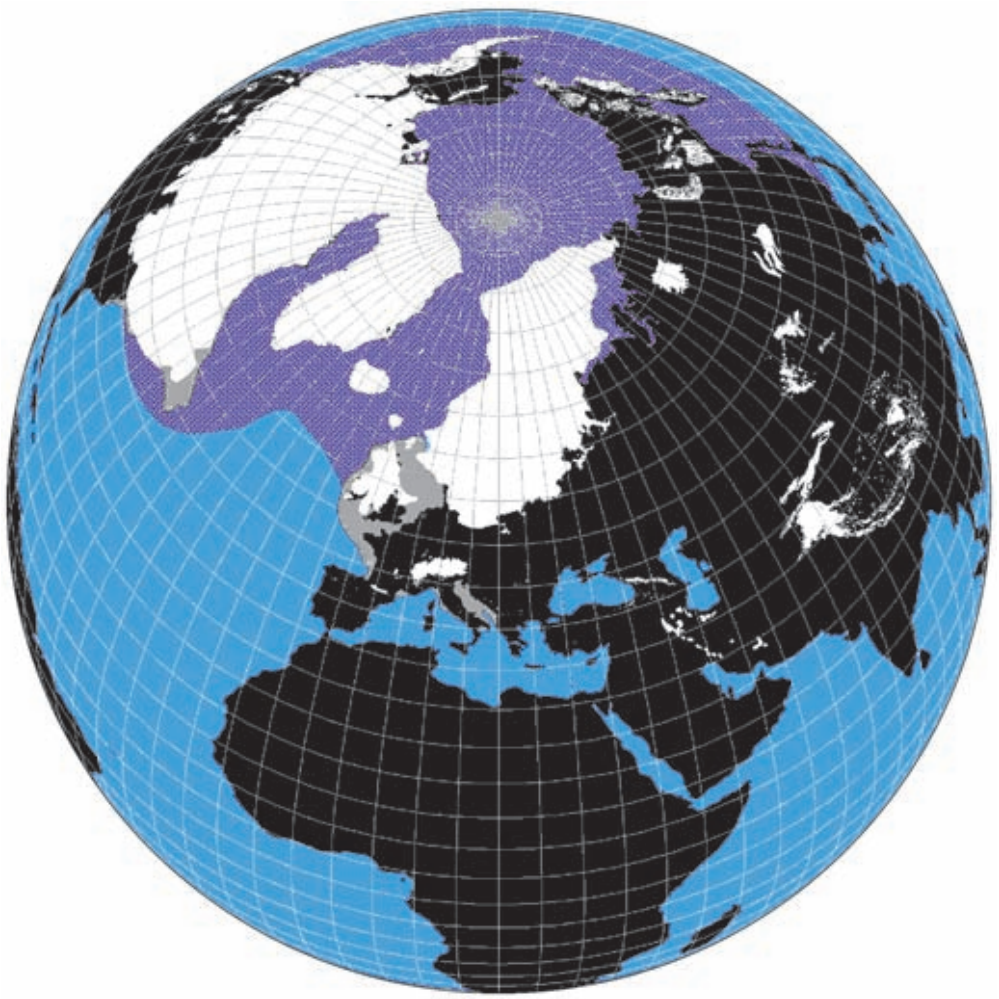
Alice Ledent, PhD student @ULiege

Welcome to migrants in a borderless Europe

Bryophytes show the way to go

International Biogeography Society, Malaga 2019

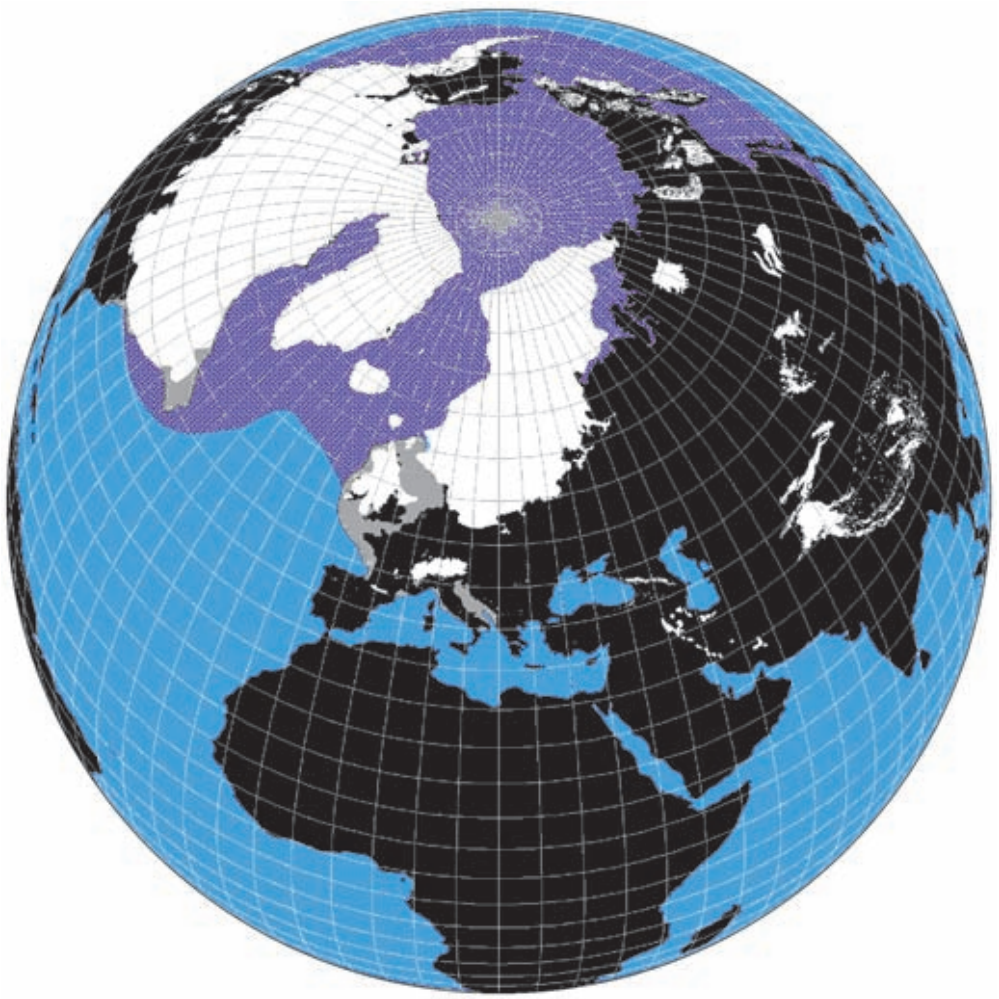


Ehlers & Gibbard, 2008

Maximum extent of LGM ice sheets

- Quaternary glacial/interglacial cycles
  - Largely responsible for current species distribution
- Last Glacial Maximum
  - 26,000 – 19,000 years BP
  - Ice sheets = maximum extent

Introduction



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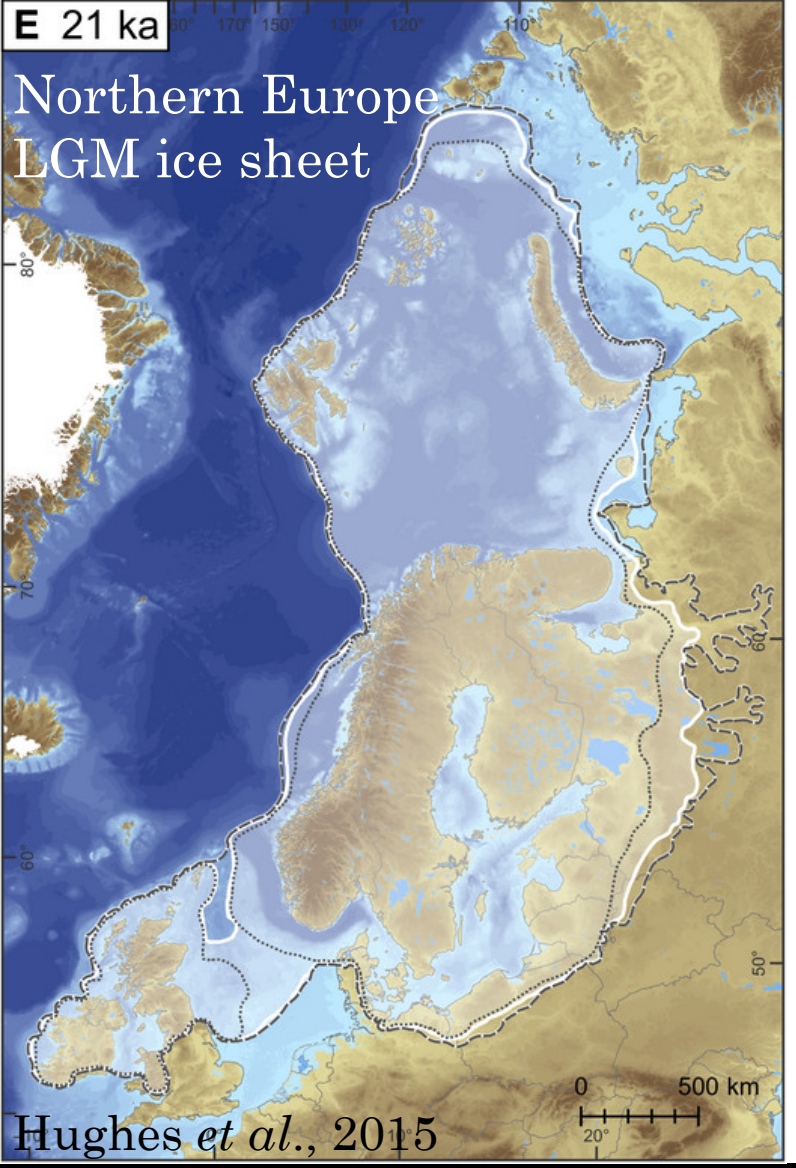
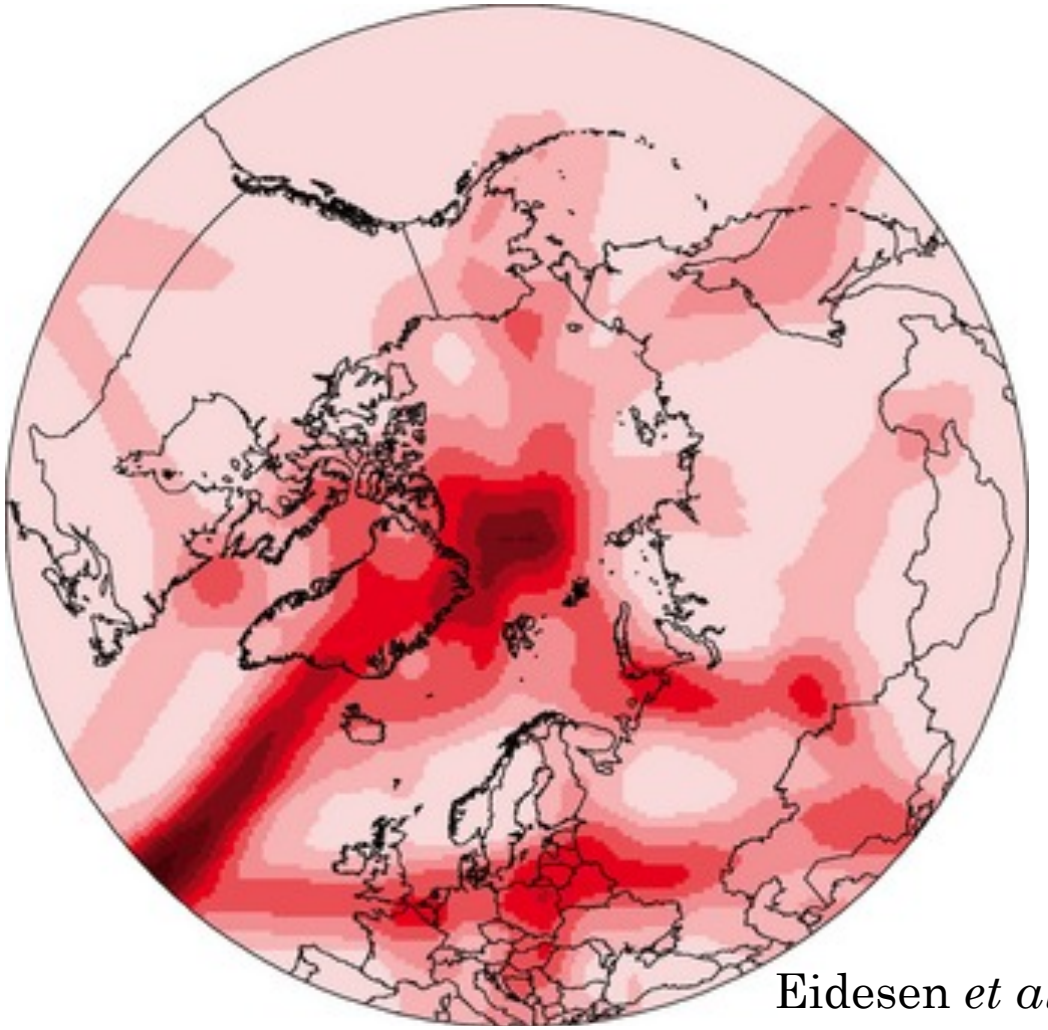


