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Interactive comment on "Indicators of Necessary Storages for Flood and Drought Management: Towards Global Maps" *by* Kuniyoshi Takeuchi and Muhammad Masood

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RESPONSE TO THE REVIEWER #2'S COMMENTS

We are grateful to Reviewer #2 for the helpful and insightful comments. The provided comments have contributed substantially to improving the manuscript. Accordingly, we have made significant efforts to revise the manuscript with the details being explained as follows.

Point #1

COMMENT: This is a very stimulating study on the geographical variations of "necessary storages". The sample river basin is the Ganges-Brahmaputra-Meghna basin in

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South Asia. Distributed river discharge data was calculated by a numerical hydrological model, BTOPMC. What is "necessary storage" is not easy to describe very simply here in a limited space. But, I try to explain shortly what "necessary storage" is in this study as far as I can understand. Let's take a point or a place or a location in a river basin (and in the river channel network of the basin). In terms of "necessary storage" for flood, at the specified location, let's try to imagine how much volume of storage is necessary to keep flood water in the storage for releasing only reasonable water-flow to the downstream. In terms of "necessary storage" for drought, let's imagine how much volume of storage is necessary at the specified location to maintain required water flow during a drought period in the downstream. Here, they do not mean an actual dam-reservoir would be constructed. "Necessary storage" is a virtual or hypothetical variable for representing a hydrological characteristic at the specified point in a river basin or in a river channel network. Please refer to the manuscript for more detailed and exact definitions. The authors expanded relatively old methodologies published in 1970's and 1980's or sometimes in 1950's and 1960's, and tried to apply those methodologies to a continental-scale or outputs of a continental-scale numerical hydrological simulation.

RESPONSE: Thank you very much for your positive comment. Thank you also for your clear interpretation of "necessary storage". It is indeed "not an actual dam-reservoir would be constructed . . . but a virtual or hypothetical variable for representing a hydrological characteristic at the specified point in a river basin or in a river channel network." The foci of this paper are the importance of the study of hydrological heterogeneity in storage domain and for that purpose the use of FDC-DDC based calculation is useful.

Point #2

COMMENT: In the above, I mentioned "stimulating". It is true. I basically enjoy reading this manuscript. Their trial is somehow a novel one which I have never seen. In addition, this is a paper for the special issue in Honor of Eric F. Wood. Prof. Wood carried out studies on probabilistic aspects of hydrology in his 70's and 80's, and he carried

out continental or global-scale modeling and remote-sensing studies in 90's and in 21st century. Thus, this manuscript by Takeuchi and Masood is very good for the special issue because they try to connect studies in 50-80's to contemporary continental-scale research. We sometimes neglect studies done in 50's, 60's and 70's. In this occasion, this can be a valuable paper. However, I should mention that the structure and presentation of this manuscript is far from satisfactory. I do not know when is the deadline of this special issue, but I should demand thorough revision to the manuscript in terms of structure and presentation. I do not refer to problematic sentences and figures point-by-point, but I believe the authors can completely re-write this paper because they have experiences of writing papers in major journals.

RESPONSE: Thanks for the comments. We are clearly aware of the incompleteness of the paper and will completely rewrite it especially clarifying the focus and intention. The concrete plan of rewriting is in the next Point #3.

Point #3

COMMENT: Apart from the structure and presentation of the manuscript, for the contents of this paper, I also have several comments and I would recommend additional analyses in the following. At first, the impact of climate change is not much important (and not much interesting, at this moment) in the context of this research. Thus, I recommend the authors to remove the aspects of climate change impact from this paper. Then, the paper will be a bit much more organized.

RESPONSE: Thank you for your comment. We agree that a sharper focus of the paper is necessary to make the objective of the paper clearer. Accordingly, we remove the climate component of the presentation. This accords with quite many comments and suggestions of other reviewers, too.

