# IPA Action Group Rock glacier inventories and kinematics

## Kinematics as an optional attribute of standardized rock glacier inventories

*(Comments to version 1.0)*

*https://www3.unifr.ch/geo/geomorphology/en/research/ipa-action-group-rock-glacier (Action Group website)*

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## Box 0 – Preamble

No comment

## Box 1 – Purpose of integrating kinematics in rock glacier inventories

Aerial instead of areal

I'm a little bit confused about the purpose of integrating kinematics in rock glacier inventories. I assume that a rock glacier inventory is already available, and kinematic information might be an optional attribute to be included. Of course, an automatic rock glacier detection would be of high interest supporting manual delineation/work. AI, such as machine learning (CNNs, etc.), could contribute a lot. Rock glacier inventories, incl. multi-spectral, multi-temporal orthophotos, DOMs/DTMs, velocity data, etc. could serve as valuable training data. But this is another topic.

Second paragraph: replace "attribute(s)" by "attributes" (the plural includes the singular as a particular case).

Page 3, penultimate paragraph: Replace "feature(s) and moving area(s)" by "features and moving areas" (the plural includes the singular as a particular case).

I suggest that the term kinematics should be defined as it is not clear to every reader what the authors mean exactly.

line 3: not only different methodologies, but also different purposes (mapping of pf indicators or mapping of ice bodies to quantify water sources makes a difference). This is also a reason why we find so diverse inventories from diverse communities.

Does the geomorphological approach also allow the activity assessment (from geomorphological indications), even when no kinematic data are available?

regional or national rock glacier inventories - have various dates - using different criteria

## Kinematics as an optional attribute in standardized rock glacier inventories?

## Box 2a – Background

"When speaking about the spatial heterogeneity of the velocity, a general explanation about how we could overcome this challenge is written (“However, …”) This is missing for the temporal variability of the velocity, where different variations are listed but no way to solve this potential issue in the framework of RG inventories is explained.

I would just add one sentence at the end (for ex. “However, in the framework of the rock glacier inventories, we are interested in adding a semi-quantitative (order of magnitude) kinematic information that has to be – as far as possible – representative of the annual behaviour”)."

The technologies currently used to continuously measure the velocity (e.g. a permanent GNSS station) collect data only for one/few points, whereas a spatially distributed velocity field can be measured with other methods (satellite SAR, UAV, photogrammetry,...). However, only the former technology can take measurements all over the year (independently from the snow cover). Therefore, to evaluate the sub-yearly and sub-seasonal velocity variations it is necessary to integrate different kind of measurements with very different spatial coverage (point vs. flow field). This should be taken into consideration, and the choice of the point used for continuous measurements should be made very carefully (i.e. representativeness).

I would detail the spatially heterogeneity a bit more (as for the temporal changes), speaking of frontal parts and rooting zones, as well as on different lobes on top of each other, with different rates and patterns.

"I'm just confused what ""latter"" and ""as so"" mean in the sentence: The velocity is spatially heterogeneous over a rock glacier. However, the flow field must display a high degree of coherence in a moving area (polygonal area) for the latter to be considered as so.

## Box 2b – Basic principles

Unclear what is the kinematical category.

Last sentence is confusing. The velocity class of a moving area and the kinematic attribute have just been listed separately before (and I think it is good) and then mixed again in the last sentence.

## Box 2c – Aim

"Aim" is not the right title. I suggest to simply remove this title and let this section in th same as the previous one.

Detail about last sentence: really long. If no significant change in the next version: rephrase. For ex: “The suitability and compatibility of the different types of produced data for characterizing rock glaciers and/or moving areas related to rock glaciers must be evaluated. The objective is to define standards applicable at global scale, which thus needs to be technology independent.”

Is it also the aim to differentiate between rock glaciers that are monitored continuously and rock glacier that are "just" inventoried once? Snapshot inventory versus monitoring.

# Proposition of standards

## Box 3a – Moving areas

"I wonder if “coherent/coherence” is the good terminology. In one hand, it can be confusing because it has another meaning in InSAR. And in addition, in its “common sense” meaning, it refers to some interpretation (what do we understand as “logical”/”consistent”). Maybe use “homogenous” instead? More descriptive/neutral somehow…

Another thing: “…the observed flow field (direction and velocity)…” Some techniques do not directly allow for documenting the direction. How do we practically deal with it? As the focus in on semi-quantitative velocity classes, I wonder if it is not safer and more practically realistic to just acknowledge this limitation, without starting to use too many assumptions (reprojection for ex)

Additional detail: First paragraph “There are basically two types of approaches…” could be moved to “2.1 Background”."

