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Extreme precipitation events in the Czech Republic in the context of climate change

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Abstract. As an introduction, short survey of two analyses of long-term fluctuations of annual precipitation totals in the Czech Republic is presented. The main focus of this paper is to contribute to investigation of precipitation trends in the Czech Republic by another point of view. For every pixel of 1 km^2 size, annual maxima of daily precipitation were obtained for time period of 112 years (1895–2006). Based on these time series, we were trying to answer question if there are some changes of area size/distribution of annual maximum of daily precipitation totals. Courses and trends are analyzed for some parameters of area distribution of annual maximum of daily precipitation totals in the area of the Czech Republic. No significant climate changes of tested precipitation characteristics were found.

1 Introduction

Long-term precipitation changes in the Czech Republic are illustrated by the example of annual series from the Prague, Klementinum (Fig. 1) and Brno (Fig. 2) secular stations, which were presented in Climate Atlas of Czechia (2007). While in the case of the Prague, Klementinum series, original measurements were used (including possible inhomogeneities), for Brno, a homogenized series of measurements performed in various parts of the city, completed by the missing data for the years 1838–1847 (Auer et al., 2005), was analyzed. The series of the annual precipitation totals from both stations do not show any strong long-term tendencies, confirming the fact that they do not include any statistically significant linear trends (Climate Atlas of Czechia, 2007). Decreasing or increasing tendencies in precipitation are thus only apparent within shorter periods of time. The long-term variation indicates that precipitation fluctuations have a cyclic character. Regarding Brno station, the reference period 1961–2000 appears drier in comparison with previous periods. This is particularly evident in the case of the annual totals, where a period of lower precipitation only occurred in the 1930s and during the years 1855–1875. The second dry period can be quite clearly seen in the Prague series; it is associated with a decrease in summer precipitation as well as a decrease in spring and autumn totals. Summer precipitation has the strongest impact on the character of annual precipitation fluctuations, while autumn has the lowest correlation with the fluctuations in the annual precipitation totals (Climate Atlas of Czechia, 2007).

The annual and seasonal trends of precipitation for northeast subregion of the so called Greater Alpine Region were analysed by Auer et al. (2007). This subregion contains historical data from two stations in the Czech Republic, too (Brno, Tábor). Trends for different periods of 1800–2000 are presented in Table 1. There are only small significant changes for some periods of the last 200 years. Focussing on the time period 1975–2000, relatively large increase (more than 11% of 1901–2000 average total) of autumn precipitation can be detected in this region.

The main focus of this paper is given to the question if there are statistically significant time changes of frequency distribution of area occurrence of annual maxima of daily precipitation, especially:

– Are there any changes of the range within it annual maximum of daily precipitation total occurs on the given size of area of the Czech Republic?

– Are there any changes of annual maxima of daily precipitation total which is not exceeded on the given size of area of the Czech Republic?

Question of floods (large precipitations), not of drought, is analysed.

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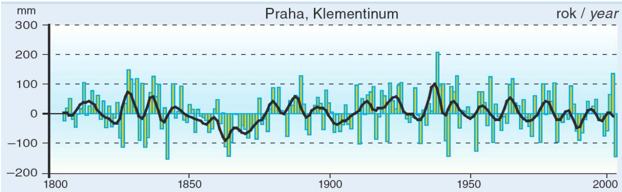

Fig. 1. Long-term fluctuations in the annual precipitation totals at the Praha, Klementinum station, expressed as deviations from the average value for the period 1961–2000. Smoothed by Gaussian filter for 10 years.

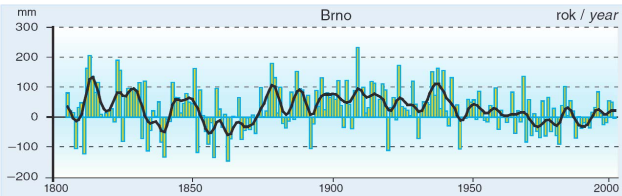

Fig. 2. Long-term fluctuations in the annual precipitation totals at the Brno station, expressed as deviations from the average value for the period 1961–2000. Smoothed by Gaussian filter for 10 years.

2 Data and methods

Precipitation measurements of the most of stations have more or less breaks and inhomogeneities of different origin. Time series homogeneity is essential when studying climatic changes over time. Different methods are used to this (WMO, 2004; Szentimrey, 1996, 1999, 2003; Květoň and Žák, 2004). On the other hand, it should be noted that homogenization necessarily contains subjective features and contemporary homogenization methods deal with annual, seasonal and monthly data (WMO, 2004). Homogenization of time series of extreme events and filling of gaps by estimated values seems to be very questionable. This problem is extraordinary large when studying trends of extreme precipitations measured on single station. From this reason, only careful measurement data checking (both local and spatial revision) was made with respect to the aim of this paper. Method used for data pre-processing and analysis is supposed to decrease importance of inhomogeneities problems.

