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

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and

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Outline

Improvements for the inverse model for GOSAT L4A

- Terrestrial biosphere, ocean carbon cycle, atmospheric transport and fossil fuel emissions

Ongoing developments

- Kalman smoother application with coupled transport.
- Cumulus cloud mixing
- Biospheric model optimization with inversion

Summary

Tracer transport model development

Options	Model			
	NIES-05 ¥SML¥0.5	NIES-08 ¥VL¥1.25	NIES-08 ¥VL¥0.625	NIES-08 ¥Pr¥2.5
Numerical Scheme	Semi-Lagrangian	Flux-form (flux version)		
		3-order van Leer		2-order Moment
Resolution, deg	0.5	1.25	0.625	2.5
Number of vertical levels	47			
Meteo dataset	JMA/GPV dataset			

GPV meteorological dataset with resolution of 0.5 × 0.5 degrees for 21 pressure levels - special product for GOSAT by JMA (added extra levels in LT, 3 hourly vs standard 6 hourly)

v. 08 VL: Van Leer, 2nd order shape function

v. 05 Pr: Prather, with 2nd order moments

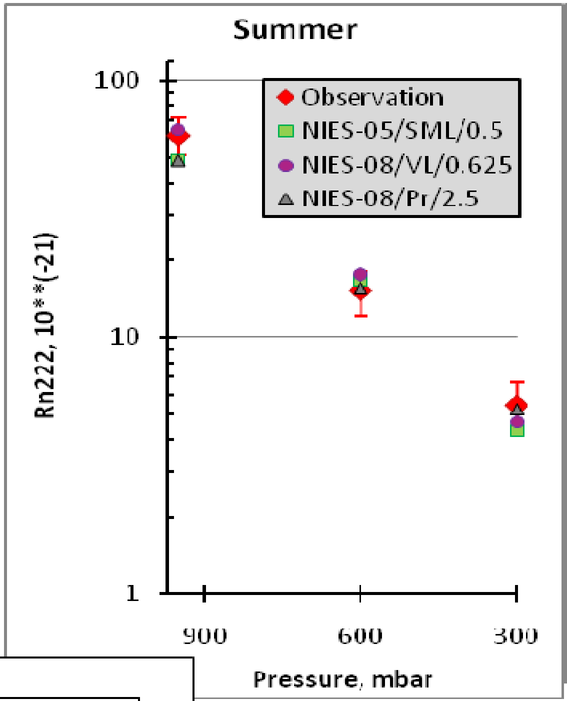
v. 05 SML: Semi-Lagrangian, bilinear interpolation

