



# Climate Change Effects on New England's Forests: Shorter and Warmer Winters

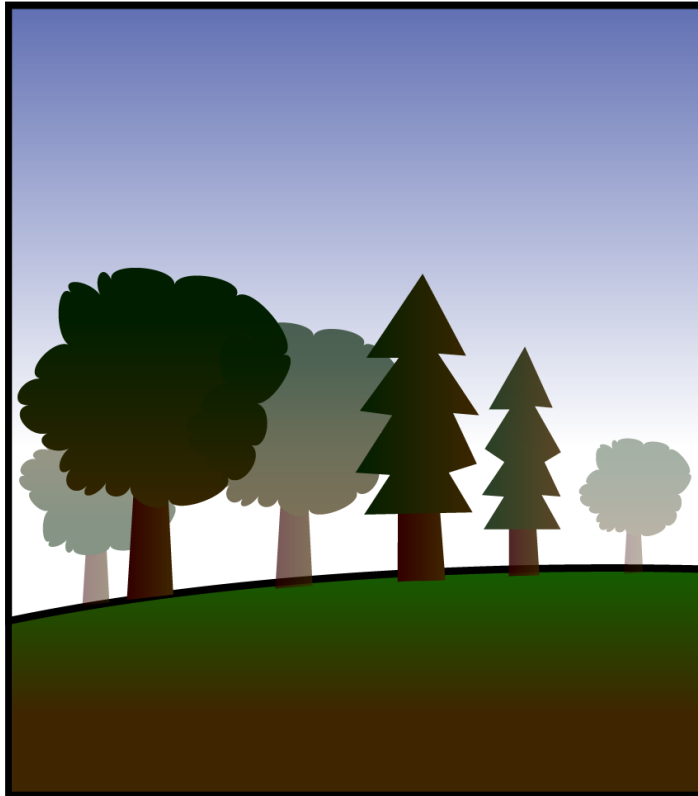
Dr. Pamela Templer

Boston University  
ptempler@bu.edu



Climate Change

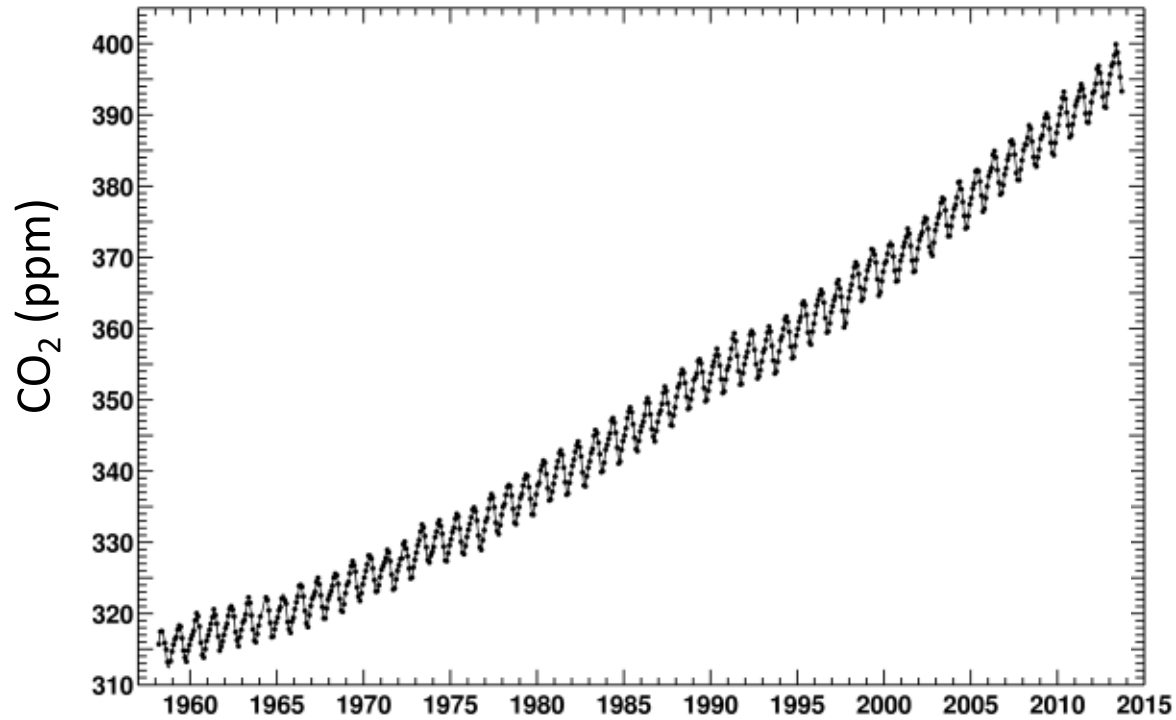
Air Pollution



Land-Use Change  
Urbanization

Introduced Pests

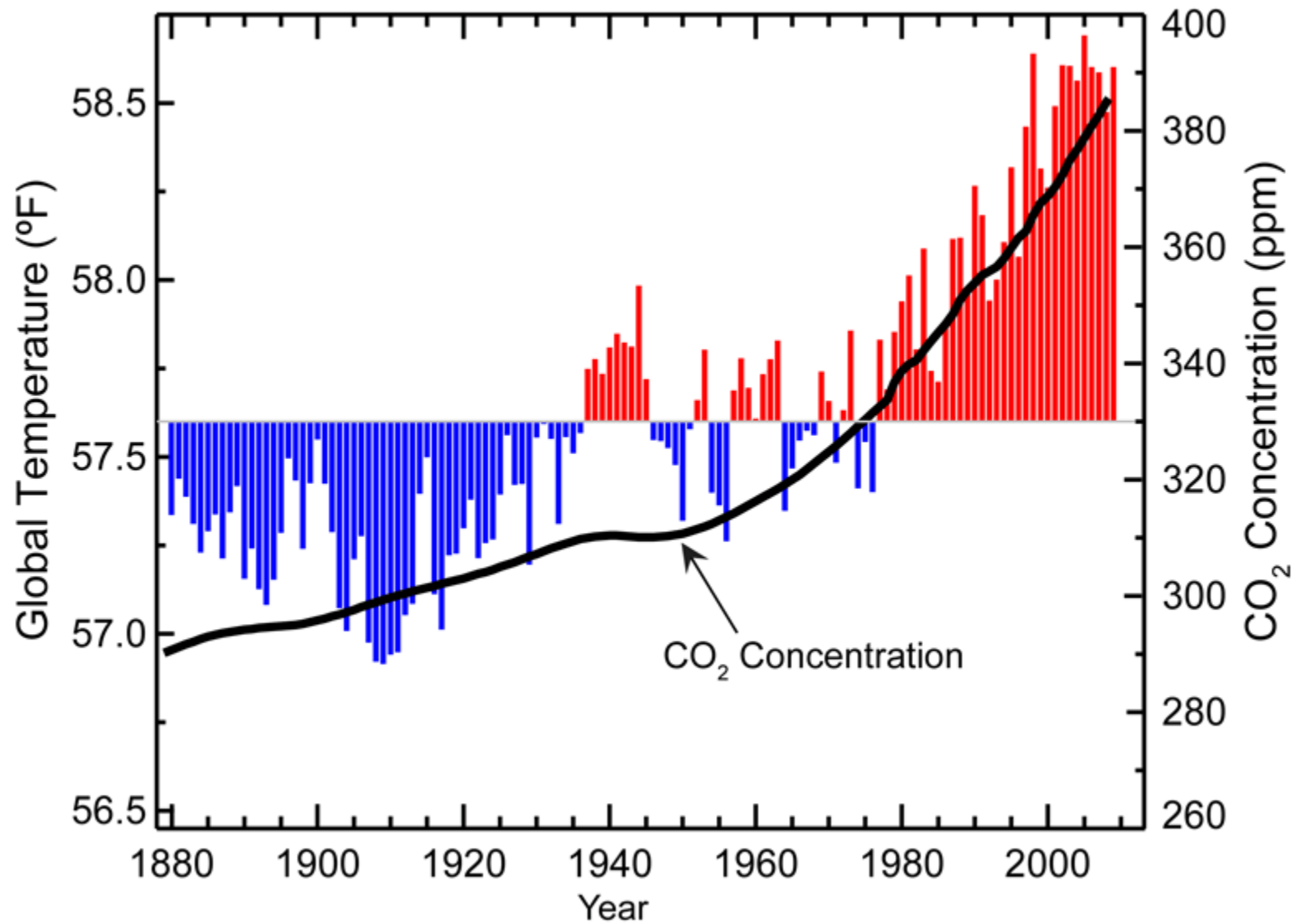
# Atmospheric CO<sub>2</sub> at Mauna Loa Observatory, Hawaii

