Pol. J. Environ. Stud. Vol. 23, No. 1 (2014), 149-155

Original Research

Changes in Meteorological Conditions in a Polish City, 1848–2009

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Received: 22 April 2013
Accepted: 2 October 2013

Abstract

The main aim of this work was to determine the changes of meteorological conditions in Poznań, Poland, in the period 1848-2009. The onset of the analyzed period coincides with the launch of conducting instrumental meteorological measurements in Poznań. Professor Smosarski's analyses and data were taken into account for the examination of the period 1848-1922, while data from NOAA and the Meteorological Yearbooks were applied for the years 1960-2009. It has been concluded that the mean annual temperature for the period 1848-1922 was 0.9°C lower than for 1960-2009, while for 2000-09 it was as much as 1.9ºC higher. It also has been established that a period without ground frost incidences was prolonged and the frost season shortened. Koeppen's criterion was used to determine the frequency of the conditions leading to landscape stepping.

Keywords: Poznań, Smosarski, climate, weather

Introduction

Instrumental measurements of meteorological parameters in Polish territories were launched in the first half of the 19th century. In 1847 the Prussian Meteorological Institute was established, which led to creating a regular network of meteorological stations in the area of Poland. These stations were built in cities such as Bydgoszcz, Chojnice, Koszalin, and Poznań [1] in western Poland, where the landscape is very mosaic [2]. The station in Poznań started to operate in 1848, and since that time it has conducted the regular instrumental measurements of meteorological parameters [3]. The data obtained from the station became an important part of the research of Professor Władysław Smosarski, the first head of the Meteorology Department in the Agriculture and Forest Management Faculty of the university in Poznań. He was an author of many publications about climate in the regions of Wielkopolska, Silesia, and Pomerania. Smosarski described the period of 1848-1922, whereas this work attempts to point out the extent that meteorological conditions in Poznań have changed over the past 160 years.

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Material and Methods

Conditions for the years 1848-1922 were determined on the basis of the research conducted by Smosarski [1, 4-6], while the conditions for 1960–2009 were described on the basis of the data from NOAA (National Oceanic and Atmospheric Administration) [7] and Polish Meteorological Annuals [8]. Data quality was checked as recommended by the World Meteorological Organization (WMO) [9]. Mean daily air temperatures, maximum and minimum temperatures, and precipitation data were analyzed. The target was to find the changes in the length of the frost season, light frost incidence, and the period without light frost. The research employs Walter Lieth diagrams, which illustrate the changes in meteorological conditions in 1848-2009.

Climate Walter Lieth [10] diagrams created in the study indicate mean monthly temperatures and precipitation patterns for individual months. They cover the years 1848-1922, and 1960-2009 (Figs. 1 and 2). The second period was divided into five decades, which were also illustrated by means of Walter Lieth diagrams (Fig. 3A-E).

The subsequent part of the work presents daily courses of meteorological parameters such as mean temperature and maximum and minimum temperature (Figs. 9-12) values. These courses were determined on the basis of daily data using the kriging method [11]. Additionally, temperature courses were established on the basis of mean monthly temperatures. Daily mean values for the meteorological station in Poznań in 1848-1922 were used for the analysis [4]. Part of the data was derived from the Bulletin of International Meteorological Observations, while mean monthly values for the period of 1960-2009 were calculated on the basis of mean daily values determined from eight daily measurements.

The Koeppen criterion [12] was calculated for the years 1960-2009. The following formula was applied for this purpose:

$$R_1=2\ (t+14)$$

...where: t stands for mean annual temperature expressed in ºC. In this equation, when R_1 is higher than the yearly precipitation expressed in centimeters, then it is accepted that the phenomenon of landscape stepping occurs.

