Response to reviewer' comments

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We wish to thank the reviewer for their valuable suggestions. We agree with most of the critiques raised during the review process, and we will do our best to incorporate them in the revised paper.

Here is a detailed response [in italics] to each point raised during the review [underlined font].

<u>1. The literature review for frequency-based effect estimate of compound-event flooding (Line 69-76) is obscure. What is the missing link in the current research and why most of the studies failed to or avoided to explore the frequency and risk assessment of the compound flooding? It seems in this study the authors designed several compound scenarios to consider the probability of precipitation and surge as a solution to the shortcoming associated with compound flood risk assessment. If this is the case, more details on the related theories and methodologies should be presented in the introduction.</u>

We thank the reviewer for this comment. We will modify the introduction to provide a better framework for this study and highlight the importance of this work. We will improve the literature background to highlight more clearly what is missing in current research, and what this work is addressing. We will rephrase the introduction, and we will clarify better adding the text below

"In low-lying coastal areas, the co-occurrence of high sea level and precipitation, resulting in large runoff may cause compound flooding [CF] [Bevacqua et al., 2019]. When the two hazards interact, the resulting impact can be worse than when they occur individually. Both storm surges and heavy precipitation, as well as their interplay, are likely to change in response to global warming [Field et al., 2012].

Major research has been conducted on the assessment of damages to the power system components or other related infrastructures, and proposing design and operation countermeasures and remedies [i.e. Kwasinski et al. 2009; Reed et al. 2010; Abi-Sarma and Henry, 2011; Chang et al., 2007; de Bruijn et al., 2019; Pearson et al., 2018; Pant et al., 2018; Dawson, 2018]. Nonetheless, despite the CF relevance, a comprehensive hazard assessment on critical infrastructure is missing, and no studies have examined CF in the future.

The first step to investigate and assess the impact of CF on the power grid is to perform a systematic risk analysis. To deal with CF coming threats and challenges, there is a need to develop efficient frameworks for exploring a wide range of actual and what-if scenarios in a system that could inform short- and long-term decisions. Scientists must investigate not only how severe these events might be but also how commonly they are likely to occur. We propose a new strategy for providing this information: identify water levels and extent nearby critical infrastructure by observing real-world phenomena and drawing information from simulations.

When a hurricane approaches, providing a few extra hours' notice for infrastructure management is critical. By simulating the impact using possible storm paths, this framework offers more accurate medium-term risk evaluation. It can be used to assess the vulnerability of the infrastructures to current and future events."

<u>2. In section 2.3, it is better to use a table to describe these compound scenarios and their related hurricanes, SLR, tide conditions, and other attributes.</u>

We thank the reviewer for this comment. The manuscript currently presents the scenario in two different tables [table 4 and 5]. These two tables represent the peak flow, precipitation, total water level (tide + SLR) for all the scenarios at all the study locations. Considering this comment, in the revised manuscript we will provide an updated table, similar to the below one.

Table R1: Tide, Surge at the maximum total water level instance, Accumulated precipitation & peak flows (with return period reported within brackets) for the simulated scenarios. The readers should refer to Chapter

2.2 for a detailed description of each hurricane scenario (IR for Irene, SD for Sandy, FL for Florence). Events marked with "" denotes scenarios having sea level rise (SLR) added to the surge. Critical infrastructures are labelled CI1 to CI8 according to Table 1.*

