The Prairie Heating and CO_2 Enrichment (PHACE) experiment: Synthesizing 8 years of data

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The Prairie Heating and CO_2 Enrichment experiment in native grassland near Cheyenne, Wyoming completed its final season of ecosystem manipulations in 2013. Our project is moving into final stages of data-model development and synthesis. Our principal goal was to understand direct and indirect effects of elevated CO_2 and climate warming on grassland biogeochemistry and community changes. Year-to-year precipitation inputs ranged two-fold, from 500mm in 2009 to 250mm in 2012. Precipitation variability was the primary driving factor for all the ecosystem processes examined. This is not surprising for this water-limited semi-arid grassland that receives on average about 400mm precipitation annually. However, elevated CO_2 (600 ppm) and experimental warming (+3C nighttime, +1.5C daytime) did have important effects. Our multi-year dataset is providing new insights into grassland responses to these global changes:

1) Effects of warming and elevated CO_2 on ecosystem greenness are seasonally variable, with warming enhancing greenness during wet periods and elevated CO_2 during dry periods. Yet these phenological differences balance to yield largely neutral effects over the entire growing season. 2) Plant species composition is relatively resistant to inter-annual variation in precipitation, and also rendered more stable under elevated CO_2 conditions. Increased stability derives from a decrease in the relative abundance of dominant species and increase in the relative abundance of subdominant species. 3) We calibrated a semi-mechanistic model of ecosystem respiration within a Hierarchical Bayesian framework. Modeled annual ecosystem respiration was stimulated under elevated CO_2 in most years of the project. Antecedent soil moisture content and soil temperature were critical factors for predicting ecosystem respiration. Indeed, most of the treatment differences were driven by antecedent conditions. 4) 14C measurements revealed that soil respiration derived from recent plant inputs was less temperature sensitive than soil respiration derived from soil organic matter. Further, decomposition of soil carbon >5 y years old increased with warming in the field and laboratory. The short mean residence time of new plant inputs, and evidence from a fallow experiment suggest that the effect of plant inputs on temperature sensitivity of soil respiration is short-lived. In contrast, sustained temperature sensitivity of slow-turnover soil carbon with an absence of new inputs suggests potential for soils to lose C with climate warming.

Taken together, the continuous set of annual observations and cumulative effects over 8-years of experimental manipulations has yielded critical insights into ecosystem dynamics and partitioning of global change effects from background variation in precipitation.