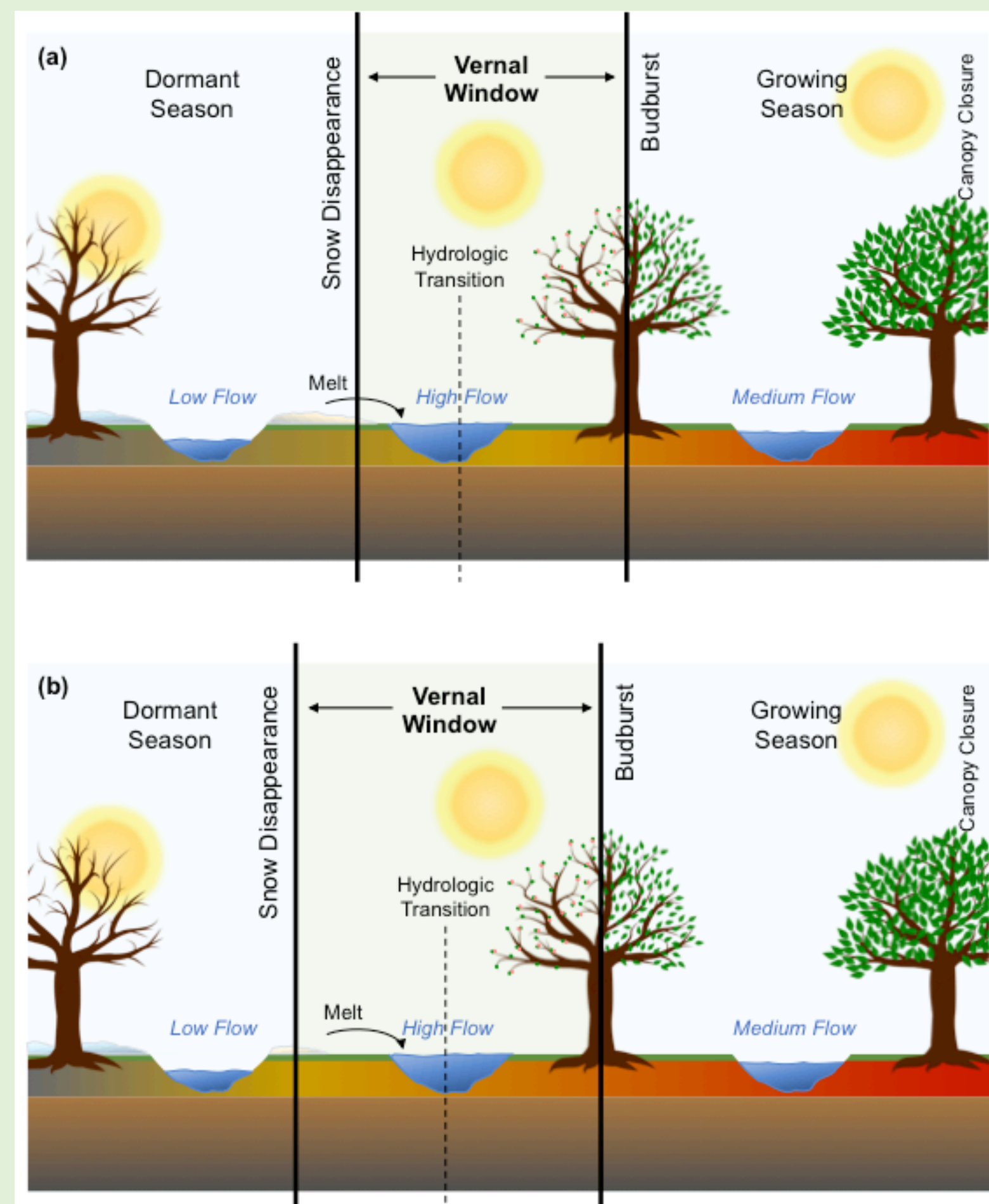




What is the vernal window?

- Transition between winter and spring
- Begins with snow disappearance
- Ends with canopy budburst
- Important control on spring hydrology and ecosystem function in seasonally snow covered regions.



Conceptual model of changes to the vernal window:
 (a) HISTORICAL: The timing of both the start and end of the vernal window drive the timing of the spring hydrograph.
 (b) FUTURE: The timing of snow disappearance and budburst advance to earlier days of the year, but at different rates. This leads to an overall lengthening of the vernal window. Spring high flows also occur earlier, with implications for ecosystem hydrology.

