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Interactive comment on “Physical forcing and physical/biochemical variability of the Mediterranean Sea: a review of unresolved issues and directions for future research” by P. Malanotte-Rizzoli et al.

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Answers to comments of reviewer 4 – Reviewer’s comments are in quotes

General comments

1) “The overview of the existing characteristics of the Med in the ms must not be limited to POEM and PRIMO, but to take into account also results from previous to the above projects works, as well as from recent contributions which based on in-situ data and on numerical applications assimilating in situ-data. References to key and important

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works are missing, such as for example to the French and Russian pioneers in the Med, back in the 50s and 60s, and to the new contributions in the frame of works funded by the EC, such as for example the CYCLOPS project and of several other national or bilateral projects throughout the basin”.

We do not agree with the reviewer. The paper is NOT attempting to present the history of oceanography in the Mediterranean sea and has not the ambition to present/describe the large number of research projects and initiatives which have occurred in more recent years. The focus of the paper is the identification of unresolved issues and research priorities in the basin. This is very clear from the Introduction, last paragraph. To make the history of oceanography in the Mediterranean would require an entire volume. POEM and PRIMO however have a special place in this history. They were the FIRST programs that gave a detailed description of the general circulation patterns in the western and eastern basins respectively, in different seasons and in different vertical layers , thus also defining the thermohaline status of the sea. Their results were obtained through large, coordinated, mostly multi-ship observational surveys. They were the FIRST programs to identify the dominant scales of motion, from the basin-scale, to the wind-driven upper thermocline sub-basin gyres to the mesoscale, based on quasi-synoptic observations and not on the synthesis of sporadic measurements in space and time. And that is why this paper stems from the November 2011 workshop held in Rome in occasion of the 25th anniversary of POEM. However, references to previous works have been added when proper and the CYCLOPS results have been discussed in many revised sections, for instance 2.3 and 2.4.

2)“The important role of the operational ocean forecast in obtaining reliable information of the physical and dynamical conditions of the entire Med, thanks to the assimilation of in-situ data and of satellite altimetry, is almost absent from the ms.”

We have included in various sub-sections information on the efforts of operational oceanography (operational systems and data assimilation models) and stressed their

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importance towards more reliable ocean predictions and for long-term reanalysis simulations. See, for instance, sub-section 2.2; sub-section 3.2, issue no 1. We emphasize again however that the focus of the paper is on the identification of unresolved scientific issues. Operational ocean forecast is NOT an unresolved scientific issue.

3)“The ms include suggestions for further studies in the Med that are already were addressed, as for example: a) the definition of the flow features in the E.med, b) the AW flow path in the E.Med using in situ data; c) the use of high resolution forcing ; d) the quality control of data and the new data and the new data basis generated during EC funded projects such as SeaDataNet, EDMODNET, MyOCEAN; e)the application of high resolution numerical flow models assimilating in situ data and satellite imagery. The latter is well covered the last 6-7 years in the frame of several EC funded projects, such as those MFSTEP, ECOOPO, MERSEA, MyOCEAN with downscaled operational models , with resolution 1Km and even in some cases down to 500 m. all nested hierarchically in the regional Med model”

We completely disagree with the reviewer that because some studies have or are already been addressed the related issues do NOT need any further attention : being addressed, does NOT mean that they are RESOLVED. The IPCC report that in 2007 won the Nobel peace price addressed all the major issues related to climate change and global warming. The SAME issues have been revisited with new , and sometimes contrasting, results in the recently released new IPCC. For each major topic examined in each sub-section we propose a list of UNRESOLVED issues, be they addressed already or not, and this list represents the collegial consensus of the scientists contributing to this paper, NOT of an individual. A specific comment provided by one of the present authors states: “Finally, I don’t agree that there can be research issues already addressed (closed), especially in a region where we already encountered significant surprises “

4)“ While the AW in the EMed is known that is a sub-surface water mass and its flow path can be defined using only in-situ data, description of the flow is provided in the

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ms from a certain number of works, which based on the use of SST or surface drifters. In contrary , nothing is mentioned about recent works assimilating thousand of drifters and in-situ data, both showed a clear picture of the AW flow path in the E. Med. The famous story with the so called generation of eddies along the coastal current in the W.Med, derived using SST images, is not applicable to the E.Med.”

