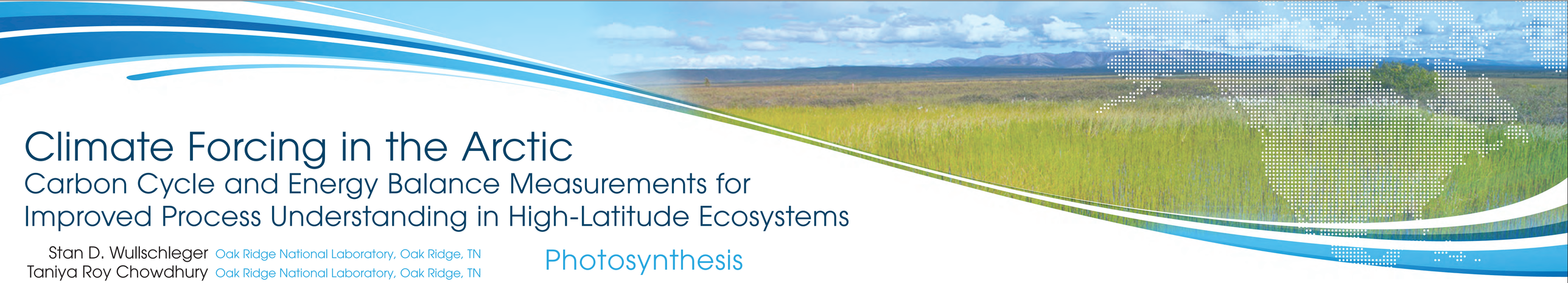


Climate Forcing in the Arctic

Carbon Cycle and Energy Balance Measurements for Improved Process Understanding in High-Latitude Ecosystems

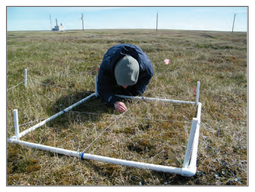
Stan D. Wullschleger Oak Ridge National Laboratory, Oak Ridge, TN
Taniya Roy Chowdhury Oak Ridge National Laboratory, Oak Ridge, TN
John Bryan Curtis Lawrence Berkeley National Laboratory, Berkeley, CA
David E. Graham Oak Ridge National Laboratory, Oak Ridge, TN
Colleen M. Iversen Oak Ridge National Laboratory, Oak Ridge, TN
Keith F. Lewin Brookhaven National Laboratory, Upton, NY
Alistair Rogers Brookhaven National Laboratory, Upton, NY
Victoria L. Sloan University of Bristol, Bristol, United Kingdom
Lydia J. Smith Lawrence Berkeley National Laboratory, Berkeley, CA
Margaret S. Torn Lawrence Berkeley National Laboratory, Berkeley, CA

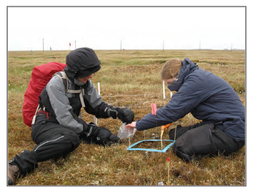
Introduction

Characterizing spatial variability of processes is critical for modeling ecosystem-climate feedbacks in permafrost landscapes. The Next-Generation Ecosystem Experiments (NGEE Arctic) project, sponsored by the Department of Energy, Office of Science, seeks to accelerate improvements in climate prediction through an approach that integrates field, laboratory, and modeling activities. Here we illustrate that philosophy by focusing on measurements of carbon-cycle and energy-balance dynamics being made in connection with field sites near Barrow, Alaska.

Plant Community Composition

Surveys of plant community composition were combined with geomorphological analyses using high-resolution LiDAR to determine fractions of plant functional types (PFTs) in the landscape.





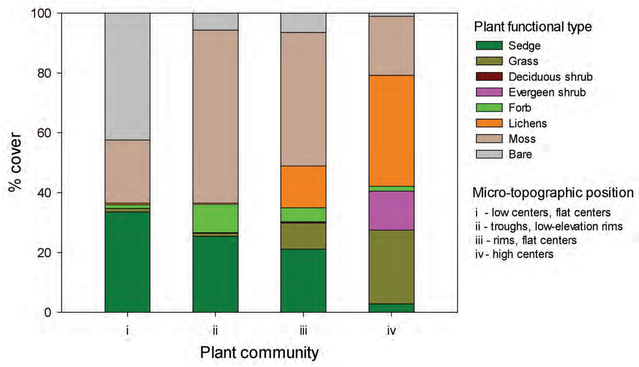


Figure 1. Plant functional type (PFT) composition and micro-topographic locations of four plant communities identified across high-centered, flat-centered and low-centered polygons on the Barrow Environmental Observatory, Alaska.

