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... SNOW Part II



Little Ice Age

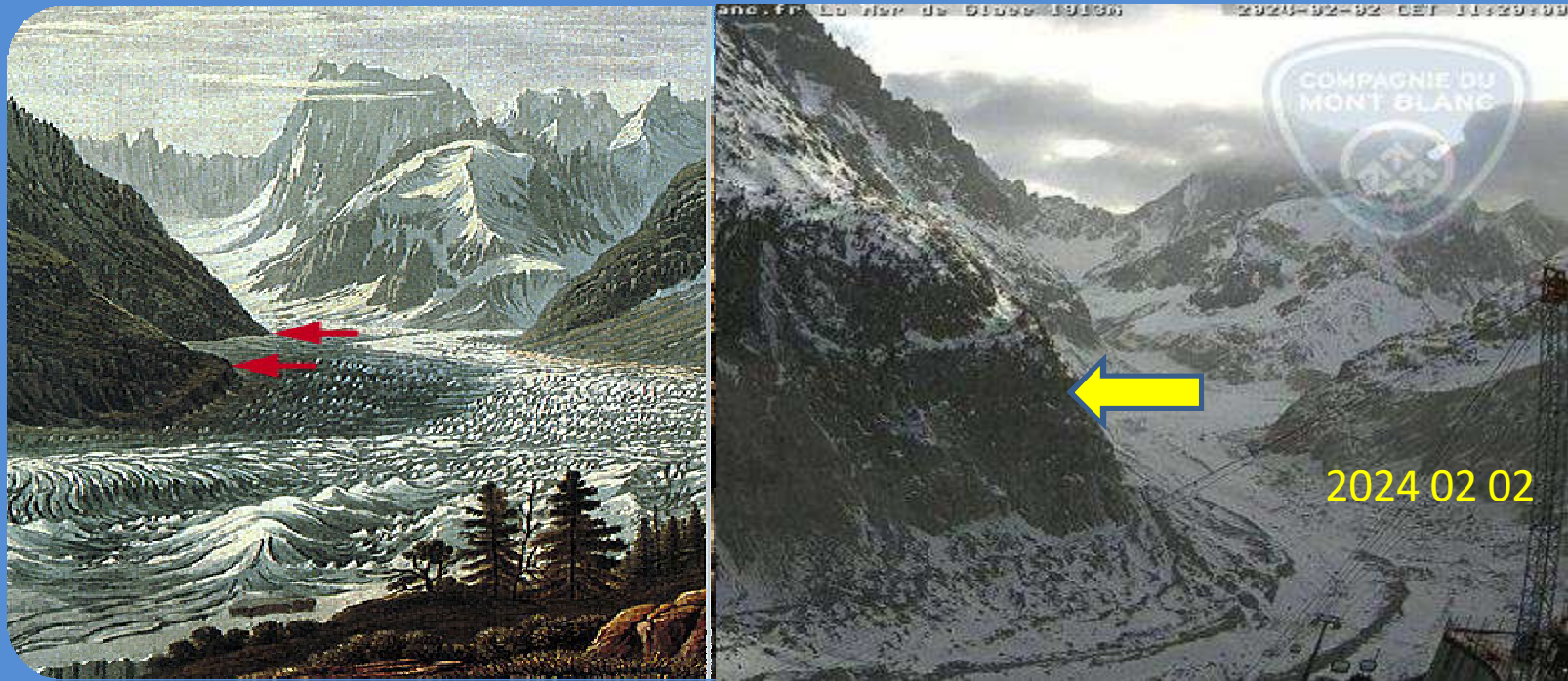
The time period that led to the expansion of valley and cirque glaciers worldwide, with their maximum extent reached around 1700-1850 AD in many temperate regions and around 1900 in Arctic regions.



The , Mont Blanc region, French Alps. The left image is an excerpt from a Birman painting just after the Little Ice Age maximum. The photograph on the right was taken from a similar location in 2000. Arrows indicate similar positions on the glacier margins and indicate the level of subsidence of the glacier surface.

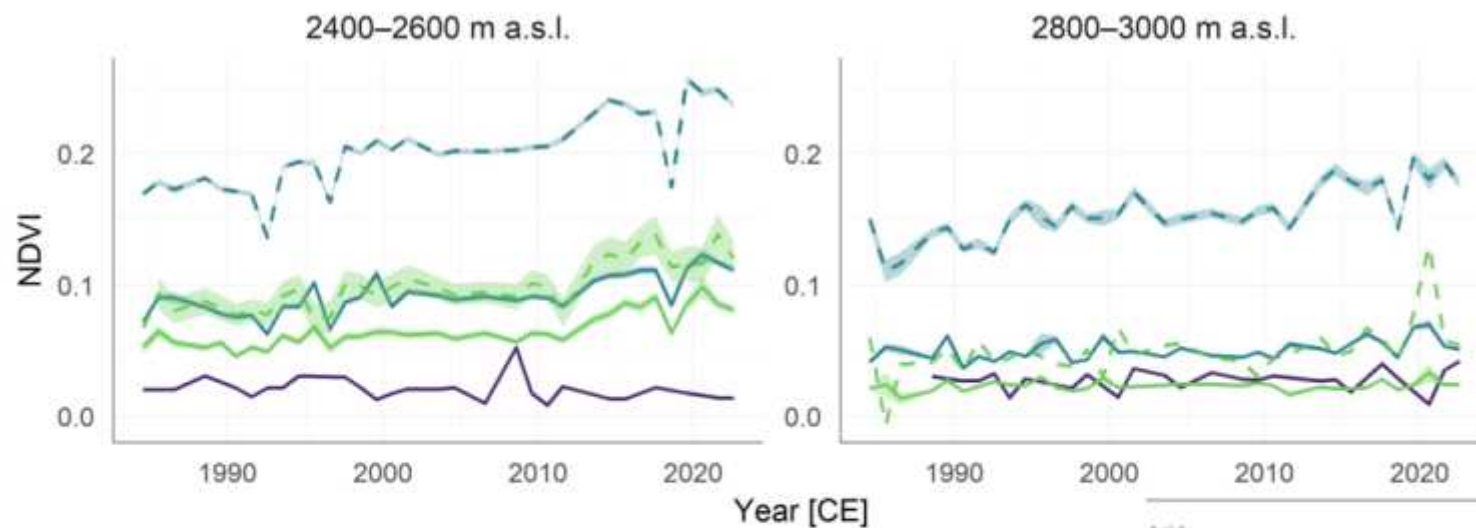
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Innalzamento di quota anche della vegetazione,



— Bare rocks
 - - Sparsely Vegetated Areas

Article
NDVI Analysis for Monitoring Land-cover Evolution on Selected Deglaciated Areas in the Gran Paradiso Group (Western Italian Alps)

Simona Gennaro ^{1,†}, Riccardo Cerrato ^{2,†}, Maria Cristina Salvatore ^{1,2,3}, Roberto Salzano ^{4,5}, Rosam Salvatori ^{4,6}, and Carlo Baroni ^{1,2,3}

