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Terrestrial Ecosystem Science 2017 ECRP Annual Report: Tropical Forest Response to a Drier Future: Turnover Times of Soil Organic Matter, Roots, Respired CO2, and CH4 Across Moisture Gradients in Time and Space

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TROPICAL FOREST RESPONSE TO A DRIER FUTURE: TURNOVER TIMES OF SOIL ORGANIC MATTER, ROOTS, RESPIRED CO_2, AND CH_4 ACROSS MOISTURE GRADIENTS IN TIME AND SPACE

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Accomplishments

1. What are the major goals of the project?

Moisture may be more important than temperature in driving soil carbon storage and emissions in the tropics, while the role of moisture on soil carbon dynamics is underrepresented in current land surface models. Data on belowground carbon cycling in the tropics is sparse, making extrapolation from field experiments to the tropics as a whole uncertain and limiting our ability to test and improve land model performance. The overall goal of my Early Career research is to constrain belowground carbon turnover times for tropical forests across a broad range in moisture regimes. Focusing on the Neo-tropics where climate projections indicate a drier future (Figure 1), my group is using ^{14}C analysis and modeling to address two major objectives:

1. Quantify age and belowground carbon turnover times across tropical forests spanning a moisture gradient from wetlands to dry forests and test the following hypotheses:
    - Hypothesis 1: Moisture is the dominant regional-scale climate driver for belowground carbon turnover times across large precipitation gradients in tropical forests.
    - Hypothesis 2: In seasonally dry forests, the age of respired CO_2, emitted methane, and DOC shift to reflect new photosynthates during the wet season.
    - Hypothesis 3: With decreasing precipitation, roots become distributed more deeply in the soil profile and their relative importance to deep soil carbon cycles increases.
2. Identify specific areas for focused model improvement and data needs through site-specific model-data comparison and belowground carbon modeling for tropical forests.

2. What was accomplished under these goals?

This report covers the first year of this project, during which time considerable efforts have been made to establish collaborations and develop the research team. We have attained published and unpublished soil ^{14}C data; secured access to archived soil samples; received newly collected soil and air samples from collaborators; and established access to several research sites. Early results, in collaboration with Jennifer Pett-Ridge (LLNL), indicate considerable variability in soil ^{14}C profiles within Luquillo Experimental Forest (LEF) in Puerto Rico that are coincident with differences in soil type (Figure 2). We have also built a working collaboration with the Accelerated Climate Model for Energy- Land Model (ALM) development team (at LBNL and ORNL), run ALMv0, extracted model data for sites, and performed initial land model-data comparisons for soil carbon stocks and ^{14}C using a combination of previously published, unpublished, and new soil measurements. Early results are consistent with land model underestimation of carbon stocks and turnover times for forests in Puerto Rico, Costa Rica, and Brazil.

3. What opportunities for training and professional development has the project provided?

K. McFarlane attended a training workshop for SoilR (the reduced complexity modeling platform we are using for soil carbon and radiocarbon and derivation of parameters for ALM runs) at the Max Planck Institute for Biogeochemistry in Jena, Germany. This workshop was held by the creator of SoilR, Carlos Sierra, and was critical for learning how to SoilR for the advanced tasks required for this project. This project enables K. McFarlane to mentor a new post doc (Kari Finstad) and graduate student (Nina Zhang), both of whom will attend a Radiocarbon Short-Course to be held at the Max Planck Institute for Biogeochemistry in September 2017. The project is also supporting K. McFarlane's lab manager, Alexandra Hedgpeth, in attending the Tropical Peat Workshop at the

University of Hawaii in June 2017. This workshop supports A. Hedgpeth's training as she extends her experience in high-latitude peatlands to the tropics and will help in establishing collaborations with scientists working in forested peatlands for the benefit of this Early Career Research, as we currently only have access to peatlands in northern Panama through the Smithsonian Tropical Research Institute (STRI).

