Response to Anonymous Reviewer #1

The research group thanks Anonymous Reviewer #1 for their detailed comments and supportive suggestions. This feedback allows our group to make appropriate updates to the manuscript in preparation for uploading an improved version. Our answers to the General comments and Specific comments are as follows (denoted with a > symbol and blue text):

General comments:

(1) Although the impact of storm surge has been discussed in the introduction, there is no indication of how this study is specifically linked to storm surge. All analyses in this study appear to be based on data of the entire Shenzhen rather than the coastal regions of Shenzhen which are actually vulnerable to storm surge risk. This study appears to be an attempt to quantify the social vulnerability of Shenzhen to all types of natural disaster. Thus the authors might want to reconsider the title of this study.

> Yes, it is a good observation about this paper. Due to a data acquisition limitation, it is very difficult or impossible to find perfect indicators with a long-term record specifically linked to storm surge in China. This work is a creative attempt to analyze publicly available "macroscopic" data in order to explain the "microscopic" phenomena for such similar Chinese coastal cities. Furthermore, the data's spatial coverage is a narrow, 20 km length in the north-south direction across Shenzhen City and therefore most areas of Shenzhen are threatened during storm surges. Additionally, some directly related indicators of storm surge are selected, rather than other types of natural disasters such as "fishery output value" and "port cargo throughput", and used in the indicator system for evaluating social vulnerability. We believe our results address the problem to a certain extent. From this research, it becomes feasible for us to deliver suggestions to local governments about the need to collect and archive statistical data for most threatened coastal communities. Also, we will make an appropriate title change to fit this study more closely.

(2) In this study, the authors did not establish any connection between their social vulnerability index (SVI) and storm surges, i.e. validation of the SVI is not included. For example, Su et al. (2015) used total economic loss of hazards to examine the performance of their SVI which consequently show their SVI is linked to loss due to hazards. The authors could address this problem by relating SVI to economic loss, number of injuries due to storm surges, number of fatalities due to storm surges etc.

> Yes, this is a very constructive idea. We considered adding a validation strategy but public data of economic loss due to storm surges in Shenzhen is simply unavailable. Economic loss data was found to be available for Guangdong province (i.e. a broader scale dataset) which is where Shenzhen is located. We assume that the loss from a storm surge disaster in Shenzhen and Guangdong province are in direct proportion. We will add a validation section to this manuscript.

(3) There are a lot of statements and claims in this paper but the authors did not include the source of information or the studies to support those statements and claims. (Some of them are listed in the specific comments).

> Yes, thank you for your reminder. We will add all necessary sources of information to support our statements and claims, while satisfying your comment.

Specific comments (Technical corrections):

Page 2, lines 36-38: Reference is needed.

> The following citations account for the mentioned catastrophic events within lines 36-38 and were added to the manuscript:

Forbes, C., Rhome, J., Mattocks, C., and Taylor, A. A.: Predicting the storm surge threat of Hurricane Sandy with the National Weather Service SLOSH model, J. Mar. Sci. Eng., 2 (2), 437–476, https://doi.org/10.3390/jmse2020437, 2014.

Frank, N. L., and Husain, S. A.: The deadliest cyclone in history? Bull. Am. Meteor. Soc., 52 (6), 438–445, 1971.

Fritz, H. M., Blount, C., Sokoloski, R., Singleton, J., Fuggle, A., McAdoo, B. G., Moore, A., Grass, C., and Tate, B.: Hurricane Katrina storm surge distribution and field observations on the Mississippi Barrier Islands, Estuar. Coast. Shelf Sci., 74 (1-2), 12–20, https://doi.org/10.1016/j.ecss.2007.03.015, 2007.

Fritz, H. M., Blount, C., Thwin, S., Thu, M. K., and Chan, N.: Cyclone Nargis storm surge in Myanmar, Nature Geosci., 2 (7), 448–449, https://doi.org/10.1038/ngeo558, 2009.