Scenarios		CI1	CI2	CI3	CI4/ CI5	CI6	CI7	CI8
FL1	Tide (m)	0.99	0.99	0.99	0.94	0.94	0.94	0.17
	Surge (m)	2.51	2.51	2.51	2.56	2.46	2.56	3.33
	Accumulated precipitation (mm)	128.5	147.5	165.1	192	203.9	200.7	289.2
	Peak flow, m3/s (return period)	51.3(<2)	87.4(5)	74.9(<2)	106.1(13)	113.3(8)	143.2(51)	93.1(6)
FL2*	Tide (m)	0.99	0.99	0.99	0.94	0.94	0.94	0.17
	Surge (m)	3.12	3.12	3.12	3.17	3.07	3.17	3.93
	Accumulated precipitation (mm)	128.5	147.5	165.1	192	203.9	200.7	289.2
	Peak flow, m3/s (return period)	51.3(<2)	87.4(5)	74.9(<2)	106.1(13)	113.3(8)	143.2(51)	93.1(6)
SD1	Tide (m)	0.82	0.82	0.82	0.4	0.4	0.4	0.01
	Surge (m)	2.37	2.37	2.37	2.3	2.3	2.3	1.87
	Accumulated precipitation (mm)	24.8	24.7	21.5	17	17.7	15.1	8.9
	Peak flow, m3/s (return period)	3.4(<2)	9.3(<2)	3.3 (<2)	4.7(<2)	1.3(<2)	0.9(<2)	0.03(<2)
SD2	Tide (m)	1.01	1.01	1.01	1.13	1.13	1.13	-0.15
	Surge (m)	2.56	2.56	2.56	2.8	2.8	2.8	1.95
	Accumulated precipitation (mm)	24.8	24.7	21.5	17	17.7	15.1	8.9
	Peak flow, m3/s (return period)	3.4(<2)	9.3(<2)	3.3 (<2)	4.7(<2)	1.3(<2)	0.9(<2)	0.03(<2)
SD3*	Tide (m)	1.01	1.01	1.01	1.13	1.13	1.13	-0.15
	Surge (m)	3.12	3.12	3.12	3.4	3.4	3.4	2.564016
	Accumulated precipitation (mm)	24.8	24.7	21.5	17	17.7	15.1	8.9
	Peak flow, m3/s (return period)	3.4(<2)	9.3(<2)	3.3 (<2)	4.7(<2)	1.3(<2)	0.9(<2)	0.03(<2)
SD4	Tide (m)	1.01	1.01	1.01	1.13	1.13	1.13	-0.15
	Surge (m)	2.56	2.56	2.56	2.8	2.8	2.8	1.95
	Accumulated precipitation (mm)	555.3	546.9	526.8	338.2	330.2	316.6	323.7
	Peak flow, m3/s (return period)	242.4(316)	319.1(326)	201.7(28)	178.3(98)	168.4 (48)	197.0(301)	94.7(6)
SD5*	Tide (m)	1.01	1.01	1.01	1.13	1.13	1.13	-0.15
	Surge (m)	3.12	3.12	3.12	3.4	3.4	3.4	2.564016
	Accumulated precipitation (mm)	555.3	546.9	526.8	338.2	330.2	316.6	323.7
	Peak flow, m3/s (return period)	242.4(316)	319.1(326)	201.7(28)	178.3(98)	168.4 (48)	197.0(301)	94.7(6)
IR1	Tide (m)	1.16	1.16	1.16	1.1	1.1	1.1	0.93
	Surge (m)	1.94	1.94	1.35	1.42	1.42	1.42	1.1
	Accumulated precipitation (mm)	187.8	177.8	173.5	98.1	91.6	86.1	58.5
	Peak flow, m3/s (return period)	158.5(56)	201.1(58)	126.7 (26)	93.9(5)	85.7(5)	93.5(5)	30.8(3)
IR2*	Tide (m)	1.16	1.16	1.16	1.1	1.1	1.1	2
	Surge (m)	2.54	2.54	1.94	2.03	2.03	2.03	1.7
	Accumulated precipitation (mm)	187.8	177.8	173.5	98.1	91.6	86.1	58.5
	Peak flow, m3/s (return period)	158.5(56)	201.1(58)	126.7 (26)	93.9(5)	85.7(5)	93.5(5)	30.8(3)

<u>3. In section 2.4, which site does Figure 5 present for? The red rectangle shows a window of 48 hrs, not 24 hrs. What criterion is used for selecting the window size?</u>

We thank the reviewer for this comment. The rectangle was to bring attention to the peak, and highlight the changes in depth for the different scenarios. In the revised manuscript, we will improve the figure to avoid confusion, and we will add clarification on the caption regarding the location.

