Nat. Hazards Earth Syst. Sci. Discuss.,
https://doi.org/10.5194/nhess-2020-101-AC1, 2020

Natural Hazards and Earth System Sciences
Discussions

Interactive comment on "A nonstationary analysis for investigating the multiscale variability of extreme surges: case of the English Channel coasts" *by* Imen Turki et al.

Imen Turki et al.

imen.turki@univ-rouen.fr

Received and published: 22 August 2020

Dear Anonymous Reviewer

We appreciate the time spent by the editor and the reviewer to assess the manuscript and we appreciate the constructive comments and suggestions proposed. We have taken into account all comments and we feel the manuscript has certainly benefited in terms of both clarity and content. Best Regards Imen Turki (also on behalf of the co-authors)

I present the answser to the comments above. I send it also in a pdf document.

Reviewer 1 : General Suggestions # Review on the paper "A nonstationary analysis for investigating the multiscale variability of extreme surges: case of the English Channel coasts" ## General comments In the research manuscript, the authors present an analysis of time series of storm surges in five stations along the coast of the English Channel. The study is two-fold: a first part is related to the analysis of the monthly extreme storm-surges signals, by using a multi-scale wavelet analysis in order to describe the

Answer to Reviewer 1 : Thank you for the different suggestions and comments useful for the improvement of the manuscript. The text of the manuscript has been checked by the authors and has been simplified to make easier the writing and the understanding of the different sections, in particular the discussion and the methodology. Also, some information has been moved from the methodological part to the results. Two illustrations related to the original hydrodynamic data (Figure 4 in the new version) and the morphological defects (Figure 2 in the new version). The answers will be addressed for each specific comment. ### 2. Data It no very clear in the paper if storm surge or the sea level height data is used. Only the later is measured by the tide gauge, and thus a pre-processing step is required to filter out the tides and the sea-level rise. The description of this pre-processing seems to be missing in the paper. Another question is about the availability of the large-scale atmospheric circulations indices (NAO, AMO...) during the whole period covered by the tide gauges. In particular, the Brest station has measurements from 1850, so one could wonder if the indices are available from the date, and what could be the quality of such values. I think that the paper could benefit from some discussion on this point. Answer Thank you for this suggestion. According to the determination of surges, a new part explaining this extraction has been added in the new version: part 3.1; According to the availability of the large-scale atmospheric circulations indices (NAO, AMO. . .), they have been extracted from the NCEP-NCAR Reanalysis fields with the same period of the surges. a. Timeseries of surges Weymouth: 1991-2018 Brest: 1846-2018 Dunkirk:1964-2018 Dover: 1958-2018 Cherbourg: 1964-2018

b. Timeseries of the correlations Climate index - maximum surges The correlation has been carried depending on the length of the

AMO/BREST: 1880 – 2017 NAO /Brest : 1865-2017 SLP /Brest : 1948-2017 ZW /Brest : 1865-2017

AMO – NAO – SLP - ZW/ Cherbourg - Dunkirk : 1964-2017 AMO – NAO – SLP - ZW/Douvres : 1958-2017 AMO – NAO – SLP- ZW/Weymouth : 1991-2017

The methodological approach has benefit from this information.

Extraction of surges: A new part has been added in the manuscript (lines 191-213) 3. 1 Extraction of residual sea level: ‘surges’ The total sea-level height, resulting from the astronomical and the meteorological processes, exhibits a temporal non-stationarity which is explained by a combination of the effects of the long-term trends in the mean sea level, the modulation by the deterministic tidal component and the stochastic signal of surges, and the interactions between tides and surges. The occurrence of extreme sea levels is controlled by periods of high astronomically generated tides, in particular at inter-annual scales when two phenomena of precession cause systematic variation of high tides. The modulation of the tides contributes to the enhanced risk of coastal flooding. Therefore, the separation between tidal and non-tidal signals is an important task in any analysis of sea-level time-series. By the hypothesis of independence between the astronomical tides and the stochastic residual of surges, the nonlinear relationship between the tidal modulation and surges is not considered in the present analysis. Using the classical harmonic analysis, the tidal component has been modelled as the sum of a finite set of sinusoids at specific frequencies to determine the determinist phase/ amplitude of each sinusoid and predict the astronomical component of tides. In order to obtain a quantitative assessment of the non-tidal contribution in storminess changes, technical methods based on MATLAB t-tide package have been applied to the seal level measurements, demodulated from long-term components (e.g. mean sea level, vertical local movement), for estimating year-by-year

