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# Towards a transdisciplinary framework for studying the DYNAMICS OF WOODY ALPINE VEGETATION in a WARMING CLIMATE CONTEXT

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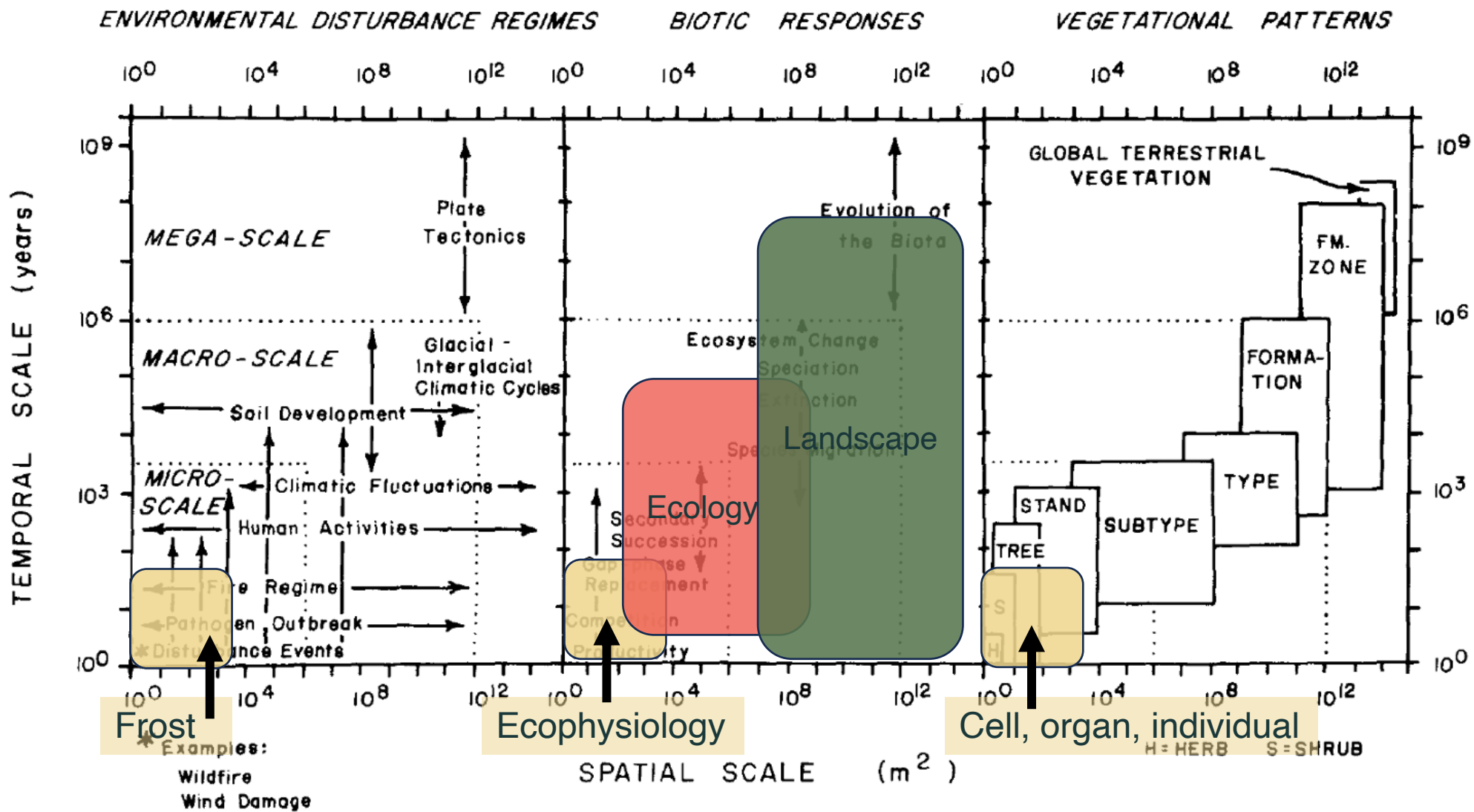
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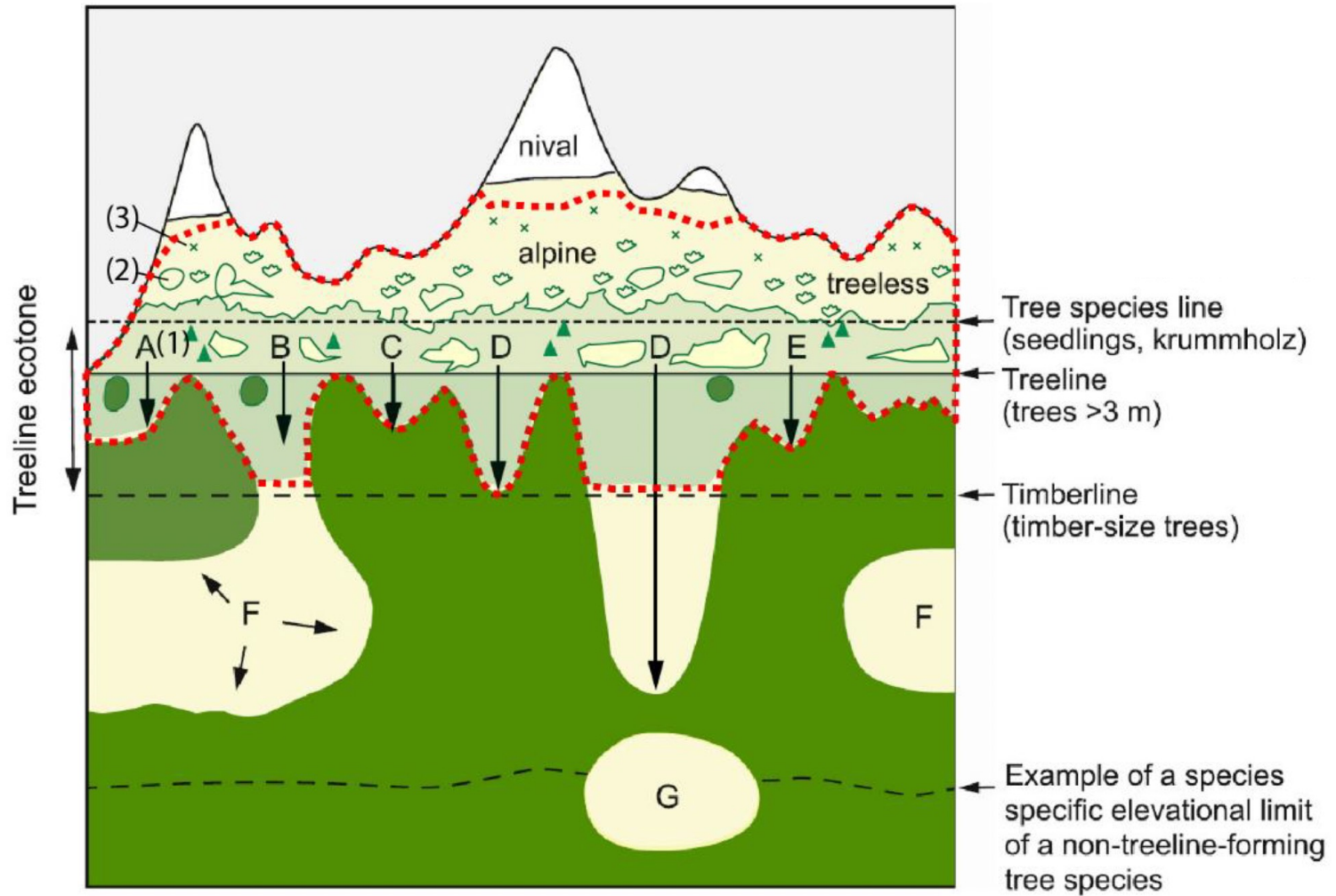
# Towards a transdisciplinary framework for studying the **DYNAMICS OF WOODY ALPINE VEGETATION** in a **WARMING CLIMATE CONTEXT**

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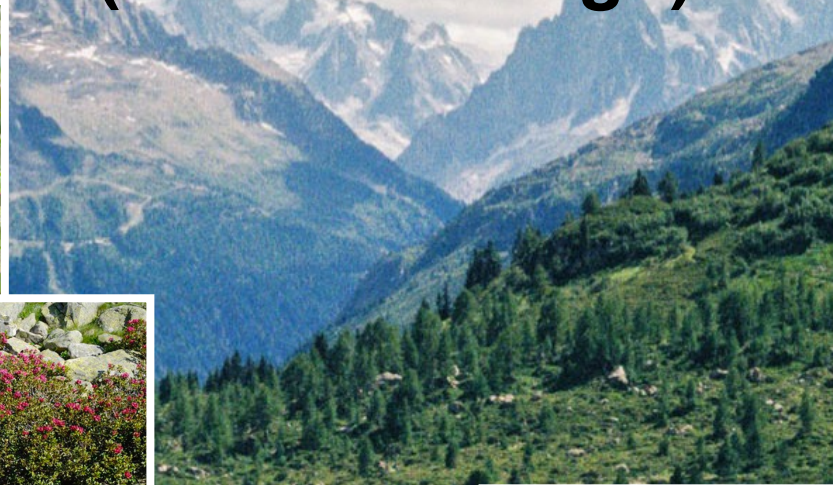
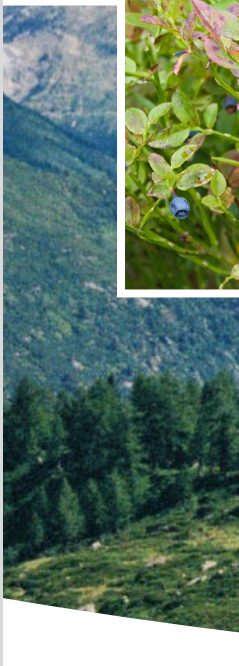
# INTRODUCTION



# The treeline ecotone and the alpine tundra



Woody plants in the  
alpine zone: TREE  
SPECIES INDIVIDUALS  
and SHRUBS  
( $< 3$  meters high)



# The treeline ecotone and the alpine tundra



Mont-Blanc, France



Valais, Switzerland

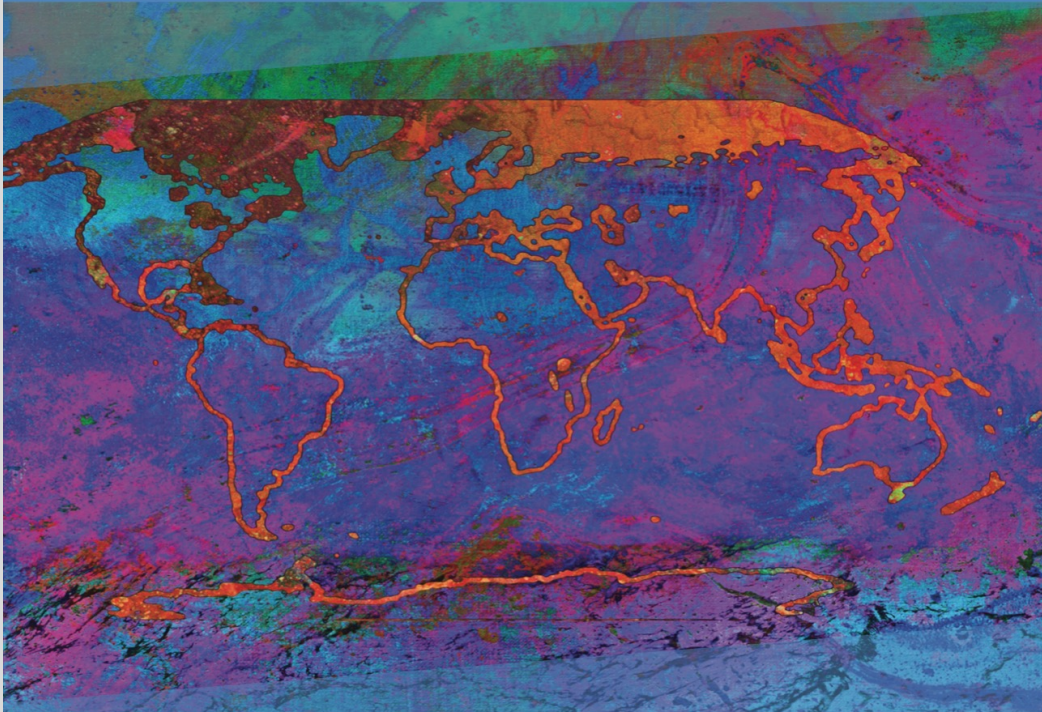
# The treeline ecotone and the alpine tundra



