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Improvements to SMOKE Processing of Canadian On-Road Mobile Emissions

***Junhua Zhang¹, Qiong Zheng¹, Michael Moran¹, Mark Gordon¹,
John Liggio¹, Paul Makar¹, Brett Taylor², and Craig Stroud¹***

1. Air Quality Research Division, Environment Canada, Toronto, Ontario, Canada
2. Pollutant Inventories and Reporting Division, Environment Canada, Gatineau, Quebec, Canada

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Highlights of Outcomes

- Improvement to Spatial Distribution of Emissions
- Improvement to Temporal Allocation of Emissions
- Improvement to Canadian On-Road Mobile Emissions Inventory for Road Type
- Improvement to Chemical Speciation of Particulate Matter (PM) Emissions

Goal of This Study:

Better Representation of Canadian On-Road Emissions for Air Quality (AQ) Modelling

Canadian On-Road Emissions Inventory

Temporal:

Monthly Totals

Spatial:

Mostly Provincial Totals

Pollutants:

PM, VOC, NO_x, etc.

Source Category:

By Vehicle Type, e.g., LDGV, LDDV, but not by Road Type

SMOKE

Right Time
Right Location
Right Species
Right Amount

AQ Model Inputs

Temporal (Weekly & Diurnal Profiles):

Hourly

Spatial (Spatial Surrogates):

Each Grid Cell, e.g., 42 km, 15 km, 2.5 km

Chemical Species (Chemical Speciation Profiles):

PM Species:

Sulphate, Nitrate, Ammonium, Elemental Carbon, Organic Matter, Crustal Material

VOC Species:

Propane, Alkenes, Alkanes, Toluene, Isoprene, etc.

NO_x Species:

NO₂, NO

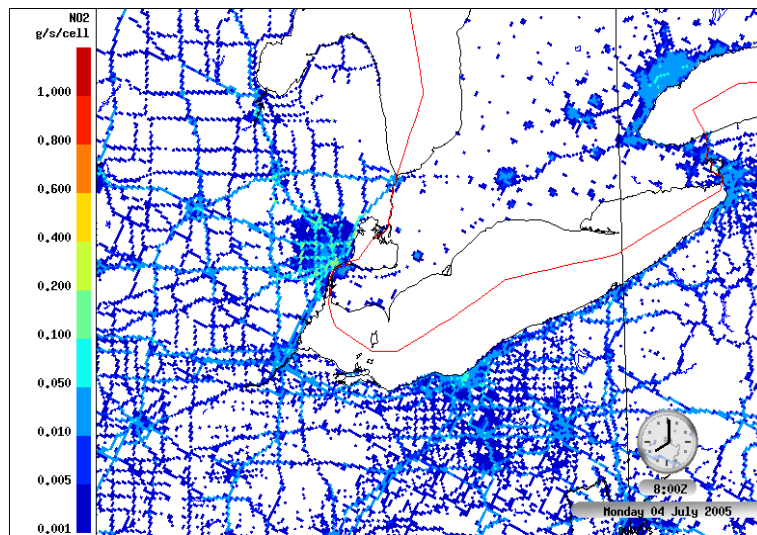


Issues with Canadian On-Road Emissions Processing (1)

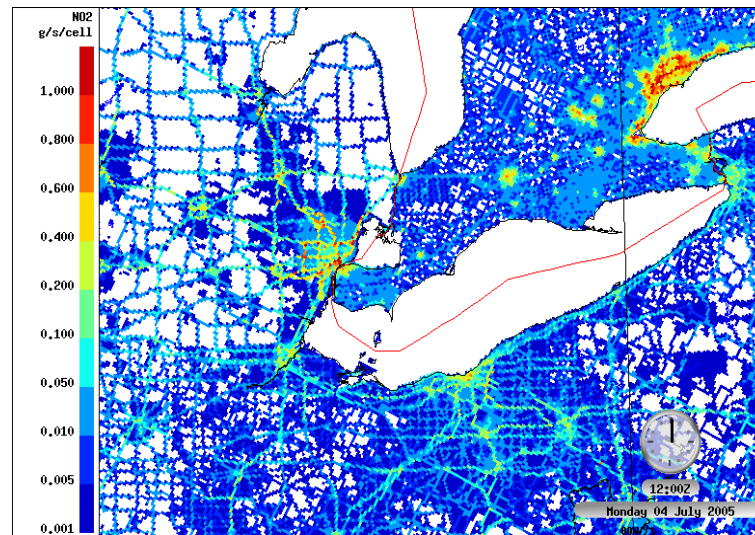
NO2 emissions

Zhang et al., 2010, 19th International Emission Inventory Conference

NO2 Emissions, 4:00 am Local Time (8Z)



NO2 Emissions, 8:00 am Local Time (12Z)



- (1) High-resolution (2.5km) emissions processing for the 2007 BAQS-Met study (Makar et al, ACP 10, 11151-11173, 2010) identified differences between Canadian and US mobile emissions
- (2) Locations of the major highways in the US are obvious, but major Canadian highways cannot be distinguished from smaller roads
- (3) The Canadian on-road emissions appear to be overweighted to city centres (compare Detroit and Toronto) and also to smaller roads
- (4) Canadian emissions are significantly smaller than the U.S. emissions a few hours before dawn, e.g., 4 a.m. local time



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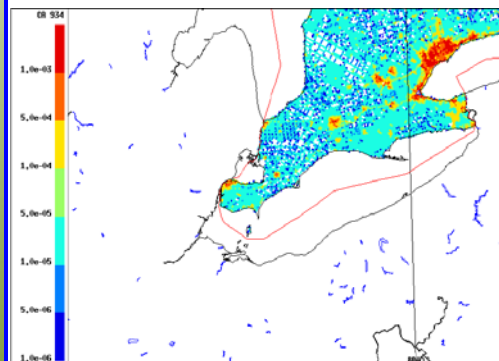
Issues with Canadian On-Road Emissions Processing (2)

