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CHANGES IN THE EXTREME AIR TEMPERATURE IN CZECH REPUBLIC

Abstract: This study is focused on air temperature in Czech Republic in relation to selected climatological indices for extreme hot and extreme cold days for the period 1961-2017. The number of summer days (SU) and number of tropical days (SU30) have been chosen as the indicators of extreme hot days. For the indicators of extreme cold days, the number of frost days (FD) and number of icing days (ID) have been analyzed. The analyses are based on the daily data for air temperature measured at eight meteorological stations situated at the regions with different geographical and climate conditions. The data are freely available from the website of the Czech Hydrometeorological Institute. The results of the study show negative trend of extreme cold events and positive trend of extreme hot temperatures. With a few exceptions, the trend is statistically significant at p=0.05. The trend values for the indicators of cold days are higher than those for the indicators of warm days. The results show a faster change in air temperature for the cold part of the year

Key words: frost days, icing days, summer days, tropical days, Czech Republic

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Introduction

Recently the interest to extreme climate events has been increased and often the analyses were related to extreme temperature at regional scale (Martinikova & Hanel, 2016; Ruml et al., 2016; Valerianova et al. 2017). High air temperatures could lead to the increase convective precipitation (Martinkova & Hanel, 2016) or drought intensification (Nikolova et al., 2016). Based on the global land surface daily air temperature dataset Zhang et al. (2019) found significant (at the 5% level) increase of air temperature during the period 1976-2015 while in the period 1951-1975 the values of trend are low and not statistically significant. The authors found larger changes in the minimum temperatures compared to the maximum ones. Valerianova et al. (2017) investigated high temperature extremes in Czech Republic and established that the number of events related to high air temperature increased during the last decades. This is in accordance with the tendencies in global climate change pointed out by IPCC (2014, 2018).

In order to reveal the regional peculiarities of extreme air temperature changes many authors analyzed extreme temperature indices (Fonseca et al., 2016; Sun et al., 2017; Popov et al., 2018; Matev, 2019, 2019a). Like the previous publications, in the present study we analyze heat and cold indices as an indicator of the change in extreme air temperature in Czech Republic. The aim is to describe the variations in observed extreme temperatures for different regions in Czech Republic.

Study area, data and methods

Czech Republic experiences moderate climate. From western part towards the eastern of the country the impact of continentality increases. Climate characteristics are formed under the combined influence of Atlantic, Mediterranean, and continental air masses and orography. In the western part of the Czech Republic the influence of the air masses from the Atlantic Ocean prevails, while in the east the inflow of warm and humid air from the Mediterranean is more often observed (Martinkova & Hanel, 2016). In general, the warmest areas relate to the large lowlands in central and south-east part of the country. From the opposite point of view, the coldest areas we can find in highlands and mountain ranges, mostly situated in the border areas with all neighboring countries. Based on Quitt's climatic classification Vondráková et al. (2013) have identified three regions in Czech Republic: warm, covering the lowlands (25% of the Czech Republic), moderately warm – the central parts (66% of the territory) and cold - the higher regions (9% of the country).

The present analysis is based on daily air temperature data for the period 1961-2017 measured at eight meteorological stations located at different regions of the Czech Republic (Fig. 1.). The data are freely available from the website of the Czech Hydrometeorological Institute (CHMI). The selection of stations was determined by the published time-series with continuous measurements and without missing data for the study period and by the geographical location of the stations. The meteorological stations used for the present work can be classified as urban, rural and mountainous. The altitude of the stations varies from 241 m (Brno-Turany) to 1,322 m (Lysa hora).

Tab. 1. List of meteorological stations used for the research

Meteorological stations	Type	Latitude (N)	Longitude (E)	Altitude (m)
Brno-Turany	Urban	49°09'	16° 41'	241
Lysa hora	Mountain	49° 31'	18° 26'	1,322
Ostrava-Mosnov	Urban	49° 41'	18° 06'	253
Pribyslav-Hriste	Rural	49° 34'	15° 45'	533
Praha-Ruzyne	Urban	50° 06'	14° 15'	364
Liberec	Urban	50° 46'	15° 01'	398
Primda	Rural	49° 40'	12° 41'	743
Milesovska	Mountain	50° 33'	13° 55'	831