For this paper, precipitation data from all stations in the area of the Czech Republic without gap in observation in every given year were used from period 1895–2006. The count of stations differs year-to-year (Fig. 3) and different stations have also different number of years with observation (Fig. 4).

For every year, annual maxima of daily precipitation totals were interpolated from available precipitation stations in the whole area of the Czech Republic in Geographic information system (GIS). This way of method means, that space interpolation was often made between stations or data originat-

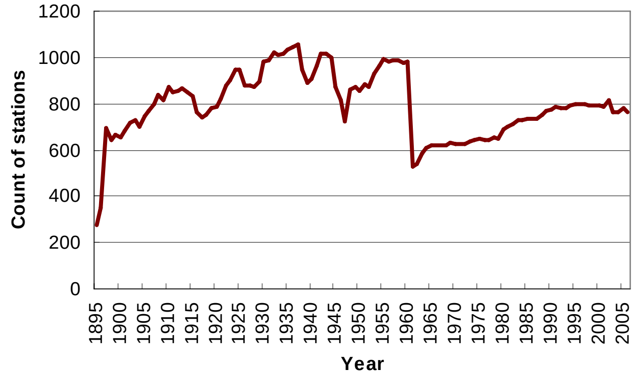

Fig. 3. Count of stations used for analysis for period 1895–2006.

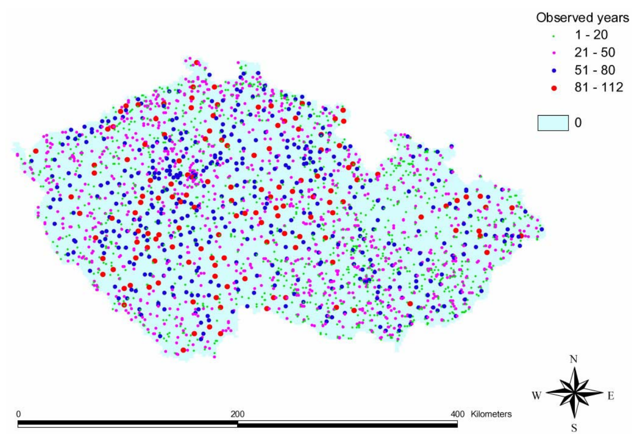

Fig. 4. Position of used stations with color-indicated number of observed years.

ing from different precipitation episodes (different regional rains, local thunderstorm rains) (Šercl et al., 2004, Faulkner, 1999). The orographic interpolation by Květoň et al. (2000) was used. Squares (pixels) of 1-km size were distinguished.

By this method, time series were created for every 1-km pixel (square) of the Czech Republic from grids. Resulted 78961 time series (period 1895–2006, i.e. 112 years) of the annual maxima of daily precipitation totals were used for further analyses. For precipitation data, it can be supposed that they have log-normal distribution. Histogram of logarithmic transformed data is presented on Fig. 5.

From annual maxima of precipitation totals that have been given in irregular spacing, regular grids have been gained by interpolation. From these grids percentile values over a region have been computed for every year. Note, that interpretation of percentile is that precipitation less or equal to $P-$th percentile occurred on P% of area of Czech Republic in the given year (i.e. it is a value not greater than this threshold). Figure 6 demonstrates values that have not been exceeded for 1st to 100th percentile (i.e. proportional size of affected part of CR area) in year 2002. It means, that in this year on 1 pixel

Table 1. Long-term annual and seasonal precipitation trends in the north-east subregion of the Greater Alpine Region in two 100-year, four 50-year and two (recent) 25-year subperiods (Auer I. et al., 2007). Trends are in % per decade and bold figures mark 90% significance according to Mann-Kendall trend test.

