AUTHORS’ RESPONSE TO REFEREE #1

Research article: “Regional tropical cyclone impact functions for globally consistent risk assessments” (Nat. Hazards Earth Syst. Sci. Discuss., https://doi.org/10.5194/nhess-2020-229; in review, submitted on 09 July 2020)
Authors: Samuel Eberenz, Samuel Lüthi, David N. Bresch

We thank anonymous referee #1 for their comments, which have improved the quality of the manuscript. The original comments from the referee are listed below directly followed by our responses in *blue and italic* and changes to the manuscript in **blue and bold**.

This manuscript by Eberenz et al. evaluates the model-simulated damages from trop- ical cyclones, and provides suggestions to improve this assessment and reduce the uncertainty of simulations by using regionally calibrated data. While the premise of the paper seems straightforward (e.g. "improving the calibration of the model will re- sult in closer simulation of observed events"), the execution of the work in the paper is well done as it explores the limitations of their proposed approach. While overall the manuscript is well-presented and organised, there are opportunities to improve the text, particularly the analysis in the case study for the Philippines.

1.1a) Some initial minor comments include better consistency in the risk language used in the paper; overall, it is good but there are some errors, e.g. para 35: "natural risk" –> is this hazard? risk? and para 180 “from natural catastrophes are records are available”
and following line (“natural disasters”). As you might well know it is a common refrain in the disaster/hazard community that "there are no natural disasters" – so do double check for the consistency.

We would like to thank the referee for pointing out the inconsistencies of terminology. We have revised wording in the paragraphs mentioned by the referee. As for the lines 38f, we suggest replacing “natural risk” with “risk from natural hazard”. In lines 178f, we suggest restructuring both sentences to tackle the issue raised above and improve readability at the same time.

On a side note: Originally, the wording “natural and technological disaster” was taken from the EM-DAT data description: “EM-DAT distinguishes between two generic categories for disasters: natural and technological.” (https://www.emdat.be/explanatory-notes, last accessed 29/09/202). Still, we agree with the comment that this wording is not necessarily the most broadly accepted.

Suggested changes to the manuscript:
L. 38f: “~~Natural risk~~ **Risk from natural hazards** is frequently modelled as a function of severity and occurrence frequency, [...]”

L. 178f: “~~Damage estimates from natural catastrophes are records~~ **Reported damage estimates for disasters worldwide** are available from the International Disaster Database EM-DAT (Guha-Sapir, 2018). EM-DAT provides ~~global~~ data ~~on natural and technological disasters~~ **per event and country**, including disaster type and subtype, date of the event, and impact **estimates** ~~data at the country level~~.”

1.1b) I also think that in para 55 where you say "one [...] function... might be inappropriate [...]", as this is the main argument of your work, could be made even stronger to create a deeper impression of the purpose of your research.

Indeed, this paragraph in the introduction is formulated more cautiously than what previous studies and our results indicate. Therefore, we follow the referee’s suggestion to reformulate the sentence to express our position in a more confident way:

L. 56ff:
“However, due to global heterogeneities in the tropical cyclone climatology (Schreck et al., 2014), building codes, and other socioeconomic vulnerability factors (Yamin et al., 2014), **it is inadequate to use a single** ~~one~~ universal impact function ~~might be inappropriate~~ for global TC risk assessments.”

1.2) I find it interesting that the model over-simulates damages in the NWP basin, as it could be easily imaged that the damage function would not be able to simulate the myriad impacts of the associated hazards you mention such as the storm surges. In line with this I think it would have been interesting to provide an hypothesis for your research question, for example in para 70 where you pose this question.

This point is well taken! An attribution of the interregional differences in vulnerability to TC damage to the drivers of vulnerability would be really interesting to look at. While such an attribution study would be out of scope of this study, we agree that it is important to discuss the different drivers and factors determining the vulnerability, that is, the shape of the calibrated impact functions.
In the manuscript, this is already touched upon, e.g. in the introduction:
L. 56f:
“[...] global heterogeneities in the tropical cyclone climatology (Schreck et al., 2014), building codes, and other socioeconomic vulnerability factors (Yamin et al., 2014) [...]”

… and in the discussion:
L. 501ff:
“[...] the results for the North West Pacific region (WP4), consisting of Japan, South Korea, Macao, Hongkong, and Taiwan, deviate substantially from GAR 2013. Simulated relative AAD in the region ranges from 0.2-0.8 ‰ as compared to 3.1 ‰ in GAR 2013. This difference implies that, besides the use of building type specific impact functions, the TC impact model of GAR 2013 substantially overestimates TC damages in WP4 compared to reported data.”

In order to give a clearer message regarding attribution to the readers of the paper, we propose to add the following brief paragraphs to the manuscript:

In Section 1 (Introduction):
"While the attribution of vulnerability to regional drivers is outside the scope of this study, the results can serve as a starting point for further research disentangling the socio-economic and physical drivers determining vulnerability to TC impacts locally and across the globe."