Source: CHMI

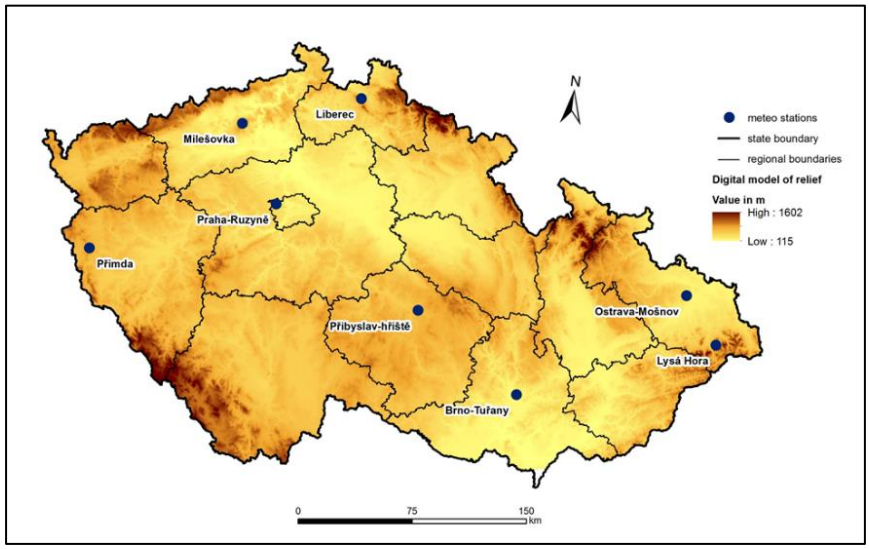

Fig. 1. Geographical location of the meteorological stations used in the research

Changes in temperature extremes are analyzed at a local scale based on the daily temperature records for the period 1961-2017. For the purpose of this study four basic indices have been chosen: two of indices are for the extreme cold days and the other two ones for the extreme hot days:

1. Extreme cold days:

- Number of frost day (FD): the days on which the minimum air temperature falls below 0 °C;
- Number of icing days (ID): the days on which the maximum air temperature remains whole day below 0 °C.

2. Extreme hot days:

- Number of summer days (SU): the days on which the maximum air temperature reaches at least 25 °C;
- Number of tropical days (SU30): the days on which the maximum air temperature reaches at least 30 °C.

The FD, ID and SU indices are proposed by Expert Team on Climate Change Detection and Indices (ETCCDI)[2] and Climdex project[3] and SU30 index is calculated according to Ciupertea et al. (2017) and Salameh et al. (2019). All indices were calculated at monthly and annual level. Based on monthly average values the annual cycle of each index was analyzed. The trend of the annual sums of each index was investigated by linear regression ($y=b_0+b_1*x$) for the period 1961-2017. Trend coefficients were calculated using AnClim software (Štěpánek, 2008), and the statistical significance at level p=0.05 of the trend was determined by t-test.

Results and discussion

Extreme cold days

Frost days occur most frequently than other extreme temperature events during the winters. It is an indicator with the least extreme conditions of air temperature of four investigated in the present analysis. Average values for the investigated period 1961-2017 show between 20 and 25 frost days in winter months (December – February) and in mountainous station Lysa hora frost days in winter months reach 27-30 (Fig. 2). Frost days occur also in spring and autumn months – April and October and at the station with the altitude above 500 m also in May.

The second indicator (number of icing days) shows approximately a half of values of the number of frost days. Icing days usually occur only during winter season but also in March and November (Tab. 2). There are also bigger differences among stations, especially caused by their altitudes. At the altitude 1,322 m (station Lysa hora) icing days was observed during April and October. The average annual number of icing days for the investigated period varies between 99 days in mountainous station Lysa hora and 31 – 32 days in urban stations Brno-Turany, Ostrava-Mosnov and Praha-Ruzyne.

In the 57 observed years we can see quite clear trend of decrease of annual number of frost days within majority of stations. The trend is with values between -2.4 and -5.6 per 10 years and is statistically significant in all of stations (Tab. 3). The most visible changes relate to mountain and rural stations with higher altitude. For the investigated period 1961-2017 the trend of annual sums of icing days is negative with values between -1.6 and -5.3 days/10 years. With exception of urban stations in the other stations the trend of annual number of icing days is statistically significant (Tab. 3). The results of present study confirm the results from previous scientific publications which show winter warming and decrease of frost days in global (Frich et al., 2002; Zhang et al., 2019) and regional (Brazdil et al., 2009; Croitoru & Piticar, 2013; Buric et al., 2014; Matev, 2019a) scale.

