The Cryosphere Discussions

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Comment on tc-2021-390

Anonymous Referee #2

Referee comment on "Reversal of ocean gyres near ice shelves in the Amundsen Sea caused by the interaction of sea ice and wind" by Yixi Zheng et al., The Cryosphere Discuss., https://doi.org/10.5194/tc-2021-390-RC2, 2022

The authors address an intriguing question regarding the ocean circulation in front of Antarctic Ice Shelves. The presented observations in front of the Thwaites Ice Shelf are novel themselves with otherwise little knowledge on the ocean circulation close to the ice shelves. Since the ocean currents deliver oceanic heat to the vulnerable ice shelves in the Amundsen Sea and export melt water away from the ice shelves, exploring the circulation patterns and their drivers are of great relevance. The authors address the question of what determines the direction of the gyres observed in front of the Pine Island and Thwaites Ice Shelves, and they use an idealized barotropic model set up with MITgcm to systematically study the ocean response to different wind stress and sea ice conditions. The model simulations show how the gradients in surface stresses across the sea ice edge superimpose the wind-induced stresses. The strong impact of the sea ice on the gyre strength and circulation highlights the need of good knowledge on sea ice conditions - both in terms of good resolution of sea ice concentration and the impact of the sea ice on ocean surface stresses - to accurately model the ocean circulation.

The results and the methods are well presented and certainly of interest for readers of JPO and the general GFD community. The study is a great combination between novel observations and a systematically approached idealized modeling study, and the figures are clear and easy to understand. I recommend publication of the manuscript and suggest the following changes mainly on the text that are meant to improve the readability, and to emphasize the motivation and the importance of the findings.

General comments on the introduction/ abstract:

The circulation in the PIB is well described (ll 35-49) and the observed reversal of the circulation in PIB by Webber et al (2017) is a great motivation to study the mechanisms

that alter the gyre circulation in an idealized framework. From the abstract it is not clear that an anticyclonic circulation has been observed previously.

While I understand that the PIB gyre is the most observed one (and the observed reversed circulation is a good motivation of this study), the importance of the study could be further highlighted discussing other gyres/ the little attention that has been on small wind-driven gyre. I.e. ll 351-360 could be moved into the introduction. As by now the introduction generally has a strong focus on the PIB circulation, while the circulation in the Thwaites area only follows in section 2. Parts of section 2 could be moved to the introduction.

ll 53-54 (and 108): The difference in sea ice coverage in the two regions is nicely mentioned as a possible mechanism to alter the gyre circulation. Given the strong focus of the impact of sea ice on ocean circulation in your study, it would be nice to expand a little on how sea ice coverage influences ocean surface stresses, i.e. having one paragraph describing what determines the local circulation and the importance of including sea ice in the calculation of ocean surface stresses. Only later in ll. 144-149 it is mentioned that sea ice can both increase and reduced the ocean surface stresses, but it should be mentioned already in the introduction (ll. 314-322 could be moved to introduction).

Specific comments:

ll 18: I suggest writing something like "a range of idealized sea ice conditions typical for the region" without mentioning the satellite images, given the very idealized setting used and the large range of different angles and stress transfers explored in this study.

ll 51: Highlight here that a cyclonic wind field would induce a cyclonic gyre circulation in the open ocean without any other influences (only mentioned in ll. 75-76)

ll 73 and Figure 3: Any reasons why the velocities are only shown in the upper 450m when the currents were measured in the upper 980m? Please elaborate.

ll 144: It was not clear to me at first how sea ice is represented in the model. "No active sea ice model" can be understood as if there was a sea ice model included that simply does not interact with the ocean thermodynamically. Please clarify that no sea ice is included in the model simulations, but accounted for by changing the strength of the ocean surface stresses in the sea ice covered area.

ll 157: What do you mean by “unchanged”?

ll 173-175: The OSS reduction by sea ice (0% tau) is not mentioned in the text (only in Figure 9a).

ll 187-188: Please quantify the speed and stream function for the 400m depth simulations.

Section 4.2.2: Figures 10 and 11 neatly summarize the impact of the ocean surface stress and the sea ice angle on the ocean circulation. Since both figures contain a lot of information, the section could benefit from an introduction into the figures and a more logic order. For example in line 209, it could be introduced that the figure is for the cyclonic wind stress only and it might be more logic to start with paragraph ll. 222-228.

Figure 11 (also in 10): It would be nice to mark the experiments presented in Fig. 8 and 9 for reference.

ll 202-208: I would highlight already here that you find this relationship for most model simulations, but that there are certain conditions under which the circulation can be reversed. This makes a nice transition to Figure 11 which shows more details on the conditions for reversed circulation.

ll 214-221: Fig. 11 is one of the substantial figures in the paper and the logic of the results seems disrupted starting this paragraph with Fig. 10. I suggest framing this paragraph around the results shown in Fig. 11 rather than basing it on Fig. 10.

ll 235: Results are already shown in Fig. 10 and 11. -> The spacial distribution of the OSSC and the circulation pattern are shown in Fig. 12.

ll 259: specify that it’s the wind stress transferred to the ocean by sea ice/ within the sea ice covered area.

ll. 340-343: Due to the large influence of the sea ice on ocean surface stresses explored in this study, it would be worth to include a broader discussion on the quality of sea ice satellite products, their resolution and the data coverage, as well as the state of the art in terms of sea ice contribution to ocean surface stress. As you showed nicely in your paper, there is a strong need in resolving whether sea ice enhances or reduces the surface stress on the ocean, while the available sea ice products are still far from resolving this

information in the needed resolution, as detailed information on sea ice thickness and roughness would be needed.

ll. 361: I suggest to add a new section: 6 Conclusions, for easier navigation.

Technical corrections:

ll 51: Influenced by the same climatologically-cyclonic wind field, -> same wind field as what?

ll 69: covered by sea ice all year round?

ll 74: units not in italic (106 m3 s-1)

ll164: due to the lack OF surface intensification ...

ll 232: remove 'although'

ll. 273: Section 4.4.4 -> 4.2.2

ll. 335: remove 'can contain' ?

Figure 1: Is it correct that the plotted velocity data are on a 0.25x0.125 resolution? It looks more like 0.5x0.125 in this Figure.