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CONTEMPORARY WARMING AND DAILY VALUES OF TEMPERATURE (ON THE EXAMPLE OF WARSAW)

Abstract. This paper aims at presenting changes in everyday air temperature values, triggered by the contemporary warming process. The analysis has been based on the mean, maximum, and minimum daily temperature values measured in Warsaw between 1951 – 2003. The mean daily temperature in that period was between -24.6 and 28.4°C, absolute minimum temperature was -30.7°C, absolute maximum temperature amounted to 36.4°C.
Calculations indicate that the number of days with mean temperature ≤ -5.0°C (minimum < 0.0°C, maximum < 0.0°C) in the last several years decreased. This trend slowed down at the beginning of 21st century, nevertheless, the number of days with mean daily temperature > 20.0°C and maximum temperature > 25.0°C was growing, particularly in the 1990's and even more so in early 2000's. Also since 1990's, there has been increasingly more nights with minimum temperature > 15.0°C, which has been particularly apparent in 2001. Contemporary warming is then marked with an increasing frequency of the hottest days and decreasing frequency of the coldest days. These changes were asymmetrical beyond 1950's, yet, in late 1990's they coincided.

Key words: contemporary warming, mean daily temperature, maximum temperature, minimum temperature.

The current warming, increasing in particular at the end of the 20th century, is ascertained first of all on the basis of the average values of temperature: monthly, seasonal and annual. For a person living in a warming climate these values are, however, an entirely abstract construct, derived from calculations, while humans perceive, respond and adapt to the temperature of the air in each particular day. For that reason, this paper aims at determining changes in the temperature values characteristic for each day and night: the daily average and the minimal and maximal values. The focus of the paper is mostly on the lowest and highest temperature values in the period under investigation.

The basis of this study consists of everyday values of the average daily temperature and the minimal and maximal temperature values from the period 1951–2000, sometimes supplemented by data from the years 2001–2003. The data are taken from the weather station Warszawa-Okęcie, located on the south-western outskirts of Warsaw, in a non-urban area.

GENERAL THERMAL CHARACTERISTIC OF THE PERIOD 1951–2000 IN WARSAW

In the second half of the 20th century the mean annual value of air temperature in Warsaw was 7.9°C and was increasing by 0.20°C during each 10-years period. The average multiannual monthly temperature oscillated between -2.7°C in January and 18.2°C in July. The minimal temperature had the following average values: 3.8°C (annual), -5.5°C (in January) and 12.9°C (in July); the average maximal temperature values were, respectively: 12.1°C, -0.1°C and 23.6°C. The range of temperature during the period 1951–2000 is determined by the absolute minimum -30.7°C (January 8, 1987) and the absolute maximum 36.4°C (August 1, 1994). During the years 2001–2003 these values were never exceeded.

The main daily temperature in the second half of the 20th century in Warsaw oscillated between -24.6°C (January 31, 1956 and January 14, 1987) and 28.4°C (July 25, 1963); in January it oscillated between -24.6°C and 10.4°C, in July between 10.6°C and 28.4°C. The range of oscillations of the mean daily temperature during the period from December through February was 34–35°C, and from July through September it was approximately half of that: around 18°C.

Two ranges of values occurred most often: from 0.1°C to 2.0°C (8.9%, on the average 32–33 days per year, from October through May) and from 14.1°C to 16.0°C (8.6%, approx. 31 days per year, from March through October). The range 6.1–8.0°C, which includes the mean annual air temperature (7.9°C), occurs only in 6.6% of days per year (approx. 24 days), which, however, can occur in as many as ten months of the year: they do not occur only in July and August. During the whole year, however, the range of mean daily temperature values from 10.1°C to 12.0°C can occur; it forms 7.0% of cases (25–26 days). In reality this “all-year-round” range of temperature is determined by the values 10.1°C and 11.0°C; i.e. the mean temperature in the warmest day of January (10.4°C) was practically the same as in the coldest day of July (10.6°C).

To determine the changes of the mean daily temperature during the half-century 1951–2000, the number of days with the temperature ≤ -5.0°C (the coldest days) and > 20.0°C (the warmest days) was investigated during consecutive years. The coldest days occur only from October through March and form 6.9% (on the average 25 days per year), while the warmest days occur only from April through September and form 6.5% (on the average 24 days per year).

