This manuscript assesses the influence of snow redistribution on snow-thickness simulations using the Icepack model and conducts sensitivity analyses to evaluate the parameterisation of snow redistribution. The topic is important for the snow and sea-ice modelling community. However, the manuscript requires further improvement before it can be recommended for publication.

Response:

We thank you for your encouragement and pertinent comments. Your constructive comments have indeed greatly improved the manuscript. We have revised the article based on the specific comments below and responded to them point-to-point.

Major points:

1. The authors use MOSAiC observations to compare with the model simulations. However, it is not clear which MOSAiC transects or loops were used in the analysis. The MOSAiC snow observations include the Southern Loop, Northern Loop, runway, ridges, and summer transects, which represent different sea-ice types and surface conditions. It is unclear whether the authors combined measurements from all ice types or selected a specific subset. More information should be provided in the revised manuscript. The underlying sea-ice type is highly relevant to snow depth and wind-driven snow redistribution. In Figures 1 and 2, sea-ice thickness is provided, but ice age or ice type, for example first-year ice vs second-year ice, is not clearly described. These different ice types may behave very differently in terms of snow accumulation and redistribution (https://doi.org/10.1525/elementa.2021.00115). In particular, the parameter P, defined as the ratio of snow mass on ridges to that on level ice, is likely to depend strongly on ice age, ice type, and surface roughness. This should be discussed and, where possible, supported by observational information.

Response:

We thank the reviewer for this valuable comment. We would like to clarify that the observations used in this study are derived from seven MOSAiC Snow and Ice Mass Balance Array (SIMBA) buoys (Lei et al., 2022), rather than from the snow transects (e.g., Northern Loop, Southern Loop, runway, or ridge surveys). We revised the text in response to this concern:

"Observed snow thickness was obtained from the Snow and Ice Mass Balance (SIMBA) array (Lei et al., 2022). **In this study, seven buoys were selected according to their operational periods, and their mean snow thickness and mean ice thickness were used to evaluate the simulated snow and ice thickness (Table 1). According to the site descriptions summarized by Perovich et al. (2023), these buoys were deployed over both first-year ice (FYI) and second-year ice (SYI).** Snow observations were converted to snow water equivalent (SWE) using fitted SnowMicroPen (SMP) density – SWE relationships (Wagner et al., 2022)."

We agree that sea-ice type and surface morphology can influence snow accumulation and wind-driven snow redistribution. We have added a discussion in the revised manuscript:

"Previous studies have shown that snow accumulation and redistribution vary among different sea-ice regimes because of differences in ice age, ice type, deformation state, and surface roughness (Clemens-Sewall et al., 2022). Therefore, the parameter P and the performance of snow redistribution parameterizations may also vary under different sea-ice conditions. The observational dataset used in this study includes both FYI and SYI conditions. However, the limited number of available SIMBA buoy sites does not allow a robust evaluation of individual schemes for specific ice regimes. Consequently, the optimized parameter values and the conclusions presented here should be interpreted as representing the average snow redistribution behaviour across the range of sea-ice conditions sampled during MOSAiC rather than universally applicable values. Future studies with expanded observational datasets are needed to quantify how snow redistribution processes and model performance depend on ice age, ice type, deformation, and surface roughness."

Table 1. Characteristics of the seven MOSAiC Snow and Ice Mass Balance Array (SIMBA) buoys used in this study, including deployment site, sea-ice type, observation period, and initial snow and ice conditions. The selected buoys were deployed over both first-year ice (FYI) and second-year ice (SYI) during the MOSAiC expedition (Perovich et al., 2023; Salganik et al., 2023). CO refers to the Central Observatory, L1-L3 are Local Scale Distributed Network sites located within a few kilometers of the Central Observatory, and

M6 is a Mesoscale Distributed Network site located tens of kilometers from the Central Observatory.

