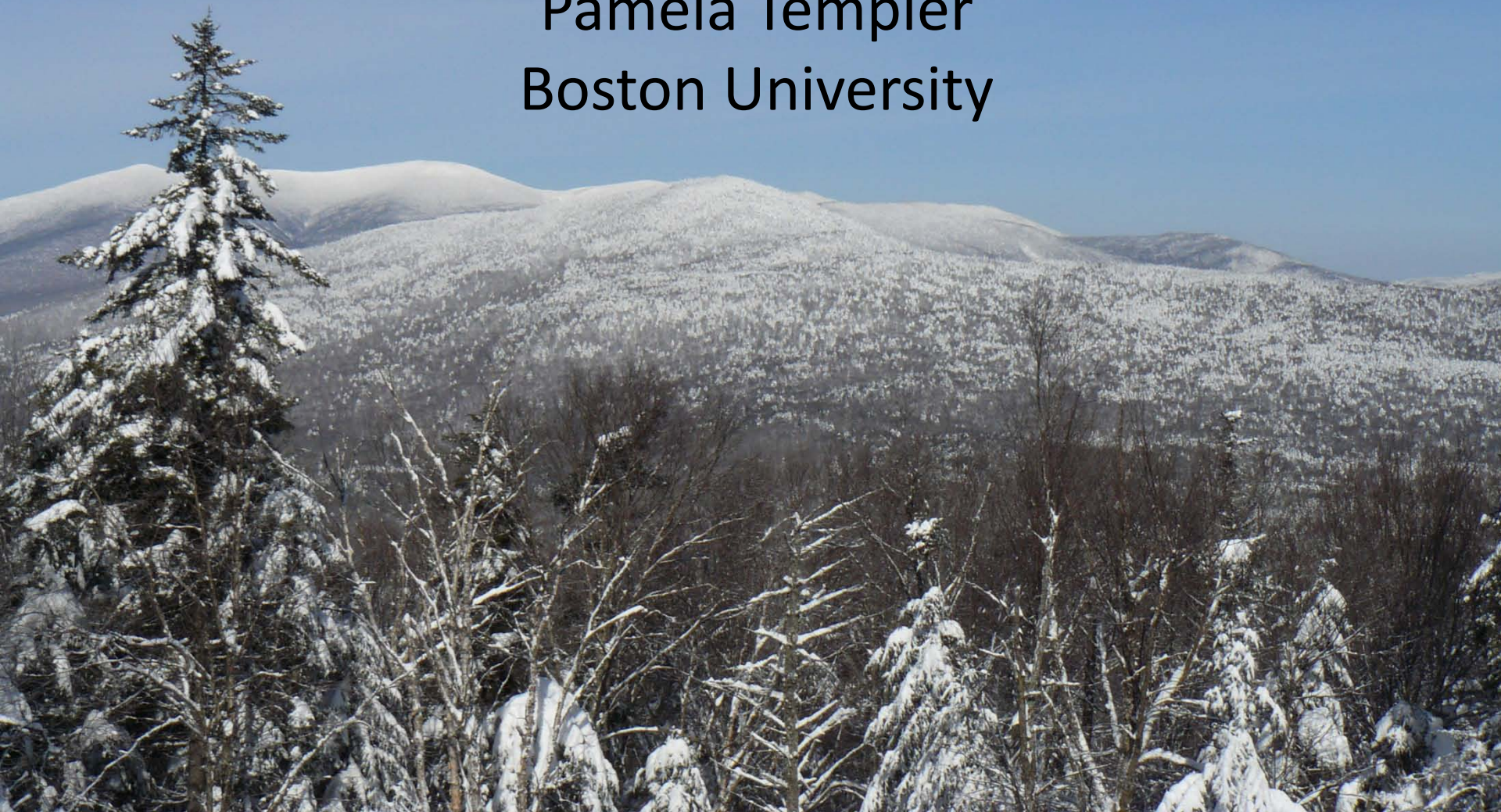
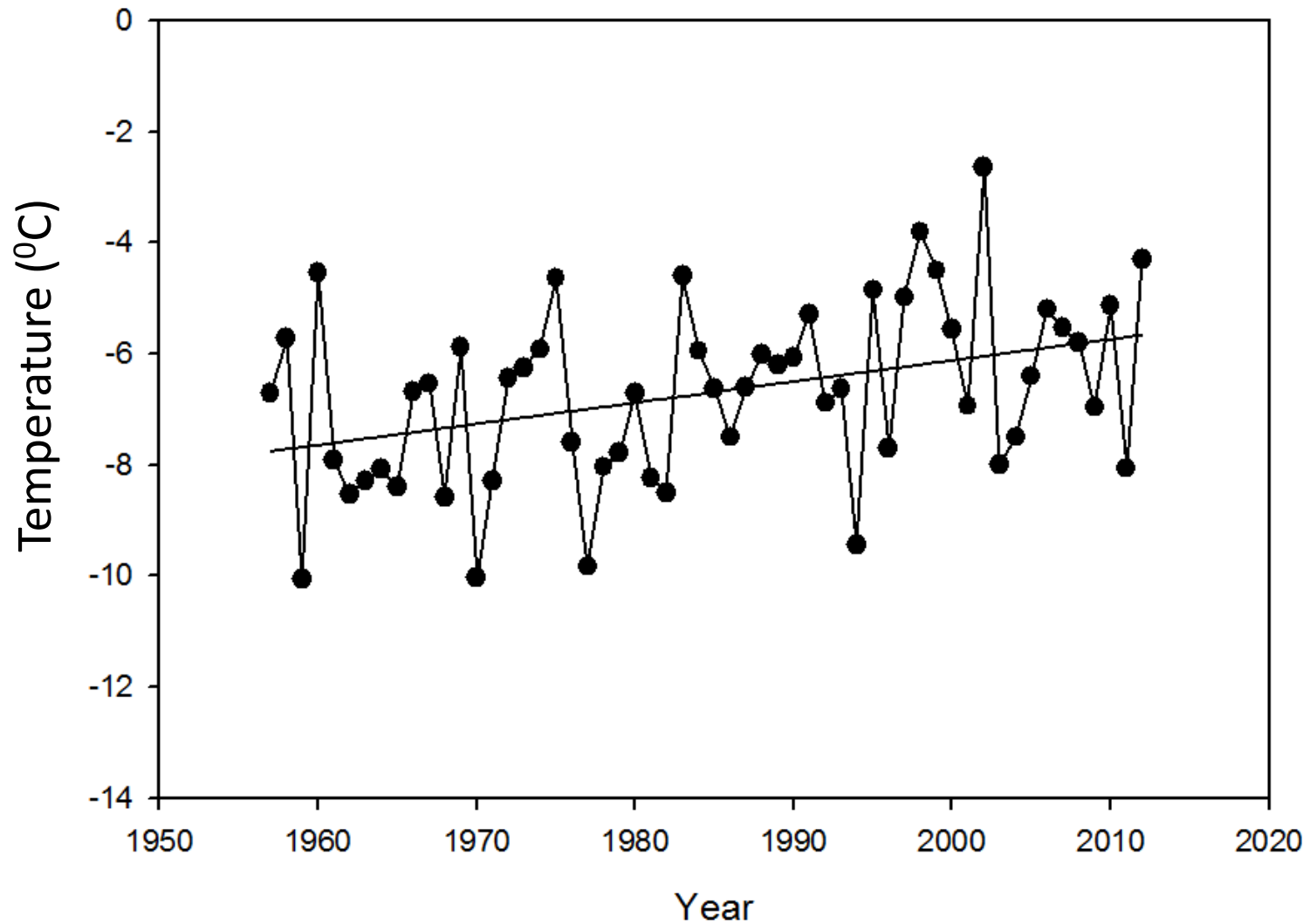


Influence of Winter Climate Change on Forest Biogeochemistry

Pamela Templer
Boston University

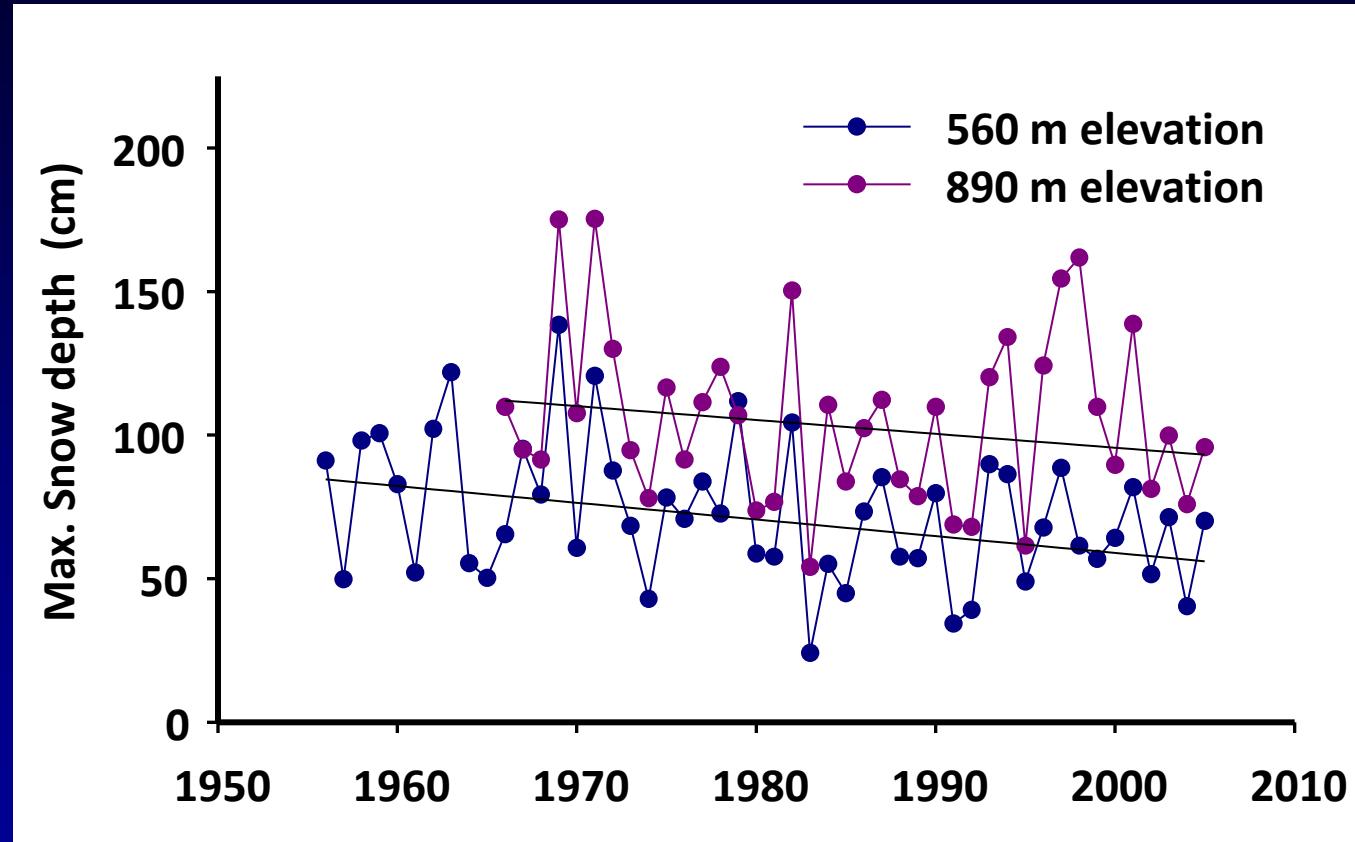
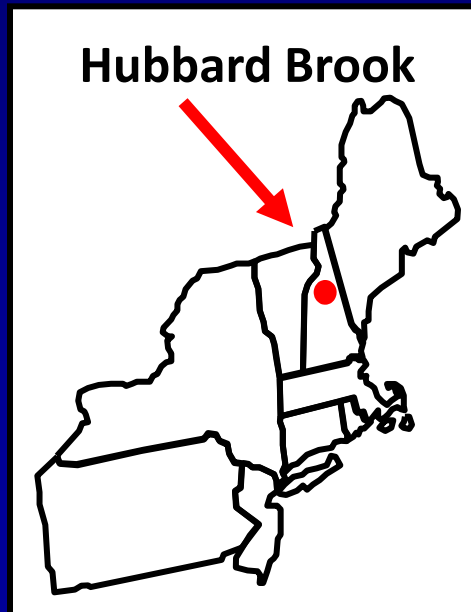


Winter Air Temperatures Rising in New England



Station 1 at Hubbard Brook (December - February)

Snowpack Depth Decreasing in New England



Help, the mountains are melting!

The case of the disappearing ski slopes

By NOAH SCHAFFER | November 7, 2012



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CHRONICLE ONLINE

Nov. 10, 2010

In 100 years, maple sap will flow a month earlier

By Krishna Ramanujan

As the climate warms this century, maple syrup production in the Northeast is expected to slightly decline by 2100, and the window for tapping trees will move earlier by about a month, reports a Cornell study.

Currently, the best times to tap maple trees are within an eight-week window from late winter to early spring when temperatures cause freezing at night and thawing by day.

"By 2100, we can expect to begin tapping maples closer to Christmas in the Northeast," said Brian Chabot, professor of ecology and evolutionary biology and a co-author of a paper on climate changes and maple sugar production that appeared earlier this year in the journal *Climate Change*.

