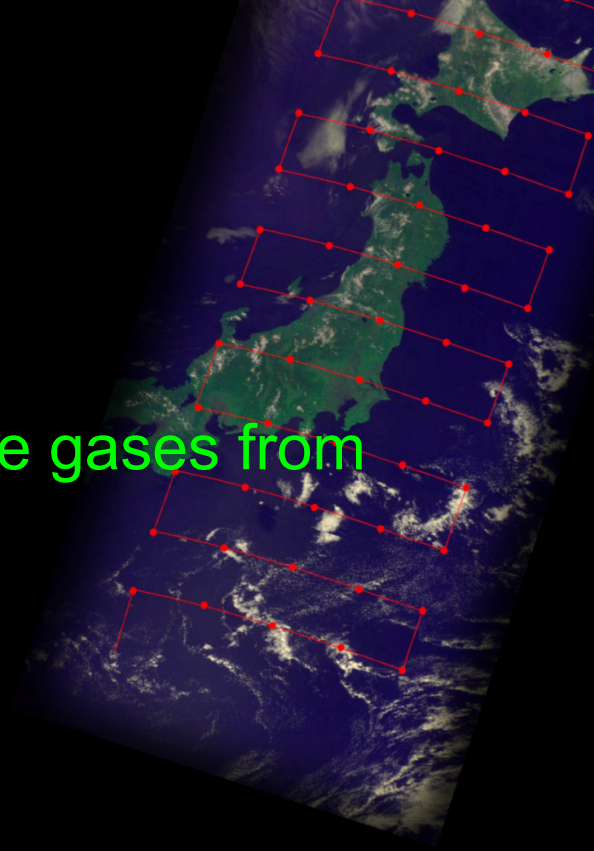
Greenhouse gases GOSAT PROJECT Observing SATellite

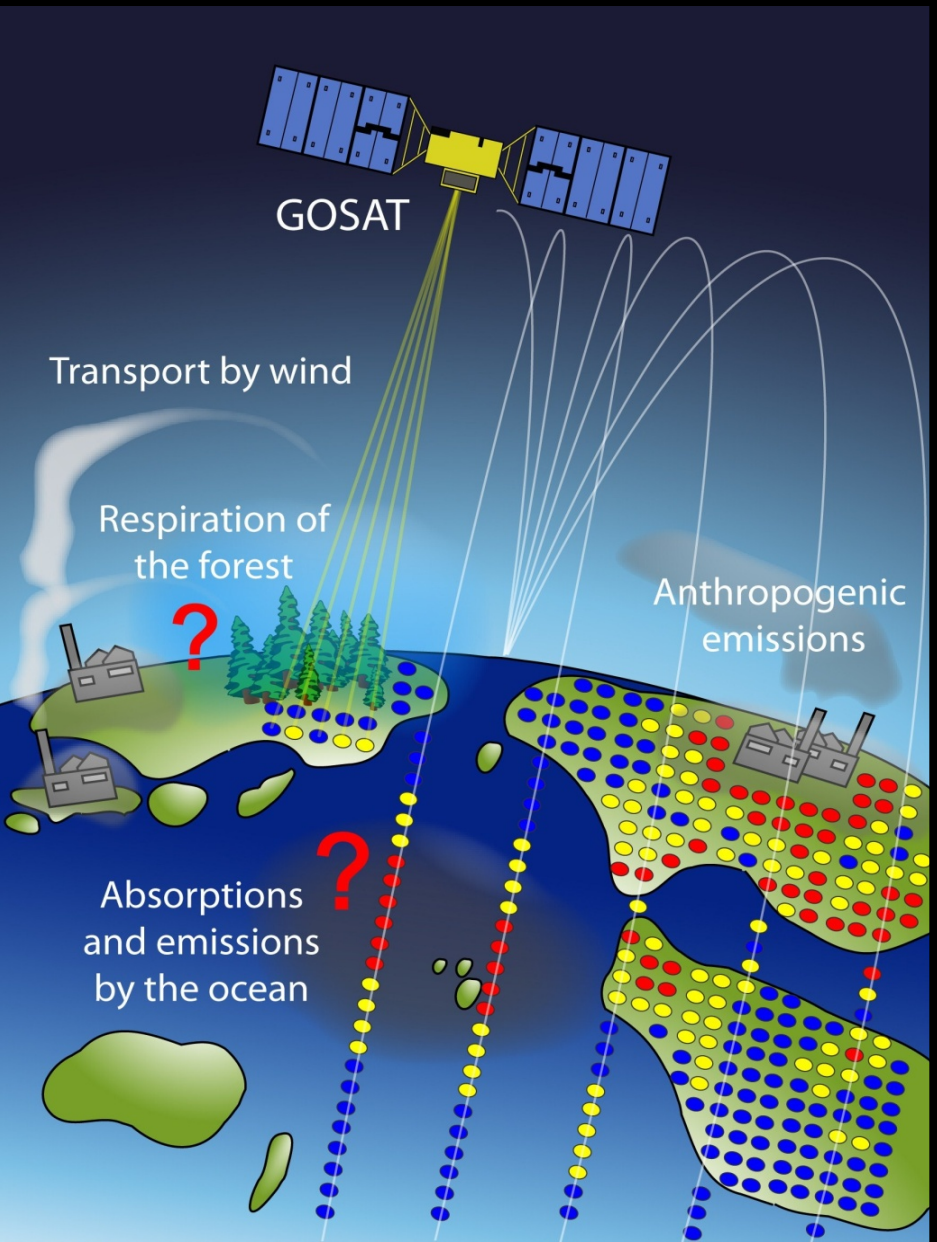
Cooperative Partnership



# A first year of monitoring the greenhouse gases from space with GOSAT

*Shamil Maksyutov, Hiroshi Takagi, Makoto Saito, Yuji Koyama, Ryu Saito, Tomohiro Oda, Vinu Valsala, Dmitry Belikov, Tazu Saeki, Yukio Yoshida and Tatsuya Yokota*

# Overview of GOSAT Observation




- Flying altitude: 666 km
- 44-revolutions / 3 days
- Three-day recurrence

- Fourier transform spectrometer onboard (→ Column-averaged concentrations ($XCO_2$) are derived from absorption spectra)

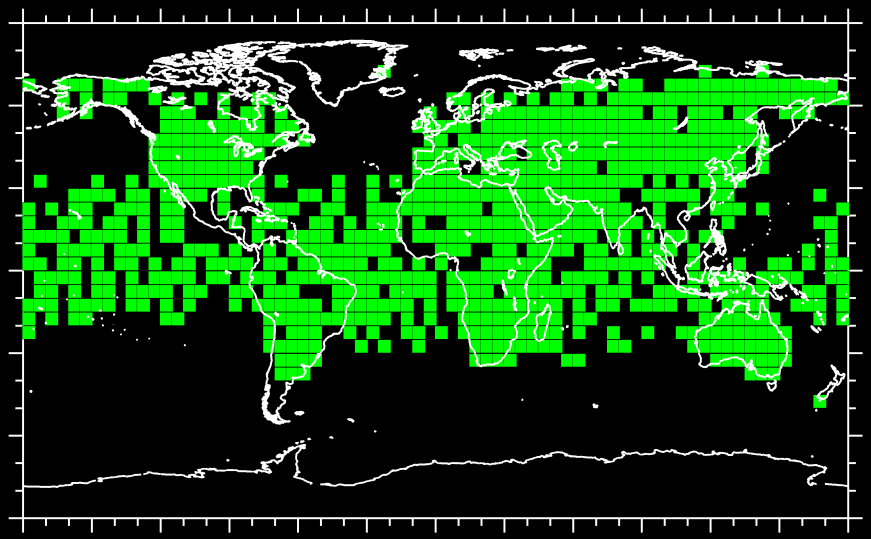
$CO_2$ concentrations are not direct indicators of local $CO_2$ emissions and absorptions.

↓

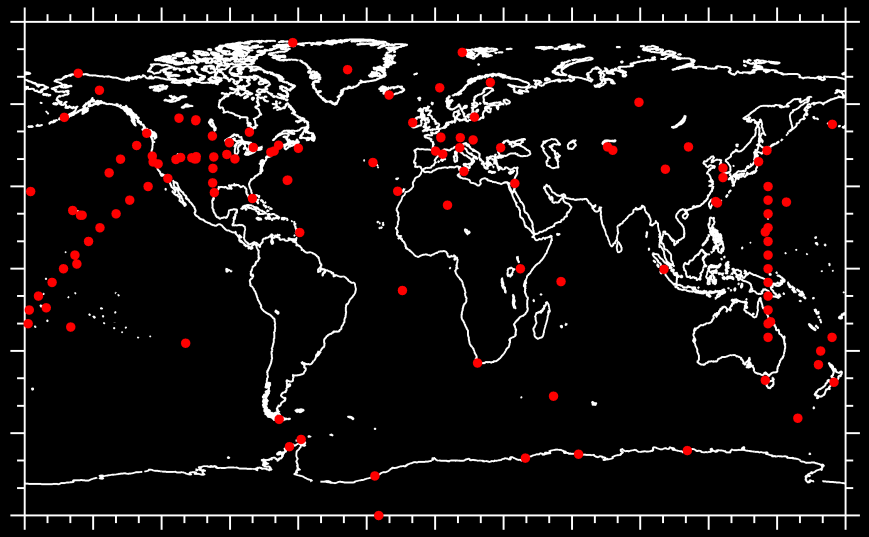
Sources and sinks can be estimated from $CO_2$ concentrations using an atmospheric transport model.

