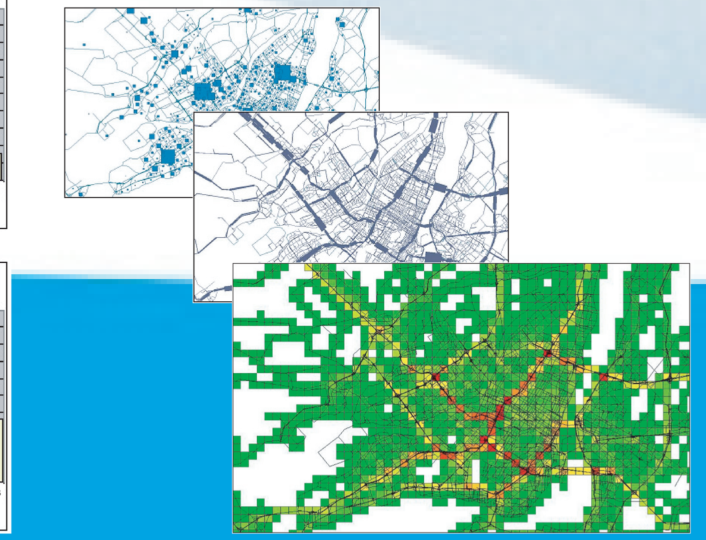
Temporal factors

Temporal factors, based on traffic count data (2000-2003), are used to extrapolate the Fall matrices to produce hourly matrices for the rest of the year



Hourly Mobile Emissions on a fine Grid (1km²)

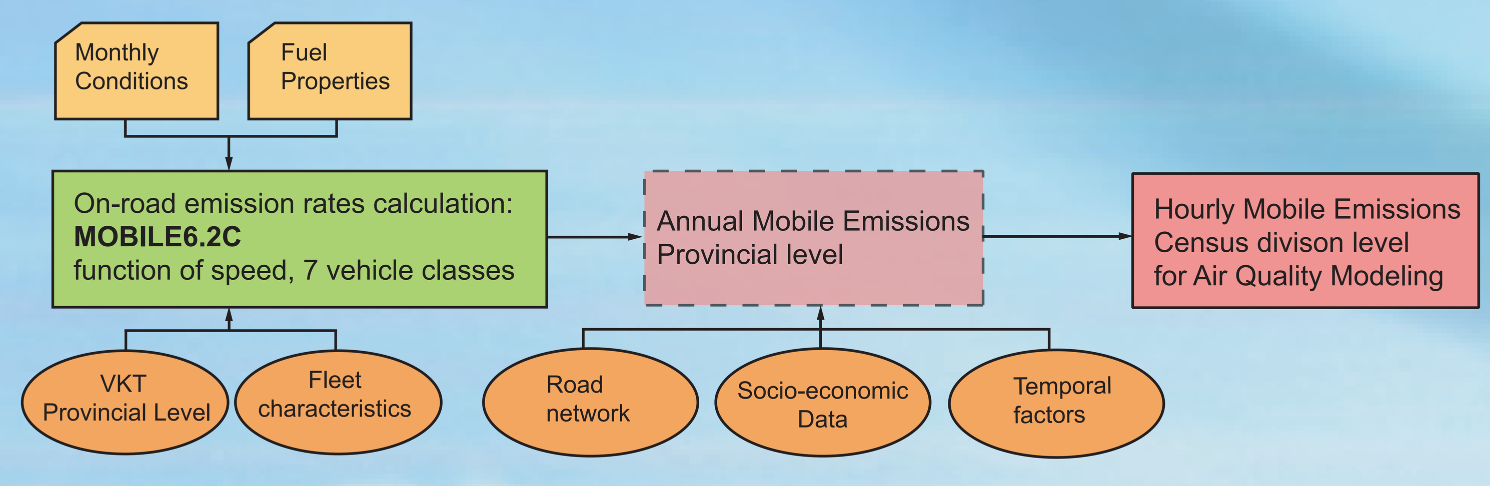
Finally, emissions on centroids and links are summed on a fine grid on an hourly basis



