Alpine biota under environmental change

- The mountain world
- Environmental change
- The vulnerability issue

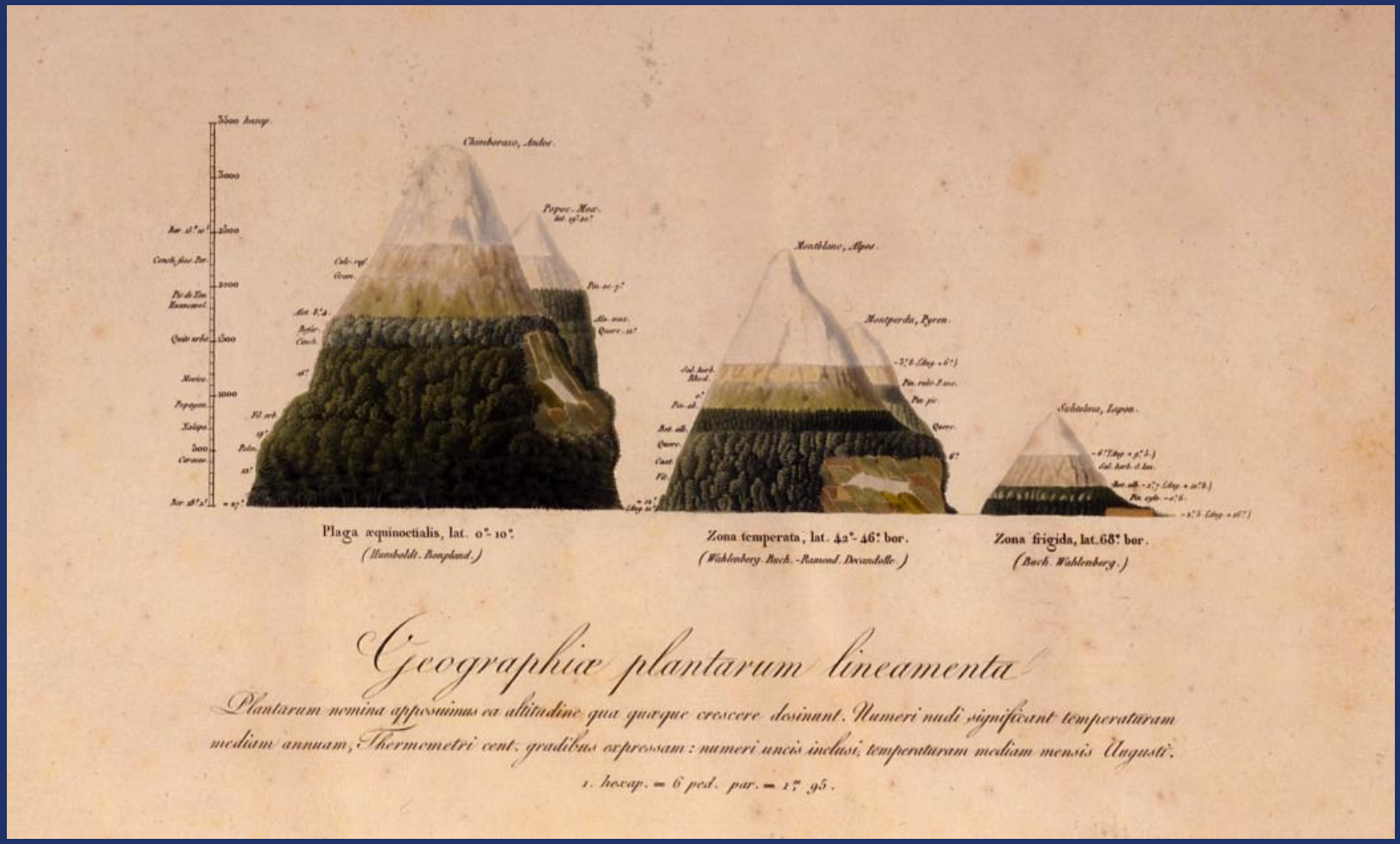
Christian Körner

Institute of Botany
University of Basel, Switzerland

Innsbruck, 10. August 2019 – International Mountain Conference

Alexander von Humboldt‘s 250th birthday

→ Humboldt invented the isotherm concept



Elevation *per se* does not matter. What matters is climate

Globally

Bioclimatic belts in mountains

Mio km^2
0.5
3.0
12.5

Nival

Snowline

Uplands

Alpine

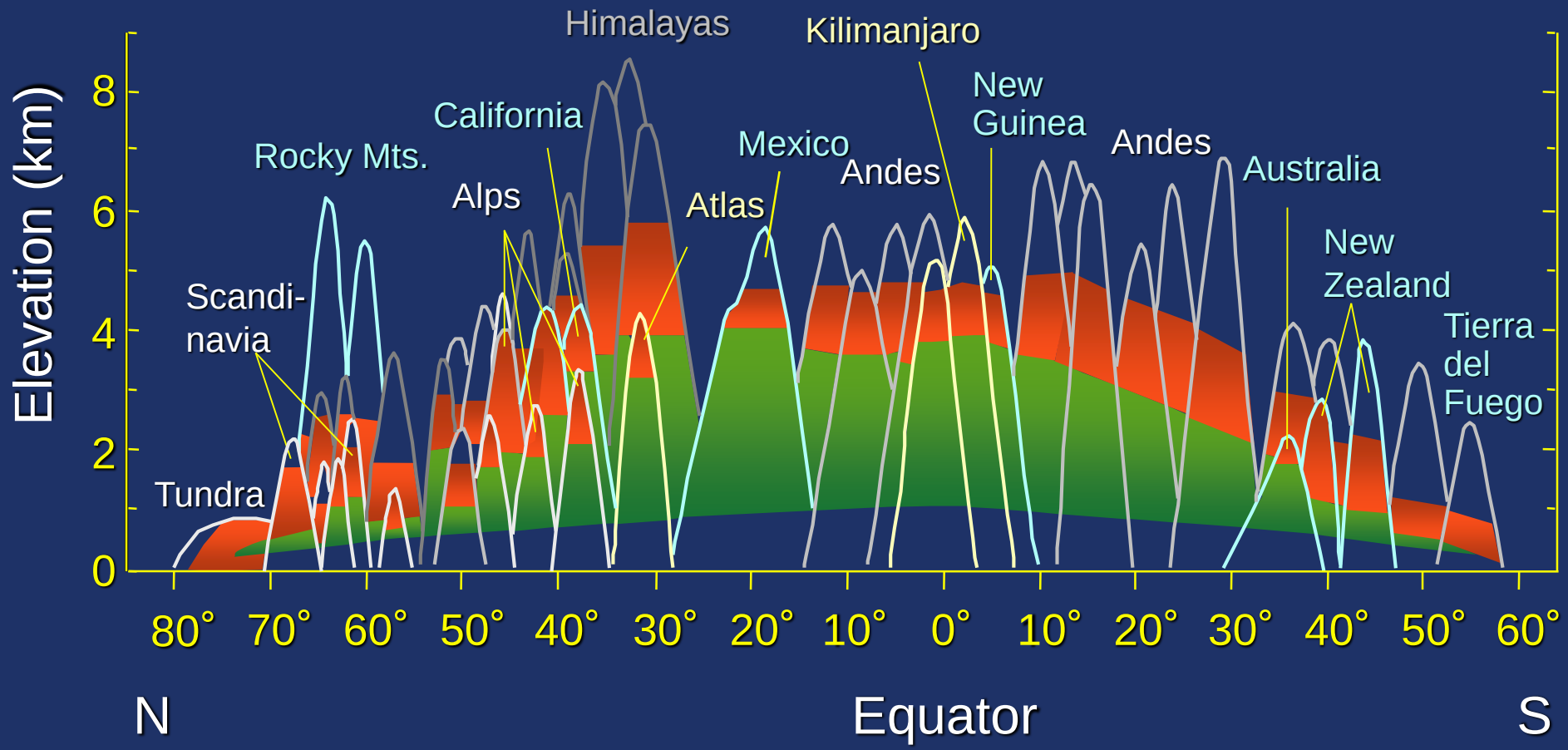
Treeline >6 ° C, >91 d

Montane

Lowlands

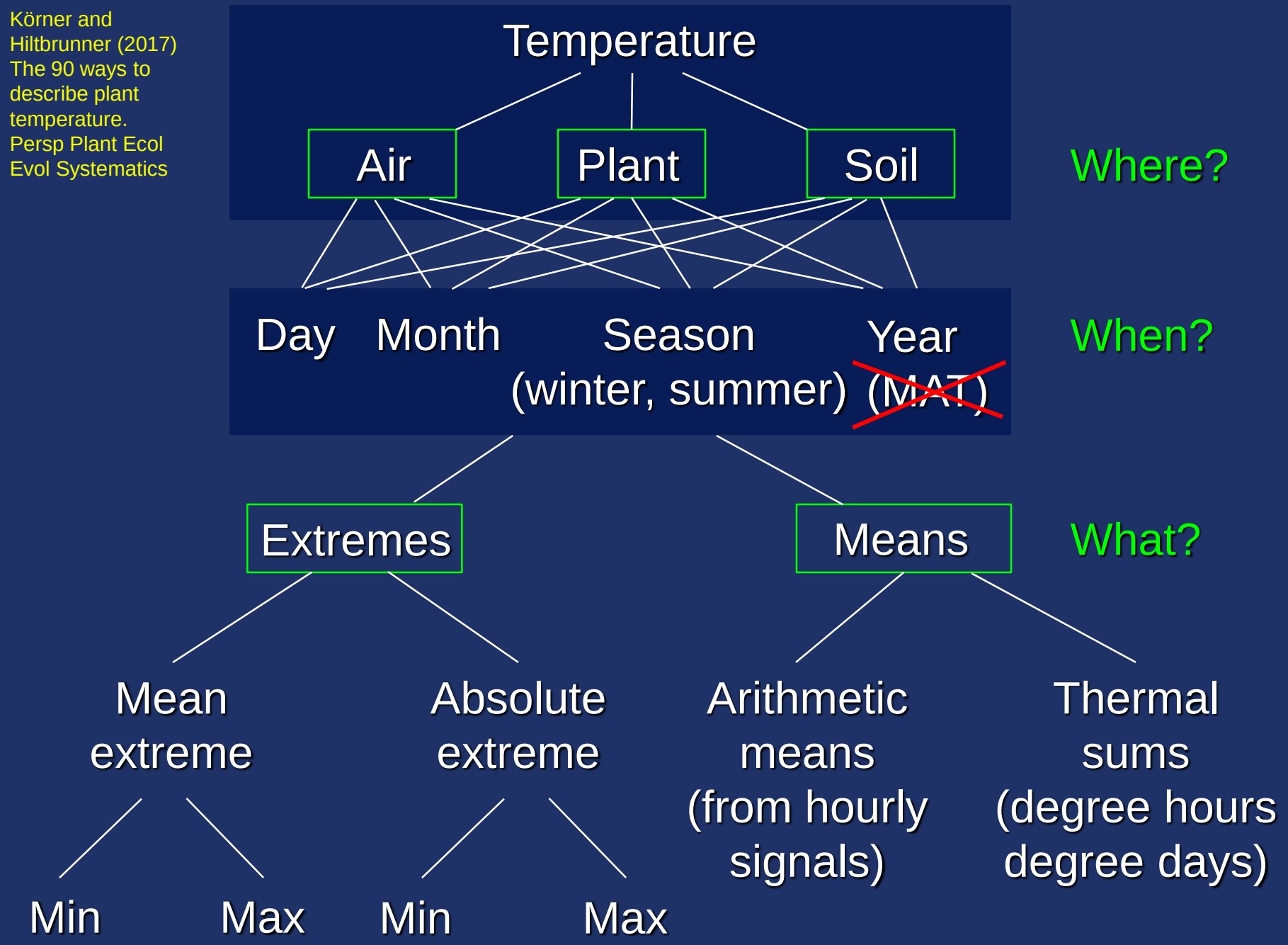
Application of Humboldt's isotherm concept:

The alpine and montane belts globally

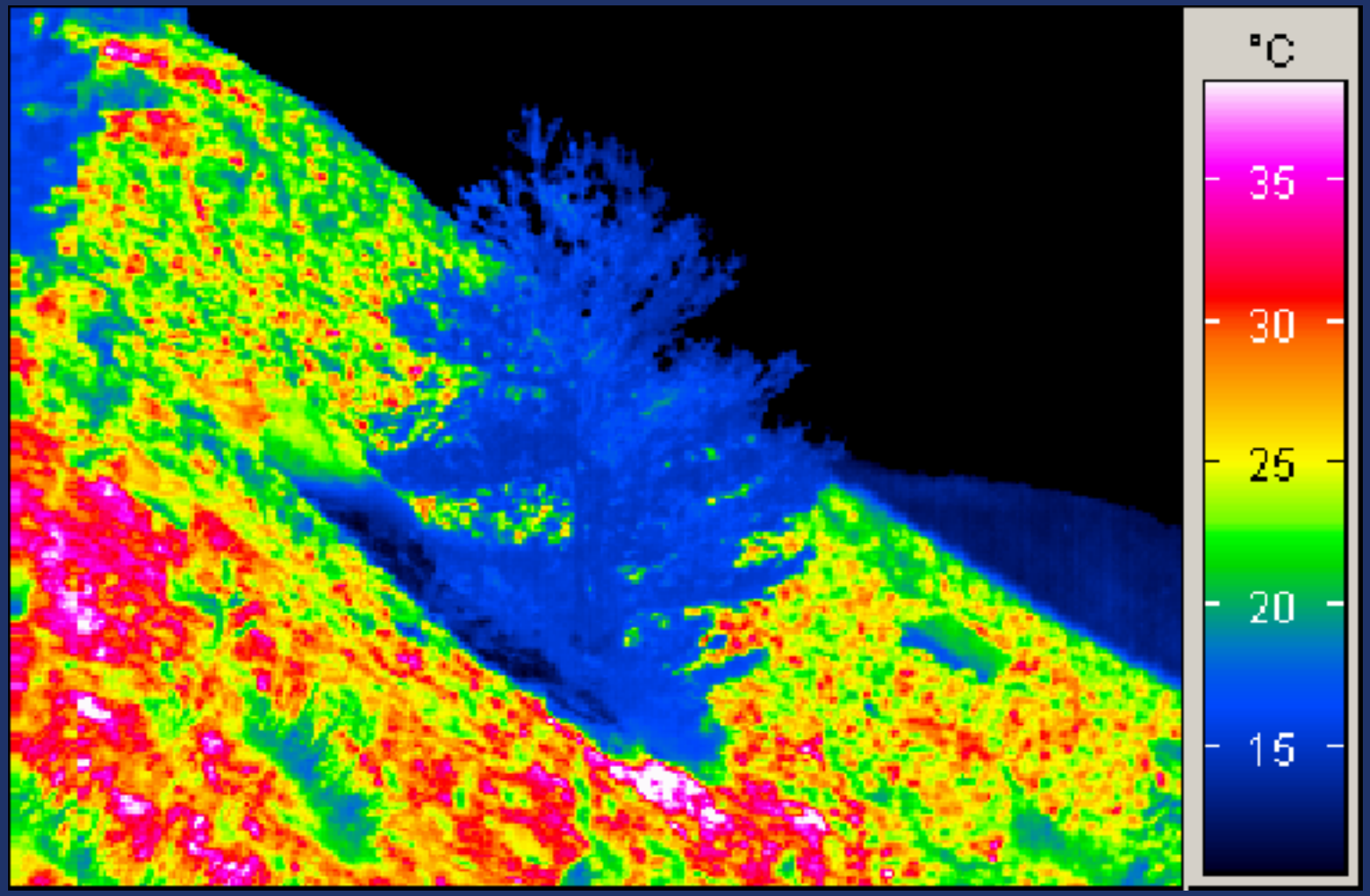


Körner C (2003) Alpine plant life. Springer, Berlin

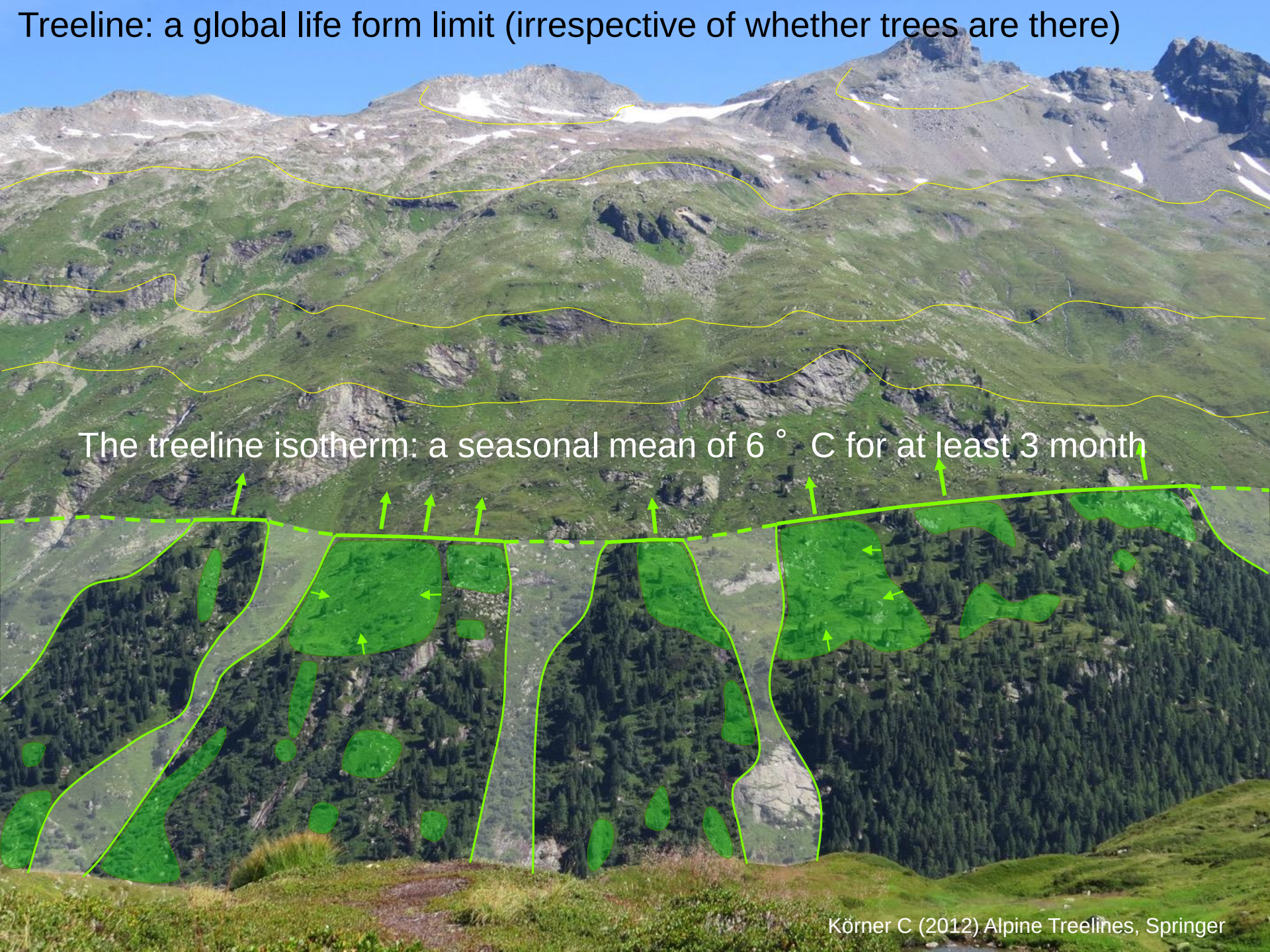
Körner and Hiltbrunner (2017) The 90 ways to describe plant temperature. Persp Plant Ecol Evol Systematics



Low stature plants do not experience the climate weather stations report,
but trees do ...



Treeline: a global life form limit (irrespective of whether trees are there)



Körner C (2012) Alpine Treelines, Springer

Evergreen Oaks at 4270 m, N-Yunnan, China
Not the trees are peculiar! The climate is....

What makes a mountain?

Not elevation *per se*. Not low temperature *per se*.

- compression of climatic belts over small geographical distances
- ruggedness and thus, habitat diversity for life
- destructive action of gravity (erosion, land slides, avalanches, ...)

The number one pre-requisite for life in mountains?

- stable slopes
- intact soils
- a diverse vegetation that secures soils and slopes

Soil conditions define life conditions for both, humans and biota

Slope stability and soil integrity secure life in mountains

Central High Caucasus

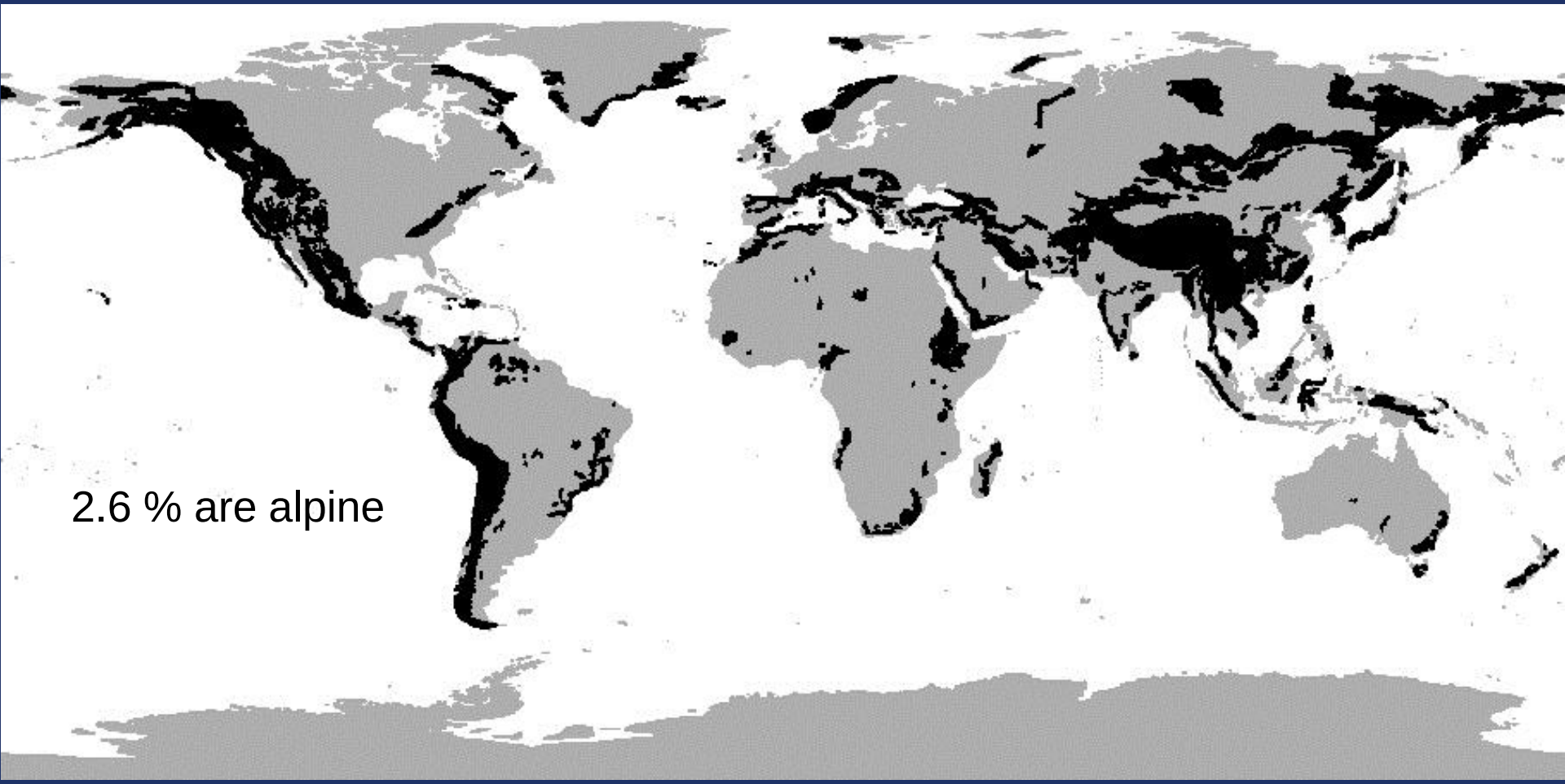
Mountains are more biodiverse than expected by their area because of topographic diversity

GMBA is a platform for international and cross-disciplinary collaboration on the assessment, conservation, and sustainable use of mountain biodiversity.

