

IMPACTS OF SOIL-SURFACE FLUXES AND NIGHT-TIME LEAF RESPIRATION ON THE GLOBAL COMPOSITION OF ^{18}O IN ATMOSPHERIC CO_2

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ABSTRACT

The oxygen isotopic composition of atmospheric CO_2 can help constrain local- to global-scale biophysical processes and partition measured net ecosystem CO_2 fluxes into gross fluxes. Although current models still lack key features controlling gross ecosystem CO^{18}O fluxes, considerable improvements have been achieved in the last four years. In this study we examine the influence on atmospheric CO^{18}O of 1) a delayed seasonal cycle in soil water isotopes (relative to rain water) and 2) a new one-way flux model of night-time leaf respiration [Cernusak *et al.*, 2004]. The latter covaries with enhanced night-time stomatal conductance, for which evidence arose recently [e.g. Snyder *et al.*, 2003].

RESEARCH OUTLINE

The Merged ECHAM BETHY model (MECBETH) is a global three-dimensional model of $\delta^{18}\text{O}$ in atmospheric CO_2 [Cuntz *et al.*, 2003a; 2003b]. It includes all processes described in the pioneering publications of Ciais *et al.* [1997a; 1997b] plus soil invasion [Tans, 1998], reduced carbonic anhydrase activity [Gillon and Yakir, 2001] and non-steady-state leaf water enrichment [Dongmann *et al.*, 1974]. It was recognised with MECBETH that mean soil water isotopic composition and rain water isotopic composition are not accurate predictors of the soil water isotopic composition impacting soil-surface CO^{18}O exchange. On the other hand, the importance of respiration relative to assimilation CO^{18}O fluxes is probably underestimated in MECBETH. Other factors such as stratospheric ^{18}O enrichment of CO_2 due to enriched stratospheric ozone are estimated to be of minor importance [Boering *et al.*, 2004; Cuntz, 2002].

Process descriptions have improved since the last update of MECBETH. For example, 1) Riley *et al.* [2002] treated in detail the isotopic composition of soil water and the soil-surface CO_2 flux, 2) Farquhar and Cernusak [2005] generalised the description of leaf water isotopic enrichment, and 3) Cernusak *et al.* [2004] reformulated night-time CO^{18}O exchange between plants and the atmosphere. All these improvements emphasise respiration CO^{18}O fluxes relative to assimilation CO^{18}O fluxes. As stated above, the importance of CO^{18}O respiration fluxes relative to CO^{18}O assimilation fluxes is probably underestimated in MECBETH so that the new descriptions potentially improve the model markedly.

However, the importance of the last two descriptions 2) and 3) depends greatly on the behaviour of stomatal conductance during evening and night. Historically stomata were assumed to be almost completely closed during the night but recent evidence suggests that they might be open at night with as much as 30% of maximum daytime stomatal conductance [Barbour *et al.*, 2004; Snyder *et al.*, 2003]. The covariance between the one-way flux model of night-time leaf respiration and enhanced stomatal conductance at night alters the implications of 2) and 3) and reduces their suggested great influence.

We therefore hypothesise that a more realistic soil water description could bring measured and modelled CO^{18}O into better agreement, whereas the suggested importance of night-time leaf exchange is partly offset by enhanced night-time stomatal conductance.

With these model improvements, interpretation of CO^{18}O measurements should contribute to several important issues in carbon cycle and global climate change research: for example 1) constraining ecosystem gross CO_2 exchange, 2) as a strong constraint on biogeochemical models of ecosystem exchanges, including land-surface schemes in global circulation models, and 3) helping to interpret the effectiveness of land management designed to sequester CO_2 .

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