Application of the transport models for inverse modeling of the greenhouse gas fluxes.

S. Maksyutov, H. Takagi, Y. Koyama, T. Saeki, T. Shirai, V. Valsala, T. Oda, R. Saito, D. Belikov, M. Saito[1], H-S. Kim[2]

[1] CGER, NIES, Tsukuba [2] RIHN, Kyoto

Nov 09, 2010 NIES SC workshop

Outline

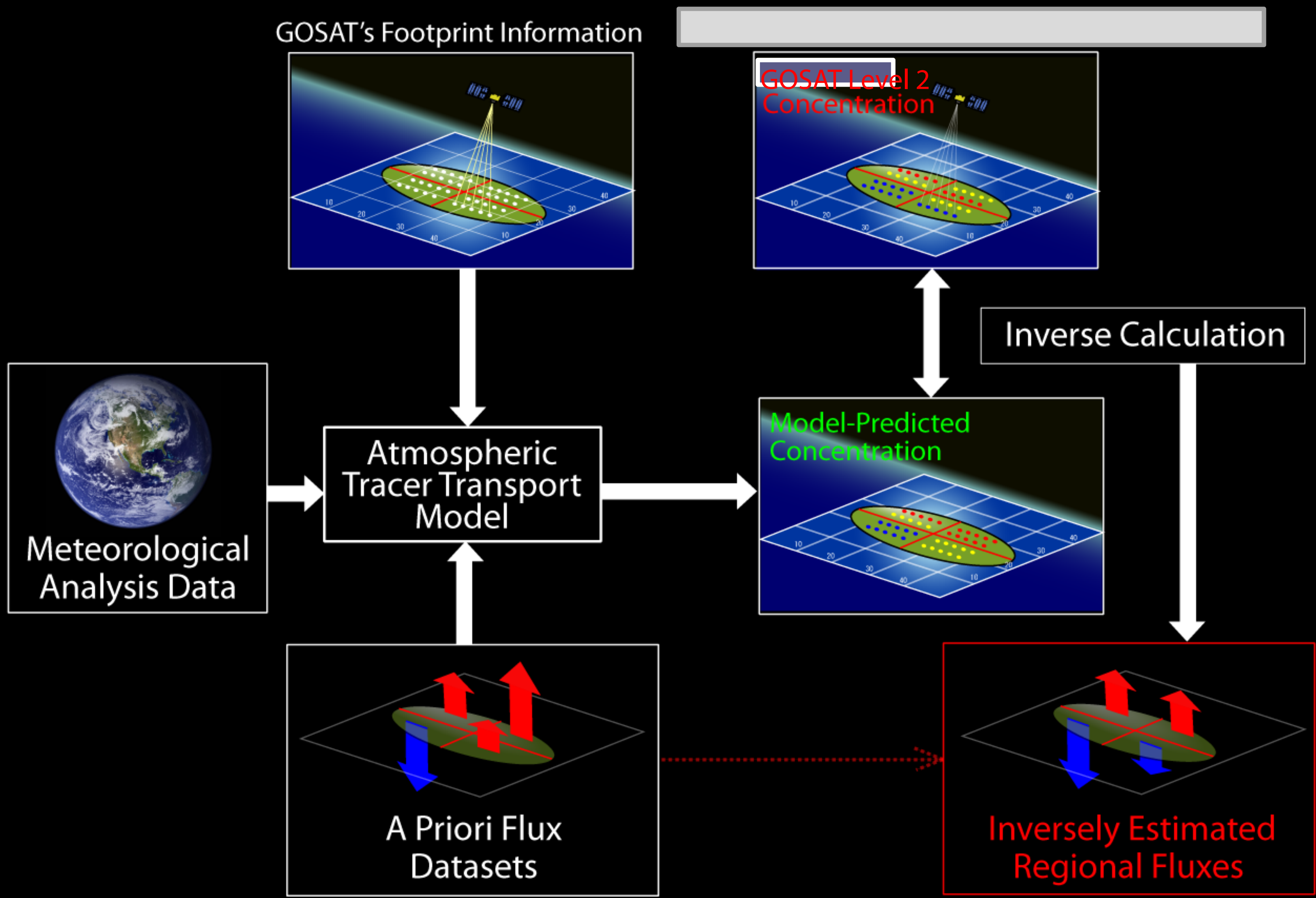
1. Inverse model analysis of the GOSAT CO_2 observations

2. Other results

- Optimization of the terrestrial biosphere model VISIT
- Atmospheric transport with isentropic coordinate model
- Comparison with JAL CO_2 observations: CONTRAIL-TMI
- CO_2 transport simulation with coupled Lagrangian-Eulerian global tracer transport model and 1 km resolution fluxes
- Data assimilation of CO_2 fluxes with adjoint code
- Siberian methane emission estimation with inverse model

3. Summary

Overview of Regional Sources/Sinks Estimation

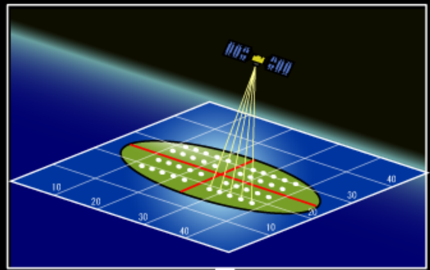


GOSAT Level 4A Data Product

(Monthly fluxes estimated for 64 sub-continental regions)

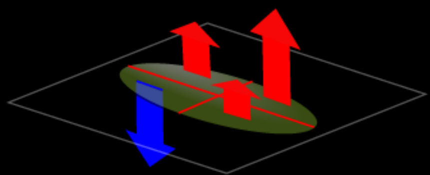
A Priori Flux Data Used in the Inversion

