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Reply on RC2

Jiachang Tu et al.

Author comment on "Assessment of building damages and risk under extreme flood scenarios in Shanghai" by Jiachang Tu et al., Nat. Hazards Earth Syst. Sci. Discuss., <https://doi.org/10.5194/nhess-2021-382-AC2>, 2022

Dear Reviewer,

The authors appreciate the reviewer's time and effort in reviewing the manuscript. We are pleased with the comments and useful suggestions. We have diligently read through the remarks and adjusted the manuscript accordingly.

Please find our response and revised text blocks (in black) below your comments (in black bold).

General Comments

Building damage assessment is very important in urban flood risk management. This study presents an assessment of possible exposure and damage losses of buildings in Shanghai. The topic of this study is valuable, and However, the quality and innovation of the current manuscript are not satisfactory. First of all, lots of figures are poor in quality and hard to read. Besides, the building damage assessment method used in this study lack of innovation. In any case, I have a few recommendations that I believe will help the authors to clarify their contribution and improve the readability of the text in a few passages.

We are grateful for the reviewer's general comment on the study. Flood risk assessment approaches are widely implemented in many regions and the approaches themselves have been well developed. However, 1) there is not sufficiently flood risk assessment in Shanghai; 2) the possibility of extreme flooding has not been addressed; 3) the economic section (such as buildings) is underdeveloped and overlooked. Above all, to make the innovation and emphasis of our work clearer, we rewrote and reorganized the following three portions of the manuscript:

- Flood risk assessment based on low probability-high impact flood scenarios on buildings (residential, commercial, office, and industrial buildings) in Shanghai have not been sufficiently analyzed so far. Evidence on low probability-high impact events however become increasingly relevant due to the effects of climate change on hazard occurrences and the need for sustainable adaptation measures. We stressed it in the abstract to announce our statement at the outset (abstract. Line 1-5):

"Flood risk assessment is crucial in decision making, especially in protecting enormous

wealth megacities from low probability-high impact flood events. Plenty of various measures have been taken to mitigate flood risk in Shanghai, including the construction of sea dikes and floodwalls. However, the combined effects of intensified rainstorms, sea-level rise, land subsidence, and rapid urbanization are exacerbating potential flood risk in this fast-developing coastal city. In light of these changes, [...]"

On the other hand, we rewrote and rearranged the literature review presented in the first paragraph of the introduction of the article presenting based on the framework and necessities of flood risk assessment (p.1. Line 1-5):

"Integrated flood risk assessments, which have been used in different cities, make the assumption that flood defenses may fail and acknowledge the impossibility of completely preventing floods (De Moel et al., 2015; Sairam et al., 2021). A city-scale flood risk assessment improves the understanding of water supply (Yang et al., 2013), health care (Paterson et al., 2018), infrastructure maintenance (Yang, 2020; Bubeck et al., 2019), etc., given their importance to society, the economy, emergency management and reconstruction (De Moel et al., 2015)."

de Moel, H., Jongman, B., Kreibich, H., Merz, B., Penning-Rowsell, E., and Ward, P. J.: Flood risk assessments at different spatial scales, Mitigation and Adaptation Strategies for Global Change, 20, 865-890,doi: 10.1007/s11027-015-9654-z, 2015.

Sairam, N., Brill, F., Sieg, T., Farrag, M., Kellermann, P., Nguyen, V. D., Lüdtke, S., Merz, B., Schröter, K., Vorogushyn, S., and Kreibich, H.: Process-Based Flood Risk Assessment for Germany, Earth's Future, 9, doi: 10.1029/2021EF002259, 2021.

Yang, L., Zhang C, C., and Wambui Ngaruiya, G.: Water supply risks and urban responses under a changing climate: A case study of Hong Kong, Pacific Geographies, 39, 9-15, 2013.

Bubeck, P., Dillenardt, L., Alfieri, L., Feyen, L., Thielen, A. H., and Kellermann, P.: Global warming to increase flood risk on European railways, Climatic Change, 155, 19-36, 10.1007/s10584-019-02434-5, 2019.

- After reviewing the current literature on what each flood scenario is like in Shanghai (general comments from #1Reviewer), we found flood scenarios and their hydrology impacts/situations have been widely developed and discussed. But, the extreme compound flood scenario, for example, over a 1000-year return period, has not been considered (p.5. Line 57-69):

