How old is the carbon that forests respire? Seasonal patterns in soil and ecosystem $^{14}CO_2$ from a hardwood forest in Northern Wisconsin.

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Introduction

Radiocarbon (^{14}C) is often substantially more abundant in soil CO_2 than in the atmosphere or plant respiration, making it a potential tracer for detecting soil contributions to whole forest respiration.

We conducted a coupled soil-atmosphere study of $^{14}CO_2$ dynamics at a deciduous forest in Northern Wisconsin, to assess whether soil emissions can be detected in atmospheric $^{14}CO_2$ abundance.

Questions:

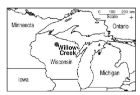
1) How does soil-respired ^{14}C-CO_2 vary seasonally at Willow Creek Ameriflux site? With environmental drivers?

2) Can signals from soil respiration be detected in canopy $^{14}CO_2$ using mixing equations?

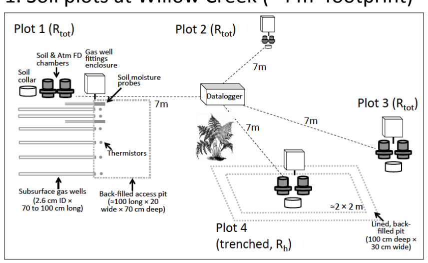
3) How do whole-forest emissions impact $^{14}CO_2$ far above the canopy, at a nearby tall tower? (LEF, Park Falls, WI)

Approach

We monitored CO_2 fluxes and $^{14}CO_2$ abundance in 2011 & 2012, at three nested spatial scales.



1. Soil plots at Willow Creek (~4 m² footprint)

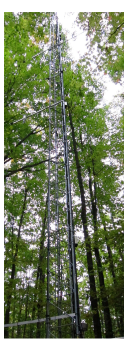


Four plot array, including one trenched (no live roots)

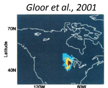
Subsurface CO_2/$^{14}CO_2$, Temp, Moisture

Surface fluxes (hourly)

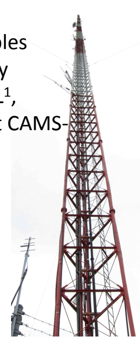
2. Willow Creek Eddy Covariance Tower (30 m agl, 1 to 10 km² footprint)



3. LEF, Park Falls (450 m agl) $^{14}CO_2$ samples collected by NOAA-ESRL[1], analyzed at CAMS-LLNL

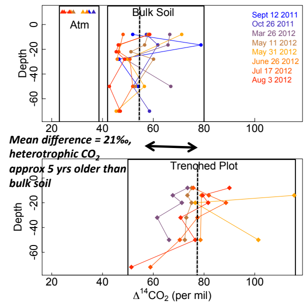


10^6 km² footprint

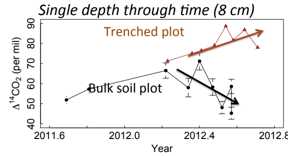


Soil $^{14}CO_2$ Dynamics

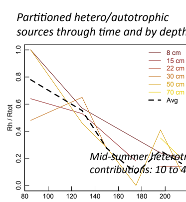
1. ***In situ* $^{14}CO_2$ in bulk soils was intermediate between the atmosphere and a trenched (heterotrophic) soil plot,** reflecting contemporary C respired by roots.



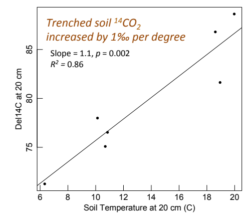
2. **$^{14}CO_2$ dynamics through 2012 growing season seemed driven primarily by relative levels of root activity.**



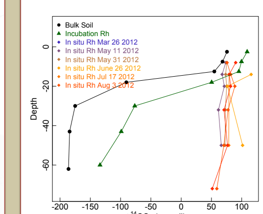
Bulk soil: Increasing root contributions through summer decreases $^{14}CO_2$



Trenched plot: $^{14}CO_2$ increases with temperature

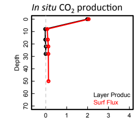


3. ***In situ* CO_2 was enriched in $^{14}CO_2$ compared to lab incubations, because of high relative respiration rates in shallow subsurface where substrates are enriched ^{14}C.**

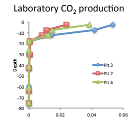


Even in the trenched plot without roots, *in situ* $^{14}CO_2$ was contemporary throughout profile, and much higher than $^{14}CO_2$ produced by soils incubated in lab.

Both *in situ* and lab incubation estimates of CO_2 production indicated activity was concentrated near-surface.



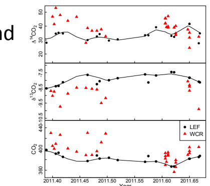
Example production profile in trenched plot, Aug 2012



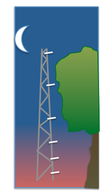
Respiration rates from soil incubations (duration 2 to 125 days)

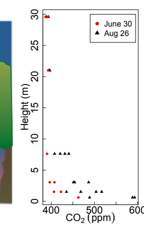
Can we detect soil CO_2 in whole-forest emissions?

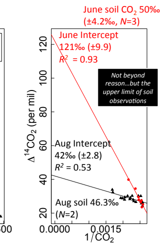
Compared to background atmosphere (LEF), WCR CO_2 is enriched in ^{14}C, consistent with soil emissions



Two nocturnal canopy profiles in 2012 produced Keeling intercepts similar to soil $^{14}CO_2$

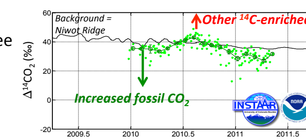




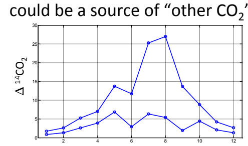


Can we detect soil CO_2 in regional emissions?

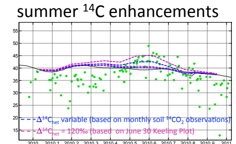
Many tall towers have shown lower $^{14}CO_2$ than free troposphere due to fossil fuel emissions, but LEF has ^{14}C enrichment during summer.



1-D boundary layer budget analysis suggested heterotrophic soil flux could be a source of "other CO_2"



Heterotrophic soil ^{14}C flux was sufficient to partially explain summer ^{14}C enhancements



Conclusions and Future Directions

1. Soil $^{14}CO_2$ was produced mainly from shallow substrates enriched in ^{14}C, and showed seasonal variation primarily related to root activity.
2. ^{14}C enrichment above the forest canopy indicated soil contributions, but estimates of ^{14}C in canopy-level emissions were variable.
3. Summer ^{14}C enrichment at LEF may be partially related to elevated soil activity during summer.
4. Ongoing soil analysis includes modeling to assess the expected sensitivity of soil $^{14}CO_2$ to changes in SOM turnover.
5. Ongoing atmospheric work includes footprint analysis to constrain potential sources of CO2 at LEF.