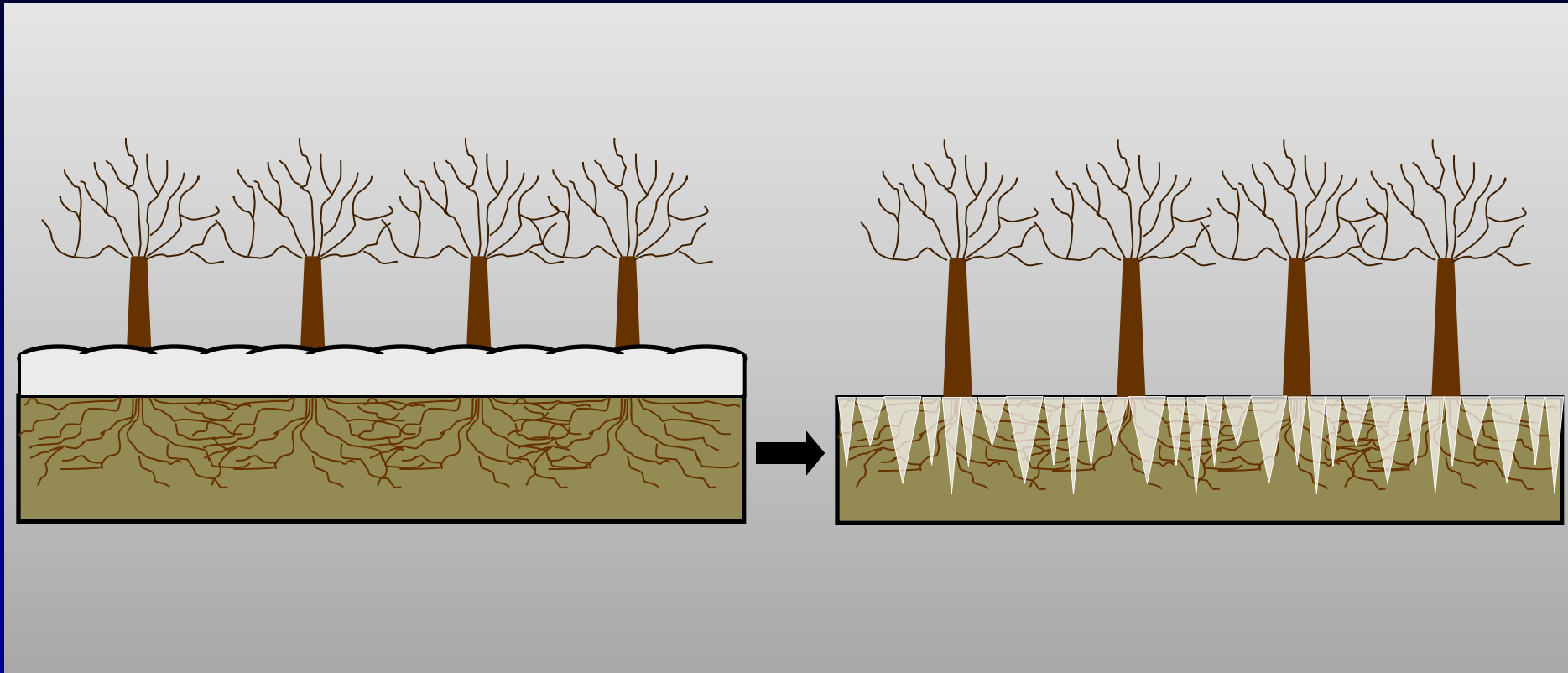
Sap flow is related to pressure changes in the trees' xylem, which are tubes beneath the bark that carry sap from the maple's roots up to the leaves. As maple trees freeze in winter, gases are pushed out of the xylem into surrounding tissues, and negative pressure is created within the xylem compared with atmospheric pressure. When the trees thaw, the gases expand and dissolve back into the sap.



Brian Chabot

Mike Farrell, director of the Uihlein Sugar Maple Research and Extension Field Station in Lake Placid, N.Y., taps a maple tree.

Reduced Snow Pack Leads to Increased Soil Frost

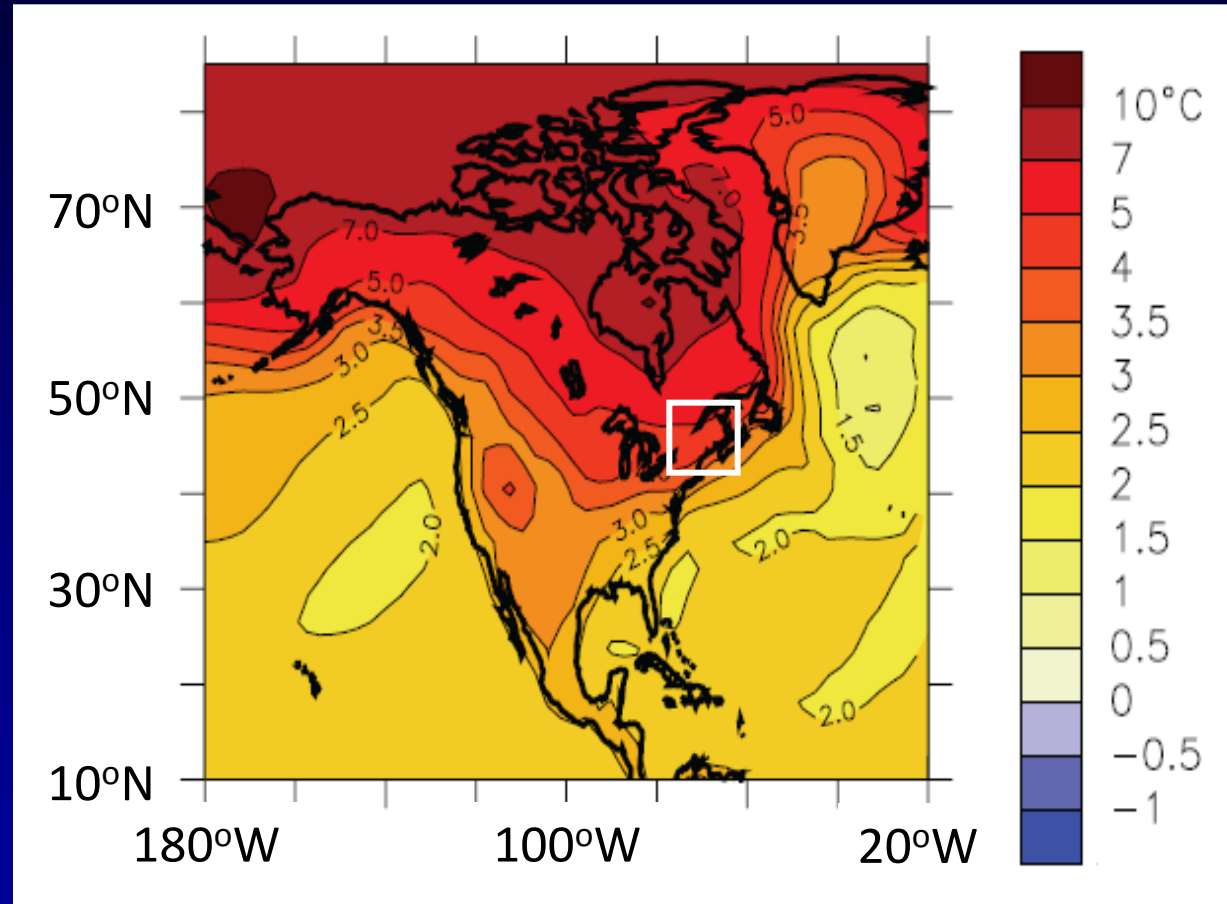


Insulating Properties of Snow

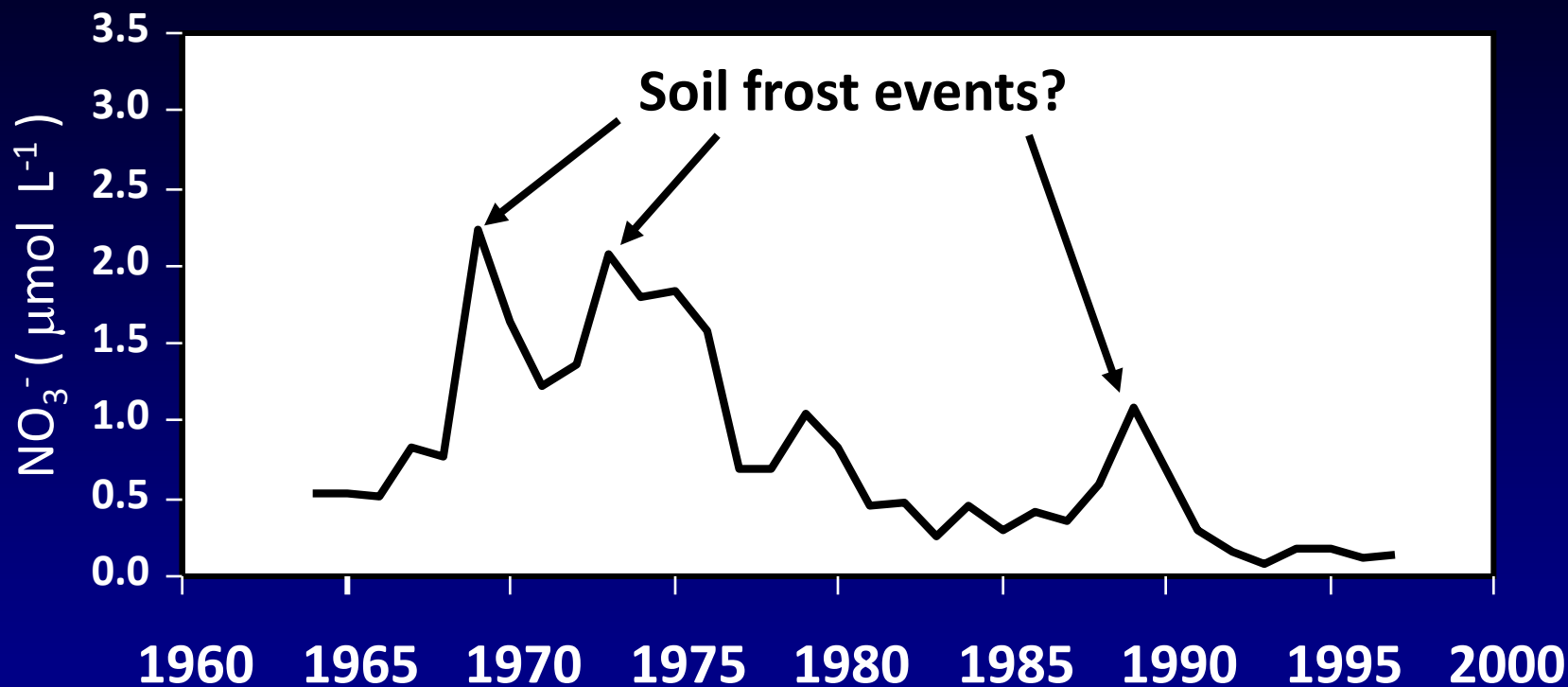


Winter Climate Change in the Northeastern U.S. Over Next 100 Years

- 4 to 4.5 °C warmer
- Reduced winter snowpack
- Increased soil frost

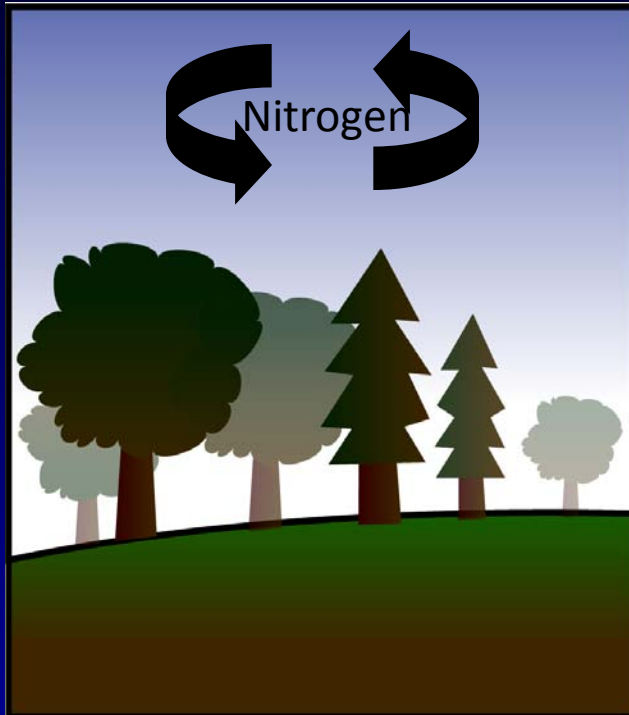


Link Between Soil Frost and Nitrogen Leaching



Hubbard Brook

Why Care about Nitrogen Leaching?



NO_3^- Leaching



- Release of N_2O
- Reduced forest productivity
- Acidification of stream water
- Eutrophication (algal blooms)
- Methemoglobinemia (blue baby syndrome)

Why Does Reduced Snow Pack and Increased Soil Frost Lead to N Leaching?

