Climate change and alpine flora: Predicting future plant distributions

Antoine Guisan
Pascal Vittoz, Christophe Randin, Robin Engler, Peter Pearman

Swiss Global Change Day 2008

Outline

Part 1: Biological Fingerprints

Part 2: Predicting future distributions

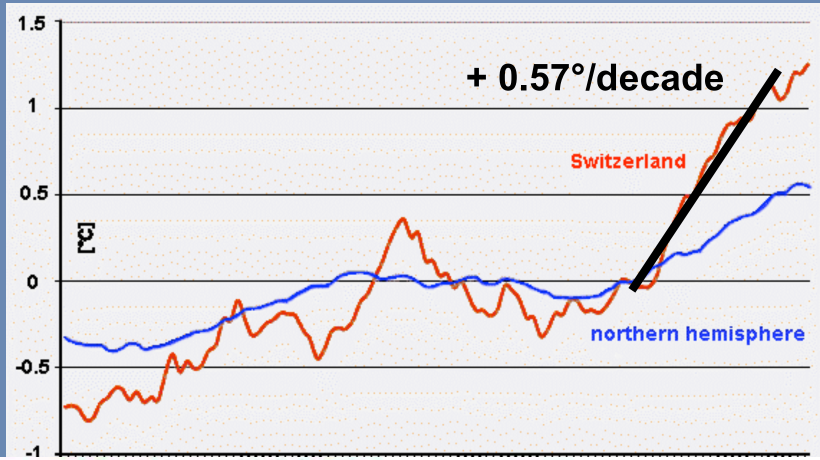
Part 3: Challenging the projections

Conclusion

Part 1:

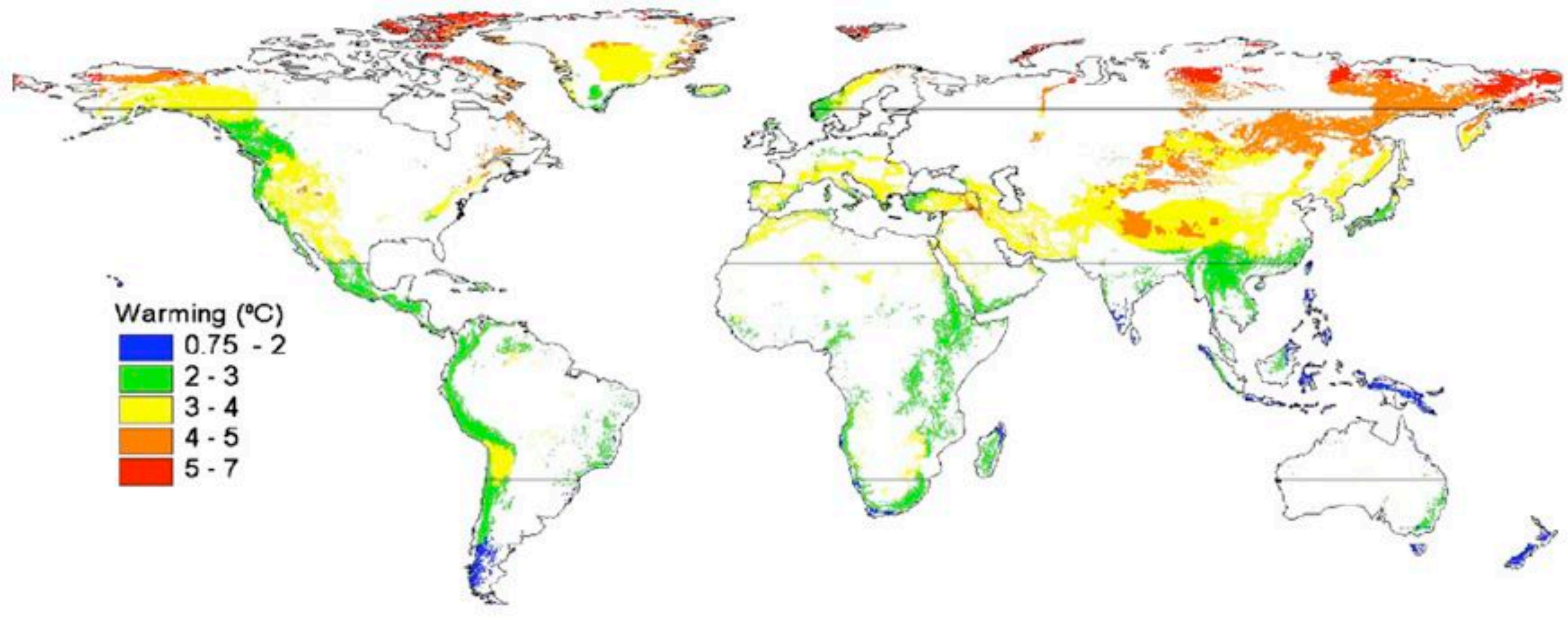
Biological fingerprints of climate change in mountain flora

Warming planet – warming mountains !



observed

Projected by 2080



Rebetez & Reinhard 2007 *TAC* | Nogues-Bravo et al 2007 *GEB*

How can plant respond to climate change?

- Adapt to the changing climate
- Track suitable climate (migration)
- Get extinct

Studies of Holocene climate changes suggest that at least many species shifted their range rather than adapted to unsuitable climate

Do we have any evidence of biological changes resulting from recent climate change?

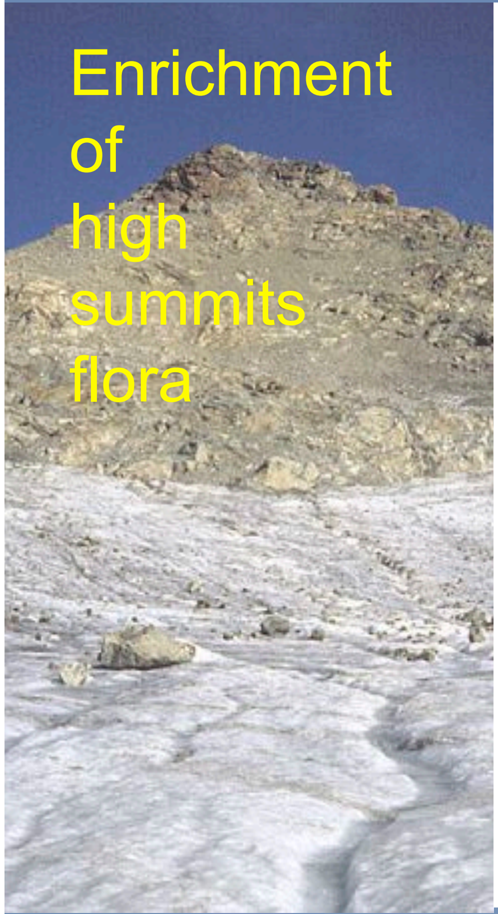
Theurillat & Guisan (2001) *Climatic Change* | Huntley (1991) *Annals of Botany*

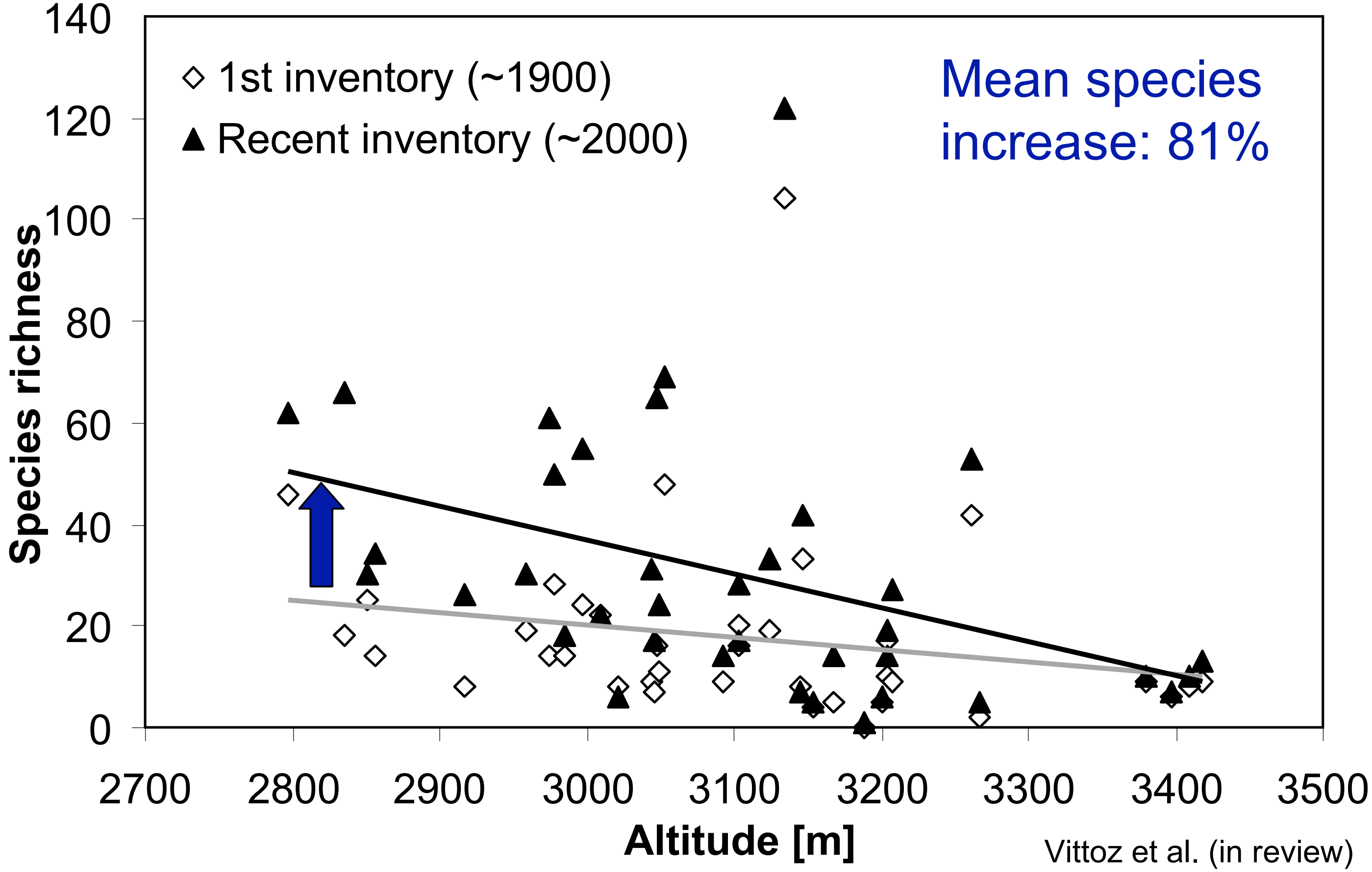
Glacier retreat and vegetation colonisation

Picture 2005: P. Vittoz

P. Vittoz, permanent.plot.ch project archives

Upward species migrations

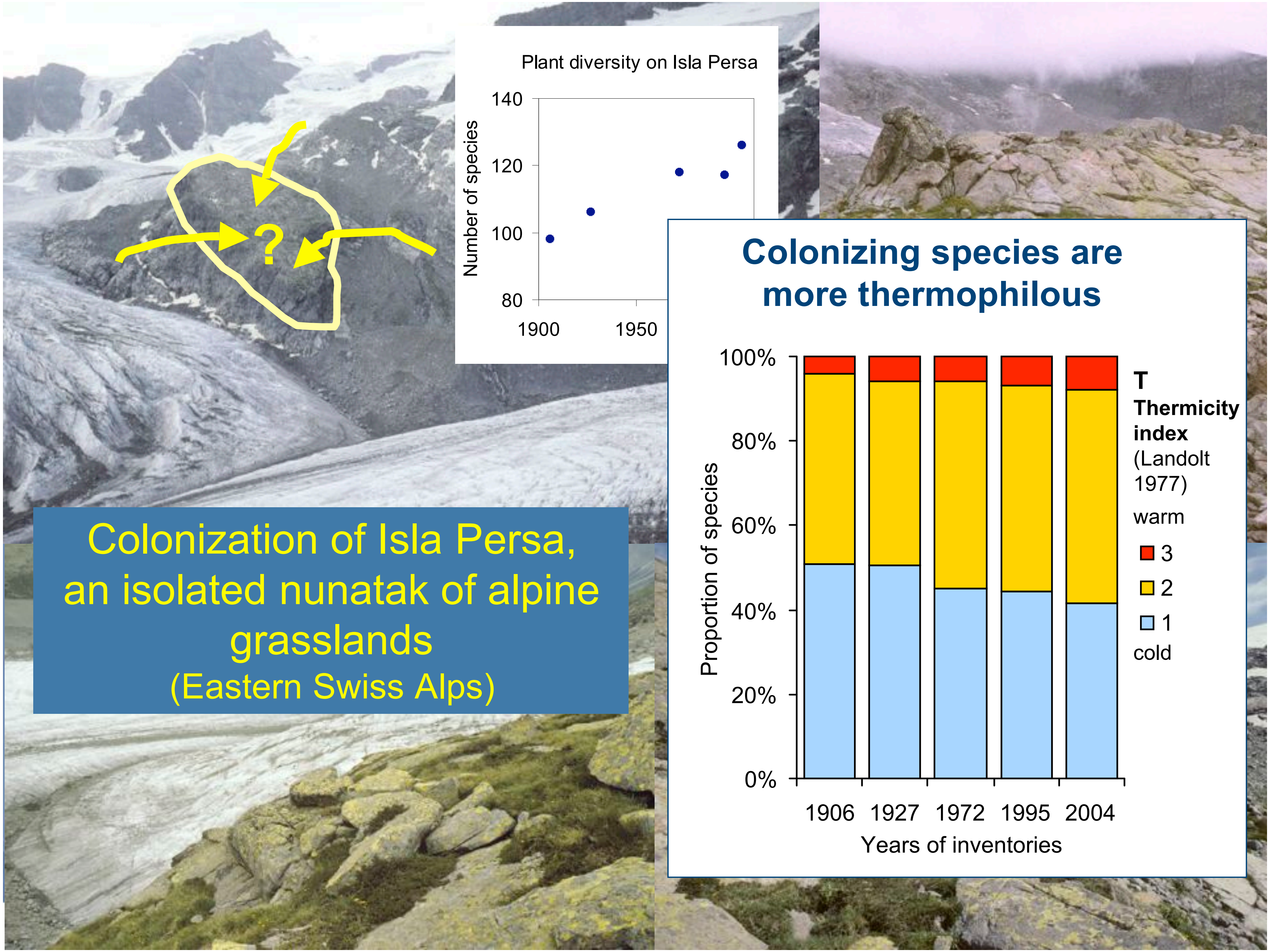




Vittoz et al. (in review)

Due to: - expanded growing season (spring 15-19 days earlier)
- high invasibility of open alpine/nival habitats

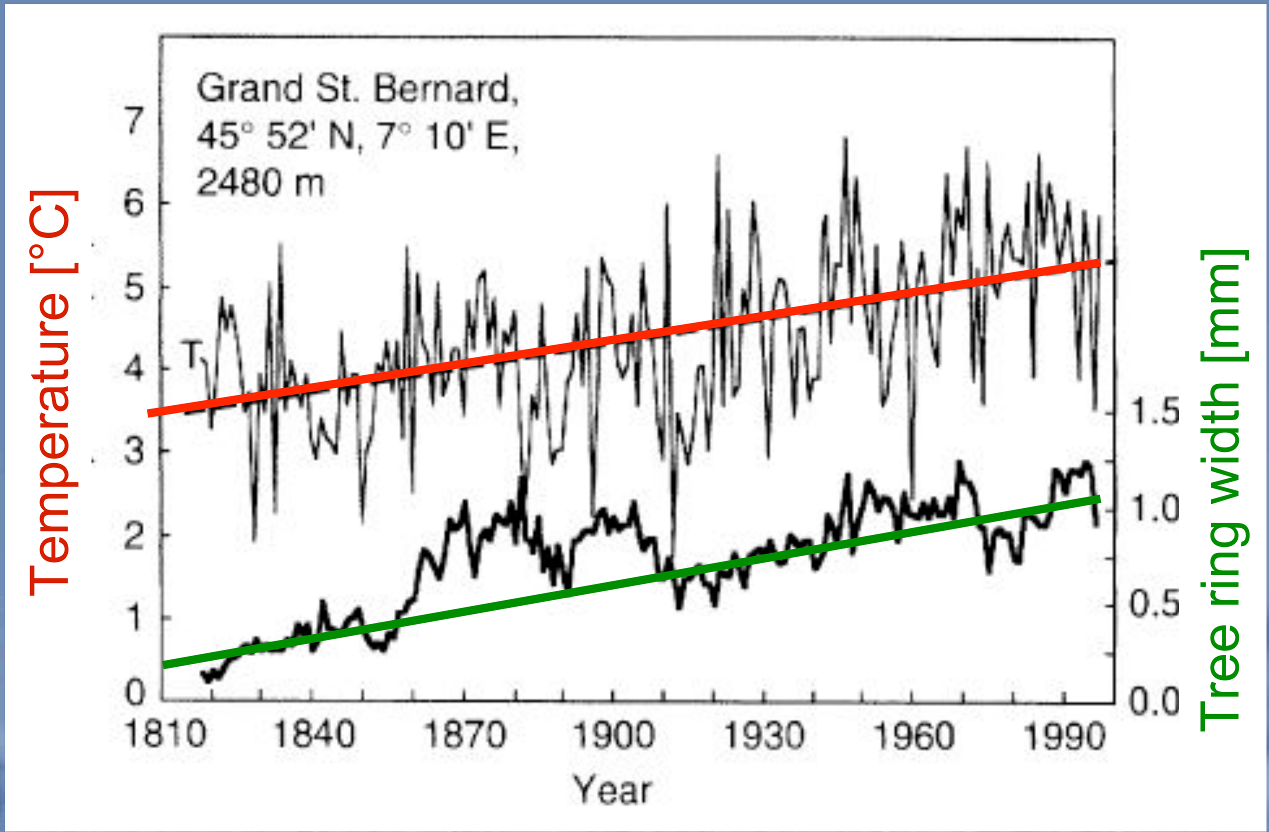
PERMANENT.PLOT.CH data bank: Braun-Blanquet 1955, Hofer 1992, Grabherr et al. 1994, Walther et al. 2005, Vittoz et al. 2006