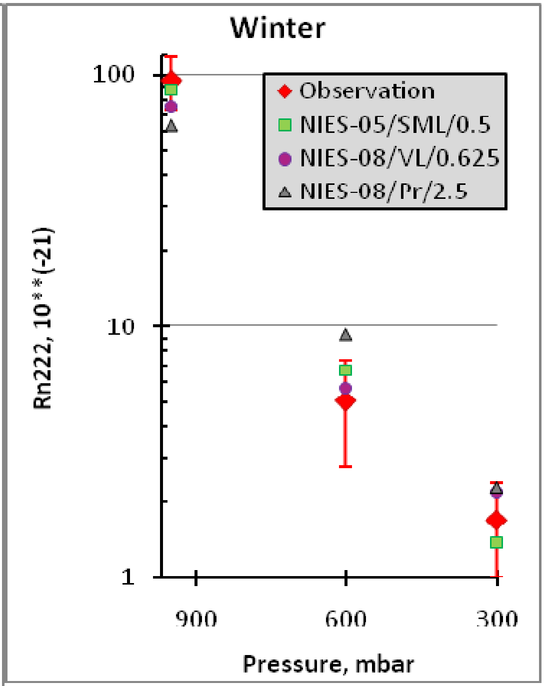
Tracer transport model performance

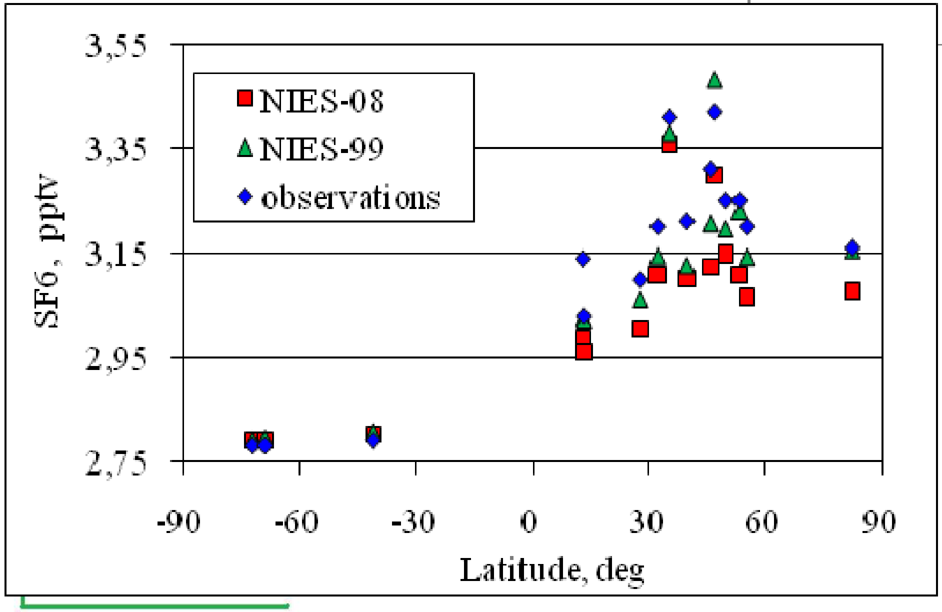
Resolution		NIES-08 Val Leer	NIES-08 Prather	NIES-05 SML
2.5°×2.5° (2°×2° for SML)	CPU, sec	10.21	292.90	6.08
	emin	6.22E-04	1.38E-04	-5.37E-03
	emax	-2.86E-03	-3.48E-04	2.16E-03
	err1	-6.66E-03	-5.96E-08	6.09E-02
	err2	1.17E-03	1.02E-03	5.08E-03
	Memory, Gb	0.72	0.77	0.72
1.25°×1.25° (1°×1° for SML)	CPU, sec	55.93	1755.77	20.86
	emin	1.57E-04	-5.95E-05	-0.229E-06
	emax	-3.66E-03	1.03E-06	0.00E+00
	err1	-3.50E-03	4.78E-03	1.93E-02
	err2	8.94E-04	8.48E-03	9.90E-03
	Memory, Gb	0.98	1.10	0.98
0.625°×0.625° (0.5°×0.5° for SML)	CPU, sec	370.975	12683.15	82.20
	emin	3.93E-05	-5.11E-06	-1.04E-07
	emax	-2.44E-03	-5.21E-03	7.95E-08
	err1	-1.75E-03	5.55E-03	1.59E-02
	err2	6.15E-04	1.18E-04	1.74E-02
	Memory, Gb	1.94	2.46	1.94

