Response to the reviews of tc-2023-79 “Understanding influence of ocean waves on Arctic sea ice simulation: A modeling study with an atmosphere-ocean-wave-sea ice coupled model” by Chao-Yuan Yang, Jiping Liu, Dake Chen

<u>Responses to comments by Reviewer #1</u>

We would like to thank the reviewer for the helpful comments on the paper.

Review on “Understanding influence of ocean waves on Arctic sea ice simulation: A modeling study with an atmosphere-ocean-wave-sea ice coupled model” by Yang et al.,

The authors have made detailed revisions according to the previous-round review comments, and the manuscript has basically reached the state of being ready for publication. Here, I mainly raise some specific comments on unclear expressions and editorial issues:

1) The spelling rules for the author's name in English are not consistent for all authors. I understand that Chaoyue is the the first name as Jiping and Dake.

Response: The spelling for the authors’ first name in English is consistent with the spelling on their passport.

2) Line 24 and other text: Sea-ice: I don't think it's necessary to use hyphens.

Response: Thanks, we changed them.

3) Line 54: The increased surface wind speed: So far, there is no study indicating an increasing trend in the near surface wind field over the Arctic Ocean (e.g., Zhang et al., 2022 as you cited)

Response: Thanks for the reviewer’s helpful comment. We mainly want to address the correlation between wave height, fetch and surface wind as shown in the previous studies. We changed the sentences to “Previous studies suggested that the Arctic fetch and surface wind speed over the ice-free ocean correlate well with wave heights in the Arctic Ocean (e.g., Casas-Prat and Wang, 2020; Dobrynin et al., 2012; Liu et al., 2016; Stopa et al., 2016; Waseda et al., 2018).”

4) Line 58: Sea ice with mostly smaller floes has larger surface areas, particularly lateral surfaces.-- This expression makes me very vague. It would be better change to: The ice pack, with the same concentration, has larger surface area for the ice floes with smaller sizes, particularly lateral surfaces.

   Response: Thanks for the suggestion. We changed the sentence.

5) Line 97-99: The coupled effects of ocean waves and sea ice include; the amplitude of ocean waves decays as the waves travel under the ice cover due to the combination of scattering and dissipation-- These two sentences appear incomplete and incoherent. It would be better change to: The coupled effects of ocean waves and sea ice also include the decay of amplitude of ocean waves as they travel under the ice cover due to the combination of scattering and dissipation.

Response: Thanks. We changed the sentences.

6) Line 337-342: In the equation (2), the user-defined coefficients for the wave attenuation are set as $c2 = 1.06 \times 10^{-3}$ and $c4 = 2.3 \times 10^{-2}$ (case 1), which follow the polynomial of Meylan et al. (2014, hereafter M14) from the observations with 10-25m floe in diameter in the Antarctic, and $c2 = 2.84 \times 10^{-4}$ and $c4 = 1.53 \times 10^{-2}$ (case 2), which follow the polynomial of Rogers et al. (2018, hereafter R18) based on the observations for pancake and frazil ice in the Arctic. --These parameters are all derived from the areas close to the ice edge. How applicable are they to the regions with higher ice concentration?

Response: In this study, these user-defined wave attenuation parameters are uniform for the entire domain, and their effects are scaled by sea ice concentration of each cell (Equ. 3). Also, the choice of different parameters is mainly trying to qualitatively investigate how sea ice responds to different wave strength under sea ice. As we addressed in the

discussion section, the attenuation by sea ice is associated with ice properties. A recent observational study also suggested that ocean waves decay faster under ice thickness over 0.5 meter (Huang and Li, 2023). That is, the parameters applied in this study may not be applicable to the regions with thicker ice.

Huang, B. Q., and Li, X.-M.: Wave attenuation by sea ice in the Arctic marginal ice zone observed by spaceborne SAR. Geophysical Research Letters, 50, e2023GL105059. https://doi.org/10.1029/2023GL105059

7) Line 410 the larger total ice surface area due to smaller floe size increases the efficiency of Exp-PFSD extracting energy from the ocean-- This process should generate positive feedback, That is to say, the lateral melting of sea ice would reduce the sea ice area, and then increase the absorption of heat (shortwave radiation) by the upper ocean, promoting sea ice melting, including at the ice bottom. Therefore, my question here is whether the numerical model can capture this feedback, that is, although some of the heat content is consumed by sea ice melting, it will also promote the ocean to absorb heat from the atmospheric in the warm melting season.

