Soil freezing effects:

- Runoff versus infiltration.
- Root (and tree) mortality.
- Disruption of nutrient cycles:
  - Increases in N, P, Ca loss.
  - Effects on DOC?
- Increases in nitrous oxide flux.
- Decreases in methane uptake.
- Effects on overwinter CO_2 flux?

Winter climate change research at Hubbard Brook (people and funding):

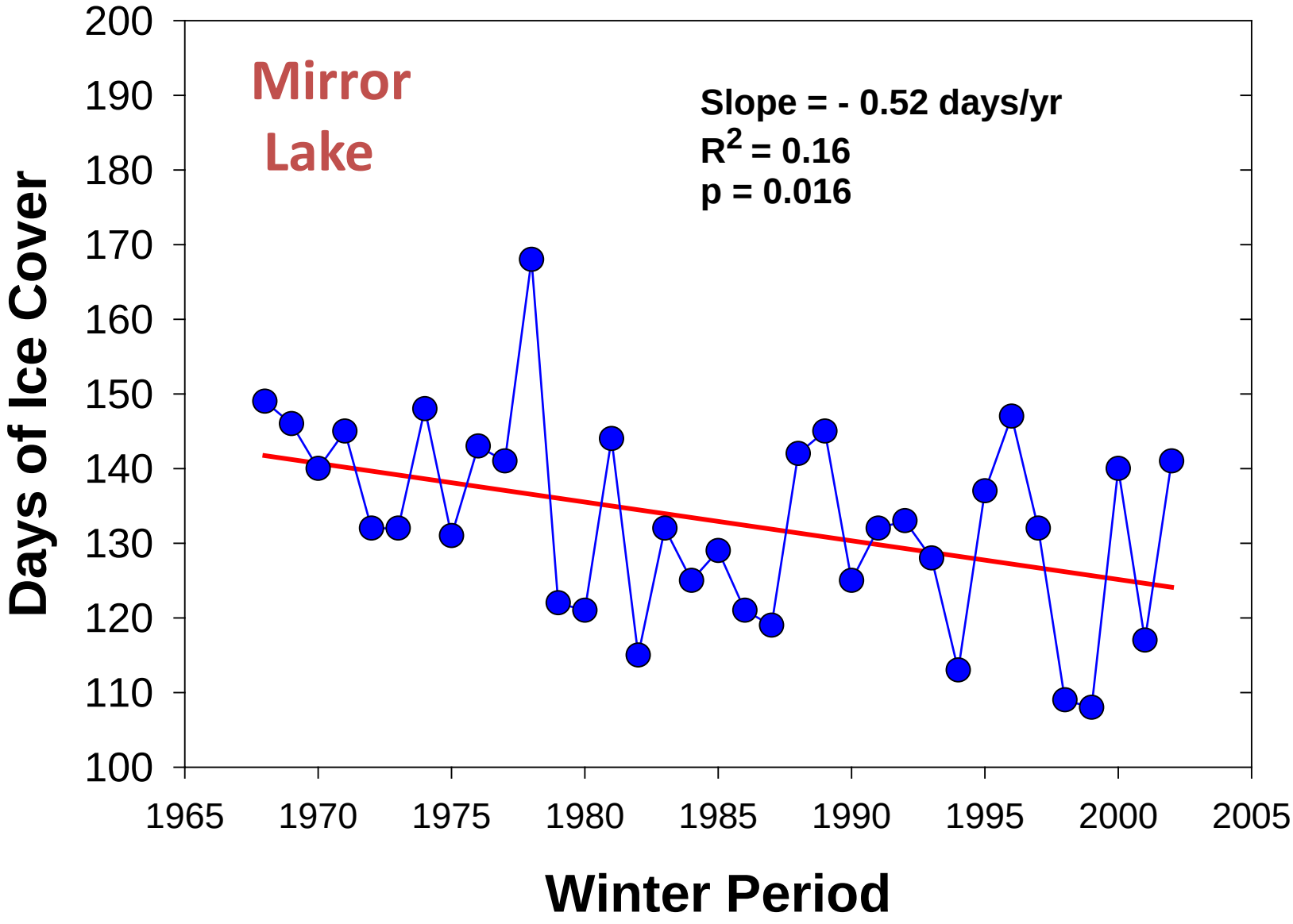
- Personnel :
  - Peter M. Groffman
  - Charley Driscoll
  - Melany Fisk
  - Pam Templer
  - John Campbell
  - Natalie Cleavitt
  - Geri Tierney
  - Adam Welman
  - Lynn Christenson
  - Janet Frankenstein
  - Tim Fahey
  - Janet Hardy
  - Gene Likens
  - Myron Mitchell
  - Ross Fitzhugh
  - Jason Demers
  - Lisa Martel
  - Annie Socci
  - Rae Melloh
  - Karen Henry

- Funding: NSF Ecosystem Studies, LTER

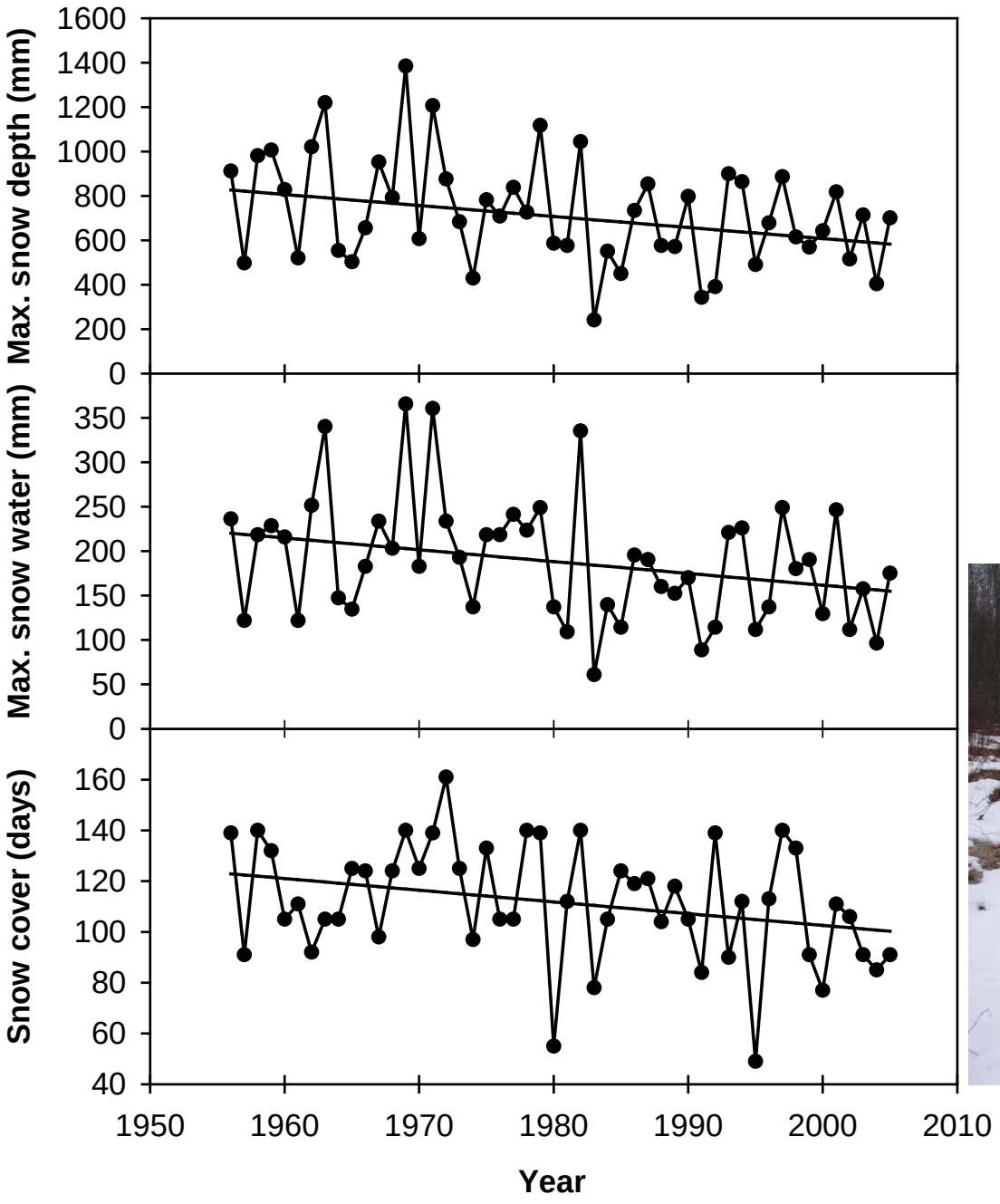
Winter climate change research at Hubbard Brook (projects):