GRID vs Criteria Air Contaminants Inventory

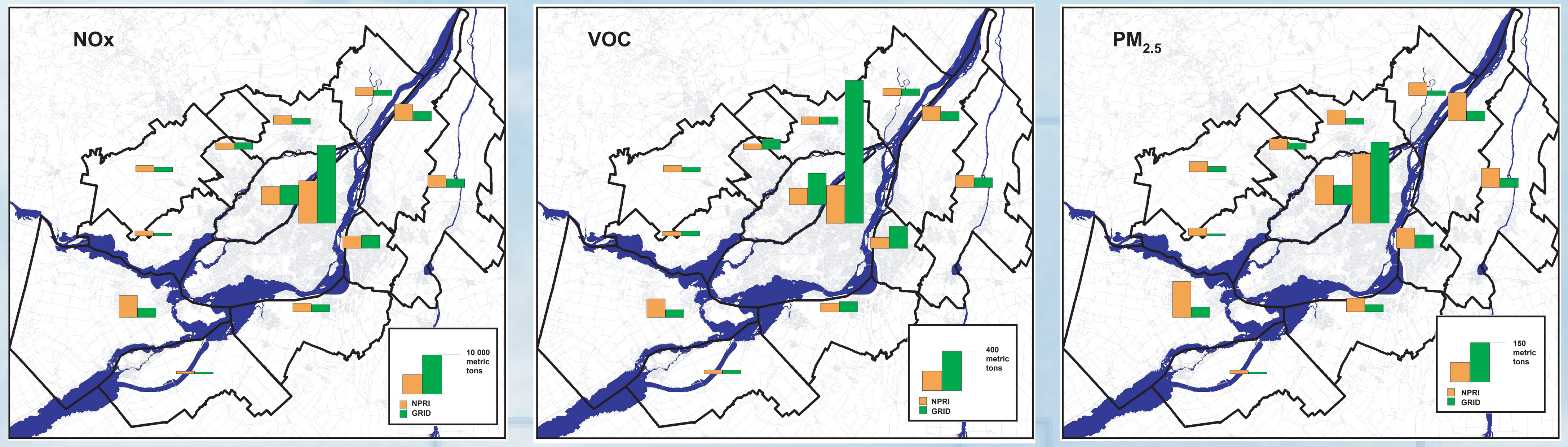
Building and modifying the on-road emissions Criteria Air Contaminants Inventory

The Criteria Air Contaminants Inventory (CAC) approach processes Porvincial/Territorial data through MOBILE6.2C to generate mobile emissions on a monthly basis, then it sums them to get annual provincal/territorial level estimates. For the purpose of Air Quality Modeling, these provincial estimates need to be broken down spatially and temporally. Spatial distribution was performed using geographic (road network) and socio-economic indicators in a GIS. Temporal allocation was here produced using factors produced by the US-EPA for the Sparce Matrix Operator Kernel Emissions (SMOKE) modeling system. SMOKE is an emissions processing tool developped by the Community Modeling and Analysis System (CMAS) At the University of North Carolina.



