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Ocean Science
Discussions

Interactive comment on "About the seasonal and fortnightly variabilities of the Mediterranean outflow" *by* C. Millot and J. Garcia-Lafuente

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Comments by Vincenzo Artale

The paper entitle "About the seasonal and fortnightly variabilities of the Mediterranean outflow" by C. Millot and J. Garcia-Lafuente, tackle an important and hot scientific issue regarding the analysis of climatological and updated observations within the Gibraltar Strait, and in particular in three different sites (Cs, Es and Ms following figures of the manuscript), to study or at least increase the understanding about the physical mechanisms that drive the variability of the MOW; focusing on the main ocean phenomena observed in Gibraltar Strait, like mixing between different types of water of Mediterranean and Atlantic origin. The present paper is also relevant for ocean climate variability studies and in particular for research and simulation of the interaction

between Mediterranean Sea and North Atlantic. For all these reasons that the results of this paper are very interesting for the oceanographic communities and in particular for those scientists more implicated on the Mediterranean-Atlantic interaction or on its parameterization in numerical climate models. Therefore I recommend this paper to be published, but some revision is necessary before to be published.

General comments and major revision:

Because the phenomena analysis described in the paper is very complex from technical point of view and in order to be useful for a larger scientist community, I suggest to the authors to improve significantly the clearness of some sentences and concept, and in general all the paper: it is very difficult to read the paper in the present version. In order to improve the understanding of this paper my suggestion is to put in more evidence the link between the Alboran Sea sub-basins- the Strait of Gibraltar - the Gulf of Cadiz, in order to obtain a more readable paper (you can put this along the introduction and/or conclusion and discussion). Actually, this scheme is not very far from the present paper organization and therefore the authors should not spend more extra time to do that. The reason why I think that this new organization may improve significantly the paper came from the following consideration.

The main results of the paper can be summarize as the following: the Strait of Gibraltar is the first obstacle that the mediterranean outflow found along its traveling to the North Atlantic and the strait represents the first site where the pure MWs undergoes a strong mixing and entrainment with the inflowing Atlantic waters; but (very important!) the authors investigate in details where the mixing take place and what type of water take part on this events. Moreover the paper underline the variability of these mixing events in relation of time (tide) and of the space (the bifurcation of MWs between Cs and Ms). The novelty of this approach can improve the connection between the dynamics simulated by the numerical model and the in situ observations (the validation of the numerical model!). For example the mixing in Cs is more pronounced because the hydraulic control produces an hydraulic jump and consequently more vertical mixing is

enhanced (see fig. 17 of Sannino et al., 2004, or see figure below, where is possible to find further indication of the strong mixing induced by tides in the Strait of Gibraltar and its particular place). Furthermore, when the mediterranean water pass over Cs has lost its original characteristic, taking now the properties of the source water of the MW that will be later observed in the North Atlantic. The authors conclude that the outflow within the strait display a spatial heterogeneity (an other important point!), moreover it's well know that after passing the Strait of Gibraltar, in the Gulf of Cadiz, the main core of MW divides into two major cores: Mediterranean Upper (MU) Water and the Mediterranean Lower (ML) Water: the MU, the less dense warm core (36.5–37 and 13–14 °C), flows along the Spain–Portugal continental shelf (300–800 m), while the denser core ML (36.5–37.5 and 10.5–11.5 °C) flows at depths around 1100–1400m, both waters can produce meddies. Is there a relationship between that two phenomena: spatial heterogeneity and bifurcation? For example Siedler (1968) put forward the hypothesis that the two maxima were the consequence of tidal mixing within the Strait of Gibraltar, moreover Zenk (1975b) shows that tidal currents have a strong effect on the formation of preferred outflowing water types. An other important results is related to atypical neap-tide, I'm very curious to know about a possible effect of these events on the interannual variability of the lents of mediterranean water observed first in the Gulf of Cadiz and than in the North Atlantic (e.g. number of meddies for year). In Fusco et al., 2008 and the figure below, we observed an interannual variability on the production of salt anomaly at intermediate level.

minor revision:

line.... introduction, again is not clear what are the major/new results of the paper; line 27 the word "concept" seem to me not appropriated, "result" could be better? line 44-45 the sentence in not clear; line 53-54 appropriate reference about the two branches in which the MW's core splits (e.g. Borenas, K.M., Wahlin, A.K., Ambar, I., Serra, N., 2002. The Mediterranean outflow splittingâĂŤa comparison between theoretical models and CANIGO data. Deep-Sea Research II 49, 4195–4205) line 89 -90 (day1,

d1)? no clear; line 207 the concept "atypical" is important, please one more sentence in order to be clear.

