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Reputation Resources Results

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Generating an Hour-By-Hour Model-Ready Marine Emission Inventory

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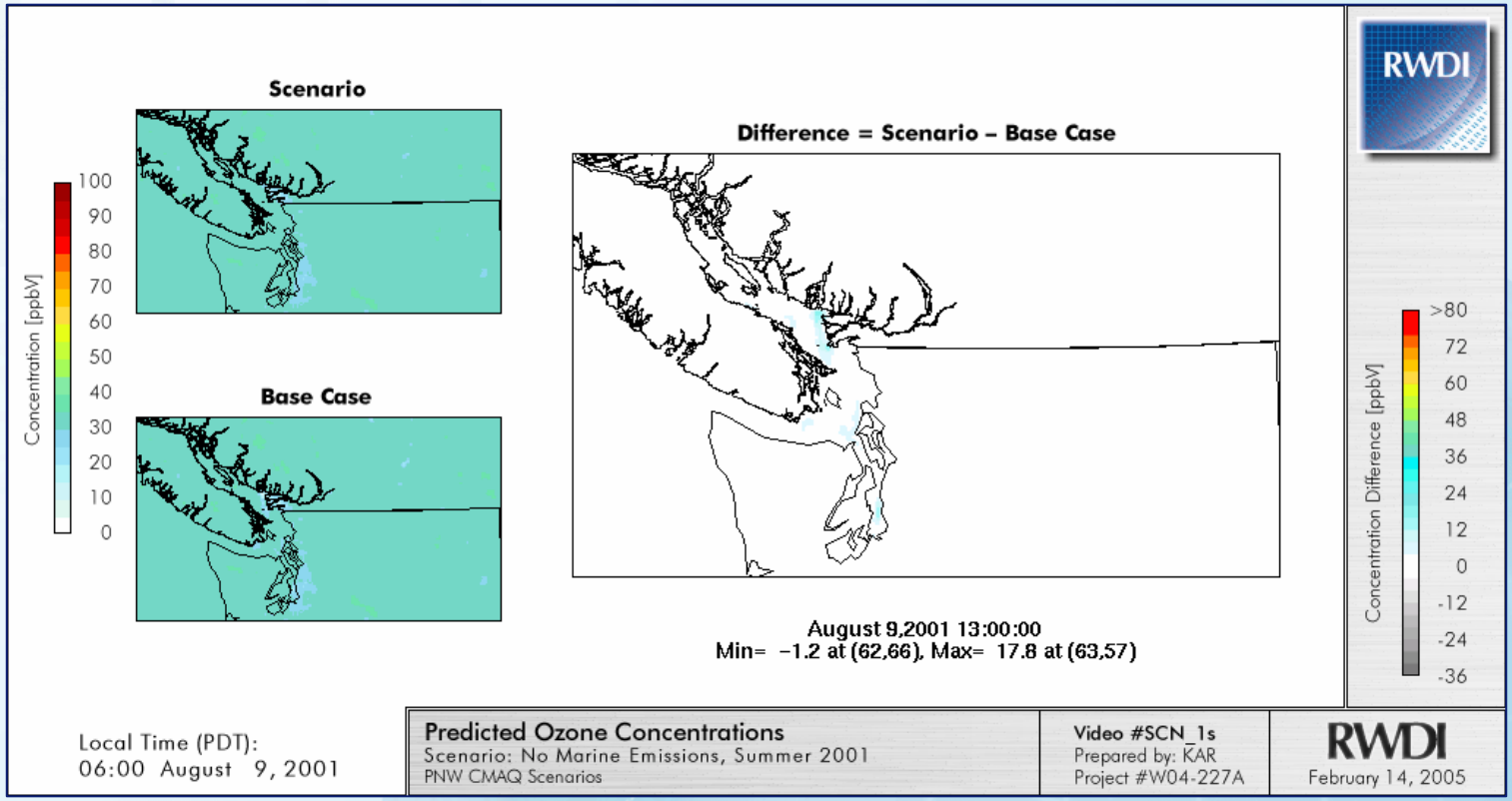
US EPA 17th International Emission Inventory Conference
"Inventory Evolution – Portal to Improved Air Quality"
June 2-5, 2008, Portland, Oregon

Purpose of the Study

1. Quantify impacts of a Sulphur Emission Control Area (SECA) on smog ($PM_{2.5}$, O_3), visibility, acid deposition, etc.
2. Enhance the PNW-CMAQ modelling system



Previous results for O_3 – <u>all</u> marine vessel emissions removed

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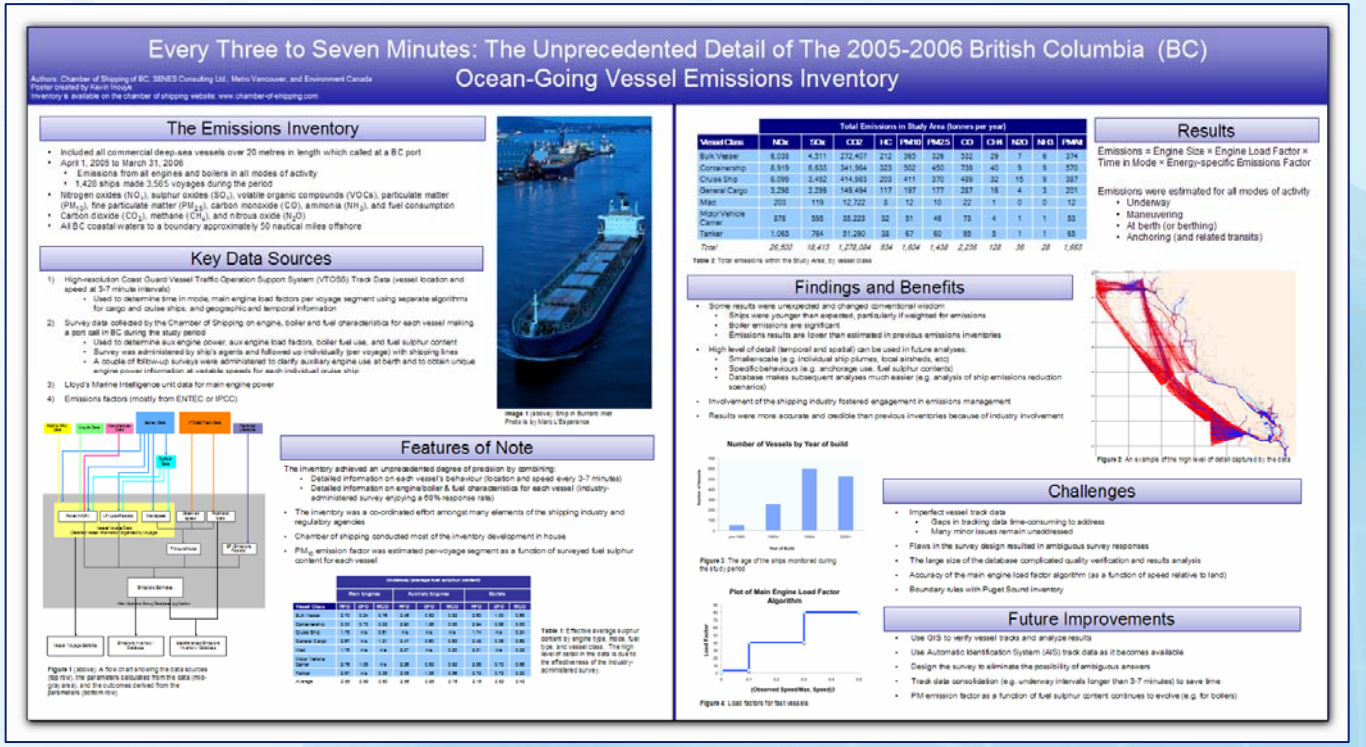
Related Presentation

