Cover letter

Dear Editor:

We thank you and two anonymous reviewers very much for the constructive comments and suggestions for the paper ‘The sensitivity of landfast sea ice to atmospheric forcing in single-column model simulations: a case study at Zhongshan Station, Antarctica’ submitted to *the Cryosphere*. They are very valuable and very helpful for improving our manuscript. We have made a substantial revision according to the comments and suggestions from you and the two reviewers, and replied to them one by one below. We have quoted the text from the paper and displayed in bold the changes/additions.

Qinghua Yang and Bo Han

On behalf of all the authors

Responses to Editor

Editor

Comments to the author:

Dear Authors,

Please see 2 referee reports below. While both referees acknowledge improvements of the revised manuscript, they point out remaining issues. Referee 1 finds the presentation of the conclusions unclear and referee 2 addresses concerns regarding the sensitivity experiments, the impact of not accounting for snowdrift and how representative the point observations are for the entire model grid cell.

Based on their reviews and on my own reading of the revised manuscript I would like you to focus on the following points in your revision:

1. Your Discussion section is mainly about Shortcomings. I would recommend you to name it as "Shortcomings" and include discussion of snowdrift and to discuss potential errors by applying point observations for model grid cell. Fig. 3b shows periods of snow decline which are not simulated at all giving some indication of an important missing process. Can you provide information about spatial gradients by including neighbouring grid cells? Which fraction of the grid cell is actually land-fast ice and which fraction is land with topography?

Response:

Thank you for your constructive comments. We have revised the text according to your advice. We named the 'Discussion' section to 'Shortcomings' and rewrote a new 'Discussion' section.

In the 'Shortcomings' section, we first discussed the potential effect of omitting the melt pond process; then, we pointed out that ICEPACK needs to distinguish the flooding process for landfast sea-ice from packed sea ice:

‘Superimposed ice is present in early autumn when the snow starts to melt (Kawamura et al., 1997) and contributes significantly to sea ice growth (up to 20% of mass) (Granskog et al., 2004). Superimposed ice usually corresponds to liquid precipitation or melted snow that permeates downward to form a fresh slush layer and refreezes. The superimposed ice is implemented in ICEPACK via the melt ponds parametrization but has not been considered in this study because the deformation information of sea ice is not available. Therefore, the simulation may underestimate sea ice thickness and overestimate snow depth compared to observation in November. We will apply the melt ponds scheme in the follow-up research work.

The snow-ice formation might be overestimated on the landfast sea ice in ICEPACK. Flooding-induced snow-ice formation is common in the Antarctic ocean because of the thin ice and heavy snowfall (Kawamura et al., 1997). It can contribute to considerable ice mass (12%-36%) and reduce the snow depth by up to 42-70%, depending on the season and location (Jeffries et al., 2001). The parameterization of the flooding process in the ICEPACK is based on Archimedes’ Principle for the pack ice, which might be problematic for the coastal landfast sea ice. With a much larger volume and shallower seawater around than the pack sea ice, part of the coastal landfast sea ice might contact the sea bed rather than float in the sea. Thus, the flooding should be much weaker even with weighted snow cover. Besides, the change in density of ice due to the flooding process is significant (Saloranta, 2000) but not well considered in ICEPACK. For example, a slushy layer of 10 cm depth would refreeze within three days from observation (Provost et al., 2017), while the process only needs one day in ICEPACK. Hence, the landfast sea ice growth due to snow-ice formation needs improvement in ICEPACK, especially when the input precipitation is significantly exaggerated, e.g., the ERA5 forcing.’

In the ‘Discussion’ section, we discussed the potential contribution of the snowdrift process on snow depth simulation and how an overestimated surface wind will modulate the snow depth simulation in ICEPACK. The importance of oceanic forcing is also mentioned:

'Surface drifting snow particles play an essential role in the surface mass balance (Van den Broeke et al., 2004). Figure 3b shows that the observed snow depth has quickly decreased from 32 cm on August 2 to 15.5cm on August 10, which should be attributed to the snowdrift because the surface wind is > 8 m s^{-1} in most of this period (Figure 2c). Friction velocity becomes sufficiently high to overcome the gravity and bonds between snow particles in this strong wind and raise the snow particles from the surface (van den Broeke et al., 2006; Thiery et al., 2012; Tanji et al., 2021). However, the mean surface wind in ERA5 is convergent around the observation site during the intense wind period (Figure 8), which might not be expected for snow depth decrease due to snowdrift. The coarse resolution of the atmospheric reanalysis might not produce a realistic surface wind field, which is primarily determined by the topography (Van Den Broeke et al., 1999; Frezzotti et al., 2005). In addition, surface sublimation of drifting snow particles, which is most significant in warm, dry, and windy weather (Thiery et al., 2012), plays an important role in surface mass balance (Van den Broeke et al., 2004) but has not been involved in ICEPACK yet.

