Project ID: **Fly-Radar**

Project Title: ***"Low-frequency multi-mode (SAR and penetrating) radar onboard light-weight UAV for Earth and Planetary exploration"***

Call: **H2020-MSCA-RISE-2020**

WP6 - Validation and test field campaign

D6.1: Field Campaign plan

Lead contributor	IRSPS
Other contributors	

Due date	31 01 2023
Delivery date	27 03 2023
Deliverable type	Report
Dissemination level	Public

Document History

Version	**Date**	**Description**
V1.0	23 03 2023	Final
V1.1	27 03 2023	Final

This project has received funding from the European Union's Horizon 2020 research and innovation programme under MSCA-RISE2020 grant agreement No 101007973.

Table of Contents

1. Publishable Summary

This document defines the planning of the operations of the test experiments. First, it will be presented several possible test ranges in different settings. We will consider two types of tests: i) the test to define the flight capabilities of the integrated systems and the radar signal performance; ii) the scientific test that will be performed in the dry environment of the Moroccan desert to test the potentiality of the integrated system in term of both operativity and scientific data. The first type of the tests are short and performed near the premises of Hyperion or of the Universitè de Lyon. If necessary, these tests could be carried on in Southern Alps if it will be decided for some scientific relevant experiments. This issue of the document will deal with these issues.

The planning of the tests is a quite delicate activities because it is necessary to tarde off among scientific objectives, logistics and budget. A further issue will include the detailed planning and will be based on the early outcome of the analysis of radar **capability.**

2. Preliminary test ranges

The first test ranges to be described are the ones in Southern Alps and in other alpine areas. These tests are not mandatory and will be organised only if necessary to test technological and scientific issues. Currently the drone has been tested by flying it with the real antenna and the mock-up of the electronic (Fig. 1)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under MSCA-RISE2020 grant agreement No 101007973.

Fig. 1 - The first fly of FlyRadar

These tests have demonstrated that the drone that the mass and volume of the antenna is not influencing in a sensible way the trim and flight capability of the drone. Moreover, the drone is able to carry on the entire mass of antenna and electronics of the radar.

3. Test ranges in Alpine and polar locations

Characteristics of possible test sites for FlyRadar project:

3.1 Active rock glacier Vallaccia in Dolomites

Active rock glacier ***Vallaccia*** is situated in the Rio dei Monzoni catchment area of Marmolada Group/Vallaccia Subgroup in Dolomites (Italy, Trentino-Alto Adige, San Giovanni di Fassa; fig. 2, 3). The coordinates of rock glacier are N 46,39580, E 11,72084.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under MSCA-RISE2020 grant agreement No 101007973.

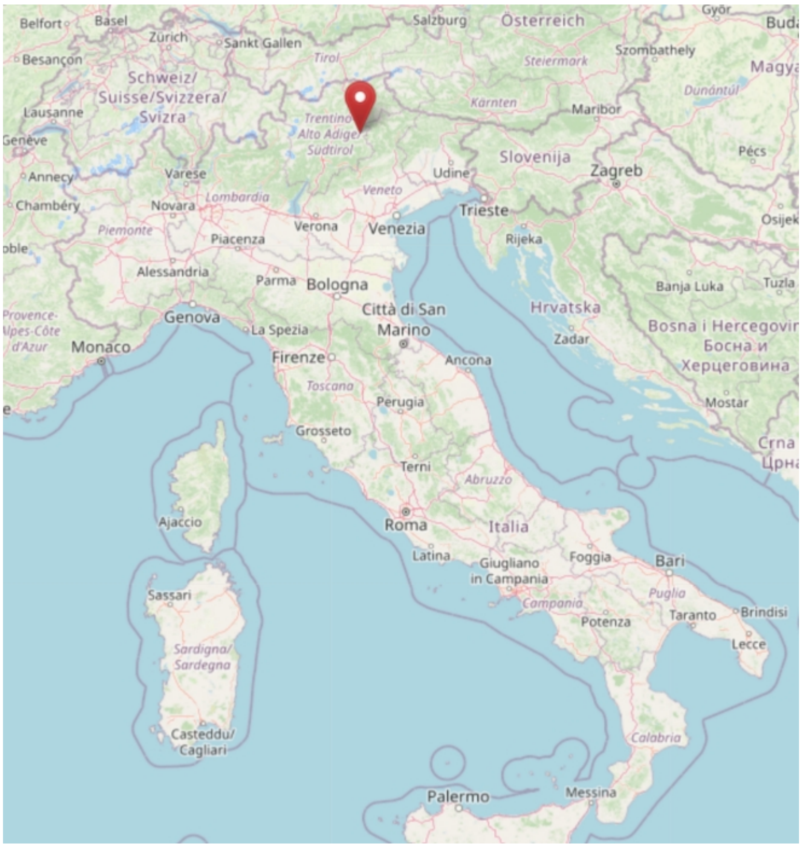


Fig. 2 - Location of Vallaccia test site

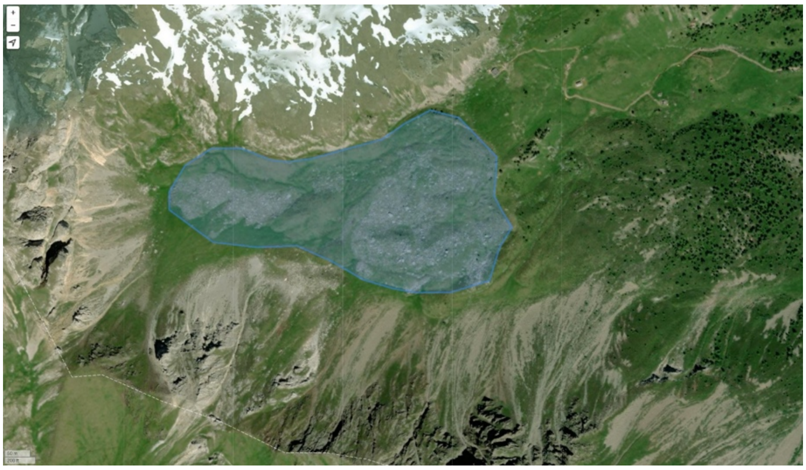


Fig. 3 - Active rock glacier Vallaccia

Vallaccia is a lobate, active rock glacier of 630 m length, and 220 m mean width. It covers an area of 0,14 km^2. The front of the rock glacier terminates at an elevation of 2250 m; the rooting zone is at 2350 m. The rock glacier is exposed towards east, and it is bordered by a steep wall in its south, west and north. Mean slope of the rock glacier surface is 9°.

The rock glacier has a tongue-shaped morphology with well-developed surface morphology (fig. 4). There are lateral and frontal ridges with steep distal slopes. Inner part

This project has received funding from the European Union's Horizon 2020 research and innovation programme under MSCA-RISE2020 grant agreement No 101007973.

has hummocky morphology with big thermokarst sinkholes and possible melt water channels. There are a lot of big boulders on the surface.

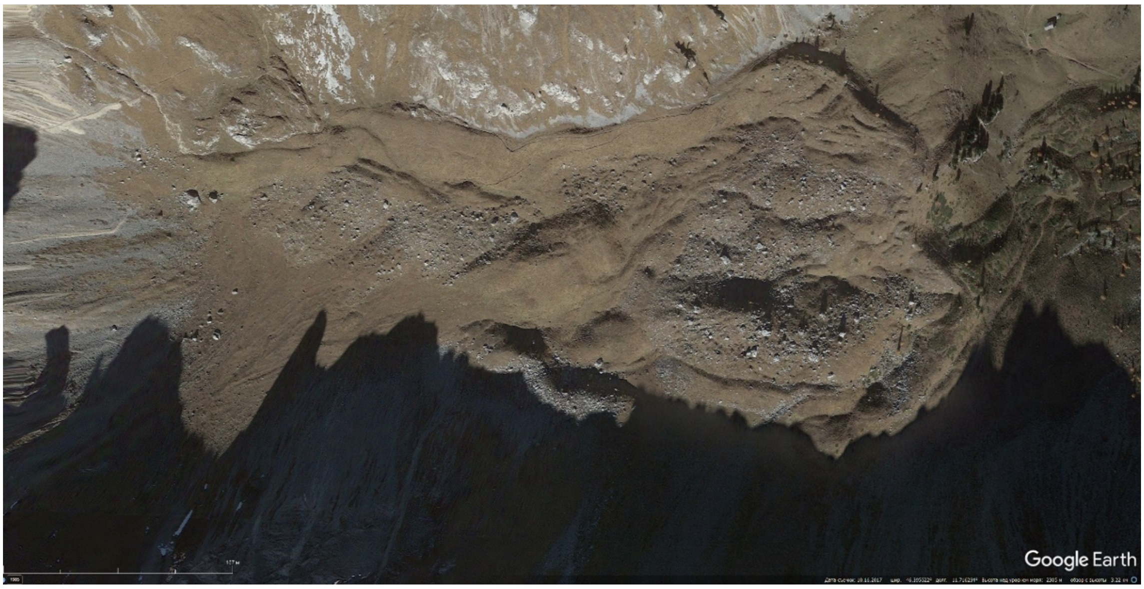


Fig. 4 - Surface morphology of the Vallaccia rock glacier

Debris cover thickness is unknown but probably ice exists here since the glacier is active. It can preserve at a depth of more than 2-3 m of debris cover. The debris was accumulated here as a result of slope mass movement and probably glacial ablation. The entire rock glacier is in the vegetation zone and partly covered with grass. Shrubs and trees are very rare.

