A GLOBAL BIOPHYSICAL MODEL OF ^{18}O IN TERRESTRIAL WATER AND CO_2 FLUXES

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The abundance of ^{18}O in atmospheric CO_2 can potentially differentiate changes in atmospheric CO_2 associated with changes in the terrestrial biosphere from other direct influences such as those from burning fossil fuel, volcanic inputs and oceanic sources. The amount the ^{18}O in atmospheric CO_2 is largely determined by the effect of gross photosynthetic and soil respiratory fluxes. These fluxes are strongly influenced by the isotopic state of the water. As such, the isotopic state of all water pools in the biosphere must be understood, and quantified, to begin to interpret the terrestrial $CO^{18}O$ signal.

The isotopic concentration of precipitation, the input to the terrestrial hydrology, is governed by climatological influences during evaporation, transport, and condensation in association with moist processes in the atmosphere. Net photosynthetic discrimination against $CO^{18}O$ is due to the differential flux of $CO^{18}O$ molecules across leaf stomata. The differentiation arises because the flux into leaves has the atmospheric signature whereas the flux diffusing back out of leaves is equilibrated with the water of the leaf. A similar exchange occurs in soils where respired CO_2 equilibrates with the soil water strata as it diffuses to the surface. Although the isotopic equilibration associated with these processes does not itself change the isotopic state of the water reservoirs, biospheric processes do modify the water isotopes through, for instance, enrichment during soil evaporation and transpiration. Additional terms in the global $CO^{18}O$ budget come from exchange with the stratosphere, biomass burning, and fossil fuel sources.

The NCAR Land Surface Model (Bonin, 1996) has been adapted to simulate globally the isotopic state of all water pools and CO_2 fluxes as an extension of the site level model described by Riley et al. (2002). Prognostic variables include vertically resolved soil water, leaf water and vapor in the canopy. The adaptation for global simulations lead to the inclusion of additional isotopic reservoirs for snow, water intercepted by the canopy and runoff. With these quantities, and knowledge of the CO_2 exchanges, the ecosystem flux of $CO^{18}O$ can be calculated. Detailed analysis shows this formulation is capable of accurately capturing diurnal variations at the canopy level and responds well to recharge by infrequent precipitation events. Here, the model is forced with daily mean data from the isotopic version of the Melbourne University GCM (Noone and Simmonds, 2002). This GCM is capable of providing the ^{18}O concentration of precipitation and atmospheric water vapor required to drive the isotopic biosphere model. Results shown in Figure 1 are the mean annual cycle from a 10-year simulation, at a spatial resolution of 5.6×5.6 degrees, over four geographic regions (North America, Siberia, Equatorial Amazonia and Australia). The results show the simulated canopy vapor is depleted with respect to the precipitation, and reflects the prescribed atmospheric vapor. At high latitudes the annual cycle in precipitation shows more depletion in the cold winter while the tropics have greater depletion in the wet season. In the Amazon the precipitation signal is reflected in all reservoirs. On the other hand, high latitude regions show that leaf water pools are active only once the growing season has commenced. The leaf water represents a balance between replenishment from the soil reservoir and enrichment during transpiration. In Australia, for instance, semi-aridity leads to little replenishment from the roots and very enriched leaf water results due to evapotraspiration of the lighter isotopes in the summer. Similarly, water on the canopy becomes enriched when the humidity

