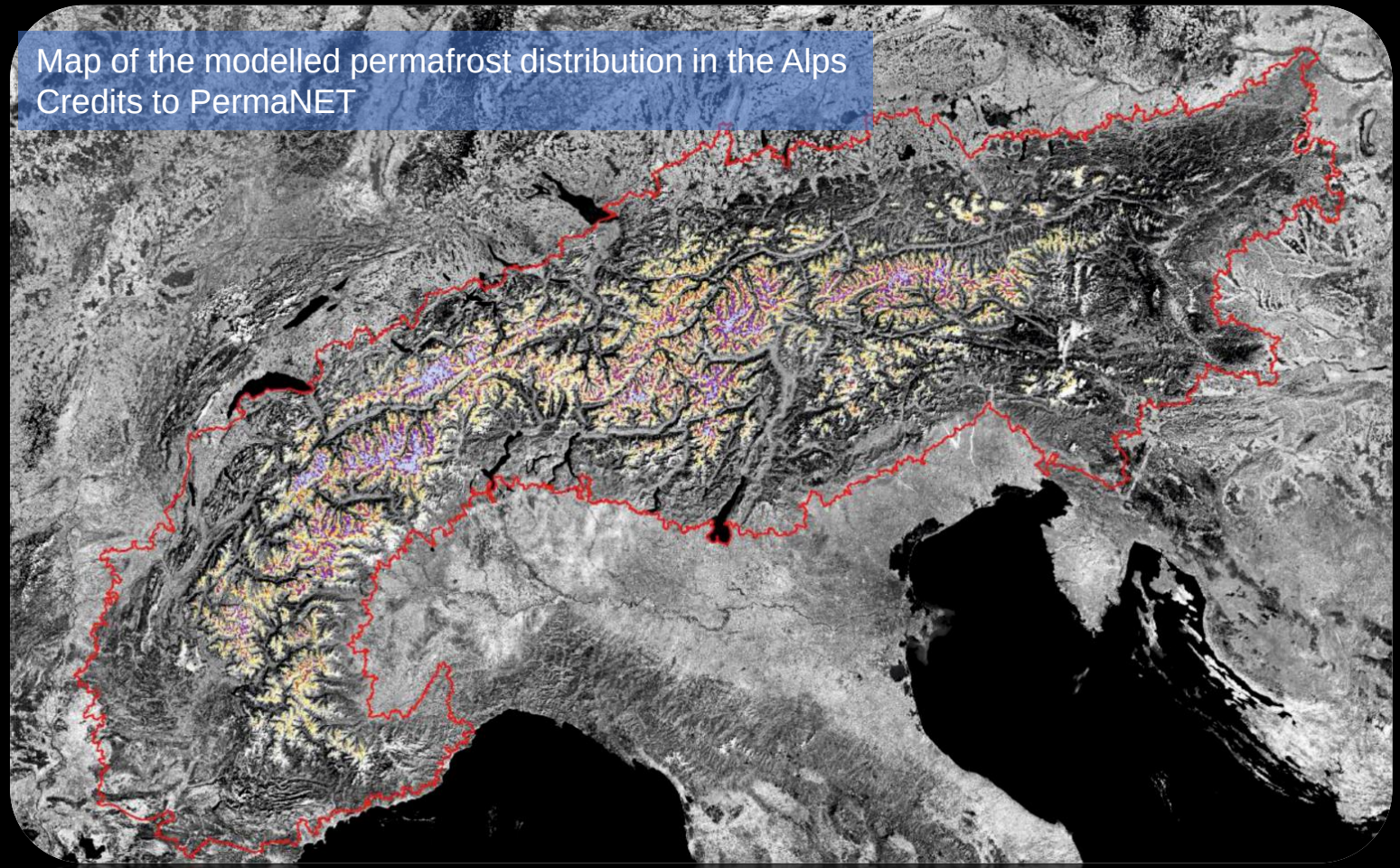
Permafrost and climate change:

