Interactive comment on "Statistical Characterization of Environmental Hot Spots and Hot Moments and Applications in Groundwater Hydrology" by Jiancong Chen et al.

Jiancong Chen et al.
nigel_chen1993@berkeley.edu
Corresponding to rubin@ce.berkeley.edu

We thank the reviewer for reviewing our manuscript and appreciate all the helpful suggestions and comments. Below, we present our responses to reviewer's comments and the plan to revise the manuscript correspondingly.

1. **Restructuring the paper**. In the revised manuscript, we will improve the readability by streamlining the introduction and the objectives of the work, followed by a much clearer separation between the presentation of the framework, the illustrative examples and the discussion, as requested by the reviewer. Any duplication will be carefully handled in the revised manuscript.

2. **Definition of 'disproportionate'**. Based on the complex nature of HSHMs, it is not practical and beneficial to look for a universal mathematical definition using percentage or proportion. For example, a 60^{th} percentile denitrification rate may trigger HSHM at a riparian site, but may fail to indicate HSHM condition at other sites as other static and/or dynamic factors can also control HSHM occurrences significantly. However, our proposed statistical framework provides a very flexible approach that can incorporate different types of HSHMs through static and dynamic contributors, modeled with indicator random variables and stochastic processes. For example, the permanent control points (as defined by Bernhardt et al., 2017) can be modeled with static-only indicators whereas activated control points will require both static and dynamics indicators. The cutoff values, percentage or proportion are defined by users and can be modified at will, as in equation (1). One can change these quantities based on prior information, risk tolerance or through statistical quantities. For certain HSHMs that have negative influences on ecosystems, thresholds are often introduced in environmental regulations in order to identify levels of contamination above which to consider a site as contaminated. In addition, activation thresholds may be used for chemical reactions that are necessary for biogeochemically driven HSHMs.

3. **Novelty**. We appreciate the reviewer's recommendations of relevant references and studies. We agree with the reviewer that there are many theoretical, empirical models and experimental approaches dealing with the HSHM dynamics. There are also various approaches to define 'hotness' as summarized in Bernhardt et al. (2017), such as simple comparison to average or matrix; substantial percentage of total flux; outlier in distribution of data; statistically significant difference between or among landscape elements or time periods categorized a priori; and contribution to flux/total area or time. However, most of these quantitative methods are derived based on site-specific data or simulation results, which limits the transferability from one site to other sites; and from one type of HSHM to other types of HSHMs. Thus the challenge is not how we define a single cutoff value for a specific HSHM at a specific site, but rather to develop a

statistical framework, capable of handling a generality of cases, and therefore progressing beyond local conditions. From this perspective, our proposed framework is novel and beneficial for future HSHM studies, summarized as follows: (a) With the indicator formulation, the framework is flexible enough to handle different scenarios of cutoff values (see point #2); (b) Our proposed framework is unified and allows us to investigate HSHMs under conditions of uncertainty; (c) Our framework can integrate results from HSHM studies using different approaches, whether results from Monte-Carlo simulations or direct data based quantifications; (d) Probabilities are assigned to the entire domain and time of HSHM concerns and modeled with corresponding stochastic processes; (e) Our framework can be easily integrated with Bayesian concepts such as conditioning as well as utilization of prior information from other sites. Based on the above points, we believe the statistical framework can make contributions to the HSHM community. In the revised manuscript, we will clearly outline these advantages.