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Interactive comment on "New insight from CryoSat-2 sea ice thickness for sea ice modelling" *by* David Schröder et al.

Anonymous Referee #2

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General Comments

In this paper, the authors evaluate the ice thickness from a standalone CICE model forced with NCEP-2 Reanalysis atmospheric forcing against CryoSat-2-derived ice thickness during 2010-2017 to determine the cause of the model's underestimation of the central Arctic winter ice thickness. A multi-year simulation is performed (CICE-free) for the period of 1980-2017 on a 40 km CICE (v5.1.2) grid using a simple mixed layer ocean model where the ocean temperature is restored to climatology on 20-day restoring time scale and utilizes monthly mean climatological ocean currents. Model defaults include a prognostic melt pond, elastic anisotropic rheology, ridging and the Delta-Eddington radiation scheme. Comparisons against CryoSat-2 (CS2) sea ice thickness from CPOM, AWI, and NASA for the months of November – April all reveal a significant

under-prediction in the winter Central Arctic ice thickness. The CS2 data is binned into five CICE model ice thickness categories ranging from the first category with < 0.6 m of ice to the fifth category with ice > 3.6 m on a rectangular 50 km grid and used to initialize a series of experiments. The paper discusses the treatment of snow for each CS2 dataset in deriving the ice thickness. In their study, the authors chose a region in the Central Arctic (Fig. 3) with a minimum ice thickness of 0.5 m and a region where ice growth is dominant over the impact of sea ice dynamics. A series of 7 studies are performed for the multi-year periods beginning in November of 2010 and continuing for 15 months and repeated through 2016/2017. Experiment are initialized with all three CS2 ice thickness fields and use different CICE options documented in Table 1.

An experiment was performed by decreasing the longwave radiation by 15 w/m2 and reducing the air temperature by 2 K everywhere and for all times. They found some differences in the mean September ice thickness, but little change in winter ice thickness; concluding that the under-prediction in winter ice growth can not be explained by errors in forcing data.

Experiments were conducted which studied the impact of increased total ice surface albedo by releasing more melt water into ocean; thus reducing ponded water over the surface of ice. This study (CICE-mw) only revealed a small improvement in winter ice thickness.

Another set of experiments applied the form drag parameterization of Tsamados et al. (2014) to investigate sea ice advection and turbulent heat fluxes (CICE-mw-form). They found a small ice thickness increase attributed to a reduce ice drift speed resulting in a weaker ocean-ice heat flux. Another set of experiments increased the emissivity of snow from 0.95 to 0.976 (CICE-mw-form-e) impacting the longwave radiation budget. They found that the summer melt was reduced by only a few cm, but no noticeable change was found in winter.

The most significant improvement was found with the implementation of a snow drift scheme based on Lecomte et al. (2014) which reduced the snow depth by 20-40% (CICE-mw-form-e-sd) which lowered the winter ice thickness errors from 0.8 to 0.25 m. They found that the reduction of snow led to larger winter ice growth as well as an increase in the summer melt due to the earlier disappearance of snow. A final set of studies (CICE-mw-form-e-sd-bubbly) increased the conductivity for colder temperatures (Pringle et al., 2007) and further reduced the errors to less than 0.1m. This configuration is referred to as "CICE-best".

Using the CICE-best configuration, the authors studied the length of the melt season and found a 7-day reduction from 107 to 100 days versus the "observed" value of 94 days. They performed studies using "cold forcing from the 1980's" which led to an increase in the September ice thickness of 0.8 m, but only 0.11 m in April.

The authors conclude that warm winters are not responsible for the observed sea ice thinning in the Central Arctic over the past decade; rather it depends strongly on atmospheric conditions from May to June in particular, with the start of the melt season and formation of melt ponds, thus preconditioning the strength of the positive albedo feedback. They found that the recommended improvements to the CICE model outweigh the impact of initialization with CS2 ice thickness fields.

This is a very well written and thorough paper with carefully designed model experiments. I highly recommend it for publication.

Specific Comments

Throughout the paper your refer to 1-year experiments with the CS2 data, but your time series plots look like the experiments run from (for example) Nov 2010 – January 2012, so a 15-month experiment?

The CICE tripole grid has a resolution of ∼40 km. Why wasn't the CS2 data interpolated onto that same 40km grid (instead of 50 km)?

Please review the use of colors chosen for Figures 1, 5, 8, 10, and 11. Some colors are

a bit difficult to differentiate. Perhaps including dashed lines and reducing the number of colors could help.

Technical Corrections

Page 2 line 2: replace "Blockley et al" to "Blockley and Peterson"

Page 2 line 28: Spell out ORCA

Page 2 lines 33,34: replace "Libscomp" to "Lipscomb"

Page 5 line 20: add "by 2 K during the whole simulation. . ."

Page 6 line 2: replace "satellite products" to "satellite products (not shown)"

Page 8 line 21: should be "Maaß"

Page 13 Table 1 caption: should be "Note that all model changes. . ."

Page 15 Figure 1 caption: replace "998." With "99.8%"

Page 22: Why are AWI/NASA both showing up as solid grey lines? Can one be shown as dashed?

Page 24, 25: same question as above

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