The Great Lakes Binational Toxics Strategy
PCB Workgroup Meeting
17th – 18th May 2005

Spatially Resolved Models of POP Transport in the Environment

Experience of CAM/POPs Model

Sunling Gong
Meteorological Service of Canada

Meteorological Service of Canada
Environment Canada

Outlines

Meteorological Service of Canada
Environment Canada

CAnadian Model for POPs

- Framework
  - Transport Models
  - Emissions
  - Exchange Modules
  - Aerosol Module
- PCB Simulation Results
  - Comparison with observations
  - Global budgets

Objectives

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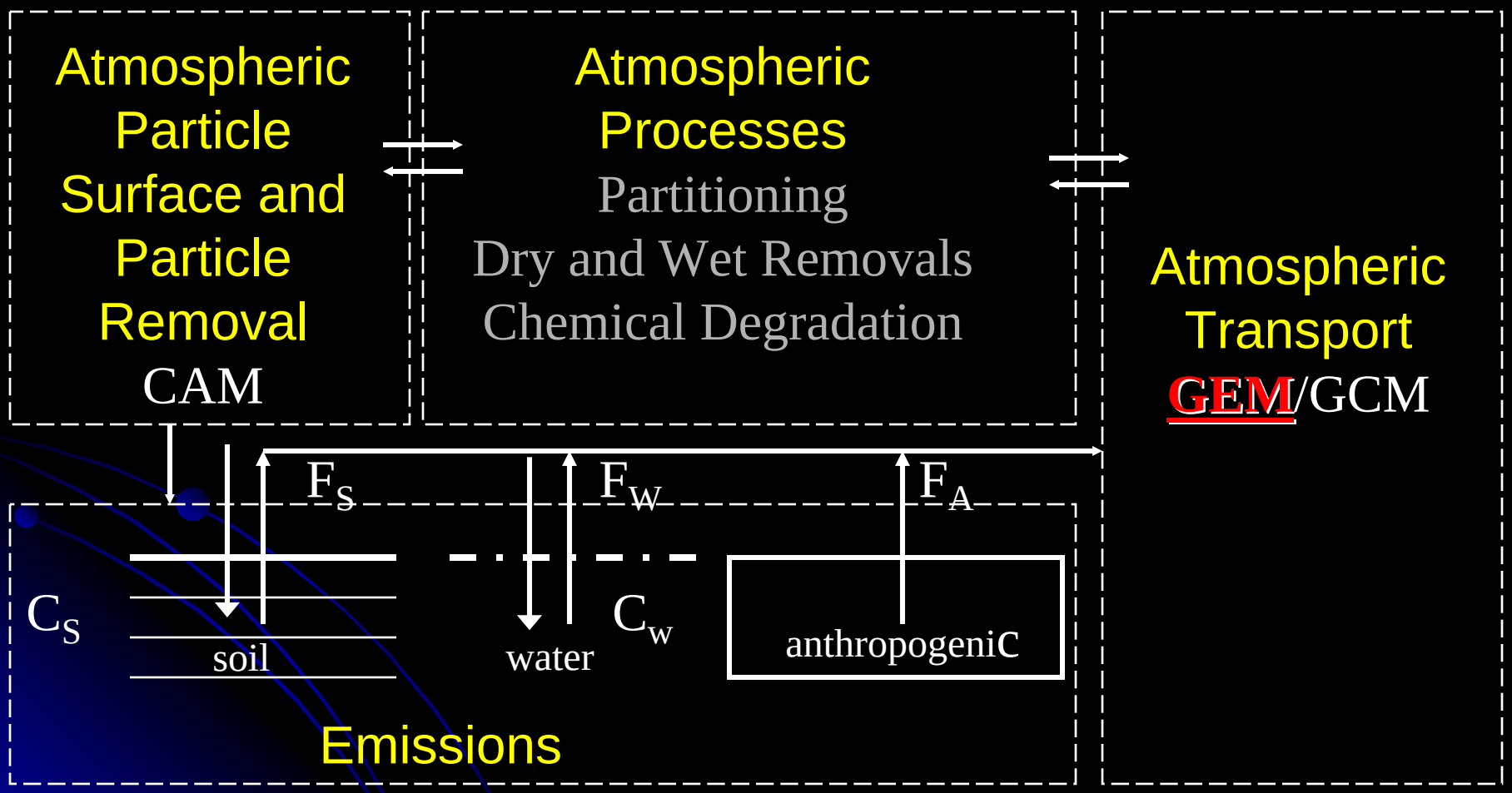
- Short-term
  - To investigate global transport patterns of PCBs and hence the contribution of various sources to Canadian PCB levels as measured at the Alert, Tagish, Dunai and Egbert monitoring stations from Northern Contaminants Program (NCP) and the Integrated Atmospheric Deposition Network (IADN).
- Long-term
  - To investigate other POPs in the atmosphere and their impacts to Canada

Framework

Meteorological Service of Canada
Environment Canada

- Transport Models
- Emissions
- Atmospheric Processes
- Aerosol Module

Fundamentals of POPs



Transport Model

GEM
Global Environment Model

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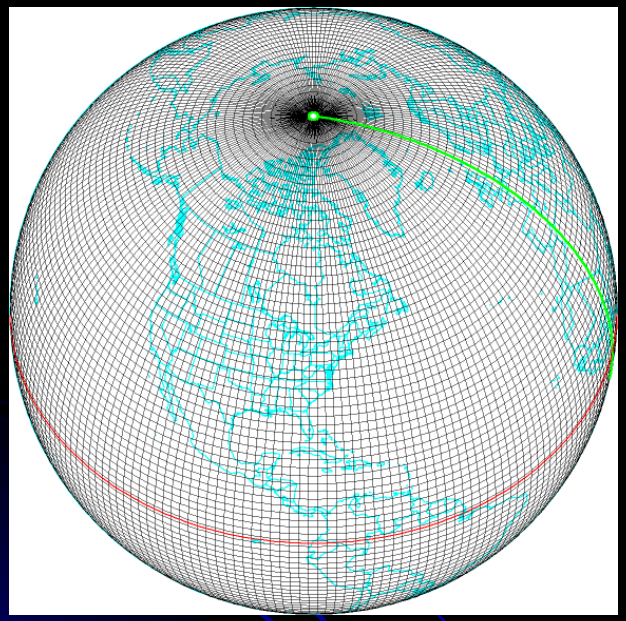
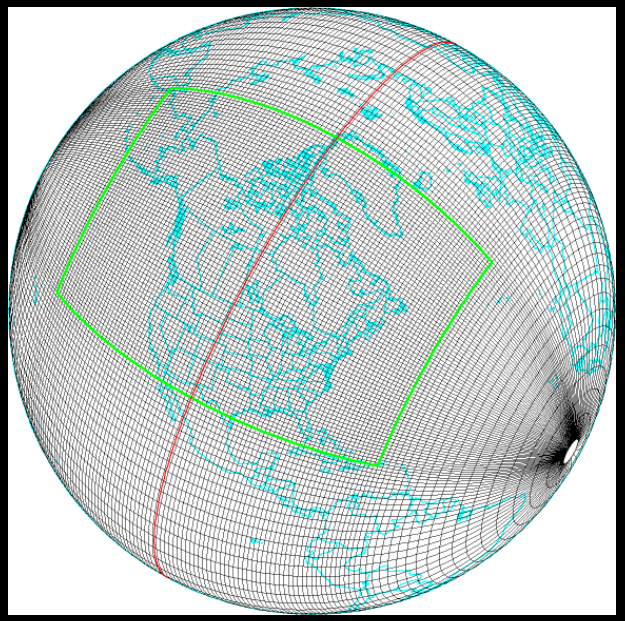
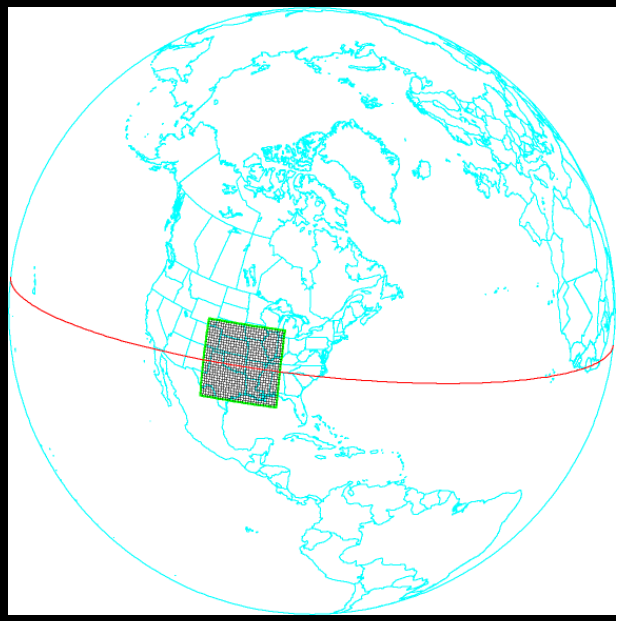
Canadian Weather Forecast Model



Global Uniform
400x200 ~ 90 km



Variable Global
Focused ~ 25 km



Limited Area
~ 200 m

Properties by Transport Model

- Advection
- Vertical Mixing
- Metrological Parameters

  Wind speed, clouds, precipitation,

  T, P, RH ....

Emissions

Air/Water Exchange

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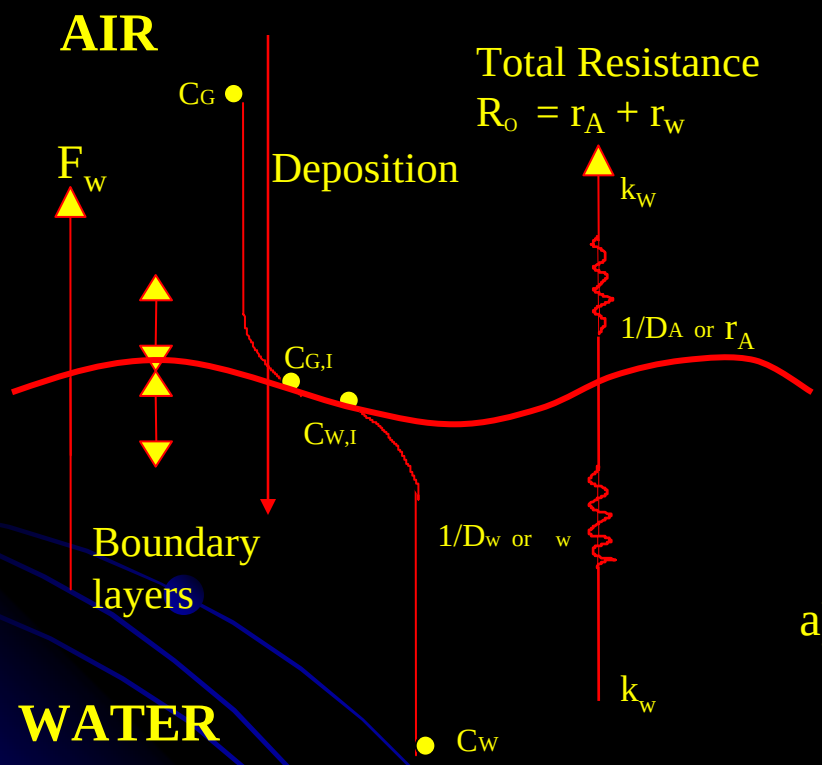

