Author response to reviewer Sarah Gille's comments on "The mesoscale eddy field in the Lofoten Basin from high-resolution Lagrangian simulations" by Dugstad et al.

The reviewer's comments are given below in black Times New Roman font, with our response in red Arial font.

Reviewer 1– Sarah Gille

This manuscript uses a novel approach to assess the contributions of eddies to the Lofoten Basin. In this study, Lagrangian particles are simulated numerically using the ROMS model and are diagnosed using multivariate wavelet ridge analysis, an approach which allows the authors to readily identify the presence of coherent vortex like structures. The manuscript was written as part of the lead author's PhD thesis, which I also had the pleasure of reviewing, and in a second reading, I remain impressed by the effectiveness of the analysis approach and the clear delineation of contributions from anticyclonic vortices, cyclonic vortices, and ambient flow. The approach is effective, the results are clearly presented, and the findings will be relevant to readers of OceanScience.

I have considered the 15 criteria provided for Ocean Science reviewers, and on the whole, I think the manuscript is in excellent shape.

We thank you for your constructive comments. They have led to a much improved manuscript, including a completely new flux calculation and a new Figure 13. Re-considering the flux calculations has also lead us to reduce the discussion about 2D drifters, since 3D drifter trajectories are thought to be more representative of actual flow paths. We address your specific comments below.

There are a few issues that should be addressed prior to publication.

First, the analysis in section 3.5 examines the net transport into and out of the Lofoten Basin due to ambient flow, anticyclonic vortices, and cyclonic vortices. Although the analysis approach is clever and original, I think that it runs the risk of over-interpreting effects. The analysis pairs separate trajectories for flow into the basin and flow out of the basin to consider the net impact on the basin. However, as the authors note, very few particles actually transition from being in an anticyclonic flow on entrance to a cyclonic flow on exit (or vice versa). If particles don't actually experience this change, then using a bootstrapping approach to assess the net contribution due to this unrealistic scenario seems risky. The manuscript would be stronger if the authors simply examined the net flux into the domain from each of the categories of particles and then separately examined the net flux out of the domain from each category of particle. (Alternatively, if pairing particles at entrance with particles at exit seems imperative, then this should be done using single particles only, without randomly matching entrance particles with other exit particles.)

Your comment here is certainly well received. We have thought quite a bit more about how to present and interpret these kinds of estimates. But we do believe it is important to present temperature and vorticity fluxes in an approximately mass-conserving framework. We have therefore avoided computing fluxes from the entries and exits separately. However, your point that very few drifters actually switch from e.g. anticyclones to cyclones is one we have addressed in the revised manuscript. In a revised calculation, we follow your second suggestion, and follow the identity of each drifter and compute net fluxes (flux in – flux out) for each of these.

Specifically, we now compute the temperature/vorticity fluxes from drifters for the following 6 categories:
- Drifters that enter in anticyclones but then exit as any of the three categories
- Drifters that enter in cyclones but exit as any category
- Drifters that enter with the ambient flow but exit as any category
- Drifters that enter as any category but exit in anticyclones
- Drifters that enter as any category but exit in cyclones
- Drifters that enter as any category but exit with the ambient flow.

The results are given in Figure 1 below - this will be a new Figure 13 in the manuscript. Please note that we will now use ‘AF’ for ambient flow, and not ‘AM’, due to comments from reviewer Stefanie Ypma. The results from this alternate calculation are largely in agreement with the previous calculation in that both heat and vorticity fluxes into the central Lofoten Basin appear to be dominated by the ambient flow.

We now show and discuss flux estimates only for 3D drifters, because these offer a better representation of real flow paths. For Figure 12 of the manuscript (see below) we compare 3D and 2D drifters to investigate the relation between vertical movement and temperature changes. However, retaining the 2D drifters in the discussion of fluxes does not add to the manuscript. As a result, we also omit reference to the 2D estimates when we later discuss the contribution of filaments. On that note, we also shorten the discussion on the specific role of filaments, particularly with reference to flow having vorticity larger than $f/2$. This threshold value was relatively arbitrary, and a thorough investigation into this will be deferred to later work. Here the revised text will largely limit the discussion to the observation that the large vorticity fluxes from the ambient flow category likely implies small scales, e.g. filaments, rather than large-scale mean flow.

