

SIMULATING GLOBAL ATMOSPHERIC [CO₂] FOR THE YEAR 2000 AND [COS] FOR A CONTINENTAL MIXED FOREST

S. L. Conner Gausepohl¹, A. S. Denning¹, S.R. Kawa², J. Berry³, S. Montzka⁴, T. Conway⁴, A. Andrews⁴, I. Baker¹, J. Kleist¹

¹Colorado State University, Department of Atmospheric Science, Fort Collins, CO 80523 US;
sheri@atmos.colostate.edu

²NASA Goddard Space Flight Center, Code 613.3, Greenbelt, MD 20771 US

³Department of Plant Biology, Carnegie Institution of Washington, Stanford, California 94305 US

⁴NOAA Climate Monitoring and Diagnostics Laboratory, Boulder, CO 80305 US

ABSTRACT

In order to further our understanding of the biophysical and biogeochemical mechanisms that control the fate of fossil fuel carbon emissions, we are simulating an hourly global atmospheric carbon dioxide concentration field ([CO₂]) for the year 2000 with realistic diurnal, synoptic and seasonal variability, including quantified errors. In addition, we are simulating carbonyl sulfide (COS) for a continental mixed temperate forest to test a hypothesis that errors in seasonal simulations of CO₂ result from incorrect specification of springtime onset of photosynthesis rather than incorrect timing of ecosystem respiration.

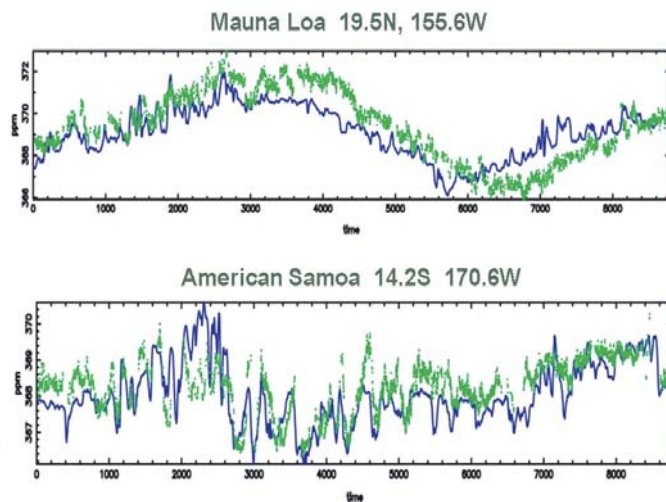
Our simulations of [CO₂] show quite good agreement with the observations at synoptic timescales and in the amplitude of the seasonal cycle. However, in the Northern Hemisphere mid-latitudes our simulated [CO₂] field exhibits a systematic error in the seasonal cycle, with early drawdown of atmospheric CO₂ by the biosphere in the spring and early recovery of atmospheric CO₂ in the autumn. We consider a number of hypotheses to account for this bias in our simulation, including our parameterizations of respiration and interpolation of satellite-derived greenness indices. However, simulating CO₂ is not sufficient to evaluate the mechanisms causing the shift. Thus, we are simulating COS at a continental site to evaluate the simulated difference in [COS] in the boundary layer and the free troposphere versus the observed with the goal of isolating the photosynthetic mechanisms associated with this shift in seasonality.

GLOBAL ATMOSPHERIC [CO₂]

For our simulations of the biosphere, we show results from Colorado State University's Simple Biosphere Model v. 3.0 (SiB3) [Schaefer *et al.*, 2002], a land-surface parameterization using satellite vegetation, with improved treatment of soil hydrology and soil and snow-pack thermal properties, as well as prognostic canopy temperature, moisture, CO₂ and isotopes. For the atmosphere, we show results from Goddard Space Flight Center's Parameterized Chemical Transport Model (PCTM) [Kawa *et al.*, 2004], derived from Goddard Space Flight Center's finite volume General Circulation Model and including sub-grid-scale transport calculated using the Goddard Earth Observing System, Version 4, data assimilation system (GEOS-4 DAS) cloud mass flux and turbulent diffusion coefficients. To simulate [CO₂], we are coupling these models in a step-wise fashion, both driven by assimilated meteorological fields from the GEOS-4 DAS for the year 2000.

