Adv. Sci. Res., 8, 87–91, 2012
www.adv-sci-res.net/8/87/2012/
doi:10.5194/asr-8-87-2012

Advances in Science & Research
Open Access Proceedings

11th EMS Annual Meeting and 10th European Conference on Applications of Meteorology (ECAM) 2011

Has the frequency or intensity of hot weather events changed in Poland since 1950?

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Received: 15 January 2012 – Revised: 2 April 2012 – Accepted: 10 April 2012 – Published: 26 April 2012

Abstract. Various indices of hot weather frequency and intensity were analysed in the area of Poland in the period between 1951 and 2006. An increase of majority of them was shown in the whole year and all summer months but September, when significant decrease in all indices was apparent. The correlation of selected hot weather indices and precipitation totals in a month of hot weather event and the preceding months were also calculated to check if prolonged dry weather can constitute a forcing factor for hot event creation. Because significant correlations appear mainly in the cases when precipitation is for the same month as the hot weather index, it seems that in Poland the presence of high pressure systems is a more important factor of hot event creation than dry weather.

1 Introduction

There is increasing evidence that the frequency and intensity of extreme weather events have changed considerably since the middle of the twentieth century (Trenberth et al., 2007). Moberg and Jones (2005) have shown that all tails of minimum and maximum temperature distribution (defined on the percentile basis) have increased since the beginning of the twentieth century. The increase in upper tail of daily maximum and minimum temperatures in summer relates to the rise in frequency and intensity of hot events. Extreme hot events exert strong social, economic and environmental impacts. They can cause the death of people, forest fires and energy losses. Besides climate warming, hot events are believed to become more frequent, intense and prolonged (Beniston, 2004; Schär et al., 2004). So it is important to find a mechanism triggering their occurrence and/or to link it to atmospheric circulation. Della-Marta et al. (2007) have shown the relationship of heat waves over western Europe to large scale forcings and the anomalous high pressure systems over Scandinavia and central western Europe. Garcia-Herrera et al. (2010) connected occurrence of prolonged hot weather with quasi-stationary anticyclonic circulation anomalies. It corroborates the results of Wibig et al. (2009) that heat waves in Poland are accompanied by higher than normal pressure over central and eastern Europe, with the strongest positive pressure anomalies located just in the east of Poland. Some authors have found that heat wave occurrence can be influenced by precipitation deficit and preexisting dry soil conditions (Della-Marta et al., 2007; Fischer et al., 2007). The aim of this paper is to check if prolonged dry weather can constitute a forcing factor for hot event creation in Poland.

2 Data and methods

Daily maximum temperatures from 21 stations from Poland (Fig. 1) from the period 1951–2006 were used for describing the hot event frequency and intensity. Monthly precipitation totals from the same stations and period were used for analysis of the influence of drought events on hot event development. The homogeneity of records of mean monthly maximum temperature and monthly precipitation totals were tested with Standard Normal Homogeneity Test by Alexandersson (1986).

The hot event frequency was assessed by means of monthly and annual number of days with $T_{max} > 25\,^{\circ}C$ and $T_{max} > 30\,^{\circ}C$. The hot event intensity was characterized by monthly and annual sum of T_{max} exceeding 25 °C and 30 °C as well as by the annual number of days with T_{max} above

Figure 1. Location of IMWM stations with data on monthly precipitation totals and daily maximum temperature (1951–2006).

95 and 99 percentiles of $T_{\max}$ in the reference period 1961–1990, the longest spell of days with $T_{\max} > 30\,°C$ in the year and the highest sum of $T_{\max} > 30\,°C$ on all days within one such spell.

The trends of these indices were calculated using linear regression with parameters obtained with the least square method and statistical significance tested by Student t-test. Impact of droughts on hot weather frequency was tested correlating precipitation totals in one, two and three months preceding the specific month with monthly number of days with $T_{\max} > 25\,°C$ and $T_{\max} > 30\,°C$ and with monthly sum of degree-days exceeding 30 °C on this month.

3 Results

3.1 Hot weather occurrence and its long-term variability

In lowland Poland, days with $T_{\max} > 25\,°C$ occur mainly from May to September, but in extreme cases they can appear also in April and October. An example from Legnica is presented in Fig. 2, but similar pictures can be obtained for all analysed station, but a few located at the sea side or in the mountains. There are more than ten such days in July and August, 7–8 in June and about 3 in May and September. The number of degree-days exceeding 25 °C vary from 0 to about 150 during extremely warm months. Days with $T_{\max} > 30\,°C$ occur mainly in July and August, but they can happen also in May, June and September. There are about five such days in July and August and only about one in July. The number of degree-days exceeding 30 °C vary from 0 to about 50 during extremely hot months.

