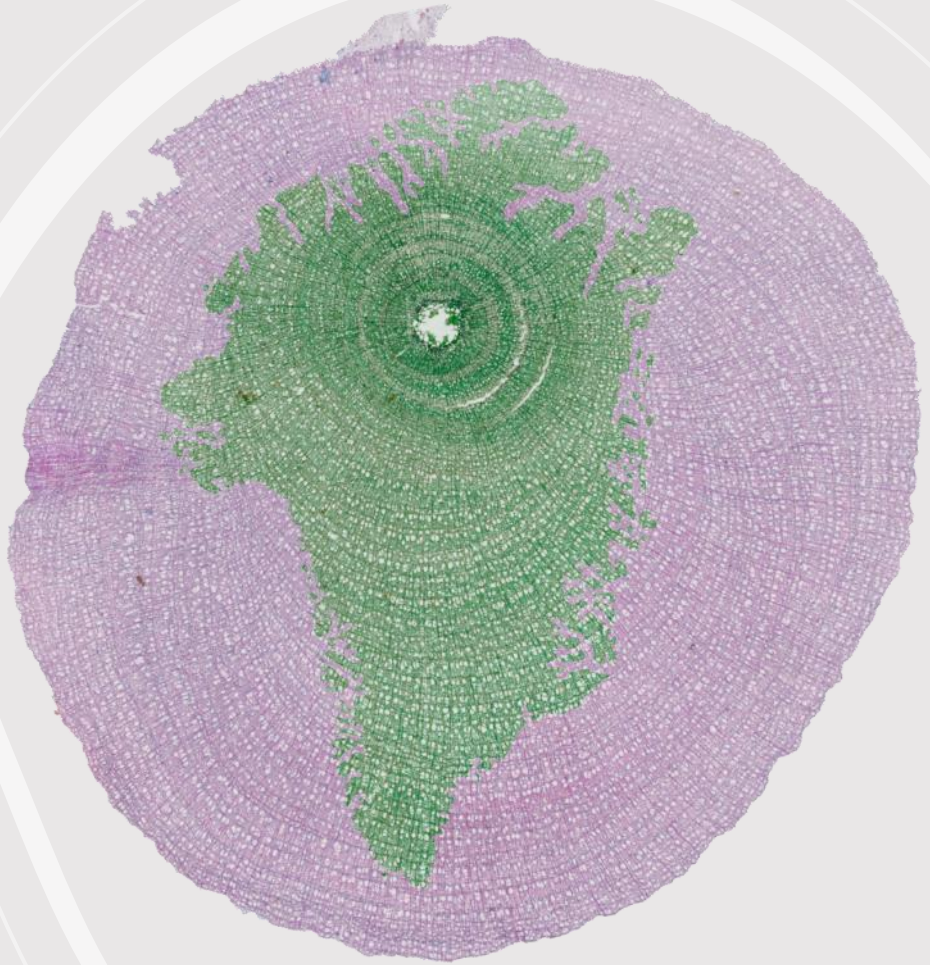
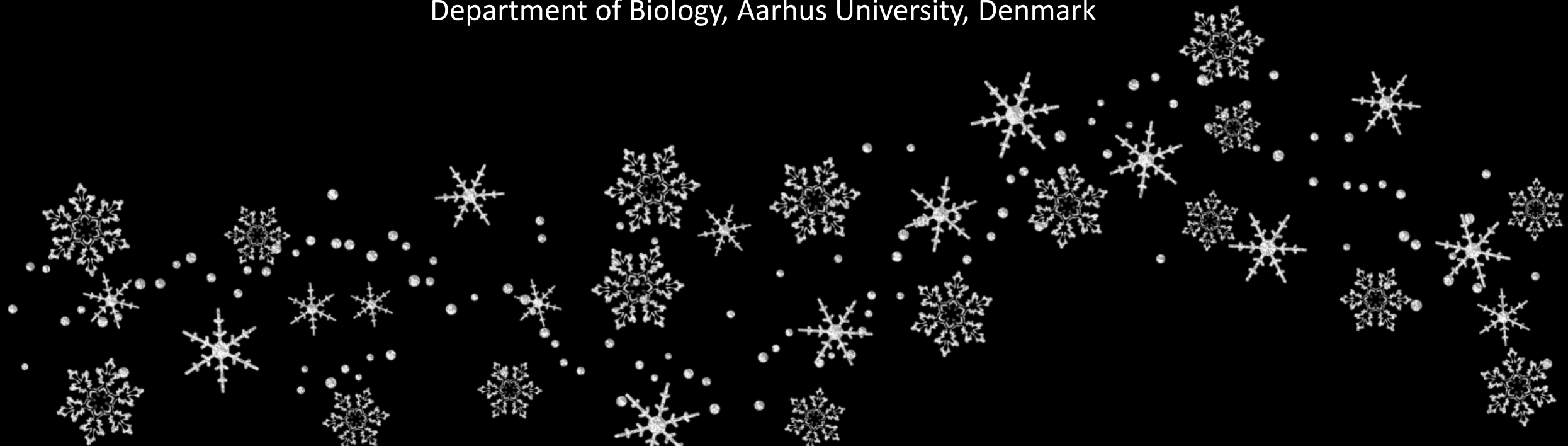


Hydraulic traits of Arctic shrubs differ with soil moisture, but not snow depth, in a snow-fence experiment on Disko Island

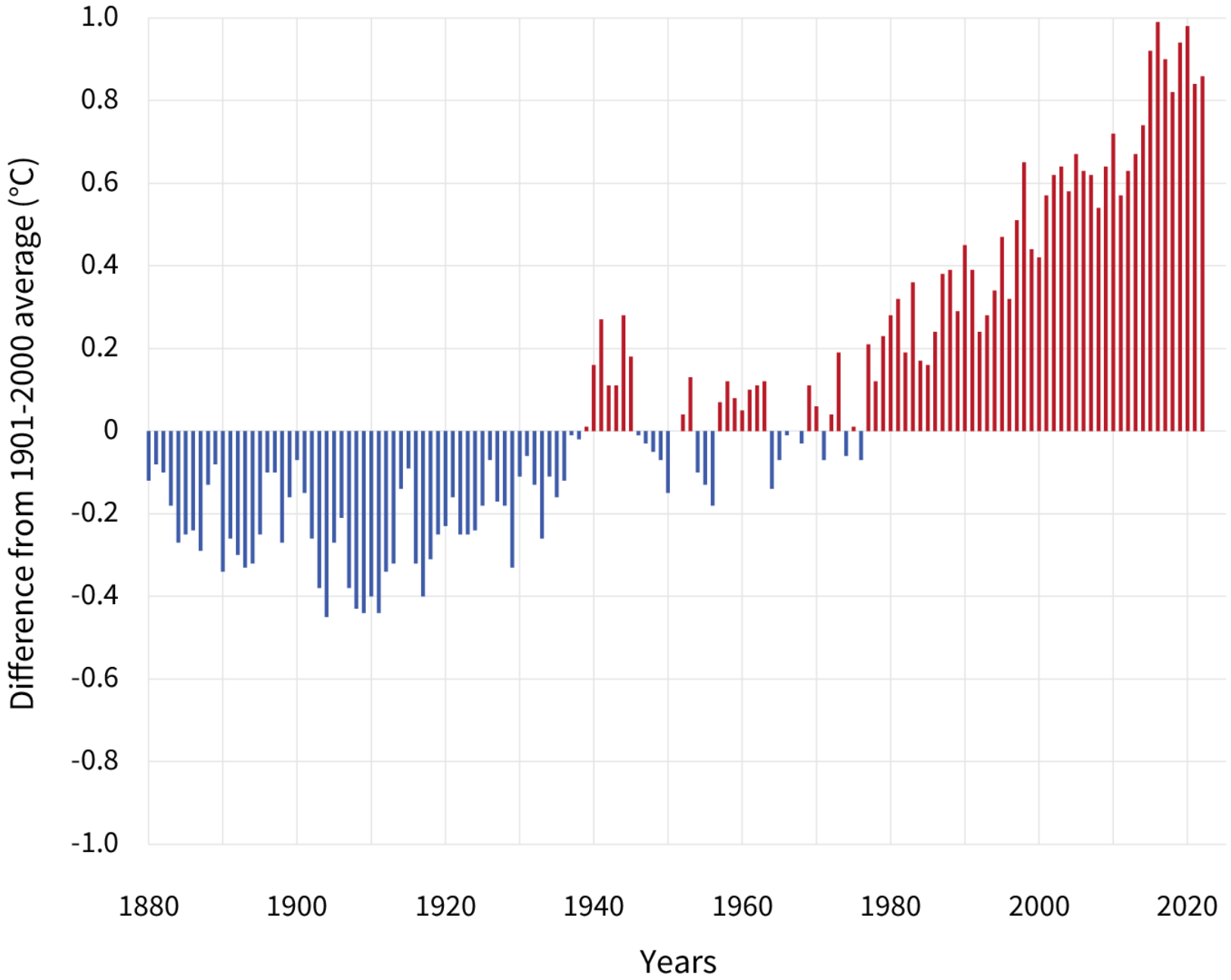
Candice Power

Department of Physical Geography and Geoecology, Charles University, Czech Republic

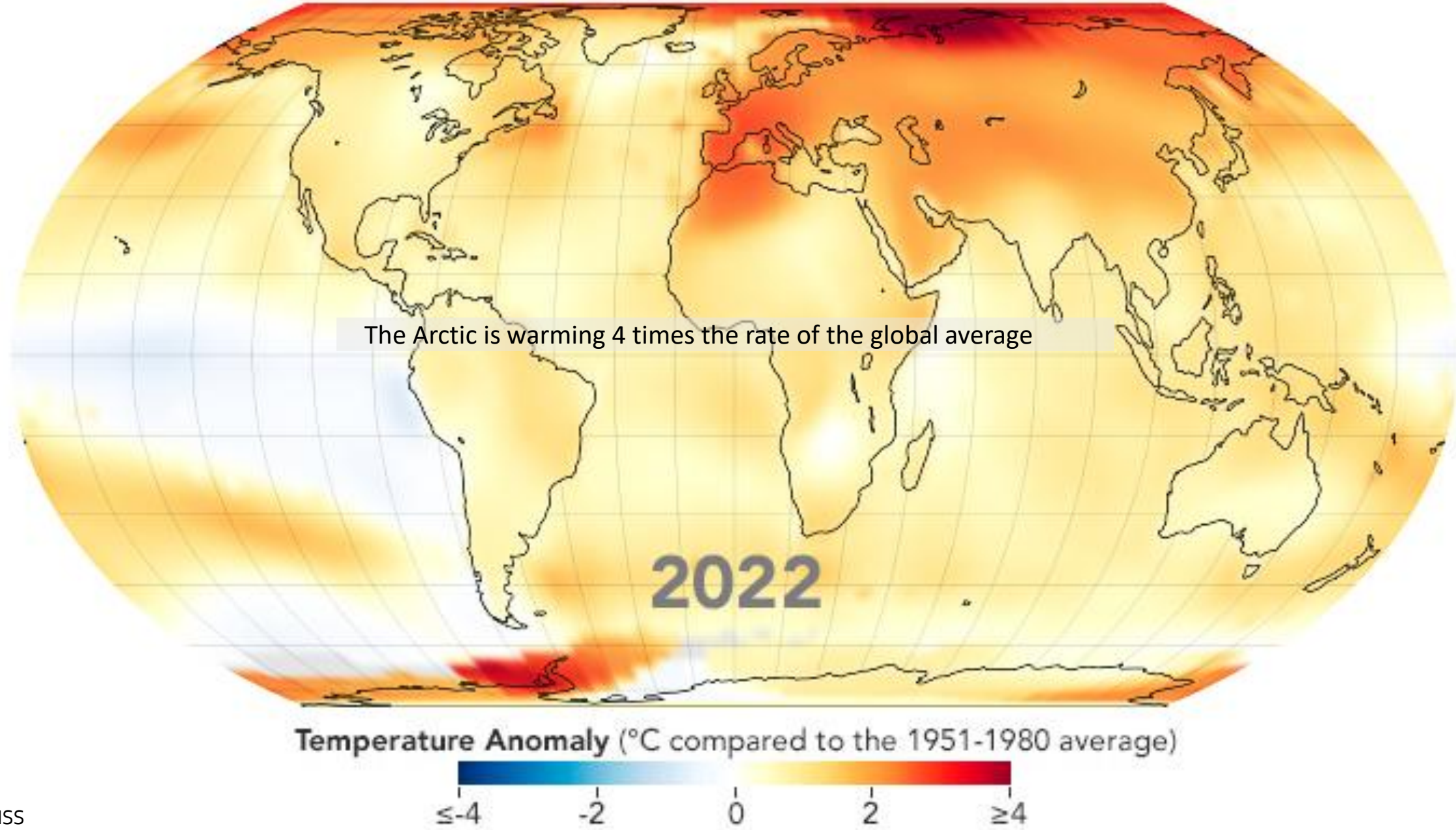
Department of Biology, Aarhus University, Denmark



GLOBAL AVERAGE SURFACE TEMPERATURE



NOAA Climate.gov



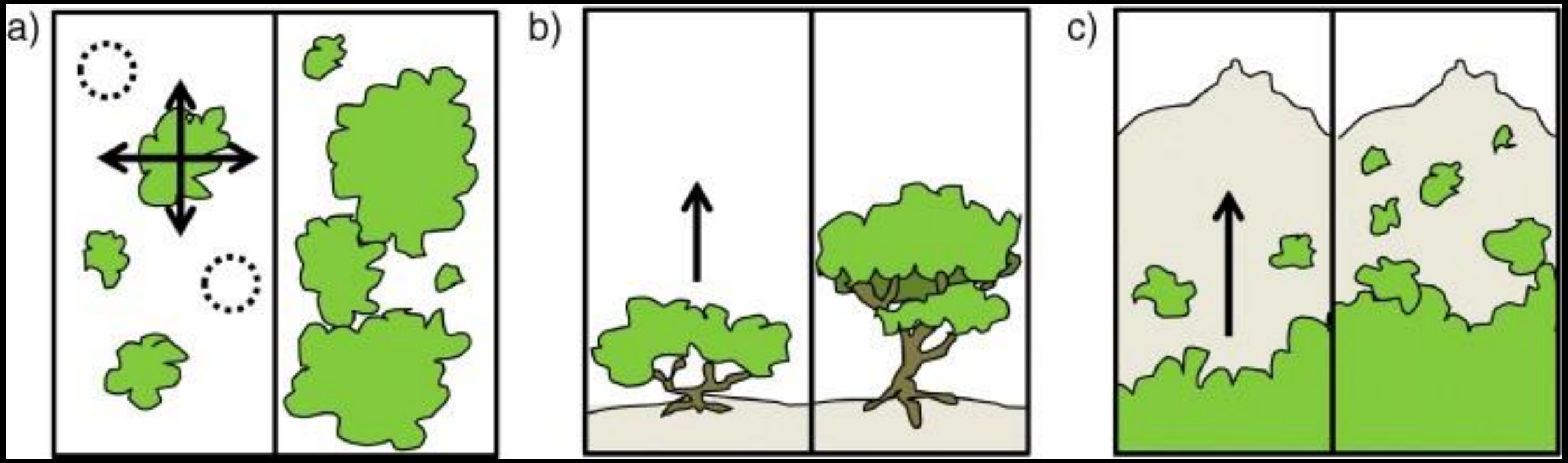
NASA-GISS
Rantanen, et al. *Commun. Earth Environ.* 2022

Shrubification

Infilling existing patches

Increasing in growth

Advancing shrubline

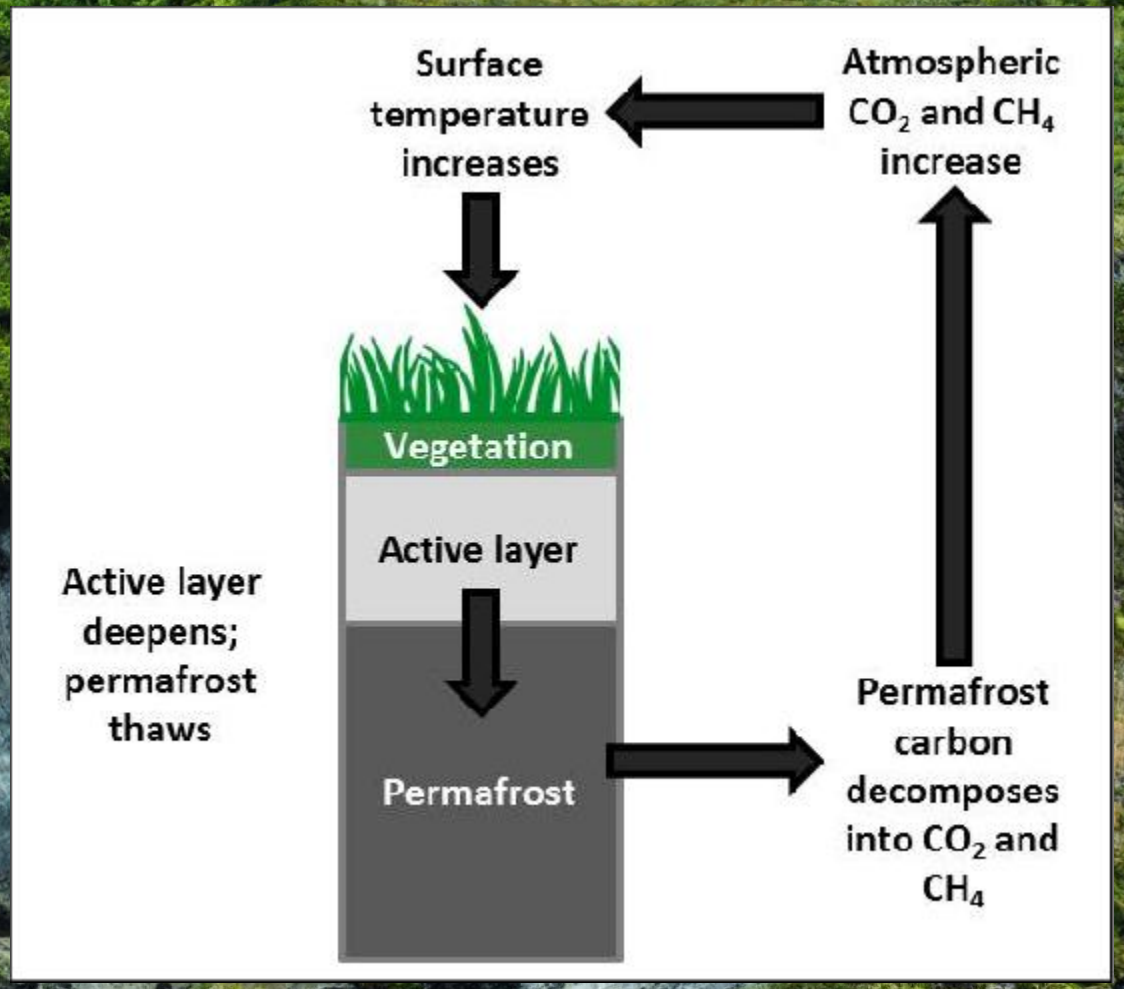


Myers-Smith et al. *Environmental Research Letters.* 2011

Herschel Island, Yukon, Canada

Photos: Myers-Smith et al. *Ecological Monographs*. 2019

Photo: Weronika Murray



Kessler. *Climate Change Economics*. 2017.

Photo: Weronika Murray

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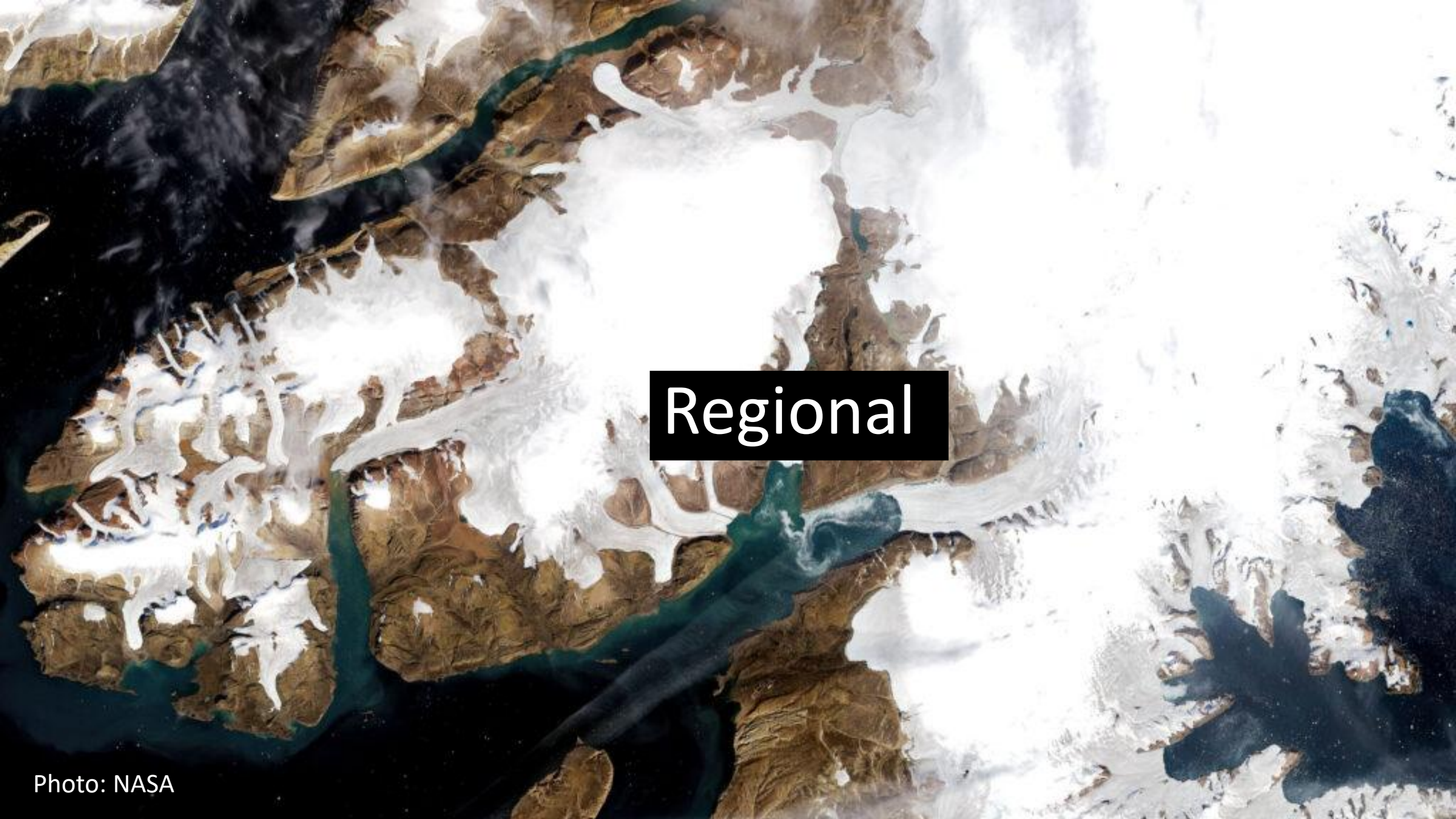

