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Discussions

Interactive comment on "Melt in Antarctica derived from SMOS observations at L band" *by* Marion Leduc-Leballeur et al.

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Thanks to devote time to the review of our manuscript. The manuscript has been revised following your comments and suggestions. In particular, we enhanced the comparison between 1.4 GHz and 19 GHz to highlight their complementary climatological information. We answered your comments (introduced by '»') in the following.

»Interesting demonstration of SMOS (1.4 GHz) capability for melt detection compare to higher frequency (19 GHz). To my knowledge this is the first time that such a comparison has been done. Even if the observed results were expected : less sensitivity at 1.4 than at 19 GHz, the differences are well described and analysed. I suggest that the authors put more emphasis on these differences that could bring comple-

mentary climatological information compared to SSMIS. In that sense, the Fig. 7 is very interesting (mean melting days detected at 1.4 GHz but dry at 19 GHz). What are the temporal variations of such observations over the SMOS period? Do you observe particular events, for particular years? For example, the years 2002/2003 and 2015/2016 are known to be particularly wet in the Antarctic Peninsula due to a strong ENSO events. See Zheng et al. 2019 RSE, 232 : Variations in Antarctic Peninsula snow liquid water during 1999–2017 revealed by merging radiometer, scatterometer and model estimations. This is unfortunate that the Fig. 1 stops in April 2015, because 2016 could be a good example of differences between 1.4 and 19 GHz data? See also Wiesenekker et al., 2018. A Multidecadal Analysis of Föhn Winds over Larsen C Ice Shelf from a Combination of Observations and Modeling. Atmosphere 9(5), 172. https://doi.org/10.3390/atmos9050172 for the relationship between particular Föhn events and melting.

In order to improve the comparison between 1.4 GHz and 19 GHz, we extended the Section 4 with a more detailed view of the case, when day is detected as melting by SMOS but dry by SSMI. We mainly based this analysis on the articles that you suggest and added a focus on the Antarctic Peninsula. We focused the analysis on the period 2013-2013 2013-2016 when the variation are stronger. Fig. 1 have been extended over this period, and we added a new figure (Fig 1r) with some Peninsula maps to better highlighted the temporal variation. Thus, we added the following text in the end of the Section 4 and putted the figure previously named 'Figure 7' in the following of this Section:

However, it also happens that some melting days are detected with the 1.4 GHz observations but not with the 19 GHz observations. This case is illustrated with the example of the Antarctic Peninsula provided by Figure 1r for the three summer seasons from 2013 to 2016. This area is known to be submitted each year to a long melting season, but an interannual variability is observed. Zheng et al. (2019) studied the Antarctic Peninsula with satellite radiometer and scatterometer as well as climate model. They found that over the period 2010-2017 the lower wet snow extend is observed in during the 2013/14 summer season, whereas the largest is observed during 2015/16. These minimum and maximum are also retrieved by SMOS and SSMI during this period. Figure 1r (bottom) shows the number of days detected as melting at 1.4 GHz but dry at 19 GHz. In 2013/14, 2.6 days on average are only detected as melting by SMOS over a surface of 35,625Âăkm2 (57 pixels). In 2015/16, 12.3 days on average are only detected as melting by SMOS over a surface of 83,125Âăkm2 (133 pixels), which is 57% and 24% larger than in 2013/14 and 2014/15, respectively. As 2015/16 is known to be submitted to an intensive melting event in Antarctic Peninsula due to a strong El-Nino event (Nicolas et al., 2017), this could suggest that 1.4 GHz provide another information than 19 GHz in the case of intense melting events. In this way, Wiesenekker et al. (2018) showed that a stronger than normal foehn wind, which is a hot, dry wind on the downwind side of a mountain range, happens over the Peninsula in 2015/16. This generates an increasing in melt near the foot of the Antarctic Peninsula mountains. This area matches the pixels where 1.4 GHz observations detected more than 20 days not detected by 19 GHz (Figure 1r). Moreover, Datta et al. (2019) also found that high melt occurrence induced by foehn wind are observed in 2015/16, and they highlighted that the foehn wind increases the meltwater percolation up 2-m depth along the mountains. This suggests that SMOS observations could provide information about a part of snowpack in depth, which is not reaches by SSMI observations.

Figure 7 (now 6) maps for the whole continent the mean number of melting days detected at 1.4 GHz without concurrent detection at 19 GHz during summer season over our dataset. It shows that the geographical distribution is related to the total number of melt event (Figure 3), meaning that all the areas are concerned by the differential detection at both frequencies. On average, 10$\pm$8 days are detected only by SMOS. Moreover, over a total of about 117,000 melting days taking all pixels and summer seasons together detected at 1.4 GHz, 28% are not concurrently detected at 19 GHz. These melting days happen on 1 February $\pm$ 23 days on average, i.e. at the end of summer season. Conversely, over 225,000 melting days detected by 19 GHz during

the same period, 66% are not concurrently detected at 1.4 GHz.

Figure 1r: Annual melting duration (days) over the Antarctic Peninsula detected with observations (top) at 1.4 GHz and (middle) at 19 GHz from 2013/14 to 2015/16. (bottom) Number of days detected as melting at 1.4 GHz but dry at 19 GHz.