Reference to the recent works of Poulain et al. (3012) and Menna et al (2012) based on drifters is now referred to, see for instance the discussion in the new sub-section 4.3. Regarding the “so-called generation of eddies. . . , we are obliged to refer to two distinct views already existing in the literature. However clarification of the method used to obtain each description has been added, and this discussion is in the revised sub-section 2.2

Specific comments

1)“Abstract. Interesting about the importance of the Med to the World Ocean, but not enough coverage about the topic of the ms. It is known that the renewal of the Med waters take something around 70-100 years. Is the small volume of 0.xx of the Med waters able to influence the World Ocean thermohaline circulation ?”

Following the recommendation of reviewer 1, the abstract has been rewritten in a completely different manner. The discussion about the importance of the Med. now belongs to the Introduction. Also, the answer to the reviewer question concerning the effect of Med waters on the global thermohaline circulation is:

YES

Enough to quote the seminal paper by Reid, Progress in Oceanography, 1994, 33, pp 1-92.

2)“Page 5. Since POEM there were several programs, at European and national levels which added knowledge regarding the Med sea and its worth to refer to them.”

We have already addressed this comment in the answers to point 1 of the general com-

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ments. Furthermore, the acknowledgment of the findings of the successive programs is done in the different sub-sections wherever appropriate.

3)“Page 6, section 2.1 What about the use of numerical model assimilating in-situ and satellite altimetry ? 3rd paragraph: propose to the authors to take into account the discussion about from the recent book “ The climate of the Mediterranean” P.Lionello ed. 2012”

Section 2.1 has been completely revised. Use of numerical models and data assimilation is a strategy (NOT an issue) applicable to WHATEVER issue, it is pointless to repeat it everywhere. In the book edited by P.Lionello the review provided by Schroeder et al. (Circulation of the Mediterranean Sea and its variability) is different from , and complementary to, what we give here, i.e. ,as the title states , “ a review of unresolved issues “. In any case, the P.Lionello book is referred to in the paper wherever appropriate.

4)“Section 2.2, 1st paragraph: the AW in the W.Med flow at surface then at sub-surface in the E.Med. Add reference to Gertman et al. 1991 (CIESM conference) regarding the formation of deep waters in the NW Levantine. 2nd paragraph: Modify the sentence “ The flow is unstable. . .” This is not true in the E.Med. The use of SST to derive the circulation in the E.Med. is not applicable. Use the analysis of in-situ data. There are thousands of in-situ data after POEM collected across the E.Med. Add more references regarding the flow features and flow pattern in the E.Med to works after POEM, used in-situ and numerical models with assimilation of in-situ data”

Section 2.2 has been completely re-written. Regarding the different use of SST (W.Med) and in-situ (E.Med) to infer the circulation, we have already addressed this comment in the answer to the general comment, point 4 above, and the related discussion is in the revised sub-section 2.2. All the important papers regarding formation of deep waters in the Levantine are properly referred to. Again, numerical models and data assimilation is an “ubiquitous” strategy(the reviewer seems to be obsessed with

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it) and it is pointless to repeat it everywhere.

“ 3rd paragraph: the switch of the deep water formation from Adriatic to Aegean was also reported in 50s-70s to occur periodically, add references to those papers. “

Regarding the periodical switch of deep water formation from the Adriatic to the Aegean, we have referred to the most known event of the 1970s giving the appropriate references (sub-section 2.2). To the best of our knowledge, for the 50s-70s there is no description of such an event published in the refereed literature up-to-now.

5)“Page 8, 1st paragraph. The expressed need to develop a combination of observation and modeling is already done in the frame of operational ocean forecasting. The authors to look the MONGOOS (former MOON) developments. Add references to those works.”

The answer to point 2 of the general comments applies also here. We must point out that we refer to the need to combine observations and models to investigate “scientific “ issues. Operational ocean forecasting does NOT care about science, just predicts the weather of the ocean.

