Response to 2nd Review Comments for

"Seasonal evolution of snow density and its impact on thermal regime of sea ice during the MOSAiC expedition"

Yubing Cheng, Bin Cheng, Roberta Pirazzini, Amy R. Macfarlane, Timo Vihma, Wolfgang Dorn, Ruzica Dadic, Martin Schneebeli, Stefanie Arndt, and Annette Rinke

Note: Reviewers' comments are in black clolor; authors' responses are in blue color.

Reviewer comments:

Comments from Referee 1

Review Summary:

The paper discusses the temporal evolution of snow density on Arctic sea ice during the MOSAiC campaign. The observational data are compared with several snow density parameterizations of varying complexity to assess how well they represent changes in snow density. Modeling results are then used in a sea ice model to calculate snow and ice temperatures as well as sea ice thickness.

The results of the mean snow density calculations show relatively good agreement with observations. However, the temporal variations in snow density are not well captured, which affects the accuracy of the resulting sea ice thickness estimates.

The core idea of the paper is clear, and the findings offer a valuable contribution to the understanding of snow compaction processes on Arctic sea ice. The study is particularly relevant for improving snow representation in climate and remote sensing models.

However, the narrative is at times disorganized, and several sections—particularly the introduction and methods—lack structure, which can confuse the reader. The volume of the manuscript is also quite large. For better readability, the **conclusion** section should be separated from the **discussion** and significantly shortened.

There are also methodological and conceptual issues that require clarification:

- **Line 13:** It is not totally clear why the focus is on the top 3 cm of the snowpack. It would be helpful to explain this in the introduction, potentially in relation to remote sensing relevance or surface energy balance.

  There are several reasons for us to define the top 3 cm of snow as the "surface snow layer" and focus on its changes. 1) The "surface snow layer" typically refers to the uppermost layer of snow that is directly in contact with the atmosphere. This layer is characterised by new snow deposition, the surface radiative and turbulent energy fluxes balance, which results in the variation of surface skin temperature, and high sensitivity to weather conditions (e.g., changes in air temperature and wind). 2) For snow and sea ice process modelling, a surface layer between 1 – 5 cm is usually defined depending on the model's vertical resolution. The HIGHTSI model typically has 10 layers in snow and 20 layers in ice. For a snow depth of 20 cm, the surface layer is accordingly 2 cm. 3) Finally, the MOSAiC in situ snow observations were carried out with a vertical layer increment of 3 cm, as this was the size of the density cutter. Accordingly, the vertical resolution of the dataset is 3 cm.

We have added the following text to explain the surface snow layer more clearly in the introduction:

“Surface snow layer refers to the uppermost layer of snow that is directly in contact with the atmosphere. This layer is characterised by new snow deposition and surface skin temperature varying according to the surface energy balance controlled by the radiative and turbulent fluxes. Hence, the layer is sensitive to variations in the air temperature, wind speed, and surface albedo. The bulk snowpack density, on the other hand, is critical for the sea ice mass balance. Accordingly, we address it separately from the snow surface density to highlight the different roles of the surface layer and the bulk snowpack in the sea-ice simulation.”

- **Lines 37–38:** More details on the origin and significance of the snow surface layer (SSL) would strengthen the introduction. Some content from section 3.2 (e.g., lines 222–225) could be relocated here.

  Agreed, we moved the surface scattering layer (SSL) description with some additions to the Introduction.

  SSL develops when the surface of sea ice melts and the brine channels preferentially melt, revealing a porous structure that resembles snow. It originates from the underlying ice and has no snow included in it. Its isotopic signature is purely from the underlying ice. The preferential melting of ice crystal boundaries produces the SSL (Smith et al., 2022), a porous, snow-like layer where the density increases with depth (Macfarlane et al., 2023a). The SSL is less dense than the sea ice from which it is generated. The surface meltwater originating from the melting SSL drains vertically through the ice column, when the ice porosity allows, and laterally into melt ponds and leads, leaving the SSL relatively dry. As the top SSL melts, there is a simultaneous transformation of the underlying bare ice to the SSL. Thus, the thickness of the SSL remains almost stable throughout the summer.

