Constraining Biospheric Exchange Processes over North America by Joint Assimilation of Atmospheric CO_2 and $\delta^{13}C$

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Droughts can cause widespread decline of carbon uptake by plants, which respond to droughts by reducing their stomatal aperture to limit water loss. Given the complex feedbacks that exist between the terrestrial biosphere and climate, the future of the land carbon sink remains uncertain in a world where droughts may be more extreme and frequent. However, the ratio of $^{13}C/^{12}C$ in atmospheric carbon dioxide (CO_2) (reported as $\delta^{13}C$ in ‰), which we measure, provides insight into climate-carbon coupling. This is because photosynthesis imposes distinctive isotopic fractionation patterns upon atmospheric $\delta^{13}C$. Variations of $\delta^{13}C$ in the atmosphere reflect spatially coherent changes in stomatal conductance and/or in the relative contributions from C3 (e.g. forests) and C4 (e.g. maize) plant growth, but as shown in Fig. 1, we cannot simulate $\delta^{13}C$ accurately with our biosphere model. In an effort to improve biosphere models, we have developed an inverse model capable of assimilating $\delta^{13}C$ and CO_2 data. In this system we estimate the magnitude of isotopic fractionation during photosynthesis. This could help us better understand the biogeochemical interactions between the atmosphere and vegetation, and help us to improve parameterization of the main controls of carbon exchange in biosphere models.

We focus on CO_2 and $^{13}CO_2$ flux estimation over North America using a dense synthetic data set for both tracers and a Lagrangian particle dispersion model WRF-STILT. By comparing modeled with pseudo 'observed' CO_2 and $\delta^{13}C$ data at surface sites we can optimize our prior flux estimates derived from a biosphere model. We will present comparisons between our optimized values and those observed, and discuss the current strengths and shortcomings of our framework. We find that our system can retrieve meaningful signals in isotopic fractionation when the total CO_2 budget is fairly well determined in a first step. In addition, we mainly get information on isotopic fractionation upwind of sites, which tends to represent a large fraction of the productivity of the continent. Unlike for CO_2, these regional fractionation estimates would be adequate, because we are most interested in the relationship between isotopic fractionation and stomatal response in plants during droughts.

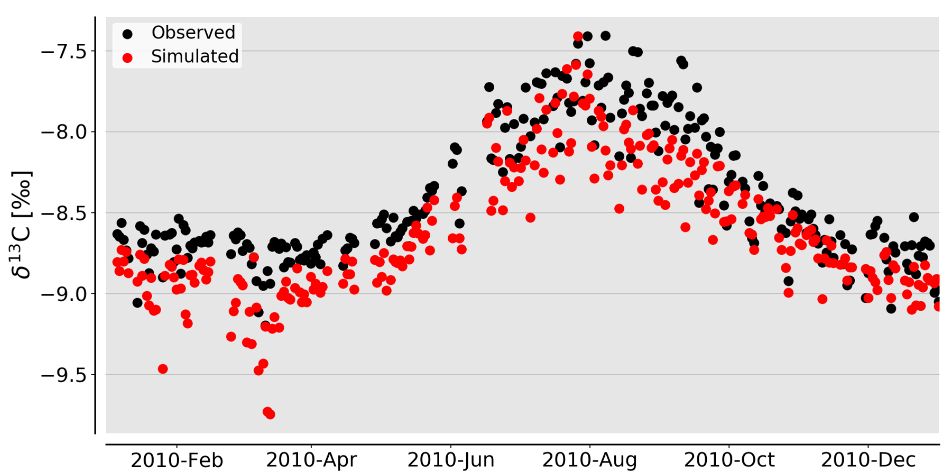

Figure 1. Observed $\delta^{13}C$ (black) together with simulated $\delta^{13}C$ driven by SiBCASA fluxes (red) for Park Falls Wisconsin. The seasonal cycle of $\delta^{13}C$ is anti correlated with CO_2. Less negative values indicate the atmosphere is more enriched with $^{13}CO_2$ relative to $^{12}CO_2$ during the growing season due to photosynthetic fractionation [data provided by INSTAAR].