Tracer transport model: model validation

Vertical mixing test:
Radon simulation

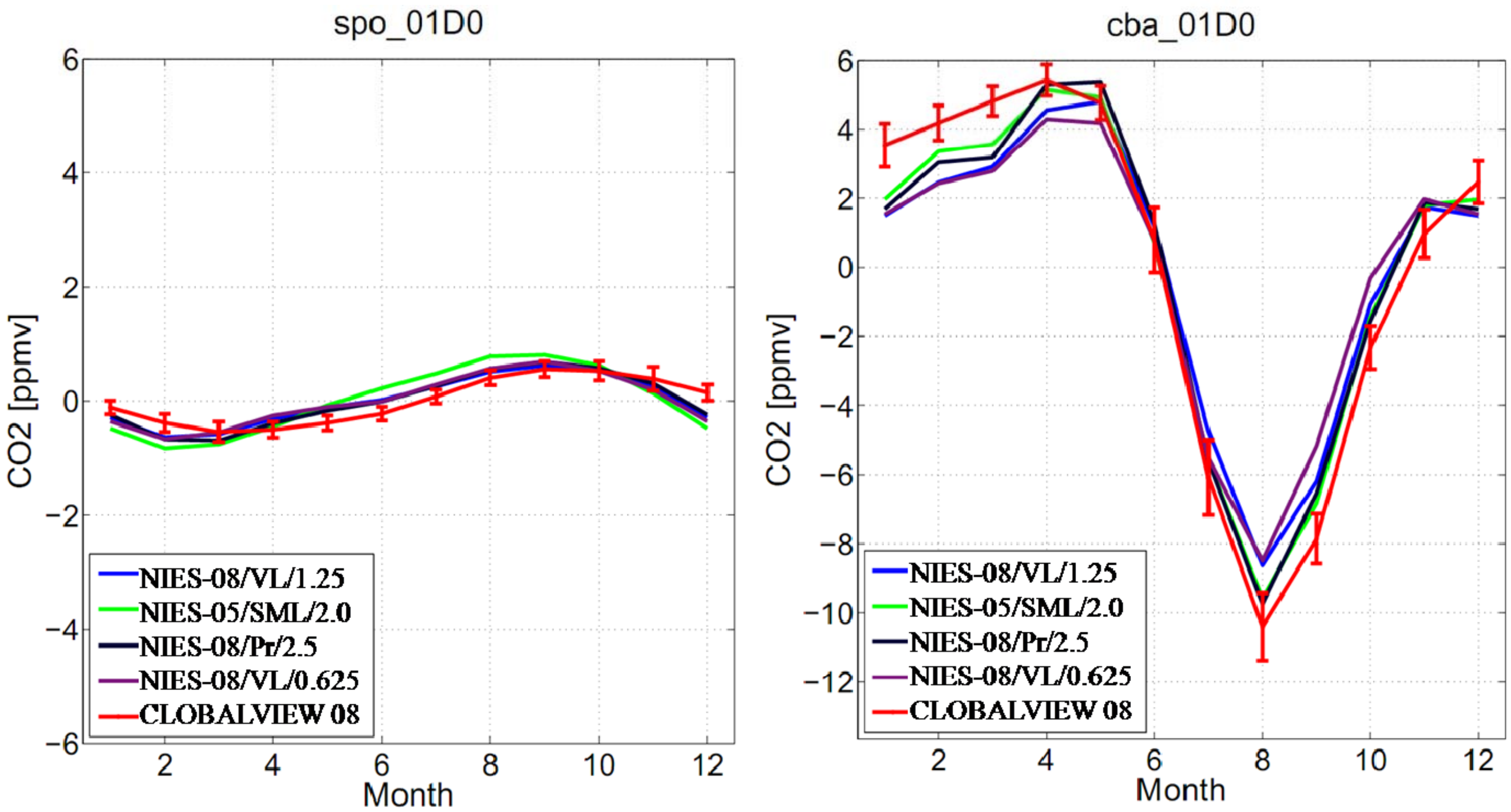






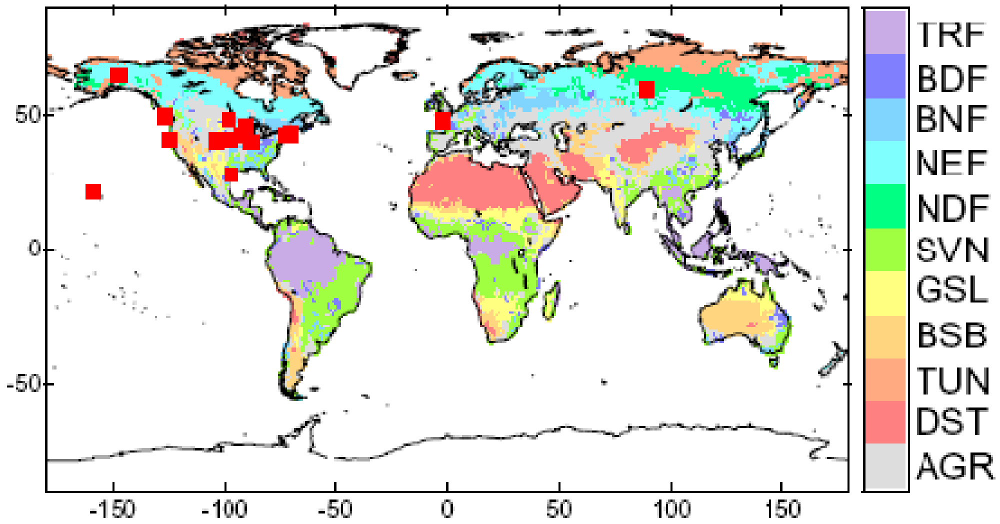
Interhemispheric mixing test:
SF6 simulation

Tracer transport model: model validation



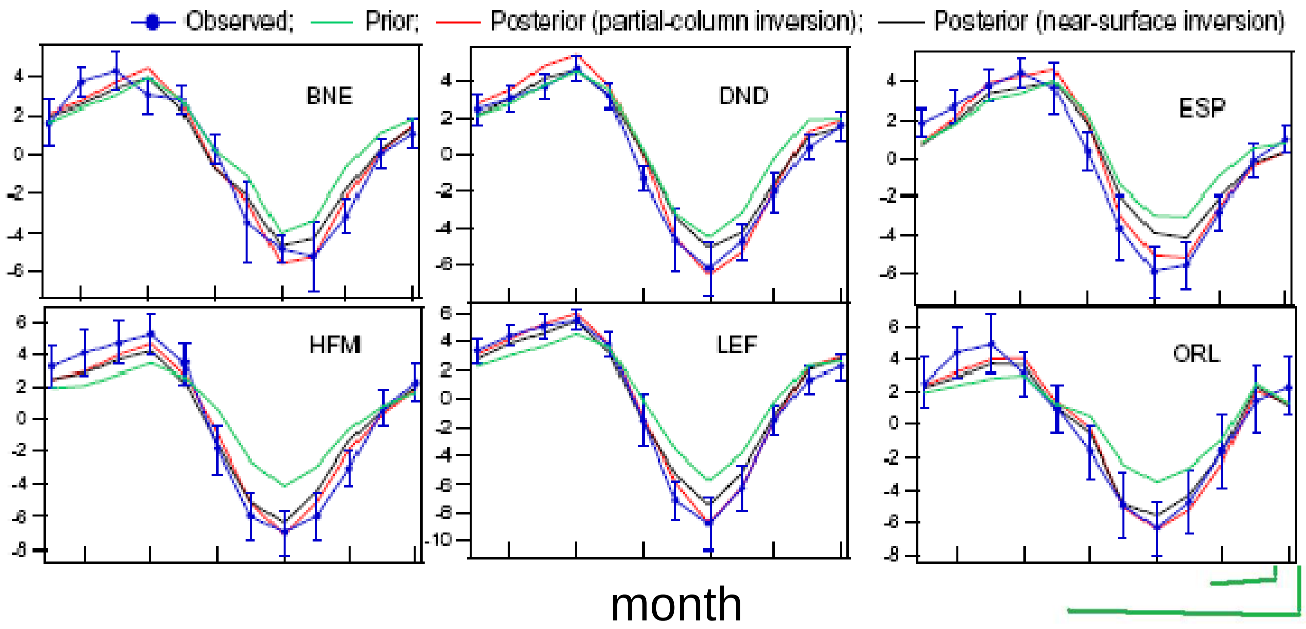
Seasonal cycle of CO_2 over South Pole (-89.98;-24.80; 2810) (a) and Cold Bay in Alaska (55.20; -162.72; 25) (b) for 2008, ppmv

Land CO_2 fluxes: improved simulation seasonal cycle in atmospheric CO_2 partial column abundance



