

Curso de sismología ambiental

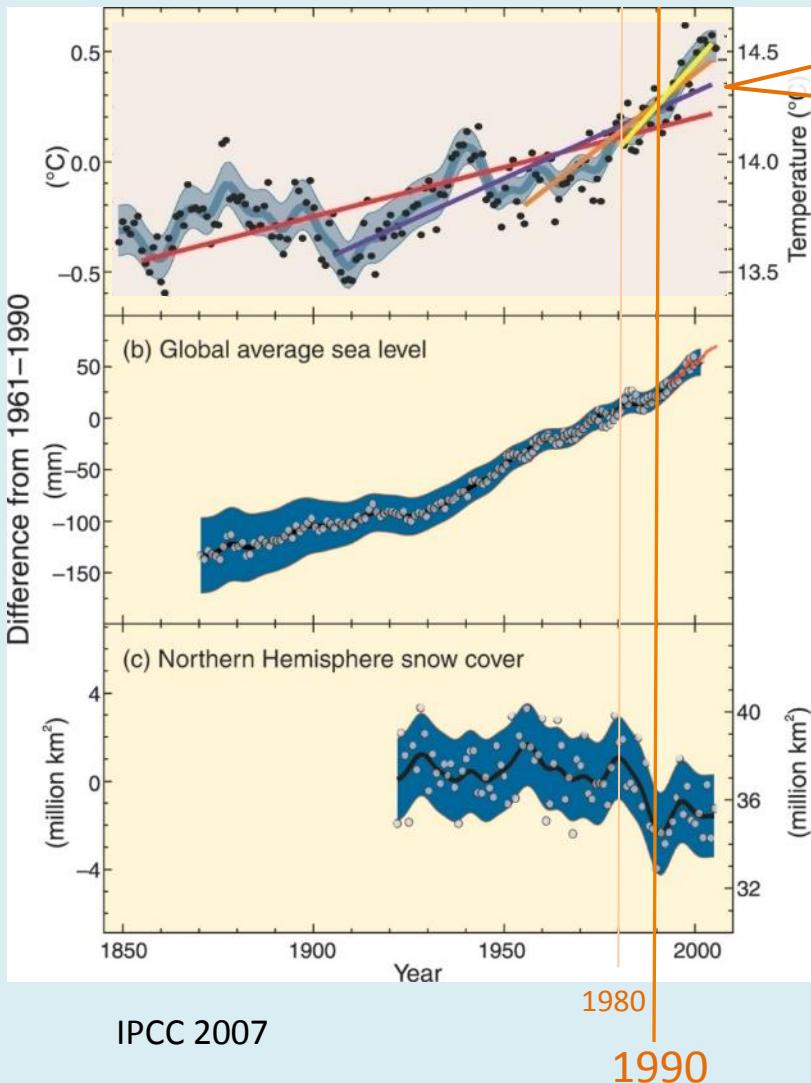
*Características, tipologías y impacto
de los Procesos Geológicos Superficiales (PGS)*

5 – Natural Instability in Glacial and Periglacial Alpine
Areas under a Changing Climate

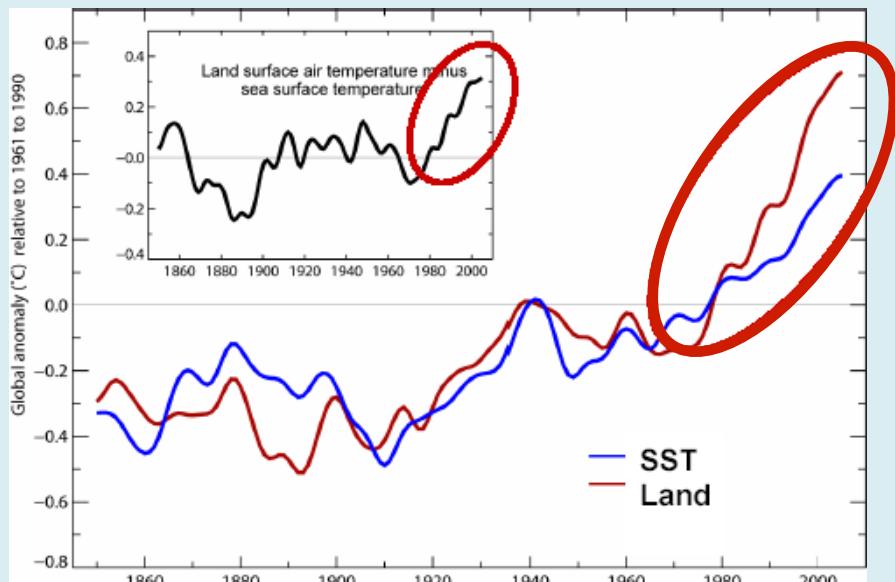
Velio Coviello - vcoviello@geociencias.unam.mx

Thanks to Marta Chiarle, CNR IRPI (Italy)

Very few scientists now question the conclusion drawn by the Intergovernmental Panel on Climate Change that Earth's climate is changing and is likely to become warmer throughout this century

