Improving spatial allocation of construction emissions in Canada

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Abstract

In Canada, construction operations are a significant source of dust emissions, and can have a substantial impact on regional air quality. Primary $PM_{2.5}$ emissions from this sector account for 19% of the total anthropogenic $PM_{2.5}$ in the Canadian 2006 inventory. This sector is broken down into heavy construction (75%), road construction (24%) and residential/non-residential construction (1%). As Canadian area emissions inventories are calculated at the provincial level, the accuracy of the gridded model-input emissions files is highly dependent on the choice and quality of the spatial surrogates. A new set of spatial surrogates was developed with several vectorized geographical features. For example, mines, pits and industrial areas, were used for heavy construction surrogate; population growth between 2006 and 2011 were used for residential/non-residential construction surrogate; and the Canadian National Road Network (2007) from Natural Resources Canada was used for road construction surrogate. In addition to spatial surrogates, one key adjustment to dust emissions is a correction called transportable fraction (TF). In Alberta, land use data for oil sands region was updated with mining development for TF calculations. These changes in emission were implemented in a step-wised manner for the Canadian 2006 emissions inventory. The result showed a significant change in gridded PM_{10} and $PM_{2.5}$ emissions in urban and rural areas. Detail changes in the modeled air quality emission will be presented.

Introduction

Construction operations are a significant source of dust emissions, and can have a substantial impact on regional air quality. The accuracy of air quality model performance is directly related to the correct emissions representations of input emissions. In model-input emissions processing, spatial and temporal allocations become highly critical, as we need emission allocated for each domain grid cell and each hour over a model simulation period.

1. In the current Canadian emissions processing, the spatial and temporal allocation processes are not well-represented as we continue to experience high concentration of pollutants in large populated areas. The root cause of these inaccuracies can be attributed to several causes: The Canadian fugitive dust emissions from road dust and construction sectors are reported as annual area sources on a provincial level.

2. The transportation fraction needs to be recalculated using revised land use/land cover.
3. Spatial surrogates which are based on socio-economic data need to be adapted to each emission source.
4. Temporal allocation based mostly on default profiles need to be revised.

The use of high quality digital cartographic data is an important step towards resolving the spatial allocation problem. CanVec is a raster land-use dataset produced by the Natural Resources Canada (http://geogratis.cgdi.gc.ca/). The dataset covers entire Canada and includes more than 90 categories, many of which can be adopted for emissions spatial allocation. We plan to use this to produce allocation surrogates at different grid resolutions.

Following sections presents improvements to the Canadian fugitive dust emissions for inputs to air quality models. The first phase involves improvements in the fugitive dust emissions by applying the gridded transportable fraction to the census divisions. The second phase presents improvements to the fugitive dust spatial and temporal allocation.

Fugitive Dust Inventory

In the 2006 Canadian emissions inventory, fugitive dust emissions were reported as area sources on a provincial level and annual totals. Fugitive dust inventory were subdivided into six subsectors: agriculture, unpaved and paved road dust, commercial construction, residential construction and heavy construction. Following table shows the breakdown of PM_{10} and $PM_{2.5}$ emissions by associated source category codes (SCC):

SCC	SCC Description	PM_{10}	$PM_{2.5}$
2311030000	Roads, Bridges and Tunnels Construction	261,690	52,329
2311020000	Industrial, Commercial, Institutional, Heavy Construction	822,806	164,653
2311010000	Residential Construction	15,925	1,030
2294000000	Dust from paved roads	622,605	148,955
2296000000	Dust from unpaved roads	2,597,406	387,212
2800000000	Agriculture activities	1,095,664	57,066

Table 1: 2006 total PM from road dust, construction and agriculture sectors in Canada, no transportation fraction applied.

A significant amount of total dust emissions come from unpaved roads and non residential construction sites. In the 2006 emissions inventory, fugitive dust represent 93% of total particulate matter emissions; most of it comes from road dust (55%), followed by construction sector (19%) and agriculture (19%).

These emission inventories are converted from province level to census division level using surrogate ratios. Census division surrogate ratio is calculated using sum of surrogate fraction within a census division divided by the total surrogate within a province in which the census is located. For example, if paved road network is being used to create a spatial surrogate for "Paved road dust", than the surrogate ratio for a census division is equal to the total length of all paved roads in the census division divided by the total length of all paved roads in the entire province.