the South-Western Alps perspective


Map of the modelled permafrost distribution in the Alps
Credits to PermaNET

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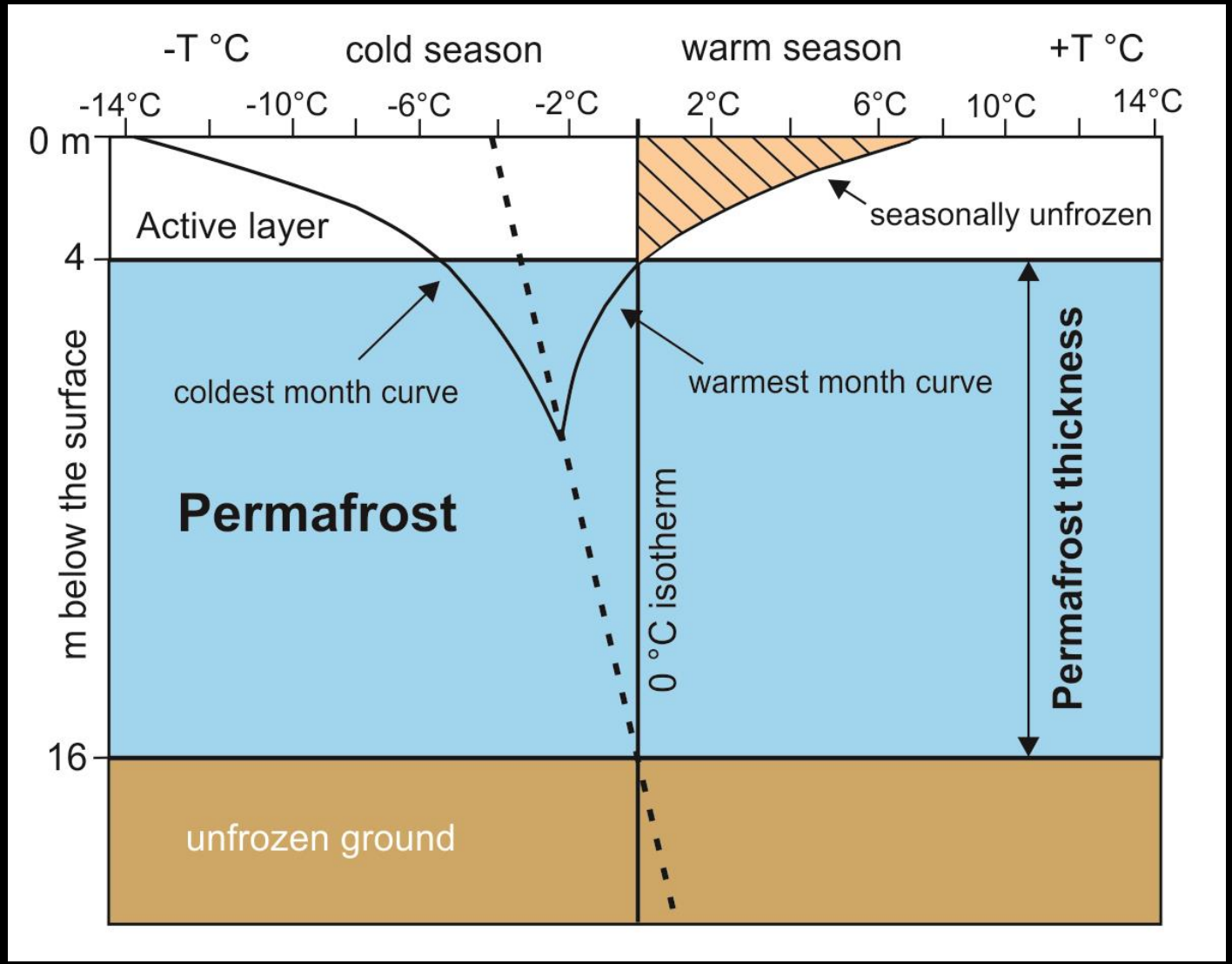
Permafrost is defined as ground (soil and/or rock, including ice and organic material, plus air/gas in unsaturated ground) that remains at or below 0 °C for at least two consecutive years.

