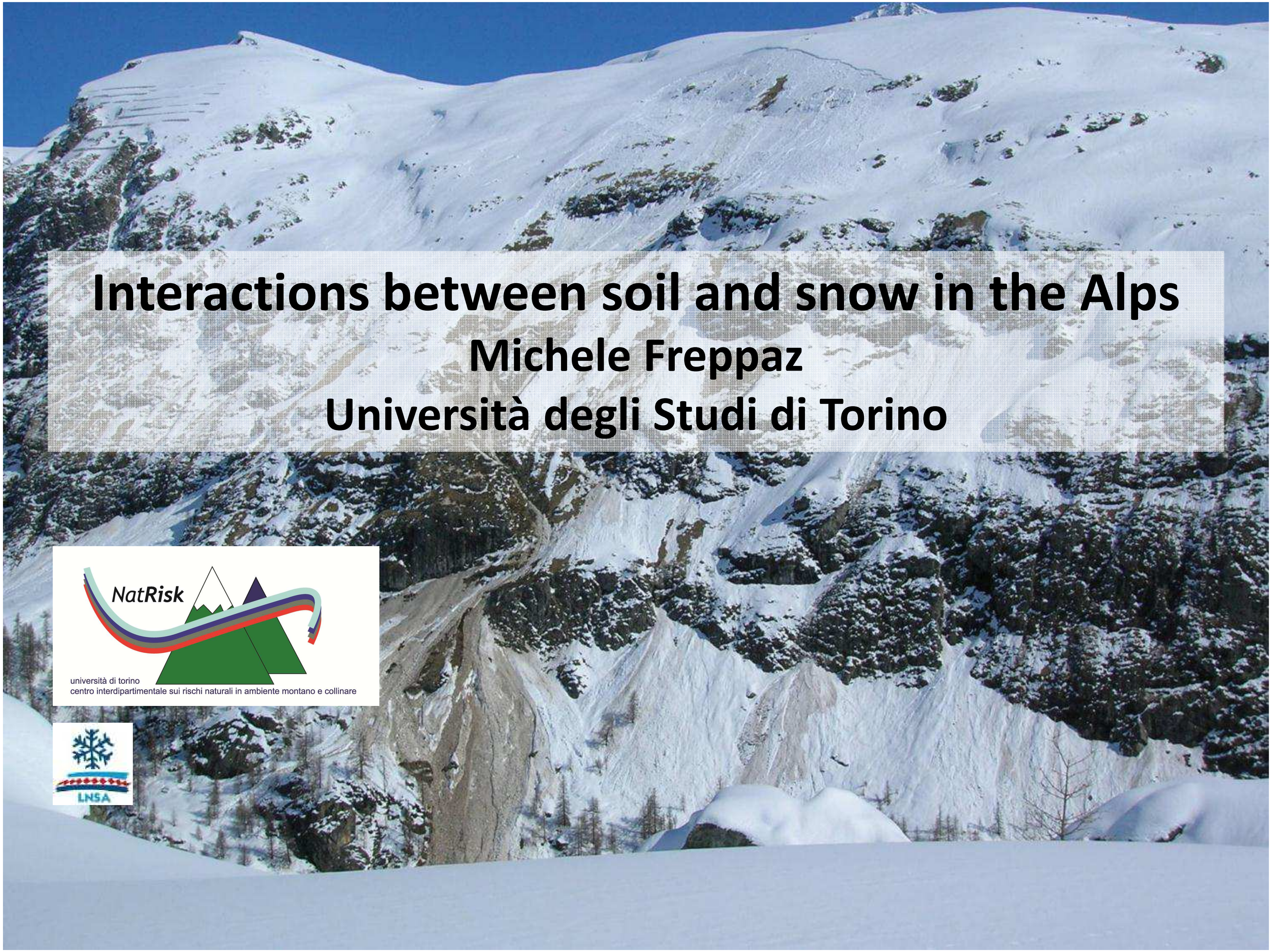

Interactions between soil and snow in the Alps

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LNSA

Summary

"The two domains, soil and snow, are obviously connected, and perhaps continuous, system" (Guymon GL, 1978).

The Rock Analogy

"It could be useful to view the snowcover as a type of sedimentary rock composed of consolidated layers of deposited minerals in their solid state (ice) – thus **a snowcover is analogous to a sedimentary rock** formed of ice, the mineral whose principal property is its temperature (McKay & Adams, 1981)". **But…..**

The Soil Analogy

" As the rates of snowcover metamorphism are very rapid, the **"rock analogy"** is not useful for describing the dynamic nature of a snowcover. For this purpose **snow might be considered as being more like soil**, which is also characterized by layering of particles of different grain size, shapes…but which, contains appreciable quantities of air and water and which is highly dynamic…. (McKay & Adams, 1981)".

Snow cover structure

- An important characteristic of snow covers is the stratification of their physical structure.
- Snow stratification results from successive snowfalls over the winter and processes (metamorphism) that transform the snow cover between snowfalls.
- A new snowfall creates a new surface layer that will undergo various transformations before being buried by the next snowfall.


2.4 – 18 kg ha-1

Snow/Soil interactions

- Snow is a reservoir of water, released into the soil in a short time (Italian Alps, 2000 m, SWE=320 mm).

Snow/Soil interactions

- Snow is a reservoir of nutrients. During the spring melt period, meltwaters deliver nutrients to the soil, up to 2-4 kg ha^{-1} of N within a period of a few weeks.
- 50 to 80 per cent of the solute species are eluted in the first 30 per cent of melt water (**ionic pulse**).
- **Preferential elution** from snow to soil in the sequence SO_4^{2-}>NO_3^->Cl^- was confirmed from field and laboratory measurements.

Ionic Pulse

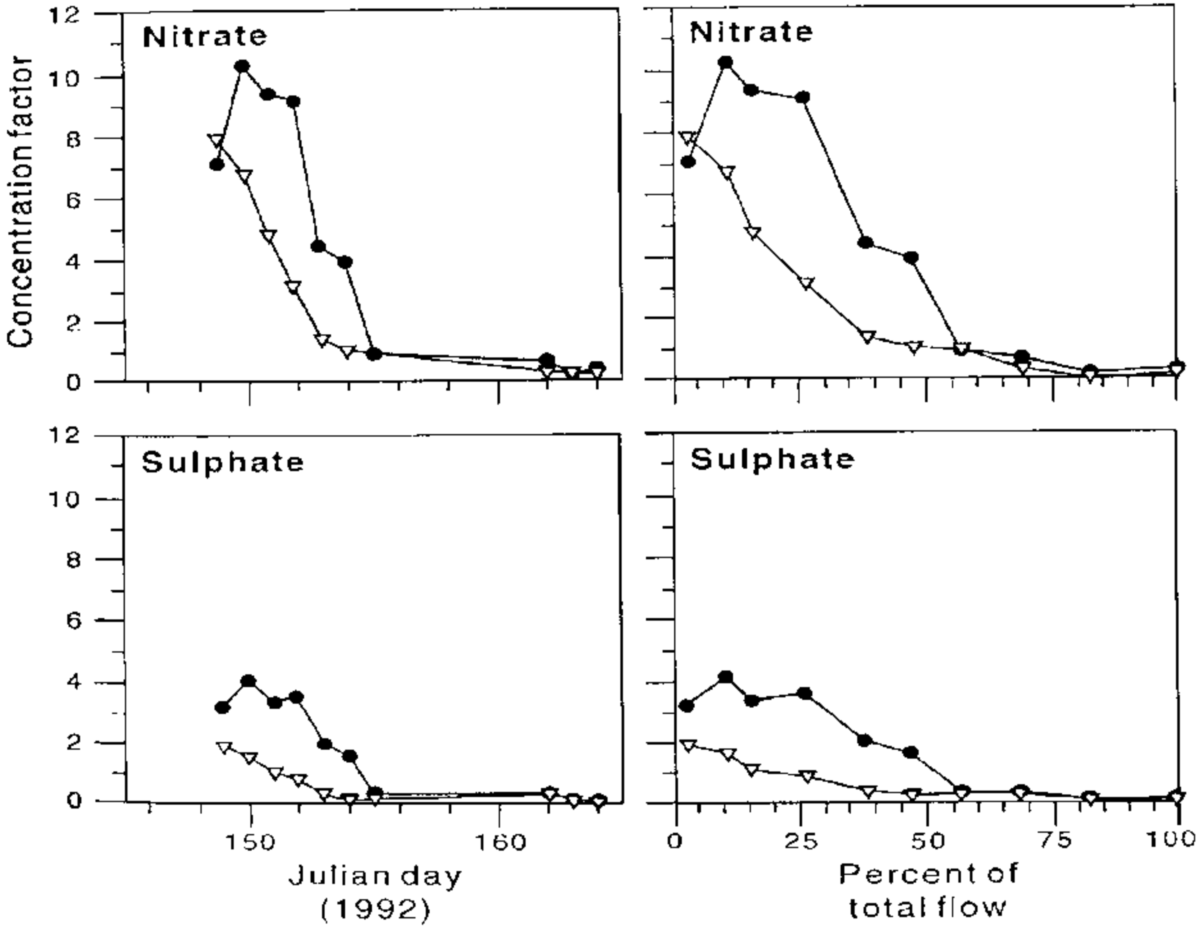
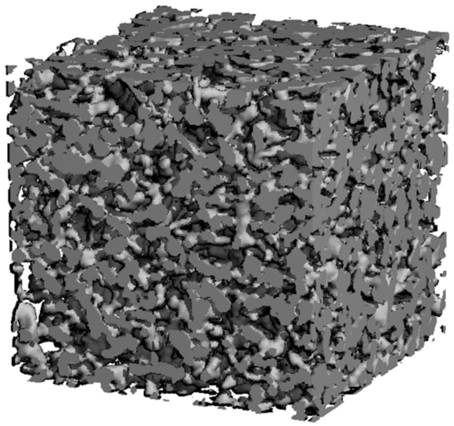


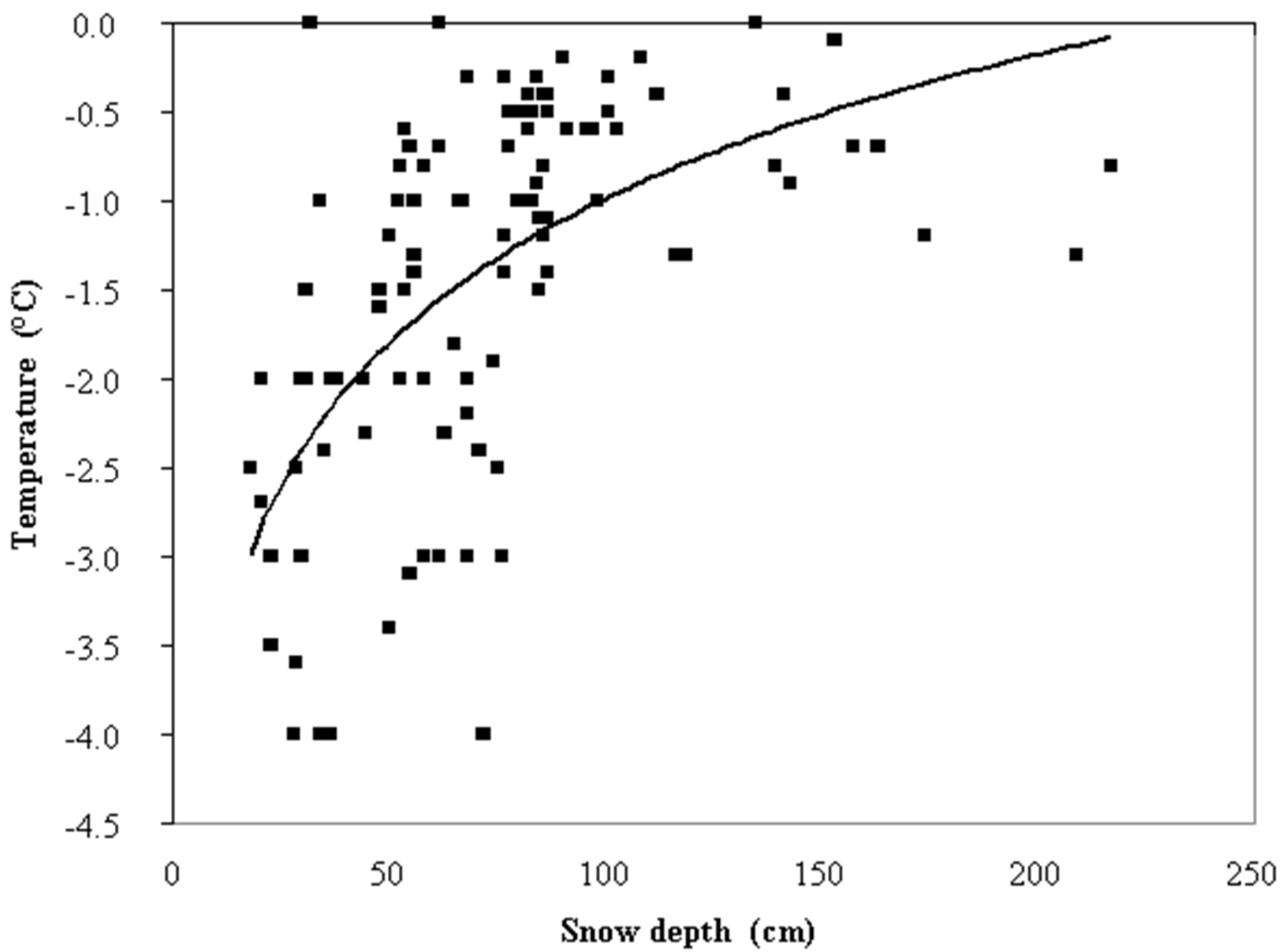
Figure 3.6. The impact of flow rate on the concentration factor of SO_4^{2-}, NO_3^-, and Cl^- in snowmelt. Open symbols denote high rates; closed symbols denote low flow rates (after Marsh and Pomeroy, 1993).

Snow/Soil interactions

- As a porous medium with a large air content, snow has a high insulation capacity and plays an important role protecting soil from severe winter temperatures.
- The thermal conductivity of a snow cover is low compared with soil surfaces and varies with **snow depth** and **snow density**.

