Review of "Implementation of an intermediate complexity snow-physics scheme (ISBA-Explicit Snow) into a sea-ice model (SI³): 1D thermodynamic coupling and validation" by Brivoal et al.

In this manuscript, Brivoal et al. describe the implementation of the detailed snow physics scheme ISBA-Explicit Snow (ISBA-ES) into the SI³ sea-ice model, which is part of the forthcoming CNRM-CM climate model configurations. The ISBA-ES scheme enables the simulation of realistic snowpack characteristics - including density, grain size, and thermal conductivity - offering a significant advancement over the simpler slab snow model originally used in SI³. Notably, the integration is achieved directly, without a coupler, by compiling ISBA-ES within the SI³ framework.

The study is a valuable contribution to the field of snow and sea ice modeling and falls well within the scope of the journal. However, I believe that substantial revisions are necessary before the manuscript can be recommended for publication.

We are deeply grateful for this perceptive and helpful review. We also believe this work is a substantial step forward in polar climate modelling. We have improved as much as possible our article following the advice provided.

Note that all line numbers refer to the manuscript version with untracked changes.

Major Comments

1. **Justification for Using SHEBA Observations**

   The manuscript does not sufficiently explain why the SHEBA dataset was selected for model evaluation. Given the availability of the more recent MOSAiC dataset which is (i) publicly accessible, (ii) covers a different region of the Arctic, and (iii) spans a full annual cycle, it would be highly beneficial to include a comparison using MOSAiC data in your analysis.

We wanted to perform a comparison with the data from the MOSAIC campaign (See figure below), but we found that the data was hardly suitable for a validation of a 1D simulation of our snow model. There are several reasons for that:

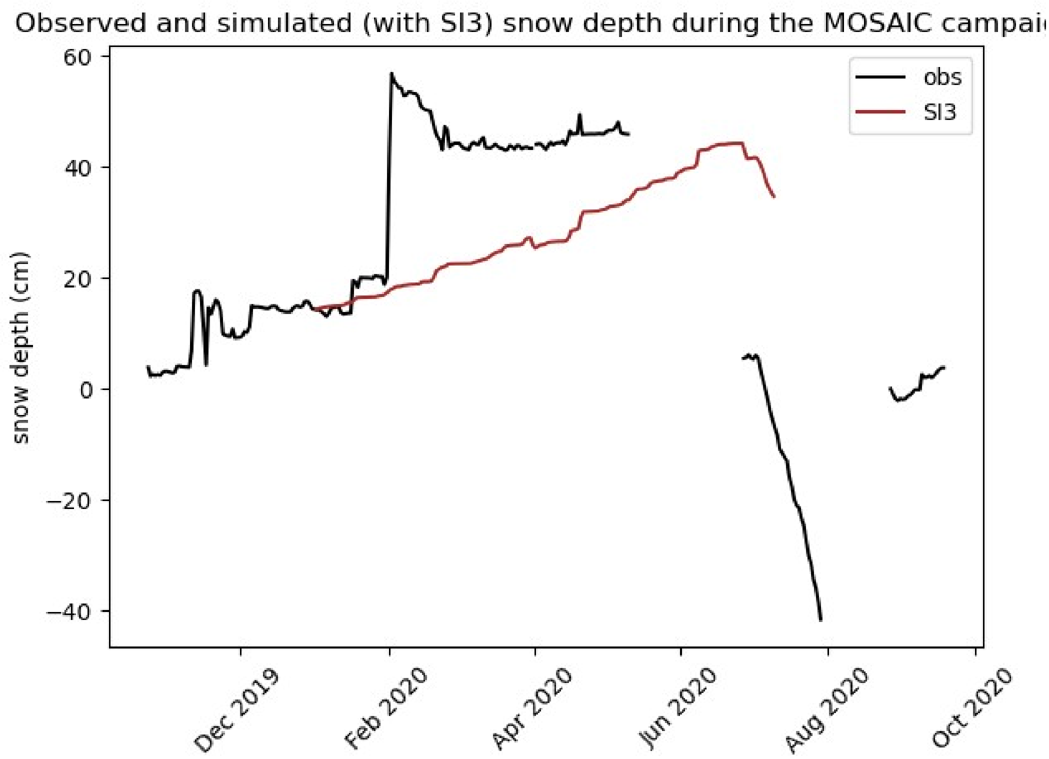
- The cumulative snowfall on all transects of the MOSAIC campaign is represented in Wagner et al., 2022, Figure 10,a and b (https://tc.copernicus.org/articles/16/2373/2022/tc-16-2373-2022.html). We can see a lot of concerning differences between the cumulative snowfall measured on the transects. On some transects, the accumulated snow can be almost 10 times higher than the average of the transects. This is due to strong blowing snow events occurring during the campaign. This differences in cumulative snow between the transects is much higher than at SHEBA, where the snow depth was found to be only 30% higher on ridges than on level ice (Sturm et al., 2002), suggesting less strong blowing snow events during the SHEBA campaign than during MOSAIC.

