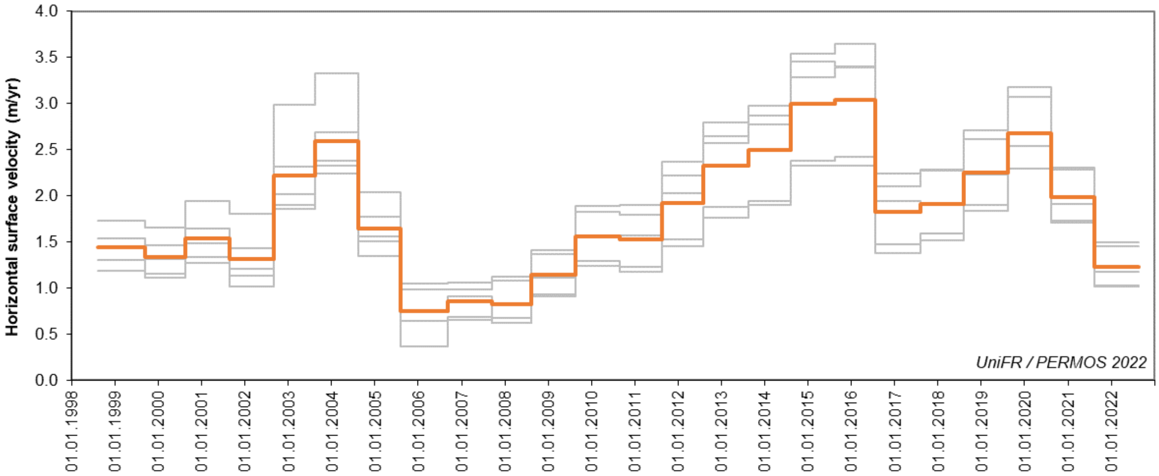
IPA Action Group Rock glacier inventories and kinematics

Rock Glacier Velocity as associated product of ECV Permafrost

Practical concepts

(Version 1.2)



www.rgik.org *(Action Group website)*

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Authors and contributions

This document has been edited by (in alphabetical order) Chloé Barboux, Reynald Delaloye, Cécile Pellet and Sebastián Vivero (University of Fribourg, Switzerland), with the contribution of the members of the Action Group RGV Committee, namely Xavier Bodin (EDYTEM, France), Alessandro Cicoira (University of Zurich, Switzerland), Yan Hu (Chinese University of Hong Kong, China), Christophe Lambiel (University of Lausanne, Switzerland), Line Rouyet (NORCE, Norway), Gernot Seier (University of Graz, Austria) and Julie Wee (University of Fribourg, Switzerland), who met in Fribourg (Switzerland) on 25-26 November 2022.

The purpose of this document is to provide practical concepts permitting the standardized generation of Rock Glacier Velocity time series as a product of the GCOS Essential Climate Variable (ECV) Permafrost.

How to cite

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Acronym

RGV_PCv1.2

Contents

Preamble

Rock Glacier Velocity (RGV) has been integrated as a new associated product to the ECV Permafrost in the implementation plans of the Global Terrestrial Network Permafrost (GTN-P) 2021-2024 and the Global Climate Observation System (GCOS) 2022-2026. The documents elaborated by the International Permafrost Association (IPA) Action Group *Rock glacier inventories and kinematics* (2018-2023) **serve as a reference** for the development of RGV.

Task 2 of the Action Group aims at **generating the RGV product.** It is divided into three subtasks:

- 2.1: definition of the main concepts and principles (RGV_BCv3.2),
- 2.2: establishment of practical concepts (the present document and the associated *Factsheets*),
- 2.3: establishment of a technical (operational) manual on how to compile RGV in an open-access database.

The baseline concepts defined in Sub-Task 2.1 result from a workshop that took place in Fribourg (Switzerland) on 11-13 February 2020 (Workshop II) and follow-up work by the RGV scientific committee and IPA Action Group members. The present document is an extension of those baseline concepts, which will be merged into a single document at a later stage. The main text is complemented with illustrations, allowing for a better understanding of the described rules and concepts. Suggestions for further or alternative illustrations are welcome.

ECV Permafrost products should contribute to document how climate change is impacting the state and distribution of the frozen ground on the Earth. Hence, RGV should be measured/computed globally, covering as many regions as possible worldwide.