- 5-point raster scanning over land
- Footprint size: 10.5 km (diameter)

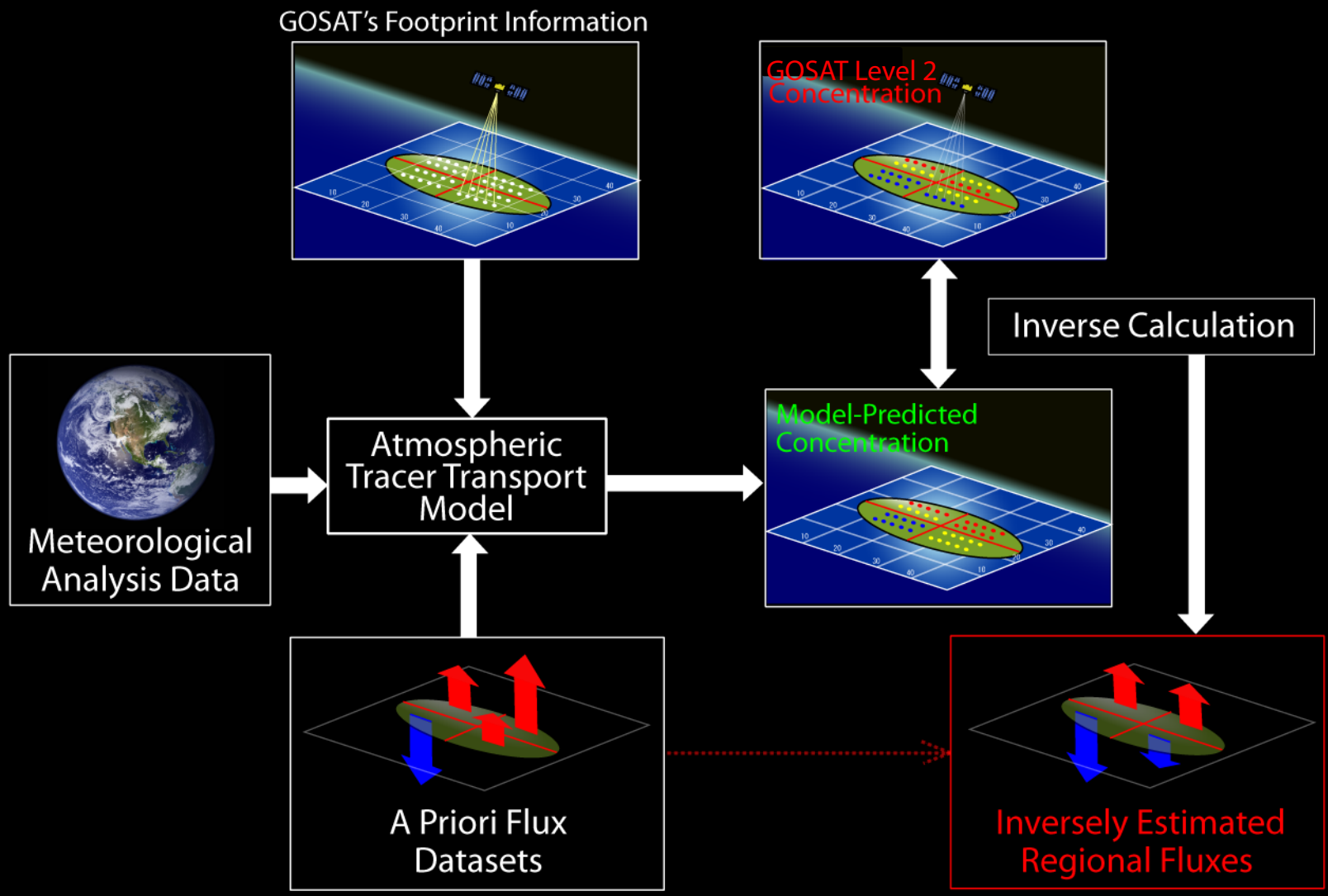
## GOSAT Level 2 Data Product
(5°×5° average)



## Ground-based Observation Points
(GlobalView network)

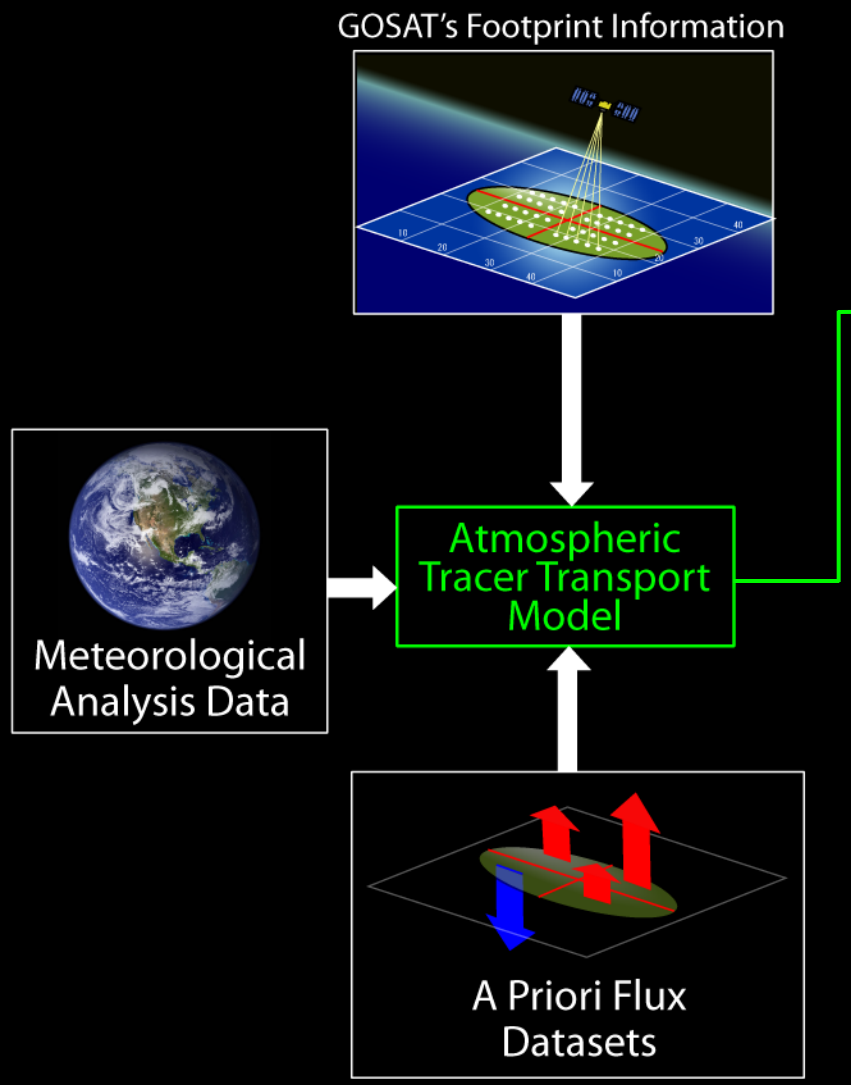


# Overview of Regional Sources/Sinks Estimation




GOSAT Level 4A Data Product

# System Component 1: Atmospheric Transport Model



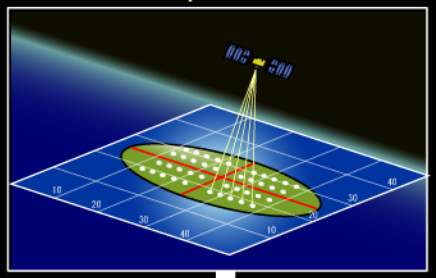

## NIES-08 Transport Model

(Runs on NIES Supercomputer System)

- Horizontal Resolution: 2.5˚ × 2.5˚
- Vertical Resolution: 15 layers
- Transport calculation forced with JCDAS Met. Analysis Dataset (2.5˚ × 2.5˚ resolution)

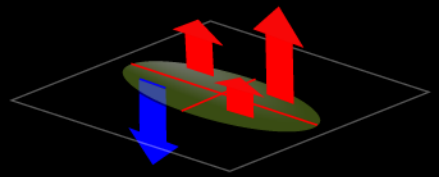
# System Component 2: A Priori Flux Data Generation

GOSAT's Footprint Information



Meteorological Analysis Data

Atmospheric Tracer Transport Model

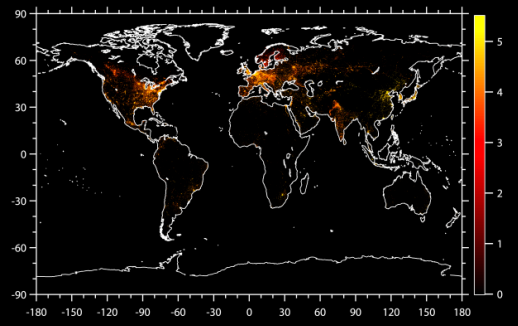


A Priori Flux Datasets

## Anthropogenic Emission Data

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

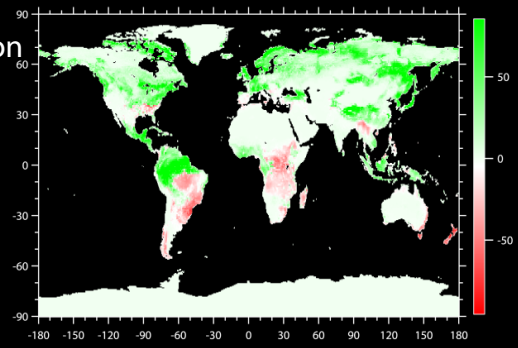
Oda et al., 2009 submitted to Atmos. Chem. Phys.



