



UNIVERSITÀ DEGLI STUDI DI MILANO



Glaciers: the melting heart of our mountains

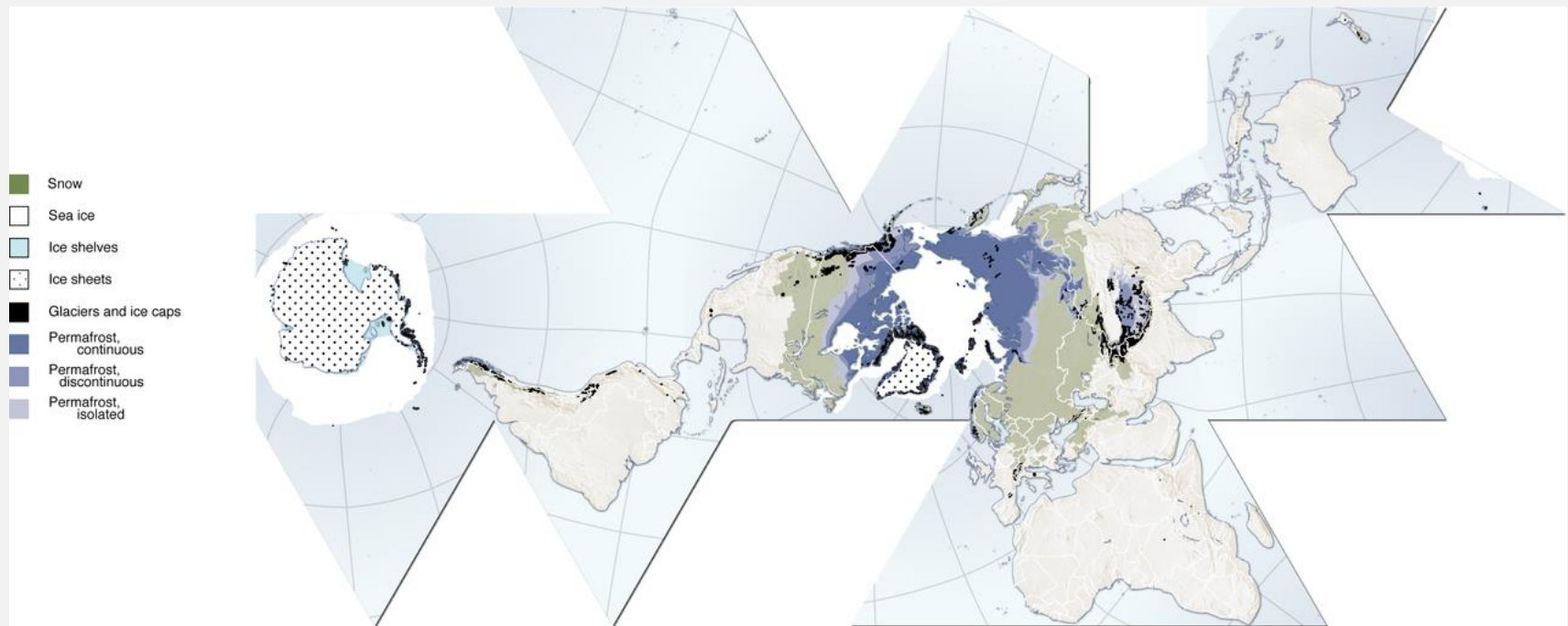
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(ESP)

Università degli Studi di Milano

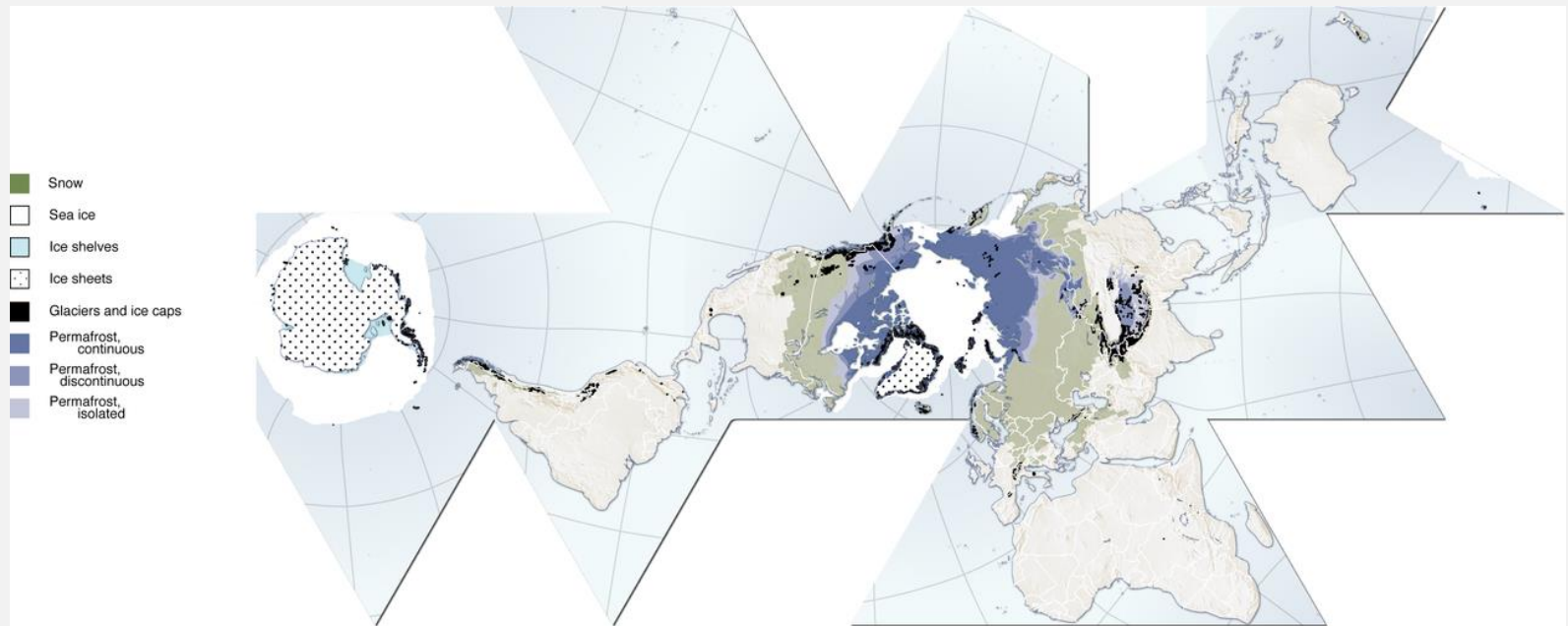
1. Main definitions

The **cryosphere** is those portions of Earth's surface where water is in solid form.



The cryosphere

The **cryosphere** is those portions of Earth's surface where water is **in solid form**, including sea ice, lake ice, river ice, snow cover, glaciers, ice caps, ice sheets, and frozen ground (which includes permafrost). Thus, there is a wide overlap with the hydrosphere.





Are really glaciers the best witnesses of climate change?

Glaciers are surely the best witnesses of climate change!



Photo by V. Sella, 1890



Photo by P. Casati, 1929

Glaciers are surely the best witnesses of climate change!



Photo by A. Desio, 1947



Photo by C. Smiraglia, 2018

Moreover...glaciers are boxes of freshwater!



Glacier ice is deeply different from sea ice!!!