Spatial Allocation - Surrogates

Zhang et al., 2010, 19th International Emission Inventory Conference

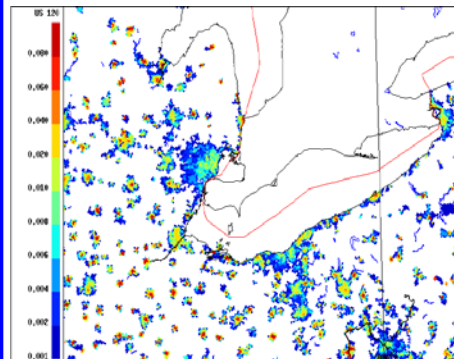
Canadian Surrogate

Pop * Road Length * # of Lanes

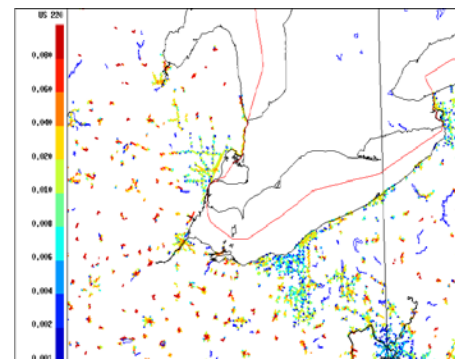


The U.S. EPA Surrogates

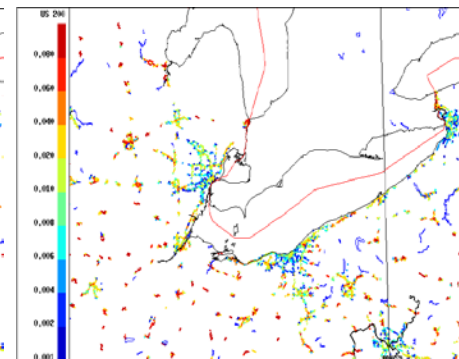
Urban Local Road



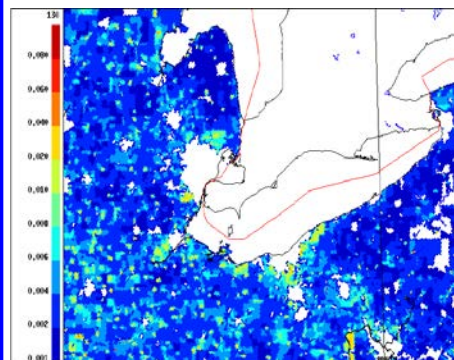
Urban Secondary Road



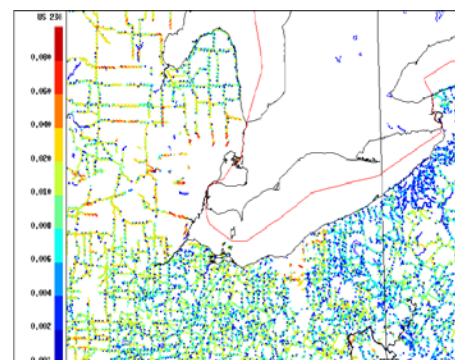
Urban Primary Road



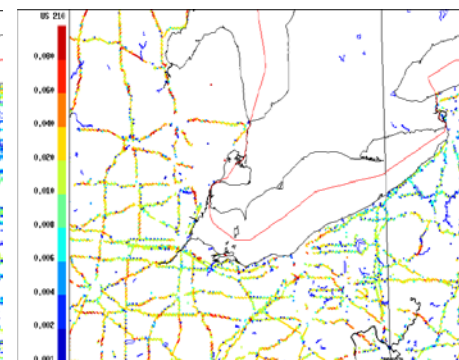
Rural Local Road



Rural Secondary Road



Rural Primary Road

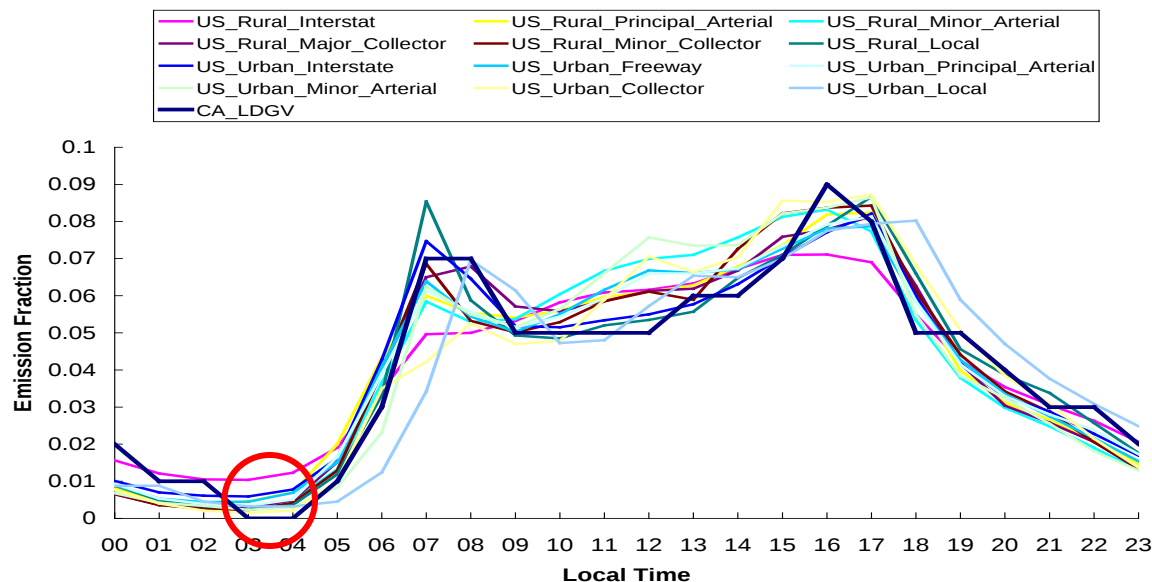


Issues with Canadian On-Road Emissions Processing (3)

Temporal Allocation

Zhang et al., 2010, 19th International Emission Inventory Conference

Weekday Diurnal Profiles for LDGV



- (1) 12 diurnal profiles for the U.S. LDGV vehicle type representing 12 road classes, but only one for Canadian LDGV due to lack of road class information in the inventory
- (2) No emissions at 3 & 4 a.m. from Canadian LDGV, resulting in Canadian emissions that are significantly smaller than the U.S. emissions a few hours before dawn
- (3) Different weekday and weekend profiles for U.S. emissions, but only one profile for both Canadian weekday and weekend emissions.