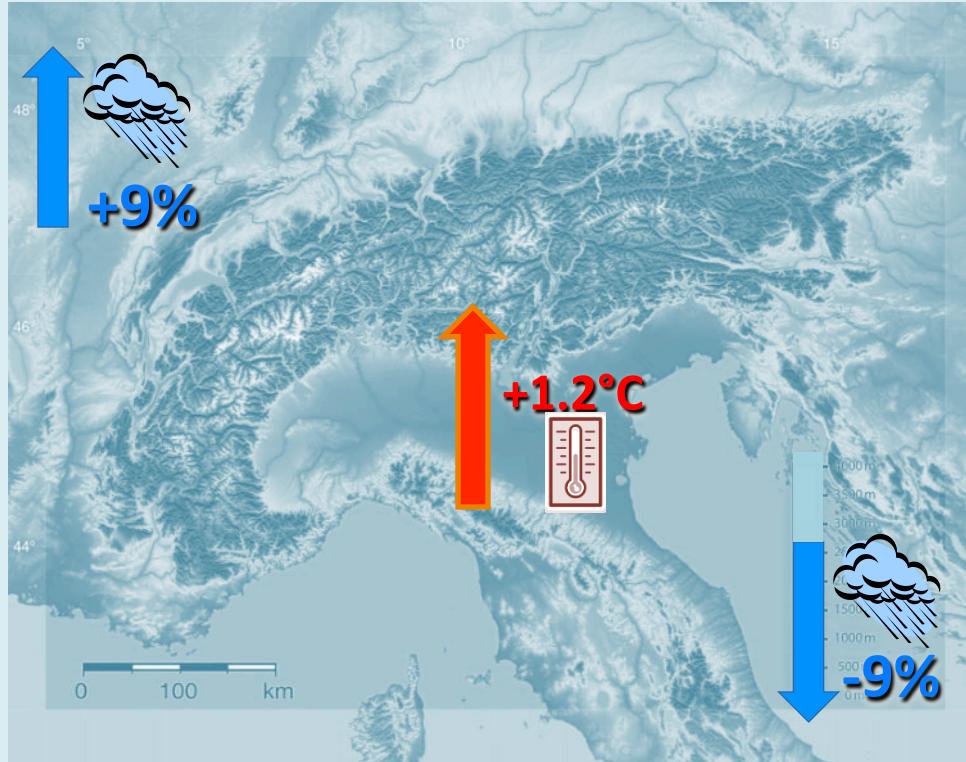


Warmest 12 years:
1998, 2005, 2003, 2002, 2004, 2006,
2001, 1997, 1995, 1999, 1990, 2000



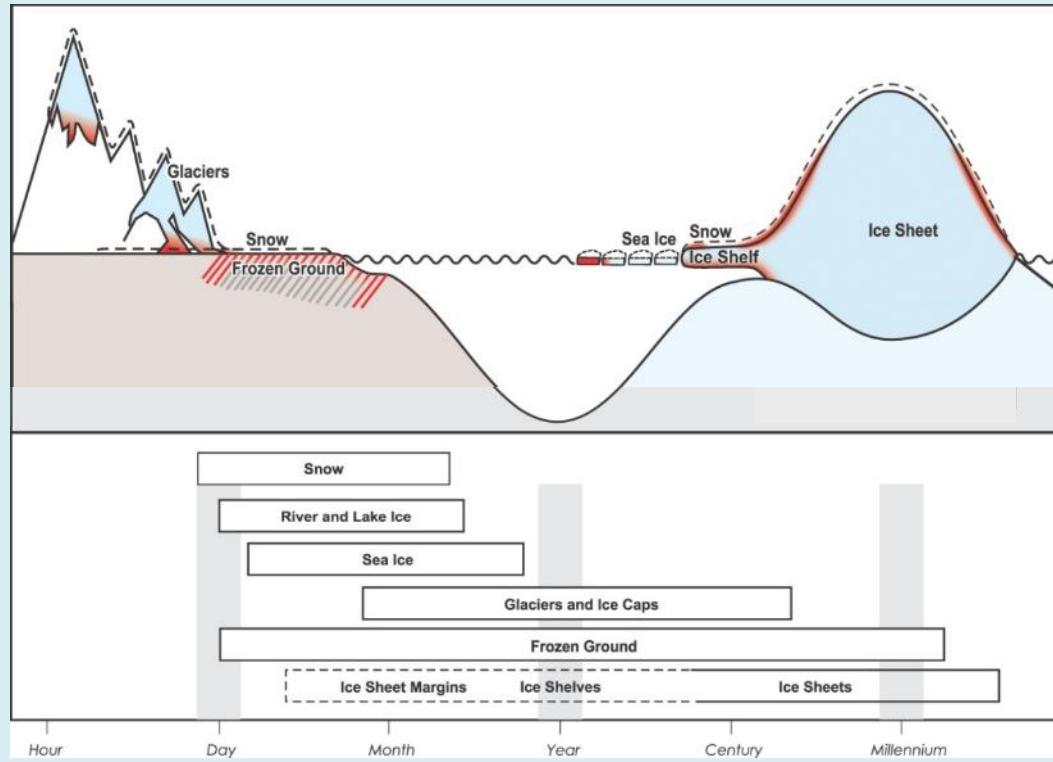
"Warming of the climate system is unequivocal, as is now evident from observations of **increases in global average air and ocean temperatures**, widespread **melting of snow and ice** and **rising global average sea level**"