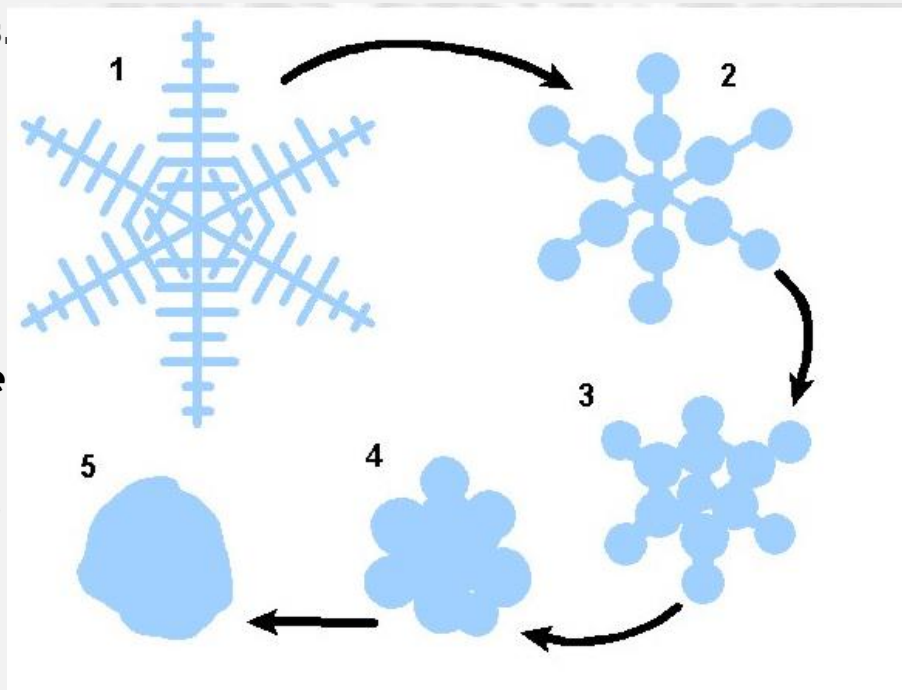
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CONVERSION OF SNOW TO GLACIER ICE

Fresh Snow: 50/200 kg/m³ depending on the weather conditions when snowfall occurs.

Increase in density. Melting pulls the water inward toward the center of the crystal that it refreezes



With greater pressure (deeper burial) the firn grains fuse together and become a solid mass of crystalline GLACIER ICE (917 kg/m³)

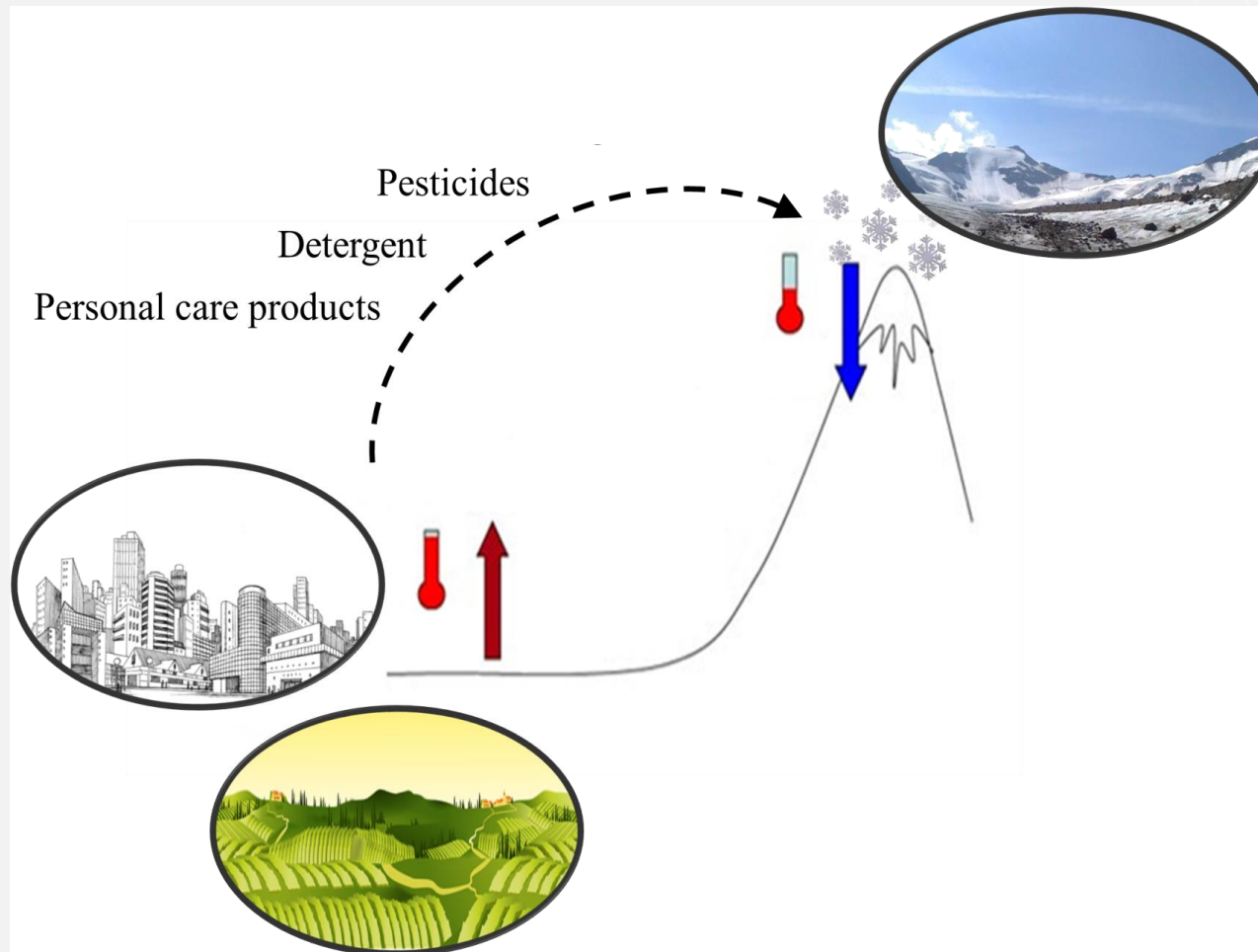
The process continues, serving to concentrate the mass of the water closer to the center of the original snowflake.

The ice has lost its flake-like original shape and has become a well-rounded granule of ice

FIRN: 400-830 kg/m³

WHAT CAN I FIND IN THE ICE?

Due to its origin, glacier ice includes several pollutants and chemical components thus witnessing the human impacts on the atmosphere and the environment



3) Glaciers are moving! They aren't static features!



Glaciers are always moving, they are flowing down also when we observe their retreat!



Forni Glacier was 17.80 km^2 at the End of the Little Ice Age (LIA, ~ 1860), it was 11.36 km^2 in 2007 (-36.2%), in the period 1850-2007 it retreated of about 2 km.

What is the colour of glacier ice?

white?

blue?



Glaciers are not white features! Why are they darkening fast and faster?



Glaciers are becoming grey, they are changing their surface, it is the so called «darkening effect»

The ongoing climate change is driving a deep change of glacier «skin»

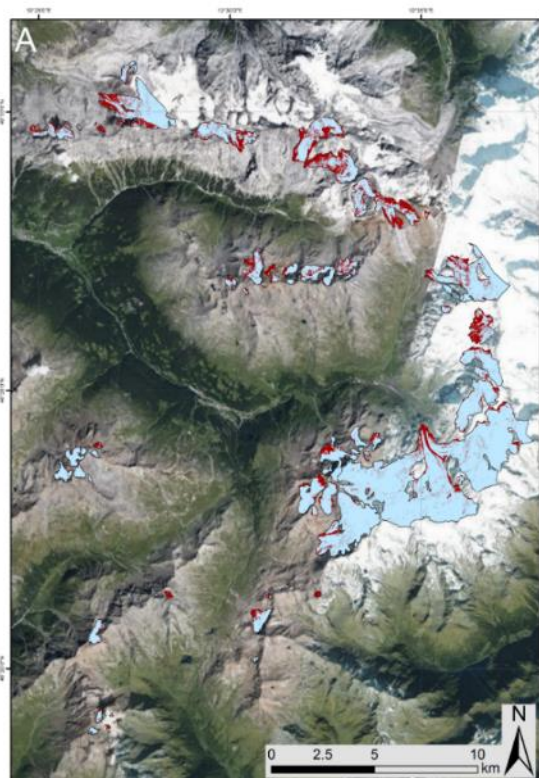


In the space there are several eyes which are surveying our Planet and they describe the main features of glacier surfaces, the darker glacier «skin» !

