UNIVERSITÀ DEGLI STUDI DI MILANO

Glaciers: the melting heart of our mountains

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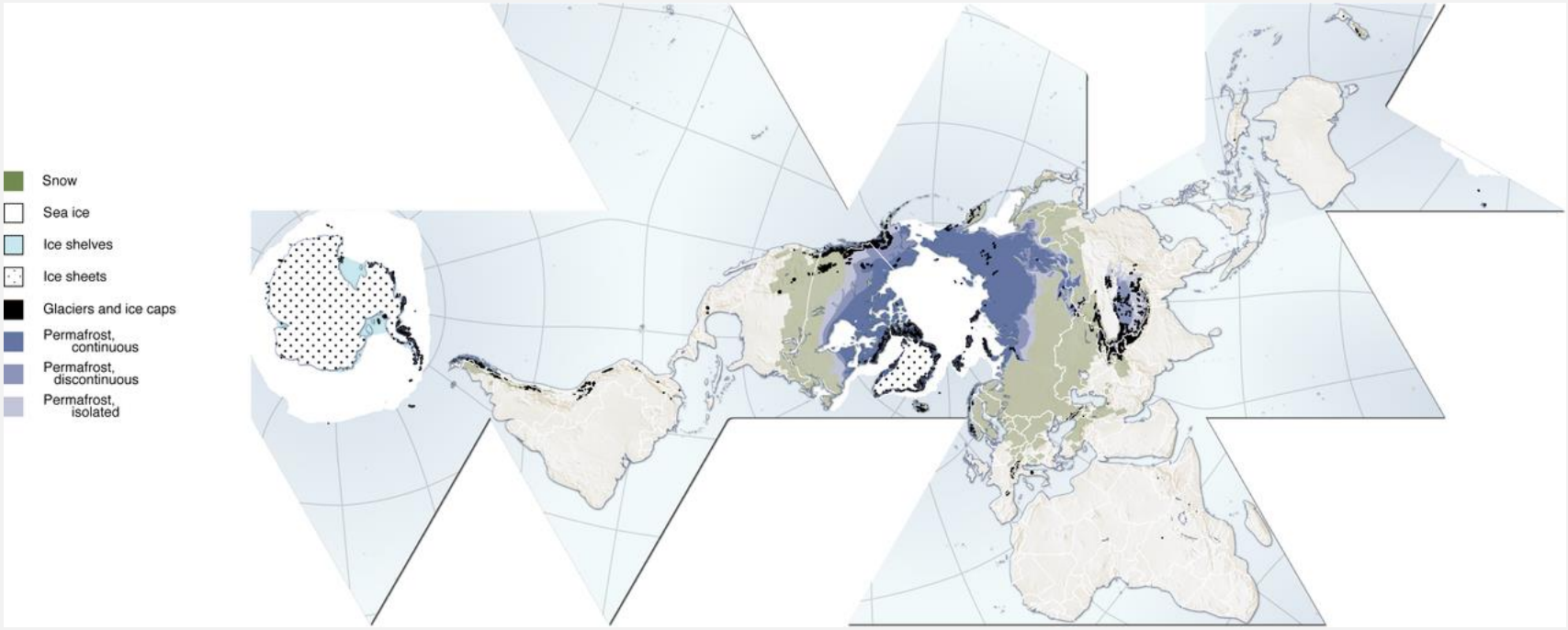
1. Main definitions

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

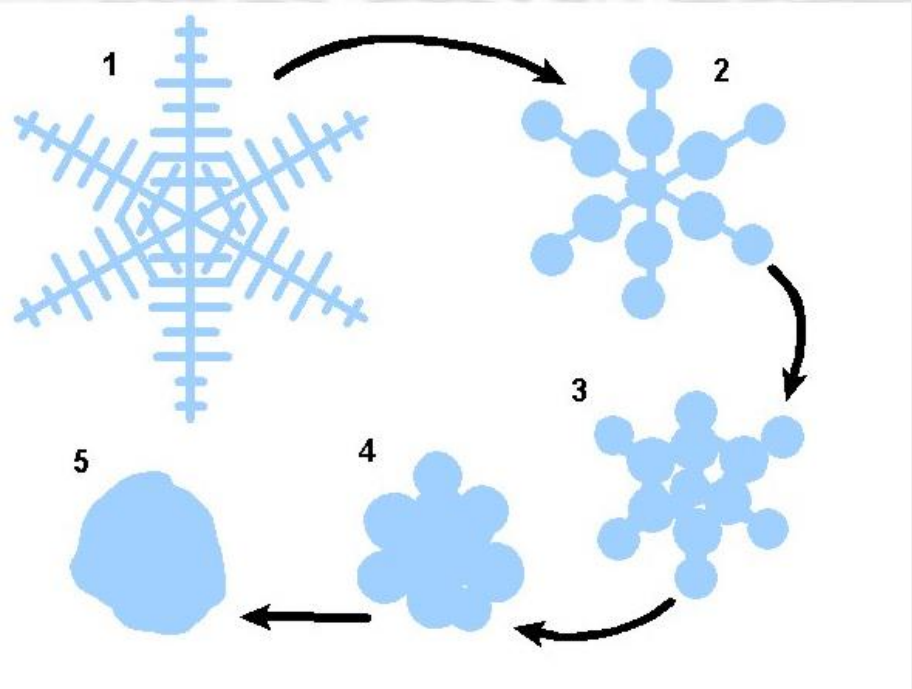
Moreover…glaciers are boxes of freshwater!

Glacier ice is deeply different from sea ice!!!

≠

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)

