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Natural Hazards and Earth System Sciences
Discussions

Interactive comment on "Model sensitivity for the prediction of extreme sea level events at a wide and fast-flowing estuary: the case of the Río de la Plata" *by* Matías G. Dinapoli et al.

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As we mentioned to the Editor, we are grateful for your revision which certainly contributed to a significant improvement of the article. Your comments were carefully considered and changes were done accordingly.

This is a manuscript which fits the theme of NHESS but which needs major revisions before publication. Before proceeding to the discussion of the modifications in the manuscript we want to mention that it was substantially changed. Therefore, it will be impossible to describe the detail of every modification in this answer. We remit the reviewer to the annotated version of the manuscript that we are sending together with

the final revised one. In what follows we will discuss the essentials of the modifications made in relation to your comments.

The writing can be improved. Some sections can be shortened or summarized. The manuscript was almost fully rewritten. Sections were shortened and summarized as much as possible, and a full revision of English usage was made. In particular: 1) The original "Introduction" section was much reduced, and a discussion on nonlinear interactions between the surge, the tide and the runoff in estuaries was included. Efforts were made to clearly highlight the aims of the work.

2) A new "Study area" section was added, where the Río de la Plata Estuary and its impact is discussed.

3) Morris analysis is now presented for two different wind data bases of the different resolution and the differences in the model response are discussed.

4) The former Section 3.2 was eliminated.

5) A new complete section discussing the nonlinear interactions between the tide, the surge and the runoff was included.

6) In a last section the effect of changes in the runoff is quantified.

7) The "Conclusions" section was fully rewritten, as follows:

"In this work, we discussed a sensitivity analysis (SA) based on Morris methodology, which is particularly well suited for models with large computational demand, to determine the sensitivity of numerical solutions for the Southwestern Atlantic Continental Shelf with emphasis in the wide and fast flowing RdP estuary to different parameters. An evaluation of the overall model SA the most critical storm event for the inhabitants of the region and for navigation, known as Sudestada, was permormed. The results from the SA reduce the required number of simulations needed for model calibration, reducing the future work to the fine calibration of the most sensitive inputs. ROMS_AGRIF model was chosen to build the pre-operational forecast model. It was

applied in a hierarchy of 2-D one-way nested grids with refinement of the solutions over the RdP estuary. The SA was made including the bottom friction quadratic (cD) and linear (cl) parameterizations. Due to the scarcity of direct wind observations over the estuary and the limitations in the numerical modelling of the winds in the area, wind data becomes a significant source of errors and uncertainties for any ocean forecast model. Hence, wind speed (through a factor I) and direction (Θ) were included in the SA. Finally, the RdP is very mighty, and continental discharge can vary significantly (in a range of around 80,000 m3 s-1) in the period of a few months, becoming also an important input which influence must be assessed. The ranges of existence of every input were set using values from literature, the RMSE with respect to observations, and extremes observed values, respectively. The sensitive analysis showed significant model response to all the considered inputs. The most important, with nonlinearity in the model response, was the wind speed (I). In particular, the model response showed to be very sensitive even to small changes in this forcing. The next most important input is Q, which response is more linear and presents a regional dependence, becoming less important towards the outer estuary (i.e., downstream). Finally, model solutions are relatively much less sensitive to Θ, cD and cl. With the objective of further helping on the decision of how to built a numerical forecast strategy for SSH anomaly in the RdP, we also analyzed the interactions between the surge, the tide and the runoff. Results indicate that the interactions are important, accounting for around 10% of the total SSH anomaly during the storm. The most significant interaction (approximately 90% of the total) occurs between the surge and the tide, maximizing at Samborombón Bay and the upper RdP. The interaction between the tide and the runoff is much weaker, of the order of 10% of the amplitude of the tide. Finally, the interaction between of the runoff and the surge is of similar order of magnitude than that of the tide with the runoff. The last two interactions maximize at the upper estuary (where the tributaries flow to the RdP) and decay offshore, being almost negligible at the outer RdP. The results of this research provide information that will allow an optimal calibration of the model with only a fine tuning and a minimum number of simulations in the next future. They also

highlight some the needs to face the construction of an accurate numerical forecast system for the prediction of extreme surges in the RdP. In this sense, we can conclude that: a) The fact that the model solutions are extremely sensitive to small uncertainties in the wind speed indicates that the most obvious way of improving the surge forecast is either improving the atmospheric forcing or at least quantifying the forecast error due to the uncertainties. Some ways of improving the wind forcing is by increasing the temporal and spatial resolution, and the diversity of physical processes included in the simulations, by the use of regional numerical models and/or assimilating data on the simulations. For this, more direct observations over the RdP would be necessary. As an intermediate step, an empirical adjustment of the winds could be attempted. The uncertainties in the SSH anomaly forecast can be quantified by ensemble modelling.