- In addition, the cumulative snowfall averaged over all transects is quite low (72 to 107 mm SWE) as well as the mean snow depth (which peaked at 30cm, Itkin et al., 2023 https://online.ucpress.edu/elementa/article/11/1/00048/195302/Sea-ice-and-snow-characteristics-from-year-long) compared to SHEBA where the cumulative snowfall were around 179mm and where the mean snow depth peaked at 42.8 cm, with an average depth of 37.3 cm, Sturm et al., 2002).

We initially performed a simulation using the SI3 model (forced by ERA5) following the path of the MOSAIC experiment), starting in january 2020 (we wanted to start from the beginning of the MOSAIC campaign later on, but this was a first test to see if the MOSAIC data was suitable to validate our model). The results are shown in the figure below, where we plotted the snow depth simulated by SI3 (red curve) and measured at the metcity tower (black curve). We see that the measured snow depth strongly shifts from ~20cm to 60cm in february in the observations. In Wagner et al., 2022, they stated that this was due to a strong snowdrift event, that cannot be captured from a reanalysis forcing (due to its horizontal resolution) or from using the mean cumulative snowfall measured during the campaign as forcing. A better comparison could be achieved by comparing SI3 to the mean snow depths from all transects, but given the very little snow accumulation during the campaign (Itkin et al., 2023), we though it will not add any value to the comparison with the SHEBA dataset already presented in the paper (

In addition, the SnowModel-LG data used in the paper was not available during the MOSAIC period.

In the text, we added clarifications about this from line 274 to line 281, starting from “More recent campaigns…….”



Nonetheless, we will use the MOSAIC data in the near future, alongside with other observations of snow on sea ice available (e.g: Aircraft / satellite / buoy measurements) in a validation of the future 3D version of the model including the effect of the sea-ice dynamics on snow.

2. **Impact on Sea Ice Thickness Evolution**

   While the results are clearly presented, they lack a critical assessment of how the new snow representation affects sea ice thickness. I strongly recommend including a comparative analysis between the updated SI³ model (with ISBA-ES) and the original version, ideally benchmarked against observed sea ice thickness data from relevant Arctic field campaigns.

We agree that the paper would benefit from an assessment of the impact on the sea-ice thickness. We added a new figure (which is now the figure 8) and a new paragraph in sec 3.1.2, from line 468 to line 478, starting from "In all ISBA-ES simulations….", and in the discussion, from line 528 to line 535, starting from "In ISBA-ES, the sea-ice is more insulated….."

3. **Relevance of the Snow-Ice Section**

   The discussion on snow-ice formation currently feels disconnected from the rest of the study. If the intention is to explore this process in depth, I suggest using data from campaigns where snow-ice formation was directly observed, such as N-ICE2015, or from ice mass balance buoys that have recorded such events.

We agree with this comment, (which was also addressed by Reviewer 1), and we decided to delete this part. It would be more relevant to investigate the impact of the snow-ice formation with the future 3D version of the model, accounting for the sea-ice dynamics.

Minor Comments

All minor comment have been adressed directly in the updated text.

- Please ensure the manuscript undergoes thorough English language proofreading.
- **Line 35**: Replace "accumulated" with "accumulates".
- **Lines 85–86**: The thermodynamic component of CICE, Icepack, includes many snow processes mentioned here. Please cross-check and clearly specify what aspects are novel in your implementation.
- **Line 110**: Capitalize "turbulent" to "Turbulent".
- **Line 111**: Replace "2m temperature" with "2m air temperature".
- **Line 259**: Correct "magnoprobes" to "magnaprobes".
- **Line 297**: A parenthesis is left open, please close it.
- **Lines 300–301**: Why was SnowModel-LG used for initial snow density instead of SHEBA observations? Please clarify.

  We use the snow density from SnowModel-LG because the density measurement on sheba were only made during an extensive measurement period in april, thus we do not have the information for the initial density at SHEBA at the beginning of the simulation. We clarified this also in the text at line "301": "We also use the

SnowModel-LG density for this date (191 kg/m³) to initialize ISBA-ES simulations since the density at SHEBA was not measured at this date”

- **Figure 4a**: The SHEBA observational line is not visible. Consider improving its visibility.
- **Lines 422–424**: Move the phrase “but in ISBA-ES” to follow “by Sturm et al. (2002)” for better clarity.
- **Line 472**: Replace “freeboard” with “ocean surface”.