European Geosciences Union
EGU General Assembly 2021

Monitoring the dynamics of an alpine rock glacier with repeated UAV and GNSS data

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ACKNOWLEDGMENT
The research is founded by the Italian MIUR project Dipartimenti di Eccellenza 2018-2022

1. INTRODUCTION AND OBJECTIVES

Time series of rock glacier movements in the European Alps indicate an acceleration in permafrost creep in recent decades in relation to an increase in ground temperatures and water input. In this study, the morphological changes of an active rock glacier were investigated with UAV (Unmanned Aerial Vehicle) surveys, GNSS measurements and ERT (Electrical Resistivity Tomography) profiles.

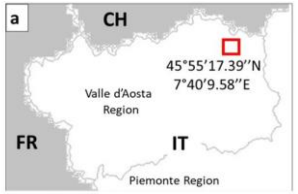
The aims of this work consist in (i) analysing the surface variations and the velocity rates of the rock glacier, (ii) validating the movement rate obtained by manual tracking on the orthophotos against repeated GNSS measurements and (iii) understanding how the extension of frozen ground across ERT profiles affects the surface velocity.

2. STUDY AREA AND DATASET

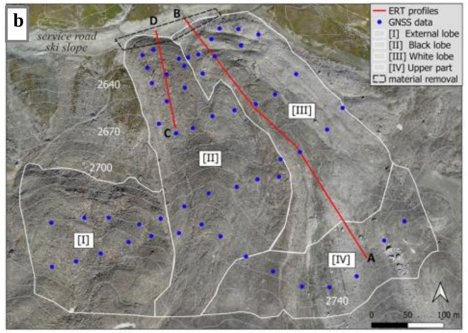
The Gran Sometta is an alpine active rock glacier located in the south-western Alps, in Valtournenche Valley (AO, Italy).

Dataset:

- 5 UAVs surveys between 2015 and 2019;
- GNSS campaigns carried out annually since 2012;
- 2 ERT profiles in 2015.



Phantom 4



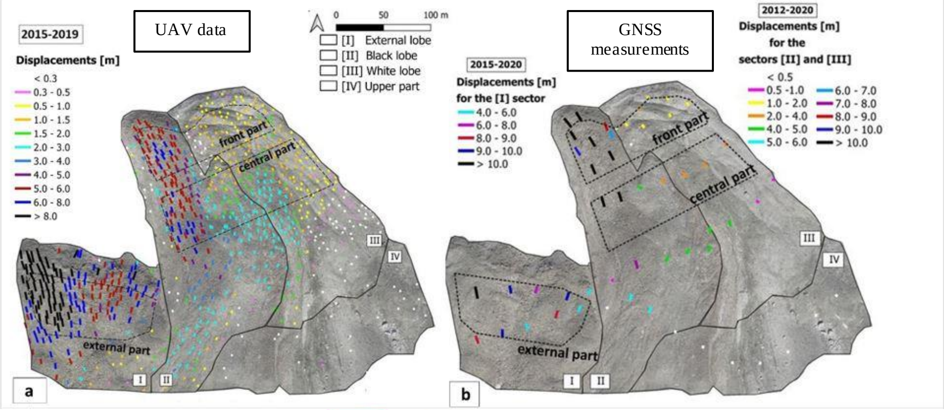
3. METHODS

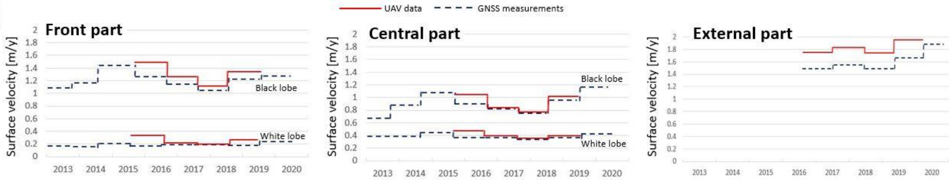
- The Structure from Motion (SfM) technique was used to generate dense point clouds, orthophotos and DSMs (Digital Surface Models);
- Multi-temporal 3D point cloud-based quantification was computed using M3C2 (Multiscale Model to Model Cloud Comparison) plug-in (Lague et al., 2013);
- The LOD (Level Of Detection) was calculated for each 3D model to estimate surface changes;
- Correlation analysis of surface horizontal velocity was computed between orthophotos manual identifications and GNSS measurements.