In Section 6 (Conclusion and Outlook):
"**The substantial over-estimation of TC damages in the North West Pacific with the default impact function opens the question for the drivers of the apparently lower vulnerability in this region. Considering the inability of the model setup to directly represent the impacts from TC surge and pluvial flooding, one would rather expect aggregated calibrated impact functions to be steeper than the default wind impact function. Therefore, we suggest investigating interregional differences in possible other drivers, including building standards but also damage reporting practices."**

My main comments are related to the case study of the Philippines.

1.3) Firstly, there is some confusion in the TC nomenclature which should be addressed for consistency (Table A4). For example, Ondoy is the local name and Ketsana is the international name.

We would like to thank the referee for helping to clarify the confusion around the Typhoon names in the Philippines. Both in the text and in Table A4, we will adapt the following event names for consistency, mentioning the local names in brackets:

- "Bopha" → **"Bopha (Pablo)"**
- "Pedring (Nesat)" → **"Nesat (Pedring)"**
- "Pepeng (Parma)" → **"Parma (Pepeng)"**
- "Ondoy (Ketsana)" → **"Ketsana (Ondoy)"** *(also in L. 459 and Figure 6c)*
- "Fengshen (Franck)" → **"Fengshen (Frank)"**

Change in L. 422f, also removing double mentioning of water supply:
"~~Most events~~**TCs in the Philippines** inflict damage on several sectors, most costly on housing and agriculture, but also on schools and hospitals, power and water supply, roads, and bridges (Table A4). Single events were also reported to damage and disrupt airports and ports (Typhoon Haiyan) **and**~~,~~ dikes (~~Pedring~~**Nesat and Xangsane**)~~, and water supply (Bopha and Fengshen).~~"

1.4) Additionally this case study of the Philippines is very brief and only an assessment of asset exposure, and not vulnerability. I think that this section could use more context of the vulnerabilities associated with the Metro Manila region, enhanced by locally-led scientific literature on vulnerability (e.g. Porio 2011) as well as an analysis of the hazard events themselves to give the reader more context (see e.g. the work of Lagmay et al, Abon et al re: Ketsana and Haiyan (incl. effect of mountain ranges to improve your Done 2019 reference), Cayanan et al 2011 and Cruz/Narisma on SW monsoon effect on TCs, Yumul et al on TC Fengshen). Indeed I think these references could also be visited as Espada (2018) is often your only reference (Table A4).

See combined reply to 1.4 and 1.5 in next point.

1.5) There are some paragraphs that could use more attention and more geographical nuance, for example para 470 on Typhoon Haiyan (2013). This TC impacted mainly Tacloban City; indeed, this reflection of imbalanced damages appears to be simulated in your model output (Figure 6c) but Iloilo and Cebu cities are mentioned in lieu of this.

Thank you very much for providing additional insights and references with regards to the case study of the Philippines. We answer both comments 1.4 and 1.5 together, since the improvements requested in 1.5 can be improved with reference to the additional literature suggested in comment 1.4.

We agree to the referee that integrating more local context and geographical accuracy will improve the informative content and accuracy of the case study. Doing so actually helps sharpen the argument of the whole of Section 4, that is, adding further support for the hypothesis that (1) a differentiation of urban and rural exposures and vulnerabilities would increase the accuracy for sub-regional TC damage simulations, and (2) explicitly modeling of damage caused by sub-perils like storm surge and torrential rainfall would substantially improve TC damage simulations in the Philippines. Thus, an integration of the additional information will improve the manuscript while not affecting but rather strengthening the conclusions we draw from the case study.

At the same time, the case study is intended as an explorative excursion and not the main focus of the paper. Therefore, we suggest to incorporate the additional context most relevant for the discussion while not overly inflating the text body of Section 4 altogether.

As a consequence, we propose to incorporate additional local context provided by the proposed references in Sections 4.1 to 4.3 of the manuscript as follows:

Section 4.1 Tropical cyclones in the Philippines:
L. 419f:
"In summary, TCs making landfall in the Philippines cause damage due to large wind speed, storm surge, as well as rain induced floods and landslides. **Meteorologically, the storm systems interact with the monsoon season, affecting both dynamics and the severity of torrential rain (Bagtasa, 2017; Cayanan et al., 2011; Yumul et al., 2012). TCs in the Philippines** ~~Most events~~ inflict damage on several sectors [...]"

Section 4.2 Urban vs. rural exposure:

L. 430ff:

"Most of the asset exposure value of the Philippines is concentrated around the metropolitan area of Manila **(Metro Manila).**~~, located~~ **Located** around 14.5°N, 121.0°E (Fig. 6a)**, Metro Manila is Philippine's political and socio-economic center (Porio, 2011)**. The Typhoons Angela (1995), Xangsane (2006), and Rammasun (2014) are prominent TCs hitting ~~the Manila region~~**Metro Manila** directly. In our analysis, ~~they~~ these TCs come with particularly large EDRs, [...]"