Photo: NASA

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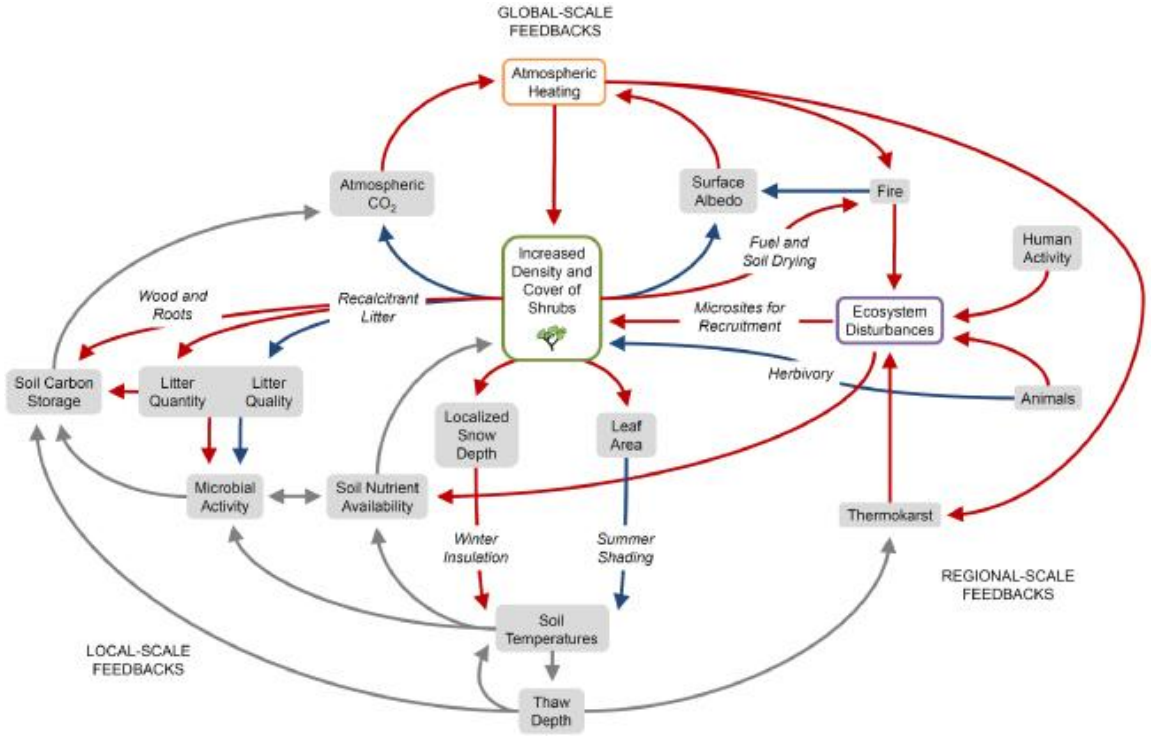
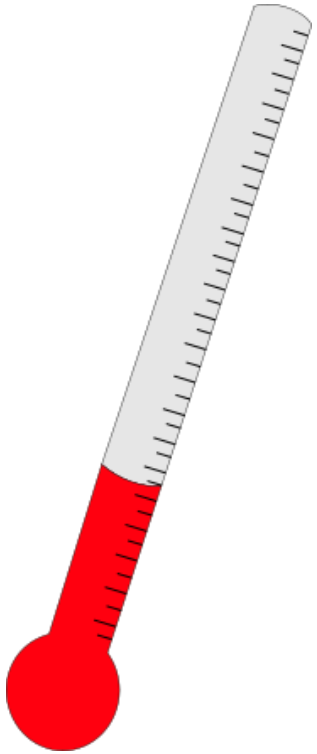
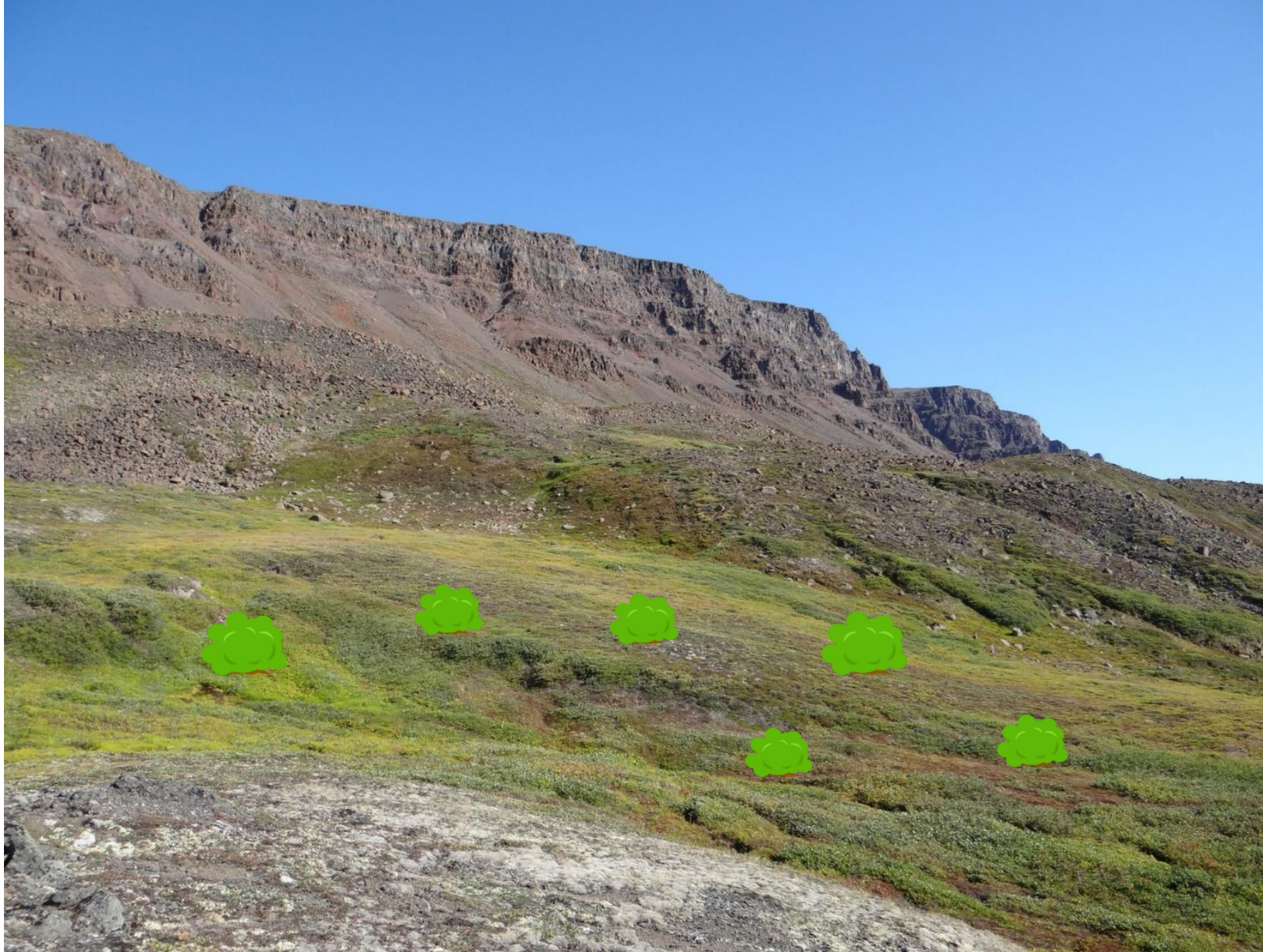
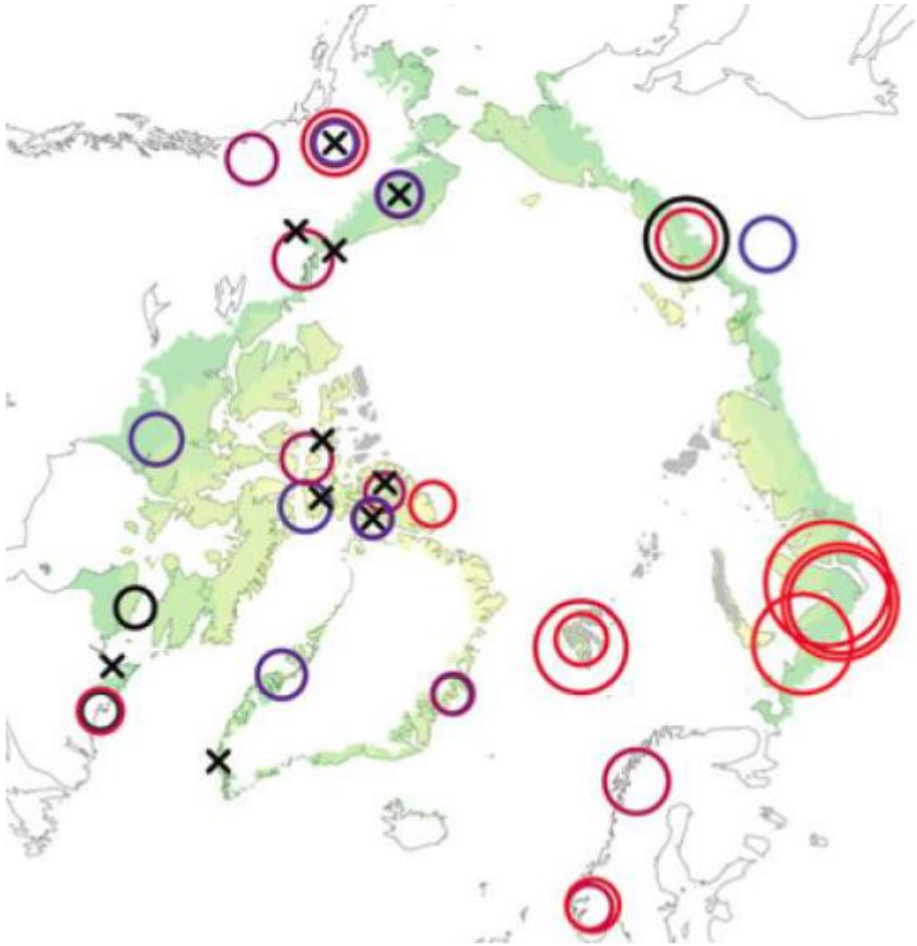


- Complex system with many feedback loops, interactions, and uncertainties

Myers-Smith et al. *Environmental Research Letters.* 2011







No climate sensitivity

Negative summer temperature sensitivity

Summer temperature sensitivity model with slope near zero

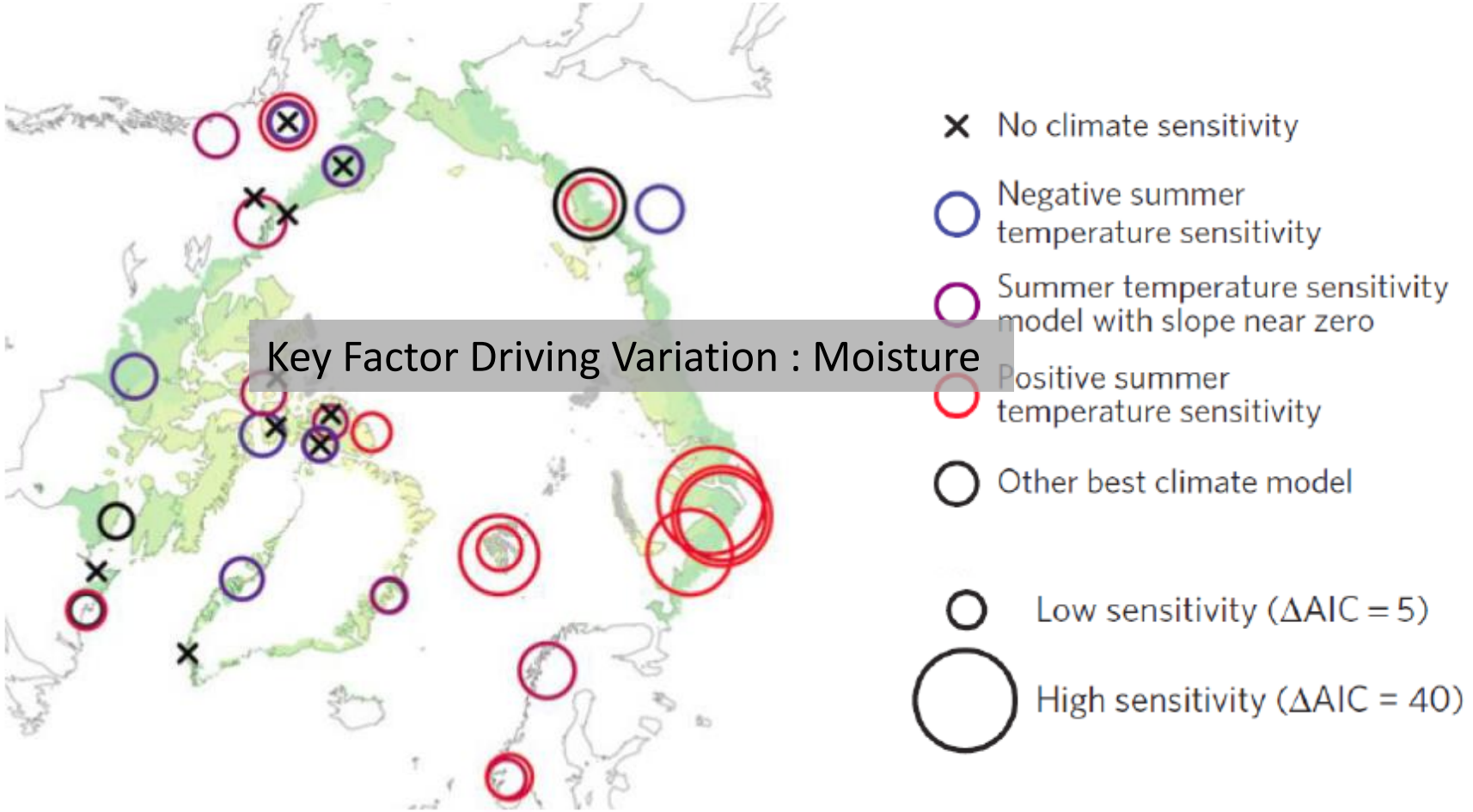
Positive summer temperature sensitivity

Other best climate model

Low sensitivity (ΔAIC = 5)

High sensitivity (ΔAIC = 40)

Myers-Smith et al. *Nature Climate Change.* 2015



Myers-Smith et al. *Nature Climate Change.* 2015

ARCTIC SHRUBS ARE CHANGING, BUT ARE
NOT RESPONDING THE SAME EVERYWHERE

ARCTIC SHRUBS ARE CHANGING, BUT ARE NOT RESPONDING THE SAME EVERYWHERE

KNOWLEDGE GAP: HOW AND WHY SHRUBS RESPOND DIFFERENTLY

ARCTIC SHRUBS ARE CHANGING, BUT ARE NOT RESPONDING THE SAME EVERYWHERE

KNOWLEDGE GAP: HOW AND WHY SHRUBS RESPOND DIFFERENTLY

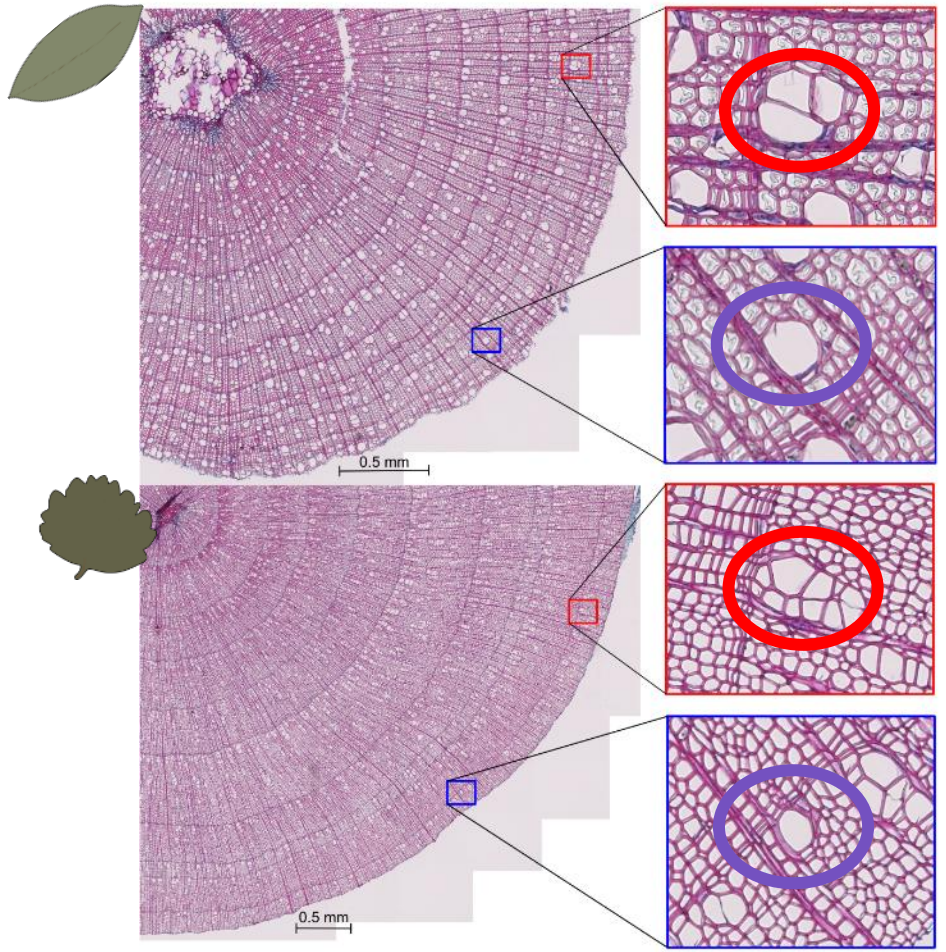
ADDS UNCERTAINTY TO PREDICTIONS OF FUTURE GLOBAL CHANGE

- Annual Radial Shrub Growth

Broadening our perspective by zooming in

- Annual Radial Shrub Growth
- Xylem Anatomical traits

Wood anatomy - Vessels



Grouped

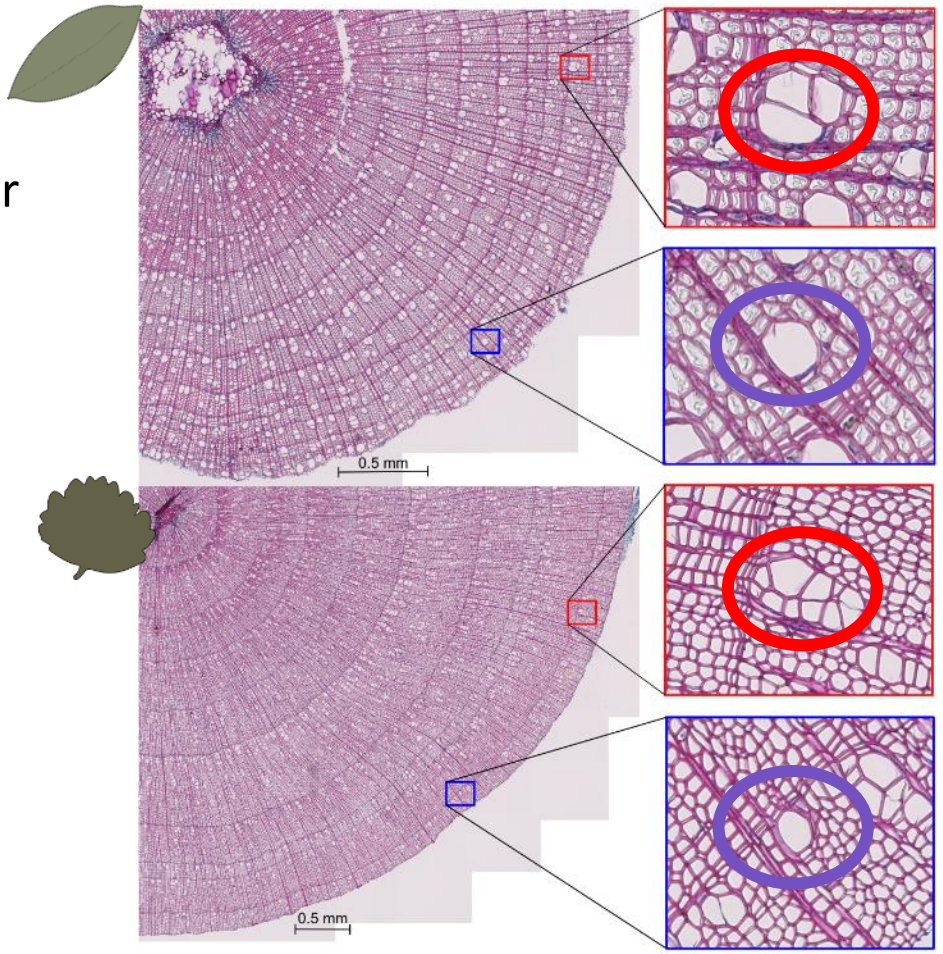
Solitary

Grouped

Solitary

Wood anatomy - Vessels

- Larger vessels and larger vessel groups increase water transport
  - But larger vessels are also more vulnerable to damages



Grouped

Solitary

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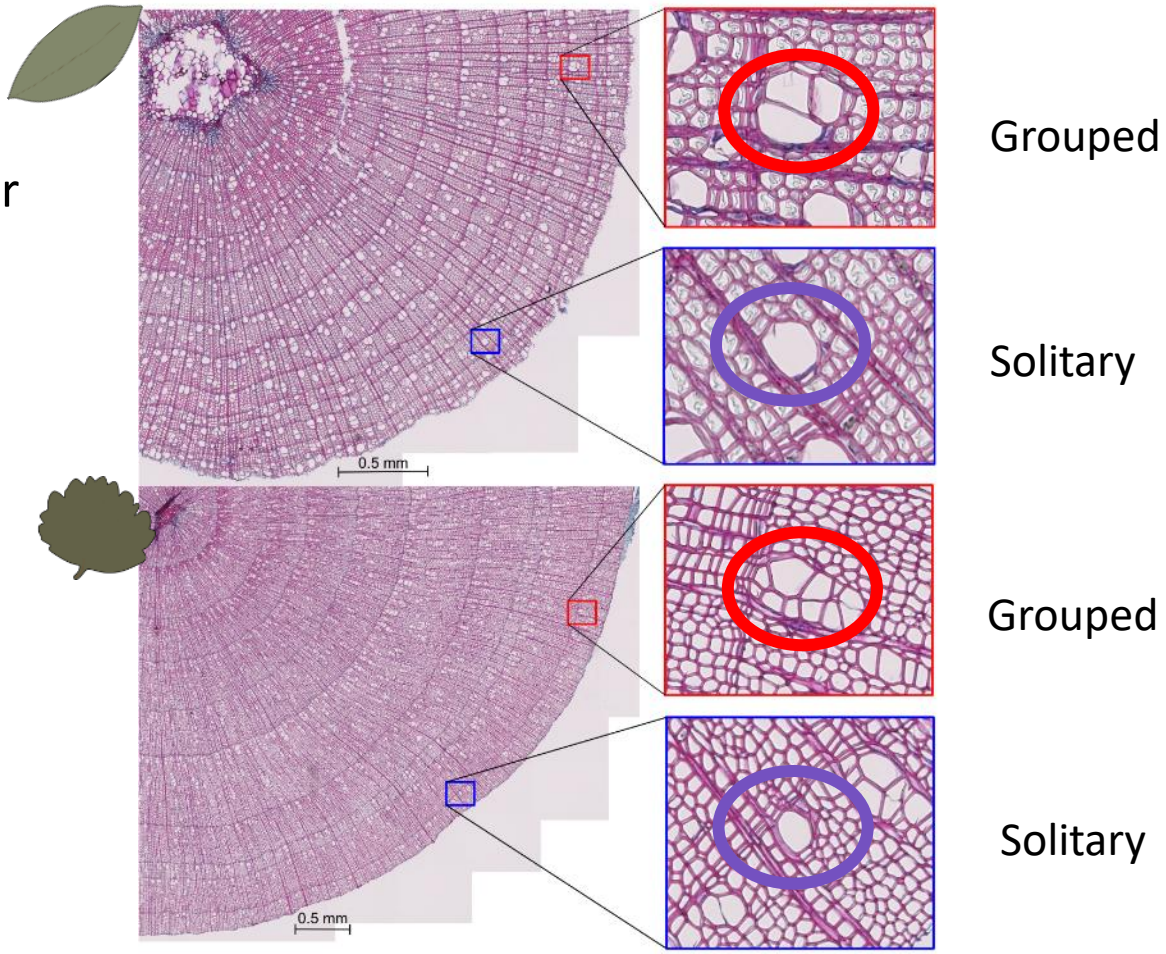
Tyree et al. *IAWA J.* 1994

