Environment Canada Environnement Canada

Canada

# Development of an activity-based marine emissions inventory over the Georgia Basin

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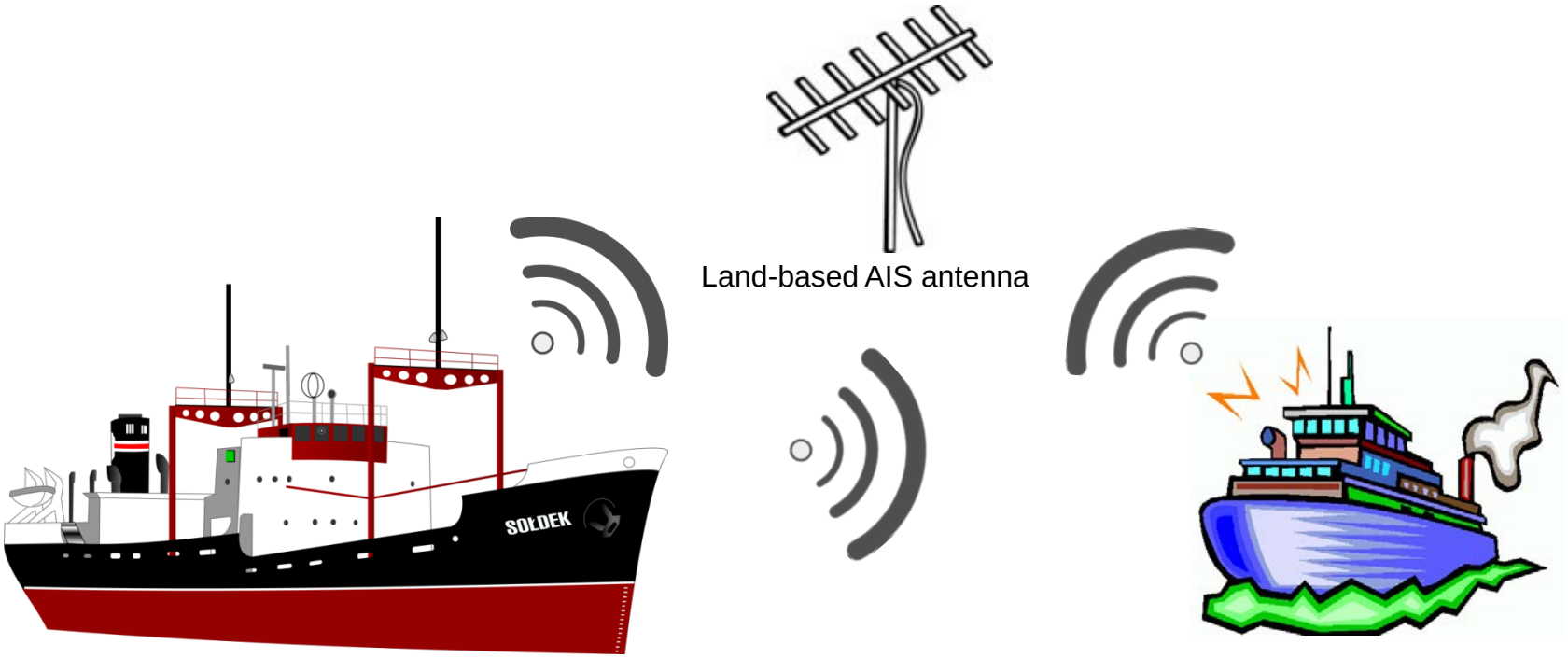
# Motivation

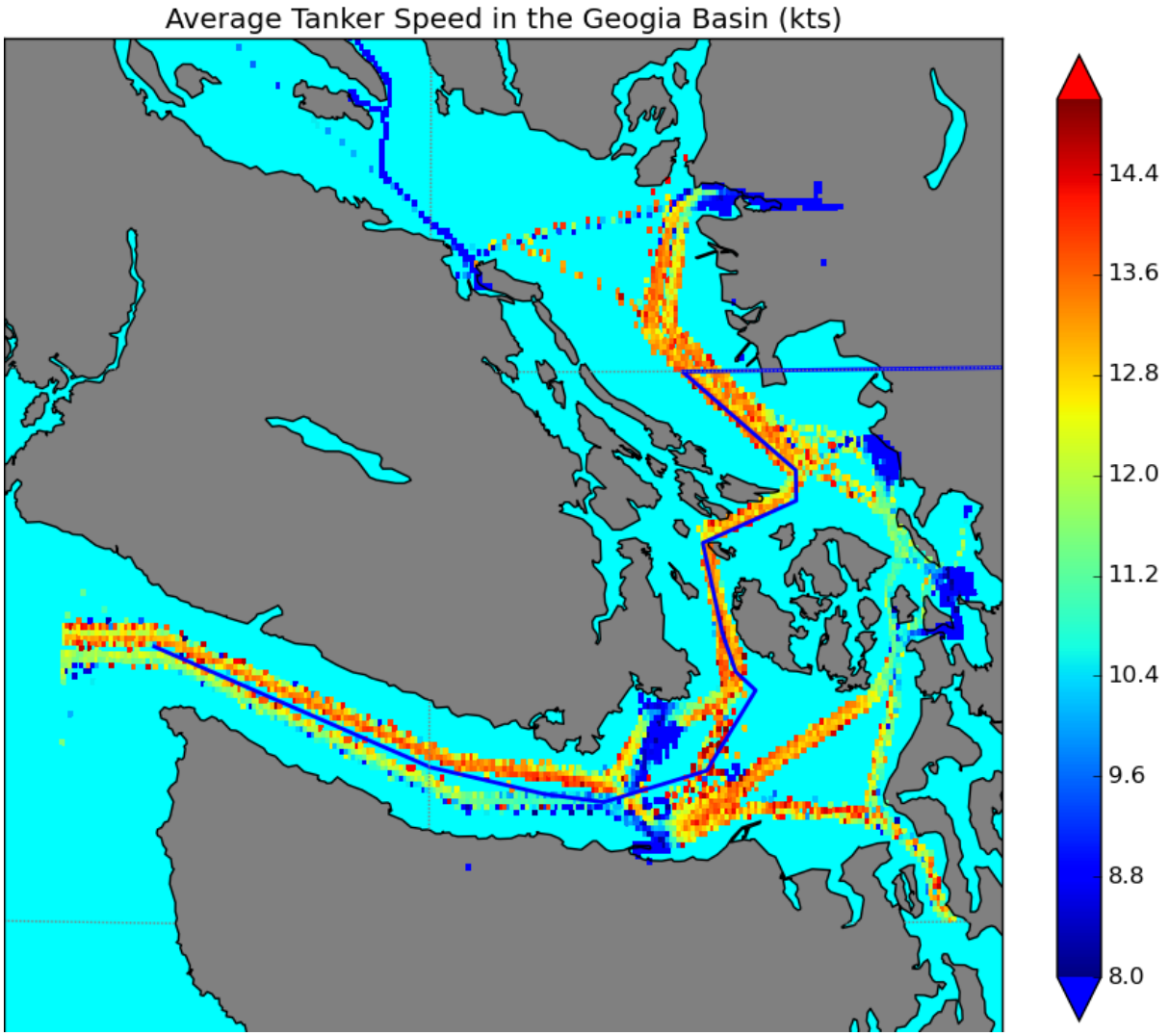
- ECCC supports Canada's efforts to reduce marine air emissions by:
  - Updating and maintaining national marine emissions inventory
- Marine petroleum transport is a source of fugitive VOCs:
  - VOCs generated during loading, offloading of tankers and barges, and to a lesser extent during transit and anchorage.
- Most tankers and many oil barges are equipped with VOC emission control equipment but control of fugitive VOCs from marine transport is not a regulated requirement in Canada.
- Pilot study aimed at:
  1. Testing feasibility of using activity-based methods to calculate marine emissions
  2. Calculating fugitive emissions from petroluem product loading and transit
  3. Calculate impacts of vapour controls regulations on ozone and PM2.5