The ground layer that thaws on a seasonal basis is called “active layer”

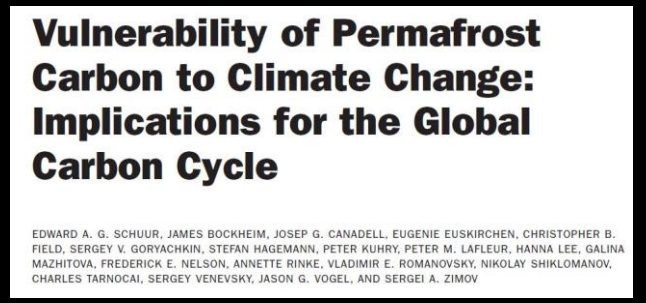
Permafrost is one of the components of the Earth’s cryosphere, i.e.portions of the Earth surface where water is in solid form

(i.e sea ice, lake ice, river ice, snow cover, glaciers and frozen ground, which includes permafrost)



Permafrost interacts with climate, ecosystems and human systems

The aggradation (i.e. formation) and degradation (i.e. melting) of permafrost usually occur in association with a change in mean ground temperature due to microclimatic and climatic variations. Among these causative changes the main air temperature is the most important, but also the regime of precipitations (solid and liquid) and snow cover depth and duration play an important role. The degradation of permafrost is seen as a major challenge in the current discussion of globally rising air temperatures



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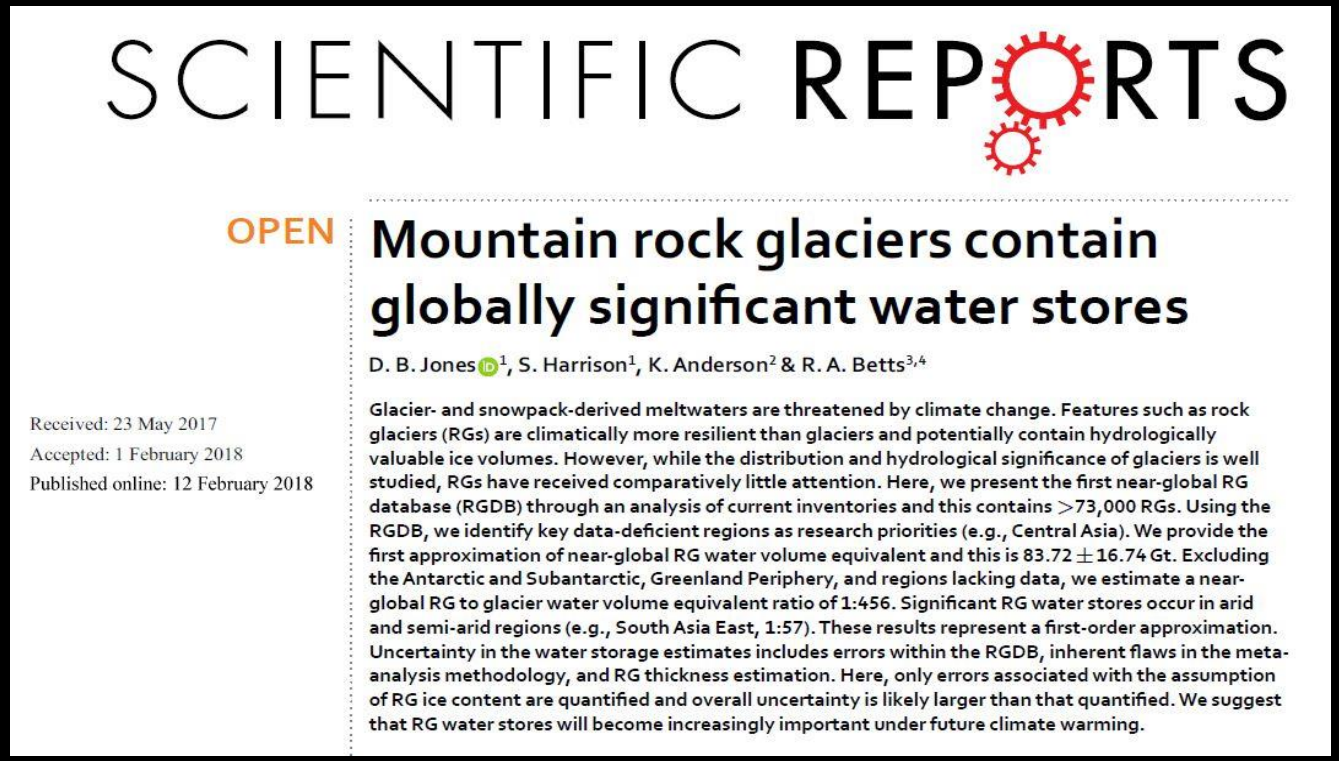
The Alpine cryosphere has demonstrated to be highly sensitive to climatic and environmental changes

- The climate-forced transformations in the state of alpine permafrost are critical to people and ecosystems. They induce a general destabilization of mountain slopes, changes in geomorphic processes, variation in basin hydrogeology and related hazard scenarios. These phenomena may affect populated areas and high-altitude infrastructures (ski resorts, mountain huts, roads, etc.), representing a serious hazard and a challenge for local authorities.

