# Global change: plant ecology and phenology

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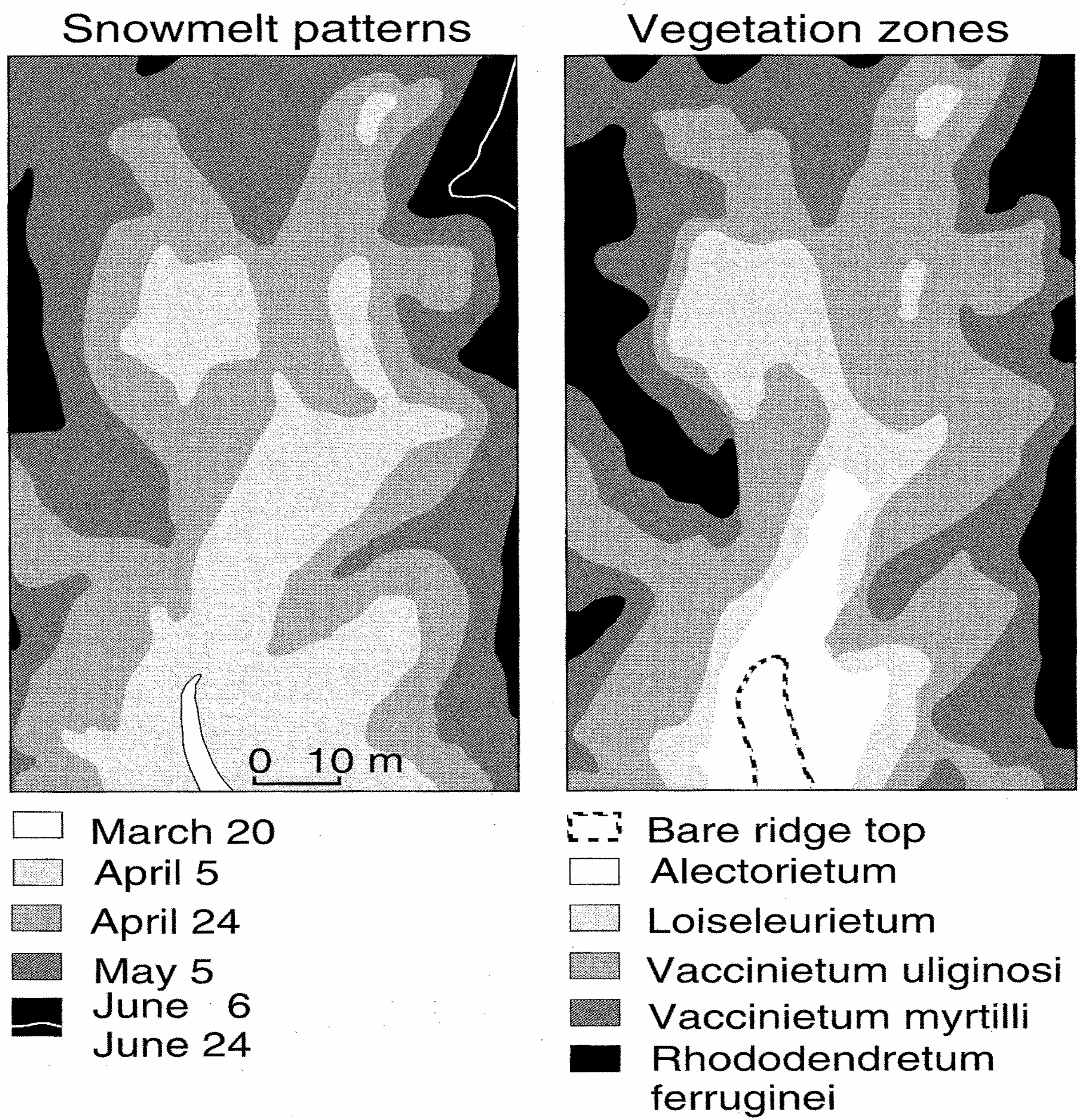


Snowmelt patterns
Vegetation zones
0 10 m
March 20
April 5
April 24
May 5
June 6
June 24
Bare ridge top
Alectorietum
Loiseleurietum
Vaccinietum uliginosi
Vaccinietum myrtilli
Rhododendretum ferruginei





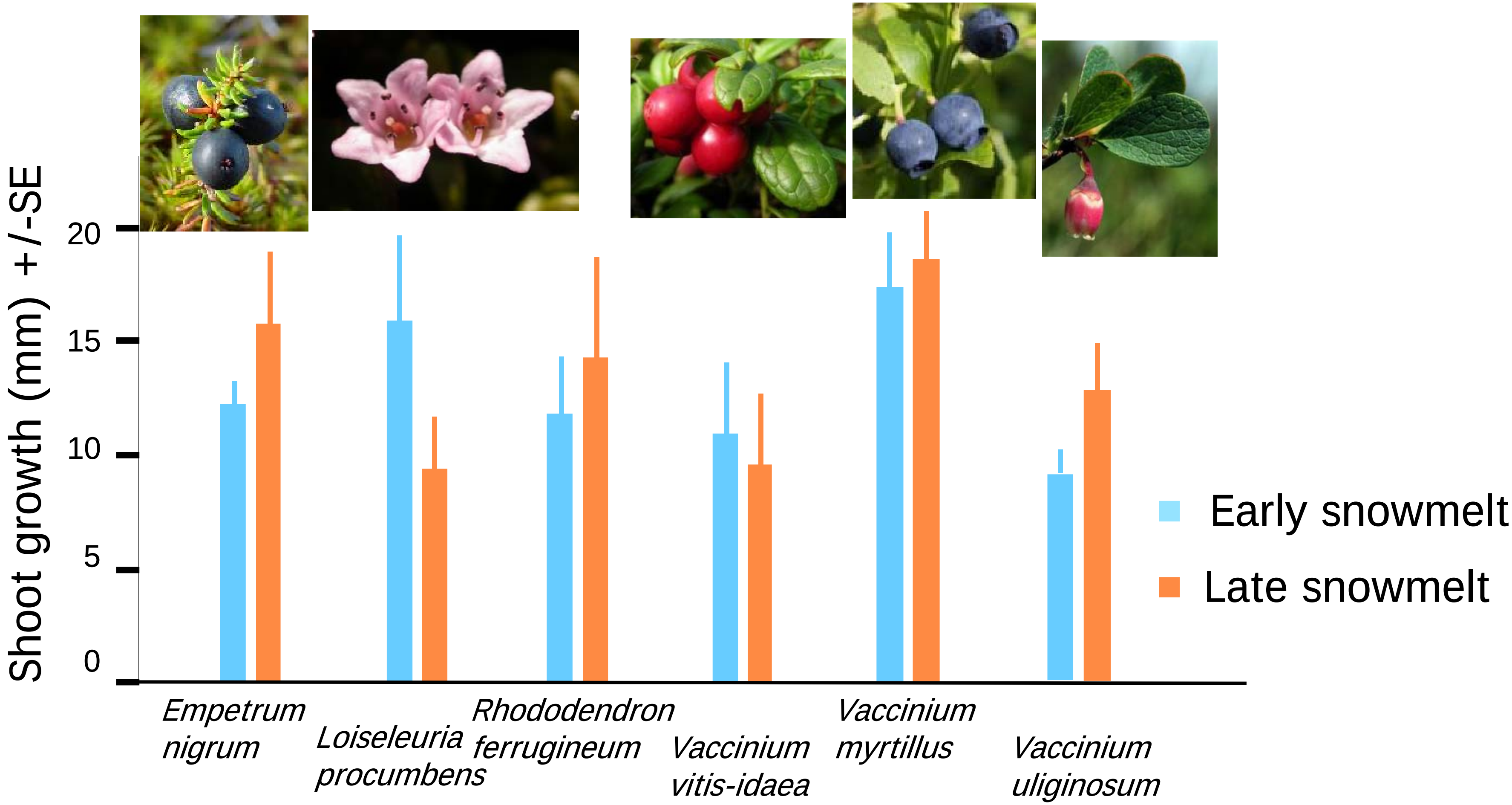


# Snow cover change

Changing snow cover in a changing climate: consequences for alpine vegetation

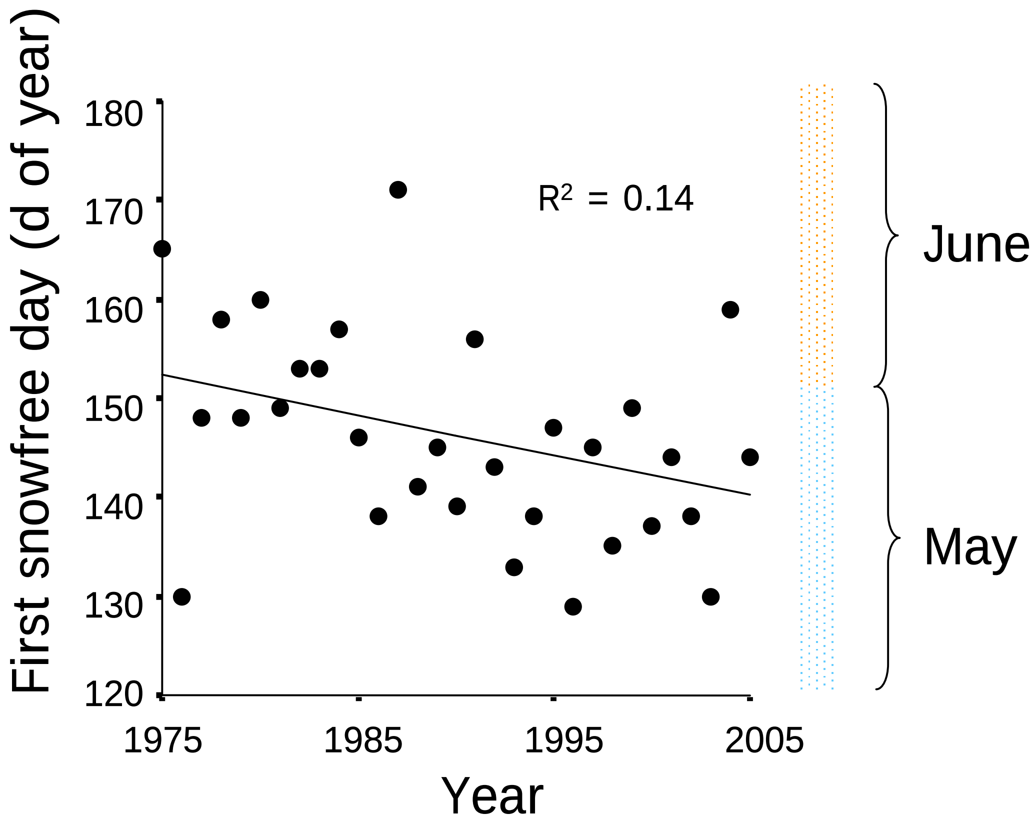
(Wipf 2007; Wipf, Rixen & Mulder 2005 GCB)

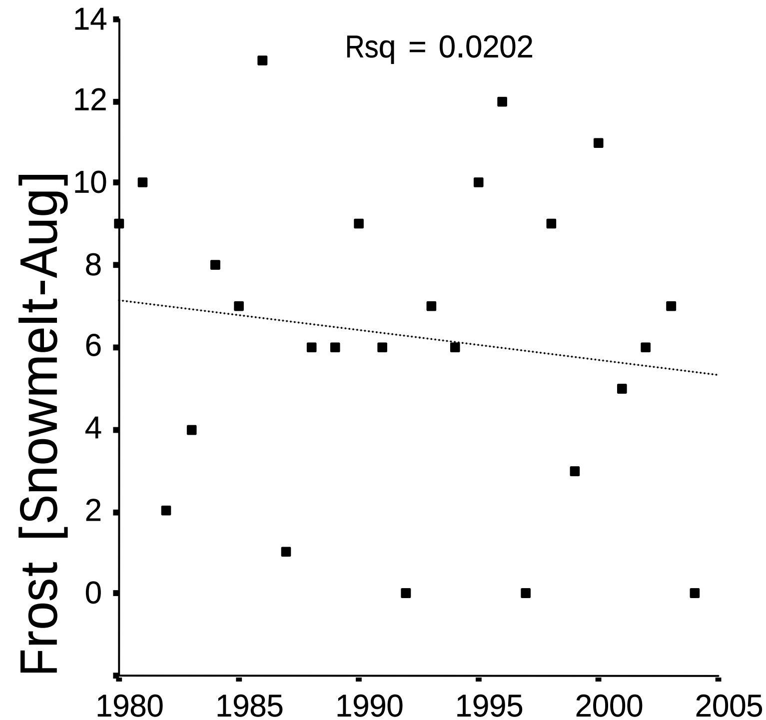
# Snow cover changes




Most plants grew less after earlier snowmelt; only species with a positive growth response: *Loiseleuria procumbens*

# Snow cover changes



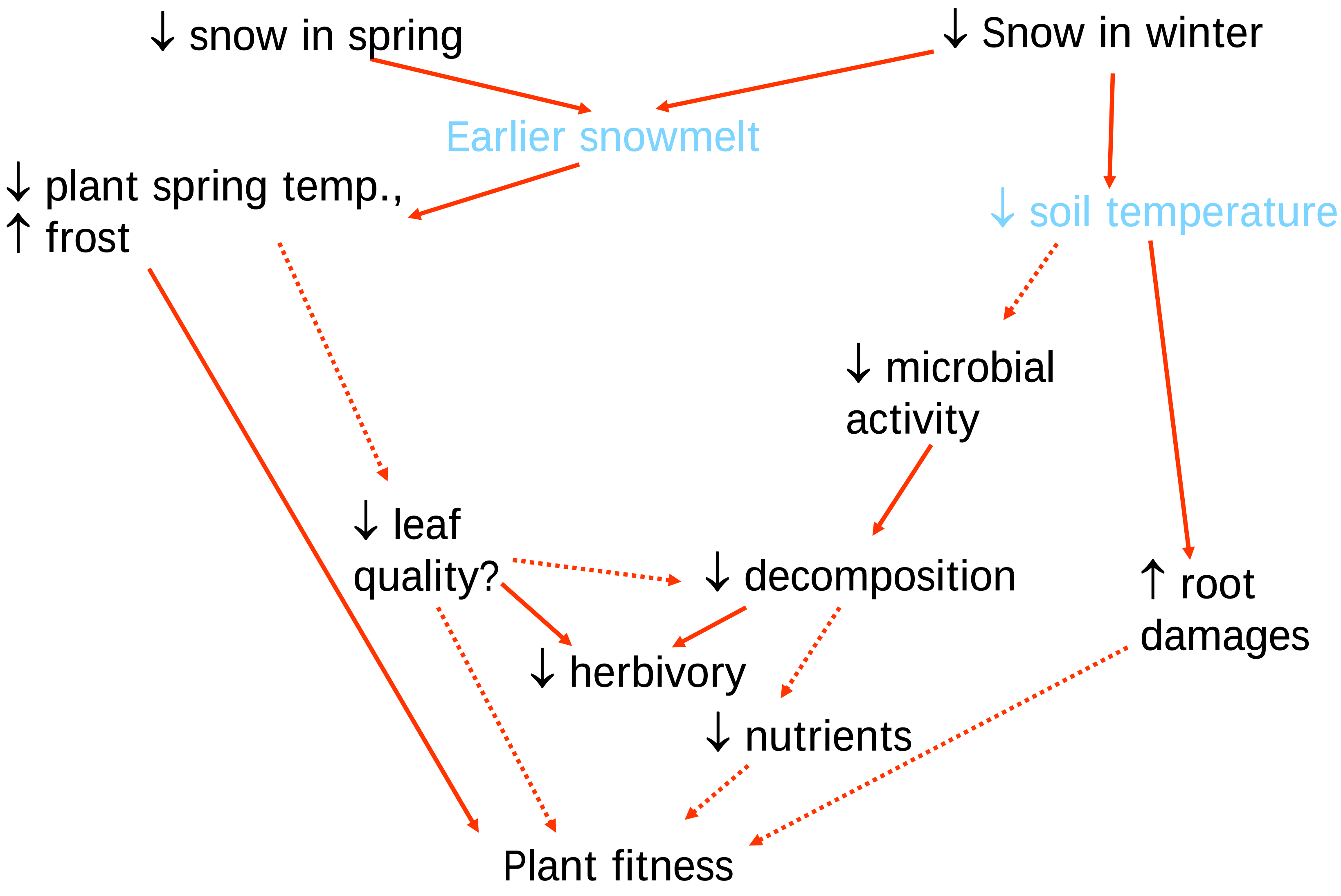




Date when snow has melted advanced by 5 days / decade ($p<0.05$), from early June towards mid May

# Snow cover changes


(Wipf, Rixen & Mulder 2005 GCB)

# Snow cover changes



# Take-home messages

Climate change at high elevation will be most effective via changes in snow cover.

A longer vegetation period due to less snow cover does not necessarily result in more benign growing conditions.