- No changes in microbial N production
- Increased root mortality



Groffman et al. and Tierney et al. 2001; Cleavitt et al. 2008

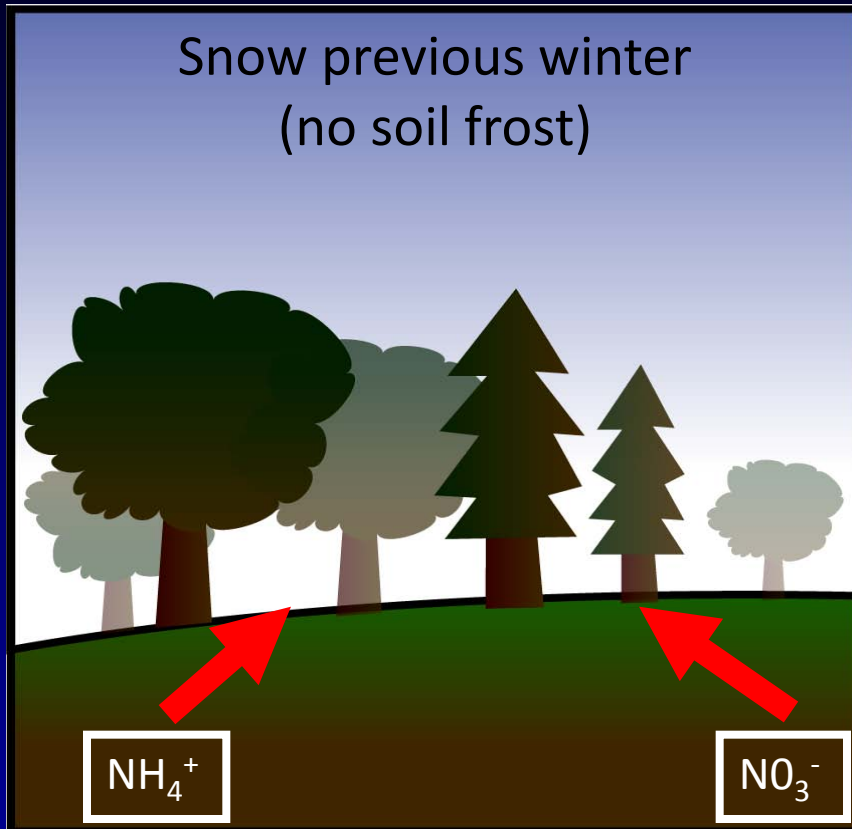
Why Does Reduced Snow Pack and Increased Soil Frost Lead to N Leaching?

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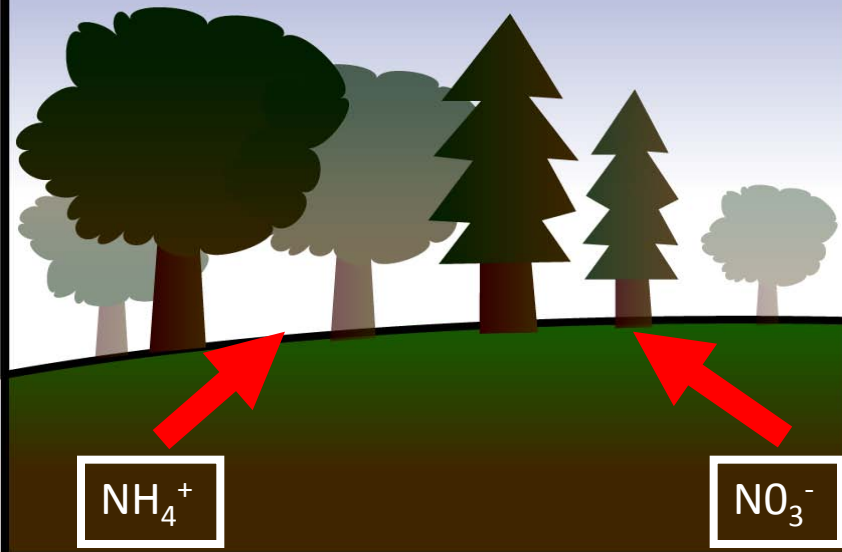
Groffman et al. and Tierney et al. 2001; Cleavitt et al. 2008

Nitrogen Uptake by Trees

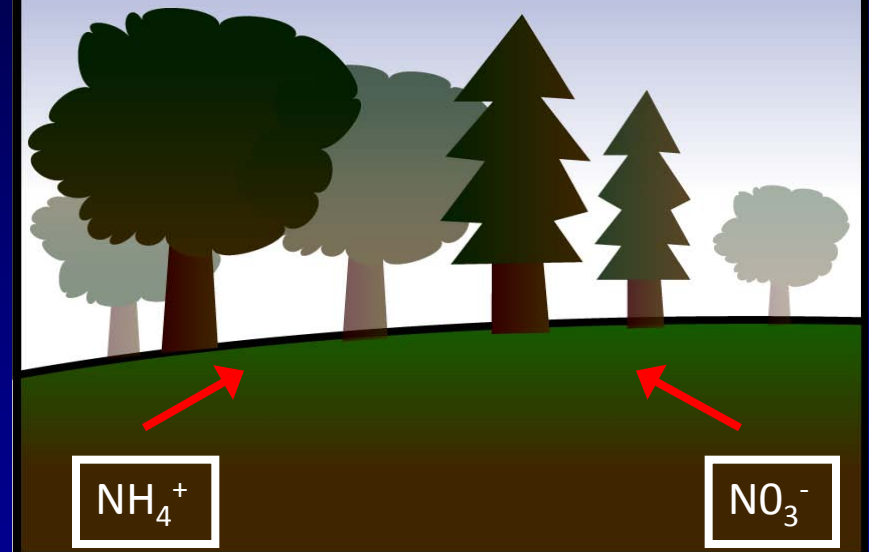


Nitrogen Uptake by Trees

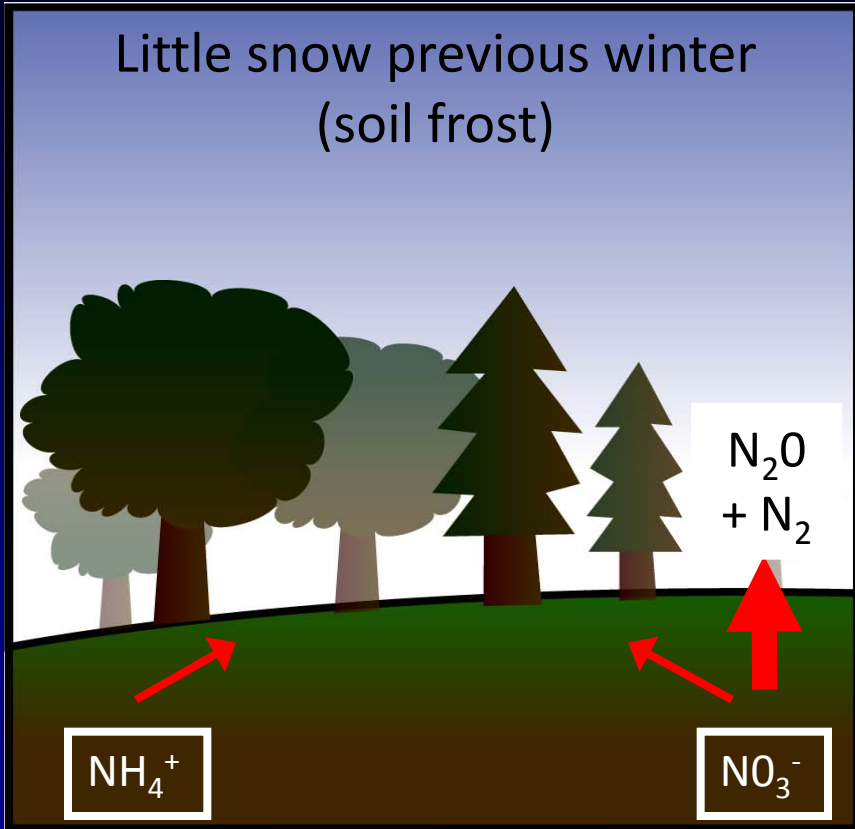
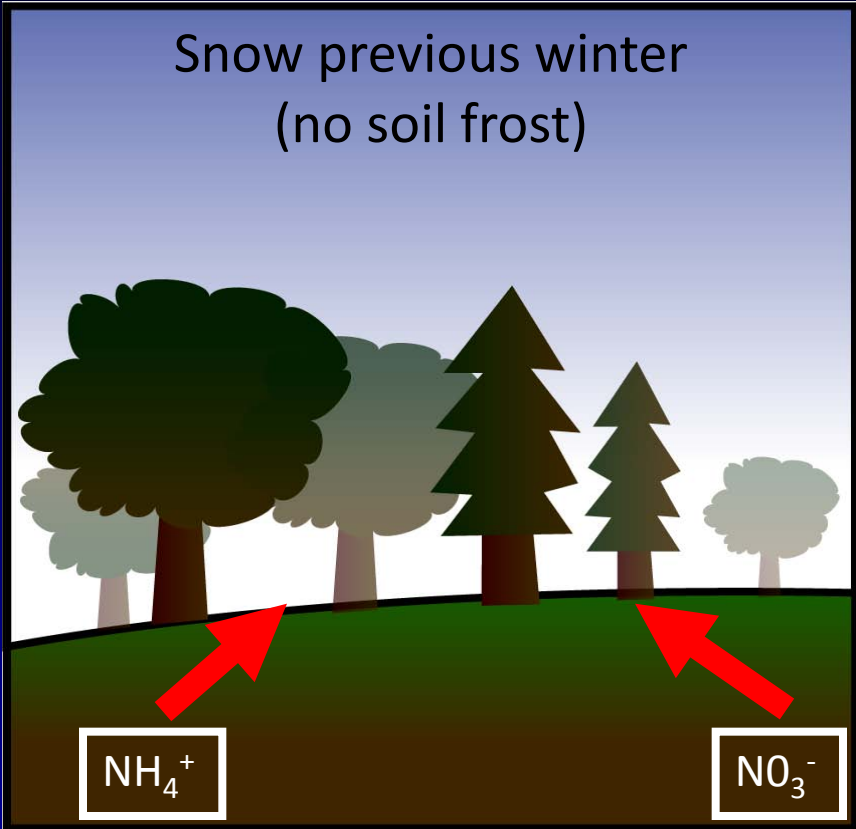
Snow previous winter
(no soil frost)



Little snow previous winter
(soil frost)



Nitrogen Uptake by Trees



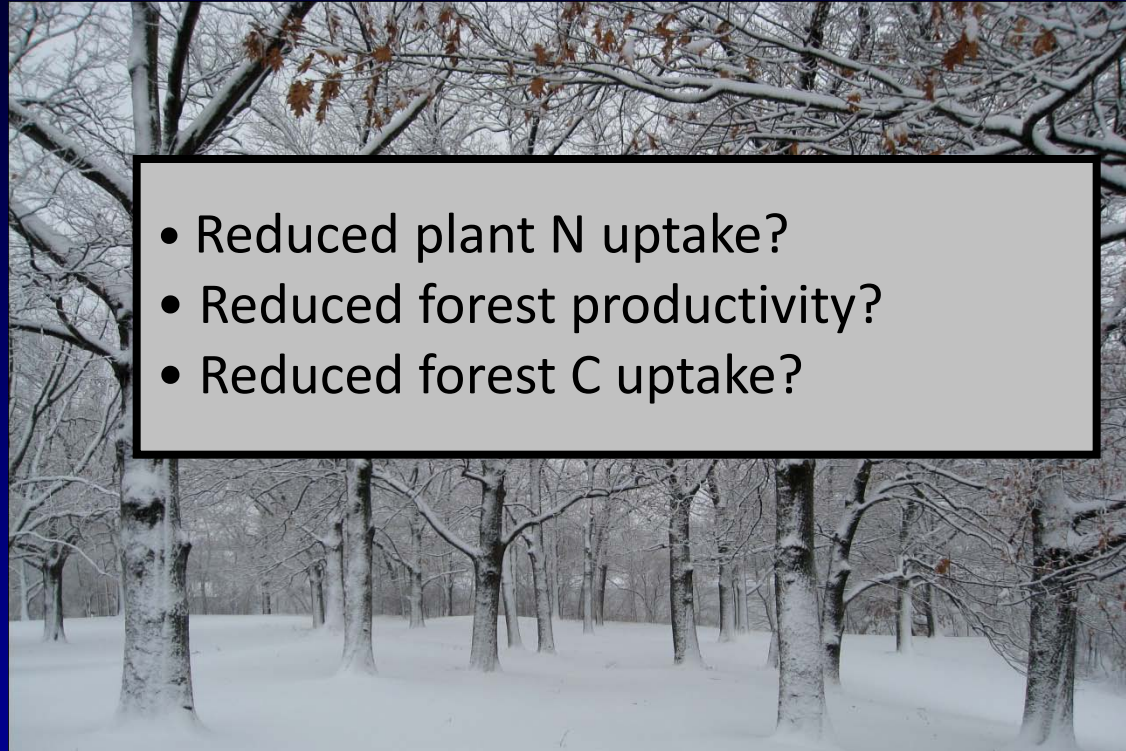
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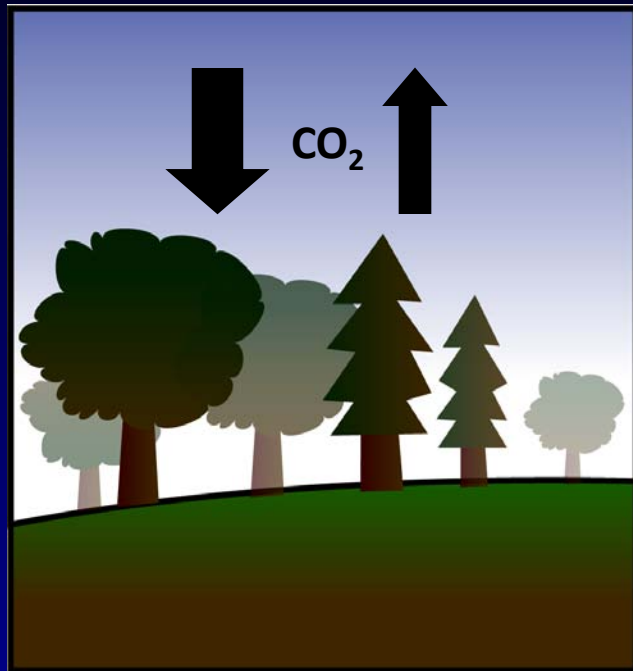


Why Does Reduced Snow Pack and Increased Soil Frost Lead to N Leaching?