tidal constituents. A year-by-year tidal simulation (Shaw and Tsimplis, 2010) has been applied to the sea-level time-series to determine the amplitude and the phase of tidal modulations using harmonic analysis fitted to 18.61-, 9.305-, 8.85-, and 4.425-year sinusoidal signals (Pugh, 1987). The radiational components have been also considered for the extraction of the stochastic component of surges (Williams et al., 2018). Detailed information related to Climate Oscillations A new part has been added in the manuscript (lines 183-189)

Monthly time-series of climate indices have been provided by the NCEP-NCAR Reanalysis fields (http://www.esrl.noaa.gov/psd/data/gridded/data.ncep.reanalysis.derived.html) until 2017. The different indices have been extracted during the same period of the sea-level observations at the four stations Cherbourg, Dunkirk, Dover and Weymouth. For the longest timeseries of Brest (1850 - 2018), the use of climate indices has been limited according to their initial date availability (AMO: 1880 – 2017; NAO: 1865-2017; SLP: 1948-2017; ZW: 1865-2017)

3. Extreme value models The authors use the classical extreme value distribution (GEV) to model the monthly maxima of storm surges, making the distribution non-stationary by incorporating climate indices as covariates. Although the presentation of the model is rather clear, the data on with the model is applied is not as clear to me: is it on the initial time series of storm surges or on the spectral components? On L200, it seems that the model is applied to each spectral component, but the justification of using a GEV distribution is then questionable since the component by itself is not extreme nor a maxima, and thus an extreme value distribution is not justified. Marginal distributions of the variable on which the GEV is fitted could give some insight on the adequacy of a GEV, in addition to the QQ plots of Figure 10. I have another remark about model selection: the authors do not show the fitted parameters values nor the associated confidence intervals, but only the AIC values in Table 3. Such values would be necessary to address the fit and to discuss whether or not the influences of the indices are significant. The authors are only selecting the parameter that cannot be considered

are stationary, but not the index that is relevant to explain the non-stationary.

Answer The authors try to add more clarifications related to the application of the GEV model. Indeed, the maxima of surges has been decomposed to different frequencies to which the model has been applied. This approach has been applied by Turki et al., 2019 ; 2020. The low and the high frequencies of the maxima highlight the different fluctuations of the signal and their multiscale variability. The prediction of each fluctuation has been investigated by the use of nonstationary GEV model with the incorporation of climate indices.

Some information related to the calculation of the return periods/levels and confidence intervals has been added 3.3 Stationary and Nonstationary extreme value model (lines 261-263) The non-stationary return levels, return-periods and the confidence intervals have been calculated by the use of a Bayesian inference models with the Maximum Likelihood Estimation. ### 4. Multi-timescale variability of extreme surges The authors describe the results of the continuous wavelet transform (CWT) on the monthly maxima of storm surges to assess the non-stationary behavior; Answer The authors have used the CWT to identify the spectrum of the extreme signal and its distribution in space (between station) and time (during the period of study); (Figure 2). The authors have shown also (Fig 3) that the low frequencies (lower than 10 year) are clearly observed from the CWT of the extreme surges, and less identified from the mean surges. In this part, a quantification of the spectral components has been presented (Figure 4).

5. Large-scale climate North-Atlantic oscillations and their link to extreme surges in the English Channel

This section is two-fold : first, exhibit the link between the indices and the monthly maxima of storm surges and fit the GEV distribution to the components of the storm surge. The authors look at the wavelet coherence to address this question and conclude that: Each timescale exhibits mainly strong links with its associated climate index (L313) Such a conclusion seems rather obvious to me because the indices are constructed

that way and is not sufficient to my point of view to do variable selection in the GEV model of the following section before fitting the model.