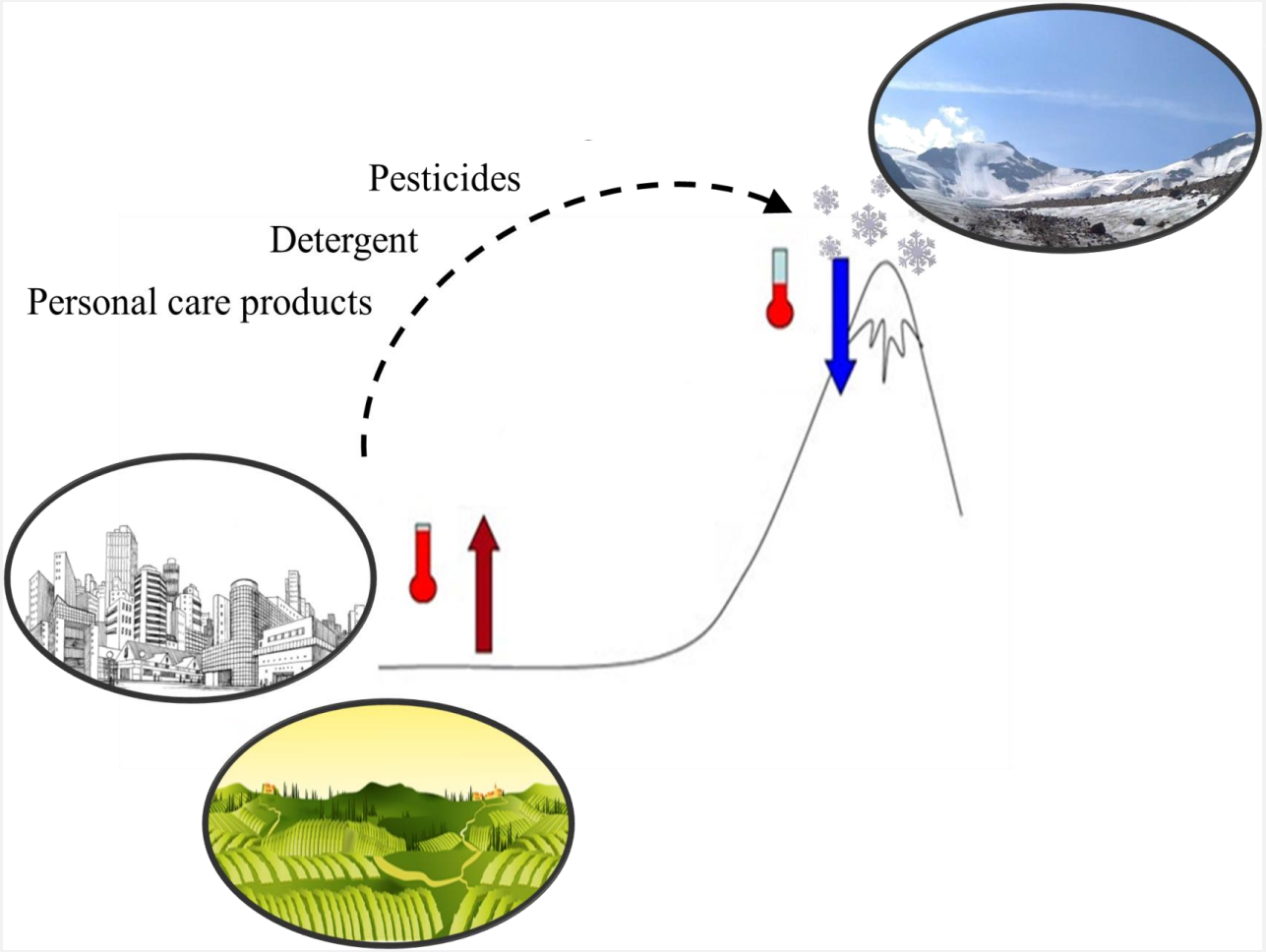
The process continues, serving to concentrate the mass of the water closer to the center of the original snowflake.

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 polluttants 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?

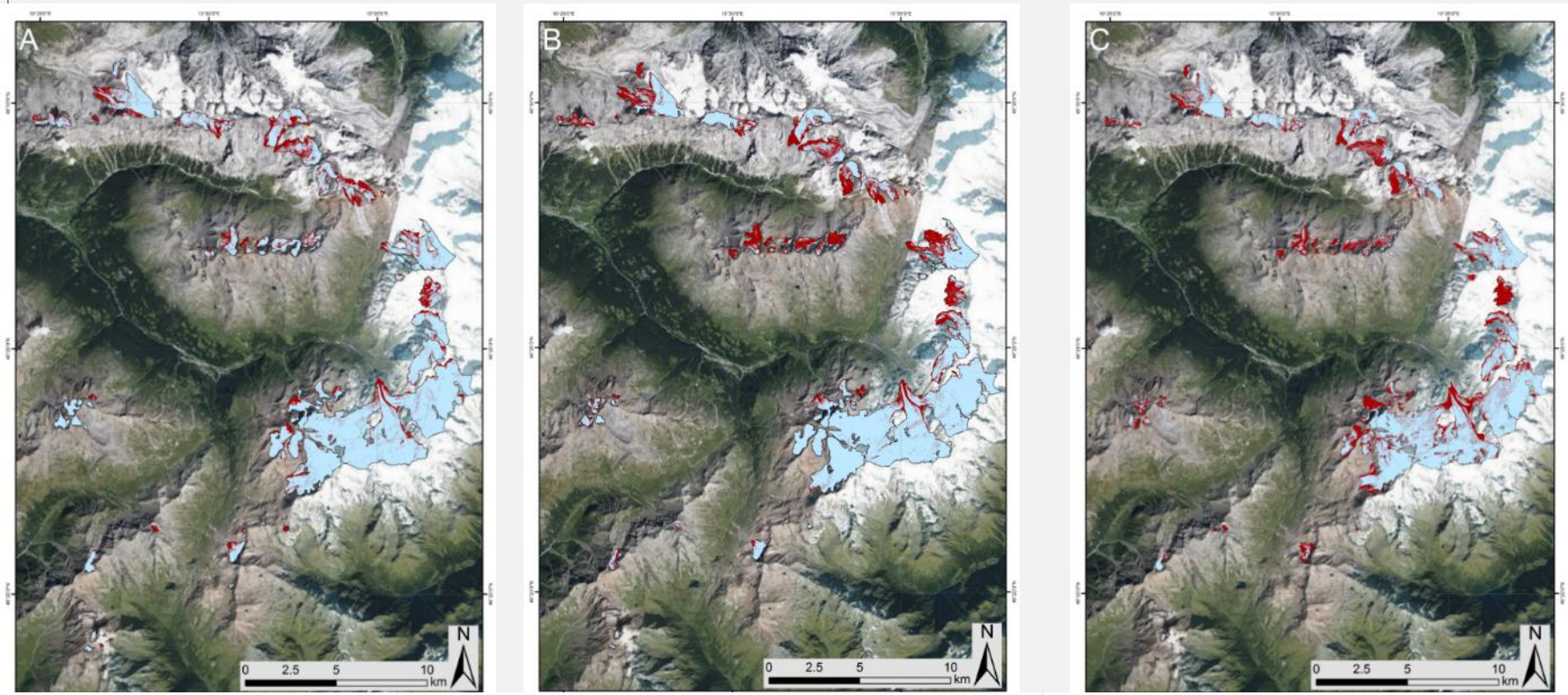
Glaciers are becoming grey, they are changing their surface, it is the so called «darkening effect»