Irish, J. L., Resio, D. T., and Ratcliff, J. J.: The influence of storm size on hurricane surge, J. Phys. Oceanogr., 38 (9), 2003–2013, https://doi.org/10.1175/2008JPO3727.1, 2008.

Lagmay, A. M. F, Agaton, R. P., Bahala, M. A. C., Briones, J. B. L. T., Cabacaba, K. M. C., Caro, C. V. C., Dasallas, L. L., Gonzalo, L. A. L., Ladiero, C. N., Lapidez, J. P., Mungcal, M. T. F., Puno, J. V. R., Ramos, M. M. A. C., Santiago, J., Suarez, J. K., and Tablazon, J. P.: Devastating storm surges of Typhoon Haiyan, Int. J. Disast. Risk Re., 11, 1–12, https://doi.org/10.1016/j.ijdrr.2014.10.006, 2015.

Rosenzweig, C., and Solecki, W.: Hurricane Sandy and adaptation pathways in New York: Lessons from a first-responder city, Glob. Environ. Change, 28, 395–408, https://doi.org/10.1016/j.gloenvcha.2014.05.003, 2014.

Xian, S., Feng, K., Lin, N., Marsooli, R., Chavas, D., Chen, J., and Hatzikyriakou, A.: Brief communication: Rapid assessment of damaged residential buildings in the Florida Keys after Hurricane Irma, Nat. Hazards Earth Syst. Sci., 18, 2041–2045, https://doi.org/10.5194/nhess-18-2041-2018, 2018.

Yi, C. J., Suppasri, A., Kure, S., Bricker, J. D., Mas, E., Quimpo, M., and Yasuda, M.: Storm surge mapping of typhoon Haiyan and its impact in Tanauan, Leyte, Philippines, Int. J. Disast. Risk Re., 13, 207–214, https://doi.org/10.1016/j.ijdrr.2015.05.007, 2015.

Page 4, lines 121-122: Reference is needed.

> The following citation accounts for the content about Shenzhen's GDP on line 121-122:

Zünd, D. and Bettencourt, L. M. A.: Growth and development in prefecture-level cities in China, PLoS ONE, 14(9), e0221017, https://doi.org/10.1371/journal.pone.0221017, 2019.

Also, a change from "attributed to the highest per capita Gross Domestic Product (GDP) in mainland China" to "attributed to one of the highest Gross Domestic Product (GDP) per capita in mainland

China...” due to the current GDP ranking, i.e. 1. Shanghai 2. Beijing 3. Shenzhen 4. Tianjin. The small city of Ordos (rich in natural resources) is noted as being the leader in the highest GDP per capita in mainland China although its significantly smaller in geographic size.

Page 6, lines 168-169: Full form of AHP and PCA are needed.

> The terms analytic hierarchy process and principal component analysis were added to the text.

Page 6, lines 175-176, 178: References for these methods would be needed.

> Replace the words with “Firstly, the construction of an optimized social vulnerability evaluation indicator system, based on the idea of rough set theory (Das et al., 2018), is completed. Second, the entropy method (Zhou and Yang, 2019), the Technique for Order Preference by Similarity to an Ideal Solution (TOPSIS) method (Kuo, 2017) and the coefficient of variation method (Zhou et al., 2004) are used to weigh the indicators and aggregate SVI separately. Then, the consistency of different evaluation results is tested by using the compatibility test method, i.e., Kendall consistency test (Wen and Hu, 2002).” All of the references have been included already.

Page 6, lines 183-184: What is “a theoretical framework” referring to?

> “a theoretical framework” was changed to “vulnerability theory”

Page 7, line 216, equation 2: What does “lnn” mean?

> Equation (2) was changed to
In case you cannot see the formula clearly, a larger picture is shown below.

$$e_j = -(\ln n)^{-1} \sum_{i=1}^{n} \bar{r}_{ij} \ln \bar{r}_{ij} \, (0 \le e_j \le 1, j = 1,2,3,\cdots,m)$$

Page 10, line 289-290: I doubt that Shenzhen faces storm surges accompanied by extratropical cyclones on regular basis. Could you please provide studies to support your statement?