The area of rock glacier has dry and cold winters and warm summers. According to Köppen and Geiger (www.climate-data.org), this climate is classified as subarctic climate (Dfc). The Dolomites receive less precipitation than do the majority of the Alps. The closest weather station is Arabba (1667 m a.s.l.) with mean annual air temperature +1,7° and annual precipitation 1667 mm (1198 mm in summer and 479 mm in winter). Presumably there should be permafrost because it is believed that the discontinuous permafrost in Dolomites is common above 2300-2500 m a.s.l.

This rock glacier is very easily accessible. The road (but with traffic limitation – ZTL) runs very close to the rock glacier front (less than 2 km). There is also cabin (Rifugio Vallaccia) near the rock glacier front. The cabin situated at 2275 m height and in 1,8 km from the end of the road. The trail goes to the cabin and along left side of rock glacier (fig. 5).

There is no information about previous surveys.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under MSCA-RISE2020 grant agreement No 101007973.

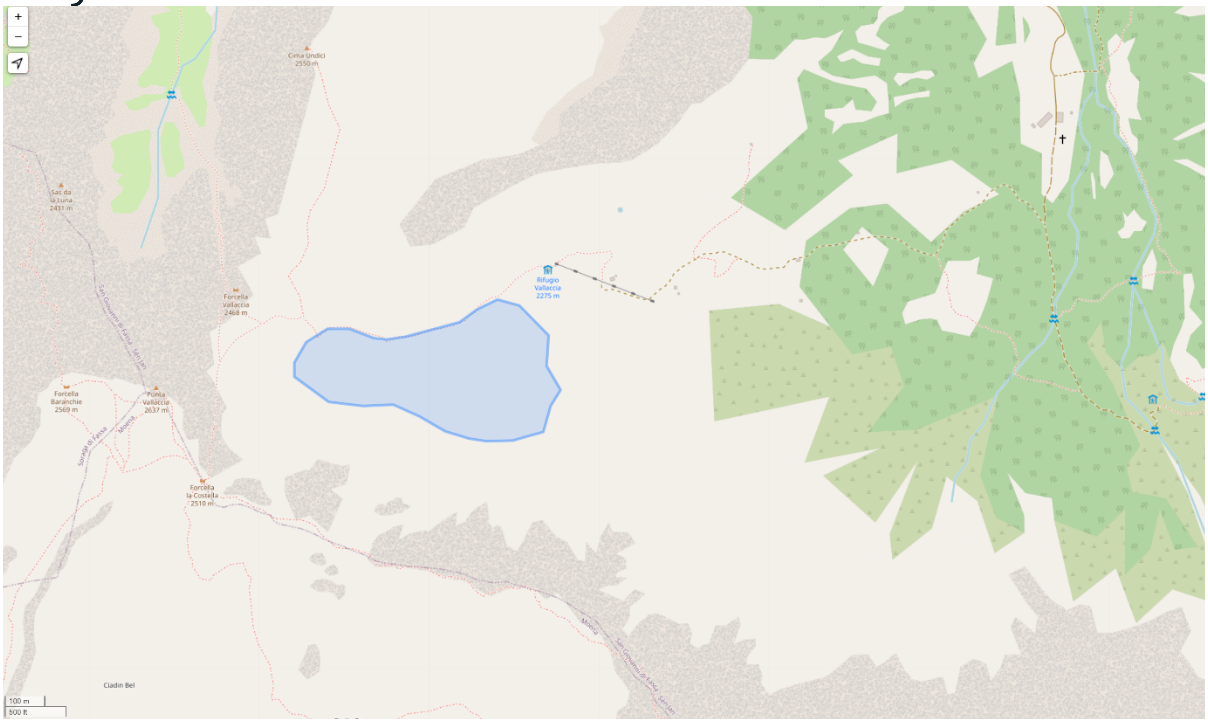


Fig. 5 - Location of roads, trails and rifugio near Vallaccia rock glacier

3.2 Relict rock glacier Val Tegnousa in Dolomites

Relict rock glacier ***Val Tegnousa*** is situated in the Pellegrino Pass area at Costabella / Cima dell’Uomo Chain of Marmolada Group in Dolomites (Italy, Trentino-Alto Adige, Soraga di Fassa; fig. 6, 7). The coordinates of rock glacier are N 46,39100, E 11,81042.

This project has received funding from the European Union’s Horizon 2020 research and innovation programme under MSCA-RISE2020 grant agreement No 101007973.

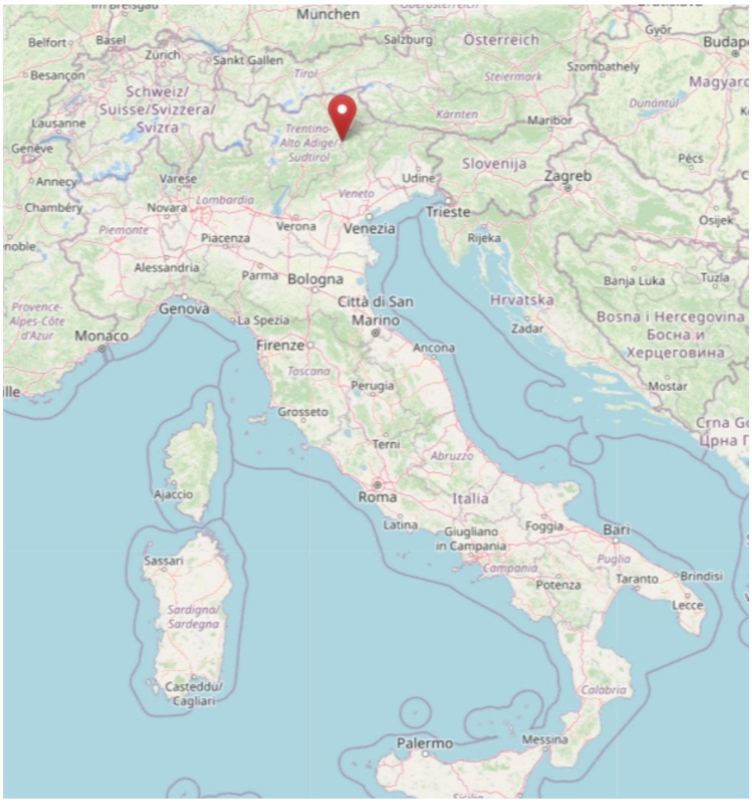


Fig. 6 - Location of Val Tegnousa test site

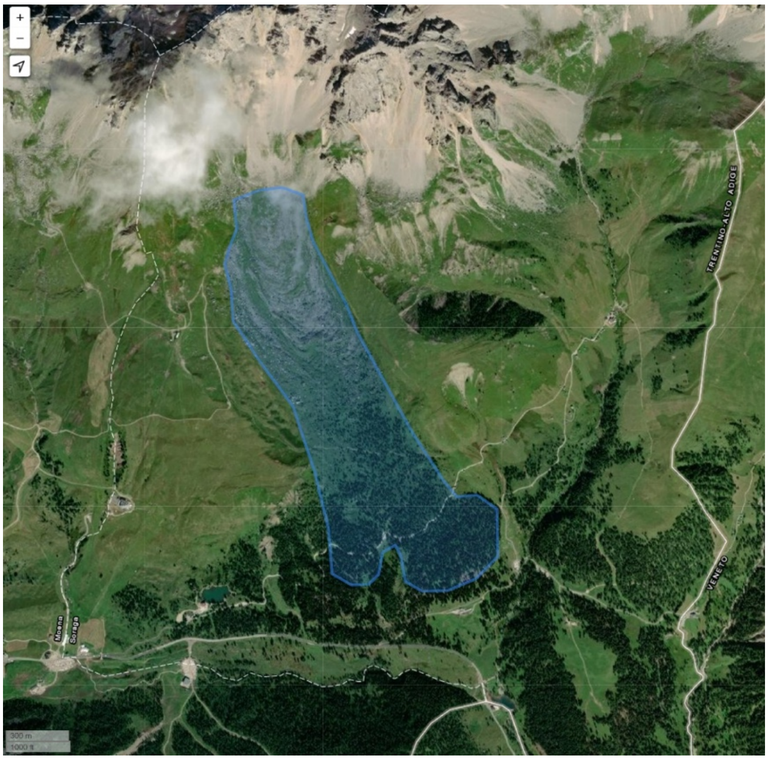


Fig. 7 - Relict rock glacier Val Tegnousa

This project has received funding from the European Union's Horizon 2020 research and innovation programme under MSCA-RISE2020 grant agreement No 101007973.

