permafrost
cci

CCI+ PHASE 1 – NEW ECVS
PERMAFROST

CCN1 & CCN2
ROCK GLACIER KINEMATICS AS NEW ASSOCIATED PARAMETER OF ECV PERMAFROST

D2.3 End-to-End ECV Uncertainty Budget (E3UB)

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EXECUTIVE SUMMARY

The European Space Agency (ESA) Climate Change Initiative (CCI) is a global monitoring program that aims to provide long-term satellite-based products to serve the climate modelling and climate data user community. Permafrost has been selected as one of the Essential Climate Variables (ECVs) that are elaborated during Phase 1 of CCI+ (2018-2021). As part of the Permafrost_cci baseline project, ground temperature and active layer thickness were considered to be the primary variables that require climate-standard continuity as defined by the Global Climate Observing System (GCOS). Permafrost extent and zonation are secondary parameters, but of high interest to users. The ultimate objective of Permafrost_cci is to develop and deliver permafrost maps as ECV products primarily derived from satellite measurements. Algorithms have been identified, which can provide these parameters by ingesting a set of global satellite data products (Land Surface Temperature LST, Snow Water Equivalent SWE, and Landcover) in a permafrost model scheme that computes the ground thermal regime. Annual averages of ground temperature and annual maxima of thaw depth (active layer thickness) were provided at 1 km spatial resolution during Year 1 of Permafrost_cci. The data sets were created from the analysis of lower level data, resulting in gridded, gap-free products.

In periglacial mountain environments, the permafrost occurrence is patchy, and the preservation of permafrost is controlled by site-specific conditions. Three options initiated within CCN1 and CCN2 address the need for additional regional cases in cooperation with dedicated users in characterizing mountain permafrost as local indicator for climate change and direct impact on the society in mountainous areas. Started in October 2018, CCN1 is led by a Romanian team focusing on case studies in the Carpathians. The specific objective of CCN1 is to develop and deliver maps and products for mountain permafrost, such as (i) rock glacier inventories, (ii) kinematical time series of selected rock glaciers and (iii) a permafrost distribution model, primarily derived from satellite measurements. Started in September 2019, CCN2 consists of two options led by Swiss and Norwegian teams focusing on the investigation and definition of a new associated ECV Permafrost product related to rock glacier kinematics. Early 2020, Rock Glacier Kinematics (RGK) has been proposed as a new product to the ECV Permafrost for the next GCOS implementation plan (IP). It would consist of a global dataset of surface velocity time series measured/computed on single rock glacier units. A proper rock glacier kinematics monitoring network, adapted to climate research needs, builds up a unique validation dataset of climate models for mountain regions, where direct permafrost (thermal state) measurements are very scarce or even lacking totally. The international Action Group *Rock glacier inventories and kinematics*, under the IPA (International Permafrost Association), gathering about one hundred members, supports this integration and CCN2 is working closely with this Action Group [RD-10 to RD-13]. Following the recommendations of this IPA Action Group, the overall goal of CCN2 is achieved through the development of two products: (i) regional rock glacier inventories and (ii) kinematical time series of selected rock glacier. User Requirements, Product Specifications and Data Access Requirements are described in D1.1-1.3 of CCN1-2 [RD-6 to RD-8].

This End-to-End ECV Uncertainty Budget (E3UB) documents the sources of errors and uncertainties for the three products of CCN 1&2. For RGI and KTS, it discusses them in relation to the techniques applied for measuring kinematics (InSAR, SAR offset tracking and feature tracking on repeat optical airphotos) and the standards for the development of comparable rock glacier inventories and kinematical time series. Methodologies to estimate uncertainties are presented and possibilities for documenting uncertainties and reporting the accuracy are listed for each product.

1 INTRODUCTION

1.1 Purpose of the document

The products required within CCN1 and CCN2 of the ESA Permafrost_cci project for mountain permafrost regions include (i) regional rock glaciers inventories, including a kinematical attribute (RGI), (ii) kinematical time series on selected rock glaciers (KTS), and (iii) a mountain permafrost distribution model in the Carpathians (MPDM). The End-to-End ECV Uncertainty Budget (E3UB) documents the error sources and uncertainties of the products, generated with the processing line described in the CCN 1&2 ATBD.

1.2 Structure of the document

- Section 1 provides information about the purpose and background of this document.
- Section 2 documents the sources of errors and uncertainties affecting the products.
- Section 3 describes the methodology to estimate uncertainties.
- Section 4 summarizes which accuracy will be reported in the final products.

1.3 Applicable documents

[AD-1] ESA. 2017. Climate Change Initiative Extension (CCI+) Phase 1 – New Essential Climate Variables - Statement of Work. ESA-CCI-PRGM-EOPS-SW-17-0032.

[AD-2] Requirements for monitoring of permafrost in polar regions - A community white paper in response to the WMO Polar Space Task Group (PSTG), Version 4, 2014-10-09. Austrian Polar Research Institute, Vienna, Austria, 20 pp.

[AD-3] ECV 9 Permafrost: assessment report on available methodological standards and guides. 2019-11-01. GTOS-62.

[AD-4] GCOS-200. 2016. The Global Observing System for Climate: Implementation Needs. GCOS Implementation Plan, WMO.

1.4 Reference Documents

[RD-1] Bartsch, A., Westermann, S., Strozzi, T. 2019. ESA CCI+ Permafrost. D2.1 Product Validation and Algorithm Selection Report (PVASR), v2.0.

[RD-2] Westermann, S., Bartsch, A., Strozzi, T. 2019. ESA CCI+ Permafrost. D2.2 Algorithm Theoretical Basis Document (ATBD), v2.0.

[RD-3] Westermann, S., Bartsch, A., Heim, B., A., Strozzi, T. 2019. ESA CCI+ Permafrost. D2.3 End-to-End ECV Uncertainty Budget (E3UB), v2.0.

[RD-4] Westermann, S., Bartsch, A., Heim, B., A., Strozzi, T. 2019. ESA CCI+ Permafrost. D2.4 Algorithm Development Plan (ADP), v2.0.

[RD-5] Heim, B., Wieczorek, M., Pellet, C., Delaloye, R., Barboux, C., Westermann, S., Bartsch, A., Strozzi, T. 2019. ESA CCI+ Permafrost. D2.5 Product Validation Plan (PVP), v2.0.

[RD-6] Barboux, C., Bertone, A., Delaloye, R., Onaca, A., Ardelean, F., Poncos, V., Kääb, A., Rouyet, L., Christiansen, H.H., Strozzi, T., Bartsch, A. 2019. ESA CCI+ Permafrost. CCN1 & CCN2 Rock Glacier Kinematics as New Associated Parameter of ECV Permafrost. D1.1 User Requirement Document (URD), v1.0.