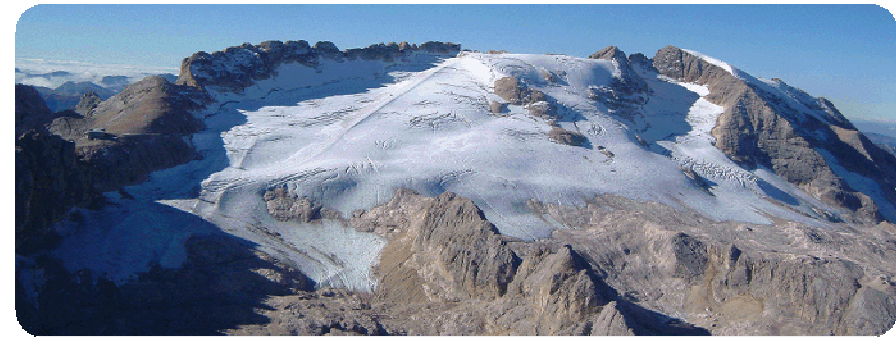
<https://www.mdpi.com/2072-4292/15/15/3847>

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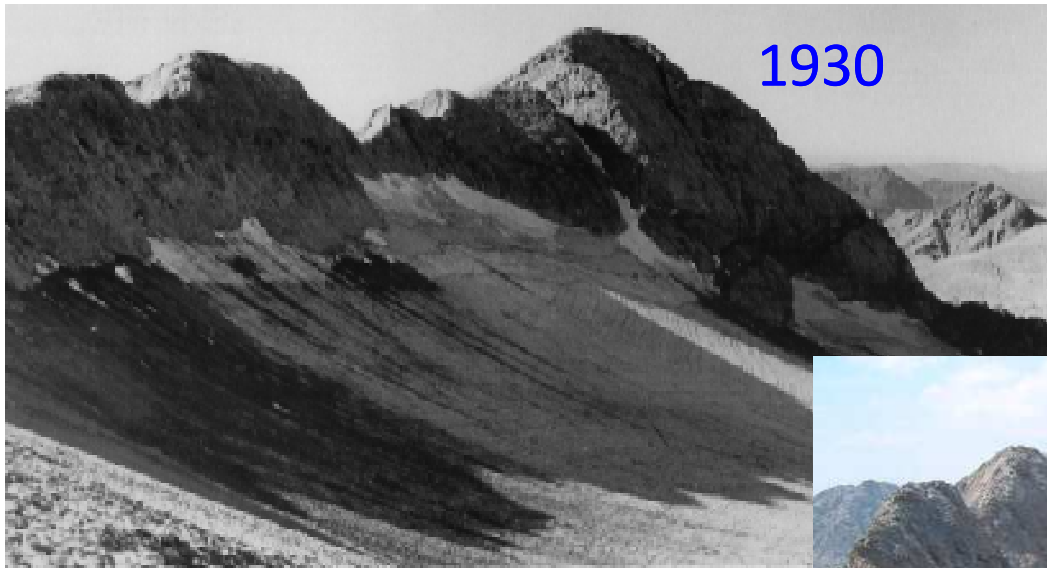
LA MARMOLADA



In the 2000s.
The following were being
proposed These photos



VEDRETTA DEL VERNALE



In the 2000s.
The following were being
proposed These photos



FRADUSTA



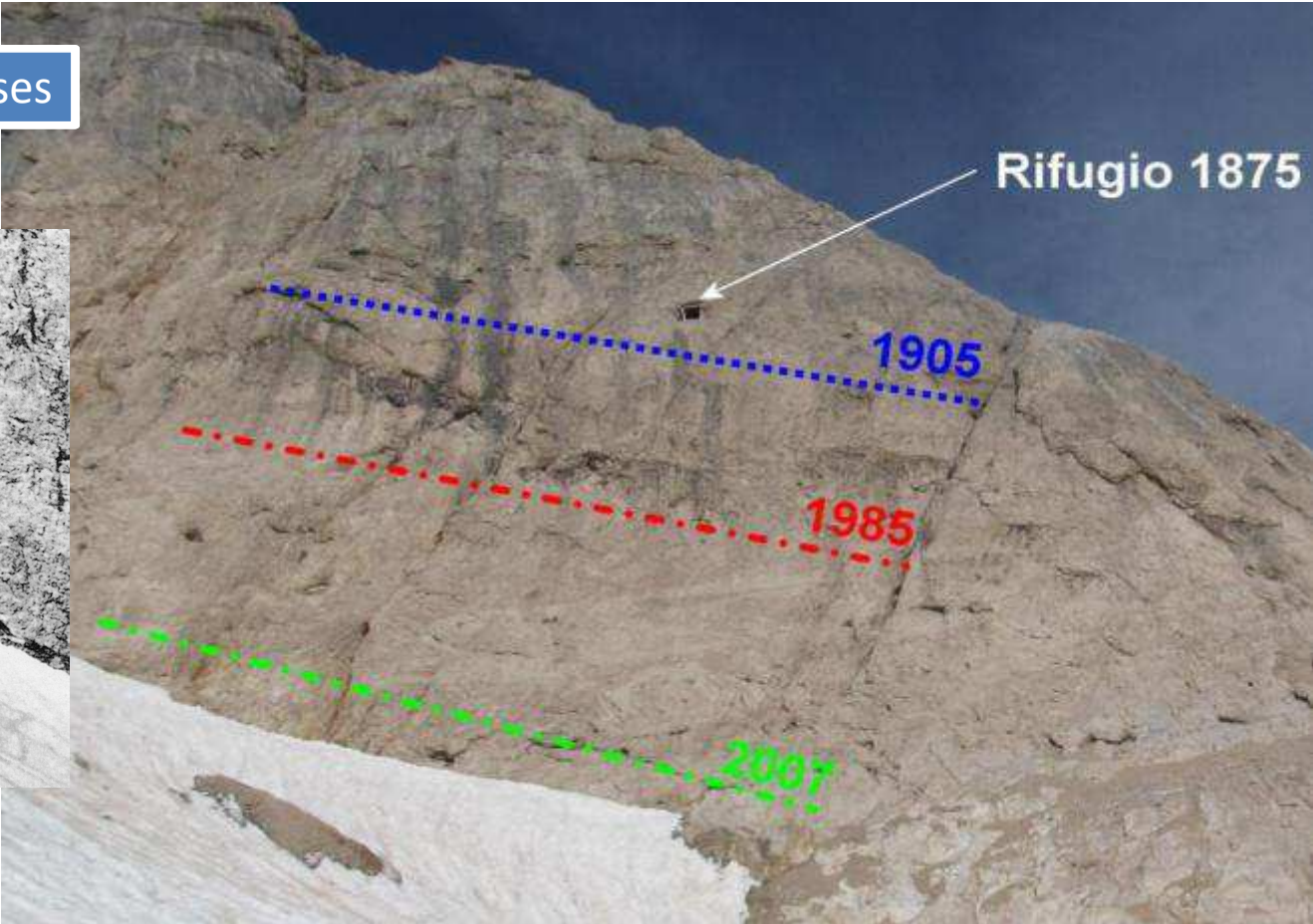
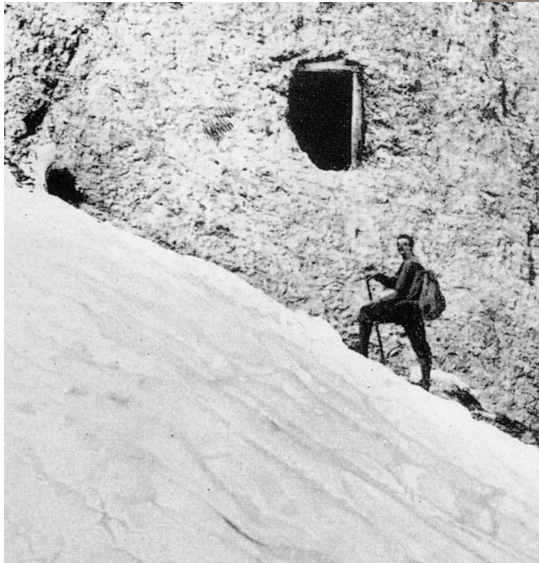
In the 2000s.
The following were being
proposed These photos