The coldest days (Fig. 1a) in the specific cold seasons (from October through March of the following year) occurred with a very varied frequency: from 1 day (1974/5) to 65 days (1962/3). Five more seasons (all of them after 1982) were distinguished by a small number (5–8) of days with temperature ≤ -5.0°C, while the season 1995/6 was distinguished by a very large number (52) of such days (Fig. 1a). Generally, the seasons from 1984/5 through 1986/7 were

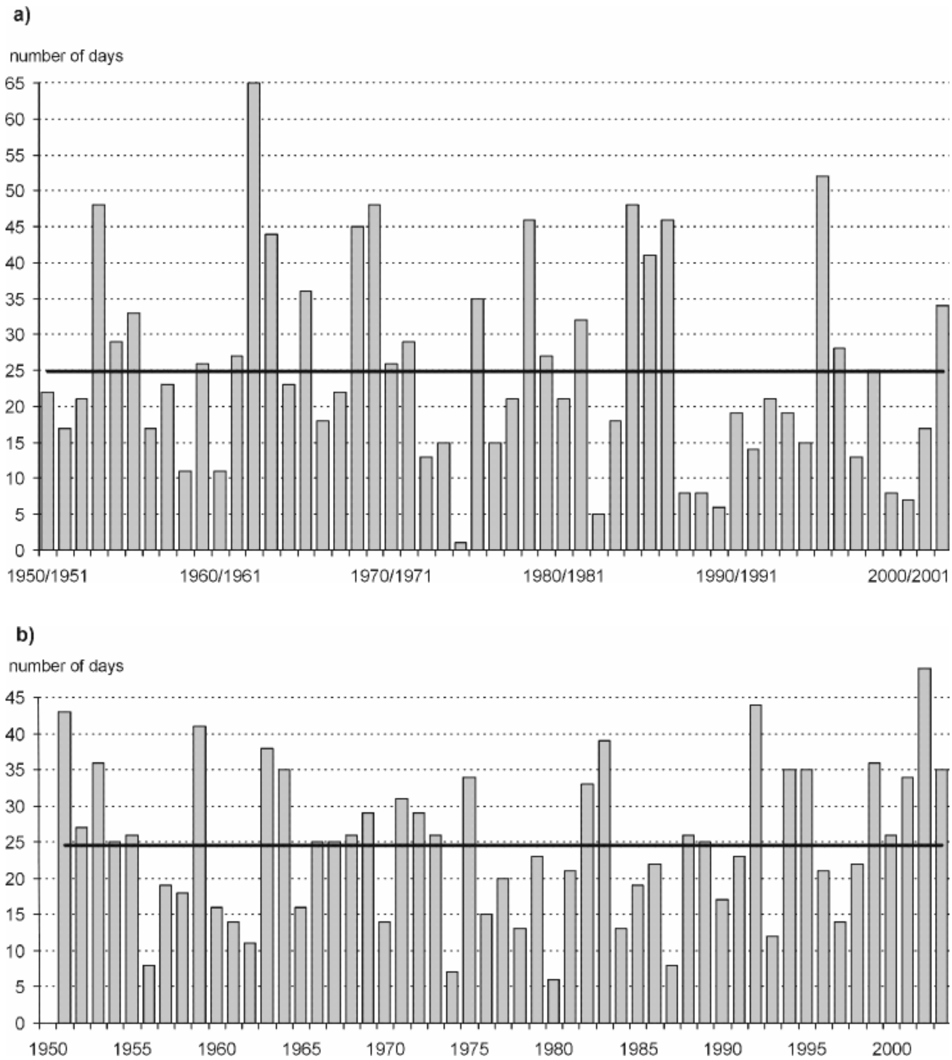

Fig. 1. The number of days with the mean daily temperature ≤ -5.0°C (a) and > 20.0°C (b) in Warsaw during the period 1951 – 2003.

distinguished by a large number of coldest days: 45 days on the average; similarly, the seasons from 1961/2 through 1971/2 had a large number of such days: 35 days on the average. The periods from 1972/3 through 1983/4 and from 1987/8 through 1999/2000, however, were distinguished by a small number of coldest days: on the average 19 days and 18 days, resp. The end of the 20th century was thus characterised by a distinct decrease of the frequency of the coldest days (except for the season 1995/6) and this tendency persists in the first years of the 21th century, although in the season 2002/3 there were again more such days than on the average during the half-century 1951–2000 (34 days). This can thus be regarded as a distinct symptom of warming, although one should point out that the phenomenon of warming defined in this way does not occur gradually from the beginning of the period 1951–2000, because the largest number of coldest days occurred only in the second decade of this period.

