Impacts of Drought Stress on $C^{18}OO$ Ecosystem Fluxes in an Agricultural Field: Measurements and Modeling

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Drought stress affects plant photosynthesis and transpiration, as well as soil respiration and evaporation. In a coupled plant and soil system, drought can strongly impact the exchange of ^{18}O in CO_2 between the ecosystem and atmosphere. In this study we present diurnally resolved measurements of $\delta^{18}O$ values in ecosystem water pools in a sorghum field in the ARMCART SGP region (Oklahoma, USA). Over a 4-day period we measured continuous ecosystem CO_2 and H_2O fluxes using eddy correlation; soil moisture and temperature; $\delta^{18}O$ of soil water in 4 soil layers, leaves, and stems 4 times per day; and ^{18}O in H_2O at 2 heights above the plant canopy. Ecosystem CO_2 fluxes reflect the impact of midday water stress. Measured soil water $\delta^{18}O$ values showed strong diurnal patterns reflecting soil-surface evaporation during the day and recharge from deeper soil layers at night. Diurnal soil water $\delta^{18}O$ values in the top soil layers varied by up to 6‰. The $\delta^{18}O$ values of stemwater also varied over the course of the day, but to a smaller extent. Leaf water $\delta^{18}O$ values increased by up to 10‰ over the day. To interpret these data and to estimate $C^{18}OO$ ecosystem fluxes we applied a mechanistic model, called ISOLSM, which simulates $H_2{}^{18}O$ and $C^{18}OO$ ecosystem stocks and fluxes between ecosystems and the atmosphere. ISOLSM includes modules to compute canopy vapor, leaf water, and vertically resolved soil water $H_2{}^{18}O$ content; leaf photosynthetic and retro-diffusive fluxes of $C^{18}OO$; root and microbial production of CO_2; soil diffusive fluxes of CO_2 and $C^{18}OO$ and equilibration of CO_2 with ^{18}O in soil water; and abiotic soil exchanges of $C^{18}OO$. The model has been tested in a C_4 dominated tallgrass prairie site close to the field studied here. Drought stress strongly affected the variability of the ^{18}O content of near-surface soil water. The low soil moisture levels impacted the soil-surface $C^{18}OO$ fluxes via interactions with the soil-gas diffusion coefficient, microbial and root CO_2 production, and the heavy near-surface soil water. Drought stress also impacted stomatal conductance, which in turn affected transpiration, the canopy air space vapor and vapor ^{18}O content, and leaf $C^{18}OO$ exchange. Finally, we present a sensitivity analysis of the ecosystem $C^{18}OO$ exchange to the method used to quantify the impacts of plant water stress.