In accordance to the ECV product requirements set by GCOS and to offer some flexibility in the monitoring design, the RGV product requirements follow the three-level quality defined by the following thresholds: "*minimal*", "*medium*" and "*ideal*".

Note: this part will be integrated into the Baseline Concept document.

Minimal: The minimum requirement: the value that must be met to ensure that data are useful. *Medium*: One or more values that enable additional uses within climate monitoring. The additional uses need to be described in the "derivation" section. *Ideal*: The ideal requirement above which further improvements are not necessary with current technology. This is likely to evolve as applications and technologies progress.

Provisional timeline

The present document (RGV_PCv1.2) integrates the comments from the Action Group (consulted in Spring 2023). The merging of RGV_PC with the *Baseline concepts for Rock Glacier Velocity as associated product of ECV Permafrost* (RGV_BCv3.2) as one single document is foreseen at a later stage.

4. RGV monitoring

The RGV monitoring strategy is proposed with respect to the GCOS monitoring principles.

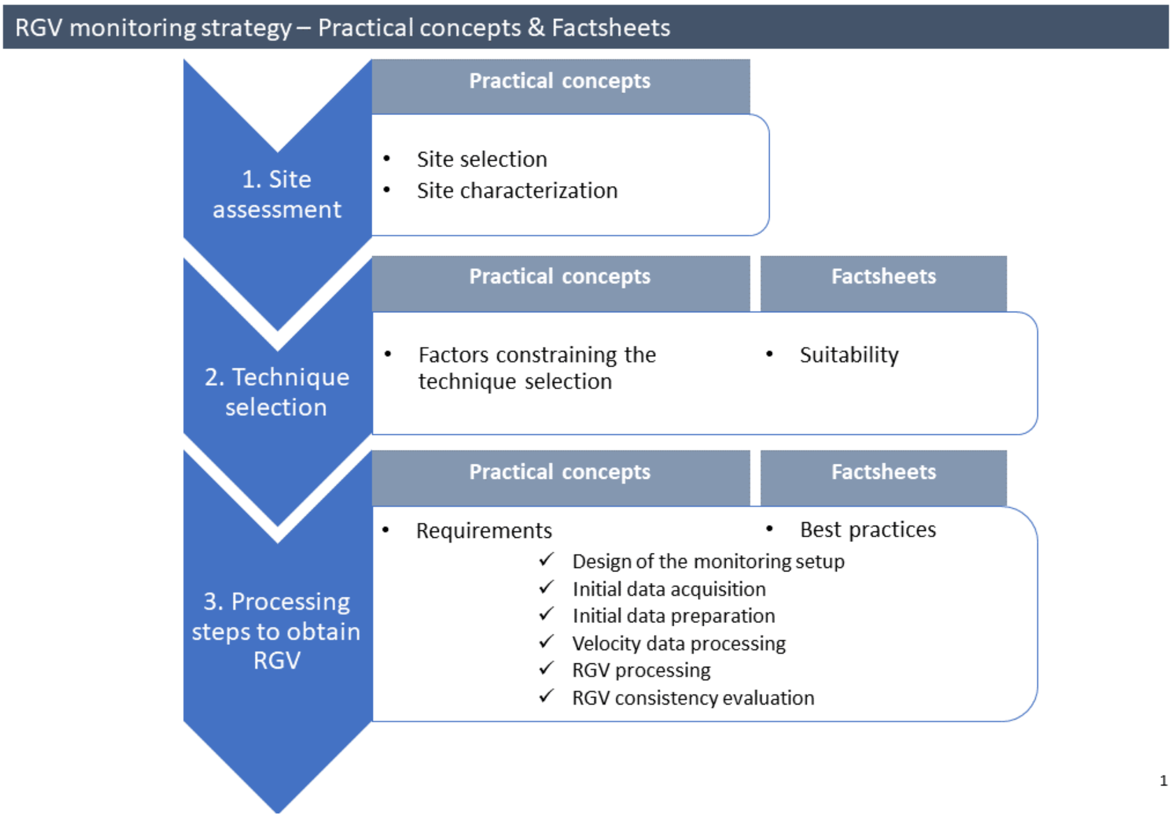

Figure 4.1: RGV monitoring strategy.

