Precipitation variability in the Czech Lands since AD 1500: How strong is the signal contained within documentary sources?

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Objective

Quantitative precipitation reconstructions derived from natural proxies, such as tree rings, are quite infrequent; moisture-stressed proxies are rare compared to temperature-sensitive ones. We test whether a significant amount of information on past precipitation variability can be derived from a series of precipitation indices interpreted from various documentary sources available for the territory of the Czech Republic (CR) and whether these indices can be used as an explanatory variable for quantitative reconstruction of seasonal precipitation totals for the Czech Lands from A.D. 1500.

Data and methods

Available documentary sources from the Czech Lands (e.g. narrative written reports, visual daily weather records, personal correspondence, special prints, official economic records, etc.) were critically evaluated and interpreted in terms of monthly precipitation indices on a seven-degree scale from -3 (extremely dry conditions) to +3 (extremely wet conditions). Seasonal and annual indices were calculated as the sum of corresponding monthly values. Precipitation indices cover period 1501-1854 period. However, as no relevant information on precipitation for some months appeared, missing index values were filled in from the parallel index series that are available for Germany and Switzerland. The mean CR precipitation series completed from long and homogenized instrumental series for 14 stations and covering the 1804-2010 period was used as the target data. The results of correlation analysis quantifying common signal strength in CR precipitation indices and measured precipitation totals for three different overlapping sub-periods are summarized in Fig. 1.

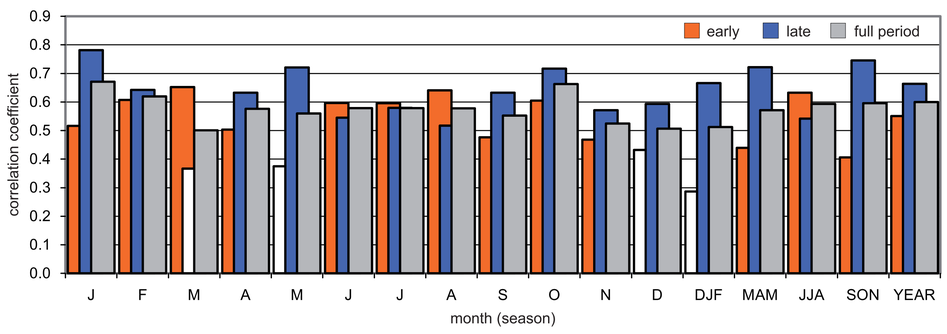


Figure 1 *Correlation coefficients between precipitation indices derived from documentary evidence and mean monthly, seasonal and annual precipitation totals for the Czech Lands over the early (1804-1829), late (1830-1854) and full (1804-1854) overlapping periods. Empty bars indicate non-significant correlations at p = 0.05*

Significant correlations between proxy and target data in full overlapping period allow calibration of precipitation indices to instrumental measurements in early/late sub-period and verification of the result on independent data in late/early sub-period. Strong verification statistics then support the final reconstruction. This is based on transfer function derived from linear regression over the full overlapping period. Individual steps of the whole process are summarized in Fig. 2.

