NASA Carbon Monitoring System

http://carbon.nasa.gov

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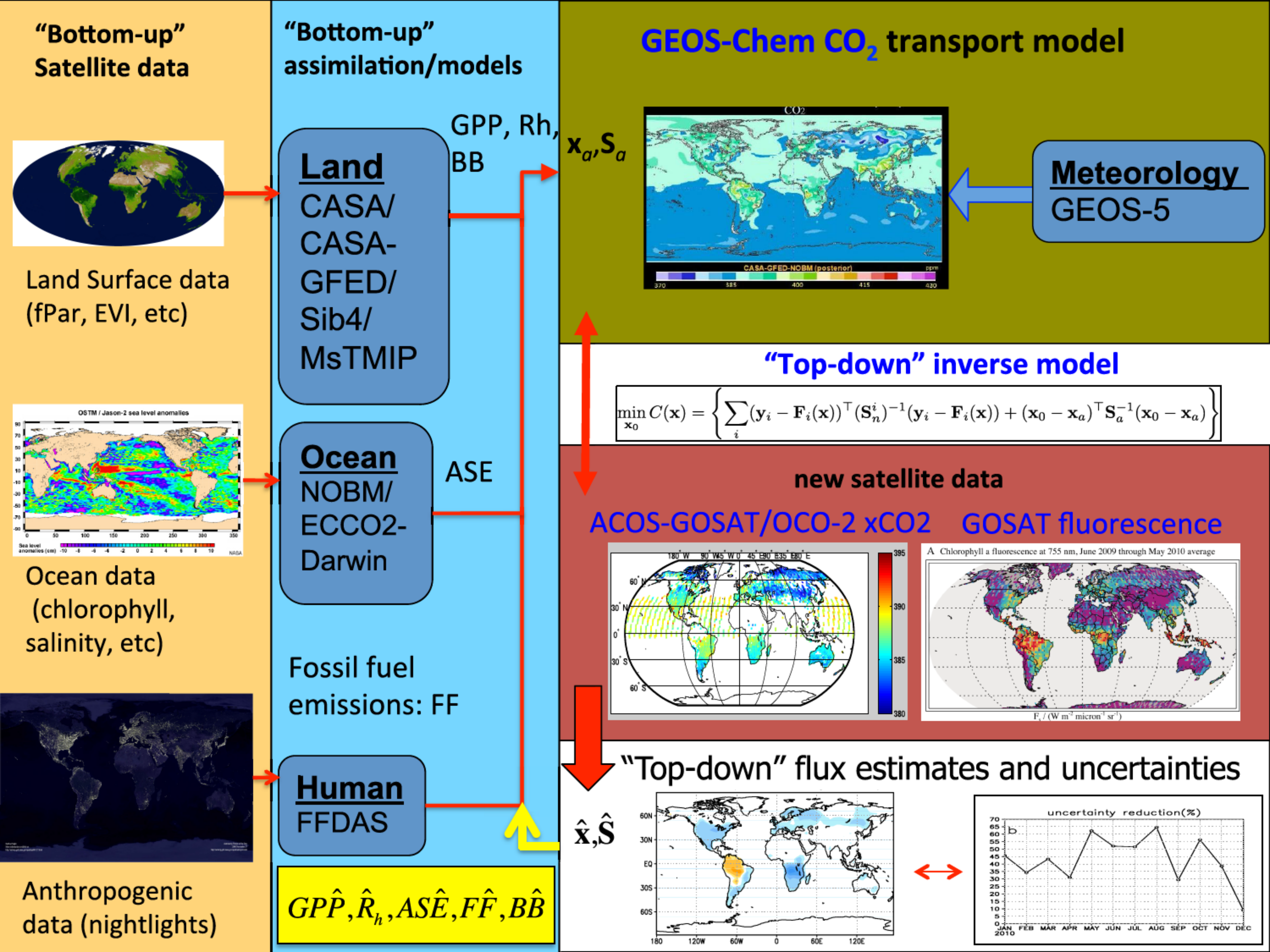
The objective of the NASA CMS Flux Project is to incorporate the full suite of NASA observational, modeling, and assimilation capabilities to attribute climate forcing to spatially resolved surface fluxes across the entire carbon cycle.



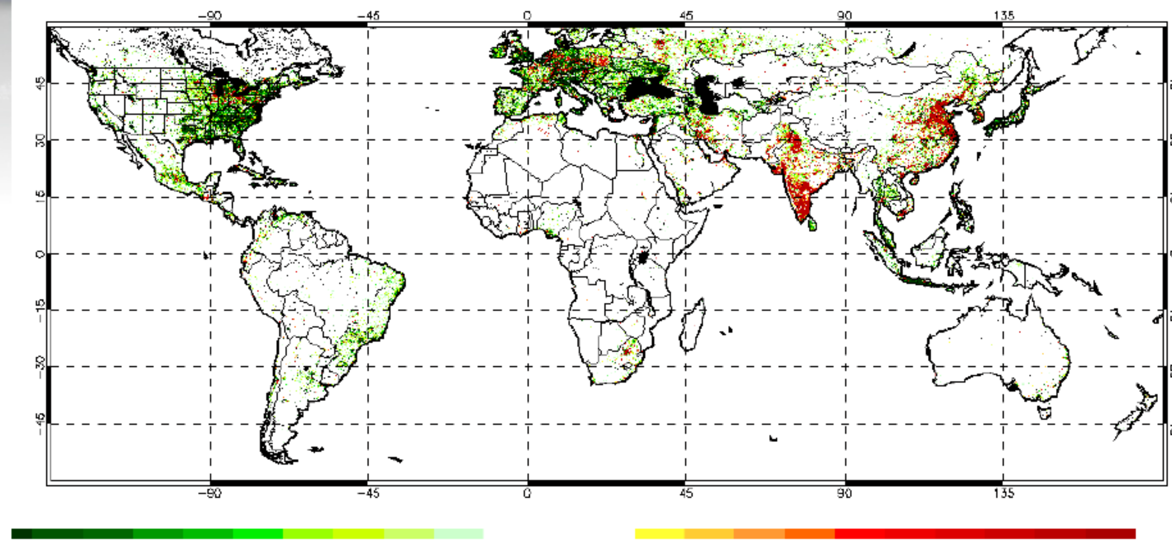
"Bottom-up" Satellite data
Land Surface data (fPar, EVI, etc)
OSTM / Jason-2 sea level anomalies
Ocean data (chlorophyll, salinity, etc)
Anthropogenic data (nightlights)
"Bottom-up" assimilation/models
Land
CASA/ CASA-GFED/ Sib4/ MsTMIP
GPP, Rh, BB
Ocean
NOBM/ ECCO2-Darwin
ASE
Fossil fuel emissions: FF
Human
FFDAS
$\hat{GPP}, \hat{R}_h, \hat{ASE}, \hat{FF}, \hat{BB}$
GEOS-Chem CO_2 transport model
x_a, S_a
CO_2
CASA-GFED-NOBM (posterior)
Meteorology
GEOS-5
"Top-down" inverse model
$\min_{x_0} C(x) = \left\{ \sum_i (y_i - F_i(x))^\top (S_n^i)^{-1} (y_i - F_i(x)) + (x_0 - x_a)^\top S_a^{-1} (x_0 - x_a) \right\}$
new satellite data
ACOS-GOSAT/OCO-2 xCO2
GOSAT fluorescence
A Chlorophyll a fluorescence at 755 nm, June 2009 through May 2010 average
"Top-down" flux estimates and uncertainties
$\hat{x}, \hat{S}$
uncertainty reduction(%)
JAN 2010 FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC

Fossil Fuel Data Assimilation System (FFDAS)

FFDAS is based on a series of observational proxies within a dynamical model of energy consumption.