The monitoring strategy comprises three stages (Fig. 4.1), namely: the site assessment (section 4.1), the evaluation of factors constraining the choice of the technique (section 4.2) and the processing steps to produce RGV (section 4.3). All three stages must be assessed and refined using all newly acquired data until a stable monitoring strategy is found. Afterwards, the monitoring strategy and the resulting time series must be regularly evaluated at pre-defined intervals that are tailored to the monitoring technique used and the velocity of the rock glacier. Adaptations to the monitoring strategy, if needed, should follow requirements given in this document.

Only technique-independent concepts are described in the present document. Aspects related to a specific technique are presented in separate documents called "*Factsheets*". These *Factsheets* are being developed for a (non-exhaustive) list of techniques to assist users with the technique selection, the design of the monitoring setup as well as the processing steps to produce RGV.

4.1. Site assessment

This section explains how to evaluate the **relevance** of a site for RGV monitoring and which **characteristics** need to be assessed.

4.1.1 Site selection

a) Site relevance

Which rock glacier should be selected for RGV monitoring?

The motivations for monitoring rock glacier velocities are diverse. In the context of the ECV product, the goal is the generation of long-term time series in a climate-oriented perspective. In particular, the following selection criteria should be regularly assessed based on available data (at least each year or based on available data):

- **RGV monitoring must be performed on active or transitional rock glacier units (RoGI_PC) whose deformation mechanism is dominantly related to permafrost creep**.
- Rock glaciers with surface movement dominantly caused by other processes than permafrost creep (e.g. ice melt-induced subsidence, landform destabilization (RoGI_BC 36, 37, 29, 84) must be avoided.
- Multi-decennial monitoring must appear to be feasible at the selected site (see section 4.1.1b).

b) Long-term monitoring

Is RGV monitoring feasible and for how long?

RGV must be produced consistently over a long-term period, i.e. decadal consistency shall be possible for the site of the RGV monitoring. RGV production is limited by various constraints preventing the feasibility of a long-term monitoring. These constraints should be evaluated regularly:

- *Landform constraints*: e.g. development of large scarps (onset of a rock glacier destabilization phase, RoGI_BC), occurrence of rock falls, significant instability of surface boulders (rotation, tilt, fall), onset of ice-melt induced subsidence, change in the landform kinematic behavior.
- *Technical constraints*: e.g. data availability (e.g. satellite revisit period), data quality (e.g. sensors shift, drift or failure), feasibility of measurements (e.g. not or partially covered by aerial/satellite image), technological development.
- *Practical constraints*: e.g. site accessibility, people and installations safety, permit for instrumentation and/or field visits.
- *Resource constraints*: e.g. funding, expertise.
- *Processing constraints*: e.g. availability of processing tools, computing power, data property.

Landform should only be selected if long-term RGV consistency is considered to be possible after evaluating the constraints. The constraints listed above may change over time. They may lead to necessary adaptations of the RGV monitoring strategy and must be regularly assessed.

4.1.2 Site characterization

Which rock glacier units' characteristics must be described at RGV monitoring sites?

The monitored rock glacier units must be identified, located and fully characterized (including kinematic attribute) in accordance with the inventorying guidelines (RoGI_PC Section 5).

4.2. Factors constraining the technique selection

Which technique(s) is(are) suitable for RGV monitoring at a selected site?

The suitability of a technique for RGV monitoring depends on site-related specificities (e.g. topography, location, vegetation, velocity range) **but also on operators' experience**. Techniques' characteristics are listed in Table 4.1 to help operators select the appropriate monitoring technique(s) according to the expected observed velocity. As a complement, Table 4.2 provides the main **limiting factors** related to:

- technique characteristics,
- rock glacier characteristics,
- external factors.

Finally, the *Factsheets* provide detailed descriptions of the advantages, disadvantages and limiting factors of each technique enabling operators to select suitable one(s).

Table 4.1 is an extended version of Table 1 provided in RGV_BC.

Table 4.1: Characteristics of available technologies able to provide velocity time series over rock glaciers.