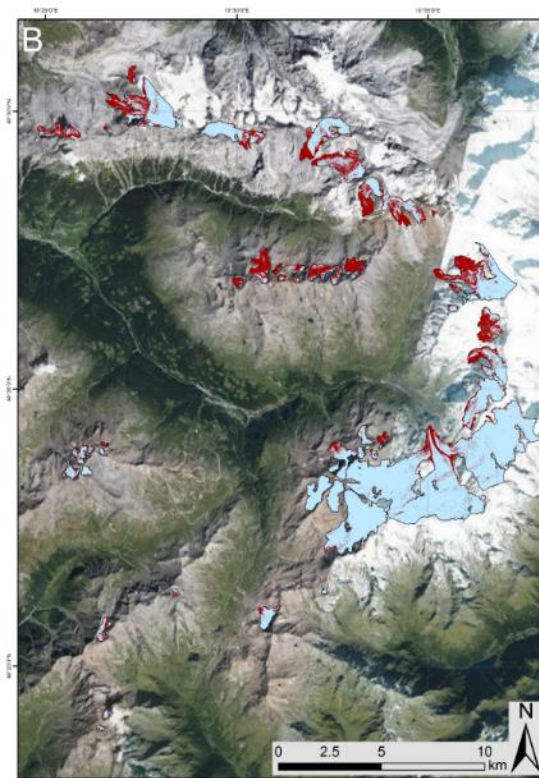


REMOTE SENSING IS A USEFUL METHOD TO DESCRIBE GLACIER SURFACE AND ITS CHANGES

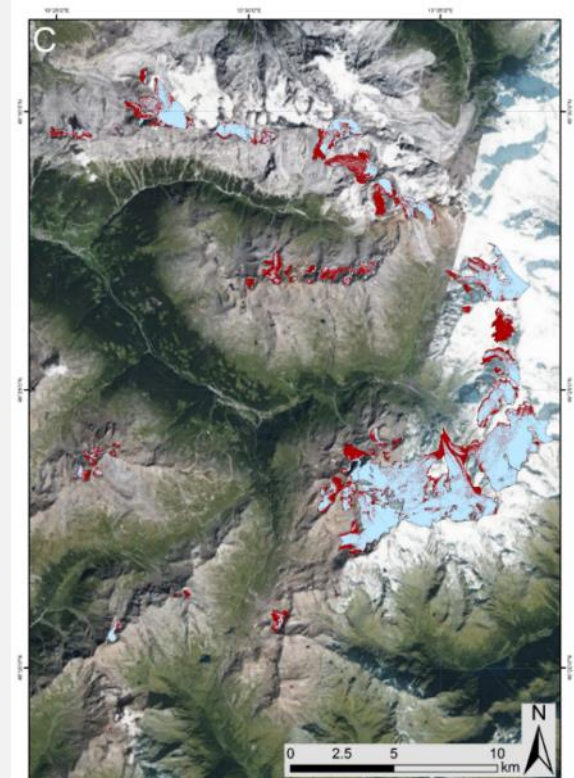
In the Stelvio National Park we found a strong increase of supraglacial rock debris (from 16.7% to 30.1% of glacier area). This is impacting and will impact on glacier melt (data in Azzoni et al; PPG 2018).



2003 → 16.7%



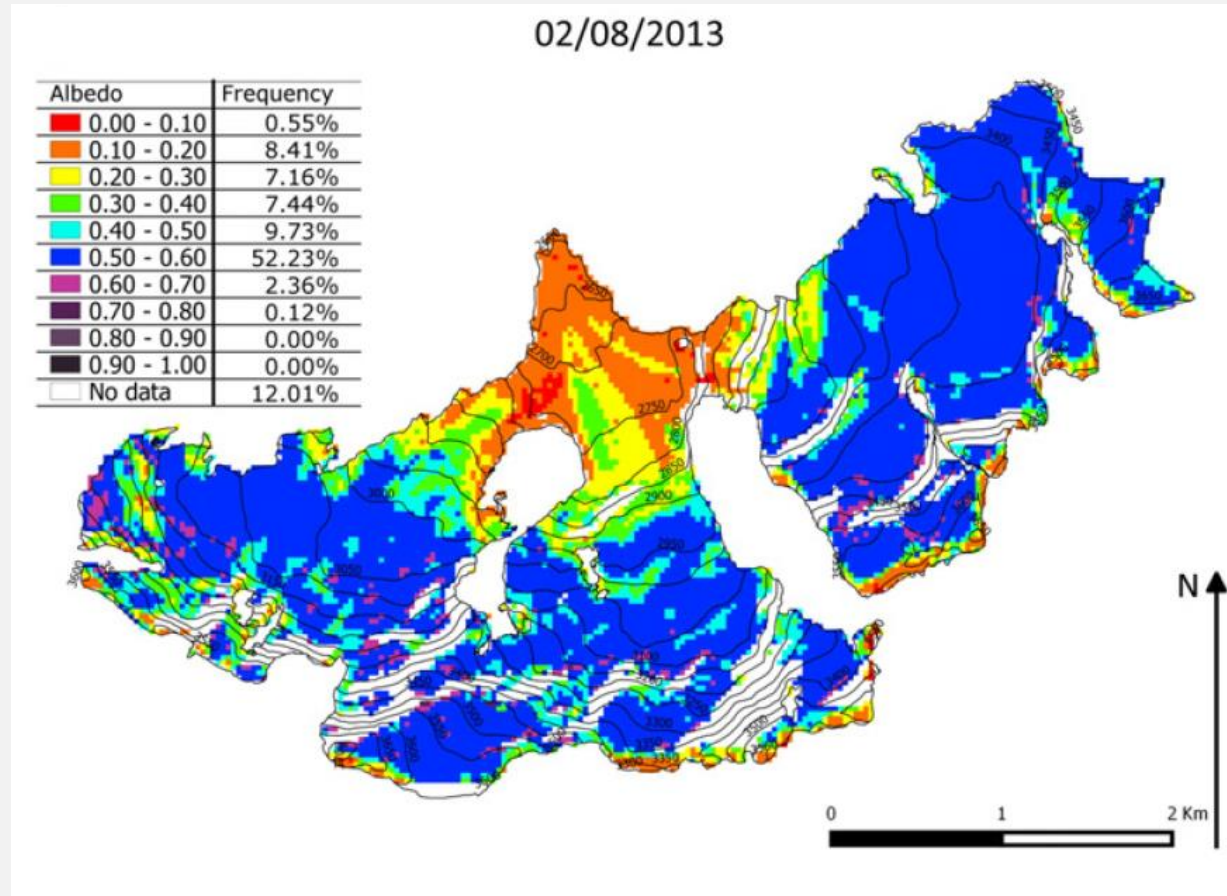
2007 → 22.5%



2012 → 30.1%

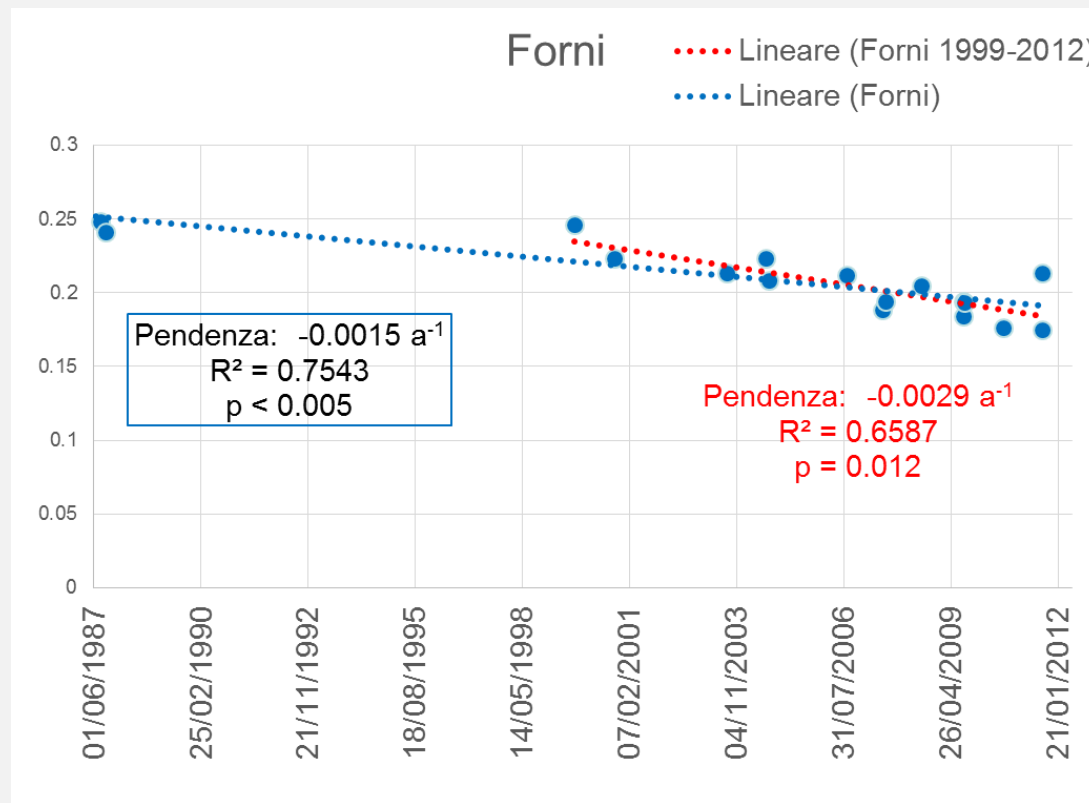
Remote sensing is also capable to describe glacier albedo