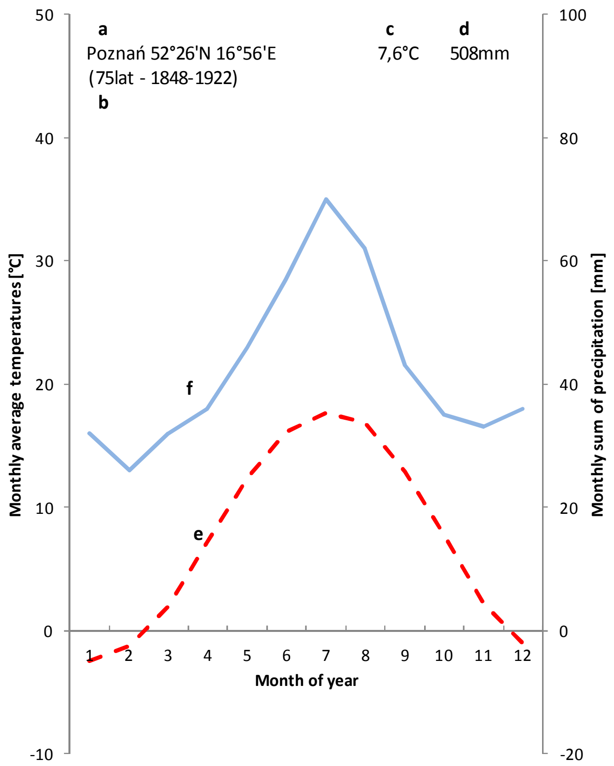

Fig. 1. Walter Lieth diagram for Poznań, 1848-1922.
a – name of the site, b – length of the observation period for temperature and precipitation, c and d – mean annual temperature and precipitation total, f – curve of mean monthly temperatures, e – curve of monthly precipitation.

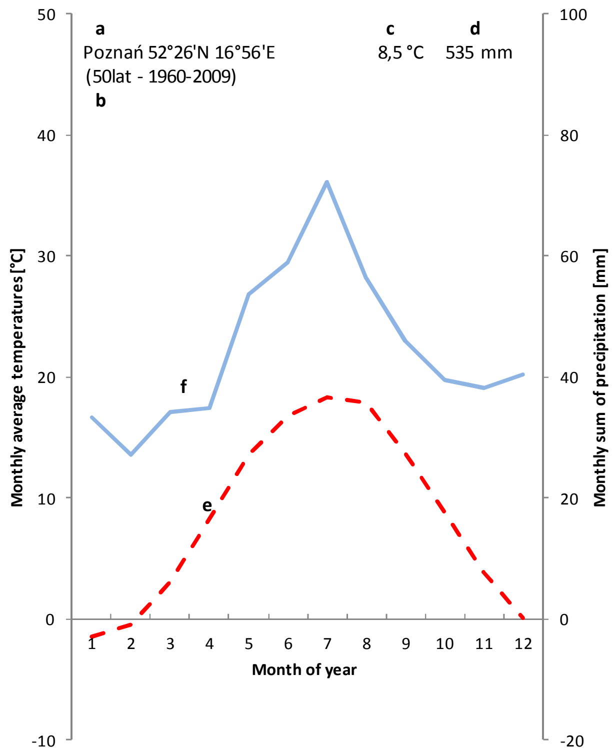

Fig. 2. Walter Lieth diagram for Poznań, 1960-2009.
a – name of the site, b – length of the observation period for temperature and precipitation, c and d – mean annual temperature and precipitation total, f – curve of mean monthly temperatures, e – curve of monthly precipitation.

Results and Discussion

The years 1848-1922 are characterized by the mean annual temperature of 7.6ºC and the mean precipitation of 508 mm (Fig. 1). Judging from the size of the gap between the line determining mean monthly temperatures and the one that presents the mean monthly precipitation pattern, this period can be described as humid [13]. Its extreme temperatures occur in July and December. Due to the scarcity of data from such a distant period, the values from the Climatic Table for Poznań and from Smosarski's research were applied [1, 4-6]. The data for the five decades of 1960-2009 were presented in Fig. 2. The mean temperature for 1960-2009 is 8.6ºC and it is 1ºC higher than for 1848-1922. Precipitation in the years 1960-2009 increased by 27 mm in comparison to the period of 1848-1922 and its annual mean was 535 mm.

Fig. 3 presents diagrams of decades in order to compare the conditions in the five decades of the years 1960-2009 with the period 1848-1922.

In the decade 1960-69 (Fig. 3A) the observed mean annual temperature was 0.5ºC higher than in the period of 1848-1922. For the next two decades mean temperature values were constant and 0.1ºC higher than for 1960-1969. The lowest annual precipitation in the second half of the 20th century was observed in the 1980s and its mean annual was 483 mm (Fig. 3C).

