



UNIVERSITÀ DEGLI STUDI DI MILANO



# Glaciers: the melting heart of our mountains

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# Il team UNIMI di Glaciologia e scienza del clima studia i ghiacciai in diverse aree del pianeta....





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**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!!!



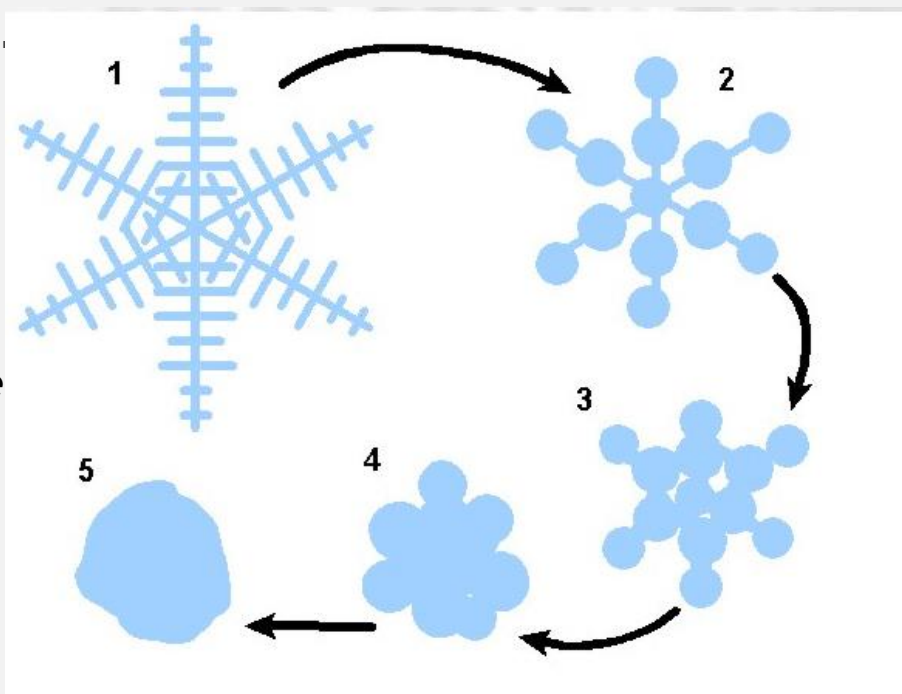
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# CONVERSION OF SNOW TO GLACIER ICE

Fresh Snow: 50/200 kg/m<sup>3</sup> 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/m<sup>3</sup>)

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

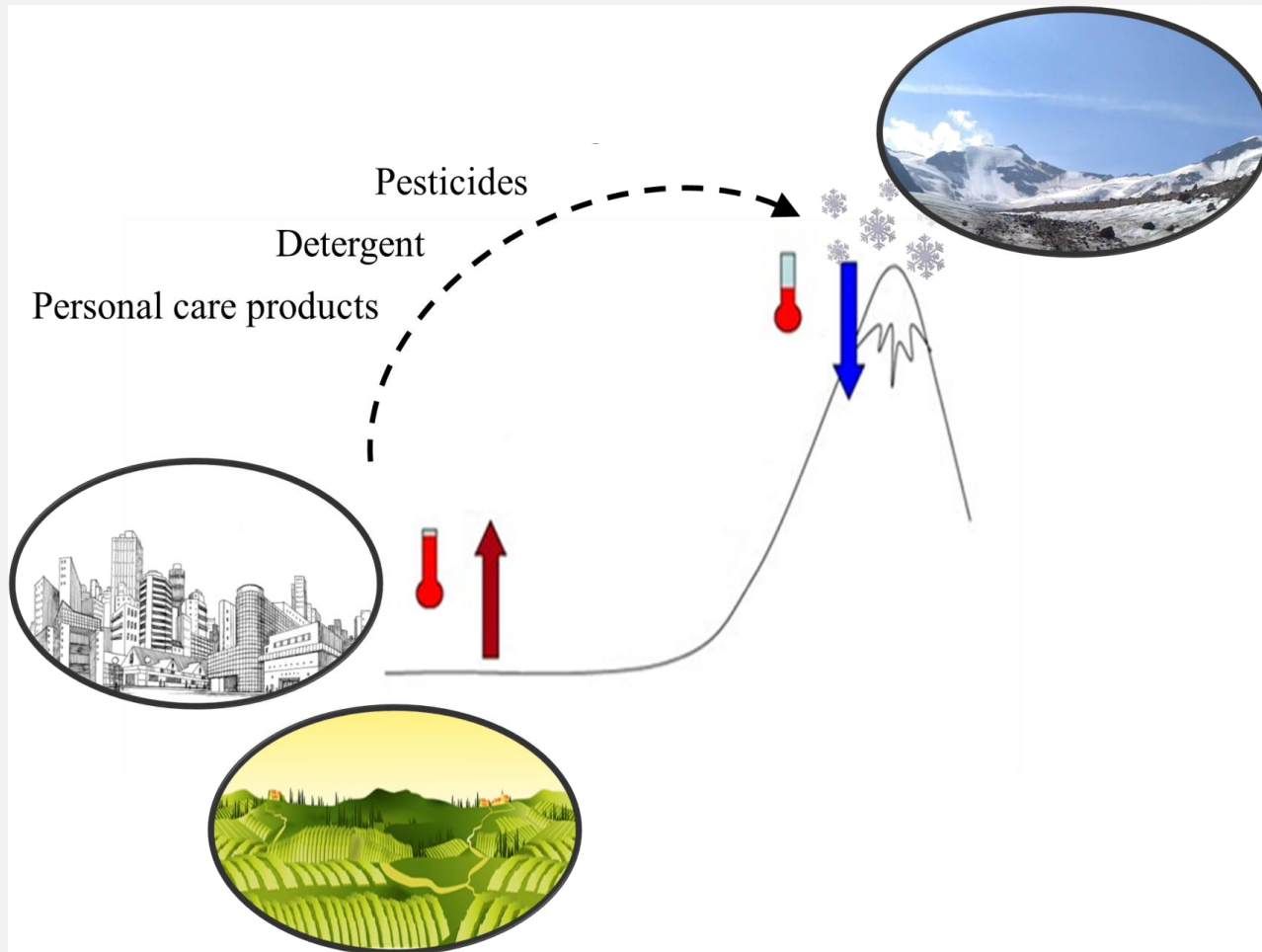
The ice has lost its flake-like original shape and has become a well-rounded granule of ice

