Responses to reviewers' comments

Title: A global Lagrangian eddy dataset based on satellite altimetry

MS No.: ESSD-2022-411

We sincerely thank three reviewers for their careful reading, helpful comments, and constructive suggestions, which have significantly improved the manuscript. We have carefully considered all comments and made modifications to the manuscript. Below, we provide a point-by-point response to the comments, with the original comments in black and our responses in blue.

Reviewer 1

I am satisfied with the way the authors have handled my major comment #1 and all my detailed remarks. Thanks to their new contributions or clarifications, the manuscript seems to me to have gained in quality.

On the other hand, I remain largely unsatisfied with their response to my major comment #2 on the notion of transport achieved by the coherent eddies identified by the atlas. In the current state of the revision process (response to my comment and content of the revised manuscript), I am compelled to ask for a new major revision, on this precise point.

The authors misinterpret the calculation of the transport associated with the movement of an eddy. Contrary to what they wrote in response to my comment, what matters is the added volumes of the eddies transferred across a control longitude (or latitude) segment over a given period, whatever their travel speed.

And no, a faster propagating eddy will NOT move mass, heat, etc. MORE EFFICIENTLY than its slower propagating counterpart. Efficiency here would be measured more in terms of an 'eddy gun': it is the number of such eddies crossing a reference line over a given period of time that matters, not their individual travel speed. Efficiency would also be measured in terms of porosity and property exchange with the neighboring ocean, rather than in terms of the speed at which the eddy moves.

With the formalism proposed by the authors, it is a bit like measuring the leakage of a tap by providing the individual momentum of the water drops (their volume multiplied by their velocity) rather than just their volume and number.

The transport approach is legitimate for qualifying permanent flows, but appears much less suitable for documenting sporadic flows such as those produced by the propagation of individual eddies, except after averaging over a given period when such eddies may follow one another. In the case of an isolated eddy, the information on its propagation speed is interesting in itself, but it does not combine well with the volume of the eddy to derive a transport index.

In the method used for the study, multiplication by the travel speed of the eddies is actually used to normalize the diagnosis by the number of times the same eddy is present in the same geographical grid cell, in order to avoid counting the passage of this eddy several times. In other words, the multiplication of the volume of the eddy by its travel speed is only made necessary by the nature of the counting carried out, i.e., the blind use of successive maps of eddies without consideration for the dynamic correspondence (same eddies that moved to different locations in the same grid cell) that exists between these maps.

One concern with the proposed calculation is that the travel speed of an eddy may not be constant in time and thus in space. This variability, possibly induced by the interaction of the eddy with its dynamic environment (such as other mesoscale structures) or geographical environment (bottom topography, coastline, etc.), introduces an error in the diagnosis which is not quantified in the study.

Finally, in my mind, the notion of local instantaneous transport associated with an eddy could ultimately refer to the volume of the eddy divided by the time it needs to completely cross a given control line, i.e. Ve Cx / (2 R), if the vortex is considered as a cylinder of diameter 2 R. This value can be maximized by simply considering the apparent cross-section of the vortex, in the direction transverse to the motion, in which case this transport is written as 2 R h * Cx (with h the eddy vertical extent). In contrast, the quantity Ve Cx introduced in line 278 has a physical meaning which is more of a momentum, but is certainly not transport.

Therefore, I ask that the revised version of the article be rigorous in its interpretation of the proposed transport. This is not the case with the current version, and the review process suggests that this may be due to a flawed understanding of the concept by the authors. Hence my initial request that meticulous care be taken in the presentation of the meaning and usefulness, as well as in the interpretation of the quantity calculated quantity.

Response: Thanks for your positive feedback on our revisions in the last round. Given that both Reviewer 3 and editor think the estimate of eddy transport is beyond the scope of ESSD, we decide to remove this part in the new manuscript. And we have changed the related text in Abstract, Section 3, and Section 5 (in red).

According to your comments, we provide our explanations here as a discussion.