## Terrestrial Biosphere-Atmosphere Flux Data

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

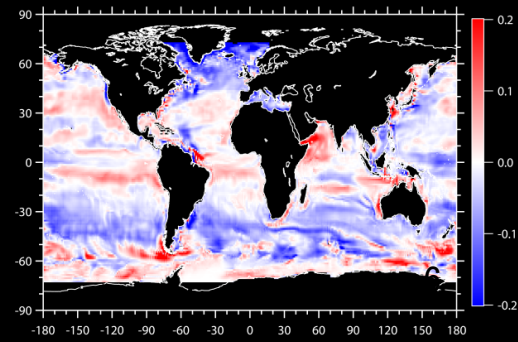
Ito, 2010



## Ocean-Atmosphere Flux Data

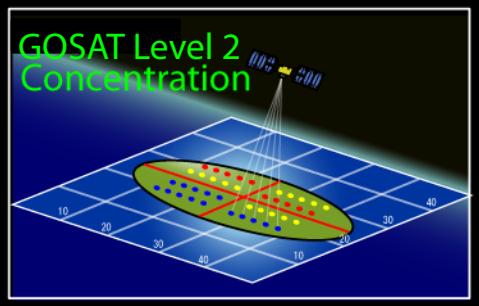
- Generated with ocean transport model OTTM
- Monthly data
- Resolution 1˚ × 1 ˚

Valsala et al., 2008 J. Climate



# GOSAT Level 2 Data Product

## Column-Averaged Volume Mixing Ratio of $CO_2$ ($XCO_2$)



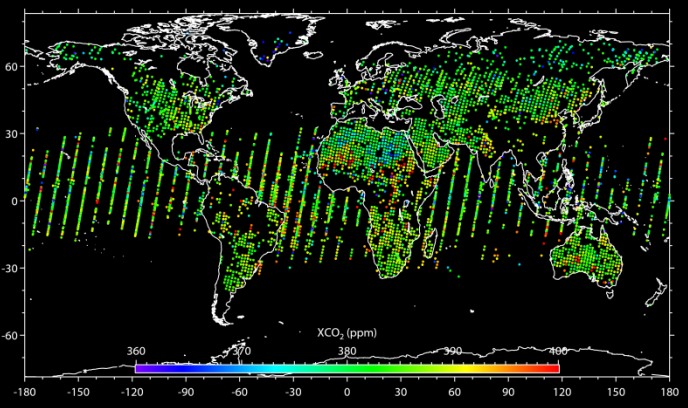

## Data versions: 00.10, 00.20, and 00.30

Data period: June 2009 through April 2010 (11 months)

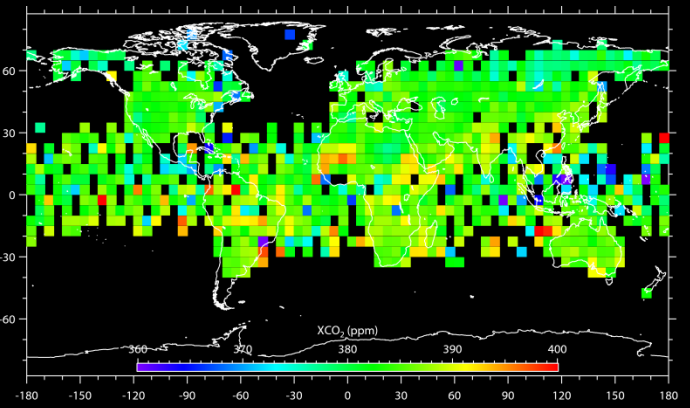
Bias correction → +10 ppm (based on data validation results)

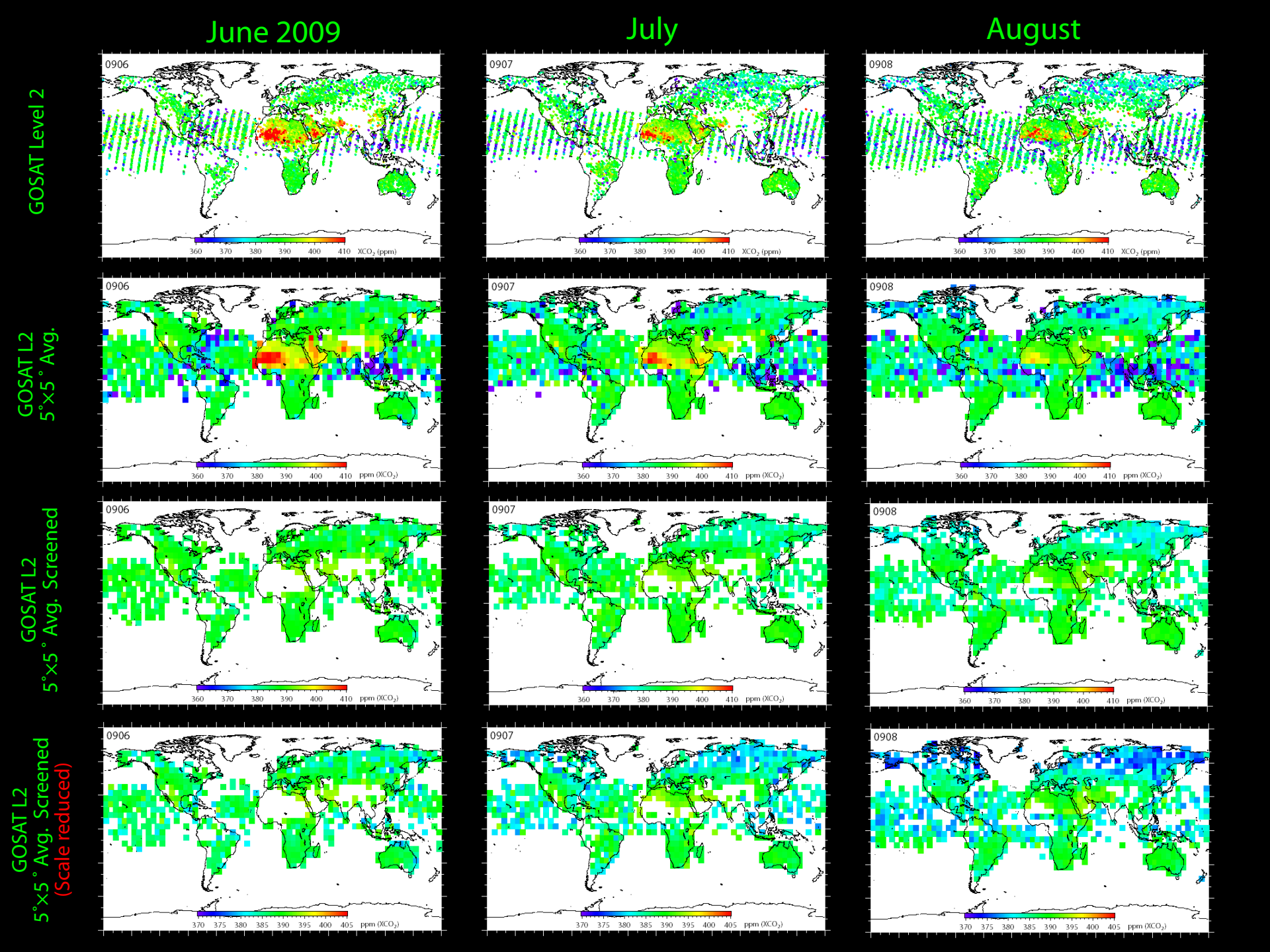
Data rejection criteria:

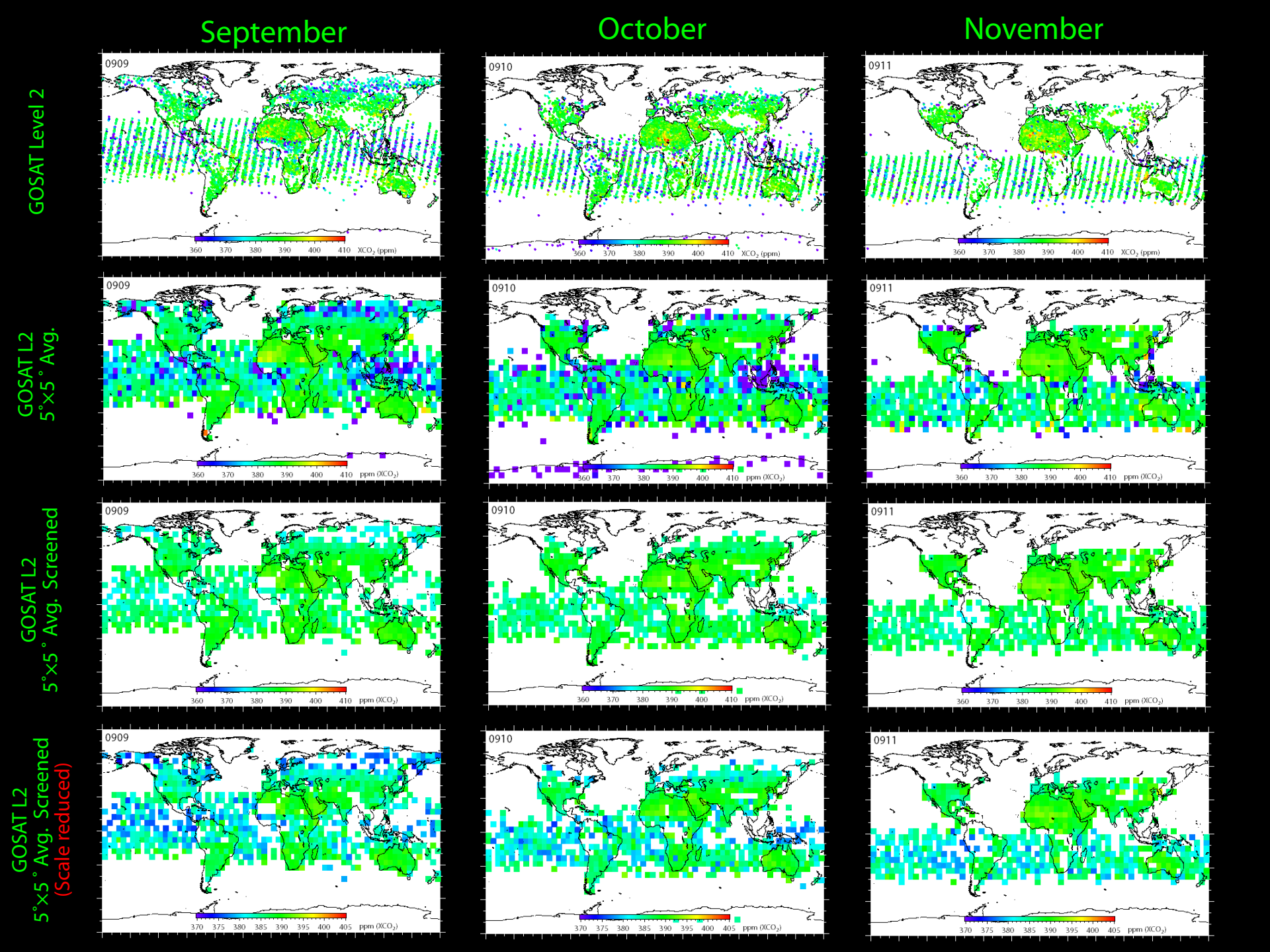
| | | |
|---|---|---|
| Chi square test | ≥ 5 | Rejected |
| Signal-to –noise ratio: | ≤ 100 | Rejected |
| Degree of freedom of signal: | ≤ 1 | Rejected |
| Observations nearby shorelines: | | Rejected |
| Prediction-Observation mismatch: | > 8 ppm | Rejected |

