Overall impression

The paper investigates the physical and biogeochemical characteristics of mesoscale eddies at the surface of the Southern Ocean – a region of global importance for heat and carbon exchange and biogeochemical cycles, concurrently a region dominated by eddies. This study involves many novel aspects compared to previous studies and tackles relevant topics for the community. It distinguishes between warm-core anticyclonic eddies (AEs), cold-core AEs, cold-core cyclonic eddies (CEs), and warm-core CEs (termed here as 'normal' and 'abnormal' AEs and CEs).

The authors have done a great job in improving the manuscript. I find that the introduction is a lot clearer now, and generally, the text flows a lot better. I also like that the discussion is deeper now, and the figures that are kept in the main text are analyzed at sufficient depth. My other suggestions were addressed adequately too. I just have a few minor suggestions which should be addressed before publication.

Response: We would like to thank the reviewer for the positive comments and valuable suggestions to improve the manuscript. We hope the answers and information presented here would respond to what was demanded.

General comment

1. As eddy-induced Ekman pumping should have a larger effect in high-wind regions, it would be great to check if there are more 'abnormal' eddies in high-wind areas than elsewhere. If not, then how do we explain it? Please add a few sentences about this in the discussion/conclusion section.

Response: We appreciate your insightful suggestion. We calculated the number of "abnormal" eddies occurrence in each 1° × 1° latitude-longitude bin over the analyzed period 1996–2015 in the SO. Then, we averaged the eddy number at the binned wind speed intervals of 1 m s^{-1}, as shown in Fig. 1 below. In low-wind regions, specifically with wind speeds less than 6 m s^{-1}, the occurrence of "abnormal" eddies is scarce. However, as wind speed progressively increases, we observe a corresponding increase in the number of "abnormal" eddies. Considering that eddy-induced Ekman pumping is expected to exert a more pronounced influence in high-wind regions, this result indicates the effect of eddy-induced Ekman pumping on the generation of "abnormal" eddies. We have incorporated this result into the discussion/conclusion section.

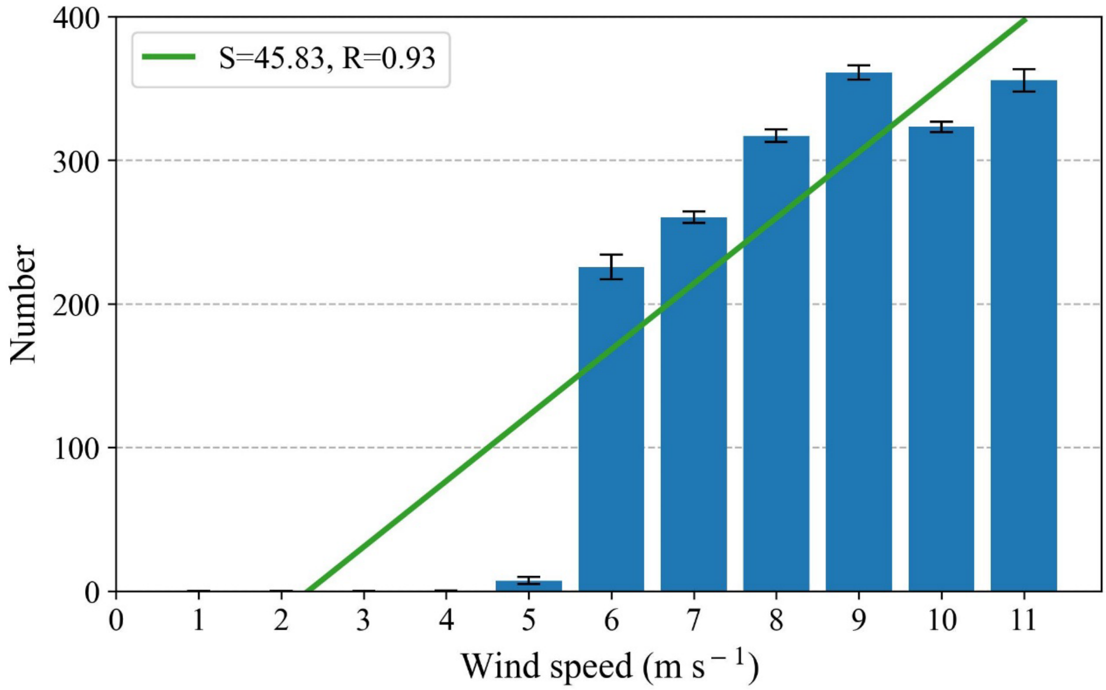

Figure 1. The mean number of "abnormal" eddies as a function of wind speed in the SO. The blue bars denote the number of "abnormal" eddies occurrence in each 1° × 1° latitude-longitude bin over the analyzed period 1996–2015, which is averaged at the binned wind speed intervals of 1 m s^{-1}. The black error bars denote the standard error. The green line denotes the regression line obtained from least squares fitting with S being the slope and R the correlation coefficient.