4. How have the results been disseminated to communities of interest?

New results have been presented in poster presentations at the American Geophysical Union Fall Meeting, North American Carbon Program/AmeriFlux Joint PI Meeting, Earth System Science PI meeting, and will be presented at the 2017 Fluxnet Workshop in June. Project plans were also presented in a poster at the NGEE-Tropics and Earth System Science PI meetings.

5. What do you plan on do during the next reporting period to accomplish the goals?

For measurements, we plan field sampling at sites at STRI in Panama, which include one AmeriFlux site (Barro Colorado Island, BCI) and 48 additional sites that are part of a precipitation and soil fertility gradient (driven by soil type and parent materials). We are finalizing plans during summer 2017 in coordination with Daniela Cusack (UCLA), who is working at 15 of the gradient sites in her Early Career project on root-soil interactions, and Ben Turner, the soil scientist at STRI. In addition to collecting new soil samples, we plan to take advantage of B. Turner's extensive soil archive to provide us with a time series of soil measurements to better constrain soil carbon turnover times. This work will generate a manuscript for peer review led by K. Finstad. We also plan to perform repeated sampling across wet/dry seasons, measurements of ^{14}C of soil respired CO_2, and partitioning of autotrophic and heterotrophic respiration with ^{14}C, which we hope to expand across several AmeriFlux sites for a second peer-reviewed manuscript. Finally we will discuss with B. Turner archived soil samples from other sites that might strengthen our model-data comparisons and meta-analysis.

For land modeling, we will run ALMv1 in individual site mode for our study sites. We are currently discussing with collaborators at LBNL (Bill Riley and Qing Zhu) and ORNL (Peter Thornton and Dan Ricciuto) how to set up runs to facilitate participation in model inter-comparison activities for ALM. We plan to start with the version of ALMv1 that LBNL has used for similar activities, but are considering comparing several versions. For this project, we plan to start by evaluating the model performance in "default mode" and then manipulate rooting parameters, as one of our hypotheses is that rooting depth with change across the gradient from wet to seasonally dry forest and that this will impact soil C and ^{14}C profiles (and subsequently, carbon turnover times). This work will produce a dissertation chapter for N. Zhang and a peer-reviewed publication.

Finally, we will continue to develop collaborations and establish access to additional sites, archived samples, and soil radiocarbon data. For example, K. McFarlane will continue working with J. Pett-Ridge (LLNL) at TRACE (Tropical Responses to Altered Climate Experiment), a DOE/USFS supported ecosystem-warming experiment. Collaborations and partnerships still in development, and in addition to those listed previously, include those with Melanie Mayes (ORNL) and Jennifer Powers (University of Minnesota), both of whom are currently funded by BER for work in tropical forests. In addition, Whendee Silver (UC-Berkeley) and K. McFarlane have identified a graduate student of hers who is interested in working on soil carbon storage, turnover, and saturation at sites in Puerto Rico where W. Silver has worked previously. The student, Allegra Mayer, has pending applications for fellowships to help support this work.

Products – Details

1. Publications (including details such as journal, publication date, doi, authors, acknowledgement of DOE support, etc.)

1. J Pett-Ridge, K McFarlane, E Green, A Campbell, K Heckman, S Reed, A Plante, T Wood. *Into the Deep: Variability in Soil Microbial Communities and Carbon Turnover Along a Tropical Forest Soil Depth Profile.* Data collected, manuscript partially drafted. Partially supported on DOE-BER SCW1478 and SCW1572.