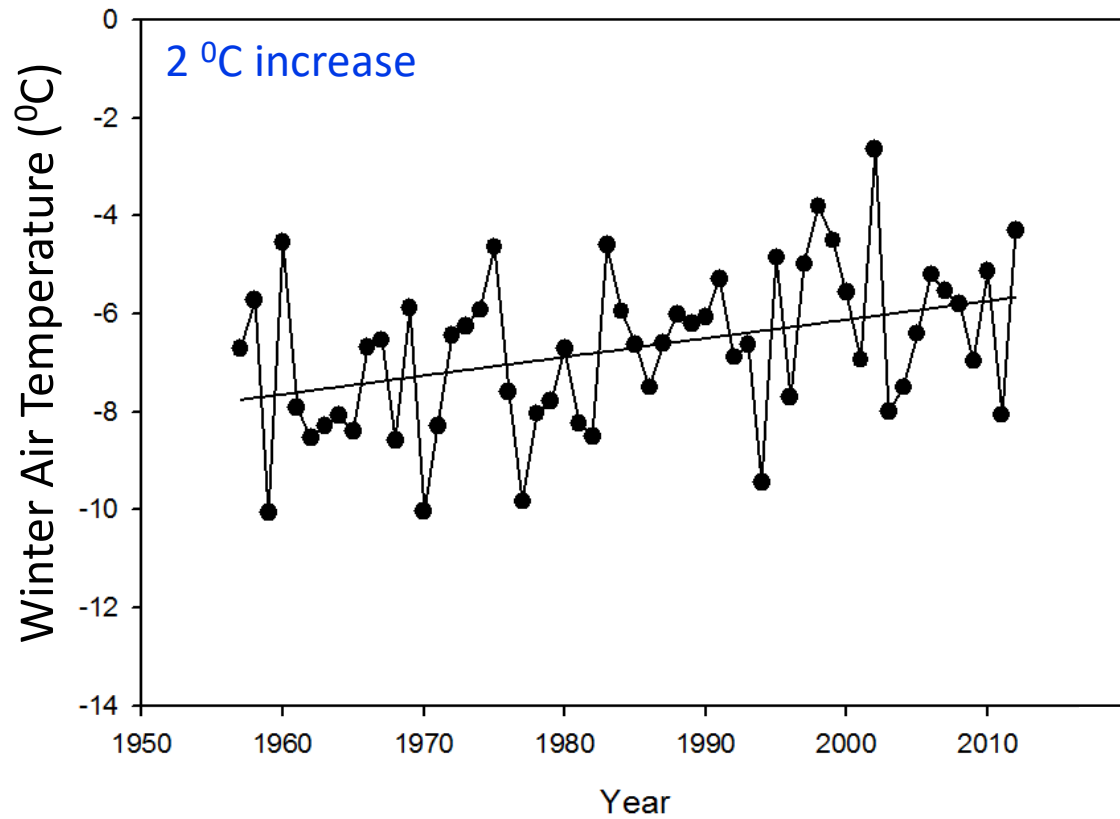


Scripps Institution of Oceanography

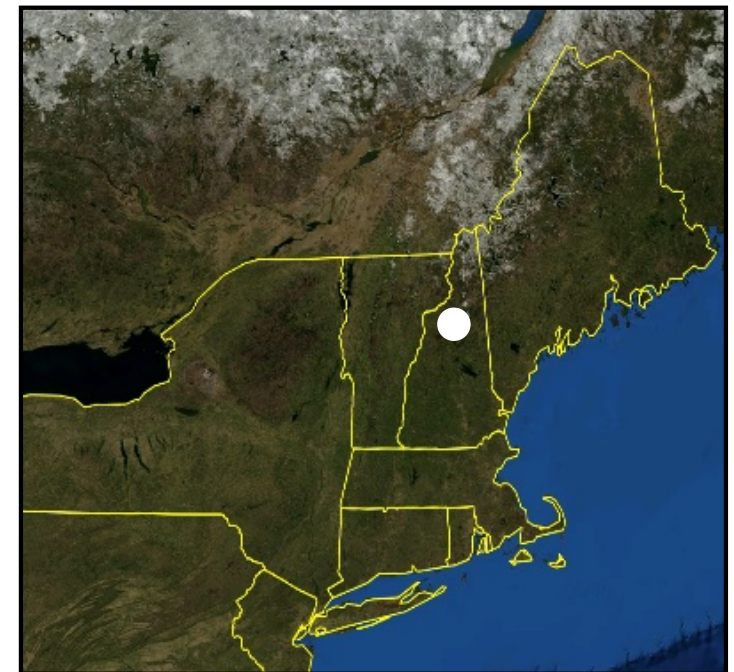
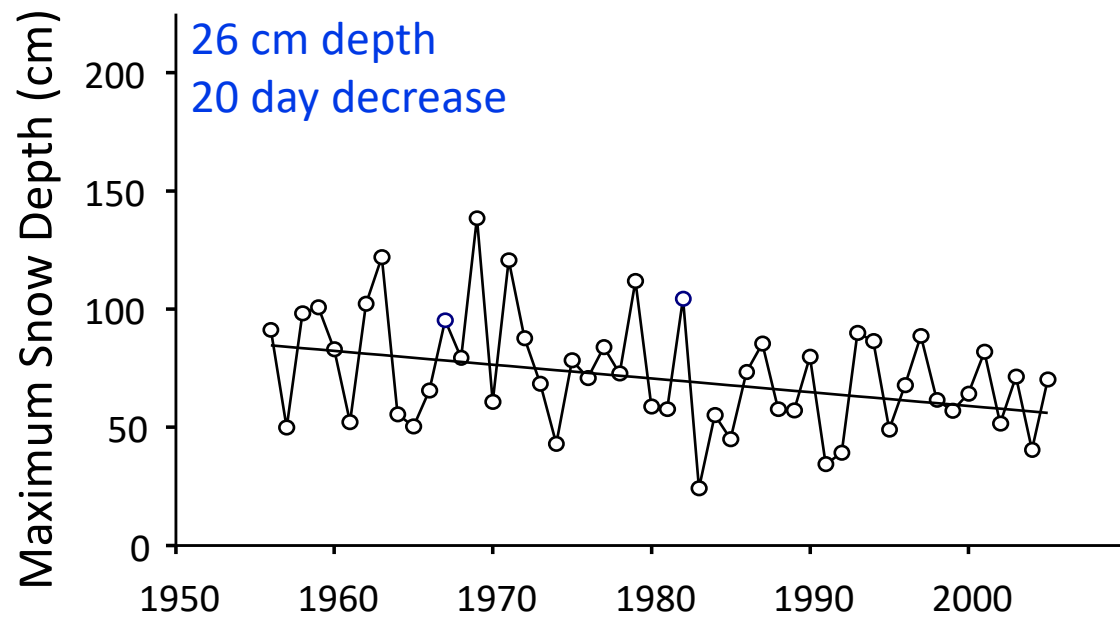


# Global Temperatures Rising





Winter Air  
Temperatures  
Rising and  
Snowpack  
Shrinking



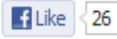
Hubbard Brook

# THE PHOENIX

## Help, the mountains are melting!

The case of the disappearing ski slopes

By NOAH SCHAFFER | November 7, 2012



© THOMAS JAMES



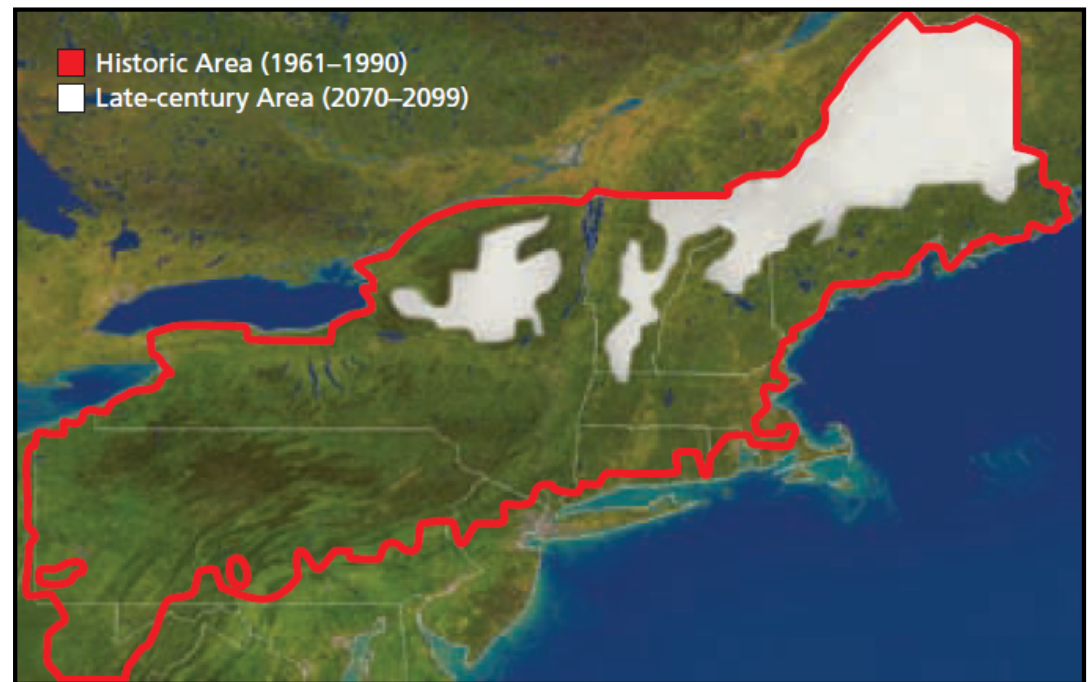
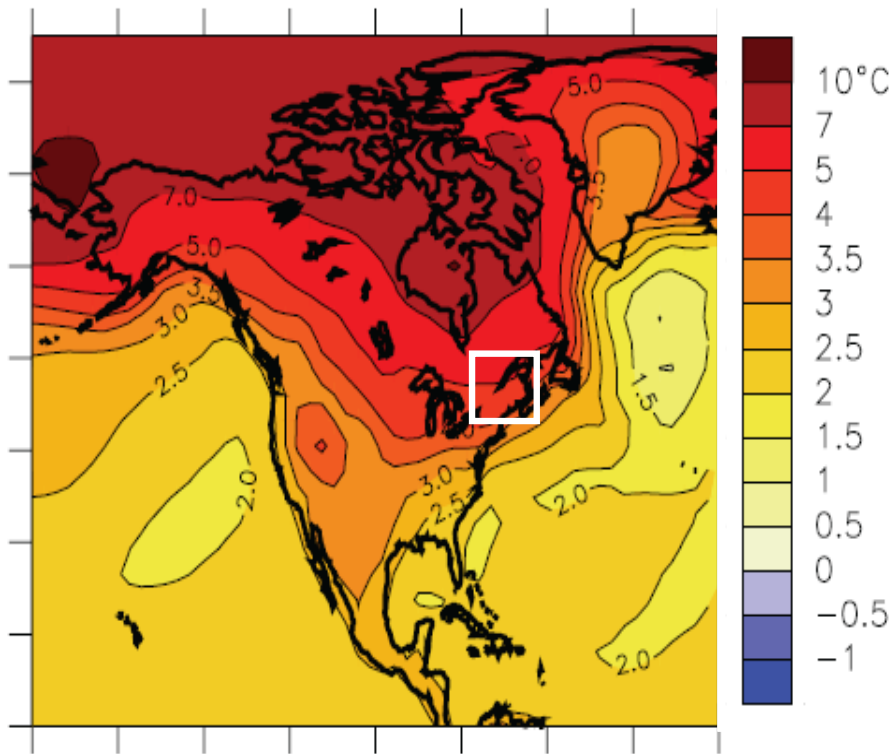
# The Boston Globe