The glaciers of the Dolomites

- In the 2000s, there was a sense that something had been changing for about 10 years, and photographs with historical comparisons, were used to look for objective evidence



Reduction of thicknesses



Marmolada Glacier



The climate-driven disaster of the Marmolada Glacier (Italy)

Aldino Bondesan^{1,2}, Roberto G. Francese^{3,4}

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²Department of Military Geography, Faculty of Military Sciences, University of Indonesia, Jakarta, South Africa
³Department of Chemistry, Life Science and Environmental Sustainability (ICES), University of Parma, Parma, Italy
⁴National Institute of Oceanography and Applied Geophysics (OGS), Trieste, Italy

<https://www.sciencedirect.com/science/article/pii/S0169555X23001071>
<https://www.sciencedirect.com/science/article/pii/S0169555X23001071>
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Riduzione della estensione
 Crolli

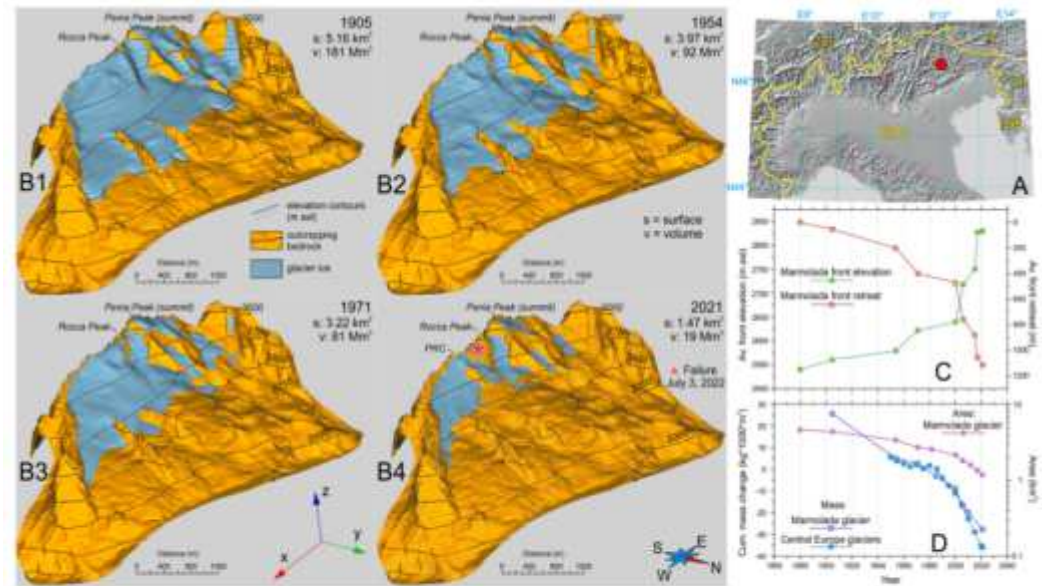


Fig. 1. Evolution of the Marmolada Glacier in the last 140 years. (A) Location map. (B1–4) 3D model of the northern slope of the massif from 1905 to 2021 showing the dramatic glacier retreat and fragmentation. The red asterisk (B4) marks the location of the failure while the label PRC indicates a meteorological station. (C) Frontal retreat and its change in elevation show a marked increase in velocity since 2000. (D) The mass change of the Marmolada Glacier nicely correlates with the mass change of Centrale Europe Glaciers (WGMS, 2021). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

Table-1

Synthesis of 2004 and 2014 calculated areas, ice volumes and w.e. of the Marmolada glacier.

	2004	2014	Percentage variation
AREA	1402000 m ²	1097000 m ²	-22%
ICE VOLUME	25267000 m ³	17499000 m ³	-30%
WATER EQUIVALENT ^a	16.2 m	11.5 m	-30%

^a Considering an ice density equal to 900 kgm⁻³ and the 2004 area.

We estimate the mean ice thickness in 2004 to 18.0 m, with a maximum close to 50 m. In 2014 the average ice thickness decreased to 12.9 m, while the maximum thickness lowered to about 40 m. By integrating the two data sets, we observe a volume reduction equal to 30%, while the area covered by ice decreased by 22%, with new ice-free zones in 2014 not only related to the retreat of the front, but also within the glacier area. This caused a division of the previously unified glacier in separated ice bodies especially in its western part. If the Marmolada Glacier keeps reducing its volume at the same estimated rate of the 10 glaciological years analyzed (2004–2014), it will likely disappear by the year 2050 (i.e. in 25–30 years from now). Few small ice patches fed



End of summer skiing in Marmolada in 2007

<https://www.sciencedirect.com/science/article/pii/S0034425719304614>

Remote Sensing of Environment
Recent evolution of Marmolada glacier (Dolomites, Italy) by means of ground and airborne GPR surveys

