Monitoring the last Apennine glacier: recent in situ campaigns and modelling of Calderone glacial apparatus

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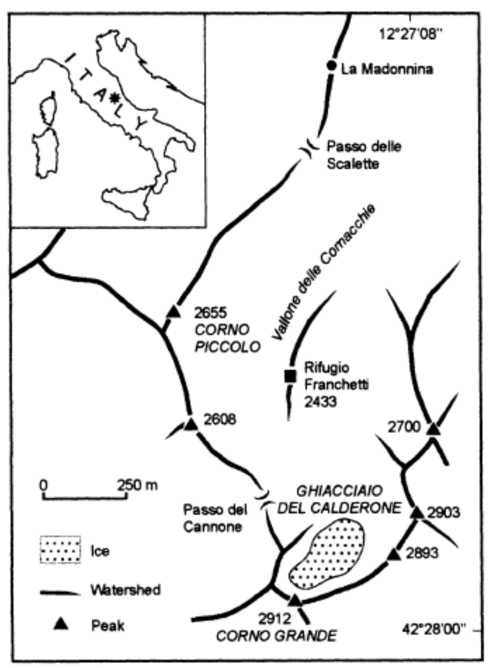
Session: Geophysical and in-situ methods for snow and ice studies

ROMA TRE UNIVERSITÀ DEGLI STUDI | Comitato Glaciologico Italiano | SAPIENZA UNIVERSITÀ DI ROMA | Center of Excellence CETEMPS Telesensing of Environment and Model Prediction of Severe events | CNR-IIA

The Calderone glacier is at present the most southern glacier in Europe (42° 28' 15’’ N)

The glacial nature of the Calderone has been debated since the XVI century (De Marchi, 1573)



After D’Orefice et al., 2000

At the Little Ice Age time, the total hypothetical size of the glacier was about 105.000 m^2 and presently it has been reduced of about 50% (~65% of his original thickness)

The two glacierets are located in a deep northward valley forming from the top of the Corno Grande d’Italia (2912 m asl) in the centre of the Gran Sasso d’Italia mountain range (Central Italy).

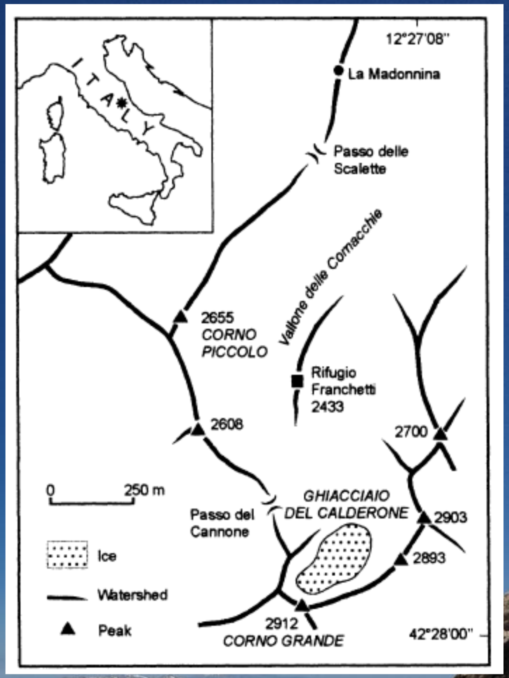
It is a debris-covered glacier: the debris acts as a protective layer for the underlying ice

The glacial apparatus is split into two ice bodies (*glacierets*) since 2000.

The Calderone glacier is at present the most southern glacier in Europe (42° 28' 15'' N)

However, considering the importance of the glacier as a witness of glacial geomorphological processes and as a "sensor" for the climate change, the Calderone is still included in the World Glacier Monitoring Service

The last Mediterranean glacier?