Val Tegnousa is a lobate, relict rock glacier of 2200 m length, and 330 m mean width. It covers an area of 0,74 km^2. The front of the rock glacier terminates at an elevation of 1810 m; the rooting zone is at 2320 m. The rock glacier is exposed towards south, and it is bordered by a steep wall in its north. Mean slope of the rock glacier surface is 12°.

The rock glacier has a tongue-shaped morphology. Its surface can be divided into two parts: the upper one – with well-developed morphology (fig. 8, 9), the lower – with less well-developed morphology. The upper part is the most recent generation of rock glacier. It has 2200 m length, 270 m mean width, and covers an area of 0,2 km^2. The front of the upper part terminates approximately at an elevation of 2180 m. Mean slope of the upper part surface is 11°. There are transverse ridges with steep frontal slopes and deep thermokarst sinkholes with steep slopes in the upper part (the most recent generation) of the rock glacier. Transverse ridges and sinkhole slopes consist of big boulders.

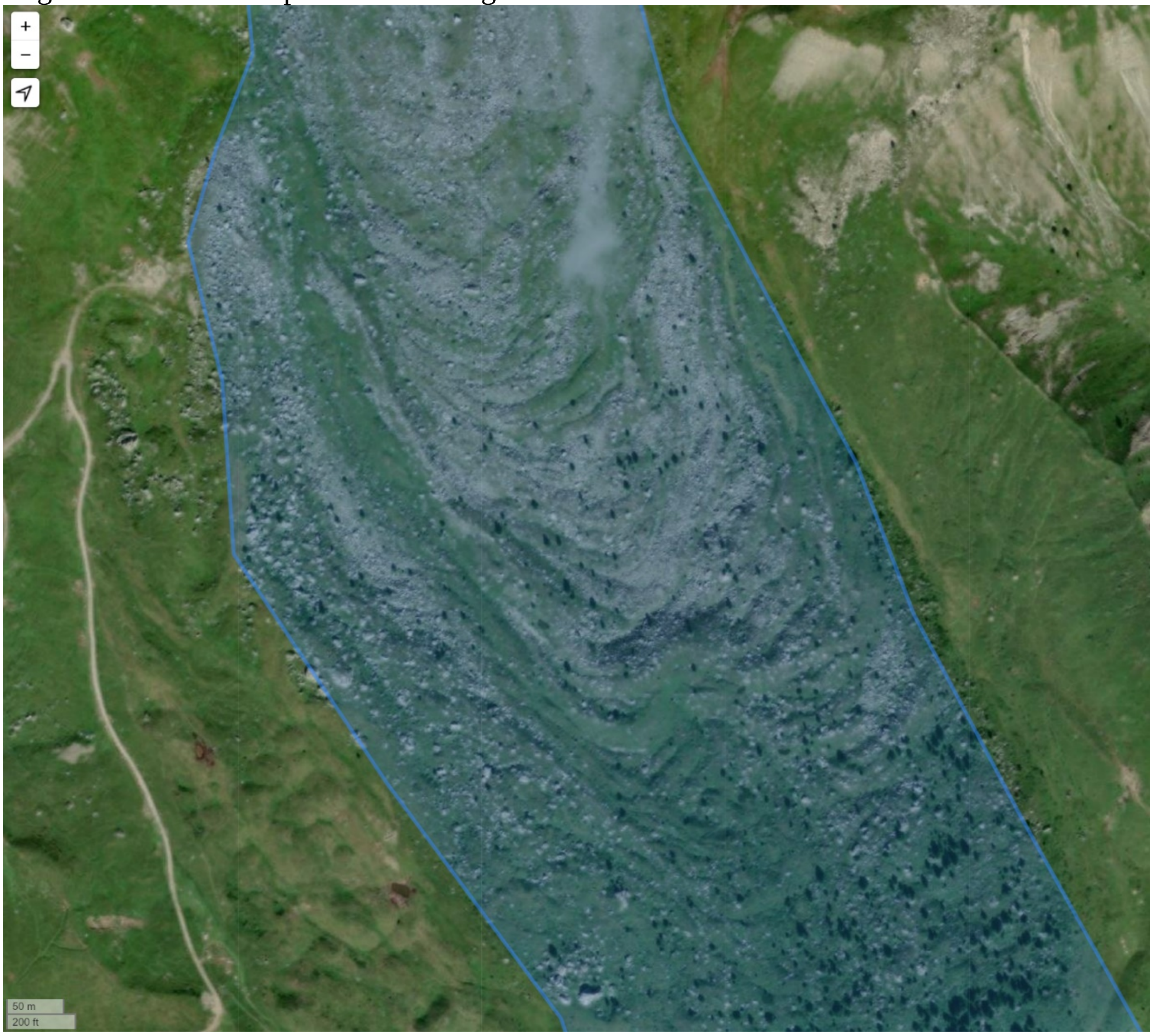


Fig. 8 - Surface morphology of the upper part of Val Tegnousa rock glacier

This project has received funding from the European Union's Horizon 2020 research and innovation programme under MSCA-RISE2020 grant agreement No 101007973.

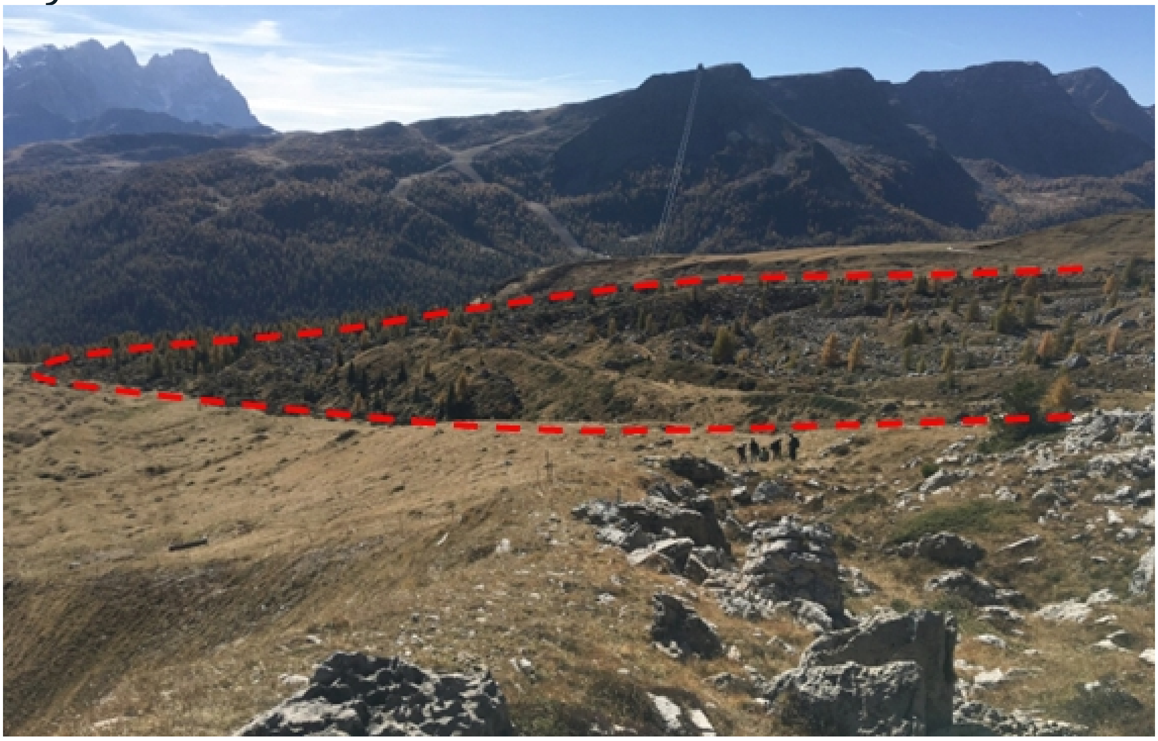


Fig. 9 - View of the upper part of Val Tegnousa rock glacier

Debris cover thickness is unknown but perhaps the ice is completely absent here since the glacier is not active. Separate remnants of small ice cores that cannot lead to the movement of the entire glacier could still be preserved at a depth of more than 3-5 m of debris cover only in the upper part (the most recent generation) of the rock glacier. The debris was accumulated here as a result of slope mass movement and probably glacial ablation. The entire rock glacier is in the vegetation zone and can be divided into three parts: the upper one – partly covered with grass and sometimes shrubby vegetation, the middle – completely covered with grass and sparse shrubs and trees, except for individual outcrops of large boulders, the lower – covered with forest, the density of which increases downwards, without outcrops of large boulders.