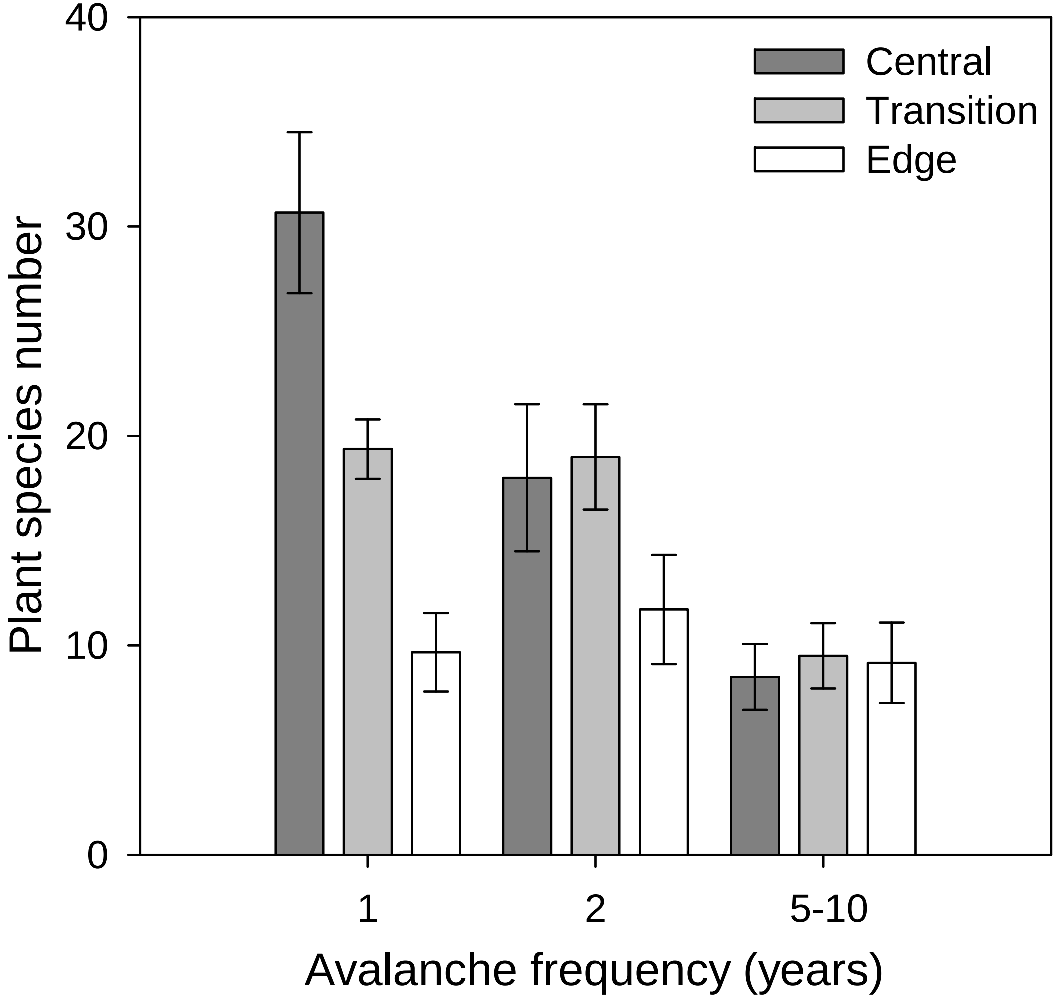
Climate change will probably not simply result in an uphill migration of all vegetation zones.

Future plant communities may look different from those today.

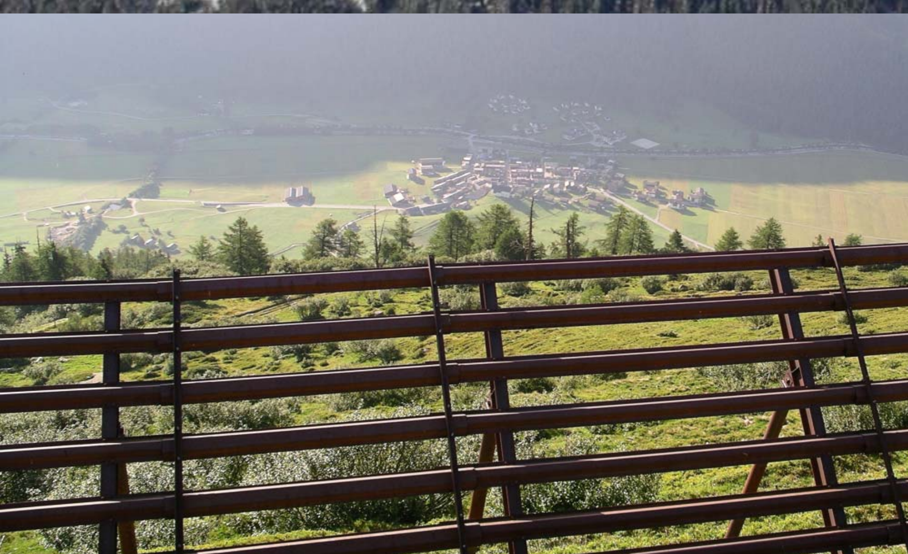
# Avalanche disturbance

Natural disturbance shapes landscape, habitat and plant diversity in the subalpine forest belt

# Avalanche disturbance

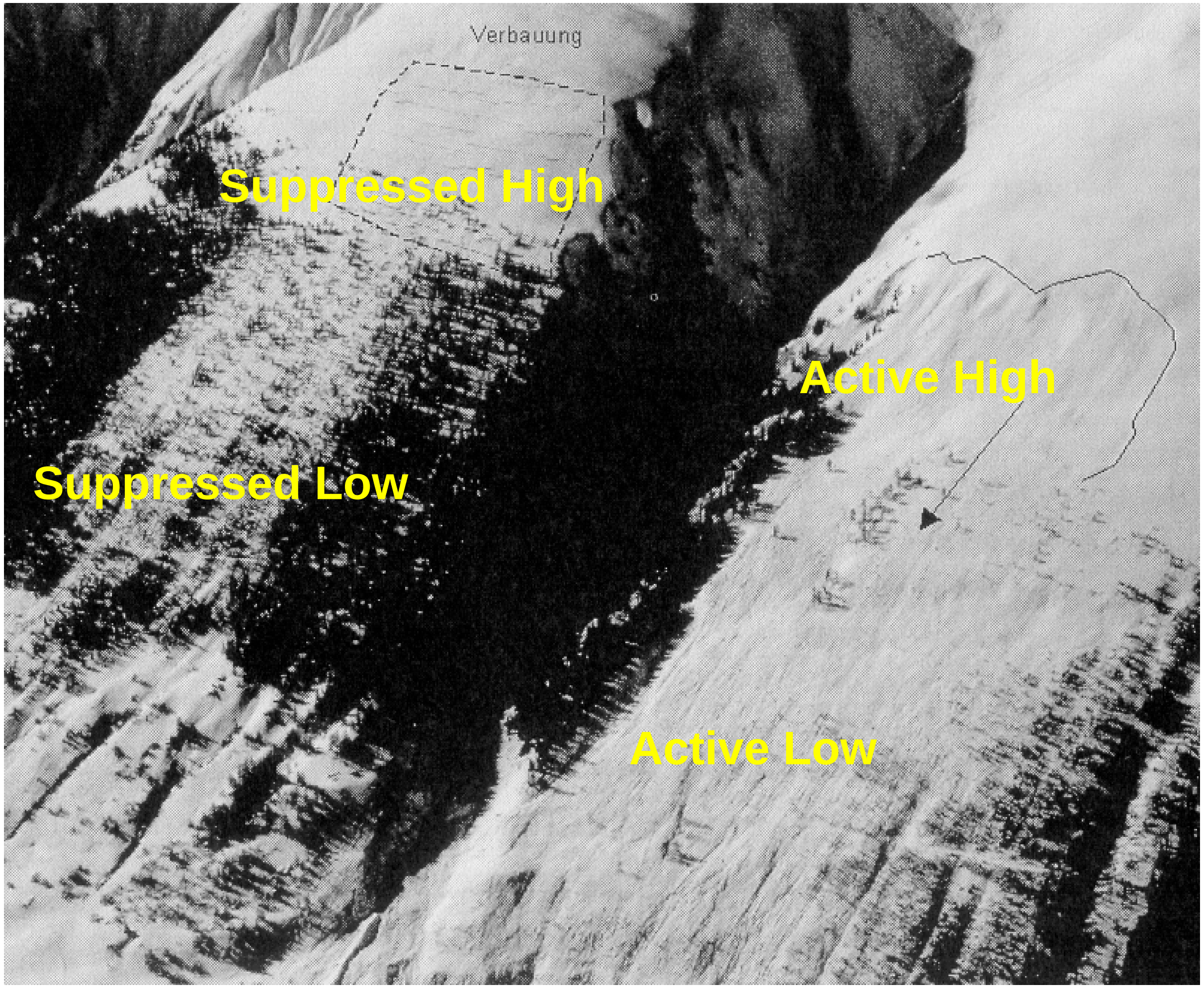


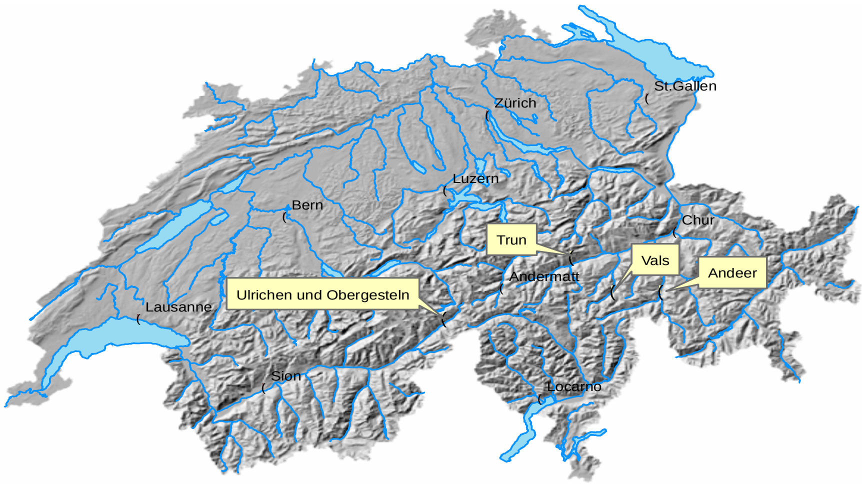

(Bebi, Kulakowski & Rixen,
For. Ecol. Manag. in press)

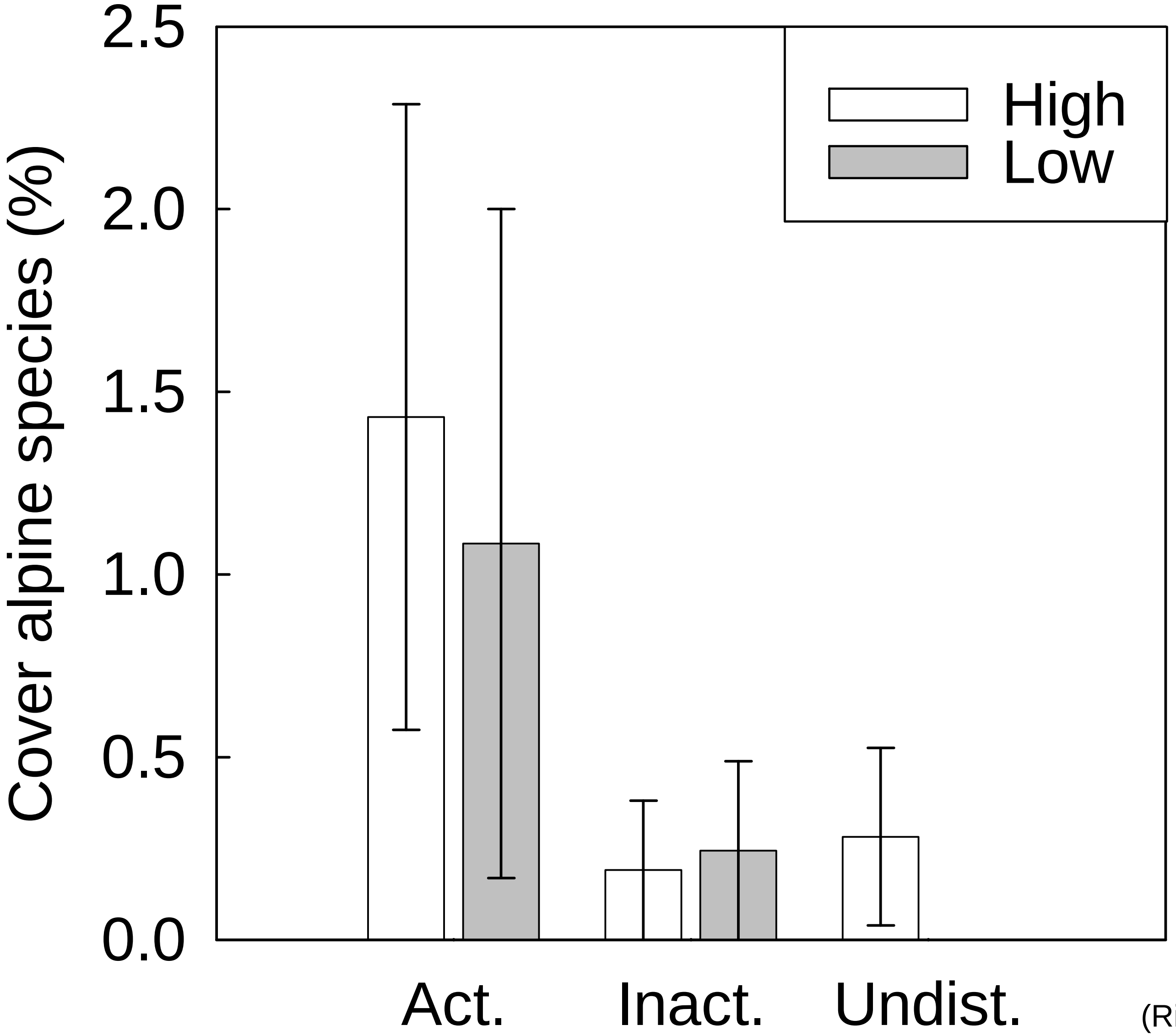

# Habitat structure

Tracks with and without suppression of disturbance



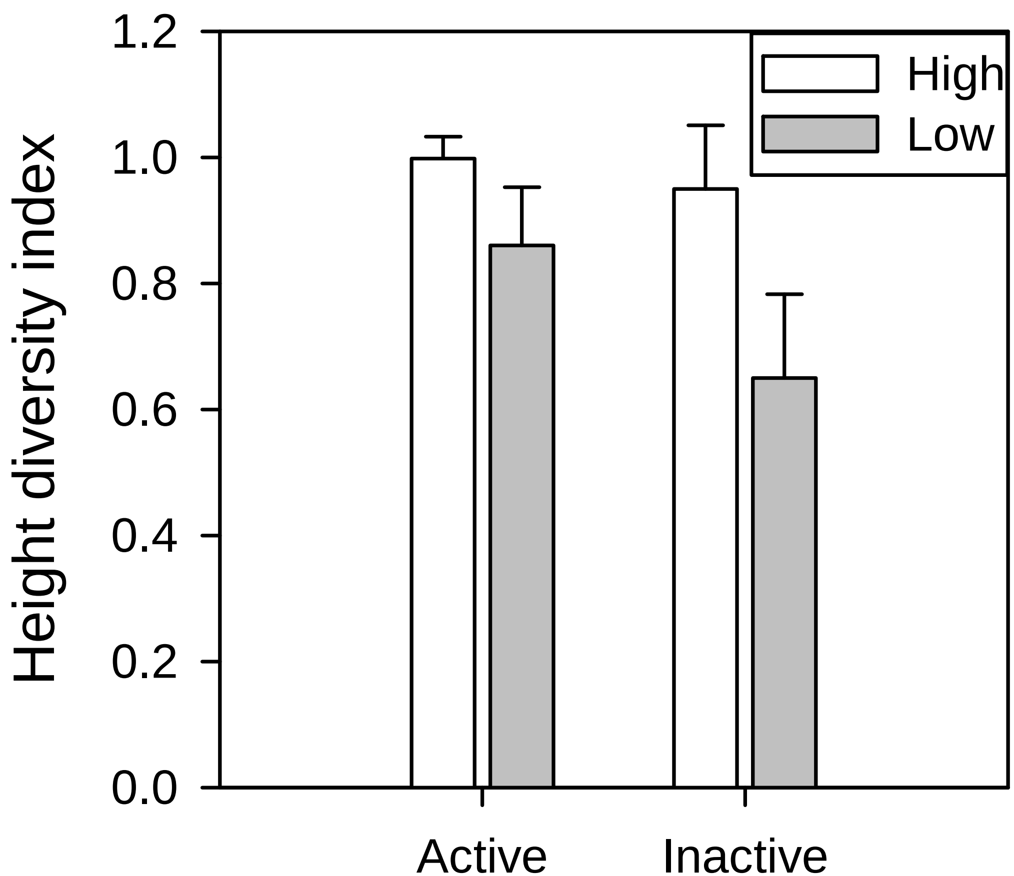



# Species compostion




(Rixen, Kulakowski& Bebi 2007)