Response: The average of all ice-cells (e.g., Fig. 3, 4, 5) may not be clear to see this increased energy input from the atmosphere to the ocean in the warm melting season that compensates the energy consumption by the increased ice surface area. By changing the view based on the regional average (e.g., Fig. 7), it is clear that less sea ice area can lead to more energy absorbed by the ocean in the melting season. That is, the model can capture this feedback in certain degree.

8) Line 414 “Energy loss from the ocean through air-sea heat flux that further cools the upper ocean”-- As with the previous question, in summer, the increase in ocean area does not necessarily mean the loss of heat.

Response: Thanks for the reviewer's comment. We modified the sentence and now it reads "Energy loss from the ocean through air-sea heat flux in winters that further cools the upper ocean, freshwater input (e.g., ice melting, precipitation) that raises the freezing point, as well as non-physical numerical oscillations (Naughten et al., 2017; Yang et al., 2022), are potential contributors that lead to increased frazil ice formation of Exp-PFSD as shown in Fig. 3a-b and Fig. S2g."

9) Line 478 "), and more melting potential in December 2017 in the LK region": I have a question here. In December, shouldn't the LK region be covered fully by sea ice? Will sea ice melting occur in the early winter season here?

Response: In Figure 7b, e, the LK region in Exp-PFSD is still not fully-covered by sea ice in December. In the preceding summer, less sea ice area in the LK region results in more energy stored in the ocean (Fig. 7k), which likely delays the ice growing in the LK region in December and leads to the corresponded sea ice area and melting potential shown in Fig. 7b, k.

10) Line 502 "Combined with the warmer upper ocean in Exp-PFSD after January 2020 in the ATL region" ——In spring 2020, the sea ice transported from the Arctic Ocean to the Greenland and Barents seas should have increased due to abnormal atmospheric circulation (Zhang et al., 2023). Can the impact of the increased sea ice outflow from the central Arctic Ocean on the local mass budget of sea ice and heat fluxes be captured in numerical models?

Zhang, F., et al., 2023: The impacts of anomalies in atmospheric circulations on Arctic sea ice outflow and sea ice conditions in the Barents and Greenland seas: case study in 2020, The Cryosphere, 17, 4609–4628, https://doi.org/10.5194/tc-17-4609-2023.

Response: The fully-coupled configuration, model biases, and limited constraints from boundary conditions of the WRF, ROMS models make the simulations analyzed in this

study may not capture the actual changes in the Arctic during the period of 2016-2020. Further efforts are required to improve the fully-coupled model as we addressed in the discussion section so that the model can be better reproduce the changes in the Arctic.

11) Figure 1: Is the terminology of the subregions appropriate as it includes not only the peripheral seas but also the central Arctic Ocean, extending to 85N? For example, the LK region includes most of the basin areas located north of the LK Seas, and the same applies to other subregions.

Response: We agree with the reviewer's comment that the spatial coverage extended to 85N also includes the part of the central Arctic Ocean. We also have used different coverage (e.g., 80N) and the behaviors shown in Fig. 7 and Fig. 8 remain similar to current spatial coverage. We modified the description for the subregions and now it reads "Based on geographic features, we define the following subregions for further analysis: 1) Barents and Greenland Seas (ATL, 45W-60E, 65N-85N), 2) Laptev and Kara Seas (LK, 60E-150E, 65N-85N), and 3) Beaufort, Chukchi, and East Siberian Seas (BCE, 150E-120W, 65N-85N, see black boxes in Fig. 1 for the geographic coverage of subregions). …The ATL region is only partially-limited by ice-covered areas while the LK and BCE regions can be fully-covered by sea ice in winter. Though these subregions also include part of the central Arctic Ocean, they will still be addressed by the main peripheral seas in the subregions in the following discussion for simplicity."