CCI+ PHASE 2
PERMAFROST

CCN4
MOUNTAIN PERMAFROST: ROCK GLACIER INVENTORIES (ROGI) AND ROCK GLACIER VELOCITY (RGV) PRODUCTS

D2.5 Product Validation Plan (PVP)

VERSION 1.0

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Executive summary

The European Space Agency (ESA) Climate Change Initiative (CCI) is a global monitoring program, which aims to provide long-term satellite-based products to serve the climate modelling and climate user community. The objective of the ESA CCI Permafrost project (Permafrost_cci) is to develop and deliver the required Global Climate Observation System (GCOS) Essential Climate Variables (ECV) products, using primarily satellite imagery. The two main products associated to the ECV Permafrost, Ground Temperature (GT) and Active Layer Thickness (ALT), were the primary documented variables during Permafrost_cci Phase 1 (2018–2021). Following the ESA Statement of Work for Permafrost_cci Phase 2 (2022–2025) [AD-1], GT and ALT are complemented by a new ECV Permafrost product: Rock Glacier Velocity (RGV). This document focuses on the mountain permafrost component of the Permafrost_cci project and the dedicated rock glacier products.

In periglacial mountain environments, permafrost occurrence is patchy, and the preservation of permafrost is controlled by site-specific conditions, which require the development of dedicated products as a complement to GT and ALT measurements and permafrost models. Rock glaciers are the best visual expression of the creep of mountain permafrost and constitute an essential geomorphological heritage of the mountain periglacial landscape. Their dynamics are largely influenced by climatic factors. There is increasing evidence that the interannual variations of the rock glacier creep rates are influenced by changing permafrost temperature, making RGV a key parameter of cryosphere monitoring in mountain regions.

Two product types are therefore proposed by Permafrost_cci Phase 2: Rock Glacier Inventories (RoGIs) and Rock Glacier Velocity (RGV) time series. This agrees with the objectives of the International Permafrost Association (IPA) Standing Committee on Rock Glacier Inventories and Kinematics (RGIK) [RD-5] and concurs with the recent GCOS and GTN-P decisions to add RGV time series as a new product of the ECV Permafrost to monitor changing mountain permafrost conditions [AD-2 to AD-4]. RoGI is an equally valuable product to document past and present permafrost extent. It is a recommended first step to comprehensively characterise and select the landforms that can be used for RGV monitoring. RoGI and RGV products also form a unique validation dataset for climate models in mountain regions, where direct permafrost measurements are very scarce or lacking. Using satellite remote sensing, generating systemic RoGI at the regional scale and documenting RGV interannual changes over many landforms become feasible. Within Permafrost_cci, we mostly use Synthetic Aperture Radar Interferometry (InSAR) technology based on Sentinel-1 images that provide a global coverage, a large range of detection capability (mm–cm/yr to m/yr) and fine spatio-temporal resolutions (tens of m pixel size and 6–12 days of repeat-pass). InSAR is complemented at some locations by SAR offset tracking techniques and spaceborne/airborne optical photogrammetry.

This Product Validation Plan (PVP) defines the rules for unbiased validation and the criteria applied for the two mountain permafrost products (RoGI and RGV). It describes the planned validation activities and lists the available datasets at the different study sites. It presents the timeline related to the validation documents and endorsement. This is an updated version (version 2.0) including minor corrections and updates including complementary information of validation data.

1 Introduction

1.1 Purpose of the document

The mountain permafrost component of Permafrost_cci Phase 2 focuses on the generation of two products: Rock Glacier Inventory (RoGI) and Rock Glacier Velocity (RGV). The Product Validation Plan (PVP) describes the planning for the validation of the products, as introduced in the PSD [RD-1].

1.2 Structure of the document

Section 1 provides information about the purpose and background of this document. Section 2 defines the rules for unbiased validation and the validation criteria. Section 3 describes the planned validation activities and recalls the justification of the selected algorithms. Section 4 provides an overview of validation documents and endorsement. A list of acronyms is provided in Section 5. A glossary of the commonly accepted permafrost terminology can be found in [RD-18].

1.3 Applicable documents

[AD-1] ESA. 2022. Climate Change Initiative Extension (CCI+) Phase 2 – New Essential Climate Variables – Statement of Work. ESA-EOP-SC-AMT-2021-27.

[AD-2] GCOS. 2022. The 2022 GCOS Implementation Plan. GCOS – 244 / GOOS – 272. Global Observing Climate System (GCOS). World Meteorological Organization (WMO).

[AD-3] GCOS. 2022. The 2022 GCOS ECVs Requirements. GCOS – 245. Global Climate Observing System (GCOS). World Meteorological Organization (WMO).

[AD-4] GTN-P. 2021. Strategy and Implementation Plan 2021–2024 for the Global Terrestrial Network for Permafrost (GTN-P). Authors: Streletskiy, D., Noetzli, J., Smith, S.L., Vieira, G., Schoeneich, P., Hrbacek, F., Irrgang, A.M.

1.4 Reference Documents

[RD-1] Rouyet, L., Schmid, L., Pellet, C., Echelard, T., Delaloye, R., Brardinoni, F., Sirbu, F., Onaca, A., Poncos, V., Brardinoni, F., Kääb, A, Strozzi, T., Bernhard, P., Bartsch, A. 2024. ESA CCI+ Permafrost Phase 2 – CCN4 Mountain Permafrost: Rock Glacier inventories (RoGI) and Rock glacier Velocity (RGV) Products. D1.2 Product Specification Document (PSD), v2.0. European Space Agency.

[**RD-2**] Rouyet, L., Pellet, C., Schmid, L., Echelard, T., Delaloye, R., Brardinoni, F., Sirbu, F., Onaca, A., Poncos, V., Kääb, A, Strozzi, T., Bartsch, A. 2024. ESA CCI+ Permafrost Phase 2 – CCN4 Mountain Permafrost: Rock Glacier inventories (RoGI) and Rock glacier Velocity (RGV) Products. D1.1 User Requirement Document (URD), v2.0. European Space Agency.