[RD-7] Barboux, C., Bertone, A., Delaloye, R., Onaca, A., Ardelean, F., Poncos, V., Kääb, A., Rouyet, L., Christiansen, H.H., Strozzi, T., Bartsch, A. 2019. ESA CCI+ Permafrost. CCN1 & CCN2 Rock Glacier Kinematics as New Associated Parameter of ECV Permafrost. D1.2 Product Specification Document (PSD), v1.0.

[RD-8] Barboux, C., Bertone, A., Delaloye, R., Onaca, A., Ardelean, F., Poncos, V., Kääb, A., Rouyet, L., Christiansen, H.H., Strozzi, T., Bartsch, A. 2019. ESA CCI+ Permafrost. CCN1 & CCN2 Rock Glacier Kinematics as New Associated Parameter of ECV Permafrost. D1.3 Data Access Requirement Document (DARD), v1.0.

[RD-9] Strozzi, T., Sîrbu, F., Onaca, A, Ardelean, F., Poncos, V., Bartsch, A. 2019. ESA CCI+ Permafrost. CCN1 Rock Glacier Kinematics in the Carpathians (Romania). D2. Algorithm Development Document, v1.0.

[RD-10] IPA Action Group Rock glacier inventories and kinematics. 2020. Towards standard guidelines for inventorying rock glaciers. Baseline concepts. Last version available on: https://bigweb.unifr.ch/Science/Geosciences/Geomorphology/Pub/Website/IPA/CurrentVersion/Current_Baseline_Concepts_Inventorying_Rock_Glaciers.pdf

[RD-11] IPA Action Group Rock glacier inventories and kinematics. 2020. Kinematics as an optional attribute of standardized rock glacier inventories. Last version available on: https://bigweb.unifr.ch/Science/Geosciences/Geomorphology/Pub/Website/IPA/CurrentVersion/Current_KinematicalAttribute.pdf

[RD-12] IPA Action Group Rock glacier inventories and kinematics. 2020. Rock glaciers kinematics as an associated parameter of ECV Permafrost. Last version available on: https://bigweb.unifr.ch/Science/Geosciences/Geomorphology/Pub/Website/IPA/CurrentVersion/Current_RockGlacierKinematics.pdf.

[RD-13] IPA Action Group Rock glacier inventories and kinematics. 2020. Response to GCOS ECV review – ECV Permafrost. ECV Product: Rock Glacier Kinematics. Available on: https://gcos.wmo.int/en/ecv-review-2020.

[RD-14] van Everdingen, Robert, ed. 1998 (revised 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/; accessed 23.09.2009).

1.5 Bibliography

A complete bibliographic list that supports arguments or statements made within the current document is provided in Section 5.1.

1.6 Acronyms

A list of acronyms is provided in Section 5.2.

1.7 Glossary

A comprehensive glossary of terms relevant for the parameters addressed in Permafrost_cci is available as part of the Reference Documents of the baseline project [RD-1 to RD-5] and of CCN 1&2 [RD-6 to RD-9], as well as in [RD-14].

2 SOURCES OF ERRORS AND UNCERTAINTIES

2.1 Regional rock glacier inventories, incl. kinematics (RGI)

2.1.1 Rock glacier inventories

The challenges for standardization and risk for discrepancies between operators when producing rock glacier inventories are detailed in CCN D2.1 PVASR and summarized here in Table 1.

Table 1: Analysis of key criteria for rock glacier inventories (RGI): Identified challenges and risk for discrepancies between operators

Minimum size of inventoried rock glaciers	The minimal detectable size varies according to the input data and technical limitations. It also depends on the purpose and scale of the inventory.
Rock glacier morphological system and units	Rock glaciers with complex morphology (e.g. multiple generations, multiple lobes, coalescent lobes, and heterogeneous dynamics) are common and difficult to characterize unequivocally. The variable spatial resolution and quality of input data may have an unwanted impact on the results of the morphological system and units' definition.
Rock glacier outlines	Technically defining a rock glacier as a landform implies an outlining task, and for various practical issues (e.g. area calculation) it has to be a closed polygon, but the operation retains some degree of subjectivity, in particular regarding the upper limit of the rock glacier (see following point).
Spatial connection of the rock glacier to the upslope unit	The geomorphological unit located directly upslope of a rock glacier system can hold implications on the characterization of the latter (e.g. internal structure and composition, ice origin, ice content), as well as the designation of attributes (e.g. landform outlining, definition of the rooting zone). The term "derived" has to be avoided because it implies an interpretation on the origin of both debris and/or ice.
Rock glacier activity	Rock glaciers have been most commonly classified into the following categories of activity: Intact (active/inactive) and relict. The classical categorization was considering the activity rate of rock glaciers as almost constant over the long term (decades to centuries), the observations of the rock glacier kinematical behavior, in particular in the European Alps, have shown that an acceleration by a factor 2 to 10 of the surface velocities between the 1980s and the 2010s has been a common feature in many investigated sites, probably in response to increased permafrost temperature resulting from warmer air temperatures. Whereas a significant majority of the monitored rock glaciers follows this regional trend, some features manifest singular behaviors (e.g. reactivation, rapid acceleration, destabilization or decrease in velocity). In cold permafrost regions (e.g. Arctic or high-altitude Andes), rock glaciers, which are almost not moving or only very slowly, may accelerate in response to warming. These scientific observations have revealed the need of redefining and/or refining the categorization of rock glacier activity.
Rock glacier destabilization	The motion rate of some rock glaciers may be characterized by a drastic acceleration that can bring the landform, or a part of it, to behave abnormally fast (i.e. not following the regional trend anymore) for several years at least. The term destabilization has been progressively used since the 2000s to refer to rock glaciers with obvious signals of abnormally fast behavior but is misleading if considered in a geotechnical sense.
Time frame and update	Different times of production of rock glacier inventories (observation time window and time frame) can lead to products that are not fully comparable. Updates are recommended but pragmatic temporality has to be considered.

2.1.2 Moving areas using InSAR

Several sources of errors and uncertainties have to be taken into account when processing InSAR (e.g. Massonnet and Feigl (1998), Bamler and Hartl (1998), Rosen et al. (2000), Rocca et al. (2000), Hanssen (2001), Kampes (2006), Ferretti (2014)). They are summarized here in Table 2.