Buoy ID	**Site**	**Ice Type**	**Start Date**	**End Date**	**Initial Ice Thickness (m)**	**Initial snow Thickness (m)**
2019T56	CO	SYI	2019-11-02	2020-07-03	0.42	0.18
2019T62	CO	SYI	2019-10-30	2020-07-05	0.80	0.20
2019T63	L2	SYI	2019-11-25	2020-07-27	1.08	0.12
2019T64	M6	SYI	2019-11-27	2020-08-01	1.70	0.16
2019T66	CO	FYI	2019-10-30	2020-08-02	0.42	0.10
2019T67	L1	SYI	2019-11-09	2020-07-07	1.36	0.22
2019T70	L3	FYI	2019-10-10	2020-07-11	0.48	0.06

Perovich, D., Raphael, I., Moore, R., Clemens-Sewall, D., Lei, R., Sledd, A., & Polashenski, C. (2023). Sea ice heat and mass balance measurements from four autonomous buoys during the MOSAiC drift campaign. Elementa: Science of the Anthropocene, 11(1), 00017. https://doi.org/10.1525/elementa.2023.00017

Salganik, E., Lange, B. A., Itkin, P., Divine, D., Katlein, C., Nicolaus, M., et al. (2023). Different mechanisms of Arctic first-year sea-ice ridge consolidation observed during the MOSAiC expedition. Elementa: Science of the Anthropocene, 11(1), 00008. https://doi.org/10.1525/elementa.2023.00008

2. Based on the observation dates in Fig 1, it appears that observations until late July were included. Therefore I assume the in-situ snow data from the summer transects were also used. However, the summer transects were not always located in the same areas as the Northern Loop and Southern Loop, which were sampled from November to May. Note that the summer transects

has a small spatial overlap with the Nloop site (https://doi.org/10.1525/elementa.2021.000072). This change in sampling region may introduce bias into the time-series analysis shown in Figures 1, 2, and 4, because the ice conditions may differ substantially between these regions. The authors should clarify whether the same ice floe/region was followed throughout the analysis or whether different transects were combined. If different regions were combined, the potential effect on the interpretation of the time series should be discussed.

Response:

We thank you for this comment. We would like to clarify that the observations used in this study are not derived from the MOSAiC snow survey transects (e.g., Northern Loop, Southern Loop, or Summer Transects). Instead, the observational dataset consists of snow and ice thickness measurements from seven MOSAiC Snow and Ice Mass Balance Array (SIMBA) buoys (Lei et al., 2022). Therefore, the potential sampling differences among the Northern Loop, Southern Loop, and Summer Transects do not affect the analysis presented in this study. The selected SIMBA buoys remained attached to and drifted with the sea ice during their operational periods, providing continuous measurements at their respective locations.

3. The study mainly analyses differences in the model simulations under different snow-redistribution schemes. However, more results and discussion based on the observations should be included when comparing the model results. For example, in lines 310–328, the authors interpret that the snwITDrdg scheme leads to increased snow-ice formation and increased snow thickness over thinner ice. Then my question is whether enhanced snow-ice formation was actually observed in the field? This means, more generally, for the results shown in Figures 1–4, the manuscript should not only describe how the simulations differ between schemes, but also integrate the available observations to evaluate which scheme is correct or more appropriate and under what conditions. This would help the authors generalise the results and identify the climatic, dynamic, or ice-type conditions under which each modelling scheme is most suitable.

Response:

We thank the reviewer for this insightful comment. We agree that observational evidence is essential for evaluating the realism of the simulated processes.

In the revised manuscript, we have expanded the discussion of Figures 1-4 by placing greater emphasis on the comparison between simulations and observations. Rather than only describing the differences among model schemes, we now discuss their performance relative to the observed snow thickness and ice thickness derived from the seven MOSAiC SIMBA buoys. The comparison shows that the snow redistribution schemes generally improve the simulation of snow thickness relative to the default configuration, indicating that accounting for snow redistribution is important for reproducing the observed snow evolution.