2. Intellectual property

N/A

3. Technologies and techniques

N/A

4. Other products (** indicates invited)

1. K. McFarlane. Constraining carbon turnover times in tropical forests across a moisture gradient. ESS Annual Principal Investigators Meeting, Invited Break-Out Session Talk, April 2017. **
2. K. Finstad, A. Campbell, C. Koven, G. Miller, J. Pett-Ridge, A. Plante, E. Veldkamp, N. Zhang, and K. McFarlane. Measurements and modeling of carbon turnover time in tropical forest soils. ESS Principal Investigators Meeting, Poster Presentation, April 2017.
3. K. Finstad, A. Campbell, J. Pett-Ridge, A. Plante, E. Veldkamp, and K. McFarlane. Measurements and modeling of carbon turnover time in tropical forest soils. ESS Principal Investigators Meeting, Poster Presentation, April 2017.
4. J. Pett-Ridge, K.J. McFarlane, K.A. Heckman, S. Reed, E.A. Green, P.S. Nico, M.M. Tfaily, T.E. Wood, A.F. Plante. Digging a Little Deeper: Microbial Communities, Molecular Composition and Soil Organic Matter Turnover along Tropical Forest Soil Depth Profiles. AGU Fall Meeting, Poster Presentation, Dec 2016.
5. K. McFarlane. Tropical forest response to a drier future: turnover times of soil organic matter, roots, respired CO2 and CH4 across gradients in time and space. NGEE-Tropics Principal Investigators Meeting, Poster Presentation, September 2016.

Participants and Other Collaborating Organizations

1. Participants (including role, person months worked, description of contributions to the project, identification of international collaboration and travel)

Karis McFarlane, Principal Investigator. Lead project, develop collaborations, mentor and supervise other project participants. 9 person-months.

Kari Finstad, LLNL Postdoctoral Researcher. Correspond with collaborators with sites in Costa Rica and Peru; prepare samples for chemical and isotopic analysis, including radiocarbon; data management and analysis; field sampling planning; dissemination of research through poster presentations. 9 person-months.

Zina Zhang, LLNL Student Employee and Colorado State University PhD Candidate. Extract CLM4.5 BGC model data for study sites (soil carbon stock and radiocarbon profiles); ACME Land Model runs; field sampling and model run planning. 6 person-months.

Ryan Gini, Student Intern. Miscellaneous lab work in natural radiocarbon sample preparation and graphitization laboratory. 1 person-month.

Alexandra Hedgpeth, LLNL Natural Radiocarbon Laboratory Manager. Support for sample preparation and training of other participants in sample preparation techniques; development of collaborations for tropical peatland sites. 1 person-month.

2. Partners (e.g., facilities support):

STRI, NGEE-Tropics and AmeriFlux Data Management Teams.

3. Other collaborations:

Name	Affiliation	Experiment/Research Site
Jennifer Pett-Ridge	LLNL	TRACE, LEF
Edzo Veldkamp	Georg-August-Universität Göttingen	La Selva AmeriFlux Site
Gretchen Miller and Georgianne Moore	Texas A & M	Soltis Center Ameriflux Site
Enrico Yepez	Instituto Tecnológico de Sonora	Alamos Flux Site
Bill Riley and Qing Zhu	LBNL	ALM
Peter Thornton and Dan Ricciuto	ORNL	ALM
Charlie Koven	LBNL	CLM
Ben Turner*	Smithsonian Tropical Research Institute	BCI Ameriflux Site; various STRI sites
Daniela Cusack*	UCLA	Panama precipitation gradient
Jennifer Powers*	University of Minnesota	Various seasonally dry forests
Oliver van Straaten*	Buesgen-Institute	Various sites in Peru
Whendee Silver*	UC-Berkeley	Luquillo Experimental Forest
Jeff Chambers*	LBNL/NGEE-Arctic	Manaus
Melanie Mayes*	ORNL	Icacos, LEF and Boco del Torro, Panama

*Indicates collaborations in development at the time of this report.

Impacts

1. What is the impact on the development of the principle discipline(s) of the project?

This project has started to push development of ^{14}C as a model diagnostic through the generation of new data for model-data comparisons.

2. What is the impact on other disciplines?

N/A

3. What is the impact of the development of human resources?

This project has enabled the post-doctoral and graduate training of two women scientists at LLNL.

4. What is the impact on physical, institutional, and information resources that form infrastructure?

N/A

5. What is the impact on technology transfer?

N/A

6. What is the impact on society beyond science and technology?

N/A

7. Foreign spending

$1600 was spent by K. McFarlane in Germany while attending the SoilR workshop.