GOSAT's Footprint Information



JCDAS
Analysis Data

NIES-08.0
Transport Model

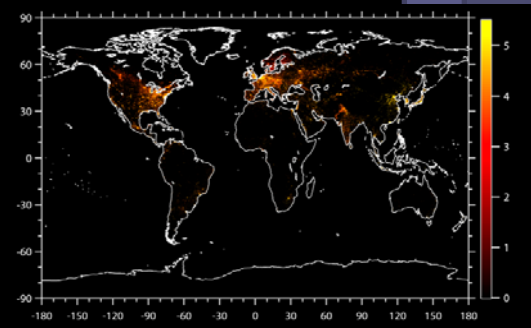


A Priori Flux
Datasets

Anthropogenic Emission Data

- Monthly data
- Resolution: 1 km × 1 km (→ Remapped to 1° × 1°)
- Data base year: 2007

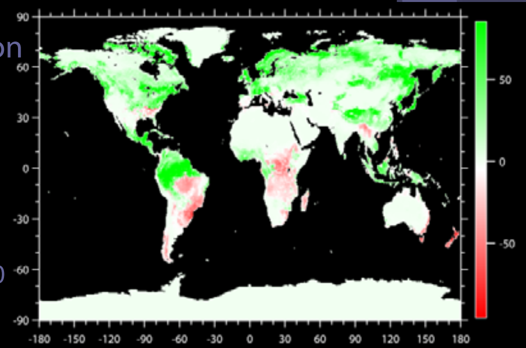
Oda & Maksyutov ACPD 2010



Terrestrial Biosphere-Atmosphere Flux Data

- Generated with vegetation process model VISIT
- Daily data
- Resolution: 0.5° × 0.5° (→ Remapped to 1° × 1°)