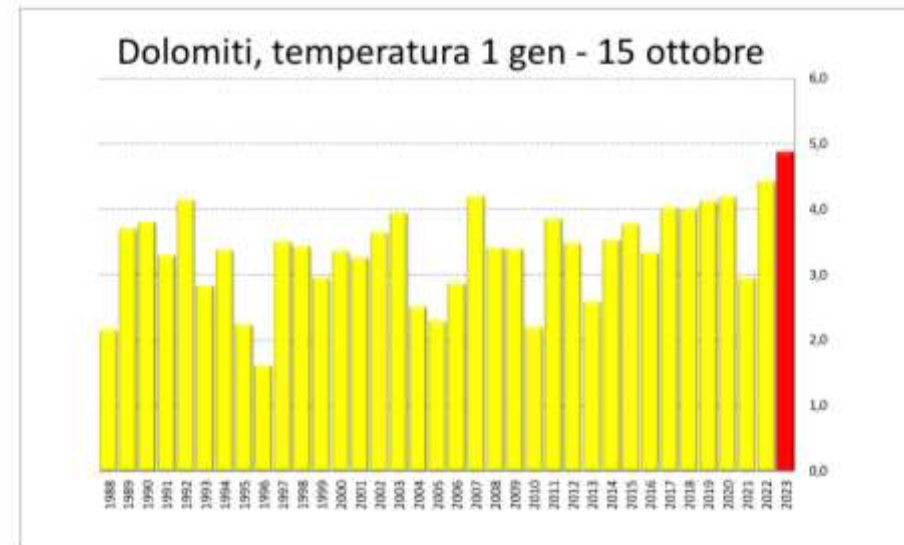
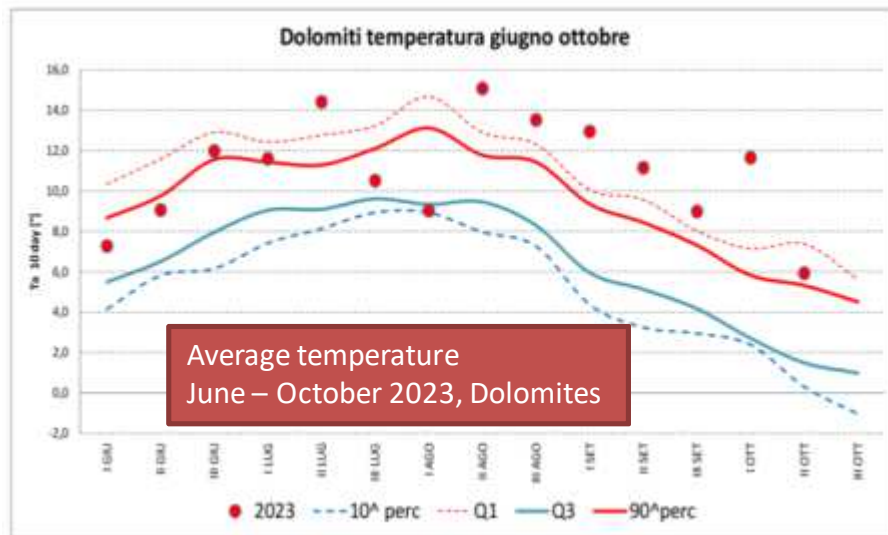
È solo l'ultimo capitolo di una storia cominciata dieci anni fa sul ghiacciaio della Marmolada (la Regina delle Dolomiti, dove lo stop definitivo allo sci estivo arrivò nel 2007 al termine di una lunga agonia), proseguita sul Presena l'anno successivo e quindi in Val Senales nel 2013. I teli estivi — utilizzati ovunque contro il sole estivo — si sono rivelati una semplice cura palliativa, inutile per curare il male terminale che affligge i ghiacciai da quasi quarant'anni. Sulle Alpi italiane lo sci estivo resisteva solo sullo Stelvio, il valico più alto d'Europa, caso unico di una stazione sciistica aperta solo d'estate ormai da cinquant'anni e palestra storica per i campioni dello sci italiano. Il campione altoatesino Gustav Thoeni su questi versanti è sempre stato di casa, ma sulle piste del Livrio ci veniva tutta la valanga azzurra ad allenarsi durante la bella stagione. Ora gli impianti di risalita sono fermi e solo l'acqua, che scorre a valle incessante, giorno e notte, rompe il silenzio della

<https://www.repubblica.it/cronaca/2017/08/22/news/c-era-una-volta-lo-sci-d-estate-la-risa-esa-dell-ultimo-ghiacciaio-173564734/>

STELVIO

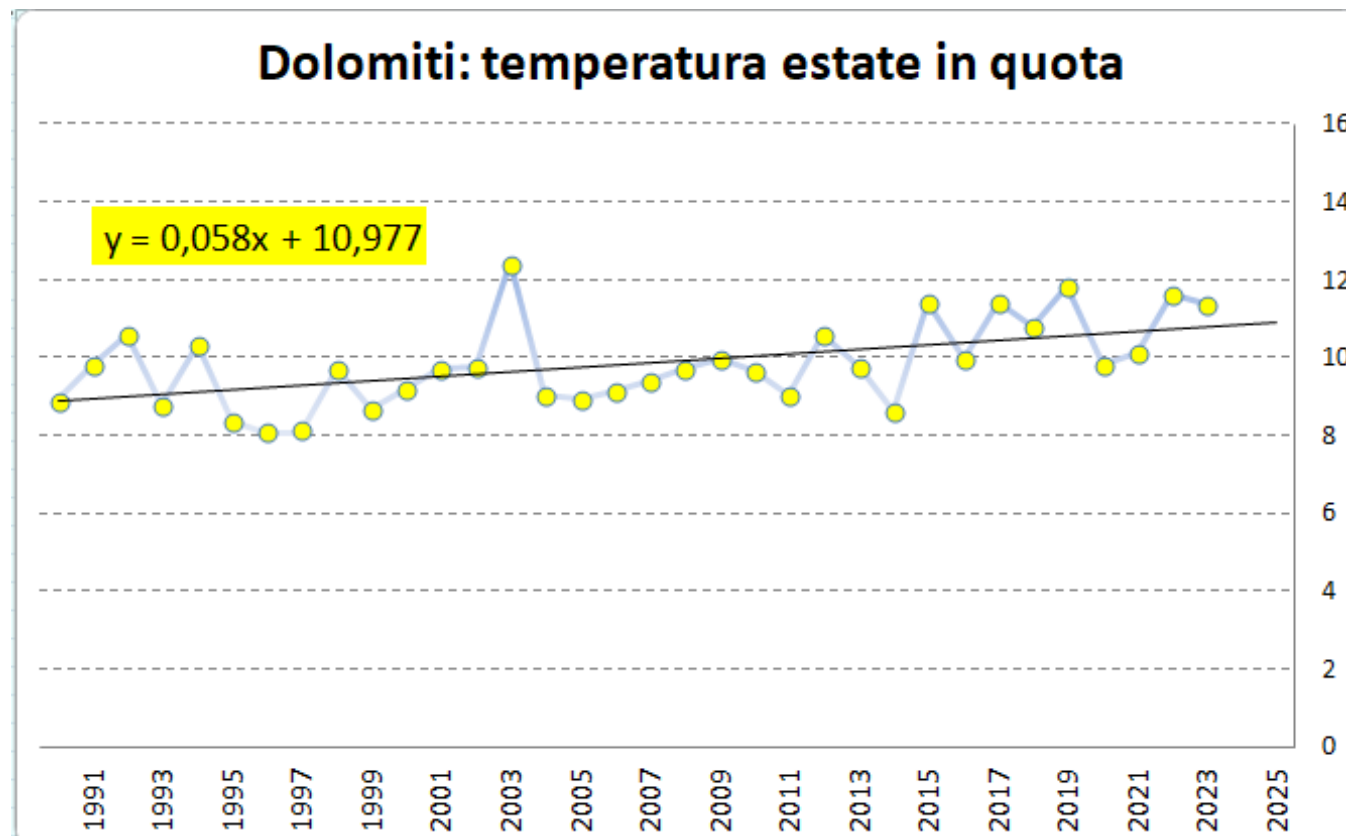


One of the causes is high temperature



Very hot summers (summer 2023)

average temperature for the months of June, July and August. The positive trend of about 0.6°C every 10 years (+2.4°C in 40 years!!) can be observed.



News

Diario di bordo

Il WSL sui social media

Cambiamenti climatici e ... permafrost

05.12.2023 | Jochen Bettzleche | WSL News | SLF News

Il terreno permanentemente ghiacciato - il permafrost - sta diventando sempre più raro sulla Terra. Si riscalda a causa dei cambiamenti climatici fino a scongelarsi. Questo lo rende un buon indicatore per rilevare i cambiamenti climatici. Allo stesso tempo, aumentano i pericoli alpini, perché con il disgelo del terreno aumenta il potenziale di instabilità dei pendii.