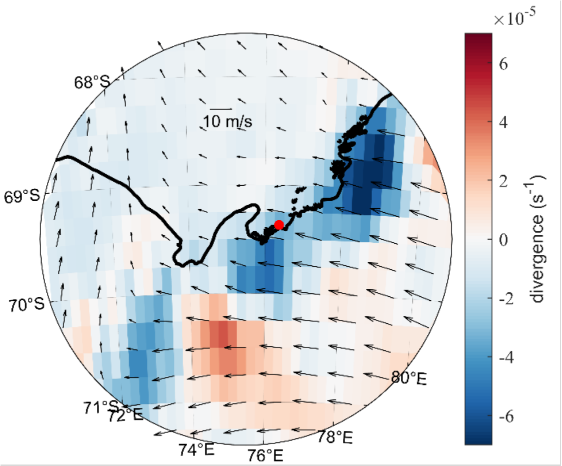

Figure 8 The mean ERA5 surface wind and divergence from August 2 to 10. The black line represents the coastline, and the red point represents the observation site.

The surface wind can affect the snow depth by changing the surface heat fluxes

(Fairall et al., 2003). Compared with Sim_Obs, Sim_ERA_W gives a -2.5 × 10^4 W m^{-2} lower latent heat flux (positive downward) on average (Figure 9b), i.e., a larger sublimation (Figure 9c), and a reduction of about -3.4 cm of the snow depth (Figure 9a). Therefore, the overestimation in the surface wind from ERA5 partly neutralizes the effect of overestimated precipitation.

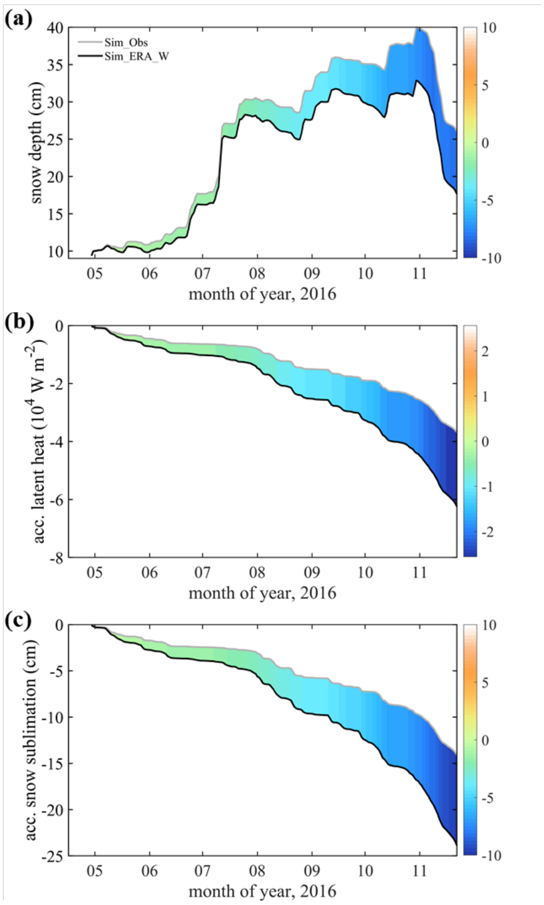

Figure 9 Times series of (a) snow depth, (b) accumulated latent heat flux, and (c) accumulated snow sublimation. The gray line represents the simulation using wind from the observation (Sim_Obs). The black line represents the simulation using wind from ERA5 (Sim_ERA_W). The color bar represents their difference (Sim_ERA_W – Sim_Obs).

The oceanic forcing also plays an essential role in sea ice evolution (Uotila et al., 2019). Heat flux from the ocean boundary layer changes the sea ice energy balance (Maykut and Untersteiner, 1971). The ocean heat flux is mainly impacted by summer insolation through open leads, thin ice, melt ponds (Perovich and Maykut, 1990), and upward heat transfer through vertical turbulent mixing (McPhee et al., 1999). Because the oceanic observations under sea ice are challenging, most sea ice

models directly use some empirical values, like the default value in CCSM3, to build the ocean boundary condition (e.g., Yang et al., 2016b; Turner and Hunke, 2015). In this study, although some oceanic variables, like the water temperature and salinity, are from observation, while others, like the mixed layer depth, simply refers to previous studies. The uncertainty in oceanic forcing might be as important as the atmospheric ones, which will be focused in our coming work. '