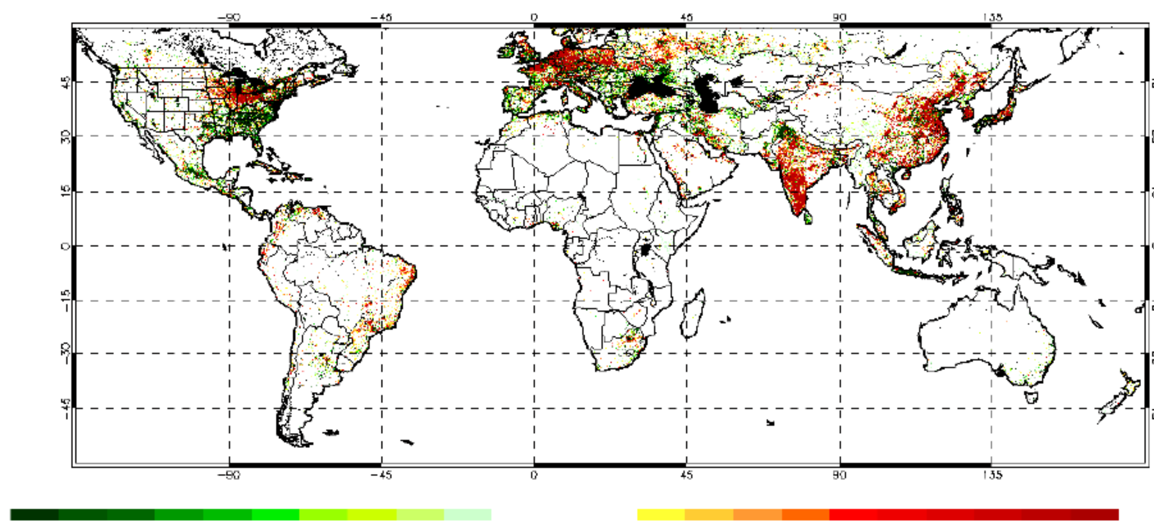
2009 Fossil fuel CO_2 Emission anomalies

