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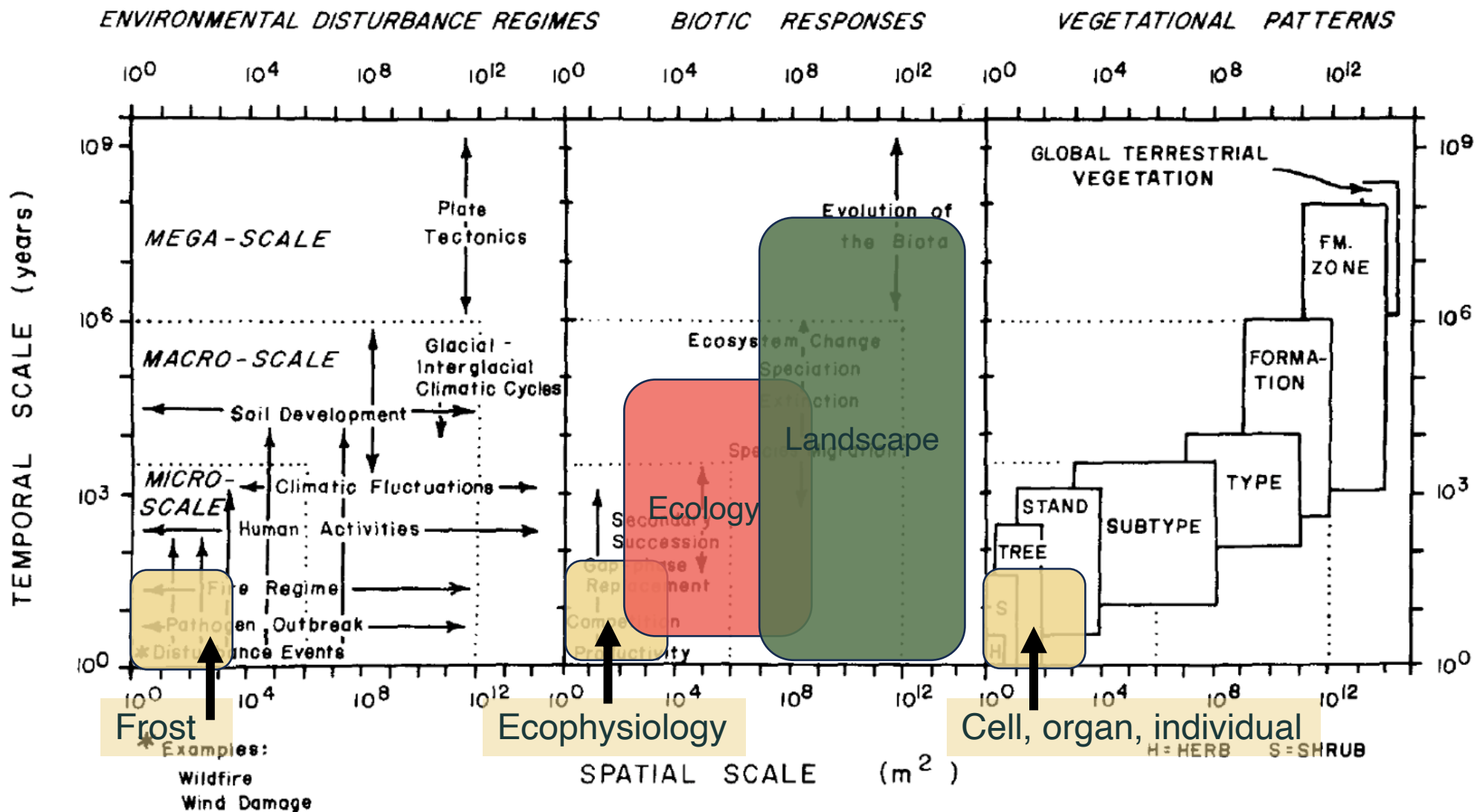
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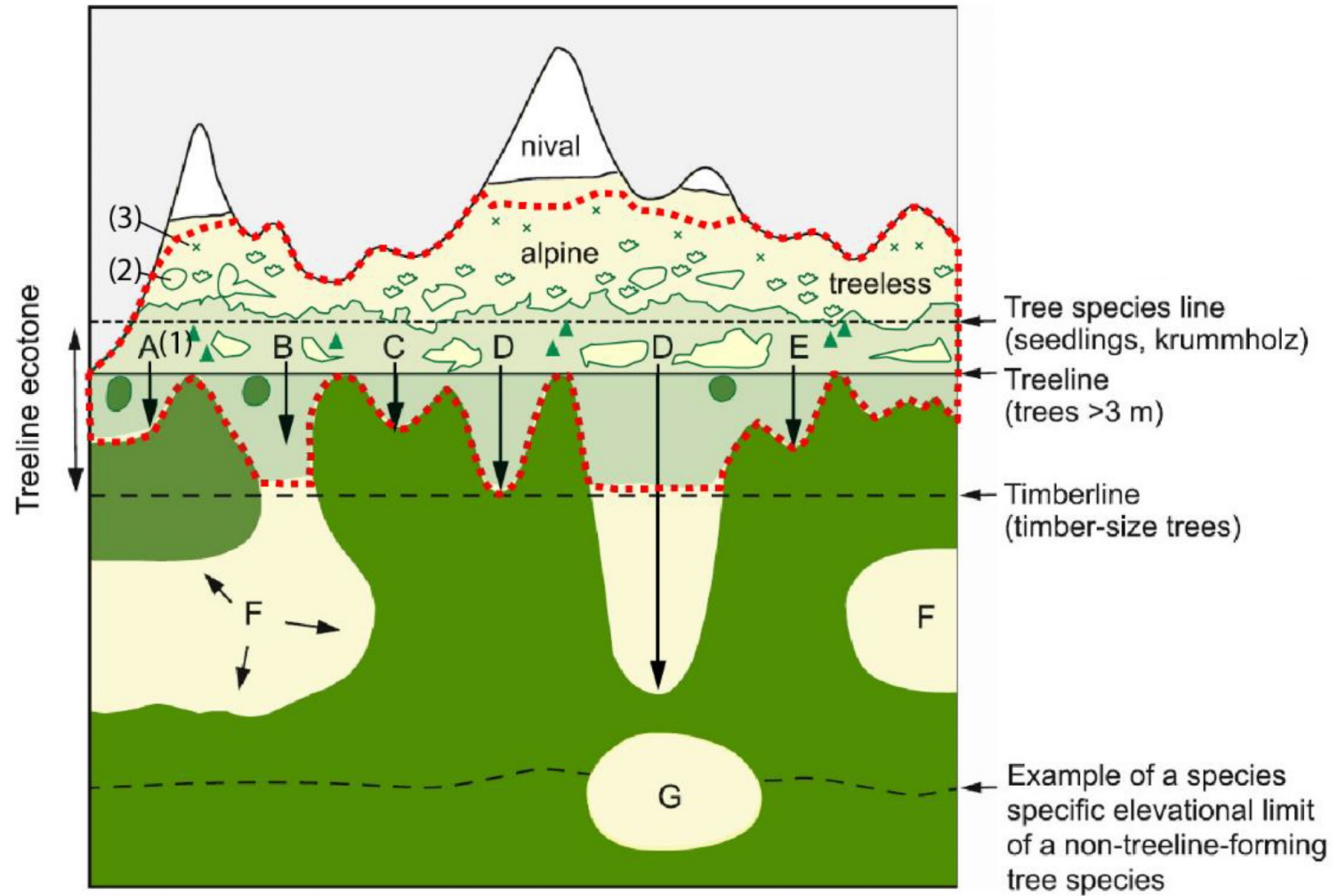
Towards a transdisciplinary framework for studying the **DYNAMICS OF WOODY ALPINE VEGETATION** in a **WARMING CLIMATE CONTEXT**

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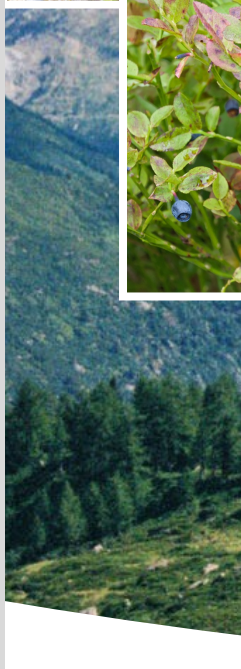
INTRODUCTION



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

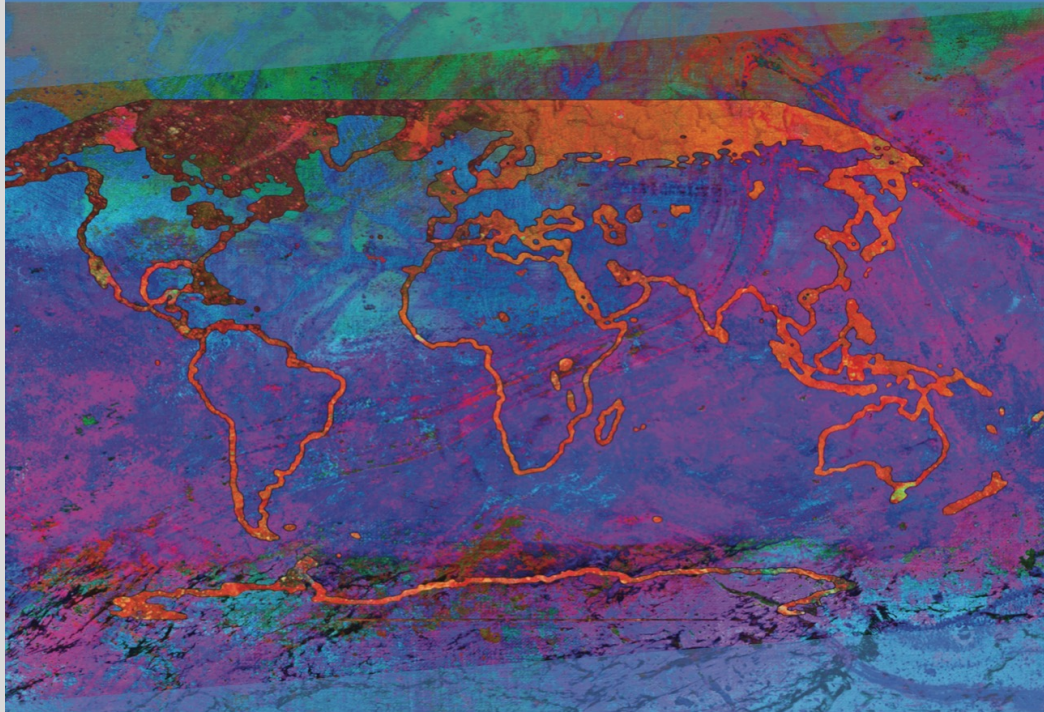
The treeline ecotone and the alpine tundra