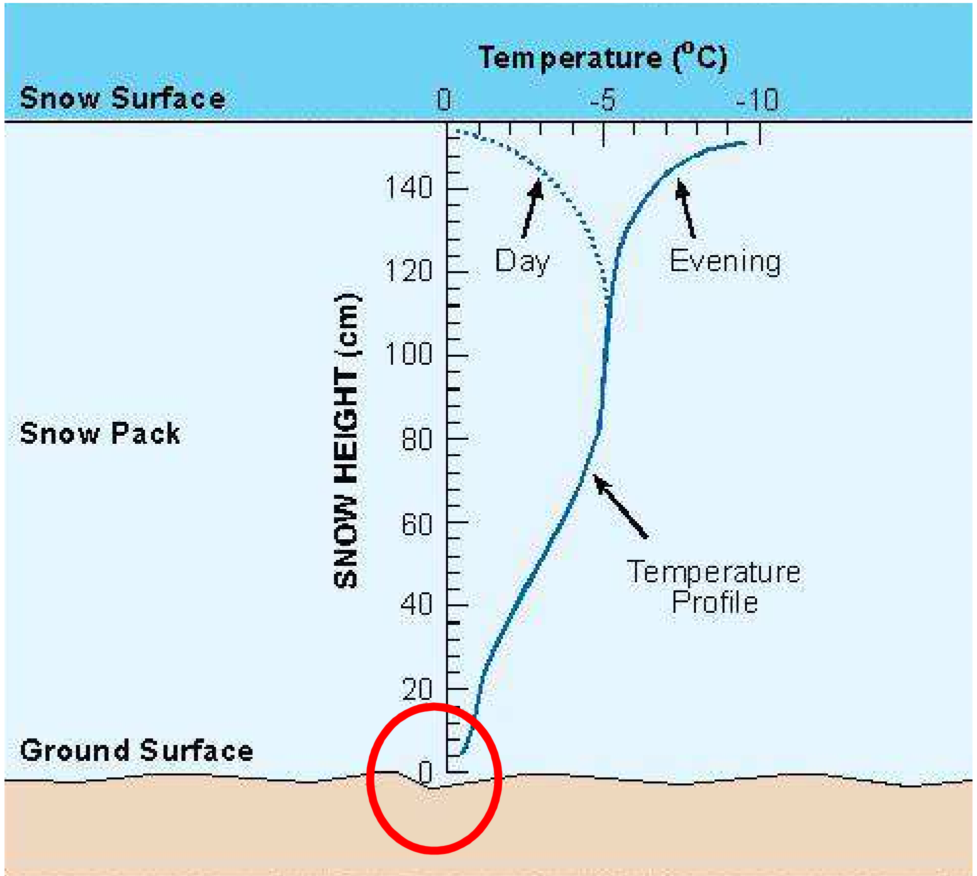


Snow depth vs Soil temperature (snow/soil interface)