FIRN: 400-830 kg/m<sup>3</sup>



# 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  $17.80 \text{ km}^2$  at the End of the Little Ice Age (LIA,  $\sim 1860$ ), it was  $11.36 \text{ km}^2$  in 2007 (-36.2%), in the period 1850-2007 it retreated of about 2 km.

# What is the colour of glacier ice?

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**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»

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

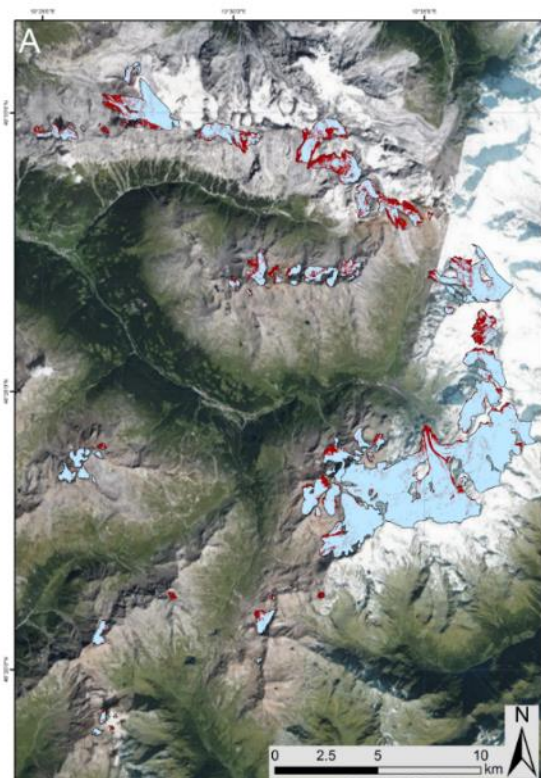


In the space there are several eyes which are surveying our Planet and they describe the main features of glacier surfaces, the darker glacier «skin» !

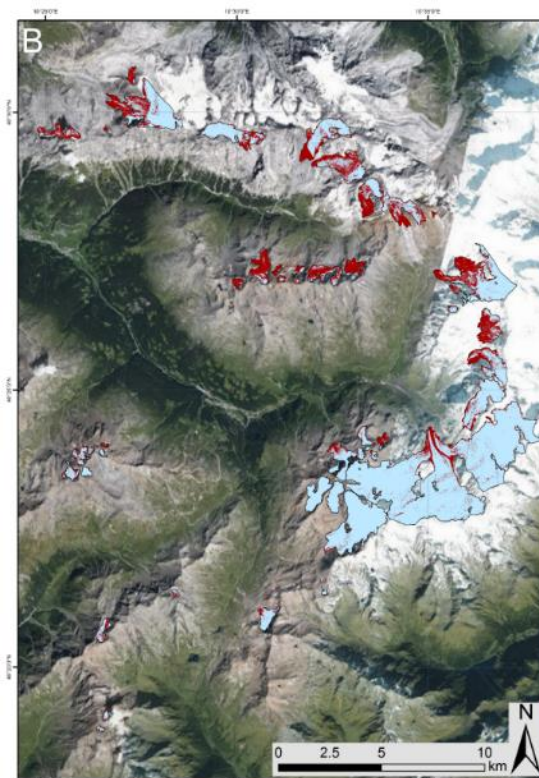


# REMOTE SENSING IS A USEFUL METHOD TO DESCRIBE GLACIER SURFACE AND ITS CHANGES

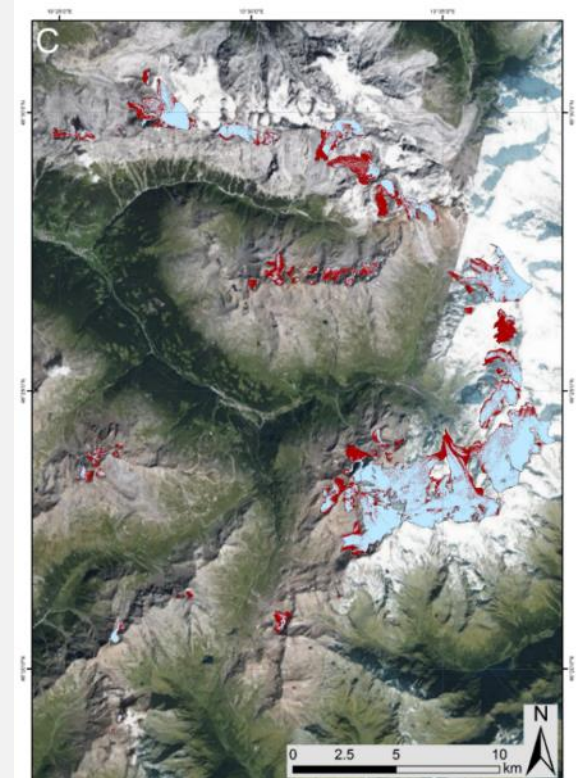
In the Stelvio National Park we found a strong increase of supraglacial rock debris (from 16.7% to 30.1% of glacier area). This is impacting and will impact on glacier melt (data in Azzoni et al; PPG 2018).



