

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

General comment:

Though the paper again improved through several revisions made by the authors for this new version of the paper, I am still not convinced from the outcome. The review for the European mountain cryosphere is still rather chapter wise and not cross-cutting, which, however, would be particularly attractive to be done for the mountain cryosphere. In order to make my statement clear I show one example:

Chapter 2.2 discusses past and future glacier changes and gives good overview on existing studies for e.g. future glacier scenarios of the Alps (Marzeion et al., 2012; Radic et al., 2014; Huss and Hock, 2015). The subsequent chapter 2.4 on changes in meltwater hydrology mentions the relevance of future glacier loss, however references totally different publications (Beniston, 2012; Pellicciotti et al., 2014; Hanzer et al., 2017) for the same topic as in chapter 2.2. Why not cross-link to chapter 2.2 when discussing the topic of volume loss of glaciers in chapter 2.4.? Additionally, in particular M. Huss published a lot on glacier/snow melt and related discharge in Switzerland/the Alps, which is not reflected in chapter 2.4 and is more representative than the papers listed under chapter 2.4.

This brings me to another general comment to the Beniston et al. paper. I can't derive clear logic in your system for referencing relevant papers for particular topic of mountain cryosphere research. Is it just by example or is it that you list authors who contributes first for the particular topic, or is it the most recent work/study performed related to the particular topic? You should make this clear and follow it throughout the paper.

I do not like your repeating statements of the high uncertainty in results from observations and modelling efforts for the individual cryosphere components (snow, glacier, permafrost). Clearly your statement is true, but it would rather interesting for the cryo-community to get more ideas to overcome the high uncertainties by new approaches.

Finally, there is high number of typos in the new paragraphs added to the paper, e.g. in the abstract (mid-range altitudes, understanfing, future cryospheric reserch, ...), which is not expression for careful work. Similarly, the section on snow has high number of typos.

Concluding my review and considering what was said by the other reviewers, I see some value of the work of Beniston et al. for scientists new to the field of mountain cryosphere research and in the compendium of existing literature related to mountain cryosphere research in the Alps and Norway. However, I see this paper also as a missed opportunity to provide a state of the art review on the status of mountain cryosphere in Europe.

Detailed comments:

P2/13: Make the meaning of "drastic consequences" more clear. Does it link to drinking water, irrigation and hydropower production? In fact you show in the paper that changes for hydropower production will be minor. Why is it drastic for irrigation or drinking water supply?

P4/13: What do you mean by NAO influence on pressure field? NAO is a simple index of the pressure field over the Atlantic. Please make more clear the cascade of impacts.

The section on snow has particular high number of typos. Please correct.

P6/30: Can't understand your sentence: „To date, the combined evolution of snow amount, type (dry, wet), and density in complex mountain topography remains 30 virtually unknown.” Do you mean snow type or type of avalanches?

P7/11: What do you mean by “potentially higher instability levels”? Please specify.

P8/21-22: Why should there be a relationship between NAO and glacier mass balance? I guess because of the relationship between NAO and temperature/precipitation. Thus, because of spatial and temporal differences in NAO-precip/temperature relationship there is also a similar relationship between NAO and glacier mass balance. Your statement “In the European Alps, the relationship between the NAO and glacier surface mass balance is less pronounced (Marzeion and Nesje, 2012; Thibert et al., 2013).” is rather lacking relevant information. Either make more detailed or skip.

P8/24-26: Engelhardt et al., 2015 is not a study considering sensitivity of ablation to albedo but sensitivity of mass balance to climate (temperature/precipitation) in general.

P11/11: You introduce the term “thickness of the seasonal thaw layer” here, but elsewhere you are using the term “active layer”. Either rephrase or make clear if you use the two terms with different meaning.

P15/25-26: You mention the observational time series of Rhine river here. Please specify what is measured since 1808.

It would be good to describe by few sentences the study on River Rhine streamflow in the past 100 years:

http://www.chr-khr.org/sites/default/files/chrpublications/asg-rhein_synthesis_en.pdf,

as this is a very detailed study on the impact of glaciers and snow cover on discharge for the Rhine catchment (unfortunately not fully published by peer-review papers).

P16/4: Your statement on “general trend towards drier summer” needs clarification. Is this based on drought indices? Specify how you define “drier” here and make some temporal reference. Some sentences below you reference van der Schrier et al., 2007 which showed no increase in droughts for the Alpine region.

P16/4-5: Your statement on more frequent severe flooding due to heavy/extended precipitation is valid for Switzerland only (at least from your listed references). Could you make clearer if this is valid for the entire Alps. Could you also make clear how changes of the cryosphere relate to changes in flooding (and also droughts, in the past and in the future). Are there no studies from Norway or Sweden on the changes in meltwater hydrology in Scandinavian mountains which should be mentioned here?

P16/7-9: Please rephrase this sentence: “It must be noted, however, that a cutoff beyond which ROS events will decrease with increasing temperatures is expected after snow cover extent has significantly reduced (Beniston and Stoffel, 2016).” Not clear what you mean here.

For chapter 2.5 please make the impact of cryosphere on hydrology and related water management activities clearer. Currently, it is rather fuzzy from your paper what will be the impact of the cryosphere and what are impacts of climate change in general.

P16/23: Your statement on reduced soil water content needs reference.

P16/25: Please specify “more frequent droughts” (for the future?).

P17/2-3: I guess you mean “weather and climate conditions” and not “meteorological and climate conditions”.

P17/10-11: You could list studies from other countries, too. (e.g. Austria where hydropower is particular relevant)

P17/21: Your review is on winter tourism only. Either make this clear in the chapter heading or add something for summer tourism, too.

P18/20: I would mention not only topography itself but also atmospheric processes related to the interaction with topography.

P23/4: Do not understand your statement: “In its solid form, it determines the level of the snowline”. I would say air temperature defines snowline.

P23/9: What do you mean by “homogenized precipitation stations”. You always have undercatch for precipitation at high elevations (which is much higher than 30%) and which make homogenization for precipitation in mountain regions not possible.

P23/19: How can you quantify solid precipitation and liquid precipitation by laser (ALS, TLS)? You can quantify snow distribution but this is clearly different from precipitation.

P23/19: Could you specify the progress in measuring snow distribution (methods, approaches).

P23/31: Glacier retreat and permafrost thaw are noticeable on yearly time scale. However, estimating significant trends needs longer observation periods.

P24/3: Strasser et al., is not a proper reference for showing the importance of long-term monitoring programs in general, as it only describes the example of the Ötztal catchment.

P24/31: replace “glacier ice” by “glaciers”.

P25/14-15: As mentioned above: make the “drastic impacts” clear.

P25/24: You mention air temperature and precipitation as drivers here. What about radiation? (which is the main driver for glacier melt and permafrost thaw).