Prendin et al. *Tree Phys*. 2018

Wood anatomy - Vessels

- Larger vessels and larger vessel groups increase water transport
  - But larger vessels are also more vulnerable to damages
- Smaller vessels and larger vessel groups may provide protection in extreme conditions



Grouped

Solitary

Grouped

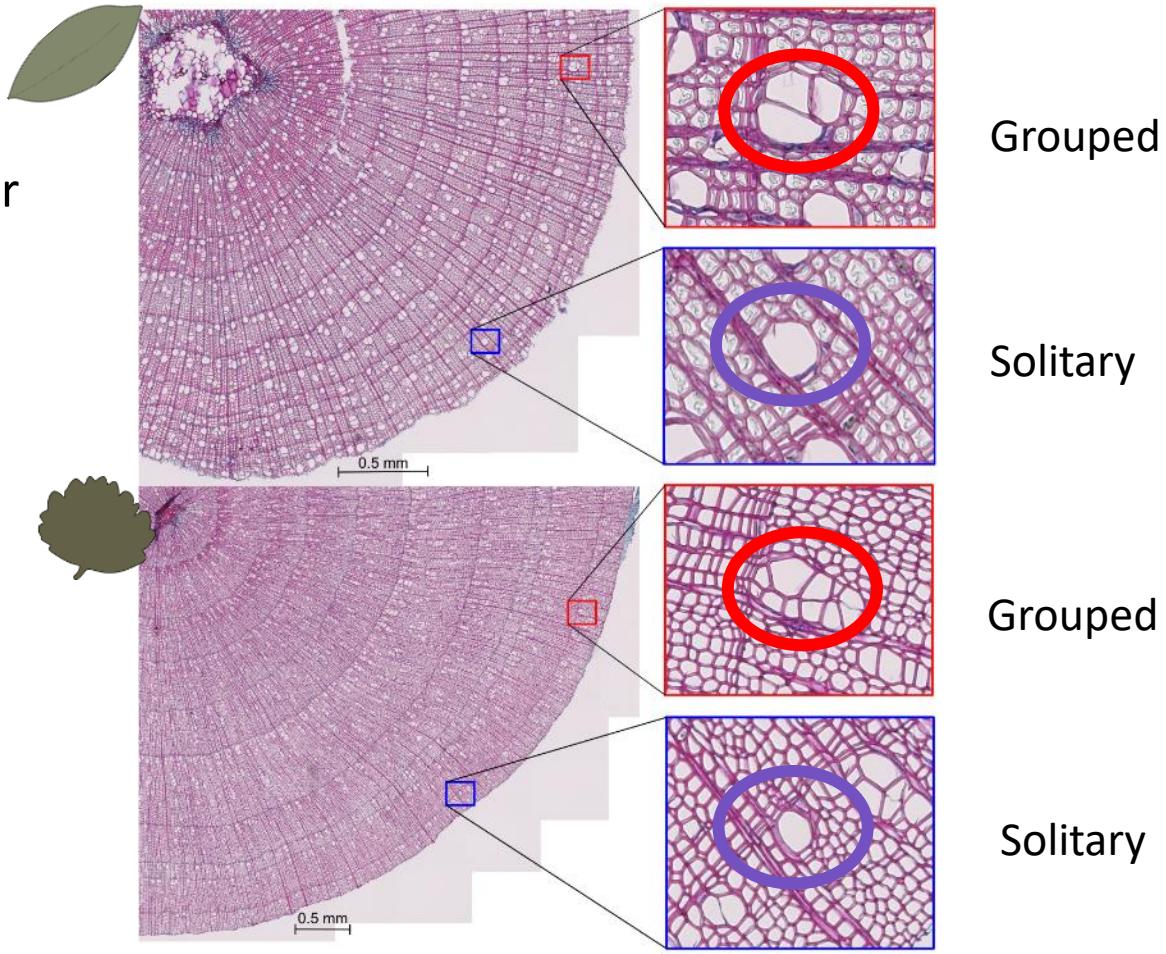
Solitary

Tyree et al. *IAWA J.* 1994

Prendin et al. *Tree Phys*. 2018

Wood anatomy - Vessels

- Larger vessels and larger vessel groups increase water transport
  - But larger vessels are also more vulnerable to damages
- Smaller vessels and larger vessel groups may provide protection in extreme conditions
  - Though vessel connectivity may also be detrimental

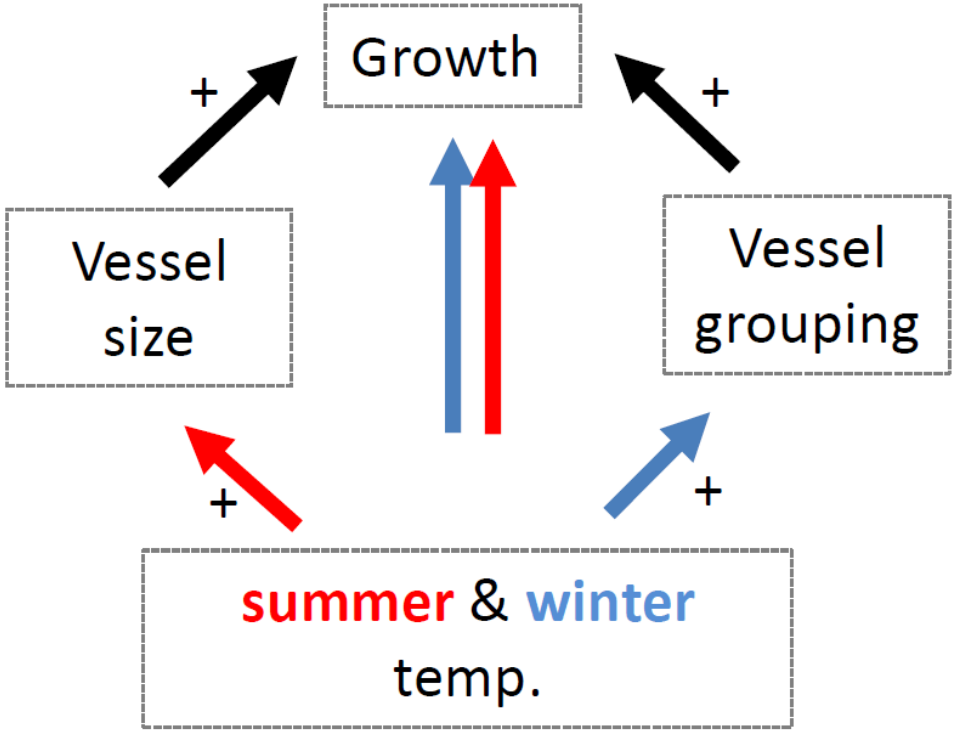


Tyree et al. *IAWA J.* 1994

Prendin et al. *Tree Phys*. 2018

Linking Growth and Hydraulic Traits: A Multi-proxy approach

- Growth and hydraulic traits can be influenced by climatic and environmental factors
- Combining ring widths and hydraulic traits provides insights into water transport and growth



Nielsen et al. *Arc. Antarc. Alp. Res.* 2017

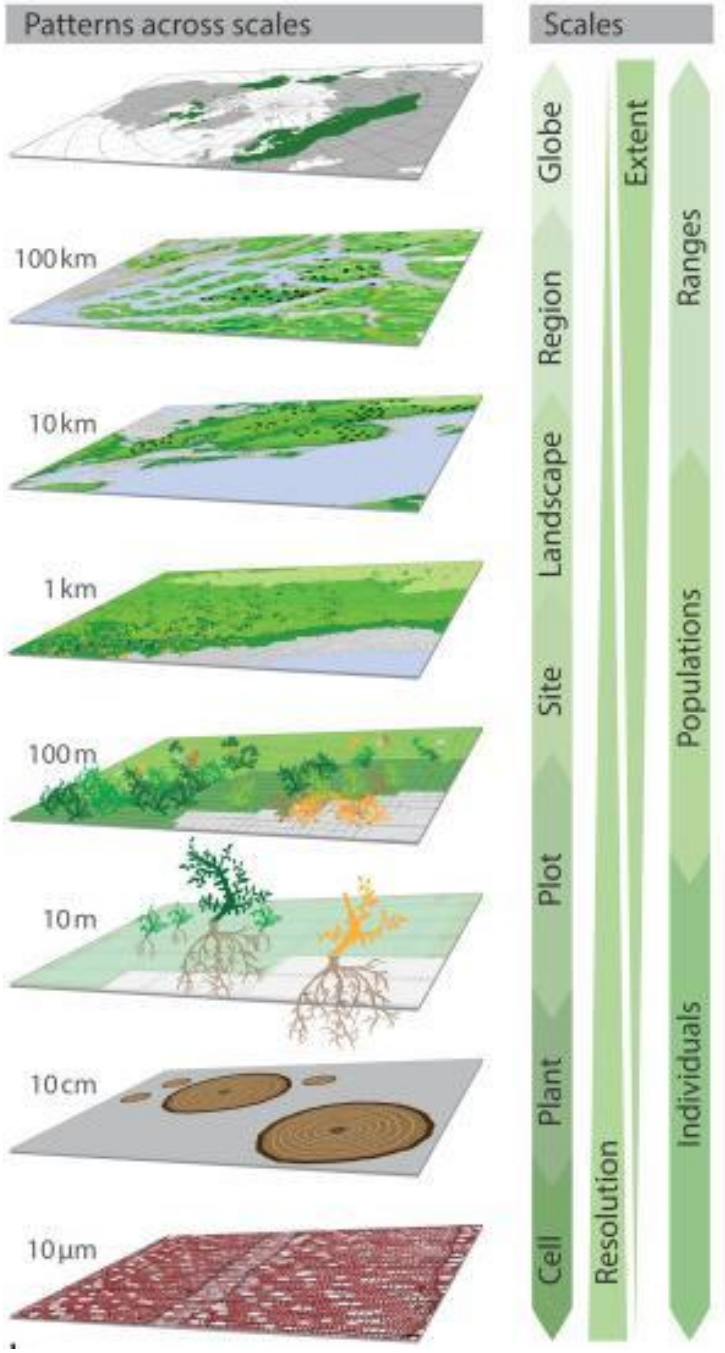
Overall aim:

- Improve our knowledge of past and current Arctic shrub changes
    - Lead to better predictions of future global change
    - Inform mitigation strategies

Overall aim:

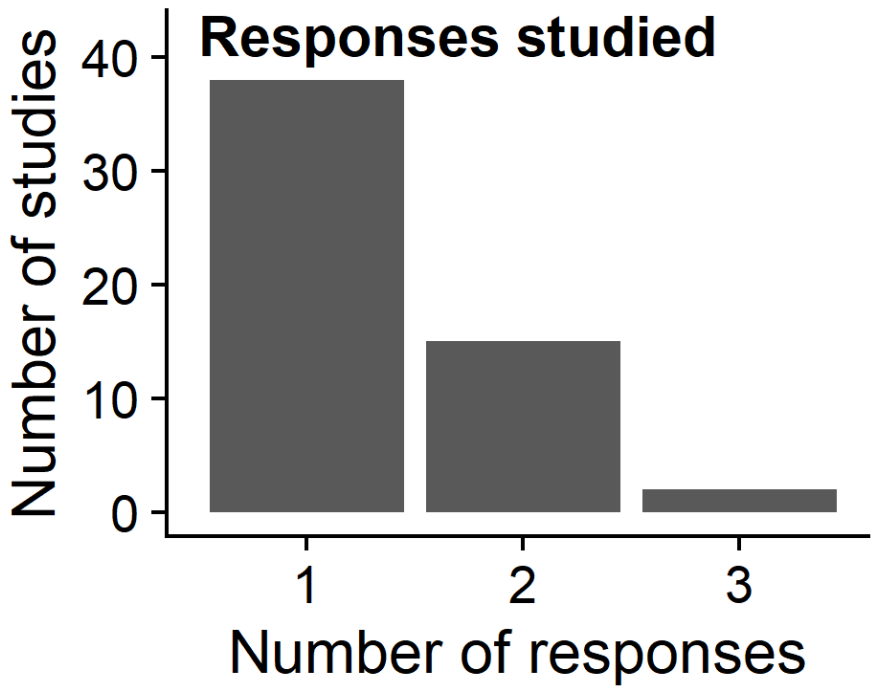
- Improve our knowledge of past and current Arctic shrub changes
    - Lead to better predictions of future global change
    - Inform mitigation strategies
- To contribute to disentangling the drivers of Arctic shrub changes across different scales

Perspective: integrating a broader and more multidisciplinary approach in dendroecological research could strengthen cross-scale insight into shrub dynamics



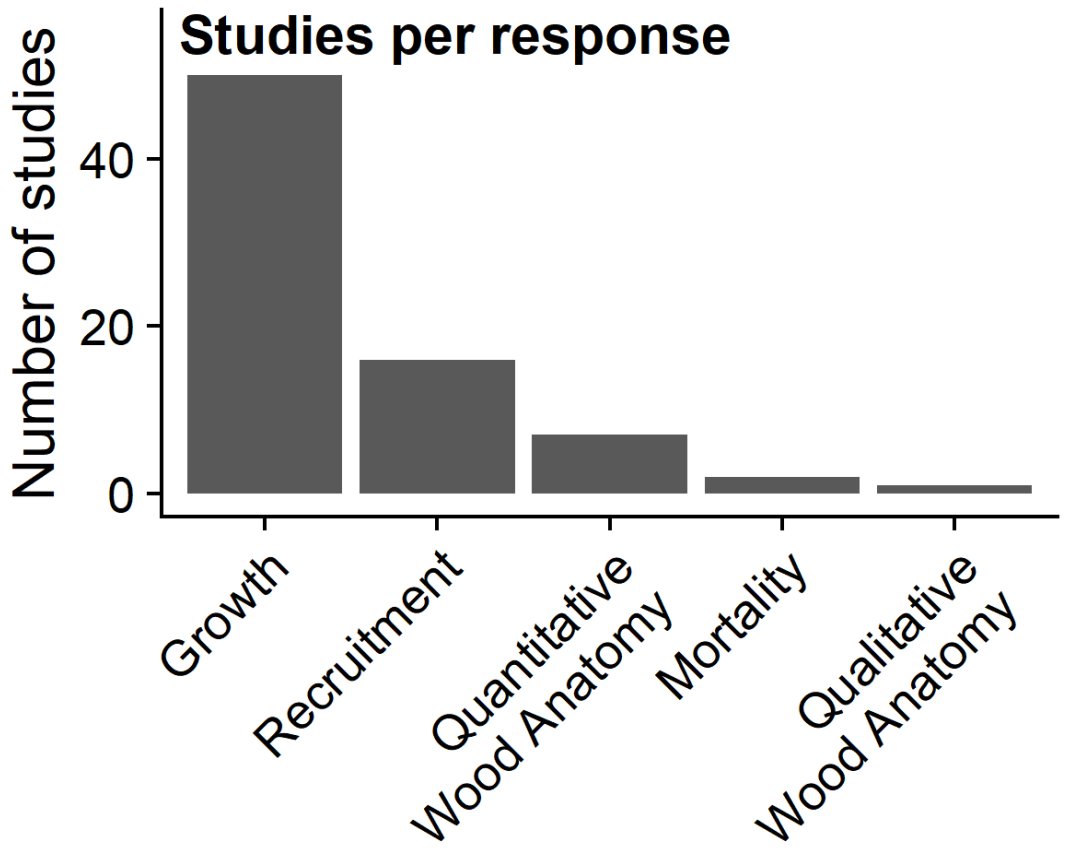
Power et al. *Sci. Total Environ.* 2022

Most Arctic shrub dendroecological studies assess **one response** – mainly growth



Power et al. *Sci. Total Environ.* 2022

Most Arctic shrub dendroecological studies do not assess the **anatomical mechanisms behind growth response**



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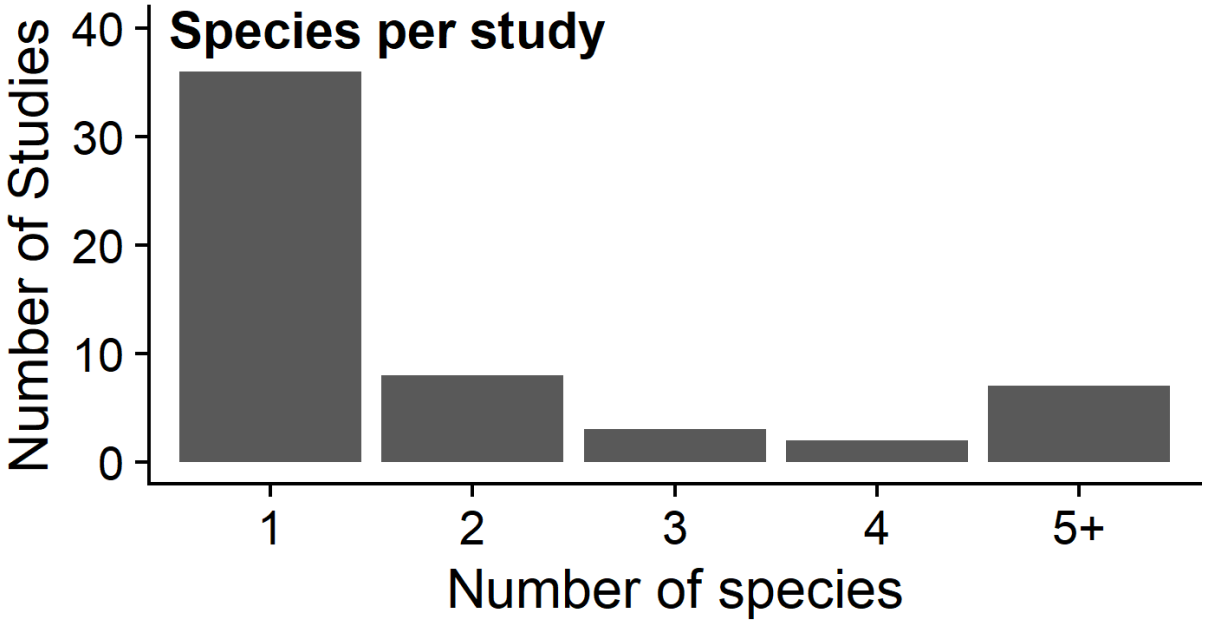
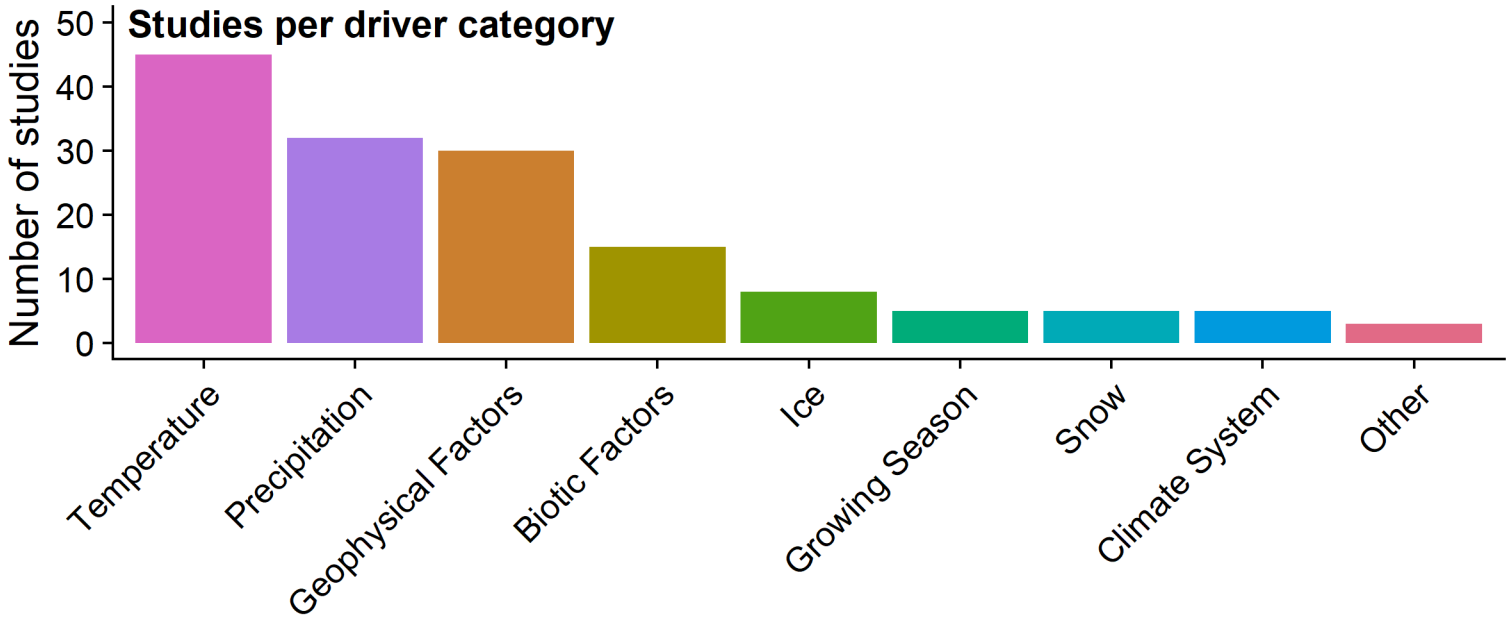
Most Arctic shrub dendroecological studies assess **one species**



Power et al. *Sci. Total Environ.* 2022

Most Arctic shrub dendroecological studies assess the impacts of **summer climate**



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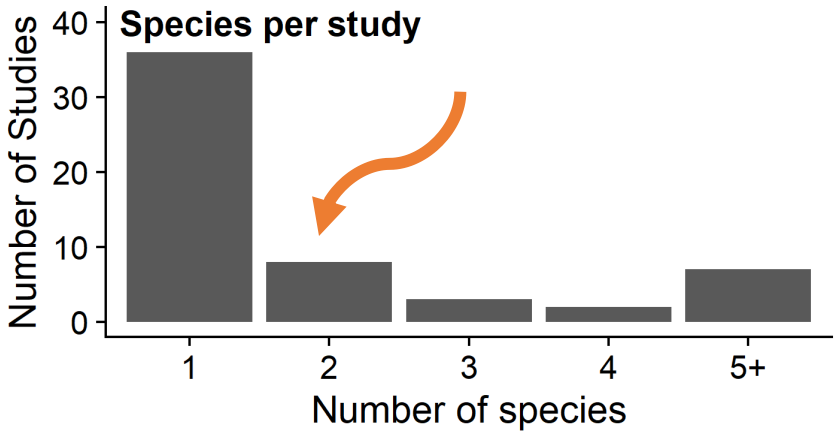
Power et al. *Sci. Total Environ.* 2022, 2024



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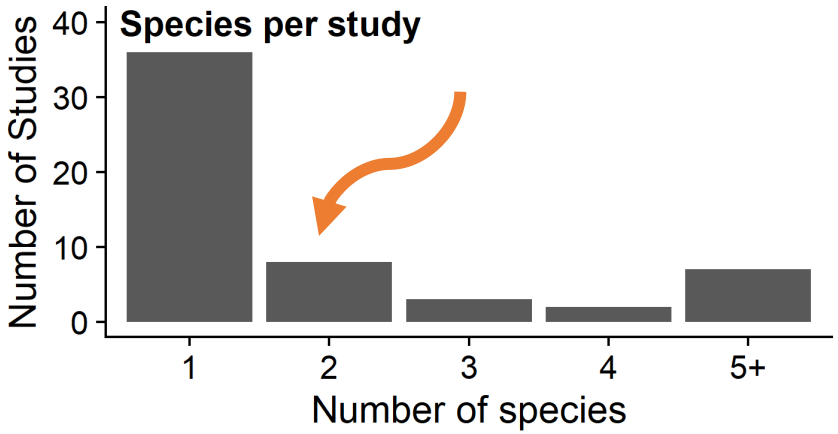