On a slope to the east of the rock glacier at an altitude of approximately 1980 m there are water springs that do not dry up even at the end of the ablation season in October. They may be the result of the melting of the rock glacier ice cores remnants or the release of underground karst waters.

The area of rock glacier has dry and cold winters and warm summers. According to Köppen and Geiger (www.climate-data.org), this climate is classified as subarctic climate (Dfc). The Dolomites receive less precipitation than do the majority of the Alps. The closest weather station is Arabba (1667 m a.s.l.) with mean annual air temperature +1,7° and annual precipitation 1667 mm (1198 mm in summer and 479 mm in winter). Presumably there is no permafrost because the movement of the glacier is absent. Besides, it is believed that the discontinuous permafrost in Dolomites is common above 2300-2500 m a.s.l.

This rock glacier is very easily accessible. The road (but with traffic limitation – ZTL) runs very close to the rock glacier front (less than 1,5-2 km). There are 3 cabins near the rock

This project has received funding from the European Union's Horizon 2020 research and innovation programme under MSCA-RISE2020 grant agreement No 101007973.

glacier: Rifugio Fuciade (1982 m), Chalet Cima Uomo (2012 m), and Rifugio Albergo Mirolago (1920 m). The trails and cableway Cima Uomo go to the cabins and cross rock glacier (fig. 10).

There was LiDAR survey by Servizio Geologico della Provincia Autonoma di Trento in 2006 (Carton et al., 2021).

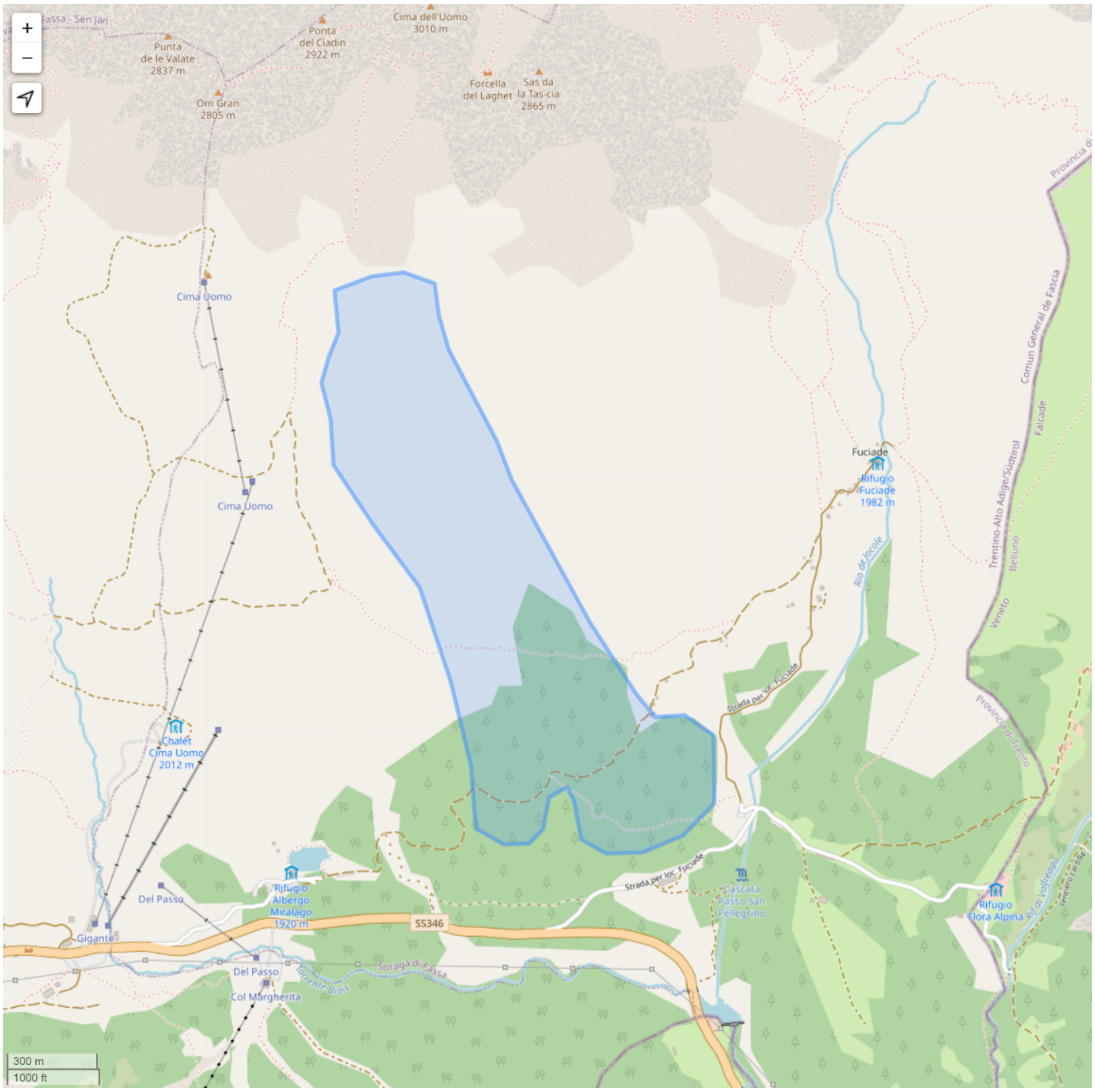


Fig. 10 - Location of roads, trails and rifugio near Val Tegnousa rock glacier

This project has received funding from the European Union's Horizon 2020 research and innovation programme under MSCA-RISE2020 grant agreement No 101007973.

3.3 Debris-covered glacier Miage in Western Alps

Debris-covered glacier ***Miage*** is situated in the Aosta Valley catchment area of Mont Blanc massif in Alps (Italy, Valle d’Aosta, Courmayeur; fig. 11, 12). The coordinates of glacier are N 45.78677, E 6.89511.

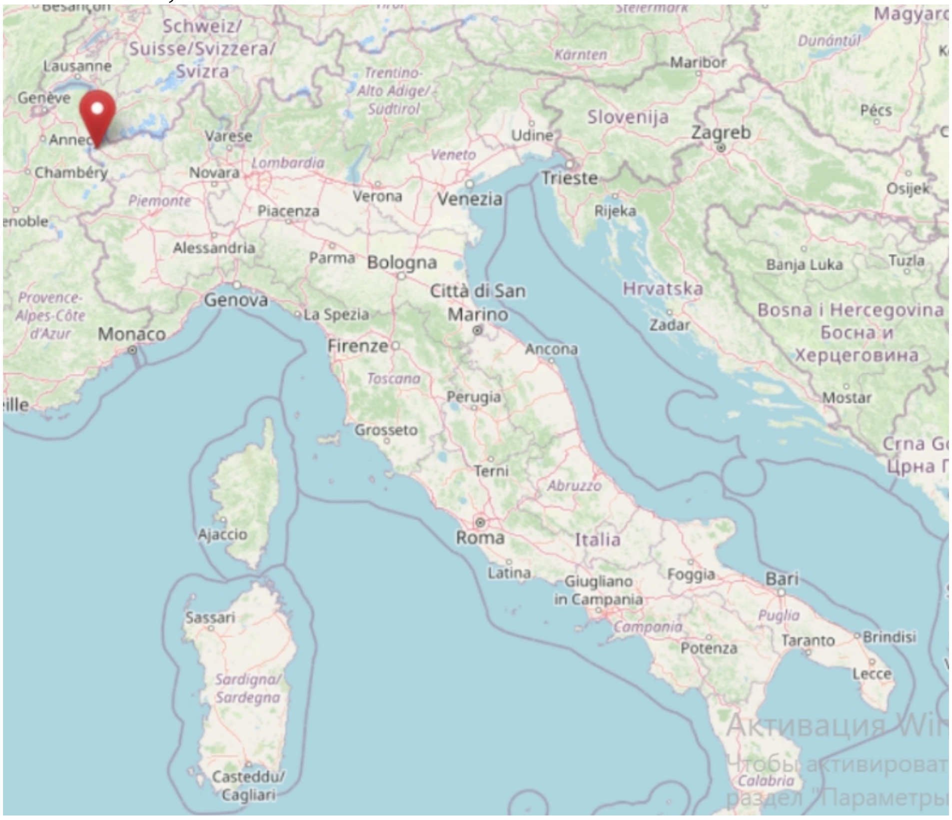


Fig. 11 - Location of Miage test site

This project has received funding from the European Union’s Horizon 2020 research and innovation programme under MSCA-RISE2020 grant agreement No 101007973.

