Reviewer #2

We are particularly thankful to the anonymous referee for her/his numerous comments and suggestions on our manuscript. We agree with most comments and have modified and/or updated the manuscript accordingly. Details and answers are provided below in italics.

Comments to the Authors

General Comments: This paper integrates numerous different oceanographic observations from a unique cruise in the Arabian Sea. The observations of particle size distribution throughout the oxygen minimum zone provide new insights into the dynamics of particles in this biogeochemically important and poorly understood zone. It was unclear if the model used to assess the statistical funnels of sinking particles was applied in a true hindcast manner for the period of interest. It says 3 years of model data were used, so was data from these three years averaged together? Why was 2009 and 2011 model data used for a backward Lagrangian analysis for the interpretation of 2010 observational data? Further explanation is necessary as well as a discussion of the uncertainties that these approaches (eg. averaging) would introduce.

Method was unclear indeed. The statistical funnels were computed with the trajectories seeded at the time of the cruise in the Arabian Sea, i.e. between March and April 2010. Additionally, we ran simulations for years 2009 and 2011 to assess the inter-annual variability of the circulation patterns (not shown). We have clarified this in the material and method section 2.7 (last paragraph):

"From the trajectories we quantified the statistical funnel, i.e. the backward in time trajectories from their initial depth to the surface. The statistical funnels were computed with the trajectories seeded at the time of the cruise in the Arabian Sea, i.e. between March and April 2010. Then we computed the envelope containing 75% of the particles to quantify the possible source of particles at the surface only if more than 100 particles have reached the surface."

The fluxes computed from the PSD data utilize a global parameterization that assumes particles of a certain size are sinking at a given velocity. If some of the features in the particle abundance profiles are a result of laterally transported slowly sinking or neutrally buoyant particles common in intermediate nephloid layers, then this flux estimation approach could overestimate the actual vertical flux in those layers. A discussion of the potential limitations of this approach in this particular application is needed.

The reviewer is right and there are limitations to the use of PSD to estimate particulate flux as described in Guidi et al 2008 and used in several other papers. However, the use of transmissometer showed that the nepheloid layers were largely made of small particles that do not contributes to the

vertical flux. As described in Guidi et al. 2008, most of the particle flux is made of particles >300µm and this is reflected in the nature of the exponential relationship between PSD and flux. Therefore, only a small error on the estimations of particles flux will be due to an important load of small particles in the nepheloid layer.

It is important to keep in mind that these particle fluxes remain estimates. Even if errors are made, the error would propagate in the studied area and patterns would remain similar. This short discussion has been included in the manuscript (section 4.4) in order to present the limitation of the method.

Not all figures are referenced in the text, and the ordering could be improved to reflect the sequence discussed in the text.

Done

Specific comments:

P 19274, L9: Include dates of cruise here

Done

P 19275, L13 replace “was” with “were”; and “than” with “as”

Done

P 19275, L19 How was sensor drift assessed and evaluated?

Post-cruise calibrations performed by SEABIRD (on July 2010) indicate that the oxygen sensor did not show a significant drift over time. This was confirmed by a comparison with oxygen values from the WOA09 climatology. We can also check that oxygen values inside the OMZ core did not present any evidence of temporal and spatial drift by considering for example oxygen value at 500m depth (Figure 1) : the mean is 2.88 µmol.kg-1 with a standard error of 0.15.

We thus have completed the material and methods (section 2.3) to include these technical details.