- No changes in microbial N production
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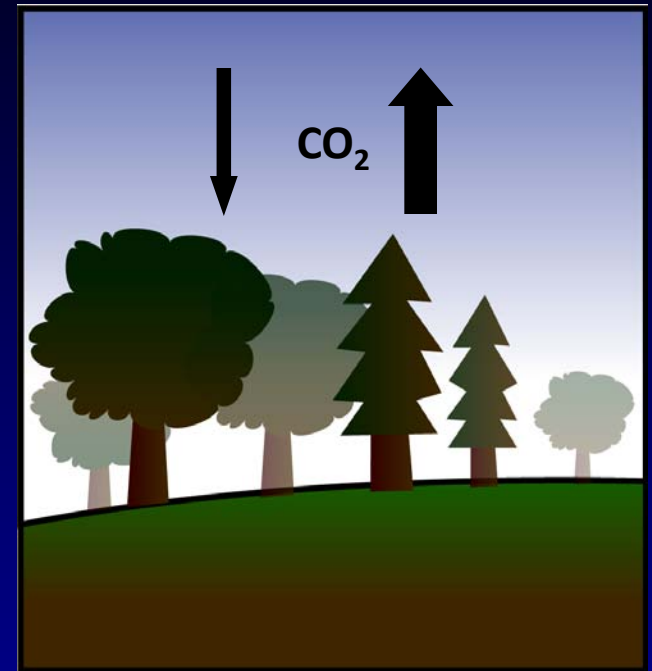
Soil Frost and Canopy Uptake of CO₂



Little soil frost



Less canopy
C uptake?



Increased soil frost

Hypotheses

Reduced snow pack and increased soil frost result in decreased:

- root health and nutrient uptake
- sap flow and canopy uptake of carbon
- aboveground productivity





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

Snow and Soil Frost Depth Measurements

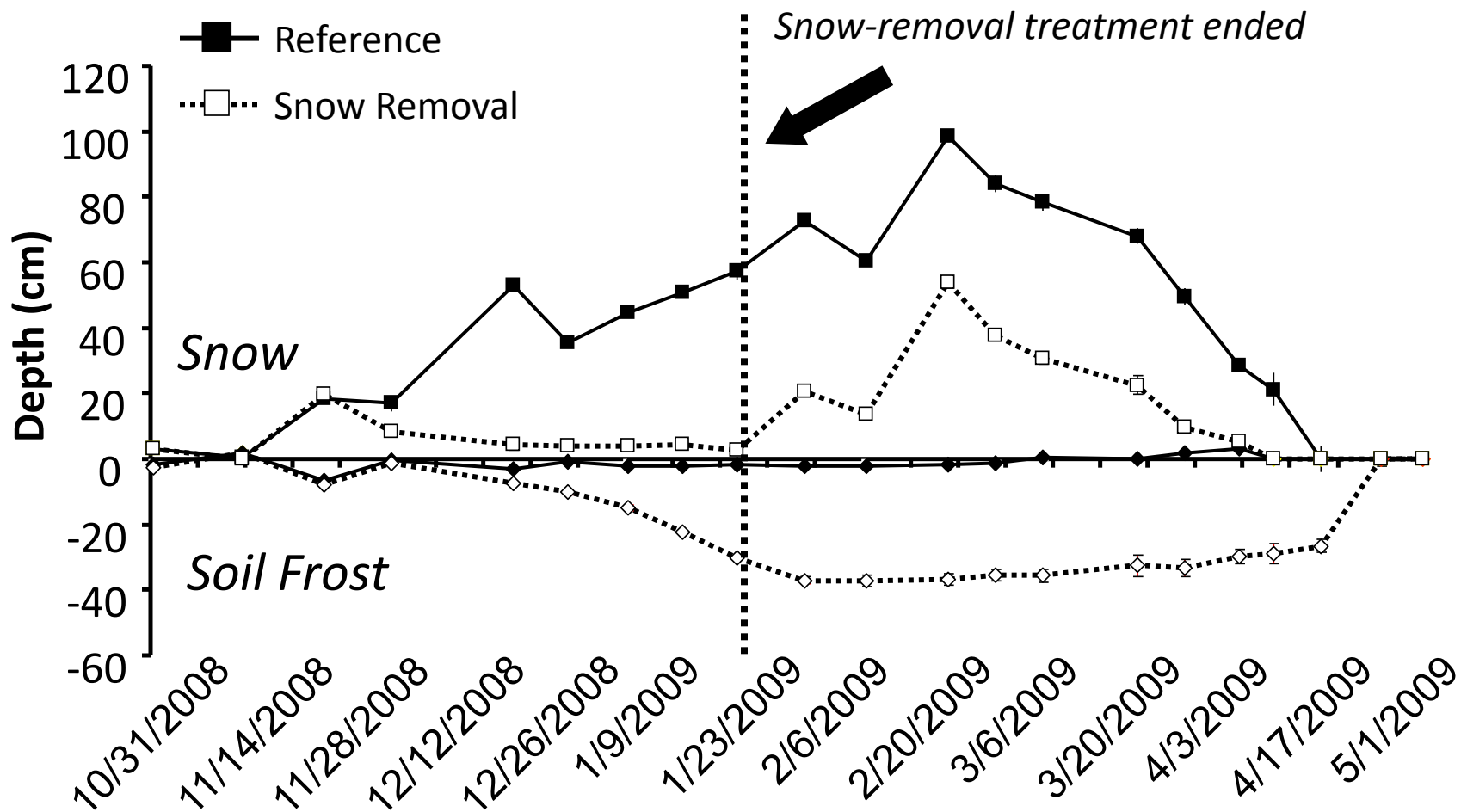


Snow Depth

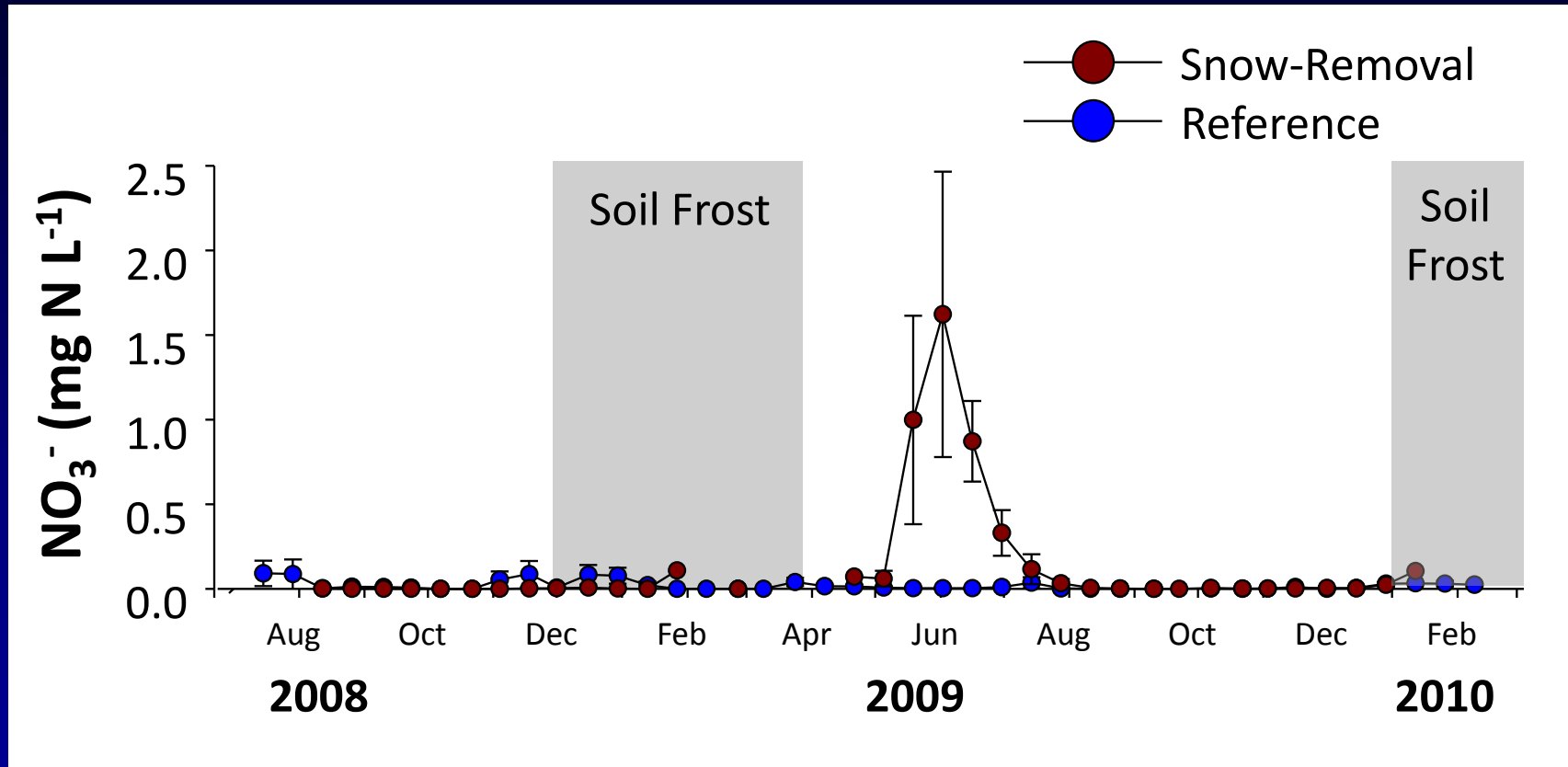


Frost tubes with
methylene blue dye

Snow and Soil Frost Depth



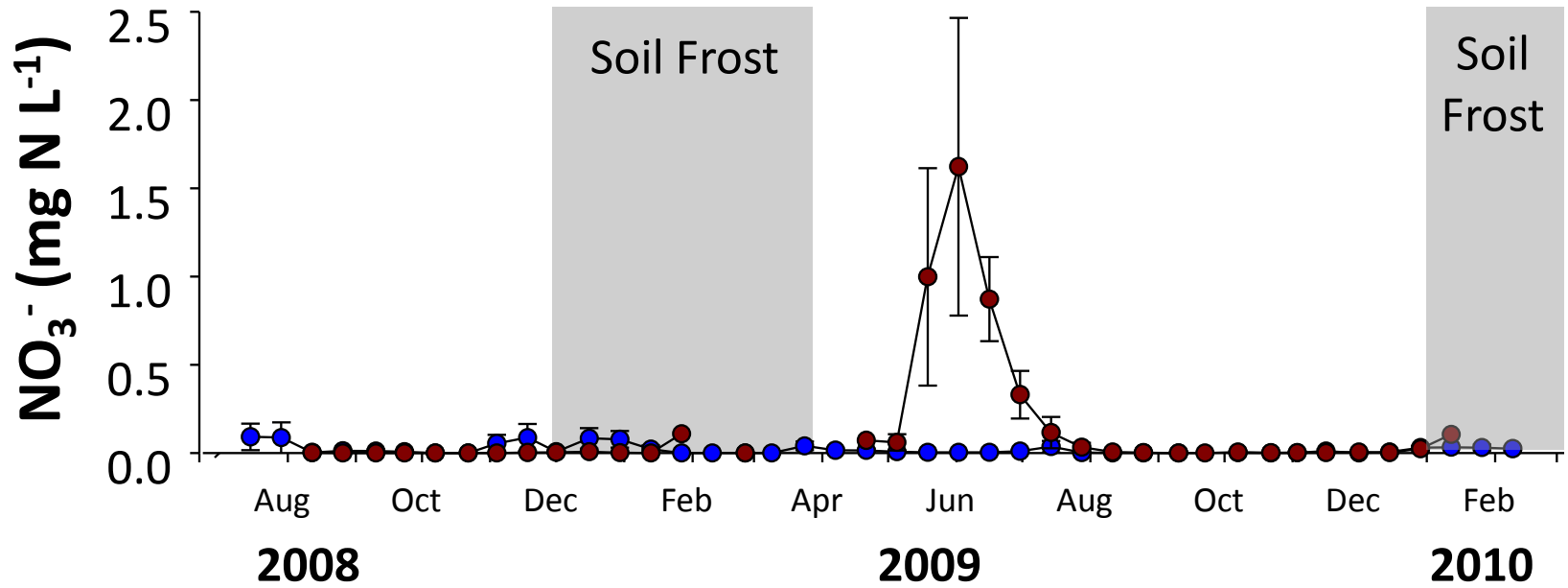
Soil Frost Results in Elevated NO_3^- in Leachate



Soil Frost Results in Elevated NO_3^- in Leachate

What explains elevated NO_3^- ?

