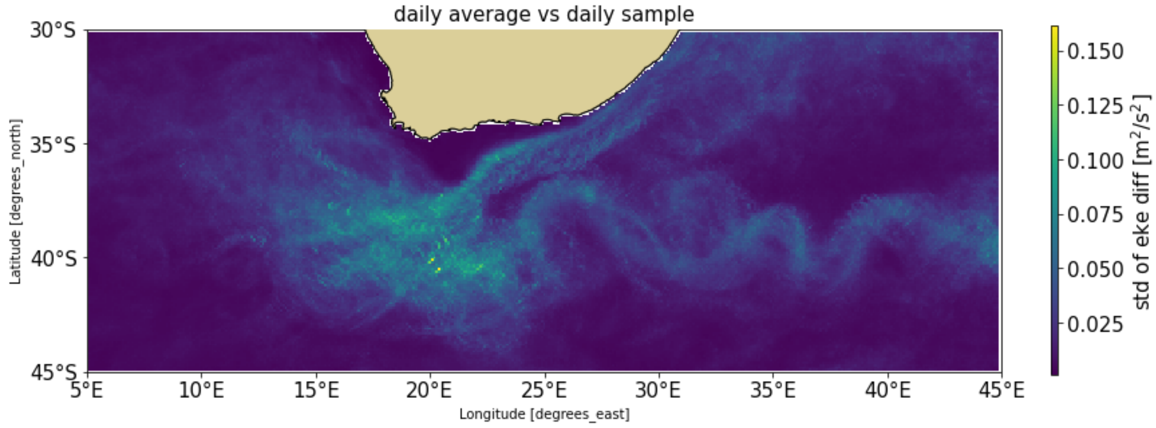
Reply: 1st community comment

Major comments

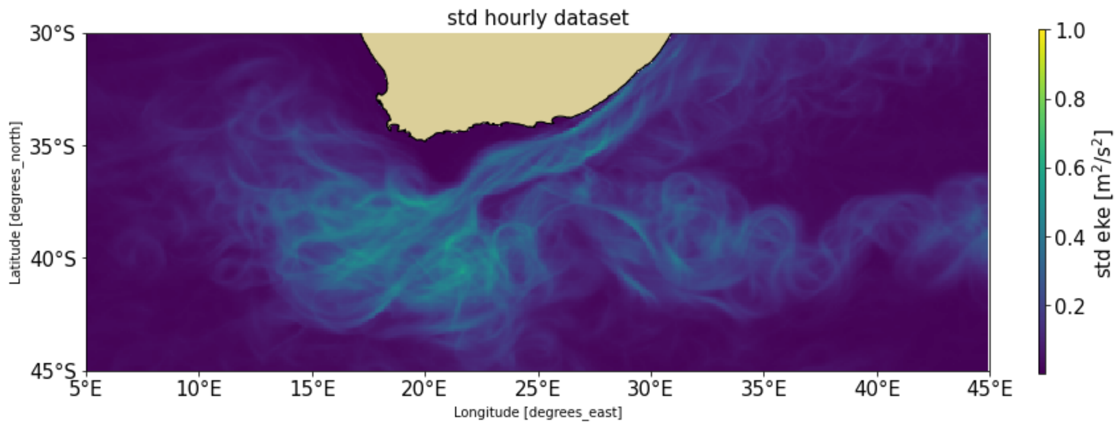
1. Lines 260-290: The methods described here aim to show the potential of the SWOT mission to observe smaller mesoscale eddies (sometimes called larger submesoscale eddies) and the associated energy cascade. However, in addition to the instrumental noises, the SWOT-derived SSH at mesoscale also contain large signals of unbalanced internal tides and internal gravity waves. So, you can not directly calculate the geostrophic current and thus the EKE from the SWOT data based on geostrophic relation. Actually, how to remove the "noise" signals of unbalanced motions from the SWOT SSH data is still a large challenge for the community. So, I suggest you explain more clearly here to what degree can your data and methods represent the context and potential of SWOT data in reality.

