

Mesoscale eddies and submesoscale structures of Persian Gulf Water off the Omani coast in Spring 2011

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1 General comments

Thanks to the suggestion of the referees we deeply changed the structure of the article, moving entire sections and re writing others to make it easier to follow.

In particular, after describing the data and their processing, we wrote a first section focusing on the surface signature of 2011 compared to its climatological one. A second section focused on the surface signature of the different mesoscale structures driving the circulation in the Arabian Sea and Sea of Oman. These maps are then related to the vertical section measure during the experiment and the dynamical information they provided. In regards of the dynamical context of March 2011 we then describe the water masses, in particular the Persian Gulf Water, its structure across the basins and the evolution and origins of the different patches. A focus is put on the submesoscale lenses that are recorded in the Arabian Sea and in the Sea of Oman.

We also deleted some figures and re work some in the same aim to make it easier to follow. We add some diagnoses on the formation of the lenses or the lateral injection around the mesoscale eddies. This corrected version is thus very different from the earlier one, keeping the observational approach but adding theoretical diagnoses. We hope that the resulting article will answer the reviews of the referees.

1.1 Referee #1

When I read the title and abstract of the manuscript, I have high expectations that this manuscript will be an important observational study to fill in some gaps in the mesoscale research in the Sea of Oman and Arabian Sea. However, I have to stop my reading due to the confusions and mixed-up in the descriptions in the text, inconsistency in the figures, captions, and text and poorly prepared figures. For example, in the text, the authors keep talking about A# and C# mesoscale eddies. However those numbers are not marked in the figures or clearly described in the captions, which give me a difficult time to understand and follow the descriptions in the paper. Another example, figure 4 and its caption are not consistent. Many of the descriptions in the text cannot find in Fig. 4. Therefore, I think this is a poorly written paper and it is unacceptable in its current format. I did not read the second part of the paper, so have no comments on the second part.

We thank the referee for reading the first part of this article. Indeed the mesoscale situation is difficult to describe. We will indicate the numbers of the eddies on the figures and correct the caption that are misleading. Furthermore, the descriptions in the text will be revised to have a clearer vision of the mesoscale circulation seasonal evolution.

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1.2 Referee #2

The authors discuss the properties of mesoscale eddies and sub-mesoscale structures that are created by the outflow of dense saline water from the Persian Gulf based on in-situ measurements. The material, exclusively based on field observations, can be of interest to the scientific community. Overall it is rather difficult to follow the text. While the authors name some structures in the text as C1 or A2, for instance, these identifiers are not shown in the actual figures, only in the captions. I suggest that each individual structure referred to in the text should carry some consistent identifier that is also displayed in graphs. According to the introduction, one of the objectives of the paper is to describe the structure of sub-mesoscale fragments and to explore their recurrence. I don't see that the authors achieve this objective. For instance, statistical methods could have been used to derive typical length scales etc. Overall I believe that the material presented is publishable in Ocean Science, but the manuscript requires substantial revision.

We thank the referee for reading this article. The text and figures will be revised to make it easier to follow. We will also provide more details about the sub-mesoscale structures observed during the experiment but it is difficult to study the recurrence of the structures with our database. We will approach this subject in the last part of the article with the measurements of the ARGO floats.

2 Specific comments

2.1 Referee #1

Following are some comments I wrote when I read the first part.

Page 2746, lines 8-13. My understanding is there are still some debates about the PGW pathway through the Persian Gulf and in the Sea of Oman in the literature. I suggest to read and cite papers including but not limited to Seniyu et al. (1998), Lee et al. (2000), Bower et al. (2000) and Wang et al. (2013) etc. They all discussed the measurements of the PGW patches/ mesoscale eddies in the Sea of Oman and Arabian Sea.

Page 2746, lines 14-18, using ARGO data to investigate the mesoscale eddies in the Sea of Oman is also discussed in Wang et al. (2013).

We will implement these corrections.

