

Ocean Sci. Discuss., referee comment RC2
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Comment on os-2021-16

Anonymous Referee #2

Referee comment on "Thermodynamic processes affecting the winter sea ice changes in the Bering Sea in the Norwegian Earth System Model" by Huiling Zou et al., Ocean Sci. Discuss., <https://doi.org/10.5194/os-2021-16-RC2>, 2021

Review of the manuscript "Thermodynamic processes affecting the winter sea ice changes in the

Bering Sea in the Norwegian Earth System Model" by Huiling Zou et al. [OS-2021-16]

General comments:

The authors examined the role of the thermodynamic process on the wintertime sea ice variability in the Bering Sea, which is the Pacific-side of the seasonal sea ice region in the Arctic, based on the CMIP-type model output under the present climate condition for the past several decades. In this study, the authors diagnostically examined the simulated outputs of the sea ice growth rate and melting processes on seasonal to interannual timescales, and found that the seasonal cycle of the sea ice volume is determined by snow ice formation process and the interannual variability of sea ice is well explained by the thermodynamic process due to congelation ice formation process.

The physical process controlling the sea ice distribution in the Bering Sea has been investigated by many researchers through statistical examination of atmosphere-ice variables (Sasaki and Minobe, 2005) and an ice-ocean coupled model simulation technique (Zhang et al. 2010). Although the importance of the congelation ice in the Bering Sea is consistent with the above research, the importance of snow ice on the Bering sea ice fluctuations seems to be new and this study actually promotes the understanding of future projection of sea ice cover in the seasonal sea ice region and contributes to the climate modeling community. However, the several results of statistical analyses based on climate model simulation and their interpretations are still questionable for me. I feel, therefore, major revisions are required for the recommendation to be published in Ocean Science.

Major comments:

- The authors evaluated the representation of sea ice variability derived from the historical experiment of NorESM1-M by using the EOF analysis of sea ice concentration in the Northern Hemisphere. However, this study focuses on only the Bering Sea ice variability and thus the authors should evaluate the reliability of the simulated sea ice variability based on the EOF analysis of sea ice concentration in the Bering Sea. Moreover, I recommend to evaluate the representation of ocean temperature and current fields in NorESM1-M, because the sea ice advance in the Bering Sea is highly influenced by ocean heat advection (e.g., Nakanowatari et al. 2015, Stabeno et al. 2017).
- The authors examined the influence of the thermodynamic process on wintertime sea ice variability based on the climate model outputs, and found that a large amount of the sea ice fluctuation is explained by the thermodynamic process. However, an ice-ocean coupled modeling study pointed out that the wind-induced sea ice drift is crucial for the sea ice advance in the offshore area in winter (Zhang et al., 2010). Therefore, the authors should discuss the weakness of the sea ice drift process in NorESM1-M. I guess that the model resolution of NorESM1-M might underestimate the influence of the sea ice drift due to the insufficient representation of sea ice velocity and ocean current system.
- Based on the statistical analysis between sea ice area and the thermodynamic process derived from NorESM1-M, the authors found that the interannual variability of sea ice is well explained by the thermodynamic process due to congelation ice formation. However, I suppose that this term includes the sea ice formation at the interface between atmosphere and ocean, which is known to be a large contribution on the sea ice variability (Zhang et al. 2010). Since this term does not appeared in this sea ice model, the authors should make effort to explain the configuration of the sea ice model and the derived term in details in section 2.2 or 2.3.
- The authors found that the conversion of snow to ice process is crucial for the seasonal evolution of sea ice in the Bering Sea. This result seems to be new finding, but the supportive information such as snow fall rate seems to be lack in this paper. If this result is a main body in this study, the authors should show the observed evidence or additional results to support the importance of the snow ice in the Bering Sea.

Minor comments:

- Line 11: Please specify the season focused in this study here.
- Lines 12-14: Although the authors present the result for EOF analysis based on sea ice concentration in the Arctic region, the meaning of this result is not clear for me. I recommend that the authors should describe the result for the evaluation of the simulated SIC variability in the Bering Sea.
- Line 26-29: Please specify the season focused in this section at first, because the possible mechanism for the Arctic sea ice change is different in season and area. The authors provide the information of the possibility of the active role of the sea ice reduction in winter on the climate change in lower latitudes, but the description seems to be insufficient. The authors carefully should describe the possible mechanisms of the linkage between the Arctic sea ice reduction and the mid-latitude climate by citing the earlier studies (e.g., Honda et al. 2009; Inoue et al. 2012; Petoukhov and Semenov 2010; Vihma 2014; Screen 2014; Cohen et al. 2014; Mori et al. 2014).
- Line 30: dynamic mechanism -> thermodynamic mechanism?
- Line 32: The authors describe the role of the remote influence of atmospheric and ocean process related to the NAO on the Arctic sea ice change, but the description seems to be insufficient for some readers. Please describe the finding shown in the

earlier study more clearly.

