Isotopic Partitioning of CO₂ fluxes revises understanding of mechanisms of forest carbon sequestration

Scott Saleska (saleska@email.arizona.edu) - University of Arizona (PI), Adrien Finzi, Boston University; Paul Moorcroft, Harvard University; Eric Davidson, Woods Hole Research Center; Rick Wehr, University of Arizona; William Munger, Harvard University (Co-PIs).

Ecosystem models differ widely in their predictions of how forest carbon dynamics will interact with a changing climate, and that interaction is a large source of uncertainty in predictions of future climate. We are investigating the mechanisms controlling carbon allocation and sequestration at the Harvard Forest by integrating stable carbon isotope analyses with a suite of approaches including eddy covariance, soil chambers, plot trenching, and minirhizotrons. The data are being integrated in - and used to refine - the Ecosystem Demography 2 (ED2) model. Here we present some of this year's key results; other presentations at this meeting focus on the root measurements (Abramoff et al.) and the trenching experiment (Savage et al.).

Using eddy covariance measurements of the forest-atmosphere exchange of 12CO₂ and 13CO₂, we partitioned the net ecosystem-atmosphere CO₂ exchange (NEE) into photosynthesis and respiration on an hourly timescale - a longstanding goal in carbon cycle science. This partitioning revises our picture of the seasonal pattern of canopy photosynthesis at Harvard Forest, which increased through the summer and early fall despite concurrent declines in light, stomatal conductance, and leaf internal CO₂ concentration. In other words, canopy photosynthetic efficiency increased through the summer, counter to expectation from standard NEE partitioning approaches.

The isotopic partitioning also showed that ecosystem respiration declined with soil water content, a finding qualitatively corroborated by our chamber and fine root respiration measurements. More surprisingly, moisture was more limiting during the day than at night, perhaps due to local drawdown of soil water around the roots of transpiring trees. Due to these moisture effects, standard NEE partitioning models considerably overestimated ecosystem respiration and photosynthesis in hot and dry conditions.

The 10-day mean isotopic disequilibrium (i.e. the composition of photosynthates minus that of ecosystem respiration) was found to be fairly stable at +1 ‰ through the growing season. Thus seasonal variation is not a viable explanation for the longstanding sign discrepancy between models and observational studies. Additionally, the seasonal decline in isotopic discrimination at our site agrees with previous continental-scale observations, suggesting that Harvard Forest isotopic patterns might be representative of North American ecosystems more broadly.

We are assimilating these measurements into an isotopic version of ED2 to explore the implications of ecosystem carbon allocation mechanisms for carbon sequestration and feedbacks to climate.