Mountain biodiversity: where, how much, why?
Linking biodiversity with environmental drivers & human well-being

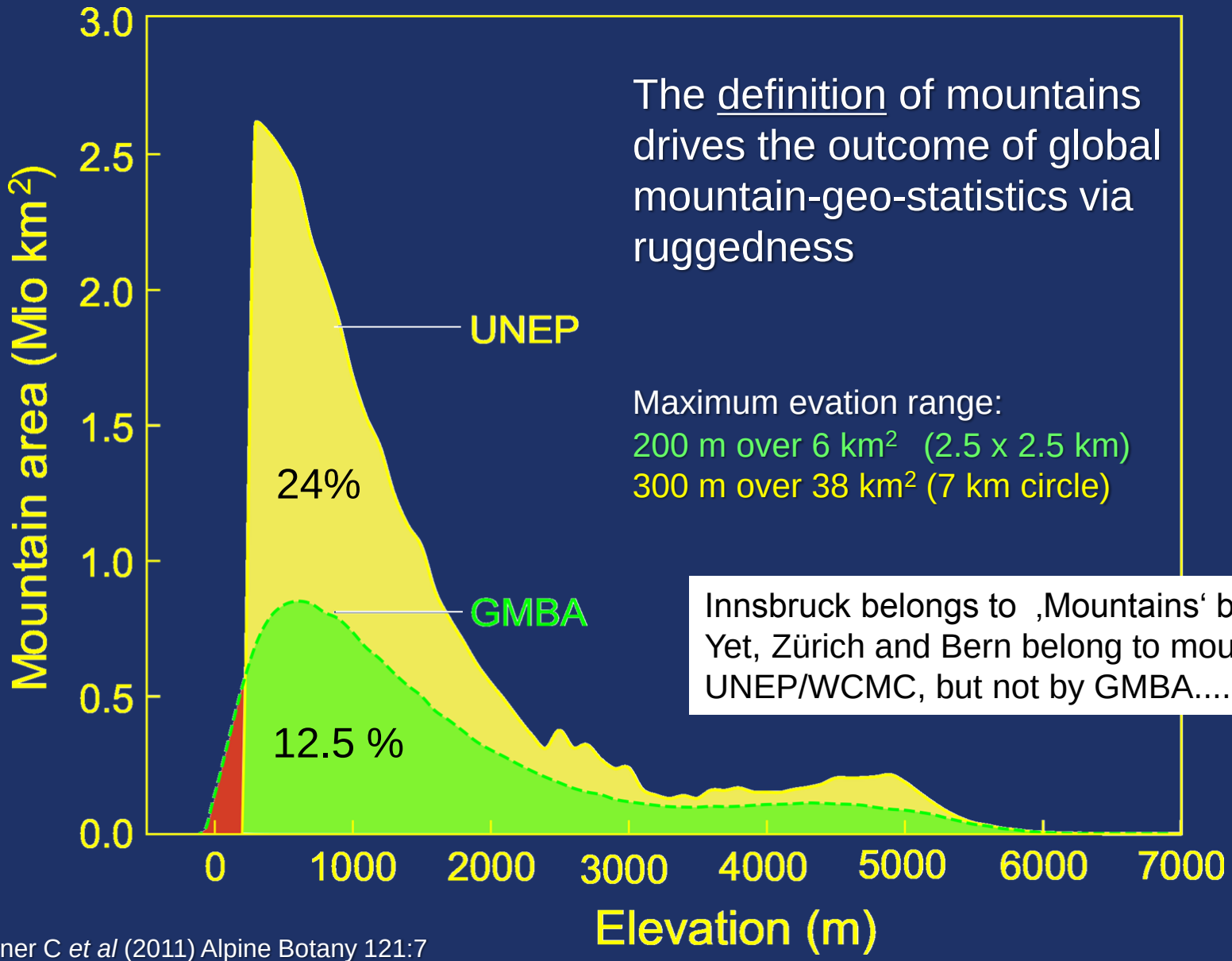
→ global mountain inventory stratified by climatic belts
→ the mountain portal in cooperation with MOL:
www.mountainbiodiversity.org

Global mountain area as defined by ruggedness only: 16 Mio km^2 or 12.5 % of land outside Antarctica



Körner C *et al* (2011) Alpine Botany 121:7; Körner et al (2017) Alpine Botany 127:1-15

Ruggedness defines mountains: old and new definition



The definition of mountains drives the outcome of global mountain-geo-statistics via ruggedness

Maximum evation range:
200 m over 6 km² (2.5 x 2.5 km)
300 m over 38 km² (7 km circle)

Innsbruck belongs to ‚Mountains' by both. Yet, Zürich and Bern belong to mountains by UNEP/WCMC, but not by GMBA.....

Körner C *et al* (2011) Alpine Botany 121:7

Organismic inventory of the high alpine Furka pass region

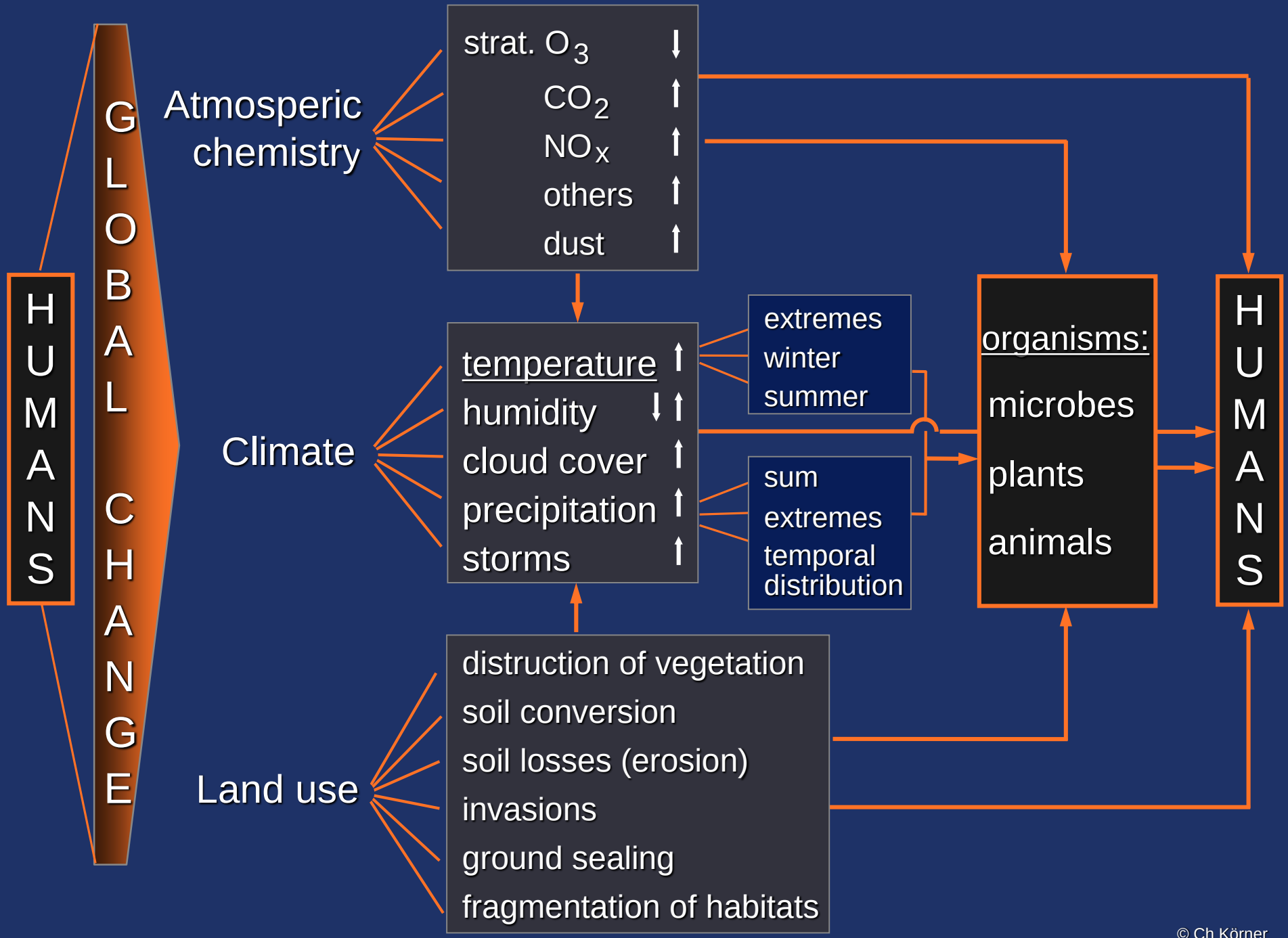
Number of named species at 2500 m,
350 m above treeline, across 1 km^2

554 Insects (incl. chilopods)
313 Fungi (Basidio-, Asco-, Glomeromycota)
304 Flowering plants
300 Lichens
215 Diatoms
166 Mosses
128 Spiders and Mites
30 Vertebrates (birds, rodents, amphibia, reptiles)

In total 2098 species

excluding
Bacteria (ca. 1000)
Nematodes (ca. 50 ?)
Collembols (ca. 50)

Hotspot Furka
Hiltbrunner E, Körner C (2018)


HUMANS
GLOBAL CHANGE
Atmosperic chemistry
strat. O_3
CO_2
NO_x
others
dust
Climate
temperature
humidity
cloud cover
precipitation
storms
extremes
winter
summer
sum
extremes
temporal distribution
organisms:
microbes
plants
animals
HUMANS
Land use
distruction of vegetation
soil conversion
soil losses (erosion)
invasions
ground sealing
fragmentation of habitats

(1) Temperature

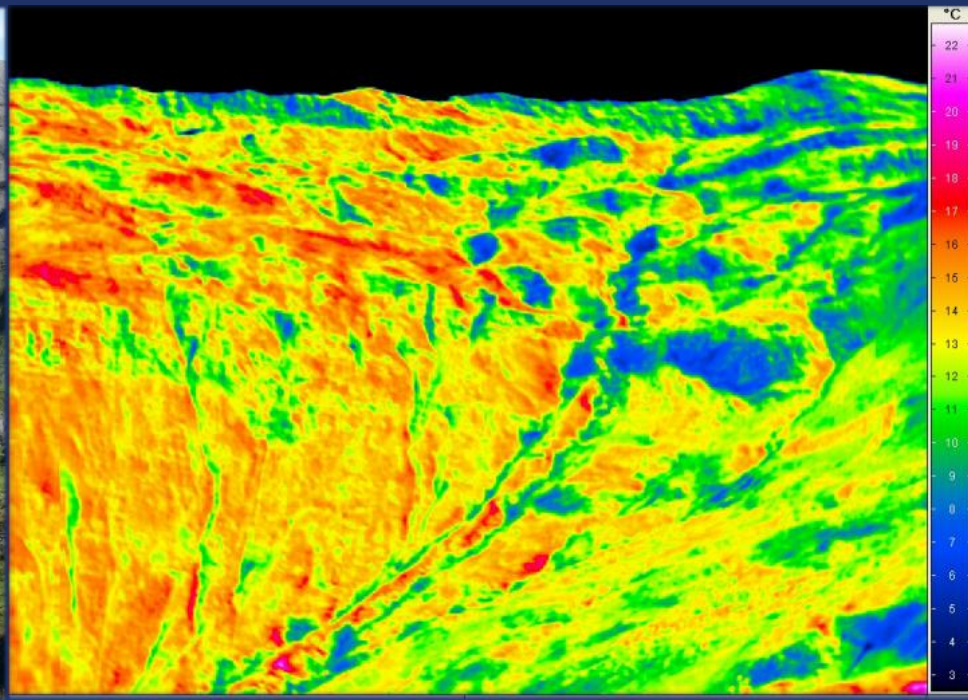
Climatic warming opens new land


Geodiversity rules
biodiversity

Thermal habitat diversity explains regional species diversity

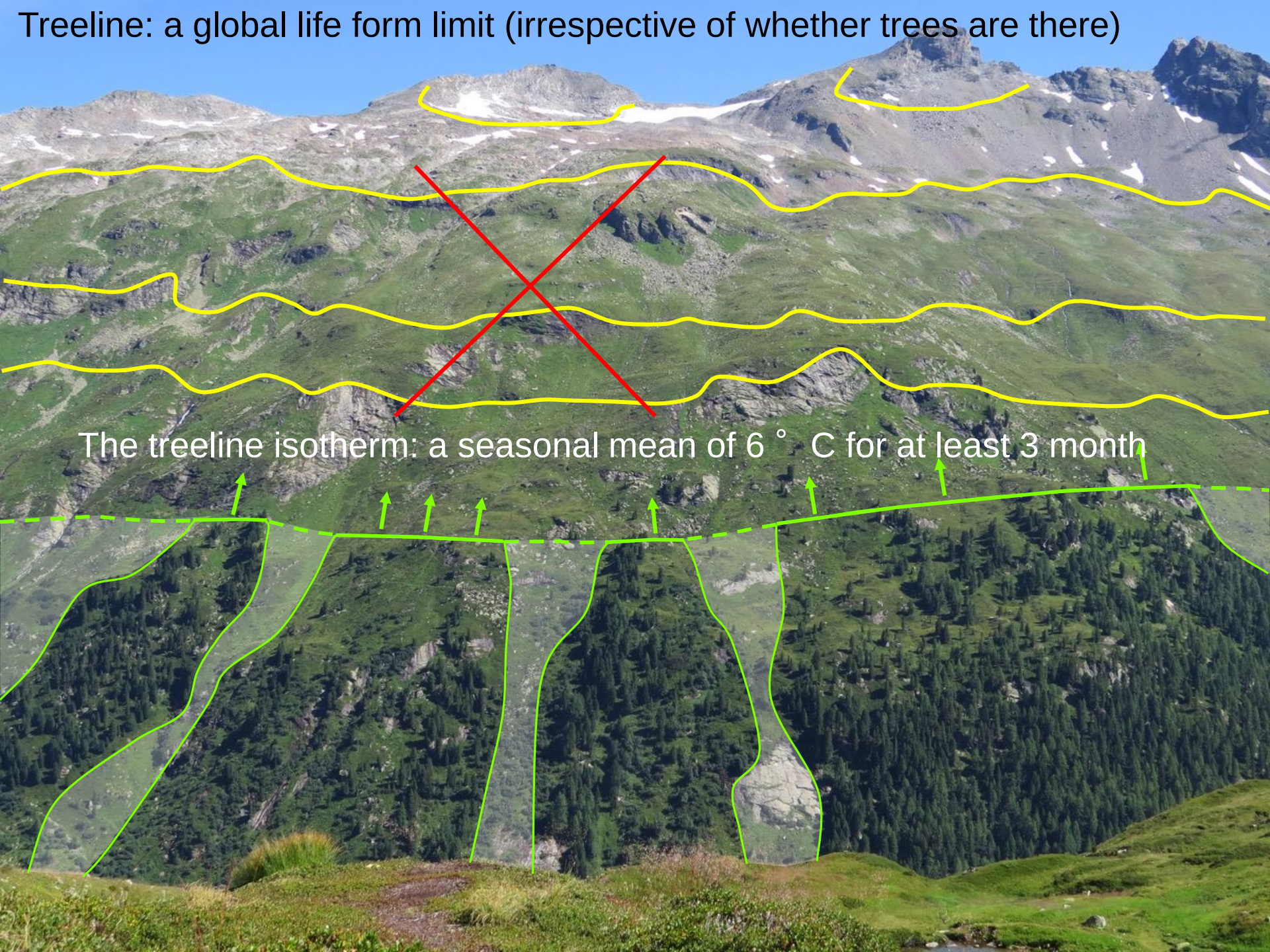
A 10 K range of seasonal mean habitat temperature at 2500 m

