“Challenges and future avenues when reconstructing the past and predicting the future geographic distribution of rare plants in the Mediterranean Alps under changing climates ”

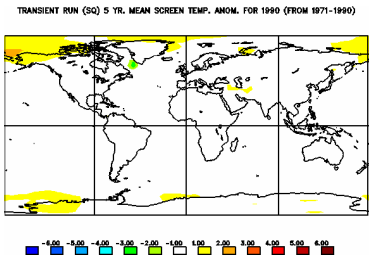
Christophe RANDIN
Uni. Lausanne – Dept. of Ecology & Evolution

MISTRAL workshop, Oct. 17 2017

Photo: C.Randin

Where are we standing?

The modelling cascade from GCMs to SDMs



Large scale (continental to regional)

Natural perturbations

Emissions (GHGs, aerosols)

Global Climate Models (GCMs)

Regional Climate Models (RCMs)

Land use / landcover

Downscaling

Outputs for policy / management decisions

Impact models

Hydrological (e.g. PREVAH, CHYM, SnowModel)
Land-use change (e.g. CLUE)

Calibration

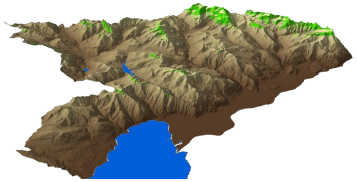
Species Distribution Models (SDMs)

Feedbacks from SDMs

Calibration (current conditions)

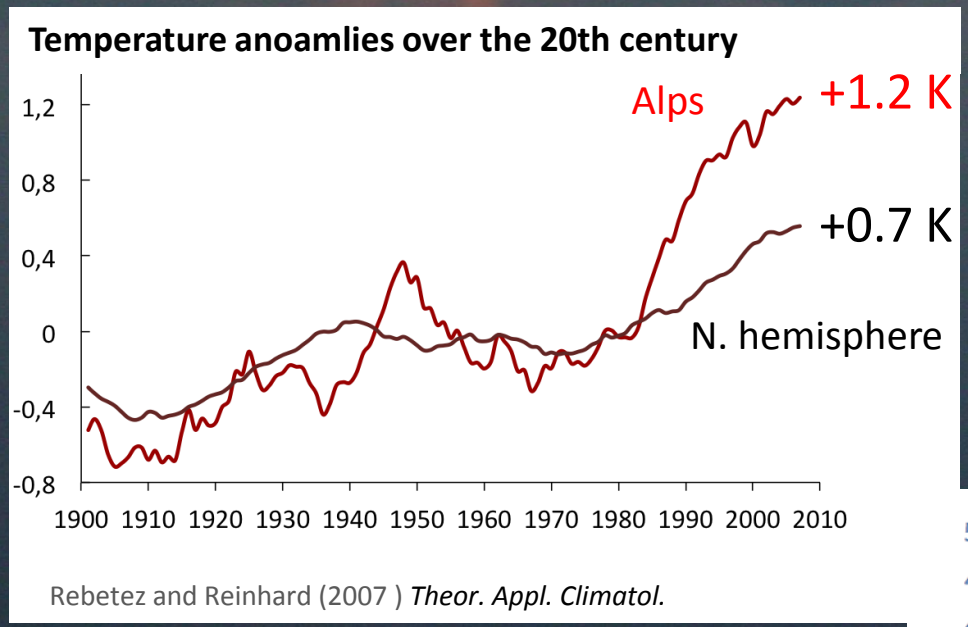
Observations (species occurences ~ climate data)

Upscaling - generalization

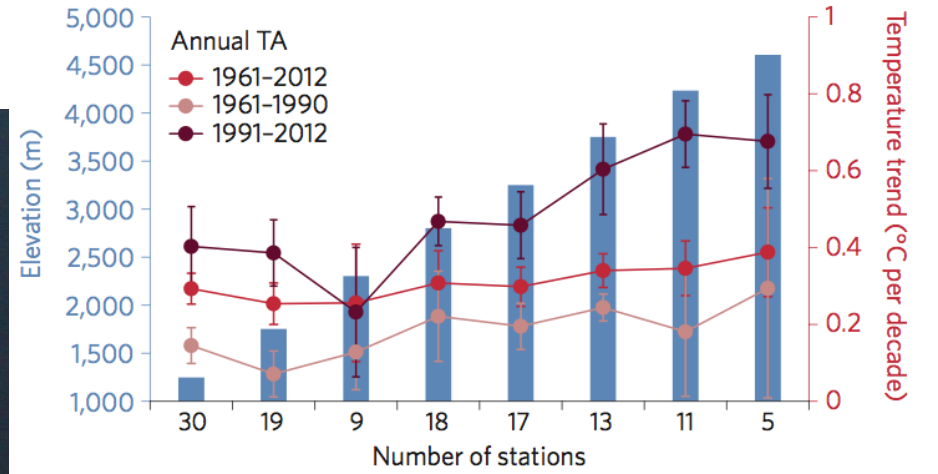


Fine scale and high resolution (regional to landscape)

The starting point: climate change in the Alps



Rebetez and Reinhard (2007) *Theor. Appl. Climatol.*



Bradley *et al.* (2015) *Nature Climate Change*
Mountain Research Initiative EDW Working Group (2015)

...warming is also elevation depedendent in mountain regions!

Photo: C.Randin

Why assessing biodiversity changes in mountain regions?

“ An eye accustomed to flowery pastures and waving harvests is astonished and repelled by this ***wide extent of hopeless sterility.*** *The appearance is that of matter* ***incapable of form or usefulness, dismissed by nature from her care and disinherited of her favours,*** *left in its original elemental state, or quickened only with one sullen power of* ***useless vegetation.”***

Samuel Johnson, 1775
(*A Journey to the Western Isles of Scotland*)

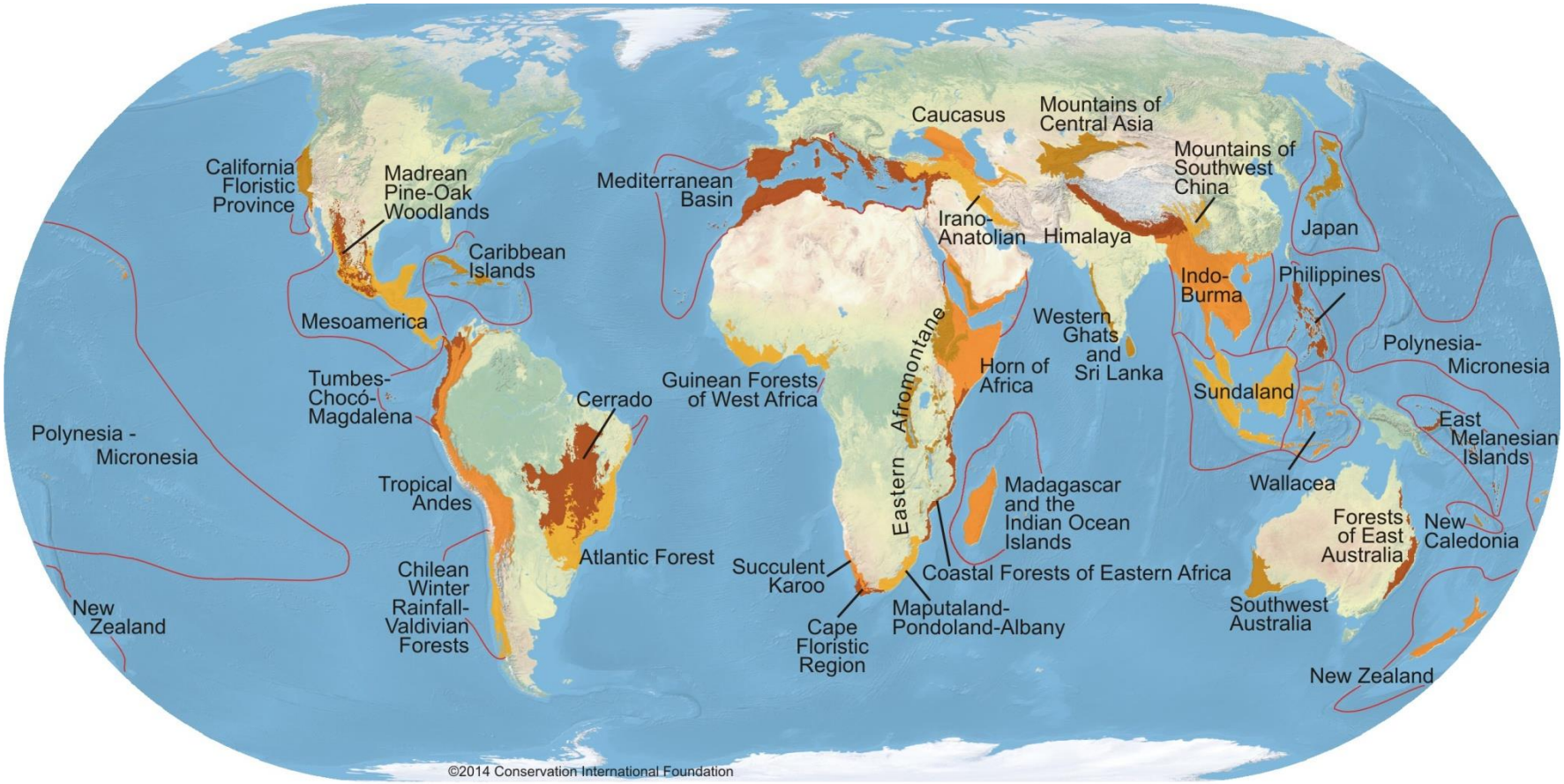
Are mountain tops ugly and sterile?

34 Biodiversity hotspots worldwide: **50% enclosed in mountains**

25% of the European plants are found above the treeline

i.e. **only 3%** of the continent surface

(Biodiversity International; Chape *et al.*2008)



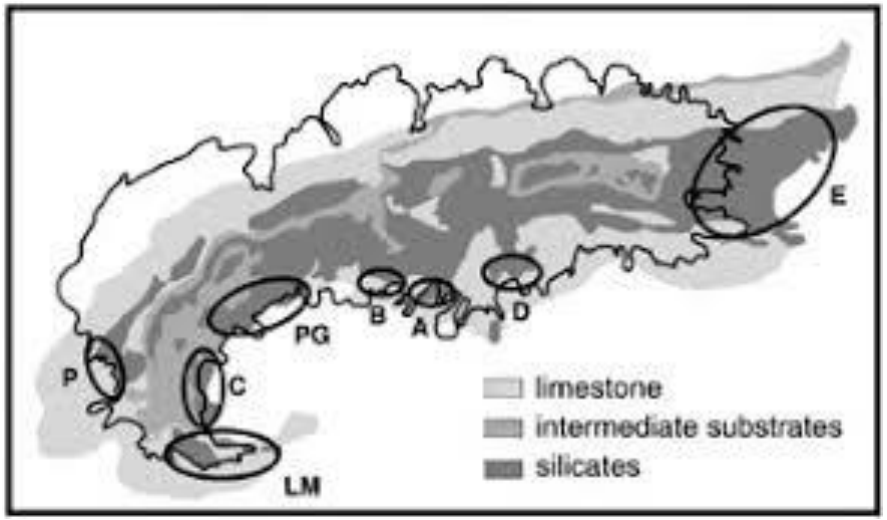
Conservation International, 2005

And Mediterranean Mountains are:

- Important species refugial areas during the glaciations of Pleistocene

- **High levels of endemism**

(Bennett *et al., 1991;* Tzedakis, 1993; Hewitt, 1996; Taberlet and Cheddadi, 2002)



Schönswetter *et al.* (2003) *Molecular ecology*

Photos: T.Patsiou & C.Randin

How do mountain plants react to climate change?

Persist and adapt

(Climate change ready)

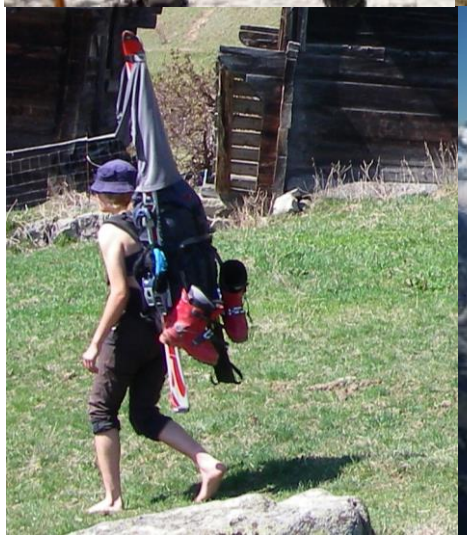
(phenotypic / genotypic plasticity)

