The Cryosphere Discussions

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Comment on tc-2022-160

Anonymous Referee #2

Referee comment on "The response of sea ice and high-salinity shelf water in the Ross Ice Shelf Polynya to cyclonic atmosphere circulations" by Xiaoqiao Wang et al., The Cryosphere Discuss., https://doi.org/10.5194/tc-2022-160-RC2, 2022

Using a regional ocean-sea ice-ice shelf model they investigate the role of meso and synoptic scale cyclones in sea ice production, HSSW formation and export from the Ross Ice Shelf polynya.
The authors found that the Cyclone caused an increase in the sea ice production rate due to changes in offshore winds and a consequently Enhancement of HSSW formation and export.

While I think that this paper could potentially give an important contribution to the understanding of the processes involved in the dense water formation in the Ross Sea, there are several issues that still need to be addressed before publication.

1 The main results of the manuscript are based on the HSSW salinity and volume increase in the RISP, in response to the increase of sea ice production due to the strengthening of off-shore winds during cyclone events.
While the increase of SIP occurs in the RISP (Figures 5 and 9), the increase of HSSW salinity and volume takes place in the region west of Ross Island (Figures 6 and 10), which is not in the RISP polynya, but in what is called the McMurdo polynya. Moreover, in this region there is no increase in SIP, so how do you explain the increase in Salinity there?

I suggest setting the western limit of the RISP at Ross island (approximately 169.5° E; see Tamura et al., 2008; Orsi and Wiederwohl 2009; Drucker et al., 2011) and recalculating the HSSW salinity and volume. In this case, I suspect that you will not observe anymore a significant increase in HSSW salinity and volume during the cyclones events.

Moreover, from the TS diagram in Figures 6 and 10 is not easy to see the change in salinity of the RISP except for the end-members (higher salinity values), it would be easier to make salinity time-series of the surface, intermediate and the bottom layer at a different location along the RISP.

2 One of the main focuses of this work is to estimate the export of HSSW from RISP. If you considered the RISP from 163° to 187° E, why do you draw a meridional transect (S1) in the middle of the polynya? Where the water in S1 is exported from?

3 Because the modelled ocean currents data are crucial to the paper discussion, it would be appropriate to validate those data with in-situ observations. You could use in-situ mooring data in a few areas of the Ross Sea. In the Ross Sea, mooring observations are available from different National programmes (USA, NZ and Italy).

4 The proposed mechanisms in paragraphs 3.4 and 3.5 are not convincing (in other words, too speculative). I think that the discussions need solid improvements. See below.

5 Many works have shown the direct role of the winds on the DSW formation, and because the cyclone influences the local wind dynamics, it is obvious that changes in the position and scale of a cyclone may have slightly different effects on the dense water formation. A more interesting work would be to statistical analysis of the cumulative effect of cyclones on the HSSW formation during the winter season and on the HSSW salinity trends and interannual variability.

Line 28-30: in this paper, you have chosen to represent positive along shelf velocity with a westward current, but in general in Oceanography a positive zonal component is considered to be positive in the eastward direction, so it is a bit confusing. Therefore, here I suggest explicit the direction of the correlation: transport direction (eastward or westward) with the wind direction (northward or southward)

Line 190-191: In order to define and identify HSSW in the Ross Sea I suggest using the definition proposed by Orsi and Wiederwohl (2009) that is more commonly used by the Ross Sea community. This definition uses both traditional thermohaline parameters (potential temperature and salinity S) and neutral density.

Line 216-221: The sentence “three-dimensional along-shelf and cross-shelf momentum equations are…, where ð☐☐¢ and ð☐☐£ are the alongshore and cross-shore components of velocity,” is a bit confusing. it is not clear if the currents are along-shelf (parallel to the shelf-break?) or along- shore (along the Ross Ice shelf?). I suggest to use along and across the Ice shelf.

Lines 236-237: looking to figure 3a I can see the lowest density in the western ross sea (dark blue), lower than the eastern Ross Sea (light blue) and the highest density outside the Ross Sea, west of Cape Adare.

Lines 237-238: you should change the wording to explain the figure better. I see a higher density at 180° outside the continental shelf and not close to the RIS.

Line 294: Salinity is overestimated (See Orsi and Wiederwohl 2009; Jacobs et al., 2022). The region 163°E–164°E is not in the RISP (Tamura et al., 2008; Orsi and Wiederwohl 2009; Drucker et al., 2011).

Lines 294-296: Here you suggest that the increase in salinity occurs in the region 163°E–164°E, when is observed an increase in SIP. From figure 5, I can see the increase in SIP in the region east of Ross Island (169.5), how the increase in salinity in the region 163°-164° E (that is outside the RISP) is explained by the increase in SIP west of 169.5 at about the same time (The distance between these 2 regions is not less than 150 Km)?