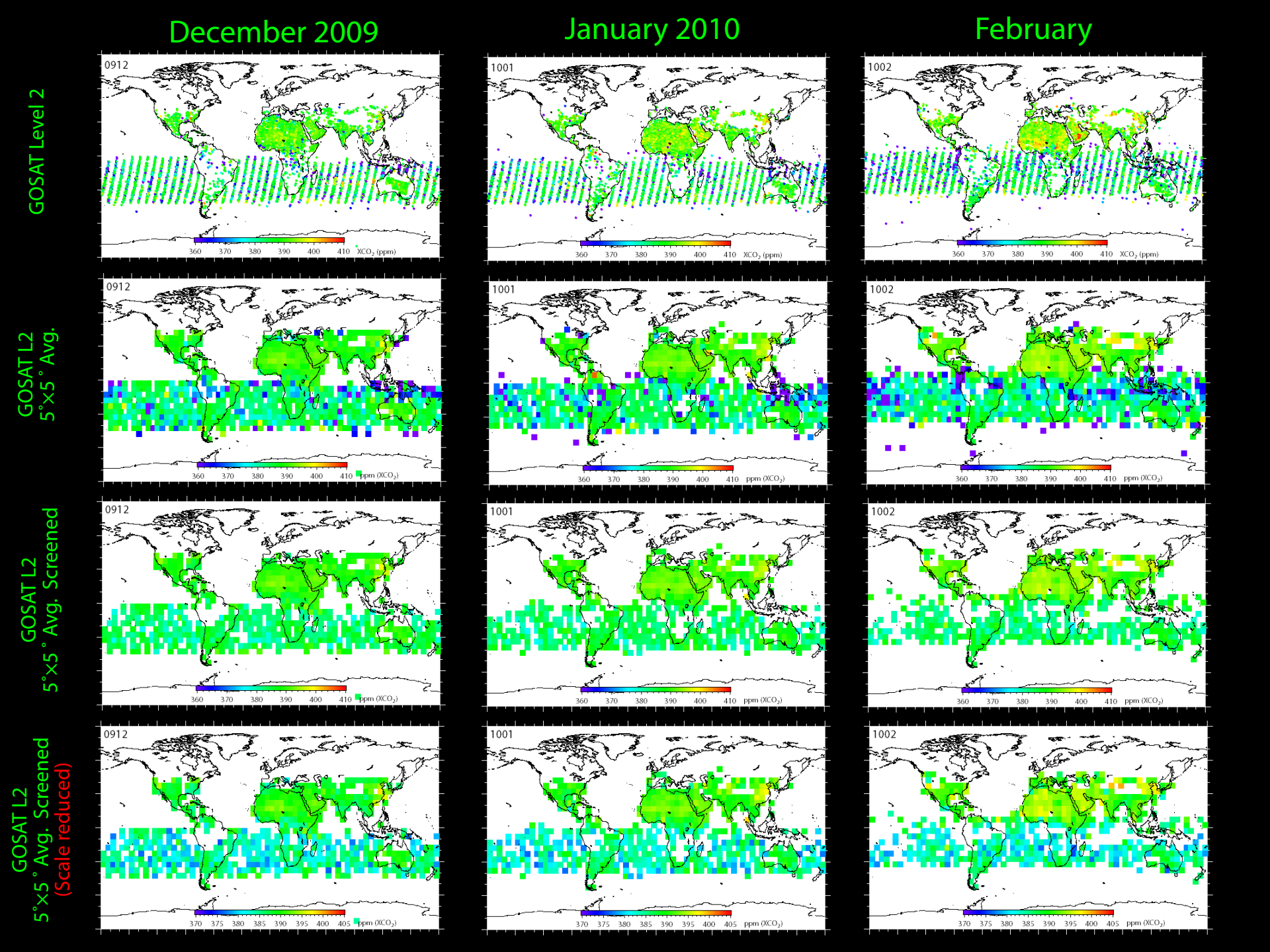



Gridded Monthly Averages (5°×5°)




June 2009
July
August
GOSAT Level 2
GOSAT L2
5˚×5˚ Avg.
GOSAT L2
5˚×5˚ Avg. Screened
GOSAT L2
5˚×5˚ Avg. Screened
(Scale reduced)
0906
0907
0908
360 370 380 390 400 410 XCO2 (ppm)
360 370 380 390 400 410 ppm (XCO2)
370 375 380 385 390 395 400 405 ppm (XCO2)

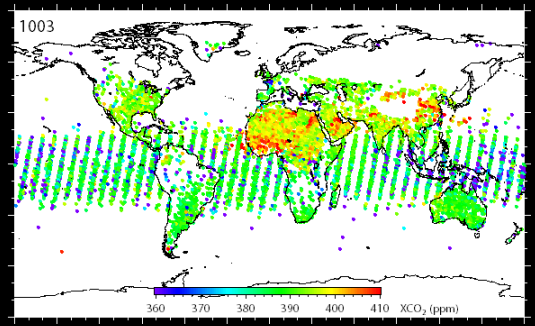

September
October
November
GOSAT Level 2
GOSAT L2
5˚×5˚ Avg.
GOSAT L2
5˚×5˚ Avg. Screened
GOSAT L2
5˚×5˚ Avg. Screened
(Scale reduced)
0909
0910
0911
360 370 380 390 400 410 XCO2 (ppm)
360 370 380 390 400 410 ppm (XCO2)
370 375 380 385 390 395 400 405 ppm (XCO2)

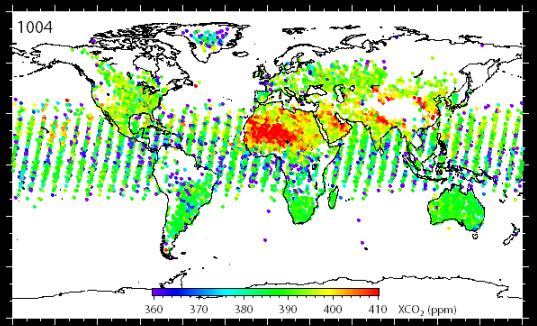

December 2009
January 2010
February
GOSAT Level 2
GOSAT L2
5˚×5˚ Avg.
GOSAT L2
5˚×5˚ Avg. Screened
GOSAT L2
5˚×5˚ Avg. Screened
(Scale reduced)
0912
1001
1002
360 370 380 390 400 410 XCO2 (ppm)
360 370 380 390 400 410 ppm (XCO2)
370 375 380 385 390 395 400 405 ppm (XCO2)

March

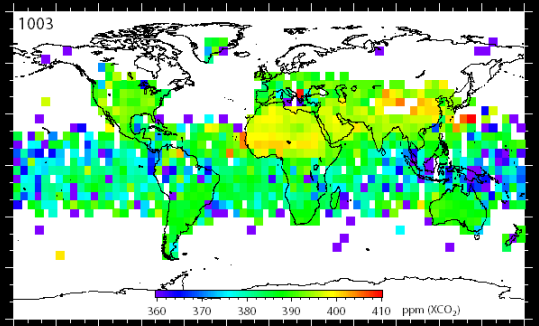
April

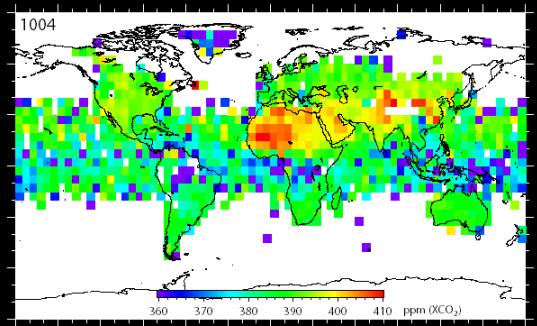
GOSAT Level 2



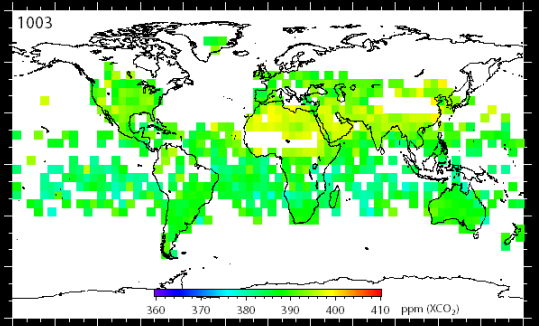



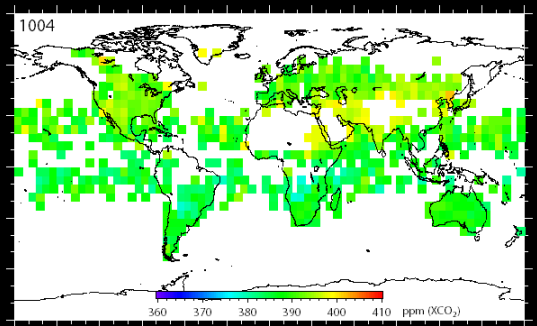

GOSAT L2
5˚×5˚ Avg.