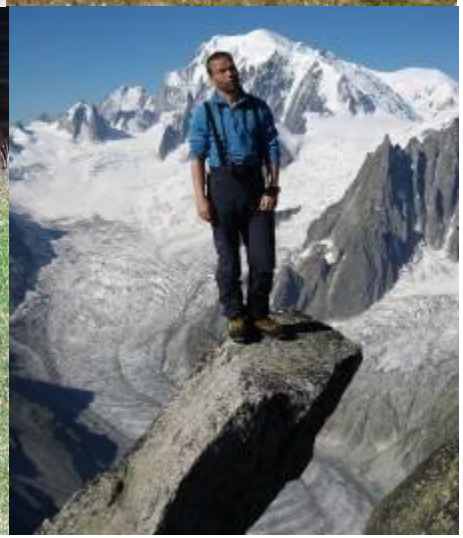
Stay and get extinct

Sessile organisms

Adapted for dispersal

"Migration" of seeds





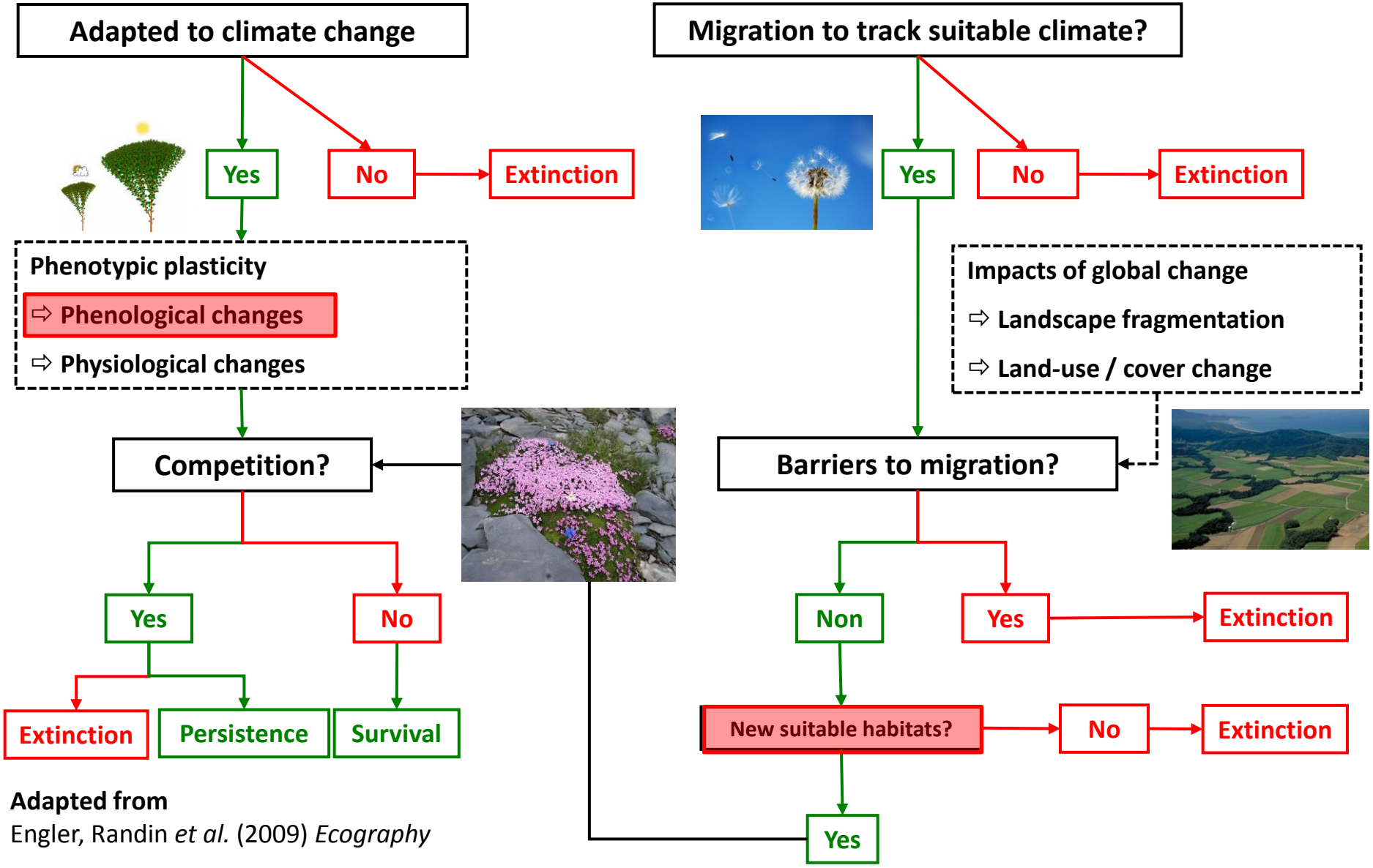
Adapted for dispersal +

Suitable habitats

Migration + colonization of suitable habitats

Photos: C.Randin, M.Rebetez

How do mountain plants react to climate change?



Adapted from
Engler, Randin *et al.* (2009) *Ecography*

Impact of climate change on plant distribution in mountain regions

Assessments from past observations

Global Change Biology (2007) 13, 147–156, doi: 10.1111/j.1365-2486.2006.01282.x

Signals of range expansions and contractions of vascular plants in the high Alps: observations (1994–2004) at the GLORIA*master site Schrankogel, Tyrol, Austria

HARALD PAULI, MICHAEL GOTTFRIED, KARL REITER, CHRISTIAN KLETTNER and GEORG GRABHERR

nature climate change LETTERS
PUBLISHED ONLINE: 10 JANUARY 2012 | DOI: 10.1038/NCLIMATE1329

Continent-wide response of mountain vegetation to climate change

Michael Gottfried[1], Harald Pauli[2]*, Andreas Futschik[3], Maia Akhalkatsi[4], Peter Barančok[5],

Recent Plant Diversity Changes on Europe's Mountain Summits
Harald Pauli *et al.*
Science **336**, 353 (2012);

Projections for the future

Climate change threats to plant diversity in Europe

Wilfried Thuiller*[†§], Sandra Lavorel*[¶], Miguel B. Araújo*[#], Martin T. Sykes**, and I. Colin Prentice[††]

PNAS 2005

Global Change Biology
Global Change Biology (2011), doi: 10.1111/j.1365-2486.2010.02393.x

21st century climate change threatens mountain flora unequally across Europe

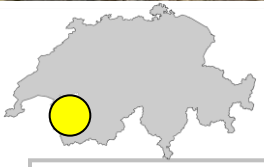
ROBIN ENGLER*, CHRISTOPHE F. RANDIN†, WILFRIED THUILLER‡, STEFAN

nature climate change LETTERS
PUBLISHED ONLINE: 6 MAY 2012 | DOI: 10.1038/NCLIMATE1514

Extinction debt of high-mountain plants under twenty-first-century climate change

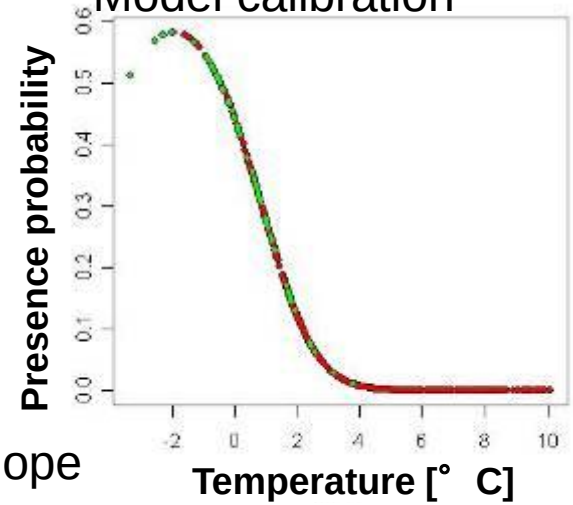
Stefan Dullinger[1,2]*, Andreas Gattringer[1], Wilfried Thuiller[3], Dietmar Moser[1],

Species Distribution Models (SDMs)?



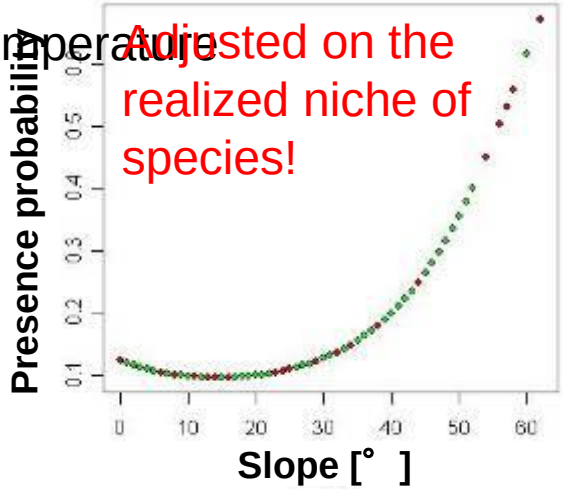
	Temperature	Slope
0	8.1	2
1	- 2.3	48
…	Calibration database	

Statistical software:
Model calibration

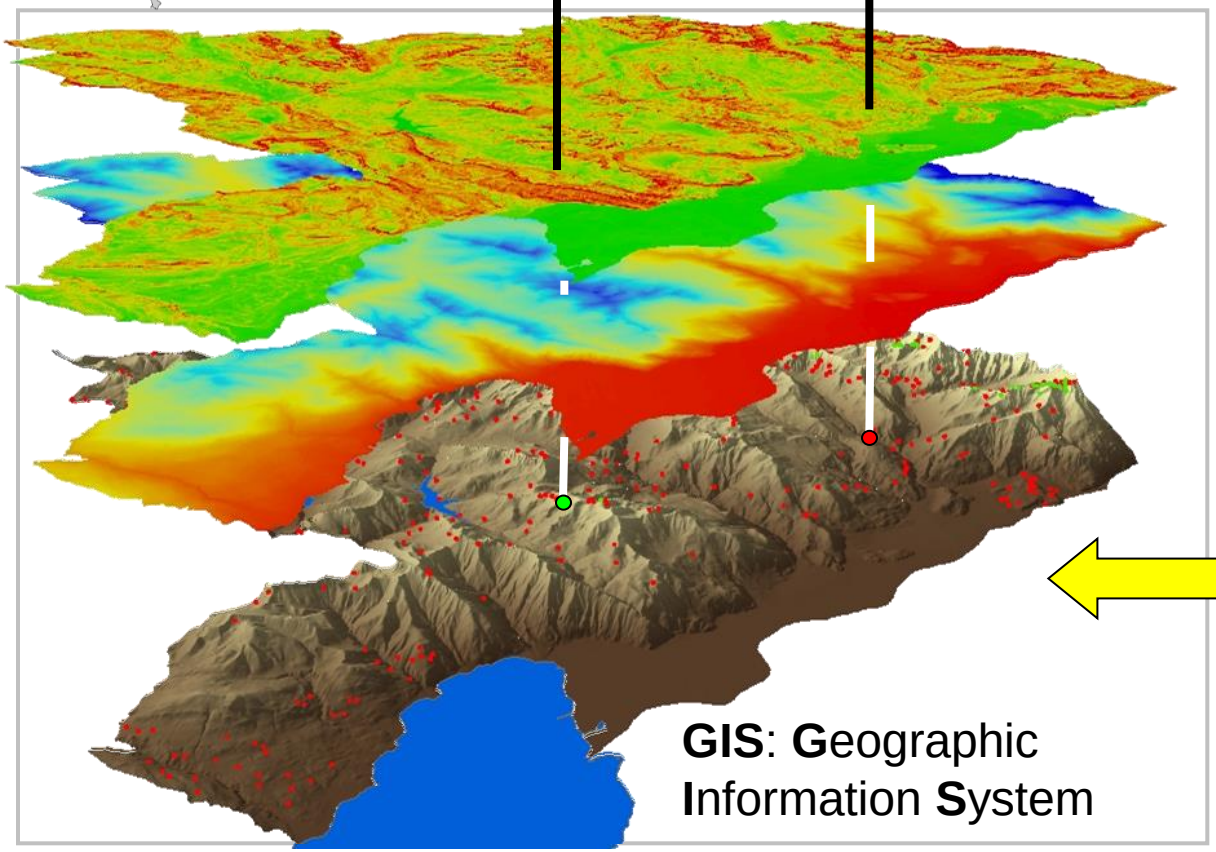


Slope

Temperature



Adjusted on the realized niche of species!

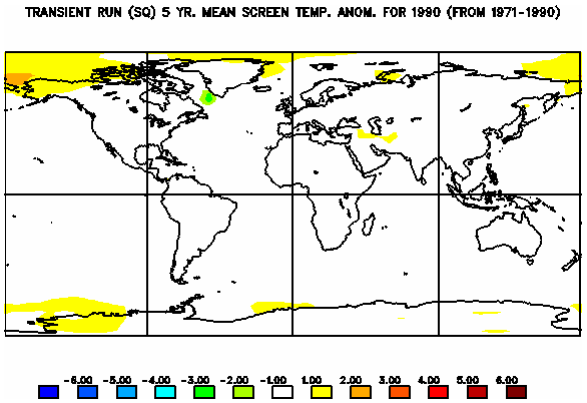


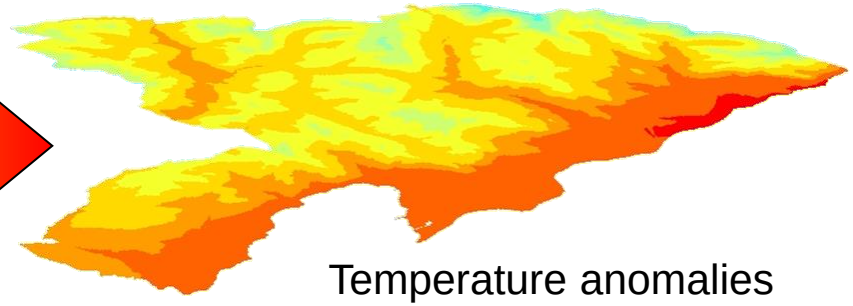
GIS: **G**eographic **I**nformation **S**ystem

Presence **Absence**

Potential distribution

Species distribution models and climate change scenarios





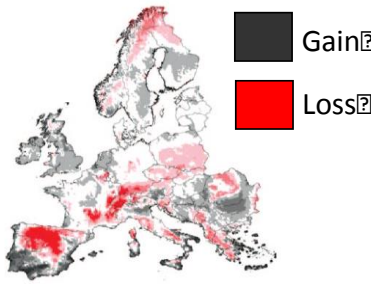
Temperature anomalies derived from Global / Regional Circulation models

Potential distribution

- 2000
- 2025
- 2050
- 2080
- 2100

Climate change threats to plant diversity in Europe

Wilfried Thuiller*†‡§, Sandra Lavorel*¶, Miguel B. Araújo*‡‖, Martin T. Sykes**, and I. Colin Prentice††



Projected species richness (late 21st century)

*"Despite the coarse scale of the analysis (pixels of 16x16km), **species from mountains** could be seen to be disproportionably sensitive to climate change (**60% species loss**)."*

Thuiller *et al.* (2005) *PNAS*

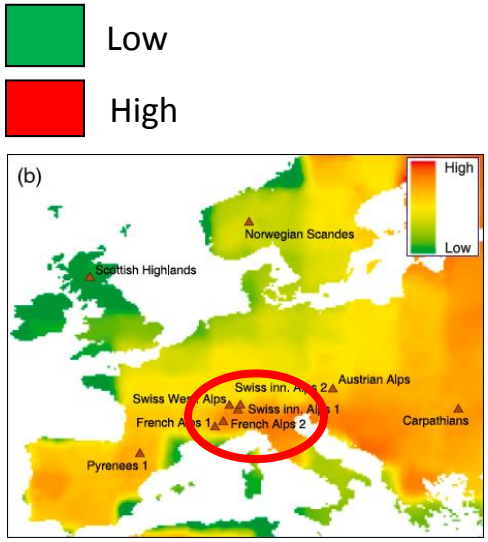
Global Change Biology (2011), doi: 10.1111/j.1365-2486.2010.02393.x

21st century climate change threatens mountain flora unequally across Europe

ROBIN ENGLER*, CHRISTOPHE F. RANDIN†, WILFRIED THUILLER‡, STEFAN DULLINGER§,¶, NIKLAUS E. ZIMMERMANN‖, MIGUEL B. ARAÚJO**††, PETER B. PEARMAN*‖, GWENAËLLE LE LAY*, CHRISTIAN PIEDALLU‡‡§§, CÉCILE H. ALBERT‡,

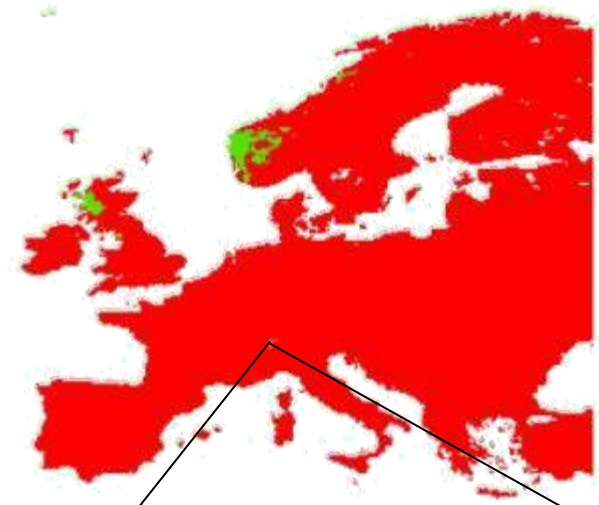
"Projected habitat loss is greater for species **distributed at higher elevations;** depending on the climate scenario, we find **36–55% of alpine species** lose more than 80% of their suitable habitat by 2070–2100."