?
Plant diversity on Isla Persa
Number of species
140
120
100
80
1900
1950
Colonizing species are more thermophilous
Proportion of species
100%
80%
60%
40%
20%
0%
1906
1927
1972
1995
2004
Years of inventories
T
Thermicity index
(Landolt 1977)
warm
3
2
1
cold
Colonization of Isla Persa, an isolated nunatak of alpine grasslands
(Eastern Swiss Alps)

Treeline changes

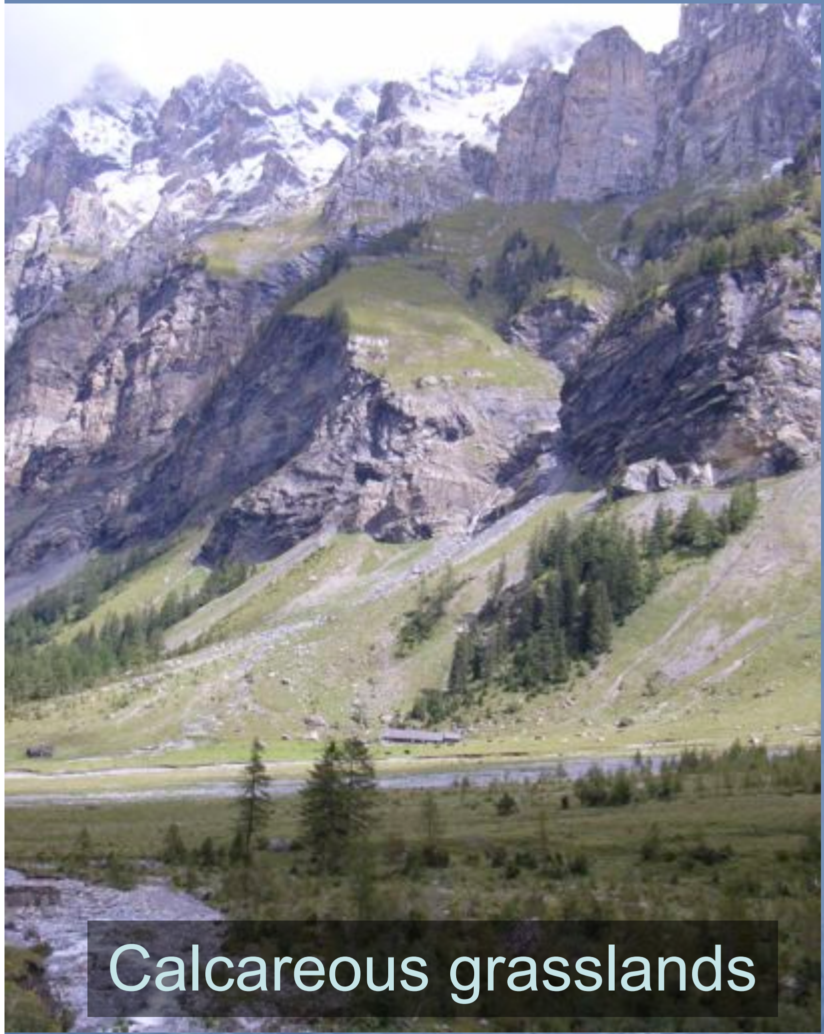
- Upslope tree expansion observed in many mountains (e.g., Norway, USA, Ural)
- Increased radial growth of trees at treeline

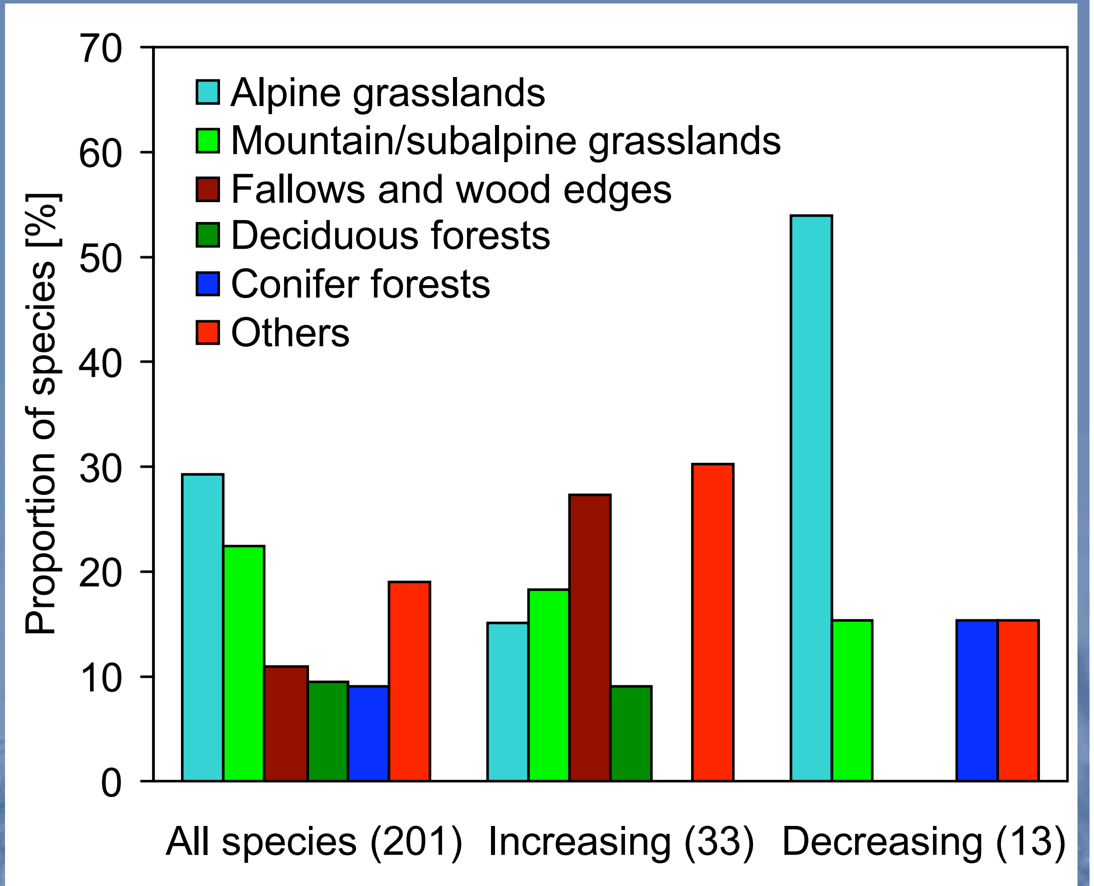


Kullman 1986, Taylor 1995, Shiyatov 2003, Gehrig-Fasel et al. 2007 | graph by Paulsen et al. 2000

Community changes in subalpine grasslands

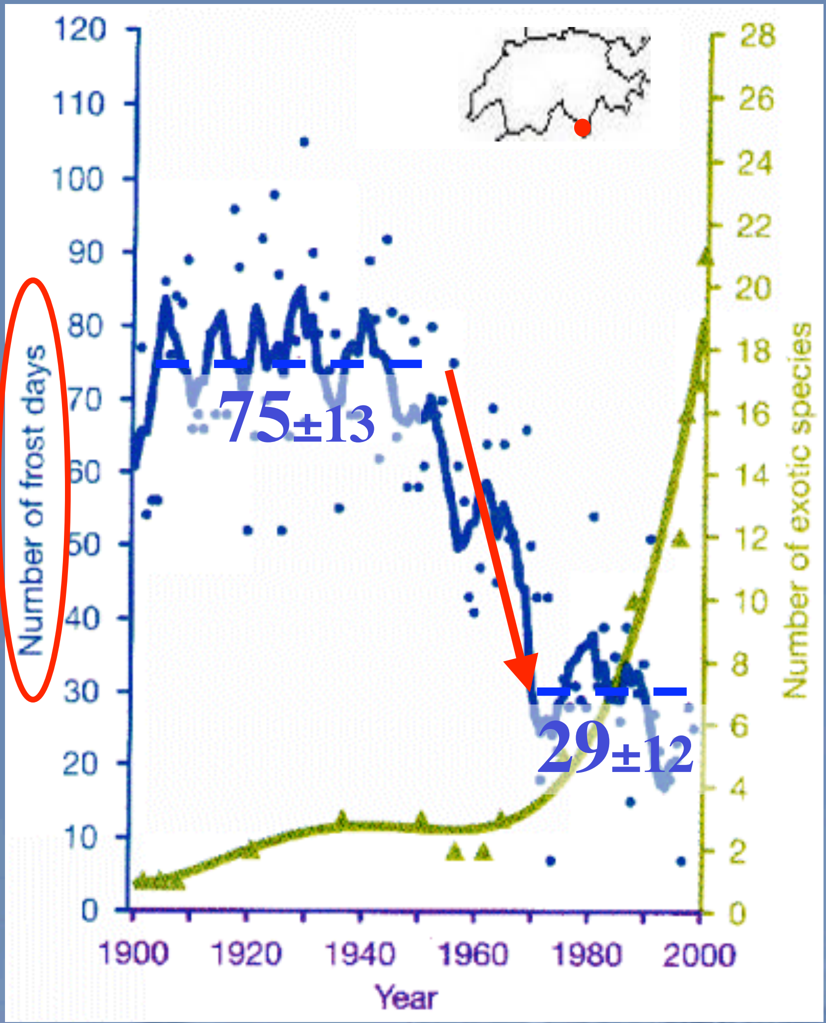
- Western Swiss Alps (1370-1815 m)
- 19 permanent vegetation plots
- Comparison 1970 -2006





Vittoz et al. (in review)

Lowland invasions



Trachycarpus fortunei near Lugano
Picture and graph: G.-R. Walther

Walther *et al*. (2002) *Nature*

Part 2:

Predicting future distributions of alpine plants

Future impact of climate change on alpine plant diversity?

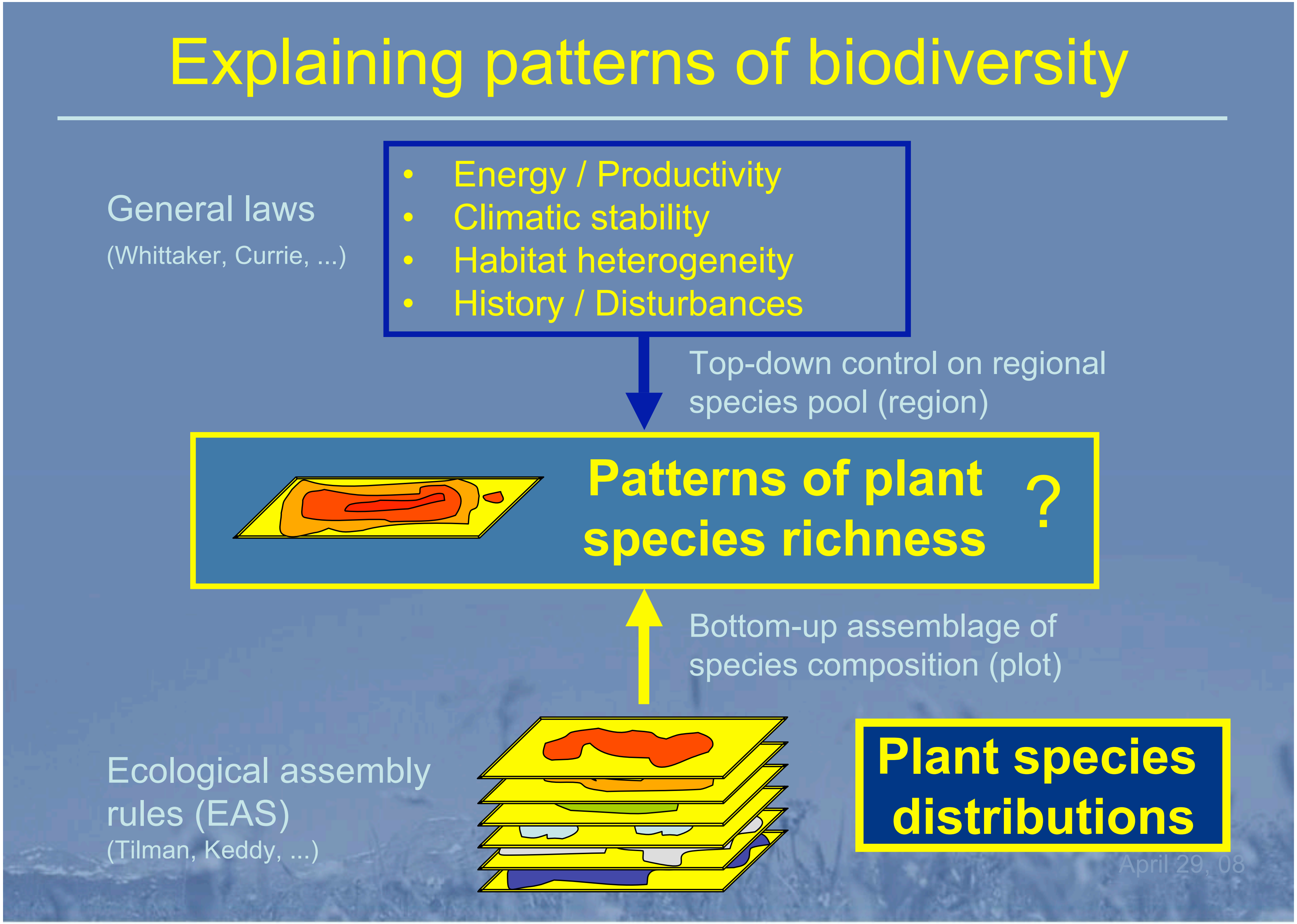
?

