# ACTA HYDROLOGICA SLOVACA

Volume 21, No. 2, 2020, 197 – 204

# THE DYNAMICS OF ANNUAL AND SEASONAL PRECIPITATION TOTALS IN THE CZECH REPUBLIC DURING 1961–2019

Jaroslav Rožnovský\*, Jaroslav Střeštík, Petr Štěpánek, Pavel Zahradníček

The long-term change in precipitation has been estimated for 300 stations in the Czech Republic using values of monthly precipitation totals. Annual totals for the whole country show a very slight decrease, in units of mm, there can be significant fluctuation on a year-to-year basis. Long-term changes of annual totals vary at different stations and in different regions. In southern and western Bohemia, precipitation totals increased more, in Elbe lowlands and in large parts of Moravia, a rather small decrease in rainfall has been observed. Long-term changes depend only slightly on the absolute value of annual rainfall at the respective station or region. Summer precipitation totals increased more than annual averages, while spring precipitation totals decreased. During the remaining seasons, the change is negligible. In the meantime, the annual variation in precipitation has changed slightly: maximum values have shifted from June to July.

KEY WORDS: long-term change, regions, annual precipitation totals, seasons

#### Introduction

With regard to their significance, precipitation is studied from many points of view. Basically no large rivers flows into the Czech Republic. This means that all water sources are represented by atmospheric precipitation and springs. Their occurrence is affected by circulation (Labudová et al., 2013).

The amount of water in springs, however, also depends on atmospheric precipitation. It is therefore obvious that the precipitation amount, annual precipitation totals and their long-term changes are of major importance (Tolasz et al., 2007). In recent years, it has been very important to analyze climate changes, which manifest themselves especially by global warming (Zahradníček et al., 2020; Střeštík et al., 2014a). It is assumed that the global average air temperature will continue to rise and that the rate of this increase will be higher in the future. However, this means an increase in evaporation (Novák, 1995), and more frequent droughts (Rožnovský et al., 2012). Extremes of precipitation totals play an important role (Bhatia et al., 2019). Climate change analysis also includes precipitation. In contrast to air temperature, some authors believe that the precipitation amount will decrease (Räisänen et al., 2004; Střeštík, 2013), meaning drought periods will be more common. Information on the occurrence of precipitation is important, but also their estimates of its occurrence in the future (Jiang et al., 2017). Kožuchowski and Marciniak (1990) presented a study, which shows that precipitation amount in western and northern Europe is increasing and will

continue to increase in the future, unlike in southern and eastern Europe where they believe precipitation amount has been decreasing and will continue to decrease. The Czech Republic lies in the region of expected precipitation decrease. This trend has also been proven by more recent studies (Střeštík, 2014b). Information on precipitation totals of both historical and current data can be found on the portal of the Czech Hydrometeorological Institute (http://portal.chmi.cz/). Precipitation affects processes in the soil, while soil moisture is crucial for plants (Guderle and Hildebrandt, 2015). Precipitation and their use represent a very wide range, from measurement methods, through quantification of water circulation phases, etc., to methods of maintaining water in the landscape. (Rožnovský, 2020).

#### Materials and methods

Assessment of precipitation dynamics is based on monthly values of the so-called technical series from 267 stations in the Czech Republic (Štěpánek, et al., 2011; 2013). This data was statistically processed and average annual and seasonal amount calculated for each station as well as average annual value for each year for the entire country as a whole, including trends etc.

#### **Results and discussion**

Average annual rainfall for the entire Czech Republic for the period 1961–2019 is 691.7 mm. However, the individual annual values are often quite variable. In the driest year 2003 only 513 mm was measured, in 2015 547 mm and 1982 it was 551 mm. The wettest year observed was 2010 894 mm, 1966 with 860 mm, followed by 2002 (854 mm) and 1981 (852 mm). The difference between the driest and wettest year is 381 mm, it is 43% of the wettest year, about 55% of the annual total.

Here are large differences in the precipitation amounts at different stations (Fig. 1). Highest precipitation amounts are observed at mountain stations, especially in the northern parts close to the borders. Stations with highest annual precipitation amount during the entire period were Labská bouda in Giant Mountains (1444 mm) and Lysá hora in Beskids (1422 mm). The absolute highest observed annual precipitation (in one year) was at the station Lysá hora in 2010 (2127 mm).