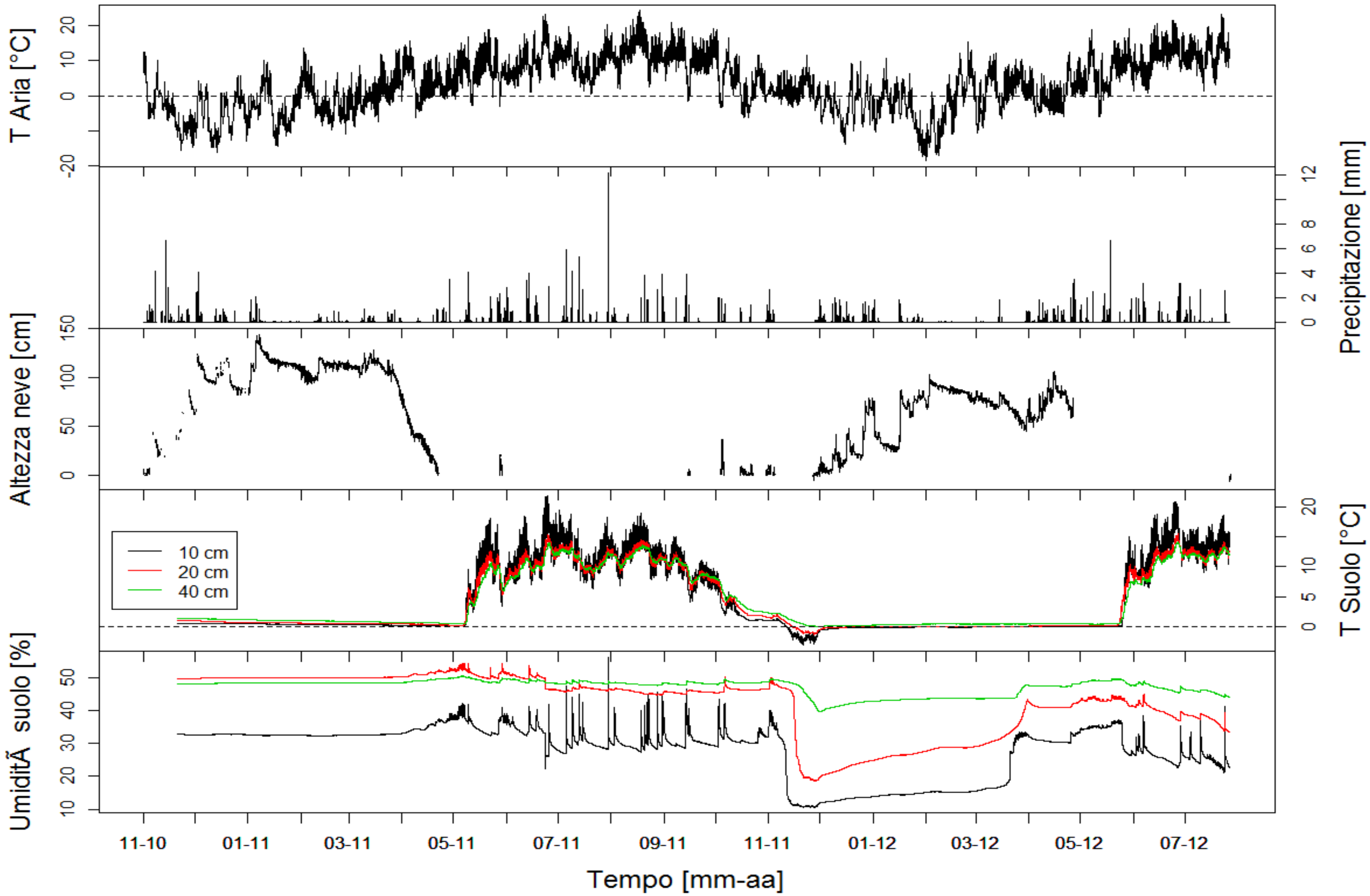


Snow insulation effect

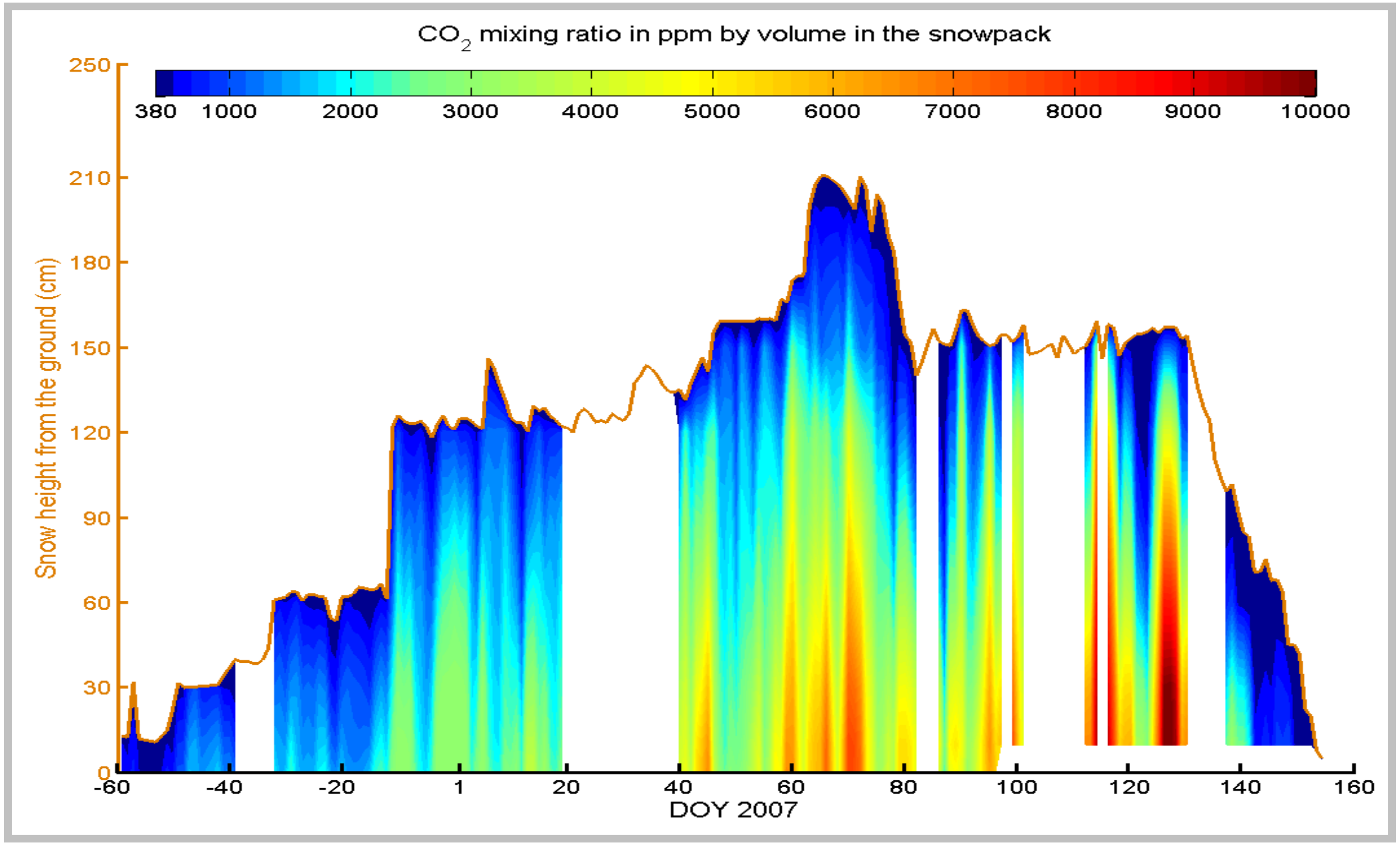
- Low thermal conductivity of snow



Courmayeur **2076 m asl**

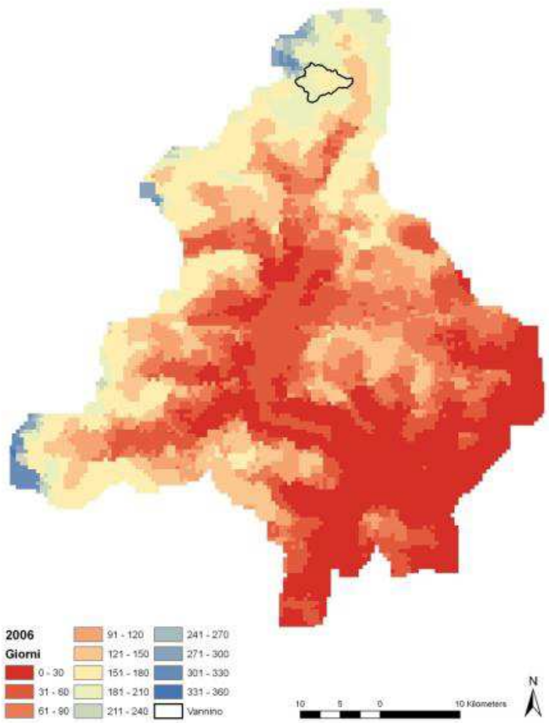


Soil CO2 emission



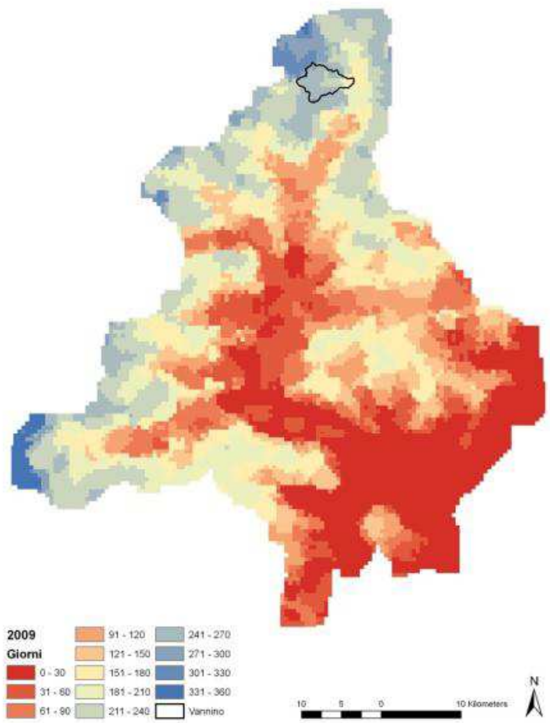
Snow cover at 2000 m asl

151-180 days



2006

241-270 days



2009

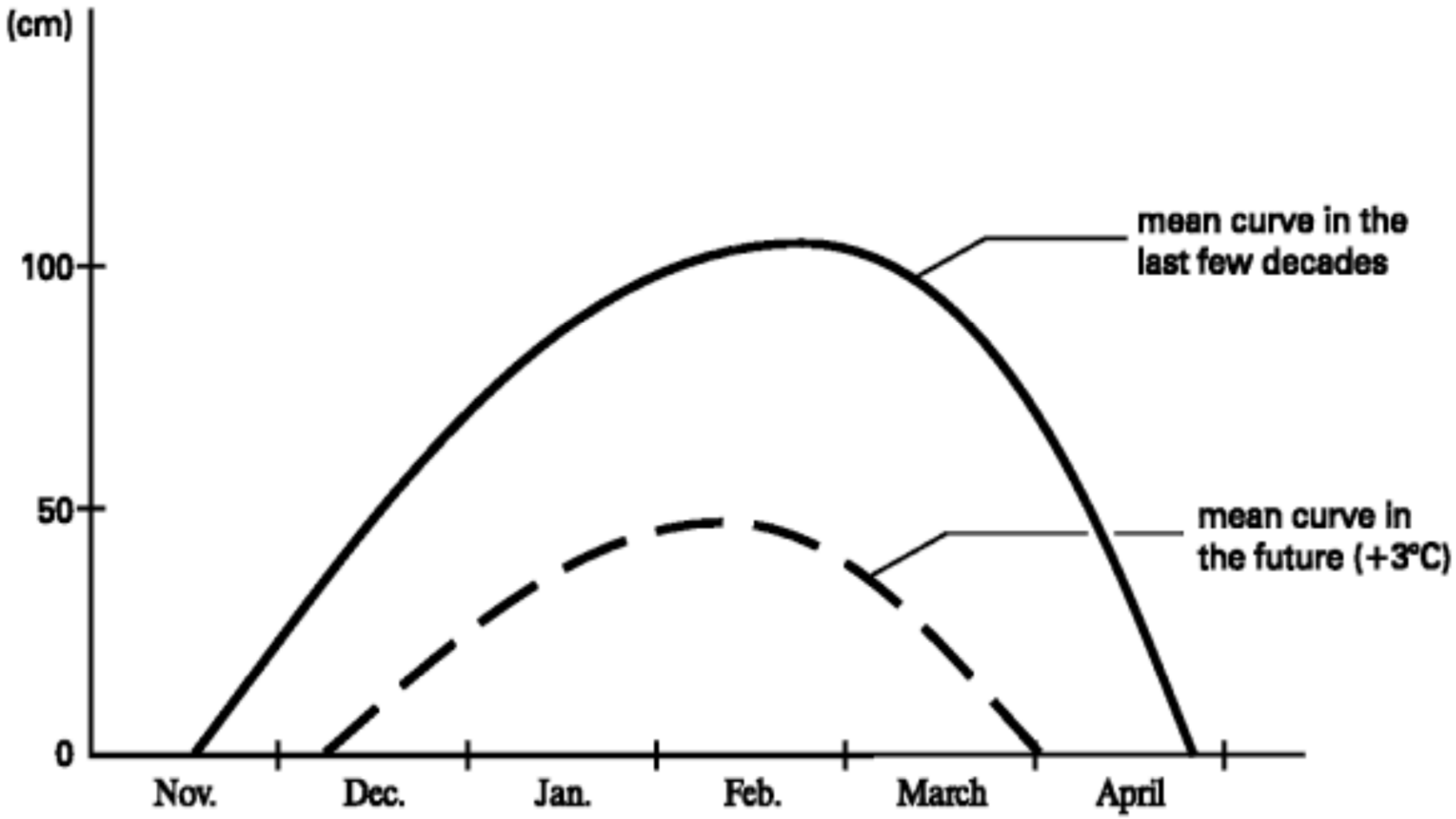
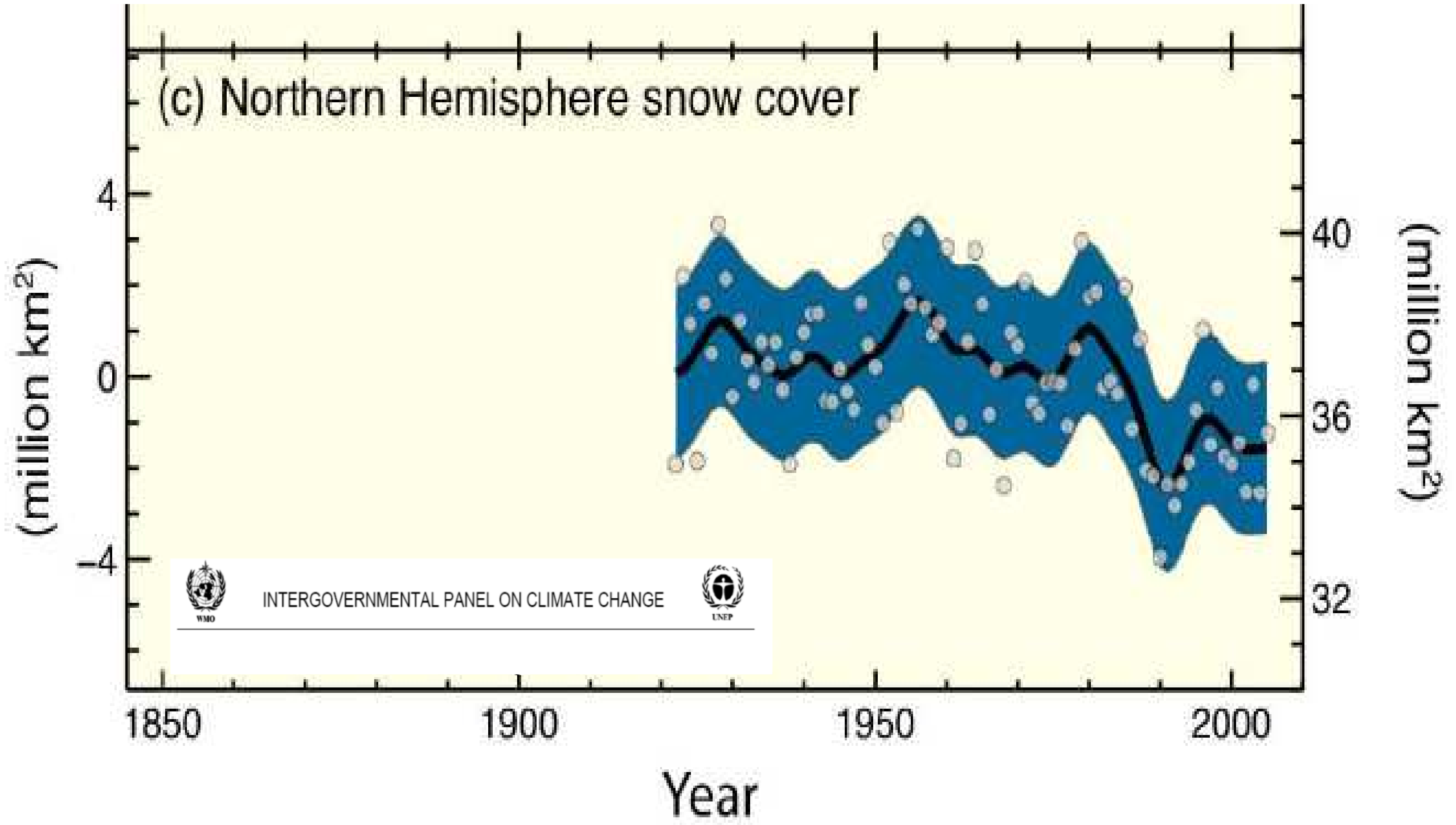
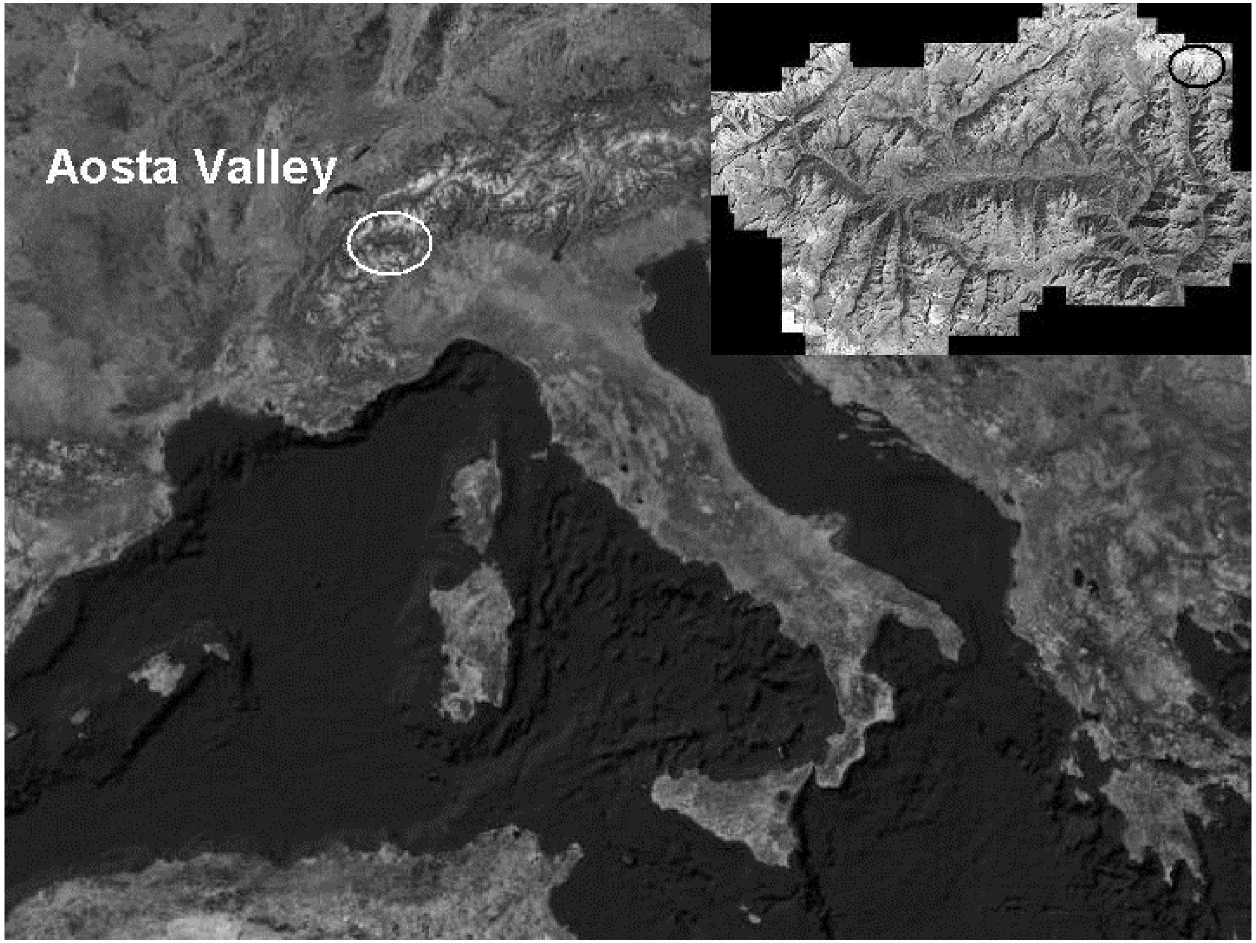
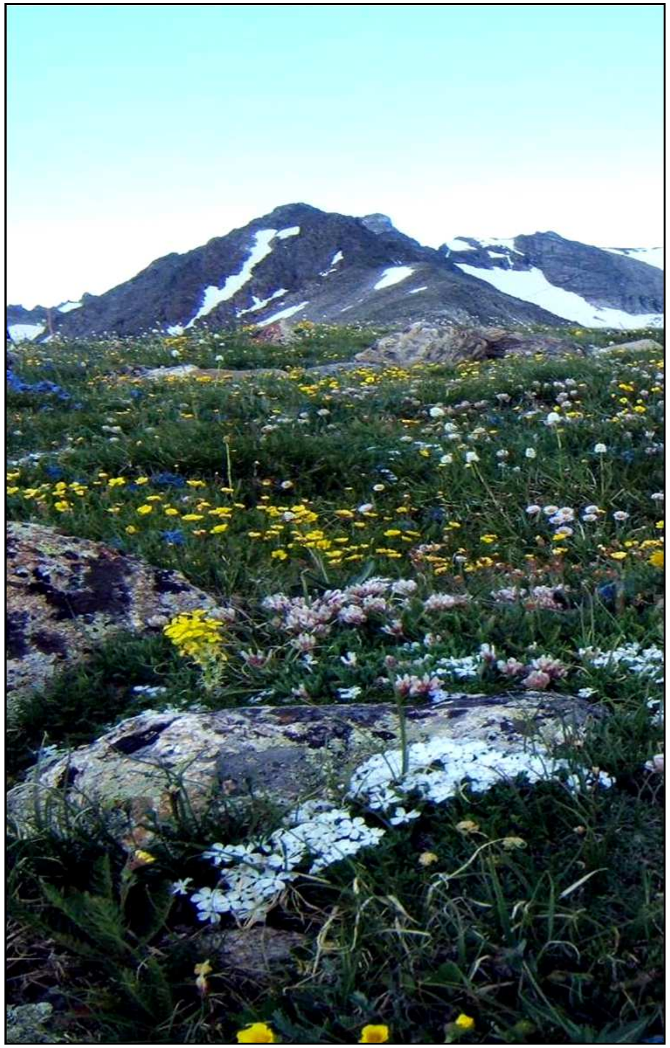


Figure 5 Snow depth and duration of snow cover at an altitude of 1500m in the last decades and in the future (schematic illustration). *Source*: Foehn, 1991


(c) Northern Hemisphere snow cover
4
0
−4
(million km2)
40
36
32
(million km2)
1850
1900
1950
2000
Year
INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE
WMO
UNEP

The study site

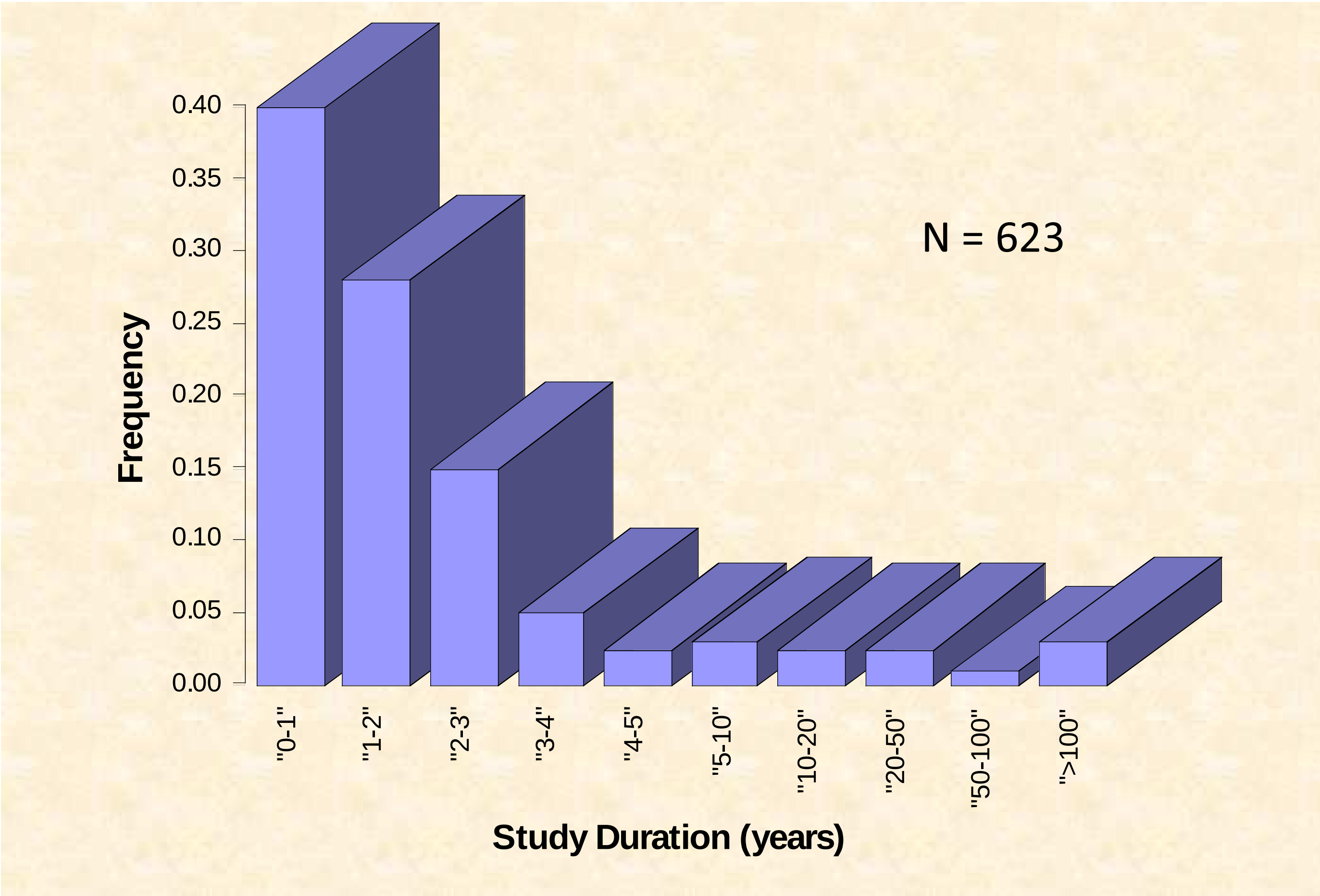




Outline

- The need for long-term research
- Niwot Ridge LTER examples
- LTER program overview
- Recommendations for developing long-term research programs