This is an important point for any analysis of alongtrack altimetry or SWOT 2D SSH data, but the relative importance of the internal tides and internal waves versus mesoscale eddy cascades varies from one geographical region to another. As mentioned in the text (lines 164-166), the Agulhas region has very strong mesoscale energy and cascades that largely dominate any internal tide signals at these relatively high latitudes. This is particularly the case for our statistical eddy diagnostics based on EKE or strain, which accentuate the shorter 2D space-scale dynamics. Indeed, since we have model fields, we could have separated the balanced and unbalanced motions analytically, e.g. with a Helmholtz decomposition or temporal filtering, as in Qui et al., 2018. However, our objective was to use the model's surface fields as Pseudo SWOT SSH data, and thus to not have the full temporal evolution of the high-frequency flow components. With this in mind, we made a careful analysis of our methodology and the impact of the high-frequency residuals in the zone we are studying. The second paragraph of the discussion treats this point (lines 504 - 516), and we have added a short point on these high-frequency residuals in Appendix C in the revised manuscript. A detailed description of our approach is given in the following.

a. We compared modelled geostrophic EKE and strain rate statistics computed from a) the full hourly time series, b) one hourly snapshot taken every day (eg. as in the SWOT 1-day orbit sampling), and c) the daily average. Each of these datasets represents slightly different high-frequency dynamics. The full hourly dataset represents the full dynamics, including the hourly evolution of the mesoscale/submesoscale structures, internal gravity waves and internal tides (barotropic tides and the Dynamical Atmospheric Correction have been removed). The daily snapshot represents only a fraction of the high-frequency dynamics <24h, and as such does not represent the full amplitude of the evolving coherent and incoherent internal gravity waves. The daily averaged data minimises the variations < 24h, and we use it as a proxy for the geostrophic motion. The top image shows the yearly std of the difference between the daily sampled and daily averaged data (std(x')). We see that the dominant differences are centred around the mean current, these are fast dynamics with a period <24h that we filter out when averaging the data over one day. These dynamics do not have the typical structure of internal gravity waves or internal tides, they could be due to the rapid movements of the energetic currents over time. Here we have imposed geostrophic balance over both slower and faster dynamics even though the latter may be due to rapid ageostrophic adjustments.



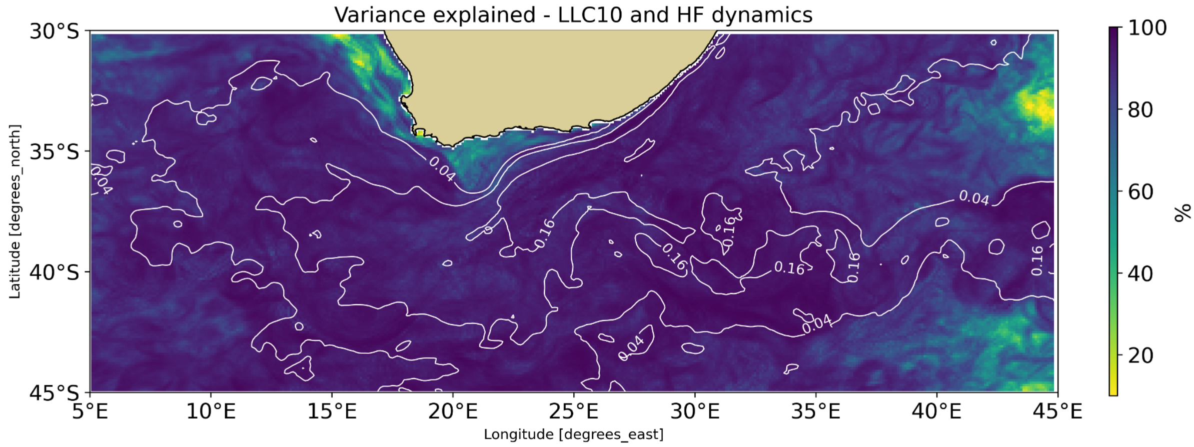
The central image shows the std of the EKE from the full hourly dataset over one year (std(x)). We can see here how well correlated the high-frequency differences are with the full std (EKE): it is dominated by high-frequency modulations of the most energetic currents (note the difference in energy level: the high-frequency variations < 24h are an order of magnitude smaller than the std (EKE).