- Snow-Removal
- Reference



Hypotheses

Reduced snow pack and increased soil frost result in decreased:

- root health and nutrient uptake
- sap flow and canopy uptake of carbon
- aboveground productivity

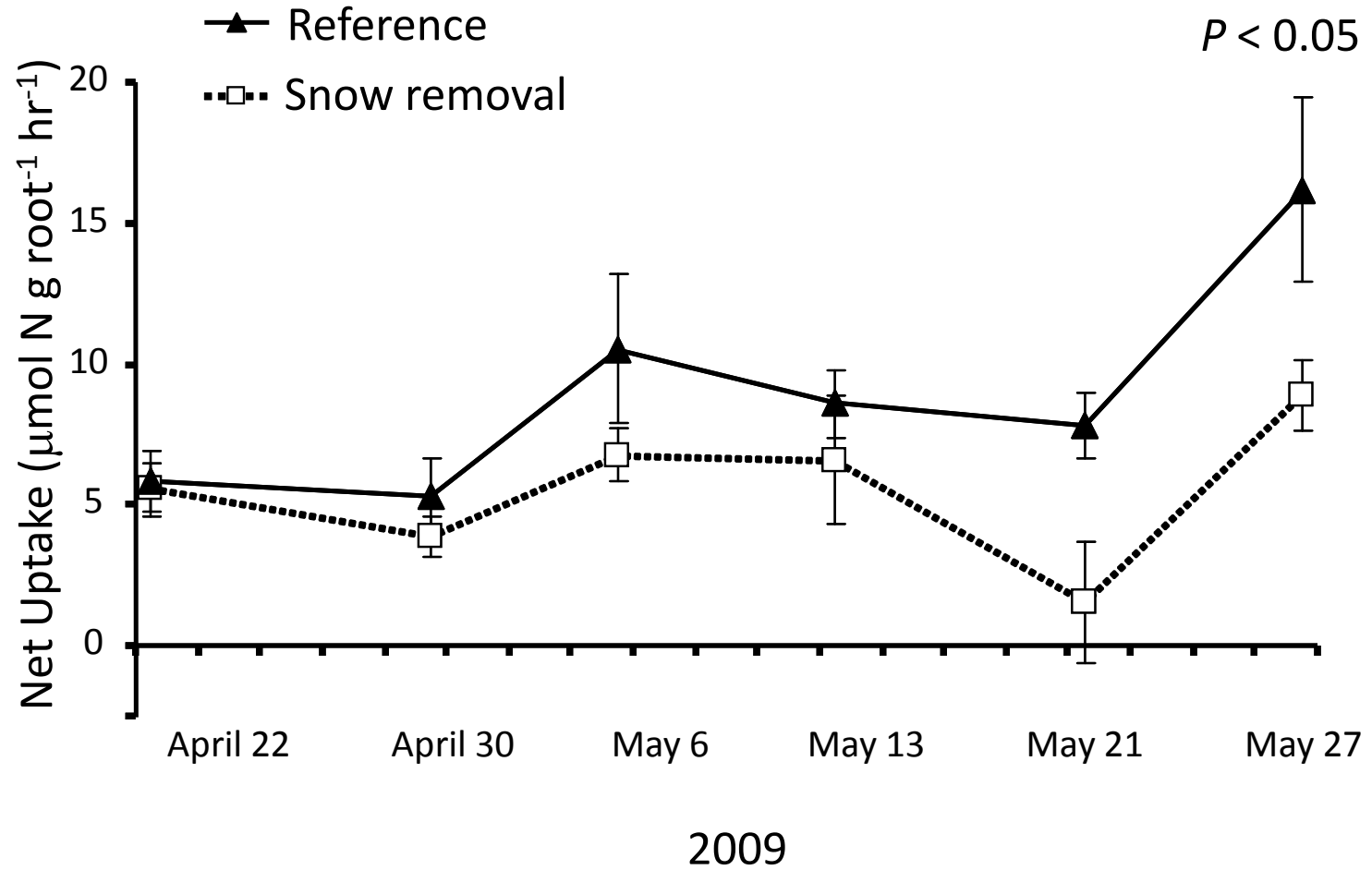


Uptake of Nitrogen by Trees by Sugar Maple Trees

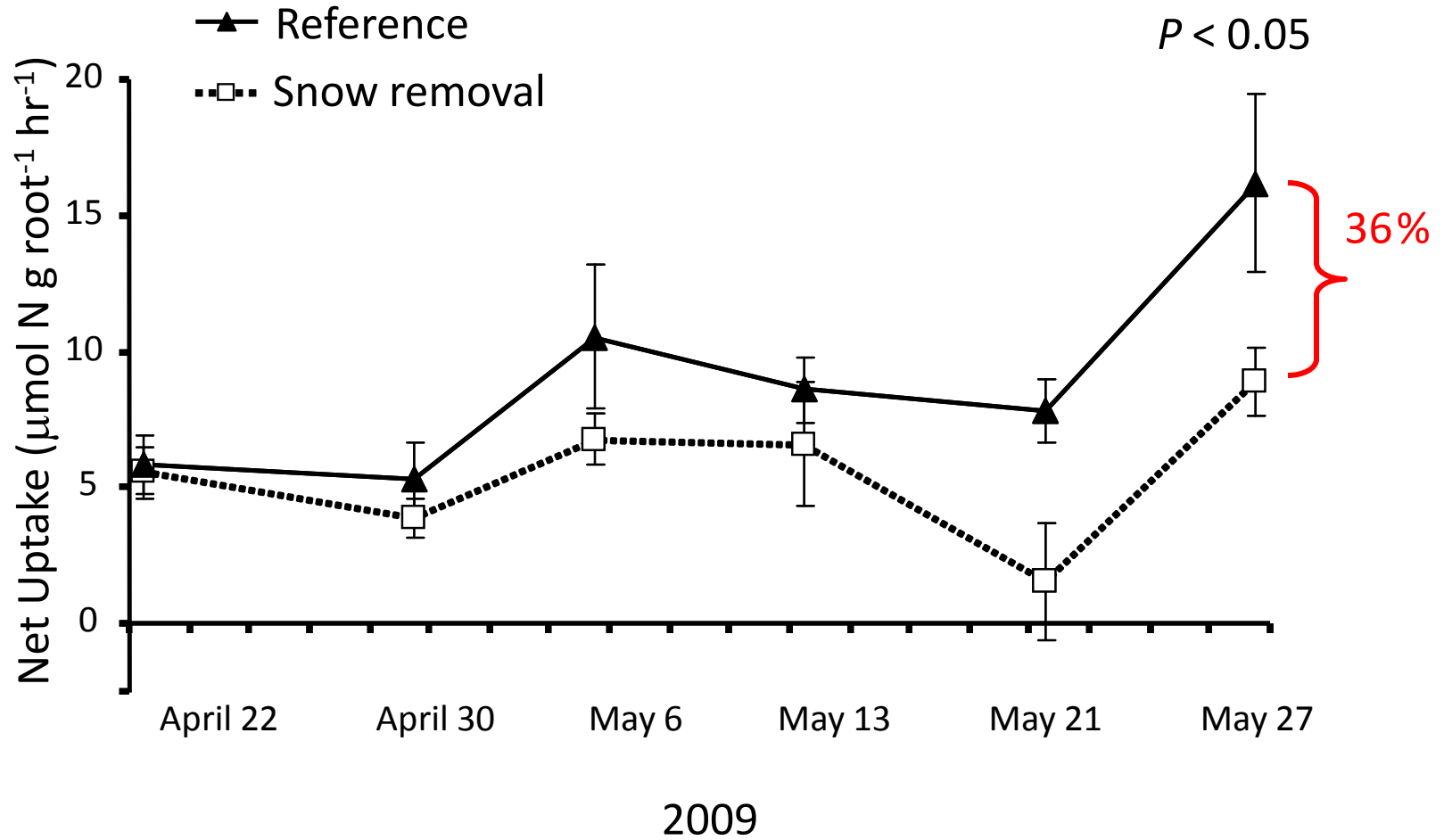


Socci and Templer (2011)
Plant Ecology and Diversity

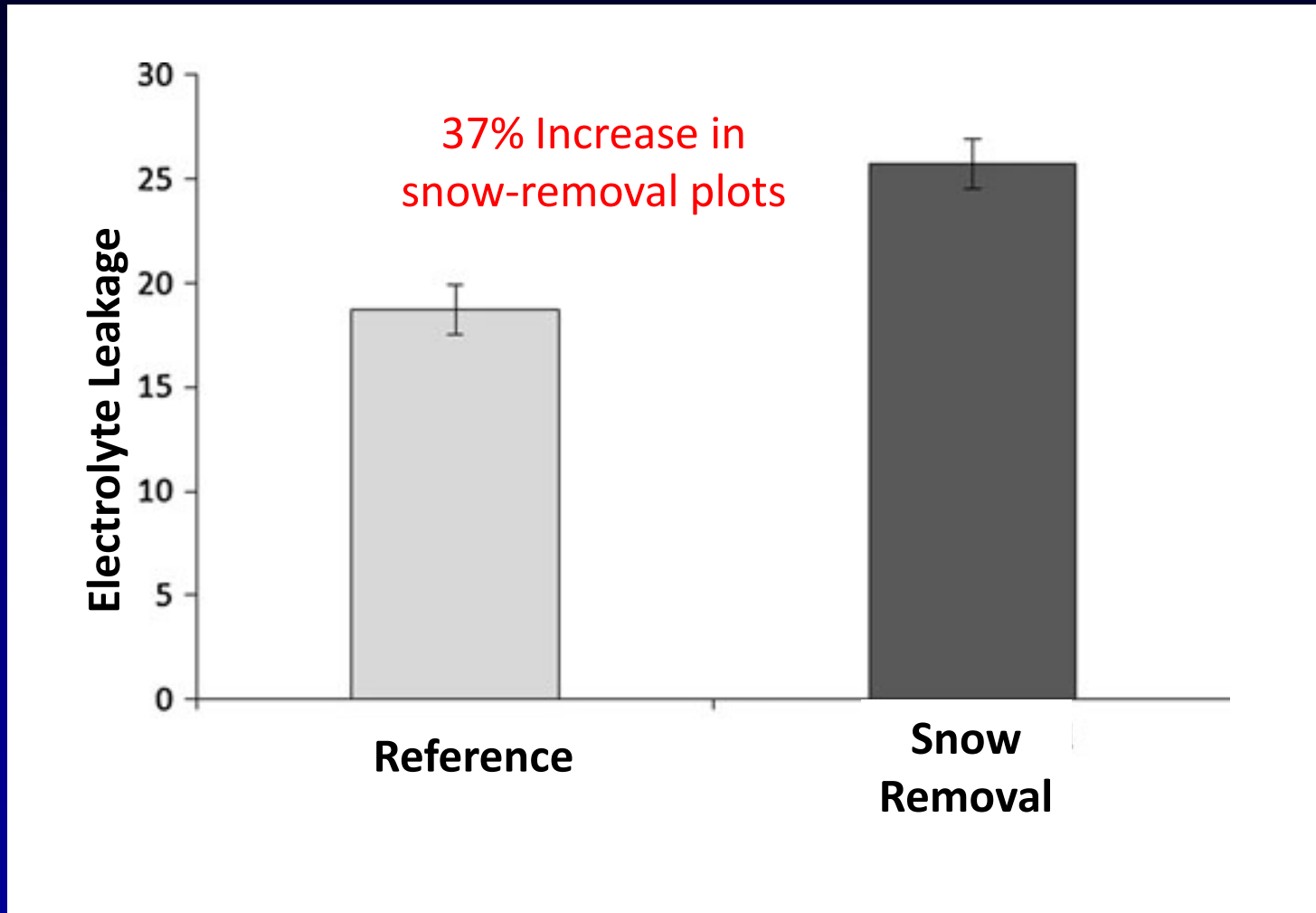
Uptake of Nitrogen by Trees by Sugar Maple Trees



