CZECH HYDROMETEOROLOGICAL INSTITUTE

HYDROLOGY

Trends in summer hydrological droughts in Czechia with respect to the scaling hypothesis

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1. Introduction

Between 2008 and 2010, a grant project devoted to the evaluation of hydrological drought in Czechia run. A lot of outcomes based on mean daily discharges from 118 water-gauging stations produced by the Nizowka program (see e.g. Tallaksen and van Lanen, 2004) have been left intact until today. Now, significant changes of some valuable characteristics connected with two hydrological periods 1931-2007 (70 stations) and 1961-2007 (118 stations), and delineated by the 95th percentiles of respective empirical flow duration curves (for the reference period 1961-2005) are subjected to the trend analysis to find out if some and where exactly significant changes (or differences) may be expected. Here, special focus was on addressing issues regarding the presence of short-term persistence (STP) or long-term persistence (LTP, scaling behaviour) in such time series which may adversely influence the results of many trend tests (see e.g. Khaliq *et al.*, 2008, 2009 or Khaliq and Sushama, 2012). Particularly, four tests were applied to the data. Some of them have already been examined in the literature, some of them not and are, therefore, proposed for the first time in hydrology.

2. Data

Inspired by the study of Hisdal *et al.* (2001), the series of following drought-related indicators were acquired:

- summer sum of deficit volumes (SSV95, in thousands m^3),
- summer maximum deficit volume (SMV95, in thousands m^3),
- summer sum of drought durations (SSD95, in days),
- summer maximum drought duration (SMD95, in days),
- summer frequency of drought occurrences (SF95).

Only the summer part of the year (April-October) was chosen for the investigation due to the fact that the fixed 95th percentile of discharge is really low and is commonly exceeded in winter in Czechia.

The underlying mean daily discharges were downloaded from the regime hydrological database of the Czech Hydrometeorological Institute (CHMI). Apart from some minor exceptions in Bohemia (for which a filling-in process had to be carried out), the series were complete and uninterrupted.

3. (a) Generalized equivalent sample size modification of the Mann-Kendall (GESS-MK) test

This test combines the Yue-Wang (YW; Yue and Wang, 2004) and the Ehsanzadeh-Adamowski (EA; Ehsanzadeh and Adamowski, 2010) equivalent sample size approaches to the modification of the original variance of the nonparametric Mann-Kendall (MK) test. The first one deals with STP, while the other with LTP. When the presence of LTP in time series is confirmed, the second modification is used. On the other hand, when STP is detected, the test swiches to the first modification, which accounts for serial independence as well.

The discrimination between STP and LTP is perfomed via two so-called unit root tests, Phillips-Perron (PP) test (Phillips and Perron, 1988) and the Kwiatkowski-Phillips-Schmidt-Shin (KPSS) test (Kwiatkowski *et al.*, 1992), in similar way as done in Fatichi *et al.* (2009) or Ledvinka (2015a, 2015c). Sometimes, there is not enough information in the series and hence one cannot decide. The same, probably caused by measurement errors, applies to the unit roots detected that are not so typical in geophysics (see Barbosa et al., 2008). For the spatial distribution of trends identified by this test (at both 0.05 and 0.1 significance levels) see Fig. 1.