# Automatic Identification System (AIS)




- AIS used to assist in safe marine movement and allow maritime authorities to track and monitor vessel positions.
- All vessels above 300GT and all passenger vessels are required to have AIS
- Every few minutes a vessel sends out a ‘ping’ giving speed, direction, draught, status

# Advantages of AIS-based inventory




Hydrodynamics shows:
power ~ speed$^3$
And thus emissions:
emissions ~ speed$^2$

Spatial and temporal allocation

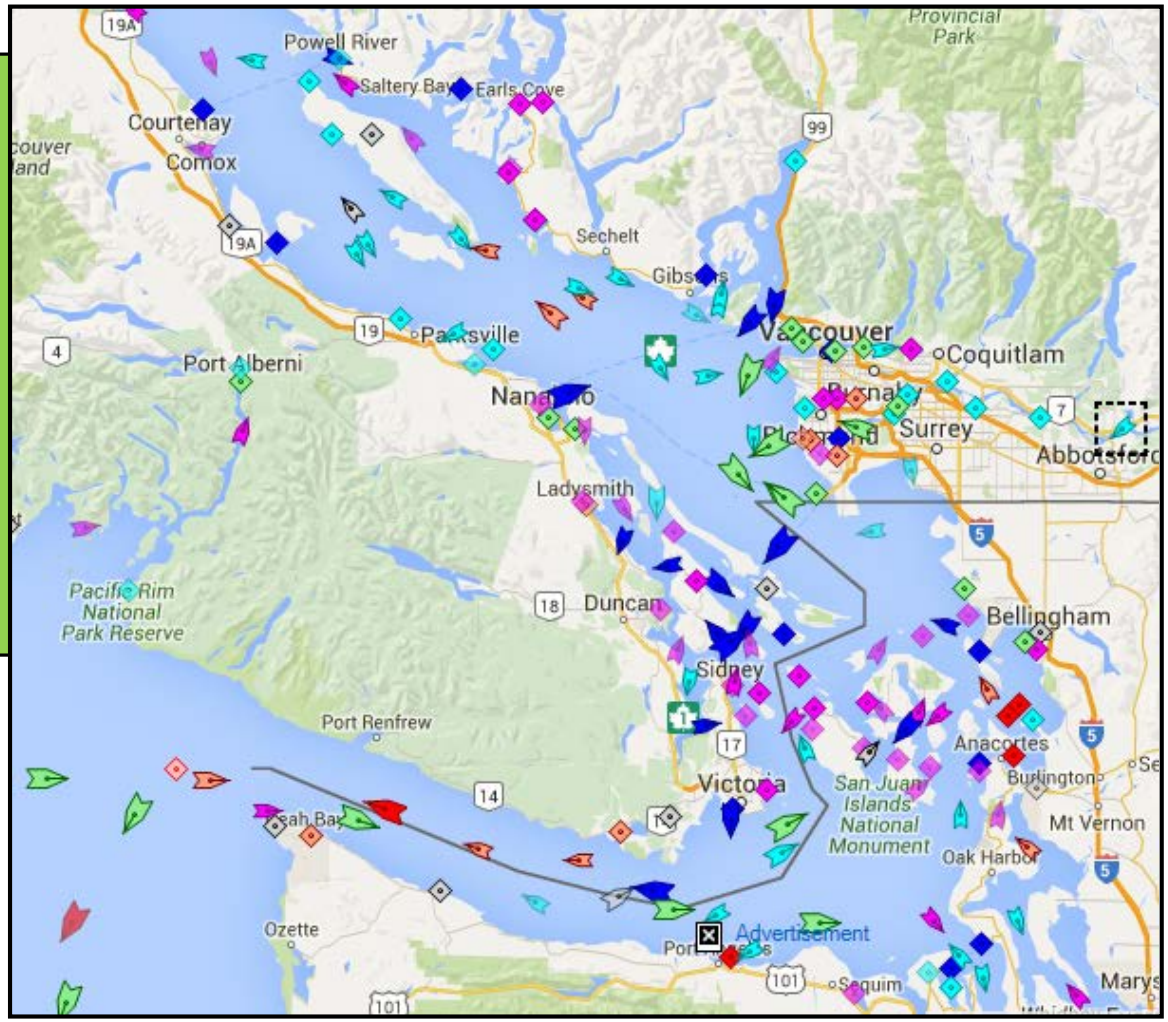
Match movement with exact engine characteristics

# Bottom-up construction of a marine fugitive VOC emission inventory using web-based AIS data

Every 15-minutes, MSC grabs AIS data via a web-based ship tracking website.

