Air Quality Modelling Applications Section

Meteorological Service of Canada

Environment and Climate Change Canada

REPORT # AQSC-18-031

Documentation for SMOKE-Ready 2015

Air Pollutant Emission Inventory (APEI)

Package version 1

Abstract

This air-quality modelling package includes version 1 of the 2015 Canadian criteria-air-contaminants (CAC) emissions inventory, also referred to as the Air Pollutant Emission Inventory (APEI), in SMOKE-ready format. The APEI is compiled by the Pollutant Inventories and Reporting Division (PIRD) of Environment and Climate Change Canada. The 2015 inventory database compiled by PIRD was then modified by the Air Quality Modelling Applications Section (AQMAS) of Environment and Climate Change Canada for emissions processing with SMOKE for the 2015 Canadian air quality modelling platform. This document describes the delivery contents, including the source-sector-specific SMOKE-ready emission inventory files and all ancillary files needed to generate spatial surrogates and to process the inventory files using the SMOKE emissions processing system.

DOCUMENT HISTORY

Date	Auteur	Modifications
28/08/2018	Mourad Sassi	First draft
30/10/2018	Mike Moran	Revisions, added Section 2.2 text
13/12/2018	Junhua Zhang	Revisions to Section 2.1 for Cdn NPRI points

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Table of Contents

List of Acronyms

Acronyms	Description
APEI	Air Pollutant Emission Inventory
AQMAS	Air Quality Modelling Applications Section
BAU	business as usual
CAC	criteria air contaminants
CEPA	Canadian Environmental Protection Act
CWFIS	Canadian Wildland Fire Information System
ECA	Emission Control Area
ECCC	Environment and Climate Change Canada
EEA	Economic Exclusion Area
E3MC	Energy, Emissions and Economy Model for Canada
EPG	Electric Power Generator
FEPS	Fire Emission Production Simulator
GEM	Global Environmental Multiscale model
GHG	Greenhouse Gas
I/M	inspection and maintenance
LTO	landing and takeoff
NAESI	National Agri-Environmental Standards Initiative
NAICS	North American Industry Classification System
NPRI	National Pollutant Release Inventory
ORL	One-record-per-line (SMOKE input format)
PEMA	Pollutant Emission Management Area
PIRD	Pollutant Inventories and Reporting Division
REQA	Réponse aux enjeux en qualité de l'air
SCC	Source Classification Code
SMOKE	Sparse Matrix Operator Kernel Emissions
TF	Transportable Fraction
UNECE	United Nations Economic Commission for Europe
UOG	upstream oil & gas

Delivery Contents

	Archive files included in this delivery:	
# 1	2015CA_Inv_Package_surrogates.tar.gz (1.6Gb)	This .tar file includes the GIS shapefiles used to generate the set of gridded spatial surrogates needed to allocate Canadian 2015 emissions (see details in section2.2).

# 2	Canada_2015_inventory_v1_svn70.tar.gz 	
	    \<ancillary>
	    \<documentation>
	    \<inventory>
	        \<2015>
	            \<area>
	            \<point>
	            \<ag>
	            \<transportation>
	            \<wildfire>
		This .tar file contains the Canadian 2015 SMOKE-ready Air pollutant emissions inventory files for point, area, agriculture and transportation categories. Fire inventory is also included.

D O C 1	\<documentation>
	    ➢ A18031_2015_Canadian_CAC_EmissionsInventoryPackage_version1.docx
	
	    This is the present document.	

D O C 2	\<documentation>
	    ➢ 2017APEIR2016-12-21_v3.1.docx
	
	    This document describes the Canadian air pollutant emissions inventorie (APEI).	

1 -   2015 Canadian Inventory Description

1.1   Overview

The 2015 Air Pollutant Emissions Inventory (APEI), previously known as the Canadian CAC emissions inventory, was compiled by the Pollutant Inventories and Reporting Division (PIRD) of Environment and Climate Change Canada (ECCC) using both top-down and bottom up approaches (ECCC, 2016). For example, point source emissions were compiled using a bottom-up approach based on the facility level emissions reported to the National Pollutant Release Inventory (NPRI) (EC, 2015), whereas area source emissions were mainly compiled using a top-down approach based on source-specific activity data and emission factors. The PIRD inventory database was further processed by the Air Quality Modelling Applications Section (AQMAS/ECCC) to generate a SMOKE-ready version for the 2015 Canadian air quality modelling platform (Sassi *et al.*, 2016). The source-sector-specific updates included in this delivery are described below in three main sections: point sources (section 1.2); area sources (section 1-3); and all transportation sources (section 1.4).