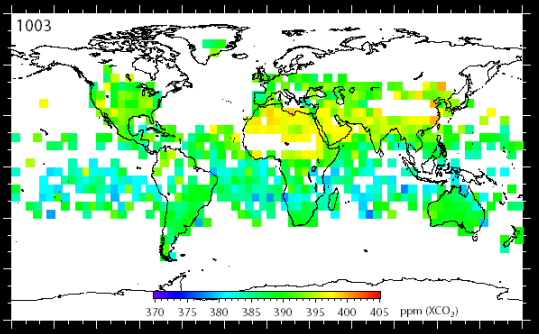



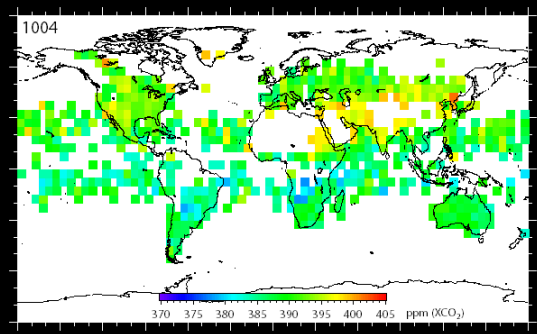

GOSAT L2
5˚×5˚ Avg. Screened




GOSAT L2
5˚×5˚ Avg. Screened
(Scale reduced)



# Inverse Modeling Scheme

## Kalman Smoother Technique

### Kalman Update Equation

$$S' = S_p + [H^T R^{-1} H + Q^{-1}]^{-1} H^T R^{-1} (z - HS_p)$$
$$Q' = [H^T R^{-1} H + Q^{-1}]^{-1}$$

(Bruhwiler et al. 2005 ACP)

### Analysis Months (For 2009)

| 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|

Calculation in one big batch

| 6 | 7 | 8 |
|---|---|---|

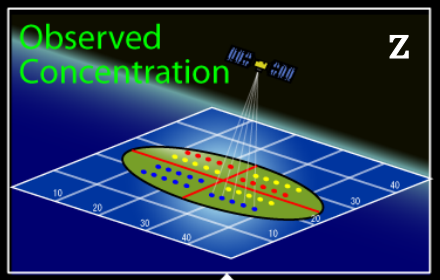
| 7 | 8 | 9 |
|---|---|---|

| 8 | 9 | 10 |
|---|---|---|

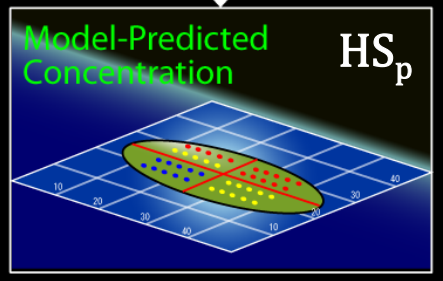
| 9 | 10 | 11 |
|---|---|---|

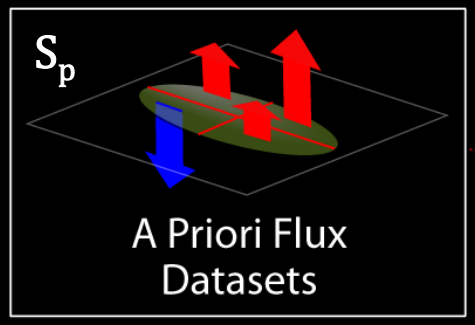
| 10 | 11 | 12 |
|---|---|---|

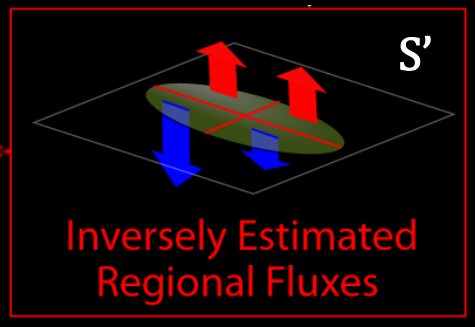
3-month inverse calculation window




R (model-observation mismatch)



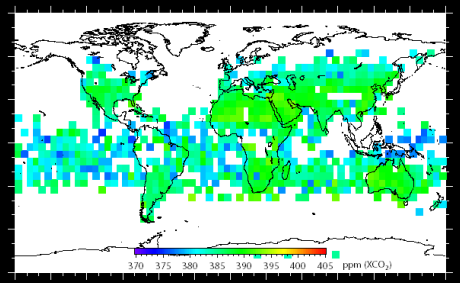




Q (Prior flux uncertainties)

# Flux Estimation in 64 Regions

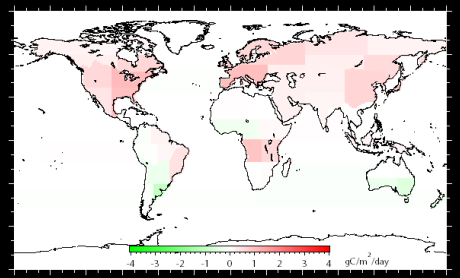
In the following slides you will see :

Top



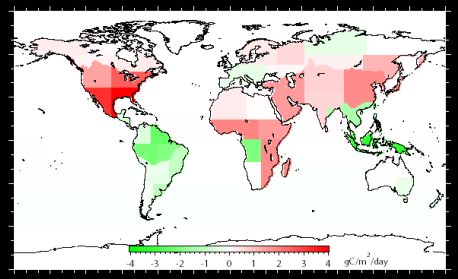

GOSAT Level 2 $XCO_2$ (unit : ppm)
(5˚× 5˚ Monthly average, screened)

Middle



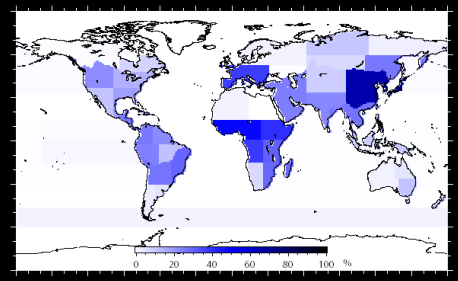

Prior Fluxes in 64 regions (unit : $gC/m^2/day$)
(Ocean + Land Ecosystem + Anthropogenic Emissions)

Middle




Posterior (Estimated) Fluxes in 64 regions
(unit : $gC/m^2/day$)

Bottom

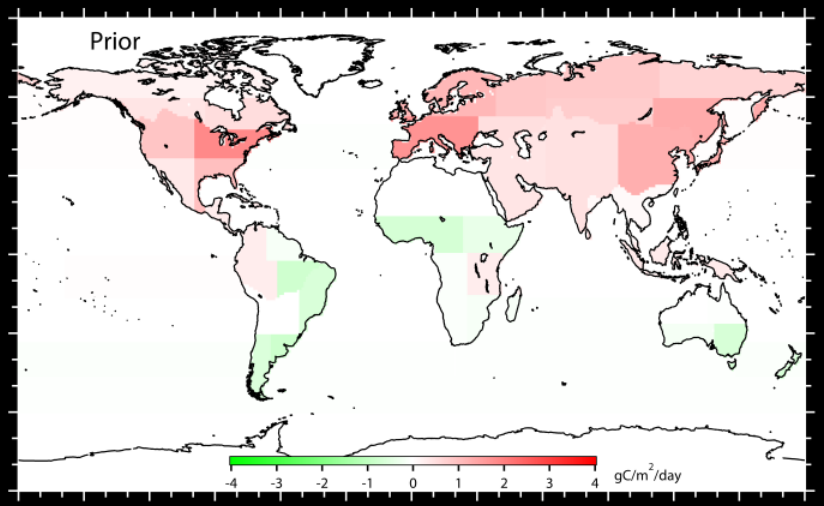



Uncertainty Reduction Rate (%)