The Global Financial Crisis



2010 Fossil fuel CO_2 Emission anomalies

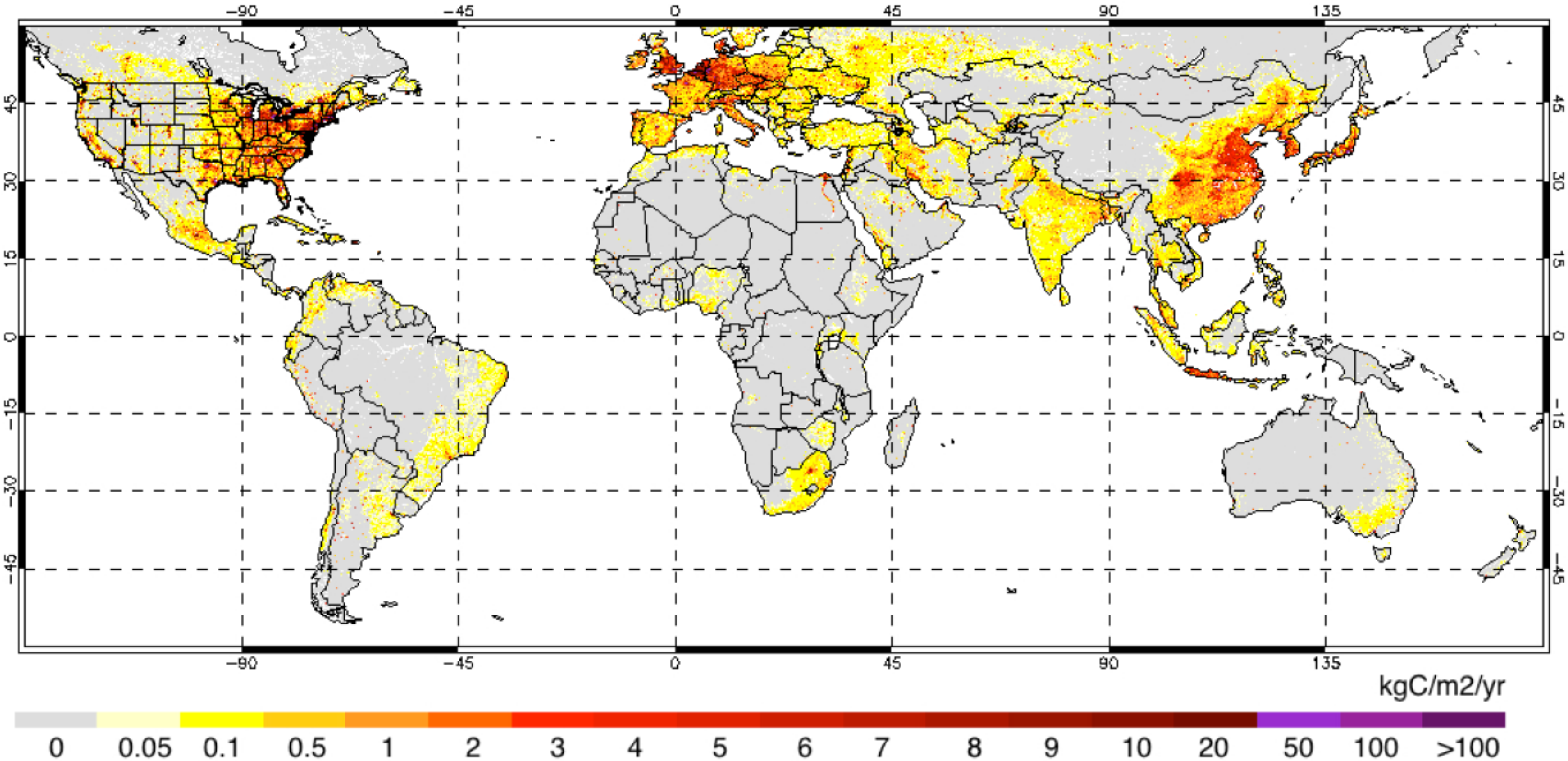
Recovery with sub-national variation



negative positive

ASU

FFDAS Uncertainties



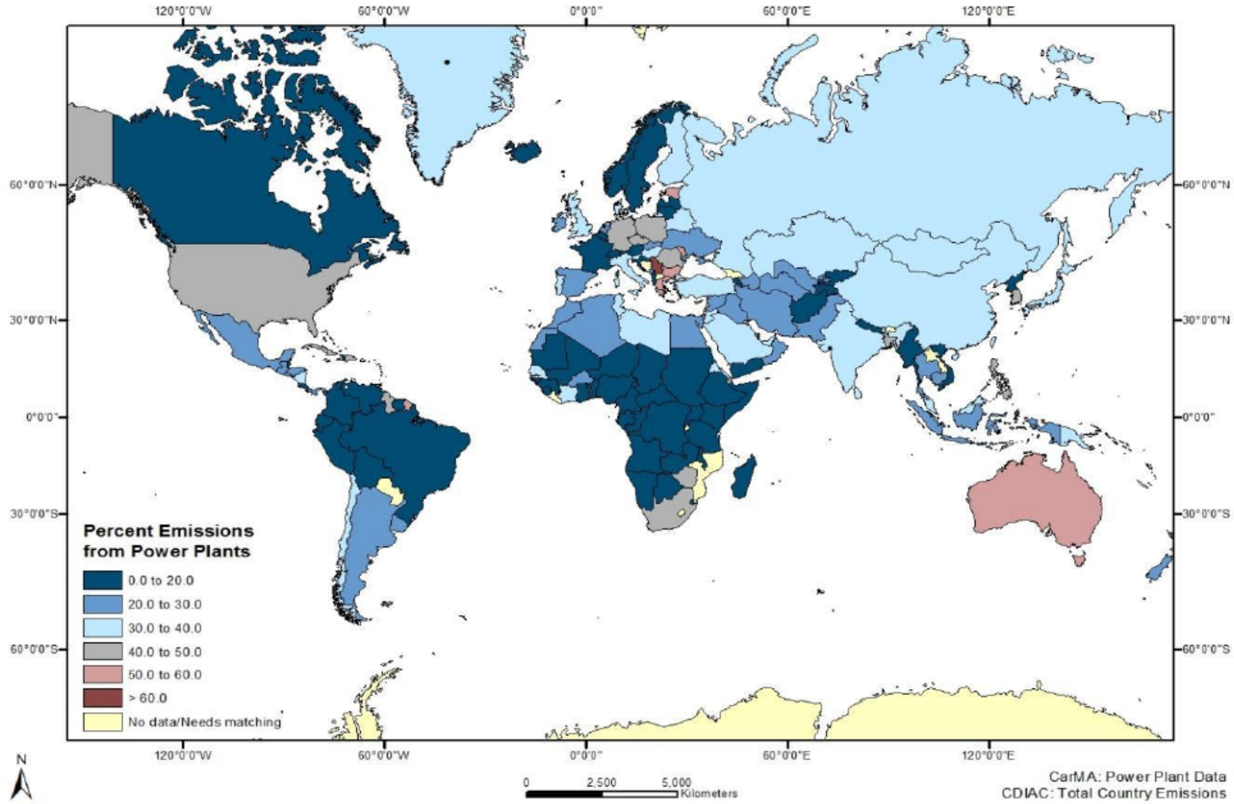
Uncertainties at regional scales can be significant even if the global total is not.

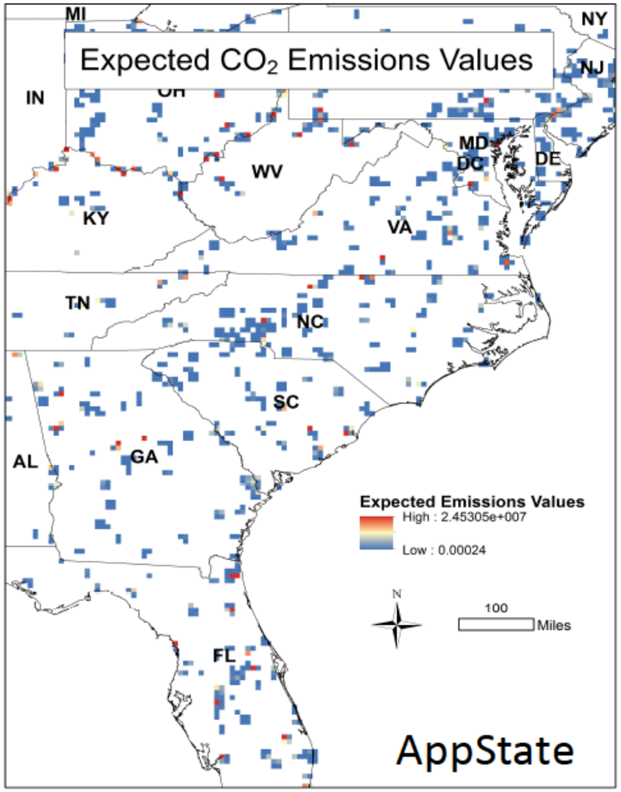
Uncertainty in fixed point sources

In the US, 1/3 of all emissions comes from only 311 sites.

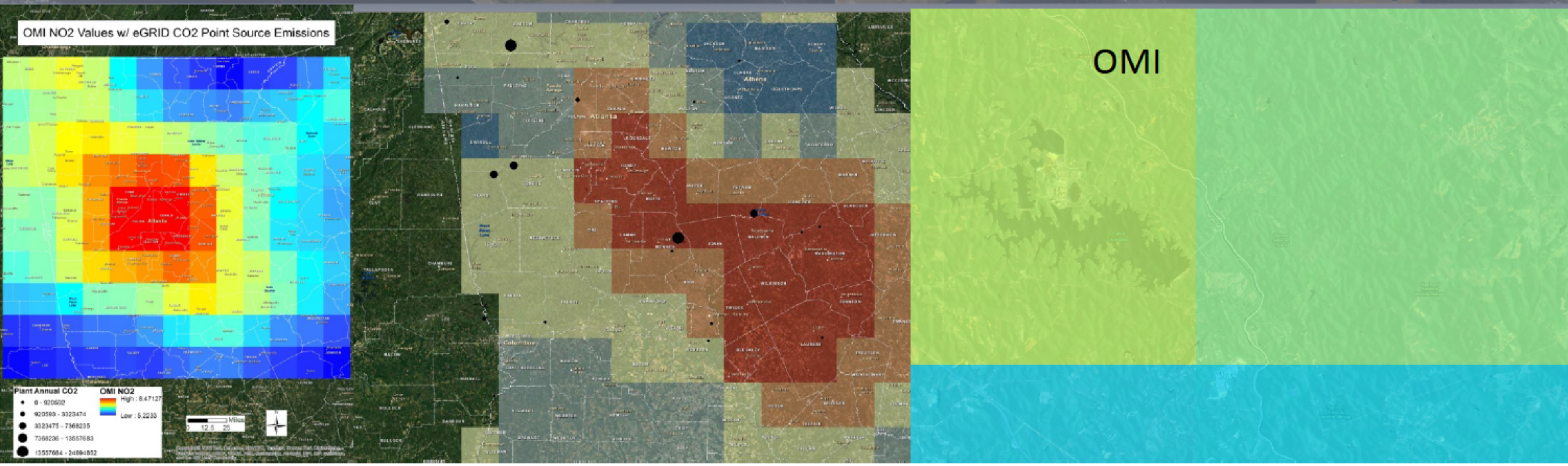
A novel uncertainty measure is based on Monte Carlo simulated expected values for spatial error combined with stack measurement and fuel flow uncertainties for magnitude.