Since 1951, the number of days with $T_{\max} > 25\,°C$ has increased in Poland in the period 1951–2006. The increase was the strongest in August, when it was statistically significant at more than 70 % of analysed stations (Fig. 3). An increase was also observed in July, May and in the year as a whole. A decreasing trend at 16 stations out of 21, and significant at 7 stations, was observed in September. In the case of days with $T_{\max} > 30\,°C$ significant increasing trends were observed at more than 60 % of stations in July and about 30 % of stations in June. A significant decreasing trend was detected at about 45 % of stations in September. The number of degree-days exceeding 25 °C has increased significantly at more than 60 % of station in July and more than 50 % of stations in August. At the same time, the number of such days has decreased significantly at more than 50 % of stations in September. The number of degree-days exceeding 30 °C has increased significantly at almost 50 % of stations in July, at about 35 % of stations in June and about 20 % of stations in May and August. At the same, time the number of degree-days has decreased significantly at 35 % of stations in September.

An example of long-term course of the annual number of days with temperature exceeding 95 and 99 percentile for the reference period 1961–1990 is shown in Fig. 4. The increasing trend of both records is well seen. Statistically significant trends in both records were observed at more than 80 % of analysed stations.

Figure 5 presents an example of long-term course of the longest annual spell of consecutive days with $T_{\max} \geq 30\,°C$ and the most intensive such spell in degree-days. Graphs for other stations are similar. The maximum values in extremely hot years 1994 and 2006 are well seen. Positive linear trends characterise both records at the majority of stations, but because the distribution of data is far from normal, the significance of these results cannot be assessed using a simple t-Student test.

3.2 Relation of hot event occurrence to pre-existing precipitation deficit

To analyse the influence of prolonged drought on hot event occurrence, the precipitation totals in one, two or three months with monthly number of days with $T_{\max} > 25\,°C$ were calculated. In one version, the last month of precipitation data agrees with the month of hot event index (i.e. precipitation totals from March, April and May with the number of days with $T_{\max} > 25\,°C$ in May); in the second, the last month of precipitation data precedes the month of heat wave index (i.e. precipitation totals from March, April and May with the number of days with $T_{\max} > 25\,°C$ in June). In the first case, significant correlations at more than 50 % of stations occurred in all cases (precipitation totals from one, two or three months) from June to September (Table 1). In the second case, only in September significant correlations appear at more than 30 % of stations. It means that the month with a hot event has to be simultaneously dry. Because the quasi-stationary high pressure system located over Poland or in its neighbourhood corresponds both to hot weather (Wibig

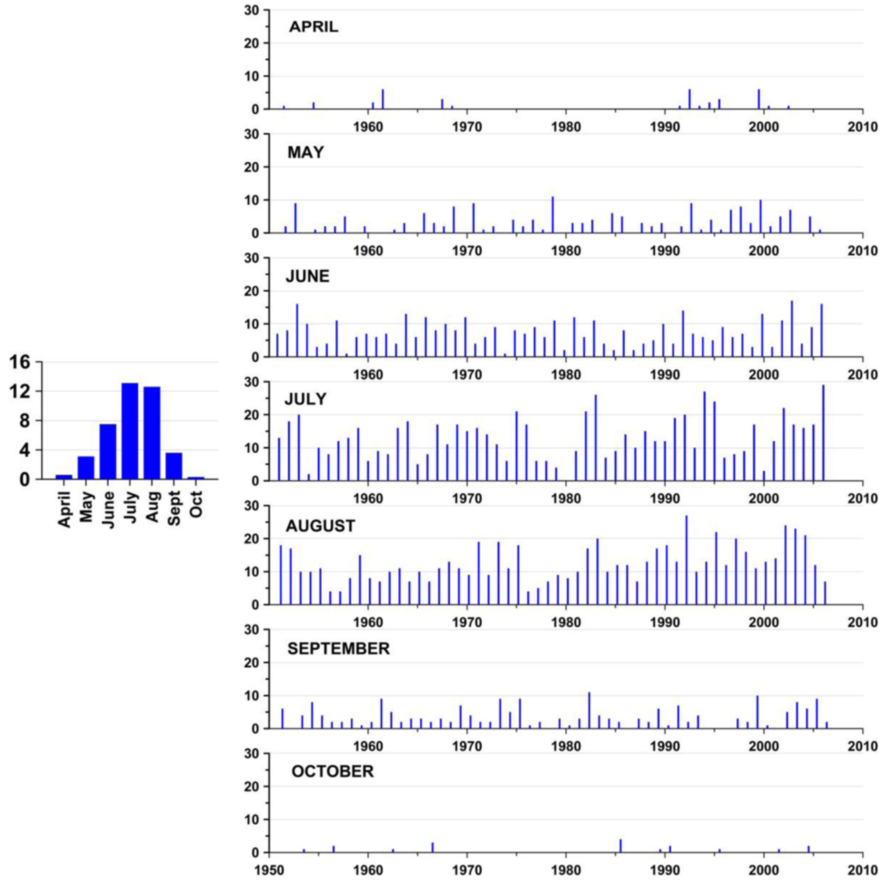

Figure 2. The intraannual distribution (left) and the long-term course of the number of days with $T_{max} > 25\,^{\circ}$C in the period 1951–2006 (right). An example from Legnica.