Issues with Canadian On-Road Emissions Processing (4)

PM Speciation - AQ Model Specific

On-road PM Inventory:

- Exhaust PM from both gasoline and diesel vehicles
- Brake-lining dust from all vehicle types
- Tire dust from all vehicle types

PM Speciation:

Only one PM speciation profile used for all types of on-road PM emissions

Creation of a Unified Canadian Road Network Shapefile (1)

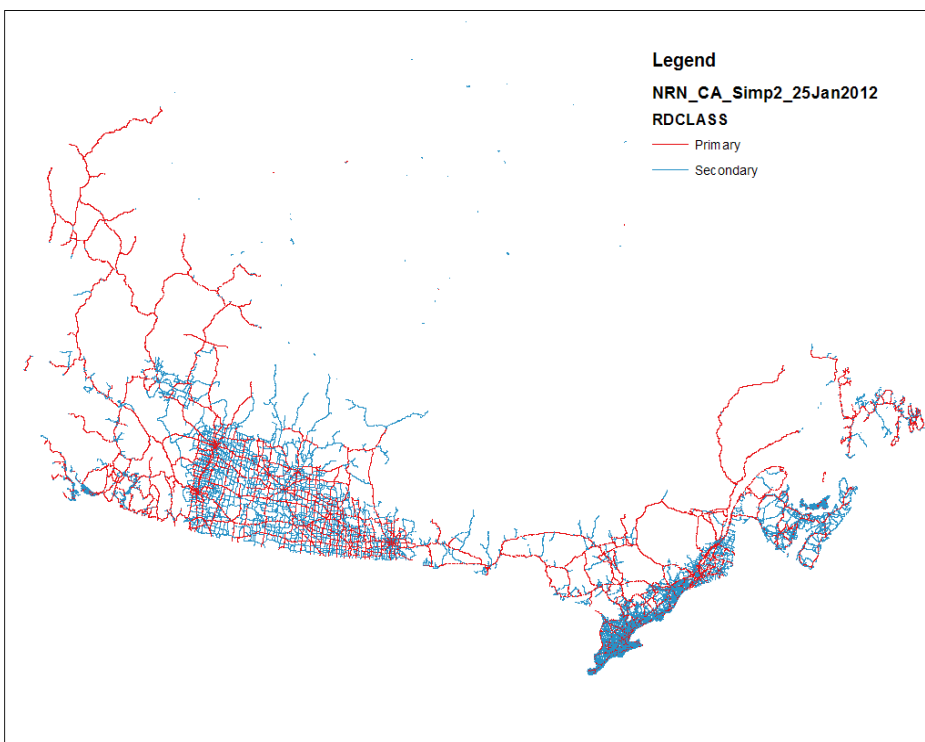
- 13 heterogeneous provincial and territorial road network shapefiles from GeoBase - National Road Network (NRN) with a total of 13 possible road types (<http://www.geobase.ca/geobase/en/data/nrn/index.html>)
- The road types in the individual provincial shapefile vary from province to province
- A single homogeneous national road network shapefile was built with two composite road types: primary highways and secondary highways
- Traffic emissions on local and other minor roads mainly depend on the number of people reside in the surrounding areas and will be represented with rural/urban population density, therefore these roads are excluded

Number of Segments of Five Major Road Types for the 13 Provinces/Territories

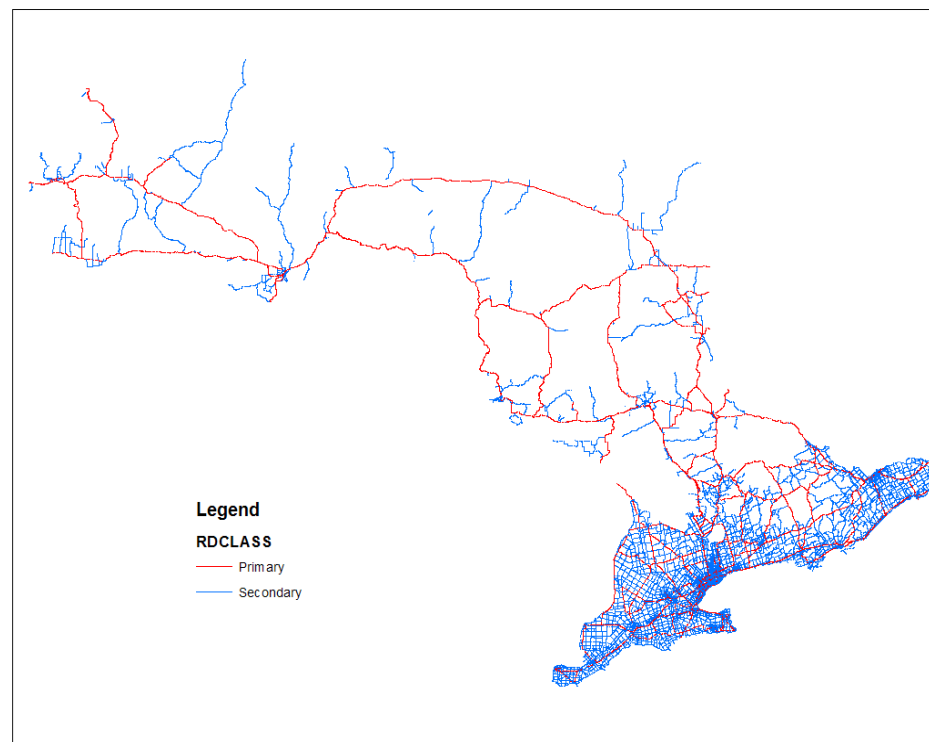
Province	Freeway	Expressway/Highway	Ramp	Arterial	Collector
Alberta	0	6,345	8,260	25,696	160,977
British Columbia	1,535	9,051	3,299	18,684	29,841
Manitoba	57	19,475	1,023	0	42,897
New Brunswick	1,421	10,817	1,458	0	17,124
Newfoundland and Labrador	429	6,533	589	18	12,179
Northwest Territories	0	800	14	184	465
Nova Scotia	875	1,538	1,097	5,423	5,528
Nunavut	0	0	0	0	890
Ontario	6,285	12,840	8,967	84,078	41,631
Prince Edward Island	0	105	134	1,209	4,866
Quebec	7,684	20,815	7,007	13,998	30,953
Saskatchewan	173	18,904	842	7	141,285
Yukon	0	1,083	0	350	170

Creation of a Unified Canadian Road Network Shapefile (2)

Primary and secondary highway networks over Canada



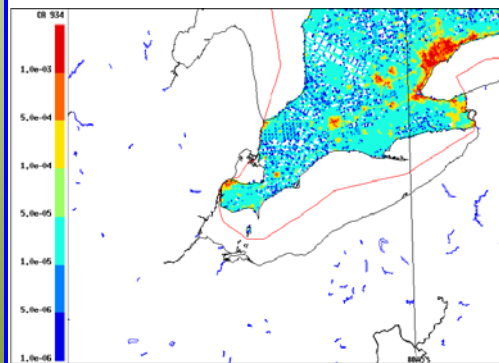
Primary and secondary highway networks over the province of Ontario