Although the lengthy discussion about the visual inspection is interesting and may worth it, a proper statistical method to select the variable should be preferred. Once the model is fitted, the paper falls short : since there is no variable selection and no use of the fitted model, what is the fit used for? We only can see with some difficulties the return levels of each component for the Brest station, but with little extrapolation. As is, the relevance of using a GEV model is questionable. Answer Thank you for these suggestions. Indeed, according to the previous works, the effects of the climate patterns is important and should be considered for predicting the variability of extreme surges. In the present research, the novel approach that an excellent prediction of the total signal requires a good multi-timescale prediction, i.e a prediction of each spectral component (provided by the MODWT analysis) which is described by an appropriate climate index (the most appropriate one has been selected basing on the wavelet coherence and the monte carlo iterations for each component). Indeed, the non-linear interaction between the physical mechanisms of climate patterns is very complex and could not considered at the same time to predict the extreme surges. To investigate this interaction our hypothesis consists on developing a statistical model able to predict the spectral component with the incorporation of the most adequate climate information. The development of a full model useful for estimating the extreme surges needs the integration of the GEV models associated to the different timescales ($\sim$ 2-4 years; $\sim$ 5-8 years; $\sim$ 12-16 years) by the means of mathematical methods; which is the objective of the further works. The present work brings a novel hypothesis to resolve the complex effects of climate patterns on the local variability of surges. This step is very important to introduce a new model considering the different timescales of extreme surges.

More clarifications related to the selection of the most appropriate climate oscillation (lines 264-283) 2. 3. 4 Determination of the most appropriate climate oscillation connected to each timescale extreme surges for GEV models As suggested previously, the main hypothesis presented in this research is that effects of the physical mechanisms on the extreme surges varies according to the timescale and each scale should be related to a given climate oscillation. This hypothesis has been supported by two approaches: (1) a spectral approach based on the use of wavelet techniques (wavelet multiresolution and wavelet coherence as detailed in section 3.2) for optimizing the physical relationship between climate index and the extreme surges at each timescale; (2) a Bayesian approach has been used also for assessing extremes in a changing climate oscillation (NAO, SLP, ZW and AMO) at each timescale by making inferences from the Likelihood function. In our case where many parameters of GEV distribution should be optimized by including the most appropriate climate oscillation, Markov Chain Monte Carlo (MCMC) techniques have been implemented based on multiple simulations (the number of simulations varying as a function of the length of the timeseries; it is around 100.000 simulations). For generating the sequences of simulated values, we have applied the evbayes package within R software. By the use of this algorithm, a sequence of parameters with a normal distribution (a mean value equal to the previous value in the chain and a given variance). The most suitable climate oscillation maximizing the fitting between the observed and the simulated data is identified when a burn-in-period is reached.

Please also note the supplement to this comment:
https://nhess.copernicus.org/preprints/nhess-2020-101/nhess-2020-101-AC1-supplement.pdf

Interactive comment on Nat. Hazards Earth Syst. Sci. Discuss., https://doi.org/10.5194/nhess-2020-101, 2020.

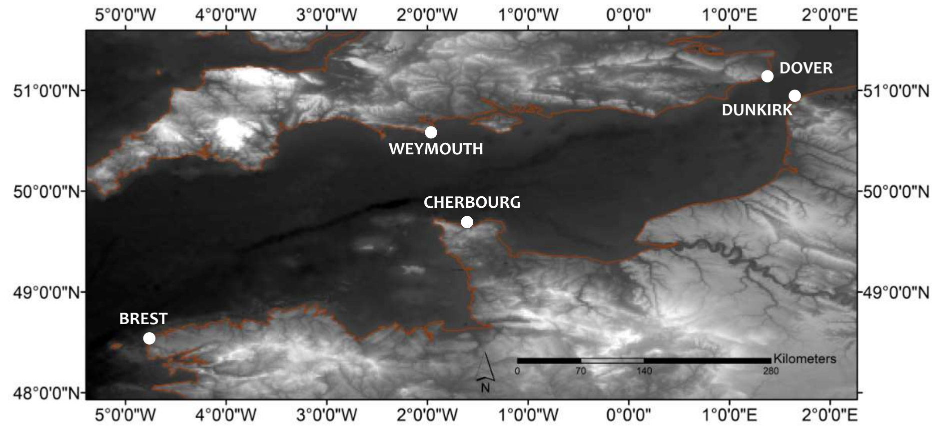

Fig. 1. Figure 1 Geographical location of the study area and the different tide gauges along the English Channel coasts: Brest, Cherbourg, Dunkirk (NW France); Dover and Weymouth (SW UK).