Requires

- understanding the climatic drivers of plant diversity
- quantifying these in models for current patterns
- predicting future patterns with the models

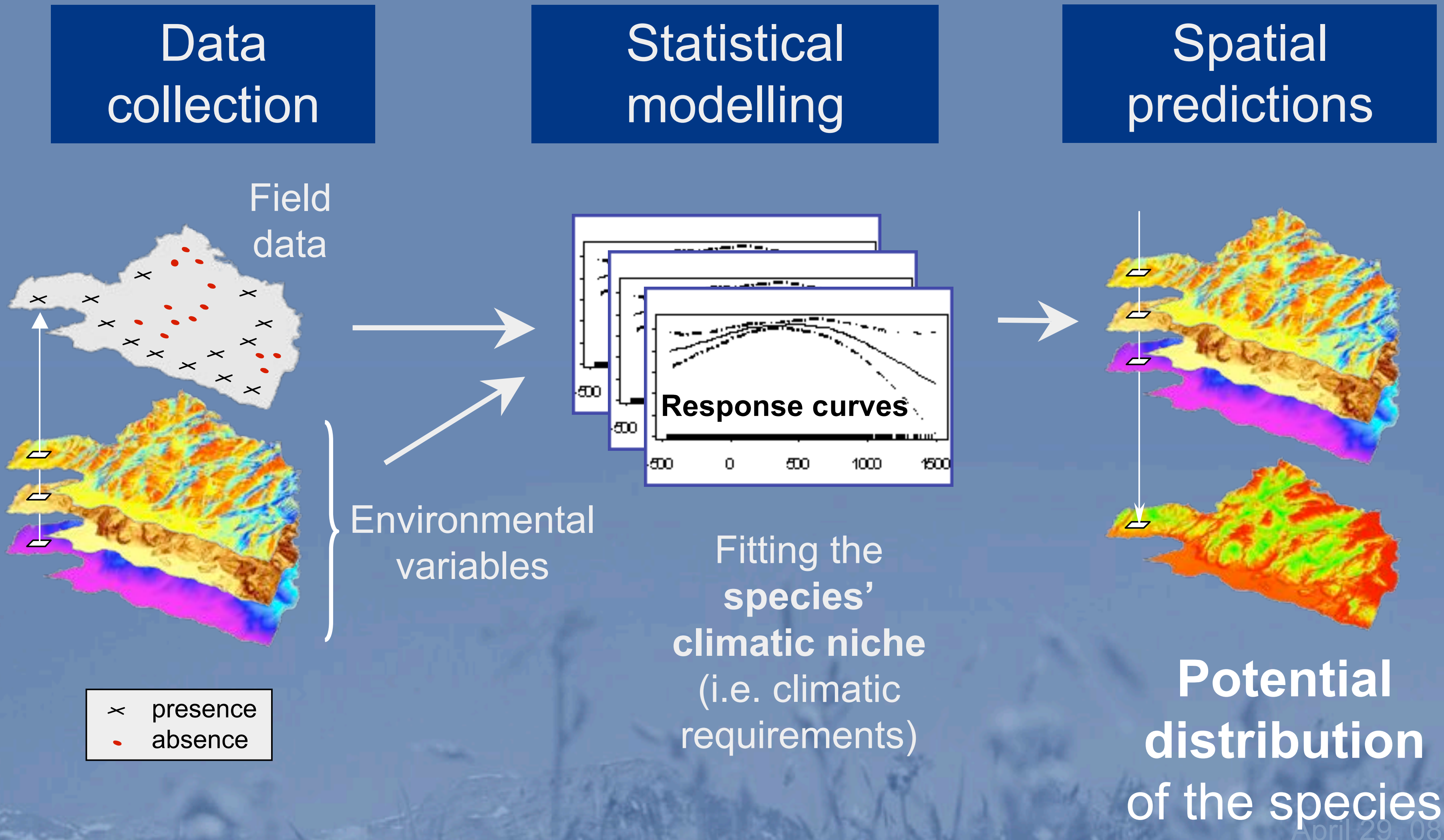
What do we know about drivers of biodiversity?

Can we use current knowledge to predict future patterns?



Ferrier & Guisan (2006) *J. Applied Ecology*

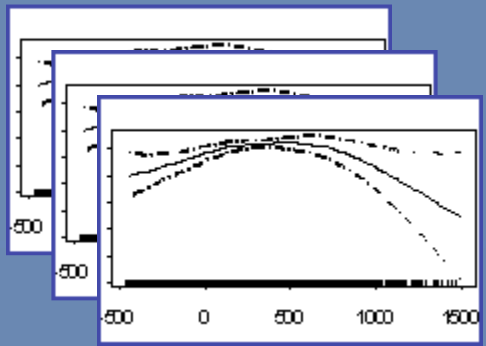
Predicting species distributions

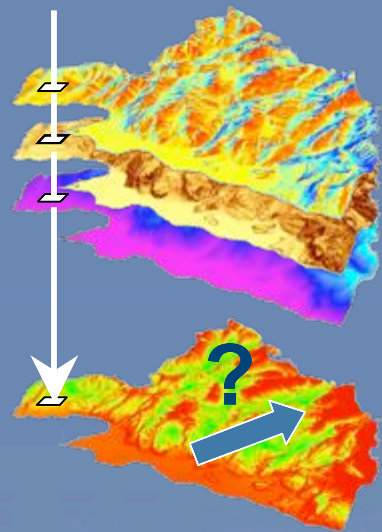


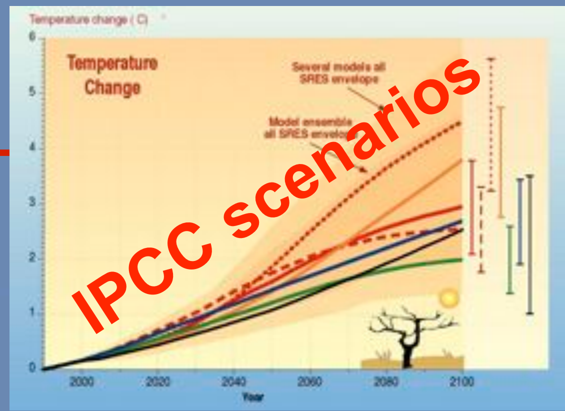
Guisan & Zimmermann (2000) *Ecol. Mod.* | Guisan et al. (2002) *Ecol. Mod.* | Guisan & Thuiller (2005) *Ecol. Letters*

Deriving projections in space or time

1. modifying the input climate maps







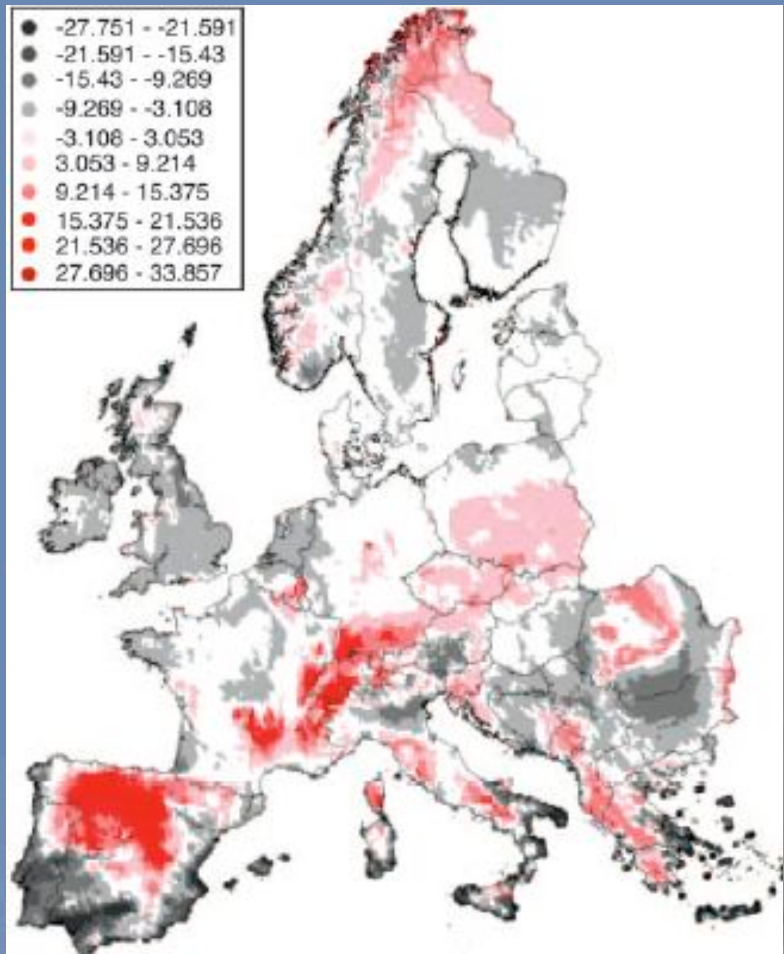
2. reapplying the niche model

New potential distribution in time or space

Guisan & Theurillat (2000) *Integrated Assessment* | Guisan & Theurillat (2000) *Phytocoenologia*

Climate change threats to plant diversity in Europe

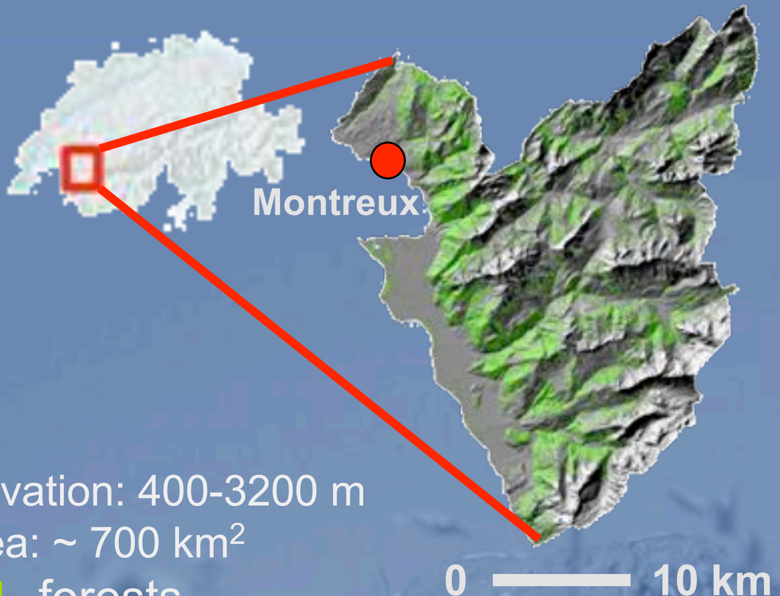
Wilfried Thuiller*[†‡§], Sandra Lavorel*[¶], Miguel B. Araújo*[‡‖], Martin T. Sykes**, and I. Colin Prentice[††]



"Despite the coarse-scale analysis, species from mountains could be seen as disproportionably sensitive to climate change (~60% species loss)"

Thuiller et al. (2005) *PNAS*

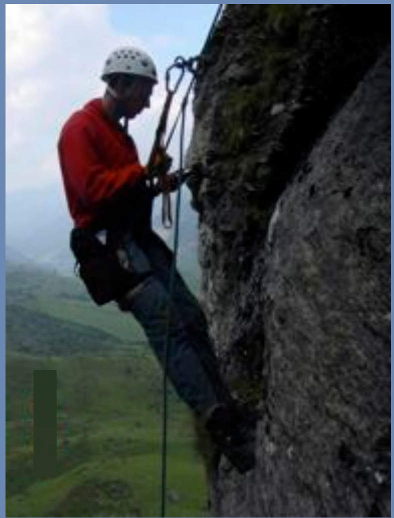
A local study on the flora of the Western Swiss Alps: The MODIPLANT project



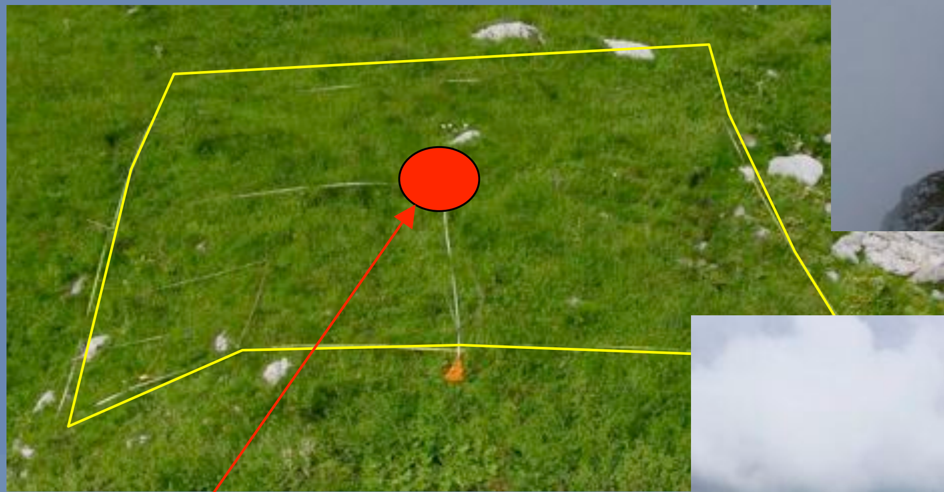
Elevation: 400-3200 m
Area: ~ 700 km^2
forests

Guisan (2005) in: *UNESCO Report*

Sampling vegetation plots

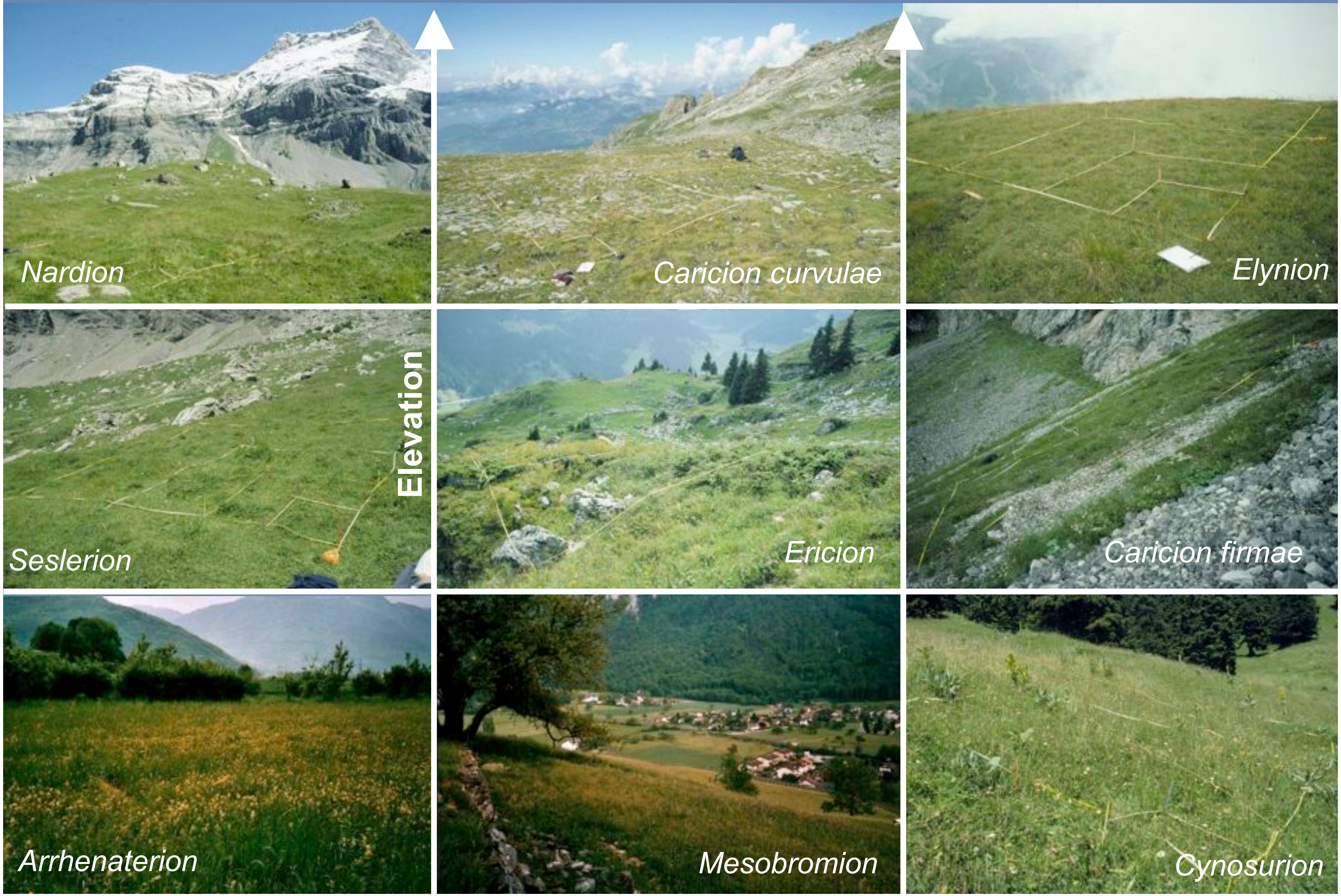


- Random-stratified design
- GPS location
- Exhaustive list of plant species
- Abiotic descriptors