The main revision and restructuring of the manuscripts are as follows: 1. Rewriting the whole manuscript with clearer structuring and explanations. 2. Introduction 1 states two main foci clear: geographical distribution of necessary storages and the use of FDC-

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DDC to calculate necessary storages. 3. Removal of climate change analyses of 4.1.2 and related paragraphs. 4. Major improvement of 4.2.2 and Fig 12 on heterogeneity analyses of necessary storages. This will be done by adding extra analyses of sub-basins and new figures of topography, precipitation, vegetation cover, simulated root zone moisture contents etc. Also by zooming up of the wide variation of necessary storages in months at the left edges of Fig. 12 or in the smaller catchment areas. 5. Case study area 3.1 will be moved to earlier section 1 as the region is introduced in early stage. 6. Introduction of range theory 4.2.1 merges to 2.3 with other theories. 7. Captions of tables and figures will be improved such as adding a legend of Fig. 1 and Fig. 6-8 etc.

Point #4

COMMENT: Next, although the authors can show the geographical distributions of outputs and variables as basic information like as Figure 6, 7, 8, I do not think geographical distribution is enough for what the authors want to discuss. As clearly seen in those figures in this paper, values of "necessary storages" are very much different between the main stream of a large river and a tributary. Whether the pixel is in the main stream (where the number of upstream pixels is several hundreds) or the pixel is in a tributary (where the number of upstream pixels is only several) affects "necessary storage" a lot. In accordance with what I wrote just above, the fact that two lines for Ganges and Brahmaputra in Figure 12 are separate is not much surprising. Those two lines just correspond to the main streams of two large rivers. Actually, dots in the same line (for the same major river) should not be treated independently.

RESPONSE: Thanks for the comments. Fig. 6 shows mean annual precipitation, mean annual discharge in m3/sec, its standard deviation in m3/sec and coefficient of variation. Geographical information is indeed too little. Accordingly, topographical and landcover data of elevation, soil, vegetation and land use classification were added. Besides, Simulation results of root zone moisture were added that was analysed by Gao et al. (2014). Gao, H., M. Hrachowitz, S.J. Schymanski, F. Fenicia, N. Sriwongsi-

tanon, H.H.G. Savenije (2014), Climate controls how ecosystems size the root zone storage capacity at catchment scale, Geophysical Research Letters, 41, 7916-7923, doi: 10.1002/2014GL061668.

Point #5

COMMENT: What the authors want to show should not be the difference in “necessary storage” due to the difference in the number of upstream pixels (= upstream area). The difference in “necessary storage” due to the difference in the number of upstream pixels is not hydrological heterogeneity. In Figures 7 and 8, what can be seen most clearly is main streams of major rivers. That is probably not what the authors firstly want to show. Rather, what the authors may be able to show is the impact of various parameters (like soil types, geology, arid or wet, snow-affected or not, hilly or not) on “necessary storages”. For such an analysis, areas of catchments for analysis should be the same or similar. Such an analysis roughly corresponds to dots in the left edge in Figure 12. Why dots in the left edge in Figure 12 are very much scattering?

RESPONSE: Thanks for your comments. As stated above, in addition to the difference with the upstream catchment area, relation with forcing input (unfortunately except snowfall so far), soil, vegetation, land use etc. will also be added. They would control the impact of catchment area on how soon the necessary storages converge to its areal average.

Point #6

COMMENT: Even when the authors want to show the relation of “necessary storage” to catchment area, the authors are required to take different independent catchments; at least, even in the same large river system, two independent tributaries should be taken for analysis. Or, in Figure 12, two different major rivers are converging to two different lines/points. This is somewhat interesting. Thus, another result which may be highlighted is various different converging lines/points of various major rivers of the world. For it, the simulation of the Ganges-Brahmaputra-Meghna only is not enough. Also,

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as written in the abstract, if the authors want to highlight representative elementary area of necessary storages which may be seen in Figure 12, more detailed analysis and discussion are appreciated. Even when the samples are only two (Ganges and Grahmaputra), detailed analysis and discussion will of help. By the way, what about Meghna?