The potential errors by applying point observations for model grid cells have been put in '**Materials and methods**' section:

'For comparison and evaluation against observations in the Antarctic, ERA5 is bilinearly interpolated with 4 surrounding grid points to the observation site (described in 2.1). **Directly using atmospheric forcing from coarse grid cells to interpolate to the observation site, although widely accepted in the previous studies (e.g., Urraca et al., 2018; Wang et al., 2019b), may cause errors. We have checked the performance of ERA5 and found that the spatial difference of surface atmospheric variables around the observation site is relatively small, indicating the choice of interpolation techniques will not affect the conclusion of this study.**'

2. Extend and revise “Conclusions” as proposed by Referee 1.

Response:

We have revised the text as Referee 1 suggested.

'This work uses the single-column sea ice model ICEPACK forced by the ERA5 atmospheric reanalysis and atmospheric *in situ* observations to simulate snow depth and sea ice thickness at Zhongshan Station, Antarctic. The main results are listed below:

(1) Forced by atmospheric variables from *in situ* observations, the ICEPACK can well simulate the sea ice evolution but significantly overestimates the snow depth. When using atmospheric forcing from ERA5, sea ice thickness simulation is close to observation before July 11, but then suddenly increases in an extremely large precipitation event. For the entire simulation period,

ERA5 obviously causes an overestimation in snow depth compared to observation.

(2) **Although sea ice sensitivity (-0.032 cm/%) is small and snow thickness sensitivity (0.135 cm/%) is moderate to precipitation in ICEPACK, the significant deviation in the reanalysis's precipitation contribute to the largest bias in both sea ice thickness and snow depth. On average, about 2 mm day^{-1} more precipitation in ERA5 is found during the observation period, which produces about 14.5 cm excess in sea ice thickness and 17.3 cm more snow depth.**

(3) **The flooding process can be triggered by a heavy snowfall episode, like on July 11. It efficiently produces ice at the sea ice surface, decelerates the snow accumulation, and inhibits sea ice's basal growth.**

(4) **The interaction between sea ice and its covering snow determines their response to snowfall. When the snowfall is weak, the snow layer thickens quickly and hampers the sea ice growth through its insulation effect. When the snowfall increases to a certain degree (~1 mm day^{-1}), it will trigger a continuous flooding process, accelerating the sea ice growth and slowing down the snow layer thickening.'**

3. Address the concerns regarding the sensitivity experiments. In my view this can be done by adding new experiments or by being more precise how to interpret the current experiments.

Response:

Thank you for your advice. We have carried out a new set of experiments to calculate the sensitivity of each atmospheric forcing in '**3.4 Sensitivity analysis**'：

'The results from Sim_ERA are connected with the sensitivity of sea ice and snow depth to atmospheric forcing change. To determine the sensitivity of sea ice and snow depth near Zhongshan station on atmospheric forcing, we designed a set of numerical experiments named SEN1. In the control run, the forcing of the

simulation directly used the means of observed atmospheric variables (Mean_Obs in Table 3). For a specific atmospheric variable, we build a set of sensitive runs. The focused atmospheric variable changed from its mean (Range in Table 3), and other variables are the same as the control run. Considering the actual range in each observed variable, we set the maximum change in T_a, Θ_a, and ρ_a to 2%, and other atmospheric variables to 50%. Then, we concluded the sensitivity of sea ice and snow to each atmospheric forcing from its corresponding sensitive runs. Because sea ice and snow depth show a quasi-linear response to the change in each specific atmospheric forcing (not shown), the choice of the variable's range will not alter the sensitivity results.

Table 3 The atmospheric forcing (Mean_obs for the control run and range for the sensitive run), sensitivity, and potential bias from SEN1.

Variable	Mean_Obs (Control)	Range (%)	Sensitivity		Potential Bias	
			Ice (cm/%)	Snow (cm/%)	Ice (cm)	Snow (cm)
R_{sd} (W m^{-2})	67.714	±50	-0.033	-0.008	-0.295	-0.069
R_{ld} (W m^{-2})	198.023	±50	-0.368	-0.201	3.559	1.944
T_a (K)	257.809	±2	-1.247	-0.526	0.565	0.238
Q_a (10^{-4} kg kg^{-1})	8.247	±50	-0.025	0.029	0.230	-0.270
P (mm day^{-1})	0.660	±50	-0.032	0.135	-9.712	40.974
Θ_a (K)	259.437	±2	-1.297	-0.491	-0.145	-0.055
ρ_a (kg m^{-3})	1.322	±2	-0.054	0.021	0.086	-0.033
U_a (m s^{-1})	4.228	±50	-0.054	-0.022	-2.748	-1.116