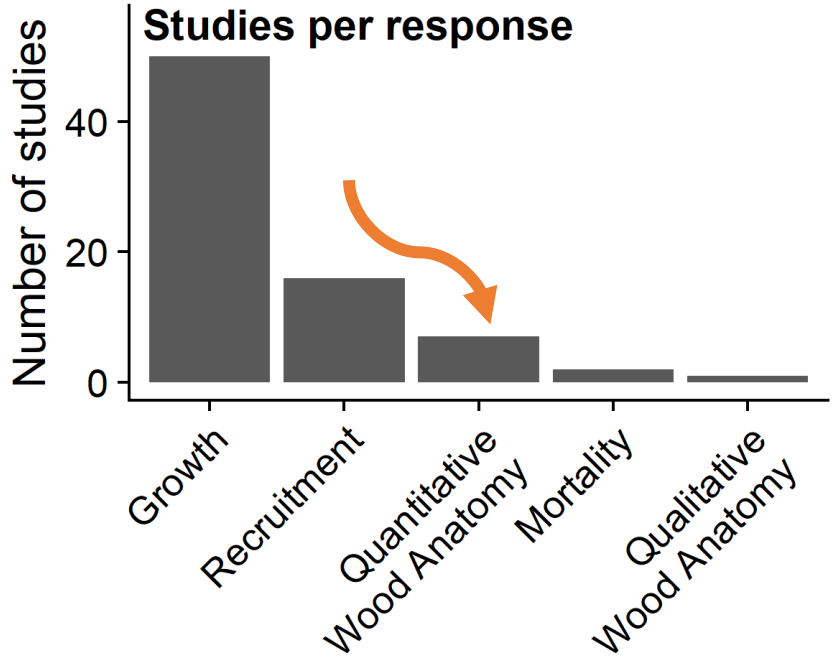

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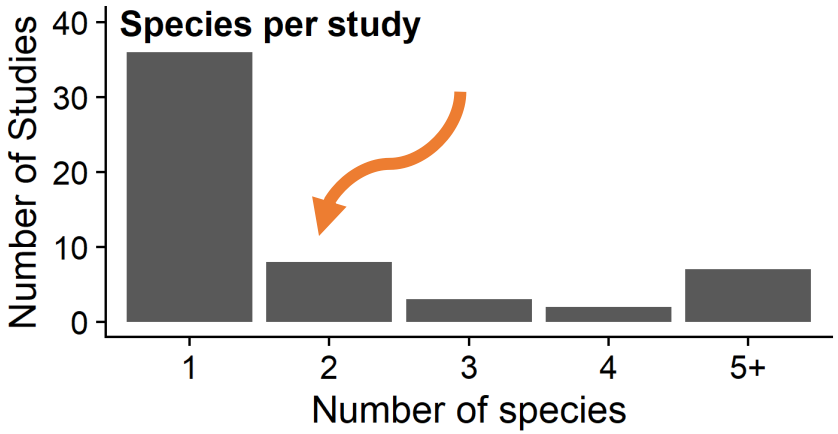

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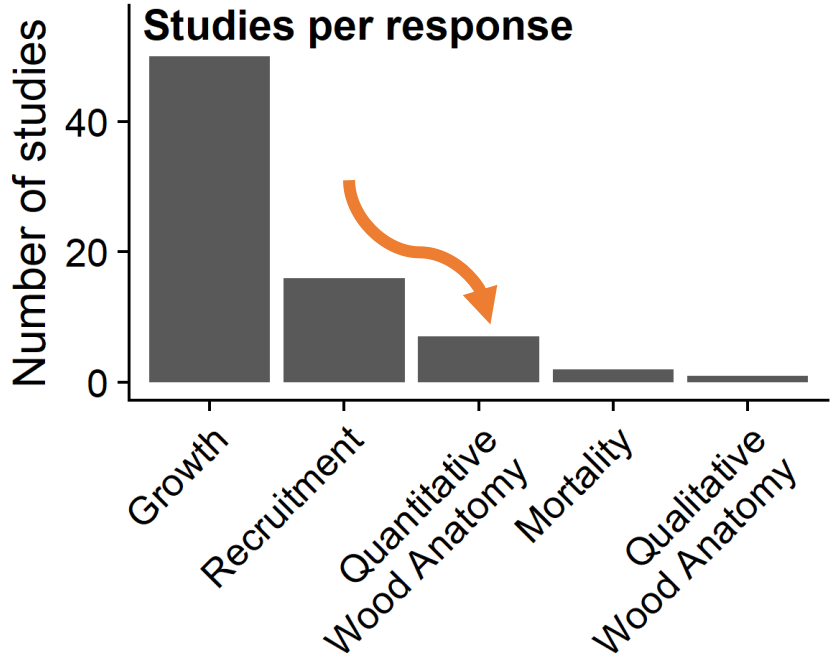
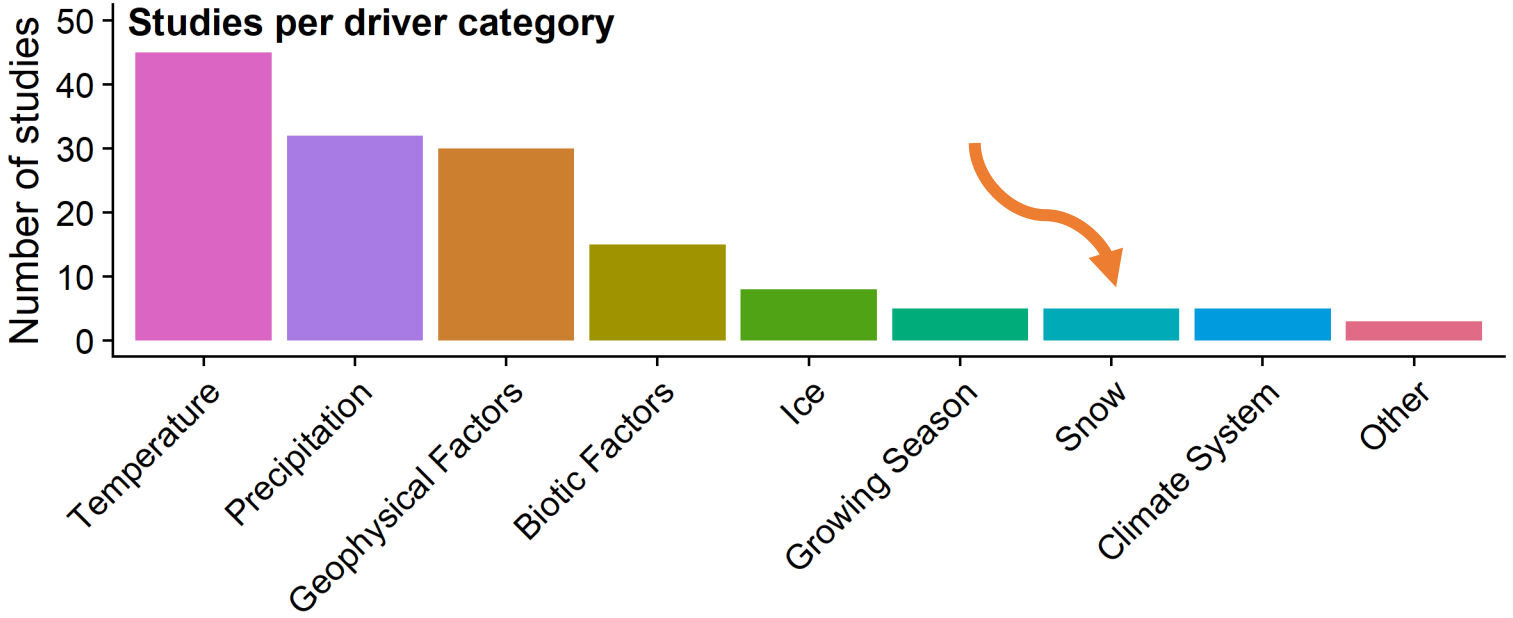




Power et al. *Sci. Total Environ.* 2022, 2024

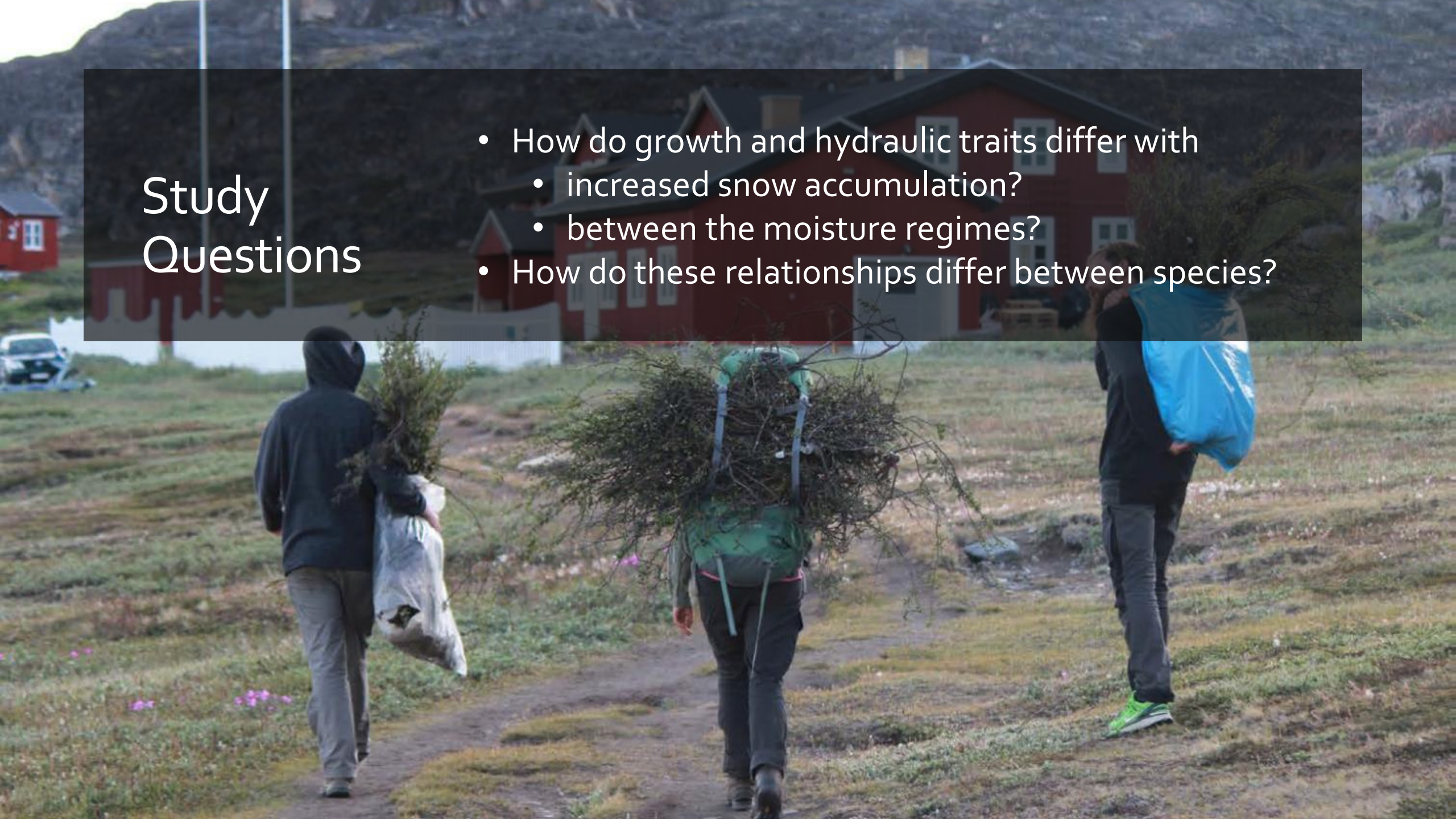
Main Study Aim

What?

- To assess how snow cover and moisture regime influence species-specific growth and anatomical responses

How?

- Analyze growth and hydraulic traits of shrubs growing under different
  - snow depths
  - moisture regimes

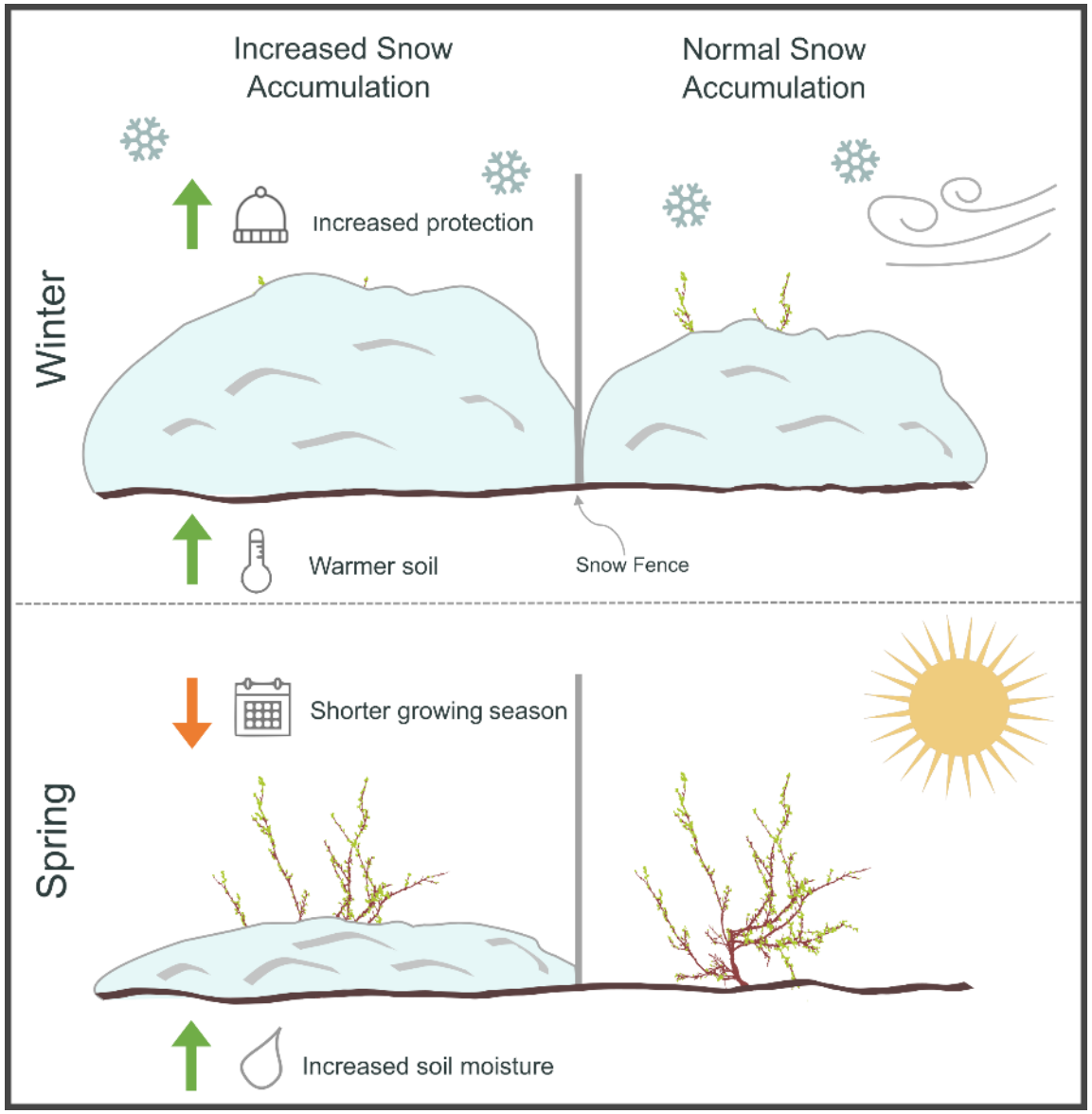


Study Questions

- How do growth and hydraulic traits differ with
  - increased snow accumulation?
  - between the moisture regimes?
- How do these relationships differ between species?

Hypotheses

The (Potential) Role of Snow in Shrub Dynamics



Negative

Positive

Snow Cover

Growing Season

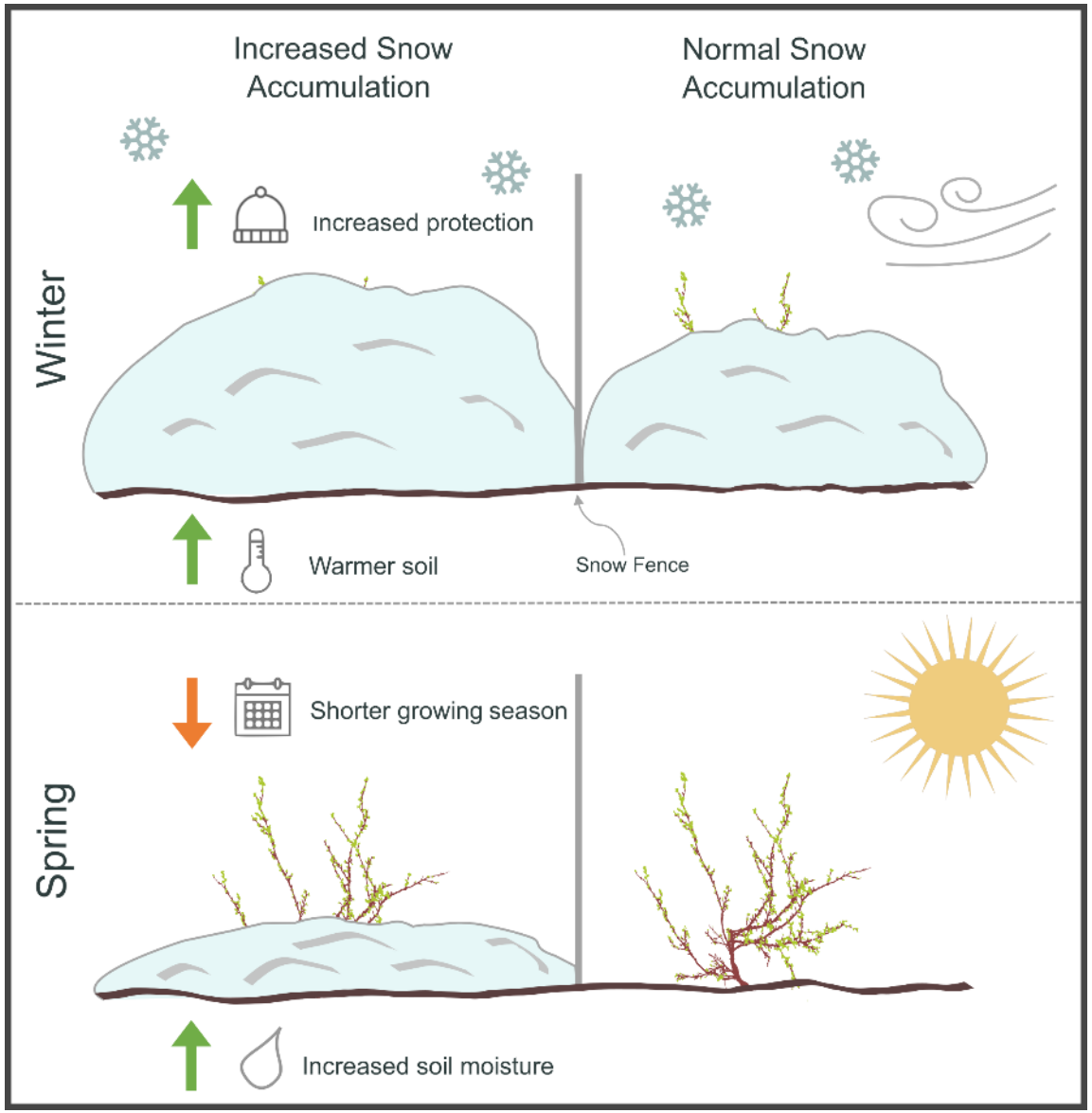
Soil Temperature

Soil Moisture

Protection

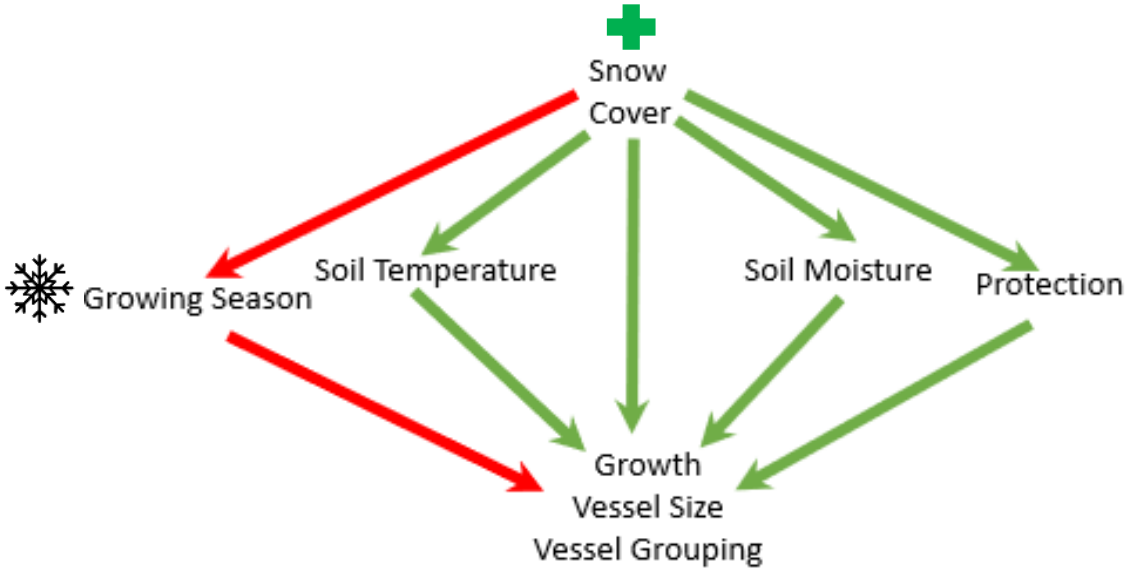
Hypotheses

The (Potential) Role of Snow in Shrub Dynamics



Negative

Positive



Snow Fences

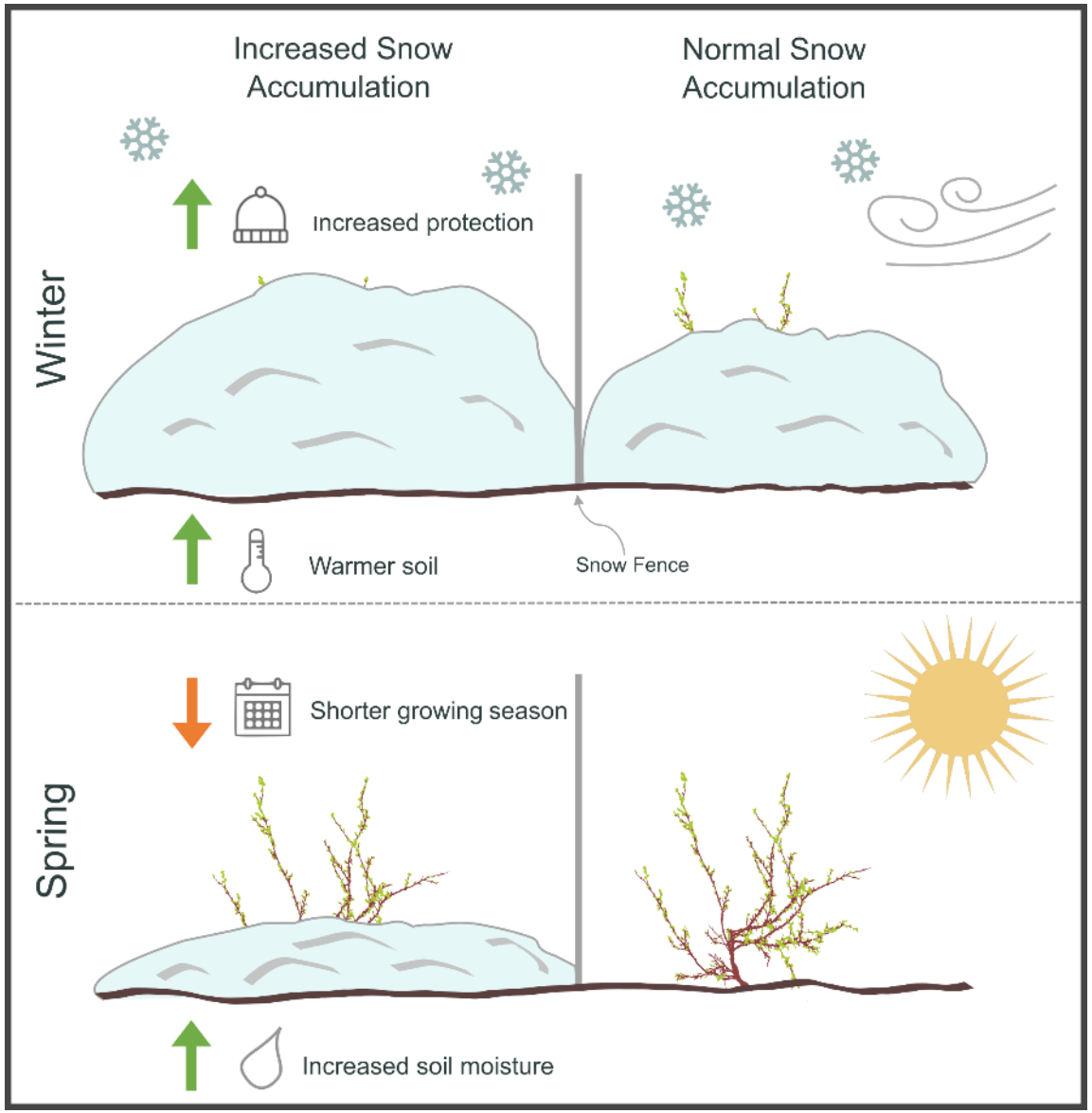

Increased Snow Accumulation
Normal Snow Accumulation
Increased protection
Winter
Warmer soil
Snow Fence
Shorter growing season
Spring
Increased soil moisture