Transportable Fraction

The transportable fraction is the amount of fugitive dust not captured and deposited by the surrounding land cover. The emission fraction is assumed to be emitted and transported when input to an air quality model. Fugitive dust inventory provides the highest emissions of PM in the Canadian inventory. A transportable fraction is calculated and applied on a per county basis to both PM_{10} and $PM_{2.5}$

In this work, the transportable fraction is calculated at a 4km resolution using 230 soil and vegetation types from the 1km resolution BELD3 dataset and the 2000 Canadian National Forest Inventory. Table 2 shows the mapping of the BELD3 land use types and the associated capture fraction. Currently transportable fraction is defined only for the four land use/land cover (LULC) categories.

LULC Category	**TF**	**CF**
Urban	50%	50%
Agriculture/Grassland/Shrubland	75%	25%
Forest	0%	100%
Barren/Water	100%	0%

Table 2: Land use categories and the associated Transport/Capture Fraction

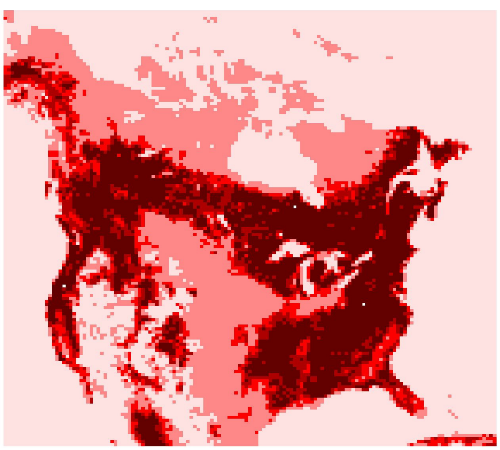

Figure 1: Gridded Capture Fraction at 4km resolution

In order to have a uniform method across all provinces and to achieve mass conservation for the input emissions at all grid resolutions, the transportation fraction was calculated in census division level spatial scale. This resulted in increases and decreases in transportable fraction as function of the census division's dominant LULC category.

The TF is averaged over census divisions. This resulted in both increases and decreases in the transportable fraction. However, this provides a consistent method to estimate the amount of fugitive dust across the Canada as well as a more accurate representation of emissions since we have mass conservation for all grid resolutions.

SCC	**SCC Description**	**PM_{10}**	**$PM_{2.5}$**	**TF_{AVG}**
2311030000	Roads, Bridges and Tunnels Construction	92,768	18,550	35%
2311020000	Industrial, Commercial, Institutional, Heavy Construction	310,247	62,069	38%
2311010000	Residential Construction	5,459	313	30%
2294000000	Dust from paved roads	141,226	33,783	23%
2296000000	Dust from unpaved roads	796,279	119,060	31%
2800000000	Agriculture activities	273,916	14,266	25%

Table 3: Total PM from road dust and construction sector in Canada, TF applied for all censuses.

Spatial allocation

Spatial allocations of emissions to model domain grids were reprocessed using the CanVec digital cartographic data from Natural Resources Canada. Three new surrogates were processed for the construction sectors using different CanVect categories. Following sectors describe the steps in more detail.

Heavy construction:

CanVec product contains more than 90 topographic entities thematically organized into 11 distribution themes: Administrative Boundaries, Buildings and Structures, Energy, Hydrography, Industrial and Commercial Areas, Places of Interest, Relief and Landforms, Toponymy, Transportation, Vegetation and Water Saturated Soils. CanVec data was used to generate heavy construction surrogate using high resolution land cover classes. Areas from Oil Sands regions and Oil and Gas mining developments were added to the surrogate. However urban areas were excluded.

Figure 2 shows the spatial allocation of heavy construction emissions for Alberta using the original surrogate and average TF by province. In Figure 3, we use the new CanVec surrogate and the average TF by census divisions.