Regarding the enhanced snow-ice formation simulated by the snwITDrdg scheme, we would like to clarify that this result is derived from model diagnostics rather than directly confirmed by observations. The observational dataset used in this study consists of the mean snow thickness and ice thickness from seven MOSAiC SIMBA buoys. Among these buoys, snow-ice formation was identified at only one site, while the remaining buoys did not show evidence of snow-ice formation. Consequently, enhanced snow-ice formation is not evident in the averaged observations. We have therefore revised the manuscript in response to this concern:

"Additionally, **model diagnostics indicate enhanced snow-ice formation in the snwITDrdg scheme relative to the bulk scheme.** In addition to depositing a portion of snow particles into open leads, the snwITDrdg scheme diagnostically redistributes snow among ice thickness categories. This redistribution, modulated by the ridged-ice fraction and surface type within each category, results in increased snow thickness over thinner ice categories, making the ice more susceptible to surface flooding and subsequent snow-ice formation. **However, enhanced snow-ice formation is not evident in the averaged SIMBA observations used in this study. Furthermore, previous studies have suggested that Icepack may overestimate snow-ice formation (Gu et al., 2022).**"

The observational dataset used in this study includes both first-year ice (FYI) and second-year ice (SYI) conditions. However, the number of available buoy sites is insufficient to robustly evaluate the performance of individual schemes separately for different ice regimes. Therefore, the conclusions presented here should be interpreted as representing the average behaviour across the range of ice conditions sampled during MOSAiC. We agree that identifying the climatic, dynamic, and ice-type conditions under which each redistribution scheme performs best is an important topic and have highlighted this for future work. We have added a discussion in the revised manuscript:

"**Previous studies have shown that snow accumulation and redistribution vary among different sea-ice regimes because of differences in ice age, ice type, deformation state, and surface roughness. Therefore, the parameter P and the performance of snow redistribution parameterizations may also vary under different sea-ice conditions. The observational dataset used in this study includes both FYI and SYI conditions. However, the limited number of available SIMBA buoy sites does not allow a robust evaluation of individual schemes for specific ice regimes. Consequently, the optimized parameter values and the conclusions presented here should be interpreted as representing the average snow redistribution behaviour across the range of sea-ice conditions sampled during MOSAiC rather than universally applicable values. Future studies with expanded observational datasets are needed to quantify how snow redistribution processes and model performance depend on ice age, ice type, deformation, and surface roughness.**"

Gu, F., Yang, Q., Kauker, F., Liu, C., Hao, G., Yang, C.-Y., Liu, J., Heil, P., Li, X., and Han, B.: The sensitivity of landfast sea ice to atmospheric forcing in single-column model simulations: a case study at Zhongshan Station, Antarctica, The Cryosphere, 16, 1873–1887, https://doi.org/10.5194/tc-16-1873-2022, 2022.

Specific points:

Line 36: The statement that snow accumulation can lead to flooding should be clarified. Please explain under what conditions flooding occurs and what is meant by flooding in this context. This would make the sentence clearer for readers who are less familiar with sea-ice processes.

Response:

Thanks for your advice. we revised the text in response to this concern:

”Snow accumulation can also lead to flooding **when the snow load depresses the ice surface below sea level, allowing seawater to infiltrate the overlying snow layer. Subsequent refreezing of the flooded snow may form snow-ice,** a process well documented in Antarctic first-year ice (Jeffries et al., 2001; Leppäranta, 1983; Maksym & Jeffries, 2000; Massom et al., 2001).”

Section 2.2: Please add more information about the MOSAiC expedition data used in this study, including ice types, loop positions, transect types, and the temporal coverage of each dataset.

Response:

Thanks for your advice. We revised the text in response to this concern:

“In this study, seven buoys were selected according to their operational periods (**Table 1**), and their mean snow thickness and mean ice thickness were used to evaluate the simulated snow and ice thickness. According to the site descriptions summarized by Perovich et al. (2023), these buoys were deployed over both first-year ice (FYI) and second-year ice (SYI)”

Table 1. Characteristics of the seven MOSAiC Snow and Ice Mass Balance Array (SIMBA) buoys used in this study, including deployment site, sea-ice type, observation period, and initial snow and ice conditions. The selected buoys were deployed over both first-year ice (FYI) and second-year ice (SYI) during the MOSAiC expedition (Perovich et al., 2023; Salganik et al., 2023). CO refers to the Central Observatory, L1-L3 are Local Scale Distributed Network sites located within a few kilometers of the Central Observatory, and M6 is a Mesoscale Distributed Network site located tens of kilometers from the Central Observatory.

