

## ***Interactive comment on “A century of sea level data and the UK’s 2013/14 storm surges: an assessment of extremes and clustering using the Newlyn tide gauge record” by M. P. Wadey et al.***

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Dear Matthew,

Thank you for your comments. Below we address each in turn.

"Their research raises several questions which I hope our community will investigate in the future, and perhaps could have been considered in this work: 1. The authors find a strong link (but how statistically significant?) between the North Atlantic Oscillation index (NAO) and the clustering of extremes; however, what is the overall trend of the NAO in the last 100 years? For example, is the amplitude of NAO oscillation increasing or trending to more negative events (etc.). This may help us under-stand what future

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patterns of extreme events may be like; i.e. should we expect more clustering of coastal flooding events in the future?"

This is a good point. It is well known that a negative NAO can allow more southerly storm tracks hence the possibility of more surges at Newlyn (see Haigh et al., 2010). The projected behaviour of NAO and other modes in climate models was reviewed within the AR5 IPCC study, and there is suggestion of a general trend towards a positive NAO in the 21st century. However, as we have shown, in an added table to our paper (Table 5) the correlation with NAO and storm count is weak at Newlyn; probably because of the complex interaction of the different sea level components. Therefore it is difficult to conclusively say how this might impact clustering at Newlyn. It is also possible that large year-to-year changes in NAO may be more influential than the season's particular NAO value at Newlyn. Other authors have previously suggested that in the region around Newlyn, the NAO is not a very good discriminator of surge activity suggesting factors such as "intra-month volatility of parameters used to derive the NAO index and of other monthly variables considered" (we have added this citation to our revised manuscript): Betts, N. L., Orford, J. D., White, D. & Graham, C. J. 2004. Storminess and surges in the South-Western Approaches of the eastern North Atlantic: the synoptic climatology of recent extreme coastal storms. *Marine Geology*, 210, 227-246.

"2. Essentially, the authors use a Peaks Over Threshold approach for their extreme value theory analysis with the threshold of a "1 year return period", but why choose this threshold? what would happen if a lower threshold or the R largest approach method was used?"

We would like to clarify that we did not undertake an extreme value statistical analysis using the Peaks over Threshold Method, or any method. We simply used the 1 in 1-year return level, defined in a national study and examined the high waters that exceeded that threshold. The 1 in 1 year return period level, and all others we mention were based on levels defined in another previous study commissioned by the Environment

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Agency. In that study, a recently developed statistical method (the 'Skew Surge Joint Probability Method (SSJPM)'), was used to estimate sea-level probabilities at the 40 national tide gauge sites that lie on the English, Scottish and Welsh coastlines, in addition to 5 other sites for which long tide gauge records were available. A multi-decadal model hindcast of sea-levels was then used to dynamically interpolate these estimates around the whole of the English, Scottish and Welsh coastline at 12 km resolution. We used their estimates of the extreme sea-level probabilities, expressed in terms of levels for return periods (1, 2, 5, 10, 20, 25, 50, 75, 100, 150, 200, 250, 300, 1,000 and 10,000 year), for Newlyn using the information listed in Table 4.1 of the EA's report (p.2014 L10 in our paper). We simply use their predefined levels as a threshold and then count events and identify years associated with temporal 'clusters' of extreme high waters. Second, choice of the 1 year return period threshold is somewhat arbitrary. If you choose a threshold that is too high, you don't have enough to do a meaningful analysis; whereas if you choose a threshold that is too low, you have a large number of events, the majority of which are not particularly extreme. The 1 in 1 year level is nice balance between the two providing a reasonable number of events that are relatively large. We do, in several figures and in the text also refer to the high waters that exceed the 1 in 5 and 1 in 10 year return levels, to show result for higher thresholds.

"3. The NAO is typically being used to describe extreme water-levels (and for good reason - as the authors point out); however, what about other measures of weather patterns in the northern Atlantic (which the authors do elude to); for example – what would the comparison be for clustering of extremes to factors such as: AO (Arctic Oscillation), Northern Annular Mode (NAM), or the Atlantic Multi-decadal Oscillation (AMO)?"

For this paper we have focused entirely on the NAO, and have since strengthened the analysis by including correlation coefficients, as described above. We briefly attempted a correlation using the AO and AMO (with the seasonal counts of 1 in 1 yr event exceedances) and found only very weak correlations. However, we agree it would be good to undertake a more detailed analyse using the additional climate indices you

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suggest. This is something we are currently working on in a follow on paper in which we assess sea level records for the whole of the UK.

"4. In a global context, do we see an increase in the magnitude and frequency, and clustering, of extreme water-level events?"

This is a good, but complex question. Clearly, the number of high waters exceeding given thresholds will continue to increase (as has been observed for the last century; Fig. 2a) as MSL continues to rise, and will accelerate with accelerations in MSL. However, future changes with storm activity are more complex and could increase or decrease clustering depending on how the magnitude, frequency and tracks of storms vary. We have added a paragraph towards the end of the discussion section to briefly comment on this.

All the best,

Matthew, Ivan and Jenny

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Interactive comment on Ocean Sci. Discuss., 11, 1995, 2014.

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