	Total station	**GNSS**	**Terrestrial laser scanning**	**Terrestrial photogrammetry**	**Terrestrial radar interferometry**	**UAV-borne photogrammetry**
Platform, tool, method	Terrestrial: on site	Terrestrial: on site	Terrestrial: ground base close to site	Terrestrial: ground base close to site	Terrestrial: ground base close to site	Remote: drone
Measurement footprint	Local	Local	Local	Local	Local	Local
Measurement resolution	Single point(s) based measurement	Single point(s) based measurement	Area based, cm	Area based, cm	Area based, m @ 1km	Area based, cm
User dependent parameter	Positioning	Positioning	Positioning and distance from the object	Positioning and distance from the object	Positioning and distance from the object	Distance from the object
Image information	Not applicable	Not applicable	Referenced images, point cloud coloring	Multiband image information	Radar image	Multiband image information
Natural radiation	Independent	Independent	Independent	Dependent	Independent	Dependent
Temporal resolution (time interval measurement)	User defined	User defined	User defined	User defined	User defined	User defined
Data value and dimension	Direct 3D point coordinates of a single point	Direct 3D point coordinates of a single point	Direct 3D coordinate of random surface points	Indirect 3D coordinate of random surface points	Direct 1D distance in the line of sight	Indirect 3D coordinate of random surface points
Geometric reference[1]	Lagrangian	Lagrangian	Lagrangian or Eulerian	Lagrangian or Eulerian	Eulerian	Lagrangian or Eulerian
Dimensionality (value provided by motion analysis)	3D coordinate differences (Displacement of an object)	3D coordinate differences (Displacement of an object)	2.5D-3D coordinate differences (horizontal shift of a surface patch & Dz at a defined location in CS)	2.5D-3D coordinate differences (horizontal shift of a surface patch & Dz at a defined location in CS)	Direct 1D coordinate differences in line of sight	2.5D-3D coordinate differences (horizontal shift of a surface patch & Dz at a defined location in CS)
Accuracy (between 2 measurements)	cm	cm	cm	cm	mm	cm-dm

[1] *The observation of surface velocity can be performed according to two geometric reference frames:*

- *In the Lagrangian specification of the flow field, the trajectory of one or more specific points is recorded by following their positions moving with the flow (e.g GNSS). The velocity is calculated from the changing position of a point over time. The velocity values attributed to a rock glacier unit or a defined area result from an aggregation in the case of several points. The number of specific points used for the aggregation refers to the spatial resolution (see section 3.3).*
- *In the Eulerian specification of the flow field, the surface velocity values are computed for locations or areas, whose coordinates are fixed in space (e.g. InSAR). The network (number of aggregated points) used to derive a velocity value attributed to a rock glacier unit or defined area refers to the spatial resolution (see section 3.3).*

	Airborne laser scanning	Airborne photogrammetry	Spaceborne photogrammetry	Spaceborne SAR interferometry	Spaceborne SAR offset tracking
Platform, tool, method	Remote: plane/helicopter	Remote: plane	Remote: satellite	Remote: satellite	Remote: satellite
Measurement footprint	Local to regional	Local to regional	Regional to global	Regional to global	Regional to global
Measurement resolution	Area based, cm-dm	Area based, cm	Area based, cm	Area based, m	Area based, m
User dependent parameter	no	no	no	no	no
Image information	Referenced image, point cloud coloring	Multiband image information	Multiband image information	Radar image	Radar image
Natural radiation	Independent	Dependent	Dependent	Independent	Independent
Temporal resolution (time interval measurement)	User defined (or depending on country authorities)	User defined (or depending on country authorities)	Days to years depending on sensor	Days to years depending on sensor	Days to years depending on sensor
Measurement value and dimension	Direct 3D coordinate of random surface points	Indirect 3D coordinate of random surface points	Indirect 3D coordinate of random surface points	Direct 1D change of distance in the line of sight	Indirect 2D coordinate of random surface points
Geometric reference	Lagrangian or Eulerian	Lagrangian or Eulerian	Lagrangian or Eulerian	Eulerian	Lagrangian or Eulerian
Dimensionality (value provided by motion analysis)	2.5D-3D coordinate differences (horizontal shift of a surface patch & Dz at defined location in CS)	2.5D-3D coordinate differences (horizontal shift of a surface patch & Dz at defined location in CS)	2.5D-3D coordinate differences (horizontal shift of a surface patch & Dz at defined location in CS)	Direct 1D coordinate differences in line of sight. Potentially 3D by combining both ascending and descending modes with assumption about a plane where the motion occurs, e.g. no motion along the N-S direction or surface-parallel flow	2D coordinate differences (line of sight and azimuth)
Accuracy (between 2 measurements)	Cm-dm	cm-m	dm-m	mm-cm	dm-m

Table 4.2: Feasibility of the technique according to three limiting factors

Table 4.2 will be implemented progressively with the creation of *Factsheets*.