Oisans, France

Climate Change 2021

The Physical Science Basis



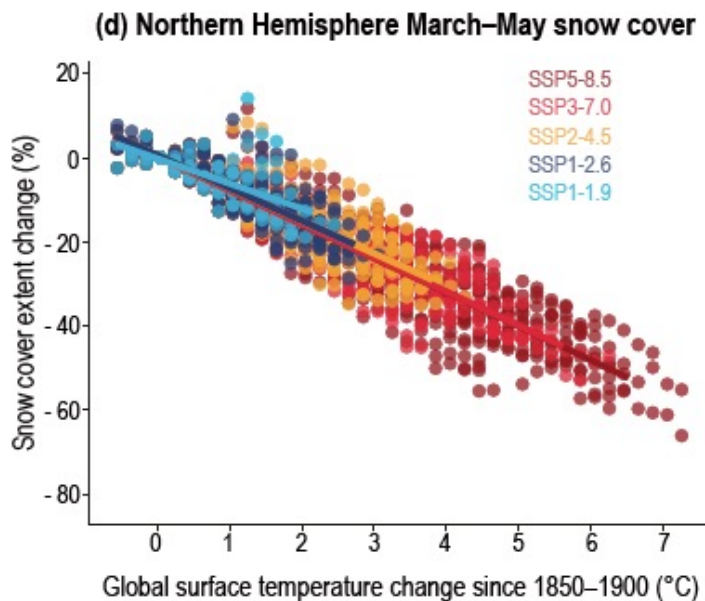
CLIMATE CHANGE

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

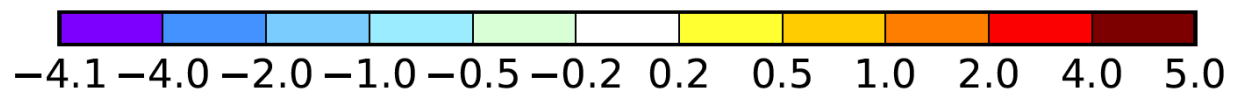
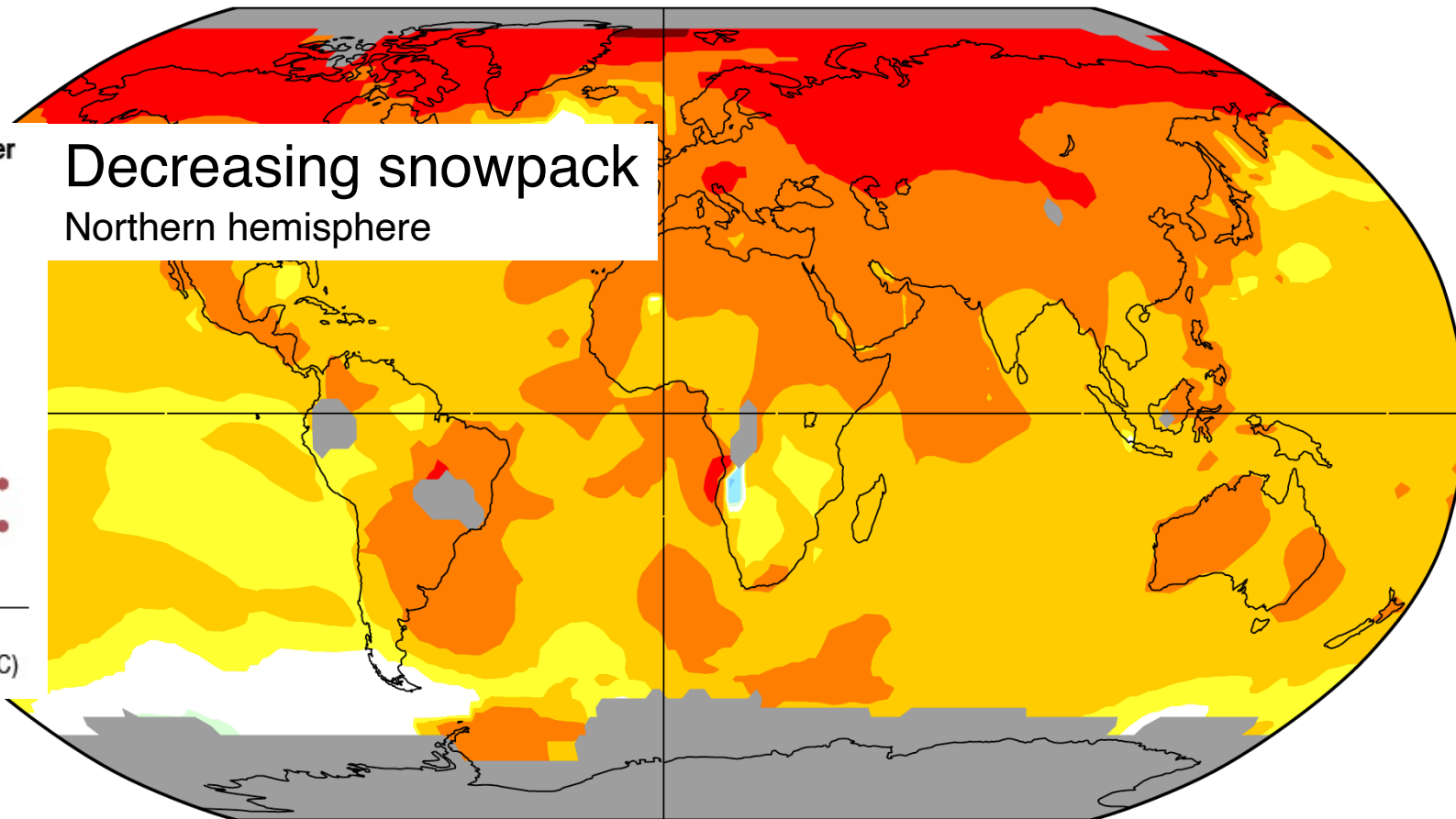
“Over the last 50 years, **global temperature has increased at a rate unprecedented** in at least the last 2000 years”

CLIMATE CHANGE IN TUNDRA ECOSYSTEMS

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



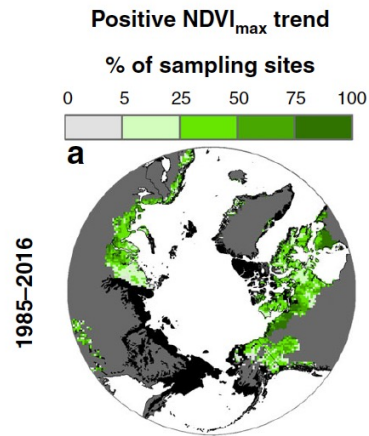
Decreasing snowpack
Northern hemisphere



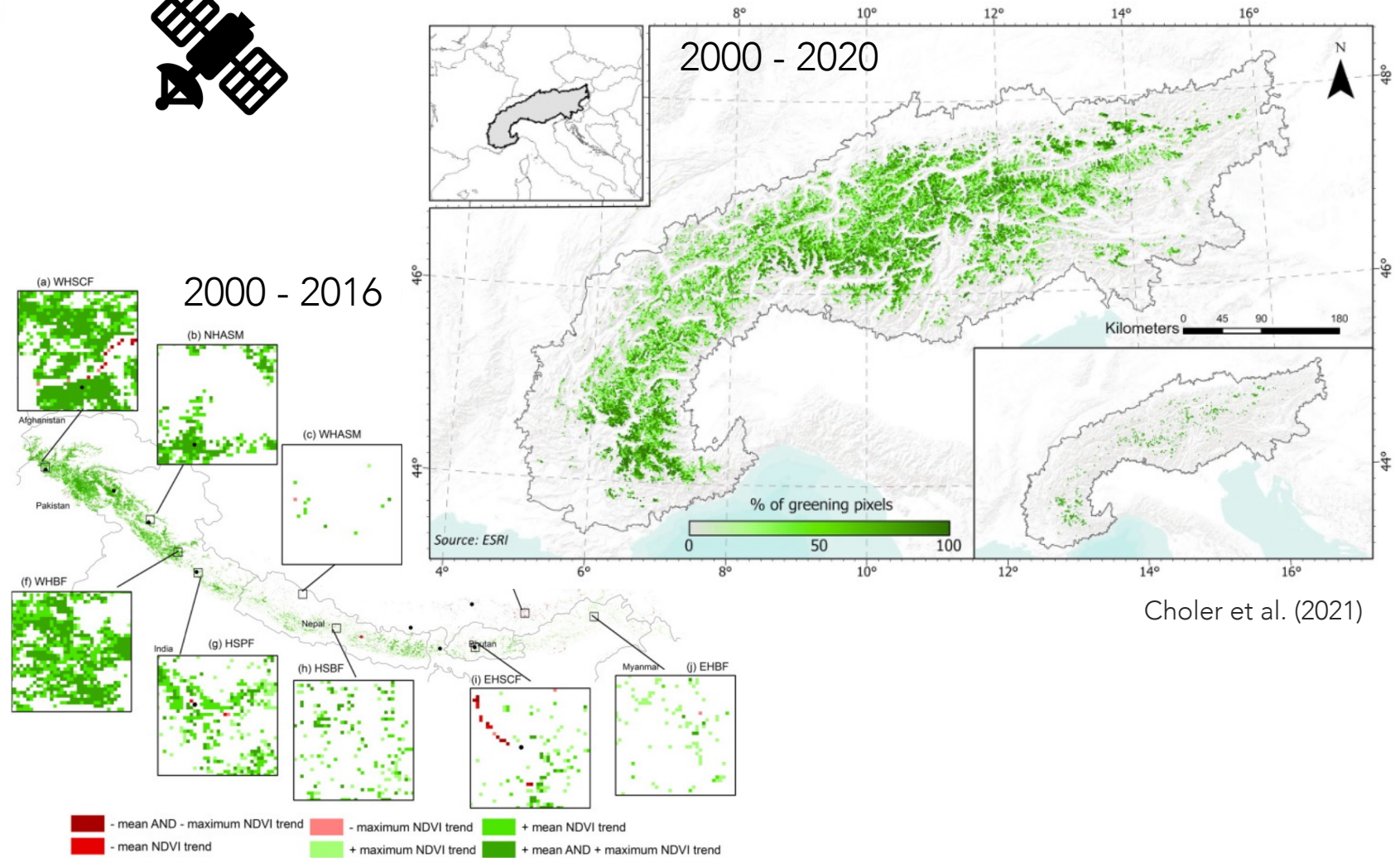
- ✓ +1.2°C in average
- ✓ +2.5°C in the Alps
- ✓ At least +4°C in the Arctic

VEGETATION GREENING

ECOSYSTEM RESPONSE: VEGETATION GREENING



Berner et al. (2021)



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)