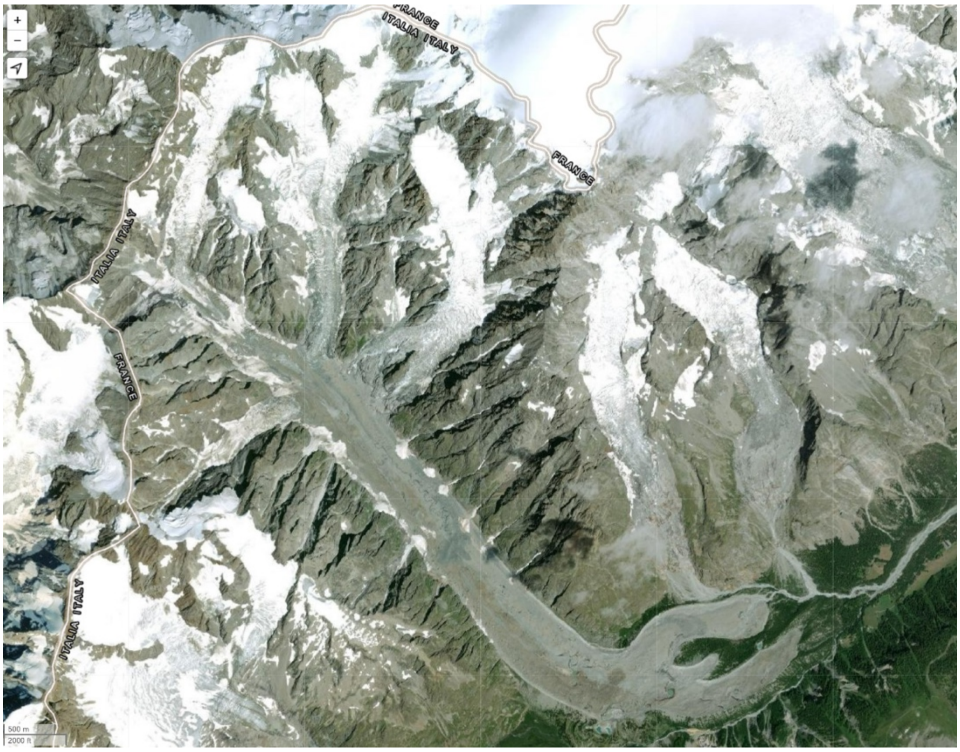


Fig. 12 -. Debris-covered glacier Miage

Miage is a valley glacier. It covers an area of 11 km^2. The front of the right glacier tongue terminates at an elevation of 1730 m. The glacier is bordered by steep walls and exposed towards south-east.

The entire lower 6500 m of the glacier until elevation of 2450 m is completely covered with debris (fig. 13, 14). It is 41,5 % of total area. Mean slope of the debris cover surface is 6° (for the right tongue). Inner part of debris cover has hummocky surface with a lot of thermokarst depressions sometimes with lakes. Most often, there are no clearly defined ridges, but there are coloured stripes along the glacier in accordance with the debris lithology. The edges of the debris cover are represented by steep slopes.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under MSCA-RISE2020 grant agreement No 101007973.

Fig. 13 - Surface morphology of the lower part of Miage glacier debris cover

Fig. 14 - View of the lower part of Miage glacier debris cover

Average value of debris cover thickness is around 20-40 cm (Mihalcea et al., 2008; fig. 15). The maximum value is around 50-60 cm in the lowest parts of the lobes. The debris was accumulated here as a result of glacial ablation. There is no vegetation in the inner part of debris cover. However, sparse tree vegetation is widespread on the slopes along the edges of the cover (fig. 13, 14). On the surface there are numerous thermokarst lakes, meltwater channels and ice wall exposures. On the fronts of both tongues of the glacier there are sources of rivers. There is also Miage marginal lake on the right snout of the glacier.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under MSCA-RISE2020 grant agreement No 101007973.

The area of glacier has moderate wet climate. According to Köppen and Geiger (www.climate-data.org), this climate is classified as a tundra climate (ET). The closest weather station is Courmayeur (1261 m a.s.l.) with mean annual air temperature -0,4° and annual precipitation 1346 mm (635 mm in summer and 711 mm in winter). Presumably there is no permafrost due to low elevation. Thus, the ice is not preserved by the debris cover and the glacier continues to degrade.

This glacier is very easily accessible. The road runs very close to the glacier front (less than 1 km). There is also cabin (Rifugio Combal) near the glacier tongue. The cabin situated at 1969 m height and in 2,6 km from the end of the road. The trail along the river Dora di Veny goes to the cabin (fig. 16). There is also 2 campings at the road in around 3 km from the glacier front.

There were field surveys of debris thickness measurement in 1997 (Mihalcea et al., 2008).

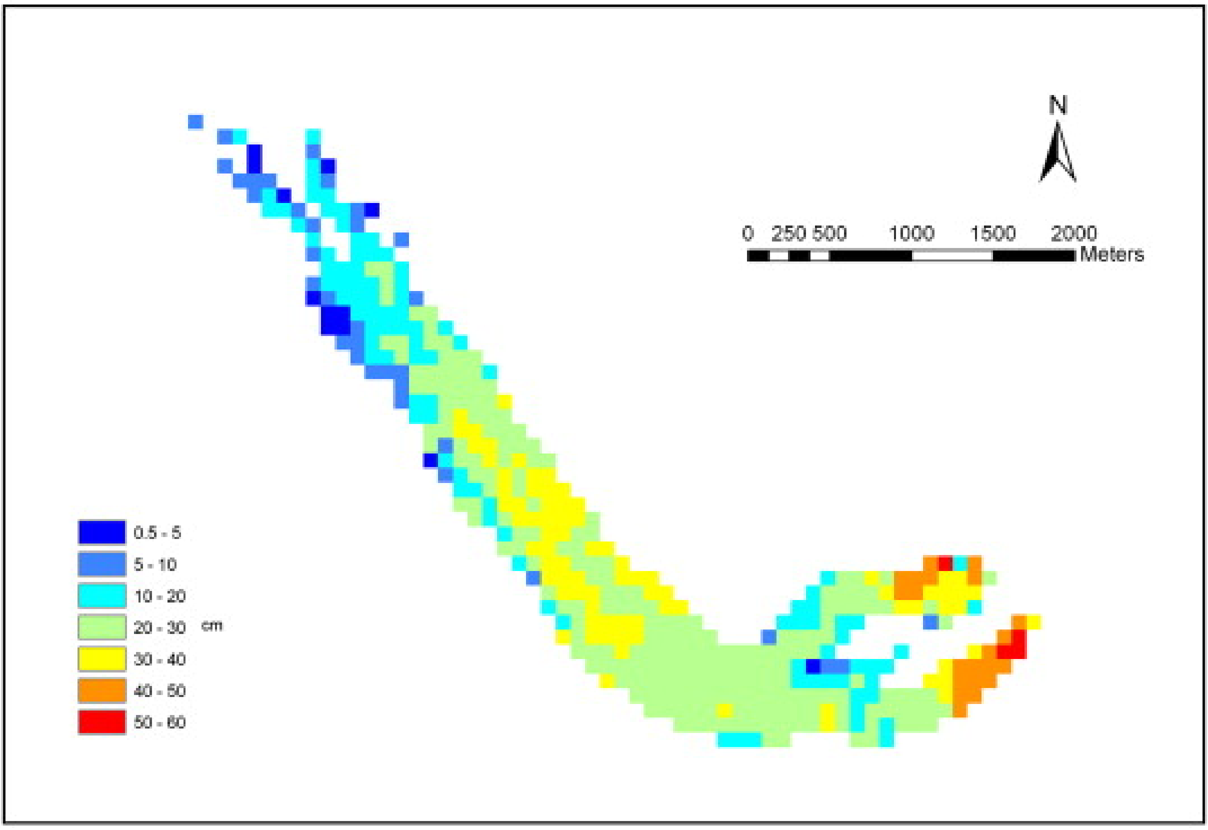


Fig. 15 - Debris cover map distribution derived from ASTER image (Mihalcea et al., 2008). The debris thickness is expressed in cm

This project has received funding from the European Union's Horizon 2020 research and innovation programme under MSCA-RISE2020 grant agreement No 101007973.