Lowest precipitation amounts are observed in lowlands, at stations Tušimice in Sub-Ore Mountains Lowland (444 mm) and in Prague-Karlov (445 mm). Absolute lowest observed annual precipitation amount in the entire period was 238 mm in 2008 in České Budějovice (Budweis). The wettest region is eastern Bohemia (average of 892 mm) and northern Moravia (average of 827 mm). Driest region is central Bohemia (average of 556 mm) and southern Moravia (average of 593 mm).

In general the precipitation amounts show a significant positive correlation with elevation (coefficient of 0.72), to a certain extent also with latitude (coefficient of 0.29), however, this is due to the fact that higher mountains are located mostly in the northern part of the country.

The trend during the 1961–2019 period shows a negligible increase in precipitation amount, supplemented by large fluctuations from year to year (Fig. 2). These do not display any regularity or periodicity (e. g. wet years are not usually followed by dry years). The same is valid also for decades and for the 20- or 30-year averages. Their values are given in Table 1.

The course of precipitation amounts for the individual stations or regions is in some extent similar to the course in the entire country. Individual maximums and minimums show a similar pattern. A dry year is a dry year in all regions and at all stations and similarly a wet year is a wet year everywhere. This is because the total area of the Czech Republic is not very large.

But the change in precipitation amount in the individual regions is different. Big differences appear among different regions though the total area of the country is relatively small. An example of different long-term change of precipitation amounts is given in Fig. 3. A strong increase is observed at the station Jirkov-Otvice in Sub-Ore-Mountains Lowland and a strong decrease appears at the station Nedvězí in Bohemian-Moravian Highlands. As a measure of the decrease or increase the slope of the respective regression line can be used. These slopes have been calculated for all stations and are presented in Fig. 4. The highest rate of increase is observed in Sub-Ore-Mountains Lowland and in southern and western Bohemia. In contrast, a decrease was observed in southern and in northern Moravia. The most significant increase was observed at the station Jirkov-Otvice, Sub-Ore-Mountains Lowland (slope 3.47), the largest decrease at the station Nedvězí in Bohemian-Moravian Highlands (slope -3.18). However, at most stations the respective increase or decrease is much weaker and remains far under the limit of the statistical significance.



Fig. 1 Distribution of average annual precipitation in the Czech Republic (1961–2019).



Fig. 2. Course of annual precipitation amounts in the Czech Republic (1961–2019). Dashed lines represent average  $\pm$  standard deviation.

| Table 1. | Average precipitation amount [mm] in the individual decades and 20 and 30- |
|----------|--|
|          | year periods in the Czech Republic (1961–2019)                             |

| 1961–1970 | 1971–1980 | 1981–1990 | 1991–2000 | 2001-2010 | 2011-2019 |  |
|-----------|-----------|-----------|-----------|-----------|-----------|--|
| 702       | 673       | 673       | 693       | 736       | 647       |  |
| 1961–1980 | 1971–1990 | 1981–2000 | 1991–2010 | 2001–2019 |           |  |
| 687       | 673       | 683       | 715       | 695       |           |  |
| 1961–1990 | 1971-2000 | 1981–2010 | 1991–2019 |           |           |  |
| 683       | 680       | 701       | 694       |           |           |  |



*Fig. 3.* Course of annual precipitation amounts in two selected stations in the Czech Republic (1961–2019), with regression lines and equations of these lines.



Fig. 4. Distribution of increase and decrease in annual precipitation amount in the Czech Republic (1961–2019). The stations used in Fig. 2 are marked by a bigger point with a boundary of another color.

Despite of these high slopes of the regression lines the real decrease or increase must not be necessarily significant. It is due to high fluctuation from year to year. The significance can be simply guessed when the whole period is divided into two parts (1961-1990 and 1991-1019) and the difference between average values of precipitation amounts in these parts (with respect standard deviations) is tested using the Student's t-test. For the stations given in Fig. 7 are the t-values 3.72 (Nedvězí) and 4.45 (Jirkov-Otvice). Hence, the change in these stations is statistically significant (the limit value for the 95% significance with 30 points in each part is t=2.04). Roughly said, the increase in precipitation totals at stations marked in Fig. 3 by a dark-blue point and the decrease at stations marked by a red point can be considered as statistically significant.