- Cold-adapted taxa
  - *Tabula rasa* hypothesis
    - Species expand in lowland areas
  - *Nunatak* hypothesis
  - Southern mountains *nunatak* hypothesis

Introduction

Cold-adapted taxa demographic hypotheses



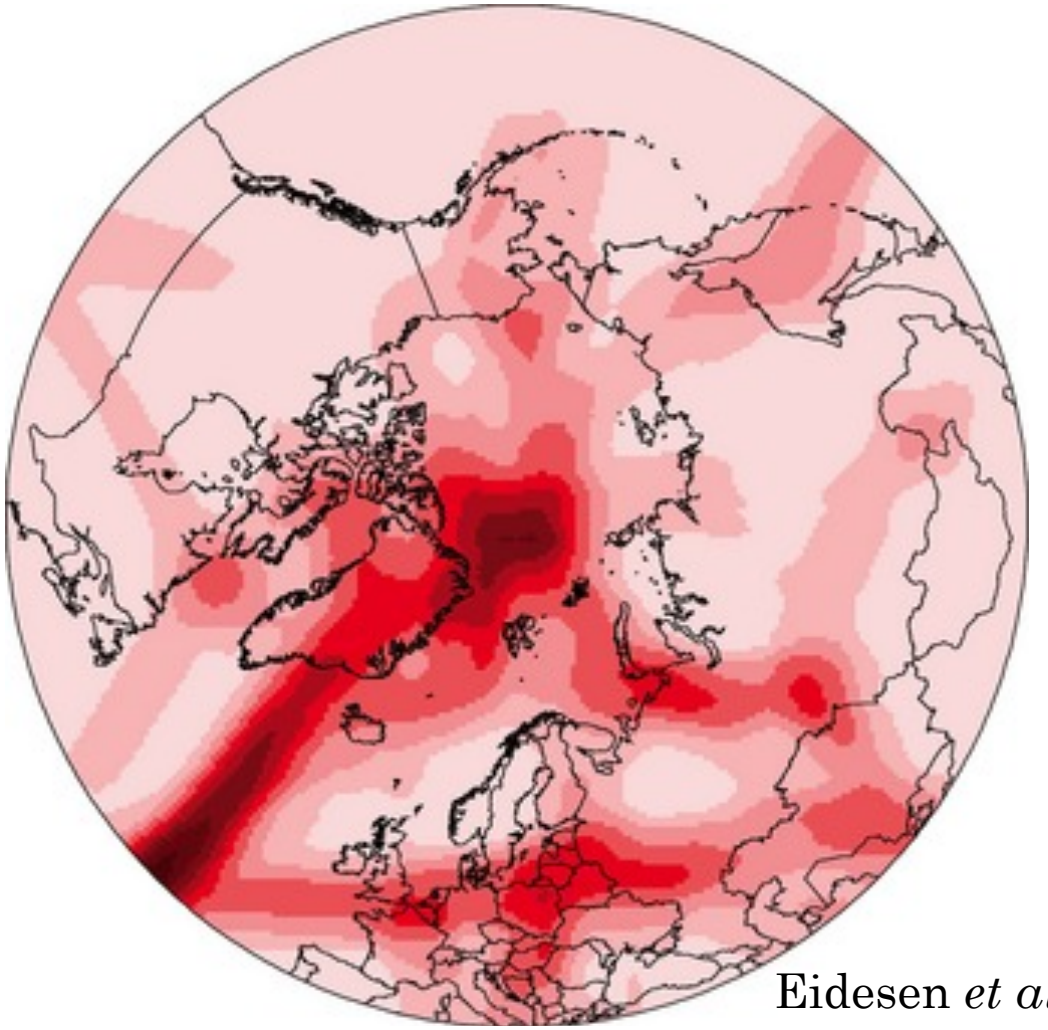
Eidesen *et al.*, 2013

Drought index at LGM : light → dark red

- Cold-adapted taxa
  - *Tabula rasa* hypothesis
  - *Nunatak* hypothesis
    - Lowland areas too dry
    - Micro-refugia within the ice-sheets
  - Southern mountains *nunatak* hypothesis

Introduction

Cold-adapted taxa demographic hypotheses



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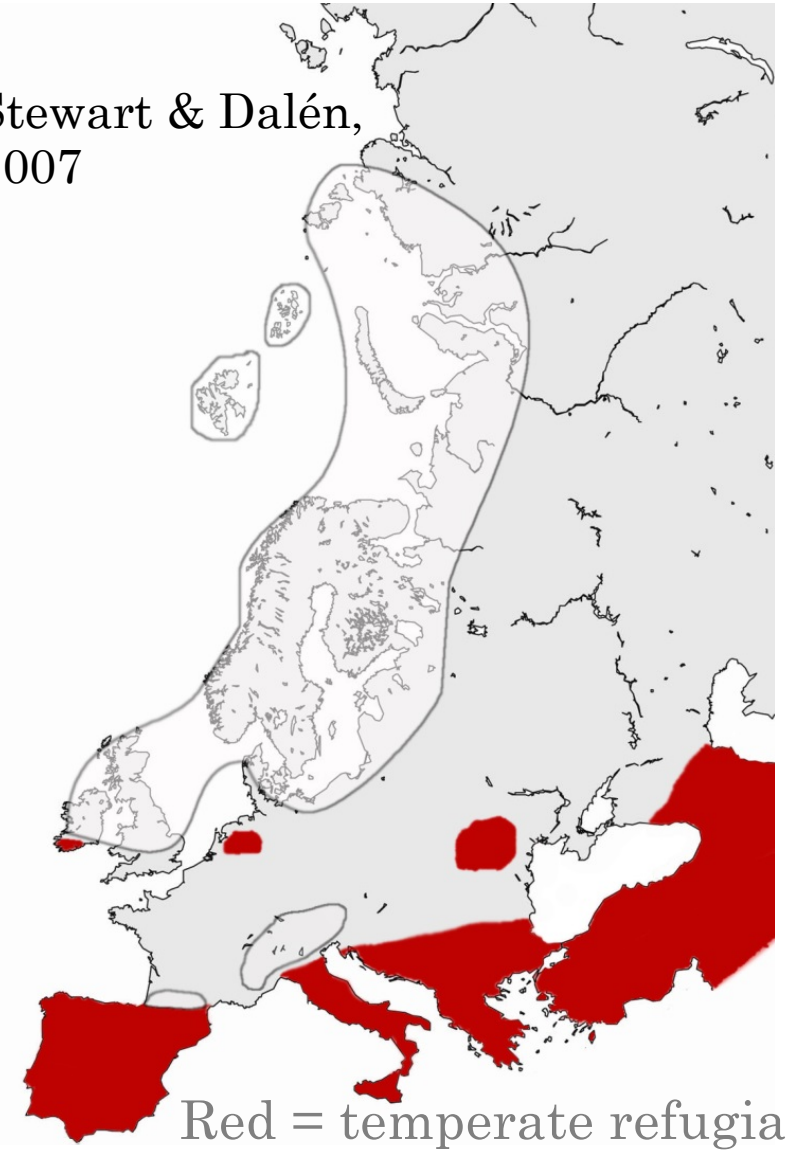
Drought index at LGM : light → dark red

- Cold-adapted taxa
  - *Tabula rasa* hypothesis
  - *Nunatak* hypothesis
  - Southern mountains *nunatak* hypothesis
    - Micro-refugia only in the southern mountains
    - Northern area back-colonized from them

Introduction

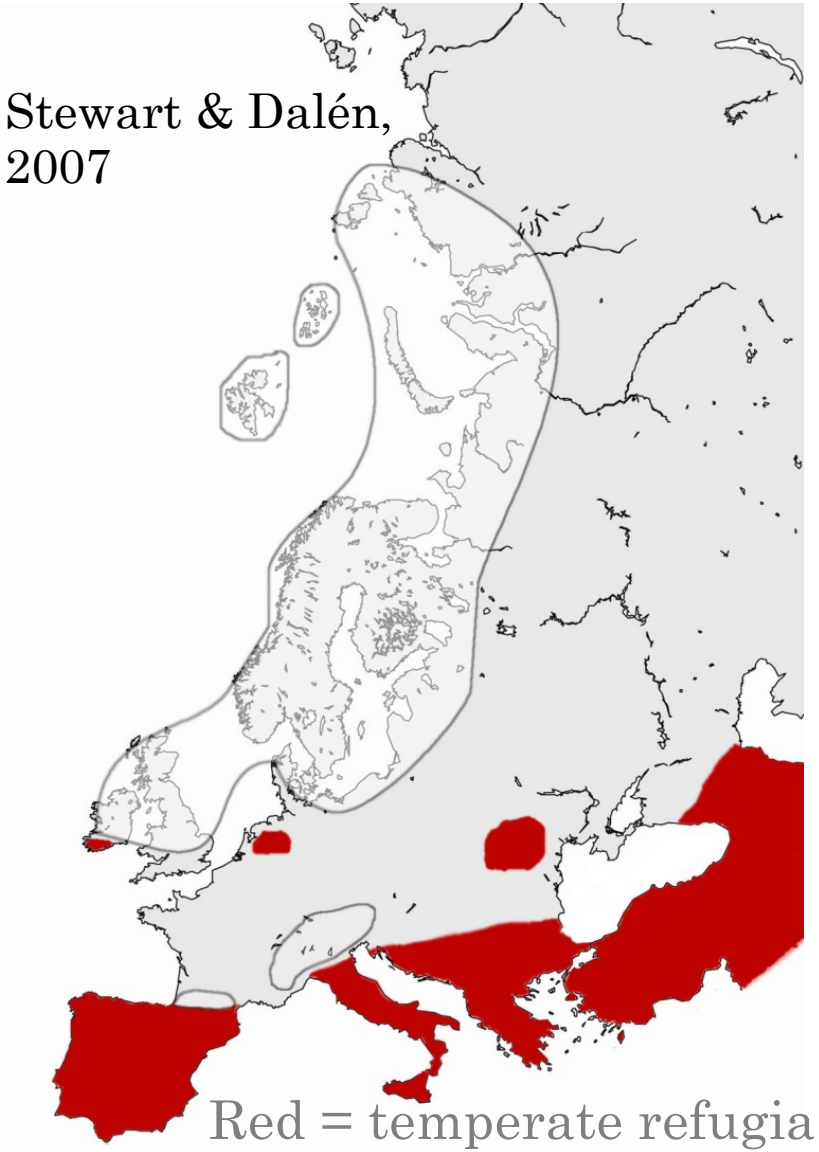
Cold-adapted taxa demographic hypotheses



- Temperate taxa : refugia
  - Southern refugia hypothesis
  - Northern micro-refugia hypothesis

Introduction

Temperate taxa demographic hypotheses



- Temperate taxa : refugia
  - Southern refugia hypothesis
  - Northern micro-refugia hypothesis
    - Predicted from life traits (Bhagwat & Willis 2008)
      - Short generation time
      - Small seed sizes
      - Reproduce under harsh conditions