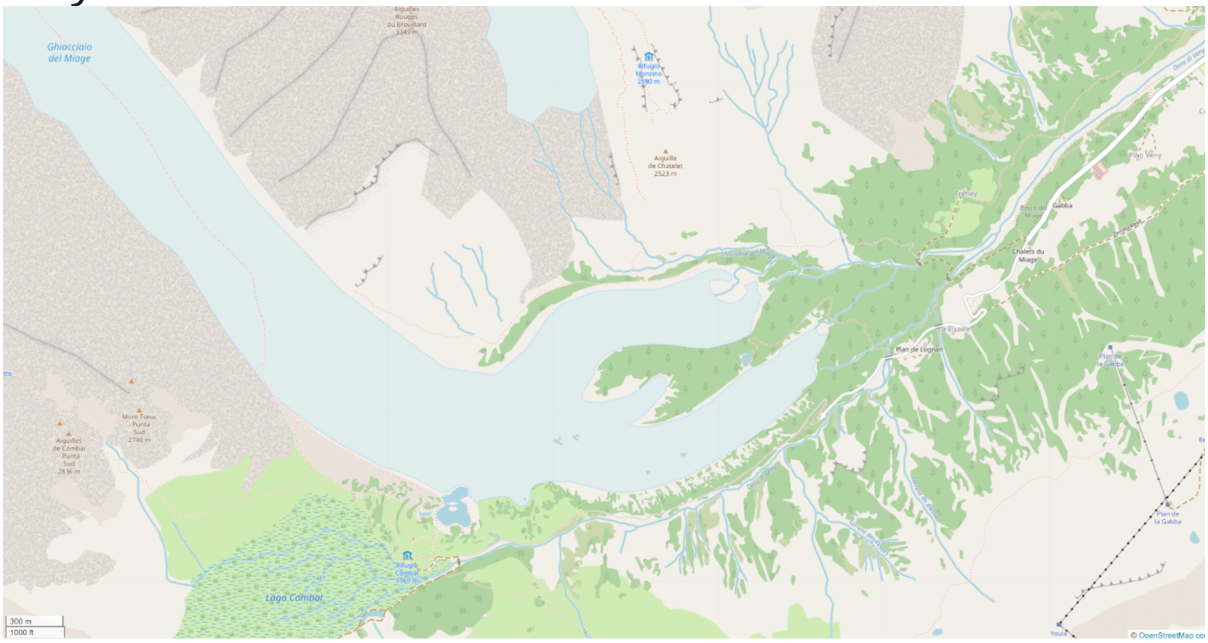


Fig. 16 - Location of roads, trails and rifugio near Miage glacier

3.4 Ash-covered glaciers The Knife Creek in Alaska

Ash-covered glaciers ***The Knife Creek*** are situated in the Valley of Ten Thousand Smokes area at Mt. Katmai in Alaska (USA; fig. 17, 18). The coordinates of one of the The Knife Creek glaciers are N 58.21292, W 155.06332.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under MSCA-RISE2020 grant agreement No 101007973.

Fig. 17 - Location of The Knife Creek test site

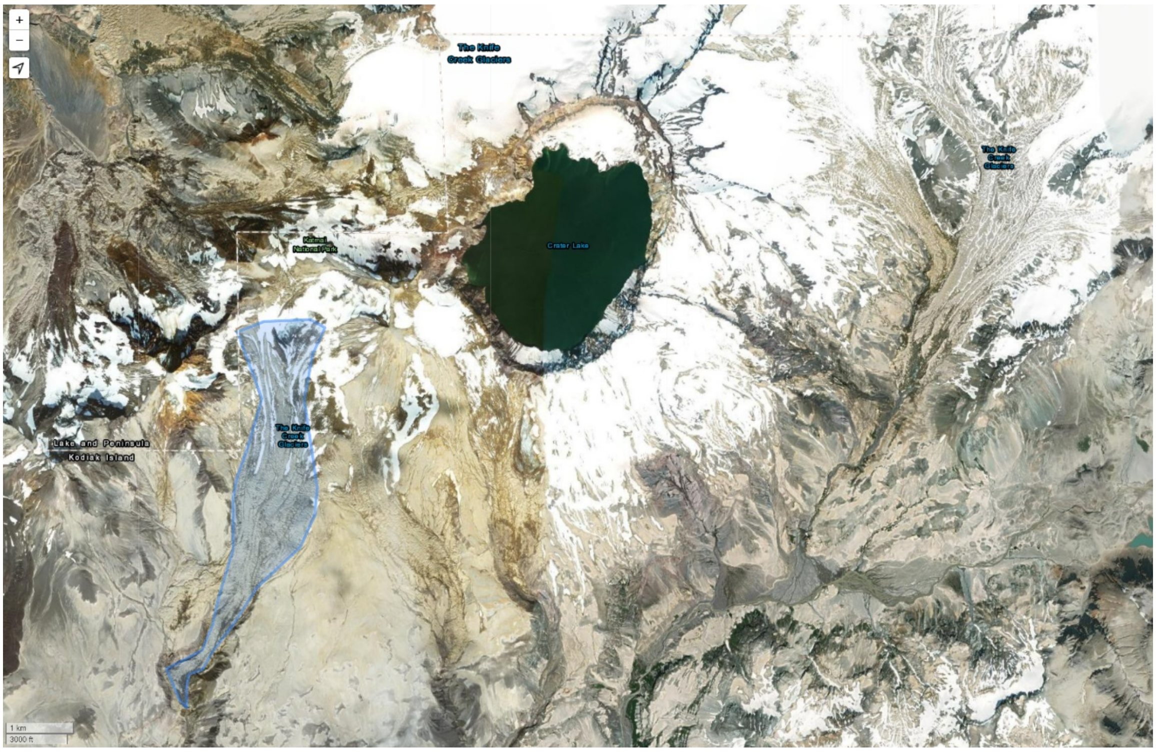


Fig. 18- Ash-covered glaciers The Knife Creek

This project has received funding from the European Union's Horizon 2020 research and innovation programme under MSCA-RISE2020 grant agreement No 101007973.

The Knife Creek is a valley glacier of 6550 m length. The front of the glacier terminates at an elevation of 460 m. The glacier is exposed towards south.

The entire glacier until elevation of 1350 m is completely covered by debris. Mean slope of the debris cover surface is 7,7°. Debris cover has chaotic erosional surface with a lot of longitudinal meltwater channels and transvers crevasse-fill trenches (fig. 19, 20). Most often, there are no clearly defined ridges.