In Table 3, the sensitivity of ice thickness and snow depth to each atmospheric variable are listed. Comparing the individual sensitivity, it turns out that the sea ice thickness and snow depth are most sensitive to T_a and Θ_a. However, since T_a and Θ_a from ERA5 is close to the *in situ* observation, the potential bias contributed by these two terms is relatively small. In contrast, the most significant overestimation in P in ERA5 is the primary source for the simulation bias for sea ice thickness and snow depth.'

Responses to referee #1

Reviewer 1

General comments

Thank you for incorporating my previous comments into your revised manuscript. I think this updated version is a definite improvement, and I offer some further specific suggestions below.

My main general comment is that I had hoped to see a re-written conclusions section that brought together the main results more clearly, and I would suggest this is revisited before 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.

Specific comments

P8 L207 Be more explicit about what is meant by strong events in this sentence.

Response:

Thanks. We have revised this sentence to 'Nevertheless, using precipitation from Progress II for Zhongshan Station may be questioned as well because of the distance of about 1 km to Zhongshan Station. **Moreover, the snowdrift due to strong surface wind can affect the precipitation observation and the local accumulated snow mass, which may further cause a significant bias in precipitation between ERA5 and observation.**'

P12 L291 Consider changing table description to be a bit more specific, eg: 'Mean bias in ice thickness and snow depth and bias ratio for each forcing variable'. Mention that these are the bias ratios from table 1.

Response:

Thanks. We have added sensitivity experiments and changed the table description to **'Table 3 The atmospheric forcing (Mean_obs for the control run and Range for the sensitive run), sensitivity, and potential bias from SEN1.'**

P13 L296 I am a bit confused by this sentence. Rld has already been mentioned, so I am not sure why it is mentioned again, and if Qa is to be mentioned it could be included in the previous sentences?

Response:

Thank you for your advice. We have found that this sentence is irrelevant to the following content, so we have deleted it.

P18 Onwards (Section 4). While this discussion section is improved from the previous version, I feel it need some introduction to make the scope clear – ie that it explores specific model limitations that may affect the comparison. It could perhaps have a more specific heading as well. The first sentence should mention sea ice thickness.

Response:

'Thank you for your constructive comments. We have revised the text according to your advice. We took part in the 'Discussion' to 'Shortcomings' and rewrote the 'Discussion' section.

In the 'Shortcomings' section, we first discussed the potential effect of omitting the melt pond process; then, we pointed out that ICEPACK needs to distinguish the flooding process for landfast sea-ice from packed sea ice:

'Superimposed ice is present in early autumn when the snow starts to melt (Kawamura et al., 1997) and contributes significantly to sea ice growth (up to 20% of mass) (Granskog et al., 2004). Superimposed ice usually corresponds to liquid precipitation or melted snow that permeates downward to form a fresh slush layer and refreezes. The superimposed ice is implemented in ICEPACK via the melt

ponds parametrization but has not been considered in this study because the deformation information of sea ice is not available. Therefore, the simulation may underestimate sea ice thickness and overestimate snow depth compared to observation in November. We will apply the melt ponds scheme in the follow-up research work.

The snow-ice formation might be overestimated on the landfast sea ice in ICEPACK. Flooding-induced snow-ice formation is common in the Antarctic ocean because of the thin ice and heavy snowfall (Kawamura et al., 1997). It can contribute to considerable ice mass (12%-36%) and reduce the snow depth by up to 42-70%, depending on the season and location (Jeffries et al., 2001). The parameterization of the flooding process in the ICEPACK is based on Archimedes' Principle for the pack ice, which might be problematic for the coastal landfast sea ice. With a much larger volume and shallower seawater around than the pack sea ice, part of the coastal landfast sea ice might contact the sea bed rather than float in the sea. Thus, the flooding should be much weaker even with weighted snow cover. Besides, the change in density of ice due to the flooding process is significant (Saloranta, 2000) but not well considered in ICEPACK. For example, a slushy layer of 10 cm depth would refreeze within three days from observation (Provost et al., 2017), while the process only needs one day in ICEPACK. Hence, the landfast sea ice growth due to snow-ice formation needs improvement in ICEPACK, especially when the input precipitation is significantly exaggerated, e.g., the ERA5 forcing.'