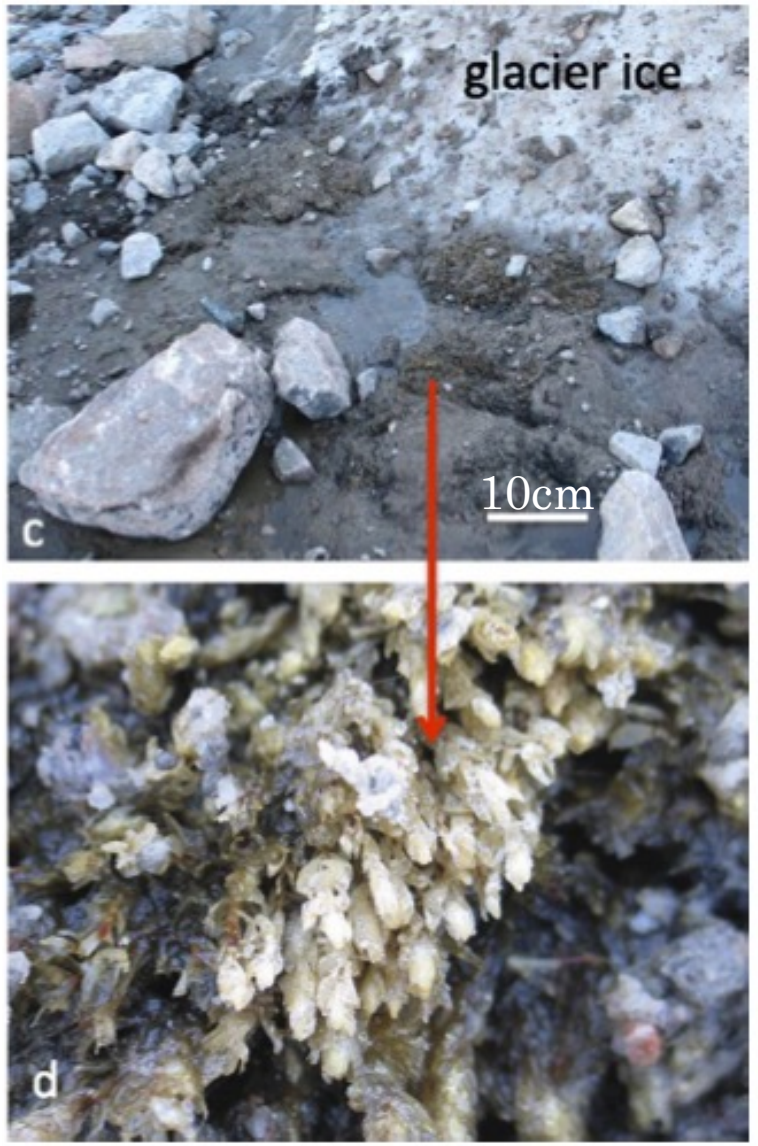
Introduction

Temperate taxa demographic hypotheses

Introduction

- Bryophytes
  - **High cold tolerance**
  - Survive in ice and regenerate after 100's to 1000's of years

    → Good candidates for the *nunatak* and the northern micro-refugia hypotheses
  - **High dispersal capacities**
  - **Scarcity of the fossil records**



La Farge *et al.*, 2013

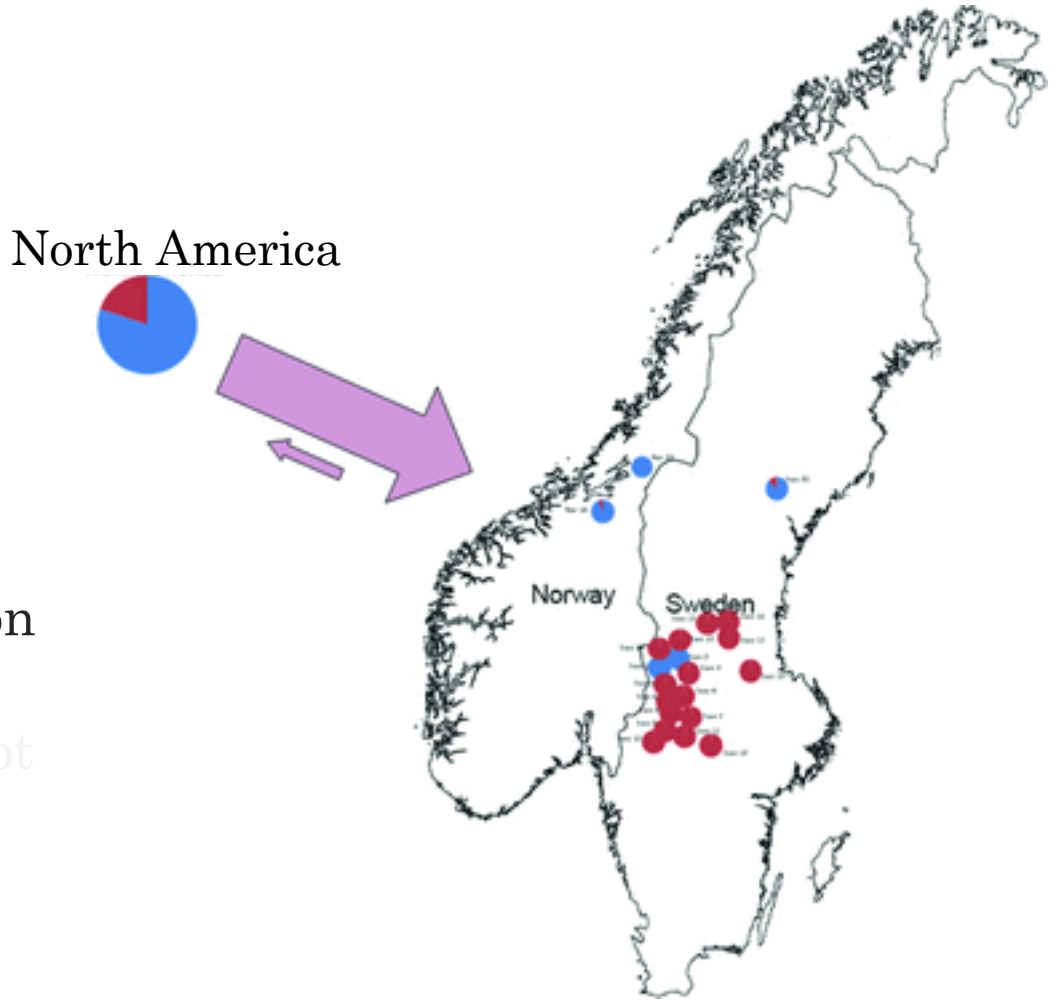
Aulacomnium turgidum out of the glacier

Introduction

- Bryophytes
  - **High cold tolerance**
  - **High dispersal capacities**
  - Ability to cross oceans

    → Good candidates for an extra-European post-glacial recolonization hypothesis

    → Current dispersal patterns do not reflect demographic histories
  - **Scarcity of the fossil records**



Stenoien *et al.*, 2011

Sphagnum angermanicum:
American haplotype spreaded in Europe

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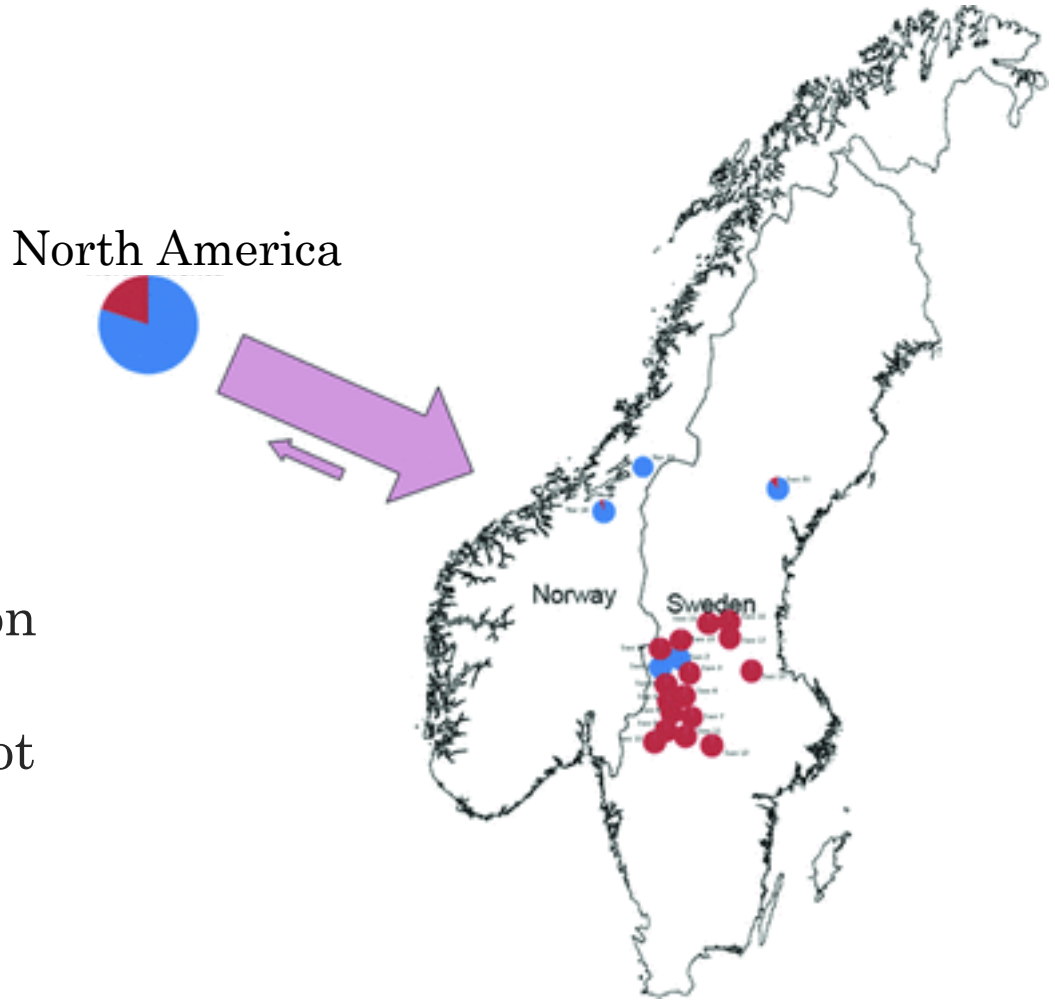

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Introduction

- Bryophytes
  - **High cold tolerance**
  - **High dispersal capacities**
    → Current dispersal patterns do not reflect demographic histories
  - **Scarcity of the fossil records**

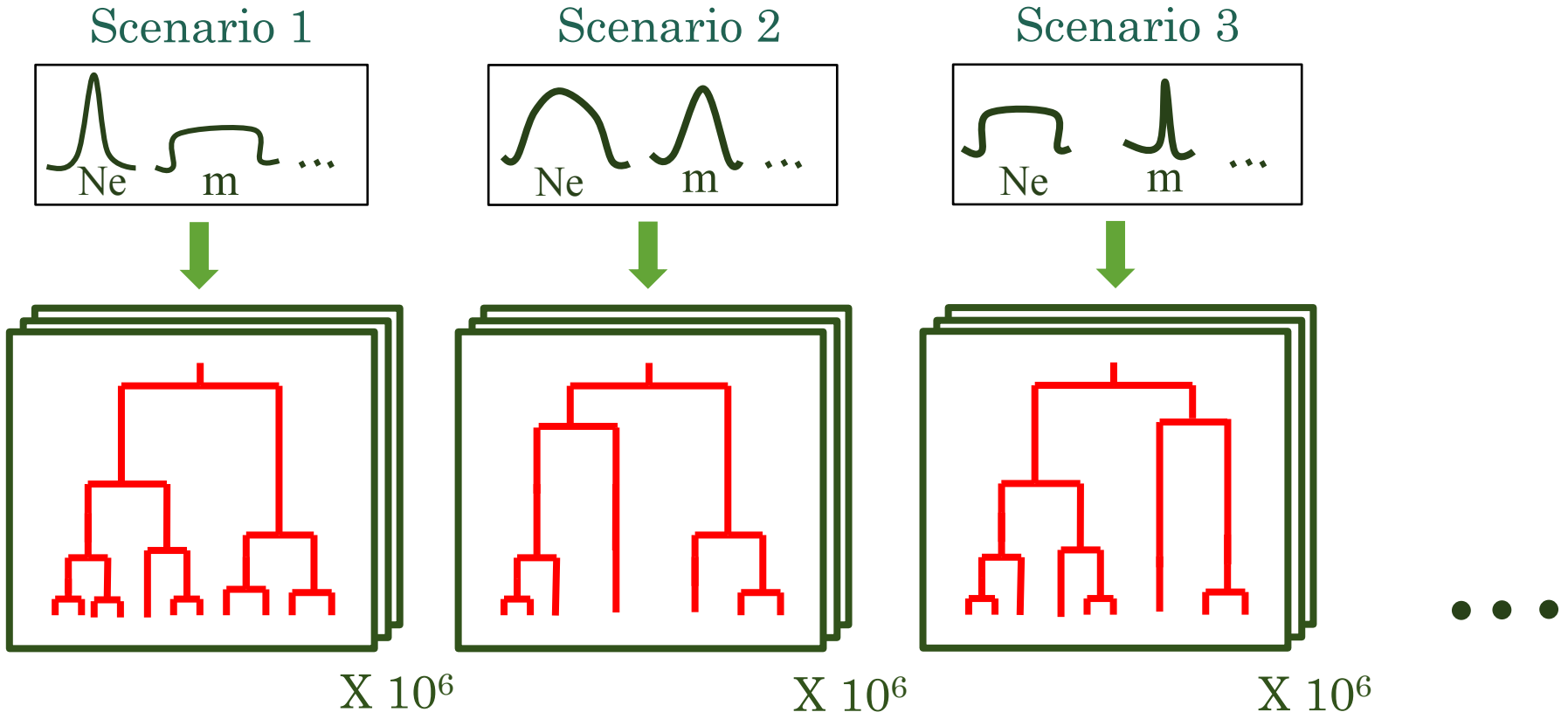
→ Need for molecular phylogeography analyses

