A Lengthening Vernal Window: Asynchronies in energy, water, and carbon balance

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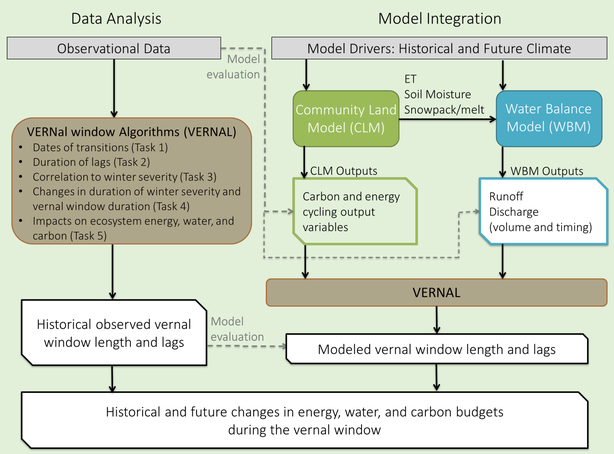
The vernal window[1,2] is a key period for the functioning of seasonally snow-covered, forested ecosystems encompassing a time when neither a snowpack nor a closed forest canopy is present, allowing for direct inputs of solar radiation to soils and water bodies[3,4].

Hypotheses:

1. The vernal window will lengthen in a warming climate.
2. Lags between important thermodynamic and biogeochemical transitions will become longer, leading to asynchronies in ecosystem energy, water, & carbon cycles.
3. Extreme shift into a snow-free regime will replace vernal window with a prolonged period of increased net radiation into terrestrial and aquatic ecosystems between senescence and leaf out that may fundamentally alter ecosystem function.

Integrated Data-Model Approach:



References:
[1]Contosta et al. 2017, *Global Change Biology*
[2]Creed et al. 2015, *Hydrological Processes*
[3]Tockner et al. 2010, *Freshwater Biology*
[4]Grime, 1994, *Ecophysiological Processes Above- and Belowground*
[5]Pierce et al. 2014, *J Hydrometeorology*
[6]Wisser et al. 2010, *Hydrol. and Earth System Sci.*
[7]Grogan, D. *Doctoral Dissertation*
[8]Hufkens et al. 2018, *Methods in Ecol. and Evol.*

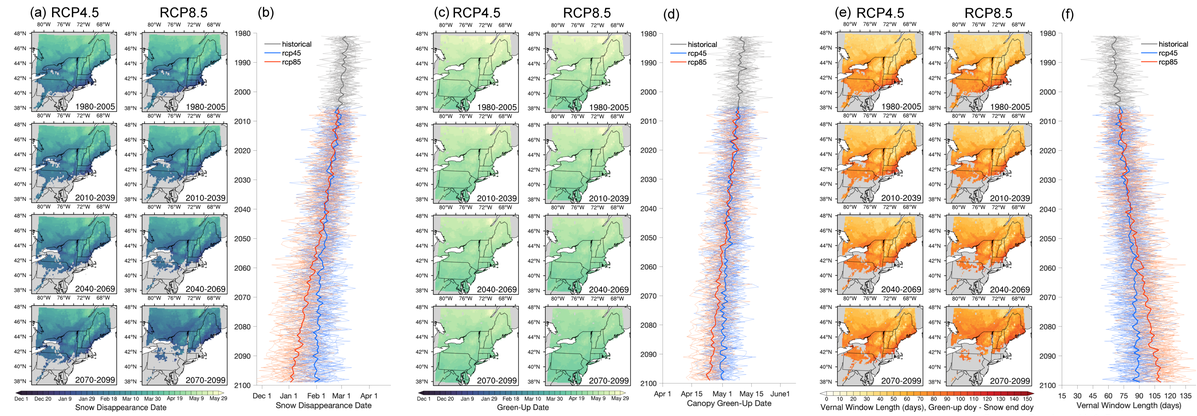
The vernal window lengthens 2-3 weeks in a warming climate by 2100.

