Ecologie et Dynamique
des Systèmes Anthropisés
FRE 3498 CNRS-UPJV
www.u-picardie.fr/edysan

Combining large-scale vegetation plot databases with a plant-community-based approach to assess fine-grained thermal variability within 1-km² climatic units across Northern Europe

HETEROCLIM workshop – Tours – 10-14/06/2014

Photo: Jonathan Lenoir

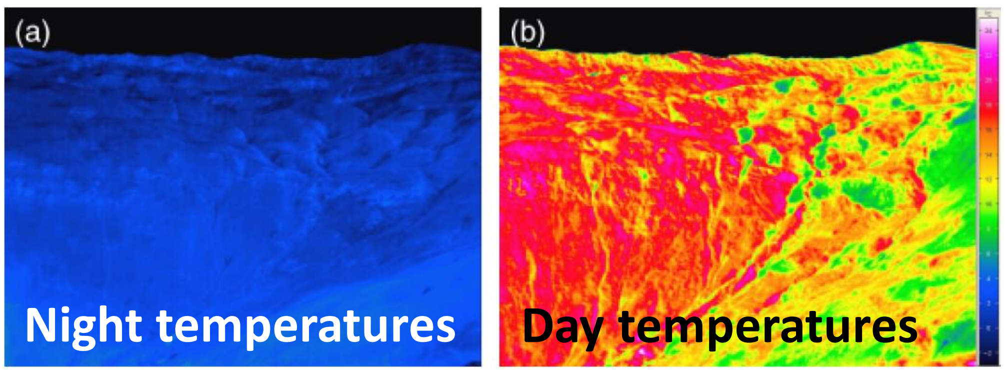
Why caring about fine-grained thermal variability?

Global Change Biology

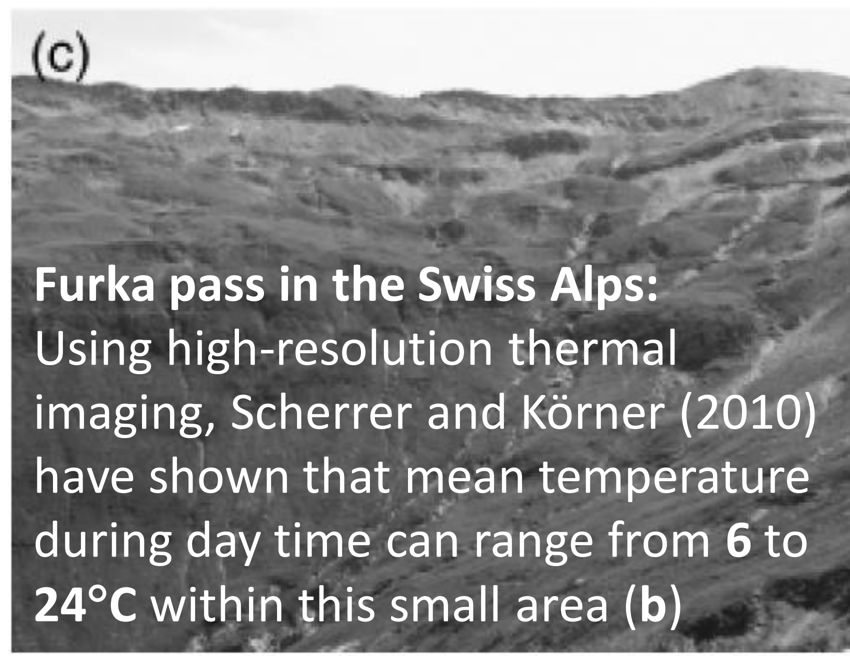
Global Change Biology (2010) **16**, 2602–2613, doi: 10.1111/j.1365-2486.2009.02122.x

Infra-red thermometry of alpine landscapes challenges climatic warming projections

DANIEL SCHERRER and CHRISTIAN KÖRNER



Ccl: Short-distance escapes are available for plants to persist locally amidst unfavorable regional climatic conditions suggesting plant biodiversity to be less endangered than is expected by climate warming projections



Can we assess it across broad spatial extents?

- **Issue:**

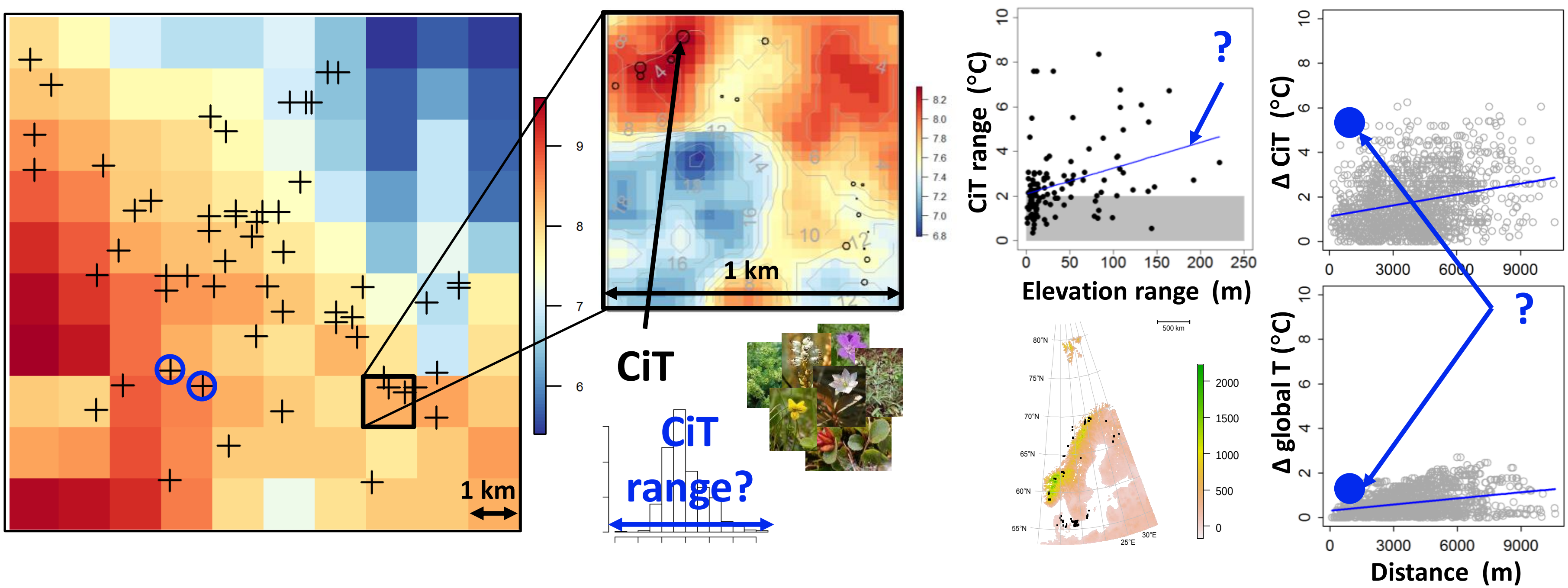
- The cost of using networks of miniature data loggers or high-resolution thermal images across large spatial extents is a limiting factor

- **Solution:**

- Vegetation geodatabases are already available across large spatial extents and can be used in combination with semi-quantitative plant species indicator values to infer biologically relevant temperature conditions from plant assemblages within <1000-m^2 units (**community-inferred temperatures: CiT**)