Percentage of Total National CO_2 Emissions from Power Plants



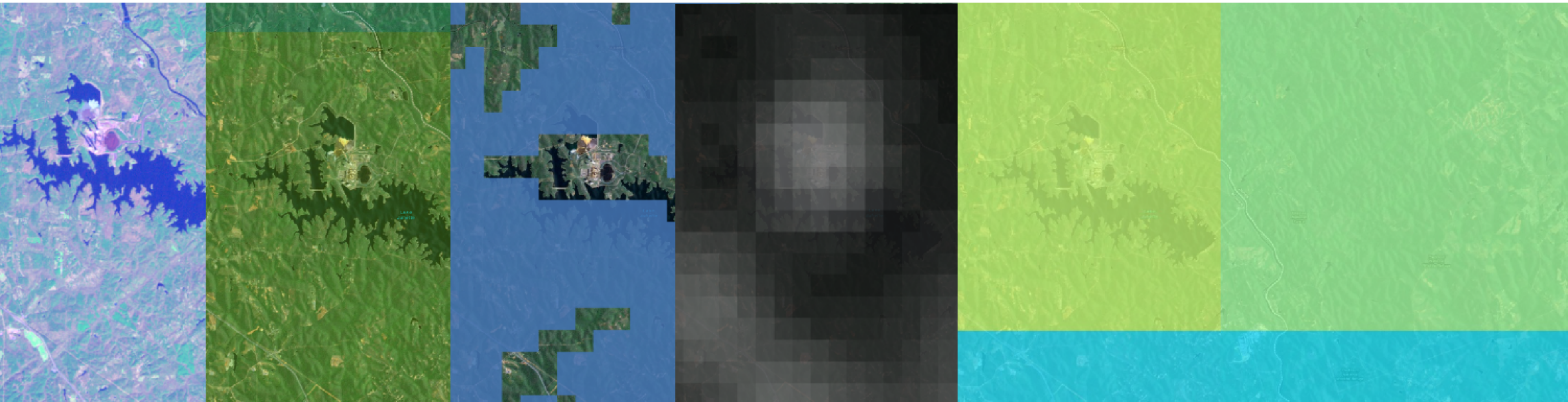


Remote sensing: fusion and scale

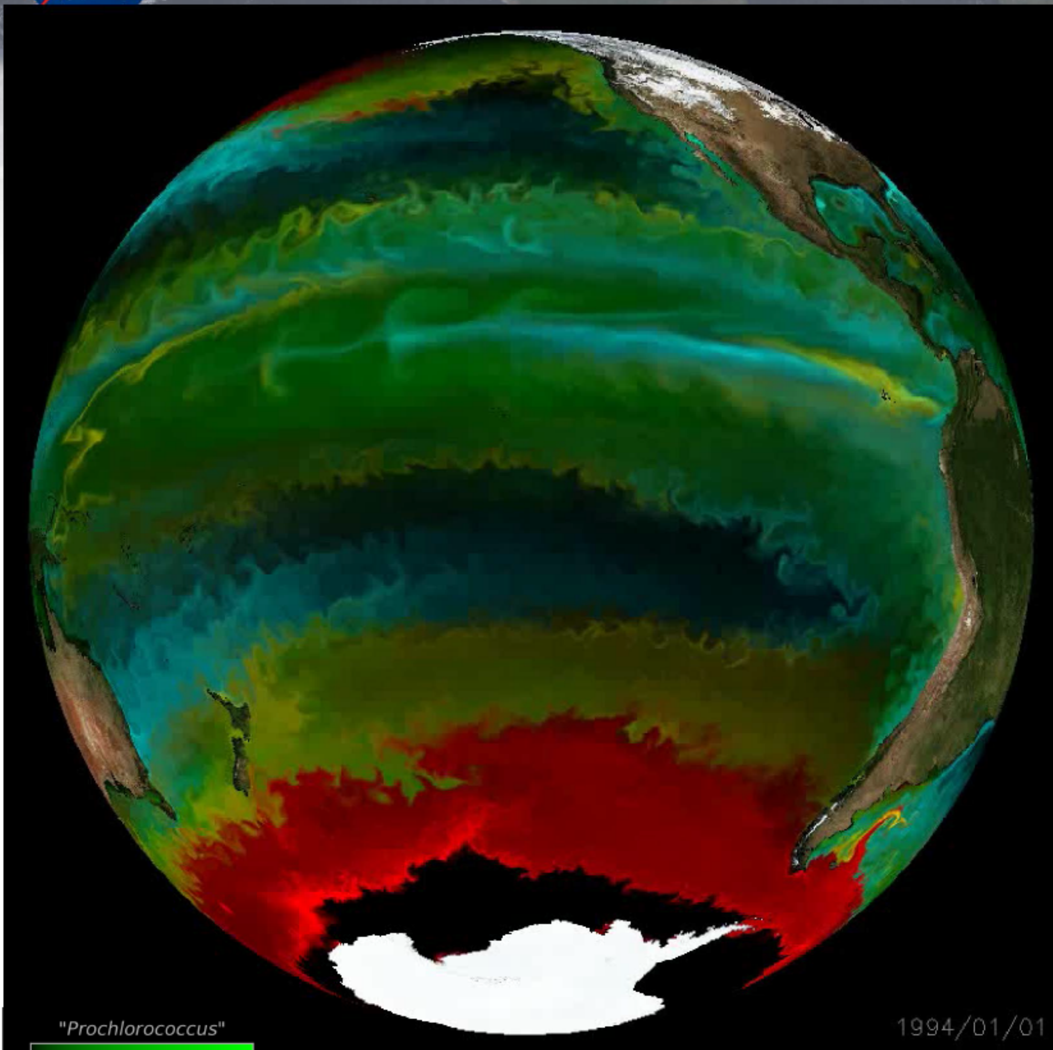


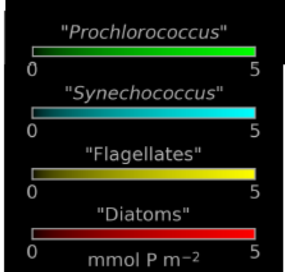
Estimating Point Sources from NASA Data Products

Landsat Thermal, Anthro Biomes, Gridded Population, Night Lights, OMI data sources



ECCO2-Darwin ocean biogeochemical model





Distribution of major groups of phytoplankton in the Darwin ocean ecosystem model. The Darwin model simulates 78 species of virtual phytoplankton, which can be categorized into the four broad functional groups mapped by the color shading.

ECCO2: Eddying Global-Ocean and Sea Ice Data Synthesis

18 km cubed sphere physical ocean with adjoint method data assimilation (Menemenlis et al, 2008)

Darwin ocean ecology model (Follows et al., 2007)

Ocean biogeochemistry is constrained by a Green's function approach (least squares)