RESPONSE: Thanks for your comments. In fact the Meghna case is already included in red color in Fig 12. But as you suggest we will add some sub-basin details. We select two sub-basins in the Ganges and one each from the Brahmaputra and the Meghna. Their distribution at the left edge and the converging lines in Fig 12 will be zoomed up and related with their basin characteristics in climate, topography, geology, land cover etc. Some upward conversing lines seen in the Ganges (in green dots) in Fig. 12 will also be examined why those increasing lines of sub-basins are formed both in FDC and DDC. They all are approaching to the high converging line of the Ganges. They seem to imply that the overall converging line is determined by trends of the sub-basins. In other words, as the Ganges sub-basins have the increasing trend, the final converging line is high.

Point #7

COMMENT: I really appreciate the contribution of the authors to this special issue by trying to connect relatively old studies for catchment or local scale in 50's-80's to modern continental-scale research in the 21st century. This would be a very good contribution to the special issue for the Honor of Eric F. Wood. However, as a summary of what I mentioned above, and for making this manuscript to be published in HESS, I would recommend as follows: - thorough revision to the presentation and structure of the manuscript. Here, I at least point out that: a) "case study area" and "data used" should come earlier because even Figure 1 uses the data, b) 4.2.1. may be combined with 2 as a theoretical framework, and how 4.2.1. was used for analysis, discussion and conclusion is unclear, c) captions of figures and tables should be written with enough information to understand figure/table adequately..

RESPONSE: Thanks for your very positive comments. We certainly will do revision according to your suggestions as described in #3. We will do our best for improving clarity and readability.

Point #8

COMMENT: - I would recommend to stop showing the impact of climate change for making this manuscript simple, concise, clear, and appealing. I do not mean, climate change impact assessment is not of interest. But, because of time limitation and for highlighting what the authors want to say, I would recommend the authors to focus on hydrological characteristics under the current climate condition.

RESPONSE: Thanks for your comments. We will remove all climate change discussions except mentioning its applicability showing before and after of FDC and DDC in Fig 9 which we believe enough to indicate potential climate change analysis in the future.

Point #9

COMMENT: - Try to carry out additional analyses focusing on independent tributary catchments (which have similar catchment areas, and belonging to different tributaries). For "necessary storages" of those catchments, the authors may be able to show influential parameters (soil types, geology, arid or wet, snow-affected or not, hilly or not) in a quantitative or qualitative way. I know, dots in the left edge in Figure 12 are outputs after standardization by average monthly flow. That is good. But, just showing a huge vertical scatter is not enough. We want to know what makes this vertical scatter. Only speculation is written in this manuscript. Additional analyses are necessary, even though this paper is a first trial and a first step.

RESPONSE: Thanks for your suggestion. Yes, we consider this is the major point we have to revise. We will select some independent sub-basins as indicated in #6, draw an equivalent of Fig. 12 and analyse their distribution from left edge to the converging

points in relation to topography, soil types, rainfall, vegetation, landuse etc. We hope more insights will be obtained about the hydrological heterogeneity in storage domain.

Point #10

COMMENT: - Of course, two different converging lines for Ganges and Brahmaputra is interesting, but at least a few more examples would be appreciated. Also, discussion on why those two converging lines are different should be made.

RESPONSE: Thanks for your comment. As mentioned in #6 and #9 above, independent sub-basin analyses will be added. The difference in converging level indicates the relative magnitude of variation of discharge which reflects variability of precipitation the basin receives and the surface and sub-surface retardation function of the basin. The quantitative relation needs much more study and this paper will only indicates the qualitative relations.

Point #11

COMMENT: Finally, again, a stimulating paper is very important. Nowadays, well-organized but nonstimulating papers are dominating. That's not fun. But, well-organized or adequatelyorganized is necessary for publication. Depending on the focus of this study, the authors may not take all the points I raised.

RESPONSE: Thank you so much for your encouraging comments. We will do our best for the improvements at all points you pointed out and we responded above.

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