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Interactive comment on "The SUMup Dataset: Compiled measurements of surface mass balance components over ice sheets and sea ice with preliminary analysis over Greenland" *by* Lynn Montgomery et al.

Anonymous Referee #2

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Review of Montgomery et al. (2018) paper

This paper presents the SUMup data compilation, which consists in standardized datasets of Arctic and Antarctic snow/firn density, snow accumulation on land ice and snow depth on sea ice. These data are expected for the monitoring of spatial and temporal changes in snow characteristics and are expected to offer information to improve validation data for surface mass balance modelling. Measurements in the dataset are analysed to assess whether data present time and spatial gaps. The authors analyse the Greenland ice sheet density dataset and show that data from the first 1 m do not

show a strong relationship with annual temperature. They also compare the data with the MAR model density, showing that the estimated densities by the model are lower than the SUMup measurements.

The dataset is important for the community in particular for model validation and deserves to be published. However, in its present state, this paper is not sufficiently clear and does not inform on the interest of the database and on the potential biases of the different subsets. I suggest that the authors take a very different approach in order to present the interest of the datasets in a more direct manner, and thus re-write the paper accordingly:

1. Data are from very different origins, for instance, "The measurement methods include density cutters of different sizes (generally from 100 - 1000 cm3) used in snow pits, gravitational methods used on ice core sections, neutron-density methods performed in boreholes, X-ray microfocus computer tomography performed on snow samples, gamma-ray attenuation in boreholes and pycnometers used on snow samples". These technics present very different accuracies and there is no reason to believe that indirect density estimates (i.e., using a neutron probe for instance) are clearly equivalent to direct density values obtained with mass to volume ratios. In the present version, the authors write that high-depth resolution density data (i.e., 97% of the dataset) were removed in the analysis to provide a more realistic overview of the fraction of the density measurements, because they were including a bias in the histogram representations. It would be really more interesting for the reader to know whether these data are including a bias in the accumulation or density values when compared to direct field accumulation or density measurements.

2. The temporal and spatial distribution are not the most crucial aspect in order to know whether the datasets are accurate or not. Comparisons with data obtained in similar areas but with different techniques may offer more crucial information.

3. Comparisons with previous available datasets is not explored here to inform on data

quality: e.g., Antarctic snow accumulation from Vaughan et al. 1999 (updated by Favier et al. (2013) and Wang et al. (2016)), or snow density from ITASE traverses (e.g., JARE, ANARE datasets), accumulation and firn/ice density from Thomas et al. (2017), snow accumulation, etc. In particular, data are missing over large areas compared to previous available datasets. Does the SUMup dataset provide new information in the regions where other datasets present a lower data density?

4. The SUMup dataset gives high spatial resolution information along transects, and gives a vertical description in snow accumulation and density variations allowing to study particular processes such as topographically induced dunes caused by gravity waves. This aspect may be explored here.

5. Several Ground Penetrating Radar data from traverses are missing in the present dataset and should be included (e.g., Figure 3c in Scambos et al. (2012) paper). I suppose the data owners did not distribute the data, but please justify why these data are not collected here?

6. Comparison with density from the MAR model is not convincing. I suppose that the snow density in the model is largely parameterized using temperature and precipitation occurrence? Could the authors provide more information on the MAR modelling? Why do they analyse snow density only? Is there any interest in comparing snow accumulation with their datasets?

As a consequence, in its present state, this paper does not accurately present the datasets and needs to be largely rewritten. I suggest that the authors deepen their study and 1) perform an intercomparison between data sources in order to say whether data obtained with different techniques present the same level of confidence, 2) to compare data with previous databases in order to justify the interest and new contribution of the SUMup dataset, 3) to remove the comparison with the density given by the MAR model or (if the authors want to keep an analysis with modelled data) to compare with SMB and snow accumulation data on sea ice and/or land ice. Is there any interest

in comparing with ERA-interim and/or RACMO2 model data (data are available in the Quantarctica3 distribution: http://quantarctica.npolar.no/about.html)?

Minor comments

Page 1 line 36: “This change is evident by declining sea ice extent (e.g Ritcher-Menge and others, 2016) and the recent acceleration of mass loss from the Greenland Ice Sheet (GrIS) and Antarctic ice sheets (AIS), (e.g. Velicogna and others, 2014; Shepherd and others, 2012), “ => the decline in sea ice extent is only true in the northern hemisphere. Moreover, changes at the ice/atmosphere interface are not trivial in Antarctica. Warming is not clear on East Antarctica (e.g., Clem et al. 2018), and mass loss increase in Antarctica is related to changes in ice dynamics. Actually the SMB is increasing in Antarctica (Thomas et al. 2017). Please rephrase

Page 2 line 50 : Vaughan and others, 1999 => actually it has been updated by Favier et al. (2013) and Wang et al. (2016). Please also refer to Quantarctica effort (Matsuoka et al., 2018).

