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Discussions



# *Interactive comment on* "Transformation of Levantine Intermediate Water tracked by MedArgo floats in Western Mediterranean" *by* M. Emelianov et al.

**M. Emelianov et al.**

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The authors would like to express their gratitude for the positive reviews of the manuscript by Dr. Claude Millot and Dr. John Gould. Their comments seem to us very constructive and important, and allowed us to improve considerably the manuscript. In the sections below we reply to each general and specific comments by the two referees.

1 Reply to C. Millot

We agree that using "density range" (the first general comment) as criterion to determine the LIW layer can lead to including in the analysis waters that are situated above and/or below LIW. We have re-calculated the clusters according to C. Millot recommendations. In this new approach, and previous to the clustering, the program analyzes all the information, profile by profile, to determine the layer of LIW. The pressure of the LIW core is determined as the average pressure between that of the absolute maximum of salinity and that of the closest relative maximum of potential temperature. Once this core pressure is located, we extract the data included in the range from -200 db to +200 db around this point. This is done in a profile by profile basis, so for each profile its LIW, and only that, is taken into account for further processing, independently of at which depth LIW is present. The general results of clustering are the same as before, with differences only significant at the level of details. For example, LIW from cluster 7 is situated not only in the area close to the Sicily channel, but also in the central part between Sardinia and Menorca, marking more clear the transition between less transformed LIW from the eastern part of the analysed area and more transformed LIW from the western part. Results confirm the hypothesis about LIW structure proposed in the paper, and now we are sure to have avoided the influence of depth and any other "no Levantine water" in the clustering analysis. The sub-clustering results (only on the biggest cluster #1) also have now more clear spatial distribution with less transformed LIW in the east and more transformed in the west, all embedded in a warmer, saltier background. We have rewritten the paper to take account of these significant modifications on the processing and modified the text according to the new results and other recommendations from C. Millot.

Below we state the detailed responses to other general and specific comments by C. Millot: We introduced changes in the text according to the second general comment following the idea that LIW itself creates and maintains the circulation in the intermediate depth (“LIW spreads and circulates”). We also eliminated the sentence about LIW entrainment by the Algerian current. We agree with the referee that the surface Algerian current can not capture the intermediate LIW. We improved figures 2(b) and 5(b), changing the symbols and numbering of clusters according to the LIW transformation degree. Now “cold” colours and higher cluster numbers correspond to more transformed LIW, and clusters with less transformed LIW have smaller cluster number



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and “warm” colours. We added figures with representative profiles enveloped in all T,S profiles of the same cluster, providing the differences between profiles within each cluster and differences between “neighbouring” profiles belonging to different clusters. As we changed the determination of LIW layer from “density range” to “pressure range” we “automatically” resolved the specific problem of the bathymetry and of the location of the MWs veins, which is the objective of the last major comment. Now the clustering tool searches the absolute maximum of salinity in the pressure range between 200 and 600 decibars. It must be an extremum point in the salinity profile. If it is not an extremum point, it means that lower salinity values do not exist below the found salinity maximum (the case of profile “cut” by the bathymetry), and the profile will be eliminated from the clustering analysis. As we explained in our first author comments, the pressure of LIW core is determined as the average pressure between that of the absolute maximum of salinity and that of the closest relatively maximum of potential temperature. The range of +/- 200 db around LIW core was considered as the LIW layer. If the LIW core lies close to 600 db and the distance between it and the lower limit of the analysed layer (600 db) is less than 200 db, the clustering tool takes in the analysis the distance (in db) between LIW core and 600 db.

Specific comments:

- P.570, l.24: “westward path”. If the authors agree with my diagram, what I suppose, they should avoid using westward E.

Response: We changed “westward path” to “displacement”.

- P.570, l.25: “more to the west than the most transformed one” is unclear. First, it must be specified that the sentence concerns LIW along the slope of Sardinia in the Algerian subbasin. Second it should be more convenient to say “that LIW as unmixed as the LIW generally found alongslope can be found nearby in the interior of a subbasin”.

Response: We changed the sentence according to C. Millot recommendations.