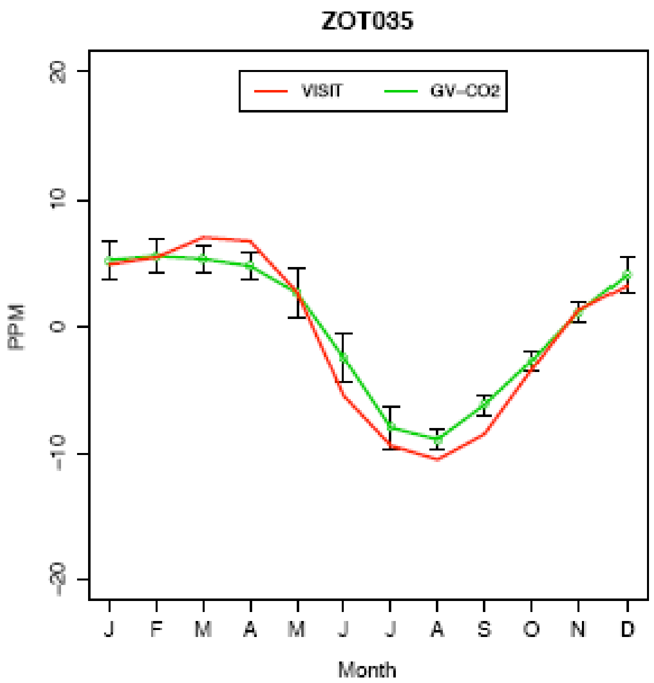
Parameter values for each ecosystem
(1) light use efficiency for NPP
(2) temperature coefficient of respiration
Optimized independently for each vegetation type, completed for CASA model, working on VISIT (A. Ito, M. Saito)
Nakatsuka & Maksyutov Biogesci. Disc. 2009

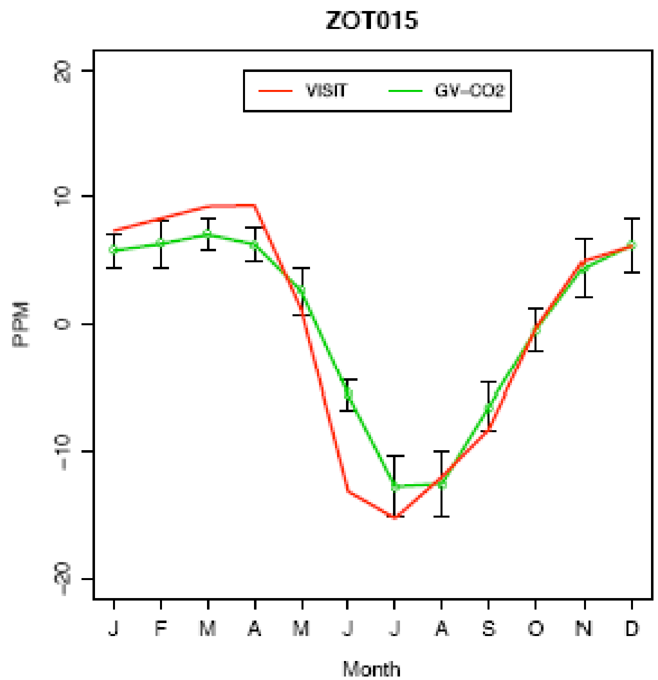
Seasonal variation of CO_2 partial column, with ecosystem model optimized with observations. Result: monthly CO2 flux maps at 1x1 deg res.



Land CO_2 fluxes: improved simulation seasonal cycle in atmospheric CO_2 partial column abundance

Seasonal variation of CO_2 vertical profile column, with VISIT ecosystem model before optimization.
Red – VISIT Green – Globalview08





Plan – optimize q10 and photosynthetic capacity (and ~ 15 other parameters) with inverse model

Ocean CO2 flux. 4D-var assimilation of the surface ocean pCO2

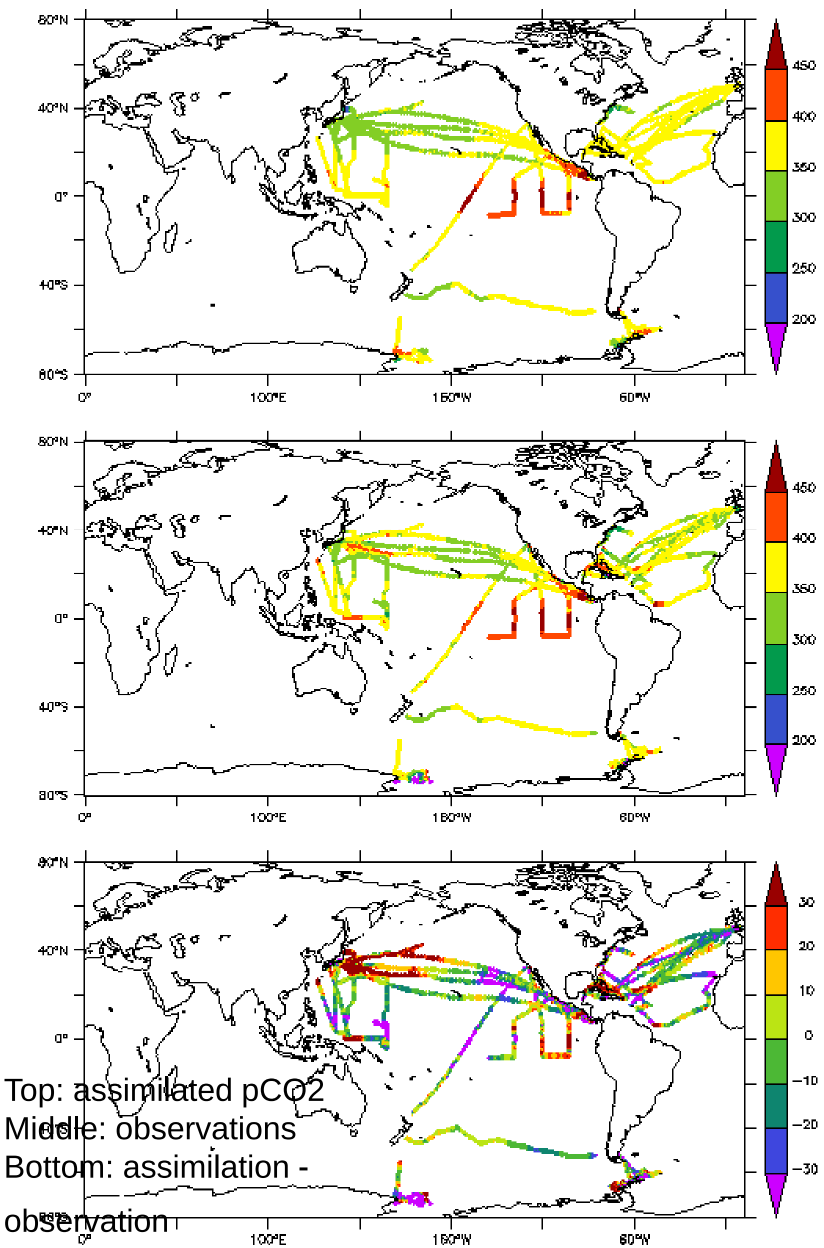
GOSAT Greenhouse gases Observing SATellite