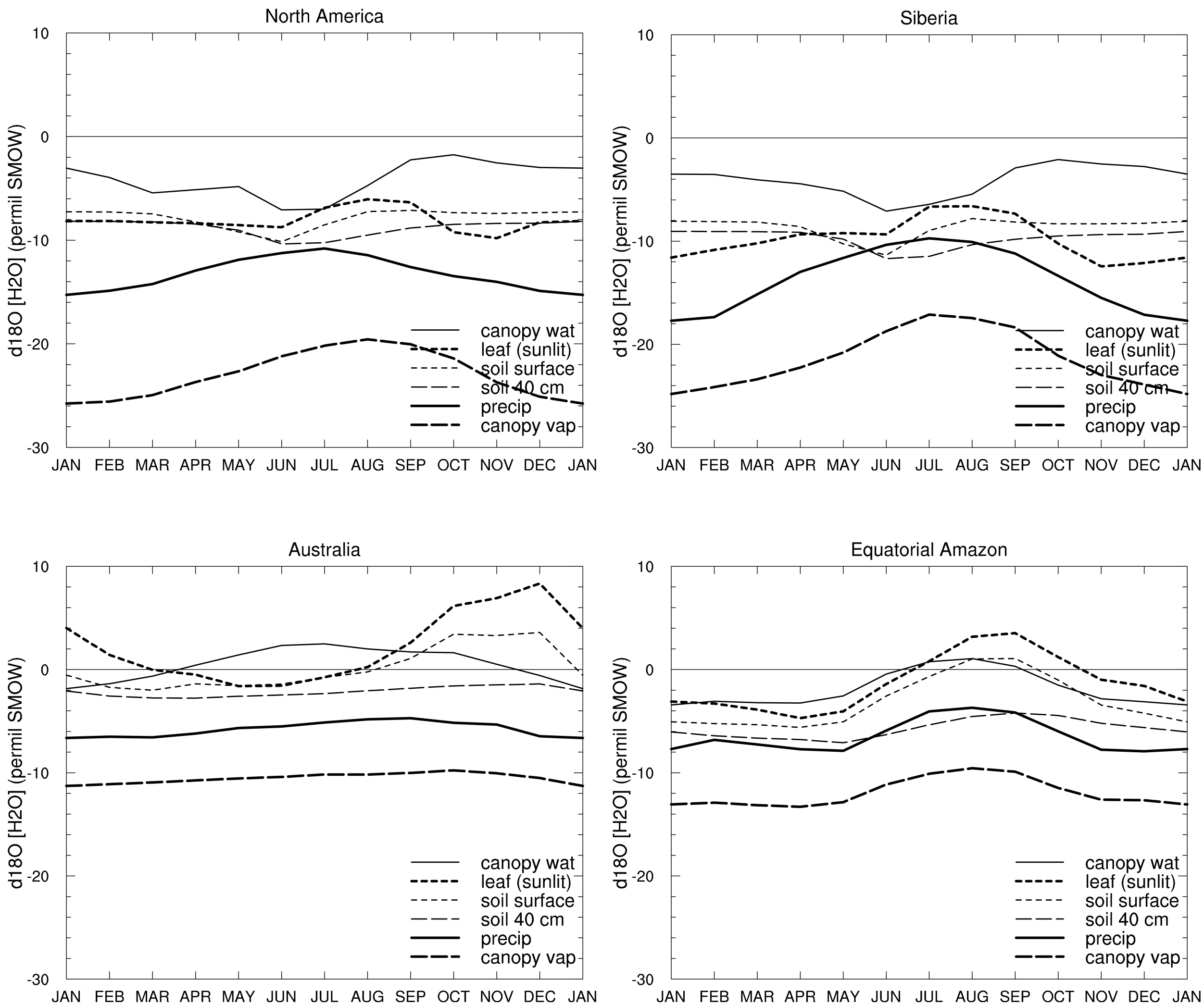

Figure 1: Isotopic concentration of simulated water pools. Data are spatial averages over North America (45-80N), Siberia (45-170E, 45-80N), Equatorial Amazon (30S-10N) and Australia. Isotopic concentrations are shown as "delta" values where $\delta^{18}O=(R/R_{standard})-1$.

is low. Otherwise, it reflects equilibrium with the canopy vapor. The amplitude of the seasonal cycle reduces with depth in the soil water, with deeper layers lagging due to the gravitational drainage.

These initial tests, and detailed tests at individual sites, demonstrate the ability of the model to simulate the main physiological response of the biosphere. Coupling this scheme to an atmospheric GCM is underway to enable direct comparison with the global monitoring networks.

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