Referee's comments are in black text, authors' responses are in blue.

Review of "A numerical investigation on the energetics of a current along an ice-covered continental slope" by Leng et al.

In this manuscript the authors build on recent work exploring the impact of sea ice cover on ocean dynamics and baroclinic instability. The simulations are well chosen, the theoretical work is generally clear, and the results are compelling.

However, I think the manuscript would be easier to read if it were slightly restructured. I also have a few minor suggestions.

Edward Doddridge

Thank you very much for the comments and helpful suggestions. We have restructured the manuscript and addressed all comments. Below are our point-by-point responses. The line numbers mentioned below refer to the lines in the tracked-changes version of the manuscript.

Comments

Structure and story

The manuscript contains a lot of great science, however, it is not as easy to read as it could be. The names of the control and sensitivity experiments are all very similar, and the current structure requires readers to remember all of the different simulations and use that knowledge while reading all of the paper. The paper would be easier to digest if the sensitivity experiments were introduced in section 3.2 when they are discussed.

Thank you for the suggestion. We have moved the introduction of the sensitivity experiments to section 3.2. This does make the paper easier to read.

Eddy spin down

There is a wealth of previous work examining the impact of surface stress on mesoscale eddies outside of the sea ice zone. The manuscript would be strengthened by engaging with this literature, for example Munday et al. (2021) and Seo et al. (2019), and the references within. In particular, the discussion in lines 366-367 would benefit from this addition.

Thank you for sharing these papers. We have discussed the spin-down of eddies caused by relative wind stress and compared this with the damping effect of ice friction (Lines 473-477).

Minor comments

Line 85: The description of the initial velocity state would be clearer if equations 1a) and 1b) were swapped. As written, the x dependence of the initial velocity field is not immediately obvious – I spent longer than I care to admit looking for an x in the right hand side of 1a).

We have simplified equation 1 to clearly show that the initial velocity is x- and z-dependent (Line 88).

Lines 104-105: positive downward radiation would act to melt the ice, not maintain it.

Sorry for the misleading wording, we have rephrased the sentence and mentioned that those are representative winter-time downward radiations in the Arctic (Lines 112-115). The ice melting is very weak in our experiments, so the model domain is covered by packed ice throughout the simulation.

Line 136: This should be rho_0 to be consistent with the Boussinesq approximation used by MITgcm. E.g Nycander (2011).

We have replaced "rho" with "rho_0" in the calculation of KE (Line 150) and updated all figures which show the results of KE. The new calculated KE is almost the same as our old calculation.

Line 149: why is the power from the ice friction an estimate? These variables can be directly obtained from the model and power calculated exactly.

We have replaced "estimated" with "calculated" (Line 164) since we calculated the power from the model output variables exactly.

Line 161-162: A statement regarding the magnitude of the relative vorticity would help justify ignoring the relative vorticity of the mean flow.

We have provided a scaling analysis to show that the relative vorticity of the mean flow is small and can be neglected (Lines 175-177). Note also that we calculate the PV gradient at the center of the front, where the background relative vorticity is zero.

Lines 239-243: This paragraph is poorly phrased. The phrase 'steady state' is used to refer to the evolving state prior to the generation of eddies – this is not a steady state since the flow and density surfaces are evolving. Only in an actual steady state would the intersection of streamlines and density surfaces require a diapycnal transport.

We admit it is confusing to refer to the evolving state prior to the generation of eddies as the 'steady state'. We have rephrased the paragraph to illustrate that the ice-induced overturning does not drive significant diapycnal transport (Lines 272-277).

Line 281: "maintains"? Should probably be 'remains' or 'is'.

We have replaced "maintains" with "is" (Line 345).

Lines 288-289: Does interior friction refer to viscosity?

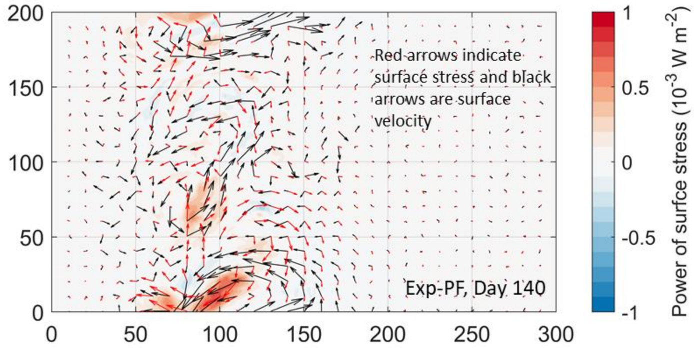
Yes, we have mentioned this in Line 350.