	Total station	**GNSS**	**Terrestrial laser scanning**	**Terrestrial photogrammetry**	**Terrestrial radar interferometry**	**UAV-borne photogrammetry**
Technique characteristics						
Rock glacier characteristics						
External constraints						

	Airborne laser scanning	**Airborne photogrammetry**	**Spaceborne photogrammetry**	**Spaceborne SAR interferometry**	**Spaceborne SAR offset tracking**
Technique characteristics				- Need appropriate SAR data. - Need accurate DEM. - Layover & shadow. - Line of sight observation.	
Rock glacier characteristics				- Match time interval to expected velocity. - Take care of unrepresentative pixels. - Minimal size of Rock glacier unit: 10 x range resolution	
External constraints				- Weather conditions (snow-free, rainfall). - Vegetation. - Atmosphere.	

4.3. Processing steps to produce RGV

Reminder RGV_BC:
Rock glacier velocity (RGV) is defined as a **time series of annualized surface velocity values expressed in m/y and measured/computed on a rock glacier unit or a part of it**. RGV is computed for rock glacier units identified and located according to the inventorying guidelines (RoGI_PC) and refers to observed surface velocities related to permafrost creep. The annual surface velocity values, which build up RGV are called **RGV values**.
RGV values are measured/computed from velocity data of **any dimension** (1-3D), which are **spatially** and/or **temporally aggregated** following a technique-dependent procedure.
Per rock glacier unit, one RGV value should be measured/computed as far as possible **each yea**r, following a **methodology** that **must be precisely documented and remain consistent over time**.
In case of a high degree of spatial heterogeneity of surface displacement over a rock glacier unit (i.e. several recognized moving areas for the same unit), several RGV can be measured/computed for the same rock glacier unit.

The production of **RGV** follows several steps from the design of the monitoring setup to the data acquisition and its transformation into the final RGV product. The term **initial data** refers to the surface velocity/displacement or positioning data obtained with the applied technique (Table 4.1-2). Initial data may have different geometric references, units, dimensions, as well as spatial and temporal resolutions (Table 4.1). They will be converted into surface velocity values – the **velocity data** – and used for RGV processing.

To produce RGV, the following steps are required (Fig. 4.2):

- *Design of the monitoring setup* (section 4.3.1), which controls initial data acquisition.
- *Initial data acquisition* (section 4.3.2), which yields initial data.
- *Initial data preparation* (section 4.3.3), which pre-processes and evaluates initial data yielding quality-controlled initial data.
- *Velocity data processing* (section 4.3.4), which calculates and provides cleaned velocity data that can be used for RGV processing.
- *RGV processing (section 4.3.5),* which temporally and spatially sorts and aggregates the velocity data to produce RGV.
- *RGV consistency evaluation* (section 4.3.6), which evaluates the consistency of the RGV during the entire chain of RGV production and provides recommendations for long-term monitoring.

Most of the above-mentioned steps are (partially to fully) technique-dependent and are therefore described in the respective *Factsheets*. In the following sections, only the technique independent concepts and the standard requirements of RGV are described.