[2] http://etccdi.pacificclimate.org/list_27_indices.shtml
[3] https://www.climdex.org/learn/indices/

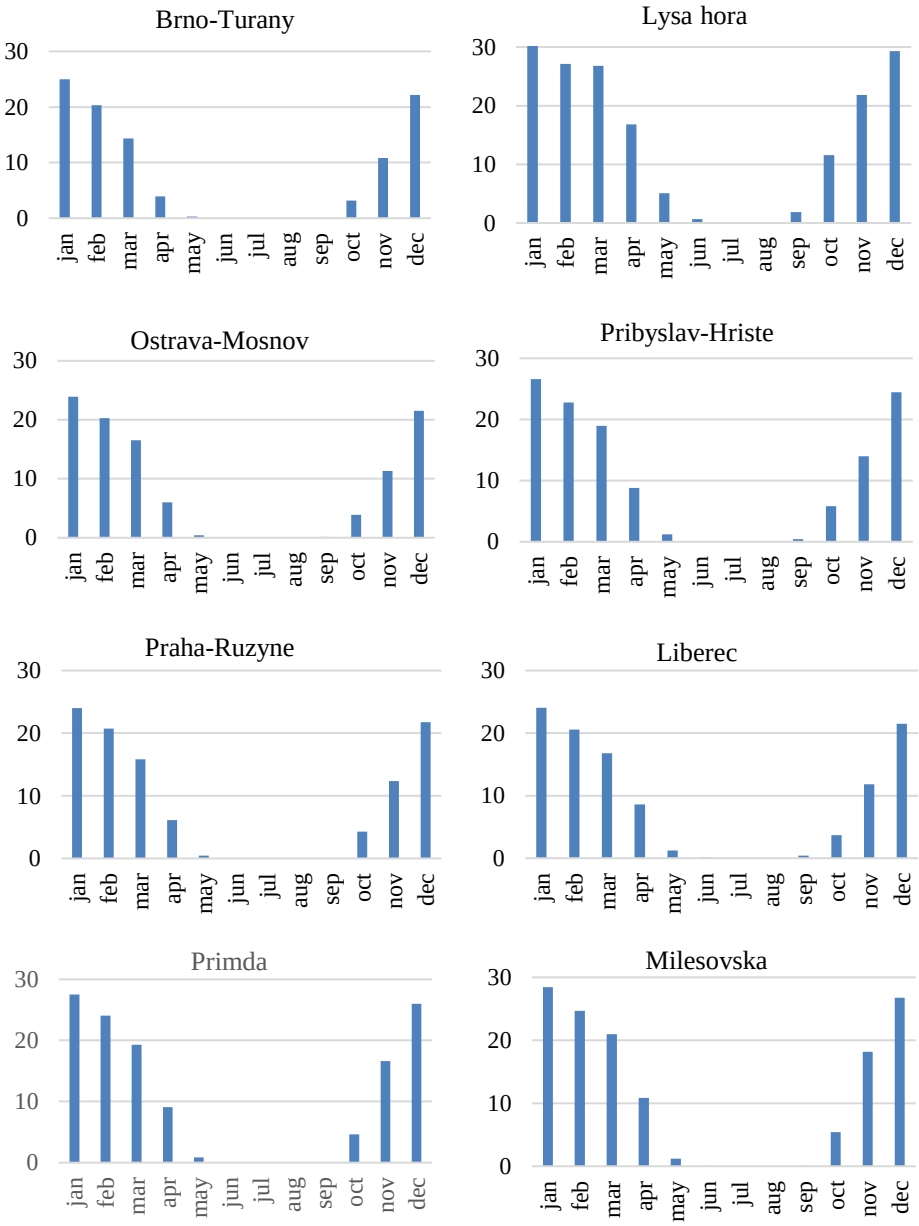

Fig. 2. Number of frost days – monthly average for the period 1961-2017

Tab. 2. Number of icing days – average for the period 1961-2017.

Meteorological stations	Jan	Feb	Mar	Apr	Oct	Nov	Dec
Brno-Turany	13	6	1	0	0	2	9
Lysa hora	24	20	15	5	3	12	21
Ostrava-Mosnov	12	7	2	0	0	2	9
Pribyslav-Hriste	16	9	3	0	0	4	13
Praha-Ruzyne	12	7	2	0	0	2	9
Liberec	13	8	2	0	0	2	10
Primda	19	13	4	0	0	7	17
Milesovska	19	14	5	1	0	7	17

Tab. 3. Trend of annual sum of extreme cold days (number of days/10 yr)

Meteorological stations	Frost days	Icing days
Brno-Turany	-4.1 *	-1.8
Lysa hora	-4.7 *	-4.5 *
Ostrava-Mosnov	-2.4 *	-1.6
Pribyslav-Hriste	-4.7 *	-2.9 *
Praha-Ruzyne	-5.1 *	-1.8
Liberec	-2.8 *	-3.3 *
Primda	-5.6 *	-5.3 *
Milesovska	-5.4 *	-4.5 *

* Statistically significant at level p=0.05

Extreme hot days

Days with the maximal daily air temperature at least 25 °C (summer days) was observed mainly in June, July and August. On the other side the long-term data from the Czech Hydrometeorological Institute show that in last decades summer days occurred also in spring (May) and autumn (September), Fig. 3.