In the European Alps, climate change resulted in a temperature increase of about 1.2°C in the 20th century, **almost double the global average** of 0.74°C (Auer et al. 2007)



South of the Alps, precipitation decreased about 9% over the same period, due to a reduction in the number of wet days, as **precipitation intensity shows a positive trend** (Brunetti et al. 2004)

The cryosphere is a sensitive indicator of climate change,
and is promptly reacting to atmospheric warming
(Kääb et al., 2007)

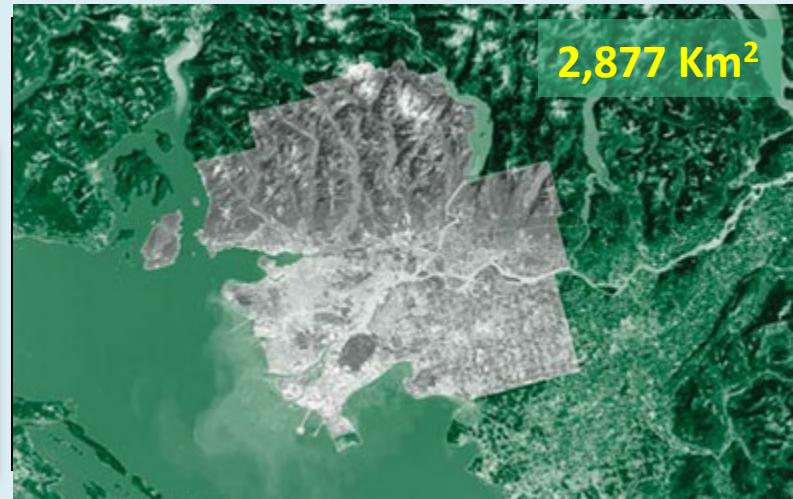


But the cryosphere is a complex system, whose components (snow, permfrost, glaciers) react in different ways and at different time scales

Glaciers in the Alps

The only complete Alpine inventory available is from 1970s (*Zemp et al. 2007*):

- glaciated area > **2,900 km²**
- ice volume ca. 100 km³
- **5,154** glaciers
- **82% < 0.5 km²** and cover 21% of total glaciated area
- only 7 glaciers are > 20 km² and cover 10% of total glaciated area



The Alps experienced a **50 % decrease in ice cover** since 1850.

The percentage loss in ice cover between the 1970s and 2000 is almost three times greater than the mean decadal loss between 1850 and the 1970s.

The most recent mass balance data show a continuation of the negative trend: **mass balance of glaciers in 2003 exceeded the average of 1967–2001 by a factor of nearly seven** (*Zemp et al. 2007*).



Permafrost in the Alps

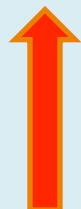
- **sporadic** at elevations ranging from 2,000 up to 3,200 m, becoming more continuous at higher elevations
- Permafrost **thickness is usually ca. 20 m**, even if it can reach 200 m (Passo dello Stelvio)
- Active layer is usually 1-3 m
- Permafrost temperature is $> -3^{\circ}\text{C}$

(Guglielmin 2006)

Permafrost temperatures in the Alps have risen over the past 20–30 years.

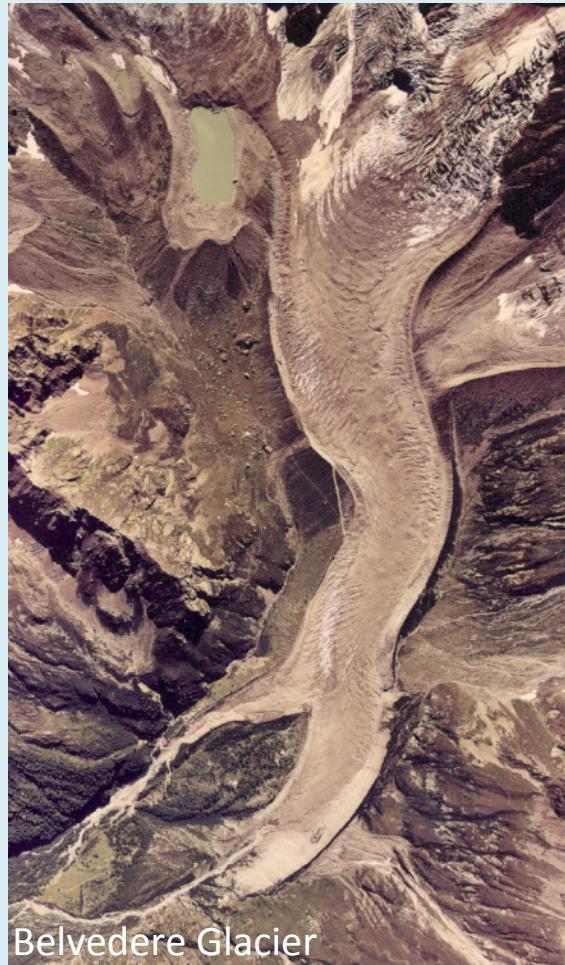
Warming, although spatially variable, is typically 0.5-2°C at the depth of zero annual amplitude.