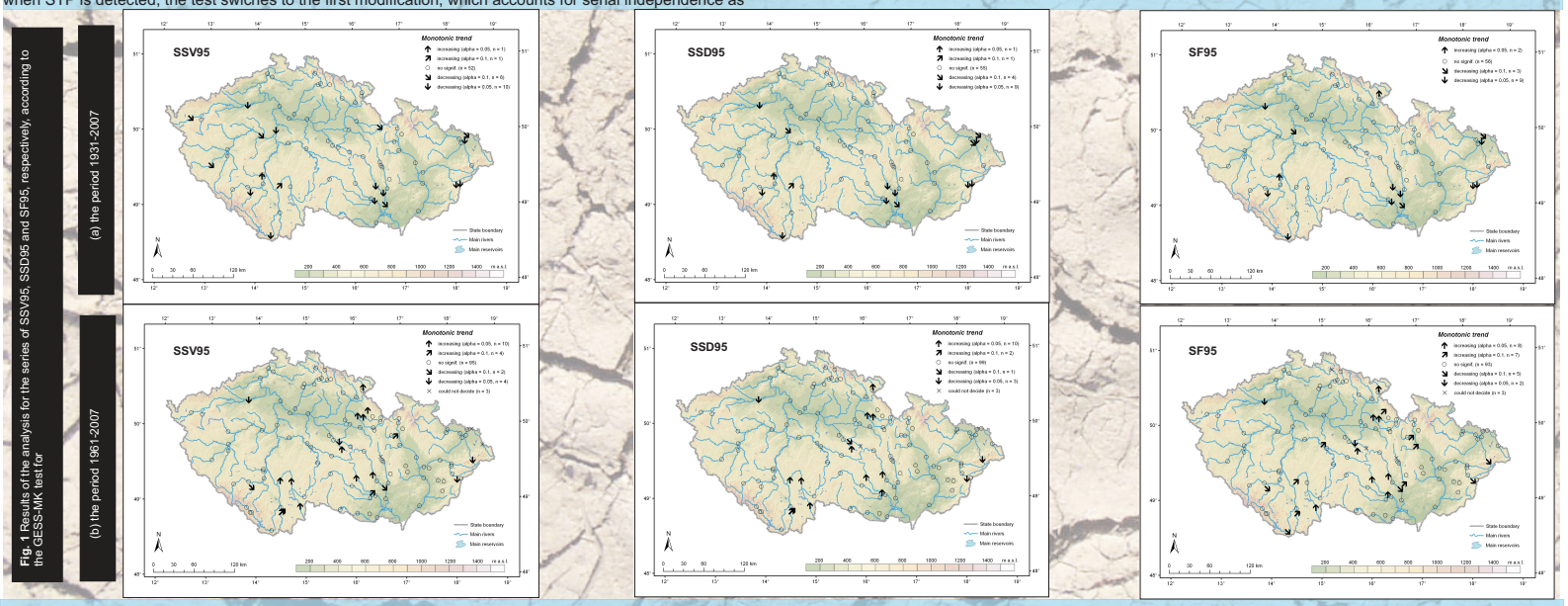

Fig. 1 Results of the analysis for the series of SSV95, SSD95 and SF95, respectively, according to the GESS-MK test for

3. (b) Automatic block bootstrap Mann-Kendall (ABBS-MK) test

In this procedure, first, the optimal block length is found based on the autocorrelation structure of a time series. Afterwards, the selected number of samples (here 1000) is generated, from which the quantiles corresponding to the prescribed significance levels can be found. If the original MK statistic falls outside the confidence interval delineated by the quantiles, the trend is significant. More details on the technique can be found in Ledvinka (2015b) who finally suggested that especially the series revealing STP should be assesed through this test.

(c) Maximum entropy bootstrap Mann-Kendall (MEBOOT-MK) test

The rationale is similar to the preceding ABBS-MK test. First, mimic (by the use of the maximum entropy bootstrap; see Vinod and Lopez-de-Lacalle, 2009) the autocorrelation structure of a time series and then (using 1000 samples here) find the confidence interval corresponding to the desired significance level that can be compared with the original MK statistic.

(d) Adjusted likelihood ratio test (ALRT)

The same approach as in Cohn and Lins (2005) was conducted here. To deal with LTP and STP simultaneously, the FARIMA(1,1,0) processes were considered to underlie the series. Since this test is parametric, the mean-subtracted series were divided by their standard deviation first. Selected results associated with these three tests are shown in Fig. 2.

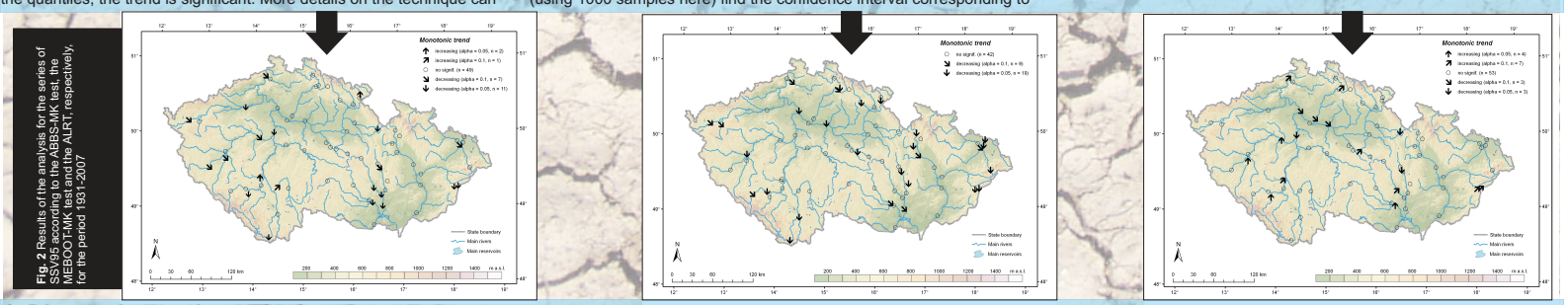

Fig. 2 Results of the analysis for the series of SSV95 according to the ABBS-MK test, the MEBOOT-MK test and the ALRT, respectively, for the period 1931-2007

4. Discussion and conclusion

The main finding here is that the series of drought-related characteristics hardly exhibit significant changes. However, some places indeed reveal significant trends both at the 0.1 and even at the 0.05 levels. The maps regarding the hydrological periods 1931-2007 and 1961-2007 suggest that Czechia experienced more drastic hydrological droughts in the past, especially in the 1930s and 1940s. It can be documented by the flippng arrows notably at the sites above which the water resevoirs were constructed in the 1950s.

Also, there are some important insights concerning the methodology employed. It seems that the MEBOOT-MK test and the ALRT shoud be investigated more in the future. The first one owing to the evident misinterpretation of the upward trends, the second one owing to the fact that Cohn and Lins (2005) designed their technique particularly for the cases with LTP (where fractional differencing parameter *d* ranges from 0 to 0.5) and the series obeying a Gaussian distribution, which Khaliq *et al.* (2009) circumvented by the use of the shifted Gamma process. The author recommends studying the effect of antipersistence in such a trend analysis as well.

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