1.2   Point source emissions

1.2.1   NPRI point sources

The NPRI point source inventory consists of emissions reported by industrial facilities to ECCC and published under the authority of Sections 46–50 of the *Canadian Environmental Protection Act,* (ECCC, 1999). Facilities are required to report emissions of any species for which the annual emissions exceeds a specified threshold. For example, the reporting threshold for SO_2, NO_x, and CO is 20 metric tons/year while it is 10 metric tons/year for VOC species (ECCC, 1999). NPRI facilities are only required to report emissions at their facility level and not by process. Therefore NPRI emissions are only provided with generic SCC codes and more specific SCC values have been assigned by AQMAS to each facility based on its North American Industry Classification System (NAICS) source sub-category. Emissions from some tall smokestacks are separated out with additional VOC species reported.

The air-quality-modelling version of annual NPRI inventory consists of five files (see files #1-5 in Table 1-1). The first file contains the emissions for all the species except VOCs. For reference, total VOC emissions are contained in the second file. In order to give the user a choice, two other files containing VOC's emissions for different chemical speciation mechanism, namely CB06 and ADOM-II are included. Finally, one raw VOC inventory consists of detailed individual VOC species and is provided with CAS numbers.

1.2.2   UOG point sources

There are numerous, but relatively small facilities under the Upstream Oil and Gas (UOG) sub-inventory, including oil and natural gas emissions through exploration, production, and processing to transport to market. Emissions from many UOG facilities are below the NPRI reporting limits (see Section 1.2.1). Therefore, they are not normally included in the NPRI point source inventory file and their inventory data is compiled separately (see file #6 in Table 1-1). Specifically excluded are oil sands mining, extraction and upgrading, petroleum refining, and distribution of refined petroleum products, which are included in the NPRI point sources inventory described in section 1.2.1. The UOG emissions has been developed using a bottom-up approach from individual facilities and their

associated equipment to the primary emissions sources for fuel combustion, flaring, CO_2 formation and releases, venting (reported and unreported), fugitive and other unintentional releases such as equipment leaks, storage and handling losses, accidental releases and finally, indirect emissions due to fossil-fuel generated electric power consumption. The UOG inventory for year 2015 was projected by PIRD from a 2011 base-year inventory. UOG emissions are provided with SCC codes and facility-level emissions similar to the NPRI, with information for stack parameters for some of the tall stacks.

1.2.3   Wildfire emissions

This is a day-specific wildfire emissions inventory for Canada for the Canadian "fire season" from April 2015 to October 2015. The wildfire emissions estimation is based on the information of active wildfires or "hotspots" provided by the Canadian Wildland Fire Information System (CWFIS, http://cwfis.cfs.nrcan.gc.ca/home), which is operated by Natural Resources Canada (NRCan). The CWFIS detects active wildland fires using the observations from the NASA MODIS and the NOAA/AVHRR satellite-based detection systems. This data file (file #7 in Table 1-1) contains daily fire locations by latitude and longitude. Environment and Climate Change Canada's GEM model forecasts are then used to determine weather conditions at fire locations and estimate the fuel consumption. The daily total emissions for each fire "hotspot" are calculated based on the BlueSky Fire Emission Production Simulator (FEPS) module for Environment and Climate Canada's FireWork system (Chen *et al*., 2012). See Pavlovic *et al*. (2016) for more details on the FireWork system. Note also that there is no plume-rise pre-calculations performed for these wildfire emissions. Fire emissions are provided in IDA and EMS-95 format.

Table 1-1. Emission inventory filenames for all point sources.

Point sources archives files content	Description
(1) PS_2015_FF10_noVOC_20181102.csv	NPRI point sources without VOC
(2) PSVOC_2015_FF10_VOC_20181102.csv	NPRI point sources VOC only
(3) PSVOC_2015_FF10_CB6_20181102.csv	NPRI point sources CB06 mechanism
(4) PSVOC_2015_FF10_ADOM_20181102.csv	NPRI point sources ADOM II mechanism
(5) PSVOC_2015_FF10_Species_20181102.csv	NPRI point sources raw VOC species
(6) PS_2015_FF10_UOG.csv	UOG point sources
(7) ptfire_2015_raqdps020fw.tar.gz	Wildfire daily point sources
(8) Airport_LTO_Point_2015_FF10_20180824.csv	Aircraft LTO point sources

1.2.4   Agricultural emissions

The 2015 agricultural monthly emissions inventory includes emissions from 56 types of agriculture sources over 274 Canadian census divisions. This inventory data for this sector is compiled as 6 files containing monthly emission values (files #9-14, Table 1-2).