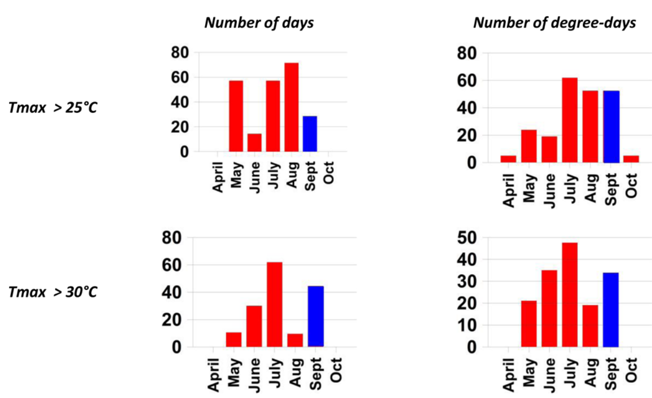

Figure 3. The percentage of stations with significant increasing (blue) and decreasing (red) trends.

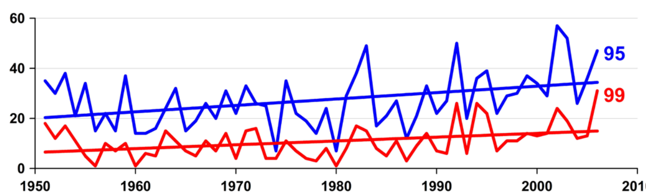

Figure 4. Number of days with maximum temperature exceeding 95 and 99 percentile according to the reference period 1961–1990 based on the example of Kalisz.

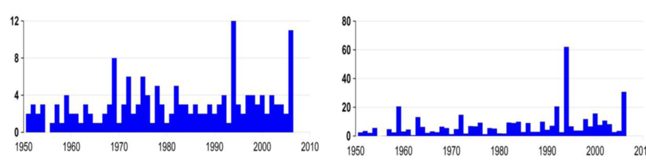

Figure 5. The longest annual spell of consecutive days with $T_{max} \geq 30\,^{\circ}$C (left) and the most intensive spell in degree-days (right), an example from Slubice.

et al., 2009) and lower than normal precipitation (Piotrowski, 2010) it appears that in Poland it is a much more important factor in creation of hot events than dry weather.

On persistent blocking high pressure system as a trigger of heat wave indicated also Beniston and Diaz (2004) for Switzerland, Xoplaki et al. (2003) for Greece and Carril et al. (2008) for the north-western Europe and Eurasia (2008). However according to some investigations dry soils in spring

Table 1. The number of stations with correlation coefficients between the precipitation totals and monthly number of days with $T_{max} > 25\,^{\circ}C$ significant at 5 % level.

	April	May	June	July	August	September	October
	last month of the period of precipitation total in line with that of the index						
1 month	1	1	14	21	15	17	1
2 months	1	2	14	20	17	19	0
3 months	1	1	11	18	15	17	0
	last month of the period of precipitation total precedes that of the index						
1 month	4	1	2	2	2	9	0
2 months	4	1	2	2	3	7	0
3 months	5	1	1	1	3	11	2

over over Mediterranean areas favor and maintain hot summers in this region (Vautard et al., 2007).

4 Summary

All analysed indices of hot event frequency and intensity have shown an increasing trend in July, August and the whole year, in some cases also in June. At the same time, all hot weather indices in September have decreased. An increase in hot event frequency and intensity is still insignificant in the eastern part of Poland.

There is a strong relation of hot weather occurrence with precipitation (dryness). This relation is significant when the periods of precipitation and hot event occurrence overlap. It means that a month with a higher than average number of hot days simultaneously has precipitation below average. A question arises: is it a direct effect of precipitation lack or of the fact that in summer high temperature and low precipitation occur when the quasi-stationary high pressure system is located over Poland or in its neighbourhood?

Acknowledgements. The author thanks the IMWM for kindly providing the data and has been funded by the project Nr. 0533/B/P01/2009/36 of MS&HE.

Edited by: I. Auer
Reviewed by: two anonymous referees

The publication of this article is sponsored by the European Meteorological Society.

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