Response to the comments of Referee #1 on “Impacts of spatial resolution and representation of flow connectivity on large-scale simulation of floods” by Cherry May R. Mateo et al.

Note: This document provides authors’ responses to the comments of Referee #1. We have formatted the comments made by the referee in italic and black-colored fonts and our response in upright and blue-colored fonts. To distinguish the modifications made in the manuscript from our response to the referee’s comments, modifications are formatted in a different font type (Times New Roman). The page and line numbers within brackets or parentheses indicate the location of the modifications in the revised manuscript.

The revised manuscript as well as the manuscript with all revisions tracked are provided as supplementary documents. A document that provides our responses to the comments of the two referees is also provided as a supplement.

Response to the comments of Referee #1

This paper reports on the application of a new model structure in the CaMa-flood Global River Model (GRM) to the simulation of the Thailand 2011 flood. The new model structure introduces extra connectivity in CaMa-flood to allow better simulation of river flows in cases where the simple assumption of a single downstream drainage path, which is the common drainage structure used in GRMs, does not apply (for example in deltas where there is river bifurcation). The need for improved connectivity and better river representation in GRMs has been identified as an important area of research, therefore this paper is a very timely and important contribution to the evolution of GRMs in general.

The paper is mostly well written and clear except for the few typos listed below. Figures are also of good quality and informative. Analysis on the whole seems thorough and appropriate. Where I think there are some issues is in the interpretation of the findings and some claims which maybe a bit overconfident, given the evidence. I feel the paper should be published after some minor additional discussion to cover these conceptual issues.

We thank the referee for recognizing the timeliness and importance of our work. We greatly appreciate the time and effort that the referee have spent in reviewing the manuscript. The suggestions made by the referee are very helpful in improving the discussions in the revised manuscript. We have corrected the typos pointed out by the referee. We have also modified the parts which readers may find to be overconfident. Where necessary, we have included a brief discussion to support our claims. Please refer to the revised manuscript for the changes made.

Conceptual issues: (1) In the abstract (line 24), it is stated that the findings are universal. However I do not think evidence is provided to back up this claim. I agree that, in theory they should be, but without wider testing or evidence, this is an over bold claim. I would suggest, either rewording this to “findings should be universal” or providing a better argument as to why the authors consider them universal, for example through a clear geomorphological explanation as to why the findings here equally apply elsewhere.

We thank the referee for pointing this out. We do recognize the point made by the referee that while the findings are universal in theory, the paper shows the validity of the theory in only one region. Further tests may be needed to support the claim. Hence, we have modified the statement in the abstract according to the referee's suggestion:

"While a regional-scale flood was chosen as a test case, these findings should be universal and can have significant impacts on large- to global-scale simulations especially in regions where mega deltas exist." [page 1, lines 24-25]

We have also toned down a statement in the introduction from "With this verification exercise, two fundamental questions with regards to large- to global-scale simulation of floods can be answered…" to "With this verification exercise, we attempt to answer two fundamental questions with regards to large- to global-scale simulation of floods…" [page 4, lines 6-7]

We argue that because the mechanism behind our findings is physically-based, the findings should theoretically be applicable globally, but the impacts will be more evident in river mega deltas. The reasons for the decline in the capability of GRMs using *SDC* scheme to simulate flooding in floodplains and mega deltas in finer spatial resolution have been discussed in 6.1. We have added a few lines in the section to further improve the discussion (please see page 10, line 17 to page 11, line 5 of the revised manuscript).

(2) The link between the real river system and the model representation of that system is not very well explained or developed. While GRMs will obviously necessitate approximations, as they strive for higher resolution representation and improved physical representation, it is important that these additions/improvements are providing the right results for the right reasons. For example, interconnecting flood flows across floodplains occurs through two main processes, diffusive overland flow and channelized flow. Many of the smaller channels are not explicitly present in the DEMs used in the models and even the finer resolution reach-scale hydrodynamic models struggle to include this complexity. The method to improve connectivity in the CaMa-flood model seems to be a diffusive flow method between cells and will not explicitly capture smaller floodplain channels. Any smaller channels present on the floodplain in the CaMa-flood model will be DEM drainage paths rather than real observed channels, so it is not clear how the extra model connectivity relates to the real river systems. The reason this is important is that there is a danger of introducing too much connectivity. This will have the effect of improving the models ability to capture a flood but at the expense of over prediction. I would suggest that the representation of real observed flood connectivity is covered in more detail in the discussion (there are plenty of good papers on this topic – including on the Chao Phraya).

Thank you for raising this important issue. We generally agree with the referee on the points made. We have added a few lines to describe how the MDC channels are derived in the model in section 3.1:

"The algorithm for extracting bifurcation channels is described in detail in Yamazaki et al. (2014b) and will only be described briefly in this paper. Using data from HydroSHEDS and SRTM3, the algorithm searches for possible flow pathways which cross unit-catchment boundaries. A "bifurcation threshold height" above the main channel of each unit-catchment is set for computational efficiency. The algorithm searches for pixels (grid cells in the SRTM3 DEM) which are at unit-catchment boundaries and are at an elevation lower than that of the bifurcation threshold. The pixel is identified as a valid bifurcation point if its elevation is higher than that of an adjacent pixel which is located in another unit-catchment. Using HydroSHEDS flow directions, a bifurcation channel is defined as the pathway from each bifurcation point to the main channel pixels of its upstream and downstream unit-catchments. Bifurcation channels in floodplains are represented by overland pathways, while those with persistent bifurcated flow are represented by river pathways. Persistent bifurcated flow is detected using the SRTM Water Body Data (SWBD) water mask (NASA/NGA, 2003)." [page 6, lines 5-14]

