Discussion of "Critical Values for Şen's Trend Analysis" by Richard H. McCuen

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It is well appreciated that the author of the original paper tried to avoid the qualitative subjectivity and proposed a quantitative approach for trend identification in a given hydrometeorology time series. He considered that there are not quantitative publications on Şen's innovative trend analysis (ITA) in the literature, which is not correct, because there are a few papers published on the quantitative ITA trend estimation methodology (Şen 2017a, b). He also mentioned that trends are embedded into measurement data due to land cover or climate changes, which are systematic components in a given time series, but they are considered random variables, and therefore their identification needs probabilistic and statistical tests on the basis of some confidential limits, which are considered in practical applications as 5% or at the maximum 10%. Although trends may occur in temporal, spatial, or spatiotemporal spaces, the ITA method and original paper consider trends in time scale only. The purpose of this discussion is to support the explanations from the original paper on one hand, and on the other to indicate some of the invalid explanations and discussions throughout the text.

It is true that Şen did not provide any statistical mathematical quantitative test in the first publications concerning the ITA approach (Şen 2012, 2014), but later on some quantitative methodologies were presented (Şen 2017a, b). The author criticizes the statistical significance tests because of their significance level decision, but adaptation of 5% or 10% has become very common in the literature. The original paper considers the following three points as important:

1. The trend existence is modeled by the least-squares statistical approach.
2. An extensive simulation study through Monte Carlo technique is carried out on the basis of different lengths (from 10 to 150) and a set of significance levels (0.1%, 1%, 2.5%, 5%, and 10%). The synthetic data generation is based on the serially independent stochastic structure with the normal probability distribution.
3. Some power of the proposed trend existence test is presented based on some empirical formulas based on the simulation study.

The author's criticism of the breakthrough point within the half-point of a time series is also very valid. He explains Şen's (2012) ITA methodology clearly within four steps. Later in the text, he provided some actual and simulation annual flood data, but unfortunately did not construct ITA graphs, which could stimulate better explanations.

As for the "Proposed Test Statistic" section, the author has the right view that small deviations from the 1:1 line imply random variations without a trend component in the time series. Hence, the lack of trend will have a straight line with a slope of 45°, i.e., 1:1. Hence he proposes one parameter model as in his Eq. (1). However, the statement "If the series does not include a trend, then b should be approximately 1.0" is very misleading because there may be parallel lines to 1:1 lines in the upper or lower triangular areas of the ITA graph with trends, and these lines do not need to cross through the origin (Fig. 1).

It is obvious from this graph that there may be trends with smaller or bigger slopes than 1 in increasing or decreasing manner.

In the section of "Critical Values of Test Statistic," $b = 1$ is suggested as the population value, but as one can see from Fig. 1, the null hypothesis cannot be accepted as a trendless case. The b values greater than or less than 1 do not mean any critical value as for the trend existence or nonexistence. Although the author has made extensive simulation study in the computer for depicting coefficients for the critical test, according to the preceding explanations, they are meaningless. In particular, the restrictive assumptions of sample length, normal probability distribution, and serial independence do not bring any additional dimension for the trend identification test.

Subsequently, the critical values are described by some empirical formulations [Eqs. (3)–(5)], but their scientific foundations are not clear in the original paper. There is no logical scientific basis for their suggestion, and therefore the reader is confused as to their validity. It is stated in this section again that an increasing trend is

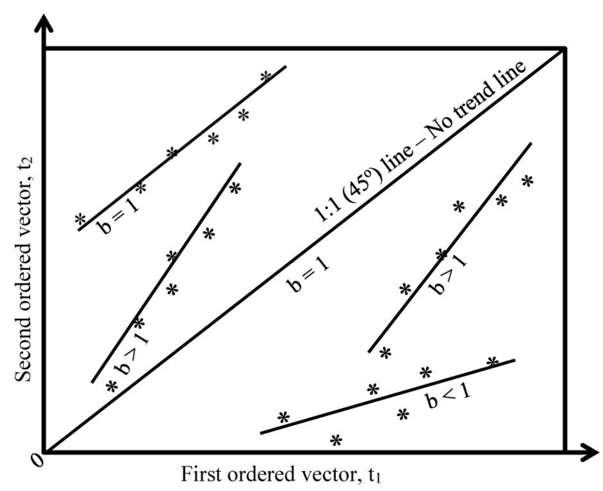

Fig. 1. Various ITA trend components.

