Mountain ecosystems in a changing climate

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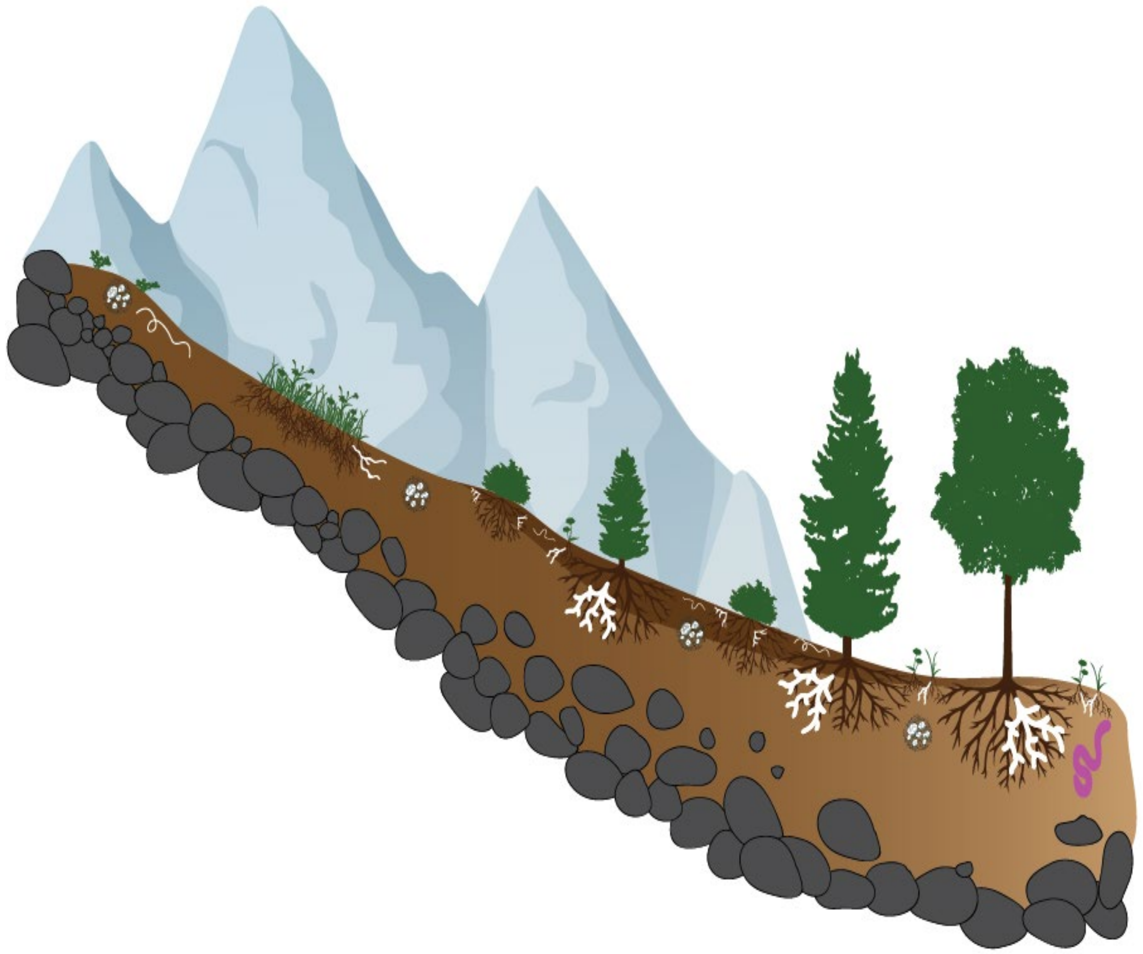
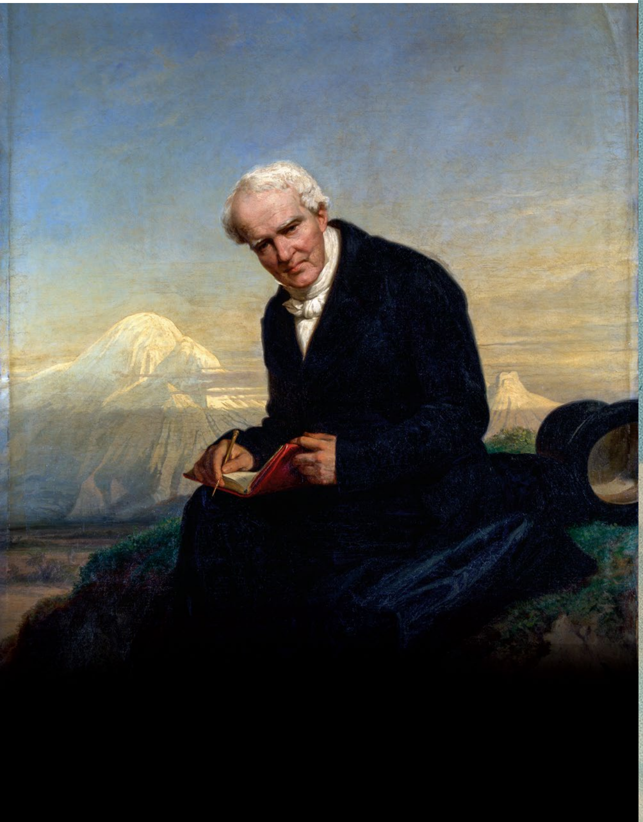
Photo: Andreas Rigling WSL

Outline

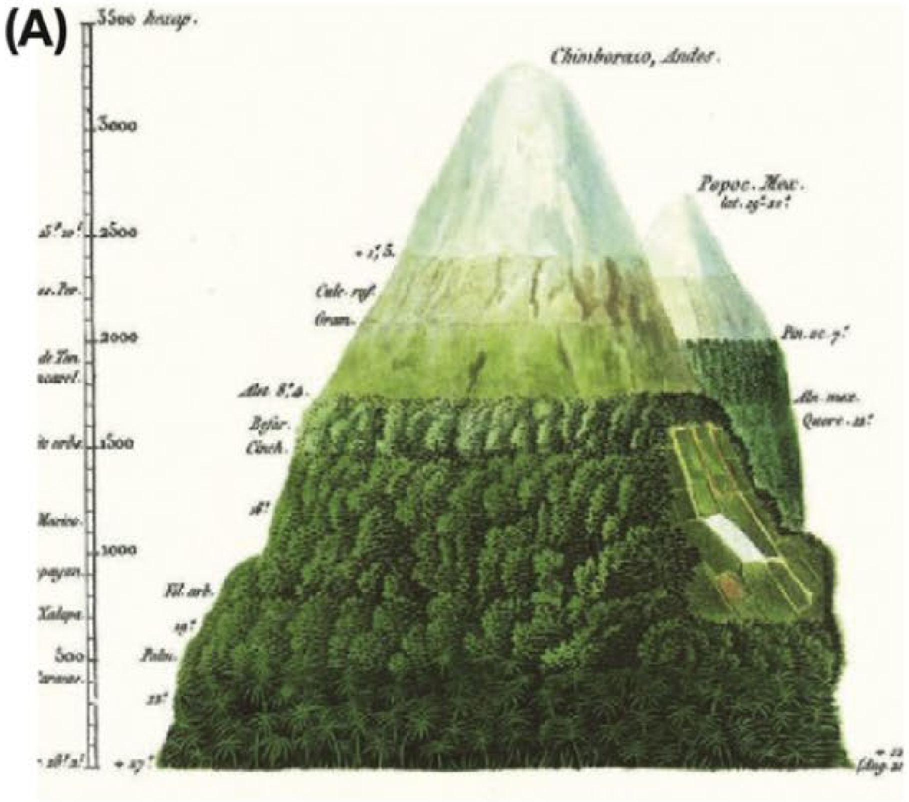


1. Climate shapes mountain ecosystems
2. From the cryo, hydro- to the biosphere
3. Carbon and nutrient cycling in warmer climate
4. Carbon dynamics in high alpine soils

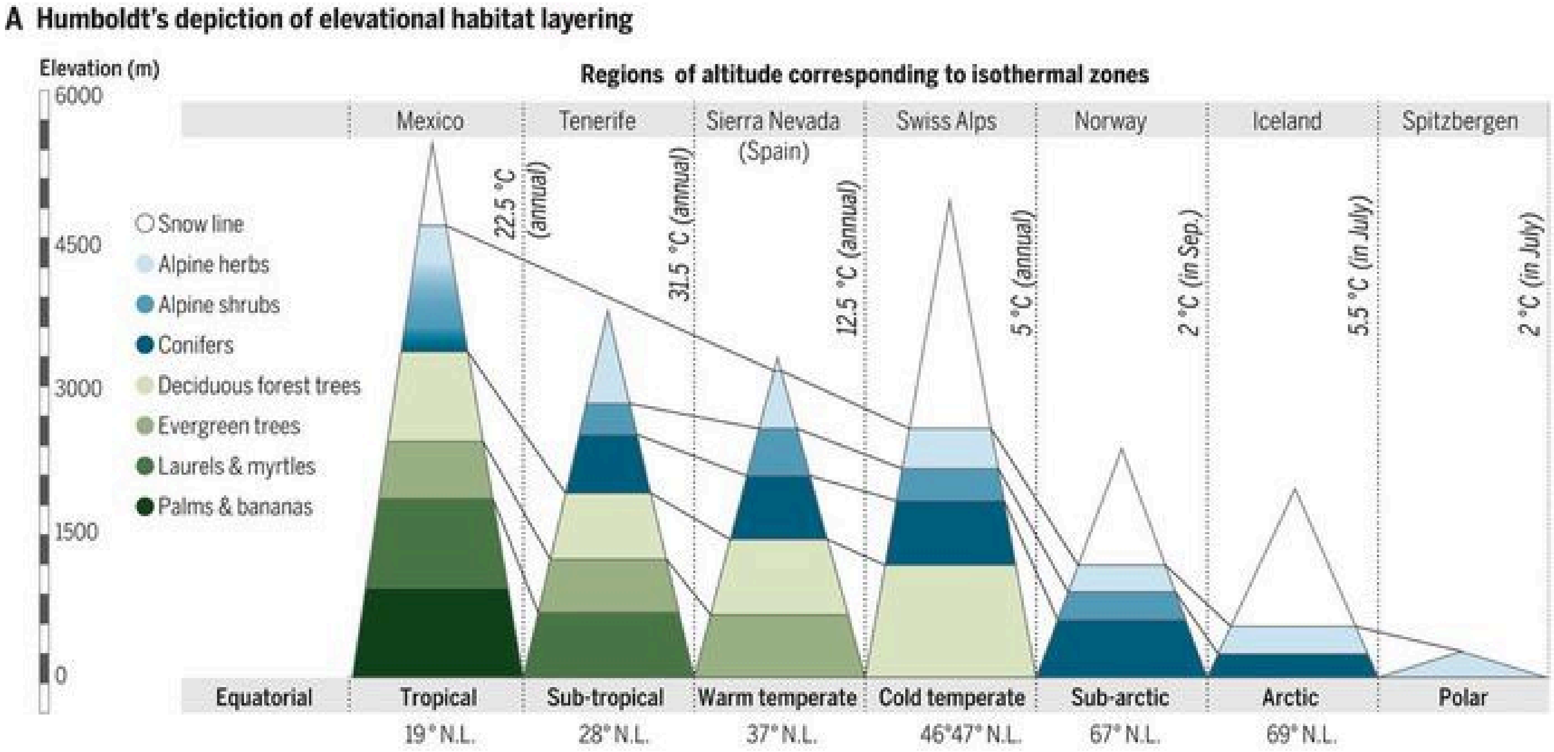
A. von Humboldt (1807): Tableau Physique



A. von Humboldt (1807): concept of climatic belts



Climatic belts on Chimborazo
«Everything is connected»



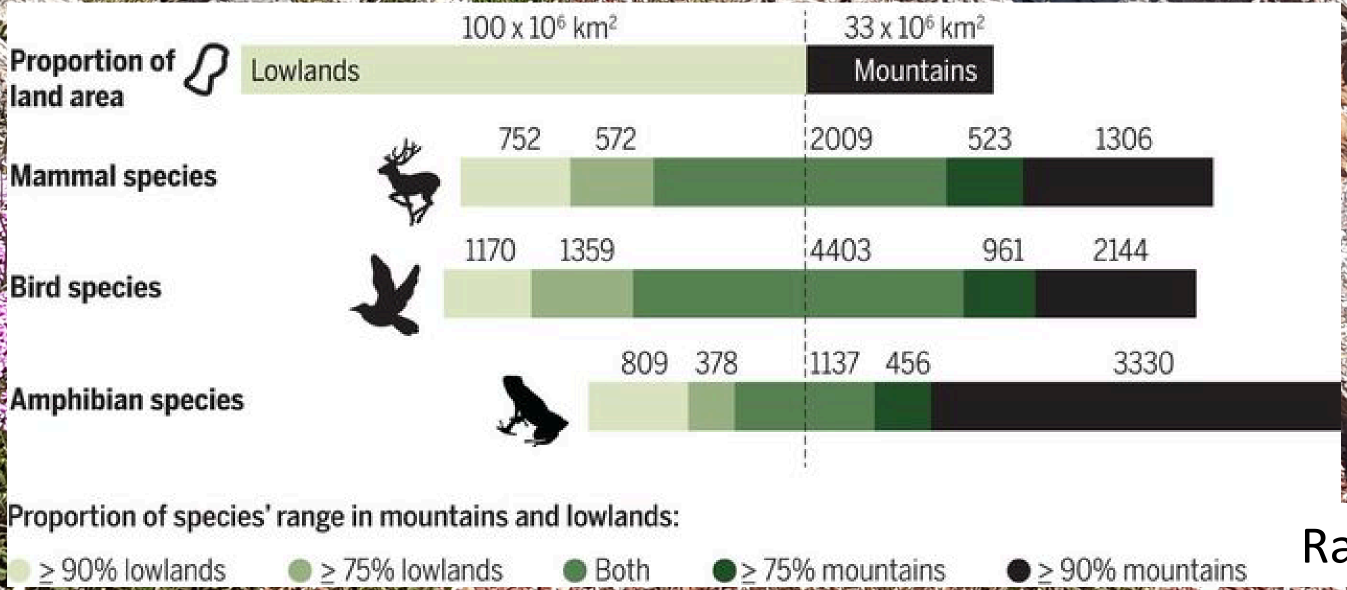
Rahbeck et al. (2019) *Science*

Humboldt Bonplant (1807)
Ideen zu einer Geographie der Pflanzen nebst einem Naturgemälder der Tropenländer