## New England winters are on the decline due to climate change, study says

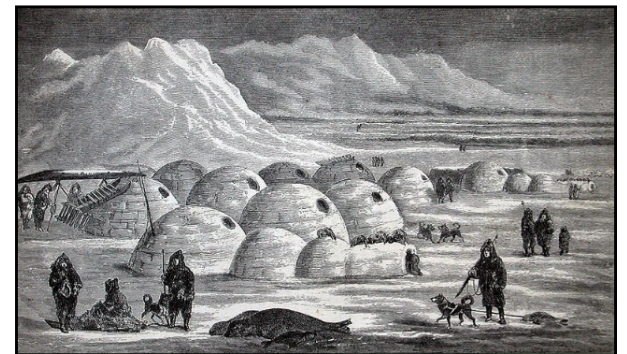
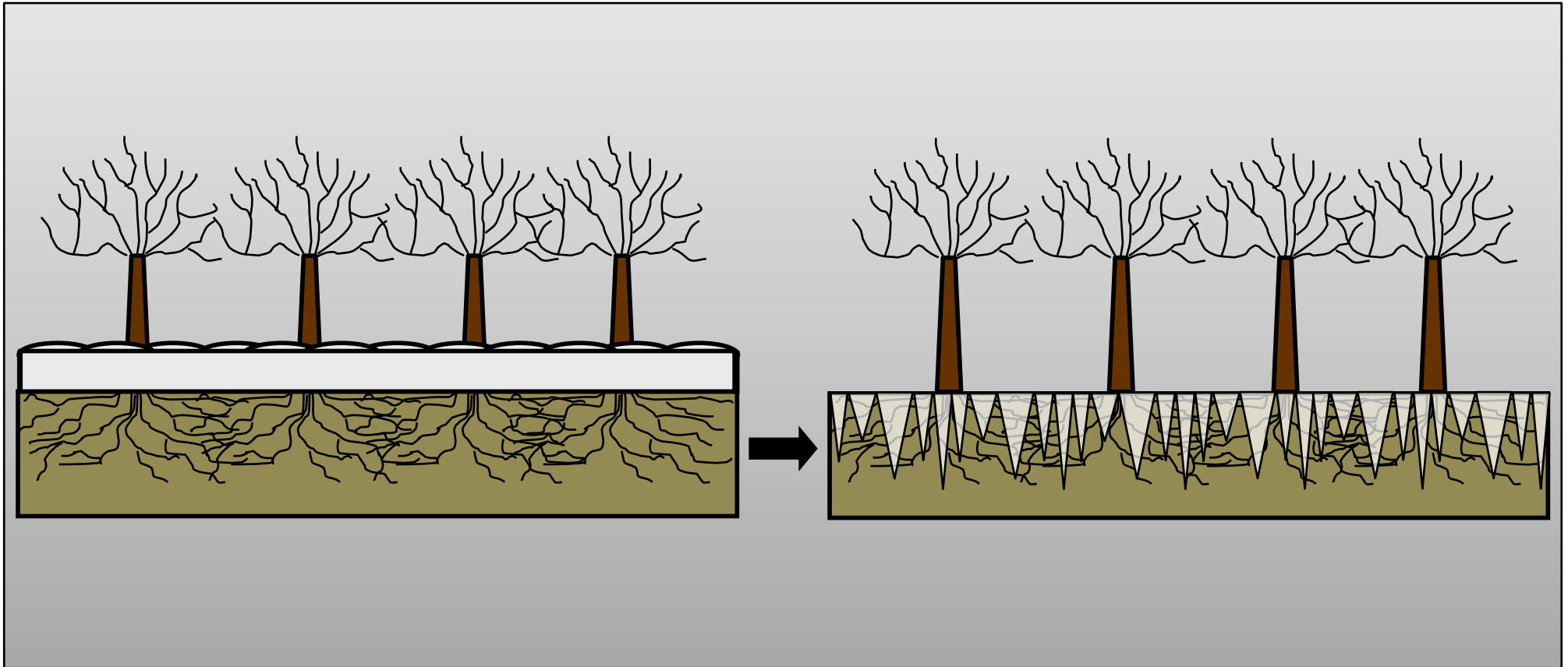
By Maria Lovato Globe Correspondent, October 7, 2019, 1:35 p.m.



# Increased Winter Temperatures and Reduced Snowpack Extent Over Next 100 Years in Northeastern United States



# Reduced Snowpack Leads to Soil Freezing



# Why Focus on Soil Freezing?



Could damage biota in forests:

Plant Roots

Microbes

Arthropods



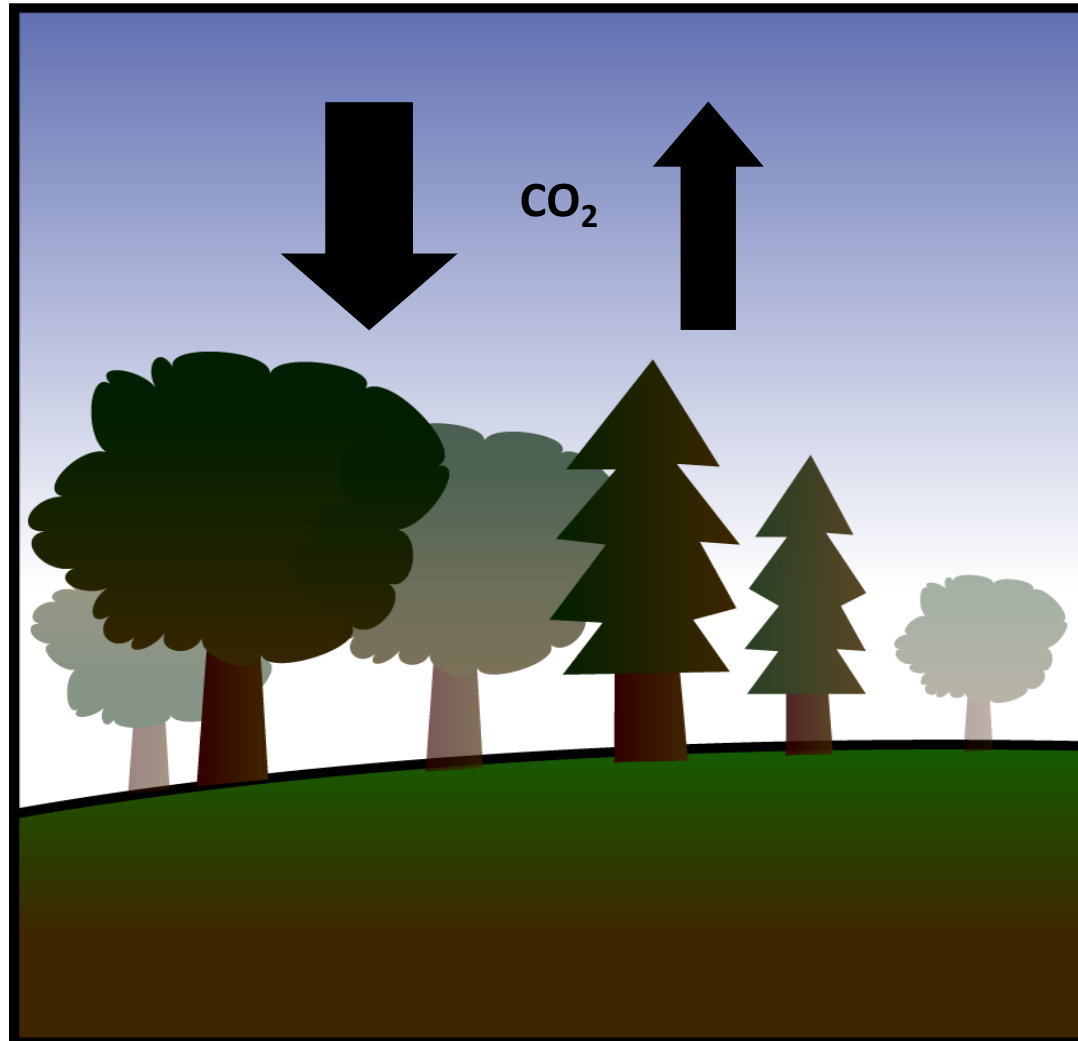
Water & Air Quality

Carbon Storage in Forests

Why does this matter?