Improvement to Spatial Surrogates: e.g., BAQS-Met 2.5km AURAMS domain

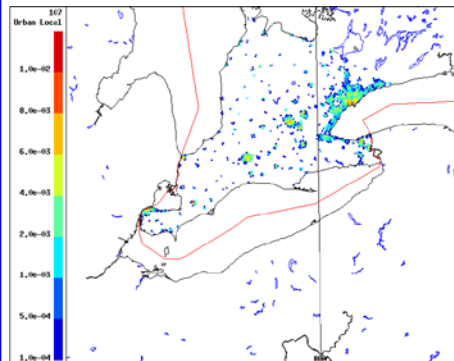
Old Surrogates

Pop * Road Length * # of Lanes

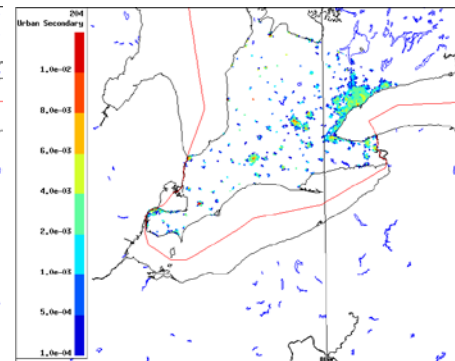


New Surrogates – Based on National Road Network & Population

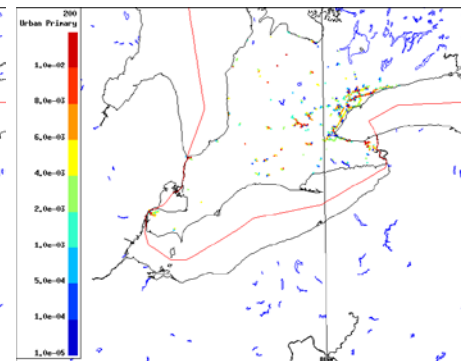
Urban Local Road



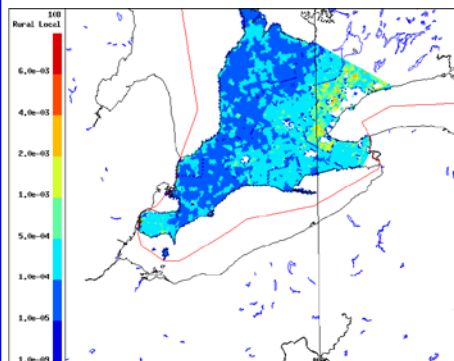
Urban Secondary Road



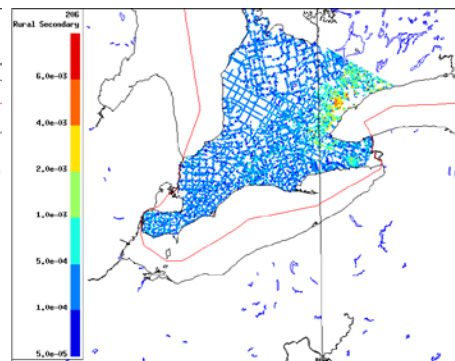
Urban Primary Road



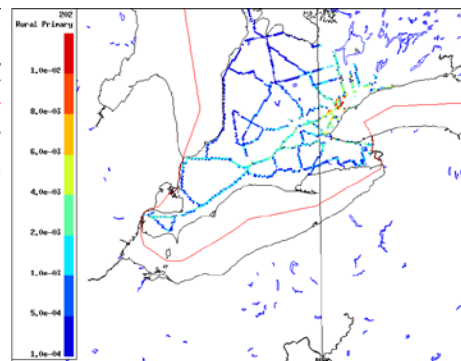
Rural Local Road



Rural Secondary Road



Rural Primary Road

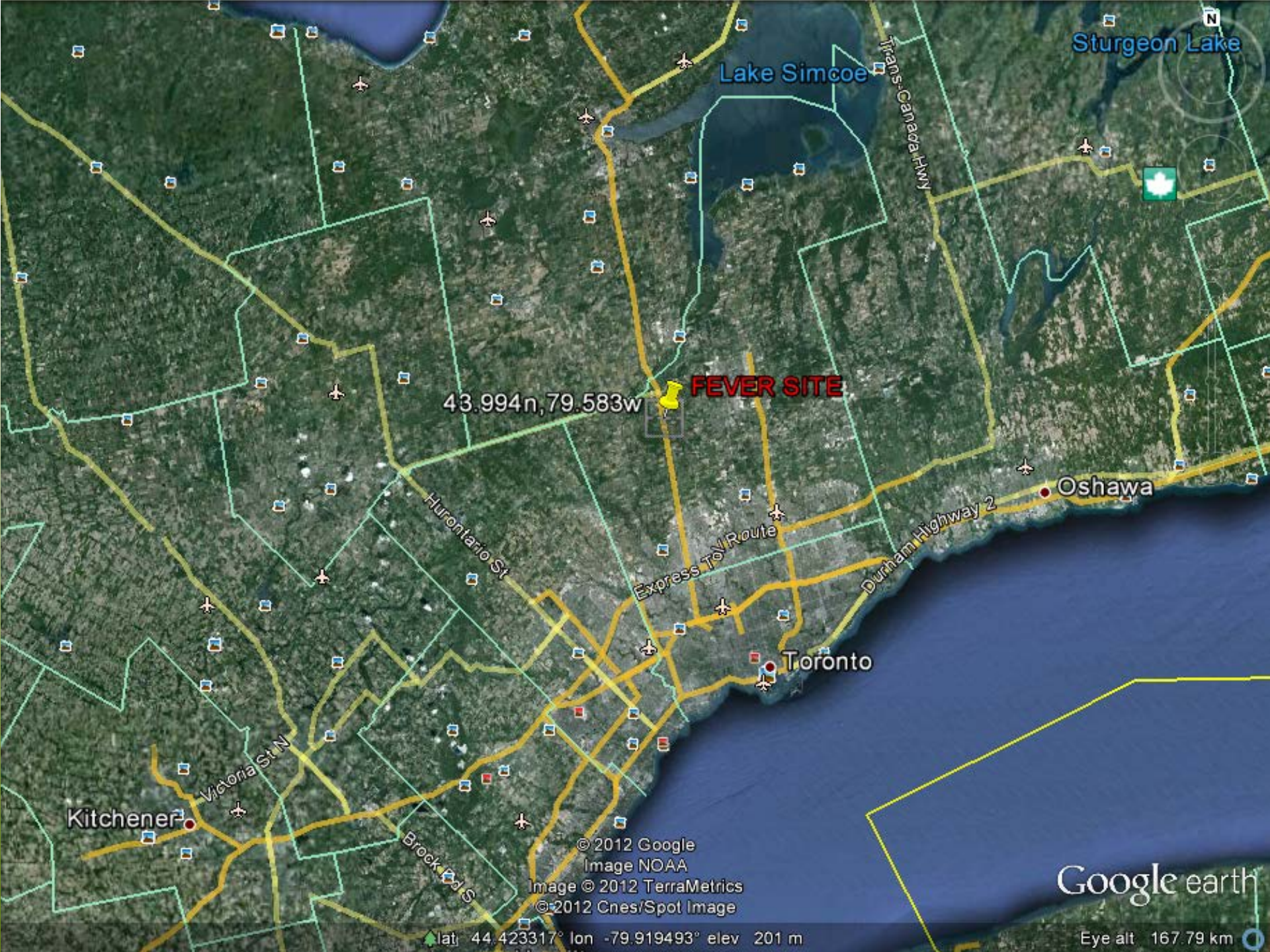


Improvement to Temporal Profiles (1):

