Response to the reviewers' comments on the manuscript "Performance of the Adriatic early warning system during the multi-meteotsunami event of 11-19 May 2020: an assessment using energy banners" by Tojčić et al., submitted to NHESS (nhess-2020-409)

The authors, despite being extremely surprised to discover major revisions in the second review that were not mentioned in the first one, appreciate the careful consideration given by the reviewer to the presented work. Most of the revisions were implemented in the new version of the article and they definitely improve the manuscript. However, the authors feel that major revisions asked in points 3 and 5 are essentially based on a misunderstanding of what early warning systems can achieve. First, the presented CMeEWS is a research product still under development and, second, even well-funded early warning systems, such as the NOAA hurricane early warning system (NHC, https://www.nhc.noaa.gov) or the CEA European tsunami early warning system (CENALT, Schindele et al., 2015), often fail to forecast extreme sea-levels and require many human interventions. The authors hope their detailed arguments will suffice to convince the reviewer of the quality of the presented methods and results.

Anonymous Reviewer #1

The description of the "The Croatian Meteotsunami Early Warning System" (section 2) should be placed inside the Methods section.

Response: Accepted. The description of the Croatian Meteotsunami Early Warning System is moved to the now renamed Model, Data and Methods section.

The observation/model comparison presented in the bottom panels of Fig. 1 is too small and therefore not useful for model validation (even qualitatively). Therefore, I strongly suggest putting these panels in a separate figure with appropriate labels.

Response: Accepted. The panels are put in a separate figure (Figure 2).

In my opinion, the use of the energy banners presented in figures 3-5 and discussed in Section 5 could not be used for providing a quantitative assessment of the model performance. I do understand that simulating meteotsunamis and their tsunamigenic conditions at the right timing and location is challenging and therefore it is correct to analyze model results in the neighbourhood of the monitoring station. However, it is not acceptable - even considering the scale of the perturbations - to present a comparison using model results extracted at locations hundreds of kilometres far from the monitoring stations (e.g. Or-W2, Ve-W1, .. in Fig. 3). Therefore, figures 3-5 are mostly useless for the model assessment. The authors should consider only results at a reasonable distance from the monitoring station.

Response: The authors believe that the above comment of the reviewer is linked to an inherent misconception of the methodology proposed in Section 4 (previously Section 5).

First, as a reminder, the methodology is comparing - along the western coast, the middle and the eastern coast of the Adriatic - the time evolution of the spectral analysis of the strongest atmospheric disturbances modelled and measured.

Second and foremost, the observation network is extremely sparse as, for example, along the Italian coast only three stations cover around 600-km of coastline. It is thus impossible to know if the recorded meteotsunamigenic disturbances at the Ancona, Ortona and Vieste stations are the maximal disturbances during the meteotsunami event. Indeed, these stations are separated by 150-km to 200-km of coastline and the "real" strongest meteotsunamigenic disturbances can occur anywhere between the stations. In this sense, the fact that the strongest model results are extracted 100-km further from the station which recorded the strongest meteotsunamigenic disturbances is not necessarily pointing to the location of the atmospheric disturbance in the model being 100-km further from the strongest real disturbance. Obviously, the comparison Ve-W1 mentioned by the reviewer is typically an excellent example when the model is definitely generating disturbances far too north compared to the reality. This leads to our third point.

Third, "Essentially, all models are wrong, but some are useful." (George E. P. Box, Robustness in the strategy of scientific model building, 1979). In this article, the authors are showing the usefulness of the deterministic component of the AdriSC modelling suite which provides atmospheric parameters to the stochastic component despite being sometime/often "essentially wrong". It is worth mentioning here that the operational model forecasting meteotsunami in the Balearic Islands (to this date, the only meteotsunami forecast running continuously for years) also struggles to deterministically predict meteotsunamis in Menorca (Mourre et al., 2020). As mentioned in Denamiel et al. (2019), the deterministic forecast of meteotsunami requires to push the use of the atmospheric state-of-the-art models beyond their original goals. As a consequence, it is not surprising that deterministic forecast of meteotsunamis often fail.

In brief, Section 4 provides a first estimate on how the atmospheric forecast of the AdriSC modelling suite succeeds to capture the intensity and presence but fails to reproduce the location of the observed meteotsunamigenic disturbances. It is in this sense an honest evaluation of the forecast capacity compared to the sparse observational network available in the Adriatic Sea. Additionally, Section 4 demonstrates the absolute necessity to use the stochastic component of the AdriSC modelling suite.

Even if no tsunamigenic disturbances were recorded during the 12th and 13th May, it would be useful to see model results for this period, also for checking if the system provides false alarms.

Response: Accepted. The model has been run for 12th and 13th of May. Results are presented in Figures 2, 4, 5 and 6, and analyzed in Section 4.

