Response to Referee #3

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1 Comments

- The subsections 2.2.2–2.2.4 should be one subsection, same for subsections 2.2.5–2.2.7. This would also match the authors intent reflected in Figure 1b about the two drag forces.

Response: We thank the reviewer for the helpful suggestion. We have combined Subsections 2.2.2–2.2.4 into one subsection titled "Oceanic forcing", and Subsections 2.2.5–2.2.7 into "Atmospheric forcing".

- In Section 2, the draft does not seem to mention what happens when the sea ice floes hit the boundary of the spatial domain. Boundary conditions for the atmosphere dynamics seem to be missing as well.

Response: We thank the reviewer for pointing this out. In our model, periodic boundary conditions are applied to the sea ice floes, as well as to the ocean and atmospheric components. This choice eliminates artificial boundary effects and reflects the spatial homogeneity assumed in our idealized setup.

To make it clear, we have revised our manuscript: (i) for the sea ice floes, we have added the following in line 101: "Periodic boundary conditions are imposed in both the x and y directions to ensure continuity in the domain." and (ii) for atmosphere dynamics, we have added the following description between line 165 and 170 to explicitly state that: "The two-layer fully saturated PQG model with periodic boundary conditions imposed in both the x and y directions yields the following equations."

- Both Brownian motions and Wiener process are used. Maybe stick to one of them?

Response: We appreciate the reviewer's pointing out the notation difference. To maintain consistency throughout the manuscript, we have revised the text in "line 306" to use the term Wiener process exclusively when referring to stochastic forcing.

- Both ”the l-th floe” and ”the lth floe” are used in the manuscript.

Response: We appreciate the reviewer's comment. We have revised the manuscript to enforce consistent notation "l-th floe" throughout the draft.

- Page 10, Line 194, use Φ_1^a and Φ_2^a instead of Φ_1 and Φ_2?

Response: We appreciate the reviewer's comment. We have revised the manuscript to correct the notation.

- There is a discrepancy between the Δt value reported in lines 399, 459 and in Table 2.

Response: We thank the reviewer for carefully identifying this inconsistency. To clarify, the atmospheric model uses a time step of $\Delta t^{\mathrm{a}} = 58.2$ seconds, while the discrete element method (DEM) sea ice model, to reduce the computational cost, operates on a coarser time step of $\Delta t^{\mathrm{ice}} = 80 \times \Delta t^{\mathrm{a}} \approx 1.29$ hours. In the data assimilation setup, observations are assumed to be available every 1500 atmospheric model time steps, corresponding to approximately $\Delta t^{\mathrm{obs}} = 24.2$ hours which is close to the true frequency of acquiring satellite images.

We haved added the following in the revised manuscript before Table 5.:

> *" It is worth noting that the atmospheric model uses a time step of* $\Delta t = 58.2$ *seconds, while the DEM sea ice model is updated every 80 atmospheric steps, giving* $\Delta t \approx 1.29$ *hours. Observations for data assimilation are assumed to be available every 1500 atmospheric steps, or* $\Delta t^{obs} \approx 24.2$ *hours."*

- Please check the physical units for E_i and E_o in Table 2.

Response: When we look at the units of E_i and E_o again, we can see why it may have caught your attention. We are not using the units of a surface flux, which typically include m^{-2} to describe the flux of a quantity across a unit area. Instead, we are using units of $\mathrm{kg\,kg^{-1}\,s^{-1}}$, which represent the change of the atmospheric total water mixing ratio per unit time. We use these units, rather than the units of a flux, because vertical transport is not resolved in the atmospheric boundary layer in our model. Instead, evaporation is represented in a simple parameterized form, and it represents the change in (height-averaged) total water mixing ratio in the lower tropospheric layer.

- Please check the physical units for the background vertical gradient of total water in Table 4.

Response: We have double checked the units of $d\tilde{q}_t/dz$, and we think they are correct in the original submission as $\mathrm{kg\,kg^{-1}\,km^{-1}}$, which represents the change in the mixing ratio (units of kg kg^{-1}) per change in height. We have also double checked that this is also used in the reference [Edwards et al., 2020] (aside from different choices in units of mixing ratio of g kg^{-1} versus kg kg^{-1}).

References

[Edwards et al., 2020] Edwards, T. K., Smith, L. M., and Stechmann, S. N. (2020). Atmospheric rivers and water fluxes in precipitating quasi-geostrophic turbulence. *Quarterly Journal of the Royal Meteorological Society*, 146(729):1960–1975.