In the 'Discussion' section, we discussed the potential contribution of the snowdrift process on snow depth simulation and how an overestimated surface wind will modulate the snow depth simulation in ICEPACK. The importance of oceanic forcing is also mentioned:

'Surface drifting snow particles play an essential role in the surface mass balance (Van den Broeke et al., 2004). Figure 3b shows that the observed snow depth has quickly decreased from 32 cm on August 2 to 15.5cm on August 10, which should

be attributed to the snowdrift because the surface wind is > 8 m s^{-1} in most of this period (Figure 2c). Friction velocity becomes sufficiently high to overcome the gravity and bonds between snow particles in this strong wind and raise the snow particles from the surface (van den Broeke et al., 2006; Thiery et al., 2012; Tanji et al., 2021). However, the mean surface wind in ERA5 is convergent around the observation site during the intense wind period (Figure 8), which might not be expected for snow depth decrease due to snowdrift. The coarse resolution of the atmospheric reanalysis might not produce a realistic surface wind field, which is primarily determined by the topography (Van Den Broeke et al., 1999; Frezzotti et al., 2005). In addition, surface sublimation of drifting snow particles, which is most significant in warm, dry, and windy weather (Thiery et al., 2012), plays an important role in surface mass balance (Van den Broeke et al., 2004) but has not been involved in ICEPACK yet.

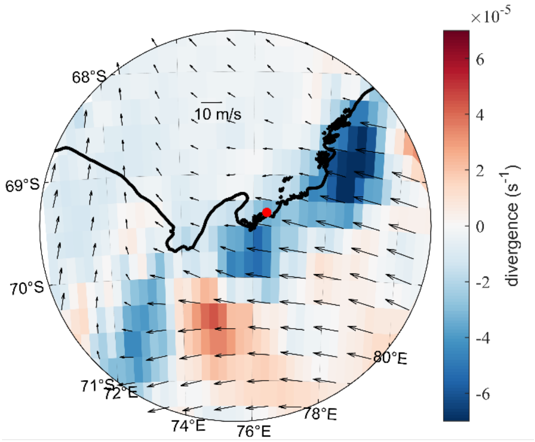

Figure 8 The mean ERA5 surface wind and divergence from August 2 to 10. The black line represents the coastline, and the red point represents the observation site.

The surface wind can affect the snow depth by changing the surface heat fluxes (Fairall et al., 2003). Compared with Sim_Obs, Sim_ERA_W gives a -2.5×10^4 W m^{-2} lower latent heat flux (positive downward) on average (Figure 9b), i.e., a larger sublimation (Figure 9c), and a reduction of about -3.4 cm of the snow depth (Figure 9a). Therefore, the overestimation in the surface wind from ERA5 partly neutralizes the effect of overestimated precipitation.

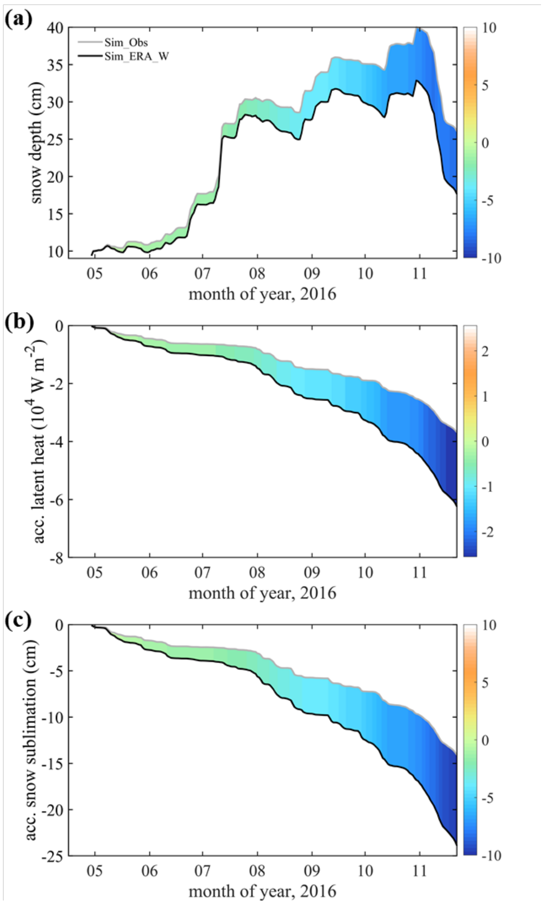

Figure 9 Times series of (a) snow depth, (b) accumulated latent heat flux, and (c) accumulated snow sublimation. The gray line represents the simulation using wind from the observation (Sim_Obs). The black line represents the simulation using wind from ERA5 (Sim_ERA_W). The color bar represents their difference (Sim_ERA_W – Sim_Obs).