Mountains: Hot spots in biodiversity

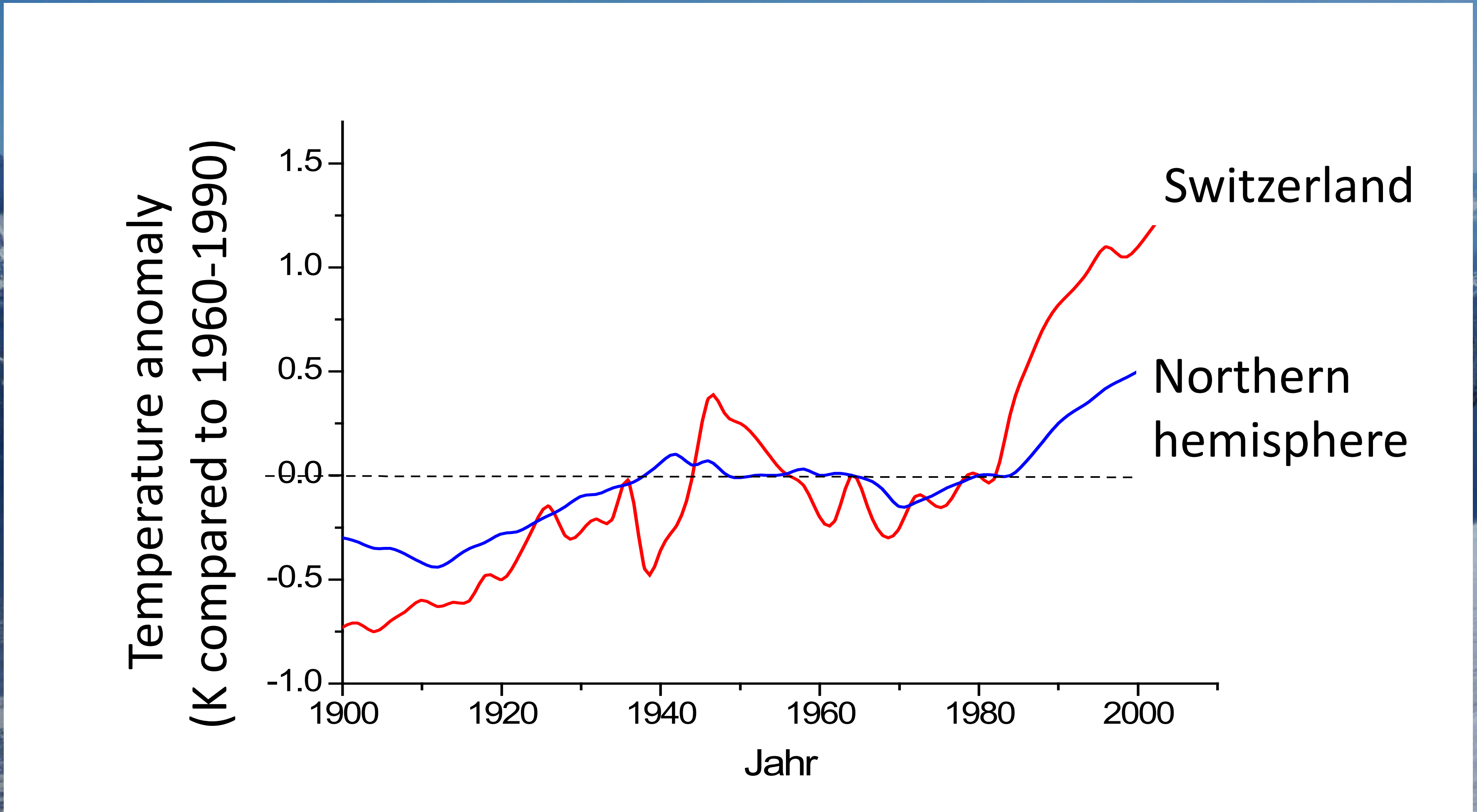
→ Strong gradients in climate and geology over short distances

→ High endemism: Island effects



Rahbek et al (2019) *Science*

Particular strong warming in mountain regions



Mountain Research Initiative (2015) *Nature Climate Change;* Reinhard & Rebetez (2002) *Climate Change*

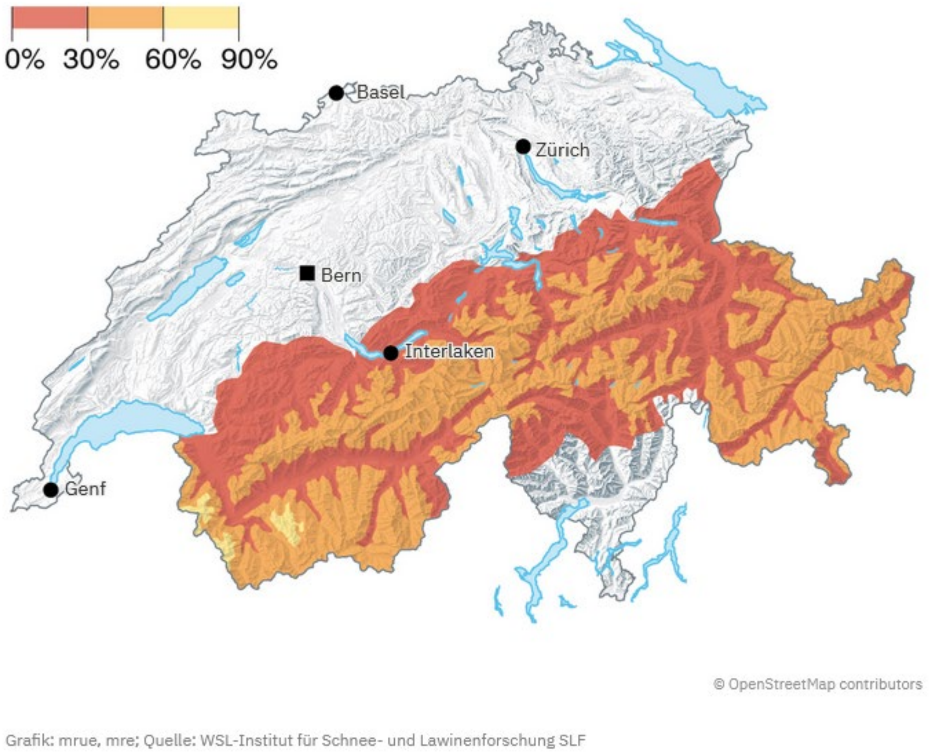
Snow cover decreases

→ **Decreases in snow cover duration (8.9 days / decade**)** Rumpf et al. (2022), *Science*

Villars-sur-Ollon 31.12.2022; Photo: Tagesanzeiger, 5.01.2023

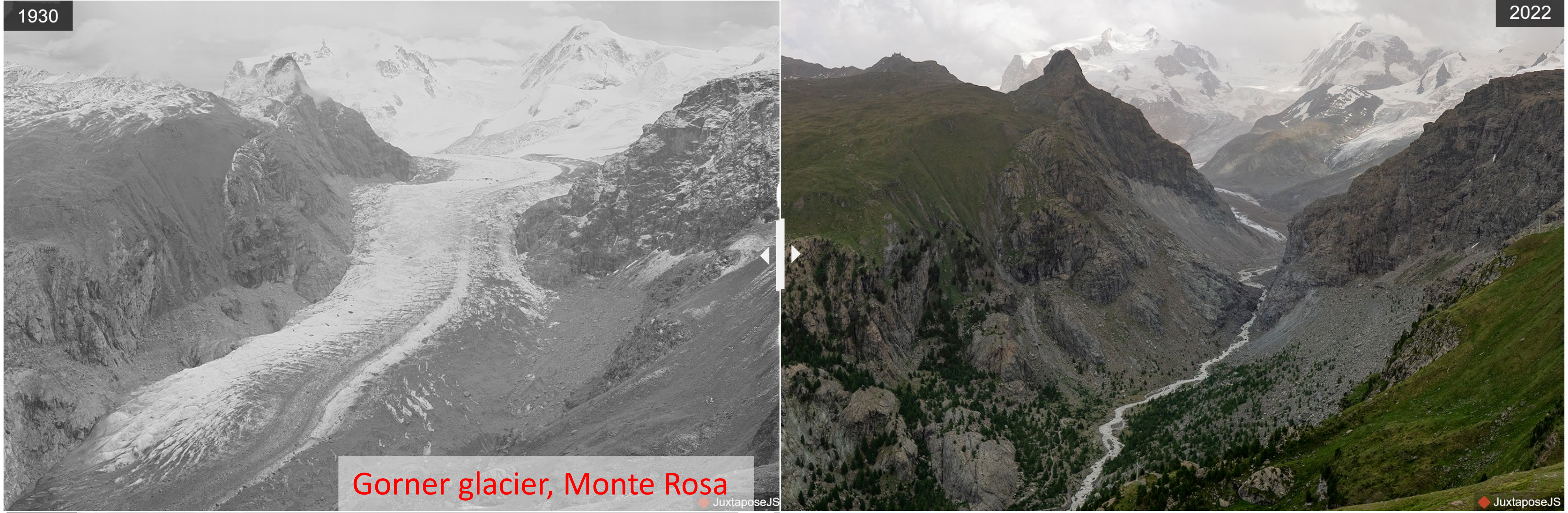
February 2023

Snow height compared to long-term average



SLF, 22.02.2023

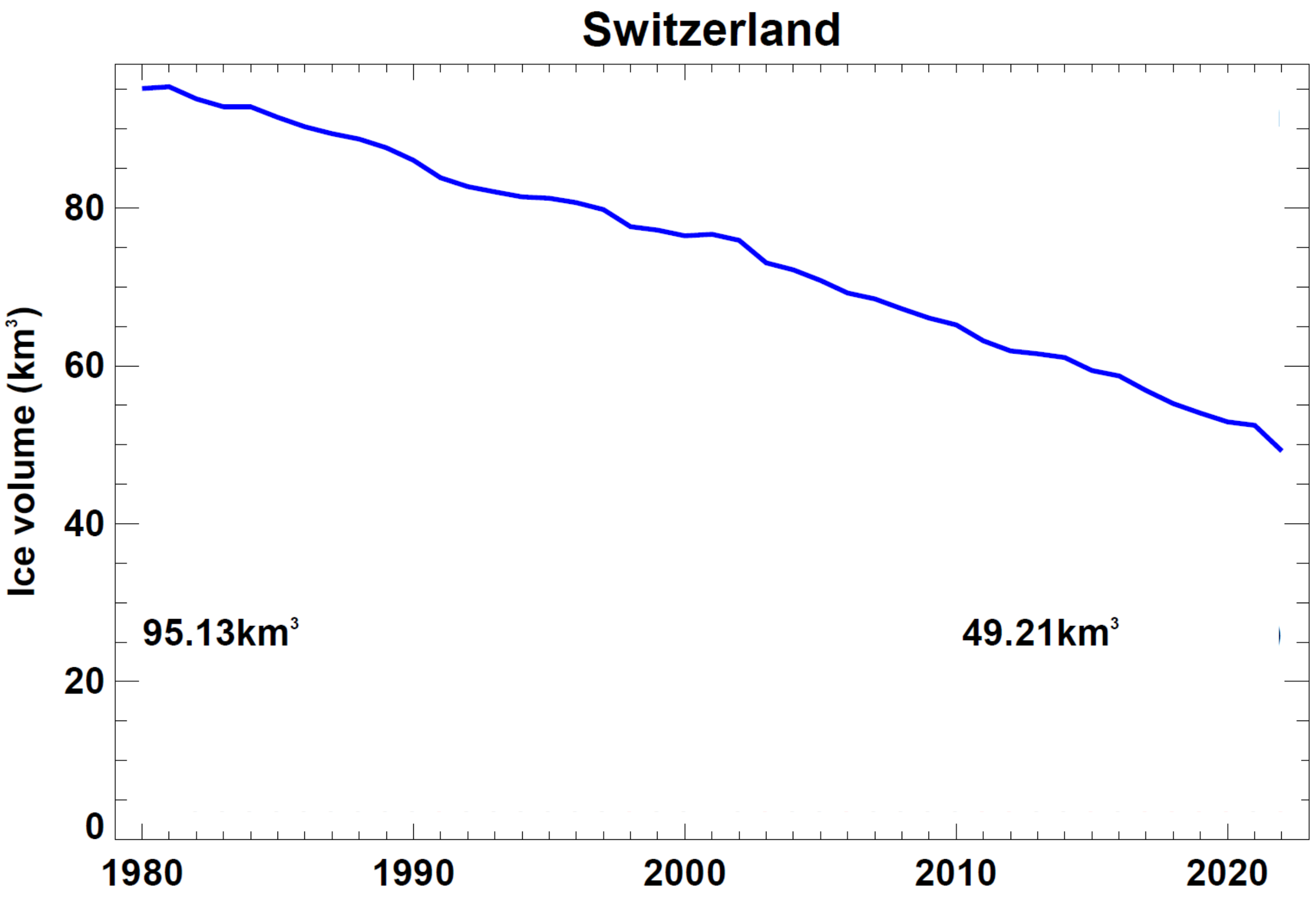
Record melt 2022 Tortin Glacier (VS) Christoph Lambiel, Tagesanzeiger