Oisans, France

# Climate Change 2021

## The Physical Science Basis



# CLIMATE CHANGE

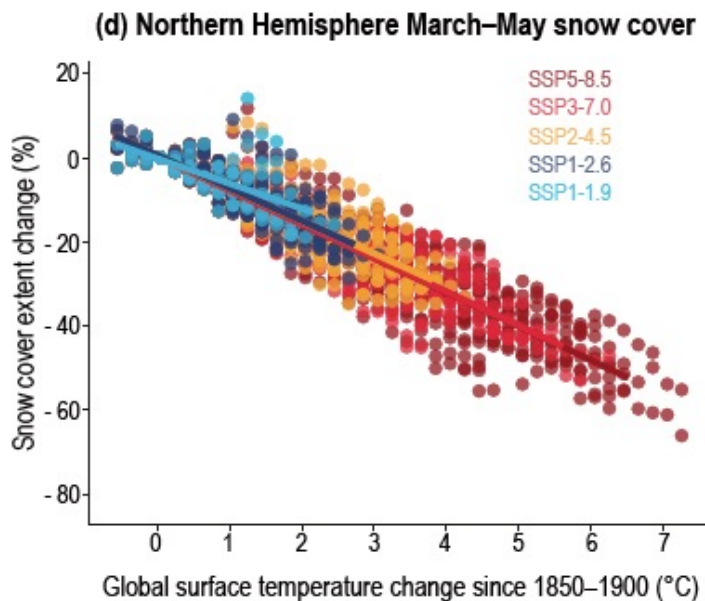
“Global surface temperatures are more likely than not **unprecedented in the past 125,000 years**”

“Over the last 50 years, **global temperature has increased at a rate unprecedented** in at least the last 2000 years”

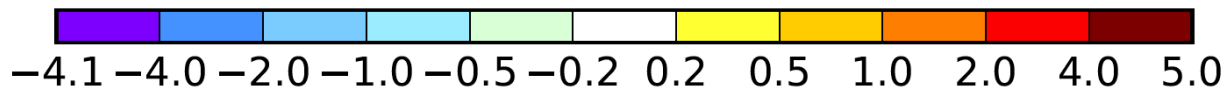
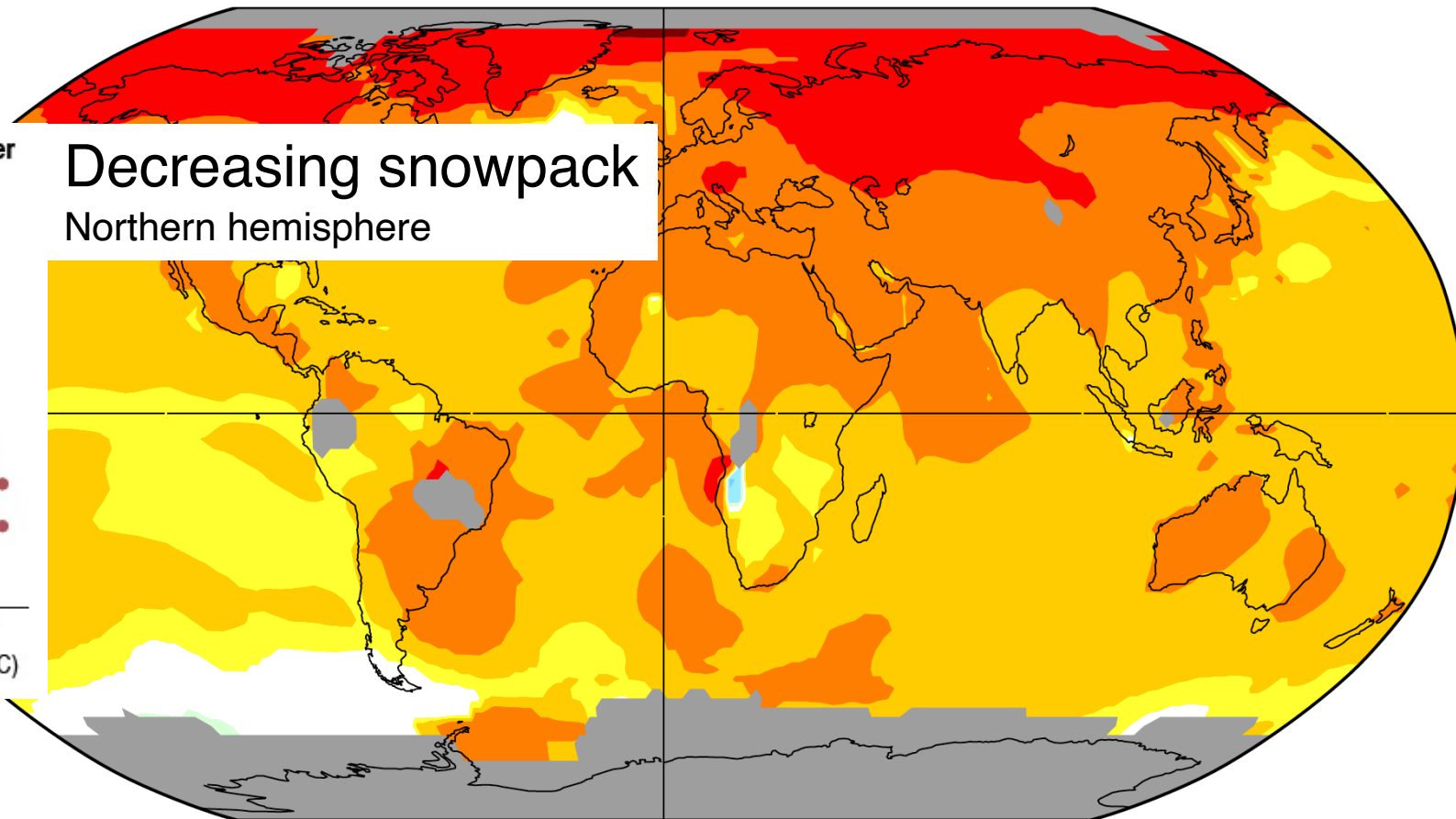


# CLIMATE CHANGE IN TUNDRA ECOSYSTEMS

Global temperature increase (2001-2020)  
(vs 1881-1910)



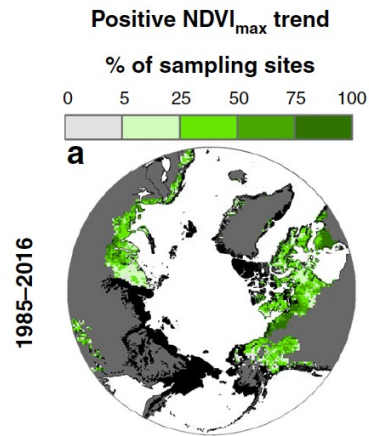
Decreasing snowpack  
Northern hemisphere



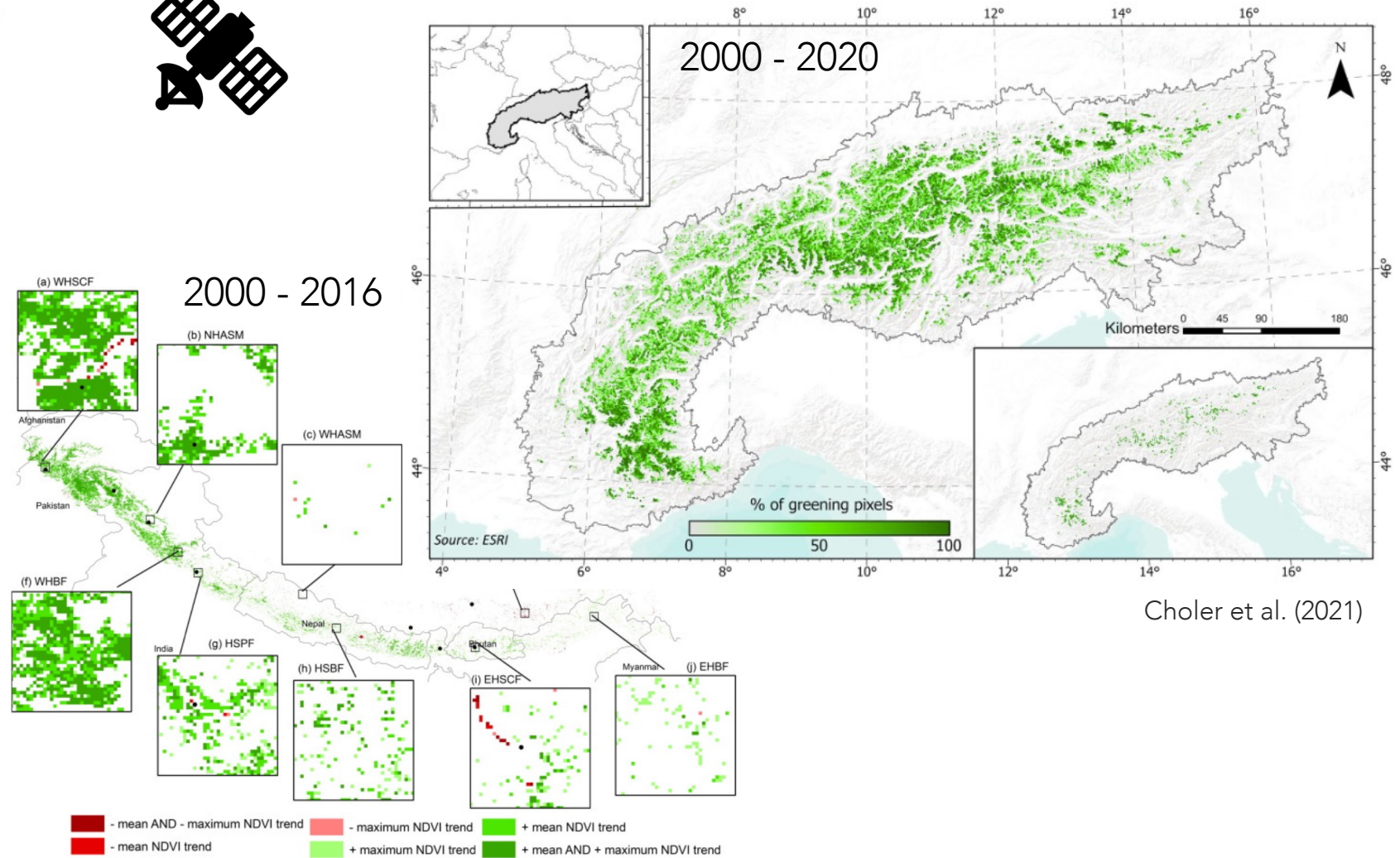
- ✓ +1.2°C in average
- ✓ +2.5°C in the Alps
- ✓ At least +4°C in the Arctic