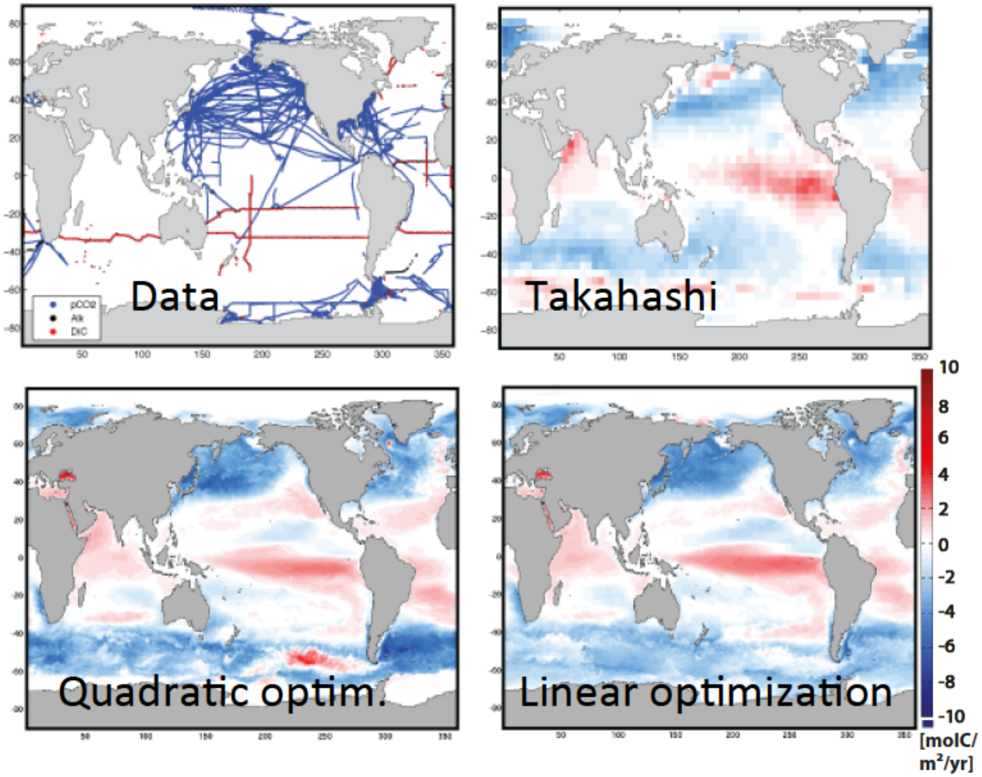
Model: $\boldsymbol{y} - G\,[\mathbf{x}_b] \approx \mathbf{G}\,(\mathbf{x} - \mathbf{x}_b) + \mathbf{n}$

Solution:

$$\mathbf{x} = \mathbf{x}_b + (\mathbf{G}^T\mathbf{G})^{-1}\,\mathbf{G}^T\,(\boldsymbol{y} - G\,[\mathbf{x}_b])$$

G is a kernel matrix whose columns are computed using a GCM sensitivity experiment for each parameter in vector **x**, which are the initial conditions. Subscript "b" represents baseline GCM integration used to linearize problem.

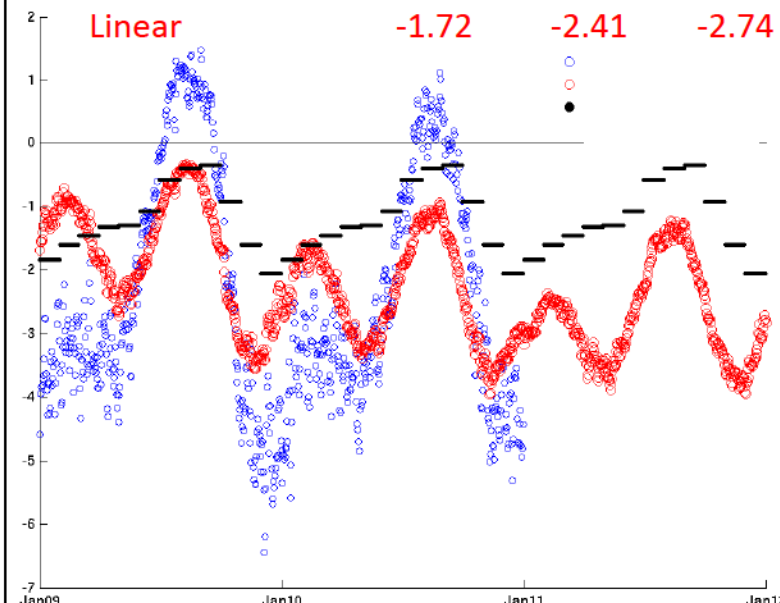
Assimilation of pCO_2, DIC, and alkalinity, 2009-2011
Optimization of air-sea gas exchange parameterization



Seven ECCO2-Darwin sensitivity integrations differing in their initial conditions (IC) for dissolved inorganic carbon (DIC), alkalinity (Alk), and oxygen and in biogeochemical parameterizations were used for the optimization.

Simulated mean air-sea CO_2 fluxes during 2009-2011 in PgC/yr:

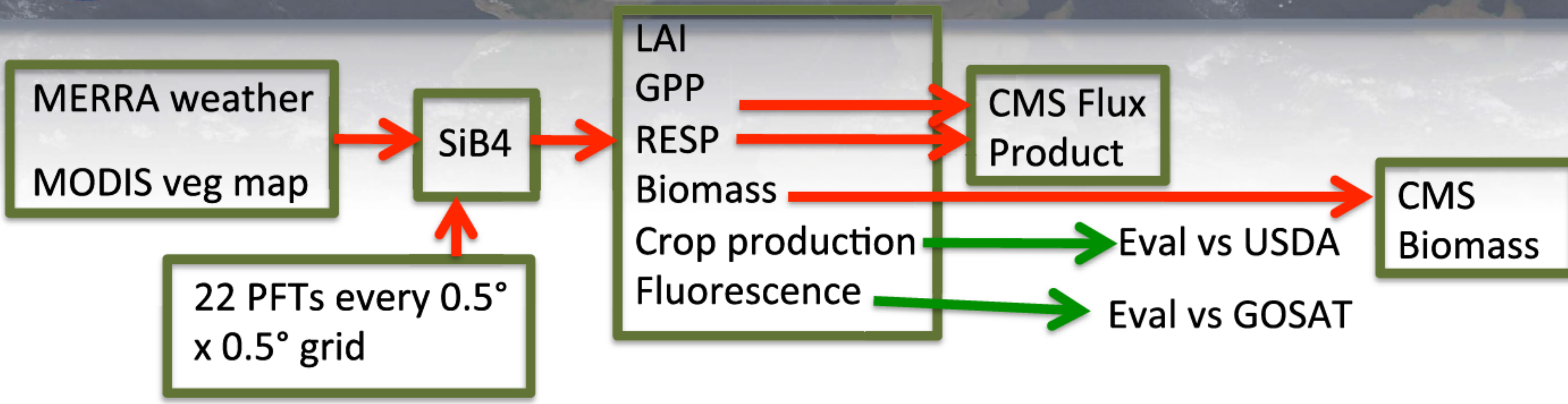
	2009	2010	2011
Quadratic	-2.25	-2.54	
Linear	-1.72	-2.41	-2.74

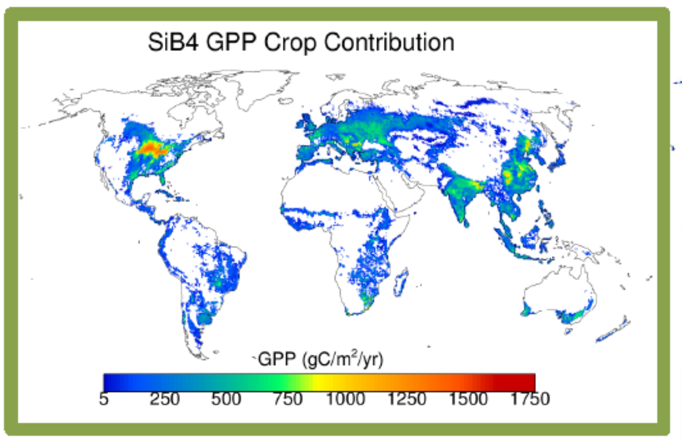


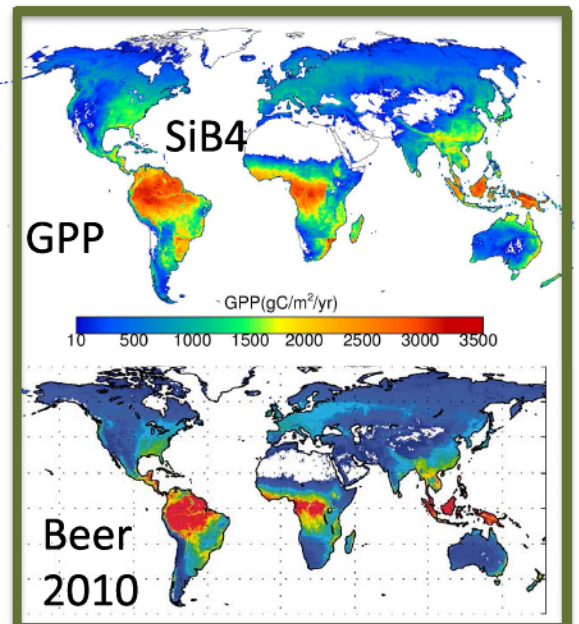
For comparison: Takahashi (2000): -1.1 PgC/yr