[RD-3] Delaloye, R., Barboux, C., Bodin, X., Brenning, A., Hartl, L., Hu, Y., Ikeda, A., Kaufmann, V., Kellerer-Pirklbauer, A., Lambiel, C., Liu, L., Marcer, M., Rick, B., Scotti, R., Takadema, H., Trombotto Liaudat, D., Vivero, S., Winterberger, M. 2018. Rock glacier inventories and kinematics: a new IPA Action Group. Proceedings of the 5th European Conference on Permafrost (EUCOP), Chamonix, 23 June – 1st July 2018.

[RD-4] RGIK. 2022. Towards standard guidelines for inventorying rock glaciers: baseline concepts (version 4.2.2). IPA Action Group Rock glacier inventories and kinematics, 13 pp.

[RD-5] RGIK. 2022. Towards standard guidelines for inventorying rock glaciers: practical concepts (version 2.0). IPA Action Group Rock glacier inventories and kinematics, 10 pp.

[RD-6] RGIK. 2022. Optional kinematic attribute in standardized rock glacier inventories (version 3.0.1). IPA Action Group Rock glacier inventories and kinematics, 8 pp.

[RD-7] RGIK. 2023. Guidelines for inventorying rock glaciers: baseline and practical concepts (version 1.0). IPA Action Group Rock Glacier Inventories and Kinematics, 25 pp. https://doi.org/10.51363/unifr.srr.2023.002.

[RD-8] RGIK. 2023. InSAR-based kinematic attribute in rock glacier inventories. Practical InSAR guidelines (version 4.0). IPA Action Group Rock glacier inventories and kinematics, 33 pp.

[RD-9] RGIK 2022. Rock Glacier Velocity as an associated parameter of ECV Permafrost: baseline concepts (version 3.1). IPA Action Group Rock glacier inventories and kinematics, 12 pp.

[RD-10] RGIK 2023. Rock Glacier Velocity as an associated parameter of ECV Permafrost: practical concepts (version 1.2). IPA Action Group Rock glacier inventories and kinematics, 17 pp.

[RD-11] RGIK 2023. Instructions of the RoGI exercise in the Goms Valley (Switzerland). IPA Action Group Rock glacier inventories and kinematics, 10 pp.

[RD-12] Bertone, A., Barboux, C., Delaloye, R., Rouyet, L., Lauknes, T. R., Kääb, A., Christiansen, H. H., Onaca, A., Sirbu, F., Poncos, V., Strozzi, T., Caduff, R., Bartsch, A. 2020. ESA CCI+ Permafrost Phase 1 – CCN1 & CCN2 Rock Glacier Kinematics as New Associated Parameter of ECV Permafrost. D4.2 Climate Research Data Package Product Specification Document (CRDP), v1.0. European Space Agency.

[RD-13] Sirbu, F., Onaca, A., Poncos, V., Strozzi, T., Bartsch, A. 2022. ESA CCI+ Permafrost Phase 1 – CCN1 & CCN2. Rock Glacier Kinematics in the Carpathians (CCN1 Budget Extension). Climate Research Data Package Product Specification Document (CRDP), v1.0. European Space Agency.

[RD-14] Bertone, A., Barboux, C., Bodin, X., Bolch, T., Brardinoni, F., Caduff, R., Christiansen, H. H., Darrow, M. M., Delaloye, R., Etzelmüller, B., Humlum, O, Lambiel, C., Lilleøren, K. S., Mair, V., Pellegrinon, G., Rouyet, L., Ruiz, L., Strozzi, T. 2022. Incorporating InSAR kinematics into rock glacier inventories: insights from 11 regions worldwide. The Cryosphere. 16, 2769–2792. https://doi.org/10.5194/tc-16-2769-2022.

[RD-15] Rouyet, L., Echelard, T., Schmid, L., Pellet, C., Delaloye, R., Onaca, A., Sirbu, F., Poncos, V., Brardinoni, F., Kääb, A, Strozzi, T., Jones, N., Bartsch, A. 2023. ESA CCI+ Permafrost Phase 2 – CCN4 Mountain Permafrost: Rock Glacier inventories (RoGI) and Rock glacier Velocity (RGV) Products. D3.2 Climate Research Data Package (CRDP), v1.0. European Space Agency.

[RD-16] Pellet, C., Bodin, X., Cusicanqui, D., Delaloye, R., Kääb, A., Kaufmann, V., Thibert E., Vivero, S. and A. Kellerer-Pirklbauer, A. 2023. Rock Glacier Velocity. In Bull. Amer. Soc. Vol. 105(8), State of the Climate in 2023, pp. 44-45. https://doi.org/10.1175/2024BAMSStateoftheClimate.1**[RD-17]** Adler, C., Wester, P., Bhatt, I., Huggel, C., Insarov, G.E., Morecroft, M.D., Muccione, V. and A. Prakash. 2022. Cross-Chapter Paper 5: Mountains. In: Climate Change 2022: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, UK and New York, NY, USA, pp. 2273–2318. https://doi.org/10.1017/9781009325844.022.

[RD-18] van Everdingen, R. Ed. 1998, revised in May 2005. Multi-language glossary of permafrost and related ground-ice terms. Boulder, CO: National Snow and Ice Data Center/World Data Center for Glaciology. http://nsidc.org/fgdc/glossary.

1 Rules for unbiased validation and validation criteria

The Permafrost_cci project team shall ensure independency for the validation implying that the assessment of the rock glacier inventories (RoGI) and rock glacier velocity (RGV) products and the documentation of the uncertainties are established with suitable statistical approaches and using independent datasets. The validation criteria vary for the two mountain permafrost products (RoGI and RGV).

2.1 Rock glacier inventory (RoGI)

The geomorphological elements of the inventories, i.e. the identification of the rock glaciers, the definition of the units/systems, the delineations of the landforms, the spatial connection of the rock glacier to the upslope unit and the activity follow the recommended methodology and guidelines, developed by RGIK [RD-7] (see also PVASR and ATBD).

The kinematic components of the inventories, i.e. the identified and characterized moving areas as well as the kinematic attribute and related characteristics (validity time frame, data used, spatial representativeness and reliability) follow the recommended methodology and guidelines developed by RGIK [RD-7] [RD-8] (see also PVASR and ATBD).