# VEGETATION GREENING

## ECOSYSTEM RESPONSE: VEGETATION GREENING



Berner et al. (2021)



Choler et al. (2021)

Mishra and Mainali (2017)

However:

Greening is widespread but not uniform: “Sparsely vegetated ecosystems on north-facing slopes and experiencing prolonged snow cover duration are the most highly responsive to ongoing warming” Choler et al. (2021)

About remote sensing methods: “measured reflectances and derived indices and trends are subject to biases” Bayle et al. (2024)

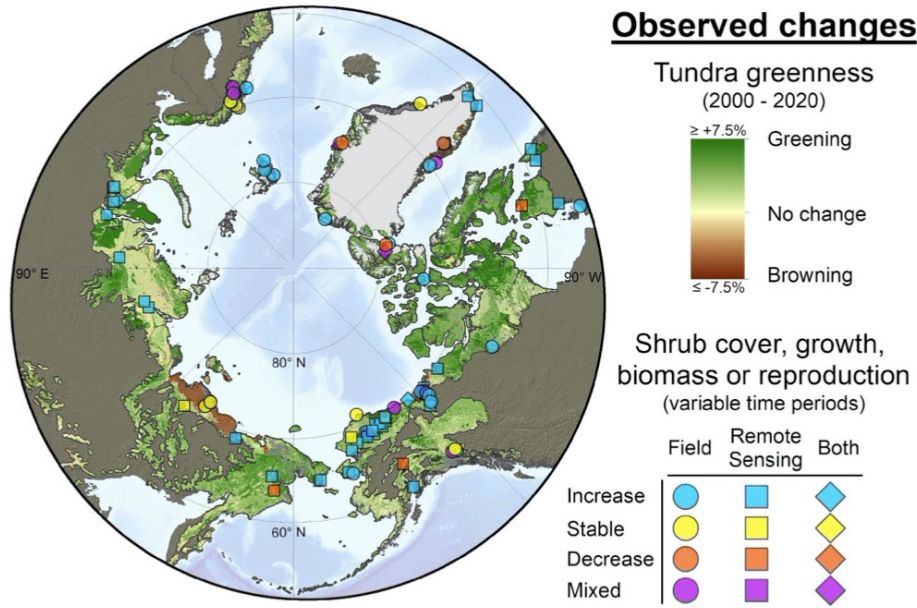
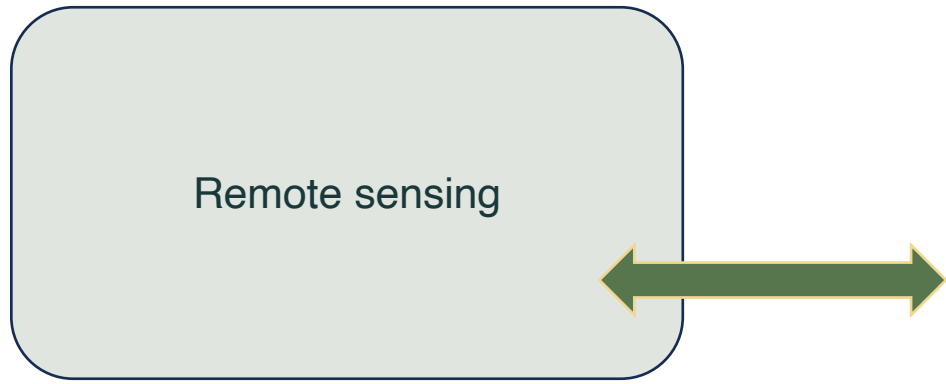
The ecophysiological processes underlying alpine greening have rarely been investigated

→ Especially in complex mountains terrains

remotely sensed vegetation indices are subject to biases and need validation from the ground

In the Arctic, the **increasing woody vegetation cover** is the main driver of greening

# VEGETATION GREENING



Mekonnen et al., (2021)

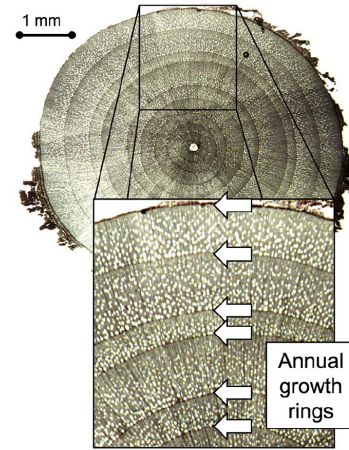
Dendroecology

Archives:  
phytosociological relevés,  
photos, other doc...

Ecophysiology:  
Dendrometry

**Not existing or very rare**

a) Annual growth rings in *Salix alaxensis*



Myers-Smith et al., (2015)



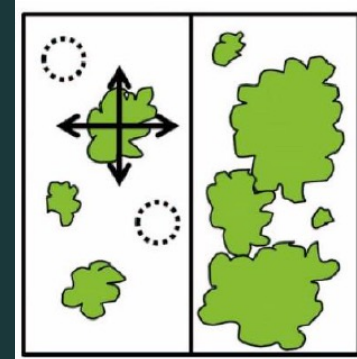
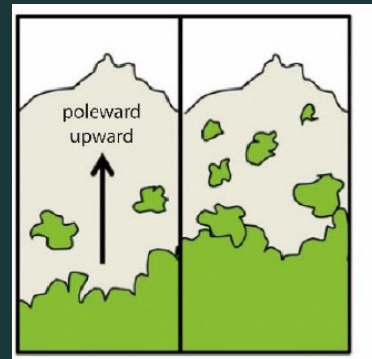
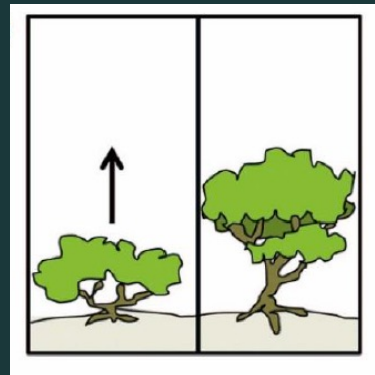
Tape et al., (2006)

In the Arctic, the increasing woody vegetation cover is the main driver of greening

**Such observations remain  
lacking in mountain regions**

This overall **trend towards greenness** should be reflected in the landscape through **landscape changes** linked to **woody vegetation dynamics** and **ecophysiological processes** at different **temporal and spatial scales**:

Increasing **radial growth**, increasing **canopy height**, increasing **number of individuals**, increasing **patchiness** and shifting **treeline** and **shrubline**



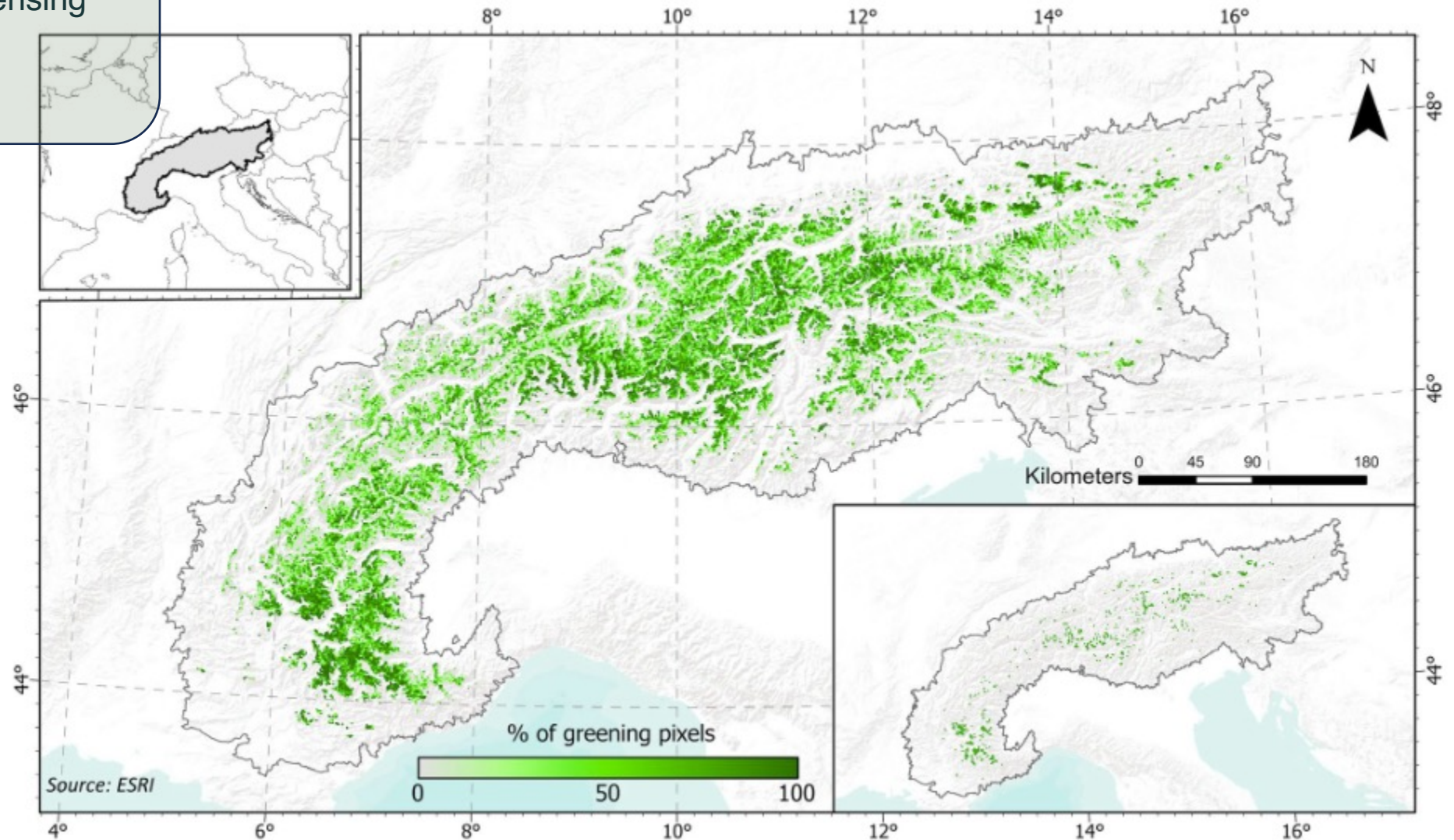
In order to quantify the response of **woody vegetation to climate change** and its **spatial and temporal dynamics** across mountain ranges, we call for a **transdisciplinary approach combining the four compartments.**