Engler, Randin *et al.* (2011) *GCB*



Relative sensitivity of florae between European mountain ranges (late 21st century)

Coarse-resolution continental vs High-resolution regional projections

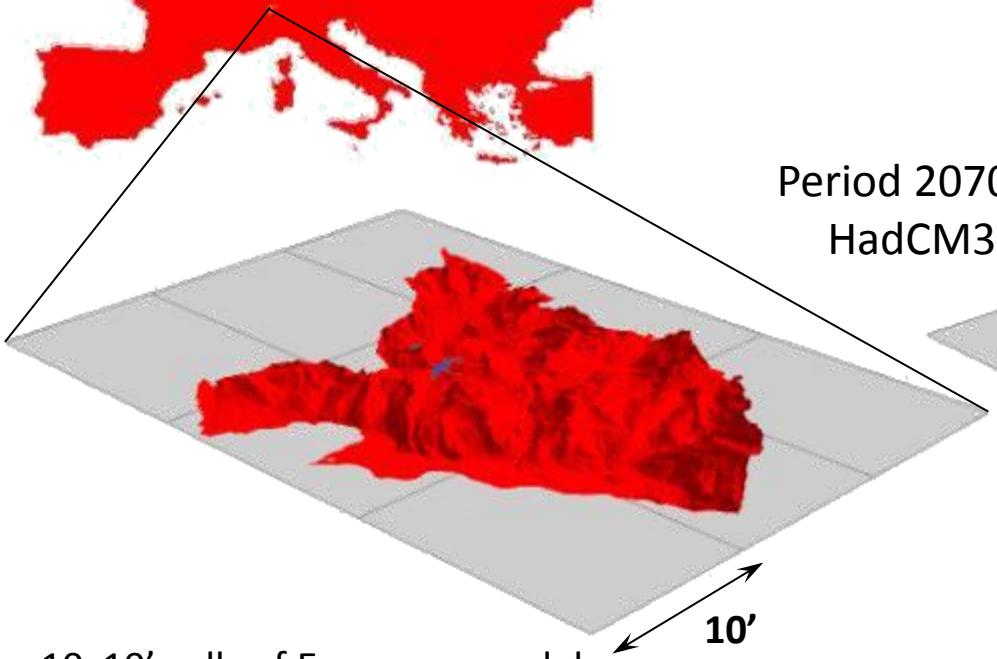


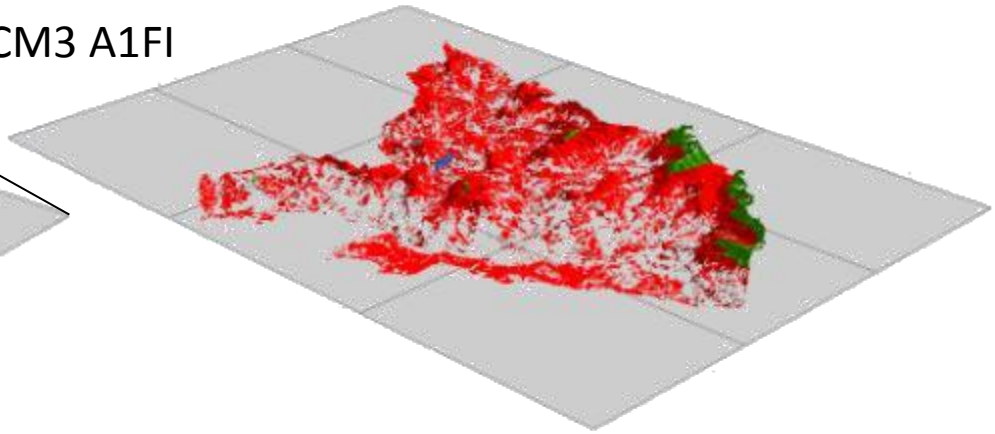
Predicted presence of species

Predicted absence of species

Saxifraga oppositifolia

Period 2070 - 2100
HadCM3 A1FI

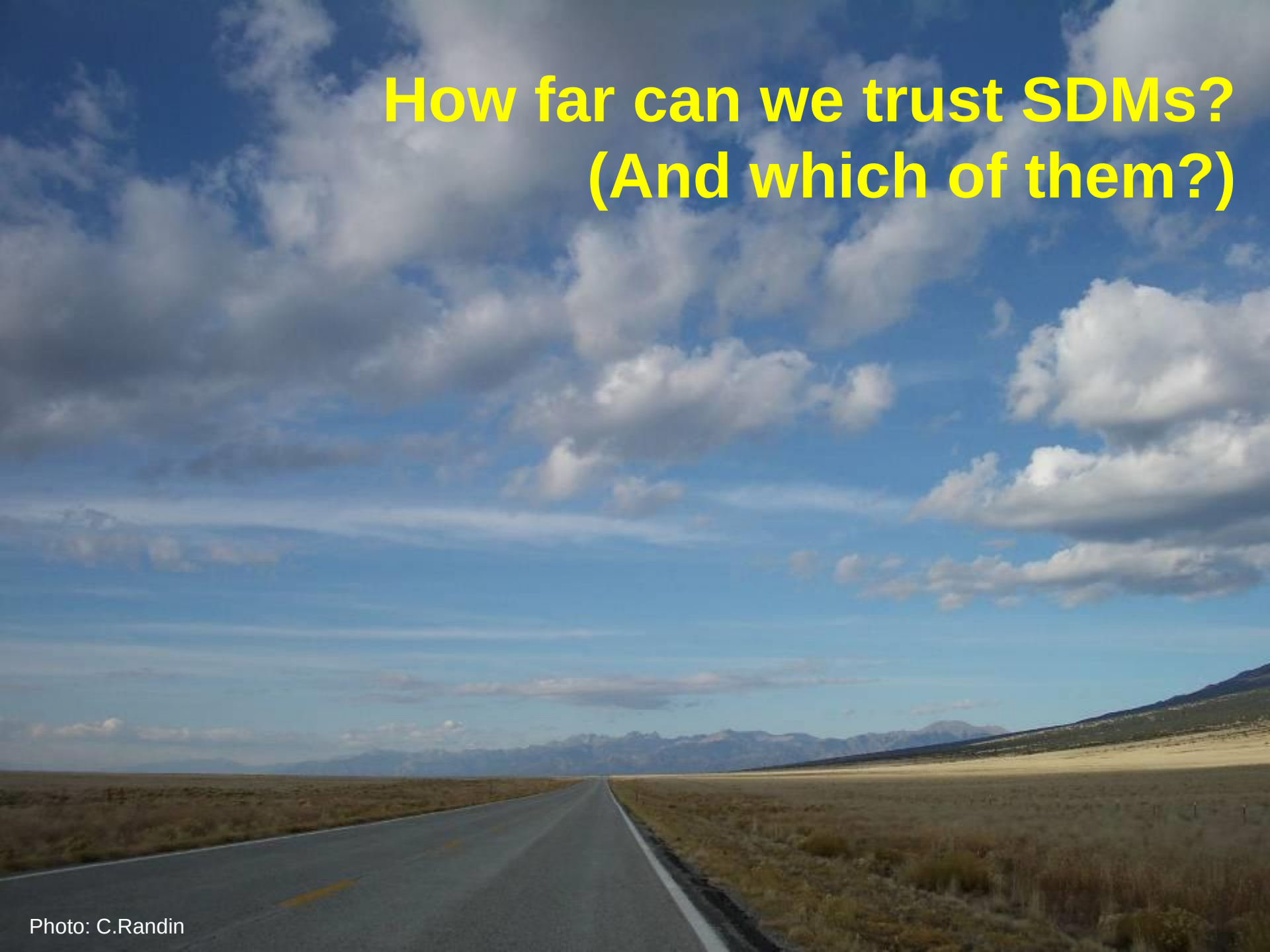




10x10' cells of European models projected at the local scale

Local models (25x25m resolution)

Randin CF, Engler R, Thuiller W *et al.* 2009 *Global Change Biology*


How far can we trust SDMs?
(And which of them?)
Photo: C.Randin

Photos: C.Randin

Dr. Christophe Randin & Prof. Elena Conti (PIs)

Theofania Patsiou & Spyros Theodoridis (PhD students)

Prof. Niklaus Zimmermann & Prof. Christian Körner (collaborators)




Zurich – Basel
Plant Science Center

FNSNF
Swiss National Science F

Parc national du Mercantour

Parco naturale Alpi Marittime

mri mountain research initiative

DIVERSITAS an international programme of biodiversity science

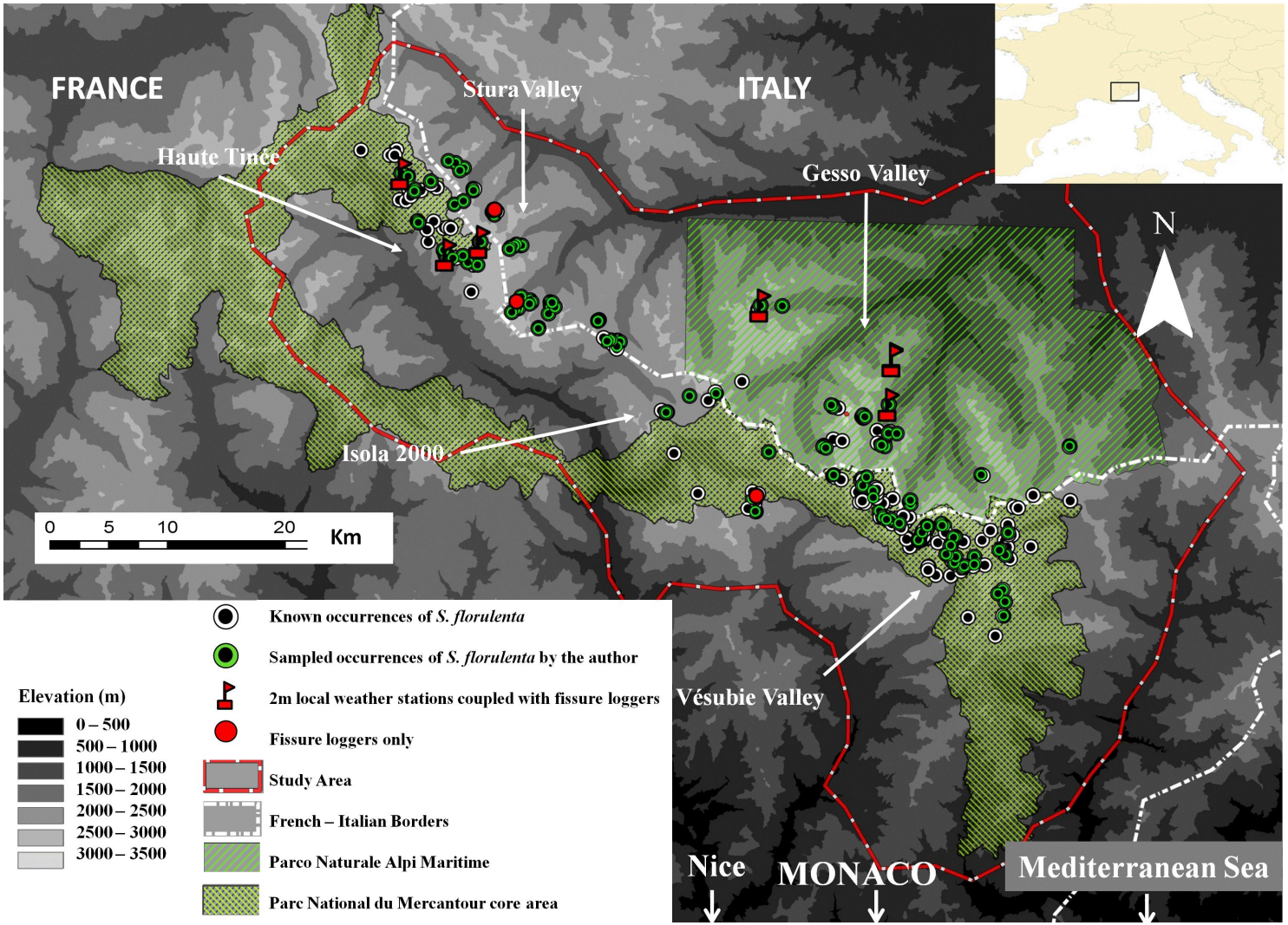
GBMA

Appropriate system to study the persistence of alpine species

Study System: *Saxifraga florulenta*

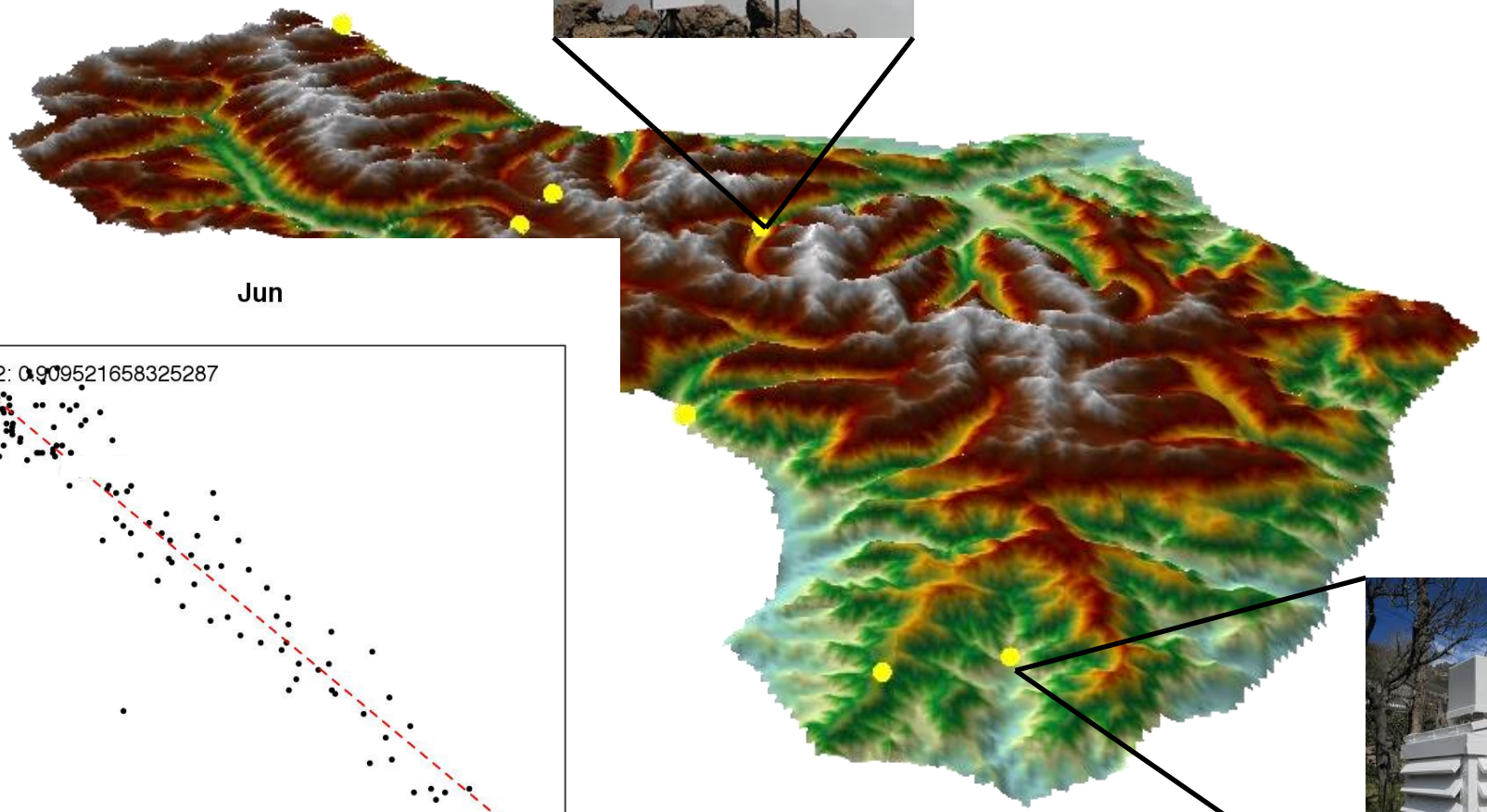
- **Rare endemic** of the **Maritime Alps**: narrow geographical distribution
- **Phylogenetics**: isolated branch in the phylogenetic tree
- **Little genetic variation** (Szövényi *et al.,* 2009)
- **Long life span:** 10-40 years

