Impact of SPRUCE warming and CO_2 treatments on vegetation phenology, 2015-2024

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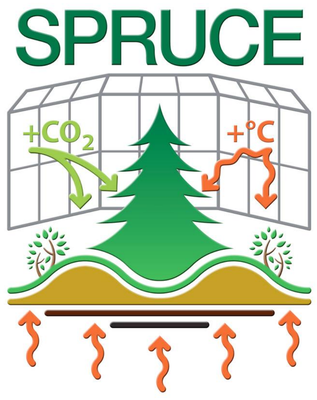
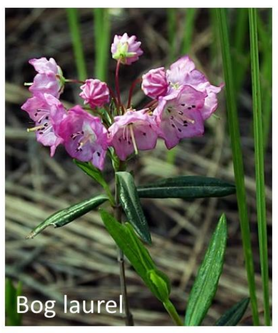
Overarching research questions

1. Is the effect of SPRUCE warming treatments on vegetation phenology linear or is there evidence it is constrained by photoperiod?
2. Is there an effect of SPRUCE CO_2 treatments on vegetation phenology?
3. How do these patterns vary among species and vegetation types?
4. What are the implications for shifts in vegetation phenology by 2100?



Methods

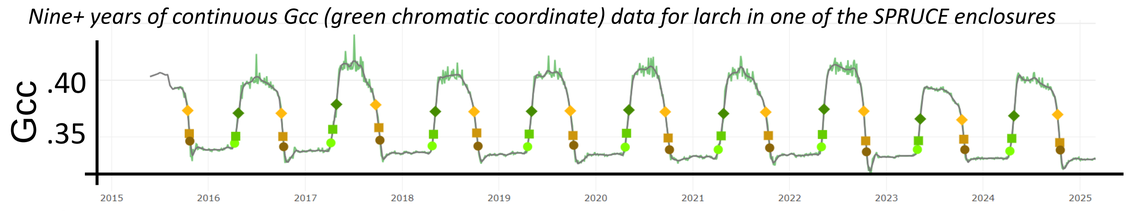
We are tracking phenological responses to the experimental treatments in two ways. (1) Since August 2015, we have monitored the vegetation within each enclosure using digital repeat photography — the PhenoCam method. We distinguish between three vegetation types: evergreen black spruce, deciduous larch (tamarack), and a mixed shrub layer dominated by leatherleaf and Labrador tea. At the end of 2017, an additional set of cameras was installed at ground level to better track the shrub layer phenology. **These data are available in real-time through http://phenocam.nau.edu/.** (2) Since April 2016, we have made weekly ground observations of vegetative and reproductive phenology on a variety of woody and herbaceous species. ***All data through the end of 2024 have been contributed to the SPRUCE data archive.***



PhenoCam results 2024

Significant effects of temperature on vegetation phenology continue to be observed for all three vegetation types, with warmer temperatures advancing spring green-up and delaying autumn senescence. Results are generally consistent over multiple years of observation, although temperature sensitivities vary from year-to-year as warming treatments interact differently each year with the weather as the seasons progress.

Nine+ years of continuous Gcc (green chromatic coordinate) data for larch in one of the SPRUCE enclosures



