

What are the impacts of climate change on maple syrup production and can we manage for them?

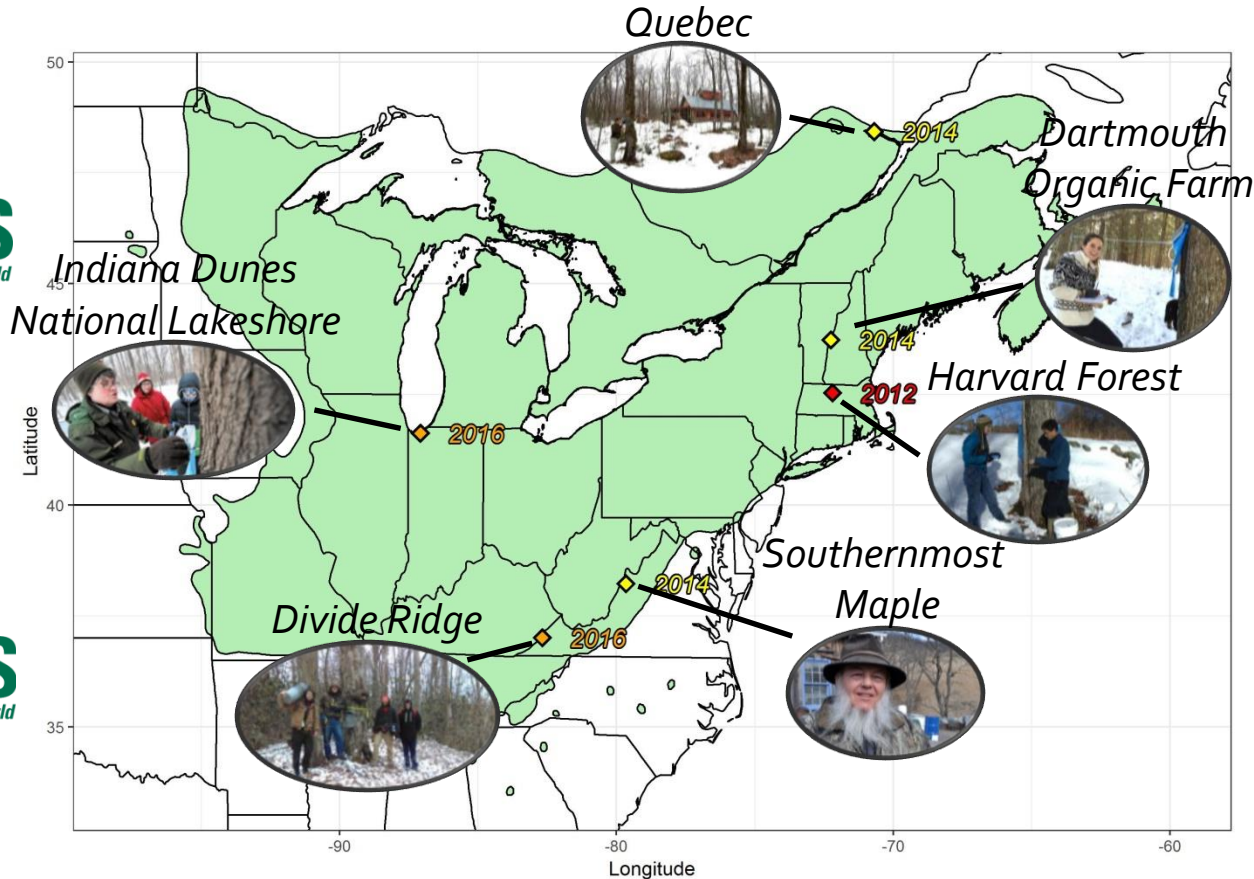


2017 FOREST ECOSYSTEM
MONITORING COOPERATIVE
CONFERENCE

ACERnet: Acer Climate and Socio-Ecological
Research Network

ACERnet – Acer Climate and Socio- Ecological Research Network

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- Dartmouth Organic Farm
- UMass
- Dartmouth Environmental Studies Program
- Harvard Forest
- Tufts University
- Hollins University
- University of Virginia at Wise
- Montana State University
- National Institutes of Health NIGMS Montana IDeA Network for Biomedical Research Excellence
- Universite du Quebec a Chicoutimi

ACERnet – Acer Climate and Socio- Ecological Research Network

- How are the timing of the maple tapping season and the amount of syrup produced influenced by climate?
- How could climate change impact the maple tapping season?
- How is sap chemistry, which contributes to syrup flavor, influenced by climate?
- How are maple producers recognizing and responding to climate change?

Finding the sweet spot: climate optimum for maple syrup production



Joshua Rapp

University of Massachusetts Amherst and Harvard Forest

How is maple syrup produced?

- Xylem sap collected by 'tapping' maple trees
- Tapping season is late winter / early spring when frequent freeze-thaw cycles occur
- Sap is concentrated, most commonly by boiling
- Sugar maple is the most commonly tapped tree species



Photo by Hannah Leitheiser

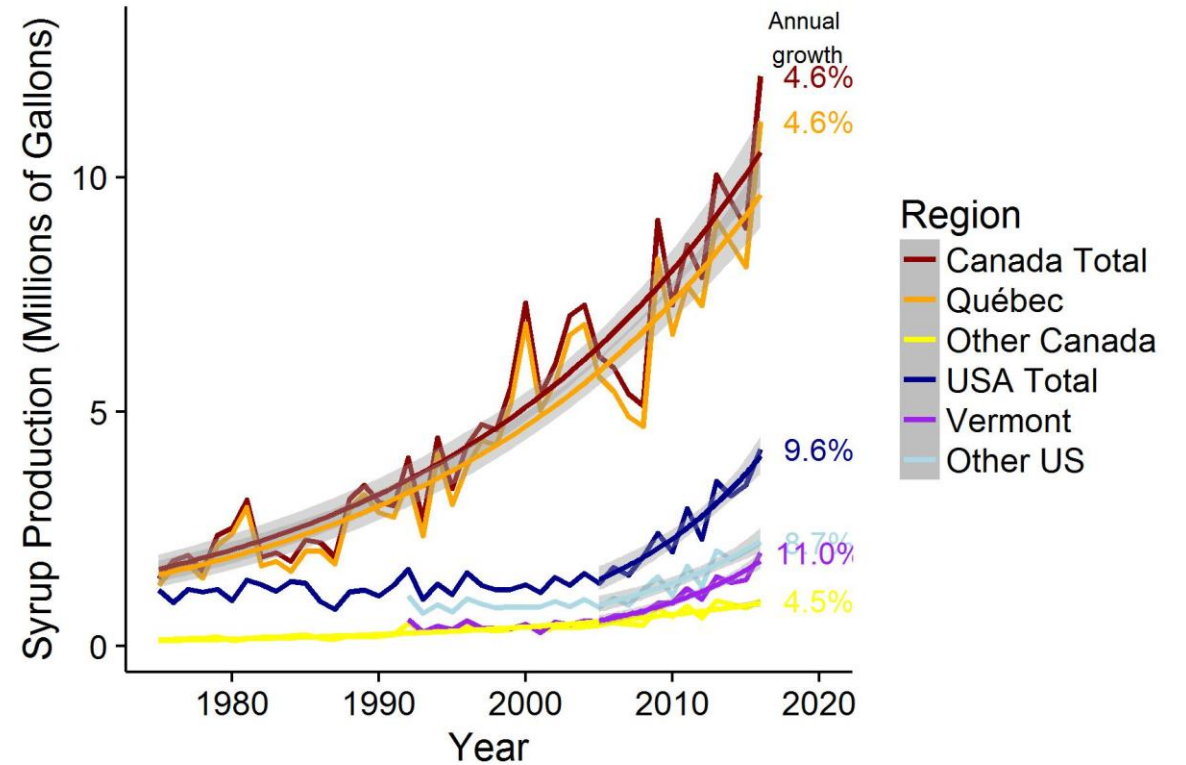
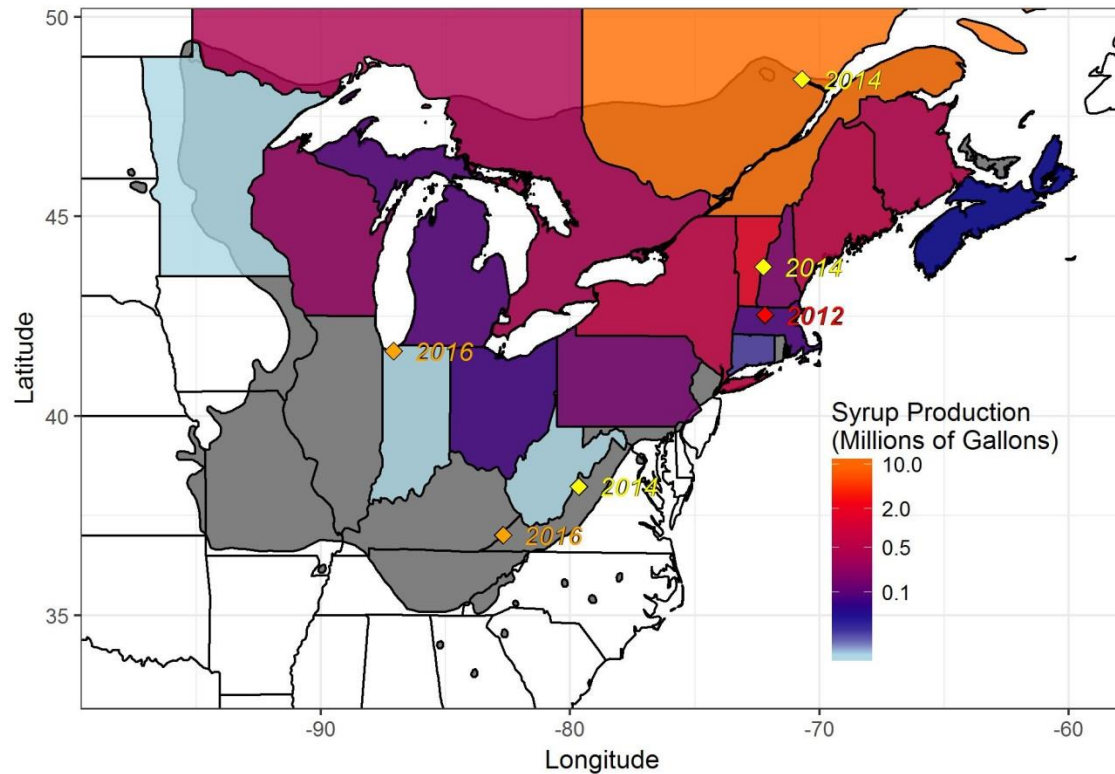


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Eastman Johnson, *Sugaring Off*, c. 1865, oil on canvas, Museum of Art, Rhode Island School of Design

Where is maple syrup produced?



What are the potential impacts of climate change on maple syrup production?