- Long-term USFS interest in snow:
  - 50 year record of soil frost and snow depth, water content and snow cover duration.
- Days of ice cover for Mirror Lake
  - 49 year record.
- Excursions in the long-term watershed nitrate export record.
- Shoveling studies
- Natural gradient studies


MIRROR LAKE



Source: Gene Likens



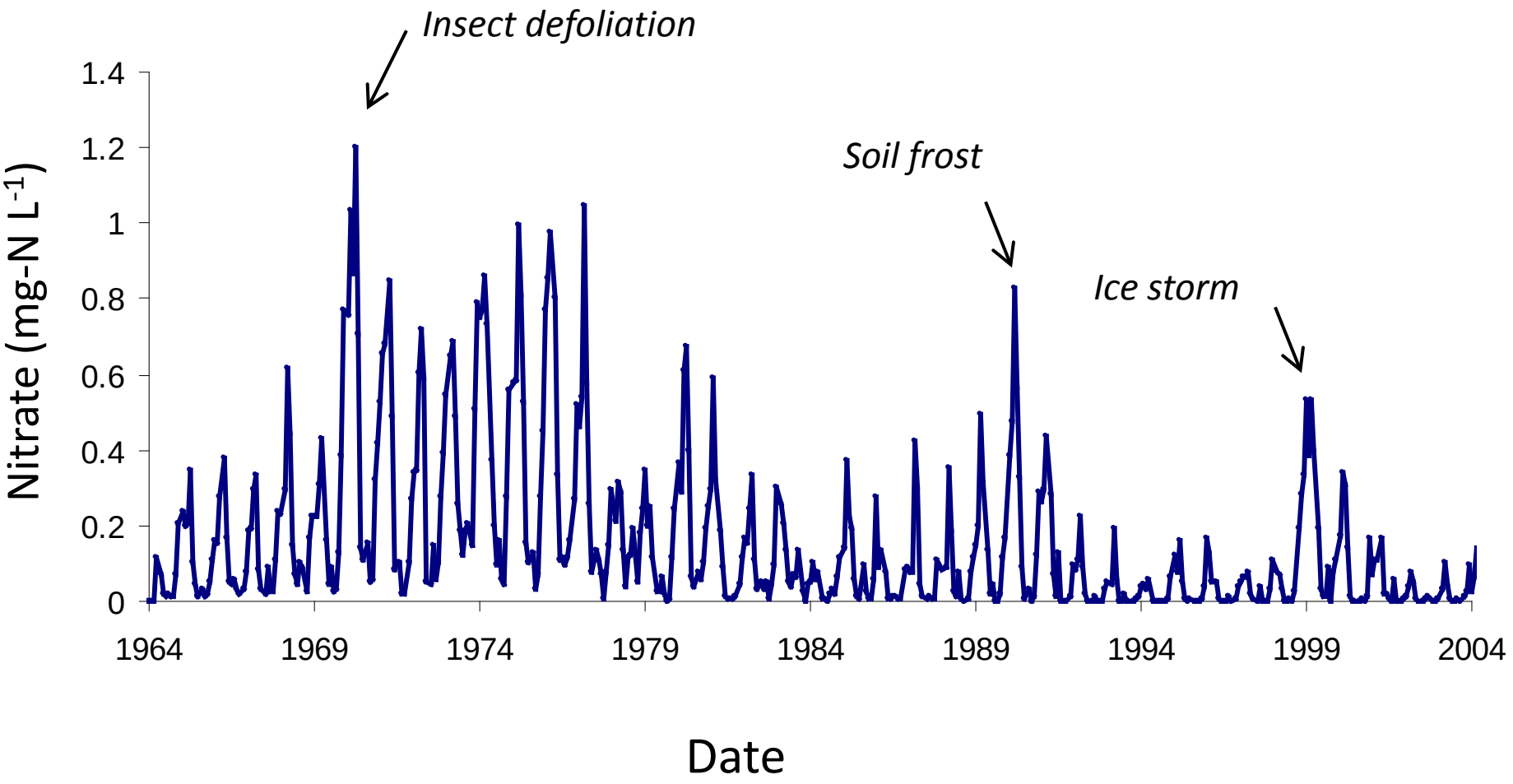
Snow course data from Station #2, monitored continuously since 1955.

Campbell et al. (2007)

Hubbard Brook – February 6, 2006

Source: Don Buso

Monthly Stream Nitrate Concentrations (W6)