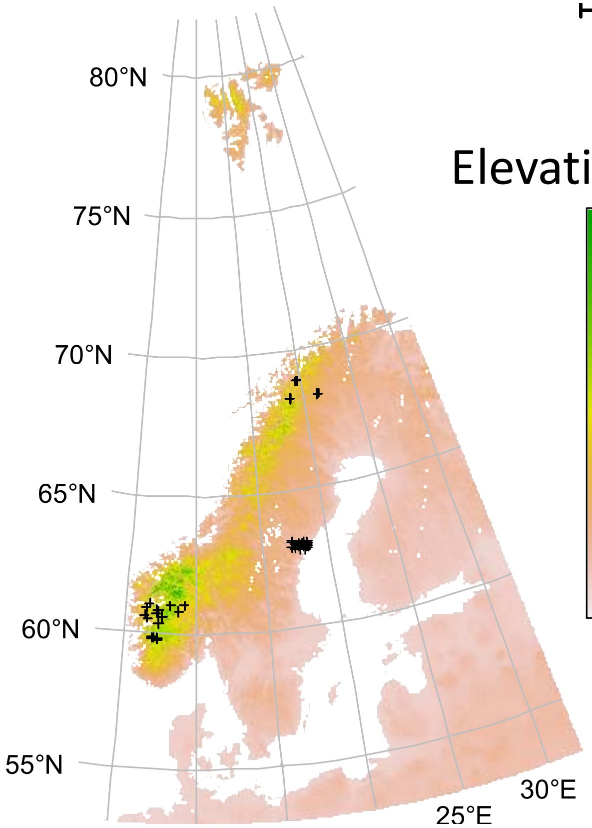
Aims

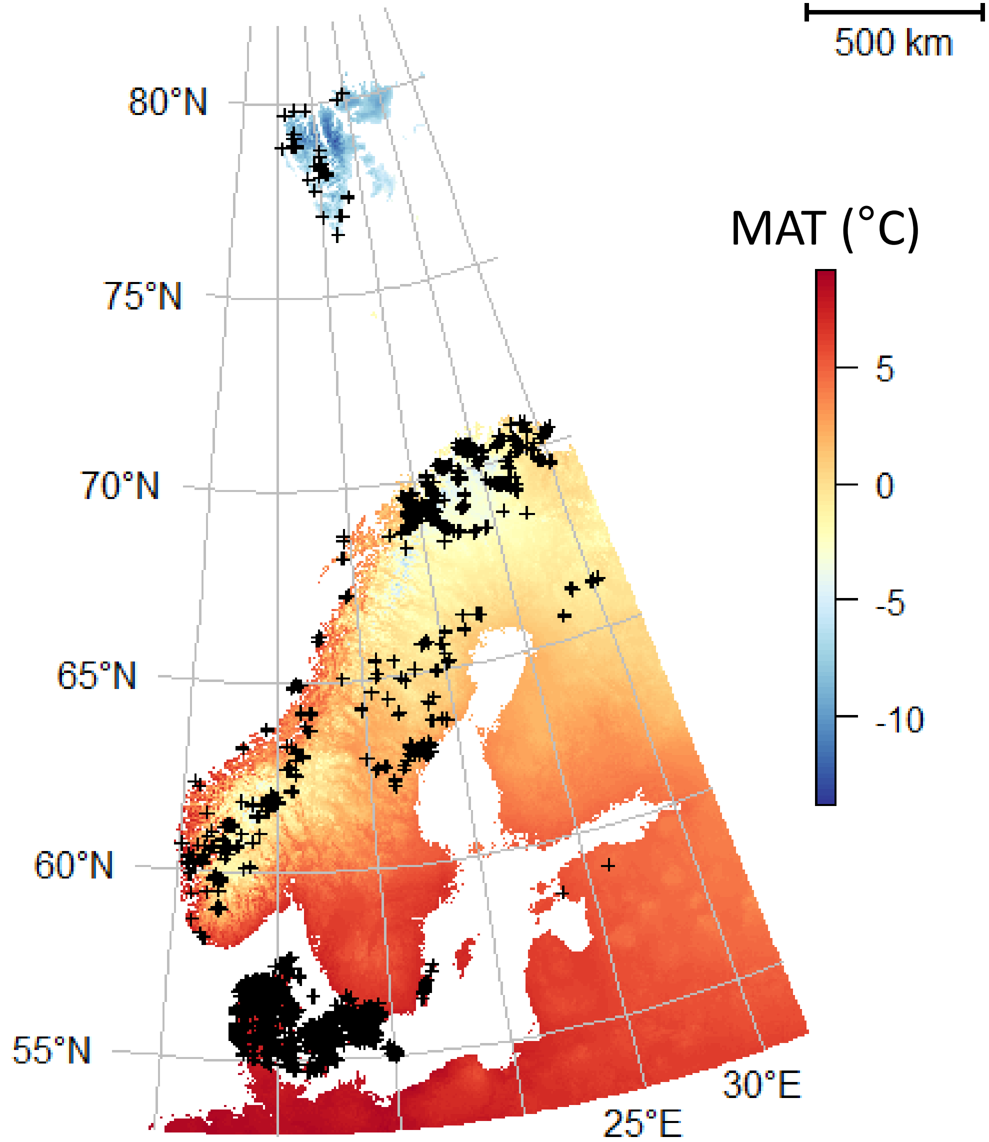
- Assessing thermal variability (CiT range) within 1-km^2 units (cf. WorldClim climatic unit, http://www.worldclim.org/)
- Analyzing the relationship between CiT range and variables reflecting terrain complexity (elevation range, roughness, etc.) at 1-km resolution
- Testing whether or not spatial turnover in CiT is greater than spatial turnover in globally interpolated temperatures (cf. WorldClim temperature grids)



Plot-scale data

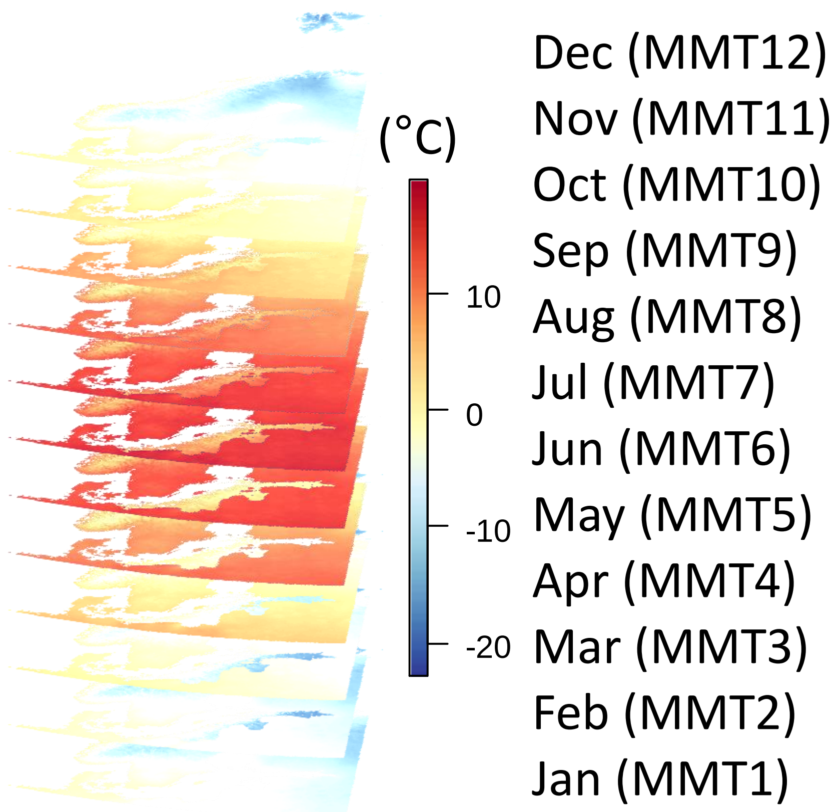
- 42117 vegetation plots across Northern Europe
- 138 of these plots are equipped with miniature soil data-loggers



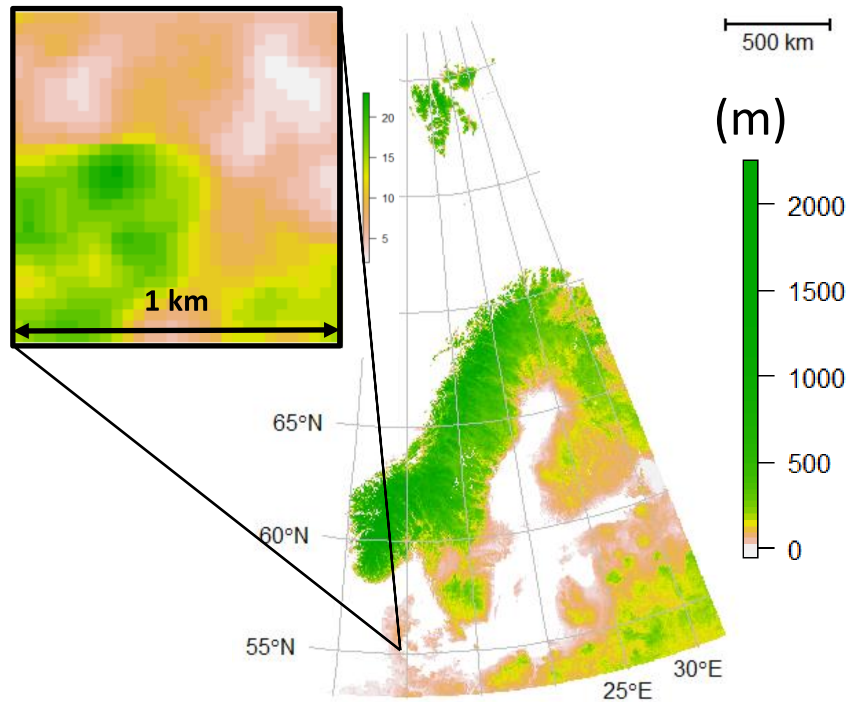


Gridded data

- 12 mean monthly temperature grids across Northern Europe at 1-km resolution (WorldClim)

