

Review of Beniston et al., The European mountain cryosphere: A review of its current state, trends and future challenges

Based on the reviewer's comments the paper was clearly improved. However, I am still struggling with my decision for this paper, by hesitating between reject and possibly accept after revisions. The paper is still a weak summary report on the status of European mountain cryosphere, unfortunately, without showing significant new results and without deriving any clear conclusion (which is my main concern). Additionally, I also do not see a strong review work of the status of research on European mountain cryosphere. I really wonder if such paper is needed to support cryospheric sciences and the research community. Maybe there is some value of the paper as a result of the Riederalp workshop mentioned in the acknowledgements. But, why is it not possible to make something more significant out from this workshop material?

According to my understanding a review article should do a critical, constructive analysis of the existing literature by summarizing, classifying, analyzing and comparing. This needs real work to be done and, to some degree, this is what I miss in the Beniston et al. paper.

General comments:

The title of the paper was slightly changed. The title of the paper is now "The European mountain cryosphere: A review of its current state, trends and future challenges". This is also reflected by the general structuring schema of the paper, which seems logical. However, the structure is filled up with too weak content. Even with good will, I hardly can derive any useful take home message after reading the paper. Additionally, the paper follows a concept of rather subjective examples selected (e.g. for cryosphere impacts), which is hard to understand.

As the aim of the paper is a review of European mountain cryosphere, I would like to see the introduction to be more informative on this topic. Is this the first review of European mountain cryosphere? Probably it is the first one covering all cryosphere components, but there are several reviews for single cryosphere components (e.g. snow cover or glaciers). Though the topic is on European mountains, there is no clear definition which mountain regions are included and how "mountain regions" are defined for this study. Obviously, Svalbard is included (and is not defined as Arctic cryosphere). What about other mountain regions in Europe e.g. of the Russian territory? Shouldn't they be part of a review on European mountain cryosphere?

Given the new title of the paper, it would be good to define at the beginning of the paper how you quantify both the "current state" and "trends" of the cryosphere components. Ideally, it should be done by some comparable statistical measures, but clearly practice could be different. I wonder how you define the "status" of a cryo component. For glaciers you provide data on area and volume. For permafrost you only show borehole temperatures (as it is the standardized GTN-P variable). Would be good to show the areal extent of permafrost from empirical modelling efforts, though there is significant uncertainty on the data. Otherwise, what is the current status of permafrost (a ground temperature)? Additionally, you have borehole data from Switzerland and France but not from Germany, Italy or Austria? Are there no useful data from there? Are your borehole temperature data representative for the entire Alps then?

For some of the cryosphere components your review of the status and changes of the European mountain cryosphere is based on snapshots only. SWE (as the example for snow shown in Figure 1) excludes e.g. Scandinavian and Carpathian Mountains or the Pyrenees. Why not use an example where you have all regions covered by you snow example.

My main concern, however, is related to the conclusions of the paper. Currently, the paper concludes that:

- (i) Mountain cryosphere research urgently needs data of high quality
- (ii) Access to state of the art models with high spatial and temporal resolution are needed for better understanding of feedbacks and future behavior
- (iii) Communicating research results is a challenge and needs careful consideration
- (iv) From the focus of impacts cryosphere is key element of environmental changes in high mountain regions.

These four items from above are nothing relevant and there is no real conclusion related to the presented material of the paper. In particular, there is no conclusion related to the topic of the paper: the current status, trends and future challenges of mountain cryosphere (maybe the presented conclusion could be somehow related to future challenges, but the drawn conclusions are nothing new). Such results (type of conclusions) could be useful as a workshop report but not for a scientific review paper.

The authors also state that in their paper much attention has been devoted to data issues. Data issues are clearly an important task of cryosphere sciences. However, the discussion on data issues remains rather general/superficial and on topics which are quite well known. Important topics such as gaps in observations, standardization of measurements, best practices for observations, data quality control and data homogenization are not really captured in-depth. Again, I can't see much value in a paper which remains that generally and which excludes the relevant challenges of science.

Uncertainty: The paper explains the difference between uncertainty and error as well as the different meaning of forecast and scenario. However, nothing, with respect to uncertainty, is related to the cryosphere data itself. This is not useful. The different meaning of uncertainty vs error and forecast vs scenario can be found in many textbooks of climatology, no need to explain it here. However, it would be good to get some information on uncertainty of presented data of glacier/permafrost/snow status and changes. I also still see no much value in Figure 9 (difference between gridded data of precipitation from different sources). Without going into more details of gridding procedure and underlying observational networks this Figure is hard to understand.

Page 14/10: The comment of increased severe flooding in the Alps for the future is on weak basis and is not appropriate. There are large number of papers on this topic for the Alpine region showing that the general statement covering the entire Alps is not useful, consequently a regionalized focus on floods is needed (e.g. Blöschl et al., 2015). Gobiet et al. (2014), so generally an important contribution, is not a good reference for floods in the Alpine region. The same is for droughts. Your reference to Gobiet et al. (2014) is fuzzy if you argue an increase of occurrence and severity. Do you speak about future scenarios? There is no increased trend of droughts observed for the Alpine region (as described in Gobiet et al., 2014).

Page14/25: You mention in the introduction of your paper that you do not capture lake ice. However it is mentioned here under the heading of "changes in meltwater hydrology". This is rather unmotivated and I suggest to cover the topic of lake ice right from the beginning or to omit it entirely.

I am not convinced by your example of alpine ibex for impacts of cryosphere on ecosystem functioning, as this species is particularly vulnerable not only to impacts from climate and cryosphere

change but also from disease (e.g. scabies). I guess there are other more robust examples like plant species.

Blöschl, G., Gaál, L., Hall, J., Kiss, A., Komma, J., Nester, T., Parajka, J., Perdigão, R. A. P., Plavcová, L., Rogger, M., Salinas, J. L. and Viglione, A. (2015), Increasing river floods: fiction or reality?. *WIREs Water*, 2: 329–344. doi:10.1002/wat2.1079

Minor comments:

The paper still needs major revision, which makes it not useful to list all minor issues here. Thus I focus on comments to Figures only:

Figure 1: In the light of paper title would be very good/needed to cover also other regions of the European mountains for showing snow (SWE) trends

Figure 2: Why not include glaciers from Russian mountain regions? Or make clear why they are excluded!

Figure 3: see my previous comment (borehole temperatures from Germany, Austria, Italy).

Figures 4 and 5: these Figures are rather site specific in terms of a review of all mountain regions in Europe (would like to see more on cryosphere changes in mountain region in Europe in general)

Figure 6: Again this Figure is rather site specific. Why not aggregate it into one Figure with the useful results from various simulations done by Huss et al., for Switzerland or similar simulations for all other mountain regions in Europe?

Figure 7: See my previous comment (I think this example is too speculative and there are other, more powerful, examples for impacts of snow on ecosystem functioning)

Figure 9: See my previous comment. Additionally, if you use this Figure you have to explain all acronyms.

Figure 10: Motivation to show this Figure appears rather weak to me. In particular if you set the number of Figure with marginal information on status/change of European cryosphere (5 figures) against the number of figures providing information on the key topic of the paper (5 figures from which 2 are with site specific information for Switzerland only)