30 > H (for PCB's) > 0.1

0.01 > K_{AW} > 10^{-5}

- **Flux (mol/m²/s)**

$$F_W = K_{TA} (C_W \cdot K_{AW} - C_G)$$

- **Mass transfer coefficient K_{TA} (s/m)**

$$1 / K_{TA} = 1 / k_A + K_{AW} / k_w$$

a) in water (Wanninkhof, 1992)

$$k_w = [\, 2.5 \,(\, 0.5246 + 1.6256\text{x}10^{-2} \,.T + 4.9946\text{x}10^{-4}\, T^2 \,) + 0.3u^2_{10} \,].(Sc/660)^{-1/2}$$

b) in air (Mackay *et al.*, 1983)

$$k_A \text{ (m/s)} = 10^{-3} + 4.62\text{x}10^{-04} \text{ x } (6.1+0.63u_{10})^{0.5}\, u_{10}\, [Sc_{pcb,air}]^{-0.67}$$

Air/Soil Exchange

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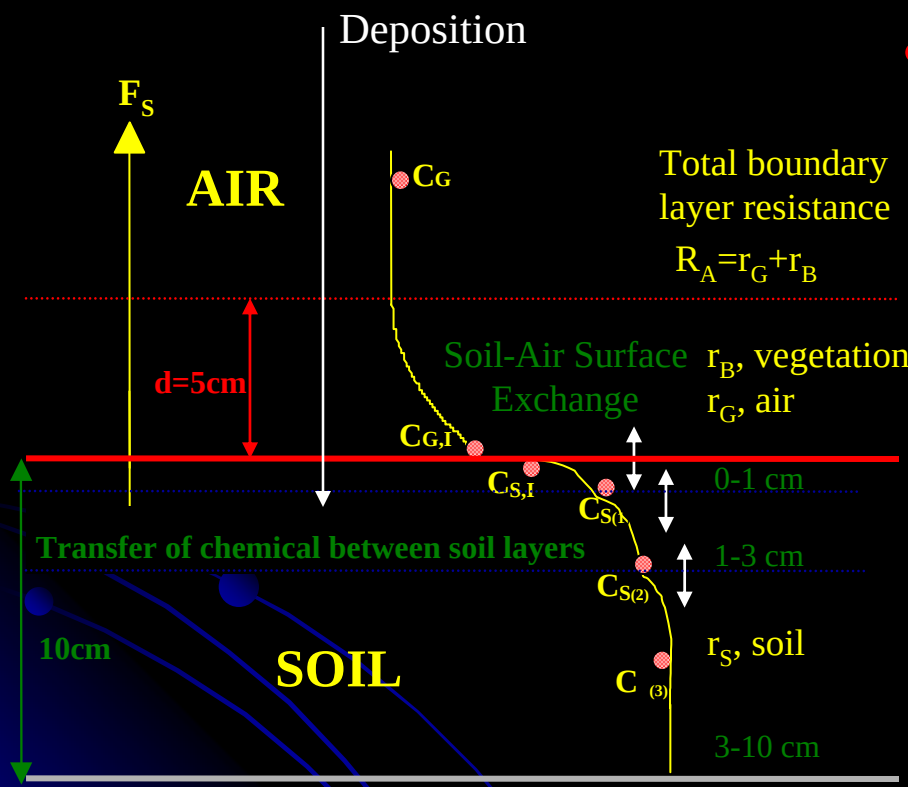

- **Flux (mol/m²/s)**

$$F_S(0,t) = \frac{1}{R_T}\left(C_{G,soil}(0,t) - C_{G,air}(0,t).K_{SA}\right)\left[1-\exp\left(\frac{-L^2}{4D_{ES}.t}\right)\right]$$

- **Total resistance (s/m)**

$$R_T = \left[K_{SA}R_A + r_s\right]$$

K_{SA} the soil-air equilibrium coefficient and D_{ES} (m^2/s) the effective diffusivity of the chemical in the soil matrix

Anthropogenic PCB

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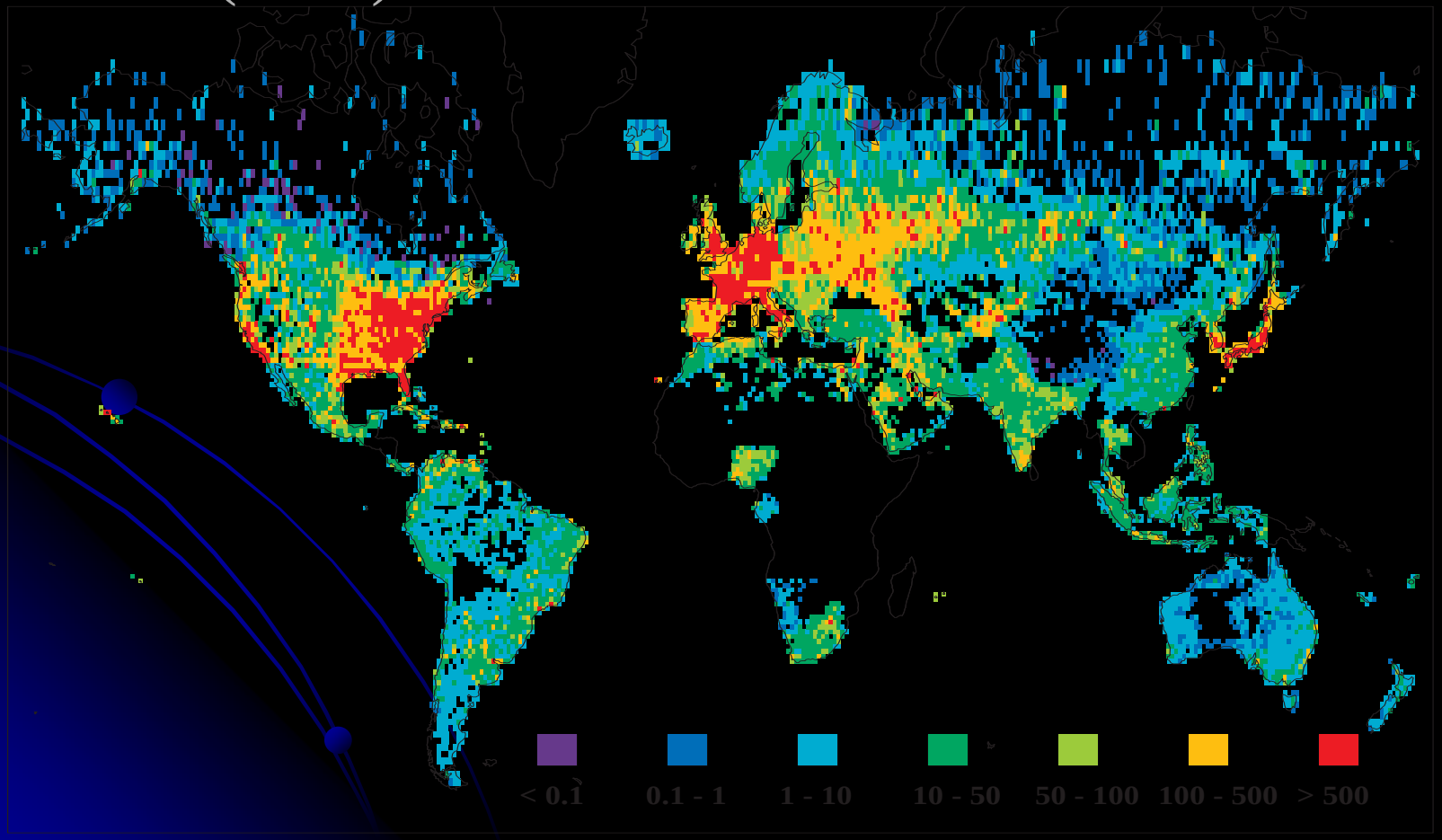
Estimated cumulative global usage of PCBs (T)

Breivik (2001)



PCB Atmospheric Processes

Removals

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- Dry deposition

  Water, Snow and Vegetation

- Scavenging

  Snow and Rain

- OH Reaction

Partitioning

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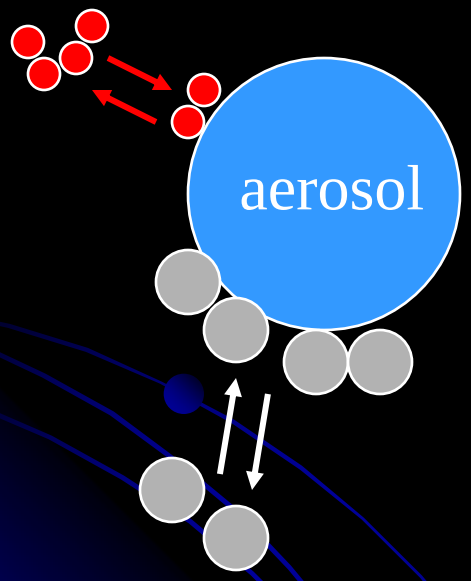