Buoy ID	Site	Ice Type	Start Date	End Date	Initial Ice Thickness (m)	Initial snow Thickness (m)
2019T56	CO	SYI	2019-11-02	2020-07-03	0.42	0.18
2019T62	CO	SYI	2019-10-30	2020-07-05	0.80	0.20
2019T63	L2	SYI	2019-11-25	2020-07-27	1.08	0.12
2019T64	M6	SYI	2019-11-27	2020-08-01	1.70	0.16
2019T66	CO	FYI	2019-10-30	2020-08-02	0.42	0.10
2019T67	L1	SYI	2019-11-09	2020-07-07	1.36	0.22
2019T70	L3	FYI	2019-10-10	2020-07-11	0.48	0.06

Perovich, D., Raphael, I., Moore, R., Clemens-Sewall, D., Lei, R., Sledd, A., & Polashenski, C. (2023). Sea ice heat and mass balance measurements from four autonomous buoys during the MOSAiC drift campaign. Elementa: Science of the Anthropocene, 11(1), 00017. https://doi.org/10.1525/elementa.2023.00017

Salganik, E., Lange, B. A., Itkin, P., Divine, D., Katlein, C., Nicolaus, M., et al. (2023). Different mechanisms of Arctic first-year sea-ice ridge consolidation observed during the MOSAiC expedition. Elementa: Science of the Anthropocene, 11(1), 00008. https://doi.org/10.1525/elementa.2023.00008

Section 2.3: Could it be combined with Section 2.1, which introduces the Icepack model?

Response:

Thank you for your suggestion. We respectfully retain Section 2.3 as a separate section because its primary purpose is not to introduce the Icepack model itself, but to provide a detailed description of the snow redistribution parameterization used in this study. While Section 2.1 presents the general Icepack model framework, Section 2.3 focuses on the specific parameterization scheme, including its formulation, and its role in the experiments. We believe that separating these sections improves the clarity and readability of the manuscript

Section 2.3: The equations are not numbered.

Response:

Revised as suggested.

Lines 173–184: This paragraph seems somewhat disconnected from the surrounding text. It may fit better in the Introduction or Discussion?

Response:

Thank you for this suggestion. We agree that this paragraph includes information on the assumptions and limitations of the blowing-snow redistribution scheme. However, because these assumptions are integral to the formulation and implementation of the snow redistribution parameterization in Icepack, we believe that they are most appropriately described in Section 2.3. To improve the flow of the manuscript, we have revised the paragraph and strengthened its connection to the preceding description of the snow redistribution process:

"**In addition to the redistribution mechanisms described above, the snwITDrdg scheme relies on several simplifying assumptions that influence the representation of blowing-snow processes in Icepack**. Snow loss to leads therefore occurs both through direct snowfall onto open water when sea ice concentration is below unity and through wind-driven snow erosion when wind speed exceeds a threshold. Icepack assumes local conservation of snow mass during blowing-snow redistribution, neglecting non-local transport between grid cells (Lecomte et al., 2015). Snow redistribution directly modifies the snow thickness associated with each ice thickness category and therefore affects the thermodynamic evolution of snow and ice. However, because Icepack assumes a uniform snow thickness within each category, subgrid-scale spatial heterogeneity in snow redistribution is not explicitly resolved. Although snow thickness directly affects the thermodynamic mass balance, the effects of its spatial variability are primarily represented through the surface radiation scheme, which responds to changes in effective surface fractions (Hunke et al., 2022)."

line 179: it mentions that Icepack assumes a uniform snow thickness. However, observations show strong spatial variability in snow thickness at sub-grid scales (https://doi.org/10.1017/jog.2022.18 and https://doi.org/10.5194/tc-20-2825-2026). Would this uniform-snow assumption introduce bias or uncertainty into the results presented in the manuscript? This issue should be discussed.