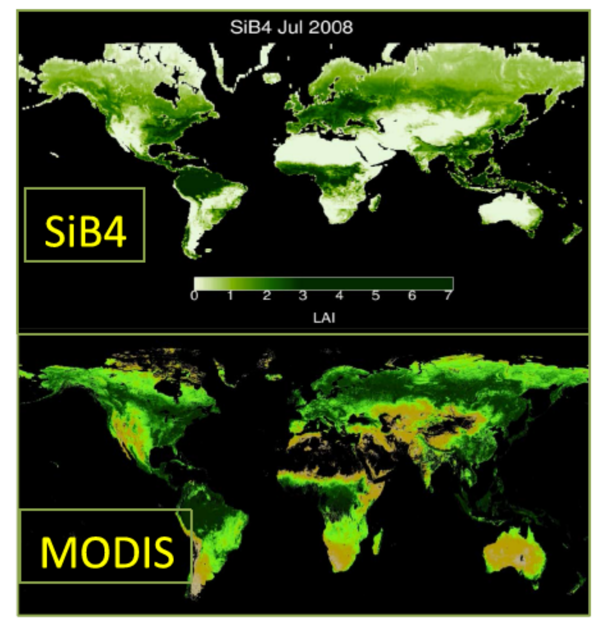
A second set of calculations was performed using a linear instead of a quadratic air-sea flux parameterization. Brix et al. (2013), in preparation

Sib4: prognostic calculation of ecological variables





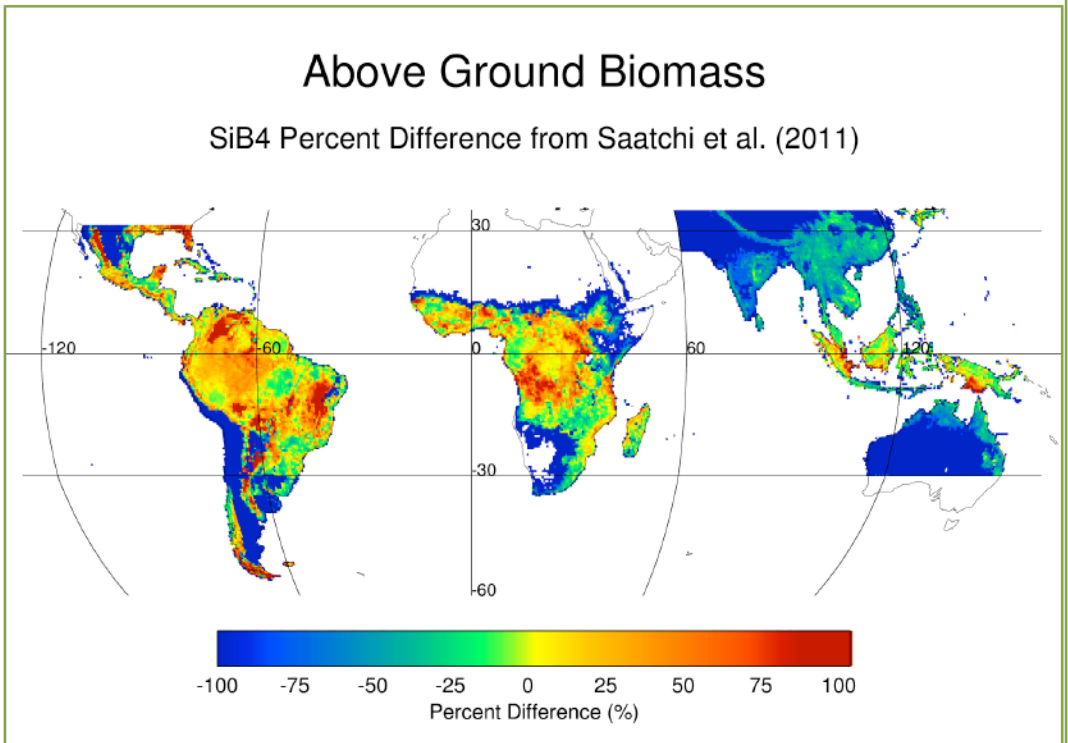


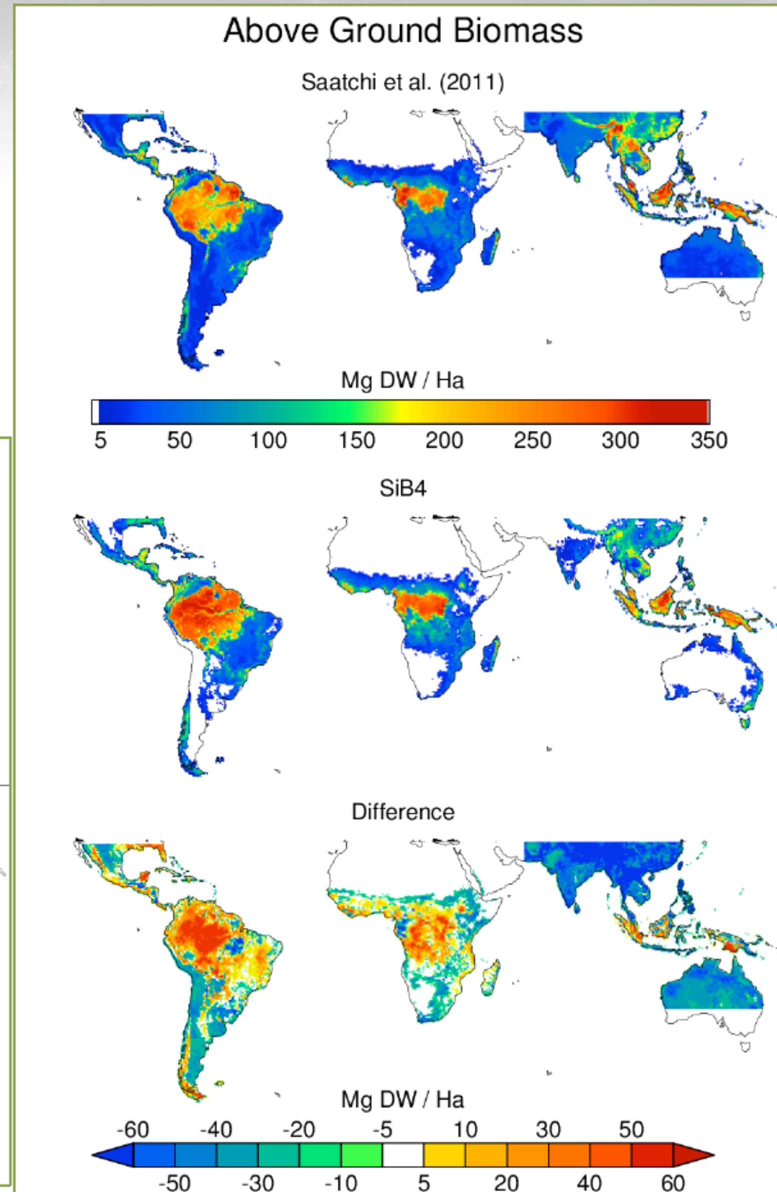


Self-consistent prediction of fluxes and biomass with prediction of multiple satellite products