2003 → 16.7%



2007 → 22.5%

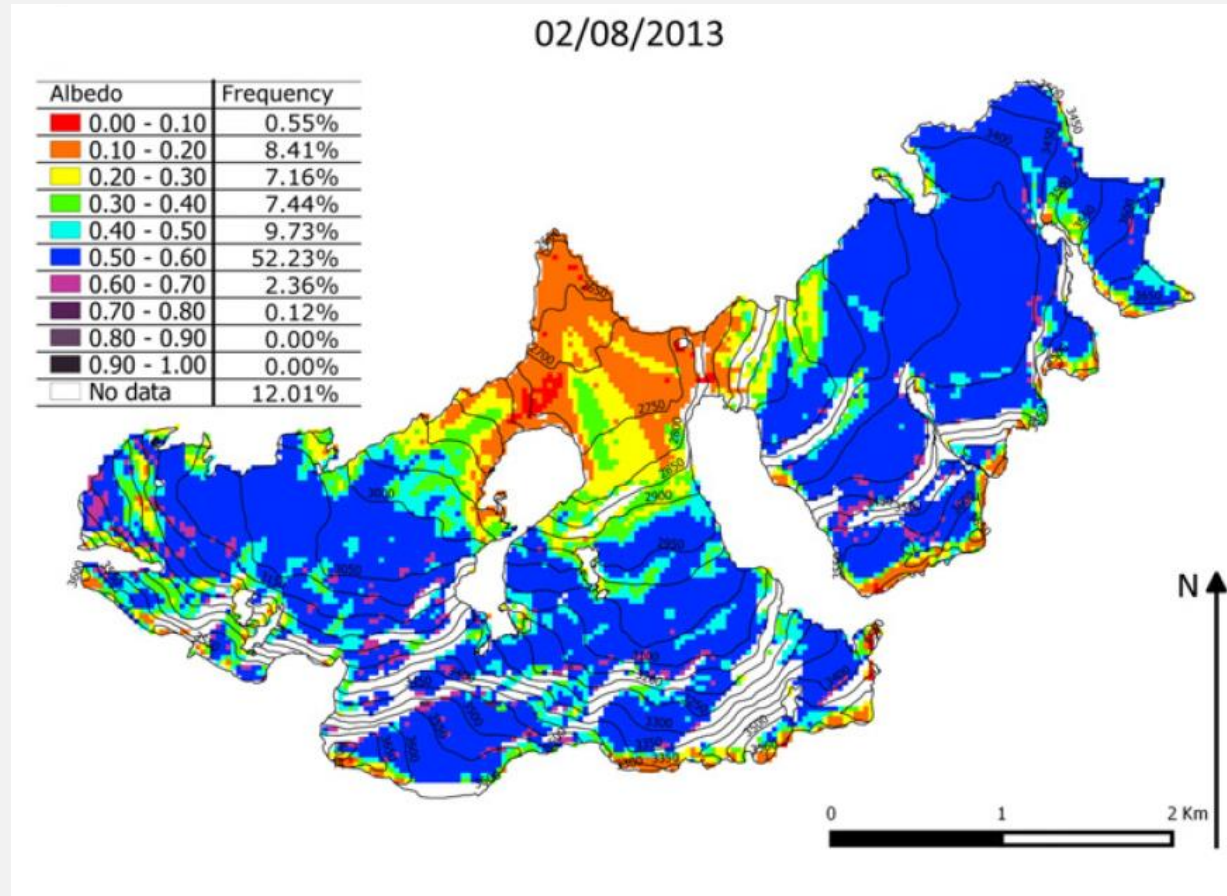


2012 → 30.1%



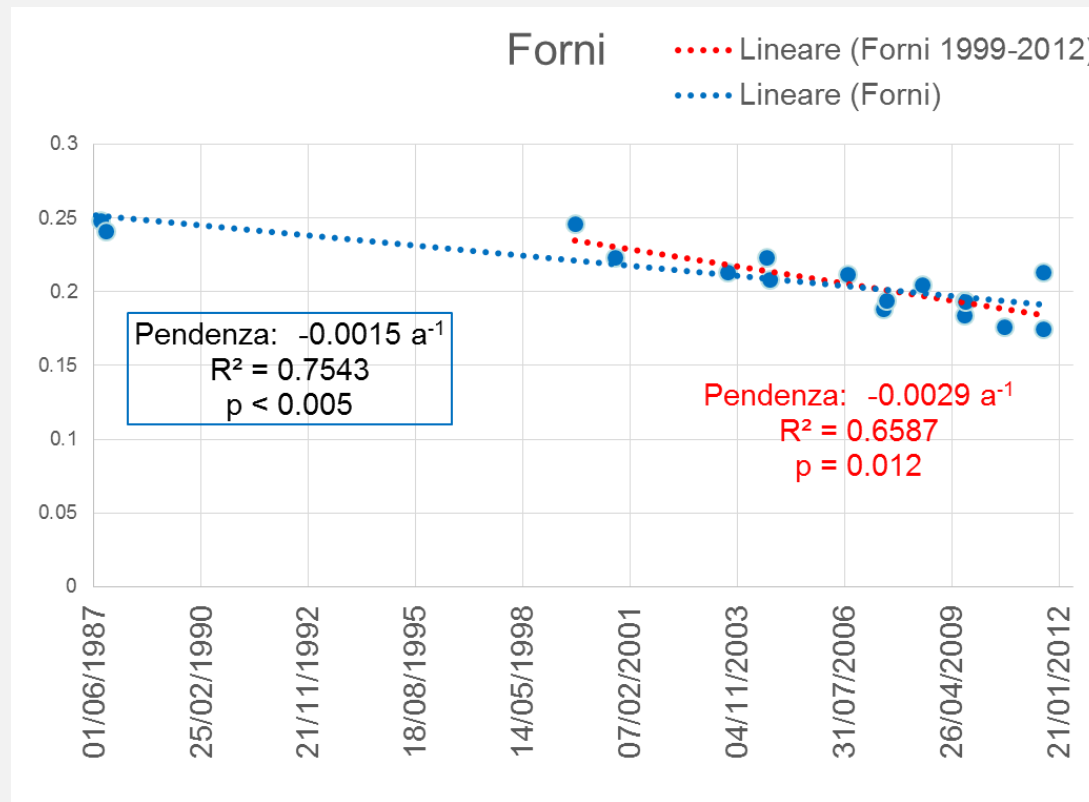
# Remote sensing is also capable to describe glacier albedo