The warmest days, that is, days with the mean daily temperature > 20.0°C (Fig. 1b) occurred with the average frequency slightly below 24 days per year. In particular warm seasons this value ranged from 6 days (1980) to 44 (1982); three more seasons (1956, 1974 and 1987) were also distinguished by a small value (7–8 days), while two more seasons (1951 and 1959), by a large value (over 40 days). In general, one can point out periods with a relatively low frequency of the warmest days (1956–1960: around 18 days and 1974–1991: about 20 days) and periods with relatively high frequency (1951–1955: around 31–32 days and 1963–1973 and 1992–2000: about 27 days each). Thus at the end of the 20th century the number of days with the main daily temperature > 20.0°C increased in comparison with the earlier years (1974–1991), but it wasn't the highest such number during the half-century 1951–2000; such days occurred most frequently at the beginning of this period (1951–1955). A large number of warmest days occurred again in the first years of the 21st century, and in the year 2002 there were more such days (49) than at any time during the half-century 1951–2000. It is worth noting that at the end of the 20th century may be observed, for the first time, both a decrease in the number of coldest days and an increase in the number of warmest days.

The minimal and maximal temperature values form a basis for distinguishing the so-called characteristic days. In this paper, the following kinds of days are taken into account: frost and ice days, hot and very hot days, warm and very warm nights.

Frost days are days in which the minimal temperature falls below 0°C, while the maximal temperature remains above this value. During the period 1951–2000 in Warsaw there were, on the average, 71 such days per year (Fig. 2); they occurred from September through May. In particular seasons the number of such days ranged from 50 (1985/6) to 102 (1973/4). This value, however, is not a good indicator of the severity of the winter, because such days can occur both during a mild winter (since the temperature remains above 0°C during the whole 24-hours period) and a severe one (when the temperature remains below 0°C during the whole 24-hours period).

Ice days are days with the maximal temperature above 0°C, that is, with the temperature below 0°C during the whole 24-hours period. During the period 1951–2000 such days occurred, on the average, about 40 times per year (Fig. 2), from November through March. During 2–3 days from among 40, the temperature remained below -10°C (extremely cold days). Ice days were recorded from 7 times per year (1974/5) to 82 times per year (1995/6) and 79 times per year (1962/3). Extremely cold days occurred only in 28 seasons of the half-century under investigation; the largest number of them (21)

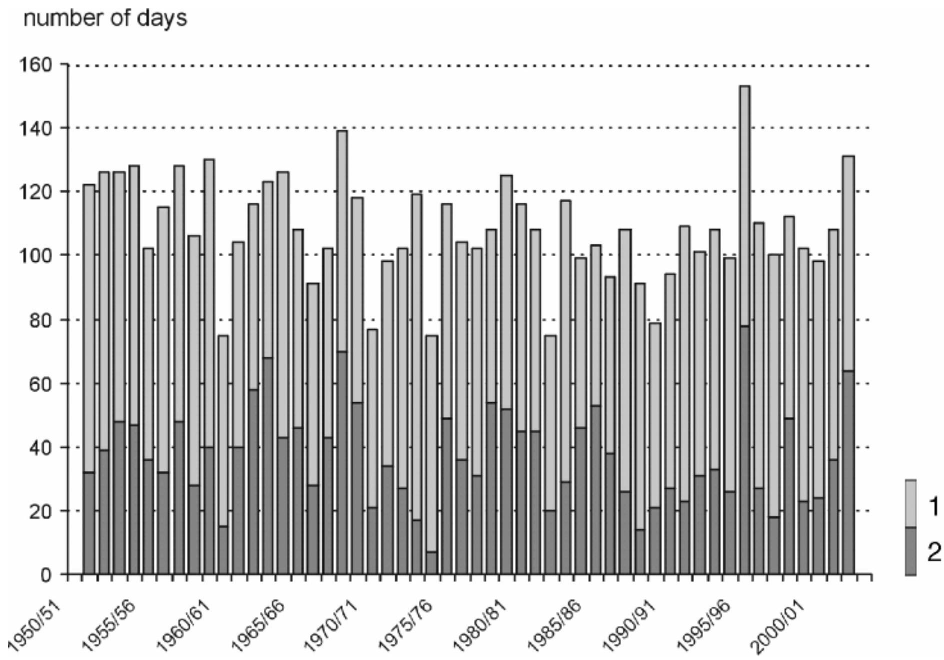

Fig. 2. The number of frost days (1) and ice days (2) in Warsaw during the period 1951 – 2003.

occurred during the winter 1962/3. During the winter 1995/6, which had the largest number (82) of days with the maximal temperature < 0°C, there were only four extremely cold days, while during the winter 1986/7, when the absolute minimum (-30.7°C) occurred, there were 15 such days.