~ 11 million separate vessel reports for 2015

Use to construct activity-based emissions based on location, speed, vessel status

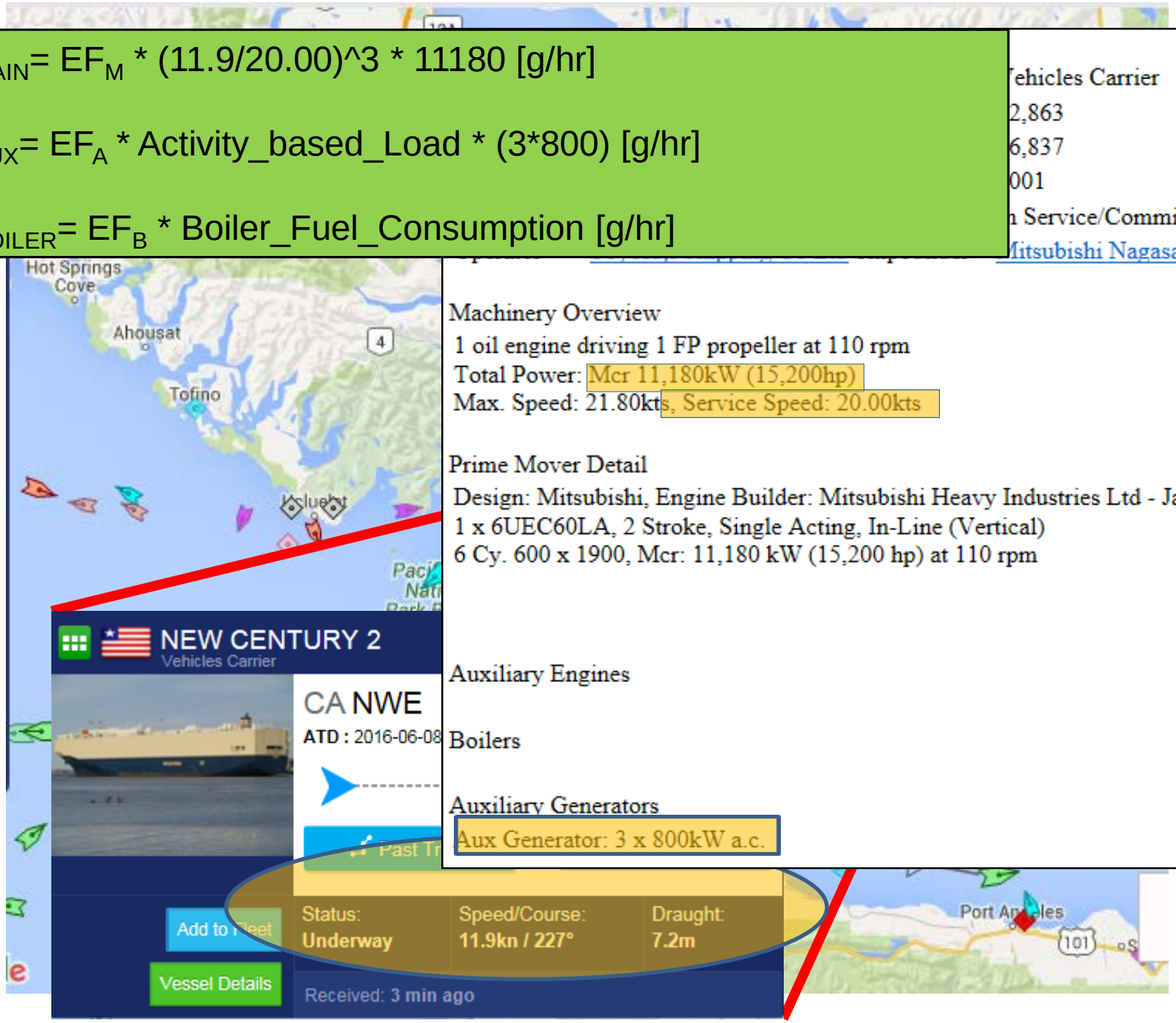



Vessel positions June 8th 1530 from http://www.marinetraffic.com

$E_{MAIN} = EF_M * (11.9/20.00)^3 * 11180$ [g/hr]

$E_{AUX} = EF_A * Activity\_based\_Load * (3*800)$ [g/hr]

$E_{BOILER} = EF_B * Boiler\_Fuel\_Consumption$ [g/hr]




ehicles Carrier
2,863
6,837
001
n Service/Commission
Mitsubishi Nagasaki

Machinery Overview
1 oil engine driving 1 FP propeller at 110 rpm
Total Power: Mcr 11,180kW (15,200hp)
Max. Speed: 21.80kts, Service Speed: 20.00kts

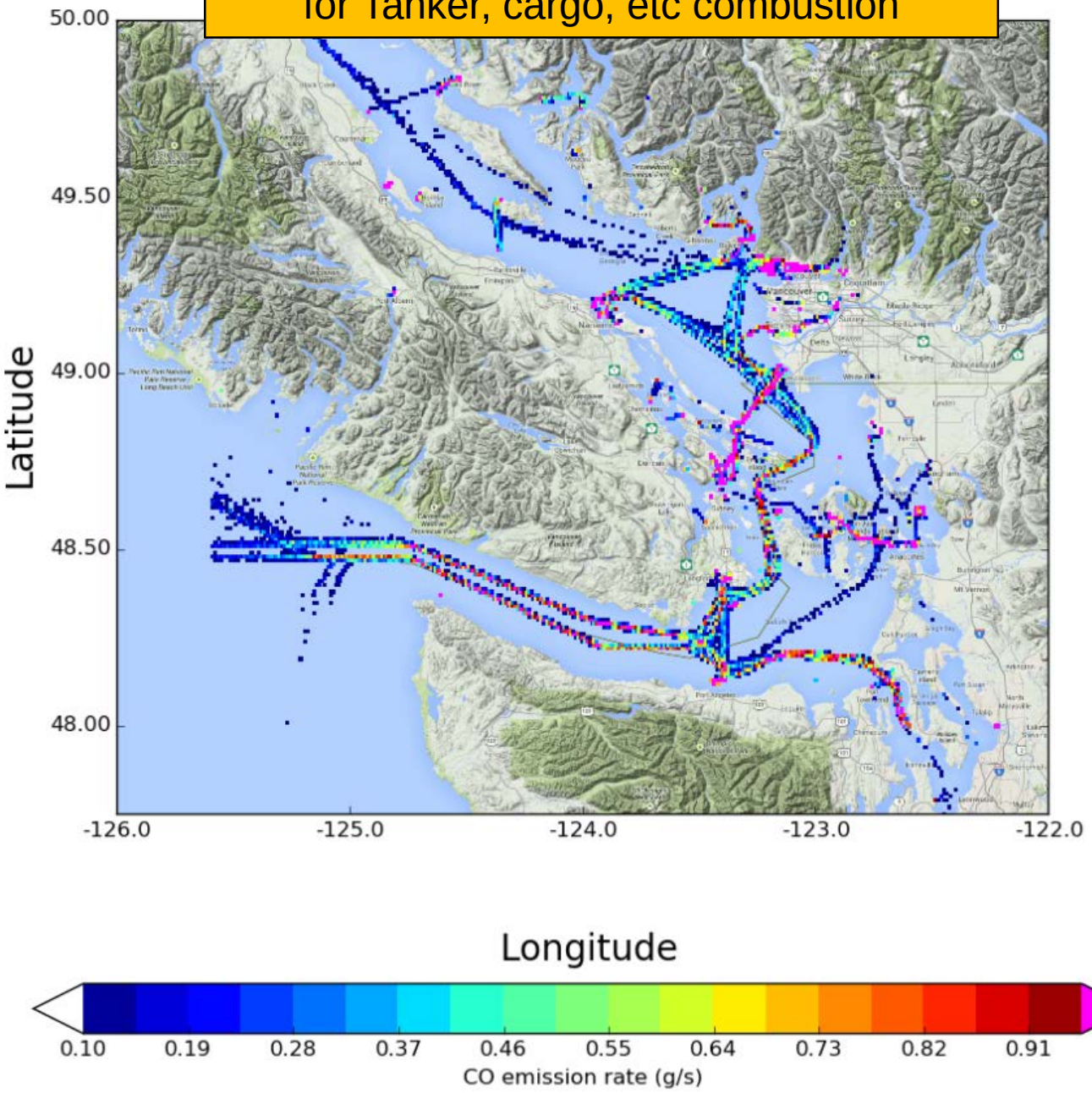
Prime Mover Detail
Design: Mitsubishi, Engine Builder: Mitsubishi Heavy Industries Ltd - Japan
1 x 6UEC60LA, 2 Stroke, Single Acting, In-Line (Vertical)
6 Cy. 600 x 1900, Mcr: 11,180 kW (15,200 hp) at 110 rpm