# The greening in the European Alps

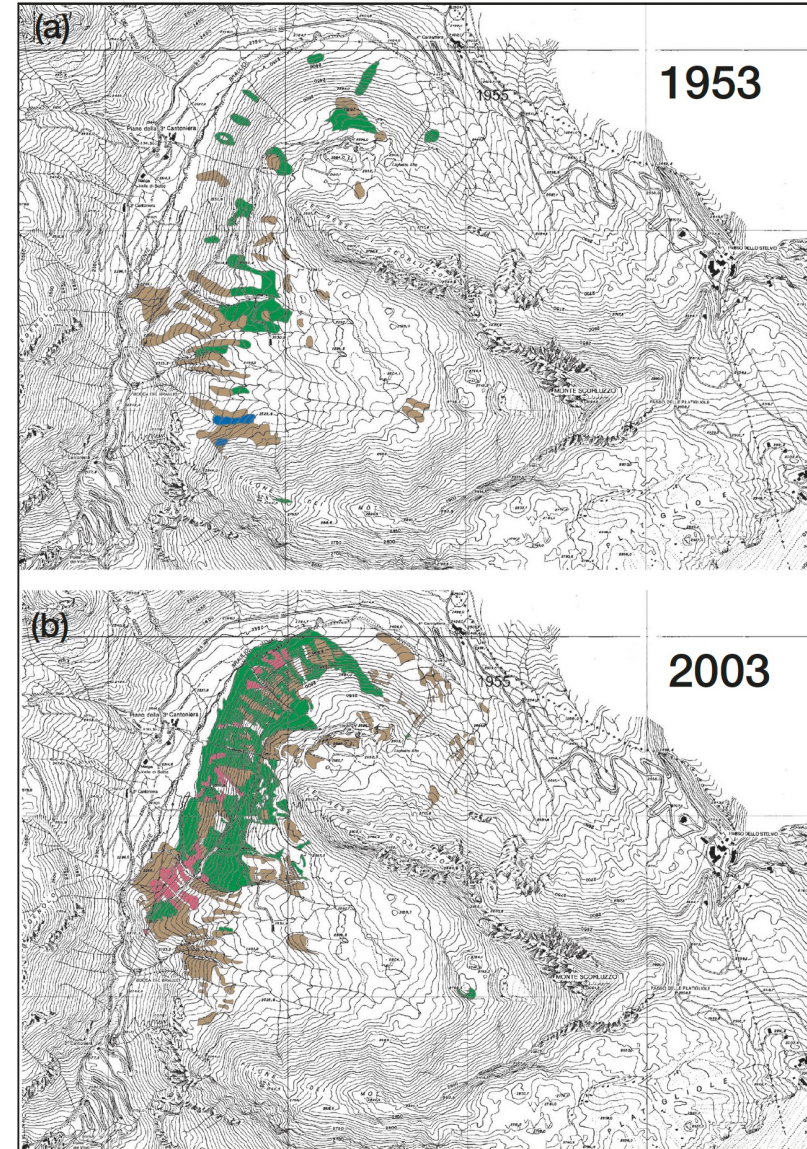
Remote sensing



Archives:  
phytosociological relevés,  
photos, other doc...

Example: The use of  
historical phytosociological  
maps allows to compare with  
current state of vegetation

# The input of past archives



Dendroecology

# The input of dendroecology

*Rhododendron ferrugineum*



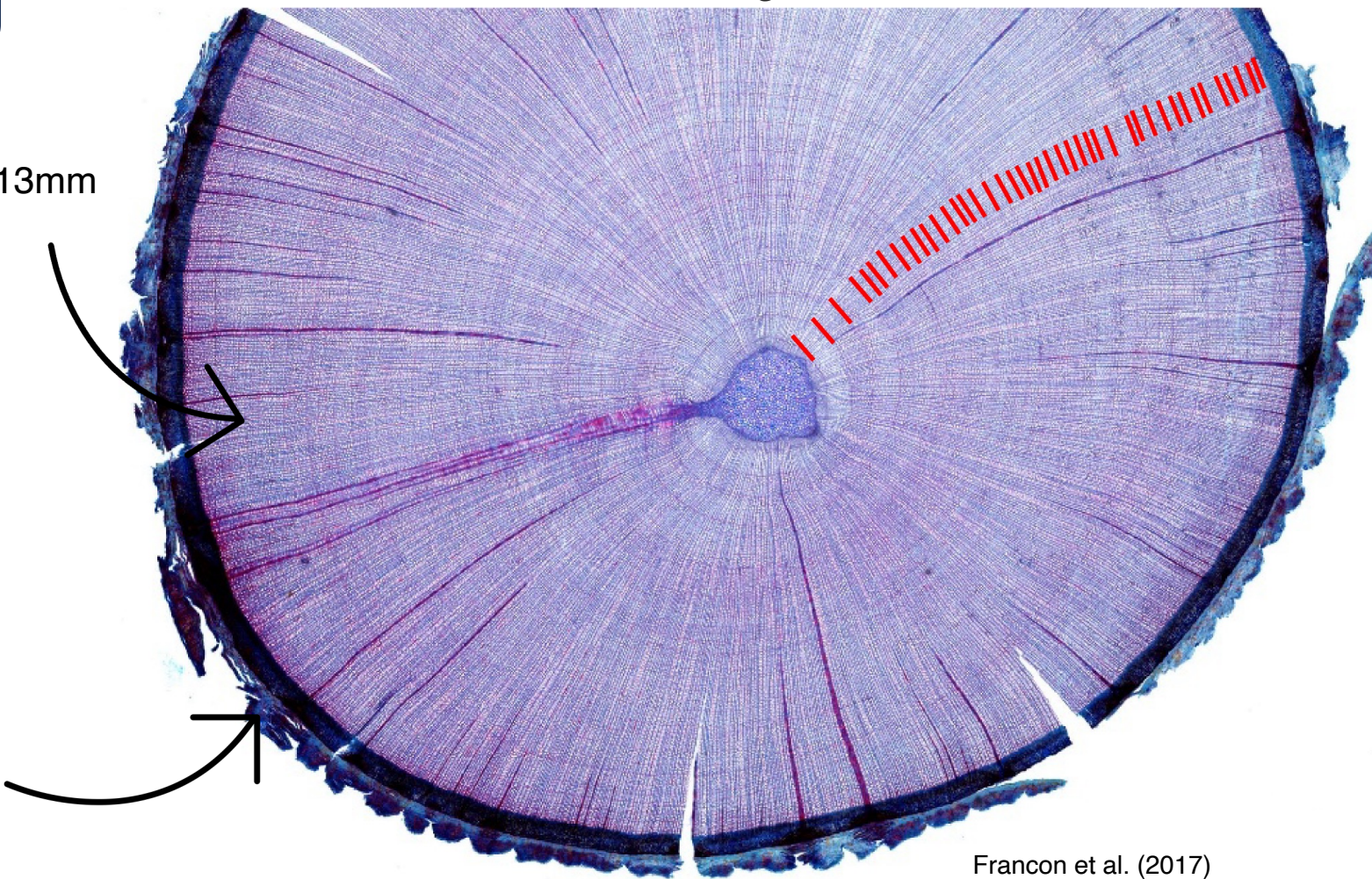
# EXAMPLE: THE EUROPEAN ALPS

Dendroecology

*Rhododendron ferrugineum*

Mean ring width = 0.13mm

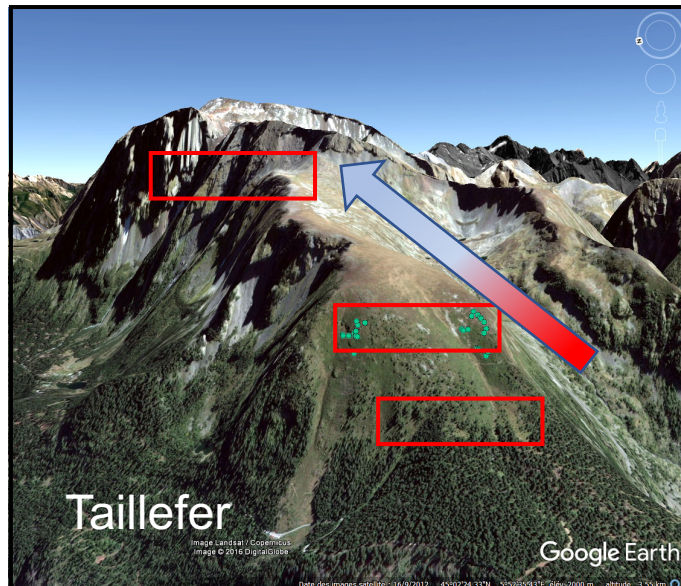
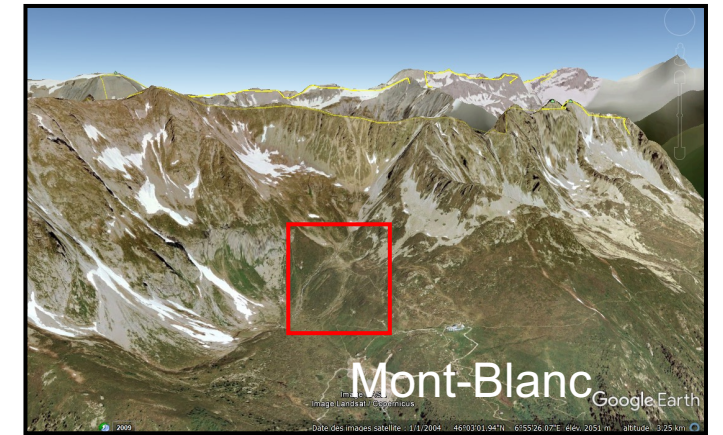
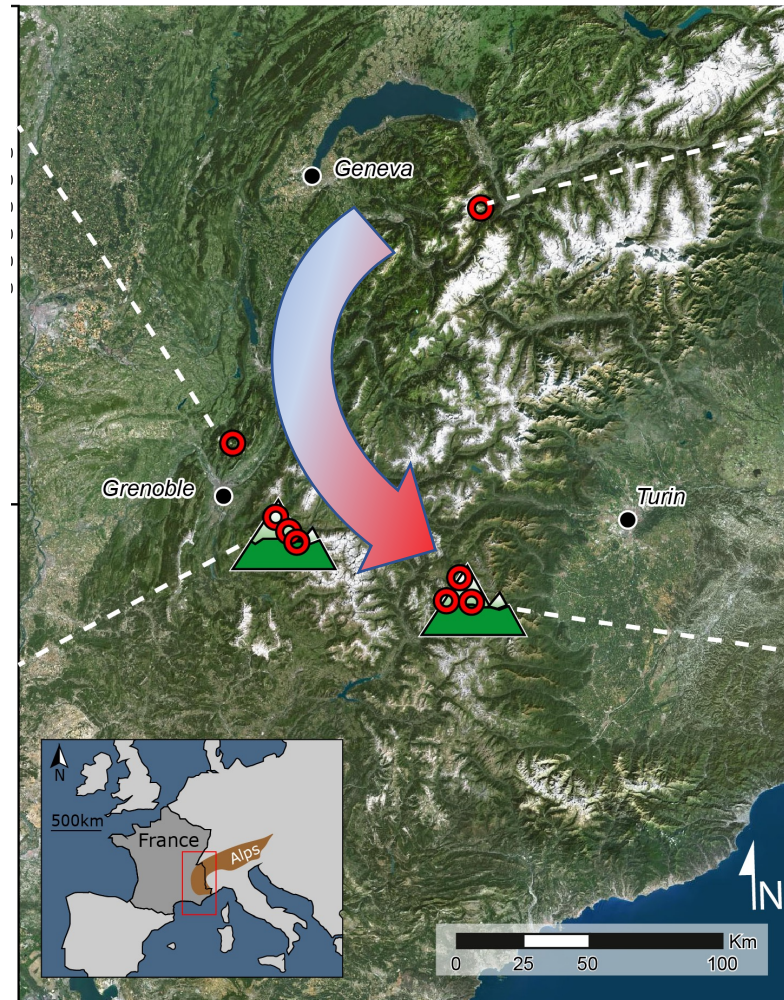
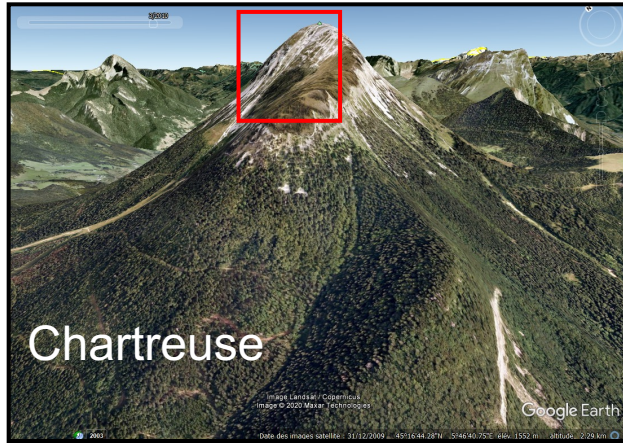
Maximal age: 215 years