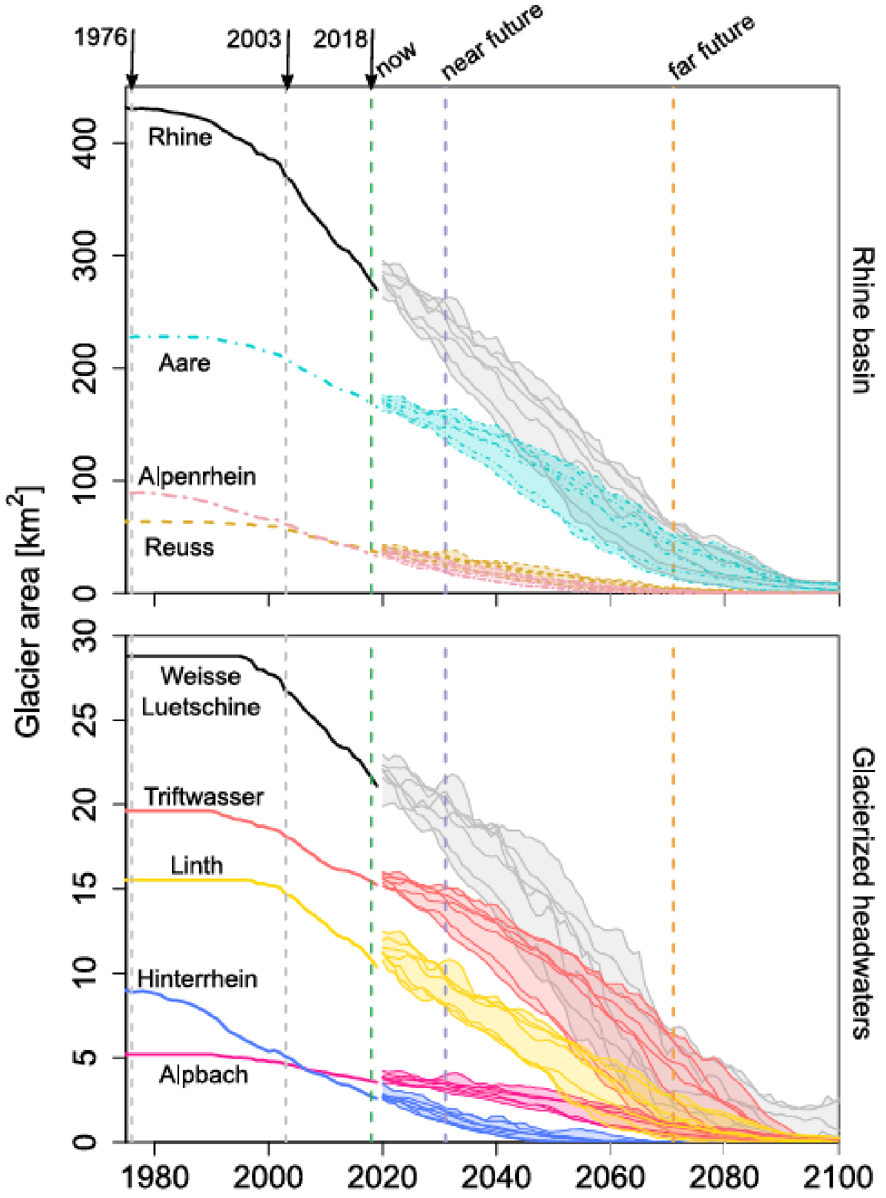


Schytt-Mannerfeld
et al. (2022):
The Cryosphere

Thermokarst in the Alpine

Photo: M. Zehnder, SLF





www.glamos.ch

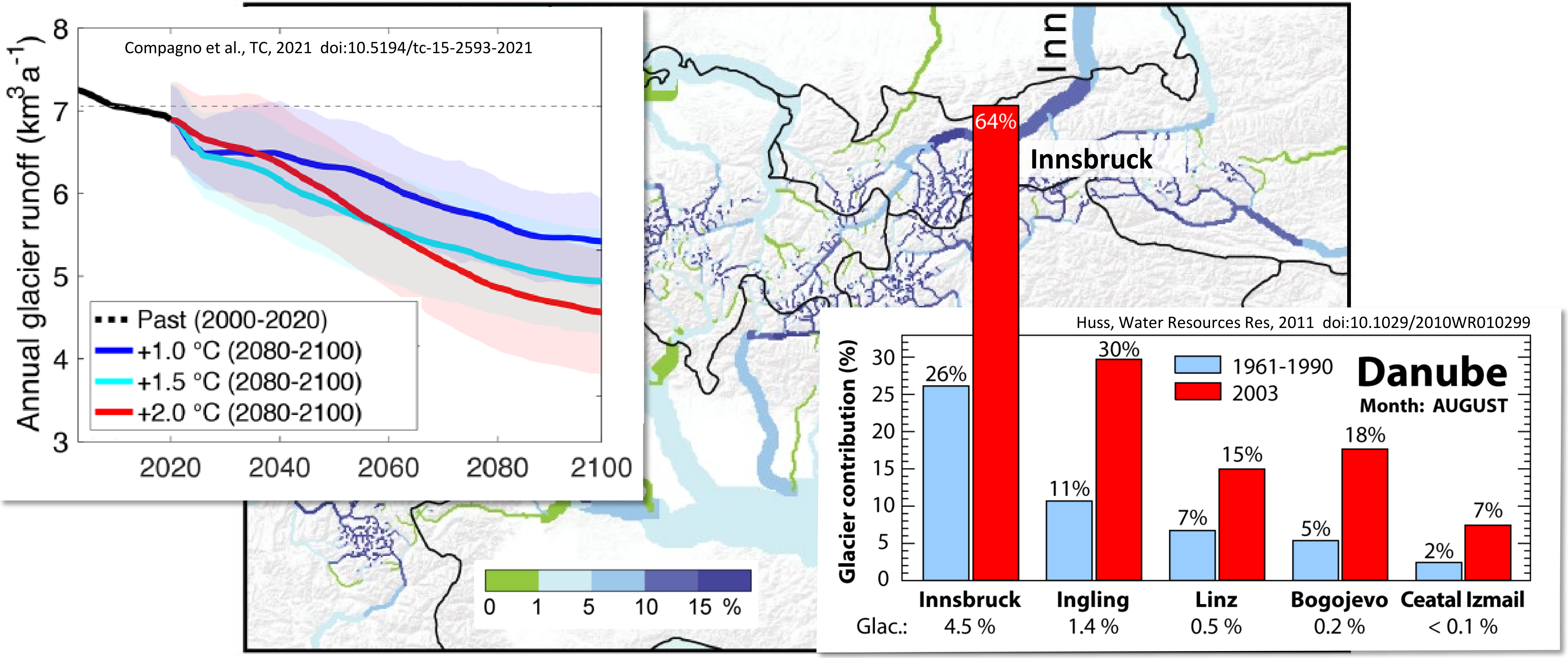
GLAMOS 1881-2021, The Swiss Glaciers 1880-2018/19,

Van Tiel et al. (2023) *Advancing Earth and Space Science*

Why does it matter?

The Alps: "Europe's water towers"

Mean annual runoff contribution from glacierized areas (avg 1980-2009)



Farinotti et al. (2016) Env. Res. Letters

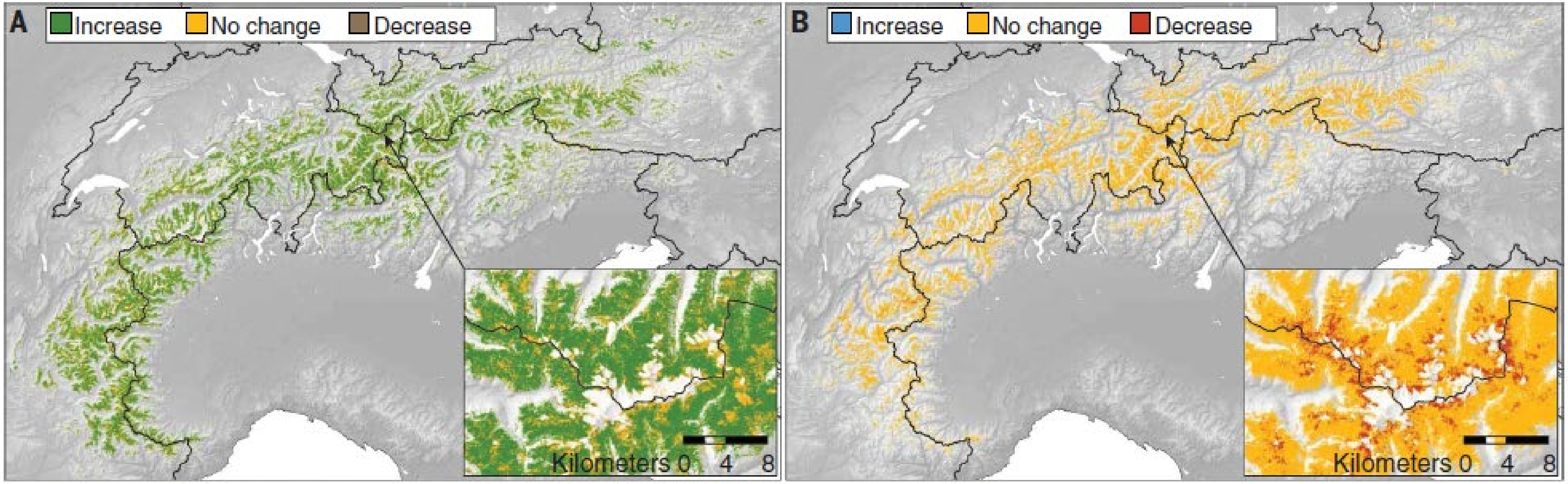
from Farinotti

Emme, 21.06.2022 Beat Mathys

CLIMATE CHANGE

From white to green: Snow cover loss and increased vegetation productivity in the European Alps

RESEARCH | REPORT

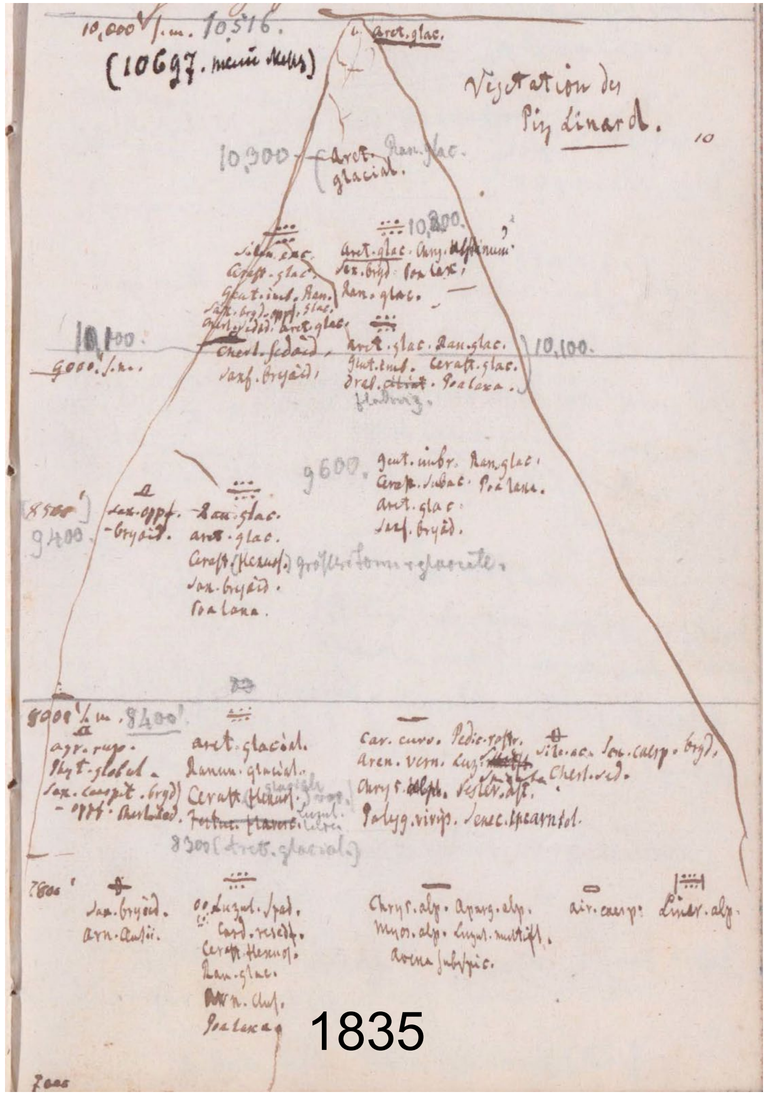


77% of European Alps experienced greening; Rumpf et al. (2021) *Science*

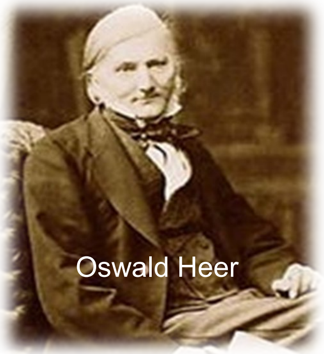
Biodiversity monitoring started 180 years ago!