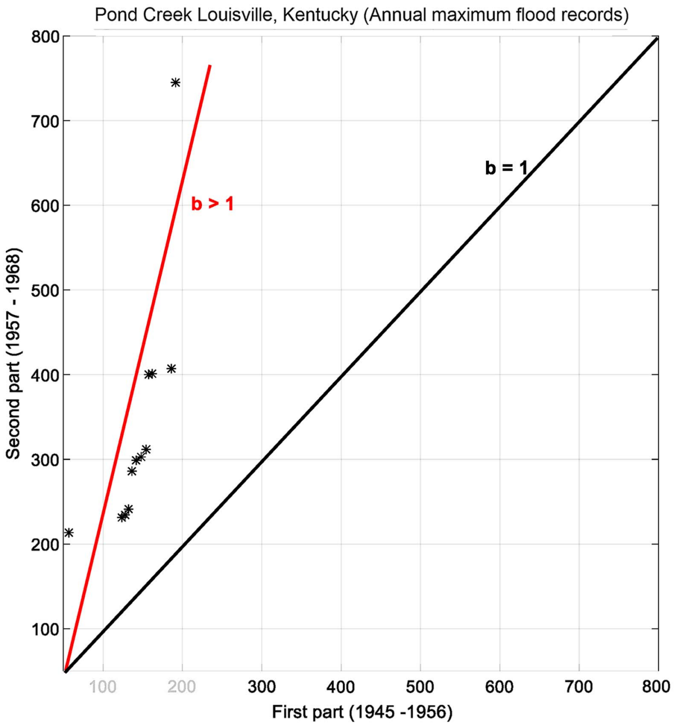

Fig. 2. Pond Creek watershed annual maximum flood series, ITA template.

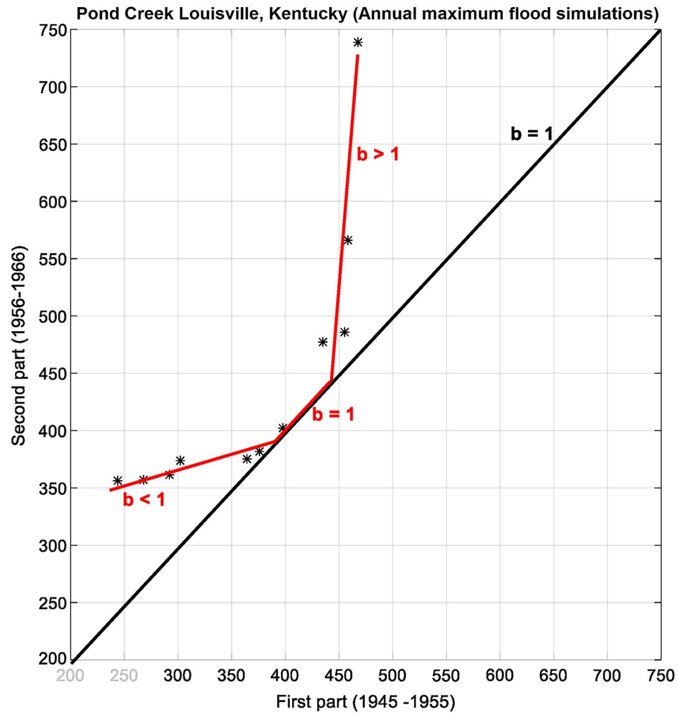

Fig. 3. Pond Creek watershed annual maximum flood simulations, ITA template.

expected such that the value of b should be greater than 1.0, but as shown in Fig. 1 there are even decreasing trends with $b < 1$ or $b > 1$ in the lower triangular part of the ITA template. The use of upper or lower critical values in Table 2 are irrelevant.

In the "Power of Test" section, there are classical statistical significance suggestions that are available in the open literature. The word *strength* is used for the trend and hence there remains confusion whether it applies to the trend slope. Trend tests are dependent on the sample size, level of significance, and strength of the trend, but there is no mention about the probability density function (PDF) type, which is also important in such tests. Eq. (1) cannot be used for the power of the test statistics because it represents all the straight lines that cross through the origin, but there are cases where trends might not pass through the origin as is shown in Fig. 1.

In the "Application of Test" section, the author unfortunately did not look for the data behaviors on the ITA template. Figs. 2 and 3 are for annual maximum flood series records and simulation sequences, respectively, because they are mentioned by the author.

It is obvious that in Fig. 2 there is a single monotonic trend with $b > 1$ in the annual maximum flood series in the Pond Creek catchment, whereas for the flood simulation values there are at least two trend components, one with $b > 1$ and the other with $b < 1$. It is rather surprising to notice that the simulation results do not resemble the actual annual maximum flood behavior. On the other hand, the author did not apply his critical values for the trend test at the Pond Creek watershed records.

The "Discussion and Implications" section contains some inconsistencies. For instance, the author mentions with an unfortunate statement that a level of significance of 5% is often adapted regardless of the importance of the problem; this should be avoided because it cannot be considered in practical engineering applications because as a general tendency 5% or at the maximum 10% error bands are accepted in all water resources system studies. The author rightly pinpoints the fact that although the true break point is not known generally, its selection influences both the decision and the statistical power of the final decision.

After all that has been explained, there are recent publications that have given additional information about the quantification of the Şen (ITA) method (Şen 2017a, b; Mohorji et al. 2017).

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