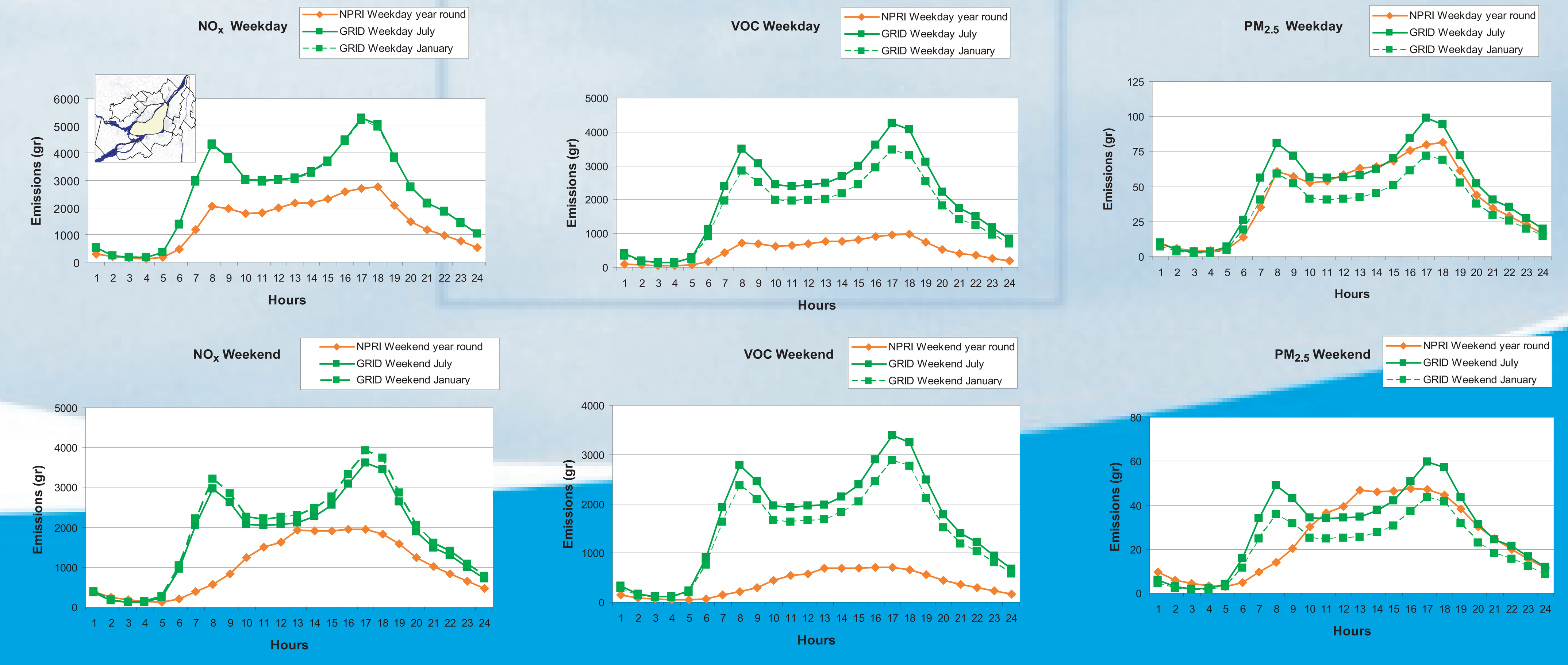
GRID *vs* CAC Annual Emissions

For comparison purpose with CAC, GRID's 1 km^2 cells were aggregated into census division. For year 2000, annual emissions of NO_x, VOC and $PM_{2.5}$ were always higher on the Montréal Island (high population density) according to the GRID approach. On the other hand, in lower density areas (suburbs), they tend to be equal or smaller than CAC's in general.



GRID *vs* CAC-SMOKE Hourly Emissions

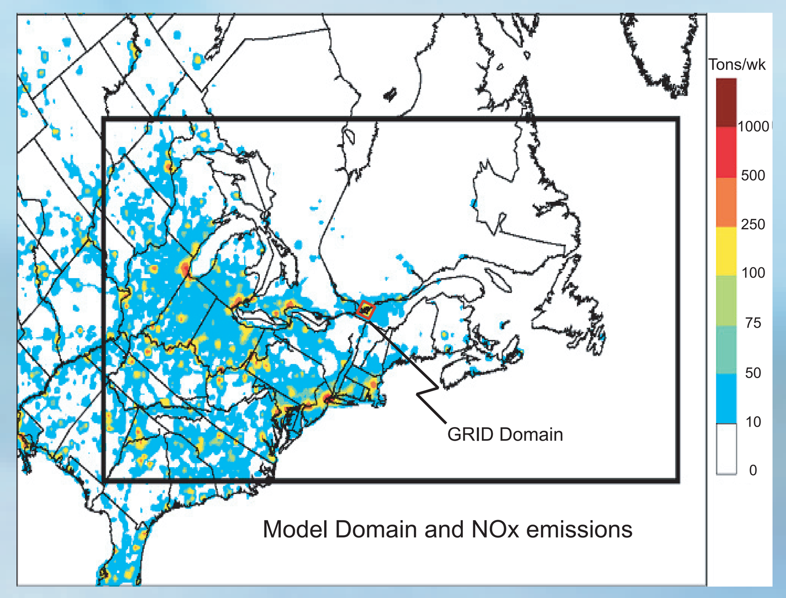
In the figures below, SMOKE's temporal factors were used to fraction CAC's annual totals of 2000 for the Montréal Island into hourly distributed emissions. GRID's bottom-up approach allows capturing seasonal variation due to traffic and climatic variations, which is not the case with the top-down approach that was applied for the CAC inventory. However, as it can be observed on weekend figures, GRID's and CAC's general distribution shapes differ. Due to a lack of information, GRID's hourly distribution for weekends is a weighting for weekdays distributions.