Carbon uptake by ecosystems  
offsets fossil fuel emissions of  
CO<sub>2</sub> by ~30%

# Carbon Uptake by Forests Offsets 30% of CO<sub>2</sub> Emissions from Fossil Fuel Combustion



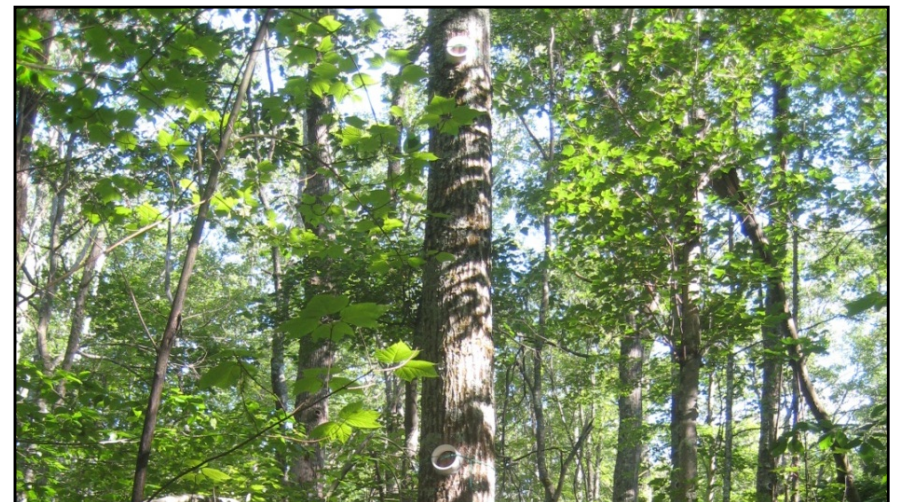
Do reduced snowpack and increased soil frost decrease nutrient uptake by trees and ecosystem carbon storage in forests?



# Snow-Removal Experiments at Hubbard Brook and Harvard Forest



Sugar maple - American beech



Red maple - Red oak

# Snow-Removal Experiments at Hubbard Brook and Harvard Forest



n = 4 reference and 4 treatment plots at Hubbard Brook  
n = 3 reference and 3 treatment plots at Harvard Forest