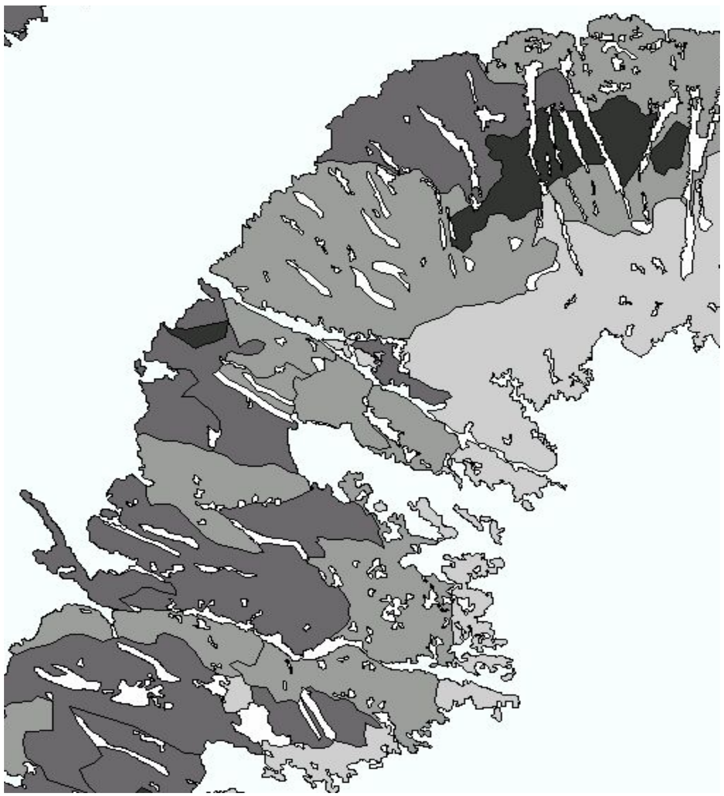
# Height Diversity Index



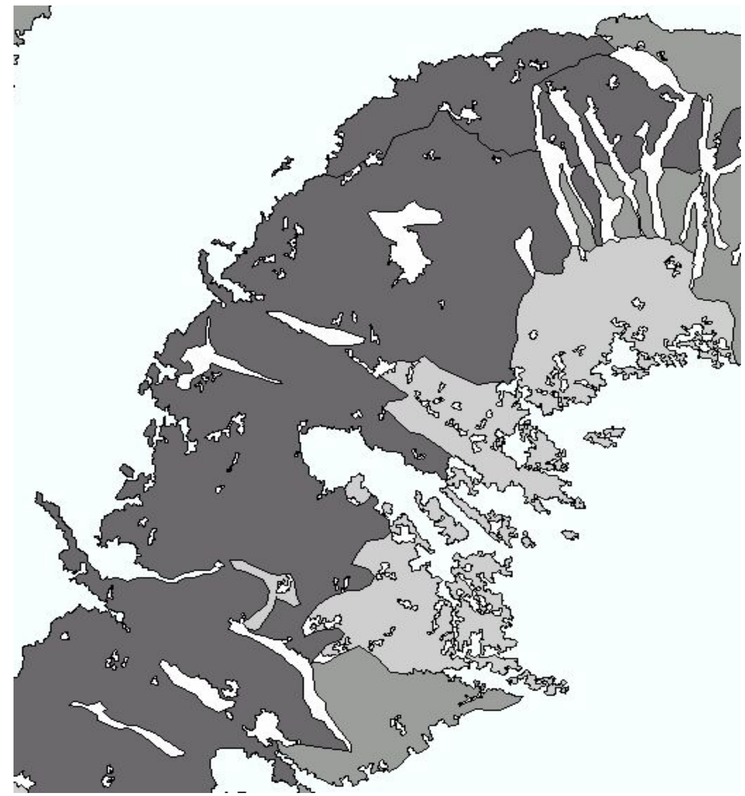

(Kulakowski, Rixen & Bebi 2005)

# Forest development Davos

1950



2000



Decrease in Shannon Diversity (derived from forest patches)

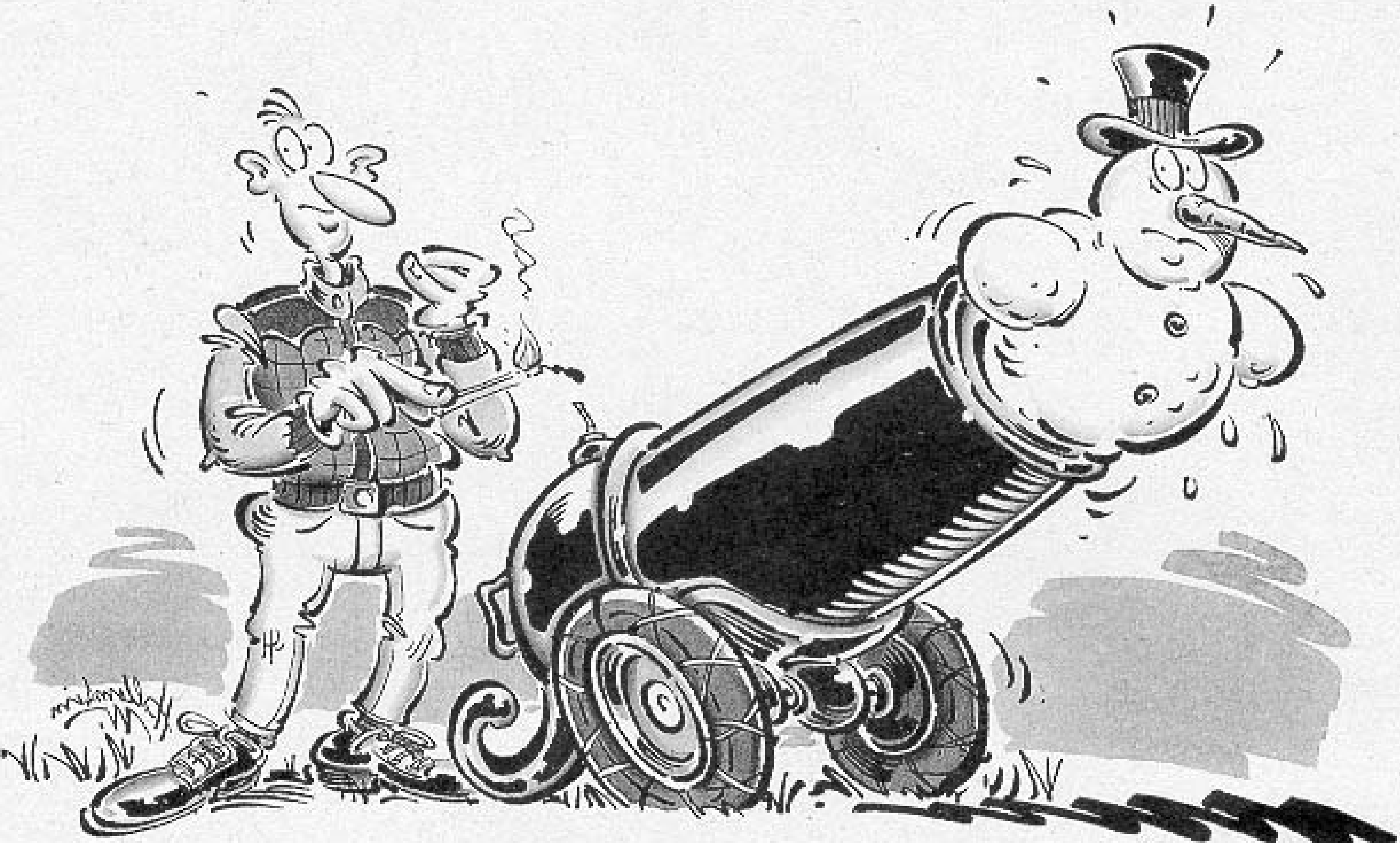
# Take-home messages

Avalanches need to be controlled where humans or human settlements are threatened. But…

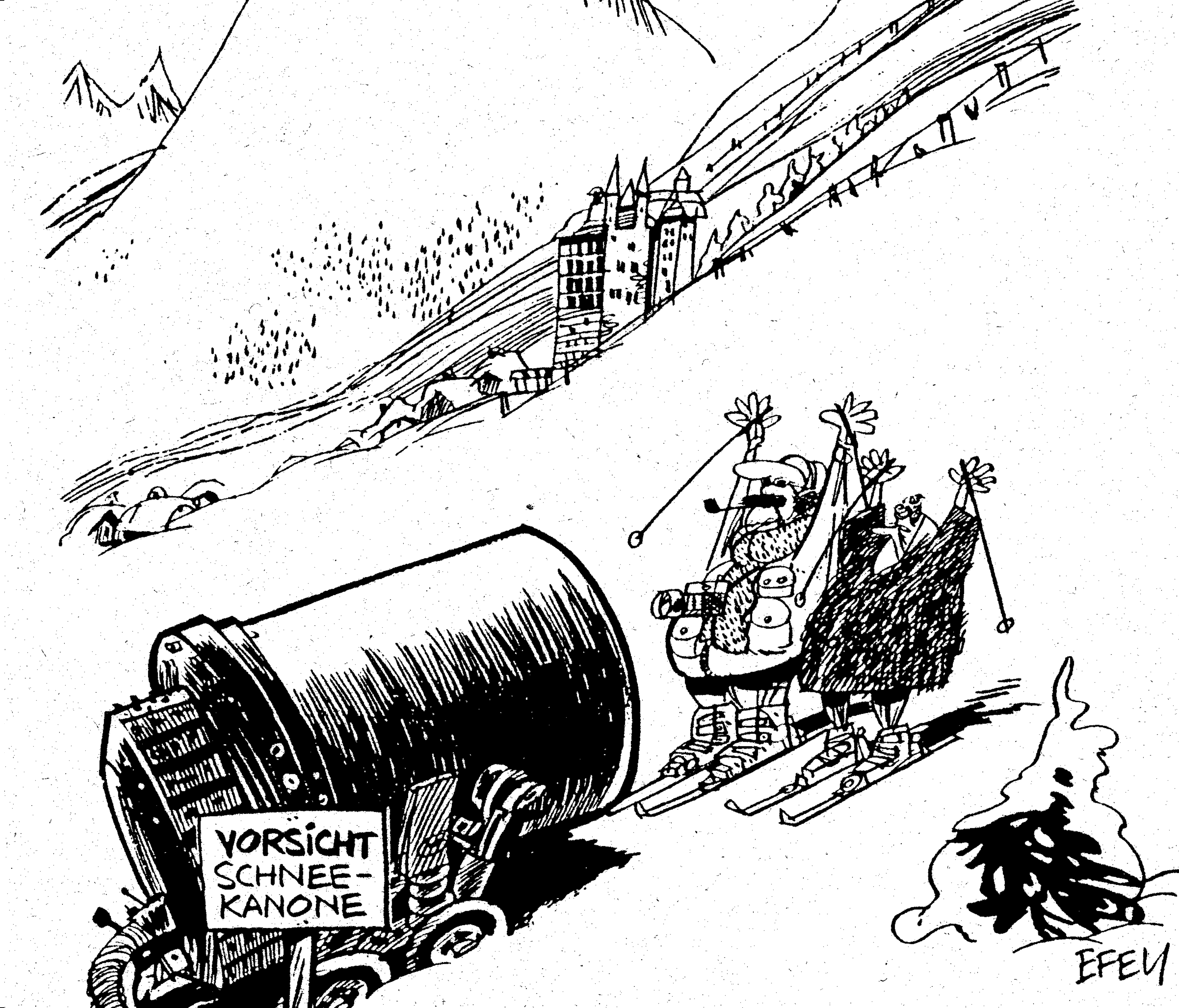
Ecologically, natural disturbance by avalanches is an important factor in subalpine forest creating and maintaining divers habitat and species richness.

This message also holds for other disturbances like windthrow, floodings but not necessarily for clear-cuttings or ski runs.

Extreme snowfall events are likely to increase due to CC.




SWITZERLAND

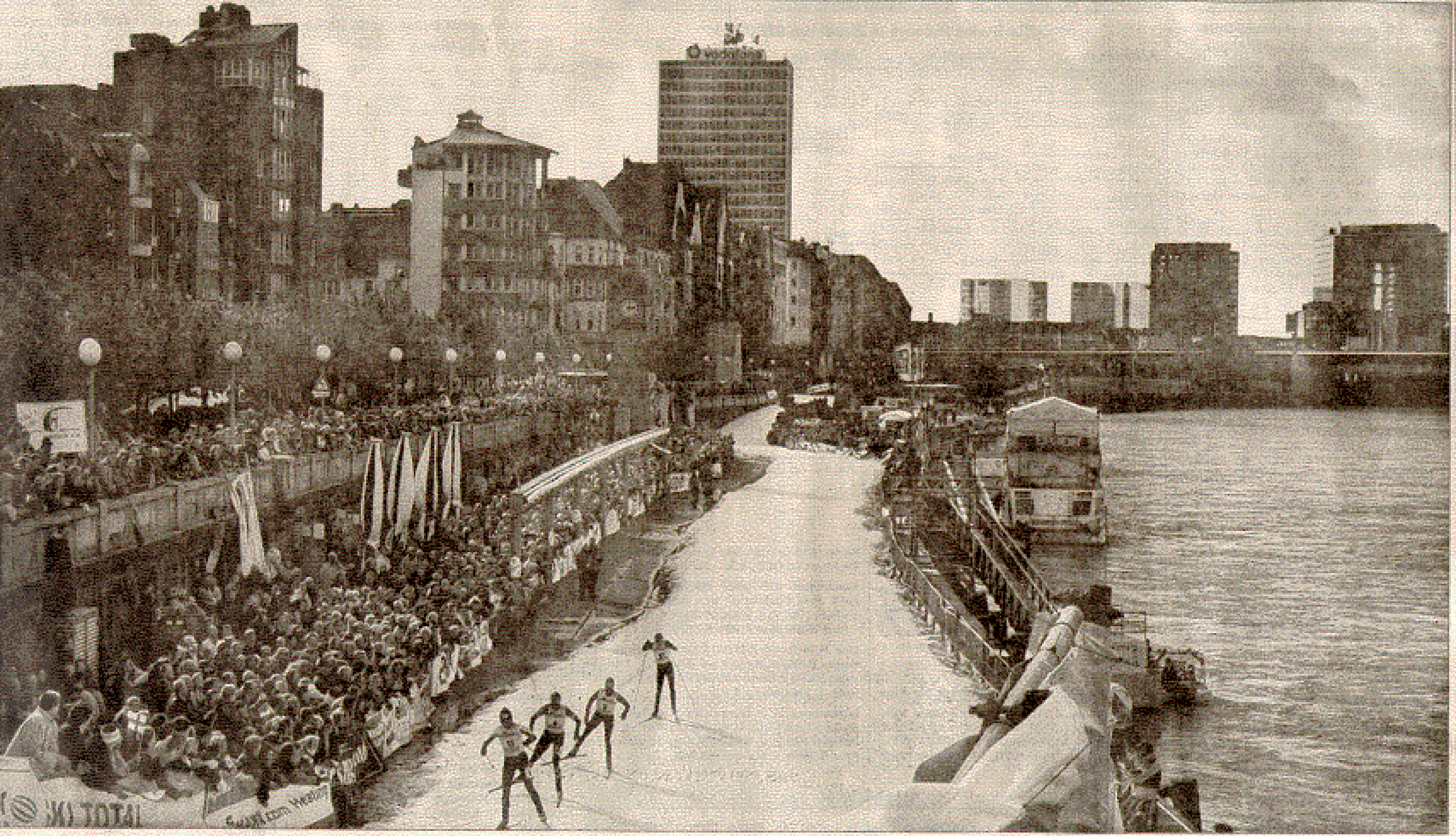

VORSICHT
SCHNEE-
KANONE
EFEU


SAVOGNIN schneit für Sie

**Einladend trotz Kunstschnee: Die mit Schneekanonen präparierte Loipe in Sils.** Keystone

# *Künstliche Loipe schwingt sich durch die Landschaft*

SILS – Spaziergänger auf künstlicher Langlaufski-Loipe in Sils GR im Engadin: Trotz der bitteren Kälte in diesen Tagen machte sich der Schnee im Engadin rar. Aus diesem Grund mussten die Loipen sowie die Skipisten mit Kunstschnee präpariert werden.