→ Compare demographic scenarios

→ Approximate Bayesian Computation (ABCtoolbox2.0, including fastsimcoal2)

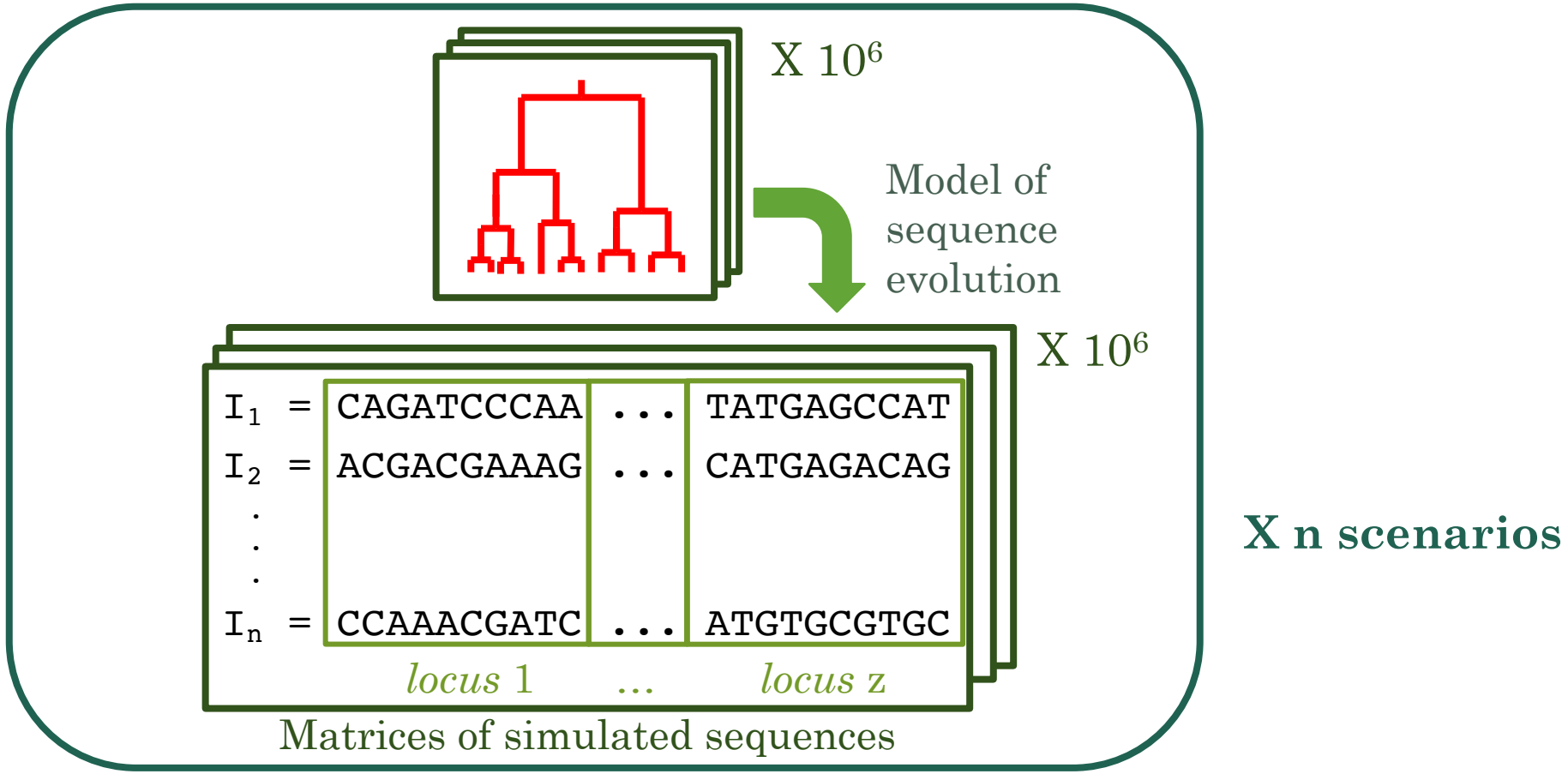
ABC in a nutshell

1. Simulation of alleles genealogies
   - Coalescence technique
   - Through definition of *prior* range of values of demographic parameters
     - Effective population size (Ne)
     - Migration rate (m)



ABC in a nutshell

2. Matrices of sequences simulation
   - Simulation of nucleotide matrices along each of the demographic genealogies using substitution models

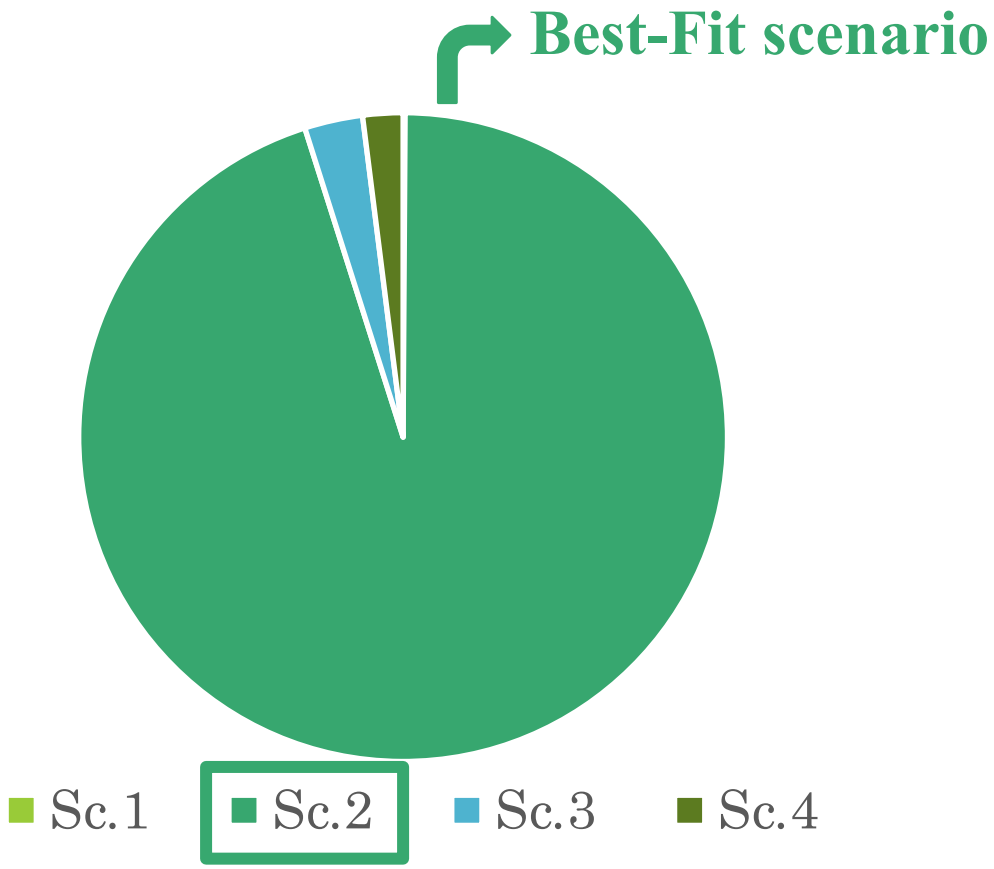


ABC in a nutshell

3. Selection of the best-fit scenario
   - Describe observed and simulated matrices with summary statistics
   - Determine the *posterior* probability of each scenario through an ABC-GLM approcah
   - Identify the best-fit scenario
     - Compute *posterior* distribution of values for each parameter

	Sc.1	Sc.2	…	Sc.4/6
PP	0.001	0.95	…	0.02

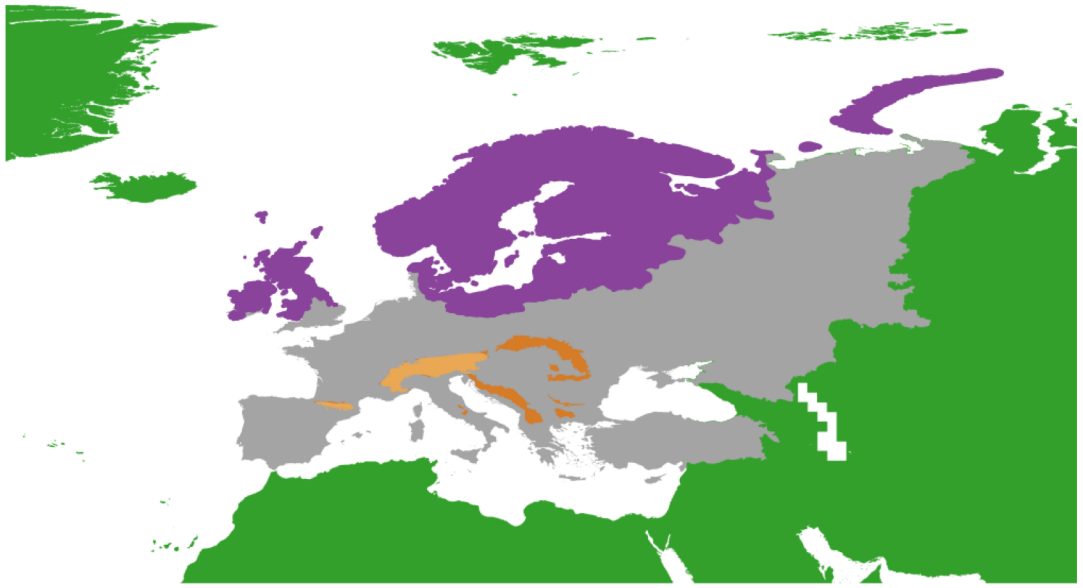
Best-Fit scenario



Material & methods

Cold-adapted taxa

- 3 species



= extra-European range
= northern range iced at LGM
= southern mountain range iced at LGM
= southern mountain range ice-free at LGM
= lowland range

Temperate taxa

- 12 species

= extra-European range
= northern range
= southern range

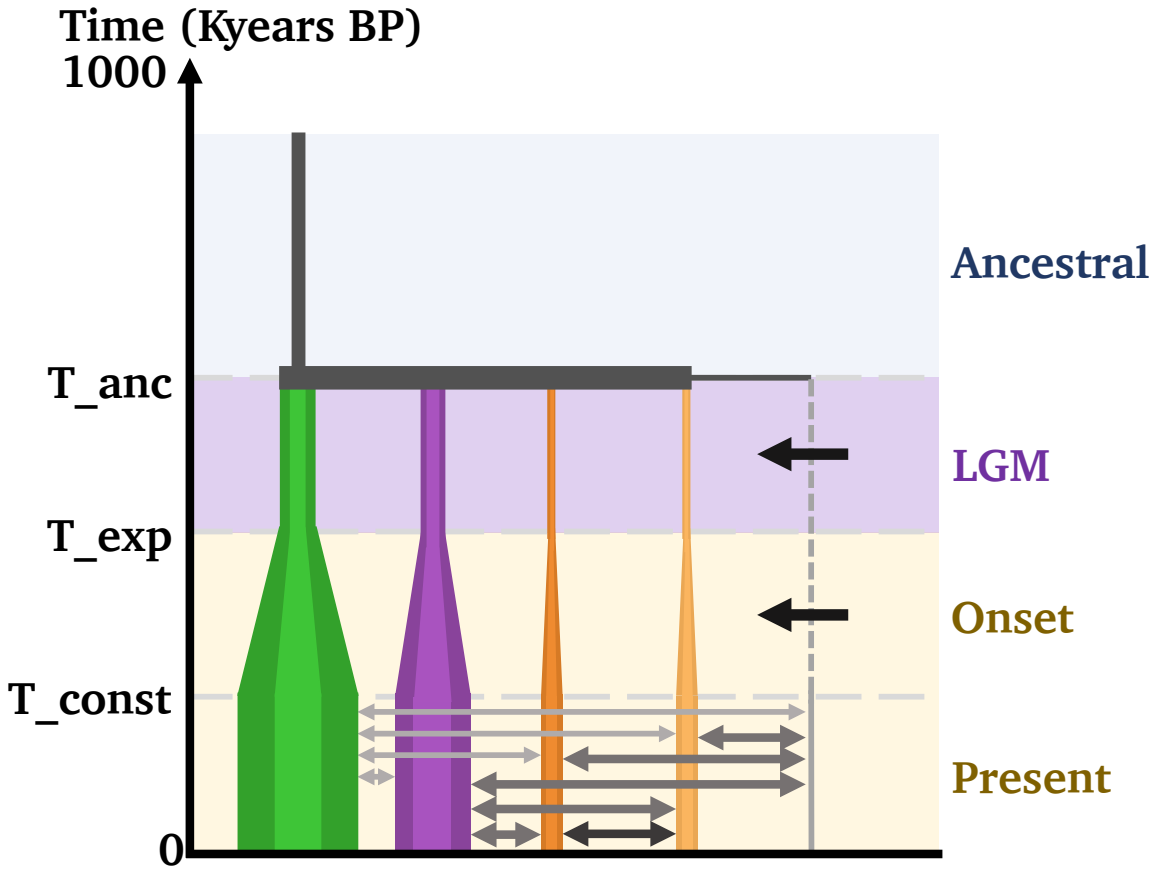
- 2/3 cp loci + 1/3 n *loci* / species

Demographic scenarios

Cold-adapted taxa

- ***Nunatak* / micro-refugia**

- Present
  - Population sizes stable
  - Migrations with **extra-Europe**
  - Migrations between **European** populations
- Onset
  - Progressive bottleneck in all populations
- LGM
  - Population sizes stable