- Tree availability
- Tree health
- Timing and length of the tapping season
- Quantity and quality of sap



Tree availability

- Range shifts predicted but timing uncertain

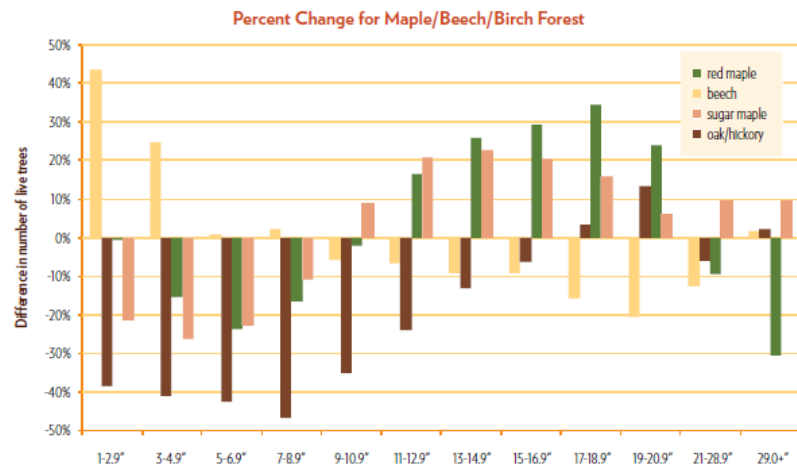
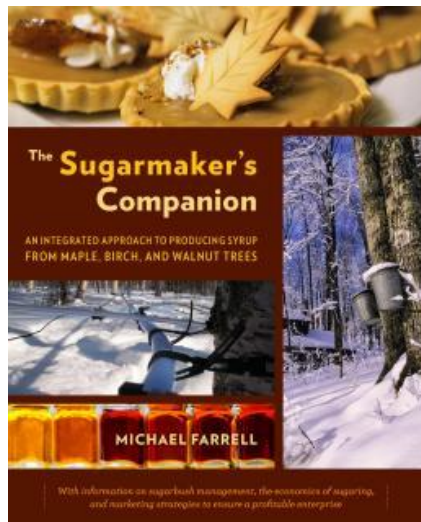
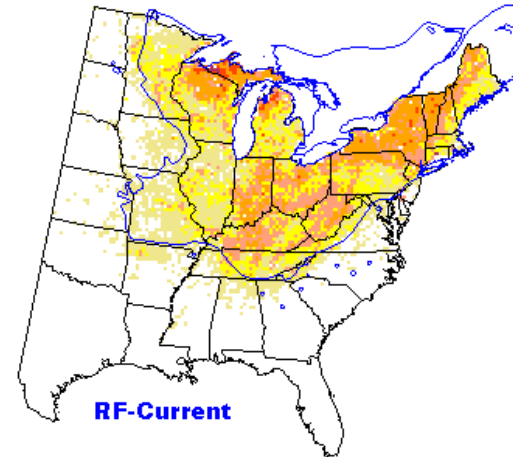
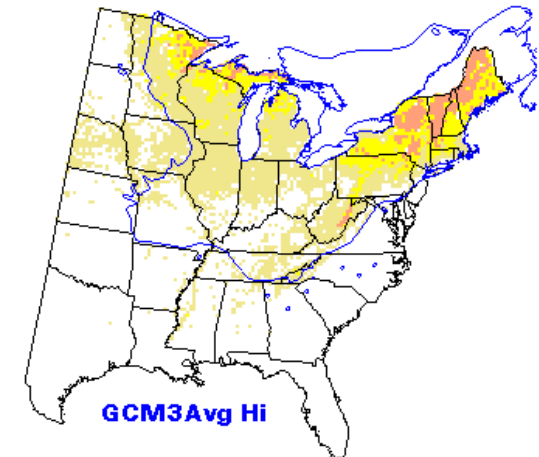


FIGURE 16.4. Percent difference in total number of live trees from oldest to most recent FIA survey for maple/beech/birch forest types in eastern United States.

Current Sugar Maple Habitat



Projected Future Habitat



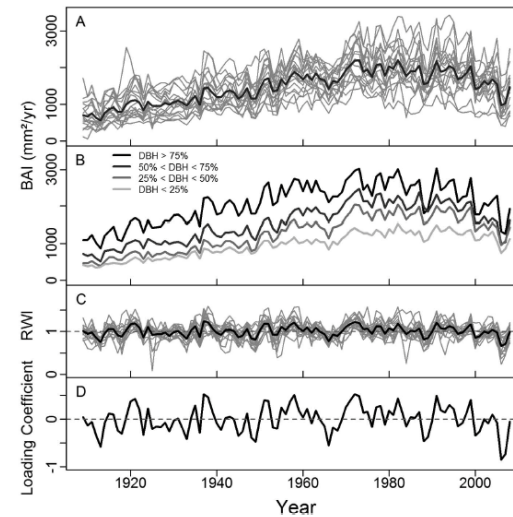
Prasad, A. M., L. R. Iverson., S. Matthews., M. Peters. 2007-ongoing. A Climate Change Atlas for 134 Forest Tree Species of the Eastern United States

Tree health

- Many aspects to tree health
- Growth effects negative to positive depending on context

Regional growth decline of sugar maple (*Acer saccharum*) and its potential causes

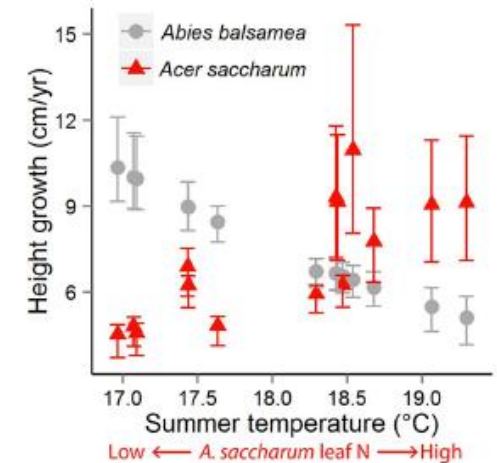
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Adirondacks – canopy trees

Temperature and leaf nitrogen affect performance of plant species at range overlap

NICHOLAS A. FISICHELLI,¹ † ARTUR STEFANSKI,² LEE E. FRELICH,² AND PETER B. REICH^{2,3}



Great Lakes - saplings

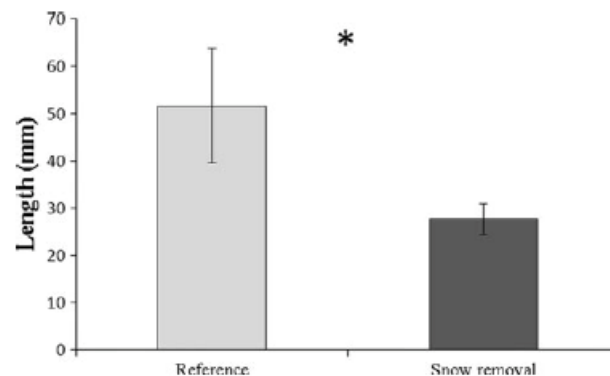


Fig. 2 Mean terminal shoot lengths (\pm SE) for sugar maple trees from reference and snow removal plots. Asterisk means are statistically different at $P = 0.058$ based on ANOVA analysis

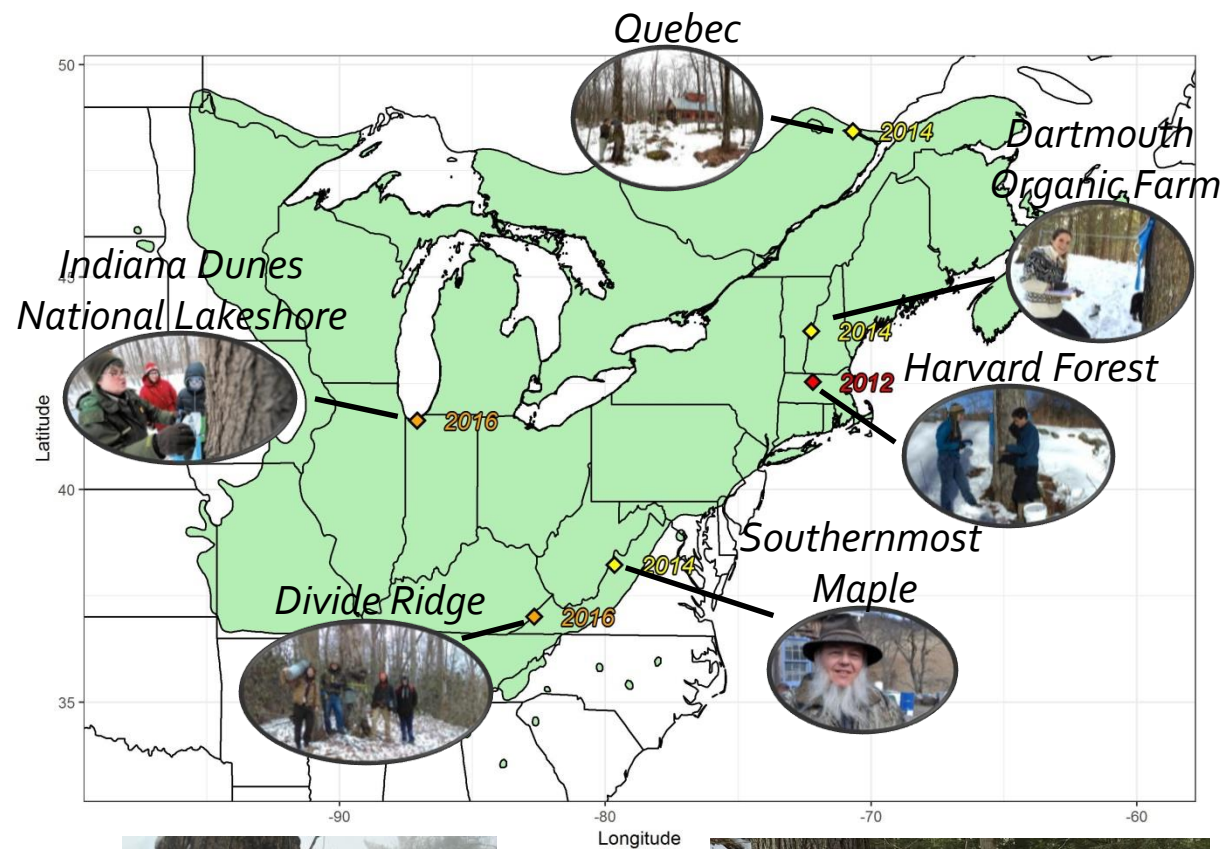
How does climate influence syrup production?

- Research questions:
 1. How does climate impact the timing of sap flow?
 2. How does climate impact the total sap collected in a season?
 3. How does climate impact sap sugar content?
 4. How has/will climate change impact maple syrup production?



Sap sampling

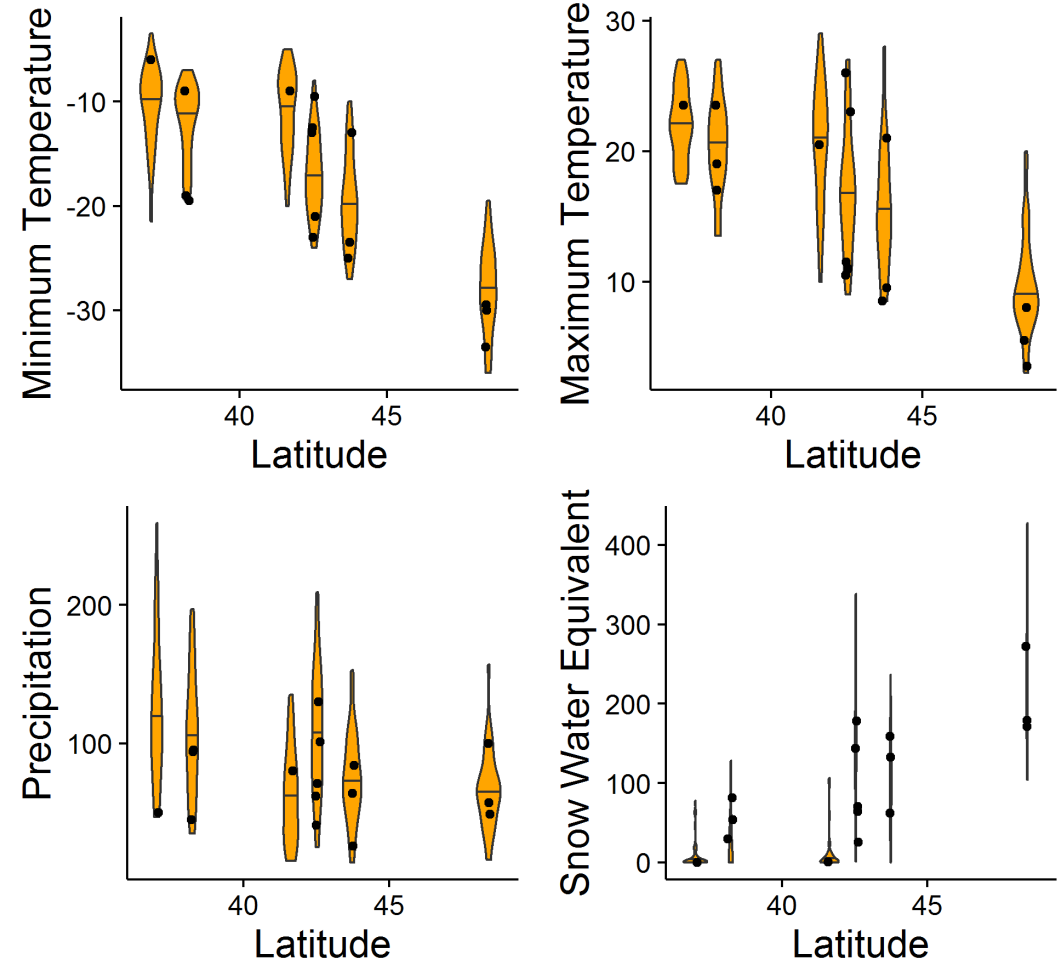
- 6 sites
- Sap samples over 2-6 years per site
- 20 sugar maple trees tapped at each site
- Gravity (bucket) tapping
- Sap weight and sap sugar content measured on sap flow days



