Émilie Bresson

Université du Québec en Abitibi-Témiscamingue
550 Rue Sherbrooke W.
West Tower, 19th floor
H3A 1B9 Montreal (QC)
Canada

Montreal, September 29th 2017

Response to reviewers' comments

Dear Editor,

First, we want to warmly thank the two reviewers for their helpful and constructive comments and suggestions. Their involvement has enabled us to consistently improve the quality and, hopefully, the readability of our manuscript.

The main text has been substantially restructured to make it more flowing and avoid the duality between both regions of interest (France and Bulgaria). We now focus more wave and storm surge hindcasts evaluations. Thus, figures have been rearranged, three tables and one figure have been added. The Section 2 (technical aspects) is now divided in two parts: downscaling techniques explanations followed by wave and storm surge models descriptions. Results (Section 3) presents first an example for downscaled meteorological fields, second the wave hindcast study, then the storm surge hindcast and finally the early 20th century cases. For all the results subsections, a global analysis is provided before the presentation of some examples. The introduction and conclusions parts have been also restructured and completed to better highlight the importance of the downscaling methods to provide better atmospheric forcings for wave and storm surge models that represents the core of the paper.

Here is a detailed answer to all comments from the two reviewers. We hope the new version of our manuscript is of publishable standard for your journal. We remain at your disposal and will gratefully receive any additional comments and suggestions.

On behalf of the co-authors,

Émilie Bresson

Response to Anonymous reviewer #1

The manuscript presents an interesting study on the quality of wave hindcasts and storm surges as a function of different wind forcings. Despite the usefulness of the study I have some concerns regarding the methodology, and serious concerns regarding: knowledge of basic concepts, references completeness, the way results are presented, and, most of all, the quality of the text. There is only so much one can correct, hence the authors should revise the text beyond my corrections. My advice is to move to a second iteration of reviewing, pending on the (major) corrections and alerts I raise below.

Thanks a lot for your interest in our study. We hope that we adequately addressed your suggestions in the new version of our manuscript, and that you consider our paper worthy of publication.

P1, L1: What is FP7 IncREO? Please define all acronyms properly.

FP7 IncREO is the "Seventh Research Framework Programme Increasing Resilience through Earth Observation". The modification has been made in the revised manuscript.

P1, L7: Add "directly" after "wind".

Done.

P1, L8: What is 4D blending?

4D blending stands for 4-dimensional blending.
The modification has been made in the revised manuscript.

P1, L11: Replace "soil" with "soils".

Done.

P1, L13: Add "storm" after "events".

Done.

P1, L17: beset?

The right word is "hit". The modification has been made in the revised manuscript.

P1, L18: Intense storms have by definition high winds speeds, no? What are "high winds"? High wind speeds might be better. What are "powerful swells"? All this sentence is full of inaccuracies and lose use of non-scientific and inaccurate terms. Please revise.

We modified the phrasing of "high winds" in "high wind speeds" according your comments, as well as "Powerful swells" modify for "strong swells". Furthermore a quantitative example of "high wind speeds"

and "powerful swells" is presented in the Introduction with the description of the Xynthia storm to present some representative values of what we call “strong wind speeds” and “strong swells”.

P2, L3: Global change of what?

It is global change of climate. The modification has been made in the revised manuscript.

P2, L17: Replace “model” with “models”.

Done.

P2, L18: What do you mean with “not fully resolved”?

"Not fully resolved" was removed in the revised text. The point here is the fact that with a coarse resolution the reanalyses do not represent the wind characteristics providing from the small-scale processes.

P2, L21: Sentence starting with “The technique. . .” is confusing. Please revise.

This sentence is revised with a more detailed explanation:
Although we can use the finer reanalysis as initial conditions for a given event it turns out that mesoscale processes related to the formation of strong winds such as sting jets (Hewson and Neu, 2015) are absent even in ERA-Interim, the reanalysis with the highest resolution. As described in Reistad et al. (2011); Li et al. (2016), a dynamical downscaling can be applied on these reanalyses using high resolution numerical model to better resolve the horizontal scales involved together in the mid-latitude cyclone development processes and interaction with fine resolution coastal topography.

P2, L25: Add “subsequent” before “dynamical”. Replace “fully” with “better” (are you sure that you can “fully” resolve it?).

