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Interactive comment on "How much snow falls on the Antarctic ice sheet?" *by* C. Palerme et al.

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Replies to reviewer 1.

We thank reviewer 1 for comments on our paper which have improved the manuscript. We answered to all the questions, except for a few questions for which we did not think it was the best way for improving the manuscript. The way comments were accounted for is described below.

Corrections :

Specific Comments 1. Title The paper doesn't actually answer the question in the title. The authors tell us the estimate in the CloudSat domain (i.e., north of 82S). This is indeed the scientifically careful thing to do, but I think that the authors have enough information that they could make a reasonable estimate over all of Antarctica, which is

what the non-specialist community really needs to know (and what the title promises).

The aim of this study is to document Antarctic precipitation from observations to benchmark climate models. Thus, we do not want to use climate models for assessing Antarctic precipitation until the south pole. We think we answer to the title in term of spatial variability of Antarctic precipitation even if the method does not provide information between 82°S and 90°S.

2. What does CloudSat miss? The authors point out that diamond dust is the dominant precipitation type on the high plateau. I'm not sure that they are as clear as necessary about how much diamond dust CloudSat actually sees, although P.1287,L.15-16 and P.1288,L.25-26 raise the issue after the fact.

We want to point out that CloudSat miss all the precipitation below 1300m over the surface (not only diamond dust, but all the precipitation which occurs below 1300m). This kind of precipitation is called shallow precipitation in our paper. The diamond dust is only mentioned in the introduction.

Therefore, "the weak refectivity of small hydrometeors" refers to the size of the hydrometeors detected by CloudSat (altitude > 1300m) on the Antarctic plateau. On the Antartic plateau, the size of the hydrometeors is small, thus the radar reflectivity of these particle should be small.

Page 7, lines 234-236. The sentence : "Moreover shallow precipitation missed by CloudSat, and CloudSat sensitivity to very light snowfalls that occur in the interior could induce this difference." has been changed for " Moreover shallow precipitation missed by CloudSat, and the weak reflectivity of small hydrometeors in the interior could contribute to this difference."

One result is that the analysis potentially conflates the notion of deposition (P.1289,L.3-6) with very light precipitation. I can believe that deposition occurs, but the calculated value, although reasonable, could well be missed diamond dust, right?

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It is likely that shallow precipitation missed by CloudSat is the main issue. However, the contribution of deposition (hoarfrost formation) is unknown over the Antarctic plateau. Thus, we mention both causes as possible issues.

3. “flags” The terminology of “flags” usually seems to be what we would call “over-passes” or “samples”.

Flag is the terminology used in the CloudSat 2C-PRECIP-COLUMN product and its description. Page 4, lines 109-110. The following sentence has been added : "Thus, we redefined new flags from the original 2C-PRECIP-COLUMN flags".

4. P.1282,L.12 Presumably “sixth bin” is following a DEM? Readers aren’t experts on this.

Page 3, line 73. The following sentence has been added : "The radar bin containing the surface is determined with a digital elevation model."

5. P.1283,L.20-25 I’d say authors should point out that this approach, while reasonable, invariably inflates the fractional coverage by precipitation occurrence. The same is true in P.1284,L.1-3 for the “mixed” class.

Page 4, line 115. The following sentence has been added : "It is relevant to note that this method tends to inflate the precipitation occurence". Page 4, line 121. The following sentence has been added : "For the precipitation phase, this method tends to inflate the mixed precipitation class".

6. P.1284,L.10 Please state what the remapping scheme is to take the ERA-I grid to the 1x2 analysis grid.

We did not interpolate the ERA Interim dataset on the 1°x 2° analysis grid for the comparison of table 1, but the nearest grid cell of the ERA Interim reanalysis has been taken into account for comparing the datasets. Page 6, line 198. The following sentence has been added : "The nearest grid cell of the ERA Interim reanalysis has been taken into account for comparing the datasets".

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But the ERA Interim dataset has been interpolated on the 1°x 2° analysis grid for creating the new figure 4. Page 7, line 219. The following sentence has been added : "For comparing the datasets, ERA Interim reanalysis have been interpolated on the same 1° x 2° grid as CloudSat."

7. P.1284,L.15 I'd like to see the authors go on to be clear about what this means in terms of the parameterized microphysics, parameterized sub-grid-scale creation of precipitation mass, and explicit grid-scale creation of precipitation mass.

Page 4, line 128. The following sentence : "The 6 h forecasts of precipitation are used here" has been changed by "The 6 h and 12 h forecasts of precipitation are used here".

Page 5, lines 130-133. "No precipitation observation is inserted in the numerical model, but precipitation is predicted by the model using other observations such as temperature and humidity." has been changed by : "Direct precipitation observations are not assimilated into the model, but precipitation is modified in the analysis through the four-dimensional variational assimilation of other variables such as temperature and humidity (www.ecmwf.int) ."

Page 5, lines 134-136. The following paragraph has been added : "ERA Interim has been chosen in this study because it likely offers the most realistic depiction of Antarctic precipitation (Bromwich et al., 2011). However, it has been shown that ERA Interim could have a dry bias over the East Antarctic plateau (Bromwich et al., 2011; Favier et al., 2013)."

