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Resolving Conflicting Physical and Biochemical Feedbacks to Climate in Response to Long- Term Warming

Xiao-Jun Allen Liu[1], Serita D. Frey[2], Ken M. Kemner[3], Jerry M. Melillo[4], Bhoopesh Mishra[5], and Kristen M. DeAngelis[1*]

[1]University of Massachusetts-Amherst, Amherst, MA
[2]University of New Hampshire, Durham, NH
[3]Argonne National Laboratory, Argonne, IL
[4]Marine Biological Laboratory, Woods Hole, MA
[5]Illinois Institute of Technology, Chicago, IL

Contact: deangelis@microbio.umass.edu

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Warming accelerates the decomposition of stored carbon (C) in soils, though long-term trends suggest that this effect extends beyond a kinetic response. Microbial C use efficiency (CUE) and the dynamic nature of physical protection of soil organic matter (SOM) have emerged as control points in the temperature sensitivity of microbial feedbacks to climate. In a field experiment at the Harvard Forest in Massachusetts, where soils have been exposed to 27 years of warming at 5 °C above ambient, periods of soil C degradation have been punctuated by periods of changes in soil microbial dynamics. While long-term warming has caused the soil system to act as a positive feedback to climate, our studies show microbes acting to promote negative feedbacks to climate. We hypothesize that long-term warming has altered the mineral association of SOM such that soil C in heated plots is less physically protected and more vulnerable to microbial degradation and subsequent mineralization to CO_2. Further, we hypothesize that microbial efficiency of complex SOM utilization (*e.g.*, requiring considerable extracellular degradation) is decreasing, which may account for the large loss of soil C over time. Soils were collected from the long-term warming study and macroaggregates and microaggregates (250 – 2000 and < 250 µm) were isolated. Two short-term incubations were conducted (1) with glucose, cellobiose and cellulose, and (2) with intact and crushed aggregates. Compared to macroaggregates, microaggregates had greater soil nitrogen, microbial biomass C (MBC), dissolved organic C (DOC), DNA content, consistent with the idea that SOM is more physically protected in microaggregates than in macroaggregates. Using metabolic quotient as a proxy for CUE, measured as the respiration CO_2-C produced per unit of microbial biomass, we find that microaggregates have a smaller metabolic quotient, indicating a higher CUE compared to macroaggregates. Soil microbial DNA was labeled with heavy water ($H_2{}^{18}O$, 97 atom%) and will be analyzed to determine how long-term warming affects CUE for different aggregate sizes. To understand how bulk C chemistry of soils changes due to long- term warming, X-Ray Raman scattering measurements were conducted at sector 20-ID of APS. C signal of the measured samples suffers from low signal to noise ratio due to high background from soil mineral content, making it difficult to analyze the samples meaningfully and quantify the differences. These experiments would serve as a justification for beam time at European Synchrotron Research Facility in Grenoble, France where samples could be measured at an energy (6 KeV) below the excitation energy for Fe (7.2KeV) using 72 detectors as opposed to 19 at APS. This approach will likely 1) reduce background from mineral content in the soil and 2) improve statistics significantly due to four-fold improvement in detection capability. Once quantified, the contributions of CUE and physical protection to C cycling can be incorporated into the MIMICS model, which can then be slotted into the decomposition module of our global biogeochemical model, the Terrestrial Ecosystem Model (TEM). Modeling and sensitivity analysis will test the relative magnitude and interactions of physical protection and CUE for substrates of varying complexity, which will also be validated in lab

studies of CUE of whole versus crushed aggregates. This work will improve the integration of physical protection and C complexity into climate models, and scale measured biological, chemical and physical parameters to improve predictions of global C cycle feedbacks in a warmer world.