Methods

Use daily Localized Constructed Analogs (LOCA) 29-member ensemble¹:

- Minimum air temperature
- Maximum air temperature
- Precipitation

to force the Water Balance Model (WBM)^{2,3} and Phenor⁴ thermal time phenology model.

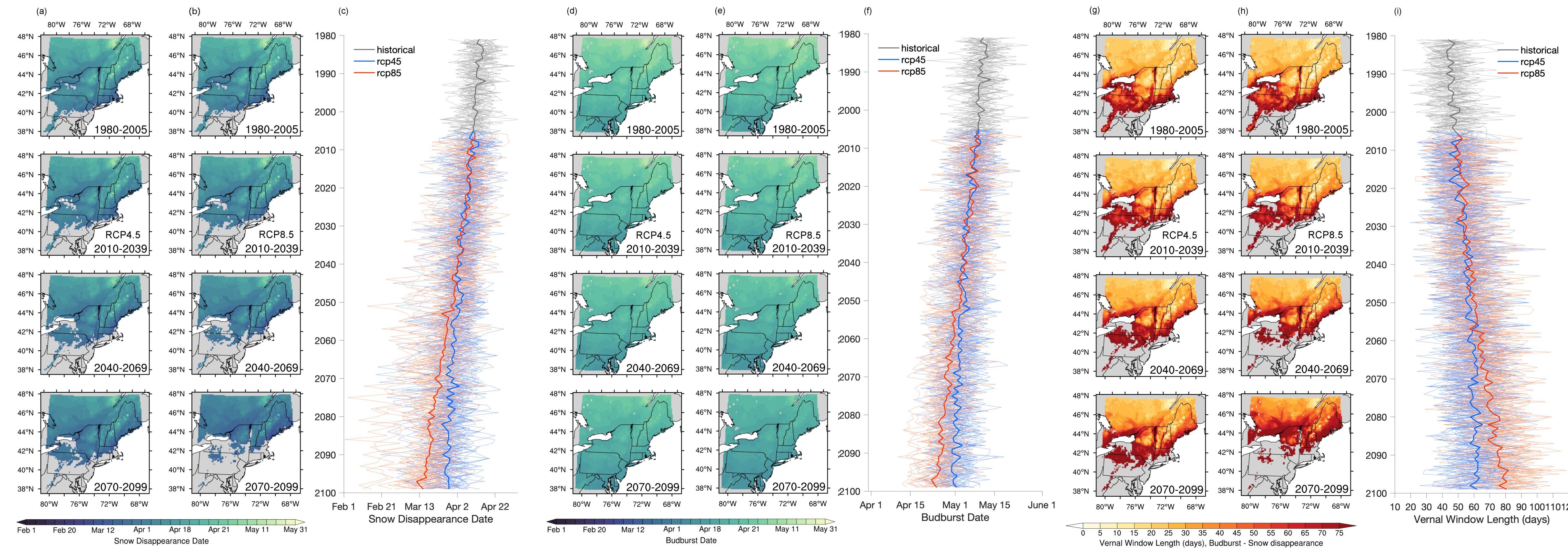
Calculate vernal window metrics:

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

Multiple linear regression on COV metrics

Results

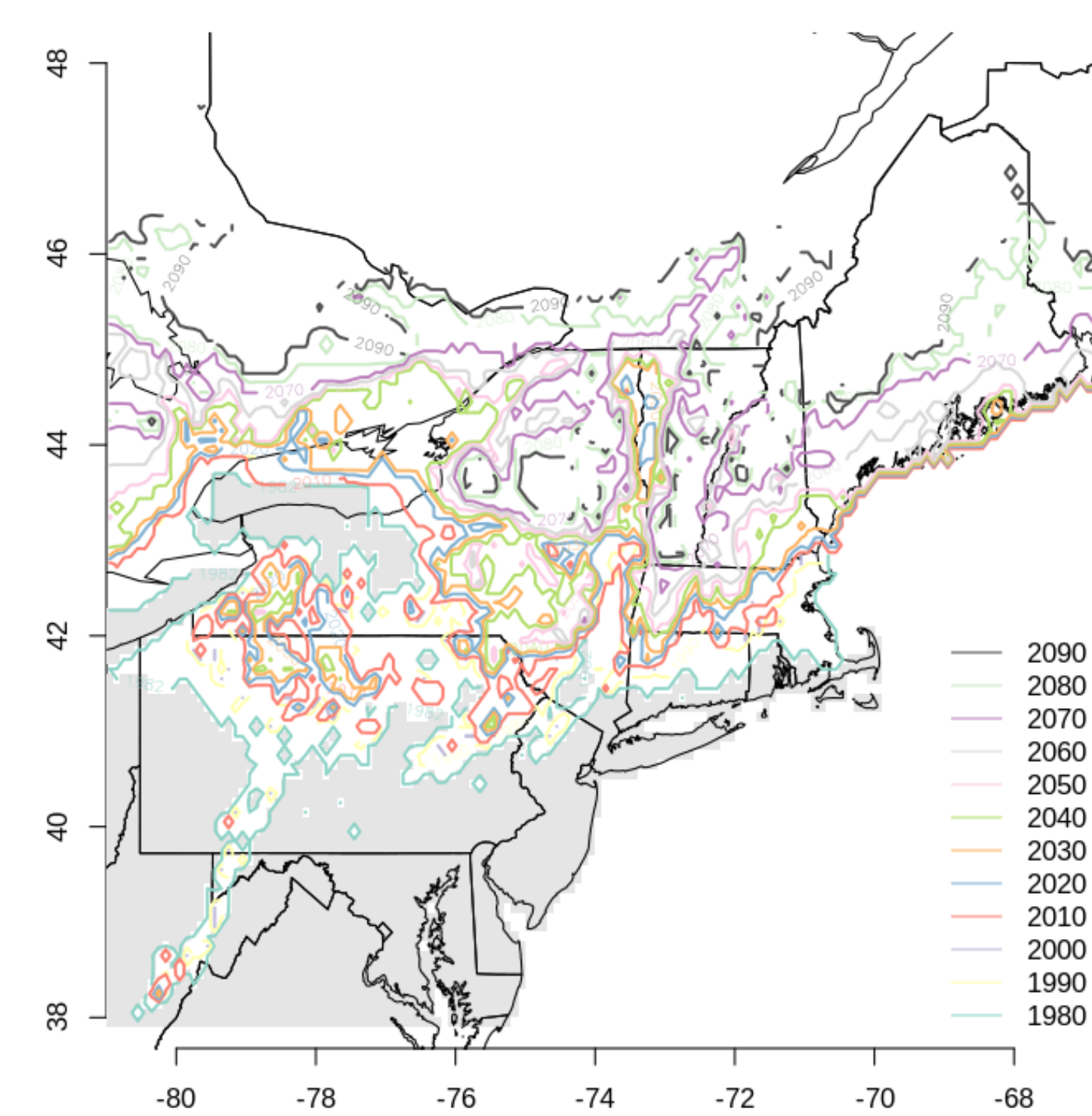
1. The vernal window lengthens and disappears across northeastern North America