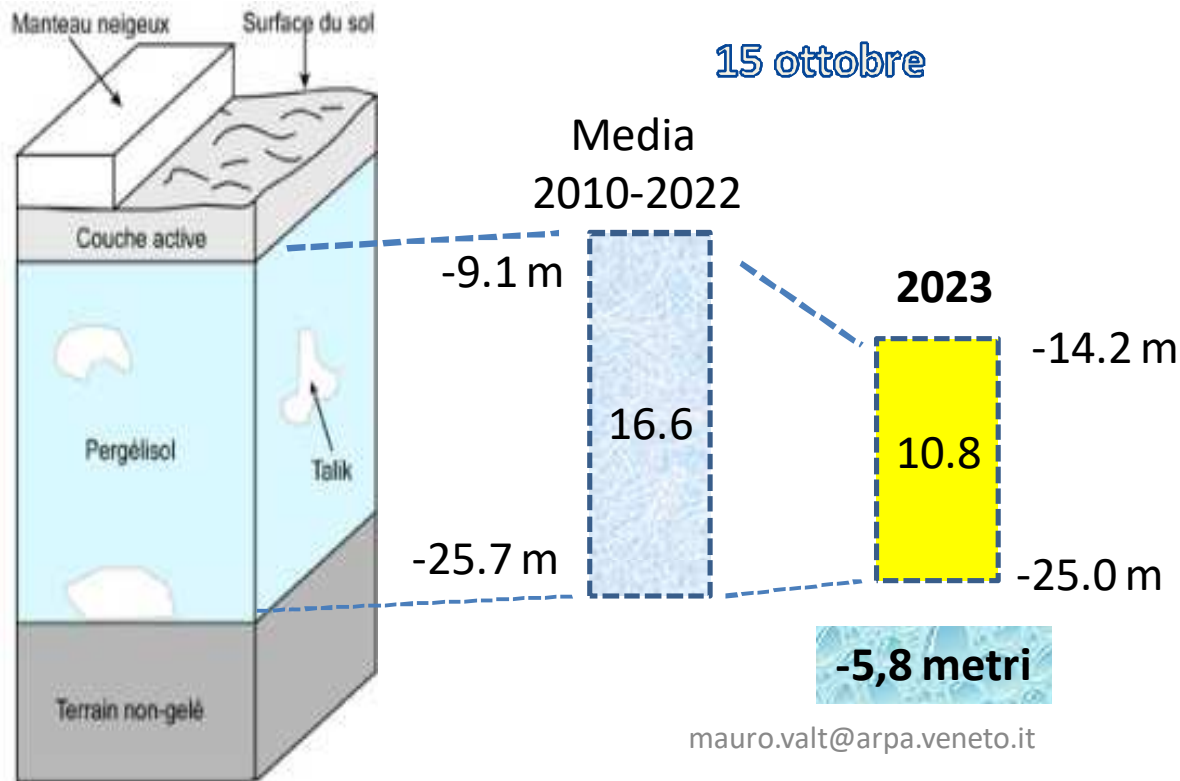
Costruire sul permafrost: supporto galleggiante
(Foto: Marcia Phillips / SLF)

Il permafrost nelle Alpi si sta riscaldando di circa un grado per decennio. Questo ha conseguenze dirette per le persone e l'economia. Nelle regioni d'alta montagna con permafrost, c'è il rischio che in futuro si verifichino più frequentemente cadute di massi e frane, il che è altrettanto pericoloso per gli appassionati di sport di montagna che per gli insediamenti e le infrastrutture. Le stazioni ferroviarie di montagna, i tralicci, i ristoranti, i rifugi, le condutture idriche, i paravalanghe, i sistemi di telecomunicazione, le gallerie e i binari ferroviari svolgono un ruolo importante in montagna per il turismo, la comunicazione, l'approvvigionamento energetico o la protezione dai rischi naturali - e sono a rischio se il permafrost si scioglie.

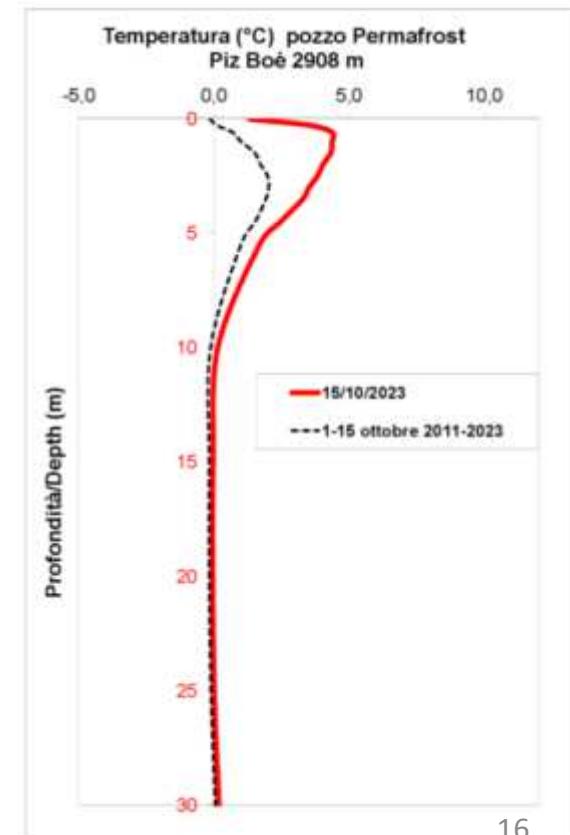


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Permafrost- Piz Boè 2908 m

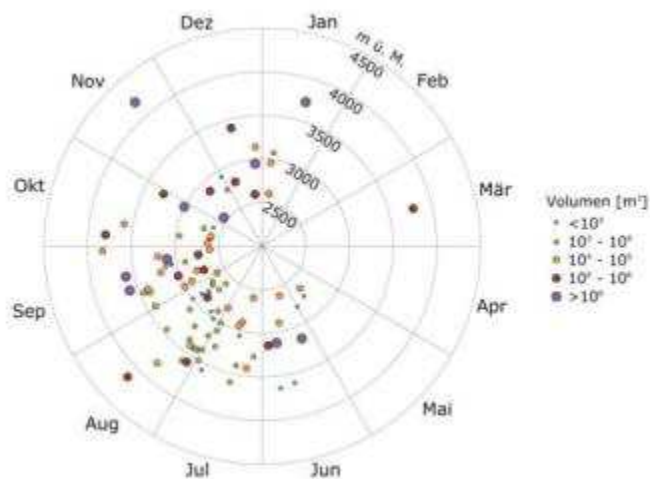


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Collapse, infrastructure damage

Esposizioni tipiche, Svizzera



<https://www.slf.ch/it/permafrost/permafrost-e-pericoli-naturali/crolli-di-rocce-nel-permafrost/>