Junge-Pankow Partition

(Junge, 1997; Pankow, 1987)

$$\Phi = \frac{c.\Theta}{P_L^0 + c.\Theta} = \frac{C_P}{C_P + C_G}$$

Θ - the aerosol surface area available for adsorption (m^2 aerosol/m^3 air),

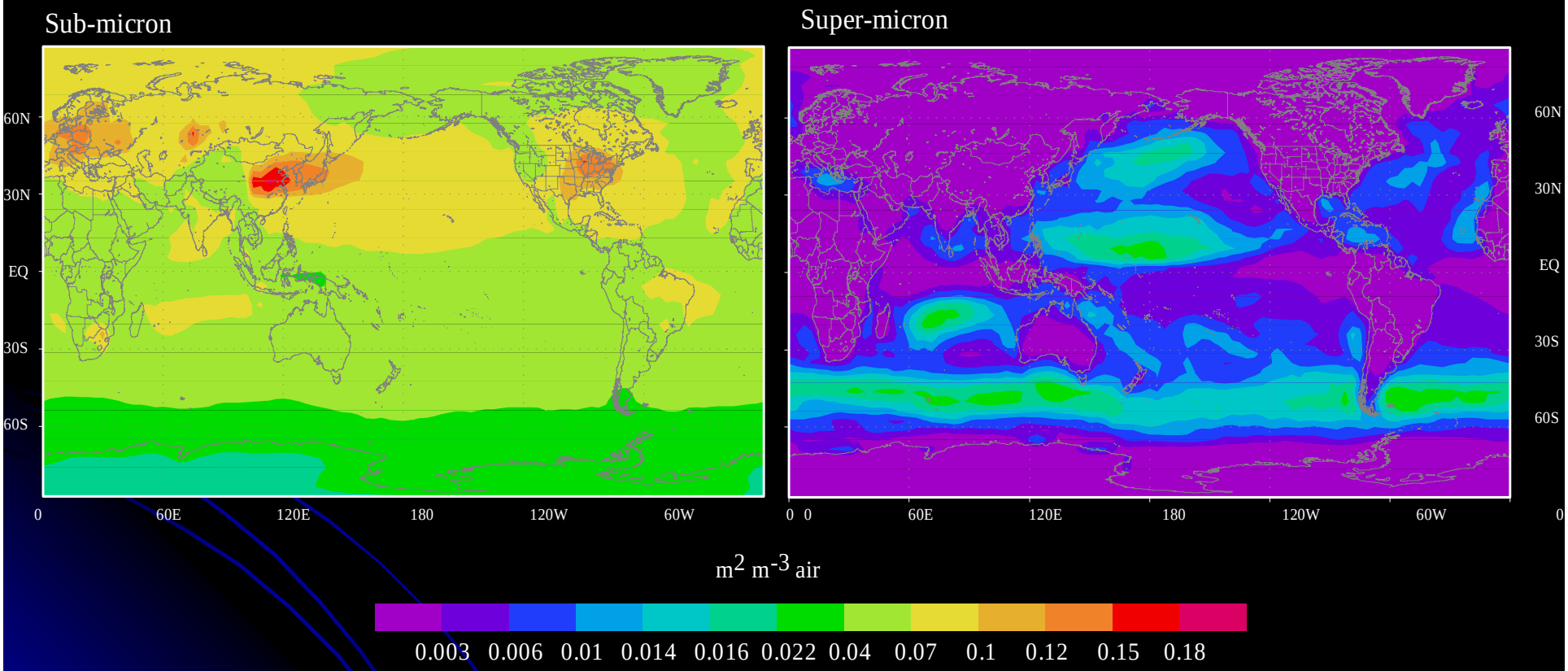
P^0_L - the liquid-phase saturation vapour pressure of pure compound (Pa)

c - a parameter that depends on the thermodynamics of the adsorption process and surface properties of the aerosol (Pa.cm).

Aerosol Module

Global Aerosol Surface Areas

Θ - Global Aerosol Surface Area of Sea-salt and Sulphate



PCBs partitioned to aerosol particles will be removed from the atmosphere by the same mechanism as the aerosol particles by dry deposition, in-cloud and below-cloud removals.

This is done through the CAM modules.

Aerosol Module

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Canadian Aerosol Module

Multi-Component size distributed aerosol algorithm implemented in air-quality or climate models:

(1) Five major aerosol types: sulphate, sea-salt, BC, OC and soil dust.

(2) 12 size bin representation of size distributions. Mass balance prognostic equation is used for each type aerosol and each size bin.

(3) Aerosol dynamics: hygroscopic growth, coagulation, nucleation/condensation, clear-sky and cloud sulphur chemistry, aerosol-cloud interactions, dry and wet depositions

Simulation Results

Model Configurations

- Year 2000 meteorology
- 2º x 2º resolution
- 20 minute integration time
- GEIA Emissions for aerosols
- PCB emissions (Breivik et al. 2001)
- Initial atmospheric, soil and water PCB concentrations from MSC-E modeling results.

Annual PCB 153

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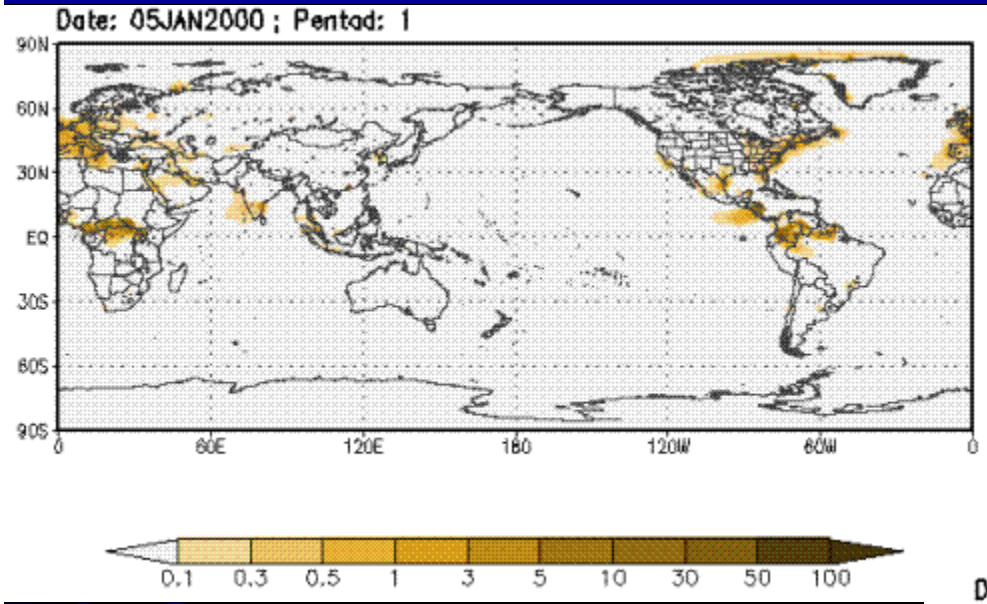
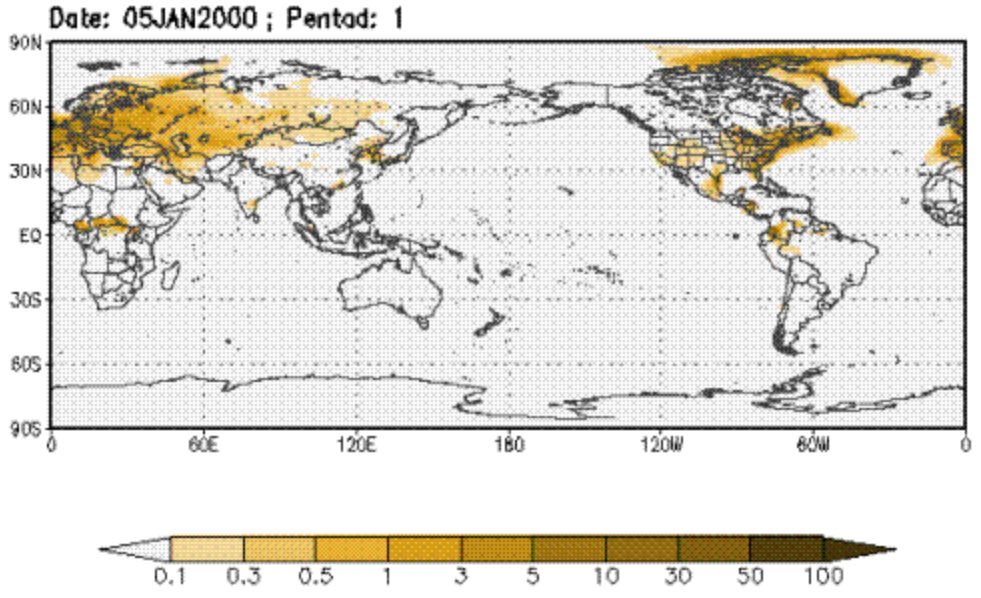
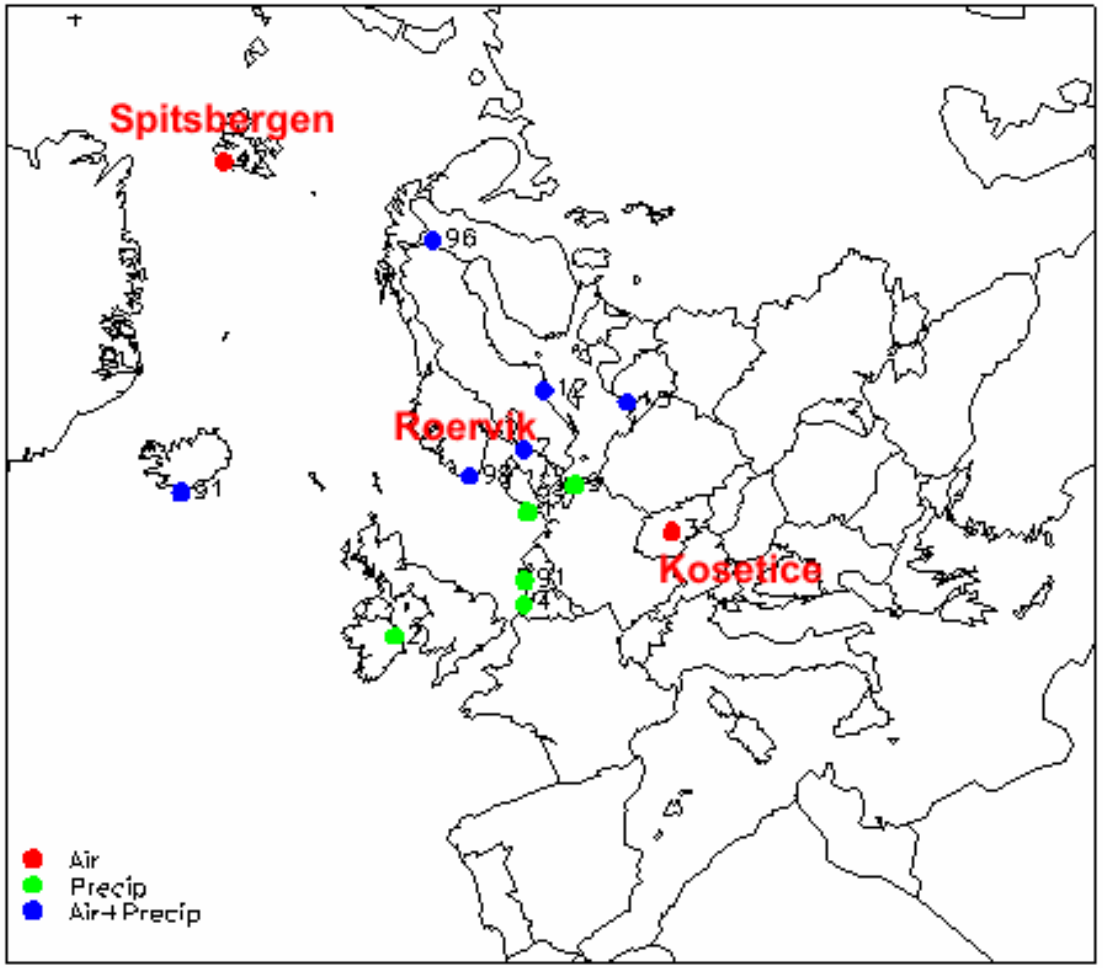


