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Interactive comment on "Ensemble-based assimilation of fractional snow covered area satellite retrievals to estimate snow distribution at a high Arctic site" *by* Kristoffer Aalstad et al.

Anonymous Referee #2

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Ensemble-based assimilation of fractional snow covered area satellite retrievals to estimate snow distribution at a high Arctic site

The Cryosphere, Aalstad et al., 2017

This paper shows an analysis of the results of three different assimilation algorithms applied to snow variables (in particular SWE, fSCA and sub-grid coefficient of variation) over an Arctic study site. The assimilation algorithms used are the Ensemble Smoother (ES), Particle Batch Smoother (PBS) and a newly introduced Ensemble Smoother Multiple Data Assimilation (ES-MDA) technique. The results show significant improvements in all evaluation metrics for the ES-MDA technique, matching or

improving the results obtained using the ES and PBS. The ES-MDA is more robust as it avoids degeneracy and other problems of the other two techniques however this comes at an expended computational cost.

The paper is well written (albeit it needs more work in terms of grammar/phrasing, I recommend one final review by native-english speaker) and very clear. The methodology section might be improved by including examples of the method using figures. As it is right now is very mathematical, which is fine but reduces the possibility of understanding the workings of the method by other researchers on the field. The literature review is very comprehensive and might be improved if condensed. The paper further illustrates the extreme utility of data assimilation frameworks in the context of snow process estimation and I recommend it for publication after minor revisions.

Specific comments:

Page 2

2-3: The amount of smoothing depends on the type of terrain - wouldn't expect this effect to be significant beyond smoothing microtopography (i.e., 1-2 m vertical scale). 13: Probably only precipitation and wind are space-time variant, topography and vegetation shouldn't be considered as dynamic. Radiation is also space-time variant however the direct component climatology might be relatively invariant every year - though I would expect that for high latitudes this is not necessarily true,

Page 4

17: Maybe it is worthy citing Cortés et al. (2016; 2017) for a more direct comparison with PBS metrics derived over similar study regions. Both papers include similar validation data (snow surveys), while Margulis et al is focused on point-data (stations).

Page 5

31: Define undulating. 32: Typo (ground)

Page 9

7: Please clarify what do you mean by this term? Also - clarify what “external” processes are not considered (wind redistribution?)

Page 10

26: Is there a range defined for this parameter?

Page 11

10: Is the daily time step a result from aggregating internal hourly calculations?

Page 13

4-5: It would be useful to include a quantification of how many images were available per assimilation season for each site. How were clouds identified and masked out?

Page 15

7: Curious if the use of independent multiplicative biases for accumulation and melt would result in inconsistent accumulations? (For example b*M>b*P?) 8: When you mention constant multiplicative biases - does this mean the bias is unaltered throughout the year? 13: The PBS requires that the ensemble includes the observation, thus if no bias is assigned a priori then the PBS might not be applicable as some degree of bias correction is needed.

Page 20

6: The reduction in spread is a direct consequence of any assimilation algorithm, it would be more useful to assess if the constrain in uncertainty of the posterior is consistent with the observations (i.e., are you underestimating uncertainty after assimilation?)

Page 21

A scatterplot would be useful to compare the posterior results for all methods. Including

the stats is correct but scatterplot allows for more context.

Page 26

Table 5: A perfect correlation of 1.0 was obtained? Would be useful to have the scatterplots in order to inform the reader with more details on the results.

Page 27 32: It is very difficult to compare RMSE across studies due to the differences in methodology/data. I would stick to the comparison performed within the paper as it allows for more controlled conditions.

Page 28 3-4: More than biased, if the prior ensemble doesn’t cover the observations then the PBS would be unable to replicate the observation. Bias in the ensemble per se is not a problem for the PBS. The comparison between PBS/ES from previous papers with the current method is not as straightforward, asides from the obvious differences in regions there are differences in validation methodology and particularly in the number of fSCA measurements assimilated. Landsat fSCA assimilation results in 10-15 observations per year, while MODIS probably results in an order of magnitude greater.

References:

Cortés, G., Girotto, M., & Margulis, S. (2016). Snow process estimation over the extratropical Andes using a data assimilation framework integrating MERRA data and Landsat imagery.ÂăWater Resources Research,Âă52(4), 2582-2600.

Cortés, G., & Margulis, S. (2017). Impacts of El Niño and La Niña on interannual snow accumulation in the Andes: results from a highâĂŘresolution 31âĂŘyear reanalysis.ÂăGeophysical Research Letters.

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