Table 2: Error sources and uncertainties in case of InSAR

	Error sources and uncertainties in InSAR
Spatial resolution	The spatial resolution of SAR images varies according to the sensor (and its acquisition mode) and is different in azimuth and range direction. The initial ground resolution of the main inputs of the project (Sentinel-1 Interferometric Wide Swath mode) is approx. 5m (range) x 20m (azimuth). The final resolution used for delineating moving areas can be down to 20mx20m, 40mx40m or 60mx60m depending on the *multi-looking* (averaging looks to provide a better signal quality). If the velocity of a rock glacier is heterogeneous, InSAR may in an unrealistic way smooth the results and small areas affected by high velocity can be missed by averaging.
Geometrical distortions	In mountainous areas, SAR images are affected by *geometrical distortions* due to the side-looking geometry of the satellite. *Foreshortening* appears on the slopes facing the radar, resulting in compressed pixels on the ground. The opposite effect gives better resolution on slopes facing away from the radar. For steep-looking spaceborne radar systems, the slant range differences between two points located on foreslopes of mountains are smaller than they would be in flat areas. In the extreme case, *layover* appears when the top of a hill is closer to the radar than the foot of the hill. In this case, the received signal from at least two different altitudes is added into one slant range resolution cell, leading to an ambiguous and very high radar amplitude return. On the other side of the mountain, *shadow* occurs in the area not being illuminated by the radar. Both layover/shadow areas can not be documented when using a single geometry, but this limitation can be overcome by using different geometries.
One-dimensional measurements	The analysis of phase changes between two acquisitions at two different times can provide information about ground deformation along the *line-of-sight (LOS)* of the SAR sensor. InSAR is only sensitive to displacements that have a component in the LOS direction, which depends on the flying orientation of the satellite (track) and the incidence angle of the radar beam. Steeper the incidence angles lead to better sensitivity to vertical displacements. Looking toward the West, a descending orbit gives mainly non-distorted coverage in west facing slope, and an ascending orbit covers mainly east facing slopes. Sensitivity is very low in cases where the actual surface displacement vector is near perpendicular to the LOS. Due to the, roughly, North-South orbit direction, the sensitivity to surface displacement in this plane is near zero.
InSAR coherence and decorrelation	The phase accuracy in SAR interferometry is mainly affected by phase noise and decorrelation. Phase decorrelation is due to changes in position of individual scatters within the resolution cell and is one of the main limitations for successful use of InSAR. Decorrelation is mainly due to either SAR imaging geometric effects (*spatial decorrelation*), or temporal backscattering changes (*temporal decorrelation*). Spatial decorrelation is related to the spatial baseline between the sensor at the different acquisitions. Temporal decorrelation is due to changes in geometrical or electrical properties of the surface, as function of time between the acquisitions. The interferometric SAR signal will decorrelate when the variability within a pixel is higher than half the wavelength during the selected time interval. This variability may be caused e.g. by moving parts of vegetation or changes of the land surface. Terrain containing variable liquid water, such as e.g. areas covered with wet snow, will also have different scattering properties from one observation to the next. The scenes acquired during winter season can be unusable if snowfall occurs, which reduces the observation time window in mountainous areas. The temporal decorrelation

	phenomenon is dependent on the radar wavelength; longer wavelengths are less sensitive to small scale surface scattering changes, however with reduced sensitivity to displacement.
Atmospheric effects	We have to take into account the *atmospheric effects*. A radar interferometer measures the phase difference with accuracy on the order of a fraction of the wavelength; more than accurate enough to be influenced by atmospheric path delay. Phase propagation delay due to atmospheric variability is one of the main error sources in repeat-pass InSAR. It is common to divide the atmospheric path delay into one component coming from *turbulent mixing processes*, and a *stratified component correlating with elevation*. Turbulent mixing comes from mixing processes in the inhomogeneous atmosphere, while stratification results from variations in the vertical refractive index profile. The second is correlated with the local topography. Both can be mitigated during the processing using digital elevation model and spatial-temporal filtering techniques, but unwanted phase components can remain. However, as rock glaciers are relatively small landforms, they highlight a deformation-related phase component at a scale that is easily differentiable from the atmospheric effects.
Unwrapping	A wrapped interferogram is composed by a succession of fringes when the phase exceeds half the wavelength. The process of restoring the correct multiple of 2π to each point of the interferometric phase image i.e. to convert the cyclic phase difference into a continuous phase difference is called *phase unwrapping* and can be performed by visual interpretation or automatically. The procedure uses the assumption that the true displacements field of the landform under study has a spatial continuity and thus the spatial variation of the phase is supposed to be smooth. If the movements are spatially discontinuous, for example in the case of a localized quick event, we can fail to retrieve correct solutions. The interferometric SAR signal can become ambiguous when the displacement gradient between adjacent pixels is higher than a quarter the wavelength during the selected time interval, which practically provides the theoretical detection limit of the InSAR technique. Areas can be decorrelated due to changes in scattering properties within the resolution cell between the two acquisitions. Such decorrelation effects can contaminate large areas in the interferograms and create discontinuous coherent patches. This makes the retrieval of absolute phase a challenging task.

The detection of moving areas can be also complemented at more local scale by SAR offset tracking of SAR or feature tracking on repeat optical airphotos. These techniques are particularly useful to overcome some limitations of InSAR on fast moving landforms and to cross-validate the results. Their error sources and uncertainties are presented in Sections 2.2.2 and 2.2.3.

The procedure for identifying moving areas based on interferograms also includes specific uncertainties. Rules for a standardized way to categorize the semi-quantitative classes of velocity are described in detail in CCN 1&2 2.2 ATBD. The challenges for standardization and risk for discrepancies between operators are summarized here in Table 3.

Table 3: Identified challenges and risk for discrepancies between operators for identifying moving areas based on interferograms

Definition of moving area (extent and uniformity)	The level of detail varies depending on the operator. Isolated movements or unreliable areas can lead to an unrepresentative delineation of moving areas. The definition of uniformity or spatial consistency of the movement is partly subjective. The detected signal can be related to different processes, not only permafrost creep.
Velocity classes of moving areas	The detection capability and the dimensionality (one- to three- dimensional displacement measurements) depend on the technology. Moving areas should be defined in accordance with the methodology used. Using 1D InSAR data, the downslope velocity can be significantly underestimated if the movement direction

	deviates significantly from the line-of-sight. The reliability (or degree of confidence) needs to be documented. There is a subjectivity of the class attribution when the detected movement is close to the limits between classes.

2.1.5 Standard kinematical attribute

The challenges for standardization and risk for discrepancies between operators when assigning a kinematical attribute to an inventoried rock glacier are detailed in CCN 1&2 D2.1 PVASR and CCN 1&2 D2.2 ATBD and summarized in Table 4.