# Snow and Soil Frost Depth Measurements

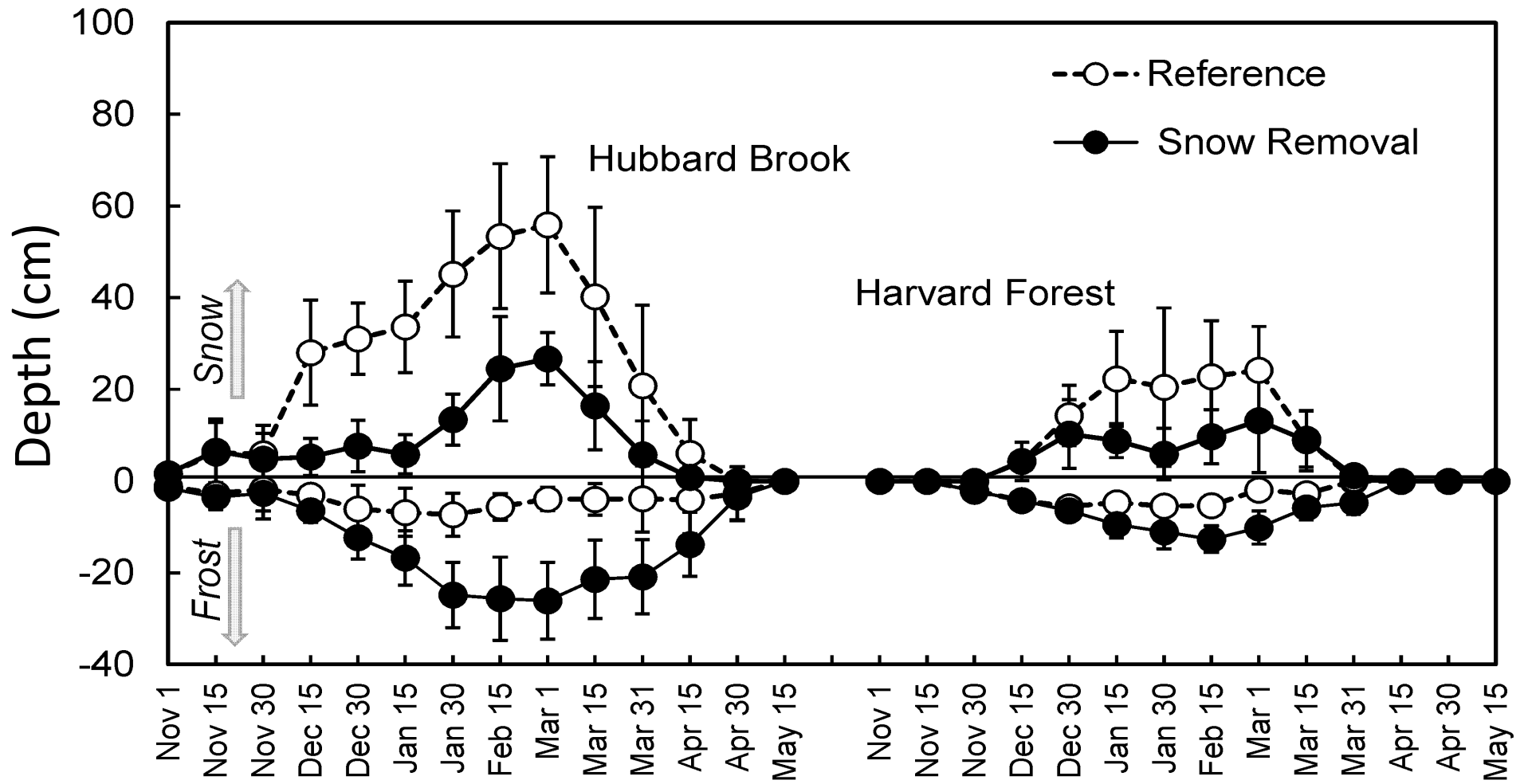


Snow Depth

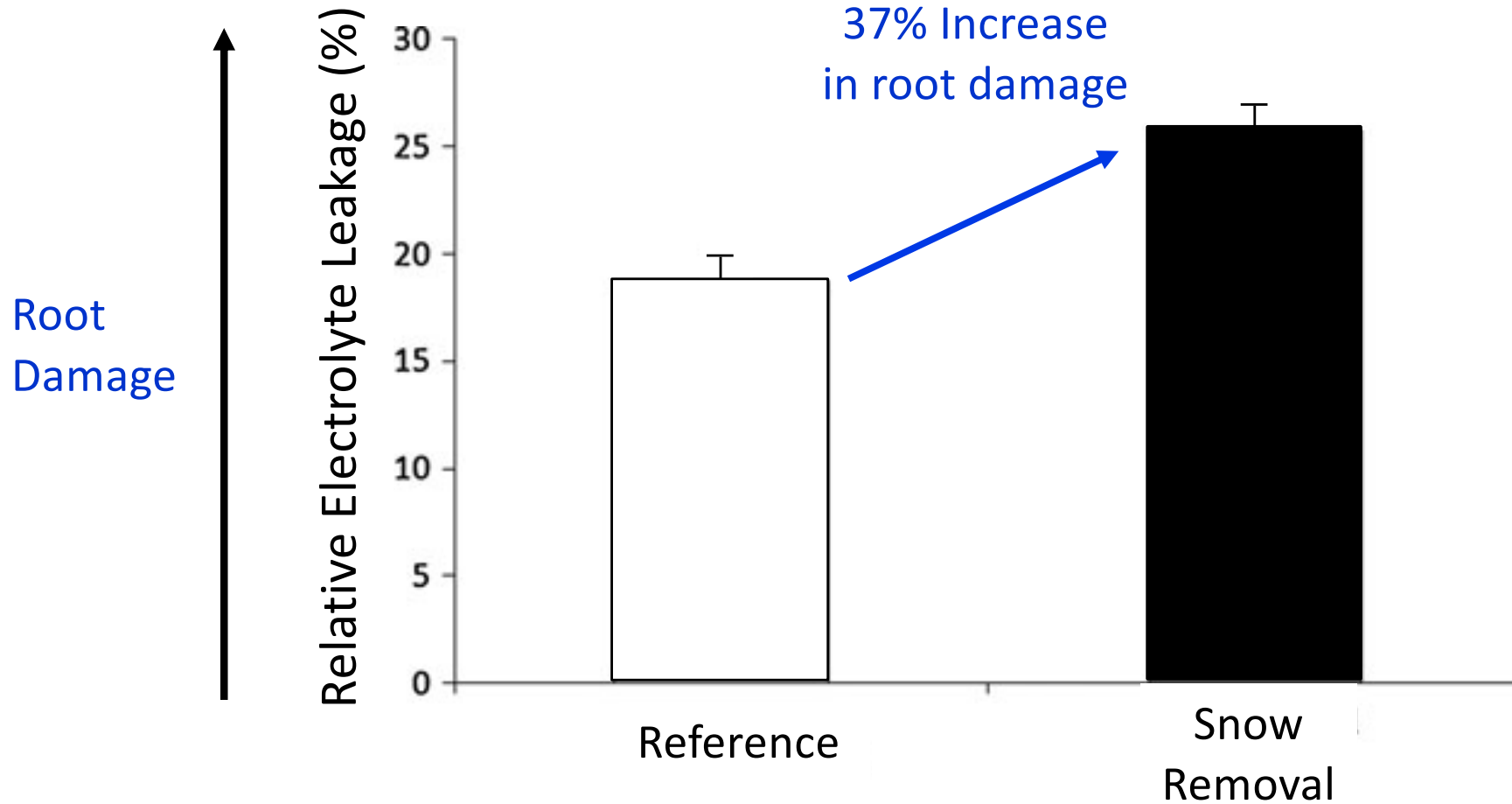


Frost tubes with  
methylene blue dye

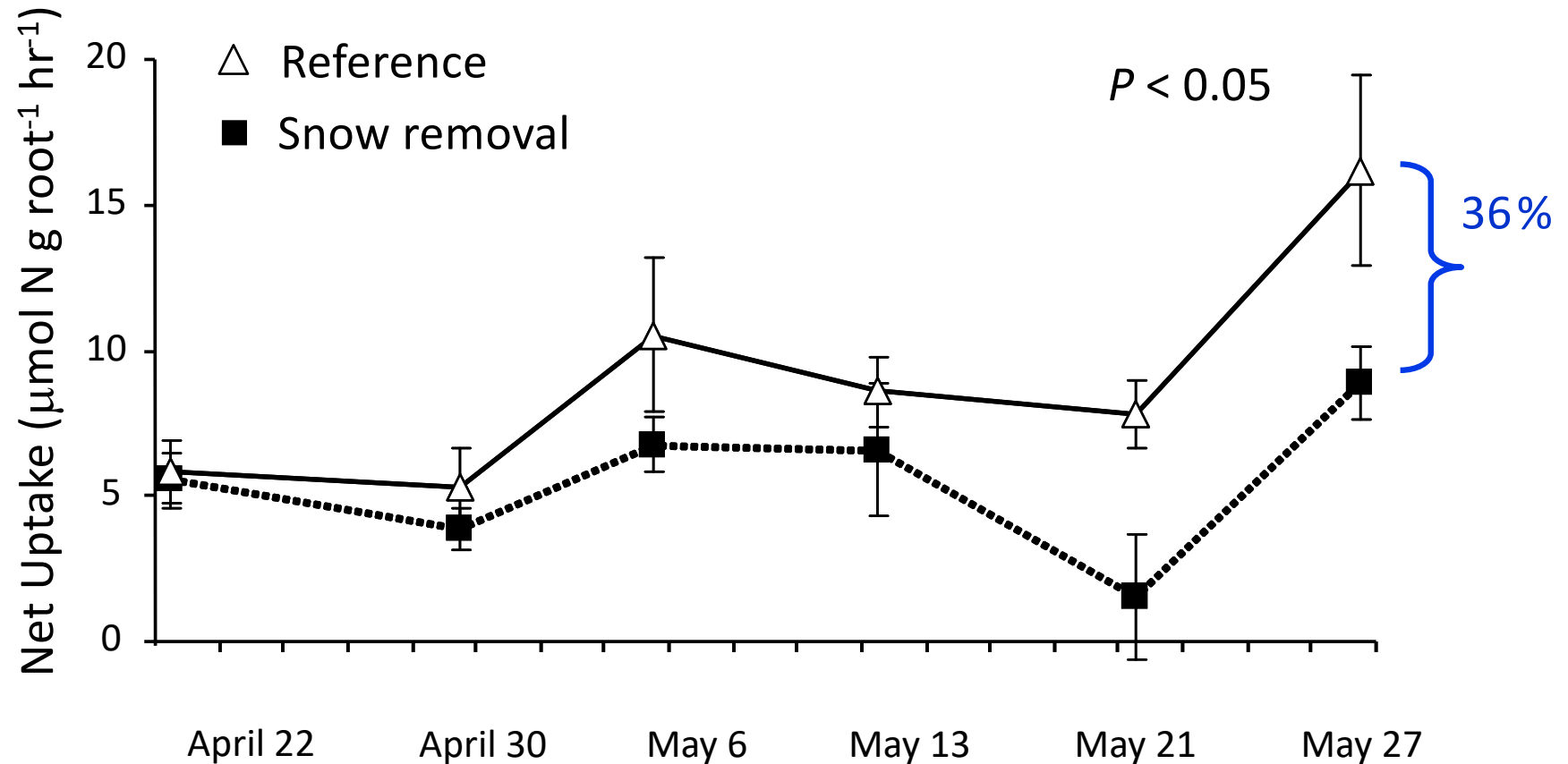
# Smaller Snowpack Increases Soil Frost Depth