During the RoGI production, several operators perform the work to provide a consensus-based solution and reduce the impact of single operator's subjectivity. A cross-validation procedure is applied to evaluate the quality of the final products and report the degree of (dis)agreement between operators (see Section 3.1). The standard products will be made available to the community and evaluated by experts in mountain permafrost. The feedback from the RGIK members (about 200 people in Spring 2024), as well as additional selected experts, is used at the validation stage. We plan to complement the future dissemination of the products by a survey about the general utility of the datasets and ask for volunteers to contribute to the evaluation.

2.2 Rock glacier velocity (RGV)

The retrieval of RGV products follows the recommended methodology and guidelines developed by RGIK [RD-9] [RD-10] (see also PVASR and ATBD). The products are evaluated and validated against in-situ GNSS data acquired at the selected pilot sites (see Section 3.2). As defined in the GCOS ECV requirements [AD-3], the required measurement uncertainty depends on the applied methodology (uncertainty of position or displacement measurement) and the spatio-temporal aggregation procedure used to measure and compute the annual velocity value for a defined rock glacier unit. The uncertainty has to be converted into m/yr for each annual velocity value. The ratio between this uncertainty and the considered annual velocity value has to be lower than 20% (threshold value). The comparison between RGV and complementary datasets has to show a difference below the accepted uncertainty threshold to be considered as valid.

As for RoGI, the standard products will be made available to the community and evaluated by experts in mountain permafrost. The feedback from the RGIK members (about 200 people in Spring 2024), as well as additional selected experts, is used at the validation stage. We plan to complement the future dissemination of the products by a survey about the general utility of the datasets and ask for volunteers to contribute to the evaluation.

2 Planned validation activities

3.1 Rock glacier inventory (RoGI)

All steps of the RoGI procedure, including the characterization of the morpho-kinematic attributes, is performed by a group of multiple operators from different institutions. The cross-validated final output is the results of a consensus between the team operators.

The degree of subjectivity of the procedure is evaluated by documenting the discrepancies between operators for all the attributes of the RoGI output layers. The uncertainty is reported as the degree of disagreement, expressed as the percent of results discarding with the consensus-based final decision.

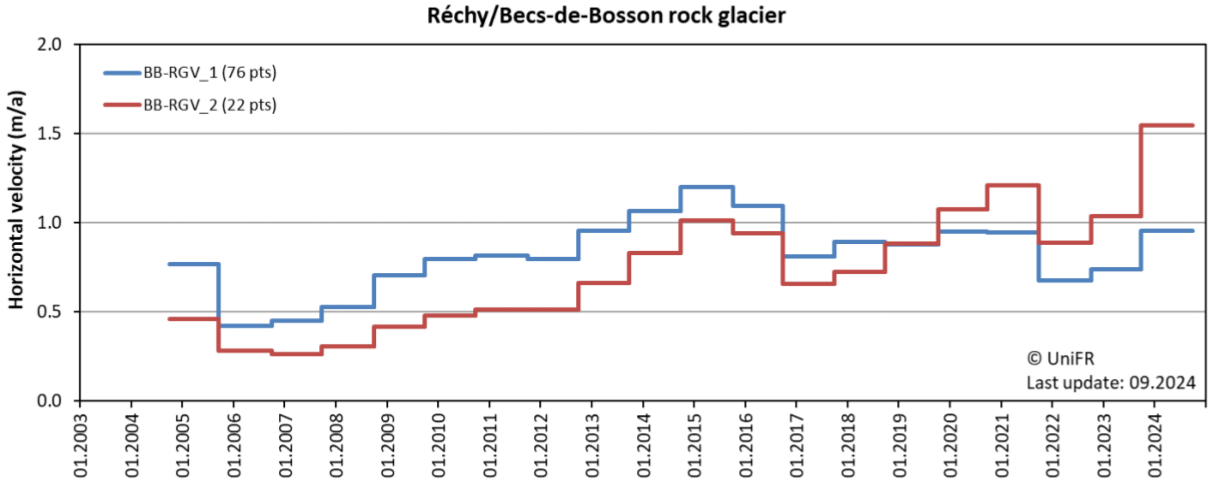
3.2 Rock glacier velocity (RGV)

The InSAR-RGV will be generated following the procedure described in the ATBD. The selected pilot sites and available validation data are summarized in *Table 1*. When available, the results will be compared with the GNSS-RGV at the same sites. As we aim for documenting the interannual velocity trends, the comparison will focus on the relative velocity changes (%) instead of the absolute values.

In total 36 rock glacier units have been selected as pilot sites (see PSD [RD-1]). Among these, 11 rock glaciers have in-situ validation data (see Sections 3.2.1–3.2.10), shown in the following sections. In Switzerland, the sites are part of a long-term monitoring strategy led by the University of Fribourg (Unifr). Data acquisition is foreseen in the coming seasons, which will ensure follow-up validation potential when updating the products in the future. Except for Steintälli and Bru (recent monitoring sites), additional information about the sites and the available in-situ data can be found on the Unifr website (see hyperlinks in the headers of the following sections). For the Lazaun rock glacier (Italy), GNSS, UAV and GB-SAR validation data are available (see Section 3.2.11). The other sites listed in *Table 1* do not have in-situ validation data. At these locations, cross-validation strategies may be applied, using complementary remote sensing techniques (optical photogrammetry).

In addition, as part of the RGV intercomparison exercise, three rock glaciers have been selected in the Alps, for which in-situ, radar and optical data are available and are being processed by several operators (see ATBD). Information about the selected sites is summarised in *Table 2*.