Piz Linard, 3414 m

Using historical summit flora data to detect change

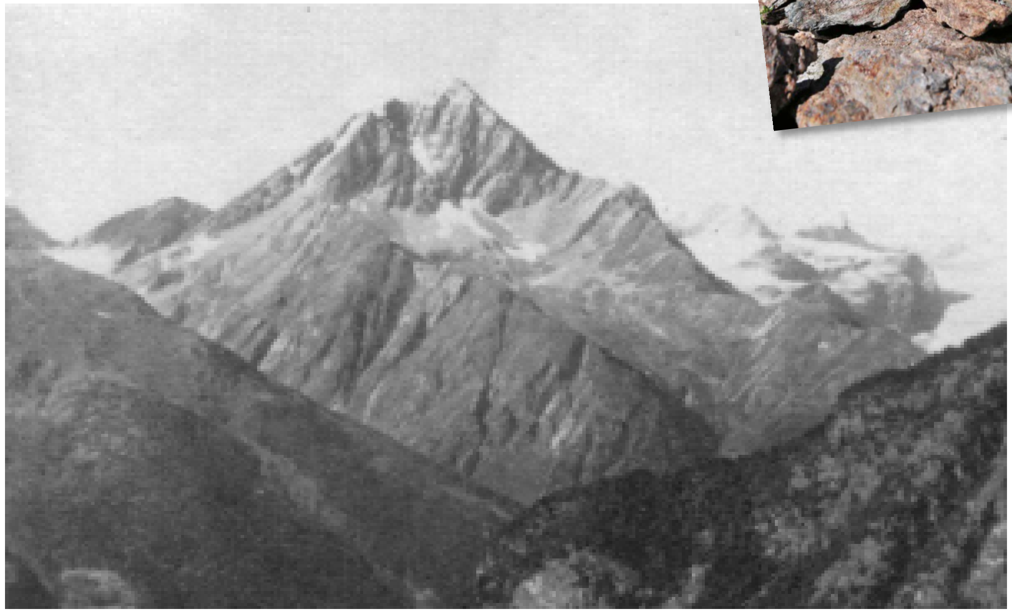


Androsace alpina (Aretia glacialis)
Alpenmannsschild



Oswald Heer

Josias Braun-Blanquet



EIN JAHRHUNDERT FLORENWANDEL
AM PIZ LINARD (3414 m)

VON

J. BRAUN-BLANQUET.

From Christian Rixen, WSL

Using historical summit flora data to detect change

	Presence on Piz Linard summit								
Species	1835	1864	1895	1911	1937	1947	1992	2003	2011
Androsace alpina (L.) Lam.	**	**	**	**	**	**	**	**	**
Leucanthemopsis alpina (L.) Heywood		**		**	**	**			*
Ranunculus glacialis L.		**	**	**	**	**	**	**	**
Saxifraga bryoides L.			**	**	**	**	**	**	**
Saxifraga oppositifolia L.			**	**	**	**	**	**	**
Poa laxa Haenke				**	**	**	**	**	**
Draba fladnizensis Wulfen				**	**	**	*	*	*
Gentiana bavarica L.				*	*	*	*	*	*
Cerastium uniflorum Clairv.					*	*	*	*	**
Saxifraga exarata Vill.					*	*		*	**
Luzula spicata (L.) DC.							*	*	*
Cardamine resedifolia L.							*		*
Sedum alpestre Vill.								*	*
Doronicum clusii (All.) Tausch								*	
Cerastium pedunculatum Gaudin									**
Erigeron uniflorus L.									*
Gnaphalium supinum L.									*
Total species number	1	3	5	8	10	10	10	12	16

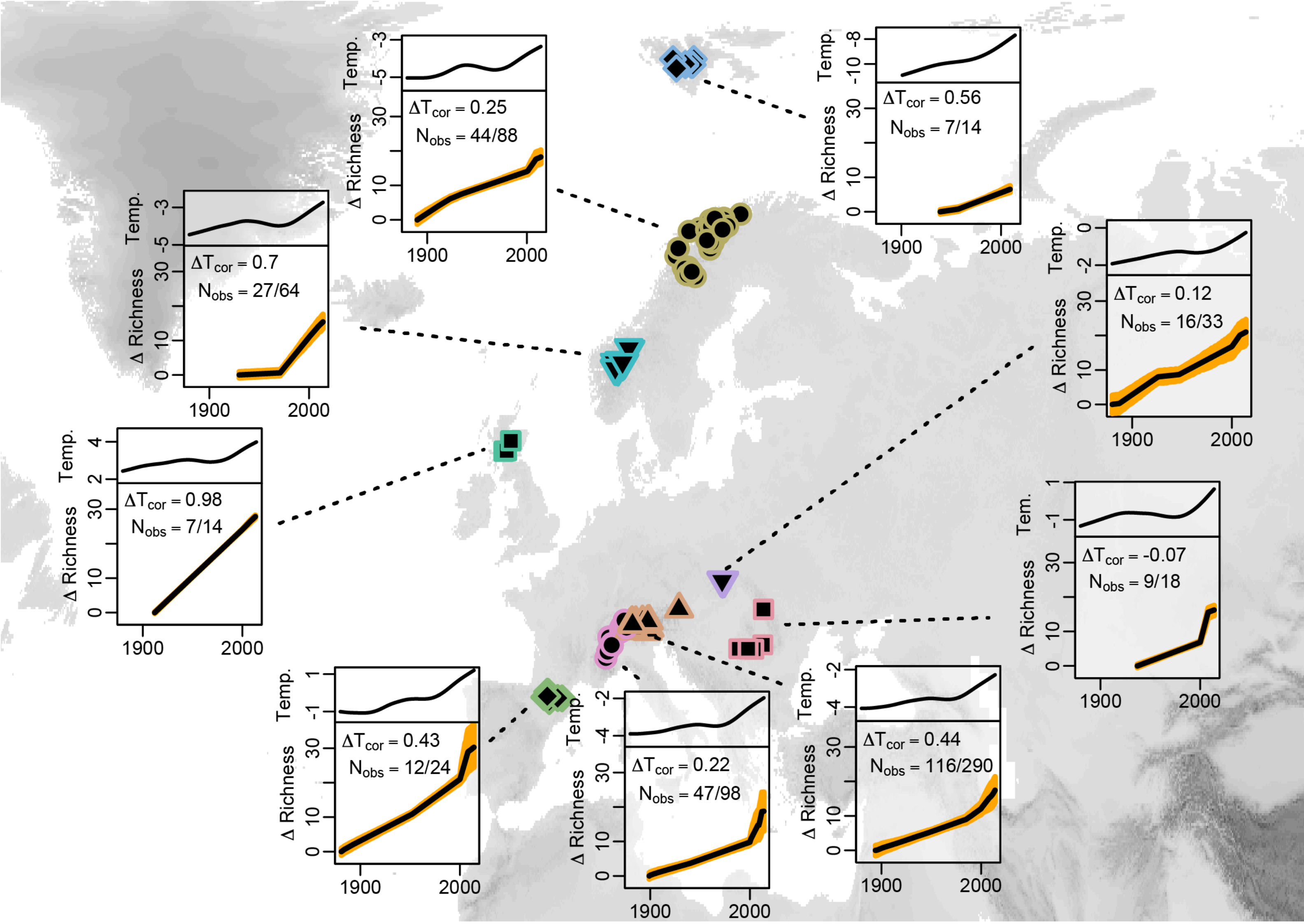
[+] found at higher altitude on Piz Linard in 1911

Source: [1] Schibler 1897, 1929; [2] Rübel 1912; [3] Heer 1885; [4] Braun 1913

Wipf et al. (2013): *Plant Ecology and Evolution*

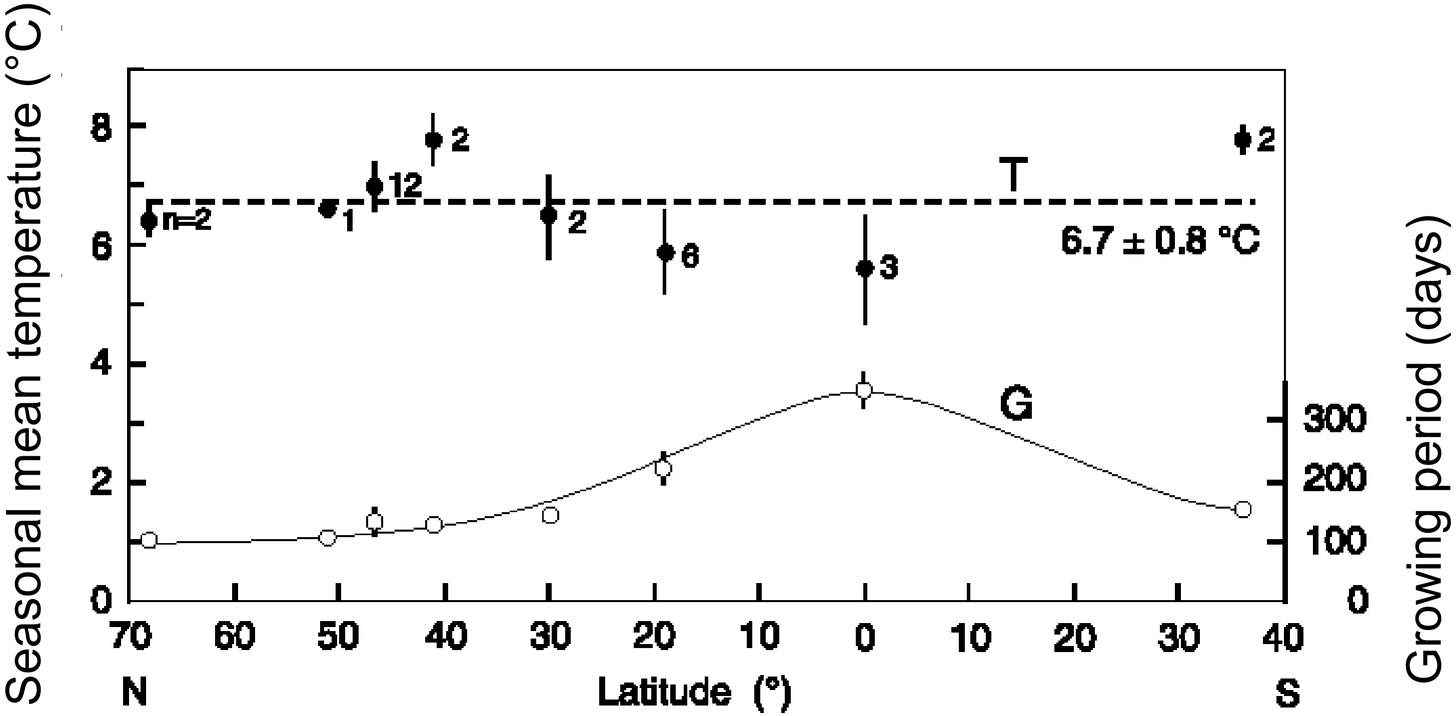
Warming accelerates increase in plant species richness

(Steinbauer et al. 2018)