Period	Annual precipitation (% of 1901-2000)	Seasonal precipitation (% of 1901–2000)			
		Spring	Summer	Autumn	Winter
1800–1900	−0.6	1.1	−0.6	**−1.8**	**−1.9**
1900–2000	**−0.8**	−0.9	−0.2	−1.2	−1.1
1800–1850	−1.7	−2.4	−0.4	−3.1	−4.2
1850–1900	**2.7**	**4.8**	2.0	2.0	3.2
1900–1950	−1.0	−3.4	−0.6	−0.5	1.3
1950–2000	−0.6	0.8	−2.1	1.8	−2.8
1950–1975	−2.0	1.1	3.4	−6.6	−9.0
1975–2000	3.3	4.4	1.5	**11.1**	−8.7

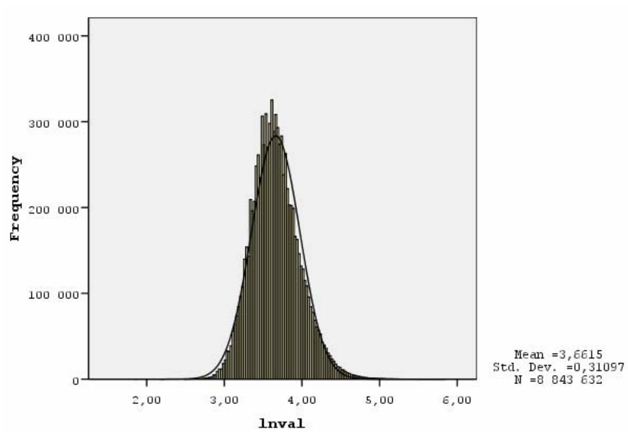

Fig. 5. Histogram of annual maxima of daily totals for the whole area of the Czech Republic from 1895–2006 – after logarithmic transformation. Normal curve is given, too.

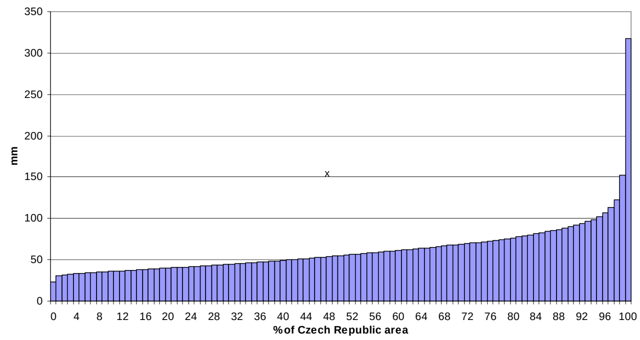

Fig. 6. Values not exceeded by annual maximum of daily precipitation totals depending on proportional size of affected part of CR area in year 2002.

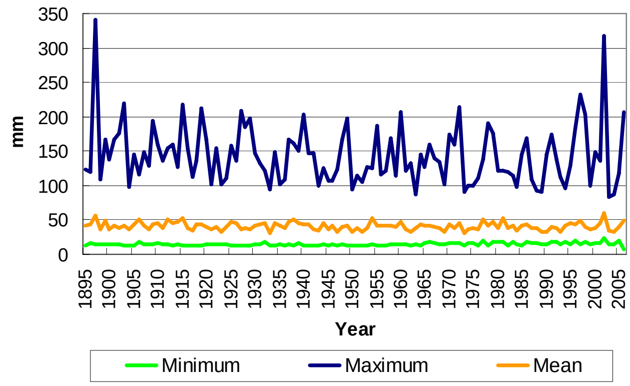

Fig. 7. Minimum, maximum and area arithmetic mean of highest annual daily precipitation total in the Czech Republic (1895–2006).

(area of 1 km^2), annual maximum of daily precipitation total was 23 mm, in half size of area of the Czech Republic it was no more than 55 mm and on 1 pixel it was 317 mm. Note, the area with precipitation less or equal to given threshold may not be continuous.

Time series were constructed for selected percentiles as well as for differences between selected percentiles. Time changes of these series were analyzed by linear and cubic regression (in SPSS software, logarithmic transformation of time series was used).

3 Results

Values of area minimum, maximum and arithmetic mean of highest annual daily precipitation total in the Czech Republic in 1895–2006 are depicted in Fig. 7.

There are large changes of maximum year-to-year, while mean and minimum vary small. Long-term fluctuations of values not exceeded by annual maximum of daily precipitation totals for 1, 5, 95 and 99%-part (Fig. 8) and for 98, 90, 80 and 50 %-part (Fig. 9) of area of CR are presented.

Table 2. Model summary of regression analysis of time variation of values not exceeded by annual maximum of daily precipitation totals (ln transformation) for selected sizes of CR.