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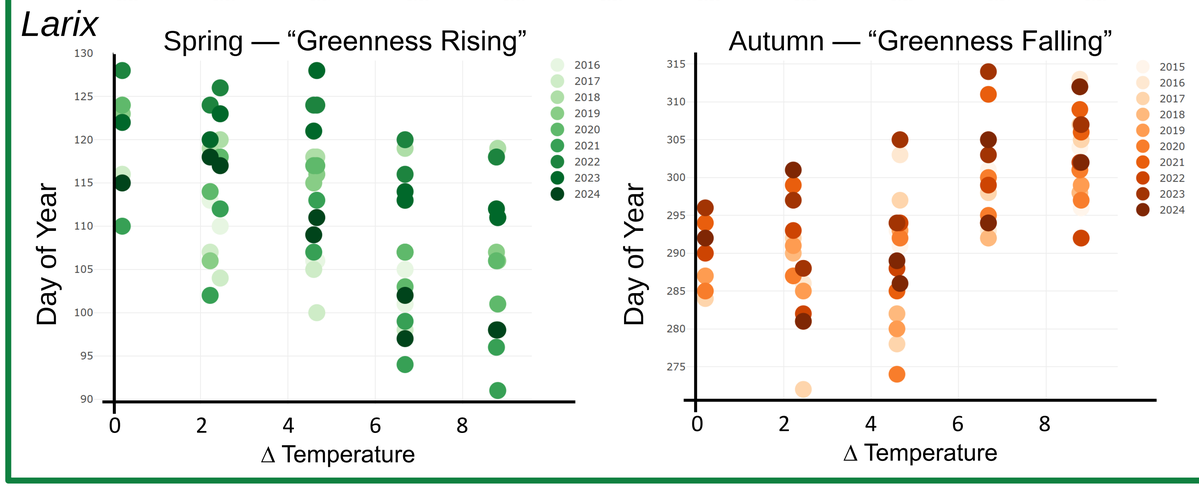
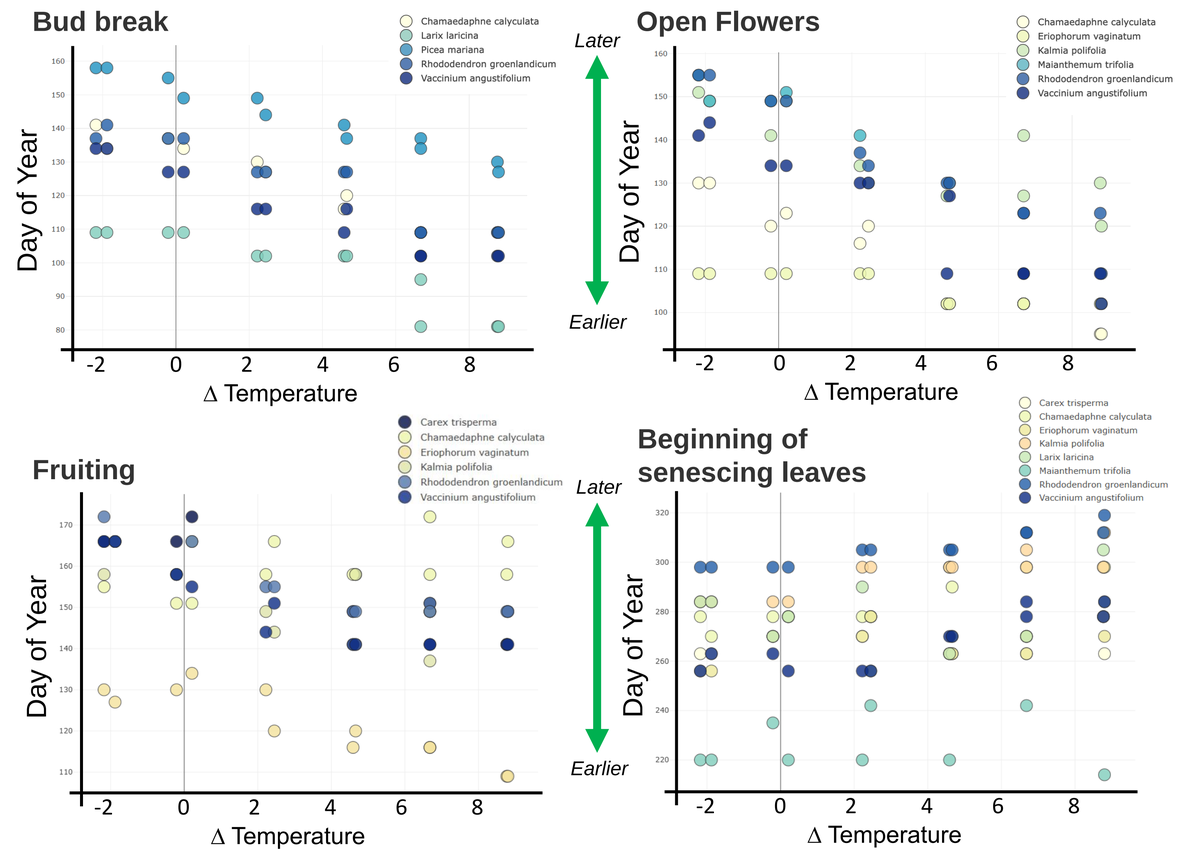


