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Statistical Characterization of Environmental Hot Spots and Hot Moments and Applications in Groundwater Hydrology

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The paper presents present a probabilistic formulation of hot spots and hot moments (HSHMs) geared towards hydrology and in particular, though not exclusively, groundwater applications. There is a substantial literature on this topic in environmental engineering, yet upon reading what is a complete introduction, the reader gets the impression that the approach proposed by the authors is substantially more general than most previous applications. This impression is substantiated by the methodology presented in the following, which views HSHMs occurrence as a binary event in space/time and identifies indicator geostatistics as the tool of choice to adopt. A Bernoulli distribution is chosen to model the binary random variable, and this is due to a specific property of the Bernoulli distribution, which somewhat detracts from the generality of the model. A positive aspect of the methodology presented is the option to adopt different choices for activation thresholds: concentration, reactivity, mass, flux, percentiles, extremes. Three different HSHM categories are identified, i.e. induced by a) static, b) static and dynamic indicators, and c) multiple dynamic indicators. The stochastic formalism allows comparing alternative HSHM via information or Bayesian information criteria. Several examples are described via specific case studies for the three different categories and for groundwater hydrology. A more detailed illustrative example to groundwater hydrology based on classical stochastic hydrology theory valid under ergodicity is then illustrated. Wider pdfs of the indicator are associated with larger logconductivity variances, and a convincing explanation is presented in detail. The Appendix presents a recapitulation and/or extension of classical results in stochastic subsurface hydrology.

The paper looks as a mature contribution almost ready for publication. Given the topic and the type of paper, I see little room for further improvement. Results are of interest to the readership of *Hydrology and Earth System Sciences*. The methods are adequate, the paper subdivision into sections sound, and the figures illustrative. I reviewed only the revised version, but I can tell there were substantial improvements and clarifications upon looking at the earlier version and to the extent of the modifications. On the reviewers side, the remarks were extensive and provided a noteworthy input to the paper quality.

There is a general question that deserves the author's response, i.e.:

- How crucial is the assumption of a Bernoulli distribution for the indicator variable ? Could they develop a more general theory without it, maybe subject to other limitations ?

and a minor correction:

- Note that at line 425, 4.3 → 4.2.