

The Cryosphere Discuss., referee comment RC2  
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## Comment on tc-2021-167

Camilo Rada Giacaman (Referee)

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Referee comment on "Brief communication: A framework to classify glaciers for water resource evaluation and management in the Southern Andes" by Nicole Schaffer and Shelley MacDonell, The Cryosphere Discuss., <https://doi.org/10.5194/tc-2021-167-RC2>, 2021

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### General comments:

1) The manuscript is well written and presents a sound classification schema of glaciers based on their sensitivity to environmental change. The methodology has solid support in the literature, and the consideration of this new classification is likely to be a valuable contribution to the management of glaciers, especially concerning their hydrological services.

2) The work is presented as a contribution towards the development of GPL, particularly as a solution to inadequate definitions in the Chilean GPL projects. In that sense, there is no clear articulation between the proposed classification and the GPLs. Both Chilean and Argentinean GPLs avoid conflict and ambiguities by protecting all glaciers equally, regardless of their type, size, location or debris cover. In that context, it is hard to understand how this classification schema can help the design of a law proposal of consensus and without the "legal issues" mentioned for the Argentinean GPL. If the authors propose a type-dependent level of protection (as stated in lines 224-225, 261), that should be clearly stated and followed with well-elaborated reasoning to support that proposal. Arguably, a type-dependent level of protection will only complicate things, especially given that the classification is sometimes ambiguous (lines 115-116) and changes with time (lines 159-164). In some sections, it even seems that the authors suggest a case-by-case assignation of the level of protection (lines 274-278). Much emphasis was put on the usefulness of the proposed classification for glacier management. However, the Argentinean GPL and Chilean GPL proposals aim to protect glaciers, not to manage them.

If the authors are mainly suggesting a type-dependent monitoring program or the addition of this classification to national inventory fields (as stated in line 271), this should be

clearly stated from the start. In such a case, they should also include a more detailed explanation of how this classification will help water resources management and a throughout motivation of the methodology. For example, why a classification is better than a "sensitivity index" or case-by-case modelling.

3) Following the facts detailed in lines 31-32, it seems inaccurate to refer to glaciers/landforms as sensitive/insensitive. The differences seem to be related only to the timescales of their response to environmental changes. Maybe fast/slow response might be better terminology.

4) The main proxy to assess glacier change is mass balance, which depends on accumulation and ablation. However, this works seems to focus entirely on the ablation part of the equation.

In avalanche-fed glaciers, which is often the case for categories 2 or 3 (semi-sensitive and insulated), there could be a high climatic sensitivity associated with the snow accumulation on surrounding slopes that are not even part of the glacier. While such glaciers would "melt away slowly" due to their debris cover, their mass gain mechanism might have a very high sensitivity to environmental changes. In these cases, their water storage capability at inter-annual timescales would also have a high sensitivity to environmental change.

5) The use of the term "landform" makes the manuscript very confusing. While it can refer to anything (a glacier, a ridge, a mountain), it is often used to refer to a glacier, where the direct use of the term "glacier" would make the text much clearer. In some cases, for the same glacier the text says that it is a landform composed of multiple glacier types, and that it is a glacier composed of multiple landform types (line 118: "Where a landform is made up of multiple glacier types (Fig. 1a [Tapado Glacier])", lines 125-126 "Tapado Glacier [Fig. 1a] is made up of the three distinct landform types..."). Other sections use the concept of "glacier morphology" (line 161). More consistent use of the terminology is necessary: "Glacier" and "surface-type" could be better concepts to use (instead of randomly interchange either of those by "landform").

6) In the context of GPL and glacier inventories. It seems that the authors propose the use of their methodology nationwide or throughout the Andes. However, the examples presented in figures and Table 1 are biased to the semi-arid Andes; the same is true regarding the accuracy check proposed in line 234. All examples are within four degrees of latitude. It must be clear what is the geographical area for which this methodology has been designed. If the application area is the whole of the Andes, the authors should address the different challenges posed by tropical and Patagonian glaciers.

## **Specific comments (numbers refer to manuscript version 2) :**

7: In the context of this paragraph and in particular the GPLs, "landform types" have a very different and more specific meaning than used in the rest of the text, as the most controversial definitions that have hindered consensus of the Chilean GPL are the definitions of Glacier, Periglacial, and permafrost. However, "landform types" in the manuscript refers interchangeably to glaciers or parts of a glacier with a distinct surface type (based on debris cover). This difference gives the impression to the reader that this work offers a direct solution to the definitions controversy that, has been in part, the cause of the lack of consensus, which is wrong.

21-22: Given that the authors seem to be opening the discussion over the idea of not protecting all glaciers equally but depending on their hydrological behaviour. It seems very important to elaborate on what legal issues have hindered the application of the Argentinean GPL, or at least give a reference for that affirmation.

23-24: This requires further elaboration. It is unclear how distinguishing between glacier types can reduce the legal ambiguity. In general, one would think that the current approach of Chilean and Argentinean GPLs (protecting all glaciers regardless of type) is less ambiguous than differential protection based on a glacier classification schema.

39: The switch between the "glacier" terminology and the use of "landform" should be explained here. Otherwise, simply keep using "glacier."

77-80: It seems against the objectives of this work to base the threshold of debris thickness on a single glacier. Arguably, debris type can have a significant influence, as well as the partitioning of the different melt processes affecting a glacier. In areas where sublimation is the primary melt process, a thin layer of debris might be enough to reduce melting significantly. In other cases, such as the temperate glaciers of New Zealand and Patagonia, a large amount of the melting is due to rain, and perhaps a much thicker debris cover is required to reduce melt rates. Pirámide glacier might be representative only of glaciers where shortwave radiation is the dominant melting process.

121-123: Again, it seems against the objectives of this work to include ambiguous criteria like this (what is "very minor"?).

Figure 2: Please include coordinates or some ID (either in the figure or caption) for all unnamed glaciers (b-f). Alternatively, add to the caption a reference to the additional information available in Table 1.

144-149: It is confusing to use the term "landform" when you mean "glacier". Unless the authors want to refer to different sections of a glacier but with different surface types, however, if that is the case, it does not make sense to say that the insulated part of Tapado Glacier is insensitive to environmental change while its accumulation area is a sensitive "landform".

159: "It is likely" seems a euphemism for something that unquestionably will happen.

Table 1: What is the point of comparing this article classification with DGA/IANIGLA classification? Each of these is classifying completely different attributes of the glacier: Glacier sensitivity to environmental change in this article, glacier shape/main characterizing feature for DGA, and glacier debris cover for IANIGLA.

214: Which are the distinct hydrological roles? The authors only point to differences in the timescales and the degree to which these glacier types play a role as water reservoirs.

227-229: While that might be more objective, it seems a nightmare from a legal point of view. One can picture a development project affecting a sensitive glacier because a logistic regression happens to assign it to the wrong category.

256-257: As for line 214, it seems that "role" is not the best word to distinguish between the hydrological effects of different types of glaciers.