Climate forcings of past droughts in the Czech Lands

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Introduction

Frequency and intensity of local droughts is governed by a complex interaction of diverse processes, originating from internal dynamics of the climate system as well as its responses to external forcings. Separating and quantifying the effects of individual drought-inducing agents is a nontrivial task, often approached via statistical methods. In this presentation, we employed multiple linear regression to identify components attributable to various forcing factors, both external (solar irradiance, volcanic activity, anthropogenic greenhouse gases and aerosols) and internal (North Atlantic Oscillation - NAO, Southern Oscillation - SO, Atlantic Multidecadal Oscillation - AMO), in the monthly series of selected drought indices (SPI, SPEI, Z-index, PDSI) characterizing various sites within the territory of the recent Czech Republic (CR) during the 1883-2010 period.

Target area

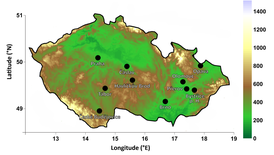

Fig. 1: Locations of Czech weather stations providing temperature and precipitation data employed for calculation of the drought indices. The color scale represents terrain elevation above sea level (m)

The analysis was performed on drought index series calculated from temperature and precipitation records at 10 Czech weathers stations (**Fig. 1**) in the 1883-2010 period, and on the respective areal means. The drought descriptors analysed included:

- Standardized Precipitation Index (SPI)
- Standardized Precipitation Evapotranspiration Index (SPEI)
- Palmer moisture anomaly index (Z-index)
- Palmer Drought Severity Index (PDSI)

Short-term variants of drought indices were investigated (SPI-1, SPEI-1, Z-index) along with their long-term counterparts (SPI-12, SPEI-12, PDSI).

Target & Explanatory variables

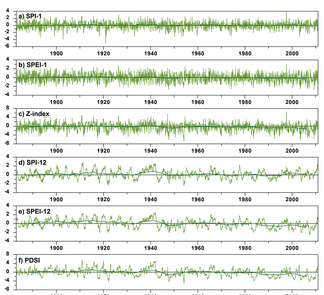

Fig. 2: Time series of mean Czech areal values of the drought indices. Light green line shows series of the index, darker line represents its 10-year moving average

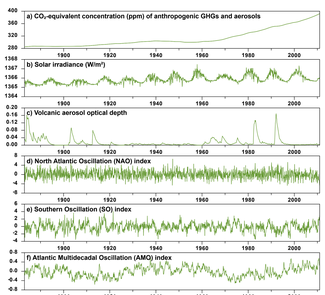

Fig. 3: Time series of the explanatory variables (predictors) employed in the analysis (monthly temporal resolution, 1883-2010 period)

Analysis setup

The analysis was carried out using multiple linear regression, separating contributions from six potentially influential explanatory variables (**Fig. 3**) to site-specific and area-averaged drought indices (**Fig. 2**). The regression coefficients were estimated by the least squares method and their statistical significance evaluated through moving block bootstrap (with block size set to 3 months for short-term drought indices and 48 months for the long-term ones, to account for the effect of residual autocorrelations).

The possibility of time-delayed responses in the predictand-predictor relations was investigated by application of time-shifted predictors, with the offset value Δt ranging from -12 to +12 months (**Fig. 4**). After considering the physical plausibility of the dependencies detected, as well as their robustness, a single unified Δt setup was employed for all the regression mappings, with Δt = 3 months for the volcanic aerosol forcing and Δt = 0 for the rest of the predictors. For short-term drought indices, the predictor series entered the regression in their native monthly resolution, while time-averaged variants were used in the case of long-term indices, with the method of averaging reflecting the definition of the particular index.

Main results

Among the short-term drought indices, SPI-1 exhibited almost no relation to anthropogenic forcing, in contrast to strong links detected for SPEI-1 and Z-index at most locations (upper part of **Fig. 5**). Negative correlations were detected between the drought indices and volcanic aerosol amounts, although only a few locations exhibited a connection on a statistically significant level. The relation to NAO index was quite strong for SPEI-1 and Z-index, less so for SPI-1. Only weak and largely statistically insignificant links were detected between SO index and either of the short-term drought indices; no significant connections to solar activity or AMO phase were found.

The general patterns of predictand-predictor relations were similar for the longer-term drought indices, though some differences emerged (lower part of **Fig. 5**, **Fig. 6**) and the fraction of variance explained was generally higher. The links of SPEI-12 and PDSI to anthropogenic forcing were strong, unlike for SPI-12. Statistically significant links to volcanic activity were indicated for some locations. Values of all three indices were linked to NAO phase, though the connection was generally stronger for SPEI-12 and PDSI. The most noticeable difference between the time scales was found regarding the influence of the Southern Oscillation: Compared to its inconclusive imprint in the short-term drought indices, SO links to the long-term drought descriptors were more distinct and statistically significant for mean Czech series as well as several of the individual locations. The connections to solar activity or AMO were again weak and statistically insignificant.

