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Assessing the seasonal cycle of simulated photosynthesis using carbonyl sulfide (COS) at a continental mixed forest site

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Simulated hourly global atmospheric CO2 for the years 2000, 2001 and 2003 exhibit a systematic error in the seasonal cycle of simulated Net Ecosystem Exchange (NEE) in the Northern Hemisphere mid-latitudes, characterized by early spring drawdown of CO2 relative to the observations. We have evaluated the simulation of carbonyl sulfide (COS) in SiB3, a land-surface model, at a continental mixed-forest site to separately assess seasonal variations in simulated photosynthesis and ecosystem respiration. Preliminary results of our simulation at the WLEF tall tower in Wisconsin, US show that the calculation of photosynthesis (rather than ecosystem respiration) is the primary cause of the systematic error in the simulated seasonal cycle of atmospheric CO2.

The seasonal cycle of NEE, as simulated by Colorado State University's Simple Biosphere Model v. 3.0 (SiB3) *[Sellers et al., 1996, Baker et al., 2003]*, 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, CO_2 and isotopes, is shifted by several weeks compared with the observed seasonal cycle at many Northern Hemisphere mid-latitude sites. Identifying the mechanisms causing this shift is difficult as sources of CO2 in the biosphere (autotrophic (plant) and heterotrophic (microbial) respiration) are convolved with sinks (photosynthesis) due to their similar dependencies on temperature and moisture.

COS is consumed in plant tissues by a reaction catalyzed by carbonic anhydrase, an

enzyme that catalyzes the decomposition of COS into CO2 and H2S in leaf mesophyll cells. Kesselmeier [*Sandoval-Soto et al.,* 2005] has shown that COS uptake by vegetation follows a pathway through the stomata of leaves similar to that of CO2 in photosynthesizing plants; however, there appears to be no corresponding source of COS in leaves. Thus, COS behaves as a tracer of stomatal conductance and gross photosynthesis over land surfaces. In addition, recent work by Montzka and Tans [2004] has shown that the amplitude of the seasonal cycles of COS and CO2 are strongly correlated in the Northern Hemisphere mid- and high-latitudes. Thus, the ratio of COS uptake to CO2 uptake should provide a sensitive indicator of the ratio of photosynthesis to respiration.

Also, 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 CO2.

Based on this research, we have performed 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 [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*].

Simulated surface exchanges of COS systematically led those derived from observations by several weeks in the spring, indicating that the simulated initiation of photosynthesis, rather than the timing of ecosystem respiration, is the primary cause of the systematic error in the simulated seasonal cycle of the flux of CO2. The results of this work indicate that measurement and modeling of COS could provide a new window on the carbon cycle by providing insight into the terrestrial biosphere sinks of CO2 and an additional constraint on the mechanisms that control these sinks.

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