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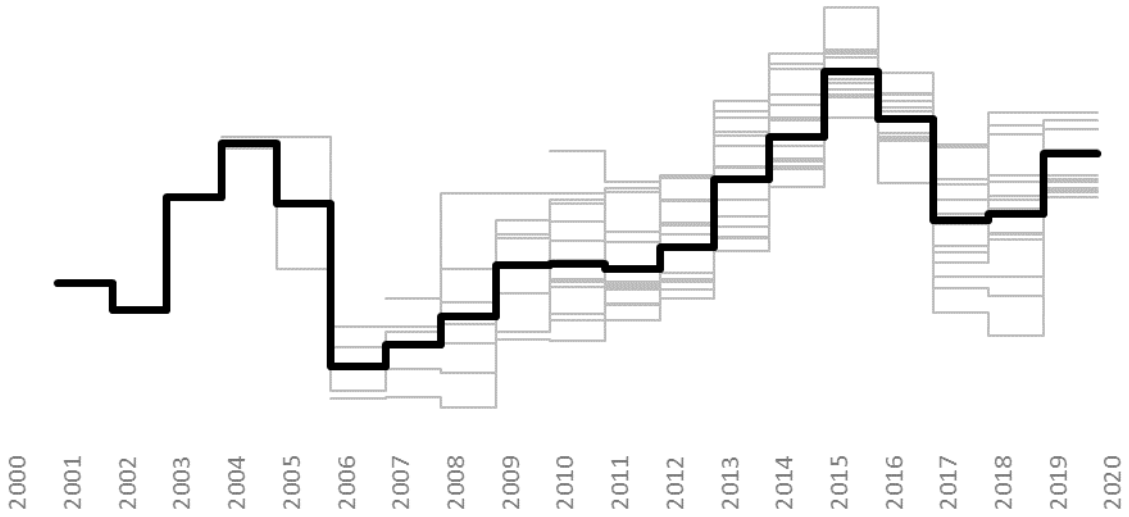
IPA Action Group Rock glacier inventories and kinematics

Rock Glacier Kinematics as an associated parameter of ECV Permafrost

(Comments to version 2.0)



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

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Box 0 – Preamble

- In the first paragraph, a sentence explaining what "rock glacier kinematics time series in a climate-oriented perspective" means is currently missing.
- Some words about the observed trends in Europe, Asia (others?) and that they are connected to the climate would explain it. A reference to the later sections in the document.
- One sentence with: "how to cite" would be beneficial.
- Little detail: I believe it should be "kinematic time series" (without s at kinematic when it is used as an adjective)
- Maybe just one thing that is missing at the beginning (purpose/relevance/background) or potentially at the end (as a conclusion, to close the loop) is to basically explains the final products we hope for (relative veloc. changes). There is explanation about the concomitant regional behavior etc. but for somebody that has not be in the whole discussion, it may not be so obvious what the final RGK products are.

Box 1 - Purpose

- Institutionalised in CH with PERMOS, anywhere else?
- "Motion rate" is not a technical term in kinematics. Please use displacement rate, or velocity for instantaneous values.
- In the second paragraph, one sentence to explain that this is the reason why monitoring rock glacier kinematics would fill the gap.
- In the footnote: "understood".
- I think there is some confusion in the text, I am not sure what you want to say, let me explain: shearing is the general word to indicate deformation due to shear stress (not in compression, tension or torsion). This does not necessarily refer to a specific forcing or process. *Answer: Rock glacier (or permafrost) creep has to be understood here as a generic term referring to the variable combination of both internal deformation within the crystalline structure of the frozen ground (creep stricto sensu) and shearing in one or several discrete layers at depth. (cf. Baseline concepts for inventorying rock glaciers that have been approved)*
- I suggest to add references, especially in the first paragraph (to give value to what has been done so far and provide a more profound basis for this initiative).
- Sentence "rock glacier velocity (kinematics) monitoring has been substantially expanded and institutionalized" is a bit clumsy: may be changed to: "The monitoring of rock glacier velocity (hereafter referred to as kinematics) has been substantially expanded and institutionalized."
- Sentence "The systematic and long-term monitoring of temporal changes in rock glacier kinematics provides information about the impact of climate on...": could be "... the impact of climate change on..."
- I think the first half of paragraph 2 could come at first (until "...in most regions on Earth."), as this is the main reason we aim to use RGK as an associated ECV parameter. So basically have it structured as: 1) relevance 2) why rock glaciers can be used as a climate change indicator (currently 1st paragraph) and then finish with remote sensing techniques?
- I don't really get the end "contribute to point out some specific evolutions of mountain permafrost." a bit vague I believe. Do you mean to identify specific regional patterns or common global ones? Or both?