→ Protection against regional species loss



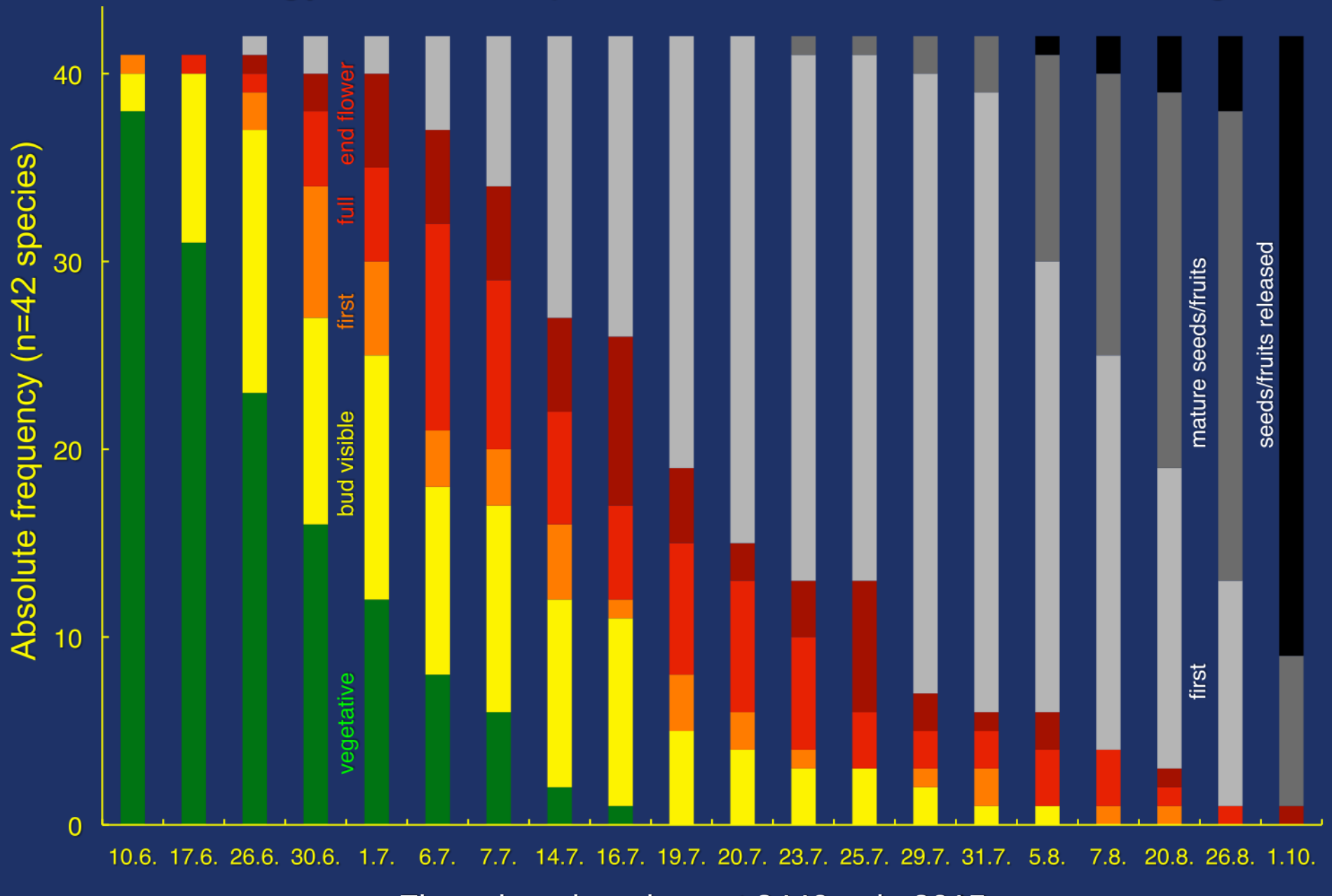
Scherrer D, Körner C, (2009) Infra-red thermometry of alpine landscapes challenges climatic warming projections. Global Change Biology 16:2602-2613

Scherrer D, Körner C (2011) Topographically controlled thermal-habitat differentiation buffers alpine plant diversity against climate warming. J Biogeogr 38:406-416

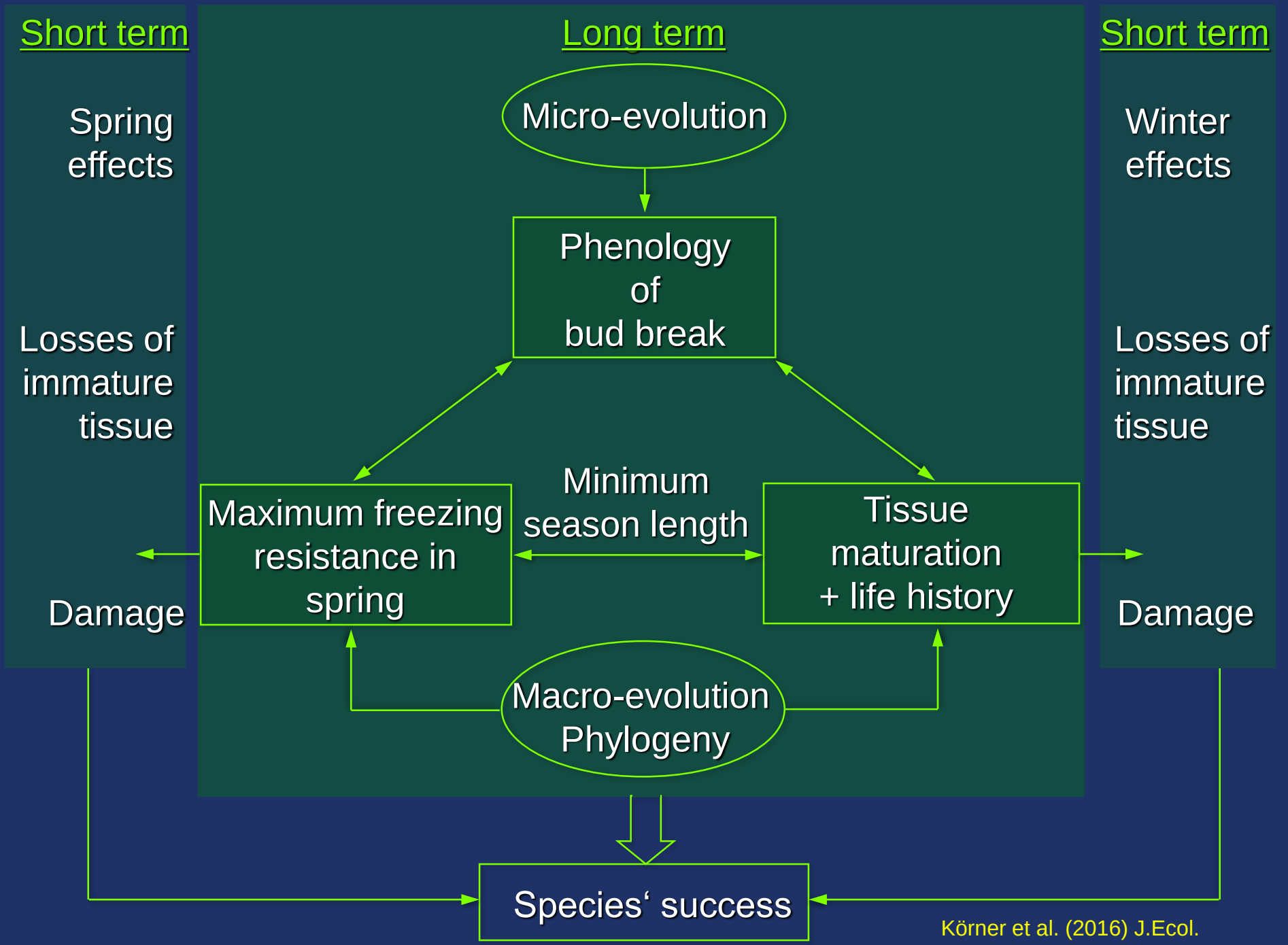

Treeline: a global life form limit (irrespective of whether trees are there)
The treeline isotherm: a seasonal mean of 6 ° C for at least 3 month


Snow distribution: photoperiodism vs opportunistic phenology

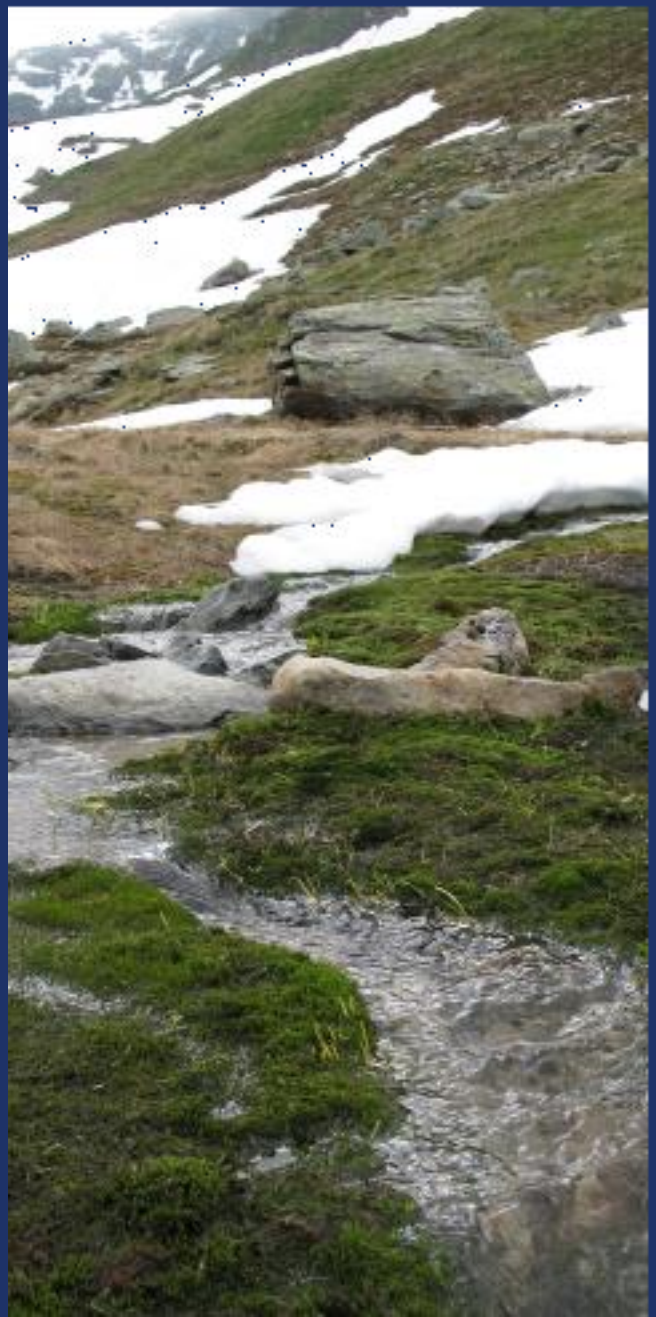
Phenology secures reproduction and minimizes freezing risk