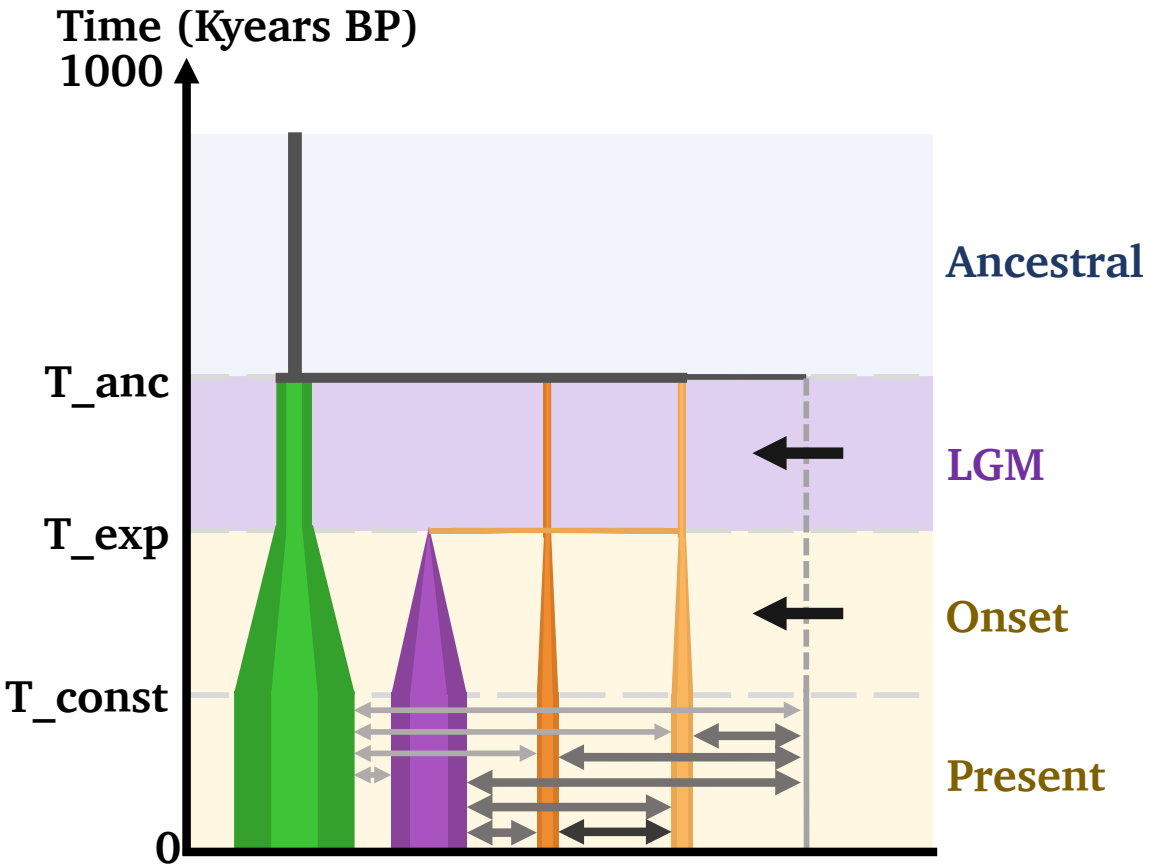


Demographic scenarios

Cold-adapted taxa

- **Southern mountains *nunatak* hypothesis**

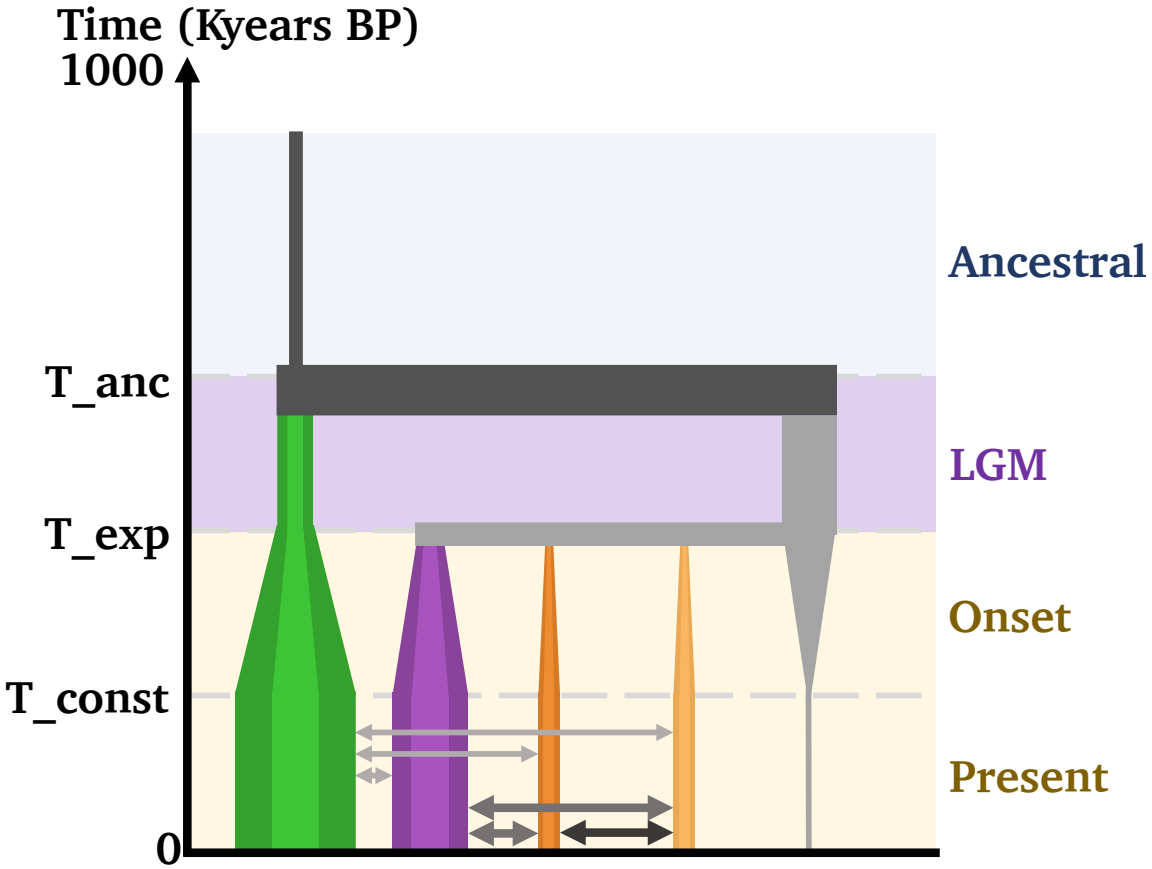
- LGM
  - Colonization of **N** from **ice-free/iced southern mountains**



Demographic scenarios

Cold-adapted taxa

- ***Tabula rasa***

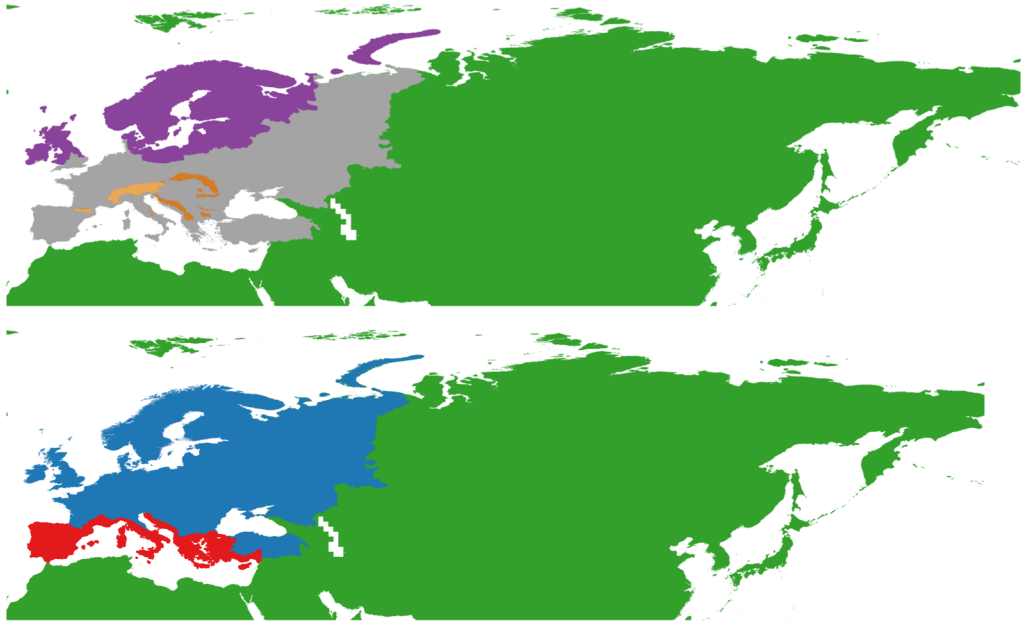


- Onset
  - Progressive bottleneck in all populations
  - Expansion in **Lowland**
- LGM
  - Colonization of **Europe** from **Lowland**

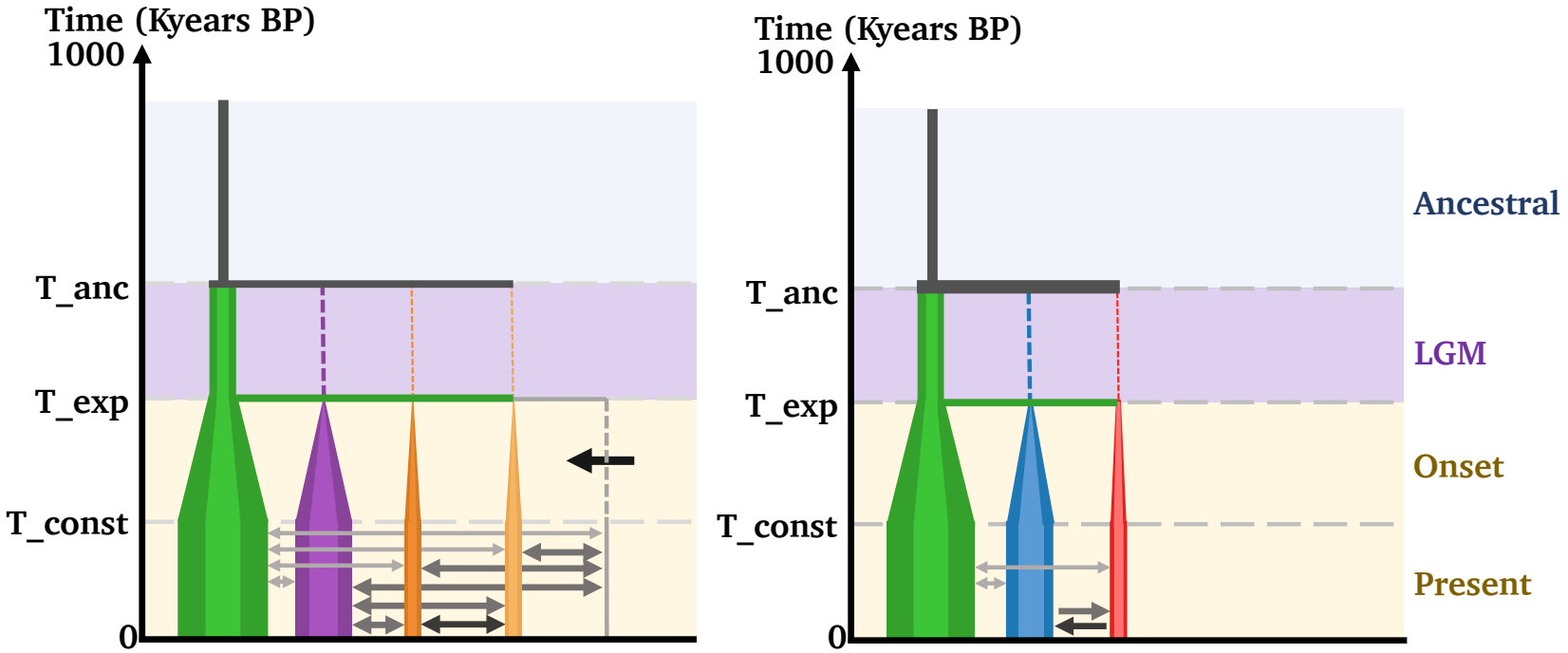
Demographic scenarios

Cold-adapted/Temperate taxa

- **Extra-European post-glacial recolonization**



- Onset
  - Strong bottleneck in **Europe**
- LGM
  - Colonization of **Europe** from **extra-Europe**
  - Potential micro-refugia in **Europe**