The oceanic forcing also plays an essential role in sea ice evolution (Uotila et al., 2019). Heat flux from the ocean boundary layer changes the sea ice energy balance (Maykut and Untersteiner, 1971). The ocean heat flux is mainly impacted by summer insolation through open leads, thin ice, melt ponds (Perovich and Maykut, 1990), and upward heat transfer through vertical turbulent mixing (McPhee et al., 1999). Because the oceanic observations under sea ice are challenging, most sea ice models directly use some empirical values, like the default value in CCSM3, to build the ocean boundary condition (e.g., Yang et al., 2016b; Turner and Hunke, 2015). In this study, although some oceanic variables, like the water temperature and salinity, are from observation, while others, like the mixed layer depth, simply refers to previous studies. The uncertainty in oceanic forcing might be as

important as the atmospheric ones, which will be focused in our coming work. ’

P20 Conclusions: see my general comment above, and also:

(1) Provides a summary of the simulation forced with the in-situ observations, but there is no equivalent summary for the ERA5-forced simulation.

Response:

We have revised the text in response to this concern:

‘**(1) Forced by atmospheric variables from *in situ* observations, the ICEPACK can well simulate the sea ice evolution but significantly overestimates the snow depth. When using atmospheric forcing from ERA5, sea ice thickness simulation is close to observation before July 11, but then suddenly increases in an extremely large precipitation event. For the entire simulation period, ERA5 obviously causes an overestimation in snow depth compared to observation.**’

I would say more about the snow-ice formation, and the fact that there may be too much of this in the ERA5-forced simulation.

Response:

Thank you for your advice. We have added a conclusion about snow-ice formation in the text:

‘**(2) Although sea ice sensitivity (-0.032 cm/%) is small and snow thickness sensitivity (0.135 cm/%) is moderate to precipitation in ICEPACK, the significant deviation in the reanalysis’s precipitation contribute to the largest bias in both sea ice thickness and snow depth. On average, about 2 mm day^{-1} more precipitation in ERA5 is found during the observation period, which produces about 14.5 cm excess in sea ice thickness and 17.3 cm more snow depth.**

(3) The flooding process can be triggered by a heavy snowfall episode, like on July 11. It efficiently produces ice at the sea ice surface, decelerates the snow accumulation, and inhibits sea ice’s basal growth.’

P20 L456-458 I don’t understand this sentence – can it be re-worded.

Response:

We have revised the text in response to this concern:

‘(4) The interaction between sea ice and its covering snow determines their response to snowfall. When the snowfall is weak, the snow layer thickens quickly and hampers the sea ice growth through its insulation effect. When the snowfall increases to a certain degree (~1 mm day^{-1}), it will trigger a continuous flooding process, accelerating the sea ice growth and slowing down the snow layer thickening. ’

P20 L461 New paragraph needed here.

Response:

Revised as suggested.

P20 L463 onwards. A potential two-dimensional simulation is mentioned, but I am unclear how the methodology from this paper would be extended to two dimensions as it requires specific in situ observations for the forcing which would not be available over the whole Southern Ocean? Could this be clarified.

Response:

Thank you for your advice. We have found that it is irrelevant to our conclusions, so we have deleted it.

Technical corrections

P1 L29 Change ‘inhibits’ to ‘inhibit’

Response:

We have changed ‘inhibits’ to ‘inhibit’.

P3 L73 Change ‘at’ to ‘of’

Response:

We have changed ‘at’ to ‘of’.

P5 L125 The measurement accuracy of the ice thickness is mentioned twice.

Response:

We have deleted one of them.

P12 L280 Capital letter needed at start of sentence

Response:

Revised as suggested.

Responses to referee #2

Reviewer 2

Suggestions for revision or reasons for rejection (will be published if the paper is accepted for final publication)
The revised manuscript have improved most detailed questions, however some major issues still existed. The authors tried to assess the sensitivity of landfast sea ice to atmospheric forcing and carried out sensitivity experiments with ERA5 reanalysis to compare with experiment with observed atmospheric variables. I confused a bit by the design of the sensitivity experiments.

Through the comparisons in the Table 3, the authors concluded that P (Precipitation) and Ua (wind speed) were the most sensitive factors for snow and ice thickness simulations. However I don't agree with that. Take the factor P as example, the large biases showed for ice thickness (14.519 cm) and snow thickness (17.312 cm) come from the large bias of P itself (303.509%), which cannot support the conclusions that the simulations of snow and ice thickness are sensitivity to P.