“3rd paragraph (regarding the Specific issues). Several projects were carried out to understand the long term variability of the circulation in the Med. Add references to some of these. 5rd paragraph(regarding the specific issues). The proposed ways for observation here are out of days. Nowadays Argo floats (EuroArgo, MedArgo) and glider (EGO,GROOM) are the modest and efficient way for in-situ monitoring of the Med., from the surface to the deep.”

We re-iterate that section 2.2 has been completely re-written. Regarding the last comment, saying that the shipboard surveys are old-fashioned , in our opinion, constitutes no argument. We have shown , instead, (section 2.2) that these surveys, when conducted appropriately, can provide information of the mass and flow fields throughout the Mediterranean that neither the point moorings nor the Argo or the Glider floats

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can offer. We have stressed the need for both modelers and sea-going scientists to pursue and exploit the information originating from direct in-situ measurements of flow velocities in the entire water column.

6)“Page 9 Section 2.3 1st paragraph: add reference to CYCLOPS project and those of other similar activities. 2nd paragraph: The E.Med. particularly the SE Levantine is extremely oligotrophic compared to the W.Med. The authors to look the results-papers of the CYCLOPS project regarding the nutrients limitation, are different for W.Med. and different for E.Med. 6th paragraph (regarding the Specific issues): there is a number of recent experiments for the Gibraltar dynamics, the authors look for these papers (a French project)”

References of previous works have been added when proper and the CYCLOPS results have been discussed in the revised sections 2.3 and 2.4. As for Gibraltar, it is true that observations became more systematic in the last decade and data are, therefore, increasing. What is still missing is on one hand an analysis on pluriannual or long term variations in fluxes which may impact Mediterranean stocks and, on the other hand, a robust estimate of the role of entrainment and mixing among different water masses because of the peculiar functioning of the Strait. Models have provided important insights but, to date, no single term of the nutrient budget of the basin is really solid. This is striking considering the size and the closeness of the basin. This has been clarified in section 2.3.

7)“Page 10, 1st paragraph. Nowadays the operational oceanography systems (MON- GOOS) and those of MyOcean already provide daily data to support the trace of the bio-chemical processes in the Med. Add references here. Page 11, Section 2.4 1st paragraph. The authors to look the results of the CYCLOPS project in order to improve the description in this paragraph. 4th paragraph (regarding the Specific issues). The story of the generation of eddies is not applicable for the E.Med. Page 14 section 3.1 2nd paragraph. It is not clear up to which water depth the stability is reduced, its too general. Modify this part.”

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The reviewer repeats himself considerably and we have already answered many of the above comments. In any case, sections 2.3 and 2.4 have been amply revised to avoid ambiguities. More specifically, for section 2.4, 1st paragraph : an extensive quotation on the findings of the functioning of the microbial community in ultra-oligotrophic conditions obtained during the CYCLOPS project has been added to the “Present knowledge” section together with references. Regarding the 4th paragraph, we agree with the referee that mechanisms working in the E.Med, and W.Med, in producing mesoscale structures may be different (as quite different is the physiography of the two sub-basins) but in this paragraph only the biological implications are discussed. There is no need of discussion on the mesoscale dynamics per se, which is treated elsewhere in the paper (sub-section 2.2). We stick therefore to the original version of the paragraph.

8)“Page 15 3.2 1st paragraph: The discussion about the circulation and constrains with smaller scales and the shelf/slope to be deleted. It is a general one and does not add anything here. Page 16 1st paragraph: To much description of the circulation based on works used SST. There are no any works based on in-situ data describing the circulation ?? 2nd paragraph The AW in the E.Med. is a subsurface one. The eddies are stable and are not generated by the current as Gerin et al.2009, who used surface drifters. In contrary, Menna et al. 2012 come to a different conclusion when assimilated thousand of drifters with the geostrophy. The story mentioned in this paragraph regarding the circulation , unstable eddies, eddies generation in the E.Med. are based on SST images only and on one numerical simulation, the results of which are far from the ground truth. In contrary, the works based on in-situ data and numerical models with assimilation of in-situ data show a different picture of the flow dynamics in the area.”