Fast Evolution of Vehicle Emissions from Roadways (FEVER) Study

(Liggo et al., 2010, Gordon et al., 2012)

- Conducted Aug. 17 – Sep. 17, 2010 on a multi-lane highway in the Toronto area in Ontario
- **A traffic camera was used to record the traffic. Traffic density, composition and speed were then determined from the video recording**
- Weekly and diurnal profiles were derived for light duty vehicles (LDV) and heavy duty vehicles (HDV)



Sturgeon Lake

Lake Simcoe

Trans-Canada Hwy

43.994n, 79.583w

FEVER SITE

Oshawa

Durham Highway 2

Express To Route

Toronto

Huronario St

Victoria St N

Kitchener

Brook Rd S

© 2012 Google
Image NOAA
Image © 2012 TerraMetrics
© 2012 Cnes/Spot Image

Google earth

lat 44.423317° lon -79.919493° elev 201 m

Eye alt 167.79 km

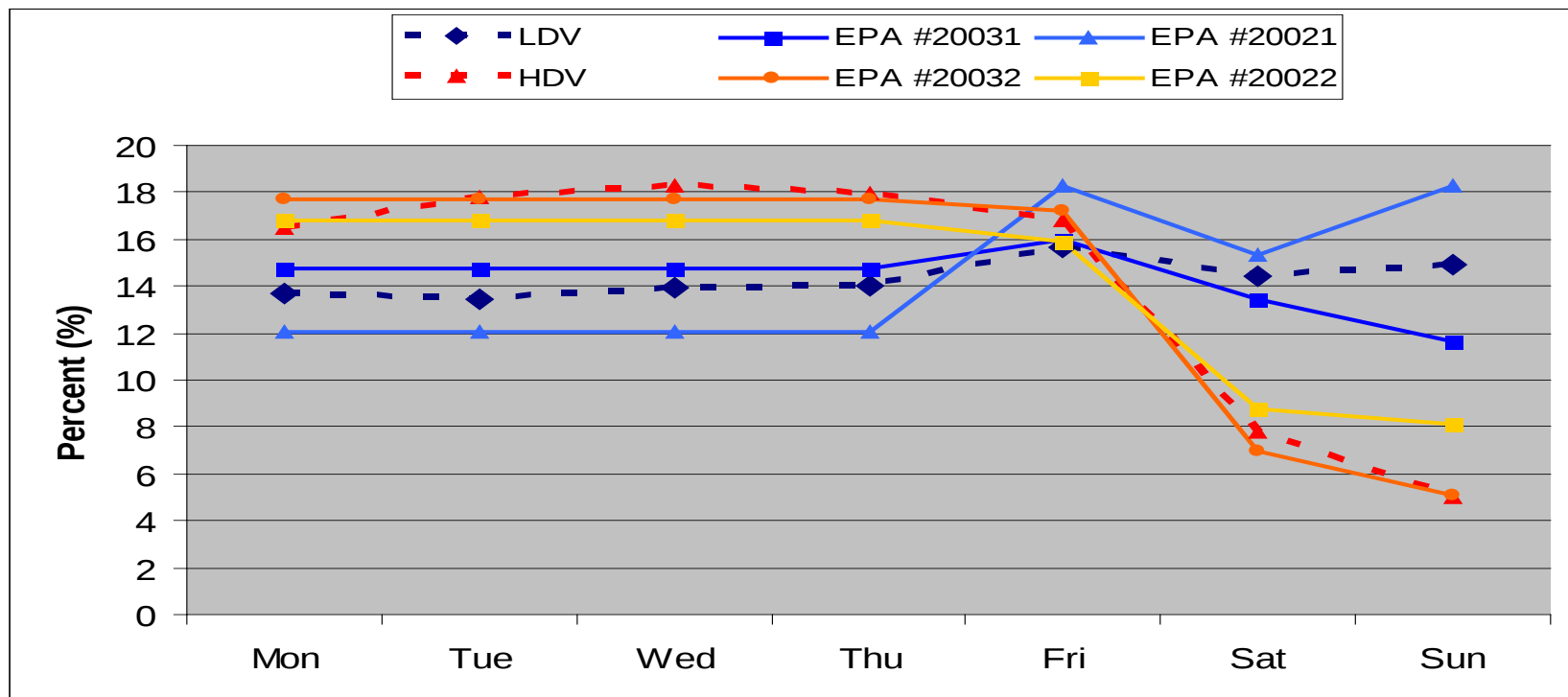
Improvement to Temporal Profiles (1):

Weekly Profiles for On-Road Mobile Emissions

Weekly profiles derived from FEVER traffic count vs. those used by the U.S. EPA:

20031: urban LDV **20021: rural LDV**

20032: urban HDV **20022: rural HDV**

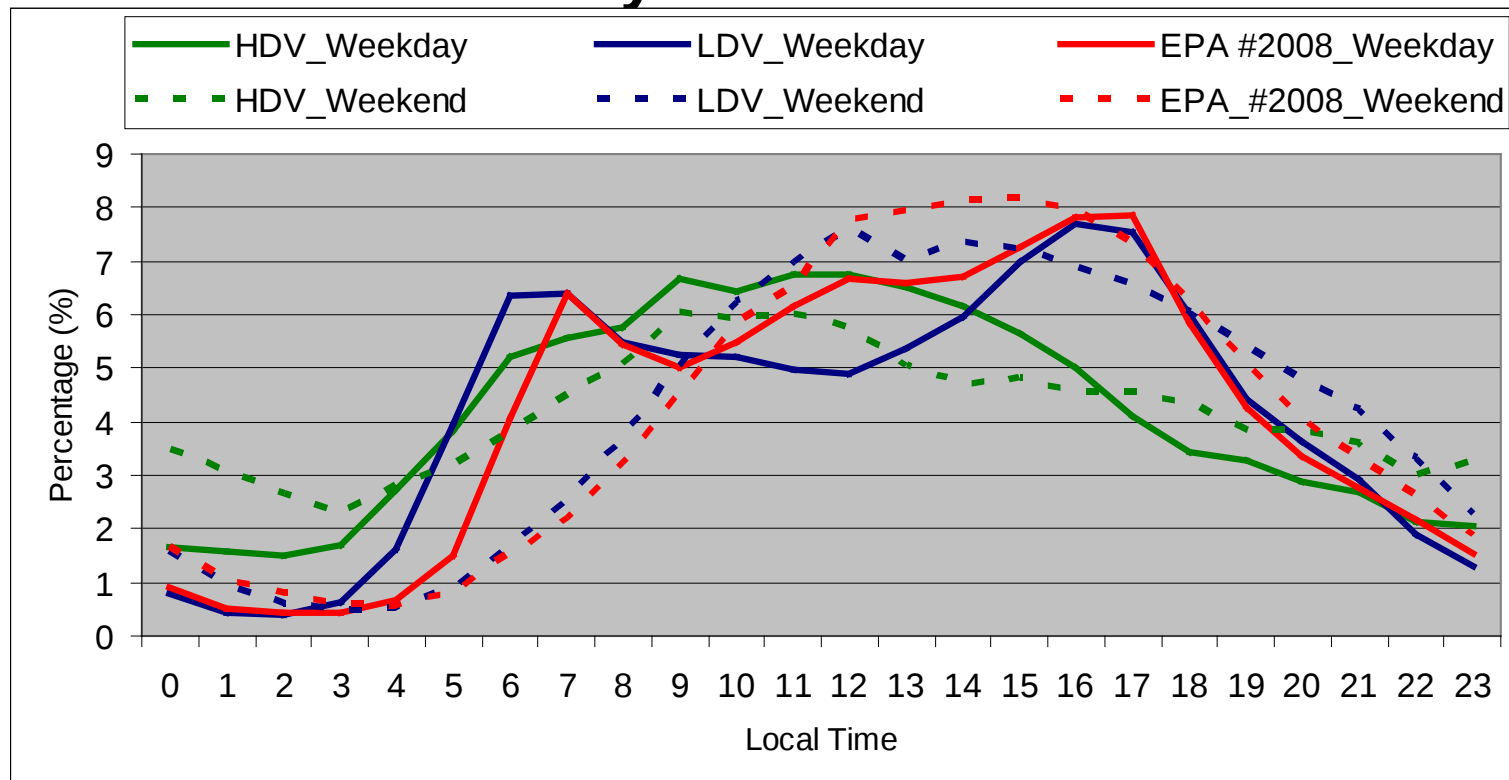


Improvement to Temporal Profiles (2):

Diurnal Profiles for On-Road Mobile Emissions

Diurnal profiles derived from FEVER traffic count vs. those used by the U.S. EPA:

#2008: urban freeway



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Improvement to Temporal Profiles (2):

Diurnal Profiles for On-Road Mobile Emissions

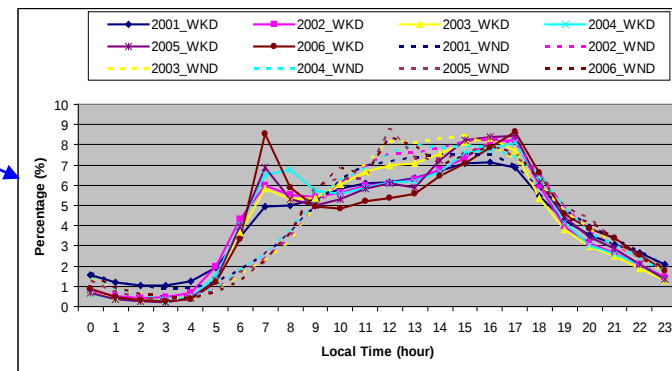
12 profiles for Light Duty Vehicles from EPA for 12 Road Classes

1 derived profile from FEVER for Heavy Duty Vehicles for All Roads

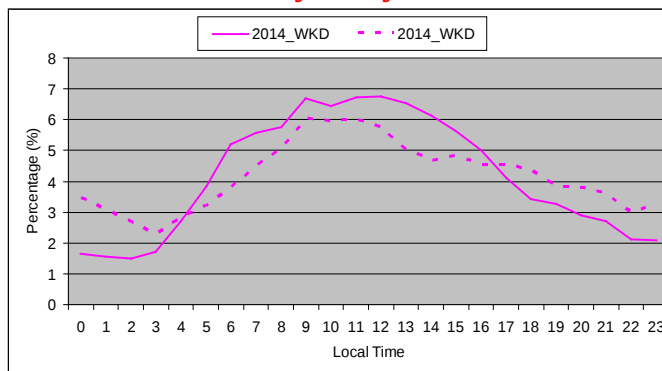
Urban Interstate
Urban Freeway
Urban Principal Arterial
Urban Minor Arterial
Urban Collector
Urban Local

Rural Interstate
Rural Principal Arterial
Rural Minor Arterial
Rural Major Collector
Rural Minor Collector
Rural Local

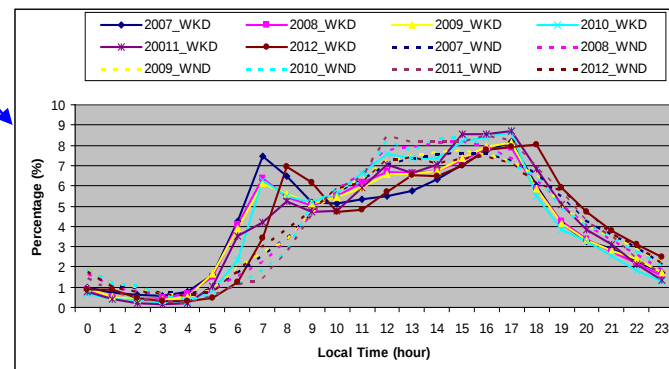
Urban Roads: 6 Road Classes



New Profile for Heavy Duty Vehicles: All Roads



Rural Roads: 6 Road Classes

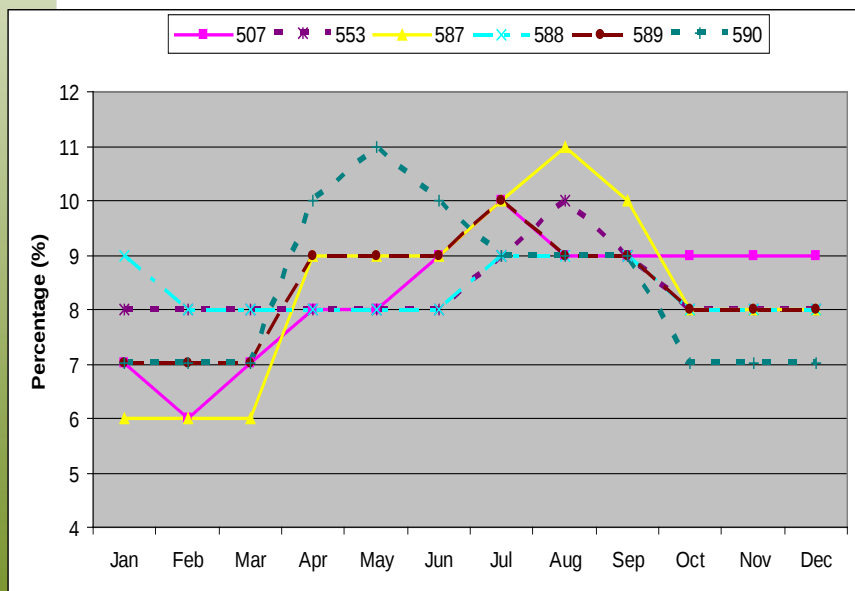


Improvement to Temporal Profiles (3):