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Torre Trepbor 07/06/2004 17

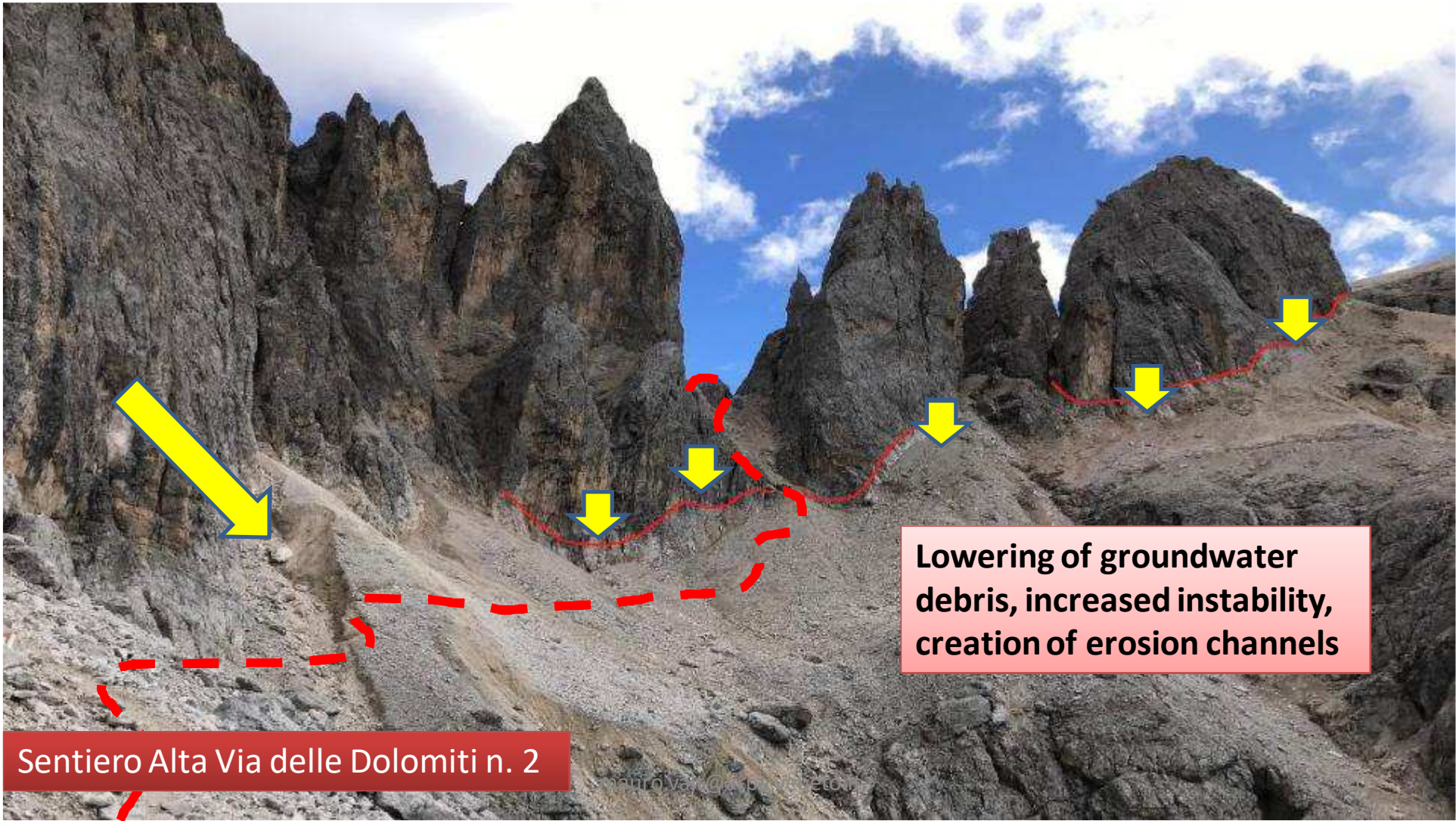
TOFANA permafrost rescue project



Schema di funzionamento impianto seggioviario



**INCREASED
ROCKFALL,
DISRUPTION**



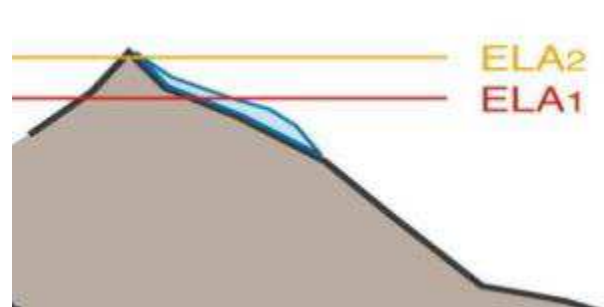
Lowering of groundwater debris, increased instability, creation of erosion channels

Sentiero Alta Via delle Dolomiti n. 2

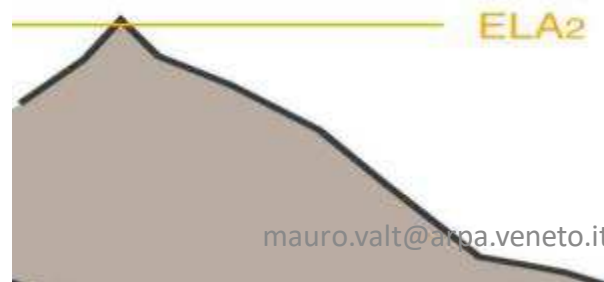
Before climate change



During the change in the readjustment phase.