The bottom image quantifies the variance explained between the low-frequency (LF) dynamics EKE (averaged over one day, dynamics > 24h) and the full hourly EKE:

$$\left(1 \; - \; \frac{var(LLC10_{EKE} - LF_{EKE})}{var(LLC10_{EKE})}\right) \; * \; 100$$

This tells us how much the low and high frequencies dynamics contribute to the total std. We see that the % variance is large everywhere, meaning that the full dynamics is mainly represented by the lower frequency dynamics, except on the shallow plateau and off the Benguela coast where higher frequency dynamics dominate. The white contours represent a mean EKE of 0.04 m^2/s^2 and 0.16 m^2/s^2 (ref Figure 3a). In the region of stronger EKE (>0.04 m^2/s^2), 7% of the total std is due to some HF dynamics that are difficult to separate from the mean dynamics clearly, but that do not have the typical structure of internal gravity waves or internal tides.



b. In most of the regions analysed in this paper (Agulhas Current, Retroflection, Extension, Cape Cauldron), there is very little difference in the EKE or strain, whether we use hourly or daily snapshots or daily-averaged data. The exception is around 30-32°S in the Atlantic where a larger component of internal gravity waves and internal tides are present in the zone. When analysing geostrophic currents from SSH gradients, there would be a small contribution in the direction perpendicular to the wave propagation and very little parallel. So, even near 30°S, the signature of the internal gravity waves would be small in the cross-propagation velocities in EKE, and negligible in the velocity gradients which are then used to compute the strain rate. Snapshots of the LLC10 strain rate do not present any strong gradient or shape linked to internal gravity waves and internal tides. So, we don't expect this to be a dominant feature in our zone.
c. Of course, this might not be the case in the tropics or subtropics where the signature of internal gravity waves and internal tides is much higher, nor in regions of strongly incoherent tides. In this case, special treatments would be necessary to correct these contributions, as in Zaron and Ray, 2017 or in Le Guillou et al., 2021. In our region, Qiu et al., 2018 show that balanced motions are the dominant dynamic.

<u>Old text</u>

Line 511-512 : "To verify the impact of this on our eddy diagnostics, we compared the daily averaged EKE derived from the full LLC10 fields versus a daily snapshot from the hourly LLC10 model data. In the high-energy Agulhas region, the differences were minimal".

<u>New text</u>

"To verify the impact of this on our eddy diagnostics, we compared the daily averaged EKE derived from the full LLC10 fields versus a daily snapshot from the hourly LLC10 model data. In the high-energy Agulhas region, the differences were minimal (see appendix C)".

2. Lines 307-315: The residual and smaller scales of EKE and strain rate you defined here (i.e. difference between the results of LLC10 and the DUACS) also contain the contributions of the cross terms. You should clarify this point more explicitly.

Indeed, the cross terms are contained in the residual EKE and strain. Thank you for pointing out that this requires a more thorough explanation, we have updated the manuscript accordingly. The contribution of the cross terms is quantified in Figure 5 and Figure 6 which present the temporal series of EKE and strain rate over four different regions of the Agulhas system. The cross terms are present in both cases, but they never dominate the EKE or strain rate. You will find an in-depth answer to this point in comment 2 of the first anonymous review.

3. Lines 393-395: Could you explain the possible reasons accounting for the difference between your results and those in Sasaki et al. (2014)? By the way, I also suggest the authors briefly discuss the generation mechanisms of the smaller mesoscale eddies (sometime called larger submesoscale eddies) here. Are they generated by mixed-layer baroclinic instability?

