MODELING TERRESTRIAL CO_2 SOURCES, SINKS, AND ATMOSPHERIC TRANSPORT USING ASSIMILATED METEOROLOGICAL FIELDS

S.R. Kawa[1], A.S. Denning[2], S.L. Conner-Gausepohl[2], D.J. Erickson[3], G.J. Collatz[4], S. Pawson[5], Z. Zhu[1], A.E. Andrews[6], K. Schaefer[6]

[1]*NASA Goddard Space Flight Center, Code 613.3, Greenbelt, MD 20771; kawa@maia.gsfc.nasa.gov*

[2]*Colorado State University, Department of Atmospheric Science, Ft. Collins, CO 80523*

[3]*Oak Ridge National Laboratory, MS 6016, Oak Ridge, TN 37831*

[4]*NASA Goddard Space Flight Center, Code 614.4, Greenbelt, MD 20771*

[5]*NASA Goddard Space Flight Center, Code 610.1, Greenbelt, MD 20771*

[6]*Climate Monitoring and Diagnostics Laboratory, NOAA, 325 Broadway, Boulder, CO 80305*

ABSTRACT

Progress in determining CO_2 sources, sinks, and their response to environmental forcing will rely on utilization of more extensive and intensive CO_2 and related observations including those from satellite remote sensing. Full exploitation of new observations will require new modeling and analysis techniques, especially those that can use information at finer spatial and temporal scales than has traditionally been employed in "top-down" carbon flux studies. We report on a modeling effort to reduce uncertainty in carbon cycle processes that create the so-called missing terrestrial sink of atmospheric CO_2 using transport fields derived from NASA's GEOS-4 meteorological assimilation analyses. Our overall objective is to improve characterization of CO_2 source/sink processes globally with improved formulations for atmospheric transport, terrestrial uptake and release, biomass and fossil fuel burning, and observational data analysis. We show results from an advanced biosphere model (SiB3) constrained by remote sensing data and coupled to the global transport model to produce distributions of CO_2 fluxes and concentrations that are consistent with actual meteorological variability. Use of analyzed meteorological data allows comparison to observations on a wide range of temporal and spatial scales. Here we compare with local-to-global data for hourly to annual CO_2 simulation. The results will help to prepare for the use of satellite CO_2 and other data in a multi-disciplinary carbon data assimilation system for analysis and prediction of carbon cycle changes and carbon/climate interactions.

INTRODUCTION

Global CO_2 distributions produced by the Goddard transport model using assimilated winds with climatological sources and sinks have shown significant skill in simulating observed CO_2 changes [*Kawa et al.*, 2004]. The real-time meteorological variability contained in the assimilated fields can produce daily, synoptic CO_2 variability, even with monthly averaged sources and sinks, that appears to be correlated with continuous observations over land and ocean. This has led us to seek more sophisticated CO_2 source/sink distributions, ones that are constrained by real-time observations and can respond to changing weather. Improved models of this sort, along with enhanced data, are needed to make progress in understanding the terrestrial sink. New modeling capability will certainly be required to exploit planned new observations including global remote sensing data from satellites. New and planned satellite data products include atmospheric CO_2 column abundance, location and intensity of biomass burning, vegetation photosynthetic activity, and improved land use/land cover change. Here we report results from the Simple Biosphere version 3 (SiB3) model [*Denning et al.*, 1995; *Schaefer et al.*, 2002] linked to the Goddard assimilated meteorology and global transport to produce CO_2 fluxes and concentrations that vary on hourly to interannual time scales.

SIMULATIONS

Hourly CO_2 fluxes from SiB3 have been generated globally at 1° resolution for the year 2000 forced by meteorological data from GEOS-4 and Normalized Difference Vegetation Index (NDVI) from the Moderate resolution Imaging Spectrometer (MODIS). Figure 1 shows an example of the CO_2 flux on July 1, 2000. The diurnal sweep of photosynthesis-uptake and respiration-emission from the surface vegetation can be seen in the flux modulation around longitudes. The fluxes also respond to observed greenness and weather, e.g., cloudiness, temperature, and drought stress. The hourly vegetation CO_2 fluxes have been run through the transport model with 3-hourly met fields and monthly ocean and fossil fuel fluxes to produce global CO_2 distributions hourly at 2°x2.5°. An example of the modeled diurnal interaction of CO_2 flux and planetary boundary layer growth and decay, and comparison with continuous observations is shown in Figure 2. The coupled SiB3/transport simulations are evaluated through comparison to CO_2 observations globally on time scales from seasonal to synoptic to diurnal. The sensitivity of the CO_2 fluxes and mixing ratios to the input meteorology is tested. As a result, parameterization of processes is being improved. The fields are also useful to help optimize sampling and retrieval procedures for planned and potential satellite CO_2 sensors.

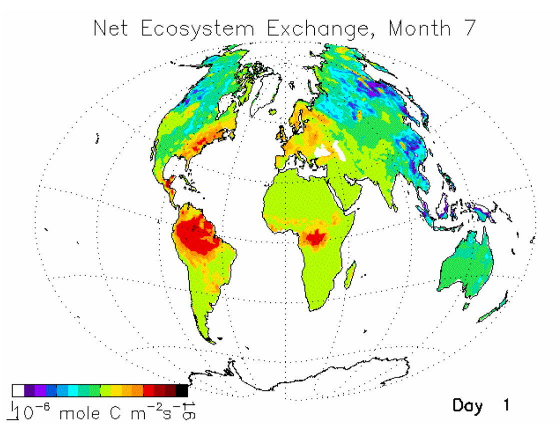

Fig. 1. CO_2 flux from SiB3 for July 1, 2000 at 00Z.

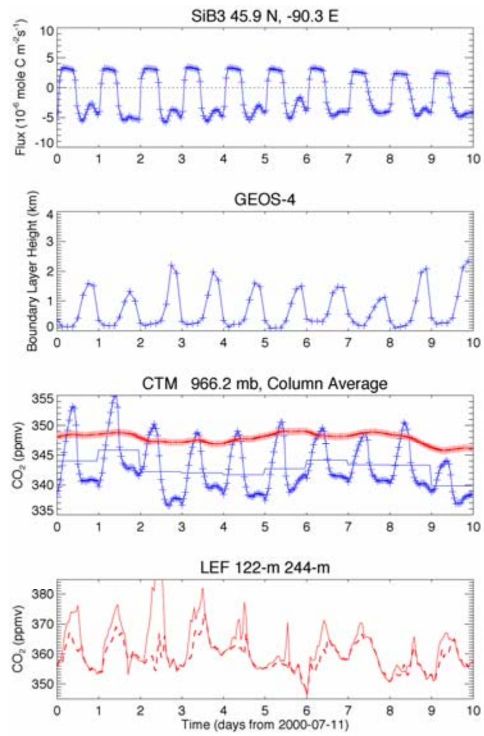

Fig. 2. Model time series and in situ observations (bottom panel). Thick red curve in third panel is hourly column average mixing ratio.

SUMMARY

We have coupled an advanced biosphere model, constrained by remote sensing data, with the global transport model using analyzed meteorological fields to produce distributions of CO_2 fluxes and concentrations that are consistent with actual meteorological variability. Continued analysis and development is expected to result in a closer link between top-down and bottom-up estimates of processes and their sensitivities such that global uncertainties in terrestrial CO_2 sources and sinks are significantly reduced.

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