The aim of this study is to quantify the performance of the Croatian meteotsunami early warning system (CmeEWS). Such a system has been run retroactively in operational (hindcast) mode. It is however not clear to me if potentially the system could be used in operational mode since many operations depend on the direct human interventions (e.g. selection of transects and extraction of the input parameters of the stochastic surrogate model). The authors should provide a clear scheme of the operational setup including the role of forecast operators.

Response:

As explained in the introduction of the article: "… the recently developed Croatian Meteotsunami Early Warning System (CMeEWS) is based on an observational network of pressure sensors and tide gauges, as well as on the deterministic AdriSC modelling suite (Denamiel et al., 2019a) and the stochastic meteotsunami surrogate model (Denamiel et al., 2019b, 2020). It provides meteotsunami hazard assessments depending on forecasted and measured air pressure disturbances but is, unfortunately, not used operationally since November 2019 due to a lack of high-performance computing resources needed to execute in real-time such numerically demanding suite."

The CMeEWS has thus been run in operational mode for about a year after which, due to a lack of sustainable funding and available numerical resources, it was unfortunately stopped. The authors hope to re-start the operational system in a near future and, meanwhile, decided to continuously develop/evaluate the numerical models with every new meteotsunami event.

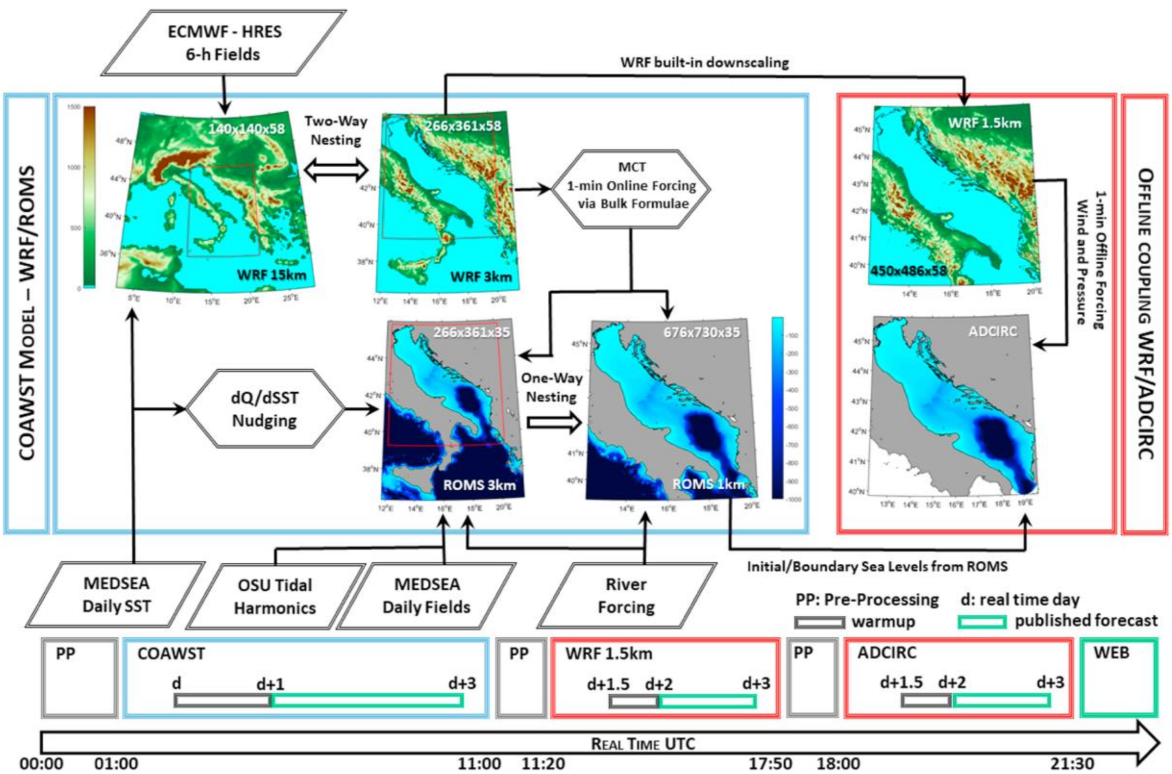

Figure R1. Extracted from Denamiel et al. (2019a)

The scheme of the operational setup was already provided in previous studies (Denamiel et al. 2019a, 2019b) and are presented in Figures R1 and R2.