- Moreover, permafrost-affected terrains are long-term reservoirs of frozen water and are likely to become increasingly important water sources under global-warming conditions.



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Mountain rock glaciers contain globally significant water stores

D. B. Jones[1], S. Harrison[1], K. Anderson[2] & R. A. Betts[3,4]

Glacier- and snowpack-derived meltwaters are threatened by climate change. Features such as rock glaciers (RGs) are climatically more resilient than glaciers and potentially contain hydrologically valuable ice volumes. However, while the distribution and hydrological significance of glaciers is well studied, RGs have received comparatively little attention. Here, we present the first near-global RG database (RGDB) through an analysis of current inventories and this contains >73,000 RGs. Using the RGDB, we identify key data-deficient regions as research priorities (e.g., Central Asia). We provide the first approximation of near-global RG water volume equivalent and this is 83.72 ± 16.74 Gt. Excluding the Antarctic and Subantarctic, Greenland Periphery, and regions lacking data, we estimate a near-global RG to glacier water volume equivalent ratio of 1:456. Significant RG water stores occur in arid and semi-arid regions (e.g., South Asia East, 1:57). These results represent a first-order approximation. Uncertainty in the water storage estimates includes errors within the RGDB, inherent flaws in the meta-analysis methodology, and RG thickness estimation. Here, only errors associated with the assumption of RG ice content are quantified and overall uncertainty is likely larger than that quantified. We suggest that RG water stores will become increasingly important under future climate warming.

Permafrost interacts with climate, ecosystems and human systems.

nature reviews microbiology

Review Article | Published: 12 May 2014

The microbial ecology of permafrost

Janet K. Jansson & Neslihan Taş

Nature Reviews Microbiology **12**, 414–425(2014) | Cite this article

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Warming effects on permafrost ecosystem carbon fluxes associated with plant nutrients

Fei Li, Yunfeng Peng, Susan M. Natali, Kelong Chen, Tianfeng Han, Guibiao Yang, Jinzhi Ding, Dianye Zhang, Guanqin Wang, Jun Wang, Jianchun Yu, Futing Liu, Yuanhe Yang

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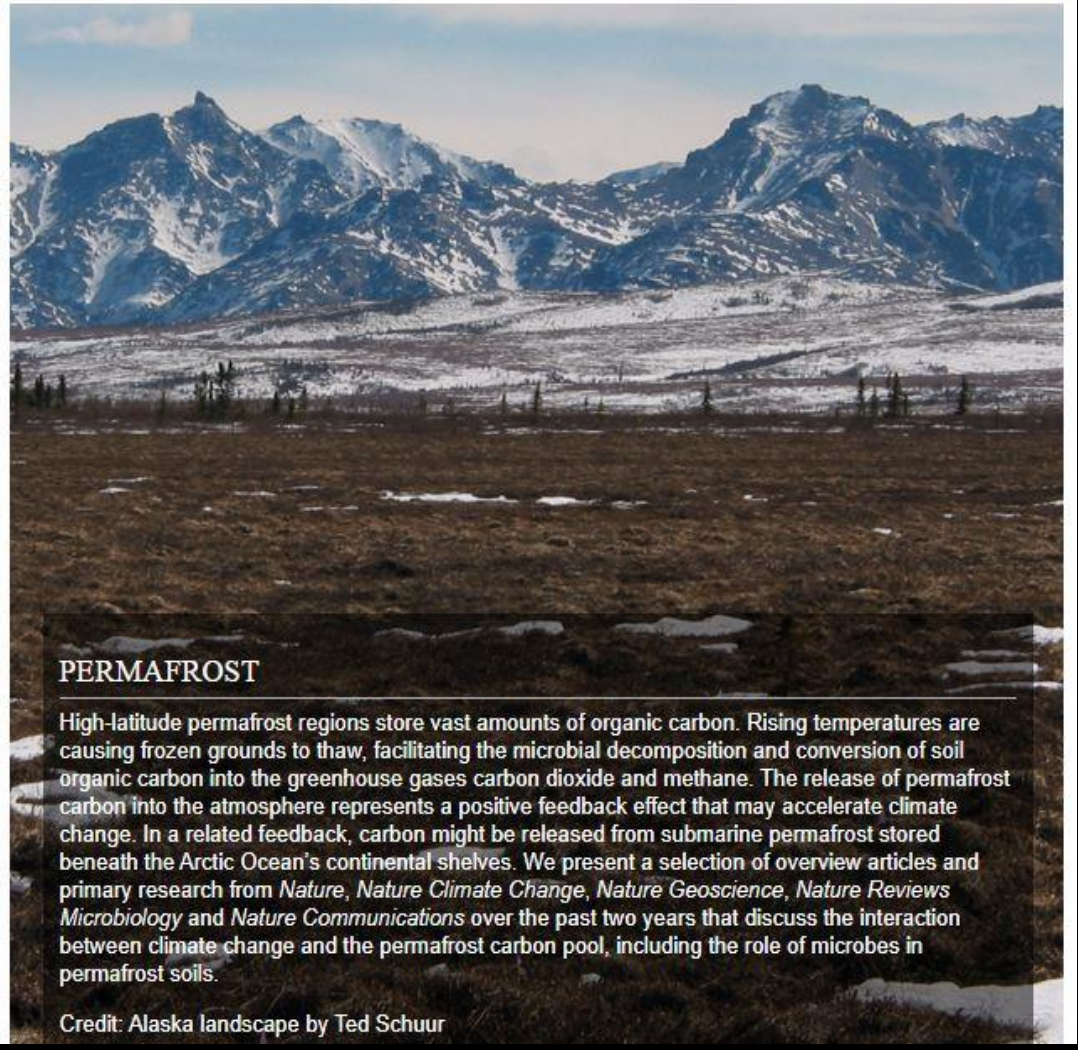


