THE EXPRESSION OF BIOSPHERE RESPONSE TO LIGHT LEVEL CHANGES ON δ^{18}O OF ATMOSPHERIC CO_2

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ABSTRACT
Observations suggest the global reflectivity of Earth changed during recent decades. Although there is some ambiguity surrounding these findings, it is clear that, should there be changes in clouds or scattering aerosols, a change in the total solar radiation received at the surface and the fraction of diffuse light could result. Intriguingly, the δ^{18}O of CO_2 time series measured at Mauna Loa shows variability during the 1990s that does not match secular trends in CO_2 concentration or δ^{13}C. While a decrease in total solar radiation alone would reduce biospheric productivity, an increase in diffuse light can increase productivity, as has been argued for the period following the eruption of Pinatubo. Moreover, since the changes in radiation affect the surface latent energy exchange, the isotopic composition of terrestrial water with which CO_2 interacts (specifically leaf and soil water) will be modified and can thus drive a change in isotopic fluxes.

RESULTS
Three experiments with the isotopic version of the NCAR Land Surface Model have been constructed to see how changes in radiation affect these fluxes. The first experiment repartitions 7.5% of the direct radiation to diffuse (a 15% total change). The second reduces the global downwelling solar radiation by 4%, and the third experiment incorporates both of these changes. The model is forced with meteorological data from the NCEP reanalysis. In the first experiment (where the amount of diffuse light is increased) the global average evaporation from the soil decreases slightly (less than 1%), while the canopy evaporation increases by 1.3%. For the other two experiments, soil water evaporation decreases by about 4%, and canopy evaporation decreases by 3%. Furthermore, the repartitioning to diffuse radiation tends to increase global mean photosynthesis by 3% and transpiration by 2.3%. However, the decrease in downwelling solar radiation decreases photosynthesis by 2% and transpiration by 3%. Figure 1 shows how the forcing changes the zonal mean isoflux from soil and leaves. With less direct radiation, reduction in evaporation tends to reduce the isotopic enrichment in soil water, and consequently soil respiration $C^{18}OO$ flux. Similarly, with more diffuse radiation, the increased transpiration tends to increase the enriching effects of leaf-atmosphere exchange on δ^{18}O of atmospheric CO_2. Both of these responses support the suggestion that the observed variability in δ^{18}O of CO_2 is related to light level changes. These changes are greatest during the growing season in each hemisphere. These positive differences suggest the atmospheric δ^{18}O would become more enriched. Clearly, the response to increased diffuse radiation compensates for the decrease in solar radiation. Our results show that a 1% decrease in solar radiation would require a 1% partitioning to diffuse radiation for the global mean leaf isoflux to be unchanged, and a 4.5% repartitioning would be required for the soil isoflux, indicating that soil water does not directly respond to changes in diffuse radiation. Figure 1g and 1h show that isoflux responses to both solar and diffuse radiation changes are not the simple sum of the individual impacts. Specifically, the leaf isoflux has an almost linear response (i.e., 3.7% - 2.1% = 1.6%), while the soil isoflux does not (0.8% - 0.9% = -0.1%), underlining the need to understand the more subtle controls on

soil water $\delta^{18}O$ values when interpreting the CO_2 isoflux response. In the context of the Mauna Loa record which shows a gradual decrease in $\delta^{18}O$ from 1991 to about 1996, our results suggest that during this period isotopic changes are consistent with the effects of the reduced solar downwelling outweighing the effects of increased diffuse radiation. After this period $\delta^{18}O$ values begin to increase, consistent with an increase in either the diffuse radiation fraction or in direct beam solar radiation.