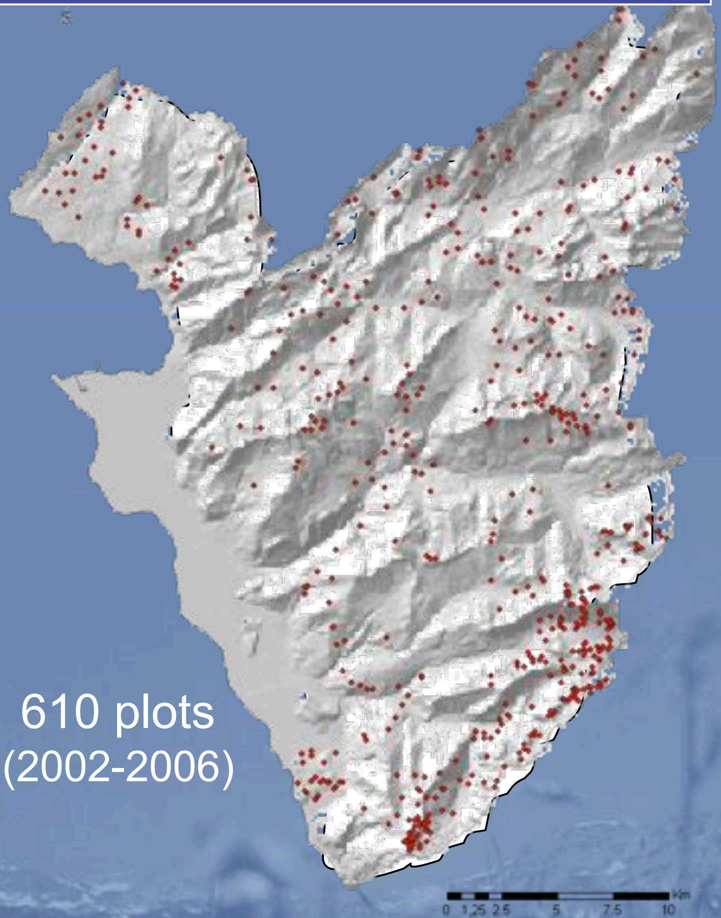
Randin et al. (2006) *J. Biogeography*

Visiting a variety of vegetation types



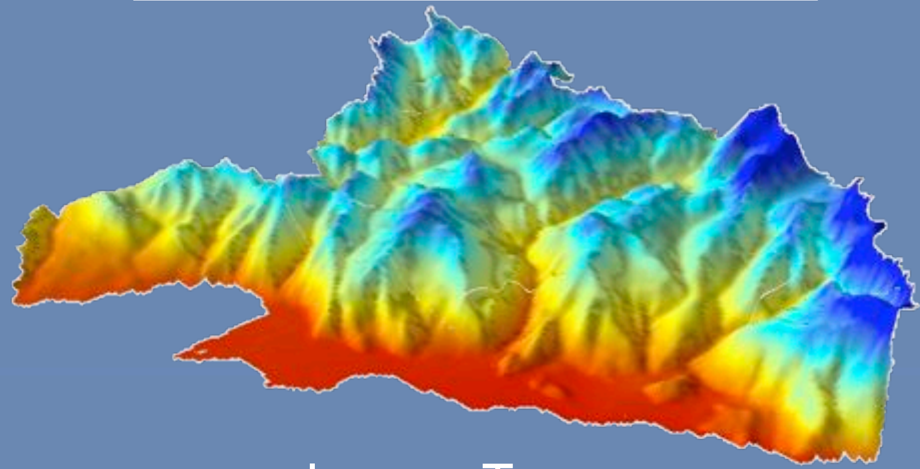
Data for modelling

Random-stratified vegetation sampling



610 plots
(2002-2006)

Environmental maps



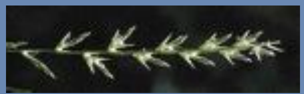
- annual mean T
- degree-days (sum T)
- moisture index (P- ET)
- snow cover duration
- solar radiation
- geology
- land use/cover
- topography

Collaboration:
IGAR (FGSE)
EPFL (LaSIG)
WSL, Birmensdorf

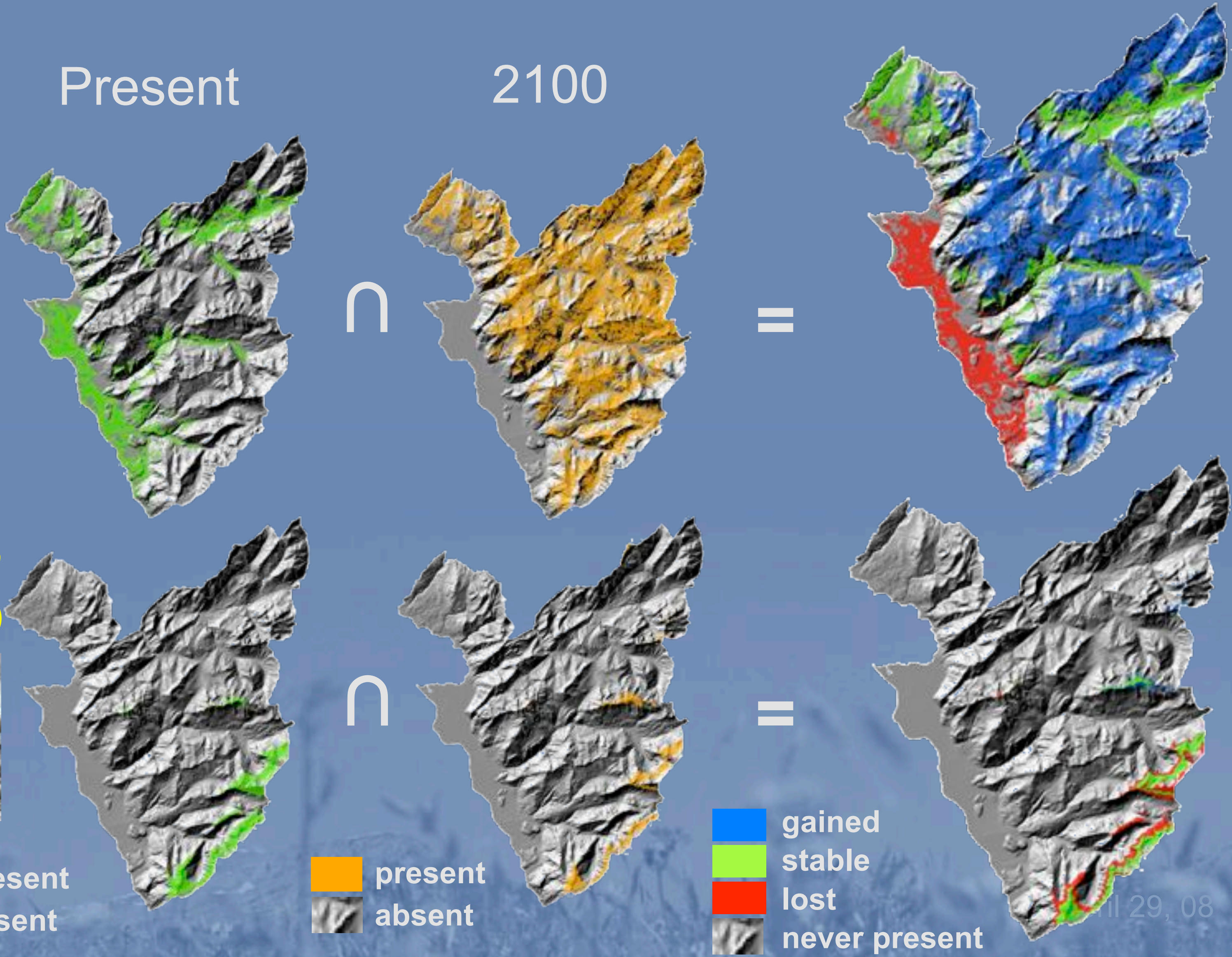
Randin et al. (2006) *J. Biogeography*

Deriving climate change projections

Winner:
Lolium perenne
(Poaceae)

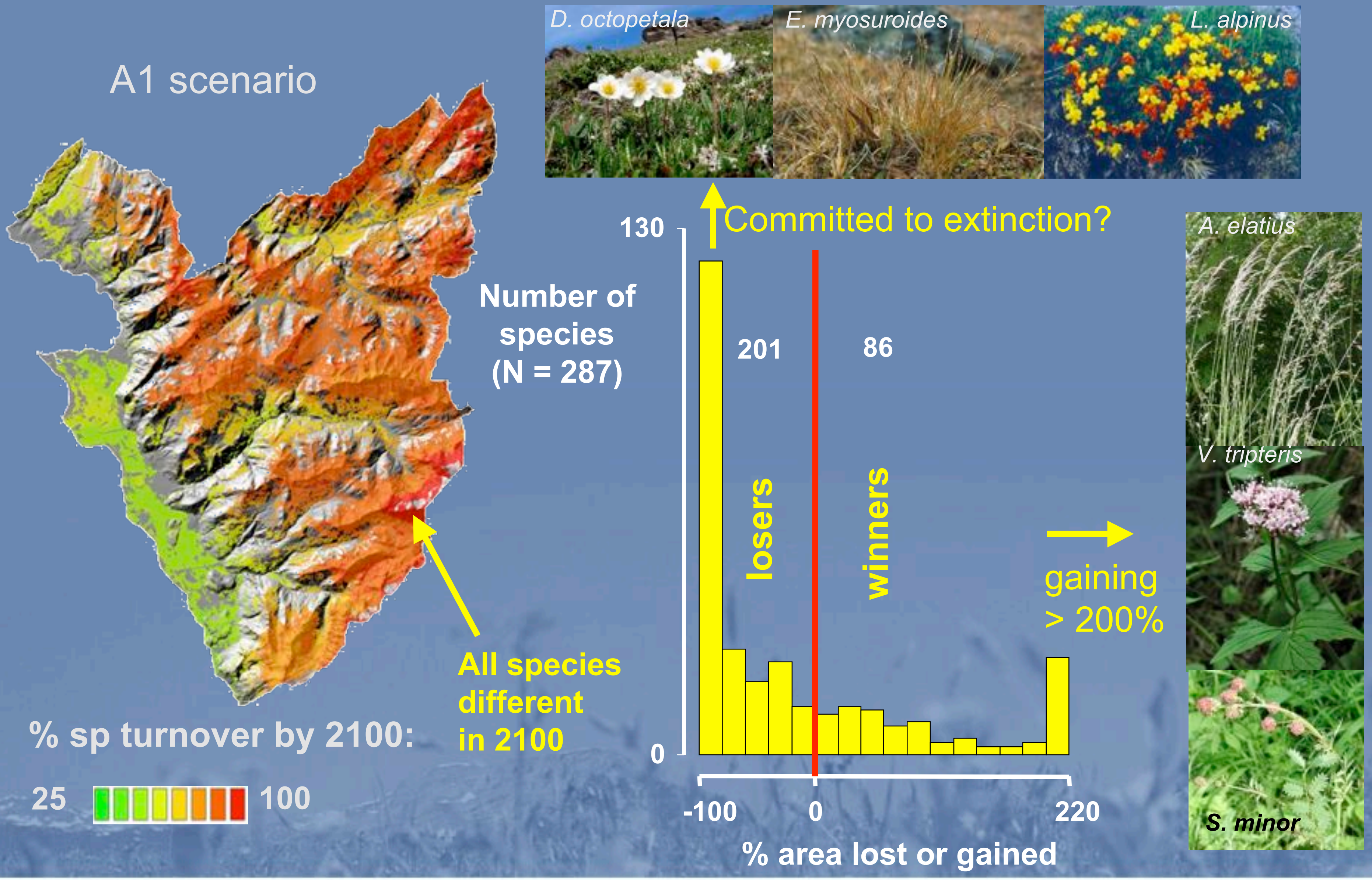


Loser:
Saxifraga oppositifolia
(Saxifragaceae)



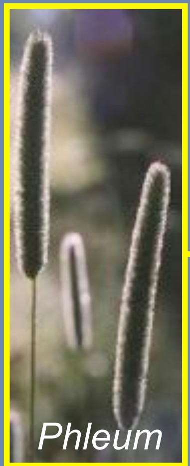
Randin et al. (in prep.)

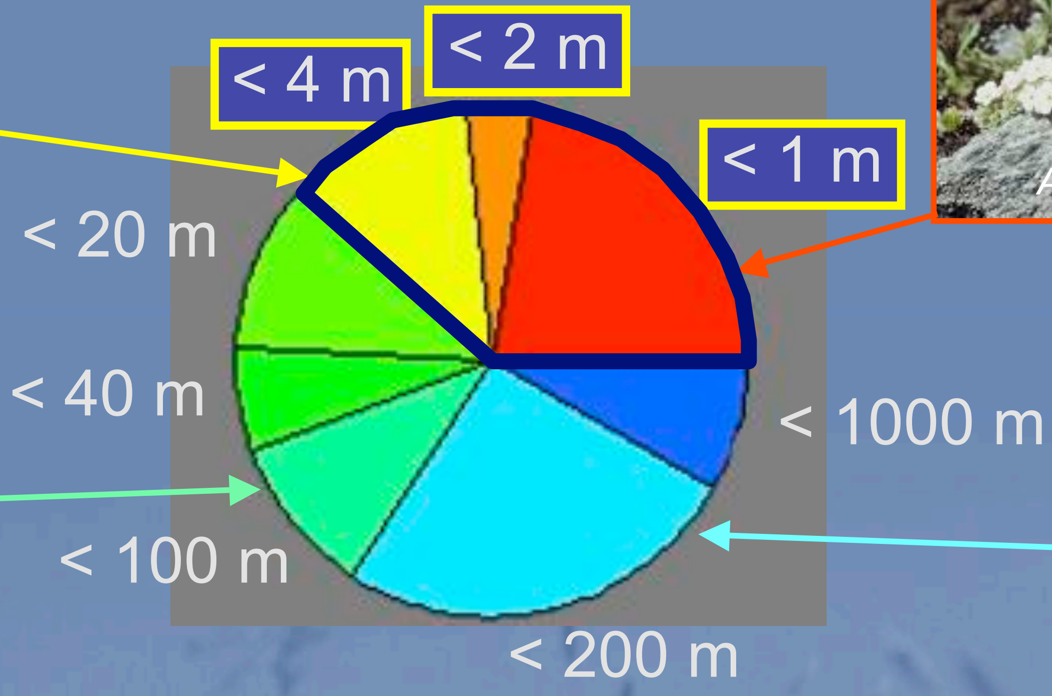
Species turnover and extinctions



Randin et al. (in review) *GMBA Book*

Dispersal types among declining species





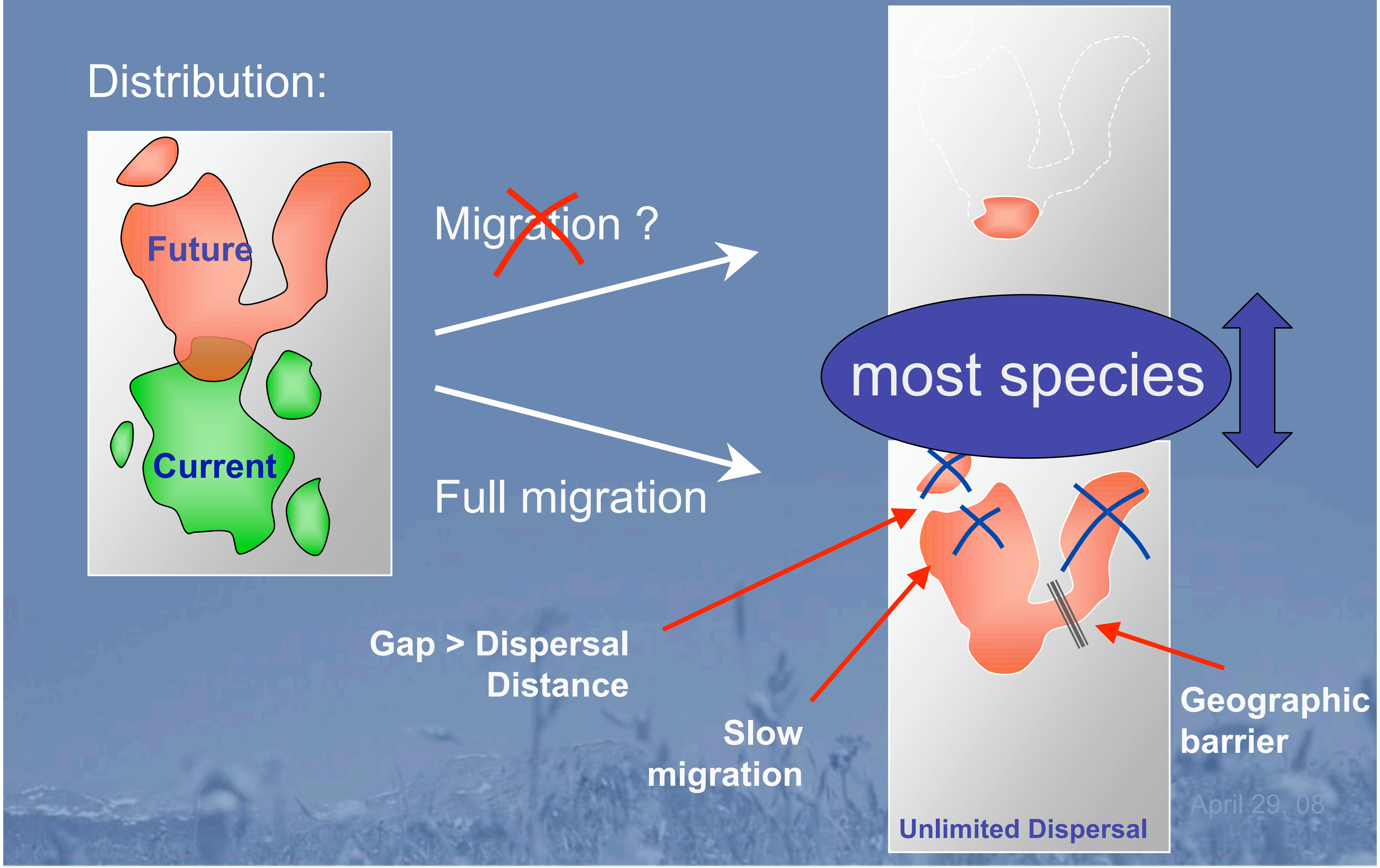
→ A large third of species has **limited dispersal abilities**

