Respond to Reviewer #1

Dear reviewer,

Thank you very much for your detailed comments on the manuscript, which are constructive and will help our paper to reach a high quality. We have conducted careful revisions following your suggestions and all the comments are responded to one by one in RED.

The main updates are listed here:

(1) The time series analyzed in our manuscript has been extended from the original 10-day to7 months although several interruptions occurred during the period.

(2) The parameterizations and formulas in the revised version were further simplified, making them clear to the readers.

(3) We added a large-scale analysis that combined our observations with AMSR2 sea ice concentration and Mercator ocean products, trying to explain the long-term variations.

(4) The Results and Discussions sections were reconstructed and further analyzed.

Best regards,

The co-authors.

A) General comments:

1) The presented time series of just seven days is particularly short, compared to other similar data sets in both hemispheres. How do you justify the significance of this data record? It is not 100% clear to me how this data set sets itself apart from any other. Further, you only mention an instrument malfunction at the very end of Ch.5, which is likely the cause for the short data record, right? Why is this not mentioned right at the beginning of your data description?!

Responses:

Thanks for the reviewer's comments. As you mentioned, ice-ocean interface layer observations have been conducted by the previous studies, while most of the long-term time series were in the Arctic, but not in Antarctica, especially the landfast ice zone covering an entire growing season. The ocean-ice interactions in this landfast ice zone in Prydz Bay, where Chinese Zhongshan Station and Australian Davis Station were located, were affected by both local polynya and large Amery Ice Shelf, therefore our observations will help to understand this special complicated ice-glacier-ocean system.

The data interruption at the end of April was due to improper operation, which caused battery

exhaustion and observations ceased. There were two reasons we chose to analyze the short time series in the original manuscript, the first one was that we worried that interrupted data would affect the effectiveness of long-term analysis, and the second one was the ice-ocean interface layers showed the largest changes in the early frozen period, compared to other months.

However, based on the suggestions made by the reviewers, we recognized the problem of the short data in the original article, so in the revised manuscript we extended the time series to one year of observations. Although there were data interruptions in several months, the new results of the analysis are still good, and the annual variation characteristics of each element are given, which is of great significance to the study of the ice-sea interaction along the Antarctic coast.

2) The manuscript often mentions the apparent benefits of "minute resolution" measurements, without clearly differentiating between the different data sources. For instance, the SIMBA measurements of vertical temperatures are only available four times a day (hence, imprinting on presented heat fluxes). Please revise the respective parts carefully.

Responses:

Thanks for the reviewer's suggestions. In the original manuscript, the expressions were indeed misunderstood. In the revised manuscript, we cautiously use "minute resolution" and express accurately to avoid misleading readers.

In this study, the observation intervals of ADV and ACTD are 40 s and 30 s respectively, which can be used to observe the oceanic parameters on a minute scale. Based on the seawater velocity data observed by ADV and the seawater temperature and salinity data observed by ACTD, the oceanic heat flux on the 2-min scale was calculated by different parameterizations, which can reflect the instantaneous change of heat flux and capture more details of sea ice growth.

However, the SIMBA temperature chain obtains the temperature information of atmosphere-sea ice-sea water every 6 hours. Based on Stefan Law, the oceanic heat flux was calculated and analyzed. Based on these two kinds of methods, we first explored the minute-resolution oceanic heat flux in this landfast ice zone.

3) The authors apparently decided to leave out a "traditional" chapter on the applied methodology to process and analyze the recorded data. Later in the text in the context of results (Ch.3.6), at least the heat flux calculations are explained. However, I consider these parts as misplaced. I would recommend a new separate chapter on methodical aspects & data processing prior to the results section. In this context, Chapters 3.6.1 and 3.6.2 could also be thoughtfully merged and at the same time streamlined to the most relevant aspects.

Responses: Thank you for the suggestions. We moved the methods chapter (the original 3.6.1 and 3.6.2, as well as the calculation formulas of temperature and salinity) out of the Results section and formed a new Data and Methods section, which is more in line with the reading habits of the reader.

4) Almost all figures require a careful overhaul, be it due to the lack of proper labelling, low resolution images, non-barrier-free colormaps or "just" an insufficient / too short caption. You will find more detailed comments on all these below, right after specific comments to individual chapters.