Objective:
Provide ocean CO_2 flux priors for GOSAT L4A inverse model.

Physical : Oceanic TM (Valsala et al., 2008)
Chemical: OCMIP-II (Watson and Orr, 2003)
Biological: McKinley et al. 2004
4D-var: Ikeda and Sasai (2002)

Currents: ECCO (or GFDL)

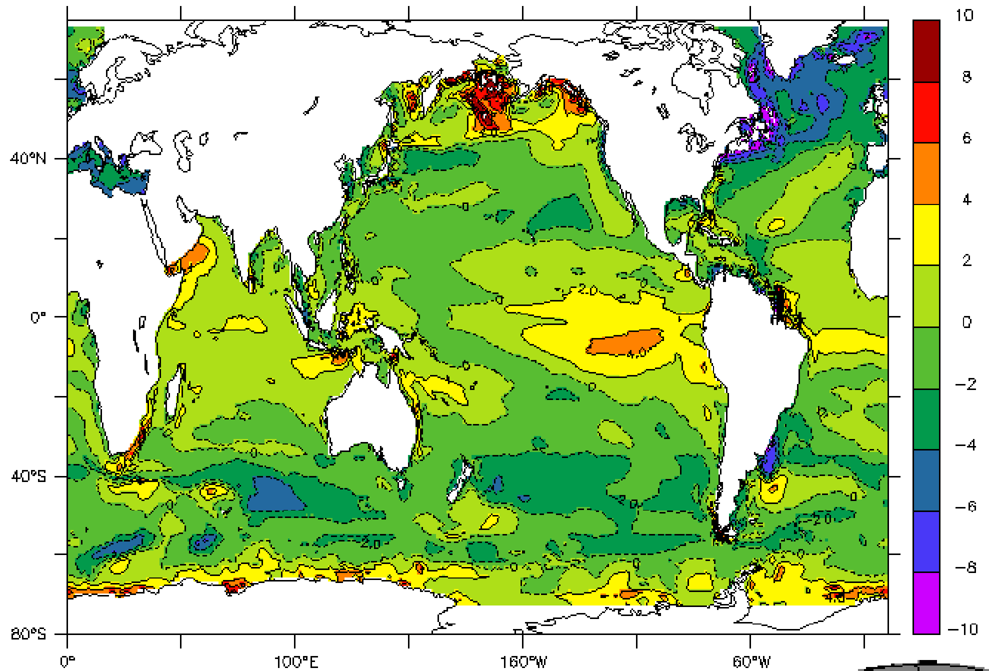
DIC/pCO2 observations:
LDEO database, Takahashi 2009



Top: assimilated pCO2
Middle: observations
Bottom: assimilation - observation

Ocean fluxes: assimilation output

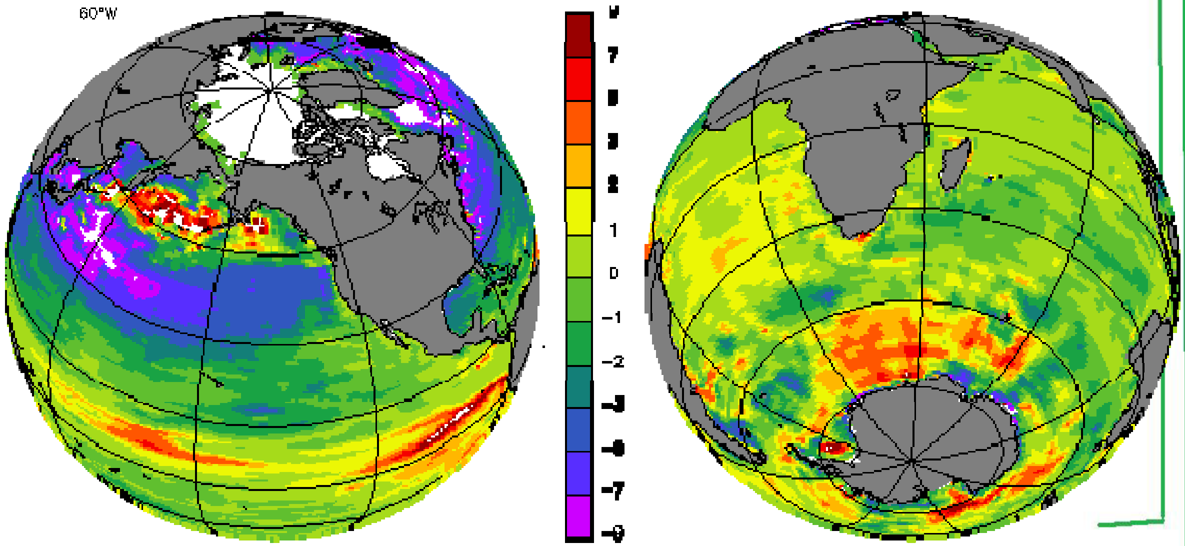
ECCO annual mean co2 flux (spin up; mole/m2/yr)