Table 4: Analysis of key criteria for kinematical attribute in rock glacier inventories (RGI): Identified challenges and risk for discrepancies between operators

	Identified challenges / risk for discrepancies
Semi-quantitative categories of kinematical attribute (order of magnitude)	There is subjectivity involved in the choice of a category/order of magnitude. The use of absolute velocity values would be valuable but pragmatically problematic to integrate for measurements from different techniques. An order of magnitude estimate is sufficient to assess the activity of a rock glacier unit (as a complement to morphological evidences) but is still also affected by subjectivity if the detected movement is close to the limits between categories. There is a risk for subjectivity in the choice of a category/order of magnitude and thus a need for explicit rules to transfer velocity classes observed from an InSAR derived moving area to the category of the kinematical attribute of the rock glacier unit.
Temporal representativness of kinematical attribute	Some techniques allow for the observation of displacement during summertime only and not from one summer to the next. A result is that the velocity value cannot be measured over an annual time interval. Other techniques allow for the measurement of annual velocity or multi-annual velocity only. Kinematical measurements representing single intra-annual variation have to be avoided and when the technique allows for a minimum observation time window lower or equal to one year, the temporal frame should be at least 2 years.
Spatial representativness of kinematical attribute	Isolated movement, unreliable areas and unrepresentative moving parts can lead to misleading documentation of kinematics. Incomplete coverage can be problematic, e.g. when using single point measurements that are not representative to larger moving areas.

2.2 Kinematical time series on selected rock glaciers (KTS)

2.2.1 Kinematics time series from InSAR

The sources of errors and uncertainties presented in Table 2 apply also for KTS retrieval.

Monitoring the kinematics of rock glaciers with InSAR might be limited by the spatial resolution of the SAR data, in particular using Sentinel-1 data with a spatial resolution of about 15 m on the ground for a multi-looking factor of 4 pixels in range and 1 pixel in azimuth. It is, therefore, essential to select a representative point over the rock glacier, where the spatial variability of the motion around is low, in order to extract a meaningful time series of motion.

In addition, InSAR suffers in rugged terrain from incomplete spatial coverage due to layover and shadow and the sensitivity to motion is restricted to the LOS. The InSAR LOS motion must be therefore projected along the maximum slope direction.

2.2.2 Kinematic time series from SAR offset tracking

Several sources of errors and uncertainties have to be taken into account when processing SAR with offset-tracking procedures (e.g. Paul et al., 2017). They are summarized here in Table 5.

Table 5: Error sources and uncertainties in InSAR

	Error sources and uncertainties in SAR offset tracking
Matching window size	In the implementation of the normalized cross-correlation algorithm, the choice of the matching window size and the oversampling factor have a direct consequence on the precision of the estimates, the noise level, as well as the computational time required. The choice of the matching window size will also depend on the target being observed and on the spatial resolution of the source data. For SAR sensors, estimates using very large window sizes (e.g. 512 × 512 pixels) are generally more precise for large structures, but are not applicable to small (e.g. < 500 m width) landforms such as rock glaciers. This drawback could be overcome by using iterative algorithms with a variable matching window size although at the cost of the processing time.
Orbital offsets	Orbital offsets are determined by fitting a bilinear polynomial function to offset fields computed globally from the SAR images, assuming absence of displacement in most of the image.
Stereo offsets	Stereo offsets are relevant for the range-offset field, and depend on the height of the target, the baseline between the two satellite orbits, the height of the satellites above the Earth's surface, and the incidence angle of the satellite. Stereo offsets can be avoided by co-registering the two SAR images with topography considered, which necessarily requires an accurate DEM.
Ionospheric offsets	SAR sensors are sensitive to ionospheric scintillations, causing shifts in azimuthal position (“azimuthal streaking”). They are especially visible in SAR images of high latitudes and depend on solar activity. The streaks are visible in azimuthal offset maps and can be reduced by high-pass filters along the range direction (e.g. Wegmüller et al., 2006). The wavelength employed by the radar sensor has a large impact on ionospheric artefacts, which are typically larger at lower frequencies.

2.2.3 Kinematic time series from feature tracking on repeat optical airphotos

Several sources of errors and uncertainties have to be taken into account when processing feature tracking on repeat optical images (e.g. Kääb and Vollmer, 2000; Debella-Gilo and Kääb, 2011, Paul et al. 2017; Kääb et al 2019). They are summarized here in Table 6.

In addition, the error bounds and biases will typically vary over time with temporal variations in the errors listed in Table 6. Often, the longer back in time the larger the uncertainties get, mainly due to lower image quality and larger distortions in older images. Temporal changes on the rock glaciers might cause gaps in KTS over some areas, such as snow cover or loss of visual coherence.

Table 6: Error sources and uncertainties in feature tracking on repeat optical airphotos

	Error sources and uncertainties in feature tracking on optical images
Geometric offsets	(i) The two optical images to be matched may not be correctly co-registered leading to a global offset between them that directly biases displacement measurements. This type of error is typically detected by analyzing stable-ground offsets, i.e. mean offset between the images, and mitigated by sound image co-registration. (ii) The two images to be matched might be correctly co-registered, but the image pair, or image stack, might contain as a whole a shift with respect to true ground

	coordinates. If small (< a few meters) such error in absolute geo-reference does not affect the displacement measurements as those are relative. For large georeferenced shifts, those might be detected by comparison of the images to other georeferenced data. Given the typically quite good availability of global reference data (national orthoimage and map servers, GoogleEarth, etc.) this error source is nowadays less of a problem.
Geometric distortions	Distortions in the original images from unknown lens distortions, scanning distortions, or wrong image storage may lead to local geometric distortions in the measured displacements that may be hard to detect and correct if they only affect moving ground features. Else, stable-ground matches over large areas around the rock glaciers give an estimate for this type of distortions. While these distortions of the original images are typically only considerable for old historic airphotos and historic spy satellite images (e.g. US Corona series), all types of images are affected by orthoprojection distortions from errors in the DEM used for orthoprojection. Similar to image distortions, these orthoprojection errors are local and hard to correct for. Again, stable-ground offsets give an indication of the existence and order of magnitude. These errors can be detected by matching displacements in stereo-orthoimages, in case orthoimages over the same site and same time are available from different overlapping stereo-images. This is typically the case for traditional survey-grade airphoto acquisitions.
Spatial resolution	The spatial resolution of the input images with respect to the block sizes on the rock glaciers impacts on the success and accuracy of the matching. While the matching error can be given as a function of spatial image resolution, this relation degrades when the image resolution gets too low to depict features on the rock glacier that can be tracked.
Matching window size	Choosing a suitable matching window size tries to optimize between two divergent processes: (i) the smaller the window the less robust the derived displacements get against noise from image noise or feature-similarity (see below on ‘mismatches’). This argument favors large windows. (ii) The larger the window gets the more averaging of local gradients in the displacement field is involved, perhaps even including stable ground. This favors the choice of small windows. The optimal final choice of window use is not strict, and an expert decision based on image resolution and quality, type of displacement field, and features suitable for tracking. This expert choice can be made more transparent by providing several product layers, based on matches with different pre-set window sizes.
Image quality	Reduced image quality, in particular relevant for historical air and spy-satellite images, blurs features and contrast to be tracked, and reduces matching accuracy in a way similar to reduced image resolution.
Mismatches	Even under optimal image conditions, mismatches occur for several reasons: low-contrast areas (fine-grained surface, snow); self-similar features (several blocks or block-patterns look too similar to be reliably discriminated); temporal changes (surface changes over time that destroy/cover features, e.g. snow cover changes, erosion). Typically, such mismatches are indicated by low correlation values, or displacement vectors that show large difference to surrounding ones and can be filtered by setting thresholds on vector length, direction, or similarity to surrounding vectors. Still, manual removal of remaining mismatches will often be useful.
Visual coherence	Insufficient image quality or resolution, or surface disruption over time due to erosion, ruptures, local slides, etc., reduce the visual coherence (i.e. ability to track features) or lead to mismatches.