Responses: Thank you very much for your suggestion. In the revised manuscript, the pictures will be redrawn in strict accordance with your suggestion.

5) There is no further information on the larger scale environmental conditions (sea ice cover, atmospheric / ocean reanalysis, etc.) at all. Even if you omit to directly relate these conditions to your own data, it would be extremely helpful to have those for a proper context.

Responses: According to the reviewer's suggestions, we analyzed the time series of sea ice extent, air temperature, and ocean circulation from satellite products and reanalysis datasets in the Prydz Bay in a year, and combined with the variations of ocean-sea ice heat flux calculated in this study to give a reasonable context for our study.

6) Please pay attention on using a (relevant) number of digits after the decimal point. Often, there is unnecessary detail given, especially when the numbers end with ".0". In addition, try to be consistent throughout the manuscript.

Responses: In the revised manuscript, the appropriate reserved digits will be selected for the accuracy of the values, and the consistency of the values in the manuscript will be ensured.

7) You describe your results/measurements in past tense (e.g., "Figure 6 showed") → please use the present tense in that regard.

Responses: In the revised manuscript, we will certainly pay attention to the grammar.

B) Specific comments：

Abstract

P.1, L.14: "COMPACT-CTD" → there is only an ACTD mentioned in the manuscript. Please explain, also why capital letters are used here.

Responses: Thanks for your reminder**.** "COMPACT-CTD" and ATCD are the same instrument. We revised to use one expression in the new version.

P.1, L.16: Not all measurements are minute-resolution, right? SIMBA → six-hourly

Responses: Yes, not all measuring instruments have a resolution of minutes, and we indeed ignored the distinctions between the time resolutions of different instruments in the abstract. Here, the sampling intervals of ACTD and ADV are 30 s and 40 s respectively, which provided the time series of ocean temperature, salinity, density, and velocity in minute resolution, while the temperature observed by SIMBA was a 6-hour interval. In the revised manuscript, strict attention will be paid to describing the sampling interval of the observation data.

Ch.1: Introduction

P.2, L.37: Fraser et al. (2021) would be another good reference here (DOI: 10.5194/tc-15-5061-2021)

Responses: Thanks for your suggestion and we cited it in the revised version. The deep analysis of Antarctic landfast ice in this paper makes us a deeper understanding of Antarctic landfast ice, which is worthy of my in-depth study.

P.2, L.60: 8 psu salinity → salinity of the sea ice? More specific please

Responses: Thanks for the suggestion, we changed "based on 8 psu salinity" to a clearer expression "based on a sea ice salinity of 8 psu".

P.2, L.62: Explain abbreviation "HIGHTSI" and give the respective reference

Responses: Thanks for your advice. In the revised manuscript, we explained in detail the first occurrence of abbreviations in the text and cite references appropriately as follows.

"High-resolution thermodynamic snow and ice model (HIGHTSI) (Launiainen and Cheng, 1998; Vihma, 2002; Cheng et al., 2006)"

Cheng, B., Vihma, T., Pirazzini, R., and Granskog, M. A.: Modelling of superimposed ice formation during the spring snowmelt period in the Baltic Sea, Ann. Glaciol., 44, 139–146, https://doi.org/10.3189/172756406781811277, 2006.

Launiainen, J. and Cheng, B.: Modelling of ice thermodynamics in natural water bodies, Cold Regions Science and Technology, 27, 153–178, https://doi.org/10.1016/S0165-232X(98)00009-3, 1998.

Vihma, T.: Surface heat budget over the Weddell Sea: Buoy results and model comparisons, J. Geophys. Res., 107, 3013, https://doi.org/10.1029/2000JC000372, 2002.

P.3, L.67: "there are few studies" →so there are some apparently?

Responses: In Prydz Bay, some previous studies calculated or simulated the oceanic heat flux by some indirect methods, but no direct observation of ocean-interface parameters. Our observations tried to establish a direct estimation of oceanic heat flux, which can fill the data gap and provide strong support for the study of landfast ice growth.

P.3, L.75: please give a reference for the "modified Stefan's law", or explain briefly

Responses: The references Zhao et al.(2019) was added to this sentence.