Session: Innovative EI Development

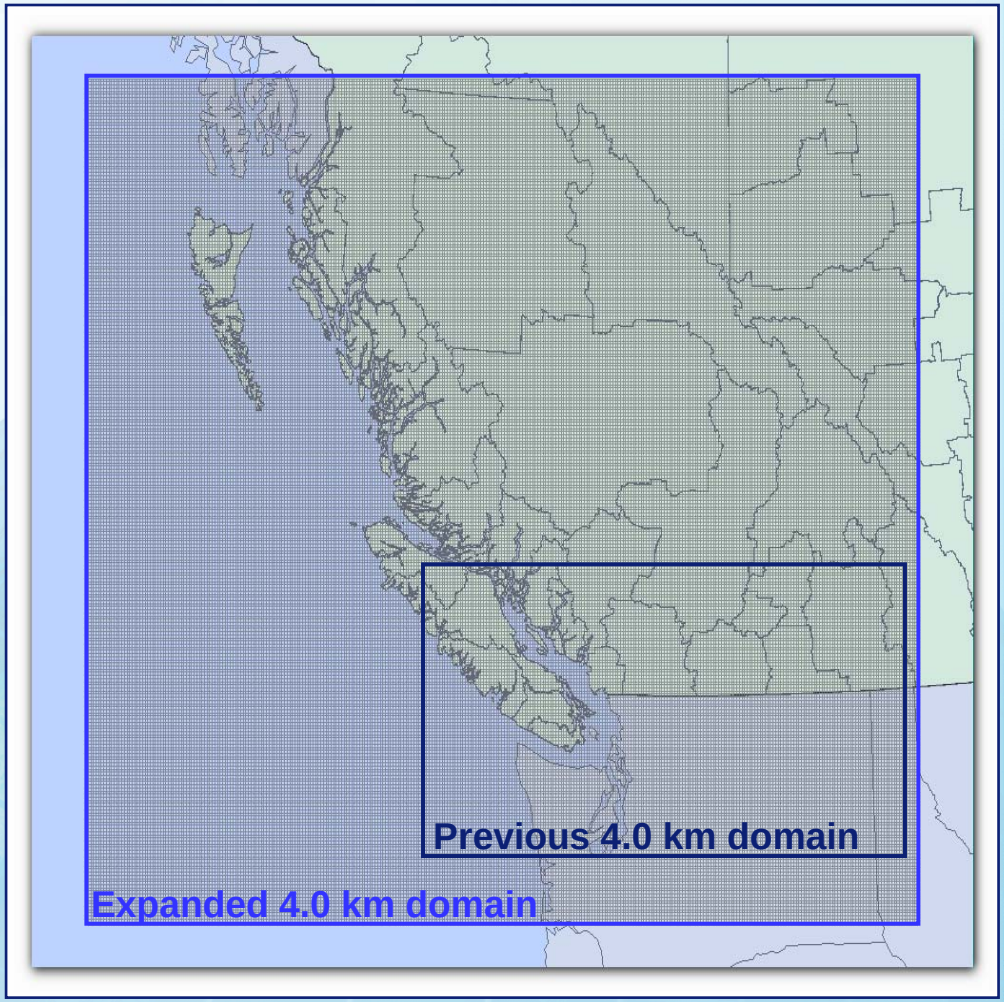
Presenter: Andrew Green (Environment Canada)

Focus: BC Chamber of Shipping (COS) activity data compilation and emission inventory preparation



PNW-CMAQ Model Configuration Meteorology

- Migrated to GEM 2.5 km outputs:
  - Summer (Aug 09-31, 2001)
  - Winter (Dec 01-13, 2002)
- Modified GEM-MCIP
- Domain expanded to ~350,000 km^2 at 4.0 km grid resolution to cover primary shipping routes
- ~87,000 grid cells (~ 7 x more than the US 36 km national domain)



PNW-CMAQ Model Configuration Emissions & Photochemistry

Emissions Processing

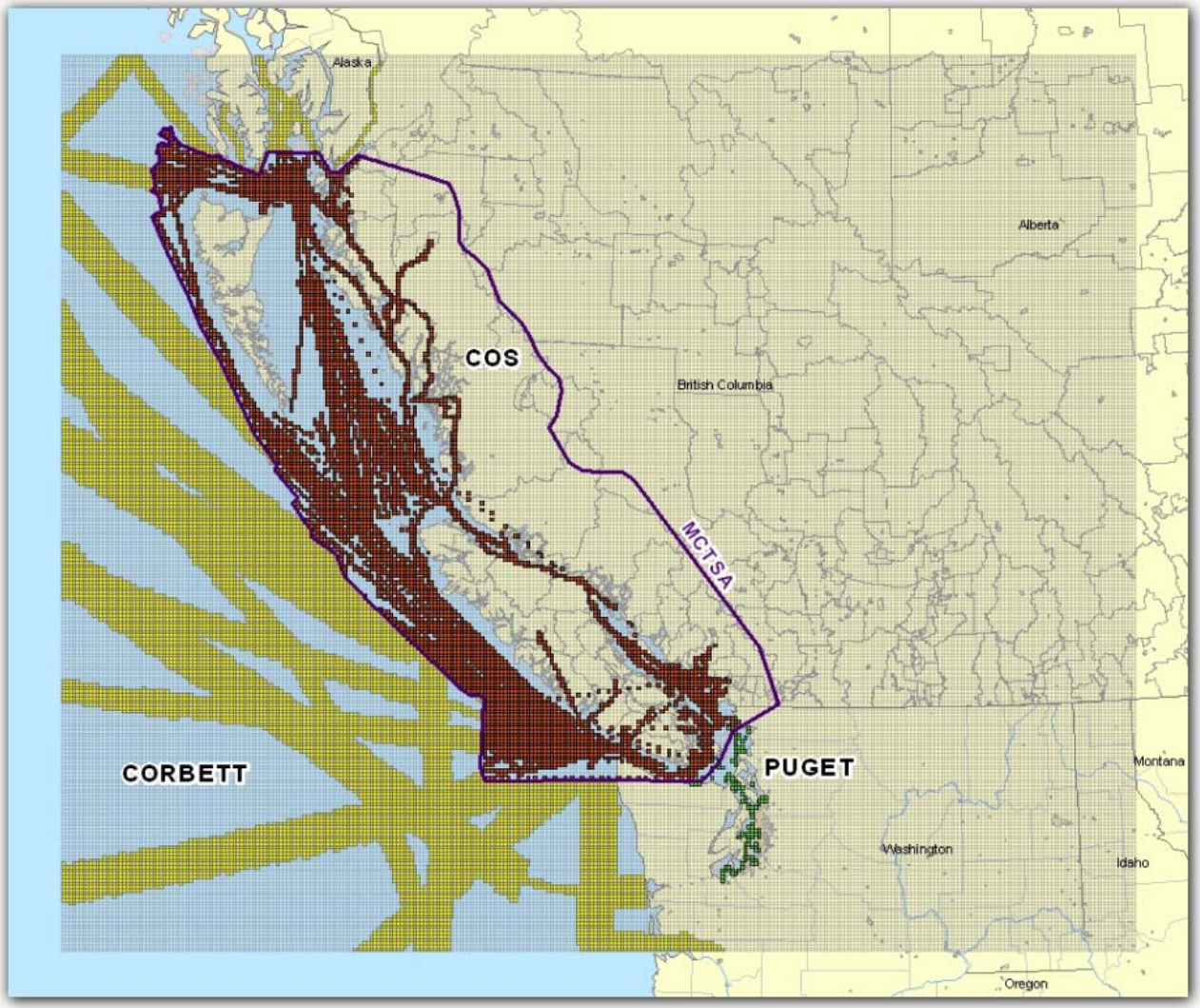
- 2002 US NEI + 2002 Env Can CAC EI base inventories
- Biogenic emissions generated using MEGAN (ver 2.04) with updated land cover data (pre-processed in ArcGIS)
- Migrated from SMOKE version 2.1 to version 2.3
- Spatial surrogates for new domain generated in EIGIS