Gas Phase

Particle Phase

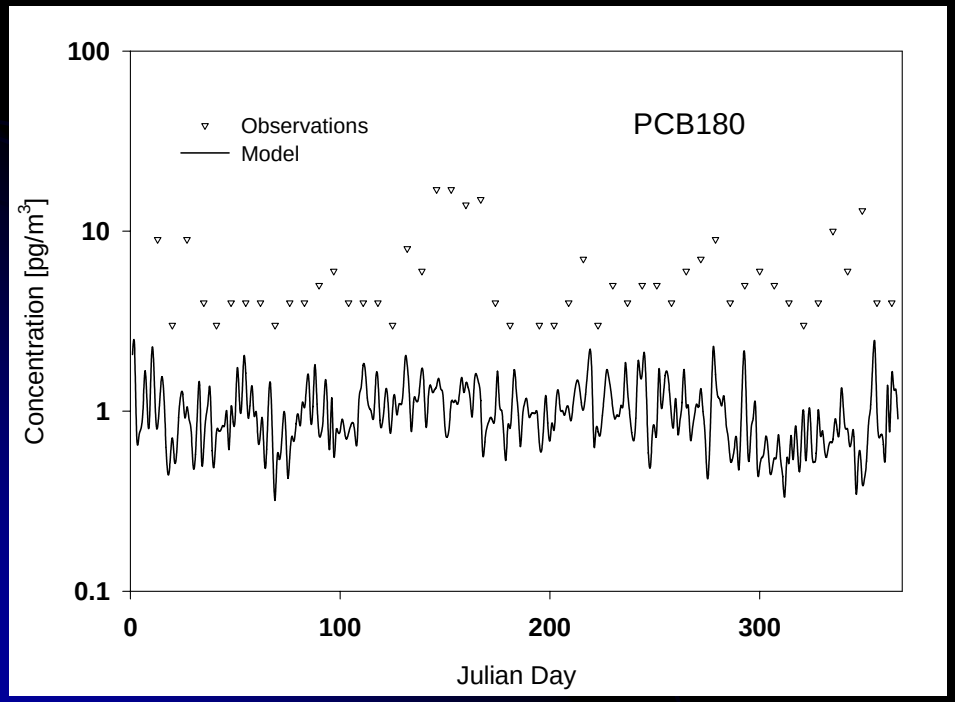


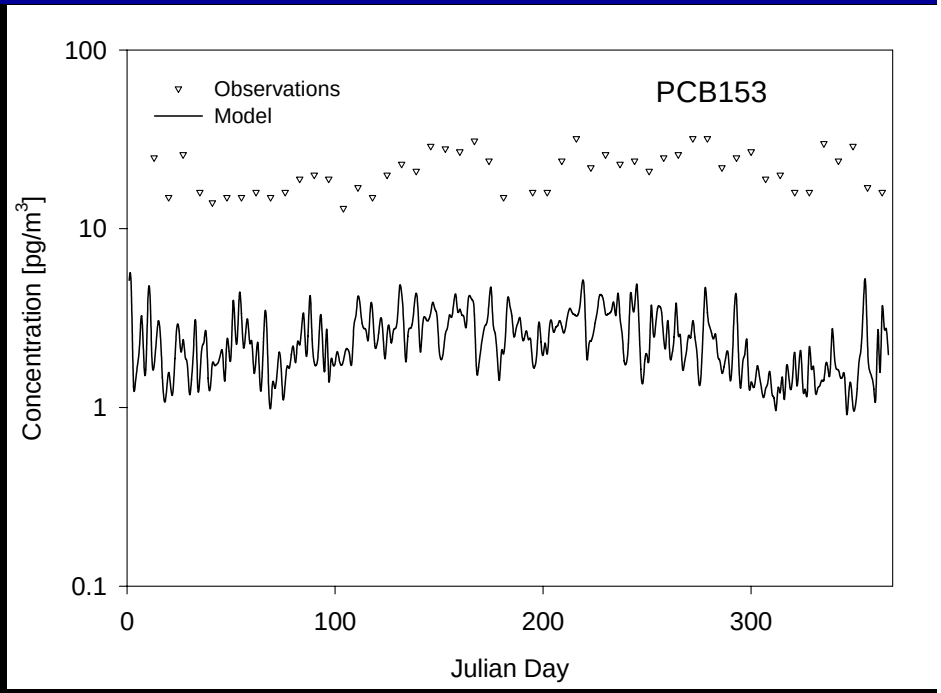
EMEP POP Stations



Daily PCB 153 vs PCB 180

Kosetice





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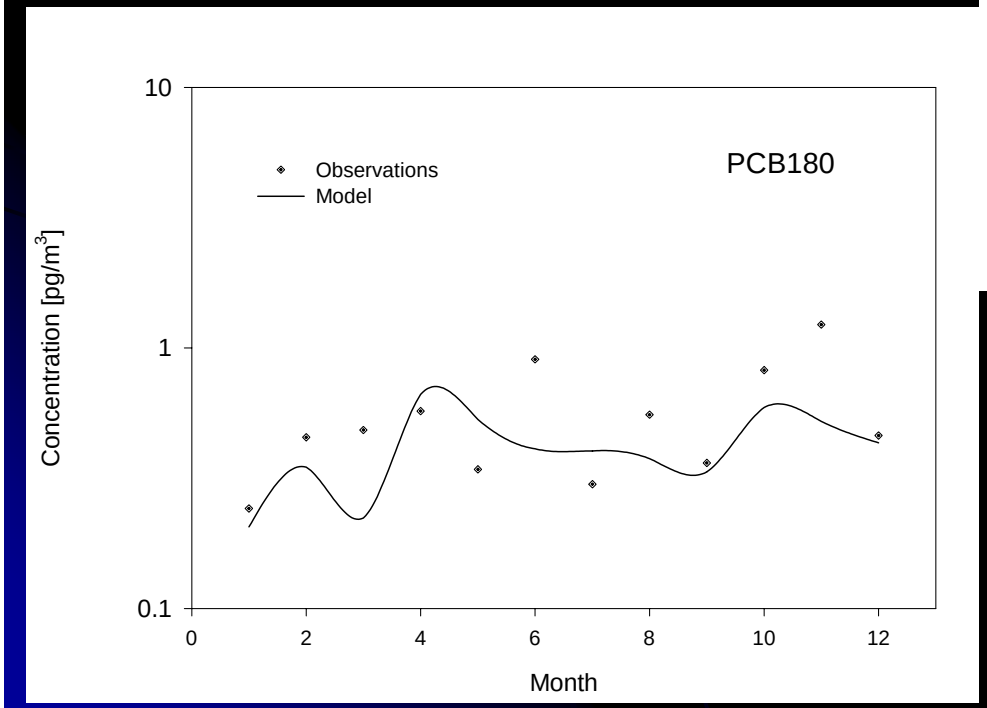
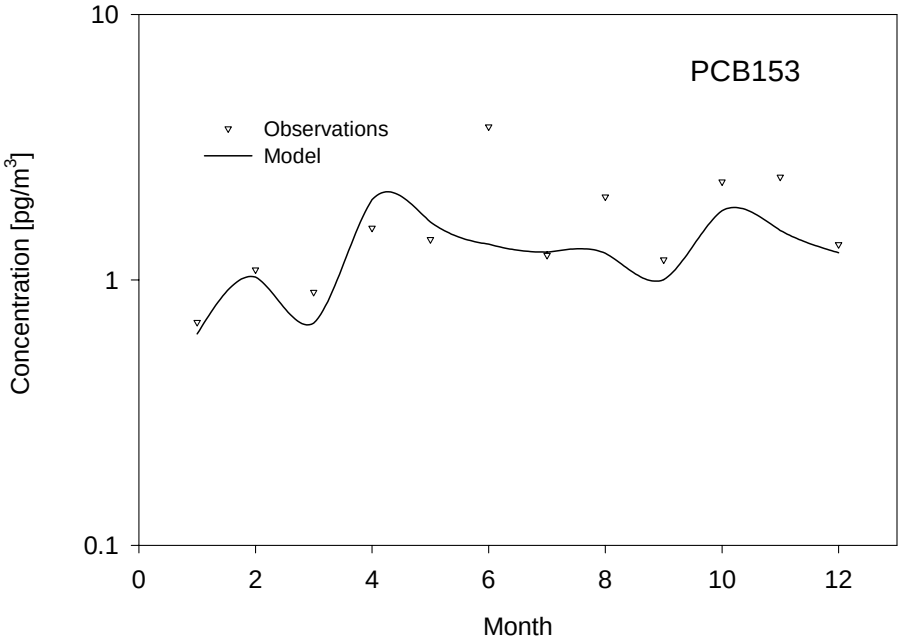
Monthly PCB 153 vs PCB 180