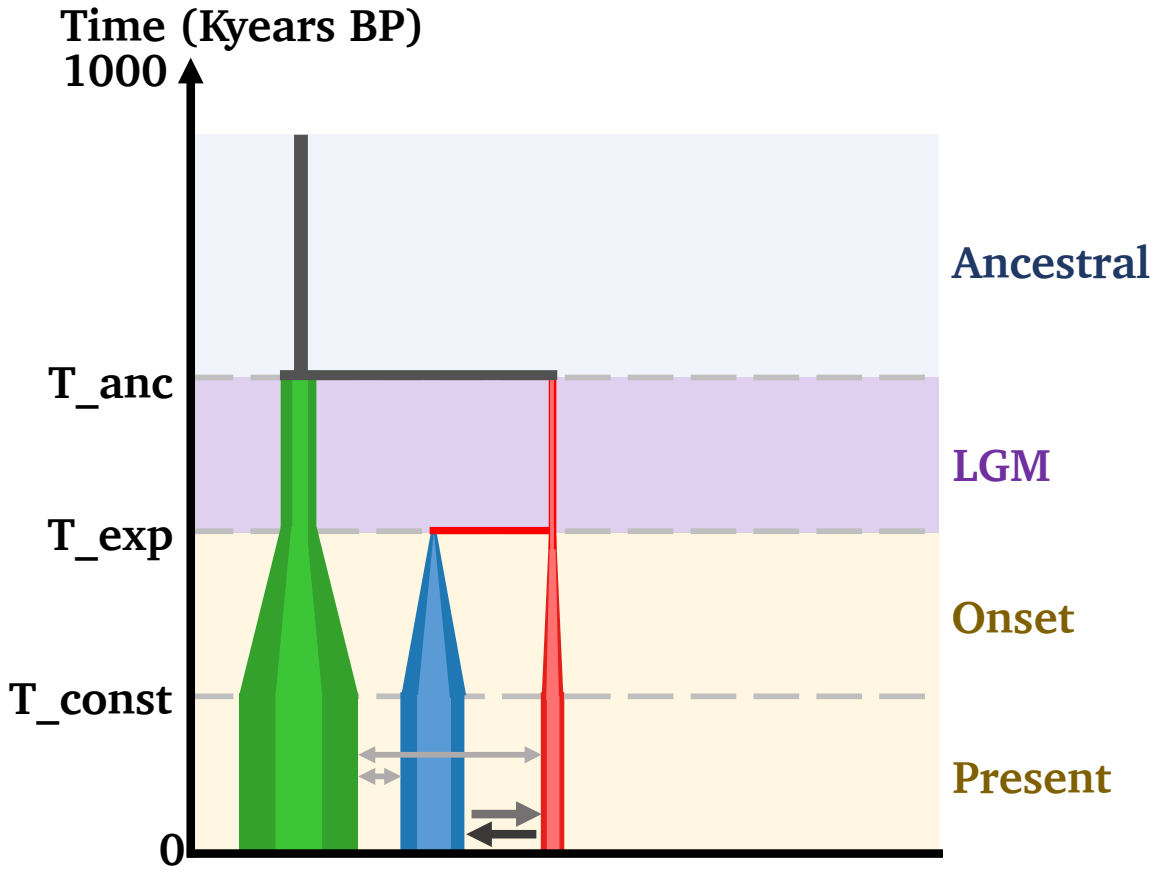


Demographic scenarios

Temperate taxa

- **Southern refugia**

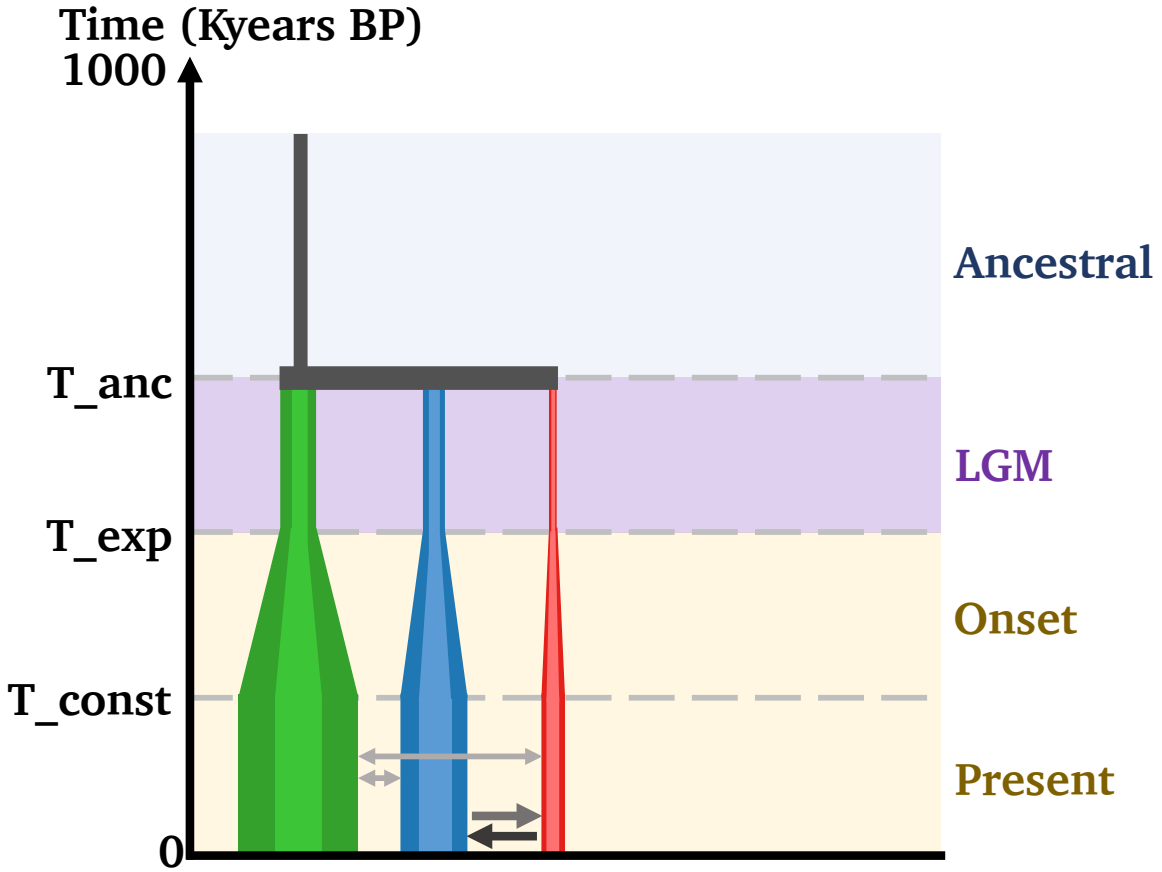
- Onset
  - Strong bottleneck in **N**
- LGM
  - Colonization of **N** from **S**



Demographic scenarios

Temperate taxa

- **Northern micro-refugia**



- Onset
  - Progressive bottleneck in all populations

Results

Cold-adapted taxa

- Best-fit scenarios

- Expected
  - *Nunatak*/Micro-refugia : 2/3 species
- Classical
  - *Tabula rasa* : 1/3 species

Results

Cold-adapted taxa

- Best-fit scenarios

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  - *Nunatak*/Micro-refugia : 2/3 species ✓
- Classical
  - *Tabula rasa* : 1/3 species ✓

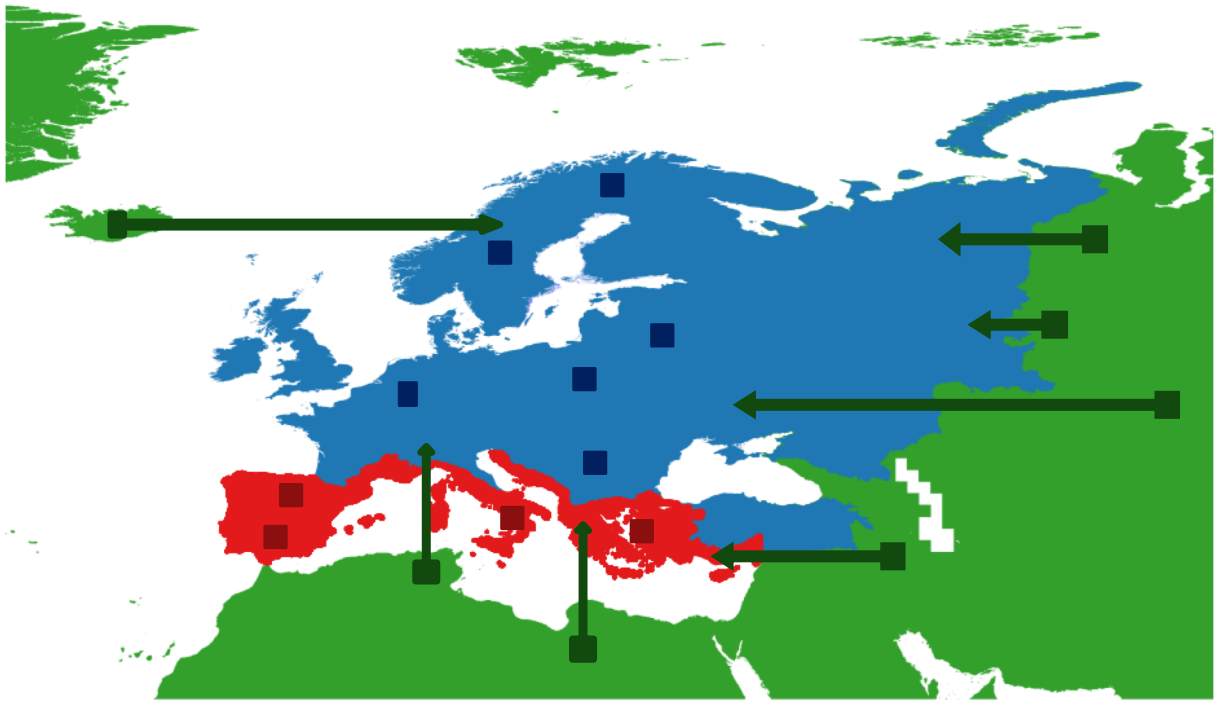
Temperate taxa

- Best-fit scenarios

- Expected
  - Northern micro-refugia : 2/12 species ✗
- Classical
  - Southern refugia : 3/12 species ✗

- **Extra-European post-glacial recolonization : 7/12 species**
  - Posterior distribution : > 90% of extra-European migrants

Results



Temperate taxa

- Best-fit scenarios
  - Northern micro-refugia : 2/12 species ✗
  - Southern refugia : 3/12 species ✗
  - **Extra-European post-glacial recolonization : <u>7/12 species</u>** ✓
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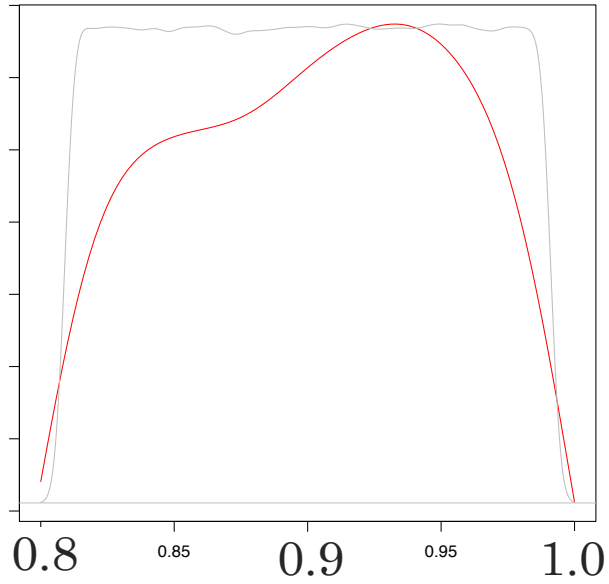

