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Interactive comment on "Evolution of Ossoue Glacier (French Pyrenees) since the end of the Little Ice Age" *by* R. Marti et al.

Anonymous Referee #2

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This paper presents a comprehensive assessment of long-term changes in a Pyrenean glacier. The authors have compiled an extensive basis consisting of various field data and geodetic surveys that allow reconstructing the evolution of Ossue Glacier since the end of the Little Ice Age. As glaciers in the Pyrenees are not well studied (e.g. in comparison to glaciers in the Alps) this article is a valuable addition to the literature. Furthermore, the processes determining the mass balance and the response of very small glaciers to climate change is not yet well known and new process understanding can be transferred to glaciers in other mountain ranges.

However, a considerable amount of work is required before this paper can be accepted. Most of my substantive comments refer to the presentation of the material. The paper is significantly too long at present with too many tables (see comments below). Fur-

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thermore, the description of some approaches needs to be clarified.

Substantive Comments:

(1) Positioning of study: The actual aim of the study should be better specified. What do the authors want to find out with their data compilation? Was is the main research question? The argument of utilizing glaciers as a climate archive is somewhat delicate in my opinion as long-term meteorological measurements in the Pyrenees (also at high elevation, Pic du Midi) exist, and are used to interpret glacier data. However, I am sure that various other interesting questions could be defined and be addressed with the Ossue data set.

(2) Length of the paper: More than half of the tables could be removed without a loss in clarity. Furthermore, also the text could be shortened and be made more concise which facilitates the reading. I provide specific suggestions below.

(3) Glacier indicators: One subtopic of the paper are the so-called “glacier indicators”. This part is weak and could be completely removed. First, it does not become clear what “glacier indicators” are (the term also seems to be inappropriate). Second, the definition is highly qualitative. Third, it remains unclear what can actually be learned from this analysis. A more quantitative approach would be more beneficial. Lastly, the presentation of the glacier indicators (Results, Discussion) is very short and leaves the reader with more questions than answers.

(4) Calculation of geodetic mass balances: For the calculation of elevation changes, glacier is subdivided into two regions: (1) the area ice-covered in both DEMs and (2) the margin (only covered by one DEM). This approach is uncommon to studies of glacier volume change and geodetic mass balances and it makes interpretation of the results more difficult. For the calculation of the geodetic mass balance see e.g. Zemp et al. (2013). In response to this comment Table 10 and the text should be revised.

(5) Future of Ossue Glacier: The simple assessment of future glacier evolution should

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be revised / rethought. It is, for example, unclear why the authors define thickness classes that are “multiples of 1.5”. The simplest approach would be to subtract the average distribution of surface mass balance 2011-2013 (in ice equivalent) from the measured thickness distribution in each year. This would be transparent, easy to describe and also account for the more negative mass balances in glacier center (page 2459, lines 10-20)

(6) Comparison to glaciers in the Alps: One of the most promising potential aspects of this study would be a more detailed comparison of the long-term changes in Ossue Glacier in comparison to glaciers in the Alps. Such a comparison (in terms of annual mass balance / long-term volume change) would not be difficult to achieve but very interesting regarding differences in the most important driving factors between the Pyrenees and the Alps.

(7) English language: Throughout the paper the language could be improved (native English speaker).

Details Comments:

- Page 2433, line 4: What does this elevation mean? It does not seem to be related to the study site. Should be removed.

- Page 2436: Although this historical overview is interesting, it would benefit from some shortening

- Page 2436, line 8: Time periods for area changes in European Alps should be given; should be consistent with that of the Pyrenees.

- Equation 3: I suggest following Zemp et al (2013) here (as elsewhere in the paper). Normally geodetic mass balance is expressed in m w.e. a-1. The time components is missing in the present formulation

- Page 2443, line 20: I do not completely agree with that. This assumption would only hold if the entire firn coverage has been completely (!) removed already by 1983. This

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was most likely not the case. In contrary, I expect firn thickness to be at a maximum (after some glacier mass gains) and has almost disappeared until now resulting in a volume loss with a density <900 kg m-3.

- Equation 4/5: If the systematic error (bias) is known / can be quantified, the DEM should be corrected accordingly. In that case, the error would not appear in the uncertainty assessment. Obviously, the authors were able to quantify their systematic errors. They could thus simplify this section.

- Equation 7/8: The subscript “bias” for a random error seems to be inappropriate. Bias normally means a systematic error.

- Page 2447, line 4: I have the impression that this approach is not feasible: When measuring surface elevation change using a dGPS both the contribution from melting and ice dynamics (flow) are measured. These results can, thus, not be directly compared to local surface mass balance and would result in a too high error estimate. Of course, the impact of glacier flow will not be very large on a small glacier but the aim is to quantify uncertainties in the range of decimetres.

- Page 2447, line 15: I have troubles to follow the authors’ approaches here. Should be clarified.

- Page 2447, line 21: The unit should be m w.e. a-1

- Page 2449, line 10-23: These data should be presented in a data section

- Page 2450, line 17: What is the rationale of using Spearman’s rho instead of the more often used correlation coefficient r2? The latter would, in my opinion, by easier to interpret and understand.

- Page 2452, line 9: Avoid separating “current” glacier area and margin and state geodetic balances. Consequently, most of this chapter should reformulated.

- Page 2452, line 10: Here and throughout the paper. The stated periods are only de-

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fined by the dates of the available maps and are unrelated to actual climate variations! Interpretations should account for this.

- Page 2454, line 8: What is “monthly” summer ablation? Has ablation been measured in monthly resolution?

- Page 2457, line 18: also here, the stated periods should discussed with care. 1999 did not mark the end of any period – recession continued until today.

- page 2459, lines 10-20: This a different topic (spatial distribution of surface mass balance) and should be separated from the discussion of expected future evolution

Tables and Figures:

- Table 1: Could be removed. The important information (elevation range, length, location) are already given in the text. The rest is not necessary for understanding the paper. Alternatively the authors could envisage publication of this table as a supplementary material.

- Table 2: This Table is important and should remain in the main paper. However, it would benefit of some shortening by using less text (e.g. abbreviations for methods, remove source characteristics – already available from text)

- Table 4: remove or put into supplementary material

- Table 5: remove or put into supplementary material

- Table 6: These thresholds are highly qualitative and only valid for this single glacier. I would completely remove this topic (glacier indicators) from the paper

- Table 7: This information is directly shown in a figure (where it is easier to understand). Therefore, this Table is not necessary and should be moved into the supplementary material

- Tables 8 and 9: same comment as for Tab 7

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- Table 10: This table contains important data on the direct observation of mass balance, as well as seasonal components. I suggest swapping rows and columns to make it easier to read. The cumulative MB can be omitted.

- Table 11: also here: swap rows and columns. The symbols (B_w etc) should be explained in the caption

- Figures 8 and 9: Provide label for y-axis!!

- Figure 10: too small to read. Omit this topic completely (see comments above)

- Figure 11: Provide label for y-axis, including units!! Furthermore, I would suggest to combine Figs 11 and 9 (at least for some variables) as the goal is to establish a link between variations in the glacier and climate (T, P, NAO, AMO)

Interactive comment on The Cryosphere Discuss., 9, 2431, 2015.