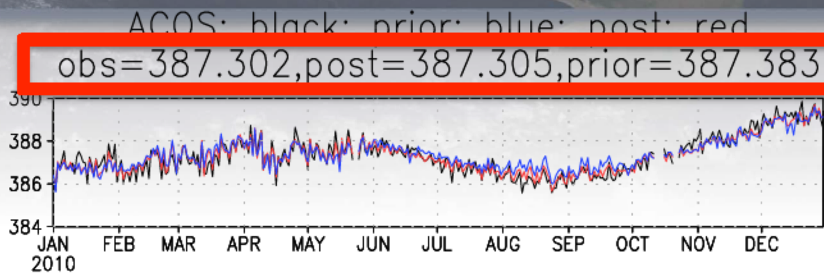
Sib4: Linking Flux and Biomass

Prediction of both biomass and GPP/Rh allow CMS-Flux to link with CMS-biomass.

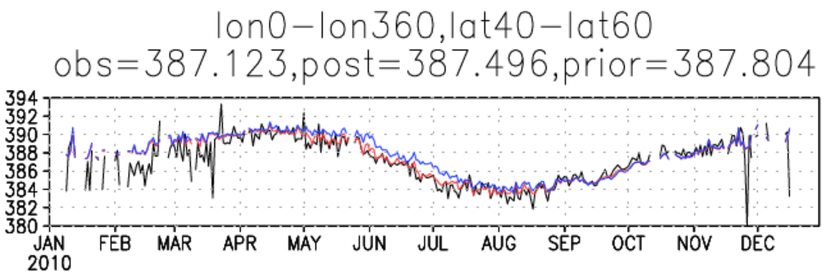


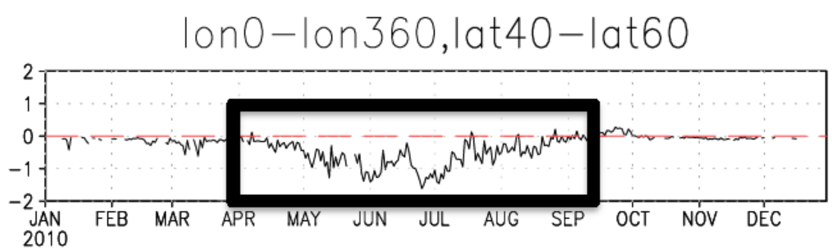


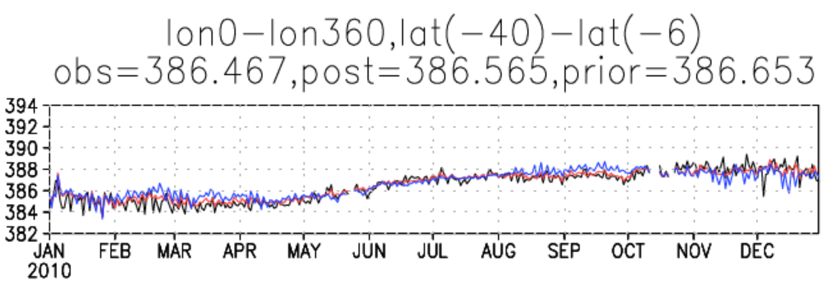
Comparison of CMS-Flux to GOSAT

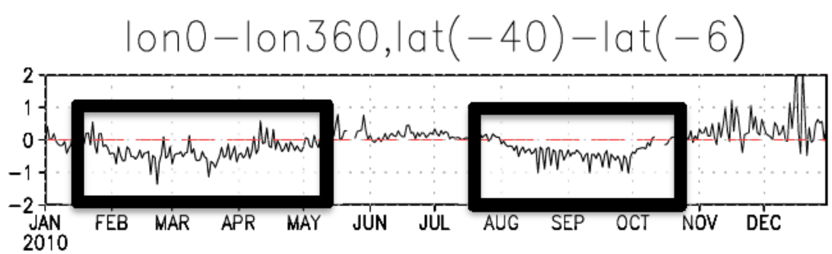


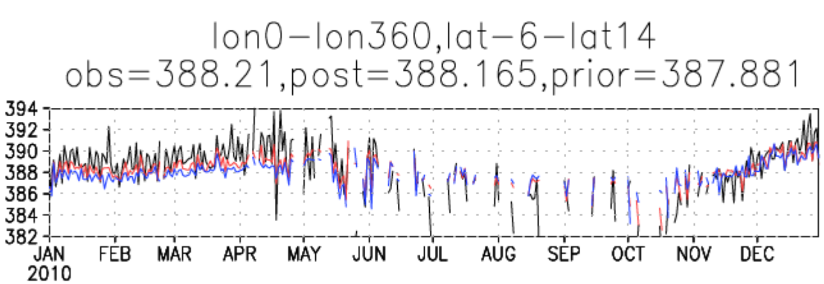
- CMS-Flux total annual flux agrees with GOSAT to within 0.01 ppm.
- Zonal and seasonal differences range from 0.5 to 1 ppm

