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Interactive comment on "Modelling deep-water formation in the North-West Mediterranean Sea with a new air-sea coupled model: sensitivity to turbulent flux parameterizations" *by* Léo Seyfried et al.

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Response to Referee #1

The paper has been revised according to the comments from the reviewers and we thank both reviewers for their very helpful comments and suggestions. Our point-by-point response is inserted in the reviewer's comments.

Reviewer's Comment: The authors are presenting a novel study assessing the ability of a regional ocean atmosphere coupled system to correctly represent ocean convection,

especially the sensitivity of the system to the parameterization of turbulent fluxes. First, the authors assessed the model results through detailed comparisons with different observational datasets and show that the coupled system satisfactorily simulates the formation of deep water. After evaluating the uncertainties associated with the different turbulent fluxes parameterizations, the authors carried out several simulations based on 3 commonly used turbulent flux parameterizations. Their results highlight that the choice of the turbulent flux parameterization strongly influences the simulation of open ocean deep convection, especially in terms of volume of newly-formed deep water that can be different from one order of magnitude according to the parameterization choices. Open ocean deep convection plays a key role in the ocean circulation and the results found by the authors are important and will be certainly useful not only for the research groups working on the Mediterranean Sea but also in the North Atlantic, Nordic Seas, and/or Antarctic Seas. From my point of view, the manuscript represents an important contribution to our understanding of modeling deep water formation. If the scientific and presentation quality of this article are good in general, I have some (minor) comments for the authors:

RC: p5,l16 & p8,l31: What do you mean by "departure"?

Authors' Answer: These two sentences have been rephrased: "However, the difference between COARE3.0 and ANDREAS only occurred from wind speeds greater than 16 $m\,s^{-1}$ (as compared to 8 $m\,s^{-1}$ for the sensible heat flux)." "As the results were found in good agreement with the observations and did not reveal significant difference between the simulations, they are not presented here. "

RC: p6,l11: the "MAW" are not introduced before. What is the difference with the AW?

AA: The Atlantic Water corresponds to the recent surface water which enters the Mediterranean at the Gibraltar strait and spreads in the southern basin. Along its path-way into the Mediterranean basin, this Atlantic water is modified under the effect of surface heat fluxes and of vertical mixing in the convective regions. It becomes the

Modified Atlantic water (MAW).

Modified text in the manuscript "In summer (Fig. 3a), the most stratified water ($SI(1000\ m) > 120\ kg\ m^{-2}$) present in the south corresponds to recent Atlantic Water (AW), while the less stratified water ($SI(1000m) < 80\ kg\ m^{-2}$), confined to the north of the deep basin (above 42 $^{\circ}N$), corresponds to an older Atlantic water mass, which along its pathway into the Mediterranean basin has been modified under the effect of surface heat fluxes and of vertical mixing in the convective regions."

RC: P6,l27: "(ECMWF) with a horizontal resolution of $\frac{1}{8}$" is it the horizontal resolution of the grid choose to export the reanalysis, or is it the resolution of the atmospheric model ?

AA: It is the resolution of the ECMWF atmospheric analysis (16 km)

RC: P8,l8: What do you mean by "sound interpretation"?

AA: "sound interpretation" has been replaced by "rigorous analysis"

RC: p8,l10 : "two simulations do".two simulations.

AA: Seems correct with do.

RC: P9,l1 : "give good agreement" are in good agreement

AA: Done

RC: p9, l24: Maybe you could had that if the SST does'nt decrease at that time, it's because the mixed layer is deepening and SI continue to decrease.

AA: Done

RC: p10,l3 : "... the water column experienced ..." the water column could experience [...], in absence of horizontal advection

AA: Done

RC: p11,l12-15: Maybe you could quantify this , for example by calculating RMSE for each case and add them to the table. What about the excess of mixing outside the deep-mixing area, is it due to the ocean model or the air-sea flux? Is it more important using the MOON simulation? To answer these questions, it might be interesting to look at the bias in different sub-regions (Northern Current, Deep Mixing, NBF-South) instead of a single one.

AA: RMSEs have been included in Table 3 and the following text added in the manuscript: "The slightly better performance of MOON is confirmed by the RMSEs which are weaker for MOON than for COARE and ANDREAS, including for DEWEX Leg 2 at 1500 m and 2000 m depths."

The excess of mixing outside the deep-mixing area, for all simulations, is probably due to the inaccurate initial conditions in the Algerian basin.. In the northern part of the domain and south of the NBF, the initial conditions have been corrected following Estournel et al, 2016, but due to the lack of observations initial conditions remained unchanged over the Algerian basin. By advection, any excess of mixing in the Algerian basin will propagate and eventually contaminate the NBF-south region. This issue is currently under investigation and has to be addressed before running multi-year simulations.

The reviewer's suggestion regarding sub-domain analysis is interesting and was explored. However, for Dewex Leg 2, due to the limited number of observations, the results were found very sensitive to the definition of the sub-domains. These results are not included in the paper.

RC: P12, section 5.3.2 Are you expecting to really be able to simulate the exact timing of convective mixing as in the obs? Is the too early mixing in MOON due to too important BMF? By looking figure 11, the stratification at the end of January in the obs seem to be small. Maybe adding the MLD superimposed to the 4 different sections and a 5th sub-panel with a comparison of IS calculated from the simulations and the observation would be clearer for the reader to appreciate the time evolution of the mixing and the difference between simulations and observations.

AA: To simulate the exact timing of deep convection is a tricky issue due to the weak stratification prevailing before the convective events (end of January). Small differences in the BMF in January can delay (or advance) the triggering of convection from one strong wind episode to the next (or previous) one. The too early mixing in MOON is probably induced by a too large BMF. However, this error on timing is only of a few days and the MOON simulation reproduces fairly well the succession of mixing events. As suggested by the reviewer, the MLD has been superimposed on the 3 simulated sections to ease the comparison. Unfortunately, the lack of observations in the surface boundary layer did not allow the provision of a similar figure for the observations.

RC: P13, l12-14: " Our study demonstrates that are strongly sensitive to the turbulent flux parameterizations, not only air surface temperature and moisture but also sea surface temperature" you should simplify this sentence. For example: In addition to air surface temperature and moisture , sea surface temperature is also strongly sensitive to the turbulent flux parameterizations.

AA: Done

RC: P13: l26: " In terms of stratification, the effect of MOON was also found to be positive, with again a general reduction of the bias between observed and computed parameters." you should simplify this sentence to make it clearer (e.g.: In terms of stratification, the use of MOON also led to a general reduction of the bias between observed and computed parameters.

AA: Done

RC: Table2: It seems that there are extra zero in front of some first digits.

AA: Corrected

RC: Figures: A lot of the figures are very low resolution (label difficult or impossible to

read) and should be of better quality before being published (increase dpi or export in pdf) -

AA: The quality of the figures has been improved. The new figures have been uploaded.

RC: Figures 4,6,7: you should add in the legend that the grey shaded areas correspond to strong wind periods. The grey areas are also very difficult/impossible to see and should be darker, or you could replace the grey shade by an horizontal line on the upper and lower part of each panel.

AA: The grey areas have been made darker and their meaning added to the caption.

RC: Figure 11: During the mixing period in mid-February The instrument at 500m and 700m seem to give a lower potential density that the upper and lower instruments (> 29.12). Is it a calibration issue or a colorbar effect ?

AA: Unfortunately, this is due to a calibration issue. The 500 m observations have been removed from the plot to avoid confusion.

Please also note the supplement to this comment:
https://www.ocean-sci-discuss.net/os-2017-43/os-2017-43-AC1-supplement.pdf

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