2.2.4 *Standard time series*

The challenges for standardization and risk for discrepancies between operators when producing kinematical time series on selected rock glaciers are detailed in the CCN 1&2 D2.1 PVASR and summarized in Table 7.

Table 7: Analysis of key criteria for kinematical time series on selected rock glaciers (KTS): Identified challenges for standardization and risk for discrepancies between operators

	Challenges for standardization / risk for discrepancies
Horizontal resolution, i.e. spatial distribution of select rock glaciers	The objective of developing regional indexes requires the integration of a significant amount of representative rock glaciers in a region. The number of sites allowing for the definition of a regional trend has to be defined.
Horizontal resolution (2), i.e. surface velocity value	The dimensionality (one- to three- dimensional displacement measurements) varies depending on the technology. Depending on the technology, the time series can be based on point or areal measurements. The spatial representativness of the selected point/area on a rock glacier is challenging. Considerations related to spatial representativness of a kinematical attribute in Table 6 apply also here.
Time resolution, i.e. frequency and observation time window	Depending on the applied technique, this velocity value might only be obtained for a shorter observation time window than an annual one (e.g. snow-free summer period for InSAR). The consistency of the series can be affected if the observation time window is modified from a year to another. If we aim for including past data, it might be difficult to require an annual frequency due to data gaps.
Timeliness, i.e. time needed for data processing	Time needed for data processing has to be considered to set up a monitoring strategy.
Required measurement uncertainty of the velocity value	The uncertainty is given by the specificities of the sensor/platform and the algorithm used for the data processing. Depending on the observed velocity, different techniques can be better suited than others. Documenting a relative measurement uncertainty may ensure technology-independent standards.
Stability, i.e. consistency over time	The velocity value is an annualized displacement rate derived from methodologies allowing either for displacement measurement (i.e. from permanent location, point or area with always the same coordinates, e.g. photogrammetry) or for position measurements (i.e. from moving position, e.g. GNSS). On the long term, the stability is not ensured in the case of a displacement measurement, as the location of this measurement is constant over time whereas the creeping mass is moving. Likewise, in the case of position measurement, the stability is not ensured on the long term since the location is moving over time and the creeping mass is subject to change of topography, for instance.

2.3 Mountain permafrost distribution model in Southern Carpathians (MPDM)

There are two error sources for the modeling process:
a) The errors related to data used for input and validation of the model:

- The errors present in DEM and satellite images, mountain topography being generally a source of errors in both DEM and satellite images, among which the most common and important errors are the existence of artifacts. The use of a RF based model reduces the influence of these errors.

- The errors related to GST and in geophysical measurements. There are always errors in measurements; however, the errors can be reduced by using different methods for the same study area.

b) The errors and uncertainty of the modeling process.

3 METHODOLOGY TO DETERMINE UNCERTAINTIES

3.1 Rock glacier inventories, incl. kinematics (RGI)

3.1.1 Rock glacier inventories

For each geomorphological attribute of the rock glacier inventories, the standards include possibilities to estimate and document the uncertainty. Several elements, summarized in Section 4.1.1 (Table 8), help the operator to remain careful in case of uncertainty when characterizing and delineating rock glaciers.

The validation is qualitative and consists of an evaluation of the final products by experts in mountain permafrost, as described in CCN 1&2 2.5 PVP.

3.1.2 Moving areas

For the moving areas, the standards include possibilities to estimate and document the uncertainty. Several elements, summarized in Section 4.1.2 (Table 9), help the operator to remain careful in case of uncertainty when delineating moving areas.

When possible, inventoried moving areas must be compared with available field data recorded at (or around) the same temporal frame. Pre-existing inventories of slope movements (landslide and/or rock glaciers), terrestrial geodetic survey data (DGPS, Total station, Lidar, etc.), as well as air-borne photogrammetry data are, for instance, precious sources of validation and will be used when existing to assess the quality of the results.

In the absence of terrestrial data, only the analysis of several interferograms and a good knowledge of the corresponding geomorphology allow the signal to be interpreted as a movement and not attributed to noise or atmospheric artifacts. However, the presence of a clear signal on a wider time interval, which confirms the activity of the landform, is an absolute prerequisite for attributing the signal to a change in the topography rather than to noise. In any case, the interpretation of the dataset by a second user is highly recommended in order to improve the overall quality of the inventory.

As the aim is to provide homogeneous RGI, external partners will be asked to perform a practical exercise in order to learn the standardized methodology and be known with the guidelines. Results of this practice will be analysed in order to assess the homogeneity in between partners. If needed, a webinar, technical support, etc. will be provided. In this way, the delivered standardized regional rock glaciers inventories (consisting of an update of existing morphological rock glacier inventories and/or slope movement inventories) will rigorously follow the defined guidelines and ensure the homogeneity.

3.1.3 Standard kinematical attribute

For the kinematical attribute, the standards include possibilities to estimate and document the uncertainty. Several elements, summarized in Section 4.1.3 (Table 10), help the operator to remain careful in case of uncertainty when attributing the category.

When available, inter-comparison with other remote sensing or in-situ data (see Section 3.2.1 and CCN 1&2 2.5 PVP) may be performed to verify that the documented rock glacier unit falls into the correct category (order of magnitude of the mean velocity).

3.2 Kinematical time series on selected rock glaciers (KTS)

3.2.1 Kinematical time series using InSAR

There are various approaches to estimate the uncertainty of InSAR measurements, including a formal description of the error terms, internal quality measures, analysis of interferometric phase on stable ground, comparison against results from other SAR data or optical feature tracking, and ground-based measurements (e.g. from GNSS).