4D-Var assimilation of ocean CO_2 flux

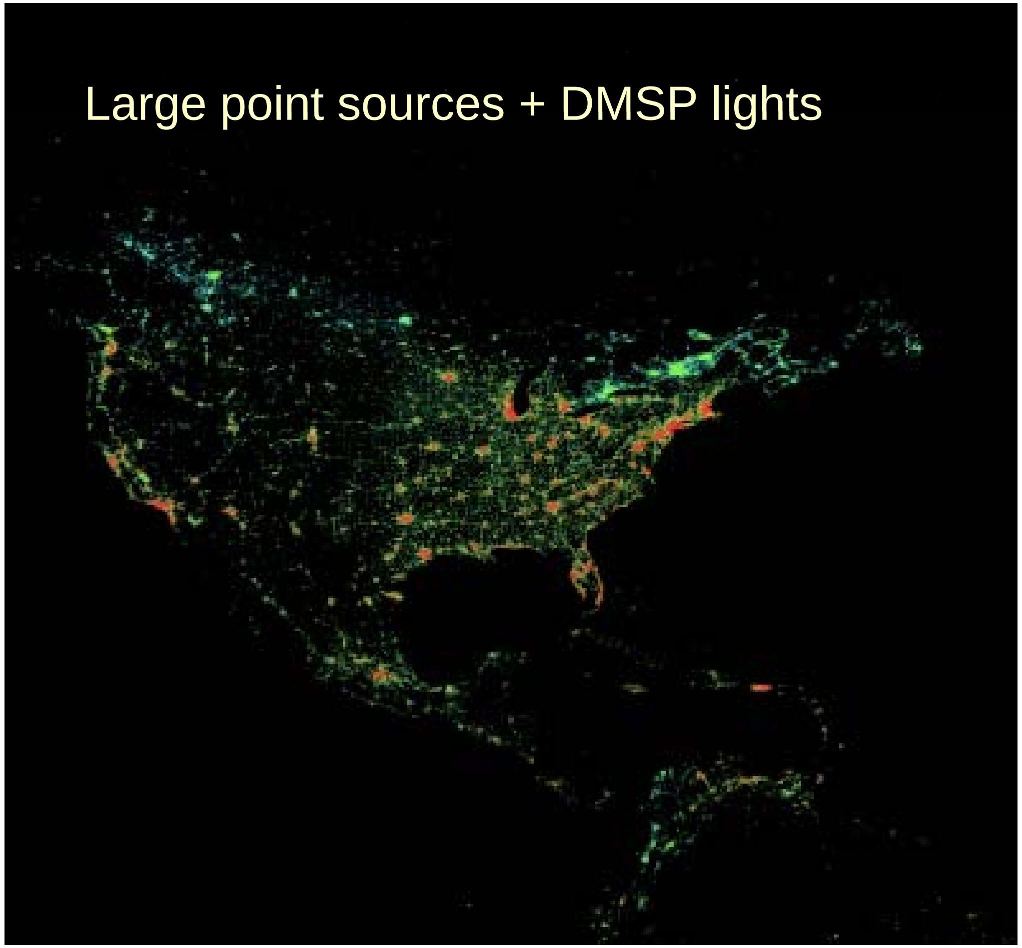
Period:
Near-Real time
Completed w GFDL: 1996-2004.
With ECCO: 2004-2009.
Animation Multi-year assimilated air-sea CO_2 flux .

Ocean currents by ECCO reanalysis (MIT ocean GCM) are available with approximately 1 month delay.



By V. Valsala et al, ICDC8, 2009

High resolution fossil fuel emissions.



Using 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) in US.