Photo: Automatic camera (arktiskstation.ku.dk)

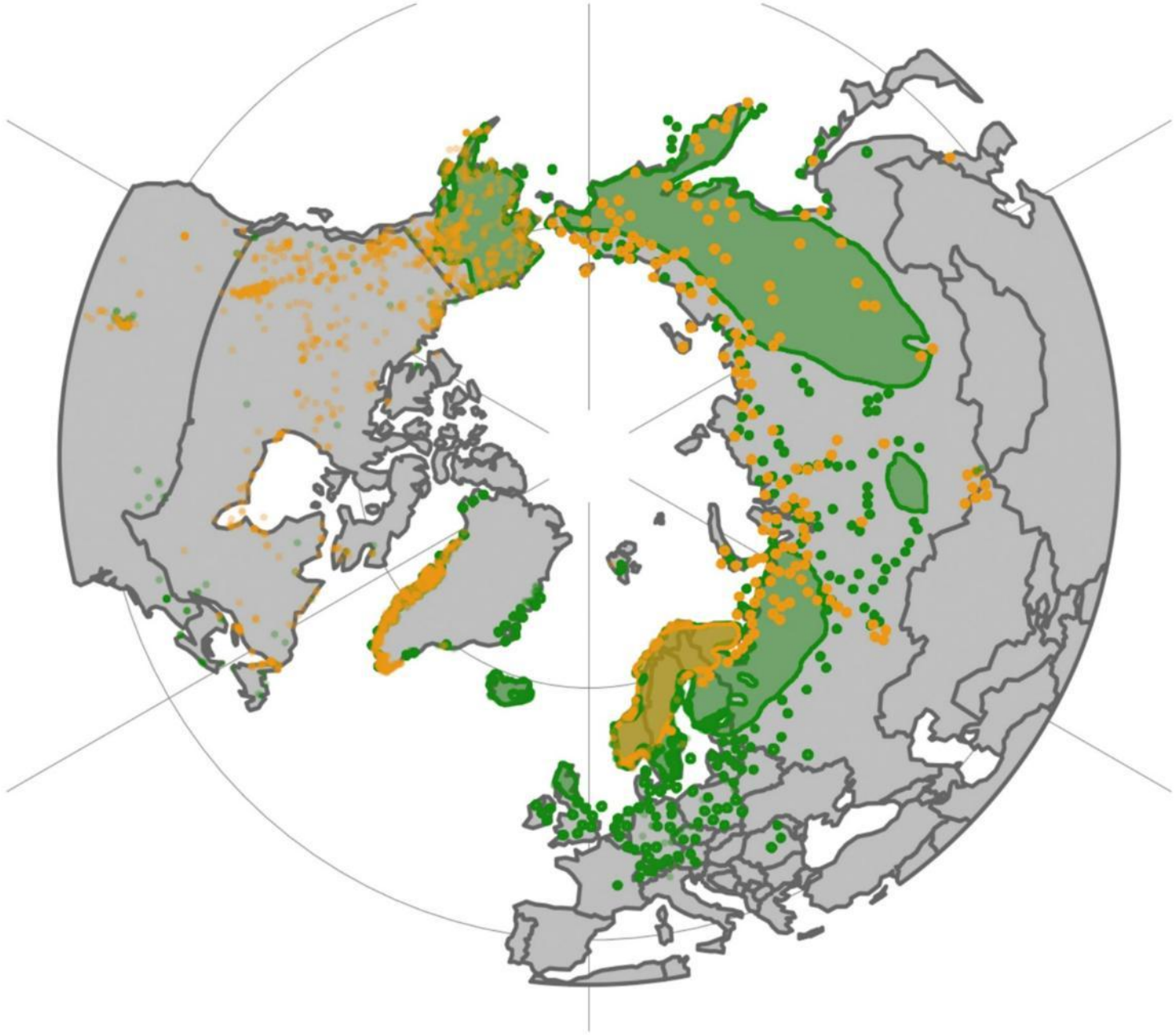
Study Site: Disko Island, Greenland
(69°16′N, 53°27′W)

MODIS Rapid Response Project


CENPERM
Center for Permafrost
UNIVERSITY OF
COPENHAGEN

Dry

Wet



Species

Betula nana

Salix glauca

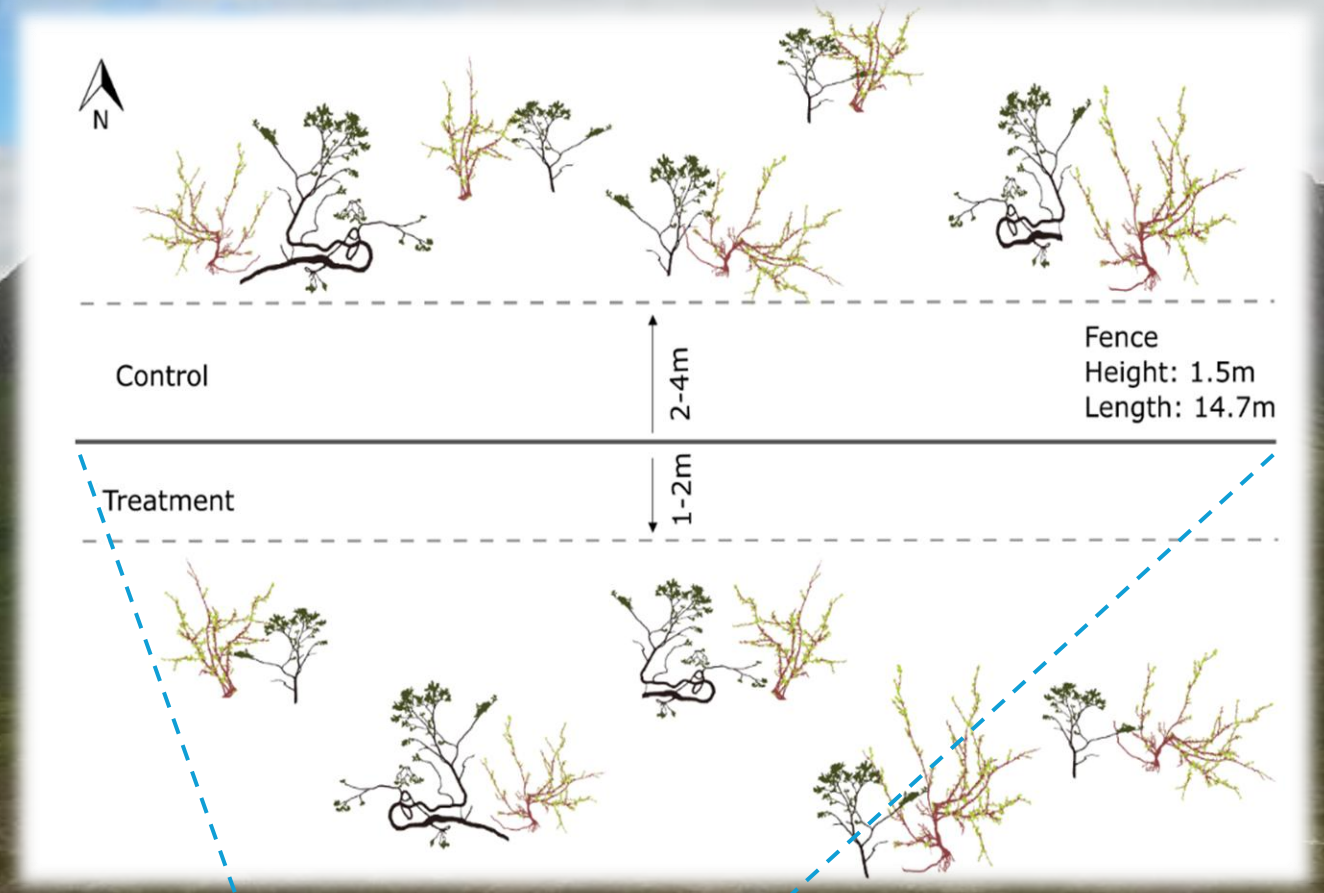
Post et al. PNAS. 2020.

40 *S. glauca*

Ages 10-30

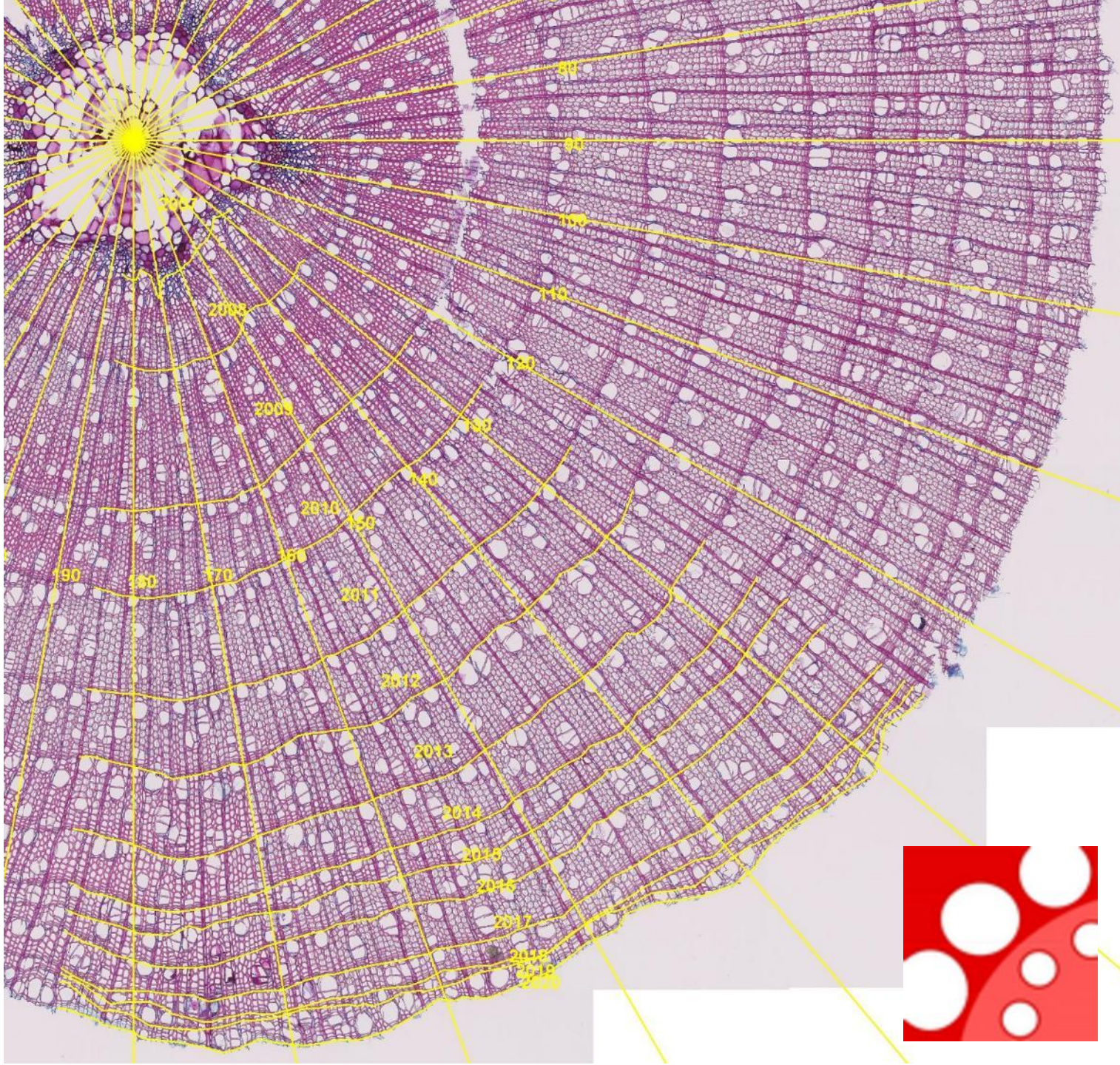
40 *B. nana*

Ages 10-23



Responses Tested

- **Radial growth**

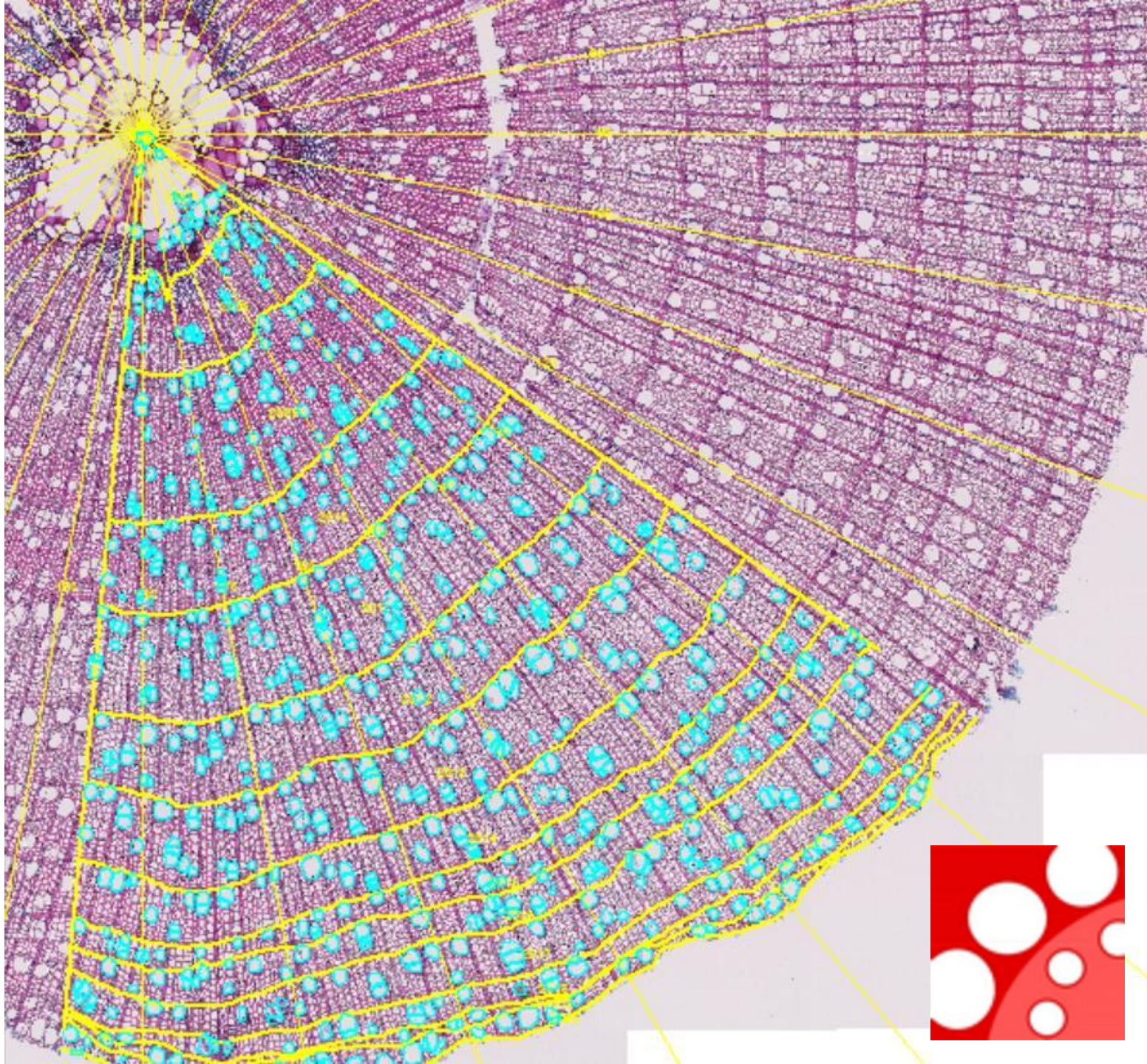


Responses Tested

- **Radial growth**

- **Hydraulic Efficiency**
  - Theoretical xylem-specific Hydraulic conductivity (Ks)

"Hydraulic conductivity"



Responses Tested

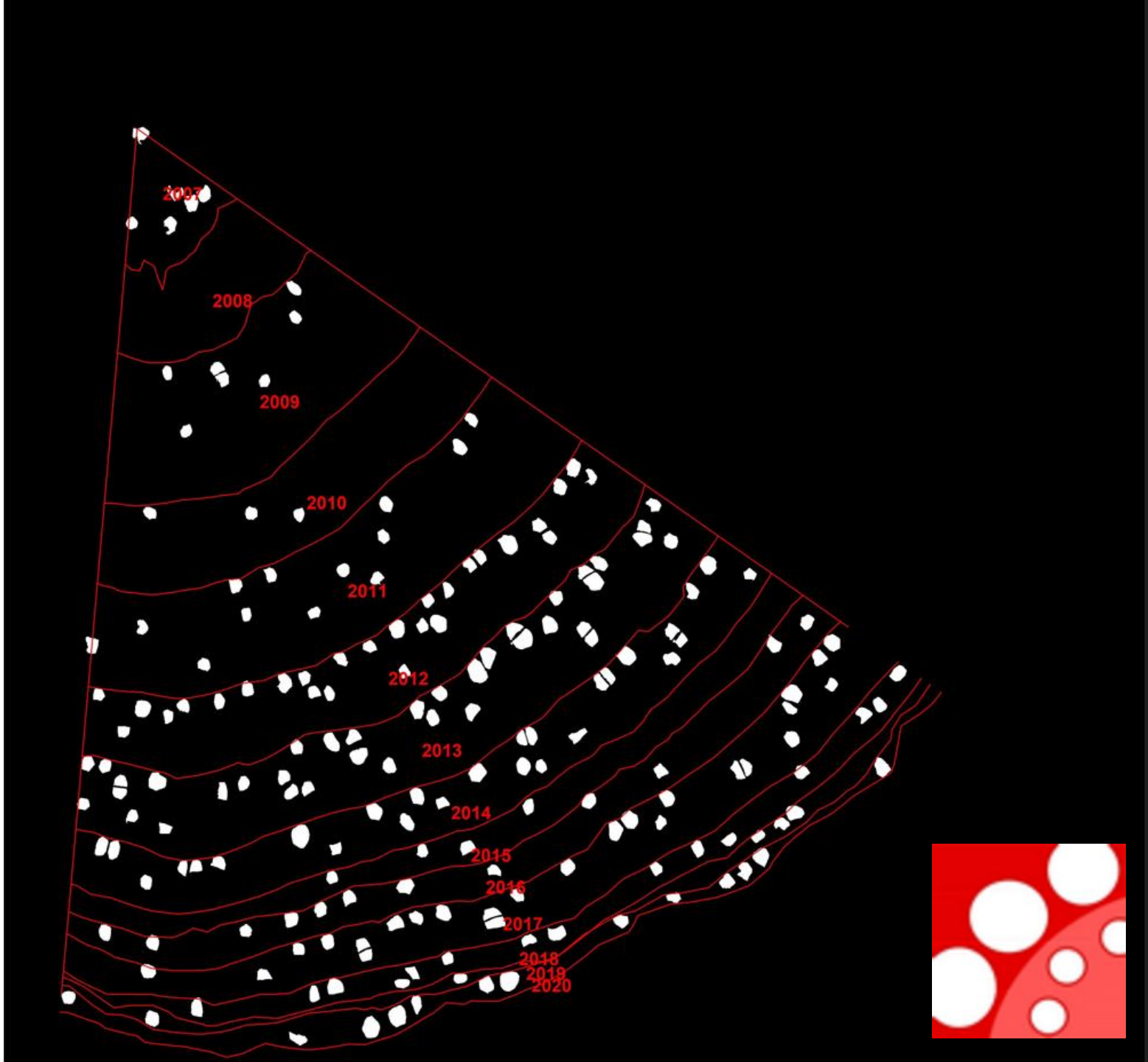
- **Radial growth**

- **Hydraulic Efficiency**
  - Theoretical xylem-specific Hydraulic conductivity (Ks)

"Hydraulic conductivity"

  - 95th percentile of vessel lumen area (La95)

"Early wood vessel size"



Responses Tested

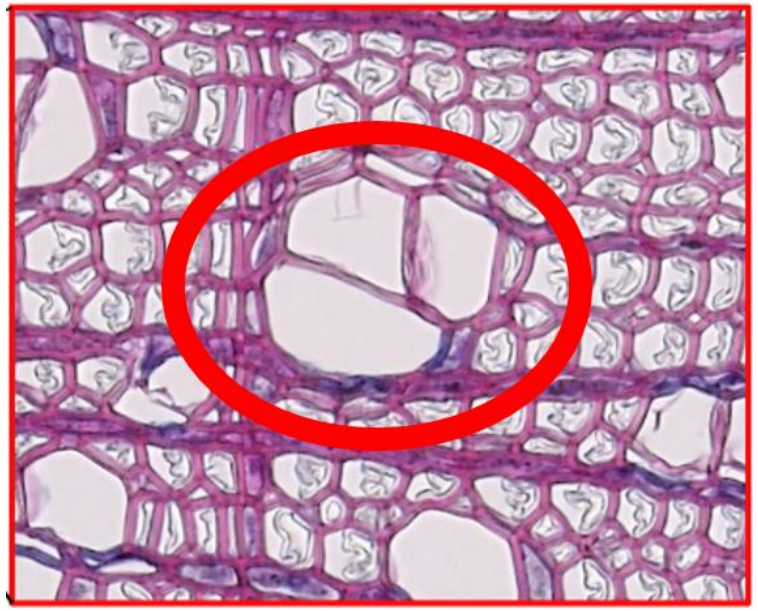
- **Radial growth**

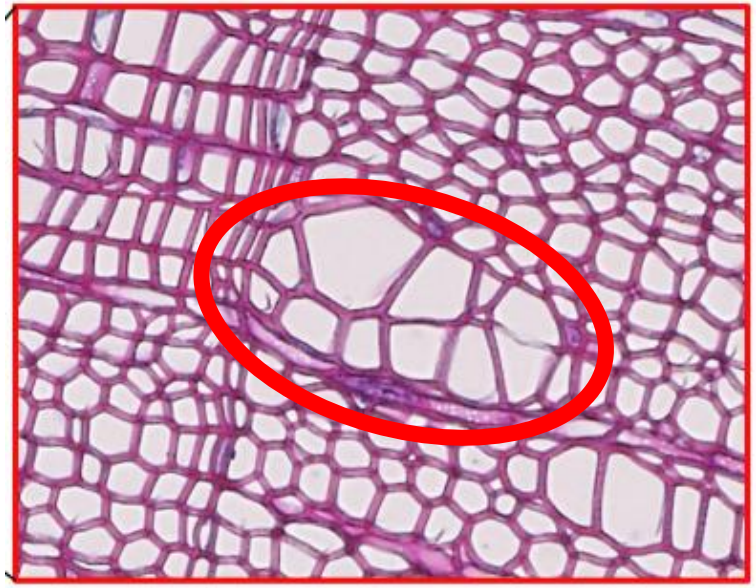
- **Hydraulic Efficiency**
  - Theoretical xylem-specific Hydraulic conductivity (Ks)