Zhao, J., Yang, Q., Cheng, B., Leppäranta, M., Hui, F., Xie, S., Chen, M., Yu, Y., Tian, Z., Li, M., and Zhang, L.: Spatial and temporal evolution of landfast ice near Zhongshan Station, East Antarctica, over an annual cycle in 2011/2012, Acta Oceanol. Sin., 38, 51–61, https://doi.org/10.1007/s13131-018-1339-5, 2019.

P.3, L.77: Please explain abbreviations in the text; as they are used for the first time here

Responses: Thank you for your suggestion, the second part of the article has a more specific description of the instruments used in the study, but the acronym does need to be described in detail here, which will be modified in the revised manuscript.

P.3, L.78-80: Can be left out → phrasing in its current form

Responses: The current description of the structure of the article is indeed a bit brief, which will be carefully modified in the revised manuscript so that readers can better understand the structure and content of the article.

Ch.2: Observations

P.3, L.82: Coordinates misplaced; move to beginning of next sentence

Responses: Revised.

P.3, L.84: Reference for the landfast ice cover duration?

Responses: We added the reference Zhao et al. (2020) in the revised version.

Zhao, J., Cheng, B., Vihma, T., Heil, P., Hui, F., Shu, Q., Zhang, L., and Yang, Q.: Fast Ice Prediction System (FIPS) for land-fast sea ice at Prydz Bay, East Antarctica: an operational service for CHINARE, Ann. Glaciol., 61, 271–283, https://doi.org/10.1017/aog.2020.46, 2020.

P.3, L.86-88: Are these own observations or is the reference missing?

Responses: Those expressions came from our previous studies, we added references here in the revised version.

P.3, L.91-96: Please indicate reference papers/reports for the respective measurement devices (could also be moved to a table in general; together with other instrument characteristics)

Responses: Revised according to the reviewer's suggestions.

P.4, L.101: "every five days" → in a seven-day data record, it is sufficient to call that "twice"

Responses: Revised.

Ch.3: Results

P.5, L.120: You write that the ice-water interface was determined by a simple threshold (freezing point temperature of seawater). Can you elaborate more on that topic, especially how you handled noisy data and the given uncertainty for the IMB temperature measurements?

Responses: The resolution of the SIMBA temperature sensors is 0.0625 degrees, causing noisy values appeared during observation. Therefore, 3-points smoothing is used in our data processing, which was also used in Zhao et al.(2017) and discussed in detail. They adopted a simple threshold (freezing point temperature of seawater), compared their results with the drilling observation, and found a good agreement, with the average deviation of 3.2 cm. Therefore, it is reasonable to adopt this simple threshold during the ice growth season in the winter of the southern hemisphere.

Zhao Jiechen, Yang Qinghua, Cheng Bin, et al. Snow and land-fast sea ice thickness derived from thermistor chain buoy in the Prydz Bay, Antarctic. Haiyang Xuebao, 39(11), 115-127, https://doi.org/10.3969/j.issn.0253-4193.2017.11.011, 2017.

P.5, L.123: "observed in the field" → do you mean direct measurements, for instance by a drill?

Responses: Yes, the ice thickness near the instrument are measured by winter team members at Zhongshan Station in winter by drilling.

P.5, L.131: "2m below the ice surface" → how thick was the ice at this position?! I would assume that at least platelet ice could fairly quickly become a problem for CTD measurements at this depth…

Responses: In April, at the beginning of CTD deployment, the thickness of sea ice is about 40 cm, and then the sea ice continues to thicken, about 100 cm in July and about 130 cm in September. If you look at the whole winter, the thickness of sea ice reaches its maximum in November, about 142 cm, so most of the time CTD is within the range of 50~150 cm below the ice bottom. As the reviewer said, more platelet ice has been observed at the bottom of the ice along the coast of Zhongshan Station, but we think that the CTD at the 50~150 cm below the bottom of the ice should not be affected.

P5, L.134: with "about 0.1m above the ice bottom" – do you mean the lowest 10cm? Please rephrase

Responses: Yes, the expression here may not be accurate enough, which means that the average temperature of the 10 cm at the bottom of the sea ice is -3.12±0.71℃. We changed the expressions "about 0.1 m above the ice bottom" to "the lowest 10 cm of sea ice".