1 cm

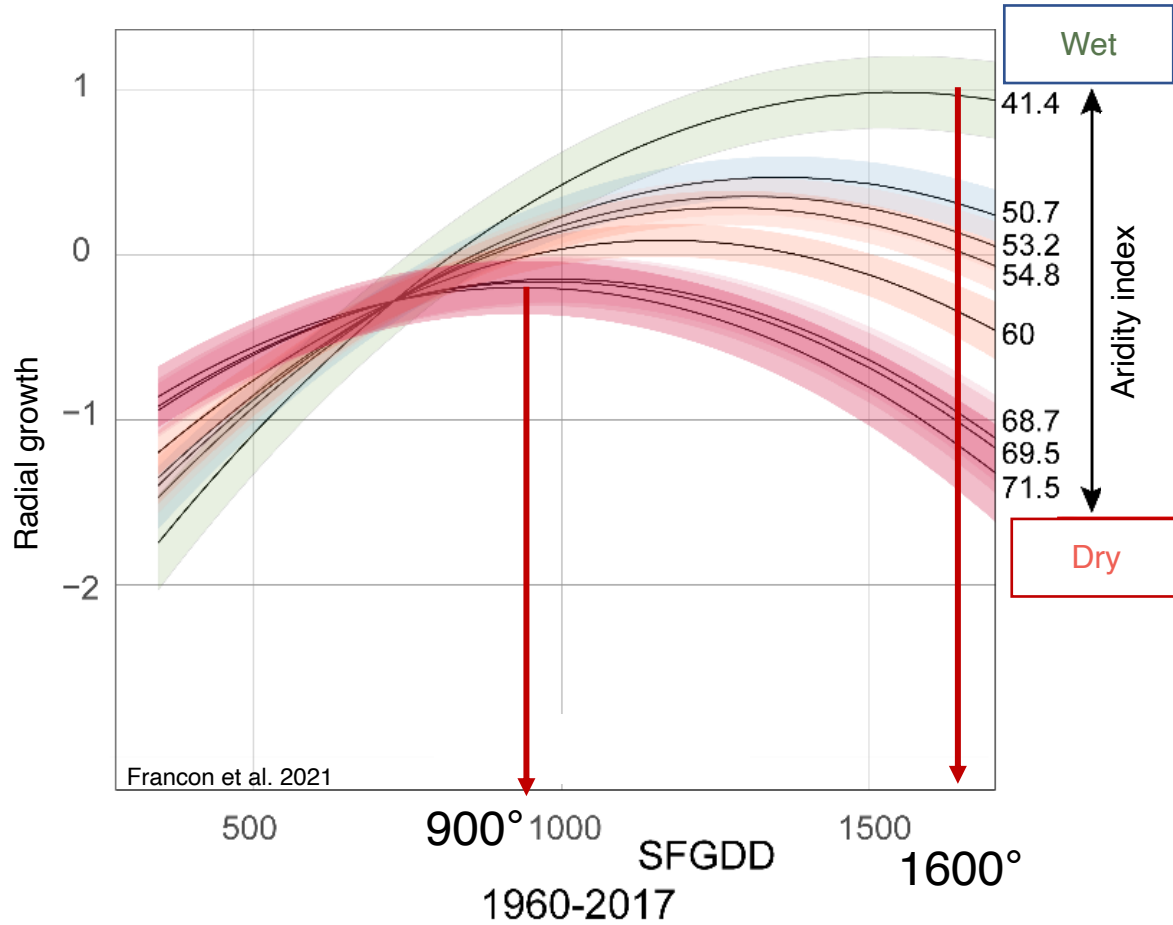
Francon et al. (2017)

# 8 sites-network designed to be representative of the topographic and climatic contrasts across the French Alps

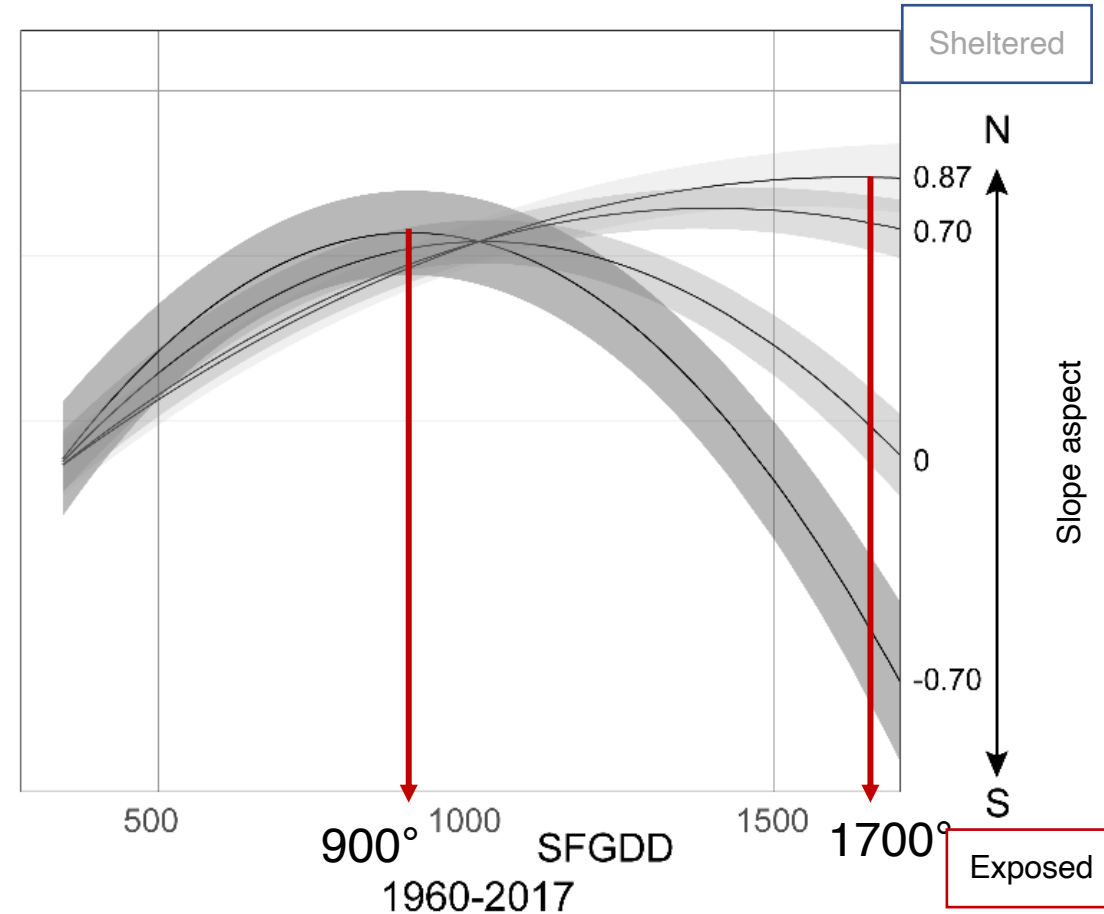


# SHRUBS CLIMATE SENSITIVITY (1960-2017)

Inner vs. outer Alps



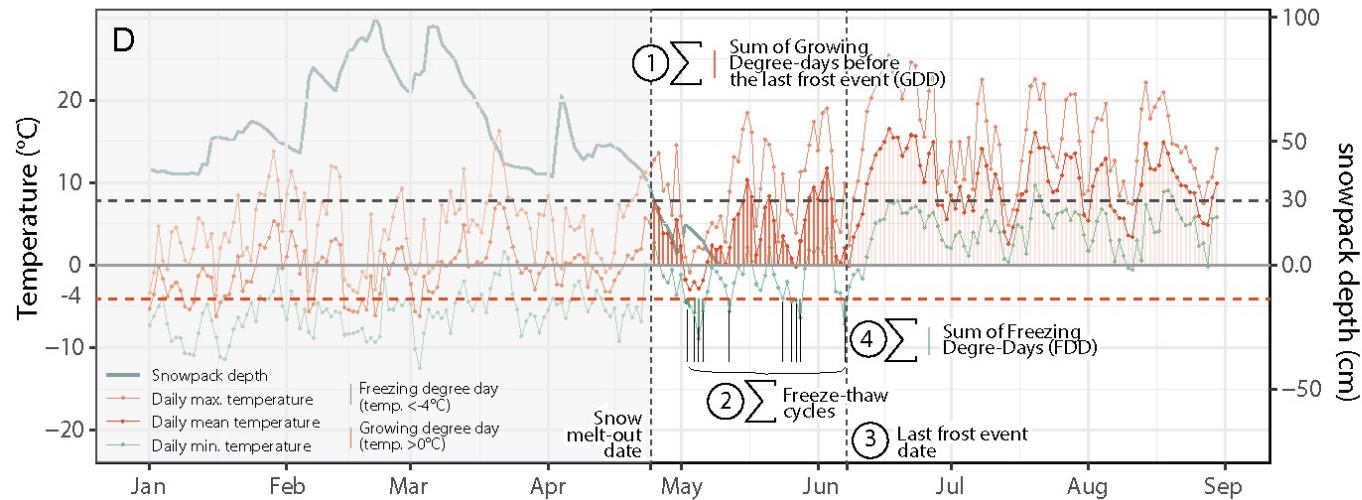
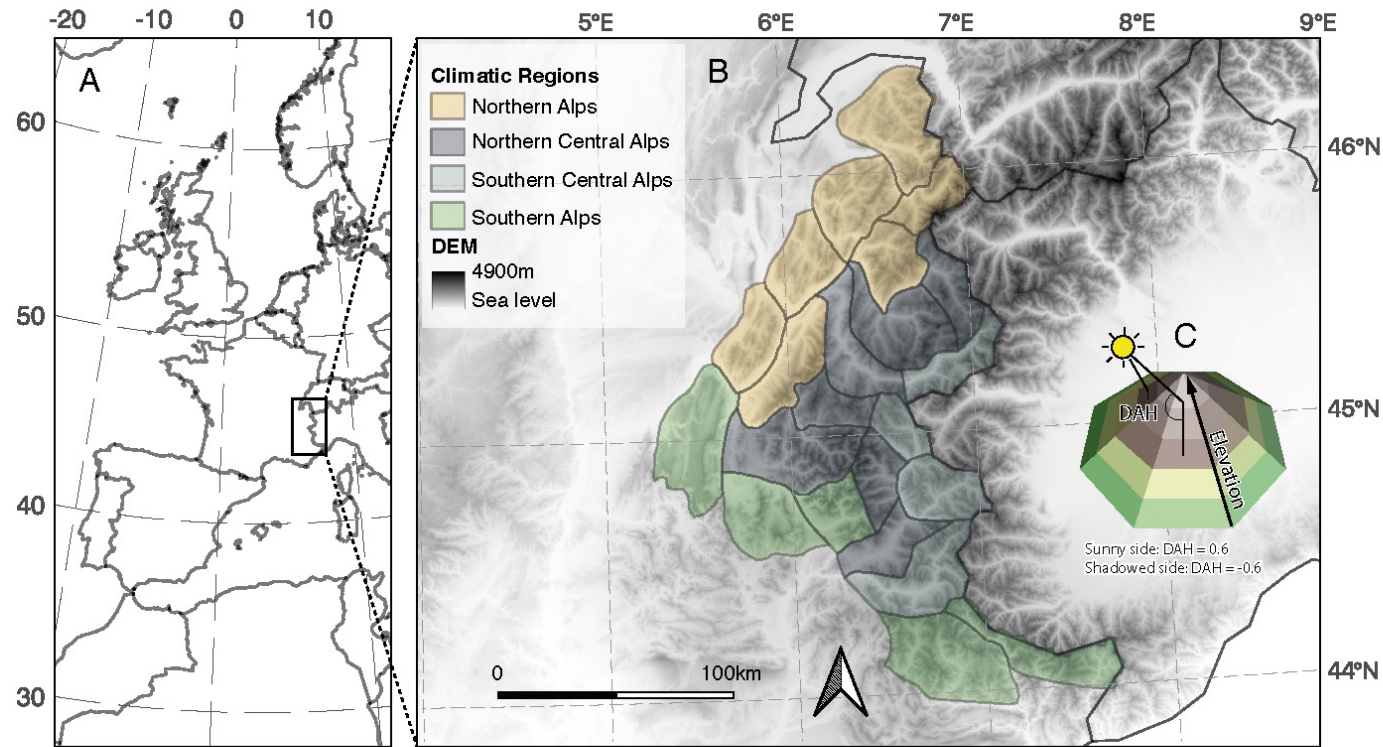
South vs. North slopes