Formal description of error terms

For single measurements at C-band, an error of 6 to 7 mm, partly attributed to noise (1 to 2 mm) and partly to atmospheric artifacts (5 to 6 mm), was estimated in a major validation project over urban areas (Crosetto et al., 2009), where a similar high degree of coherence over a multiannual period is typically observed as in 6 to 12 days over rock glaciers. This error translates to a LOS measurement uncertainty of ±0.4 m/a for Sentinel-1 interferograms over six days and of ±0.2 m/a for Sentinel-1 interferograms over 12 days and can go down to a mm accuracy using multi-temporal techniques. A similar phase error of one quarter of a phase cycle due to signal noise and atmospheric artefacts is typically observed also for X-band (Strozzi et al., 2010). For TerraSAR-X interferograms over 11 days, this error corresponds to a measurement uncertainty in LOS displacement of ±0.1 m/a. At L-band the total phase error is minor (Sandwell et al., 2008), for example, one eighth of a phase cycle, leading to an error in LOS displacement of the JERS-1 interferogram over 88 days of ±0.1 m/a.

Internal quality measure

An internal quality measure of the interferometric phase is the complex correlation coefficient, or *complex coherence* $|\gamma|$. The values of $|\gamma|$ are between 0 and 1, where a coherence value of 1 corresponds to perfect phase correlation between the two measurements. Coherence values less than unity correspond to reduced phase correlation. The phase noise standard deviation as a function of the coherence varies with the applied multi-looking factors (Fig. 1). The estimate tends to be biased (overestimation of low coherence) with a low multilooking factor (Fig. 2). This leads to a trade-off decision: high multi-looking factor improving the signal statistics and the coherence estimate but reducing the spatial resolution (Bamler & Hartl, 1998).

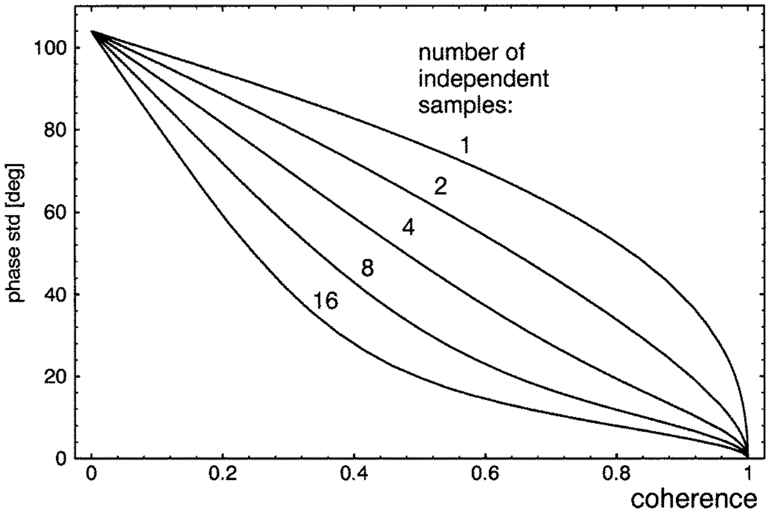

Figure 1: Interferometric phase dispersion (degrees) as function of interferometric coherence for various looks (Bamler & Hartl, 1998)

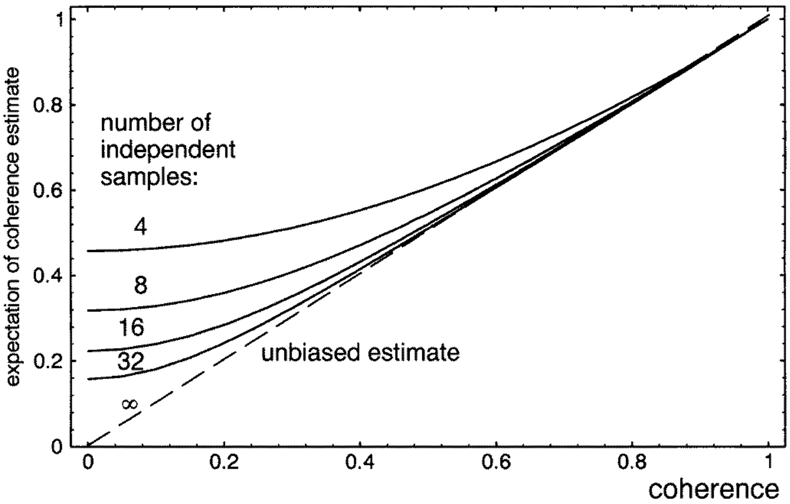

Figure 2: Bias of the coherence estimate, depending on the multilooking factor (Bamler & Hartl, 1998)

Stable area test

Another internal method widely applied for quality assessment of displacement products is the analysis of stable ground where no motion is expected. This gives a good overall indication for the bias introduced by the displacement retrieval algorithm.

Comparison against results from other remote sensing data

The comparison of displacement fields generated from independent data sets from different sensors covering the same period can be also be used for uncertainty estimation. It has however to be considered that often the temporal and spatial representativeness of the data is not assured, introducing additional constraints on the validation.

Intercomparison with in-situ data

A quantitative way to determine the uncertainties is to compare the InSAR-measured displacement values with other independent displacement measurements (e.g. in-situ) at the same location. This is based at the validation step of the project (see CCN 1&2 D.2.5 PVP). However, several issues complicate the comparison of space-borne and in-situ estimates. Though highly precise, the temporal and spatial representativeness of the in-situ data compared to the area and time covered by the image data to be validated will vary and is not strictly known. Also, in-situ measurements refer to a single point, whereas image-based measurements represent a larger area.

3.2.2 Kinematical time series using SAR offset tracking

Within Glacier_CCI, Paul et al. (2017) investigated the uncertainty of SAR offset tracking for ice surface velocity estimation in various aspects, including internal quality measures, matching on stable ground and ground-based measurements (e.g. from GNSS). Here we recall the quality tests defined within Glacier_CCI with a special focus on comparatively small landforms such as rock glaciers.

Map local quality measures

Within the offset-tracking processing chain local quality measures, like the Cross-Correlation coefficient (CC) and the signal to noise ratio (SNR), are estimated. These measures quantify the quality of the local estimates and are attached to each measurement of each product. They allow the user to select an appropriate threshold value for each case in order to remove very likely outliers. Note, this threshold and filtering is not absolute; correct measurements might have low quality, and high-quality estimates might result in outliers. Reasons include low-contrast areas, self-repeating patterns, or strong surface changes over the measurement period.

Stable area test

Another internal method widely applied for quality assessment of displacement products is the analysis of stable ground where no motion is expected. This gives a good overall indication for the bias introduced by the end-to-end displacement retrieval including co-registration of images.