→ The degree to which posterior flux is constrained by the GOSAT Level 2 data

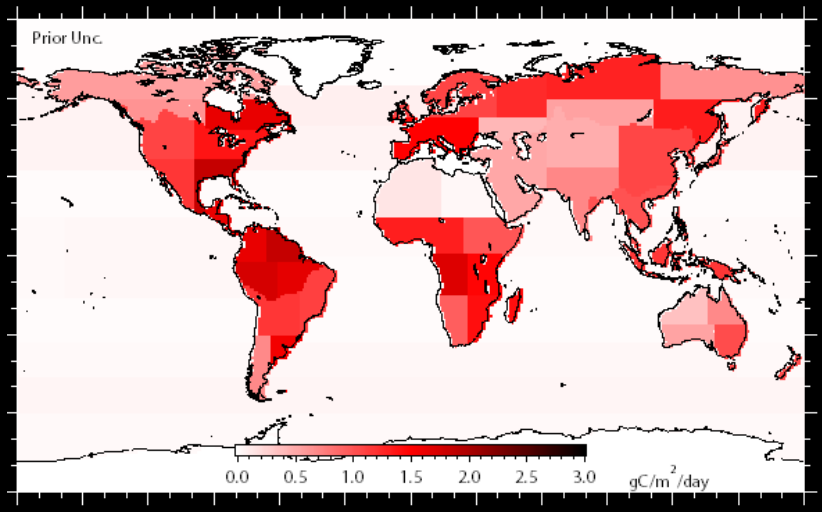
# Prior Flux and uncertainty

## Prior Flux



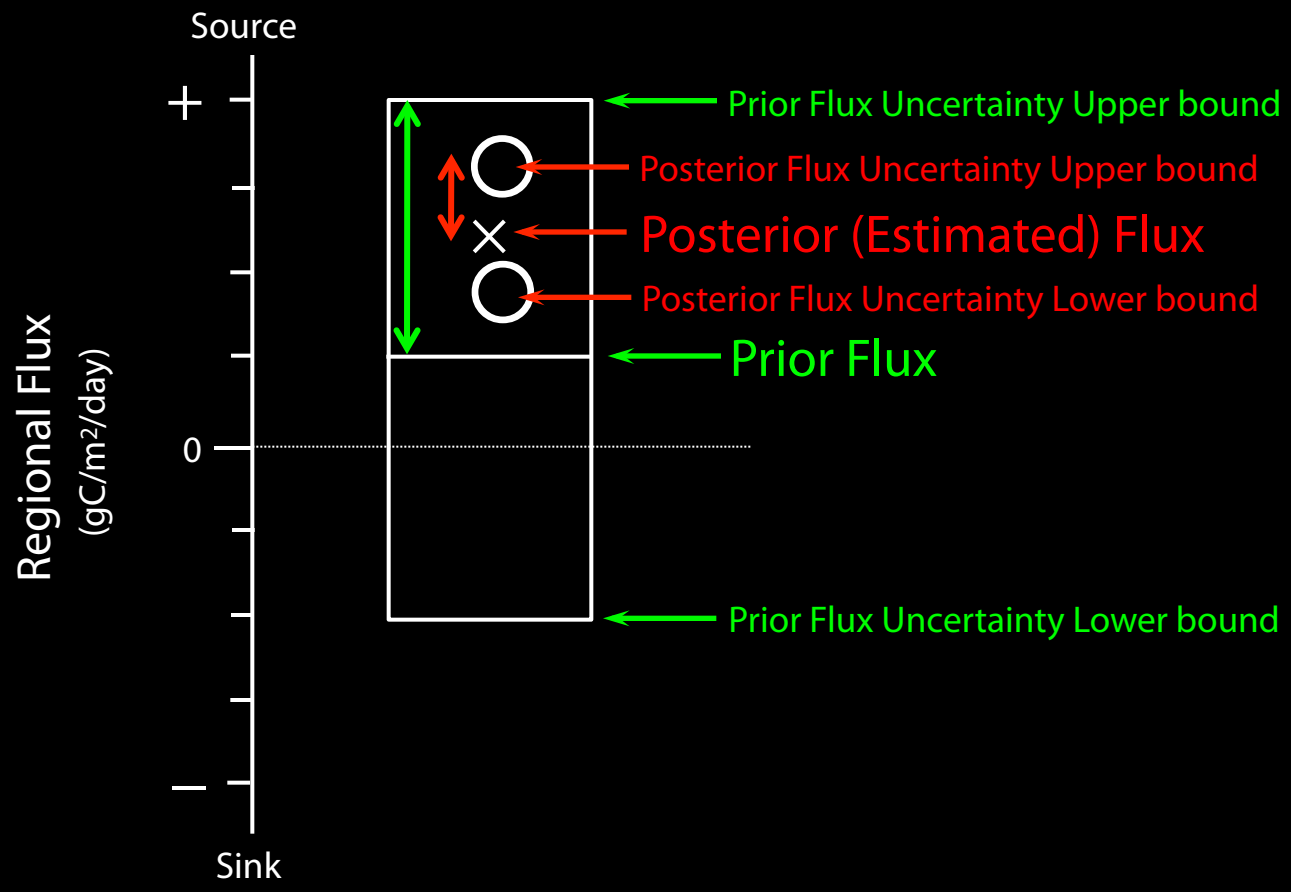

Ocean-Atm. Fluxes +
Land ecosystem-Atm. Fluxes +
Anthropogenic Emissions

## Prior Flux Uncertainties




Ocean & Land Flux
standard deviations + model errors

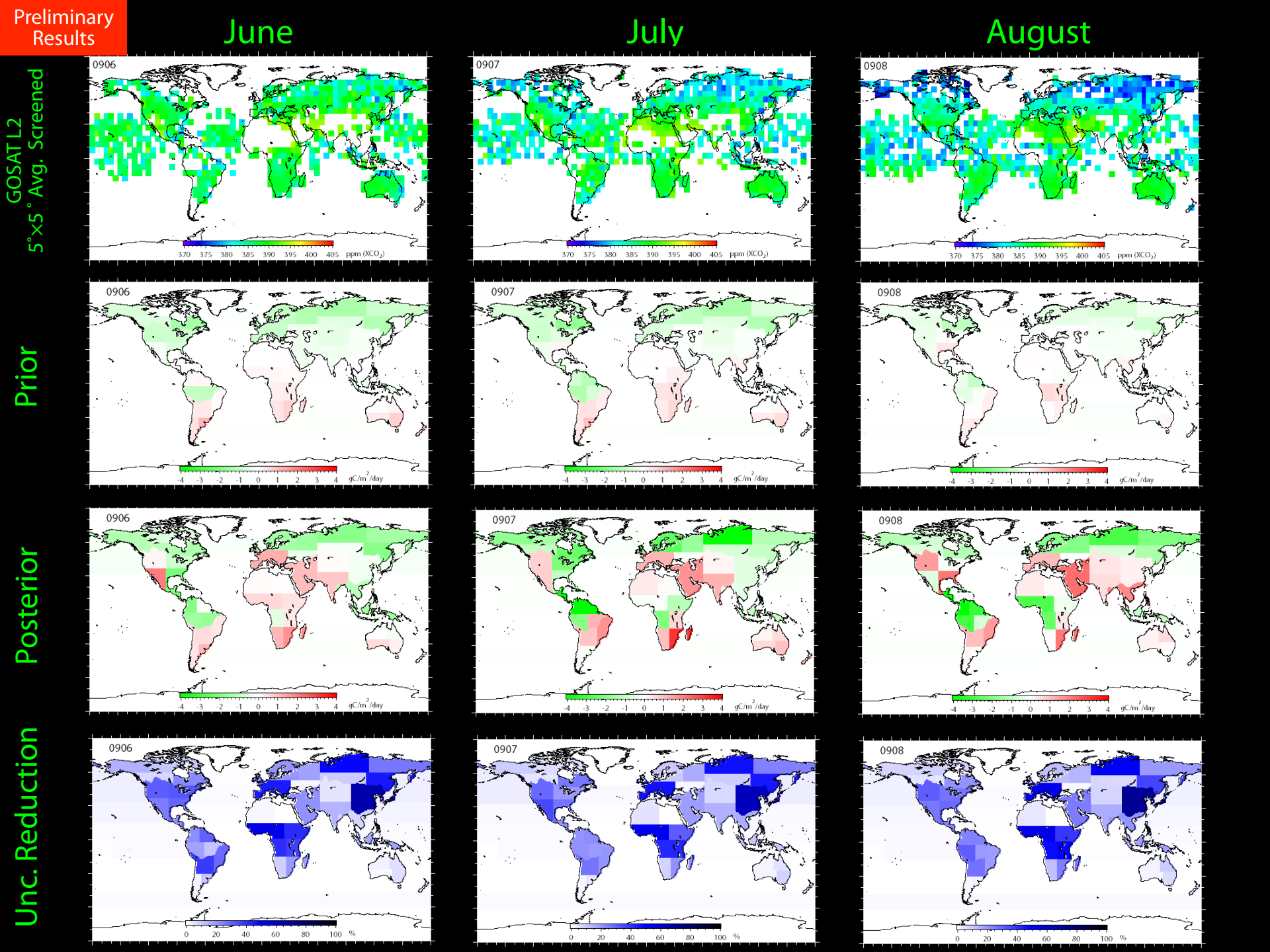
# Flux Uncertainty Reduction




Uncertainty Reduction Rate (%) =>

The degree to which posterior flux is constrained by the observation data

Preliminary Results



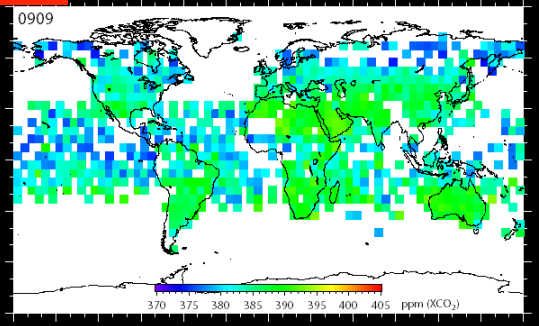
Preliminary Results

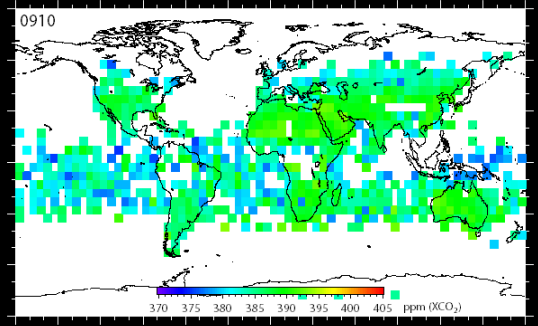
# September

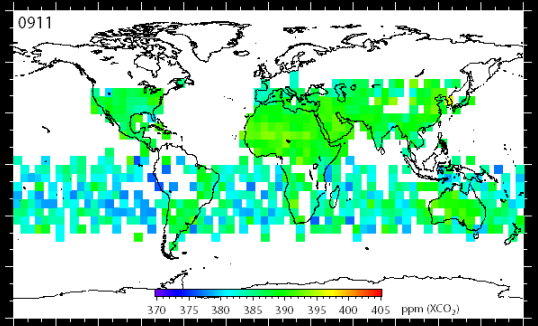