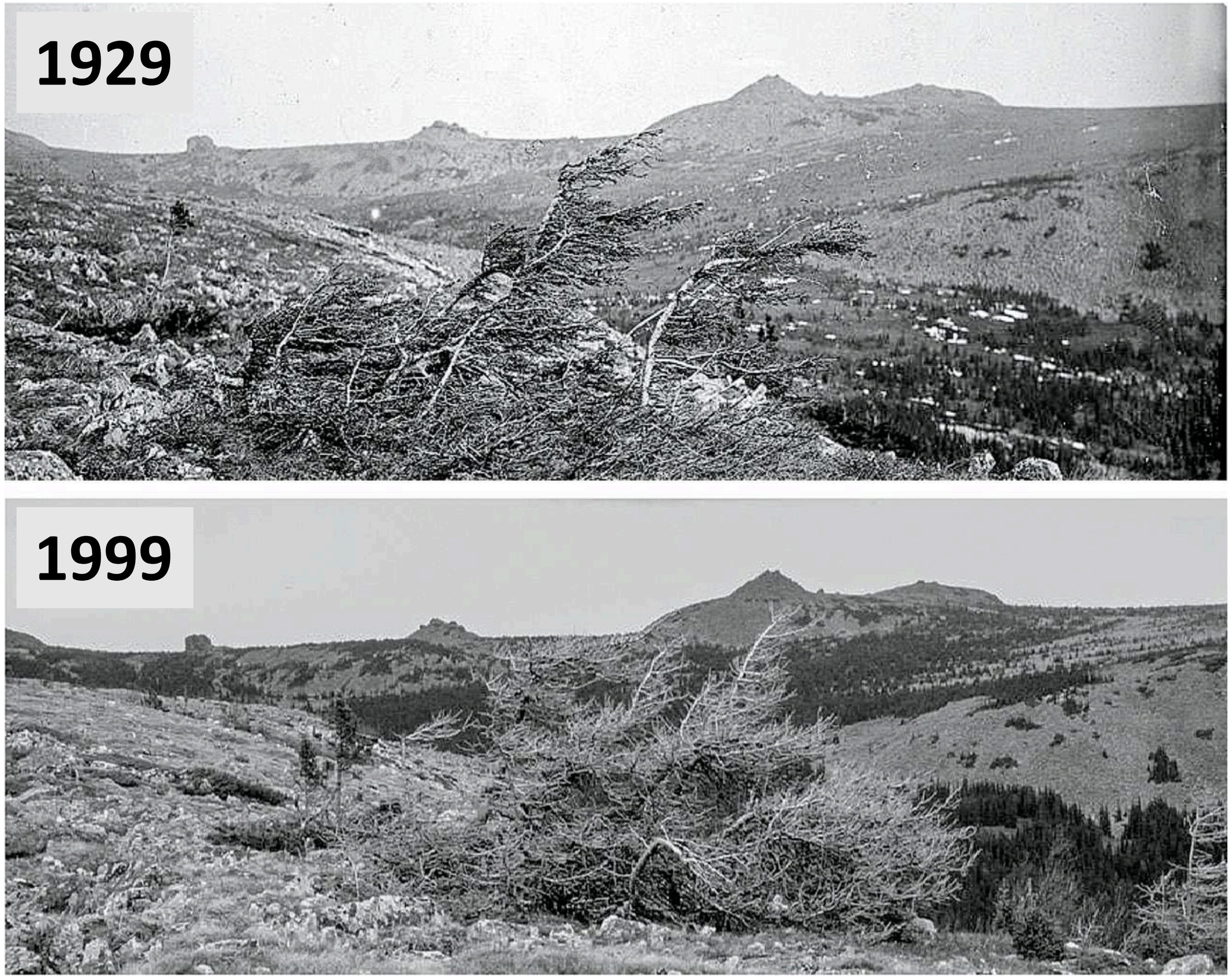
Monitoring on 302 mountain peaks

Treeline position limited by summer temperature



Körner & Paulsen (2004): *Journal of Biogeography*

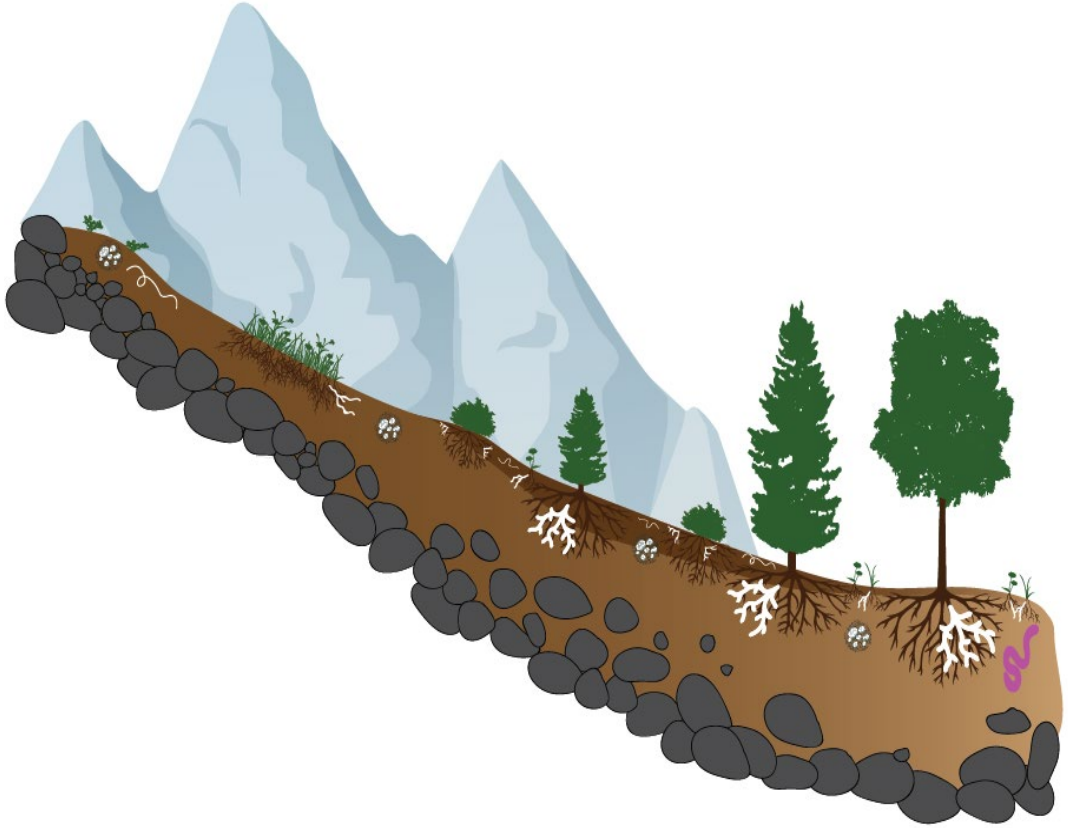
Treeline shifts



Iremel, Ural mountains; 60-80 m shifts in 100 years

Hagedorn et al. (2019) *Science*

Species shifts lag behind climate change



Hagedorn et al. (2019) *Science*

0.65°C temperature change/100 m in elevation

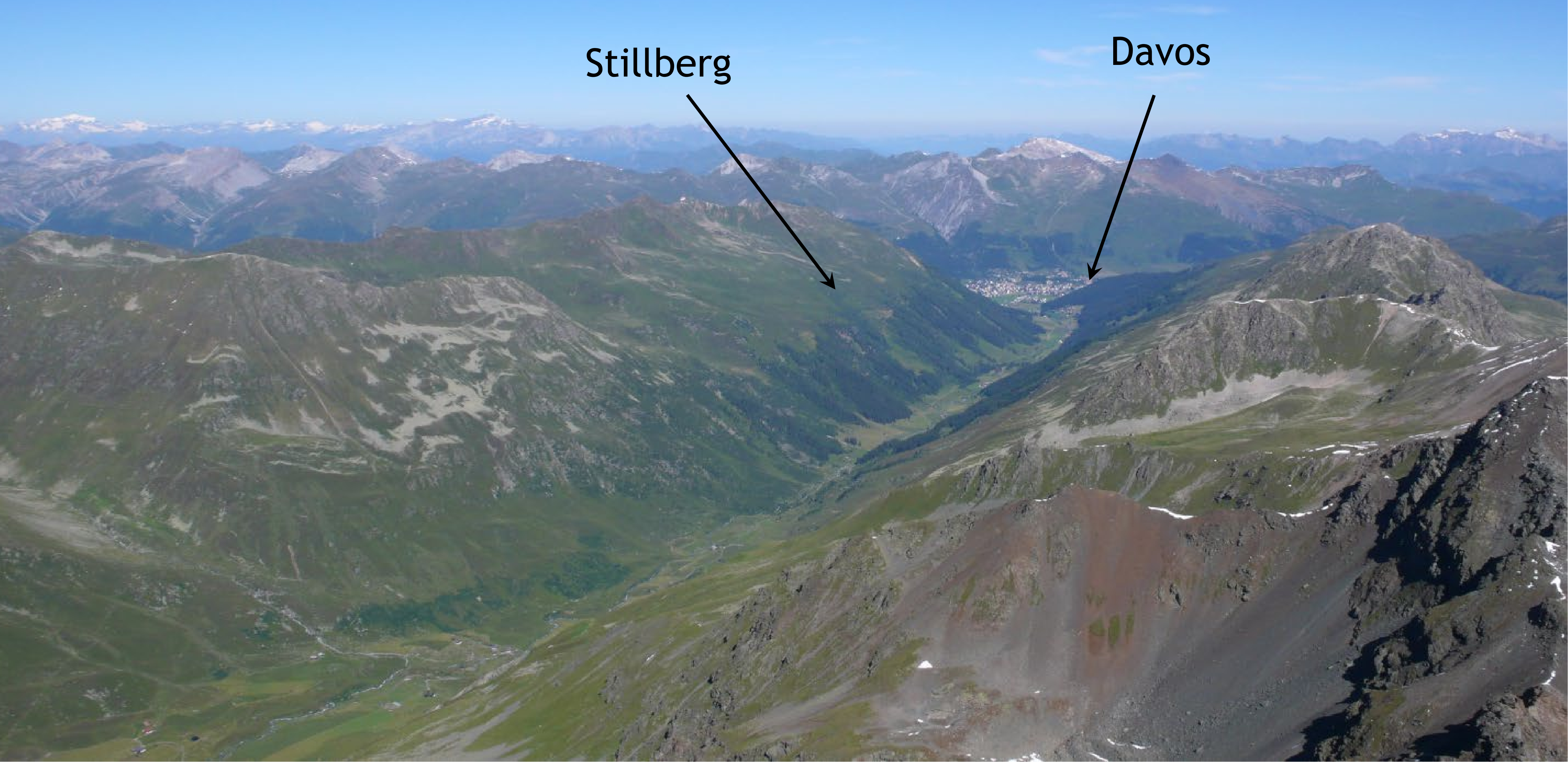
2°C warming => 300 m

>> Observed range shifts: 0-100 m in elevation

1. Seed dispersal + recruitment
2. Competition
3. Lacking fungal symbionts
4. Slower soil development, nutrient availability

What are the impacts of warming on carbon and nutrient cycling?

Alpine treelines in a warmer world



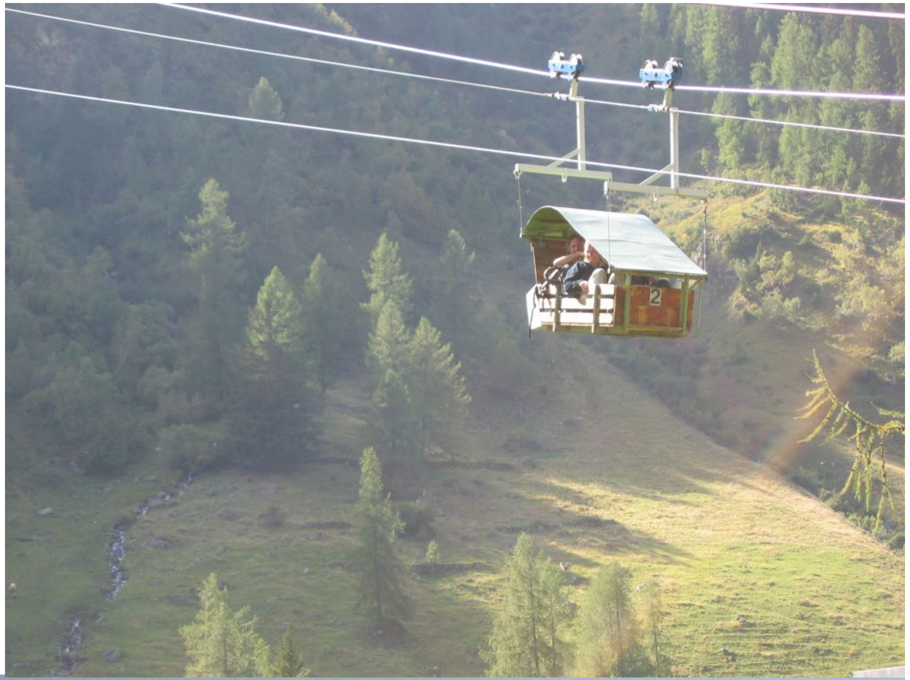
Alpine treelines in a CO_2-rich and warm world

Experimental afforestation (1975)

Pinus mugo

Larix decidua

‘Swiss’ Infrastructure



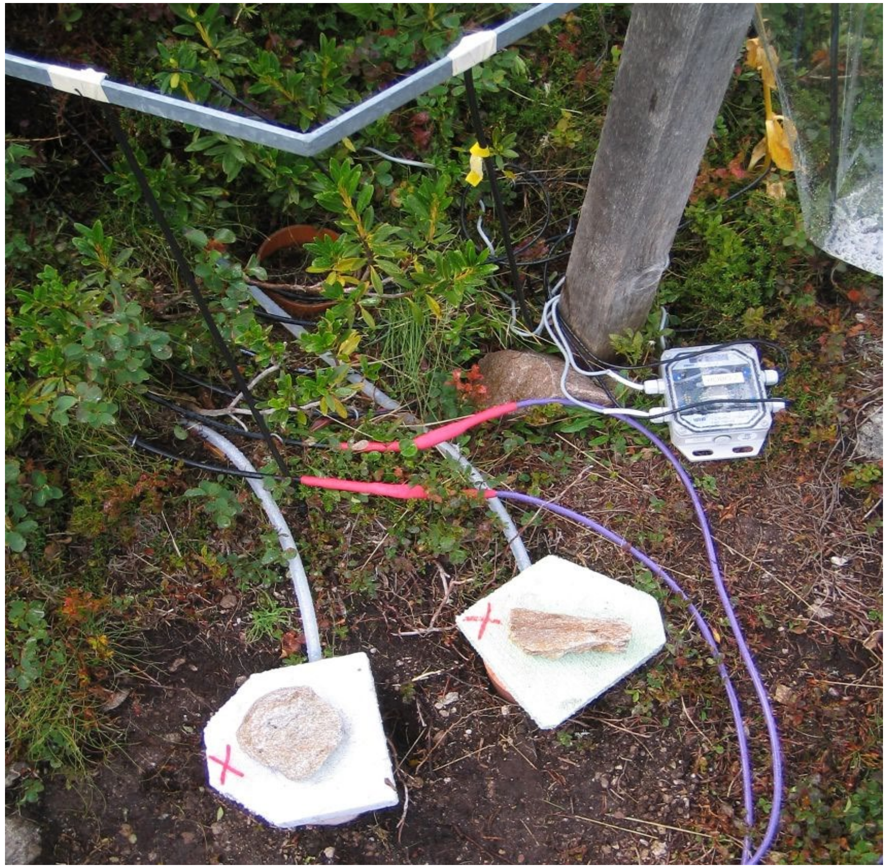
Alpine treelines in a CO_2-rich and warm world