by Oda & Maksyutov, ICDC8, 2009

Development of a coupled transport model

1. Objective;
   Develop a new transport model LPDM (Flexpart) coupled with NIES-TM for use in inverse modeling

2. Progress;
   Model has been validated using ESRL flask and NIES continuous greenhouse gases observations 1996-2007.

3. Plan
   Extend model to using GOSAT column observations

Y. Koyama et al, ICDC8

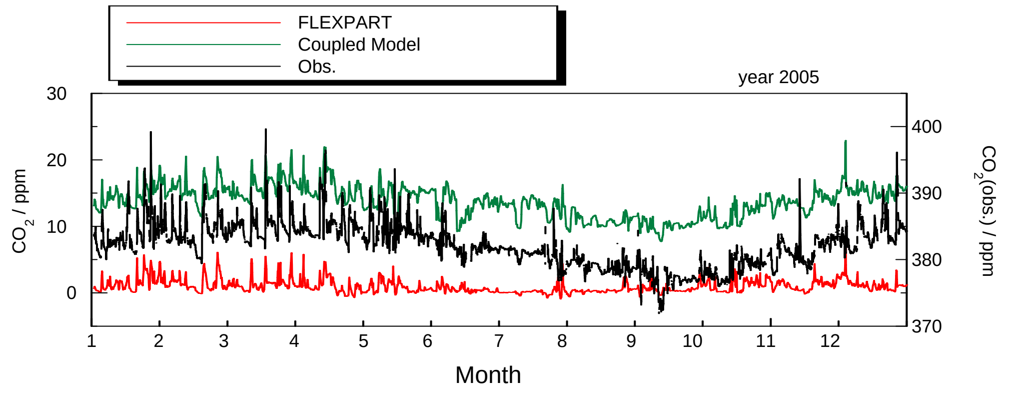
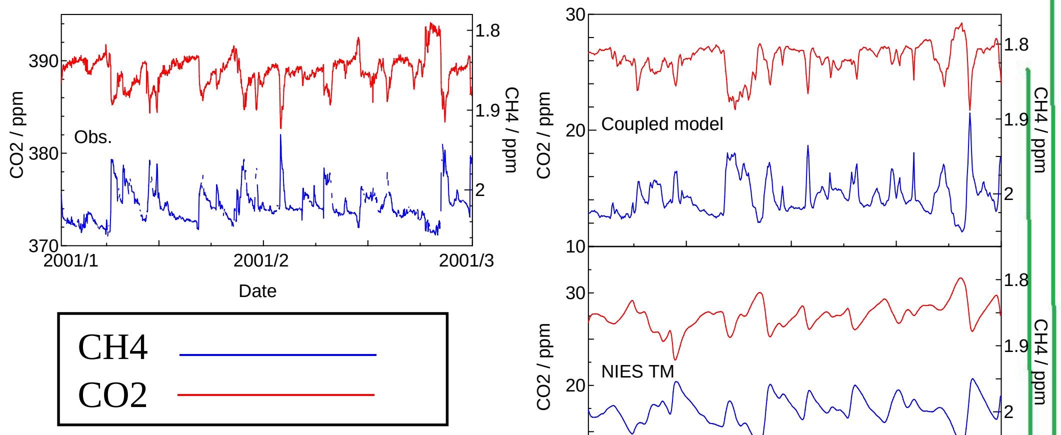


Fig. 1. CO2 variation at Hateruma for year 2005.



NIES TM : 2.5x2.5
Coupled : 0.5x0.5

Fig. 2. CO2 and CH4 variations at Hateruma for winter season, year 2001.

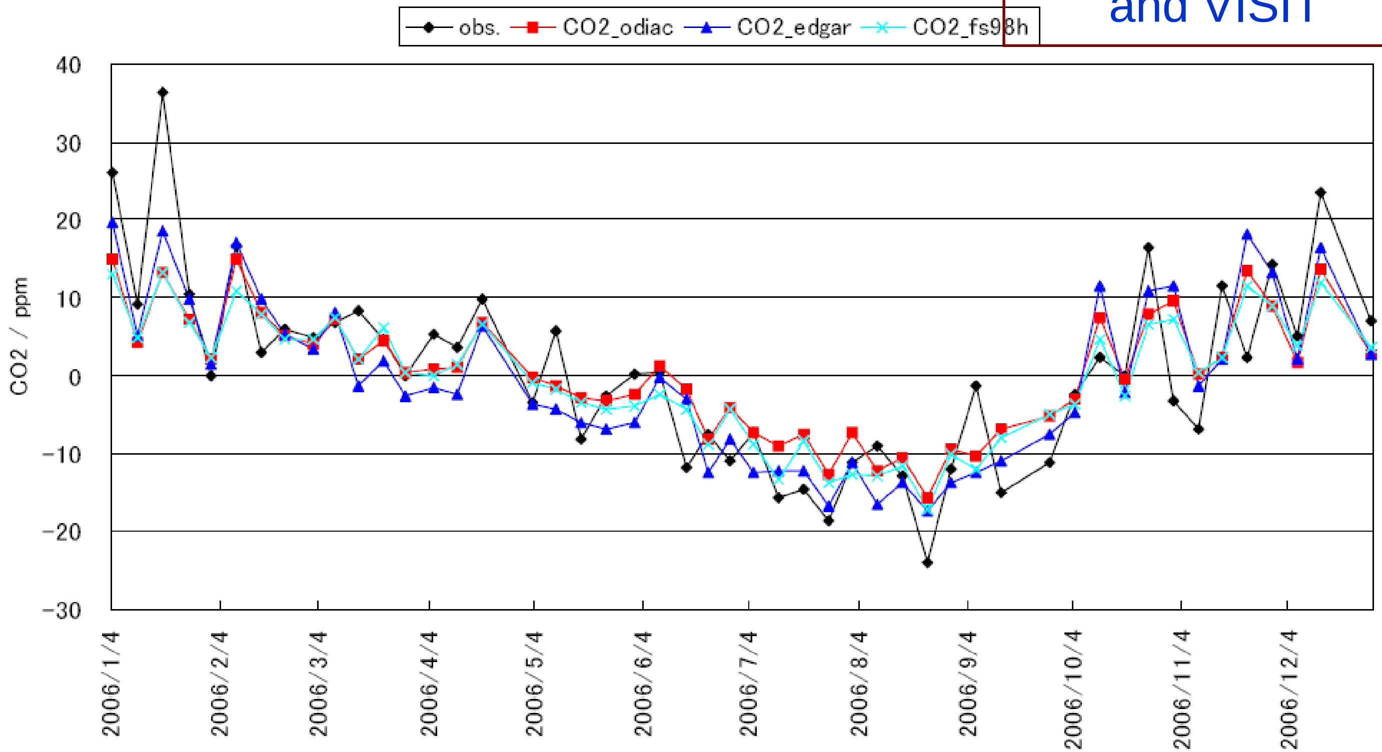
Coupled transport model with 5-10 km resolution fluxes