Despite the relatively small total area of the Czech Republic one can also see some pattern with regards to geographical longitude. Western half of the country shows mostly increase (with the exception of Elbe Lowland and its vicinity), whereas eastern half of the country shows either only very minor increase or, more frequently, a decrease in precipitation amount, with the exception of high-elevation regions of Jeseníky Mountains and Beskids. This means there is a significant negative correlation between precipitation amount and longitude (coefficient of -0.43). There is no significant between absolute average correlation annual precipitation amount and the trend (increase or decrease) (coefficient of just 0.06).

With regard to the need for water in the landscape, the occurrence of precipitation during the year is important. Their distribution into individual seasons for individual climatic areas is shown in Table 2. However, the differences among the regions are small, at most 1-2 percent more or less than the average for the entire Czech Republic.

Changes in seasonal precipitation amounts during 1961–2019 differ significantly from the course of annual precipitation amounts (Fig. 5). The individual maxima and minima do not correspond to each other and this can easily be explained. For example, an exceptionally dry or wet year might not be very dry or wet in each of its seasons. A dry spring can be (but not necessarily) compensated by a subsequent very wet summer or autumn. In fact even many weather sayings suggest that an exceptionally dry or wet season usually does not continue in the subsequent months. Different is also the long-term precipitation trend in the individual seasons (Fig. 5).

In the spring, precipitation totals fall slightly, which can be unpleasant for agricultural crops with a larger decline. The same applies to differences between regions in the case of seasonal precipitation as for year-round precipitation: greater growth is observed in the west, less growth or decline in the east, this also applies to individual stations. In the spring, when a nationwide decline is observed, precipitation totals increase only at a few stations in the border mountains.

| Region                       | Spring | Summer | Autumn | Winter |
|------------------------------|--------|--------|--------|--------|
| Czech Republic               | 23.2   | 36.4   | 22.0   | 18.4   |
| Sub-Ore Mountains Lowland    | 22.2   | 33.2   | 23.1   | 21.5   |
| Western and Southern Bohemia | 23.9   | 38.5   | 21.0   | 16.6   |
| Central Bohemia              | 23.9   | 39.1   | 21.0   | 16.0   |
| Eastern Bohemia              | 22.2   | 33.4   | 22.5   | 21.9   |
| Bohemian-Moravian Highland   | 23.4   | 36.2   | 21.4   | 19.0   |
| South Moravia                | 23.6   | 37.4   | 22.6   | 16.4   |
| North Moravia                | 23.8   | 36.9   | 22.2   | 17.1   |

Table 2.Proportion of seasonal precipitation amount from the annual total grouped<br/>by different regions [%]



*Fig. 5.* Course of seasonal precipitation amounts in the Czech Republic (1961–2019). *Figure shows approximate regression line in the same color.* 

The season with highest precipitation amount is summer (Jun-Aug), on average 36.4% of annual total. This value differs only very slightly in the individual regions. Relatively wettest summers are in central Bohemia (39.1%), relatively driest in Sub-Ore-Mountains Lowland (33.2%). The differences for the individual stations, however, are much more profound. Highest ratio of precipitation in summer is observed in Český Krumlov (44.6%), absolute highest was the summer of 1997 in Vítkov in Odra Hills (63.3%). In contrast, the long-term lowest ratio of summer precipitation is at the station Vrchlabí (25.5%), record low was the summer of 1983 at the station Rychorská bouda (8.6%), both in Giant Mountains. Percentage of summer precipitation amount also fluctuates from year to year (Fig. 6). Overall, driest summer was the one in 1962, when only 23.9% of the annual total precipitation amount was observed. On average, the highest summer precipitation ratio was in

1966 and 2011 (47.3%). Long-term change is negligible, based on the regression line the ratio of summer precipitation increased from 36.1% to 37.5%. There is also no periodicity.