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 DECRIBE GLACIER SURFACE AND ITS CHANGES

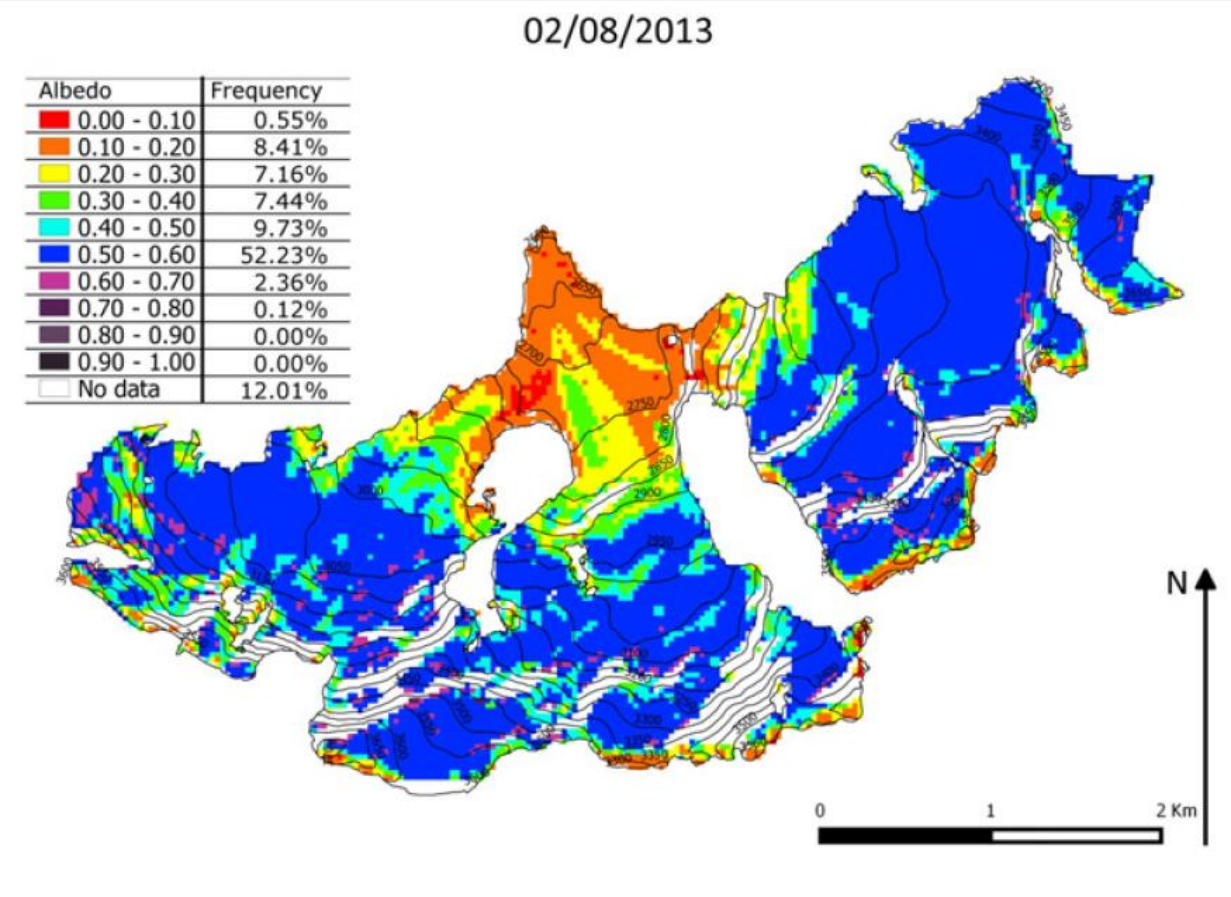
In the Stelvio National Park we found a strong increase of supraglacial rock debris (from 16.7% to 30.1% of glacier area). This is impacting and will impact on glacier melt (data in Azzoni et al;PPG 2018).



2003 → 16.7% 2007 → 22.5% 2012 → 30.1%

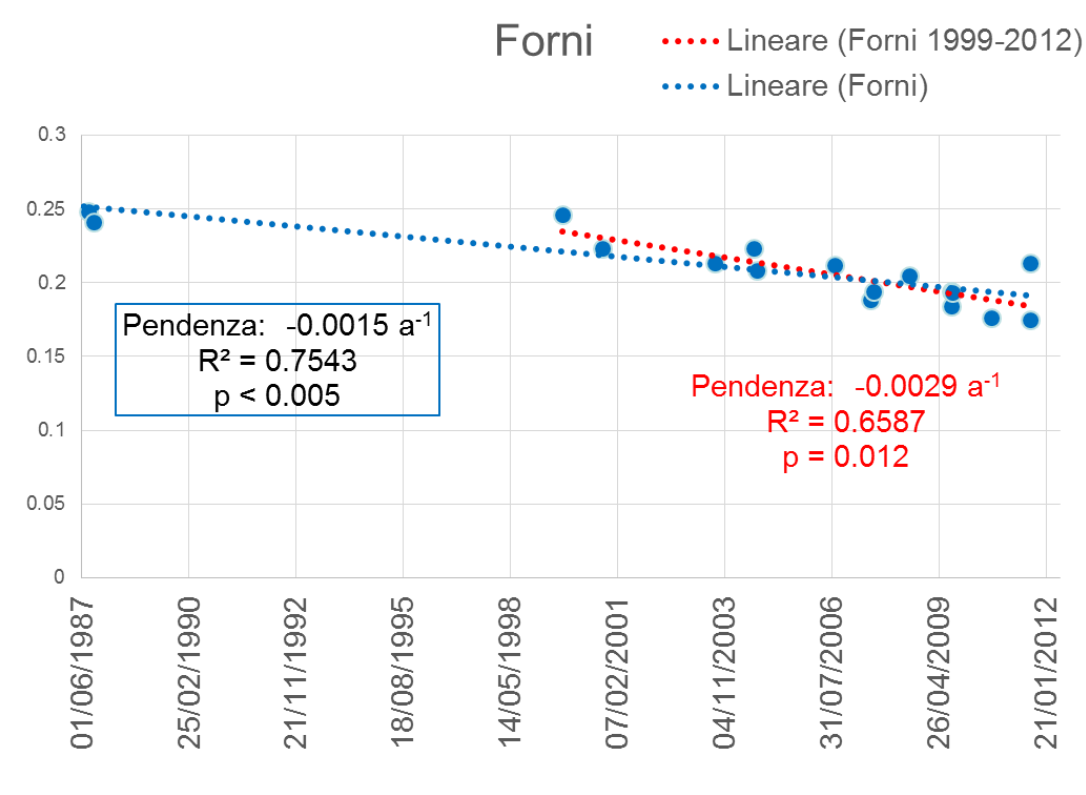
Remote sensing is also capable to describe glacier albedo