# Soil Frost Induces Root Injury of Sugar Maple Trees

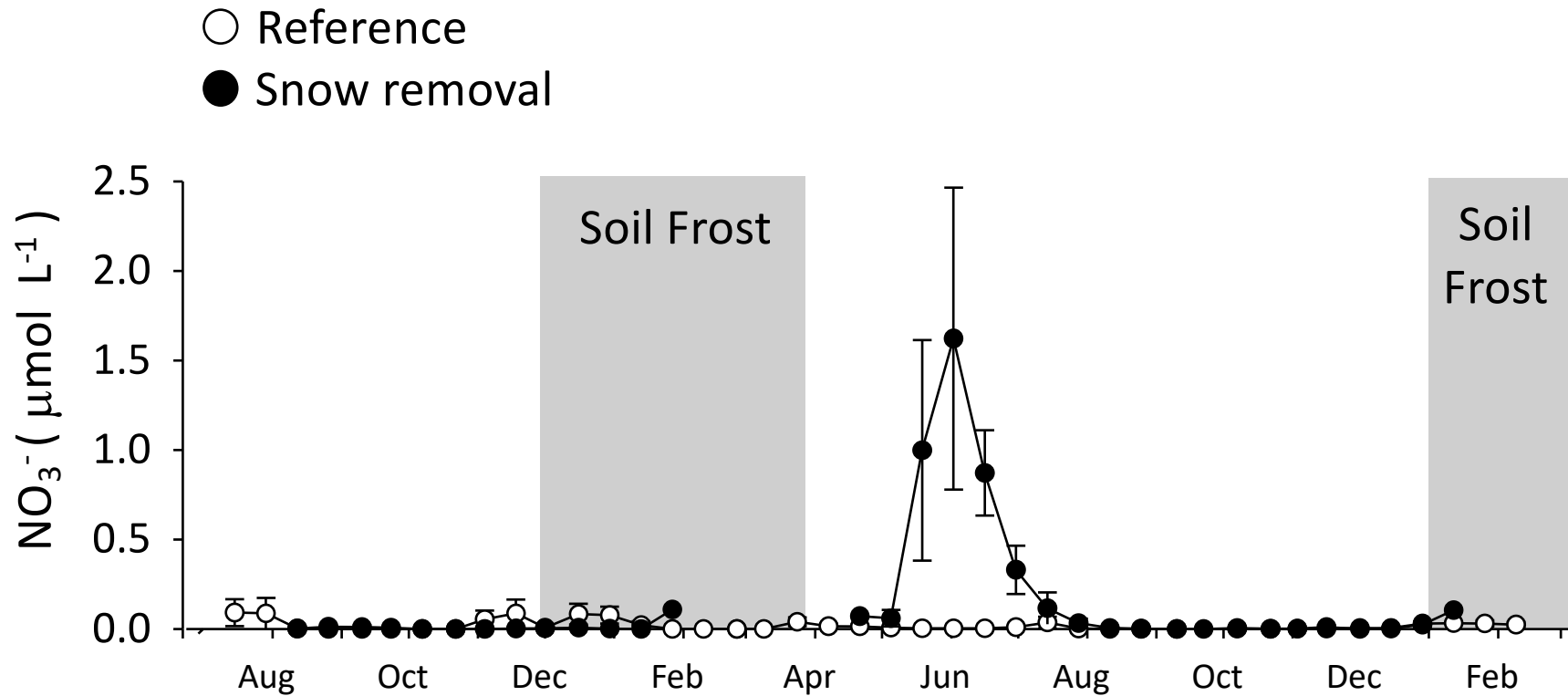


# Soil Frost Reduces Nitrogen Uptake by Sugar Maple Trees

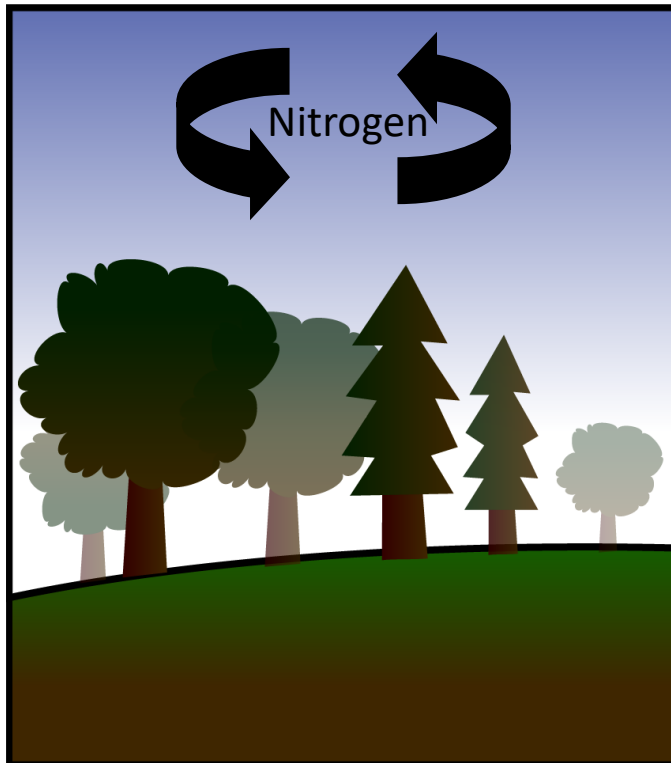


Socci and Templer (2011); Campbell et al. (2014)

# Soil Frost Induces Elevated $\text{NO}_3^-$ in Leachate



# Why Care about Nitrogen Leaching?



NO<sub>3</sub><sup>-</sup> Leaching



- Release of N<sub>2</sub>O
- Reduced forest productivity
- Acidification of stream water
- Eutrophication (algal blooms)
- Human health effects

# Reduced Snowpack and Increased Soil Freezing

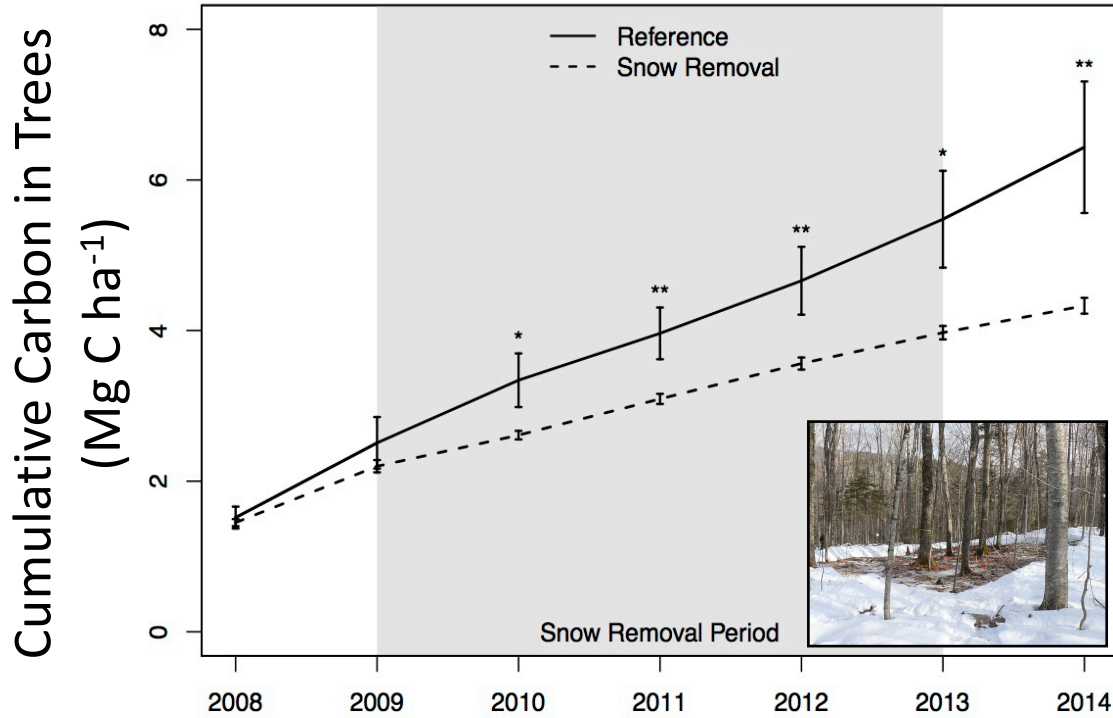
- damage roots and reduce nitrogen uptake by maple trees  
(Comerford et al. 2013, Campbell et al. 2014)
- increase nitrogen leaching  
(Campbell et al. 2014)



Do reduced snowpack and increased soil frost decrease ecosystem carbon storage in forests?



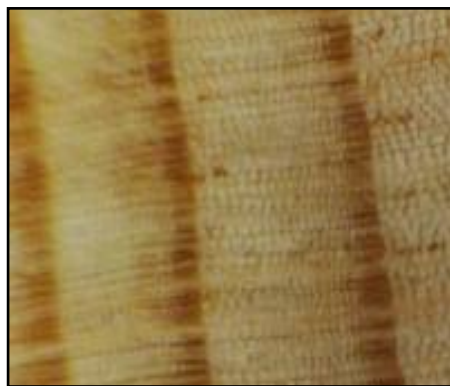
# Snowpack Declines Decrease C Storage in Forests



Stem Respiration (CO<sub>2</sub> Losses)



Photosynthesis (CO<sub>2</sub> Uptake)

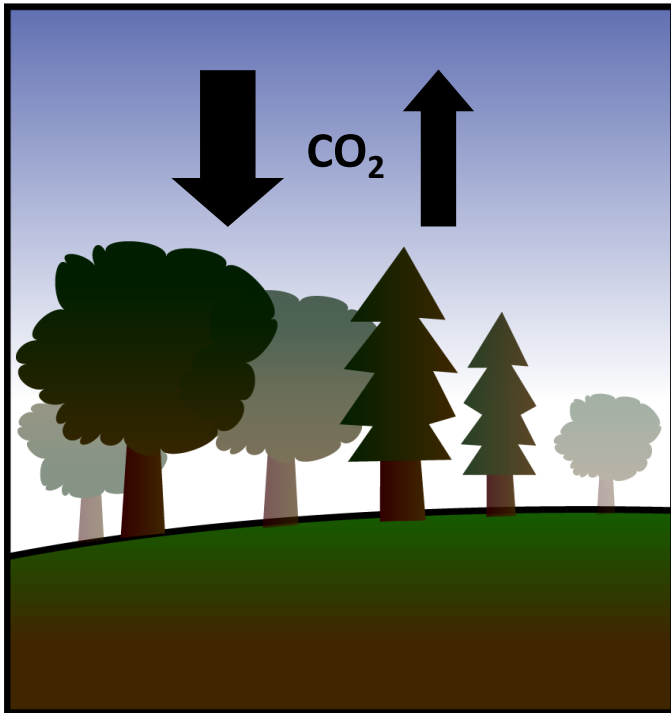


Tree Growth (CO<sub>2</sub> Uptake)



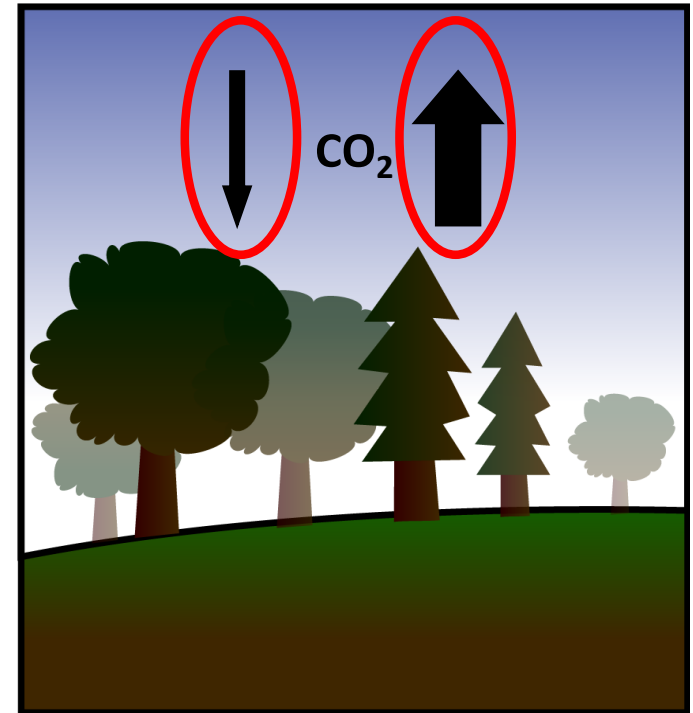
Soil Respiration (CO<sub>2</sub> Losses)