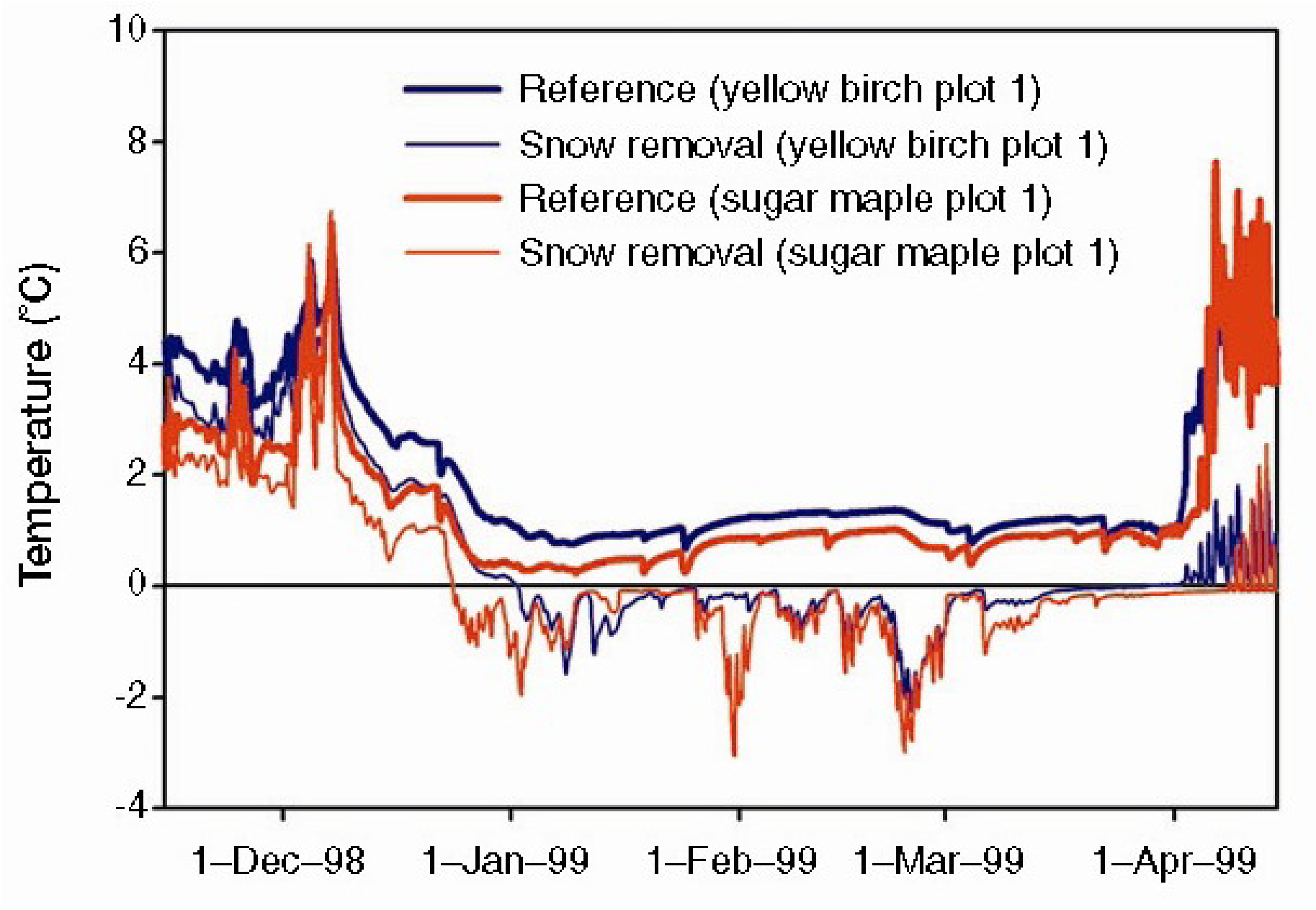
Modified from Likens 2004

Big ideas:

- Snow is an insulator of the forest floor.
- Lack of snow results in soil freezing, root and microbial mortality and accelerated nutrient loss and soil acidification.
- Climate change could lead to increases in soil freezing episodes.
- These events occur now.

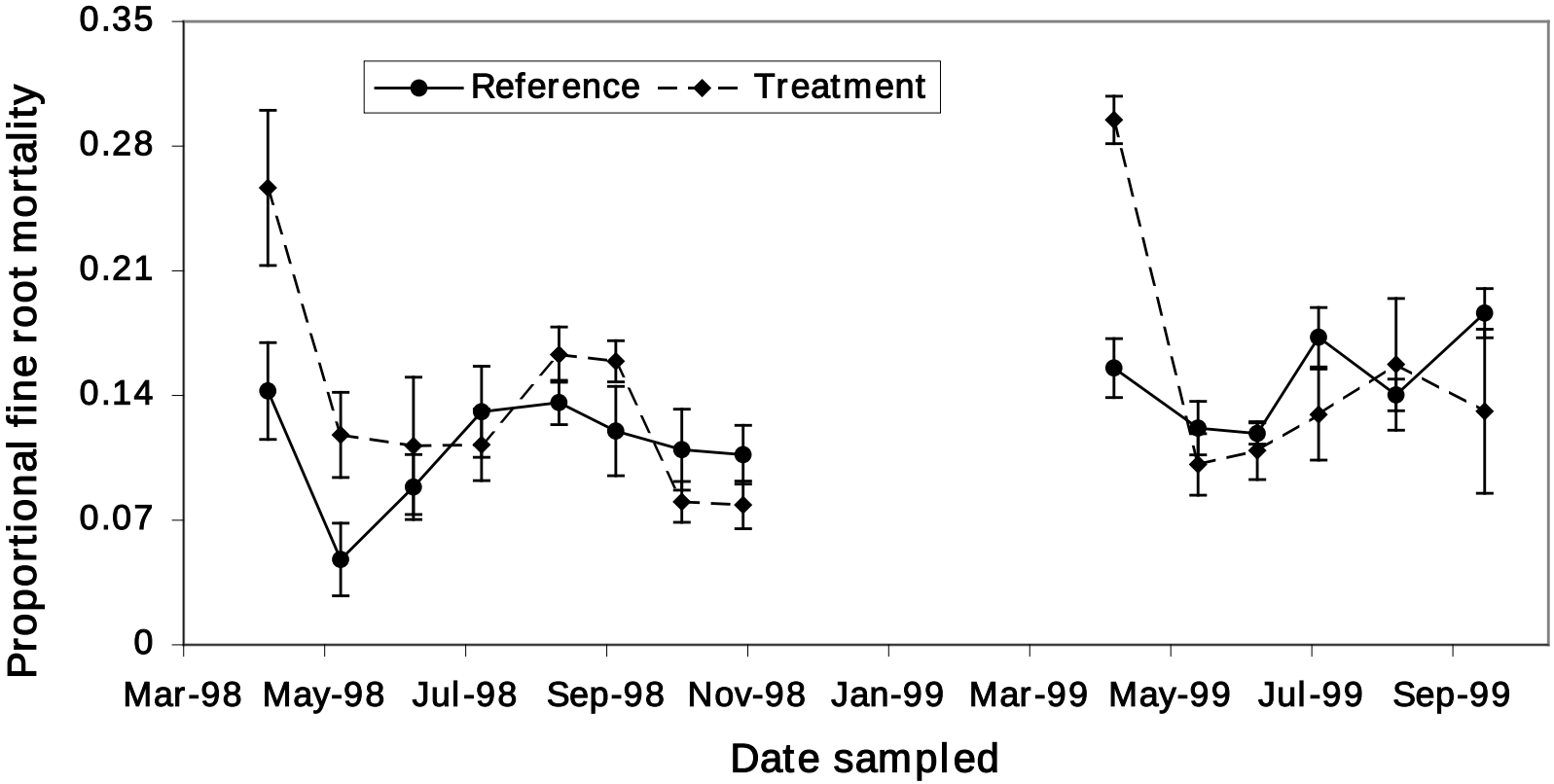
Origins:

- Long term USFS interest in snow.
- Mitchell et al. 1996. Climatic control of nitrate loss from forested watersheds in the northeastern United States. Environ. Sci. Tech.
- Sugar maple decline in Canada.
- Work in the western U.S., e.g., Niwot Ridge (Williams, Brooks, et al.), Wyoming (Reiners et al.), Alaska.



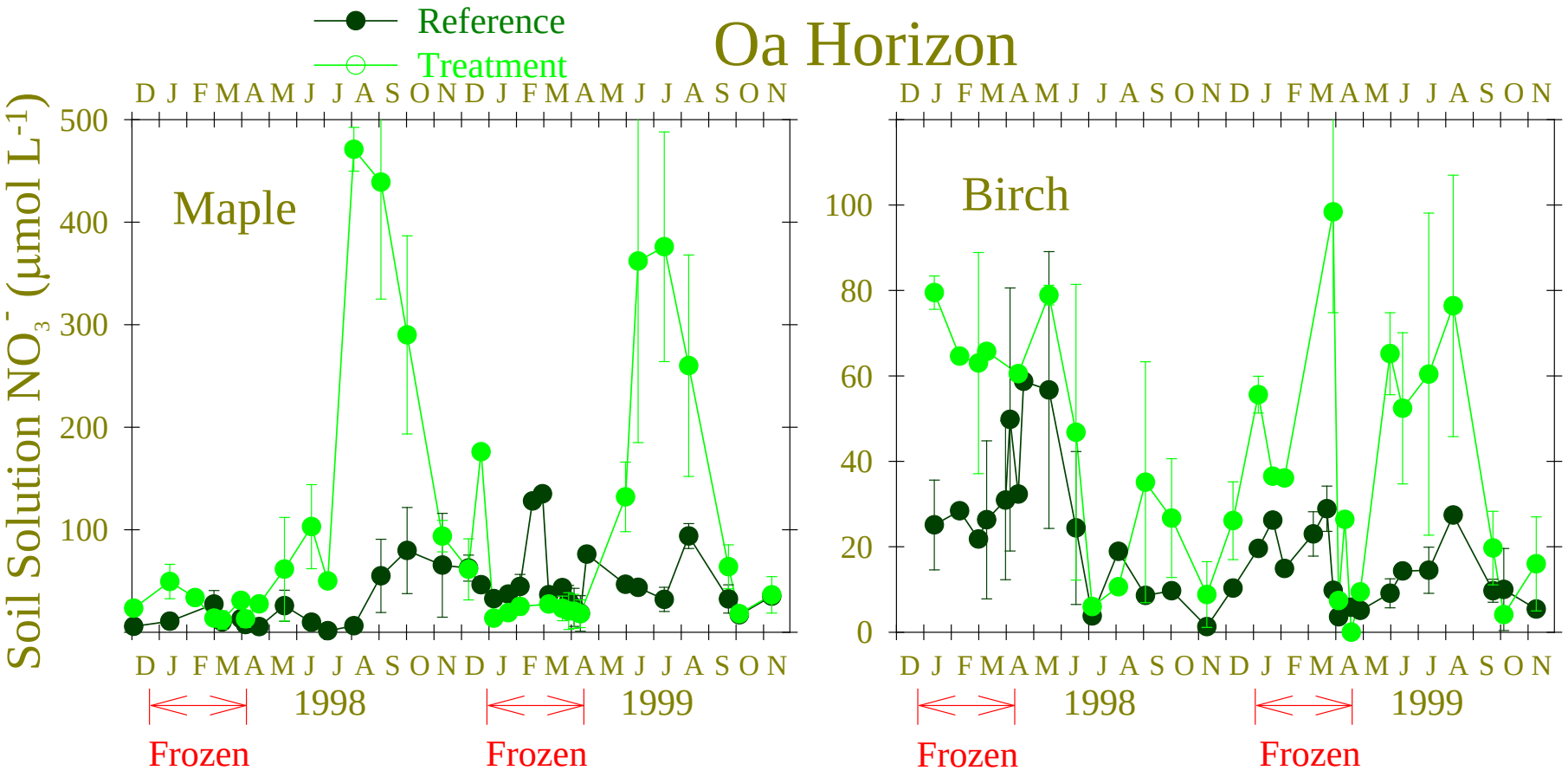
Hardy et al. (2001)