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

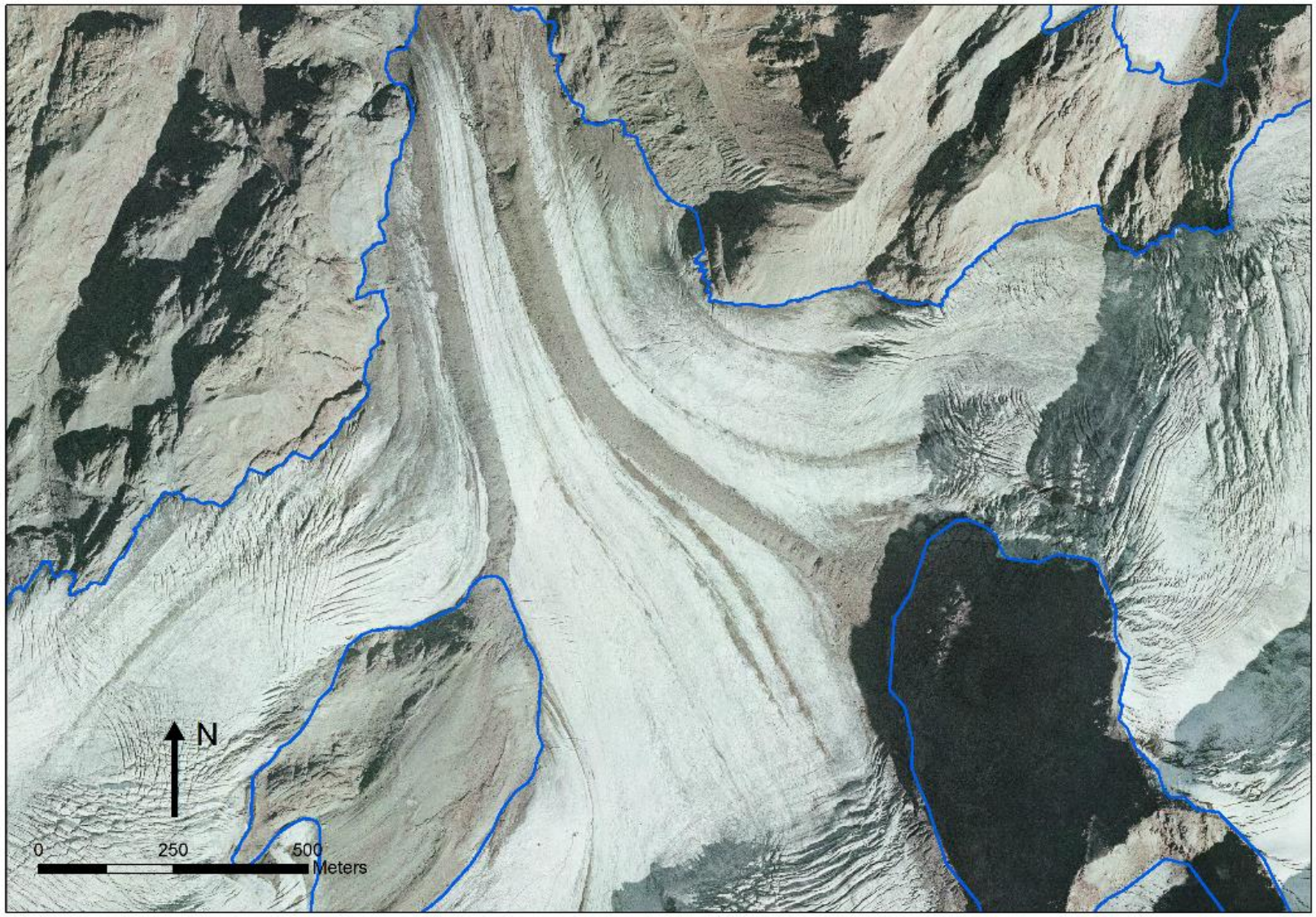


DARKENING and its effects on ALBEDO

- 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



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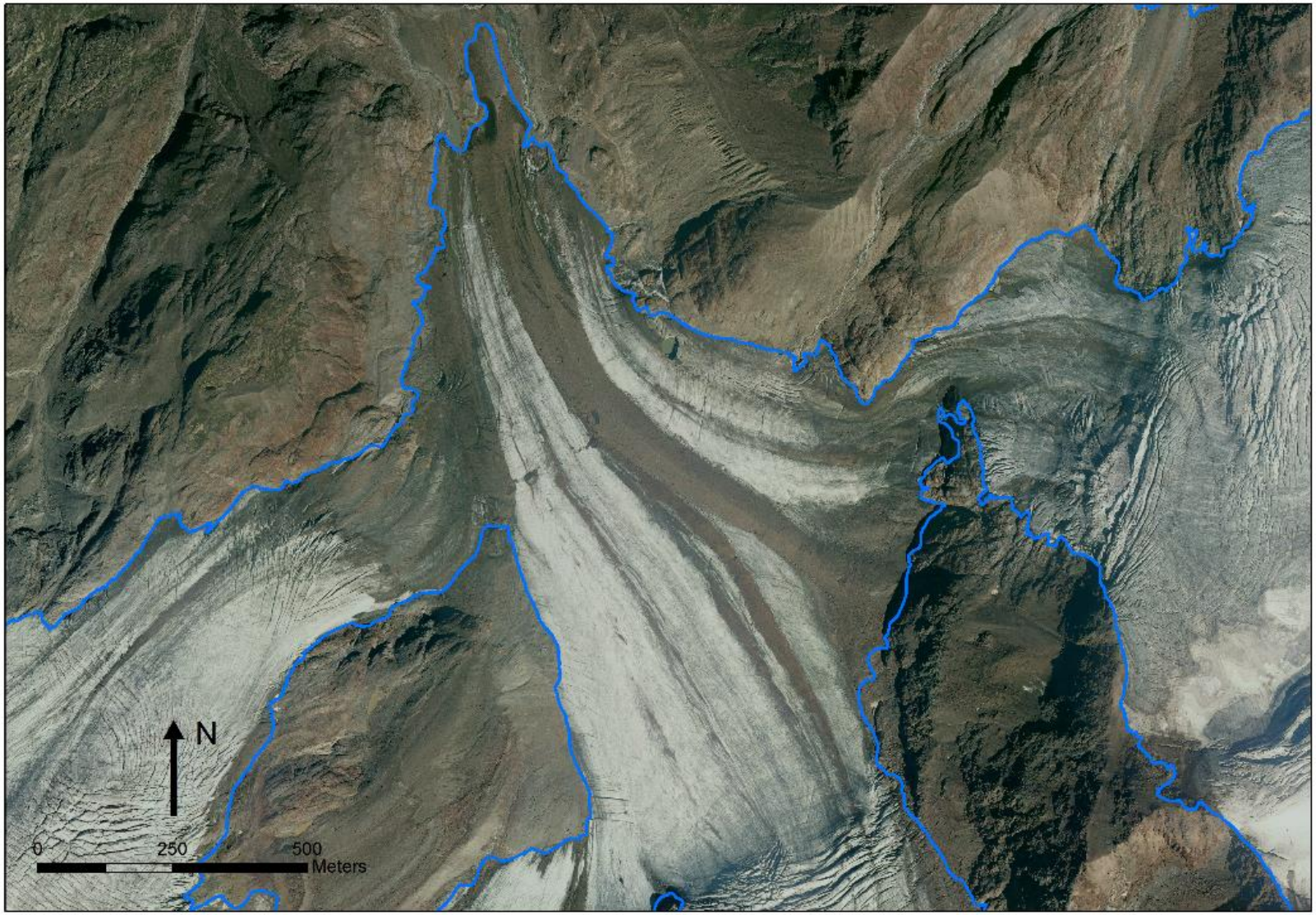