Intercomparison with in-situ data

The comparison of satellite derived displacement products with in-situ measured data represents the highest level of validation. However, several issues complicate the comparison of space-borne and in-situ estimates. Though highly precise, the temporal and spatial representativeness of the in-situ data compared to the area and time covered by the image data to be validated will vary and is not strictly known. Also, in-situ measurements refer to a single point, whereas image-based measurements represent of a correlation window, i.e. include also small-scale gradients.

In general, Paul et al. (2017) estimated the reliability of the cross-correlation algorithm to return co-registration parameters in the order of 1/10 of a SAR image pixel. However, rock glaciers are rather small landforms and offset tracking is at the limit of its applicability even with very high-resolution SAR images with a resolution of about 2 m. In addition, also the rate of motion of rock glaciers (max. a few m/year) is much slower than that of glaciers (many hundreds of m/year), requiring much longer time intervals of observation. The measurement uncertainty over rock glaciers is, thus, larger than assessed over fast-flowing (e.g. > 300 m/a) and large (e.g. > 10 km) Arctic glaciers over shorter (e.g. few days) time periods.

3.2.3 Kinematical time series using feature tracking on repeat optical airphotos

The uncertainties for KTS from optical feature tracking and according quality tests are very similar to above SAR tracking (section 3.2.2; Paul et al, 2017) and are thus not repeated in detail (See also Table 5). Cross-correlation or signal-to-noise values for individual displacement measurements give an indication of their reliability, but are not sufficient to capture all types of mismatches. Stable-ground matches are a very useful method to estimate the overall accuracy of matches, and related Gaussian or robust statistical measures should accompany the displacement measurements. Comparison of optical displacements to SAR tracking, InSAR, or in-situ measurements can also be used to characterize uncertainties (Strozzi et al., 2020).

As a specialty for optical images, displacements can be measured from different combinations of stereo-orthoimages, if available, giving an indication for orthoprojection errors and distortion of individual original images (Kääb and Vollmer, 2000; Kääb et al., 2016, see also Table. 5).

Under optimal conditions, displacements from repeat optical imagery can be measured with an accuracy of 1/10 of a pixel resolution. For images of lower quality and being affected by distortions, an accuracy around 1-pixel resolution is more realistic. Over a typical time interval of 10 years, these accuracies translate to accuracies for displacement rates of around 1-10 cm/yr for favourable and less favourable images available, respectively.

3.2.4 Standard time series

The absolute uncertainty is given by the technology (specificities of the sensor/platform and the algorithm used in the data processing). For instance, uncertainty for geodetic position measurement are <1 cm, uncertainty for position measurement using GNSS are 2-3 cm and uncertainty for displacement measurement using photogrammetric processing are a few dm. The uncertainty can reach up to several meters for displacement measurement using photogrammetric processing from low resolution optical satellite images. Depending on the observed velocity, different techniques can be better suited than others. Documenting a relative measurement uncertainty may ensure technology-independent standards.

Thus, the uncertainty depends on the applied methodology (uncertainty of position or displacement measurement), on the procedure (for instance aggregation) as well as on the observation time window used to measure and compute the annual velocity value for the selected rock glacier unit. The uncertainty has to be converted to m/yr for each annual velocity value. The ratio between this uncertainty and the considered annual velocity value has to be lower than values defined thereafter [RD-13]:

- **Goal (G):** 5%: Relative measurement uncertainty allowing for the reliable analysis of velocity trend over time (relative change of the RGK). Easily reachable for a fast moving rock glacier whatever the technology and reachable using improved measurement techniques for slow moving rock glaciers.
- **Breakthrough (B):** 10%
- **Threshold (T):** 20%: Relative minimal measurement uncertainty allowing for the reliable analysis of a velocity trend over time (relative change of the RGK). Easily reachable for fast and slow moving rock glaciers whatever the technology.

3.3 Mountain permafrost distribution model in Southern Carpathians (MPDM)

The MPDM has two built in functions for error and uncertainty estimation. A RF model uses multiple classification trees. Each classification tree uses a randomly selected data set for validation and error estimation. The error is then computed for the entire classification giving a good estimate of the modelling accuracy. The model has a second built-in function that can produce an uncertainty map for the permafrost map. Because each pixel of the output is classified by each classification tree in the RF model, each pixel was classified a number of times as present and a number of times as absent. The pixels which have been classified unanimously are considered having a low uncertainty while the pixels having been classified an equal number of times into both categories are considered having a high uncertainty.

4 ACCURACY TO BE REPORTED

4.1 Rock glacier inventories, incl. kinematics (RGI)

4.1.1 Rock glacier inventories

For the morphological elements of RGI, possibilities for qualifying and documenting uncertainties are summarized in Table 8.

Table 8: Documentation of uncertainties for RGI

Minimal size of inventoried rock glaciers	The minimal size of inventoried rock glaciers may depend on the properties of the input data. The type and spatial resolution of the input data used for identifying rock glaciers have to be documented.
Rock glacier morphological system and units	Recommendations consider complex cases: composite rock glaciers (multiple lobes). Simple or complex (sub)-units have to be characterized.
Rock glacier identification and outlines	The recommendation is to use a point feature manually positioned on the landform, able to identify the location of the rock glacier unit, and discriminate it clearly from other units without ambiguity. Delineating rock glacier boundaries with a closed polygon (extended and restricted geomorphological footprint) is optional. The inventorying strategy requires to a) detect and identify a rock glacier (detection of moving areas and identification of the related landform based on ortho-imagery or DEM-derived products) b) locate the rock glacier (primary marker/ID) and c) characterize it (main attributes). If the outlines are too uncertain, the inventory remains at the level of the primary mark (incl. attributes).
Spatial connection of the rock glacier to the upslope unit	Category “Other”: if none of the other categories corresponds to the geomorphological sequence. Category “Poly-connected”: Two or more upslope connections in cases there is no large dominance of one type of upslope connection.
Rock glacier activity	Category “Undefined”: if data are inadequate for discriminating between the activity classes.
Rock glacier destabilization	Optional attribute: Attribute remains undefined if data are inadequate to evidence destabilization.

Metadata should include information about satellite scenes (date, path, row, sensor, processing), additional kinematical data (applied techniques, acquisition dates, measured points/areas, accuracy, precision), date/source/spatial resolution of the available DTM and orthoimages, available slope movement inventories and/or morphological rock glacier inventory as well as the name of the operators and the date/region of the analysis. References, acknowledgments and any other important metainformation are documented.

4.1.2 Moving areas

For the moving areas, possibilities for quality assignment and documenting uncertainties are summarized in Table 9.