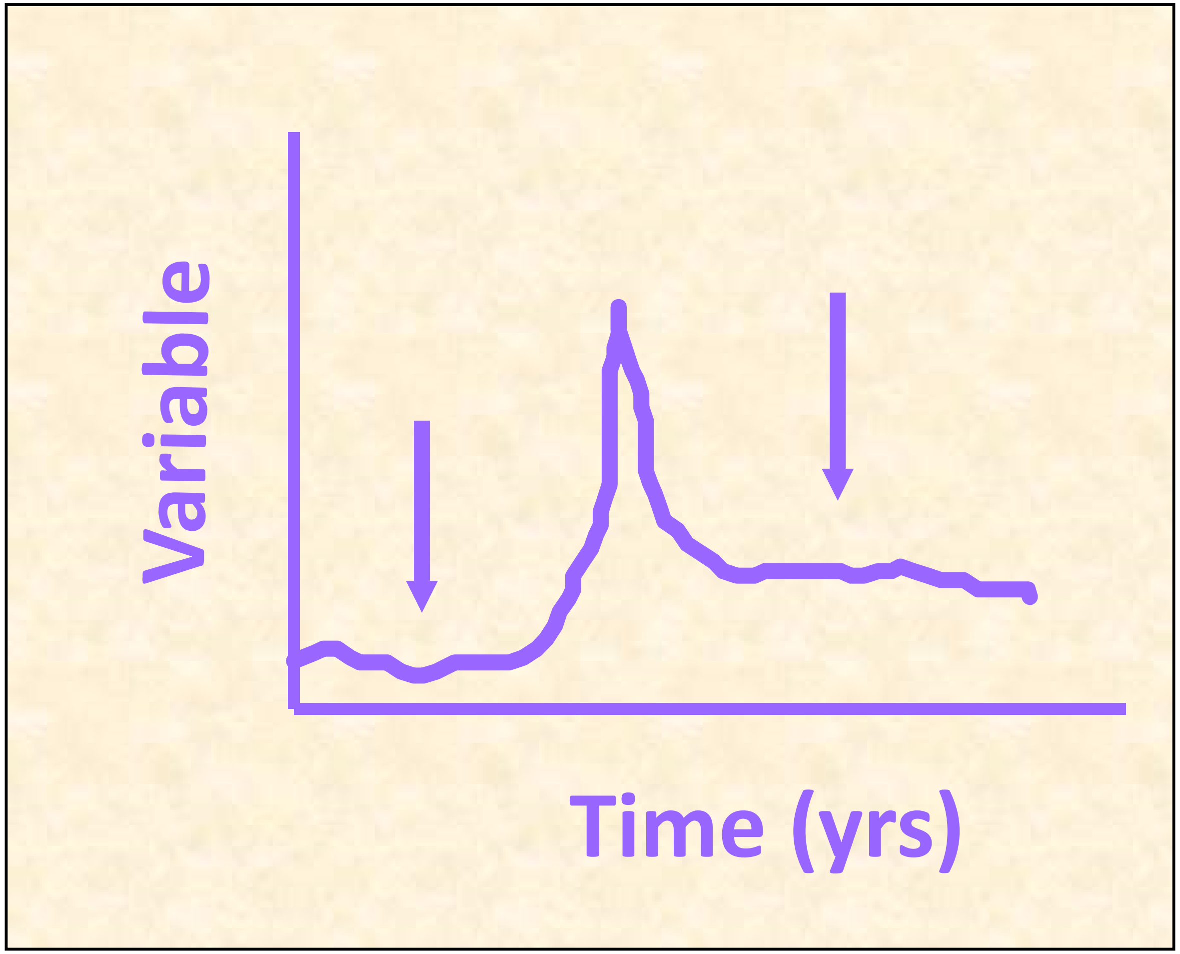
Duration of all observational and experimental studies



Eighty percent of studies in the ecological literature last less than three years

From Tilman, D. 1989. Ecological experimentation: strengths and conceptual problems. pp. 136-157. In Likens, G.E. (ed). Long-Term Studies in Ecology. Springer-Verlag, New York.

Only 10 percent of studies capture unusual events



Unusual events reset systems. Short-term studies initiated before and after a rare event are viewing different system states.

High-elevation areas are important bellwethers of global change: we need long-term research

LTER Europe
LTER Italia

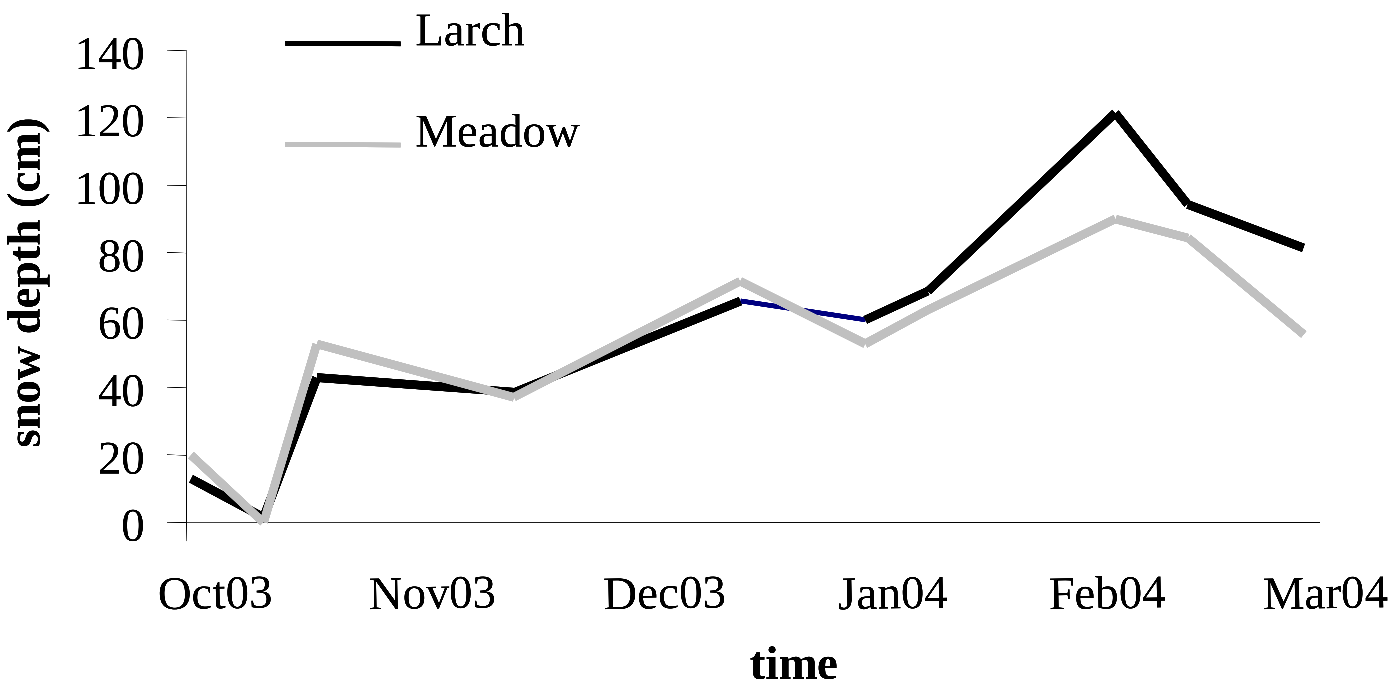
- Valle del Lys, montane forest (*Larix decidua*) and meadow
- 1450 m asl
- MAAT: +4°C
- MAP: 1100 mm
- Inceptisols

Winter 2003-2004: Altered snow regime by snow shovelling

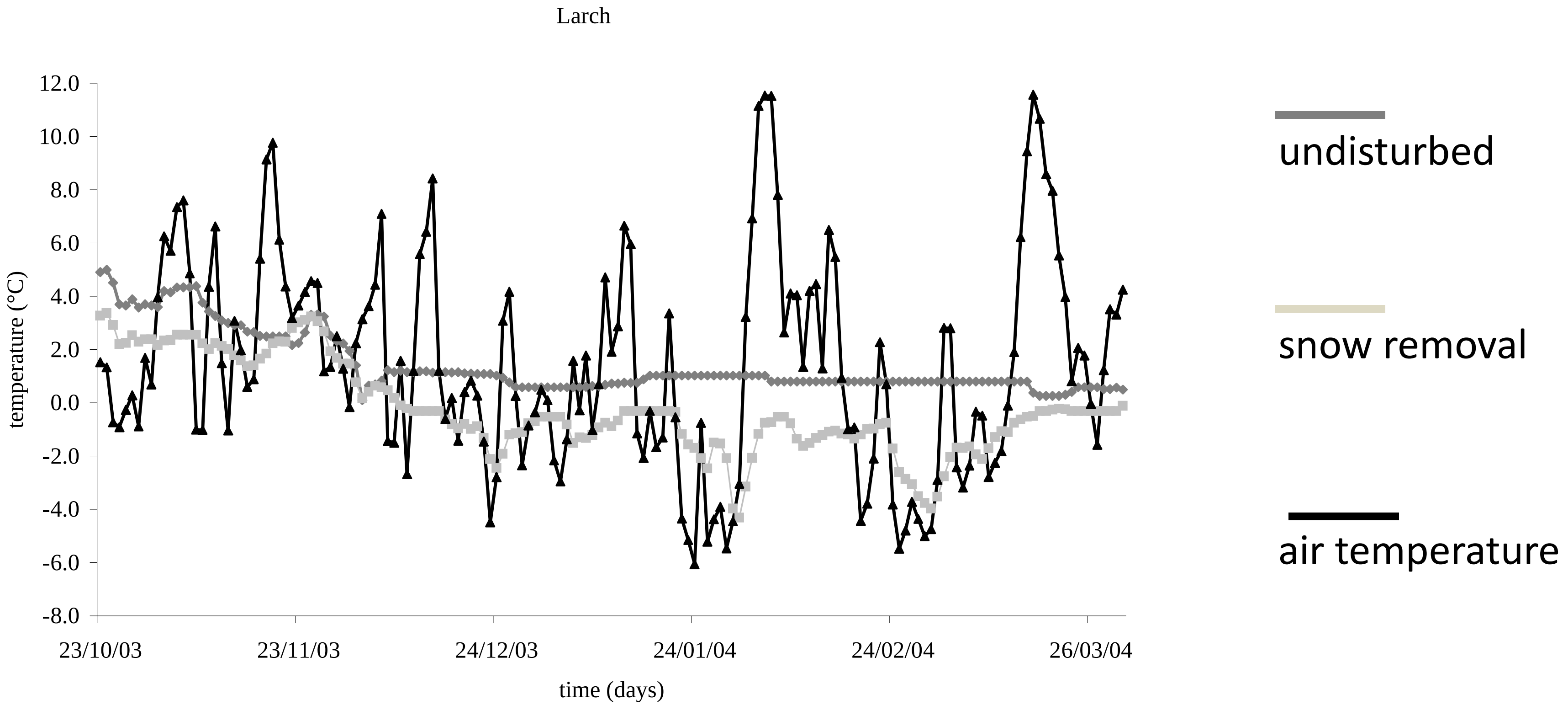
Winter 2003-2004: The snow removal sites

- Larch and meadow
- *Buried bag technique* (Eno, 1960; Adams et al., 1989)
- 10 cm depth
- Soil C and N forms
- Soil temperature

