Nat. Hazards Earth Syst. Sci. Discuss.,
https://doi.org/10.5194/nhess-2018-23-RC2, 2018 ©

Natural Hazards and Earth System Sciences
Open Access
Discussions

Interactive comment on "Implementation and validation of a new operational wave forecasting system of the Mediterranean Monitoring and Forecasting Centre in the framework of the Copernicus Marine Environment Monitoring Service" by Michalis Ravdas et al.

Anonymous Referee #2

Received and published: 3 April 2018

The paper is rather well organized and well-written, supported by interesting data. It could deserve publication on NHESS provided some further aspects are discussed and cleared. Most of all, I think that better acknowledgements or pin-pint to existing publications referring to the atmosphere-ocean-wave interactions should be given. At the moment, this is just very briefly mentioned in the Introduction (line 9). This part remains indeed in the shadow; however, although this is surely not the core of the MS discussion, it should be clearly stated that fundamental steps have been taken into the direction of "coupled" modeling.

We thank the reviewer for his/her interesting and helpful comments which have all been taken into account and answered. In the revised version of the manuscript, we have enriched the introduction and the conclusions with text related to atmosphere – ocean – wave interactions through a full coupling indicating possible impacts on wave model performance.

I will then address to some possible references concerning the Adriatic sea (where the model performs at its minimum) and other regions, since course similar efforts exist also in other regions of the Mediterranean.

In the introduction and in the conclusions of the manuscript we have taken into account suggested work adding appropriate references:

Carniel S.et al., 2016. Scratching beneath the surface when coupling atmosphere, ocean and waves: analysis of a dense-water formation event. Ocean Modelling, 101, 101-112.DOI: 10.1016/j.ocemod.2016.03.007

Ricchi A. et al., 2016. On the use of a coupled ocean-atmosphere-wave model during an extreme Cold Air Outbreak over the Adriatic Sea. Atmospheric Research, 172-173, 48-65. DOI: 10.1016/j.atmosres.2015.12.023

The fact that this MS is using off-line currents is a step into the right direction, but it does not exempt the authors to mention that this should follow a real coupled approach. There are, therefore, two main aspects that need to be well recalled in this work. a) The need of a real, full two-way coupling has to be recalled and well stated b) 1/16° is probably a too coarse resolution to expect improvements from the wave-currents feedbacks!

a) In the conclusions of the manuscript we mention that one of our near future goals in the framework of CMEMS is the two-way coupling between the oceanic and wave component of the Mediterranean MFC. This is a collaborative approach between the CMCC scientific team who leads the modelling of the physical part and the HCMR team who is responsible for wave forecasting within MED MFC. Preliminary results of this work are shown in Clementi et. al. (2017).

b) The following figure (fig1) shows the Symmetrically Normalized RMSE (SNRMSE), which has been found to be more robust than RMSE when comparing data with similar level of performance (Hanna and Heinold, 1985), between wave buoy observations at individual wave buoy locations (red dots) and 1/24º (top numbers) and 1/16º (bottom numbers) surface currents forcing respectively, for 1 year period (2014). Top numbers highlighted in green indicate a better metric value compared to bottom numbers (i.e. 1/24 better than 1/16). Otherwise, bottom numbers correspond to a better or equal metric value. The figure shows that a small improvement (< 2%) occurred with the increased resolution surface currents forcing at 20 out of the 31 buoys examined. The increase of surface currents resolution from 1/16º to 1/24º pertains to the following version of the CMEMS MED MFC Waves System.