Auxiliary Engines

Boilers

Auxiliary Generators
Aux Generator: 3 x 800kW a.c.

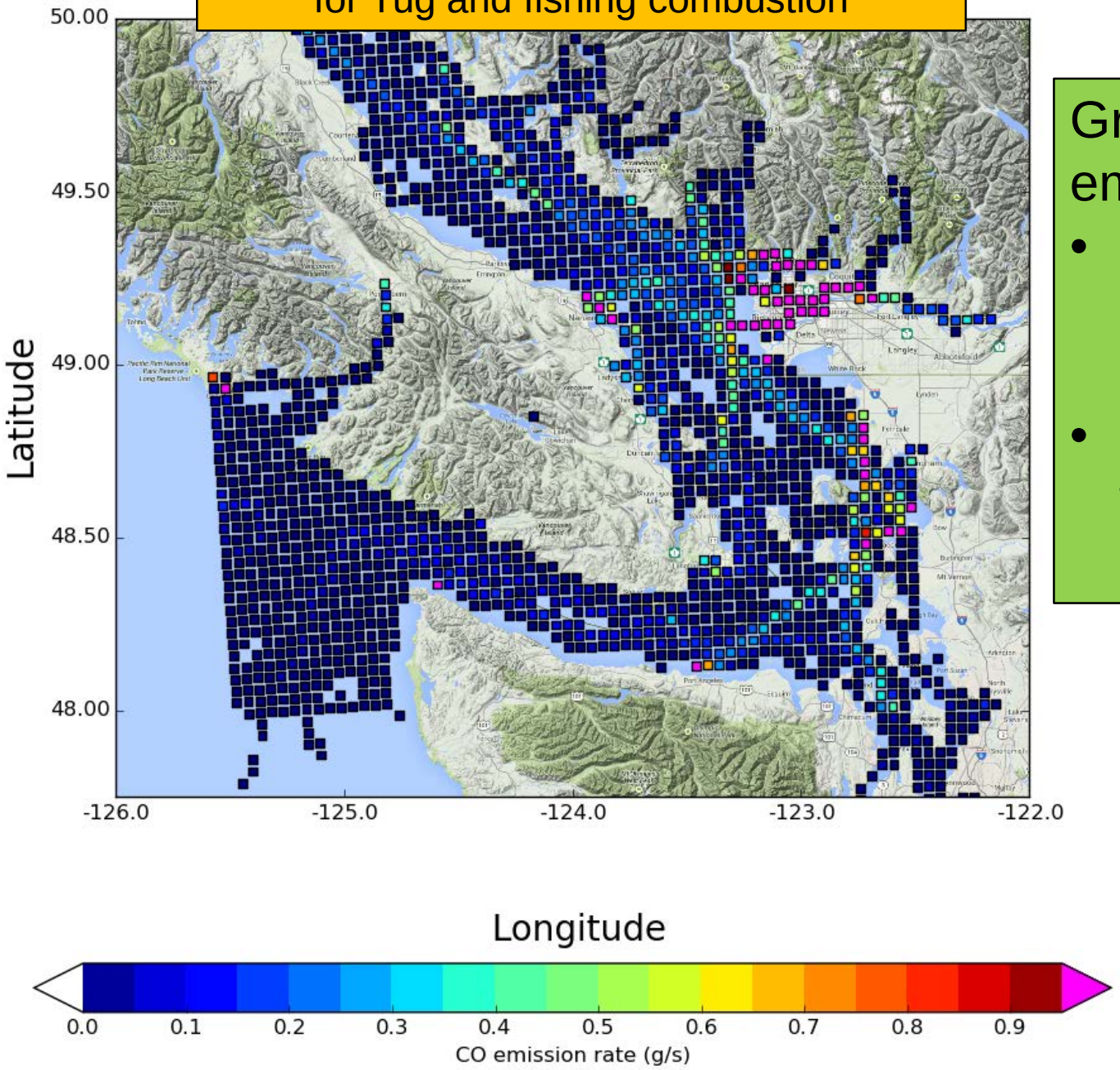
CO Point Emissions as seen by AURAMS for Tanker, cargo, etc combustion




Gridded point emissions for:

- Tanker, cargo, etc combustion emissions
- Loading emissions

# CO Area Emissions as seen by AURAMS for Tug and fishing combustion




Gridded area emissions for:

- Tug and fishing boat combustion emissions
- Fugitive transit tanker and barge emissions

# BCF Fuel Consumption -Horseshoe Bay & Departure Bay

BRITISH COLUMBIA FERRY SERVICES INC.
FUEL ROUTE CONSUMPTION/ JUNE 2008

| SHIP | DAYS NOT IN SERV | DAYS IN SERV | LITRES OF FUEL CONSUMED TOTAL | NOT IN SRV MDO/ STBY | NOT IN SRV Mtce/ Lay-up | NOT IN SRV Move | NOT IN SRV Refit/ Capital | IN SERVICE | VALUE OF FUEL CONSUMED TOTAL | NOT IN SERV | IN SERV | RTE | ROUND TRIPS | CONSUMPTION LITRES PER ROUND TRIP | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| COASTAL RENAISSANCE | 6 | 24 | 804,546 | | | | 13,400 | 791,146 | 880,635 | 14,667 | 865,968 | 2 | 94 | 8,415 | *1 |
| COASTAL INSPIRATION | 15 | 15 | 675,246 | | | | 92,082 | 583,164 | 641,717 | 87,510 | 554,207 | 30 | 60 | 9,719 | *1 |