We agree with the referee that the issue of representing connectivity (as well as other processes that influence flow pathways) should be discussed more in the paper. To address this issue, we have added a paragraph in section 6.3 (caveats and future works):

"While the use of the *MDC* scheme in CaMa-Flood resulted in improvements in the simulation of flood dynamics in large floodplains, it should be noted that uncertainties remain in the representation of *MDC* pathways in the model. The *MDC* pathways in the model may not necessarily correspond to or explicitly represent the actual flow pathways, especially the small channels (e.g. small artificial canals) in the river basin. Small *MDC* channels in the model which are not covered by the SWBD water mask are currently represented as overland pathways. As channel bathymetry is not considered in overland pathways, this assumption may lead to the underestimation of flows in small *MDC* channels in the model (Yamazaki et al., 2014b). The accurate representation of *MDC* pathways in the model still depends on the resolution and accuracy of the DEM used (3-arcsecond or ~90m SRTM3 DEM by Farr et al., 2007 in this study). The explicit representation of small artificial channels with widths which are narrower than the grid resolution of the DEM used and other small scale flow connectivity between rivers and floodplains is still difficult to achieve in large scale simulations. A finer resolution DEM or a tool for extracting or deriving smaller channels from open street maps will be very helpful in improving the accuracy of the representation of *MDC* pathways in the model. The use of new data-driven approaches to derive flood-mediated *MDC* pathways and connectivity (e.g. progressive nearest neighbour search or progressive iterative nearest neighbour search by Zhao et al., 2017) may also be explored in the future. It should also be noted that the changes in channel network (by sedimentation, subsidence, and other geological processes, or by levee breaks, water diversion, and other anthropogenic impacts) and operation of artificial canals are not represented in the current model. Such natural or anthropogenic influences which add to the complexities in real flow pathways have significant impacts on the connectivity and flood dynamics in floodplains (Syvitski et al., 2005; Alsdorf et al., 2007; Schumann et al., 2011; Trigg et al., 2013). However, even catchment scale hydrodynamic models implemented in fine spatial resolution have difficulties in representing such complex processes. The representation of such complexities will require the integration of more detailed models and data (e.g. landscape, sedimentation, anthropogenic, etc.) with flood models. " [page 13, lines 10-29]

Minor typos and suggested edits:

(1) Page 1, line 14: "simplified representations" instead of "simplified representation"

(2) Page 2, line 20: "simplified representations" instead of "simplified representation"

(3) Page 2, line 31: "flood hazard maps for 1 x 1 km grids" instead "flood hazard maps at 1 x 1 km grids"

(4) Page 3, line 29: "model has been" instead of " model have been"

(5) Page 4, line 18: "This paper assessed". . ... papers don't assess, people do. Perhaps "In this paper we assess". Also "flood in the Chao Phraya River Basin" instead of "flood in Chao Phraya River Basin"

(7) Page 5, line 5: "based on fine-resolution" instead of "based from fine-resolution"

(8) Page 5, line 8: "DEM" instead of "DEMs"

(9) Page 6, line 27: "The simulation" instead of "Simulation" and "The calculation" instead of "Calculation"

(10) Page 7, line 16: "simulation for different" instead of "simulation at different" and "spatial resolutions" instead of "spatial resolution"

(11) Page 7, line 21: "explain" instead of "explicate"?

(12) Page 7, line 22: "dynamics are discussed" instead of "dynamics is discussed"

(13) Page 7, line 24: there is a missing close bracket ")"

(15) Page 8, line 16: "relatively high" instead of "relatively higher" and also "govern more than other flood" instead of "govern over other flood"

(16) Page 9, line 12: "process resulted in an increase" instead of "process resulted to an increase"

(17) Page 9, line 24: "do not have explicit upstream-downstream channel relationships" instead of "do not have upstream-downstream relationships"

(18) Page 9, line 29: "shows an increasing number of unit-catchments with backflow" instead of "shows increasing number of unit-catchments in backflow"

(19) Page 10, line 13: "results in more rivers" instead of "results for more rivers"

(20) Page 14, line 3: "result in low errors" instead of "result to low errors"

We thank the referee for pointing out the typos and suggesting how to edit them. We have revised the manuscript and incorporated the suggested edits.

(6) Page 4, line 30: "flood in recent history" instead of "flood in history" or define the time period of history.

The EM-DAT records flood in recent history (1900 to present). Thank you for pointing this out. We have changed the wording to "flood in recent history." [page 4, line 30]

(14) Page 8, line 10: first mention of dams on the system. Might be good to add a bit of info on the dams and their role in section 2

Thank you for the suggestion. We have added a few lines about the dams in section 2:

"Two huge artificial reservoirs (Bhumibol and Sirikit) and several smaller artificial reservoirs are operational in the Chao Phraya River Basin. In this study, the impacts of reservoir operation on flood flows are removed by using naturalized flows (see Appendix for details) and assessing flood extents on dates when both reservoirs are already full and are assumed to have minimal impact on flooding." [page 5, lines 1-4]

References:

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Trigg, M. A., K. Michaelides, J. C. Neal, and P. D. Bates (2013). Surface water connectivity dynamics of a large scale extreme flood. J. Hydrol., 505, 138–149. doi:10.1016/j.hydrol.2013.09.035.

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Zhao, T., Q. Shao, and Y. Zhang (2017). Deriving Flood-Mediated Connectivity between River Channels and Floodplains: Data-Driven Approaches. Sci. Rep. 7, 43239. doi: 10.1038/srep43239.