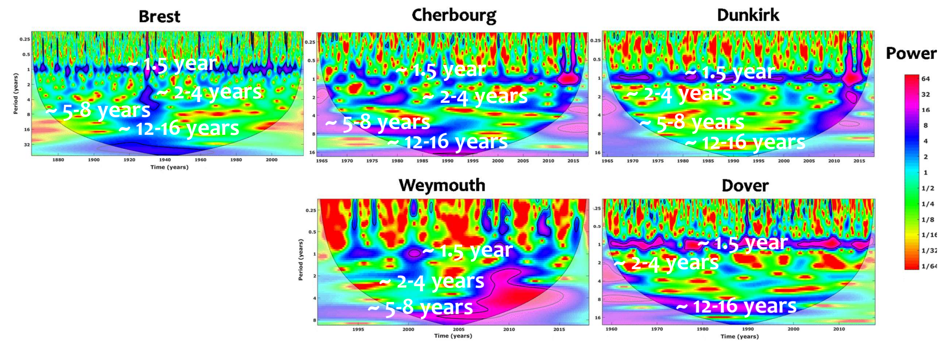

Fig. 2. Figure 2. CWT of monthly maxima of surges in Brest, Cherbourg, Dunkirk, Dover and Weymouth.

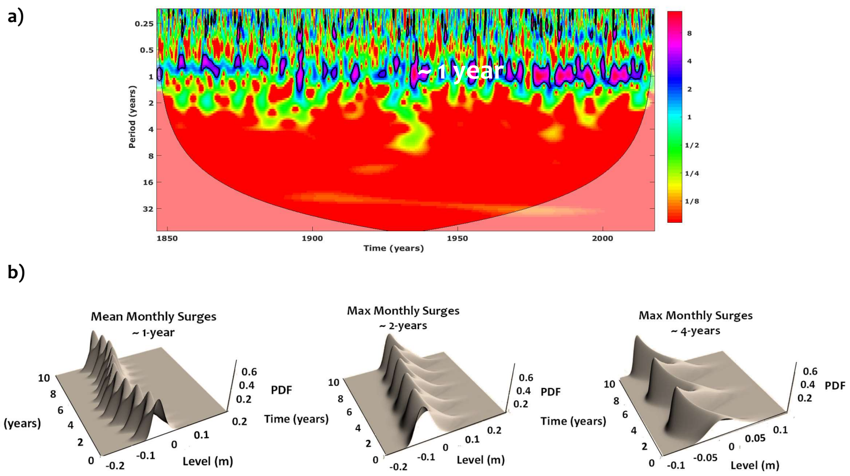

Fig. 3. Figure 3. Multiscale variability of the monthly mean and maximum surges in Brest. (a) CWT of monthly mean surges; (b) Interannual variability of monthly and extreme surges

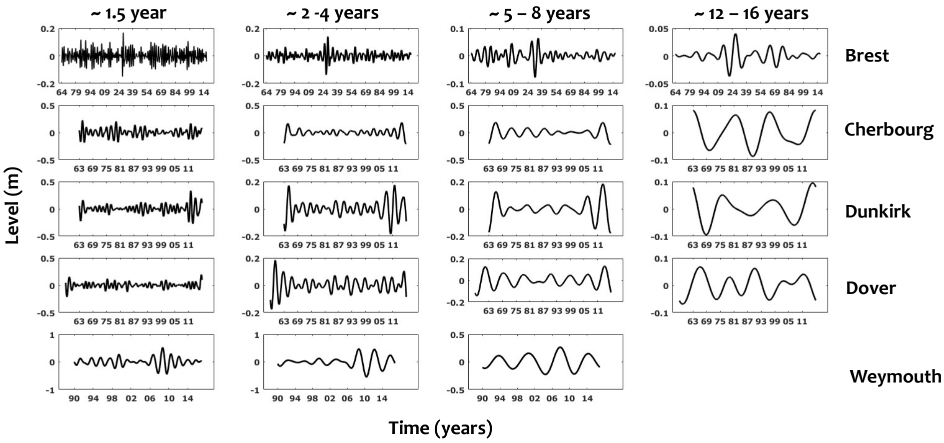

Fig. 4. Figure 4 Wavelet details (components) resulting from the multiresolution analysis of surges at the interannual (∼ 1.5-yr , ∼2-4-yr and ∼5-8-yr) and interdecadal (∼12-16-yr) time scales for all sites (