In Section 4.3 Impact of storm surge and torrential rain:

L. 461ff:

"**While urban vulnerability to strong winds in Metro Manila appears to be overestimated by the calibrated impact function, Metro Manila is known to be highly exposed and vulnerable to regular, large scale flooding (Porio, 2011). The main drivers of flood vulnerability are its geographical setup, largely unregulated urban growth and sprawl, and substandard sewerage systems, especially in low-income areas (Porio, 2011).** Tropical Storm **Ketsana, locally known as** Ondoy (2009) is an example with very low simulated damages **coinciding with large reported damages associated to flood in Metro Manila: Ketsana's** ~~Ondoy's~~ EDR is 0.002, i.e. its simulated damage is more than two orders of magnitude smaller than reported. The large reported damage (NRD=401 million USD) was mainly due to floods and landslides: Torrential rainfall caused severe river flooding in the ~~Manila metropolitan region~~**Metro Manila** and landslides around Baguio City, resulting in severe damages (Abon et al., 2011; Cruz and Narisma, 2016; Nakasu et al., 2011; NDCC, 2009a). ~~These~~ **The flood** damages were not resolved by the wind-based impact model, with intensities well below 50 ms-1 and neither affecting Manila nor the northern Baguio City directly (Fig. 6d). **Notably, even for TCs with large overestimation of simulated damage due to high wind speeds in Metro Manila, namely Fengshen and Xangsane, a substantial part of the reported damage was actually caused by pluvial flooding and landslides and not by wind alone (Yumul et al., 2008, 2011, 2012).**"

L. 470ff:

"It should be noted that ~~these~~ sector specific impacts are not resolved in the impact model and Haiyan did not affect Manila directly. ~~However, r~~**R**elatively large damages were simulated **around Tacloban City, Leyte, which was actually devastated by Haiyan's storm surge. Large wind impacts were also simulated further West** around the cities Iloilo and Cebu (Fig. 6c) **that were not as exposed to surge as Leyte province."**

In Table A4:

Add references per event, associated disasters, and affected assets for TCs Haiyan, Ketsana, Fengshen, and Xangsane. Additional information are based on the following publications: **Abon et al. (2011), Cruz and Narisma (2016), Lagmay et al. (2015), and Yumul et al. (2008, 2011, 2012)**.

1.6) Having more context would also provide you an opportunity to refute an argument you pose earlier in your paper related to the CLIMADA setup, in that "[...] no impact is expected for low wind speeds," when it is evident many high-impact events in exposed and vulnerable regions cannot be estimated on wind speeds alone; geography/topography, exposure and vulnerability, local climate conditions (e.g. SW monsoon) play a significant and sometimes, larger role in realised damages from TCs.

See point 1.2 above and combined reply to 1.6 and 1.7 in next point.

1.7) With a better focus on this I think it would provide a richer and more meaningful assessment of exposure and vulnerability that give better context to your paper and the need for more regionalised calibration of damage estimates from TCs.

Reply to both comments 1.6 and 1.7: We agree that the limitations of a TC impact model based on wind speed as the only hazard intensity can not be stressed enough. Generally, we believe that the manuscript reflects upon these limitations and uncertainties to a sufficient degree and the need for more regionalized calibration, especially for local applications, have already been firmly emphasized in the discussion and outlook sections of the manuscript. For instance, in the last paragraph of Section 6:
“Limitations of our research motivate future work. For TC impact models, we echo the call for a more refined representation of TC hazard as a combination of wind, surge, and rain induced flood and landslide events. Furthermore, our case study for the Philippines suggests that differentiating between urban and rural asset exposure, considering topography in wind speed estimations, and the inclusion of exposed agricultural assets could further increase model accuracy.” (L. 587f)

The case study on the Philippines, with the improvements suggested in comment 1.4 and 1.5, adds detail and evidence of the discussion of these uncertainties and recommendations for further model development in the outlook.

Regarding the specific argument regarding low wind speeds from Section 2.2.3, we suggest to narrow the statement and also emphasize the learnings from the case study in these regards in Section 4.4, see suggested changes in the manuscript below:

L. 144 (Section 2.2.3):
“Since no ~~impact~~ **directly wind induced damage** is expected for low wind speeds, [...]”

L. 476ff (Section 4.4):
“The case of the Philippines reveals limitations of the model and calibration due to the lack of an explicit representation of sub-perils such as storm surge, torrential rainfall, and landslides (Sect. 4.3). **The flood damage caused by Ketsana is a showcase example for severe damages associated with a TC with relatively low wind speeds, that is, an event that cannot be adequately reproduced with a wind-based impact function.** Adding to the stochastic uncertainty, the magnitude of rainfall during a TC events in the Philippines is not only

determined by the intensity of the TC event, but also by the coinciding monsoon season, as in the case of the Typhoons Fengshen and Haiyan (Espada, 2018; IFRC, 2009**; Yumul et al., 2012**)."