Winter 2003-2004: The undisturbed site



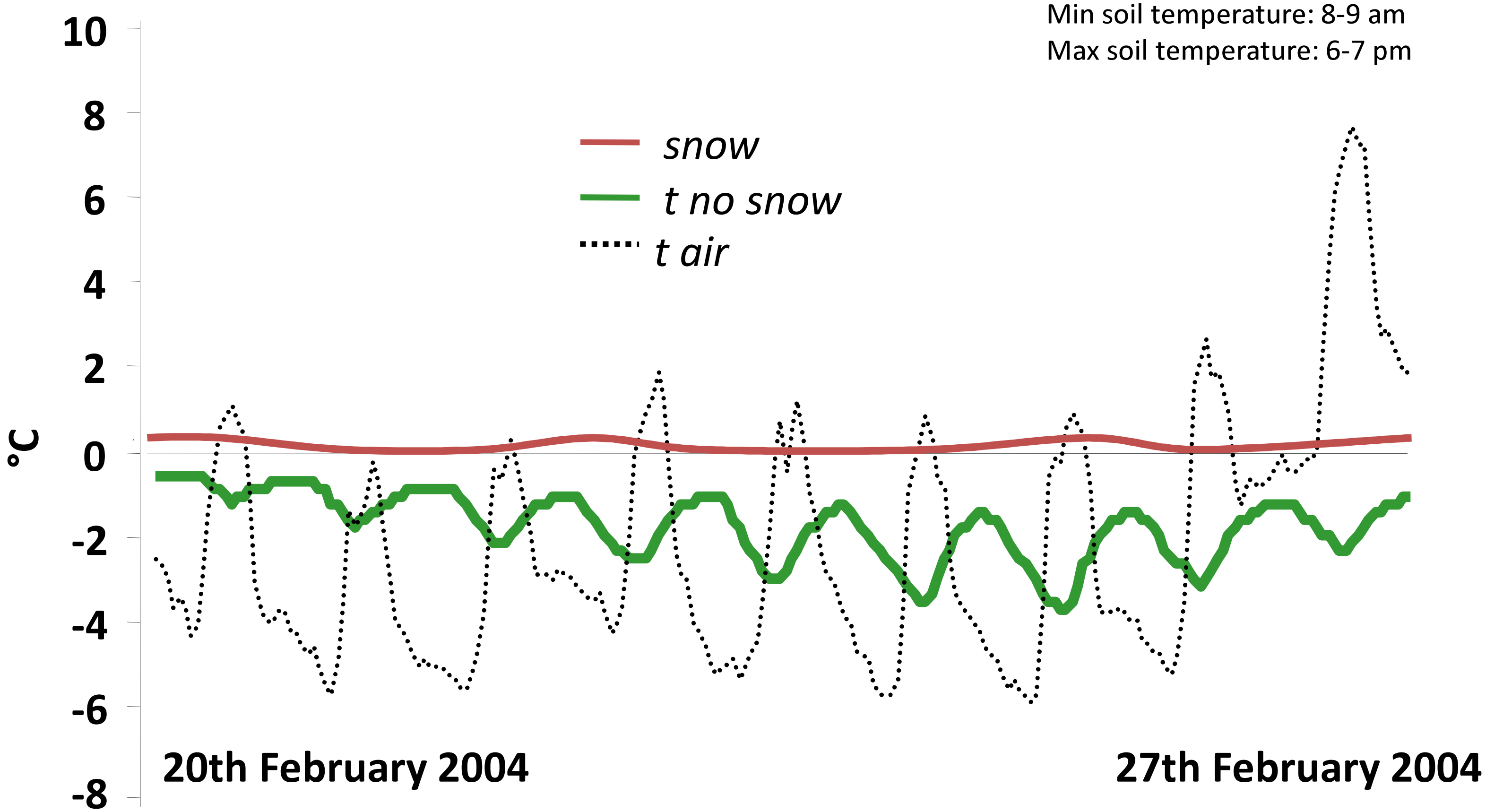
Winter 2003-2004: Soil and air temperature



Soil and air temperature

Min air temperature: 6-7 am
Max air temperature: 3-4 pm

Min soil temperature: 8-9 am
Max soil temperature: 6-7 pm



▪During the winter 2003-2004 our snow removal manipulation produced relatively **mild freezing events** (soil temperatures seldom decreased below –4°C) but the effects were significant during spring time…..


With snow


Without snow

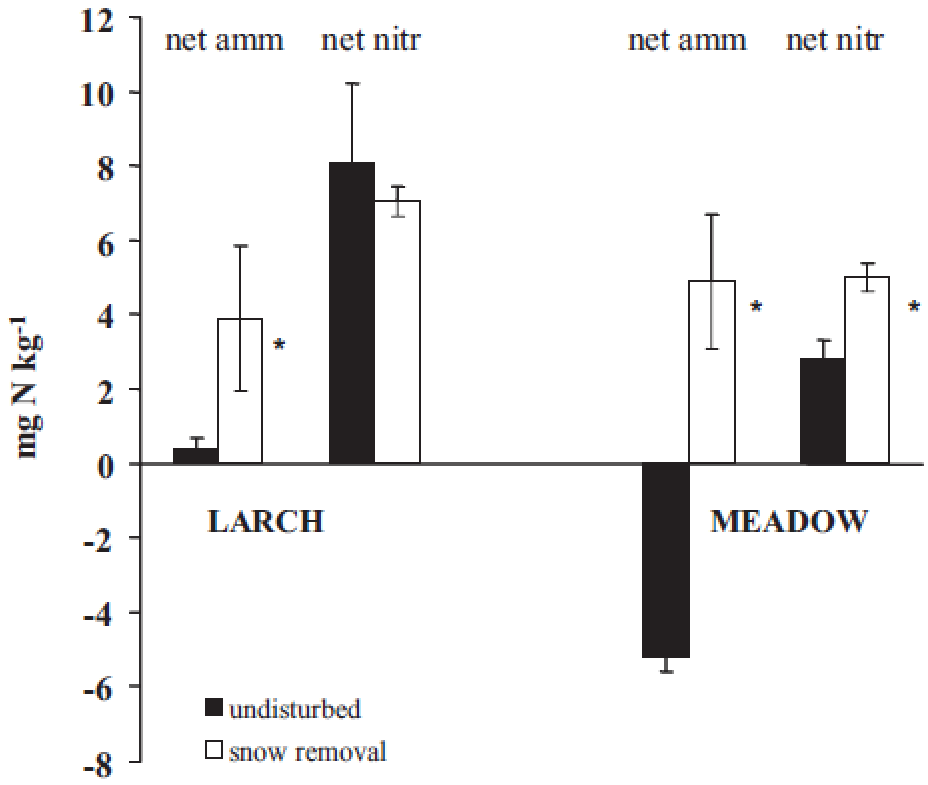


Figure 6: Net ammonification (net amm) and net nitrification (net nitr) recorded in the soil under meadow and under larch. Asteriscs indicate significant differences between treatments (one-way ANOVA, $p < 0.05$).

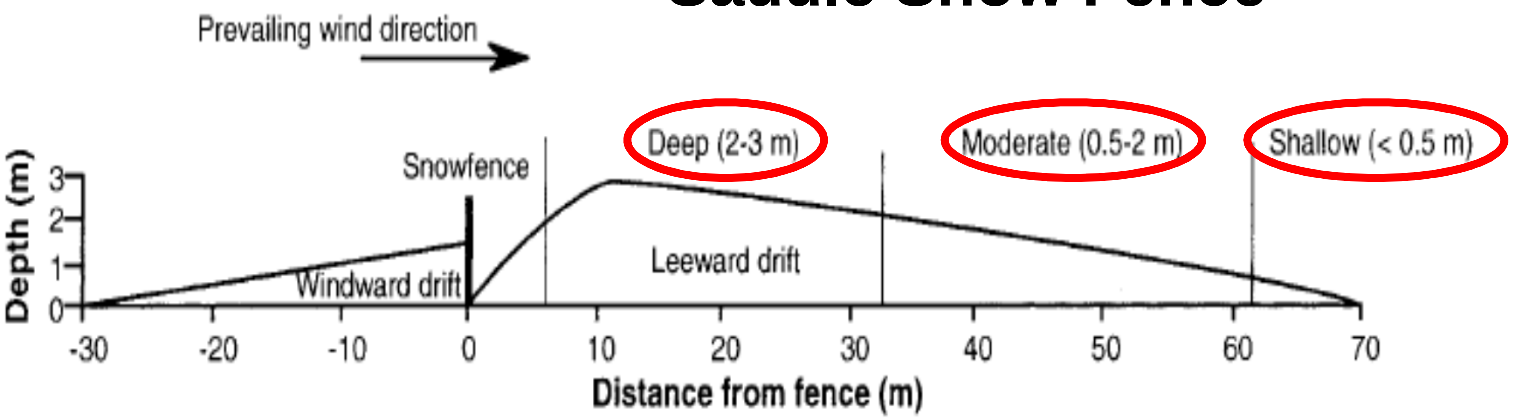

Political Map of USA
N
CANADA
WASHINGTON
OREGON
IDAHO
MONTANA
NORTH DAKOTA
MINNESOTA
SOUTH DAKOTA
WYOMING
NEVADA
CALIFORNIA
UTAH
COLORADO
NEBRASKA
IOWA
KANSAS
MISSOURI
ILLINOIS
INDIANA
OHIO
WISCONSIN
MICHIGAN
NEW YORK
PENNSYLVANIA
MAINE
NEW HAMPSHIRE
VERMONT
MASSACHUSETTS
RHODE ISLAND
CONNECTICUT
NEW JERSEY
MARYLAND
DELAWARE
WEST VIRGINIA
VIRGINIA
KENTUCKY
NORTH CAROLINA
TENNESSSEE
SOUTH CAROLINA
ARIZONA
NEW MEXICO
OKLAHOMA
ARKANSAS
MISSISSIPI
ALABAMA
GEORGIA
TEXAS
LOUISIANA
FLORIDA
MEXICO
Pacific Ocean
Atlantic Ocean
GULF OF MEXICO
ALASKA
CANADA
HAWAII
Pacific Ocean
Map Not To Scale
Copyright © 2006 Compare Infobase Limited

Tundra Lab

- Niwot Ridge, Colorado 3500-4085 m, LTER site
- MAAT: -3.5℃
- Annual precipitation: 1050 mm
- Cryochrepts

Alpine tundra

Saddle Snow Fence



Since 1993:

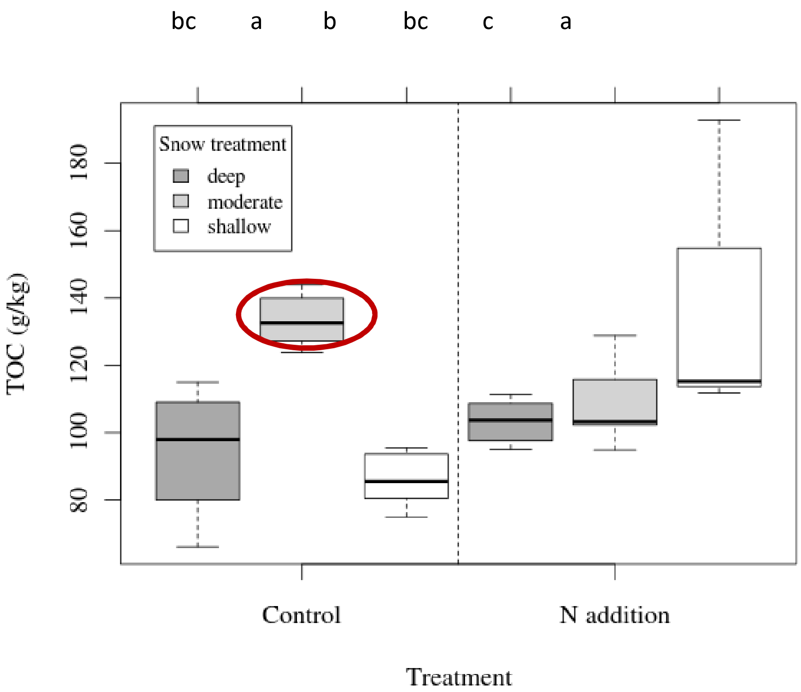
- N addition (20 g N m^{-2})

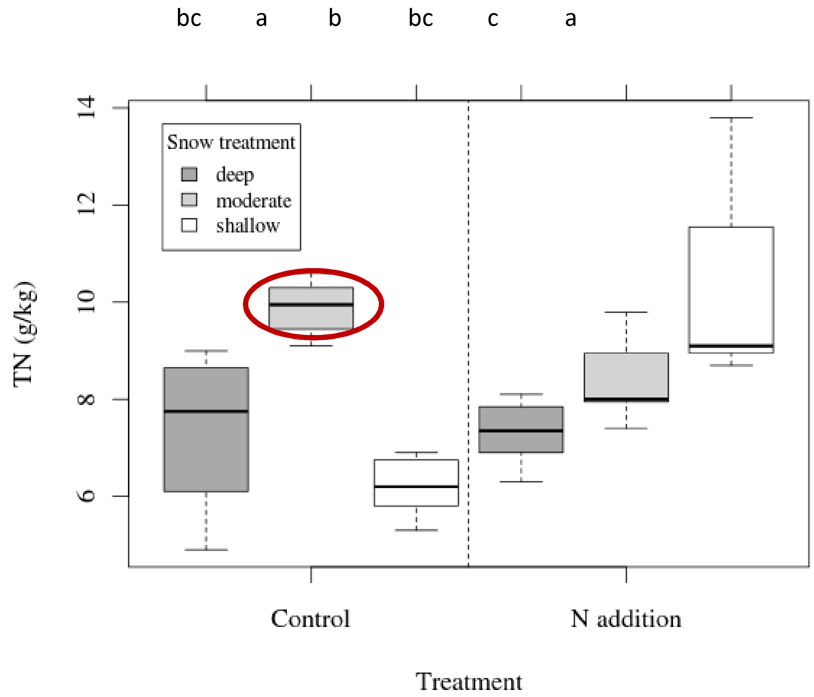
- Soil temperature
- Soil N dynamics
- Soil development

Soil characteristics

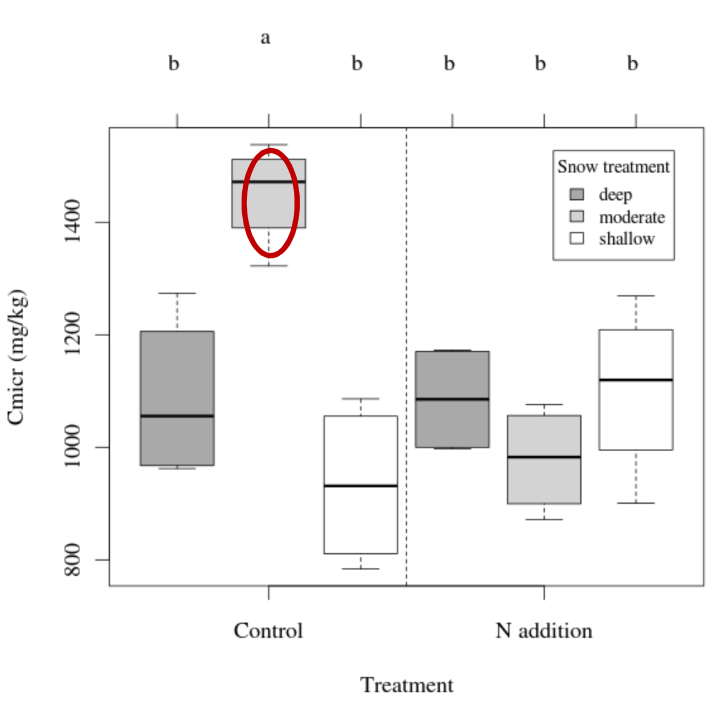
- Organic-rich A horizons
- 7.5YR colors
- Acidic pH
- Weak subangular blocky subsurface structure
- Low base saturation