Monthly Profiles for Road Dust Emissions Based on Monthly VKT Statistics

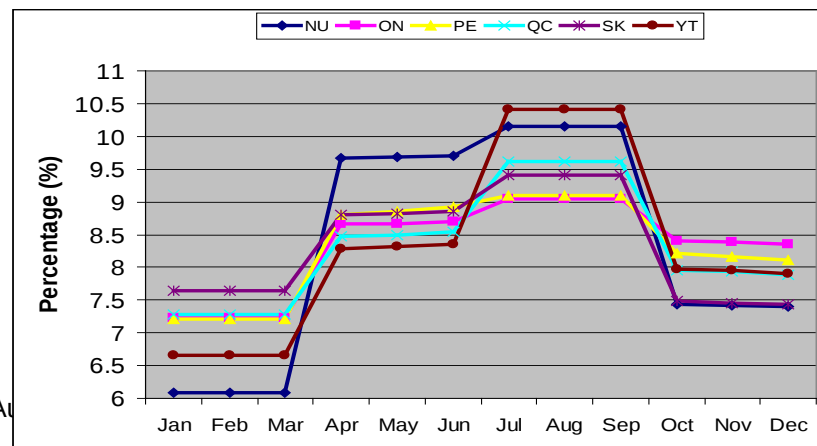
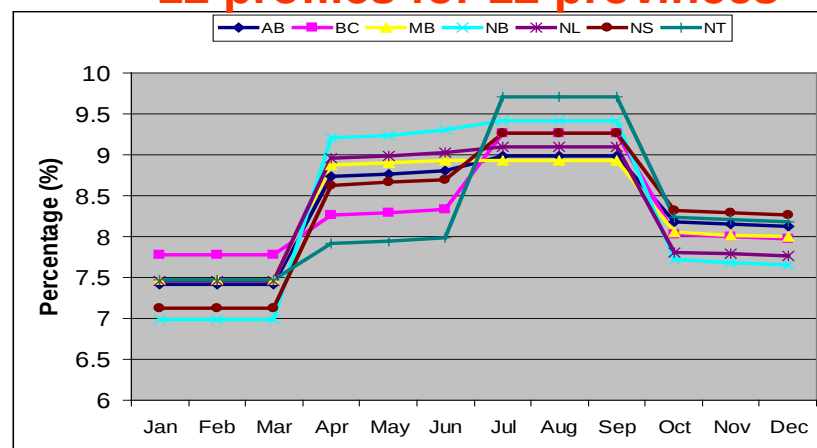
Old Profiles

6 profiles for 12 provinces



New Profiles

12 profiles for 12 provinces



Improvement to Canadian On-road Emissions Inventory

Existing 2006 Canadian national on-road emissions inventory is separated by vehicle type only



Split On-road Emissions between 12 Road Classes

- Vehicle-type-specific species-averaged split factors calculated from the 2005 V4 U.S. on-road inventory
- Split factors vary from province to province
- U.S. states were selected as proxies based on their geographic proximity to each Canadian province as well as the similarity of their topographic and climatic characters and their urban/rural population ratio to specific Canadian provinces:

BC <== WA, AB <== CO, SK <== MN, MB <== MN, ON <== NY

QC <== PA, NB <== ME, NS <== ME, PE <== ME, NF <== ME

YT <== MT, NW <== MT, NU <== VT

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Improvement to PM Chemical Speciation - AQ Model Specific

Originally only one PM chemical speciation profile for all on-road PM emissions



5 PM chemical speciation profiles now used based on the SPECIATE4.3 database:

92050, exhaust PM from all gasoline vehicles (GV)

92042, exhaust PM from all light duty-diesel vehicles (LDDV)

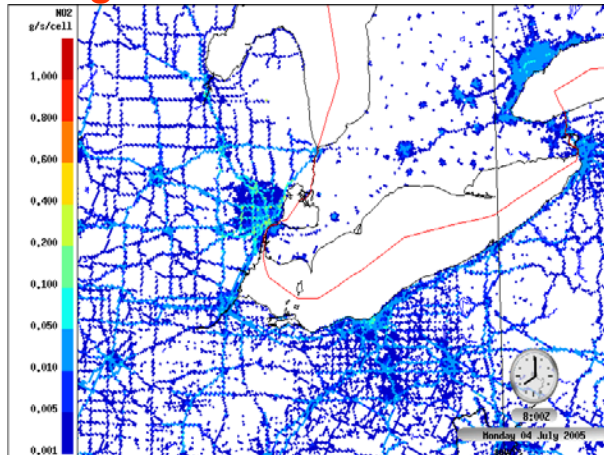
92035, exhaust PM from heavy-duty diesel vehicles (HDDV)