8. P.1284,L.22-24 I realize that the study is being done at the 1x2 scale, but I think it's highly relevant at this point to also report the fractional coverage on the original CloudSat footprint scale. In part, this is important information related to the typical sizes of precipitation systems over Antarctica.

We agree with the reviewer, a supplementary material file has been added with a map of the fractional coverage inside. Page 4, lines 103-107. The following sentence has

been added : "Moreover, the ratio of the surface directly observed by CloudSat over the surface of the ice sheet is shown in figure S1. Even for latitudes less than 82°S, the surface directly covered by CloudSat is only a fraction of the total surface of the ice sheet. However, the spatial scale of precipitation events and the overpass frequency ensure adequate statistical sampling over the duration of the study (supplementary material S1)."

9. P.1285,L.9 I think you need to add “in the area observed by CloudSat”.

Page 5, line 155. In Fig.3, the part of the continent with surface elevation over 2250m represents 50% of the surface of the entire ice sheet (including the part of the continent between 82°S and 90°S). We added "(including the part of the continent between 82°S and 90°S)".

10. P.1286,L.8 I think you need to be explicit about the limitations, something like “for 4.5 years of curtain data accumulated on 1x2 grid boxes”. Also, in the following sentence you should probably say “relative uncertainty”.

Page 6, line 188 : We added "for 4.7 years of curtain data accumulated on the 1° x 2° grid boxes", and we added "relative uncertainty" instead of "uncertainty" in the following sentence.

11. P.1286,L.14 I do not understand “the part of”.

Page 6, line 194. "the part of" has been changed for "the relative contribution of".

12. P.1286,L.27 You have not motivated why a threshold is necessary. I suspect it’s because ERA-I drizzles most of the time.

Page 7, line 209. The following sentence has been added "This threshold is necessary because the ERA Interim precipitation rates were strictly positive 60 % of the time between 2006 and 2011 at Dumont D’Urville station".

13. P.1287,L.11 I don’t understand the “likely lower” statement.

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Page 7, line 222. "likely lower" has been changed for "probably lower".

14.P.1289,L.14-15 New information shouldn't be introduced in the conclusions – it belongs back in the main body of results.

This information has been moved from the section "4. Discussion and conclusion" to the new section "3.3 Comparison of the snowfall rate from CloudSat to surface mass balance observations".

Page 8, lines 277-279. The following sentence has been added : "Assuming that accumulation has not significantly changed during the last 50 years (Monaghan et al., 2006a; Frezzotti et al., 2013), the accumulation from Arthern et al. (2006) represents 95 % of the snowfall over the Antarctic ice sheet north of 82 °S."

Page 10, lines 315-318. The following paragraph has been added : "Expectedly, the surface accumulation of snow is on average less than snowfall. However, it appears to exceed snowfall in areas of lesser precipitation where uncertainties on both precipitation and accumulation reports are largest. A significant contribution of hoarfrost to the surface mass balance of these areas may not be excluded."

15. P.1289,L.27 This statement is so general, I'm not sure it's useful.

"Near surface reflectivity is sensitive to the size of hydrometeors, and on the plateau, particles are probably too small to increase the near surface reflectivity above the threshold precipitation certain".

We think it is an interesting explanation of the new figure 2 c). But this statement has been moved from the conclusion to the section 3.1 Precipitation characteristics from CloudSat (P5, lines 160-162).

16. Fig.3 is pretty low in information content; could it be integrated with Fig.1?

We agree with the reviewer. Fig.3 has been integrated with Fig. 1. And the transects have been removed from this figure.

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Technical Corrections :

17. P.1281,L.17 “did not give quantities” is “was not quantitative”, I think.

Page 2, line 51. "did not give quantities" has been changed for "was not quantitative".

18. P.1281,L.20 “measure” is “estimate” – this is remote sensing.

Page 2, line 54. "measure" has been changed for "estimate".

19. P.1282,L.3 “cloud particles and hydrometeors” – cloud was the point of CloudSat.

We do not understand the comment and in L.3 it is not written "cloud particles and hydrometeors" but : "the power backscattered by hydrometeors according to the distance from the sensor".

20 P1285, L.3 : “if” should be “on whether”.

Page 5, line 150 "if" has been changed for "on whether".

21. P.1285,L.16 “A lot of” should be “Relatively more”.

Page 6, line 169. "A lot of" has been changed for "Relatively more".

22. P.1287,L.20 “due to” should be “as good as” – it’s not the forecasts that are chance, it’s their skill.

Page 7, line 239. "only due to chance" has been changed for "as good as random draw".

23. P.1289,L.9 “was still lacking so far” isn’t correct English; maybe “has yet to be established”.

Page 9, line 311. "was still lacking so far" has been changed for "has yet to be established".

24. Fig.2 caption “flags sorted as” isn’t correct English; maybe “cases of”.

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Fig.2 caption : "flags sorted as" has been changed for "flags indicating".

25. Fig.5 The vertical axis requires a label.

Figure 5 has been replaced by the new figure 4. The transects have been replaced by four maps.

Interactive comment on The Cryosphere Discuss., 8, 1279, 2014.