Changes – Problems

1. Changes in the approach and reasons for change

The proposal specified a hypothesis for Objective 2 that models underestimate turnover time for soil carbon because of inappropriate soil organic matter model structure (i.e., first-order Century-style decomposition cascade). We have learned that the current ALM development plan includes the parallel development of multiple versions of ALM by ORNL and LBNL teams and model inter-comparison before selection of one version of ALM for incorporation into ACME. These versions vary considerably in model structure from the first-order models used previously. We have decided that at this time it makes the most sense for us to work *with* the development teams to run and compare different versions rather than explicitly assess model structure through the reduced complexity model as planned. While collaborating with the ALM development teams on different model versions, we will place more focus on input and vertical translocation parameters under this project in the coming year. This seems particularly relevant considering recent work by B. Riley's group at LBNL and has not to our knowledge been addressed in ALM with the level of detailed site data we will have for the precipitation gradient in Panama. This approach also fits better with the hypotheses under Objective 1 pertaining to root inputs, differences across gradients in moisture, and importance in driving soil carbon dynamics in the subsurface.

2. Actual or anticipated problems, delays and actions or plans to resolve them

N/A

3. Changes that have a significant impact on expenditures

N/A

4. Significant changes in use or care of human subjects, vertebrate animals, and/or biohazards

N/A

5. Change of primary performance site location from that originally proposed

N/A

6. Carryover amount

The carryover amount from the end of FY2017 into FY2018 is expected to be $367k.

The carryover amount from the end of FY2016 into FY2017 was $476k (note, funds were received in July in 2016).

Figures

Figure 1. Study sites for soil ^{14}C in the Neo-Tropics to date. Yellow stars indicate sites with data generated by this project during this reporting period. Orange stars indicate sites planned for new data during the next year. Pink stars indicate sites where data is available in the literature.

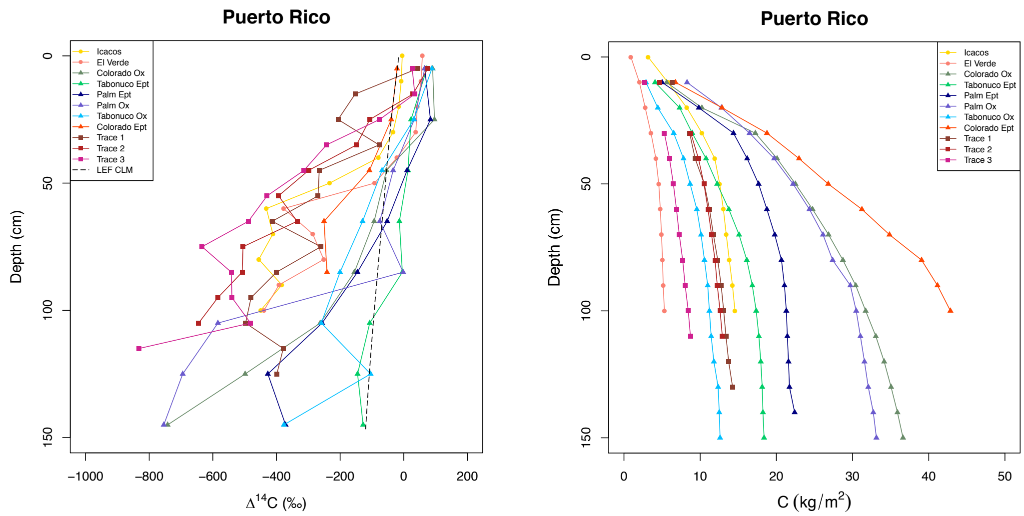

Figure 2. Left: Soil ^{14}C profiles from 12 soil pits across 14 soil pits at LEF show considerable variability, which seems partly explained by differences in soil type, with highly weathered Oxisols having older soil carbon than less weathered Entisols. Right: Cumulative soil C stocks with depth also show considerable variability that does not appear driven by soil type alone. Pett-Ridge *et. al.*, in prep.