Response to Summary of Review Comments and Recommendations provided by Editor M Sivapalan, regarding the manuscript "Large-Sample Hydrology: A Need to Balance Depth with Breadth" by HV Gupta, C Perrin, R Kumar, G Blöschl, M Clark, A Montanari and V Andréassian.

September 30, 2013

Comment (1): This paper should eventually be published in HESS, and will make an important contribution to the literature, especially in the context of the new Panta Rhei initiative, which requires an understanding of catchment behavior even beyond what was achieved under PUB.

I thank the authors for responding positively to my invitation to contribute a paper to the special issue.

However, for the paper to provide guidance to the future, the paper needs to undergo moderate to substantial revisions. I list below a few summary comments based on my own reading of the paper, and the many constructive comments and suggestions of the reviewers.

Response: Thank you for the invitation and the opportunity to contribute. We are gratified that all of the reviewers found the manuscript worthy of publication, stating it to be a "*worthy contribution to the literature*" (B Jackson), "*well written and clear … recommend publication*" (H McMillan), a "*timely reminder … well presented and argued … significant contribution that will be widely read and cited*" (Anonymous), "w*ell written and may have high impact*" (D Wang), "*interesting and overall well-written*" (S Patil), and "th*e authors' plea is encouraging raising several issues worthy of attention*" (E Coopersmith). We thank the reviewers for their very constructive and thought-provoking comments, and are in the process of preparing a detailed response.

Comment (2): I note that most of the reviewers declared themselves to be of the younger generation that grew up in the era of PUB, and are totally supportive of the large-sample idea, and who do not need to be sold on this idea, which means we are at the good starting point.

Response: Certainly there is not much to _sell_ about the idea of using large samples for hydrological investigation - the concept should be obvious to any scientist, particularly with some statistical training, and has been greatly enabled by dramatic improvements in computing and information technology. The goal of our paper (clearly stated) is to *encourage a greater focus on such studies.* It is our opinion that a paper such as this can help to encourage more intensive pursuit of studies involving large sample hydrology, and increasingly more work _is being done_, which is part of the point we are trying to make. But such work is still relatively limited (and the set of reviewers represents only a sample of the community at large that has actually done such work). We will reword paragraph [8] and elsewhere to make this clearer.

Comment (3): 1. There is confusion (you might call it tension) between this being an opinion paper (as stated) and a review paper (which is what it may have turned out to be). If it is an opinion paper then it needs to be shorter and sharper.

Response: We really don't see any confusion on this score. However, a slight change to paragraph [8] viz *"The purpose of this **opinion** paper is to encourage a greater focus on 'Large Catchment Sample' type studies in hydrology, to complement the approach of intensive place-based investigation. We do this by providing some historical perspective (**note that we do not attempt to provide a comprehensive review**), motivating the need for such studies, illuminating some of the challenges, and examining issues related to the design and implementation of such studies…"* should suffice to make this clear. We have no intention of this being a review paper (which can remain an interesting challenge for others). We will certainly try to sharpen the presentation.

Comment (4): 2. There is confusion in the minds of the reviewers (and may I say the authors themselves) about their framing of large-sample hydrology. Is this paper about modeling per se (and if so it limits it to what is traditionally called regionalization as a way towards model improvement? Or is it about using the large-sample of catchments (and the data therefrom) to develop generalized understanding independent of a focus on rainfall-runoff models, or where any modeling activity is used primarily to generate understanding. As I read the paper these two sentiments are both included almost interchangeably, which makes it confusing.

Response: We have read through the reviewer comments very carefully and compiled an organized list. Again, we really don't see any confusion here. In our defense, let us be clear that we view modeling and understanding as tightly coupled processes, arguably impossible to address independently. Certainly we, as authors come largely from a background of modeling, but we do not see how this imposes any limitation on the message of this paper. Nevertheless, we will make the point of modeling vs understanding clearer in the revised paper.

Comment (5): 3. Related to the above, I have another question: what is the difference between large-sample hydrology and comparative hydrology? I am more knowledgeable about comparative hydrology (my opinion is that it is more related to activities devoted to develop generalized understanding, at least this is the way it is framed in Falkenmark and Chapman, and again in Bloeschl et al. (2013), and several papers the reviewers have also highlighted. If the authors want to separate large-sample hydrology from comparative hydrology, and want it to focus on model regionalization, then they should clearly state it, and not leave this confusion hang around.

Response: Thanks for this question. You will note that we mention comparative studies no less than 7 times in the manuscript and list 3 papers with the word in their titles. So it is not clear where has arisen the impression that we are trying to separate large sample hydrology from comparative hydrology, or what is the need to differentiate this from regionalization, all being part of a continuum. Again, it is

hard to see where the source of this confusion is in our presentation. Perhaps the Editor was expecting something else? Nonetheless, we will try to be mindful of the need for clarity regarding this during the revision process.

Comment (6): 4. *Such a clear definition and a narrower focus would help address the main criticisms of many of the reviewers, who were commenting on the non-inclusion of several recent comparative studies in HESS* (as part of the catchment classification analysis many of which used the MOPEX dataset), in WRR (part of the hydrologic synthesis project which also exploited the MOPEX dataset), and several previous studies (e.g., the work of Tom McMahon who performed statistical analyses of thousands of catchments in terms of the organization or classification of signatures of hydrological variability). None of these studies were highlighted in this paper, *which can only mean that the authors use the notion of large sample hydrology to advance model regionalization studies. If this is so, it is fine, they must acknowledge it, and re-frame the paper to remove this confusion.*

Response: Our paper is certainly much broader than simply model regionalization. Further, we do not perceive the comments of any of the reviewers as criticism, but rather as constructive comments, and we will endeavor to justify their efforts in providing comments by absorbing them in such a way as to improve the manuscript (while of course retaining our own perspective on the issues addressed). Certainly we will attempt to rectify important omissions. We hope that you, as editor, will not presume to read into our motivations in such a restrictive fashion. All suggestions are (and have been) welcome, and we will take them into account as seems appropriate.