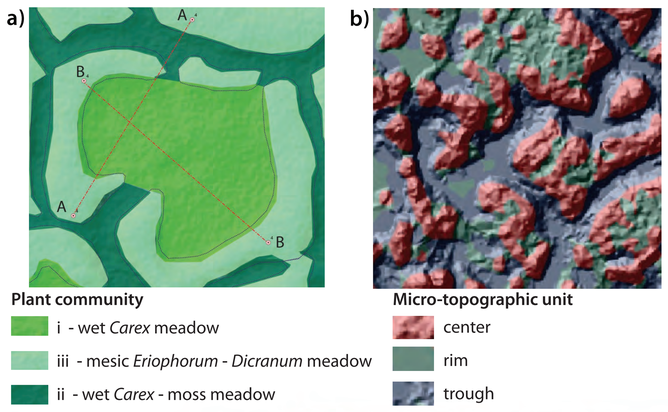


Figure 2. a) plant communities within a low-centered polygon, mapped using vegetation boundaries from field transects to determine parameterization of geomorphological analyses. b) micro-topographic units determined from LiDAR-derived metrics.

Photosynthesis

Photosynthesis was measured for a wide range of plant species using gas-analysis techniques. Component processes of carboxylation and electron transport varied in ways that were poorly represented in Earth System Models.

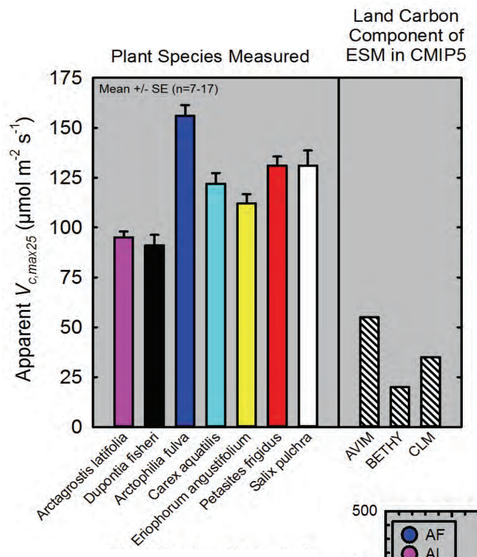


Figure 3. The response of photosynthesis to internal CO_2 was used to determine apparent $V_{c,max}$ for key wet sedge tundra plant species. All $V_{c,max}$ values were normalized to 25°C and are contrasted with the values used to represent Arctic vegetation in CMIP5 models.

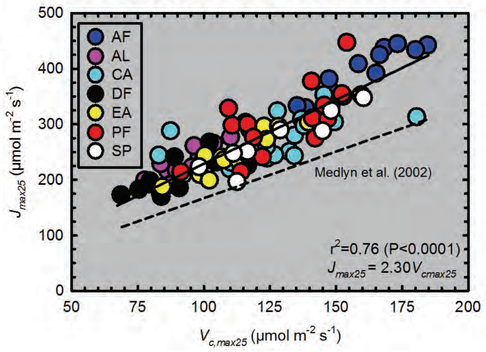
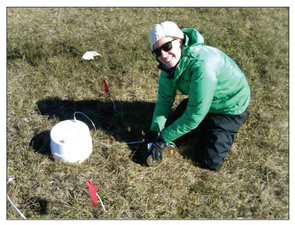


Figure 4. The JV_{ratio} determines J_{max} in ESMs and is a global constant. Leaf level modeling shows that using the higher JV_{ratio} measured in Arctic PFTs results in greater CO_2 responsiveness under temperature increases projected for the Arctic.

Methane Biogeochemistry

HHeterogeneity in surface fluxes of CO_2 and CH_4 was assessed through chamber-based measurements in the field, subsurface pore water sampling, and incubation of permafrost soils in the laboratory. For methane, carbon isotope compositions typical of acetate cleavage and CO_2 reduction were observed, and surface emissions varied in ways that could not be explained by soil moisture and temperature alone.