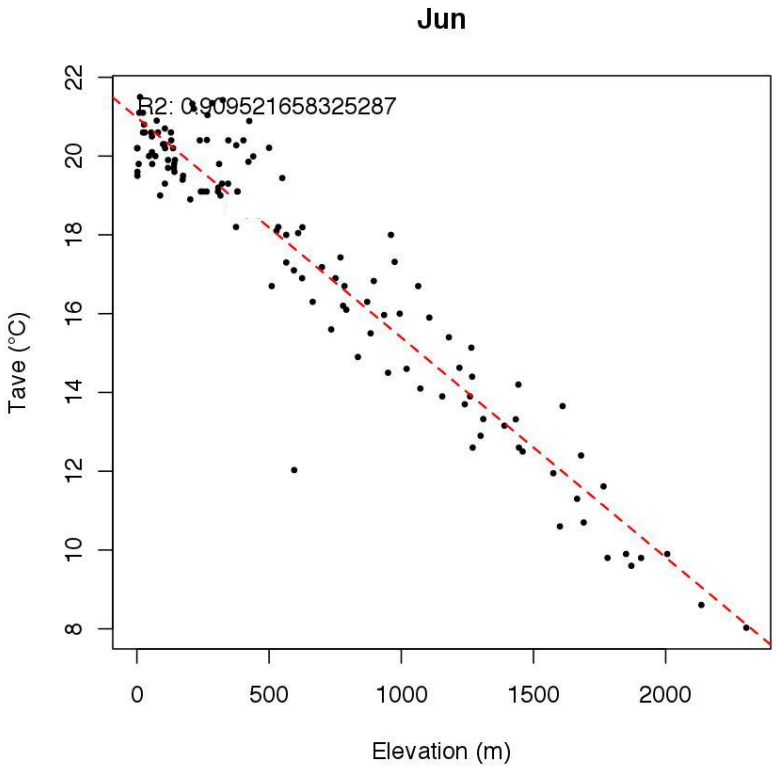
  Monocarpic, short distance dispersal, ability to self
- **Specific topo - climatic requirements:** Alpine zone, N – NW aspect
- **Specific geological requirements**: only on granitic rocks
- **Arctotertiary relictual species**



Patsiou TS, Conti E, Zimmermann NE, Theodoridis S, Randin CF (2014) *Global Change Biology*

Climate predictors for SDMs

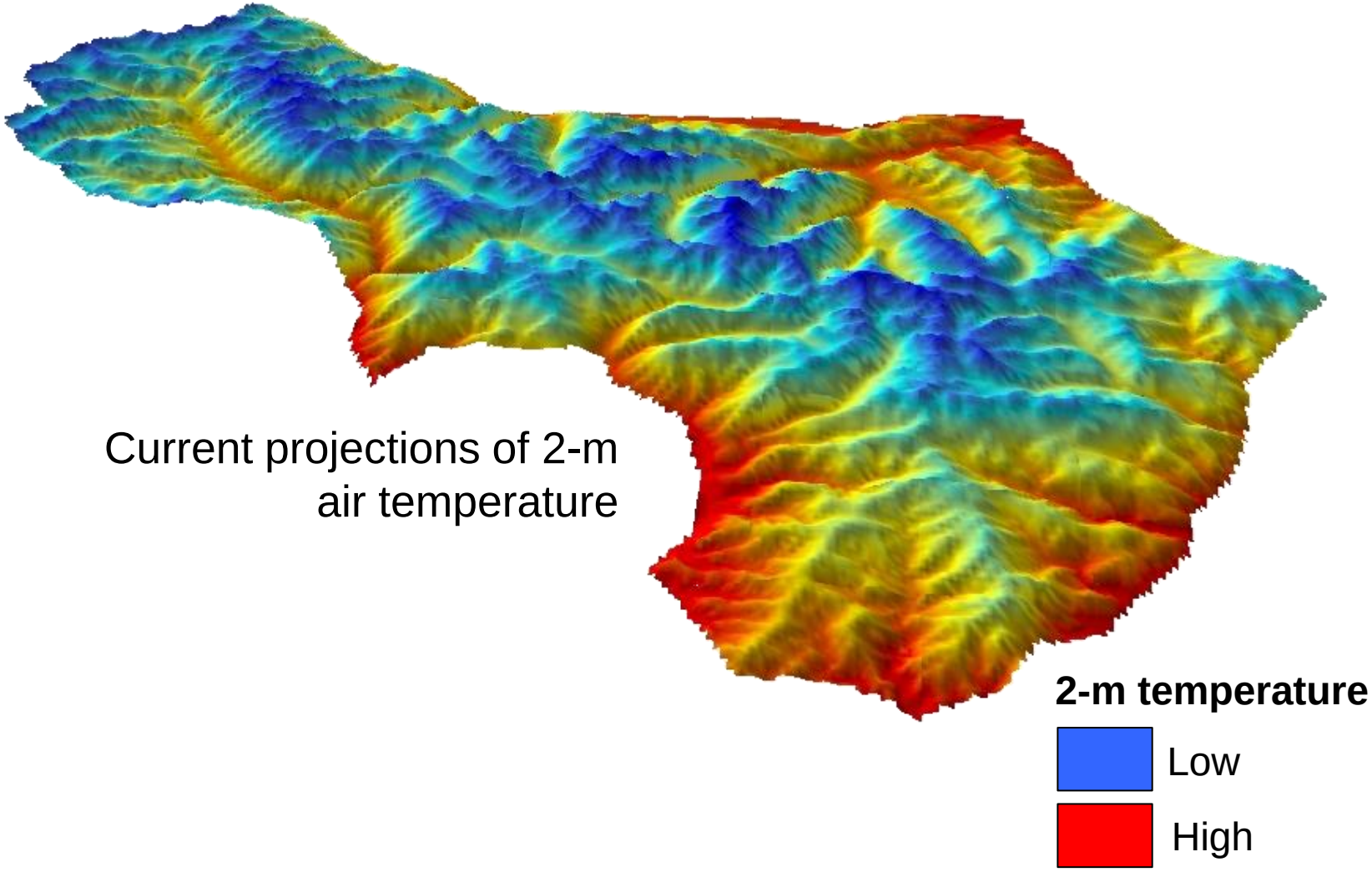




Linear lapse rate with IDW interpolation

Patsiou TS, Conti E, Zimmermann NE, Theodoridis S, Randin CF (2014) *Global Change Biology*

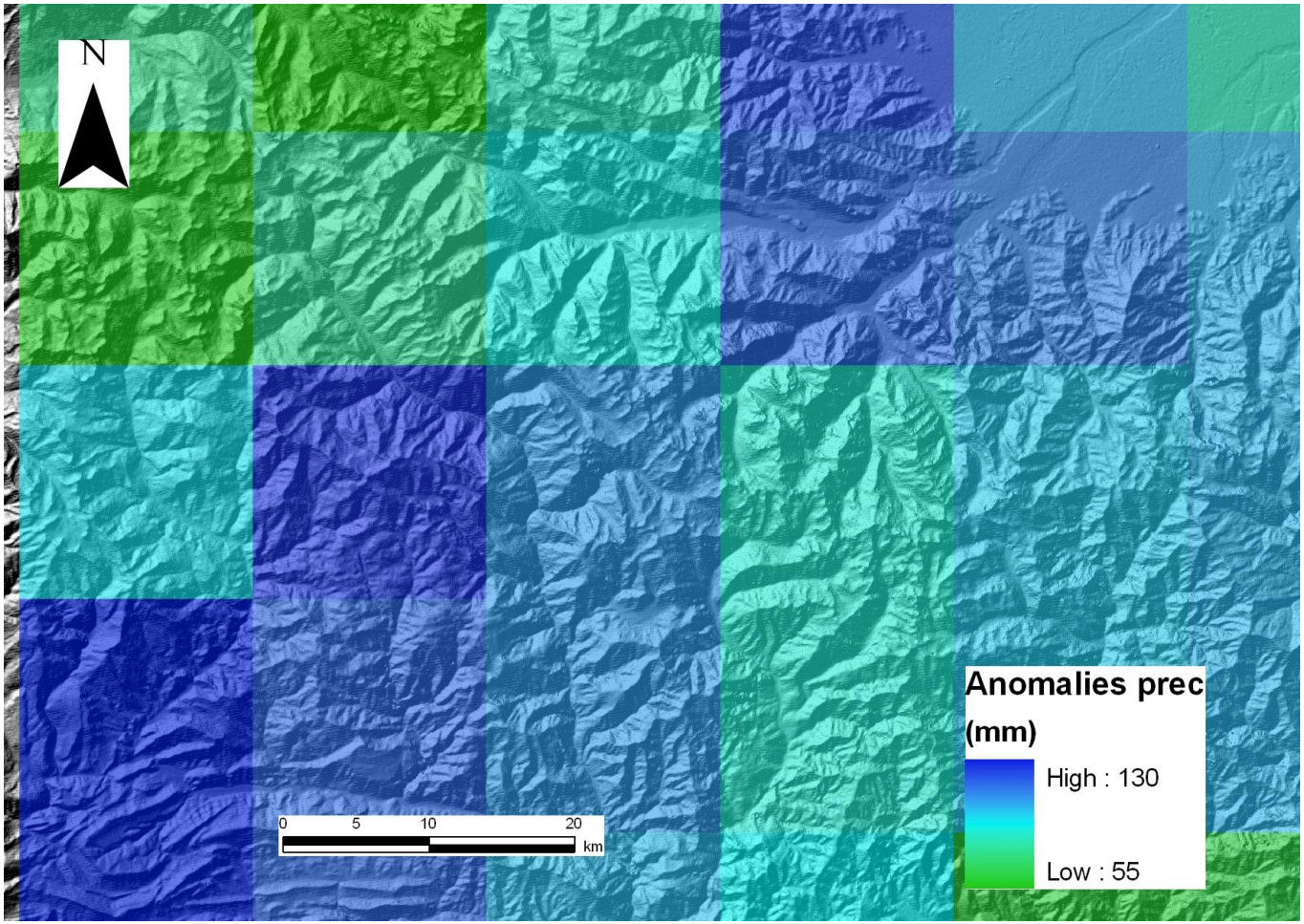
Climate predictors for SDMs



Patsiou TS, Conti E, Zimmermann NE, Theodoridis S, Randin CF (2014) *Global Change Biology*

Back to the Future!

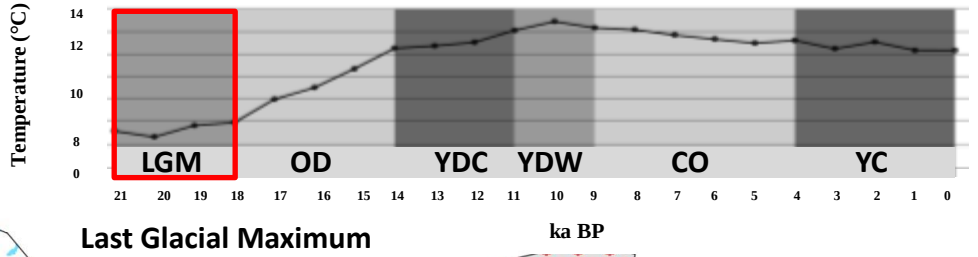
Delta Method: T and P anomalies from statistical downscaling (10'; Maiorano *et al.* 2012 *GEB*)
HadCM3 (-1ky to -21ky) 3.75° x 2.5° (Singarayer & Valdes 2010 *Quaternary Science Reviews*)