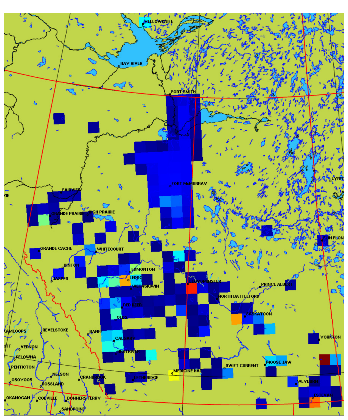

Figure 2: Heavy construction with Mining surrogate and TF by province

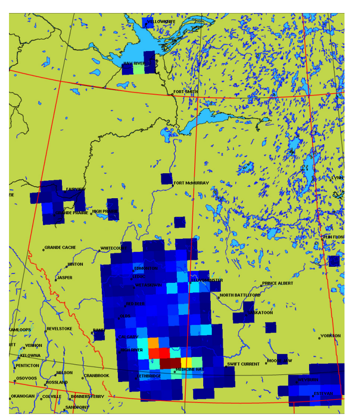

Figure 3: Heavy construction with CanVec surrogate and TF by CD

Residential construction:

Nearly 90% of Canadian population growth between 2006 and 2011 take place in metropolitan areas. We built a spatial surrogate based on population growth by using the population counts from the Canadian 2011 census. See Table 4:

Name	Population 2011	Population 2006	Population growth, 2006 to 2011	Dwelling 2011	Dwelling 2006	Dwelling growth, 2006 to 2011	Land area km2
Canada	33,476,688	31,612,897	5.6%	14,569,633	13,576,855	6.8%	9,017,699
ON	12,851,821	12,160,282	5.4%	5,308,785	4,972,869	6.3%	907,574
QC	7,903,001	7,546,131	4.5%	3,685,926	3,452,300	6.3%	1,356,367
BC	4,400,057	4,113,487	6.5%	1,945,365	1,788,474	8.1%	924,815
AB	3,645,257	3,290,350	9.7%	1,505,007	1,335,745	11.2%	640,045
MB	1,208,268	1,148,401	5.0%	512,689	491,724	4.1%	552,370
SK	1,033,381	968,157	6.3%	460,512	438,621	4.8%	588,276
NS	921,727	913,462	0.9%	442,155	425,681	3.7%	52,917
NB	751,171	729,997	2.8%	348,465	331,619	4.8%	71,355
NF	514,536	505,469	1.8%	250,275	235,958	5.7%	370,495
PEI	140,204	135,851	3.1%	66,943	62,753	6.3%	5,684
NT	41,462	41,464	0.0%	17,175	16,774	2.3%	1,140,835
YT	33,897	30,372	10.4%	16,259	15,296	5.9%	474,711
NU	31,906	29,474	7.6%	10,077	9,041	10.3%	1,932,255

Table 4: Population and dwelling counts, for census subdivisions (municipalities), 2006 & 2011

Road dust and road construction:

For road construction and paved/unpaved road dust, spatial surrogate was build using the 2007 National Road Network (NRN) v2.0 from Natural Resources Canada. NRN attributes include type of road, number of lanes, paving status, road length and more.

Unpaved road dust surrogate was built using unpaved roads network in rural areas. All urban unpaved roads were excluded from the surrogate to reduce the amount of dust from urban centers.

Paved road dust and road construction use the same surrogate. We added all paved and unpaved roads from urban and rural areas. However, we excluded urban streets as their total length creates emissions "hot spots" in urban centers.

