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Comment on "Multiscaling and skew separation in regional floods" by David R. Dawdy and Vijay K. Gupta

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Dawdy and Gupta's [1995] (hereinafter referred to as DG) paper raises a number of interesting points concerning the separation of skewness in relation to scaling theories of regional flood distributions. The paper sheds new light on this phenomenon first reported by *Matalas et al.* [1975] (hereinafter referred to as MSW). The objective of the present discussion is to provide some additional thoughts on the results and conclusions of the research.

The separation of skewness was discovered by MSW, who examined the regional behavior of estimates of skewness of annual maximum flood series in 14 regions in the United States composed of 1351 stream-gauging stations. MSW found that for all 14 regions, the skewness estimates based on 10-, 20-, and 30-year flood series were more variable than one would expect had the samples been drawn from a common regional distribution (e.g., normal, lognormal, Gumbel, Pearson, Weibull, Pareto, and uniform). This phenomenon was termed the "separation of skewness." Several studies, using flood data from various countries [e.g., *Rossi et al.*, 1984; *Ahmad et al.*, 1988], have unjustifiably used the separation effect as a criterion for the selection of distributions for flood frequency analysis on a regional as well as on an at-site basis. For example, the Wakeby distribution and the two-component extreme value (TCEV) distribution have been identified as "adequate" distributions. *Wallis et al.* [1977, p. 168] reexamined the issue of separation of skewness and concluded that "the condition of separation may be explained by either spatial or temporal mixing of values of γ (coefficient of skewness)" within a region. *Bobée and Ashkar* [1989] expressed their concern that despite the conclusions of *Wallis et al.* [1977], the separation of skewness continues to be viewed as a criterion for distribution selection. *Cunnane* [1987] presented a comprehensive review of flood frequency procedures and used the skewness separation as a criterion for discrimination between candidate distributions. Therefore we do not agree with DG's statement that "the significance of [the MSW paper] appears to have been lost in the literature" (section 1, p. 2762).

Using annual maximum peak discharge data from the state of Utah, *Ashkar et al.* [1992] examined the issue of separation of skewness and showed that it can be explained entirely by the heterogeneity in parent skewness values between sites and therefore has nothing to do with the insufficient flexibility of certain distributions. Theoretical considerations and simulations based on the bootstrap resampling technique supported the evidence that the separation phenomenon can be explained by the spatial mixing of values of the coefficient of skewness within the same region. *Ashkar et al.* [1992, p. 473] state in the conclusion of their paper that "in the presence of this spatial nonhomogeneity, one is not justified in comparing skewness averages calculated spatially with averages calculated temporally from a homogeneous distribution." DG (p. 2762) indicate that "MSW mentioned but did not explore two other possible causes of separation, namely, spatial mixing of values of skewness g among subregions within each megaregion and mixing of values of g in time." However, this is exactly the essence of the work of *Ashkar et al.* [1992] which the authors apparently ignore.

According to DG (section 6, p. 2766), MSW concluded that the separation of skewness is independent of flood frequency model assumptions. However, MSW clearly stated that the phenomenon was detected in relation to the distributions they used. In fact, the conclusions of MSW appear to have been the main reason for the use of skew separation to assess the adequacy of distributions.

Scale issues have received an increasing attention over the last few years. Previous work by the authors [*Gupta et al.*, 1994; *Gupta and Dawdy*, 1995] explored the differences between multiscaling and simple-scaling theories in regional flood frequency analysis. Simple-scaling theory is closely related to the index flood model. When regional floods are governed by simple scaling, the coefficient of variation is constant and the flood quantile-drainage area relationship is log-log linear. However, when regional floods have multiscaling properties, the hypothesis of constancy of the coefficient of variation is violated [*Gupta et al.*, 1994; *Gupta and Dawdy*, 1995]. One of the main conclusions drawn by DG is that separation would occur only if skewness mixing is of a particular kind, namely, multiscaling. The separation of skewness would clearly not occur if floods obeyed simple scaling, since this type of scaling is but a basic change of scale for which the coefficient of skew remains invariant. However, drainage area can only to a limited extent explain the heterogeneities in flood distributions. The index flood method, although in many aspects similar to simple scaling, represents a more flexible and realistic assumption. The multiscaling model (DG, equation (12)) is merely a generalization of (7) (simple scaling), in which the scaling exponent θ is a function of the moment order r, and the drainage area ratio is still the site heterogeneity measure. The multiscaling model is also a very simplistic representation of regional heterogeneity based on the assumption that drainage area explains variations in flood distributions in a deterministic way.

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Obviously, multiscaling generates separation because the skew coefficient g is no longer invariant with respect to drainage area since moment transformations depend on their order (equations (12) and (13)). However, the theoretical development of *Ashkar et al.* [1992] demonstrates that the separation effect can be induced by any other type of heterogeneity, excepting the simple change of scale. Therefore, we do not agree with the authors' statement that skewness mixing must be of a particular kind in order to cause separation. Another point concerns the statement "This result is independent of specific model assumptions about flood frequency distributions" (DG, section 3, p. 2765), which we consider to be somewhat inaccurate. Indeed, when manipulating moments, we are implicitly dealing with questions concerning the existence and the shape of distributions represented by these moments.

Since multiscaling implies separation, one may ask if, inversely, the nonoccurrence of separation (in relation to the lognormal model) implies simple scaling. The authors tried to prove this in their interpretation of the results for the Pacific Coast sites. However, one should recall that the separation effect can only occur in relation to a specific distribution and shifts with the change of the reference distribution. Hence, if sites have different flood distributions, the separation effect may not be visible, although existing.

DG's definition of homogeneity (section 4, p. 2765), which is based on the concept of regional distribution, also raises some concern. Their definition requires flood peaks, for all gauging locations within a region, to follow probability distributions, which are rescaled versions of one another, based only on drainage area and nothing else. This definition of a homogeneous region is restrictive and not much different from the definitions embedded in other regional frequency procedures such as the index flood method or canonical correlation analysis, in which a unique regional distribution is sought. In that sense, DG's definition of homogeneity is not less ad hoc than the constancy of the coefficient of variation of floods implied by the index flood assumption, which they rightfully criticize. In view of the foregoing, we believe more emphasis should be placed on formulating models that capture statistical properties of spatial deviations from regional mean values. Bayesian methods [e.g., *Kuczera*, 1982] could prove to be very efficient in doing so. We would also suggest an increased use of nonparametric simulations in such regional studies. It seems to us that resampling techniques (such as the bootstrap method used by *Ashkar et al.* [1992]) have several advantages over classical simulation methods.

The paper by DG is to be commended for introducing interesting new directions in regional flood frequency analysis and for not using the separation of skewness as a criterion for selection of flood distributions.

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