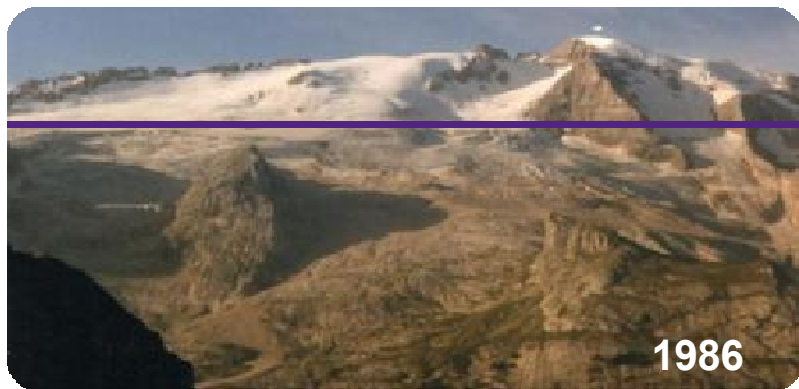


After readjustment

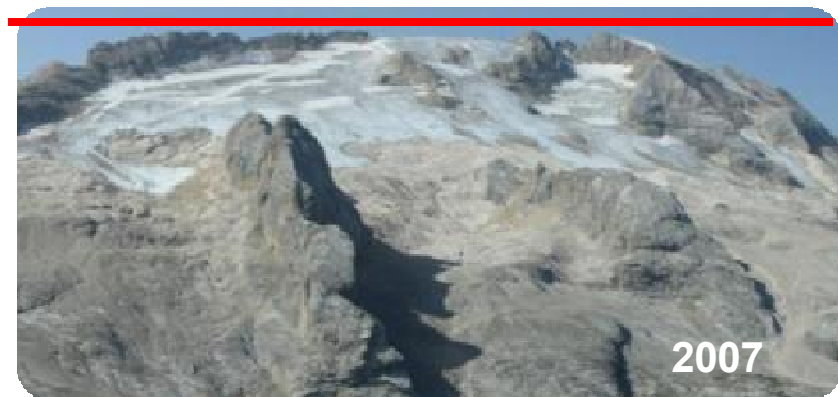


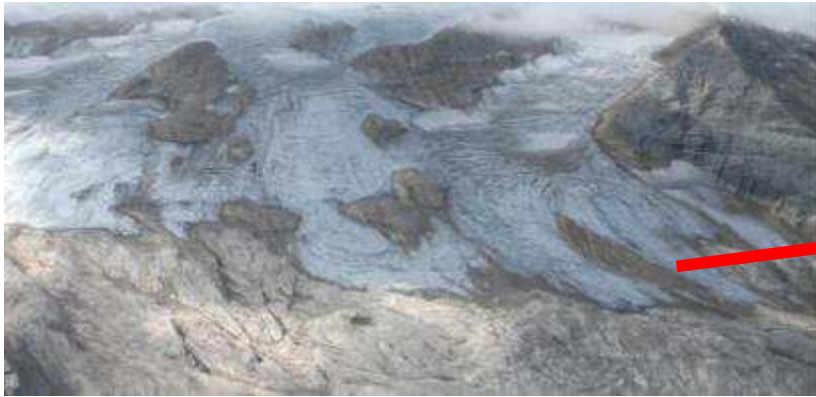
Climate change = disequilibrium

2024



↑
ELA





Death (perhaps temporary) of a glacier: from glacier to rock glacier

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Death of small glaciers



**INCREASED
ROCKFALL,
DISRUPTION**

More ephemeral lakes



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Adattamento nell' alpinismo

Cambiamento delle abitudini anche in montagna.
Negli anni '80 erano state pubblicate delle guide sull'arrampicata su ghiaccio anche per le Dolomiti.
Oggi queste "vie di ghiaccio" sono scomparse e alcune sono diventate percorsi estremi di sci alpinismo.



Adaptation in skiing: programmed snow

NEVESPORT



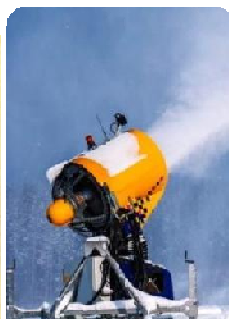
MOTORI

E' nato sotto le insegne della pace un nuovo cannone. Spara neve invece che proiettili: diventerà presto un buon amico per gli sciatori.

IL CANNONE SPUTANEVE

La sci non costituisce solo un sano divertimento per tutti, ma anche una grossa industria intorno alla quale gravitano molti e importanti interessi. Ora questa industria è per sua natura stessa soggetta all'aleatorietà delle condizioni atmosferiche: senza neve non si scia! E' per questo che, spinta dal notevole potenziale economico che gravita intorno al mondo dello sci, l'industria specializzata si è da tempo orientata verso la progettazione di macchine adatte alla « fabbricazione » di efficiente neve artificiale. Dopo i primi timidi tentativi, dopo le prime mance « nevicate », si è a poco a poco giunti alla realizzazione di apparecchiature molto avanzate per tecnica e produttività. Una di queste, certamente la più moderna e funzionale tra quelle in oggi costruite, ha fatto da poco la sua apparizione sul mercato italiano, importata da una ditta all'avanguardia nel « fronte » della neve, la Frischi di Ortisei. La nuova macchina per la neve artificiale è fabbricata in Germania dalla Lindle AG, ed ha già riscosso un notevole successo, soprattutto negli Stati Uniti, dove è da molti responsabili di stazioni invernali considerata ormai insostituibile per lavori di innalzamento veri e propri e per opere di riassetto e « cura » delle piste.

La macchina per neve artificiale Lindle ha la forma di un grosso cannone montato su una piattaforma. Il tutto non è



Nordic ski slope Slope 8 m wide, 40 cm thick cost 5,000 Euro per km
 Agordino alpine ski slope Cost 1.9-3.0 Euro per m³.

5 ski areas: 100. km of slopes, 3.2 Million hectares of snow, 1.5 Million m³ of water, average thickness 50 cm of snow on the slope.

Water/snow conversion factor 1.9 (1 m³ water, 1.9 m³ snow)

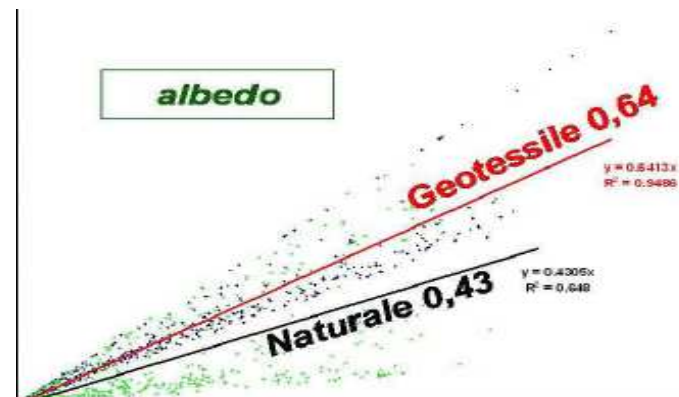
Nevesport-n.-14-30-Aprile-1969

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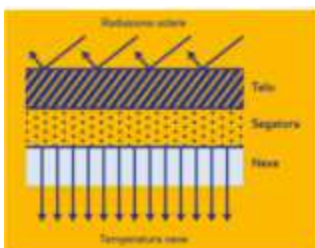
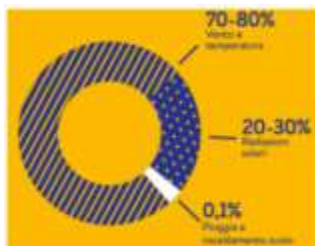
Mitigation: geotextiles for snow protection



Circa 40.000 metri quadrati di geotessile



Mitigazione: snowfarming



A Livigno la neve stoccata dall'inverno, circa **45000 m³**, viene utilizzata in due occasioni: la prima, ad Agosto, per l'evento **1k Shot e Gara da li Contrada**, **3000 m³** di neve il resto ad **anello di sci fondo** a partire da ottobre.



FUTURO?



: Alpine glaciers have reached their maximum extent in the past 10,000 years

- 1850-2015: Glaciers have shrunk areally by 60%
- Currently: Glaciers are at their lowest extent in the past 7-10 thousand years
- 21st century: Alpine glaciers will disappear below 3,000 m in the possible decades
- Glacier retreat has and will have major implications for hazard at high altitudes, water resource availability, and sea level rise, beyond any variation known to Homo Sapiens

MANTO NEVOSO

Snow cover has strong natural variations from year to year and reacts to changes in temperature and precipitation.

Because air temperature is the most robust parameter in climate models, scenarios for future snowpack evolution are most reliable at elevations with strong temperature sensitivity, i.e., low and middle elevations (up to 1500-2000 m).

Above 2000 m, even with the expected temperature changes, it will still be cold enough for it to snow, and future snowpack evolution will depend on the amount of precipitation and thus on future weather scenarios.

According to some authors, even in the future (2021-2050), natural snowfall will show wide year-to-year variability and multidecadal variability that may mask the effect of long-term warming at the regional scale.

However, simulations of regional climate models show a drastic decrease in both the duration of snow cover and water resources in Europe by the end of the 21st century.

