

## ***Interactive comment on “The European mountain cryosphere: A review of past, current and future issues” by Martin Beniston et al.***

**Anonymous Referee #3**

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I read the paper with great interest expecting a rather ambitious work. Both, the large number of authors involved as well as the long list of cited papers already reflect the great challenge and effort of such work. The objective of the paper is clearly useful for the scientific community and thus important to be done. In fact, my first thought was that the benefit of such paper would particularly come from the future issues section, thus stimulating future research. However, also a synthesizing approach (covering all components of the cryosphere) could be something for relevant new conclusions/take home messages for the reader. After reading the paper, I was surprised that the paper failed to meet one of the two aims rather clearly. My impression is that the team (though each of the authors is well-experienced and key scientist in cryosphere research) spent too less time for the work and it thus ended up with a report-like paper, summarizing to a large degree the presentations of the workshop at Riederalp/Switzerland. The rather

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subjective selection of described impacts of cryosphere on hydrology and ecosystem functioning supports my statement. I do not want ending-up too negative. As I said, the topic of the work is clearly important. However, for getting the paper impacting and relevant for “The Cryosphere”, the authors have to rework and significantly improve their paper.

General comments: My major concern is: “What can the reader learn from the paper as it stands now?” “What is the benefit of the paper in comparison to the list of individual papers summarized/extracted there”? My expectation is that from summarizing the previous studies/papers new insight/findings should result. This is what I clearly miss in the paper. It is much too much a summary of previous studies without extracting new information and introducing innovation.

Further, I do not really see the benefit of sections 2.4 to 2.6 for achieving the aim of the paper. These chapters make the paper longer and leaves the reader alone with question why exactly these topics were selected as examples (there are several things left out with respect to e.g. the cryosphere and ecosystem functioning or the cryosphere and hydrological impacts, which are important). For your discussion of past, current and future issues of mountain cryosphere the detailed description of impacts is not needed (at least not as shown in the paper now). If you want to show issues/challenges coming from the impacts you have to make this more explicit.

In section 2.1 the past and future evolution of snow is described. Surprisingly, there is no single figure on snow development in the paper. However, snow could be seen as the key component of the cryosphere, highly relevant not by itself but also as a key forcing of changes of glaciers and permafrost through direct impact and various feedbacks. Thus, at least one figure on changes of snow parameters as well as their spatiotemporal evolution would be key for a paper on the status/changes of the cryosphere.

Section 3.1 deals with data issues for cryosphere observations. Though very important, this section is clearly too vague. There is neither distinction between ground

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observations and satellite products/data nor a clear concept what is needed in the future. Without a clear concept the requirement for improving cryosphere observations is weak and not applicable for the reader. What about guidelines/best practices in cryosphere observations? Are there needs for standardization of measurement? Could existing homogenization methods be easily adopted for cryosphere variables? There are clearly more questions to be addressed under this chapter. Consequently, either the authors deal with the subject of data issues in more detail and extensive or they skip it. The current version is without real value.

If the aim of the paper is to deal with mountain cryosphere your discussion has to cover more than only glaciers, permafrost and snow, such as lake- and river ice or cave ice. At least you have to make clear that (and why) you exclude these parts of the mountain cryosphere (because of whatever reasons).

Chapters covering both the glacier changes and the changes of snow cover are rather descriptive without real understanding of underlying mechanisms, beside the impact of NAO. However, the discussion of the impact of the NAO on snow and glaciers in the Alps and Scandinavia remains general. This appears bit "old-fashioned" approach and leaves the reader with simple findings which are already well known.

Under chapter 3.7 (uncertainty) the comparison between different precipitation data sets in Europe as well as the model uncertainty for precipitation from RCMs is shown. This again comes a bit unexpected. Why is this relevant in the context of "changing mountain cryosphere"? Is it useful to discuss this here, with a few sentences only? This needs to be made more clear and better described.

Generally, the paper is too descriptive and without an integrating approach (e.g. synthesizing the findings from snow, glaciers and permafrost to new information). My impression is also, after reading the paper, that your main aim was not achieved. The challenges that need to be addressed in future research remains open. For example, you mention data-issues as a core challenge. However, your conclusion on this impor-

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tant topic are rather general and un-specific and implies no in-depth treatment of the topic.

My suggestion is to clearly rework the paper and try to make take home message much more evident for the reader. Such take home messages could come from e.g.: - Added value from putting together the information from all different components of the cryosphere (snow, permafrost, glaciers) and try to derive extensive findings, e.g. you could describe how mass balance changes of glaciers fits with changes of summer-snow at high mountain sites and how this contradicts with winter snow. Which seasonal climate sensitivity was observed for glaciers-, permafrost change and how has it changed with time since the begin of observations. How do snow trends fit to mass balances of glaciers? - Added value from putting the focus on Europe thus interpreting the findings from Scandinavia/Alps/Pyrenees for an European perspective of understanding of climate change. Do we have gaps in the observations with respect to spatial coverage? For a comprehensive view of change of mountain cryosphere I would very much like to see also other time series of changes of the cryosphere such as freshwater ice or ice in caves.

Because of the weaknesses of the paper described above, also the conclusions are rather un-specific. In a similar way, the abstract is too short giving no clear information on what could be expected (concise and complete summary) for the reader. This needs to be improved.

Specific comments: The title of the paper is about past and future issues of mountain cryosphere in Europe. However, what do the authors mean by past and future (which timescale). This is nowhere defined in the paper.

Heading 2.3.4 Modelling (please explain with respect to what?)

In chapter 2.4. you are discussing changes in hydrology, however in fact you are discussing changes in stream flow (amount) only. The references list needs to be re-worked. Many references cited are missing.

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Figures 1 and 2: Would be good to know where the measurements of glacier length/mass balance and borehole temperatures are located in Europe.

Figure 4: Figure captions has to be increased in size.

Figure 5: The figure needs to be simplified and more generalized for a review paper. What is the meaning of dashed lines?

Figure 6 and 7: See my comments under "General comments". You have two figures for this rather specific impacts but no figure on snow. My advice is to skip at least one of these figures.

Figure 9: What is the temporal reference of the figure?

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