Ocean Science Discussions

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Comment on os-2021-9

Anonymous Referee #3

Referee comment on "Global contributions of mesoscale dynamics to meridional heat transport" by Andrew Delman and Tong Lee, Ocean Sci. Discuss., https://doi.org/10.5194/os-2021-9-RC3, 2021

The study presents findings about the contribution of mesoscale dynamics to the global meridional heat transport in the Parallel Ocean Program 2 ocean model. Contrary to most previous papers that use filters in the time domain to isolate the mesoscale signal, the authors use a spatial filter to separate velocity and temperature fields into overturning, large scale and mesoscale components. They identify global patterns and key regions with significant eddy heat fluxes and address the variability of eddy heat fluxes on interannual to decadal time scales.

Overall, I think the results and questions raised by the paper are very relevant for the community. However, some improvements are necessary before I can recommend the paper for publication.

General comments:

- While I think the spatial separation into OT, M and L component is definitely interesting and should be further studied, I am not yet convinced that the method (at this stage) is "better" or "worse" than separations in the time domain. For example, section 3.3 shows that the largest signal in regions of high MHT stems from stationary transport in the western boundary currents (which would not be considered mesoscale when separating the scales in time domain). In my eyes it is at least questionable whether the time mean heat flux of a boundary current (even if it is only a few hundred km wide) should be considered an "eddy signal". Section 4 shows the differences between the methods (which is definitely very interesting), but there are no reasons provided for the observed differences and no evaluation of which method delivers the more realistic results.
- Using a fixed value of 10° longitude to separate between the large scale and mesoscale components of temperature and velocity fields poleward of 20° seems quite large. It should be appropriate in mid-latitudes, but the model domain extends far into the

subpolar regions where eddy scales are much smaller. How sensitive are the results to this choice?

- The paper is quite long, and I find some parts and especially some figures more distracting than helpful. The story needs to be streamlined to focus more closely on the main results and their relevance. For example:
  - section 2.3 includes 6 plots, but it did not convince me that 10° longitude is indeed a good scale for the separation of large- and mesoscale
  - section 3.1 only shows that the model gets the general ocean circulation right, that should be a given for an ocean model and is not relevant for the results of this study
  - section 5.1 has 14 individual time series plots that basically only show when total MHT and mesoscale MHT are in phase. They are also really hard to read on a printout

Detailed comment list:

Line 13: This assumes that dT/dy and mixing length are constant (compare line 340), which is a strong assumption. Maybe rephrase to something like "surface EKE alone is not a good proxy..."

Line 42: I would suggest adding Sun et al. (2019) as a reference here. They did a global analysis regarding the importance of the different transport mechanisms (swirl vs advection)

Line 51: If the recirculation is 100% perfectly stationary, it would be "invisible" in a time filtered mesoscale component, but it would show in the time-mean component. And if there are small fluctuations in v and T, there can be covariance and thus an "eddy" heat flux.

Line 65: A visual comparison is not a validation

Line 68: How many depth levels?

Line 70: If I understand the tripolar grid correctly, "progressively finer" is quite misleading here. The resolution is still 0.1°, but due to the convergence of the grid towards the two poles, the distances (in km) between two grid cells become smaller. It might be helpful to

compare the grid resolution in km to the local Rossby radius to check where the model resolution is fine enough to resolve eddies (see e.g,. Wekerle et al. (2017), their Fig. 2). How is the tripolar grid considered when calculating the temperature fluxes? Is the velocity field rotated to north or are the deviations between perpendicular to the grid line and north so small that it does not matter?
I also think this section should focus more on the model with respect to its "eddy capability", how well and where the model represents mesoscale processes (comparison with EKE is a good start). With 1/10° horizontal resolution the model can't be considered eddy resolving everywhere, so there will still be sub grid-scale processes that aren't resolved by the model. How does that affect the interpretation of the results? How are they parameterized on the sub grid-scale? What is the eddy diffusivity and viscosity for lateral mixing and diffusion in the model simulation?

Fig. 1: I am a bit surprised by how much lower the model EKE is when compared to CMEMS altimetry. Why is the model velocity field filtered (wavelengths < 0.5°)? Would that explain the low EKE? What filter is used here? The same 1D zonal filter as described in 2.2 or a different one?

Line 90: The separation happens before integration

Line 92: What about the z-direction? Are all values depth integrated or is this separated at every depth level and then integrated over z? Is the heat transport integrated over the full water column or limited to the surface?

Line 110-117: What is the benefit of using this particular filter method compared to other filters? E.g. Zhao et al. (2018) use a Butterworth window for their filter?

Line 118: What about Zhao et al. (2018)? If this is what inspired using the spatial filter, maybe put this in the introduction or the beginning of section 2.2

Line 119: Despite checking Delman & Lee (2020), I am not quite sure how the filter handles the basin boundaries. From Delman & Lee (2020): "Meridional velocity outside the basin boundaries (to a distance of 1/k0 from the outermost boundaries) and within interior land areas is set to zero.", "a buffer is also included at the western and eastern boundaries", "in order to conserve the large-scale structure of zonally integrated v, this non-zero vL needs to be redistributed over nearby water areas in the transect.". I must admit don't understand what has been done here exactly and I am not sure if all three steps are there to correct errors at the boundaries. However, getting the signal at the western boundary currents right is incredibly important since they are so dominant but confined within a small distance to the coast. I would therefore suggest clarifying this here.