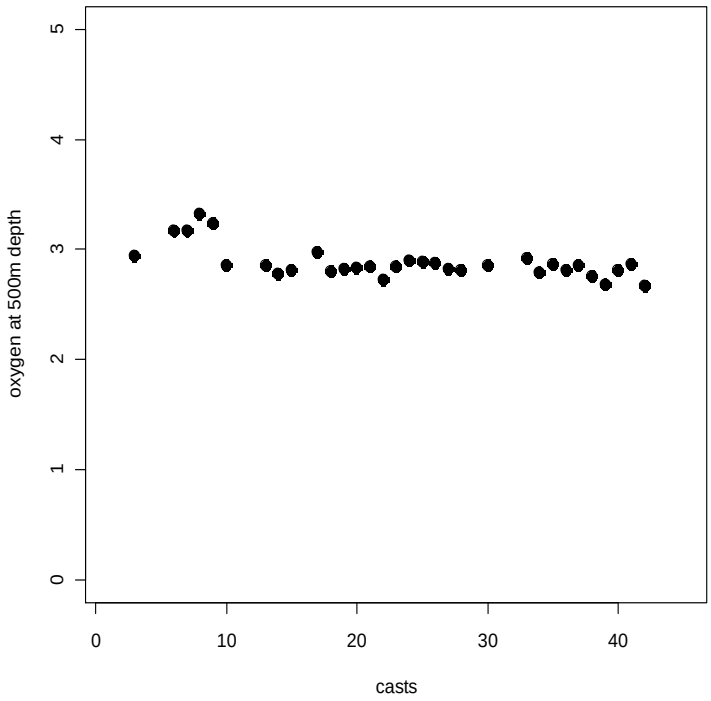

Figure 1. Oxygen at 500m from all CTD casts of stations 37 to 41.

Definition of OMZ: By using oxygen_max to calculate DI_z, and a threshold of 0.975, this would create a changing OMZ criteria for each profile, if I understand the explanations correctly. This is in contrast to picking a fixed limit of say < 20 umol. If drift was indeed verified to be negligible between profiles, it would seem appropriate to use a fixed raw oxygen estimate from the sensor, rather than the method used here. If not, please provide further justification as to why the method described is the most appropriate.

You are right. The use of the DI criterion was at first introduced to make a global comparison of the 3 OMZ sampled by the TARA vessel between 2010 and 2012 but indeed in this paper only the Arabian Sea OMZ is presented. So we decided to use an empirical threshold of 5µmol/kg of oxygen to compute the upper and lower limits of the OMZ core. This value is in agreement with previous studies of Codispoti et al. (1991, 2005) and corresponds to a working definition of suboxic conditions.

P19278, L5. “particle” not “particles”

Done

What is meant by particles cloud on P19279 L12 and how is this related to the location of the lat/long CTD locations?

This was unclear. The “particles cloud” refers to the initial position of the 500 particles used in the simulation computation associated to each station. We reformulated as follows (section 2.7):

"At the beginning of the simulation process, for each station, particles are randomly positioned in a 50km radius circle centered on the mean longitude / latitude of all CTD casts of the corresponding station. The horizontal dispersion of these initial positions was chosen to encompass all mesoscale structures < 100 km. […]"

P19283, L7 subsurface what?

Thank you for your remark. We wanted to say "a subsurface maximum". Corrected.

Section 3.7. Include references to the appropriate figure. The figure refers to 0.53 mm, while the text refers to 500µm size limits. Are these meant to be the same?

Indeed, the 0.53 mm and the 500µm particles size correspond strictly to the same particles size class. We thus have standardized the text with 0.53mm throughout.

Section 3.8. Figure reference?

19284 Add figure reference

Done

P19286 L24. Your test of this hypothesis relies on the assumption that these particles are sinking at least 1m/day. What if they were even more slowly sinking or neutrally buoyant? Do the isopycnal surfaces that these nephloid layers occur on intersect with the continental shelf or slope? Does the nephloid layer lie on the same isopycnal surface at the different stations? If so, this might support the idea of neutrally buoyant particles that can be sourced from long distances.

Only few observations combining turbidity and hydrology observations are available besides the TARA data in the OMZ region. We depicted the distribution of nepheloid layer together with the hydrological parameters during TARA (Figure 2) and along a N-S section close to the TARA section from the Gardner's worldwide data base (Figure 3) (Gardner et al 2006).