Since the thermal conditions during the cold season are determined both by the duration of the period when the temperature falls below 0°C and by the value of that temperature, one should consider the combined number of the frost and ice days. On the average, there were 111 such days per year: from 15 (1974/5 and 1982/3) to 157 (1995/6). The number of days with the minimal temperature < 0°C decreased gradually during the half-century under investigation. In the first four consecutive decades it was equal to 123, 115, 105 and 102, resp., but in the last decade it increased to 111. This value was influenced by the record number of such days (157) in the 1995/6 season; if that season is omitted, the average from the remaining nine seasons of the last decade is equal to 106 days. The number of days with the maximal temperature < 0°C also decreased, but their largest number (52) was observed not at the beginning of the half-century, but (similarly as in the case of days with the average temperature ≤ -5°C) in the second decade. If we omit the season 1995/6 in the last decade, then in the remaining nine seasons there were fewer such days (30) than previously. In the 1991 – 2000 decade, days with the minimal temperature < -20°C occurred much less frequently

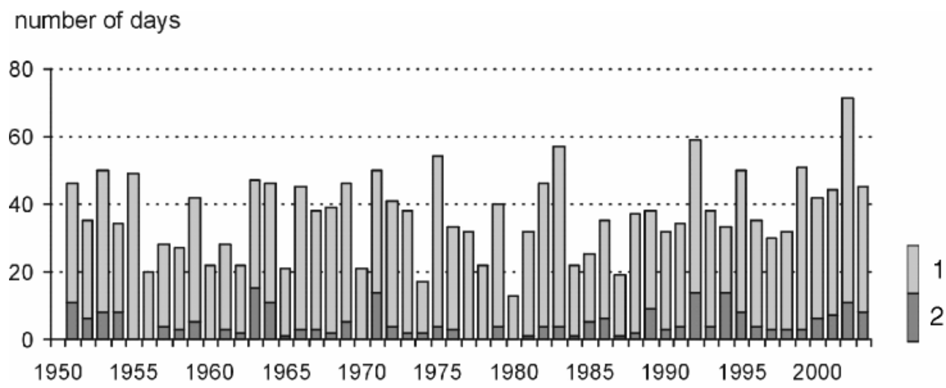

Fig. 3. The number of hot days (1) and very hot days (2) in Warsaw during the period 1951–2003.

(altogether 7 days) than in the earliest years (37 days in the 1961–1970 decade), and the maximal temperature < -20°C was not recorded at all.

The decrease of the number of the coldest days in winter seems to be halting. In the consecutive cold seasons of the 21st century the number of days with the minimal temperature < 0°C was 98, 108 and 131, resp., and the number of days with the maximal temperature < 0°C, 24, 34 and 60, resp. These numbers from the season 2002/2003 are significantly larger than the average values from the half-century 1951–2000 and are smaller than only six winter temperature values from that period.

Hot and very hot days are days in which the maximal temperature reached the value between 25.1°C and 30°C or exceeded 30°C, resp. In the second half of the 20th century in Warsaw (Fig. 3) hot days occurred on the average 31–32 times per year, from April through October; very hot days occurred 4–5 times per year, from May through September only. The number of days with the maximal temperature above 25°C was about 36 days per year; it ranged from 13 days (1980) to 62 days (1992); six more seasons (1956, 1960, 1965, 1974, 1984 and 1987) were distinguished by a low number of such days (17–22), while five more seasons (1971, 1975, 1983, 1995 and 1999), by a high number (50 and more) (Fig. 3). One should point out that after 1987, the number of days per year with the maximal temperature > 25°C was never lower than 30, and in as many as three seasons it exceeded 50. In each year of this period there were days with the maximal temperature > 30°C and it was during this period that 7 out of 10 days with the maximal temperature > 35°C recorded during the half-century under investigation occurred. The tendency of the frequency of hot days to increase can be still observed and already in 2002 the record high number observed in the second half of the 20th century was greatly exceeded: 71 days with the maximal temperature > 25°C were recorded, out of which 11 days had the maximal temperature > 30°C (the value 35°C was not exceeded).