Table 9: Documentation of uncertainties for the moving areas

Definition of moving area (extent and uniformity)	The reliability (or the degree of confidence) of the moving area has to be qualitatively documented in accordance with the quality of both the detection and the velocity classification (low, medium, high). “High” defines an evident signal, easily identified. “Medium” indicate that signal interpretation (velocity estimation) or outline is

	uncertain. “Low” indicates that signal interpretation (velocity estimation) and outline are uncertain, But that the presence of the signal has to be considered over the area (as potential movement).
Velocity classes of moving areas	The velocity refers as far as possible to the 1D LOS InSAR measurements performed on back facing slopes. The velocity class *0. Undefined* is used if it is possible to delineate a moving area but the velocity can not be accurately estimated (too low reliability of input data, North/South-facing slopes for 1D LOS InSAR measurements, etc.). Uncertainty sources are documented in the field «Remarks».
Temporal representativness of the moving areas	Observation time window and temporal frame have to be documented.

Metadata should indicate the data used for identifying and characterizing the moving areas, i.e. information about satellite scenes (date, path, row, sensor, processing), additional kinematical data (applied techniques, acquisition dates, measured points/areas, accuracy, precision), date/source/spatial resolution of the available DTM and orthoimages, available slope movement inventories and/or morphological rock glacier inventory as well as the name of the operators and the date/region of the analysis.

4.1.3 Standard kinematical attribute

For the kinematical attribute, possibilities for quality assignment and documenting uncertainties are summarized in Table 10.

Table 10: Documentation of uncertainties for the kinematical attribute

Semi-quantitative categories of kinematical attribute (order of magnitude)	The default category is *0. Undefined*. The rock glacier unit falls into this category when no (reliable) kinematical information is available, or the kinematical information is derived from a single point survey which cannot be related to any moving area, or a dominant part of the rock glacier unit is characterized by a moving area of undefined velocity.
Temporal representativness of kinematical attribute	Rock glacier units are characterized for a multi-annual validity time frame (snapshot) of at least 2 years. Observation time window and temporal frame of all the supporting kinematical data are documented. The velocity information from moving areas (based on at least one month of observation time window) should be transferred to the proper category of kinematical attribute in order to indicate the overall multi-annual rate of movement observed/estimated on a dominant part of its surface. Translation rules are described int detail in CCN 1&2 D.2.2 ATBD.
Spatial representativness of kinematical attribute	The characterization of kinematical attributes can only be performed when a dominant part of the rock glacier unit is described by reliable moving areas. If the available data is too uncertain or unreliable due to specific technical limitations (e.g. North/South-facing slopes for 1D LOS InSAR measurements, etc.), the category should be left undefined. If moving areas show a large heterogeneity over the unit (e.g. more than three moving areas with velocity classes falling into various categories), the category should be left undefined. Note that large heterogeneity can also indicate the possible need to affine/redefine the delineation of the initial morphological units.

Metadata should indicate the data used for assigning the kinematical attribute (data/technique used, dimensionality of the measurement, observation time window, temporal frame) and the spatial representativness (percent of surface that is documented by recognized moving areas) (e.g. < 50%, 50-75%, > 75%). Reliability of the assignment (low, medium, high) is documented. The producer and the date of production should be indicated.

4.2 Kinematical time series on selected rock glaciers (KTS)

We aim to make the accuracy to be reported homogeneous for kinematical time series using InSAR, SAR offset-tracking and feature tracking on repeat optical airphotos in line with [RD-13]. For the kinematical time series, possibilities for quantifying and documenting uncertainties are summarized in Table 11.

Table 11: Documentation of uncertainties for the kinematical time series

Horizontal resolution (2), i.e. surface velocity value	The horizontal resolution (2) has to be consistent over time and reported.
Time resolution, i.e. frequency and observation time window	The observation time windows has to be consistent over time and reported.
Required measurement uncertainty of the velocity value	The required measurement uncertainty to be reported is defined as the relative velocity uncertainty, corresponding to the ratio in between this uncertainty and the considered annual velocity value. The threshold value for using the individual time series for the development of the ECV Permafrost product (analysis of velocity trend based on level-2 time series and regional index is set at 20% [RD-13].
Stability, i.e. consistency over time	If the horizontal resolution (2) or the observation time window is changing two time series must be derived for the selected rock glacier unit. The merging of these two time series can only be performed in the case of existing temporal overlap.

Metadata should indicate the data used for assigning the kinematical attribute (data/technique used, dimensionality of the measure, horizontal and temporal resolutions), the measurement uncertainty and the stability (consistency over time). The producer and the date of production should be indicated.

4.3 Mountain permafrost distribution model in Southern Carpathians (MPDM)

The total accuracy of the model and an uncertainty map for the permafrost extent will be produced (see Section 3.3).

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6.2 Acronyms

AD	Applicable Document
ADP	Algorithm Development Plan
ATBD	Algorithm Theoretical Basis Document
AUC	Area Under the Receiver Operating Curve
B.GEOS	b.geos GmbH
BTS	Bottom Temperature of Snow Cover
CCI	Climate Change Initiative
CCN	Contract Change Notice
CRS	Coordinate Reference System
DARD	Data Access Requirement Document
DEM	Digital Elevation Model
ECV	Essential Climate Variable
EO	Earth Observation
ERT	Electrical Resistivity Tomography
ESA	European Space Agency
ESA DUE	ESA Data User Element
E3UB	End-to-End ECV Uncertainty Budget
GAMMA	Gamma Remote Sensing AG
GCOS	Global Climate Observing System
GFI	Ground Freezing Index
GPR	Ground Penetrating Radar
GST	Ground Surface Temperature
GT	Ground Temperature
GTOS	Global Terrestrial Observing System
GUIO	Department of Geosciences University of Oslo
INSAR	Synthetic Aperture Radar Interferometry
IPA	International Permafrost Association
LST	Land Surface Temperature
KTS	Kinematical Time Series
MAGT	Mean Annual Ground Temperature
MAGST	Mean Annual Ground Surface Temperature
MPDM	Permafrost Distribution Model
MRI	Mountains Research Initiative
MTD	Miniature Temperature Data Loggers
NMA	National Meteorological Administration
NORCE	Norwegian Research Centre AS
NSIDC	National Snow and Ice Data Center
PSD	Product Specifications Document
PVASR	Product Validation and Algorithm Selection Report
PVP	Product Validation Plan
RF	Random Forest
RD	Reference Document

RGI	Rock Glacier Inventories
RMSE	Root Mean Square Error
SAR	Synthetic Aperture Radar
S4C	Science for the Carpathians
SWE	Snow Water Equivalent
T	Temperature
UNIFR	Department of Geosciences University of Fribourg
UNIS	University Centre in Svalbard
URD	Users Requirement Document
UTM	Universal Transverse Mercator
WGS	World Geodetic System