<u>4. In Lines such as 230, 237, Table 4 should be Table 5.</u>

We thank the reviewer for this comment. We will fix these mistakes in the revised manuscript.

5. Figure 8 shows the inundated period for each site, however, it cannot be seen that any data show 20% or 90% for SD1 or SD5 in the subgraphs of CI7 and CI8.

We thank the reviewer for this comment. If a critical infrastructure shows 0%, it means that for that scenario/event the water didn't reach the substation itself. This could be due to the water flooding other upstream locations, and therefore draining away from the station, or because the topography of the landscape prevents water from reaching the area for some specific events. We hope this can clarify this question, and we will add some comments in the manuscript about this.

6. The section of concluding remarks should be enhanced. The current conclusions are not intensive enough to show the findings of this paper. At least some quantitative analysis can be summarized and presented for readers to better understand how this work promotes the current risk assessments of compound flood hazards.

We thank the reviewer for this comment. We will enhance the concluding remarks. As per the reviewer's suggestion, we will highlight the main findings of the study. We will summarize the overall impact on the critical structure in terms of flood extent and depth. We will also comment strongly on how the existing guidelines should be reformulated to protect the critical infrastructures based on our findings.

7. There are some mistakes in grammar and spelling and the authors also did not pay enough attention to punctuation, which makes this manuscript more like a draft.

We thank the reviewer for their valuable suggestion. We will proof-read the paper and improve grammar and spelling before submitting the revised manuscript.

References

A. K*wasinski, W.W. Weaver, P.L. Chapman and P.T. Krein, "Telecommunications Power Plant Damage Assessment for Hurricane Katrina – Site Survey and Follow-Up Results," IEEE Systems Journal, vol. 3, no. 3, pp. 277–287, Nov. 2009.*

B. D.A. Reed, M.D. Powell and J.M. Westerman, "Energy Supply System Performance for Hurricane Katrina," Journal of Energy Engineering, pp. 95–102, Dec. 2010.

C. N. Abi-Samra and W. Henry, "Actions Before and After a Flood – Substation Protection and Recovery from Weather Related Water Damage," IEEE Power & Energy Magazine, pp. 52–58, Mar/Apr. 2011.

D. Chang, S. E., McDaniels, T. L., Mikawoz, J., & Peterson, K.: Infrastructure failure interdependencies in extreme events: power outage consequences in the 1998 Ice Storm. Natural Hazards, 41(2), 337–358. https://doi.org/10.1007/s11069-006-9039-4, 2007.

E. Dawson, R. J., Thompson, D., Johns, D., Wood, R., Darch, G., Chapman, L., Hughes, P. N., Watson, G. V. R., Paulson, K., Bell, S., Gosling, S. N., Powrie, W. and Hall, J. W.: A systems framework for national assessment of climate risks to infrastructure, Philos. Trans. R. Soc. A Math. Phys. Eng. Sci., 376(2121), doi:10.1098/rsta.2017.0298, 2018.

F. de Bruijn, K. M., Maran, C., Zygnerski, M., Jurado, J., Burzel, A., Jeuken, C. and Obeysekera, J.: Flood resilience of critical infrastructure: Approach and method applied to Fort Lauderdale, Florida, Water (Switzerland), 11(3), doi:10.3390/w11030517, 2019.

G. Pant, R., Thacker, S., Hall, J. W., Alderson, D. and Barr, S.: Critical infrastructure impact assessment due to flood exposure, J. Flood Risk Manag., 11(1), 22–33, doi:10.1111/jfr3.12288, 2018.

H. Pearson, J., Punzo, G., Mayfield, M., Brighty, G., Parsons, A., Collins, P., Jeavons, S. and Tagg, A.: Flood resilience: consolidating knowledge between and within critical infrastructure sectors, Environ. Syst. Decis., 38(3), 318–329, doi:10.1007/s10669-018-9709-2, 2018.