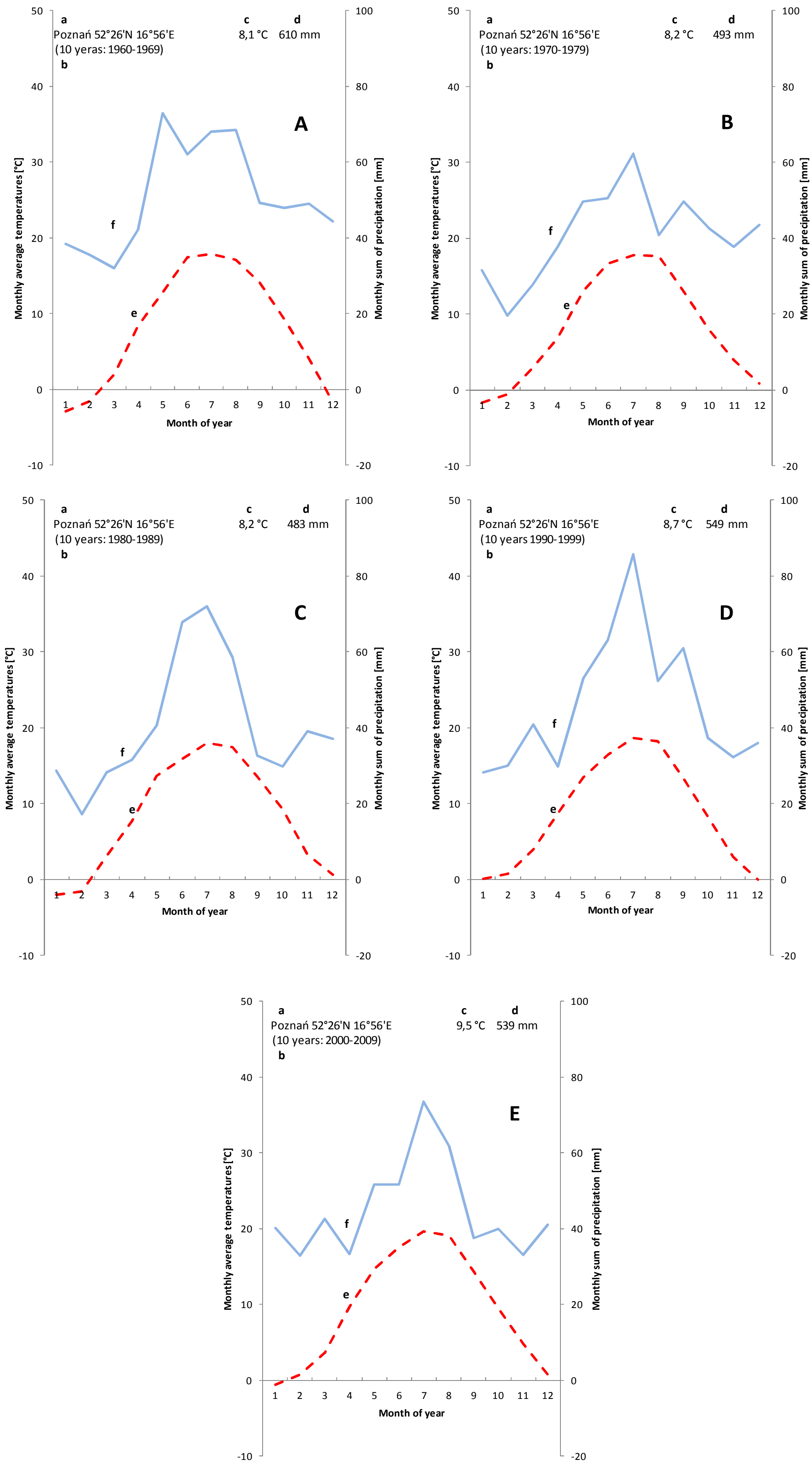

Fig. 3. Walter Lieth diagram for Poznań, 1960-69 (A), 1970-79 (B), 1980-89 (C), 1990-99 (D), and 2000-09 (E).
a – name of the site, b – length of the observation period for temperature and precipitation, c and d – mean annual temperature and precipitation total, f – curve of mean monthly temperatures, e – curve of monthly precipitation.

In the next decade, 1990-99 (Fig. 3D), the temperature was 0.6ºC higher in comparison to the decade of 1960-69 and increased by 1.1ºC in comparison to 1848-1922. The highest mean annual temperature occurred in 2000-09 (Fig. 3E). Then it was 1.9ºC higher than in the 19th and at the beginning of the 20th centuries. The Walter Lieth diagrams for the decade indicate that during the last 50 years humidity has decreased significantly in spring and autumn. Additionally, a rapid increase in the temperature in Poznań was recorded when comparing the decade of 2000-09 with both periods of 1848-1922 and 1960-99.