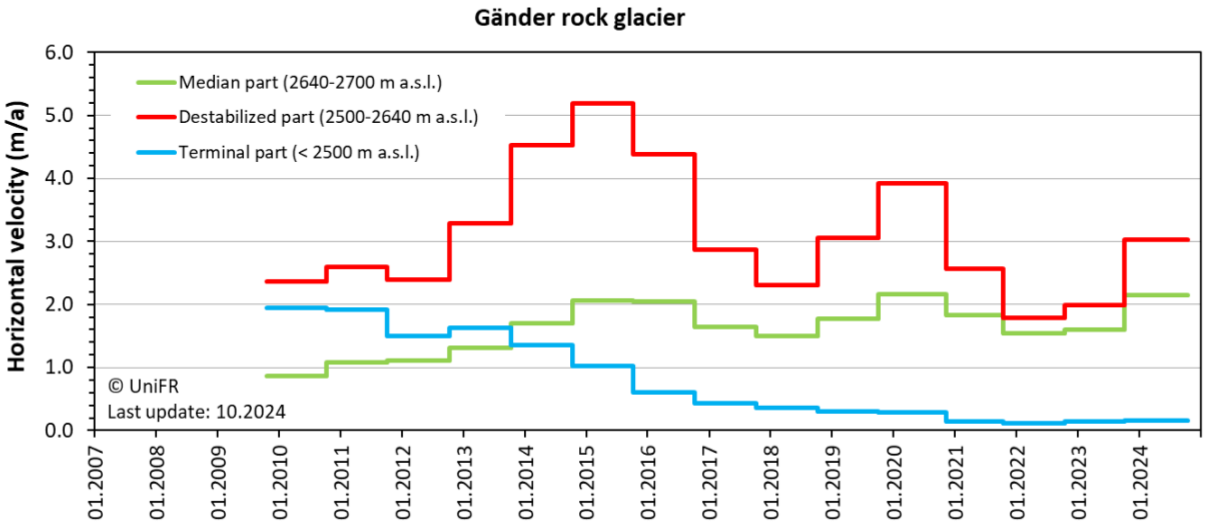
3.2.1 Réchy/Becs-de-Bosson GNSS RGV (hyperlink)



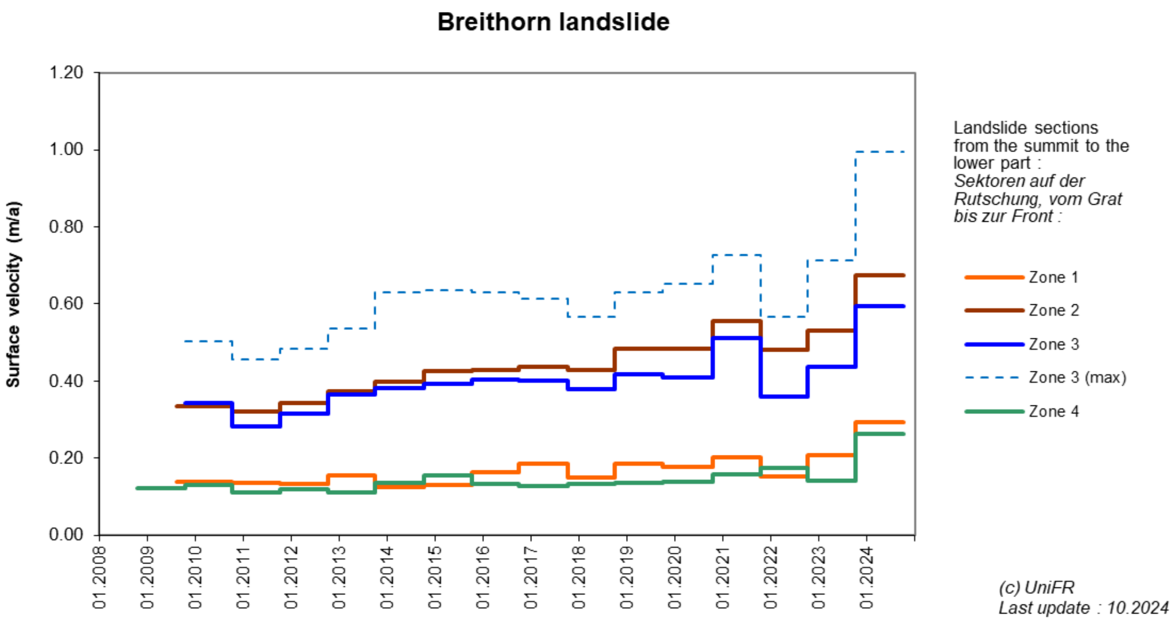
3.2.2 Steintälli GNSS RGV (recent site)

3.2.3 Bru GNSS RGV (recent site)

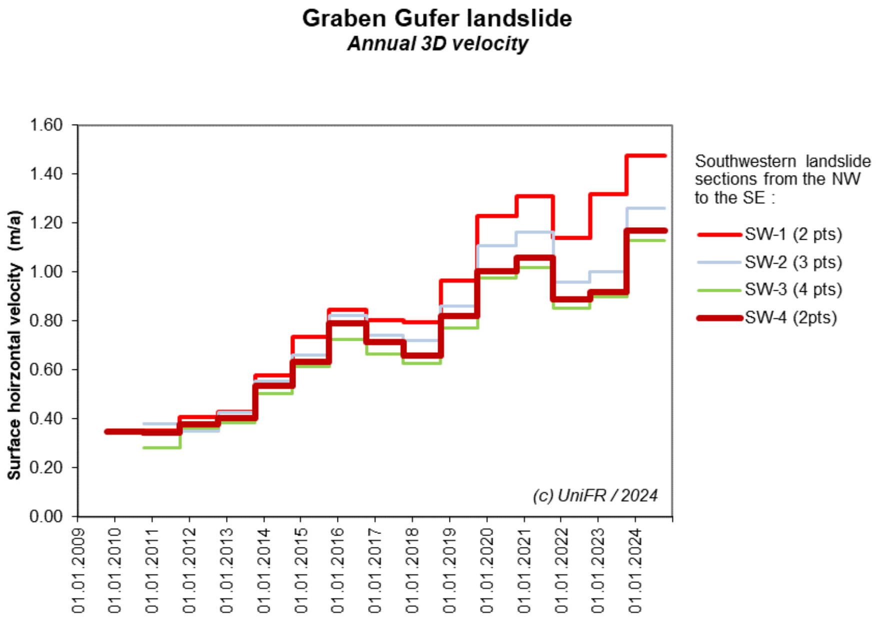
3.2.4 Gänder GNSS RGV (hyperlink)