Drought and frost effects

Francon et al. (2021)

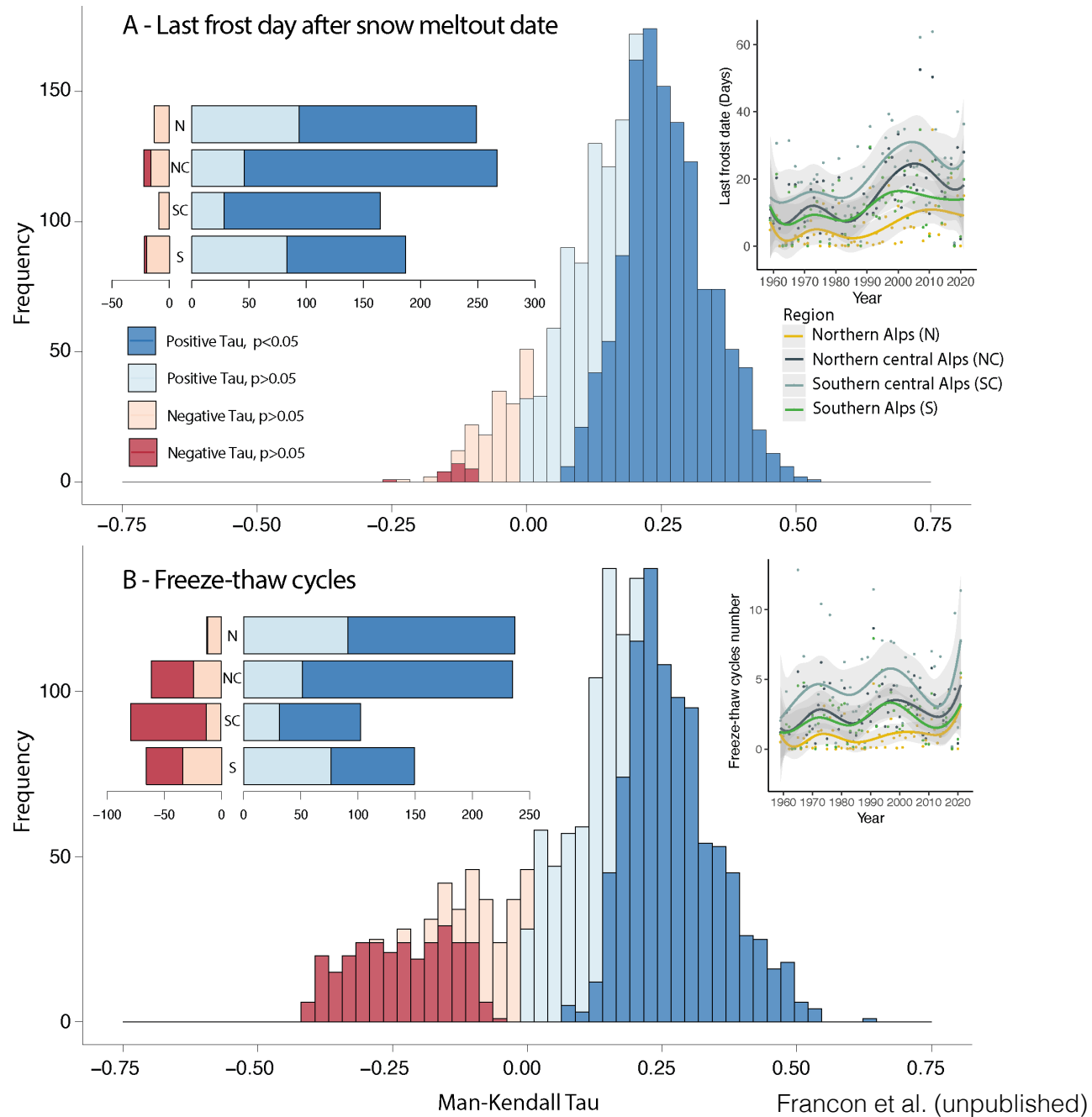
# EXAMPLE: THE EUROPEAN ALPS



Francon et al. (unpublished)

We calculate various **frost indices** for low stature vegetation, using **snowpack** and **temperature** data for the entire French Alps

# EXAMPLE: THE EUROPEAN ALPS



**Frost exposure risk** is increasing for low stature vegetation, **in most locations** within the French Alps



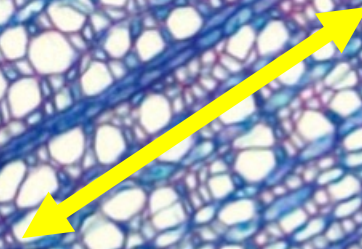
# LIMITATIONS

**Growth ring width**  
**=**  
**Black box**

- One value per year
- Integrating stressful events (frost, heat waves)

WE NEED ECOPHYSIOLOGICAL DATA

RWI



Ecophysiology:  
Dendrometry

# Hourly monitoring of diameter variations: water status and irreversible growth

Phase 1. Transpiration → (yellow) shrinkage

Phase 2. Rehydration → (orange) expansion

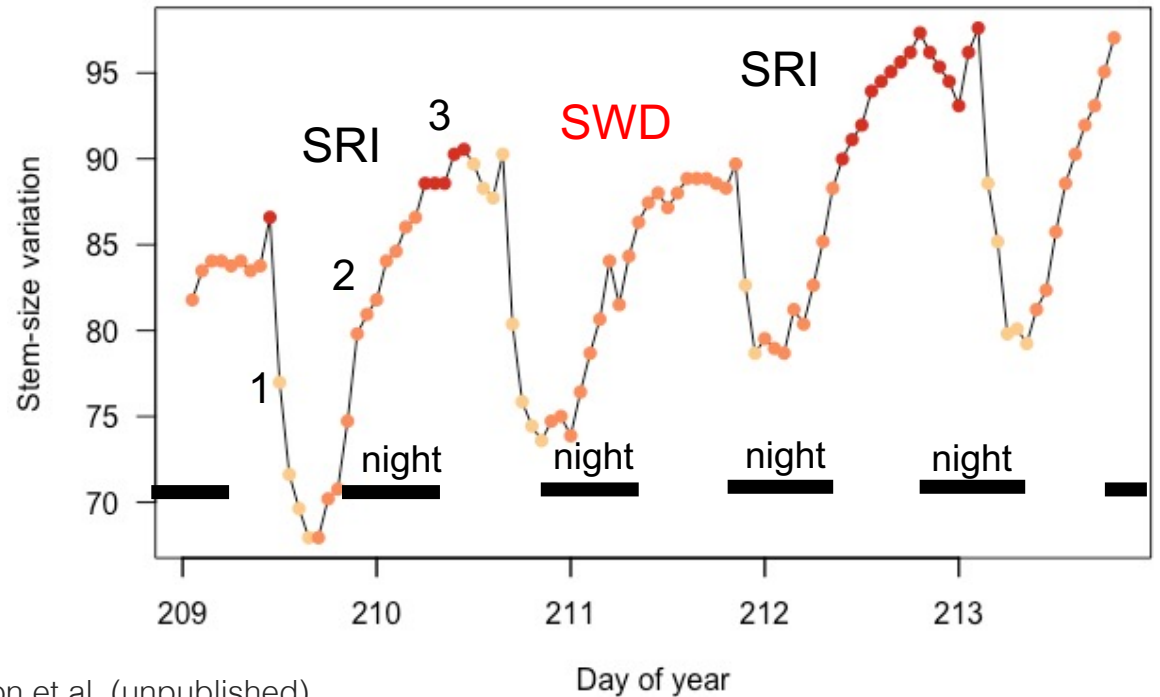
Phase 3. Growth → (red) Stem Radius Increment (SRI)

Stem Water Deficit (SWD) → stress



Francon

Sensor rhodo Bassies S152

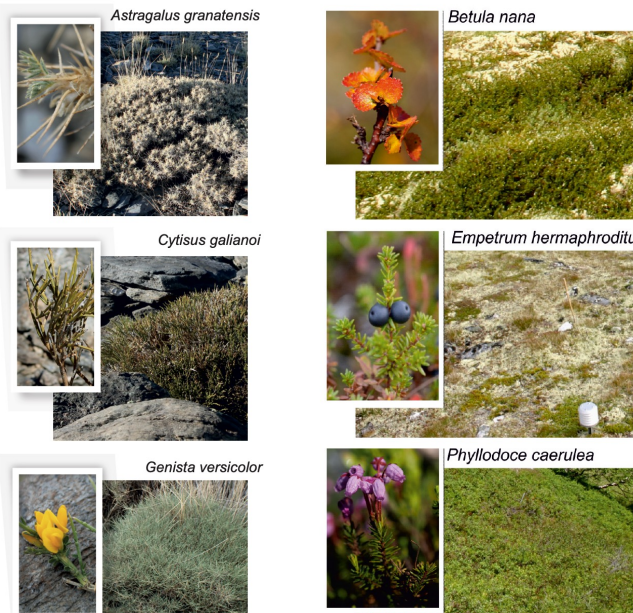


Francon et al. (unpublished)