Climate data

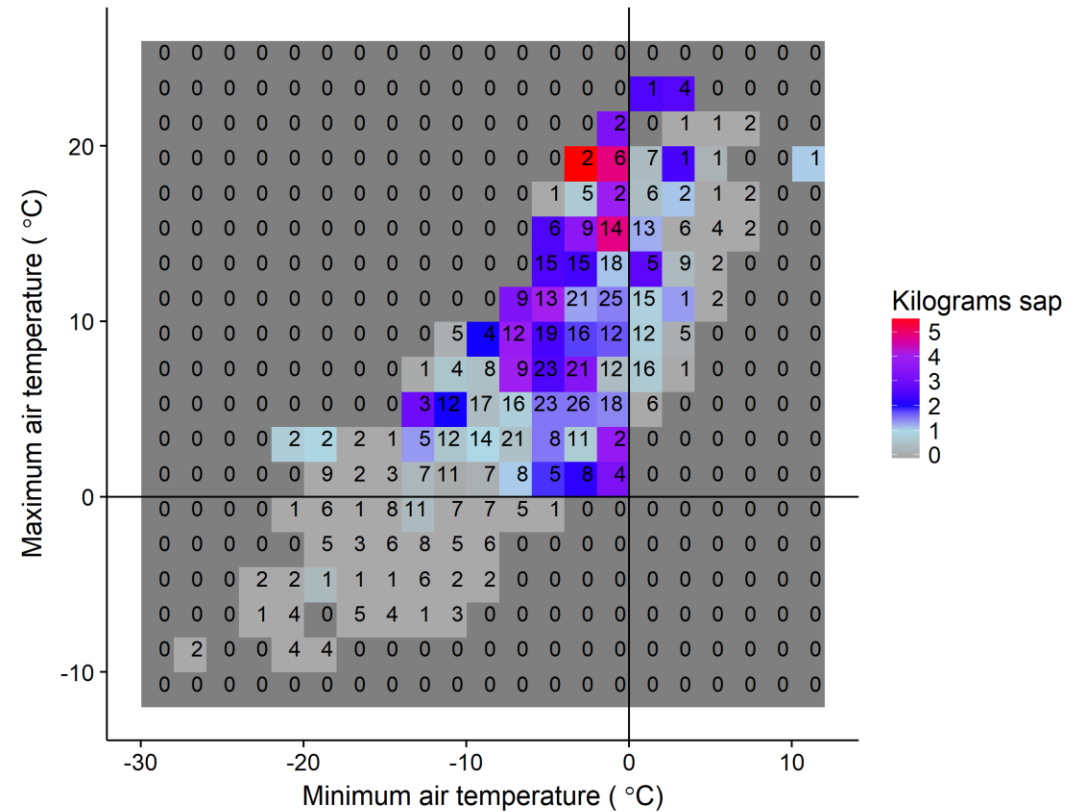
- Daymet daily data
 - Covered complete study area (including Quebec)
 - Calculated monthly means for analysis
 - Sampling period included nearly full range of climate values observed since 1980

March Climate



When does sap flow?

- When there is a freeze-thaw cycle.

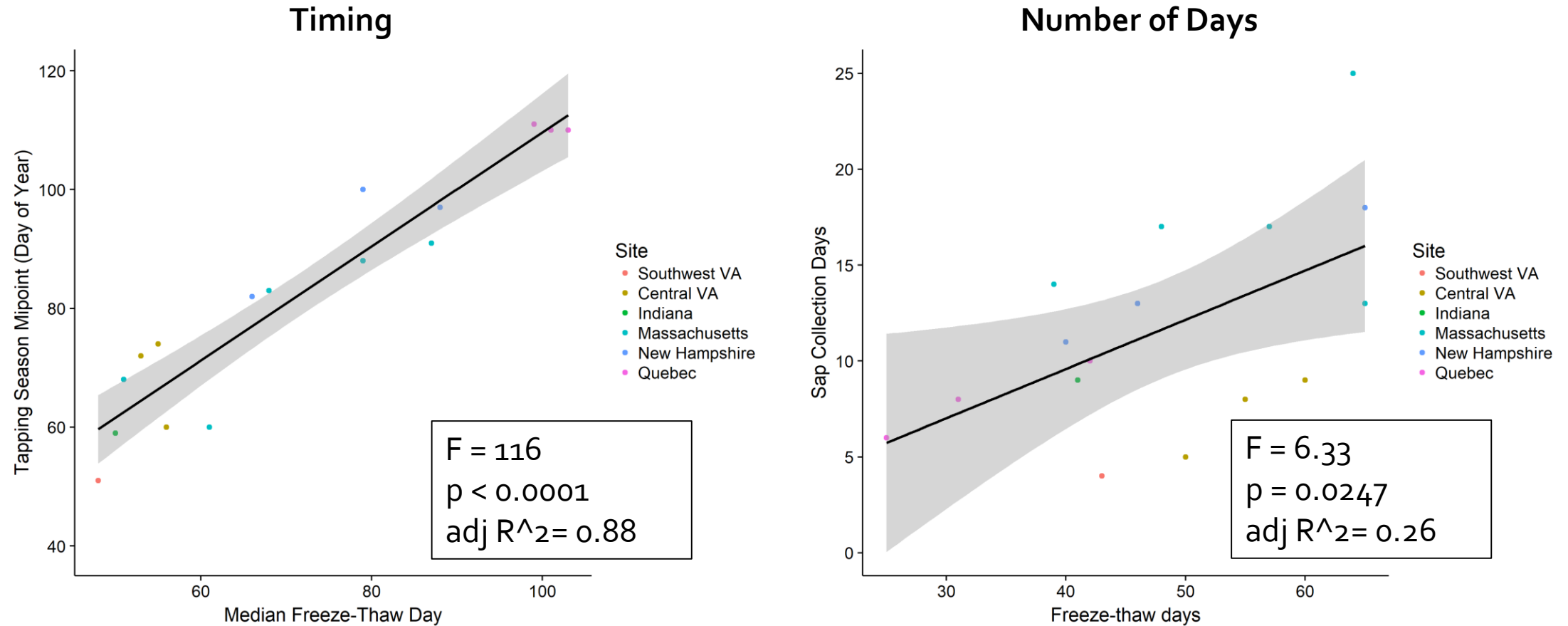


freeze/thaw cycles



sap collections

How is sap flow related to freeze-thaw cycles?

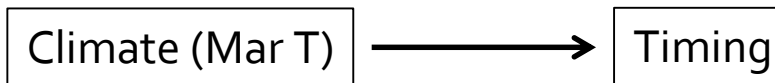
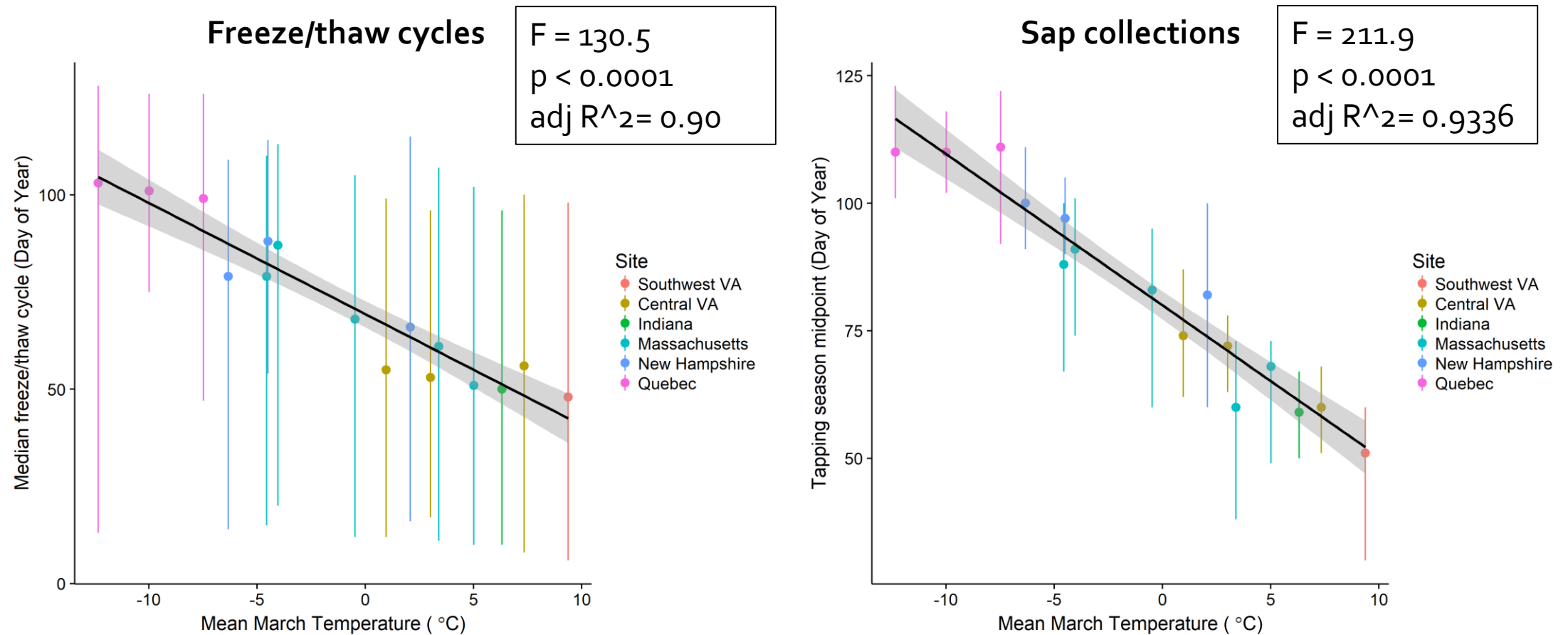


freeze/thaw cycles



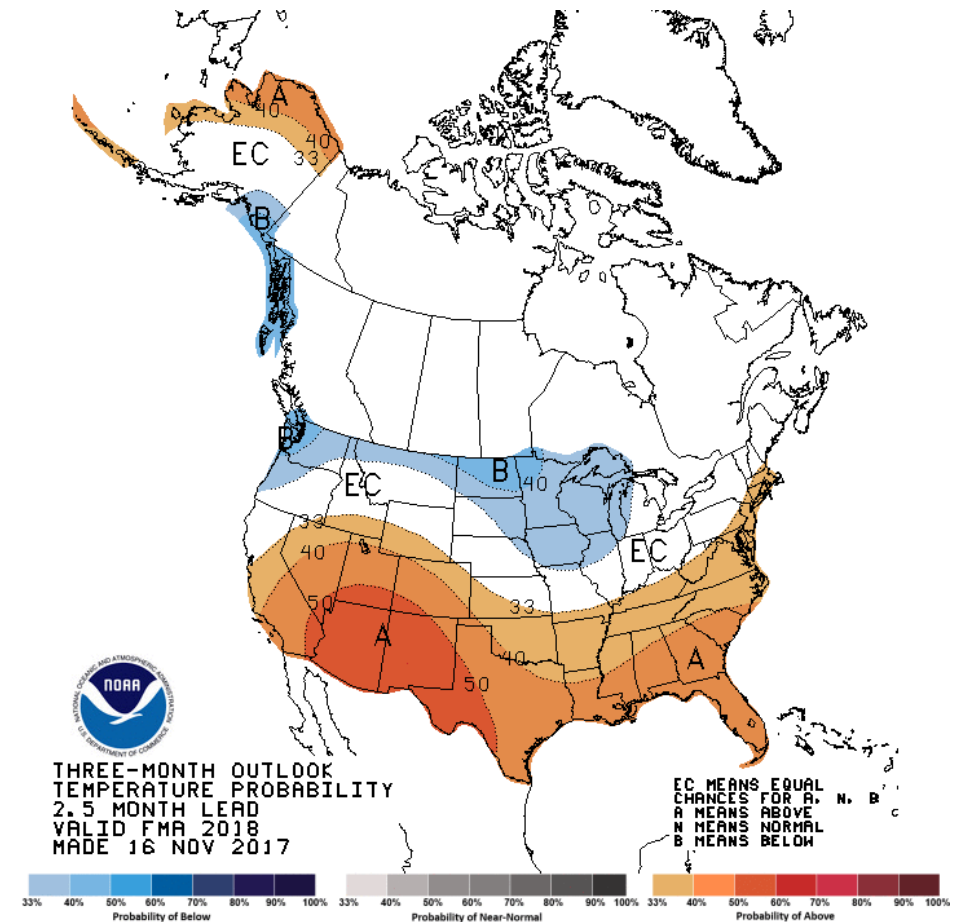
sap collections

How are the timing of freeze/thaw cycles and sap flow related to climate?