Page 2, lines 67 : “(∼2% of the accumulation subdataset predates 1950 and these measurements are included to keep complete records from ice cores.)” => this sentence is not clear. Does it mean that the ice cores were drilled before 1950? If the ice cores were drilled after 1950, a continuous set of annual accumulation values should be available until the date when the core was drilled?

Page 2, line 80 and 83-85:” Keyword searches for the first method includes searching for the words “density”, “accumulation”, and “snow depth on sea ice”. ” => This sentence does not inform whether the data collection is complete. It would be more informative to suggest a way in order to improve the data collection and get a comprehensive data collection.

Page 3 line 100 : “we expect to add additional sub-datasets on surface mass balance processes which may include, but are not limited to, snow/ice albedo,snow tempera-

ture, and short-wave/long-wave radiation measurements. The community is encouraged to contribute data or suggest missing data sources/types to add to SUMup by contacting the authors directly." => this seems quite "optimistic". The authors propose to include data which are already available elsewhere. For instance, snow temperature at 10m is generally available for ice cores. I suppose that getting new data is not easy, as reflected by the time and important work required to develop the SUMup database. If it were easy to include new information available, for instance, in the US-ITASE dataset, this information would already be in the SUMup dataset.

Page 3 line 105 :" By convention, negative latitudes represent south and negative longitudes represent west. For data that did not specify a specific date, but provided only the year, the date was entered as 'yyyy0000'. A consistent fill value of -9999 was used for unknown or unmeasured parameters" => this information should be developed in the metadata, but is not very useful in the paper.

Page 3 line 116 : "830000 point measurements of density" => this very large number is misleading because it is mainly resulting from gravitational methods used on ice core sections, neutron-density methods performed in boreholes, X-ray microfocus computer tomography performed on snow samples, or gamma-ray attenuation in boreholes and pycnometers used on snow samples. However, the number of measurement done with density cutters or on cores is not large, when these are the only real and direct density measurements (volume/mass). Other techniques (such as neutron density, X-ray tomography, gamma-ray attenuation, etc. . .) present larger uncertainties, and the database should clearly indicate data accuracy.

Page 3 line 125 : Antarctic data comprises ∼6% of the snow density subdataset and is predominantly from ice cores => it seems that data from deep ice cores are not included (see figure1/b and please compare to the dataset presented in Thomas et al., 2017)

Page 3, line 128 : "The depth of the density measurements were recorded using two

different methods, either the top and bottom depth or a midpoint depth. While a midpoint can be determined uniquely from the top and bottom depths the top and bottom cannot always be determined from the midpoint and researchers need to determine how to standardize or interpolate the depths for their specific applications." => this information is important in the dataset but does not inform on data accuracy. Please reformulate in order to offer information on data accuracy.

Page 4, Line 135 :" While most of the data are measurements of accumulation between 1950 and present (∼98%)," => this sentence is a repetition. Please try to remove.

Page 4, line 152: "The snow depth on sea ice subdataset is the sparsest within SUMup with ∼14,000 point measurements" => this is the smallest in terms of data amount, but Figures do not offer information on the spatial density of the data in order to compare to other datasets.

Page 4, line 169 : "The minimum value for accumulation in the Arctic is -0.004 m WE/a"=> It seems unlikely to measure an ablation of 4 mm we a-1. What are the accuracy and representativeness of this measurement in a region with sastrugis? There is no information on data accuracy according to the measurement techniques? Why did the authors propose accumulation data only and removed ablation measurements?

Page 4, line 170: "there are 4 months with small negative accumulation (or ablation) measurements from Summit Station." => the timescale (multi-year, yearly, monthly) of data is not clear.