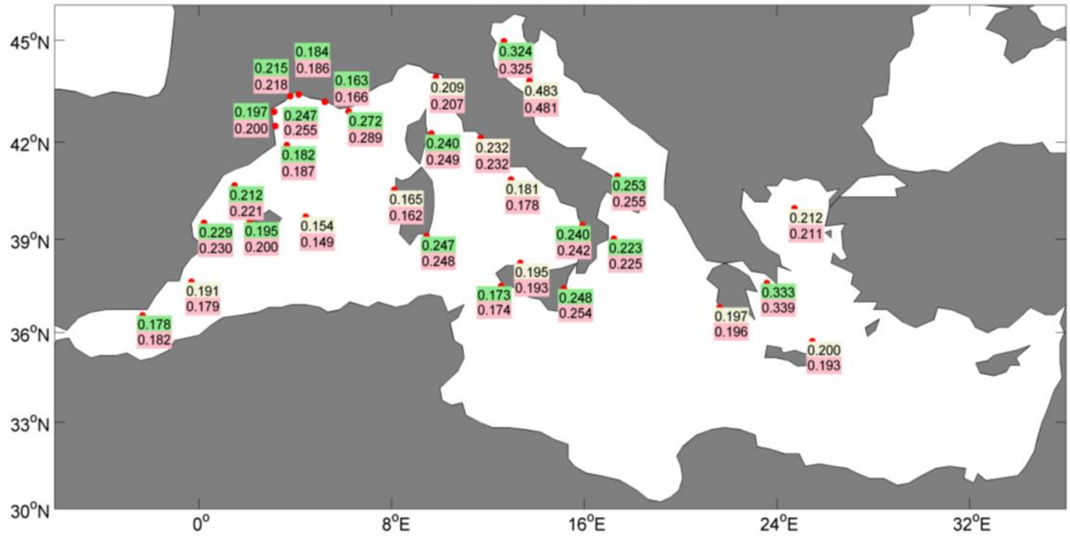

Fig.1 Off-line coupling with 1/24 surface currents does not improve the scores in the Adriatic

The authors justify the less-good performances of the model in enclosed basins and near the coast, calling for unresolved topography and fetch limitations. I would recommend some more details on the bathymetry chosen by the model, since there exist several efforts to provide a higher-resolution bathymetry of this region (see for a possible check the EMODnet portal)

The problem of "unresolved topography" refers to the inability of the relative low resolution (1/24º) wave forecasting system to resolve fine bathymetric features, encountered, for example, in regions such as the Adriatic and Aegean Seas. In addition, it refers to the inability of the relative low resolution (1/8º) ECMWF wind forcing to properly resolve fine orography. Consequently, the problem of unresolved bathymetry cannot merely be tackled by a higher resolution bathymetry (e.g. EMODNET) without the synchronous increase of wave model resolution. This would only lead to insignificant change in the performance of the system in marine areas of complex topography. Moreover, for a major improvement of the wave model performance an increase of wind forcing resolution would be required.

In general, the new forecast system provides reliable forecasts. However, model performances appear to be better in winter rather than summer, since in winter "the wave conditions are well-defined". What do the authors mean exactly by this? Could this again be linked to the specific metocean conditions? Is this valid throughout all the regions explored? Again, I wonder if this could be explained by a lacking consideration of the oceanic and mixed layer depth area dynamics, that could be introduced by a coupled model approach.

As explained in the manuscript (p8, lines 13-14, original manuscript), well-defined wave conditions refer to stormy conditions with well-defined patterns and higher waves. In other words, well-defined wave conditions are linked to strong winds which lead to a more organized sea with better-formed waves. This is a common result in the literature (references are provided in p8, lines 14-15) and is mostly associated to a better quality wind forcing in 'stormy' conditions. For example, Ardhuin et al (2007), which examined wind and wave model performance in the western Mediterranean Sea using four difference sources of wind models (including ECMWF) to force three different wave models, concluded:"The accuracy of the model wind fields depends on how well the meteorological situation is defined. In stormy, well-extended areas the models are more consistent to each other. For more uncertain situations the percent errors tend to be larger". Also, the same study found that wave model forecast skill deteriorates for low waves (Hs < 1.5 m), particularly close to the coasts. In our study, enhanced winter wave model performance is valid for all the regions explored except for the central and east Levantine Basin (lev2, lev3, lev4). Despite the difficulties in the direct comparison of wind and wave model performance due to the change of the whitecapping dissipation coefficients in WAM (see p11, lines 30-33, original manuscript) which strongly offsets bias, we found that a considerably reduced overall wind performance is observed in the Levantine Basin in winter in relation to summer with the SNRMSE being higher by 5% - 13% in the former season. This could explain why the wave model performance in the Levantine Basin in worst in winter than in summer whilst the contrary is true in all other regions. Wind SNRMSE is also worst in winter than in summer in the Aegean Sea (< 5%), in the Western Ionian Sea (ion1) and in the North West Shelf (< 1%). Wind SI is worst in winter than in summer in the Levantine Basin and the Aegean Sea. Within the remaining regions, wind performance is better in winter (no seasonal results could be obtained for the Adriatic Sea due to a lack of sufficient wind observations).