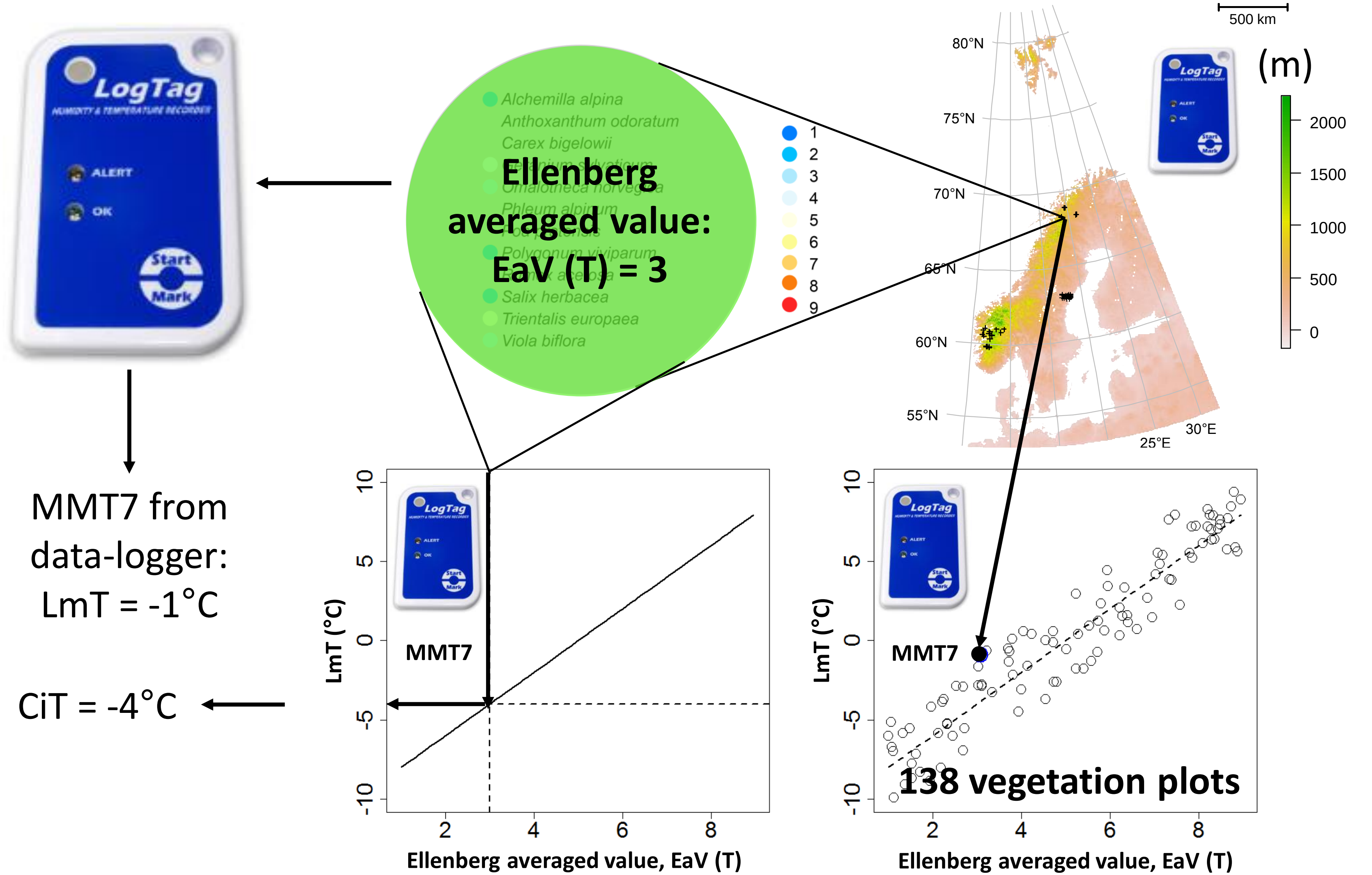


- 1 digital elevation model grid across Northern Europe at 33-m resolution (ASTERGDEM)

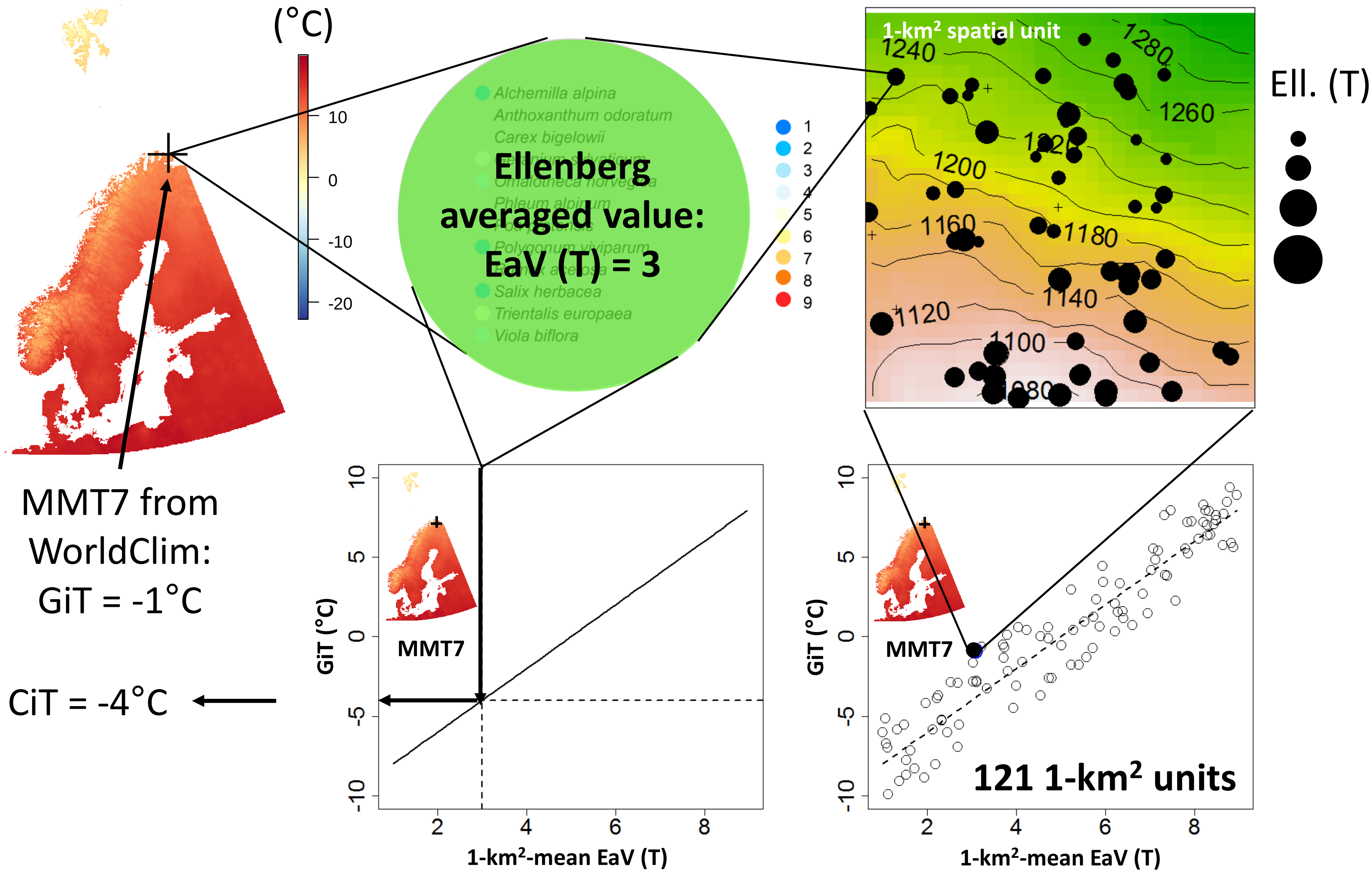


For each 1-km^2 unit, we computed: eleR, slopR, northR, eastR, expoR and roughM

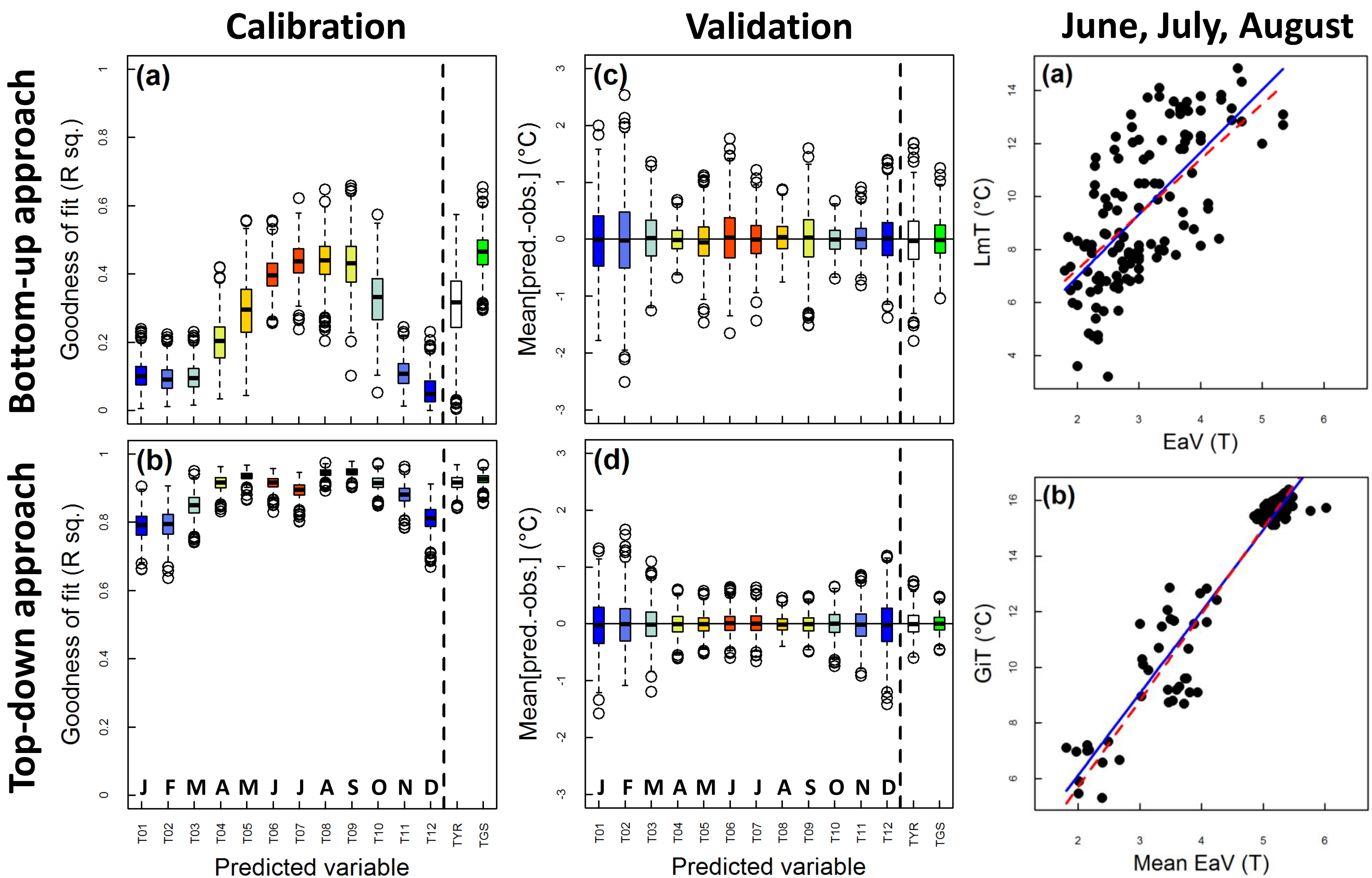
Bottom-up modeling approach to compute CiT