In most of the urban stations (Brno-Turany, Ostrava-Mosnov and Praha-Ruzyne) between 12 and 16 days in July and August were with maximal daily temperature above 25 °C, while in rural stations SU were observed in 5 to 10 days in July and August. We have to point out that for this distribution of summer days not only the type of stations is important but also the altitude has a considerable impact on air temperature and summer days occurrence in particular. At 1,322 m (station Lysa hora) only one day in July and one in August were with maximal air temperature above 25 °C.

Tropical days (SU30 - the days with maximal daily air temperature above 30 °C) was observed only in typical summer months. This indicator is characteristic mainly for the urban stations which have lower altitude in comparison to other investigated stations but the number of tropical days is low. The highest average number of tropical days was established for station Brno-Turany – 5 days in July, average for the investigated period.

Multiannual distribution of summer days for the period 1961-2017 shows good synchronicity between the investigated stations and statistically significant positive trend in all the stations (Tab. 4).

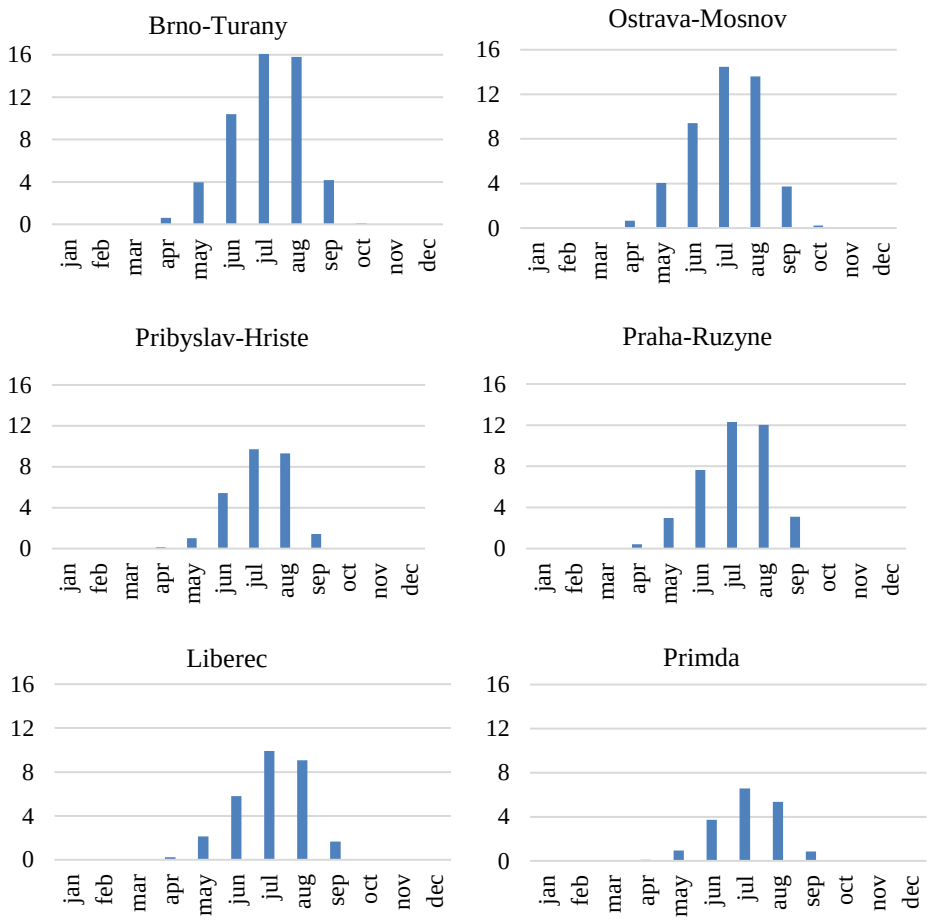

Fig. 3. Number of summer days – monthly average for the period 1961-2017

Tab. 4. Trend of annual sum of extreme hot days (number of days/10 yr)

Meteorological stations	Summer days (SU)	Tropical days (SU30)
Brno-Turany	4.0 *	2.4 *
Lysa hora	1.0 *	-
Ostrava-Mosnov	3.3 *	1.5
Pribyslav-Hriste	2.8 *	0.9 *
Praha-Ruzyne	2.1 *	0.8
Liberec	3.6 *	1.1 *
Primda	2.3 *	0.8 *
Milesovska	3.8 *	1.0 *