Classification of dispersal types: Vittoz & Engler (2007) *Botanica Helvetica*

N = 287 species

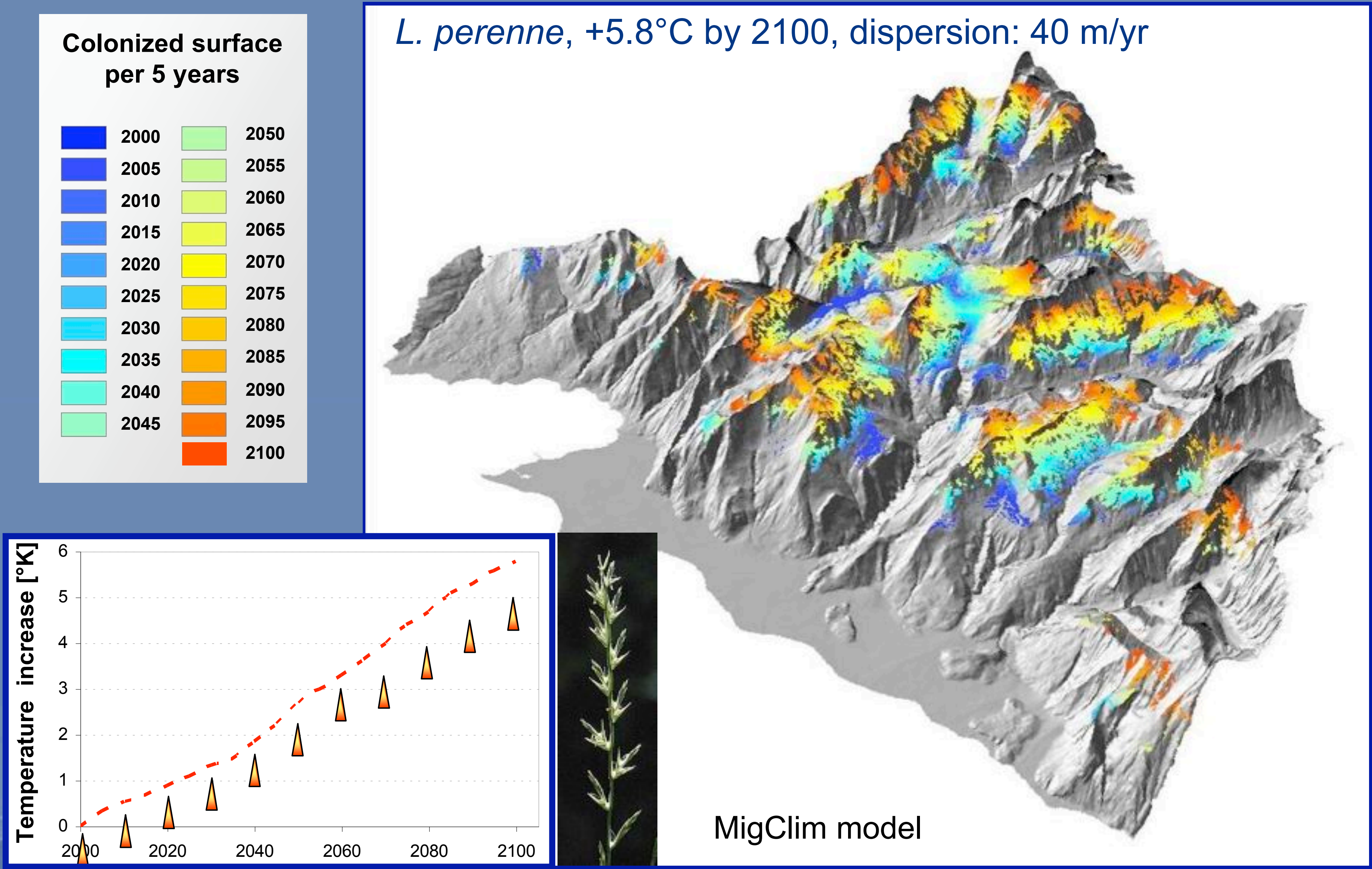
Will species be able to keep pace with rapidly changing climate?

Adding the dispersal constraint



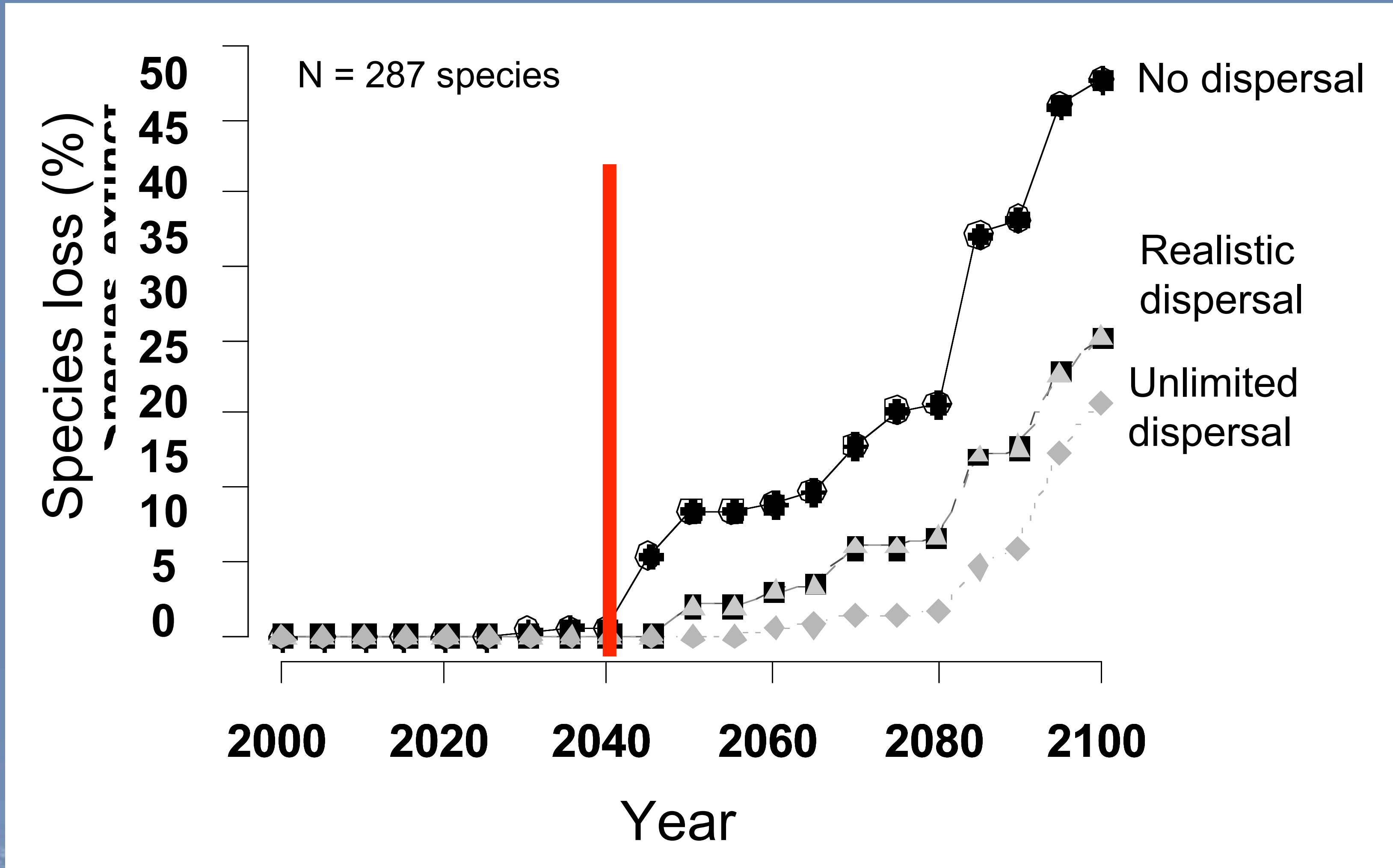
Engler & Guisan (in revision)

Transient plant dispersion with warming



Engler et al. (in prep)

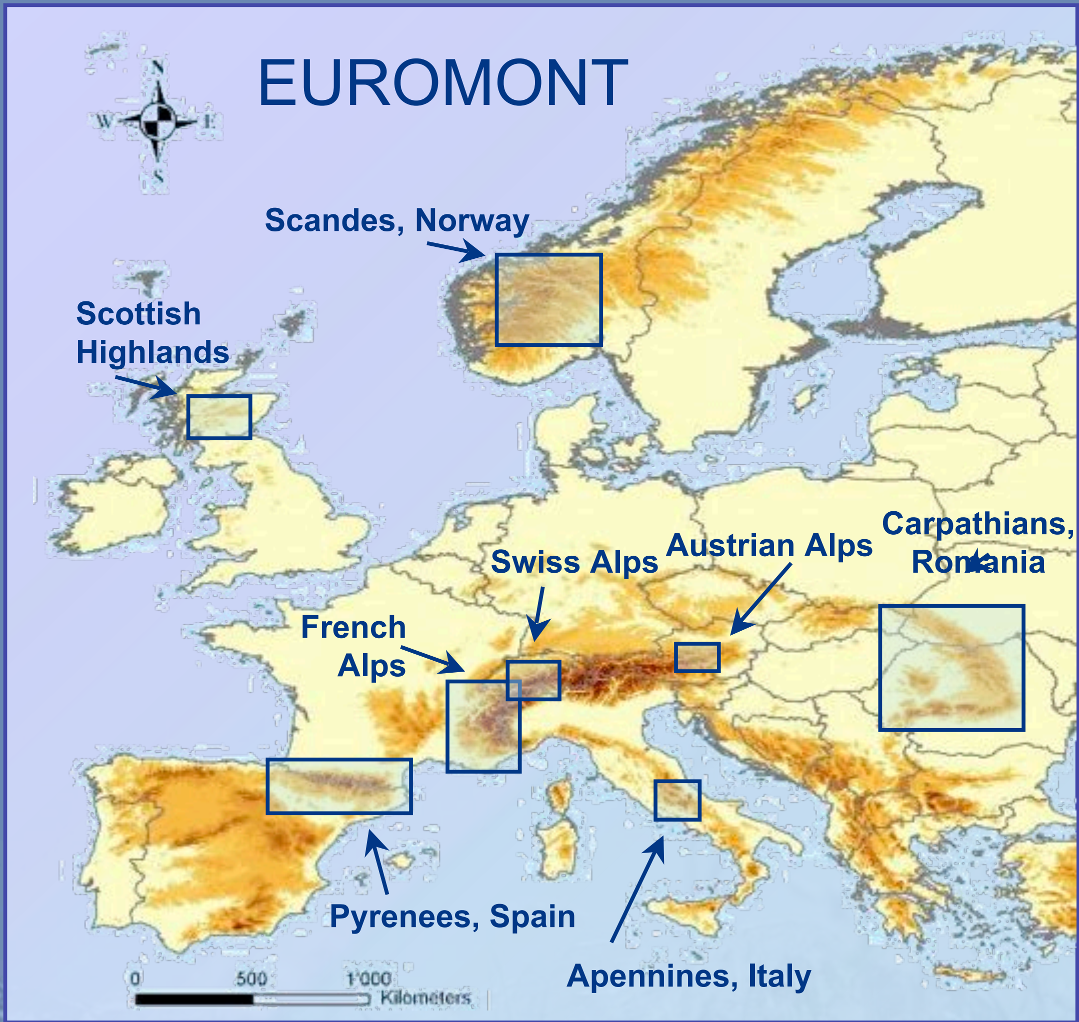
When will extinctions occur?



Randin, Engler et al. (in prep.)

How sensitive are different mountain ranges ?

Climate threat to alpine plant diversity in Europe: a broader fine-grain perspective



= approximate extent of available data

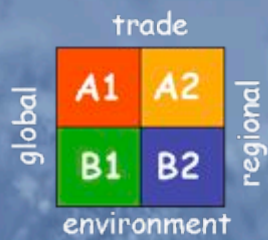
Species data:

- 1391 species
- 17'596 plots

Climate maps (100 m and 1 km):

- Average temperature
- Sum of precipitations
- Solar radiations
- Cloud cover
- Potential Evapotranspiration
- Soil moisture index

Climate change scenarios (ipcc):



April 29, 08

2 workshops in Lausanne

Guisan (2006) *MRI Newsletter* | Guisan et al. (in prep.)

The EUROMONT Consortium

Leading team

Antoine Guisan
(lead, coordination)
Robin Engler
(data preparation, modelling)
Christophe Randin
(Swiss study)
Peter Pearman
Pascal Vittoz
Gwenaelle Le Lay

Modelling experts

Niklaus E. Zimmermann
(climatic data)
Wilfried Thuiller
(modelling tool)
Signe Normand-Treier

Participating teams

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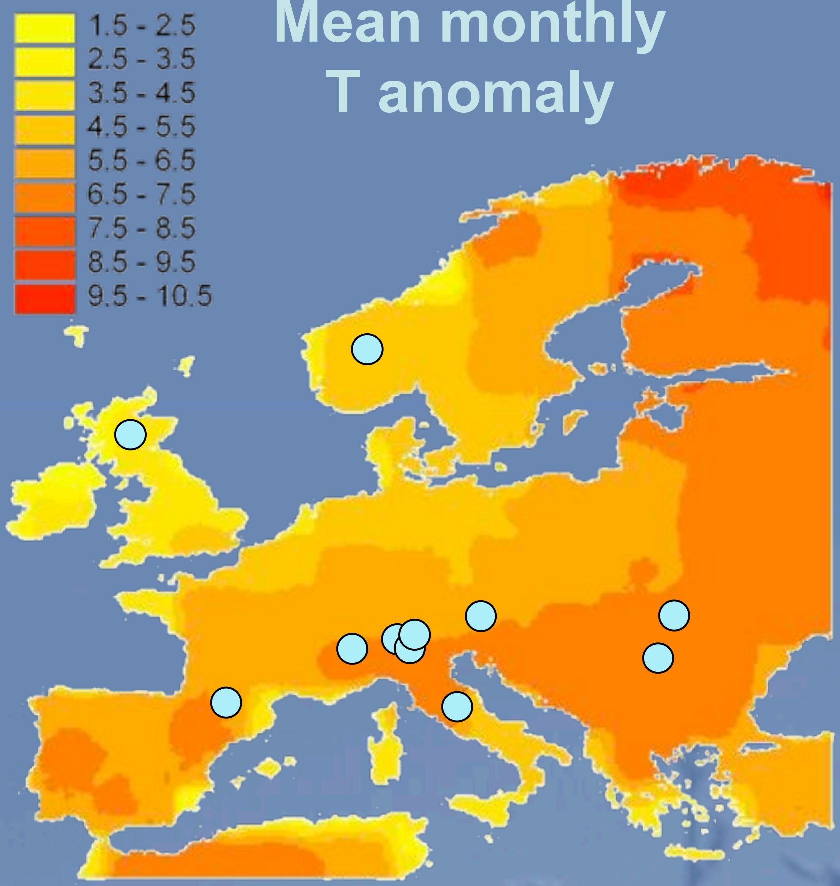
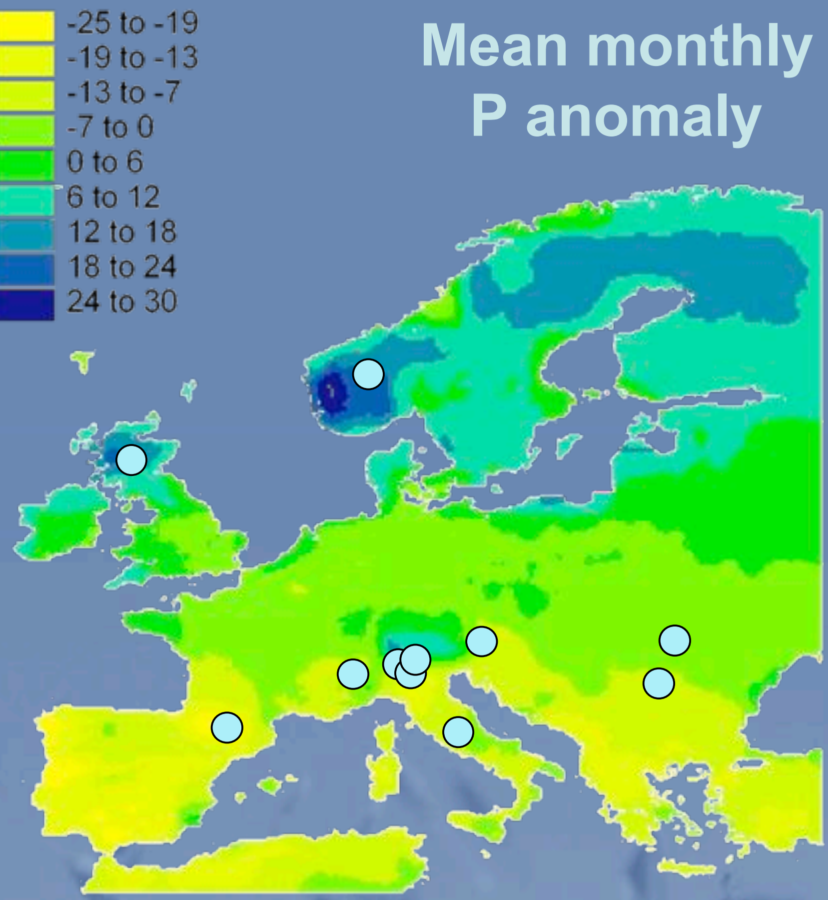
Einar Heegaard & John-Arvid Grytnes
SCOTTISH HIGHLANDS (UK)
Mandar Trivedi
SWISS ALPS
Leading team + Nick Zimmermann
FRENCH ALPS
Christian Piedallu & Philippe Choler
AUSTRIAN ALPS
Stefan Dullinger
PYRENEES (Spain)
Miguel Araújo & David Nogues
Teresa Sebastià & Xavier de Lamo
APENNINES (Italy)
Angela Stanisci, Jean-Paul Theurillat
CARPATHIANS (Romania)
Mihai Puscas