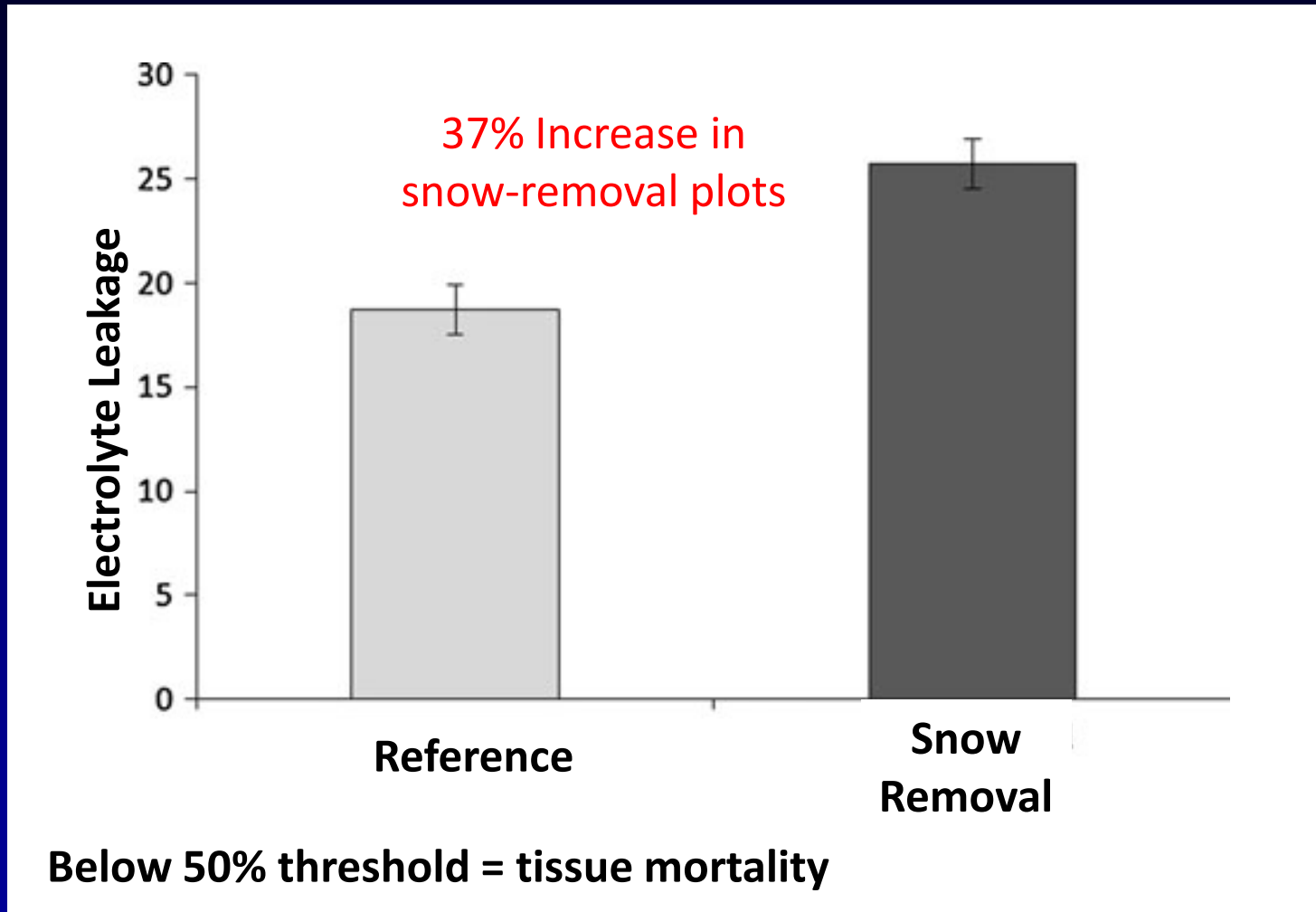
Uptake of Nitrogen by Trees by Sugar Maple Trees



Soil Frost Induces Root Injury of Sugar Maple Trees



Soil Frost Induces Root Injury of Sugar Maple Trees



Hypotheses

Reduced snow pack and increased soil frost results in decreased:

- root health and nutrient uptake
- sap flow and canopy uptake of carbon
- aboveground productivity

Sap Flow and Net Canopy C Uptake

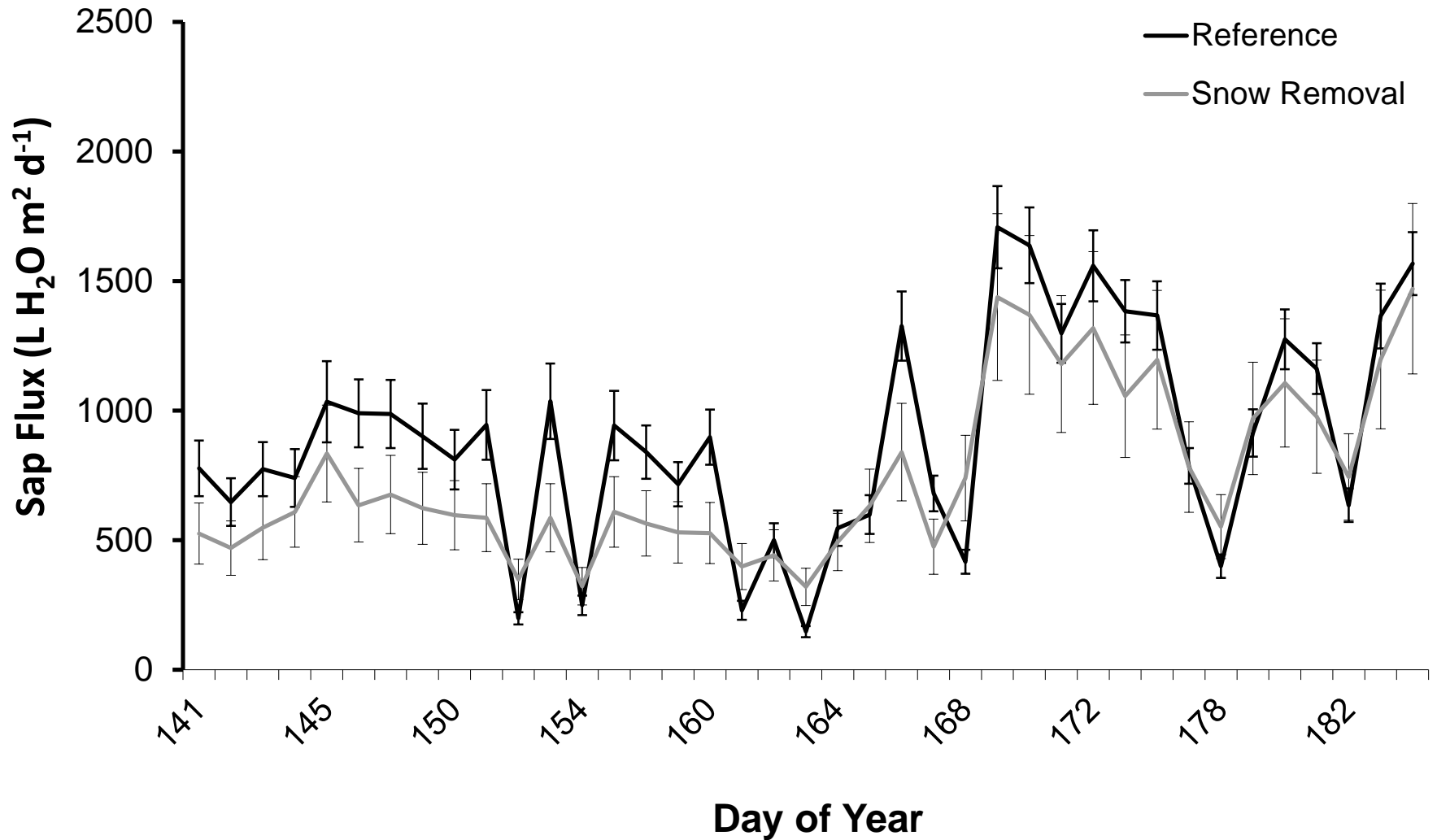


Measuring sap flow

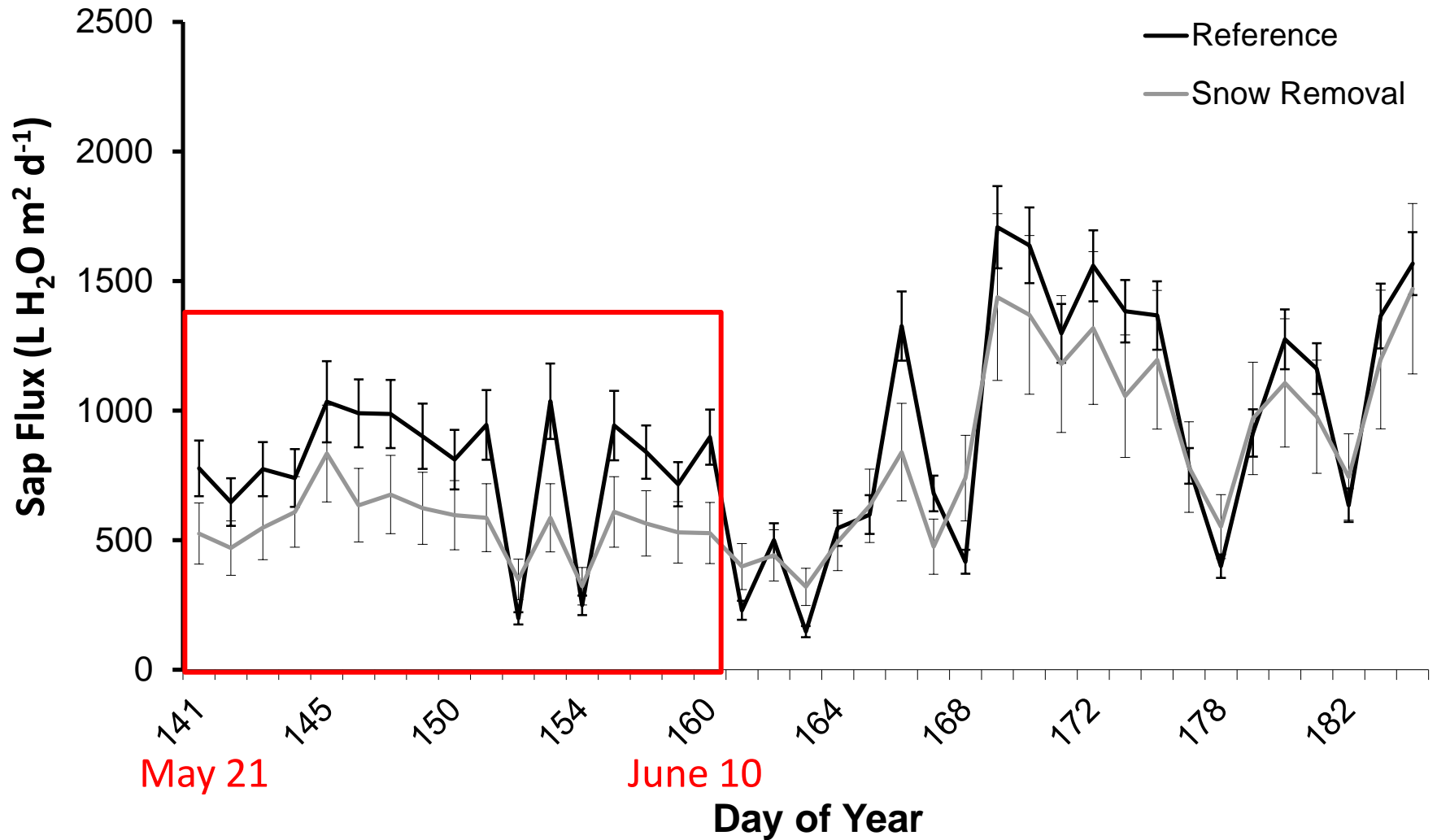


Measuring leaf-level gas exchange

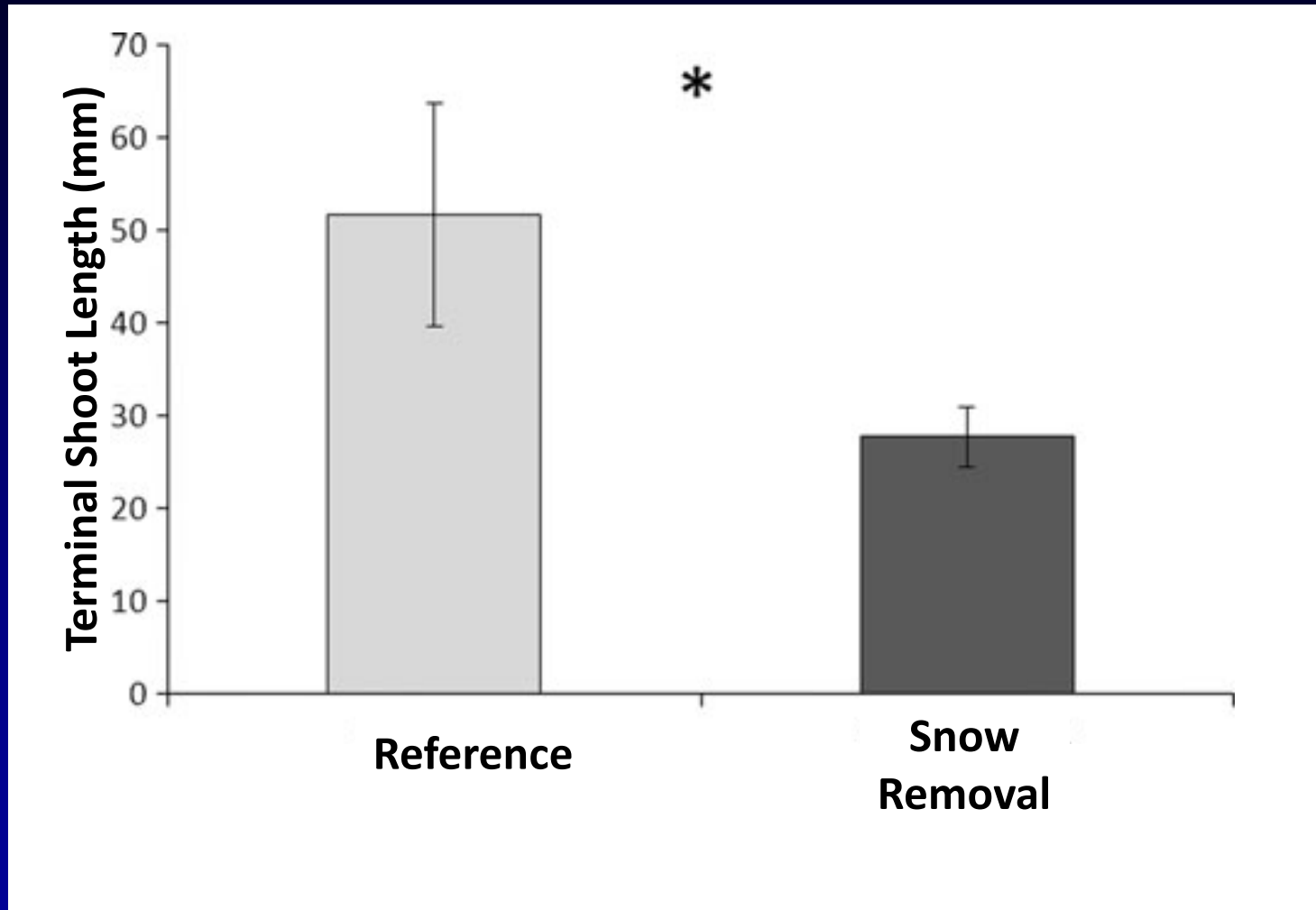
Soil Frost Reduces Sap Flow by Sugar Maple Trees