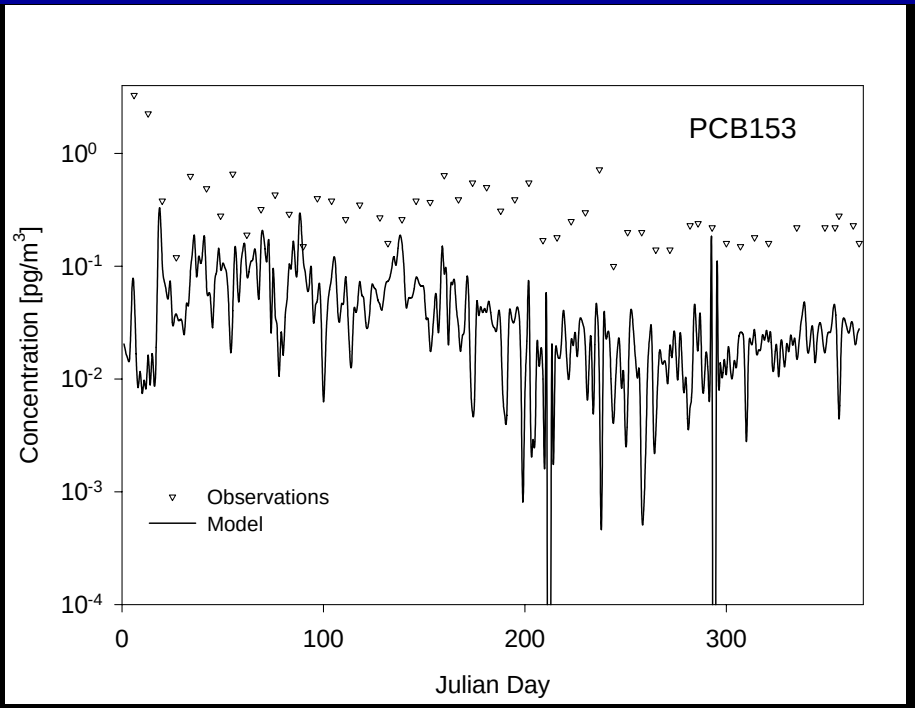
Roervik

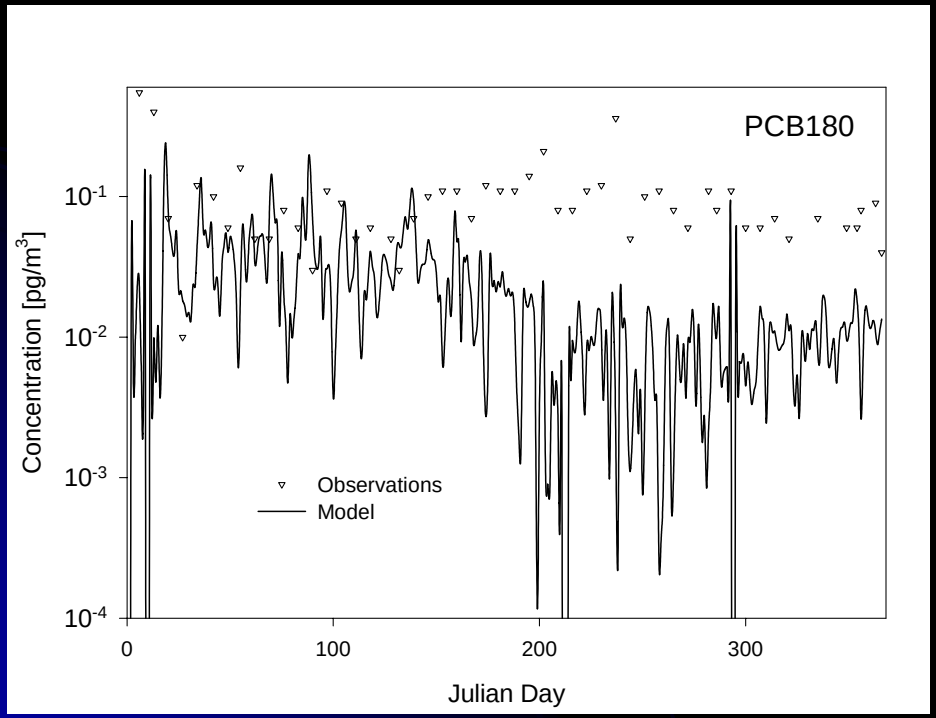




PCB 153 vs PCB 180

Spitsbergen





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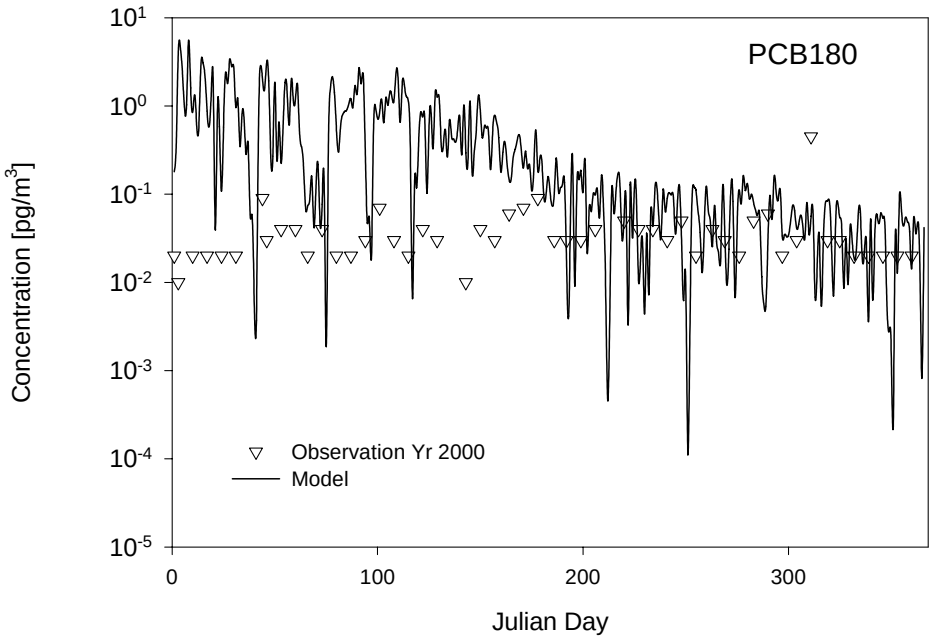
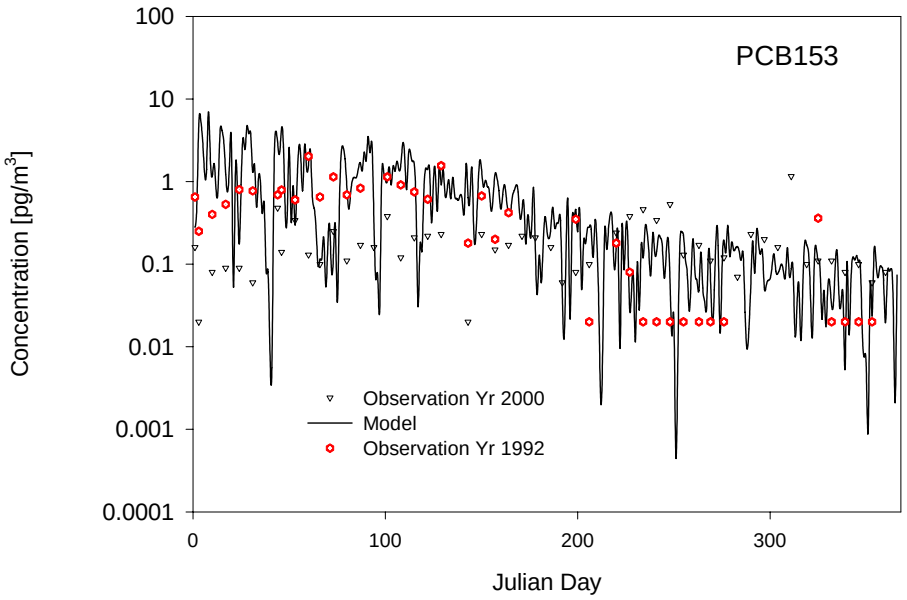
PCB 153 vs PCB 180

Arctic Alert





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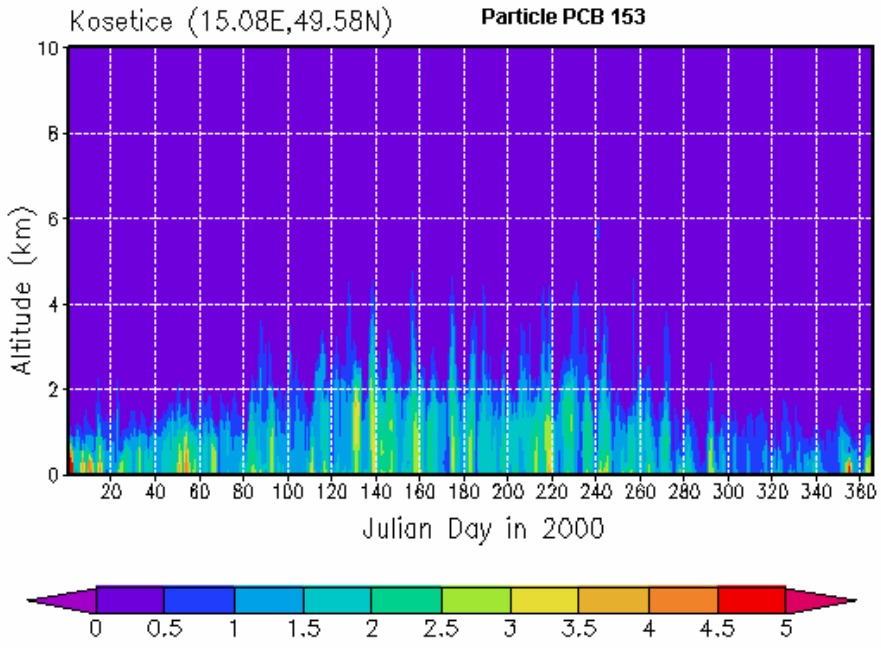
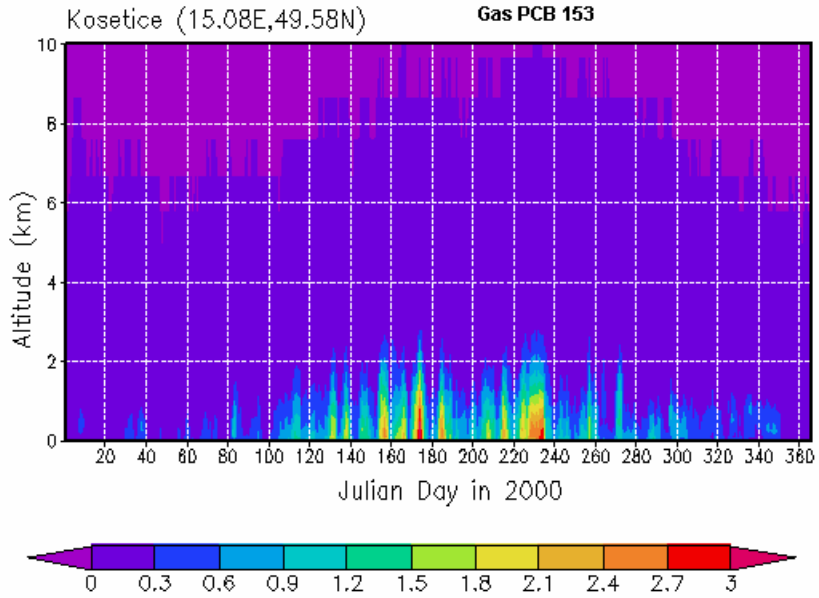
Vertical Profiles