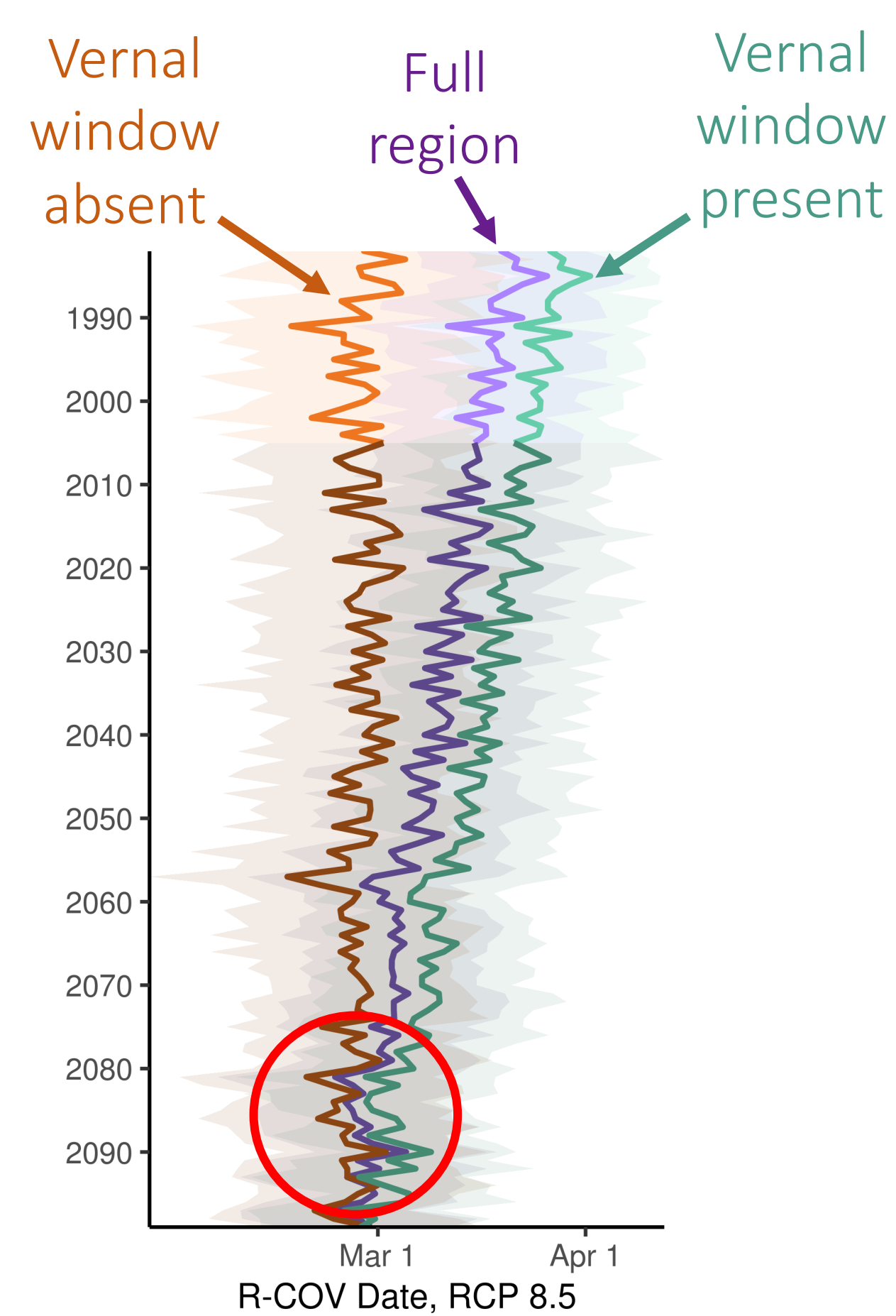
Snow-free region increases from 27% to 43 – 59% (grey).
 Snow disappearance occurs earlier.
 Bud break shifts to an earlier date, but not as early as snow melt.
 This results the vernal window lengthening by 2 - 3 weeks by 2100.

2. Snowmelt is replaced by rain as the main control of spring hydrologic fluxes

Contours show the loss of the vernal window by decade



Spring hydrology in the vernal window-present region becomes similar to that of the vernal window-absent region.



This change is explained by the shift from snowmelt to rain as the main control on runoff in the vernal window-present region.

Change in spring hydrology has implications for terrestrial and aquatic ecosystems:

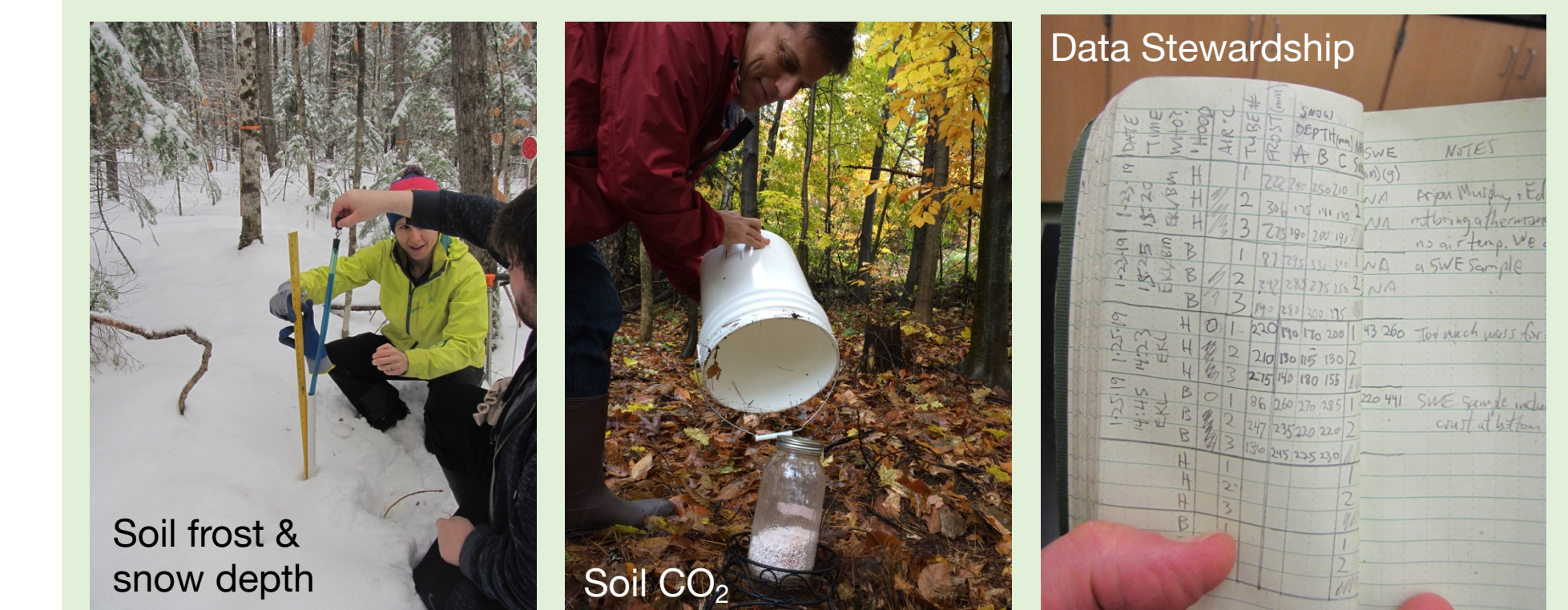
Stream metabolism is impacted by the magnitude and frequency high flow events
Fish habitat and stream metabolism are functions of water temperature
Snowmelt volume and timing influence soil moisture and forest drought resilience