Comment (7): 5. If the authors agree with my interpretation of their framing of large sample hydrology (that is a BIG IF), then I have a final question. How different is their notion of large sample hydrology (within the context of modeling) to what has already been happening in catchment hydrology in the last 10 years or less. For example, in the latest PUB synthesis book, there have been several studies cited that fall into the category of large-sample studies. So is this paper just giving a name to something that is already happening or are they heralding something new that builds on the past work, or are they introducing new concepts that have not been previously tried. This is not a new criticism - just a call to clarify so as to avoid confusion. I do not see the novelty very readily as I read the paper quickly, and hopefully their revisions can fix this problem.

Response: Please see our response to comment 3 above. Meanwhile, reproduced below is a compilation of the positive comments provided by the reviewers. You will note that there seems no confusion regarding the opinion status of this paper, as indicated by their comments. Further they make clear statements about the '*worthiness*', '*significance*' and '*timeliness*' of this contribution and its importance.

Bethanna Jackson (Referee)

1) Overall, this paper is a worthy contribution to the literature. The history provided is interesting (when placed in the appropriate sections), the point about the

importance of progressing the area is clearly made, and steps forward are suggested that are likely to advance both the number of studies and effectiveness of these studies.

2) The paper is generally well written and organized

3) The importance of this paper is to help the already emerging community exploring breadth by highlighting the broad context and the varied ways in which these studies may contribute to a broad range of hydrological challenges, as well as ways forward in establishing data protocols and calling for wider availability of good quality datasets.

4) I did enjoy reading the history/background to large-sample hydrology in section 2.

5) No technical corrections to note- the paper is remarkably free of spelling mistakes etc, congratulations to the authors.

Hillary McMillan (Referee)

6) This opinion paper argues for the benefits of using large numbers of catchments for investigations that seek to understand or model the runoff generation process. It summarizes the current state of play, discusses the benefits of large sample hydrology, and makes some observations on the practicalities and challenges of the approach. As it is becoming more common for hydrologists to use large samples, the paper will prove a useful resource and summary.

7) It is well written and clear.

8) I recommend publication in HESS, and also have some suggestions for the authors.

Anonymous (Referee)

9) This call is a timely reminder of the benefits available from analysis of large datasets drawn from a wide range of 'geo-eco-hydro-climatic' conditions.

10) The benefits are well presented and argued. LSH offers much to modern hydrology, and will be critical for developing a more complete understanding of how hydrologic processes change in space and time.

11) This manuscript is likely to frame the IAHS theme in regards to LSH and be a significant contribution that will be widely read and cited.

Dingbao Wang (Referee)

12) This opinion paper is well written and may have high impact in hydrologic research in the coming decades.

13) I fully agree with the opinion of authors that depth and breadth needs to be balanced.

14) Nice review of the history of large sample hydrological studies.

Evan Coopersmith (Referee)

15) The authors rightfully discuss the previous computational challenges associated with calibration or cross-application. Numerous young researchers are attempting to address these issues and the authors' plea is encouraging.

16) The discussion of '*Benefits'* is the objective most convincingly achieved within this paper. The authors (omitted papers notwithstanding) nicely frame the importance

of largescale studies in terms of the holistic understanding, generalization, cross-applicability of models, and uncertainty estimation they facilitate. These four pages are perhaps a bit longer than they need to be, as some of these concepts are discussed earlier in the paper and/or discussed thereafter. However, in terms of making one's case for large-scale studies, this is the strongest piece herein.

17) The discussion of '*Practical Challenges*' is also an objective that is relatively effectively achieved by this paper. The need for data availability is well described .... The authors correctly note that these large hydrologic datasets are focused upon inputs and responses rather than the underlying subcomponents.

18) The notes regarding appropriate reporting of data quality and errors therein is an important discourse – probably one could write an article exclusively focused upon this issue. The issues associated with soil texture and topography are appropriately mentioned....

19) Personally, I agree with the general opinion espoused (in the section on 'Providing Perspective') that more broadly scoped hydrologic research is tremendously important.

20) Overall, this is a well-written manuscript raising several issues worthy of attention within the hydrologic community.

Sopan Patil (Referee)

21) This is an interesting and overall well-written article. The main goal of the authors is to "provoke further discussion and participation, and to promote a potentially important theme for the upcoming IAHS Scientific Decade entitled Panta Rhei".

22) I especially enjoyed reading the historical context for large sample hydrology studies provided by the authors.

23) I completely agree with the authors' main argument that using data from more places in our research will lead to better hydrologic insight.

Manfred Ostrowski

24) The proposal to extend the database for identifying suitable model structures contains a number of interesting questions. Basically, the implementation of an extended standardised data pool for complex catchments is definitely helpful and could create impulses for new directions and most of the potential positive outcomes are addressed (Chapters 3.1-3.4).

25) From the manuscript it becomes obvious that the authors are fairly pessimistic about the reliability of present model predictions. However, they correctly cite Bergstroem (1991), who confirms that the confidence in specific models is increasing with the number and duration of model applications. I can personally confirm this statement.

Comment (8): 6. How will any of these issues be impacted by the new focus on Panta Rhei (where we will be asked to extrapolate both in space and in time)?

Response: We will attempt to clarify this point in the revision, as appropriate.

Comment (8): 7. Depending on their response to these queries, I suggest that authors revise the title, abstract and conclusions.

Response: Thanks for the suggestion, which we will take under advisement, and revisit as we prepare our response and revisions.