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Interactive comment on "Version 1 of a sea ice module for the physics based, detailed, multi-layer SNOWPACK model" *by* Nander Wever et al.

Anonymous Referee #2

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The analysis is a model demonstration of applying SNOWPACK, a sophisticated snow model, in the Antarctic sea-ice environment. The topic presented here is of great interest to the cryosphere community, and is an excellent example of transferring knowledge from the terrestrial snow environment to the sea-ice environment. The analysis is well-presented, the manuscript being clearly-written and well-organized. There are several assumptions made for the model that need further explanation, especially with regard to how these assumptions compare to the true sea-ice environment and the implications of their differences. Please find comments below that I hope the authors will find useful.

P1, L4. It's the loss of brine during melt that lowers sea-ice salinity, not so much freshwater percolation. Sea ice salinity decreases during the melt season with the

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expansion and interconnection of brine channels, leading to melt pond (and melt water) drainage through the ice.

P1, L7. Delete "and" before "to describe water..."

P2, L5-6. And the need to better represent the heterogeneity of these properties?

P2, L8. "the snow cover" do you mean the weight of the snow cover?

P2, L9. "over solely thermal growth" is confusing.

P2, L11-12. This is sentence is redundant with itself. Do you mean that the scales are poorly known because of their limited observations?

P2, L13-15. Sublimation also plays a role.

P2, L22-23. Where is this often observed?

P2, L23. Shallow relative to what?

P3, L1-2. This sentence needs to be a little more specific. There are remote sensing methods of snow that have no reliance on brightness temperatures (e.g. dual laser and radar altimetry).

P3, L13. A sentence could be added here to really set the stage. Something along the lines of:

"In this analysis, we apply SNOWPACK to the Antarctic sea-ice environment and demonstrate its ability to successfully reproduce snow-on-sea ice conditions..." etc.

P3, L22. Typo. "layer's"

P4, L15. Why does the brine freeze instantly? Wouldn't brine salinity increase with decreasing temperature until it reached the eutectic point for salt? Lines 18-19 and 22 and simulation results make me think this process is being accounted for, but this should be clarified in the text here.

P5, L11. For readers unfamiliar with the bucket scheme, a single sentence concisely describing its purpose would be appropriate here.

P9, L21-22. Brine channels become closed off during sea ice growth and thus much of the sea ice below sea level is unsaturated. How might this difference between the model and real-life play into the results?

Figure 1. The dates are not clear at the beginning of the buoy trajectories.

P11, L6. Do you mean here that comparisons between the model simulations and IMB data were made with regard to the sea ice properties only?

P11, L16-17. Please check the dates here. One of them is incorrect.

P11, L23. Typo "was" to "were"

P12, L1-2. Unless the sea ice is melting and drained, it would retain brine content above sea level.

P12, L2-3. Where do these initial values come from, and how sensitive are the results to them?

P12, L11. "measured snow depth" Measured snow depth from the snow buoys is fraught with uncertainties due to blowing and drifting snow, both during and outside of snowfall events. How representative is it to take these measured snow depth increases as snowfall events for the model?

P12, L12. Typo. Change "is below" to "is less than the"

P12, L21. Not all sea ice below sea level is saturated, and not all sea ice above sea level is salt-free. The model assumptions don't show geophysically-realistic vertical profiles of bulk salinity (please see the following for examples: https://apps.dtic.mil/dtic/tr/fulltext/u2/a312027.pdf). It would be worthwhile to discuss the discrepancies with observations, and possible pathways for future improvement of their representation. It would also be worthwhile to discuss the limited representation

of brine salinity – it also does not reflect a geophysically-realistic profile in this first example.

Figure 2 caption "dry sea ice" Technically, this is dry, porous freshwater ice.

P13, L5-6. sea level doesn't stay below the snow-ice interface for the simulation in panel b, does it?

Figure 3. It would be informative to show the temperature difference between panels b and c.

Why are there intermittent decreases in snow depth in panel a compared to what appears to be a steady increase in snow depth in panel b? It would be helpful to increase the y-axis in all of the panels so that readers can see the full range in snow depth. Alternatively, zoomed in panels could be helpful.

In panel a, is the model being re-adjusted to the measured snow depth at each time step or is it melting?

P14, L12. What is meant by an overestimated surface energy balance? If the energy budget is in balance, how can it be overestimated?

P13, L12-13. Do you mean here that snow density was too small, and thus, its insulating capacity was too high, keeping the sea ice "warmer" relative to the observed temperatures?

P15, L7-8. Isn't good agreement expected with this approach?

P15, L11. How much is slightly overestimated? It's cut off in the figure.

P15, L17-18. It would be helpful to state when (which date) flooding occurs since it's not apparent in the figure.

P15, L28-29. Can difference plots be shown? How well do they compare?

Figure 4a. The boundary between the snow and sea ice looks unusual. Is LWC actually

zero in the uppermost layers of the ice surface or is there a gap between the snow and ice in this figure?

Figure 4b. Why does the bulk salinity remain constant both vertically and horizontally in panel b? Why might this differ so much from observations? (please see the following for profile examples: https://apps.dtic.mil/dtic/tr/fulltext/u2/a312027.pdf).

Figure 5 caption, dry snow is colored grey. This description is incorrect here?

Figure 6. This is a nice simulation experiment. For figure 6d, what mechanism is causing the brine salinity to increase in the uppermost part of the snow pack during March 2015? Also, what is happening with brine salinity in the lowermost ice layers from Sept - Dec 2015?

Figure 8d. How can there be brine in the topmost layers of the snow pack?

P25, L9-10. While I agree with this statement, to bolster it, more simulations forced by ERA5 snowfall events rather than the selected events by the IMB data should be conducted and, at the very least, shown in supplementary material. Many current approaches for snow depth simulations are simplified and exclude loss terms. It would be informative to see if this approach is more effective in simulating snow depth due to its sophistication.

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