"Reviewing the current literature shows that various flood modelling techniques and scenarios have been created and validated to measure flood risks in Shanghai. Coastal floods (storm surges from the Shanghai coast) and fluvial floods (river floods from the Huangpu River) are the two types of floods focused on Shanghai. Coastal flood scenarios from the Shanghai coast are presented by forecasting in 2030 and 2050 (Yin et al., 2011), 2030, 2050, and 2100 (Wang et al., 2012) in Shanghai, respectively. These scenarios have examined the effects of factors like sea level rise and storm surge (Yin et al., 2011), or integer effects like sea level rise, land subsidence, and storm surge (Wang et al., 2012). In addition to examining the effects on the Shanghai coast, Yin et al. (2013) look at how sea level rise and subsidence combine with storm tide-induced river flooding in the Huangpu River floodplain in 2030 and 2050. Yin et al. (2015) used a 2D hydrodynamic model to estimate 1/10, 1/100, and 1/1000-year flood scenarios in the Huangpu River floodplain in Shanghai based on historical floodplain data. The flood scenarios produced in most existing studies tended to focus on the possible future flood scenario changes rather

than extreme events, e.g., the concern floods over a 1000-year return period (Yin et al., 2011; Wang et al., 2012; Yin et al., 2013, Yin et al., 2015). Therefore, Shanghai demands a low probability compound flood scenario that combines fluvial and coastal flooding.”

Yin, J., Yin, Z. E., Hu, X. M., Xu, S. Y., Wang, J., Li, Z. H., Zhong, H. D., and Gan, F. B.: Multiple scenario analyses forecasting the confounding impacts of sea level rise and tides from storm induced coastal flooding in the city of Shanghai, China, Environmental Earth Sciences, 63, 407-414, 10.1007/s12665-010-0787-9, 2011.

Wang, J., Gao, W., Xu, S. Y., and Yu, L. Z.: Evaluation of the combined risk of sea level rise, land subsidence, and storm surges on the coastal areas of Shanghai, China, Climatic Change, 115, 537-558, 10.1007/s10584-012-0468-7, 2012.

Yin, J., Yu, D. P., Yin, Z. N., Wang, J., and Xu, S. Y.: Modelling the combined impacts of sea-level rise and land subsidence on storm tides induced flooding of the Huangpu River in Shanghai, China, Climatic Change, 119, 919-932, 10.1007/s10584-013-0749-9, 2013.

Yin, J., Yu, D. P., Yin, Z. N., Wang, J., and Xu, S. Y.: Modelling the anthropogenic impacts on fluvial flood risks in a coastal mega-city: A scenario-based case study in Shanghai, China, Landscape and Urban Planning, 136, 144-155, 10.1016/j.landurbplan.2014.12.009, 2015.

- In this study, we classified building types and adopted the actual construction costs of various buildings. In this way, we are able to assess exposed groups and potential damages on small-scale on regional scale. The high level of detail characterizing the exposed objects poses an innovation compared to previous studies which usually do not divide between different building classes and storey heights.

To address our goal clearly, we changed the article title from “Assessment of building damages and adaptation under extreme flood scenarios in Shanghai” to “Assessment of building damages and risk under extreme flood scenarios in Shanghai”.

We further re-edited the figures to make them easier to read.

Please see below, for a point-by-point response to the reviewers’ comments and concerns.

Specific comments:

- **More information on the urban flood modelling by extreme flood scenarios caused by storm surges, precipitation, and fluvial floods, should be provided in the study. For example, what is the detailed combination of storm surges, precipitation, and fluvial floods.**

Thank you for this point. The methodology and details of the flood scenario have been published by the co-authors in the paper Wang et al 2019. We revised our manuscript and clarified the scenarios in the methodology. The revised text reads as follows (p.11. Line 115-123):

“The study builds on the results of Wang et al. (2019), which applied a hydrodynamic modelling approach to simulate compound flooding for the region of Shanghai. Four scenarios with return periods of 200, 500, 1000, and 5000 years were simulated considering storm surge, extreme precipitation, high tide, and river flooding at a resolution of 60 m. For this purpose, several models were applied and coupled: 1) the Fujita model simulating the atmospheric conditions; 2) the TELEMAC model simulating ocean movement; 3) the TOMAWAC model simulating the propagation of waves, and 4) the MIKE 21 model simulating the hydraulic processes.

These models were calibrated using rainfall and river discharge measurement data from Typhoon Winnie. Typhoon Winnie brought the highest recorded water level of 5.72 meters since 1900, which caused the collapse of 148 meters of floodwalls and overflowed 57 km of floodwalls and 69 km of sea dikes.”

Wang, L., Zhang, M., Wen, J., Chong, Z., Ye, Q., and Ke, Q.: Simulation of extreme compound coastal flooding in Shanghai, Advances in water science, 30 (04), 546-555, 2019.

- **Most of the figures in the manuscript are very poor in quality and hard to meet the standard for this journal, such as Figs. 5, not clear enough.**

Thank you for this point, we re-export the figure and improved the quality with clearer colors.