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

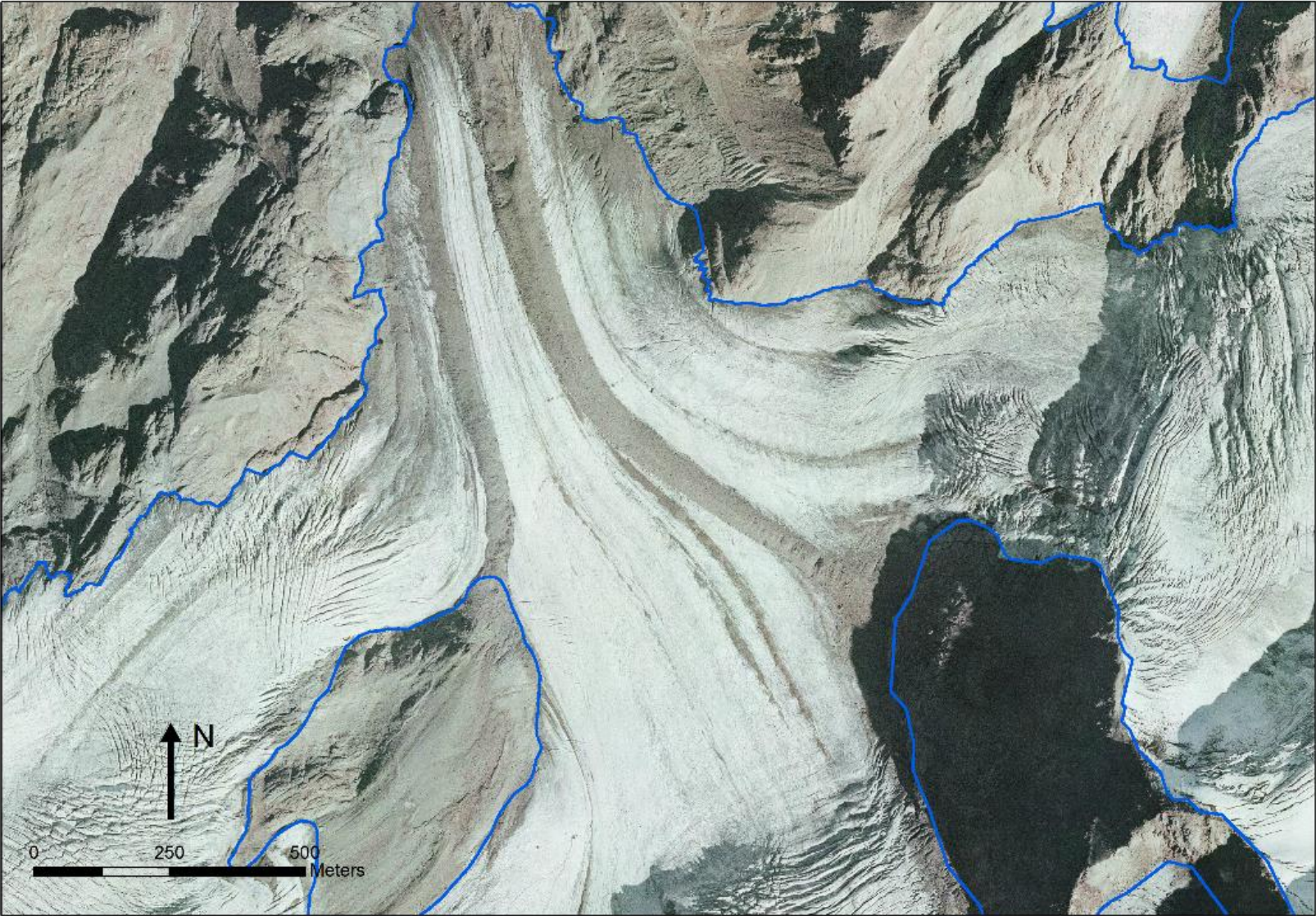


# DARKENING and its effects on ALBEDO

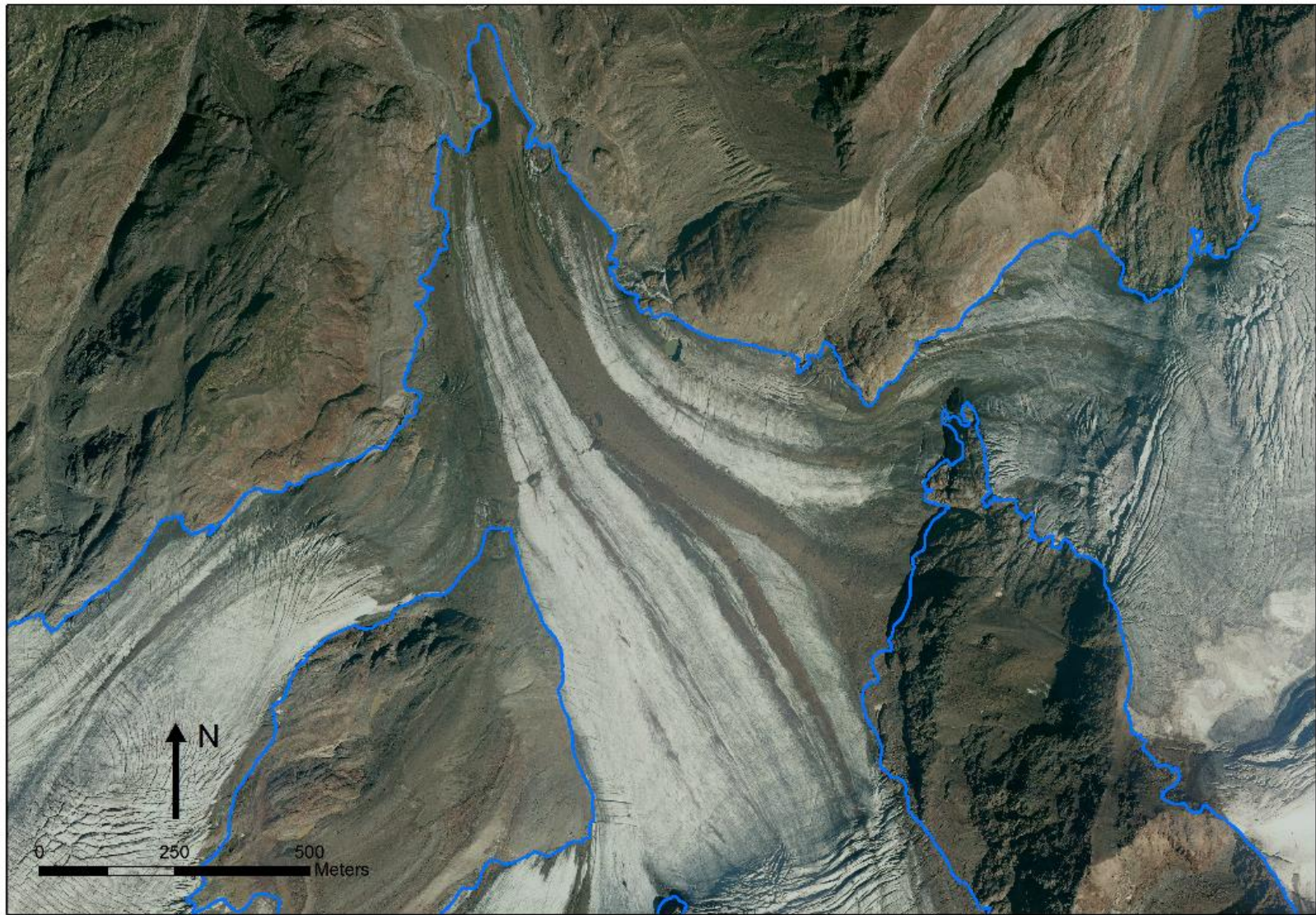
- On Forni Glacieri remote sensing show an actual decrease of surface albedo due to darkening effect (data from Fugazza et al; 2019)



# Aerial photos confirming remote sensing data and albedo values



# Aerial photos confirming remote sensing data and albedo values





**Glaciers are present on our mountains as well!**

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

**10? 100? 1000?**

# The New Italian Glacier Inventory!

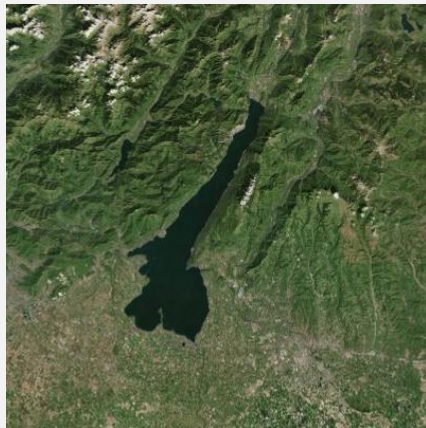
It is freely available at:

<https://sites.unimi.it/gliaciol/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 km<sup>2</sup> 903 glaciers**