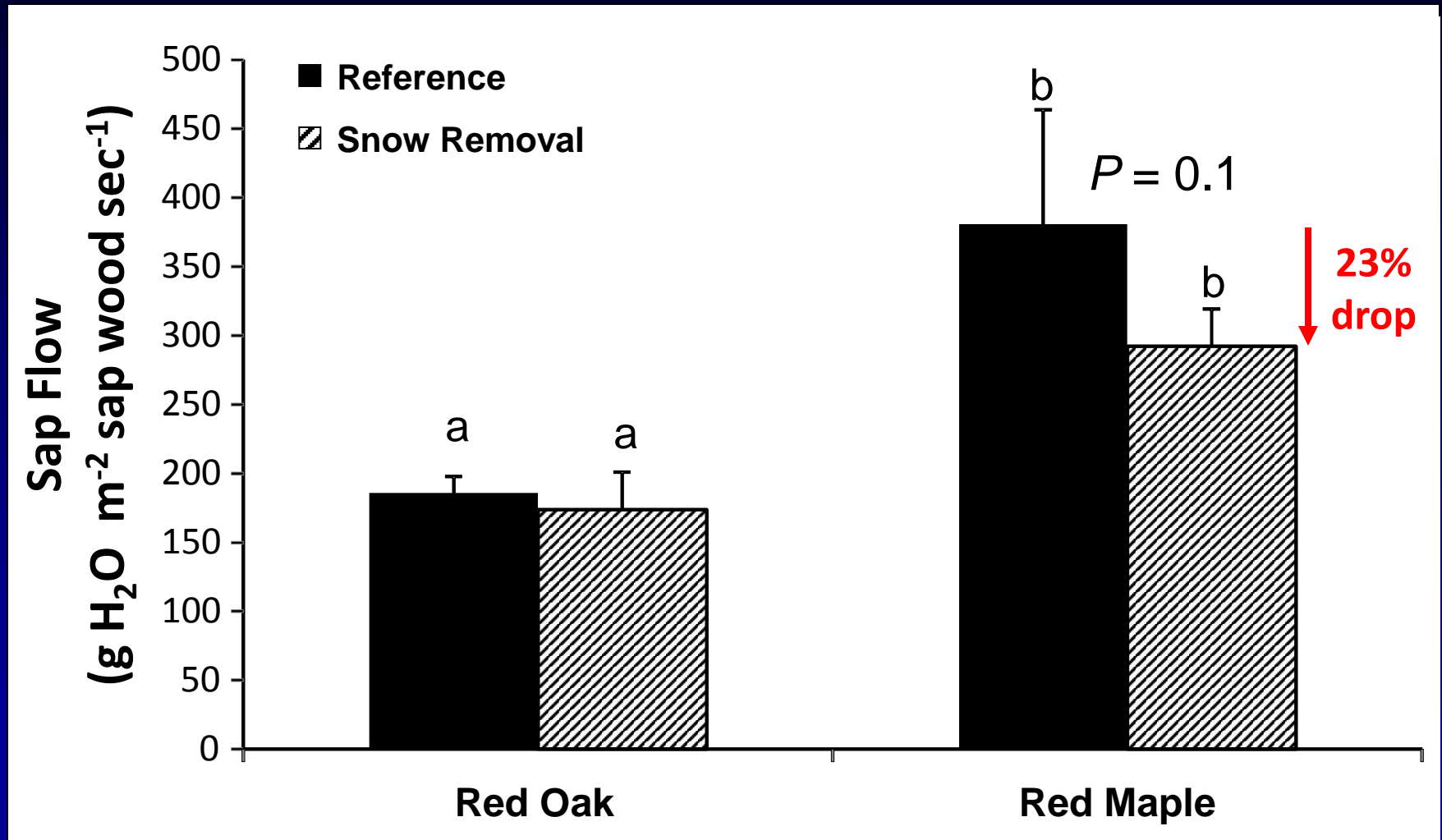
Soil Frost Reduces Sap Flow by Sugar Maple Trees



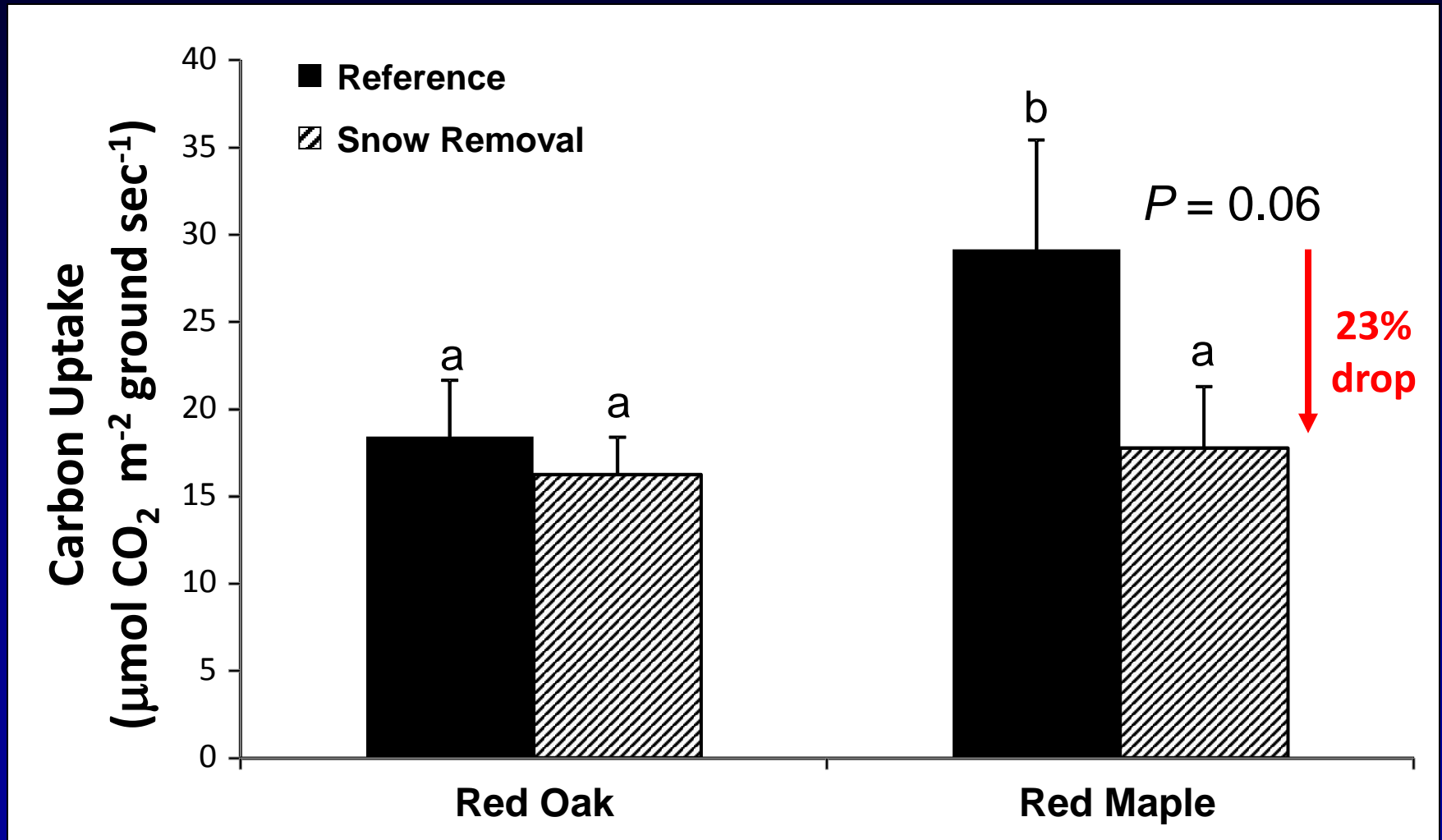
Soil Frost Reduces Growth of Sugar Maple Leaves