The explanation for this difference may be due to the specificity of this zone, and that our simulation is only 1-year long, so the “seasonal” calculations are dominated by large eddy events. In fact, we are very close to the Agulhas retroflection and separation where, during the year, each season’s dynamics can be dominated by the propagation of large-scale, transient events (Lines 328 - 346) as visible in Figure 4, Figure 5 and Figure 6. In periods where no Natal pulses occur, faster and smaller-scale dynamics are generated by barotropic instabilities (Lines 351 - 354) and can become very energetic (Figure 5b). In both cases, the lateral stirring is strong, and the seasonal mixed-layer depth remains shallow all year round, in contrast to the strong seasonal mixed-layer depth changes in the North Pacific (see climatological Figure below). So the seasonal dynamics in the Agulhas Retroflection are weak compared to mesoscale events and do not strictly follow the paradigm of mixed-layer instabilities, contrary to Sasaki et al., 2014. This point is clarified in the revised version of the manuscript.

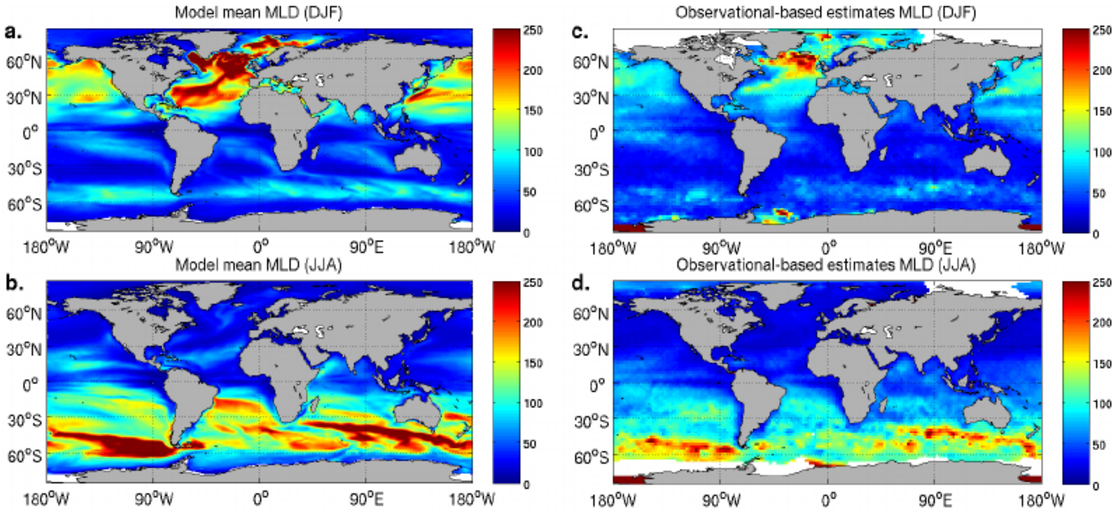


Figure: Global MLD in summer and winter from a model (left) compared to observations based on Argo analysis. The model results are computed over the 1991–2000 period from the historical simulation, whereas the observations are adopted from de Boyer Montégut et al. (2004), after Tjiputra, et al (2012). (Geoscientific Model Development Discussions. 5. 3035-3087. 10.5194/gmdd-5-3035-2012).

Old text

Lines 393-395: In contrast with Sasaki et al. (2014), there is no evidence during this one-year simulation of small mesoscale EKE in winter/spring feeding energy to larger mesoscale EKE in late spring/summer. Rather, the simulation appears dominated by more individual eddy events.