For the Alps at an altitude of 1500 m, recent simulations predict a reduction in SWE of 80-90% by the end of the century.

However, it should be noted that the increase in air temperature projected for the coming decades is accompanied by large uncertainties about changes in winter precipitation. For continental Europe, climate models show no clear change in precipitation until 2050 and a slight increase in winter precipitation.

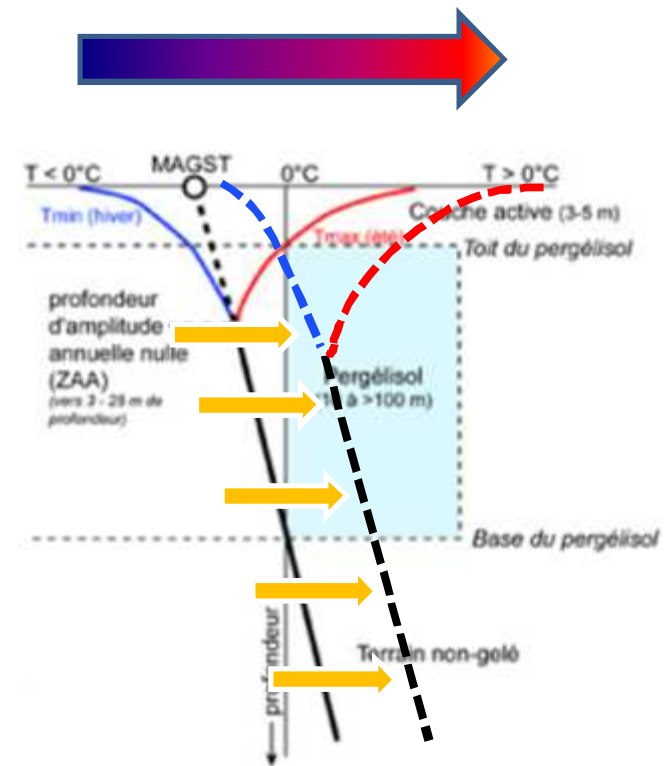
Future climate will most likely not allow for permanent snow cover during summer, even at the highest altitudes in the Alps and summer skiing, with obvious implications for remaining glaciers.

As a result of progressive warming, constraints for planned snow production will increase sharply in the European Alps, especially at low and mid-elevations up to about 1,500 m, as the time slots for snow production (today's technologies with temperature-related technical limitations) will shrink sharply at all elevations.

Permafrost

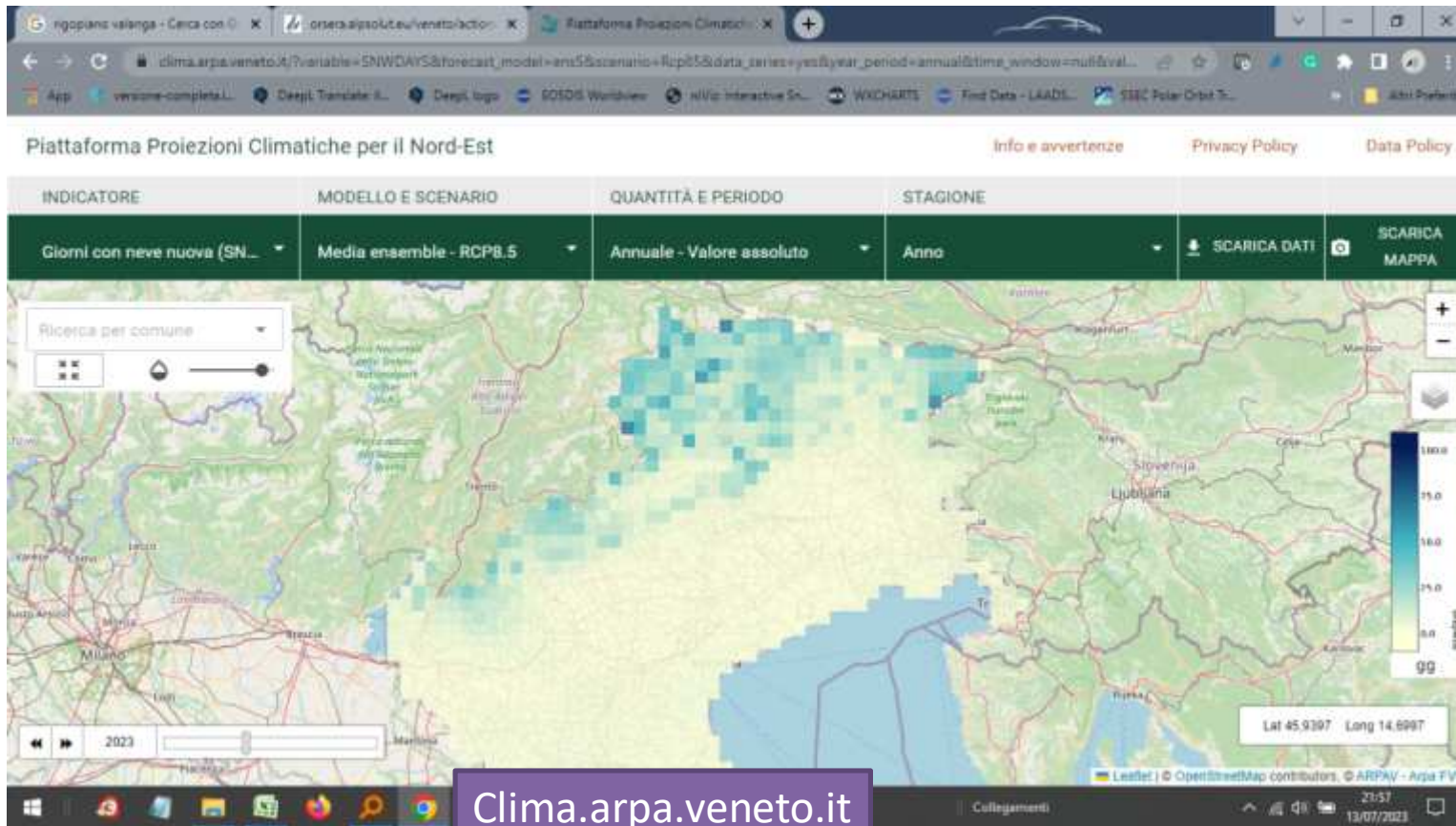
Global warming will result in:

- progressive warming of permafrost from cold to temperate (t closer to 0 °C)
- deepening of the active layer
- extension of areas no longer in equilibrium with climatic conditions
- increased instability of walls and slopes and likelihood of disruptions and interference with infrastructure
- increased frequency of phenomena



maggior propensione al dissesto dei territori interessati dal permafrost

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Variabili

- In the early 1980s, the eruption of Mexico's El Chichon volcano caused a slight cooling that counteracted the global decrease in snowfall, but this was a phenomenon limited in time



(Nortanicola, <https://www.eurac.edu/it/magazine/in-tutte-le-aree-montane-del-mondo-la-neve-si-ferma-in-media-due-settimane-in-men>).

A photograph of a single yellow tulip flower in full bloom, growing through a thick layer of white snow. The flower is positioned in the lower right quadrant of the frame. The background shows more snow and some dark green foliage peeking through in the upper left. The overall scene is a winter landscape.

Grazie per l'attenzione