Top-down modeling approach to compute CiT

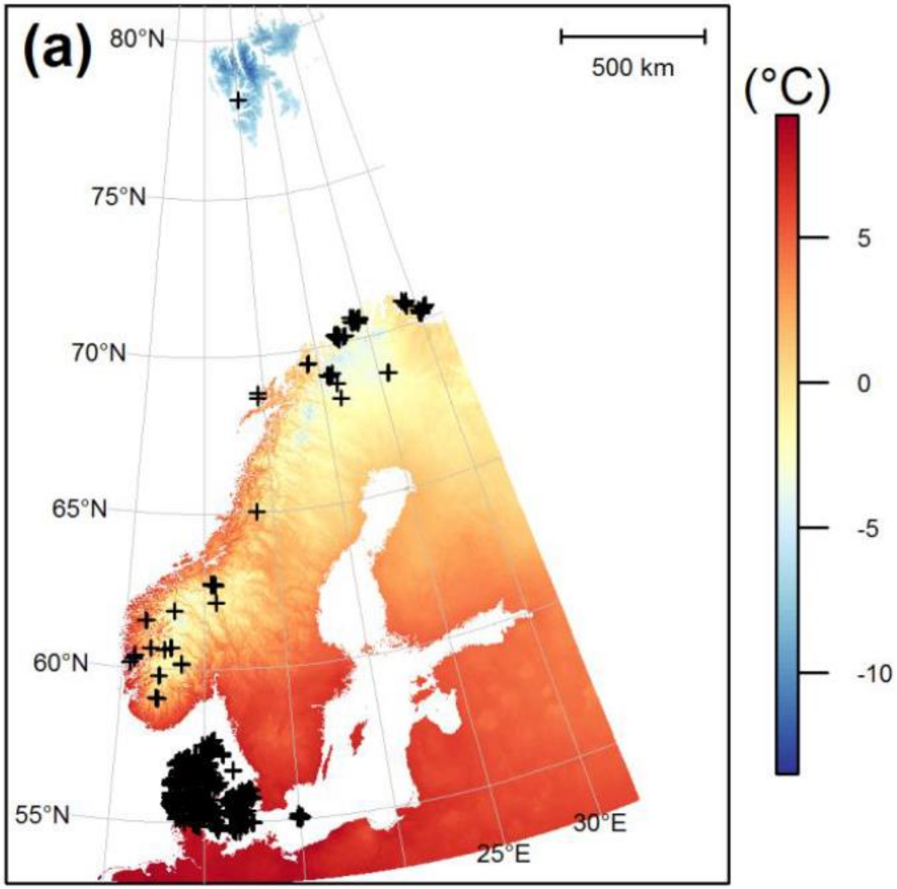


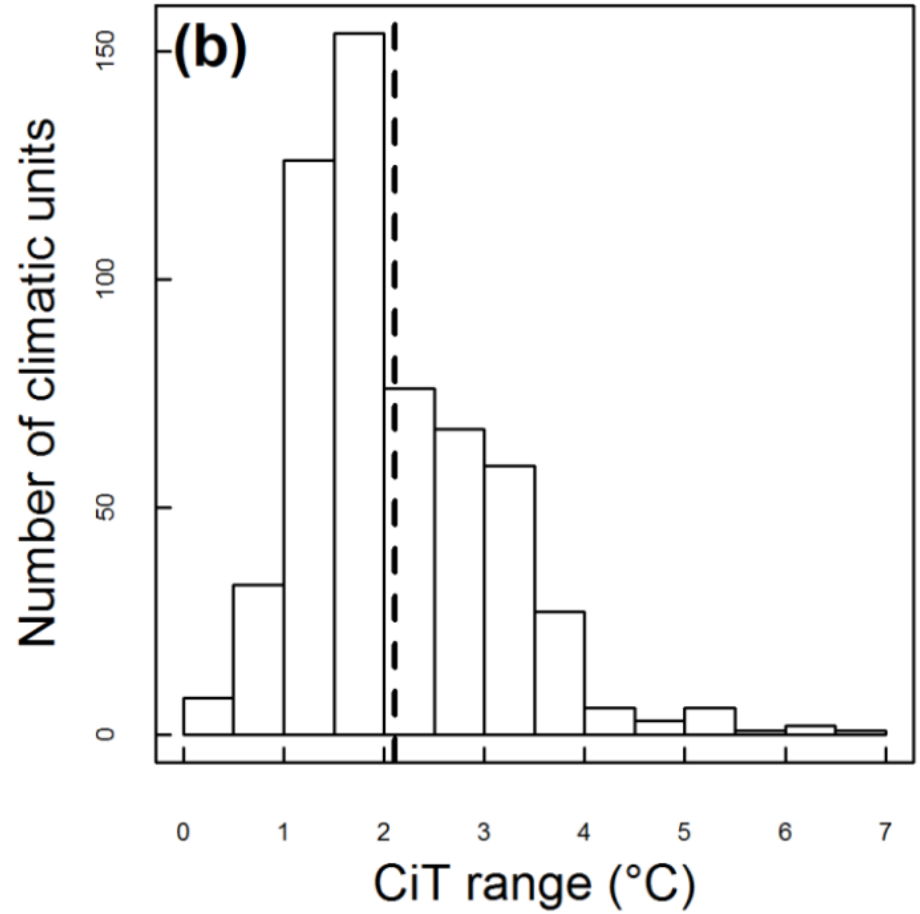
EaV reflects mean growing-season temperature



1-km² thermal variability ranges from 0 to 7°C

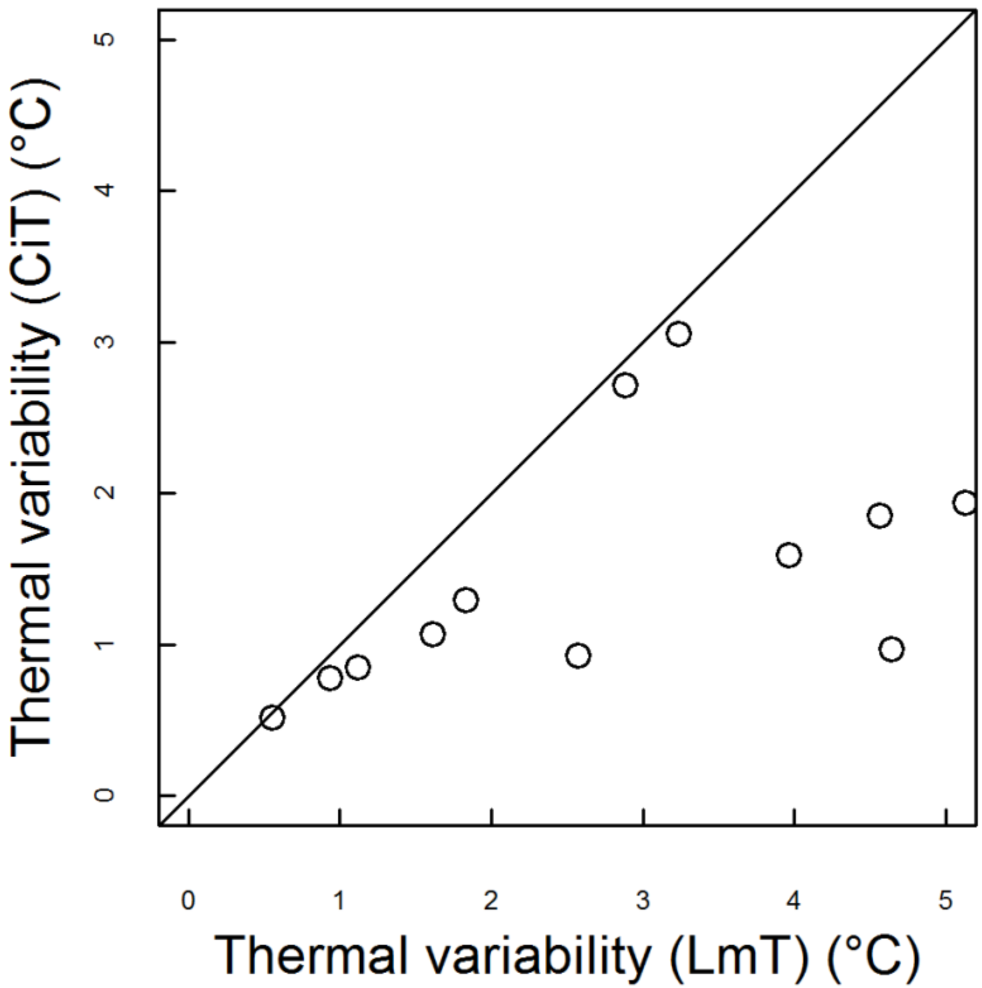
- 569 1-km² WorlClim units used to assess thermal variability across Northern Europe
- Thermal variability averages 2.1°C (SD = 0.97°C) across Northern Europe