Climate change projections (IPCC)

Mean monthly T anomaly

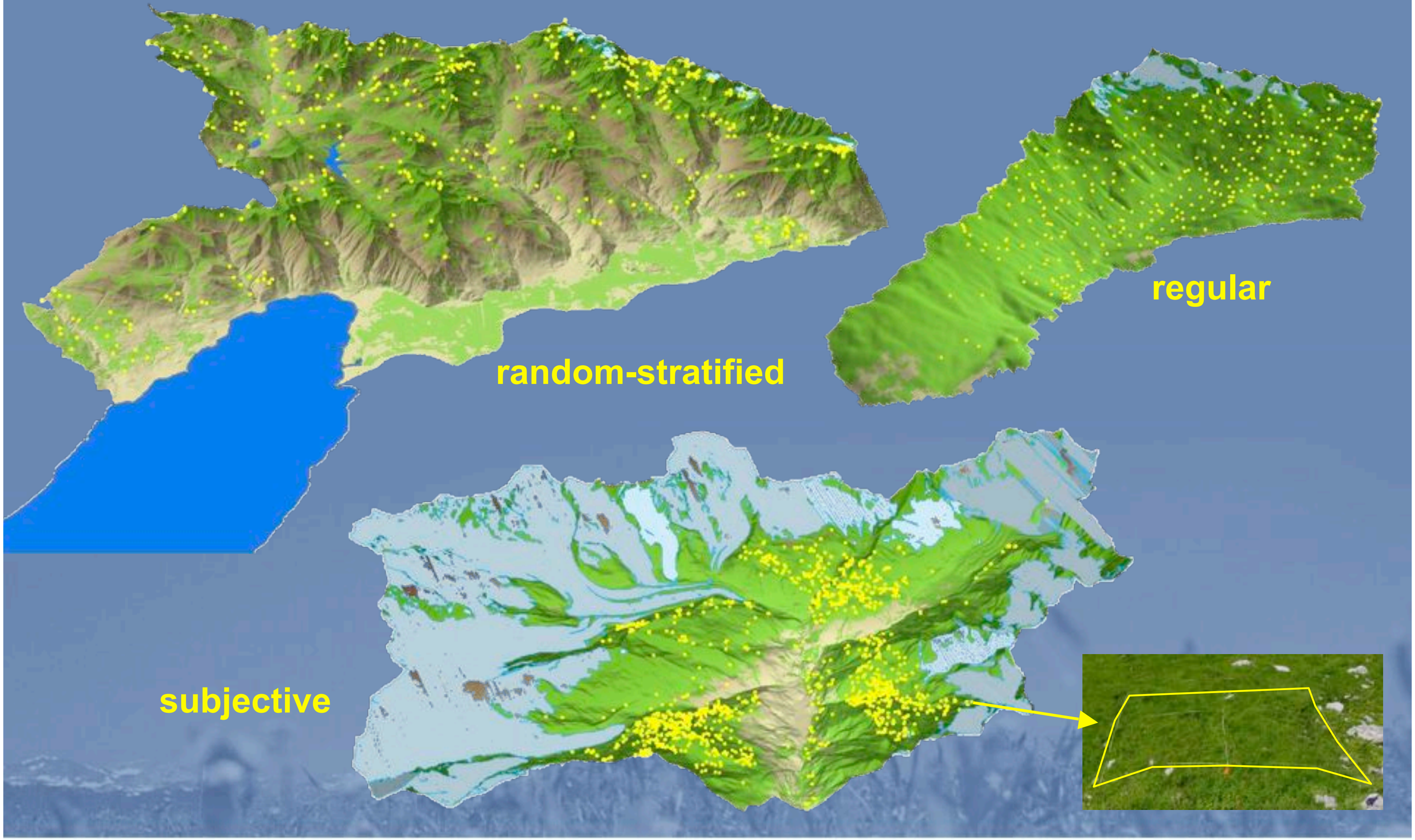


Mean monthly P anomaly

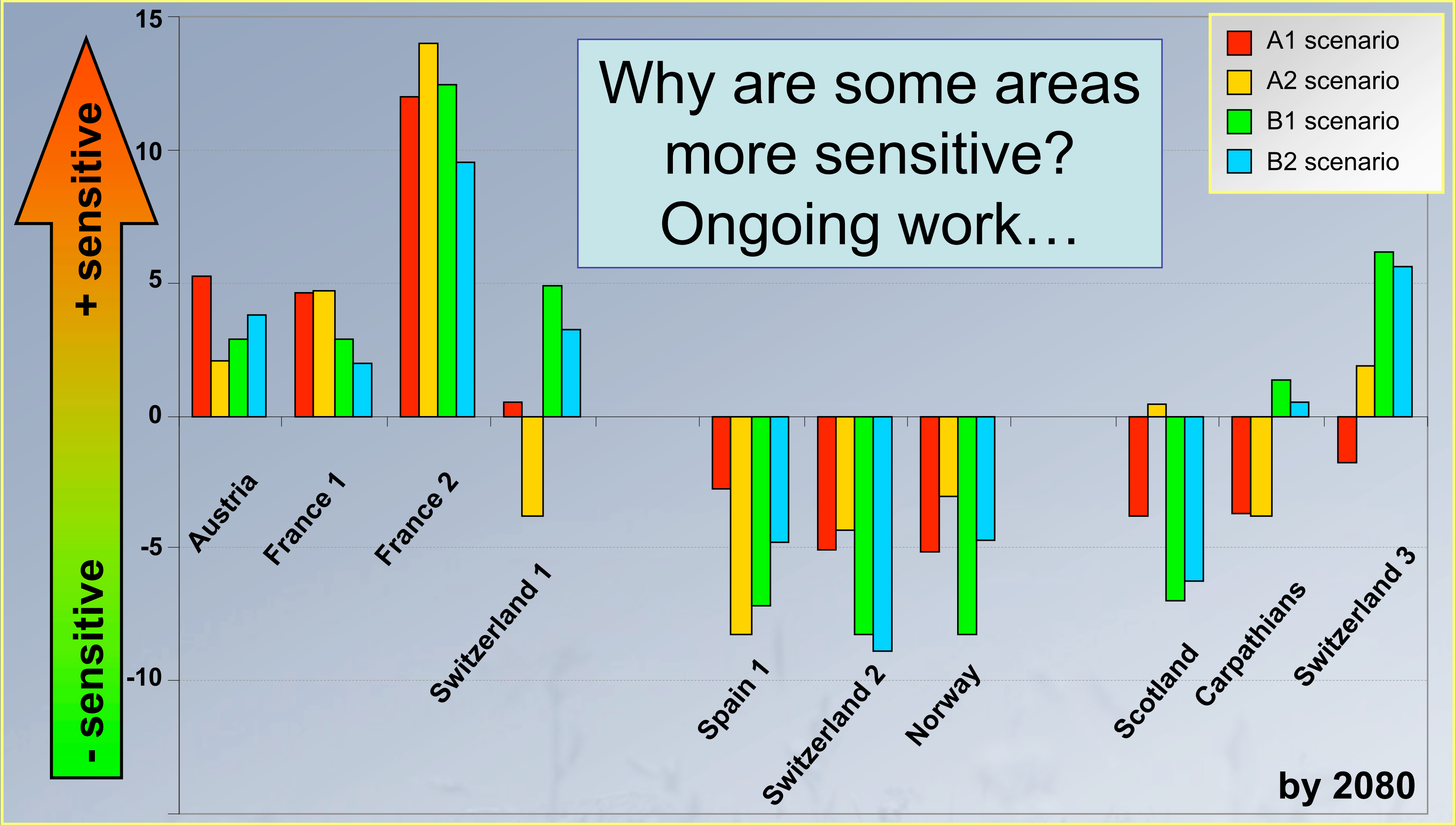


A1F1, 2080

Areas and data with varying characteristics



Adjusted species losses by area



Residuals after correction for "artefacts" in study area design
(study area extent, elevation range, species composition)

Part 3:

Challenging current projections

How transferable are models
in space and time?

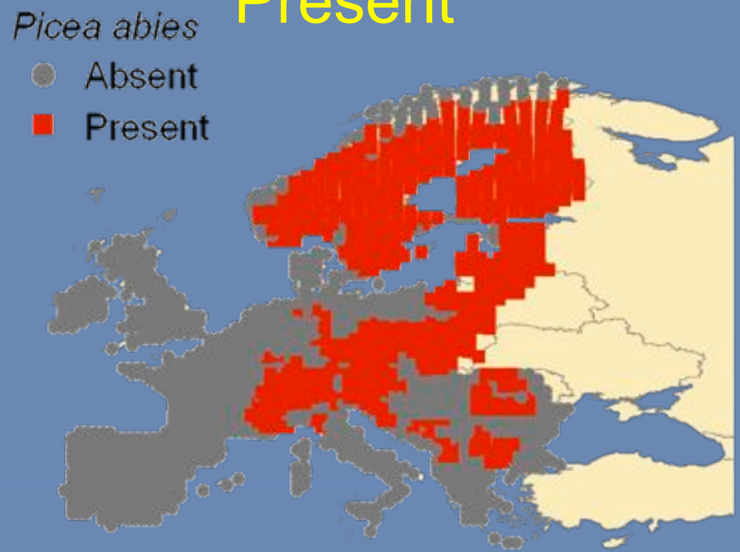
Will the climatic niche of plant species
be conserved in future climate?

Predicting the past as a key to
predict the future!

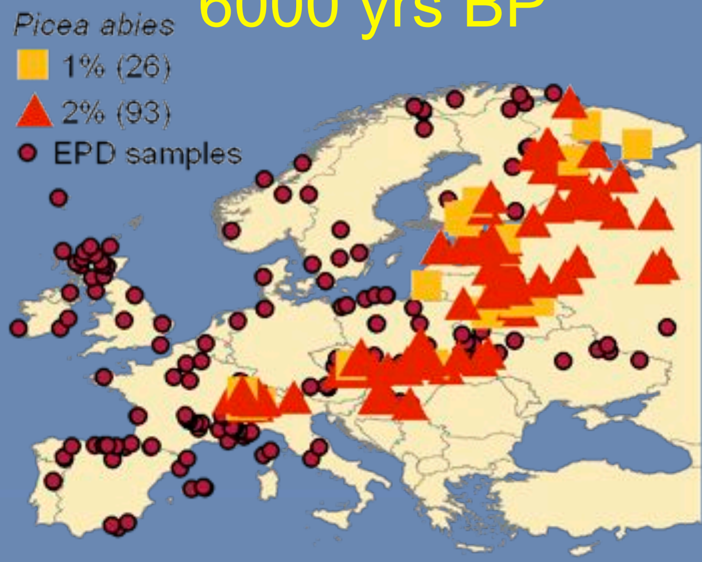
Randin et al. (2006) *J. Biogeogr.* | Botkin et al. (2007) *Bioscience* | Pearman et al. (2008) *TREE*