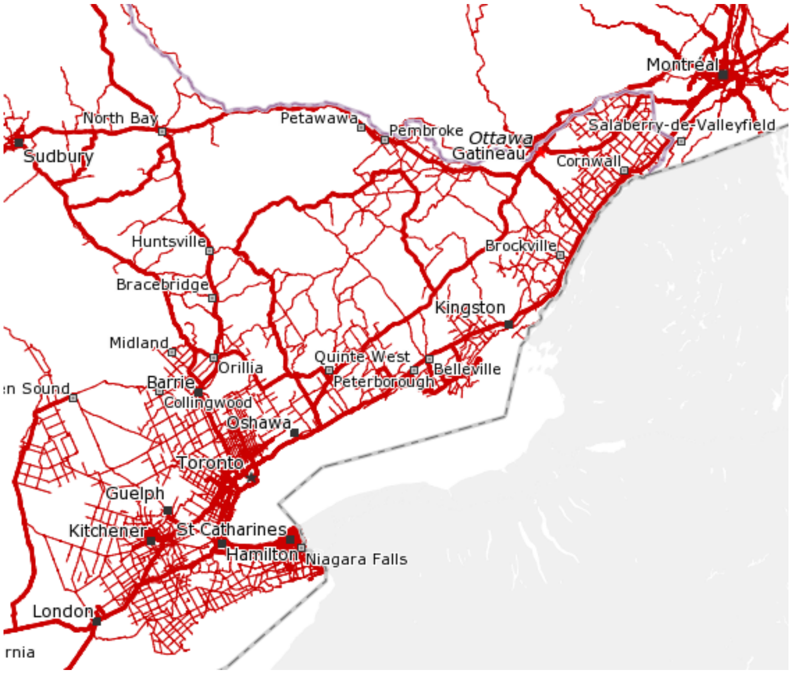

Figure 4: National Road Network (NRN) version 2.0

Temporal profiles

Depending on the level of activity, operations, and the prevailing meteorological conditions, dust emissions can vary substantially in the temporal scale. The temporal profiles of the road dust and the construction sector were modified from the default profile that was assigned in SMOKE. The construction includes residential, commercial, road and other heavy construction. Each of these categories includes monthly, weekly, and daily temporal profiles. Monthly temporal data show higher activity during the spring, summer and fall months, and lower during the winter.

For example, monthly profiles from "Asphalt Paving Industry" and "Concrete Batching & Products" would be used to temporally allocate road construction sources and non-road construction respectively. Figure 5 shows the temporal allocation factors for both road dust and construction sector.

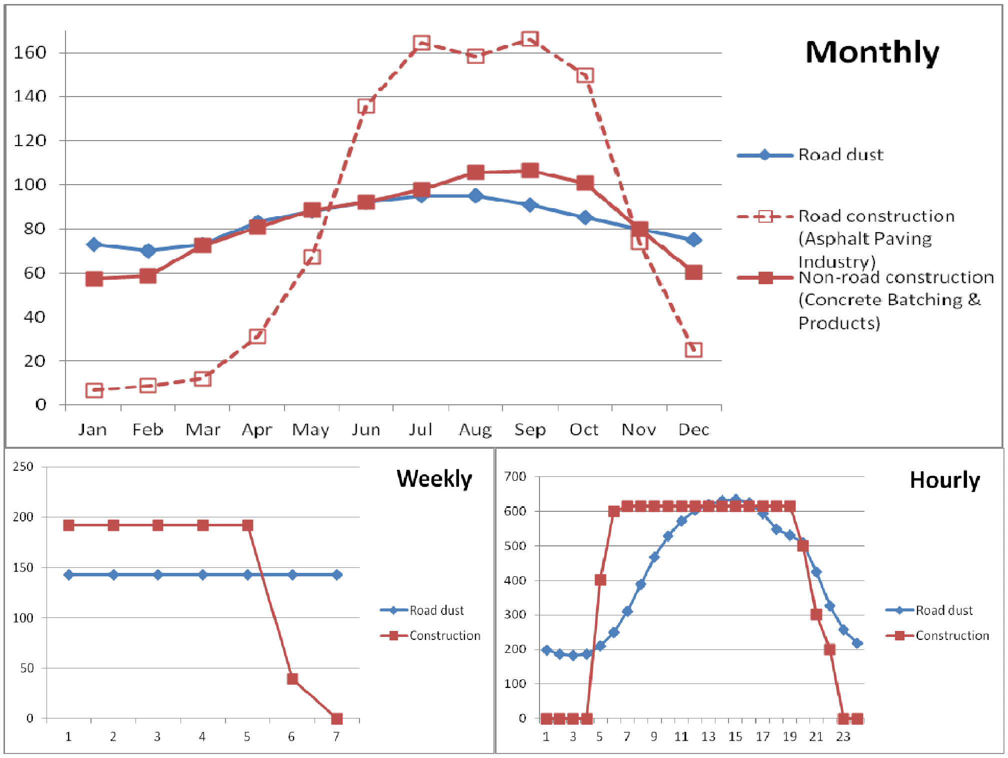

Figure 5: Temporal Allocation for Road dust and Construction sector in Canada.

Conclusion

The improvements to the 2006 Canadian construction emissions for air quality model applications are the following:

- Updated Transportable Fraction by counties calculated on a fine grid using BELD3.
- More detailed spatial surrogate for construction and road dust using high resolution cartographic data, 2011 statistic Canada censuses and 2007 National Road network data.
- A revised temporal allocation for construction and road dust.

These improvements in the generation of Canadian emissions modeling files show significant changes in the gridded particulate matter emissions in urban areas.