- Albedo from Landsat 4-7, from 1987 to 2012 (data from Fugazza et al; 2019)

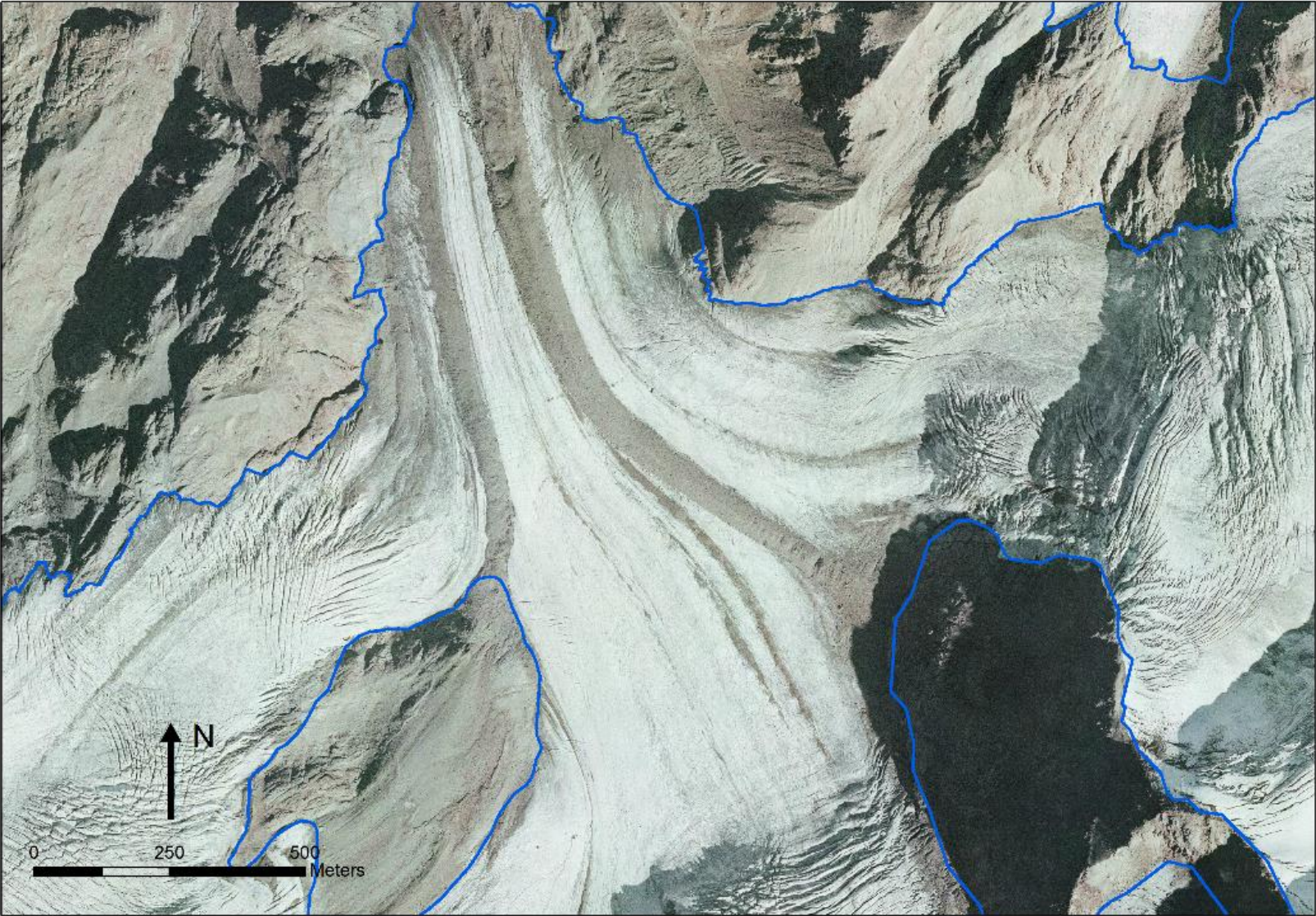


DARKENING and its effects on ALBEDO

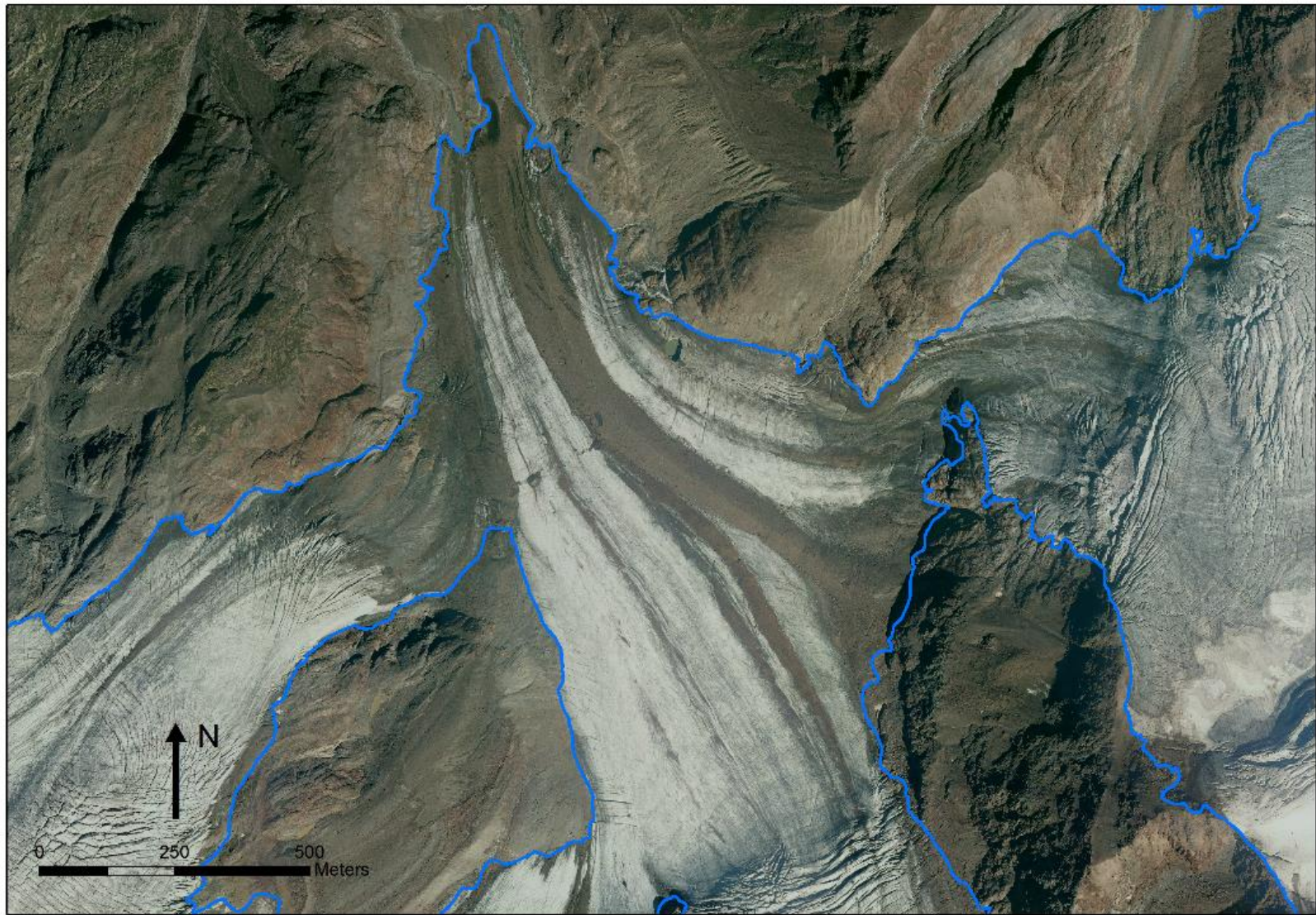
- On Forni Glacieri remote sensing show an actual decrease of surface albedo due to darkening effect (data from Fugazza et al; 2019)