PERMAFROST

High-latitude permafrost regions store vast amounts of organic carbon. Rising temperatures are causing frozen grounds to thaw, facilitating the microbial decomposition and conversion of soil organic carbon into the greenhouse gases carbon dioxide and methane. The release of permafrost carbon into the atmosphere represents a positive feedback effect that may accelerate climate change. In a related feedback, carbon might be released from submarine permafrost stored beneath the Arctic Ocean's continental shelves. We present a selection of overview articles and primary research from *Nature*, *Nature Climate Change*, *Nature Geoscience*, *Nature Reviews Microbiology* and *Nature Communications* over the past two years that discuss the interaction between climate change and the permafrost carbon pool, including the role of microbes in permafrost soils.

Credit: Alaska landscape by Ted Schuur

Among the methods adopted to detect permafrost along mountain detritical slopes and rock-walls, the most common are geophysical investigations and the thermal monitoring of ground/rock surface.

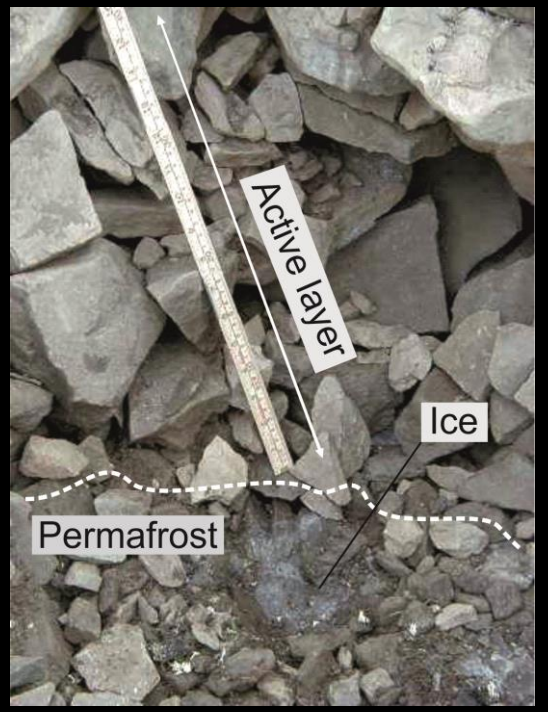
Electrical Resistivity Tomography (ERT), Ground-Penetrating Radar (GPR) and Surface Ground Temperature (SGT) monitoring are the methods used by the University of Pisa across the Alps, but specifically in the Western Alps