Comparing the resulting [CO₂] and CO₂ flux field output with observations from flask measurements, continuous analyzers and aircraft campaigns, we are diagnosing model strengths and weaknesses on various spatial and temporal scales with the goal of furthering our understanding of the terrestrial influence on fossil fuel carbon emissions. In addition to our assessment of model performance, we are calculating an error field for the [CO₂] product with the intention of assisting the scientific community in simulating regional fluxes, performing inversions and assessing the future performance of carbon-measuring satellite missions. Note that by using surface meteorology from a self-consistent source (GEOS-4 DAS) to simulate CO₂ fluxes, winds, planetary boundary layer turbulence and convective transport, we are allowing the models to "act in concert", as both CO₂ flux and transport are influenced by identical fields. In this work, we are also evaluating planetary boundary layer mixing, as this critical component of atmospheric transport and CO₂ measurement is likely quite important in understanding the models' performance.

Figure 1 shows an example of our comparisons of simulated and observed [CO₂]. At Mauna Loa and American Samoa, the simulated synoptic variability and amplitude of the seasonal cycle of CO₂ are well matched to the variability and amplitude in the continuous data; however, at Mauna Loa, the simulated seasonal cycle is biased versus the observations. We are testing a number of hypotheses to account for this bias in our simulation, by



parameterizing the seasonality of autotrophic and heterotrophic respiration explicitly and by implementing various interpolation schemes of satellite-derived greenness indices used to prescribe vegetation phenology.

However, simulating CO_2 is not sufficient to evaluate the mechanisms causing the shift: sources of CO_2 in the biosphere (autotrophic (plant) and heterotrophic (microbial) respiration) are convolved with sinks (photosynthesis) due to their similar dependencies on temperature and moisture.

Fig. 1. Comparison of SiB3-PCTM hourly $[\text{CO}_2]$ output (blue-line) with NOAA-CMDL hourly continuous measurements (green-dots)

COS IN A CONTINENTAL MIXED FOREST

Recent work by Montzka and Tans [2004] has suggested another means by which we may be able to distinguish these sources and sinks. This work has shown that the amplitude of the seasonal cycles of COS and CO_2 are strongly correlated in the Northern Hemisphere mid- and high-latitudes. In addition, previous work conducted by Kesselmeier [Sandoval-Soto *et al.*, 2005] has shown that COS uptake by vegetation follows a pathway similar to that of CO_2 in photosynthesis; however, there appears to be no corresponding source of COS in plant canopies of similar magnitude to that of CO_2 (released during respiration). Thus, the ratio of COS uptake to CO_2 uptake should provide a sensitive indicator of the ratio of photosynthesis to respiration.

Based on this research, we are performing a case study simulating COS at a well-observed temperate continental site (the WLEF tall tower in Wisconsin, US) using SiB3 to evaluate the simulated timing of spring (i.e., the seasonal change in the difference between the $[\text{COS}]$ in the free troposphere and the mixed layer) versus the observed, using flask data for 2000 - 2005. In this pilot study, we are simulating the primary sink of COS (i.e., plant uptake) in a location far removed from its primary source (i.e., oxidation of marine biomass) [Andreae and Crutzen, 1997].

Studies by Montzka and others indicate that the background concentration of COS in the atmosphere is fairly stable (circa 500 parts per trillion) and that it should be possible to integrate a model of the biogeochemical cycle of COS with that of CO_2 . By comparing the simulated difference between COS in the boundary layer and free troposphere to the difference in the observed $[\text{COS}]$ from flask data at Niwot Ridge (representing the free troposphere) and WLEF (representing the local biosphere), we may not only be able to quantify errors in our simulation of photosynthesis, but also, if our hypothesis is correct, provide a test case demonstrating that measurement and modeling of COS could provide a new window on the carbon cycle and thus on the influence of the terrestrial biosphere on the fate of fossil fuel-derived CO_2 .

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