Aerial photos confirming remote sensing data and albedo values



Aerial photos confirming remote sensing data and albedo values

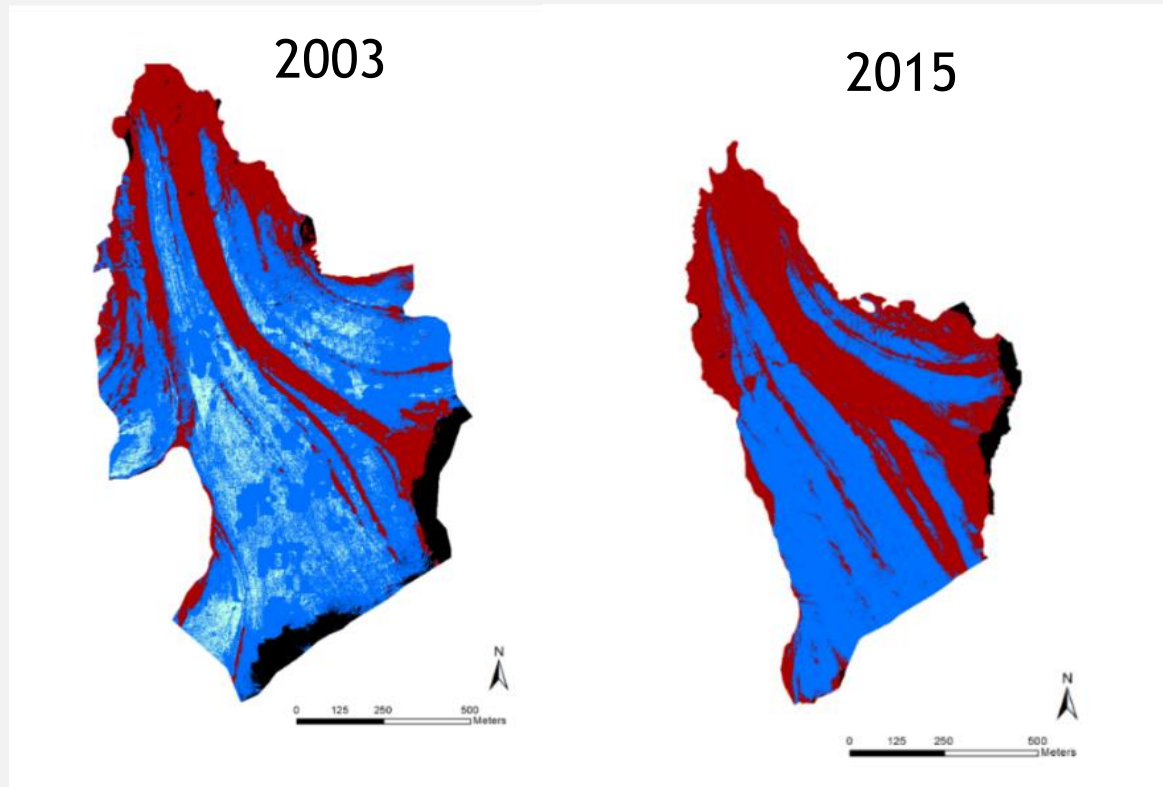


DARKENING- a phenomenon studied also by using drones (UAVs)!!!



DARKENING- a phenomenon studied also by using drones (UAVs)!!!

From our UAVs we obtained high resolution data showing ice darkening. In these maps Forni Glacier tongue is analysed (dati da Fugazza et al; NHESS, 2018)



Glaciers are present on our mountains as well!

Do you know how many glaciers are located on Italian mountains?

10? 100? 1000?

The New Italian Glacier Inventory!

It is freely available at:

<https://sites.unimi.it/giaciol/index.php/en/italian-glacier-inventory/>



How many glaciers in the Italian Alps?

The number is reported in the New Italian Glacier Inventory («Nuovo Catasto dei Ghiacciai Italiani») and in its first update, both available at the **UNIMI** website.



Present glacier extent and recent area changes

TODAY:

368 km² 903 glaciers

Change (over 60 years)

-157 km² (-30%) +68 glaciers

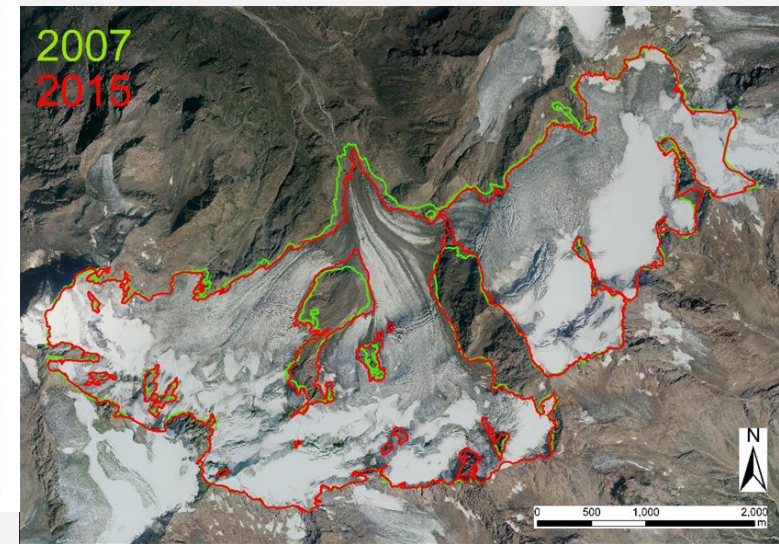
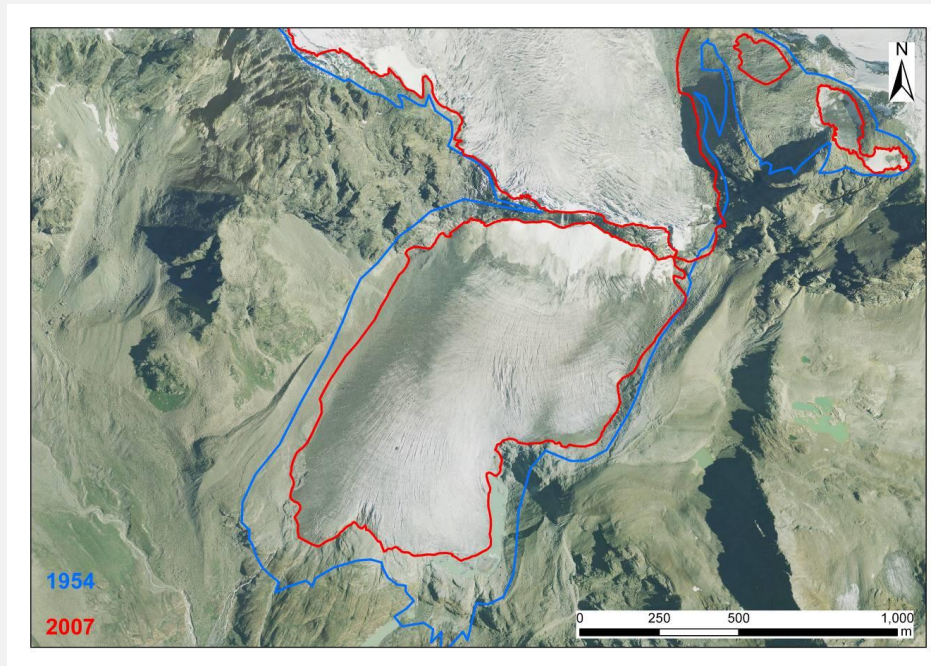



Valle d'Aosta: -48 km ²	-26%
Lombardia: -28 km ²	-24%
Alto Adige: -37 km ²	-30%
Trentino: -16 km ²	-33%
Piemonte: -27 km ²	-48%
Veneto: -2 km ²	-43%
Friuli: - 0,2 km ²	-50%
Abruzzo: 0,02 km ²	-33%

Comparing the old Inventory (CGI (1960)) with the new one (2015) we obtained a numerical increase of glaciers!

+68 glaciers? Is it real??

Yes, it derives from glacier fragmentation!





The fresh water derived from glacier ice melt is a small amount (with respect to other fresh water sources.....),

What is the role it plays? Is it really important?