P.6, L.139/140: Please be more precise here. Which temperature gets warmer, and compared to what/when? Plus: "more heat", not "more heat flux"

Responses: As mentioned in the previous analysis, there is a significant jump in ocean temperatures after April 20 compared with April 16-19, and higher ocean temperatures mean that more heat will be transferred from ocean to sea ice.

P.7, L.147/148: Did you mix up smallest & largest deviation?

Responses: Revised.

P.8, L.158-166: Multiple remarks; Please elaborate in more detail why you used this particular equation, i.e., why you consider it as suited for your observations in Prydz Bay. Further, please do not just copy the denoted symbols from the source publication without explaining them first together with the respective units (t, S, rho). Also, be more precise and consistent with the indexing, for instance in case of salinity (ice or water salinity?).

Responses: In the revised manuscript, we gave a detailed explanation of the relevant units and the words such as salinity and temperature that appeared for the first time, so that readers can understand

the parameters used in the formula more clearly.

P.9, L.182: "ROSE analysis" is not the correct wording. It's "just" a diagram.

Responses: Revised.

P.10, L.186: Please explain what you mean by "compound current"

Responses: As shown in figure 7, the observed ocean current direction was affected by topography and tide and changed with time. We tried to express this phenomenon, but used an improper word. We revised these expressions in the new version.

P.10, L.187: Please give a proper reference / data citation for the data set from the Bureau of Meteorology, Australia and introduce the abbreviation that you are using later in the text

Responses: Thanks for your suggestions, and we gave a web link reference here in the revised version.

P.13, L.222/230: "the reference layer" is only explained towards the end of the sub-section. It would be useful to have this part earlier in the text in order to avoid confusions. Also, please indicate which measurement device(s) are used for your calculations. Further, can you comment on / discuss the effect of snow on top of the sea ice when you calculate your heat fluxes?

Responses: As the reviewer's suggestion, we explained the part of the definition of "the reference layer" in an earlier position.

The snow cover doesn't affect the "the reference layer" used in our study. In the absence of vertical ice temperature observation in the previous studies, surface air temperature is often used as surface ice temperature to calculate the sea ice temperature gradient. In that condition, the snow cover will affect the calculation results. In this study, the use of vertical temperature profile data can better calculate the internal temperature gradient of sea ice and avoid the error caused by snow.

P.14, L.240-242: List references for the used constants

Responses: Thanks. We have added references to the parameters. See P.14, L.236.

Ch.4: Discussions

P.18, L.326: How does this compare to a climatology or model results?

Responses: We calculated the tide climatology in this region and compared with tide in our study

period. The analysis will be found in the new 4.1 section.

P.19, L.362: Only one sentence that relates to your own measurements? There is for sure more to discuss in the context of other studies, as well as the general context of the measurements in a large-scale and/or climatological sense.

Responses: We downloaded AMSR2 sea ice product and Mercator ocean product to analyze the relationship between the large scale and the small scale phenomena. The results will be shown in the discussion section.

Ch.5: Conclusions

P.20, L.374: These are already the conclusions, and I still don't know how exactly snow and ice thicknesses were estimated. Please explain early in the manuscript.

Responses: Thanks for the reviewer's reminds. We indeed missed the description on sea ice thickness estimations. In this study, we use simple threshold to determine the position of the ice-water interface based on SIMBA the temperature chain. Because there is no ice surface change at the observation site in winter, the upper ice surface position is fixed, and sea ice thickness can be obtained only by judging the sensor number of the ice bottom position. The explanation of SIMBA data processing will be reflected in the revised manuscript.

P.20, L.387: "increased to twice" → doubled?

Responses: Revised.

P.21, L399: "equipment malfunction" → ?? See general comment. Why is this only mentioned at the very end?

Responses: We have added the explanations at the beginning of the article. And we answered this suggestion in General comments (A).

Other aspects

Data availability: "data available on request" – please consider putting your data on a public repository. Additional benefit: You'll get a proper citable DOI.

Responses: Thanks for the reviewer's suggestions. We will put all the data in a public data website and get a citable DOI.