The amount of precipitation in the summer does not change much, the curve shows a very small, statistically insignificant decrease. It should, however, be emphasized that there is a high variability in the summer precipitation. This is due to the occurrence of intense thunderstorms. Because they are limited to a certain place, they will not show as much in the overall average as might be expected. In the summer, when growth is higher nationwide, there are more stations in Western Bohemia with more significant growth, while there are fewer stations with a decline and they are concentrated mainly in the Moravian lowlands (Fig. 6). This Figure is prepared by the same way as Fig. 4 and the same statistical significance is valid too. In comparison with



Fig. 6. Distribution of growth and decrease of summer precipitation totals on the territory of the Czech Republic in the period 1961–2019. The stations used in Fig. 2 are marked by a bigger point with a boundary of another color.



*Fig. 7.* Average monthly precipitation in the Czech Republic for four 30-year periods. In the recent period it is only 29 years (1991–2019).

annual data, the number of stations with big increase or decrease of summer precipitation totals (blue or red circles) is much lesser.

Just as the course of precipitation differs in individual seasons, the course also differs in individual months, even within the same season, but with the proviso that the three-month average must give the course shown in Fig. 4. The course of precipitation totals during the year for the observed 59 years is shown in Fig. 7 for four 30-year overlapping periods (in the last period, however, it is only 29 years).

It is surprising how the course of monthly precipitation totals during the year in the following 30-years periods differ from the first one (1961–1990). It is worth noting the gradual shift of the main summer maximum, when in the first period it was in June, over time it moved to July. This shift certainly has an impact on the emergence of drought in early summer. There are also some small changes in the spring and autumn: a small increase in March followed by a small decrease in April, and a small increase in October followed by a small decrease in November and perhaps in December. Due to the fact that precipitation amount in spring and autumn are much lower than those in summer, the meaning of the above mentioned changes is very small.

# Conclusion

Annual precipitation amounts in the Czech Republic during the period from 1961 to 2019 show a negligible long-term change, i.e., no significant decrease or increase can be taken into account. Moreover, there are large differences of annual and seasonal totals among the individual years. In general, the highest total precipitation is in summer, the lowest in winter.

In the individual seasons the long-term change of precipitation totals are a little different. In the spring, there is a small decreasing trend in precipitation amount. This means that there can be water insufficiency at the beginning of the growing season, particularly in regions where the precipitation amounts are relatively low. Though in the summer a small increase appears (but less than the spring decrease), farmers and gardeners feel the continuing water deficit. Precipitation in the autumn and winter have lesser importance from the perspective of growing season, but are of major importance from the hydrological perspective as they saturate the soil profiles and subsequently ground waters. There are also differences in the regional precipitation amounts a rather increase in the western regions and a rather decrease in the eastern regions, particularly in lowlands. Due to the short period of observation used in this study and considerable fluctuations from year to year it is not possible to declare any prediction for the next decades. Nevertheless, the decrease of precipitation amounts in some regions, though with a low statistical significance, should not be neglected. Of course, there are many factors causing the drought in the last years, and precipitation totals are only one of them. But if the decrease of precipitation amounts would continue, and it is not excluded, this factor would be more and more

important. And because the precipitations are the only source of water for our territory, it is necessary to pay great attention to their measurement and evaluation, and also to modeling their occurrence in the coming years.

## Acknowledgement

The paper was prepared with the support of the project of the Technology Agency of the Czech Republic "Revitalization of agricultural land in areas of the Czech Republic threatened by drought "(TH02030073) and project "Innovation of the Evaluated Soil-Ecological Units (BPEJ) for state administration needs", QK1920280.