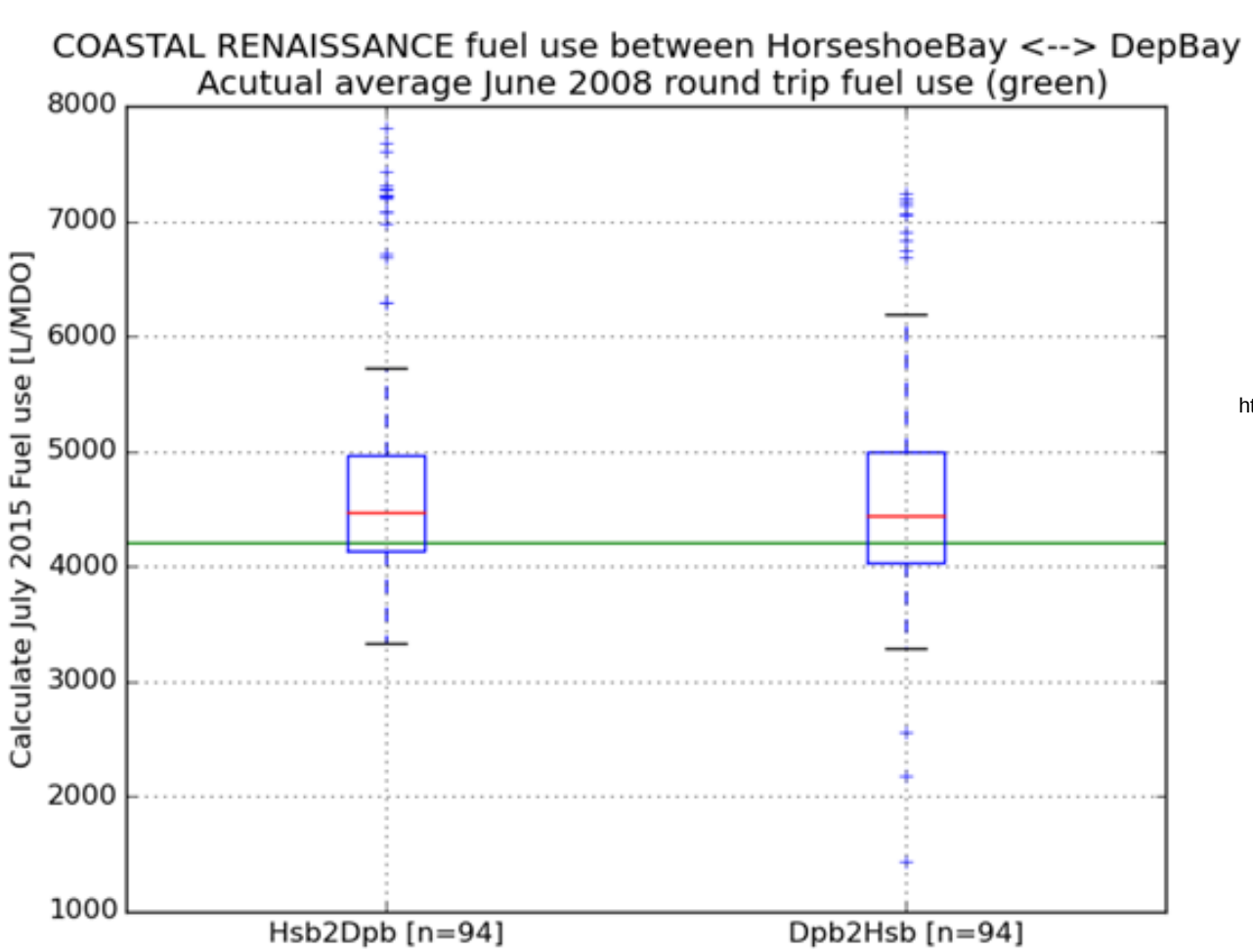
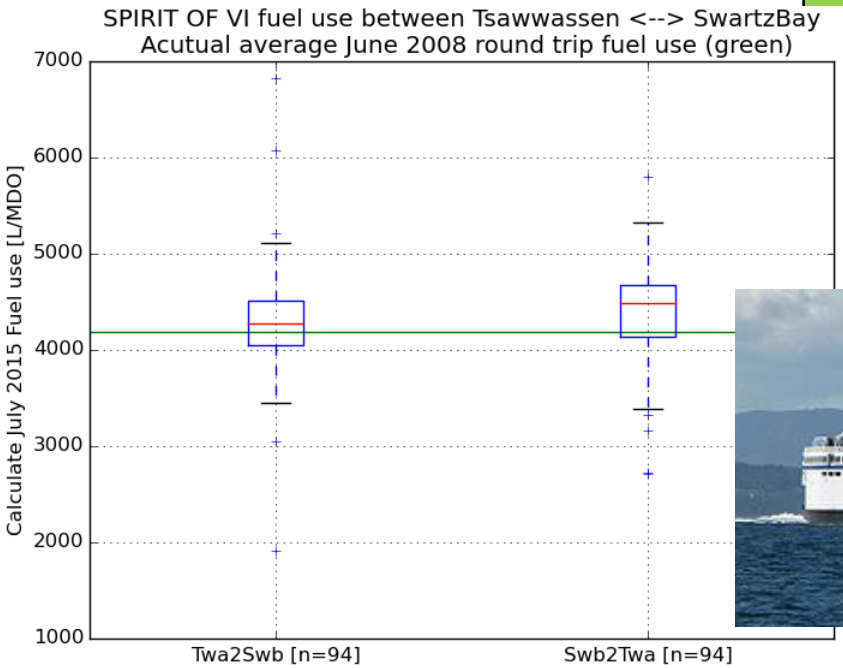