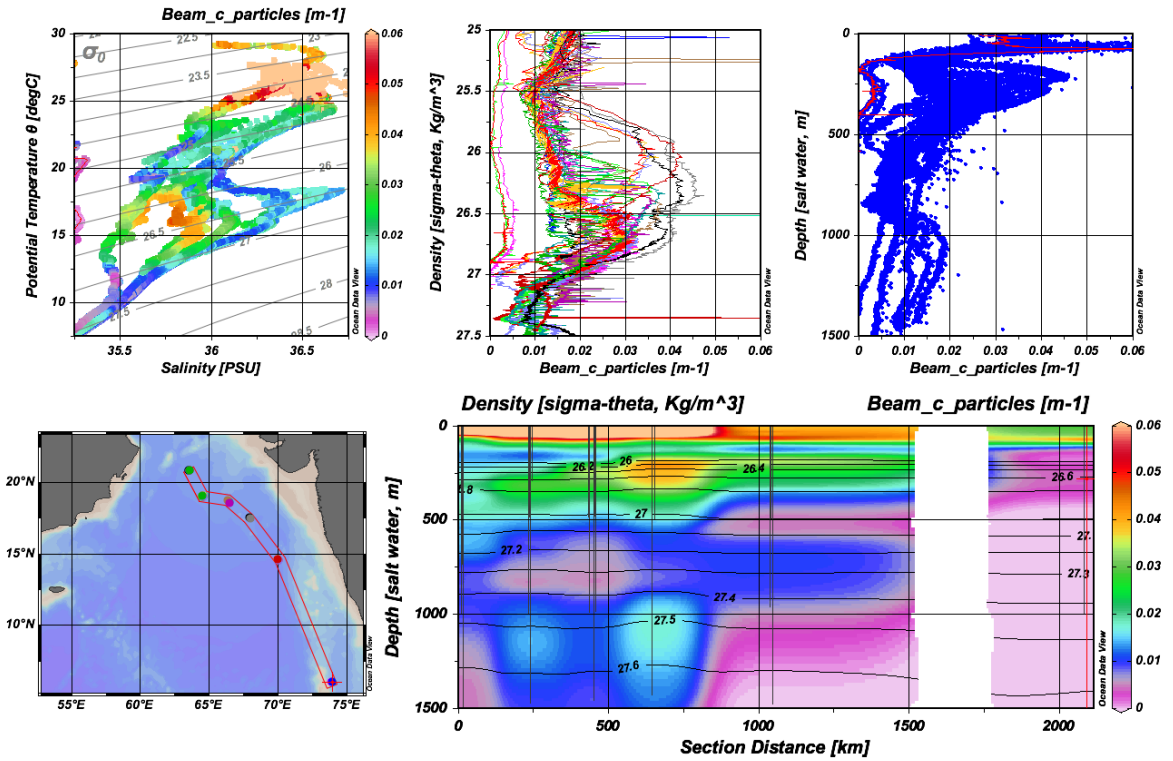

Figure 2: TARA section in 2010

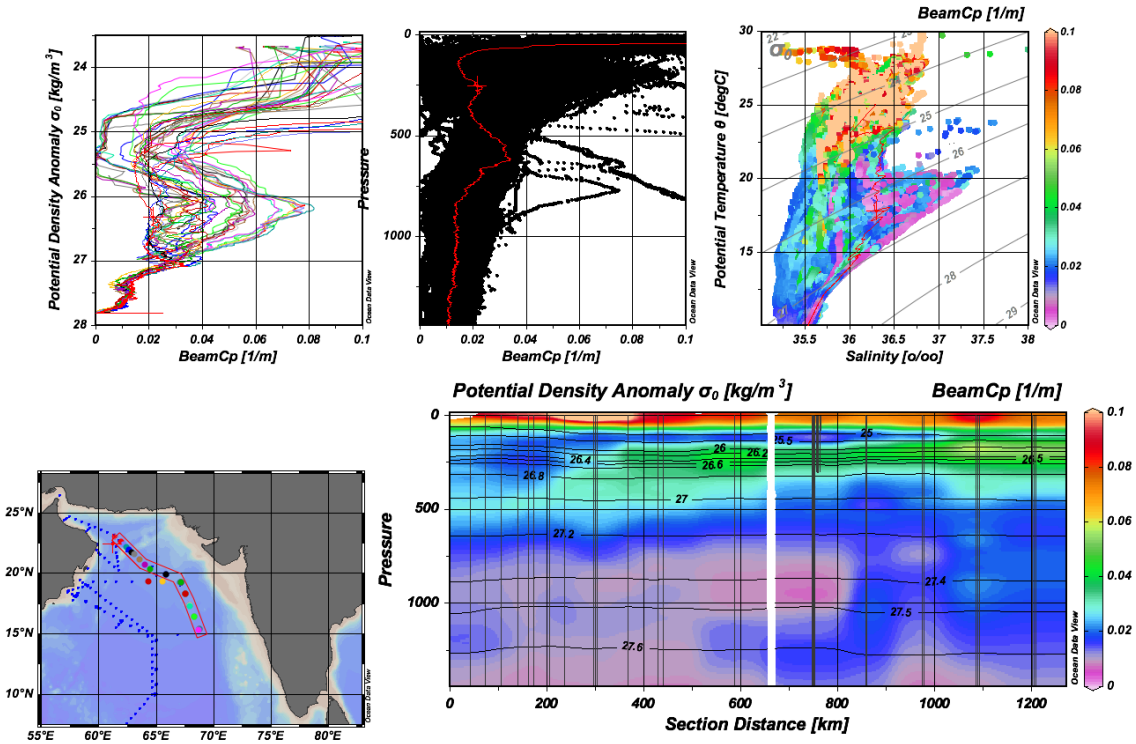

Figure 3: Data from Gardner's database (http://oceanography.tamu.edu/~pdgroup/TAMU-SMP.html).

W.D. Gardner, A.V. Mishonov, M.J. Richardson, 2006. Global POC concentrations from in-situ and satellite data. Deep-Sea Research II, 53(5-7): 718-740.

Both sections reveal similar features, with one major intermediate nepheloid layers between 150 and 400 m deep. It does not appear to be confined to specific water mass as it occurs over wide a wide density range (sigma-theta 26-27 kg/m3). A deeper secondary maximum of beam attenuation coefficient is visible below 700 m depth, that also spans a significant density range (sigma-theta 27.4-27.6 kg/m3).

The present features cannot tell whether the higher particle abundance could also be the result of neutrally buoyant suspended particles transported laterally along isopycnals from the continental margins. However Naqvi et al (1993) and Naqvi (1994) indicated, from optical measurements in the OMZ region, that the particle maxima does not exhibit a systematic onshore-offshore gradient expected from an off-shore transport of the bottom nepheloid layer detaching from the continental margin. Instead the intermediate nepheloid layer tends to intensify offshore and show a remarkable association with the maximum of nitrites (corresponding to the secondary minimum of nitrates) . He also suggested that the increase of the particle concentration in the intermediate nepheloid layer may arise from an increase of the bacterial biomass. In that case, the quasi neutrally buoyant transport of suspended matter may not be very important in providing the additional carbon required to sustain the high respiration rates.

In the revised version, we add one sentence to discuss the origin of the nepeloid layers in light of Naqvi articles.

P19287 L7 Is there any evidence from the UVP or transmissometer that the concentration of smaller particles is being reduced as the zooplankton package it into larger particles? If so, please discuss and refer to the PSD plots.

This is an interesting point that cannot be solved easily. We do not have the data available to ascertain this process. This is why it is stated as a hypothesis. To be certain, we would need the particle size distribution over the whole size range few µm to few cm and the image quality to distinguish between aggregates and pellets with confidence. The UVP provide images to sort between aggregates and pellets but only for a size >500µm but detect all particles >100µm. The transmissiometer is useful to have the bulk concentration of small particles <20µm but does not provide any information on their size.

P19287 L9-12. I can't decipher what you mean in this sentence. Please clarify.

Thank you for your remark. We changed the sentence with the following:

"Biological processes (bacterial growth, zooplankton feeding) could also be reinforced at the lower oxycline due to the sinking of fresh organic particles not degraded in the OMZ core (Wishner et al., 1995; Wishner et al., 2008)."

P19287 L28. This needs to be linked better with the data. See comment above.

Thank you for this remark. We completed the sentence by adding references to the figure 11.