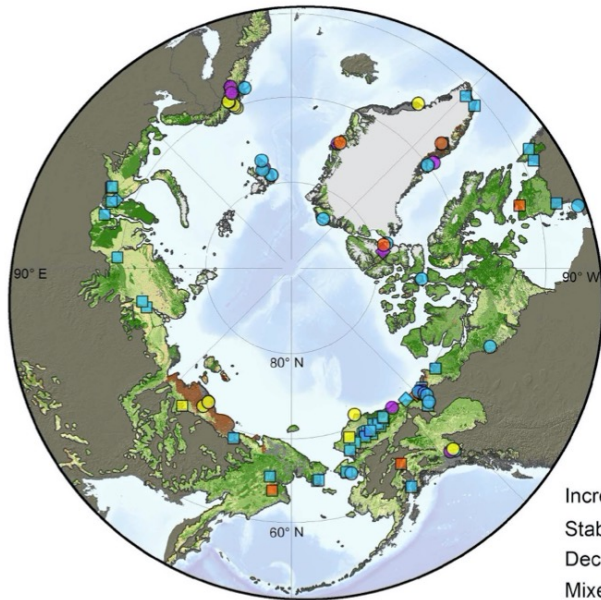
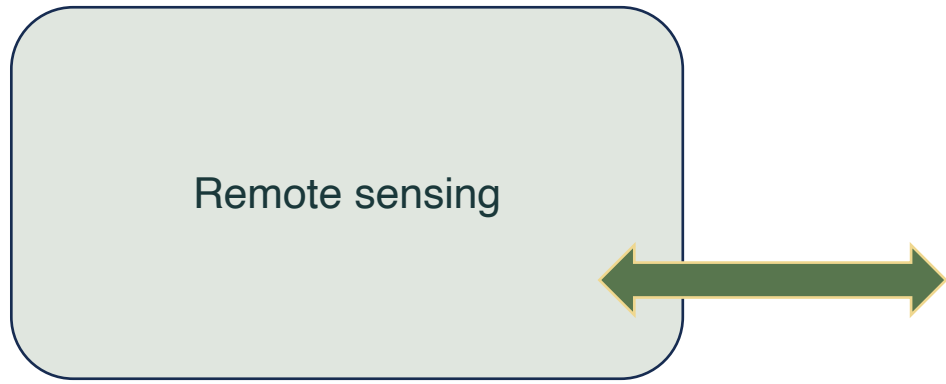
The ecophysiological processes underlying alpine greening have rarely been investigated

→ Especially in complex mountains terrains

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

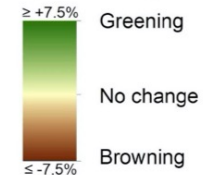
In the Arctic, the **increasing woody vegetation cover** is the main driver of greening

VEGETATION GREENING

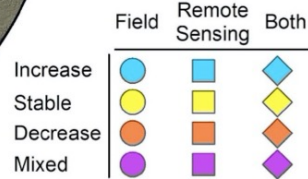


Observed changes

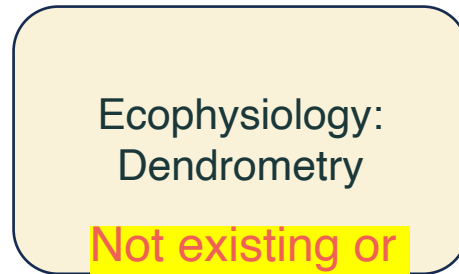
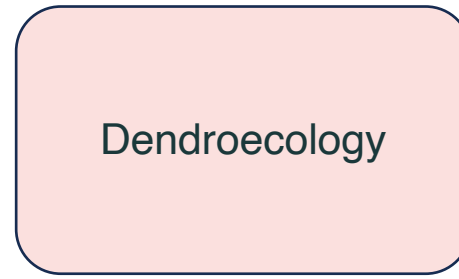
Tundra greenness
(2000 - 2020)



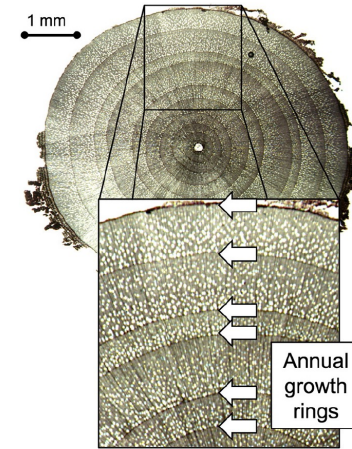
Shrub cover, growth,
biomass or reproduction
(variable time periods)



Mekonnen et al., (2021)



a) Annual growth rings in *Salix alaxensis*



Myers-Smith et al., (2015)



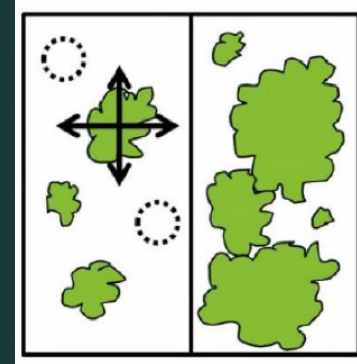
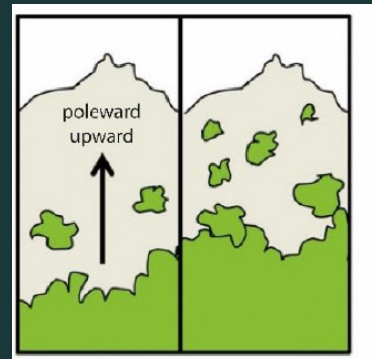
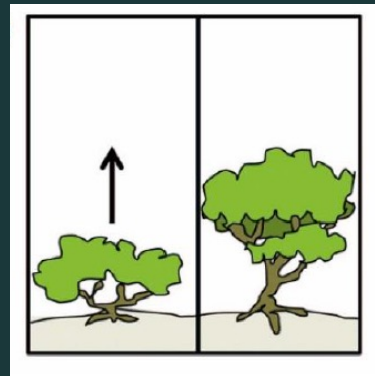
Tape et al., (2006)

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

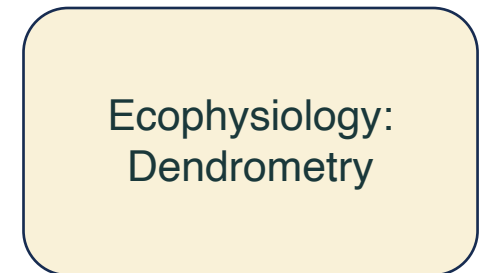
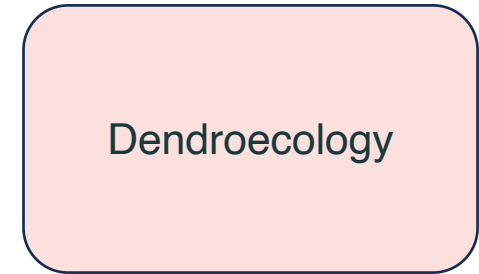
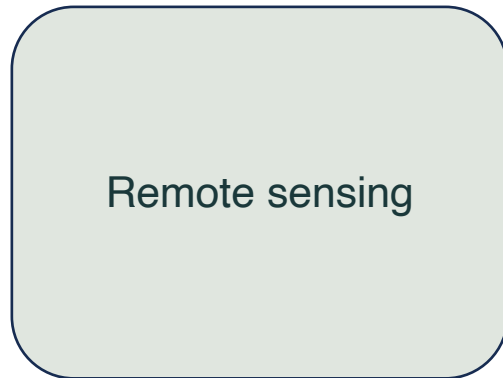
Such observations remain lacking in mountain regions

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**

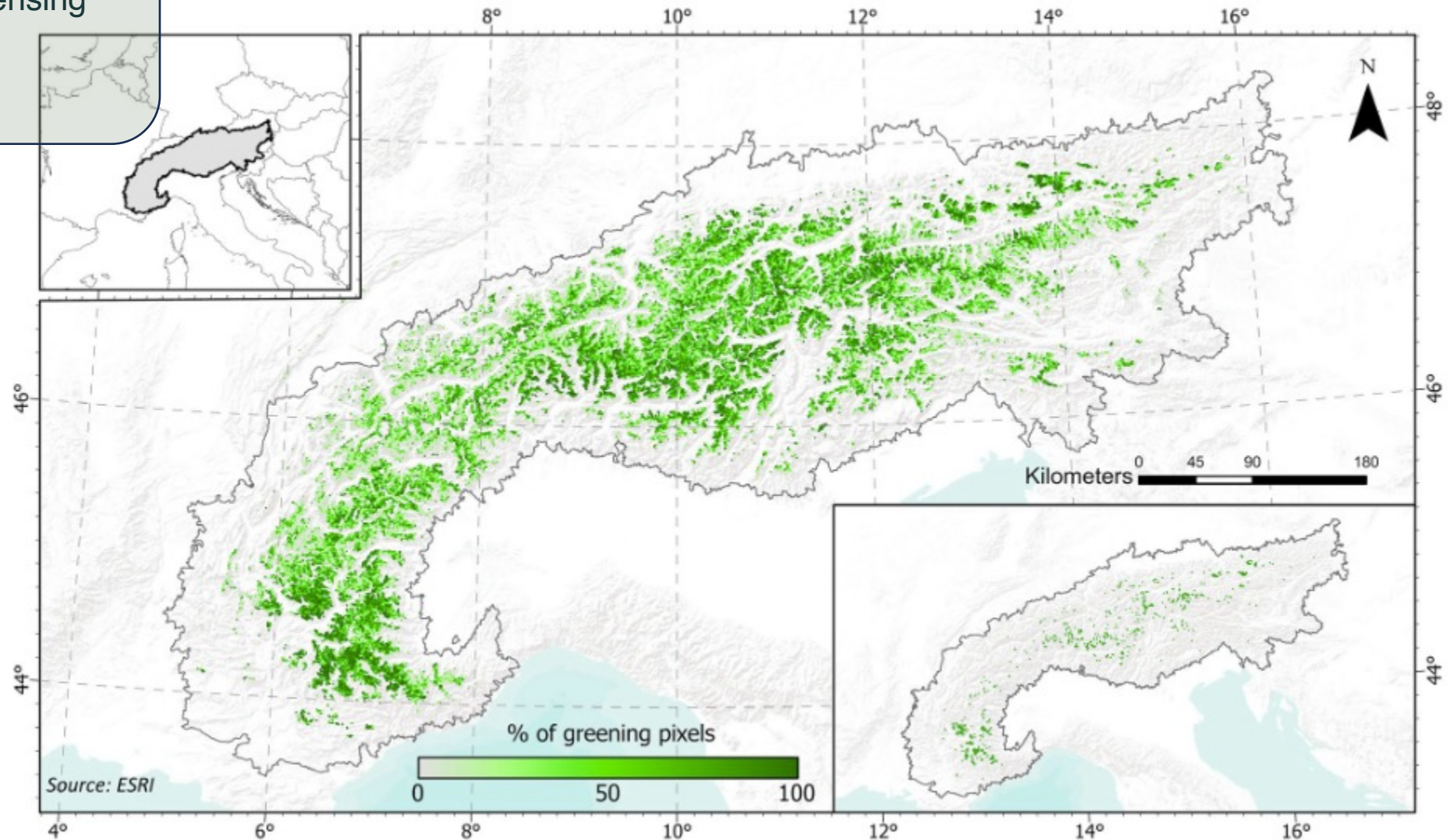


In order to quantify the response of **woody vegetation to climate change** and its **spatial and temporal dynamics** across mountain ranges, we call for a **transdisciplinary approach combining the four compartments.**