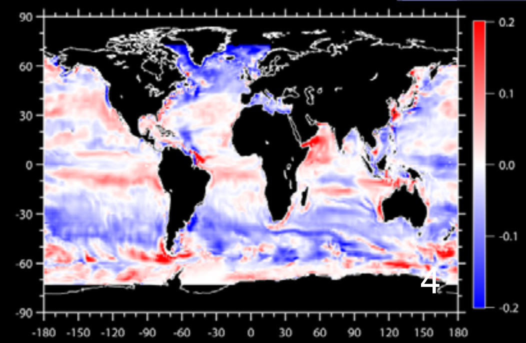
Ito, 2010, Saito et al J. Clim. 2010

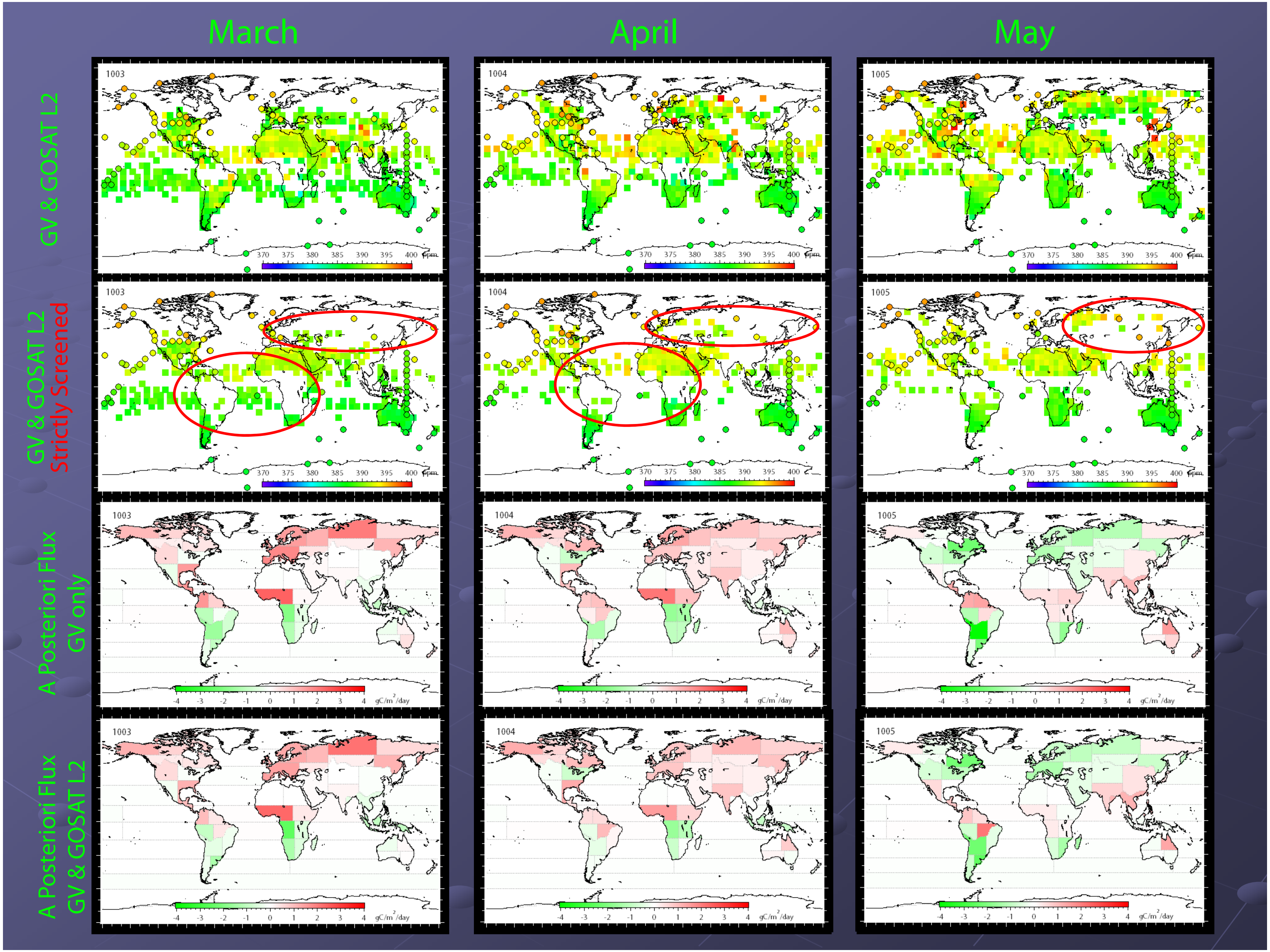


Ocean-Atmosphere Flux Data

- Generated with ocean transport model OTTM
- Monthly data
- Resolution 1° × 1°

Valsala & Maksyutov Tellus 2010



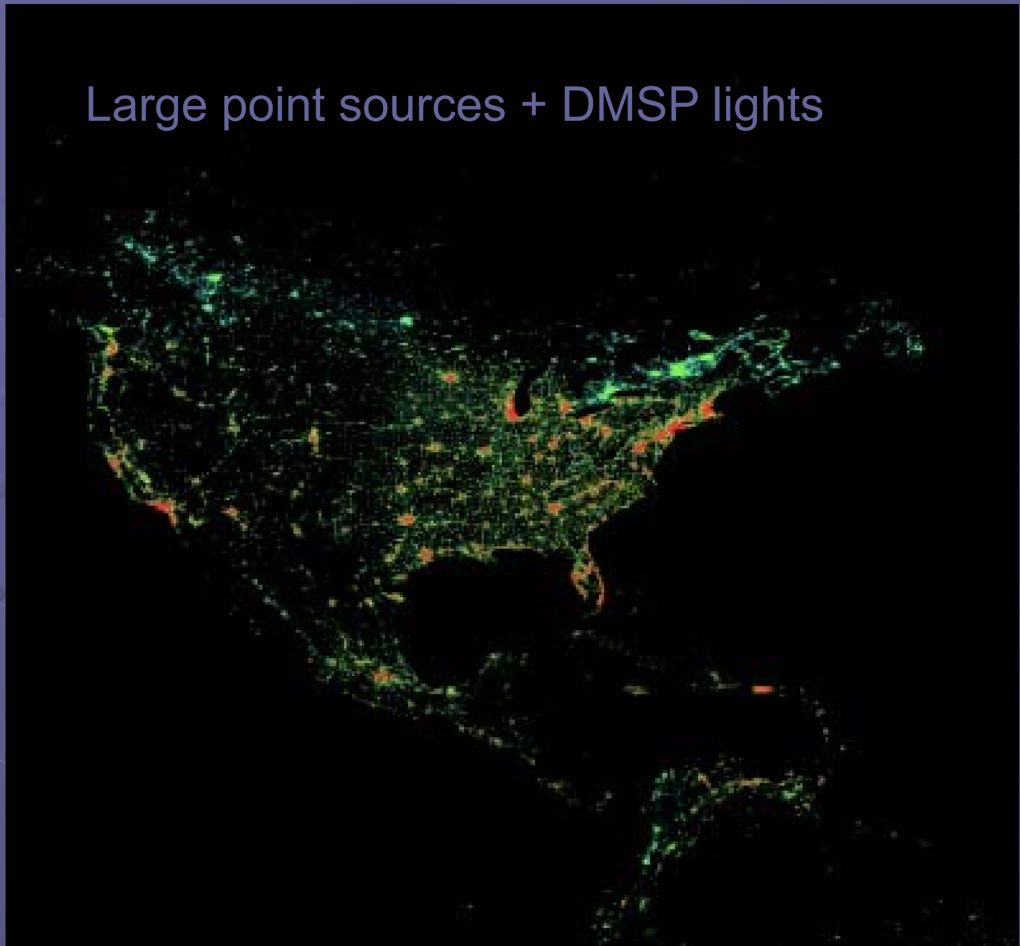


March
April
May
GV & GOSAT L2
GV & GOSAT L2
Strictly Screened
A Posteriori Flux
GV only
A Posteriori Flux
GV & GOSAT L2
1003
1004
1005
370 375 380 385 390 395 400 ppm
-4 -3 -2 -1 0 1 2 3 4 gC/m2/day

Summary

- Fluxes estimation from June 2009 to April 2010 completed
- The extended Globalview (GV) and GOSAT L2 CO2 data are used
- If a proper screening is applied 3ppm deviation from forward
- model, 60% data remains, fluxes retrieved with GOSAT + GV are similar to those estimated with GV only

Coupled model simulations with global high resolution fluxes. Step 1. High resolution fossil fuel emissions.



1 km fluxes became possible with large point source data and DMSP lights (1km res), produces good match at 50 km scale with high resolution bottom-up inventory by Vulcan project (K.Gurney) over US.

Oda & Maksyutov, ACPD, 2010

Surface fluxes: simulation of the 1 km resolution fluxes with ODIAC, VISIT, OTTM models

Method: combine high resolution pattern file with medium resolution temporal variability

Anthropogenic (T. Oda):

- 1 emission file for whole year with resolution 1km x 1km (3.5 GB), Oda 2010
- 12 monthly files with resolution 1° x1° for temporal variation (CDIAC).

