Český hydrometeorologický ústav

ČNVH

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Development of streamflow drought indices in the Morava River basin

7 November 2019

Outline

1. Introduction

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What it is about

Vír water reservoir on 12 August 2018 (photo: CHMI Brno Regional Office)

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Svratka River in Borovnice on 12 August 2018 (photo: CHMI Brno Regional Office)

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Loučka River in Dolní Loučky on 21 August 2018 (photo: CHMI Brno Regional Office)

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Morava River in Strážnice on 20 August 2018 (photo: Brno Regional Office)

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- It is also hypothesized that there are spatial and temporal changes in precipitation patterns in Central Europe where Czechia is located.

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- It is also hypothesized that there are spatial and temporal changes in precipitation patterns in Central Europe where Czechia is located.
- This situation has laid the basis for the question whether some changes are also reflected in the indices related to hydrological/streamflow drought.

- The objective of this study was, therefore, to take the long time series of discharge, possibly not much influenced by human activities (see Šercl et al., 2016), and to perform a trend analysis of the derived series of selected indices quantifying streamflow drought.

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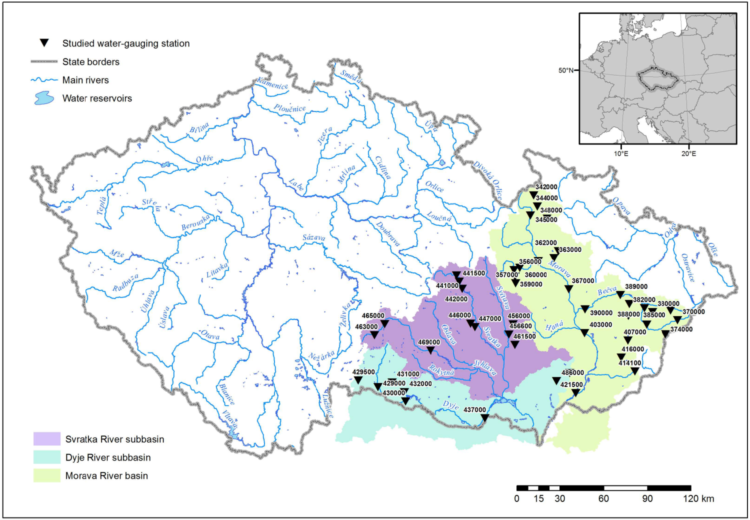
- The focus was on the basin of the Morava River, an important left-hand tributary of the Danube.

Study area and data

Location of 46 selected water-gauging stations within the territory of Czechia and their database numbers

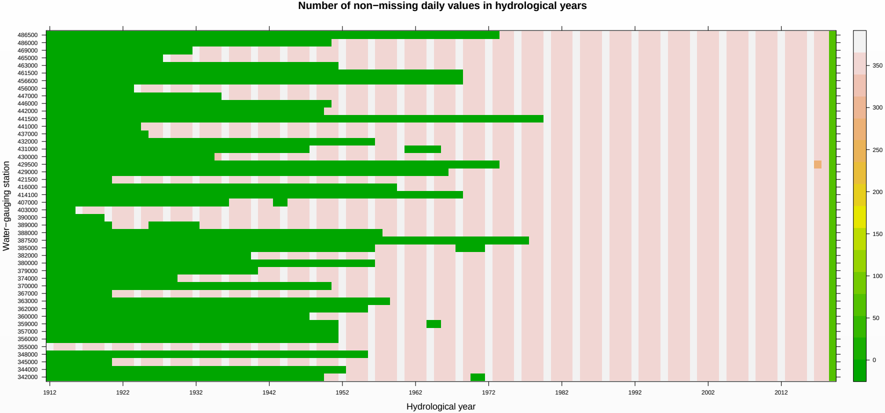


Study area and data

A closer look at the Morava River basin and the 46 investigated water-gauging stations together with their names