**Change (over 60 years)**

**-157 km<sup>2</sup> (-30%) +68 glaciers**

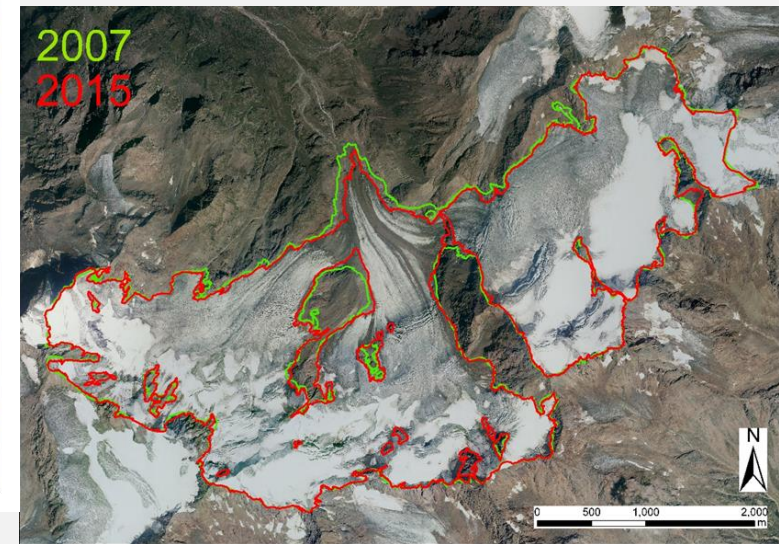
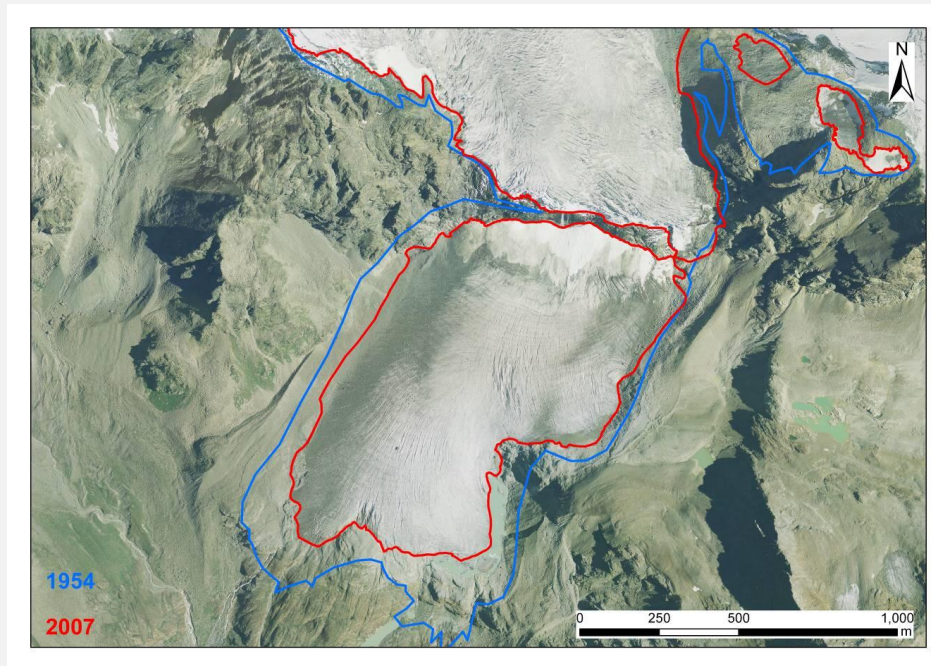


<b>Valle d'Aosta: -48 km<sup>2</sup></b>	<b>-26%</b>
<b>Lombardia: -28 km<sup>2</sup></b>	<b>-24%</b>
<b>Alto Adige: -37 km<sup>2</sup></b>	<b>-30%</b>
<b>Trentino: -16 km<sup>2</sup></b>	<b>-33%</b>
<b>Piemonte: -27 km<sup>2</sup></b>	<b>-48%</b>
<b>Veneto: -2 km<sup>2</sup></b>	<b>-43%</b>
<b>Friuli: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


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!**







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**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<sup>6</sup> m<sup>3</sup> of glacier ice which is equal to -1,5 km<sup>3</sup> 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<sup>3</sup> of water!!!!

Every Year in Lombardy liquid precipitations and snow give 27 billions of m<sup>3</sup> 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



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Cold Regions Science and Technology

journal homepage: [www.elsevier.com/locate/coldregions](http://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

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Glacier shrinkage  
Climate change  
Glacier contribution to hydropower

