USING A HIGH RESOLUTION COUPLED ECOSYSTEM-ATMOSPHERE MODEL TO EVALUATE SPATIAL, TEMPORAL, AND CLEAR-SKY ERRORS IN SATELLITE CO_2 MEASUREMENTS

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ABSTRACT

Satellite measurements of total column CO_2 can be used in inverse models to help isolate sources and sinks; however, using satellite concentrations in inversions may introduce spatial, temporal, and clear-sky errors. Using a coupled ecosystem-atmosphere model, we found that using satellite measurements to represent temporal averages will introduce large errors into the inversion and that inverse models must sample the concentrations at the same time as they are measured. Spatial and local clear-sky errors are much smaller than the instrumental errors, although they increase with domain heterogeneity. Inverse models can minimize sampling errors by using homogenous regions and sampling the CO_2 concentrations at the same time as the satellite.

INTRODUCTION

Variations of atmospheric CO_2 concentrations contain information about sources and sinks with which air interacts with as it is transported from place to place. Using atmospheric tracer transport models, inverse modelers can quantitatively estimate the strengths and spatial distribution of sources and sinks around the world from concentration data. Satellite CO_2 measurements have the potential to help inverse modeling studies by improving the data constraint due to their global spatial sampling and sheer data volume. The Orbiting Carbon Observatory (OCO), scheduled to launch in 2008, will retrieve global total column CO_2 concentrations at 1:15 PM LST with 0.5% precision. These satellite measurements can be used in inversion models to enhance our understanding of the carbon cycle; however, several errors can be introduced when using satellite measurements to optimize CO_2 concentrations in inverse studies: spatial representativeness errors may be introduced into inversions that compare CO_2 concentrations from a model grid cell to satellite concentrations sampled over only a fraction of the domain, temporal sampling errors can result from comparing OCO measurements sampled at 1:15 PM to temporally averaged concentrations in an inversion, and local clear-sky errors may exist in inversions from comparing concentrations in a grid cell that may be partially cloudy to satellite mixing ratios sampled at the same time but only over clear areas.

METHODS

This study investigates these errors using a coupled ecosystem-atmospheric model, SiB2-RAMS. We performed two simulations in August 2001. One simulation was centered on a tall tower site in Wisconsin, and the other run was a simulation in the Brazilian Amazon. Using the generated CO_2 field, we compared the clear-sky total column concentrations from emulated satellite tracks to the mean total column mixing ratio over the domain. The emulated satellite tracks in our study mimicked the OCO sampling strategy: we used total column concentrations, we assumed the satellite tracked due south, we analyzed the concentrations at 1 PM, we averaged zonally adjacent pixels to create a track width of 10 km, and we meridionally averaged the concentrations to produce one emulated concentration for the entire grid cell. Using this methodology, a 97 by 97 km grid with 1 km resolution has 88 different possible satellite tracks at any one point in time. To analyze the sampling errors, we compiled the errors from each of the different possible tracks into sampling distributions.

CONCLUSIONS

The dominant source of error was temporal sampling errors, which are errors that can be introduced into an inversion if the model uses satellite concentrations only in clear columns at 1:15 PM to optimize temporally-averaged concentrations. The main driver of the total column CO_2 variability in our simulations is not the diurnal cycle of CO_2 from biology, but instead is synoptic variability. In Wisconsin, temporal sampling errors from under-sampling fronts associated with clouds and high CO_2 caused a bias of ~-0.5 ppm compared to the domain-averaged ten-day mean. Although this negative bias occurred at a specific location during a ten-day period that included three fronts, one of which had an unusually large CO_2 concentration anomaly, the large variability of total column CO_2 concentrations associated with synoptic events indicates that satellites will not be able to represent a temporal average. To avoid these errors, inverse models will have to accurately model the synoptic-scale atmospheric transport, and inversions will have to use the measured satellite mixing ratios to optimize modeled concentrations sampled at the same time.

Both the spatial errors and local clear-sky errors on are considerably smaller than the 0.5% instrumental error; however, the precision of the measurements will depend on the size and the heterogeneity of the domain the measurements are representing. In a relatively homogeneous domain consisting of similar vegetation types, 95% of the spatial and local clear-sky errors are <0.2 ppm and are normally distributed. The errors are small for a 100 km by 100 km domain because the variability at 1 PM on that scale is limited, typically <1.0 ppm. The SiB2-RAMS simulations suggest that the errors in the total column concentration due to altered photosynthesis on cloudy vs. clear conditions are very small and that the local clear-sky errors are primarily due to advection rather than the biology. As the domain size and heterogeneity increases, the spatial variability in the domain increases. Looking at a relatively heterogeneous area in Wisconsin including portions of the Great Lakes, the spatial and local clear-sky errors on a 450 km domain both increased to a standard deviation of ~0.4 ppm. To prevent introducing spatial representation and local clear-sky errors, inverse models should obtain fluxes by optimizing concentrations over regions with relatively homogeneous vegetation coverage and by avoiding domains that include both ocean and land.