To answer this question UNIMI performed an analysis:

We compared two high resolution DTMs thus evaluating the volume changes of all the Lombardy glaciers in the period 1981-2007



In the period 1981-2007:

-1663 x 10⁶ m³ of glacier ice which is equal to -1,5 km³ of water that is equal to -1496 billions of liters of water over 26 years!

This value means an annual water discharge of about 57,53 millions of m³ of water!!!!

Every Year in Lombardy liquid precipitations and snow give 27 billions of m³ of water!

dati from D'Agata et al., 2018, CRST

Moreover, UNIMI in cooperation with POLIMI, quantified the impact on hydropower of glacier ice melt:

The impact of glacier ice melt on hydropower in the Adda River

Cold Regions Science and Technology 148 (2018) 172–184



Contents lists available at ScienceDirect

Cold Regions Science and Technology

journal homepage: www.elsevier.com/locate/coldregions



Recent area and volume loss of Alpine glaciers in the Adda River of Italy and their contribution to hydropower production



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ARTICLE INFO

Keywords:

Remote sensing
Alpine glaciers
Glacier shrinkage
Climate change
Glacier contribution to hydropower

ABSTRACT

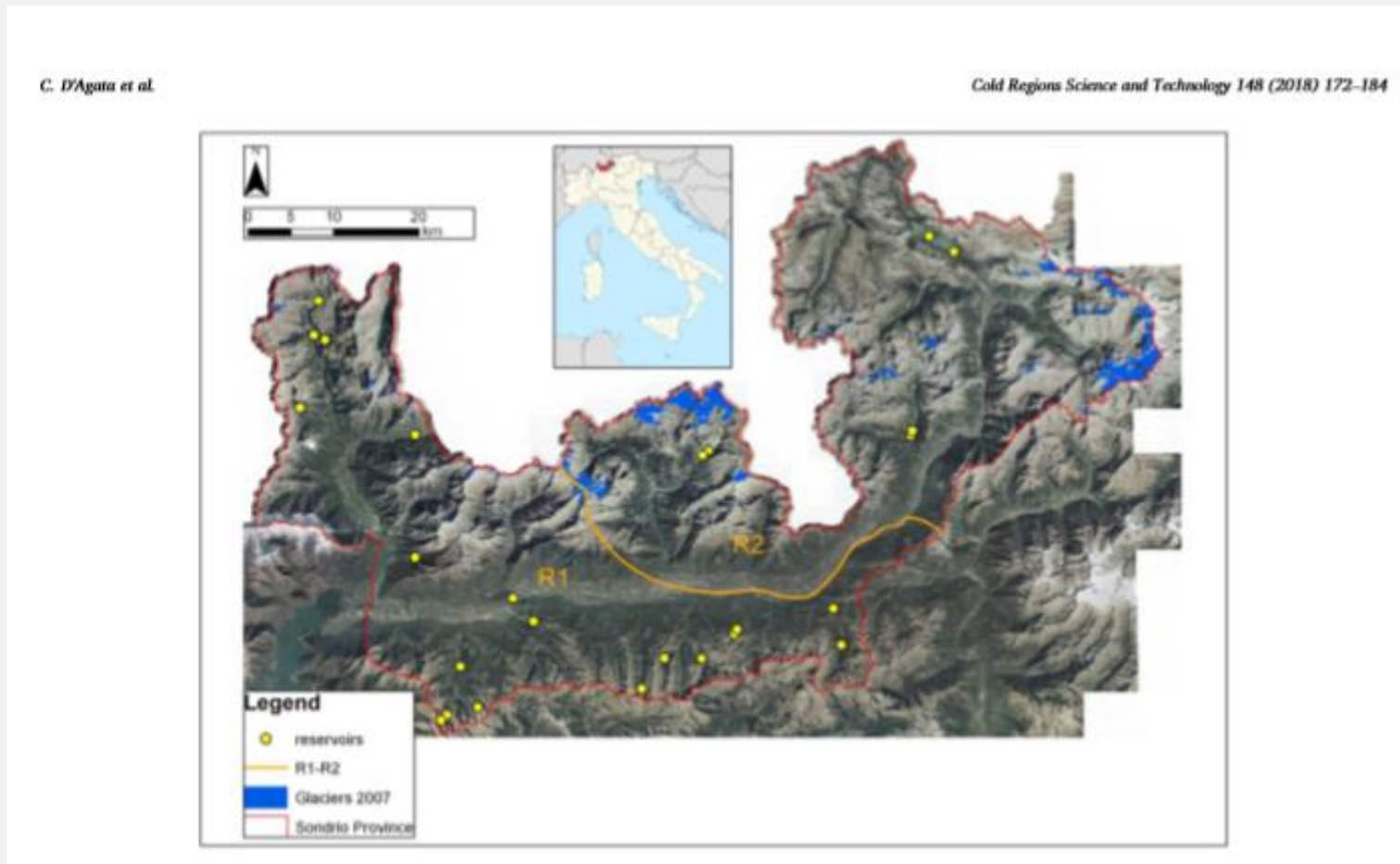
We computed and analysed the geometry changes affecting an Italian glacierized sector (the Sondrio Province, Adda River Basin). This zone was chosen because i) there is a relative abundance of high resolution remote sensing data covering the last thirty years, ii) it represents an important sector of the glacierized areas of Italy, and iii) it is first ranked within the list of Italian districts featuring highest hydro-power production.

We found large glacier reduction, with an area change of -25.41% during 1991–2007, and -30.5% during 1981–2007. Volume change during 1981–2007 was $-1353 \times 10^6 \text{ m}^3 \pm 27\%$. The mean thickness change was -14.91 m . The mean annual volume change of the Sondrio glaciers was about $-52 \times 10^6 \text{ m}^3 \text{ y}^{-1}$ of ice, or ca. $-47 \times 10^6 \text{ m}^3 \text{ y}^{-1}$ of water. We then computed the glaciers' contribution to 25 hydropower plants located in the studied area. For this purpose we divided the study region into two zones. While in the first, Eastern most region (R1) a large share of hydropower is provided by liquid precipitation, in the second Western region (R2) ca. 1/2 of the total water for hydropower is provided by solid water, i.e. snowfall and ice melt. Our results display that in areas like Region R2, where a large share of hydropower production depends upon ice melt, the expected future lack of water under glaciers' down wasting may affect energy production, and requires adaptation strategies.



Moreover, UNIMI in cooperation with POLIMI, quantified the impact on hydropower of glacier ice melt.

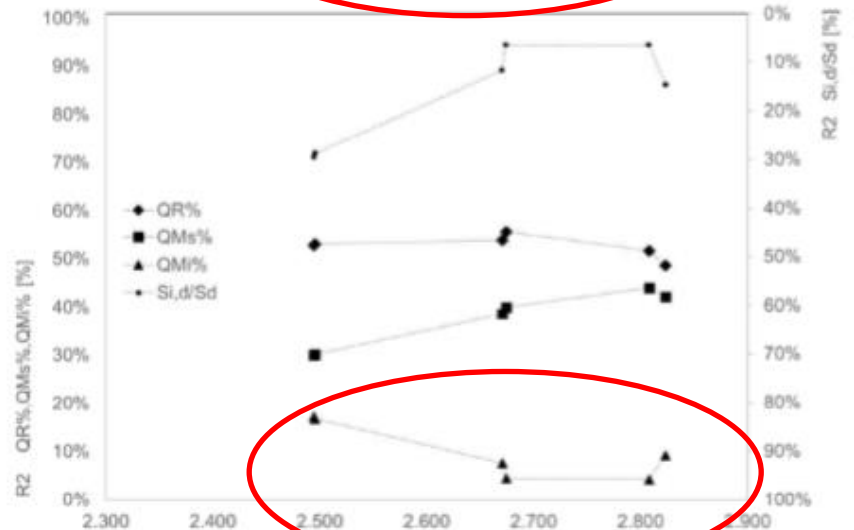
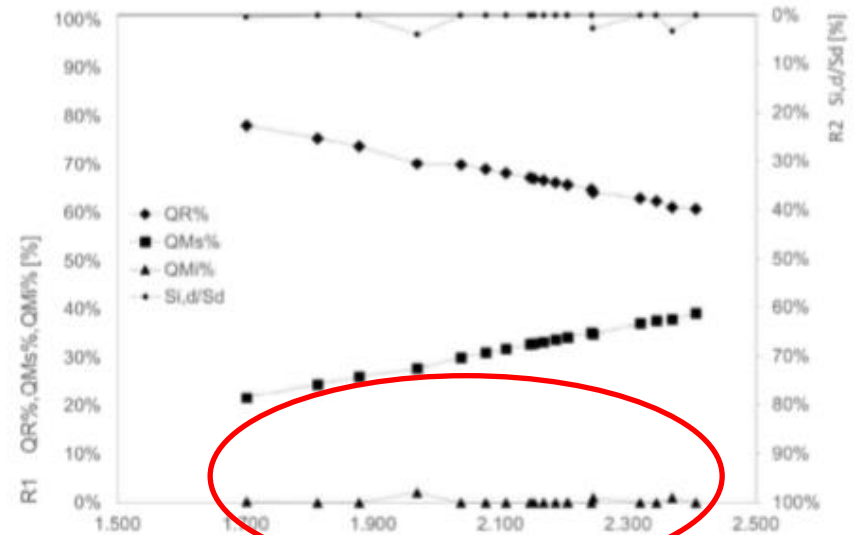
The impact of glacier ice melt on hydropower in the Adda River