Warming is greatest at higher latitudes
(Harris and Isaksen 2008).

 +0.01°C/yr
(Stockhorn, CH)



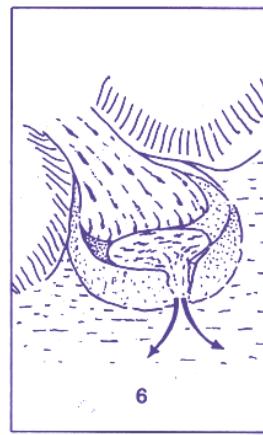
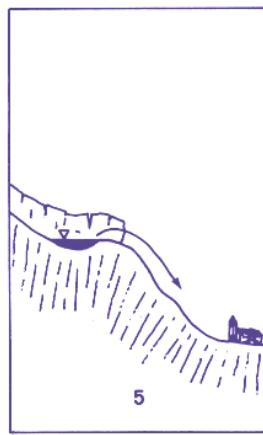
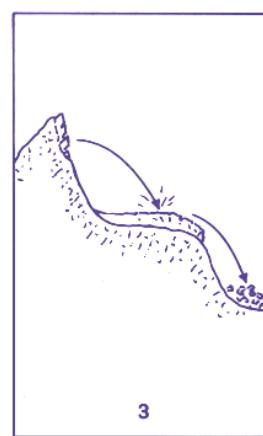
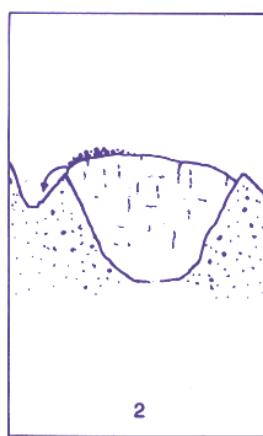
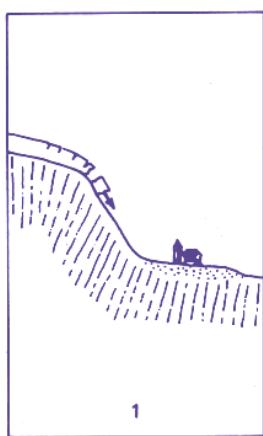
Types of glacial hazards



Belvedere Glacier



Types of glacial hazards



(Dutto & Mortara 1992)

- 1. Ice fall from snout of glacier
- 2. Supraglacial debris fall/slide outside the lateral moraine
- 3. Landslide involving ice
- 4. Rapid advance of snout of glacier

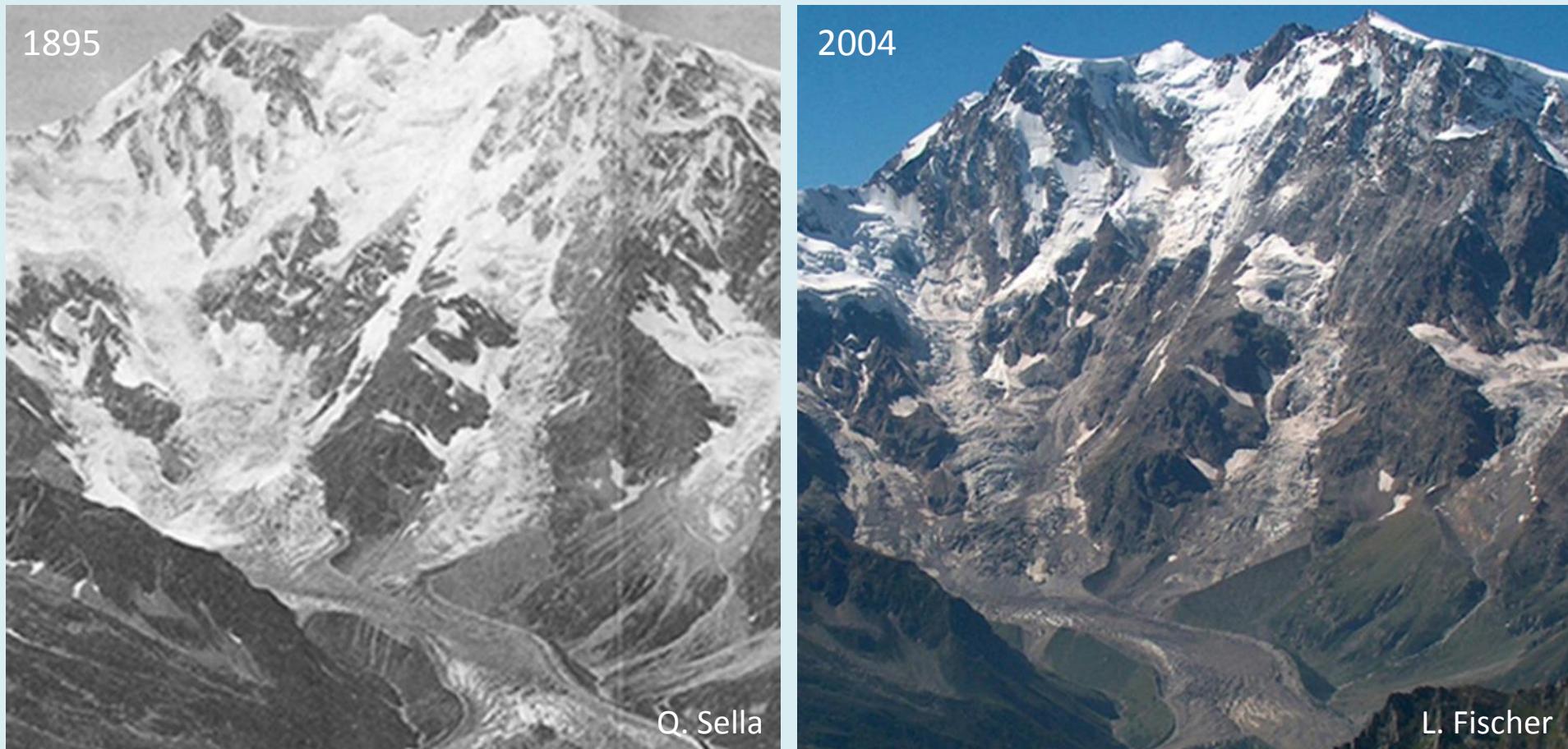
- 5. Emptying of internal water-pocket / activity of proglacial torrents
- 6. Emptying of proglacial/marginal lake
- 7. Emptying of ice-dammed lake