Biospheric (M.Saito, A. Itoh):

- global vegetation map (15 biomes) with resolution 1km x 1km MODIS IGBP
- fluxes with spatial resolution 0.5° x0.5° and temporal resolution 1 day for each biome type, interpolate spatially to each 1 km pixel for its vegetation type

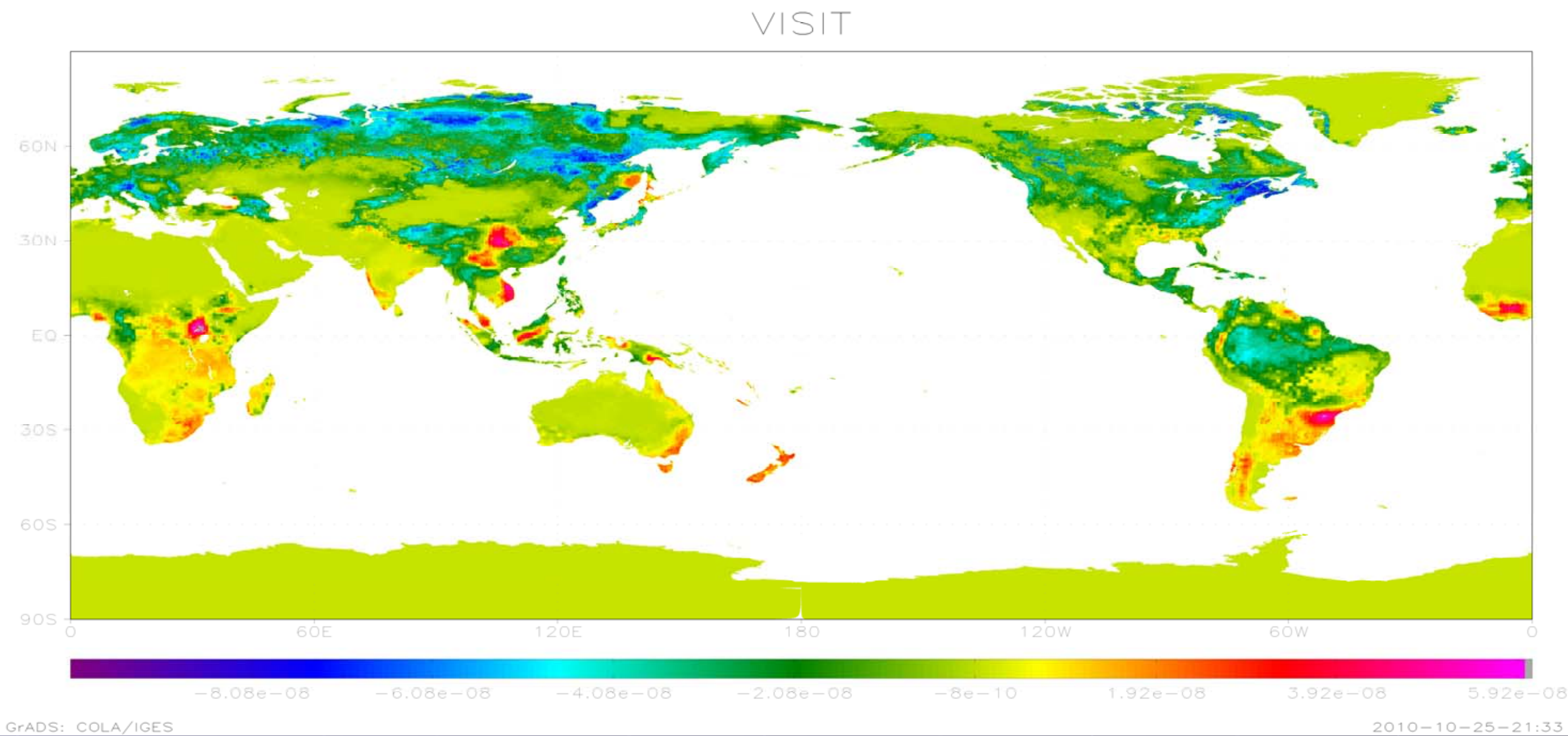
Ocean (V. Valsala):

- land-sea mask (global vegetation map from biosphere) 1km x 1km;
-12 monthly fluxes with resolution 1° x1° interpolate spatially to each 1 km pixel

Software (A. Ganshin, CAO, Russia).

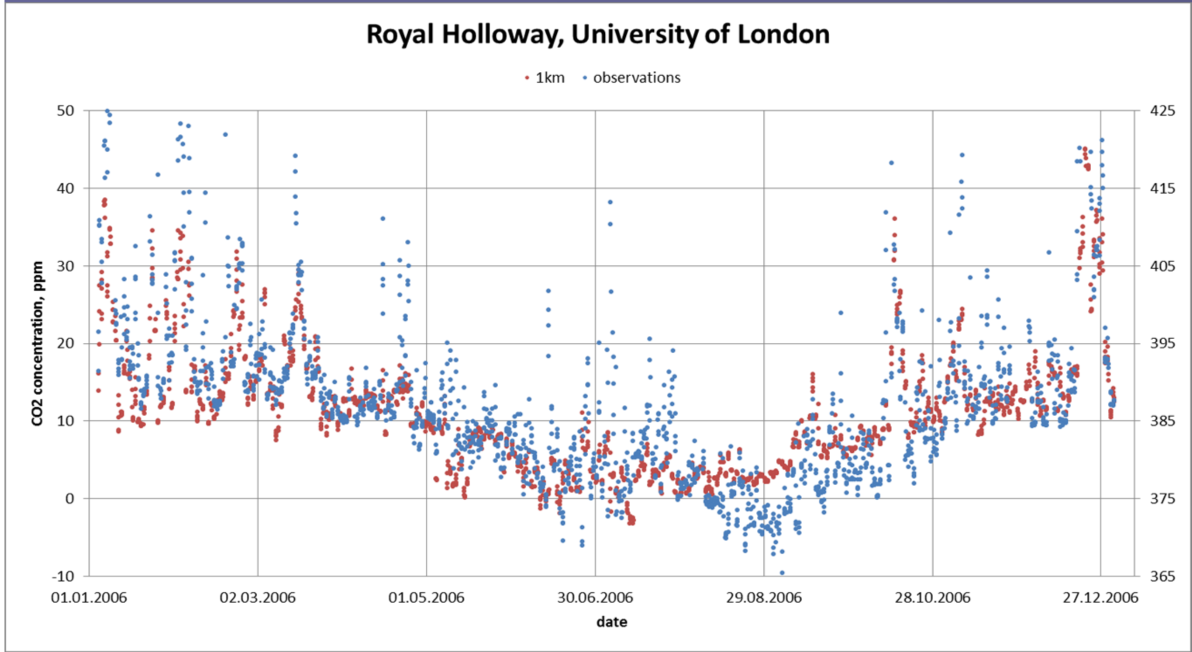
- A lot of memory if stored at 1x1 km, but by using sparse matrix storage we reduce memory footprint to about 1 Gb