> Thank you for pointing out this mistake. It is an error and we deleted “extratropical cyclones” from the manuscript, i.e. line 289. Storm surges that affect Shenzhen are mainly caused by tropical cyclones.

Page 11, lines 314-319: I am not sure about your argument here. Could you please provide studies/evidence that support your claim “students at school and women are more likely to suffer casualties outside” due to the harsh meteorological conditions? Why elderly people and people with disability are not included in the vulnerable groups? Could you please provide studies/evidence that support your claim about “social workers”? Are the authors assuming (all) people would still go to school/work despite a typhoon is affecting the city? As far as I know, when certain typhoon warning signal (yellow, orange, and red) is issued, school and work would be suspended. People would be asked to stay inside a safe building or evacuate to a safe location, i.e. majority of the people should be in safe locations. Thus I am not sure why students at school, women, and social workers are explicitly included as sensitivity indicators.

> Thanks for your detailed observation and relevant questions. With regard to the sensitivity indicators, as we know, the occurrence of storm surges is uncertain and the early warning system is not that accurate. Unfortunately, when a strong storm surge occurrence happens, it is difficult to have all students, women and social workers be held in the safe place. Additionally, elderly people and people with disabilities are included in vulnerable groups (Yuan et al., 2016), but there is no specific data captured about the elderly population in Shenzhen's statistical yearbooks. We would like to include all factors that would reach the general agreement of the marine disaster community. However, due to the lack of original data, we can only provide certain factors to the indicator system for analysis.

Also we will add the following reference (already in the reference list) to line 317:

Yuan, S., Zhao, X., and Li, L. L.: Combination evaluation and case analysis of vulnerability of storm surge in coastal provinces of China, Haiyang Xuebao., 38 (2), 16–24, https://doi.org/10.3969/j.issn.0253-4193.2016.02.002, (in Chinese), 2016.

Page 12, lines 331-333: Please provide evidence to support your claim – high income level of residents and higher living standard implies strong disaster resilience and faster post-disaster recovery.

> We will add the following reference (already in the reference list) to line 333:

Yuan, S., Zhao, X., and Li, L. L.: Combination evaluation and case analysis of vulnerability of storm surge in coastal provinces of China, Haiyang Xuebao., 38 (2), 16–24, https://doi.org/10.3969/j.issn.0253-4193.2016.02.002, (in Chinese), 2016.

Page 12, lines 342-345: It is not clear how does the categorisation of the index, which is developed by Yuan et al. (2016), can be applied to the SVI, which is developed in the current study. These 2 indices do not have the same composition! In addition, the interpretation of this categorisation is not clear. How should we use this categorisation?

> Thanks for pointing out this important mistake. We neglected the difference between the two studies and we have adjusted the categorisation in the updated manuscript.

Regarding lines 342-345:

Change the sentence "According to previous studies on disaster vulnerability, social vulnerability to storm surges discussed in this research can be approximately divided into (i) high vulnerability, (ii) relatively high vulnerability, (iii) moderate vulnerability, (iv) relatively low vulnerability and (v) low vulnerability and the corresponding critical points of SVI are 0.5873, 0.5163, 0.4452 and 0.3741, respectively (Yuan et al., 2016)." to "According to the common idea of equal division in mathematical statistics, social vulnerability to storm surges discussed in this research can be approximately divided into (i) high vulnerability, (ii) relatively high vulnerability, (iii) moderate vulnerability, (iv) relatively low vulnerability and (v) low vulnerability and the corresponding critical points of SVI are 0.5715, 0.5237, 0.4759 and 0.4281, respectively."

