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# *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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Many thanks for the comments. Individual remarks are addressed below. Please refer to the References section in the paper for citations. There were more changes made to the document based on referees comments, and described in the response to each reviewer.

548-19: The reflection of the radar signal occurs at the top of a layer formed after the last melt cycle of the previous season. The small variability in the depth retrieved from the snow radar is consistent with the depth differences of the top melt layer measured in the T and J sites sites, and it is likely the result of wind redistribution of winter snow rather than a difference in percolation depth. It is apparent in the observations taken during different campaigns that the uppermost melt layer is formed more or less at the



same time, probably by abrupt densification of soaked snow at the surface at the end of summer. Under this end-of-melt-season layer, previous stratigraphic studies indicate the presence of percolation pipes that were 10s of cm long (e.g. Benson et al., 1962; Scott et al. 2006a and 2006b; Parry et al., 2007; Helm et al., 2007). Warming during the 2012 season melted the total 2011-2012 winter accumulation, refreezing on top of the 2011 end of melt surface effectively forming one single layer at least at sites below 2200 m. Other years, melt formed multiple, closely spaced thick layers. There is evidence of meltwater percolating from one layer to another, but the heterogeneity of the snowpack and the high ice content found during the last seasons makes percolation depth difficult to assess.

548-21: The layer found in 2012 appears continuous over all J sites closely at the same depth. each site is separated by 25 km, and the layer is likely impermeable at least between J1 and J3 given layer thickness. The radar signal shows continuity for tens of km, but as noted there is also some breaks.

548-23: T5 is the site of the 2004 study made by Parry et al. (2007) and is shown in Figure 2 at the lowest site of campaign labeled 'EGIG line 2004'.

549-6: Unfortunately, there was a problem with the data acquired over this transect by OIB snow radar in 2013.

549-10: It is unlikely that wet, saturated, near-surface snowpack in the 1600-1800 m elevation range would remain unfrozen over winter due to freezing conditions. Even in springtime, this region is subject to temperatures well below the freezing point. The reason for a weaker radar signal from under the surface is likely the result of surface roughness, for instance, the extensive crevassed fields found closer to the coast in western Greenland.

552-11: The lower limit of the percolation zone is masked by the area where RACMO2.3 predicts meltwater runoff small. The elevation where this limit lies varies from year to year; the variability is less in the 1958-1999 period for which we use the

average shown in Figure 7a, while the mask is estimated individually for the years after 2000. Closer inspection to Figure 7 may show the difference, although it is not immediately apparent. A larger source of uncertainty is the differences between melt rates and actual ice content found in the field. In areas where predicted melt exceeds accumulation we assume total accumulation is in the form of ice. In other areas, we use a percentage of the total predicted melt based on the actual amount of ice found in the field.

Table 1. 2013 observations will be added here.

Figure 3a and 3b will be modified as suggested.

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Interactive comment on The Cryosphere Discuss., 9, 541, 2015.