ng m^{-3}





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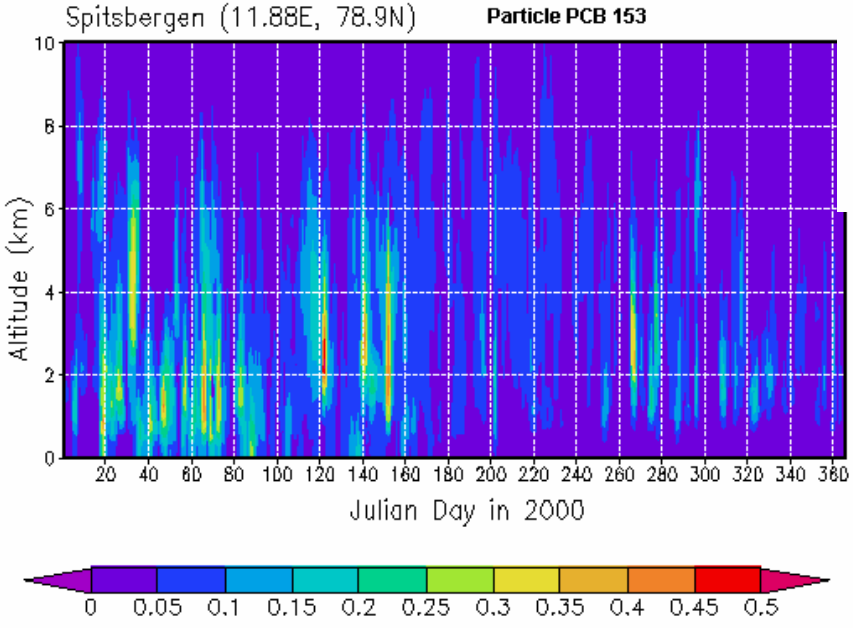
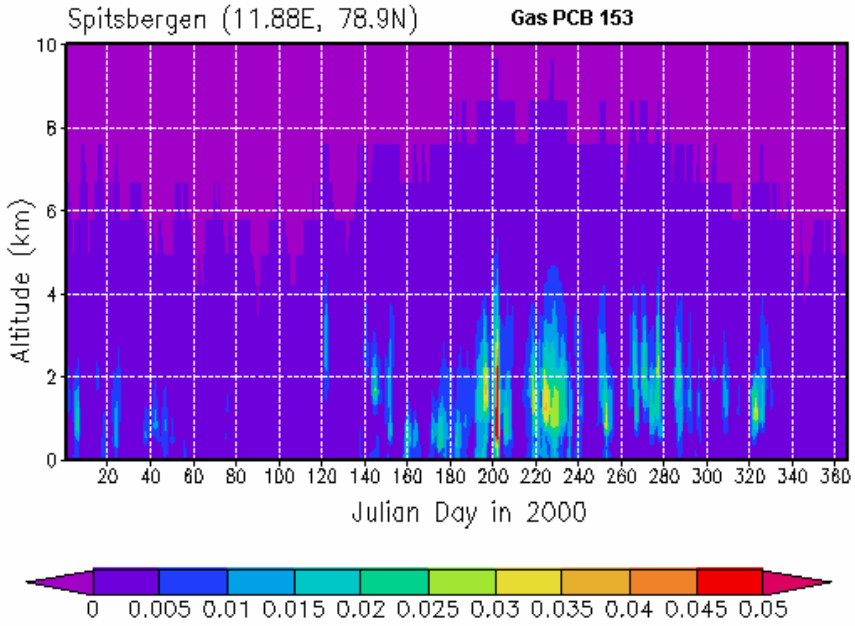
Vertical Profiles

ng m^{-3}





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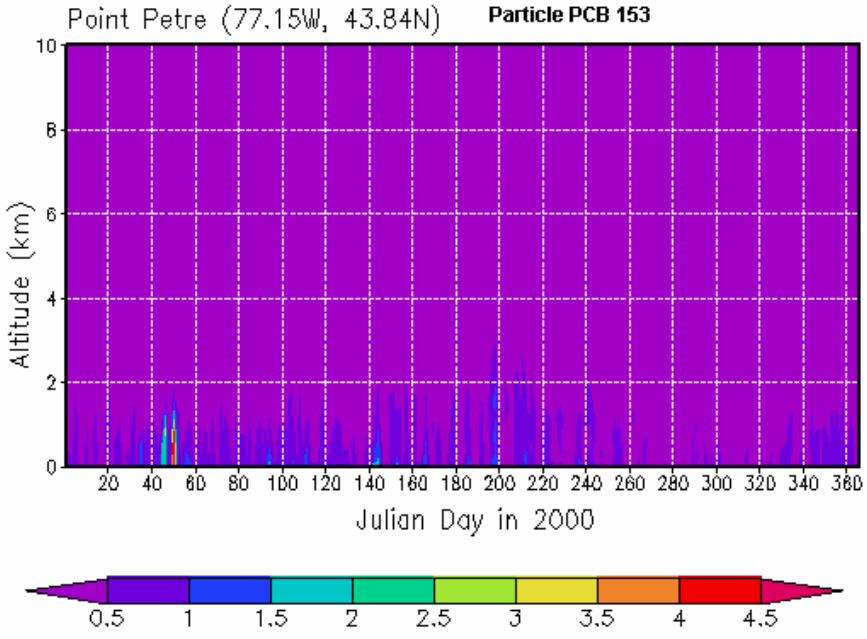
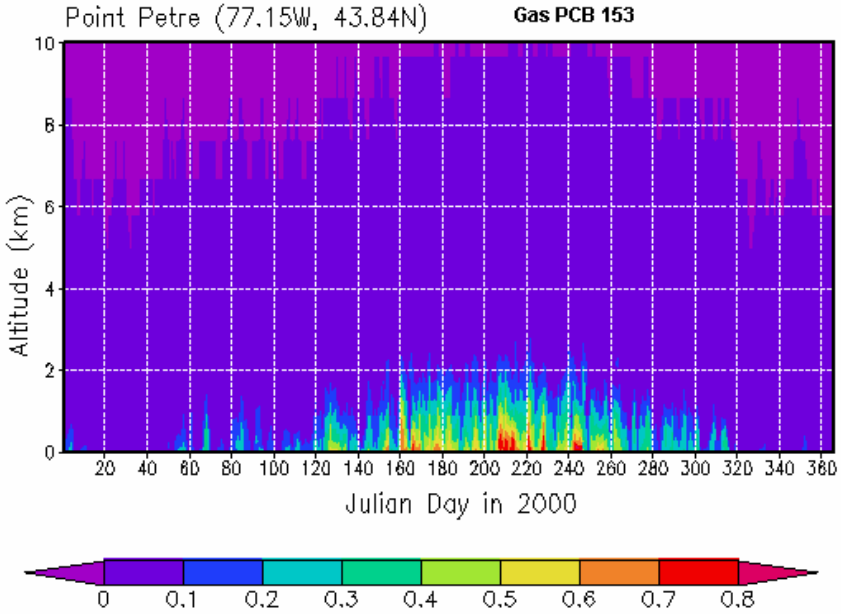
Vertical Profiles

ng m^{-3}





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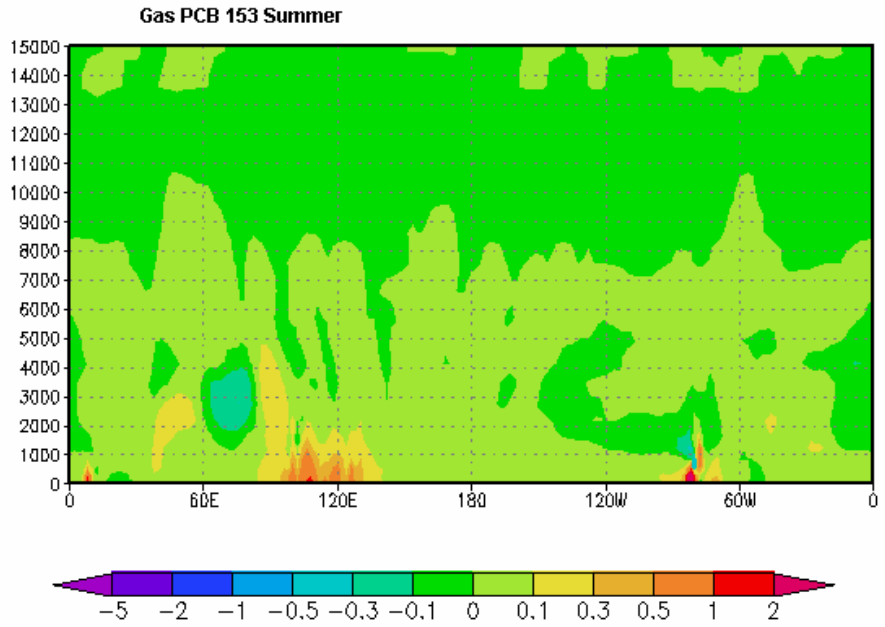
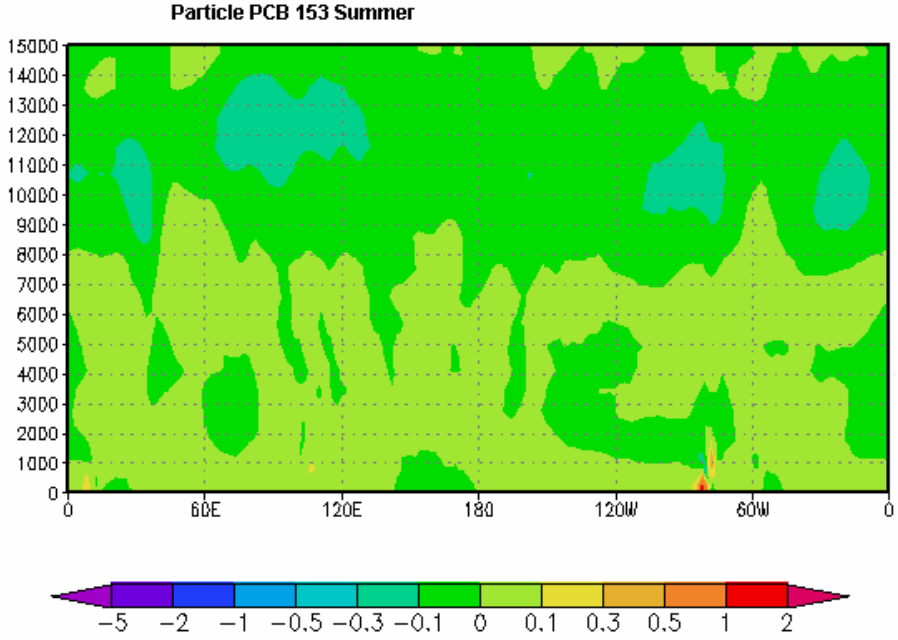
Hemispheric Transports (N – S)