Page 2751, lines 14-15, "The wind stress from summer 2010", I can only find 2011 line in Fig. 4 according to the legend. In Fig. 4, the caption indicates the red lines are 15 day means, while in the legend, the red lines are for 2011. Figures, captions and description in the text are inconsistency and very confusing. Lines 20, "see Fig. 4, right", something must be wrong here. There are only top and bottom panels. Where is the right panel? I have to skip this paragraph due to the confusion in the text and Fig. 4.

This figure will be corrected and the caption will be rewritten for an easier comprehension.

Page 2752, line 6, "this current..", which current?

We will precise that this is the Oman Coastal Current.

Page 2752 and Fig. 6, cyclones and anticyclones need to (should) be marked in Fig. 6. Because they are not indicated clearly in Fig. 6, it gives me a very hard time to understand and follow the descriptions in this section. I only went through half of this section. Need rewriting.

Fig 2. I suggest plot the locations of ARGO profiles superimposed on the contour map of salinity and temperature and remove the contour of number of floats. The contour of number of floats is very confusing and misleading.

Fig 3. What do those blue dots represent? There are many of them along the track. Are those big green dots "green circles" on the map? I could not find "green circles".

We will implement these corrections.

2.2 Referee #2

Major points

1. Introduction. What is the significance of these structures in the broader context such as the oxygen budget or carbon fluxes in the northern Indian Ocean? Why is it important to study them?
The mesoscale eddies induces strong horizontal transports whereas the submesoscale structures induces high vertical velocities, mixing the deeper water masses and providing nutrient, oxygen and carbon. We will add references about these budgets.
2. Okubo-Weiss quantity. What is the main difference between deformation- and vorticity-dominated structures? The authors show give specific reasons as to why this parameter is used in the work. The authors derive this quantity from instant measurements. Do such snapshots tell us anything about the hysteresis of structures over seasons?
3. Spiciness. The authors need to provide a reference for their spiciness formula. Isn't spiciness defined as the potential temperature θ and salinity S of sea water at a given isopycnal surface (e.g., Veronis, 1972; Munk, 1981; Flament, 2002; Huang, 2011). I don't see the causal link between this definition and how spiciness is used in this work. Please explain and add references.
4. Give specific reasons for the use of two-dimensional Ertel potential vorticity.
5. What are ADCP currents used for in this work? I understand that most of dynamic properties are derived from the (corrected) TS climatology. Please clarify.
6. In Section 5.2. the authors state: "Since a strong shear and strain is necessary to break the PGW outflow and to form lens and filaments, it is logical to observe fewer submesoscale PGW structures during the summer monsoon". Yes, this seems to be logical, but you still need to have conclusive evidence in support of this hypothesis. Without any evidence, this section should be removed.
7. Figure 9: Can the authors please explain why the geostrophic flow field looks so different from the ADCP flow field? Is there a mistake? Perhaps the geostrophic flow field was plotted upside-down?
8. Figure 14: Can the authors explain the fundamental difference between the geostrophic and ADCP flow fields? Is there something wrong here?

Minor points

1. In the abstract, the authors state: "As well, recirculation of the PGW is observed, thus having the presence of salty nearby patches with two densities". What is meant by two densities? Please clarify.
2. What is an isospice? Provide a definition. Has this been used before?
3. Figure 8: The terms salty & fresh injections are not used anywhere else in the text. So, why are they used in the legend?

Technical comments

1. In the abstract that authors state: "The different mechanisms leading to its formation and presence are assessed here." "Assessed" is probably not to correct word here. "Examined" is probably a better word choice, although the authors only provide some suggestions in the end.
2. In the introduction the authors state: "Second, to concentrate on the submesoscale fragments detached from or by the mesoscale eddies, and then on the nature, structure, recurrence and possible role of such fragments". This sentence is confusing and incomplete. Role in what? Perhaps this sentence should read: "Second, we focus on submesoscale fragments detached from or embedded in mesoscale eddies to describe their typical structure and recurrence."
3. In the results section the authors write: "This will be evidenced now with the Physindien experiment data". "Will" and "now" don't make sense in the same sentence. Better: This feature is now also documented with observational data from the PhysIndien survey.