Emissions were provided in point source format as gridded monthly totals for a national grid at 10 km x 10 km resolution. So there is no need to use surrogates to spatially allocate the emissions, but weekly and diurnal temporal profiles are still needed for temporal allocation of monthly emissions to each hour.

Table 1-2. Emission inventory filenames for all agricultural sources.

Agriculture sources inventory filelist	Description
(9) ag_animal_NH3_2015_FF10_20171214.csv	Animal NH3
(10) ag_animal_VOC_2015_FF10_20171214.csv	Animal VOC
(11) ag_havest_2015_FF10_20171214.csv	Harvest PM
(12) ag_synth_fertilizer_NH3_2015_FF10_20171214.csv	Fertilizer NH3
(13) ag_tillage_2015_FF10_20171214.csv	Tillage PM
(14) ag_winderros_2015_FF10_20171214.csv	Wind erosion PM

1.3   Area source emissions

1.3.1   Fugitive particulate matter dust emissions

The fugitive dust inventory includes dust emitted from building and road construction, paved and unpaved roads, agriculture, and mine tailings. These area emissions are treated separately, in order to apply Transportable factors (TF) as described by (Pouliot *et al*., 2010). The data are reported in one file with annual emission value (file #15, Table 1-3).   Note that Aeolian dust emissions are not considered.

1.3.2   Other area sources

All other remaining area sources are contained in an emission file, for sectors such as residential, commercial and industrial. All types of fuel combustion, solvents, etc. The data are reported in one file with annual emission value (file #16, Table 1-3).

Table 1-3. Emission inventory filenames for area sources.

Area sources inventory filelist	Description
(15) AS_2015_FF10_20180219_fdust_PM.csv	Dust inventory (PM)
(16) AS_2015_FF10_20180219_other.csv	All other Area Sources

1.4   Transportation sector emissions

All transportation emission inventory files are provided separately from point sources or area sources inventory since some are points and others are area sources. Details are given in the subsection 1.4.1 to 1.4.5.

1.4.1   Aircraft emissions

The aircraft sector includes emissions only for Landing/Take-Off (LTO) cycles. Aircraft in-flight emissions and other airport activities are not included. Emissions estimates are based on emission factors for all aircraft and fuel consumption per airport reported annually by Statistics Canada

(Report on Energy Supply-Demand). This inventory is reported as monthly point sources (file #8, Table 1-4, also in Table1-1).

1.4.2   Marine emissions

Marine emissions data are provided by the Transportation Division of ECCC. This sector is an aggregation of a number of classes of vessels (1, 2 and 3) that encompass freighters, tankers, tugs, ferries, passenger boats (inboard), fishing boats, and container ships. The marine emissions data are used for all of the Canadian provinces and territories within 200 nautical-miles from the coast referred as the Economic Exclusion Area (EEA). This inventory is reported as annual mobile sources (file #17, Table 1-4).

1.4.3   On-road mobile sources

Emission estimates from on-road vehicles were generated using a bottom-up approach: emission factors were developed for individual vehicle classes and activity data were applied to them. Generally, for non-GHGs, emission factors were developed using the MOVES2014 emissions simulator, originally developed by the EPA, with key datatables modified to reflect Canadian (provincial/territorial/regional) conditions.

This inventory is compiled as monthly emissions values for different vehicle types. It is aggregated at the provincial level except for two provinces where inspection/maintenance (I/M) programs or other sub-provincial information are available. The inventory for these two provinces was split into sub-regions: British Columbia into two sub-regions and Ontario into four sub-regions. Five road types were also used to improve the spatial allocation (files #18-19, Table 1-4).

1.4.4   Off-road mobile sources

Emissions estimates for all off-road vehicles and engines are based on the EPA's NONROAD v6.7 tool. This inventory is compiled as monthly emissions values from different types of engines and fuels. This inventory is at the provincial level except for four provinces where sub-provincial information is available: British Columbia has two sub-regions, Alberta has two sub-regions, Ontario has four sub-regions, and Quebec has two sub-regions (file #20, Table 1-4).

1.4.5   Locomotive emissions

Rail emissions were obtained from the Transportation Division of ECCC. This inventory is reported as annual mobile sources (file #21, Table 1-4).

Table 1-4. Emission inventory filenames for the transportation sector.