Done.

P3, L3-5: All paragraph is confusing. Revise.

The paragraph is modified:
Mean sea level pressure and surface wind are usually needed as atmospheric forcing to forecast wave and storm surges. In the present study, these two climate variables are obtained through reanalyses from a numerical weather prediction system conducting data assimilation to encompass past observation datasets. A dynamical downscaling is applied on global atmospheric reanalyses, since their resolution is too coarse to deliver accurate information for hindcast.

P3, L6: Which reanalyses? You start talking about reanalysis somehow “out of the blue”. How do you know they don’t resolve windstorms? This statement is speculative, inaccurate, and not backed up by previous studies (references). Reanalyses (again there are lots of reanalysis, s at this stage we don’t know about which one(s) you are talking about) might not resolve properly or accurately extreme wind events, but your

statement is not correct. Also, the tense of the verb (here and in several other parts of the text) is not correct. Revise.

All this part is modified with a restructuration of the text for the technical part. The Sections 2.1, 2.2 and 3.1 are mixed to give a clearer information about reanalyses, atmsopheric models selected and downscaling methods (Section 2.1).

You tend to make small paragraphs, sometimes with only one sentence, which is not grammatically correct, and makes the text harder to read. Revise the all text body on this aspect.

The whole text was revised in this way.

P3, L8-10: All paragraph is confusing. Please be clearer. You don't interpolate the reanalysis itself, but its parameters or output.

The paragraph was revised and made clearer. The whole downscaling methods section is modified.

P3, L13: small scales of what? What are "small scales"?

The phrasing of "small scale" referred to scale beyond the truncature of the reanalysis.

Section 2.2: The way the ECMWF ERA-40, ERA-Interim, and ERA-20C is far from correct. Revise the whole section with accurate statements and use of concepts, backed up by the proper references.

Section 2.2 is now merge with Sections 2.1 and 3.1 and becomes Section 2.1. The new Section 2.1 includes a corrected description of the three ECMWF reanalyses used in this study (Tab. 2), of the atmospheric models selected and the two downscaling methods.

Table 2. Characteristics of ERA-20C, ERA-40 and ERA-Interim reanalyses. 4(3)D-Var: 4(3)-dimensional variational analysis; VarBC: Variational Bias Correction of surface pressure observations.

	ERA-20C	ERA-40	ERA-Interim
Time period	1900 – 2010	1957 – 2002	1979 – present
IFS version	Cy38r1	Cy23r4	Cy31r2
Data assimilation system	24-hour 4D-Var; VarBC	6-hour 3D-Var	12-hour 4D-Var; VarBC
Spectral resolution	T159 (~ 125 km)	T159 (~ 125 km)	T255 (~ 80 km)
Number of vertical levels	91	60	60
Vertical scale (from the surface up to)	0.01 hPa (~ 80 km)	0.1 hPa (~ 64 km)	0.1 hPa (~ 64 km)
Pressure levels	37	23	37
Reference	Poli et al. (2013)	Uppala et al. (2005)	Dee et al. (2011)

P3, L18-19: Wrong definition of reanalysis. Revise.

The definition of a reanalysis is modified by this sentence:
A global atmospheric reanalysis is built using a data assimilation system and historical observations spanning an extended period.

P3, L19: Define ECMWF. What is ERA? (ERA stands for “European reanalysis”). Define acronyms properly.

ECMWF is “European Centre for Medium-Range Weather Forecasts”. ERA is “European reanalysis”. The modifications have been made in the revised manuscript.

P4, L12-13: What do you mean with the sentence starting with “Different. . .”. Revise.

Three coastlines, in two countries, are studied. Two options could have fit this study: working with the same atmospheric, wave and storm-surge models for the two countries, or select the more efficient model for each country and with similar technical characteristics. We considered the second approach as our goal is to present efficiency of the downscaling methods in different frames.

P4, L16: add “is” before “based”.

Done.

P4, L30: What is MFWAM (It is “MFWAM wave model”, and not “wave MFWAM model”). Is it correct to call the Meteo France version of WAM as the MFWAM model? What is the Meteo France version of WAM? At the ECMWF the use of ECWAM (the ECMWF WAM version) can be backed up by references that explain its differences to the cycle 4 WAM. Provide the same time of references to sustain the use of the MFWAM acronym and what is stands for.

