Response to referee 2

Manuscript for Natural Hazards and Earth System Sciences

Title: Global scale benefit-cost analysis of coastal flood adaptation to different flood risk drivers using structural measures

Authors

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General response

We would like to thank referee 2 for the time taken to critically review our manuscript. We are very pleased that the referee finds the manuscript to be interesting and an incremental step forward. The referee raised a number of minor and modest corrections. The referee comments on the need to more explicitly state the innovative aspects and distinction of this study from previous assessments. We have addressed this concern along with detailed comments about the approach and methodology of this assessment. We believe that these revisions to the manuscript, and those detailed below, have led to a significant improvement in our manuscript. In the following pages, we respond to the comments of each referee point by point. Our responses are shown in italics.

Referee: 2

Overall this is an interesting paper. The approach undertaken is robust and I commend the authors for their nice study. The work builds on several previous assessments, and presents an incremental step forward, rather than a step change. However, I think it has some novel elements and is certainly worthy of publication in NHESS and results will be of interest to many. I have listed 5 modest corrections that I would like to see addressed and several minor ones.

- *Many thanks for the encouraging comments. We have addressed and clarified the modest and minor corrections in the manuscript, as described below.*

Modest corrections:

- In lines 50-55, you discuss the previous studies, and then go onto say what the objectives of your paper are. I think you need to make it clearer how your paper is distinct from these previous assessments. At the moment this does not come across strongly enough.

  Thank you – we have addressed this in the revised manuscript by adding information about the distinction of this study. It now reads: 'Recent studies have shown that adaptation measures hold a large potential for significantly reducing this future flood risk (Diaz, 2016; Hinkel et al., 2014; Lincke and Hinkel, 2018). However, the number of global scale studies in which the benefits and costs of disaster risk reduction and adaptation are explicitly and spatially accounted for remains limited. Existing studies have assessed the effect of climate change, subsidence and/or socioeconomic change (Hallegatte et al., 2013; Hinkel et al., 2014; Nicholls et al., 2008; Vousdoukas et al., 2016), but have not included adaptation objectives or attributed flood risk drivers to adaptation costs. Lincke & Hinkel (2018) assessed the cost-effectiveness of structural

protection measures against sea-level rise and population growth using the DIVA model. They found that structural adaptation measures are for 13% of the global coastline feasible to invest in. However, they did not include subsidence and attribution of drivers in their modelling scheme.

In this paper, we develop a model to evaluate the future benefits and costs of structural adaptation measures at the global scale. We use it to address the limitations of current studies addressed above, and thereby extend the current knowledge on the cost-effectiveness of structural adaptation measures in several ways. Firstly, we include subsidence due to groundwater extraction. Secondly, we assess the benefits and costs of several adaptation objectives. Thirdly, we attribute the costs of adaptation to different drivers (namely sea-level rise, subsidence and change in exposure)..'

- Please provide, on lines 94 to 99, more details of how exactly you have included the tropical cyclones. Over what period was this done? How did you covert along track data into spatially varying wind and pressure fields?

  Thanks -- we have included the following information in section 2.1.1: 'All tracks over the period 1979-2004 are used and converted into wind and pressure fields using the parametric Holland model (Delft3D-WES, 2019) in order to simulate aaalternative water levels using GTSM. These water levels are combined with the time series of GTSR by using the highest water level at each GTSM cell for each time step. Extreme values are estimated using a Gumbel extreme value distribution fit on the annual extremes.'

- Lines 124 to 133: I am not clear if these subsidence rates include glacial isostatic adjustment or not. Do they? Can you make this clear. I assume you are accounting for these effects. If not, then it significantly undervalues your results.

  Thanks – in this study we only use groundwater extraction as a driver of subsidence, however, glacial isostatic adjustment is included in the regional sea-level approach. We have further clarified that in this study only groundwater extraction is used as a driver for subsidence.

- Lines 172 – 185: I found the description of the protection standards confusing. Please can you improve this section. Has this approach me validated, in regions for example, where the protect standards are known exactly. How does these compare to what Hallegate et al (2013) used in coastal cites? You cite the Netherlands as havimg a value of 1000. What are the units? Years? Please add these.

  Apologies for not referring to the validation of the coastal FLOPROS values, which can be found in the Supplementary Information. This is now amended. We have further clarified this section and moved information to the SI as suggested by referee 1. Indeed the units are in years and we have amended this.

- Why is your analysis based on 2080, and not 2100? TO me, it would seem much more sensible to go to 2100?

Thanks – the timeframe of the benefit-cost analysis is 2100 – we discount and accumulate all costs and benefits to this date. However, we have projections of climate and socioeconomic change at several points in time (2010, 2030, 2050 and 2080). Between these time-periods (and indeed after 2080) we extrapolate these values.

Minor corrections:

Line25 – I would maybe update to the special IPCC report in 2019, which is a bit more up to date.

Line 27 – there is an extra full stop after the Raftery reference.

Line 29 – you could add ‘and change in in tides.

Thanks – all are amended.