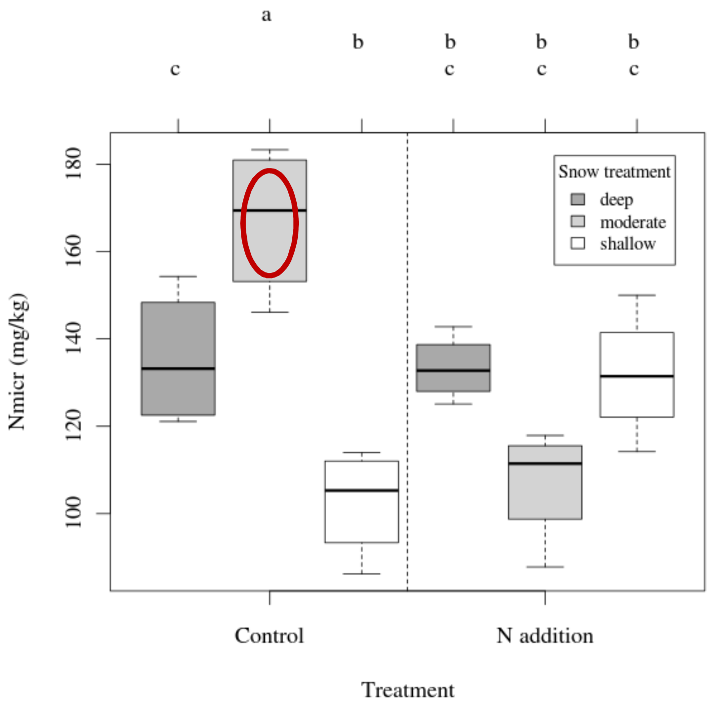
TOPSOIL: TOC and TN





TOPSOIL: Cmicr and Nmicr





Altered snow density

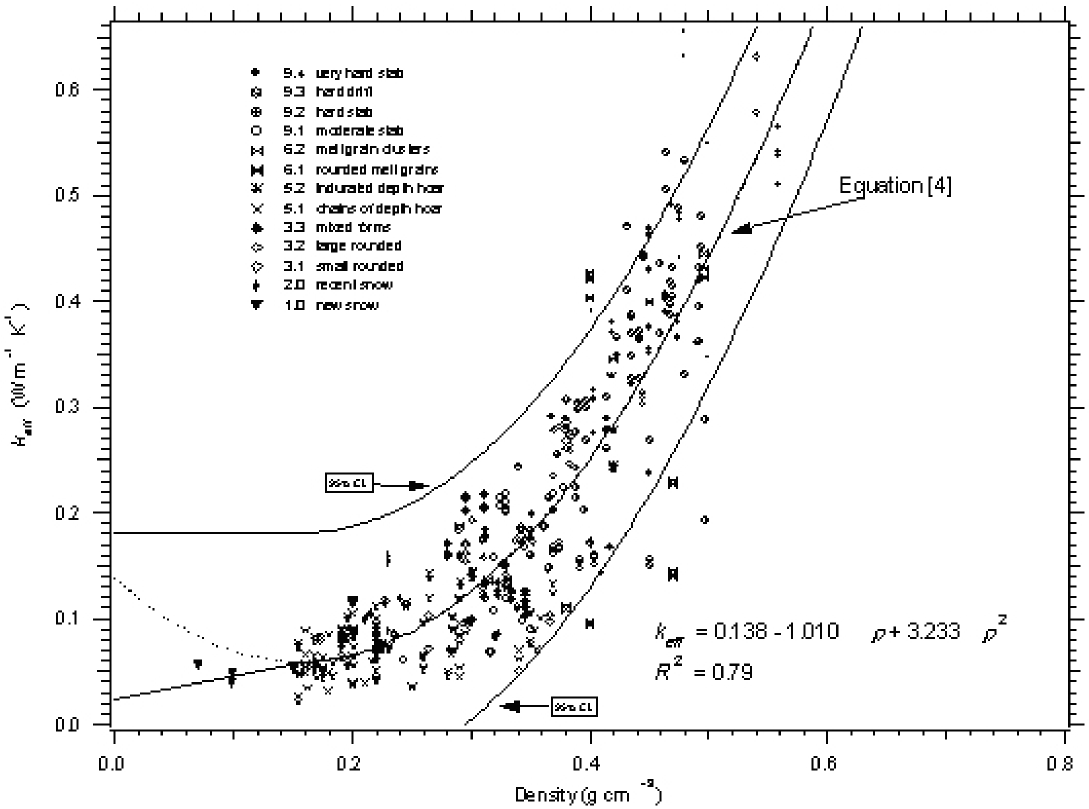
SLF
ENA
SNV
PNL

Increased snow density:

- wet snowfall;
- rain on snow events;
- snow grooming…

Snow density/Soil temperature

A typical thermal conductivity for dry snow with a density of 100 kgm^{-3} is 0.045 $W\ m^{-1}\ k^{-1}$



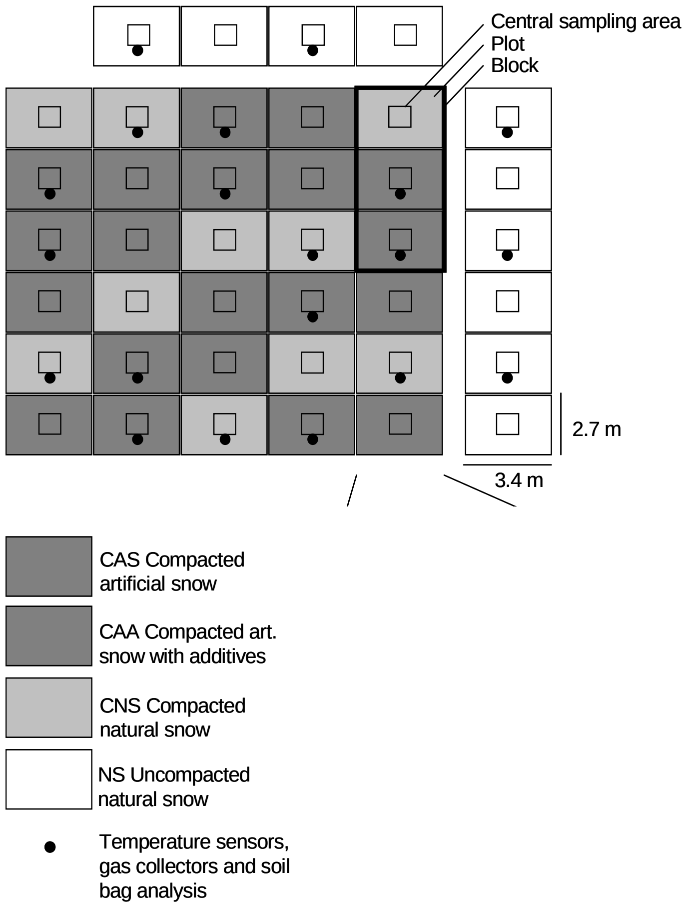
Experimental site

- Davos (CH)
- 1530 m asl
- MAAT: +2.7 °C

- *Buried bag technique* (Eno, 1960; Adams et al., 1989)
- 5-10 cm depth
- Soil temperature

SLF ENA SNV PNL

Experimental site

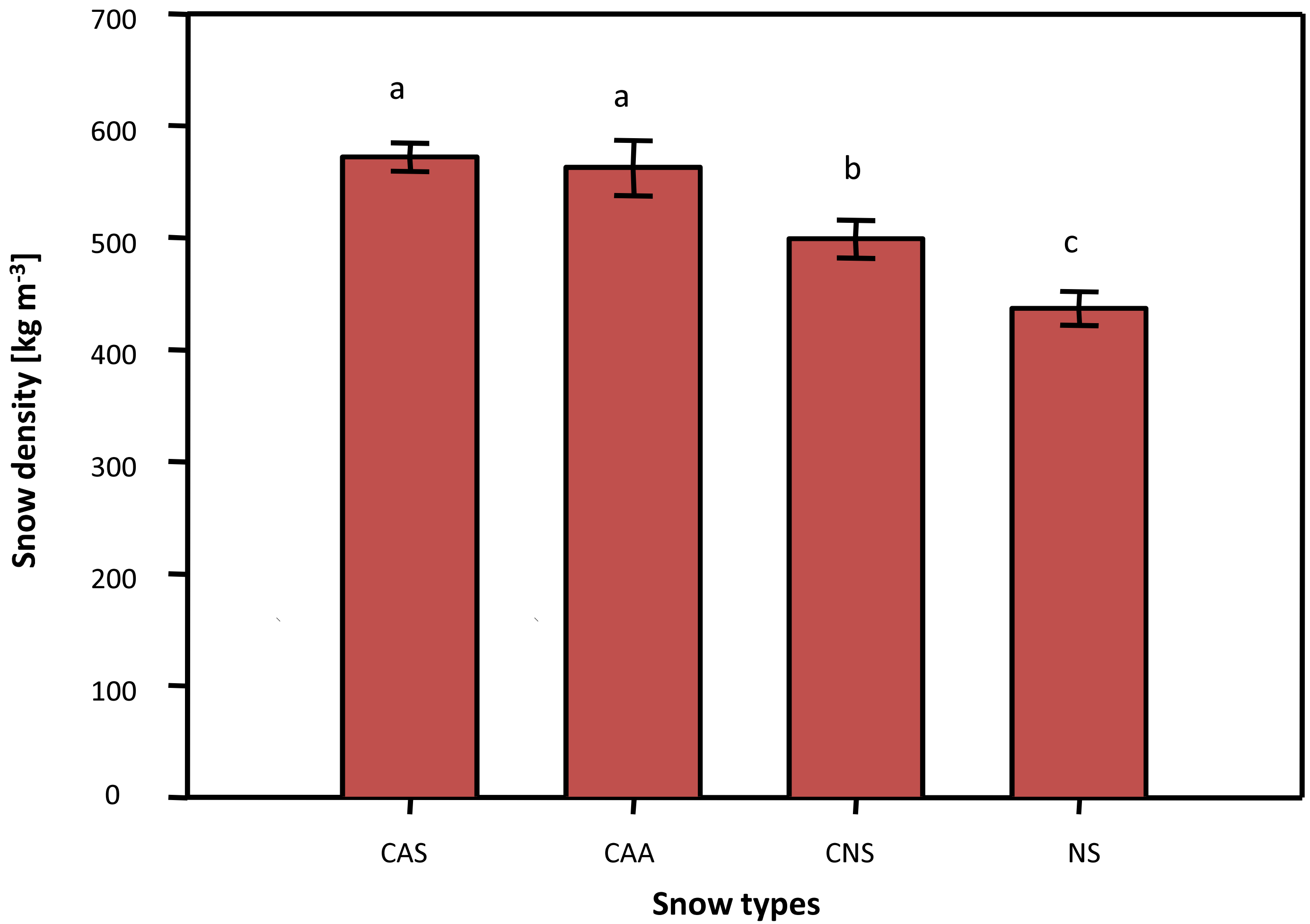


Snow characteristics

- NS: natural snow not groomed

- CAS: artificial snow groomed
- CAA: artificial snow with additivies groomed
- CNS: natural snow groomed

Snow density



Soil temperature

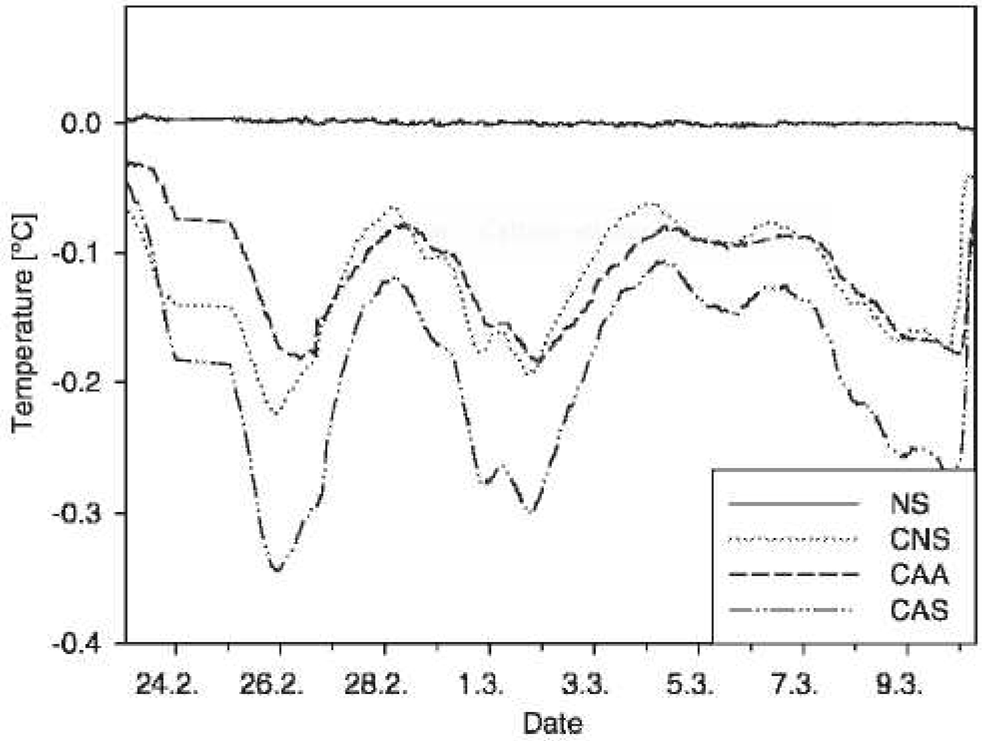
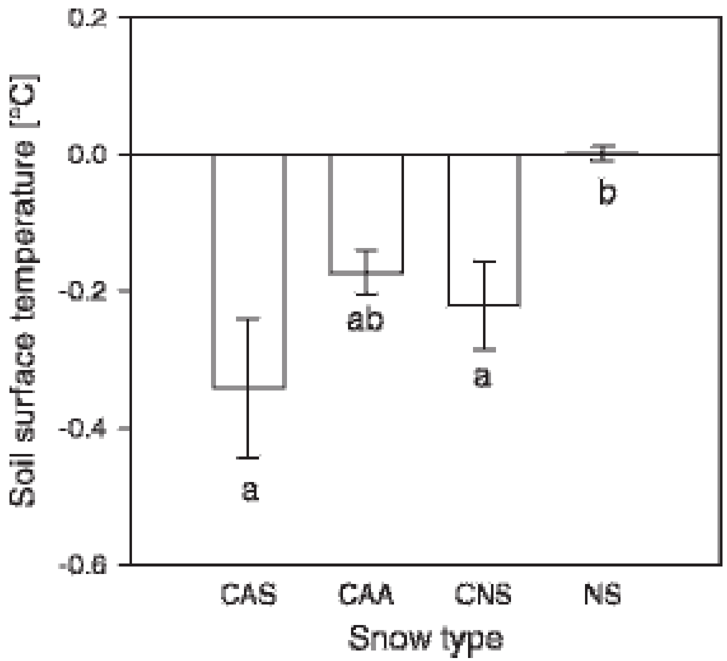
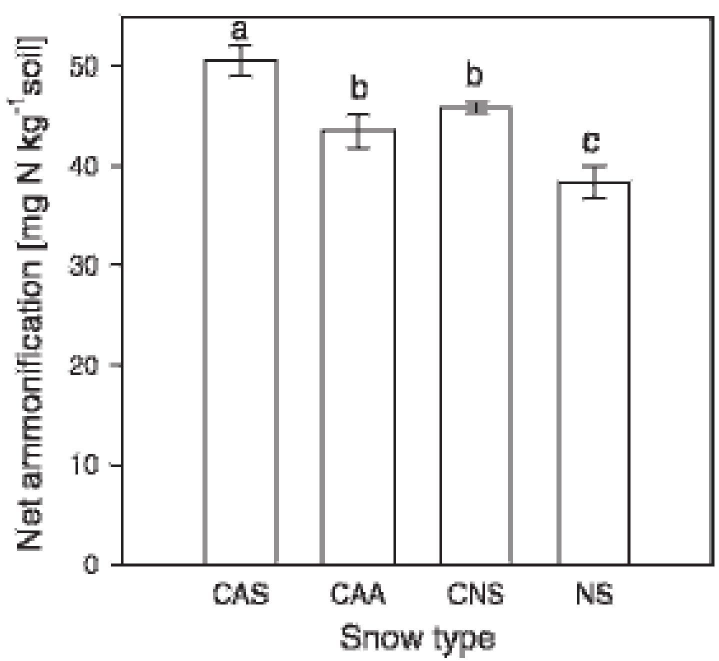


FIGURE 3. Daily mean temperature at the soil surface under the four different snow types for an example period from 23 February to 10 March 2000. Each line represents an average of five plots.

