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Evaluating collective significance of climatic trends: A comparison of methods on synthetic data

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The common approach to determine whether climatic trends are significantly different from zero is to conduct individual (local) tests at each single site (station or gridpoint). Whether the number of sites where the trends are significantly non-zero can or cannot occur by random, is almost never evaluated in trend studies. That is, collective (global) significance of trends is ignored.
We compare three approaches to evaluating collective statistical significance of trends at a network of sites, using the following statistics: (i) the number of successful local tests (a successful test means here a test in which the null hypothesis of no trend is rejected); this is a standard way of assessing collective significance in various applications in atmospheric sciences; (ii) the smallest p-value among the local tests (Walker test); and (iii) the counts of positive and negative trends regardless of their magnitudes and local significance. The third approach is a new procedure that we propose; the rationale behind it is that it is reasonable to assume that the prevalence of one sign of trends at individual sites is indicative of a high confidence in the trend not being zero, regardless of the (in)significance of individual local trends. A potentially large amount of information contained in trends that are not locally significant, which are typically deemed irrelevant and neglected, is thus not lost and is retained in the analysis.
In this contribution we examine the feasibility of the proposed way of significance testing on synthetic data, produced by a multi-site stochastic generator, and compare it with the two other ways of assessing collective significance, which are well established now. The synthetic dataset, mimicking annual mean temperature on an array of stations (or gridpoints), is constructed assuming a given statistical structure characterized by (i) spatial separation (density of the station network), (ii) local variance, (iii) temporal and spatial autocorrelations, and (iv) the trend magnitude. The probabilistic distributions of the three test statistics (null distributions) and critical values of the tests are determined from multiple realizations of the synthetic dataset, in which no trend is imposed at each site (that is, any trend is a result of random fluctuations only). The procedure is then evaluated by determining the type II error (the probability of a false detection of a trend) in the presence of a trend with a known magnitude, for which the synthetic dataset with an imposed spatially uniform non-zero trend is used. A sensitivity analysis is conducted for various combinations of the trend magnitude and spatial autocorrelation.