Chemistry Model

- Migrated from CMAQ version 4.4 to 4.6
- Migrated from SAPRC-99_ae3_aq to SAPRC-99_ae4_aq chemical mechanism with sea salt

Marine Emissions Inventories 2005 Base Year (scaled to 2001)

- CORBETT (gold)
- PUGET (green)
- BC Chamber of Shipping / COS (red)

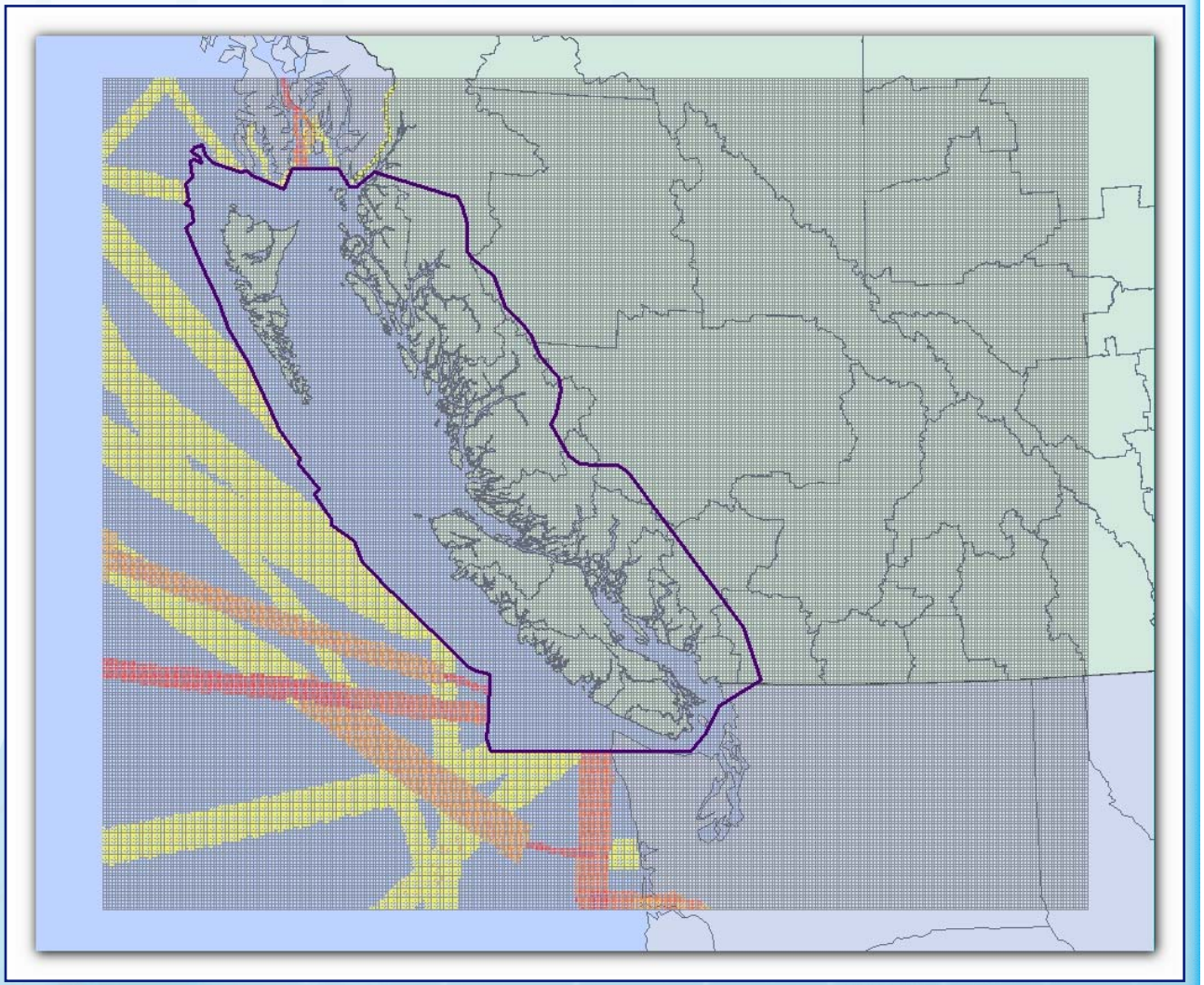


Marine Emissions Inventories
CORBETT Inventory

- Developed by Dr. J. Corbett at the University of Delaware
- Emissions geographically and temporally allocated based on empirical waterway network, historical ship movements, and ship attribute data
- Monthly and annual gridded emissions of SO_X (as SO_2), NO_X, CO_2, PM, HC, and CO
- Interpolated pre-gridded emissions to the PNW-CMAQ 4.0 km model domain and projection
- Exported as annual ORL point source format for SMOKE
- Flat temporal profile (365/24/7) assumed

Marine Emissions Inventories
CORBETT Inventory

Gridded annual SO_X emissions clipped to edge of MCTSA (purple outline)