Moreover, the duration of periods with temperatures above and below 0ºC has been analyzed (Fig. 4).

In 1960-2009 (Fig. 4) the frost season, i.e. when the mean daily temperature was below zero for the whole day, started on average on 20th December and finished on 6th February. Thus, it lasted 49 days. In contrast, in 1848-1922 the frost season was annually on average 30 days longer (Fig. 5). The work by Smosarski [1] indicates that in the years 1848-1922 in Poznań it lasted 79 days on average. The next period, i.e. the incidence of light frost, occurs

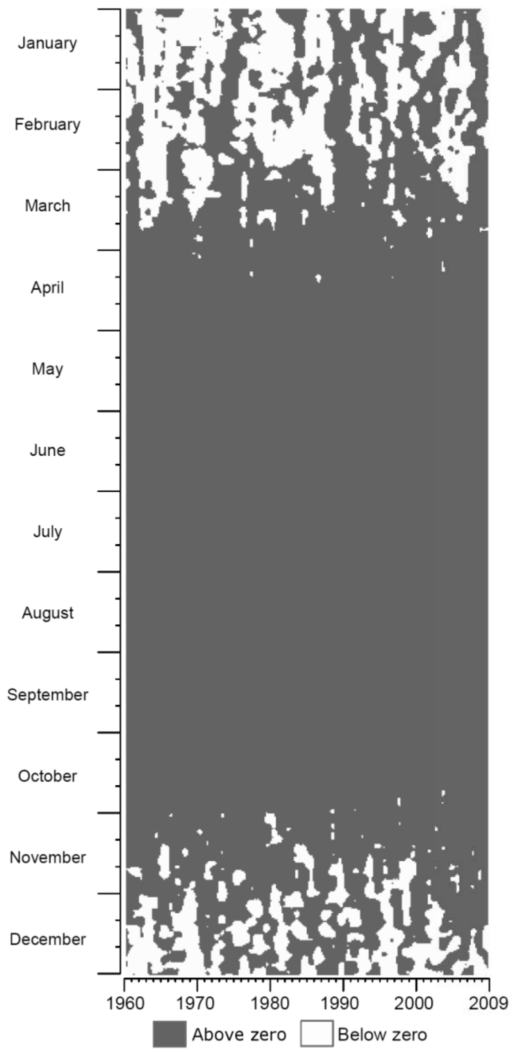

Fig. 4. The periods of incidence of temperature below and above zero in Poznań in 1960-2009.

between the frost season and the time when the mean daily temperature remains above zero throughout the day. In 1960-2009 (Fig. 4) the period of light frost incidence lasted annually for 77 days on average, whereas in 1848-1922 it was annually 23 days longer on average and lasted for 100 days (Fig. 5). The third analyzed period was the one without light frost. In 1960-2009 (Fig. 10) it lasted 240 days on average. It was annually prolonged by 53 days on average in comparison to the years 1848-1922, when it lasted only 187 days (Fig. 5). Probably the last period (without light frost) will be much longer in the next half of the century than nowadays [14].

The subsequent part of the work analyzed the courses of daily temperature values in the period 1960-2009.

This analysis (Fig. 6) demonstrates a decline in the incidence of mean daily temperatures below 10ºC in the winter months as well as increasingly higher mean daily temperatures in the summer months. A significant increase of these temperatures in spring and autumn can be observed. The spring begins earlier and is much shorter than at the beginning of the period analyzed. Summer starts earlier and lasts longer. Autumn starts later and finishes later but it is also shorter than at the beginning of the 1960s.

When analyzing maximum daily temperature values in Poznań in 1960-2009 (Fig. 7) it is easy to notice changes occurring in the fourth and the fifth decades of the described period, when there are significantly more warm days than in the first two decades.

The course of minimum daily temperatures in Poznań (Fig. 8) also demonstrates an increase in temperature values. The increase in temperatures in the summer period is prominent here as well as more frequent occurrences of above-zero temperatures in winter. Comparing the graph illustrating maximum temperatures with the one presenting minimum temperatures, it can be observed that maximum temperatures rose faster in the course of time than the minimum ones. The results of the change are as follows: a progressive disappearance of the seasons of the year and a significantly shorter duration of spring and autumn to the advantage of prolonging summer. It leads to the process of landscape stepping. This is noticeable particularly in the region of Wielkopolska, since it is an area where the water deficit is one of the most severe in the whole country [15-18]. When calculating the Koeppen criterion for the period of 1960-2009, the occurrence of landscape stepping was identified during 12 years (Fig. 9).

