

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

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Thanks a lot for your comments. Here below are our answers and/or comments.

1. I found that last sentence of the abstract confusing – the “outflow entering the strait” could be written as “Mediterranean Waters entering the strait”, while the last part of the sentence might be written as: “predicting the characteristics of the outflow to the ocean appears almost impossible.” \*\*\*We basically agree but want to stress that our remark concerns the outflow once it has cascaded at its 1000-1200-m stability level in the ocean, hence its characteristics in most of the northern Atlantic. We propose to modify our sentence such as: “Furthermore, since the outflowing waters entering the strait display marked spatial heterogeneity and long-term temporal variabilities, predicting the characteristics of the Mediterranean outflow when in the ocean appears almost

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impossible.”

2. I found the abbreviations used made the manuscript very difficult to read. I am quite comfortable with defined water masses (e.g. WIW, SAW, NACW) being described by acronyms. However the abbreviations MWs, AW, Cs, Es, and Ms should be expanded. \*\*\*We are pleased to note that you are comfortable with relatively esoteric water masses acronyms such as WIW, LIW, TDW, WMDW, SAW and NACW. Comparatively, we expected that acronyms such as MWs (for Mediterranean Waters) and AW (for Atlantic Water) could have been relatively clear and obvious; furthermore, we have been using them for years, in particular in all the first author’s papers about Gibraltar, they are frequently used in this paper and they are consistent with previous acronyms (using a W for Water). These MWs and AW acronyms are used 68 and 55 times, respectively, while the Cs, Es and Ms acronyms are used 59, 47 and 25 times, respectively, so that it seems reasonable to use them instead of expanded text. Since this is not a scientific issue, we propose to follow the Editor’s decision in both cases.

3. The first sentence of the introduction notes assumptions made by other papers; these papers need to be referenced. \*\*\*Referencing these papers is not easy. Most papers explicitly dealing with the outflow composition have considered it was composed of LIW and WMDW only. These papers are relatively recent but all other papers, many being much more ancient, which have been dealing with dynamical issues, have implicitly made such an assumption or, more precisely, have considered that the outflow was homogeneous. Even though we understand the comment, we thus do not feel comfortable in referencing papers since this would put emphasis on only some of them. We propose re-writing the sentence such as: “Historically, the outflow through the Strait of Gibraltar has been considered as composed . . . etc.”

4. There is a long description of current hypotheses of the structure of water masses within the strait on page 2046. I found this very difficult to follow, and suggest that a cartoon may be useful in showing these ideas. \*\*\* First, please note that the first author’s papers about Gibraltar express ideas dramatically different from previously ex-

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pressed ones. Even though these ideas are very simple once assimilated, they involve processes never envisaged in numerical simulations. These ideas are supported by all available data, in particular those previously re-analysed by the first author. Therefore, our paper cannot be understood easily without any knowledge about our previous results (as suggested in the Introduction). Second, such a cartoon has already been published as Fig. 5 of Millot et al. (2006), which is our first paper about Gibraltar. Note that it was inferred from the CTD time series at Cs and Ms we had at these times and from a preliminary analysis of the CTD vertical profiles available in the Cs and Ms surroundings. We did not analyse yet the Gibraltar Experiment profiles and did not envisage yet that WIW was so clearly seen within the strait (so that WIW is not schematised in this cartoon). Therefore, we have found it appropriate to include “(see Fig.5 of Millot et al (2006))” at the end of a sentence near l.18 in p.2045 which is where we first deal with the outflow structure.

5. The Moroccan Shelf data is barely used in the paper; it should be more clear at the start of the data analysis as to why this data needs to be included (or else it could be omitted). \*\*\*We disagree: -the Ms data in Fig.1c clearly illustrate the AW composition and demonstrate the occurrence of both NACW and SAW (at least on the Moroccan shelf). -the Ms data in Fig.1c provide a good idea about the “overall range” of the parameters in the study area -the Ms data in Fig.1c are necessary to validate the “towards SAW” and “towards NACW” indications that are specified in Fig.4b,c, which is essential since you agree that “The results are significant; they show a marked seasonal variability in outflow characteristics ...”. Note that MWs relatively mixed with AW can be encountered at Cs (as compared to those encountered at Es, due to their relative depths) -the Ms data in Fig.1d show that the MWs can be denser there (at 80 m) than at Es (360 m); there (at Ms) they can be even denser than at Cs (see Millot, 2009). Even when not discussed here, this result is worthy to be indicated. -as detailed in the fifth paragraph of section 2.1, the Ms data in Fig.3b show that a very similar seasonal variability occurs also in this site. -the Ms data in Fig.3b also show that MWs relatively unmixed with AW (slopes of 60-80°) can be encountered at 80 m on the Moroccan