# Do reduced snowpack and increased soil frost decrease ecosystem carbon storage in forests?

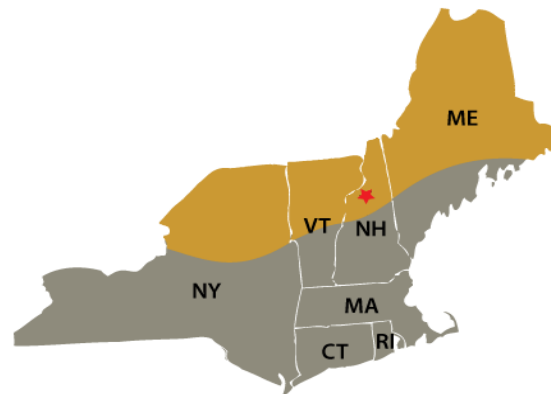


Large Snowpack  
Little soil frost

15% reduction  
C storage across  
northern forest



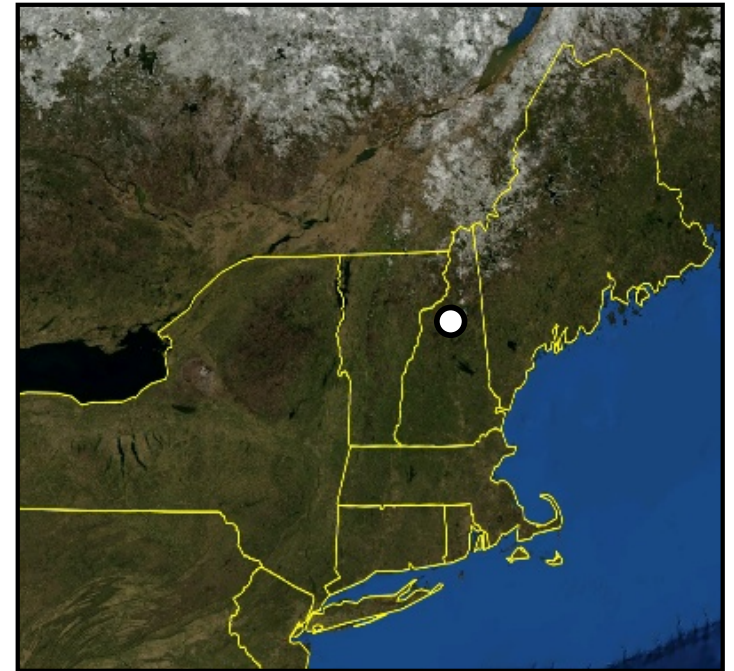
Small Snowpack  
Deep soil frost



\* Hubbard Brook

# Climate Change Across Season Effects CCASE

Determine how warmer temperatures in the growing season and smaller snowpack affect carbon sequestration in northern forests



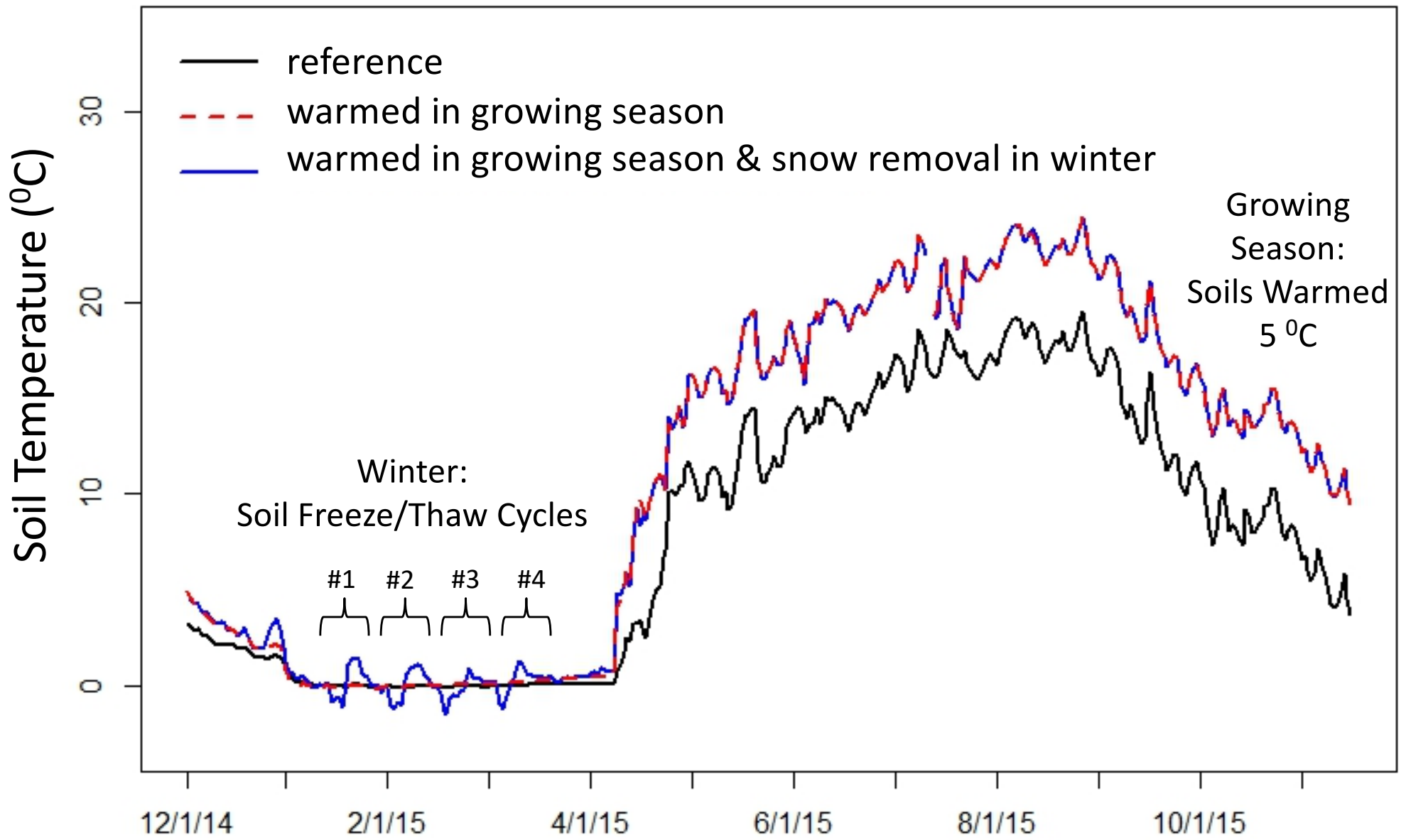
14 X 11m<sup>2</sup> plots in hardwood forest

- 2 plots: reference
- 2 plots: soils warmed 5<sup>0</sup>C in growing season
- 2 plots: soils warmed 5<sup>0</sup>C in growing season and less snow in winter