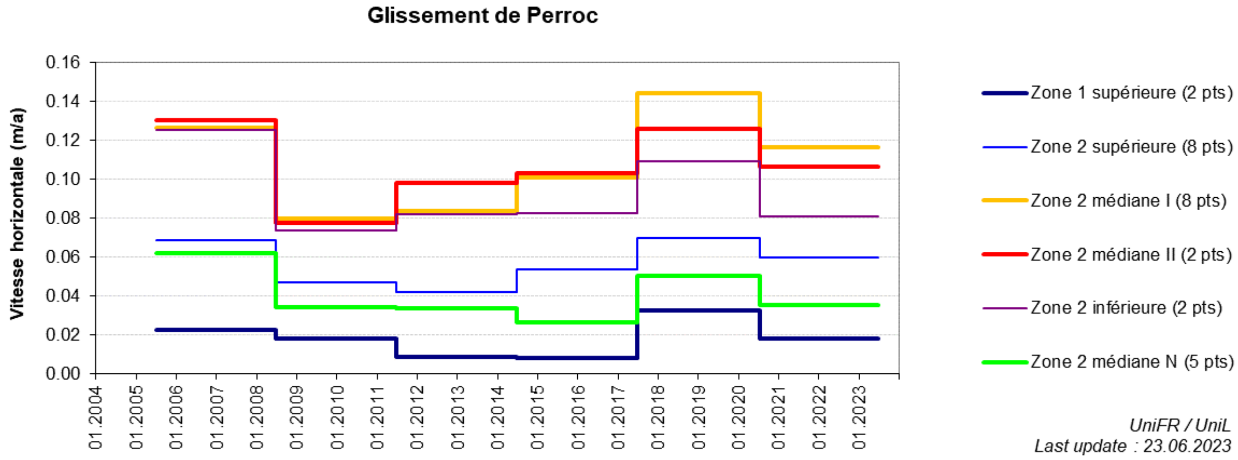
3.2.5 Breithorn GNSS RGV (hyperlink)



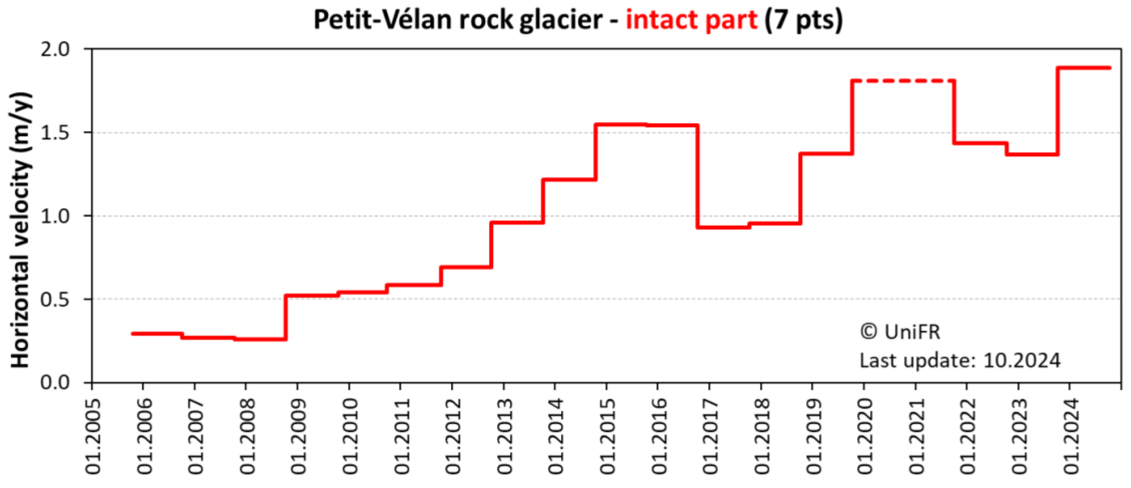
3.2.6 Grabengufer GNSS RGV (hyperlink)