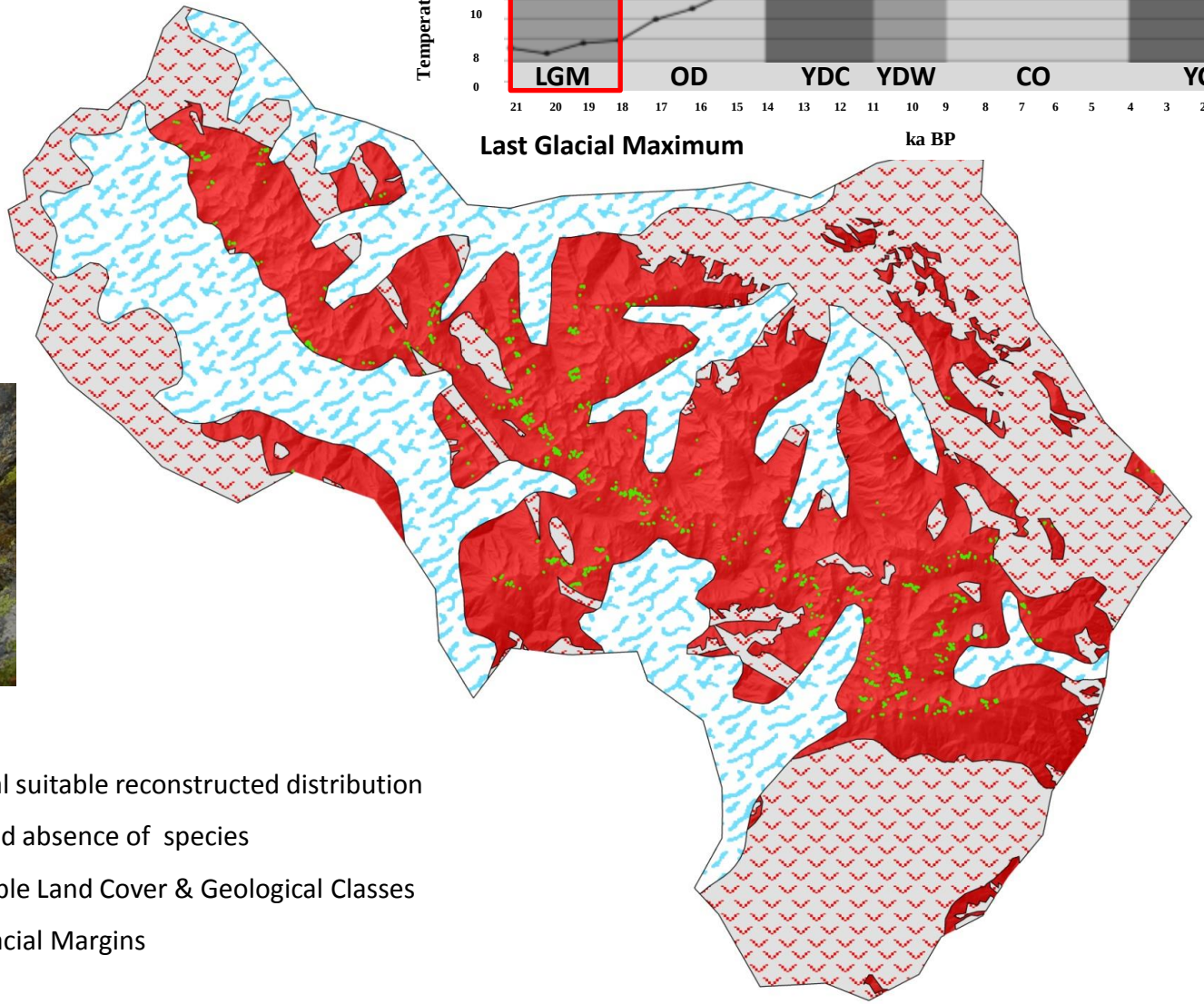
Patsiou TS, Conti E, Zimmermann NE, Theodoridis S, Randin CF (2014) *Global Change Biology*

21 ka BP

Persistence in the species projected realised niche



Last Glacial Maximum



Potential suitable reconstructed distribution

Predicted absence of species

Unsuitable Land Cover & Geological Classes

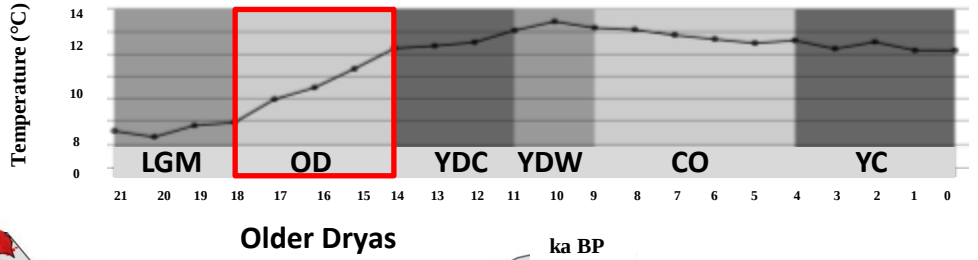
LGM Glacial Margins

Patsiou TS, Conti E, Zimmermann NE, Theodoridis S, Randin CF (2014) *Global Change Biology*

15 ka BP

Model predicts phases of extreme contractions of the species range

Persistence in the species projected realised niche



Older Dryas

Potential suitable reconstructed distribution

Predicted absence of species

Unsuitable Land Cover & Geological Classes

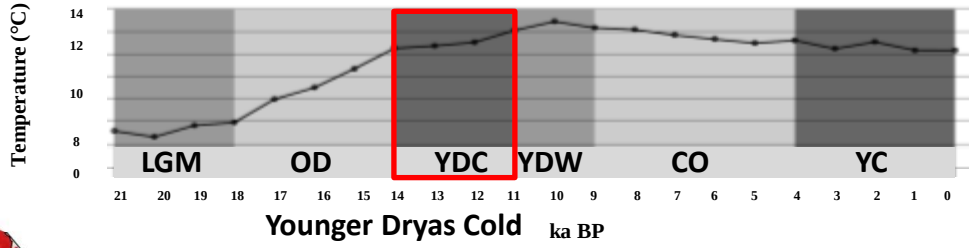
LGM Glacial Margins

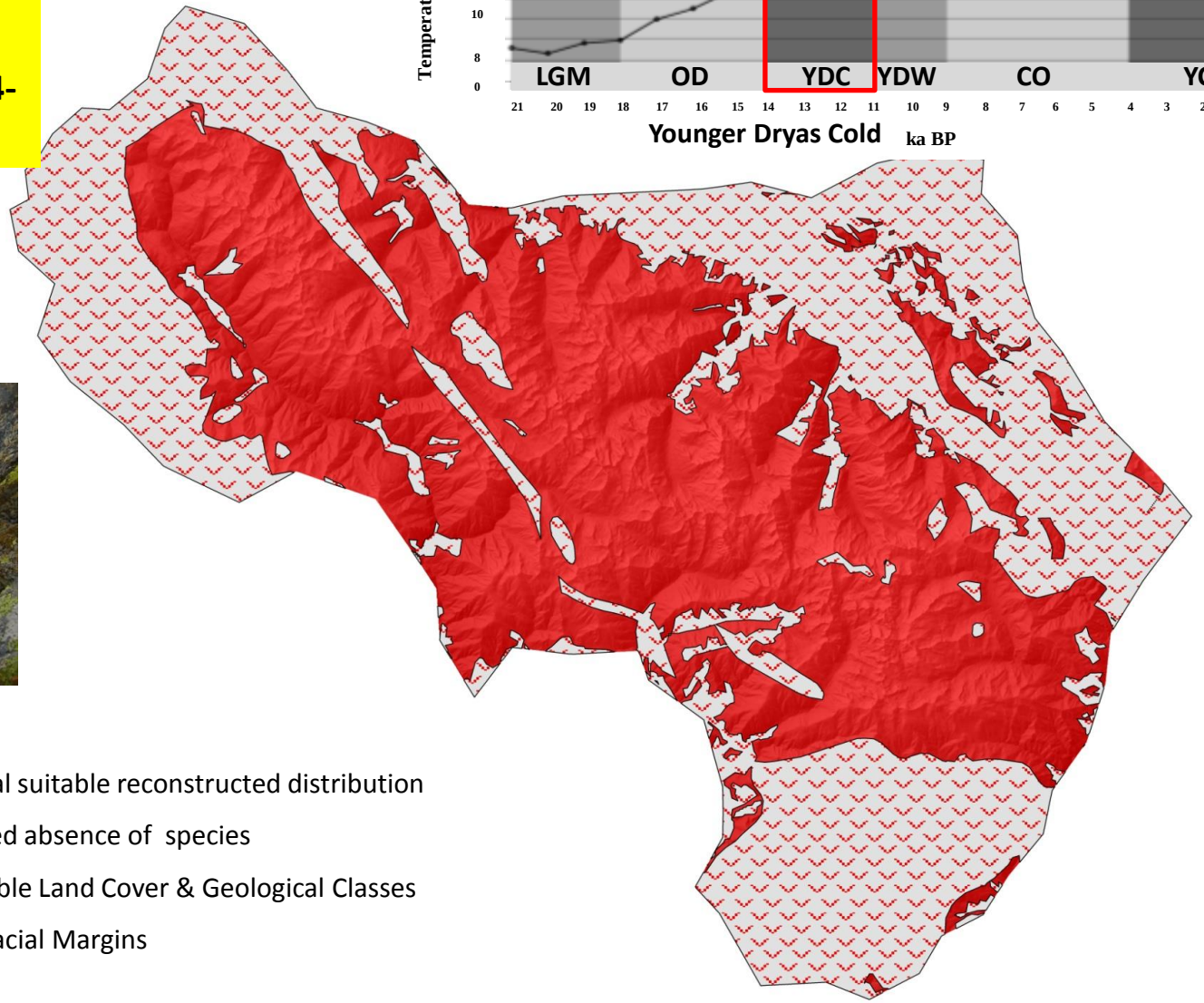
Patsiou TS, Conti E, Zimmermann NE, Theodoridis S, Randin CF (2014) *Global Change Biology*

13 ka BP

S. florulenta predicted extinct from 14-9 ka BP!

Persistence in the species projected realised niche





Potential suitable reconstructed distribution

Predicted absence of species

Unsuitable Land Cover & Geological Classes

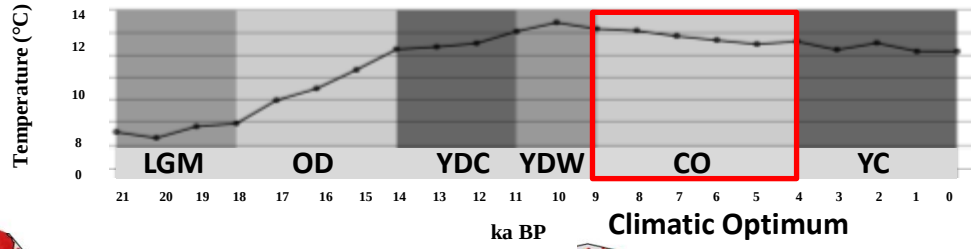
LGM Glacial Margins

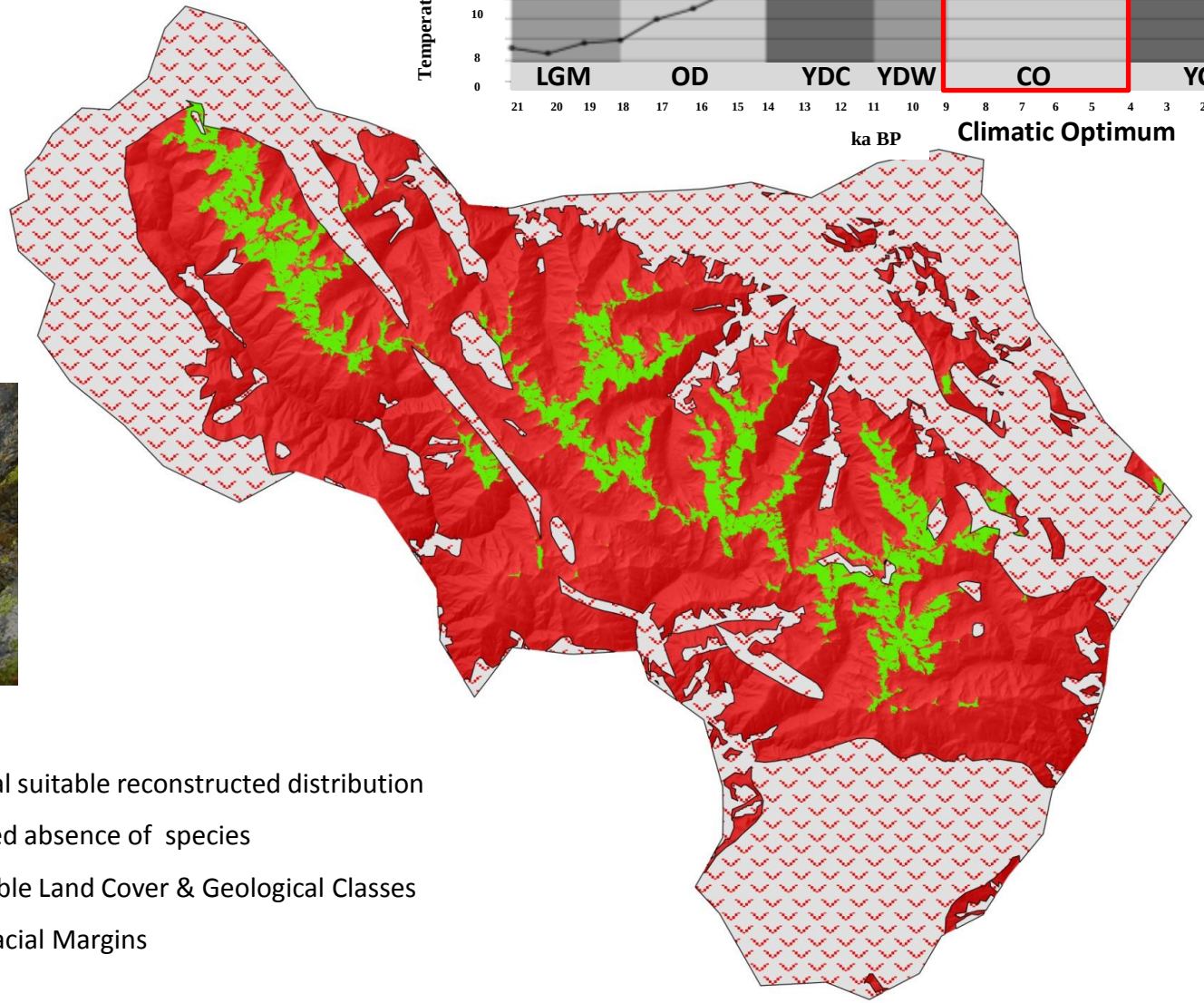
Patsiou TS, Conti E, Zimmermann NE, Theodoridis S, Randin CF (2014) *Global Change Biology*

8 ka BP

Macrorefugia: Persistence in the species projected realised niche

The species range expands at 8 ka BP!