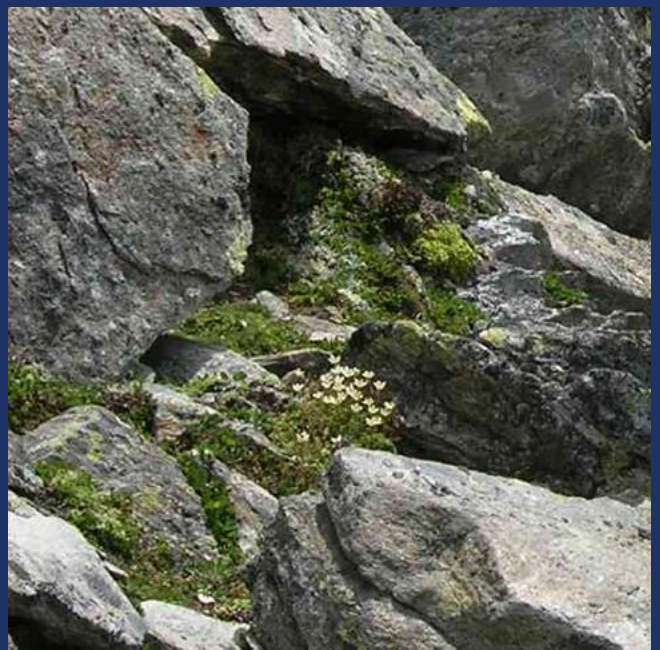


Flowering phenology at 2440 m in 2015

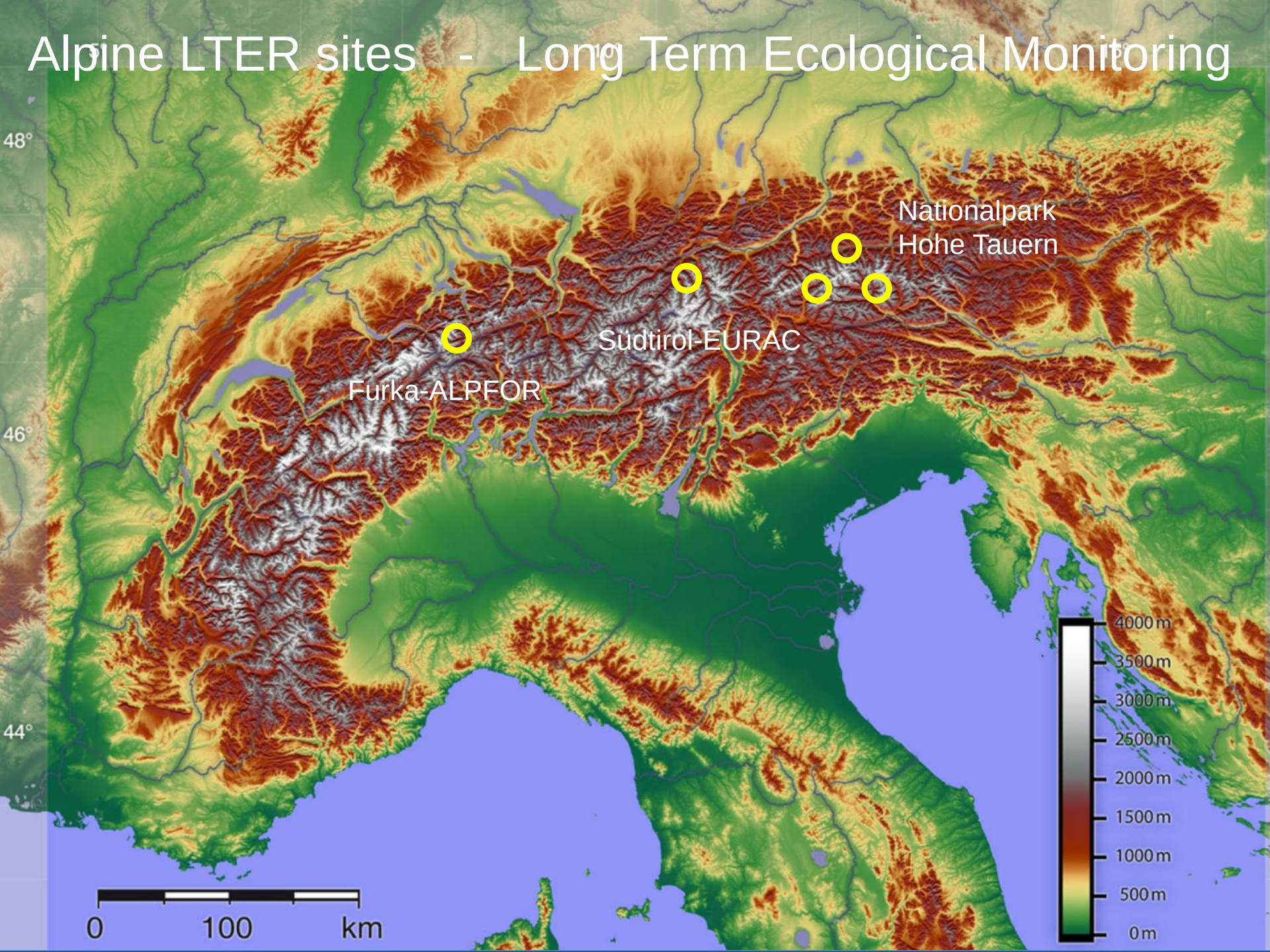

Short term
Long term
Short term
Spring effects
Micro-evolution
Winter effects
Phenology of bud break
Losses of immature tissue
Losses of immature tissue
Maximum freezing resistance in spring
Minimum season length
Tissue maturation + life history
Damage
Damage
Macro-evolution Phylogeny
Species‘ success
Körner et al. (2016) J.Ecol.

‘Experiments‘ by nature: opportunities for basic research





Alpine LTER sites - Long Term Ecological Monitoring



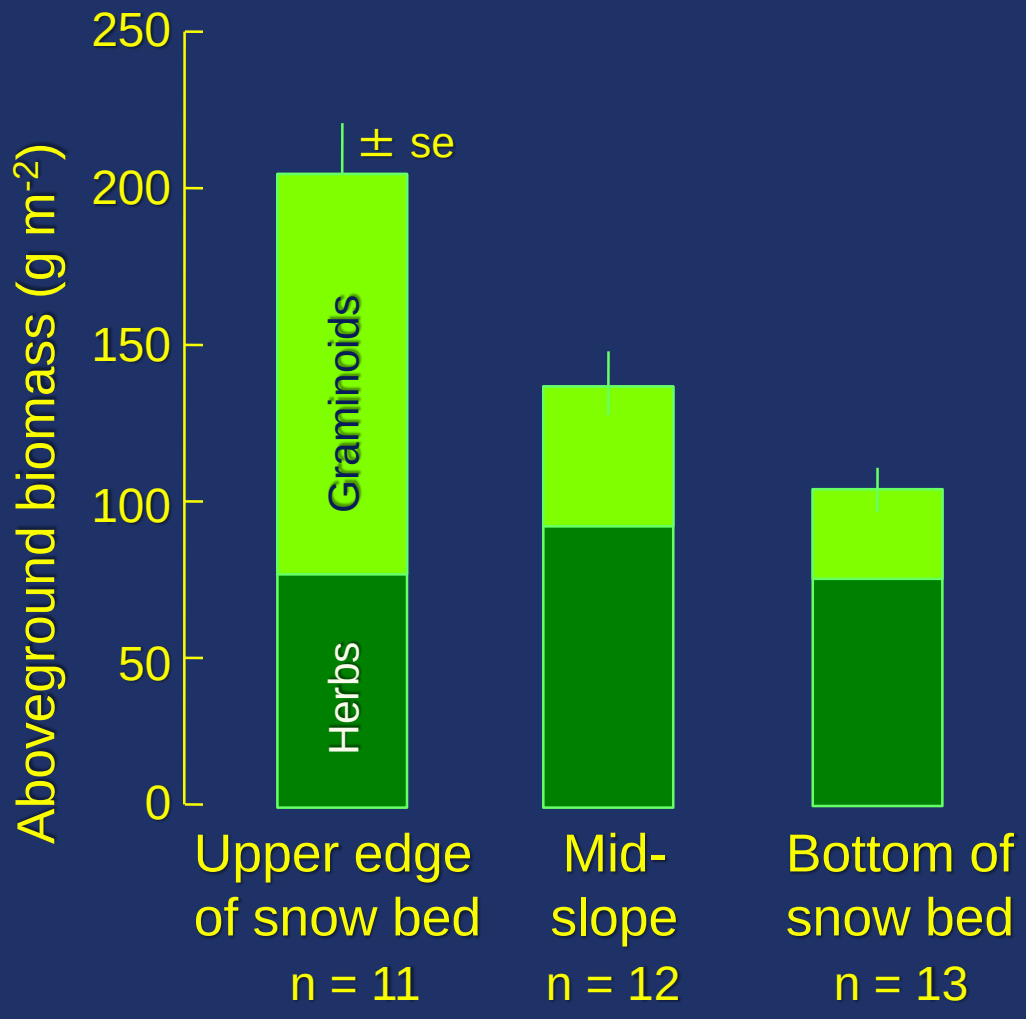
The duration of the growing season may differ by two month across a few meters:
Species range limits can be explored over short distances