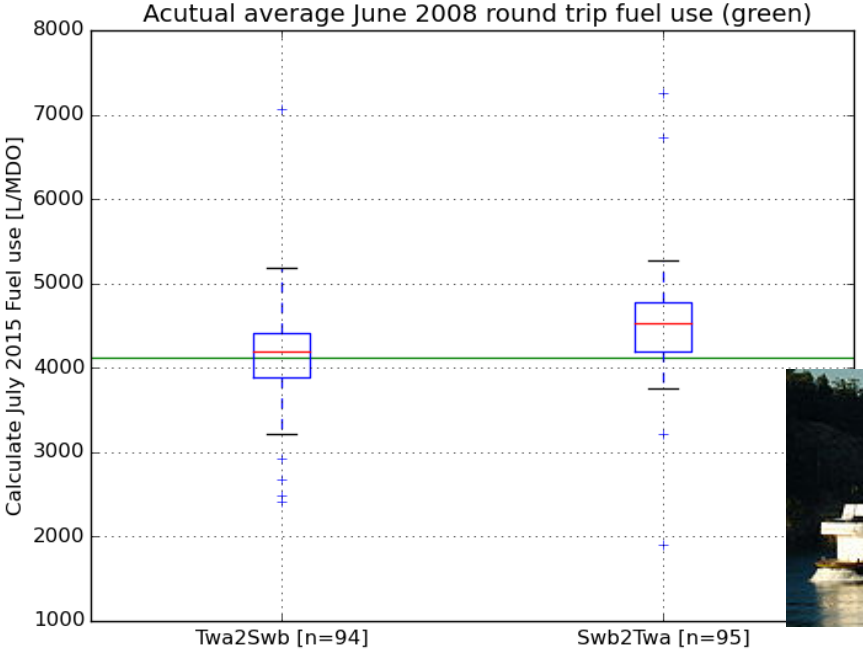
Photo Rogpsro - Own work, CC BY 3.0, https://commons.wikimedia.org/w/index.php?curid=4028443

# BCF Fuel Consumption Tsawwassen & Swartz Bay




https://en.wikipedia.org/wiki/MV_Spirit_of_Vancouver_Island







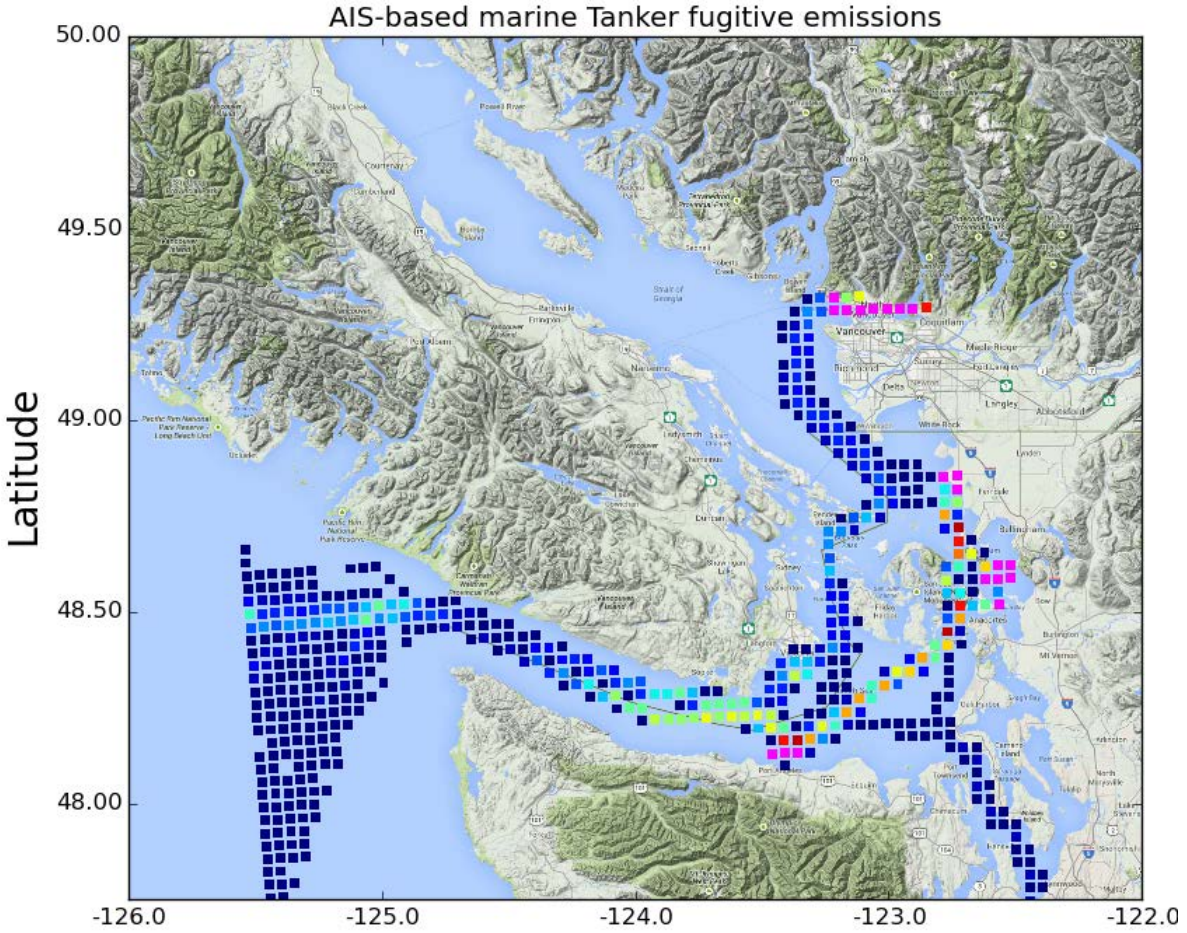
https://en.wikipedia.org/wiki/MV_Spirit_of_British_Columbia

# Fugitive VOC emissions

- Canada has no VOC reduction requirements for marine vessels or ports.
- Current Marine Emission Inventory Tool only accounts for fugitive VOC emissions from crude oil in transit, not for emissions of other petroleum products or barge transport

# Fugitive Transit Emissions - Tankers

- AIS also used to calculate fugitive transit emissions
- For tankers, use change in draught btwn arrival and departure at an oil terminal to estimate volume handled and product loaded




VolumeLoaded = (CB_observed * length * beam * 1.025 * **observed_draught**) - (CB_design * length * beam * 1.025 * design_draught) + dwt

# Fugitive Transit Emissions -Barges


"Island Trader" articulated tanker barge operated by Island Tug on the Pacific Coast, Island Tug website (http://www.islandtug.com).