Soil Frost Reduces Sap Flow by Red Maple Trees



Soil Frost Reduces C Uptake by Red Maple Trees

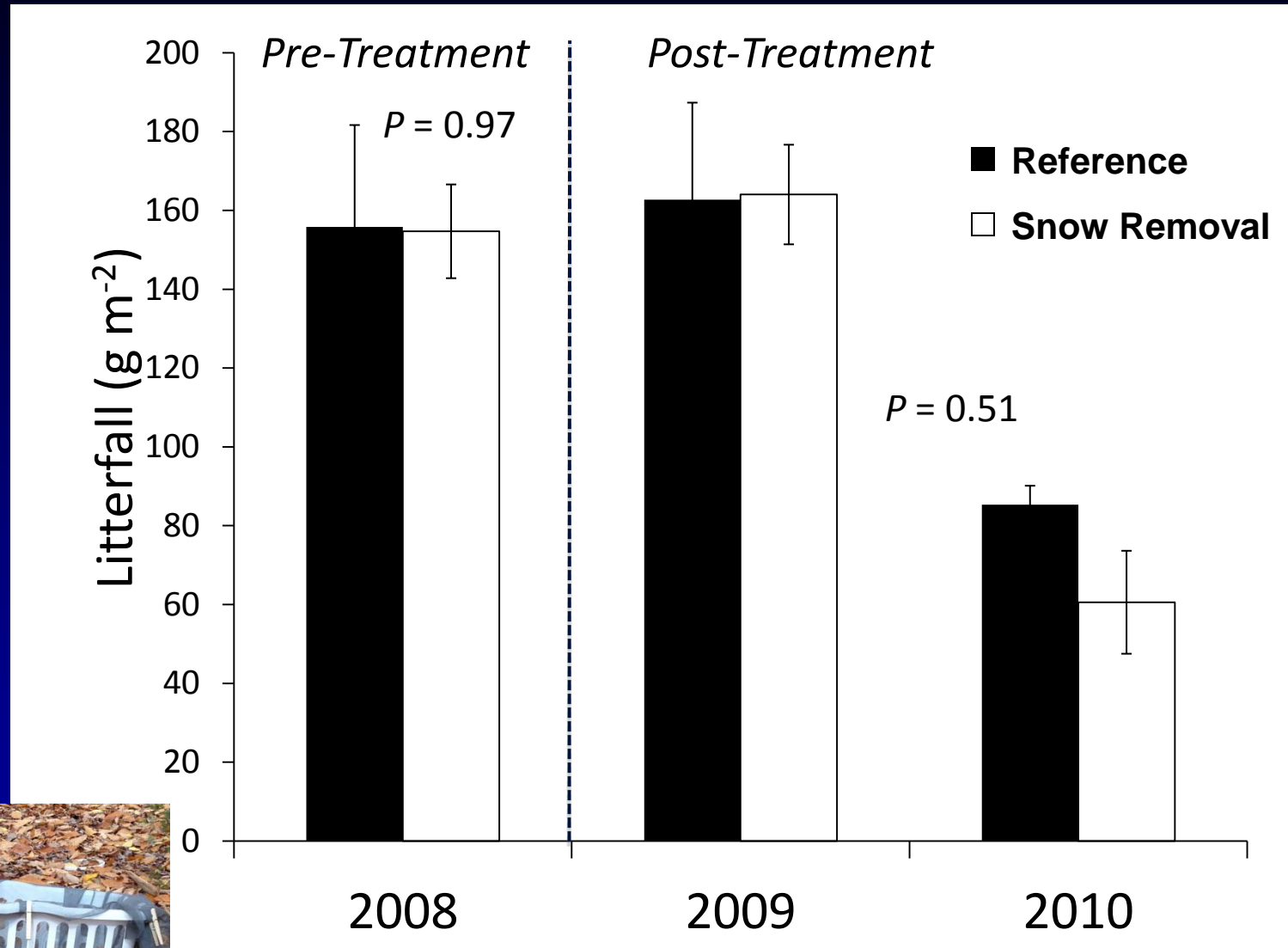


Hypotheses

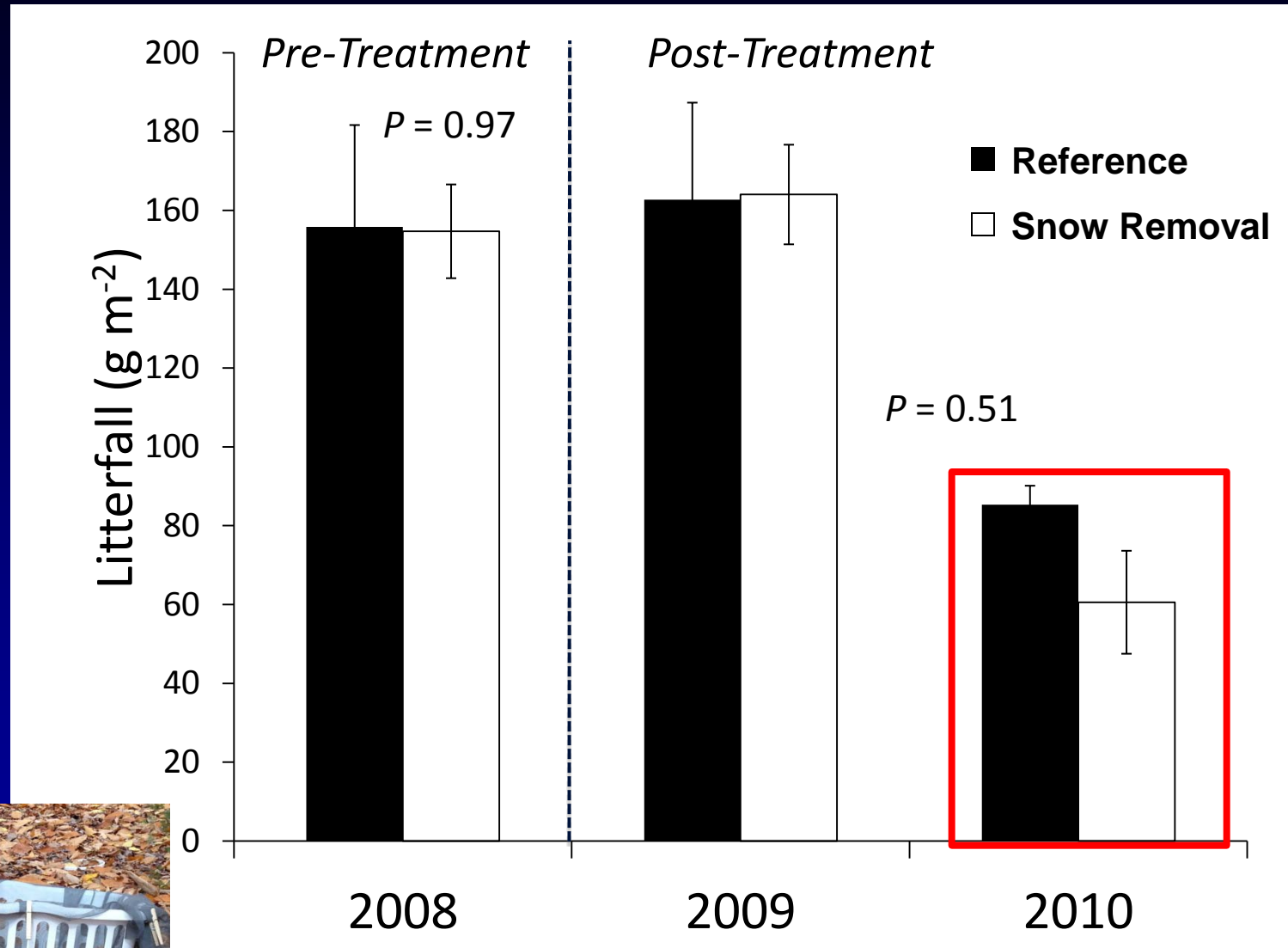
Reduced snow pack and increased soil frost results in decreased:

- root health and nutrient uptake
- sap flow and canopy uptake of carbon
- aboveground productivity (litterfall and radial growth)

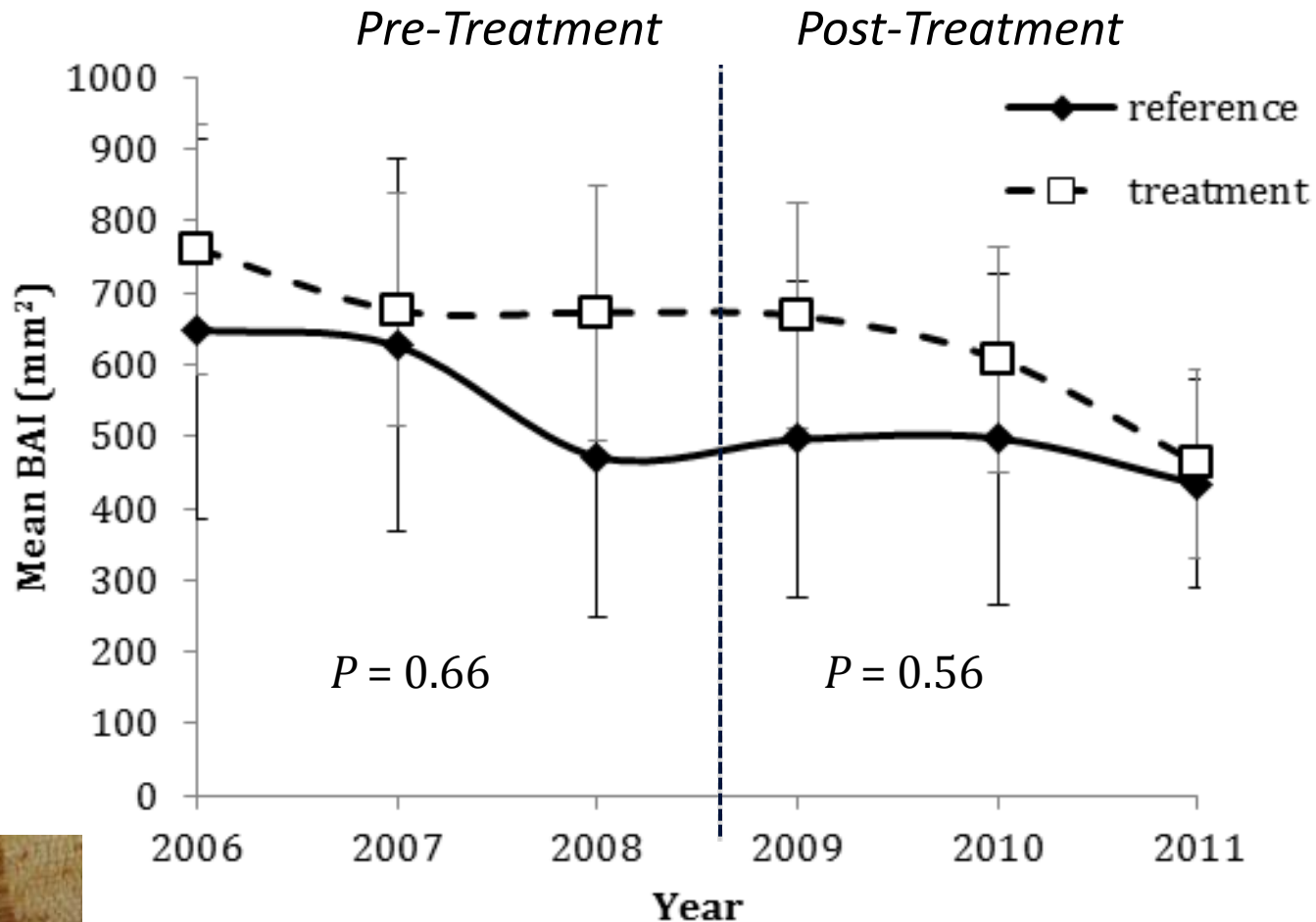
Soil Frost Does Not Affect Rates of Litterfall



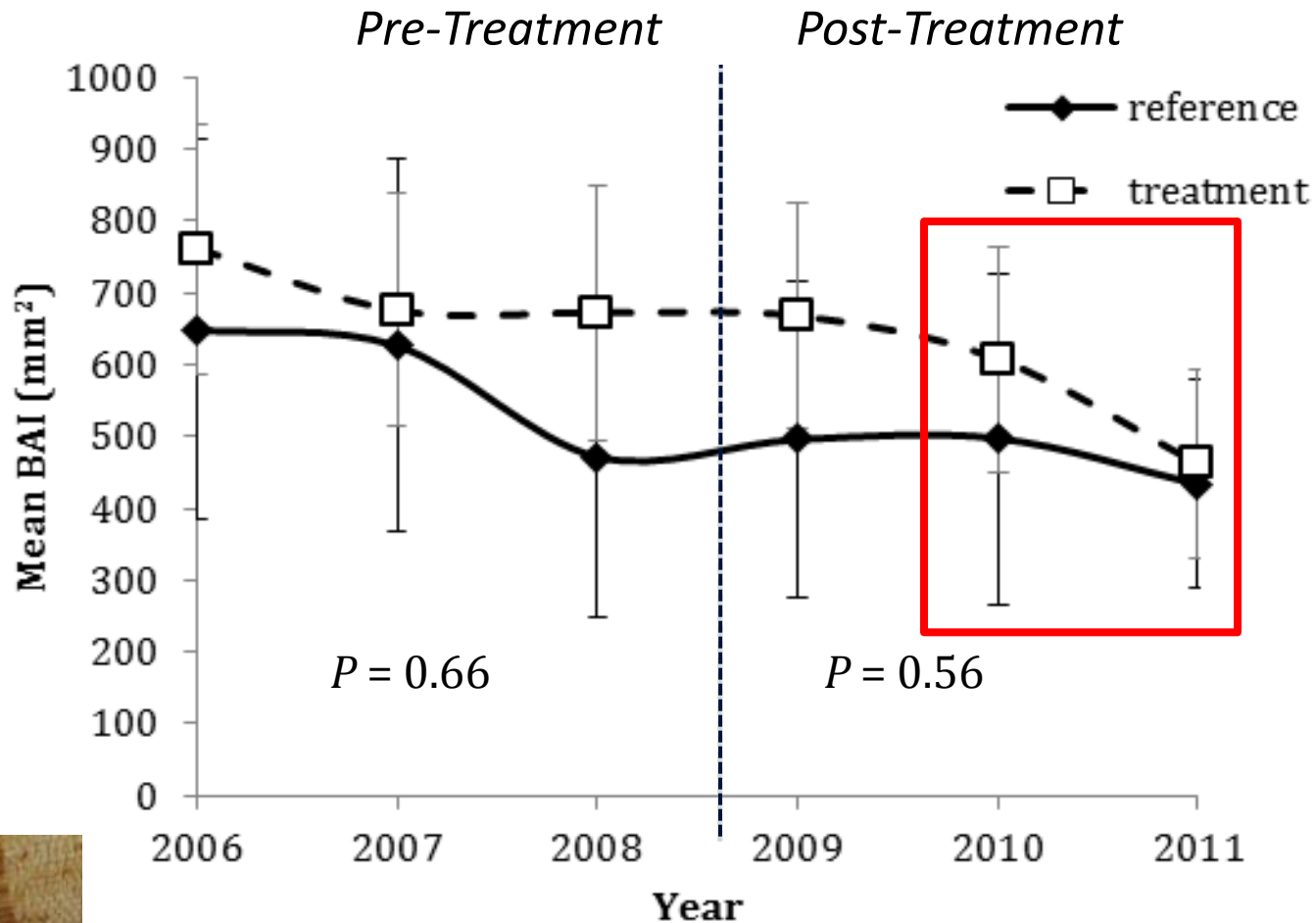
Soil Frost Does Not Affect Rates of Litterfall



Soil Frost Does Not Affect Basal Area Increment



Soil Frost Does Not Affect Basal Area Increment



Winter Climate Change Effects on Forest Ecosystems

Smaller winter snowpack and increased soil frost:

- increase NO_3^- leaching due to diminished N uptake by trees
- decrease rates of water and C uptake by maple trees
- do not affect aboveground productivity in the short-term

Winter Climate Change Effects on Forest Ecosystems

Smaller winter snowpack and increased soil frost:

- increase NO_3^- leaching due to diminished N uptake by trees
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Implications for biogeochemistry, water quality, and tree species composition of northern temperate forests.

Acknowledgements

Undergraduate Students

Rebecca Antonoplos
Komal Basra
Angelica Carreon
Keita DeCarlo
Mary Farina
Omar Gutierrez del Arroyo
Adam Jacobs
Brita Jessen
Allyssa Kilanowski
Stephanie Kubala
Michael Mangiante
Monika Mathur

High School Students

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Andrew W. Mellon Foundation