The Meteo-France WAve Model (MFWAM) is a third-generation model of the operational wave forecasting system of Météo-France. This model is based on the IFS-CY36R4 of the European wave model (ECWAM) with modified source terms for the dissipation by wave breaking and the air friction dedicated to swell damping as described in Ardhuin et al. (2010). This point is corrected in Section 2.2.1.

P5, L1-2: Why is the SWAM wave model used (and not implemented) to “investigate extreme events”? (Extreme events of what, by the way?)

In a general way, the SWAM model is the operational wave model for Bulgaria. We decided to use this model for studying extreme events of high wave, even if it totally fit with the whole types of events.
The "extreme events" referred to the studied cases of high wave cases.

P5, L16: Add “the” before “Bulgarian”.

Done.

P5, L18: Add references after “lakes”.

Done.

P5, L23: What is BUL?

BUL stands for the Bulgarian domain.

P6, L6: What is NEA?

NEA stands for North East Atlantic Ocean. The text is modified.

P6, L25-32: The explanation provided in this paragraph falls short. Revise, having in mind clarity and completeness.

P7, L1-3: Regarding the sentence stating with “Nevertheless. . .”: where do you see this in your findings? How can you back this statement? Stronger and deeper cyclones where?

The two last comments are about the lack of clarity of the subsection. Actually, the main purpose of the paper is on wave and storm surge hindcast. The present subsection is just an example of how the atmospheric component of the downscaling methods behave in the case of a very strong and relatively small scale cyclone development although it is not associated with strong waves and surge. The section is revised along that lines. The last sentences are suppressed.

P7, L5-6: Sentence starting with “NWP. . .”: confusing and speculative. Revise. What is NWP? What is NWP with downscaling? Shouldn’t it be something like “The downscaling of atmospheric parameters, like the wind field, using NWP models provide. . .”.

A NWP system is a Numerical Weather Prediction system. In the restructuration of the text, this part has been suppressed.

P7, L7: From here on you start using the acronym ERA for all reanalysis. That is not correct. You should explain and mention the exact reanalysis you are using. Comparing D1 with any of the three reanalysis means self-correlation, hence that is not correct.

The acronym ERA was used to lighten the text, the complete name of the reanalysis considered is added. The detail of each ERA-storm couple is presented in the Tab. 1.
We do not compare reanalysis fields with downscaled fields, we just compare the departure between D1 and the downscaled observations and departure between the reanalysis fields and observations.

P7, L12: Replace “are” with “can be”; replace “all the available data, such as” with “, for example,”.

Done.

P7, L13: Conceptually “evaluate” and “validate” are not the same, and you use these two words for the same task, which is to evaluate the model(s) output metrics by comparison with observations. You do not validate models, hence evaluate its performance. Correct here and in the remainder of the manuscript.

“Validate" is modified by "evaluate" in the whole text.

P7, L14: Replace “show” with “have shown”.

Done.

P5, L15: Replace “hindcasts” with “the wave hindcast”.

Done.

P5, L18: What is the depth of the ADCP measurements?

The ADCP is located at 20 m depth.

P7, L25: “model”? Which model? You don’t “evaluate models” but their output. Erase “case”.

The word “case” is erased.

P7, L28: Add “the modelled” before “significant”.

Done.

P8, L12: Replace collected with “used”; replace results” with “modelled wave heights”.

Done.

P8, L16: Replace “the good”, with “a good”.

Done.

P8, L23: Avoid the use of expressions like “perfectly”, since they do not fit in academic writing standards.

The modification has been done in the revised manuscript.

P8, L32: Replace “considered” with “chosen”.

Done.

P9, L4: Replace “winds” with “wind speeds”; add “during” after “as”.

Done.

P9, L5: Add “the” before “December”. (I am afraid you do this mistake several times; please check the whole text.)

Done.

P9, L11: add “results” after “surge”.

Done.

P9, L14: They? Who ate “They”? Revise this sentence.

“They" stands for the ERA-20C reanalyses. The sentence is modified.

P9, L18: reported or measured?

The right word is "measured". The sentence is modified.

The whole section 4.3 is very confusing. Revise.

The Section 4.3 (now Section 3.4) is revised for an easier reading.

