

Reviewer 1 — Point-by-point responses

We thank the reviewer for the positive assessment and helpful comments. We have reviewed the manuscript and revised the manuscript accordingly.

Comment 1. l.102 depth / Fig. 1a:

-What is the average depth of the seafloor on and off the ridge? Is fig1a bathymetry?

Response: Figure 1a shows the water depth of the Brazil Basin study region. The seafloor depth over the ridge region is approximately 3000 - 4500 m, while the adjacent off-ridge abyssal plain has a mean depth of approximately 5500 m. We have revised Fig. 1 and show the model bathymetry more explicitly.

Comment 2. BTC/BCC at 4000 m and other depths:

-Are the BTC and BCC components at 4000m depth balanced in magnitude? How would they compare at other depths?

Response: BTC (energy transfer for KE between the eddy field and mean flow) is consistently about one order of magnitude larger than BCC (energy transfer for APE between eddy and mean flow). We extended the BTC and BCC calculations to additional depths (3000 m and 5000 m) in the deep water column. We find that the relative magnitudes of the two conversion terms remain similar to those at 4000 m.

Comment 3. Missing units

- Please double check figures, in some instances the units are missing on colorbars or in the captions

Response: We thank the reviewer for pointing this out. We have carefully checked all figures, colorbars, and captions. Missing units have been added where appropriate, and the figure captions have been revised for consistency for Fig 2,3, A1, A3 and A4.

Reviewer 2— Point-by-point responses

We thank the reviewer for these thoughtful comments, which helped us clarify the central message and strengthen the physical framework of the manuscript. We appreciate the concern regarding the broader significance of the comparison, and we have carefully revised the manuscript accordingly.

Comment 1. Choice of resolution

- Why 1km vs 3km? Both are submesoscale permitting; what about including e.g. a coarser eddying simulation to see what actually changes when we allow for submesoscale, or a very high-resolution simulation to see if diffusivities actually converge?

Response: We thank the reviewer for this comment. Based on the scale and effective resolution of the represented bathymetry, we view the 1 km and 3 km configurations as distinct dynamical regimes in the Brazil Basin. The 3 km simulations could only marginally permit some smaller-scale motions with an effective resolution of approximately 7.5 km, while the GIGATL1 runs are indeed submesoscale-permitting in the Brazil Basin.

Nevertheless, we understand the reviewer's broader concern. To address this point, we have extended the analysis to include a 6 km horizontal resolution case, GIGATL6T, including tides. Also, for this case, we performed the corresponding Lagrangian particle experiment. The 6 km case provides a coarser comparison and shows the expected progression with resolution: coherent deep eddies are largely absent, and bathymetric smoothing prevents the formation of a bottom boundary layer where mixing increases because of energy conversion when the currents interact with the topography. As a result, the diagnosed diapycnal diffusivity is lower than in the 3 km and 1 km simulations and nearly constant throughout the water column. We have added and discussed this case in all the sections, including Fig 1, 2, 4, A2, A4, A5, and table 1 as integral to the revised manuscript.

Performing an even higher-resolution run (which would require a nonhydrostatic configuration) is beyond the scope of the current work, which aims at quantifying with a very specific example why simply increasing model resolution to km scale and/or developing AI-based parameterizations from submesoscale permitting simulations may not reduce (global) ocean models' structural uncertainty.

Comment 2. Bathymetric smoothing

There's a lot of talk in the paper about bathymetric smoothing; why not run a simulation with more/less smoothing to actually show the difference? Theoretical arguments are one thing, but simulations to back up these arguments would be very useful.