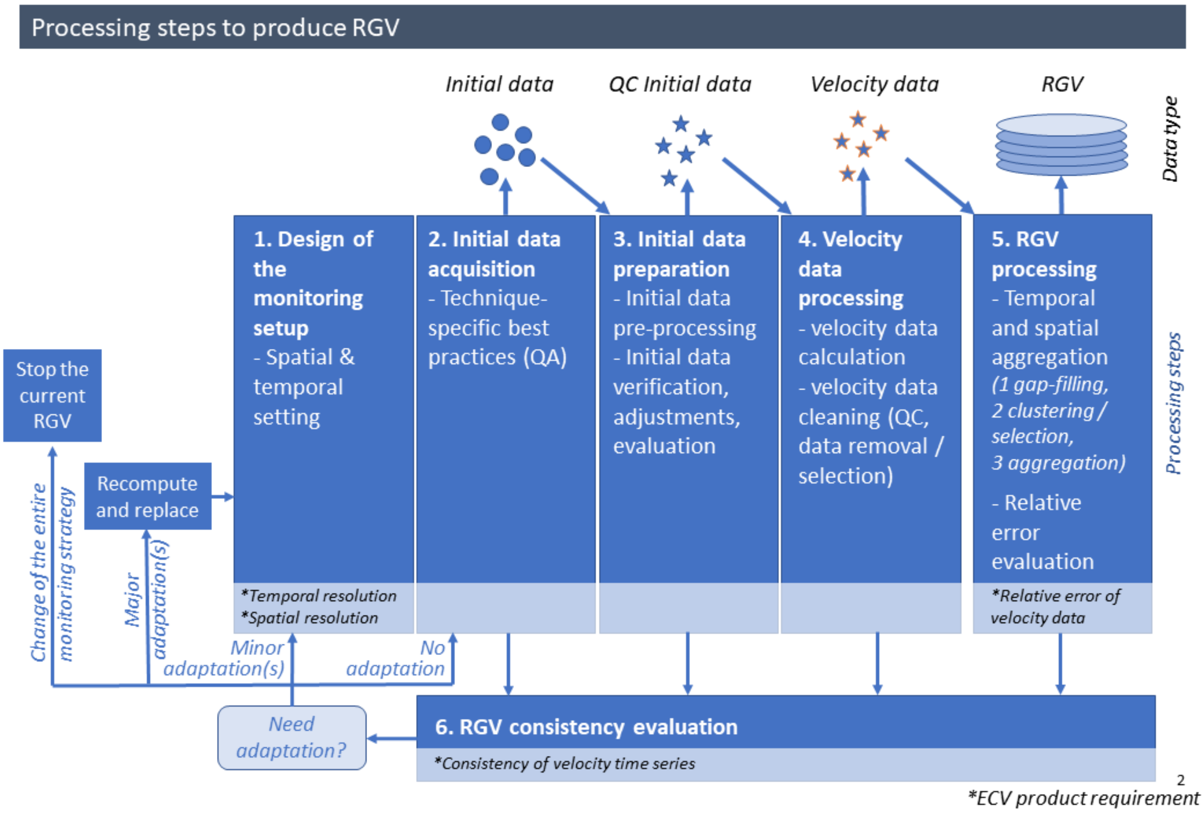

Figure 4.2: Processing steps to produce RGV.

4.3.1. Design of the monitoring setup

The respective *Factsheets* provide recommendations for the design of the monitoring setup. General technique-independent statements can be found below.

a) Temporal resolution

Reminder RGV_BC part 2.4 and 3.2: RGV is strictly stamped with a *frequency* and an *observation time window:*

- The observation time window can be seasonal.
- A minimum observation time window of 1 month ensures some smoothing of the short-term variability.
- The observation time window should be as constant as possible in time (the data acquisition must always be performed at almost the same date/period of the year).
- The maximum allowed observation time window and frequency is ~5 years.

The *ideal* setup is to use a measurement *frequency* of **once per year** and an *observation time window* of **1 year** with measurement dates/periods that remain approximately the same every year. However, depending on the chosen technique and the site characteristics this may not be possible. The corresponding *Factsheets* describe the requirements for temporal resolution as well as temporal data processing (e.g. temporal aggregation). The selected settings **must be systematically documented in the RGV metadata and remain consistent over time**. In any case, the following principles apply:

Table 4.3: RGV product requirements in terms of temporal resolution:

Quality	Value	Additional information
Ideal	Observation time window = 1 year Frequency = once per year	The dates of the measurement must remain approximately the same every year: +/- 15 days of difference.
Medium	Observation time window < 1 year Frequency = once per year	The observation time window must be at least 1 month and cover approximately the same period every year: +/- 15 days of difference.
Minimal	Observation time window > 1 year Frequency < once per year	The frequency is limited to less than once per year due to an observation time window longer than 1 year. The recommended maximum observation time window is 5 years.

b) Spatial resolution

Reminder RGV_PC part 3.3: The spatial resolution is defined as the (set of) measurement point(s) or the measurement area(s) used to measure/compute each RGV values. The spatial resolution has to be chosen in order to characterize a consistent flow field related to the surface velocity of the rock glacier unit or a part of it (i.e. must be located within a recognized moving area). It must be consistent over time.

The spatial resolution of the RGV product will depend on the *measurement resolution* of the chosen technique and can be as diverse as **single point, few discrete points or area-based measurements** (see table 4.1).