We believe that the current version of our wave system includes all the mechanisms with an important role in modifying the wave field at the current horizontal resolution. Sea-level variations during extreme weather conditions could play a significant role in modifying the wave field, however, this is true very near the shore where a coastal wave model application would be appropriate. Wave-current full 2-way coupling could be a possible mechanism for improving wave model results although we believe that the 2-way coupling approach is more beneficial for the circulation (e.g. wave modified surface stress) and hydrology (e.g. wave induced vertical mixing, additional advection through the stokes drift velocity) than for the waves.

Future improvements: authors mention data assimilation and higher resolution wind forcing. Again, no mention is done to the coupled atmosphere-ocean-wave models, although this has proven to be a not-negligible source of increased performances exactly in semi-enclosed seas (see references at the bottom).

Moreover, I would welcome few strategic lines discussing the scenarios under plausible climate change in the next decades (also with this respect I have suggested some readings to the authors)

The authors find it hard to see the relationship between the performance of an operational analysis and forecast wave system and wave climate scenarios or wave climate statistics of any nature. Hindcast or reanalysis wave products, also included within the CMEMS framework, would be suited for such a correlation.

As I stated above, the MS is too much focused on the "pure wave forecast". I think the MS would benefit a lot from an approach showing that ocean-atmosphere and waves are actually connected in a delicate interplay of energetic exchange and feed-backs. I therefore recommend to modify the Introduction and Discussion with the aim of mentioning already existing *coupled* (not just off-line as used) numerical model approaches, where the global physics of A-O-W is actually taken into account. Below here I suggest some reading/references that may be mentioned in the MS.

In the revised version of the manuscript (introduction and conclusions) we have added a paragraph related to A-O-W coupling taking into consideration the reviewer's literature suggestions and we outline the benefits and the difficulties of a full coupling system for an operational wave forecast system in the Mediterranean Sea.

For improving the introduction, where possible effects of appropriate or un-accurate wave modeling efforts mya have on the overall Adriatic basin dynamics: Boldrin A. et al., 2009. The effect of Bora wind on physical and bio-chemical properties of strati-fied waters in the Northern Adriatic. Journal of Geophysical Research – Ocean, 114, C08S92. DOI:10.1029/2008JC004837 Bonaldo D. et al., 2015. Modelling wave-driven sediment transport in a changing climate: a case study for Northern Adriatic sea (Italy). Regional Environmental Change, 15(1), 45-55, DOI: 10.1007/s10113-014-0619-7

For mentioning the relevance that coupled approaches may have in forecasting waves in the Adriatic sea, going therefore beyond the pure wind-wave relation: Carniel S. et al., 2016. Scratching beneath the surface when coupling atmosphere, ocean and waves: analysis of a dense-water formation event. Ocean Modelling, 101, 101-112. DOI: 10.1016/j.ocemod.2016.03.007 and references therein incluided Ricchi A. et al., 2016. On the use of a coupled ocean-atmosphere-wave model during an extreme Cold Air Outbreak over the Adriatic Sea. Atmospheric Research, 172-173, 48-65. DOI: 10.1016/j.atmosres.2015.12.023

For a recent assessment of wind storminess under climate change scenarios: Bonaldo D. et al., 2018. Wind storminess in the Adriatic Sea in a climate change scenario. Acta Adriatica 58(2), 195-208

Interactive comment on Nat. Hazards Earth Syst. Sci. Discuss., https://doi.org/10.5194/nhess-2018-23, 2018.