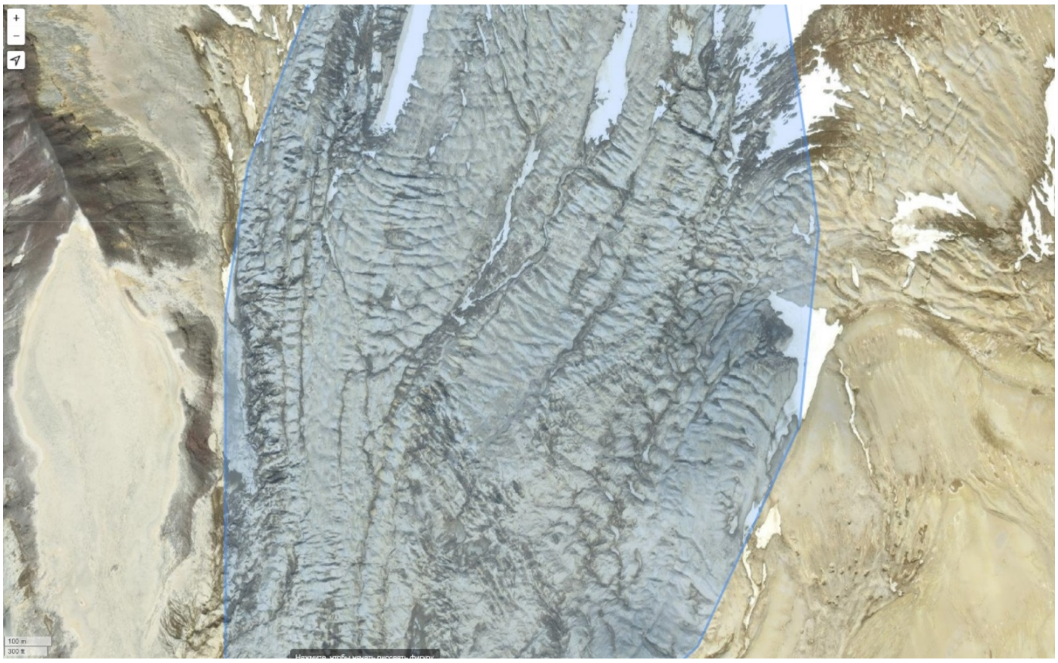


Fig. 19 - Surface morphology of the middle part of The Knife Creek glaciers debris cover

Fig. 20 - View of the The Knife Creek glaciers debris cover (Hildreth and Fierstein, 2012)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under MSCA-RISE2020 grant agreement No 101007973.

Debris cover thickness is until 2 m (Hildreth and Fierstein, 2012). The debris was accumulated here as a result of ash sedimentation. There is no vegetation (fig. 13, 14). There are numerous meltwater channels and ice walls exposures at the lower part of glacier. On the front of the glacier there is source of river.

According to Köppen and Geiger (www.climate-data.org), the area of glacier has a subarctic climate (Dfc). The closest weather station is Kodiak (9 m a.s.l.) with mean annual air temperature +4,5° and annual precipitation 1553 mm (699 mm in summer and 854 mm in winter). There is zone of isolated (0-10%) permafrost.

This glacier is very difficult accessible. There are no roads, trails and settlements (fig. 21).

There is no information about previous surveys.

Fig. 21 - No roads, trails and settlements near The Knife Creek glaciers

4. Test ranges (collocation)

The main tests will be organised in the Moroccan desert. The base will be the Ibn Battuta Centre at Erfoud. The area has been the site where the P-Band radar, build by CORISTA with support of the Agenzia Spaziale Italiana and Thales Alenia Space, has been tested a few years ago.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under MSCA-RISE2020 grant agreement No 101007973.

The radar is a heritage of FlyRadar. However, the both electronic and the antennas of P-Band were heavy and bulky (Fig 22 and 23 compared with Fig. 1). The detailed planning will be organised in detail at the end of the preliminary and informal testing campaign.

Part of the trajectory will correspond to the ones already analysed by P-band, in order to see the difference from the obtained by a conventional radar system and FlyRadar.

Fig. 22 - The P-Band radar precursor of Fly-Radar. Above the bulky SAR antenna in the middle of the chopper and the antenna for the penetration mode in middle foreward. Below, the electronic of the P-band radar. Compare this picture with Fig. 1.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under MSCA-RISE2020 grant agreement No 101007973.

Four different scenarios have been selected and all of them are actually test ranges investigated also by the Precursor P-Band.

	Site	Charateristics	Note
TS-1	Errachidia and Erfoud	Mesozoic acquifer	Subsurface water :100–200 m deep
TS-2	Alluvial plain between Oued Ziz and Rheris	Topmost subsurface	Subsurface water :4–100 m deep
TS-3	Rissani	Archeology and modern artefacts	
TS-4	ERG Chebbi	Contacts between quaternary and Paleozoic units Aquifer exposed to the surface and below the sand of the ERG	

Table 1 - Test ranges

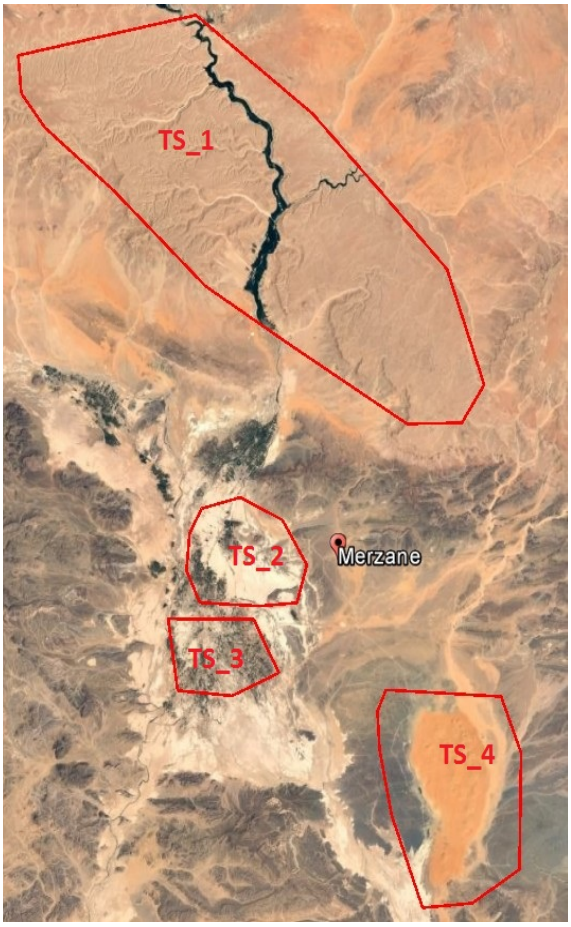


Fig. 23 - Localisation of the four Test ranges

This project has received funding from the European Union's Horizon 2020 research and innovation programme under MSCA-RISE2020 grant agreement No 101007973.

The final decision on which trajectories select and the addition opf further test ranges, scenarios and trajectories will be taken before June 2023 and will be described in another issue of this document.

The SAR mode taking into consideration the main operating parameters of the radar (opening time and length of the receiving window, RGD and SWL) have been set for all acquisitions to: RGD = 6 s SWL = 20 s The basic flight plan for SAR modes is based on two types of tracks shown in Fig. 25, namely:

1. repeated tracks, which is based on the repetition of the same track several times;

2. Ascending/descending tracks, which is based on two parallel tracks traveled in opposite directions looking at the same area of terrain.

The main operating parameters of the radar (opening time and length of the receiving window, RGD and SWL) have been set for all acquisitions to:

RGD = 6 μs SWL = 20 μs for SARL mode

RGD = 8 μs for SARH mode SWL = 12 μs

This difference is due to the fact that the antenna opening in range for SARH mode is narrower than for SARL mode. This way the covered areas will also be different. In the case of ascending/descending traces, it has been ensured that the areas covered by the two bands overlap, favouring the need to keep the angles of incidence as similar as possible. Moreover, the choice of the SWL parameter for the SARH mode is also caused by the fact of limiting the data-rate which is much greater in this case for the presence of 3 steps.

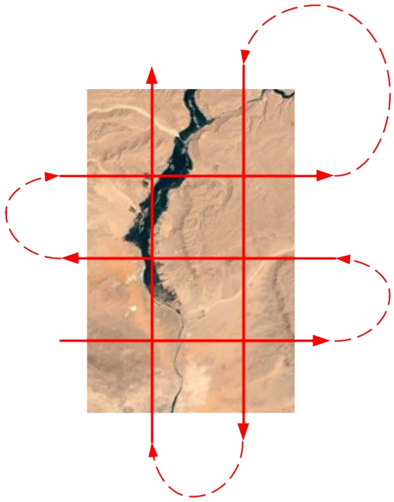
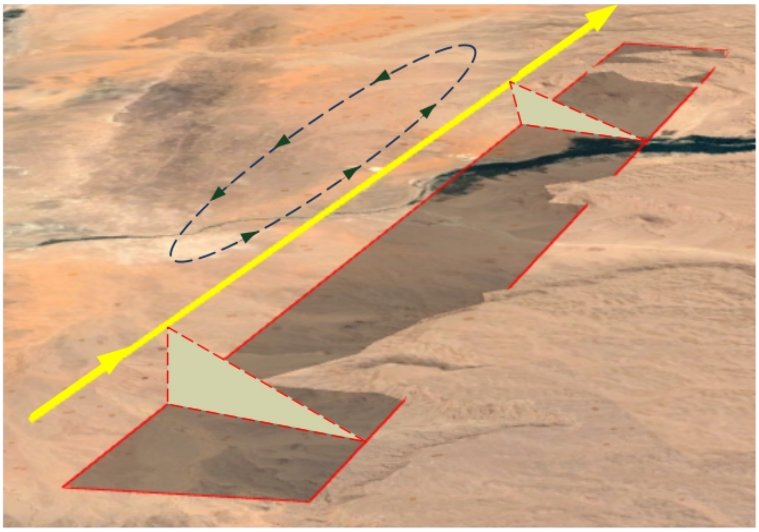


Fig. 24 - Flight plan for sounder mode

This project has received funding from the European Union's Horizon 2020 research and innovation programme under MSCA-RISE2020 grant agreement No 101007973.