To find out which variables of atmospheric forcing effect largely to snow and ice thickness simulation, the authors should carried out more experiments with random changes to every single variable, and compare which experiment showed the largest changes.

Response:

Thank you for the constructive comment. We have to admit that the sensitivity of sea ice (also snow) to atmospheric forcing needs to be distinguished from the bias in the forcing. To achieve this goal, We have carried out a new sensitivity experiment in '3.4 Sensitivity analysis', and the content is as follow:

'The results from Sim_ERA are connected with the sensitivity of sea ice and snow

depth to atmospheric forcing change. To determine the sensitivity of sea ice and snow depth near Zhongshan station on atmospheric forcing, we designed a set of numerical experiments named SEN1. In the control run, the forcing of the simulation directly used the means of observed atmospheric variables (Mean_Obs in Table 3). For a specific atmospheric variable, we build a set of sensitive runs. The focused atmospheric variable changed from its mean (Range in Table 3), and other variables are the same as the control run. Considering the actual range in each observed variable, we set the maximum change in T_a, Θ_a, and ρ_a to 2%, and other atmospheric variables to 50%. Then, we concluded the sensitivity of sea ice and snow to each atmospheric forcing from its corresponding sensitive runs. Because sea ice and snow depth show a quasi-linear response to the change in each specific atmospheric forcing (not shown), the choice of the variable's range will not alter the sensitivity results.

Table 3 The atmospheric forcing (Mean_obs for the control run and range for the sensitive run), sensitivity, and potential bias from SEN1.

Variable	Mean_Obs (Control)	Range (%)	Sensitivity		Potential Bias	
			Ice (cm/%)	Snow (cm/%)	Ice (cm)	Snow (cm)
R_{sd} (W m^{-2})	67.714	±50	-0.033	-0.008	-0.295	-0.069
R_{ld} (W m^{-2})	198.023	±50	-0.368	-0.201	3.559	1.944
T_a (K)	257.809	±2	-1.247	-0.526	0.565	0.238
Q_a (10^{-4} kg kg^{-1})	8.247	±50	-0.025	0.029	0.230	-0.270
P (mm day^{-1})	0.660	±50	-0.032	0.135	-9.712	40.974
Θ_a (K)	259.437	±2	-1.297	-0.491	-0.145	-0.055
ρ_a (kg m^{-3})	1.322	±2	-0.054	0.021	0.086	-0.033
U_a (m s^{-1})	4.228	±50	-0.054	-0.022	-2.748	-1.116

In Table 3, the sensitivity of ice thickness and snow depth to each atmospheric variable are listed. Comparing the individual sensitivity, it turns out that the sea ice thickness and snow depth are most sensitive to T_a and Θ_a. However, since T_a and Θ_a from ERA5 is close to the *in situ* observation, the potential bias contributed by these two terms is relatively small. In contrast, the most significant

overestimation in *P* in ERA5 is the primary source for the simulation bias for sea ice thickness and snow depth.'

In the Antarctic coast, snowdrift caused by strong wind is very important, which contributed to the large bias of snow thickness simulation in Figure 3b. Because the model you used don't consider the snowdrift, but only accumulate the precipitations. Under this model setup, Precipitation (P) must contributed largest. It is the disadvantage of model parameterization.

Response:

Yes, we totally agree with you that the snowdrift needs to be considered in the future. But for this study, we do not have enough time to finish this work. We rewrite the Discussion section to emphasize the importance of the snowdrift process:

'Surface drifting snow particles play an essential role in the surface mass balance (Van den Broeke et al., 2004). Figure 3b shows that the observed snow depth has quickly decreased from 32 cm on August 2 to 15.5cm on August 10, which should be attributed to the snowdrift because the surface wind is > 8 m s^{-1} in most of this period (Figure 2c). Friction velocity becomes sufficiently high to overcome the gravity and bonds between snow particles in this strong wind and raise the snow particles from the surface (van den Broeke et al., 2006; Thiery et al., 2012; Tanji et al., 2021). However, the mean surface wind in ERA5 is convergent around the observation site during the intense wind period (Figure 8), which might not be expected for snow depth decrease due to snowdrift. The coarse resolution of the atmospheric reanalysis might not produce a realistic surface wind field, which is primarily determined by the topography (Van Den Broeke et al., 1999; Frezzotti et al., 2005). In addition, surface sublimation of drifting snow particles, which is most significant in warm, dry, and windy weather (Thiery et al., 2012), plays an important role in surface mass balance (Van den Broeke et al., 2004) but has not been involved in ICEPACK yet.

