PRACE GEOGRAFICZNE, zeszyt 107

Instytut Geografii UJ
Kraków 2000

Rudolf Brázdil, Petr Štěpánek, Vít Květoň

AIR TEMPERATURE FLUCTUATION IN THE CZECH REPUBLIC IN THE PERIOD 1961–1999

Abstract: For 95 meteorological stations relative homogeneity of monthly series of air temperature is tested in the period 1961-1999. From 93 homogenised series mean temperature series for the Czech Republic is calculated by the method of arithmetic mean and by the method of grids. It exhibits statistically significant rising linear trends for January, May, July, August, seasons (with the exception of autumn) and the year. The fluctuation of the Czech temperature series is compared to the series of the Northern Hemisphere. The effect of possible forcing (solar factor, volcanic activity, equivalent CO_2, NAOI) on its fluctuation is evaluated by means of the model of multivariate linear regression.

Key words: air temperature, homogeneity, fluctuation, trend, multivariate linear regression, Czech Republic.

1. Introduction

The fluctuations of air temperature are considered the most marked expression of present changes in the climatic system which are both the reflection of natural forcing (such as the solar factor, volcanic activity, interaction ocean-atmosphere) and also anthropogenic effect (such as the production of greenhouse gases and aerosols, ozone depletion) (Houghton et al. 1996). In the Czech Republic temperature fluctuations have been studied for selected secular stations (e.g. Novotný 1995; Brázdil, Štěpánek 1998; Brázdil et al. 1999) as well as for mean series (e.g. Brázdil et al. 1994; Brázdil, Macková 1998), the effect of forcing being studied only exceptionally (e.g. Smělý 1993; Brázdil et al. 1999). The present paper is devoted to the analysis of air temperature fluctuation in the Czech Republic in the period 1961-1999.

2. Homogenisation of Temperature Series

Mean monthly air temperatures of 95 weather stations from the data base of the Czech Hydrometeorological Institute for the period 1961-1999 (Fig. 1) were the basis

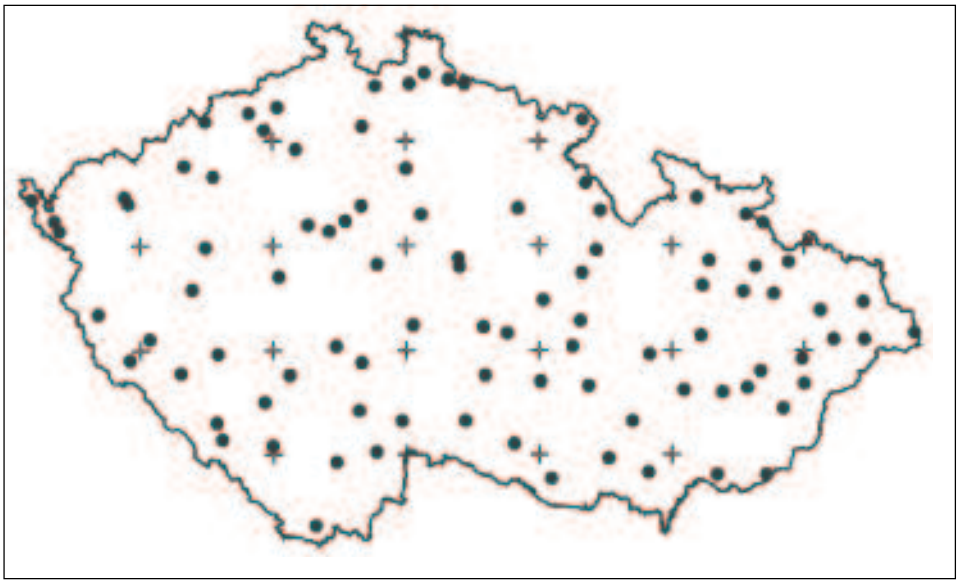

Fig. 1. Weather stations (circles) and grids (crosses) used for the calculation of the mean temperature series of the Czech Republic.