+ 200 ppm CO_2
$\delta\,^{13}C$=-30‰
n=20
2001-2009

+ 4°C Soil warming
n=20
2007-2012

Total n = 40 plots

Soil warming using heating cables



26 m heating cables/m² on soil surface

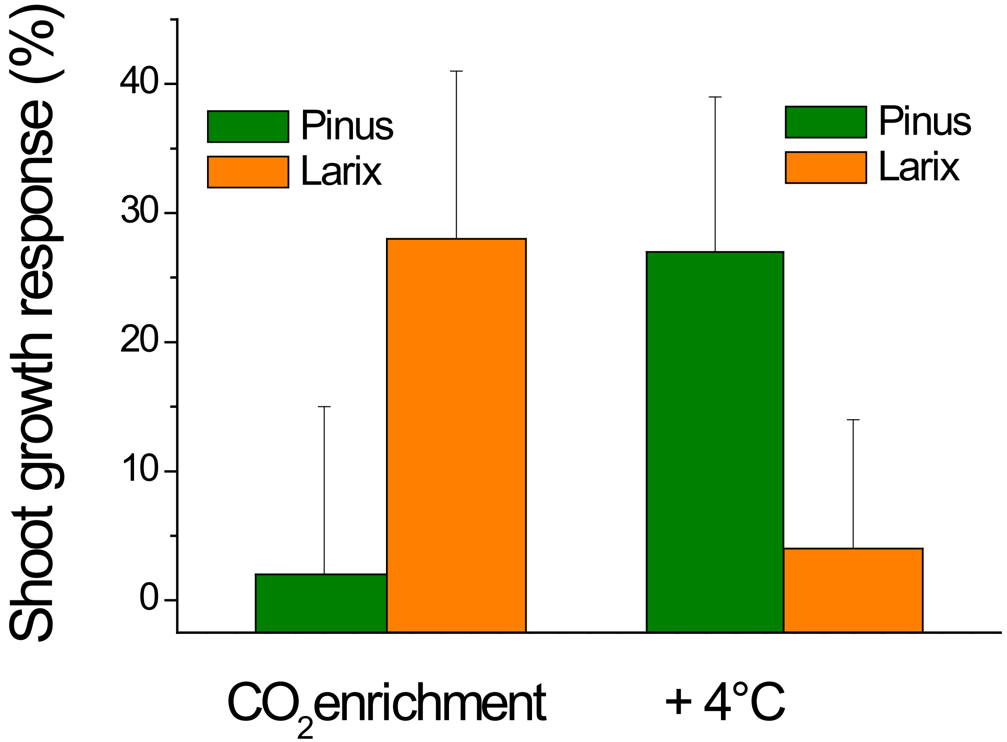
10 cm air : + 2.5°C

3 cm depth: + 4.7°C

5 cm depth: + 3.7°C

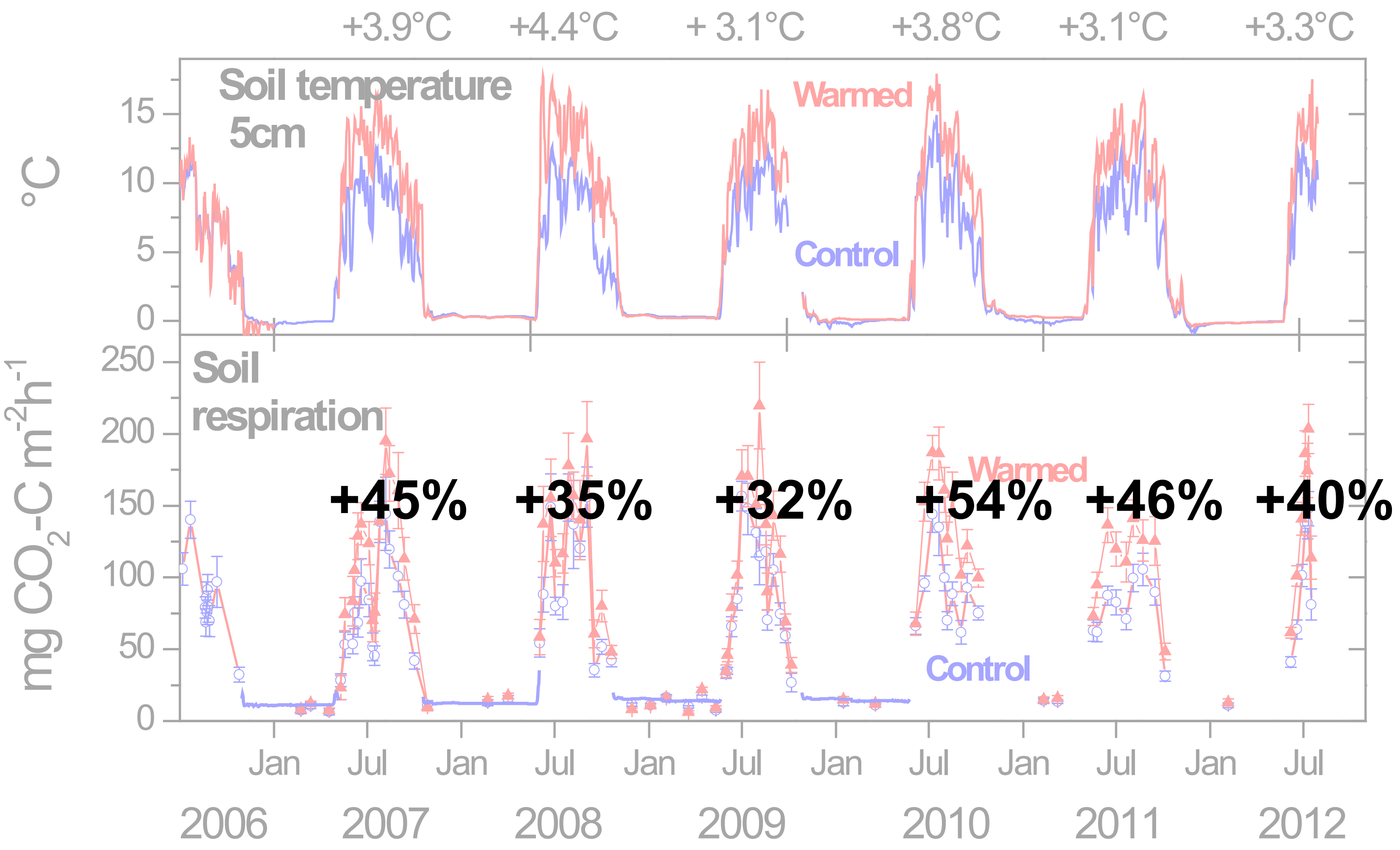
10 cm depth: + 3.2°C

CO_2 and warming effects on plant growth



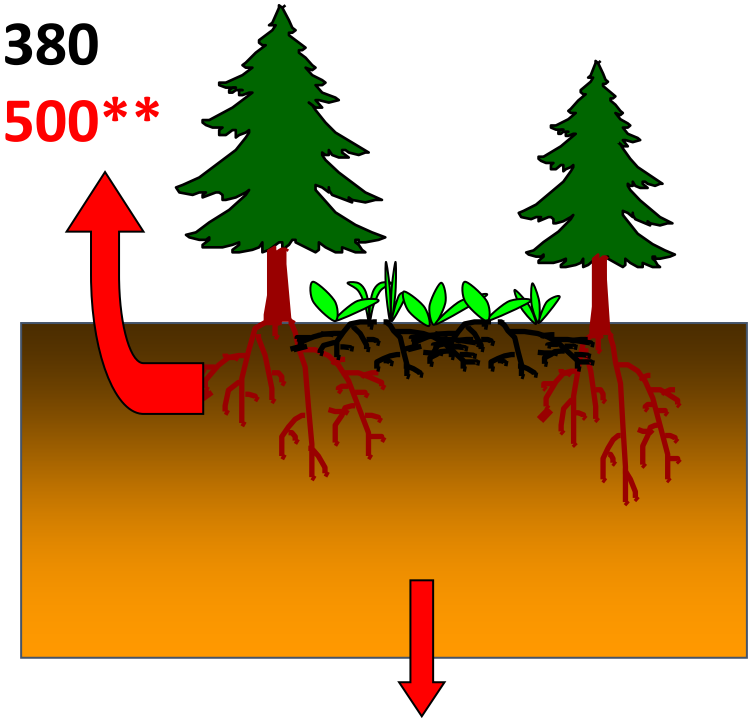
Shoot length, n=10 plots; Dawes et al. (2015) *Global Change Biology*

Warming enhances soil C fluxes



Hagedorn et al. (2010): Biogeochemistry; Streit et al. (2014): Global Change Biology

Does warming turns ecosystem into a CO_2 source?

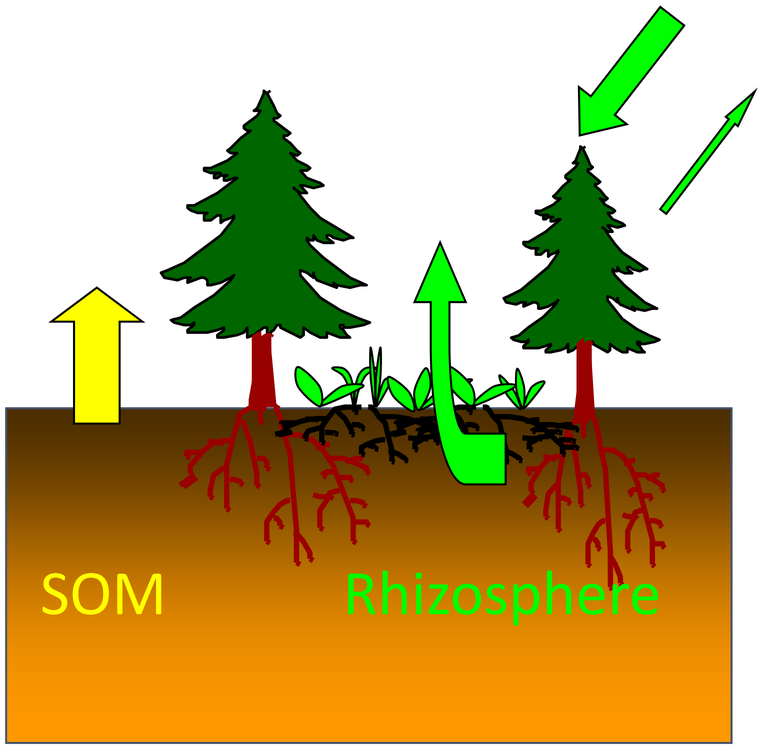


Hagedorn *et al*. (2010): *Biogeochemistry*; Dawes *et al*. (2015): *Global Change Biology*

What is the origin of the increased soil CO_2 efflux?

heterotrophic

autotrophic



if from new C

= faster C cycling

if from ‚old‘ C

= SOM losses

$^{13}CO_2$ tracer study in the field

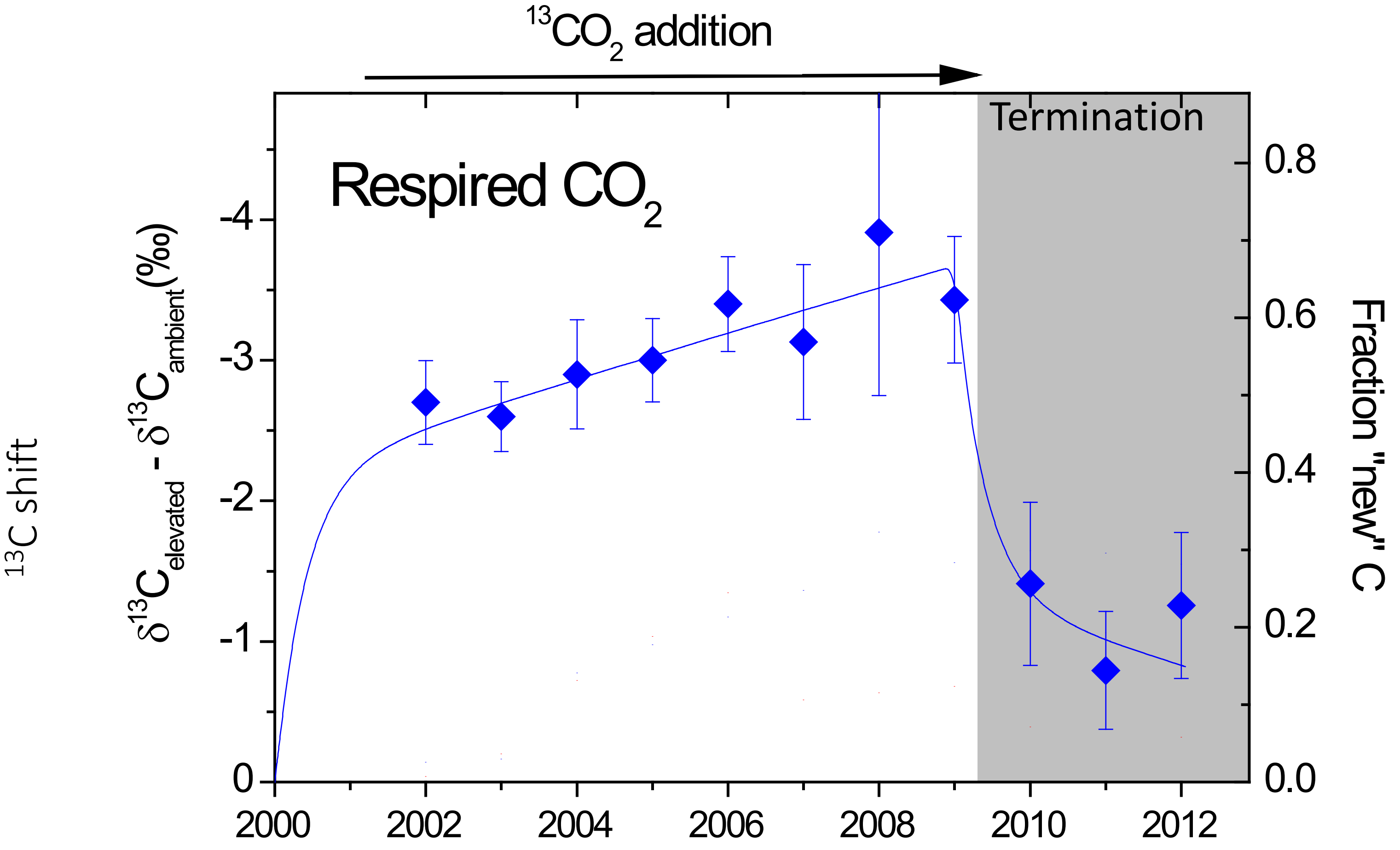
Addition and tracing of ^{13}C depleted CO_2

