The Influence of North American Carbon Flux Spatial Distribution on the Temporal Variability of Atmospheric Carbon Dioxide

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Introduction

Inverse models predict fluxes that are quantitatively consistent with atmospheric measurements, but atmospheric mixing coupled with the sparseness of observations leave the problem ill-posed and frequently under-constrained. Depending on the scale of estimation, multiple sets of surface flux estimates may be consistent with a single record of observed CO2 concentrations. To address this, the surface flux distributions of net ecosystem exchange (NEE) from four different biospheric models are used to evaluate the ability of the North American (NA) atmospheric CO2 sampling network to detect grid-scale (i.e., 1° x 1°) and regional spatial variability in land-atmospheric carbon flux.

The questions to the left are addressed using four (4) case studies. These case studies involve manipulating the surface flux distribution from the models in such a way as to isolate the influence of ecosystem-scale variability, ecosystem-scale variability, and the near-field of observation locations on CO2 concentration.

Approach

Across-Model Mean Monthly CO2 Flux 2004

1. Transport unique surface flux distributions from forward models to observation locations.
2. Apply a model-specific mean to all cells within a given ecosystem. Thus, there is a different mean flux magnitude by biome-stratified models.
3. Normalize surface flux distributions by biome. This, across models, is the same net mean flux, but individual biome flux magnitudes are different.
4. At a given locale, the estimated ecosystem-scale variability is then compared to the observed variability for each biome.

Variability in Surface Flux Distribution

The 3-hourly, 1° x 1° surface flux distribution predicted from SiB3.0 (Sellers et al. 1986; Baker et al. 2008), CASA GFEDv2 (Potter et al. 1992; Randerson et al. 1997; van der Wel et al. 2006) and VEGAS (Zeng et al. 2008) are used in conjunction at the WRF-STILT atmospheric transport model (Skamarock et al., 2005; Lin et al. 2003) to generate an atmospheric signal at continuous observation locations operating in 2004. Monthly VEGAS2 and CASA GFED2 fluxes were down-scaled to 3-hourly using the methods of Olsen and Randerson (2004). Pseudo-atmospheric concentrations were generated for all 24 hours at tall towers (~300 m) and marine boundary layer towers, and for the afternoon only at shorter towers (~< ~100m).

Much of the variability in surface flux across models is located in the agricultural regions of the Great Plains and Midwest.

Significance Testing

Two-sample, two-tailed z-tests using tower-specific model-data mismatch error derived from real data and estimated using Reduced Maximum Likelihood (RML) (Gourdj et al. In Review), is used to assess the significance of observed differences among CO2 time series. The p-value for cases 1 through 3 and each model combination are shown below. The lower the p-value, the greater the significance of the difference between resultant CO2 signals. If no significant differences are observed, then inverse modeling approaches may be unable to infer a unique surface flux distribution at the grid-scale (i.e., 1° x 1°) or even at coarser resolutions, given the current sampling network.

Conclusions

In general, distinct atmospheric CO2 signals resulting from the different biospheric models appear to be attributable to large-scale variability in flux magnitude, rather than differences in sub-ecosystem flux distributions. Towers with larger measurement footprints, and those located in more dynamic flux regions, however, do appear to be sensitive to sub-ecosystem-scale variability both in the near and far field. Highlighting those regions where variation in flux distribution do not translate into significant differences in atmospheric CO2 signals provides information about the uniqueness of flux estimations from inversions. Such information will help inform inverse modeling, and improve our understanding of land-atmosphere carbon exchange.

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