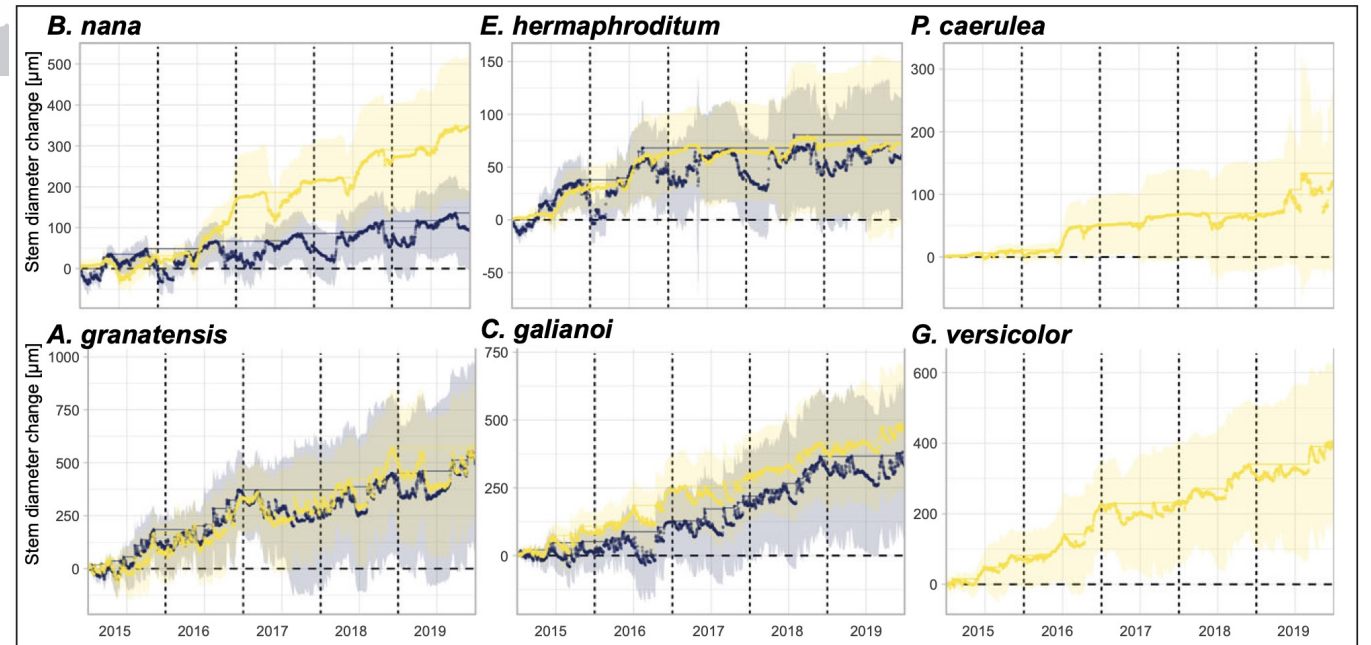
# EXAMPLE: THE EUROPEAN ALPS



Francon

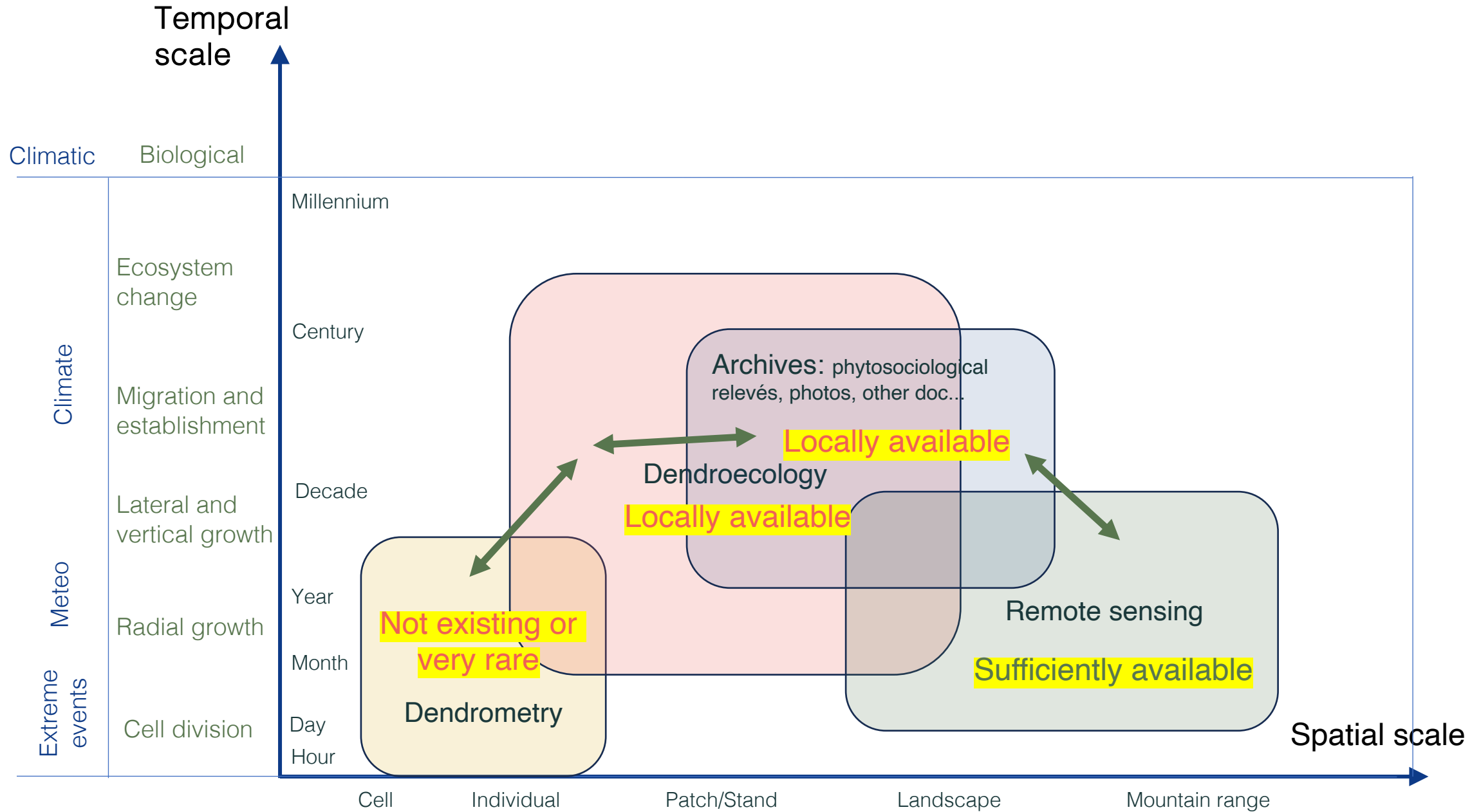


Löffler et al. (2022)

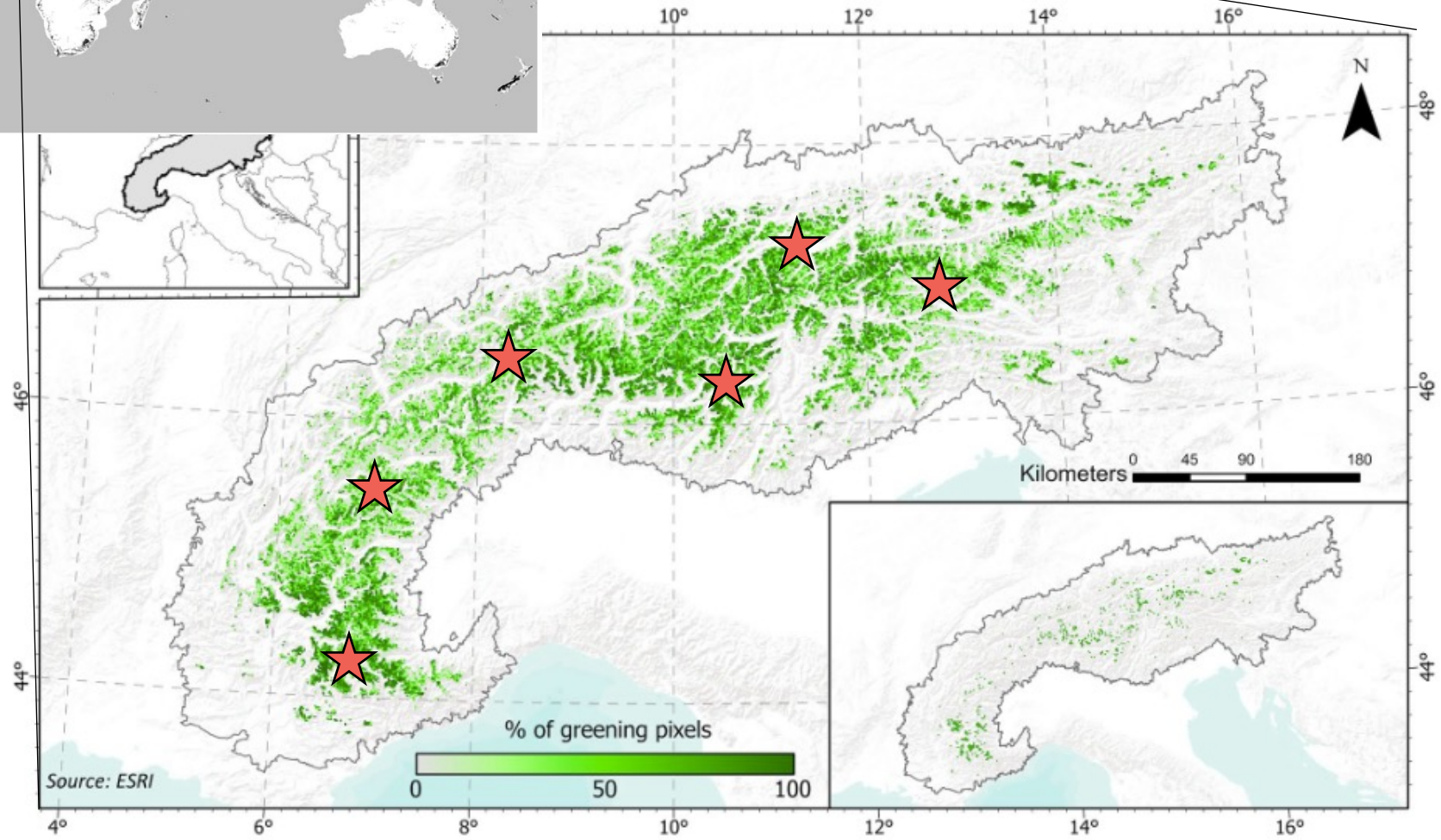
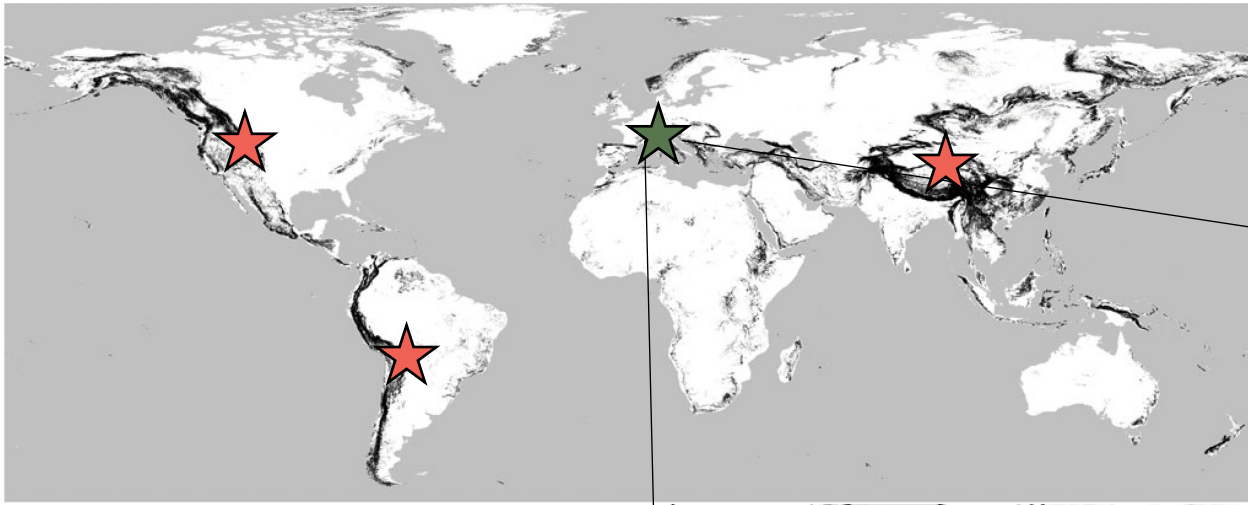