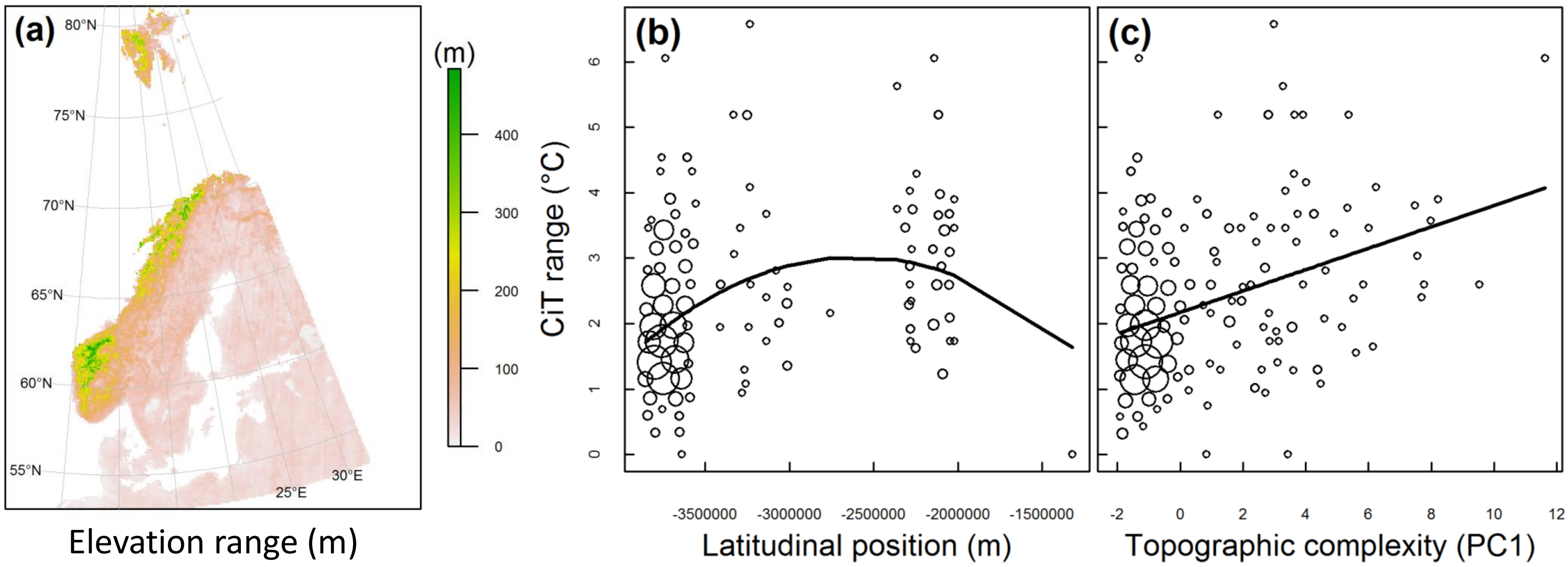
CiT underestimates fine-grained thermal variability

- Our community-based approach (CiT) underestimate the actual fine-grained thermal variability compared with localized miniature soil data-loggers (LmT)



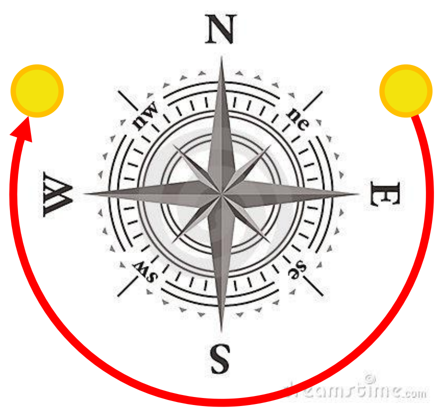
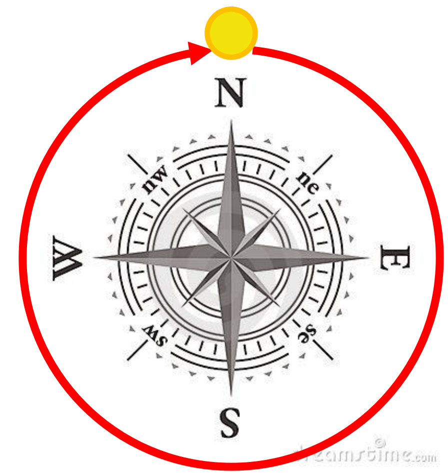
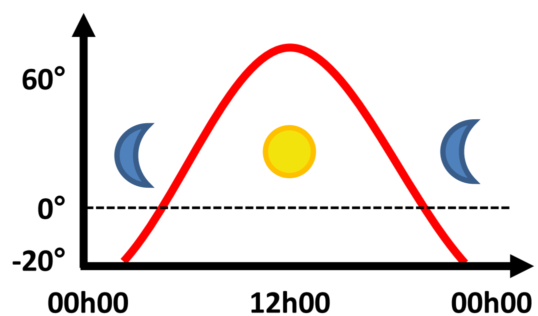
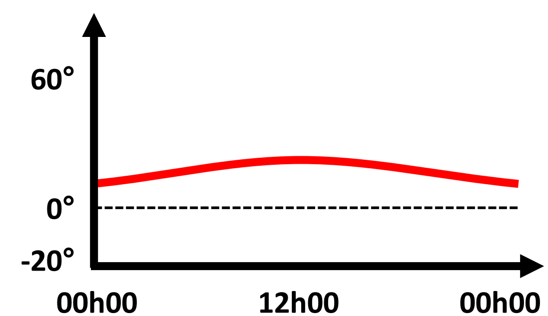
Rough terrains offer higher thermal variability

- Thermal variability peaks at 60–65°N, where rough terrains are predominant due to the gross topography from southern to mid-Norway
- Thermal variability increases with topographic complexity (terrain roughness) averaging 1.97°C (SD = 0.84°C) and 2.68°C (SD = 1.26°C) within the flattest (PC1<0) and roughest (PC1>0) 1-km^2 WorldClim units respectively