**... Natural instability is rising
as a consequence of climate change**

How does climate change affect debris flow occurrence?

- ✓ exposure of large quantities of unconsolidated, unvegetated, and sometimes ice-cored glacial sediments
- ✓ Formation/growth of glacial lakes which can outburst
- ✓ Melting of ground/buried ice
- ✓ Increase of rainfall intensity
- ✓ Increase in spatio/temporal distribution of rainfall vs. snowfall

The Belvedere glacial basin (Monte Rosa)



In the last decades, the ice cover of the Monte Rosa east face experienced an accelerated and drastic loss in extent. Many instability processes developed in the basin, making it a “natural laboratory” for studies about impacts of climate change

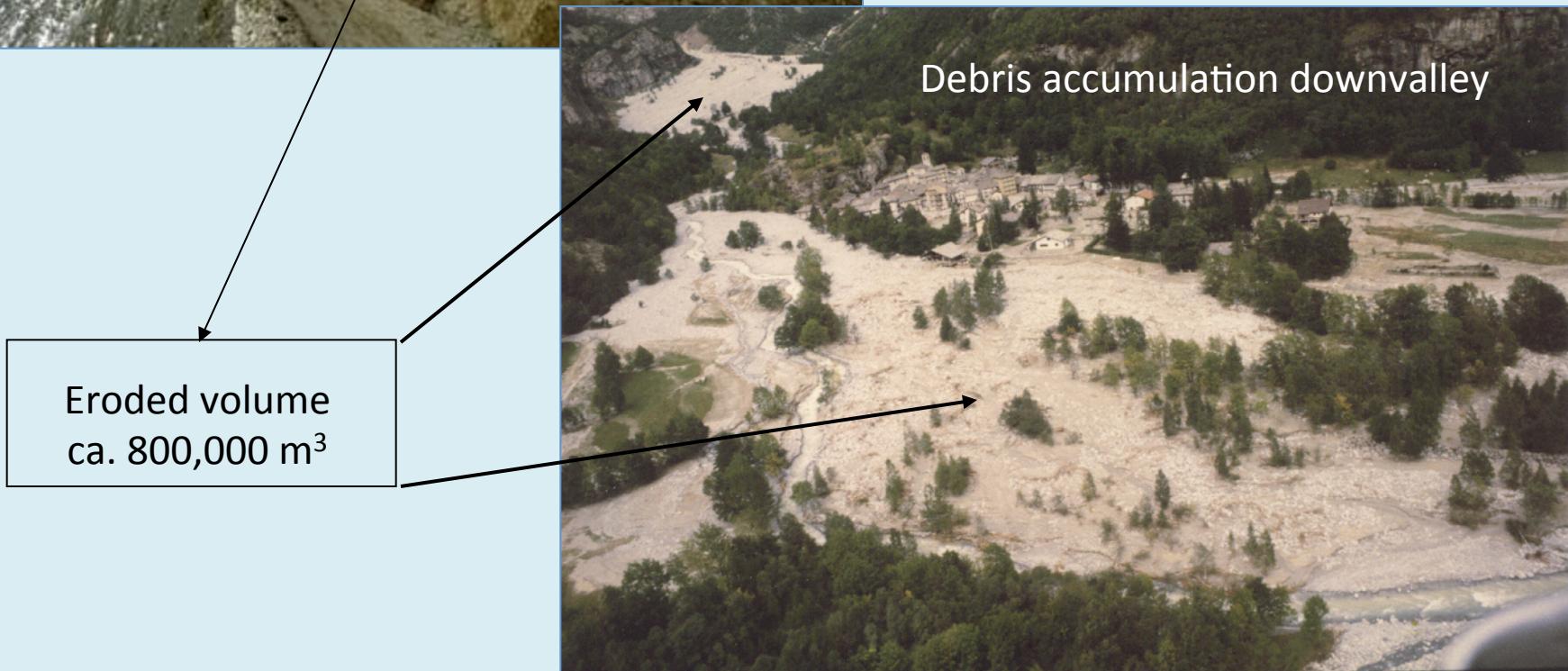
Elevation: 2610 m

Aspect: NE



Mulinet Glacier (Levanne)

Sept. 24, 1993



Eroded volume
ca. 800,000 m³

Debris accumulation downvalley

Forno Alpi Graie



How does climate change affect glacial lake development?