# October

# November

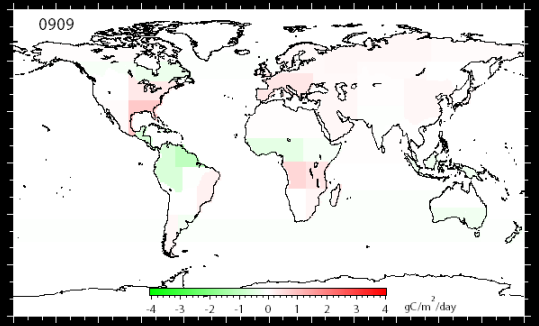
GOSAT L2
5°×5° Avg. Screened

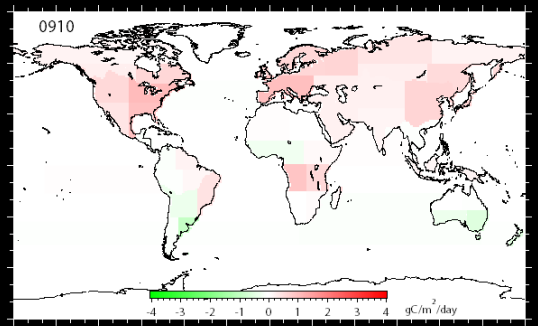


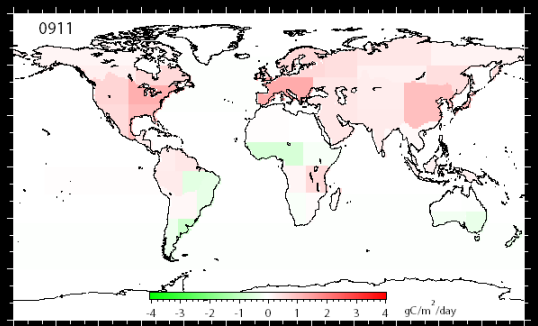



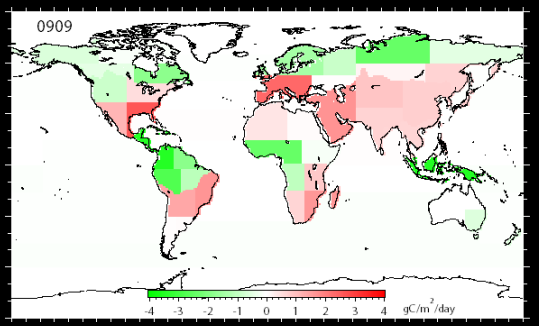

Prior

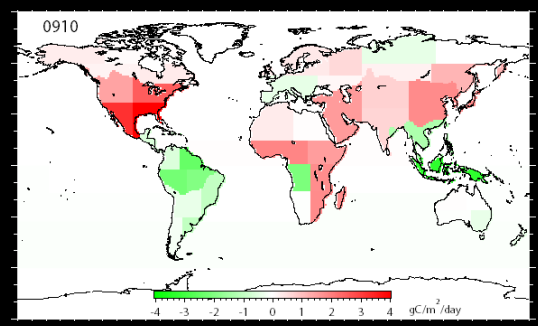


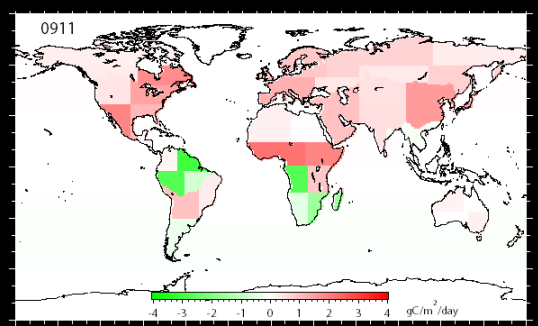



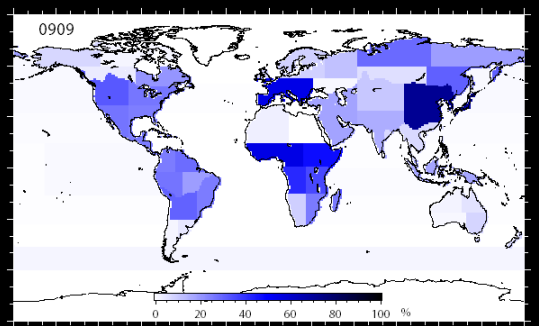

Posterior

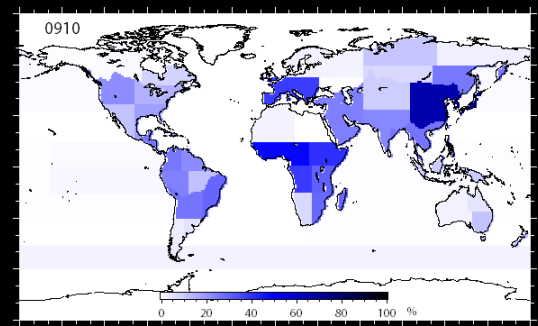


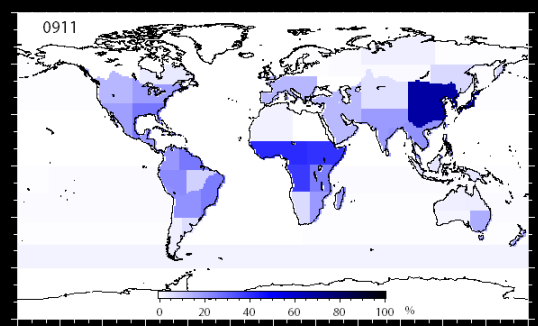



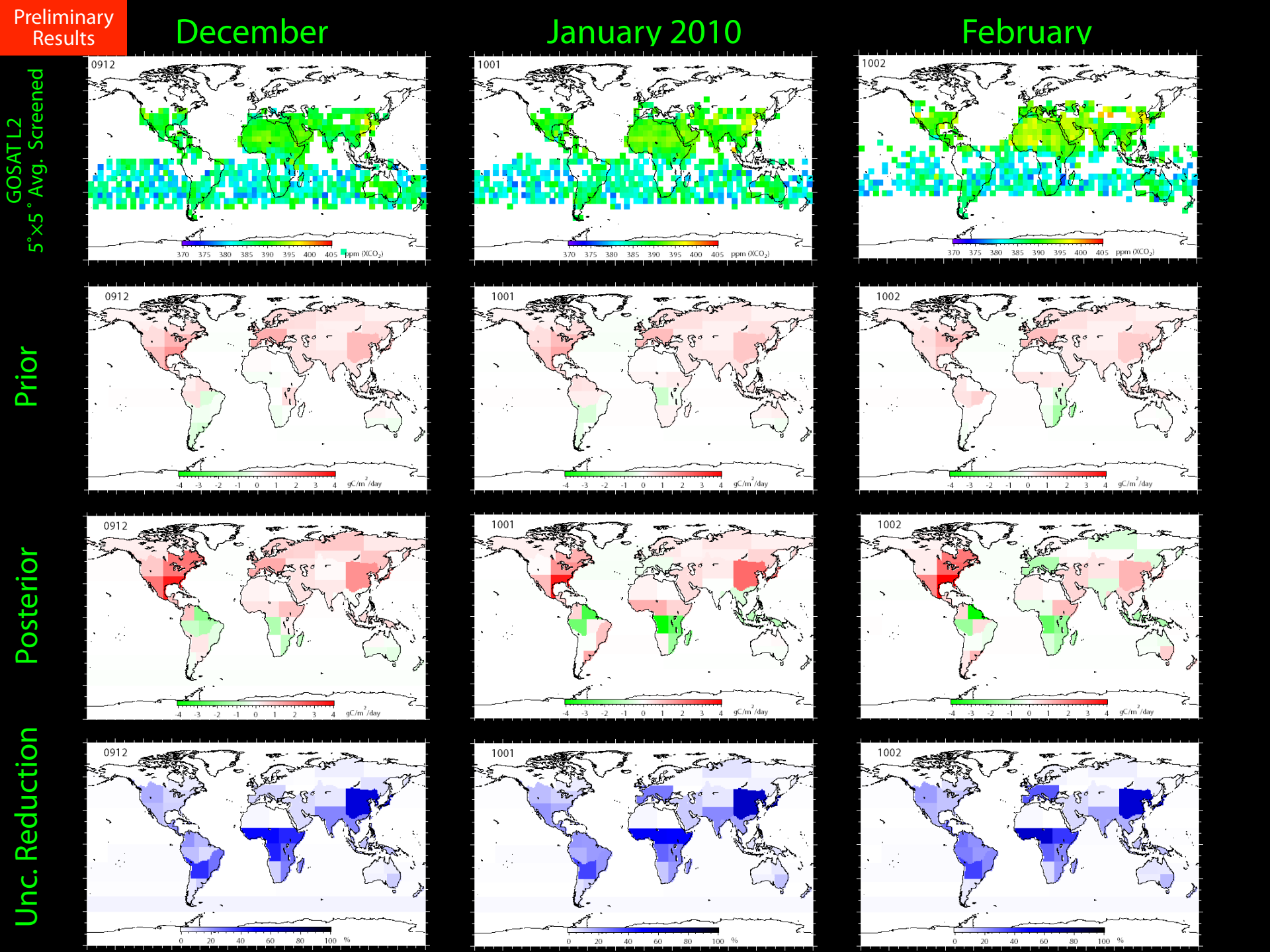

Unc. Reduction



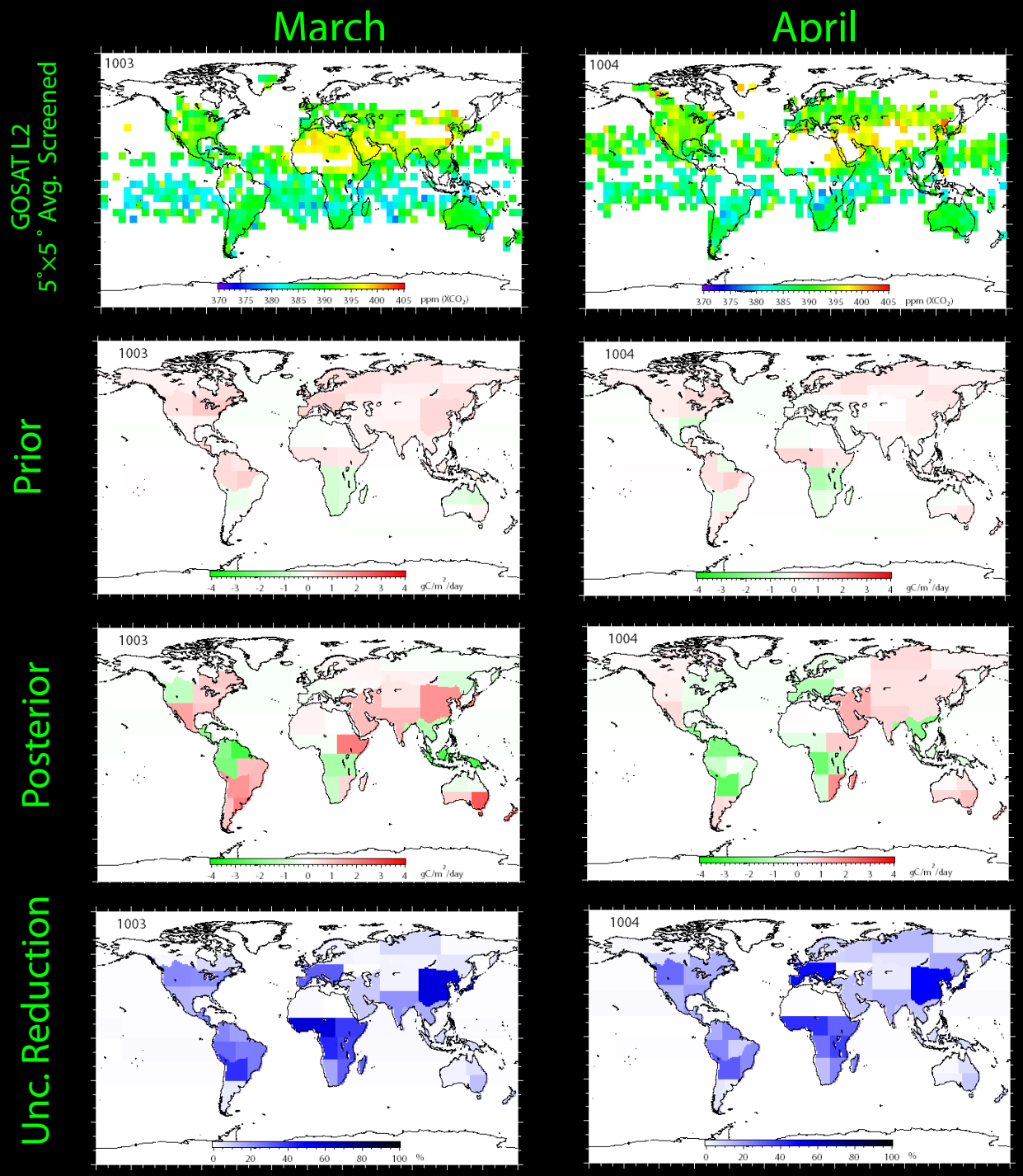



Preliminary Results

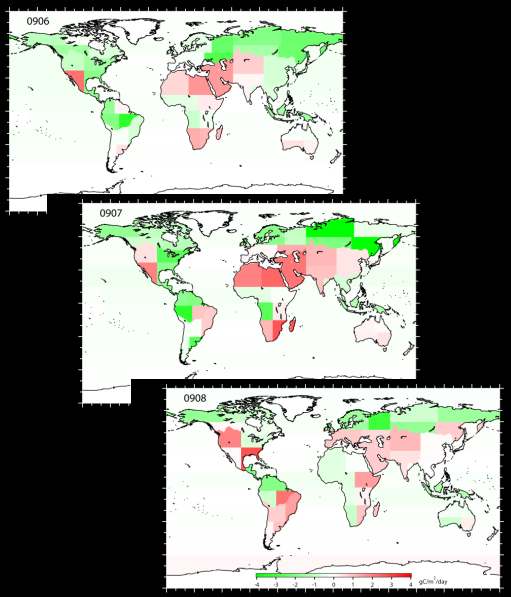


Preliminary Results



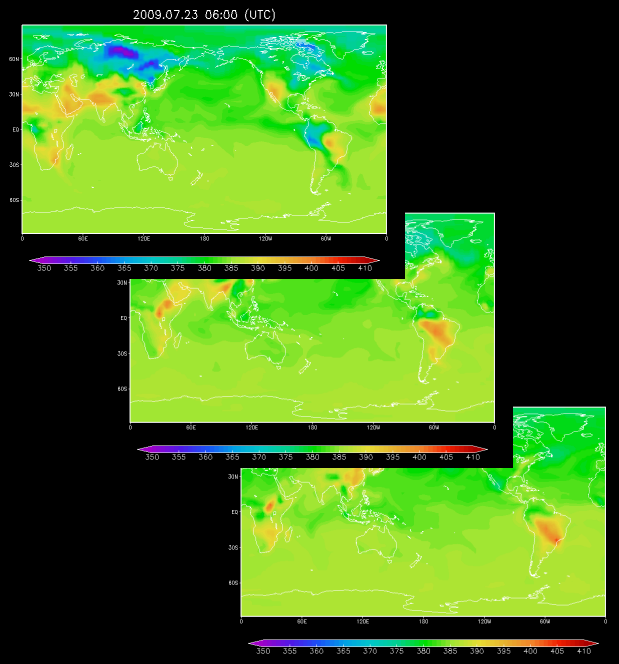
# Processing Level 4A into Level 4B Data Product

## Inversely Estimated Regional Fluxes
(GOSAT Level 4A Data Product)