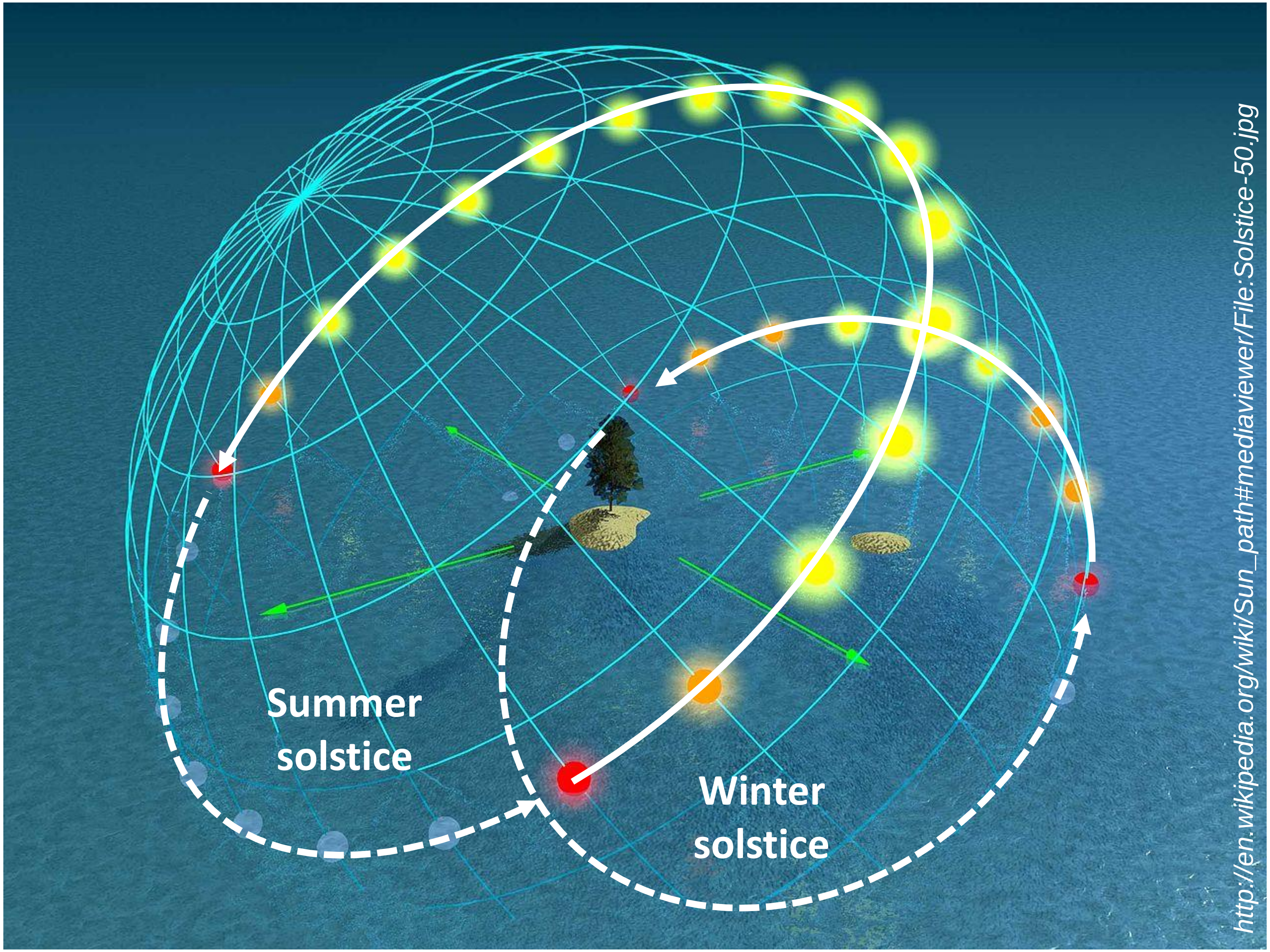


Sun path changes with latitude

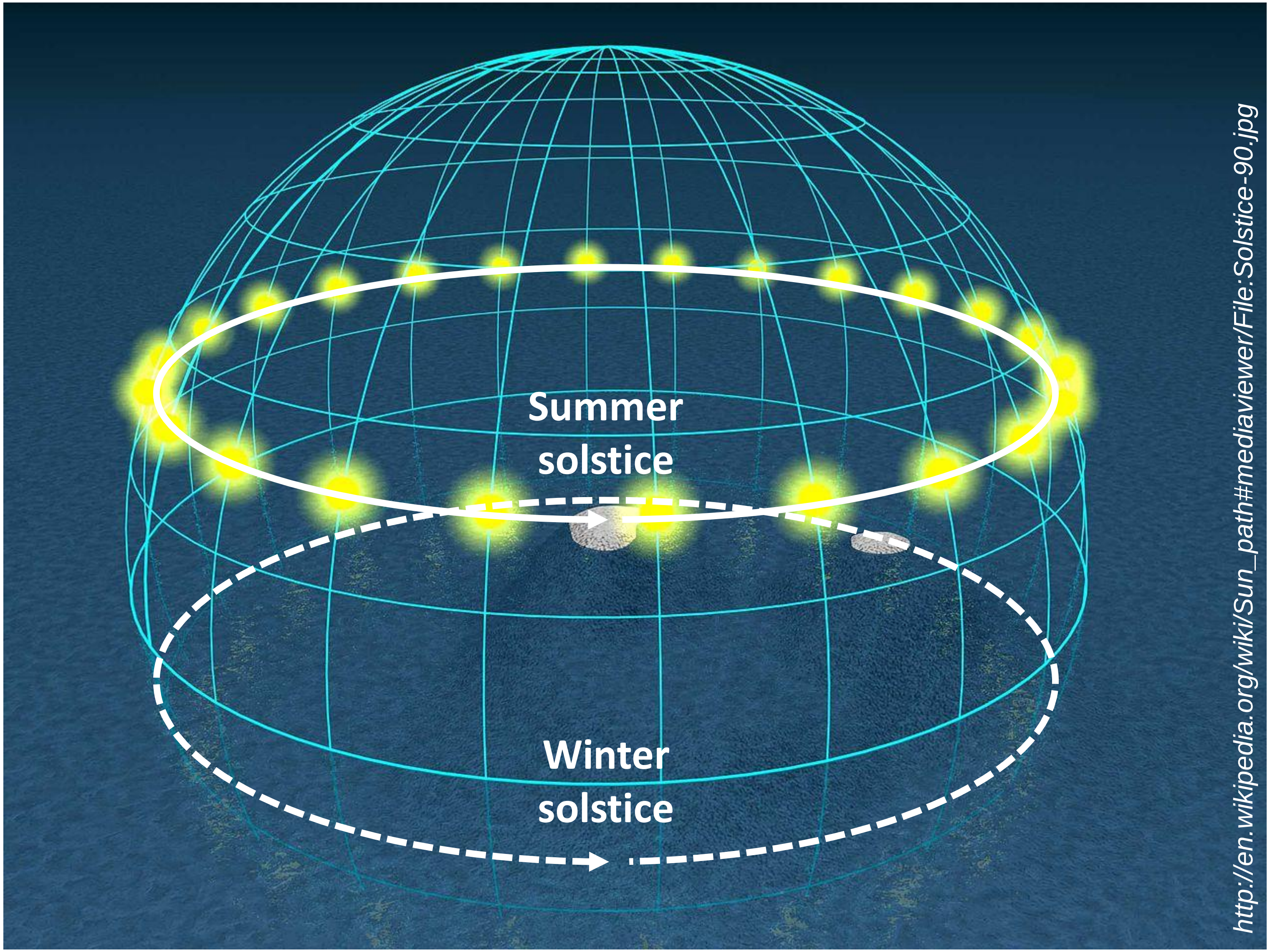
- Complex interactions between the latitudinal position and topographic complexity of a given 1-km^2 WorlClim unit affect thermal variability

	Mid latitudes (50°N)	High latitudes (90°N)
Daily solar azimuthal range during the summer solstice		
Daily solar elevational range during the summer solstice		

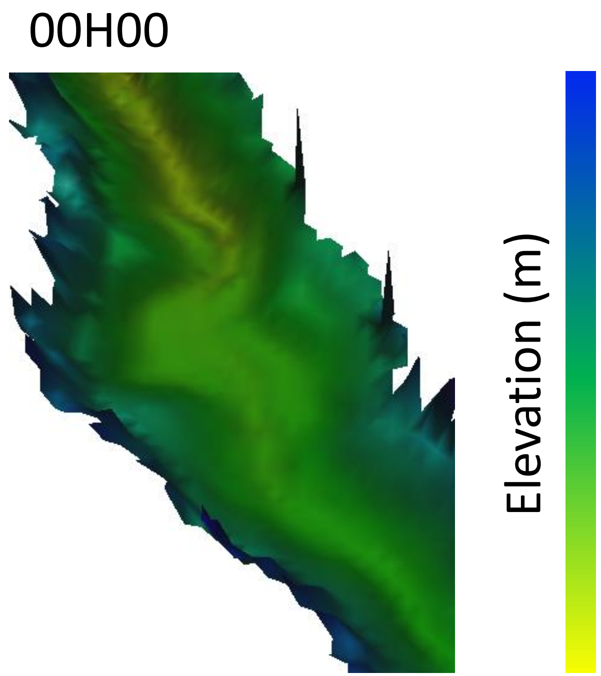
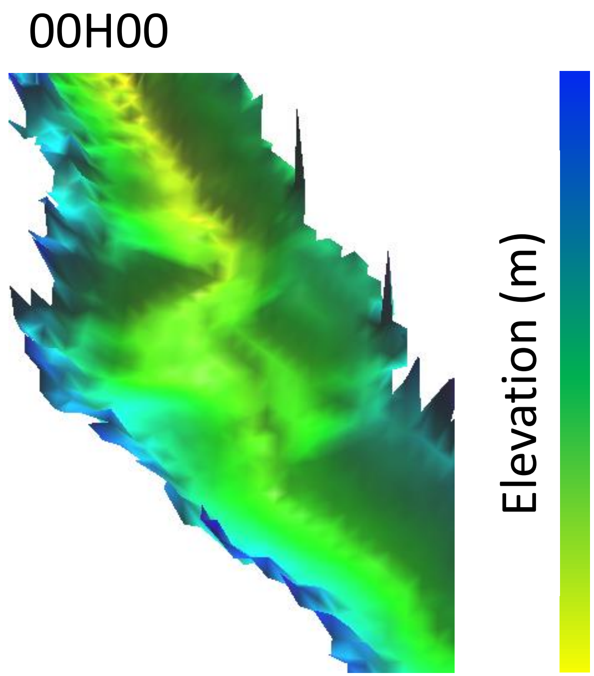
Sun path at 50°N during the solstices