The greening in the European Alps

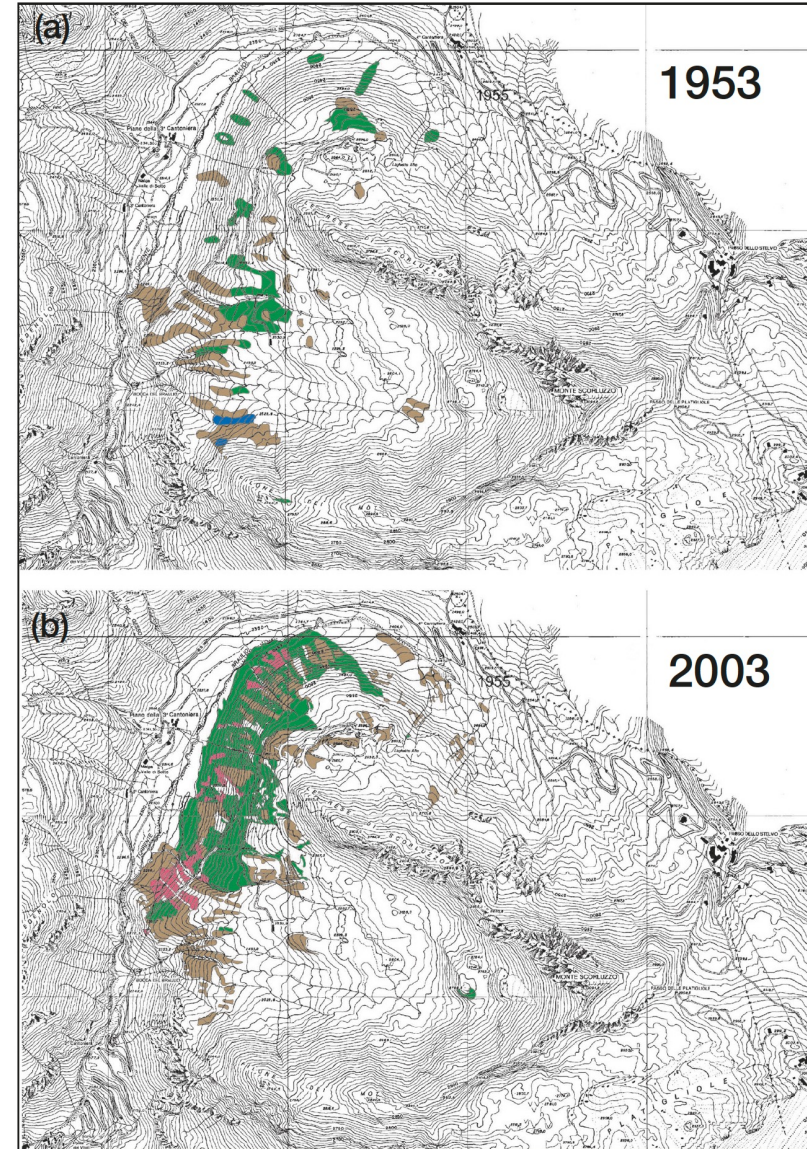
Remote sensing



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



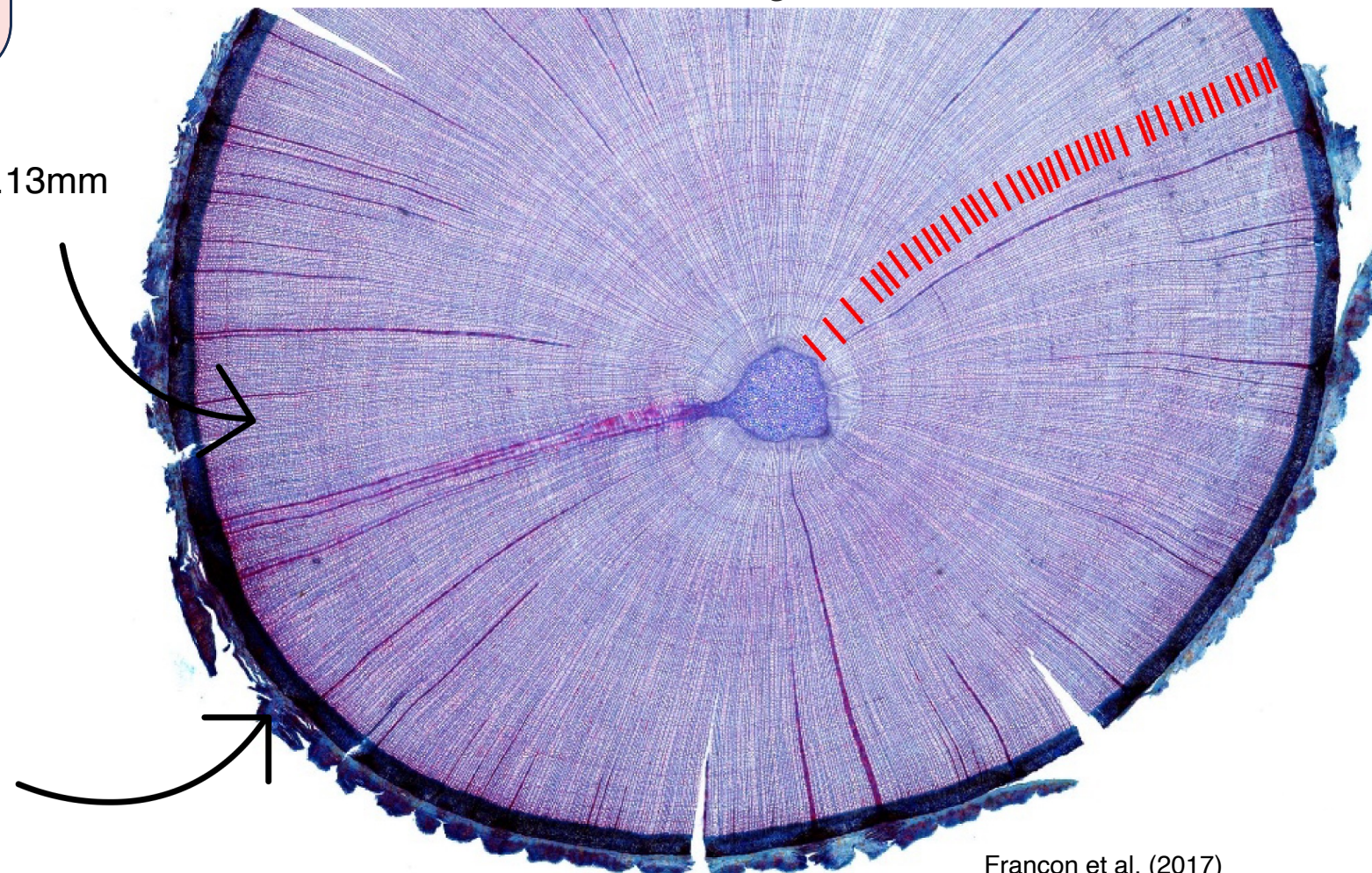
EXAMPLE: THE EUROPEAN ALPS

Dendroecology

Rhododendron ferrugineum

Mean ring width = 0.13mm

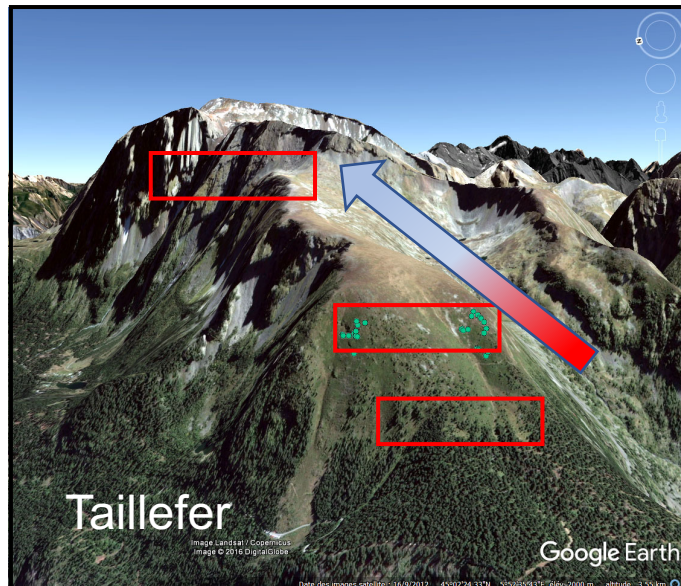
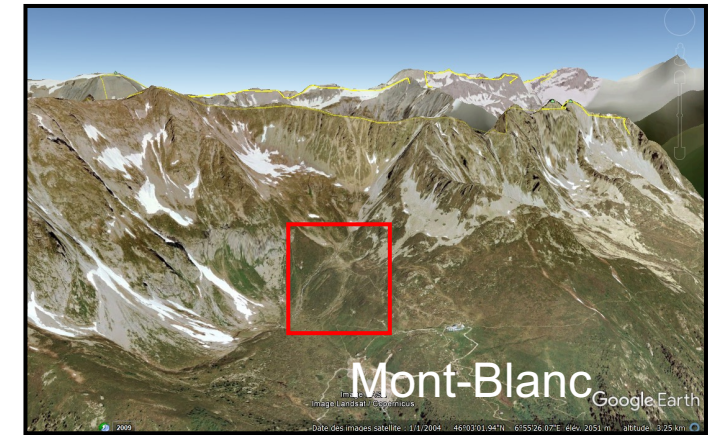
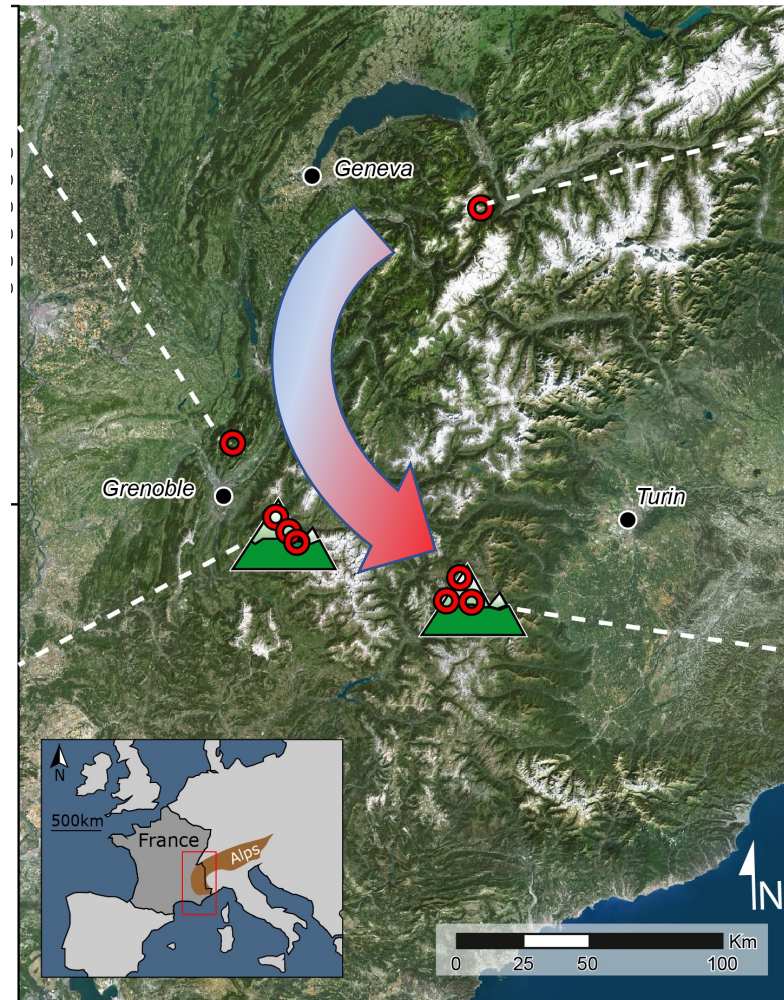
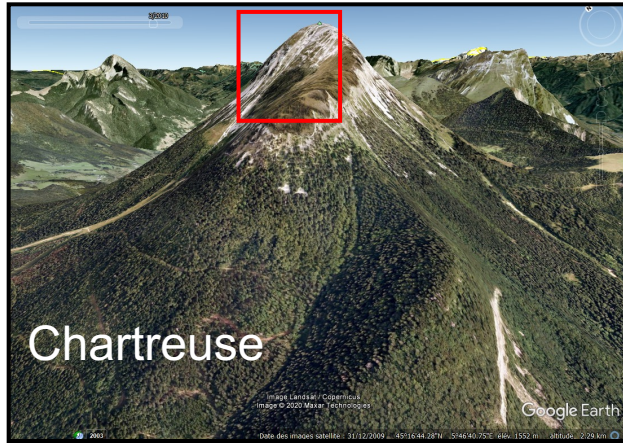
Maximal age: 215 years



