Partitioning Autotrophic and Heterotrophic Respiration at Howland Forest

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Motivation

Terrestrial ecosystem respiration is the combined flux of CO_2 to the atmosphere from above- and below-ground, plant (autotrophic) and microbial (heterotrophic) sources. Flux measurements alone (e.g., from eddy covariance towers or soil chambers) cannot distinguish the contributions from these sources. The development of improved process-based models that can predict how plants and microbes respond to changing environmental conditions requires data from field experiments and observations to distinguish among these respiration sources.

Methods

We partitioned the soil CO_2 flux into autotrophic and heterotrophic components with two different approaches:

1) A classic root trenching experiment
2) An isotopic mass balance approach, using the radiocarbon (^{14}C) bomb spike

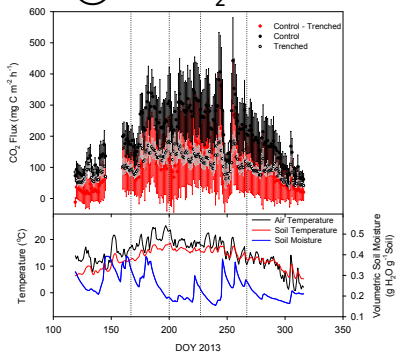
Both methods operationally define autotrophic respiration as all respiration derived from root metabolism, root symbionts, and microbes decomposing fresh root exudates, typically called rhizosphere respiration. The soil CO_2 flux was measured every 30 minutes with automated chambers. The ^{14}C was sampled 4 times during the growing season of 2013. Root trenching was done in September 2012, photos below. Results from these approaches are compared, and will be used in a model-data fusion context to better constrain the partitioning of respiration in an ecosystem model.

Site

The Howland Forest is located in central Maine, USA about 60 km north of Bangor. It is an AmeriFlux site, where eddy covariance measurements of surface-atmosphere exchanges of C, water and energy have been made for 18 years. MAT is 5.4 °C. MAP is 1050 mm, spread evenly throughout the year. The vegetation is dominated by red spruce (*Picea rubens* Sarg.) and eastern hemlock (*Tsuga canadensis* (L.) Carr.). The soils are glacial tills, acid in reaction, with low fertility and high organic composition.

Results

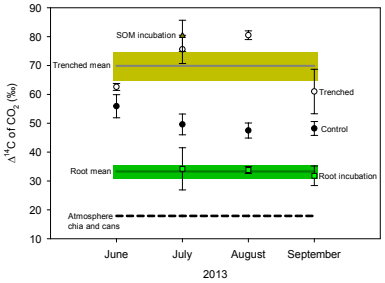
① Soil CO_2 Fluxes



Mean daily soil CO_2 flux for control chambers (total flux), trenched chambers (heterotrophic respiration), and control-trenched chambers (autotrophic respiration; top panel). Air temperature, soil temperature at 10 cm, and soil moisture at 20 cm (bottom panel). Dotted vertical lines represent the days where ^{14}C was sampled.

- When summed over the course of the growing season, the trenched chamber flux (heterotrophic respiration) accounts for 53 ± 2% of the (total) control chamber flux.
- Trenched and control-trenched chamber fluxes are similar in magnitude and have comparable seasonal patterns.
- Maximum values for all chambers are reached in July and August when soil temperatures are greatest.

② ^{14}C of Respiration

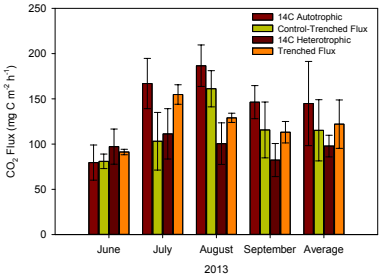


The $\Delta^{14}C$ of root incubations (autotrophic end member, less bomb ^{14}C, younger C) and SOM incubations or trenched chamber respiration (heterotrophic end members, more bomb ^{14}C, older C) are significantly different. The $\Delta^{14}C$ of control chamber respiration falls between these two end members. Together, this information allows for a ^{14}C mass balance approach to be applied to partition the soil CO_2 flux:

$$\Delta^{14}C_{SR} = F_A \Delta^{14}C_A + F_H \Delta^{14}C_H$$

- $\Delta^{14}C_{SR}$ is the signature of the soil CO_2 flux measured in the control chambers.
- $\Delta^{14}C_A$ is the signature of root respiration from root incubations and $\Delta^{14}C_H$ is the signature of SOM decomposition from soil incubations and/or trenched chamber respiration.
- F_A is the fraction of respiration from autotrophic sources and F_H is the fraction of respiration from heterotrophic sources.

③ Partitioning



A comparison of the soil CO_2 flux from autotrophic and heterotrophic sources as calculated from the two partitioning methods on the days in which ^{14}C was sampled.

- The methods generally agree, with the exception of July, in which the ^{14}C method attributes the majority of the flux to autotrophic sources, where as the trenching method attributes most of the flux to heterotrophic sources.
- This discrepancy may be due to the fact that the autotrophic component of the ^{14}C method includes both rhizosphere respiration as well as rapidly cycling (<1 year old) SOM decomposition. Trenching may have artifacts from enhanced decomposition of dead roots, as well.
- Over the 4 different ^{14}C sampling periods, the heterotrophic component ranges from 35-55% and the autotrophic component ranges 45-65% of the total flux.

Next Step - Modeling

We will assess the value of the soil CO_2 flux partitioning information for constraining a simple ecosystem model using a model-data fusion approach. We will address the following questions:

1. Does including measured autotrophic and heterotrophic respiration partitioning estimates as constraints reduce uncertainties in model based estimates of NPP in 2013?
2. How does adding measured autotrophic and heterotrophic respiration partitioning estimates as constraints influence model uncertainties for simulating C stocks and fluxes in the future?

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