Area of CR		Linear model		Cubic model	
Percentile	km^2	R Square	Significance	R Square	Significance
Minimum	1	0.080	0.003	0.100	0.003
1	790	0.009	0,311	0.029	0.201
5	3948	0.023	0.107	0.039	0.115
10	7896	0.024	0.103	0.039	0.114
15	11844	0.024	0.105	0.038	0.121
50 (Median)	39481	0.017	0.176	0.031	0.178
85	67117	0.015	0.203	0.029	0.205
90	71065	0.014	0.220	0.029	0.205
95	75013	0.011	0.263	0.027	0.227
99	78171	0.003	0.590	0.017	0.393
Maximum	78961	0.022	0.122	0.040	0.111

Table 3. Model summary of regression analysis of time variation of boundaries in which vary annual maximums of daily precipitation totals (ln transformation) in given size of area of CR.

Area of CR			Linear model		Cubic model	
Inter-percentile distance	%	km^2	R Square	Significance	R Square	Significance
P99_01	98	77381	0.000	0.936	0.002	0.914
P95_05	90	71065	0.000	0.903	0.002	0.910
P90_10	80	63169	0.000	0.939	0.002	0.920
P75_25	50	39481	0.001	0.719	0.003	0.865
P60_40	20	15792	0.005	0.445	0.008	0.634

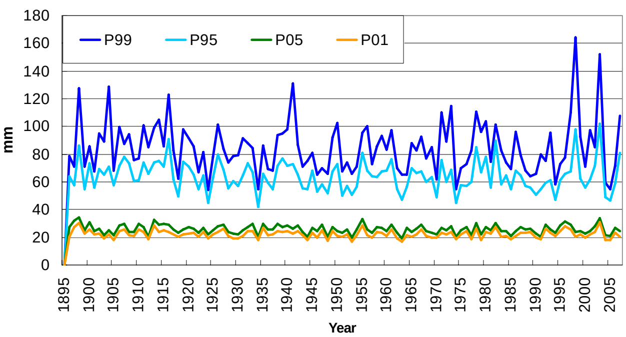

Fig. 8. Long-term fluctuations of values not exceeded by annual maximum of daily precipitation totals for 1, 5, 95 and 99%-part of area of CR. Period 1895–2006.

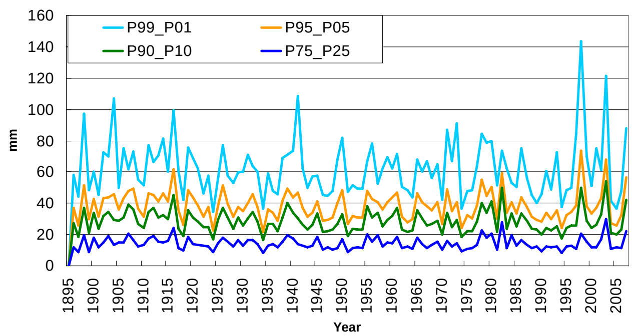

Fig. 9. Long-term fluctuations of values not exceeded by annual maximum of daily precipitation totals for 98, 90, 80 and 50%-part of area of CR. (labeled as P99_P01, P95_P05 P90_P10 and P75_P25). Period 1895–006.

Main results of trend analysis are presented in Tables 2 and 3. These tables contain model summaries of regression analyses of time variation of values not exceeded by annual maximum of daily precipitation totals for selected sizes of CR (Table 2) and of time variation of boundaries (as inter-percentile distances), in which vary annual maximums of daily precipitation totals in given size of area of CR (Table 3). Linear and cubic models were computed. Determination coefficients (R Square columns) and significance of models are given.

Significant changes ($p<0.05$) were found for 1-km^2 area only. In the other cases significant changes of values less or equal to given threshold in tested size of area of CR were not found.

4 Conclusions

There is no significant trend of change of area distribution of annual maximum of daily precipitation totals in the Czech Republic, excluding area minimum, that has significant rising linear trend ($p<0.05$). The area minimum, i.e. the lowest annual maximum of daily precipitation total in the CR represents size of 1 km^2 of the CR (it doesn't need to be the same pixel in different years), only. Such small area representative time series are very sensitive with regard to homogeneity of data and results based on them have no real importance for climate change studies. Additionally, occurrence of local extreme event with very long return period strongly influences validity of results of climate changes analysis in point (small area size) data.

These results by our opinion correspond with results mentioned in the introduction part of this paper and also with the last conclusions of the IPCC, which suppose less precipitation in low latitudes and higher precipitaions in high latitudes (e.g. Pretel, 2007). As for average annual and seasonal precipitation totals in the last 200 years in the Czech Republic there are no clear significant changes. For the NE part of the Greater Alpine Region there are also only small significant changes in the last 200 years. Focussing on the time period 1975–2000, smaller increase of autumn precipitation can be detected in this region.

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