The *ideal spatial resolution* is to use area-based or several spatially distributed measurement points allowing a complete understanding of the displacement field and the appropriate selection of the area to be considered in the RGV processing (section 4.3.5). The *medium* and *minimal spatial resolutions* use only a few (medium = 3; minimal = 1) measurement point(s) allowing a partial understanding of the displacement field and reducing the confidence level in the selection of the area to be considered in the RGV processing.

Each technique requires a specific monitoring setup, which is described in the respective *Factsheets*. The *Factsheets* provide recommendations concerning the *spatial resolution* (i.e. number and spatial distribution of initial data).

The selected settings **must be systematically documented in the RGV metadata and must remain consistent over time**. In any case, the following principles apply:

Table 4.4: RGV product requirements in terms of spatial resolution:

Quality	Value	Additional information
Ideal	Area-based or several discrete point-based measurements	RGV is computed/measured from the displacement field or several discrete measurement points allowing a complete understanding of the displacement field. The entire rock glacier unit should be covered by measurements. The displacement field or discrete measurement points should remain consistent over time.
Medium	Three discrete point-based measurements	RGV is computed/measured from a few discrete measurement points. A minimum of 3 points is required allowing a partial understanding of the displacement field. The monitoring points should be located in an area where surface movements are dominantly related to permafrost creep. The monitored points should remain consistent over time.
Minimal	Single point-based measurements	RGV is computed/measured from a single measurement point allowing a very limited understanding of the displacement field. The monitoring point should be located in an area where surface movements are dominantly related to permafrost creep. The monitored point should remain consistent over time.

4.3.2. Initial data acquisition

The respective *Factsheets* provide recommendations to **acquire initial data**, i.e. to collect QA measurements of surface velocity/displacement/position depending on the applied technology.

The chosen procedure **must be applied consistently and documented in the RGV metadata.**

4.3.3. Initial data preparation

The respective *Factsheets* provide recommendations to produce **quality-controlled initial data** that will be used for the velocity data processing (see 4.3.4). They describe how to:

- **pre-process** initial data: formatting, cleaning, and calibrating initial data.

- **verify, adjust, and evaluate** initial data: assessing and providing quality-controlled initial data.

The chosen procedure **must be applied consistently and documented in the RGV metadata**.

4.3.4. Velocity data processing

The respective *Factsheets* provide recommendations to compute the **velocity data** from **quality-controlled initial data**. They describe how to:

- **compute** velocity data: conversion of initial data into surface velocity value.

- **clean** velocity data: selection of velocity data as well as quality control.

The chosen procedure **must be applied consistently and documented in the RGV metadata.**

4.3.5. RGV processing

The respective *Factsheets* provide recommendations to compute **RGV** from **velocity data**. They describe how to:

- **spatially aggregate** velocity data to compute RGV. The computation of RGV depends on the spatial resolution of the velocity/initial data. No spatial aggregation is needed for single point and single area velocity data. Spatial data selection and aggregation are needed for discrete points and multiple (e.g. gridded) areas. The area or points considered for RGV computation (i.e. RGV spatial footprint) is defined at this stage. In case of a high degree of spatial heterogeneity of surface displacement over a rock glacier unit, several RGV can be measured/computed for the same rock glacier unit.

- **temporally aggregate** the velocity data to compute RGV. The computation of RGV depends on the temporal resolution of the velocity/initial data. No temporal aggregation is needed for initial/velocity data acquired with an annual frequency and with an observation time window of one year. Temporal data selection and aggregation is needed for initial/velocity data acquired with observation time window shorter than a year and with a shorter frequency (i.e. more than one measurement per year).

The spatial and temporal aggregation procedures both include the following steps:

  - **gap-fill** velocity data, if needed.
  - **cluster or select** velocity data: determining which velocity data is used for computing RGV, i.e. appropriate selection of the area/point(s) and/or of the time interval considered to produce RGV.

- **compute** RGV: spatial and/or temporal aggregation of velocity data and computation of descriptive statistics.

- **evaluate** RGV: The computation of the relative error of each RGV value.

The respective *Factsheets* provide recommendations to evaluate the *relative error* (see RGV_BC 3.4a), which must be specified for each RGV value. The *ideal* value of *relative error* should be <5%. The *relative error* must not exceed 20% (*minimal* requirement).