4. RESULTS

SURFACE HORIZONTAL VELOCITIES

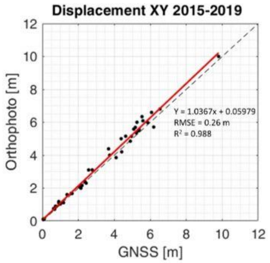
Clear distinction in creep dynamics between a faster western part (sector [I]) and a slower eastern part (sector [III]). The most upstream part (sector [IV]) has velocity below 0.1 m/y.





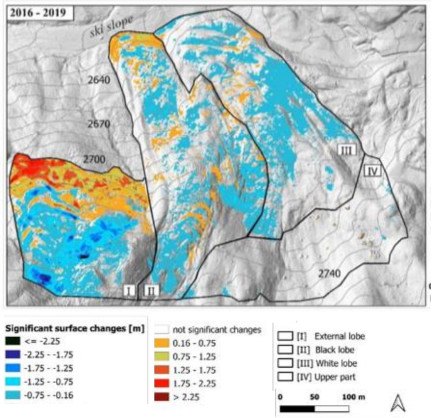
CORRELATION ANALYSIS

Surface velocity obtained by orthophotos manual identification was validated against GNSS measurements. The analysis showed a good correlation at all magnitudes with a R^2 equal to 0.988 and RMSE of 26 cm.



The velocity increased from a range of 0.17-1.1 m/y in 2013 to 0.21-1.45 m/y in 2015 and then decreased until 2018 when the smallest surface velocity is detected. In 2018, the creep velocities gradually started to increase again reaching values of 0.23 m/y up to a maximum of 1.9 m/y in the orographic left side of the rock glacier tongue.

SURFACE CHANGES

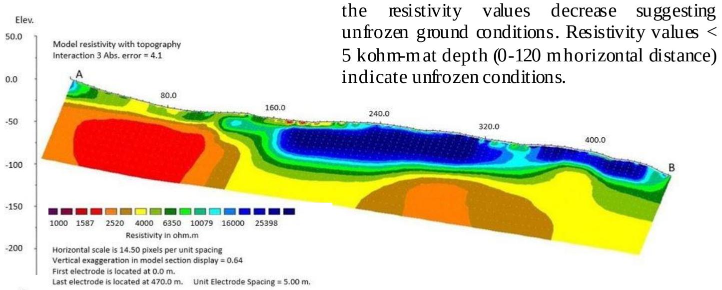


The areas with significant changes are 45% in the external lobe, 31% in the black lobe, 23% in the white lobe and only 1% in the upper part. Negative vertical changes dominate in all sectors.

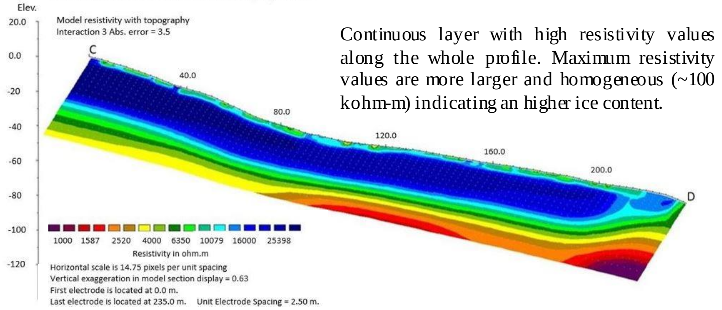
ERT PROFILES

The rock glacier revealed a complex dynamic that can be explained by the heterogeneous distribution of permafrost and related ground ice bodies which are thick enough (~ 20-30 m) for permafrost creep to occur.

Below the two high-resistive bodies (ground ice), the resistivity values decrease suggesting unfrozen ground conditions. Resistivity values < 5 kohm-m at depth (0-120 m horizontal distance) indicate unfrozen conditions.



Continuous layer with high resistivity values along the whole profile. Maximum resistivity values are more larger and homogeneous (~100 kohm-m) indicating an higher ice content.



5. CONCLUSIONS

- Based on GNSS measurements, maximum peak of surface velocity was reached in 2015, followed by a deceleration phase until 2017-2018. 2018-2019 and 2019-2020 are marked by a gradual increase in surface velocity;
- The movement rate based on orthophotos analysis agrees well with GNSS measurements;
- The heterogeneous distribution of frozen ground areas, its structure and the topographical settings seem to be key factors explaining the rock glacier flow spatial pattern.

REFERENCES

- Lague D., Brodu N., Leroux J. (2013). "Accurate 3D comparison of complex topography with terrestrial laser scanner: application to the Rangitikei canyon (N-Z)". *ISPRS Journal of Photogrammetry and Remote Sensing*, 82, 10-26.