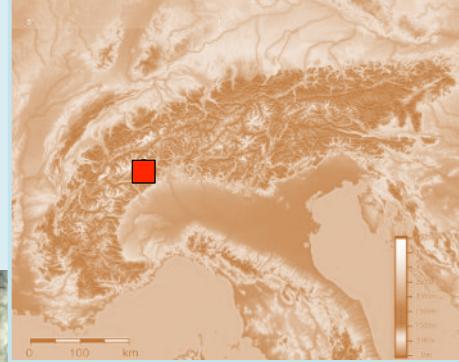
- ✓ Glacier shrinkage and depression filling
- ✓ Enhanced snow/ice melting
- ✓ Sub/englacial drainage blockage due to accelerated glacier dynamics



At the Belvedere Glacier a surge-type evolution caused the formation of a large depression at the foot of the east Monte Rosa wall, filled since 2001 by a supraglacial lake

1985

Lago Effimero Belvedere Glacier (Monte Rosa) 2002-2003



2002

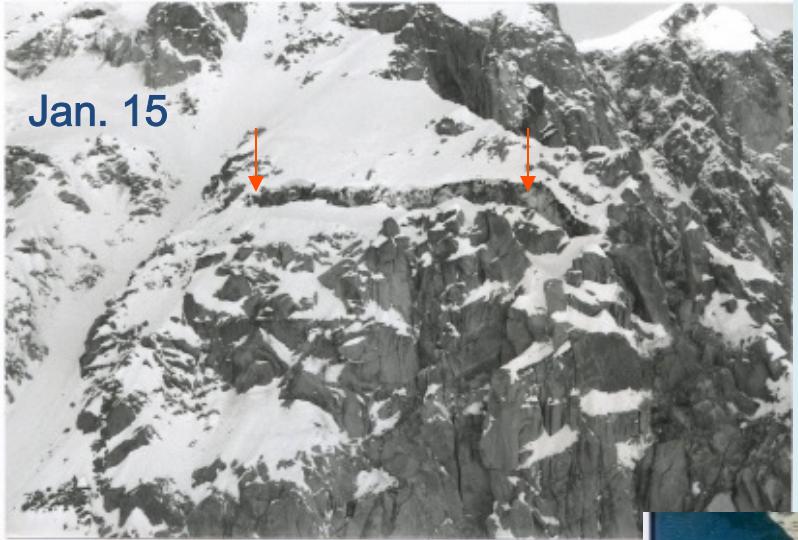
Elevation: 2100 m
Aspect: NE



The lake basin reached its maximum volume (over 3 M m^3) during an anomalous heat wave in June 2002. Considering the threat of an impending glacial outburst to the Macugnaga village 2.5 km downstream, rapid emergency actions were initiated by the Italian Civil Defense Department.

How does climate change affect rock slope stability?

- ✓ Slope debutressing
- ✓ Slope steepening
- ✓ Rock exposure to atmospheric degradation
- ✓ Permafrost melting (in rock joints)



Brenva rock-ice avalanche (Mt. Blanc)

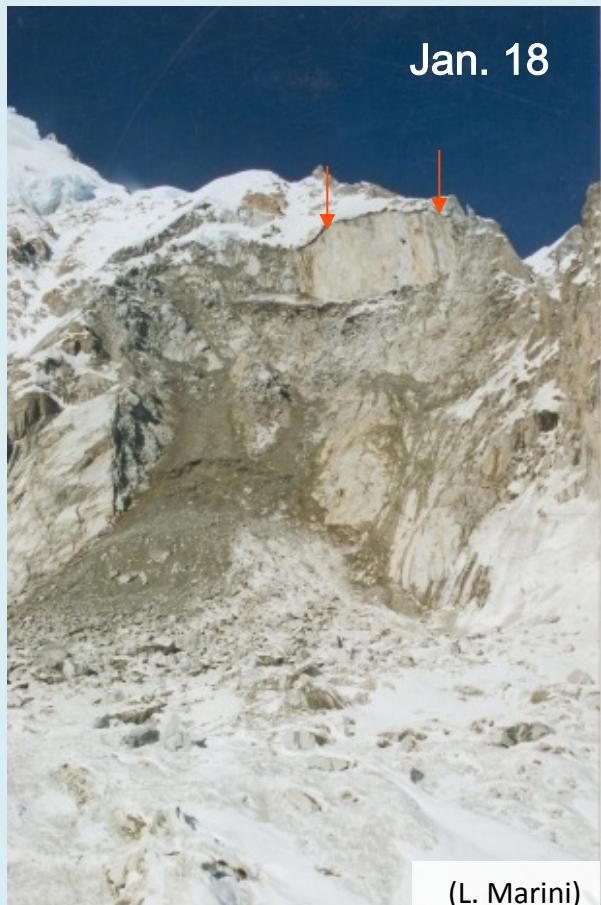
Jan. 18, 1997



Elevation: 3750 m
Aspect: SE

A large rock slide originated on the “Sperone della Brenva”, releasing a huge snow avalanche and 2 M m^3 of rock