"Describing the kinematic state of a morphic field, such as a rock glacier, is not easy. With GNSS particle tracking is carried out. The same point is observed over time. With an outlined region (rectangular area, polygon, etc.) the same area in space is monitored. The aperture/window of observation is fixed in space. The rock glacier is moving through this aperture. Ideally, the aperture has to deform in time, as being part of the rock glacier's surface. The aperture problem is significant for fast moving rock glaciers.

Of course, combining remote sensing data (area) and point data (e.g. from GNSS), both complete or incomplete in space and time, is not easy in order to get correct time series, avoiding systematic errors."

UAV is not a method, i.e. you can either use LiDAR or photogrammetry and I assume that what is done next is methods such as change detection or PIV.

What about adding information on a profile (of single point measurements) over the entire landform? This is more than a single point information and may cover different areas.

and remote sensing based approaches

## Box 3b – Velocity class of a moving area

We will have to decide how many moving areas are mapped on a rock glacier unit and how to outline them. There can be for instance a central area with velocities distinctly higher than a surrounding area, even on a simple rock glacier unit. In this cas do we map 2 moving areas ?

A velocity class should also be attributed not only to a moving area, but also to a rock glacier or a rock glacier unit.

"Semi-quantitative classes of (2D-3D) velocity: same comment than in box 3a: Considering InSAR, LOS-measurements are 1D so practically how do we aim to solve it? Systematically calculate 2DInSAR by integrating ascending/descending? Not impossible but potentially complicated at large scale (+ lost of coverage as the geometries do not necessarily overlap in case of layover/shadow f.ex). By projection? Not necessarily better as it extrapolates the measurement towards an assumption (horizontal only, downslope only, etc) that is not necessarily correct in some cases. So question: is it not safer to accept the 1D limitation as we anyway speak about order of magnitude / semi-quantitative classification.

About the proposition of velocity values: the only problem I see is for the two upper classes (30-100 / >100). With InSAR, due to phase ambiguity: with 6d Sentinel-1 interferograms we get a theoretical max velocity of approx. 85 cm/yr -> (5.6/4/6)x365. So in some cases where we get decorrelation in 6d, we cannot be sure if it moves 90 cm/yr (which would fall into 30-100 class) or if it is >100.

Additional detail: “The related time characteristics (…) must be linked imperatively” What does “linked” mean? Documented in metadata?"

Unless the deformations are corrected into deformations in slope direction, these classes will be biased by the direction of the LOS and cannot be representative / compared.

How to quantitatively define the class of a rock glacier moving area? Is it the mean velocity (+ standard dev) of the surveyed points in the case, for example, of a RG monitored with GNSS? And in the case of velocities obtained from satellite SAR or feature tracking from aerial photogrammetry, is it the mean (+ standard dev) of the velocity field?

It is recommended to add the average slope angle of the moving area to the 2D value.

## Box 3c – Rock glacier kinematical attribute

I understand the idea to move from the vel.classes to these categories but that’s not going to be easy for some cases...

Taking a case where you have a relatively homogenous velocity over the whole RG falling into the class 30-100 cm/yr, how will you categorize it using the proposed attributes? Could be dm/yr (if closer to the 30 limit), dm/yr to m/yr (if around 50) or m/yr (if closer to 100 limit). And we cannot know if we just have the classified moving areas as input. It makes me think: shouldn’t we have more initial velocity classes for the moving areas?"

The focus should be clearly on annual flow velocities, being either mean or maximum values. The time interval should be always the same, one year or multiples thereof. The time window has to be stated. For proper interpretation the geographic location (northern, southern hemisphere, latitude) is needed.

To my opinion, the classification into different moving classes is not of great importance. It's a subjective grading. For reasons of comparison it is better to provide relative data, as indicated in the second document. Even better, information on acceleration/deceleration (= change of velocity) as a relative number could be a choice. This way no scaling to a dedicated reference time, e.g. 2014-2015/

max. velocity, or any arbitrarily time epoch, is needed. Thus, observation epochs not covering the reference time can be included in the analysis/graph showing acceleration/deceleration easily. Of course, through proper double integration the correct distances (derived from the measurements) may be derived.

internationally, dm is not used frequently, as such I suggest to only use cm and then m.

We should use standardized measuring units (m) instead of diverse ones (cm or dm)

## Box 3d – Open questions

"Could add to list of open questions (that was covered in the previous version of the doc, but not anymore):

- Undefined velocity: “when the methodology does not allow for characterization of the kinematic attribute, it should remain undefined”.
- How often should the kinematic attribute be updated?"

I would strongly suggest that you add a section about limitations. I understand that this isn't a technical guideline, the document would benefit from a chapter on the sever limitations (for example topographic shadows) of the proposed technologies as it will help the discussions and further development of the document.

"Information on other slope movements related to the respective rock glacier could be added in an additional field (at first).

Question 3 is important as the combination of different methods is an benefit; e.g. if you know about the flowfields on a multi-annual base (e.g. by UAV), you can make use of information from single points in the time in between."