1. Objective;
   Test very high resolution simulation globally with 5-10 km emissions

2. Progress;
   Made comparison at Chinese site (data by H. Mukai et al)

3. Plan
   Use 1 km fluxes by Oda et al, and VISIT

Fig. 1. Oda -5km, EDGAR-10km and CDIAC 0.5° °

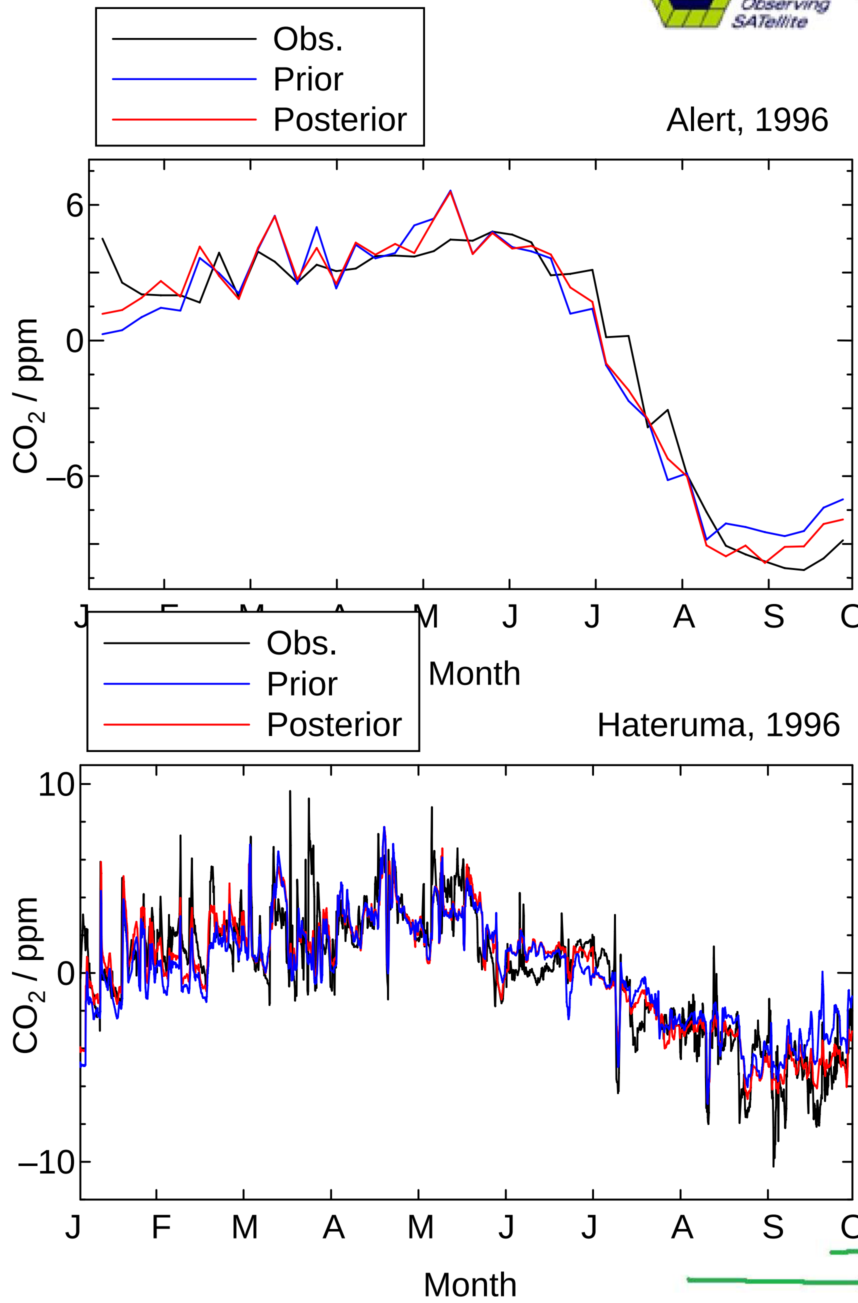


Inverse modeling with Lagrangian transport

1. Objective:
   Use each available observation without smoothing filtering (aggregation), reduce response function simulation time (5 to 10 times).

2. Present state:
   Implemented fixed lag Kalman smoother to use 3-hourly continuous observations and flasks directly in 64 region monthly inversion with 3-6 month time lag (Bruhwiler etal 2005), tested with 1996 data

3. Plan
   Complete 1980-1990 analysis in 2009, rest in 2010



Y. Koyama et al, ICDC8

Summary

Improving the algorithms for regional CO_2 flux estimation in global scale including:

- Inverse modeling with large number of observations
- Fossil fuel emissions model, high spatial resolution
- Process-based modeling of the terrestrial ecosystem fluxes
- Observation-driven data assimilation system for near real-time surface pCO_2 and ocean-atmosphere flux estimation
- High resolution transport modeling