1 cm

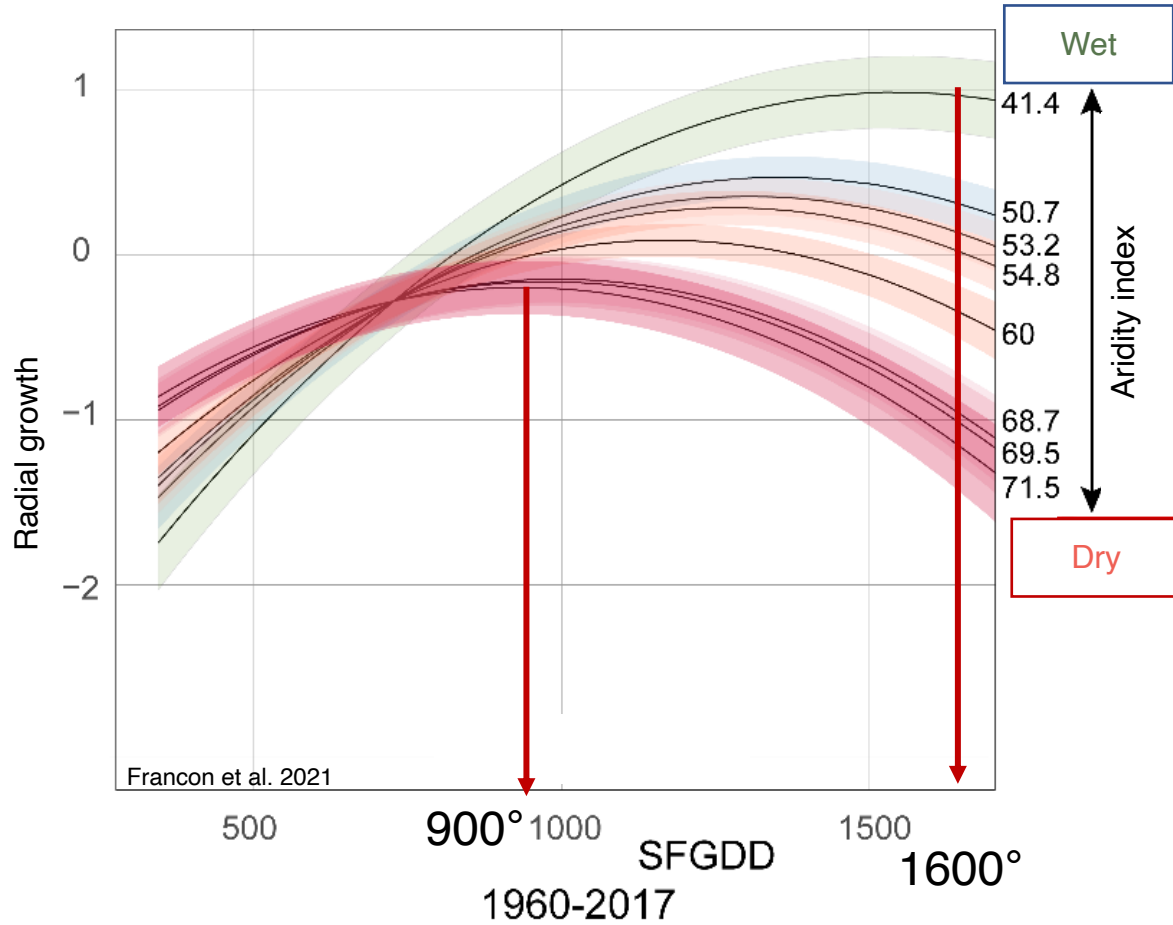
Francon et al. (2017)

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

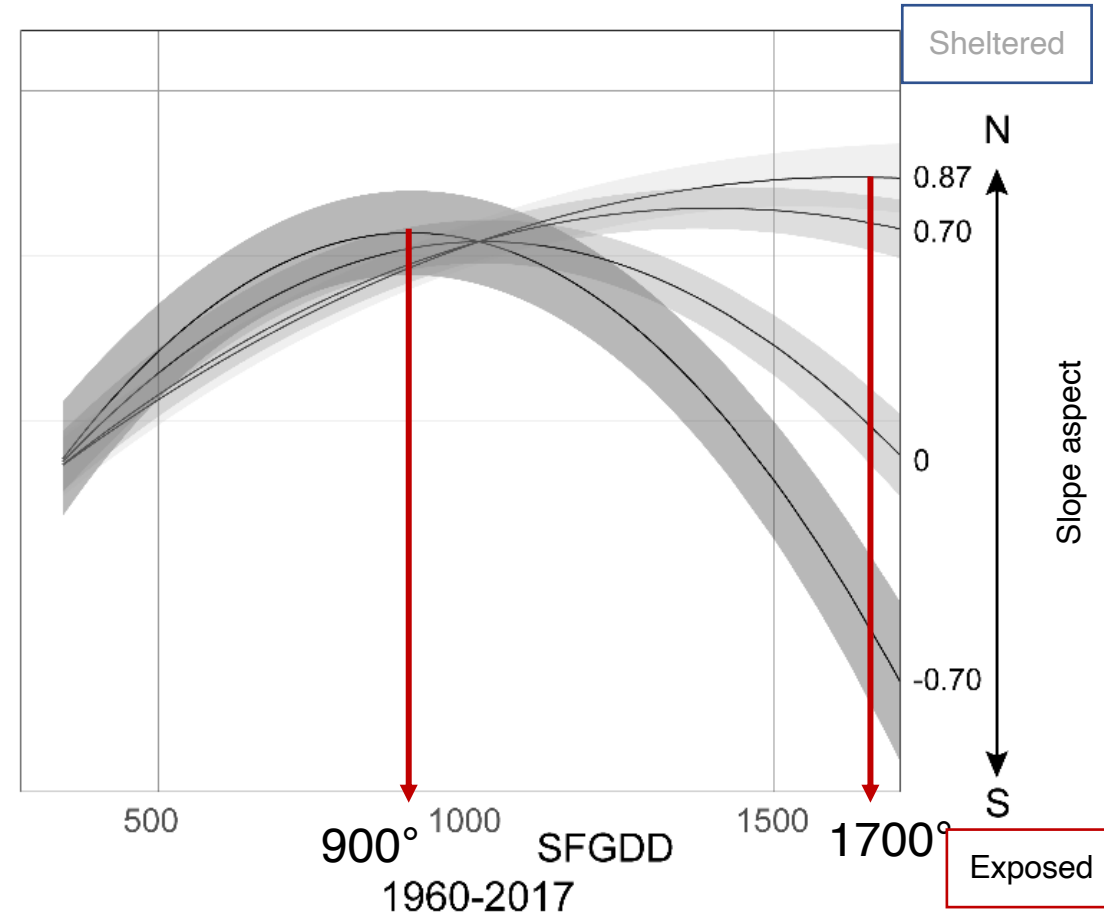


SHRUBS CLIMATE SENSITIVITY (1960-2017)