Soil freezing doubles overwinter root mortality:



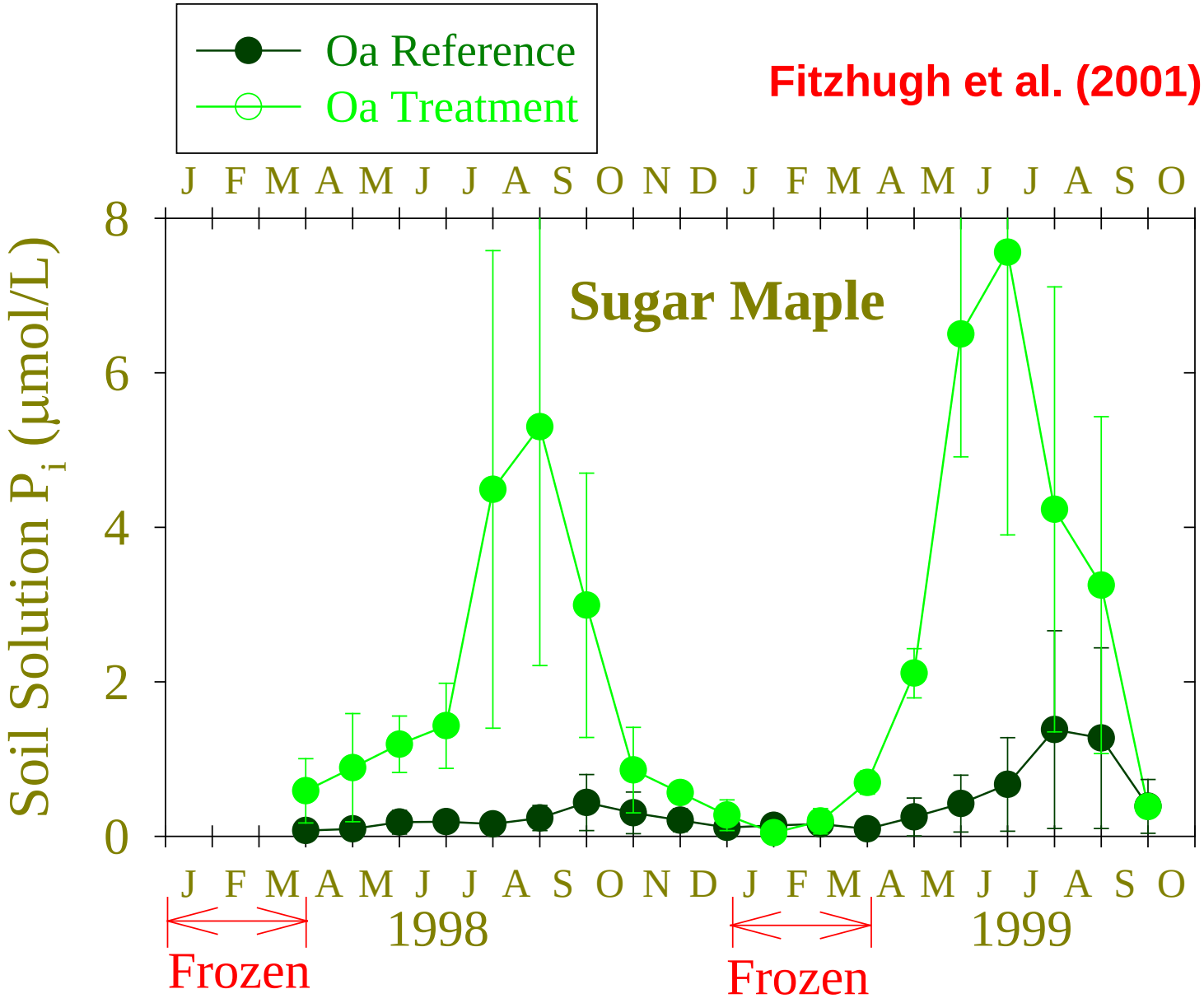
Tierney et al. (2001)

Soil freezing increases nitrate leaching:



Fitzhugh et al. (2001)

Soil freezing increases phosphorus leaching:



Findings: Mild soil frost induces:

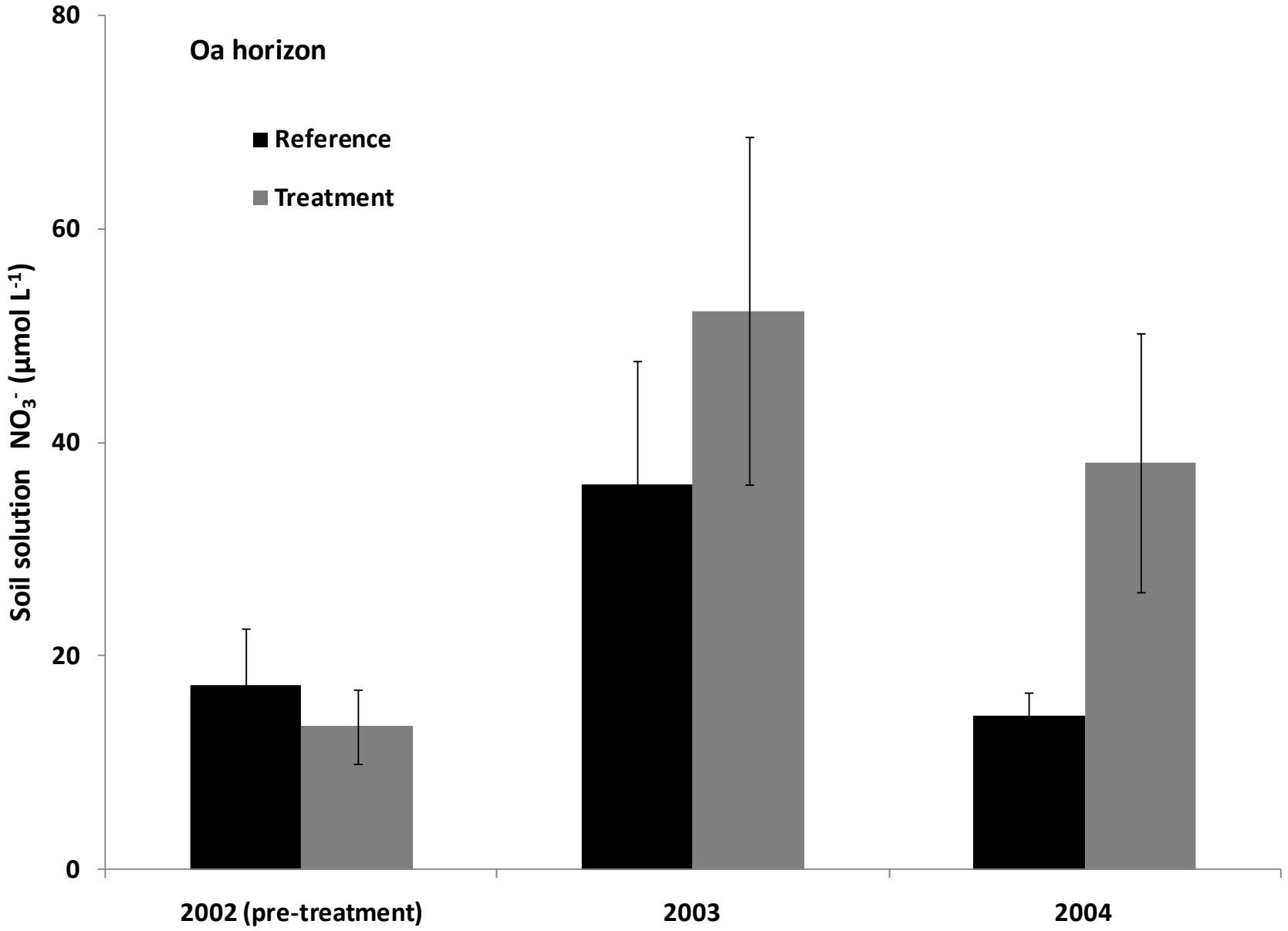
- N, P, H^+ and base cation leaching (Fitzhugh et al. 2001).
- Increase in N_2O emissions (Groffman et al. 2006).
- Decreases in CH_4 uptake (Groffman et al. 2006).
- Doubling overwinter root mortality (Tierney et al. 2001).

- But, some mysteries:
  - Big effects from mild freezing.
    - Field results much more dramatic than lab results.
  - NO change in microbial biomass and activity (including *in situ* net N mineralization and nitrification (Groffman et al. 2001).

→ Freeze effects dominated by physical/chemical/biological interactions.

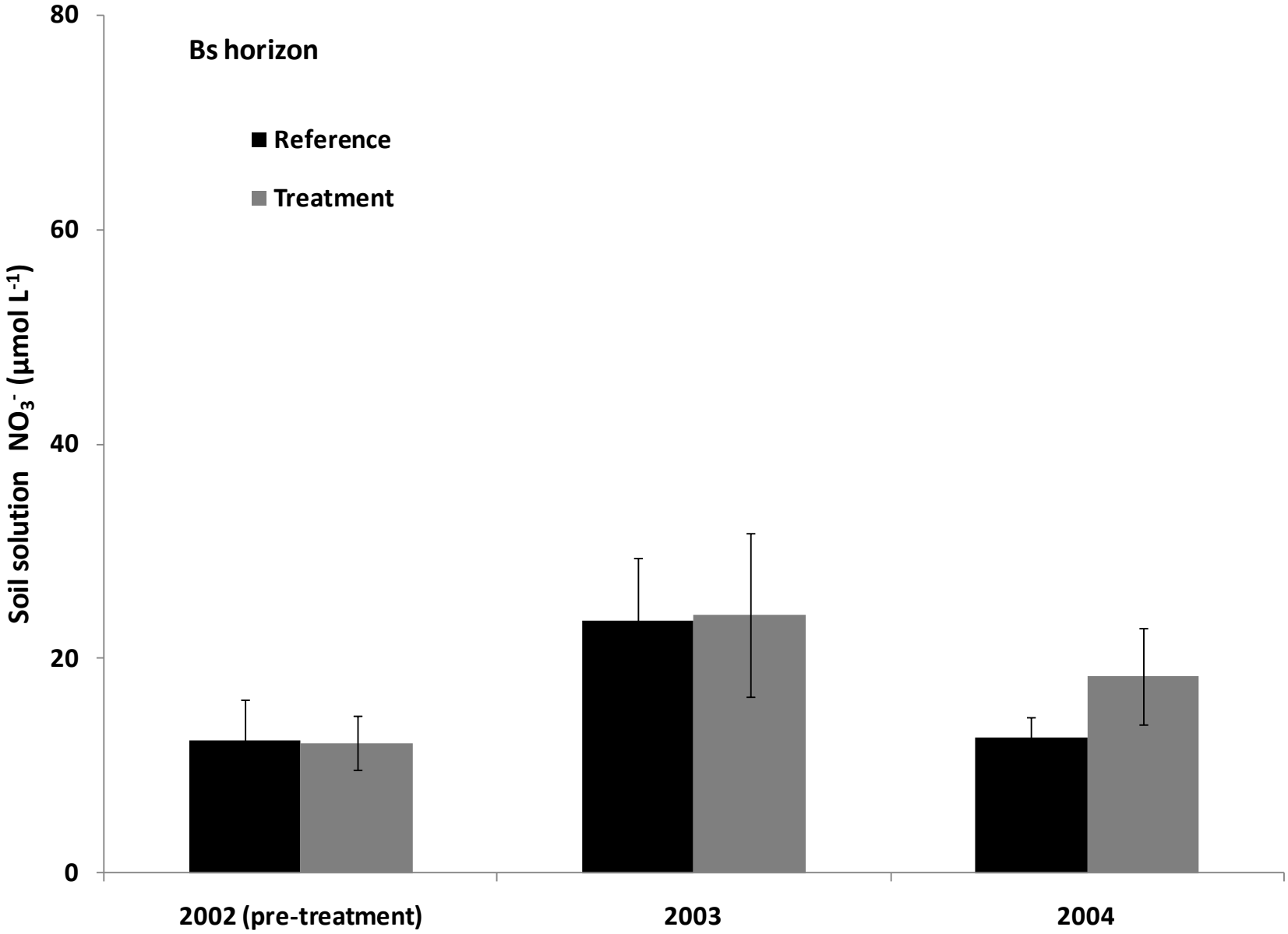
→ Can we go to society with results that we don't understand?

Nitrate response much less marked in second study:



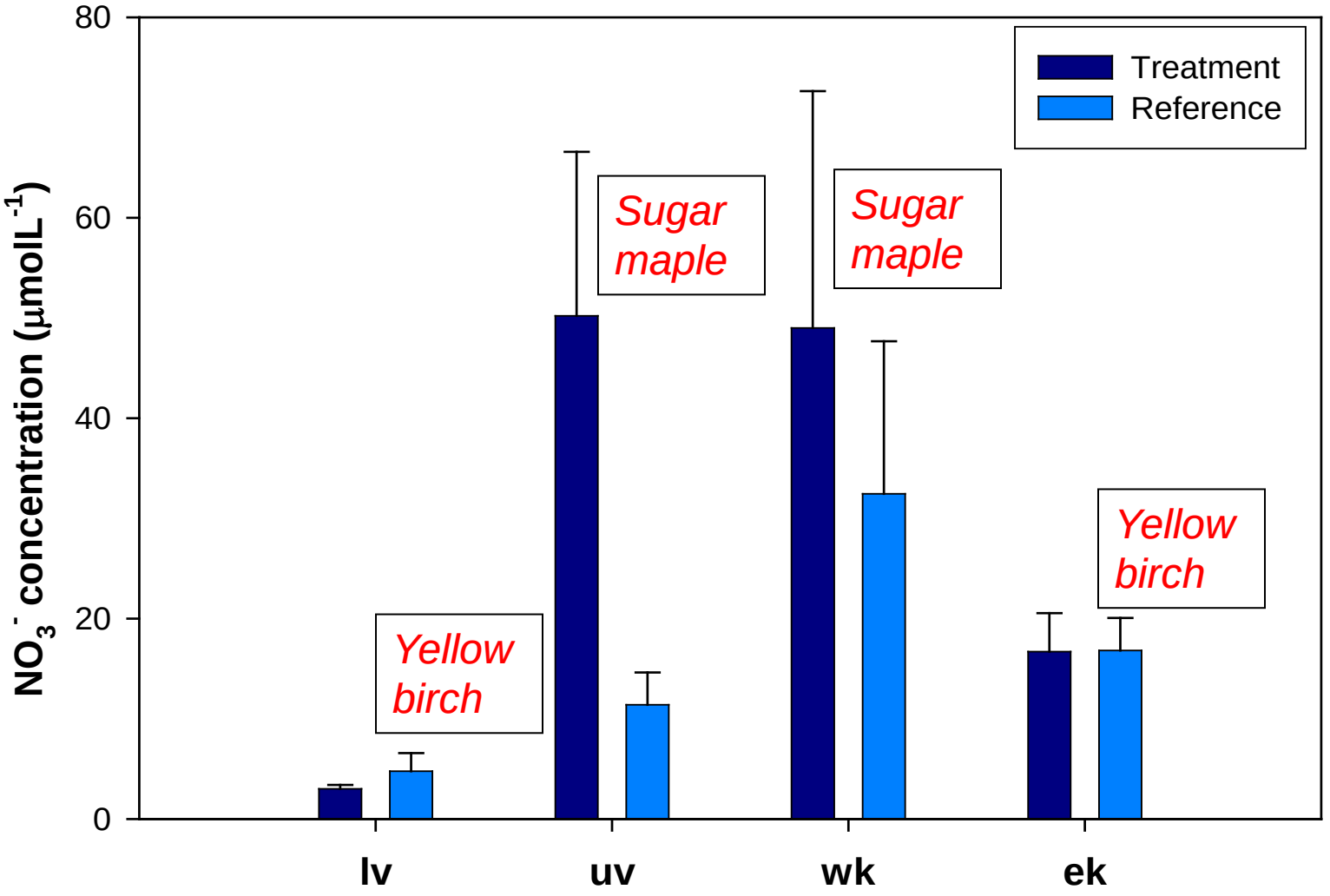
Source: Groffman et al. (2010)

Nitrate response much less marked in second study:



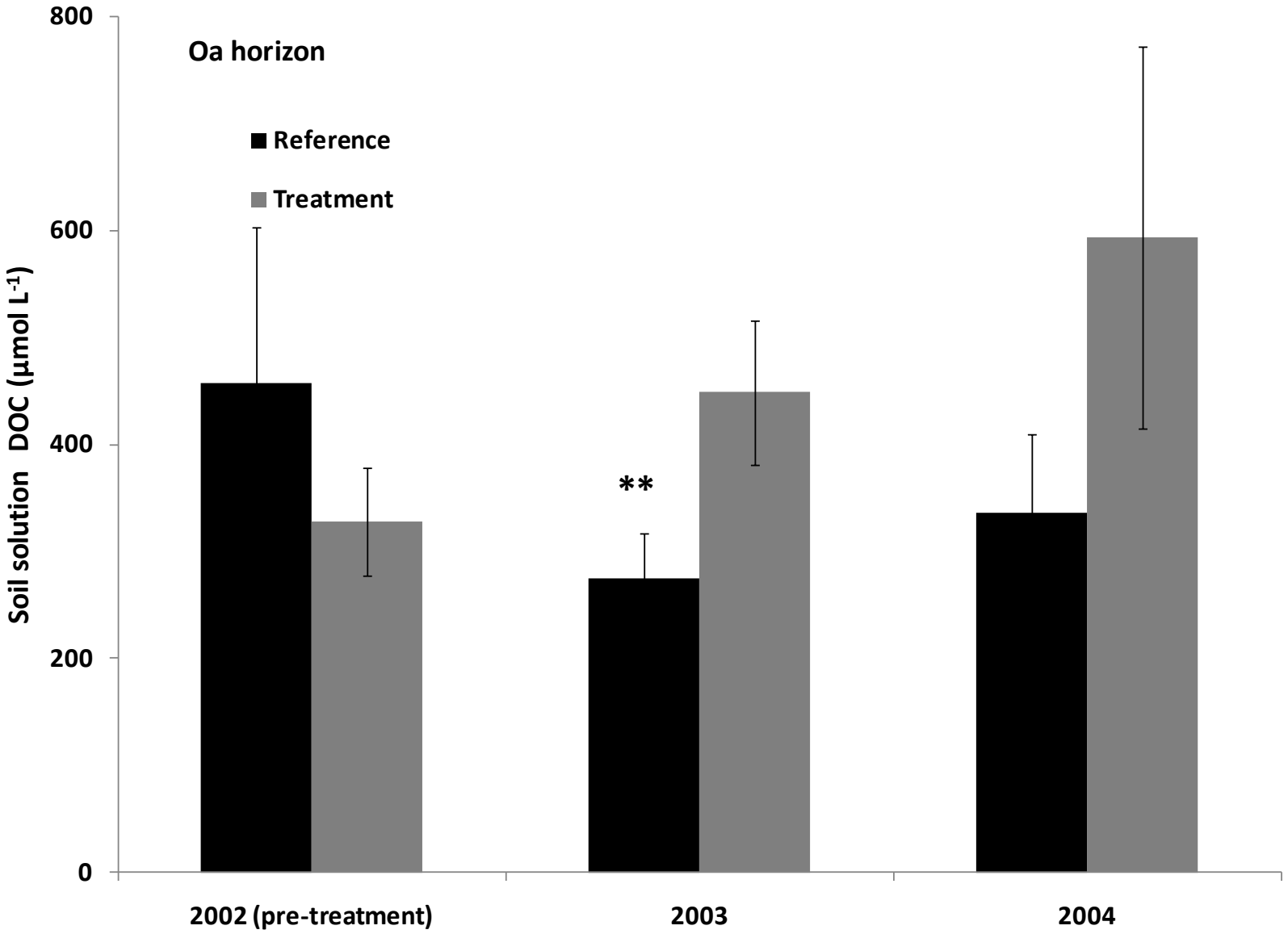
Source: Groffman et al. (2010)