Species and climatic data

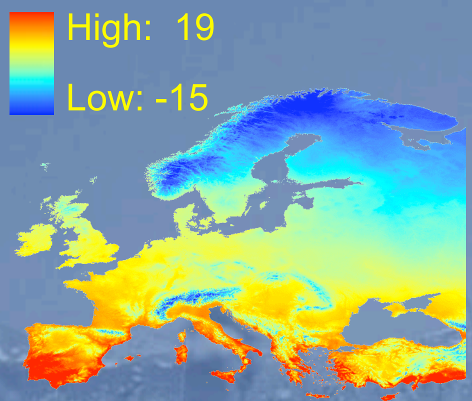
Present



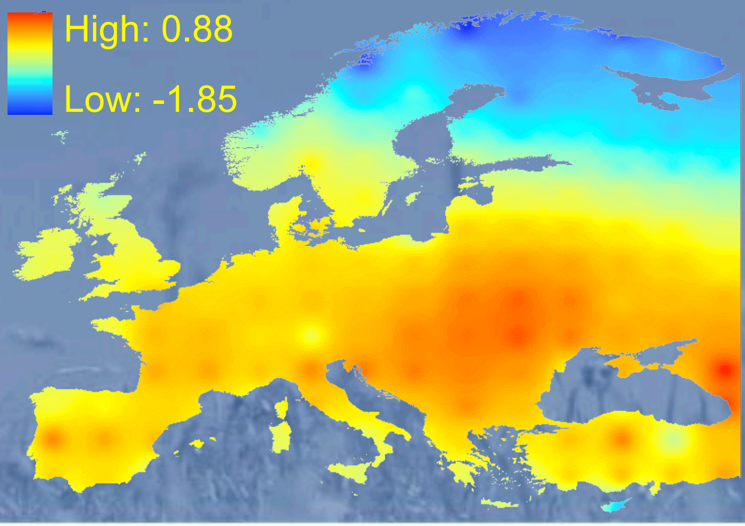
6000 yrs BP



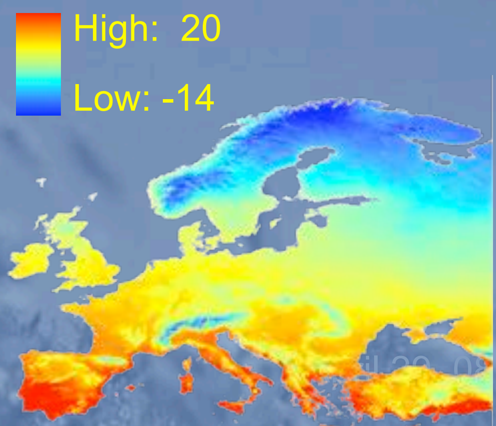
Present



Anomaly map

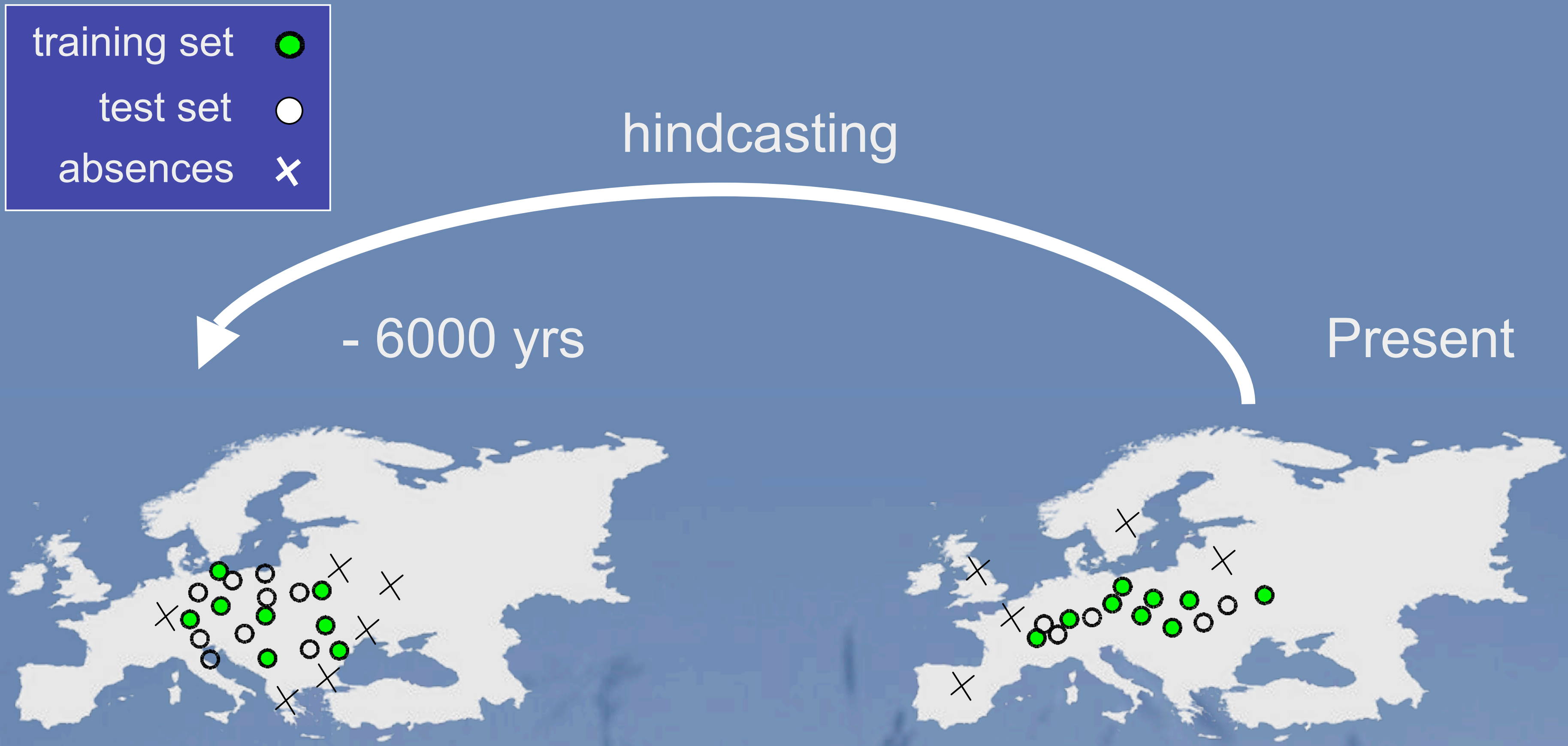


6000 yrs BP



Atlas Florae Europeae | ALPADABA and EPD (pollen) | PMIP2 UBRIS-HadCM3M2

Projecting in the past



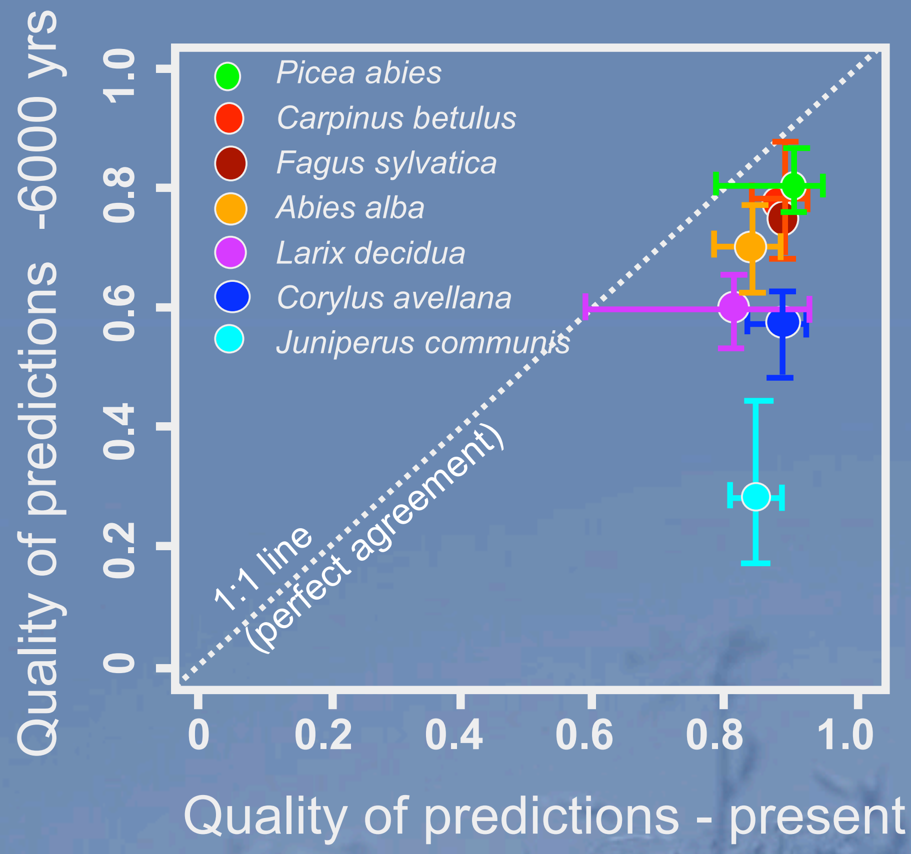
- Boosted regression trees

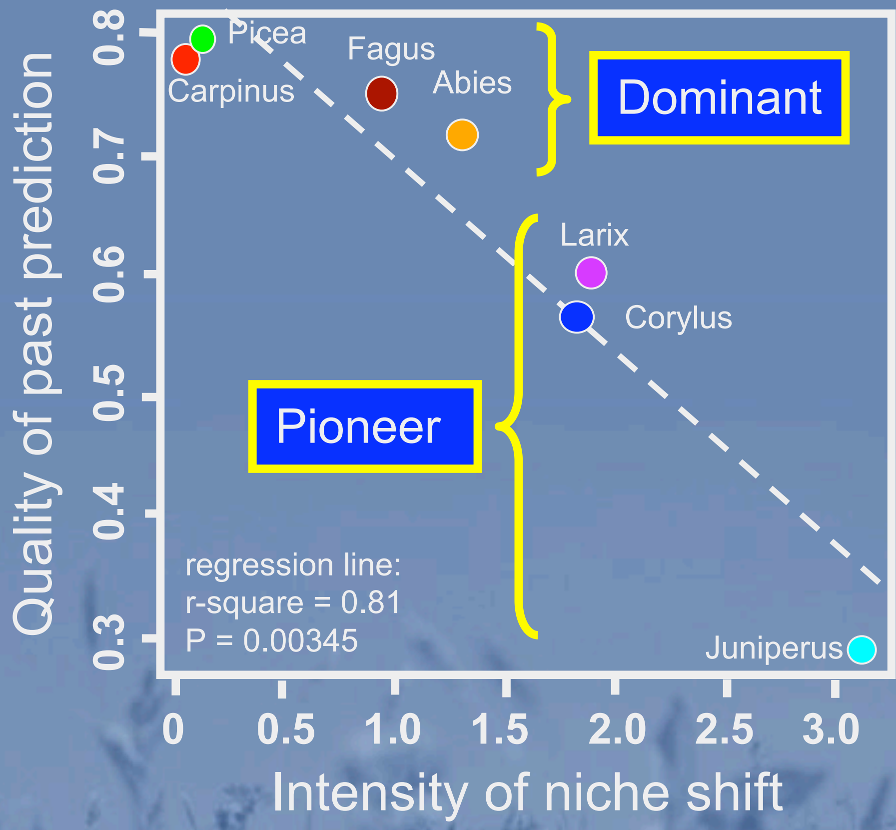
(best technique among 17 tested in Elith et al. 2006 *Ecography)* April 29, 08

Pearman et al. (2008) *Ecology Letters*

Predictions across 6 millenia

Hindcasting: Present → 6000 Ky BP





"the greater the shift, the less predictable the species"

Pearman et al. (2008) *Ecology Letters*

Conclusions

1. Signs of climate change effects on mountain ecosystems (biological fingerprints) already apparent, especially at high elevations
2. Models based on the climatic niche of species predict serious species loss (up to 50%), at least locally
3. Adding dynamic dispersal simulation allows reducing uncertainty in projections and estimating the timing of extinctions
4. Distinct mountain ranges have distinct sensitivities
5. To be projected into future, the climatic niche of species should remain stable over time
6. Open questions: Which species have stable niche? What factors affect niche dynamics?

Thank you for your attention

QUESTIONS?

Postdocs:
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P. Vittoz

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T. Czaka (GIS)
R. Engler

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H. Dietz & P. Edwards (ETHZ)
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P. Taberlet & W. Thuiller (UJF Grenoble)
P. Van der Knaap (UNIBE)
N.G. Yoccoz (Univ. Tromsoe, NO)
N.E. Zimmermann (WSL Birmensdorf)

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FGSE: M. Cosinschi, M. Jaboiedoff, M. Kanevski, H.-R. Pfeifer, E. Reynard

Species colonization

- 7 species on >20 summits in 1900 (e.g., *Saxifraga bryoides, Saxifraga oppositifolia, Ranunculus glacialis*) not retained in analyses
- 34 colonizing species (≥5 new summits)
- 60 stable species (<5 new summits)

Taraxacum alpinum
14 new summits

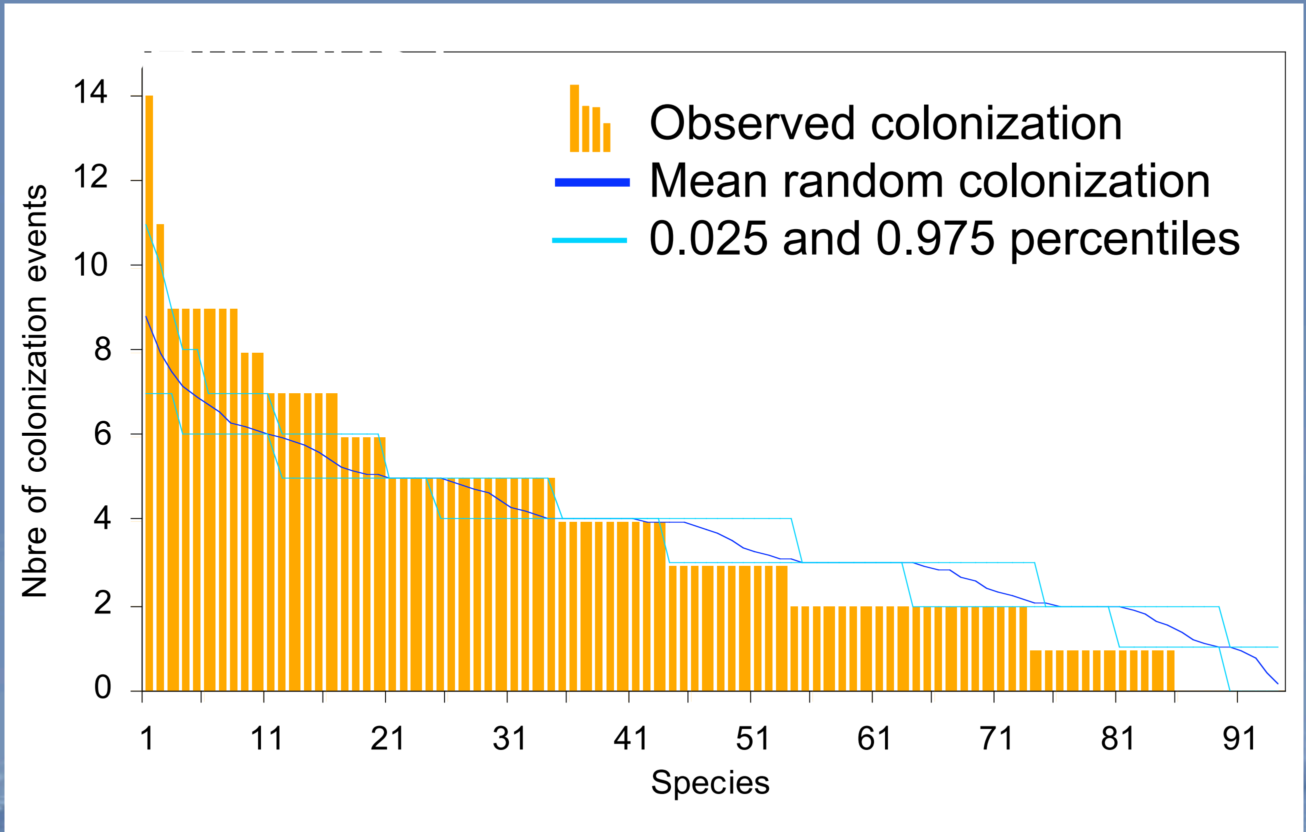
Cardamine resedifolia
11 new summits

Poa alpina
9 new summits

All with 9 new summits

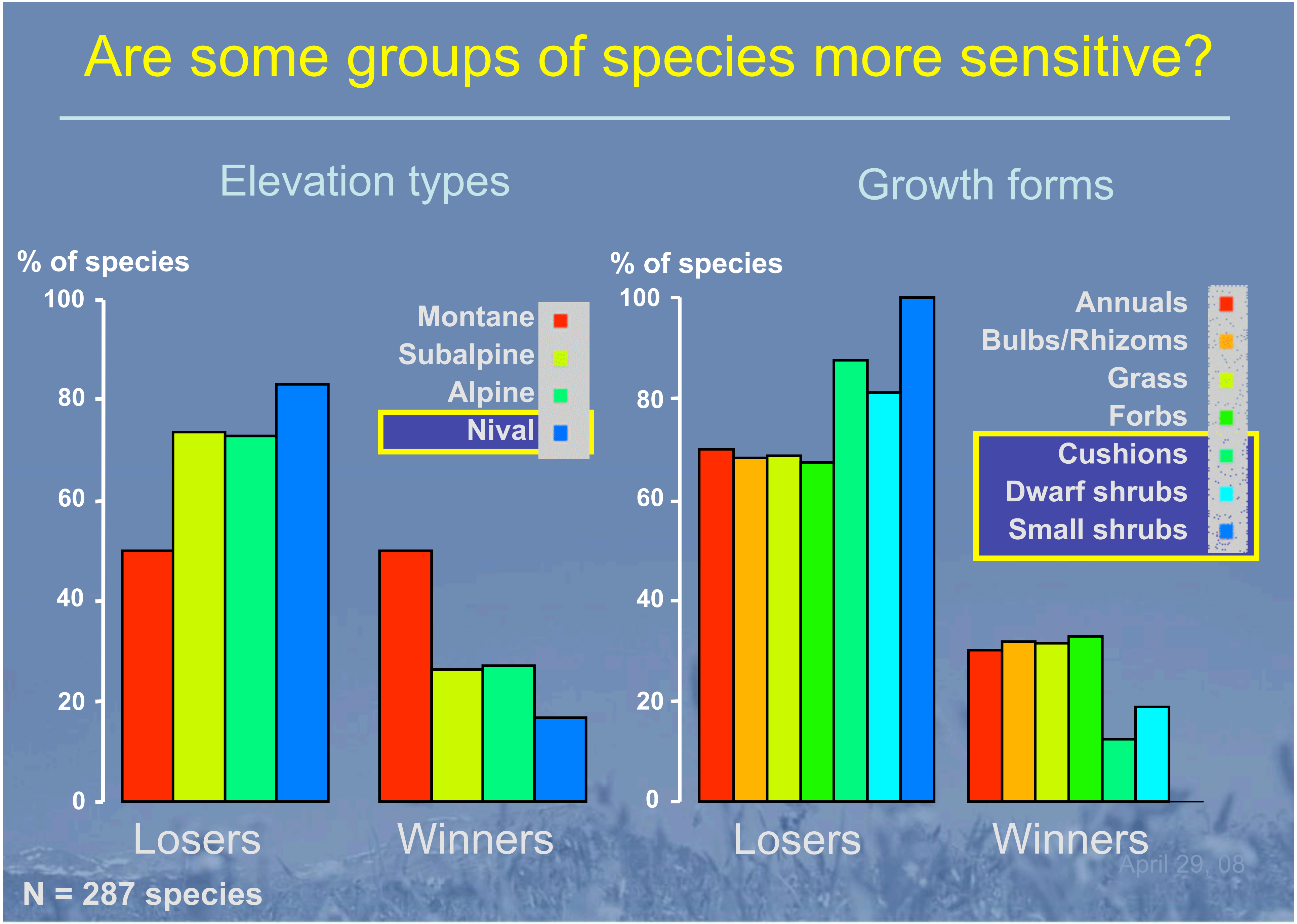
Colonization is not a random process

- Comparison of this pattern with a random distribution of 94 species on 37 summits with 394 colonization events (1000



