Response to Manuscript # hess-2020-55, "Co-incidence analysis of changes in flood magnitude and shifts in flood timing in a large tropical pluvial river basin" by P. Ganguli, Y. R. Nandamuri, and C. Chatterjee

We would like to thank the reviewer 1 for the valuable comments and for providing us an opportunity to improve our manuscript. Our responses are embedded within the comments (in BLACK) in BLUE. The new additions to the revised manuscript are embedded below in BROWN.

Reviewer #1 (Response to Technical Comments to the Reviewer)

Comment 1: The manuscript "Co-incidence Analysis of Changes in Flood Magnitude and Shifts in Flood Timing in a Large Tropical Pluvial River Basin", by Ganguli et al., aims at assessing coincidence of changes in peak discharge and shifts in its timing in Mahanadi River Basin (MRB), in India.

Many of the results that have been showed for the analyzed catchment are a summary or repetition of previous studies as also the authors declare both for what concerns analysis of trends in floods (Panda et al., 2013 – lines 452-457) and trends in flood seasonality (Ganguli et al., 2020 – lines 469-473). Therefore, this study reduces to a qualitative comparison between the two trends by introducing some explanatory hypothesis and contextualizing the finding of previous studies.

Response: Thanks for the feedback. Here we would like to point out to the reviewer that our study stands apart from other studies on various fronts. Taking the example of two studies that the reviewer has pointed out, for example, Panda et al. (2013) assessed trend in monthly streamflow records from 19 gauges for the period 1972 – 2007 and daily gridded rainfall records from 60 grids at 0.5° spatial resolution for the period 1972 – 2005 using Mann-Kendall trend statistics. Their analysis was limited to lower temporal resolution discharge records and establishing possible linkage between seasonal streamflow patterns and extreme rainfall indices over the Mahanadi River basin. While flow regime from higher temporal resolution would be necessary for precise estimation of flood timing and changes in magnitude and frequency of high flow, the Mann-Kendall trend statistics offer only identification of monotonic (or continuous) trends in the time series with no specific information of abrupt shift or change points within the time series. On the other hand, Ganguli et al. (2020) have showed the role of catchment wetness (considering antecedent soil moisture as a proxy variable) in modulating the timing and magnitude of floods. However, unlike previous assessments (for brevity we summarize in Table S1), that analyzed either trend in flood magnitude or the role of hydrometeorological drivers such as precipitation or antecedent soil moisture in flood generating mechanism, using high-quality daily streamflow records of 24 (out of 47 total) stream gauges, this study for the first time assesses following research questions for the Mahanadi River basin in India:

1. While other studies have explored the possibility of 'local' monotonic trends in flood record at individual river gauge locations, is the nature of trend significant at a regional level considering a collection of all sites? Second, is there any abrupt change in the flood time series and could the detected change point be linked to any major anthropogenic activity prelevant over the basin?

2. Is there any possible linkage between the trend in flood severity and catchment properties or processes, which were ignored in most of the previous assessment for a vast river network of Mahanadi?

3. Is there any evidence for the concurrence of trend (up/downward) in flood severity and shift (early/delayed occurrence) in flood timing that may help in identifying the "flood-rich and flood poor" (Merz et al., 2018) region over the basin?

Comment 2: The language is fluent and precise. Scientific content and methods as well as overall presentation of the results are very good but the main problem, according to my opinion, is the poor degree of novelty of the tools, data and findings. Moreover, I strongly believe that the novel content is insufficient for the relevance of the journal.

Response: We appreciate this comment from the reviewer. However, we do not agree with the reviewer regarding novelty aspects, quality of the data used and the scientific rigor of the study as pointed out. As discussed in the earlier response in comment 1, and also as shown in Table S1 (the last row, where we highlighted the novelty aspects of our study), we re-iterate our study is the first kind over Mahanadi River basin that investigated comprehensively the nature of floods and its shifting behavior over time using ranges of statistical tools, which were not implemented before over the study area in particular. Further, unlike earlier assessments that have used either 30 – 40 years records with lower temporal resolution flow data (for example, Panda et al., 2013 have used monthly time series of discharge) or a limited number of gauging sites (Jena et al., 2014; Mondal and Mujumdar, 2012; Panda et al., 2013), we have used the best quality up to date high-frequency daily streamflow observations of 47 years (1970 – 2016), with minimal gaps in the records from 24 gauges spatially distributed over the basins.