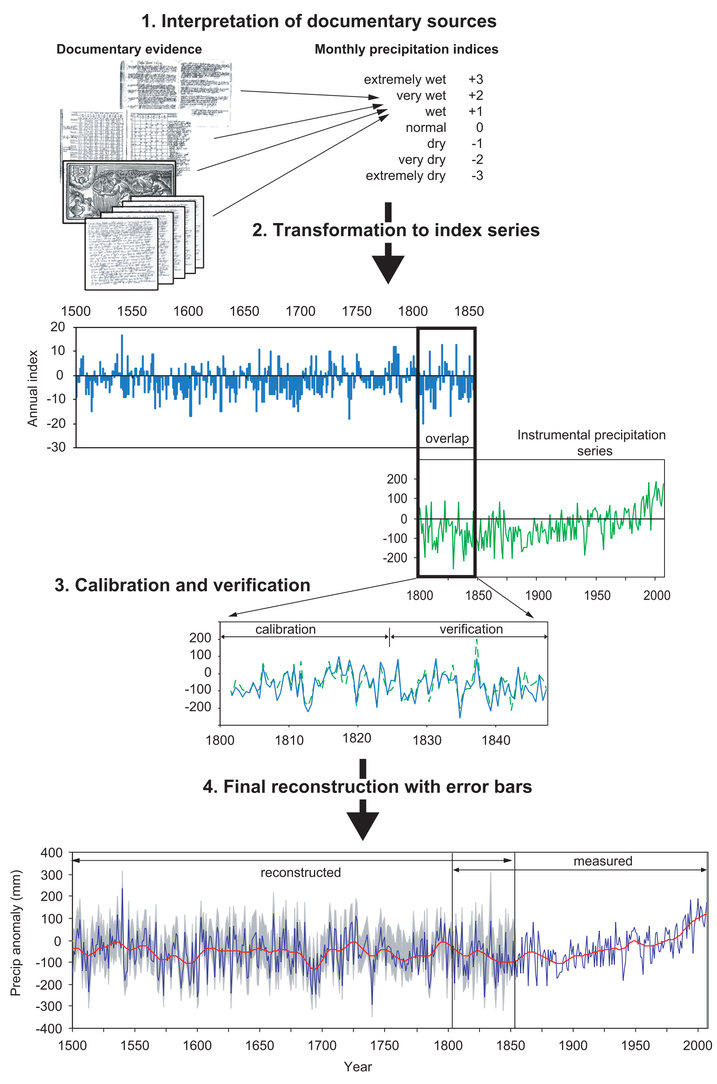
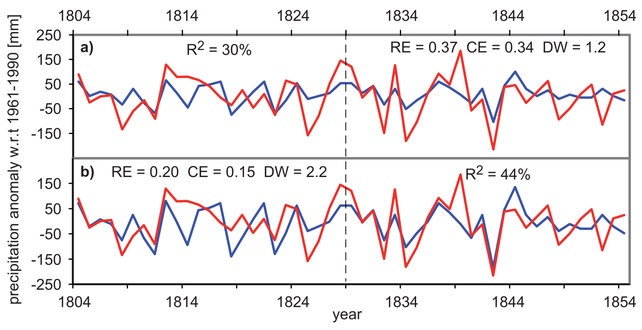


Figure 2 *Simplified diagram of the precipitation reconstruction procedure using documentary evidence-based precipitation index series*

Results

Fig. 3 presents cross-calibration/verification results for annual precipitation totals as an example. The RE and CE measures are significantly higher than zero for both configurations, indicating acceptable reconstruction skill levels for annual precipitation indices.

Figure 3 *Measured (red) and reconstructed (blue) mean annual precipitation anomalies (w.r.t. 1961-1990) for [a] early calibration (1804-1829) / late verification (1830-1854) and [b] late calibration (1830-1854) / early verification (1804-1829) completed with corresponding measures of reconstruction skill (R^2 - coefficient of determination, RE - reduction of error, CE - coefficient of efficiency, DW - the Durbin-Watson test)*



A final reconstruction of annual precipitation totals for the Czech Lands since AD 1501 is presented in Fig. 4. Values reconstructed through the ordinary least square regression were scaled to have the same variability as measured precipitation totals over the full period of overlap.