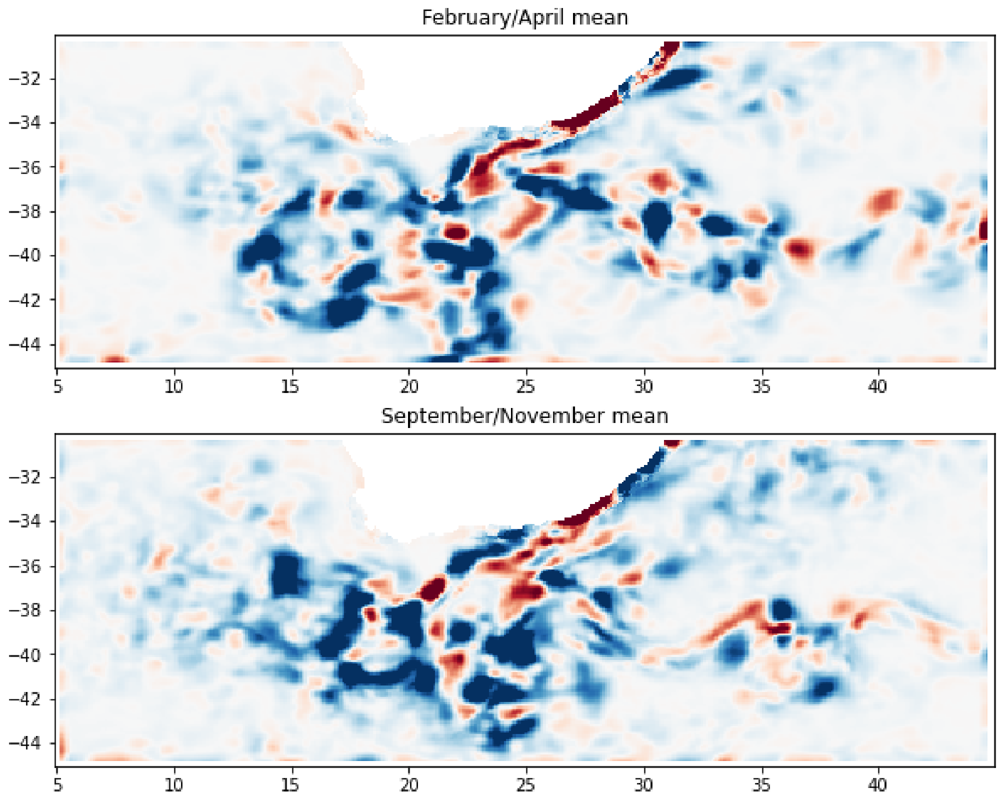
New text

In contrast with Sasaki et al. (2014), there is no evidence during this one-year simulation of small mesoscale EKE in winter/spring feeding energy to larger mesoscale EKE in late spring/summer. Indeed, the seasonal averages in this one-year simulation are dominated by more individual eddy events. The seasonal mixed-layer depth remains shallow all year round in contrast to the strong seasonal mixed-layer depth changes in the North Pacific (see climatology in Figure 5 of Tjiputra et al., 2012). So seasonal dynamics in the Agulhas Retroflection are weak compared to mesoscale events and do not strictly follow the paradigm of mixed-layer instabilities, contrary to Sasaki et al., 2014.

Minor comments

5. Section 3.3 Geographical distribution of the energy cascade: In addition to geographical distribution, it is also meaningful to discuss the seasonal variations. Does the energy cascade has a clear seasonal cycle due to the enhanced mixed-layer eddies in winter?

We do not have a quantitative response to the question on enhanced mixed-layer eddies in winter since we have only analysed the surface fields. This would indeed be an extremely interesting point to study in the future. However, we do not find a strong seasonal cycle by averaging the surface energy cascade geographical field over two different seasons (Figure below: end of Summer - top - and end of winter - bottom). As explained in comment 3, the seasonal cycle is weak in this region in contrast to the strong large mesoscale eddy events such as the Natal Pulses that tend to dominate any seasonal average, particularly since our model simulation is only 1 year long.


February/April mean
−32
−34
−36
−38
−40
−42
−44
5
10
15
20
25
30
35
40
September/November mean
−32
−34
−36
−38
−40
−42
−44
5
10
15
20
25
30
35
40