Marine Emission Inventory Tool

for the Commercial Marine Sector

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Developed For:

Environment Canada

Transport Canada

Transport Canada Transports Canada

Canada

ClearSky Engineering

EPA 18th International Emission Inventory Conference
Baltimore, MD, April 14, 2009

Background

- Need was identified to reliably develop “bottom-up” marine emission inventories:
  - IMO global initiatives: Emission Control Area (ECA)
  - Pollution Data Branch CAC Inventory, Marine Sector
- Marine Emission Inventory Tool (MEIT) originally developed in 2005 under Environment Canada contract
- Several revisions and enhancements have been added by ClearSky Engineering, SENES, Levelton under Transport Canada & Environment Canada contracts

Objectives

The Marine Emission Inventory Tool (MEIT) developed to generate emission estimates by:

- Vessel type, engine type
- Operating Mode: underway, reduced speed, manoeuvring, at berth
- Temporally: monthly and annual
- Spatially at port, regional, provincial/territorial, national levels

Scope

- Marine vessels with compression-ignition engines > 37 kW (50 hp)
- Capability to process vessel data sets from Lloyd's Register, Canadian Coast Guard (INNAV)

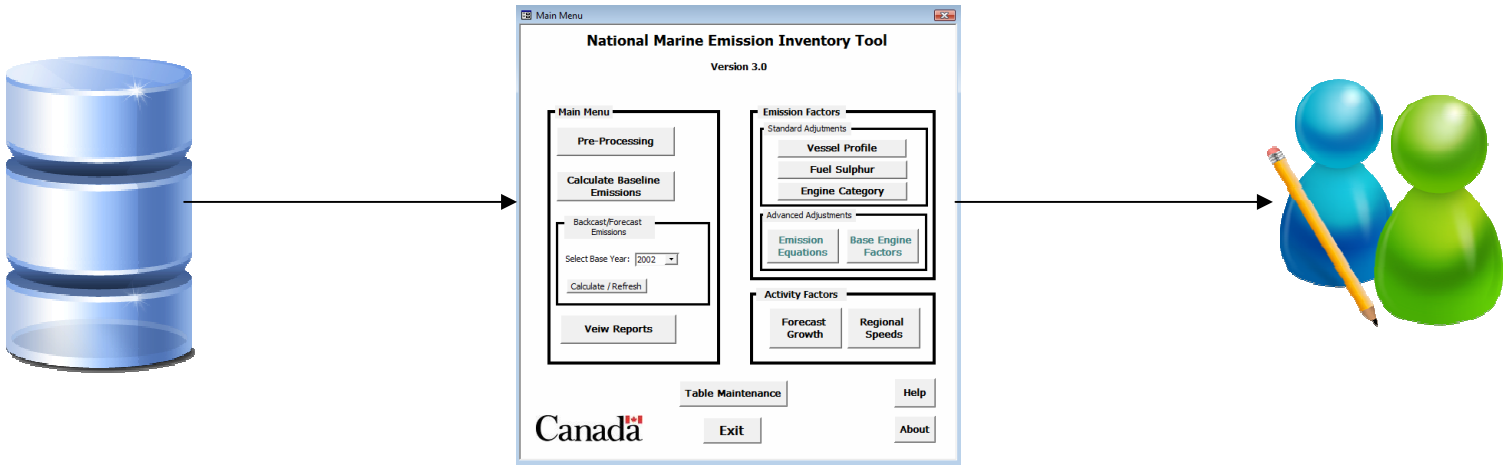
CACs	GHGs
SO_2	CO_2
NO_x	CH_4
CO	N_2O
HC	CO_2e
TPM	
PM_{10}	
$PM_{2.5}$	

Vessel Types - OGVs

- Auto
- Bulk
- Container
- Ferry
- General
- RO/RO
- Dry
- Ore
- Passenger
- Reefer
- Coastal
- Crude
- Gasoline
- Chemical
- Molasses
- Ore/Bulk/Oil
- Liquefied Gas
- Tanker
- Super Tanker
- ULCC
- VLCC
- Warship - General
- Warship Surface
- Ocean Tugs

Platform

- Database back-end run by menus
- Originally designed in MS Access
- Recently converted from Access to SQL Server 2005 (Feb, 2009)



Calculation Method 1

$$Emissions_{(NOx,\ CO,\ HC,\ CO2,\ CH4,\ N2O)} = \Sigma\ (P \times LF \times EF \times T_{Mode})$$

input file — look-up table — look-up table — calculated

P = maximum power output of main or auxiliary engine in kW

LF = engine or auxiliary system load factor as a fraction of maximum rated power output