Approach: Use daily Localized Constructed Analogs (LOCA) 29-member ensemble[5]:

- Minimum air temperature
- Maximum air temperature
- Precipitation

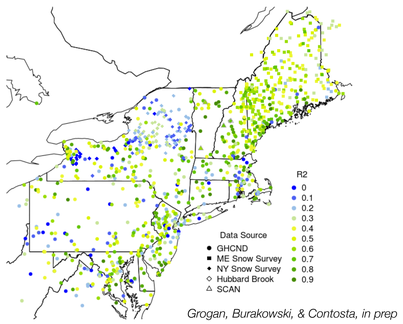
to force the Water Balance Model (WBM)[6,7] and Phenor[8] thermal time phenology model. Calculate vernal window metrics:

- Snow disappearance date
- Canopy bud break date
- Vernal window length
- Runoff Center of Volume (R-COV)
- Precipitation Center of Volume (P-COV)



Grogan, Burakowski, & Contosta, in prep

WBM simulates snow water equivalent moderately well:



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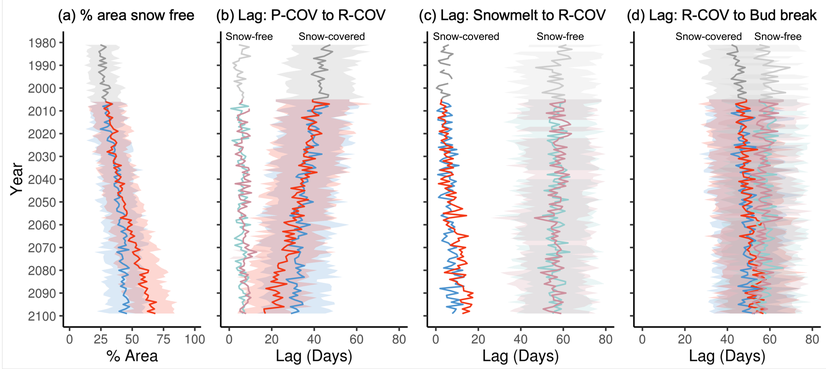
Snow free-region in Northeast increases from 27% to 43- 59% by 2100

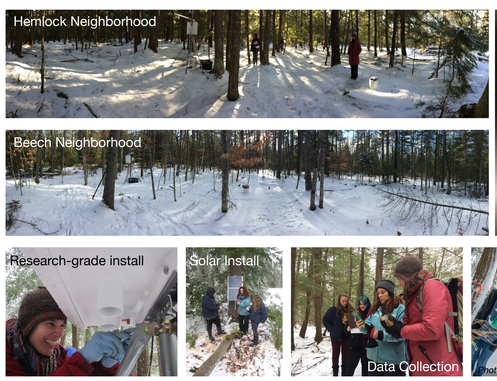


Asynchronous hydrologic transitions:

- Historically, R-COV occurred about one month after P-COV because snow stores winter precipitation.
- Under high emissions, R-COV and P-COV lag reduced to two weeks.
- Lag from R-COV to budburst remains constant.

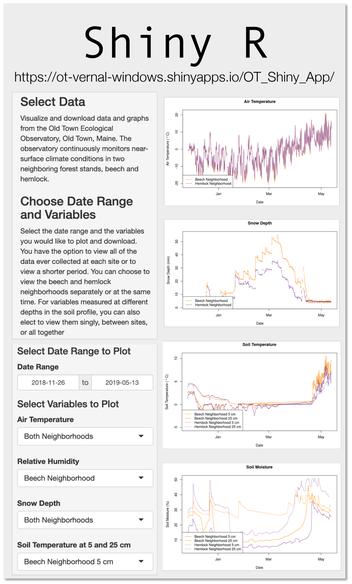
Outreach: Arduino, ShinyR and GLOBE protocols in science education

Old Town High School Arduino low-cost ($250) instrument suite will be deployed alongside research-grade equipment to track snow depth, soil temperature and moisture, air temperature, and phenology in the U-Maine Forest.



Shiny R

https://ot-vernal-windows.shinyapps.io/OT_Shiny_App/



Bundled GLOBE Protocols to track the vernal window, including snow depth, soil frost depth, and canopy green-up and a prototype soda lime base trap protocol to track soil CO_2 efflux.

Students to present at the 2019 **Northeast GLOBE Student Research Symposium.**

GLOBE Paperclip Model adapted to R.
https://github.com/daniellegrogan/Paperclip

Vernal Window Timeline Activity to hone hypothesis generation and testing skills. Evaluated at five schools, including Old Town High in Maine.