Soil temperature and net ammonification





Snow movements

FAST: SNOW AVALANCHES

SLOW: SNOW GLIDING

- Snow gliding is a downhill motion of snow on the ground (In der Gand and Zupancic, 1966).

- 3 conditions:

1. Snowpack-ground (soil) interface with little roughness
2. A temperature equal to 0°C at the snow/ground (soil) interface, which allows for the presence of free water
3. Slope angle>15°

- Glide cracks are gaping fissures that form when the entire snowpack slowly slides as a unit on the ground

- Glide cracks often don’t produce avalanches but occasionally and unpredictability they release catastrophically as a glide avalanche. The time between crack formation and avalanche release can vary widely (hours to months).

Photo Renzino Cosson, 2009

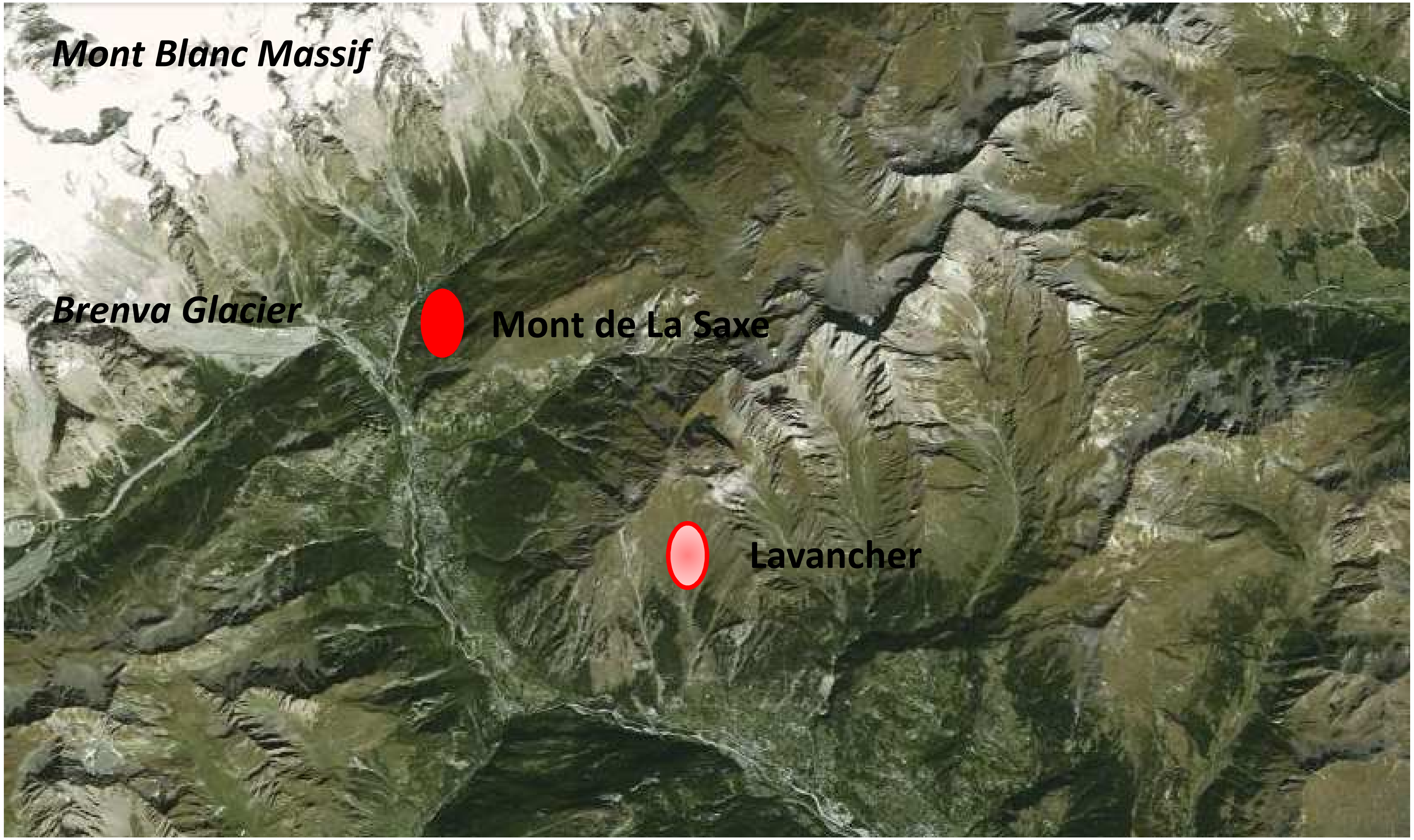
Glide avalanches

- Occur at the ground (soil)-snow interface
- Depend upon free water flowing at the ground (soil)-snow interface

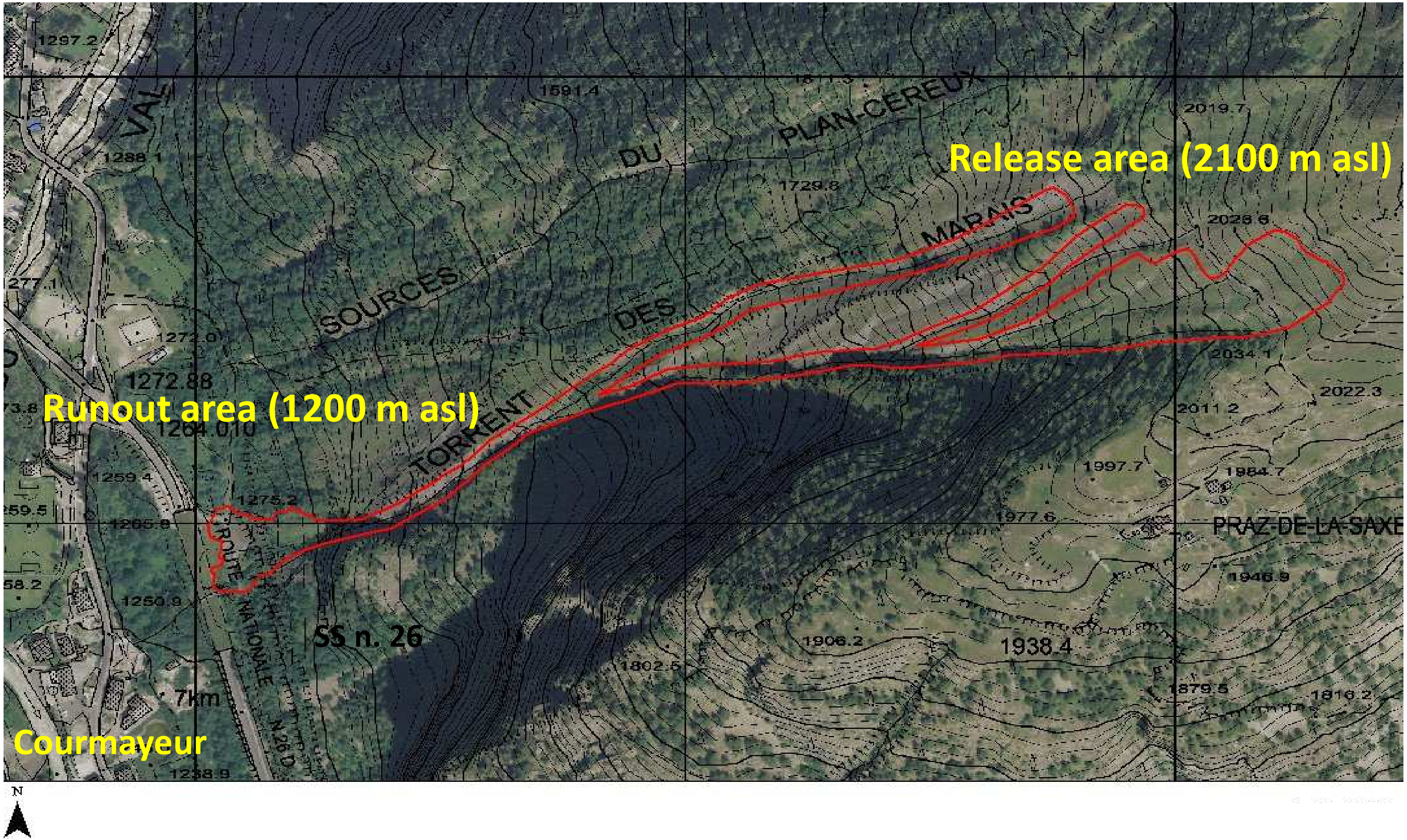
Sediment transport

- When avalanches involve the whole depth of snow or run onto snow-free areas they may incorporate large amounts of soil, organic and rock debris

The study sites



Mont de La Saxe



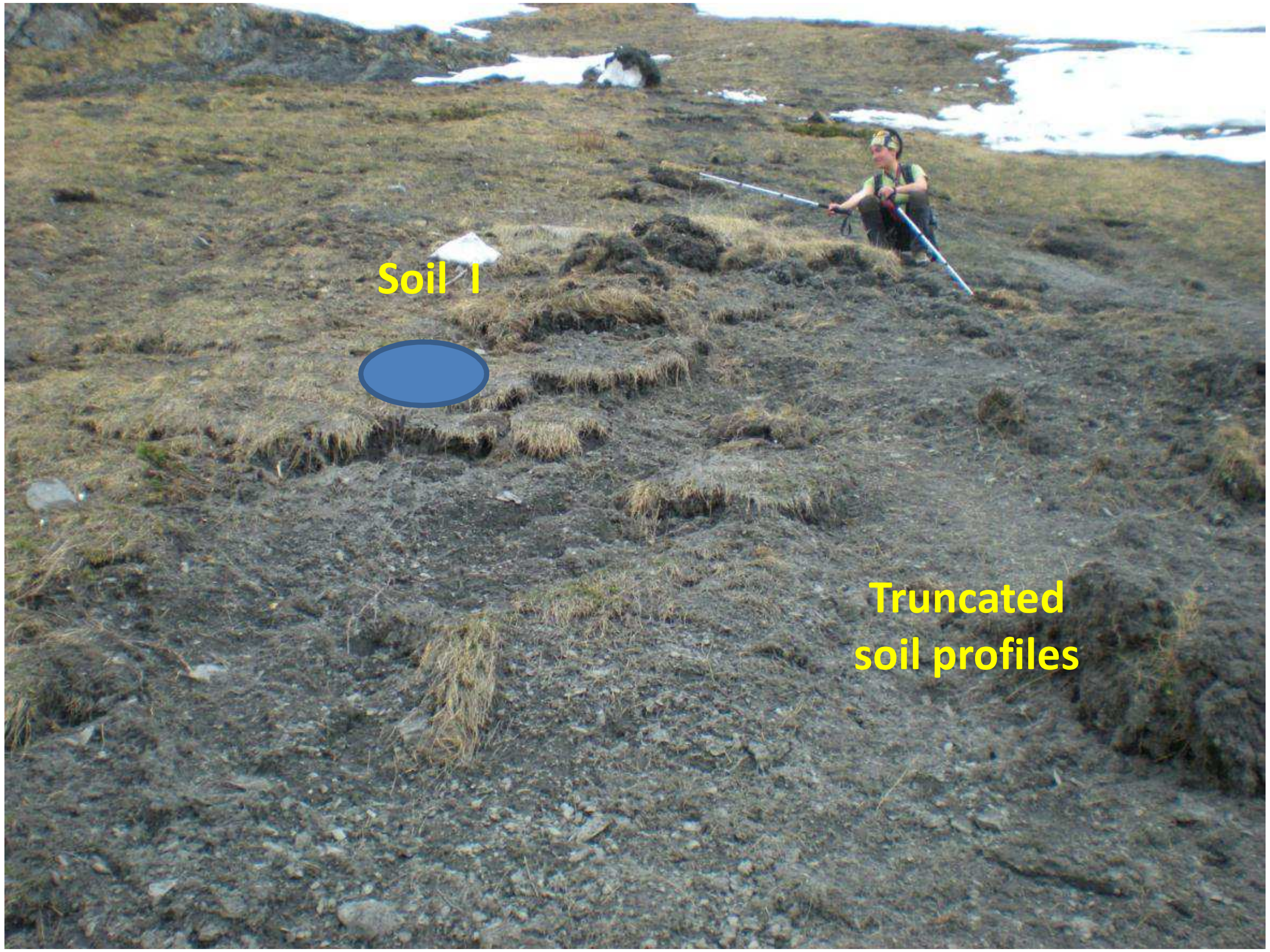

Glide Avalanche site
Snow bridges site
Photo Renzino Cosson

Glide avalanche site (Release area)

- soil surface features

Glide avalanche site (Release area)

- soil characteristics



Glide avalanche site (Release area)

- soil characteristics (I)