for the analysis of temperature patterns of the Czech Republic. They were tested for relative homogeneity according to the Standard Normal Homogeneity Test (SNHT - Alexandersson 1986) and according to the bivariate test (BT - Maronna, Yohai 1978) by means of the software AnClim (Štěpánek 2000). Arithmetic mean of the data of all stations was used as a reference homogeneous series. The results of the two tests differ in only a few cases. At the significance level $\alpha = 0.05$ - out of 1140 analysed months in the individual stations - inhomogeneity was found in 31% (SNHT) or 33% (BT) of cases, out of 475 analysed seasons and years in 50 and 51% of cases, respectively. For the homogenisation only those temperature series were selected when a demonstrable change at the station according to metadata (such as its relocation) was related to the found year of statistically significant inhomogeneity. Since, however, metadata often do not include all changes taking place at the station, the homogenisation was carried out also in the case when it was the so-called "undoubted" inhomogeneity which, although not following from metadata, it is unambiguously indicated by the results of tests and it is physically justified (see Brázdil, Štěpánek 1998). Despite that, in the employed time series there still remained 20% (SNHT) or 21.5% (BT) uncorrected months, in the case of seasonal or annual means it corresponds to 38 and 40%, respectively, of uncorrected seasons and years. Despite the seemingly high share of uncorrected inhomogeneities the mechanical homogenisation of temperature series cannot be accepted strictly according to the results of the given test (mostly at very high values of correlation coefficients). If such homogenisation

were performed, the mean values would differ from the values of the mean temperature series of the Czech Republic (see Chapter 3) in the individual years of the period 1961-1999 maximum by 0.09°C in April and September, in the other months, however, mostly by 0.05°C. From that it follows that the mean temperature series for the Czech Republic will be affected by possible uncorrected inhomogeneities to only a negligible extent.

3. Mean Temperature Series for the Czech Republic

From partly homogenised temperature series of 93 stations (excluded station Prague-Klementinum with a strong expression of the urban heat island and station Světlá Hora whose observations appeared to be of lower quality) the series for the Czech Republic was calculated on the one hand by averaging data of all 93 stations, on the other hand by averaging temperatures in 21 grid points with the step of 1° of the longitude and 0.5° of the latitude. Temperatures in the grid points were calculated by the weighted mean from the data of stations within the radius of 50 km from the given grid with reciprocals of their distances as weights. Differences between the thus calculated mean series are negligible (thus, for mean annual temperatures they do not exceed 0.04°C in the individual years), so that further work was done with only the first series. Its fluctuation for the seasons and for the year follow from Fig. 2. Well perceptible, with the exception of autumn, is above all the warm period including the late 1980s and the 1990s, impaired only by the cold winter of 1995/96 and the spring of 1996. The variation of spring and winter temperatures is most conspicuously projected to the fluctuation of annual temperatures (correlation coefficient spring - year is 0.77, winter - year 0.70), the small effect on their swings having the autumn months (autumn - year 0.15). Statistically significant linear temperature trend (at the level of significance $\alpha = 0.05$) is exhibited, with the exception of autumn, by all seasons as well as the year (values of the trend see Fig. 2), from among the individual months only January (0.74°C/10 years), May (0.45°C/10 years), July (0.42°C/10 years) and August (0.49°C/10 years). For April, October and November, the same as for autumn, the linear trends are negative and statistically insignificant. The temperature series of the Czech Republic exhibits on the whole low correlation coefficients with the temperature series of the Northern Hemisphere (Jones 1994; Parker et al. 1995), for the year 0.40, for the seasons 0.44 (spring) - 0.10 (autumn) and for the months 0.51 (March) - 0.01 (December).

4. Forcing in the Temperature Series of the Czech Republic

For the evaluation of the effect of different factors on the fluctuation of air temperature in the Czech Republic values of sunspots SN (solar factor), stratospheric aerosol optical depth SAOD for the Northern Hemisphere (Sato et al. 1993) and Smithsonian volcanic index SVI (volcanic activity), index of North Atlantic Oscillation NAOI (interaction ocean-atmosphere) and the concentration of equivalent CO_2 ($eqCO_2$ - anthropogenic factor) were used. Correlations of these characteristics with the