p=0.004
Kolmogorov-Smirnov test

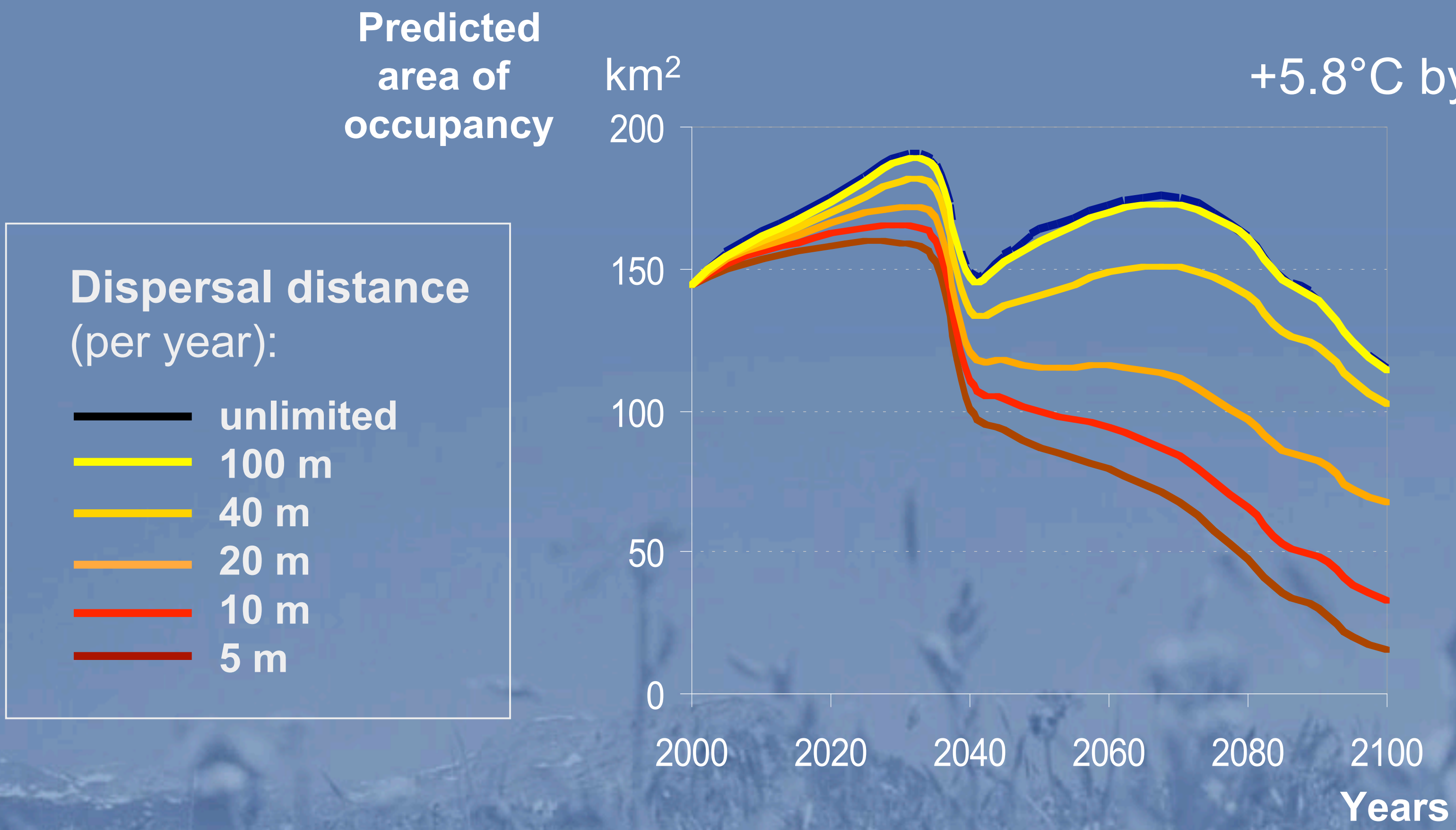
Vittoz et al. Submitted. Bas. Appl. Ecol.



Randin et al. (in review)

Effect of dispersal distance on future predicted area of occupancy

Lolium perenne



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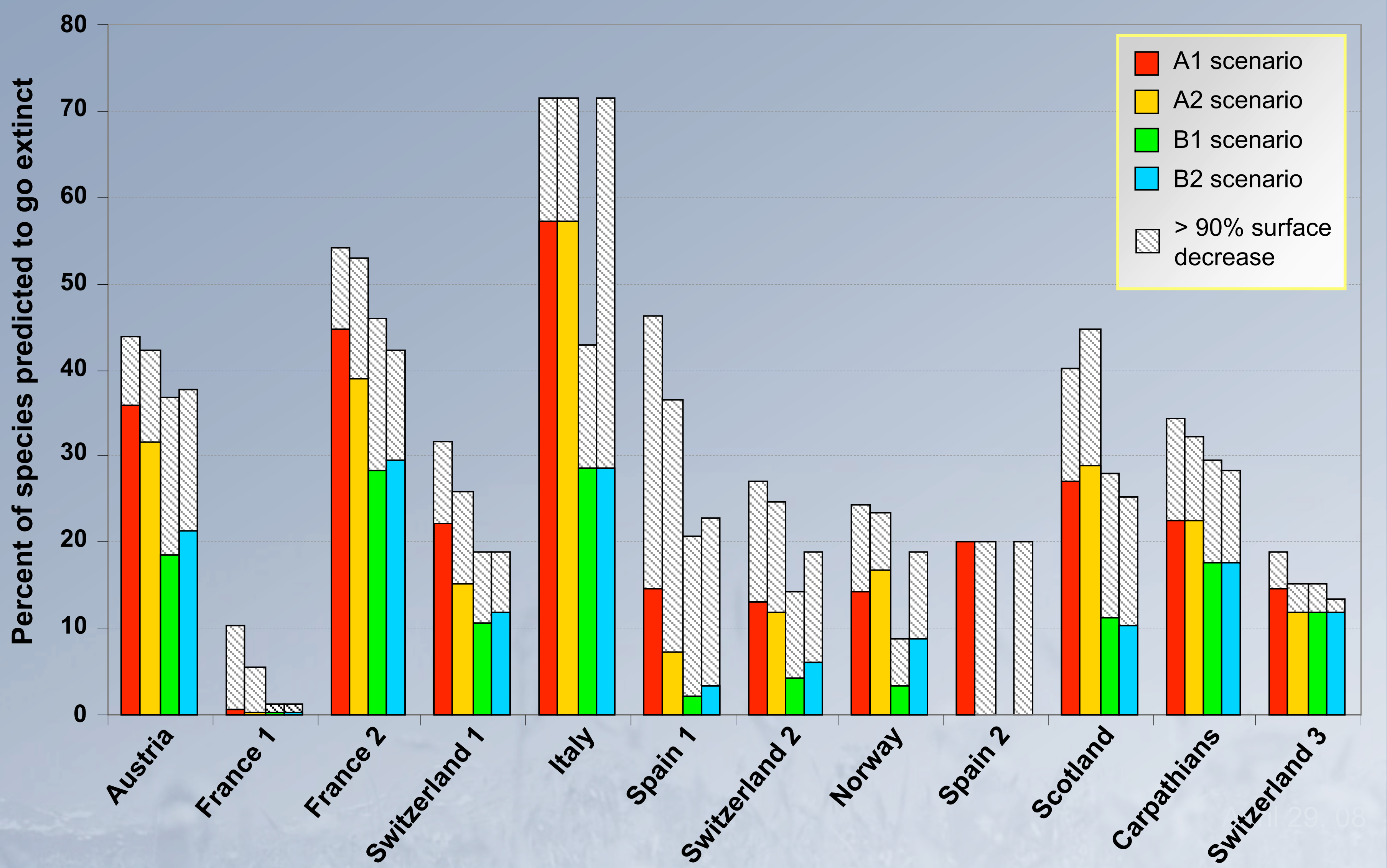
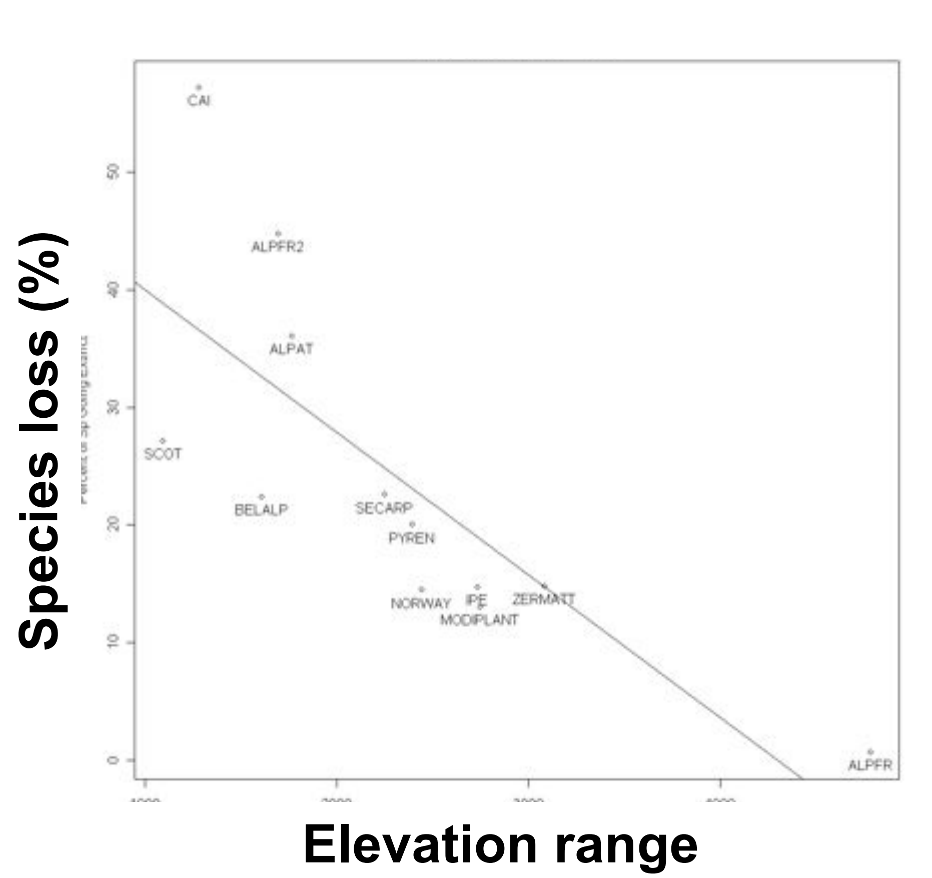
Engler & Guisan (in revision)

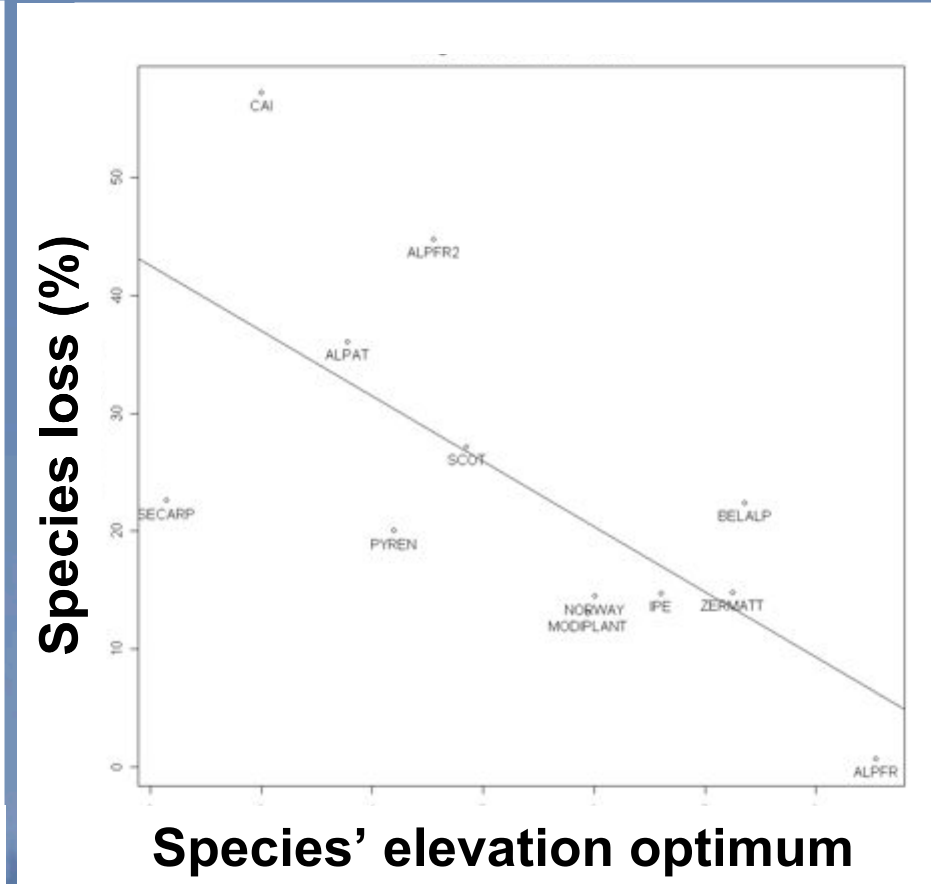
Species losses by 2080



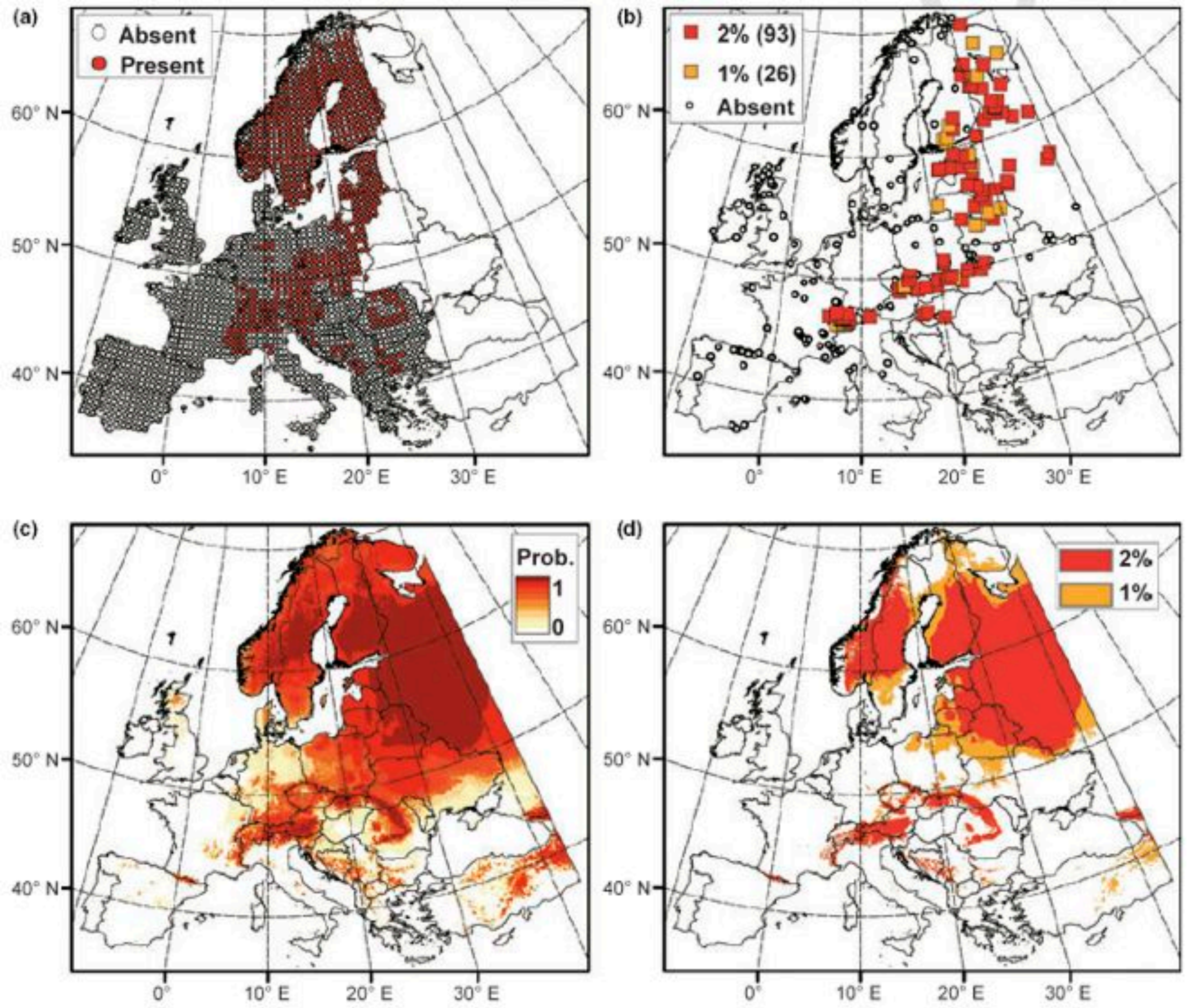
Guisan, Engler et al. (in prep.)

Species loss is a function of elevation range and species' elevation optimum





Current and predicted distribution of *Picea abies*



April 29, 08

Pearman et al. (2008) *Ecology Letters*

Current and predicted distribution of *Juniperus communis*