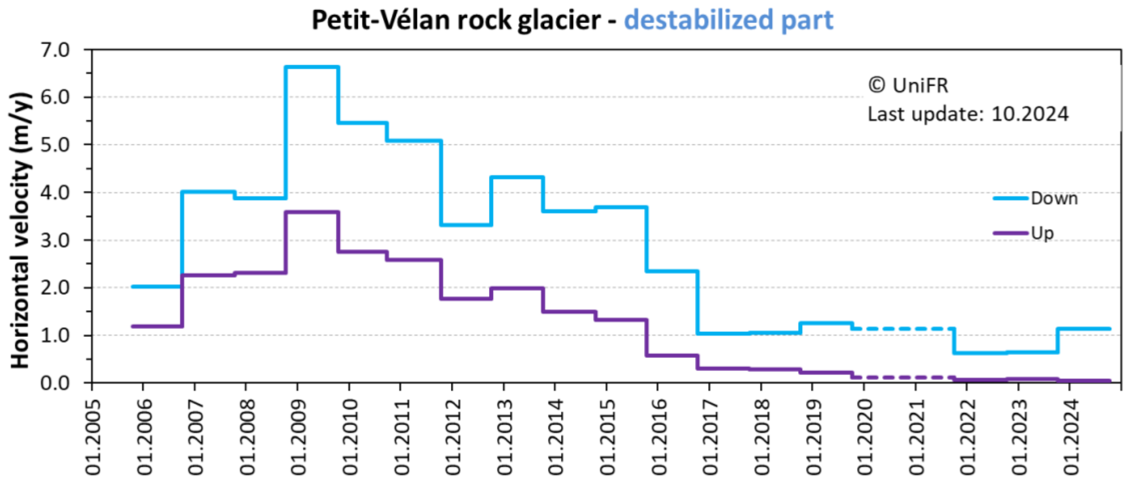


3.2.7 Perroc GNSS RGV (hyperlink) - Not measured in 2024

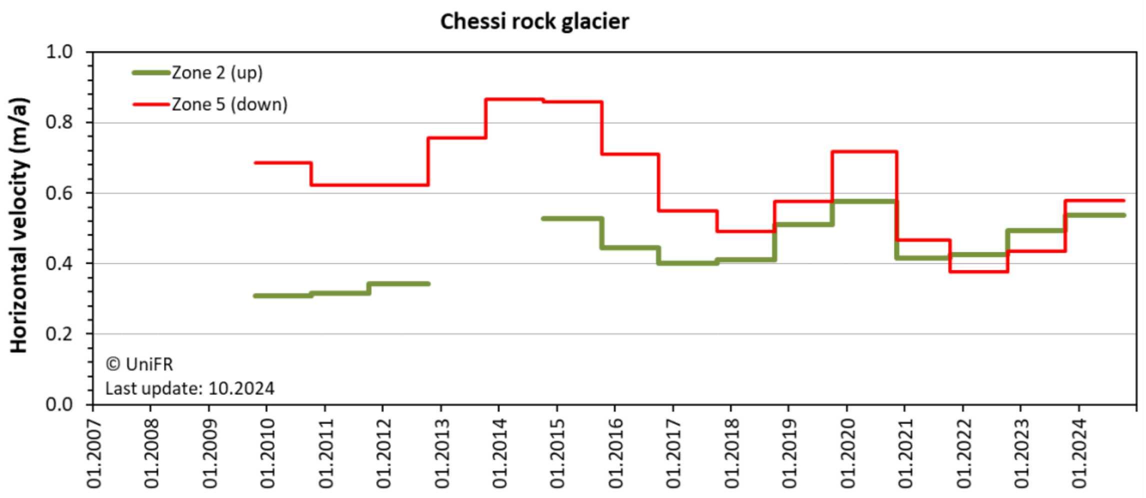


3.2.8 Petit-Vélan GNSS RGV (hyperlink)

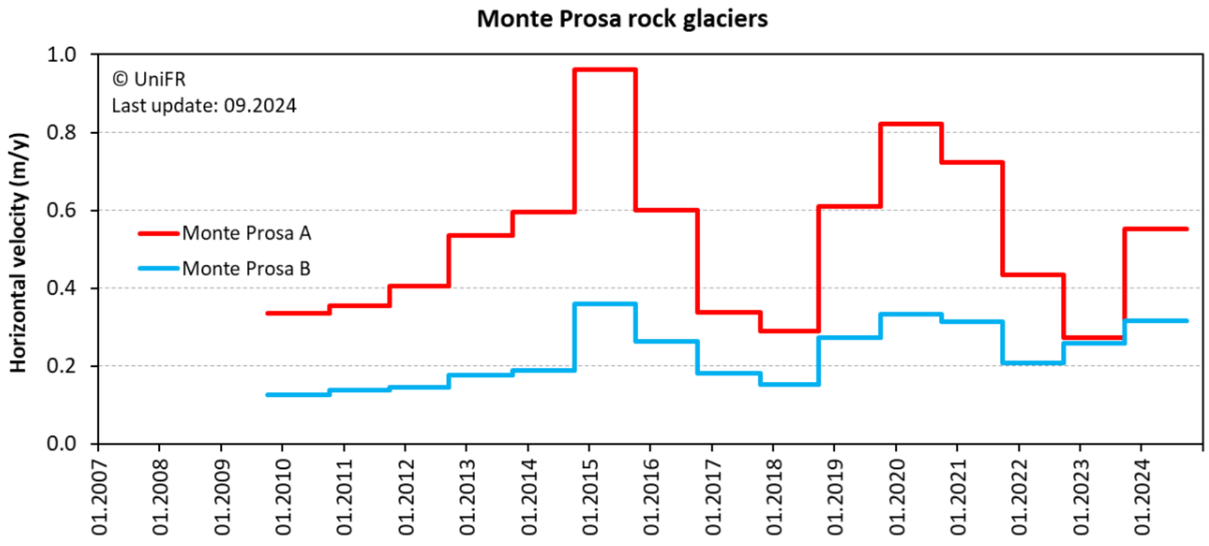




3.2.9 Chessi GNSS RGV (hyperlink)



3.2.10 Monte Prosa GNSS RGV (hyperlink)



3.2.11 Lazaun GNSS, UAV and GR-SAR validation data

The Lazaun rock glacier is located in the upper Val Senales, South Tyrol (46°44′49″N and 10°45′20″E). It covers an area of about 20 hectares, with elevation ranging between 2,480 and 2,700 m asl. Morphologically, it is a simple, mono-unit rock glacier (RGIK, 2023), with a well-defined front, lateral margins, and the typical ridge-and-furrow surface topography. The internal structure and dynamic behavior of this landform is well-known from investigations conducted by Fey & Krainer (2020) and Krainer et al. (2015). Inclinometer measurements revealed the presence of a shear layer at a depth of 24 m, including banded ice with a large content of fines. A second shear layer was detected at a depth of approximately 14 m, near the base of the upper frozen part of the rock glacier.

Available data usable for extraction of annual surface RG velocity functions include: eleven GNSS (2006–2012; 2016–2018) and six UAV (2016–2018) campaigns (Krainer et al., 2015; Fey and Krainer, 2020). See Figure 1 for location of GNSS reference points. In addition, two GB-SAR campaigns were conducted in the summer-to-early fall of 2018 (9–18.08.2018; 13.09–03.10.2018) (Bertone et al., 2023).

The surface displacement was measured on 52 survey markers between 2006 and 2012 by several GNSS campaigns, obtaining mean annual velocities up to 1.7 m/year (Krainer et al., 2015). Additional velocity measurements (via combination of GNSS and UAV surveys) were collected from 2016, showing velocities up to 2.25 m/year between 2012 and 2016, followed by a decrease from 2016 onwards, with average velocities around 1.5 m/year and seasonal velocity between 3 and 4 mm/day (Fey & Krainer, 2020).