  - 95th percentile of vessel lumen area (La95)

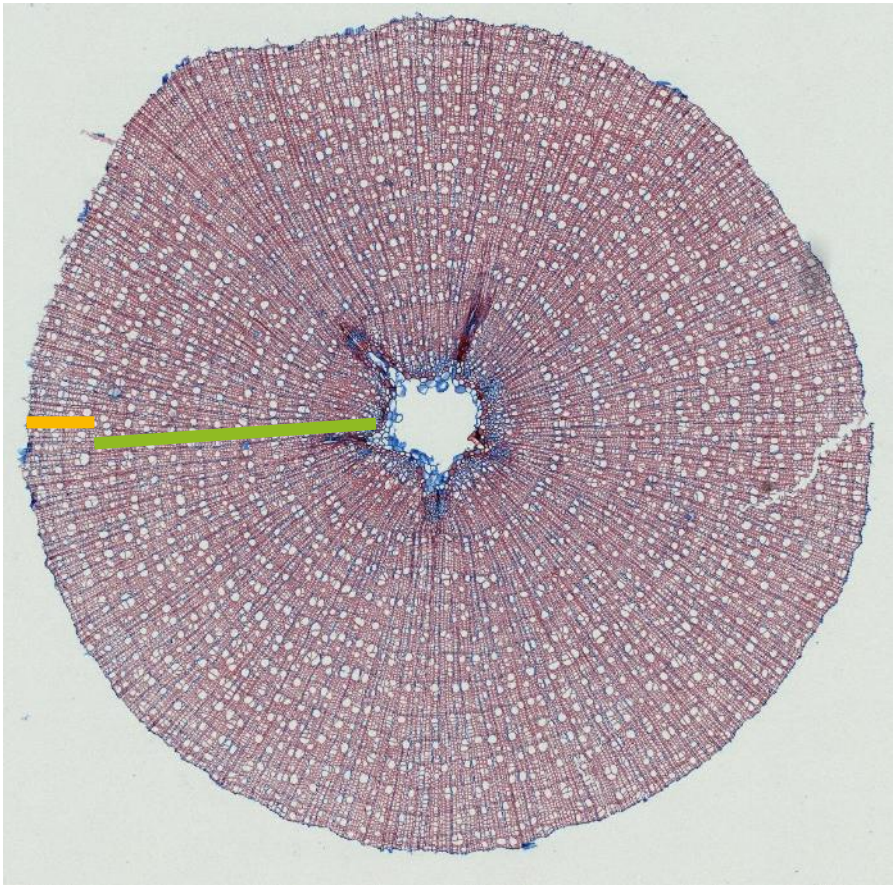
- **Spatial vessel distribution**
  - Mean group size of non-solitary vessels (RGSV)

  "Hydraulic connectivity"





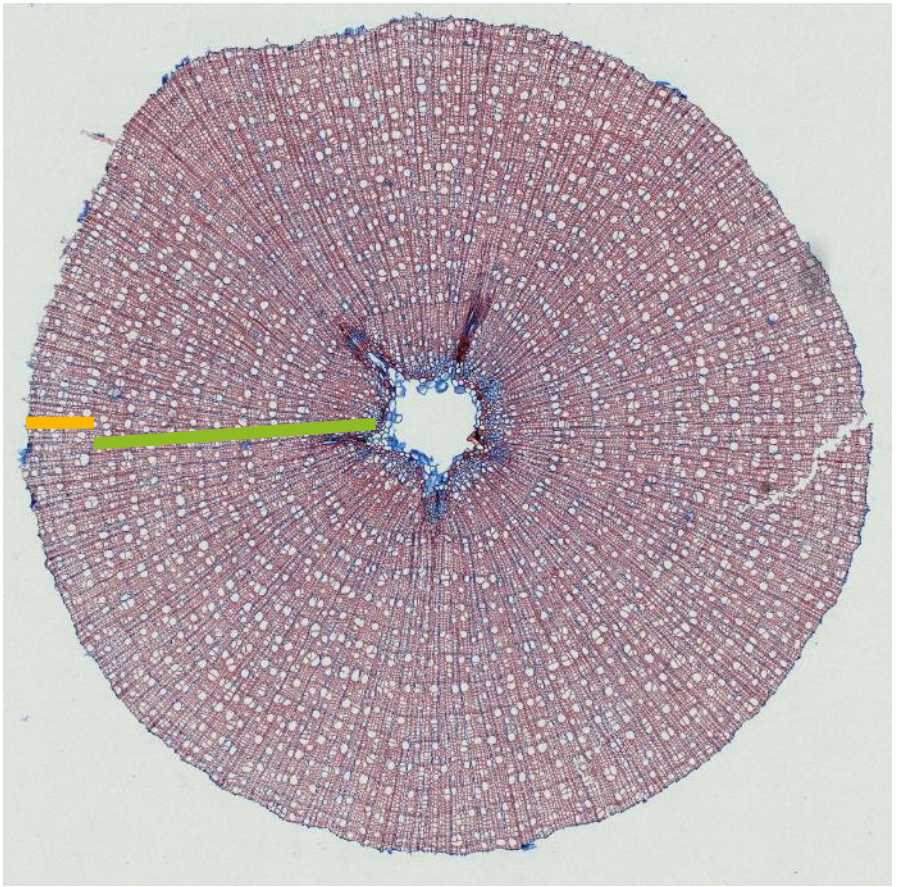
Control
(ambient snow)



Before Fence

After Fence

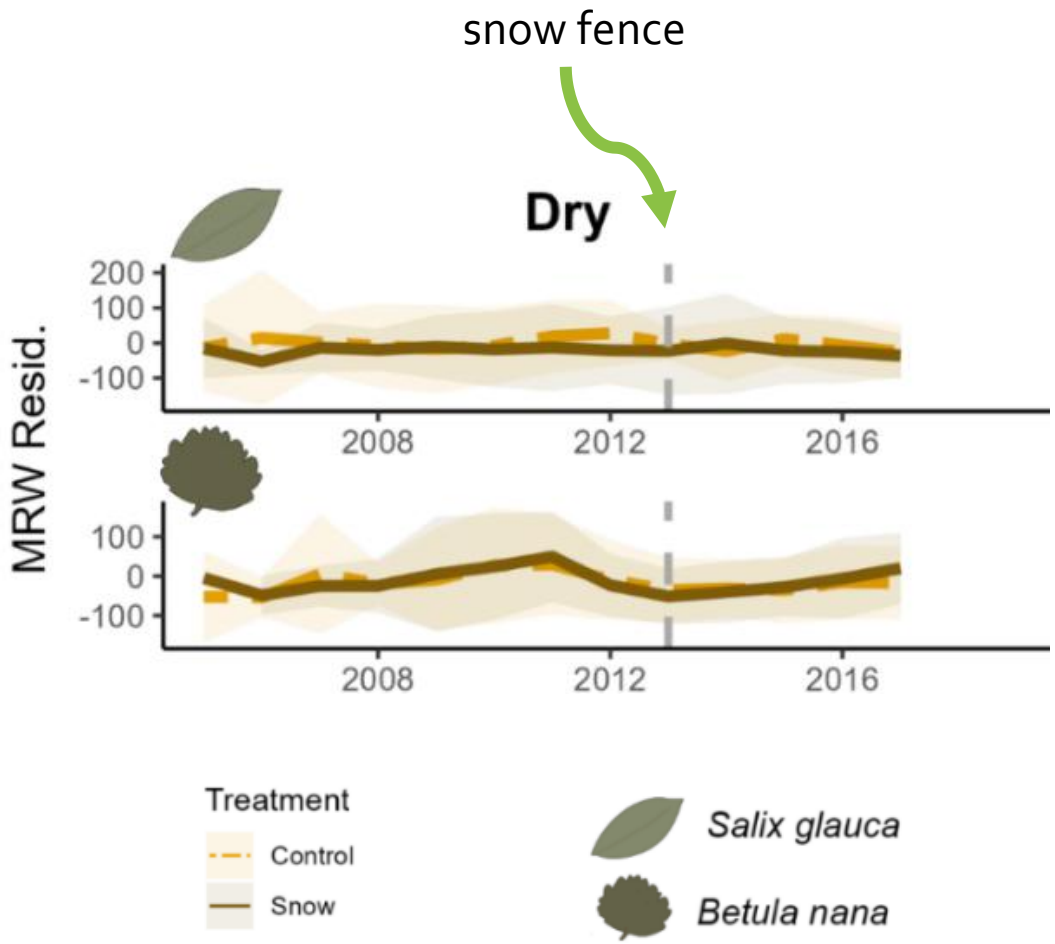
Treatment
(increased snow)



Before Fence

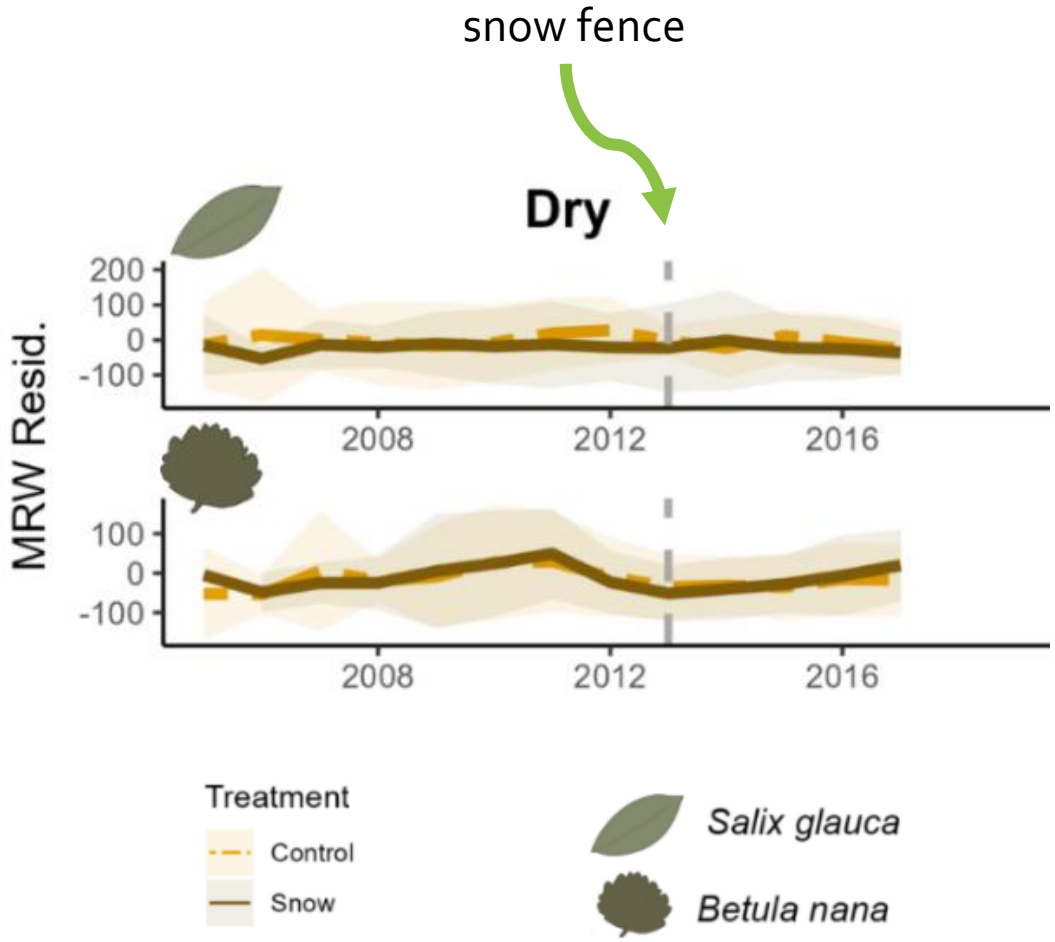
After Fence

Key Findings: Snow Treatment



Key Findings: Snow Treatment

- No effect of snow accumulation detected



Key Findings: Snow Treatment

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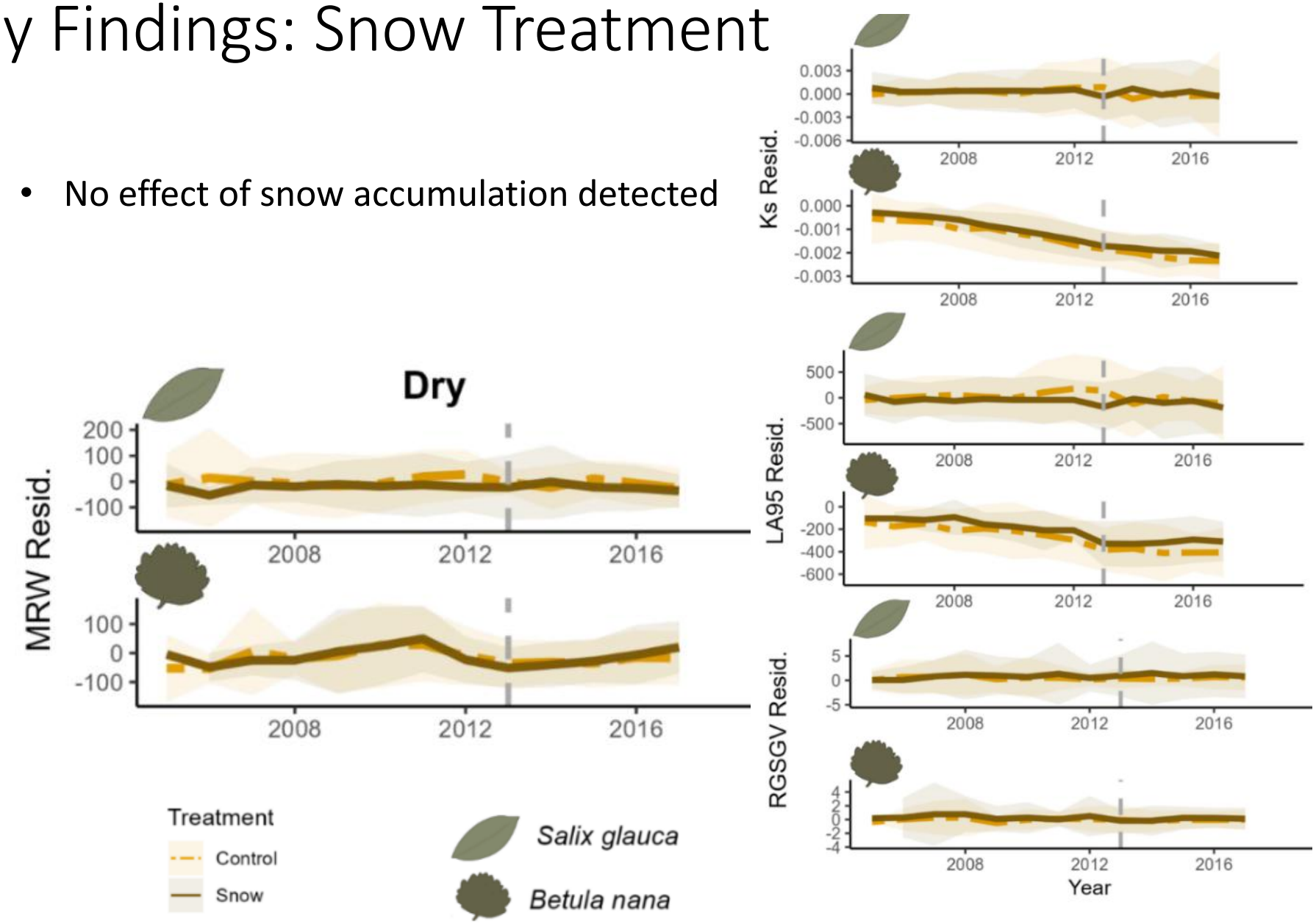

Key Findings: Snow Treatment

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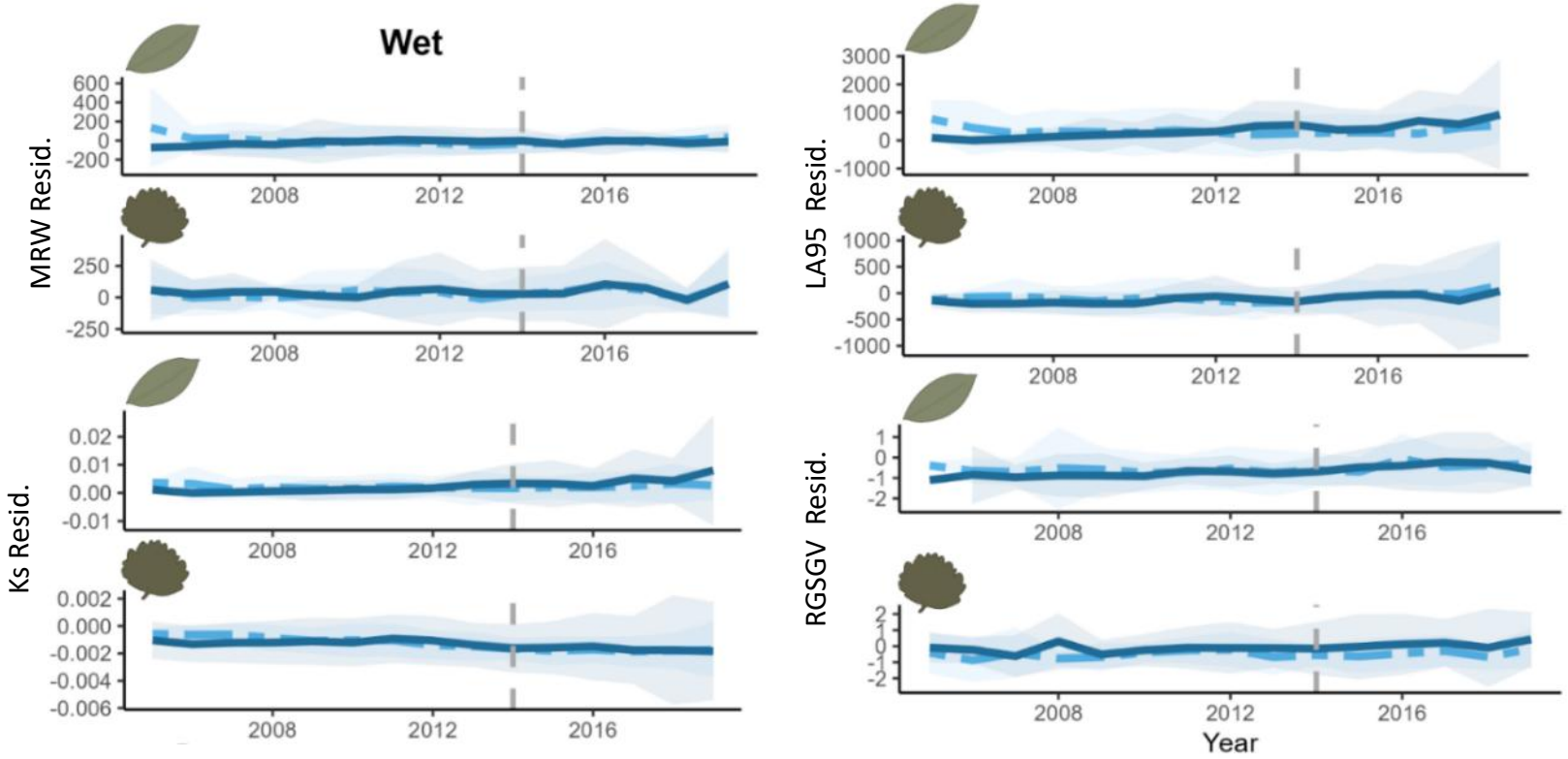
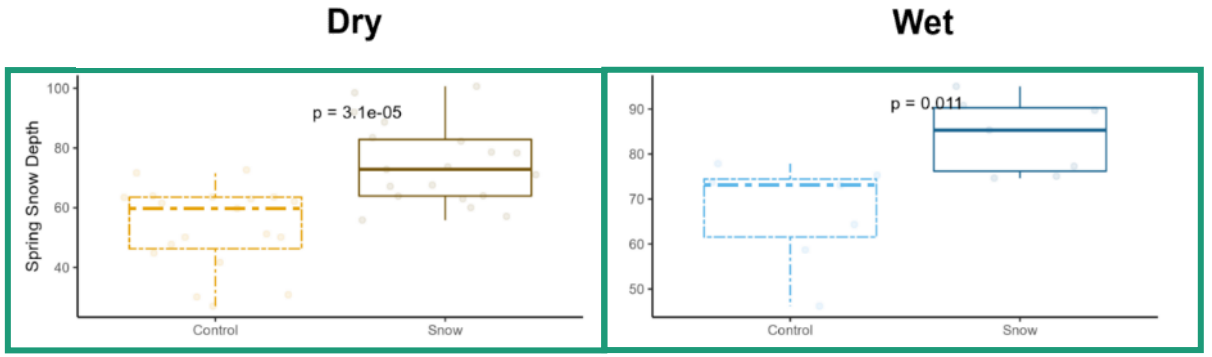
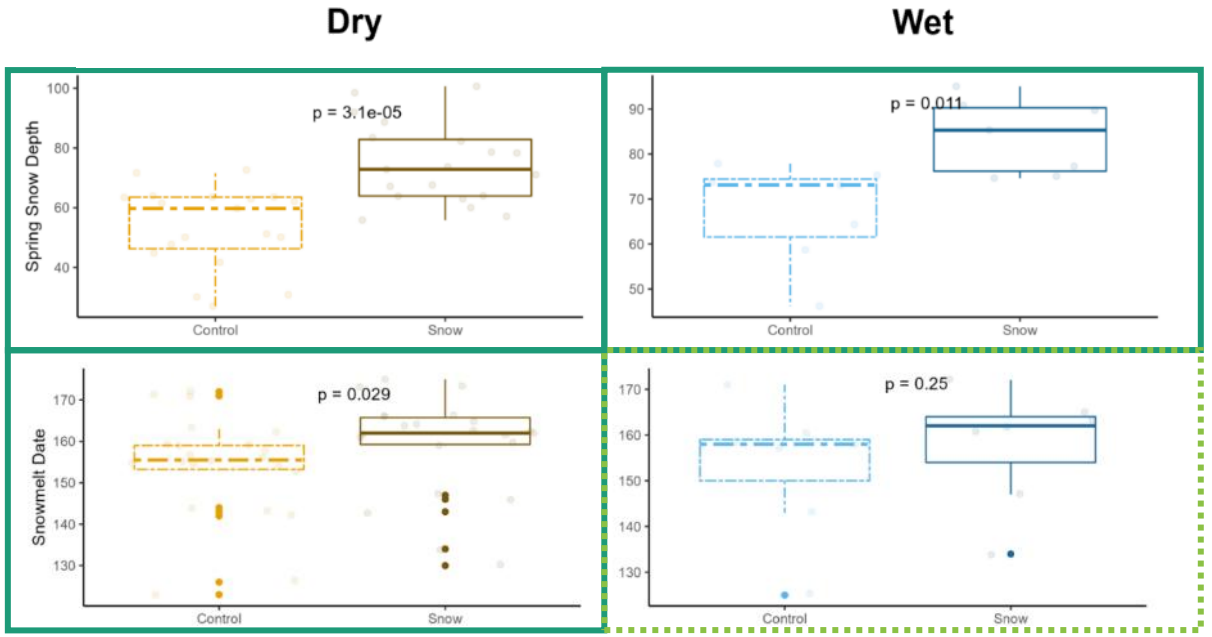


