[RG - rock glaciers, DG - debris covered glaciers]

Summary

This invited perspective manuscript discusses the application of criteria for identifying/detecting rock glaciers for two example sites, Gruben and Yerba Loca. A main focus is given to differentiating RG from DG. Following the introduction, Section 2 details how the criteria are applied to the Gruben site to distinguish the Gruben rock glacier from the neighbouring debris covered glacier. Section 3 discusses more complicated cases (contact zones of surface and subsurface ice) and concludes that *"neither the term "rock glacier" nor the term "debris-covered glacier" would be appropriate for such complex contact zones with their characteristically diffuse landforms."*

Section 4 critically states that contrasting views regarding the definition and genesis of rock glaciers exist in the scientific community, particularly regarding how RG differ and should be differentiated from DG. This section functions as a starting point for the following sections, which compare and contrast specific characteristics of RG and DG: Section 5 highlights that RG move as a result of viscous creep of permafrost. The "coherent movement pattern" of the creeping permafrost is transmitted to the surface debris, which is "interlocked" with the deeper layers. This results in characteristic furrows and ridges. In contrast, the surface debris of DG is not "interlocked" with the ice and there are no "coherent flow patterns" on the surface. Section 6 highlights that RG have oversteepened advancing fronts while advancing DG often show massive ice at the terminus. The Yerba Loca site is used as an example illustrating oversteepened fronts at RG and other features of creeping permafrost. Section 7 focuses on differences in the response of RG and DG to climate warming.

Section 8 reiterates key points made in the introduction and throughout the manuscript and concludes that RG and DG should and usually can be clearly distinguished based on the strategies developed by the IPA. Further, as stated in the introduction, the authors recommend that RG as permafrost phenomena remain under the purview of the GTN-P, while DG remain part of the GTN-G.

General comments

This is an important contribution to the ongoing discussion on identifying rock glaciers, e.g. for inventory purposes, and distinguishing them from debris covered glaciers and other landforms. A consistent approach and clear definitions are needed for RG inventorization and the RGIK/IPA guidelines provide a broadly applicable supporting framework for such efforts, many of which are currently ongoing in mountain regions around the world. The manuscript makes valuable points about separating RG from DG and will further support the development of community strategies and guidelines in this area. I am sure my comments/questions can be resolved and look forward to seeing this published in TC.

Terminology and definitions:

In my opinion it would be beneficial to explicitly include the wording of the guidelines/criteria that are applied, tested and referred to throughout, as well as clear definitions of RG and other terms. Perhaps the introduction could be expanded by a short dictionary style section listing key terminology. This could also include the brief comment on subsurface and surface ice currently in the supplement. The authors point out repeatedly that DG remain DG no matter what, given that they do not turn into RG (a central message of this manuscript). Accordingly, small dead ice bodies that can remain when glaciers melt and may be partially or completely debris covered are still considered DG ("glaciers") in the sense that they are "not rock glaciers". However, they are also no longer "glaciers" in the typical sense. The authors sometimes use the more descriptive phrase "debris covered surface ice" or similar for such cases, but the usage is not always consistent. Defining "glacier" in some way or always using variations of "surface ice" in the context of "complex cases" could help prevent terminology related confusion. The authors also mention a size limit that separates glaciers from "not glaciers" in glacier inventories. It would be helpful to state what this limit is. The readership of TC can certainly make an educated guess about this and other matters, but the clarity of the manuscript could nonetheless be improved by adding some definitions and consistently using the respective terminology.

Complex cases, ambiguous landforms:

The authors state in the introduction:

"An objective way of differentiating corresponding landforms and kinematics is essential in creating clarity when utilizing such landforms to assess where and how climate change impacts our planet, specifically the cryosphere, or when used in a regulatory/legal context, for example in view of hydrological significance; or generally, to avoid confusion and duplication."

It is certainly important to distinguish RG from DG for these purposes. It is also important to have a practical and consistent way of dealing with ambiguous landforms that cannot easily be categorised as either DG or RG particularly for inventorization purposes. When inventorization of cryospheric features is connected to regulatory measures, the measures in question often do not themselves give clear definitions of what exactly should and should not be included in the inventory. Having a community consensus on landform definitions beyond RG and DG and on dealing with ambiguity would be beneficial in such cases. Do the authors have a recommendation or further comments on how to deal with ambiguous landforms (buried surface ice as well subsurface ice other than RG) from an inventory perspective, or how a consensus based community strategy to this end might be developed?