Figs. 10-12 present the courses of mean monthly temperature values in Poznań in 1960-2009.

The courses of mean temperatures (Fig. 10) as well as maximum (Fig. 11) and minimum temperature values (Fig. 12) indicate the increase in the period of 1960-2009. It is particularly prominent in July in the years 2000-09 as well as in January and February already since 1990 to 2009.

Fig. 13 presents the course of mean annual temperatures for 1960-2009. Their values increased by 0.334ºC on average during 10 years. For maximum and minimal annual temperatures the increase was evaluated at the

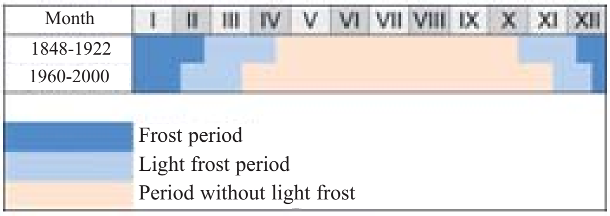

Fig. 5. Comparison of the duration of the frost season, incidence of ground frost, and the period without ground frost between the years 1848-1922 and 1960-2009.

level of 0.384ºC and 0.194ºC, respectively, during 10 years. Thus, in 1960-2009 the mean annual temperature grew by 1.7ºC, whereas the global mean temperatures over land and ocean increased by 0.5ºC [19], the maximum temperature by 1.9ºC, whereas the minimum temperature by only 1.0ºC. Global warming can be observed almost everywhere [20, 21], but the force of this effect depends on type of surface and latitude [22]. The explanation for nearly four times higher value is that temperatures over land have warmed faster than over oceans, and at higher northern latitudes temperatures increased faster.

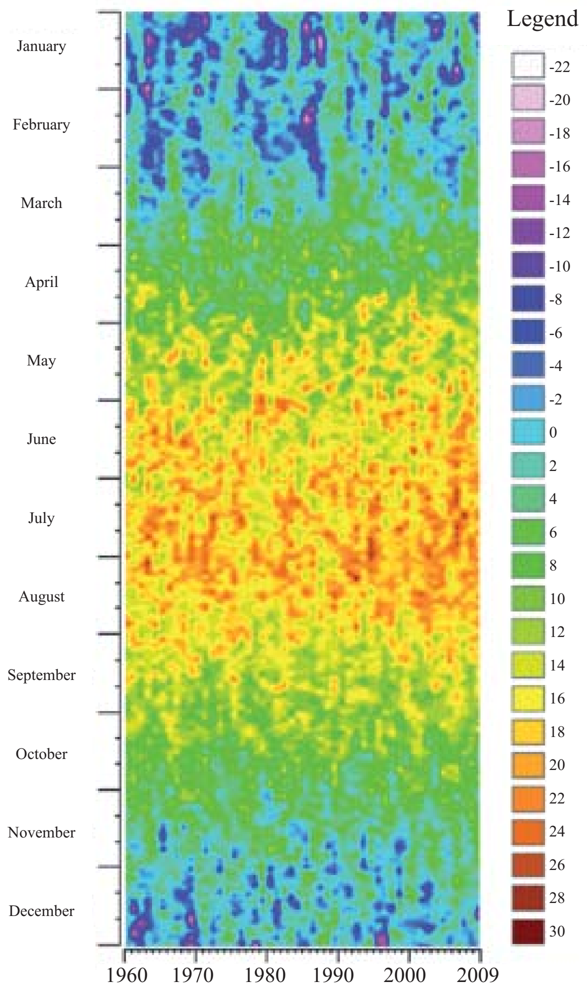

Fig. 6. Mean daily temperature in Poznań expressed in °C, 1960-2009.