Summary: timing of sap flow

- The timing of freeze-thaw cycles and sap collection are correlated
- March temperature is predictive of when freeze-thaw cycles occur and the timing of sap collection
- Implication: Long range forecasts may help syrup producers decide when to tap



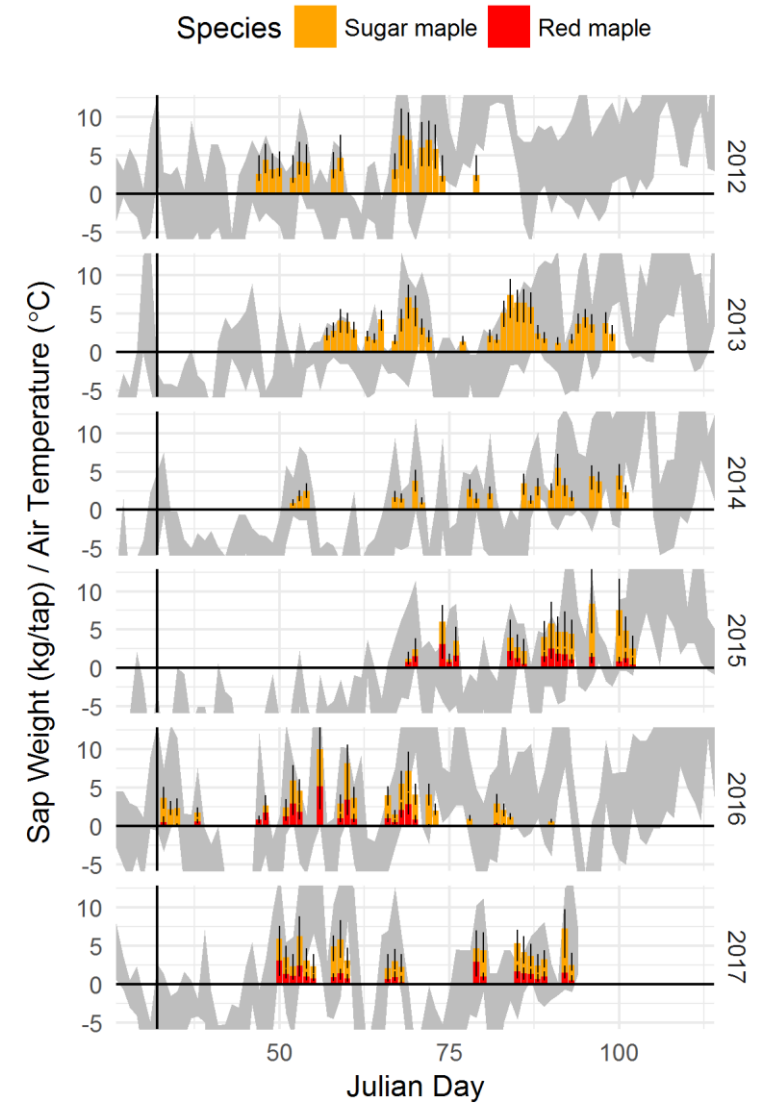
Climate (Mar T)



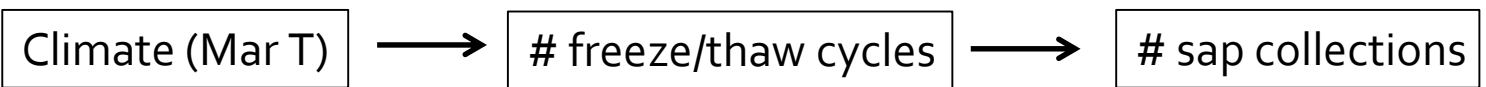
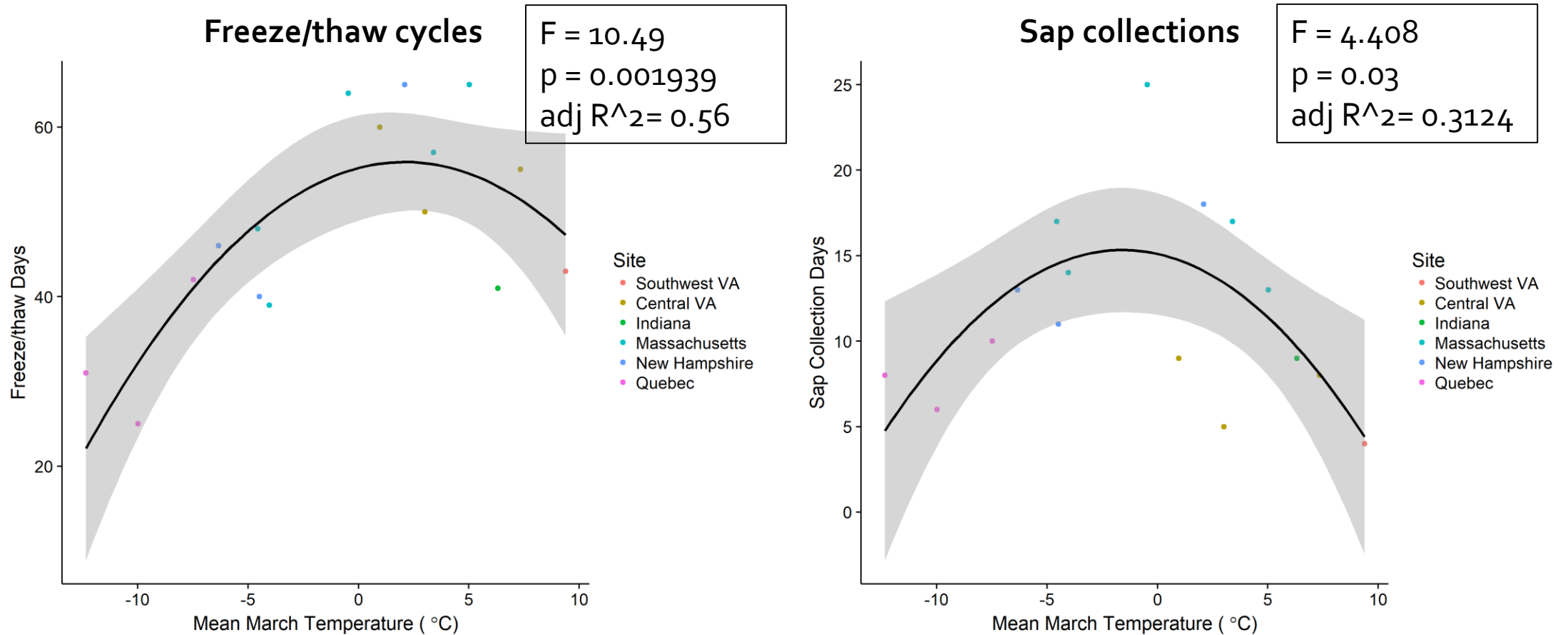
Timing

How does climate affect how much sap a producer can collect?

Sap collected = # collections X amount/collection



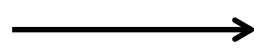
Does climate affect the number of freeze-thaw cycles and sap collections?



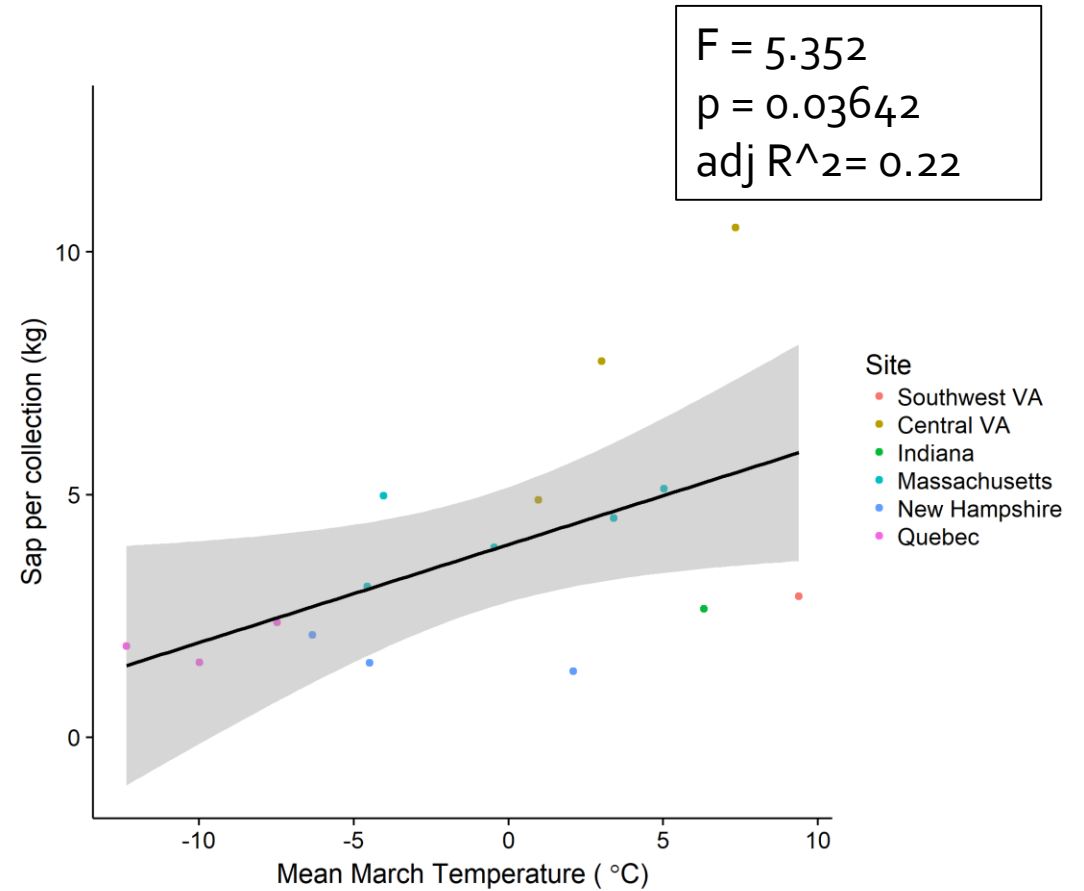
Does climate affect sap flow per collection day?