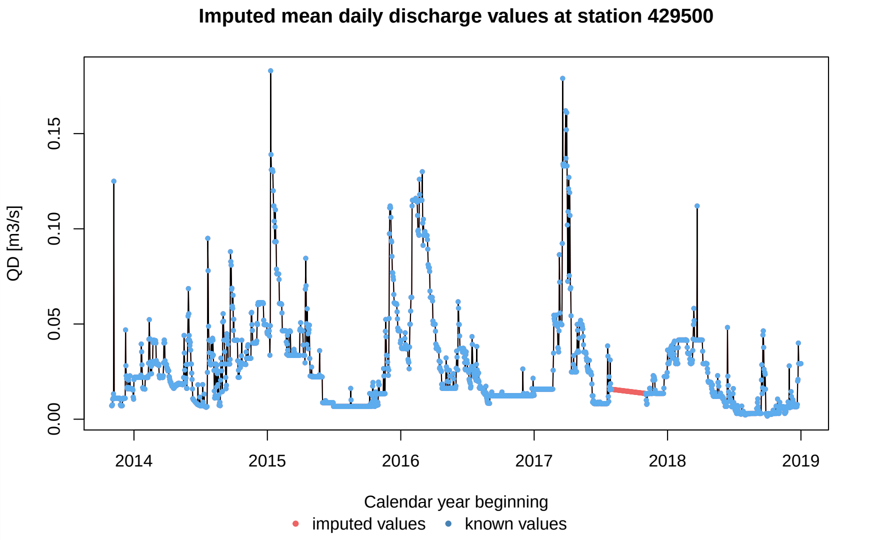
Study area and data

Mapping of missing mean daily discharge values at the 46 selected water-gauging stations, hydrological period 1912–2018



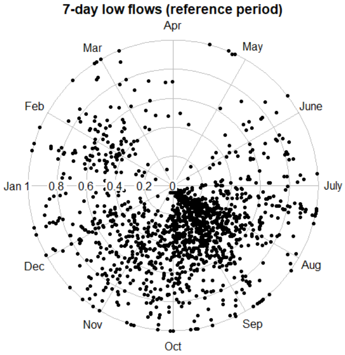
Study area and data

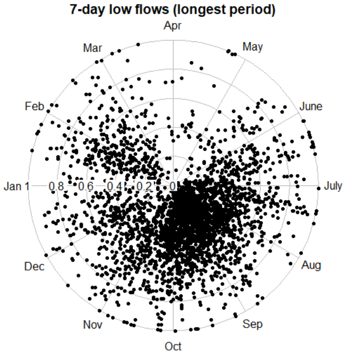
Part of the discharge series of station 429500 where missing values were imputed



Study area and data

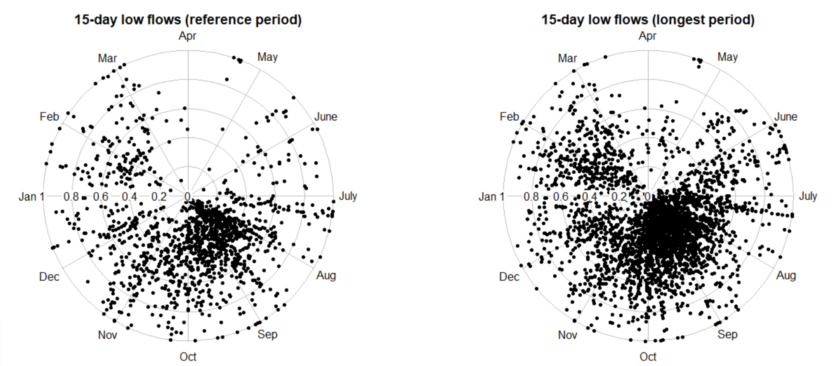
Timing of occurrences of standardized annual (either summer or winter minimum) 7-day low flows altogether in each possible hydrological year for all 46 investigated stations





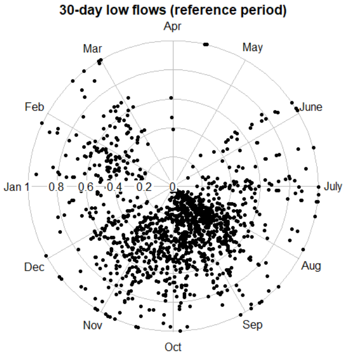
Study area and data

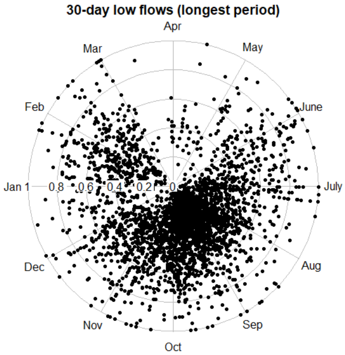
Timing of occurrences of standardized annual 15-day low flows in each possible hydrological year for all 46 investigated stations



