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Interactive comment on "Self-Organizing Maps approaches to analyze extremes of multivariate wave climate" *by* F. Barbariol et al.

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We thank the Referee for the comments and advices that will certainly improve the quality of our work. Comments are reported below, followed by our responses (*italics*: Referee's comment, **AR**: Authors' Response).

The study applies Self-Organizing Maps (SOM) method to long term wave measurements in the northern Adriatic, describing multivariate sea wave climate through three different approaches which enable better representation of extreme states. Namely, as SOM technique is not efficient where the density of events is low, the authors introduce an extra step for extreme wave states and discuss differences and benefits of varying strategies in representing the extreme wave climate. General comments: I find the pa-

per appropriate for this special issue of Ocean Science journal, with a valuable dataset presented and an interesting method and strategies proposed and discussed to better represent multivariate wave climate in the northern Adriatic. The analysis is based on the SOM method, which is described in appropriate manner, particularly focusing on the SOM publications dealing with the multivariate wave climate.

- *However, the Introduction (page 1973) should include broader view of the SOM in climatology, oceanography, climatology,... and present/cite at least some important SOM oceanographic publications outside of the Adriatic.*

  AC: We agree with the Referee, therefore in the revised manuscript the Introduction will include a broader presentation of SOM applications in the geosciences and over different oceanic contexts.

- *Page 1975, line 15: please use kilometers instead of miles, particularly since it is not clear if these are nautical miles or not.*

  AC: In the manuscript the distance of the "Acqua Alta" tower from the coastline is expressed in nautical miles. However, we accept the Referee's suggestion and in the revised manuscript we will write that "Acqua Alta" tower is located approximately 15 km off the Venice coast.

- *Page 1975, line 25-: The direction of waves in the Table 1, and throughout the text, tables and figures is given in oacenographic convention. This is not obvious for wave direction in general, and the authors should emphasize this in the text, that the angles given correspond to the direction (from North) the waves are propagating towards.*

  AC: The mean wave direction θm is defined at page 1975, line 20 as mean direction of wave propagation. In the revised manuscript, we will add the convention we used throughout the text, i.e. the convention indicating the direction of wave propagation from the geographical North.

OSD

12, C1223–C1229, 2015

- *The authors should also give more information related to the extreme Hm (5.23 m), by detailing when did the event occur, giving corresponding wave period and direction and related meteorological/wind characteristics that caused this extreme event.*

  AC: In the revised manuscript, we will add more information about the most extreme observed sea state (i.e. Hs = 5.23 m) that occurred on December 9th 1992 at 00.00UTC. In this respect, the complete triplet of the sea states is [Hs,Tm,θm]=[5.23 m, 5.36 s, 242°N], suggesting that it verified during a strong Bora storm.

- *Page 1976, line 28: three extreme states are mentioned, however, Hm=5.23 m is missing both in figure and in the text?*

  AC: The three sea states mentioned in the text are obtained from the bivariate (Hs,Tm) diagram. These sea states, therein represented by [Hs,Tm] pairs, are not sea states that have been necessarily observed. Indeed, to build the diagram, the ranges of observed Hs and Tm have been first divided in classes, and then each sea state was attributed to a proper class. Hence, the [Hs,Tm] we mentioned are centroids of the classes that are representative of the most extremes sea states. According to the bivariate experimental statistics, the most extreme sea state belongs to the class represented by [Hs,Tm]=[5.20 m, 5.38 s], which is not colored in the figure due to its very low frequency of occurrence (the sea state in discussion is the only one in this class). More detailed comments about this will be included in the revised manuscript, and the white color will be added to the color palette in order to indicate the lowest frequency pairs. In addition we will denote the class containing the maximum with a marker in the Figure.

- *Does the difference in period between these extreme events correspond to different winds at the time (Bora – shorter periods, Sirocco – longer periods)? Which directions correspond to these pairs?*

OSD

12, C1223–C1229, 2015

AC: Yes, this is correct, i.e. shorter periods are generally associated to Bora storms, longer periods to Sirocco storms. Actually, we will split this Figure into 4 Figures (one for each quadrant) in order to classify [Hs,Tm] pairs that pertain to similar directions of propagation. The SOM technique overcomes this allowing with a unique map a simple representation and practical visualization of multivariate wave climate. We thank the Referee because with this comment he/she allowed us to be clearer in the representation of the bivariate diagrams, and to remark the benefits of SOM.

- *Page 1980, line 21: Fig. 4 and similar figures (Figs. 7, 10, 13, where wave period is presented by the vector) should include a unit vector (in seconds), so that for each BMU the period could also be relatively easily deduced from the figure.*

  AC: We thank the Referee for this comment. We will add the unit vector for mean wave periods to make the map reading easier.

- *Page 1981, line 9: 0.36 seconds? Do you mean 3.6 s?*

  AC: Yes, definitely. Thanks for having noticed it.

- *Page 1981, line 24: please provide more information about the event (storm) depicted in Fig. 5. Temporal axes should include exact time of the event (also in Figs. 8 and 11) and more details about meteorological conditions related to it should be given in the manuscript.*

  AC: We will change the time axis in Figures 5, 8, and 11, in order to provide the exact date of occurrence (as days of the year) of the sea states shown. In addition, we will add meteorological information, if available.

- *Page 1983, line 11: is it "40% error on 99th percentile Hs" or "4% error on 99th percentile Hs", Table 2 says it is 4%?*

  AC: Yes, the value in Table 2 (i.e. 4%) is correct. We mistook in reporting the correct value in the text. Thanks for having noticed it.