D'Agata et al., 2018, CRST

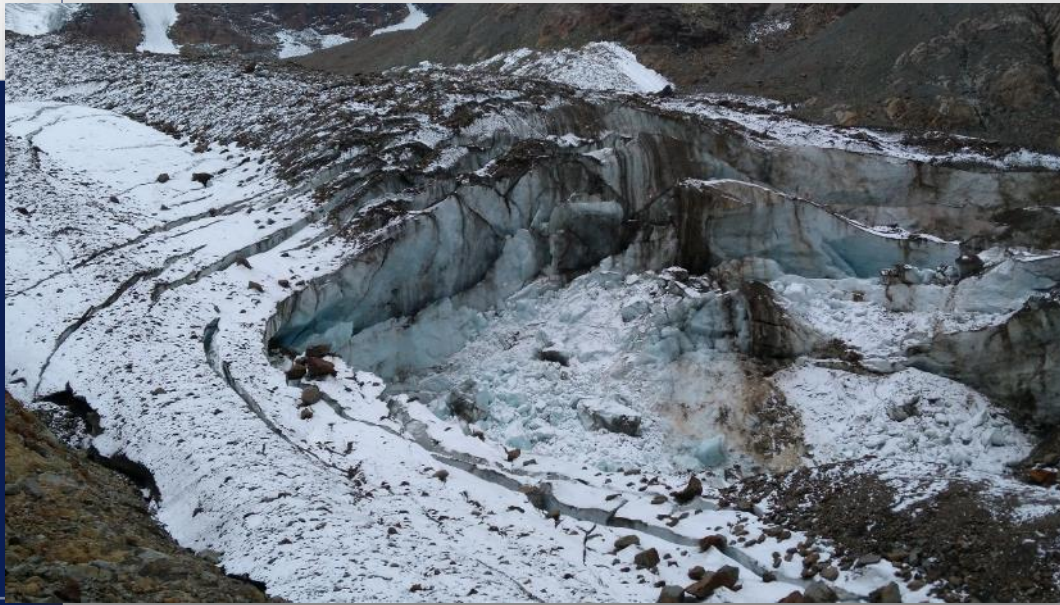
The impact of glacier ice melt on hydropower in the Adda River

- Considering 9 hydropower plants in Upper Valtellina we evaluated the impact of ice melt:
- Up to 20 % of water in the plants derived from ice melt
- Climate change scenarios will be crucial





ALPS WHITOUT GLACIERS? It is possible!





What can I do to face this issue?



What can I do to face this issue?

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Cold Regions Science and Technology 173 (2020) 103007

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Cold Regions Science and Technology

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The non-woven geotextiles as strategies for mitigating the impacts of climate change on glaciers

Antonella Senese^{a,*}, Roberto Sergio Azzoni^a, Davide Maragno^a, Carlo D'Agata^a, Davide Fugazza^a, Boris Mosconi^a, Alberto Trenti^b, Eraldo Meraldi^c, Claudio Smiraglia^a, Guglielmina Diolaiuti^a

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ARTICLE INFO

Keywords:
Non-woven geotextile
Snow melt mitigation
Dosed Est Glacier
Presena Ovest Glacier

ABSTRACT

During the past decades, there have been attempts to offset melt at glacier ski resorts. The most important method is active glacier protection, largely based on the use of geotextiles to preserve snow cover and reduce its melt. Until 2008, a scientific evaluation of the efficiency of glacier covering strategies had never been carried out in Italy, although strategies for snow melt reduction were already in place.

In this study, we show the results from three experiments carried out on Dosed Est Glacier (Cima Piazzini Group, Lombardy) and Presena Ovest Glacier (Adamello-Brasenella Group, Autonomous Province of Trento).

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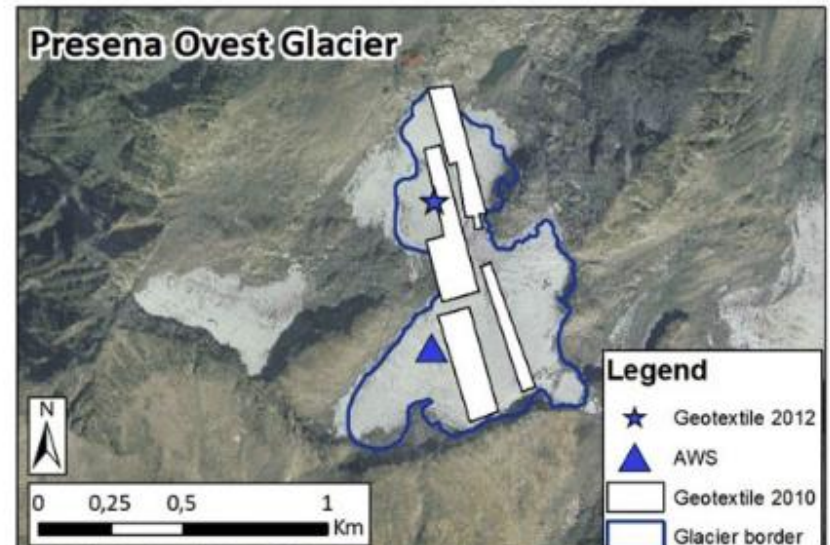
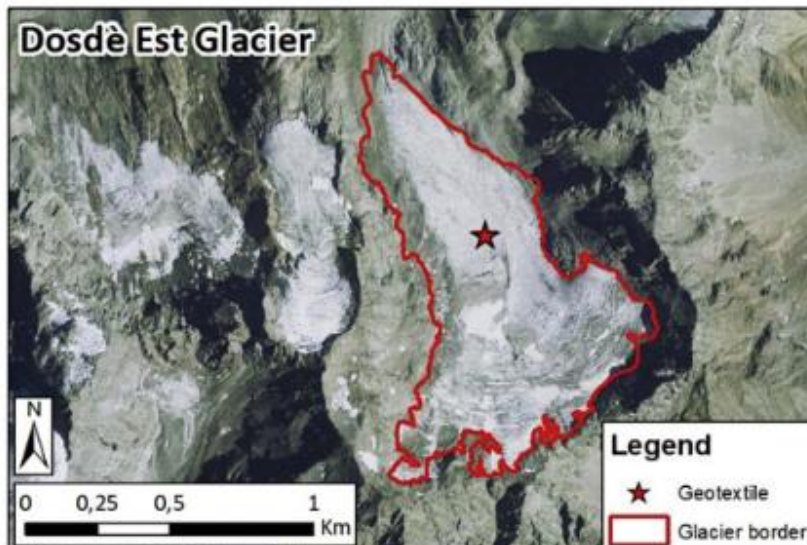
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25/04/2022

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The non-woven geotextiles as strategies for mitigating the impacts of climate change on glaciers

A. Senese, et al.

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The non-woven geotextiles as strategies for mitigating the impacts of climate change on glaciers

Table 1

Details of the non-woven geotextiles tested on Dosdè Est and Presena Ovest glaciers.