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P.571, l.12: the authors must specify what are the different areas of LIW formation in the eastern basin and provide adequate references. I do not want to influence them but in our reference I gave above, the authors can find hypotheses about why LIW has been found away from the northern Levantine subbasin (that we assume is the sole place where it is formed). Basically, we assume processes similar to those already demonstrated for the Algerian subbasin: LIW forms roughly south of Rhodes then spreads and circulates alongslope, in particular south of Crete where it can be entrained by Ierapetra and transported, eventually till Egypt, and/or south of the Peloponese where it can be entrained by Pelops in general toward the interior of the Ionian subbasin.

Response: In the new version of the paper we specify only one well-known area of LIW formation, which is Rhodes area.

- P.571, l.16: I do not understand the notion of “suspended”. Any water lies, away from the zones of dense water formation, at a level corresponding to its own density: it floats and circulates above (denser) water below and below (lighter) water above.

Response: We changed the term “suspension” for “emulsion”. From our opinion the new term describes better what we want to say about the LIW thermohaline structure. In all cases we use this term only to illustrate our hypothesis and not to approximate it to the real situation.

- P.571, l.20: “sink up” down?

Response: This is now corrected.

- P.571, l.21: I am not sure that evaporation is larger in summer everywhere in the sea; in particular, dry continental air masses entrained over the sea by violent northerly winds in winter probably induce a non-negligible evaporation; seemingly, cooling can also be induced in summer due to the northerlies.

Response: You may be right, but this is another issue, beyond the scope of this paper. We only wanted to point out the main process for LIW generation, without further details.

- P.571, l.25: This is again a personal opinion that the authors might not share but I do not think that “the picture becomes even more complicated in the western basin”. Processes driving the functioning of each basin and the circulation in it are, according to me, relatively similar and there are, in both basins, eddies either wind-induced or “current-instability induced” that can entrain the alongslope veins towards the interior of the basin.

Response: We agree with you that the mechanisms of water mass formation and circulation are relatively similar in the eastern and western Mediterranean basins. Thus we eliminate “in the western basin” from line 25, P. 571.

- P. 572, l.14, fig. 1: Obvious errors on Theta and/or S should be corrected and erroneous points on the Theta-S diagram eliminated.

Response: It has been corrected.

- P. 574, section 3: Basic information about the MEDARGO characteristics are given only in the last lines of the Conclusion. I think that they should be given just at the beginning of section 3, furthermore it is essential to know which kind of information these floats can provide us with.

Response: We add basic information about the MEDARGO floats in section 2, “Materials and methods”. We also include in this section a brief description of data quality as recommended by the other referee.

- P. 574, l. 6, fig. 2: Erroneous locations (over land; why are locations in fig. 2 not similar to those in fig. 1?) should be corrected.

Response: It has been corrected.

- P. 574, l. 6: I think that differentiating “three main groups of clusters” is not obvious and not essential for the remainder.



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Response: This sentence has been eliminated.

- P. 574, l.10: I think it is not correct to deal wit clusters located “west of islands” instead of specifying “in the interior of the Provençal and Algerian subbasins” since the specificity of these clusters is mainly to be away from the slope.

Response: The new version of this sentence is: “Less saline cluster representatives 4, 5 and 6 include the profiles placed in the interior of the Provençal and Algerian subbasins, mainly away from the shelf slope of Corsica and Sardinia islands.”

- P. 575, l. 9: names that need to be specified and are not well known need to be mentioned in a figure

Response: The not well known names have been eliminated from the text.

- P. 575, l .10: I did not understand what is “the thermohaline inversion often observed”. Please detail and comment.

Response: The new version of this sentence is: “The Theta,S curve from this cast is relatively uniform and does not have the thermohaline inhomogeneities often observed above and below LIW core in other areas of the basin. These peculiarities are mainly formed by the processes of mixing and stirring of LIW with surrounded water masses.”

- P. 575, l. 15: I understand and agree that circulation and mixing are intensified in narrow passages, which should lead to homogenisation. But I am not sure that this will lead to the complete destruction of lenses, which is not what the authors consider for the distribution of LIW in the western basin, i.e. after LIW crossed the channel of Sicily. The authors must be careful in describing the various processes concerning homogeneity and properly describe their feeling.