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shelf -finally, the Ms and Cs data in Fig.3b show that, as expected, shallower (deeper) MWs mix preferentially with shallower (deeper) AW, i.e. MWs at Ms (resp. Cs) mix preferentially with SAW (resp. NACW)

6. The seasonal variability noted here is the strongest part of the paper. The T-S diagrams clearly show a nice distinction between winter and summer mixing between the two incoming water masses. However, this section finished with a short conjecture explaining why mixing may be dependent upon seasons. It would dramatically enhance the paper if that explanation could be described more clearly and in particular backed up with some more solid evidence. \*\*\*We agree about the idea but are convinced that we lack of adequate data. Even though you should be aware of the whole set of available CTD profiles, you might be convinced by the re-analysis of the Gibraltar Experiment we made in previous papers, which can be summarized, for what concerns this specific point, by Fig.16B of Millot (2009). GIB1 (March-April 1986) and GIB2 (September-October 1986) data were collected at the same locations (1-7 from south to north), as well as the LYNCH (November 1985) data (sections 1-2 being made one after the other and just 10 days before sections 3-4). Even though fall data show, as expected, a relatively large amount of SAW, hence more stratification than during spring, note that: -at a 10-day interval (LYNCH) NACW can be present all across the strait (1-2) or absent (3-4), which dramatically modifies, at such a 10-day interval (or less!), the characteristics of the Mediterranean outflow (cf. your remark about the last sentence in the abstract) -when present, NACW can be either spread over the whole strait (LYNCH 1-2), or concentrated in the North (only at stations 6-7, GIB1), or concentrated in the south (only at stations 1-2, GIB2). -none of the available CTD campaigns was made in winter (we can understand!). However, schematically, we can illustrate our “short conjecture explaining why mixing may be dependent upon seasons” with the LYNCH data: In the simplest case, i.e. when both NACW and SAW are present one lying over the other all across the strait (LYNCH 1-2), the MWs in the deeper part of the strait (e.g. Cs, Es) preferentially mix with NACW, hence leading to MWs-AW mixing lines having relatively small slopes. Statistically, this represents a summer situation.

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In winter, when meteorological conditions essentially increase the mixing of SAW and NACW, the MWs in the deeper part of the strait (e.g. Cs, Es) preferentially mix with some kind of NACW-SAW mixture, hence leading to MWs-AW mixing lines having relatively large slopes (as during LYNCH 3-4).

7. The fortnightly variability section is relatively weak, and much more needs to be answered here. \*\*\*We agree that the fortnightly variability section is relatively weak but we think that a) a lot has already been done about such variability there, b) dealing with such variability necessarily needs to rely on data over the vertical, what we plan to do with already available ADCP data in the future, c) we just want to provide additional information inferred from the two time series we deal with. Our main intention is thus to illustrate, without carrying out computations, how dependent on the tide are time series at the two sills. During springs (Fig.4d), MWs are strongly mixed as soon as Cs and these waters are generally those that will be encountered at Es further downstream. During neaps (Fig.4e), MWs can remain unmixed at Cs while they are always mixed at Es, even if slightly than during springs. However, MWs at Cs are not necessarily those encountered at Es, as illustrated during an “atypical” neap period in Fig.4f (more on this will be dealt with in a forthcoming paper).

Are these data from summer or winter? \*\*\*We agree that this information was not specified, even though it can be retrieved from Fig.3a (the green rectangle) and Fig.3c (the cyan and violet rectangles). Data are thus roughly from spring. Whatever the case, we do not think this is major information. Indeed, both spring and neap tides have consequences that markedly vary over time (see Fig.3c). We have chosen a set of following spring and neap tides periods showing characteristics as much different as possible to clearly illustrate our basic ideas.

What defines atypical neap periods and why is the mixing so different in these cases? \*\*\*We agree that our definition of “atypical” is not clear enough and we will improve it. When considering the examples illustrating the seasonal variability (Fig.4b vs. Fig.4c) as well as the spring tide characteristics (Fig.4d), the MWs-AW mixing lines at both

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Cs and Es are superposed, which indicates that the MWs outflowing at Cs outflow more mixed at Es. This is the most frequent situation that we refer to as “typical”. This is a consequence of both Cs and Es being roughly on the same streamline. Such similarities would not have been encountered for Es located more to the south or to the north (forthcoming paper). Just as an example of such an heterogeneity, we qualified as “atypical” the period shown in Fig.4f during which the MWs outflowing at Cs were not retrieved at Es (i.e. Cs and Es were not located along the same streamline).

The data is relatively sparse, why is this? and can more be done here? \*\*\*We are sorry but do not clearly understand your comment.

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Interactive comment on Ocean Sci. Discuss., 7, 2043, 2010.