Our study suggests most of the sites show the earlier or delayed flood timing, which is coincided by an increased or decreased trend in flood magnitude over one-third of the gauges throughout. In summary, we find a larger number of gauges over Mahanadi basins showed a delayed shift in flood timing using both monsoonal maxima and peak-over Threshold (POT) flood series. This delayed shift in flood timing has direct implications in the operation of Hirakud dam, the longest earthen dam in India. The obtained results would provide valuable insights to inform the shifting nature of floods as a consequence of climate change and developing regional flood resilience strategies in densely populated areas of Mahanadi River basin.

Comment 3: The results are presented with significant details and systematic approach. The authors made a great effort for motivating the few innovative results and study, for this reason the reading is very interesting but the paper resemblances a review paper in many paragraphs and still appears bare for what concerns new contents.

Response: Here we sense a slight contradiction in the reviewer's comment; wherein the first part of the comment the reviewer has appreciated our work, on the other hand, s/he finds a resemblance with a review paper. Here we point out that, we have presented sufficient evidence regarding novelty aspects in the study as reflected in research questions posed, application of improved analyses methods and updated database for the study region. However, the reviewer has not clearly pointed out which part of the manuscript appears bare or which section s/he intends to be revised/deleted.

Comment 4: Therefore, I invite authors to continue their fascinating research on the topic and to include in a future comprehensive version of the paper a supportive analysis for the new findings that can motivate the interest of the readers. For instance, I am referring to the role of catchment processes or trends in precipitation extremes for motivating the observed coincidence of trends in peak discharge and persistence in its timing.

Response: We appreciate this comment from the reviewer. However, we point to the reviewer that catchment processes, such as watershed-response time or the delay between rainfall occurrences to flood events in small to medium sized catchments (as is the case for most of the catchments here) is dictated by number of factors, such as, area of watershed, flow length, topographic slope and flow resistance which is modulated by soil types (Berne et al., 2004; Gaál et al., 2012; Holtan and Overton, 1963; Kennedy and Watt, 1969). The review of the literature (Berne et al., 2004; Holtan and Overton, 1963; Kennedy and Watt, 1969) suggests, among many factors, the basin lag time can be primarily related to catchment area through a simple power law relationship; the larger (smaller) the catchment size, longer (faster) the time elapsed to propagate rain-induced runoff at downstream as a flood hydrograph. Here, we have already included, the analyses of scale-dependence to runoff sensitiveness, *i.e.*, dependence between peak discharge and catchment area in Fig. 3. Hence, our analysis has already taken care of catchment processes to runoff sensitiveness.

We further point to the reviewer that owing to the rain fed nature of the basin, a number of studies have already investigated the linkage between rainfall magnitude and extreme floods using both station-based (Panda et al., 2013; Rao, 1993, 1995) and gridded (Jena et al., 2014) rainfall records. Further, a few studies (Ghosh et al., 2010; Mondal and Mujumdar, 2012; Mujumdar and Ghosh, 2008; Raje and Mujumdar, 2009) have also investigated climate change signal over MRB using gridded precipitation records from general circulation models. Further, Ganguli et al. (2020) have

already shown the role of catchment wetness (considering antecedent soil moisture as a proxy variable) in modulating the timing and magnitude of floods.

The focus of present paper was not to reiterate the same findings but rather to investigate the possible linkage between the trend in flood severity and catchment properties or processes and identification of "flood-rich and flood poor" regions across the Mahanadi basin. Accordingly, we have removed the future research statements as explained in lines # 480 – 485 of the older version of the manuscript, which is already addressed in Ganguli et al. (2020) for Mahanadi River basin.

Comment 5: Specific comments

I suggest changing the 3-D plot in Figure 3 in a 2-D plot to improve its readability: may be different colors and markers just help to quantify the statistics.

Response: Agreed and revised.

Comment 6: Line 216: typesetting error.

Response: Agreed and revised.

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