Potential suitable reconstructed distribution

Predicted absence of species

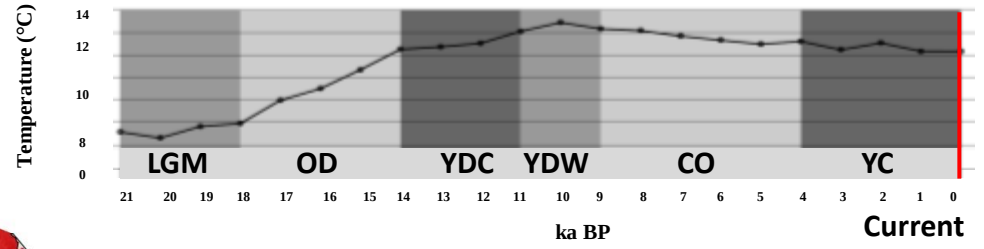
Unsuitable Land Cover & Geological Classes

LGM Glacial Margins

Patsiou TS, Conti E, Zimmermann NE, Theodoridis S, Randin CF (2014) *Global Change Biology*

0 ka BP

Macrorefugia: Persistence in the species projected realised niche



Known occurrences

Potential suitable reconstructed distribution

Predicted absence of species

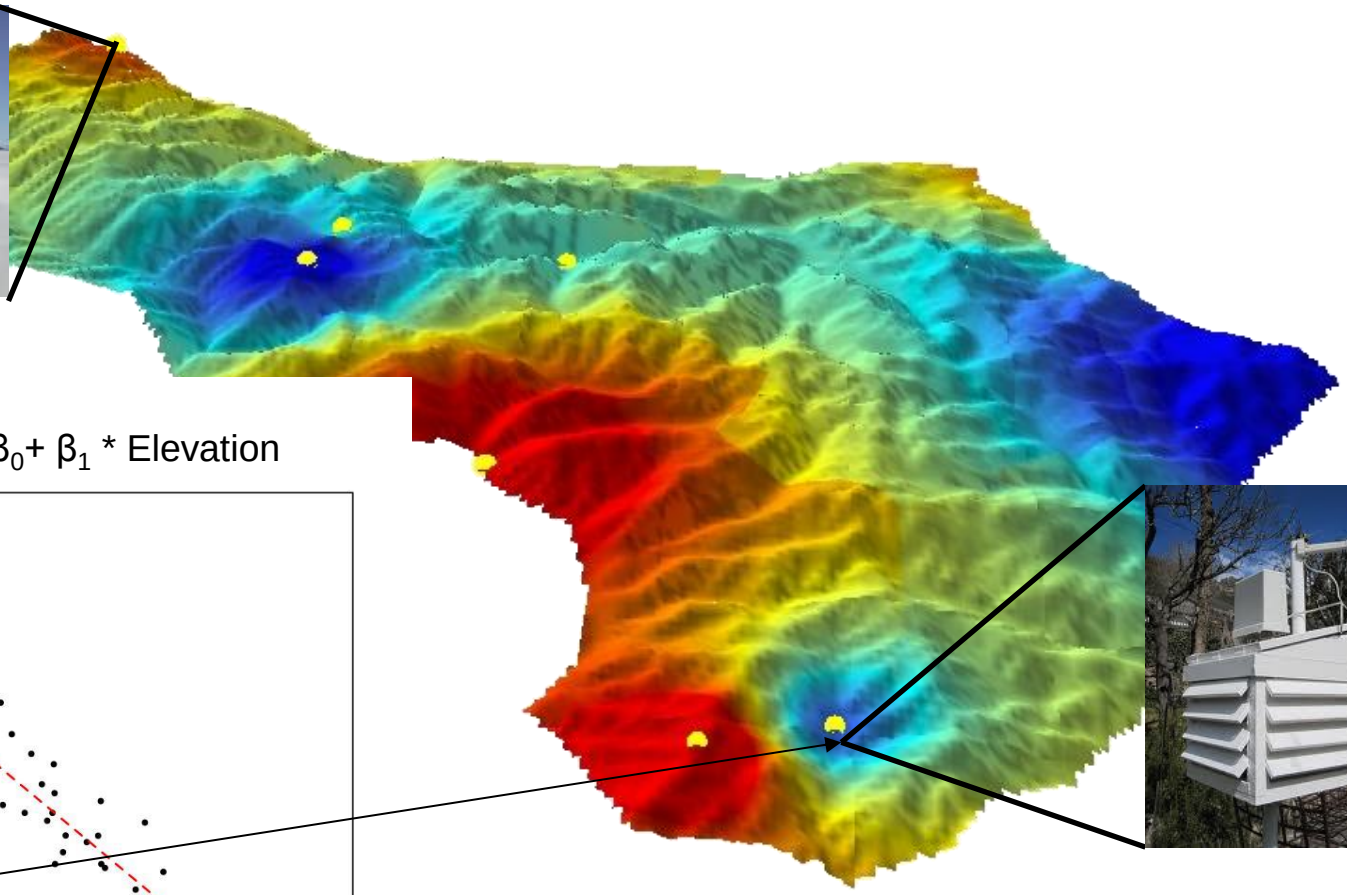
Unsuitable Land Cover & Geological Classes

LGM Glacial Margins

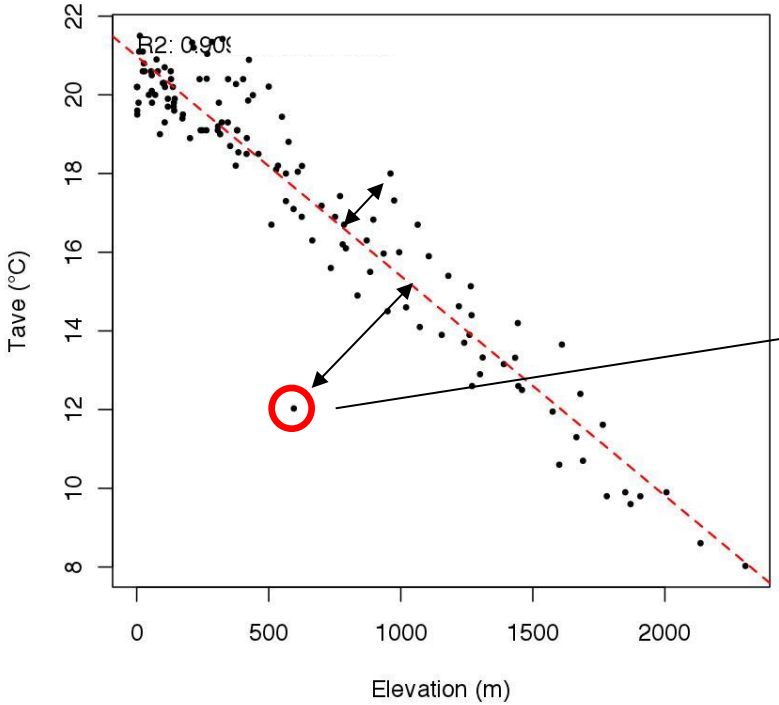
Patsiou TS, Conti E, Zimmermann NE, Theodoridis S, Randin CF (2014) *Global Change Biology*


Photo: T. Patsiou

Temperature anomalies vs. linear lapse rate



Eq: Pred. T ° = $\beta_0 + \beta_1$ * Elevation



Temperature

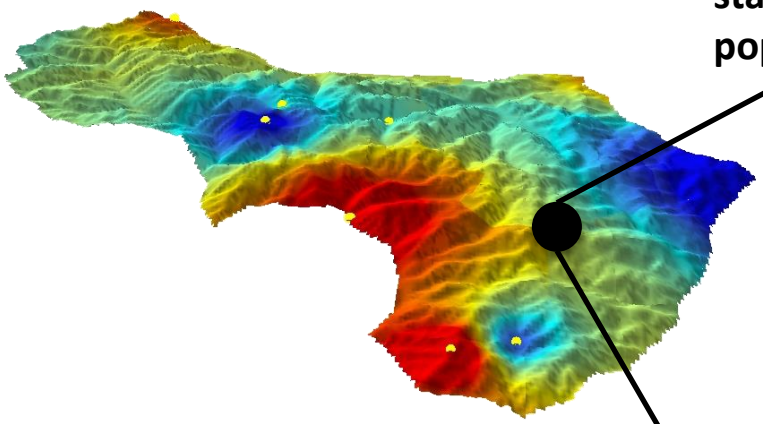
Low

High

Temperature at the regional, local and micro scales

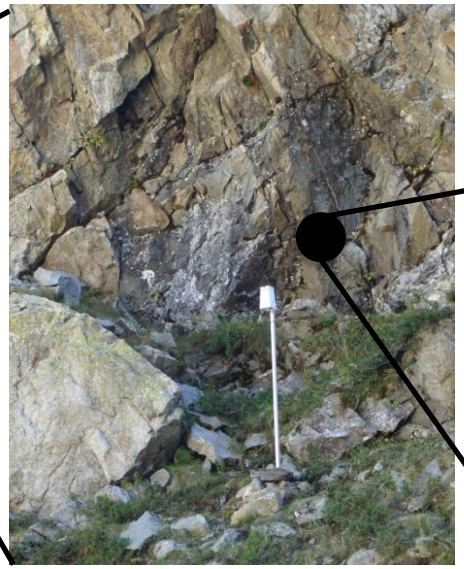
Macro-climate

Geographic **temperature projections** interpolated from national network of weather stations



Local climate

standard-**2m meteo stations** at the populations sites (local climate)



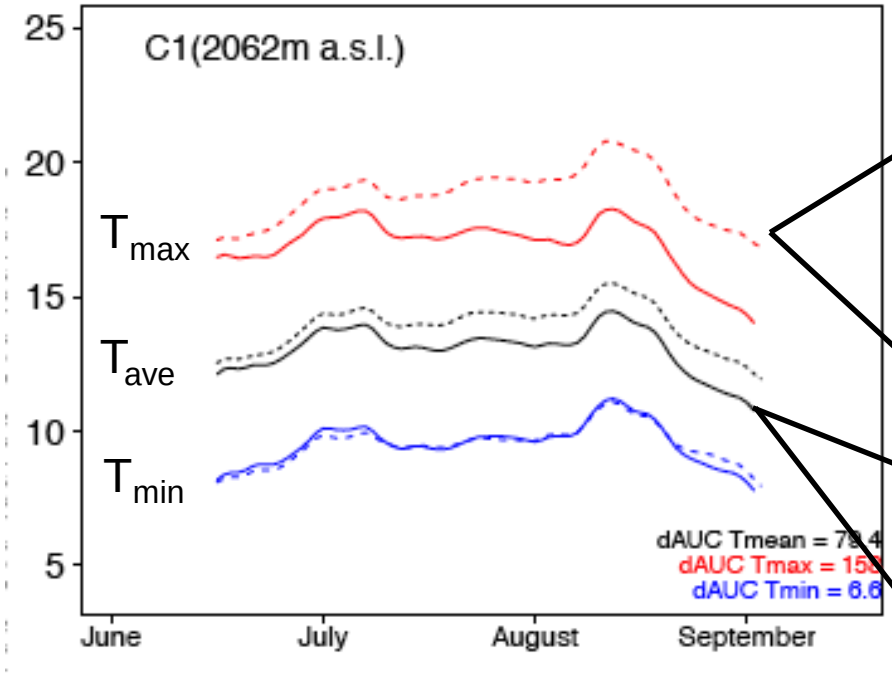
Microclimate

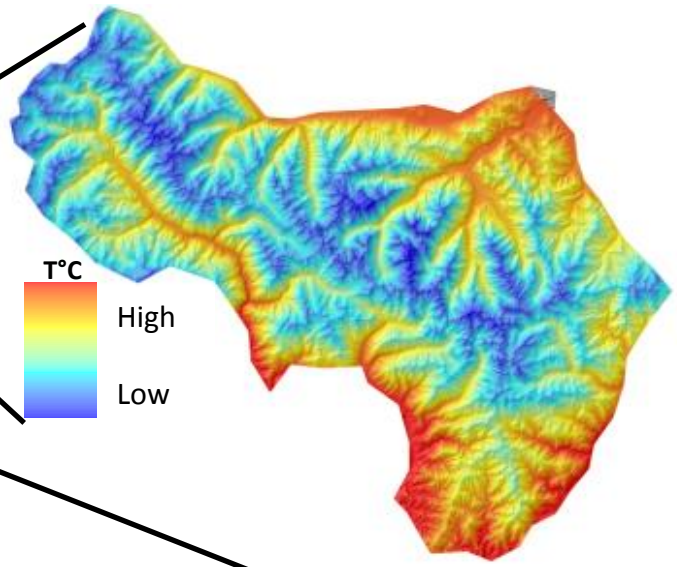
Temperature in **shadowed fissures** next to *S. florulenta* individuals

Geographic Scale

Large → **Fine**

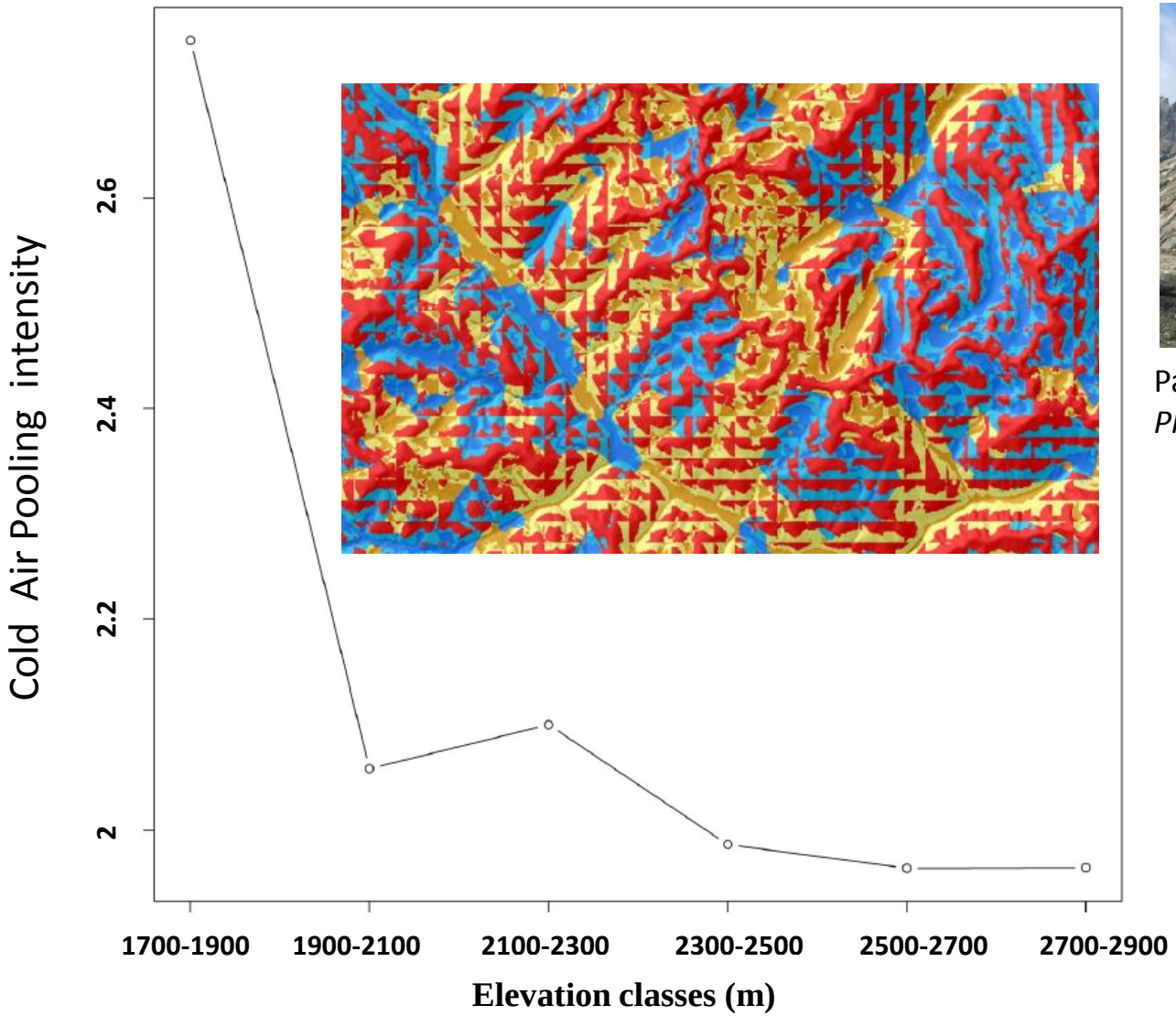
Regional projections vs. local- and micro-scale measurments





Patsiou *et al.* (2017) *Plant Ecology & Diversity*

Low and middle elevation populations of *S.florulenta* are in locations prone to Cold Air Pooling (CAP)!