- **Lines 41–42:** The statement should be corrected: snow density and depth together determine snow mass. A better phrasing could be: “Snow density and layer thickness determine the weight of the snowpack on sea ice. When the snow load is sufficient to submerge the ice surface, flooding may occur, leading to slush and snow-ice formation.”

  We partly replaced the original text with the text suggested by the reviewer: “Snow density and layer thickness determine the weight of the snowpack on sea ice”. The rest of the text has been removed because the snow-ice and superimposed ice descriptions have been presented in the previous paragraph.

- **Line 42–43:** It’s snow microstructure—not just density—that governs percolation and wicking processes.

  We have described the snow-ice and superimposed ice formation elsewhere, so this sentence was removed to avoid repetition.

- **Lines 50–51:** Consider revising to: “This results in changes to the stratigraphy and usually leads to compaction and densification of snow.”

Done.

After snowfall, snow density begins to evolve due to snow metamorphism. This results in changes to the stratigraphy and usually leads to compaction and densification of snow (Bormann et al., 2013; Helfricht et al., 2018; Judson and Doesken, 2000).

- **Line 59:** Thermodynamic metamorphism does not result from densification; rather, densification is one outcome of metamorphism. Additionally, kinetic growth during temperature-gradient metamorphism can inhibit compaction.

We improved the description accordingly

The rearrangement of snow microstructure during snow metamorphism is a significant driver of snowpack density. Sublimation and deposition of water vapor under a temperature gradient can drive kinetic growth of faceted crystals, which may inhibit compaction, whereas other metamorphic processes can enhance bonding and increase snow density.

- **Line 71–72:** Did you consider the effect of rain-on-snow (ROS) events on snow density?

The ROS was observed during MOSAiC (Stroeve et al., 2022). The events occurred during MOSAiC leg 5 beyond our modelling period. Therefore, we have not done a concrete investigation of ROS effect on snow density. Nevertheless, we present a qualitative discussion on ROS in the revised manuscript (discussion section):

During autumn, winter, and spring, rain-on-snow (ROS) events can form hard ice crusts on the snow surface (Rennert et al., 2009). During the MOSAiC campaign, a few ROS events occurred in September (Leg 5), increasing surface snow density from 150 kg/m^3 to 350 kg/m^3 within two days (Stroeve et al., 2022). Between 12 – 22 April, two warm-air intrusion episodes raised near-surface temperatures to near-melting conditions (Svensson et al., 2023), although no ROS events were documented during this period.

- **Line 84:** Please remove the thin black lines around the plots in Figure 1 and align them. Also, CO2 and CO3 are difficult to distinguish on the left map—consider improving their labels.

Figure 1 has been improved accordingly.

Line 88: What was the temporal resolution of the snow measurements?

Snow measurements were recorded at a daily temporal resolution. To ensure a spatial measurement distribution, multiple locations for snowpit timeseries were set up within and around the central observatory (CO). Snow measurements were conducted daily, rotating through these different locations. Due to the number of different locations, individual snowpit sites were revisited on a weekly or bi-weekly basis.

- **Lines 93–94:** This sentence can likely be removed to save space.

Agree, and the text has been removed.

- **Line 96:** Please clearly state that ERA5 reanalysis data were used in the calculations.

We have written in the later part of the original manuscript (L158-L161) on this matter: The meteorological parameters, including wind speed (V), air temperature (Ta), relative humidity

(Rh), precipitation (P), as well as shortwave (Qs) and longwave (Ql) radiative fluxes from the ERA5 reanalysis along drift trajectory of MOSAiC CO (Leg 1-3) were used as forcing data for the HIGHTSI model (Fig. S1).

For better clarity, we improved the text here as well.