Sun path at 90°N during the solstices



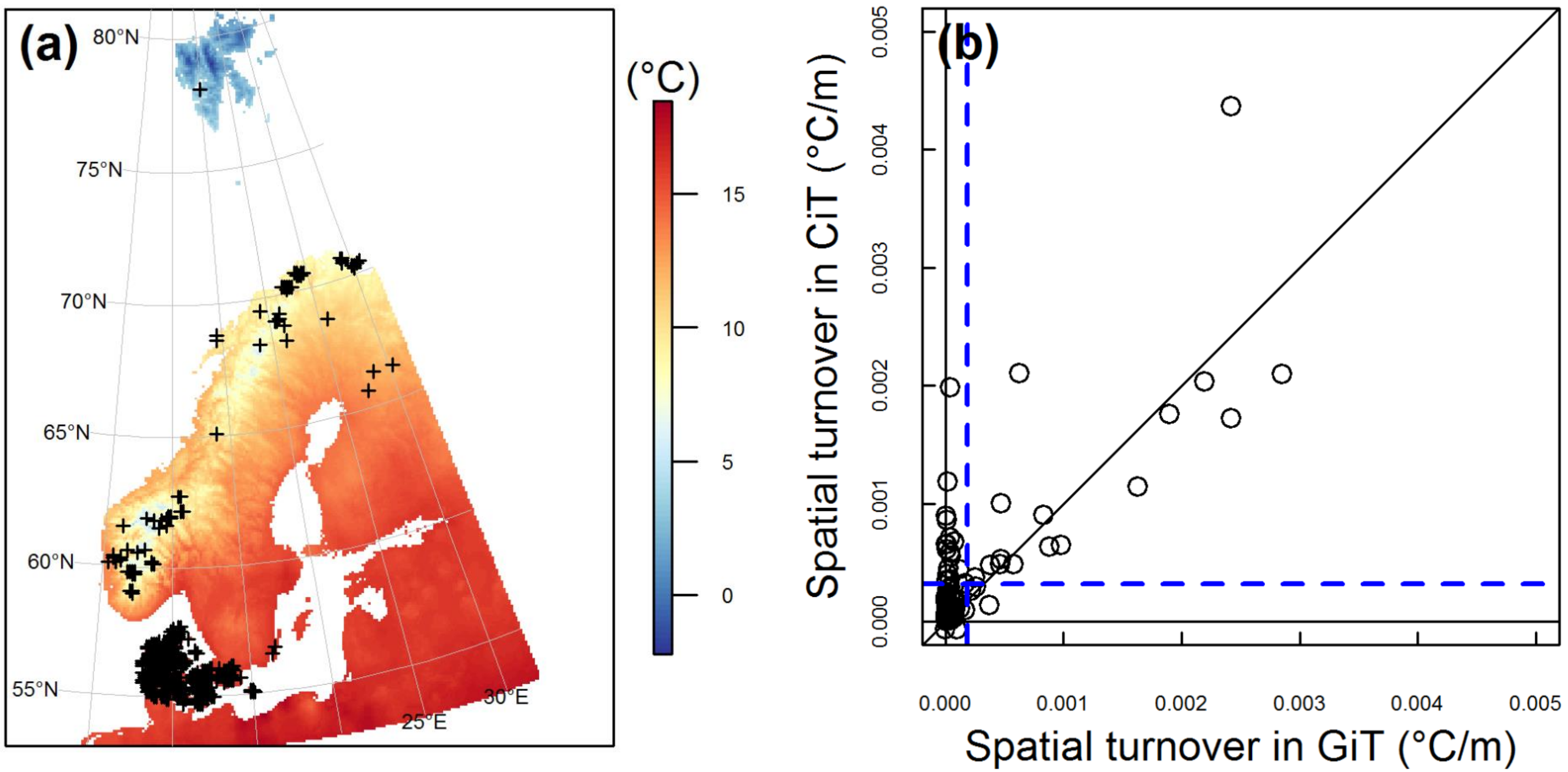
Compensation effects

	Mid latitudes (50°N)	High latitudes (90°N)
Impact of daily variations in solar azimuth and elevation angles on topographic shading during the summer solstice		

- Lower solar elevation angles during the summer solstice at high latitudes increase climatic contrasts between north- and south-facing slopes
- But a higher solar azimuthal range during the summer solstice at high latitudes decrease climatic contrasts between north- and south-facing slopes

Spatial turnover in CiT is higher

- 349 WorldClim units at 10-km resolution used to compare spatial turnover in CiT with spatial turnover in globally interpolated temperature (GiT)
- Spatial turnover in CiT within 100-km^2 units was, on average, 1.8 times greater (0.32°C/km) than spatial turnover in GiT (0.18 °C/km)



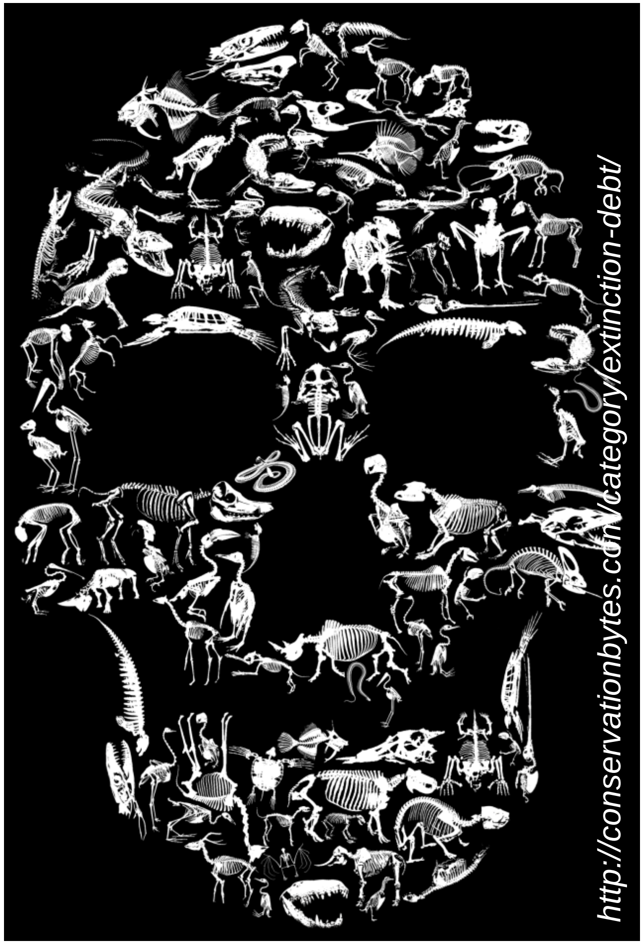
Take-home message

Fine-grained thermal variability should also be incorporated (e.g., as covariates) in species distribution models (SDMs) using WorldClim or coarser temperature grids to simultaneously:

- Decrease the probabilities of overestimated local extinction events
- Increase the probabilities of underestimated local persistence events

Both aspects contributing either to:

- Long-term survival of populations referred to as "**microrefugia**" if fine-grained thermal variability can buffer unfavorable regional climate until it returns to favorable conditions
- Or temporary relief of populations referred to as "**holdouts**" if fine-grained thermal variability cannot buffer regional climate change in the long term (i.e. extinction debt)



Holdouts but not microrefugia

TREE-1822; No. of Pages 8 ARTICLE IN PRESS

Opinion CellPress

Fine-grain modeling of species' response to climate change: holdouts, stepping-stones, and microrefugia

Lee Hannah[1], Lorraine Flint[2], Alexandra D. Syphard[3], Max A. Moritz[4], Lauren B. Buckley[5], and Ian M. McCullough[6]

- Given that future climate change conditions is unlikely to return to the present state, holdouts are more likely than microrefugia
- Fine-grained SDMs incorporating population dynamic processes are needed to improve our abilities to forecast potential holdouts and microrefugia

An application using hybrid models

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

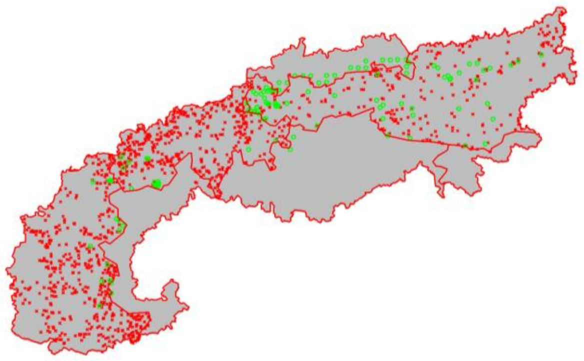
Stefan Dullinger[1,2]★, Andreas Gattringer[1], Wilfried Thuiller[3], Dietmar Moser[1], Niklaus E. Zimmermann[4], Antoine Guisan[5], Wolfgang Willner[1], Christoph Plutzar[1,6], Michael Leitner[7,8], Thomas Mang[1,2], Marco Caccianiga[9], Thomas Dirnböck[10], Siegrun Ertl[2], Anton Fischer[11], Jonathan Lenoir[12,13], Jens-Christian Svenning[12], Achilleas Psomas[4], Dirk R. Schmatz[4], Urban Silc[14], Pascal Vittoz[5] and Karl Hülber[1]

- **SDMs:** fine-grained climatic grids at 100-m resolution across the European Alps

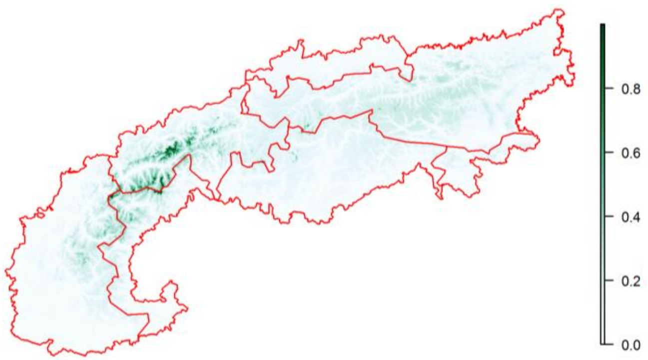
+

- **Mechanistic simulations:** dispersal limitations and persistence capabilities

