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Separating direct temperature responses from phenological control of gross photosynthesis during the short tundra growing season: measurements and process modeling from the Lena River Delta, Russia

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The photosynthetic response of tundra species with respect to incoming PAR can change rapidly through the short polar growing season. These changes are known to be caused by the comparatively rapid phenological vegetation development in this region. Concurrent to progression through phenological stages, however, photosynthetic performance of tundra species is modulated by direct temperature effects. Separating these influences on plant behavior is possible thanks to advances in measurement techniques (i.e. eddy-covariance systems) and analytical methodologies (i.e. time series analysis). This presentation evaluates the relative contribution of phenology and direct temperature effects on photosynthetic performance during the 2006 growing season in a polygonal tundra ecosystem in the Lena River Delta in Northern Siberia (72°22' N, 126°30' E). We demonstrate that the timing of warm periods (characterized by warm, dry winds from the south during late June through the middle of August) is an important determinant of the magnitude of the ecosystem's carbon sink function, as they drive temperature-induced changes in both assimilation and respiration.

In particular, these few, brief warm periods (with air temperatures exceeding 20 °C and approaching peaks near 30 °C for three to five days) have the potential to significantly alter the CO_2 balance of these ecosystems. High temperature periods drive the ecosystem's functioning away from optimal uptake, and encourage both amplified respiration and deactivation of the photosynthetic apparatus. We suggest ways to model these temperature-based processes, and quantify the reduction of CO_2 uptake during hot spells occurring in different phenological periods. Hot spells during the early portion of the growing season are shown to be more influential in the region's carbon balance than those occurring later in the season. The magnitude of the response to increased temperatures depends on growth temperature, the integrated temperature of the antecedent 30-day period. However, this response shows hysteresis depending on its timing within the phenological calendar. Earlier periods have a stronger photosynthetic apparatus with respect to maximum uptake during high light conditions, but also show an amplified response to locally extreme high temperature conditions. Understanding and quantifying these processes is an essential precursor to describing the delays and lags linking assimilation and respiration at different time scales, as it allows a more confident partition of measured net exchange over a broader range of environmental conditions.

The effects of these processes on the annual carbon balance are demonstrated for the site for one growing season, and a sensitivity analysis of the timing, magnitude, and duration of these events is used to show the importance of synoptic meteorological conditions on the local carbon budget. This question is especially urgent given likely consequences of changes in Arctic sea ice coverage and the resultant modifications of the balance between continentally- and Arctic Ocean–derived weather systems.