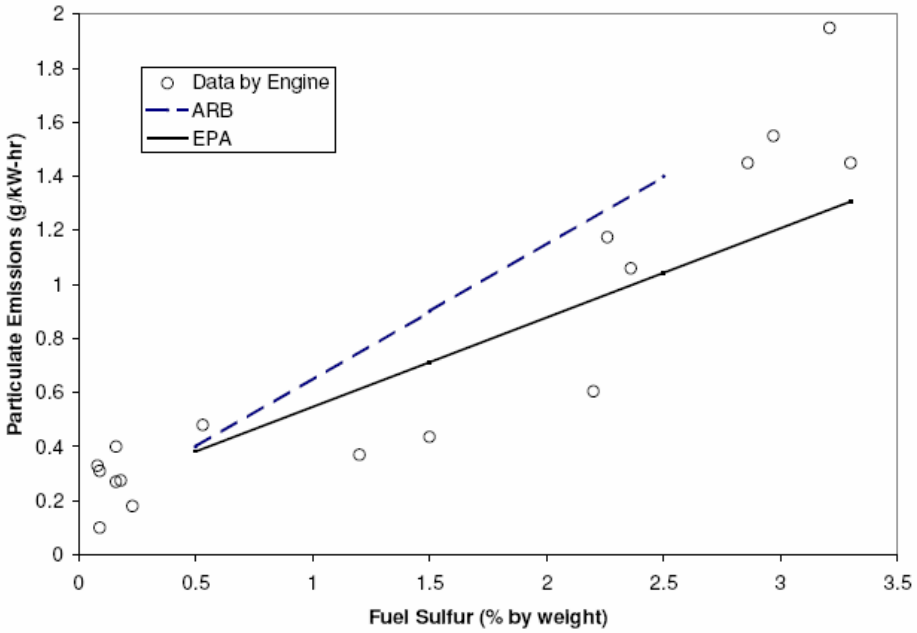
EF = emission factor (pollutant specific) in grams per kW-h engine output for main and auxiliary

T = time in mode, hours: underway, maneuvering, or dockside

Calculation Method 2

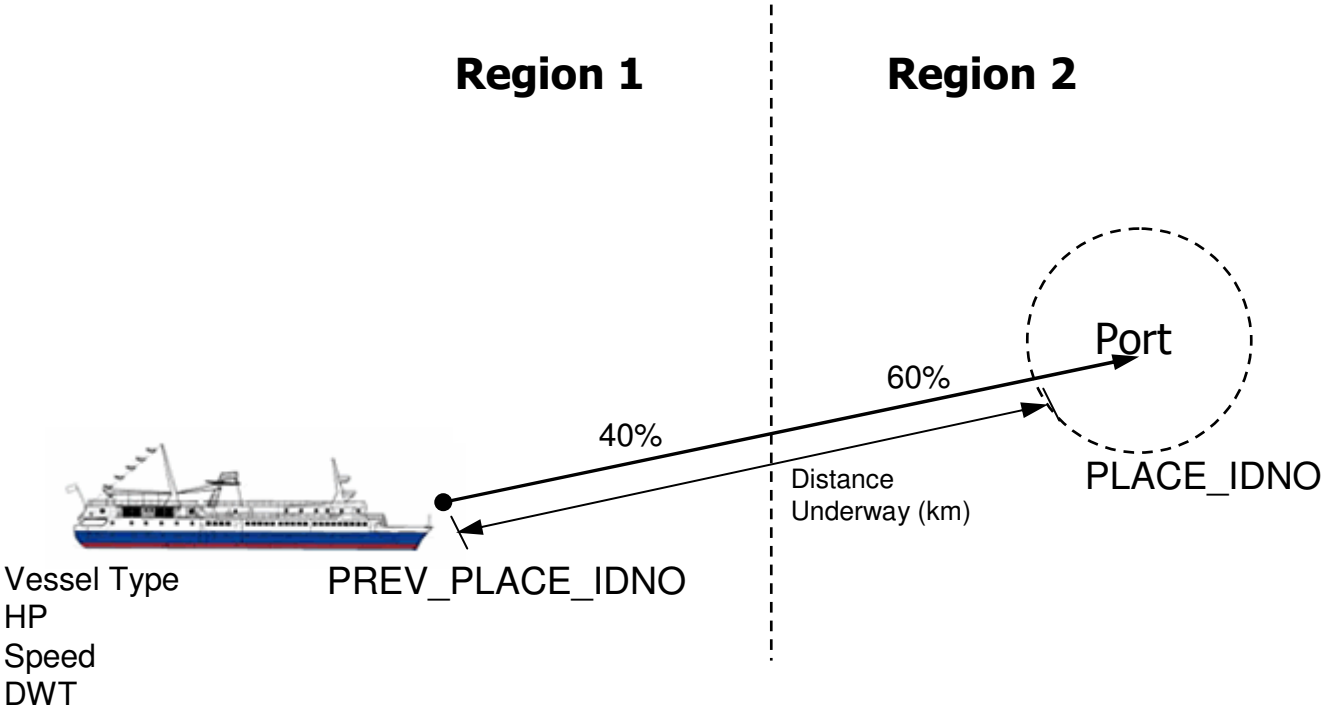
- PM, SO_x
  - Recent studies indicated a linear relationship between fuel sulphur content and engine PM emissions

Figure 4 – PM Emission Profiles



Source: SENES Consultants Ltd., 2007. Emission Factors and SECA Forecast. Produced for Transport Canada under contract with Weir Marine Engineering Ltd.