Dobbert et al. (2022)

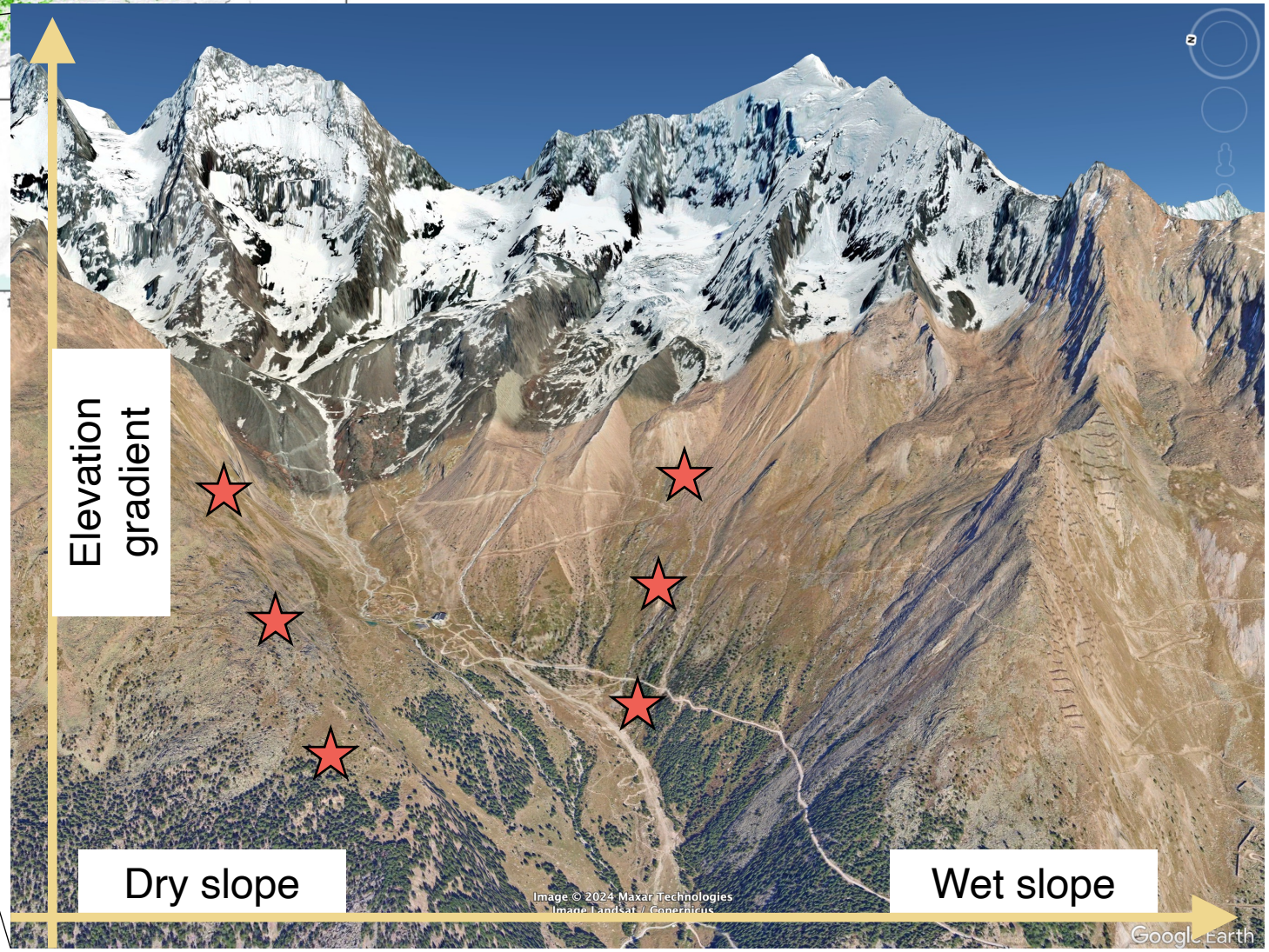
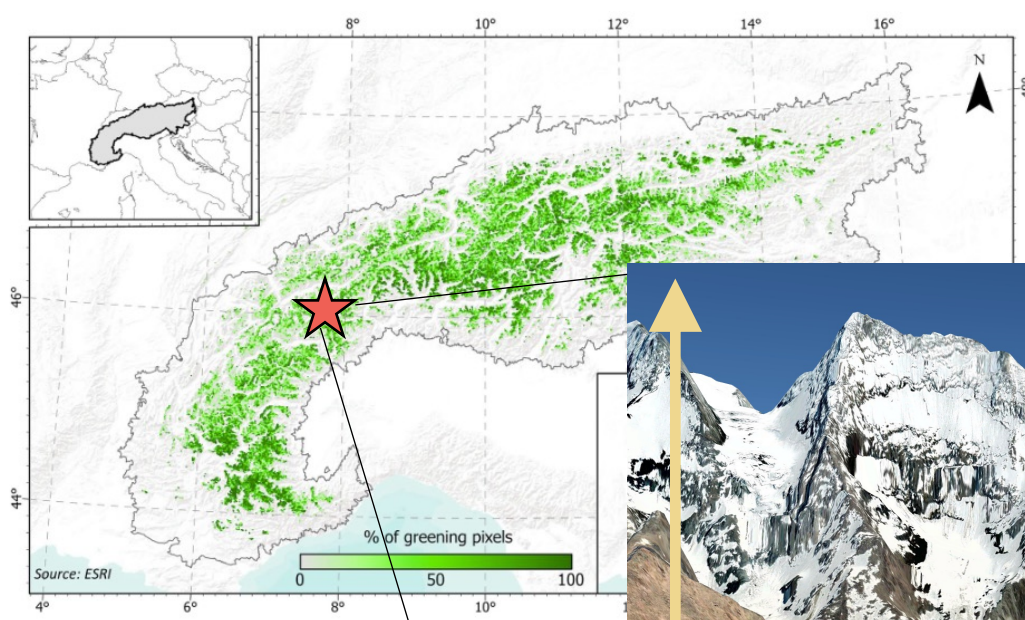
# NEW FRAMEWORK



# NEW FRAMEWORK



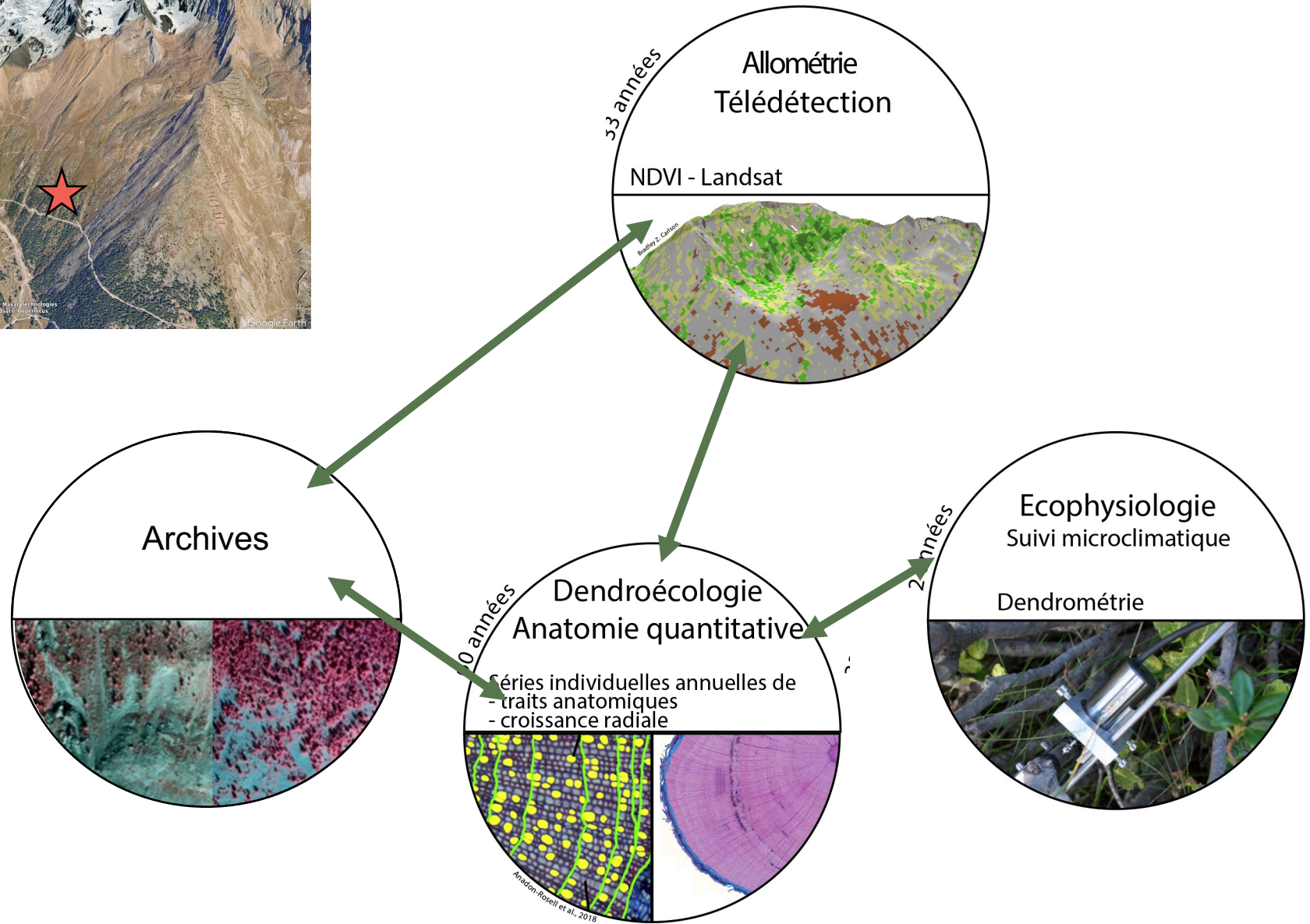
# NEW FRAMEWORK



## In each plot:

- ✓ Extraction of **vegetation indices** (greening or browning trend?)
- ✓ Research of **historical archives** (aerial images, photographs, vegetation surveys)
- ✓ Reconstruction of **trees and shrubs recruitment** using establishment and death dating
- ✓ Extraction of **dendroecological signal**
- ✓ **Dendrometers** → effect of short term climatic trends and **frost/drought**
- ✓ ...

# NEW FRAMEWORK





In order to understand trajectories of alpine landscapes on a global scale, research efforts need to be continued in the field of:

- ✓ Remote sensing studies in different mountain regions (still lacking in many areas)
- ✓ Dendroecological studies, (still lacking for many shrub species)
- ✓ Ecophysiology of shrubs, and response to extreme frost/drought events

However, the exact drivers of landscape greening are largely unknown

- ✓ **Complex topography in mountains** makes it difficult (compared to the Arctic)
- ✓ We don't know much on **ecological processes** behind greening (or browning) trends
- ✓ The **physiological mechanisms** behind landscape or individual scale response to climate change **are largely unknown**

It is therefore urgently necessary to combine different approaches:

- ✓ To fully capture landscape trajectories in time and space
- ✓ To reveal the actual drivers of vegetation change
- ✓ To predict the ecosystem response to one of the most significant environmental changes of the last millennia (or millions of years?): the anthropogenic climate change



Thank you!

Christophe Corona  
Thierry Améglio  
Guillaume Charrier  
Katline Charra-Vaskou  
Philippe Choler  
Arthur Bayle  
Baptiste Nicoud  
Markus Stoffel  
Eike Albrecht  
Jörg Löffler