Regarding lines 355-358:

Change the sentence "According to classification criteria, social vulnerability to storm surges in Shenzhen during the entire study period can be divided into four stages: (i) high social vulnerability between 1986 to 1992, (ii) relatively high social vulnerability between 1993 to 2008, (iii) moderate

social vulnerability between 2009 and 2014, and (iv) relatively low social vulnerability between 2015 and 2016. The time to maintain relatively high (low) social vulnerability is the longest (shortest) as a whole, respectively." to "According to classification criteria, social vulnerability to storm surges in Shenzhen during the entire study period can be divided into five stages: (i) high social vulnerability between 1986 to 1994 and 1999 to 2004, (ii) relatively high social vulnerability between 1995 to 1998 and 2005 to 2008, (iii) moderate social vulnerability between 2009 to 2013, (iv) relatively low social vulnerability in 2014 and (v) low vulnerability in 2015 and 2016. The time to maintain high social vulnerability is the longest and relatively low social vulnerability is the shortest as a whole, respectively. It is apparent that, after 2008, social vulnerability has been completely removed from relatively high levels."

Page 13, line 370, 371: Please provide the full form of EI, SI, and RI in the main text.

> The terms exposure index, sensitivity index and resilience index were added to the text.

Page 13, line 374-375: Reference is needed as this information cannot be found in Figure 5.

> We understand the reviewer's concern. Fiscal spending, residents' income levels, completion degree of medical conditions, and infrastructure are all included in the indicator system and they all belong to resilience indicators. In Figure 5, we can see the continuous decrease of RI and that is caused by the improvement of Shenzhen's fiscal spending, residents' income levels, completion degree of medical conditions, and infrastructure. While the conclusion cannot be found in Figure 5, it can be indicated by the trend of RI. Therefore, we believe a reference is not needed here.

Figure 2: Figure 2 is not mentioned in the main text! Please name the source(s) of the GDP data set.

> Add "Through the growth of GDP, it is found that Shenzhen's economic level is progressively advancing during our study period (Fig. 2)." at the end of the first paragraph in Section **2.1 Study area**. The source of the GDP data set is the same as Section **2.2 Data sources**.

Figure 5: It is clear that the downward trend of SVI is mainly driven by the downward trend of RI. However, it is not clear that whether RI could be negative. If RI can be negative, how should it be interpreted? If RI cannot be negative, does this study suggest there exists a threshold in RI that social vulnerability cannot be reduced by further improvement of city's resilience?

> It's true that the downward trend of SVI is mainly driven by the downward trend of RI, but RI cannot be negative. In 2016, all of the resilience indicators happen to reach their maximum, and when performing normalization, the resilience index in 2016 equals zero (zero is the minimum of RI). Social vulnerability can be reduced by further improvement of the city's resilience because when RI equals zero, it only indicates that the resilience for that year is the strongest compared with other years during the whole study period, rather than the city improving its resilience to the largest degree.

Figures 6, 7: I am not sure what does "normalized values" mean.

> The graph objects are all normalized to a uniform range for comparison. Since their dimensions are different, they are uniformly converted into dimensionless quantities. In figure 6, we use min-max normalization which means a linear transformation is performed on the original data so that the result falls into the interval [0,1]. In figure 7, we also use min-max normalization but the value of indicators

fall into the interval [0,0.25]. For SVI, we subtract 0.38 from the value to yield an interval [0,0.25]. As a result, we can easily compare the relationship between variables.

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References used by Anonymous Reviewer #1:

Su, S. L., Pi, J. H., Wan, C., Li, H. L., Xiao, R., and Li, B. B.: Categorizing social vulnerability patterns in Chinese coastal cities, Ocean Coast. Manag., 116, 1–8, https://doi.org/10.1016/j.ocecoaman.2015.06.026, 2015.

Yuan, S., Zhao, X., and Li, L. L.: Combination evaluation and case analysis of vulnerability of storm surge in coastal provinces of China, Haiyang Xuebao., 38 (2), 16–24, https://doi.org/10.3969/j.issn.0253-4193.2016.02.002, (in Chinese), 2016.