- Vancouver Island has no deep-sea oil terminal
  → ~ 2 billion litres of fuel must be delivered by barge from Vancouver
- Fugitives from barge movements more difficult to calculate:
  - AIS gives Tug names but not what they are pulling/pushing
  - Cannot use draught to estimate product volumes
  - Barges appear to move products between refineries and fuel farms
  - Uncertain how much bunkering takes place

# Emission Factors - Combustion

- AIS data gives the activity levels needed to construct inventory
- ECCC has also lead a literature review of Marine emissions combustion EFs
- Still in draft form - final report expected later this summer

# Emission Factors - Fugitive

Fugitive emission factors from vessels more difficult to measure

*AP-42 suggests:*

$$EF_T = 0.0145 \times P_v \times \rho$$

$EF_T$ transit loss from ships and barges in transported [mg/L/wk]
Pv is the true vapor pressure of the transported liquid [kPa]
ρ is the density of the condensed vapors in [kg/m3]

EFs strongly dependent on product

| Fluid | Transit Emission Factor (mg/L/wk) |
|---|---|
| Gasoline | 282 |
| Light Crude Oil (Mixed Sweet Blend) | 89 |
| Methanol | 345 |
| Medium Crude Oil (Transmountain Blend) | 46 |
| Heavy Crude Oil (Western Canada Blend) | 31 |
| Jet Fuel (Jet A) | 42 |
| Diesel (No. 2) | 0.61 |
| Fuel Oil (No. 6) | 0.004 |

Depending on product, transit emissions are not insignificant:
E = 100 000 m3 * 1000 L/m3 * 280 mg/L/week * 1/7 week
E ~ 40 tonnes/transit

# Panama Canal: Deck cooling during transit

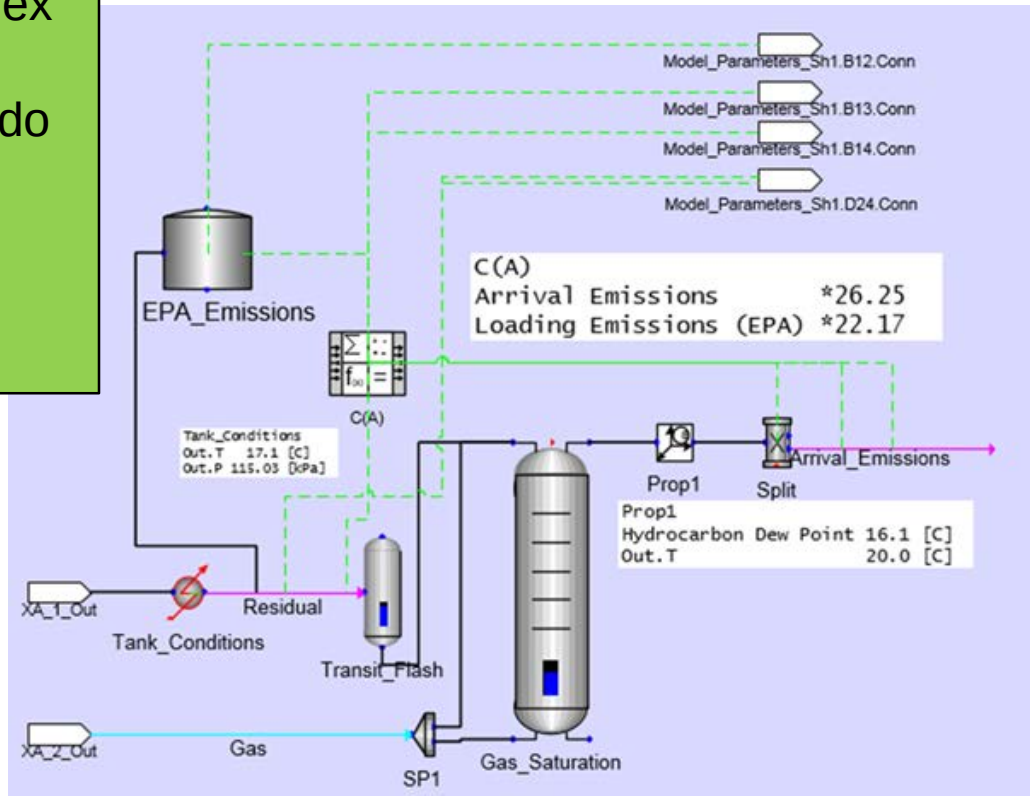
in Alerts 21 January 2016

The Panama Canal Authority will require transiting crude oil tankers, product carriers and chemical tankers carrying cargoes with flashpoints of less than 18°C, to cool their main decks with water by means of the on-deck water sprinkler system or any other means available in order to prevent automatic activation of their pressure relief valves during transit.

http://www.safety4sea.com/panama-canal-deck-cooling-during-transit/

# EF - modeling

- ECCC also interested in updating EFs
- Hired NRC to do some process modeling using VMGsim of tanker operations
- VMGsim, as a process simulator, handle equations of state for complex hydrocarbon mixtures.
- VMGsim creates a number of pseudo components for each volatile liquid and calculates the thermodynamic equilibrium based on these.
- Compare results with AP-42




VMGsim modeling of tanker loading

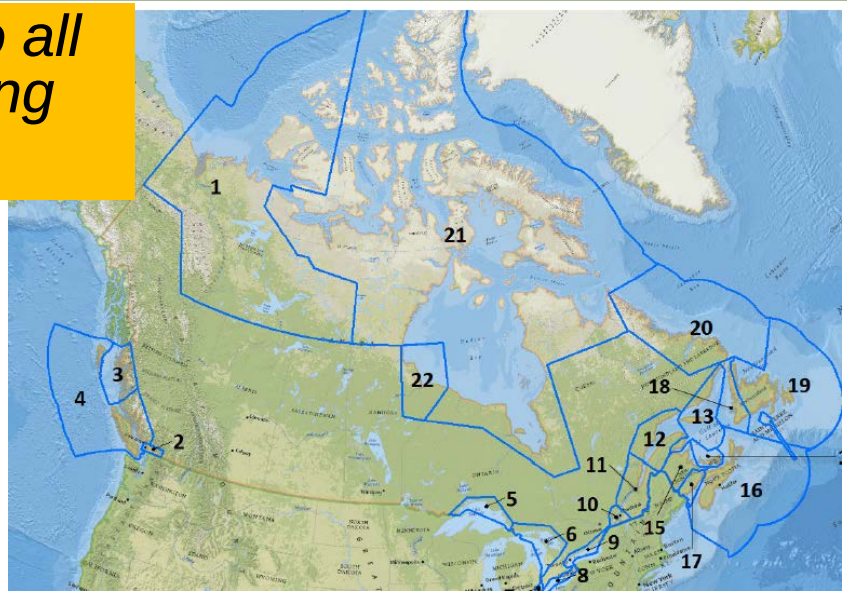
# Fugitive vapour control/capture technologies