I do not fully understand what the authors are suggesting related to the application of a size threshold and would appreciate more detail on this. Is the idea that a threshold (smaller than glaciers, thinner than underlying permafrost) helps identify the "complex cases" in a general sense, or should such thresholds be used as additional criteria alongside those of the RGIK/IPA for classification purposes? If the latter, how would this size limit be applied practically, for example when compiling an RG inventory? Should the excluded features be ignored in inventorization efforts?

Contrasting views:
The authors point out work by others that presents somewhat differing views on the distinction between RG and DG and RG genesis. Section 4 in particular is critical of these works. The authors have strong arguments that can stand alone and are not further strengthened by dismissive comments towards others. I would suggest revisiting this section and either expanding the overview of contrasting work for a more comprehensive picture (e.g. Knight et al, 2019; Jones et al, 2019, and others) or finding a more concise way of introducing the following sections.

Specific comments:
Introduction:
For clarity and to help the reader, I suggest including:

- the specific "proposed technical recommendations/guidelines" that are to be tested. Since the stated aim of the manuscript is to test and comment on the guidelines, it would be useful to explicitly mention what these guidelines are.
- the "technical definition of rock glaciers'' used by the RGIK/IPA, assuming the authors agree with this definition. A reference to section 4 of the manuscript's supplement (surface vs subsurface ice) could be added alongside the definition of rock glaciers to set the stage for the surface/subsurface arguments that follow in the later sections. Alternatively, the short paragraph explaining this as currently contained in the supplement could simply be added to the main text.

The two RGIK documents cited by the authors list two mandatory "geomorphological criteria" for rock glacier detection (front and lateral margins) and one optional criterion (ridge-and-furrow topography, section 3a in the RGIK (2022) baseline concepts). The manuscript discusses RG fronts (Section 6) and ridge-furrow topography (Section 5) but does not mention the lateral margins criterion. If the aim is to test the RGIK criteria, a brief explanation of why lateral margins as a mandatory criterion are being excluded from this exercise of testing and commenting would be helpful. If criteria other than those listed in the RGIK document are being tested, please clarify.

Section 2: Rock glacier and cold debris-covered glacier at the Gruben site
L95 *The differences are obvious, and the morphological criteria proposed by the IPA action group are adequate*
Consider specifying what these criteria are.
Fig 2: I suggest adding a reference to the very helpful Fig. Sup.-1 in the supplement to the caption of this figure.

Section 3: Complex zones with contacts between surface and subsurface ice
L 125 *not every piece of surface ice is a "glacier"*
It might be useful to briefly define your usage of the term "glacier" here or earlier in the manuscript, see general comment.

L 139 *mostly smaller than the lower size limit applied to the term "glacier" in glacier inventories*
For clarity, please state what this size limit is / give citations. Not all glacier inventories use consistent size limits and some make a case for including very small, debris covered ice bodies in regions where deglaciation is imminent. (See e.g. the discussion in Section 5.4 of Fischer et al (2021))

Section 4 - debris covered glaciers remain debris covered glaciers
L 148: What would the authors consider "adequate" in this context? Perhaps a statement could be made on minimum required quantitative information.

L151: can DG turn into "complex cases" of buried surface ice in contact with permafrost features as discussed in the previous section as a third option? If so, should that be added to the list as option C? If not it would be useful to briefly clarify.

L153 *lavastream-like*
Consider omitting in the interest of precise usage of terminology.

L163 *Nevertheless, it is useful to understand the reason why this is the case …*
Why what is the case? I find this sentence hard to follow, consider rephrasing. See also the general comment.

Section 6 … as visible at advancing fronts…
L217: *Advancing debris-covered glaciers have become exceptional under conditions of atmospheric temperature rise and predominating glacier shrinkage. In such increasingly rare cases, massive ice of the flowing glacier is usually visible at near- vertical fronts where debris cannot accumulate (Figure 4).*
Does this imply that Belvedere Glacier (Fig 4) is currently advancing? Afaik that is not the case.