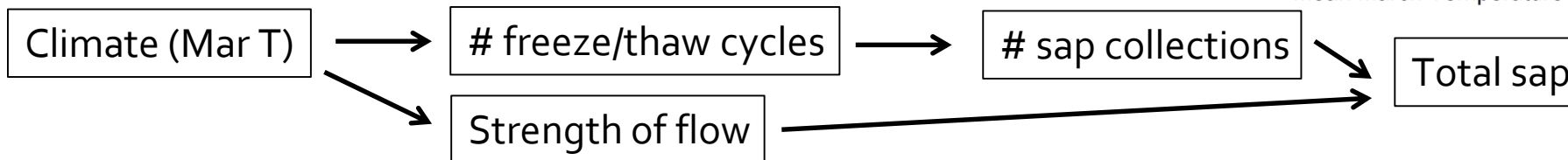
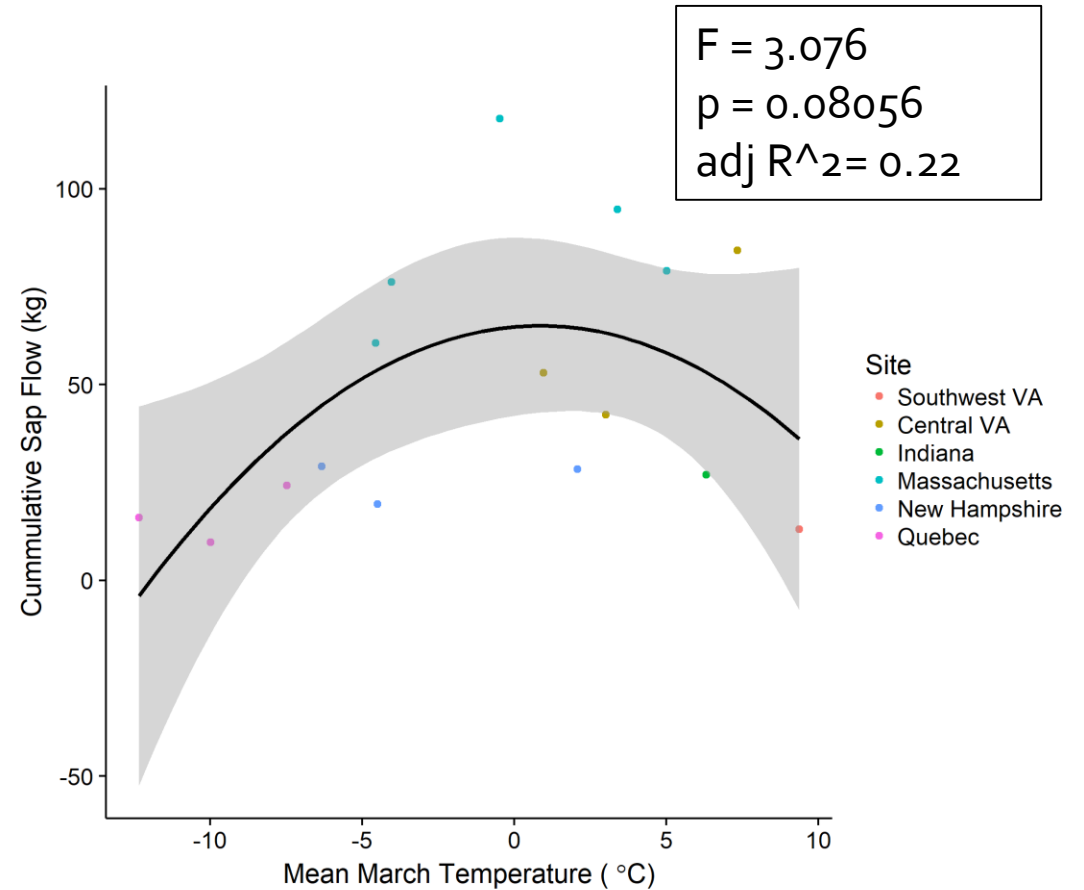
Climate (Mar T)



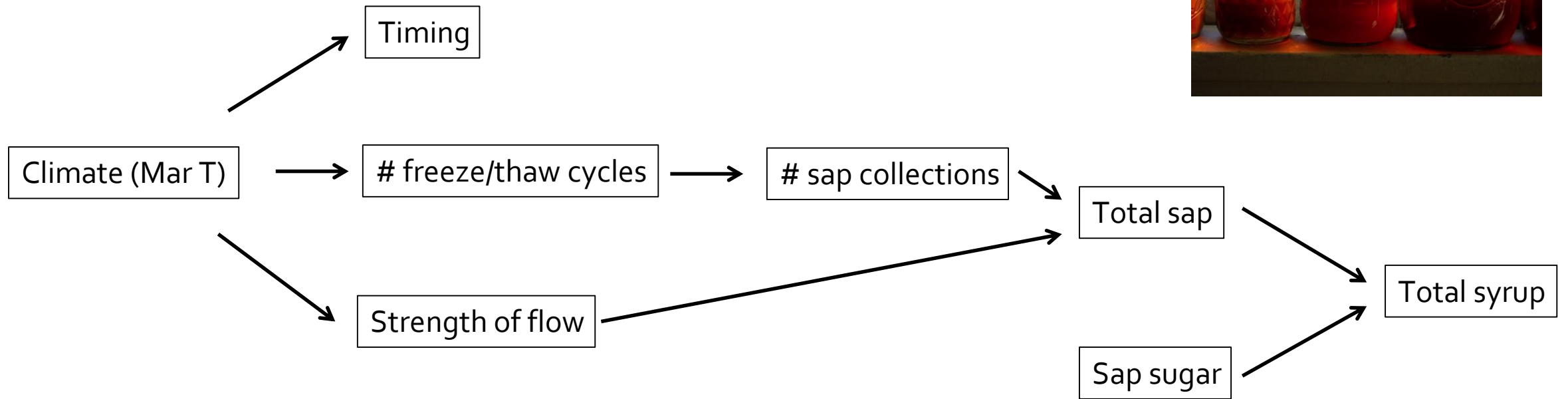
Strength of flow



How does climate affect the total sap collected over the season?

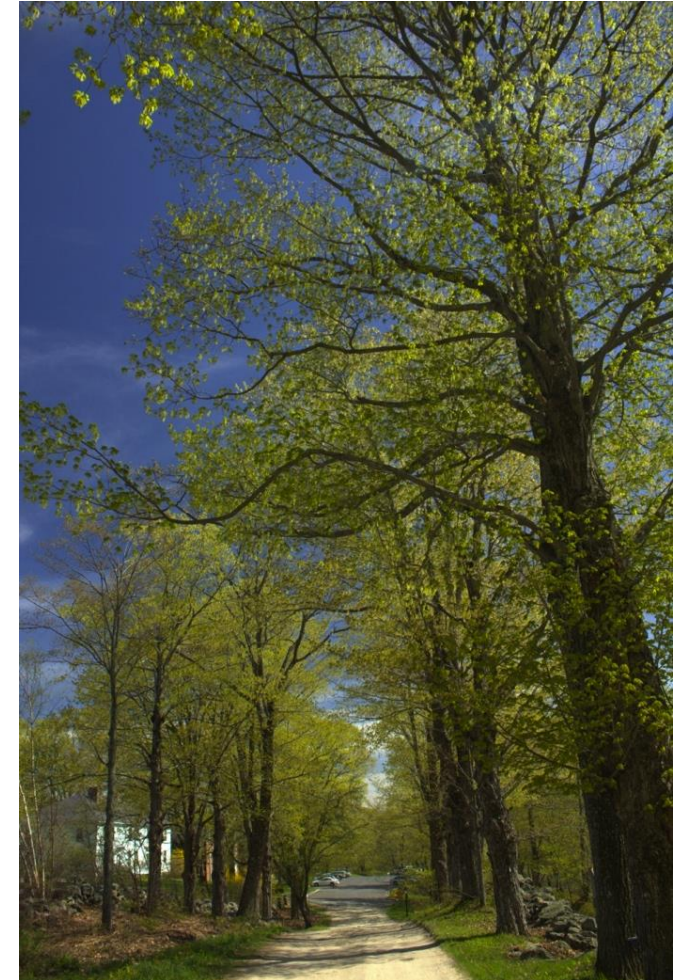


Summary: theoretical framework

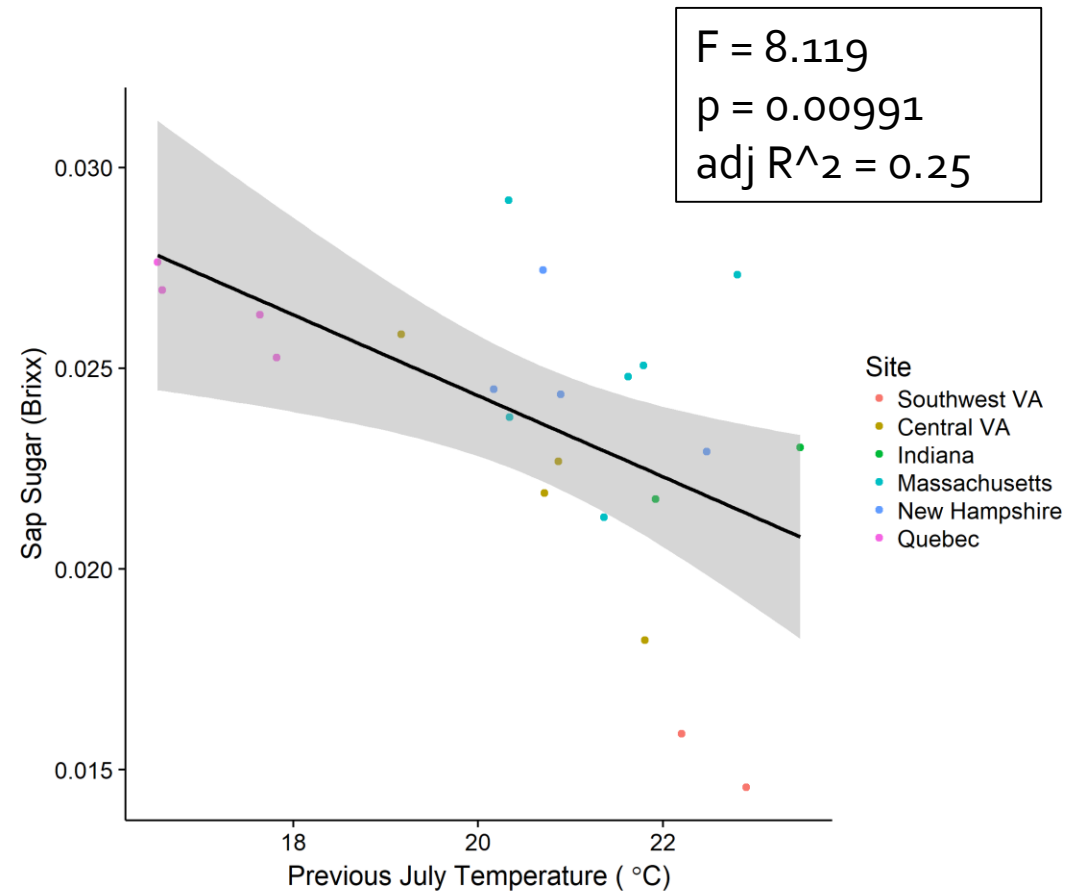
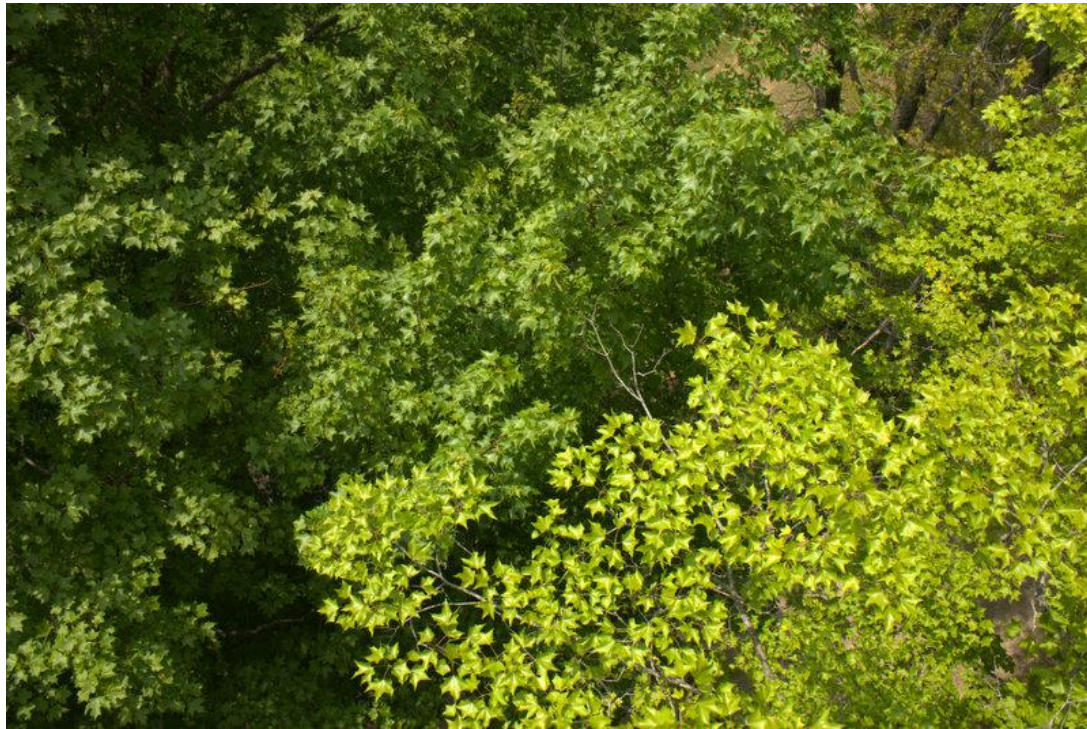


What determines sap sugar content?