Vessel Movement



Main Menu

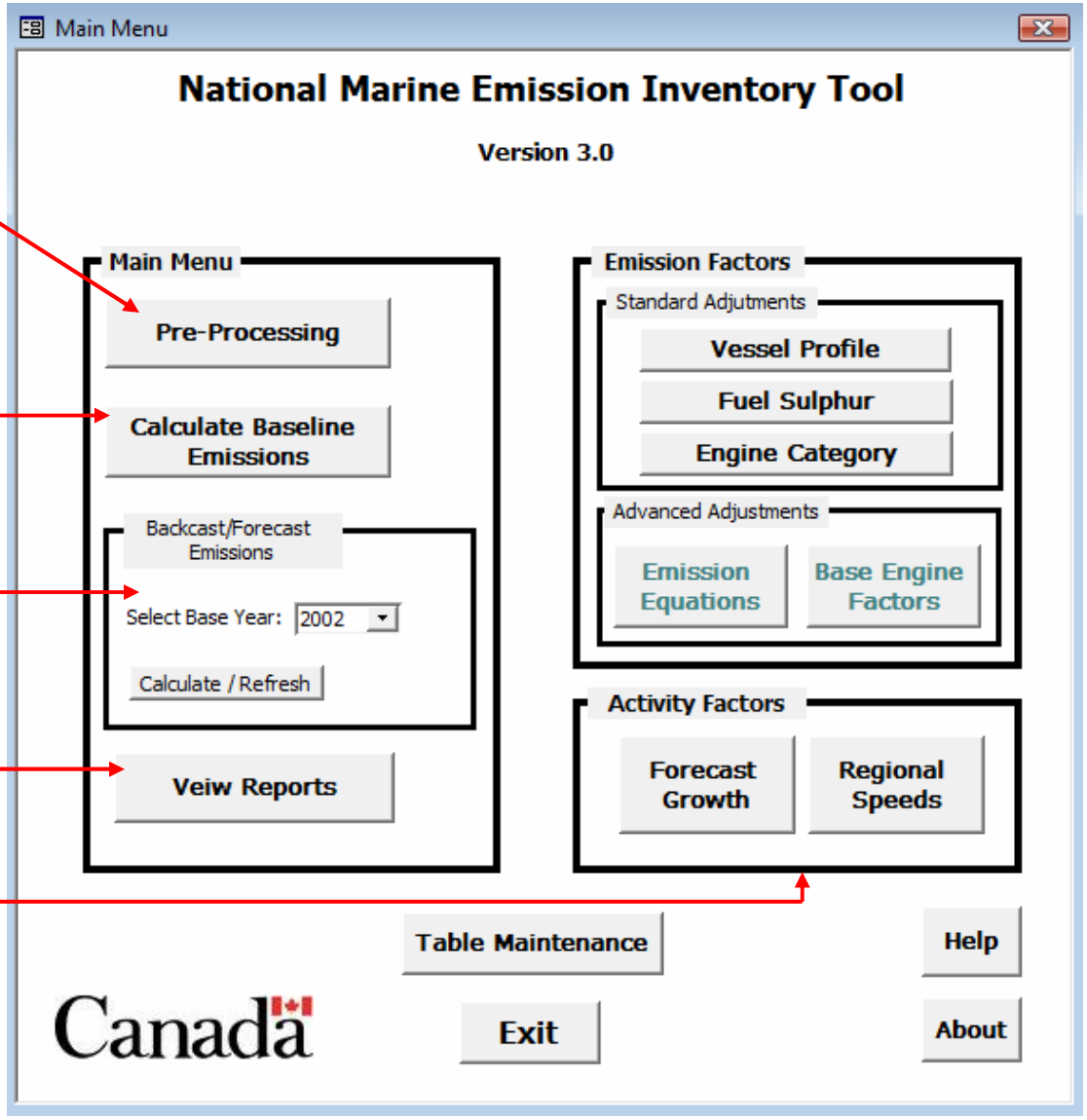
1. Pre-Processing: scan input records, data validation, error checking, flag rejected records