Nitrate in Oa horizon (2003-2004) *w/dominant tree*



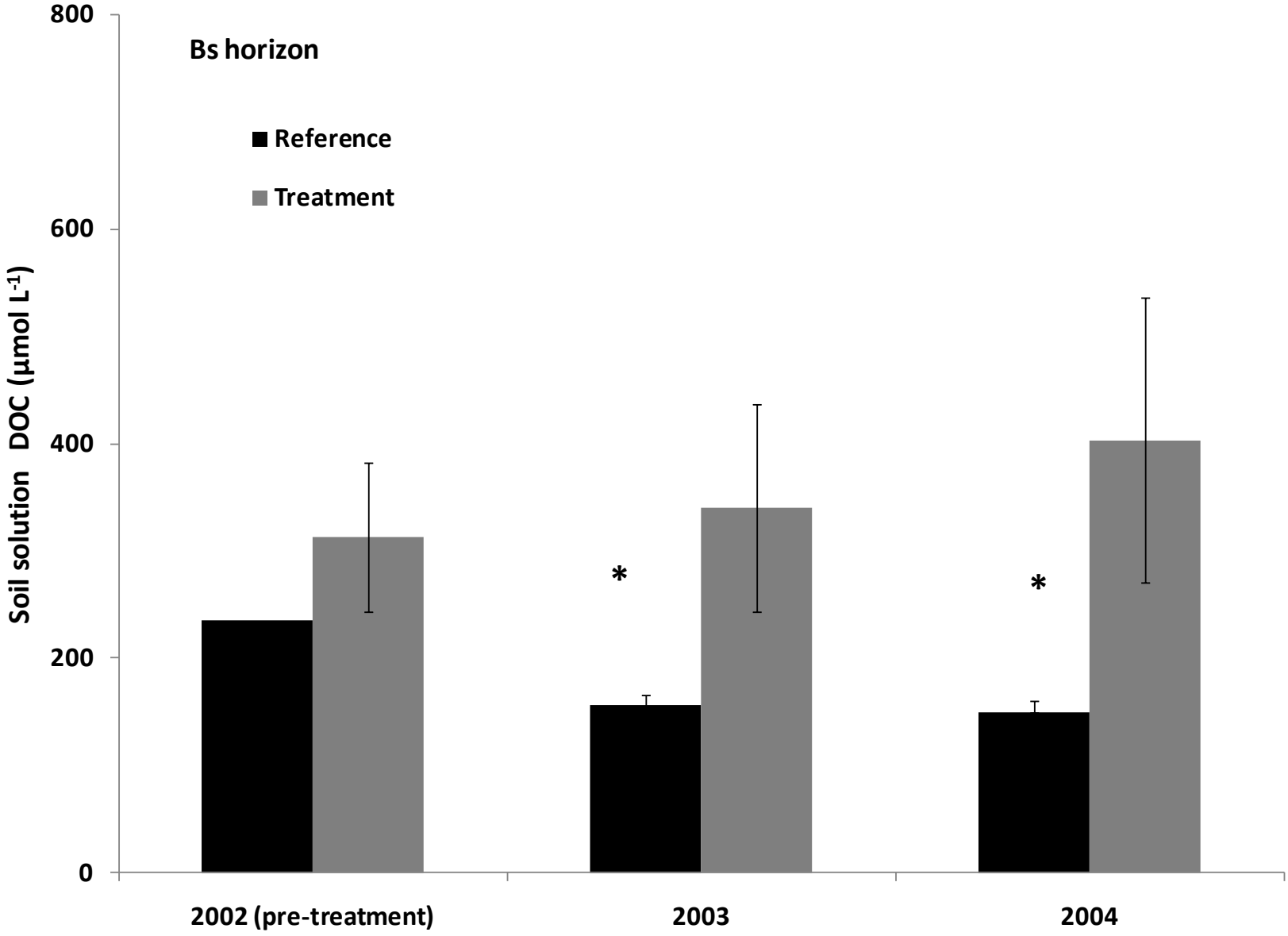
Source: Fashu-Kanu/Cleavitt/Martel

DOC response may prevent a nitrate response:



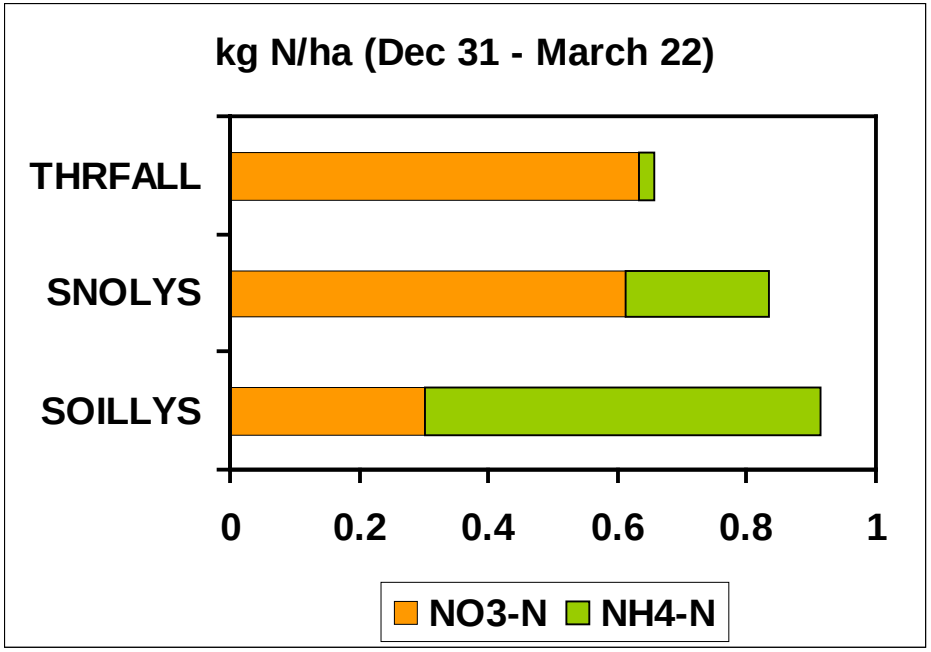
Source: Groffman et al. (2010)

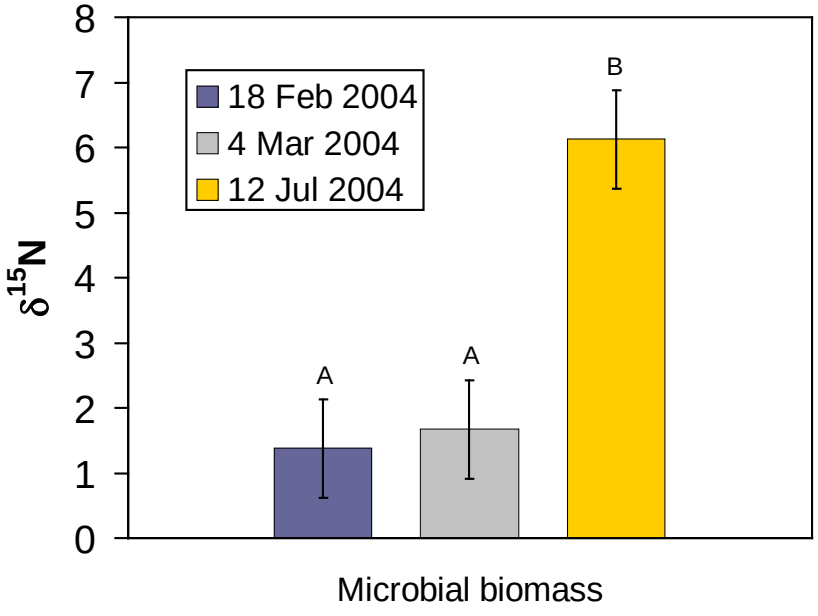
DOC response may prevent a nitrate response:



Source: Groffman et al. (2010)