Response:

Thank you for this valuable comment. We agree that observations have demonstrated pronounced subgrid-scale spatial variability in snow thickness, as highlighted in the suggested references. The assumption of a uniform snow thickness within each ice-thickness category is a simplification adopted by Icepack and represents one of the limitations of the current model. Consequently, this assumption may introduce uncertainty into the simulated snow distribution and its thermodynamic influence on sea ice.

However, the objective of this study is to evaluate different snow redistribution parameterizations under the same model framework. Since the uniform-snow assumption is applied consistently in all simulations, it is not expected to affect the relative comparison among the parameterization schemes. In addition, our evaluation is based on the mean snow thickness over the observational area rather than local-scale snow variability, and the optimized parameter values therefore represent the average snow redistribution behaviour over the sampled sea-ice conditions rather than local heterogeneity. We have added the discussion in response to this concern:
”Previous studies have shown that snow accumulation and redistribution vary among different sea-ice regimes because of differences in ice age, ice type, deformation state, and surface roughness (Clemens-Sewall et al., 2022). **Field observations have also demonstrated pronounced subgrid-scale spatial variability in snow thickness (Huang et al., 2026; Mallett et al., 2022). However, Icepack assumes a spatially uniform snow thickness within each ice-thickness category and therefore does not explicitly resolve this subgrid-scale heterogeneity, which may introduce uncertainty into the simulated snow distribution and its**

thermodynamic influence on sea ice. Consequently, the parameter P and the performance of snow redistribution parameterizations may vary under different sea-ice conditions. The observational dataset used in this study includes both first-year ice and second-year ice conditions. However, the limited number of available SIMBA buoy sites does not allow a robust evaluation of individual parameterization schemes for specific ice regimes **or subgrid-scale snow variability. Therefore, the evaluation presented here is based on the mean snow thickness over the observational region,** and the optimized parameter values and conclusions should be interpreted as representing the average snow redistribution behaviour across the range of sea-ice conditions sampled during MOSAiC. **Since the same model assumption is adopted consistently in all simulations, it is unlikely to affect the relative comparison among the snow redistribution parameterizations examined in this study**. Future work incorporating more realistic representations of subgrid-scale snow heterogeneity together with expanded observational datasets will help further quantify these uncertainties and improve the representation of snow redistribution processes under different sea-ice conditions."

Huang, L., Stroeve, J., Newman, T., Mallett, R., Willatt, R., Zhou, L., Johansson, M., Nab, C., and Fallows, A.: Snow depth distributions on sea ice of different ages and thicknesses from regional field campaigns, The Cryosphere, 20, 2825–2849, https://doi.org/10.5194/tc-20-2825-2026, 2026.

Mallett, R. D. C., Stroeve, J. C., Tsamados, M., Willatt, R., Newman, T., Nandan, V., Landy, J. C., Itkin, P., Oggier, M., Jaggi, M., and Perovich, D.: Sub-kilometre scale distribution of snow depth on Arctic sea ice from Soviet drifting stations, Journal of Glaciology, 68, 1014–1026, https://doi.org/10.1017/jog.2022.18, 2022.

Line 220: The authors state that the snwITDrdg scheme performs better than the none and bulk schemes for SWE. However, the simulated SWE remains substantially higher than the mean observations. Does this indicate that none of the three schemes fully captures the observed SWE evolution?

Response:

Thank you for this helpful comment. We agree that, although the snwITDrdg scheme performs better than the none and bulk schemes, it still overestimates SWE relative to the observations, particularly during winter and spring. This indicates that none of the three default snow redistribution schemes fully captures the observed SWE evolution under the MOSAiC conditions.