2. Calculate emissions by individual vessel movement

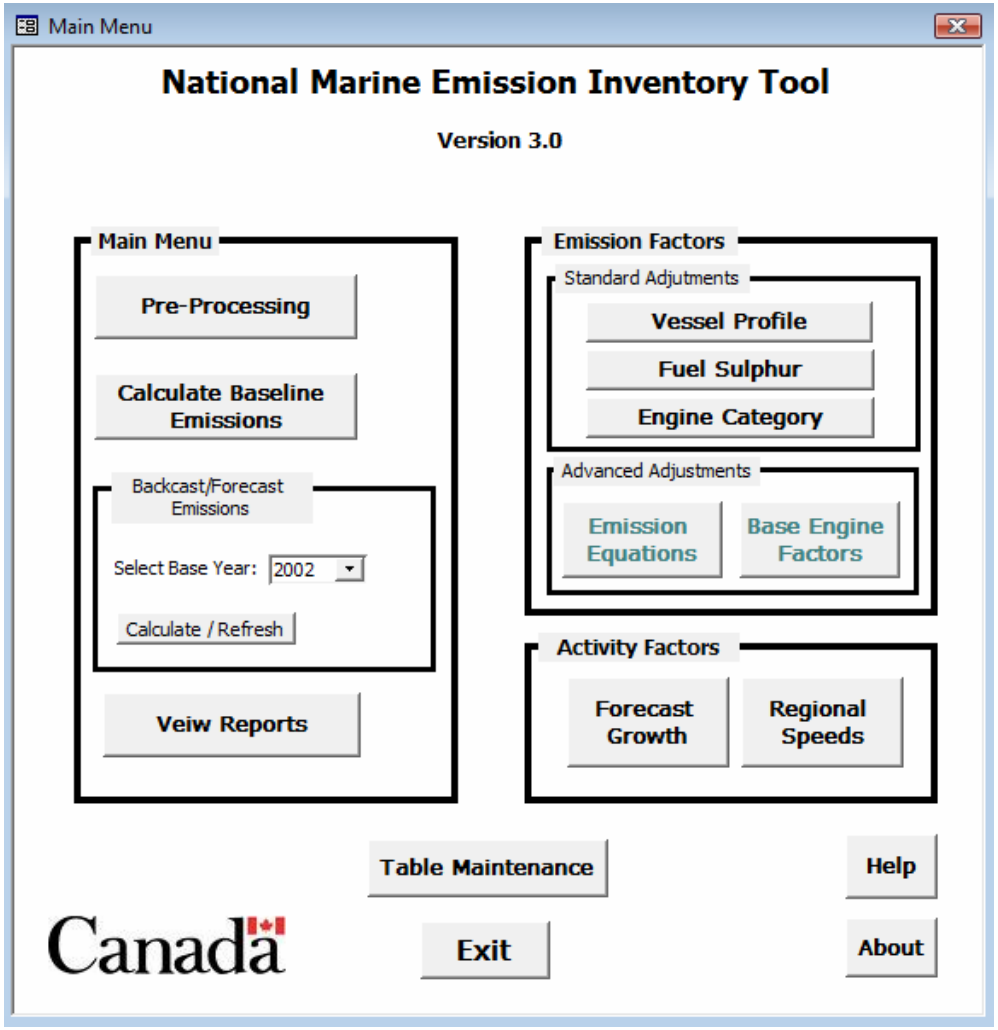
3. Generate forecasts & backcasts if required

4. View reports in Excel "pivot table" format

Modify parameters: emission factors, fuel sulphur content, etc.



Software Demonstration



Pre-Processing

- Raw Vessel movement data format:
  - Canadian Coast Guard (INNAV)
  - Lloyd's Register

Fill Data Gaps

- If HP is null, estimate based on DWT using EPA regression model
  - If DWT is null, estimate based on GT in TRENDS study
- If Vessel speed is null, look up default value if available
- If insufficient data is available to estimate above values, the record is rejected and flagged in the reject table

Range Checks

- 0 < HP < 2 x Max Value in database
- 0 < DWT < 2 x Max Value in database
- 0 < Speed < 2 x Max Value in database

Emission Factors

- Unlike diesel engines in trucks and land-based equipment, very few ocean-going vessel engines have been tested for developing emissions factors
- ICF report for the EPA described emissions factors for OGVs as “the weakest link in deep sea vessel emission inventories” (ICF, 2005) because factors continue to be derived from limited data
- Emission testing of OGVs is expensive and difficult undertaking, therefore emissions data are relatively rare

Emission Factors

- Emission factor sources:
  - *Quantification of Emissions from Ships Associated with Ship Movements Between Ports in the European Community*, Entec UK Ltd (2002)
  - *Emissions Estimation Methodology for Ocean-Going Vessels*, California Air Resources Board (CARB),October 2005
  - *Marine Emission Factor and Inventory Study*,Transport Canada, March 2007, report pending http://www.tc.gc.ca/innovation/tdc/projects/marine/g/5673.htm

