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Experimental warming delays autumn senescence in a boreal spruce bog: Initial results from the SPRUCE experiment

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Phenology is considered one of the most robust indicators of the biological impacts of global change. In temperate and boreal regions, long-term data show that rising temperatures are advancing spring onset (e.g. budburst and flowering) and delaying autumn senescence (e.g. leaf coloration and leaf fall) in a wide range of ecosystems. While warm and cold temperatures, day length and insolation, precipitation and water availability, and other factors, have all been shown to influence plant phenology, the future response of phenology to rising temperatures and elevated CO_2 still remains highly uncertain because of the challenges associated with conducting realistic manipulative experiments to simulate future environmental conditions.

At the SPRUCE (Spruce and Peatland Responses Under Climatic and Environmental Change) experiment in the north-central United States, experimental temperature (0 to +9˚C above ambient) and CO_2 (ambient and elevated) treatments are being applied to mature, and intact, *Picea mariana-Sphagnum spp*. bog communities in their native habitat through the use of ten large (approximately 12 m wide, 10 m high) open-topped enclosures.

We are tracking vegetation green-up and senescence in these chambers, at both the individual and whole-community level, using repeat digital photography. Within each chamber, digital camera images are recorded every 30 minutes and uploaded to the PhenoCam (http://phenocam.sr.unh.edu) project web page, where they are displayed in near-real-time. Image processing is conducted nightly to extract quantitative measures of canopy color, which we characterize using G_{cc}, the green chromatic coordinate.

Data from a camera mounted outside the chambers (since November 2014) indicate strong seasonal variation in G_{cc} for both evergreen shrubs and trees. Shrub G_{cc} rises steeply in May and June, and declines steeply in September and October. By comparison, tree G_{cc} rises gradually from March through June, and declines gradually from August through December. These patterns can also be seen in other daily images recorded at the site since January 2012.

Air warming treatments at SPRUCE began in August 2015, and had a substantial influence on autumn senescence of the plant community, as a whole, within each chamber. Generally, vegetation in the warmed chambers stayed green longer than that in the unwarmed chambers. We characterized the seasonality by fitting a sigmoid curve to the G_{cc} time series data, and we used the autumn half-maximum date of the sigmoid as an indicator of the timing of senescence. We found a strong linear relationship between senescence date and temperature treatment (r^2 = 0.71,n = 10). Overall, senescence was delayed by 3.5 $\pm$ 0.7 days per 1˚C of warming. Thus, although photoperiod is widely believed to be the key trigger for autumn senescence, our results do not indicate that the autumn response to warming is in any way constrained by day length.

The SPRUCE experiment is planned to running through 2025. Looking forward, we anticipate that different results may be obtained in year 2 of the SPRUCE experiment if warming treatments result in earlier spring onset, and increased evapotranspiration during spring and early summer, leading to drought conditions by late summer.