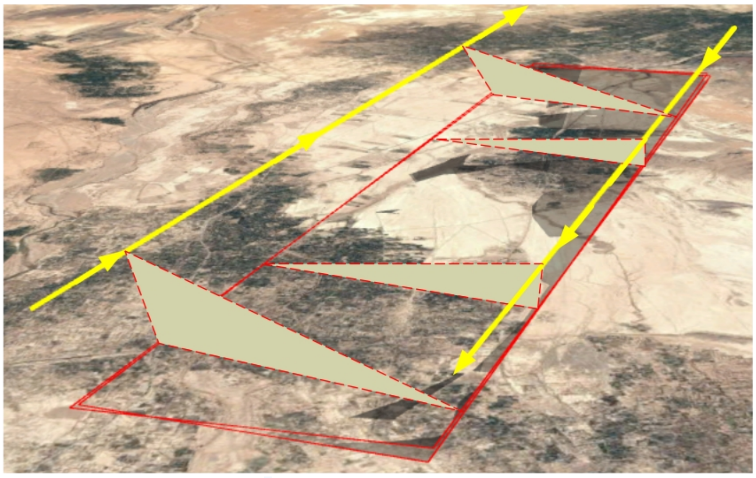


Fig. 25 - Flight plan for SAR mode: repeated tracks (left) and ascending/descending (right)

In the preparation of the detailed planning of the tests it will be taken into account the results of the experiments carried out by the precursor radar P-Band.

Clearly for the SAR mode the importance of the raw data focalization is of paramount importance. It has been realised by back projection in the time domain. The images were focused in Cartesian coordinates (azimuth and ground range), on a flat topography of elevation equal to 730 m, in accordance with the average topographical characteristics of the illuminated area. The pixel size of the focused images is 0.7 m in azimuth and 5 m in ground range. The resolution in azimuth is 1 m, which corresponds to a synthetic aperture of more than 1 Km. The angle of incidence varies depending on the distance to the ground from about 15 to 75 µ. Azimuth is the most common. The history of the distances of each target along the synthetic aperture was calculated using the differential GPS navigation data provided by Corista with data. Focused images for all polarizations based on data captured in P-Band flight 14 21 32. It is immediate to notice how in all the images some disturbances appear for

This project has received funding from the European Union's Horizon 2020 research and innovation programme under MSCA-RISE2020 grant agreement No 101007973.

distances to earth (ground range) until about 700-800 m, presumably deriving from the specular reflection from earth in nadir direction. Beyond these disturbances, we note how the images in the four polarizations are consistent with each other, and how no show, at least in first analysis, obvious artifacts. These results indicate that the acquisition system has worked properly and are a further confirmation of the validity of the approach followed for the removal of spurious components. By looking at Fig. 26 you can make a direct comparison between an optical image extracted from Google Earth and the SAR image.

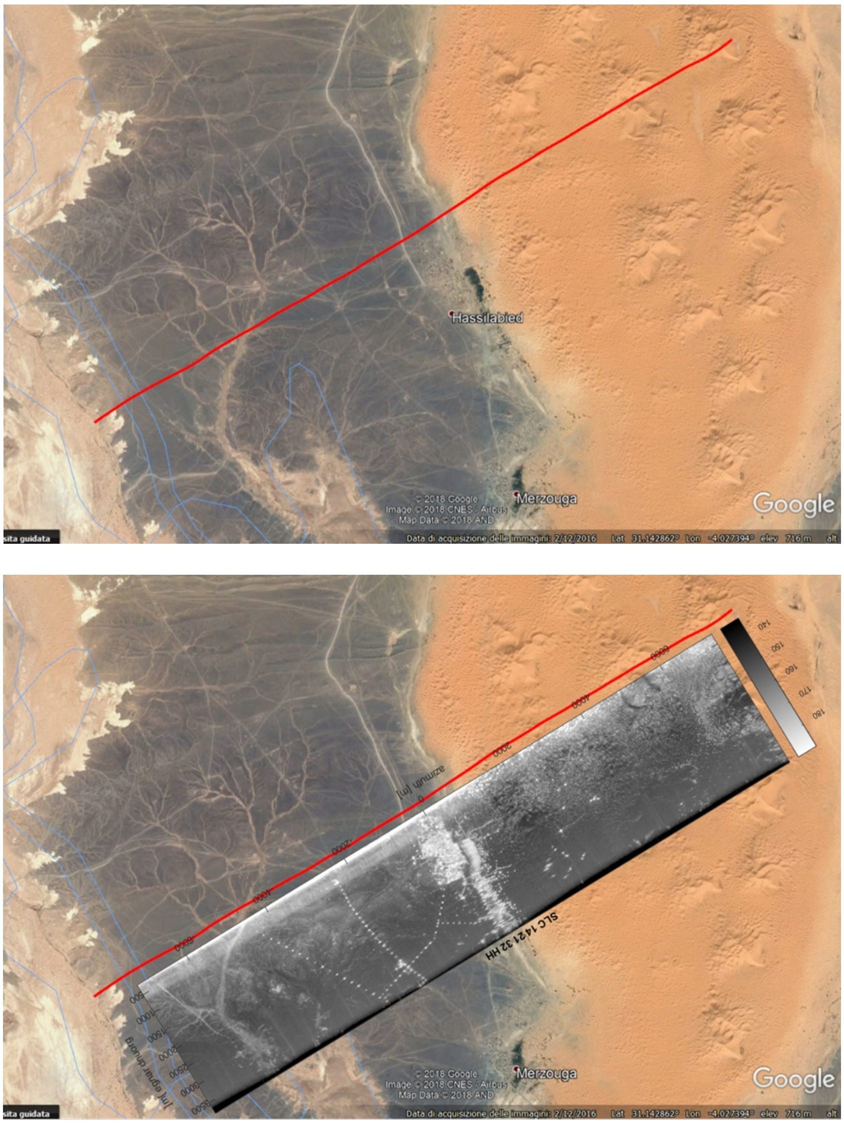


Fig. 26 - Above: Visible image (Google Earth) with in red the flight path. Below The SAR image of the Google Earth image.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under MSCA-RISE2020 grant agreement No 101007973.

5. Conclusion

The test site for the co-location have have been identified in Southeast Morocco. The Sahara test ranges are located in desert environments allowing a higher penetration of the radar signal. Moreover, the location is the same of the test of the radar precursors P-Band that operated from chopper.

Radar test sites in more logistically accessible ranges have been located in the Alps.

No misalignment with the project schedule are overseen.

6. References

Carton A., Abbà T., Bondesan A, Fontana A., Mozzi P., Surian N., Zanoner T., Breda A., Massironi M., Preto N., Zampieri D. Geomorphological map of the San Pellegrino Pass (Dolomites, Northeastern Italy). Geografia Fisica e Dinamica Quaternaria, 2021, 44 (2): 99-121. DOI: 10.4461/ GFDQ.20254.9.

Hildreth, W., and Fierstein, J., 2012, The Novarupta-Katmai eruption of 1912—largest eruption of the twentieth century; centennial perspectives: U.S. Geological Survey Professional Paper 1791, 259 p. (Available at https://pubs.usgs.gov/pp/1791/).

Mihalcea, B.W. Brock, G. Diolaiuti, C. D’Agata, M. Citterio, M.P. Kirkbride, M.E.J. Cutler, C. Smiraglia Using ASTER satellite and ground-based surface temperature measurements to derive supraglacial debris cover and thickness patterns on Miage Glacier (Mont Blanc Massif, Italy) Cold Reg. Sci. Technol., 2008, 52 (3): 341-354, 10.1016/j.coldregions.2007.03.004.

https://www.climate-data.org/

This project has received funding from the European Union’s Horizon 2020 research and innovation programme under MSCA-RISE2020 grant agreement No 101007973.

Disclaimer: This report reflects only the author's view. The Research Executive Agency (REA) is not responsible for any use that may be made of the information it contains.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under MSCA-RISE2020 grant agreement No 101007973.