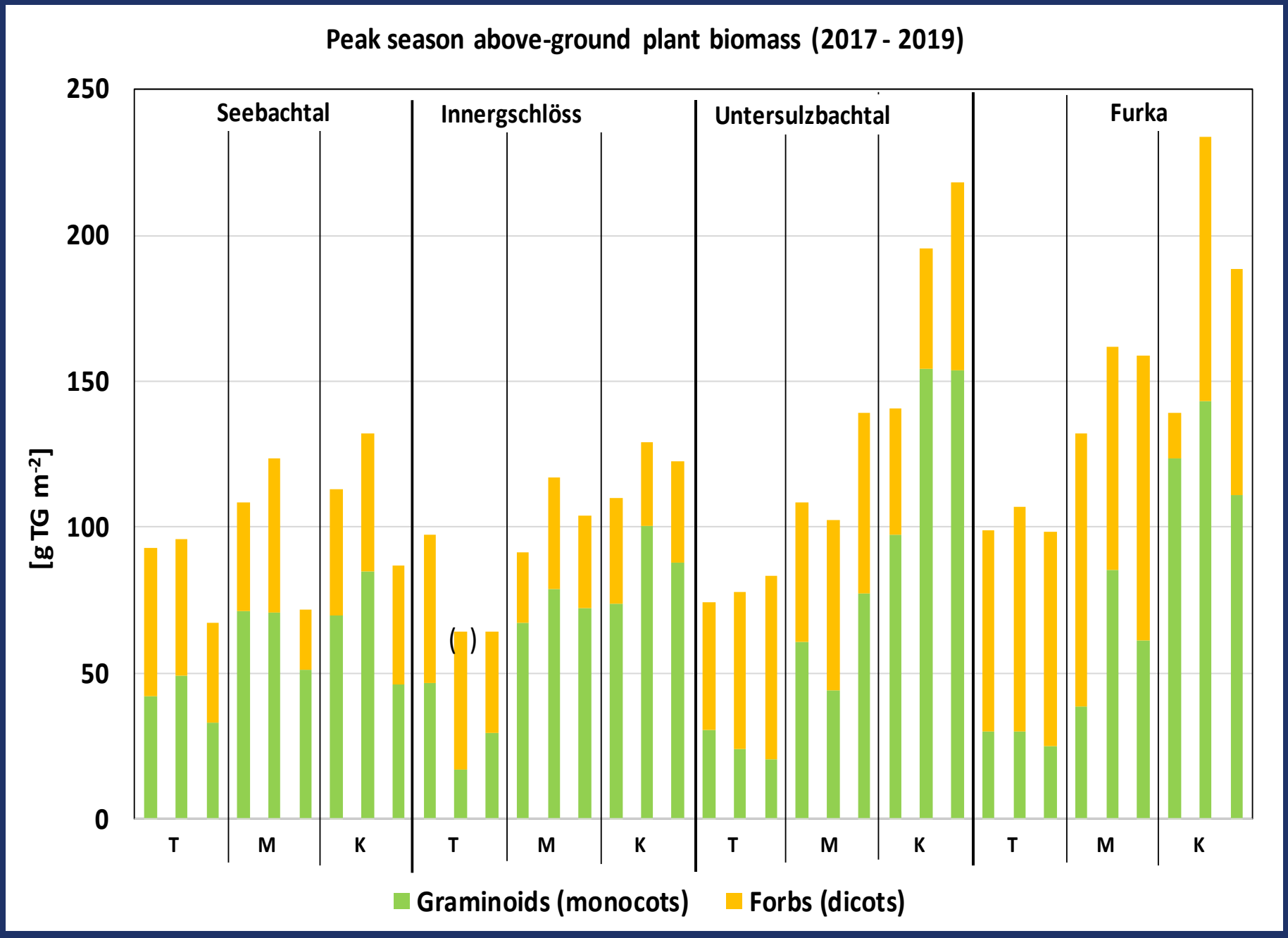
Sharp snow-melt gradients

Top of transect

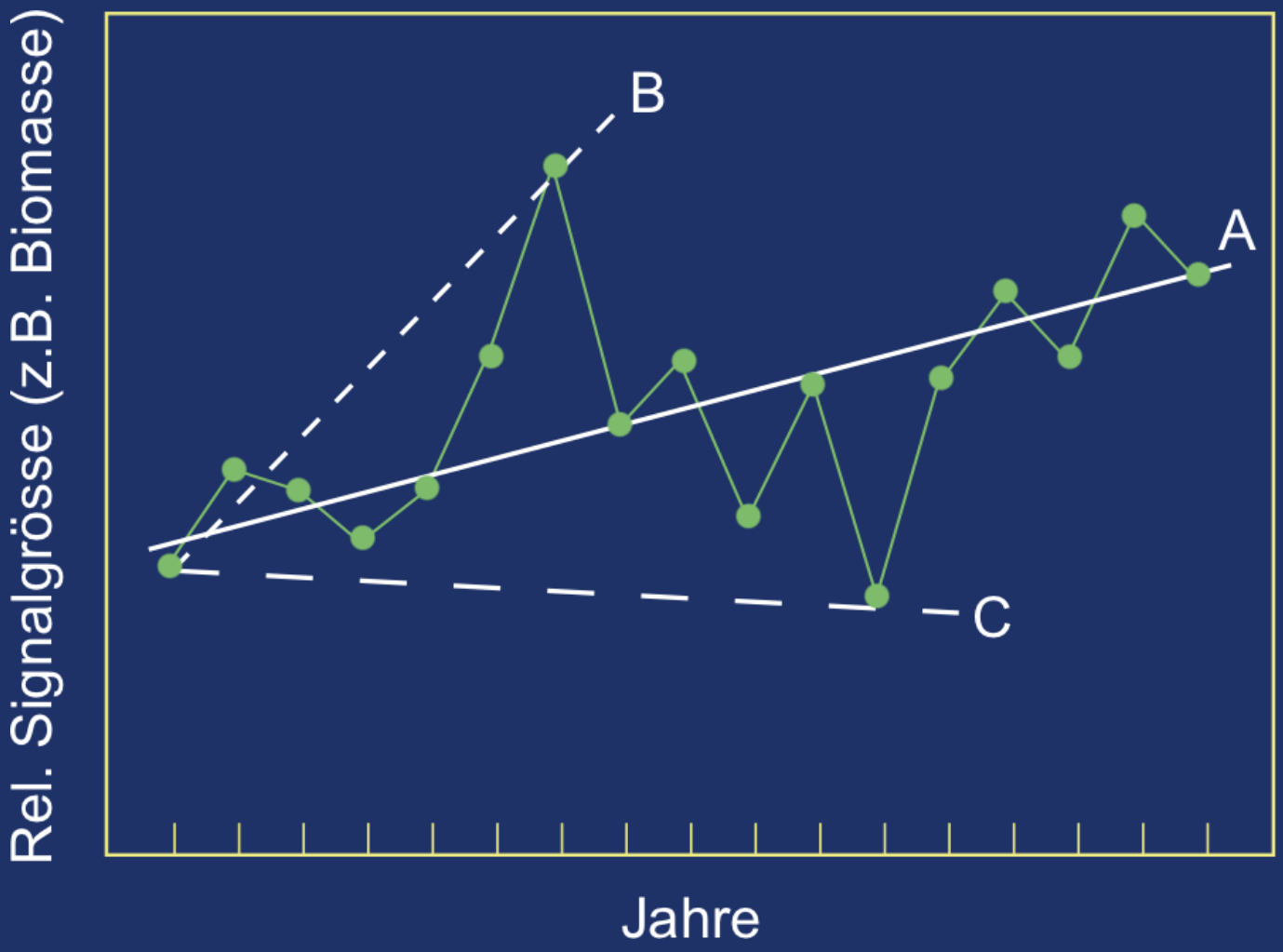
Bottom of transect

Plant biomass production along a snow-melt gradient in summer 2017, Furka-Pass, Switzerland, 2467 m a.s.l.



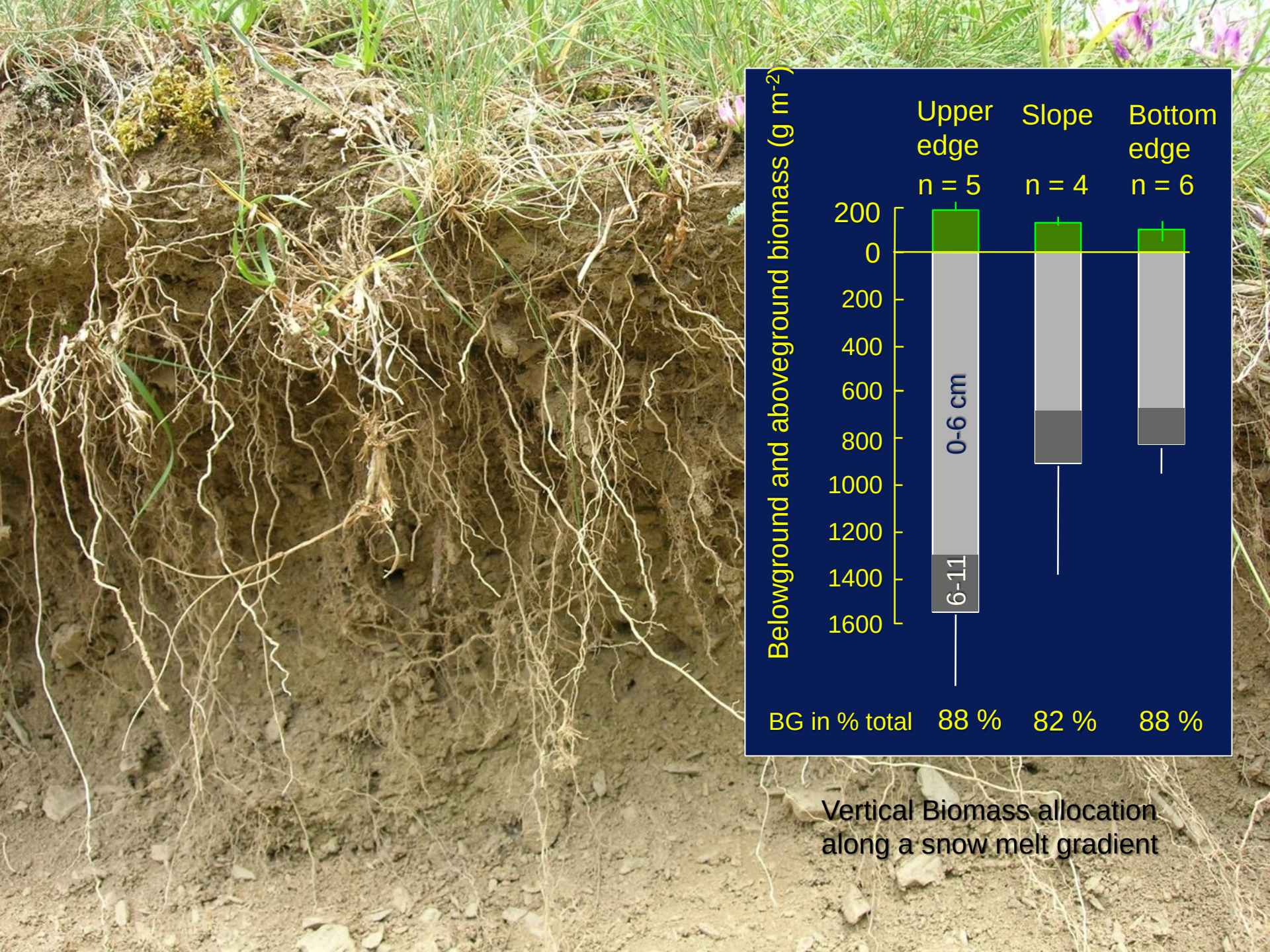

Peak season above-ground plant biomass (2017 - 2019)
250
200
150
100
50
0
[g TG m-2]
Seebachtal
Innergschlöss
Untersulzbachtal
Furka
T
M
K
Graminoids (monocots)
Forbs (dicots)

The central role of stochasticity



The problem of year to year variation in long-term observations with too large census intervals.

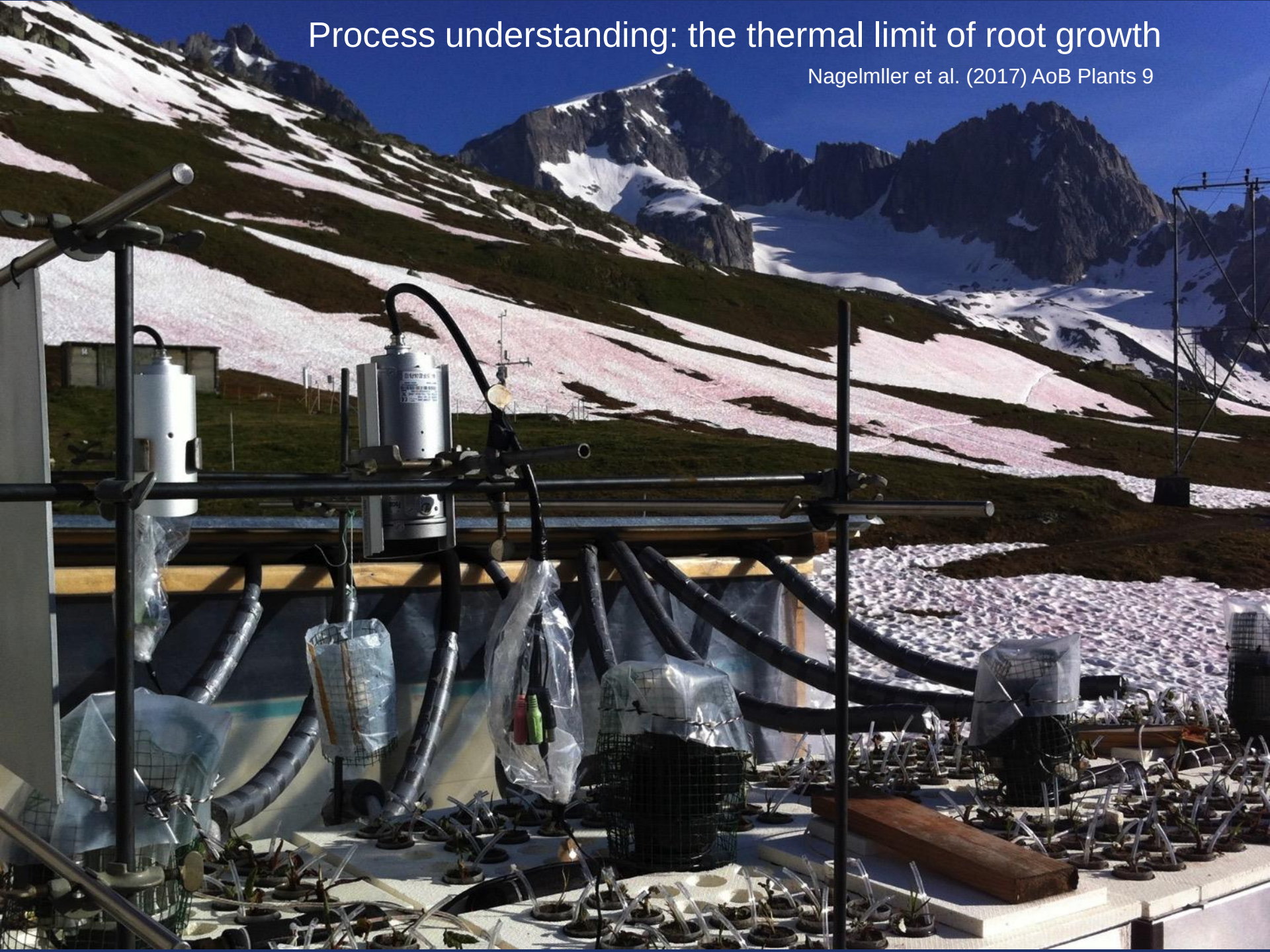
Conclusions B and C differ strongly from the trend in A.