Inner vs. outer Alps



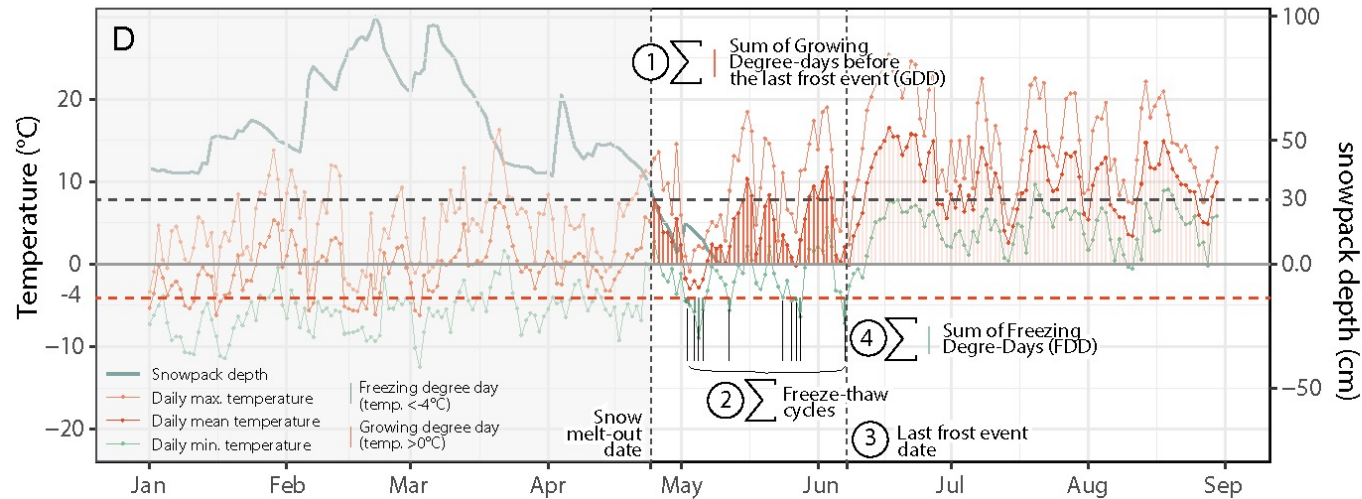
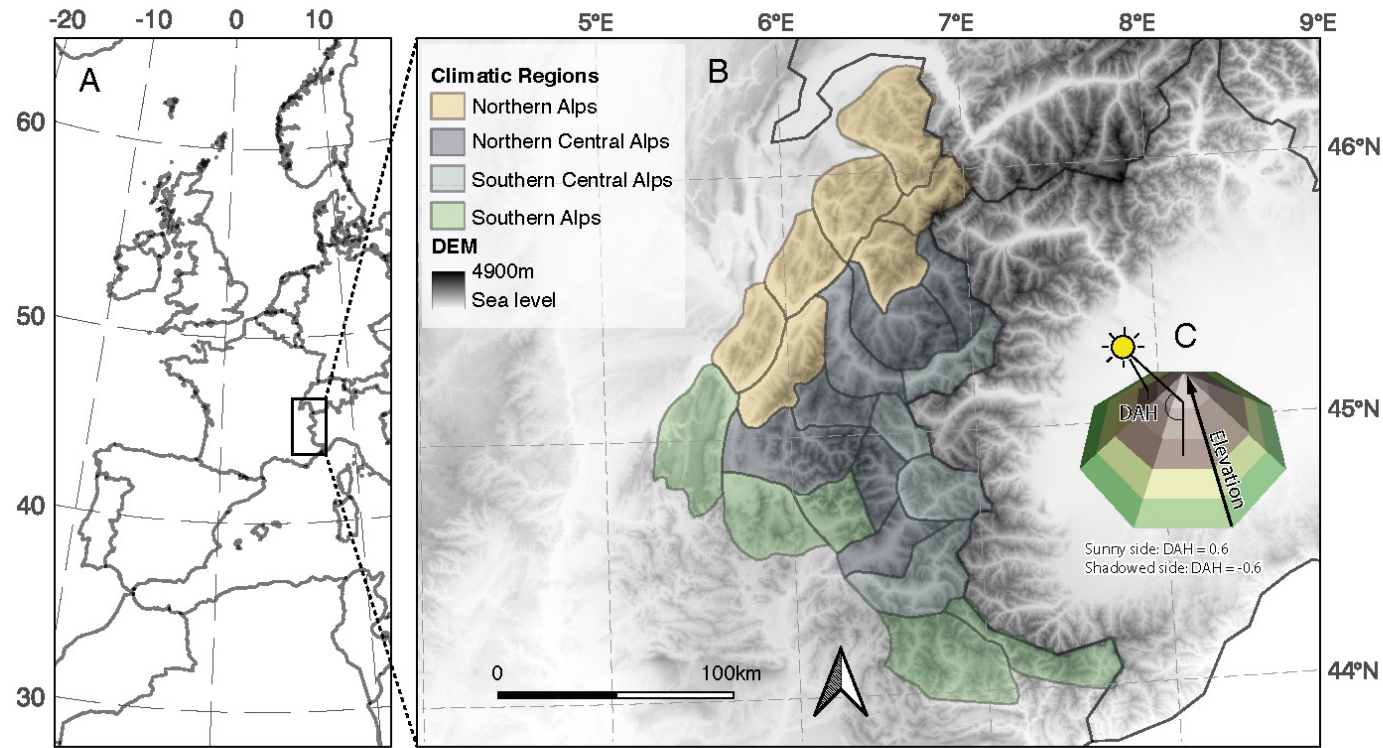
South vs. North slopes



Drought and frost effects

Francon et al. (2021)

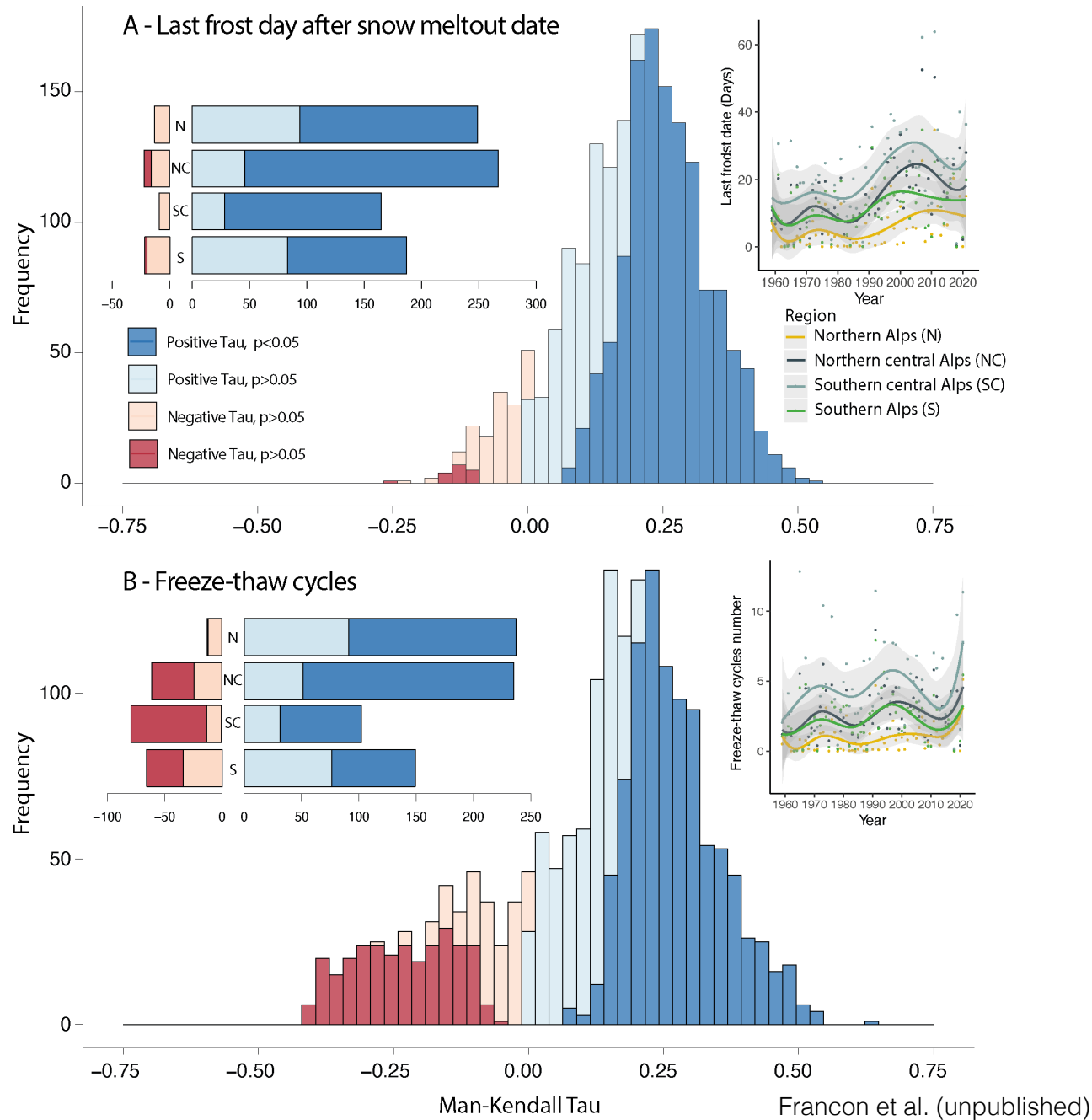
EXAMPLE: THE EUROPEAN ALPS



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

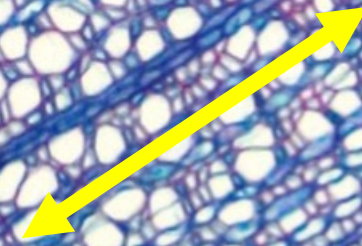
LIMITATIONS

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

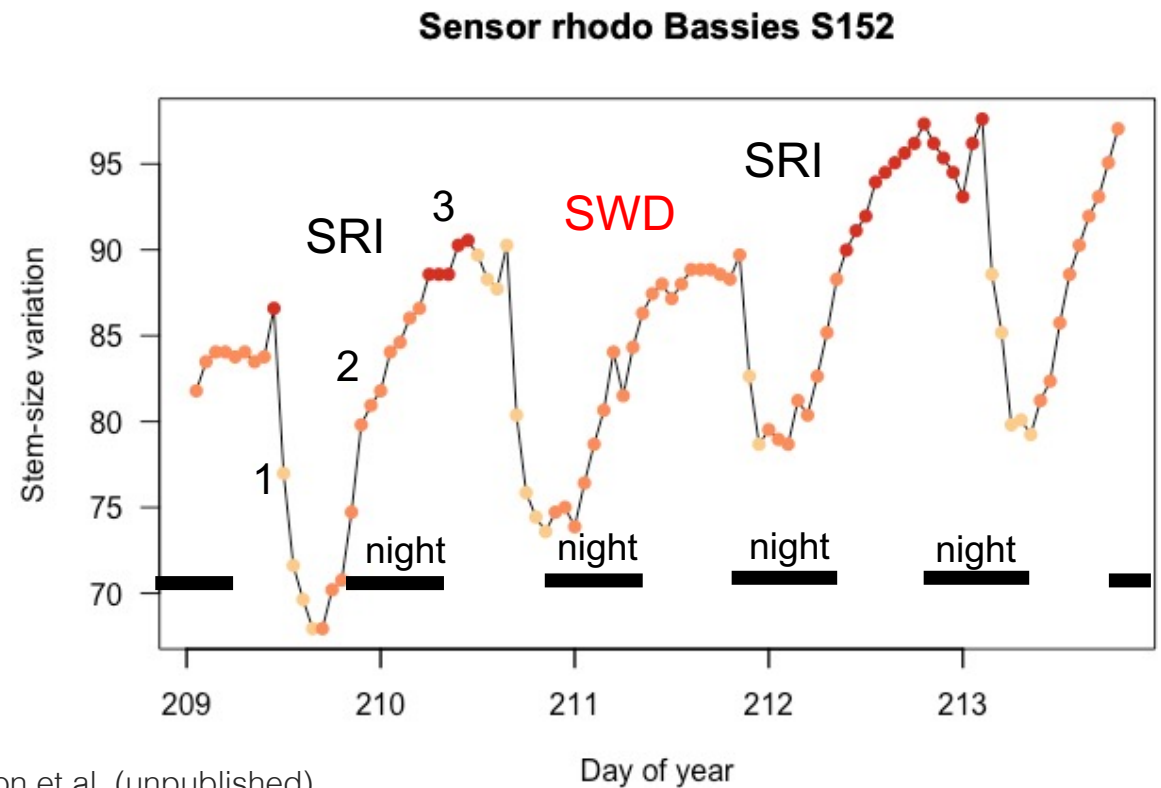
Phase 2. Rehydration → (orange) expansion