Patsiou *et al.* (2017)
Plant Ecology & Diversity

Wish list to the climate community

Saxifraga florulenta persistence could not be explained by **classical species distribution model (SDM) techniques**

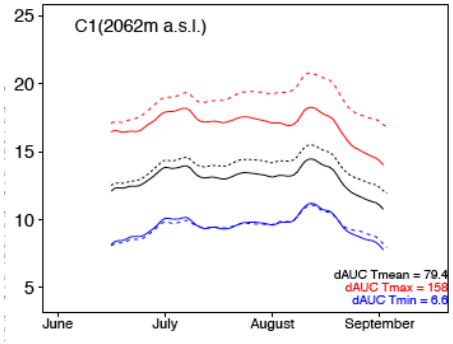
S. florulenta more likely persisted in **microrefugia (thermal microhabitat)**

Failure to predict persistence: unability of geographic climate layers to capture thermal microhabitats.

➔ **Higher <u>spatial resolution</u> climate datasets (with appropriate downscaling procedures)**

➔ **Take local physical properties of the landscape into account (CAP, inversion,…)**

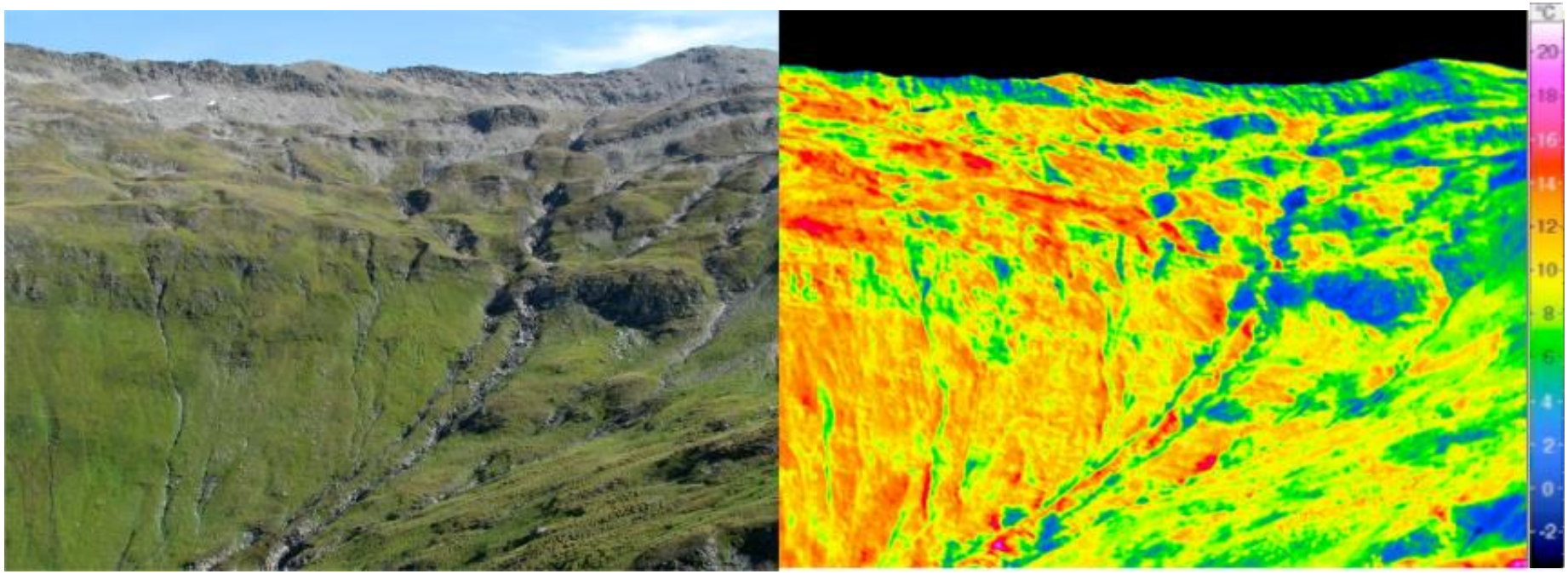
➔ **<u>Daily projections</u> (reference and future time periods)**



Topographic complexity allows the formation of thermal microhabitats

Alpine landscape

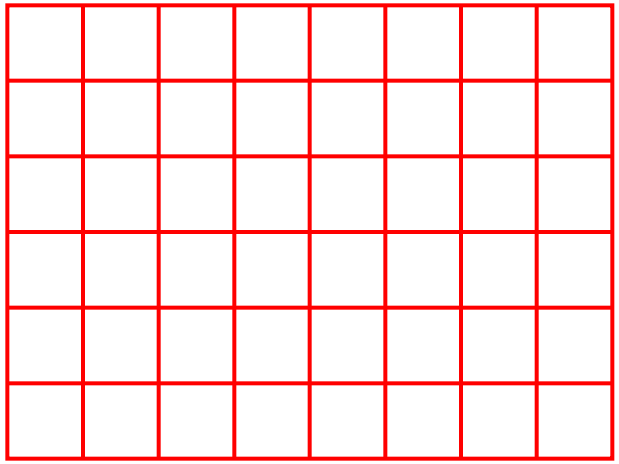
Temperature recorded with a thermal camera

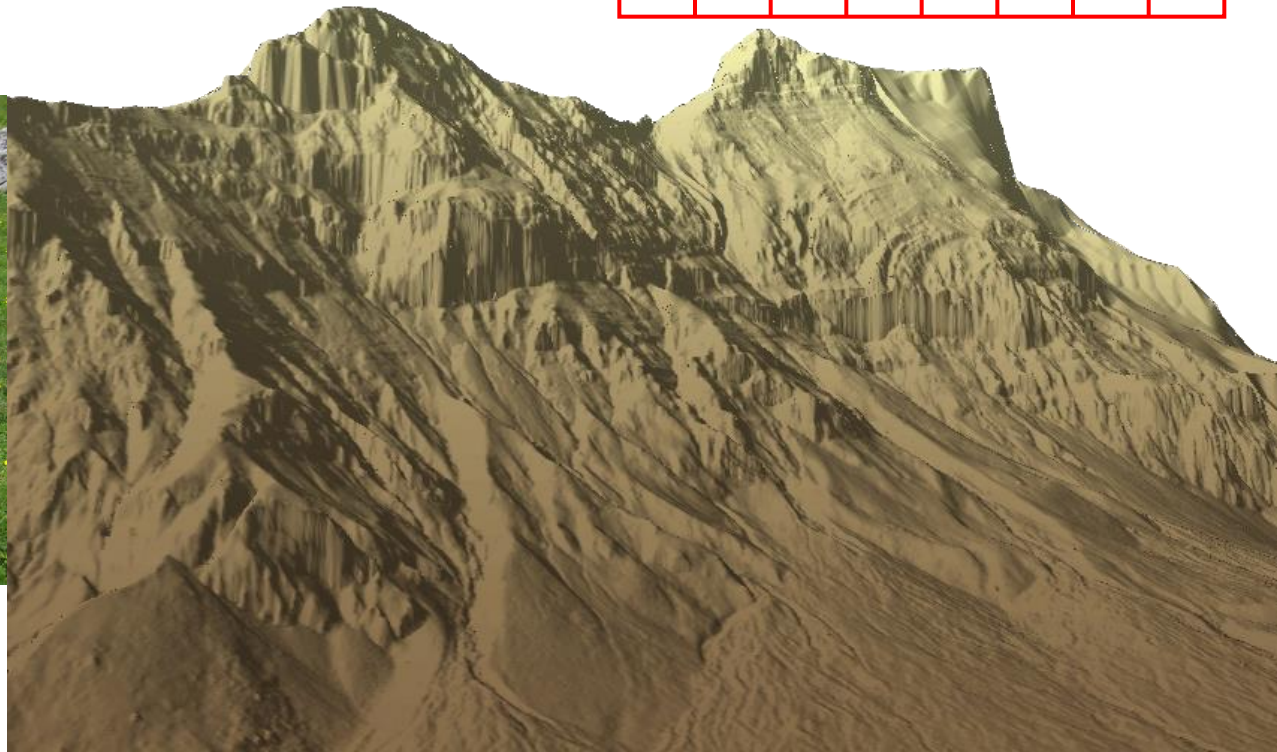


Scherrer & Körner 2011 *Journal of Biogeography*

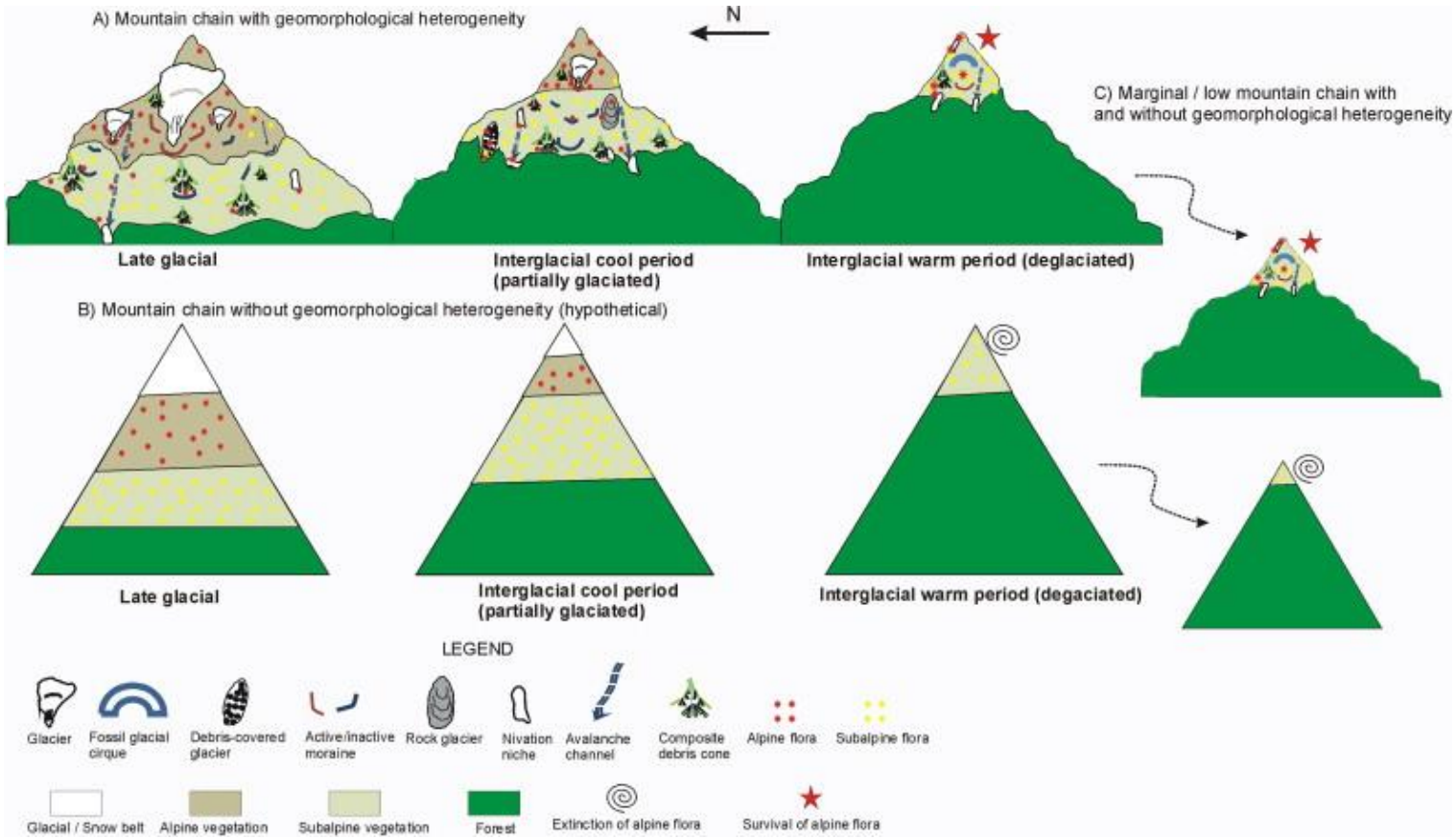
See also
Scherrer & Körner 2010 *Global Change Biology*
Dobrowski 2011 *Change Biology*

Higher spatial resolution of DEM required for climate projections?





Preserve the alpine landscape in the Mediteranean mountains!



Gentili *et al.* (2014) *Ecological Complexity*

Impacts of global change on mountain ecosystems?




Physiological processes

- **Phenological shifts (S_T)**
- Changes in growth rate

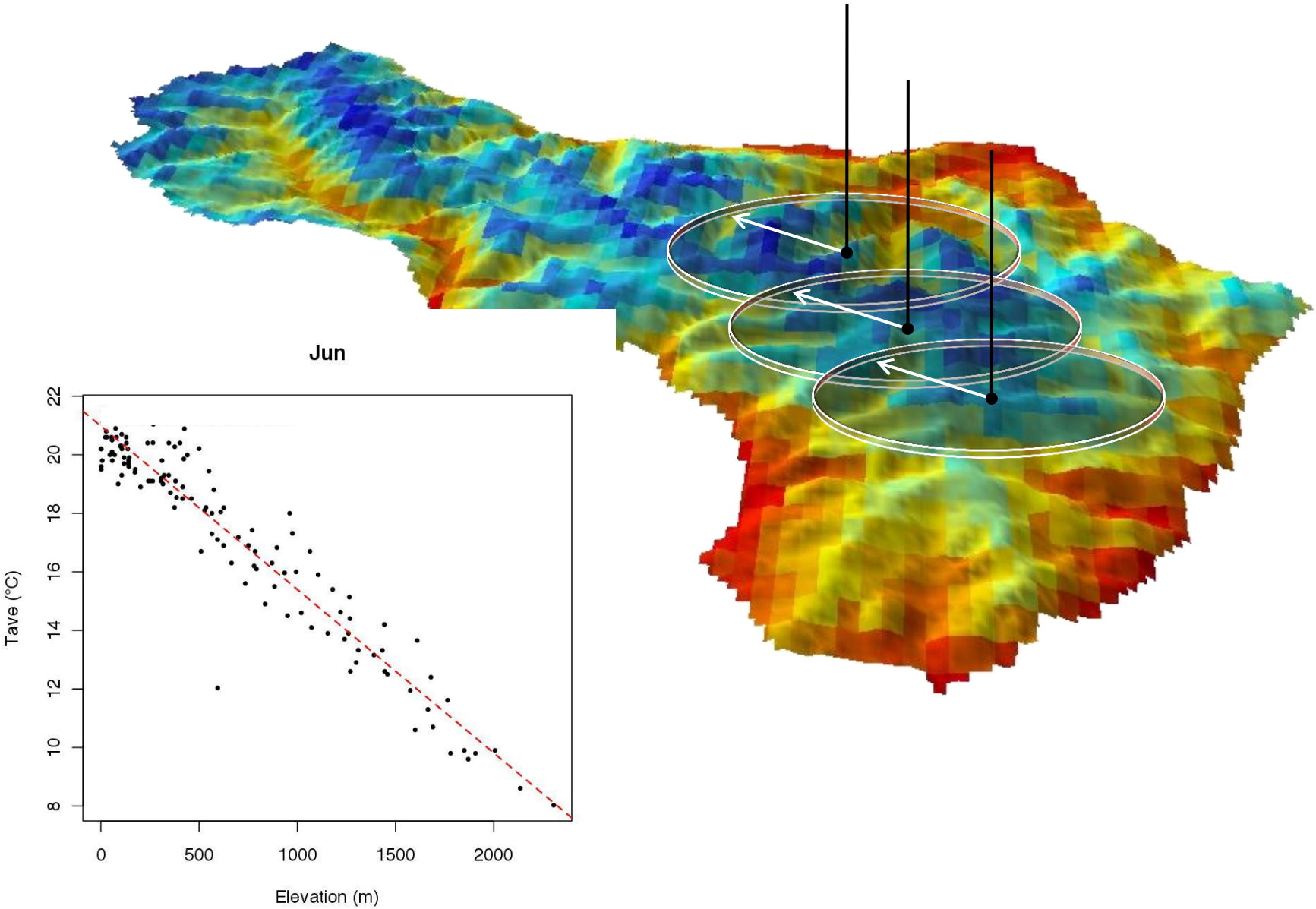
Biogeographical processes


- Range shifts
- Alterations of community composition
- Alterations of ecosystem functions and services