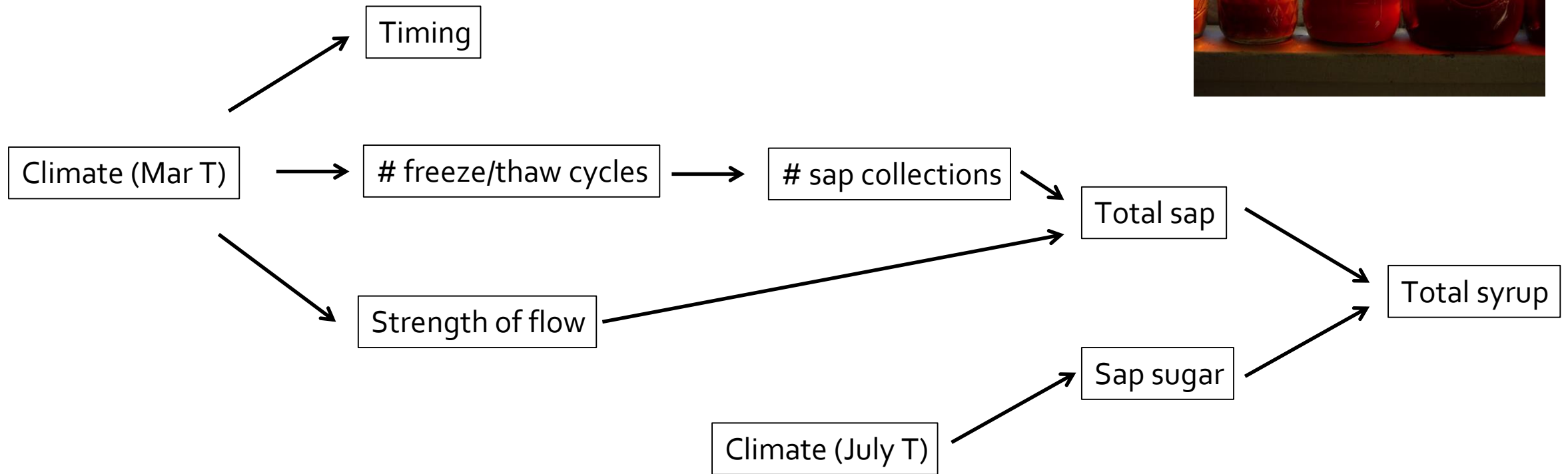
- Sap sugar derives from nonstructural carbohydrates (NSC), sugars and starches stored by the tree in wood
- NSC stores determined by balance of carbohydrate gain through photosynthesis, and use through metabolic activities including growth, reproduction, defense, and maintenance respiration
- Both photosynthesis and metabolism are influenced by temperature, especially temperature during the growing season



Does summer temperature affect sap sugar content in the following year?

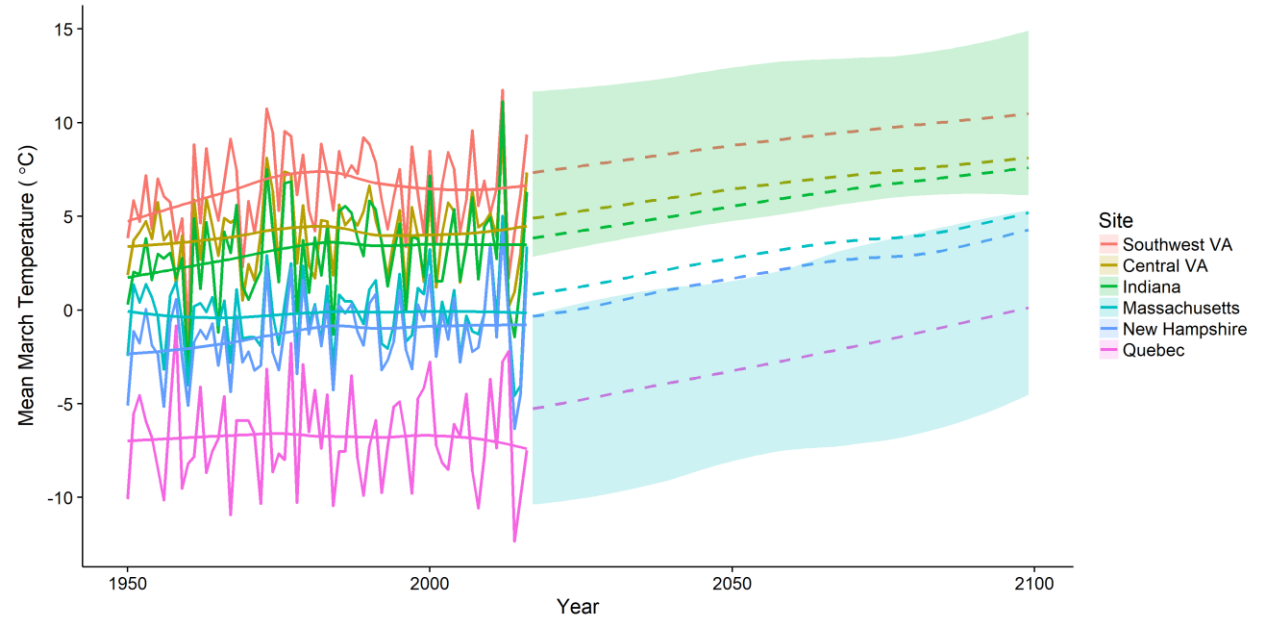


Summary: theoretical framework

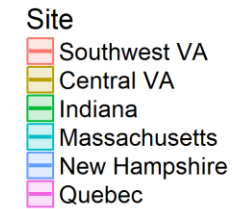
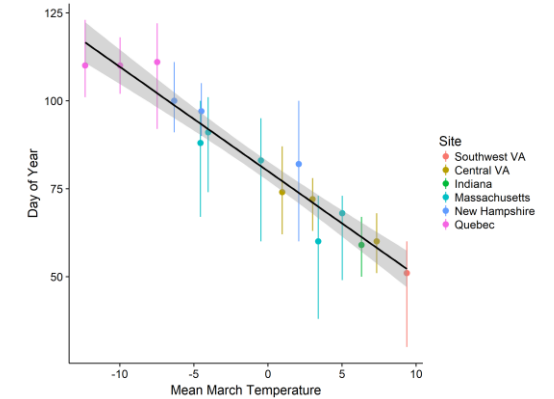
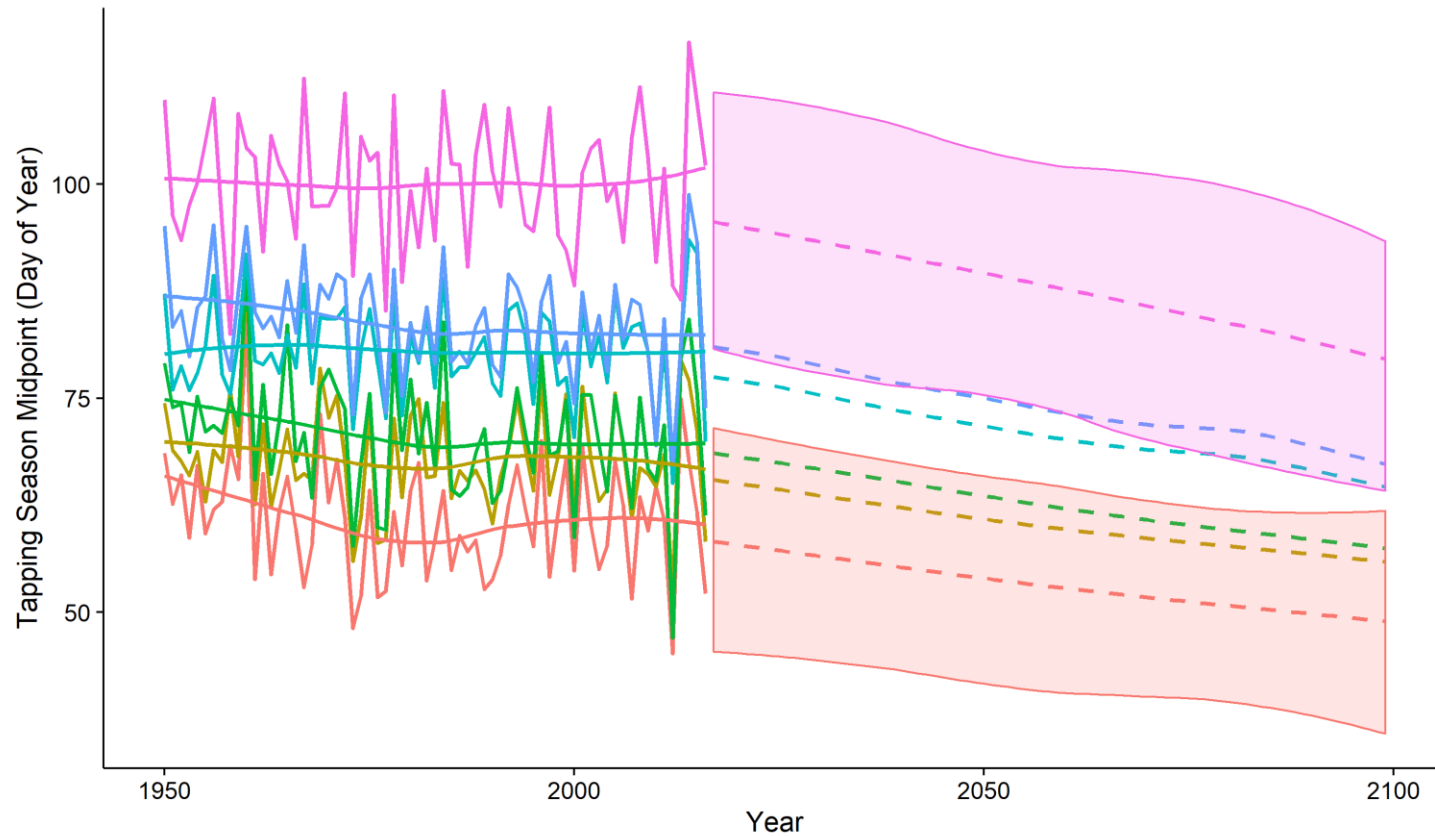