Does the eddy propagation speed matter? Our answer is yes. We used this formula $Q_x = \sum V_e C_x / N L_x$ [Eq. 1] to estimate the zonal mass transport by eddies. [Eq. 1] represents the volumetric flow rate (m3/s or Sv) but rather the net volume (m3). Imagine two mesoscale eddies with the same size and a positive temperature anomaly. Both eddies move from region A to region B. There is no doubt that the faster eddy will more efficiently heat the water of region B than the slower eddy. This principle applies equally to transport of mass, salinity, or other tracers by eddies. The eddy propagation speed is an important factor for measuring the property exchange rate with the neighboring ocean.

The fundamental definition of eddy transport/flux for a tracer q is Q=v'q' [Eq. 2], where v' is velocity perturbation and q' is tracer anomaly. [Eq. 2] also suggests that the eddy speed does matter. But, this formula relies on high spatiotemporal resolution data. [Eq. 1] was proposed based on [Eq. 2], with C_x (eddy propagation speed) being analogous to a velocity perturbation against the mean flow and V_e representing the integrated tracer anomaly within an eddy. Dong et al. (2014) and Zhang et al. (2014) estimated the eddy transport using [Eq. 1] by assuming that mesoscale eddies can always trap the interior water, and they concluded that the eddy transport is mainly induced by the trapping of individual eddies (In other words, they suggested that [Eq.1] can largely represent [Eq.

2]). These two papers have been cited about 800 times in total, and [Eq. 1] has been adopted to calculate the eddy transport by more than 50 papers.

[Eq. 1] represents the integration of all instantaneous eddy transport, which is a statistical concept. As long as an eddy snapshot (daily) exists in a grid, it is considered to contribute to the total transport, and it is counted as a sample. The eddy propagation speed was calculated according to the daily eddy position, so the evolution and travel of eddies are considered. Note that the grid length L_x in the denominator of [E1. 1], which means that Q_x is roughly the averaged zonal transport across the latitude line for each grid. This physical meaning is reasonable, but the transport degree (e.g. more than 30 Sv by Zhang et al. 2014) is **strongly overestimated**! The core problem lies in whether these eddies are coherent structure, in other words, whether they can truly trap the interior water. This is precisely the topic discussed in our paper.

If you agree that the instantaneous transport can be expressed by Q=2RhCx [Eq. 3], then we share the same viewpoint. There is no fundamental difference between [Eq. 1] and [Eq. 3] for a statistical estimate since [Eq. 1] also represents the averaged transport across a certain line (after dividing by the grid length L_x). Our previous studies (Abernathey and Haller 2018; Liu et al. 2019) did used Q=2RhCx [Eq. 3] to estimate the eddy transport. In this study, we choose [Eq. 1] for two reasons that were clarified in our last response. First, we attempt to reproduce the exaggerated transport by Zhang et al. (2014) using their widely accepted method. Second, we attempt to highlight the significant **differences** between SSH eddies and Lagrangian eddies in terms of coherence (It's a fair comparison).

In our manuscript, we have emphasized that "This is a relatively crude estimate with accuracy within an order of magnitude, and the focus here is mainly on the difference between the two types of eddies". Our estimate serves as a reminder that the actual coherent eddy transport might be far smaller than the appealing results based on Eulerian methods. Since the accurate contribution of coherent transport by eddies remains unclear, we will organize another paper to continue this discussion in the near future.

Zhang, Z., Wang, W., & Qiu, B. (2014). Oceanic mass transport by mesoscale eddies. Science, 345(6194), 322-324.

Dong, C., McWilliams, J. C., Liu, Y., & Chen, D. (2014). Global heat and salt transports by eddy movement. Nature communications, 5(1), 3294.

Abernathey, R., & Haller, G. (2018). Transport by Lagrangian vortices in the eastern Pacific. Journal of Physical Oceanography, 48(3), 667-685.

Liu, T., Abernathey, R., Sinha, A., & Chen, D. (2019). Quantifying Eulerian eddy leakiness in an idealized model. Journal of Geophysical Research: Oceans, 124(12), 8869-8886.