Land fluxes are simulated at 0.5° x0.5° for each of 15 veg. types then interpolated to each 1x1 km pixel



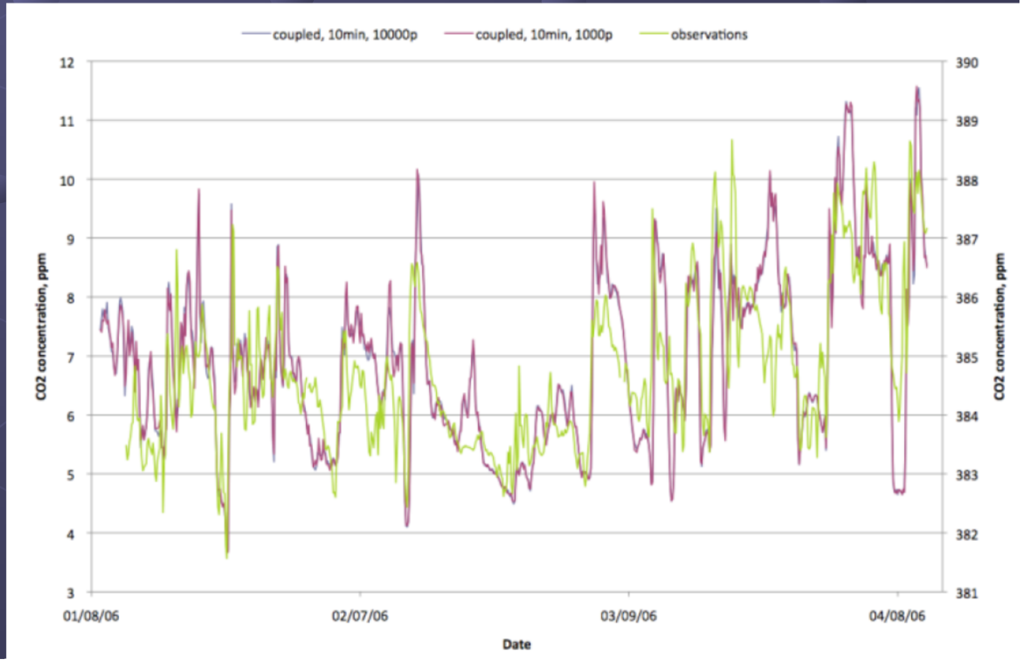
5x5 km resolution image of the surface CO_2 exchange with terrestrial biosphere (reduced from 1x1 km fluxes)

Testing coupled transport model with 1 km resolution fluxes



near London, UK, strong fossil signal

Minamitorishima remote site, clean air

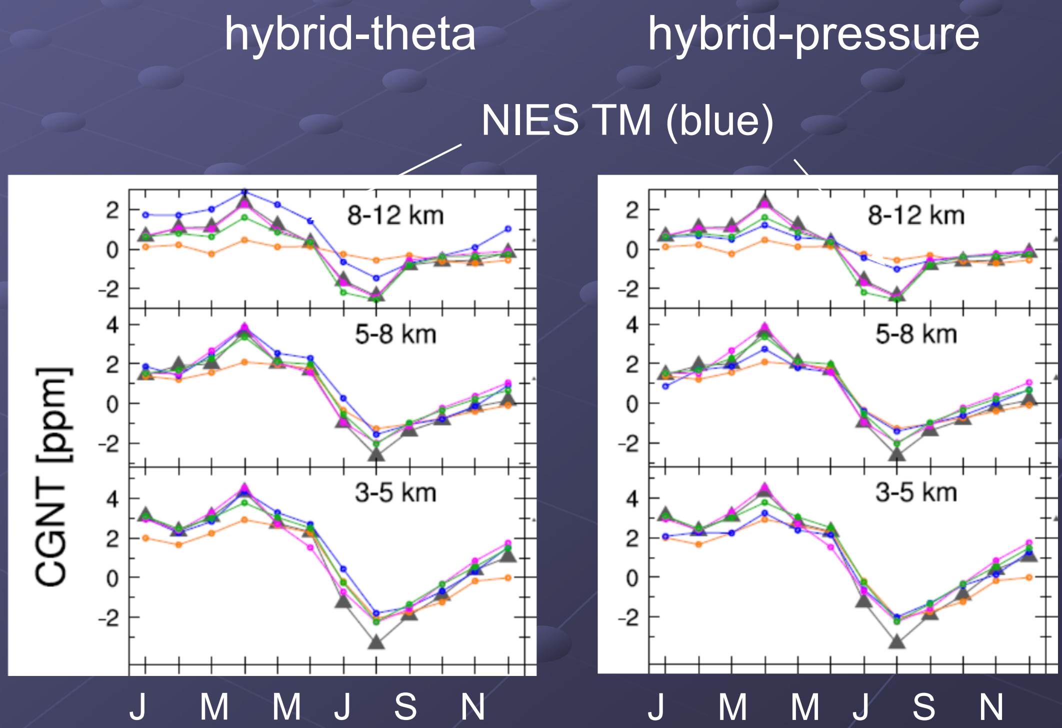


Improving vertical transport in offline model with hybrid sigma-theta coordinates

Problem: Off-line transport models use wind data from reanalysis (JCDAS, ECMWF etc), were vertical motions include waves, adiabatic motions are not resolved with 3-6 hourly sampling, that leads to short stratospheric age due to faster mixing in stratosphere.