- Line 36: The authors introduce the research papers for interannual variability in the Barents Sea and the Greenland Sea and the importance of ocean heat transport as driving force of sea ice variability. These earlier studies seem to be the motivation of this study, but these studies are not related to the Bering Sea. So far, the interannual variability of wintertime sea ice area in the Bering Sea has been investigated by many researchers by using numerical modeling (Zhang et al., 2010) and observational data (Overland and Pease, 1982; Sasaki and Minobe, 2005; Nakanowatari et al., 2015). The authors should explain the remained questions and motivation of your study based on these earlier studies.
- Line 40: Although the author used the CMIP type model output in this study, the motivation of the usage of the CMIP-type model output is unclear for me. Please describe the reason why the CMIP-type model is used in this study.
- Line 60: The authors show the EOF patterns for the observed SIC in winter in the Northern Hemisphere during 1976-2004 with positive anomalies in the Bering sea and Greenland Sea and negative anomalies in the Okhotsk Sea and Barents-Kara seas, but this anomalous sea ice pattern has already been reported by Yamamoto et al. (2006, GRL) based on the observed SIC data. Therefore, the authors should show the EOF analysis of SIC based on NorESM1-M and discuss the validity of the simulated sea ice data (Please see general comment #1).
- Line 92: Please add the model configuration of NorESM1-M used in this study (what kind of the sea ice model, atmospheric model, ocean model including their spatial resolution), although the authors cited the reference. Also, the authors should describe the reason why this CMIP type model output is adopted in this study.
- Line 101: The authors evaluate the NorESM1-M sea ice conditions by comparing with the observed SIC or PIOMAS outputs. Overall, it seems that the NorESM1-M has non negligible bias on sea ice conditions in the Bering Sea on seasonal to interannual timescales. The authors should explain the validity of the NorESM1-M sea ice conditions for your purpose, here.
- Line 120: Please move this sentence about earlier study (Sandø et al., 2014) to the introduction section, because this study is quite important motivation for your study.
- Line 155: In terms of sea ice ... -> The monthly mean sea ice mass increase is ...
- Line 162: In this paragraph, the authors show the spatial distribution of sea ice formation type and found that the conversion of snow to ice is prominent in the northwestern BS. Since this result is interesting and seems to be new finding in this study, the authors should explore the possible cause of the dominance of snow ice, which is also related to bottom ice melting, in this area. I suppose that the snow fall rate and ocean heat flux seems to be crucial for the conversion of snow to ice.
- Line 179: The authors examined the effect of thermodynamic process on the sea ice variability (SIC and thickness) in the Bering Sea in January by lead-lag correlation analysis. However, I suppose that the thermodynamic process in February-March is not needed to be examined, because the SIC in January does not lead the sea ice formation in the following months.
- Line 186: The authors mentioned the correlation between SIC and the bottom ice melting is -0.75, but Figure 5a shows the positive value.
- Line 199: Since this sentence is somewhat abrupt, it may be moved to the next section.
- Line 211: ...that the increase in sea ice concentration is accompanied with the decrease in surface air temperature...?
- Line 212: opposite -> positive?
- Line 216: Figure 5e -> Figure 6e
- Line 215: The authors mentioned that the interannual variability of SIC is well explained by the congelation ice, which is caused by the local surface air temperature based on the correlation map. I guess that the turbulent heat flux is a main factor for the local sea ice production and thus sea ice concentration. However, the authors mentioned that the correlation between the sensible (and/or latent heat flux) and sea

ice change in BS is very low (Line 134). Could the authors explain the physical meaning of the negative correlation between surface air temperature and congelation ice and/or sea ice concentration?

- Line 226: The authors discuss the imbalance between sea ice formation and melting rate in January, but I suppose that the dominance of sea ice formation is natural in winter season.
- Lines 224-235: Overall this paragraph includes quite complicated logic. Therefore, it is very difficult for me to follow the point of this paragraph.
- Line 227: In the seasonally covered regions -> In seasonal sea ice zone
- Figure 2: the reanalysis datasets -> the observed datasets
- Figure 2: Please change the unit for the SIC from 0-1 to 0-100%.
- Figure 2: The additional map for the climatological raw SIC value (%) would be helpful for readers.
- Figure 3: Since the year-to-year variability has no meaning in this comparison, I recommended that the spatial pattern for the climatological SIT distribution in winter is shown here despite of the time series of PIOMAS and NorESM1-M.
- Figure 4: The original sign seems to be better in panel c.
- Figure 4: The additional information for the spatial distribution of total ice mass would be helpful for readers.
- Figure 9: red line-> purple line
- Table 1: The additional column for the total sea ice mass in each month is helpful for readers.