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

Stem Water Deficit (SWD) → stress

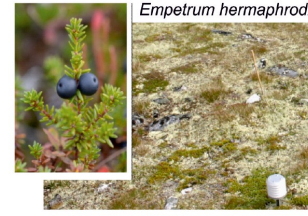


Francon

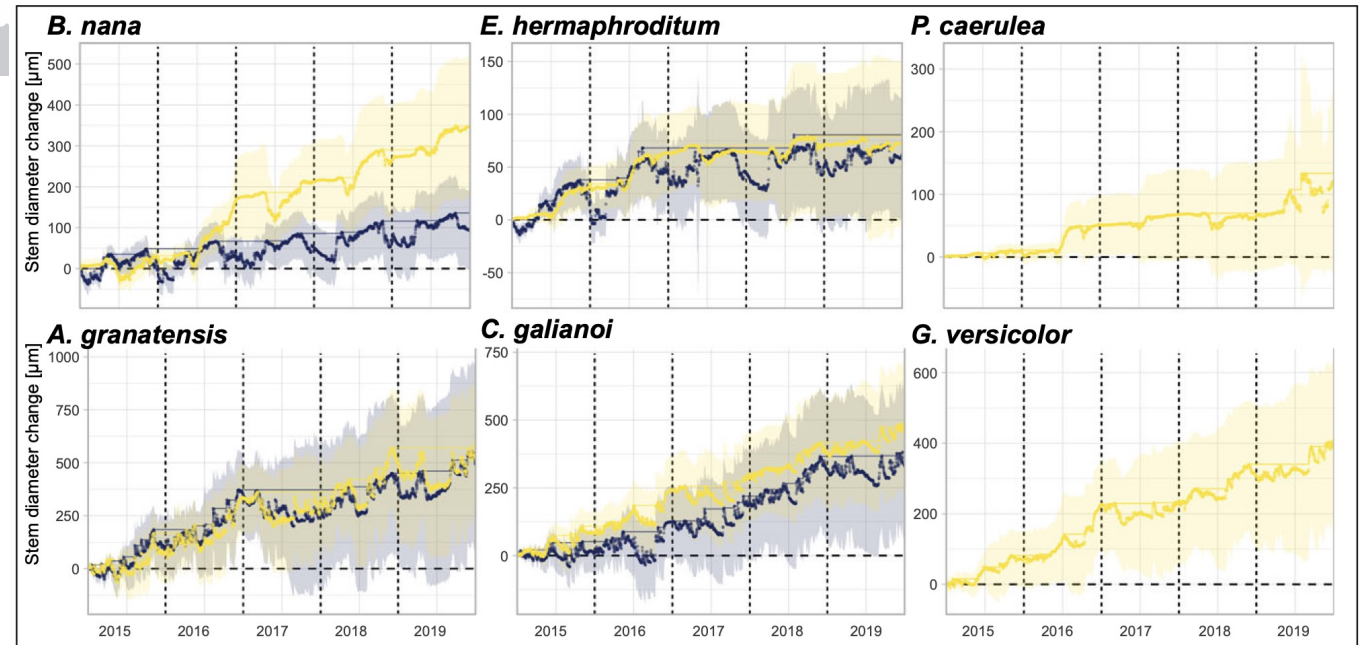


Francon et al. (unpublished)

EXAMPLE: THE EUROPEAN ALPS



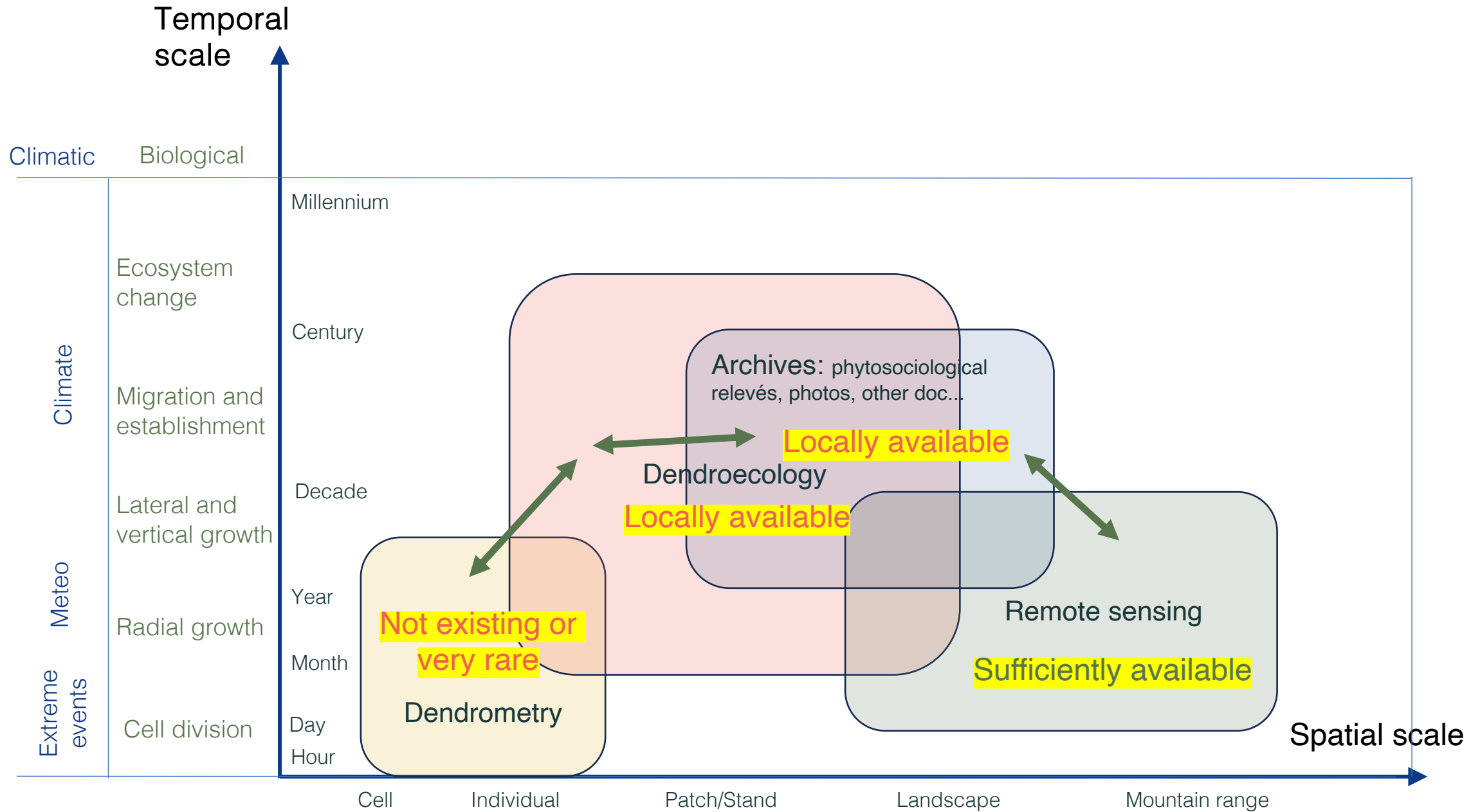
Löffler et al. (2022)



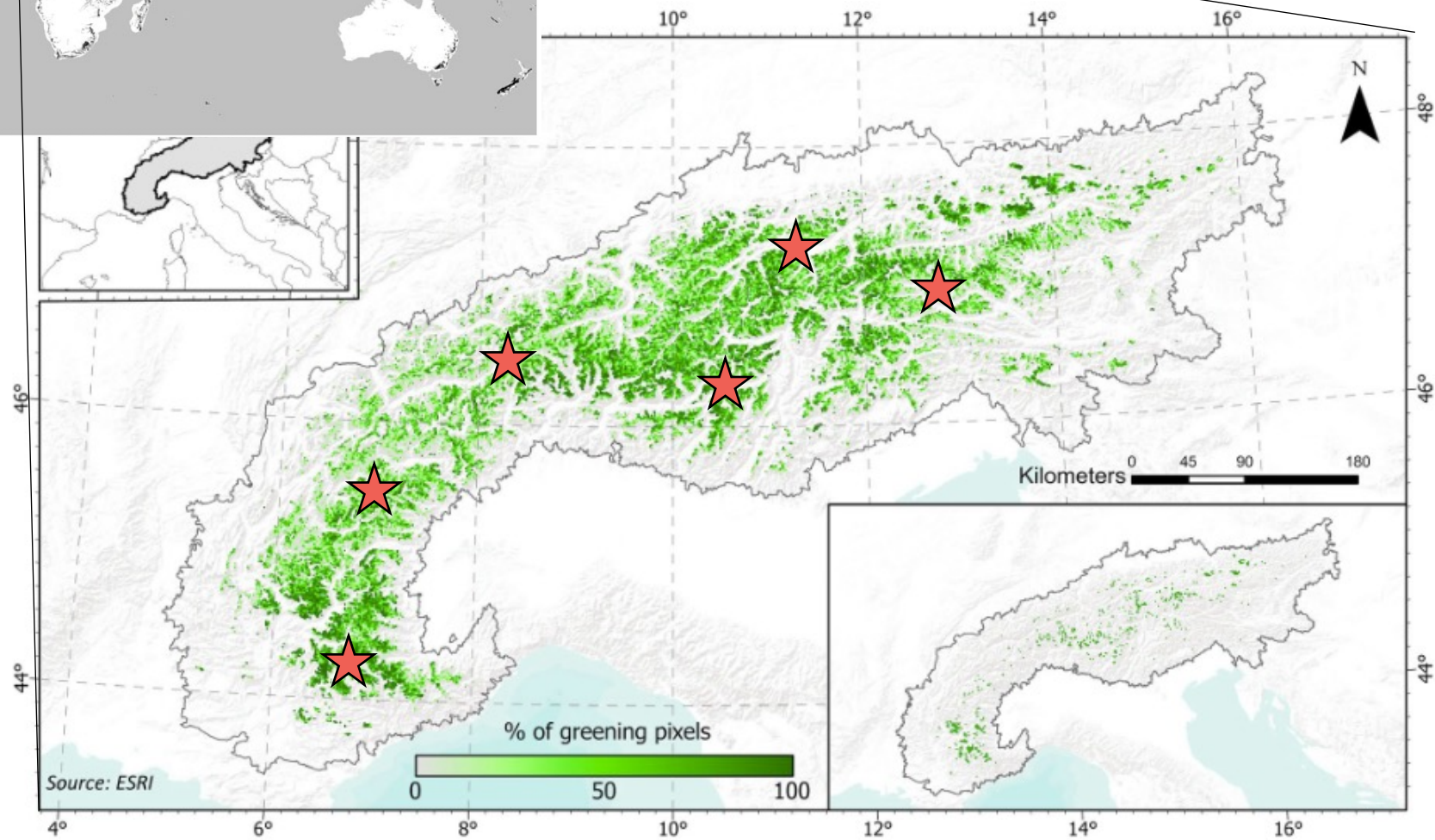
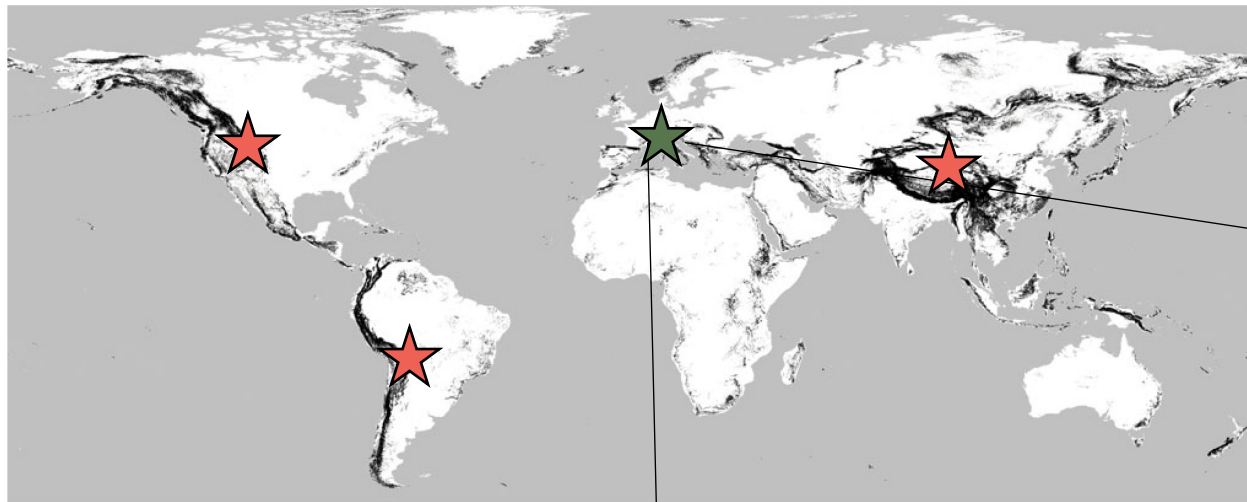
Francon

