Can we use $\delta^{13}C$ of CO_2 to understand the links between the water and carbon cycles and climate?

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The fate of the earth's climate is intricately linked to that of the global carbon cycle. Much uncertainty remains about those links and the potential responses of both systems to recent and ongoing human perturbations. Different attributes of atmospheric CO_2 (e.g. spatial gradients and relative abundances of its isotopologues) provide evidence of the mechanisms that link climate and the carbon cycle. The stable carbon isotope, ^{13}C, is a useful tracer for understanding terrestrial biosphere to atmosphere CO_2 exchange (as well as for partitioning land and ocean CO_2 fluxes) because photosynthesis discriminates strongly against heavy CO_2 (and ocean exchange does not). The degree to which photosynthesis fractionates against ^{13}C depends upon 1) plant functional type distributions, because C_3 and C_4 plants have very different discrimination, and 2) weather and climate conditions, because stomatal conductance is closely related to C_3 plant isotopic discrimination. Ascertaining patterns of C_3 and C_4 plant response to temperature and precipitation extremes will be key to anticipating which land use policies will best help us adapt our managed lands to accommodate a changing climate. C_3 plant stomatal conductance varies in concert with water availability, so that atmospheric $\delta^{13}C$ carries information not only about local and upwind drought conditions, but also about the likelihood of ground-to-atmosphere water transfer via transpiration, and the balance of latent and sensible heat fluxes. In the absence of high density or high frequency measurements of transpiration and sensible and latent fluxes, $\delta^{13}C$ offers a chance to identify key thresholds and relationships between climate anomalies/change and the modulating climate impacts of plant biosphere response. By unraveling this relationship at local to continental scales, we stand to gain crucial knowledge of how to predict future climate impacts on the carbon cycle and vice versa.

We use a two-step Bayesian inversion model to optimize 1x1 degree and 3-hourly (interpreted at the monthly scale) fields of $\delta^{13}C$ of the biosphere over North America for the year 2010. We parse the signal into the effects of C_3 stomatal conductance and the relative strength of C_3/C_4 plant exchange. We further seek to identify correlations between departures of these patterns from the best estimates of late 1980s $\delta^{13}C$ of the biosphere (from SiB2) and observed temperature and precipitation anomalies. Influence functions (footprints) are generated with FLEXPART, driven by National Centers for Environmental Prediction Global Forecast System meteorology. Prior information is from CarbonTracker 2011, and background CO_2 and $\delta^{13}C$ values are from NOAA/ESRL marine boundary layer and aircraft data. Quasi-daily atmospheric observations are from NOAA/ESRL Global Monitoring Division tall towers.

We also examine correlations between atmosphere $\delta^{18}O$ of CO_2 and climate records. This tracer offers complementary insights into biosphere atmosphere CO_2 exchange because of the close relationships between $\delta^{18}O$ and relative humidity and precipitation.