Response: We only wanted to point out the important role of the Mediterranean straits in the modification of water thermohaline structure. May be this is another issue, beyond the scope of this paper.

- P.575, l. 17-18: one understands that the process invoked is double diffusion but this is not explicitly said; in addition, it is not explained why this process would lead to heterogeneities in the horizontal. This needs to be explained more carefully.

Response: The new version of this sentence is: “After crossing the channel area, as current velocities decrease, the “emulsion of LIW” returns to be separated into continuous (background layer) and dispersed (saltier and warmer lenses) phases. The thermohaline inhomogeneities begin to appear on Theta,S profiles due to double-diffusive mixing, which tends to diminish the remaining excesses of salt and heat (Kelley, 2001).”

- P. 576, l. 2: my own understanding of “patchiness” is “juxtaposition side by side” of classes. My own analysis of fig. 5 is “superposition” of classes that are “partly crossing each others”, which is normal since the analysis is spread over a relatively large time interval and, especially in the basin interior (i.e. away from the continental slopes), characteristics are dependent on mesoscale phenomena that are moving. Concerning fig. 5, let me emphasise that sub-cluster 1.3 is clearly considering deep features that are far from being related to LIW (hence demonstrating that the 29.0-29.1 criterion is not a good one).

Response: We changed “patchiness” to “spotty character” and with the change of LIW layer definition from density range to pressure range, we avoid the presence of non LIW water in the analysis.

- P. 576, l. 6-7: I think that the overall description of the “background transformation” could be improved. I personally think about LIW (and other water masses as well) continuously changing roughly anywhere, due to continuous mixing under normal conditions, and encountering, in a discontinuously manner, changes here and there: in the narrow passages (always), when de-structured by mesoscale eddies (from time to time and during any season), when involved in the process of dense water formation (in some specific places during winter only).

Response: We don’t see any contradiction between Dr. C. Millot point of view and our



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description.

- P.577, l. 8: I do not think that profiling floats suffer some “drag” (horizontally in the authors’ mind). They are entrained horizontally by the water in which they are ascending or descending (and do not “feel” these horizontal motions; they only feel as a drag their vertical displacement).

Response: We changed “drag” to “drift”.

2 Reply to J. Gould

We totally agree with Dr. J. Gould that sensors drift could dramatically affect the clustering results, especially in the case of small searching radius. The CTD data from MEDARGO floats are real time data (data mode is “R”) with ARGO real time quality control. Delayed mode process has not yet been done at Coriolis, as we have checked after receiving the reviewer’s comments. Following these recommendations we estimated possible drifts of the conductivity sensors. The average working period for the floats we have analysed is 6 months +/- 4 months. We examined all deep profiles (until 2000 db) from the floats that worked more than 6 months and calculated the difference between the first deep profile and all consecutive deep profiles in the deepest layer of the cast (1450-2000 db). The results of this analysis are presented in table 1.

Table.1. Salinity differences between deep profiles.

| 1stFloat#/Cast# | 1stDate | Next Float#/Cast# | NextDate | DS (psu) | Remarks |
|---|---|---|---|---|---|
| PROVOR293/2 | 09/09/2004 | PROVOR293/12 | 29/10/2004 | -0.0043 | |
| PROVOR293/2 | 09/09/2004 | PROVOR293/22 | 18/12/2004 | -0.0057 | |
| PROVOR293/2 | 09/09/2004 | PROVOR293/32 | 06/02/2005 | -0.0058 | |
| PROVOR293/2 | 09/09/2004 | PROVOR293/42 | 28/03/2005 | -0.0033 | |
| PROVOR293/2 | 09/09/2004 | PROVOR293/62 | 06/07/2005 | -0.0027 | |



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PROVOR293/2 09/09/2004 PROVOR293/70* 25/08/2005 -0.0058 *Different waters