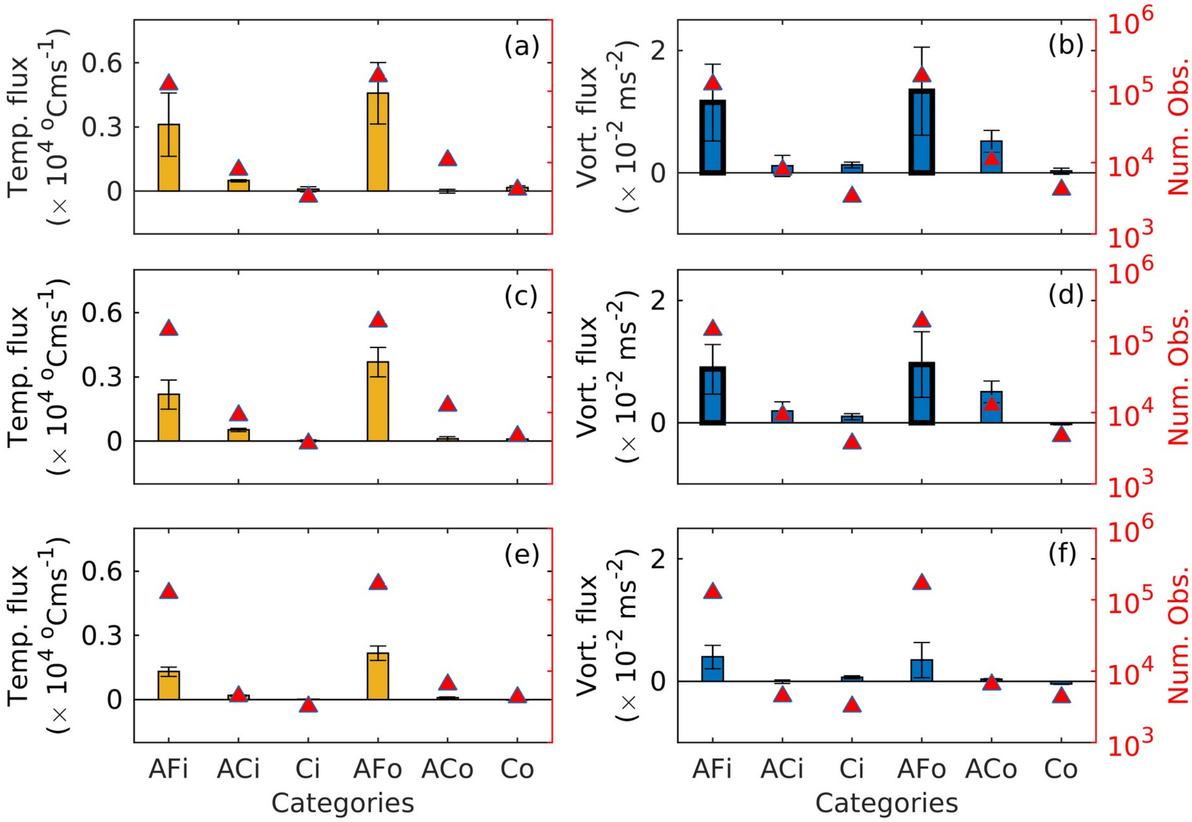

Figure 1: Temperature (a, c, e) and vorticity (b, d, f) fluxes for 3D drifters that are deployed at (a, b) 15 m, (c, d) 200 m and (e, f) 500 m. The number of observations are given with red triangles and are the same for both the temperature and vorticity fluxes. Error bars indicate twice the standard error of the mean. Abbreviations are: AFi=Ambient flow in, ACi=Anticyclones in, Ci=Cyclones in, AFo=Ambient flow out, ACo=Anticyclones out, Co= Cyclones out. Thick black edges on the AFi and AFo categories in panel (b) and (d) indicate that the bars are given as 1/3 of their actual size (for visualisation purposes).