#### ABSTRACT

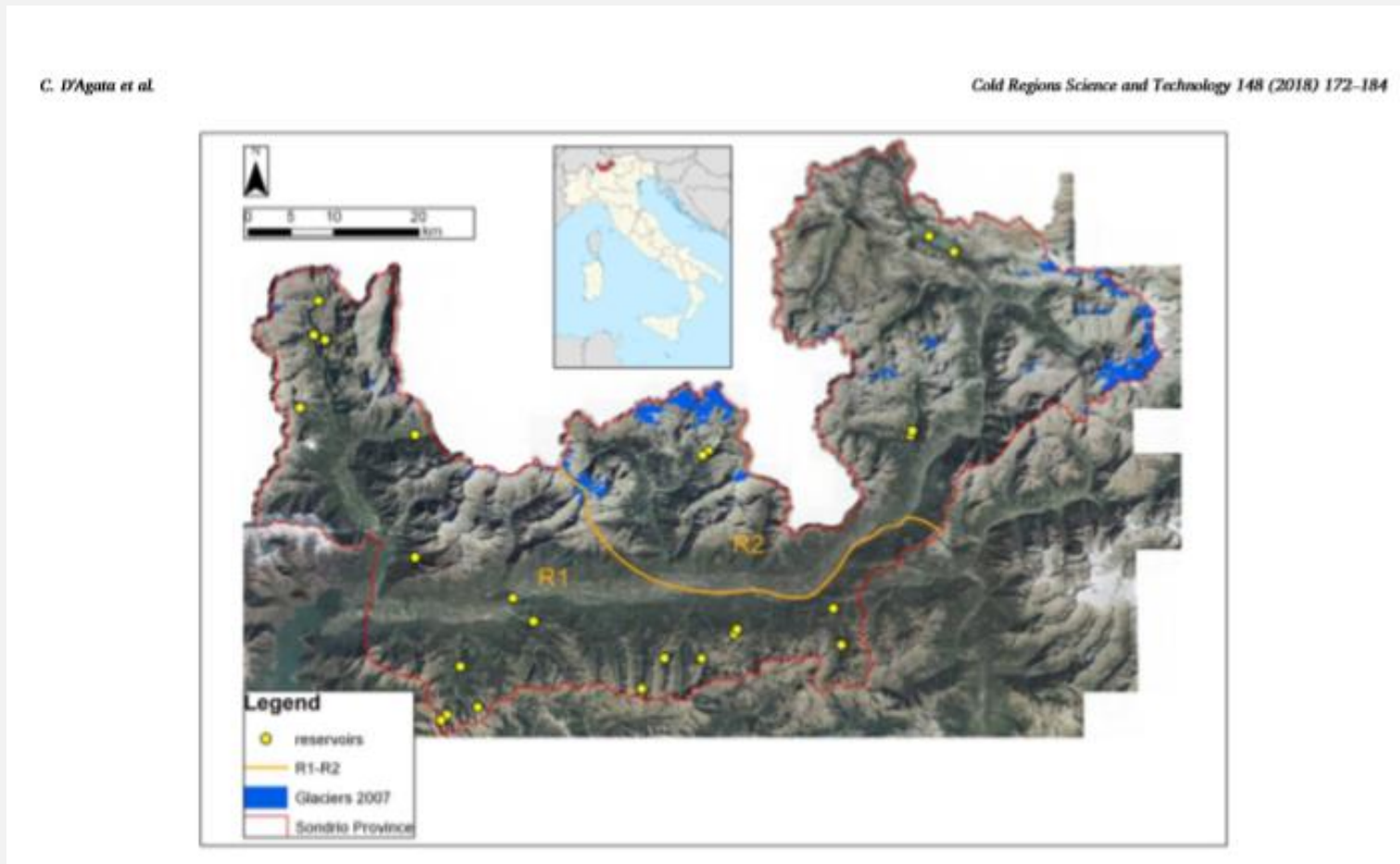
We computed and analysed the geometry changes affecting an Italian glacierized sector (the Sondrio Province, Adda River Basin). This zone was chosen because i) there is a relative abundance of high resolution remote sensing data covering the last thirty years, ii) it represents an important sector of 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  $-1353 \times 10^6 \text{ m}^3 \pm 27\%$ . The mean thickness change was  $-14.91 \text{ m}$ . 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.

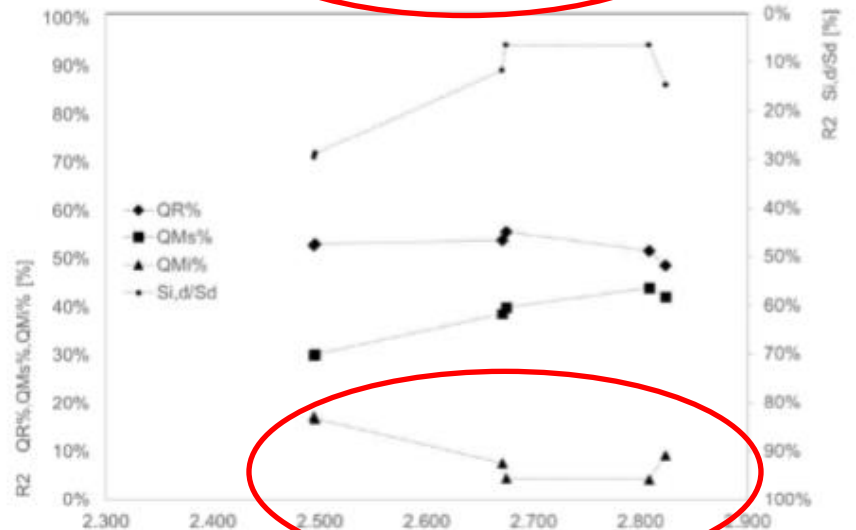
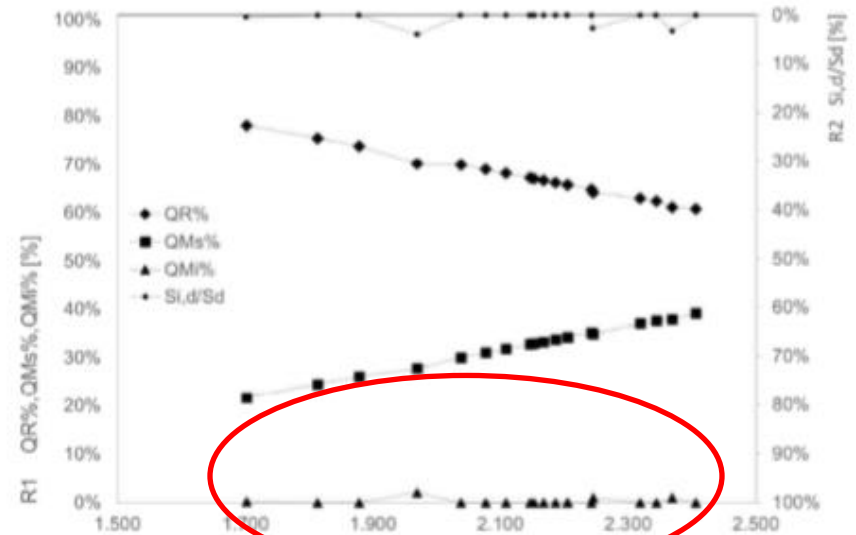
## The impact of glacier ice melt on hydropower in the Adda River