92009, brake-lining dust from all vehicle types

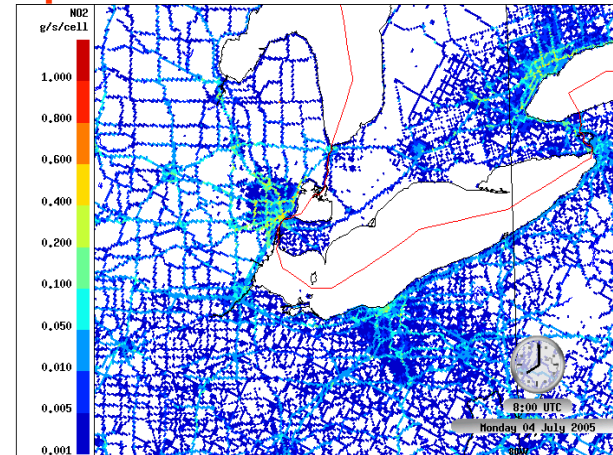
92087, tire dust from all vehicle types

NO₂ On-Road Emissions Processed for BAQS-Met 2.5km AURAMS Domain

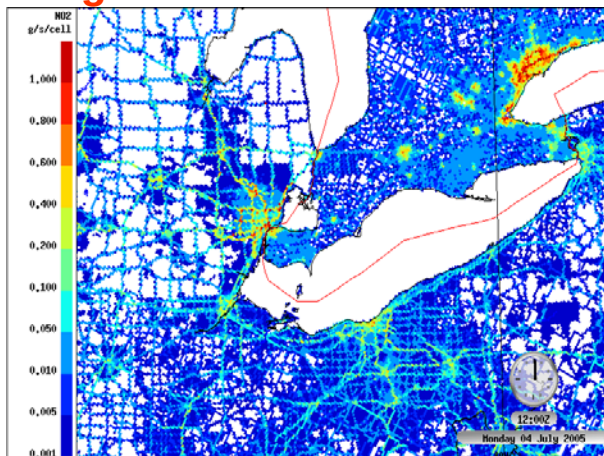
Original NO₂ at 4:00 a.m. LT



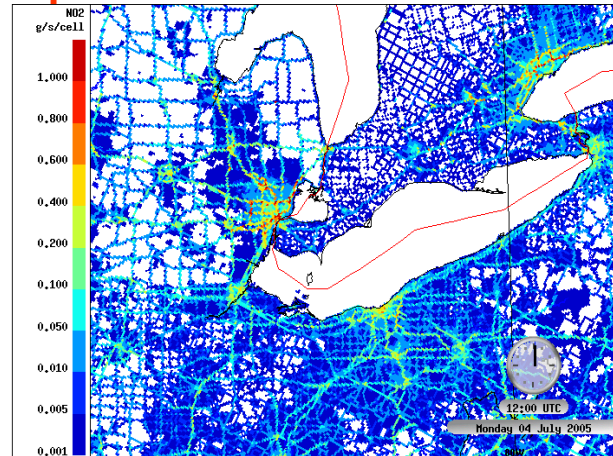
Re-processed NO₂ at 4:00 a.m. LT



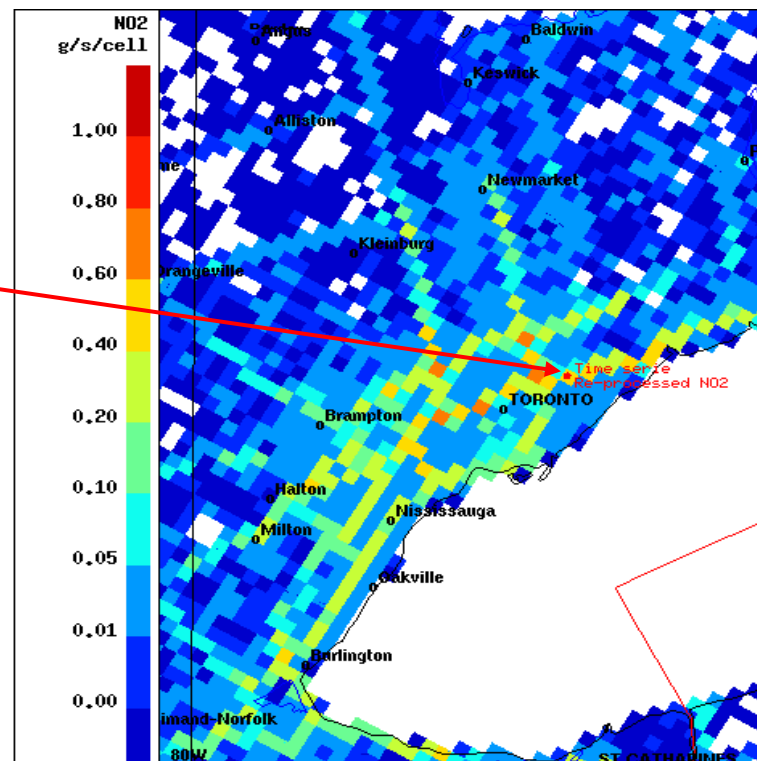
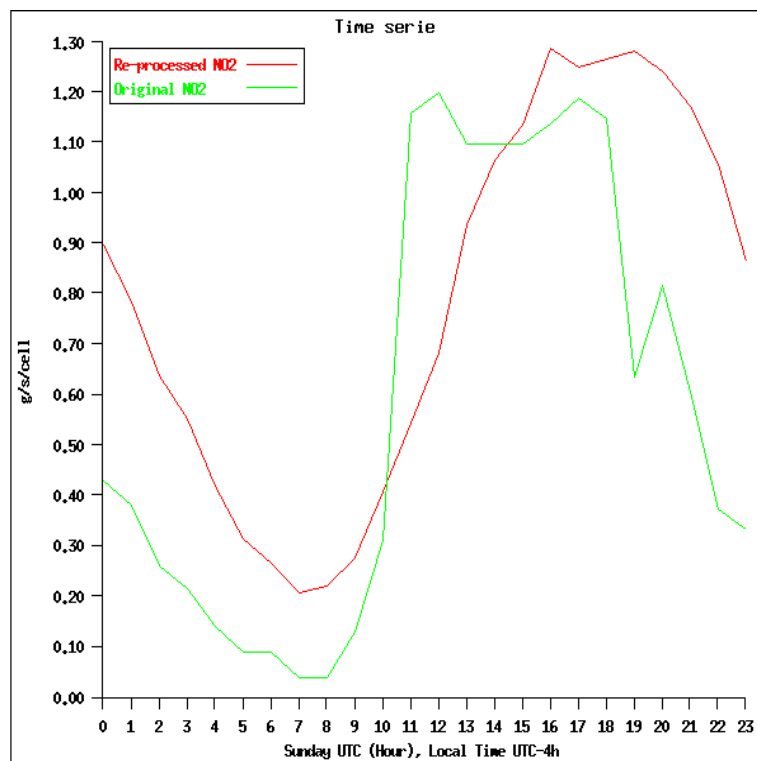
Original NO₂ at 8:00 a.m. LT



Re-processed NO₂ at 8:00 a.m. LT



Time Series of NO₂ On-Road Emissions in downtown Toronto



Conclusions

- ❖ Significant changes to space and time distribution of on-road mobile emissions were seen after implementing improvements to SMOKE processing, especially over Canadian cities
- ❖ After implementing these improvements, the distribution of emissions on the Canadian side of the domain are more comparable with the U.S. side
- ❖ These changes to the emissions will have significant impacts on air quality modelling results



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Acknowledgements

**Thanks to our colleagues in U.S. EPA
and Environment Canada**

**Adam Reff and Heather Simon of U.S.
EPA for updated PM speciation library**

**Mourad Sassi of Environment Canada
for helpful discussions**