P10, L3: replace “features” with “speed events”.

Done.

P10, L7: which reanalysis?

The term reanalyses encompassed the three selected reanlayses. The sentence is modified.

The conclusions section is also confusing, and way too simplistic/simplified. Revise carefully in line with the findings you convey in the manuscript.

The conclusions are revised and completed to better resume study findings and future work possibilities.

Response to Anonymous reviewer #2

The authors have attempted to present the results of an atmospheric downscaling with application to wave and storm surge hindcasting. It is indeed a very laudable project as it is well known that global atmospheric reanalyses currently available struggle to provide a good estimation of storm wind intensity, and hence waves and storm surge conditions needed to evaluate future hazards. This manuscript however reads more like a technical report than a paper suitable for a journal. It is my opinion that upon some restructuring, a clearer separation of the narrative (selected cases) from the statistical analysis it should become suitable for publication. Two separate areas were analysed (the French Coast up to the southern North Sea and the Bulgarian coast). Nevertheless, the manuscript currently feels like two separate papers written by two separate teams. It will greatly benefit it this duality was removed as much as possible and one common narrative was presented.

Thanks a lot for your strong interest in our study. We hope that the restructuring of the text responds to your suggestions as to the technicality and duality present in this paper.

The article structure has been revised in order to avoid the technical aspect and the feeling of study in two distinct parts. As a consequence, the Introduction was restructured. The Section 2 (technical aspects) is them divided in two parts: downscaling techniques explanations and wave and storm surge models descriptions. Section 3 presents the results with evaluation of first the meteorological fields, second the wave hindcast study, then the storm surge hindcast and finally the early 20th century cases. For all the results subsections, a global analysis is provided before the presentation of some examples.

Specific comments:

Introduction:

The downscaling of ECMWF reanalysis has been done before, For instance the Norwegian NORA-10 based on ERA-40: Reistad, M., Ø. Breivik, H. Haakenstad, O. J. Aarnes, B. R. Furevik, and J. Bidlot (2011), A high-resolution hindcast of wind and waves for the North Sea, the Norwegian Sea, and the Barents Sea, J. Geophys. Res., 116, C05019, doi:10.1029/2010JC006402.

To acknowledge the contribution by Reistad, et al. (2011), we now quote it in the introduction. Our study is a step forward since we considered three different reanalyses to encompass a large period and different areas.

Page 2, line 18: "extreme convective systems" . This seems to imply that only convective systems have very strong winds. Deep winter lows will produce very high winds but they are not necessarily what would be described as convective systems

The sentence has been modified in the restructuration of the Introduction.

Page 3, section 2.1: Can you be more specific on the interpolation method. ECMWF uses a spectral representation of their atmospheric fields with grid point representation for the surface fields (and a few others). What was done exactly? What about the vertical? Later it is mentioned that the 6 first hours of each forecast were discarded to avoid spin-up effect. How does this 6 hour window relate to the interpolation method? Why not 3 hours, instead? Does it have any impact on the results?

We agree that the lack of a technical description of the global model initialization is a major caveat of the paper. We therefore suggest to add the following sentences:
The upper-air initialization step is using the spectral coefficients of ERA reanalyses. Then we apply the Schmidt transform which is well defined in spectral space to project the fields into the ARPEGE stretched grid. The land-surface initialization is not straightforward since many differences of land-surface parametrizations and physiographic databases between the two land-surface schemes can be found. For instance, the Tiled ECMWF Scheme for Surface Exchanges over Land (TESSEL) scheme of ERA uses four soil layers with fixed thicknesses, each layer having its own water content. The land-surface scheme of ARPEGE uses only two layers in our experiments, the top layer with a fixed size of 1 cm and the second layer overlaps the first one and has a variable depth. For a given grid point soil types are very different in the two land-surface schemes. Therefore, using the raw land-surface datasets from ERA as initial conditions would be troublesome since the water saturation fraction depends on the soil type. Thus, we interpolate the surface fields so as to preserve as much as possible the surface heat and momentum fluxes (see Boisserie et al., 2016 for a thorough description of how we proceed). The procedure is based on the conservation of the Soil Wetness Index (a relevant indicator for soil water availability) during the interpolation process since soil water availability is supposed to regulate the partition of latent and heat fluxes, which, in turn, influence energy and water exchanges between the atmosphere and the land-surface.
[Boisserie, M., Decharme, B., Descamps, L. and Arbogast, P. (2016), Land surface initialization strategy for a global reforecast dataset. Q.J.R. Meteorol. Soc., 142: 880–888. doi:10.1002/qj.2688]

Two points explained this spin-up effect. First dynamically the spectrum needs time to fill up and second, a certain period is necessary to reach physical coherence between surface and fluxes. This spin-up time is about some hours. The 6-h spin-up was selected for more convenience with the 6-hourly ERA reanalyses.