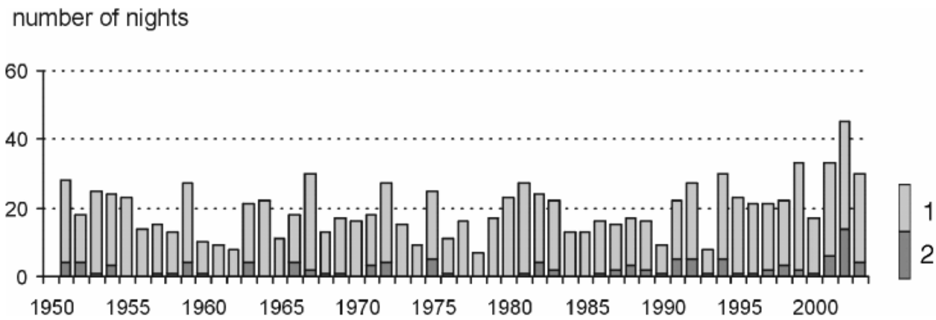

Fig. 4. The number of warm nights (1) and very warm nights (2) in Warsaw during the period 1951–2003.

Thermal perception is determined not only by the temperature during the day, but also during the night. Since the range of temperature values during any 24-hours period can be much greater in the summer than in the winter, a separate category of days has been distinguished here: days with the minimal temperature between 15.1°C and 18.0°C, and above 18°C. Since the minimal temperature occurs usually at night (strictly speaking, in the early morning), 24-hours periods with the values of temperature given above have been called warm nights and very warm nights, resp.

In the second half of the 20th century in Warsaw there were, on the average, about 17 warm nights per year (from May through September) and 1–2 very warm nights (from May through August); sporadically, in July and August, the minimal temperature slightly exceeded 20°C. There were about 18–19 days per year with the minimal temperature > 15°C. In particular years (Fig. 4) there were from 7 (1978) to 33 (1999) such days; moreover, there were few such days (8–9) in the years 1961, 1962, 1974 and 1990 and many (30 and more) in the years 1967 and 1994. The increase of the minimal temperature above 18°C did not occur in each year; when it occurred, it was no more than five times per year.

Warm nights occurred fairly often (over 20 per year) at the beginning of the half-century under investigation and in the early 1980s; the next increase of their frequency took place in the last decade (except for the year 1993). From the year 1986 on, the minimal temperature exceeded 18°C every year: in three different years this happened five times each year, while previously this occurred only in one year (1975). The values of the minimal temperature exceeding 20°C were recorded only six times during 50 years, of which three cases happened in the last decade of the 20th century. An increase of the frequency of warm nights is observed also in this century. In 2001 there were 33 such nights, that is as many as in the record year 1999, while already in the next year, 2002, this record value was significantly exceeded: the number of nights with temperature above 15°C was 45. Among them was also not previously recorded number of 12 nights with temperature above 18°C and two nights above 20°C.

CONCLUSIONS

The contemporary warming manifests itself by the increasing number of days with a high (> 20°C) mean daily temperature, as well as of days with high maximal (> 25°C) and minimal (> 15°C) temperature. A decrease of the number of days with a low (≤ -5°C) mean daily temperature and of days with low maximal (< 0°C) and minimal (< -10°C) temperature can be also observed. This process, however, is not uniform during the half-century under investigation or during any particular year: the coldest winters were in the 1960s, but the longest winter occurred in the generally warm decade of 1990s; the warmest summers were in the 1990s, but also in the early 1950s. This instability of thermal conditions occurring against the background of the general tendency of the temperature to increase can be observed not only in winter and in summer but also during the transitional seasons of the year. For instance, the last decade of the 20^{th} century included the warmest March, April and October of the half-century, but also the coldest September, October and November of the same period.

For humans, warming caused by constant temperature oscillations means more and more difficult thermal conditions: more frequent spells of heat and stifling nights in the summer and mild winters, unexpectedly interrupted by severe and long ones, to which humans are nowadays less well adapted.

English translation: Małgorzata Mikulska