Transportation sources inventory filelist	Description
(8) Airport_LTO_Point_2015_FF10_20180824.csv	Aircraft LTO inventory
(17) Marine_2015_FF10_20180824.csv	Marine inventory
(18) OnRoad_2015_FF10_20180911.csv	On-road mobile & refueling
(19) OnRoad_Refueling_2015_FF10_20180914.csv	
(20) NonRoad_2015_FF10_20180914.csv	Off-road engine & equipment
(21) Rail_2015_FF10_20180824.csv	Locomotive

1.5   Annual total emissions for this 2015 inventory

Emissions from all of the emission inventory files described in the previous sections (1.2 to 1.4) are included in the summary table (Table 1-5) below with their annual total emission for reference.

Table 1-5. Canadian air pollutant annual emissions for 2015 (From APEI14_2015).

2015 emissions in tonnes	CO	NH3	NOX	PM10	PM2_5	SO2	VOC
Industrial Sources	1,190,152	15,184	622,752	151,725	61,838	765,121	816,730
Non Industrial Sources	1,265,302	2,881	233,428	175,058	171,243	259,996	235,389
Miscellaneous Sources	9,737	712	76	18,182	16,745	88	378,510
Off-road mobile Sources	1,397,071	651	570,038	27,409	26,269	11,443	182,187
On-road mobile sources	1,573,028	6,486	389,053	23,988	13,484	1,461	125,879
Open Sources	147,490	459,280	11,320	6,851,070	1,330,700	10,709	116,434
Total w/o wildfires	**5,582,779**	**485,195**	**1,826,666**	**7,247,433**	**1,620,280**	**1,048,819**	**1,855,129**

2 -   Supplementary information

This section describes other important information also included with the package.

2.1   Ancillary files

SMOKE ancillary files, such as the temporal cross-reference file and temporal profile libraries, spatial cross-reference file, costcy and pstk are included in the ancillary directory of the archive. The spatial cross-reference file "amgref.CAN_T3_T4_PRG2013.txt" should be used for processing on-road and off-road mobile source emissions, while the other spatial cross-reference file, "amgref.CAN2006_noNAESI_12Feb2018.txt", is for processing emissions from all other non-point source emissions. Similarly, the temporal cross-reference file "CA_ptref_13Dec_2018.txt" and temporal profile library file "CA_ptpro_Feb29_2016.txt" are used for processing NPRI point source inventory (files #1-5 in Table 1-1), while the other pair of temporal cross-reference file and temporal profile library file "amptref.m3.us+can.02dec2005_29Aug2014_19Feb2018.txt" and "amptpro.m3.2001.us+can.21sep2005_29Aug2014_19Feb2018.txt" are used for processing emissions from all other sources.

2.2   Spatial surrogates for processing 2015 Canadian inventory

A set of GIS shapefiles that are used to build the set of Canadian 2015 spatial surrogate fields for Canadian emissions processing is included in the package along with control files needed by the CMAS Surrogate Allocator package (www.cmascenter.org/sa-tools/). All of these files are contained in the compressed tar file named "2015CA_Inv_Package_surrogates.tar.gz".

2.2.1 Updates to the Canadian spatial surrogate database

Since the release of the SMOKE-ready 2013 Canadian APEI package in 2017, some new GIS shapefiles and companion spatial surrogate fields have been developed and added to this package:

- 2016 Census population and dwelling data is used to generate surrogates 100–104, to replace 2006 Census data (more information about the capped population surrogates may be found in Zheng et al., 2015);
- New airport shapefile with detailed runway geometry is used to generate surrogates 901–905;
- Updated Athabasca Oil Sand shapefile is used to generate surrogate 1255;
- Updated residential wood combustion shapefile for surrogate 951, using 2011 household wood consumption data for 13 provinces and 28 Census Metropolitan Areas. The wood consumption was spatially distributed into Dissemination Areas by dwelling counts, urban/rural, the latitude, and the distances to forest (Zheng et al., 2015);
- NAESI surrogates have been removed because agriculture emissions are now reported in point source format at 10 km resolution
- More information is available in the package in files "surrogate_generation_canada_Aug2018.csv", "shapefile_catalog_CA_Aug2018.csv", "surrogate_ID_CA_Aug2018.csv", and "surrogate_specification_CA_Aug2018.csv".

2.2.2 Summary of Canadian shapefiles used for spatial surrogate generation

The following table provides a summary of the GIS shapefiles and related spatial surrogates grouped by type of surrogate.

