Carbon Cycle Data Assimilation in the GOSAT Era: An Observing System Simulation

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Abstract

We have developed and evaluated a system for assimilation of satellite retrievals of atmospheric CO2 into a comprehensive forward model of the carbon cycle. Five mechanistic component models are combined with Ensemble Data Assimilation to obtain hourly estimates of each component flux on a 2 x 2.5 global grid. Synthetic observations are constructed using hypothetical perturbations to a balanced model that are consistent with current literature, and sampled using a sun-synchronous orbit and a realistic cloud mask. Results indicate that regional fluxes can be recovered at seasonal to annual time scales with considerable skill, though biases in air-sea gas exchange are much harder to quantify than biases in terrestrial fluxes.

Component Models

- Terrestrial photosynthesis & respiration (SiB, hourly)
- *Ocean Biogeochemistry, Ecosystems, & Air-Sea Gas Exchange (WHOI, daily)
- *Fossil Fuel Emissions (DOE plus VULCAN, ~hourly)
- *Biomass burning (GFED, 8-day)
- *Atmospheric Transport (GEOS5-PCTM, 3-hourly)

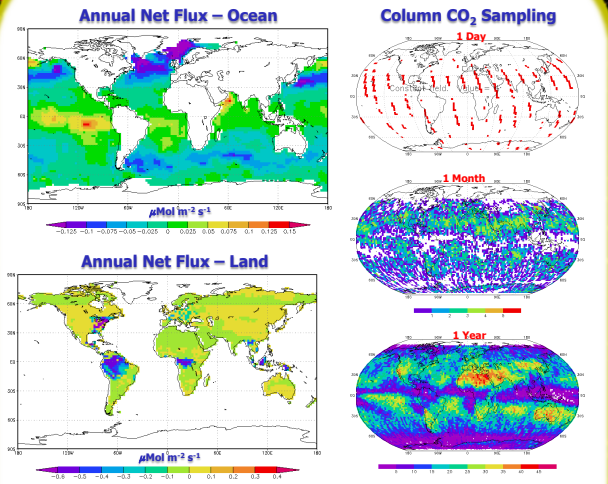
* (not included in preliminary calculation presented here)

Ensemble Data Assimilation

$$F_T(x,y,t) = (1+\beta_{FF}(x,y))FF(x,y,t) + (1+\beta_{Fire}(x,y))Fire(x,y,t)$$
$$+(1+\beta_{RESP}(x,y))RESP(x,y,t) - (1+\beta_{GPP}(x,y))GPP(x,y,t)$$
$$+(1+\beta_{Ocean}(x,y))Ocean(x,y,t)$$

Maximum Likelihood Ensemble Filter (MLEF)
Prior β=1.0 $\sigma_{\beta land}$=0.2; $\sigma_{\beta ocean}$ = 0.1
N_{ens} = 100; Assim Window = 2 weeks
Covariance Propagation using persistence
Covariance smoothing for "cold start" only

Synthetic Observations

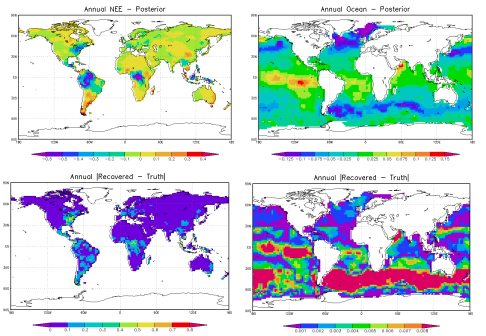


Hypothetical bias factors designed to reflect "reasonable" carbon processes: (forest regrowth, N-deposition, CO_2 fertilization, Southern Ocean changes)

Pressure-weighted atmospheric column sampling on OCO orbit (sorry!)

NCEP cloud mask, assumed 1 ppm random error in cloud-free grid cells

Results

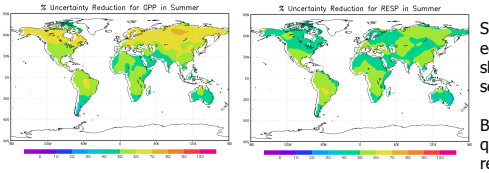


Model recovers spatial patterns of annual flux with considerable skill

Retrieval is better over land than over oceans due to stronger component fluxes (and resulting anomalies in column CO2)

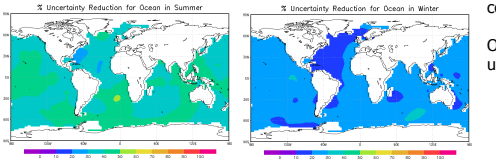
Particularly good results over tropical land

Particular poor retrieval over Southern Ocean

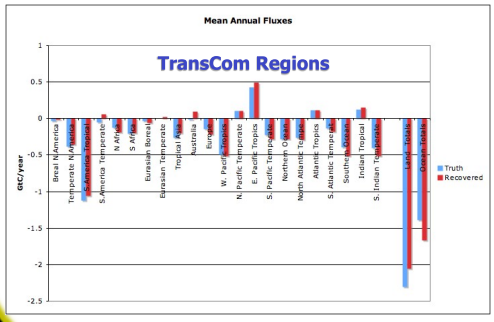


Separation of GPP and ecosystem respiration shows some skill at seasonal time scales

Biases in GPP easier to quantify than biases in respiration (stronger component flux)



Ocean fluxes more uncertain than land fluxes



When post-aggregated to TransCom regions, annual fluxes are recovered very well!

Conclusions

Decomposition of component fluxes into well-understood high-frequency variations and slowly-varying bias factors allows observational constraint to be focused on more interesting "biogeochemical" part of the science problem at hand.

Hourly fluxes times 14-day biases of each component flux on a 2x2.5 grid may not be well-constrained, but regional fluxes on annual timescales are well-determined by global clearsky observations.

Biases in component fluxes are best determined for regions and times of strong fluxes.

Acknowledgements

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