b) The inclusion of the continental discharge in a forecast model for the SSH anomaly in the RdP is fundamental. Its main effect is to introduce a setup (or SSH elevation), but also interacts with the tide and the surge, particularly in the upper estuary, where the most populated areas of the RdP coasts are located and where, in consequence, the impact of the floods maximizes. Nevertheless, the fact that the variability of the runoff is uncoupled with the surge, warranties that small uncertainties in the value of the discharge will not introduce large errors in the surge forecast. In this sense, for short term forecast the coupling of a hydrological model to the hydrodynamic one is unnecessary. c) Finally, it is absolutely necessary to include tides in the simulation. The tide has strong interactions with the surge, accounting for approximately 10% of the total signal. Furthermore, the tide interacts with the runoff, introducing more modifications in the real surge."

Finally, the title of the manuscript was changed to better reflect the new contents to " Model sensitivity and nonlinear interactions during extreme sea level events in a wide and fast-flowing estuary: the case of the Río de la Plata".

Sometimes (too) many references are attributed to a simple sentence. An example, from the Introduction: "The RdP has a huge runoff with a mean value of around 22,000

m3 s-1, ranking 5th worldwide in water discharge (Nagy et al., 1997; Jaime et al., 2002, Framiñan et al., 1999)." I wouldn't use the terms "huge", nor "runoff". Also don't see the relevance of worldwide ranking. Also don't see why such a minor sentence deserved 4 citations. It was corrected and references were reduced to those necessary.

The authors reach a somewhat trivial set of conclusions, in that *storm* surge results are most sensitive to the wind forcing and to the bottom roughness – what else should be expected in such a shallow, wide estuary? We apologize, as after rereading the manuscript we understand that the conclusions were poorly written in the original manuscript. The new version of the paper was essentially revised and new studies were added. The following major changes were made: 1) Two different atmospheric data bases were used in order to compare results and to provide an idea of the improvements that would result from a better resolution on the wind forcing (see section 3.4 and 4.1 of the revised manuscript). 2) For the analysis, we separated the "short time scales" (periods less than 30 hours) from the "long time scales" (periods more than 30 hours). The "long time scales" will reflect the effect of the surge; the "short time scales" include the tides and the atmospheric processes related to sea breeze. 3) A new section analysing the nonlinear interactions between the surge, the tide and the continental discharge was included (Section 4.2 of the revised manuscript); for this, simulations with all the forcings (tides, runoff and surge), only with tides, only with surge and only with continental discharge were run, analysed and discussed. 4) Another section was added quantifying the effects of changes in the runoff (Section 4.3 of the revised manuscript).

The new analyses improved the scope and conclusions of the article, as results are interesting and novel for the Río de la Plata and highlight the needs of a future forecast model for the Río de la Plata.

A few other remarks: - Would improve if one or more figures showed the model grids used; As the model grids are regular, plotting them does not provide much useful information to the reader. We tried to built such a figure, but it resulted too dirty.

- Why use an ocean model to simulate an estuary of 10m average depth? More flexibility would yield finer resolutions; We decided to use an oceanic model because we are also interested in the adjacent continental shelf and in the future we expect to include the baroclinic processes, so as the sediments transport. The chosen model will also allow the study of 2-way interactions.

- The discussion & conclusions is missing a more comprehensive comparison against similarly-minded papers, e.g. Zijl et al. (2015) where RMSE's are much smaller; The aim of our manuscript is on the sensitivity of the solutions to the diverse inputs and on the nonlinear interactions between the tide, the surge and the runoff. RMSE was primarily used in the Morris analysis as the chosen output. With regards to the RMSE as a measure of model skill, a number of improvements were introduced in the simulations and forcings. The performance of the model forced with ERA-INTERIM winds is satisfactory and comparable to other recent studies.

- The discussion & conclusions would benefit from a clear separation of tidal from other mechanisms contributing to the total water levels. Following your advice and that of Reviewer 1, for the analysis of the solutions, we divided them in "short time scales" and "long time scales" (see answer to the previous comment for the definition of those scales). It resulted that the model (with the introduced changes) has a better skill for the surge (or "long time scales") than for the "short time scales". Even though this can seem curious, the fact is that in the Río de la Plata "short time scales" are not only related to tides but also to short timescale wind forced processes (as for instance, the sea breeze, Simionato et al., 2005) that probably are not well represented in the reanalyses. We conclude, anyhow, that the model in its present form has a satisfactory skill for both time scales.

Please also note the supplement to this comment:
https://www.nat-hazards-earth-syst-sci-discuss.net/nhess-2016-393/nhess-2016-393-AC3-supplement.zip

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