After D'Orefice et al., 2000

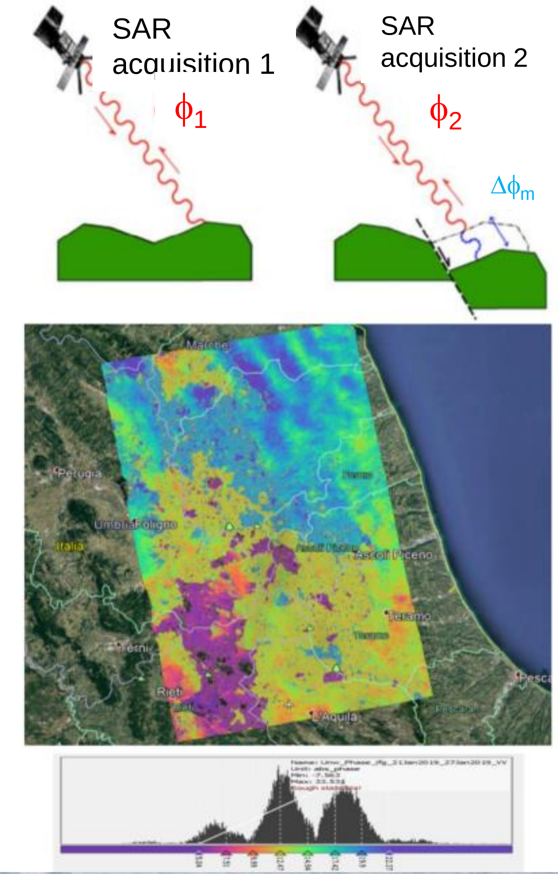
Since early 90s the Calderone glacier has been subjected to several multidisciplinary field campaigns to monitor and evaluate its role as an environmental indicator in the framework of global warming.

An interdisciplinary approach:

- **Historical series of data related to more than a century of records**
- **DinSar snow data**
- **Drone-based survey**
- **Snow pit measurements and chemical-physical sampling**
- **Ground Penetrating Radar**

Retrieving snow depth from satellite SAR

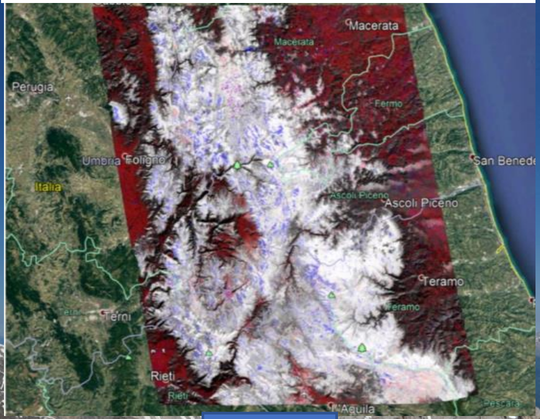
Differential Interferometry Synthetic Aperture Radar (DInSAR): from **2 SAR acquisitions**, construct a phase interferogram and, after correcting for topographic and atmospheric effects, retrieve **snow depth variation** at centimetre scale within a region of 100x100 km^2 at 10-meter (pixel) resolution



Principle: *Snow depth variation proportional to SAR differential phase (known incidence angle, frequency and snow density) for each pixel*

$$\Delta Z_s = \frac{-\Delta\phi_m}{2k_i\left(\cos\theta_i - \sqrt{\varepsilon_{rws} - \sin^2\theta_i}\right)}$$

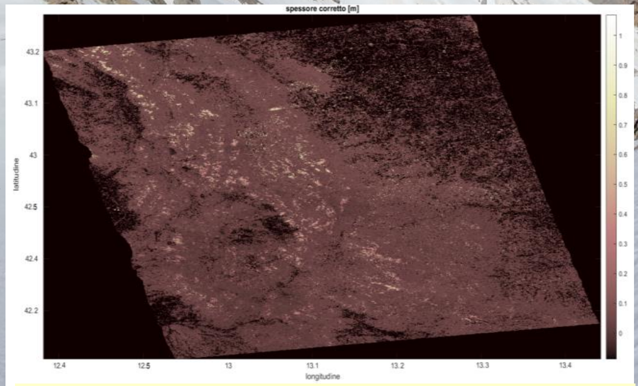
Region of interest: central Italy Apennine with Gran Sasso range and its Calderone paraglacier



Ingredients

- Electromagnetic model
- Snow column model
- Sentinel-1 SAR data
- Sentinel-2 optical data
- DInSAR processor
- Validation sites

27 Jan. 2019



Retrieved snow depth map [0-100 cm]

Distributed snow cover modelling

Distributed snow cover models permit to simulate the **snowpack properties** on a discrete grid using either measured and forecasted weather data