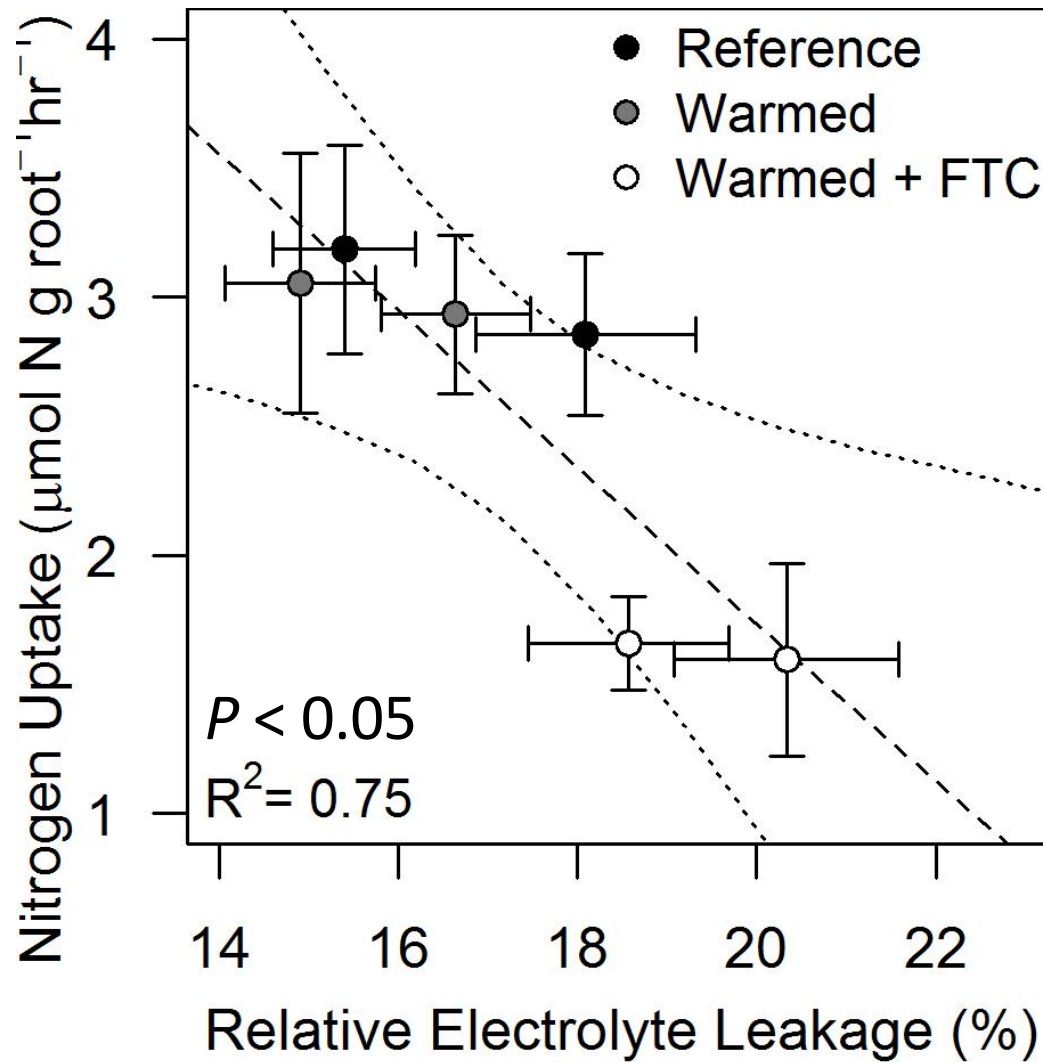
# CCASE Experiment at Hubbard Brook



# Soil Temperature at CCASE



# Soil Frost Damages Roots and Reduces N Uptake

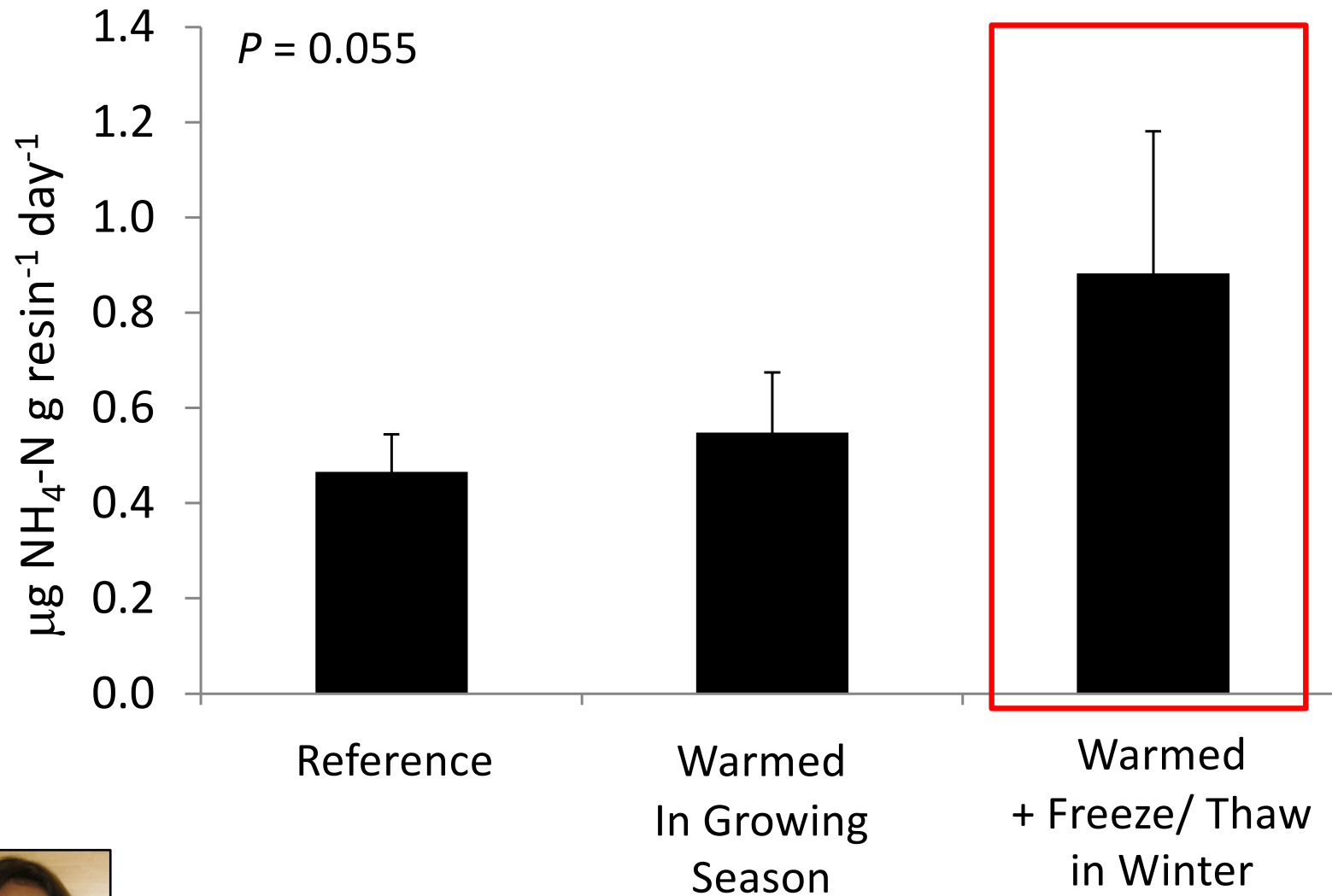


Rebecca Sanders-Demott (PhD)

Root Damage  $\longrightarrow$



# Soil Frost Induces Nitrogen Losses



Rebecca Sanders-Demott (PhD)



# Aboveground Productivity & Carbon Uptake by Trees

- Litterfall baskets: 4 per plot
- Dendrometer bands on all trees  $\geq 10$  cm diameter
- 21-24 trees per plot: mixed hardwood stand



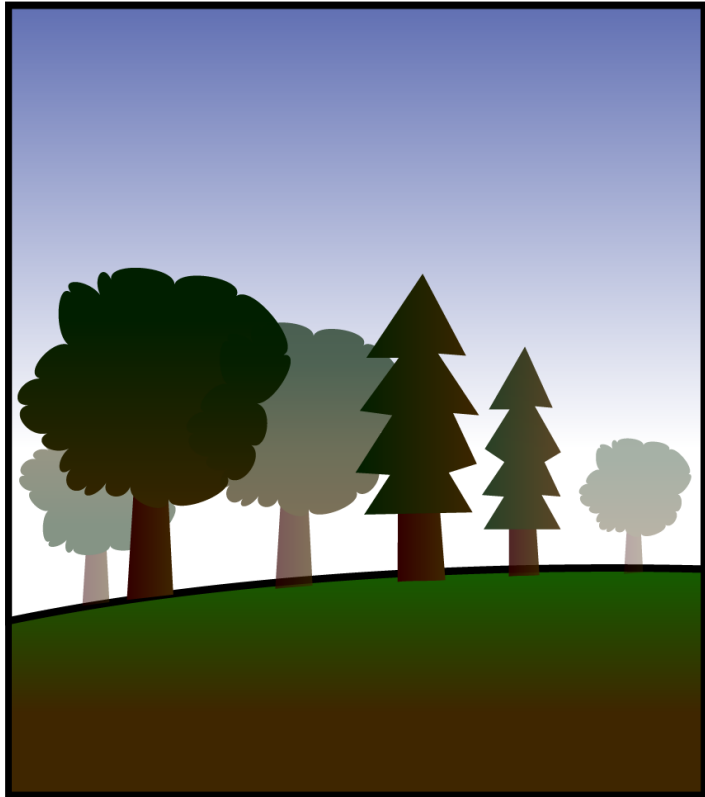
# Conclusions



- Winter freeze-thaw cycles injure roots and reduce nitrogen uptake by trees, not offset by growing season warming
- Growing season warming leads to greater tree growth and carbon uptake, but offset by soil freeze-thaw cycles in winter
- Winter injury to roots may constrain uptake of N, and therefore total C sequestered in northern forest ecosystems

Climate Change

Air Pollution

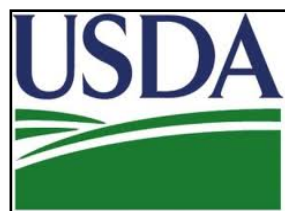


Land-Use Change  
Urbanization

Introduced Pests

# Acknowledgements

Amey Bailey, Scott Bailey, Frank Bowles, Laura Clerx,  
Steve Decina, Ian Halm, Jamie Harrison, Stephanie Juice,  
Brendan Leonardi, Mary Martin, Risa McNellis,  
Rebecca Sanders-DeMott, Patrick Sorensen, Amy Werner,  
Geoff Wilson, Jackie Wilson, Gabe Winant, Tammy Wooster





# Climate Change Effects on New England's Forests

Dr. Pamela Templer

Boston University  
ptempler@bu.edu