To assess the possible seasonality in the relations between the predictors and drought indices, the short-term drought attribution analysis was also carried out separately for individual seasons of the year (**Fig. 7**). Of the seasonal differences revealed, the most notable distinction was found for NAO index, with mostly positive (and often statistically significant) correlations in winter, contrasting with anticorrelations in the rest of the seasons as well as the year as a whole.

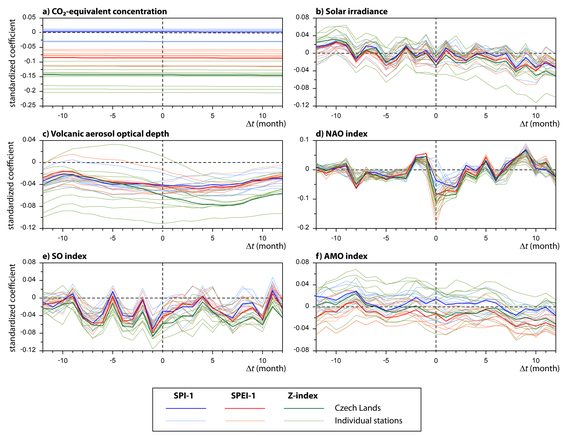

Fig. 4: Values of regression coefficients between drought indices (predictands) and explanatory variables (predictors), with individual explanatory variables shifted in time by Δt (while keeping the rest at Δt = 0). Positive values of Δt represent configurations with the predictor leading the drought index. The coefficients are shown in the standardized form, i.e. for both predictands and predictors standardized to zero mean and standard deviation equal to one

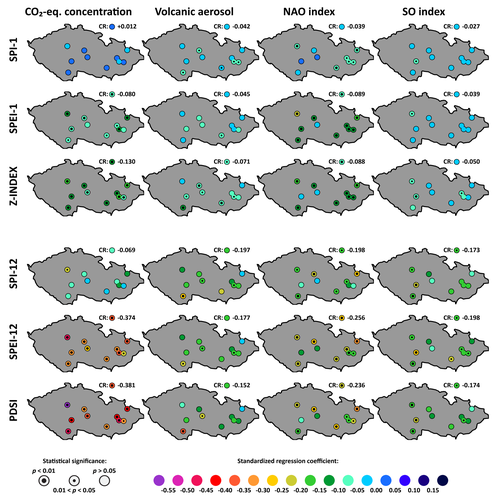

Fig. 5: Standardized regression coefficients between individual drought indices (rows) and the most influential predictors (columns) in the 1883-2010 period. Shape of the symbol represents statistical significance, color coefficient's value

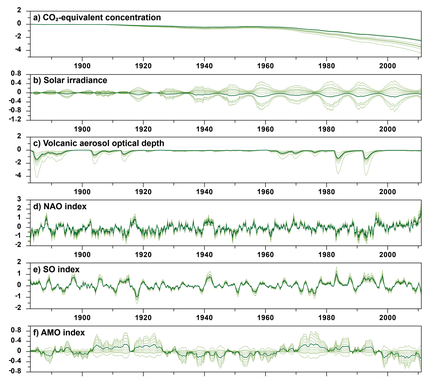

Fig. 6: Contributions of individual predictors to the PDSI series over the 1883-2010 period. Bold lines represent results for mean Czech series, thin lines correspond to individual stations. The component attributed to anthropogenic forcing is displayed relative to January 1883, solar-attributed component relative to the 1883-1893 period, the rest relative to zero value of the respective predictor

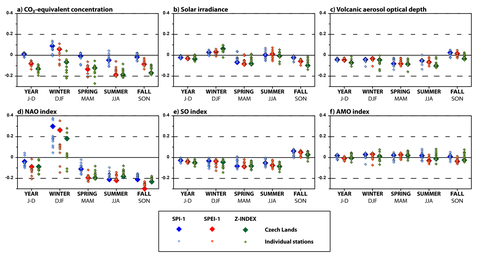

Fig. 7: Annual and seasonal values of standardized regression coefficients in the 1883-2010 period for short-term drought indices representing the Czech Lands (large symbols) and individual stations (smaller symbols)

Related publications

Brázdil, R., Bělínová, M., Dobrovolný, P., Mikšovský, J., Pišoft, P., Řezníčková, L., Štěpánek, P., Valášek, H., Zahradníček, P. (2012): Temperature and Precipitation Fluctuations in the Czech Lands During the Instrumental Period. Masaryk University, Brno, 236 pp.

Brázdil, R., Trnka, M., Mikšovský, J., Řezníčková, L., Dobrovolný, P. (2015): Spring-summer droughts in the Czech Land in 1805–2012 and their forcings. Int. J. Climatol, in print. (DOI: 10.1002/joc.4065)

Brázdil, R., Trnka M. et al. (2015): Droughts in the Czech Lands: Present, Past, Future (book in preparation)

Mikšovský, J., Brázdil, R., Štěpánek, P., Zahradníček, P., Pišoft, P. (2014): Long-term variability of temperature and precipitation in the Czech Lands: an attribution analysis. Climatic Change, 125(2), 253-264. (DOI 10.1007/s10584-014-1147-7)

Acknowledgements

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