Illustration with *Ranunculus glacialis* L., 1753

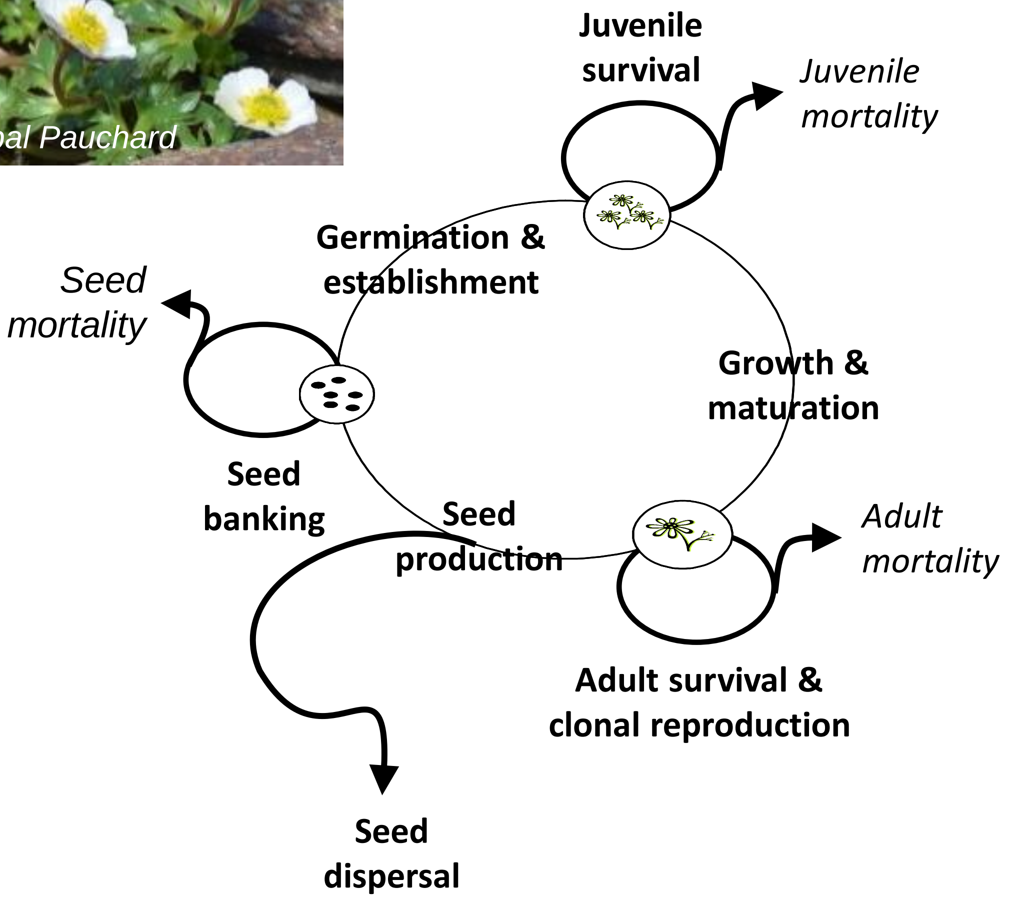


Fine-grained SDMs (100-m)



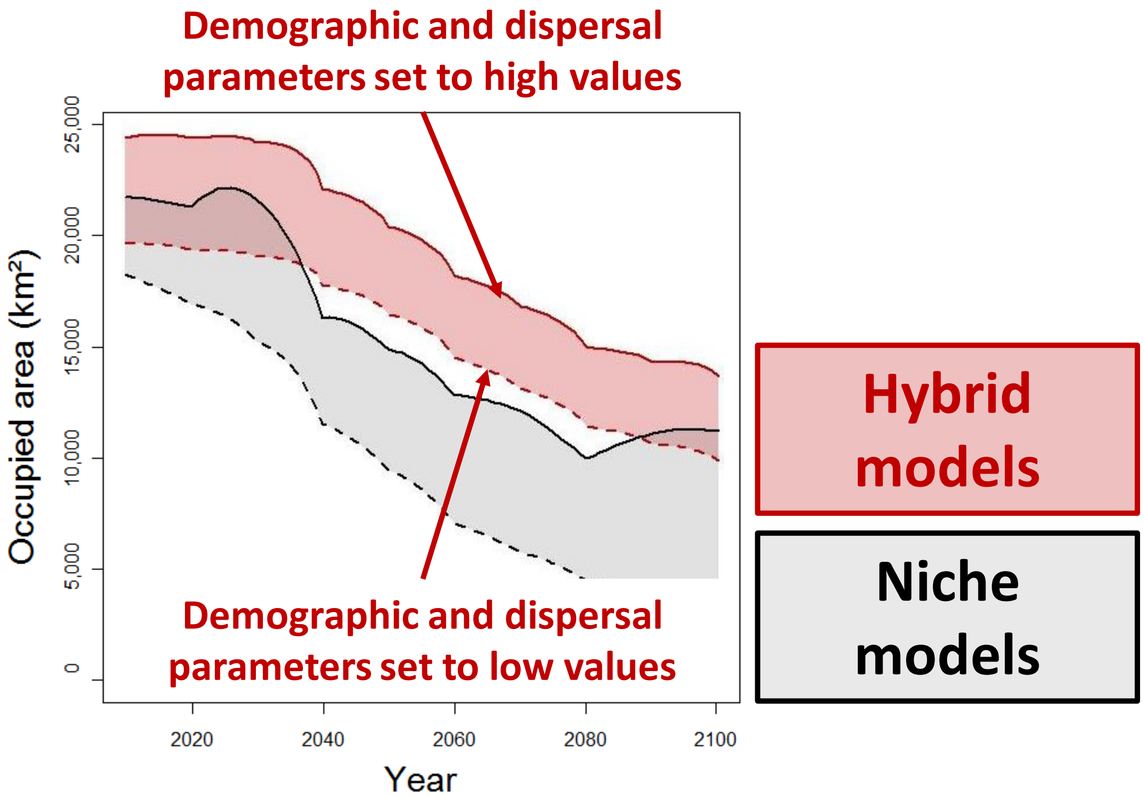
GOF = 48%
AUC = 0.86

Mechanistic simulations



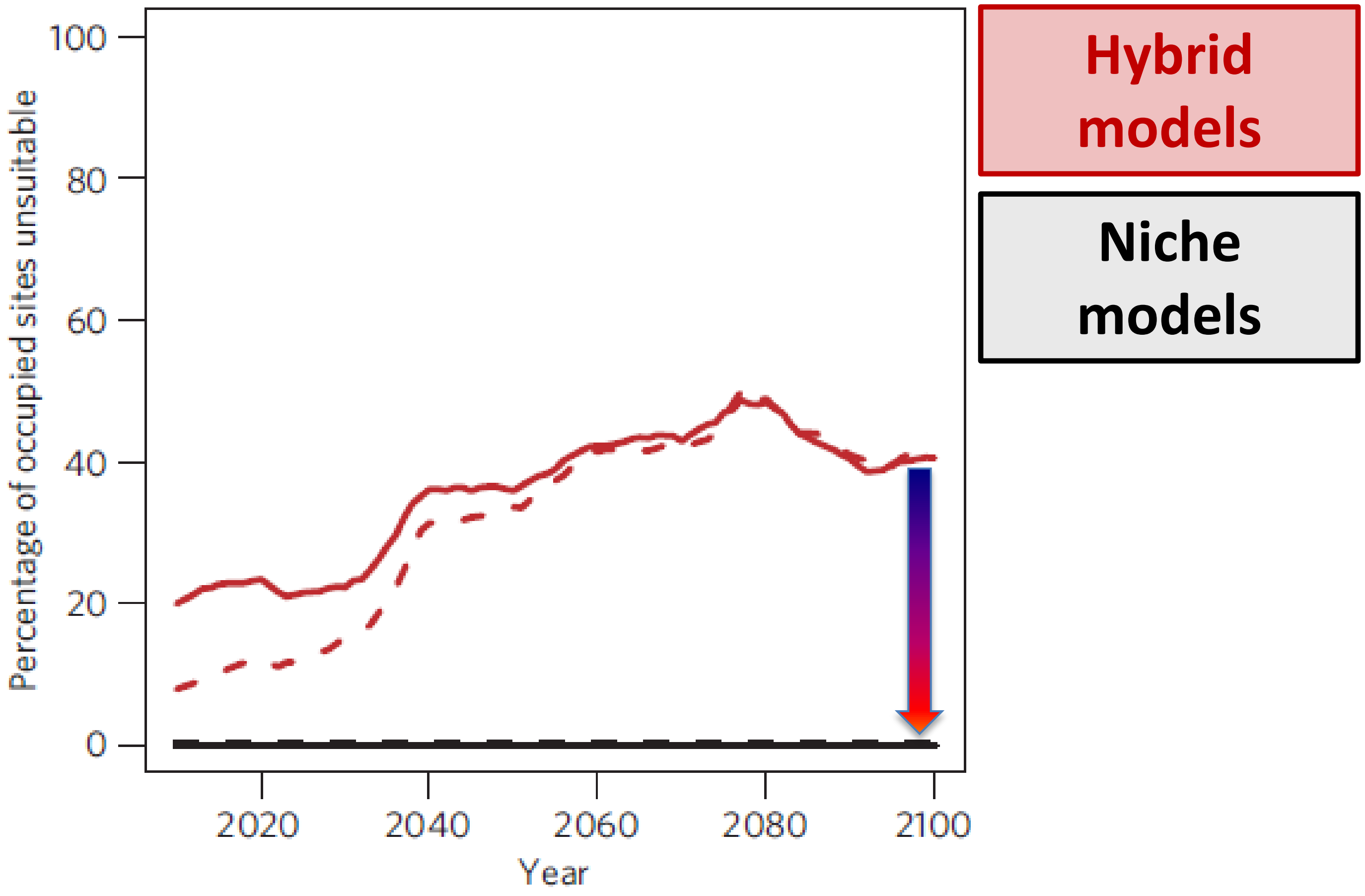
Demographic and dispersal parameters matter

Forecasted distribution changes based on future climate change for a total of 150 high-mountain plant species



Hybrid models predicts average range size reductions of 44–50% by the end of the 21st century against 49-82% for traditional niche models

Holdouts or microrefugia?



Percentage of occupied sites despite unsuitable climatic conditions will increase under future climate change and involve adult survival as well as clonal reproduction for population to persist either as holdouts or microrefugia

edysan
Ecologie et Dynamique
des Systèmes Anthropisés
FRE 3498 CNRS-UPJV
www.u-picardie.fr/edysan

HETEROCLIM

Acknowledgements

Thanks to Sylvain Pincebourde for inviting me and to all of you for your kind attention

UNIVERSITÉ de Picardie Jules Verne

CNRS

Photo: Jonathan Lenoir