Case Study 1

Marine Emission Inventory Study
Eastern Canada and Great Lakes

Transportation Development Centre (TDC)

Levelton, Dr. J. Corbett, Maritime Innovation
March 2006

http://www.tc.gc.ca/innovation/tdc/summary/14500/14564e.htm

Marine Emission Inventory Study Eastern Canada and Great Lakes

A regional emission inventory was prepared for commercial ocean-going marine vessels operating on the Great Lakes, the St. Lawrence Seaway, and the East Coast of Canada in 2002:

1. Development of a detailed inventory of emissions of air contaminants and CO_2 by mode of operation using activity-based information from the Canadian Coast Guard INNAV database using the MEIT.
2. Preparation of a baseline emission forecast for 2010 and 2020, allowing for growth in vessel traffic and changes in engine technology and the sulphur content of domestic marine diesel oil.
3. Preparation of an emission forecast for SO_x and PM in 2010 and 2020 that incorporates the emission reductions that could potentially occur by implementation of a Sulphur Emission Control Area (SECA) under Annex VI of MARPOL 73/78 of the IMO.
4. Spatial resolution of the emission inventory to regional polygons and then to 4 km by 4 km grid cells for use in regional air quality modeling studies.

Marine Emission Inventory Study Eastern Canada and Great Lakes

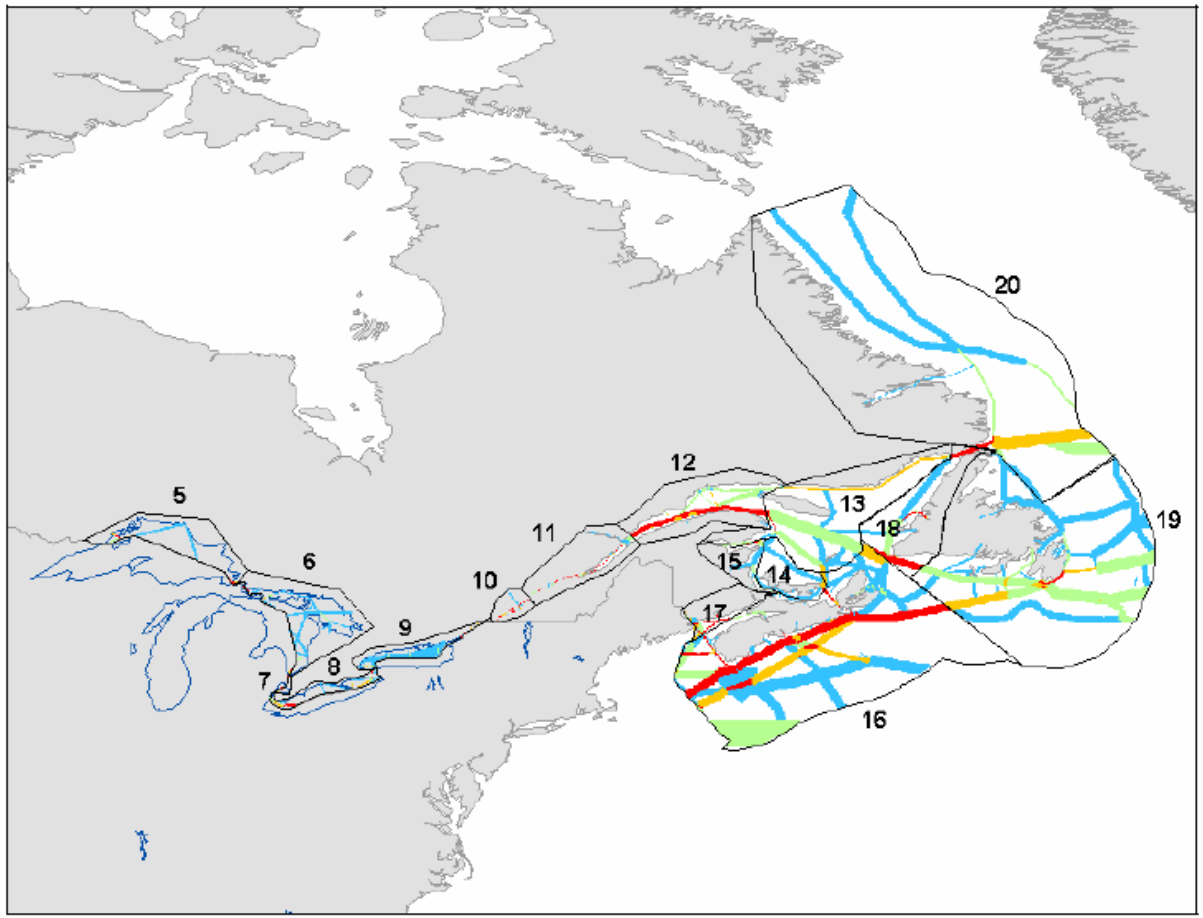
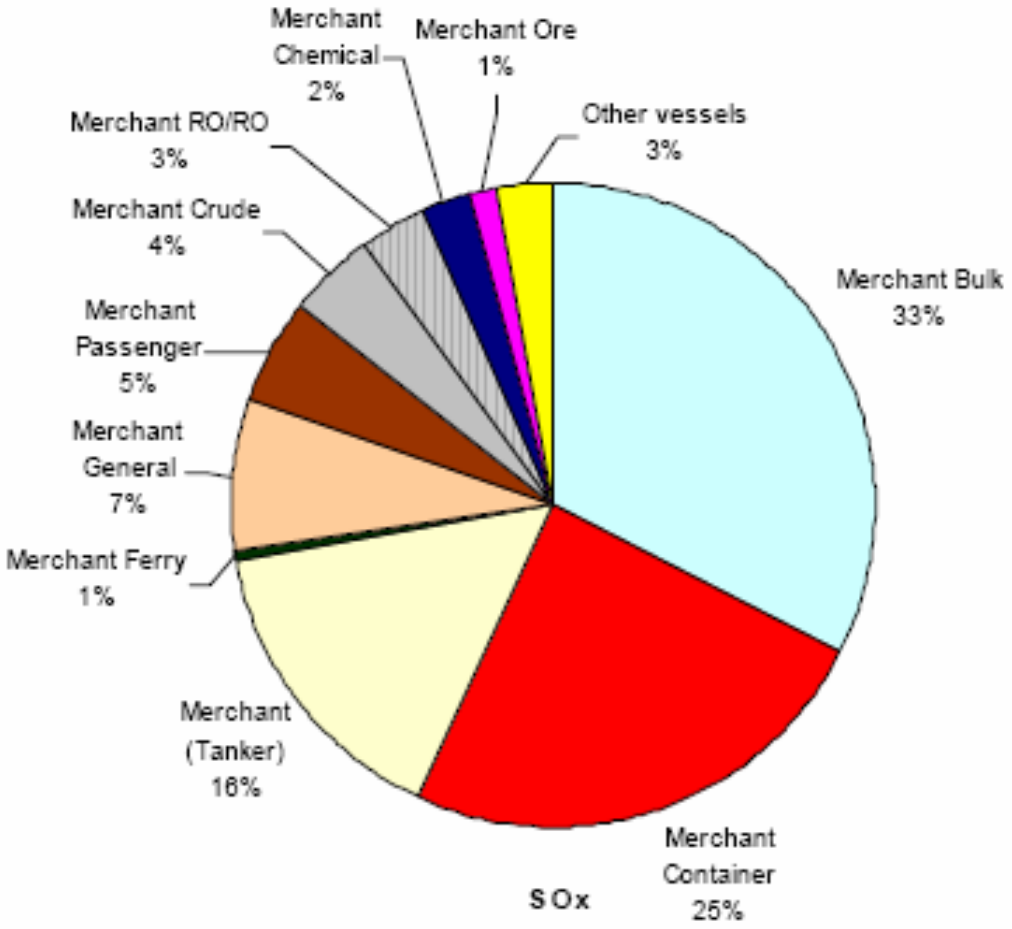