As discussed in the following section, this remaining bias motivates the parameter sensitivity analysis of the snwITDrdg scheme. By optimizing the key tuning parameter controlling snow erosion, we further improve the representation of snow redistribution and reduce the discrepancy between the simulated and observed SWE. We revised the text in response to this concern:

"However, even with blowing-snow redistribution, simulated snow thickness remains overestimated in winter and spring and melts too rapidly in summer (Figure 1d), **indicating that none of the three default snow redistribution schemes fully reproduces the observed SWE evolution. This remaining bias motivates the parameter optimization of the snow redistribution parameterization presented in the following section.**"

Lines 221–223: The authors state that the snwITDrdg scheme significantly reduces SWE, particularly during high-wind periods. However, I am not sure this is clearly supported by Figures 1b and 1d. Please provide more explanation or evidence to support this statement. In addition, the statement that "snow particles are suspended and redistributed or deposited in the leads" requires more supporting evidence or references too.

Response:

Thank you for this helpful comment. We agree that the original manuscript could cause misunderstandings. We have therefore revised the text to avoid the expression "particularly during high-wind periods" and instead state that snow redistribution is activated when the wind speed exceeds the threshold for snow erosion (approximately 3.5 m s^{-1} under the default snow density). According to the snwITDrdg parameterization described in Section 2.3 (Lecomte et al., 2013, 2015; Hunke et al., 2022), suspended snow particles are redistributed over the ice surface or lost into open leads, thereby reducing snow accumulation. We have revised the text to clarify that this statement refers to the model physics rather than direct evidence from Figure 1.

"In contrast, the snwITDrdg scheme significantly reduces SWE compared with the none and bulk schemes. **According to the parameterization described in Section 2.3, snow redistribution is activated when the wind speed exceeds the threshold for snow erosion (~3.5 m/s Figure 1b). Under these conditions, suspended snow particles are redistributed over the ice surface or deposited into open leads (Lecomte et al., 2013, 2015; Hunke et al., 2022), thereby reducing snow accumulation and improving agreement with the observations."**

Line 248: Please explain how the range of P values from 0.3 to 4 was selected. Are these values based on observations? Since the minimum MAE appears to occur at the maximum tested value of P = 4, it would be useful to know whether MAE increases again for P values greater than 4.

Response:

Thank you for this helpful comment. The sensitivity range of P was selected based on both the default Icepack configuration and available observations. The default value (P = 0.3) originates from SHEBA observations, whereas MOSAiC observations showed that snow depth on large ridges could reach approximately 5 times that on level ice (Itkin et al., 2023). We therefore increased P from 0.3 to 4.0 to investigate the model sensitivity over a range representative of the observed snow redistribution conditions.

Although the minimum MAE occurs at the upper end of the tested range, the parameter optimization was constrained not only by MAE but also by the observed accumulated snow loss into open leads. Increasing P beyond 4 would produce snow losses that exceed the observational estimates and would therefore no longer be physically consistent with the available observations. For this reason, we did not extend the sensitivity experiments to values greater than 4. We have clarified this rationale in the revised manuscript:

"In the bulk redistribution scheme, P is set to 0.3 based on estimates from SHEBA observations conducted two decades ago, which suggest that snow thickness on ice ridges is approximately 30% greater than that on level ice. However, observations during the MOSAiC campaign indicate that large ridges accumulated nearly five times the snow depth of level ice (Itkin et al., 2023). **Therefore, to investigate the sensitivity of the model over an observationally supported range, we increased P from 0.3 to 4.0 to examine its impact on simulated snow and ice thickness."**

Figure 2 caption: Explain the meaning of P and gamma in the caption so that the figure can be understood independently.

Response:

Thank you for the suggestion. We revised the text in response to this concern:

Figure 2. Time series of (a) snow thickness and (b) ice thickness from sensitivity experiments under the bulk redistribution scheme with varying P, **where P is the ratio of snow depth on ridges to that on level ice,** and (c) snow thickness and (d) ice thickness from sensitivity experiments under the snwITDrdg scheme with varying γ, **where γ is the tuning coefficient controlling the snow erosion rate**. In panels (a) and (b), the 10 colored lines represent sensitivity experiments with P ranging from 0.3 to 4.0. In panels (c) and (d), the 11 colored lines correspond to sensitivity experiments with the γ tuning coefficient ranging from 1 × 10-5 to 3 × 10-5 .