The chosen procedure **must be applied consistently and documented in the RGV metadata.** In any case, the following principles apply:

Table 4.5: RGV product requirements in terms of relative error of the RGV value

Quality	**Value**	**Additional information**
Ideal	0-5%	Relative error of the RGV value allows a reliable analysis of long-term temporal changes in RGV. The technique is chosen in accordance with the absolute velocity measured/computed of the selected rock glacier.
Medium	5-15%	Relative error of the RGV value allows a reliable analysis of temporal changes in RGV. Specific attention should be paid in the future, especially if the selected rock glacier velocity is decreasing. In that case, a change of the measurement technique or its temporal settings should be done.
Minimal	15-20%	Maximal allowed relative error of the RGV value to produce an analysis of temporal changes in RGV. If the error exceeds 20%, the site must be discarded, or other techniques should be considered in accordance with the absolute velocity measured/computed of the selected rock glacier.

4.3.6. RGV consistency evaluation

The respective *Factsheets* provide recommendations to **evaluate RGV at each processing steps to produce RGV** and to **adapt the monitoring strategy** when/if needed. General technique-independent statements are given below.

During specific years or at specific places, changes in the constraints controlling the initial data acquisition and the feasibility of long-term monitoring (see section 4.1.1b) may appear and potentially affect the long-term RGV consistency. RGV consistency is a qualitative assessment that characterize the effect of these changes on the RGV values, on the processing steps to obtain RGV and on the entire monitoring strategy. RGV consistency should be systematically evaluated and documented with each new RGV value measurement/computation. Technique-dependent changes affecting RGV consistency are listed in the respective *Factsheet* together with recommended solutions to adapt the monitoring strategy whenever feasible.

Ideal and *medium* quality of the RGV consistency imply no or minor adaptation(s) of the processing steps to obtain RGV and ensure a high or medium confidence of the RGV consistency respectively. Whereas the *minimal* quality of the RGV consistency may imply:

- Major adaptation(s) of the processing steps to produce RGV. RGV must be integrally recomputed with adjusted temporal and/or spatial settings and/or methodologies/procedures. Existing RGV values are replaced by the recomputed ones.

- Change of the entire monitoring strategy. RGV must be stopped, and a new RGV is started with a new strategy (e.g. new technique, new spatial and temporal settings) or no new RGV is started if monitoring is no longer possible. Existing RGV values are stored and a new RGV is started or not.

In any case, the following principles apply:

Table 4.6: RGV product requirements in terms of consistency of the RGV

Quality	Value	Additional information
Ideal	High	No adaptation of the processing steps to obtain consistent RGV is required. RGV consistency is ensured with high confidence.
Medium	Medium	Minor adaptation(s) of the processing steps to obtain consistent RGV is required. RGV consistency is ensured with medium confidence.
Minimal	Low	RGV consistency is not ensured (low confidence) due to: either major adaptation(s) of processing steps to obtain consistent RGV or change of the entire monitoring strategy. The RGV must either be recomputed and replaced with adjusted temporal/spatial settings and/or methodologies/procedures or stopped definitively.

Metadata

List of the essential description for RGV product.

General information:

- Source data, coordinates of the rock glacier unite, date of monitoring, provider's name, reviewer's name, etc.

Site characteristics:

- Rock glacier unit characterization in accordance with the inventorying guidelines (RoGI_PC Section 5c). See specific tables (74, 75).

Technique selection:

- Choice of technique according to constraints.
- Platform, tool, method, measurement footprint, measurement resolution, user dependent parameters, etc.

Processing steps to produce RGV:

- *Design of the monitoring setup:*
    - Temporal resolution: value and quality of frequency and observation time window.
    - Spatial resolution: location and quality of the single point, few discrete points, or area-based measurements.
- *Initial data acquisition:*
    - Description of the process to collect QA measurements of surface. velocity/displacement/position.
- *Initial data preparation:*
    - Description of the process to pre-process, verify, adjust, and evaluate initial data.
- *Velocity data processing*:
    - Description of the process to compute and clean velocity data.
- *RGV processing:*
    - Description of the process to spatially and/or temporally aggregate velocity data (gap filling, cluster or select and compute).
    - Quality of the RGV product.
- *RGV consistency:*
    - Quality of the RGV consistency.
    - Indication of adaptation and/or changes when needed.