Air Quality Modeling

Bottom-up vs Top-down smog precursors

Southern Québec experienced a regional smog episode during the July 30th - August 5th time period in 2001. The 8-hour running average of ozone concentrations exceeded the Canada-wide Standard threshold at several monitoring locations. To verify if GRID's bottom-up approach was improving air quality modeling, the Canadian AURAMS model was integrated twice on a domain covering Northeastern North America (see figure below). The first run used CAC-SMOKE-generated on-road mobile emissions, while the second run used GRID's emissions. Differences in smog precursors emissions rates over the Montréal area were shown in the previous section. The GRID procedure produces about 15% more CO, but 35% less NO_x and 55% less $PM_{2.5}$ over GRID entire domain.

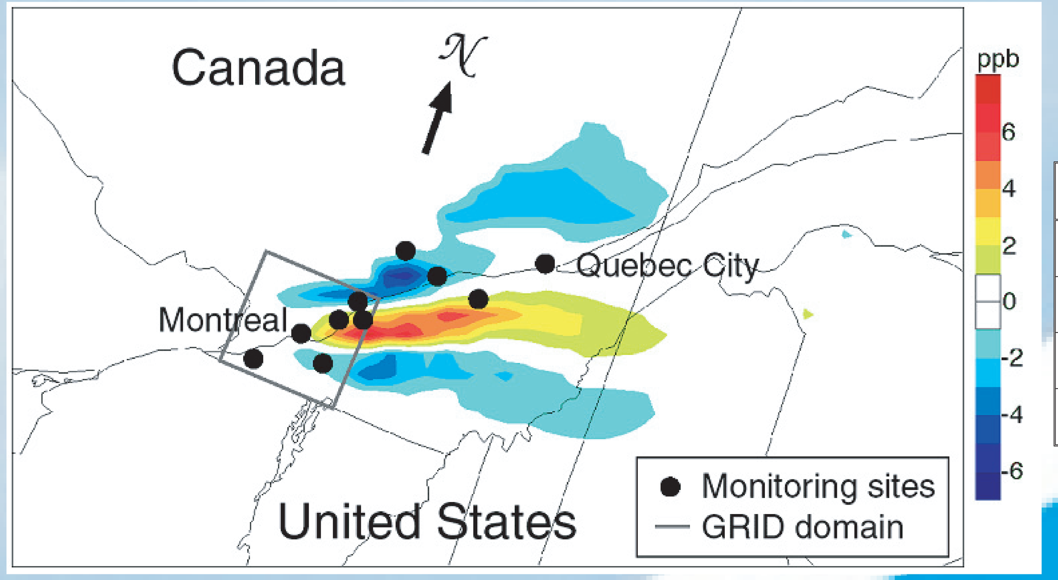


Model Domain and NOx emissions

Air Quality Modeling improvements

The daily maximum ozone concentrations predicted by the AURAMS model for August 2nd 2001 from the two scenarios differ as would be expected (see left figure below). The 3 to 5 ppb increase in ozone concentrations downwind of Montréal in a narrow plume is due to the fact that GRID's emissions are better distributed spatially with a more pronounced and sharper peak over Montréal itself and that GRID reduces NOx emissions in the suburbs. This leads to a decrease in ozone on each sides of the central plume. On the other hand, there is no noticeable difference in $PM_{2.5}$ concentrations (not shown) between the two scenarios.

Common statistics were applied to compare the air quality modeled results with observed data from 10 monitoring stations in Southern Québec (see table on the right below). This showed that the use of GRID to compute on-road emissions has positive benefits for ozone prediction near important urban cities and downwind. It reduced the bias and gave better correlation, the root mean square error was reduced and the variability of the model is closer to the observations.



Statistical parameters	GRID	CAC-SMOKE
Bias (ppb)	-1.68	-3.09
Correlation coefficient	0.36	0.24
Normalized standard deviation	0.66	0.58
Centered root mean square error (ppb)	18.9	19.8

Conclusion

A bottom-up on-road mobile emission dataset (GRID) was produced to replace the top-down data (CAC) normally used for Air Quality Modeling. A Travel Demand Model (EMME/2) was used to generate hourly traffic flows and was coupled with an emission model MOBILE6.2C which produced emission rates. The new dataset was used to simulate (AURAMS) a 2001 smog event. The new data has proven to improve the modeling results. For future development, improvements to GRID's actual settings, such as updating the demand matrices (1998 to 2003), should be completed in the near future. Validations with field data are required to better estimate the accuracy of the GRID inventory. This approach could then be applied to other Canadian major urban centers to enhance Air Quality Modeling.

Acknowledgements

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- Québec Department of the Environment
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- Transports Québec

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