- **Line 99:** Include volume and spatial resolution for the box cutter measurements. How many snow pits were excavated per measurement period (weekly?).

  The box cutter has a volume of 100 cm^3. Each snow sample has a depth of 3 cm. Line 101: "Snow pits were conducted weekly at various locations on undeformed first-year ice, second-year ice, and places close to open leads and pressure ridges. The majority of measurements were taken within the central observatories in designated clean, undisturbed snow areas. Due to limited manpower, individual snowpit sites were often revisited on a weekly or bi-weekly basis. The snow pits are composed of multiple instruments all measured within a 1m x 1m area. Transects of "quick" snow measurements, including a snow micro penetrometer, allowed for spatial quantification of the snow properties. However, in this study, we only use data from the traditional snowpit point measurements for density (100 cm^3 density cutter and the ETH SWE tube)

- **Line 110:** Please use the **International Classification for Seasonal Snow on the Ground** (Fierz et al., 2009) to describe snow types for consistency and clarity.

  These snow types are presented only for descriptive purposes. We have therefore removed them from the text.

- **Line 111:** Clarify what is meant by terms like "drifted snow," "frozen snow," and "jewel snow." For example, is "drifted snow" a wind slab? "Visible dust" is not a snow type.

  These snow types are presented only for descriptive purposes. We have therefore removed them from the text.

- **Lines 124–125:** Please provide more detail on snow depth measurements.

  We derived the bulk snow density based on snow depth and SWE measurements, measured once for each snowpit visit. The ETH-SWE tube has a scale on the side to identify the snow height that is being collected and measured. This is confirmed with a corresponding snow height measurements using a ruler placed vertically against the snowpit wall once it had been excavated.

- **Lines 127–129:** Consider moving this content to the Results section, as it presents findings rather than methods.

  Done

- **Line 152:** Clarify whether this variable was included in the model.

  Yes, this process has been taken into account in the HIGHTSI model. We have improved the text accordingly.

- **Line 163:** Snow density was measured weekly, so how was the 10-day moving average calculated from these discrete in situ observations?

  Snow density was measured daily, not weekly. We have corrected this description. We calculated 10-day moving averages applying the actual daily snow density measurements. For example, the first 10-day time window is day 1 – day 10, the next 10-day time window is day 2 - day 11, and so on.

- **Lines 166–168:** This content might be more appropriate in section 2.2 on snow density.

  Done, we moved text to section 2.2 accordingly.

- **Line 183–184:** Gravity?

  Added

  After snowfall, surface snow undergoes densification due to gravity, wind-induced compaction and temperature-driven metamorphism.

- **Line 214:** Figure 4 needs revision. For example, panel (c) lacks a color bar, which is mentioned in the caption. Including precipitation data would also enhance the figure.

  Sorry, there was a spelling mistake in the legend of Fig.4. Panel (c) contains just a black line and doesn't need a color bar. But, Panel (a) has the bottom-color bars for legs, and Panel (b) has the bottom-color for the stages. We corrected the legend "The bottom-colored bars in (a) refer to the MOSAiC legs 1-5". We have also modified this figure, and the precipitation subplot has been added.

