IPA Action Group Rock glacier inventories and kinematics

Kinematics as an optional attribute of standardized rock glacier inventories

(Version 1.0)

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

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Authors and contributions

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Workshop II will be held on 11-13 February 2020 in Fribourg (Switzerland). A part of the workshop will focus on *kinematics as an optional attribute in rock glacier inventories*. The results of the workshop will be integrated in the next version of this document.

The purpose of this document is to serve as a baseline for the establishment of practical guidelines permitting the integration of kinematics as an optional attribute in standardized rock glacier inventories.

Preamble

Task 1 of the IPA (International Permafrost Association) Action Group *Rock glacier inventories and kinematics* (2018-2022) aims at exploring the feasibility of developing widely accepted standard guidelines for inventorying rock glaciers on a global scale, including information on their kinematics. *Baseline concepts* (Sub-Task 1.1) have been worked on and defined in a common contribution of the Action Group members, and *practical guidelines* for inventorying rock glaciers (Sub-Task 1.2) will be developed in accordance in a later stage.

The *baseline concepts* specify that **kinematics could be included as an optional attribute in standardized rock glacier inventories**. However, the way this inclusion could be performed requires further investigation.

The present document (**version 1.0**) sets the necessary concepts for including kinematics as an optional attribute in standardized rock glacier inventories. It results from a preparatory work performed by the scientific committee of the Action Group Workshop II. It aims at being a provisory document, which has to be finalized during the dedicated workshop in February 2020.

Any **feedback** regarding the content of the document is nevertheless warmly welcome in advance until **2 February 2020** using exclusively the dedicated boxes inserted at the end of each section.

Greyish inserts in the text have to be discussed/developed in particular during Workshop II.

Provisional timeline

- Comments on the present document (version 1.0) are expected until 2 February 2020 and will be discussed during the Workshop II.
- A post-workshop version (2.0) will be submitted as soon as possible after the workshop and again opened to comment in March/April 2020.
- The final version (3.0) is intended to be made available in June 2020.

Workshop II will be the opportunity to discuss/decide about the technical issues regarding the implementation of a kinematical attribute in the *practical guidelines* for inventorying rock glaciers.

If you have any comment about the previous section, please use this box.

Comment box 0

1. Purpose of integrating kinematics in rock glacier inventories

Today, although many (published or unpublished) regional rock glacier inventories exist, they are not exhaustive worldwide. Existing rock glacier inventories have various ages and have been compiled using different methodologies. For these reasons, merging all inventories in a fully coherent way is presently not possible. The IPA Action Group Rock glacier inventories and kinematics (2018-2022) has thus agreed to establish standard guidelines permitting the development and the fusion of inventories in a coherent way.

The increasing emergence of open-access and high-resolution remote sensing imagery (e.g. optical, SAR) facilitates the set-up of new inventories and/or the update of the former ones. Current increasing availability of remotely sensed data (e.g. Sentinel-1 SAR images) makes an almost systematic integration of kinematic attribute(s) in rock glacier inventories potentially feasible. In its *Baseline concepts towards standard guidelines for inventorying rock glaciers*, the Action Group has agreed that:

- the attribution of an activity category to a rock glacier unit could be based on adequate kinematical data, and
- if areal or point kinematical data are available, they should be integrated as a supplementary attribute and must be considered in order to assign the category of activity.

The *baseline concepts* document also describes the two complementary approaches in use for inventorying rock glaciers. The *practical inventorying guidelines* (Sub-Task 1.2) will have to make them as far as possible compatible. The two approaches are:

- the **geomorphological approach**, which is basically the expert recognition of rock glacier features in the (imaged) landscape permitting the set-up of exhaustive rock glacier inventories, and
- the **kinematical approach**, which is the detection and characterization of moving areas (not only rock glaciers), using multi-temporal remotely sensed data (e.g. SAR-derived products, multi-temporal airborne LIDAR, high resolution optical satellite and aerial images) and in which the typology assessment (and especially the rock glacier discrimination) is mainly performed by the recognition of the association of rock glacier feature(s) and moving area(s) on optical images (geomorphological approach). The kinematical approach does not allow an exhaustive identification of rock glaciers, as non-moving rock glaciers, for instance, are missed.

The present document aims at exploring the feasibility of including kinematical information in standardized rock glacier inventories.

If you have any comment about the previous section, please use this box.

Comment box 1

2. Kinematics as an optional attribute in standardized rock glacier inventories?

2.1. Background

Within the framework of rock glacier inventories, only surface velocity measurements can be taken into consideration. It has to be accepted that surface displacements are principally dependent on the motion rate of the rock glacier (permafrost creep), but that various processes (e.g. thaw subsidence) can alter this relationship.

The velocity is spatially heterogeneous over a rock glacier. However, the flow field (direction and velocity) must display a high degree of coherence (to be defined) in a moving area (polygonal area) for the latter to be considered as so. The velocity information extracted from a point must be in coherence with the displacement behavior of the surrounding area (moving area) in order to be taken into consideration.

The velocity is temporally changing:

- from year to year (description of the potential variations between an annual velocity and a multi-annual (e.g. 5-years) velocity has to be here inserted)
- within a year : a large amplitude is possible between the seasons, with usually higher velocities during or after the warm season (description of the potential differences between for instance the summer velocity and the annual velocity has to be here inserted)
- within a season : a large amplitude is possible within a season, with usually, but not necessarily a decreasing trend during the colder season and an accelerating trend during the warmer season (description of the potential difference between for instance the summer velocity and the annual velocity has to be here inserted)
- other changes over various time frames could occur (e.g. destabilization)

If you have any comment about the previous section, please use this box.