PL=plastic limit
LL=liquid limit
IP=plasticity index

Soil Package: A1, A2 — Sliding Surface: AB

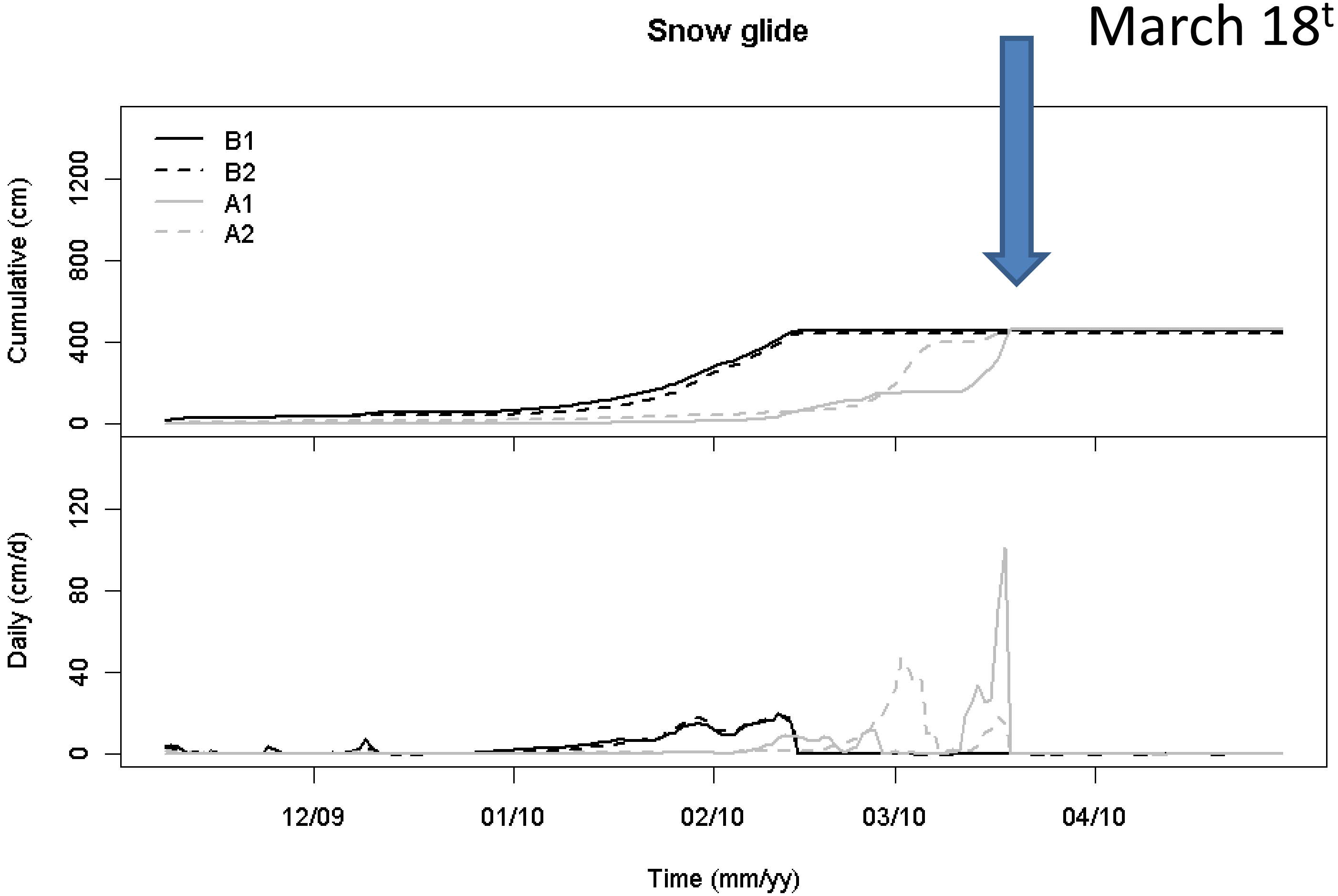
	A1	A2	AB
Depth (cm)	0-10	10-20	20-35
Rocks (%)	5	49	31
Roots	many	many	few
TOC (%)	6.0	3.7	2.1
LL (%)	72	59	55
PL (%)	59	48	38
IP (LL-PL)	13	11	17
Sand (%)	52.1	47.1	51.1
Silt (%)	29.5	35.3	31.9
Clay (%)	18.4	17.6	17.0

Glide avalanche site (Release area)

- snow gliding measurements

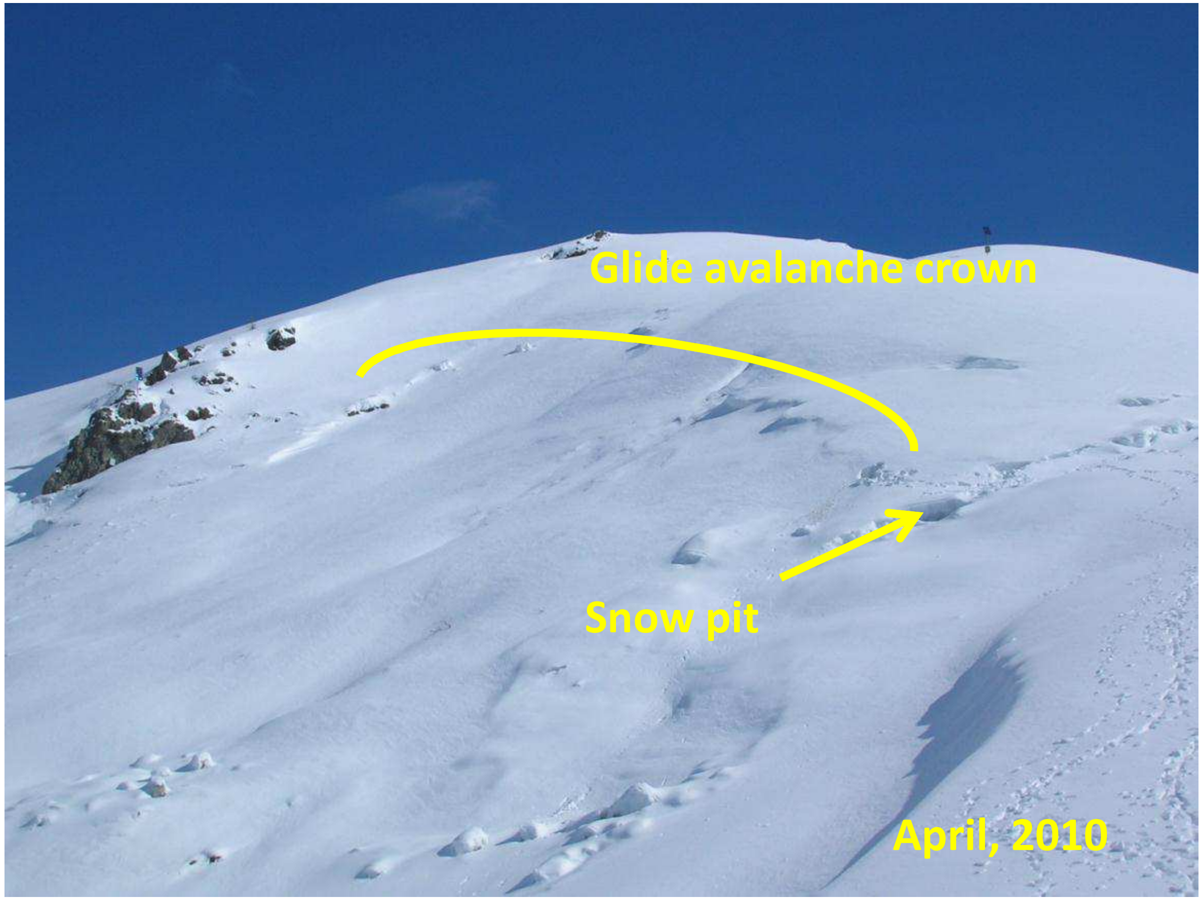
Glide avalanche site (Release area)

Glide avalanche release
March 18th, 03.40 pm



Glide avalanche site (Release area)

- snow/soil interface characteristics

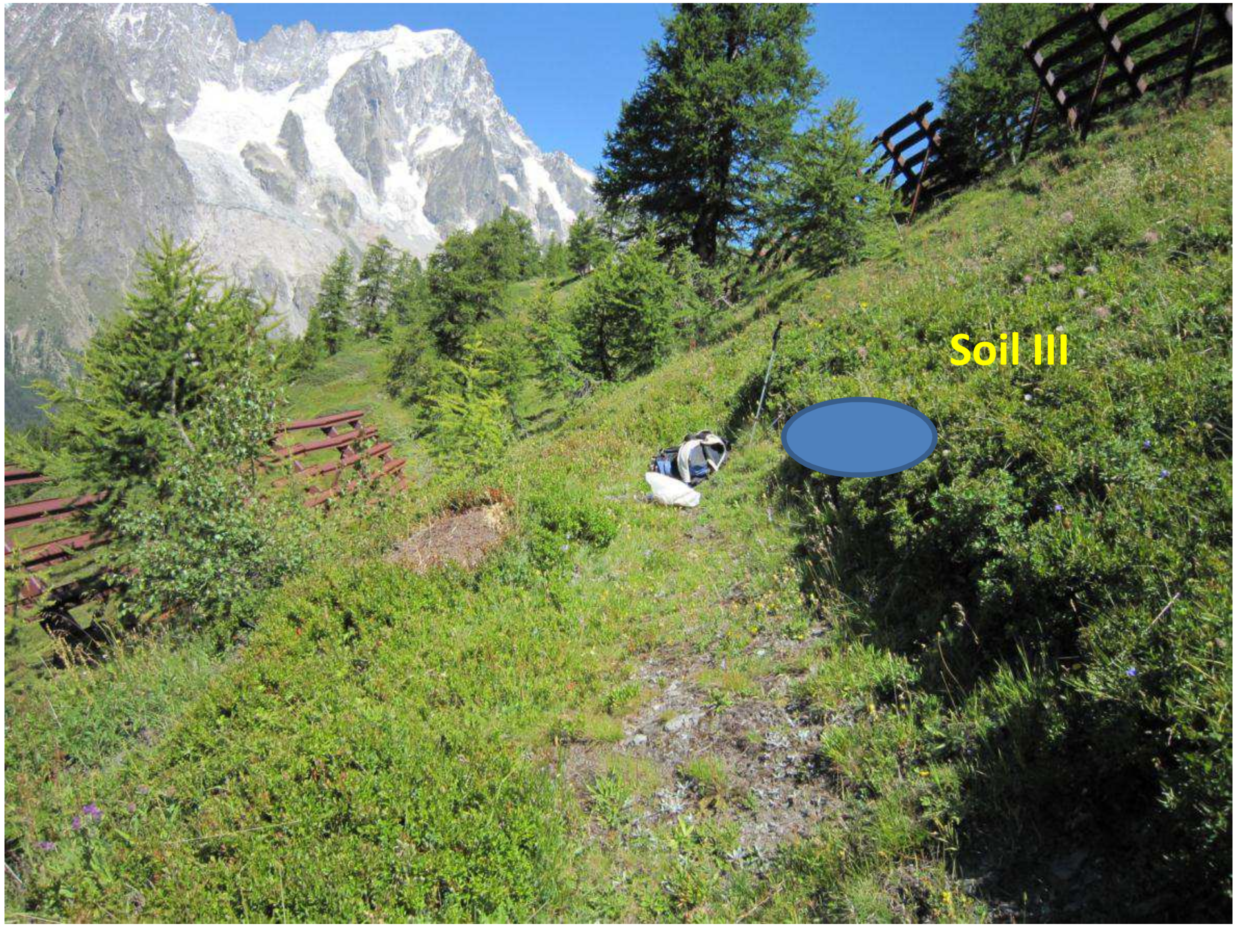


Glide avalanche site (Release area)

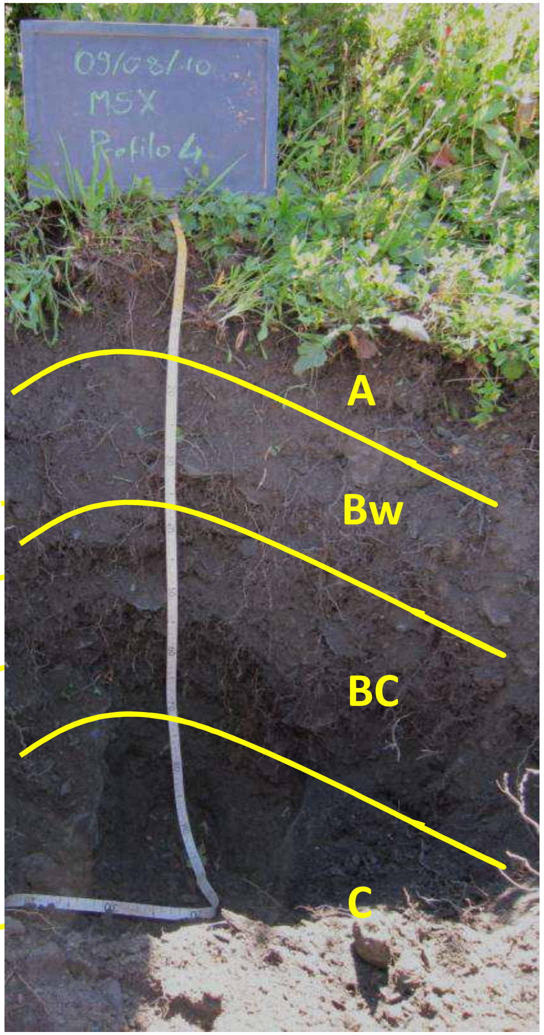
- snow/soil interface characteristics

→ The formation of a soft slushy soil film may influence the snow gliding mechanism

The snow bridges area



The snow bridges area



Soil III

	A	Bw	BC	C
Depth (cm)	0-10	10-30	30-60	60-85+
Rocks (%)	16	36	64	54
pH	5.1	4.5	4.6	4.9
TOC (%)	13.6	4.5	2.6	1.2
TN (%)	1.0	0.4	0.3	0.1
Sand (%)	52.2	43.5	62.2	72.4
Silt (%)	31.2	39.3	30.1	24.3
Clay (%)	16.6	17.2	7.7	3.3

Take-home messages (I)

- The increase of snow density caused a reduction of soil temperature (mild freezing), less important than that recorded in the absence of the snow cover.

- Mild soil freezing determined an increase of net ammonification and net nitrification.

- Long-term changes in snow properties may affect alpine soil characteristics. A greater content of soil organic matter and microbial biomass occurred under the moderate snow cover, than under shallow and deep snowpacks.

Take-home messages (II)

- The formation of a soft slushy soil film may influence the snow gliding mechanism (3.5 - 4.4 cmd-1): the more this film is thick the more the ground roughness is limited.

- The sediment transport by dirty snow avalanches is significant (several Mg).

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