References to include in the paper:

1. Borenas, K.M., Wahlin, A.K., Ambar, I., Serra, N., 2002. The Mediterranean outflow splitting, a comparison between theoretical models and CANIGO data. Deep-Sea Research II 49, 4195–4205 2. Fusco, G., Artale V., Cotroneo Y.; Thermohaline variability of Mediterranean Water in the Gulf of Cadiz over the last decades (1948-1999), Deep Sea Research Part I: Oceanographic Research Papers, Volume 55, Issue 12, Pages 1624-1638, 2008; 3. Siedler, G., 1968. The frequency distribution of water types in the outflow region of straits. Kieler Meeresforschungen 24, 59–65. 4. Zenk, W., 1975a. On the Mediterranean outflow west of Gibraltar. Meteor Forschungsergeb 16, 23–24. 5. Zenk, W., 1975b. On the origin of the intermediate double-maxima in T/S profile from the North Atlantic. Meteor Forschungsergeb 16, 35–43. 6. Sannino, G., Bargagli, A., Artale, V., 2004. Numerical modeling of the semidiurnal tidal exchange through the Strait of Gibraltar. Journal of Geophysical Research 109, C05011. 7. Sannino, G., Carillo, A., Artale, V., 2007. Three-layer view of transports and hydraulics in the Strait of Gibraltar: a three-dimensional model study. Journal of Geophysical Research 112, C03010.

Figures useful for our discussion :

Fig.1 Salinity anomaly in the Gulf of Cadiz in the last century at intermediate level, elaboration from Medar-Medatlas data set. Fig.2 from Sannino et al., 2004

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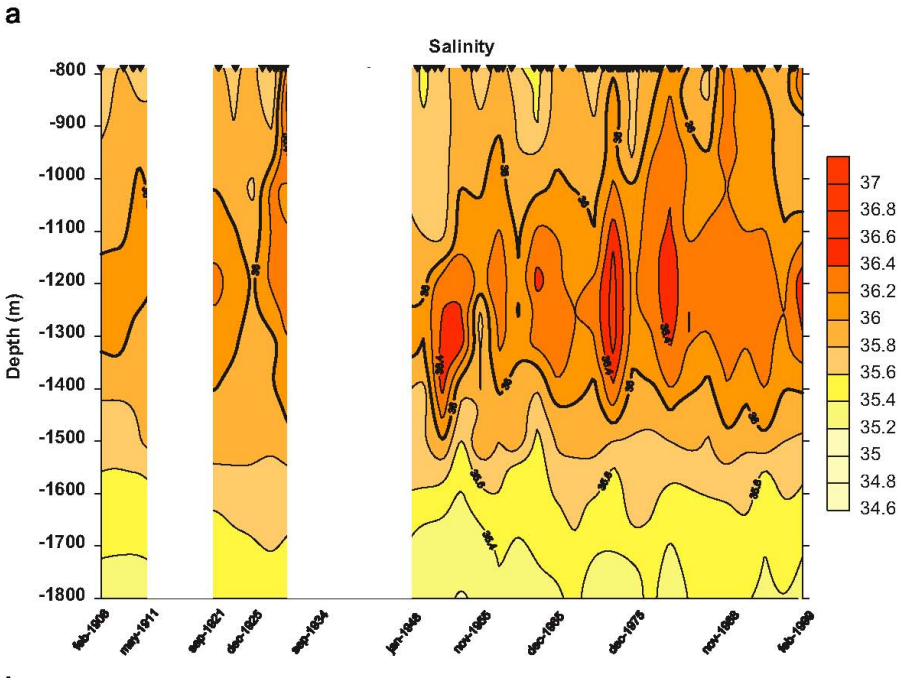

Fig. 1.

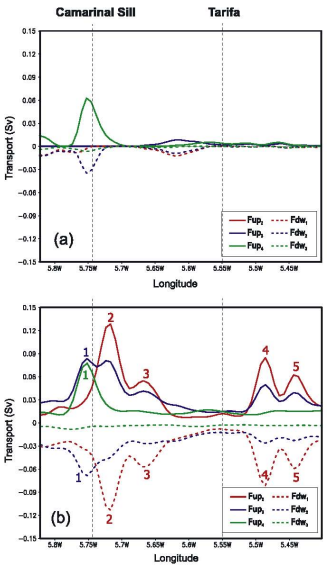

Figure 17. Along-strait time-averaged (on a fortnight period) entrained and detrained volume fluxes between layers (the same as Figure 16) for the case (a) without and (b) with tidal forcing. Positive values (solid lines) indicate upward volume flux, while negative value (dashed lines) represent downward volume fluxes. Positive red, blue, and green lines represent entrainment from L2 to L1, from L3 to L2, and from L4 to L3, respectively. Negative red, blue, and green lines represent entrainment from L1 to L2, from L2 to L3, and from L3 to L4, respectively.

Fig. 2.