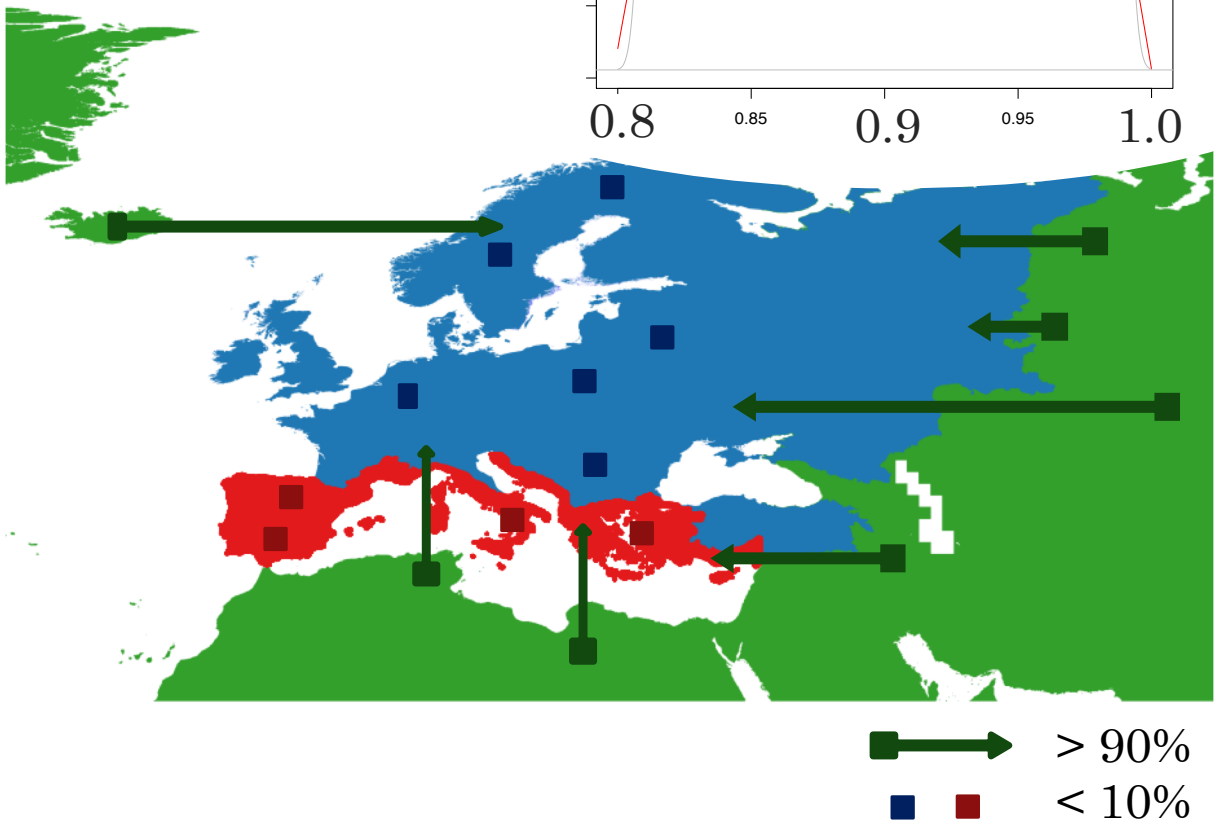

Temperate taxa

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  - Southern refugia : 3/12 species
  - **Extra-European post-glacial recolonization : 7/12 species**
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Discussion

- 1st study to **demonstrate** and **quantify** the contribution of extra-European migrants in the European bryophytes assembly

→ **Small and scattered Eu refugia VS huge waves of Extra-Eu migrants**

- Europe at LGM = largely treeless

Discussion

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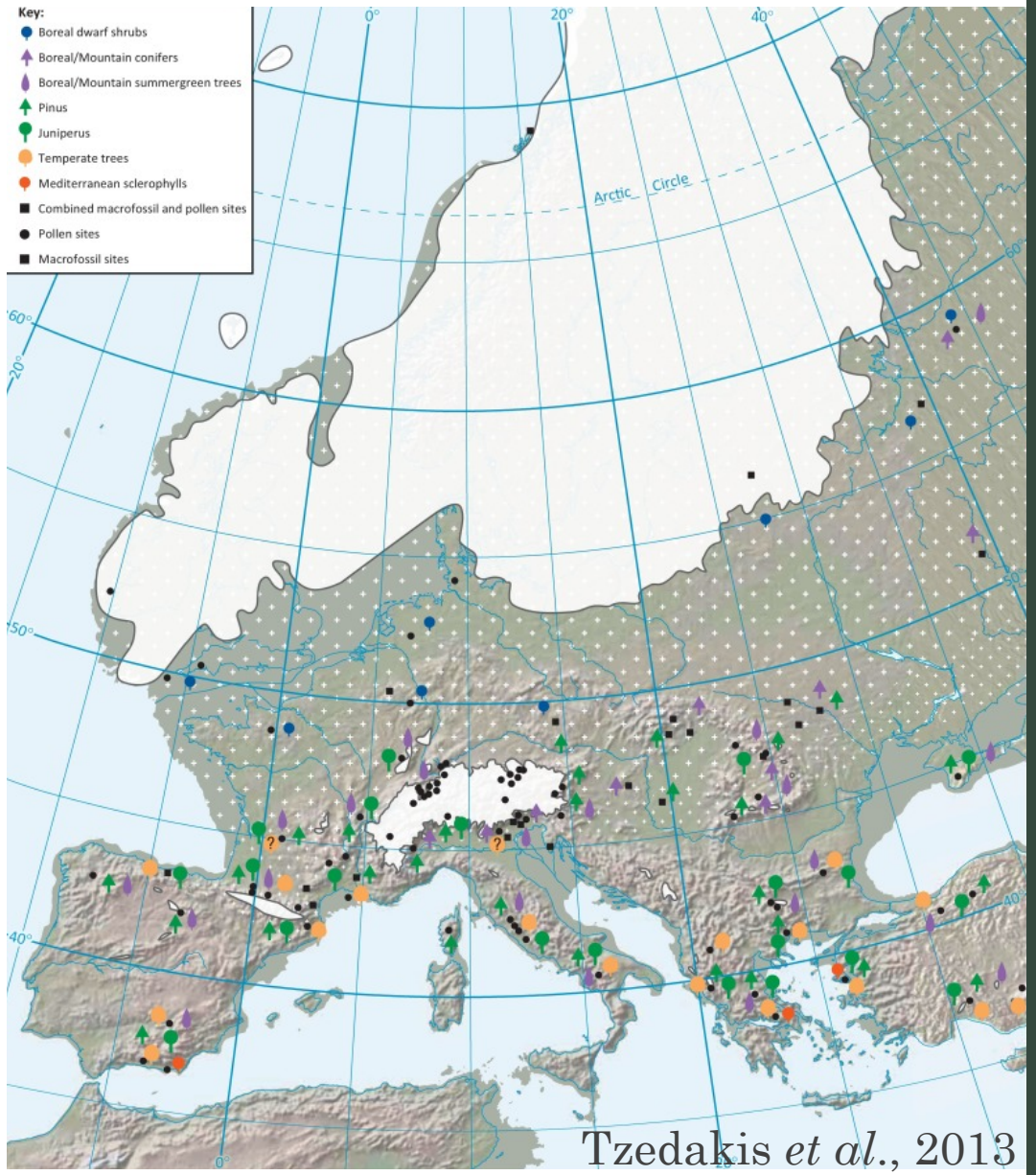
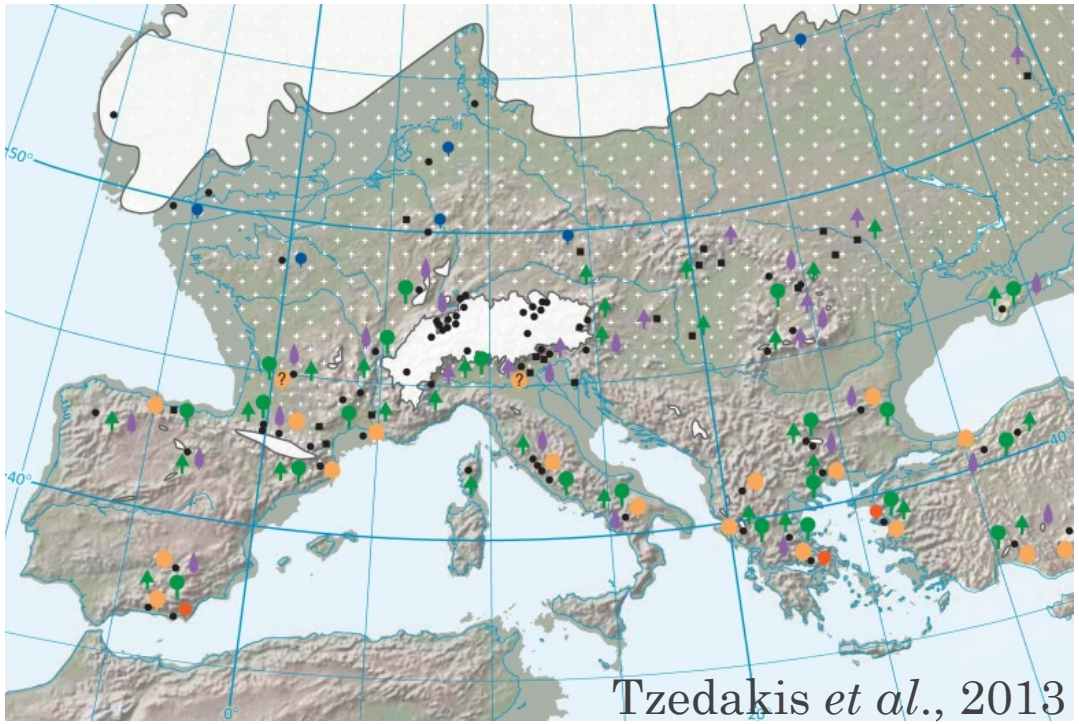


European paleoenvironments at LGM

Discussion

Paleotological reconstruction

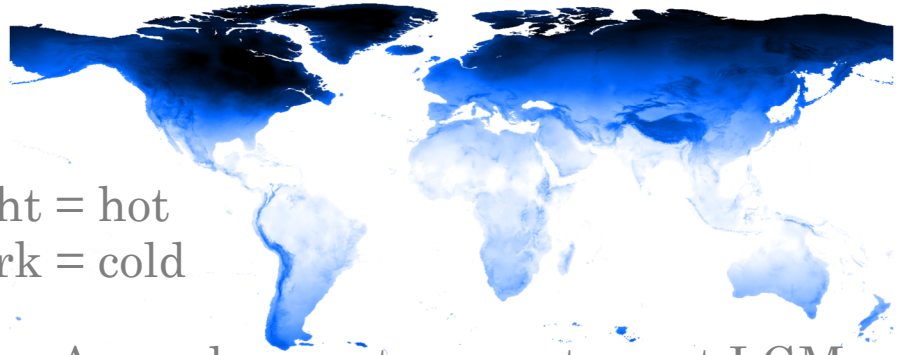
- Europe at LGM = largely treeless
  - Tzedakis *et al.*, 2013
  - Binney *et al.*, 2017