**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





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# ALPS WHITOUT GLACIERS? It is possible!



# Take home messages....

LETTERA ENCICLICA  
*LAUDATO SI'*  
DEL SANTO PADRE  
FRANCESCO  
SULLA CURA DELLA CASA COMUNE



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-Our Planet is the common house of all the people, we need to take care of it

-Our Planet is not our own property, we can use it but we need to preserve it for next generations

-Climate change impacts not only on the environment and the landscape but also on human health, on society and the human development in general;

[https://www.vatican.va/content/dam/francesco/pdf/encyclicals/documents/papa-francesco\\_20150524\\_ enciclica-laudato-si\\_it.pdf](https://www.vatican.va/content/dam/francesco/pdf/encyclicals/documents/papa-francesco_20150524_ enciclica-laudato-si_it.pdf)



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p. 6 and 7: *Ogni aspirazione a curare e migliorare il mondo richiede di cambiare profondamente gli «stili di vita, i modelli di produzione e di consumo, le strutture consolidate di potere che oggi reggono le società ».*  
*L'autentico sviluppo umano possiede un carattere morale e presuppone il pieno rispetto della persona umana, ma deve prestare attenzione anche al mondo naturale e «tener conto della natura di ciascun essere e della sua mutua connessione in un sistema ordinato».*



# Take home messages....

LETTERA ENCICLICA  
*LAUDATO SI'*  
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*P. 217 Se « i deserti esteriori si moltiplicano nel mondo, perché i deserti interiori sono diventati così ampi », la crisi ecologica è un appello a una profonda conversione interiore.*



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 **La tua Impronta**

**INFORMAZIONI PER RISPONDERE AL QUESTIONARIO**

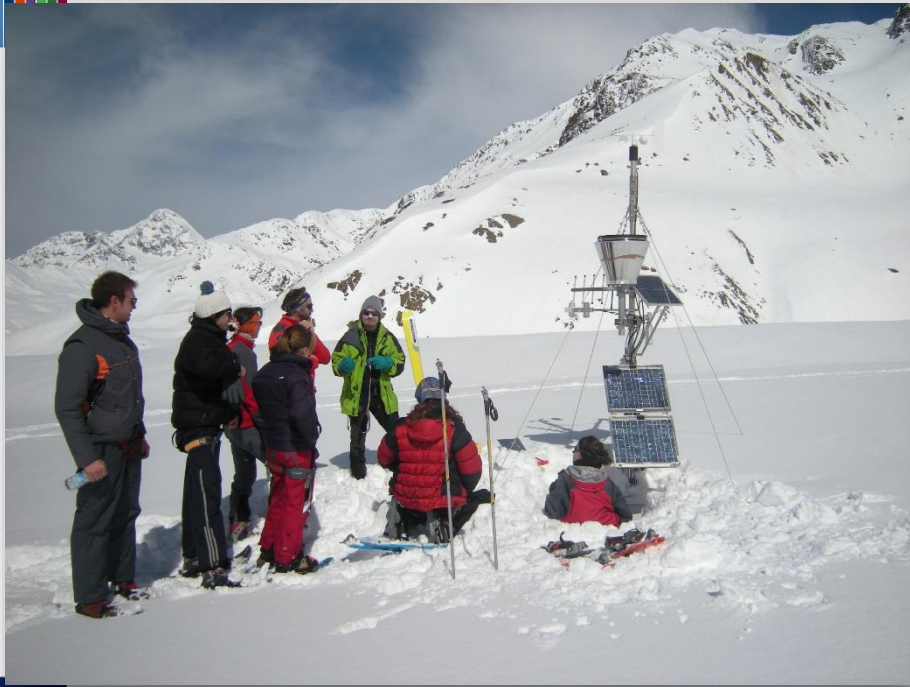
*Il questionario è articolato in quattro sezioni e le tue risposte ci permetteranno di quantificare le tue emissioni annue di composti climateranti espresse in termini di CO2 equivalenti (CO2-eq). In particolare, ci baseremo su dati relativi alla tua abitazione e a come essa è riscaldata, su come illumini 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 (ESPA) dell'Università degli Studi di Milano. Oltre a scoprire quanto contribuisca alle emissioni di CO2, fornisci un prezioso contributo per la nostra ricerca sul clima! I dati che fornirai saranno mantenuti anonimi.





# Glaciers: the melting heart of our mountains

Our team @UNIMI  
Is composed by:

**Guglielmina A. Diolaiuti, Maurizio Maugeri,  
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Davide Fugazza, Blanka Barbagallo,  
Davide Maragno, Carlo D'Agata**