Application: modeling climate change impacts on maple syrup production

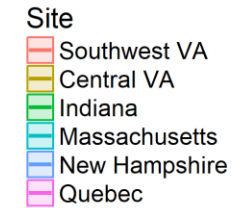
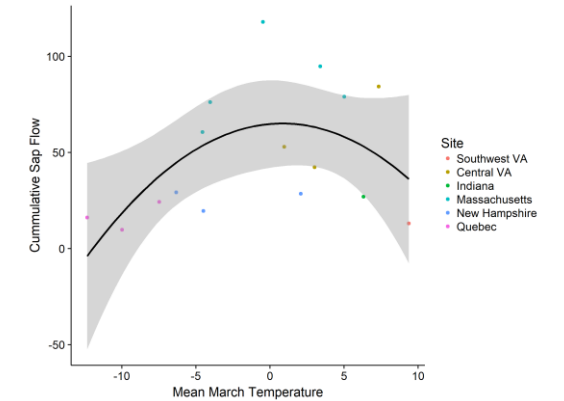
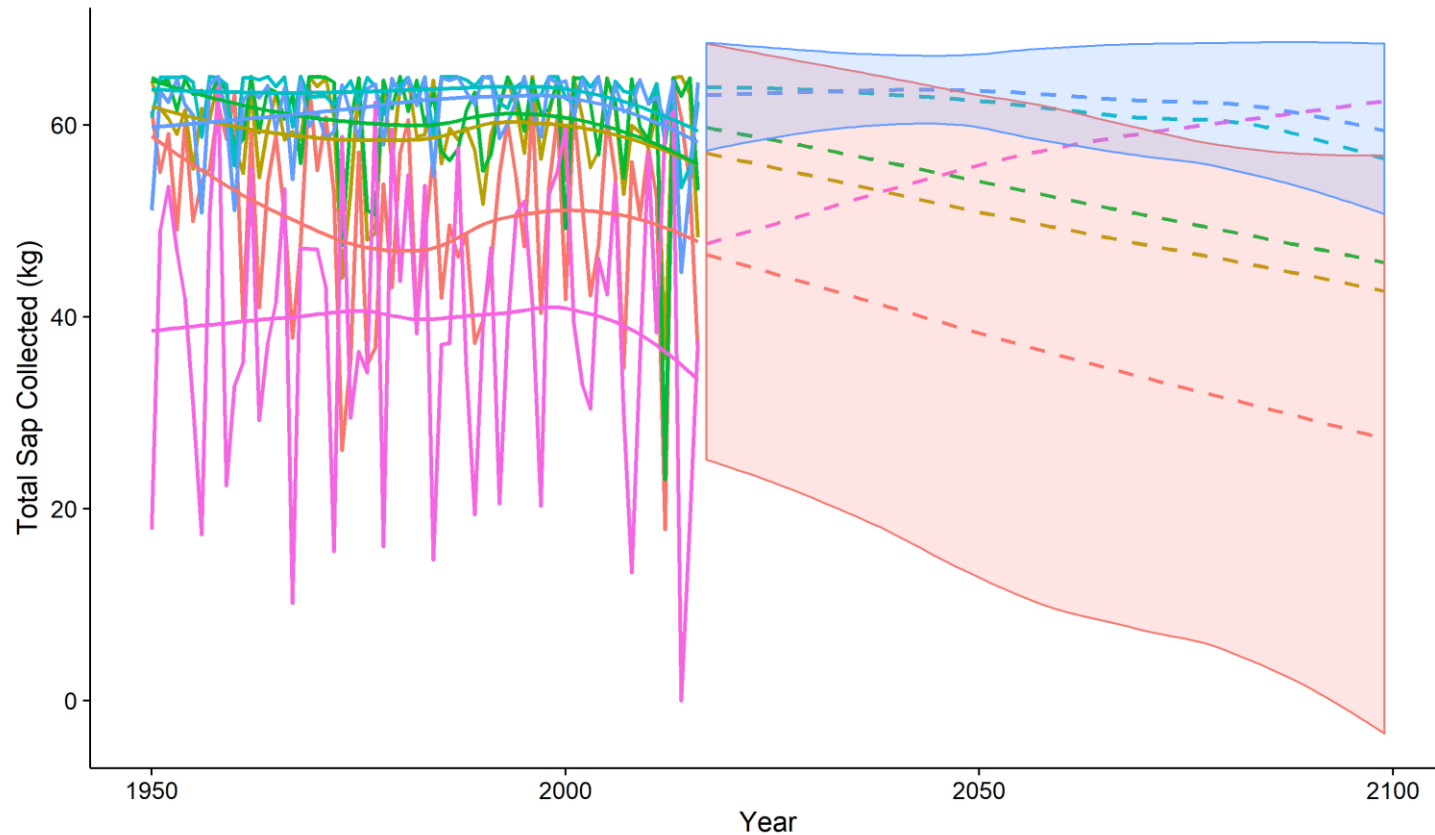
- How has climate variability and change over the past few decades affected the syrup season?
- How could future climate change impact future tapping seasons?



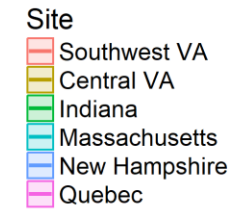
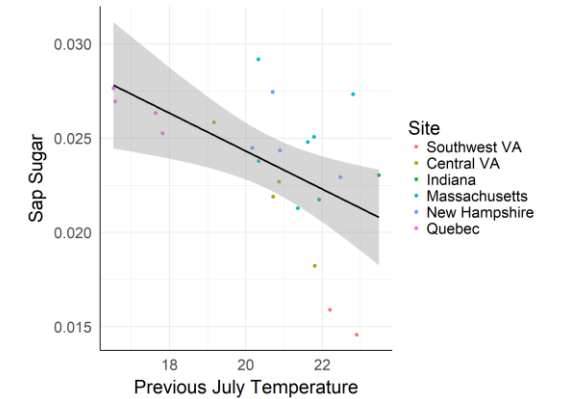
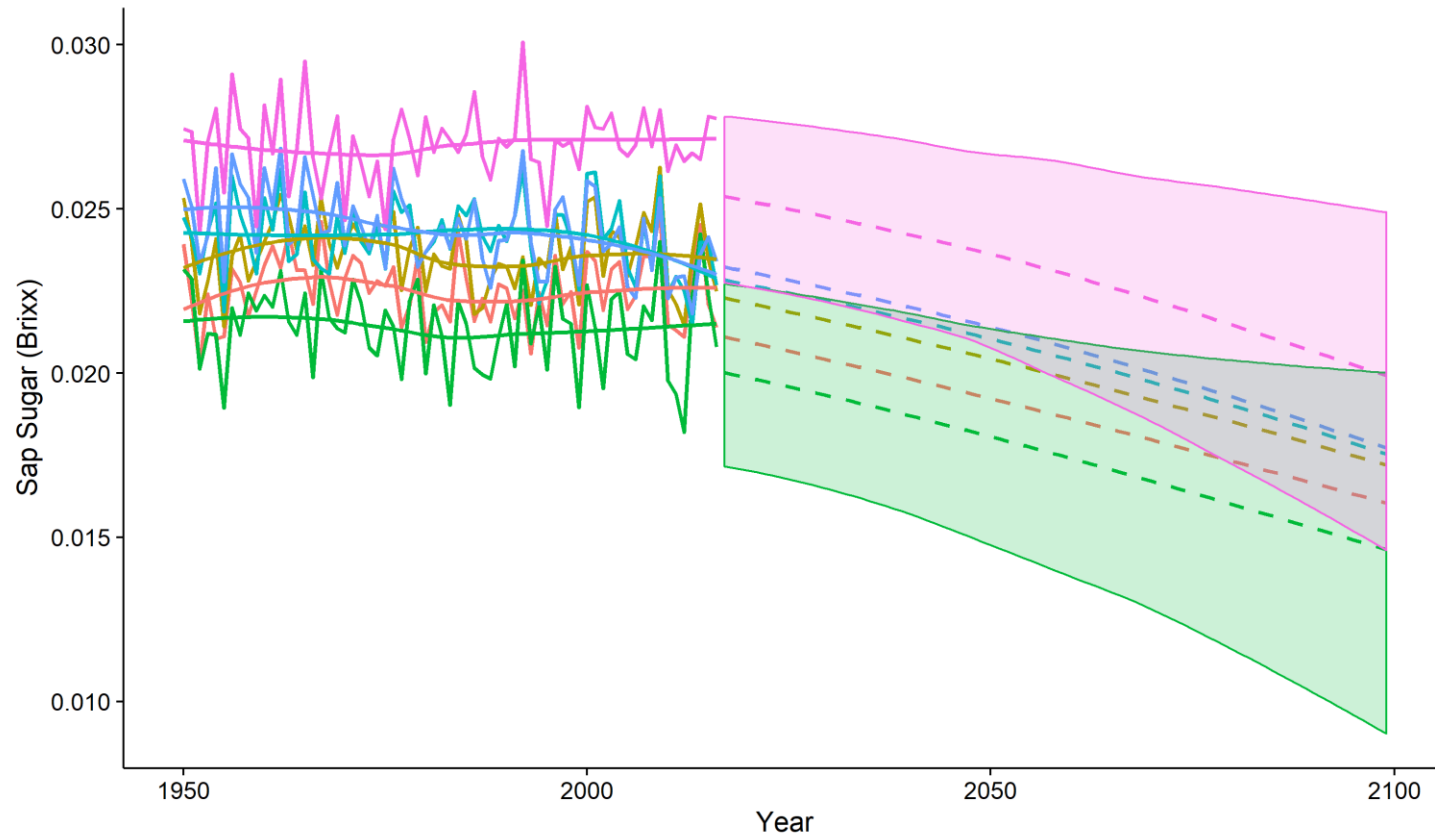
Projection: Mid-point of the sap collection season shifts earlier



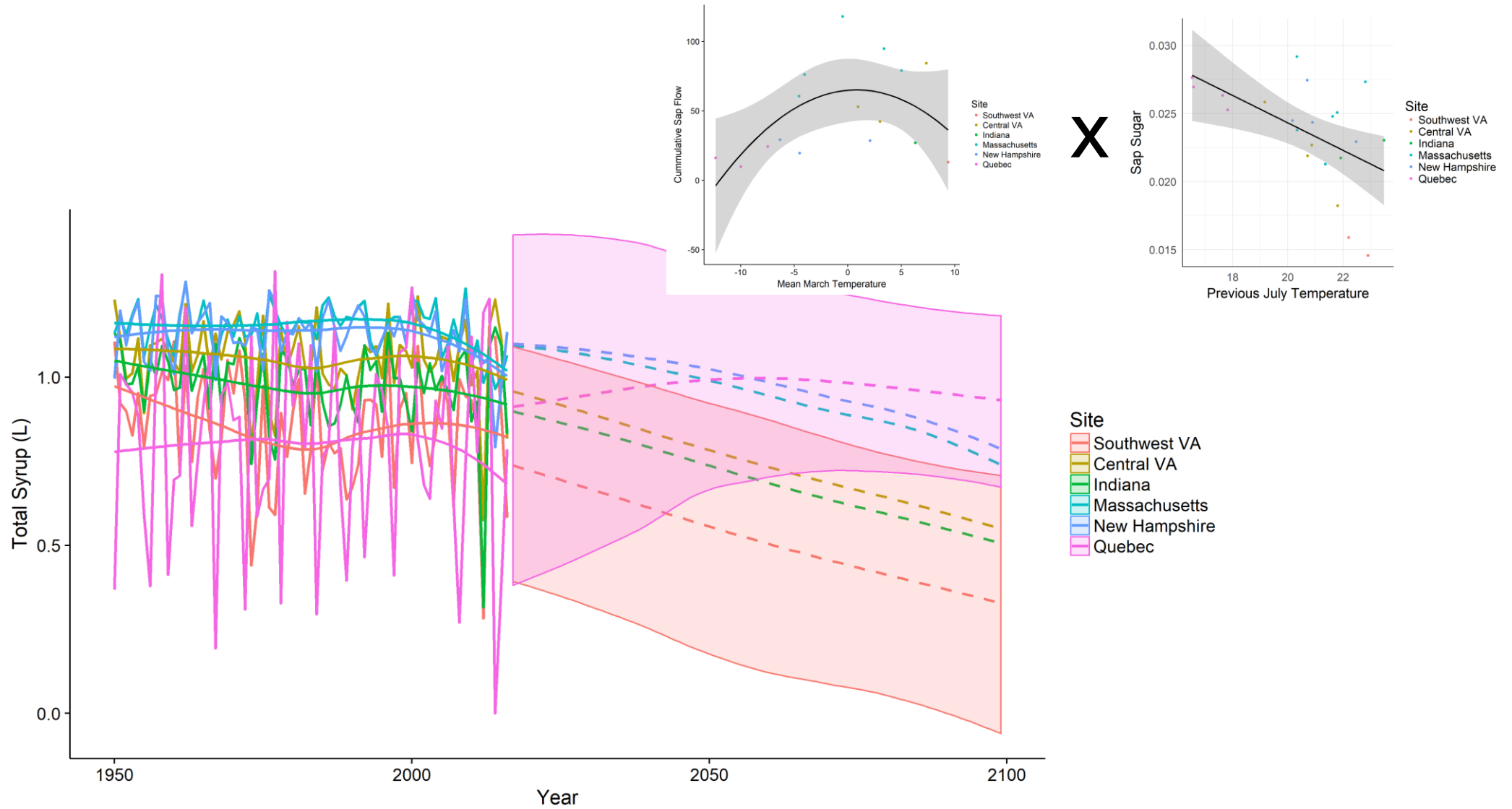
Projection: Less sap collected at warmer sites, more in the north



