Early Career Awards

Model-data scaling approaches for assessing the pan-Arctic permafrost carbon feedback

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The large amount of organic carbon stored in northern high latitude permafrost soils is vulnerable to thaw, decomposition and release to the atmosphere as a result of climate warming. This process is anticipated to be a significant positive feedback on future radiative forcing from terrestrial ecosystems to the Earth's climate system. Improving our understanding of permafrost carbon vulnerability and associated climate feedbacks is a major research priority for the scientific community. Here, we describe the development, application and potential uses of a geospatial model-data framework designed to characterize, quantify and scale permafrost carbon vulnerability across the pan-Arctic domain. The framework facilitates the spatial integration and analysis of observational, experimental and model data representing the key system components, namely: a) the rate and extent of permafrost degradation and thaw, b) the quantity and quality of soil organic matter stocks, and c) the form of permafrost carbon emissions as carbon dioxide or methane.

The approach works from the "top-down" perspective designed to provide a much needed first-order, broad-scale assessment of the drivers and responses of the Arctic system carbon cycle using data-driven scaling methods. First, we developed a pan-Arctic regionalization scheme based on a broadly-defined spatial representation of the major environmental controls on the key system components. We then use the resulting Permafrost Regionalization Map (PeRM) to organize and analyze the representativeness and variability of a series of data collections quantifying these key system components across the pan-Arctic domain. The results of this synthesis of data collections based on the PeRM allows for model benchmarking specific to high latitude processes. We demonstrate this benchmarking approach here by comparisons with the results from a terrestrial biogeochemistry model that we used to simulate the impacts of permafrost thaw on carbon cycling across the pan-Arctic. Finally, we are using this framework to identify key regions of particular vulnerability, which is guiding on-going research toward characterizing permafrost degradation and associated vegetation changes through multi-scale remote sensing. Overall, this work provides a critical bridge between the abundant but disordered observational and experimental data collections and the development of higher-complexity process representation of the permafrost carbon feedback in Earth System Modeling frameworks.