# Reduced Uncertainty in North American Carbon Uptake from a Global Synthesis Inversion

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## Global Synthesis Inversion

The global synthesis inversion method is useful for creating a test bed against which to examine sensitivities to network composition, observation types, background fluxes, prior fluxes and uncertainties, as well as comparisons to results from other inversion methods.

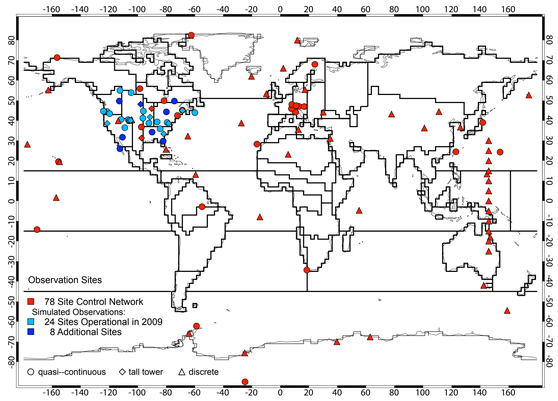
Butler et al. [2010] included continuous, high-frequency, $CO_2$ mixing ratio time series, calibrated to global standards, at several continental sites to achieve a 20% reduction in the mean annual uncertainty (relative to the uncertainty without those observations) of the 2001-2003 North American carbon sink of 1.2 ± 0.4 PgC/yr.

Here we extend this inversion to examine how including the growing North American observation network affects North American and carbon flux uncertainty estimates. We also examine the sensitivity of the inversion results to the model sampling protocol of matching model samples to the times of the observations.

## The Inversion Setup

- Inversion Model: Bayesian Synthesis Inversion in the style of the TransCom interannual inversion [Baker, et al., 2006], as modified by Butler et al. [2010].
- Flux Solution: 36 land regions and 11 ocean regions (see map at right), monthly fluxes for 2000-2004, with analysis of the 2001-2003 period.
- Forward Model: NASA PCTM [Kawa et al.,2004], with 2.0 x 2.5 degrees resolution using 6-hourly GEOS-4 meteorology for 2000-2004.
- Background Fluxes:
  - Biosphere Flux: SiB3 hourly flux, annually neutral, but with interannual variability for 2000-2004 [Baker et al., 2008].
  - Biomass Burning Emissions: GFED2 monthly flux for 2000-2004 [van der Werf et al., 2006]
  - Air-Sea Flux: Monthly climatology representative of the mid-1990s (net uptake of 1.6 GtC/yr) [Takahashi et al., 2002].
  - Fossil Fuel Emissions: Monthly spatial distribution [Erickson III, et al., 2008] scaled to the global annual emissions totals of Marland et al. [2007]
- Priors: Base level monthly uncertainties are the 3-month background exchange for the region, centered on each month.
- Data: Observations from NOAA ESRL, the WMO Global Atmospheric Watch World Data Centre for Greenhouse Gases, and the principal investigators at several continental sites. Data for continental sites are subsampled for mid-day hours. Model samples are matched in time to the observations at all sites.

## Observation Sites and Flux Regions




Networks:

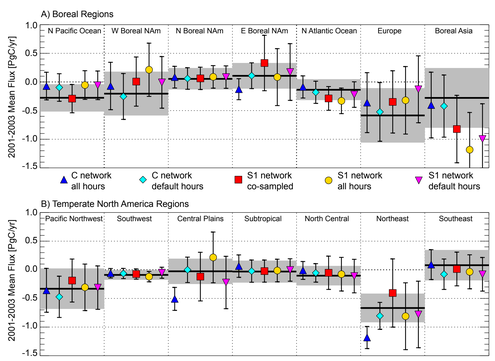
Control (78 sites): Red sites - includes 5 flux towers with high precision $CO_2$ mixing ratios calibrated to global network standards with observations in the target period for the inversion (2000-2004).