Related to this, at about line 390, the authors explain the use of a boostrapping routine to estimate the contributions of particles of different types to the net flux. It's not clear that a bootstrapping approach is necessarily needed for this. If the statistics are relatively Gaussian, then it should be sufficient to compute the mean temperature flux and the standard error of the mean, without needing to go through the computational effort to compute a large bootstrap sample. If bootstrapping is formally necessary, then a bit more explanation would help readers understand why.

We agree with this comment and also note that choosing 75% of the drifters for each iteration of the bootstrapping was also a fairly random choice. We therefore decided to replace this form of uncertainty estimate with a more classical one. Note that our drifters are deployed every week over three years (1996, 1997 and 1998) with roughly the same amount of drifters deployed each year. Instead of estimating the total temperature and vorticity fluxes through all years, we now split the drifters into three groups based on which year they are deployed. We thereby get three independent estimates for the net temperature/vorticity fluxes (from drifters deployed in 1996, 1997 and 1998). In our new Figure 13 (Figure 1 above) we show the 3-sample mean and also twice the standard errors (as a 95% confidence interval for the mean). Through this procedure, the relative importance between ambient flow and eddies is still clear.

Figures 5 and 9 are identified as probability density functions, but neither appears to be normalized so that area under the curve integrates to one. Either they should not be labeled as pdfs (perhaps "distributions of relative frequency"?) or the plotted curves should be normalized by bin width, so that integral of the area under the curve is one.
Agreed. We decided to keep the curves but to refer to these as “distributions of relative frequency” (with “PDFs” changed to “DRFs”, accordingly).

Figure 12 shows line plots that would be enhanced if statistical uncertainties could be added to the lines. This wold allow readers to judge when the LB region differs statistically from the full domain.
Thanks for the input. We have now computed the standard error and included these as vertical error bars. To be consistent with Figure 13, the error bars here also show twice of the standard error (to indicate a 95% confidence interval for the mean). We first tried to plot the standard error as a shadow in the background but had to abandon this approach due to a large number of curves that made the figure crowded. Therefore, we have computed and plotted the error bars for specific days (30 and 60) after the drifters entered the basin. To distinguish results from the basin (red) and the full domain (green), error bars are plotted with an offset of +2 days for red and -2 days for green. For better visibility, we show error bars only for 3D results in an attempt to keep the figures simple. Note that error bars are computed for all categories, but due to their small magnitudes they are hardly visible for the ambient flow. The new figure will look like the following:

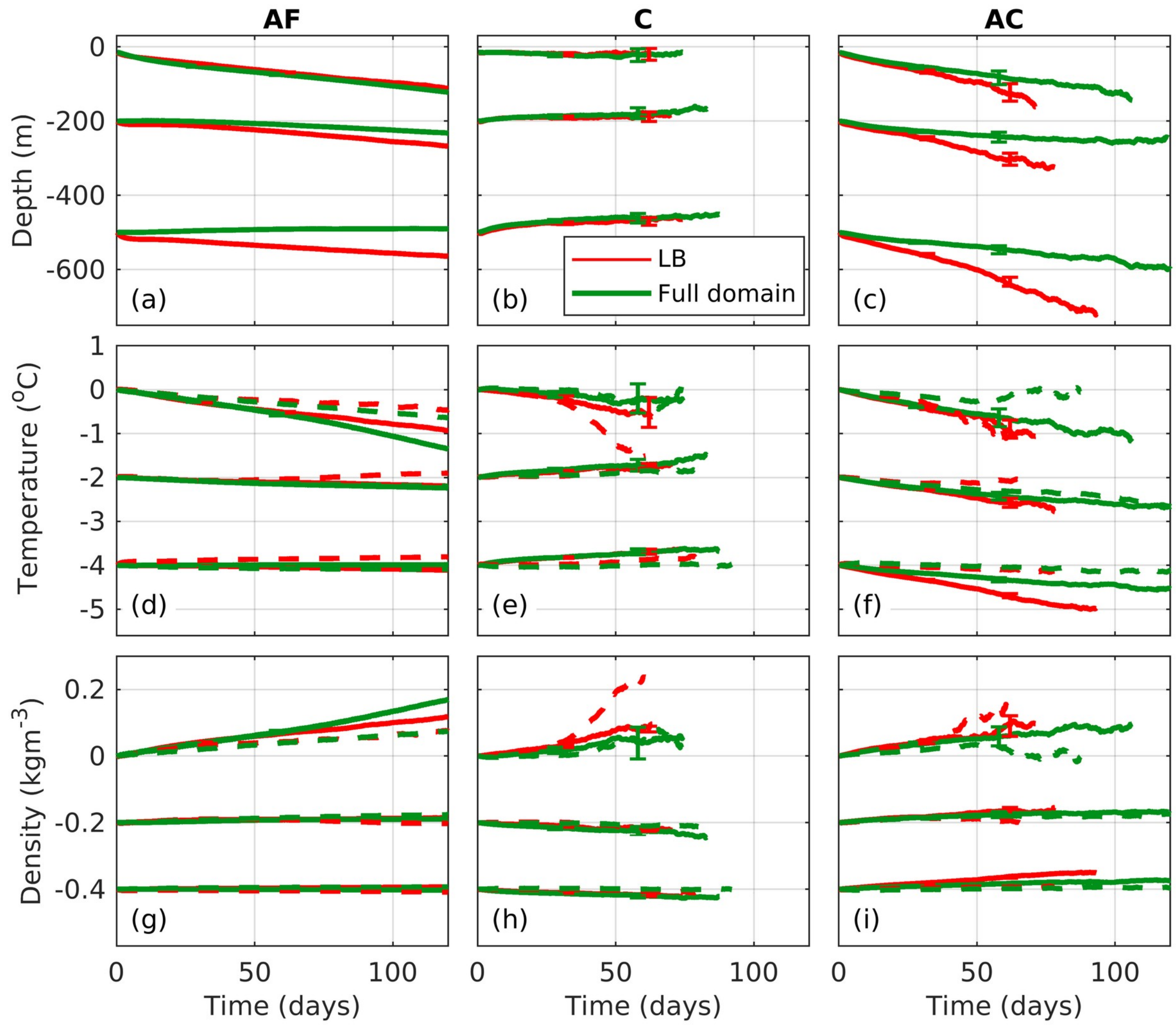

Figure 2: Time series of (a, b, c) mean vertical displacement for 3D drifters, (d, e, f) mean temperature change and (g, h, i) mean density change for 2D (dashed) and 3D (solid lines) drifters. Analyses for the LB (red) and the full domain (green) are shown for the (a, d, g) AF drifters, (b, e, h) cyclonic ridges (C) and (c, f, i) anticyclonic ridges (AC), and for different deployment depths (15m, 200 m and 500 m). To distinguish the drifters that were deployed at 15 m, 200 m and 500 m, an offset of -15 m, -200 m and -500 m is used for the vertical displacements, 0, -2°C and -4°C for the temperature changes and 0, 0.2 kg m^{-3} and 0.4 kg m^{-3} for the density. The mean is based on fewer data points with increasing time and time series are therefore stopped when the mean is based on fewer than 100 data points. Error bars that indicate twice the standard error of the mean are given at day 30 and 60 for both the LB (red) and the full domain (green). These are distinguished by using offsets of +2 days for red and -2 days for green. Error bars are only included for the 3D particles.

In Figure 2d, I'm used to seeing wavelet transforms shown with an envelope to indicate the range of validity. Is there an applicable envelope in this case?

Thanks for pointing to this. We interpret the question as being related to a “cone of influence” of the wavelet transform which tells in which range the wavelet transform is influenced by edge effects. Actually, the multivariate ridge analysis automatically performs trimming at the edges of ridges to ensure the masking of such edge effects. In this particular case (Figure 2 in the paper) the drifter was deployed in the Lofoten Basin Eddy, so the drifter was looping right from the start. However, the ridge analysis routine only starts indicating a ridge 2 days after the deployment. This is also about the period the ridge in panel c (black curve) traces at day=0 in the figure (which is actually day 2 after deployment). After the ridge ends around day=63 the drifter times series continues for several hundred days (as does the ridge analysis). The ridge detection at this end is therefore not influenced by edge effects (they’re too far away). We will clarify this in the revised manuscript.

There are a number of typos, and I will separately upload a commented version of the pdf, in which I have marked suggested edits.

Thanks. These have been corrected as suggested. An updated manuscript will be accompanied with detailed references to all specific changes.