DARKENING- a phenomenon studied also by using drones (UAVs)!!!

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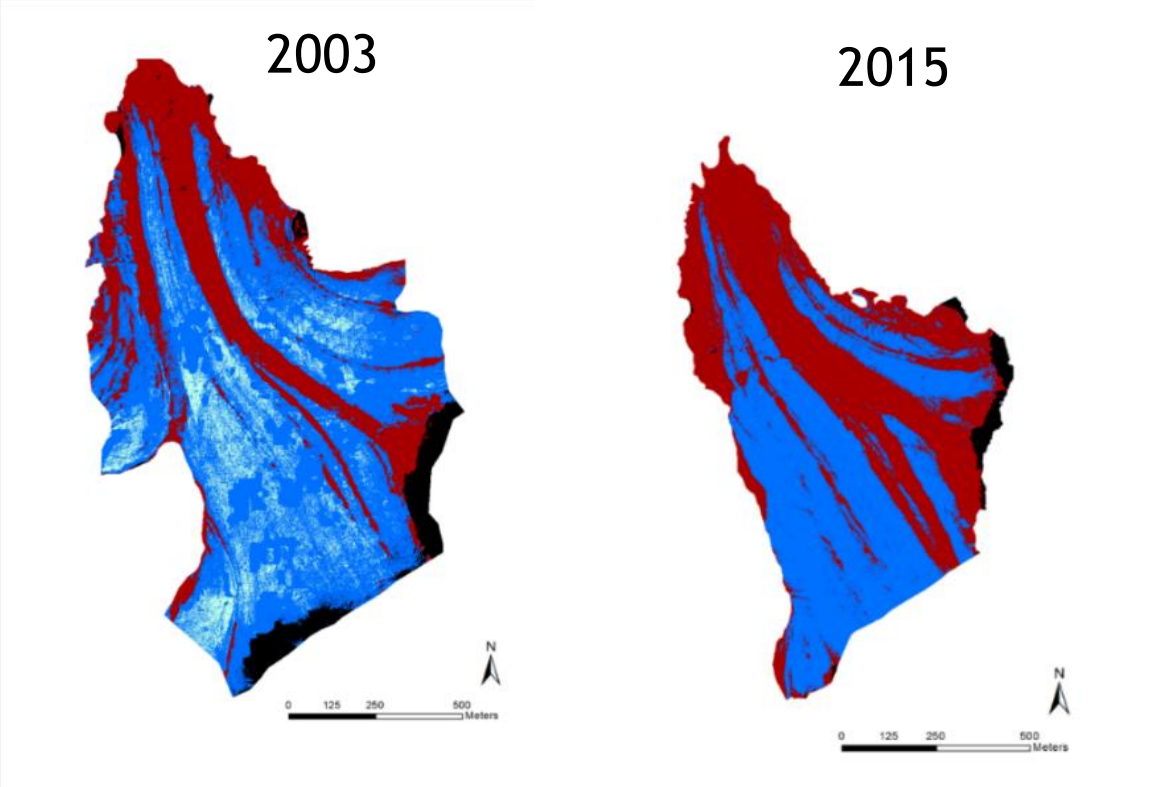
From our UAVs we obtained high resolution data showing ice darkening. In these maps Forni Glacier tongue is analysed **(dati da Fugazza et al; NHESS, 2018)**



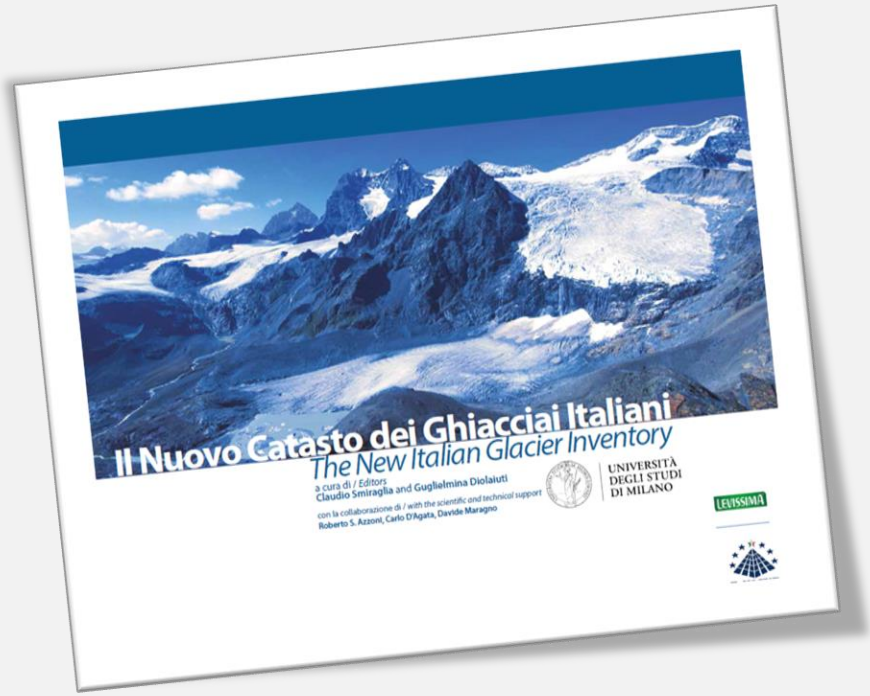
Glaciers are present on our montains as well!