Vertical Biomass allocation along a snow melt gradient

Process understanding: the thermal limit of root growth

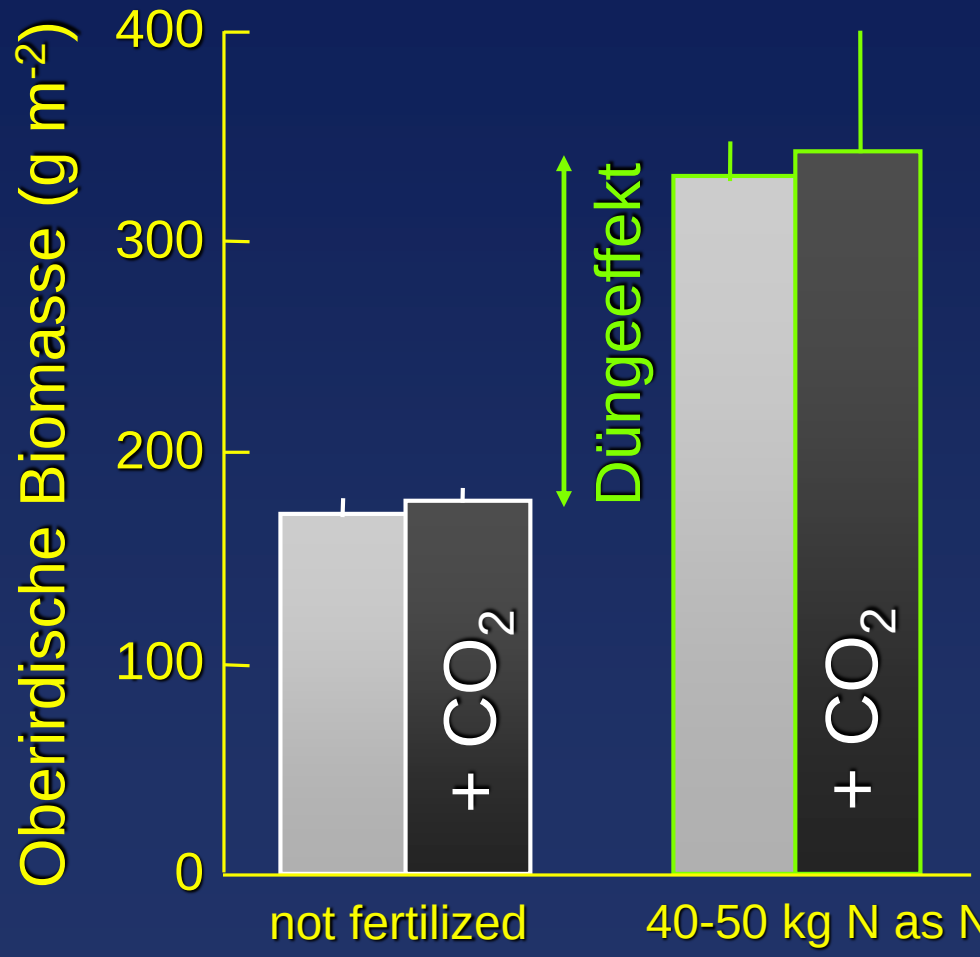
Nagelmller et al. (2017) AoB Plants 9




(2) water
Unprecedented drought at high elevation 2015, 2018

Is carbon a limiting resource?

Elevated CO_2 does not increase alpine plant growth (Furkapass, 2500 m)

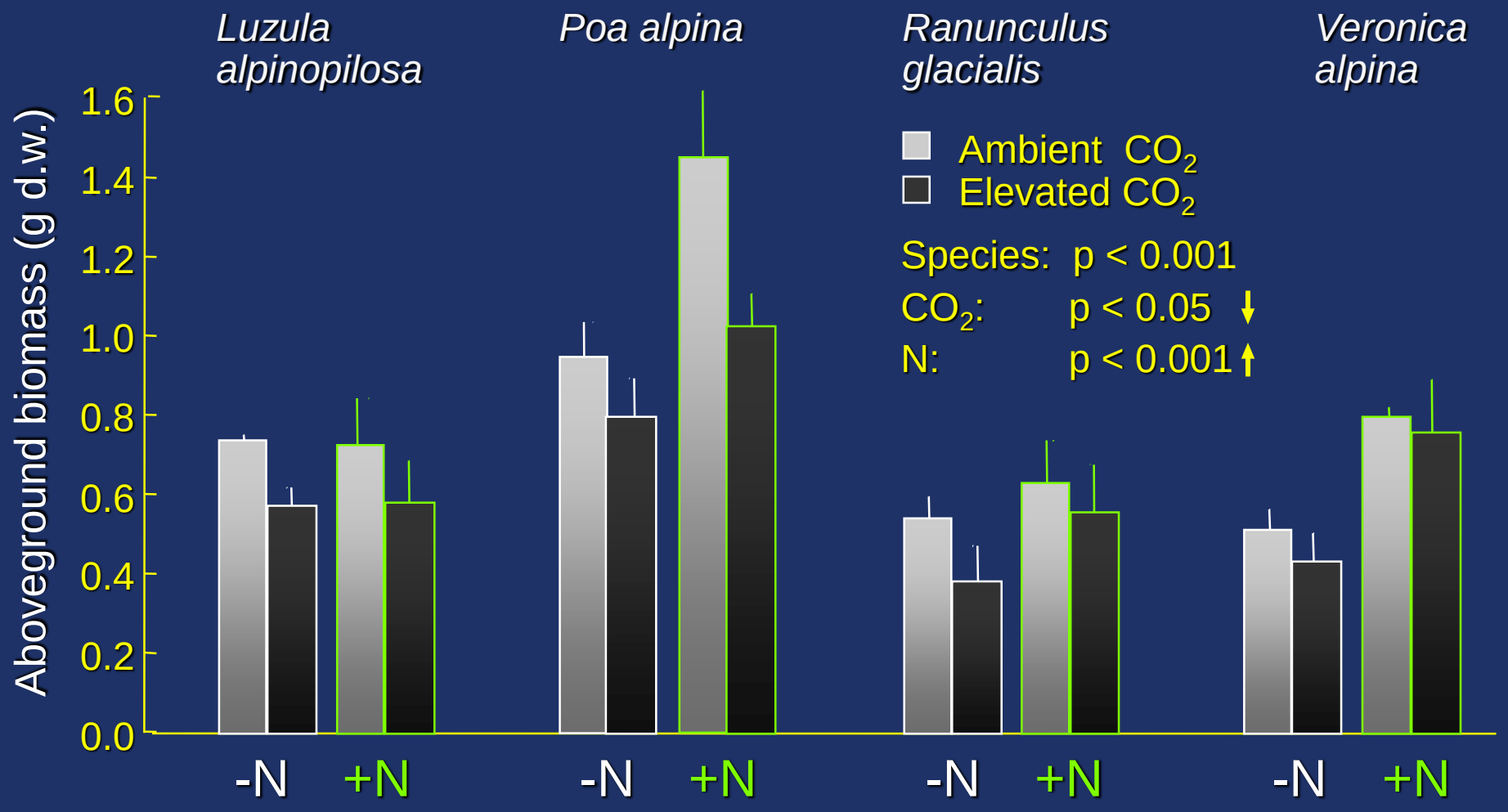


Late successional grassland 1993 -1996

Körner C *et al* (1997) Acta Oecol 18:165

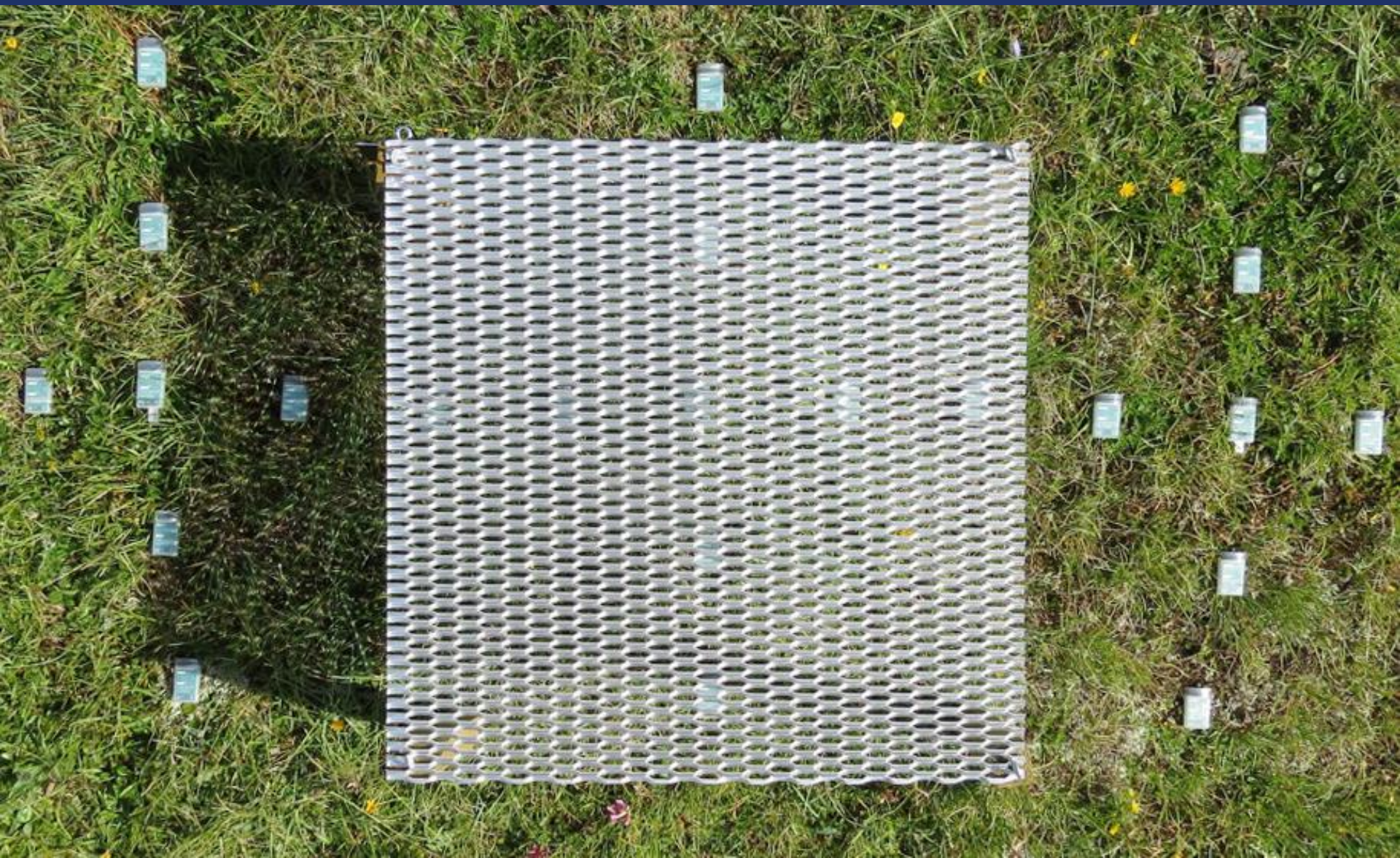
Negative effect of elevated CO_2 on plant growth

FACE-Glacier forefield plants, Furka, 2440 m 2009-2011



N Inauen *et al* (2012) GCB 18:985

…removing half of sunlight, hardly affects above-ground growth,
but there are less roots and softer tissue.....
→ No indication that NPP is C limited



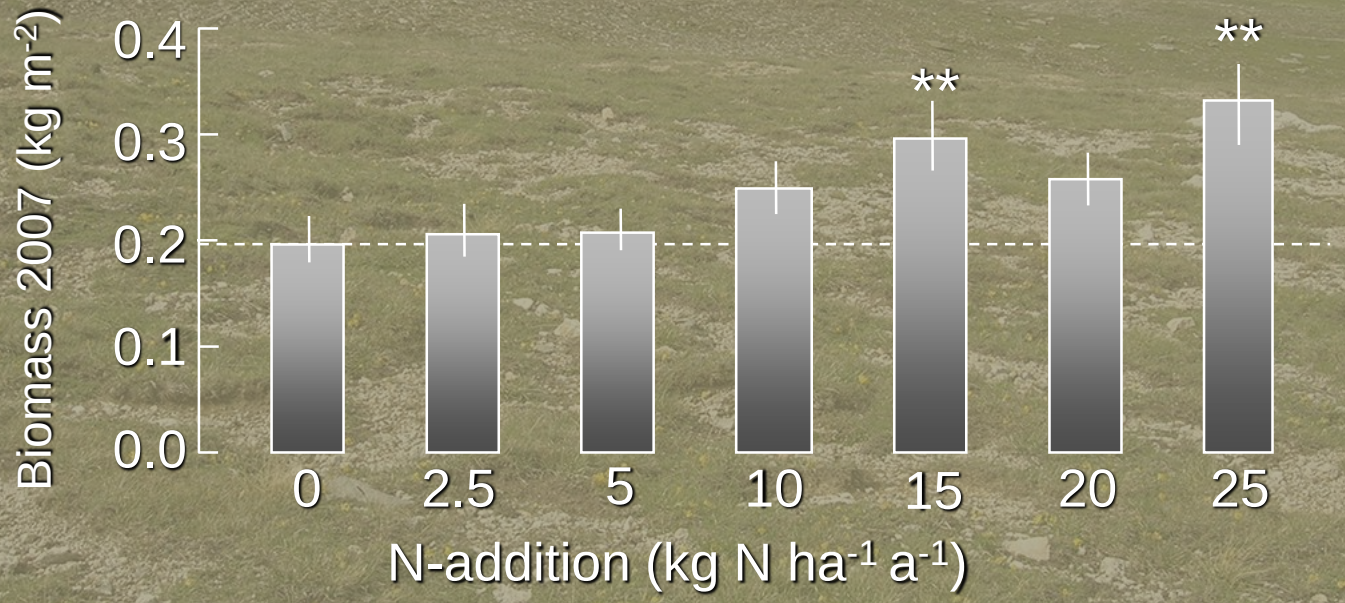
(4) Nitrogen

Atmospheric N deposion: winners and users

E. Hiltbrunner

Biomass-effect >5 kg N ha^{-1} a^{-1} after 4 years

(E. Hiltbrunner, Basel/ALPFOR)



See also:

Roth T, Kohli L, Rihm B, Achermann B (2013) Nitrogen deposition is negatively related to species richness..... in Swiss mountain grassland. Agric Ecosyst Environ 178:121-126