Site	Year	Manufacturer	ID Geotextile	Chemical composition	Mass per unit area	Thickness (mm at 2 kPa)
Dosdè	2008	Landolt	ICE PROTECTOR 500 ©	Double-bedded Polypropylene / Polyester (PET/PP)	500 g/m ²	3.80
Presena	2010	TenCate	TOPTEx GLS 340	Polypropylene (PP)	340 g/m ²	4.00
Presena	2012	Edilfloor	COVERICE 340	Polypropylene (PP)	340 g/m ²	3.20
Presena	2012	Edilfloor	COVERICE 340BIO	Poly-lactic acid (PLA)	340 g/m ²	3.00
Presena	2012	Edilfloor	COVERICE 340PET	Polyester (PET)	340 g/m ²	3.00
Presena	2012	Edilfloor	COVERICE 500	Polypropylene (PP)	500 g/m ²	3.70
Presena	2012	Edilfloor	COVERICE 500D	Double-bedded Polypropylene (PP)	500 g/m ²	4.40
Presena	2012	Edilfloor	SI400	Polypropylene (PP)	400 g/m ²	3.80

unprotected snow/ice. The geotextile was removed on 4 October 2008.

4.2. The second experiment: Presena Ovest Glacier

On 28 June 2010, a non-woven geotextile (TOPTEx GLS 340 ©, produced in Linz, Austria, see [Table 1](#)) was installed along the main flowline of Presena Ovest Glacier, covering 76,400 m² which is about 30% of the total glacier area. The aim of this experiment was to understand the effects of non-woven geotextiles on glacier radiative fluxes and albedo ([Fig. 3](#)). The geotextile was placed on snow previously compacted by snow cats, thus with a higher initial density than natural snow at the same elevation. It was removed on 14 September.

Before the installation, snow pits were dug following the AINEVA protocol ([Senese et al., 2018](#)) by personnel from the Autonomous Province of Trento (PAT), with the aim of evaluating the snow density and its features and of quantifying snow accumulation. The snow/ice ablation rate was measured every 15 days by means of ablation stakes drilled into the ice both along the geotextile borders and at specific sites



The non-woven geotextiles as strategies for mitigating the impacts of climate change on glaciers

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Fig. 7. The effectiveness of the non-woven geotextile ICE PROTECTOR 500 © on Dosdè Est Glacier: on 14th June 2008 (left) and on 4th October 2008 (right).

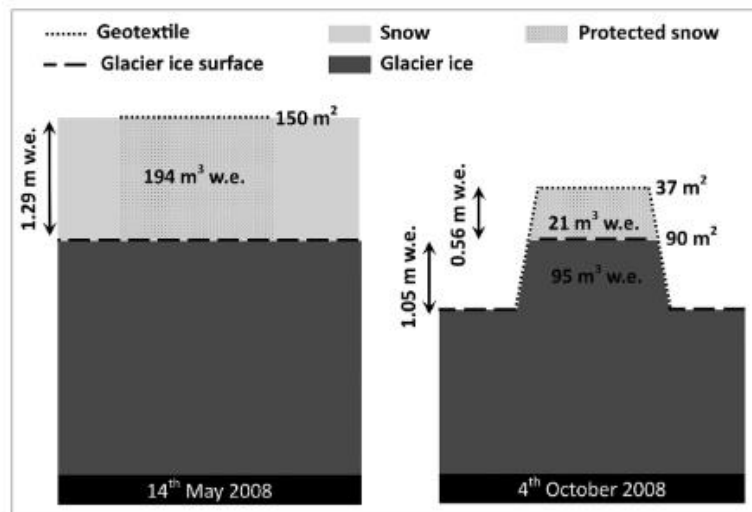


Fig. 8. Schematic drawing showing the effectiveness of the ICE PROTECTOR 500 © non-woven geotextile on Dosdè Est Glacier. Snow and ice are represented by light and dark grey, respectively. Dotted lines denote the geotextile cover and dashed lines the glacier ice surface and then the snow-ice interface.

The non-woven geotextiles as strategies for mitigating the impacts of climate change on glaciers

On The European Alps more than 2900 glaciers are located...we cannot cover all of them due to:

- potential environmental and ecological impacts
- potential landscape impacts
- high costs for installation, maintenance and removal of the blankets
- possibility of microplastics release

Then

We can apply such method on glaciers used for summer skiing.
For the others we need to look for different solutions....

You can be a conscious customer who does sustainable choices!

How can we do? We can start by knowing our climate footprint!

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La tua Impronta

INFORMAZIONI PER RISPONDERE AL QUESTIONARIO

Il questionario è articolato in quattro sezioni e le tue risposte ci permetteranno di quantificare le tue emissioni annue di composti climalteranti espresse in termini di CO2 equivalenti (CO2-eq). In particolare, ci baseremo su dati relativi alla tua abitazione e a come essa è riscaldata, su come illumini la tua casa, su quali elettrodomestici possiedi e su quanto li usi, su quanto e come ti muovi, sul tipo di alimentazione che adotti e su come smaltisci i tuoi rifiuti.

Scopri il tuo impatto sull'ambiente

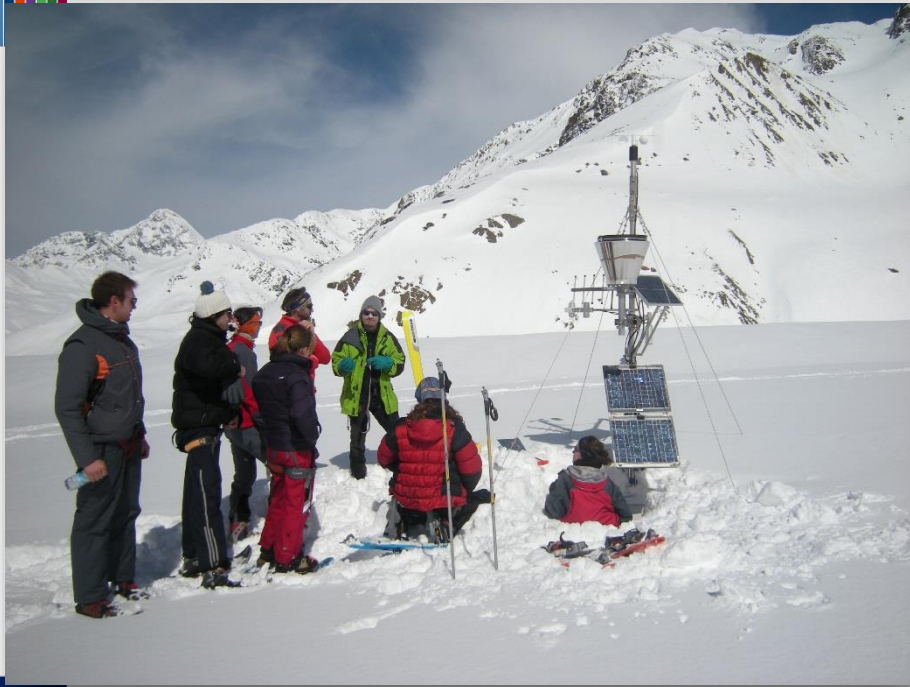
Prenditi qualche minuto per scoprire come la **tua impronta di carbonio** sia fortemente influenzata dalle tue scelte e dal tuo stile di vita. Compila questo questionario, promosso da Vaillant e sviluppato dal Dipartimento di Scienze e Politiche Ambientali (ESP) dell'Università degli Studi di Milano. Oltre a scoprire quanto contribuisce alle emissioni di CO2, fornisci un prezioso contributo per la nostra ricerca sul clima! I dati che fornirai saranno mantenuti anonimi.

We can use the carbon footprint test developed by UNIMI ESP which is freely available in the net

<http://latuaimpronta.vaillant.it/il-test#1.1>

The screenshot shows a web browser window with the URL latuaimpronta.vaillant.it/il-test#1.1. The page features a green sidebar on the left with the logo 'La tua Impronta' and a vertical progress indicator with four steps: 1.0 riscaldamento, 2.0 illuminazione ed elettrodomestici, 3.0 trasporti, and 4.0 alimentazione e trattamento dei rifiuti. The main content area is white and displays the section title '1.1 RISCALDAMENTO' followed by the question 'In quale area geografica vivi?'. Below the question are three radio button options: 'Nord Italia', 'Centro Italia', and 'Sud Italia'. At the bottom of the main area, there is a link 'Approfondisci' and a 'Continua' button.





Glaciers: the melting heart of our mountains

Our team @UNIMI
Is composed by:

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Davide Maragno, Carlo D'Agata**