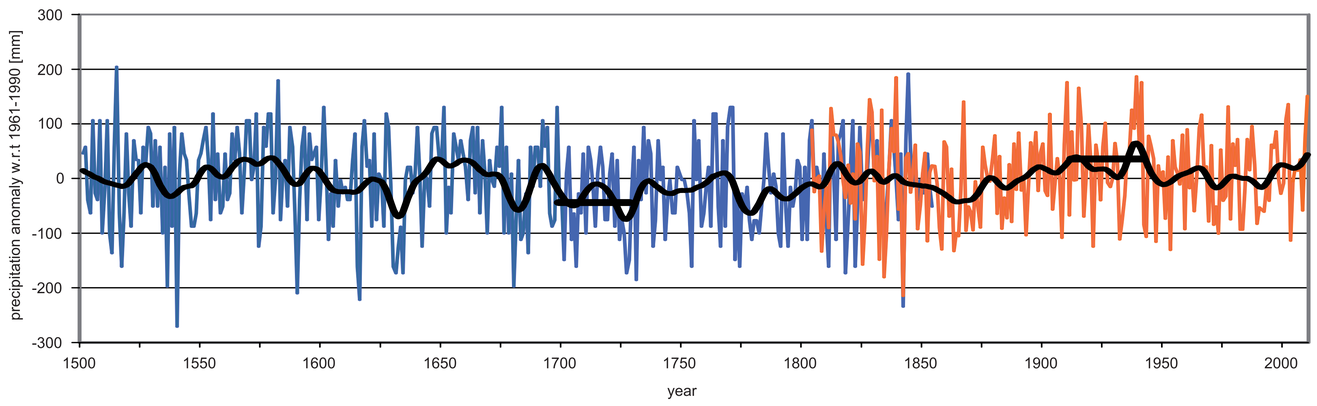


Figure 4 *Reconstructed (1501-1854, blue) and measured (1804-2010, red) annual precipitation totals for the Czech Lands expressed as anomalies against the 1961-1990 reference period and smoothed by Gaussian filter for 20 years (black). Horizontal bars indicate occurrence of the driest and the wettest 30-year periods*

Comparison

CR summer precipitation totals reconstructed from documentary-based indices were compared with the gridded multi-proxy reconstruction performed by Pauling et al. (2006). Direct comparison indicates a distinct time instability in results (Fig. 5). This can be related to several reasons such as quality and quantity of documentary records or natural spatial and temporal precipitation variability.

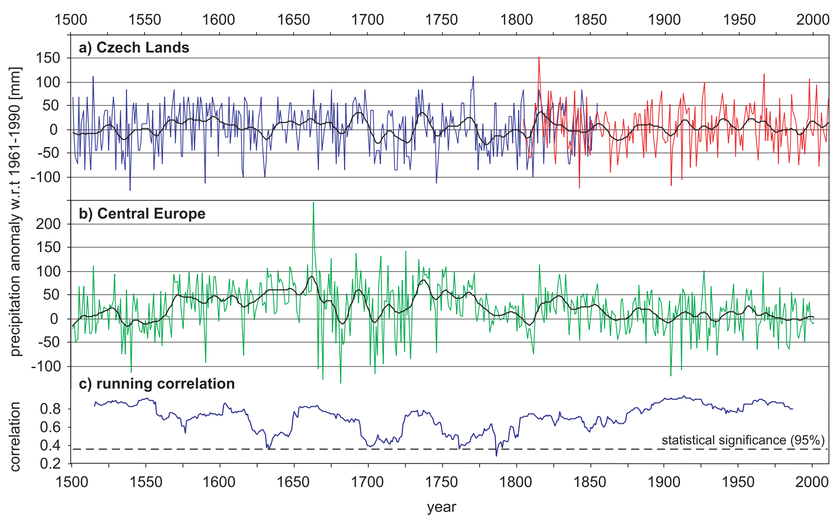


Figure 5 *Reconstructed (from documentary sources, 1501-1854, blue) and measured (1804-2010, red) JJA precipitation totals for the Czech Lands expressed as anomalies against the 1961-1990 reference period (a); JJA multi-proxy reconstruction for Central Europe (Pauling et al.2006) (b); running correlations (30 years) between the above reconstructions (c)*

Concluding remarks

- Relatively short (51 years) overlapping period of precipitation indices and precipitation measurements allows independent calibration/verification.
- CR precipitation indices correlate significantly with instrumental measurements in the period 1804-1854 no matter what the season, apart from winter.
- The common signal in the full overlapping period is at its strongest for transitory seasons (spring and autumn) and for these seasons documentary indices explain almost 50% of precipitation variance. The corresponding value for summer is 36% while the weakest signal is typical of winter.
- Verification statistics (RE, CE) are significantly higher than zero, indicating acceptable reconstruction skill levels.
- Reconstructed CR precipitation totals since A.D. 1500 show no long term trend but rather high inter-annual and inter-decadal variability.
- Comparisons with existing reconstructions (TWR and multiproxy) show temporally unstable results.

Acknowledgement

This work is an output of the CzechGlobe Centre, that is being developed within OP RDI and co-financed from EU funds and state budget of the Czech Republic (Project: CzechGlobe - Centre for Global Climate Change Impacts Studies, Reg. No. CZ.1.05/1.1.00/02.0073). P. Dobrovolný and M. Trnka acknowledge support for the Czech Science Foundation project No. 13-04291S. R. Brázdil was supported from project No. P209/11/0956.

Conference „Global Change and Resilience", Brno, Czech Republic, 22 – 24 May 2013