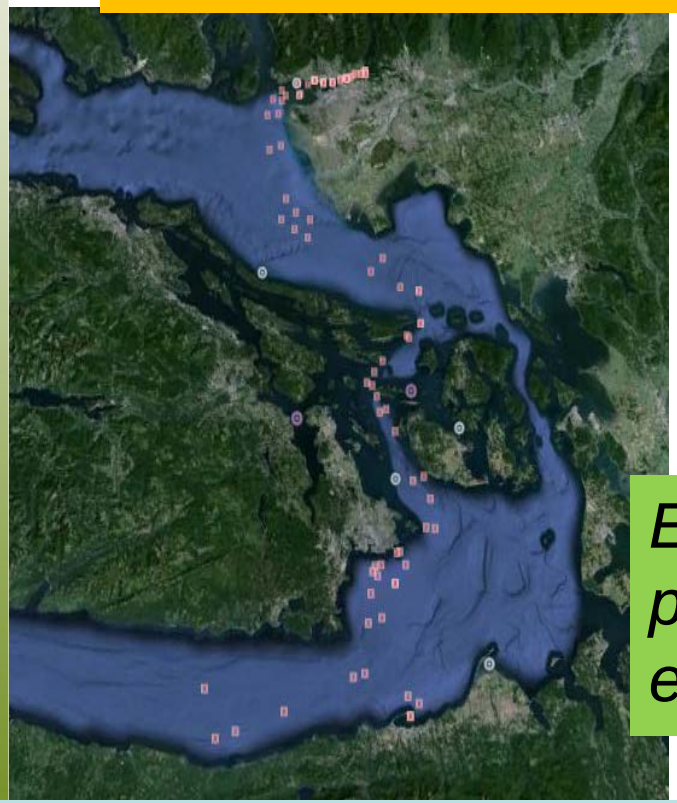
$$M = EF \times V \times (1 - \varepsilon_{cap})$$

- ECCC conducted a survey to evaluate current industry practice for voluntary VOC control at marine terminals in Canada.
- Facility survey indicates 10% of marine terminals in Canada that load petroleum use VOC emission control
  → majority of terminals assuming 0% vapour recovery during marine loading is reasonable.

# Future work – Activity based EI for all of Canada

*Extend AIS-based analysis to all Canadian marine regions using Coast Guard INNAV data*



INNAV data points for the Jasmin Joy Nov 2015

*Essentially AIS-activity data provided at key waypoints along every shipping route in Canada*

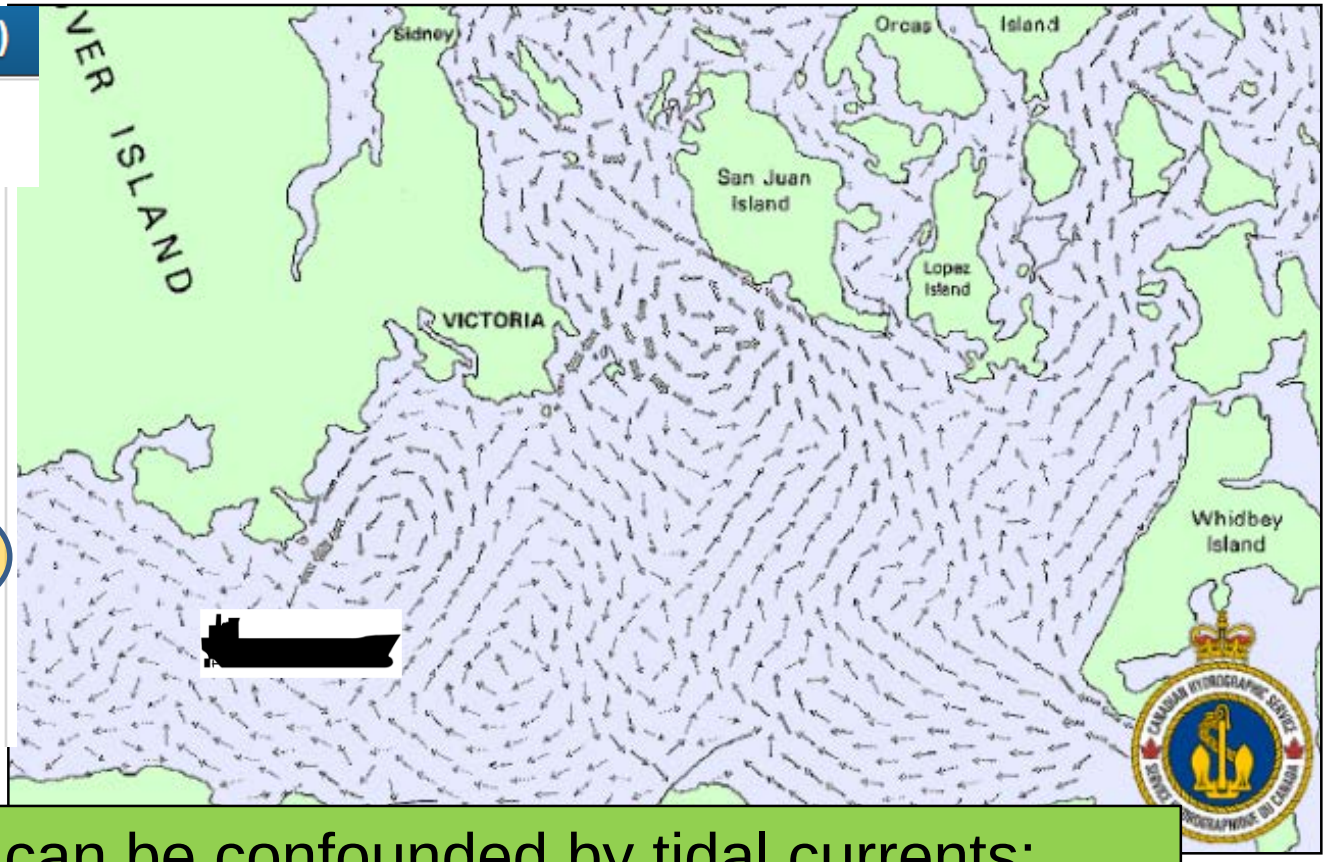
# Future Work – influence of tidal currents

**Juan De Fuca-East (#1100)**

2015 Current Tables
Timezone: PST (Z+8)

August 2015

| Turns | | Maximum | |
|---|---|---|---|
| Day | Time | Time | Knots |
| 1 | 1:04 AM | 2:48 AM | 0.6 |
| 1 | 4:17 AM | 9:09 AM | -3.2 |
| 1 | 12:48 PM | 3:48 PM | 2.7 |




Emission ($E^o$) can be confounded by tidal currents:

- High load @ low speed going against currents ($E+$)
- Low load @ high speed running with currents ($E-$)

$$(E^+ + E^-)/(E^o + E^o) = 1 + 3*(v_c/v_s)^2$$

e.g. $1+3(3.2/14)^2 = 1.16$

# Future Work – AQ modeling

- AQ simulations using this inventory and assuming different VOC capture rates
- Investigate sensitivity of ozone and PM25 to capture efficiency, activity levels and emission factors (maybe)

# Impacts on Ozone – preliminary

- This graphic shows a scenario where 5 tankers are added to baseline activity levels
- 50% VOC recovery assumed for all tankers and barges, and for all activity modes (loading, transit, and anchorage).
- Areas seeing an exceedance of 65 ppb ozone increase with increasing marine petroleum traffic.
- Some of the new exceedance areas are in the heavily populated regions around the Port.