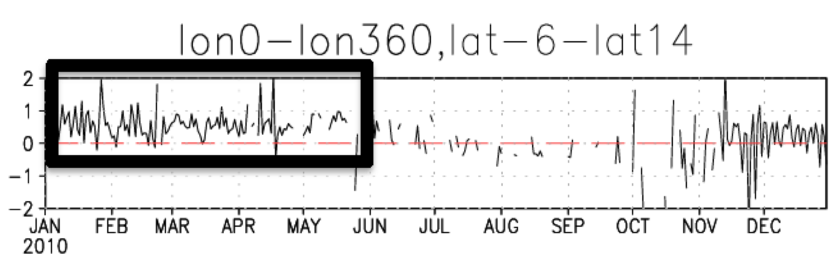






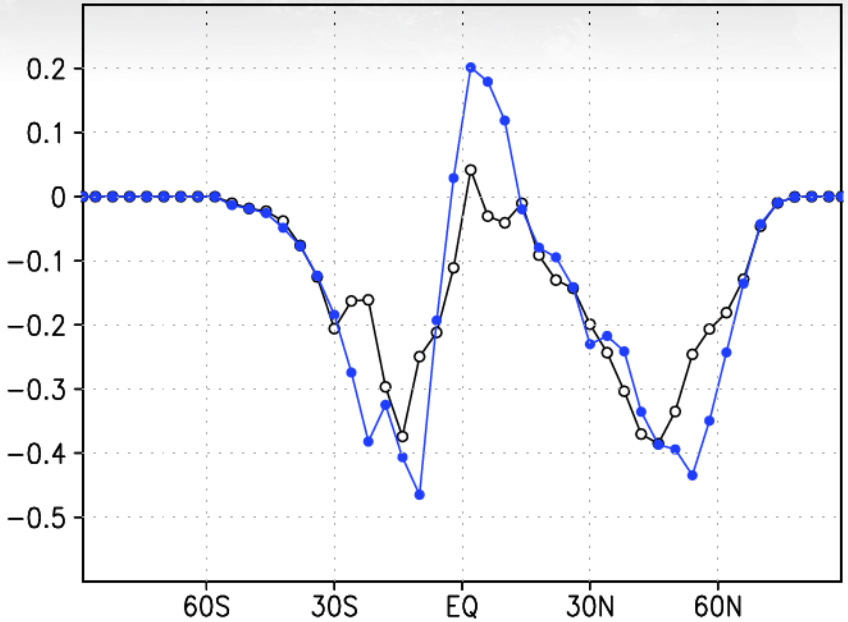




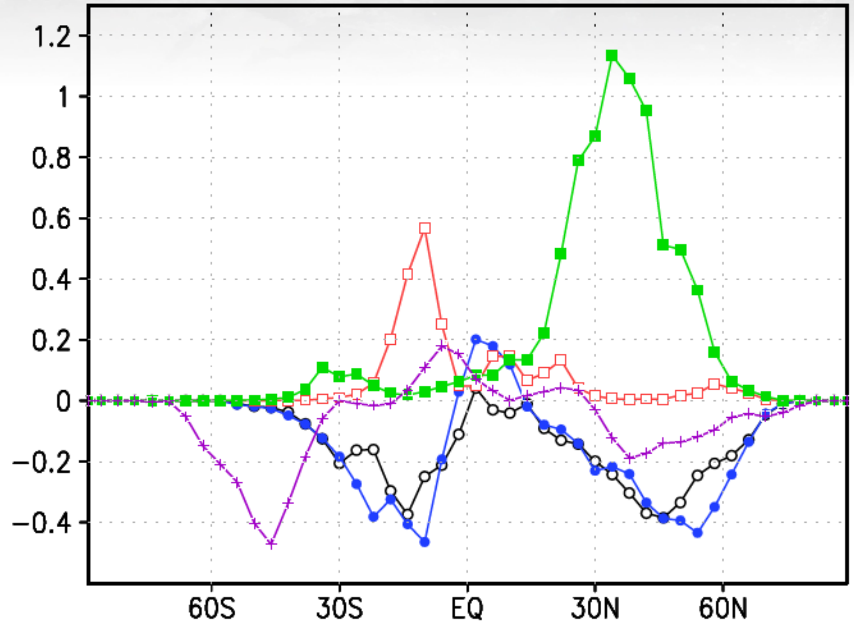


Posterior flux estimate 2010

Prior flux=-5.12GtC, posterior flux=-5.36GtC

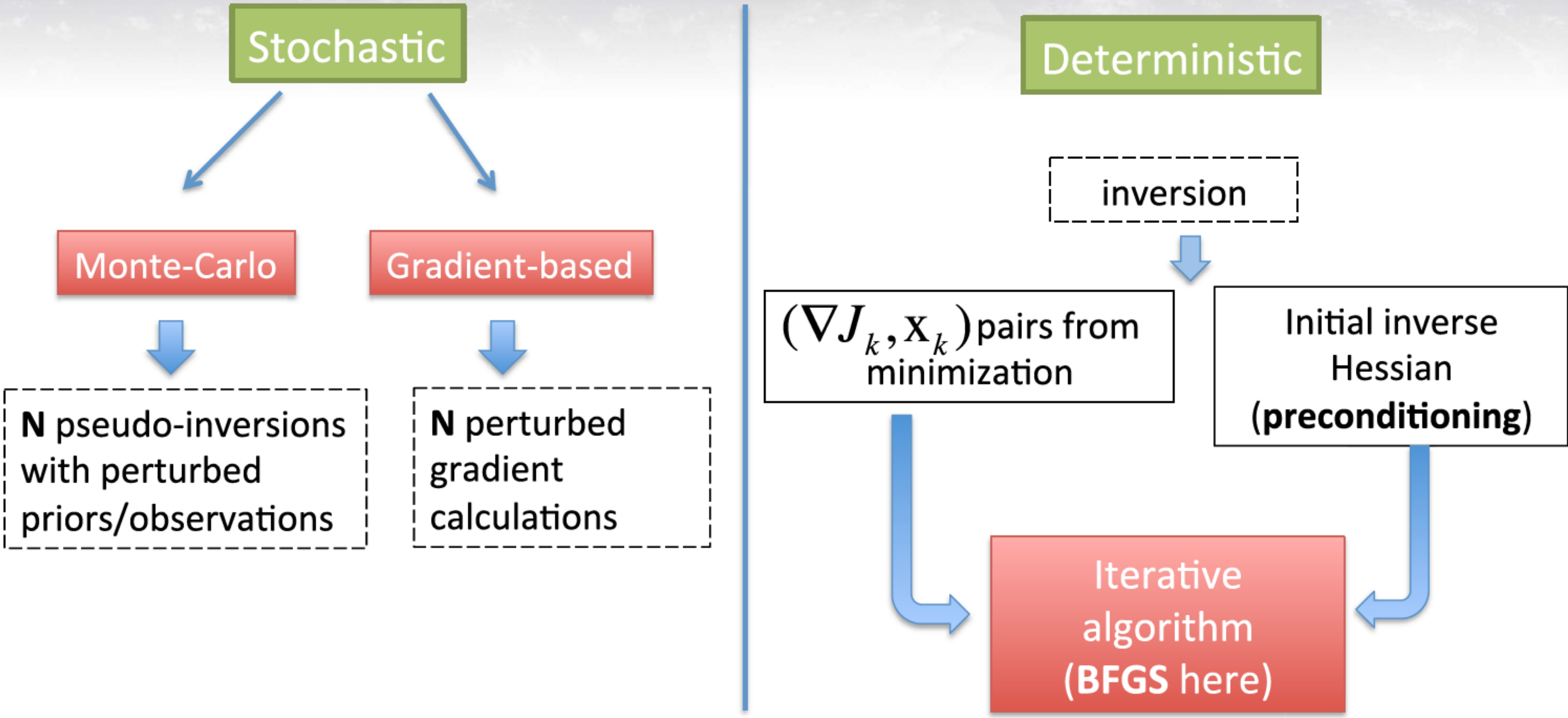


Black: prior; blue: posterior; green: fossil fuel; red: biomass burning; purple: ocean flux



- Prior flux (Black); Posterior flux (blue)
- Posterior estimate redistributes the flux merdionally.
- The posterior flux increases carbon uptake over the NH mid-latitude and SH sup-tropics while reducing uptake over the tropics relative to the prior carbon budget.
- It's important to remember that xCO2 is only sensitivity to the total flux. Uncertainties in one part of the carbon cycle can alias into the other.

Uncertainty quantification: combining stochastic and deterministic methods



Conclusions

- CMS-Flux has successfully integrated data and models across the entire carbon cycle to attribute changes in atmospheric CO2 growth to spatial drivers.
  - Preliminary results show zonal shifts
  - Role of satellite biases still a challenge to quantify
- CMS-Flux project is actively engaged with the broader CMS community
  - D. Huntzinger (MsTMIP)
  - D. Jacob (Methane)
  - J. Miller (NOAA observation evaluation)
  - S. Saatchi (Linkage between Biomass and Flux)