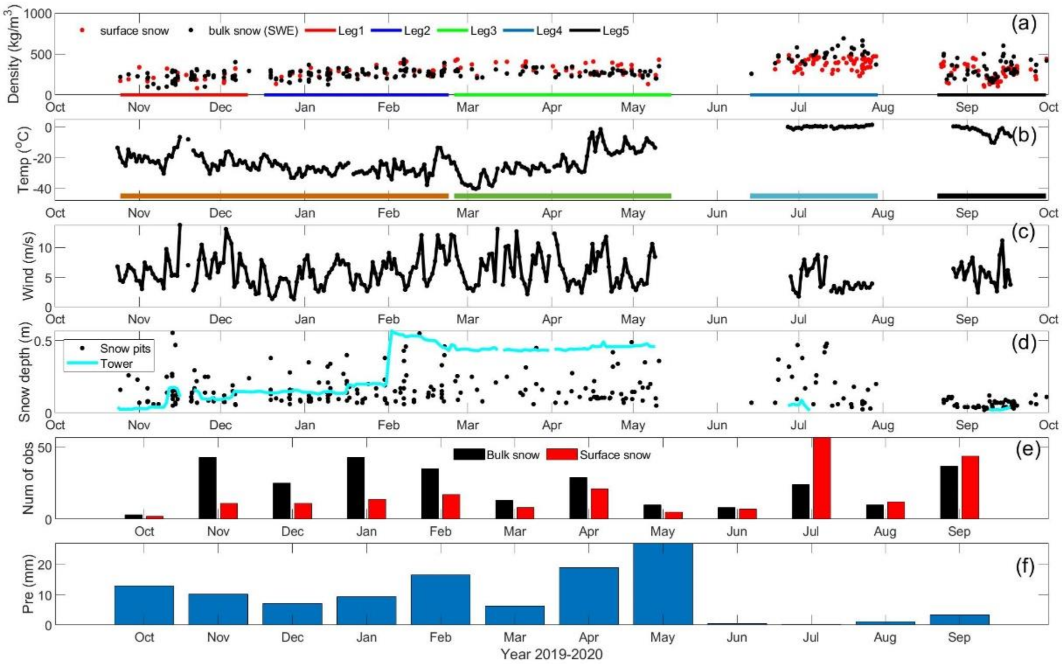


Figure 4: Time series of (a) observed snow density (kg/m^3) for surface snow (red) and bulk snow (black); observed daily average (b) 2-m air temperature (˚C) and (c) 10-m wind speed (m/s). The bottom-colored bars in (a) refer to the MOSAiC legs 1 - 5. The colored horizontal bars in (b) represent the four stages (dark red: I;

green: II; blue: III; and black: IV). (d) Time series of snow depth: black dots represent observations from snow pits, and the light blue line indicates measurements from the weather tower. (e) Distribution of the number of observations for bulk snow (black bars) and surface snow (red bars), and (f) observed monthly total precipitation.

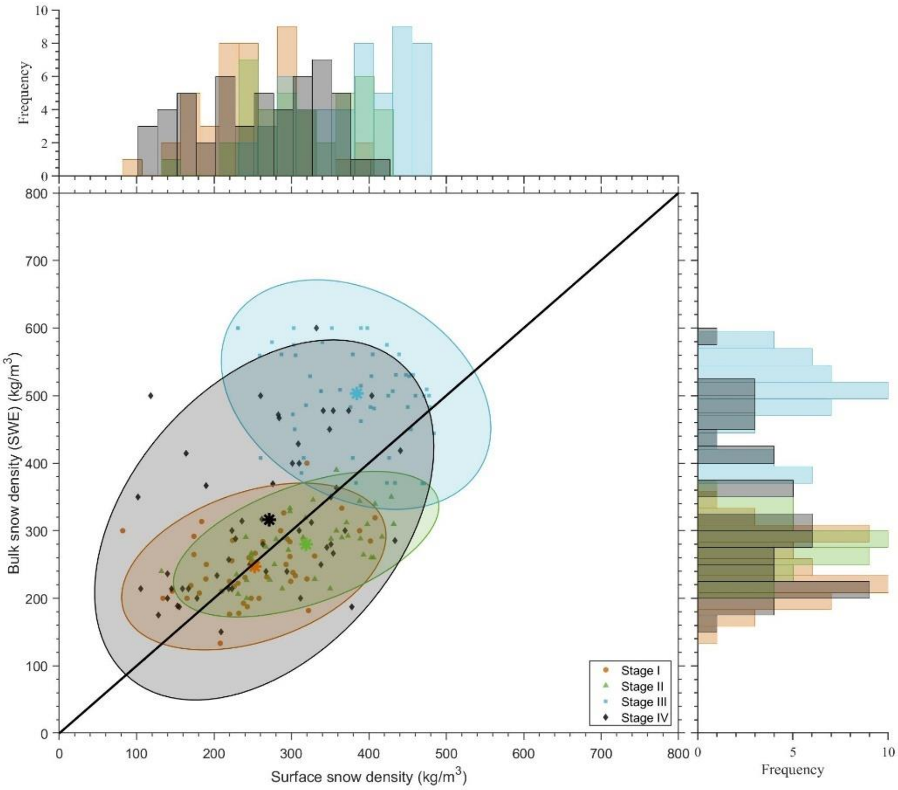
- **Lines 222–225:** This paragraph would fit better in the Introduction when the SSL is first mentioned.