Figure 6-3 Study Area Regions and Empirical Shipping Lanes

Marine Emission Inventory Study
Eastern Canada and Great Lakes



Case Study 2

Sulphur Emission Control Area (SECA), Engine Control Technologies and Emission Standards

Transportation Development Centre (TDC)

Levelton, ClearSky Engineering, Genesis Engineering

May 2008

SECA, Engine Control Technologies and Emission Standards

Evaluation of the feasibility of a SECA designation for Canada through analyses of technology options available to the marine sector:

1. Additional evaluation of the feasibility of a SECA region in Canada; Refinement of the marine emissions inventory for SO_x and particulate matter (PM);
2. Examination of technical barriers associated with fuel switching and fuel blending;
3. Determination and assessment of developing technologies for the reduction of NO_x;
4. Evaluation of benefits associated with the implementation or promulgation of emissions standards for EPA Engine 'Categories 1', 'Category 2' and 'Category 3'; and
5. Update and expand the MEIT.

SECA, Engine Control Technologies and Emission Standards

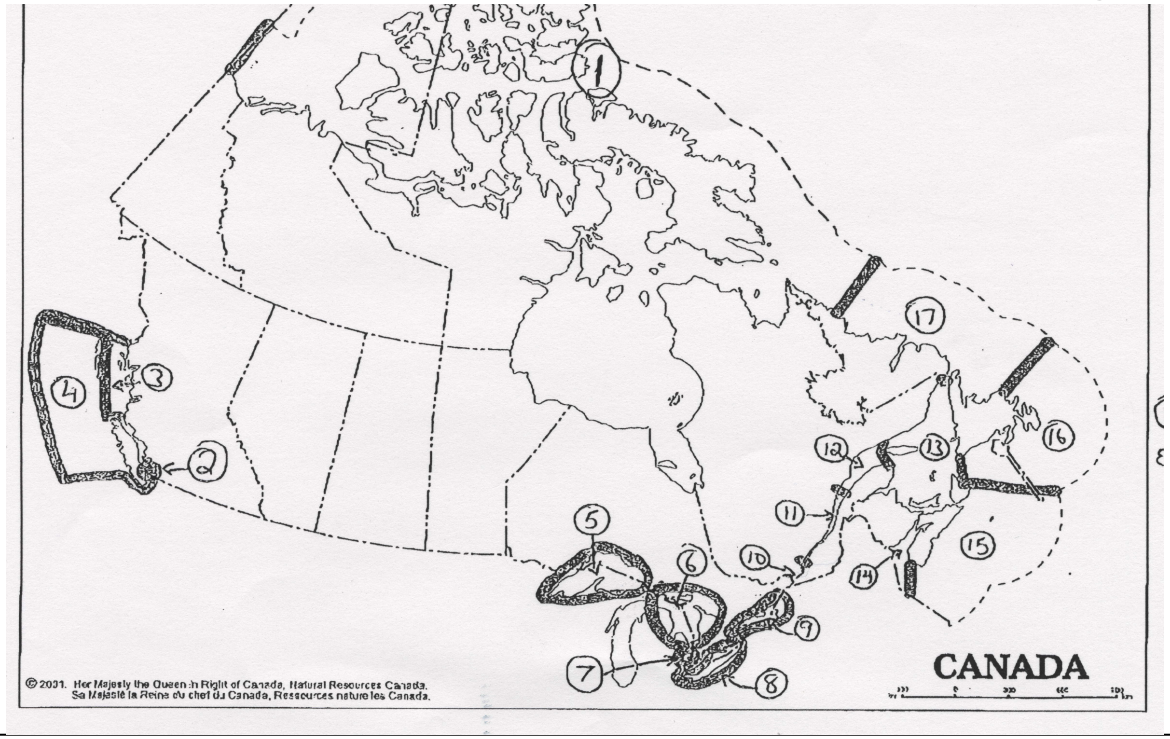
MEIT used to model 3 SECA scenarios based on an assumed limit of sulphur content in fuel of 1,000 ppm (0.1%), 5,000 ppm (0.5%), and 10,000 ppm (1.0%)

Fuel Type	Source	Sulphur Content (wt%) Scenarios				Percent Change from Baseline		
		Baseline	10,000 ppm limit	5,000 ppm limit	1,000 ppm limit	10,000 ppm limit	5,000 ppm limit	1,000 ppm Limit
HFO	Domestic	1.5	1	0.5	0.1	-33	-67	-93
HFO	International	2.7	1	0.5	0.1	-63	-81	-96
MDO	Domestic	1	1	0.5	0.1	0	-50	-90
MDO	International	1	1	0.5	0.1	0	-50	-90
MGO	Domestic	0.17	0.17	0.17	0.1	0	0	-41
MGO	International	0.2	0.2	0.2	0.1	0	0	-50