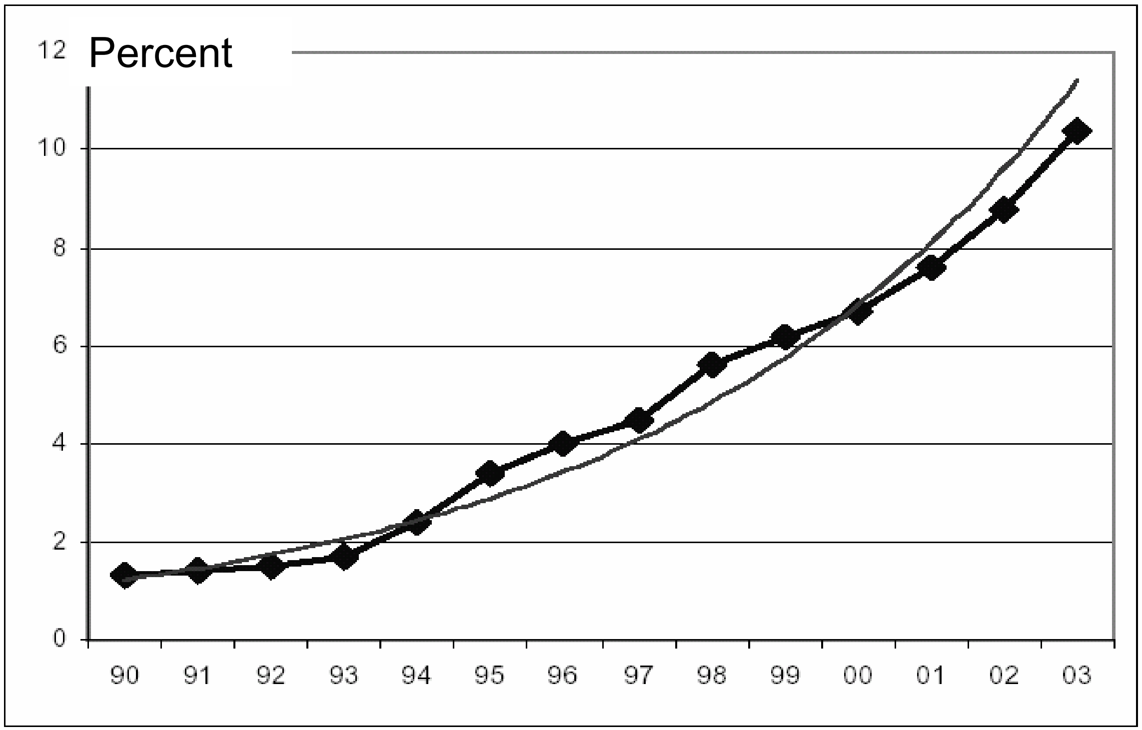


*Kein Reinfall: Zehntausende Zuschauer säumen die Strecke am Düsseldorfer Rheinufer.*

# Eine Gaudi unter Palmen und auf Kunstschnee

*Den Weltcup-Auftakt der Nordischen in Düsseldorf beobachteten Klaus Blume (Text) und Christian Beutler (Bilder)*

# Increase in snow-making



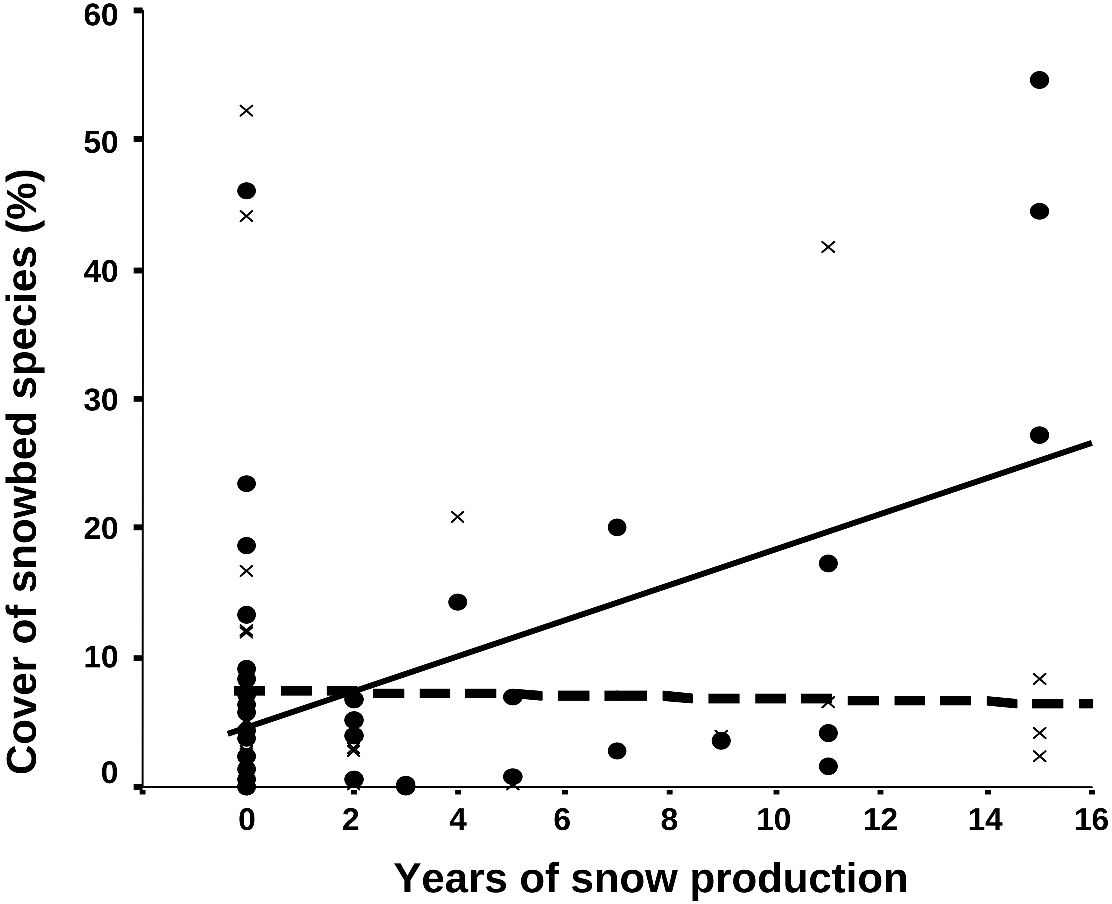

Austria: approx. 50%, South Tyrol: 59%, Alps: 30%

# Potential changes in vegetation

- Changes in species composition and biodiversity due to
  - Late snow-melt
  - Changed ground temperatures
  - Input of water and ions
  - Constructions
- Potential effects of snow additives
  - Salts for snow hardening
- Impacts due to intensified pressure on ski resorts
  - Extension of ski resorts
  - Broadening of ski pistes


Late snow-melt

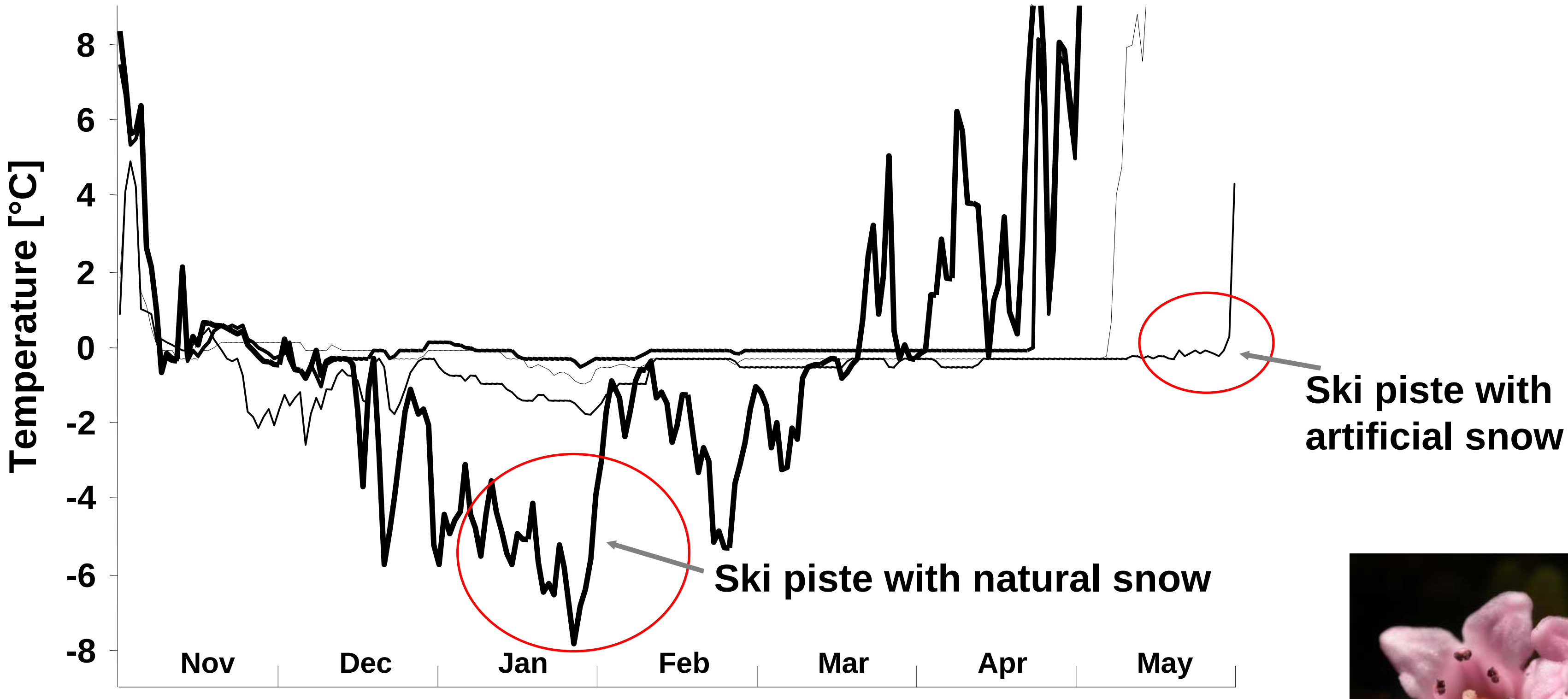
# Late snow-melt




**More snowbed species on AS pistes ($p<0.05$).**

(Wipf, Rixen, Fischer, Schmid, Stöckli 2005 JApplEcol)

# Ground temperatures




**Frost under pistes with natural snow.**

**And subsequently more wind-edge species.**

(Rixen, Häberli, Stöckli 2004 AAAR)

# Input of water and ions

| | Artificial snow | Natural snow | P |
|---|---|---|---|
| Electrical conductivity (μS) | 61 ± 30 | 15 ± 7 | ** |
| $Ca^{2-}$ (mg $l^{-1}$) | 5.34 ± 3.12 | 0.71 ± 0.51 | ** |
| $K^{-}$ (mg $l^{-1}$) | 0.75 ± 0.43 | 0.75 ± 0.28 | ns |
| $Mg^{2-}$ (mg $l^{-1}$) | 1.28 ± 1.32 | 0.09 ± 0.06 | * |
| $Na^{-}$ (mg $l^{-1}$) | 2.18 ± 2.23 | 1.03 ± 0.46 | ns |
| $Cl^{-}$ (mg $l^{-1}$) | 3.12 ± 4.31 | 1.18 ± 0.69 | ns |
| $SO_4^{2-}$ (mg $l^{-1}$) | 6.38 ± 5.84 | 0.47 ± 0.20 | * |
| $NO_3^{-}$ (mg $l^{-1}$) | 0.64 ± 0.26 | 0.53 ± 0.21 | ns |
| $NH_4^{+}$ (mg $l^{-1}$) | 0.01 ± 0.06 | 0.14 ± 0.06 | * |

**Increase in competitive plant species ($p<0.05$).**

(Rixen, Stöckli, Ammann 2003 PPEES)

# Constructions

# Snow hardeners


Donnerstag, 25. Januar 2007 | Fr. 1.80 | Redakt

Blick

Die Tageszeitung der Schweiz.

DOG STAR

SEITEN 14/15

BLICK spürt den Superhund auf

NEUE BILDER!

Wegen Kunstdünger auf Lauberhorn-Piste

Bio-Bauern wird die Milch sauer

SEITEN 2/3

- **Used for ski races to freeze wet snow**
- **Several salts are used, mostly Ammonium nitrate and Sodium chloride**
- **Application of 20 - 230 kg N per hectare**
- **Timberline Ski Area, Oregon: >500 t NaCl per year: Increae of chloride concentration in river from 1-6 mg/L to 30 mg/L.**

(Schwörer et al. 2007,

http://www.slf.ch/schnee-lawinen/grundlagenbericht/chemschneepraeparation.pdf)

# Snow hardeners

- Regionally, the nutrient input is small (4-6 t/year on 40-90 ha).
- Locally, N input much higher than „critical loads“.
- Quality of affected areas and vegetation types are largely unknown.

# > The use of snow hardeners

*for operators of race courses and promoters of snow sports competitions*

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Swiss Confederation

Bundesamt für Umwelt BAFU
Office fédéral de l'environnement OFEV
Ufficio federale dell'ambiente UFAM
Uffizi federal d'ambient UFAM
Federal Office for the Environment FOEN

> Environment in practice | > Fact sheet on snow hardeners

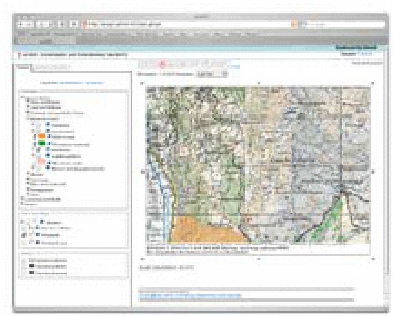
# > General rules

This fact sheet aims to optimise the use of snow hardeners on race courses. Correct use will produce better racing conditions while protecting the environment.

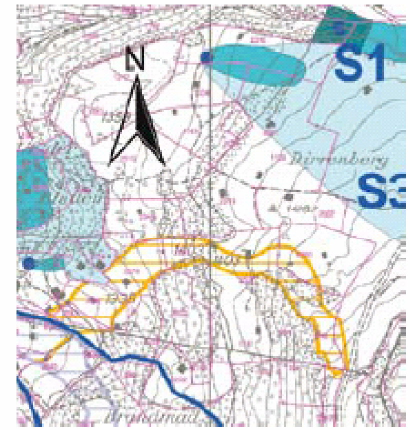
> Timely artificial snowing and mechanical preparation of the race courses can often spare the use of snow hardeners, as this will make the whole structure of the piste more stable.

> Snow hardeners must only be used as a last resort in case of unfavourable weather conditions, to ensure that a fair and safe competition can nevertheless be held.

> Snow hardeners should not be used outside snow sports competitions.



http://ecogis.admin.ch/?lang=de



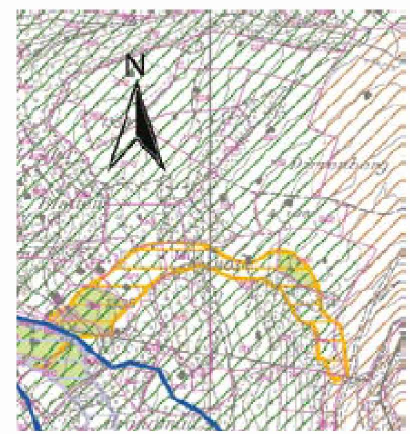




*Chart of a racing piste:*
*Race course* *Organic farms*
*Groundwater protection zone*

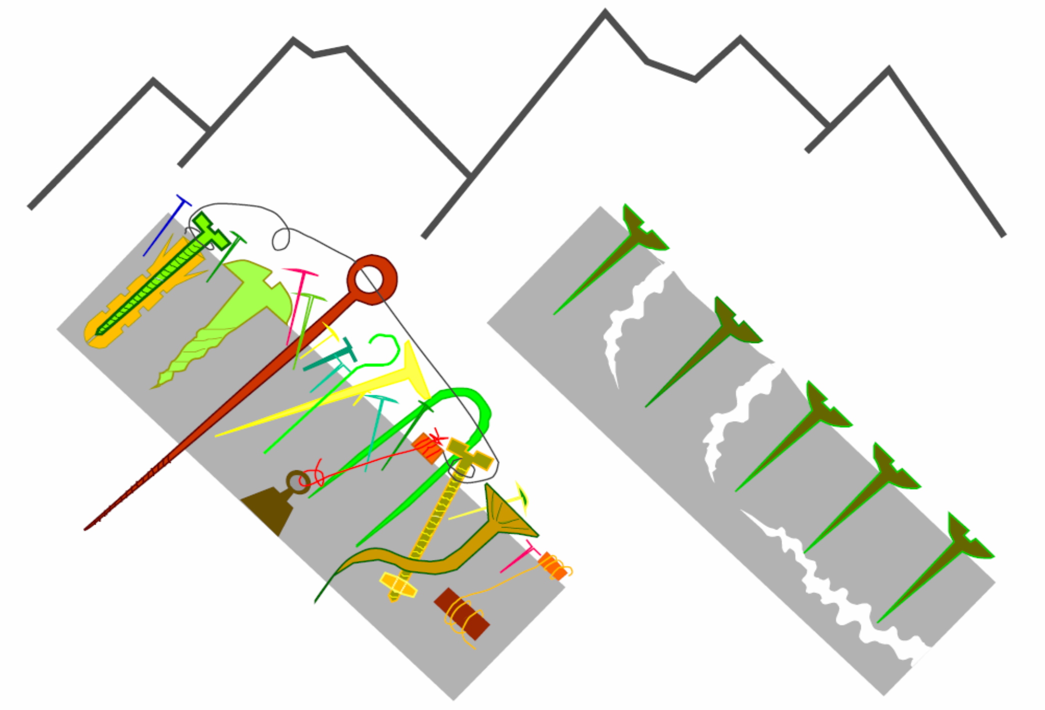
(http://www.bafu.admin.ch/publikationen/index.html?action=show_publ&lang=de&id_thema=11&series=UV&nr_publ=0731)

# Snow hardeners

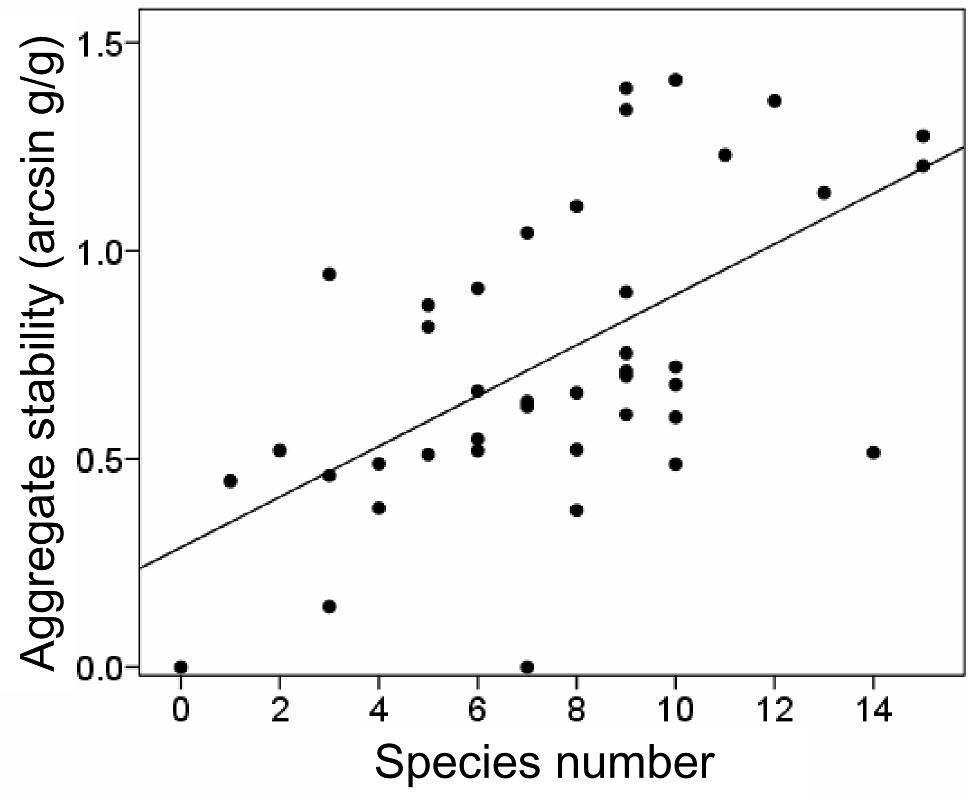
- Use of snow hardeners only at snow sport competitions as a last resort.
- All sensitive areas must be mapped (nature reserves, biotopes, natural grasslands, reed marshes, wetlands etc., as well as surface waters, areas of groundwater protection).
- Constraints are to be defined by qualified professional.
- Operator must inform organizers of race about environmental constraints.
- Operator must keep record of kind and amount of snow hardener and inform farmers.