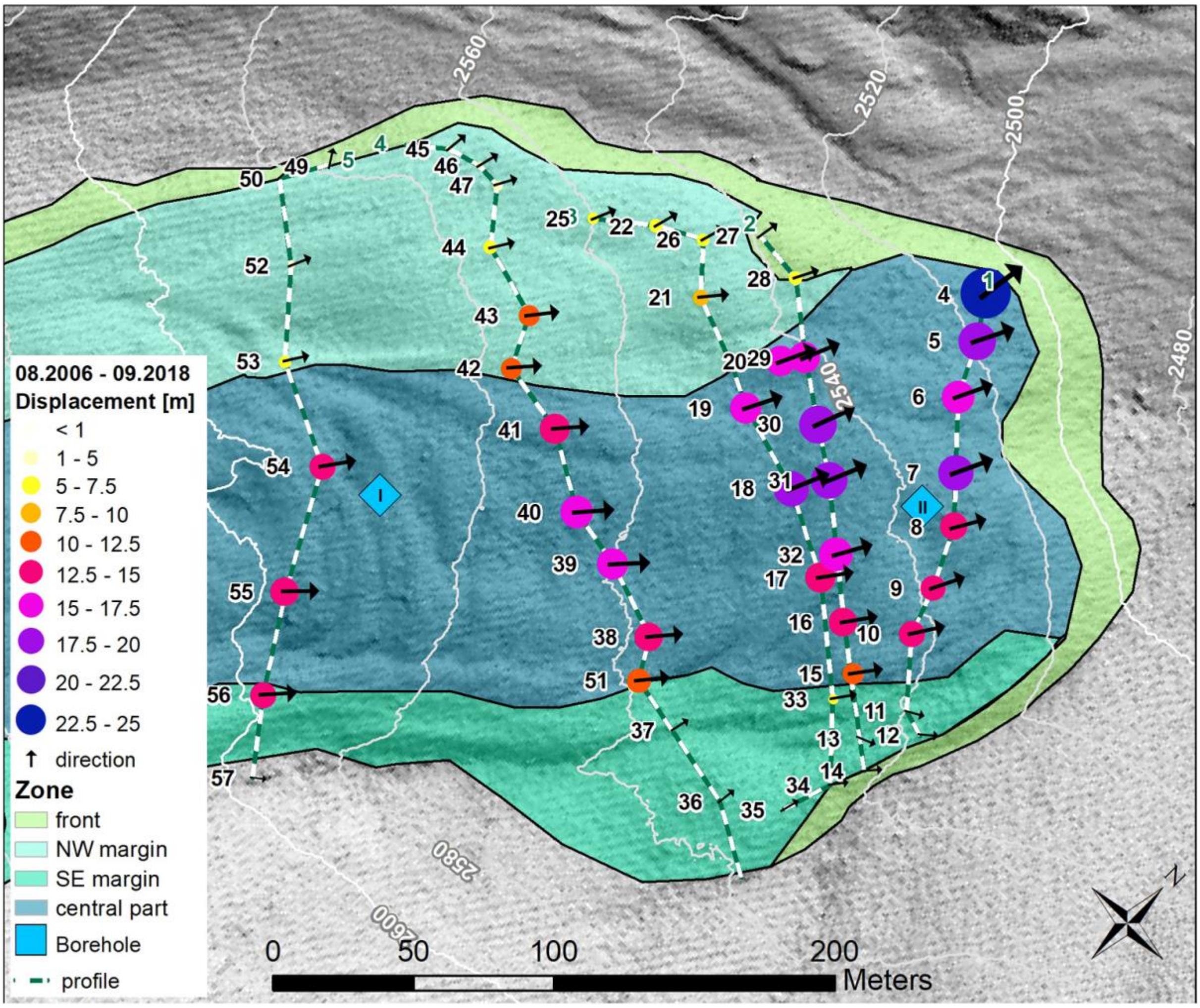


Figure 1. *Horizontal displacements (XY) derived from GNSS measurements for the period 08.2006–09.2018 (background: LiDAR-derived shaded relief image 2004). From Fey and Krainer (2020).*

Table 1. *Characteristics of the sites selected for RGV production in Permafrost_cci iteration 2. From PSD [RD-1].*

Partner institutions	Country	Name	Region	Elevation	Slope Aspect	Surface Velocity	Main applied method(s)	Validation data
UNIFR GAMMA (Baseline)	**Switzerland**	Distelhorn	Zermatt Valley	2370–2650	NW	0.5–3 m/yr (GNSS)	InSAR	
		Réchy (Becs-de-Bosson)	Réchy Valley	2610–2850	W	0.5–2 m/yr (GNSS)	InSAR	GNSS (periodic+permanent)
		Steintälli	Zermatt Valley	2960–3150	WSW	0.2–1 m/yr (GNSS)	InSAR	
		Bru	Zermatt Valley	2840–2960	NW	0.5–1 m/yr (GNSS)	InSAR	GNSS (periodic)
		Gänder	Zermatt Valley VS	2410–2770	NW	0.5–2 m/yr (GNSS)	InSAR	
		Breithorn	Zermatt Valley VS	2620–3150	W	0.1–0.7 m/yr (GNSS)	InSAR	
		Grabengufer	Zermatt Valley VS	2760–2960	NW	1–1.5 m/yr (GNSS)	InSAR	
		Perroc	Arolla Valley VS	2100–2750	W	0.1–0.3 m/yr (GNSS)	InSAR	
		Petit-Vélan	Gd-St. Bernard VS	2510–2820	NE	0.1–1.5 m/yr (GNSS)	InSAR	
		Chessi	Zermatt Valley VS	2500–2900	WNW	0.1–1 m/yr (GNSS)	InSAR	
		Monte Prosa	Gotthard TI	2430–2600	NW	0.2–1 m/yr (GNSS)	InSAR	
		Tellers Davains	Sursés Valley GR	2500–2900	W	1–2.5 m/yr (GNSS)	InSAR	
		Wassen	Uri Valley UR	2330–2520	W	0.5–2 m/yr (GNSS)	InSAR	
NORCE UiO (Option 8)	**Norway**	Adjet RGU fid 32	Skitbotndalen, Troms	600–1295	SW	cm–dm/yr (InSAR-RoGI)	InSAR	Cross-validation optical/radar remote sensing
		Adjet RGU fid 33				> m/yr (InSAR-RoGI)	OT/FT	
		Adjet RGU fid 36				> m/yr (InSAR-RoGI)	OT/FT	
		Adjet RGU fid 37				dm/yr (InSAR-RoGI)	InSAR	
		Adjet RGU fid 39				m/yr (InSAR-RoGI)	InSAR/OT/FT	
		Adjet RGU fid 40				> m/yr (InSAR-RoGI)	OT/FT	
		Adjet RGU fid 41				dm/yr (InSAR-RoGI)	InSAR	
		Adjet RGU fid 93				dm/yr (InSAR-RoGI)	InSAR	
		Adjet RGU fid 103				dm–m/yr (InSAR-RoGI)	InSAR/OT/FT	
		Sverdrup	Longyeardalen, Svalbard	70–180	ESE	dm/yr (InSAR-RoGI)	InSAR/OT/FT	
		Huset			ESE	cm–dm/yr (InSAR-RoGI)	InSAR	
		Ivarsfjord	Gamvik, Finnmark	60–170	W	mm–cm/yr (InSAR-RoGI)	InSAR/UAV FT	
UniBo GAMMA	**Italy**	Lazaun	Val Senales (NV)	2485–2750	NE	m/a (InSAR-RoGI)	InSAR	GNSS & UAV SfM
		Similaun	Val Senales (NV)	2560–2900	SW	not available yet	InSAR	