GPR

ERT

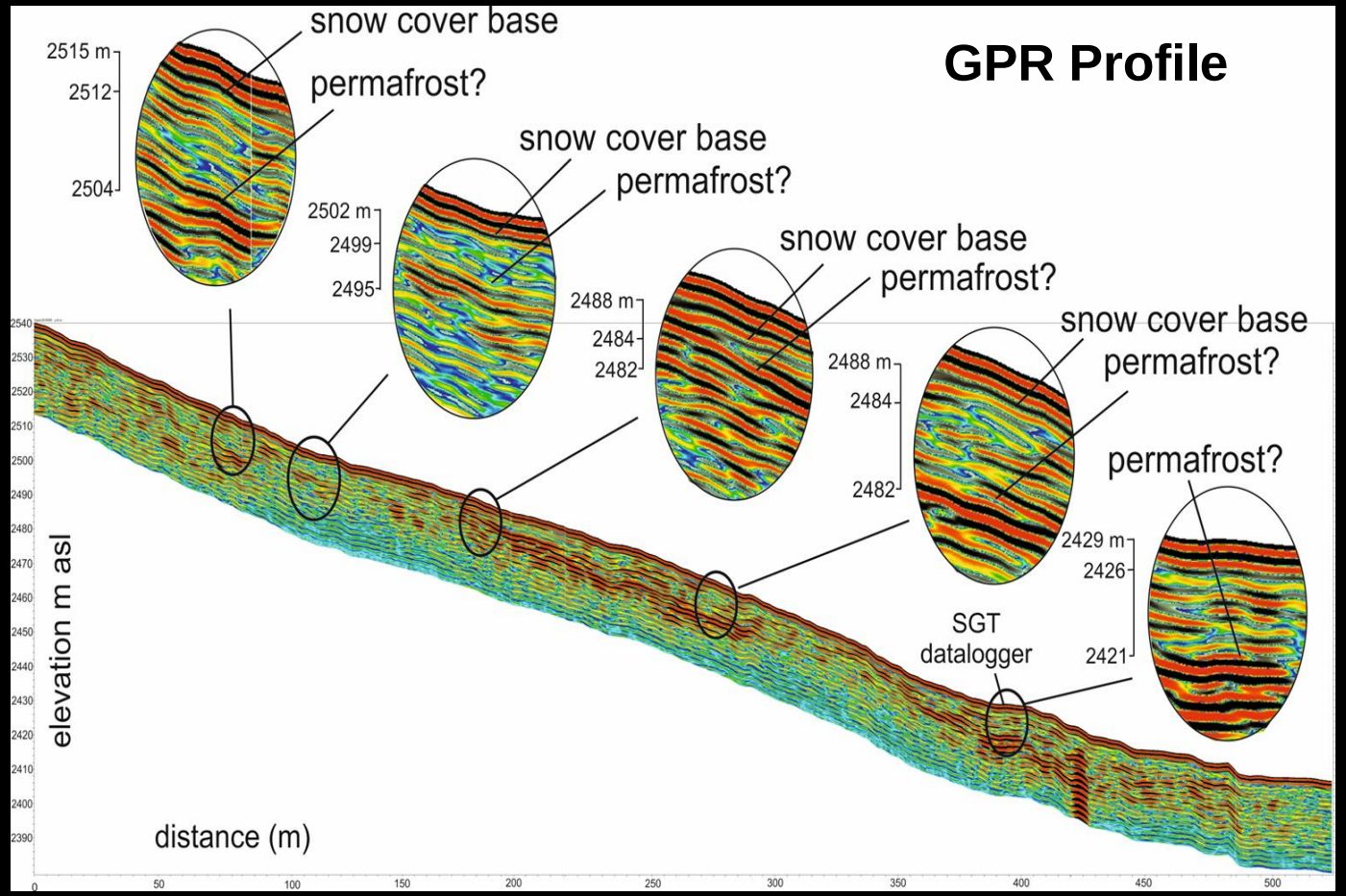
SGT

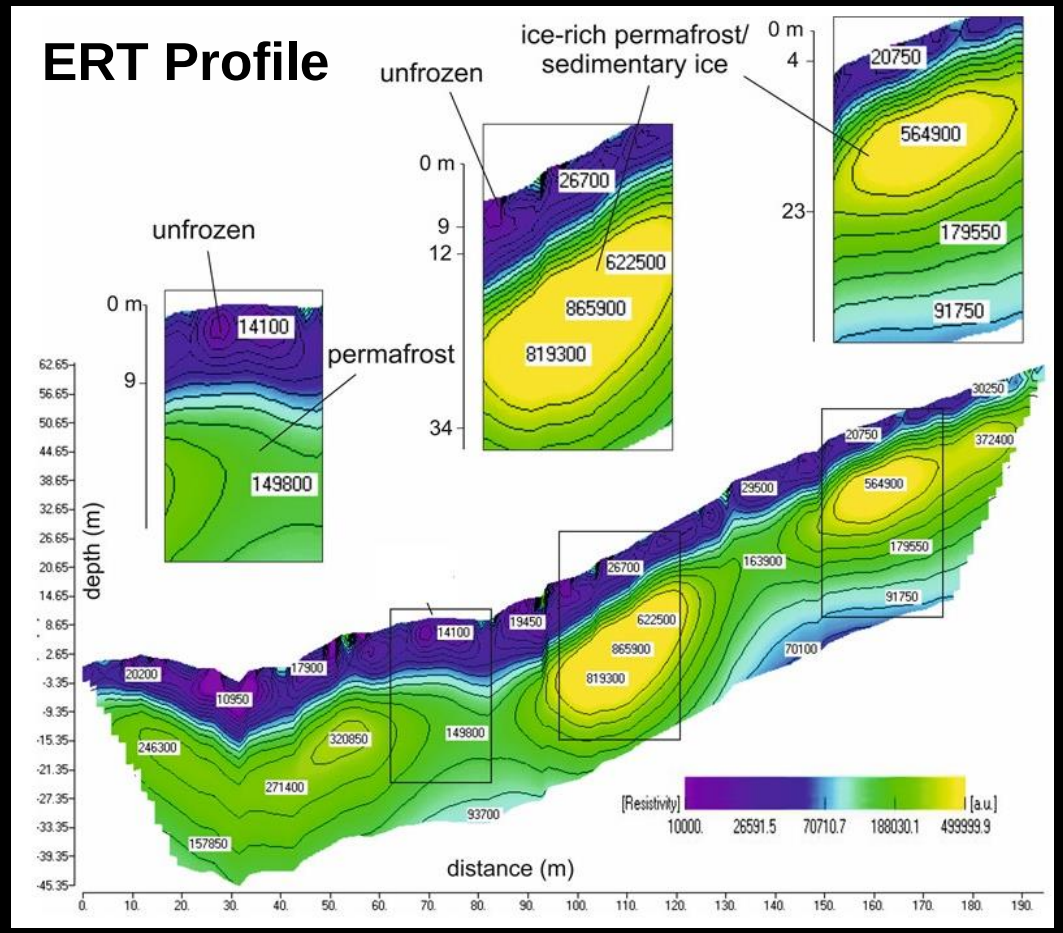
These methods are applied to rock glaciers (i.e. slow flowing mixtures of debris and ice in variable proportion) that are the clearest, most abundant and studied permafrost-related landforms in mountain regions



Red lines: Ground-Penetrating Radar profiles
Yellow line: Electrical Resistivity Tomography profile
Yellow line is 260 m long

The obtained results converge in delineating a highly probable permafrost existence at elevation above 2,500 m a.s.l. inside the rock glaciers and debris accumulations of different geneses (glacial deposits, slope debris). Below 2,300 m a.s.l. permafrost existence can be considered improbable/absent.





Resistivity in Ohm x m

Final remarks

- The results so far obtained in the Western Alps, and specifically in the Maritime Alps, point out that this is the southernmost region where permafrost is present.

- Being near the limit of climatic existence makes this component of alpine cryosphere very sensitive also to slight interannual climatic variations, so a sort of sentinel of the effects of ongoing climatic tendency

- The hydrological value of permafrost inside debris accumulation (e.g. rock glacier) has become a relevant and challenging issue in this mountain region. In this regard, rock glaciers can be considered high-mountain porous aquifers, deserving a deep comprehension of circuits of water circulation in the light of seasonal and climate change-forced ice thawing

- Ongoing projects in the Western Alps deal with the detection of permafrost by adopting modern and effective geophysical systems, along with constant thermal monitorings on some sites. The aim of these activities is the detailed exploration of rock glacier interior for ice volume estimation. This value can then be converted into water content by imposing an ice density