Projection: Sap sugar content declines



Projection: Less syrup produced except in north

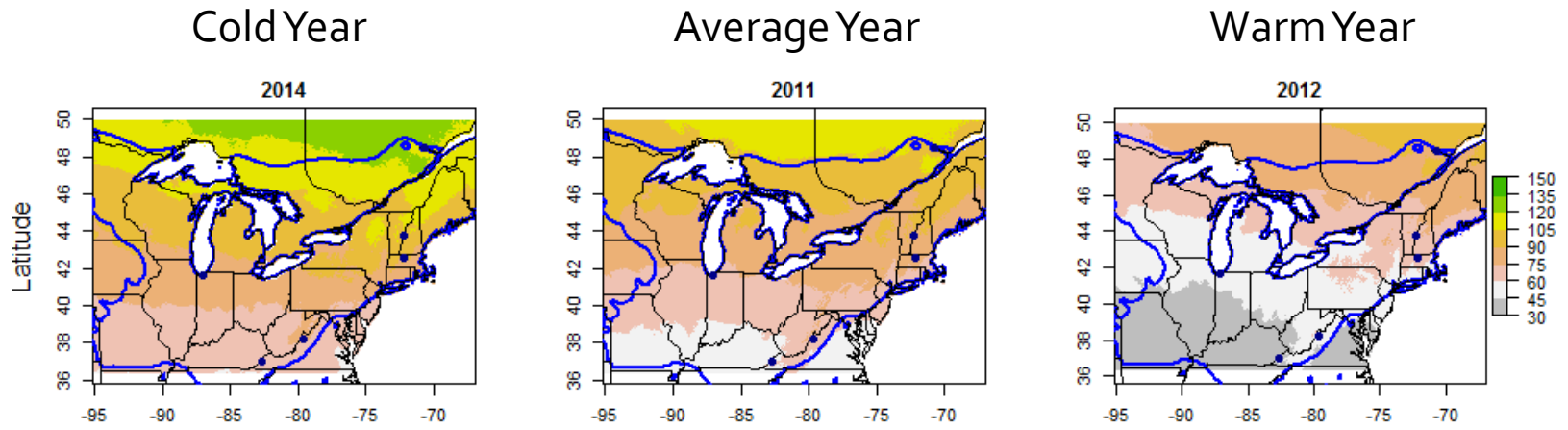


Summary

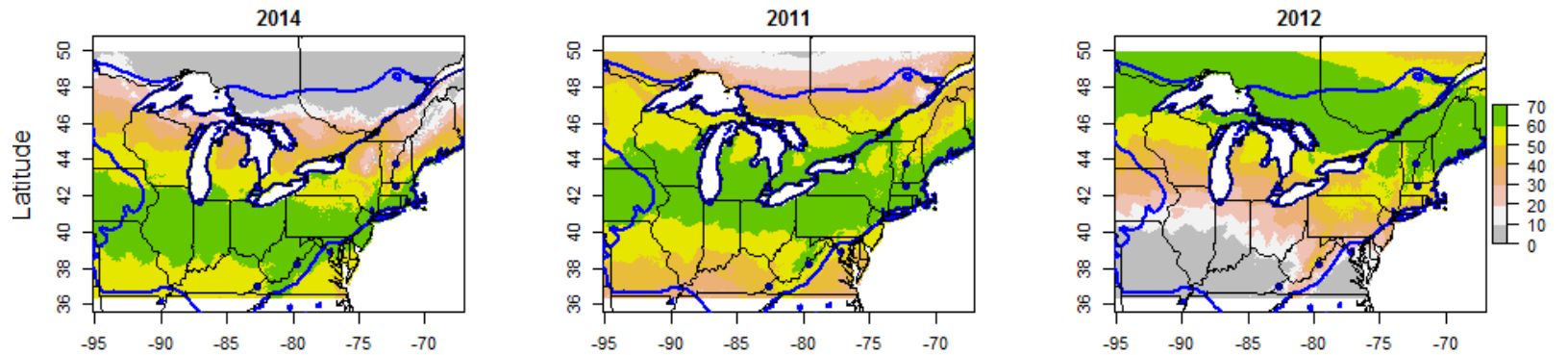
- Climate change impacts
 - Tapping season shifting up to 2-3 weeks earlier by end of century
 - Changes in sap collection depend on location (current climate)
 - Declines in sap sugar content
 - Less syrup produced per tap at most sites



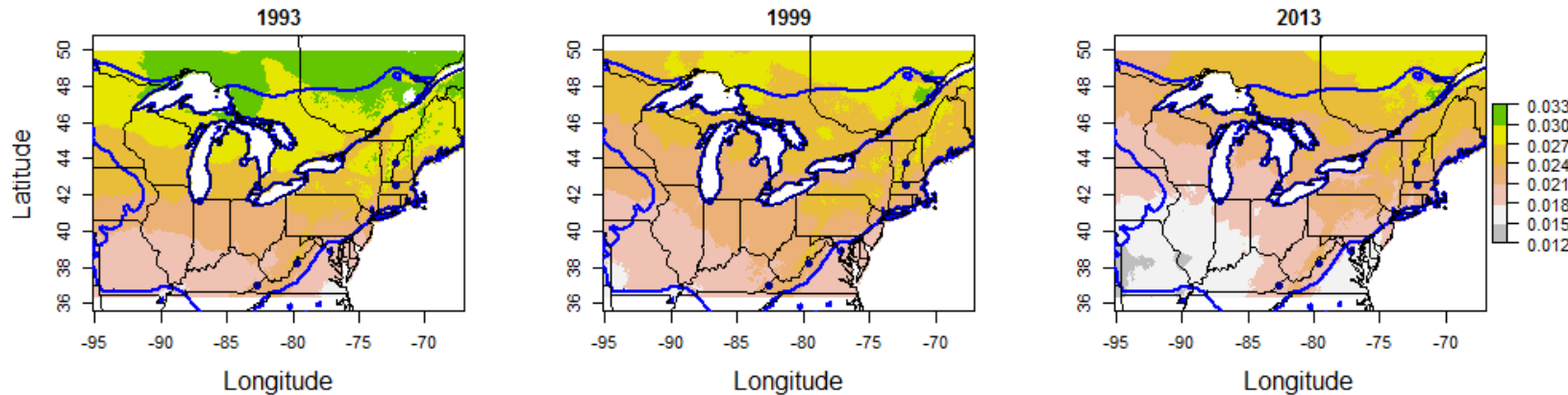
Midpoint of sap collection
(Day of Year)



Sap Flow (kg)

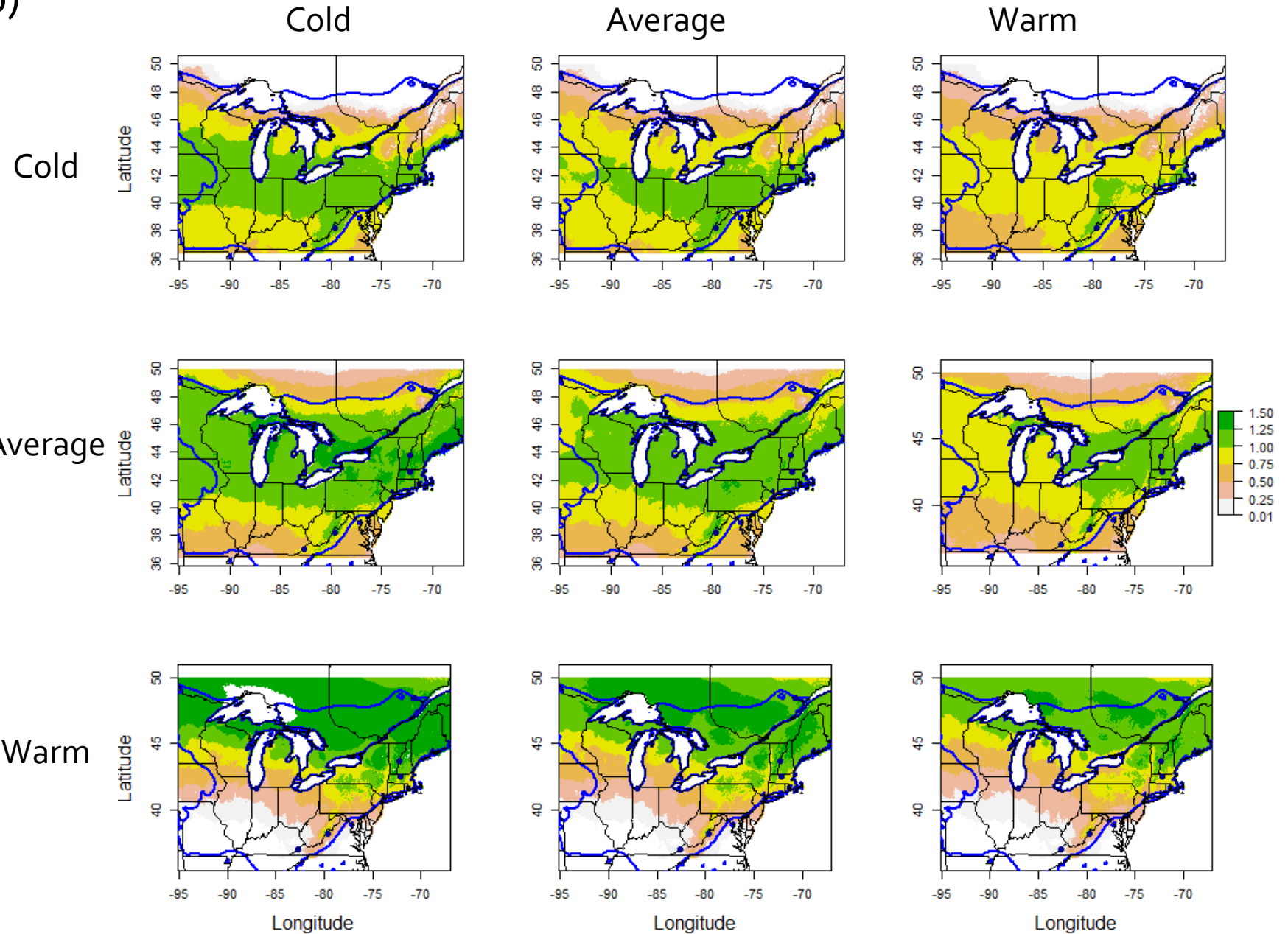


Sap sugar (Brix)

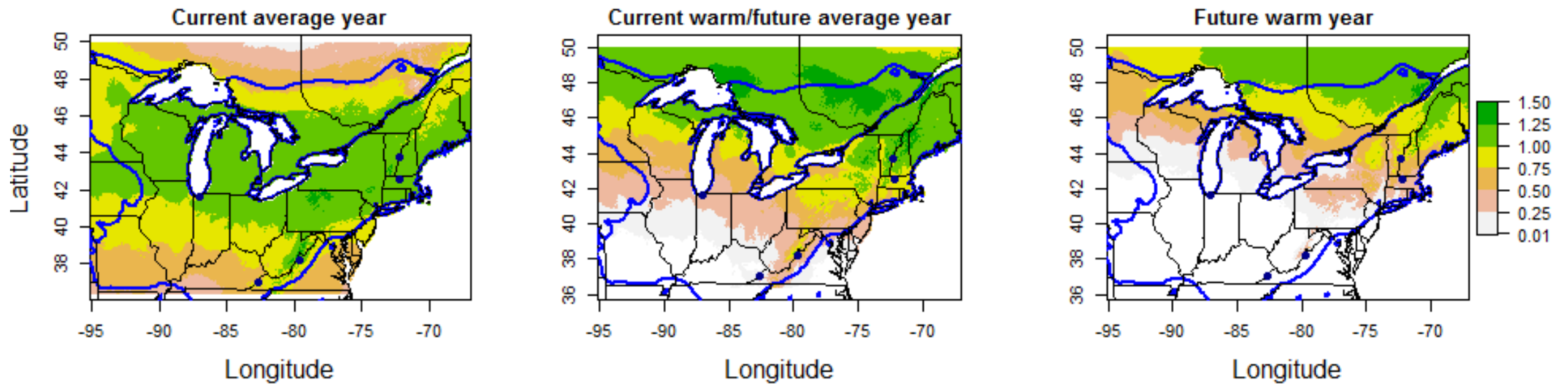


Previous July Temperature

Total syrup (L/tap)



Total syrup (L/tap)



Summary

- Climate change impacts
 - Tapping season shifting up to 2-3 weeks earlier by end of century
 - Less sap collected in most of U.S., but increases at colder/ more northern sites
 - Declines in sap sugar content
 - Less syrup produced per tap at most sites
 - Warm years of the future may not allow syrup production in much of sugar maple's range
- Need to know
 - What other factors influence sap flow and sugar content and how these interact with climate?
 - Do the observed relationships continue outside of observed range of climate?
 - What will inter-annual variability look like in the future?