Marine Emissions Inventories
Puget Inventory

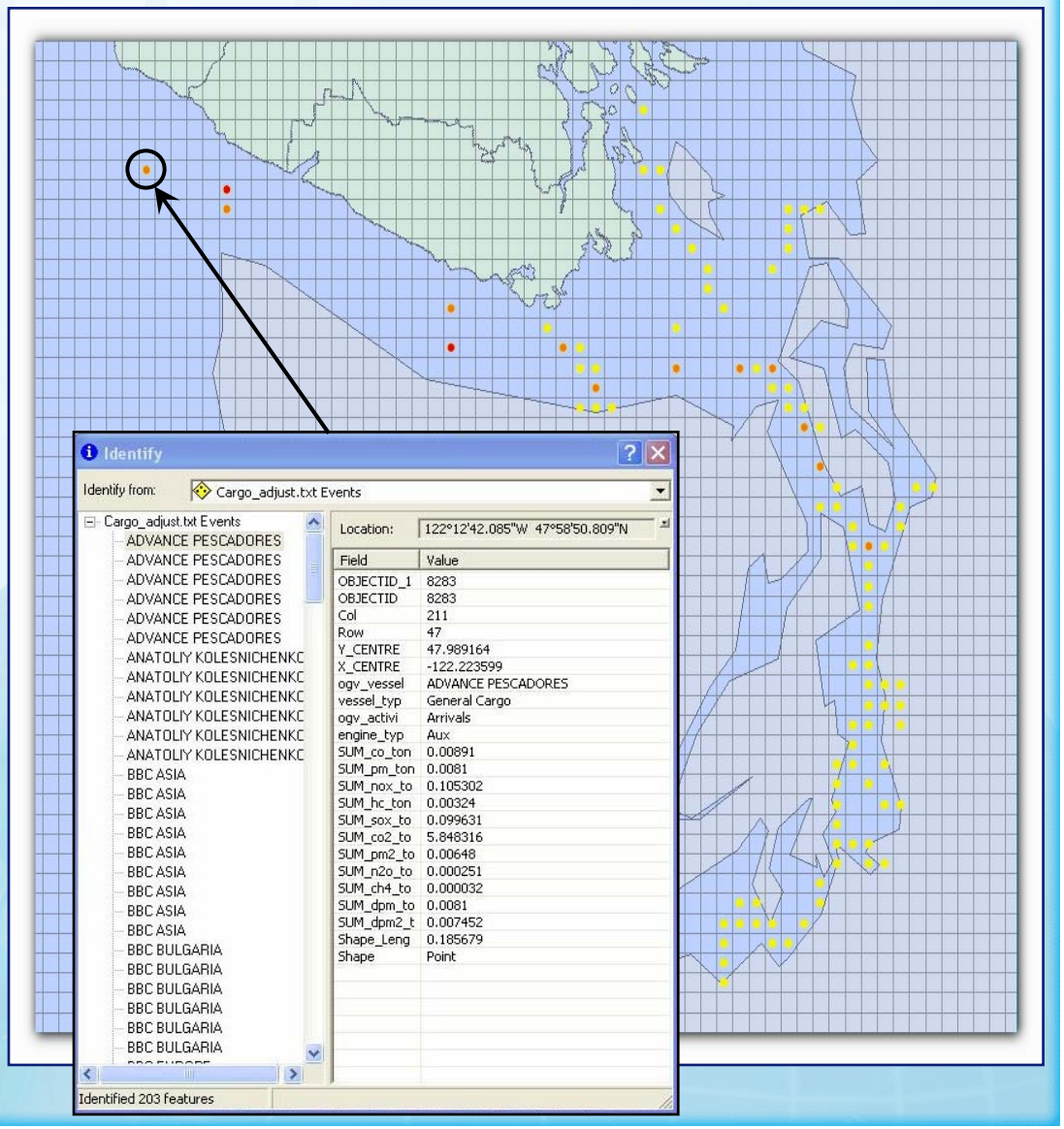
- Developed by Starcrest Consulting Group for Puget Sound Maritime Air Forum
- Emissions by vessel name and coordinate
- Annual emissions SO_X, NO_X, CO, PM, HC, N_2O, CH_4, CO_2
- No timestamps / temporal information
- Common coordinates (i.e., several records per location) resulting in localised “hot-spots”
- Lat/Lon coordinate pairs overlaid onto model grid
- Exported as annual ORL point source format for SMOKE
- Flat temporal profile (365/24/7) assumed

Marine Emissions Inventories
PUGET Inventory

Annual SO_X emissions (raw points)

Few unique locations and large distances between points

Multiple ships on multiple voyages summed into annual emissions over a small number of grid cells



Marine Emissions Inventories Chamber of Shipping (COS)

- Compiled by BC Chamber of Shipping in collaboration with Environment Canada, Greater Vancouver Regional District, and other stakeholders
- All ocean waters within the Marine Communications & Traffic Services Association (MCTSA), ~50 M offshore
- All commercial deep-sea vessels 20 m and longer that called at a BC port from April 1, 2005 to March 31, 2006
- Totals: 1,428 ships comprising 3,565 voyages
- Based on Coast Guard tracking data of vessel location and speed at **3-7 minute intervals!**

Marine Emissions Inventories Chamber of Shipping (COS)

- Vessel tracking data used to compute location, time in mode, main engine load factor per segment travelled, etc.
- Engine loads and emissions computed at terminus of each segment (i.e., destination vertex)
- Vessel surveys for engine, boiler, and fuel characteristics
- Auxiliary engine power and load factors, boiler fuel use, and fuel sulphur content all determined from surveys
- Lloyd's Register used to compute main engine power
- Emissions computed every 3-7 minutes for SO_X, NO, N_2O, VOCs, PM_{10}, $PM_{2.5}$, NH_3, CH_4, CO, and CO_2

Marine Emissions Inventories Chamber of Shipping (COS)

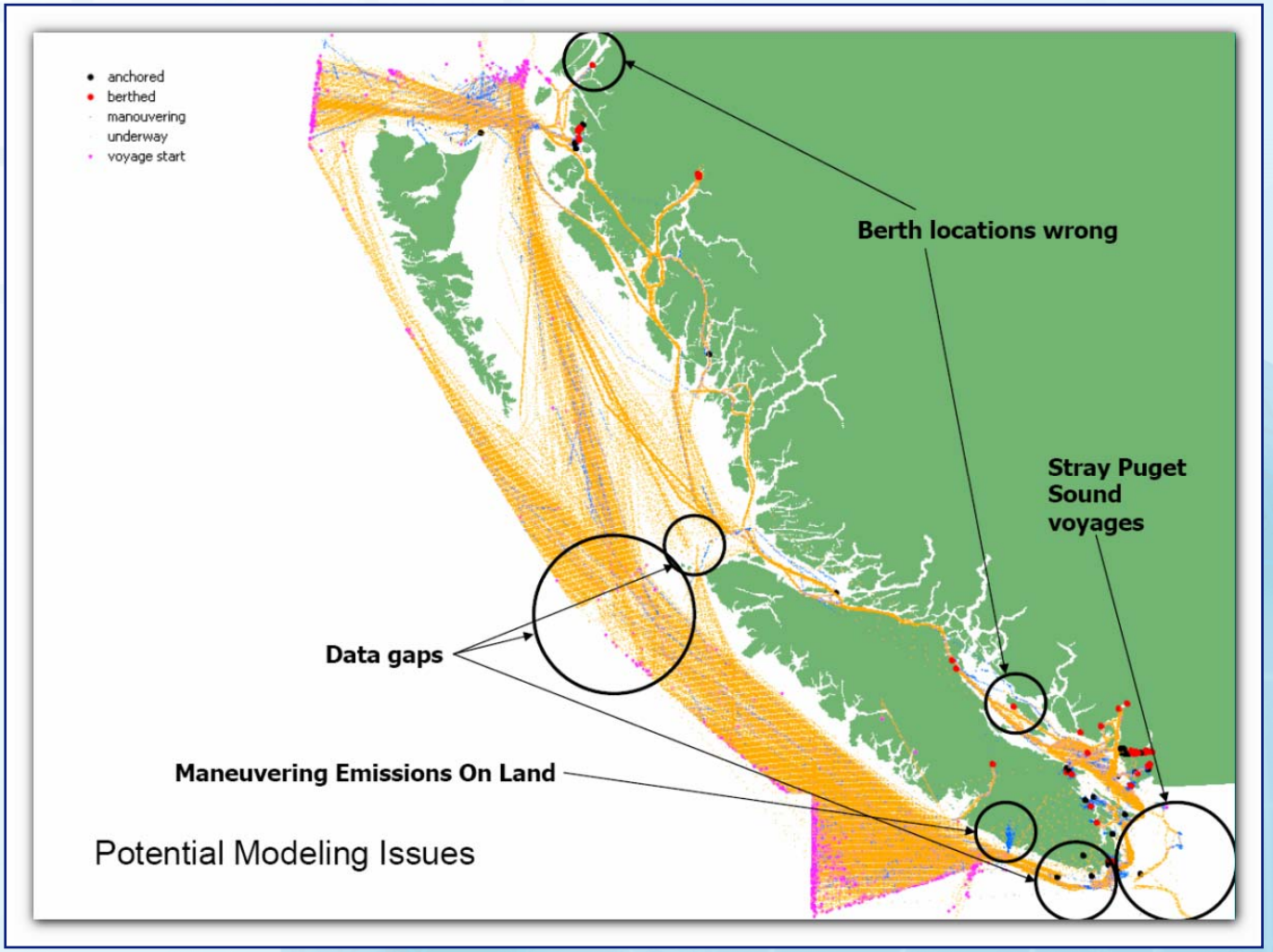
- Raw dataset (4.0+ Gb ASCII file with >4.0 Million elements) imported into SQL Server
- Separate tables created by month and vessel activity
- Migrated into ArcGIS as enterprise geodatabase
- Ship locations overlaid onto model grid
- Emissions summed by grid cell by hour for each Voyage

