Tc-2016-273

This study shows the potential use of brightness temperature data from the ESA SMOS mission for forecast model assimilation, to improve sea ice thicknesses in thin ice regions. Although the application of brightness temperature data rather than a derived thickness product is not a new concept, this is the first time that the usefulness of SMOS data has been explored in detail and the manuscript will be of interest to the observation and modelling communities. However, I have some concerns to be addressed.

We would like to thank the referee for its initial positive assessment and will now discuss each point in detail.

The manuscript currently lacks a suitable level of transparency and detail regarding a.) the uncertainties associated with modelled brightness temperature…

As there are no derived uncertainties for the ORAP5 reanalysis product we use the uncertainties of the follow-on product ORAS5 and assume that they will be of same magnitude as the uncertainties of ORAP5. Both products have the same resolution and use the sea ice model LIM2. Following this comment, we added a new table (Tab. 3) to the manuscript in section 2. It shows the uncertainties compared with the monthly variation of the physical properties. The uncertainties are ten times smaller than the monthly variations except sea ice thickness, which varies between a factor of 5 and 7 (November, March). Moreover, we analyze the impact of uncertainties on the brightness temperature simulation for both models in an additional table. The results show a large impact of sea ice thickness uncertainties on the brightness temperature simulation and far less influence by all other variables.

… and b.) the limitation of ORAP5 data in the development of a reliable brightness temperature model.

This paper does not follow the purpose to identify one of the radiative transfer models to be the correct one as the uncertainties from the reanalyzes are still noticeable, especially in the intermediate range of first year sea ice thicknesses. However, we do give a recommendation for one of the models to be more suitable for brightness temperature assimilation. This recommendation however is only based on the open water case and the saturated case over very thick sea ice, where uncertainties of sea ice concentration and sea ice thicknesses do not count. As this has been misunderstood we added a clarification in the revised version and specifically note that this is the case.

… The authors should briefly explain how each of these parameters is derived in ORAP5 and state their associated uncertainties. ..

Added to the methods.

Based on this they should expand on why using a radiative transfer model (which is itself developed from derived parameters) as a forward operator in a brightness temperature assimilation scheme for thin sea ice thicknesses is preferable to using observed thickness data.

Please note that also “observed sea ice thickness” products from SMOS over thin sea ice rely on radiative transfer models to derive sea ice thicknesses from brightness temperatures. Therefore in any case, there is always the uncertainty of an imperfect radiative transfer model. However, the advantage of a direct brightness temperature simulation is the availability of a coherent set of input data from the reanalyzes/forecast model. This allows us, for example, to take into account the sea ice concentration in our calculations which as not been possible before (Tian-Kunze, 2014). Furthermore, snow thicknesses are directly derived in the forecast model and are not taken from a general annual climatology. Another advantage of a brightness temperature assimilation is a better traceability of the errors as all variables belong to the same dataset. However, since this point led to confusion we added another sentence to section 1.

An easy and effective way to do this would be to tabulate the effects of the sensitivity study for both models. What effect (expressed as a percentage, for example) does varying each parameter to its minimum and maximum simulated value have on brightness temperature over thinner (say 10 cm) and thicker (say 50 cm) sea ice?

We followed this idea and added another table to the results section. It shows the propagating error in brightness temperatures based on the ORAS5 uncertainties. The error is expressed in Kelvin for each quantity provided by ORAP5. The dominating uncertainty (more than 80% of all variables) over first year sea ice is based on the sea ice thickness. We conclude that as beneficial for the brightness temperature assimilation for sea ice thicknesses. Most brightness temperature differences will be due to sea ice thickness and can thus be corrected, whereas the other parameters have a minor impact. Note that the sea ice concentration over first year sea ice only shows an average uncertainty of 5%.

P1 L4: It is perhaps more accurate to state that SMOS brightness temperatures have been proven to be valuable in estimating modal thin sea ice thicknesses, not mean. See for example [1].

Changed in revised version.

P3 L30: Why 2 m? 2 m is 0.5 m greater than the maximum SMOS validation thickness

We reprocessed all results with a maximum sea ice thickness of 1 meter to account for thinner first year sea ice. The changes are almost negligible that will not alter the results. However, the new figures are included in the revised version.

P5 L27: The assumption of dry snow is oversimplified. Despite this being a necessary assumption made for the model, the authors should comment on the potential impacts of a wet snow layer on brightness temperature. This is especially important, as wet snow is most common on thin FYI, such as that measured by SMOS, even in winter.

Carsey 1992 examined the influence of wet snow above saline ice on brightness temperatures (Carsey 1992, Fig. 4-26). He does not see a significant influence on brightness temperatures at 10 GHz, even more decreasing at lower frequencies. The snow moisture is described to be below 2% if the temperatures are at 268K or lower, up to 3% if the temperature is greater than 273K (Carsey 1992, Fig. 16-2). Therefore the penetration depth will be at least 1 meter and should be negligible at 1.4 GHz. We added this explanation to the manuscript.

P6 L8-19: The relevance of the brief introduction to NEMO and LIM would not be clear to someone who is unfamiliar with ORAP5. I believe ORAP5 was produced from these models, but this is not explicitly stated in the manuscript.

Considered in revised version.

Conclusion: A comment on the potential for a similar approach over thick ice would be useful. If brightness temperature can't be used, what could?

A common method to derive thick sea ice thicknesses is by using altimetry of e.g. ICESat or CryoSat-2 (Kwok et al. 2009, Laxon et al. 2013). By measuring the elevation of the sea ice surface above the water line (called freeboard) it is possible to estimate ice thicknesses above 1 m. However, systematic errors are introduced by using e.g. a snow thickness climatology or fixed snow density (Kwok 2014, Ricker et al. 2015). Thus, a similar approach to this study might improve the accuracy of the freeboard calculation by using the reanalyzes data as input. In future, even a synergy of SMOS thin and altimetry thicker sea ice thickness derivation might be feasible, as it already exists for the combined SMOS and CryoSat-2 sea ice thickness retrievals (Ricker et al. 2017).

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