- Permafrost melting (in rock joints)





L = 5750 m
H = 2325 m
V = c. 2 + 5 M m³

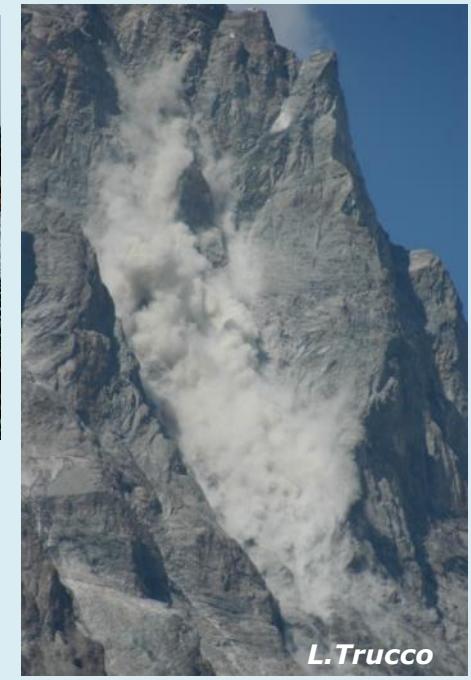
The rock avalanche excavated a wide trough down the glacier, removing about 5 M m³ of ice.

On reaching the lower part of the glacier, the rock avalanche spread in two directions. One lobe overflowed the southern lateral moraine and reached the Doire River streambed, forming a natural dam as much as 25 m high and killing two skiers. The main lobe was channeled by the south lateral moraine and reached the glacier front.

(Barla et al. 2000, Deline 2008)



D. Chiuminatto



L.Trucco



G.Mortara

The warm Summer 2003

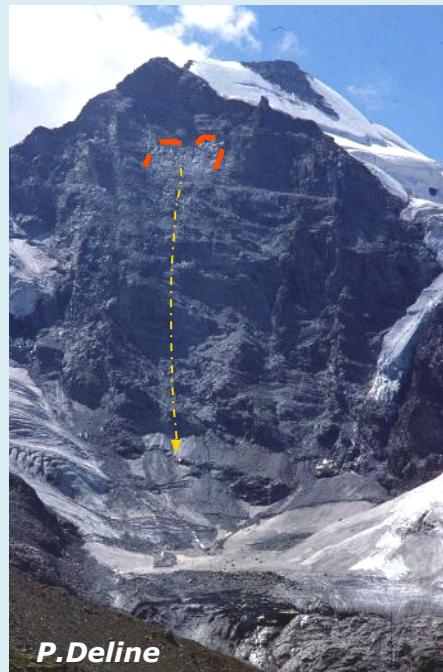
- Permafrost melting (in rock joints)



P.Deline



A.Galluccio



P.Deline

Elevation: 3600 m

Aspect: SE

13:43:09



J. Rozman

Thurwieser Peak (Ortles-Cevedale)

Sep. 18, 2004



D. Fossati



A 2.5 M m³ rock mass detached on the Southern flank
of Punta Thurwieser, at elevations between
approximately 3,250 and 3,600 m a.s.l. (Pirulli et al. 2006)

The rock avalanche dropped onto and moved across Zebrù Glacier. After crossing a rock step, the debris flowed at high velocity along the narrow Rin Mare valley.

Water was observed flowing out of the rock wall a few days before the collapse (Cola 2005), strengthening the hypothesis that degrading permafrost played a role in the landslide.