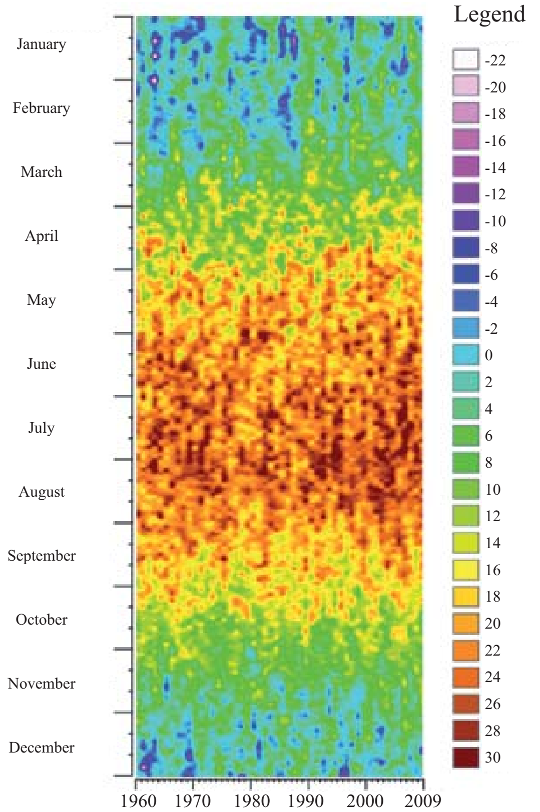

Fig. 7. Maximum daily temperature in Poznań expressed in °C, 1960-2009.

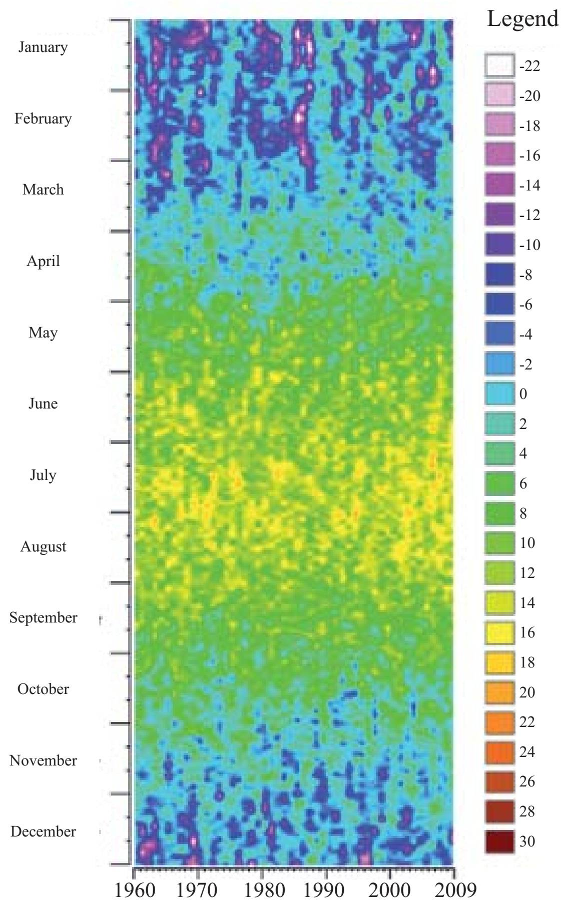

Fig. 8. Minimum daily temperature in Poznań expressed in °C, 1960-2009.

Conclusions

1. Between the periods 1848-1922 and 1960-2009 the increase in mean annual temperature was 0.9ºC.
2. Between the periods 1848-1922 and 2000-2009 the increase in mean annual temperature was 1.9ºC.
3. In 1960-2009 the observed growth of maximum temperature values was almost twice as fast as the increase in minimum temperature values.
4. It has been concluded that spring and autumn are disappearing and summer is consequently longer.
5. It has been concluded that the period without the incidence of ground frost has been prolonged and the frost season has been shortened.
6. It has been concluded that precipitation quantity is constant, which, together with the increase in temperatures, leads to the intensification of landscape stepping.

Acknowledgements

This work was supported by EU FP7 GHG-Europe FP7-CP-IP-244122-2010 project and COST Action ES0804 – ABBA (advancing the integrated monitoring of trace gas exchange between biosphere and atmosphere).

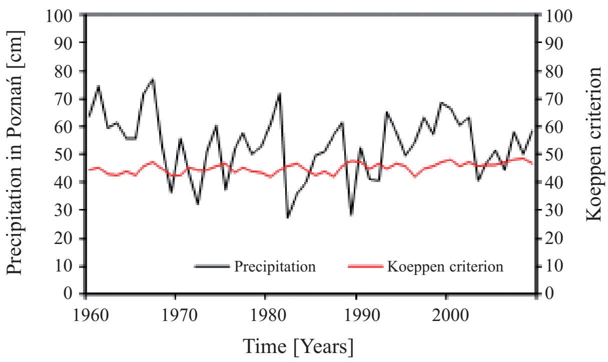

Fig. 9. The Koeppen criterion and precipitation, 1960-2009.