Figure 11e): It may be a plotting issue, but it looks as though the work done by the surface stress is larger than the reduction in mechanical energy at the start of this panel.

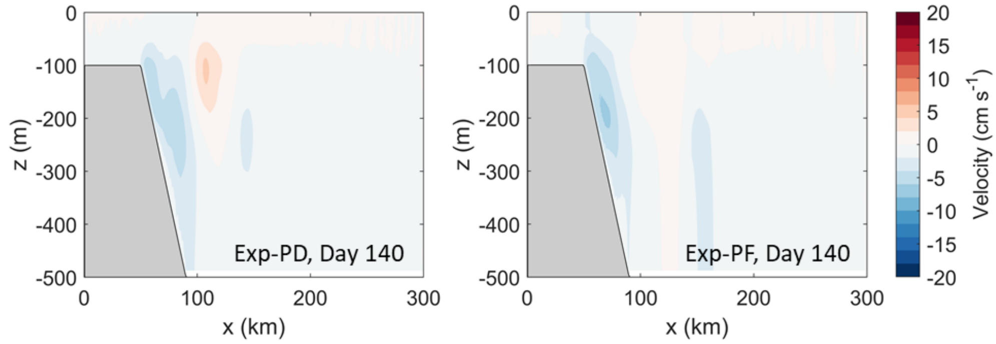
Thank you for pointing out this issue. We plotted the two curves (in each panel of Fig. 11) starting from day 0, which is OK for the change of mechanical energy since it is relative to the initial condition (the change is zero on day 0). However, the work done by the surface stress is calculated from daily output variables starting from day 1, so the red curve should start from day 1 rather than day 0. We have moved the red curve to the right by a one-day time step. The updated Fig. 11 shows that the work done by the surface stress is smaller than the reduction in mechanical energy.

From day 100 onwards, it looks as though the ice-ocean stress is putting a small amount of energy back into the ocean. What is going on here? Has the mean current reversed?

Exp-PF is forced by the surface stress diagnosed from Exp-PD. Although this stress spins down the mean flow, it does not always damp surface eddies as in Exp-PD. When $\boldsymbol{\tau} \cdot \mathbf{u}_s > 0$ (see the case in the figure below), the surface stress can do positive work on surface eddies and put a small amount of energy back into the ocean as shown in Fig. 11e. We have mentioned this in Lines 356-358.



Exp-PF has produced counter currents similar to those in Exp-PD, which are set up by the Ekman pumping as described in Lines 263-267.



Lines 355-360: The figures for mechanical energy are very instructive. Can similar time series be constructed for the APE? This would explicitly show the changing importance of Ekman pumping and baroclinic instability.

Thank you for the suggestion. We have added the timeseries for the change of APE in Fig. 11. This does help illustrate the changing importance of Ekman pumping and baroclinic instability (see the discussion in Lines 440-444).

Lines 366-367: Discussion of previous work on eddy spin down would be appropriate here

Thank you for the suggestion. We think it’s better to discuss the eddy spin down in a separate paragraph (Lines 472-477). This also leads to the following discussion about the effect of changing ice condition in the damping of eddies.

References

Munday, D. R., Zhai, X., Harle, J., Coward, A. C., & Nurser, A. J. G. (2021). Relative vs. Absolute wind stress in a circumpolar model of the Southern Ocean. Ocean Modelling, 168, 101891. https://doi.org/10.1016/j.ocemod.2021.101891

Nycander, J. (2011). Energy Conversion, Mixing Energy, and Neutral Surfaces with a Nonlinear Equation of State. Journal of Physical Oceanography, 41(1), 28–41. https://doi.org/10.1175/2010JPO4250.1

Seo, H., Subramanian, A. C., Song, H., & Chowdary, J. S. (2019). Coupled effects of ocean current on wind stress in the Bay of Bengal: Eddy energetics and upper ocean stratification. Deep Sea Research Part II: Topical Studies in Oceanography, 168, 104617. https://doi.org/10.1016/j.dsr2.2019.07.005