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Interactive Comment

Interactive comment on "Improving the WRF model's simulation over sea ice surface through coupling with a complex thermodynamic sea ice model" *by* Y. Yao et al.

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Although the model development work presented in this study does appear to improve the near surface temperature biases in the WRF model I found this analysis is quite superficial, unclearly motivated and lacking in detail with respect to the development work which was carried out. The inclusion of the sea ice thickness sensitivity experiments, again with little detail in the analysis, makes the manuscript feel unfocussed. Most importantly however, it is not clear in what way the new model is different or better than the existing sea ice thermodynamic scheme.

We thank the Anonymous Referee #1 for the comments. Substantial revisions have been made to the manuscript according to the comments.

The WRF model has been widely used in polar researches but it only incorporates a simple sea ice scheme (Noah). Previous evaluations have found that this simplicity can lead a problem of energy imbalance in simulating the sea ice. Such an energy imbalance would limit the application of WRF model for regional climate simulation over polar region. To overcome this problem, a more complex thermodynamic sea ice which can better resolve the energy balance in sea ice should be utilized in the WRF model. HIGHTSI, a complex thermodynamic sea ice model, has a higher vertical resolution than Noah and considers the snow and ice processes in more details. For example, Noah would prevent the snow depth from falling below 0.01 m while HIGHSI can treat the snow and bare-ice surface differently. More importantly, Noah does not include the process that account for the change in sea ice thickness. This would lead to energy imbalance when its simulation is specified with a varying ice thickness. HIGHTSI overcomes this problem by including the ablation and accretion processes of sea ice and utilizing an interpolation step which can ensure heat conservation during its integration. The results from offline and online simulations both confirm the benefit from this advancement in HIGHTSI.

The differences between the new model and the original one have been clearly presented and a table which summarizes these differences has been added in the revised manuscript. More analyses on the results from both the offline and online simulation have been presented in the revised manuscript to demonstrate the benefit from the advancement in the new model. The Introduction Section has been rephrased to better emphasize the importance of a reasonable sea ice simulation in current WRF model. For the sea ice thickness sensitivity experiments, a table that summarize the setup of each simulation has been added. And more analyses on the ice thickness simulation by the sensitivity experiments have been presented in the manuscript.

In terms of the motivation for the study on pages 10308 and 10309: On the one hand the authors point out that significant development work has been done by the WRF community in developing a polar focussed version and which performs well. Then on the other hand state that because WRF was developed for the mid-latitudes it only has a simple sea ice thermodynamic model, without stating why one would expect this to be an important factor.

We are sorry for the unclear presentation here. Previous development on Polar WRF includes the sea ice enhancement, but simplifications and lack of important thermodynamic processes still exist in current Polar WRF (version 3.6.1). These shortages in the WRF model can lead to problems of energy imbalance in snow and ice, which is an important issue in regional climate simulation. For example, the Noah sea ice scheme does not include the ice ablation and accretion processes and it prevent the snow depth from falling below 0.01 m. These can lead to the imbalance of energy in snow and ice. Previous researches have suggested that a more advanced scheme for sea-ice and snow could be used to reduce the problem with surface energy balance in the Polar WRF model.

We have rephrased the presentation on the motivation part, and cited more references on this issue in the revised manuscript.

For example on Page 10309; Line 12-14: The authors state that they are looking to understand what role biases in the existing thermodynamic model plays in driving biases in the longwave budget. I cannot see which of the references describes this bias and can't see how the experiment they have run can answer this.

We are sorry for the ambiguous statement here. The study on the longwave budget would includes many issues besides the sea ice component. To keep more focussed on the sea ice improvements in this manuscript, the question on radiation budget would be answered in further researches.

This statement has been removed.

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Other stated questions are “While a complex thermodynamic sea ice model can predict the change in sea ice thickness, the RCM might be able to predict the actual sea ice thickness.” The idea of using an atmosphere model coupled to a thermodynamic sea ice model in a predictive sense like this is inappropriate without taking into effect lateral fluxes of ice mass and I suggest removing all aspects of this discussion from the text.

We are sorry for the inappropriate statement here. Without a consideration of lateral fluxes of ice mass, the actual sea ice thickness could not be predicted by the thermodynamic sea ice model alone.

All the statements like this have been removed in the revised manuscript

The question “How is the sea ice thickness prescribed if a complex sea ice model is coupled to the RCM?” is an interesting topic but little is presented on these results.

To study the impact of different treatments of sea ice thickness, sensitivity experiments in which the sea ice thickness prescribed by different methods have been carried on. The empirical method is based on the relationship between sea ice concentration and sea ice thickness. This method could mimic the large-scale feature of the thickness distribution but lacks spatial details and seasonal variation. In this study, we introduced a method which is based on the complex thermodynamic sea ice model. The ablation and accretion processes of sea ice can be calculated by the sea ice model. This method initialize the sea ice thickness from the empirical estimation while the further change of ice thickness is predicted by the thermodynamic sea ice model itself. Compared to the purely empirical estimation, this method can better represent the tendency of seasonal change in sea ice thickness. However, this method depends on the initial guess of the ice thickness and the role of the dynamic processes. If the initial guess has already overestimate the sea ice thickness, a positive tendency of thickness change that introduced by this method could further enlarge this positive bias.

Detailed information on the sea ice thickness sensitivity experiment has been added in

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the revised manuscript. More analyses, especially those on the results from the new method, have been added in the revised manuscript.

Some very basic details of the HIGHTSI model itself and the coupling with WRF are missing. It is not stated in what ways HIGHTSI is different to the Noah model which is already coupled to WRF. Other details such as the frequency of the coupling timestep or the number of levels in the new thermodynamic model are not stated.

We are sorry for the unclear presentation and the lack of technical details. Compared with the Noah sea ice, HIGHTSI is more complex and shows advantages on several aspects. First, HIGHTSI has more vertical layers for both snow and ice than Noah, which means the vertical profile of temperature within snow and ice can be represented in greater detail in HIGHTSI than in Noah. Moreover, the surface and basal accretion and ablation processes of sea ice are included in HIGHTSI. Unlike Noah in which the sea ice thickness has to be specified, HIGHTSI can predict the thermodynamic change in sea ice thickness. A self adapted ice thickness is crucial for the conservation of energy in sea ice. When the ice thickness is kept constant or specified inappropriately, a misrepresentation of energy balance would be happened. Another problem that has been found in Noah is the treatment of surface characteristics. The Noah assumes that the surface of sea ice is always covered by snow, and a lower bound of 0.01 m is set to prevent the snow from becoming too thin. This assumption could lead to problems of energy imbalance in the simulation of sea ice by Noah. HIGHTSI, on the other hand, includes different treatment for the snow and bare-ice surface. When the snow is thin or melted, the solar radiance penetrated into the ice could further heat and melt the ice. These processes are also included in HIGHTSI.

The above description of HIGHTSI and Noah have been added to the revised manuscript. To summarize the differences between HIGHTSI and Noah, a table summarizing the differences between Noah and HIGHTSI has been added to the revised manuscript.

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The HIGHTSI is coupled at every time step in the WRF model. There are 10 levels for snow and 20 for ice.

Information on the details of model setup has been added to the revised manuscript

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Interactive comment on Geosci. Model Dev. Discuss., 8, 10305, 2015.