Line 120-124: Is lambda/4 a good choice here? How do you separate the signal in a channel narrower than lambda into scales larger and smaller than lambda?

Line 131: As mentioned above (general comment 2), 10° longitude for the separation between large- and mesoscale seems quite large. For example, 10° longitude at 50°N this is more than 700km. How does that compare to eddy diameters at this latitude? How sensitive are the results to this choice?
What about filtering in the meridional direction? The final section mentions the rotational and divergent eddy fluxes, but does it also affect the meridional coherence of the eddy heat transport if the underlying fields are only filtered in the zonal dimension? (I don't know the answer to this question.)

Fig. 2: How is the "mesoscale transition computed using the logarithmically smoothed spectral density" defined? What is the smoothing applied to the spectra? Why are 5 plots for the Indo-Pacific shown and none for the Atlantic? Since the same filter is applied globally, wouldn't it be enough to show one plot per latitude, or maybe even just one k/lat/spectrum-plot, where color represents the spectral density?

Section 3.1 I think this whole section is unnecessary (see general comment 4). I would assume that an ocean model has gyres.

Line 147: I find the title "spatial components" of meridional HT a bit odd (because my mind automatically goes to spatial patterns and maps), but I don't have a better idea

Section 3.2 I would suggest restructuring this section starting with the maps (pointwise temperature flux) and then looking at the integrated values (basin wide heat transport). But that might just be personal taste

Line 150: Is this related to eddies in the Agulhas Retroflection?

Fig. 4/5: Both figures have different y-ranges for the different ocean basins, which is a bit misleading. Where does the residual term come from? How is the transport integrated in the southern region? From South America to South America? And in the ACC?

Fig. 4: I am not so familiar with the Indian Ocean, but is it standard practice to ignore Australia and the Indonesian islands and just integrate over everything?

Fig. 5: Why show the ID standard deviation here and not in the section titled "mesoscale

interannual/decadal variability"?

Line 179: How are these filter parameters chosen? Are the results sensitive to the choice?

Fig 6: The colors seem to be quite oversaturated. Are the limits of the colorbar appropriate for the data?
I am very surprised by the strong northward flux in the western Labrador Sea (Fig 6a). You mention that the "picture becomes more complex", but is there an explanation for this pattern?

Line 225: "intensified boundary current jet and flanking recirculation just to the east that is shown in vM" and later in line 228: "stationary MTF contributions are associated with western boundaries"; Wouldn't that suggest that this is not really a mesoscale signal then? This relates to my general comment (1)

Fig. 8: This figure seems to combine two thoughts and looks incredibly crowded to me. On the one hand, there is the separation into large- and mesoscale and on the other hand the separation into stationary and time-varying transport, leading to 12 subplots. Are the left and middle columns really necessary?
Why is the 95m depth level shown? Anything special about that layer?

Fig. 9: This is basically just a zoomed in version of the middle column of Fig. 8. (at interesting locations). So maybe skip the middle of Fig. 8 and just show this? Why is the 95m depth level shown?

Line 245: There are also methods looking at deviations from the seasonal cycle

Line 256: Mesoscale dynamics indeed have higher frequencies in lower latitudes leading to shorter eddy time scales there. You can also just look at eddy speeds along their trajectories for that.

Line 261: Yes, that is indeed a problem. However, as shown in Fig. 8, the separation in the spatial domain makes the time-mean heat transport of the western boundary current an "eddy" signal, even though western boundary currents have very different dynamics from mesoscale eddies. See general comment 1.

Section 5.1 This section is again very long and consists of different ideas and concepts (first a map of STD, then time series, then linear regression), including 5 different figures and 18 subplots. What is the main message of this subsection? Can it be conveyed in simpler ways?

Line 278: “This indicates that mesoscale fluxes are not be particularly efficient at moving heat meridionally in subtropical eddy bands, at least in the POP simulation.” This could also be related to the small meridional temperature gradients in the subtropics

Fig 13/14/15: Maybe show only the lower panels and focus on one section per basin? What is the reason for showing all these time series other than “sometimes mesoscale MHT and total MHT are in phase” The figures are super small and on a regular printout I can’t really say anything about them. Zooming into the pdf, I can say that I disagree with some of the red dashed lines (e.g., the last two events in Fig 15 b).

Line 303-329: I am not quite sure if this part is needed. If it stays in the paper, it should probably have its own section because it is quite different from the analysis of the transport time series before.

Line 320-323: Does this mean that the separation into large- and mesoscale is off in these regions?

Equation (13): I think this should be sqrt(2EKE), since EKE=1/2(u^2+v^2), but for the question of correlation it doesn’t matter

Line 340: Mixing length and background gradient vary in space and time. A shift of the GS axis in the North Atlantic for example completely changes the locations of the major temperature gradients.

Line 357: local covariance between v’ and T’ is the definition of eddy heat flux

References:

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Wekerle, C., Wang, Q., Danilov, S., Schourup-Kristensen, V., von Appen, W. J., & Jung, T. (2017). Atlantic Water in the Nordic Seas: Locally eddy-permitting ocean simulation in a global setup. *Journal of Geophysical Research: Oceans*, *122*(2), 914–940. https://doi.org/10.1002/2016JC012121

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