Box 2.0 – Monitoring rock glaciers

- " In this context, rock glacier kinematics is defined as the quantification of the surface movement of a landform recognized as a rock glacier (cf. Baseline concepts for inventorying rock glaciers) and whose motion mechanism is dominantly related to permafrost creep" -> If the point of this is to emphasize that we should not focus on movement that are not from the coherent creep of an active rock glacier (such as subsidence in case of ice core melting, surficial erosion), maybe better to say it so more clearly?
- The following section presents... -> The following sections present...

Box 2.1 – Temporal variability

- "In addition, hydrological processes related to water infiltration (e.g. changing water content and pore pressure during snow melt or rainperiods),interactingwith the internal structureof the rock glacier,can playa significant role in short-term rock glacier kinematic behavior." I would delete "in addition" and "short term" in this sentence. In addition suggest a systematical difference between permafrost warming and water induced accelerations that does not exist. Long term changes are the sum of short term changes what makes this distinction obsolete. Changing hydrology contributes to rock glacier acceleration too.
- "The interannual variations are likely drivenbyannually fluctuating atmosphericfactors(e.g. air temperature, snow cover development)" atmospheric factors sounds strange for snow cover why not: "The interannual variations are likely driven by annually fluctuating snow cover height and timing, precipitation rates and air temperature."
- " whereas a decreasing trend is occurring throughout the cold season." better freezing season
- second last sentence: "or more frequently" is speculative. Actually these are two different processes and it is unclear which one is more frequent. Anyway, just a detail...
- Seasonal rhythm: From what I know, the seasonal variability is increasing in recent years. As far as I understand it, as the velocity is exponentially depending on temperature, so are the fluctuations. Not necessarily a constant trend, but the fastest years also have the largest oscillations.
- Regarding the last paragraph, saying "Behaviors diverging from the three above mentioned variabilities also occur and they are not necessarily associated with a direct climate impact on the rock glacier permafrost creep"... does this clearly mean that these (specific) landforms are excluded for the ECV?
- "Paragraph ""Seasonal rythm"" in a global view, in my opinion is not correct to speak about ""warm season"" and ""cold season"", i.e. for rock glaciers located al very low latitudes, where there is no a temperature-defined seasonality"
- What about making a little literature review of the key articles that evidence the RGK-temperature relationship? I remember we spoke about it for previous doc of the action group. While reading the first paragraph here I feel that could be useful to add (in a way or another) references that support the statements. I understand the point of not heavy an heavy author-date list for each sentence, but an appendix?

Box 2.2 Spatial variability

- "They also add to the observed surface motion an additional component that is not clearly related to permafrost creep." -> could be easier if writing "They add an additional movement component that is not..."