Reviewer 3

The papers is presenting a global eddy data set obtained with a Lagrangian-averaged vorticity deviation (LAVD) method. The paper is well written and of general interest. The many methods to calculate eddy boundaries have been discussed and presented in the paper. The proposed LAVD method one of these method and the authors correctly state: We encourage users of our product to be mindful of the limitations of the underlying satellite-derived geostrophic velocity fields used to derive our coherent eddies.

The authors also state that the data set is an additional option to oceanographer in studying eddies interactions as well as physical – biochemical interactions.

The paper is very well divided in three parts: methodology, statistics and availability and discussion. I would say that the paper is at 90% coherent to ESSD requirements: ESSD understands original research data as data generated by observation of the Earth system. In most cases this excludes reprocessing, postprocessing, or reanalysis of model outputs (such as climate model outputs, environmental modeling outputs, output of classification algorithms, and so forth). [ESSD - Manuscript types (earth-system-science-data.net)]

In ESSD the authors are requested to publish data that can be re-used. Probably the paragraph 3.3. has been included in the manuscript to provide an example of application and re-use. From my point of view this part should be left to another paper to be submitted to a more dedicated journal. My view is presented in the specific comment.

Specific comment

The authors calculate VeCx with Cx the propagation velocity. But while in an Eulerian system the position of a particle p in time can be written as X(p,t), in a Lagrangian system the position of the particle must be expressed only in a moving system and therefore must be written as X((p ,t),t).

Transport quantities introduced in the paper need to be clarified on their meaning. There are many limitations in the methods that have been previously underlined by the authors: assumed geostrophy, unknown subsurface vertical features of eddies, regional variability, etc. I am not sure that the Cx calculated by the authors can be used for an estimation of transport, if limitations are not discussed and quantified. And in general I would agree with referee 1: in the specific case it is quite arbitrary to calculate this quantity, as a component of the transport.

Conclusion

The paper can be published if it is only a presentation of the data sets, without the discussion on transport. Paragraph 3.3 is posing many problems and questions, and (from my point of view) is outside the ESSD scope.

Response: Thanks for your positive feedback on our work. As you suggested, we have removed the estimate of eddy transport in the new manuscript. And we have changed the related text in Abstract, Section 3, and Section 5 (in red).

We agree that the specific value of eddy transport is still unclear. In our manuscript, we have emphasized that “This is a relatively crude estimate with accuracy within an order of magnitude, and the focus here is mainly on the difference between the two types of eddies”. Our estimate can serve as a reminder that the actual coherent eddy transport might be far smaller than the appealing results based on Eulerian methods.

Regarding the detailed explanations of eddy transport (why the eddy propagation speed matters; the physical meaning), please see our response to Reviewer 1.

Editor

Public justification (visible to the public if the article is accepted and published):

In agreement with the referees comments I am convinced that this paper is well written and of general interest but, at this stage, it needs to be revised in section 3.3 where the definition of transport is questionable as argued by referee 1. Moreover this paragraph, as suggested by referee 3, can be considered outside the ESSD scope. See ESSD - Manuscript types (earth-system-science-data.net). Referee 3 suggests to produce a new version without the discussion on transport. This will overcome the debate with referee 1, leaving referee 2's suggestion as the only minor revision to be made.

Additional private note (visible to authors and reviewers only):

While referee #2 suggested to review only few details in the writing. Referees 1 and 3 indicated that the paper needs a major revision essentially for the same reason related to the definition the transport due to coherent eddies. In my opinion, their comments are reasonable and should be taken into consideration. In particular I agree with the suggestion of referee 3 about the opportunity to consider paragraph 3.3, that was the origin of the discussion with referee 1, not exactly fully within the scope of ESSD.

Response: Thanks for your positive feedback on our work. We have removed the estimate of eddy transport in the new manuscript since this part is beyond the ESSD scope. And we have changed the related text in Abstract, Section 3, and Section 5 (in red). In addition, you mentioned that Reviewer 2 proposed a few comments in the writing, but we did not receive the report in the system.