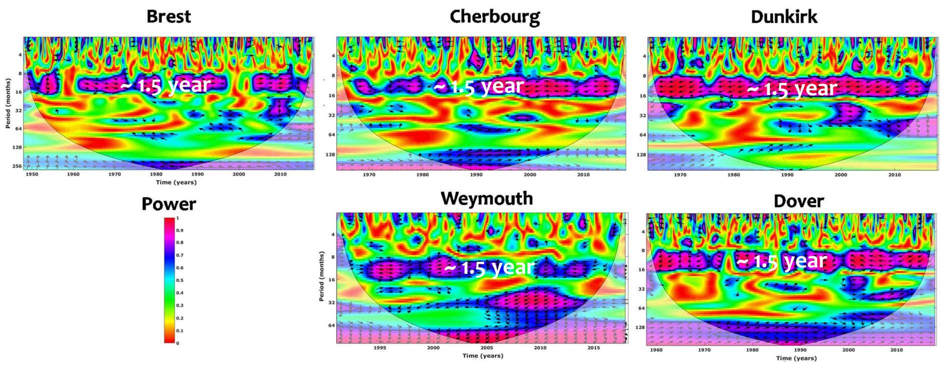

Fig. 5. Figure 5. Coherence-wavelet diagrams between monthly extrema of surges and Sea Level Pressure (SLP).

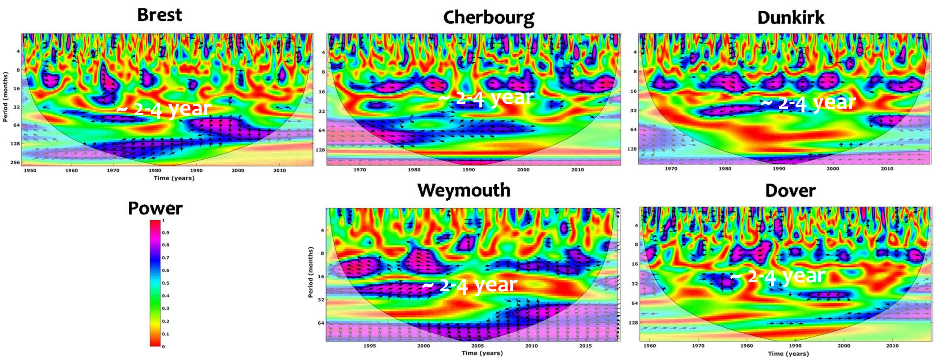

Fig. 6. Figure 6. Coherence-wavelet diagrams between monthly extrema of surges and Zonal Wind (ZW).

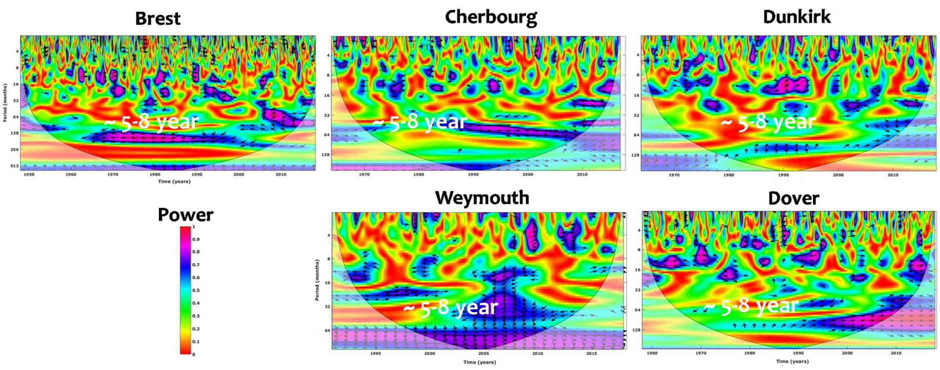

Fig. 7. Figure 7. Coherence-wavelet diagrams between monthly extrema of surges and North Atlantic Oscillation (NAO).