21 cm
(39%)



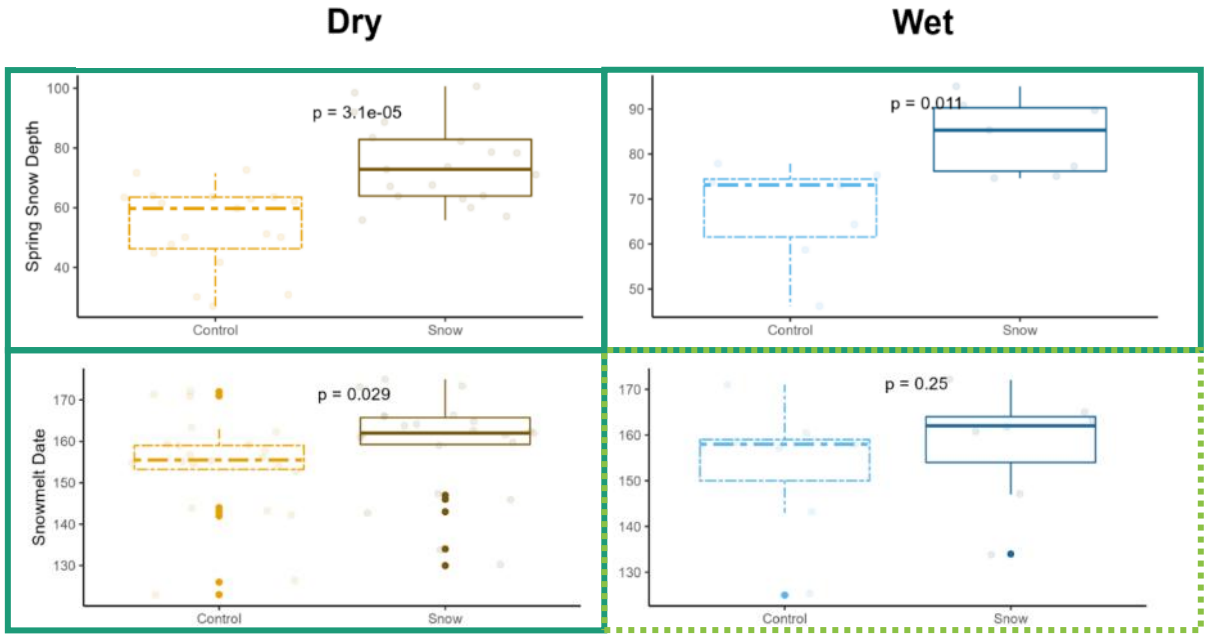
17 cm
(28%)

5 days
(2-9)

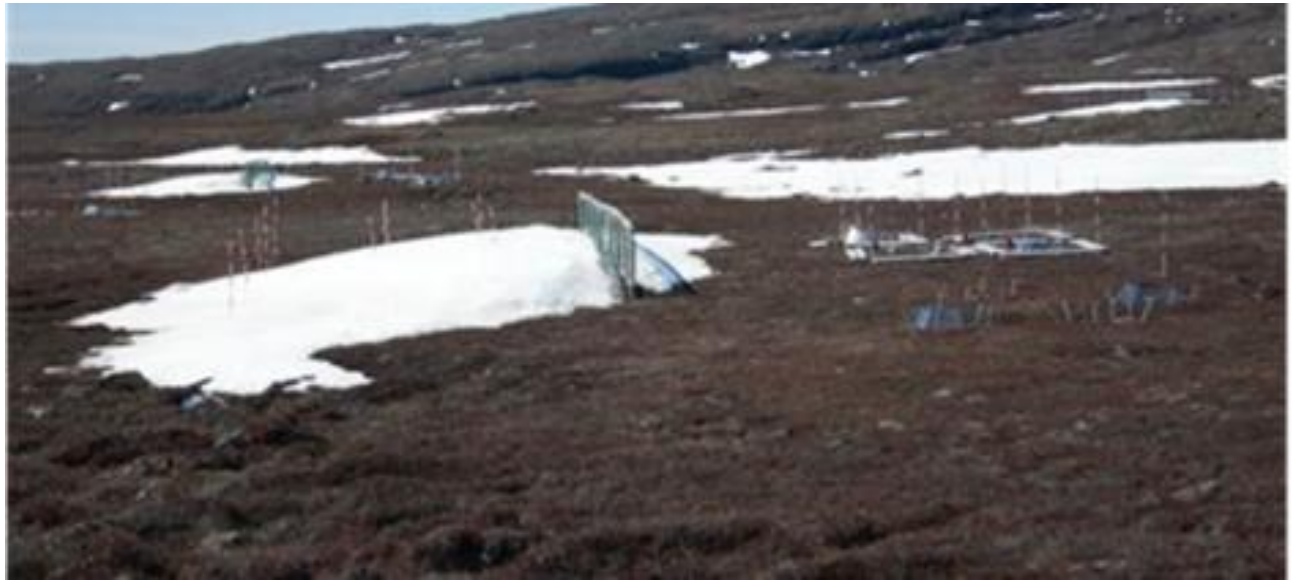


4.6 days
(1-9)

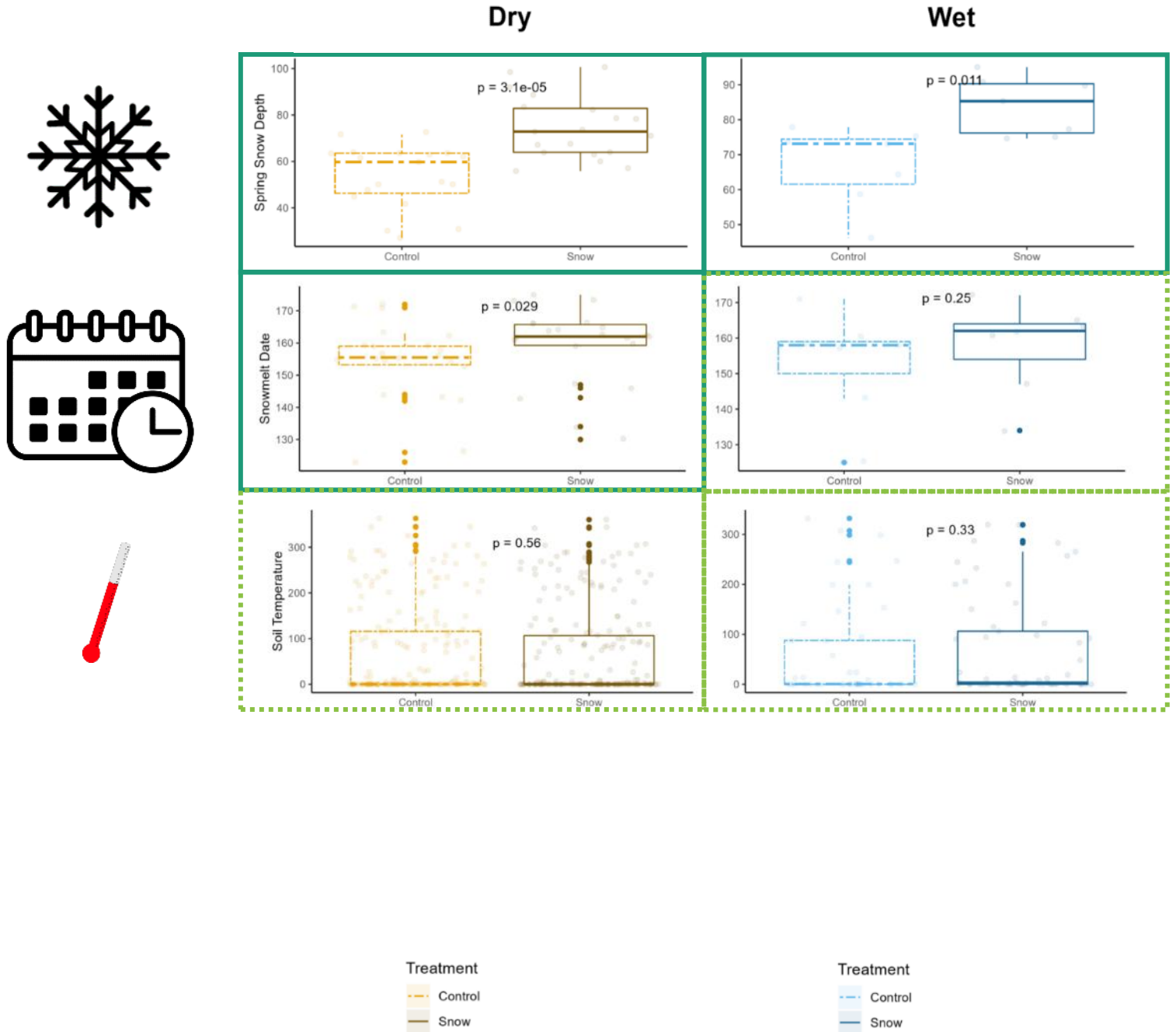
5 days

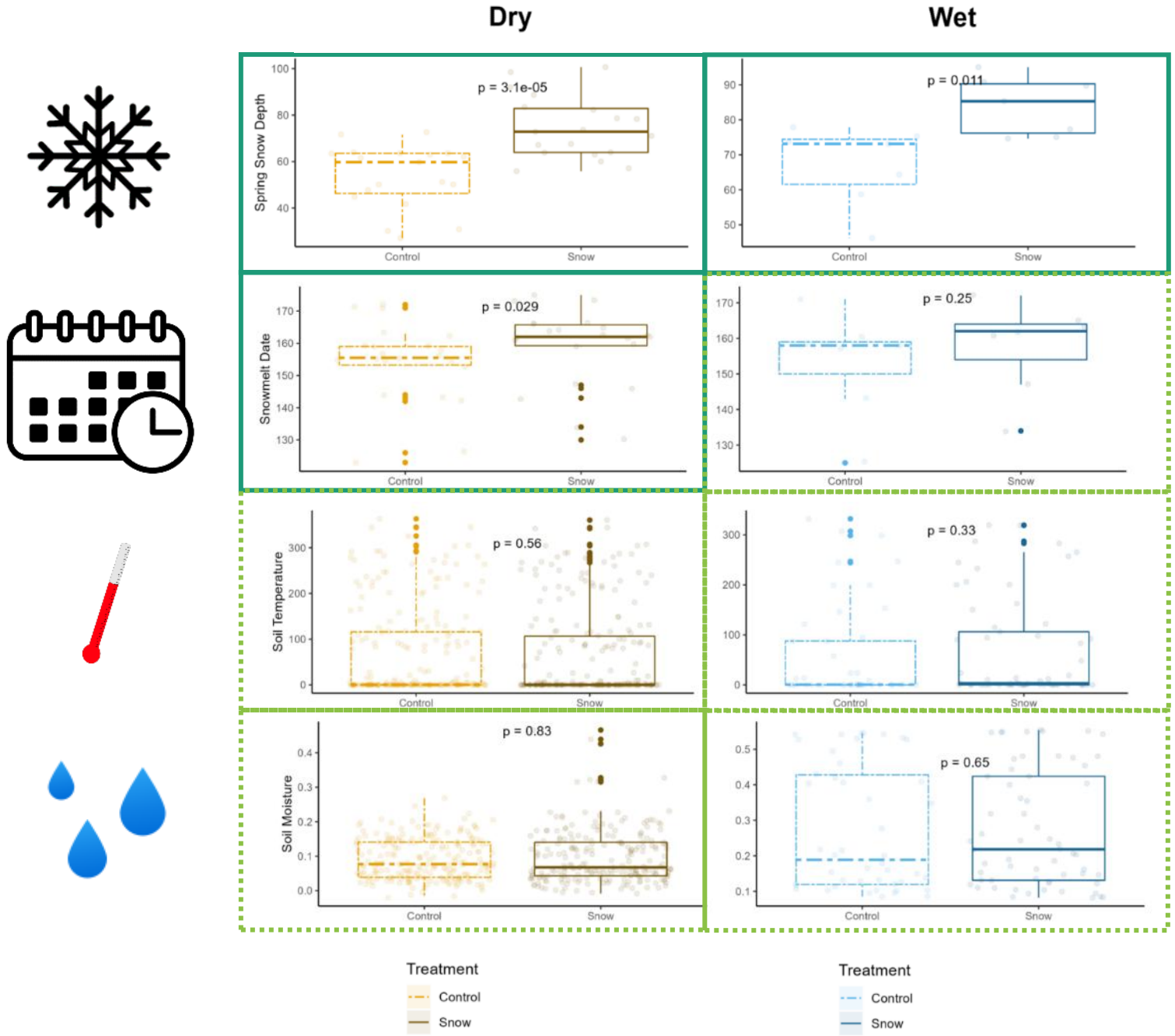


4.6 days

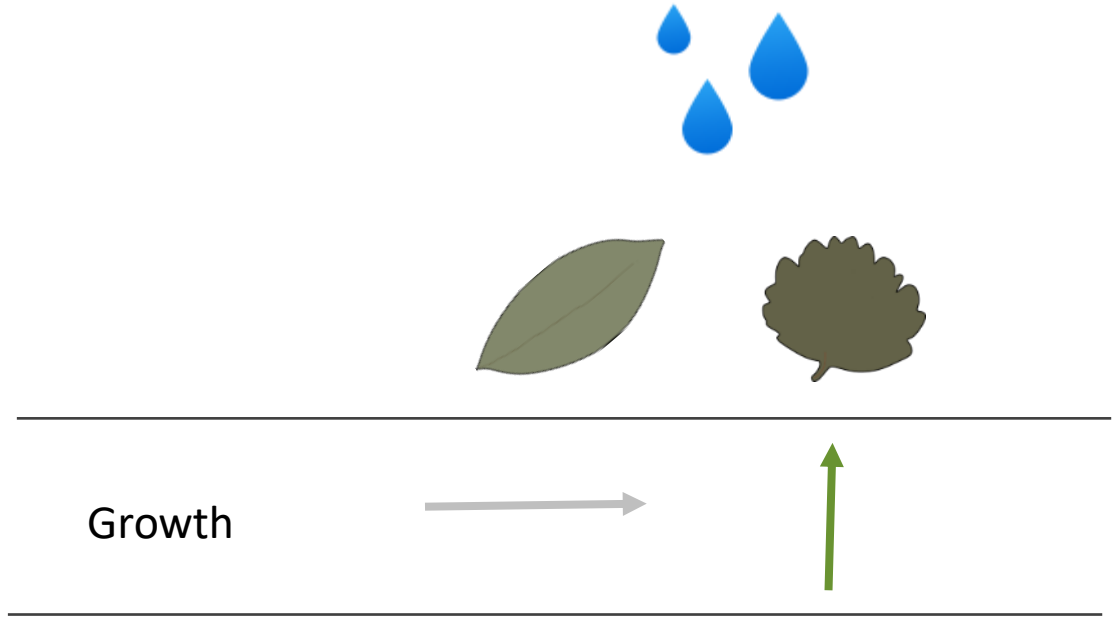


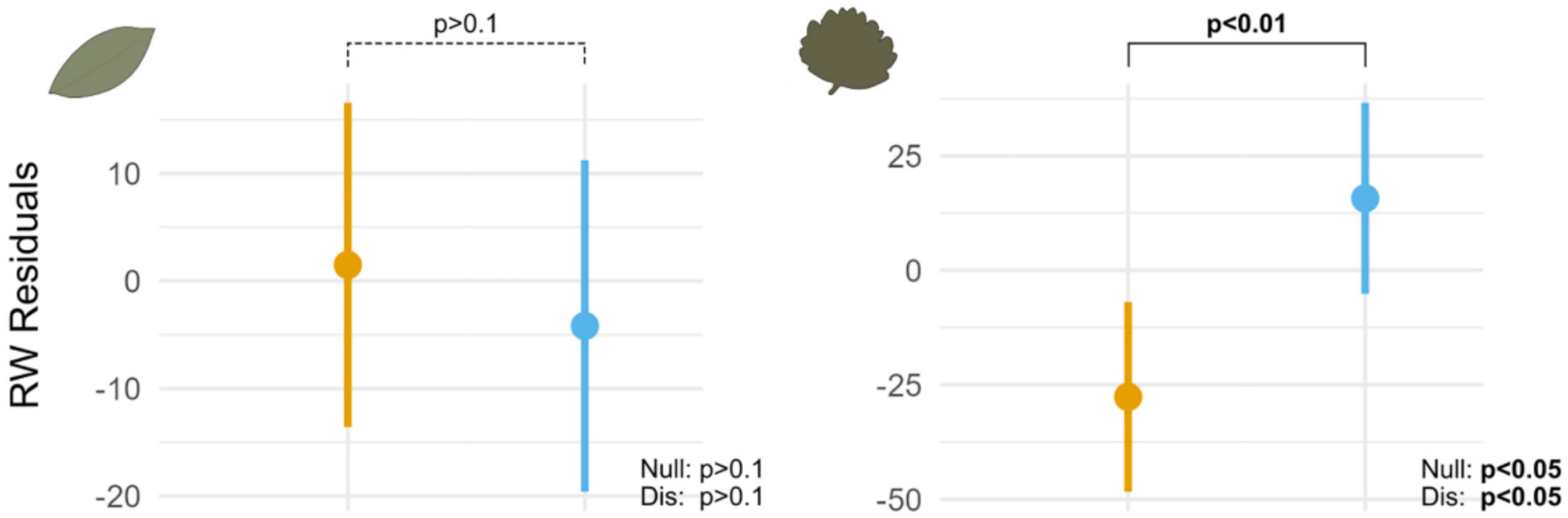
June 8 2013


Dry
Wet
Spring Snow Depth
Snowmelt Date
Soil Temperature
p = 3.1e-05
p = 0.011
p = 0.029
p = 0.25
p = 0.56
p = 0.33
Control
Snow
Treatment
Control
Snow
Treatment
Control
Snow

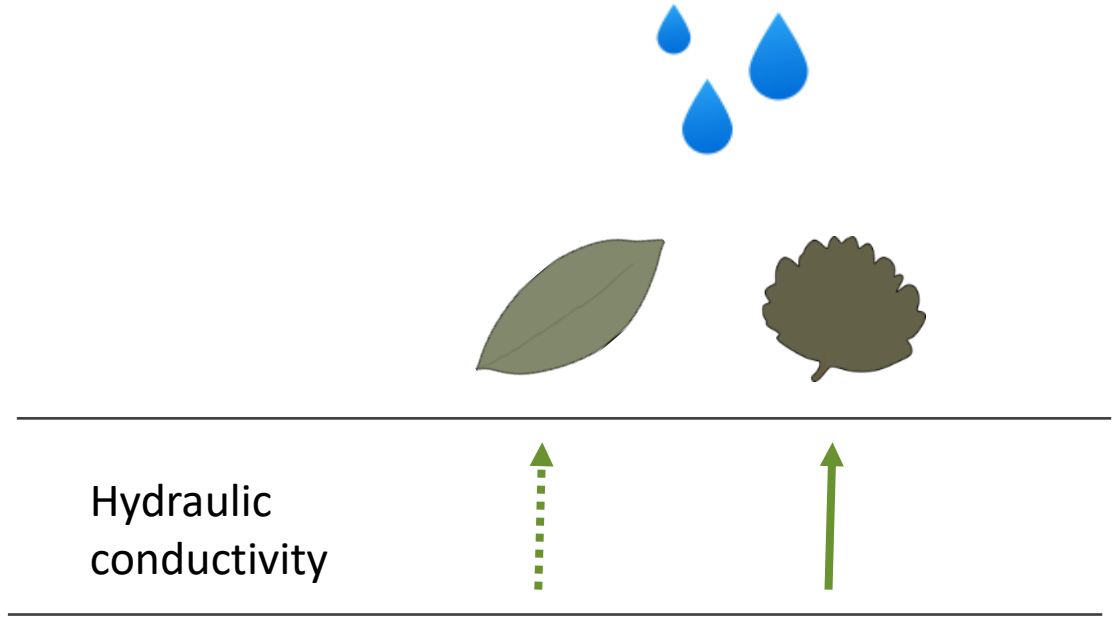

Dry
Wet
Spring Snow Depth
p = 3.1e-05
p = 0.011
Snowmelt Date
p = 0.029
p = 0.25
Soil Temperature
p = 0.56
p = 0.33
Soil Moisture
p = 0.83
p = 0.65
Control
Snow
Treatment
Control
Snow
Treatment
Control
Snow