Study area and data

Timing of occurrences of standardized annual 30-day low flows in each possible hydrological year for all 46 investigated stations





Study area and data

- Inspired by previous works, such as Khaliq et al. (2008); Fiala et al. (2010); Vlnas & Fiala (2010); Khaliq & Sushama (2012); Ledvinka (2015), we derived summer (April–November) and winter (December–March) low-flow series. Specifically, 7-, 15- and 30-day low flows were sought for each year of the reference period 1981–2010 and the longest possible periods based on the series of mean daily discharge (QD) of the Czech Hydrometeorological Institute (CHMI).

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- Furthermore, deficit volumes and corresponding durations were sought using the combination of the threshold level method (TLM; $Q_{95\%}$) and the sequent peak algorithm (SPA; Tallaksen et al., 1997; Tallaksen & van Lanen, 2004; Tokarczyk, 2013; Baran-Gurgul, 2018). Seasonal (monthly) thresholds always represented the reference period for comparison purposes.

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- Here, only summer maxima and sums of deficit volumes and durations were analyzed in a similar way as in Hisdal et al. (2001).

- Let x_k represent a time series (a centred time series) having an annual time step (for $k = 1, ..., K$). Then the MK test statistic S_{MK} is defined as follows (e.g., Hirsch et al., 1993):

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- The statistic is frequently accompanied by the estimate of Sen's slope β_S (Yue et al., 2002):

$$\beta_S = \mathrm{med}\left(\frac{x_\ell - x_j}{\ell - j}\right), \qquad \forall j < \ell$$

- For $K > 10$, an approximation of the distribution of S_{MK} by the standard Gaussian distribution $\mathcal{N}(0, 1)$ is possible. Then, one can compute the standardized MK test statistic Z_{MK} (Hirsch et al., 1993):

$$Z_{MK} = \begin{cases} \frac{S_{MK}-1}{\sqrt{\sigma^2_{MK}}} & \text{if } S_{MK} > 0 \\ 0 & \text{if } S_{MK} = 0 \\ \frac{S_{MK}+1}{\sqrt{\sigma^2_{MK}}} & \text{if } S_{MK} < 0 \end{cases}$$

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- The value of the statistic Z_{MK} is then compared to the critical values derived from the distribution $\mathcal{N}(0,1)$. A trend is found (or better, the null is rejected) if $|Z_{MK}| > u_{1-\alpha/2}$.

- First, the discrimination between long-term persistence (LTP) and short-term persistence (STP) was made where the parameter H (Hurst exponent) was estimated (Tyralis & Koutsoyiannis, 2011) and its significance evaluated (Hamed, 2008):

$$\mu_H = 0.5 - 2.874K^{-0.9067}$$
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- If H proved to be significant, Hamed's modification of the Mann–Kendall (MK) test for trend, accounting for LTP, was employed. Further explanation would be lengthy. Therefore, see Hamed (2008) for details.

