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An efficient modelling approach for probabilistic assessments of present-day and future fluvial flooding

The paper presents a probabilistic modelling approach for flood hazard maps applied at the Can Tho city in the Mekong Delta. The flood hazard was analyzed for a present scenario and climate change scenarios. Additionally, land subsidence has been taken into account. The approach is based o1D hydraulic model for the Mekong Delta, coupled with a detailed 1D/2D Model, covering the city drainage network and overland flow, to simulate the inundation depth and flow velocity in the area of interest (city center).

In a first step the 1D model was simplified to optimize calculation times, due to computational restraints. This was achieved by an iterative generalization procedure while keeping track of model performance against the observed data. For the upstream boundary condition, a streamflow generator is used to synthesize large amounts of one-year runoff series (1000) for a present and two future scenarios (RCP4.5 and 8.5). The generated runoff series are combined with 36 years of simulated extreme sea levels as downstream boundary condition, resulting in 36 000 combinations for each scenario (present, RCP4.5 and 8.5). Climate change was accounted for in terms of projected annual changes in river runoff and projected sea level rises for the corresponding climate projections.

Subsequently, the Gumbel distribution was fitted to the maximum water level for each scenario. The fitted distribution was applied to determine the water level in the study area for each return period (0.5-100 years). The shape of the corresponding flood hydrograph was approximated by analyzing the simulated flood hydrographs above a threshold for each scenario (present, RCP4.5 and 8.5). The coupled 1D/2D model was calibrated and finally used to simulate the inundation for each return period and scenario based on 15m resolution digital elevation model. To account for land subsidence effects, a subsidence rate of 1.6 cm/year was applied for the future scenarios. The results indicate a strong increase of the inundation extent for future climate scenarios. The increase, however, is explained to a large extent by the applied land subsidence.

The study addresses an important topic. Today, flood hazard maps are still mostly based on single scenario calculations without the consideration of a wider range of possible alternative scenarios. The manuscript fits well within the scope of the journal. However, I see a number of shortcomings which need to be addressed in the presented manuscript.

General Comments:

A major concern is the generation of long time series of streamflow data based on 7 years of observed data. As researchers, we often face the challenge of limited input data and the stochastic methods can help to overcome these limitations. However, to fit these models, sufficient data are needed to fit the underlying distribution functions. In my opinion, 7 years of input data seems a rather short time period to derive meaningful distributions for the upper tails in which the authors are interested. Furthermore, the method to generate daily data is based on a non-parametric resampling procedure (Nowak et al. 2010), which is only able to scale the given data. This means that only observed daily patterns of the series will be present in the generated data, and no additional variability is introduced. Also, it is unclear if daily or hourly time series were generated?

Furthermore, I could not find information regarding the validation of the generated data. Are the statistics of the observed data well captured? I also wonder if there aren´t any longer time series (2000-2006) available nowadays? One possibility to overcome the limitation of lacking stream flow data (maybe not feasible as a short time solution), would be to generate data based on meteorological data (if available for longer time spans) including a rainfall-runoff simulation (see e.g. Falter et al. 2014; Winter et al. 2019).

The headline of Chapter 4 is named Results and Discussion, however I think it mainly contains the description of the results with little to no critical review and reflection about assumptions and limitations of the presented methodology and results. The uncertainties and limitations need to be discussed in detail. Furthermore, if available, results or parts of it should be compared to existing studies. In my opinion a sound discussion chapter is missing.

I think the overall results of the study are associated with very large uncertainties. Due to the lack of critical discussion this is not clearly laid out in the presented study. Furthermore, as stated in the manuscript, the main influencing factor for the future flood hazard is based on the applied land subsidence rate. This is, however, only threated as a minor issue in the manuscript. How is the subsidence rate considered in detail? The way I understood the article, the rate is linear interpolation by 1.6 cm per year up to 2050, however is this a valid assumption? Is the subsidence rate homogeneous over space and time? Is the methodology for considering the subsidence rate by simply modifying the DEM solid and common?

Specific Comments:

P4 L.114 I understand that performance is critical, but why must the calculation time be 1 minute? Is this not a rather subjective assumption and will it not always be depending on the individual case?

Why do you speak of hourly time steps? I thought the generator is based on daily values, or did you produce hourly values?

P6. L183 Are the skill values based on the total time series? Do they also capture the extremes well? Maybe you could add a validation plot to the manuscript.
On what basis do you judge the skill values as “very good” and “excellent”?

P6. L186 Aren´t longer time series available than 2006 nowadays? In my opinion this is a very poor data basis for the applied usage.

P7. L197 As I understand the statement, a %-change is sampled out of the given range and applied to the generated data. What about the dynamic? I think there may be more complex changes in the system than only a percentage change and, more importantly, an annual change does not necessarily say something about possible extreme events. These assumptions and limitations need to be at least addressed in the discussion.

P7. L215 If you produced 36.000 series, would it not also be possible to derive the boundary conditions directly from the generated full hydrographs? Then you would not need to make any assumptions about the hydrograph. The shape of the hydrograph may change between different return period. Also, by only looking at the water level, you may miss the important factor of flood volume for the hydraulic modelling exercise (e.g. Grimaldi et al. 2013).

P7. L220 There might be a much broader variability of possible flood hydrograph shapes. Even if all 36k scenarios are analyzed, the interday variability is based on 7 years of input data. The resampling algorithms of the generator will not introduce further variability. This needs to at least be addressed in the discussion.

P8. L249 I think it is not necessary to explain how exactly the inundation grids are produced by telling which ArcGIS Tools were applied.

P9. Headline “Results and Discussion” I think these are mainly results without a sound discussion. I would advise to add a separate discussion section.

P9. L268 I cannot identify two patterns in Fig 9a). Only two cases differ in all plotted simulations for 9a), which I would not call “a pattern”.

Fig. 3 I think calibration/validation plot for the events (see comment P6. L183) would be of more interest to the reader.

Fig. 4 Fig. 4 is close to identical to Fig. 1. I think it is really helpful to understand the workflow, but it may be combined with Fig. 1

Fig. 6 The fitted distributions seem to be biased for higher return periods. This is probably related to the short input time series.

Fig. 8 I am not an expert on drainage simulations, but I do not understand the plot. Is the red line the simulated line? Why is it higher at the beginning of the simulation than the observed one? Is the plotted elapse time window appropriate?

Fig. 9 see comment P9. L268

Technical Notes:

P.2 L.62 Either use “e.g.” or “etc.”

P.4 L.104 Either use “e.g.” or “etc.”

P4. L109 Possible alternative: “not always sufficient”

P5. L135 The link doesn’t work

P5 L.135 - This could be moved to the “Code availability”-section at the end of the manuscript.

P10 L301 “inundated area” instead of “flood hazard”

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