F1 (102 sites): Control Network + 24 light blue sites: Simulated 2000-2004 observations for North American sites with high quality $CO_2$ observations in 2009.

F2 (110 sites): F1 network + 8 dark blue sites: Simulated observations for additional North American locations with current research programs.

S1 (60 sites): Control Network without any of the continental continuous sites (circles and diamonds).

## Is Co-Sampling Important?

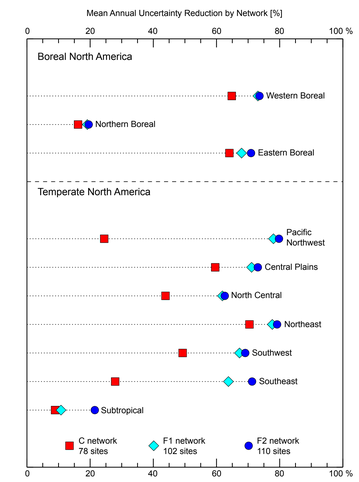



Model Sampling Protocols:
- all hours: monthly means developed from all hours
- co-sampled: same hours as the raw observations
- default: as if no observations are missing

The solid black line and shading in this figure are the posterior flux and uncertainty results from the inversion with the control network and co-sampled model output.

Continental continuous observations are sub-selected for mid-day hours to avoid local effects. We experimented with the protocol for sampling the transport model to find out how important it is to match the model samples in time with the observations. The C network, all hours (blue triangles) shows us that co-sampling is advisable for model sampling of continental observations. Even when using only sites sampling background conditions (S1 network), matching model samples to the hours of the raw observations is important.

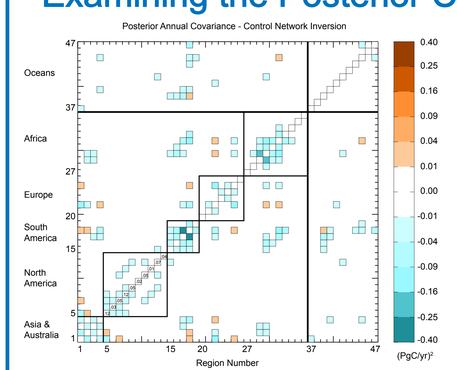
## Uncertainty Reductions Using the Additional Continental Observation Sites



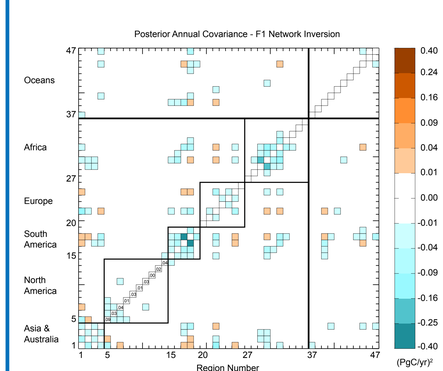

This figure shows the mean annual uncertainty reduction for the North American regions in the control network and the two simulated, expanded networks shown on the map.
Uncertainty reduction is local to the regions with the added observations (for example, Pacific Northwest). More than 2-3 sites in regions of the size used here has little additional effect on the posterior uncertainty.

Mean annual uncertainty for North America improves to 0.2 PgC/yr when using these additional sites.

## Examining the Posterior Covariance Matrix




The posterior annual covariance matrix for the Control Network (top) and the F1 simulated network (bottom) show the improvement to the North American posterior covariance structure after adding the new observations.




There is little change elsewhere globally, including interactions between the North American regions and the other regions, continents, and ocean basins.

In this figure variances for North American regions are on the diagonal. Shaded boxes contribute ≥ 0.1 PgC/yr to the region annual uncertainty.

## For More Information:

Butler et al., [2010], *Tellus*, 62B, 550-572, doi:10.1111/j.1600-0889.2010.00501.x
Butler et al. (in prep), network sensitivities
Butler et al. (in prep), methods sensitivities

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