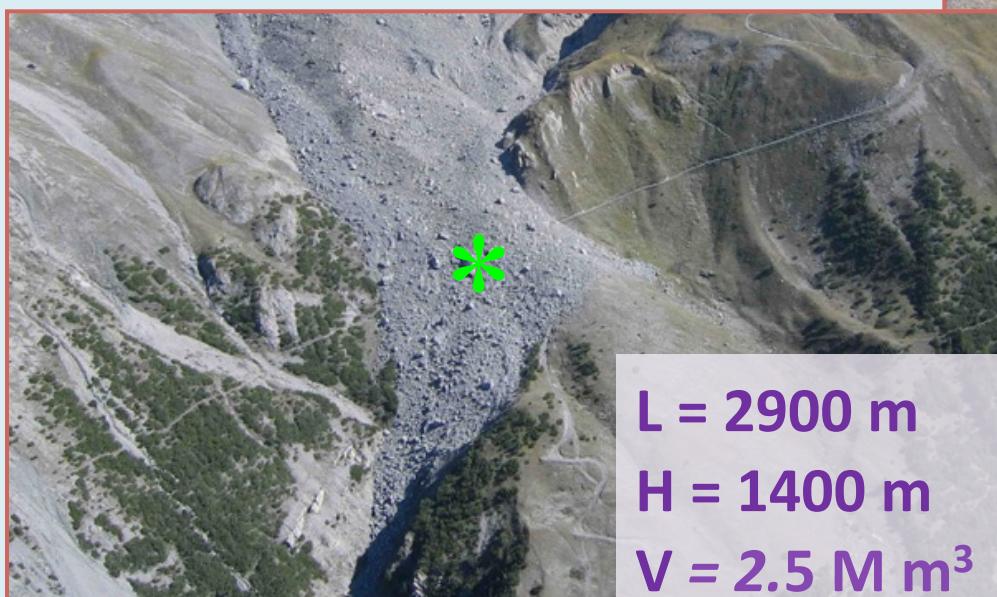


Photo: Regione Lombardia

Elevation: 3630 m

Aspect: W

Les Drus (Monte Bianco) June 29, 2005

In June 2005, Pilier Bonatti collapsed, producing a rock avalanche of 270,000 m³.

The pillar had been destabilized by a series of retrogressive failures over a 55-year period, culminating in the 2005 event.

(Deline 2008)



30 June 2005



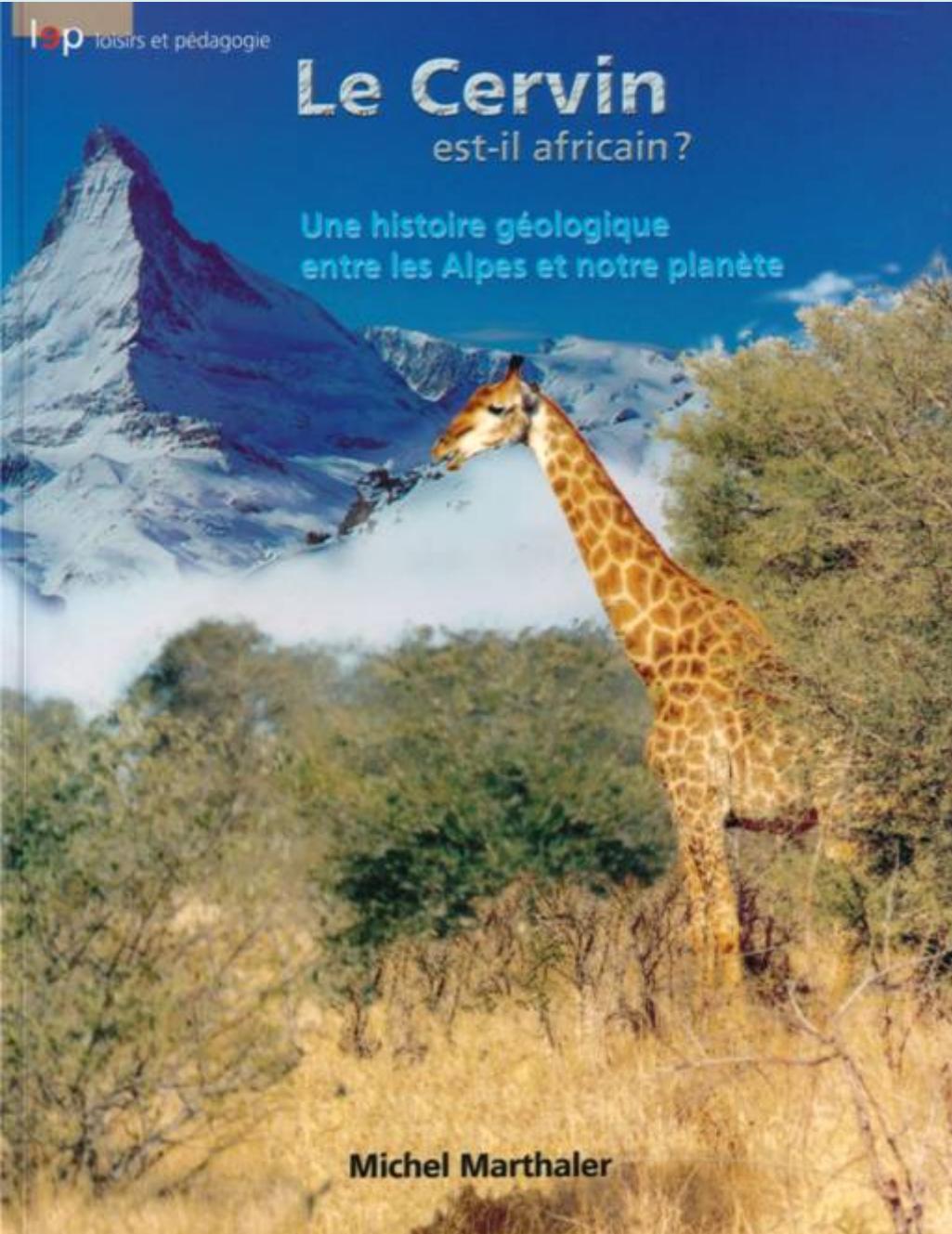
29 June 2005



Le Cervin est-il africain?

Une histoire géologique
entre les Alpes et notre planète

Michel Marthaler



And what
about
tomorrow?