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/glaciol/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

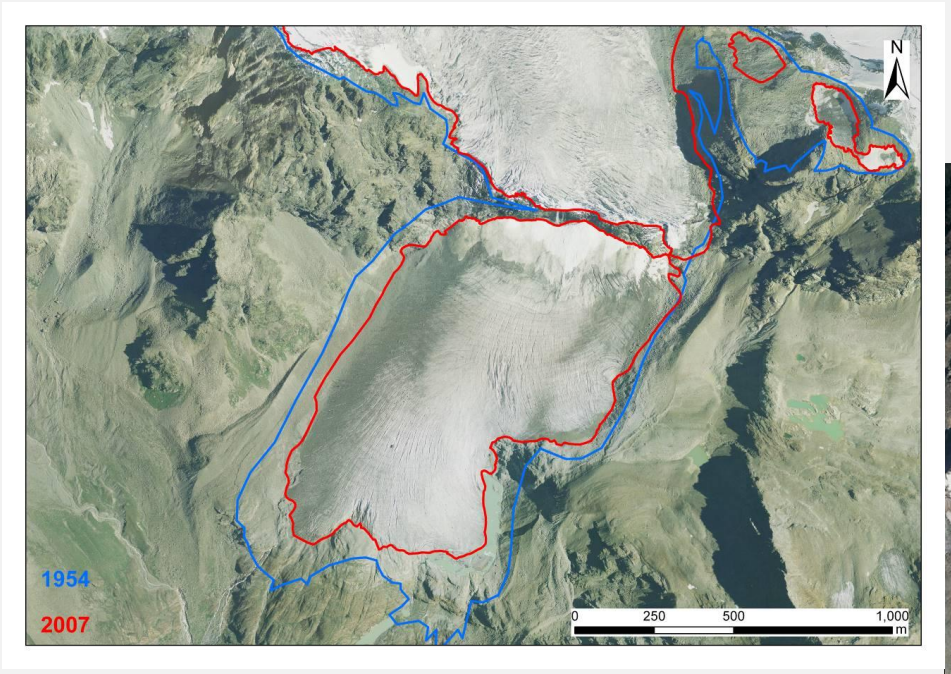
Change (over 60 years)
-157 km² (-30%) +68 glaciers

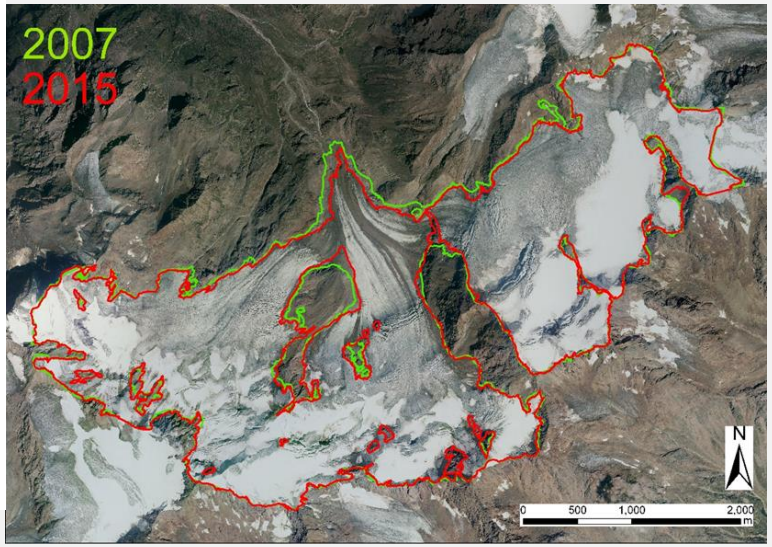
Valle d'Aosta: -48 km²	-26%
Lombardia: -28 km²	-24%
Alto Adige: -37 km²	-30%
Trentino: -16 km²	-33%
Piemonte: -27 km²	-48%
Veneto: -2 km²	-43%
Friuli: - 0,2 km²	-50%
Abruzzo: 0,02 km²	-33%

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 10^6 m^3 of glacier ice which is equal to -1,5 km^3 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 m^3 of water!!!!

Every Year in Lombardy liquid precipitations and snow give 27 billions of m^3 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

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

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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 -1353×10^6 m^3 ± 27%. The mean thickness change was −14.91 m. The mean annual volume change of the Sondrio glaciers was about -52×10^6 m^3 y^{-1} of ice, or ca. -47×10^6 m^3 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:

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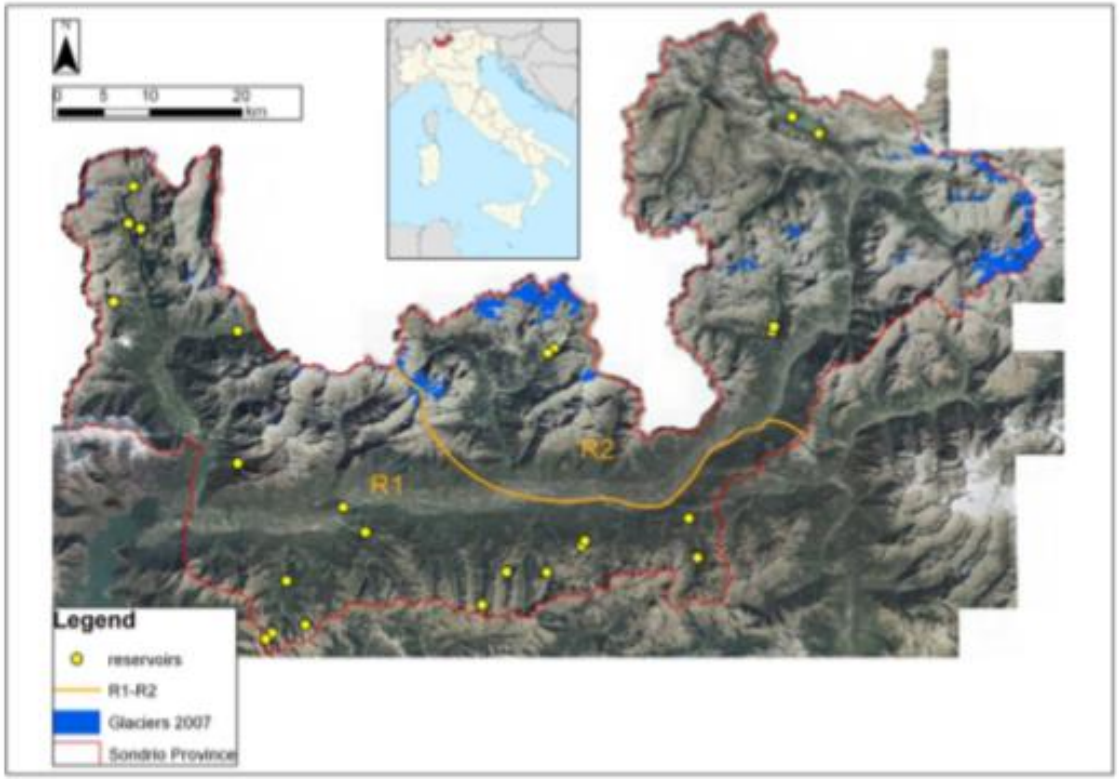
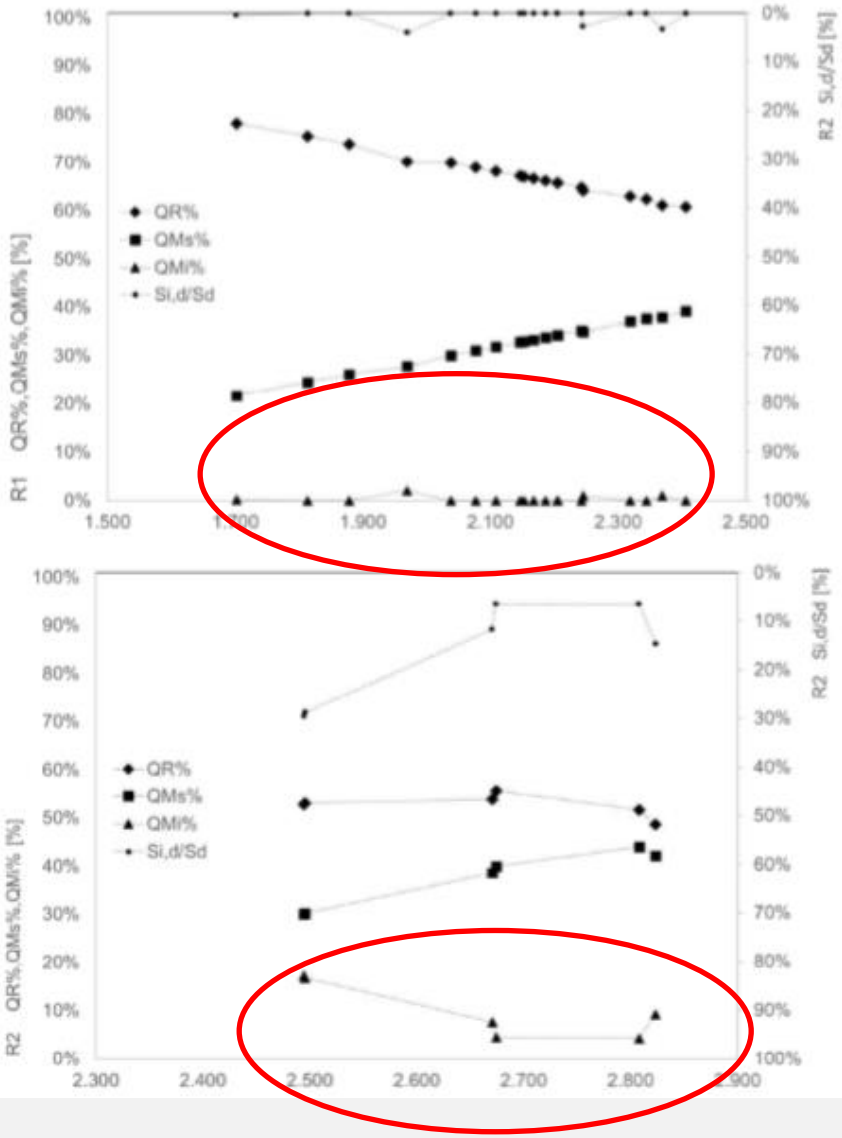


D'Agata et al., 2018, CRST

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?

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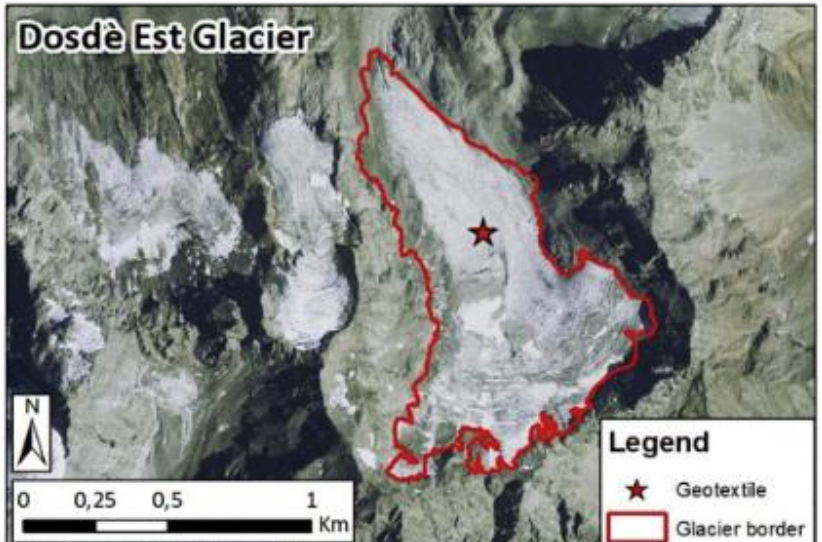
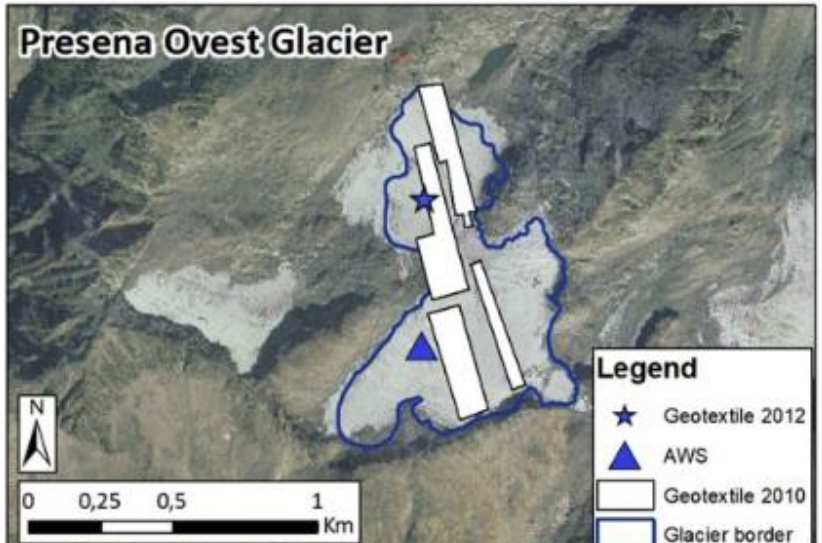
The non-woven geotextiles as strategies for mitigating the impacts of climate change on glaciers





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 m^2 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

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

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).