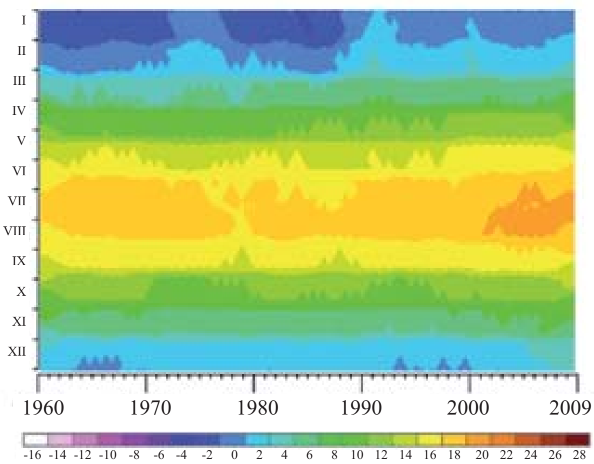

Fig. 10. Mean monthly temperature in Poznań expressed in ºC, 1960-2009.

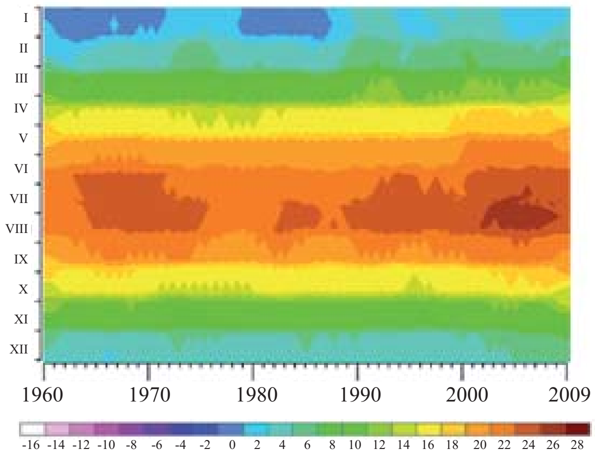

Fig. 11. Maximum monthly temperature in Poznań expressed in ºC, 1960–2009.

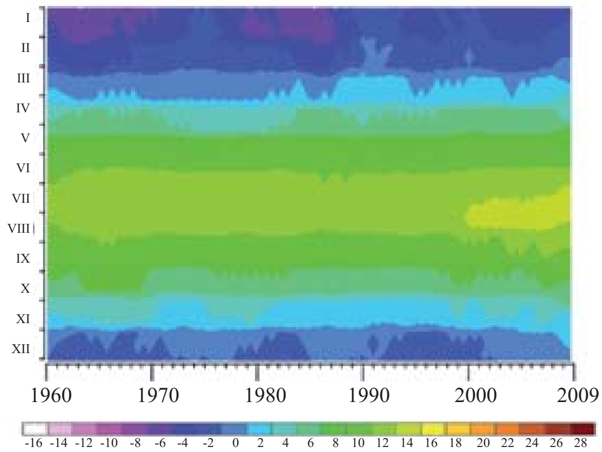

Fig. 12. Minimum monthly temperature in Poznań expressed in ºC, 1960-2009.

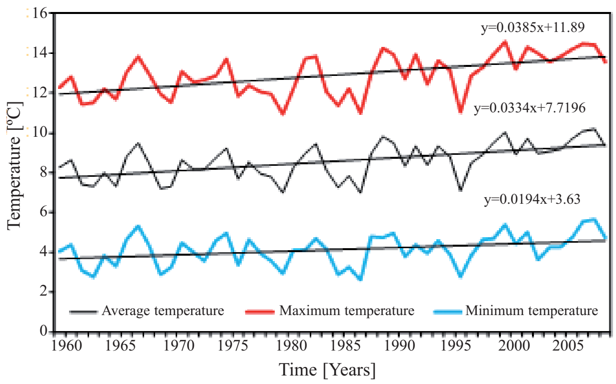

Fig. 13. Mean annual temperature in Poznań and linear trends, 1960-2009.

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