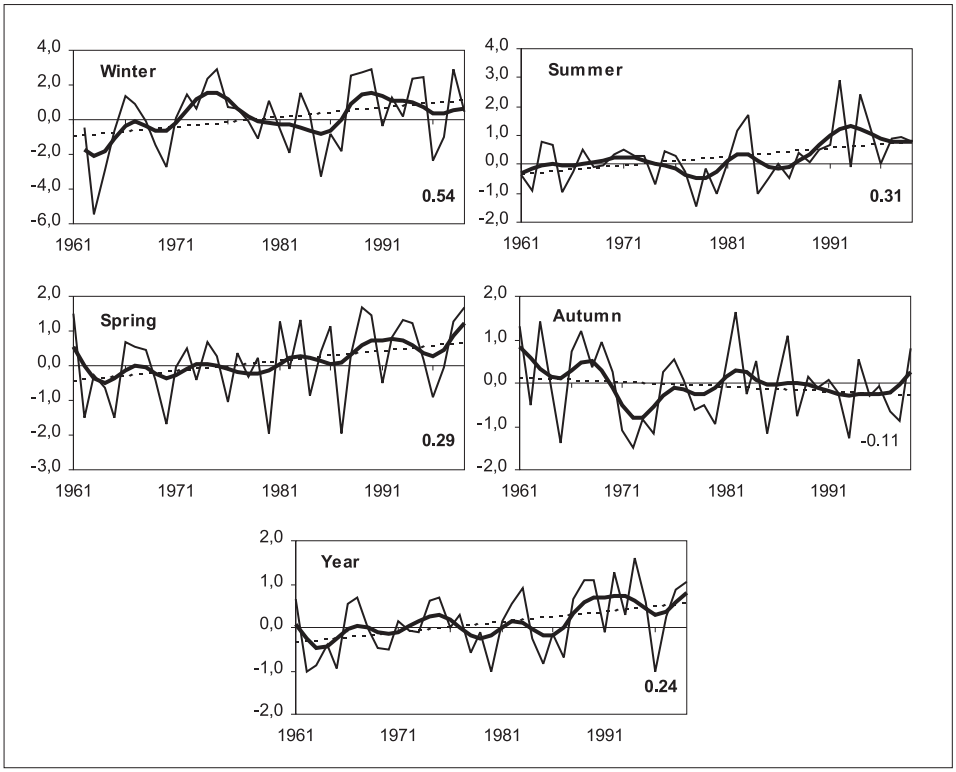

Fig. 2. Fluctuation of air temperature anomalies (°C; reference period 1961-1990) and the linear trend (dotted line, numbers in the graph - values of the trend in °C/10 years) for the seasons and the year in the Czech Republic in the period 1961-1999. Smoothed by the Gauss filter for 10 items.

temperature series are mostly very low and statistically insignificant. An exception is only the connection with NAOI in the winter months (correlation coefficient 0.75 for January and 0.68 for winter) and with SAOD in summer (0.48). For the expression of the possible temperature signal conditioned by the above factors the method of multivariate linear regression was used. In accord with Schönwiese (1989), in the calculation the shift of values of SVI by five years and that of $eqCO_2$ by 20 years was employed. The model of the multivariate linear regression applied for the series of annual and seasonal temperatures of the Czech Republic clarifies on the whole a small part of the total variance of the series (Fig. 3), particularly for spring and autumn. In the case of annual temperatures the model clarifies 52.5% of the value of variance, for winter 48.0% and for summer 44.7%. The estimated maximum temperature signal makes for the annual series of the Czech Republic in the period 1961-1999 -0.8°C for

SVI, 0.8°C for $eqCO_2$ and 1.6°C for NAOI (insignificant for the model is the characteristic SN with the signal of 0.1°C). For winter temperatures only the characteristic NAOI is significant (signal 4.7°C), in summer SAOD (1.8°C) and $eqCO_2$ (1.3°C). The above results express well the variable effect of circulation and radiation factors on the formation of temperature patterns in the Czech Republic and their temporal changes. On the other hand the dependence of the results on the choice of the individual characteristics and the limitations of the model employed is evident.

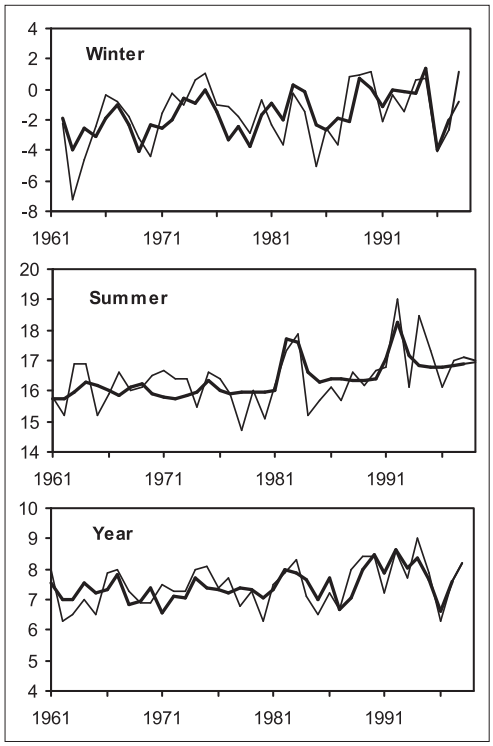

Fig. 3. Approximation of air temperature series (°C) in the Czech Republic by the model of multivariate linear regression (thick line) in the period 1961-1999.