Marine Emissions Inventories Chamber of Shipping (COS)

- Emission scenario changes (e.g., switch to 0.1% fuel sulphur content within 50 M of shore) unique by:
  - Location
  - Vessel Type / Engine Class
    - Bulk Carrier, Container, Cruise Ship, Cargo, Motor Vehicle Carrier, Tanker, Misc
  - Vessel Activity
    - Manoeuvring, Underway, Anchored, Berthed
- All emissions summed by grid cell for each hour
- Grid cell centres used as stack coordinates
- Program developed to export hourly emission files (EMS-95 CEM format, one file per day) for input to SMOKE

Marine Emissions Inventories Chamber of Shipping (COS)

Lots of data sometimes means lots of problems…



Marine Emissions Inventories Chamber of Shipping (COS)

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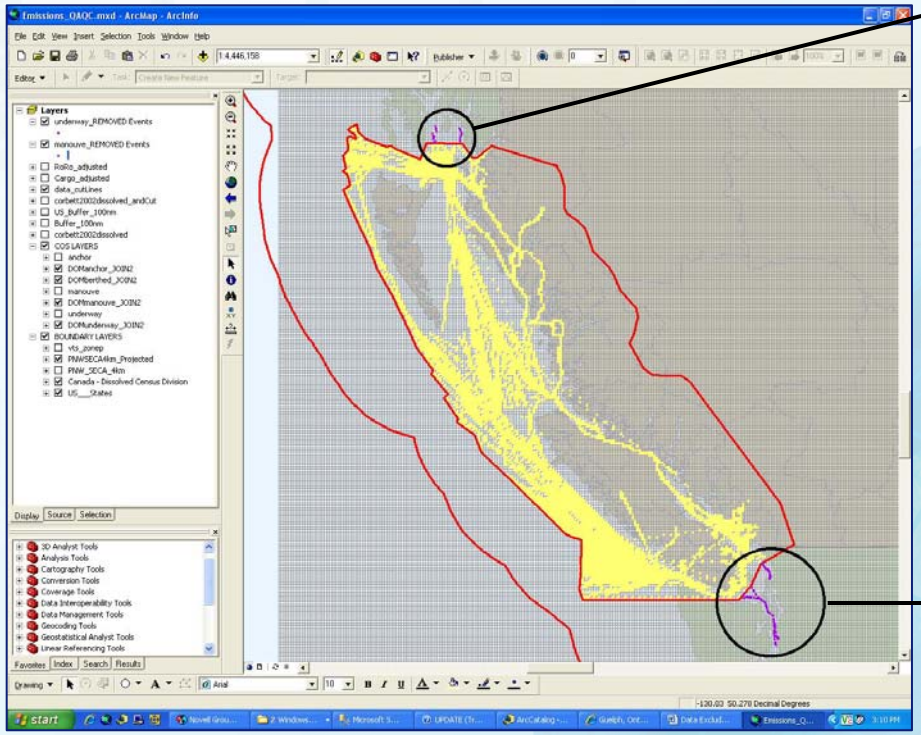
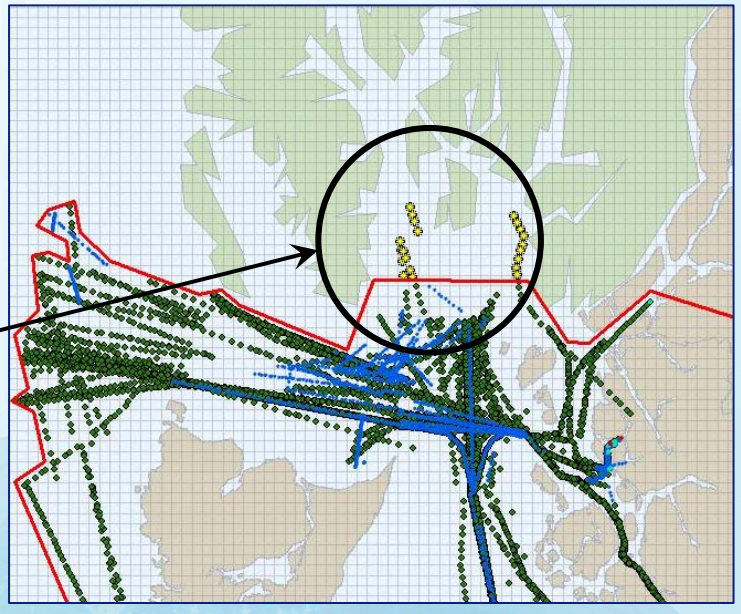
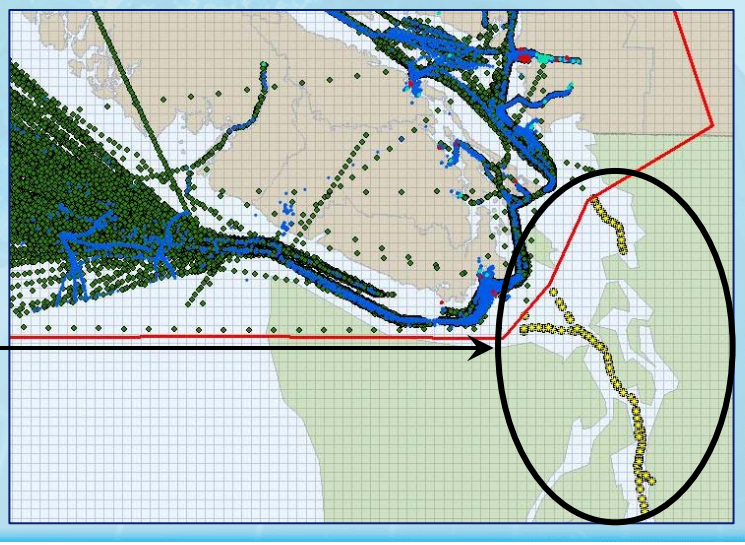
Overlapping inventories manipulated to avoid double counting…