»I also suggest to add Zheng et al. 2019 reference (and others) for mentioning scatterometer and radar capabilities compared to radiometers (not mentioned in the paper).

As you suggest in order to improve the context description in Introduction, we added sentences and provided references including Zheng et al. (2019) to highlight the capability of active sensors to detect melt on the ice sheet. We added in the text: "Various detection algorithms have been developed for active sensors (e.g. Nghiem et al., 2001, 2005; Ashcraft and Long, 2006; Kunz and Long, 2006; Hall et al., 2009; Trusel et al., 2012; Zheng et al., 2019) and passive sensors (e.g. Mote et al., 1993; Ridley, 1993; Zwally and Fiegles, 1994; Abdalati and Steffen, 1997; Torinesi et al., 2003; Liu et al., 2005, 2006; Tedesco, 2007; Tedesco et al., 2007) and applied in the Greenland and Antarctica ice sheets.".

»The DMRT-ML analysis is a very good added-value to this paper.

»Also, could you specify which ice/water mask do you used for SMOS? same as for resampled SSMI mask? source of error?

The mask used here is the mask associated to the EASEGrid 2.0 map projections. It is available on the NSIDC website: https://nsidc.org/data/nsidc-0609. Brodzik et al. (2011) derived this Land-Ocean-Coastline-Ice (LOCI) classification from the MODIS land cover product. We added this information to the SMOS observations description in Section 2.1.

As SMOS and SSMI datasets are not built in the same grid some collocation error can happen. We added a description of the used method to compare the two datasets in Section 2.2: "To compare SMOS and SSMI datasets, the SSMI observations and products are collocated within the SMOS grid using the nearest neighbour method. If the nearest neighbour is not flagged as 'land' in the SSMI grid, the pixel was removed from our analysis to avoid the error of comparison between the two frequencies. In this way, about 50 pixels are excluded, which doesn't affect the statistical significance of the comparison results."

Note that the development of a Level 3 SMOS product within a polar stereographic projection is in progress by CATDS team, but up to now the official release is available from the February 2018 to present and the whole timeseries from 2010 is not yet ready.

»Does the Fig. 5 cover the entire SMOS period and for the whole Antarctica?

Fig. 5a-c refers to the DMRT-ML simulations. On Fig. 5d, the histogram only includes SMOS pixels fulfilling the two conditions: 1) have been detected as 'melting' at least once over the period 2010-2018, and 2) the ice thickness is 1000±50Âăm. This is described in Section 5.2 at the beginning of the third paragraph. We added a cross-reference to text in the figure legend to find more information.

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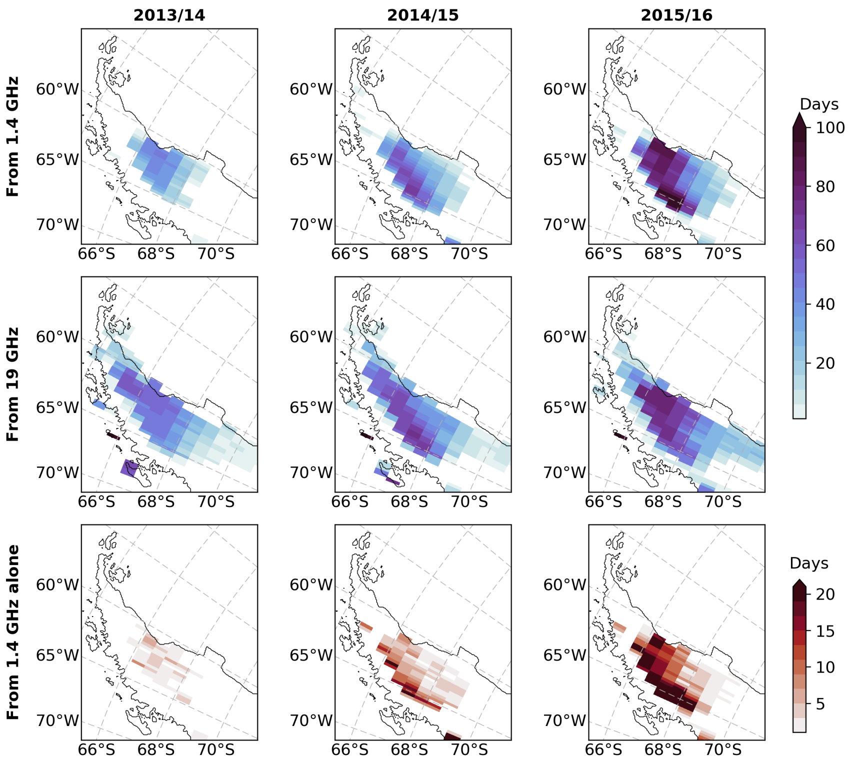

Fig. 1. Figure 1r: Annual melting duration (days) over the Antarctic Peninsula detected with observations (top) at 1.4 GHz and (middle) at 19 GHz from 2013/14 to 2015/16. (bottom) Number of days detected as m