2001-2009

Collaboration:
A. Ekblad, R. Siegwolf, M. Saurer

Master students: S. Rusch, K. Wetter, N. Portmann

Partitioning of soil C fluxes

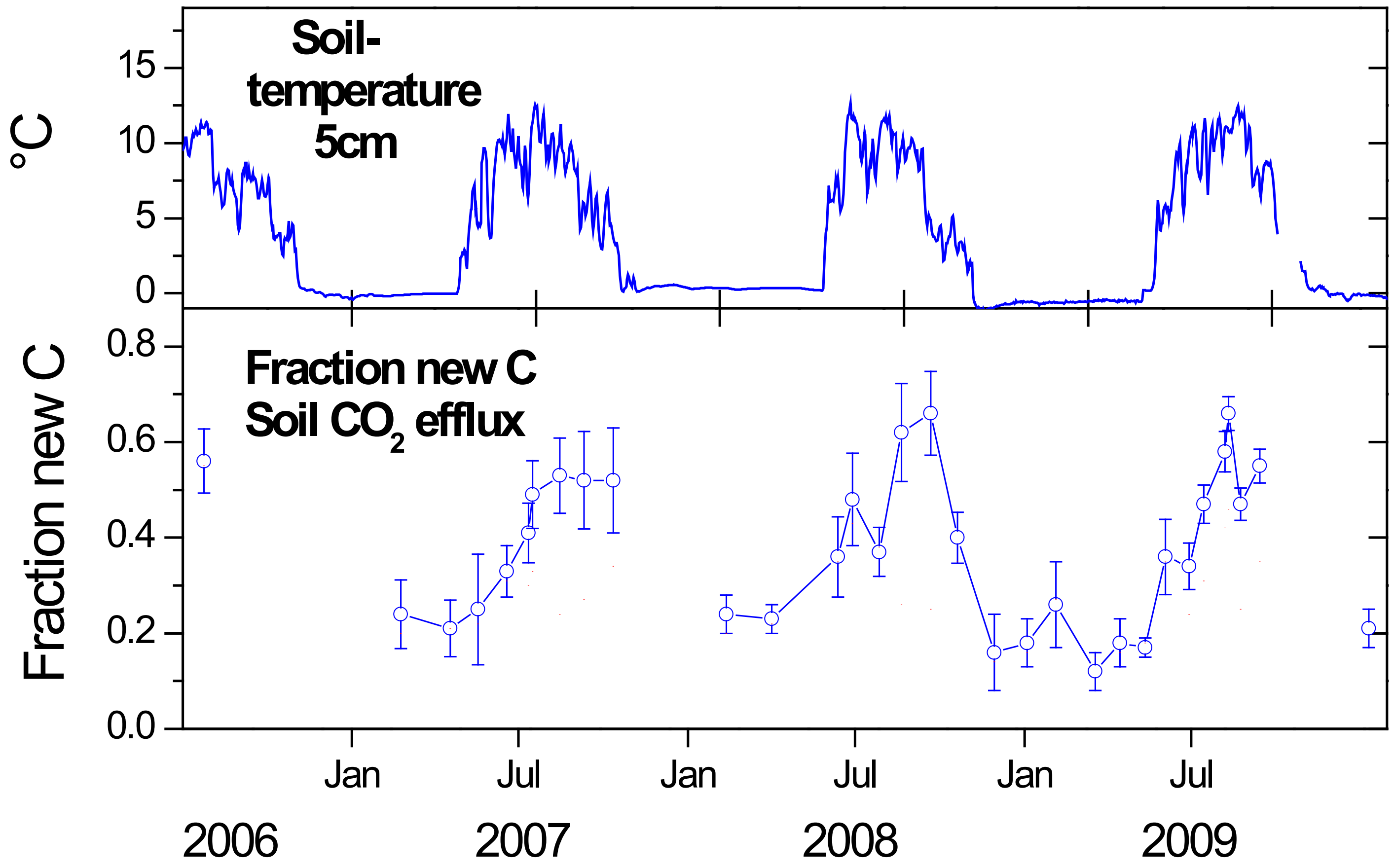


→ 'Two'-pool contribution of new C

→ Rhizosphere makes major contribution

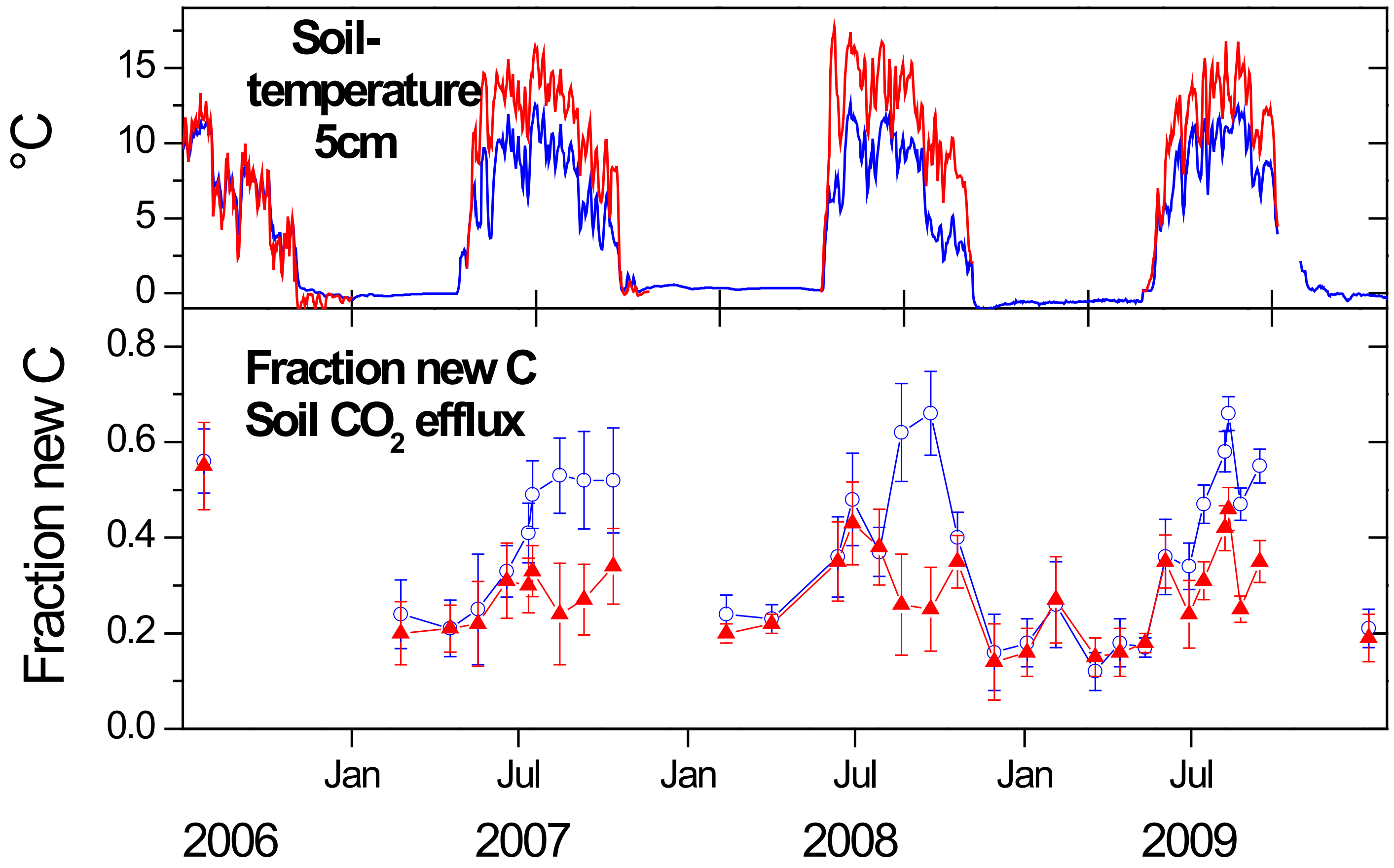
$$f_{new} = \frac{\Delta^{13}C\text{ - soil respiration}}{\Delta^{13}C\text{ - plants}}$$

Seasonal patterns of soil respired new CO_2



n=10 plots per treatment

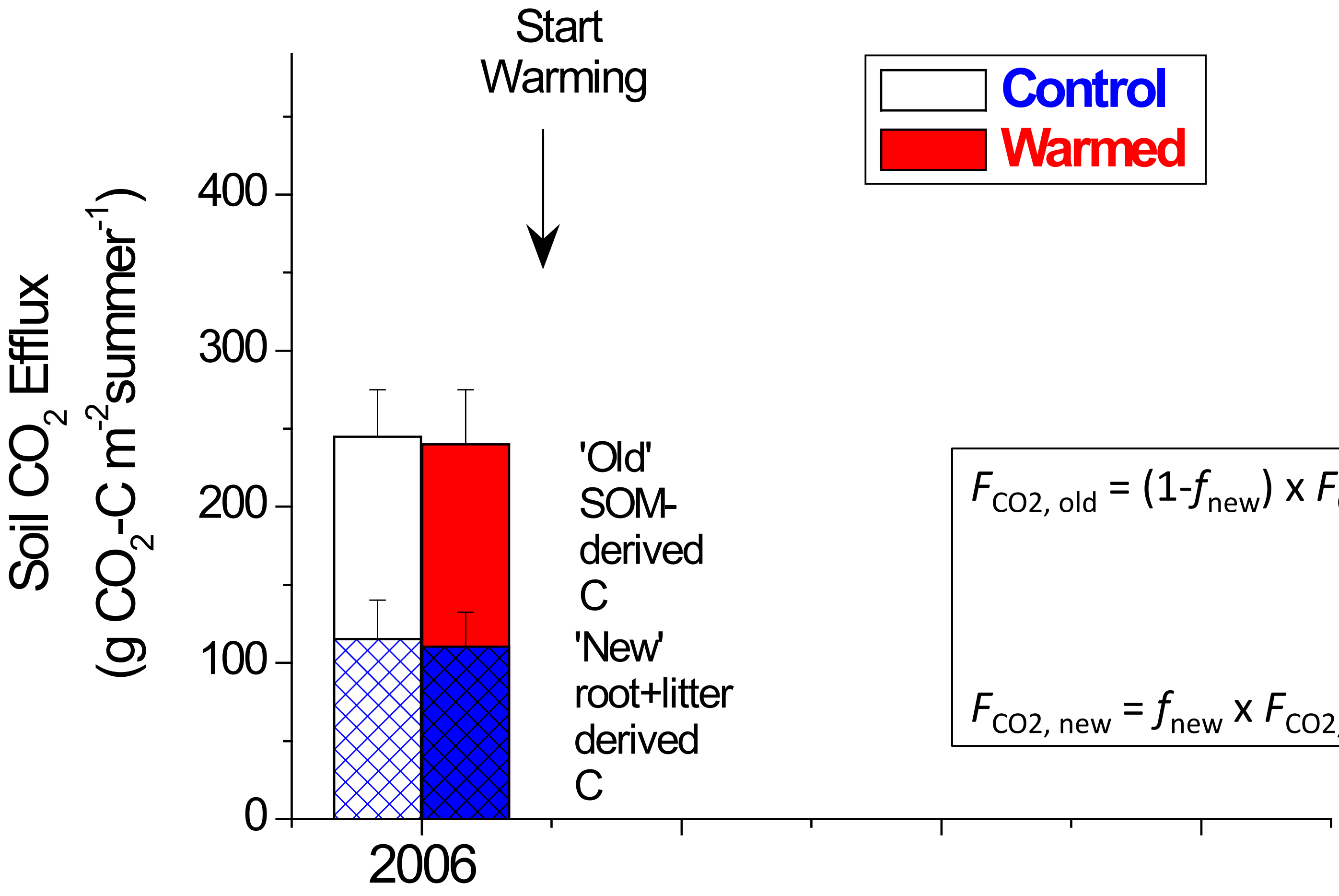
Seasonal patterns of soil respired new CO_2



n=10

Hagedorn *et al*. (2010) *Biogeochemistry*; Streit *et al*.(2014): *Global Change Biology*

Budget: New and old C soil respired CO_2



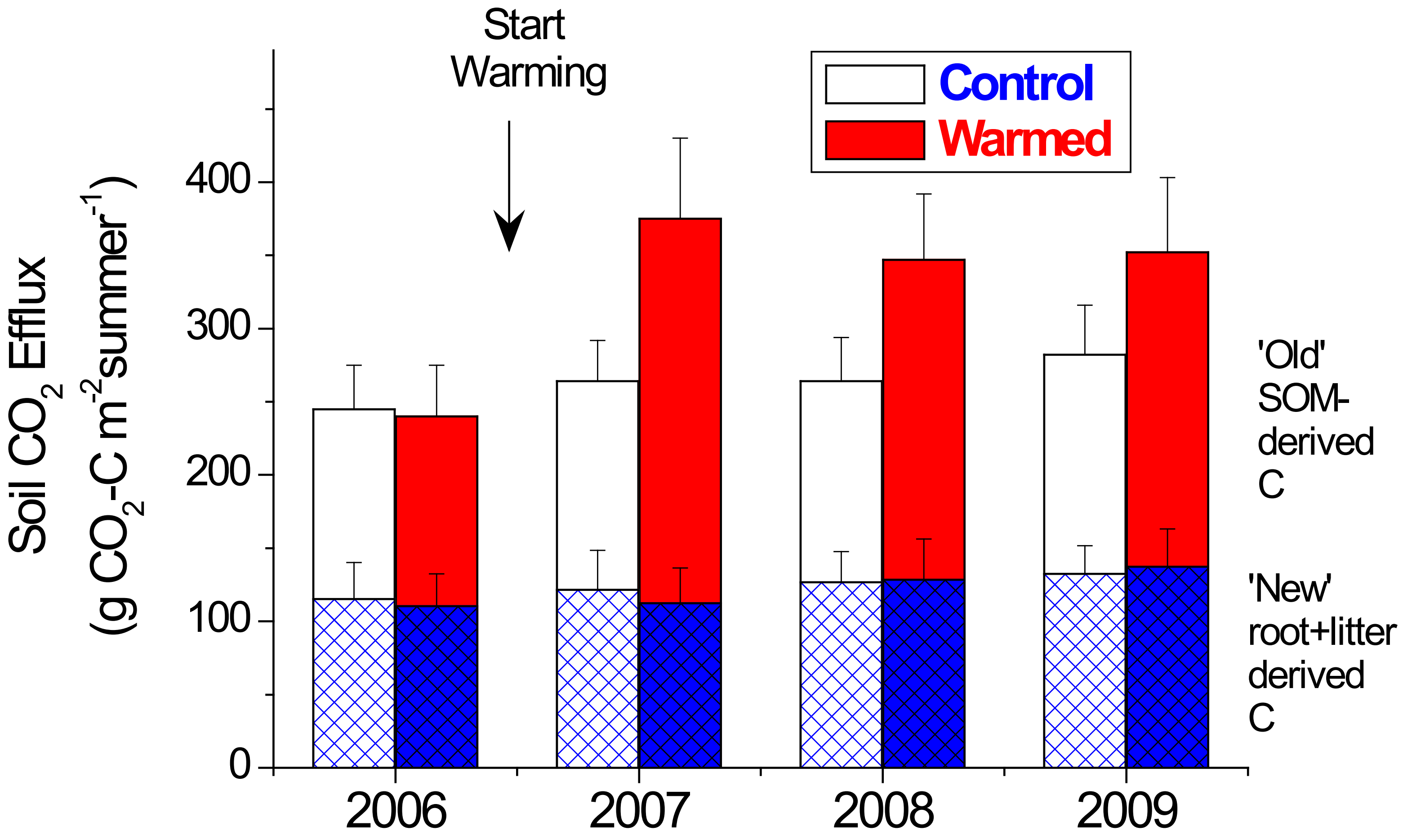
$F_{CO2,\ old} = (1\text{-}f_{new}) \times F_{CO2,\ total}$

