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Using ^{15}N natural abundance and tracer studies to constrain simulated nitrogen dynamics in forest ecosystems under changing atmospheric CO_2 concentrations

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Increasing CO_2 concentrations and future climate change will affect the ability of ecosystems to sequester carbon due to increasing nutrient limitation, in particular nitrogen (N), which is the key limiting nutrient in many terrestrial ecosystems. However, the N deficit is difficult, if not impossible, to quantify simply from the ecosystem monitoring data. One of the most common tools used is the N stable isotope composition, either at natural abundance, where the isotopic fractionation of different processes can indicate N limitation, or as added tracer in manipulative experiments to trace the fate of N in the ecosystem. Despite the wealth of data, terrestrial biosphere models do not often include the capacity to include ^{15}N in their predictions, making it difficult to use the available information.

We have developed a new terrestrial biosphere model QUINCY (QUantifying Interactions between terrestrial Nutrient CYcles and the climate system) which includes fully coupled carbon, nutrient and water cycles, as well as an improved representation of plant and soil physiological processes. Most importantly, we include a ^{15}N tracer to all soil and vegetation pools that allows us to evaluate our model against observations directly. Here, we present the first results from a land surface model which includes explicit isotope tracers.

First, we explore the trends in foliar ^{15}N during the last century at over 400 forest sites worldwide. The observed trends of foliar ^{15}N show a decline during the last decades implying increasing N deficiency in the ecosystems but attributing the driver of these changes is not straightforward simply from observations. Our model is able to replicate the observed trend and we show that it is caused by the CO_2 fertilisation effect, rather than changes in climate and N deposition.

Next, we test the model at two manipulative experimental sites, the Free-Air Carbon dioxide Enrichment (FACE) experiment at Oak Ridge National Laboratory (ORNL), where measurements of natural abundance ^{15}N allow an in-depth exploration of N limitation under elevated CO_2, and the ^{15}N enrichment experiment at Cornell, where the ^{15}N tracer allows us to explore fate of added N in soil and vegetation pools.

These three case studies showcase the utility of a terrestrial biosphere model with integrated isotope tracers to not only predict the observed state of the ecosystem but also explore the fundamental drivers and internal ecosystem processes.