kg km^{-2} season^{-1}





S→N
W→E

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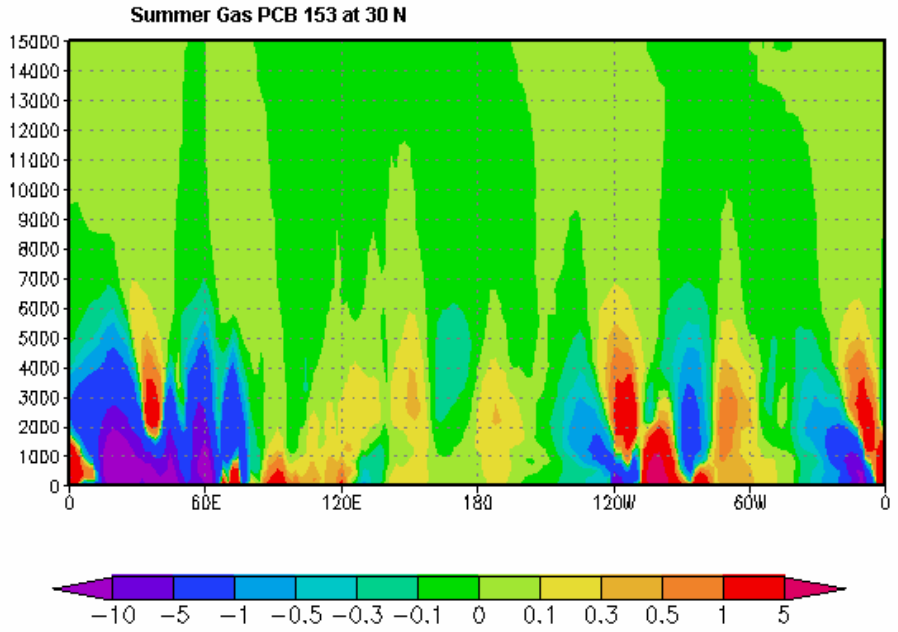
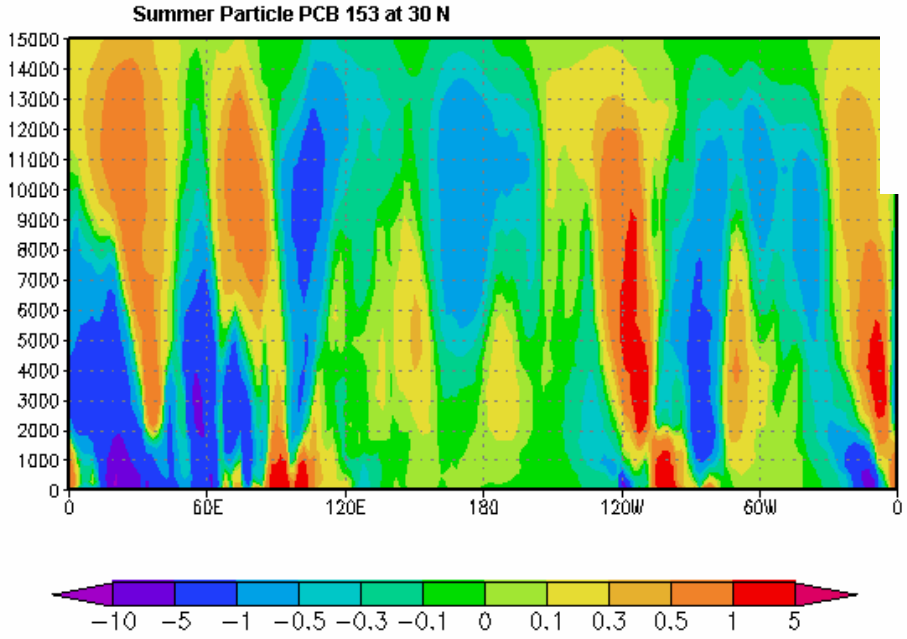
Transports Fluxes at 30 N

kg km^{-2} season^{-1}





S→N
W→E

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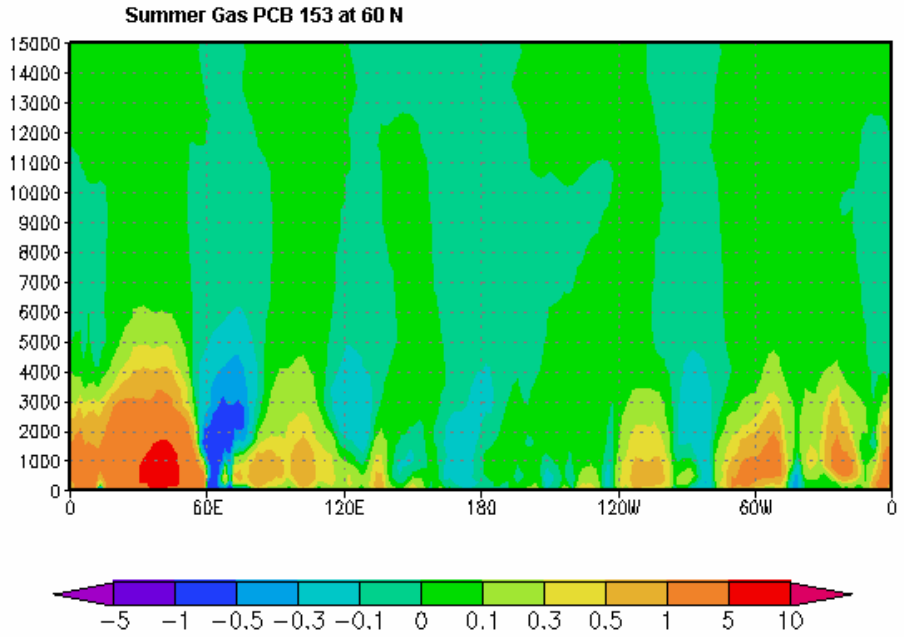
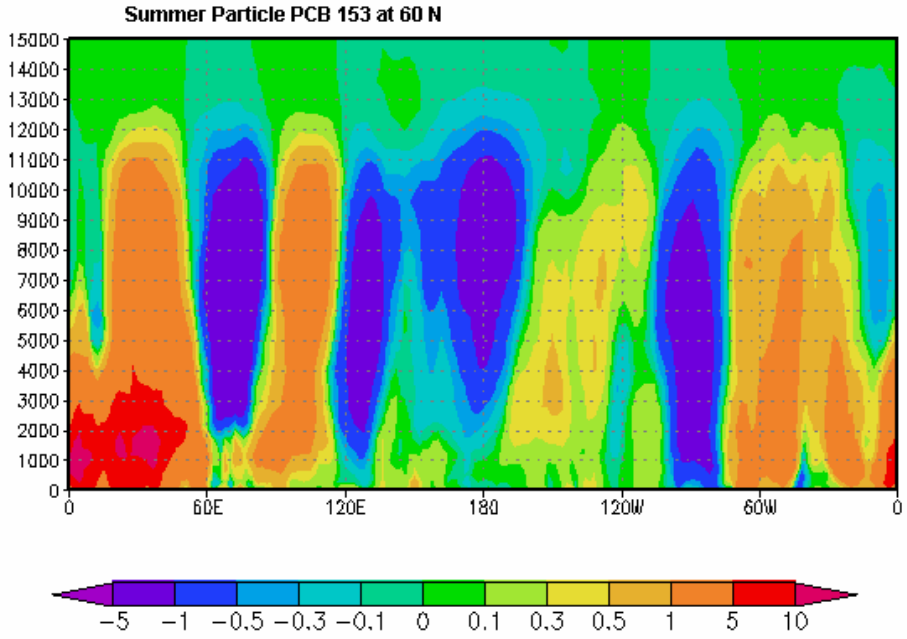
Transports Fluxes at 60 N

kg km^{-2} season^{-1}





S→N
W→E

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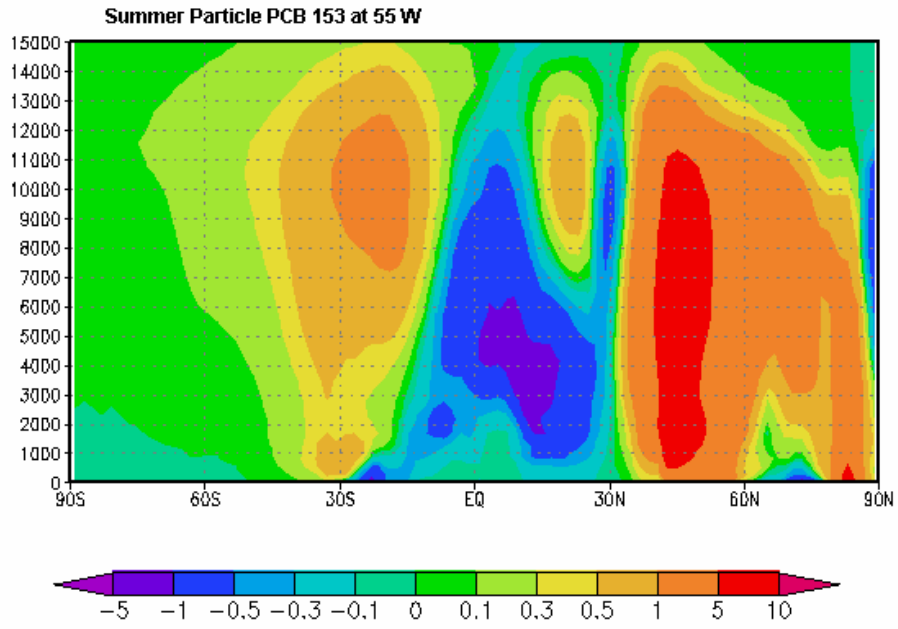
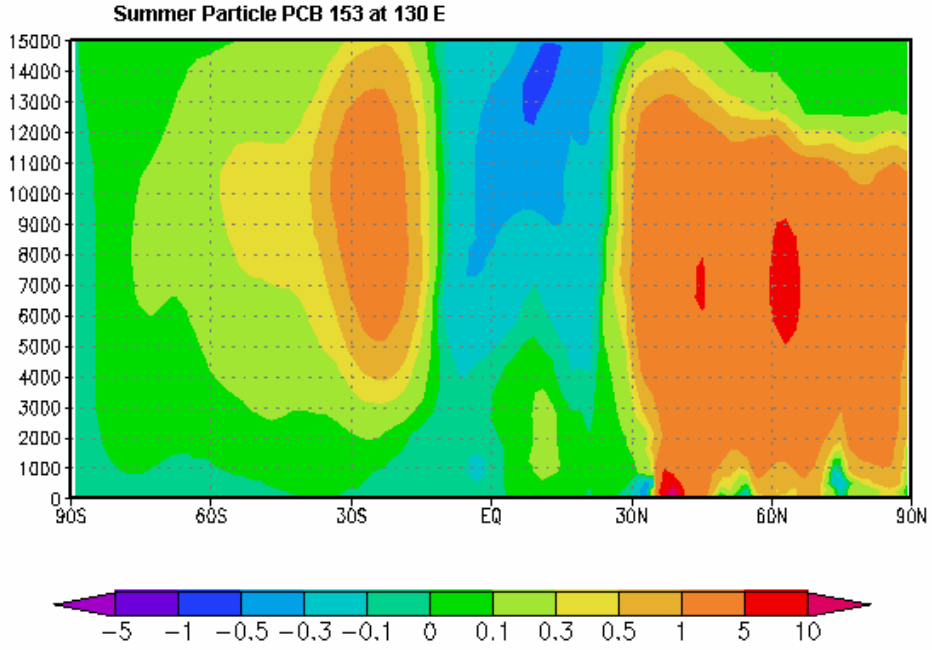
Intercontinental Transports