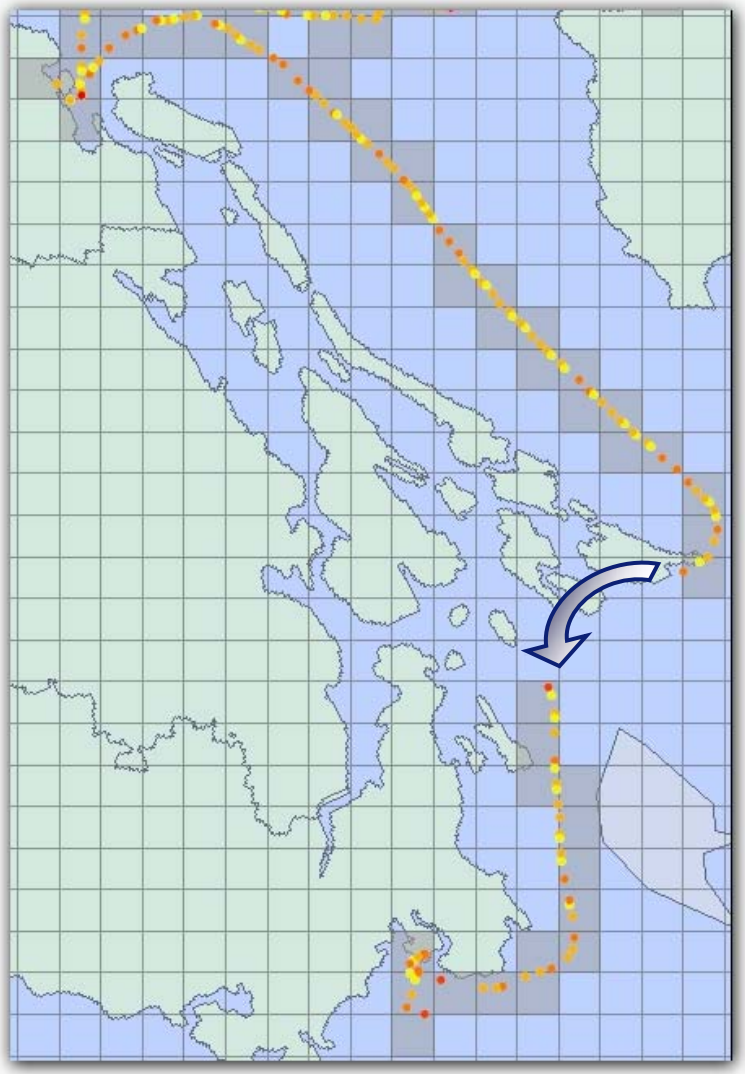


Marine Emissions Inventories Chamber of Shipping (COS)

Point by point SO_X emissions from a single “underway” vessel / voyage combination from the COS inventory

Most grid cells contain several individual emission records (points)

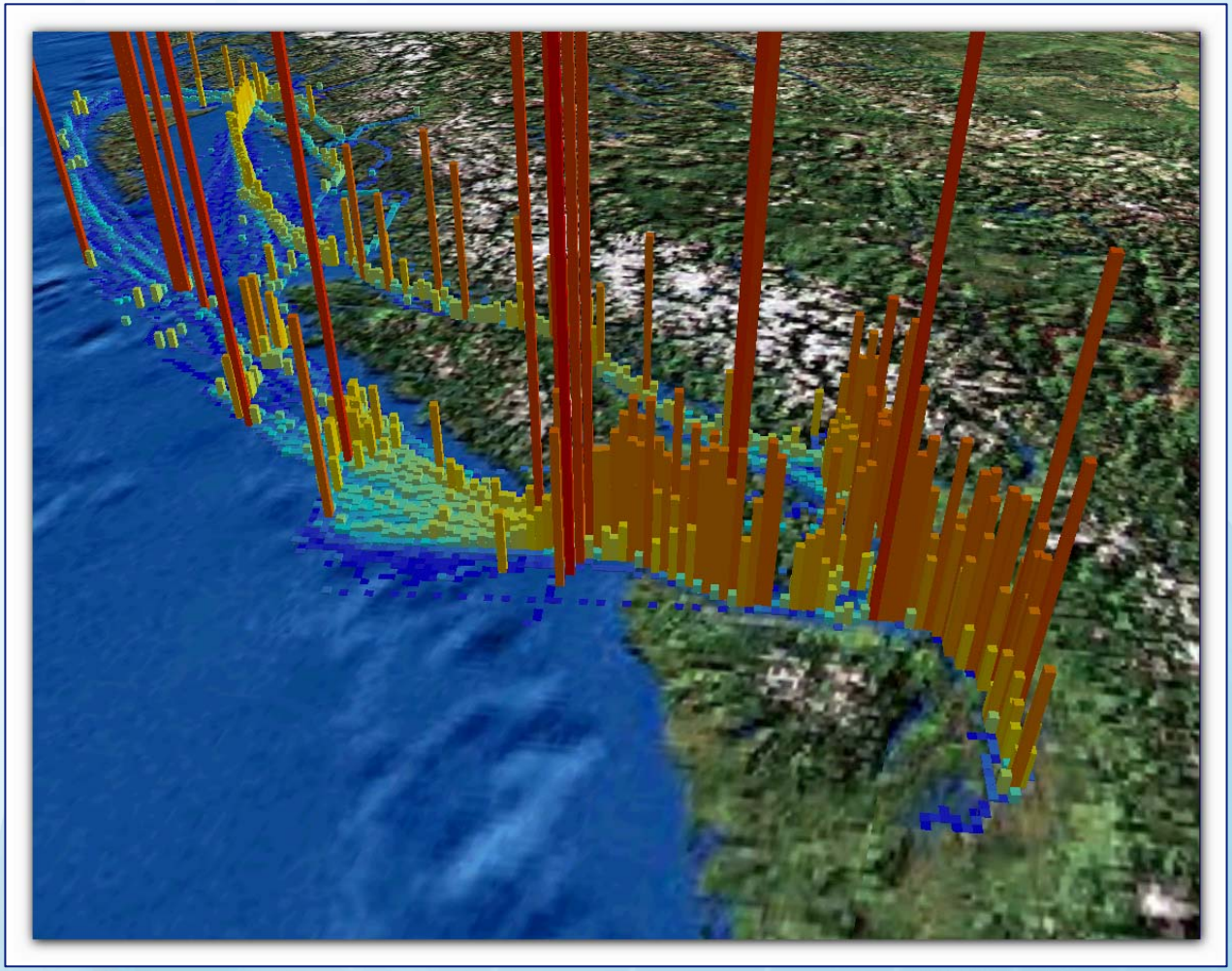
Emissions from “gaps” where the tracking signal was “lost” en route are collapsed into the next vertex for that voyage (by sequential timestamp), resulting in local hotspots



Marine Emissions Inventories Chamber of Shipping (COS)

3-D representation of SO_2 emissions for a single month from the pre-processed 2005 COS inventory

Note the spatial distribution of emissions and local “hotspots”



Marine Emissions Inventories SMOKE Modelling

Stack Parameters used in SMOKE (from EC/CARB/ EPA)

- Stack Height: 20.0 m (65.6 ft)
- Stack Diameter: 0.80 m (2.6 ft)
- Gas Exit Velocity: 25.0 m/s (82.0 fps)
- Gas Exit Temperature: 282 °C (539.6 F)

SMOKE recompiled to handle large number of point sources:

- Corbett = 11,794 point sources (annual emissions, flat profile)
- Puget = 142 point sources (annual emissions, flat profile)
- COS = 5,038 point sources with hourly varying emissions (equivalent of 120,912 sources per day)

