

Interactive comment on “Changes in the firn structure of the Greenland Ice Sheet caused by recent warming” by S. de la Pe na et al.

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We thank referee 1 Dr. Lora Koenig for her comments and recommendations. Please find the commentary and the response to specific remarks below. All changes/corrections will be shown in the final draft.

Response to Scientific Comments:

By recommendation of two reviewers the paper title has changed to “Changes in the firn structure of the western Greenland Ice Sheet caused by recent warming”.

In regards to the selection of Operation IceBridge data, the Snow Radar transect overlaps the ATM data presented, and it is the only transect that goes from the ablation zone to the ice divide repeatedly between 2011 and 2014 that also overpasses close

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to the research sites. Snow Radar observations in 2013 after the warm year of 2012 may have been a better selection but unfortunately there are errors in the data that year and can't be used. The retracker was only used below 2450 m on purpose. At this elevation, isochrones can be observed to a depth greater than 5 m, evidence that no significant amount of ice is present in the snowpack to prevent radar signal penetration. The goal of this is to show the signal from the layer of ice (and a proxy for the extent of the area where ice layers are found), not the signal caused by hoar as seen in the dry snow zone. This has been clarified in the text.

We have added to the statement referred on page 551 line 20 further explanation. We state that in order to have supraglacial transport of meltwater over firn, limited buffering conditions must exist (i.e. seasonal ice layers must inhibit percolation). The sentence is a conditional one, and it is preceded by acknowledgement that evidence of lateral meltwater transport was not found at sites. The full sentence now reads:

“We found no evidence of meltwater pathways or pond formation at our sites. If, however, melt continues to exceed total accumulation and climatological conditions that allow the formation of ice layers that limit the buffering capacity of the firn continue, it is likely that lateral supraglacial transport and eventual runoff of meltwater will reach to 2000 m elevation”.

Response to detailed comments:

1. (p543 In 7) Corrected to “firn-ice content”. 2. (p543 In 17) The logic is that total snow accumulation, either from direct snowfall or wind redistribution, was subject to melt and later refrozen. The sentences now reads as follows: “modeled annual melt and refreezing rates in the percolation zone at elevations below 2100 m surpass the annual snowfall from the previous year, implying that mass gain in the region is retained after melt in the form of refrozen meltwater.” 3. (p545 In 1) At least until now and at this elevation range, observations show refrozen meltwater that is retained within the firn and subsequently buried by winter accumulation. There is no indication in this

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region that retained ice is released at a later stage, at least not in liquid form. 4. (p545 ln 1) Corrected to “firn-ice content”. 5. (p545 ln 25) The text now specifies snow pits are 2-3 m deep. 6. (p546 ln 21) Added frequency range (2-6.5 GHz), range resolution (~5cm), and citation of Panzer et al., 2013. 7. (p547) For the Greenland Ice Sheet, RACMO2.3 is coupled with a multilayer snow model (up to 100 layers), which calculates melt, percolation, refreezing and runoff of meltwater. There is no routing scheme in the model. This may be an issue when identifying exactly where the runoff/no-runoff limit lies, which has been taken into account in the uncertainty level in the estimates for both the total percolation area and total refrozen meltwater retained. These details have been included in the referred paragraph. This however does not change our statement that mass gain in the percolation zone (in areas with no runoff) below 2100 m in 2012 was mostly in the form of superimposed ice, which is what we found in the field. 8. (p548 ln 2) We have added ice layer thickness as well as mass. 9. (p550 ln 14) Corrected. 10. (p551 ln 17) Corrected. 11. (p551 ln 24) Predicted for each period presented – the 1958-1999 average for Figure 7a, and 2012 for Figure 7b. The document has been modified to reflect this more clearly. 12. Text now states that the increase in area was of 240% 13. Figure 1. The figure has been updated as suggested. 14. Figure 4. The figure inset is meant to show with more detail the variable radar response to the layer retracked shown in the larger image. We believe adding the tracked layer to the inset would partially obscure the details, but is easily doable if editor and referee prefer it. 15. The data has been smoothed along-track. The noise observed at low elevations is still present and may be the result of surface roughness. 16. The figure has been updated as suggested, clearly showing data for 2013. 17. Corrected.

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