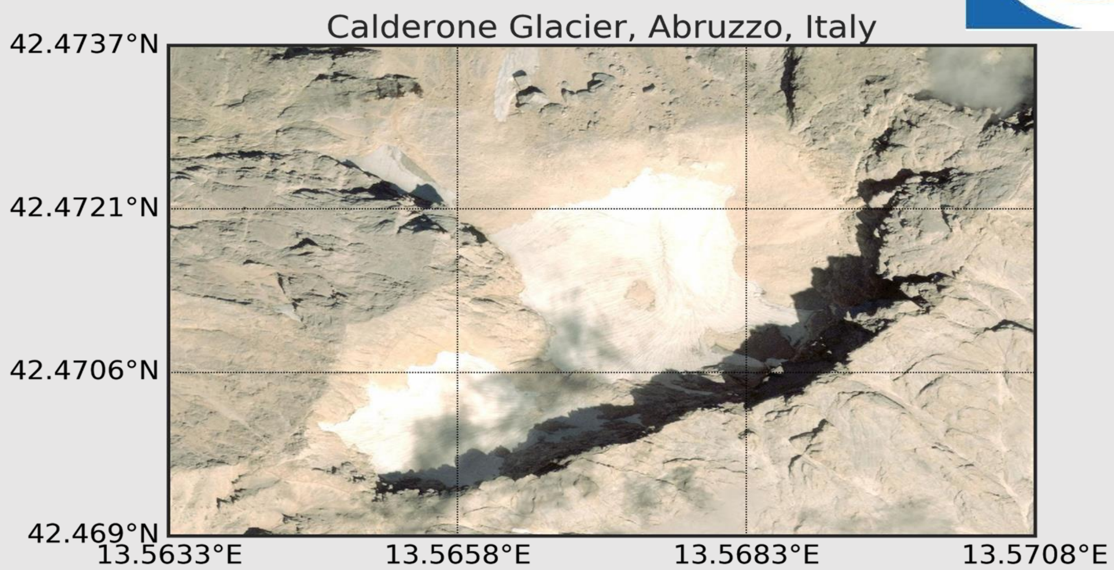
Weather Research and Forecasting (WRF) Model:

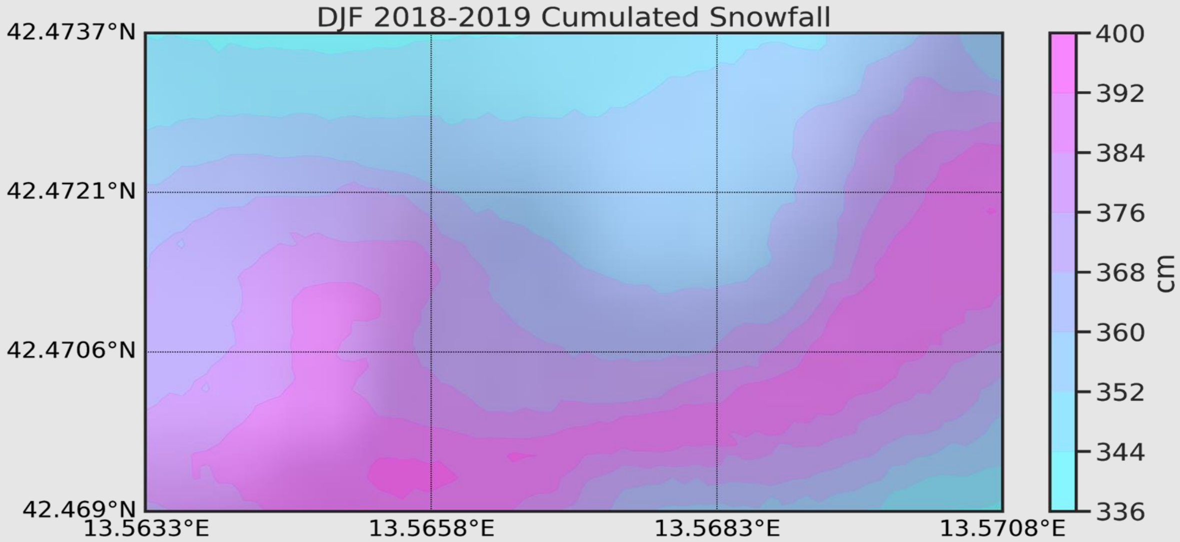
Produces simulations of atmosphere and ground surface based on actual atmospheric conditions or idealized conditions

Alpine3D:

Three-dimensional lagrangian snow cover and earth surface numerical model

Includes additional modules for snow transport, radiation transfer and runoff

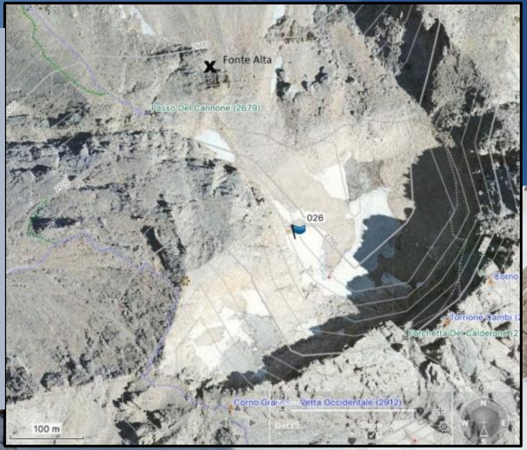




In-situ characterization of the snowpack

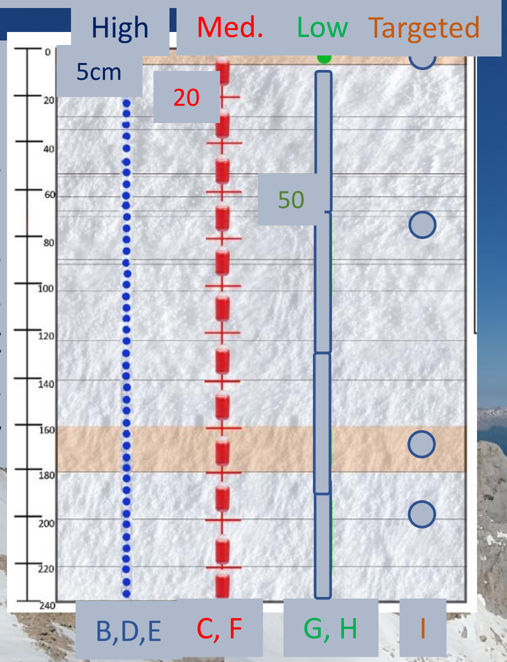
Sampling sites

Snowpit (2700m)
Fusion water (2600m)
Surface Snow (2700-2400m)
Spring water (1700m)



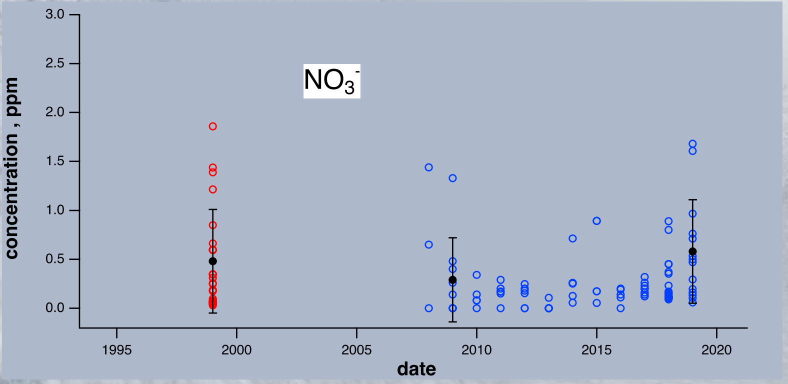
Snowpack sampling strategy

A-Snowdepth
B-Crystal shape and size
C-Density & Hardness
D-Temperature
E-Major & trace elements
F-Inorganic & organic ions
G-EC, OC
H-PAH, alkanes
I-microbiology

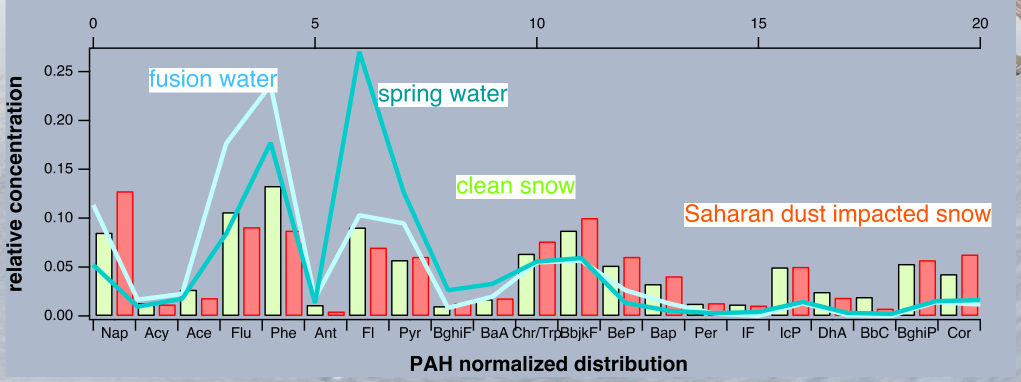


An example of results

soluble ions (1999,2008-2019)



PAH (2008-2019)