Lines 319-321: I think this expression is misleading. In this paper, the positive velocity is considered westward, whilst usually, the positive zonal velocity is considered to be eastward.

Line 368: Also in SYNO2 the salinity increases mostly west of RI, and not in the RISP.

Lines 369-371: I do not think that the HSSW salinity decreased in relation to the decrease in SIP on the eastern side of the RISP. During stage I of SYNO2 (Figure S3) the salinity increases mostly west of Ross island, therefore most probably, HSSW salinity is not affected by the SIP decrease in the eastern Ross Sea.
Moreover, In the Eastern RIS, the salinity is much lower compared to the western Ross Sea and there is no HSSW production (Orsi and Wiederwohl 2009), therefore is not clear how the SIP reduction in the eastern RISP helps to decrease the salinity of the HSSW.

Lines 465-466: you haven’t mentioned before that at S1 in Syno1 there is a 12 hours lag between HSSW export and the wind.

Lines 489-490: I suggest showing the figure in the supplementary material.

Line 491: “are displayed in the cross-shelf (Fig. 12) and along-shelf (Fig. 13) directions respectively.” Is along-shelf in figure 12 (Transect S1) and cross-shelf in Figure 13 (transect S3)?

Lines 504-507: In Figure S4, I can't see the intensified westward Ekman transport in the region 74°-76.5° S and 163°-167° E. Moreover, Why the increase in the off-shore winds intensify the westward Ekman transport only in that region of the Ross Sea? Please explain.
In addition, in case there is an increase in the pressure gradient between 74°-76.5° region and the RIS, why do we observe the increase in the eastward transport only in a part of transect S1 and not in the whole transect?
Furthermore, the geostrophic flow due to a tilt in the sea surface slope should be mostly barotropic. In figure 7 (and 11) does not look like the transport is barotropic.
You should also consider that The pressure gradients depend both on the sea surface slope and the density gradient between the RIS and the outer shelf. During cyclones, the increase in SIP and salinity close to the RIS should enhance the geostrophic flow due to the salinity differences.

Lines 511-516: In Figure S4, I can barely see the eastward flow in the upper layer. Looking at the figure all I can see is a very chaotic circulation with currents directed in the opposite direction at close nodes, especially close to the RIS and Ross Island. Moreover, along the RIS, a strong coastal current has been observed that flows westward and not eastward (Pillsbury & Jacobs 1985; Jacobs & Giulivi 1998; Smith et al., 2012; Porter et al., 2019).
Could it be useful to show a figure with the mean surface circulation across S1?
Furthermore, I do not think that in the upper layer (50 m) the HSSW can flow underneath the RIS. The RIS thickness at the front is no less than 150-200 m thick, well below the depth of 50 m.
Moreover, both Budillon et al. (2003) and Jendersie et al. (2018) show an inflow of HSSW underneath the RIS in the deep layer and not in the upper 50 m layer as observed here.

Lines 545-552: I do not agree with the sentence "The HSSW formation in the RISP demonstrated a near-instantaneous response to the wind change during the synoptic- and meso-scale cyclone events". Here, the increase of HSSW salinity and volume is observed west of Ross Island and not in the RISP polynya where the SIP increases during the Cyclones. This is clear from Figures 6 and 10. Looking at the TS diagram confirms that the HSSW salinity increase occurs west of Ross Island, where there is no increase in SIP. Therefore, the discussion below is pointless.

Lines 553-568: Following Morrison et al., 2020 the CDW intrusion and HSSW outflow are correlated, but close to the shelf break and not close to the RIS. In addition, it is the HSSW outflow that modulates the CDW intrusion and not the contrary as stated here. While it is true that the CDW may affect the DSW formation rate in the Ross Sea, the time scales are very different. The response of the RISP and therefore of the HSSW formation to a cyclone (strong winds) is much shorter than the response of the dense water formation to the CDW intrusion onto the shelf. Moreover, the spatial scales are completely different: the continental shelf in the Amundsen sea is smaller and the ice shelf is much closer to the shelf break than in the Ross Sea. In addition, the continental shelf water properties in the Amundsen Sea are completely different from the Ross Sea, in the Amundsen Sea, there is no DSW formation.
Finally, I don't understand why you compare the time lag registered in your study (related to the local ocean dynamics response to the northward wind increase during a cyclone,

with Mathiot et al., (2012) work that looks at the lag between the cumulative HSSW production during summer and export from the Ross Sea. These are processes happening at different time scales.

Figure 3: I suggest adding the trajectory of the cyclones in the figures.
Figure S4: Because this figure is important for the discussion, I suggest including it in the main text. I also suggest highlighting the region 74°-76.5° S and 163°-167° E.

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