Page 4, line 3: both ERA-40 and ERA-Interim were reanalysis for land and waves as well atmosphere, just as ERA-20C.

The sentence is modified to provide a cleared message.

Section 3.3: What is the justification of not coupling the storm surge model with the wave model? There are ample evidence that it is beneficial to both surge and waves hindcast. See for instance Bertin et al. (2015). Xavier Bertin, Kai Li, Aron Roland, Jean-Raymond Bidlot. 2015: The contribution of short-waves in storm surges: Two case studies in the Bay of Biscay. Continental Shelf Research 96, 1-15.

We thank you for this suggestion and we add this in the future work in the conclusions section. Indeed, results could have been better applying a coupling between wave and storm-surge models. Even if, our objective was to stay close the operational conditions using wave and storm surge models used in the French and Bulgarian centers.

Section 4: It is not clear which is time discretisation of the different forcing. ERA-Interim analysis data are 6-hourly and could be supplemented with 3-hourly forecasts to yield 3-hourly forcing. The down-scaled D1 and D2 fields, I assume are hourly. Consolidate and summarise the statistical analysis by avoiding to show statistics on very short time series but rather on the full sample and use instead the few selected cases as qualitative examples on the type of differences that was obtained.

ERA fields are 6-hourly. Forcing are introduced in the wave and storm surge models every 3 hours when using ERA reanalyses without downscaling and every hour when using atmospheric fields after D1 or D2 method.
The section 3 (Results) is revised in this way. A new figure according to your suggestion is added (Fig. 9). It gives an overall idea for the cases where the observations are available.
For other verification results, it not possible to have a large ensemble: for example, there is no altimeter data for every studied storm.

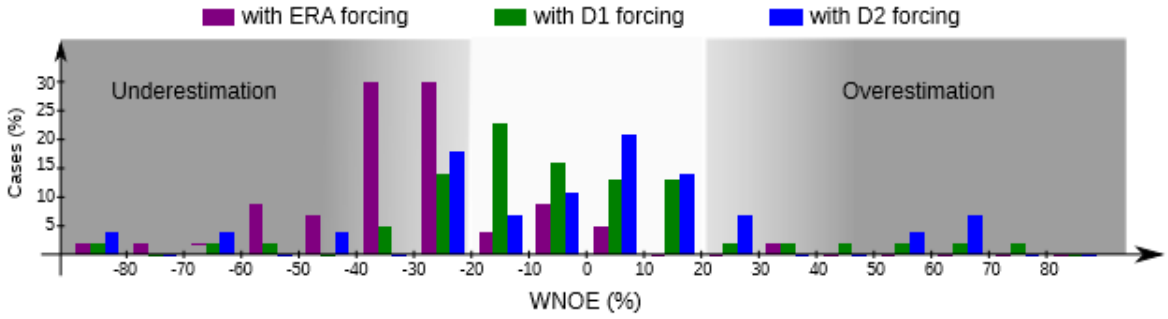

Figure 9. Percentage of cases depending of their $WNOE$ range when using ERA (purple), D1 (green) or D2 (blue) forcing. All the available observations with a maximum storm surge measurement are taken into account.

Table 6. Portion of cases (%) with $\|WNOE\| < 20\%$ for each coast (ATL: Atlantic; MED: Mediterranean Sea; BUL: Bulgarian; common cases: cases using D1 and D2 forcing).

	ERA	D1	D2
ATL	21	63	80
MED	0	54	38
BUL	33	100	–
Common cases	18	64	61

Table 7. Number of observations used for calculations of $WNOE$ for each region and each forcing.

	ERA	D1	D2
ATL	34	34	15
MED	13	13	13
BUL	9	9	0