**The Cryosphere
Discussions**

Interactive comment on "Variability of snow depth at the plot scale: implications for mean depth estimation and sampling strategies" *by* J. I. López-Moreno et al.

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Response to "Variability of snow depth at the plot scale: implications for mean depth estimation and sampling strategies" by

J. I. López-Moreno et al. Anonymous Referee #2

We want to thank to reviewer 2 the positive comments about the manuscript and the usefulness of his comments and suggestions. His main concerns are again focused on the representativeness of the dataset and the chosen plot size. Thus, answers done to referee 1 may be useful to address these concerns, and changes done accordingly reviewer 1 have helped in some cases to solve some questions raised by reviewer 2.

Below we explain the changes introduced in the manuscript according to his comments and we answer some questions done by the reviewer:

1- The limitation of such a study is that the results (reported error and number of samples needed for representativeness) may not be directly applicable to other regions.

The specific numbers given about the number of necessary number of measurements and their spacing is not directly applicable to other regions, and this is stated in the discussion, as well as in the response to R1 (see answer n19_R1). However, the analysis done with simulated series have permitted to isolate the impact of snow variability and autocorrelation in snow estimation, and numbers provided in this regard are applicable to all sites. The aim of the paper is to present an estimation of the impact of sampling strategy on error estimation at the plot scale, and the interest to conduct similar analysis in other areas like the Pyrenees where long-term survey are planned. We hope that this aim is clearer in the revised version with the changes introduced in the abstract and the conclusions following the recommendations of R1.

2- No measurement plots were positioned beneath the forest canopy where interception and subsequent ablation might be expected to strongly govern spatial covariance of snow depth during the accumulation season

We completely agree with this comment and we assume that certain environments like beneath the forest or in alpine scree slopes the covariance will be strongly determined. Response to point 1 can also be used to this comment. We did not aim to provide a universal sampling strategy to all environments; just indicate how variability and spatial autocorrelation may affect to estimation of snowpack at the plot scale. We have mentioned specifically this idea in the discussion section: "The aim of this research was not to provide guidance for sampling in other geographical areas or surface terrain characteristics, but highlights the usefulness of considering this type of analysis during the planning of snow surveys".

3- In other words, might the range actually be much greater if a slightly larger plot

overlapped both vegetated and open areas? I believe this is a particularly relevant question as the 'plot' is expanded to the 'satellite pixel' scale (i.e. 30 x 30 m).

This is a very interesting comment that we have added to the discussion section. "Moreover, it is logical to assume that the range actually be much greater if a slightly larger plot overlapped both vegetated and open areas. This is a particularly relevant question as the considered plot is of larger size than considered in this study".

4- The authors stop short of discussing survey design considerations when plot-scale variability itself is a significant variable both spatially and seasonally. A sentence or two about the dynamic nature of the variability (in space and time) might be helpful to identify pertinent future research objectives.

We include in the revised manuscript: "A better understanding of the factors that influence the spatial and temporal patterns of snowpack variability and spatial autocorrelation at the plot scale will aid efforts to obtain high quality snow datasets. We have presented information of 15 plots in two different periods of the year. However, we could find a larger range of variability and spatial correlation if a more detailed temporal resolution of the surveys, and a higher variety of environments (i.e. sub-canopy plots, high mountain areas, etc) would have been sampled. Further research could be addressed to analyze the dynamic nature of the variability (in space and time), which could reveal additional information for improving the accuracy of snow depth estimation".

5. The authors present standard deviation values repeatedly in the text and figures that lack units. Include units with all appropriate variables.

The units are the same than for the variable to which are referred (snow depth in this case). Thus is in cm. accordingly we have added it to Figure 5, 7 and 8 and we have included the units throughout the text in the manuscript.

6- Spell out common numbers under 10 throughout the manuscript.

Done

7- I think structure of the paper is acceptable, but the flow of the paper would greatly benefit from a succinct objective statement followed by a few science questions, which are later answered in the Discussion / Conclusion.

Reviewer 1 has done the same suggestion, as well as some comments regarding to the movement of some sections from introduction to data and methods. We have followed all these suggestions (see answers 3 and 5 to R1).

8- Page 1628, Lines 14-15: The sentence: 'The spatial autocorrelation of snowpack distribution can affect the local representativeness of snowpack.' is vague regarding the scale being considered. It doesn't seem to add much to the abstract. Consider removing.

The phrase has been removed

9- The point about satellite data and aerial imagery seems out of place when the topic is variability of snow depth at the plot scale. To what snow depth products do the authors refer? Be explicit and include references.

We have removed this phrase, as it does not contribute key information. In our opinion it is not worth to develop more detailed comments on satellite and aerial data and it is better to remove it.

10- Rewrite sentence for clarity. Current sentence suggests that field surveys are capable of 'considering'.

- In the revised sentence says: "It is necessary to consider the appropriate number and distribution of samples necessary to adequately assess the spatial variability of snow depth in a given area (Watson et al., 2006).

11- Change: ': : :(i.e. areas in the order of : : :' to: ': : :(i.e. areas on the order of : : :'

Done

12- Page 1630, Line 6: '10 mËĘ2' is a typo., it should be 100 mËĘ2 or 10 x 10 m.

Changed to 100 m2

13. The authors need to be more clear and explicit in the definition of the 'plot-scale'.

We have defined it as follows: "areas on the order of 100 m2 where the snow surface seems homogeneous from the perspective of a surveyor".