5. Conclusion

The performed analysis gives an idea of the fluctuation of air temperature in the Czech Republic since 1961 and of the possible effect of different factors on the observed temperature swings. The established trends are in accordance with the knowledge of the process of global warming and the occurrence of very warm 1990s. A further improvement of the results is bound to the completion of metadata of the processed stations and the use of further methods for the detection of the temperature signal (see e.g. Walter et al. 1998). An open question remains to what extent is being reflected or will be reflected the transition to automatic measurements which in the Czech Republic has been gradually implemented since 1997.

Acknowledgement

The work of R. Brázdil and P. Štěpánek has been supported from the financial sources of the Grant Agency of the Czech Republic for the solution of grant No. 205/98/1542.

References

Alexandersson A., 1986, *A Homogeneity Test Applied to Precipitation Data*, Journal of Climatology, 6, 6, 661-675.

Brázdil R., Machů R., Budíková M., 1994, *Temporal and Spatial Changes in Maxima and Minima of Air Temperature in the Czech Republic in the Period of 1951-1993*, [in:] *Contemporary Climatology*, Brázdil, R., Kolář, M. (eds.), Brno, 93-102.

Brázdil R., Macková J., 1998, *Řada průměrných ročních teplot vzduchu pro Českou republiku v období 1828-1995*, Meteorologické zprávy, 51, 1, 17-21.

Brázdil R., Štekl J. (eds.), 1999, *Klimatické poměry Milešovky*, Academia, Praha.

Brázdil R., Štěpánek P., 1998, *Kolísání teploty vzduchu v Brně v období 1891-1995*, Geografie – Sborník České geografické společnosti, 103, 1, 13-30.

Houghton J.T., Meira Filho L.G., Callander B.A., Harris N., Kattenberg A., Maskell K. (eds.), 1996, *Climate Change 1995. The Science of Climate Change*, University Press, Cambridge.

Jones P.D., 1994, *Hemispheric Surface Air Temperature Variations: A Reanalysis and an Update to 1993*, Journal of Climate, 7, 1794-1802.

Maronna R., Yohai V.J., 1978, *A Bivariate Test for the Detection of a Systematic Change in Mean*, Journal of American Statistical Association, 73, 363, 640-645.

Novotný J., 1995, *Zpracování teplotních řad na horské stanici Milešovka*, Meteorologické zprávy, 48, 5, 145-149.

Parker D.E., Folland C.K., Jackson M., 1995, *Marine Surface Temperature: Observed Variations and Data Requirements*, Climatic Change, 31, 559-600.

Sato M., Hansen J.E., McCormick M.P., Pollack J.B., 1993, *Stratospheric Aerosol Optical Depth, 1850-1990*, Journal of Geophysical Research, 98, 22987-22994.

Schönwiese C.-D., 1989, *Multivariate Statistical Assessment of Greenhouse-Induced Climatic Change and Comparison with the Results from General Circulation Models*, [in:] *DOE Workshop on „Greenhouse-Gas-Induced Climatic Change: A Critical Appraisal of Simulations and Observations"*, Amherst.

Smělý V., 1993, *Jak se jeví vliv sluneční činnosti v pražské teplotní řadě*, Meteorologické zprávy, 46, 2, 54-58.

Štěpánek P., 2000, *AnClim – Software for Homogenisation and Statistical Analysis of Climatological Time Series*, Department of Geography, Masaryk University, Brno.

Walter A., Denhard M., Schönwiese C.-D., 1998, *Simulation of Global and Hemispheric Temperature Variations and Signal Detection Studies Using Neural Networks*, Meteorologische Zeitschrift, N.F. 7, 4, 171-180.

Rudolf Brázdil, Petr Štěpánek
Department of Geography
Masaryk University
Brno
Czech Republic

Vít Květoň
Czech Hydrometeorological Institute
Prague
Czech Republic