## References

- Bhatia, N., Singh, V. P., Lee, K. (2019): Variability of extreme precipitation over Texas and its relation with climatic cycles. Theor Appl Climatol 138, 449–467. https:// doi.org/10.1007/s00704-019-02840-w
- Guderle, M., Hildebrandt, A. (2015): Using measured soil water contents to estimate evapotranspiration and root water uptake profiles – A comparative study. Hydrology & Earth System Sciences Discussions, 11, 10859–10902.
- Jiang, R., Gan, T. Y., Xie, J. et al. (2017): Historical and potential changes of precipitation and temperature of Alberta subjected to climate change impact: 1900–2100. Theor Appl Climatol 127, 725–739. https://doi.org/ 10.1007/s00704-015-1664-y
- Kożuchowski, K., Marciniak, K. (1990): Tendencje zmian temperatury i opadów w Europie śródkowej w stuleciu 1881–1980. Acta universitatis Nicolai Copernici, Geografia, XXII, zesz. 73, 22–43
- Labudová, L., Šťastný, P., Trizna, M. (2013): The North Atlantic Oscillation and winter precipitation totals in Slovakia. Moravian Geographical Reports, Vol. 21, No. 4, p. 38–49, DOI: 10.2478/mgr-2013-0019.
- Novák, V. (1995): Vyparovanie vody v prírode a metódy jeho určovania. Bratislava: SAV, 260 s.
- Portal ČHMÚ http://portal.chmi.cz/historicka-data/pocasi/ zakladni-informace
- Räisänen, J., Hansson, U., Ullerstig, A., Döscher, R., Graham,
  L. P., Jones, C., Meier, H. E. M., Samuelsson, P., Willén,
  U. (2004): European climate in late twenty first century: regional simulations with two driving global models and two forcing scenarios. Climate dynamics 27, 13–31.
- Rožnovský, J. et. al. (2012): Agroklimatologická studie o výskytu sucha na území ČR v roce 2012 a za období srpen 2011 až srpen 2012. Zpráva pro Výzkumný ústav meliorací a ochrany půdy. Český hydrometeorologický ústav, pobočka Brno, 67 s.
- Rožnovský J. (2020): Projekce změny klimatu v oběhu vody v krajině České republiky. In: Rožnovský, J. a Litschmann, T. (eds). Sborník abstraktů z mezinárodní konference "Hospodaření s vodou v krajině", Třeboň 9.– 10. 9. 2020. Praha: Český hydrometeorologický ústav, s. 21. ISBN 978-80-7653-002-7.
- Střeštík, J., Rožnovský, J., Štěpánek, P., Zahradníček, P. (2014a): Increase of annual and seasonal air temperatures in the Czech Republic during 1961–2010. In: J. Rožnovský a T. Litschmann eds. Mendel and Bioclimatology. Conference proceedings, Brno, [CD-ROM]. Brno: 2014. ISBN 978-80-210-6983-1.
- Střeštík J., Rožnovský, J., Štěpánek P., Zahradníček, P. (2014b): Změna ročních a sezonních srážkových úhrnů

v České republice v letech 1961–2012. In: Extrémy oběhu vody v krajině, Mikulov. (CD-ROM).

- Střeštík, J. (2013): The change of precipitation totals in different European localities during 1900–2000. Proceedings of the international conference "Environmental changes and adaptation strategies", Eds. Šiška, Nejedlík, Hájková and Kožnarová, Skalica.
- Štěpánek, P., Zahradníček, P., Farda, A. (2013): Experiences with data quality control and homogenization of daily records of various meteorological elements in the Czech Republic in the period 1961–2010. Idöjárás 117: 123–141,
- Štěpánek, P., Zahradníček, P., Brázdil, R., Tolasz, R. (2011): Metodologie kontroly a homogenizace časových řad v klimatologii. Praha. 118 s. ISBN 978-80-86690-97-1.
- Tolasz, R. et al. (2007): Atlas podnebí Česka. Český hydrometeorologický ústav, Univerzita Palackého v Olomouci, 255 s. ISBN 978-80-86690-26-1 (CHMI), 978-80-244-1626-7 (UP).
- Zahradníček, P., Brázdil, R., Štěpánek, P., Trnka, M. (2020): Reflections of global warming in trends of temperature characteristics in the Czech Republic, 1961–2019. In: J Climatol.; 1–19. https://doi.org/10.1002/joc.6791

RNDr. Ing. Jaroslav Rožnovský, CSc. (\*corresponding author, e-mail: jaroslav.roznovsky@chmi.cz) Mgr. Petr Štěpánek, Ph.D. Mgr. Pavel Zahradníček, Ph.D. Český hydrometeorologický ústav Kroftova 43, 616 67 Brno Czech Republic

RNDr. Ing. Jaroslav Rožnovský, CSc. RNDr. Jaroslav Střeštík, CSc. Mendelova univerzita v Brně Zemědělská 1, 613 00 Brno Czech Republic roznov@mendelu.cz