Preliminary SMOKE Model Results Gridded SO_2 Emissions

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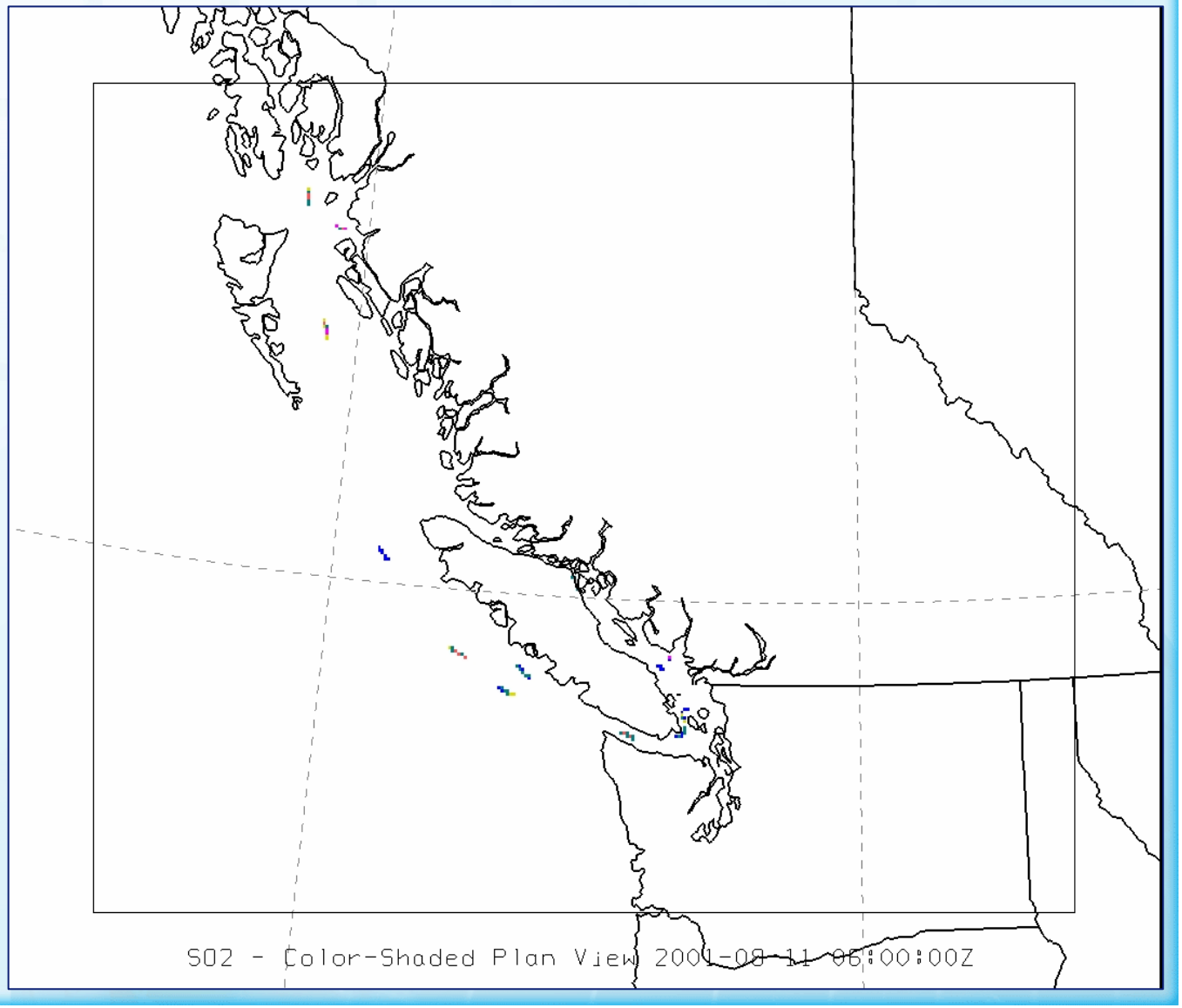
SMOKE Outputs

- SO_2 Emissions
- COS only
- Underway
- Aug. 11, 2001
- Second vertical layer (~60m)
- Colours proportional to emissions



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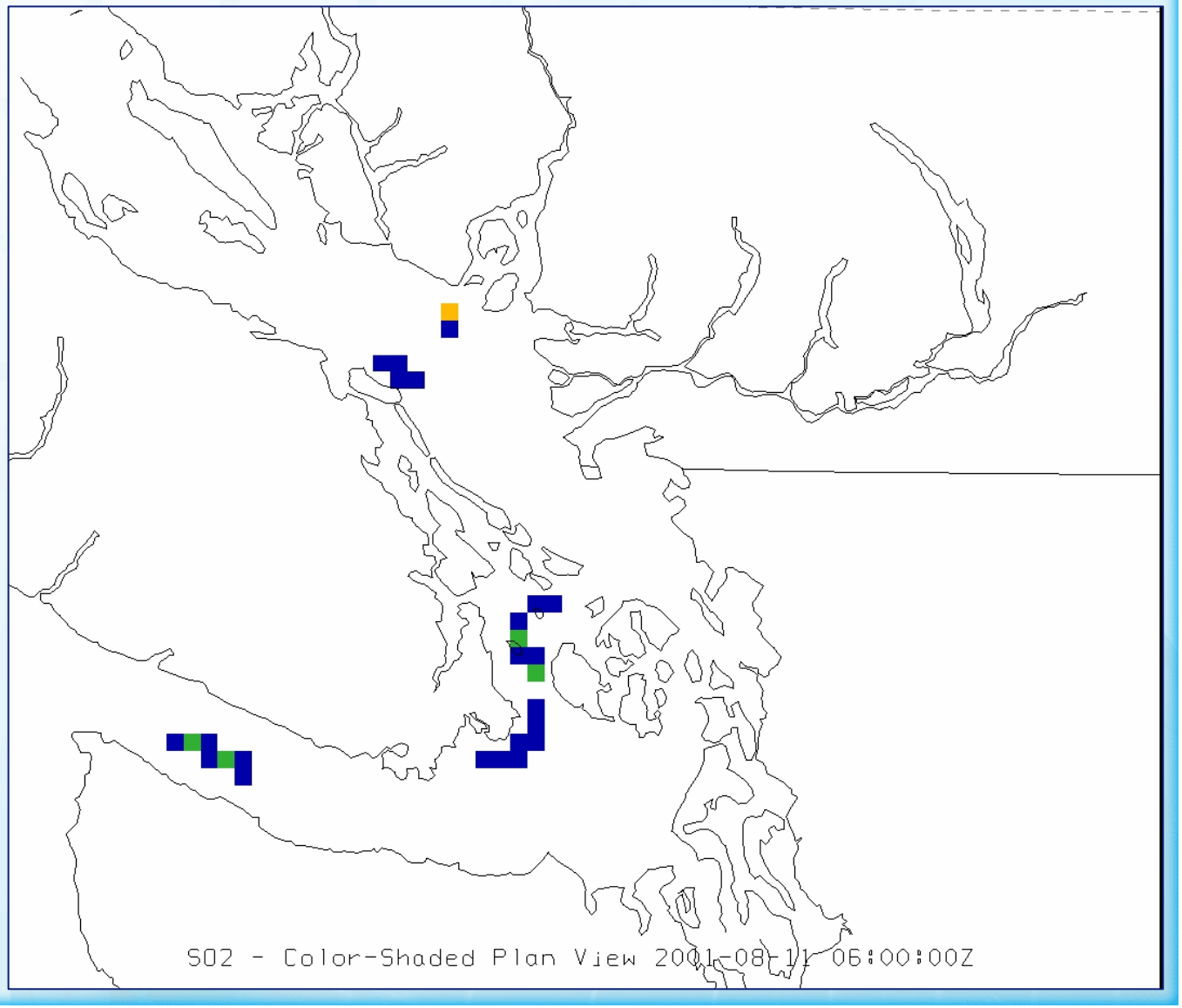