In our model, theta-coordinate used above 350 K, vertical transport is simulated with JCDAS heating rate climatology, that considerably improves simulation in the upper troposphere

Fig 1. Model and observation comparison as a part of CONTRAIL-TMI experiment



Niwa et al (in preparation) 2010

Adjoint-based data assimilation system

Flexible selection of the inverse model flux resolution is possible with the adjoint-based optimization algorithm.

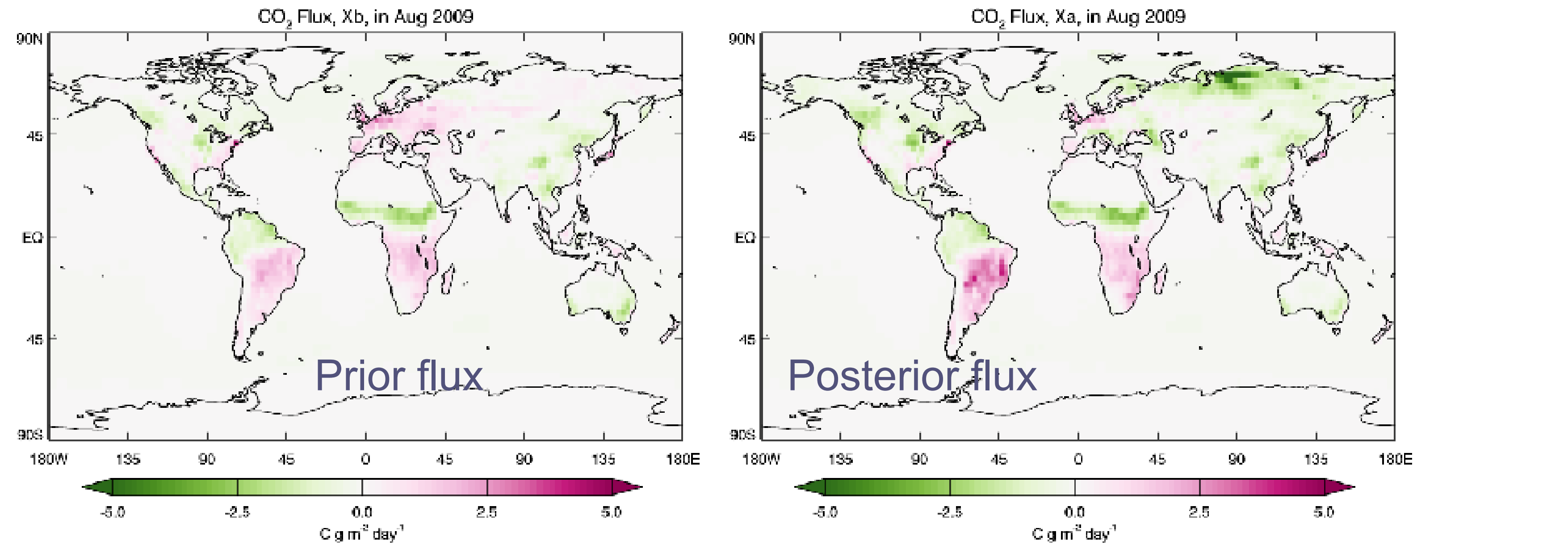
R. Saito & Maksyutov MSJ meeting 2010

Cost function to minimize

$$J = \frac{1}{2}(\mathbf{x}-\mathbf{x}_b)^T \mathbf{B}^{-1}(\mathbf{x}-\mathbf{x}_b) + \frac{1}{2}(H(\mathbf{x})-\mathbf{y})^T \mathbf{R}^{-1}(H(\mathbf{x})-\mathbf{y})$$

Model configuration:

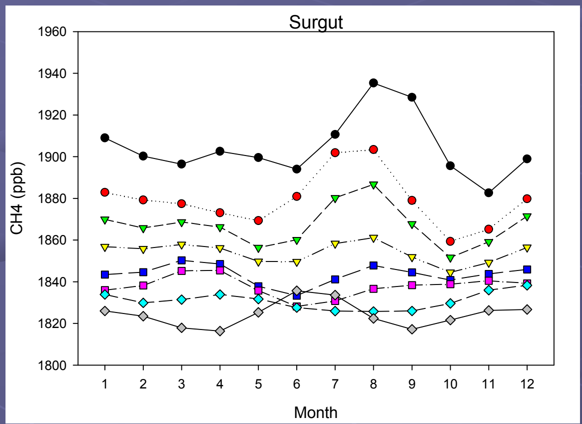
- NIES TM v08.0 2.5° x2.5° 15 lev. Belikov GMDD 2010
- derivative of the cost function by TAF compiler
- fluxes at 2.5° x2.5° monthly
- horizontal flux correlations included (Fujii et al 2001)
- single-shot GOSAT observations – no aggregation/averaging
- conjugate gradient algorithm for minimization