OSD
12, C1223–C1229, 2015

- *Page 1984, lines 18-28: the left side map in Fig. 10 is the same as the map in Fig. 4 (and the same as the left side map in Fig. 13) , i.e. it gives the SOM representation of the entire dataset, not only climate below Hs*, since some of the BMUs have Hs larger than the threshold prescribed? The line 20 on this page should be reformulated, as it says: "...the first map on the left side describes the climate below Hs*...", and is not consistent with the rest of the paragraph. The figure caption is not clear either, as it says: "Wave climate below the threshold (left panel)...". Since the left panel also includes 6 BMUs with Hs above the threshold, than the left panel partly also describes climate above the threshold. Please check throughout the manuscript.*

  AC: Yes, the Referee is right, and we thank him/her for giving us the opportunity to reformulate the sentence and the Figure captions, which are not clear as they appear in the manuscript. Indeed, the left map describes the entire wave climate at Acqua Alta, not only the climate below the threshold (herein defined according to the 97th percentile of Hs), even if extremes are poorly described for the reasons in discussion. The right map, instead, provides a more accurate description of the extreme wave climate, which is represented in the left map by the BMUs encompassed by the black line.

- *Page 1985, line 12: "Sirocco" events as discussed here are in bottom-right part of the right map in Fig. 10, not bottom-left?*

  AC: Yes, the Referee is right. The Sirocco events are in the bottom-right part of the right map of Figure 10, not bottom-left. We apologize for this mistake and thank the Referee for having noticed it.

- *Page 1985, lines 13-17: please discuss the most severe sea states along the diagonal, especially those with the highest Hs values. Apparently the largest number of extreme BMUs has direction towards 260-270°. Still, some of them (to the lower-right in top-right corner) obviously correspond to Sirocco. This could*

OSD

12, C1223–C1229, 2015

be then related to extreme Hs-Tm pairs mentioned at the bottom of page 1976 (including the one that is missing, 5.23 m, see previous comment). Which directions correspond to those extreme pairs? What was the meteorological situation during those extremes? Please provide some details.

AC: It is not straightforward to assign directions of propagation to the [Hs,Tm] pairs of Figure 3. To facilitate it and isolate Bora and Sirocco (the conditions during extremes), we will split Figure 3 in four Figures (one for each quadrant). In addition, at present, we can rely on wave propagation direction only to discuss the meteorological conditions (e.g. Bora or Sirocco) corresponding to those extremes. Hence, if additional information will be available to us (e.g. wind time series), we will better discuss the meteorological conditions during such extremes.

- *Does the majority of most extreme wave states at the Acqua Alta station correspond to Bora winds, as 260-270° seems to be more related to Bora than Sirocco? Putting a limit between the Bora and Sirocco exactly at 270° could be somewhat confusing?*

  AC: Yes, the majority of most extreme wave states at Acqua Alta propagate towards the third and fourth quadrant, i.e. the propagation directions that pertain to Bora and Sirocco waves. More precisely, Bora is the northeastern (coming from) wind, and Sirocco is the southeastern wind blowing only along the main basin axis (i.e. approximately 315°N). The 270° limit, despite arbitrary, is conventionally adopted to discriminate between this two meteorological conditions. Therefore for the purposes of a quantitative classification, we prefer to leave the 270° limit to discriminate between Sirocco (from 270° to 360°) and Bora (from 180° to 269°).

- *Page 1985, Fig. 10: colorbar for the frequency of individual BMUs in the right panel is not really useful, as all the frequencies appear almost the same. A separate colorbar (different color pallets) should be related to the right-side map*

OSD
12, C1223–C1229, 2015

BMU frequencies, perhaps for Hs too. The same thing should be done in Fig. 13, although the color visibility is not as bad as in Fig. 10.

AC: Thanks for the suggestion that we will try to follow by adding two new color palettes for each of the mentioned Figures describing the right panels.

- *Page 1987, line 13: is it completely correct/precise to tell that the left map/panel comprises only low/moderate sea states (also on page 1975, lines 1-10 where the authors propose a double-sided map). Namely, the most extreme BMUs correspond to the highest Hs values (when looking on temporal evolution of BMUs, e.g. Fig. 5 between 30th and 50th hour), but corresponding BMU reconstructions are relatively far from measurements due to the SOM characteristics/problems you described and emphasized in Introduction (rare events and distant from the others in multidimensional input data space)? Therefore the left side map represents the entire dataset, but it does not properly describe extreme sea states? That is what the authors essentially say at the top of page 1985: "Without such BMUs, the map on the left represents the low/moderate wave climate...". Please make sure to be consistent with this throughout the manuscript (e.g., Page 1988, line 23 again says that the left map represents low/moderate wave climate).*

  AC: The left map of Figure 13 (i.e. the result of a classic SOM, also in Figure 4) comprises all the sea states that occurred at Acqua Alta in the period we analyzed. However, due to SOM tendency to describe the more frequent and less intense sea states better, the map in discussion cannot properly represent the most extreme sea states. As recalled by the Referee, this is shown for instance in Figure 5, where extreme sea states are not properly described by the BMUs composing the map of Figure 4 (and Figure 3, left map). Hence, in the revised manuscript we will better explain these concepts by, for instance, avoiding denoting as low/moderate the sea states in the left map.

Interactive comment on Ocean Sci. Discuss., 12, 1971, 2015.