14. Page 1630, Line 9: Perhaps "seemingly random" effects of wind redistribution? "complex effects of : : :".

It has been changed according to the comment 6 of referee 1.

15. Page 1630, Lines 12-14: Change, ": : : averaging the measurements over different locations within a plot." to be clearer: ": : : averaging measurements made at different locations within a plot."

Changed

16. Be consistent with unit inclusivity in context of areal descriptors: (10 m x 10 m) vs. (10 x 10 m)

Done

17. How were the specifications of the standard deviation classes and levels of auto-correlation derived? Were these values and ranges determined from the results of the field data analysis? Did the authors determine the values subjectively or objectively? Be explicit with your methodology in this paragraph as the specifics have significant implications on the results and conclusions.

We have added this sentence to clarify this point: "Standard deviation classes and levels of autocorrelation were defined according to the maximum snow depth variability and spatial autocorrelation observed in the sampled plots in the study area".

18. Consider changing the measurement design descriptors from "a plus" to " : : : a '+' configuration : : :". The symbol rather than its grammatical spelling is more similar to

the 'L' configuration and emphasizes the point in a clearer fashion.

Changed in all the manuscript

19. The sentence ending with ": : : statistically significant" is miss- ing a period.

Corrected

20. Page 1635, Lines 12- 14: Does the sentence, " : : : the ANOVA test did not indicate a significant difference between the two environments." refer to a difference in the mean snow depth between the two environments? Please clarify.

The anova-test compared the coefficients of variation. It has been clarified as follows: ANOVA test confirmed that the differences in the coefficient of variation of snow depth between the two environments were statistically significant

21. Page 1636, Line 7: It is my understanding that 'loess' is an acronym for 'locally weighted scatterplot smoothing', and should thus be explained as such and included in capital letters in the text. See (and possibly reference): Cleveland, W.S. (1979). "Robust Locally Weighted Regression and Smoothing Scatterplots". Journal of the American Statistical Association 74 (368): 829–836. doi:10.2307/2286407

We have been followed the suggestion and added the reference

22. Page 1636, Lines 19-20: Shorten sentence to be more succinct: "In natural situations completely random sampling of snow is rarely achievable because of a variety of difficulties including variability in the distribution of snow-covered terrain." Could be written as: "In natural situations completely random sampling of snow is rarely achiev-able because of a variety of difficulties including terrain complexity."

Changed

23. Page 1637, Lines 1-3: Regarding the sentence, "Both figures demonstrate : : :"; Be explicit in your reference to specific figures.

Done

24. Page 1638, Lines 22-24: This sentence should be re-written, "To improve the accuracy of snowpack estimates, data for individual plots must be averaged from a set of replicate snow measurements within the plot." to remove redundancy and clarify. " : : : data from individual plots : : :" ": : : data : : : must be averaged from a set of replicate : : : measurements : : :". Is confusing as written.

We have changed it as follows: "To improve the accuracy of snowpack estimates, it is necessary to average several measurements taken within each plot".

25. Page 1639, Lines 22-24: In regard to the sentence, "An explanation for this relationship is that irregularities in the terrain are consistent in size, and thus their relative influence on the snow depth decreases as the snowpack depth increases : " What do the authors mean by 'consistent in size'? In what dimension(s)? Only the vertical? If the authors refer also to horizontal terrain patterns, are the patterns being adequately captured at the plot scale? Be specific.

Reviewer is right to point that the phrase is unclear. We think that this is solved just changing consistent by constant. The phrase is now as follows: "An explanation for this relationship is that irregularities in the terrain are constant in size, and thus their relative influence on the snow depth decreases as the snowpack depth increases"

27. Page 1639, Lines 22-24: in regard to the sentence: "In both surveys differences were found in the variability of plots in forest openings relative to those in open areas ." Be explicit and describe / reiterate the relative differences. There is also an erroneous space before the sentence's period.

We have modified the phrase accordingly to the original intended meaning: "In both surveys higher snow depth variability was found in the plots located in forest openings relative to those in open areas".

28. Page 1640, Line 6 (and elsewhere): Check the Journals preferred citation method

when including a citation within a sentence. "Holgram et al., (1998) recognized : : :". The names may need to be italicized.

Done.

29. Page 1641, Line 1: Missing a period after "a plot sized area" Ok

30. Page 1647, Figure 2: Need to include symbol descriptors in caption or in a legend.

They have been included in the Figure

31. Page 1648, Figure 3: Describe the vertical lines in the caption or remove them. We have removed them since they introduced confusion and did not provide valuable information

32. Page 1649, Figure 4: Sub-figures are not of equal size and relative orientation as such the tick marks are not properly aligned. Y-axis tick marks are slightly offset between the two figures in A. (not a result of orientation but figure creation)

Corrected

33. Page 1650, Figure 5: It seems like the authors set a benchmark error of 10 % in the text, and refer to 5 % error in the conclusions. Perhaps it would improve figure clarity if contour lines (5 %, 10 %) with labels were included indicating the standard deviation and sample size influence on these error benchmarks

We have added contour lines indicating the 5 and 10% of error. It improves noticeably the readability of the figure.

Authors would like stress again our gratitude for the useful comments which have improved the clarity and many scientific and formal aspects of the manuscript.

Please also note the supplement to this comment:
http://www.the-cryosphere-discuss.net/5/C793/2011/tcd-5-C793-2011-supplement.pdf

Interactive comment on The Cryosphere Discuss., 5, 1627, 2011.

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