- This aspect must be evaluated carefully when providing a rock glacier kinematics time series, whatever the applied technique. -> the statement could be even stronger that this I think: we should basically avoid to document these processes. Not always possible to be sure of course but in "this aspect must be evaluated carefully" is a bit vague..
- + kinematic without s when "kinematic time series" ;)

Box 2.3 Available technologies

- "very nice table, I would avoid the last raw ""specific limitations"". I find it incomplete (it would require much more explanations) and misleading."
- "Table 1: - Are you sure about that radar applications use an eulerian reference? Don't you look at different scatters (boulders) which more or less represent moving surface points? (Eulerian differences are actually useless we should not consider them.)
- There are fast progresses in the question of dimensionallity. All point cloud methods (lidar/Photogrammetry) can provide full 3D deformations under the condition that the surface structure is preserved. This is quite new and we currently try to implement this in our analysis. Even some Radar processing methods allow to receive multidimensional results.
- The limitation row is not stringent. Snow is a problem for almost all methods. vegetation for all types of photogrammetry, radar and partly even for lidar. Atmospheric distoritions such as refraction or other run-time errors affect all methods. Clouds affect all methods except GNSS and Radar.
- "Table 1: delete ""Satellite shadowing"" for Total Station. the spatial coverage for airborne data I would set to ""local to regional"""
- "Table 1, line ""shadow effect"" I do not understand why ""satellite shadowing"" for the ""total station"""
- line "specific limitations" I would add "atmosphere" also to the total station technology
- Rock glacier kinematics monitoring techniques: not sure (could be checked with a native English), but would sound more natural to me to say: "Monitoring techniques for Rock glacier kinematics"
- Terrestrial surveys -> maybe in this context better to say "in-situ" cause for ex a TLS and a Ground-based radar are also terrestrial, but remote sensing as well ;)
- Really nice explanation of the ref. frames and beautiful table!
- Column headers: close-range remote sensing vs remote sensing -> why not just writing "terrestrial" vs "airborne/spaceborne".
- Not need for a - in spaceborne btw.
- Dimensionality: What does "Direct" mean before 1D coordinate for InSAR? In general, also not sure to understand "indirect-direct" under measurement value and dimension.
- Spatial resolution: looks weird to have > cm/m for some and a few cm/m for others. > m could theoretically mean km... Maybe a range of magnitude instead?
- Airborne last scanning: no shadow effect, really?
- Spaceborne InSAR accuracy: I would write mm-cm, it depends the temporal baseline, the atmo effects, the wavelength, etc.
- "SAR offset tracking is missing."

Box 2.4 General considerations

- "spatiality: I suggest to rephrase, in fact the current indication is hardly applicable. ... areas where ice-melt induced subsidence and strong chaotic movement of single boulders is expected/suspected should be avoided for the measurements.
- "Rock glaciersmust be described according to the inventorying baseline concepts Especially, the spatial connection to the upslope unit(e.g. connected to a glacier or not)leads to specific evolution of rock glacier velocitiesand has to be considered" -> rather unclear
- "Rock glacier kinematics time series should be recorded with an annual frequency" Also this section is partly hard to understand, especially the very long last sentence. I do not agree that annual measurements are better than multiannual or continuous measurements. I agree that an annual deformation value is optimal, however this is a different problem than the measurement frequency. Annual measurements are often not carried out at the same date of the year what causes distortions. Moreover annual measurements are as well influenced by seasonal signals which are often temporally shifted between the years and thus affect the annual measurement periods differently.
- "Considered surface displacementsshould represent the downslope movement of the rock glacier related to permafrost creepand should not be significantly altered by disturbing processes(e.g. movement of isolated boulder, ice melt induced subsidence). " Should not be altered by LOCAL disturbing processes. E.g. subsidence due to ice melt can occur area wide and is than hard to distinguish from creep."
- "Rock glacier kinematics time seriesmustbe technology independent." Good point but than we should first define the required type of deformation value. I guess real 3D lagrangian displacements right?"
- Regarding Time scale, annual frequency: I would relate the annual frequency a bit more specific to the so-called "hydrological year" (which is of course different on the Northern and Southern Hemisphere)
- I like the idea (and content) of the bold statements. Just maybe look at the way to present it cause it looks a bit weird with bullet points I think.
- timescale: "over the long term" or "over long time periods" I think?
- spatiality: ...or a representative part of it. maybe?
- technique: I guess for somebody who has not followed the thousand discussions about this, the statement and following explanation would sound a bit contradictory. Maybe it could be explain a bit more extensively that despite specific dimensionality, the relative temporal variations of the measurement is expected to technology-independent.