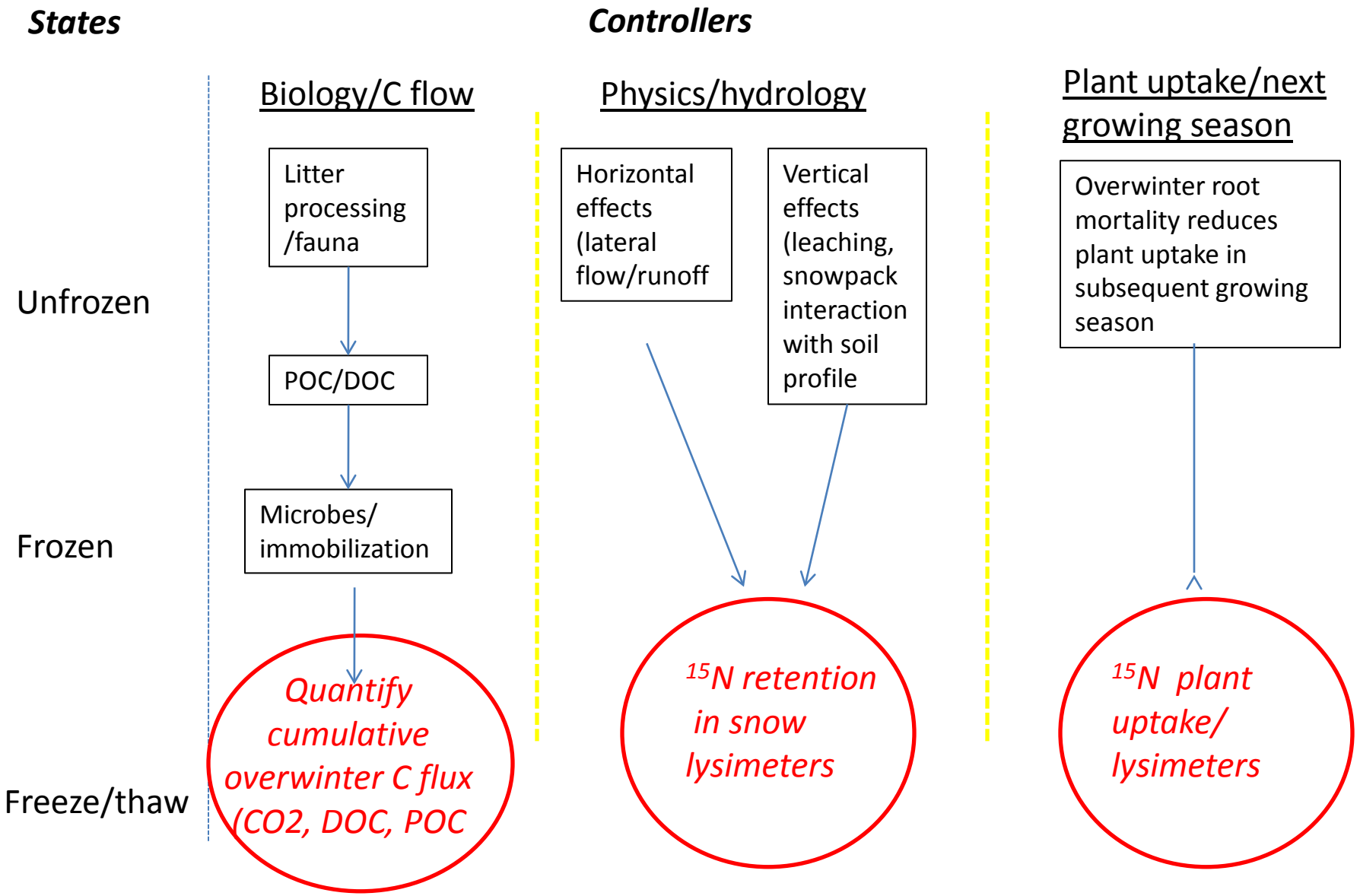
Alteration of flowpaths and abiotic processes also important.



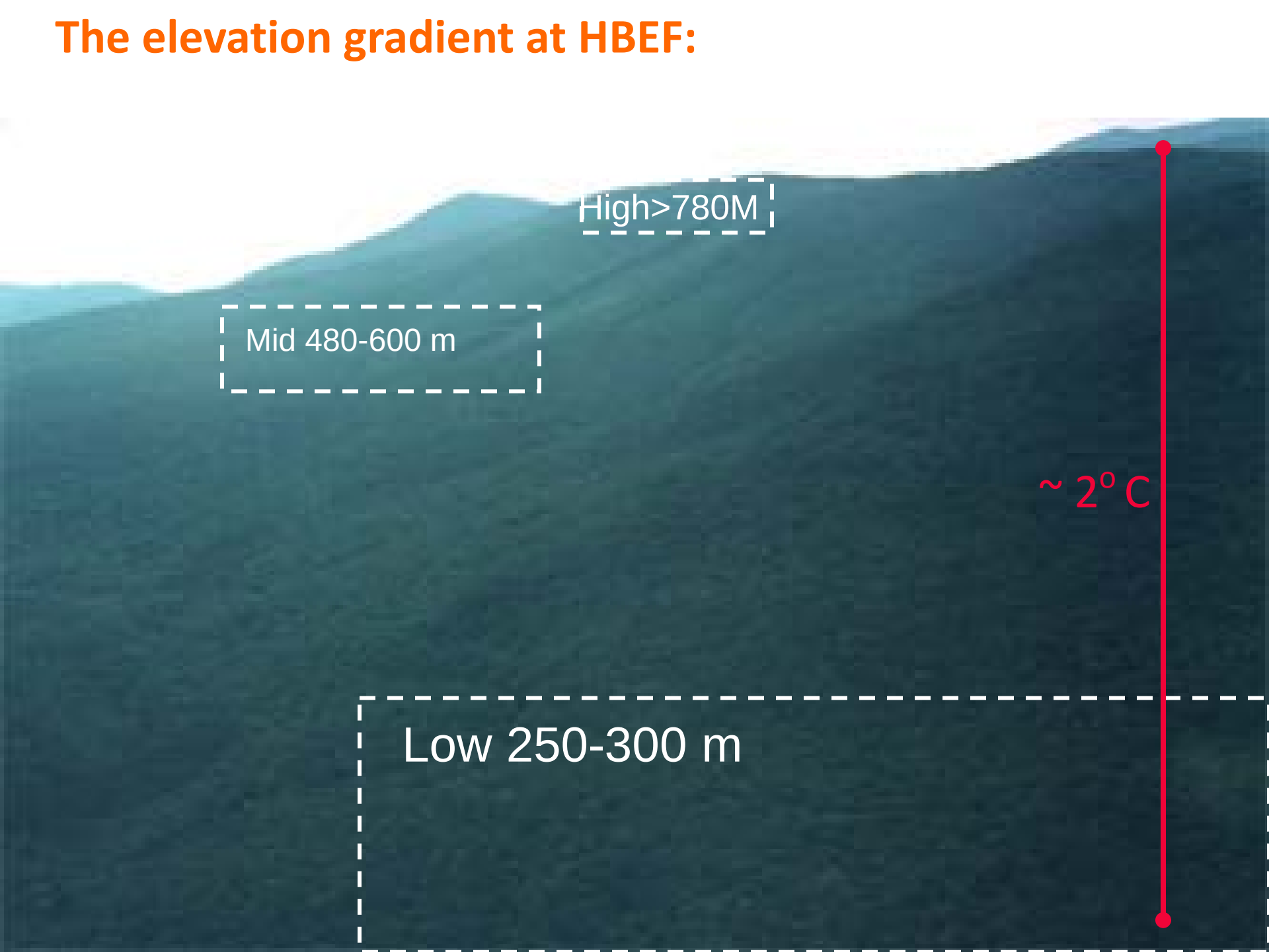


Source: Campbell et al. (2007)

Winter climate change and nitrogen retention



The elevation gradient at HBEF:



New winter climate change study:

- 20 sugar maple sites along elevation gradient:
  - 6 intensive sites (isotope studies), 14 less intensive.
  - Lysimeters, temperature, moisture, frost, snow, microbial biomass and activity.

- ^{13}C, ^{15}N-litter study:
  - Exclusion cores to study roots, microbes, hyphae.
  - Invertebrates.

New winter climate change study:

- ^{15}N snow lysimeter study:
  - ^{15}N and Br additions to snowpack.
  - Reciprocal transplants.
- Flowpath studies :
  - Does soil freezing alter the way water and nitrogen flow across the landscape?
  - Reconcile plot versus watershed scale results.
  - Compare north versus south facing watersheds.
  - Measure solutes that serve as natural tracers of hydrologic flowpaths

Summary/conclusions:

- Soil freezing, which may increase with climate warming, is potentially an important controller of forest biogeochemistry but:
  - Will we have “colder soils in a warmer world?”
  - What controls the variation in response to soil freezing at the plot scale:
    - Roots?
    - DOC?
    - Plant community composition?
  - How do plot and landscape controls interact?