A New Bayesian Synthesis Inversion

Global inversions typically use data products compiled from observations of carbon dioxide (CO₂) mixing ratio from the global measurement network to infer surface fluxes of carbon for continents and ocean basins. With relatively few continental observation sites, this network is adequate to resolve the latitudinal gradient of global sources and sinks, but is not sufficient to constrain the longitudinal distribution of sources and sinks at sub-continental resolution [e.g., Gurney et al., 2004; Baker et al., 2006].

Continuous, high-frequency measurements of CO₂ mixing ratio are also being made at hundreds of flux towers all over the world. At a few of these continental sites, CO₂ mixing ratio measurements are also carefully calibrated to global standards. This new inversion tests the inclusion of these additional continental sites in a Bayesian synthesis inversion patterned after the inversion used in the TransCom model comparison experiments.

The Inversion Setup

- **Inversion Model:** Bayesian Synthesis Inversion in the style of the TransCom interannual inversion [Baker et al., 2006].
- **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 (degraded from 1 x 1.25 degree resolution).
- **Background Fluxes:**
  - **Biosphere Flux:** SiB3 hourly flux, annually neutral, but with interannual variability for 2000-2004, provided by I. Baker and N. Parazoo at CSU.
  - **Biomass Burning Emissions:** GFED2 monthly flux for 2000-2004 [van der Werf et al., 2008].
  - **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 provided by D.J. Erickson III, ORNL and Z. Zhu, NASA GSFC, scaled to the annual emissions 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 Center for Gases, and the principal investigators at several continental sites. (Results here use simulated data.)

Observation Sites and Flux Regions

**Networks:**
1 (74 sites): **Blue** sites: NOAA ESRL observation sites
2 (112 sites): Network 1 + **Green** sites: Additional global observation networks with data archived at the World Data Center for Greenhouse Gases
3 (122 sites): Network 2 + **Red** sites: Continental data sites with high-precision CO₂ mixing ratios calibrated to the global network standards, with observations in 2002
4 (146 sites): Network 3 + **Yellow** sites: Additional sites with high quality CO₂ observations after 2002.

**Regions:**
- 11 ocean regions: as defined for the TransCom project
- 36 land regions: The 11 TransCom land regions have been partitioned into the 36 regions shown in outline above.

Better Regional Flux Estimates for North America?

**Annualized Posterior Uncertainties for 2002 for the Regions Within Temperate North America**

The additional sites can be expected to influence the posterior uncertainty in regions such as the Northeast.

There is also modest improvement in the aggregated Temperate North America region.

**Monthly Normalized Posterior Uncertainties for June 2002 for the Regions Within Temperate North America**

A goal here is for the posterior uncertainty to be smaller than the flux magnitude. This should facilitate detection of interannual variability in the fluxes.

Note that the vertical scales differ in these figures.

Continuing Work:

- Compute monthly mean observations and match all model data sampling to the time of observations.
- Duplicate the “perfect data” sensitivity tests shown here (sensitivity to prior uncertainty, to network size, to the inclusion of continental sites) with inversions using the data from the monthly mean observations.
- Compare inversion results for networks with selected continental sites. Test sites as surface layer mixing ratio observations vs. using 400 m daytime convective boundary layer estimates derived with a mixed-layer similarity method (the “Virtual Tall Tower” concept). The intent is to capture representative synoptic and seasonal variability in the model grid while minimizing the influence of the local diurnal cycle.
- Explore further the limits of detection for interannual variability in the flux solution and compare to climate variables in 2001-2003.

References and Additional Information:

A list of references and supplementary documentation, can be found at the web site noted below.

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