L220: *The advantages of adequately interpreting over-steepened fronts of creeping frozen talus/debris can be illustrated with an example from the Andes….*
Fig 5 shows oversteepened fronts marked by yellow arrows at rock glaciers (1, 2, 3) and ambiguous landforms (4, 5). What information is gained by "adequately interpreting" the oversteepened fronts and what does "adequate" mean in this context? Perhaps it would be informative to walk through all three of the RGIK/IPA criteria for rock glacier detection (fronts, lateral margins, furrow-ridge topography) for the Yerba Loca landforms to clearly show how the criteria can help separate rock glaciers from other landforms.

Section 7 … and its effects on ice loss as a response to long-term warming trends
L267: *…and hardly ever appears at advancing fronts*
Are there studies showing massive ice at advancing fronts? citations?

Section 8
L277 *The rich available quantitative knowledge basis from borehole and geophysical data in combination with advanced material- /process-related understanding enables safe and straightforward discrimination between rock glaciers as viscous creep phenomena in ice-rich mountain permafrost and debris-covered glaciers. The corresponding strategies recommended by experts of the International Permafrost Association are clear and easy to follow.*
I suggest briefly stating again what the recommended strategies are. Borehole and geophysical data are available only for a small fraction of RG, DG, and other landforms. It could be pointed out that since the RGIK/IPA strategies are informed by and developed based on the process understanding and rich quantitative knowledge basis the

authors refer to, they may be especially helpful in cases when inventories are being compiled without comprehensive geophysical information or boreholes.

L283 *Complex contact zones of surface ice (mostly perennial snow and ice patches, glacierets or small glaciers) with creep phenomena in ice-rich permafrost in cases constitute diffuse landforms beyond "either-or"- type landform classification.*

I understand that an in depth discussion may be beyond the scope of this manuscript, but would the authors consider these ambiguous landforms the responsibility of the GTN-P or GTN-G? How should they be inventoried? I agree that they are "beyond simplistic landform attribution" but they are relevant for inventories as assessments of the changing cryosphere in regulatory and or hydrological contexts.

Personally, I would like to see the conclusion link back to the stated aim of the introduction, i.e. testing the application of the guidelines of the RGIK/IPA at the Gruben and Yerba Loca sites. Perhaps a brief summary pertaining to this aspect of the manuscript could be added, maybe with some generalised conclusions regarding the usefulness of the specific mandatory and optional criteria (as per RGIK 2022, 3a) that can be derived from the characteristics of the two test sites, i.e., RG and DG in close vicinity at Gruben and different kinds of creeping permafrost at Yerba Loca.

Typos and such:

L161 & L271: I suggest replacing "safely" with "definitively" or a similar word.
L261: Check spelling of Moelg/Mölg in citation

Supplement:
Part 2, kinematics Yerba Loca: Can you indicate which of the numbered features (1-5) in Fig 5 are shown in Fig.-Sup. 1-3?
Fig. Sup-2: typos in the caption, "Sub" instead of Sup
Part 4: not referenced in the manuscript? I suggest moving this f

References:
Fischer, A., Schwaizer, G., Seiser, B., Helfricht, K., & Stocker-Waldhuber, M. (2021). High-resolution inventory to capture glacier disintegration in the Austrian Silvretta. *The Cryosphere*, *15*(10), 4637-4654.

Jones, D. B., Harrison, S., & Anderson, K. (2019). Mountain glacier-to-rock glacier transition. *Global and Planetary Change*, *181*, 102999.

Knight, J., Harrison, S., & Jones, D. B. (2019). Rock glaciers and the geomorphological evolution of deglacierizing mountains. *Geomorphology*, *324*, 14-24.

RGIK (2022). Towards standard guidelines for inventorying rock glaciers: Baseline concepts (version 4.2.2). IPA Action Group Rock glacier inventories and kinematics, 13 p. https://bigweb.unifr.ch/Science/Geosciences/Geomorphology/Pub/Website/IPA/CurrentVersion/Current_Baseline_Concepts_Inventorying_Rock_Glaciers.pdf