Assessing Sampling and Representation Errors in Inversions of Satellite CO_2 Retrievals

Final Technical Report

Katherine Corbin
A. Scott Denning, Advisor

Atmospheric inversions have provided valuable information regarding the carbon cycle from estimating the location and magnitude of surface carbon fluxes by optimizing atmospheric measurements of CO_2; however, these flux estimates are still highly uncertain, particularly as modelers shift towards high-resolution fluxes, due primarily to sparse data coverage. Due to their uniform spatial sampling and sheer data volume, satellite retrievals of the total-column dry mole fraction of atmospheric CO_2 (X_{CO2}) can be used in inversions to identify regional carbon sources and sinks and to help reduce uncertainties in the CO_2 budget.

To utilize satellite CO_2 data, inverse modelers must account for several types of representation and sampling errors. Spatial representativeness errors may be introduced into inversions that use satellite measurements to represent an entire grid cell as the satellite footprint is likely much smaller than the horizontal resolution of the grid cell; local clear-sky errors may exist in inversions that compare concentrations in a model grid cell that may be partially cloudy to total-column CO_2 concentrations sampled at the same time but only over clear areas; and temporal sampling errors can result from using single snap-shots from satellites taken only in clear conditions to represent temporal averages. We have assessed the potential magnitude of these errors using continuous tower observations, a coupled cloud-resolving model, and a global chemical transport model.

An assessment of temporal sampling errors used multi-year continuous measurements of atmospheric CO_2 at two stations located in mid-latitude forests [Corbin et al., 2006]. Comparing mid-day CO_2 on clear-sky days to all days revealed systematic differences of 1 to 3 ppm, with lower concentrations on sunny days than average. The differences at both stations are greatest in the winter and are not attributable to anomalous surface fluxes. Further analysis over a remote equatorial forest in Brazil concurred with the mid-latitude results of lower concentrations on clear days, particularly in the rainy season, that cannot be accounted for by changes in surface fluxes alone.

To further evaluate sampling errors, we performed cloud-resolving simulations of two cases using the SiB-RAMS coupled ecosystem-atmosphere model: one during the summer at a temperate forest site and one at a tropical site during the dry season [Corbin et al., 2007a]. Using simulated CO_2 fields on a fine domain (~1^o x 1^o) and a coarse domain (~4^o x 4^o), we compared clear-sky total column concentrations from 10-km wide emulated satellite tracks with a 1-km footprint to the actual domain-mean column concentrations. Spatial and local clear-sky errors were found to increase with domain heterogeneity and size, but the majority of the errors for both simulations were less than 0.5 ppm. Temporal sampling errors in representing time means from individual swaths were large, with errors exceeding 1 ppm. At the temperate site, the temporal sampling errors are negatively biased because of systematic X_{CO2} anomalies associated with fronts that were masked by clouds.

Finally, we used a global transport model to investigate clear-sky temporal sampling errors [Corbin et al., 2007b]. Using the Orbiting Carbon Observatory (OCO) sampling strategy, we compared clear-sky simulated satellite retrievals to seasonal averages. Temporal sampling errors varied with time and location and exhibited spatially coherent patterns. The errors were largest over the summer hemisphere and over land, with positive errors over the mid-latitudes in summer and negative errors during the winter. Over the tropics, positive errors were seen during the dry season, while the region had negative errors during the rainy season.

Evaluating spatial, local clear-sky, and temporal sampling errors reveals that large errors may be introduced into inverse models if satellite retrievals are used to represent temporal averages. Both spatial representation errors and local clear-sky errors remain relatively small over a variety of domain size, location, and heterogeneity; however, clear-sky temporal sampling errors are large in all our investigations. This indicates that CO_2 concentration anomalies co-vary strongly with cloud cover, and these errors vary both temporally and spatially. To avoid incurring large errors, inverse modelers cannot use satellite measurements to represent temporal averages and must accurately model the transport associated with satellite retrievals.

References

Corbin, K.D. and A.S. Denning (2006), Using continuous data to estimate clear-sky errors in inversions of satellite CO_2 measurements. *Geophys. Res. Lett., 33*, L12810, doi:10.1029/2006GL025910.

Corbin, K.D., A.S. Denning, L. Lu, J-W. Wang, and I.T. Baker (2007a), Using a high-resolution coupled ecosystem-atmosphere model to estimate representation errors in inversions of satellite CO_2 retrievals. *J. Geophys. Res*., submitted.

Corbin, K.D., A.S. Denning and N.C. Parazoo (2007b), Assessing temporal sampling errors in inversions of satellite CO_2 retrievals using a global transport model. *Geophys. Res. Lett*., in preparation.