- **Table 5 presents comparison of flood adaptation measures in Shanghai, how does it make any sense? Anyway, the discussion in this study seems meaningless.**

Sorry that the discussion section did not well present its values. The discussions attend to address the threat of extreme flood events and their simulation results. We also narrate the potential flood adaption techniques and the discrepancy between the master plan and the academic result. The discussion would be helpful in providing information to the decision-makers and a statement for the researcher to simulate the flood scenario in Shanghai in the future. We significantly revised the section and concentrate on discussing two aspects:

- Section 5.1 analyzed the uncertainty and limitations of the study, and further analyzed the direction to enhance the model performances. The suitability of transferring the model to other study areas is also discussed (p.28. Line 265-296):

“Our study shows that the damage to buildings in Shanghai grows exponentially with the decreasing likelihood of extreme flood scenarios. For instance, the resulting flood damages to residential, commercial, office, and industrial buildings under the 1/5000-year flooding scenario is more than ten times higher than the resulting damages for a 1/200-year flooding scenario. As shown in section 3.1, the area along the Yangtze River Estuary, Hangzhou Bay, and Huangpu River are broadly flooded under the 1/200, 1/500, 1/1000, and 1/5000-year flooding scenarios [...]

Our assessment of the building damages is comparatively less than those in similar studies of Shanghai. The major reason is that we adopted the construction cost as the values of different buildings, while many other studies calculated the market value of buildings and the associated properties. For instance, [...]

The integrative analysis of geospatial building asset maps, flood scenarios, and the stage-damage functions in the study makes it possible to assess the flood damage of buildings in the megacity Shanghai with a high spatial resolution. However, the accuracy of building asset values could still be improved. First, the adopted building data of location, footprint area, height, and floors didn't consider the construction materials used and years built. [...] Second, the classification of different types of buildings is quite straightforward based on the land use/land cover data. [...] In the end, the methodology of four extreme flood scenarios in Shanghai were taken from published models in Shanghai that are induced by the current physical environment [...]

- Section 5.2 discusses the future challenges and adaptation strategies in Shanghai (p.31. Line 299-330):

“Future challenges, like extreme flood events, will become more common in Shanghai. The historical data shows how Shanghai’s extreme precipitation events have increased dramatically through time (Wang and Zhou, 2005; Liang and Ding, 2017), which increases the possibility of seawall and levee failures. One 1/1000-year return period flood occurred in Shanghai in 2013, [...].

Reviewing these findings from our risk assessment and highlight the following two points, which in our opinion, might be helpful for advancing the flood risk assessment in the future in Shanghai, or even more broadly in China.

First, the parameters (such as flood hazard maps, damage models, exposure data, etc.) to help to do the flood risk assessment in Shanghai that is available to the public are not consistent and scarce. Flood hazard maps can be an example. [...].

Second, effective adaptation to increasing flood risks requires an integrated climate response strategy, which shall include a broad scope of intervention measures such as urban planning, structural flood management measures, early warning systems, nature-based solutions, flood awareness and risk financing instruments (Yang et al., 2015; Jongman, 2018; UN, 2020). In table 6, we list potential hard, soft, and hybrid implementation measures and their assumed efficacy in Shanghai. [...].”

Wang, Y. Q. and Zhou, L.: Observed trends in extreme precipitation events in China during 1961–2001 and the associated changes in large-scale circulation, Geophysical Research Letters, 32, 10.1029/2005GL022574, 2005.

Liang, P. and Ding, Y. H.: The Long-term Variation of Extreme Heavy Precipitation and Its Link to Urbanization Effects in Shanghai during 1916-2014, Advances in Atmospheric Sciences, 34, 321-334, 10.1007/s00376-016-6120-0, 2017.

Yang, L., Scheffran, J., Qin, H. P., and You, Q. L.: Climate-related flood risks and urban responses in the Pearl River Delta, China, Regional Environmental Change, 15, 379-391, 10.1007/s10113-014-0651-7, 2015.

Jongman, B.: Effective adaptation to rising flood risk COMMENT, Nature Communications, 9, 3, 10.1038/s41467-018-04396-1, 2018.

United Nations (UN): United Nations World Water Development Report 2020: Water and Climate Change, 2020.

- **The building flood damage assessment method used in this study is too simple and lacks the novelty.**

Thank you for bringing this up. As the authors clarified in their general comment, the flood risk assessment of buildings in Shanghai is thoroughly described in our paper, along with the findings. As part of the methodology, compound flood hazard modelling was done while taking storm surges, precipitation, tides, and river flooding into consideration. The precise building flood loss and risk assessment can be assessed using flood hazard modeling. In addition, based on the type of building and its construction costs, we are able to evaluate exposed, damage and risk.

- **Should be Figure 7 and Figure 8 instead of Fig. 7, Fig. 8 in Page 14.**

We have checked all figures and tables in the manuscript and updated them on this point.

- **The methods of assessment of building damages in extreme floods used in this study are mainly derived from existing studies, thus what is the main**

contribution of this study.

Thank you for the comment. On the general response and response number 4, we responded to this comment.

We hope that the changes made and the answers provided will sufficiently address your concerns. Thank you for your recommendations which helped us to improve our manuscript.

Kind regards,

All Co-authors