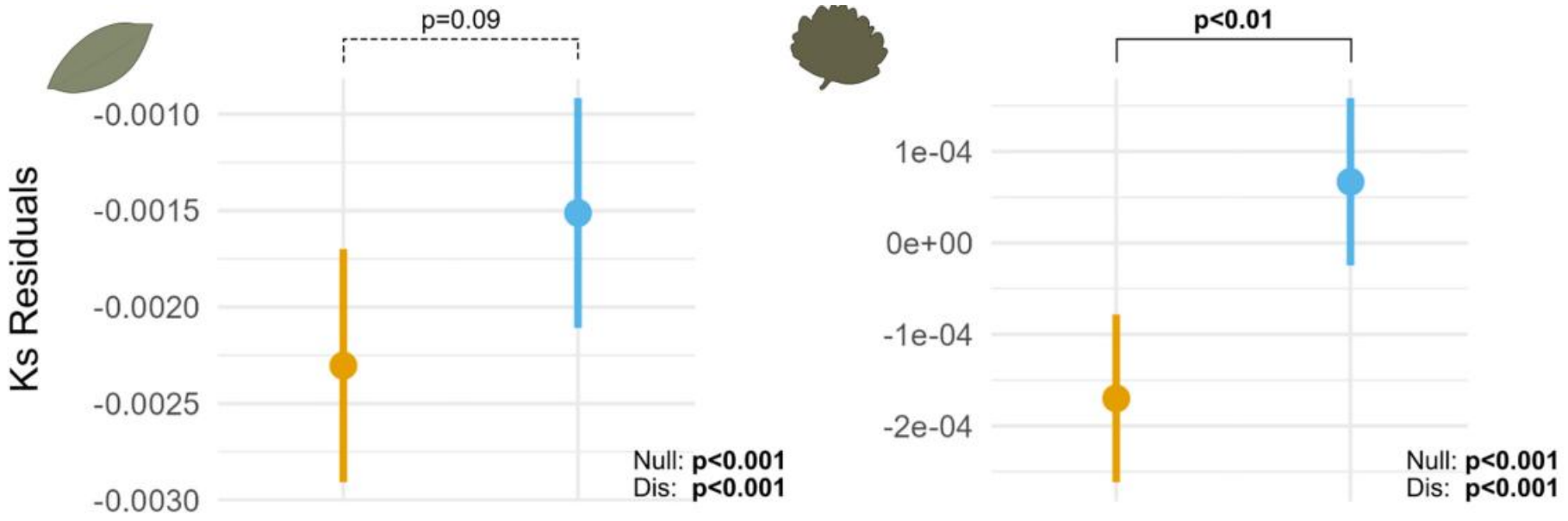
Key Findings



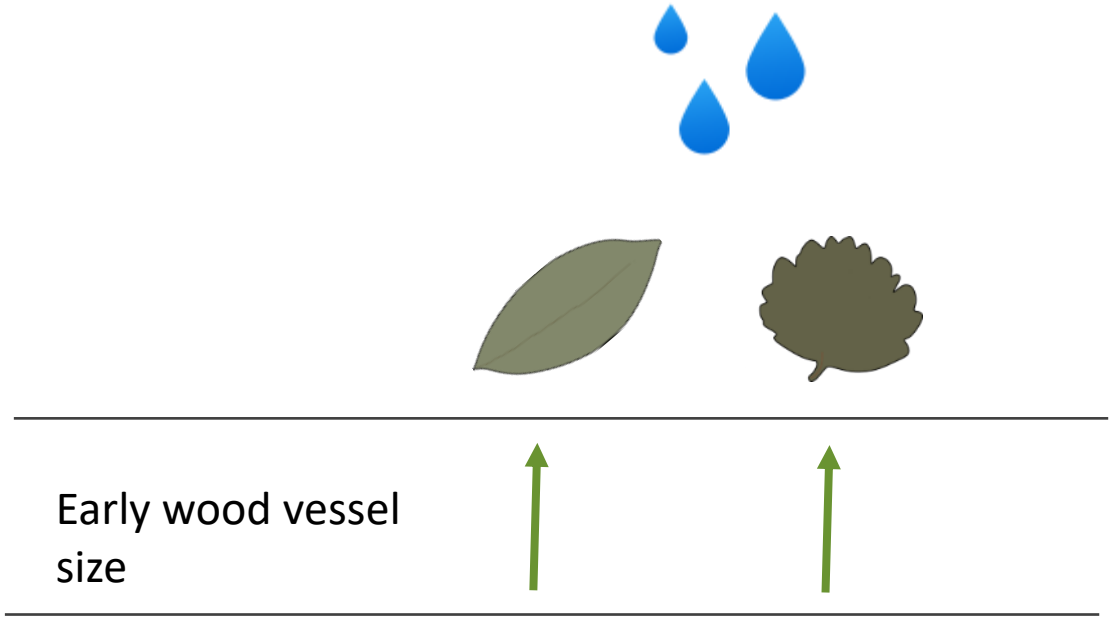


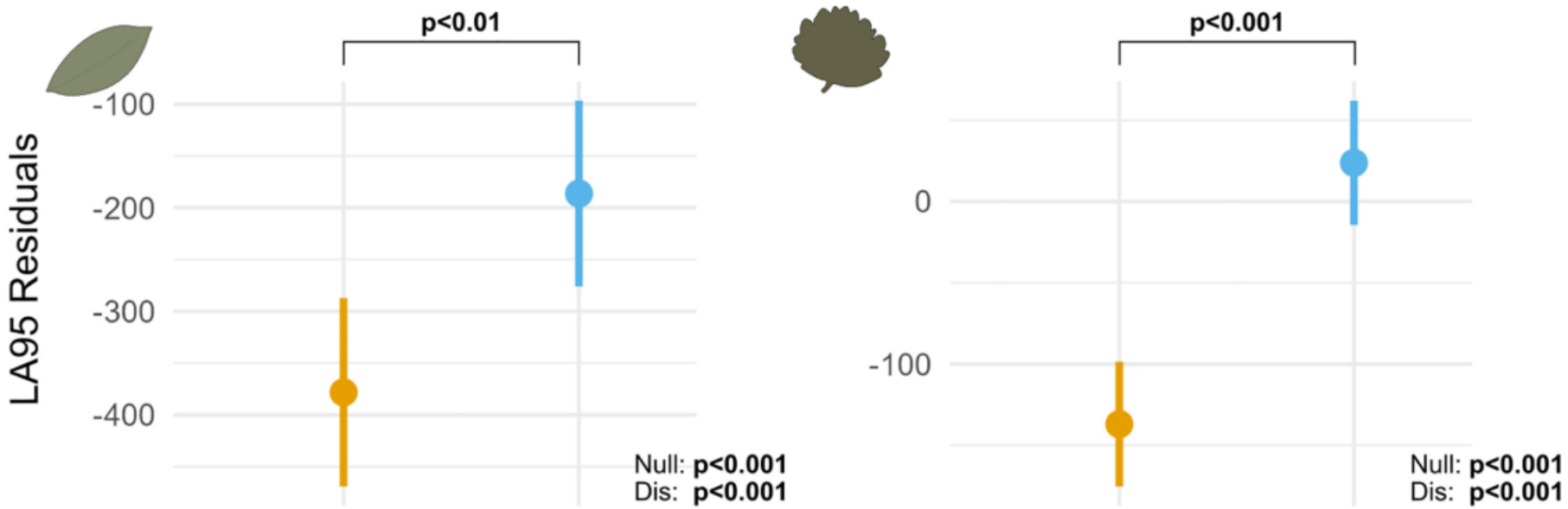
Key Findings



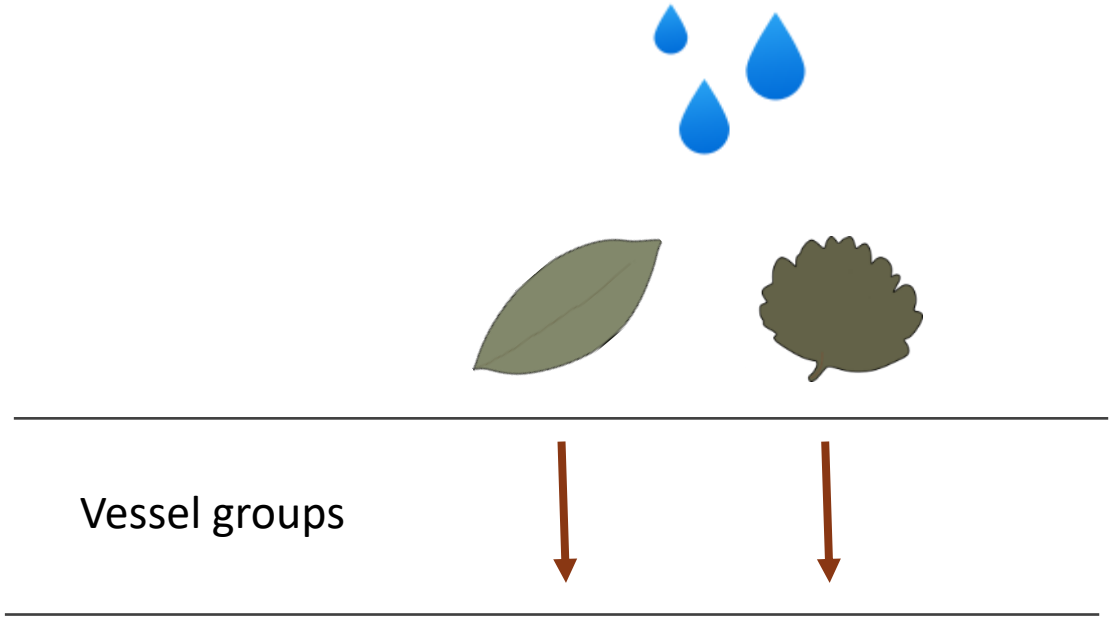


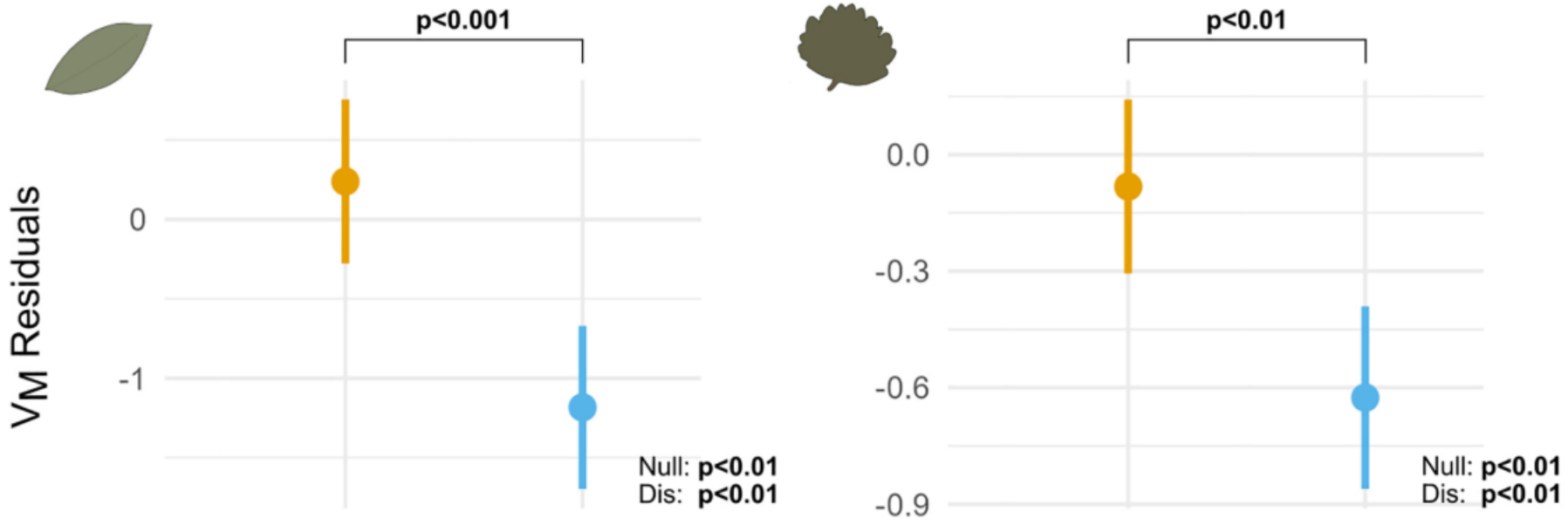
Key Findings



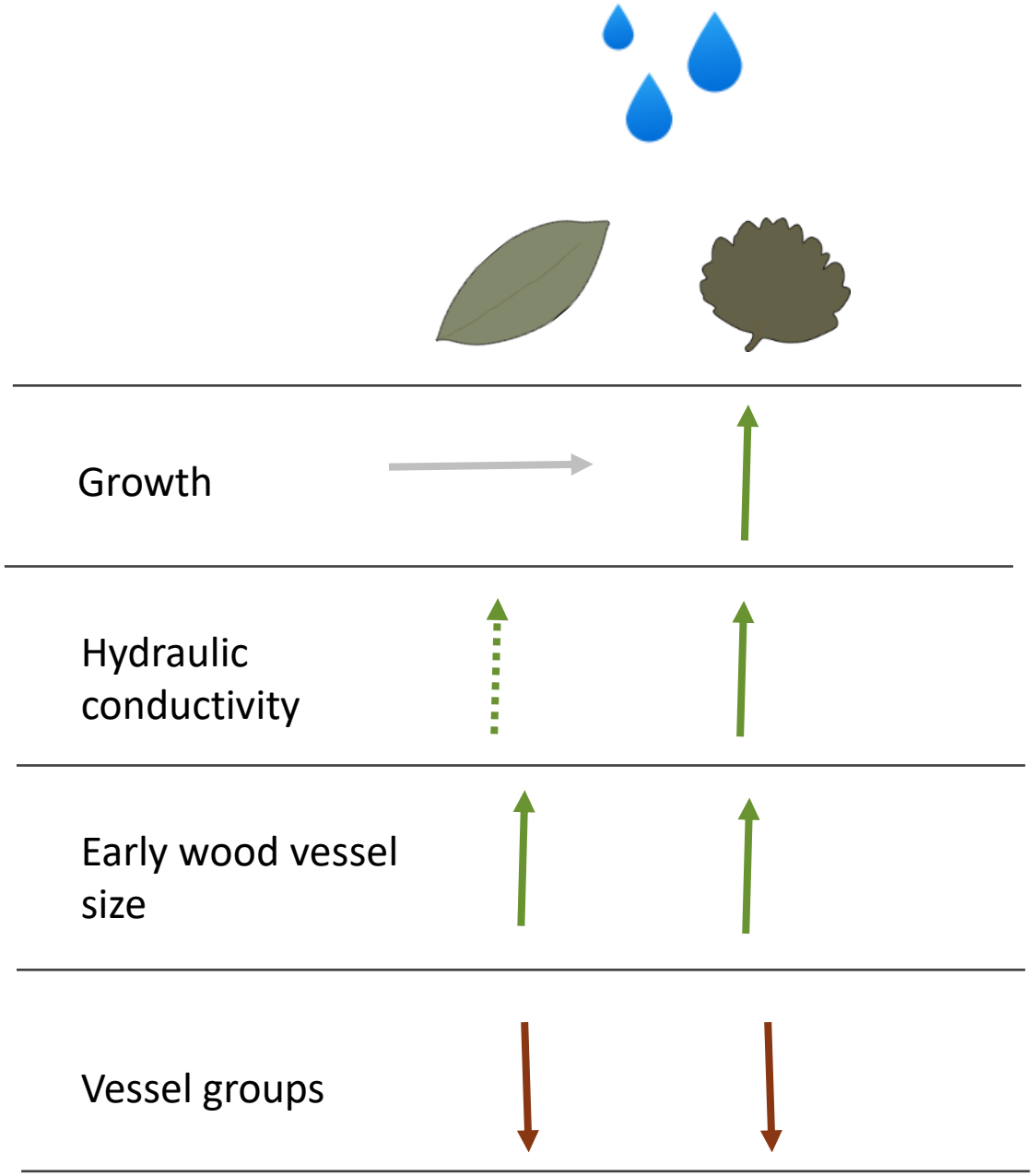


Key Findings



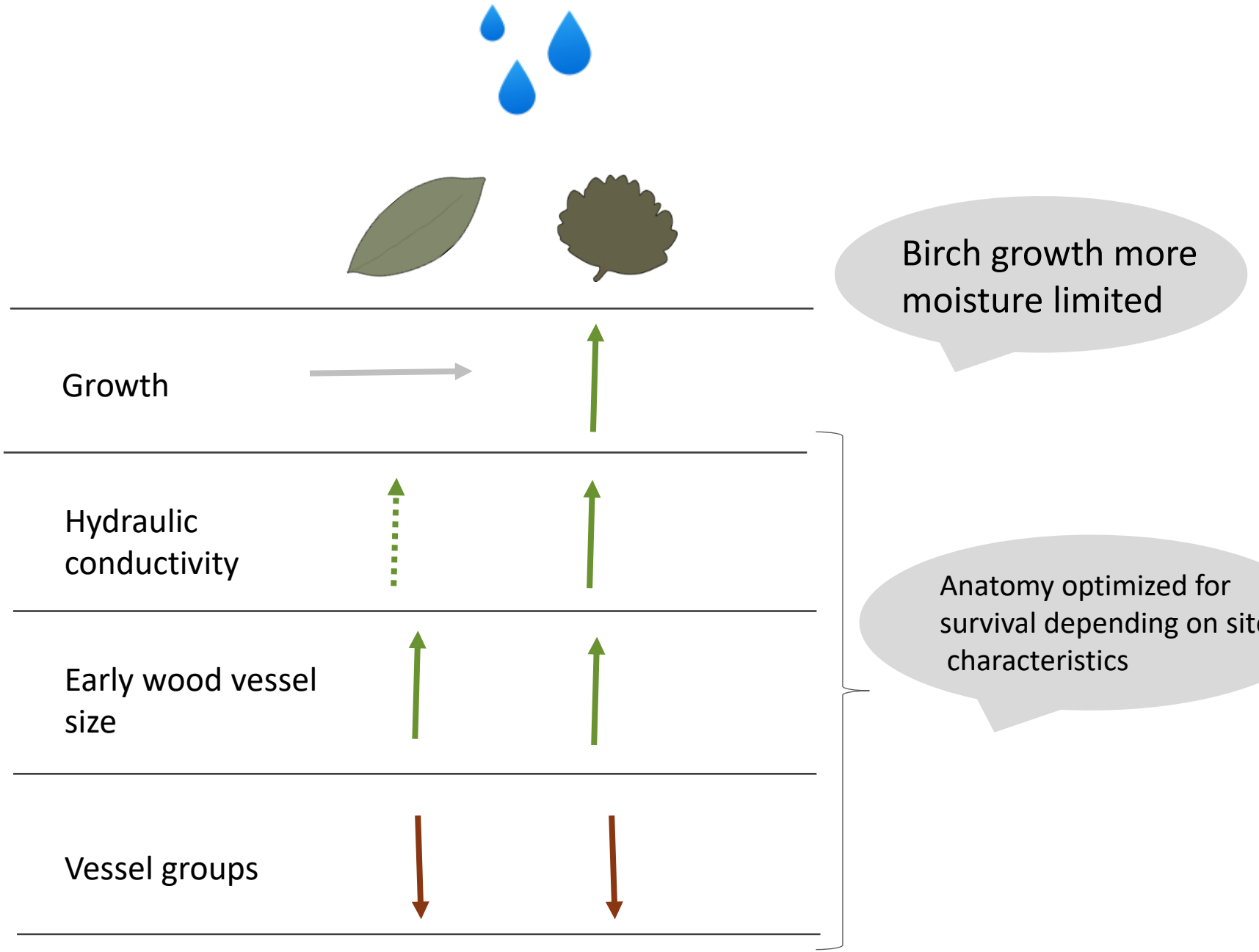


Key Findings

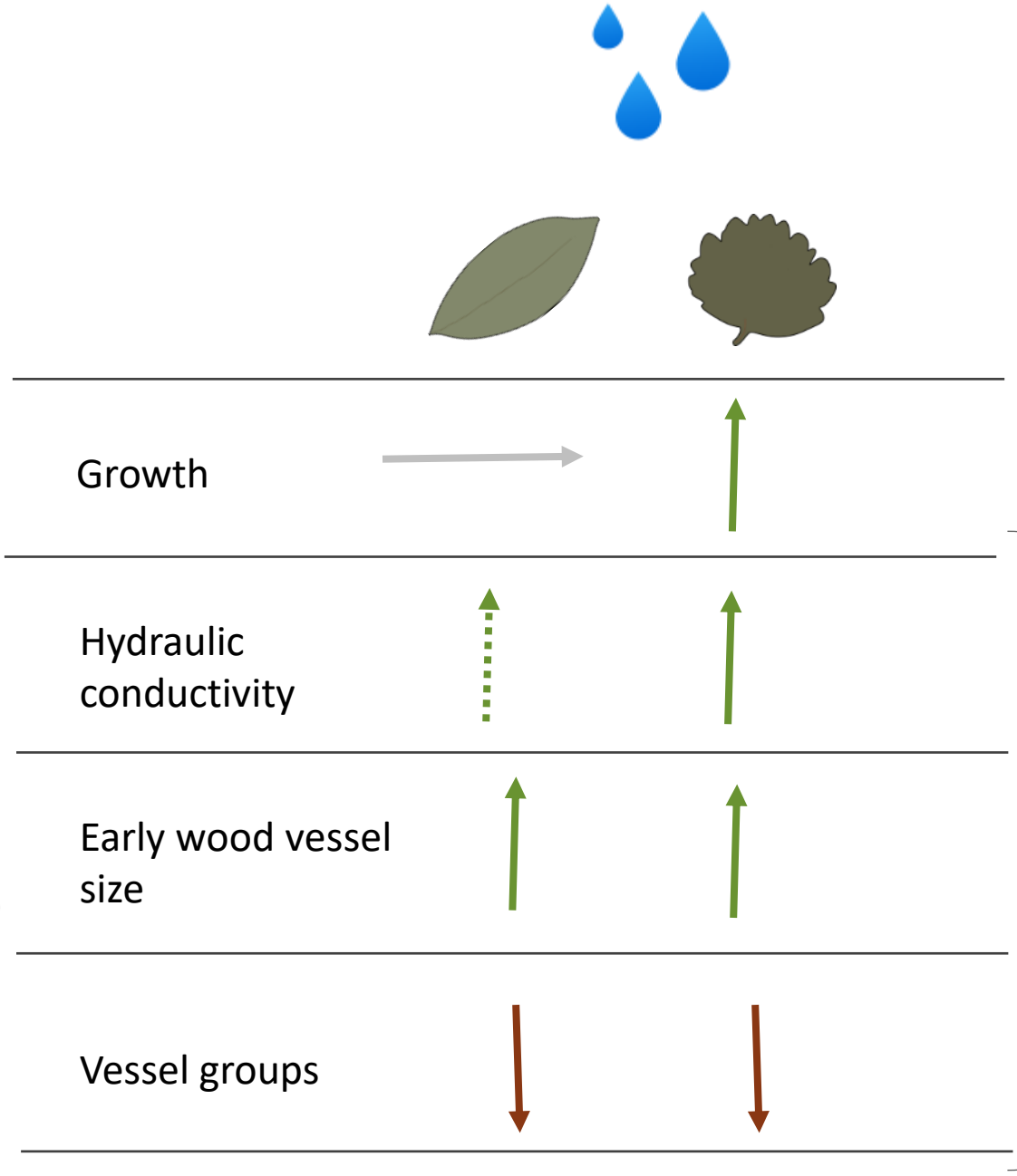


Birch growth more moisture limited

Key Findings



Key Findings



Birch growth more moisture limited

Anatomy optimized for survival depending on site characteristics

Larger groups in the dry site to prevent drought damage

Conclusions

- We found no effect of the snow treatment in our experiment
- We found interspecific differences in responses between the wet and dry sites
- Notably, while S. glauca growth did not differ, anatomical traits did

Summary & Implications

- Intra and interspecific xylem adjustments, **in relation to moisture**, may play a key role in driving within- and between-site heterogeneity
- Factors driving shrub changes are complex and can differ between and within sites – highlighting importance of **species- and site- specific analyses**
- Quantitative wood anatomy can reveal differences not detectable by growth alone – highlighting the importance of **multi-proxy analyses**

Summary & Implications

- Combining dendroecology and dendroanatomy can reveal past and current vegetation changes **across scales**
- These insights can help **improve predictions** of future ecological change

Photo: Oliver Baines

Understanding large-scale patterns….

Photo: Signe Normand

…requires a deeper **understanding of the small-scale processes driving them.**

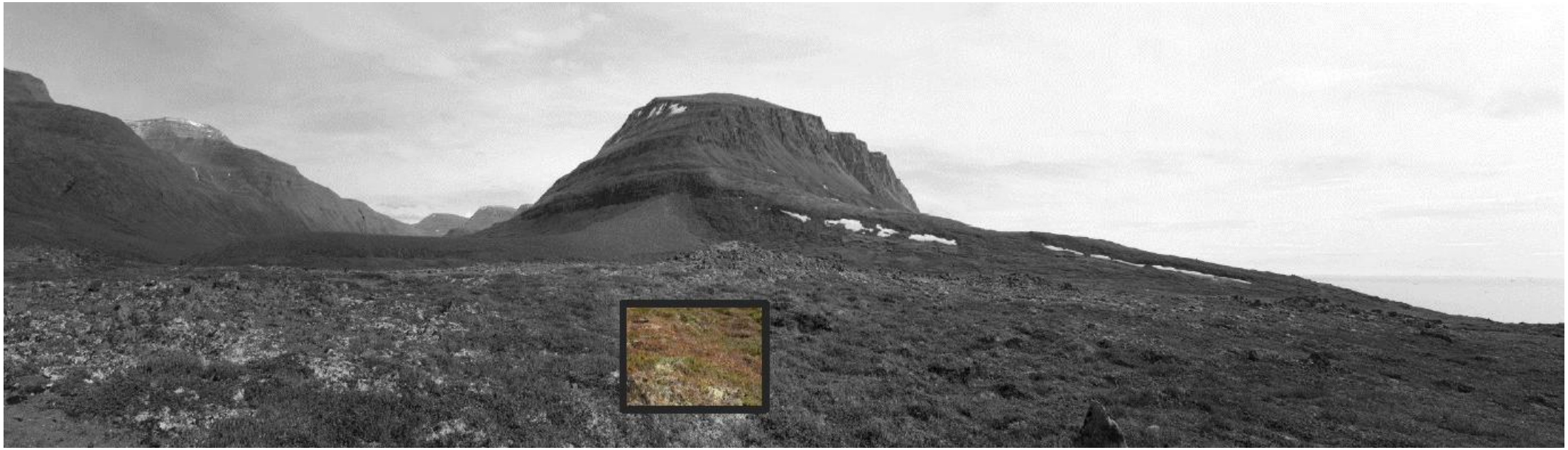


Photo: Signe Normand

Thank you!

Photo by Jonathan von Oppen

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