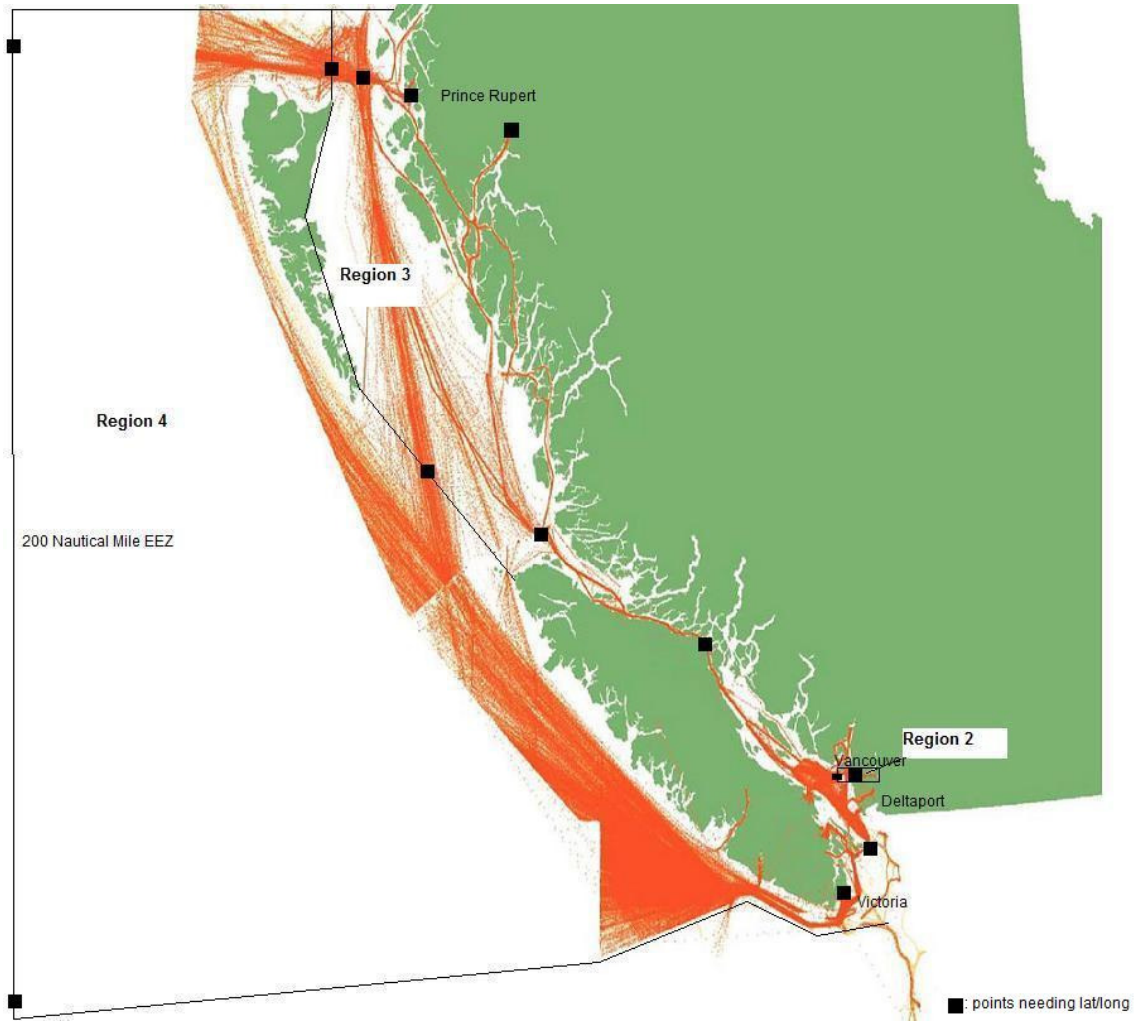
SECA, Engine Control Technologies and Emission Standards

Update and Expansion of the MEIT:

1. Updated to accept multiple years of vessel data and calculate emission forecast/backcasts yearly from 1980 to 2030
2. West coast marine vessel traffic allocated to modelling regions:



SECA, Engine Control Technologies and Emission Standards



Source: (VTOSS, Chamber of Shipping, 2007)

SECA, Engine Control Technologies and Emission Standards

Update and Expansion of the MEIT (cont.):

3. Expanded MEIT's GHG emission estimation capabilities to include CO_2e, CH_4, and N_2O based on emission factors from Environment Canada's National Inventory Report, 2008 submission
4. Fuel consumption report was expanded to show fuel quality, domestic & international fuel proportion based on each fuel type
5. Marine vessel engines categorized based on the US EPA definition:

Category	Rated Power	Displacement per Cylinder
C1	≥ 37 kW	< 5 litres
C2		≥ 5 and < 30 litres
C3		≥ 30 litres

Future Enhancements

- update GHG emission factors based on new data from Environment Canada GHG Division
- add “lock” to database tables when running 'pre-processing' and 'calculate emissions' steps
- Forecasting: modify to use actual data when base year data is available in database (ex 2002, 2003, 2004) instead of growth factors
- add an interpolate/extrapolate function to fill gaps and project forward and backward

Future Enhancements (cont.)

- Speed up long processing times by moving away from 'record by record' approach to batch updates
- investigate reducing size of 'Emissions' table (5.9 million rows), eliminate data columns based on pivot table reporting needs
- migrate existing VBA code to SQL Server stored procedures to take advantage of server's superior performance (RAM, CPU, disk)

Exercise 1

Your boss has to make a presentation this afternoon and asks you to run the Marine Emission Inventory Tool to estimate emissions for the following scenario:

- Container Ship traffic at the Port of Québec
- NO_x and SO_2 in tonnes
- 2004 base year

Exercise 2

Generate a greenhouse gas emission report for main engines from all vessels operating on Lake Erie while in cruise (underway) mode in January 2004.

Exercise 3

New economic indicators predict significant growth in container vessel shipments by 2030. Use the Marine Emission Inventory Tool to forecast SO_x and $PM_{2.5}$ emissions at a 29% growth rate by 2030.

Wrap Up

Thank-you for your interest.

Questions?

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