* Statistically significant at level p=0.05

The values of trend are between 1 and 4 days /10 years, while as it is shown above the frost days decreased with 4-5 days per 10 years. The results from the analysis coincident with the tendency of global temperature changes which shows that the trend is better expressed for the cold events (Zhang et al., 2019) and in contrast to some regional studies – Lakatos et al. (2014) for Carpathian region, Popov et al. (2018) for Bosna and

Herzegovina which state that trend values of warm temperature indices are higher and show most prominent warming

The trend of annual number of tropical days is statistically significant but in most of cases the values of trend are quite low – approximately 1 tropical day per 10 years (Tab. 4). On the other side in several of investigated stations between 65 and 83% of all tropical days occurred in the period 1990-2017. The increase in the number of tropical days is in recent decades is more significant mainly at rural and mountainous stations which have higher altitude that urban stations.

Despite the longer study period in this publication, the results confirm the conclusion of Brazdil et al. (2009) that climate change in the Czech Republic is in line with regional trends for Central Europe.

Conclusion

The present study analyses extreme temperature indices (FD, ID, SU and SU30) as an indicator for climate change in Czech Republic. The annual cycle and trend of extreme temperature indices for the period 1961-2017 were revealed. Frost days were observed from October to April, and in the mountain stations in May also. During the typical winter months (December, January and February) the average number of FD days in the individual stations is between 25 and 30. Icing days are typical mainly for the winter months, and in November and March their number is up to 7. Only in the high-mountainous regions ID were found in October and April.

The maximum number of SU was observed in July (average between 7 and 16 in the individual stations). A few tropical days (average up to 5 per month) were found in the urban stations which have lower altitude.

The linear regression of annual number of frost days and annual number of icing days shows significant negative trend. The values of the trend are higher at the stations with higher altitude – rural and mountainous. Many-years variabilities of summer days and tropical days show in most of cases statistically significant positive trend. The increase of number of hot events (summer days and tropical days) is more characteristic for urban stations mainly. The decrease in the number of frost and ice days and the increase in the number of summer and tropical days is evidence of a general increase in the thermal level in the Czech Republic, which corresponds to the climate trends for Central Europe and in global scale.

The results of the present study can be used in agriculture, land use and land management, as well as in developing plans to mitigate the negative effects of extreme climate events. Future research will focus on clarifying the causes and effects of changes in extreme air temperatures.

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ПРОМЕНЕ У ЕКСТРЕМНИМ ТЕМПЕРАТУРАМА ВАЗДУХА У РЕПУБЛИЦИ ЧЕШКОЈ

Резиме: Циљ овог рада је да утврди разлике у осмотреним екстремним температурама ваздуха за различите регионе у Чешкој. Да би се то постигло изабрани су следећи индекси екстремних температура:

- Број мразних дана (FD): дани у којима минимална температура ваздуха пада испод 0 °C;
- Број дана залеђивања (ID): дани у којима је максимална температура ваздуха читав дан испод 0 °C.
- Број летњих дана (SU): дани у којима максимална температура ваздуха достиже најмање 25 °C;
- Број тропских дана (SU30): дани у којима максимална температура ваздуха достиже најмање 30 °C.

На основу дневне температуре ваздуха са осам метеоролошких станица откривени су годишњи циклус и тренд индекса екстремних температура за период 1961-2017. Мразни дани су забележени од октобра до априла, а на планинским станицама и у мају. Током типичних зимских месеци (децембар, јануар и фебруар) просечан број FD дана у појединим станицама је између 25 и 30. Ледени дани су типични углавном за зимске месеце, а у новембру и марту њихов број износи до 7. Само у високопланинским регионима ID су забележени у октобру и априлу. Максималан број SU забележен је у јулу (просечно између 7 и 16 на појединим станицама). Неколико тропских дана (у просеку до 5 месечно) забележено је у урбаним станицама које имају нижу надморску висину.

Линеарна регресија годишњег броја мразних дана и годишњег броја ледених дана показује значајан негативан тренд. Вредности тренда су веће на станицама са већом надморском висином - сеоским и планинским. Вишегодишње варијабилности летњих и тропских дана показују у већини случајева статистички значајан позитиван тренд. Повећање броја врућих случајева (летњих дана и тропских дана) карактеристичније је углавном за урбане станице. Смањење броја мразних и ледених дана и повећање броја летњих и тропских дана сведочи о општем порасту топлотног нивоа у Чешкој, што одговара климатским трендовима у Централној Европи и на глобалном нивоу.