  Done, we shortened and moved the text into the introduction chapter:

  SSL develops when the surface of sea ice melts and the brine channels preferentially melt, revealing a porous structure that resembles snow (Smith et al., 2022). Its isotopic signature is purely from the underlying ice. The density of this porous, snow-like layer increases with depth (Macfarlane et al., 2023). The SSL is less dense than the sea ice from which it is generated, but it is much denser than snow. The meltwater drains to melt ponds and leads, leaving the SSL relatively dry. As the top SSL melts, there is a simultaneous transformation of the underlying bare ice to the SSL. Thus, the thickness of the SSL remains almost stable throughout the summer (Macfarlane et al., 2023). SSL visually looks like a snow layer. It has a surface albedo greater than that of bare ice but less than that of snow.

- **Line 240–241:** Improve the readability of the bar plots by standardizing bar sizes and labels.

  Done. The revised figure is shown below:



- **Lines 251–253:** The contribution of the top 3 cm increases as snow depth decreases. However, no correlation between surface snow and bulk density is observed, which is intriguing. This point could be emphasized more clearly.

  The lack of correlation between surface density and bulk density during the melting period (Stage III) suggests that SSL evolution is governed by different processes than those driving snow evolution during the dry period. We have addressed this issue in the revised manuscript.

- **Line 257:** Clarify how you obtained 26 snow density points from a snowpack only 15 cm thick. What was the vertical resolution of measurements?

- The 26 snow density points in Figure S3 do not represent actual snow density measurements but instead show normalized snow depth. Since the snow depth at the snow pits varied a lot during MOSAiC, we normalized the snow depth to facilitate better comparison of snow density profiles.

- **Line 264–265:** The observed drop in surface snow density from 300 to 150 kg/m^3 in May is striking. What mechanism caused this transformation?

  By looking at the density observations, we indeed see such a distinct decrease in snow density for both surface and bulk snow from April to early May. This characteristic was seen for the 10-day moving average and the optimal interpolation of daily observed snow density. The decrease of snow density in April-May may be explained by the fact that there is more abundant precipitation during spring months (Matrosov, et al., 2022).

- **Line 339 (Fig. 8):** Why is there a drop in both bulk and surface snow densities in April and May? Also, if you initialized the E1–E3 simulations with 250 kg/m^3, why do the first values on those curves begin at ~125 kg/m^3?

  In Table 1, the definitions of ρ_0 and ρ_m as “initial snow density” and “maximum bulk density” were inaccurate and misleading. They rather represented “baseline snow density”, e.g., fresh snow under minimal forcing, and the reference snow density response under the maximum environmental forcings, respectively. After the impact of environmental temperature and DOY, the snow density follows its characteristics. We have modified the text in Table 1 accordingly.

  Line 345 (Table 2): Add the initial densities used for each E1–E3 simulation scheme.

  The name “initial density” is not accurate (see previous response). It should be the “baseline snow density”, and we added it in Table 2.

- **Lines 415–417:** Could you please add some more details here on how you calculated and compared this? It’s not quite clear how 330 kg/m3 is related to the bulk values measured using the 10-day average. By snow accumulation do you mean snow depth?