A ‘native invasion‘ by *Alnus viridis* due to land use change

(5) Land use

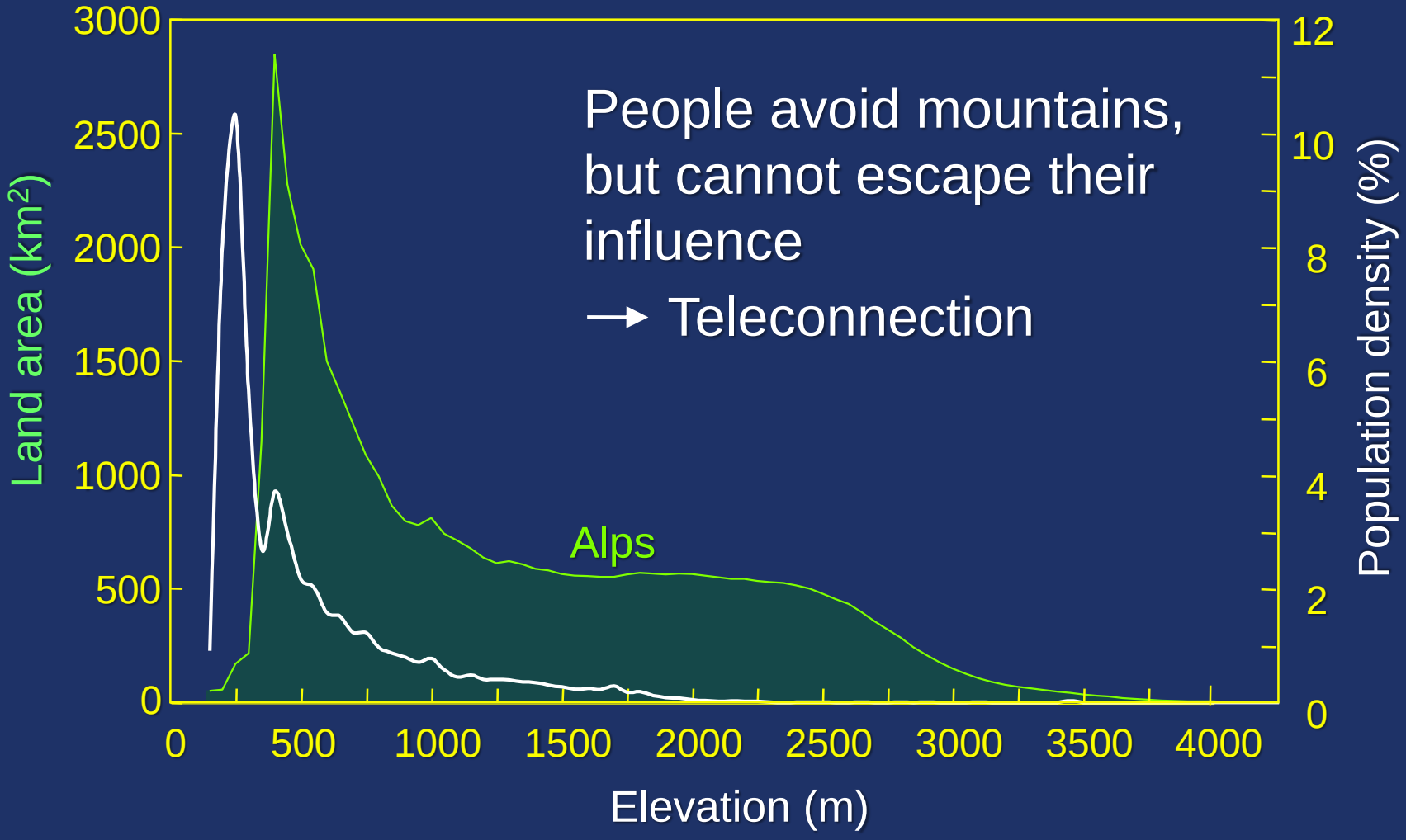
- Loss of pasture land
- Loss of species richness
- Impermeable (no trespassing)
- Eutrophication by N_2-fixation
- Excess water consumption
- Preventing re-forestation
- No avanalanch protection




Humans transform mountain ecosystems around the globe

....this is where vulnerability comes in....

Population density and mountain area by elevation in the Swiss Alps



Where are people living in mountains globally?

Human population statistics for the world‘s mountain terrain separated by major climatic belts

Climatic belt	Mountain area [10^3 km^2]	Human population in mountain terrain [10^3] (% of total population[a])		Human population densities in mountains[b] (total[c])
Nival	526	236 (96.0)	Pixel-noise	0.4
Upper alpine	743	604 (71.3)		0.8
Lower alpine	2255	2927 (59.2)		1.3
Upper montane	3367	18,485 (16.2)		5.5
Lower montane	3733	132,800 (12.9)		35.6
Warm	1338	107,830 (6.7)	Tea plantations	80.6
No freezing	4473	248,300 (5.5)	‚Banana hills‘	55.5
Total	16,435	511,164 (7.0)		31.1

2.5‘ resolution

Roughly 0.5 billion people are living in mountains,
...including the city of Innsbruck,
3 billion people are influenced by mountains....

Körner et al. (2017) Alpine Botany 127

Vulnerability in mountains is largely a gravity-effect issue

Teleconnection: upper Yangtze, Yunnan, China

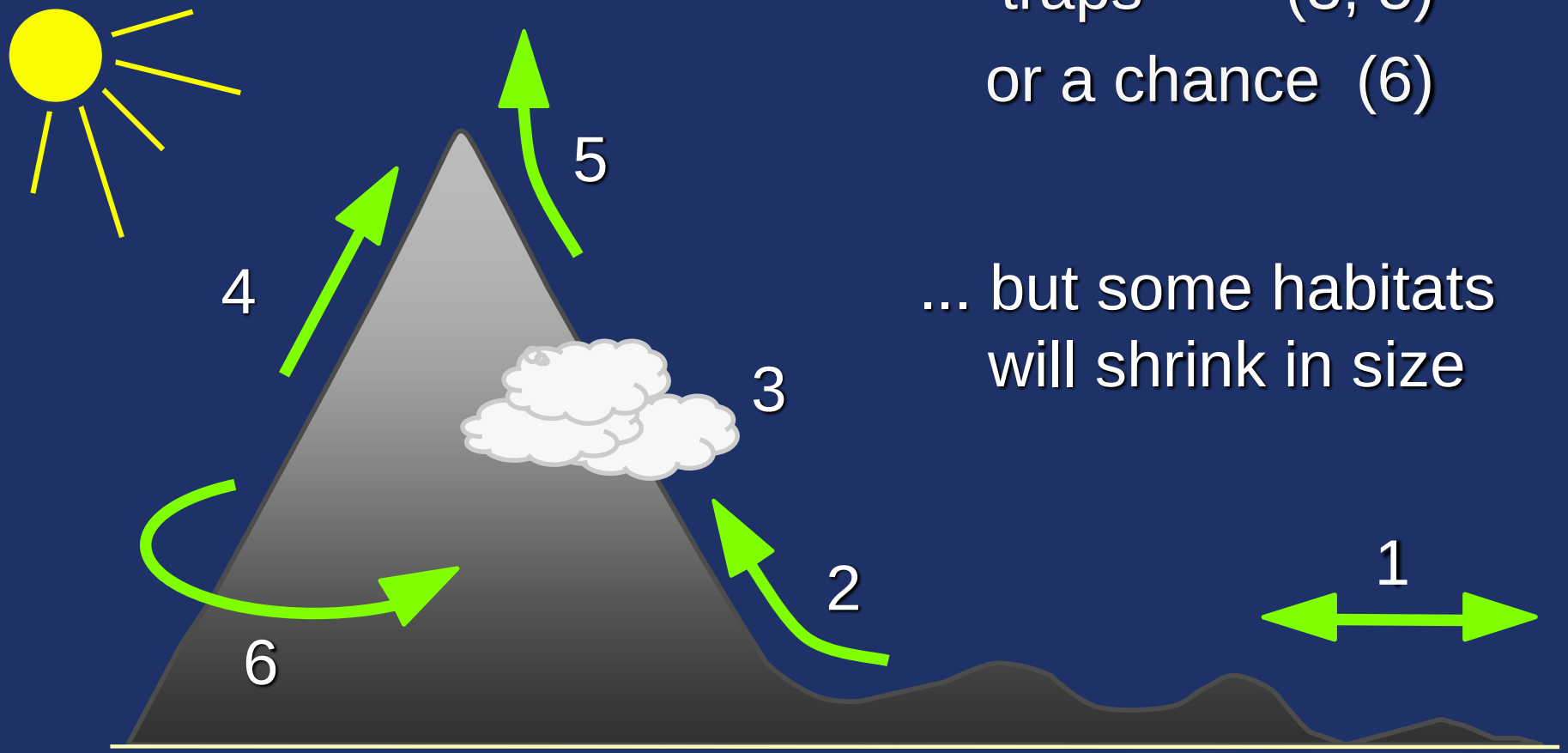
Species responses to climatic warming in mountains

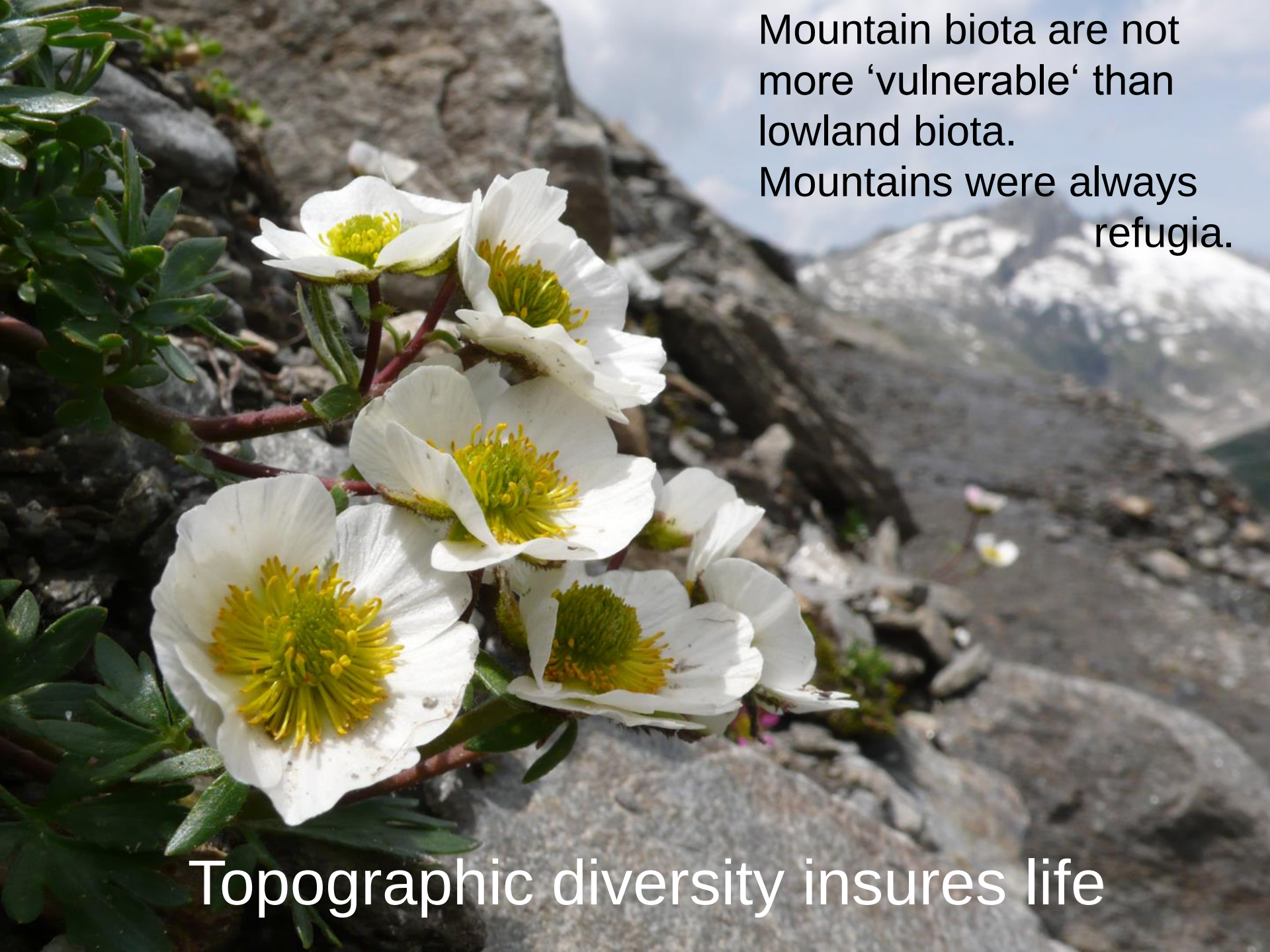
Mountains may be refugia (2, 4)

traps (3, 5)

or a chance (6)

... but some habitats will shrink in size




Mountain biota are not more ‘vulnerable‘ than lowland biota.
Mountains were always refugia.
Topographic diversity insures life