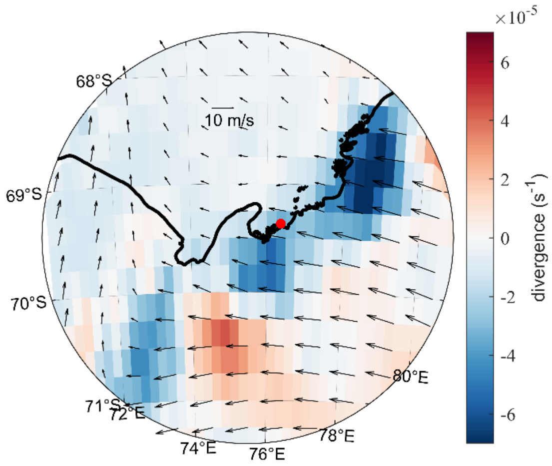

Figure 8 The mean ERA5 surface wind and divergence from August 2 to 10. The black line represents the coastline, and the red point represents the observation site.'

From another aspect, ERA5 have a large spatial resolution of 25 km, I doubt the reasonability to use the atmospheric forcing from a 25 km grid cell to compare with the near-shore observation, especially to assess the sensitivity of every atmospheric variables.

Response:

Thanks. We have revised the text in response to this concern:

'For comparison and evaluation against observations in the Antarctic, ERA5 is bilinearly interpolated with 4 surrounding grid points to the observation site (described in 2.1). **Directly using atmospheric forcing from coarse grid cells to interpolate to the observation site, although widely accepted in the previous studies (e.g., Urraca et al., 2018; Wang et al., 2019b), may cause errors. We have checked the performance of ERA5 and found that the spatial difference of surface atmospheric variables around the observation site is relatively small, indicating the choice of interpolation techniques will not affect the conclusion of this study**.'

Special comments:

Line 269: The initial ice thickness was 99.5 cm in April, which is a quite large thickness for this month. Therefore that is likely not the first year ice, but the multi-year ice. This classification will affect your model parameters, even results?

Response:

This has no effect on the model parameters and results. As long as the initial ice thickness is given, whether it is first year ice or multi-year ice, ICEPACK can distribute the initial ice thickness to each ice thickness category by using a distribution function.

$$p_i = \frac{max\ (2 \times h \times H_i - H_i^2, 0)}{\sum_i max\ (2 \times h \times H_i - H_i^2, 0)}, i = 1 \cdots N, (1)$$

Where h is initial ice thickness, H_i is the prescribed ice thickness category (0–0.6, 0.6–1.4, 1.4–2.4, 2.4–3.6, and above 3.6 m~; same as for Arctic simulations), N is the number of ice thickness categories.

Line 734: In Figure 4, accumulated flooding ice shown was large to 100 cm and basal ice started to melt in July. This order of magnitudes did not consist with the facts. Usually the flooding ice would compacted and the thickness would much decreased. The authors should considered this effects.

Response:

Thanks for your advice. As in this study, the flooding process in ICEPACK is not so well representative of observation and needs modification. We have discussed this issue in the 'Shortcomings' section in response to this concern:

'The snow-ice formation might be overestimated on the landfast sea ice in ICEPACK. Flooding-induced snow-ice formation is common in the Antarctic ocean because of the thin ice and heavy snowfall (Kawamura et al., 1997). It can contribute to considerable ice mass (12%-36%) and reduce the snow depth by up to 42-70%, depending on the season and location (Jeffries et al., 2001). The parameterization of the flooding process in the ICEPACK is based on Archimedes' Principle for the pack ice, which might be problematic for the coastal landfast sea ice. With a much larger volume and shallower seawater around than the pack sea ice, part of the coastal landfast sea ice might contact the sea bed rather than float in the sea. Thus, the flooding should be much weaker even with weighted snow

cover. Besides, the change in density of ice due to the flooding process is significant (Saloranta, 2000) but not well considered in ICEPACK. For example, a slushy layer of 10 cm depth would refreeze within three days from observation (Provost et al., 2017), while the process only needs one day in ICEPACK. Hence, the landfast sea ice growth due to snow-ice formation needs improvement in ICEPACK, especially when the input precipitation is significantly exaggerated, e.g., the ERA5 forcing. '

Saloranta, T. M.: Modeling the evolution of snow, snow ice and ice in the Baltic Sea, Tellus A: Dynamic Meteorology and Oceanography, 52, 93-108, 2000.