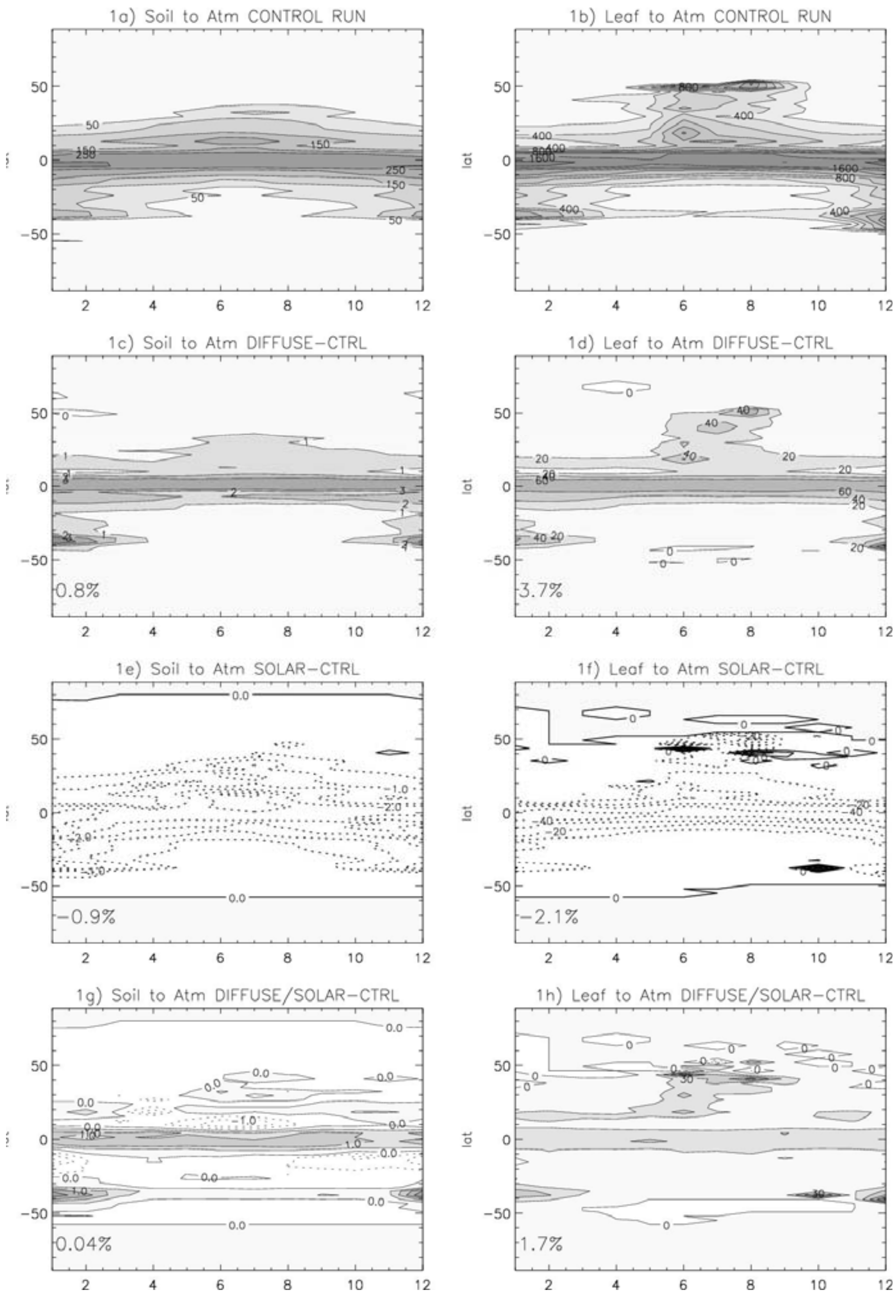

Fig.1: Zonal mean isofluxes (kg m^{-2} s^{-1} ‰) as a function of month from (a) soil and (b) leaves for the control run. Experiment response to (c and d) repartitioning 7.5% of total radiation to diffuse, (e and f) reducing solar radiation by 4% and (f and g) changes to both diffuse and solar radiation. Solid and shaded contours show positive values and dashed unfilled contours indicate negative values. Global mean annual change is given in the lower left of each panel.