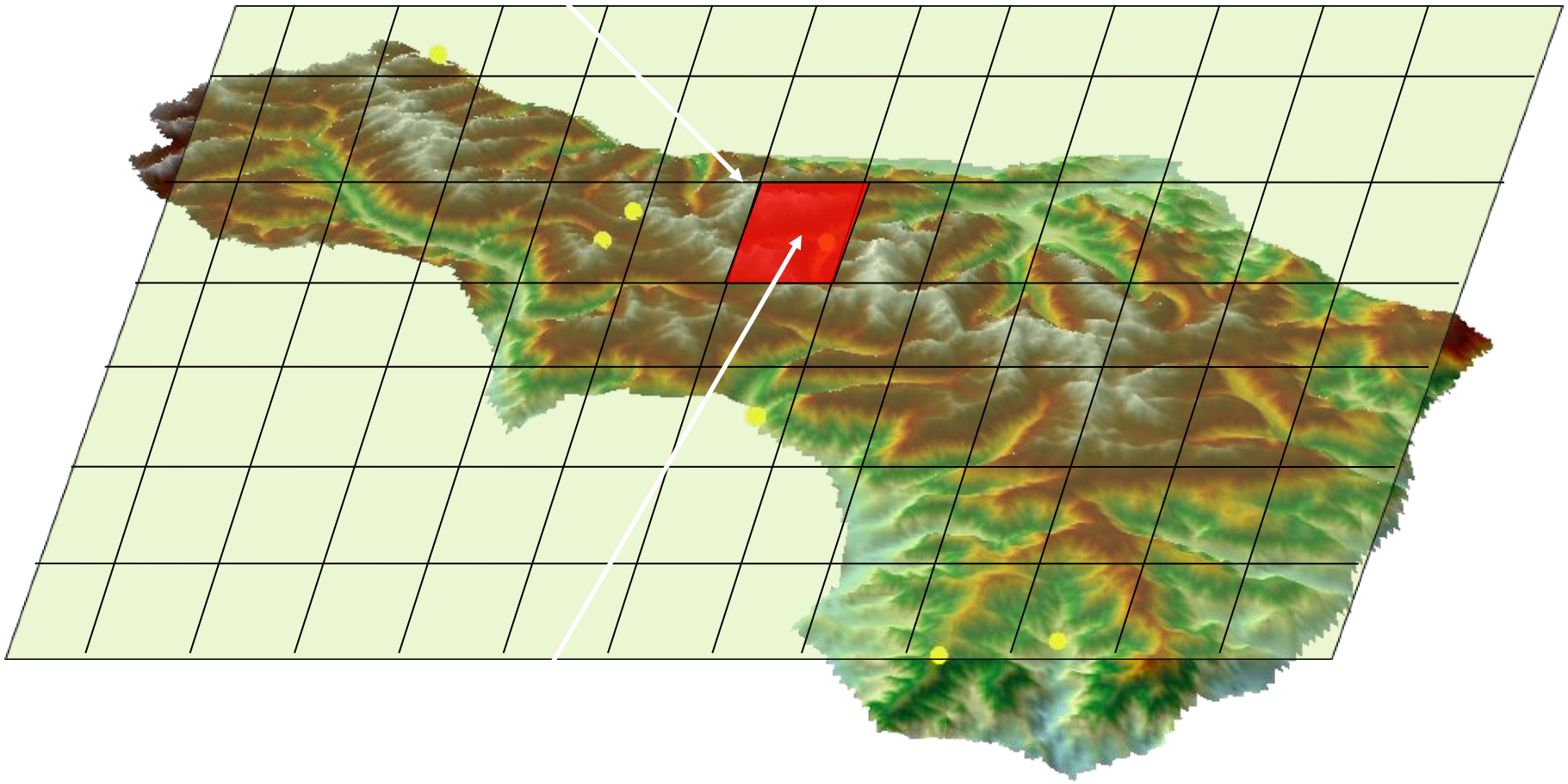
Thanks for your attention!
Questions?

Photo: C.Randin

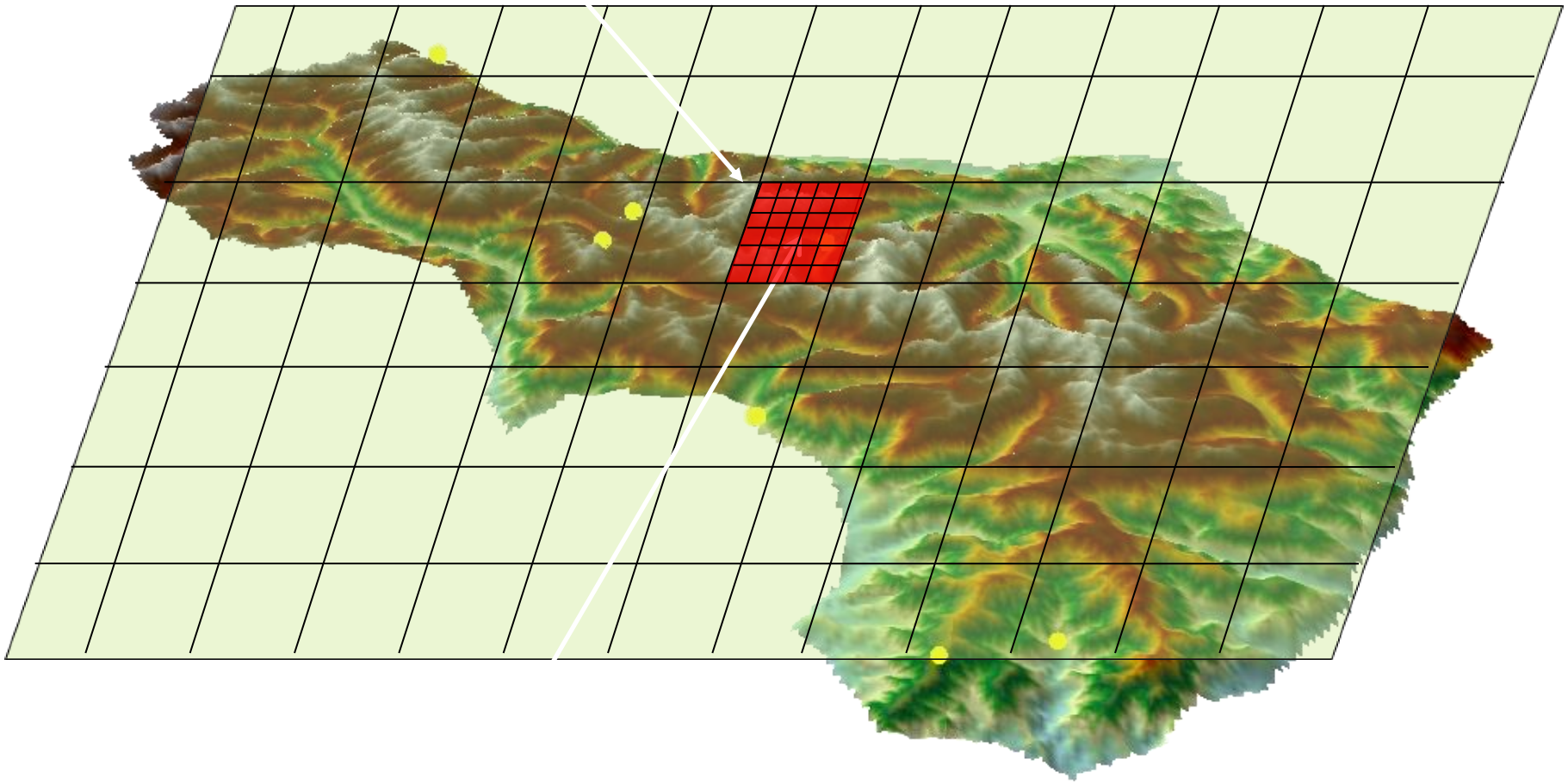
2. Empirical downscaling



2. Empirical downscaling



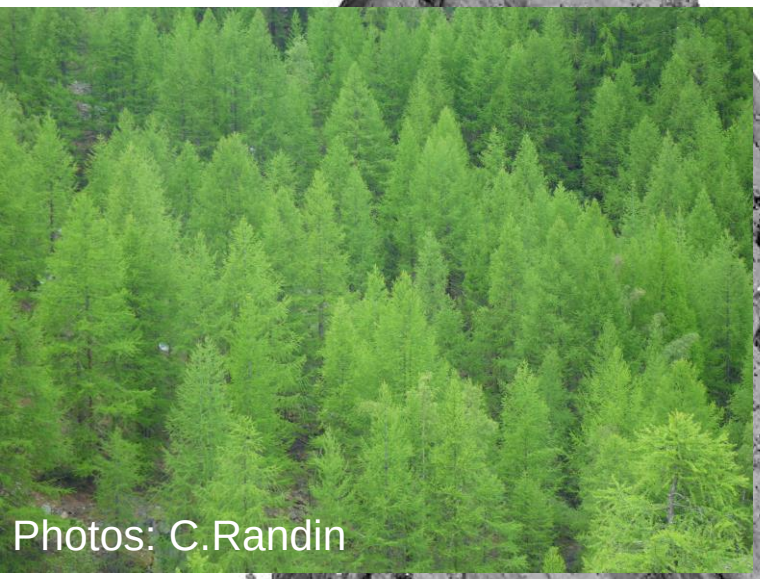
2. Empirical downscaling

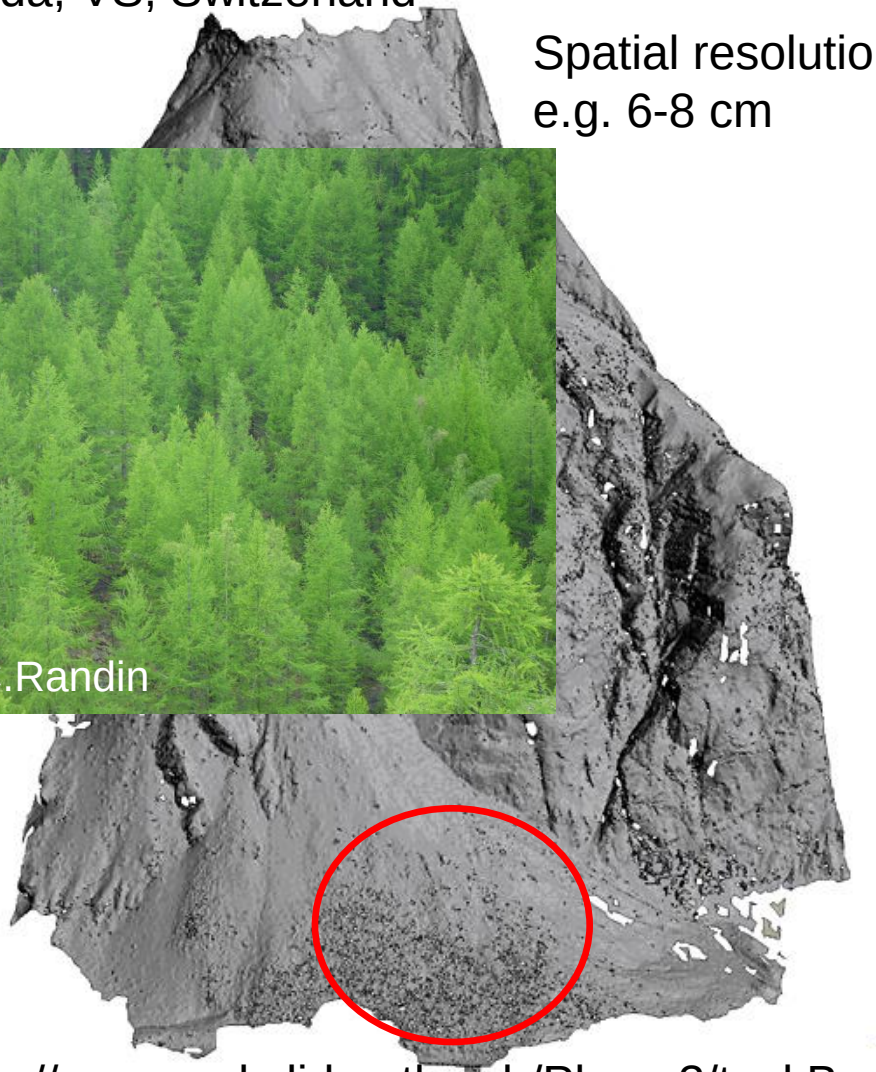


Higher spatial resolution of DEM required?

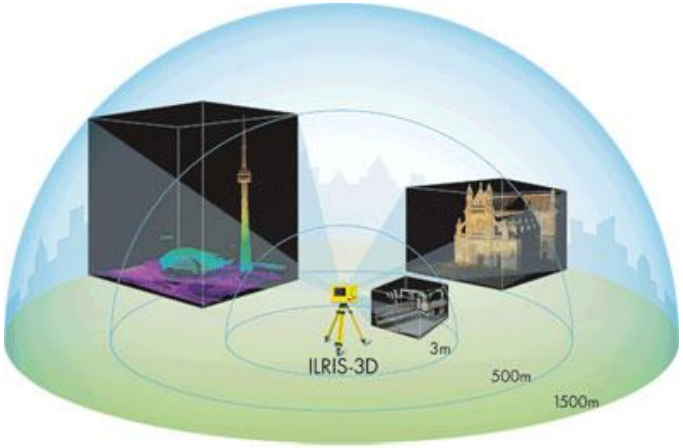
Randa, VS, Switzerland

Spatial resolution:
e.g. 6-8 cm





Portable LIDAR scanner



http://www.rockslide.ethz.ch/Phase3/taskB