Specific comments

1. L11: I suggest putting 'normal' in inverted commas too (not just 'abnormal'). Check in the whole document.

Response: Revised.

2. L45: "The variation of pCO_2 was found to be positively correlated with SST and DIC but negatively correlated with Chl-*a*… Therefore, the variation of pCO_2 within the eddies will be complex and necessitates discussion based on seasons and regions." This is not a necessary conclusion. Positive and negative correlations don't say anything about seasons and regions. Rephrase.

Response: Thanks for your valuable feedback. We revised the sentences in lines 45–48 as follows:

"The variation of pCO_2 was found to be positively correlated with SST and DIC but negatively correlated with Chl-*a* (Chen et al., 2007; Landschützer et al., 2015; Song et al., 2016; Fay et al., 2018; Jersild and Ito, 2020; Iida et al., 2021). The competing seasonal cycles of SST, Chl-*a*, and DIC would induce the seasonal variability of pCO_2 and the seasonal variation of pCO_2 within the eddies varies in different regions (Chen et al., 2007; Frenger et al., 2013; Jiang et al., 2014; Munro et al., 2015; Song et al., 2016; Jones et al., 2017; Jersild and Ito, 2020). Therefore, the variation of pCO_2 within the eddies will be complex and necessitates discussion based on seasons and regions."

3. L.49: 'recent studies'… 'Mcgillicuddy et al., 2007' 2007 is not that recent.

Response: Thanks for your suggestion. We replaced "recent studies" with "previous studies".

4. L151: 'Besides, our method achieves great accuracy and much higher efficiency than the traditional method that first detects the eddies and then uses the SST signature to classify them into normal and "abnormal" eddies.' Add a reference to this statement.

Response: Revised.

5. L158: 'in future work, we will combine multiple remote sensing data with Argo profiles to evaluate the accuracies of "abnormal" eddy identification method'. Discuss why you didn't do it in this study.

Response: Thanks for your feedback. There are several reasons why we did not incorporate this approach in the current study:

1) Data Availability and Access: The availability and access to high-quality remote sensing data and Argo profiles can vary based on geographic regions and time periods. Obtaining and processing such datasets can be a time-consuming and resource-intensive task.

2) Resource and Time Constraints: The uneven distribution of Argo floats in time and space can impact the precision and accuracy of using Argo for eddy identification. Most satellite data, on the other hand, can only monitor surface ocean information. Although it is possible to employ deep learning techniques to combine Argo and satellite data to infer three-dimensional ocean temperature and salinity with spatiotemporal continuity, this approach demands a substantial amount of time and resources for implementation and validation, which could extend the timeline of the study beyond its intended scope.

3) Suitability of the Current Approach: Our study aimed to establish the fundamental relationships and mechanisms between eddies and the oceanographic parameters of interest. The existing data and methods are sufficient to address our primary research questions.

6. L209: 'from 1996 to 2015, an average of 1991 eddies were identified daily' This

number is a lot larger than the ~1 million eddies that Frenger et al. 2015 detected in the S.O between 1997 and 2010 (~ 200 daily eddies on average). Are we sure they are all robust features?

Response: Thanks for your feedback. The discrepancy in the number of identified eddies between our study and Frenger et al. (2015) is primarily due to the differences in the data resolution and detection criteria.

1) Data resolution: The eddies detected by Frenger et al. (2015) are weekly, constrained by the weekly SSHA data they used. By contrast, the eddy dataset we used is daily, which is detected by daily SSHA and SSTA data. Therefore, the eddies identified by Frenger et al. (2015) are roughly seven times fewer than ours within the same period.

2) Lifespan limitation: Frenger et al. (2015) detected eddies with a minimum lifespan of four weeks. By contrast, we had no limitation on eddies' lifespan, as we believe that short-lived eddies are also significant.

In addition, we discarded eddies with amplitudes < 2 cm and radii < 35 km due to the limitations of the resolution capability of the SSHA data (Ducet et al., 2000), which helps to increase the robustness of eddy features. Besides, the spatial distributions of eddies are consistent with the observations reported by Frenger et al. (2015) and Dawson et al. (2018), substantiating the reliability of the eddy dataset we utilized.

7. L498: It's always good to end the paper with a strong statement. Maybe swap the last two paragraphs around.

Response: Thanks for your suggestion. We deleted the last two paragraphs.

8. Fig.1-5 captions: Name which of the fronts they are and their reference.

Response: Thanks for your suggestion. We revised the related sentences in Figs. 1–5 and S3 as follows:

"Black solid lines show the mean northern (SAF) and southern (PF) positions of the ACC major fronts (Sallée et al., 2008)"

Technical corrections

1. L275: Replace 'extremums' with 'extrema' (check whole document)

Response: Revised

Reference

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