# Extension of ski resorts etc.

# Biodiversity and soil stability

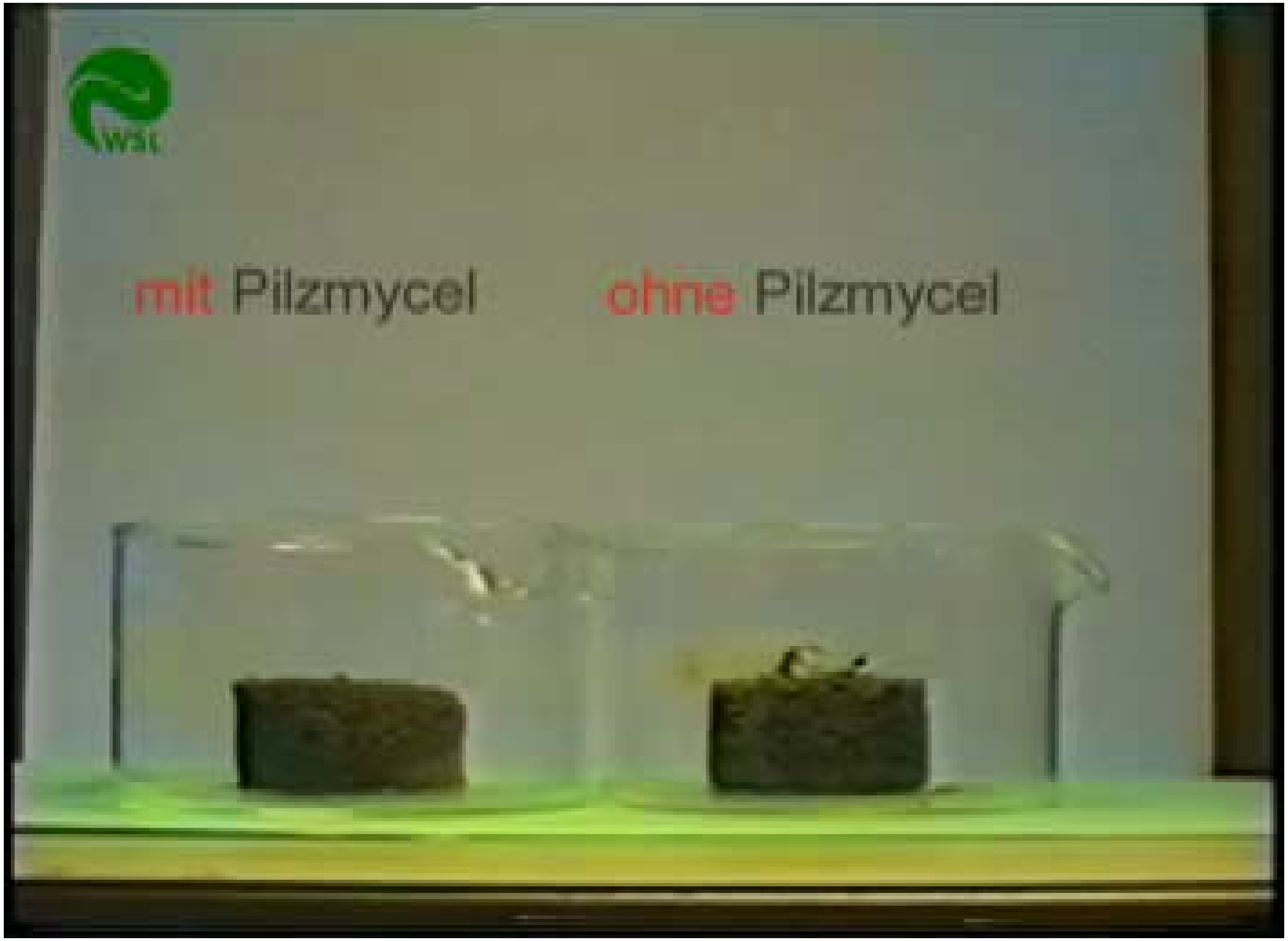


(GMBA)

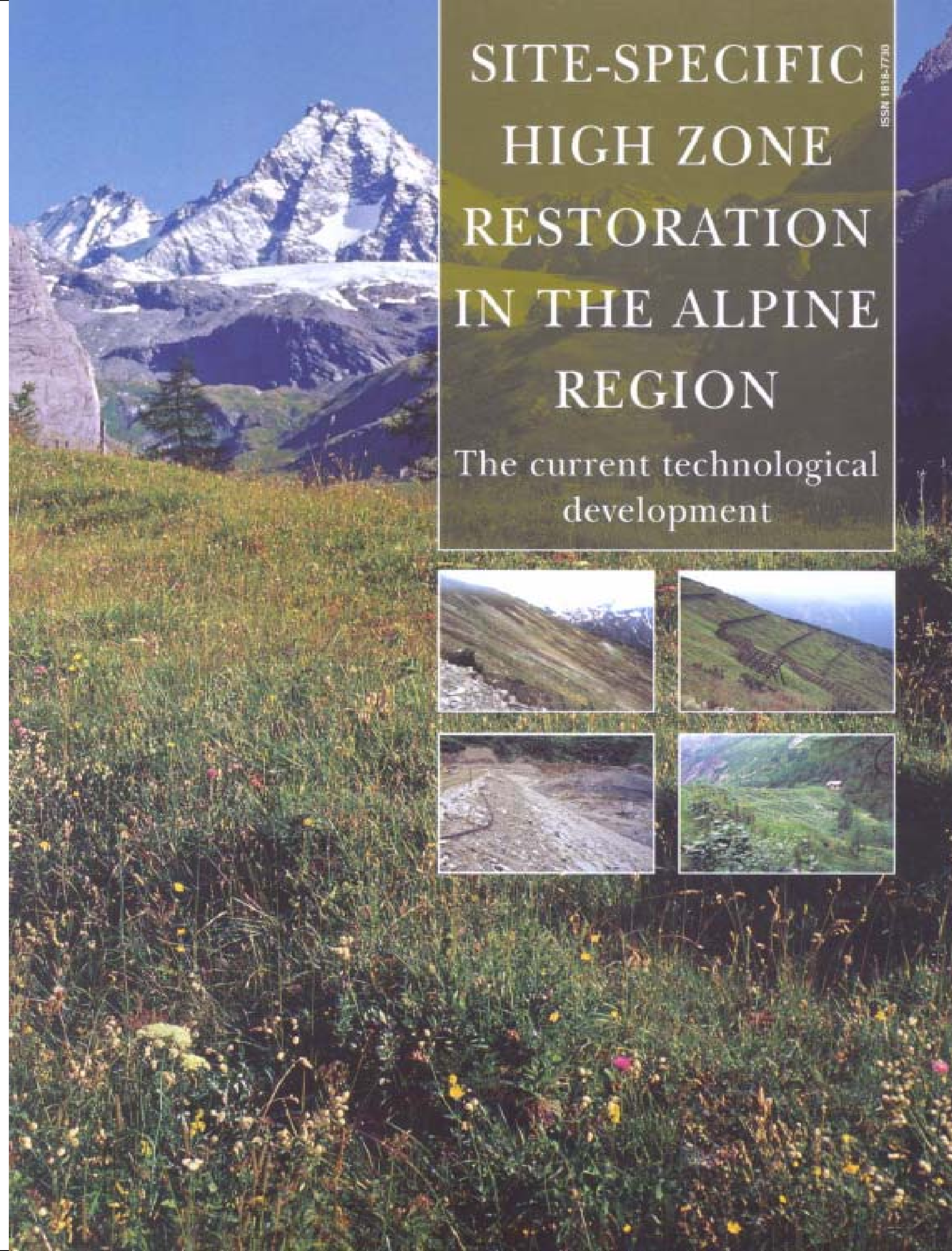



(Pohl et al. in prep.)

# Soil stability…




(Graf & Brunner 1996)




(Krautzer et al. 2006)

# Take-home messages

- Artificial snow can change species composition by late snow-melt and input of ions and water

- Problematic on nutrient-poor wetlands and dry grasslands.

- Disturbance is high on all ski pistes.

- Local input of snow additives can be very high.

- Extension of ski areas to higher altitudes problematic; current knowlegde on re-vegetation should be used.

# Automated snow stations

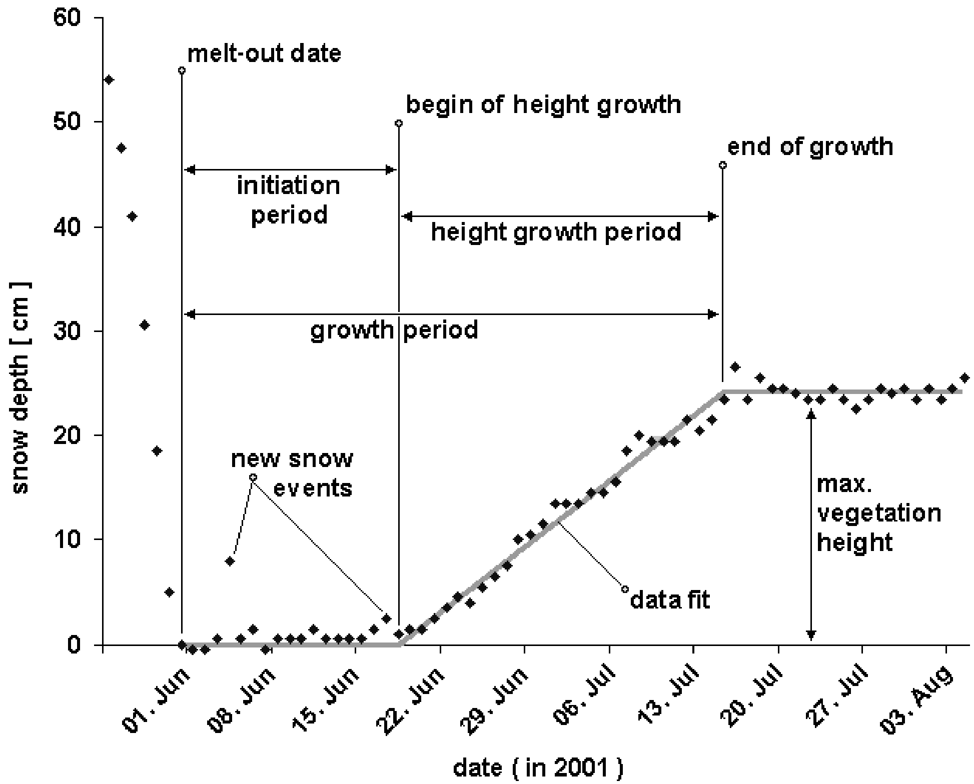
Crucial climatic factors for alpine plant communities
(Alpine meteorological network IMIS)

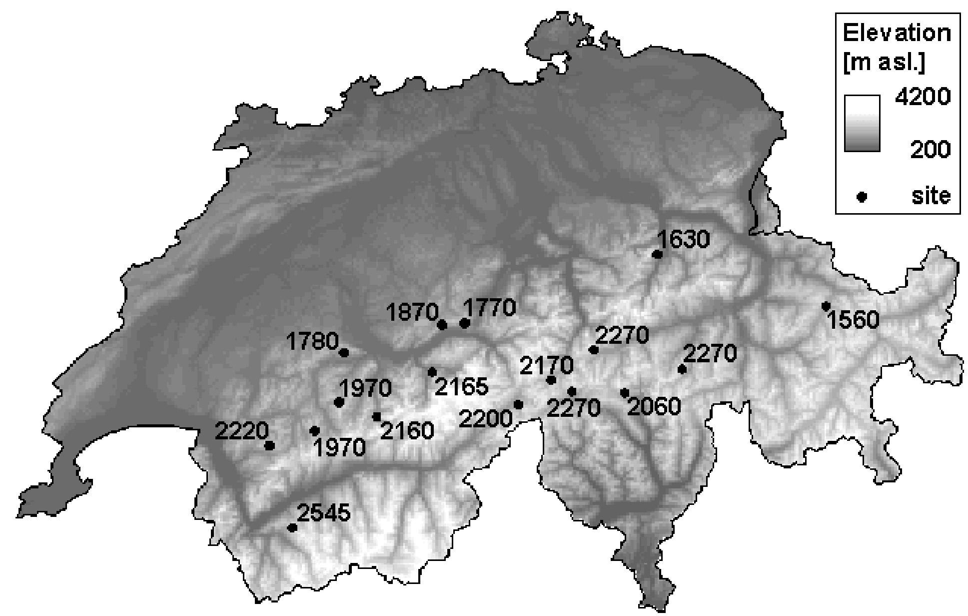
- Collaboration with Uni Bern
- Use of c. 100 automatic weather and snow stations
- Correlation of climate and plant growth
- Correlation of  stations and remote sensing (PhD in Bern)

(Jonas, Rixen, Stöckli & Sturm in prep.)