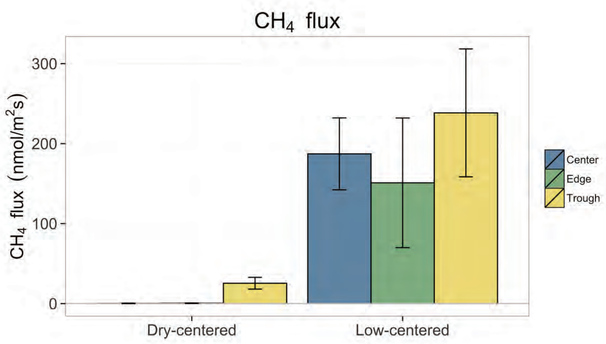


Figure 5. Mean monthly CH_4 flux from dry- and low-centered polgyons. Model selection among linear mixed effects model found differences to be highly significant, even after accounting for differences in soil moisture.

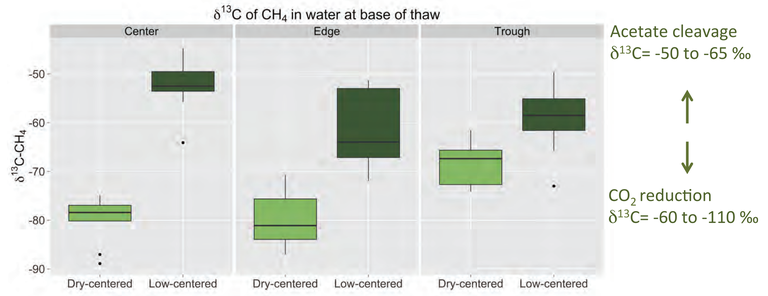
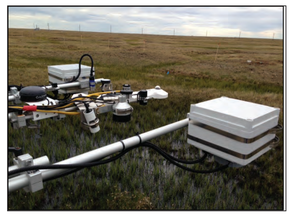


Figure 6. Mean δ^{13}C of dissolved CH_4 in water samples collected from immediately above the frost table. Mean d^{13}C-CH_4 values from all low-centered polygon features fall within the range characteristic of acetate cleavage, whereas δ^{13}C-CH_4 values from dry-centered polygon features are typical of CO_2 reduction.

Observational Tram for Energy Balance



As a complement to our focus on carbon cycle processes, an observational tram that consists of 65 meters of elevated track and a fully-automated cart that carries a suite of radiation and remote sensing instrumentation has also been deployed. Electrical resistivity tomography, soil moisture, and soil temperature sensors are co-located with the tram.

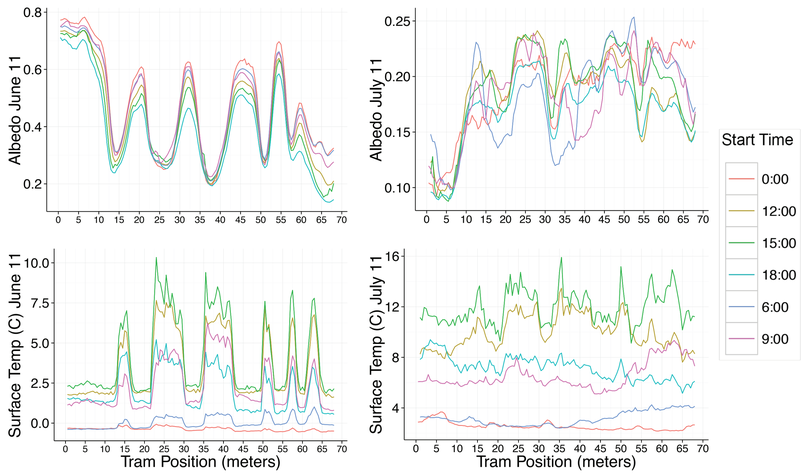


Figure 7. Diurnal climate forcing and energy balance observations from tram.

Conclusions

Multi-scale modeling is a central component of our research and, in addition to field and laboratory research, we are integrating carbon cycle and energy balance processes into models to better understand climate forcing in the Arctic.

Acknowledgements

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Next-Generation Ecosystem Experiments (NGEE Arctic)

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