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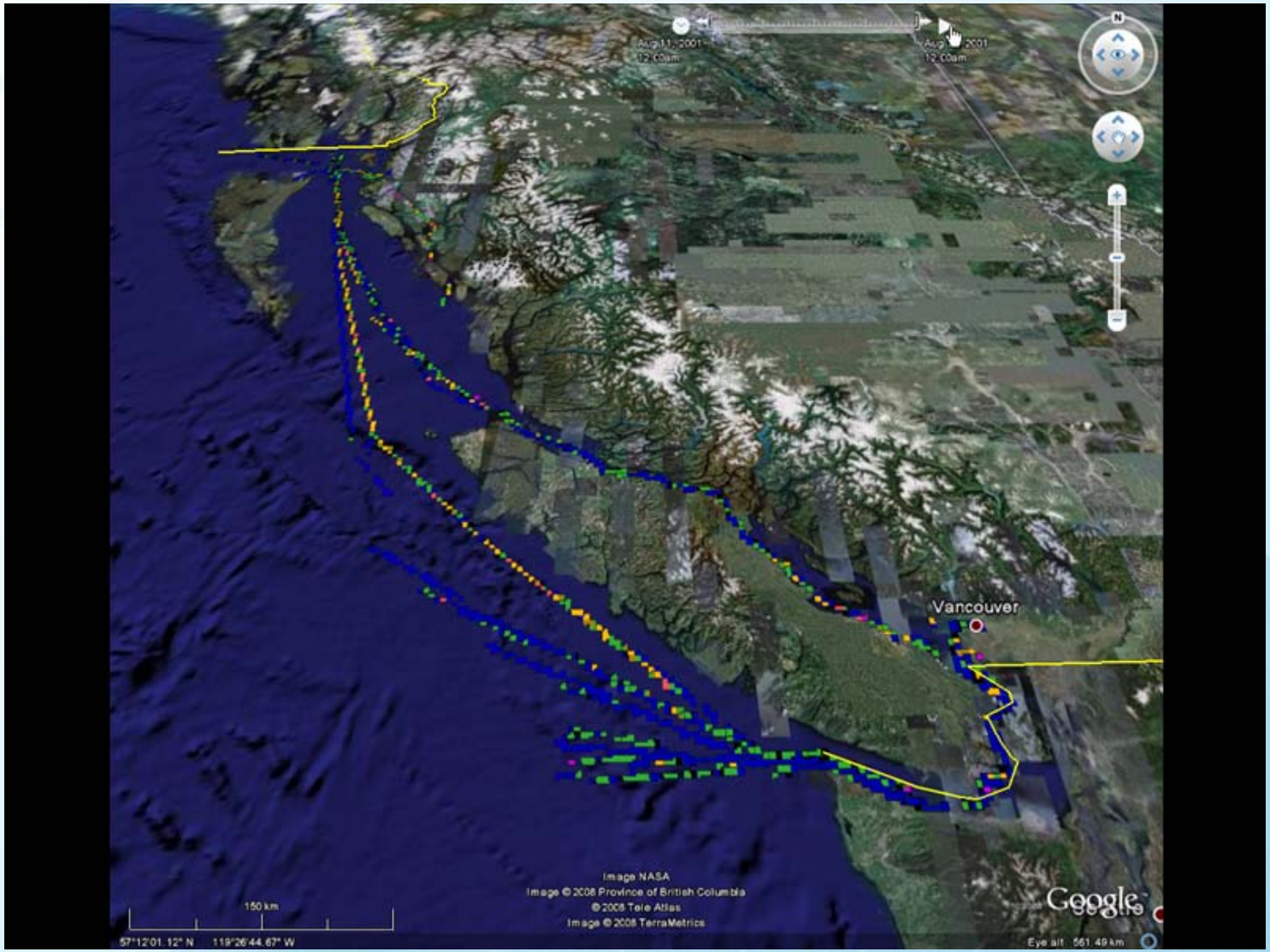
Preliminary SMOKE Model Results Gridded SOx Emissions, Aug. 11



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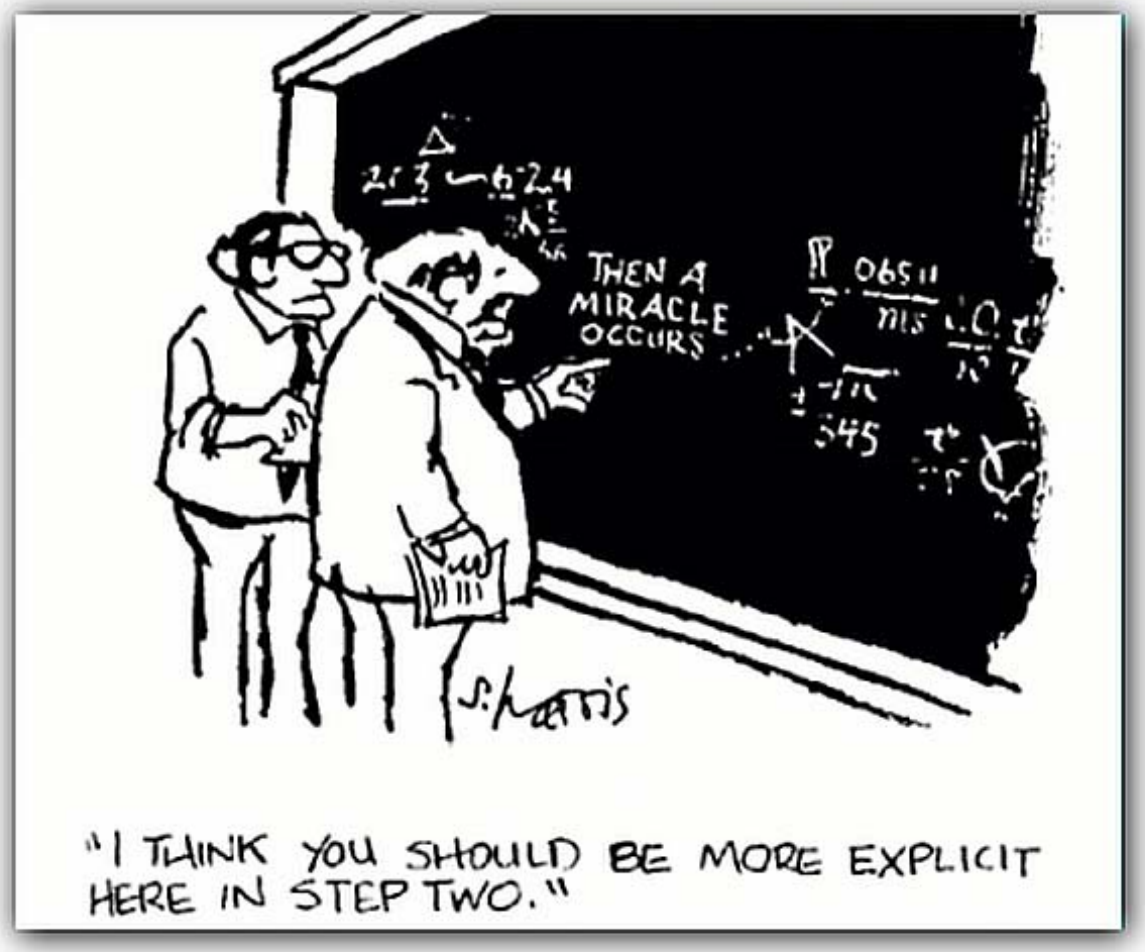
Preliminary CMAQ Model Results…



TO BE CONTINUED…

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Thank You!

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