$F_{CO2,\ new} = f_{new} \times F_{CO2,\ total}$

n=10

Hagedorn *et al*. (2010) *Biogeochemistry*; Streit *et al*.(2014): *Global Change Biology*

Budget: New and old C soil respired CO_2



n=10

Hagedorn *et al*. (2010) *Biogeochemistry*; Streit *et al*.(2014): *Global Change Biology*

Soil warming effects on soil C fluxes

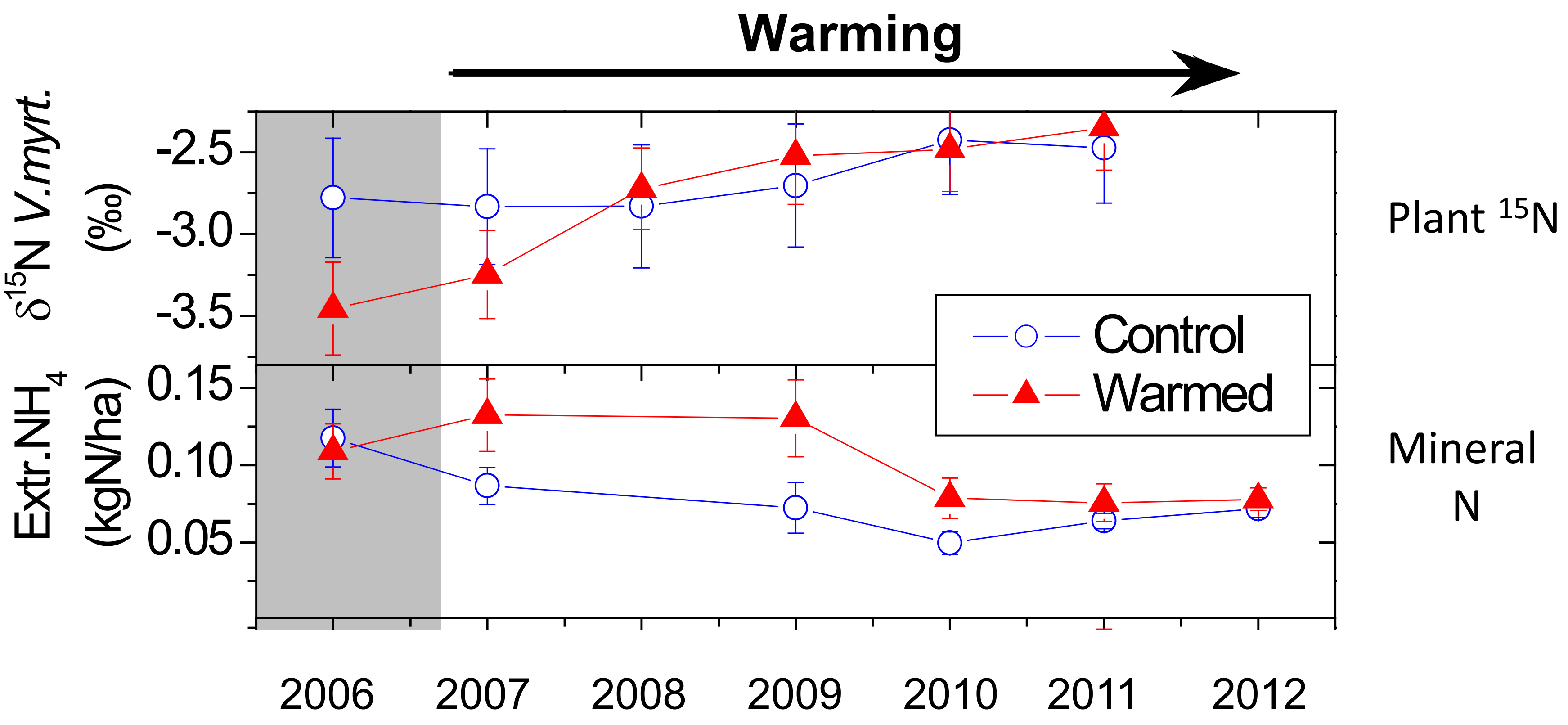
→ Warming increased loss of 'old' SOM

→ No concomittant increase in new plant-derived C inputs

→ What are the effects on N availability?

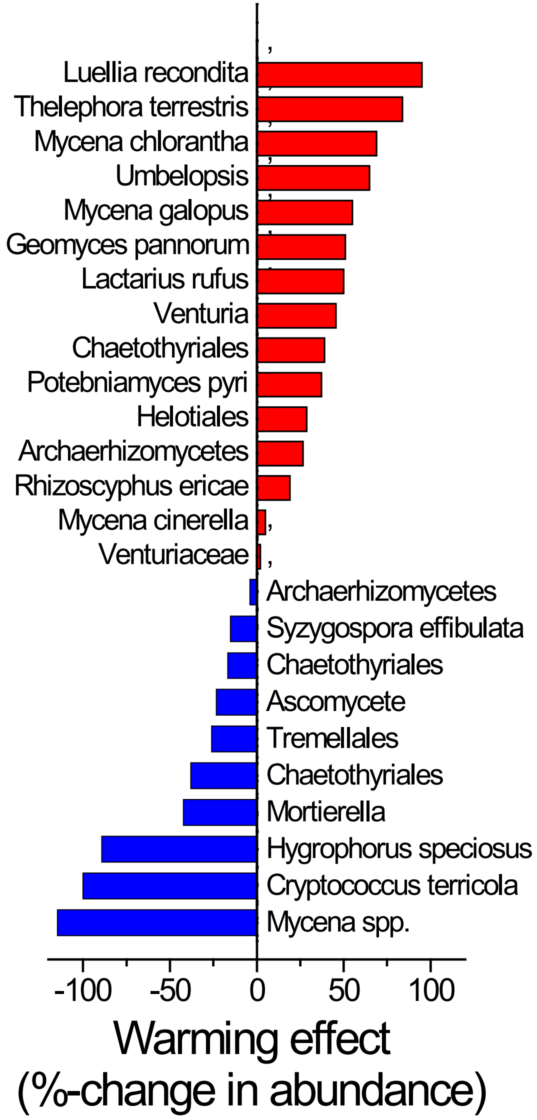
→ What consequences does this have on ecosystems?

Soil warming improves N availability



Dawes *et al*. (2016): *Global Change Biology*

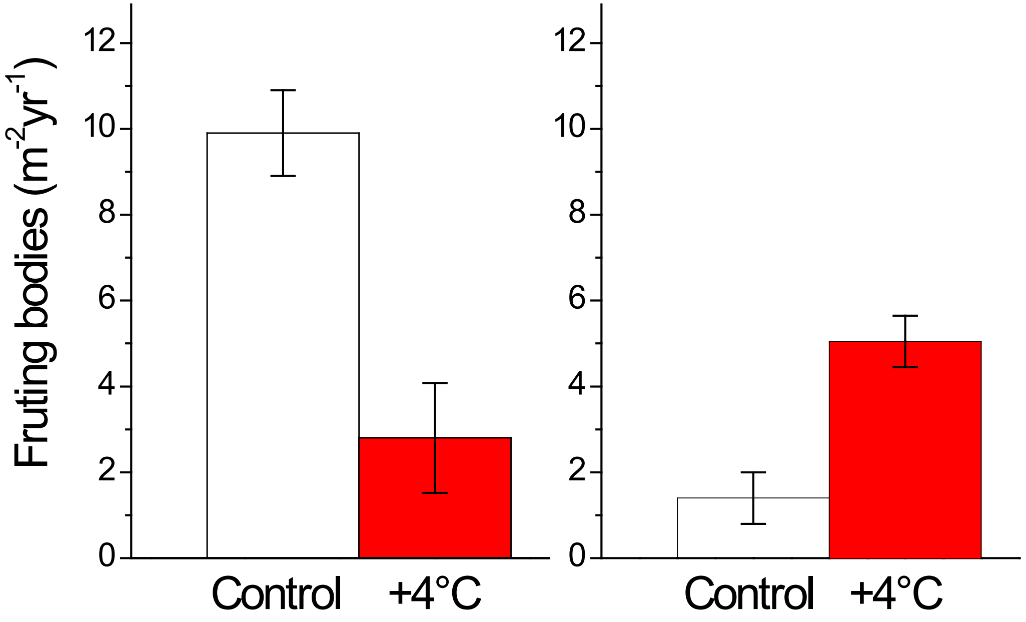
Soil warming impacts fungal communities



Hygrophorus speciosus

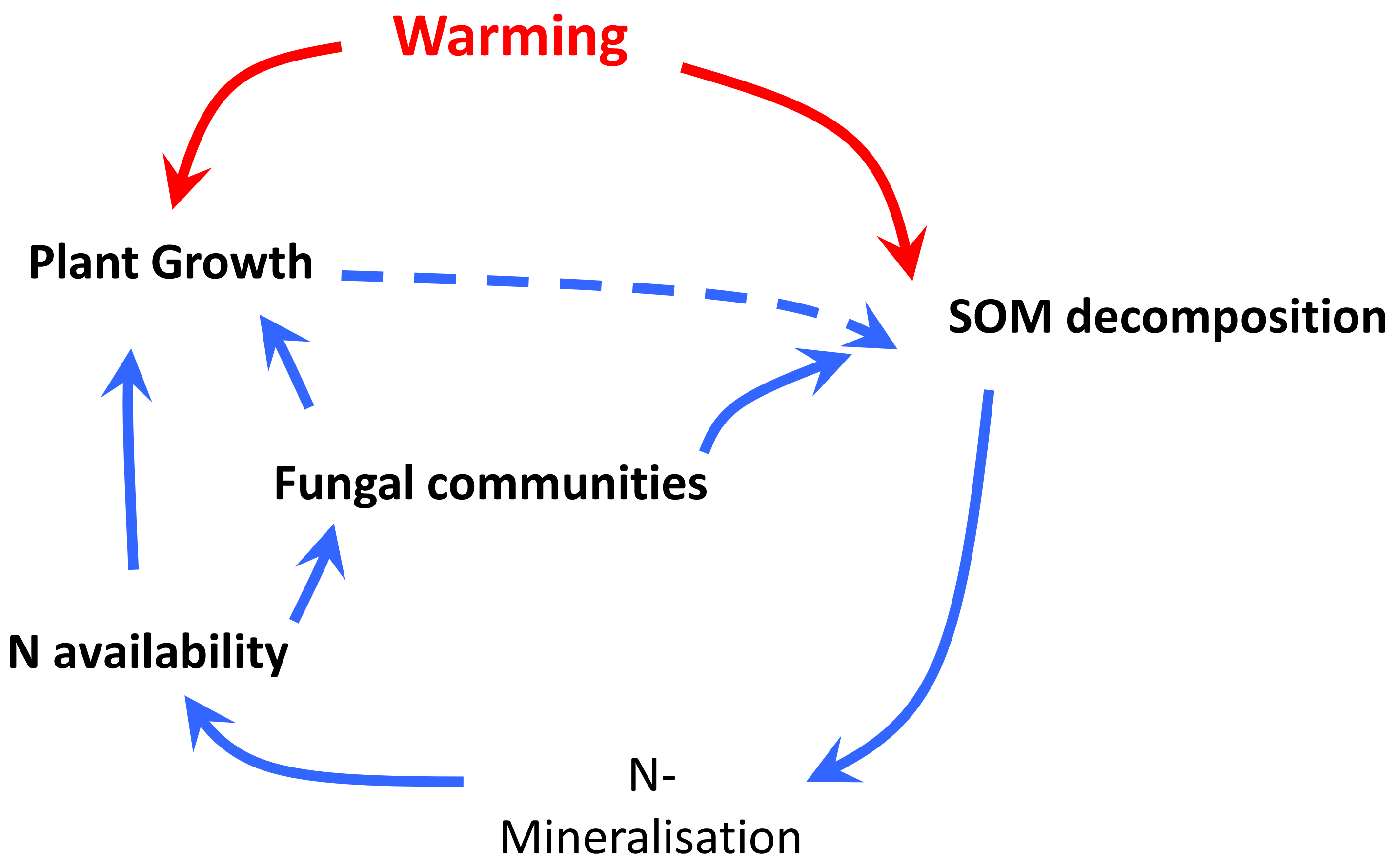
Lactarius rufus

→ Warming promotes nitrophilous species



Solly *et al.* (2017):
New Phytologist

Soil warming impacts on ecosystem functioning



Summary

Switzerland Tourism.

Visit Switzerland as long as there are glaciers

1. Mountains are shaped by climate

2. Cryosphere is highly sensitive to warming, impacting hydrosphere

3. Biosphere responses lag behind climate warming

4. Accelerated carbon and nutrient cycling feedbacks on the biosphere