  Apologies for the ambiguity. This snow density (330 kg/m^3) is unrelated to the observed 10-day average snow density. Yes, 'snow accumulation' here refers to snow depth.

  Precipitation is an external forcing for the HIGHTSI snow and ice modelling. Precipitation is given as SWE in [mm/h] in snow water equivalent. We need to convert it into snow depth. For this reason, a bulk snow density of 330 kg/m3 was used to convert SWE to snow depth in [m]. This criterion was applied in previous studies (e.g., Huwald, et al., 2005, Cheng et al., 2008, Wang et al., 2015). For an existing snow layer, the bulk snow density ρb was determined by applying the observed 10-day moving average (black dashed line in Fig. 8).

We have modified the description to make it clearer:

A constant snow density of 330 kg/m^3 was used to convert external forcing of precipitation to snow depth accumulation. For the existing snow, the bulk snow density ρb was the observed 10-day moving average (black dashed line in Fig. 8)

- **Line 441:** Separate the **Discussion** and **Conclusion** sections. The current Conclusion is overly long and makes it hard to distill the key outcomes.

  We separated the discussion and conclusion accordingly. The conclusion has been reformulated for better clarity and consistency.

- **Lines 526–527:** This statement is debatable. Consider rephrasing or providing supporting evidence.

  Higher densities over thin snow layers are due to the stronger wind compaction over smooth ice, while thicker snow is less dense because of the loose depth hoar bottom (Wagner et al., 2022).

Final Remarks:

Overall, this paper presents valuable insights into the evolution of snow density on Arctic sea ice and has the potential to make a solid contribution to the field. However, several sections require reorganization, clarification, and proofreading. Specific improvements in figures, methods, and interpretation would significantly enhance the quality and clarity of the manuscript.

Thank you for the constructive comments. We have carried out a major revision of the manuscript according to the comments from both reviewers:

1 The manuscript has been restructured for improved logical flow and clarity.

2 The text has been carefully edited, including:

a) Sections were reformulated,
b) Descriptive text was shortened to reduce overall paper length.
c) Some text was removed to avoid repetition and maintain conciseness.

3 The Discussion and Conclusions have been separated and reformulated. The Conclusions have been rewritten for better clarity.

4 We have improved the clarity of several figures.

5 We have added additional information on in situ observations and discussions for better clarity of the entire manuscript.

Comments from Referee 2

Based on sampling and measurement data from MOSAiC snow pits and thermodynamic models of sea ice, the authors investigated the seasonal variation of snow density and possible influencing factors, revealing the impact of snow density on the thermodynamic process of sea ice. The parameterization scheme of snow density and its simulation effect were evaluated, and the results can further support the optimization of the parameterization scheme of the sea ice component model in the Earth System model. It is a work worth sharing in the sea ice and even Arctic climate research communities. However, currently, the manuscript needs further improvement in terms of terminology, methodology, and analysis of results. Therefore, I recommend that the paper undergo major revisions before considering publication in TC.

Major comments:

1) The study evaluated four parameterization schemes for snow density, but did not provide recommendations on which scheme is the preferred one or what optimization is needed to better reproduce the observed seasonal changes in snow density.

One of the original objectives of this study was to identify and recommend an existing snow density parameterisation for snow/sea ice and climate modelling studies, and even to derive a new snow density parameterisation scheme based on MOSAIC data. However, we found that substantial spatiotemporal variability in snow density observations, along with physical snow sampling constraints and discontinuities in MOSAiC ice camp drift, prevented the derivation of a robust new snow density parameterization scheme. In addition, considering the MOSAiC campaign represents a specific ice drift trajectory, to have a representative snow density change along the Arctic sea ice transpolar drift corridor, one would perhaps need snow density data along several transpolar drift trajectories. Only in this way we would obtain an adequate full picture on snow density temporal spatial time series to derive a new snow density scheme.