Ground observations 2024

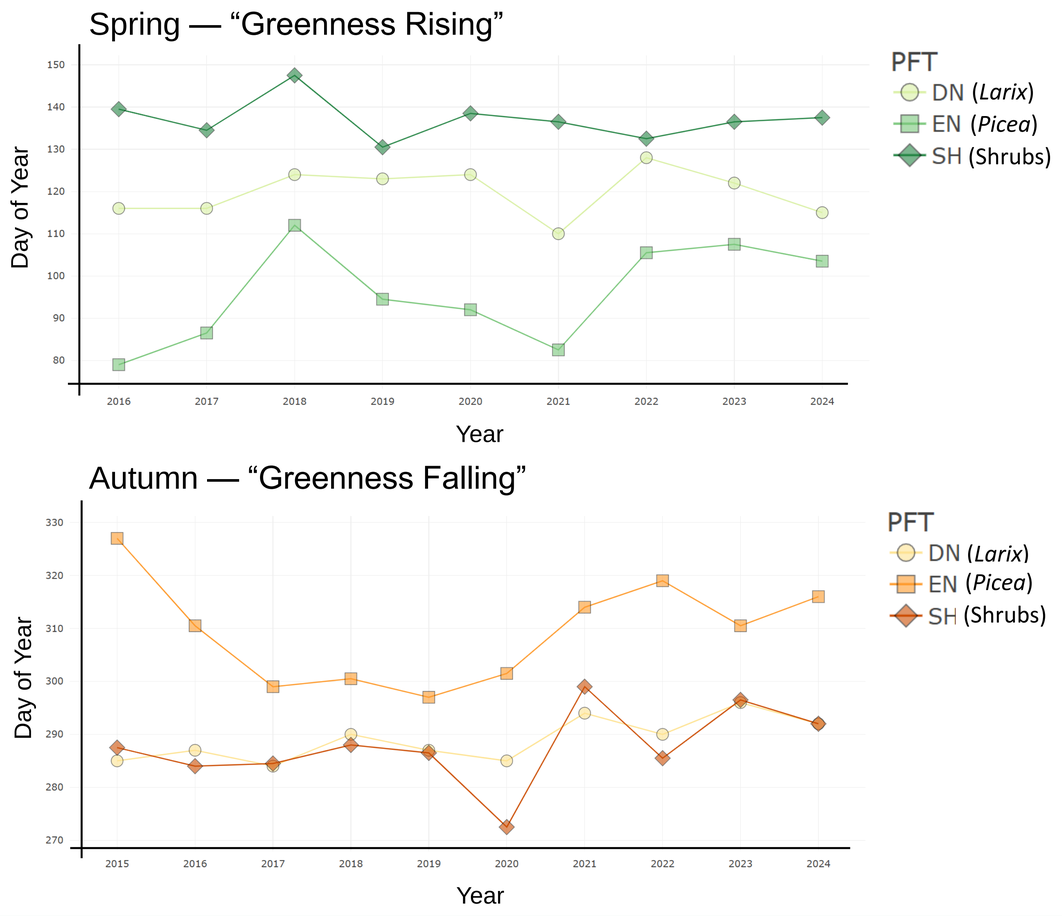
Ground observations of phenology, based on weekly surveys that target specific phenological events, including budburst and shoot elongation, flowering and fruit production, and senescence. Most springtime events are consistently occurring earlier in response to warming, while autumn events are later. For some phenophases, there is evidence of divergent responses among species.



PhenoCam interannual variability 2015–2024

Nine+ years of PhenoCam imagery at SPRUCE allow us to observe how phenological transitions shift from year to year across plant functional types (PFTs). These data from the control chambers reveal "early" and "late" years of leaf emergence and senescence, providing opportunities to assess how phenology responds to interannual variation in temperature and other environmental drivers. Disentangling climate sensitivities across PFTs through model development can help improve predictions of ecosystem responses under future climate scenarios.

Transition dates for larch (DN), spruce (EN), and the shrub layer (SH), averaged for the T0P06 and T0P19E control plots.



Conclusions

To date, results from the SPRUCE experiment show decisively that warming treatments directly influence vegetation phenology at both the start and end of annual vegetation activity. PhenoCams are also capturing transition date variability and anomaly, as well as disturbances from extreme events.

Acknowledgements

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