THE AGE OF CARBON RESPIRED FROM TERRESTRIAL ECOSYSTEMS

S.E. Trumbore[1], E.A Schuur[2], E. A. Davidson[3], PB Camargo[4], and J.T. Randerson[1]

[1] *Department of Earth System Science, University of California, Irvine, CA 92697-3100*
[2] *Department of Botany, University of Florida, Gainseville, FL*
[3] *The Woods Hole Research Center, Woods Hole, MA 02543*
[4] *Lab. de Ecologia Isotópica, CENA/USP, Piracicaba, Sao Paulo, 13416-000 Brazil*

ABSTRACT

Carbon enters ecosystems through a single process, photosynthesis, and nearly all is returned to the atmosphere through respiration, some 50-80% of which occurs below-ground. Soil (belowground) respiration integrates CO_2 derived from C that has resided in the ecosystem for periods of differing duration, ranging from relatively recent photosynthetic products that fuel root metabolism, to CO_2 derived from decomposition of plant and soil organic matter that may be decades to centuries old. A comparison of the radiocarbon content of CO_2 respired by roots, microbes, and soils with the record of radiocarbon in atmospheric CO_2 allows direct estimation of the mean age of C being respired [*Trumbore* 2000; *Wang et al.* 2000, *Cisneros Dozal et al*. 2005; *Borken et al.* 2005].

This talk will summarize data on radiocarbon signatures of soil organic matter and microbially respired CO_2 from a number of tropical, temperate and boreal ecosystems we have studied over the past several years and what each tells us about the factors controlling the response time of C in soils on different timescales. The radiocarbon content of bulk organic matter is not in itself a good predictor for the age of heterotrophically respired CO_2 but rather reflects the fact that large amounts of organic matter may be stored in forms that contribute little as microbial substrates to soil respiration. Important factors for overall soil C stocks on timescales longer than decades include the kinds of minerals and mineral coatings present. In contrast, CO_2 respired by microbes in incubations of surface litter and uppermost mineral soils integrate over the age and decomposition rate of the material being decomposed (roots, leaves, shoots, and recycled, more stable OM pools).

Vegetation and climate are the major controls of heterotrophic respiration rates, though parent material may have indirect effects [*Torn et al*. 2005]. Decomposition rates, which are independently measurable as mass loss over time in freshly applied substrates, generally decrease from tropical to boreal regions. However, the overall time lag estimated from the ^{14}C signature of heterotrophically respired CO_2 is similar for temperate and tropical forests, because of differences in the mean age of leaf litter in deciduous versus evergreen forest. In tropical forests, leaves can reside on trees for 2-3 years but they mostly decompose within the first year after abscission. In temperate forests, the lifetime of leaves is shorter, but so is the rate of decomposition. Poorly drained boreal forests have slow decomposition rates that litter often accumulates over time [*Trumbore and Harden*, 1997]; radiocarbon signatures can reflect contributions from C older than 1963 in mature forest soils.

Two important questions regarding the potential responses of the 'slow' (decadally to centennially cycling) C pools in SOM to global environmental chang: (1) is the climate sensitivity of the 'slow' pools less than those that contribute the majority of soil respiration? And (2) to what degree do 'slow' pools contribute to soil respiration and can we detect a change in that contribution in manipulation experiments? Part of the answer depends on how the 'slow' pool is defined. As defined by turnover time (decadal to centennial turnover, 'slow' pools can represent relatively undecomposed fresh organic material in boreal forest floor, older components of living root networks, or organic coatings on macroaggregates in tropical soils. When we manipulate moisture or temperature conditions, we see no apparent shift in the ^{14}C of respired CO_2, indicating that the use of all substrates is amplified.

The ^{14}C signature of C respired from soils in all ecosystems except those dominated by annual plants is higher than fresh photosynthetic products – hence terrestrial ecosystems represent a global source of ^{14}C to the atmosphere that partially offsets declines in ^{14}C caused by ocean uptake and dilution by fossil fuel CO_2. The 'iso-disequilibrium' the degree to which a difference in the isotopic signature exists between C entering and leaving the land biosphere and oceans, is an important factor limiting the use of ^{13}C as a tracer. Radiocarbon can provide a means to predict the ^{13}C isodisequilibrium.

REFERENCES

Borken W, K Savage, EA Davidson and SE Trumbore (2005), Effects of experimental drought on soil respiration and radiocarbon efflux from a temperate forest soil, *Global Change Biology*, in press.

Cisneros Dozal LM, SE Trumbore and PJ Hanson (2005), Partitioning sources of soil-respired CO_2 and their seasonal variation using a unique radiocarbon tracer, *Global Change Biology*, in press.

Torn MS, PM Vitousek and SE Trumbore (2005), The influence of nutrient availability on soil organic matter turnover estimated by incubations and radiocarbon modeling, *Ecosystems*, in press.

Trumbore SE (2000), Constraints on below-ground carbon cycling from radiocarbon: the age of soil organic matter and respired CO_2, *Ecological Applications, 10*:399-411.

Wang Y, R Amundson and XF Niu (2000), Seasonal and altitudinal variation in decomposition of soil organic matter inferred from radiocarbon measurements of soil CO_2 flux, *Global Biogeochemical Cycles, 14*: 199-211.