Therefore, we focused on assessing the performance of the existing snow density schemes and pointed out their weaknesses. However, following our initial objective and the reviewer's comment, we provided a quantitative assessment of these snow density parameterisations (Tab. 2). Based on error statistics, we concluded that snow density parameterisations E3 and E4 perform better than the others. We have now added this statement in the Conclusions and outlook section. The snow density prognostic equation developed by Anderson (1976) remains applicable for sea ice thermodynamic modelling. We emphasised the need for further optimisation (e.g., addressing spatial variability) to improve snow density parameterisations. We have improved the Conclusions and outlook accordingly.

2) MOSAiC is an observation focused on the seasonal evolution of snow and sea ice physical processes. However, its seasonal evolution also overlaps with spatial-change information, especially after spring, as the ice floe drifts southward in the transpolar stream region, significant changes in atmospheric and oceanic conditions occur. Therefore, the representativeness of the observation results and parameterized evaluations for the pan Arctic Ocean needs further discussion. In addition, the MOSAiC floe in the study year has the characteristics of faster southward drift and lower snowfall compared with other years for the sea ice in the same location. How do these factors affect the representativeness of the observation results of snow density?

Thank you for this comment. The snow density time series along the MOSAiC drift trajectory includes both temporal (October-August) and spatial variability (large-scale ice drift and sampling sites distributed around the ice camp). This spatiotemporal variation occurred simultaneously throughout the campaign. The sea ice and snow system is extremely heterogeneous. The layered nature of the snowpack produces large vertical variations in thermal properties and thickness over short distances (Sturm et al., 2002a). During the SHEBA expedition, the snow depth reached its maximum thickness in December (Sturm et al., 2002b), while during MOSAiC, snow depth was relatively thin in December (Nicolaus et al., 2022). The observed snow evolution in one location differs from seasonal snow patterns in other places, primarily due to differences in weather patterns among locations. We have added text in the Discussion section to highlight these differences.

We agree that the MOSAiC snow density observations are specific to a single drift trajectory and the environmental conditions of the studied ice floe. The accelerated southward drift and reduced snowfall during our study period significantly influenced snow metamorphic processes and density evolution. These conditions likely differ substantially from snow metamorphism patterns characteristic of the central Arctic.

On the other hand, we argue that sea ice in the central Arctic is not isolated, and the ice moves continuously along the transpolar drift corridor. The Lagrangian approach—observing the same ice floe over a period of time—allows us to isolate the temporal evolution of snow density under observed meteorological forcing, although the forcing is specific for the location of the ice floe. To fully distinguish between temporal and large-scale variations in not possible on the basis of data from a drifting ice station.

Although absolute snow density values exhibit regional variability, we maintain that the process-level relationships between snow density and meteorological drivers remain robust within the Transpolar Drift region. These relationships are well-constrained by consistent co-located observations of snow properties and meteorological variables across the ice floe. However, we recognize that pan-Arctic extrapolation requires caution, and recommend that future studies incorporate data from diverse drift regimes to enhance parameterization schemes.

We have added discussions on the representativeness of the snow density by comparing it with other observations.

Special comments

1) Line 20 "The modelled mean surface temperature" what is the surface temperature here? snow or sea ice surface?

This refers to the snow surface temperature

2) Figure 1: there are two sites that do not belong to MOSAiC CO, but the two temporary ice stations implemented after the vessel finished the drifting.

We have described it in the revised Figure legend.

3) Line 207 and other relative context: "According to the annual cycle of air temperature, we can categorize four periods": If we only look at the regime of air temperature, the second stage should last until early April. In fact, the near-surface air temperature remained at a relatively low level until early April. The snow density also began to increase only after early April.

There was debate among the co-authors regarding the definition of stages 1 and 2. The air temperature (Fig. 4b) exhibited a consistent decreasing trend from 27 October to 16 February, followed by a winter warm event (likely storm-associated) between 16 February and 3 March. From

3 March onward until 9 May, temperatures increased steadily. The key question was whether to assign the February/March winter warm event to Stage 1 or Stage 2. For clarity, we ultimately divided Stages 1 and 2 to align with MOSAiC legs 2 and 3. This separation did not impact our data analyses.