Box 3.1 Technical definition of RGK

- first paragraph: which technique can measure velocity directly? Isn't it always the result of some processing?
- 2nd paragraph: this is a repetition of what said already above. possibly delete?
- Same as for previous section, I think the sentence "the observed velocity change should not be significantly altered by the monitoring technique" is a bit too vague.
- Not sure it is necessary to write always "measured/computed". Even when you process remote sensing images with InSAR (or whatever else), the results can be called measurements. In any case you need to compute sth in a way or another (for in-situ as well). I think "measured" is enough.

- Why not simplify to: "Rock glacier kinematics (RGK) is defined as a time series of kinematic measurements on a representative part of a single rock glacier unit, with an annual or pluriannual frequency."

Box 3.2 – Kinematic data

- I think that this should be stated more clearly. Either it is possible to change methodology or it is not. If yes, some clear guidelines would make clear what ""consistent"" means. What requirements must be met?
- Are there actually going to be practical guidelines? As for the PIGs, maybe having everything in one document is more meaningful and has less repetitions.
- if exists a long enough period of overlap, maybe it is possible to change methodology within the same time series, e.g. changing from total station to GNSS. This could allow the time series to be extended.
- time-series -> time series

Box 3.3 RGK Spatial resolution

- is consistent used in the same way as above here? (same method?) I imagine that you just want to say that the point must remain the same, is it? But then, when you lose a point due to rolling or falling, is it not possible to substitute it with another one in the same area?"

Box 3.4 Temporal resolution

- When reading it, I now remember the point of measured vs computed ;)

  But I think it should be more clearly explained somewhere: continuous measurements over a season or year have to be averaged to provide an annual frequency (comparable to periodic measurements).

  Or basically just explain the measured / computed concepts at the beginning of section 3.

Box 3.5 Uncertainty

- with this definition of STABILITY, high stability means large bias. right? I am not an expert in time-series analysis, but I think that stable has a precise meaning, i.e. not going to infinity or something like that. this could be confusing without a clear definition.

- Sensor drift: suggestion to rephrase: "the relative contribution of the drift to the measurement cannot be estimated..." comment: this is not necessarily true. with inclinometer data it is possible to assess how much the boulder is rotating. some good assumptions on the center of rotation can allow the quantification of the rotation component, thus of the drift (in the example you propose). In fact, there might be always a rotational component to the movement of all boulders, mostly negligible. manual GNSS measurements are not different from the permanent stations (if an inclinometer is installed - the length of the mast is known and can be accounted for). the rest of the rotation is unknown for both methods."

- Change of surface: both eulerian and lagrangian approaches have problem with stability in the sense expressed in this paragaph. eulerian: if the mass fluxes change, the stability is compromised. (more mass coming from above or depletion of mass due to a sink downslope) lagrangian: if the topography (and the geometry as a consequence) change, stability is

compromised - straigthforward but hardly ever happens at the time scales that we monitor. to add: if external events change the surface (rockfall, collapses, large avalanches...) stability might be compromised"

- "The relative measurement uncertaintyof the kinematic data is defined as the measurement uncertaintyrelative to the magnitude of a particular kinematic data to allow the observation of velocity changes. " strange sentence
- Sensor drift: This term is probably a bit misleading as it is commonly used for measurement errors due to technical defects. What about: Secondary movements: Secondary movements are displacements of a permanent sensor platform (e.g. GNSS) which do not represent the large scale rock glacier creep (e.g. rotation of the boulder). Secondary movements cannot be estimated precisely since the causes arediverseand difficult to identify."
- Change of the observed surface: Solutions for this problem?"
- "Areas close to the margins of the moving mass may be also critical." -> may also be