Figures & tables

Fig.1:

The photo in panel (b) is not planar as indicated on the map in panel (a), which leads to several hic-ups regarding the length-scale. Also, it seems that the distances/marked locations of the ACTD, ADV etc. are way closer together than the 30m indicated in panel (c), judging from the Ski-Doo on the right side of the photo. Please reaffirm.

Data source and reference for the satellite image in (a) missing

Check grammar in the caption

Panel (c) would need a slightly better resolution (likely compression-artefacts?)

Responses: Thanks for your suggestions. We revised and redraw the figure.

Fig.2:

Units missing next to the colorbars

Panel (b): Vertical gradient (btw: note the spelling mistake) → add "of temperature"

It is not mentioned in the caption that this is a contour plot based on a limited number of measurements (four times daily)

Please also note the year on the time axis, plus time zone (UTC? local?)

Caption: Not mentioned how the ice surface & bottom were derived (algorithm or manually); none of the axis explained

Colormap not suited for readers with color vision deficiencies; better examples & background for instance here: https://zenodo.org/record/5501399

Responses: Thanks for your suggestions. We revised and redraw the figure.

Fig.3-5:

The differentiation between 2min and 1hour average values is nowhere mentioned in the text. Either note that this is purely for visualization purposes, or justify in the text why you decided to illustrate it like that.

Units missing in sub-panel headers (after mean/std)

Please also note the year on the time axis, plus time zone (UTC? local?)

In general: Anomalies in the sub-panels (b) to (i) not discussed in the paper, so either leave them out (e.g., combining the upper panels of Fig.3-5) or discuss them adequately

Caption: Spell out / explain abbreviations

Responses: Thanks for your suggestions. We revised and redraw the figure.

Fig.6:

As in previous three figures: The differentiation between 40s and 10min average values is nowhere mentioned in the text. Either note that this is purely for visualization purposes, or justify in the text why you decided to illustrate it like that.

Please also note the year on the time axis, plus time zone (UTC? local?)

Panel (c): Add "horizontal current speed"

Caption/panels (a) and (b): u-component / v-component

Caption: Spell out / explain abbreviations

Responses: Thanks for your suggestions. We revised and redraw the figure.

Fig.7:

I would recommend to choose another symbol for "Current speed" than "s". "V" is probably more common and intuitive.

Percentage values: why decimal values / not rounded?

Caption: Spell out / explain abbreviations

Responses: Thanks for your suggestions. We revised and redraw the figure.

Fig.8:

Right y-axis: Water level anomaly?

Left y-axis: Unit missing

Vector-arrows: are you sure these are 2min values and not 5min?

Caption: Spell out / explain abbreviations

Responses: Thanks for your suggestions. We revised and redraw the figure.

Fig.9:

Please also note the year on the time axis, plus time zone (UTC? local?)

Please indicate the instrument from which these fluxes where derived

Responses: Thanks for your suggestions. We revised and redraw the figure.

Fig.10:

Caption: 2min/1hour averages, not results

Please indicate what the error bars stand for. I assume +/- 1 standard deviation?

As in previous figures: The differentiation between 2min and 1h average values is nowhere mentioned in the text. Either note that this is purely for visualization purposes, or justify in the text why you decided to illustrate it like that.

Please also note the year on the time axis, plus time zone (UTC? local?)

(b) → use different colors than in (a) and previous figures

Responses: Thanks for your suggestions. We revised and redraw the figure.

Table 1:

Check wording

Add what +/- indicates

Responses: Thanks for your suggestions. We revised and redraw the table.

Fig.11:

Please also note the year on the time axis, plus time zone (UTC? local?)

Spell out abbreviations and give appropriate references

Explain "harmonic constant calculation" (it is not in text). What exactly is merged here?!

Are these hourly values averaged values? Then please indicate the respective standard deviations (by error bars, shading or similar).

Responses: Thanks for your suggestions. We revised and redraw the figure.

Fig.12:

First of all, the figure is generally hard to assess and not very intuitive. 3D plots are fancy, I know, but 2D plots might be more familiar to many potential readers.

The caption mentions the 3D-evolutiomn of ocean velocity and direction – only, where exactly is the velocity? I see temperatures, directions, Dates (again, time zone etc. missing), salinities…but no velocities! Please explain.

Responses: Thanks for your suggestions. We revised and redraw the figure.