# Automated snow stations

Crucial climatic factors for alpine plant communities (Alpine meteorological network IMIS)



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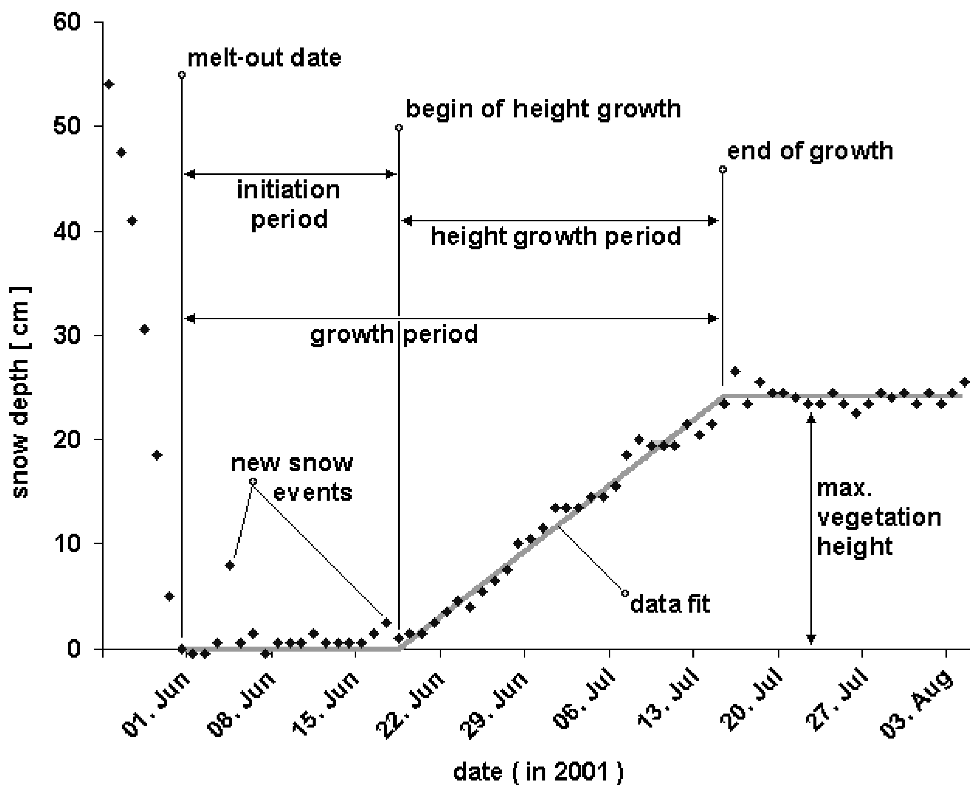
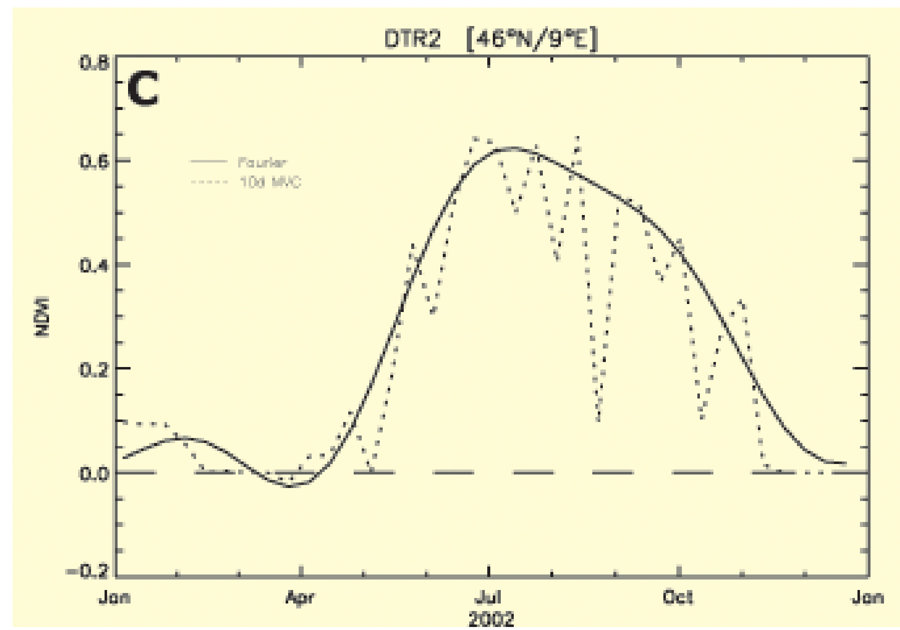
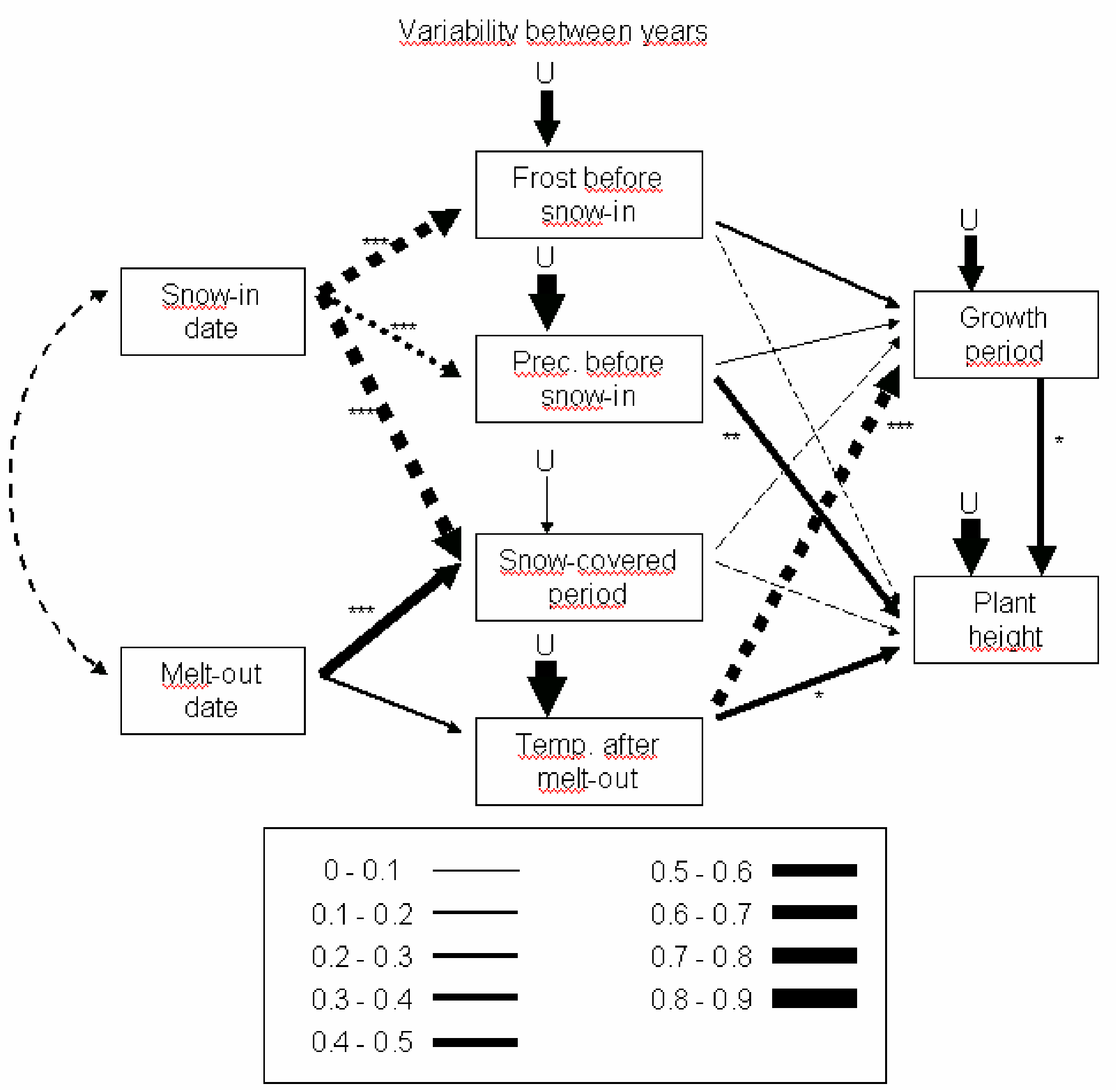



(Fontana, Rixen, Jonas, Aberegg & Wunderle 2007)

# Automated snow stations



# Take-home message

If you have data from such snow stations, I would be happy to collaborate…

# Treeline research at Stillberg, Davos

Avalanche starting zone
1950 – 2250 m asl

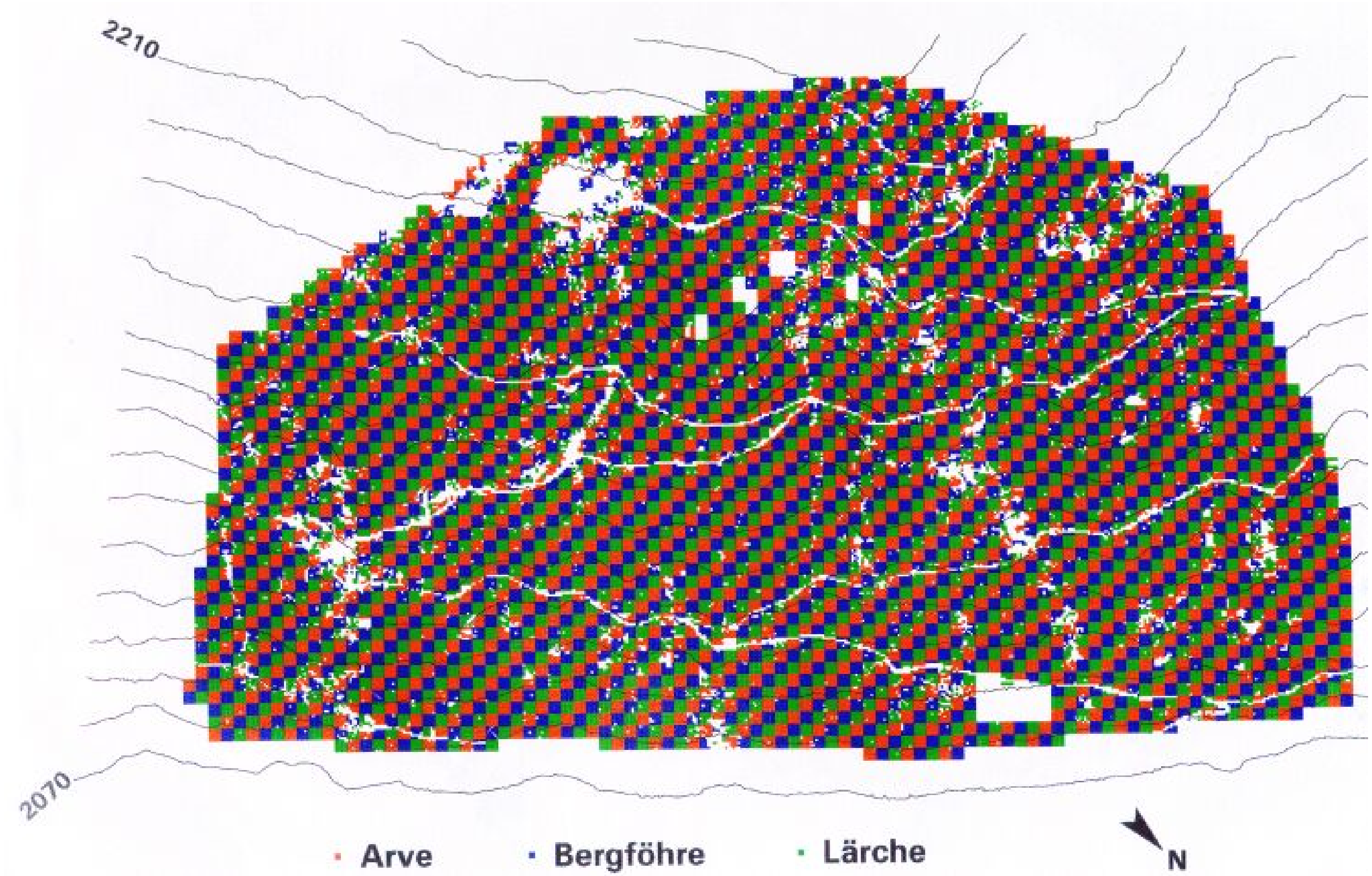
92 000 trees planted systematically in 1975

Monitoring since 1975 on vegetation, climate, disturbances

# Treeline research at Stillberg, Davos

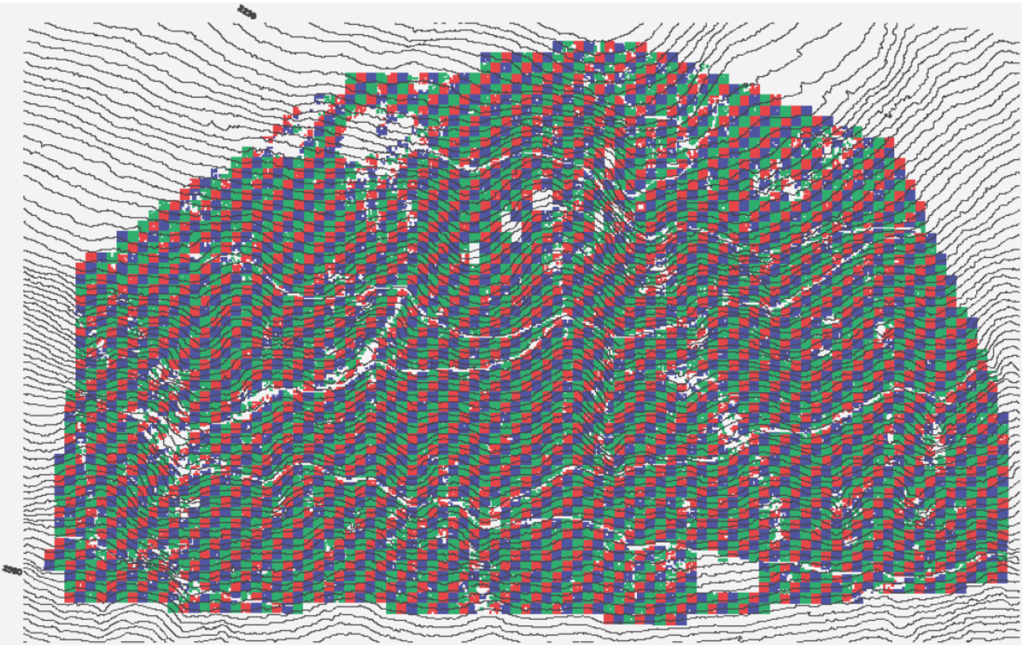
Species:

*Pinus cembra*
*Larix decidua*
*Pinus montana*

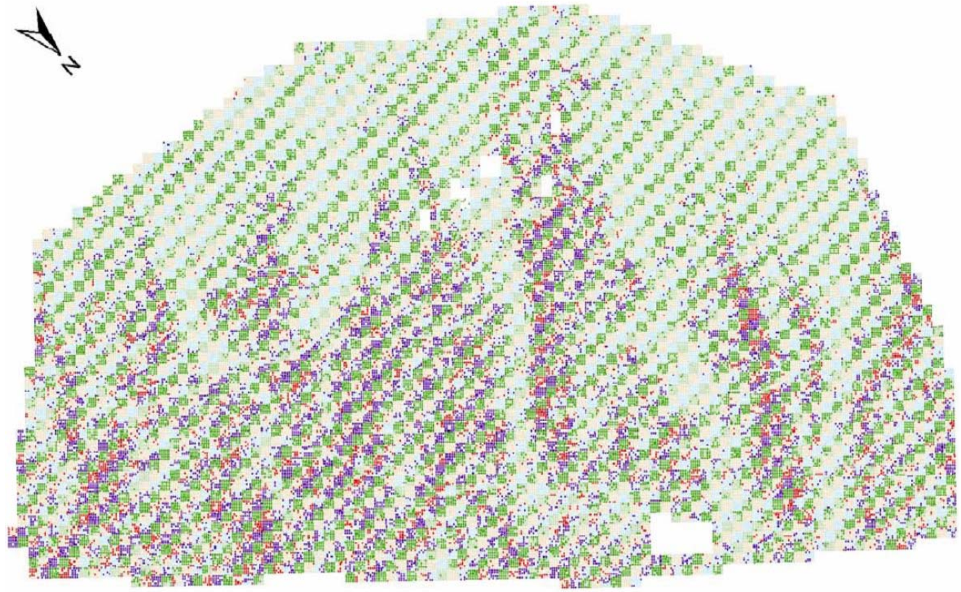


# Treeline research at Stillberg, Davos

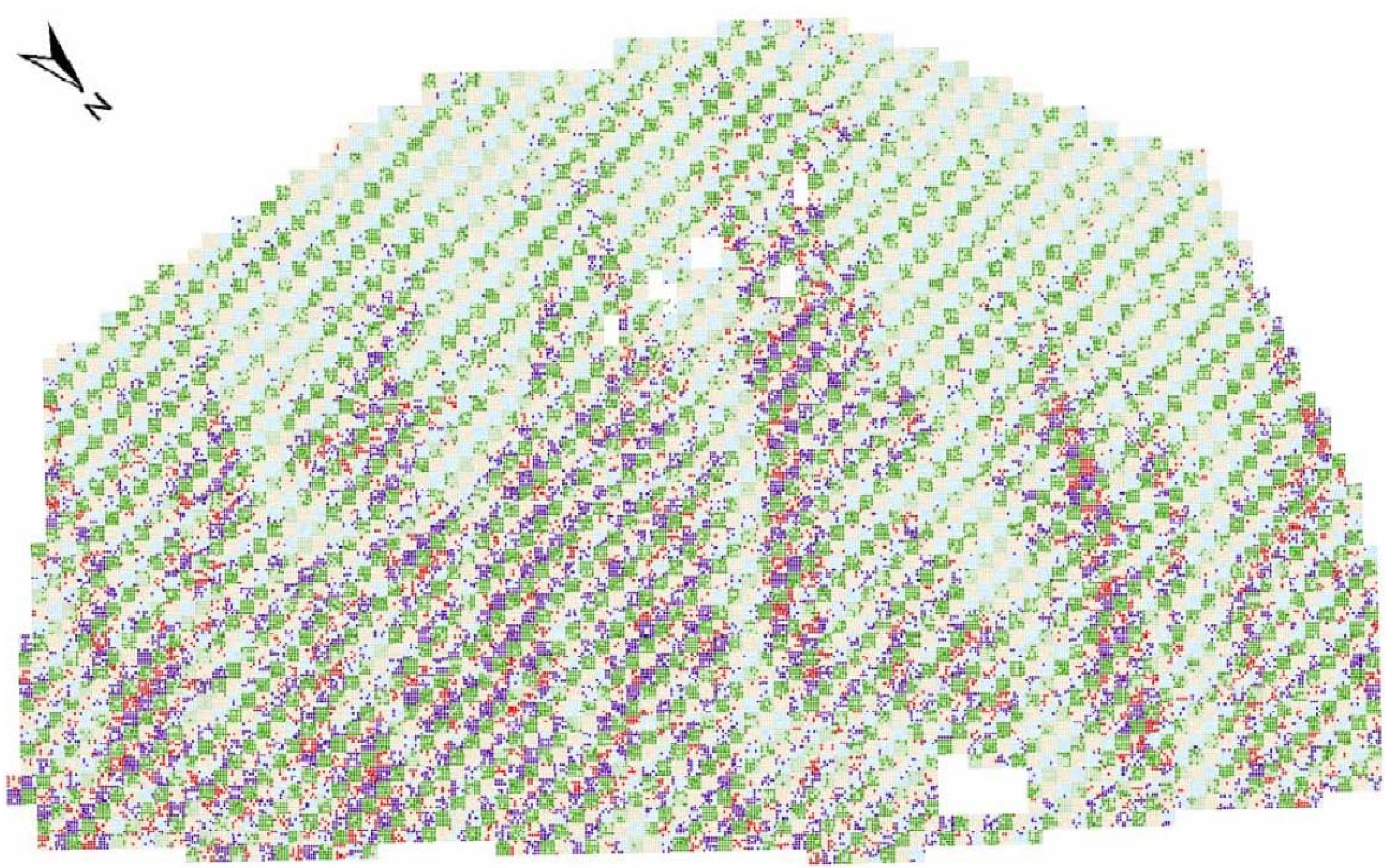
1975



1995



# Treeline research at Stillberg, Davos



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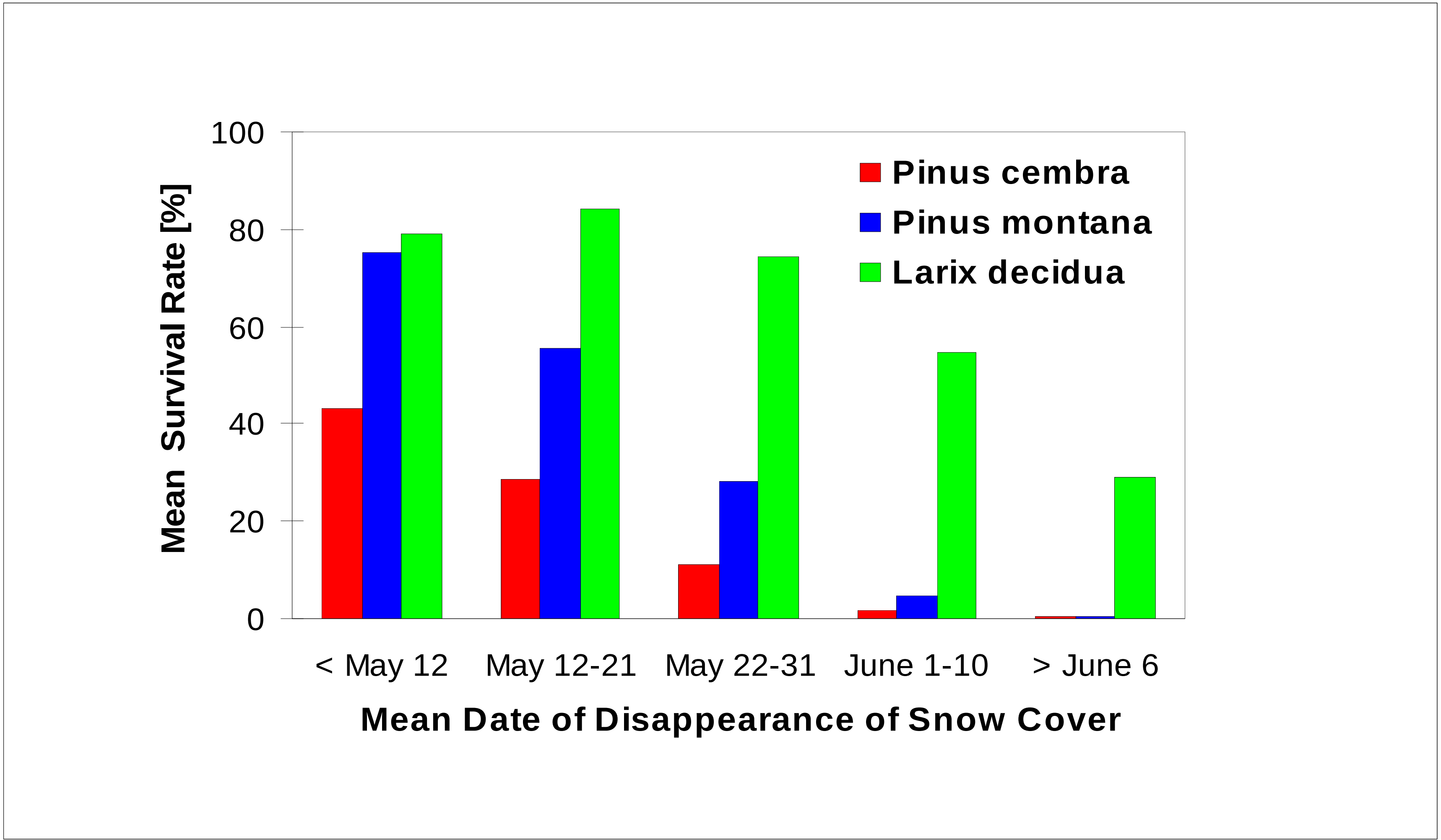


# Treeline research at Stillberg, Davos

Mortality factors:

Snow creeping

# Treeline research at Stillberg, Davos

Mortality factors:

Snow fungi *(Gremmeniella abietina, Phacidium infestans)*

Frost drought

Gremmeniella abietina (Triebsterben)

# Treeline research at Stillberg, Davos

Damages:

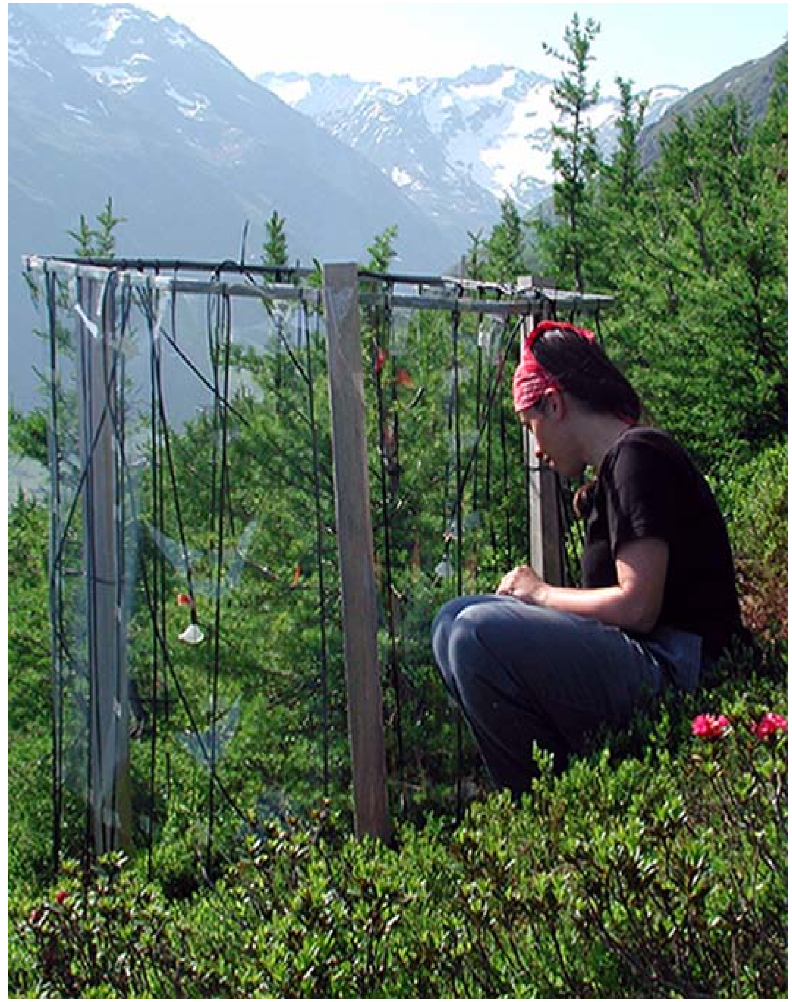
Browsing by black grouse
(*Tetra tetrix*)

# Treeline research at Stillberg, Davos

Practical application:
- Planting in groups where site conditions are promising
- Support with temporary snow supporting structures


E4L2
E4L1
E4-L2
E4P1
A4-P1

# Treeline research at Stillberg, Davos

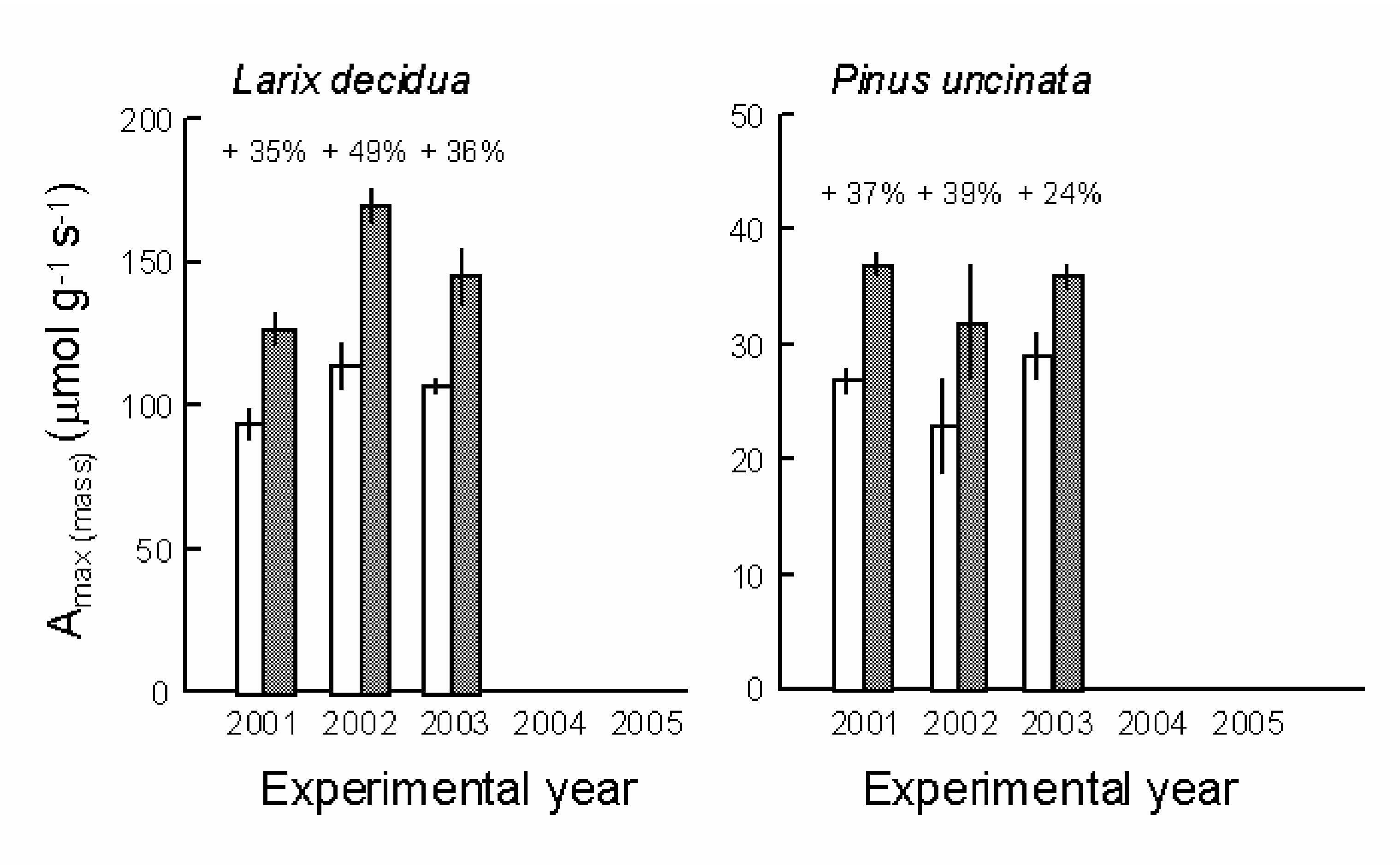


*Pinus uncinata*


arkasub ag
olten, tel. 062 287 96 66, info@mar

# Treeline research at Stillberg, Davos

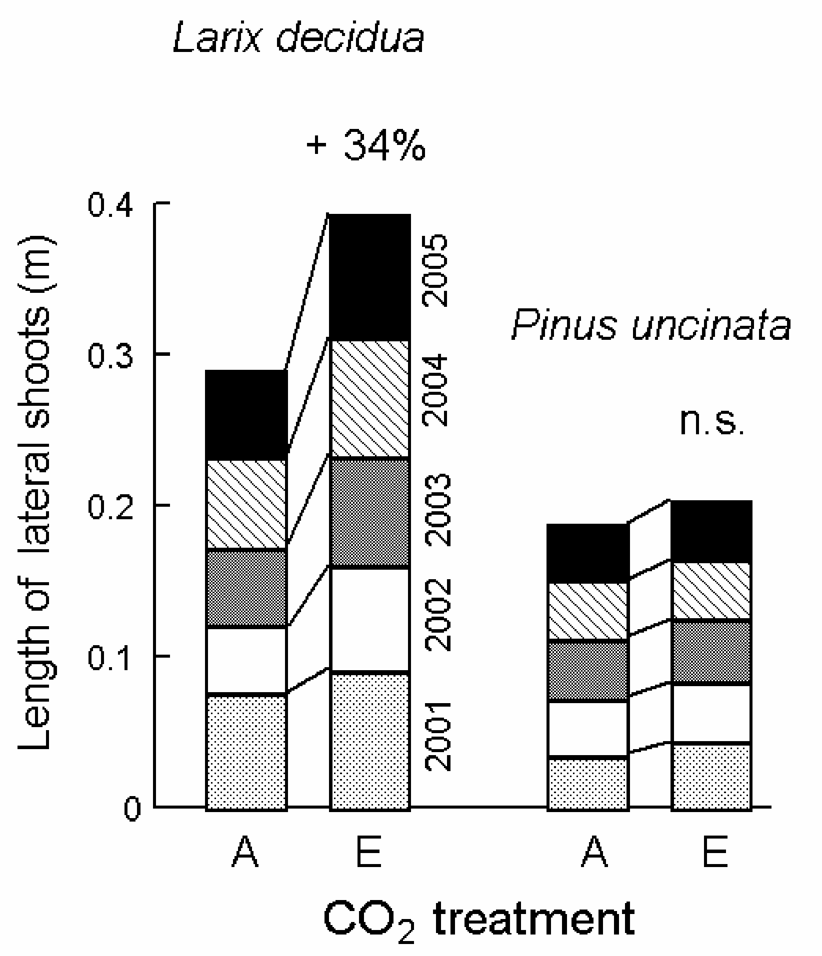
Net photosynthetic CO2 uptake




(Handa et al. 2005)