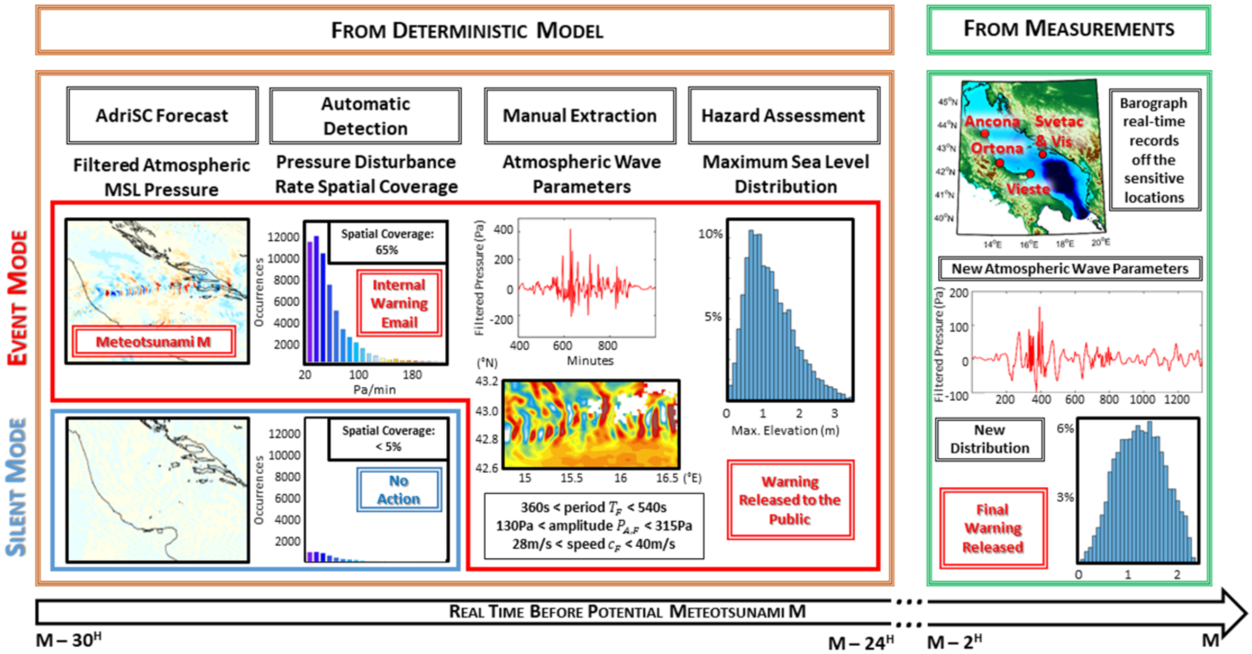

Figure R2. Extracted from Denamiel et al. (2019b)

As the reviewer can see, the Manual Extraction step is clearly defined within the CMeEWS (Figure R2). This is obviously when the intervention of the forecast operators is required.

It should be also pointed out that human interventions are often a pre-requisite of early warning systems. For example, in CEA, where the European tsunami early warning system (CENALT) is based, operators are constantly (24/7) monitoring the observational system and their roles are (1) to validate the automatic treatment of the data, (2) to eventually correct them if necessary and (3) to run the software dedicated to the computation of the timing and location the extreme sea-levels along the Mediterranean coastline generated by the recorded offshore tsunami waves (http://www.info-tsunami.fr/content.php?sec=27).

Consequently, the authors believe that the point raised by the reviewer has already largely been answered in the previous studies dealing with the CMeEWS, which is in fact following the most common practices of human intervention in early warning systems.

Lines 483-485: this is just a speculation, not the result coming from analysis. Please, remove this sentence or provide a detailed analysis supporting this statement.

Response: Accepted. The sentence is removed from the manuscript.

line 107: the unstructured currect-wave model ADCIRC-SWAN is here mentioned but SWAN is described only as part of the COAWST system.

Response: The description of the Nearshore module of the AdriSC modelling suite has been amended and now reads: “The dedicated meteotsunami module couples offline the Weather

Research and Forecasting (WRF) model (Skamarock et al., 2005) at 1.5-km of resolution with the unstructured ADCIRC-SWAN model (Dietrich et al., 2012) coupling the 2DDI (i.e. two dimensional depth-integrated) ADvanced CIRCulation (ADCIRC) model and the SWAN model with a mesh of up to 10-m resolution in the areas sensitive to meteotsunami hazard."

line 203: how are the transects selected? Manually?

Response: Yes, the transects were selected manually. This is added in the text: "For each event occurring during the 11-19 May 2020 period, the transects presented in this study are manually selected across the Adriatic Sea following the paths of highest atmospheric variances for the most energetic time-windows."

line 215: what do you mean by "visually determined"?

Response: Visually determined means that the analysis of the plots of filtered air pressure along the transect was done. The distances over which a peak of the disturbance travelled in a certain period of time were determined from these plots. The speed was then easily obtained from distance and time values.

line 283-284: not proven, it would be better to skip the sentence.

Response: Accepted. The sentence is removed from the manuscript.

Reference:

Schindelé, F., Gailler, A., Hébert, H. et al.: Implementation and Challenges of the Tsunami Warning System in the Western Mediterranean. Pure Appl. Geophys. 172, 821–833 (2015). https://doi.org/10.1007/s00024-014-0950-4