Inverse model estimation of the Siberian CH_4 fluxes

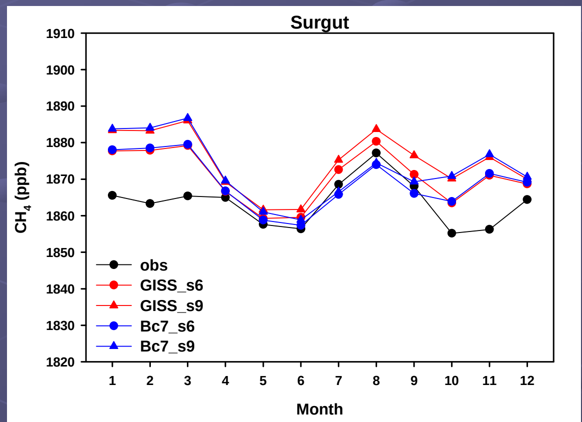
- CH_4 observations: T. Machida (NIES), Globalview-CH_4
- Transport model : NIES TM v. 99, 2.5 deg, 15L
- Inverse model: 11 land regions, 2 source categories (natural+ anthropogenic), monthly , cyclo-stationary (like Transcom CO_2)

Observations



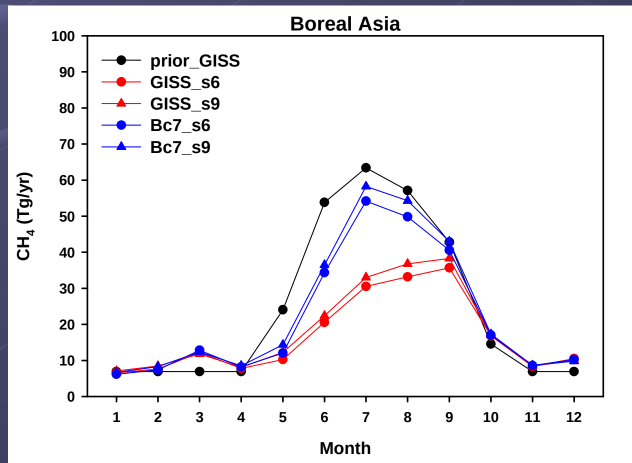
High concentration in summer caused by CH4 emissions by wetlands, in winter by gas pipelines

Model vs observations



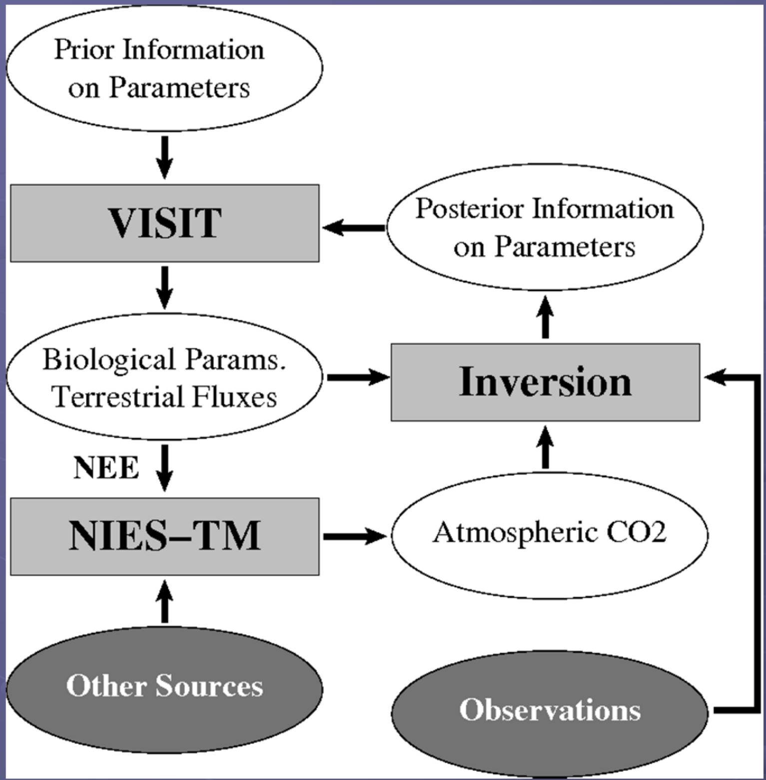
Modeled with optimized fluxes using 2 emission inventories – GISS and Glagolev et al 2010

CH_4 fluxes



Estimated fluxes differ for two different emission patterns, recent appears higher.