First, following the suggestion of reviewer 1, section 3.2 has been moved to part 4 and is now section 4.3 . Again, we remark that the reviewer repeats himself with the same criticisms. In any case, the relevant paragraphs have been shortened and focused as

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requested. Recent works of Poulain et al (2012) and Menna et al. (2012) describing the circulation based on subsurface drifters and altimeter data have been referenced and a brief description of their results concerning the stability of the coastal current and related sub-basin scale features has been added.

“4th paragraph (regarding the specific issues) What is proposed here is already exists. In the Med such models with in-situ data assimilation exist (MONGOOS), MyOcean .”

This entire section has been rewritten and restructured. A description of the recent development of high resolution models within the framework of the operational forecasting system has been added.

9)“ Section 3.3 page 19 1st paragraph The role of Meddies (Mediterranean saline water in the North Atlantic) in the ms are overestimated. There are many-many other papers dealing with the Meddies characteristics, their dynamics in the N. Atlantic. The authors to search for those papers in order to improve this part of the ms. 2nd paragraph (regarding the Specific issues)There are already exist new data sets from SeaDaraNet abd EMODNET which passed screening, quality control procedures. Section 3.4 4th paragraph (regarding the Specific issues) Already exist high quality controlled db for the Med sea as a results of the SeaDataNet, EMODNET as well MyOcean. Page 27 section 4.1 3rd paragraph : add that in the E.Med are also available multi-parameter sensors. Page 28 5th paragraph Missing information about the recent studies and their variability in the Eastern Mediterranean and Levantine Basin based on thousands of new in-situ data, including from gliders.”

Again the reviewer repeats himself with the same comments, most of them unsubstantial. Furthermore, we have already addressed them in the answers above. Even more, the above mentioned sections have been fully revised so most of these comments do not apply any longer. Finally, regarding the papers on the features of the Meddies in the N. Atlantic , we remark that this paper deals with the Mediterranean, not the N.Atlantic.

10)“Page 31, section 4.2 1st and 2nd paragraphs: The last 5-8 years in the Med exist

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frequency surface forcing with 5-10 km resolution, used to force the daily high resolution (1 km, even in some case 500 m) circulation models of the MONGOOS community. Re-write these two paragraphs to reflect the today real situation on modeling the Med.”

These two paragraphs have been revised accordingly and a description given of the high resolution/frequency surface forcing used for the daily ocean forecasts.

“ Page 32 2nd paragraph : Again and again the same story about the eddies generation in the E. Med is repeatedly mentioned in several sections throughout the ms. To correct it based on the comments done for page 16.”

This has been shortened and revised following the revisions in the former section 3.2 with a description of the circulation based on subsurface drifters added to the text.

“Delete the last sentence of the 2nd paragraph, see the comments for the page 31“
Done.

“5th paragraph (regarding the Specific issues) : already exist what is proposing here to develop !!!”

The suggestion is to develop a high resolution (downscaled) surface forcing data set using a reanalysis approach in which the system used to generate the fields is frozen. The present high frequency/resolution surface forcing fields used to drive the ocean forecasting models is based on daily forecasts using an atmospheric model which will inevitably change and be upgraded with time. To have consistent long term forcing fields it is important to use a reanalysis approach. To the best of our knowledge this has not yet been done.

“ Page 33 1st paragraph Correct MONGOOS (former MOON). The QC procedures applied to the data before the assimilation in the operational models.”

Done

11)“Conclusions 2nd paragraph 2nd sentence . Clarify if the inversion of the circulation

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concerns the Ionian Sea, its not clear”

It has been clarified. Also,see the new section 3.1.

“ 3rd paragraph: Include in the 1st sentence that not only historical but recent observations prove that the Med sea is getting saltier. Add references.”

The sentence has been modified BUT references do NOT belong to the conclusions, they can be found in the different and relevant sub-sections.

“ Add the role of the operational oceanography in the increase of our knowledge for the Med sea.”

A sentence has been added.

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