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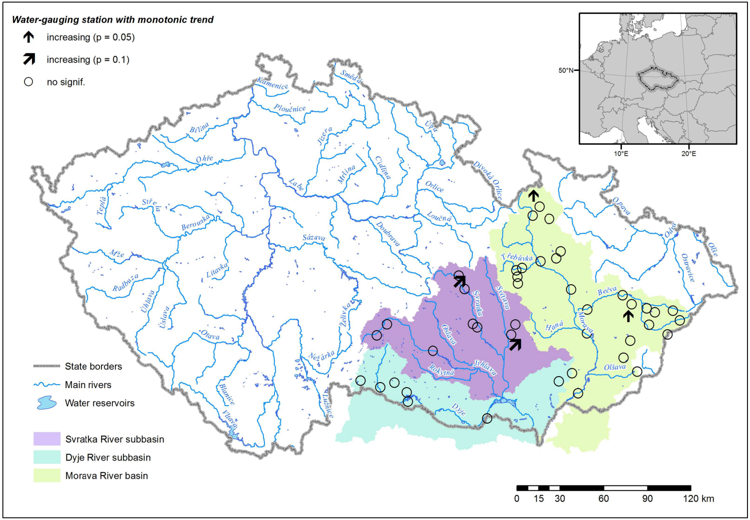
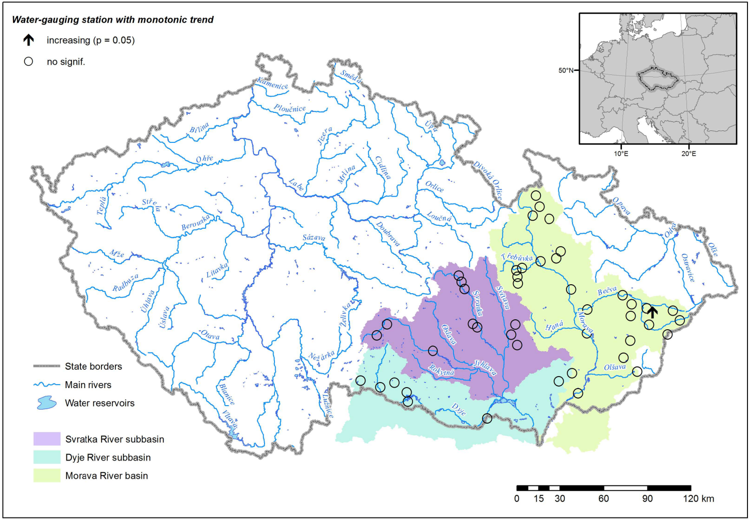
- Here, σ^2_{MK} is corrected and then substituted into the calculation of the standardized test statistic Z_{MK} (Yue & Wang, 2004):

$$\tilde{\sigma}^2_{MK} = \sigma^2_{MK} \cdot \left[1 + 2 \cdot \frac{\hat{r}_1^{K+1} - K \cdot \hat{r}_1^2 + (K-1) \cdot \hat{r}_1}{K \cdot (\hat{r}_1 - 1)^2} \right]$$

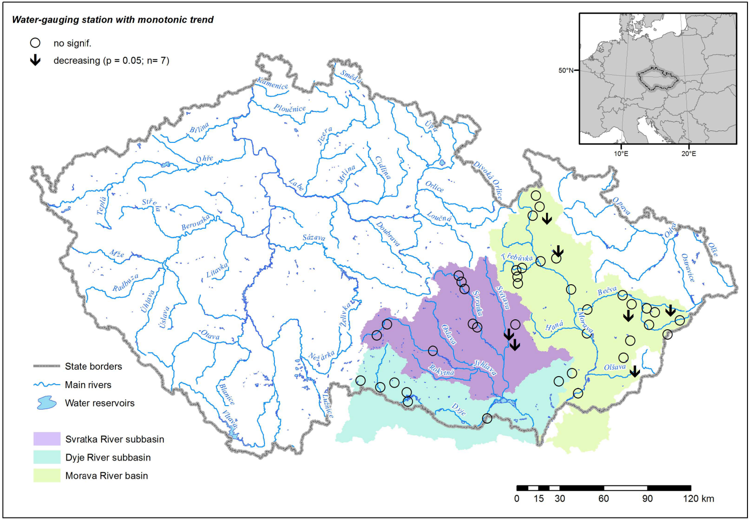
Trends in the series of summer maxima of deficit volume for the longest periods



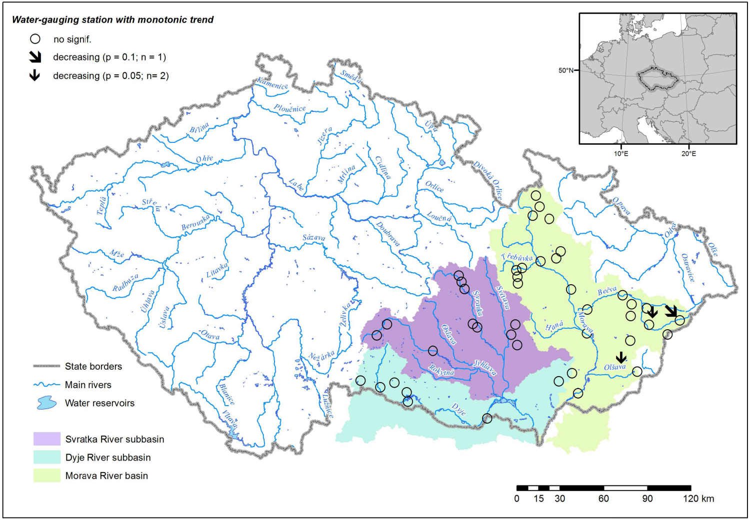
Trends in the series of summer sums of drought duration for the reference period