Dobbert et al. (2022)

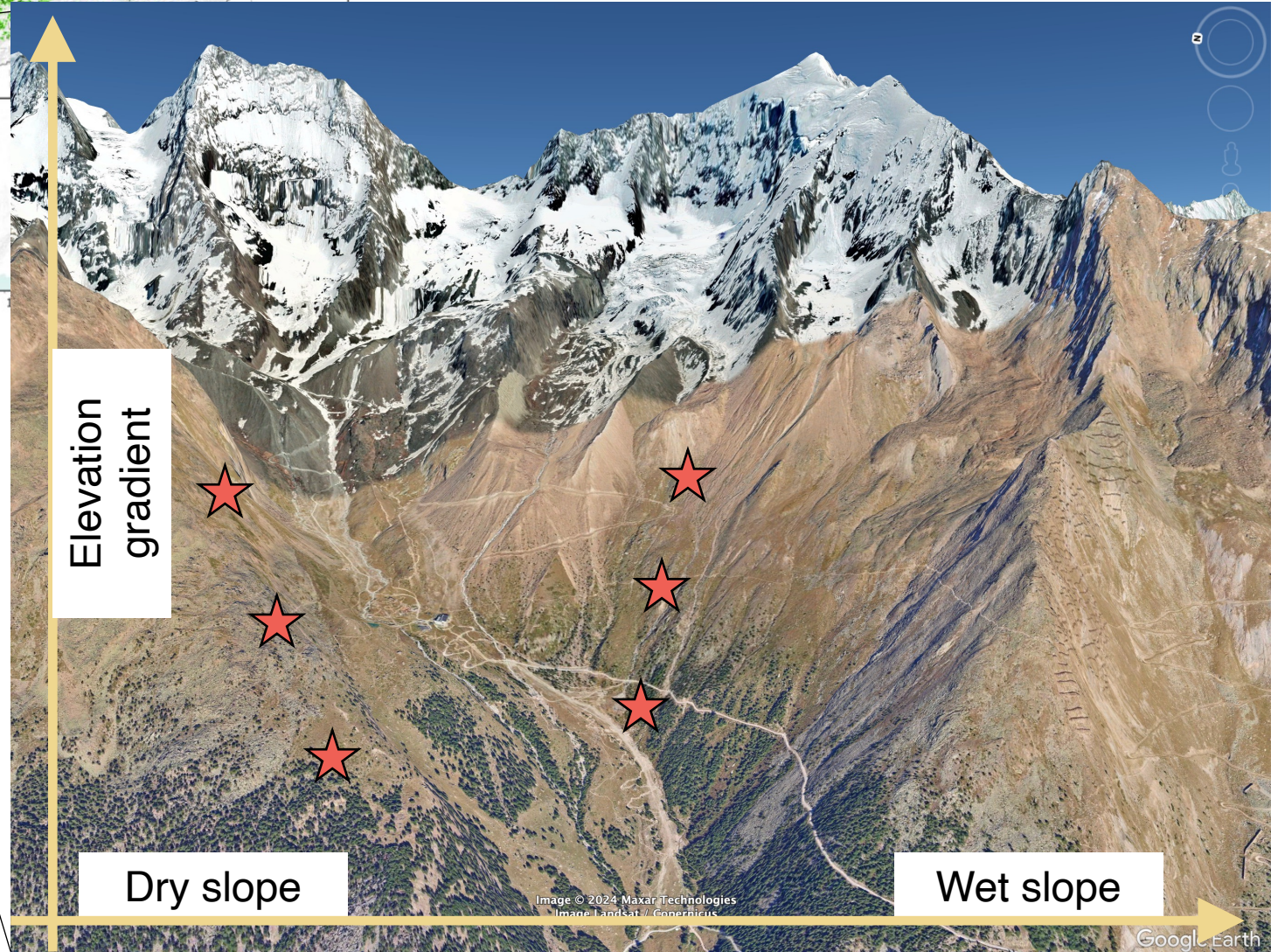
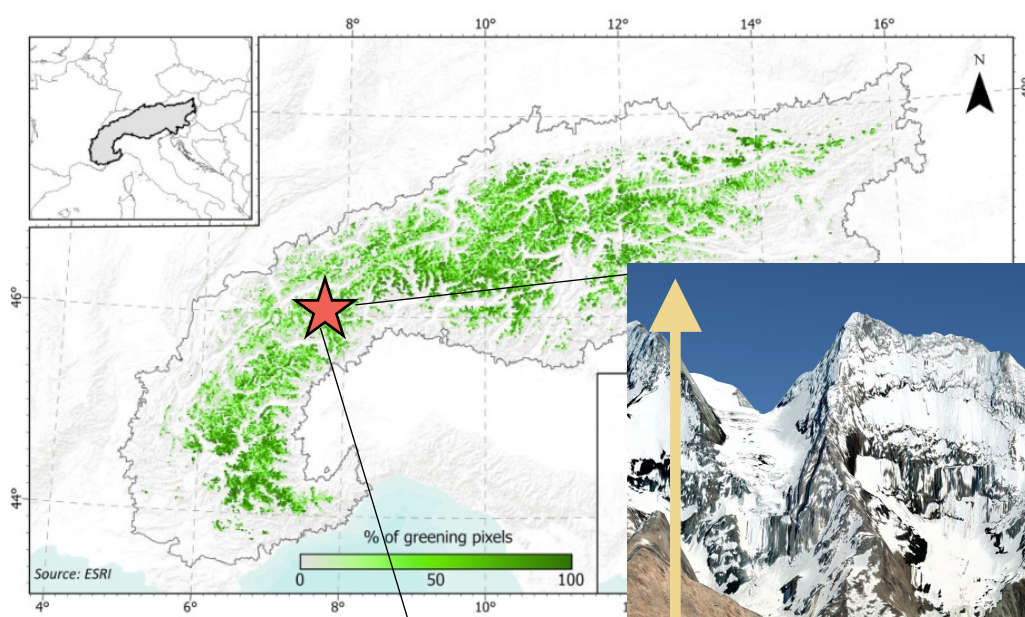
NEW FRAMEWORK



NEW FRAMEWORK



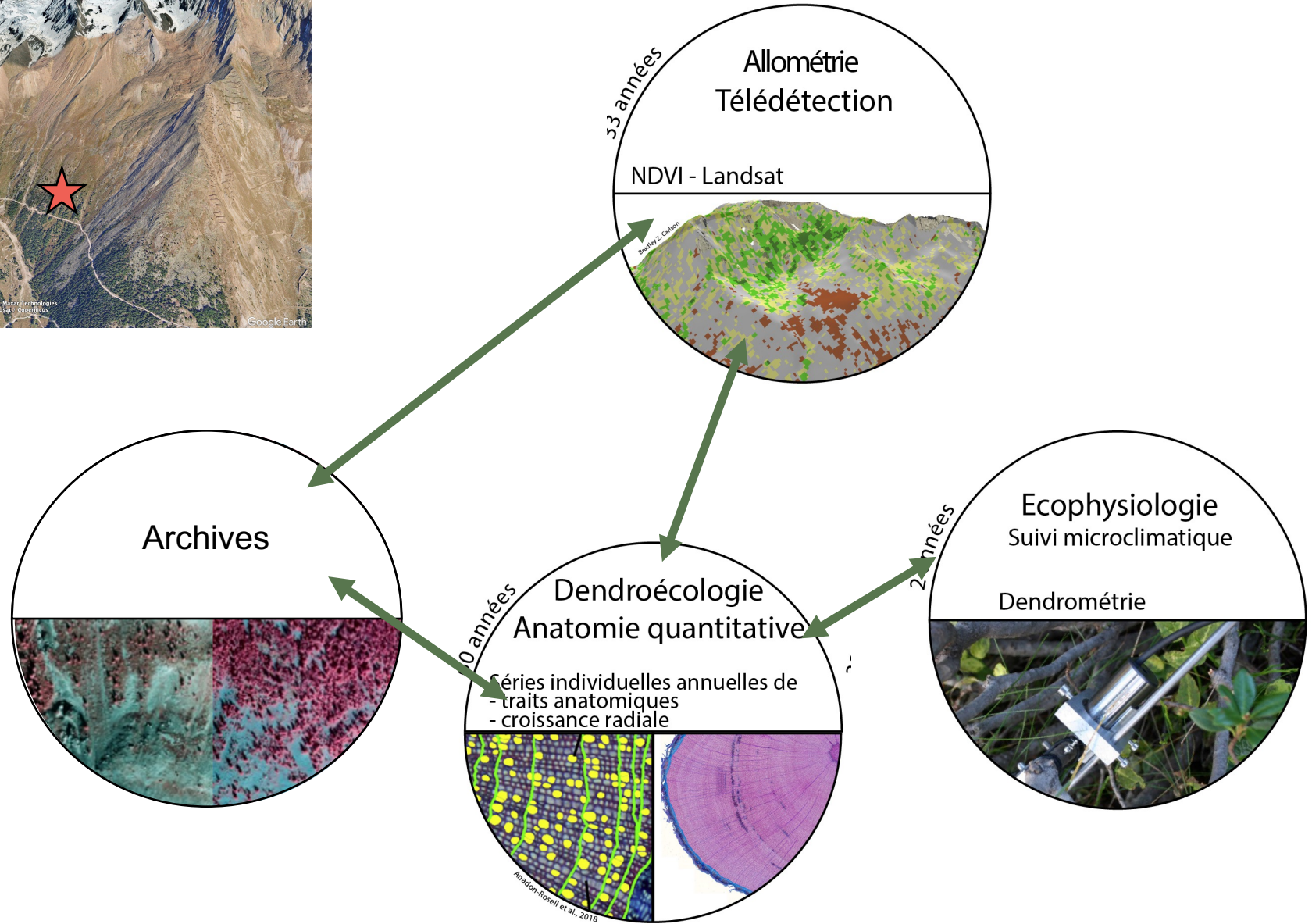
NEW FRAMEWORK



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