## Atmospheric Tracer Transport Model
(NIES-08 Model)

## 3D-Concentration Distribution Map
(GOSAT Level 4B Data Product)

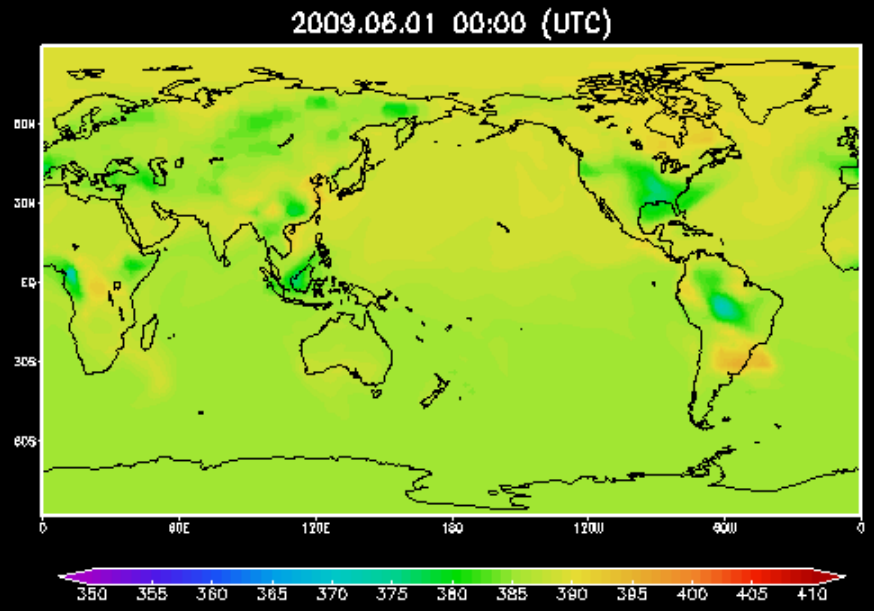


Preliminary Results

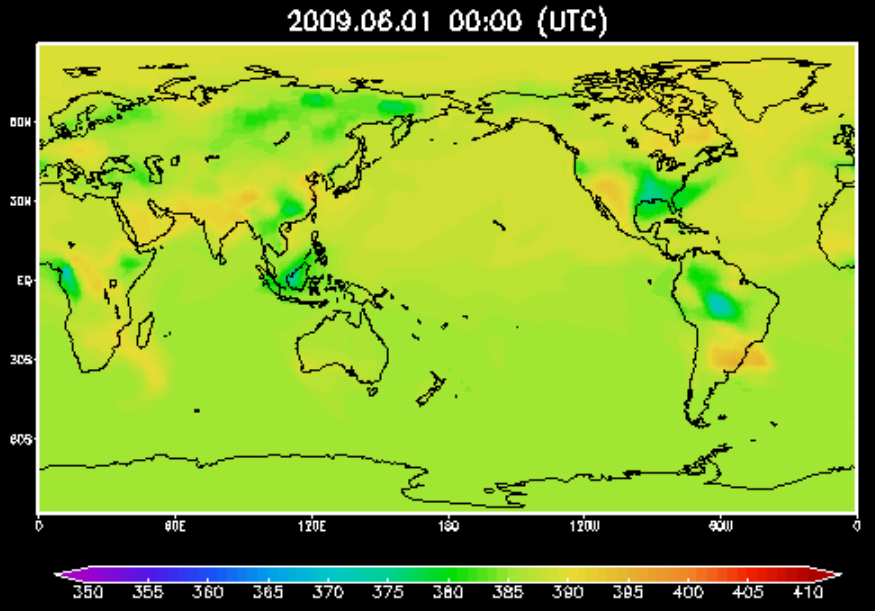
# 3D Concentration (Equivalent to Level 4B Product)

(at 0.97 σ level, 6-hour time step)

Based on Prior Flux




Based on Posterior Flux



# Future Perspective

Do inverse calculation -

- with high-resolution transport schemes (Lagrangian + Eulerian coupled model) (observation-by-observation inverse calculation)
- with GOSAT Level 2 data filtered with ensemble-model climatology data
- with improved biospheric and oceanic prior flux data
- with GOSAT Level 2 data + ground-based observation data