Catalogue	Shapefiles	Surrogates
Population and Dwelling	gpr_gda_000a16a_e_sphere_3Nov2017.shp gpr_gda_000b11a_SimpP_100m_water_Dissolve.shp gda_000b11a_e_SimpPoly_MaxOffset_100m_pop_dwell_Jul2014.shp gda_000b16a_e_PopDwell_SimpPoly_100m_noLakes_sphere_1Nov2017.shp	100, 101, 102, 103, 104, 105
On-road	gcd_000b11a_e_CDID_BC2_ON4_Simpl10m_water.shp NRN_CA_Simp2_16Apr2016_sphere.shp gda_000b16a_e_PopDwell_SimpPoly_100m_noLakes_sphere_1Nov2017.shp	200, 210, 220, 230, 240
Off-road T4	gcd_000b11a_e_CDID_BC2_Que2_ON4_Simpl10m_water.shp da2006_pop_labour_SimplifyP_MaxOffset-100m_sphere_noLakes.shp allroads.shp construction_other.shp mine.shp naesi_fert.shp unpaved_ur.shp wood_industries.shp OS_MinePit_D_v2.shp lu100.shp othjet_ll.shp CANRAIL.shp	1251, 1252, 1253, 1254, 1255, 1256, 1257, 1258, 1259, 1260, 1261, 1262, 1263, 1264, 1265
Airport, rail, and marine	Airport_movements_2006_MultiRingBuffer.shp Aviation_Extended-Runways-including-runways-with-buffer-Spring2017.shp CANRAIL.shp Off-Road-using-OSM-Apron-of-155-Aiport-Locations-with-Traffic-data-by-Province-STATCAN-2015-Spring2017.shp Surrogate-2017-matches-Inventaire-2013-by-Keys-with-FAKEFIPS-6-polygon.shp marine.shp	901, 902, 903, 904, 905, 932, 945
Land cover	CONT42_pop_water_Clip_b.shp coast_inland_water_Union_BND_m.shp treesa.shp	350, 948
Others: industrial, commercial, agricultural, and fugitive open sources	da2006_pop_labour_SimplifyP_MaxOffset-100m_sphere_noLakes.shp gda_000b11a_e_SimpP_100m_WoodConsump_1Aug2014.shp gpr_gda_000b11a_SimpP_100m_water_Dissolve.shp lowmedjet_ll.shp naesi_fert.shp naesi_livestk.shp othjet_ll.shp prov2006_Jan2012_SimplifyPo_MaxOffset-100m_water_sphere.shp	106, 111, 113, 116, 211, 212, 221, 222, 233, 308, 321, 323, 324, 326, 327, 331, 412, 448, 562, 921, 923, 924, 925, 926,

treesa.shp	927, 940, 942,
ua2001.shp	946, 949, 951,
unpaved4.shp	955, 960, 970,
unpaved5.shp	980, 990, 996
unpaved_ur.shp	

3 -   References

Chen, J., R. Pavlovic, A. Pankratz, and K. Anderson, 2012. Evaluation of wildfire emissions in the Canadian GEM-MACH air quality forecast system. *20th Emissions Inventory Conference*, 13-16 Aug., Tampa, Florida. https://www3.epa.gov/ttn/chief/conference/ei20/session2/jchen_pres.pdf

Environment Canada, 2015. Overview of Reviewed Facility-Reported Data National Pollutant Release Inventory (NPRI) 2015. (Cat. No.: En81-24-E-PDF   ISSN: 2369-7733) https://www.ec.gc.ca/inrp-npri/default.asp?lang=En&n=386BAB5A-1&printfullpage=true&wbdisable=false

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Zheng, Q., M.D. Moran, J. Zhang, E. Tanguay, D. Niemi, and M. Sassi, 2015. Development of some improved Canadian spatial surrogates. Poster, *21st International Emissions Inventory Conference*, 13-17 April, San Diego. [see http://www.epa.gov/ttn/chief/conference/ei21/poster/qzheng.pdf]

Contact

For any request regarding this delivery, please send an email to the distribution list EC.REQA.EC@canada.ca . A member of the team will get back to you as soon as possible.

AQMAS Internal information

Historical, revision information and local path locations

Canada_2015_inventory_v1_svn70.tar.gz

Final package prepared by Mourad Sassi and Rabab Mashayekhi (November 2018) based on:
https://ulysse.cmc.ec.gc.ca/svn/emission_inventory/2015 (revision #70, November 2nd 2018)

Local extraction path:
/fs/cetus/fs4/aq/afsusno/Emissions/EmissionsInventoryPackage

Local delivery package path:
/fs/cetus/fs4/aq/afsusno/Emissions/EmissionsInventoryPackage/Canada_2015_inventory_v1_svn70

All related information regarding this request will be recorded under Mantis issue #2805