References: ¹Pierce et al. 2014, *J Hydrometeorology*; ²Wisser et al. 2010, *Hydrol. and Earth System Sci.*; ³Grogan, D. *Doctoral Dissertation*; ⁴Hufkens et al. 2018, *Methods in Ecol. and Evol.*

Outreach

Global Learning and Observations to Benefit the Environment: GLOBE (www.globe.gov)

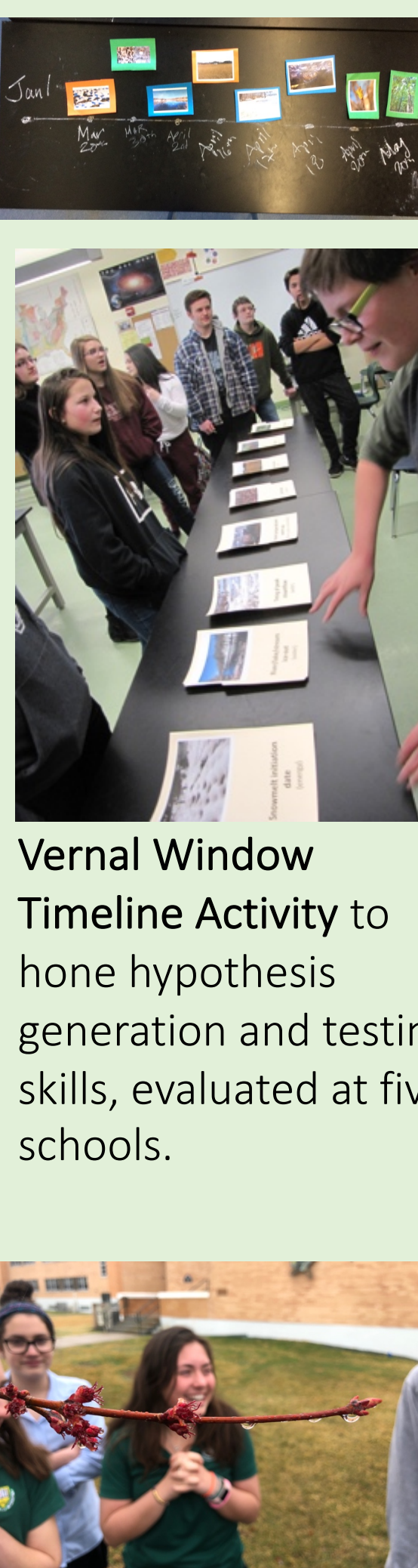
Bundled GLOBE Protocols to track the vernal window, including snow depth, soil frost depth, and canopy green-up and a prototype soda lime base trap protocol to track soil CO₂ efflux.



Students at Old Town High School in Maine implement the bundled GLOBE protocols.

Students work with real-time data through Shiny R

Students build low-cost, modular Arduino sensors to collect data alongside research-grade equipment.



Students presented at the 2019 Northeast GLOBE Student Research Symposium.

GLOBE Paperclip Model adapted to R, open source on GitHub.
<https://github.com/daniellegrogan/Paperclip>



For more information on this project's outreach, see Poster ED21D-1055 on Tuesday December 10 by Edward Lindsey et al.