(Option 9)		Hintergrath	Val di Solda (SV)	2630–2830	NE	dm–m/a (InSAR-RoGI)	InSAR	
		Razoi	Val di Solda (SV)	2545–2820	W	dm–m/a (InSAR-RoGI)	InSAR	
		Zay	Val di Solda (SV)	2395–2740	W	dm–m/a (InSAR-RoGI)	InSAR	
		Serristori-1	Val di Solda (SV)	2790–2920	WSW	dm/a (InSAR-RoGI)	InSAR	
		Serristori-2	Val di Solda (SV)	2720–2780	NW	dm/a (InSAR-RoGI)	InSAR	
		Rossbank	Val d'Ultimo (SV)	2450–2785	NE	dm/a–m/a (InSAR-RoGI)	InSAR	
		Lago Lungo	Val d'Ultimo (SV)	2385–2550	NW	dm/a–m/a (InSAR-RoGI)	InSAR	
		Sternai-1	Val d'Ultimo (SV)	2700–3005	E	dm/a–m/a (InSAR-RoGI)	InSAR	
		Sternai-2	Val d'Ultimo (SV)	2690–2875	E	dm/a–m/a (InSAR-RoGI)	InSAR	

Table 1. *Selected sites for the RGV intercomparison exercise.*

Rock glacier name/country	Lat/Long coordinates	In-situ data	Optical data	Radar data	Velocity range	Slope orientation
Gran Sommetta (IT)	45.921428 N 7.669550 E	Annual since 2012	Annual UAV from 2013	Sentinel-1 coregistrated SLC images 2014-2024	0.2–2 m/yr	NNW
Grosses Gufer (CH)	46.425292 N 8.083018 E	Annual since 2007	Aerial images from the 50ties		0.2–5 m/yr	NW
Laurichard (FR)	45.018091 N 6.399865 E	Annual since 2000			about 1 m/yr	N

4. Validation documents and endorsements

Table 3 provides an overview of the Deliverables including information about product validation, intercomparison and assessment for RoGI and RGV products. These will be complemented with the updated versions of the reference documents generated by the RGIK community, i.e. the baseline concepts for RoGI and RGV generation [RD-4] [RD-7] [RD-9] and the related practical guidelines [RD-5] [RD-6] [RD-7] [RD-8] [RD-10].

Table 3. *Documents related to validation of the Permafrost_cci mountain permafrost products.*

Deliv. No.	Name	Date	Comment
D1.1 D1.2	User Requirement Document Product Specification Document	15 August 2024 (KO+3)	Describes data format and publication
D2.1	Product Validation and Algorithm Selection Report	15 November 2024 (KO+6)	Documents the selection of the methods and criteria to provide standard products
D4.1	Product Validation and Intercomparison Report and Product User Guide	15 August 2025 (KO+15)	Provides a summary on quality and uncertainty of Permafrost_cci products and describes the delivered Permafrost_cci products
D5.1	Climate Assessment Report	15 November 2025 (KO+18)	Describes climate science study cases using the Permafrost_cci products and user's feedback

5. References

5.1 Bibliography

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5.2 Acronyms

AD	Applicable Document
AI	Artificial Intelligence
ALT	Active Layer Thickness
ADP	Algorithm Development Plan
ATBD	Algorithm Theoretical Basis Document
BR	Breakthrough Requirement
CAR	Climate Assessment Report
CCI	Climate Change Initiative
CCN	Contract Change Notice
CRDP	Climate Research Data Package
DEM	Digital Elevation Model
E3UB	End-to-End ECV Uncertainty Budget
ECV	Essential Climate Variable
EO	Earth Observation
ESA	European Space Agency
FT	Feature Tracking
GAMMA	Gamma Remote Sensing AG
GCOS	Global Climate Observing System
GNSS	Global Navigation Satellite System
GR	Goal Requirement
GT	Ground Temperature
GTN-P	Global Climate Observing System
GTOS	Global Terrestrial Observing System
IANIGLA	Instituto Argentino de Nivología, Glaciología y Ciencias Ambientale
InSAR	Interferometric Synthetic Aperture Radar

IPA	International Permafrost Association
KA	Kinematic Attribute
LOS	Line-of-sight
MA	Moving Area
MAGT	Mean Annual Ground Temperature
MAGT	Mean Annual Ground Surface Temperature
NORCE	Norwegian Research Centre AS
OT	Offset Tracking
PERMOS	Swiss Permafrost Monitoring Network
PI	Principal Investigator
PM	Primary Marker
PSD	Product Specification Document
PUG	Product User Guide
PVASR	Product Validation and Algorithm Selection Report
PVIR	Product Validation and Intercomparison Report
PVP	Product Validation Plan
RD	Reference Document
RG	Rock Glacier
RGIK	Rock Glacier Inventories and Kinematics
RGU	Rock Glacier Unit
RGV	Rock Glacier Velocity
RoGI	Rock Glacier Inventory
RMSE	Root Mean Square Error
SAR	Synthetic Aperture Radar
SfM	Surface from Motion
TR	Threshold Requirement
UAV	Unmanned Aerial Vehicle
UiO	University of Oslo
UniBo	University of Bologna
UNIFR	University of Fribourg
URD	Users Requirement Document
URq	User Requirement
UTM	Universal Transverse Mercator
WUT	West University of Timisoara
WMO	World Meteorological Organization