VISIT model optimization

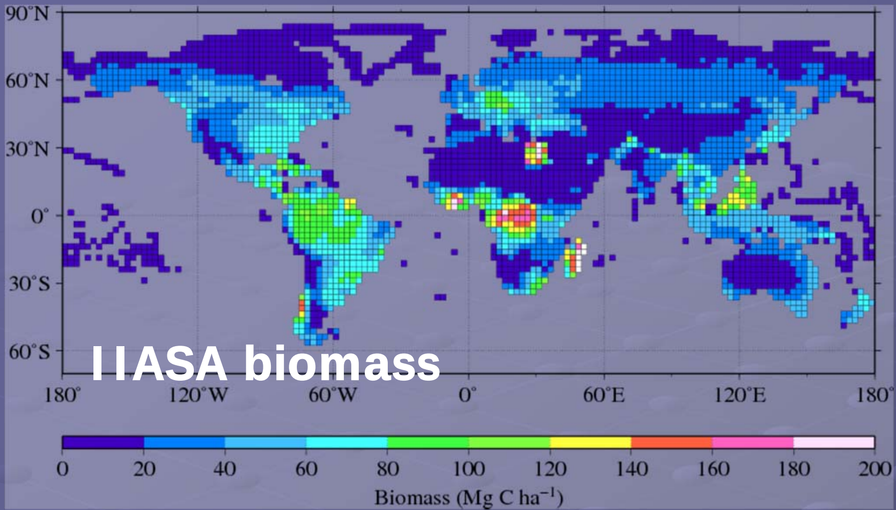


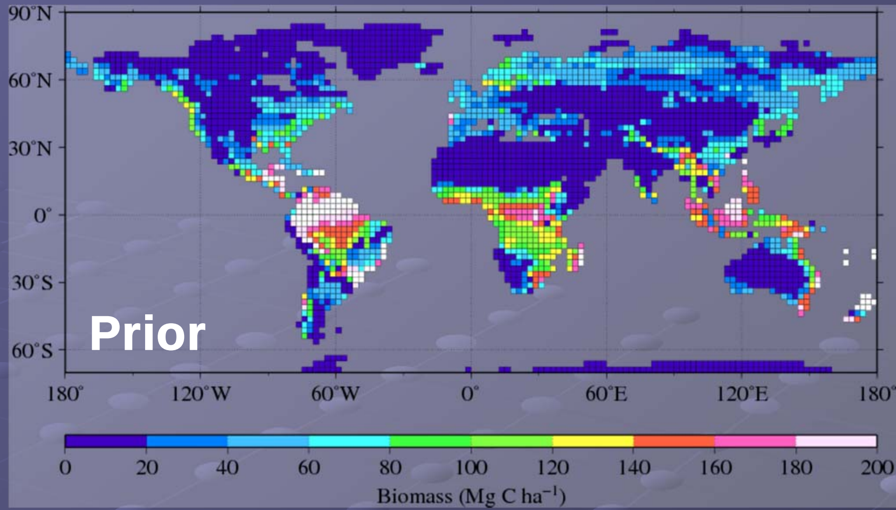
- Atmospheric CO_2 concentration:
  - ***GLOBALVIEW***
  - Monthly data in 2007
  - variables: NEE
- Biospheric CO_2 flux:
  - ***AmeriFlux Network***
  - Monthly data (original: daily)
  - variables: NEE, GPP, and RE
- Aboveground biomass:
  - ***IIASA*** (International Institute for Applied System Analysis)
  - Annual data
  - variables: Aboveground Biomass

NEE: Net Ecosystem CO_2 Exchange
GPP: Gross Primary Productivity
RE: Ecosystem Respiration

NEE = RE – GPP
< 0: CO_2 uptake from the atmosphere
> 0: CO_2 release to the atmosphere

Seasonal cycle and biomass





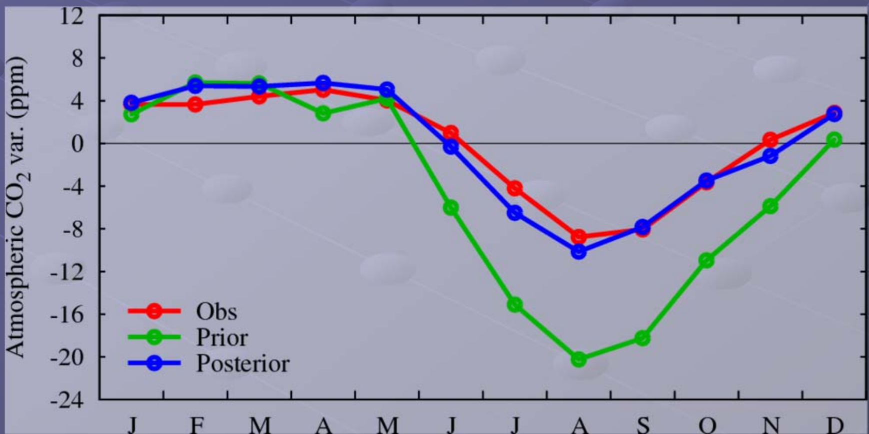


Fig. Seasonal variations in observed and modeled atmospheric CO_2 (ppm) at Mace Head in 2007.

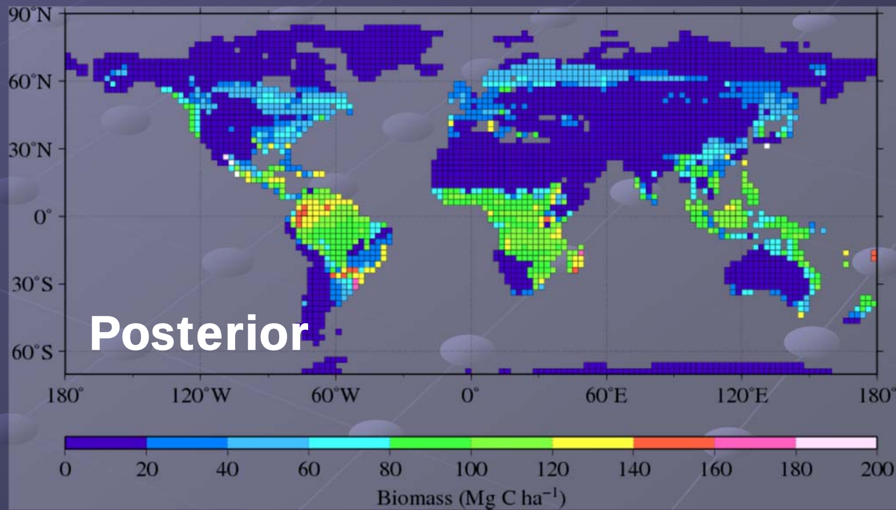


Fig. Global map of gridded mean biomass (Mg C ha^{-1}): (left) IIASA; (right top) Prior; (right bottom) posterior.

Summary

- Completed first inverse model analysis of the GOSAT CO_2 observations
- Achieved global CO2 transport simulation with 1 km resolution fluxes
- Implemented atmospheric transport with isentropic coordinate model, improved transport in upper-troposphere, match with JAL CO2 observations
- Developed data assimilation of CO2 fluxes with adjoint code
- Siberian methane emission estimated with inverse model and airborne monitoring data
- Optimized terrestrial biosphere model VISIT to match atmospheric CO_2, Ameriflux-Fluxnet CO_2 fluxes, forest biomass map