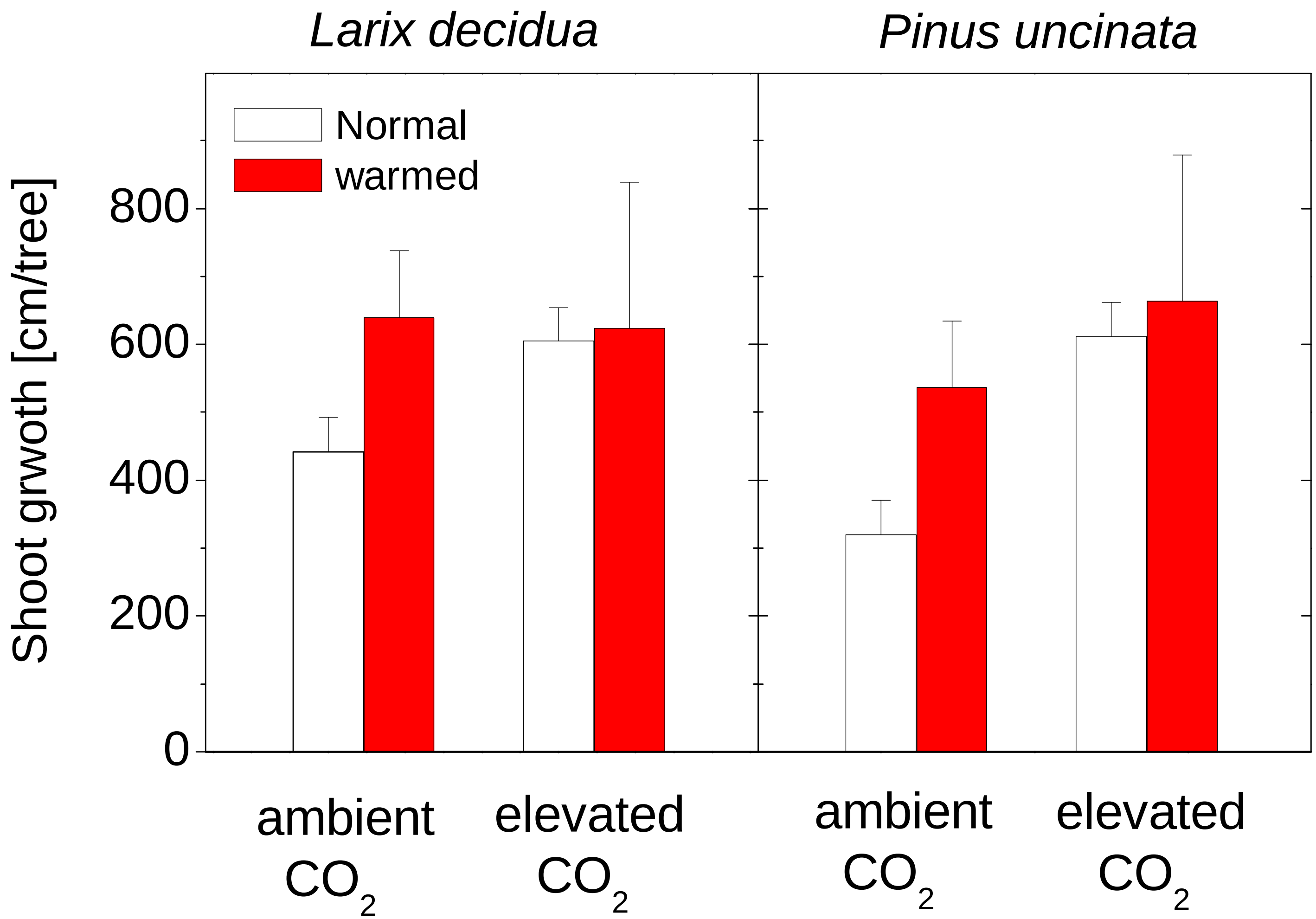
# Treeline research at Stillberg, Davos

Shoot length increment at ambient (A) and elevated (E) CO2



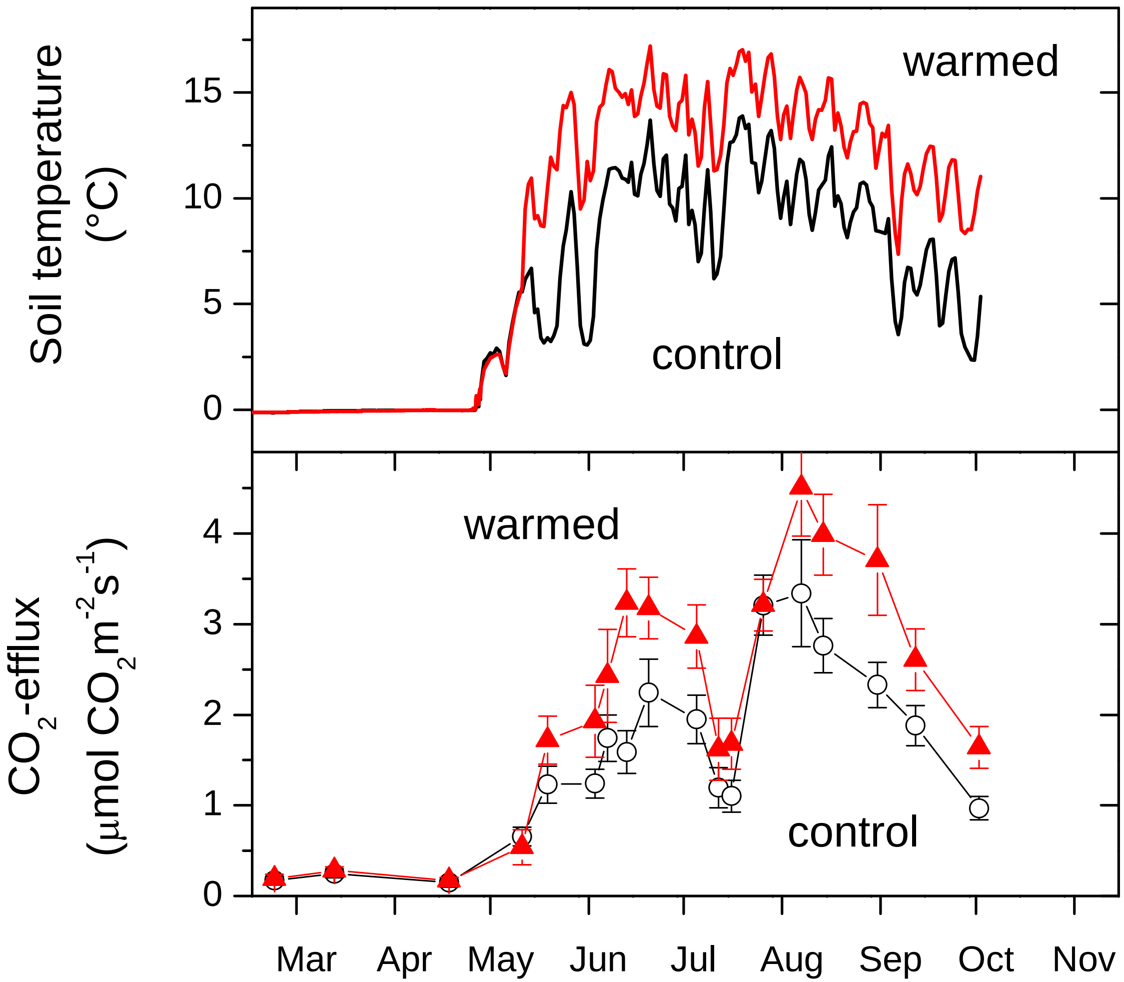

(Hättenschwiler et al. 2005)

# Treeline research at Stillberg, Davos




**Shoot growth in 2007**

# Treeline research at Stillberg, Davos




**Temperature 2007**

**Soil Respiration 2007**

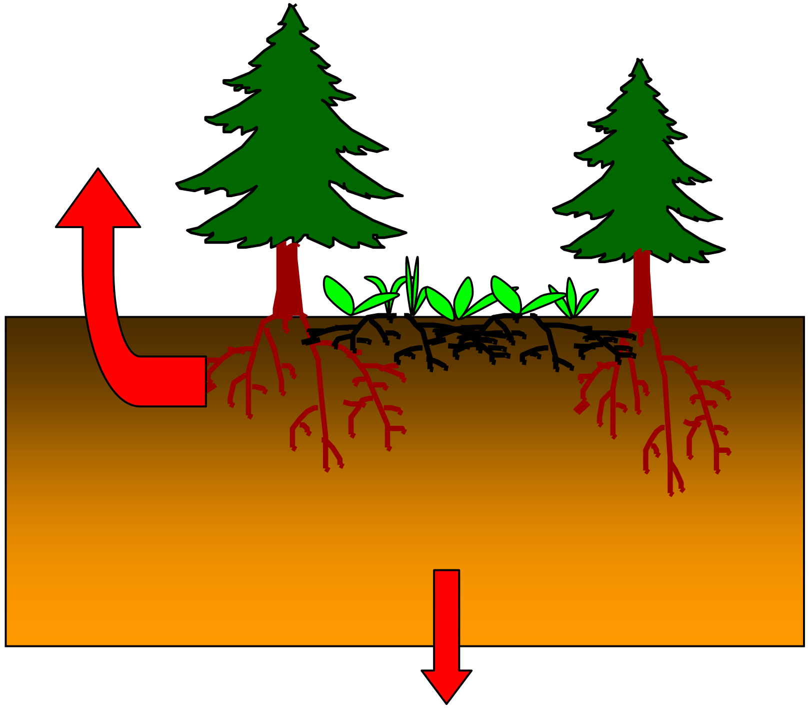
# C-fluxes from warmed soils

Soil Respiration **260** in g C $m^{-2}y^{-1}$

**370**

Growth **100**

**130**



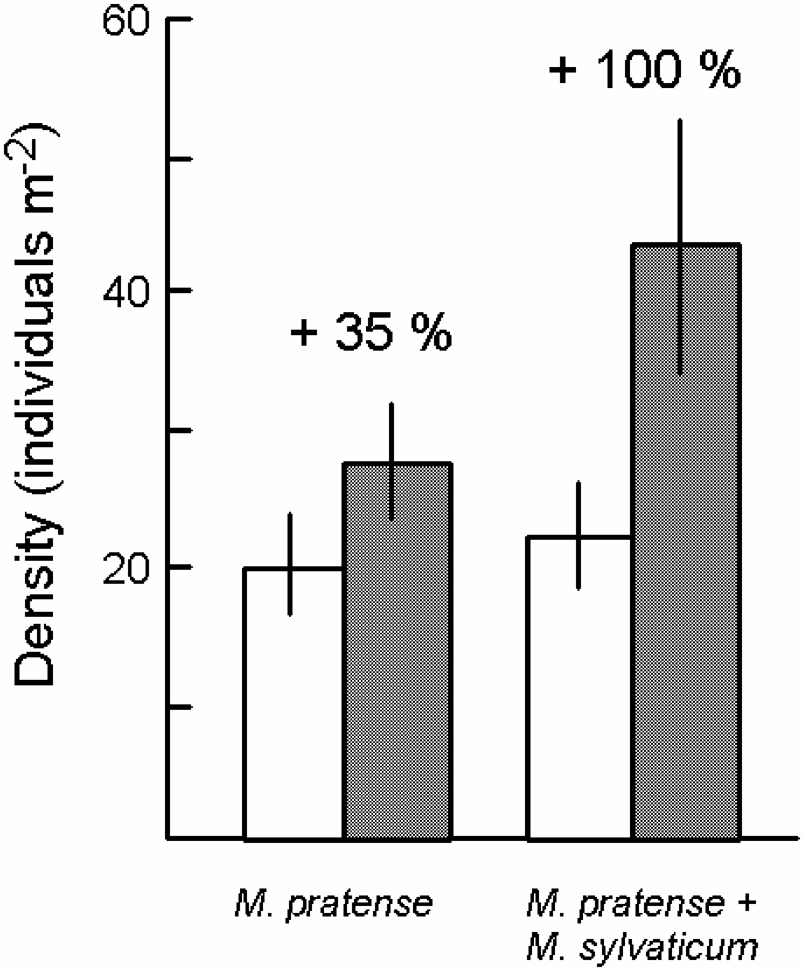
DOC-Leaching **30**

**35**

**Ecosystems loose C !**

# Treeline research at Stillberg, Davos

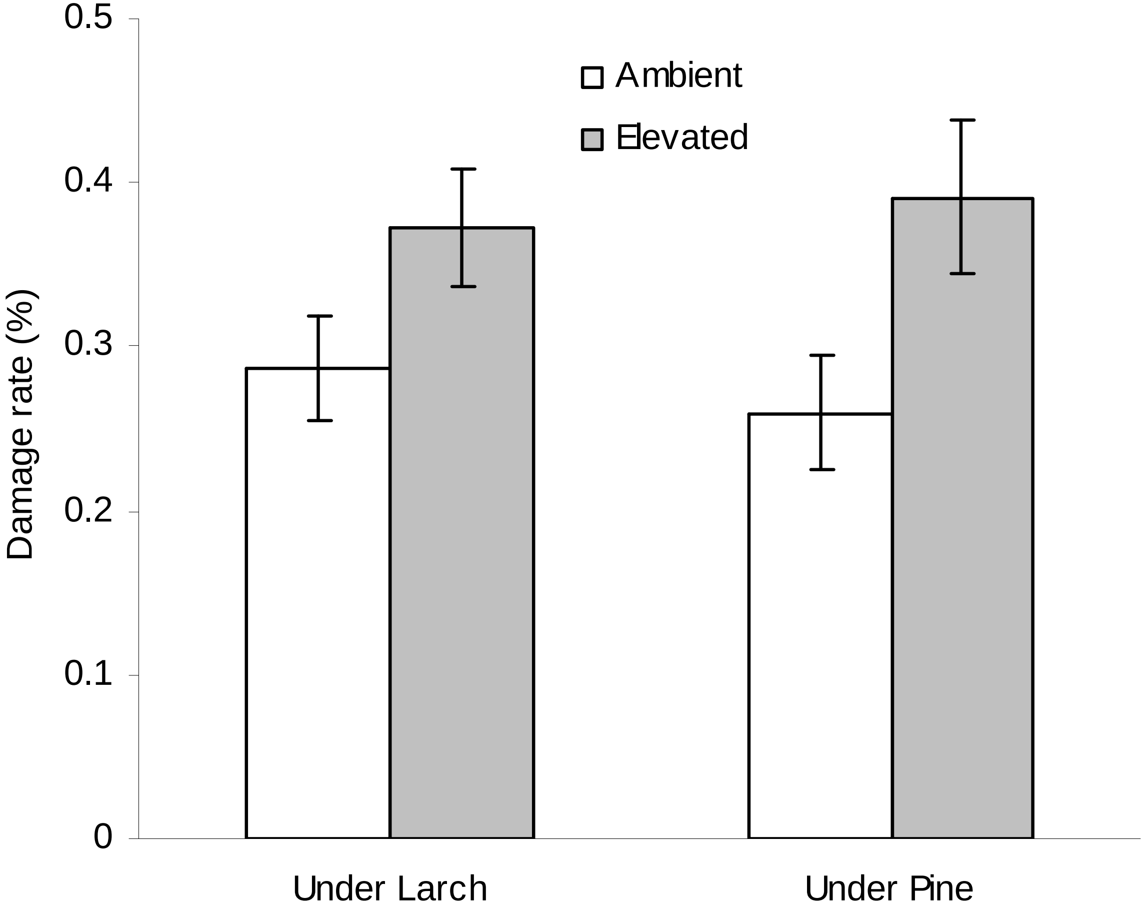
Population density of *Melampyrum* species in natural vegetation in the third year of CO2 exposure




(Hättenschwiler 2005)

# Treeline research at Stillberg, Davos

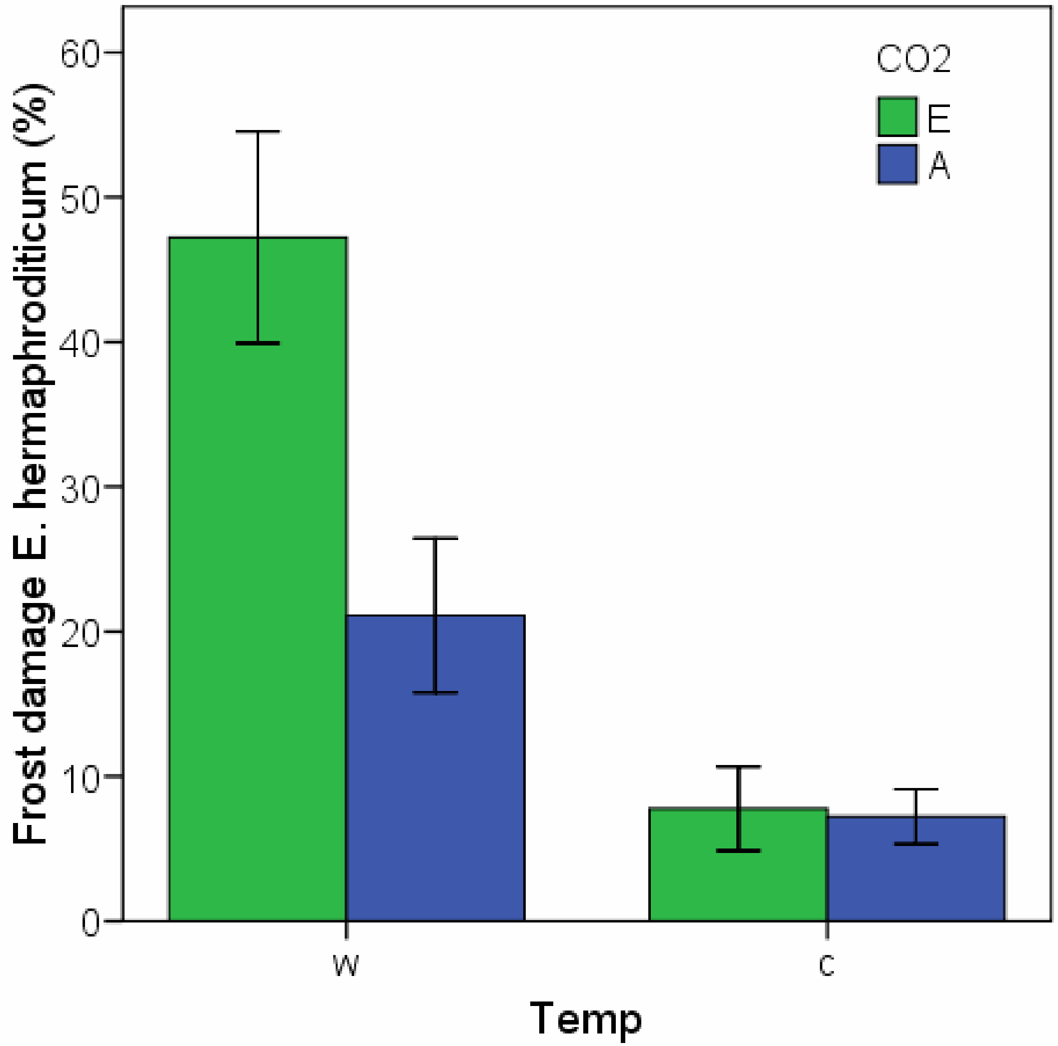
Frost damage rate of *Vaccinium myrtillus* in June 2005




(Handa et al. in prep.)

# Treeline research at Stillberg, Davos

Frost damage rate of *Empetrum nigrum* in August 2007



# Take-home messages

Elevated $CO_2$ and warming enhances growth of larch, but soil respiration is enhanced even more.

Ecosystems are becoming an initial $CO_2$-source.

Better growing conditions increase vulnerability of plants to frost.

Extreme events may counteract effects of climate change.