Comment box 2a

2.2. Basic principles

A kinematical category is attributed to a rock glacier unit. It is based on the velocity class(es) attributed to the moving area(s) related to rock glacier unit of concern.

Hence, the following sections are defining:

- the attribution of a **velocity class** to a moving area,
- the attribution of a **kinematical category** to a rock glacier unit.

The kinematical categorization, or by default the characteristics of the related moving areas, can be used to qualify the activity of a rock glacier unit.

If you have any comment about the previous section, please use this box.

Comment box 2b

2.3. Aim

The way a kinematical attribute could be integrated in rock glacier inventories needs to be standardized because it may refer to different types of values (e.g. the maximum velocity computed on the fastest area of a rock glacier unit, the mean velocity computed on the largest moving area or a range of values (min, max, mean, standard-deviation)) obtained with different techniques over different time frames.

The kinematical attribute associated to an inventoried rock glacier has to be spatially representative and should allow comparisons to be feasible in and between rock glaciers inventories at the regional scale as well as at the global one. Moreover, this attribute should be derivable from in situ measurements as well as from remote sensed based approaches. According to the measurement method and the availability of data, the considered time characteristics (e.g. time observation window, frequency) can also vary (e.g. seasonal, annual, multi-annual). 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 and interpreted from a global perspective of applicability in order to define any possible standard, which must be also technology independent. This is one of the main task of the Workshop II of the IPA Action Group.

If you have any comment about the previous section, please use this box.

Comment box 2c

2.3 Proposition of standards

There are basically two types of approach for measuring surface movements on rock glaciers: in-situ terrestrial surveys (e.g. repeated GNSS field campaigns, permanent GNSS stations) and remote sensed based approaches (e.g. InSAR, photogrammetry, UAV). Whereas some of them allow only for single location(s) on a rock glacier unit or single rock glacier(s), others offer the possibility to gain information at the regional scale allowing the characterization of a kinematical attribute for many rock glaciers in a uniform way.

2.3.1 Moving area

A moving area is an area (minimal extent to be defined) in which the observed flow field (direction and velocity) is coherent (coherence to be defined). A single point survey is basically not a moving area. However, the information provided by a single point survey could be taken into consideration only if relationships of the latter to any moving area could be stated.

If you have any comment about the previous section, please use this box.

Comment box 3a

2.3.2 Velocity class of a moving area

The velocity class is a variable characterizing the displacement rate observed in a moving area. It must refer to the dominant rate of movement observed within the area.

Some methodologies allow the observation of displacement during summertime only, making that the velocity value cannot be measured over an annual time interval. Others allow for the measurement of annual velocity or multi-annual velocity only.

Therefore, a velocity class assigned to a moving area is dependent on the technology and the conditions of observation. The related time characteristics (e.g. time observation window, frequency) must be linked imperatively.

Proposition:

Semi-quantitative classes of (2D or 3D) velocity:

- < 3 cm/yr (from no movement up to some cm/yr)*
- 3-10 cm/yr
- 10-30 cm/yr
- 30-100 cm/yr
- > 100 cm/yr**

Optional (if technologies allows for the measurement):

- < 1 cm/yr (no movement up to some mm/yr)*
- 1-3 cm/y *
- 100-300 cm/yr **
- > 300 cm/yr **

Difficulties in assigning a class when the velocity value in close to a category border.

How to attribute a velocity class to a moving area in a standardized way? Various options are feasible and must be discussed thoroughly at Worskhop II.

If you have any comment about the previous section, please use this box.

Comment box 3b

2.3.3 Rock glacier kinematical attribute

The objective is to define a kinematical attribute, which is spatially and temporally representative of the rock glacier unit of concern and allows (as much as possible) the integration of the different sources of information. Various kinds of kinematical attributes can be defined. For instance, it can refer to the maximum velocity observed on the fastest part of the rock glacier, or to the mean velocity computed over the whole moving part of the rock glacier.

The kinematical attribute associated to rock glacier inventories has to be defined in a standard way at the global scale, and must be technology independent. It should indicate the overall rate of movement observed at the surface of a rock glacier on an annual or multi-annual mean and be representative for that only.

According to the results of the User Survey provided during the Action Group Workshop I, the standard for a kinematical attribute should be representative for a magnitude order of velocity only (e.g. cm/yr, dm/yr, m/yr and higher).

Proposition:

The kinematical attribute assigned to a rock glacier unit indicates the overall rate of movement observed/estimated on a dominant part of its surface in an annual or multi-annual mean. The categorization consists of semi-quantitative classes of downslope displacement rate:

0. < cm/yr (no up to very few movement)
1. **cm/yr**
2. cm/yr to dm/yr
3. **dm/yr**
4. dm/yr to m/yr
5. **m/yr**
6. > m/yr

Categories 1, 3 and 5 are the primary classes. The others are intermediate or extreme classes. The category is assigned to a rock glacier unit, if velocity information is available for most of its surface. Assignment rules have to be discussed/developed during Workshop II.

If you have any comment about the previous section, please use this box.

Comment box 3c

2.4 Some general open questions

- Metadata - How to deal with initial datasets (level 1 products, e.g. map of slope movements, etc.)
- How to deal with other types of moving areas (e.g. landslides) next to or even directly spatially related to a rock glacier?
- How to deal with multi-source kinematics information if several methods are used in parallel over the same landform? How to merge dataset with different properties?

If you have any comment about the previous section, please use this box.

Comment box 4