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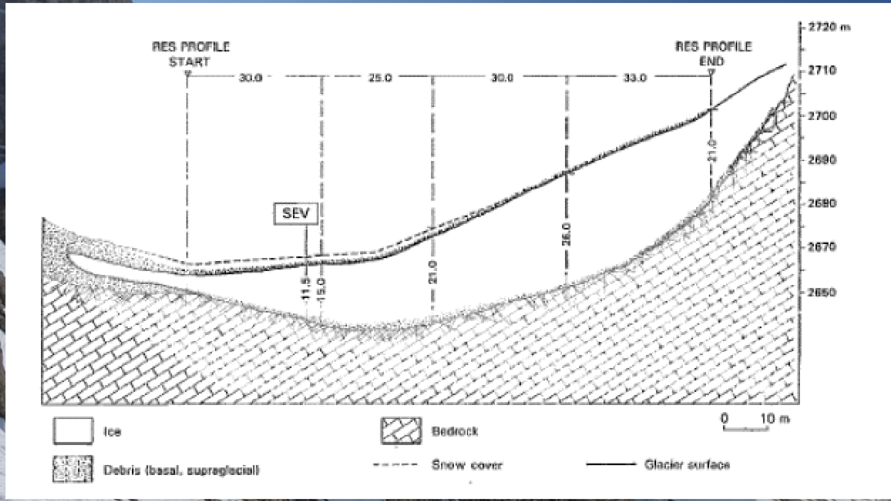
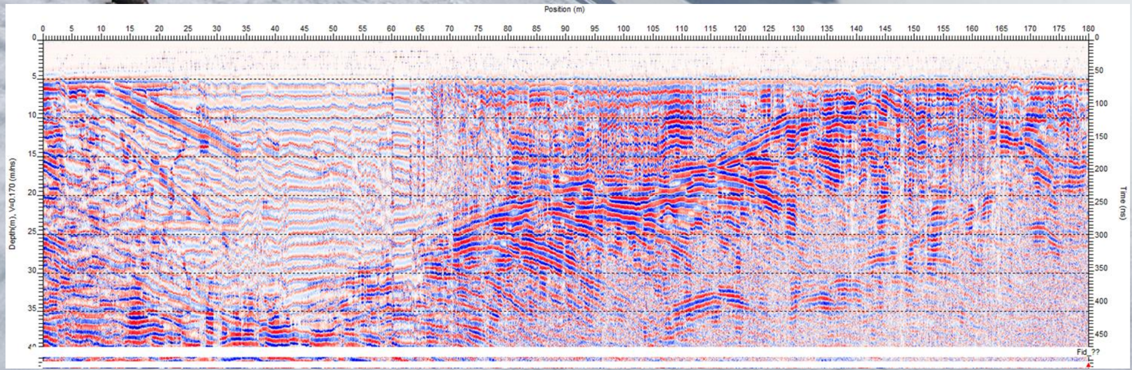
GPR measurements for the estimation of the ice thickness

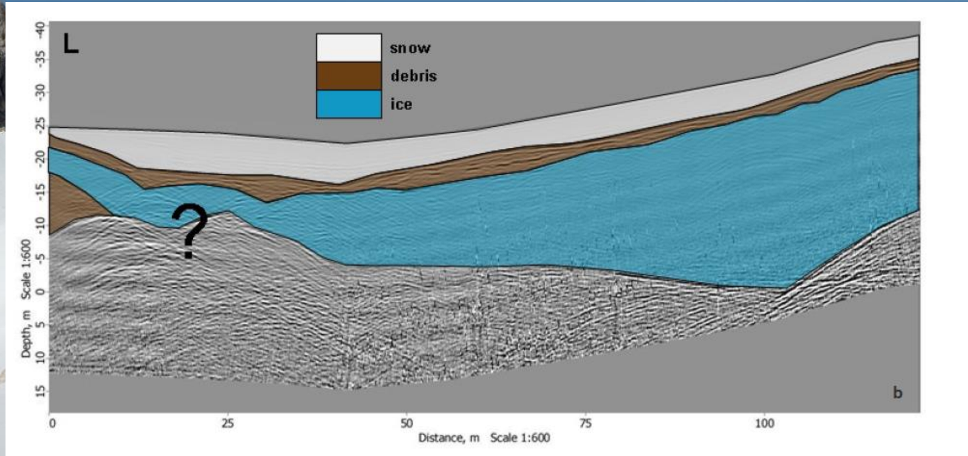


Interpretation of the glacier thickness according to Fiucci et al., (1997)

GPR data have been collected since 1990 along and across the main axis of the glacier, in order to estimate the ice thickness below the debris.



GSSI 40MHz – July 1999



150 MHz radar data acquired on the lower portion of the glacier (Monaco and Scozzafava, 2017)