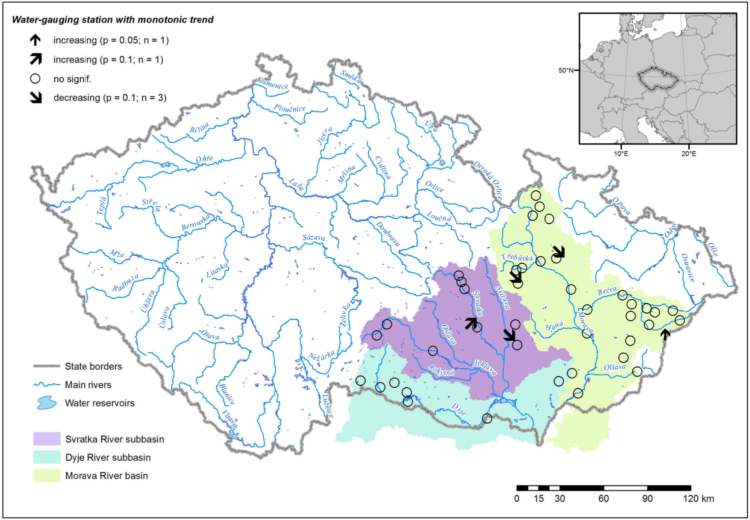
Trends in the series of summer 7-day low flows for the longest periods



Trends in the series of summer 30-day low flows for the reference period

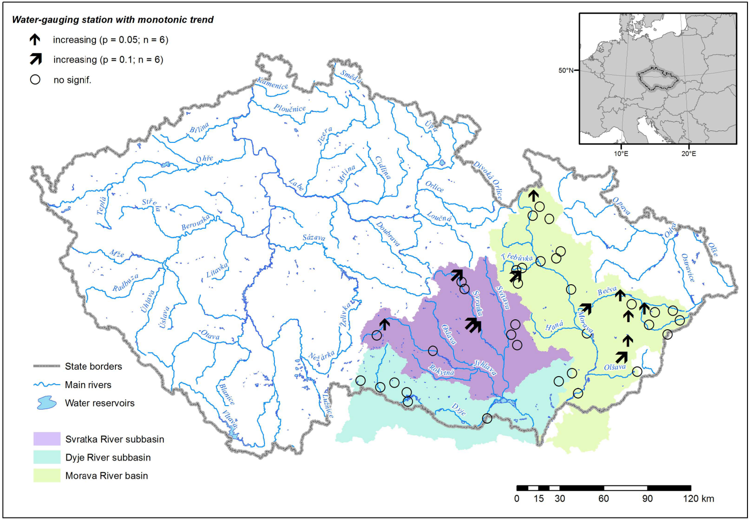


Trends in the series of winter 7-day low flows for the longest periods



Results

Trends in the series of winter 30-day low flows for the reference period



Discussion

- Not many significant trends were found, and their number may often correspond to the expected error rate (significance level).
- 30-year reference period is actually short for estimating H (Montanari, 2003) and the test modification accounting for LTP might not have been necessary.
- If some, trends cluster in karst areas and the foothills of mountain ranges.
- Climate change may be reflected in the seasonal course of hydrographs, which is likely related to earlier snowmelt or the shift from solid precipitation to liquid precipitation, increasing winter minima and decreasing summer minima (Jenicek et al., 2016; Jenicek & Ledvinka, 2019).
- Water managers should be aware of the changes not only above some of the water reservoirs.

Future

- The occurrence of snow and ice phenomena should be investigated further.
- The study of probable shifts in Julian days corresponding to the occurrence of low flows is already being in preparation.
- The issue of antipersistence (i.e., $H < 0.5$) that has been detected not only in the Czech hydrological series (see, e.g., Rivard & Vigneault, 2009) may be of great importance.
- Focus should be on various time periods using also extended series (Hamed, 2008).

Thank you all for your attention!

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