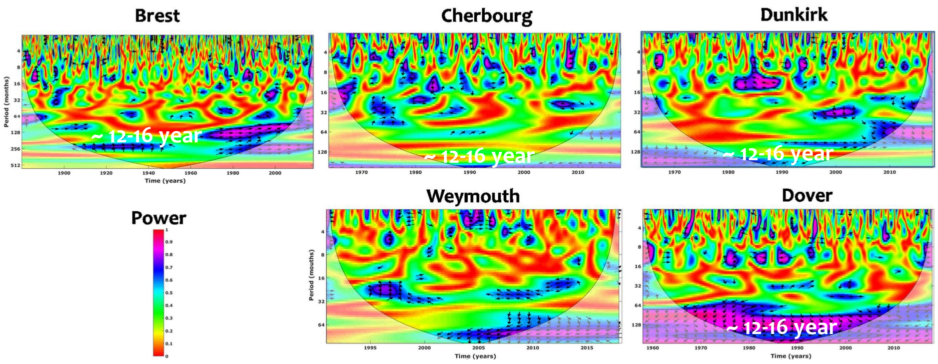

Fig. 8. Figure 8. Coherence-wavelet diagrams between monthly extrema of surges and Atlantic Multidecadal Oscillation (AMO).

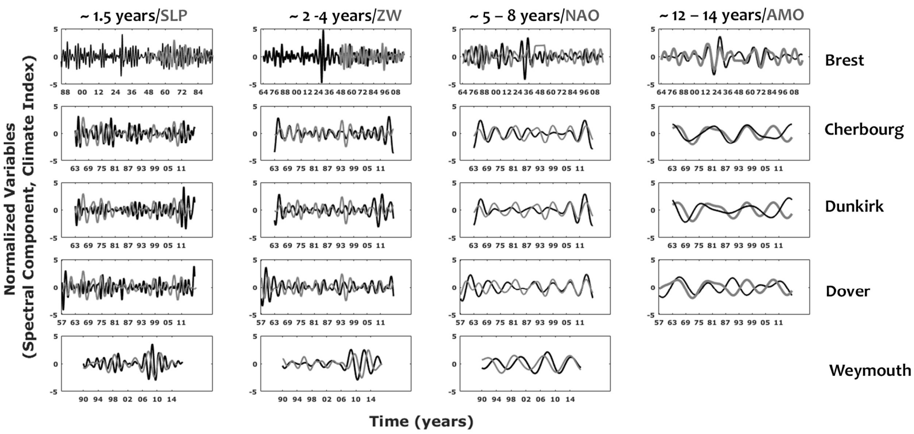

Fig. 9. Figure 9 Wavelet details of monthly extreme surges (black lines), at the interannual (∼ 1.5-yr , ∼2-4-yr and ∼5-8-yr) and interdecadal (∼12-16-yr) time scales for all sites (Brest, Cherbourg, Dunkirk

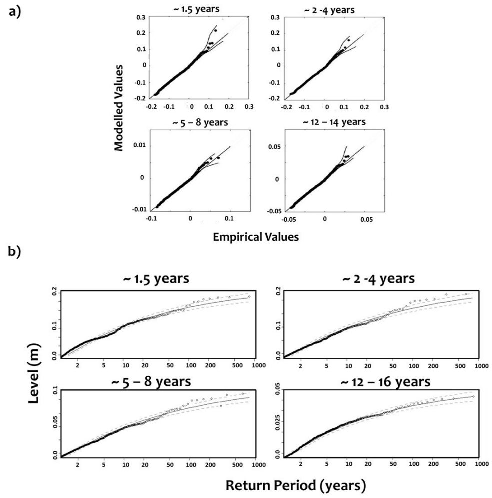

Fig. 10. Figure 10. a. The quantile plot between observed and modelled extreme surges by the use of the best GEV models, at different time scales, case of Brest. b. The Return level of extreme surges estimated