European paleoenvironments at LGM

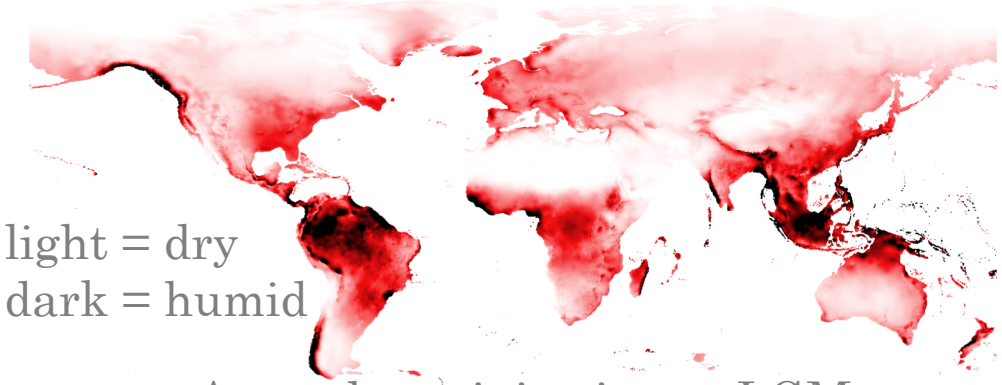
Paleoclimatic reconstruction

- Europe at LGM = covered by treed
  - Not too cold



Annual mean temperature at LGM

  - Not too dry

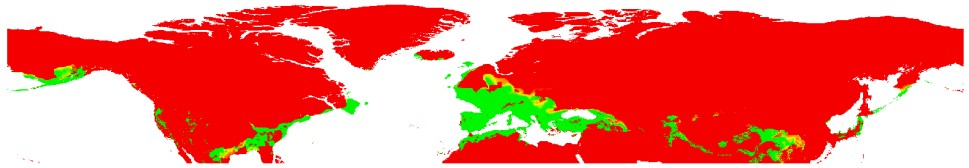


Annual precipitation at LGM

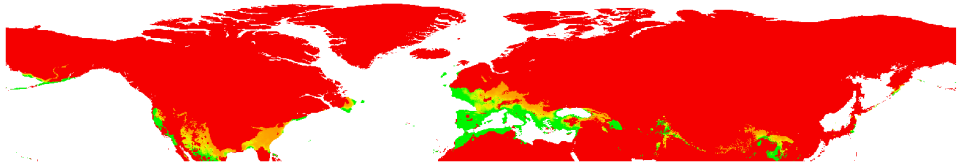
WorldClim 1.4

Discussion

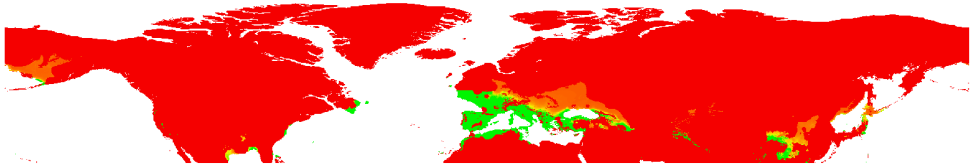
SDMs



Amphidium mougeotii



Calypogeia fissa

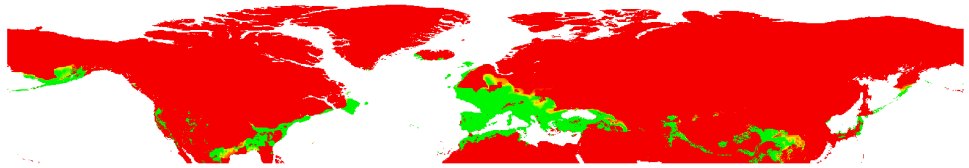


Metzgeria furcata

Results

Discussion

SDMs



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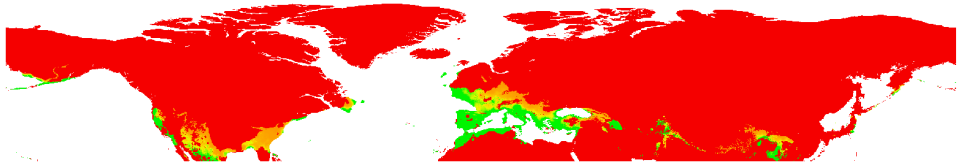

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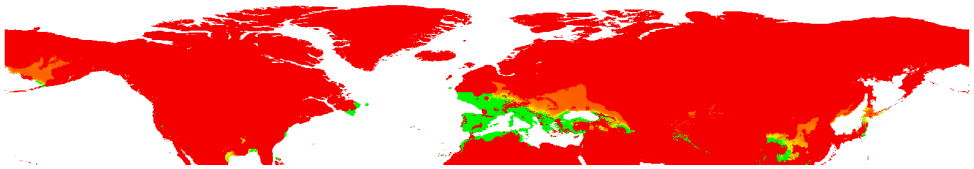

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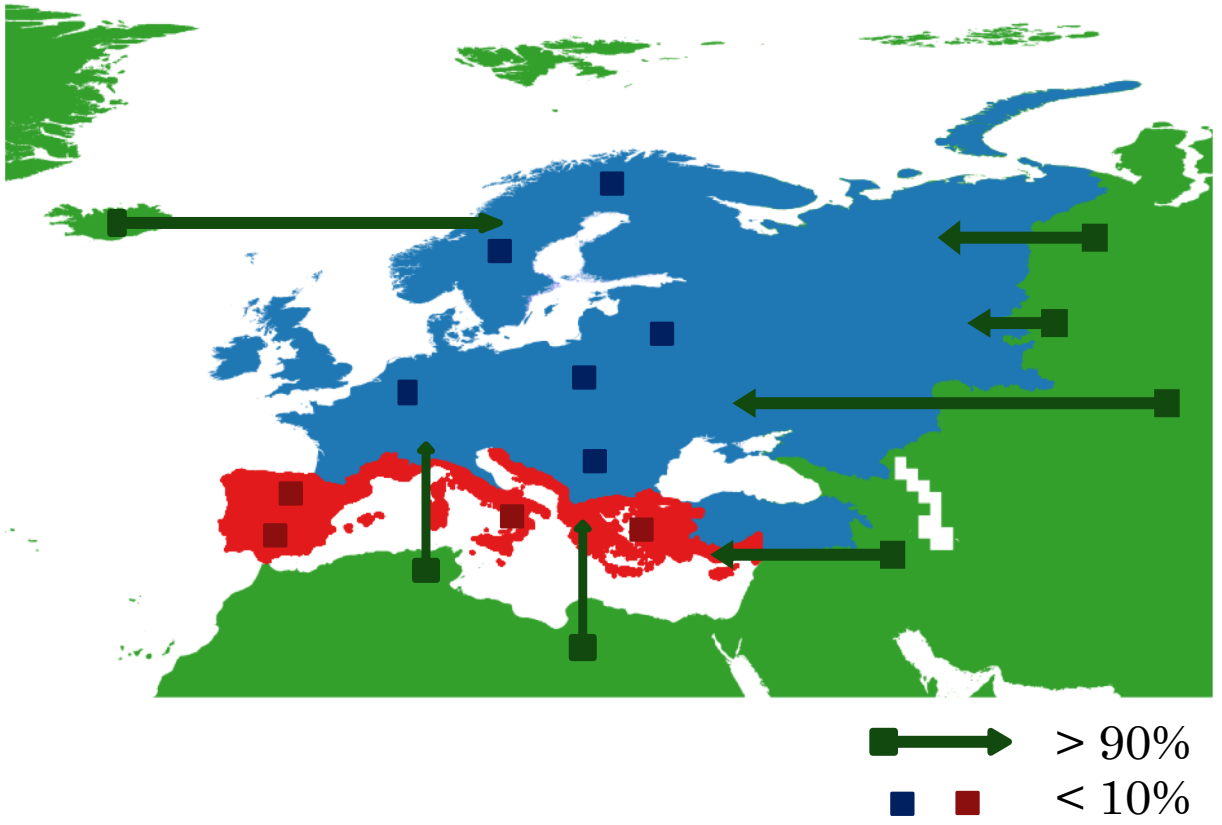
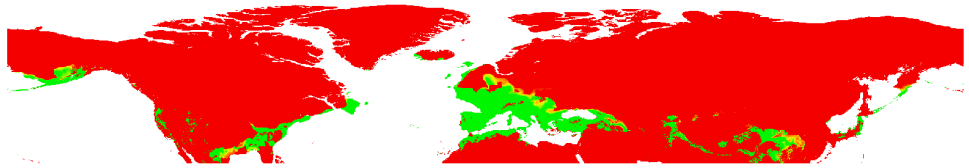
Results



Conclusion

SDMs



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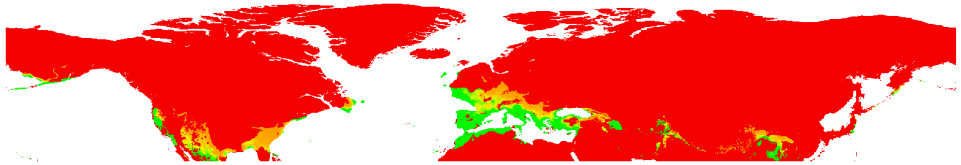

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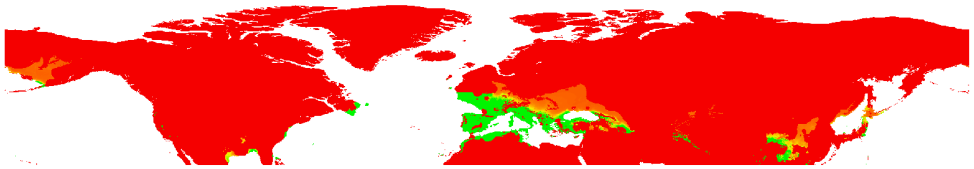
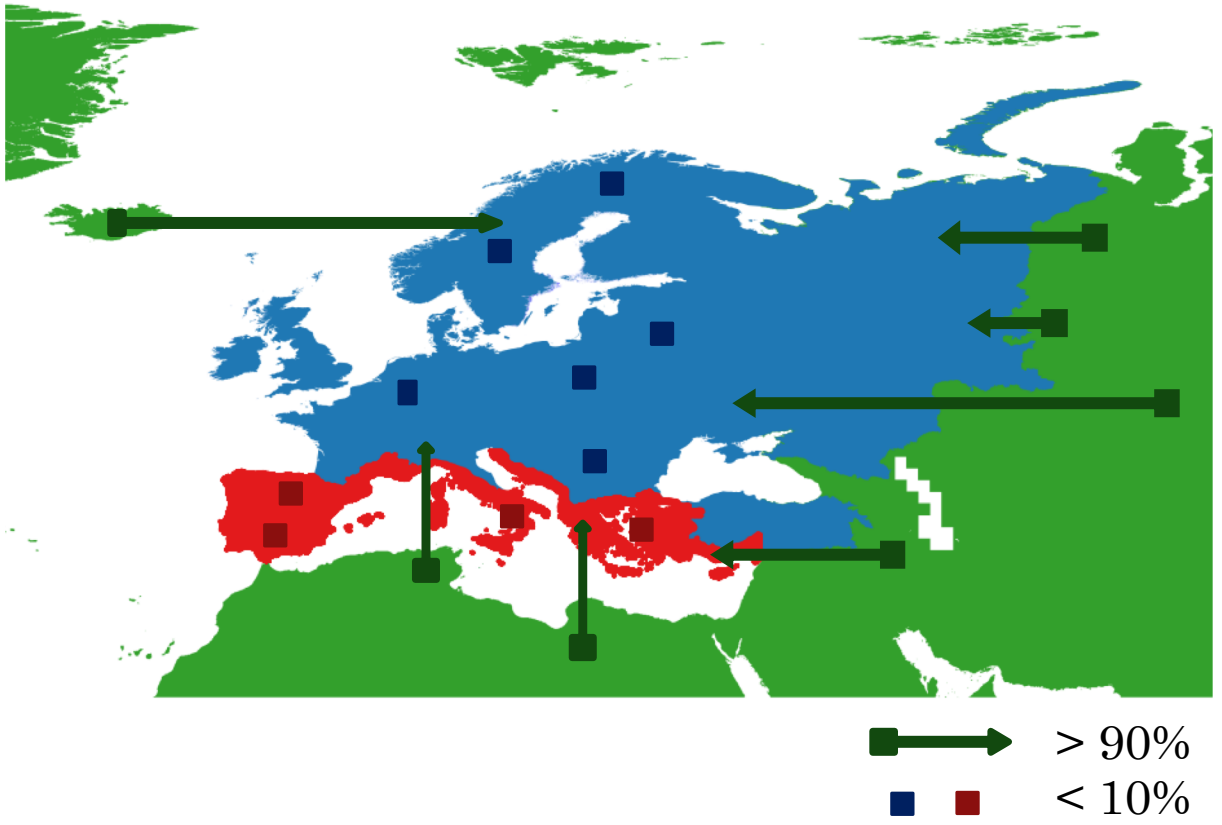


Metzgeria furcata

Results



→ LGM climatic reconstructions = too optimistic

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Florian Zanatta

Stuart McDaniel

IPNA

Jairo Patiño

ULB

Patrick Mardulyn

ULiege

Alain Vanderpoorten

Thank you very much for your attention!

Questions?