Response:

We thank the reviewer for this comment. We agree that a direct numerical sensitivity test would provide a stronger assessment of the role of bathymetric smoothing. We have run a 1 km test simulation with downscaled 3km bathymetry. This experiment develops substantially fewer coherent deep eddies and weaker relative vorticity than GIGATL1T and the resulting circulation more closely resembles GIGATL3T. Thus, increasing horizontal resolution alone is not sufficient to reproduce the energetic eddy field found in GIGATL1T. Together with the consistency with geostrophic mean circulation among GIGATL1, GIGATL3, and GIGATL6, the sensitivity experiment points to the representation of the underlying topography as a primary control on the differences in the simulated eddy field. The discussion of the sensitivity test is included in Section 4 (Lines 272- 278) with Figure A6 and Table 2.

This comment, though, prompted us also to revisit the physical framework underlying this part of the manuscript. Energy stored in the mean flow can be transferred to the eddy field through barotropic and baroclinic instabilities, while eddy–internal-wave interactions can provide a sink of eddy energy and a source of internal-wave energy. Polzin (2010) showed that internal waves propagating through a three-dimensional mesoscale strain field can exchange energy with the eddies through correlations between wave stresses and the mesoscale rate of strain. Both oscillatory tidal flows and slowly varying geostrophic currents interacting with rough bathymetry can radiate internal waves and exert topographic form drag (Bell, 1975; Nikurashin and Ferrari, 2010). Then nonlinear transfers toward smaller vertical scales enhance shear and ultimately support wave breaking and turbulent dissipation.

The geostrophic mean flow in the simulations is broadly consistent across the runs (very similar between GIGATL1, 3 and 6, and from a very preliminary analysis in agreement with ARGO-derived estimates), suggesting that strong eddy fields in the simulations are not primarily associated with a bias in the mean-flow reservoir. In contrast, GIGATL1T exhibits substantially larger EKE and shear than GIGATL3T. The diagnosed horizontal energy conversion from the eddy field to the internal-wave field and the internal-wave energy also increase in GIGATL1T, consistent with the enhanced interaction between the eddy field and

the higher-resolution topography. However, the enhancement in internal wave energy in GIGATL1T is much smaller than the increase in EKE. This supports our interpretation that, although the higher topography resolution in GIGATL1 allows more energy transfer from the eddy field to the internal-wave field relative to GIGATL3, internal-wave generation remains strongly limited even at 1 km resolution. As a result, the internal-wave pathway cannot provide a sufficiently efficient sink, especially for the enhanced eddy energy in GIGATL1.

3000–5000 m mean	GIGATL1T	GIGATL3T	GIGATL6T	Unit
Eddy Strain RMS	1.1175e-05	2.3041e-06	1.1341e-06	s ⁻¹
Eddy Kinetic Energy	2.8746e-03	3.0936e-04	1.6540e-04	m ² s ⁻²
Internal Wave Kinetic Energy	6.3305e-04	4.8929e-04	4.3792e-04	m ² s ⁻²
Eddy → Internal Wave energy conversion	1.0512e-10	4.9923e-12	1.1227e-15	W kg ⁻¹

Table. Eddy deformation and diagnosed horizontal energy conversion to the internal-wave field in GIGATL1T and GIGATL3T, averaged over 3000–5000 m in the subregion (17–20 °W, 20–22 °S)

We have temper our statements and strengthen the theoretical framework of the manuscript by diagnosing energy transfer and the physical mechanisms proposed to explain them in session 4 (Line 260-290) .

Comment 3. What would happen in non-hydrostatic simulations?

At the resolution considered, we would not expect the hydrostatic approximation alone to qualitatively change the large-scale conclusions of this study. The dominant eddies analyzed here have horizontal scales much larger than their vertical scales, so their dynamics are expected to remain largely hydrostatic. Nonhydrostatic effects would be most relevant for localized near-bottom processes, which occur at scales that are only marginally resolved, or unresolved, in the present configurations, and are further limited by the bathymetric smoothing required by the terrain-following grid. Thus, nonhydrostatic simulations would be valuable for future process studies, but we do not expect nonhydrostatic dynamics alone will change the results too much at the present resolutions. We have added this consideration into our revised summary part (Line 356-358).