Out North America →

kg km^{-2} season^{-1}





S→N
W→E

← Out Asia

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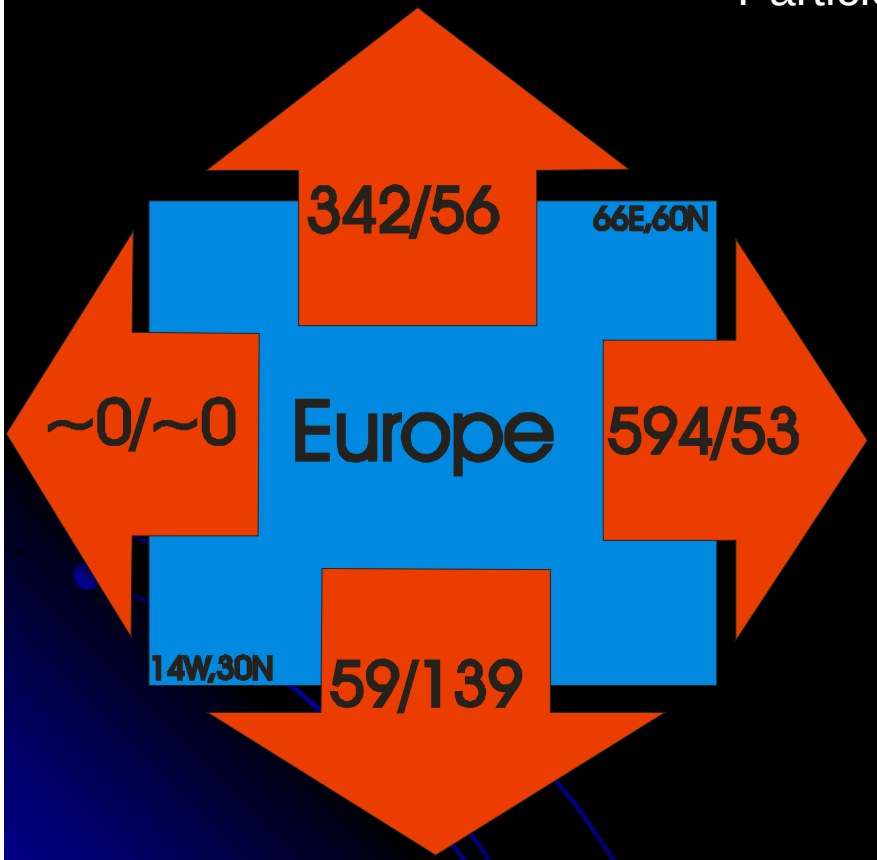
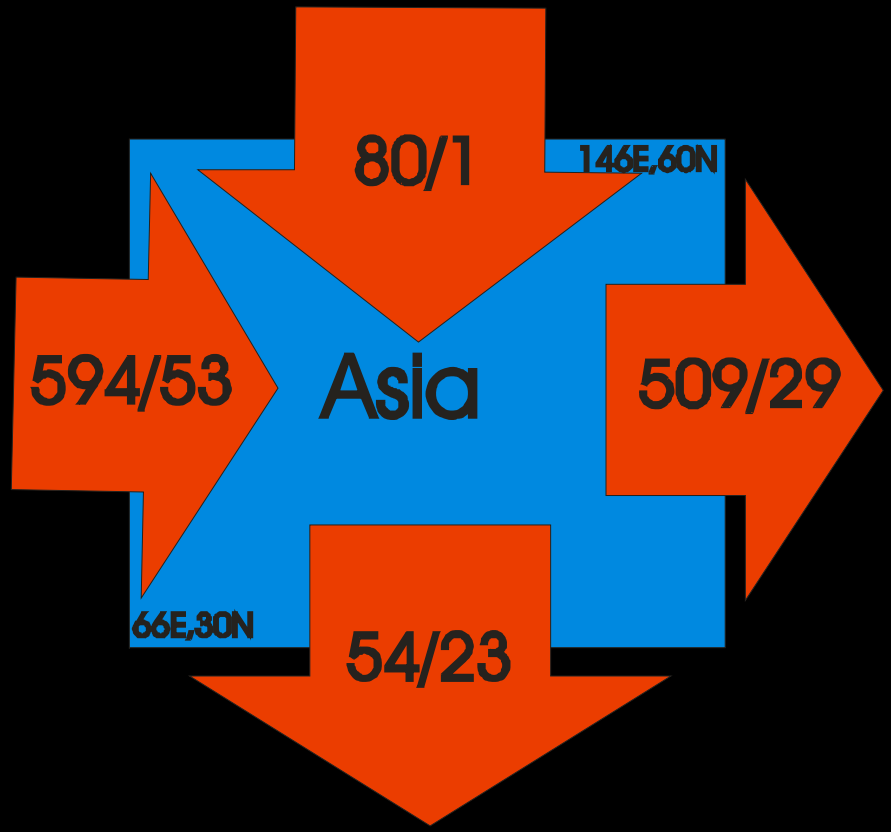
Intercontinental Transports

Particle/Gas





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Intercontinental Transports

Particle/Gas

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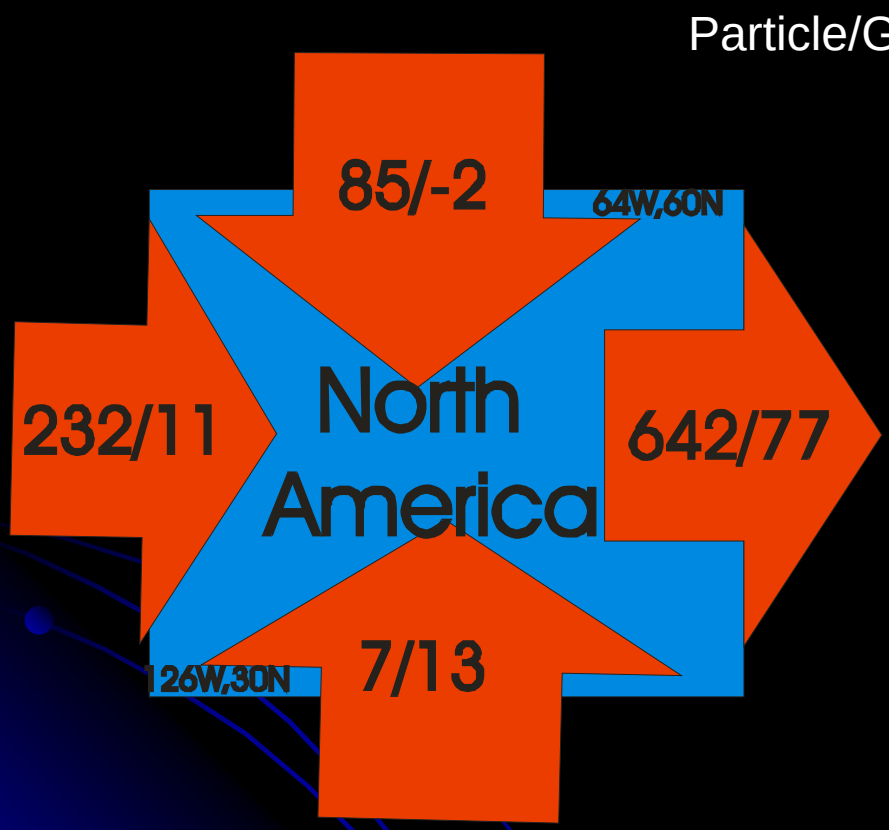
Environment Canada

Intercontinental Transports

Particle/Gas



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GLBTS Implications

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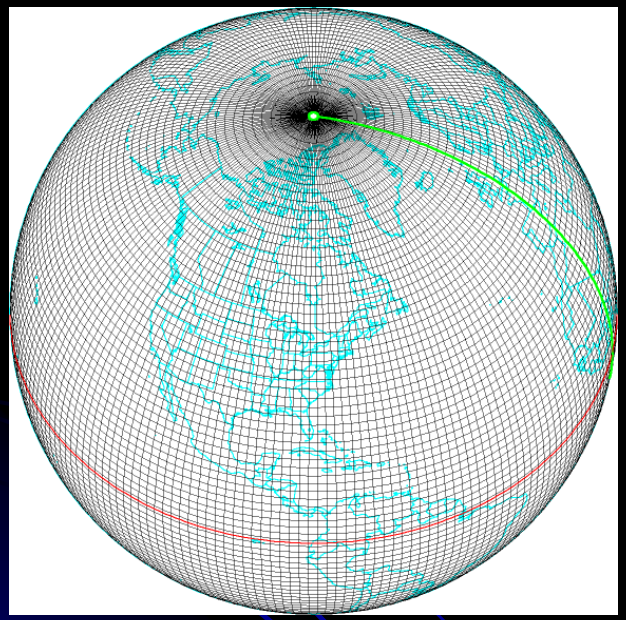
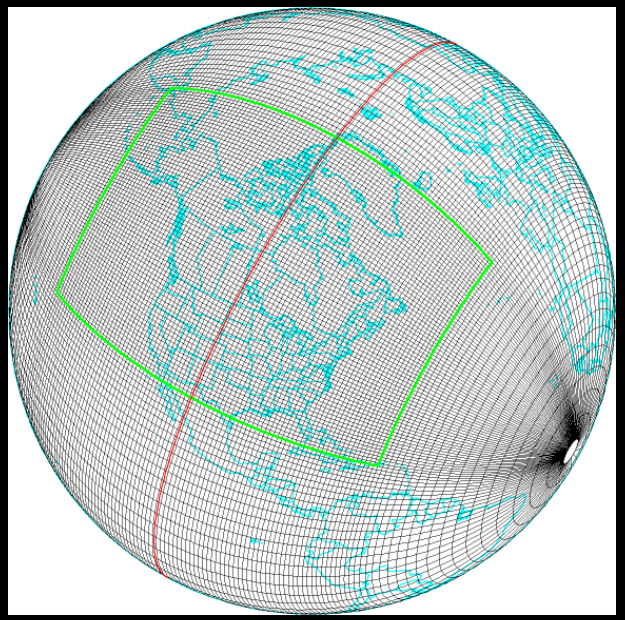
Global



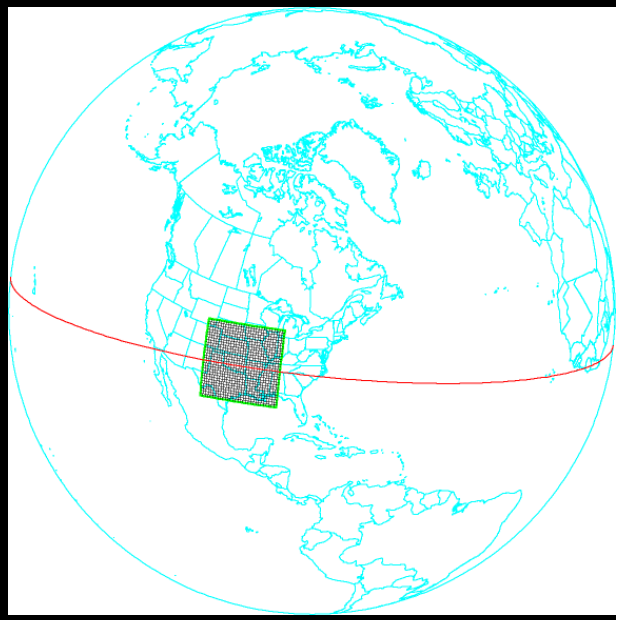
Global Emissions
1930's to 2000

Regional



North America
~ 25 km

Great Lakes



Urban
1 km

Future Works

- Global Historical Simulations (1950s – present)
  - historical deposition patterns
  - accumulated soil concentrations
- Global Future Simulations
  - depletion scenarios for PCBs
- Ocean/Lake Module
- Other POPs