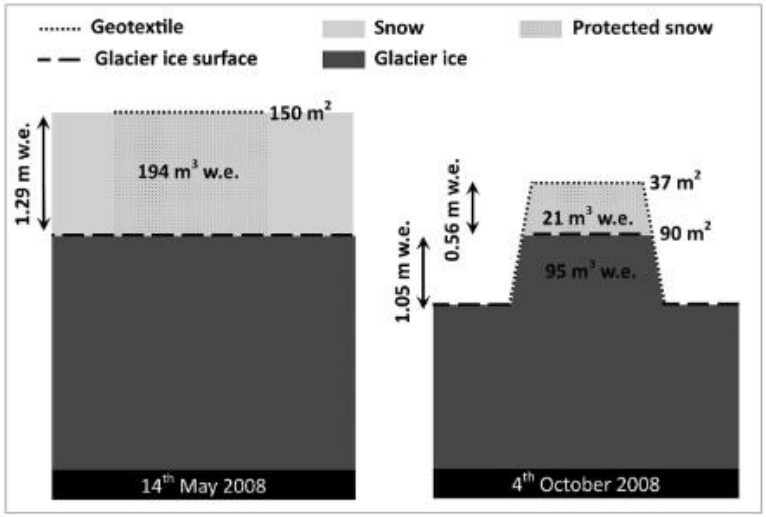


Fig. 8. Schematic drawing showing the effectiveness of the ICE PROTECTOR 500 © non-woven geotextile on Dosdè Est Glacier. Snow and ice are represented by light and dark grey, respectively. Dotted lines denote the geotextile cover and dashed lines the glacier ice surface and then the snow-ice interface.

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

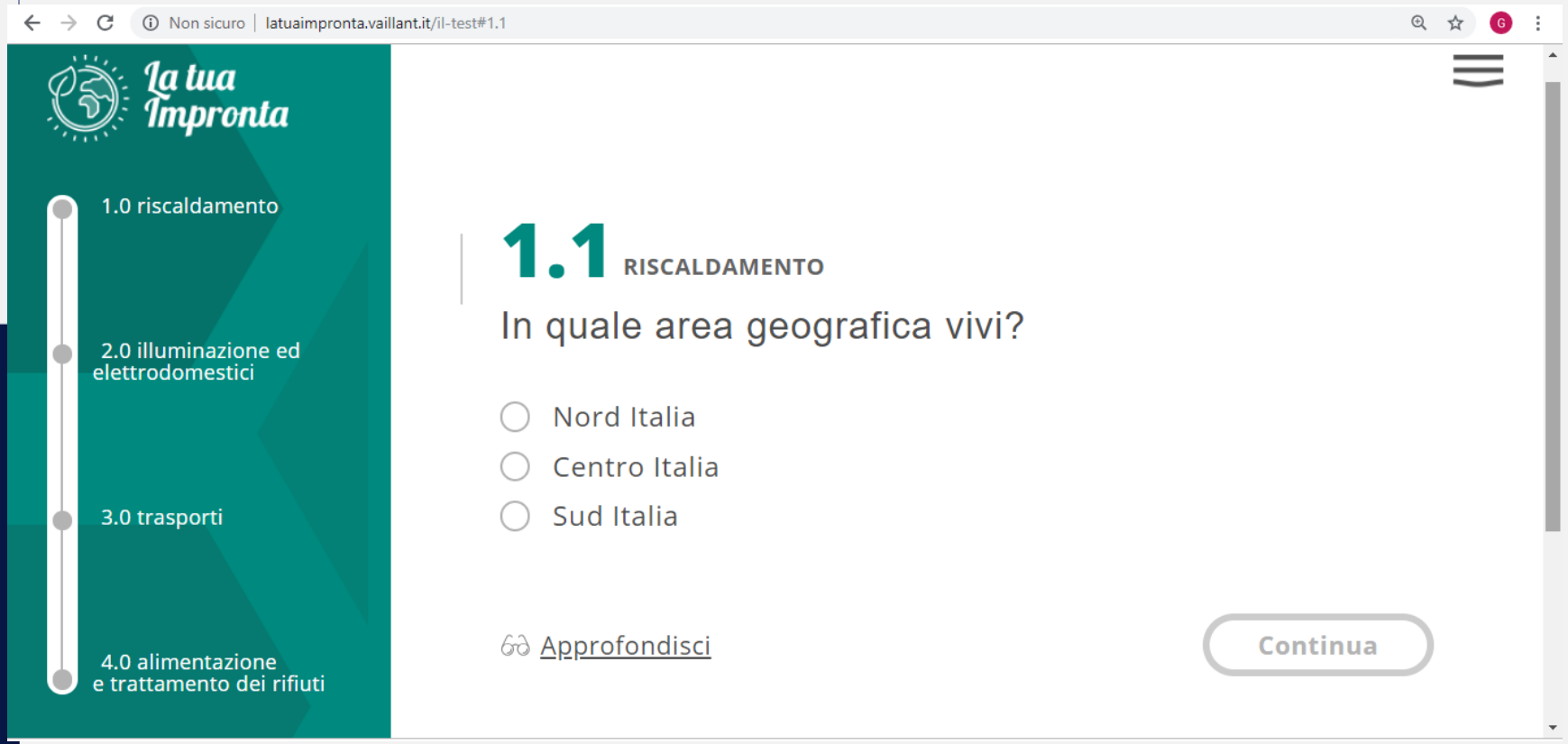
Then
We can apply such method on glaciers used for summer sking.
For the others we need to look for different solutions….

You can be a conscious customer who does sustanaible choices!

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

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

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



Glaciers: the melting heart of our mountains

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