Page 4, line 175 : "the the"

Page 4, line 179 :" is the an exception"

Page 5, line 187 :" Over 830,000 measurements were compiled of snow/firn density that cover ∼280 sites in the Arctic and ∼50 sites" => this means that there is an average of 2500 measurements at each site. This large amount of data is quite misleading because in fact the dataset offers information on 330 sites which is more "reason-

able". This is reflected by the histogram data for Greenland (Figure 2B, and 4B), which present high isolated peaks reflecting that data are from a limited number of data collections. The same comment is valid at line 228 ""The ∼230,000 measurements of accumulation rate over land ice were taken at ∼30 locations in Antarctica, and ∼35 locations in Greenland. "

Page 5, Lines 191-197 : repetitions

Page 5, line 198:" For this reason we have removed these data from the following analysis to provide a more realistic overview"=> Instead of removing the data, it would be interesting to see whether this dataset induces a bias or an decrease in the dataset accuracy.

Page 5 Line 221 :"the number of measurements decrease " => decreases

Page 5 Line 221:" Antarctic data decreases" => decrease

Page 5, Line 237: "The accumulation subdataset is dominated (97% of data) by high-spatial resolution (10's of m) radar accumulation data taken from 3 ice sheet transects"=> it would make sense to bin points within 10x10 km grid cells rather than removing data

Page 6, Line 252 : "Antarctica has a relatively even distribution of accumulation measurements until 2000 when the number of samples decreases" => I suppose that the database offers annual accumulation, please provide further information : which proportions of the data are monthly values / annual values / multi-year means?

Page 6, line 267 : "from from"

Page 7, Line 280 and elsewhere: Harron => Herron

Page 7, Line 285 : "Fausto and others (in revision) suggest two new snow surface (0-10 cm) density parameterizations, derived from a set of observations, using mean annual temperature and elevation to help modeling studies set surface boundary con-

ditions." => why do the authors use the MAR density rather than the Fausto and others (in revision) relationship? This paper is cited several times, but the detailed reference is not available. It would be relevant to give more information on this study. For instance line 292 "similar graphing techniques to those of Fausto and others (in revision) to clearly show collection bias in the observation dataset" => this sentence is quite surprising here because we don't have access to fausto et al (in revision) paper in order to analyse the data bias suggested here.

Page 7, Line 307 : "The density measurements at each location"=> at which depth? The Herron and Langway (1980) approach refers to both temperature and annual snow accumulation. How is the MAR snow density modelled?

Page 8, Line 316 : "Figure 9 plots all sites in Greenland with density coincidently sampled to depths of 10, 25, 50 and 100 cm" => Depending on the area, the 1m depth densities are not representative for the same period and should not be cross compared, or analysed according to the annual temperature (by default). Indeed, the coast presents precipitation amounts around ∼1m a-1, whereas the plateau presents accumulation amount of about ∼10 cm a-1.

Page 8, Line 320 : "in the colder, more inland areas, temperature may not be the primary process leading to densification."=> what does the Herron and Langway (1980) relationship give?

Page 8, line 340: what is the bias resulting from different data origins? What occurs if data from one origin (for instance stake data) are binned into 10km x10 km grid cells and compared to GPR data binned in the same grid cells?

Page 8, Line 352 : "A seasonal cycle is evident in the 10 cm and 25 cm depth mean densities with a decrease (trough) in density in late summer" => Here do the authors suggest that a link with temperature exists?

Tables 4 and 5 should be provided for each measurement method in order to compare

the uncertainty associated to each technique.

Figure 1b: East Antarctica and the Antarctic Peninsula are clearly under-sampled. This point is surprising considering the amount of data available in Quantarctica's distribution. This is also the case, for instance for accumulation, if we compare Figure 1a with Figure 6a from Fettweis et al. (2017). I propose that the authors include previous available datasets in the present SUMup database

Figure 2: I am not sure that the date of the density sample is relevant because it is not expected to be as variable as snow accumulation. Moreover, there is a large uncertainty in dating firn/ice layers, which largely depends on accumulation amounts: how is this expressed/addressed in the database?

Figure 3a : a high number of density data are from below 75 m, that is generally below the close off. I suggest including a description of sample characteristics (firn or ice). Since ice cores are included, I suggest that the authors include data from deep ice cores available in Thomas et al. (2017) (if we refer to Figure 1a in Thomas et al. (2017), it seems that many ice cores are not included in the SUMup database).

Figure 9 a): in Greenland, the 10 first centimetres of snow are likely to represent fresh snow with characteristics that are related to one or only few snow precipitation events. Moreover, 10cm of snow represent very different time scales according to the location (coast or plateau) and integrate different time lapses. There is no reason to find a significant correlation with mean air temperature or with mean density given by the MAR model. I am not convinced by this comparison.

Figure captions : Please refer to "GrIS" or "AIS" when then mention was omitted.

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