4) Line 230: "with the highest and lowest wind speeds recorded at 13.8 m/s and 1.3 m/s" Is this a daily value? If it's a real-time value, the highest of 13 m/s seems too small.

Yes, these are the daily average wind speed values, but not the real-time values. For the real hourly mean, the highest and lowest wind speeds were 16.3 m/s and 0.2 m/s, respectively. We clarified the meaning of the given values in the revised text.

5) Lines 249-253: Can you introduce the situation of the third stage before discussing the situation of the fourth stage?

Yes, we revised the text order and discussed Stage 3 before Stage 4.

6) 256 “in Stage I, II, II and IV, respectively” This should be a typing mistake.

Corrected.

7) The cumulative wind speed: When did this start to be calculated? How to distinguish the impacts on the fresh snow and on the old snow?

The calculation started from the beginning of the snow observation period.

The primary goal was to identify the effect of wind on both surface and bulk snow samples. The methodology did not differentiate wind effects on fresh snowfall and old snowpack. To distinguish the impact of wind on fresh and old snow, successive collections of samples of new and old snow over a long period would be necessary, which were unfortunately not available during the MOSAiC expedition.

8) What is the physical mechanism behind the decrease in snow density since April, and why can't all four parameterization schemes describe this mechanism? Can we optimize the parameterization scheme to reproduce this physical process?

This is a good question. By looking at the density observations, we indeed see such a distinct decrease in snow density for both surface and bulk snow since April. This characteristic was seen for the 10-day moving average and the optimal interpolation of snow density. The decrease of snow density in April may be explained by the fact that there is more abundant precipitation during spring months (Matrosov et al., 2022). We confirm that those snow density schemes did not take into account the impact of new snowfall. Optimizing new snowfall on density parameterization would require more in situ observations. We would rather leave this effort for future research. In the revised text, we added an explanation for the time series of observed densities.

9) Figure. 9: Does it mean that the response of such thermodynamic parameters of sea ice to changes in constant snow density is close to linear?

Yes, the reviewer is correct. For a constant snow density, the response of modelled thermodynamic sea ice parameters to increasing snow density is linear.

10) Table 4: Can you provide specific details on the measurement principle of P1-P6? What is the underlying principle of their differences?

P1 - P6 were the total snow water equivalent (SWE) observed by different sensors for our simulation period. The measurements were made by various sensors, such as, vertically pointing 35-GHz Doppler radar, optical sensor, optical disdrometer, and weighing gauge. These instruments were placed at different locations around the MOSAiC central observatory (CO).

The measurement technologies and instrumentation calibration are responsible for explaining the differentiation of the observed results. For the physical principle, we believe the following processes are likely to contribute to the differences in observed SWE: 1) The local spatial variability of snow precipitation; 2) The wind effect on snow drift; 3) The wind effect on the blowing of snowfall.

We have merged the key message of the text above into the revised manuscript.

The technical details of SWE observations are:

Vaisala PWD22 optical sensors: See Kyrouac and Holdridge (2019); PARSIVEL-2 optical disdrometers: Nemeth and Beck (2011) and Wang et al. (2019); Pluvio weighing bucket precipitation gauge: Nemeth (2008) and Bartholomew (2020); Aerosol Observing System (AOS) precipitation sensor and Siphon gauge: Kyrouac and Springston (2019).

11) Line 438 "the above processes due to snow-to-ice transformation via surface flooding and resulting snow-ice formation": Did you consider the formation of snow ice in your thermodynamic simulation?

Yes, the snow-to-ice transformation was included in the model. For runs with different snow densities, snow ice did not form because the snow depth was relatively thin compared to the initial ice thickness. However, in precipitation sensitivity run P4, snow-ice formation occurred because precipitation led to significant snow accumulation.

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