PROVOR293/2 09/09/2004 PROVOR293/80 14/10/2005 -0.0005

PROVOR293/2 09/09/2004 PROVOR293/90 03/12/2005 0.0005

PROVOR293/2 09/09/2004 PROVOR293/99 22/01/2006 0.0015

APEX281/1 20/08/2004 APEX281/11 09/10/2004 0.0002

APEX281/1 20/08/2004 APEX281/20 20/11/2004 -0.0023

APEX281/1 20/08/2004 APEX281/29 17/01/2005 0.0016

APEX280/41 28/04/2005 APEX280/49 17/07/2005 -0.0010

APEX280/41 28/04/2005 APEX280/57 06/08/2005 -0.0003

PROVOR292/2 09/09/2004 PROVOR292/11 30/10/2004 -0.0025

PROVOR292/2 09/09/2004 PROVOR292/20 19/12/2004 -0.0074

PROVOR292/2 09/09/2004 PROVOR292/29 07/02/2005 -0.0072

PROVOR292/2 09/09/2004 PROVOR292/58 07/06/2005 -0.0063

PROVOR292/2 09/09/2004 PROVOR292/68* 26/08/2005 -0.0050 *Different waters

PROVOR292/2 09/09/2004 PROVOR292/77* 15/10/2005 -0.0132 *Different waters

PROVOR292/2 09/09/2004 PROVOR292/97* 23/01/2006 -0.0187 *Different waters

PROVOR291/1 09/09/2004 PROVOR291/11 29/10/2004 -0.0015

PROVOR291/1 09/09/2004 PROVOR291/21 18/12/2004 -0.0014

PROVOR291/1 09/09/2004 PROVOR291/30 06/02/2005 -0.0005

PROVOR291/1 09/09/2004 PROVOR291/49 17/05/2005 0.0031

PROVOR291/1 09/09/2004 PROVOR291/57* 06/07/2005 -0.0011 *Different water



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PROVOR291/1 09/09/2004 PROVOR291/67 25/08/2004 -0.0003

APEX279/1 05/07/2004 APEX279/11 24/08/2004 -0.0048

APEX279/1 05/07/2004 APEX279/21 13/10/2004 0.0008

APEX279/1 05/07/2004 APEX279/31 02/12/2004 -0.0079

APEX279/1 05/07/2004 APEX279/41 01/01/2005 0.0003

APEX279/1 05/07/2004 APEX279/51* 12/03/2005 -0.0188 *Different water

APEX279/1 05/07/2004 APEX279/60* 01/05/2005 -0.0163 *Different water

APEX282/1 20/08/2004 APEX282/11 09/10/2004 -0.0006

APEX282/1 20/08/2004 APEX282/20 28/11/2004 -0.0025

APEX282/1 20/08/2004 APEX282/30 08/03/2005 -0.0006

APEX282/1 20/08/2004 APEX282/38 27/04/2005 0.0040

APEX282/1 20/08/2004 APEX282/45 16/06/2005 -0.0065

APEX282/1 20/08/2004 APEX282/52* 05/08/2005 0.0076 *Different water

APEX278/1 05/07/2004 APEX278/10 24/08/2004 -0.0028

APEX278/1 05/07/2004 APEX278/46* 12/03/2005 0.0040 *Different water

APEX278/1 05/07/2004 APEX278/55* 01/05/2005 0.0070 *Different water

PROVOR556/22 03/07/2005 PROVOR556/32 28/08/2005 -0.0013

PROVOR556/22 03/07/2005 PROVOR556/62 19/01/2006 0.0025

According to table 1 we did not encounter any systematic changes in salinity values that could be interpreted as a drift. The magnitude of the differences is of order of 10-3 and increases with changes in deep water mass, while is lower inside the same water



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mass. These salinity differences do not affect our clustering because the searching radius is one order bigger (0.0125 psu). In case of subclustering the searching radius is 0.00625 psu and we are close to the obtained salinity differences. But the clustering tool analysed the salinity profile together with the temperature one (subclustering searching radius is 0.025 žC). Thus a possible drift in salinity data would be “neutralized” with the temperature, in the sense that if there was not a significant drift in T (and this is not the case) the profiles would not be erroneously attributed to a different subcluster. They would create instead a new subcluster, shifted in salinity but not in temperature. We can conclude that the real time quality controlled MEDARGO data are good enough to be used in our clustering analysis.

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Interactive comment on Ocean Sci. Discuss., 3, 569, 2006.