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FLUCTUATIONS OF THE PRECIPITATION REGIME UNDER CONDITIONS OF TEMPERATE AND OCEANIC CLIMATES WITH CRACOW AND LILLE AS EXAMPLES

Abstract: The paper discusses the differences and similarities in the variability of the precipitation regime under conditions of temperate and oceanic climates, with the series of precipitation records from Cracow and Lille as examples. The characteristics of the statistical distribution of the precipitation totals, i.e. the means and extreme values and their frequencies, have been compared. The dispersion in the totals has been evaluated. The temporal variability in the occurrence of the month with the highest and the lowest precipitation and in the selected indices of continentality and pluvial oceanity has been presented. A significant similarity in the course of the annual totals has been evidenced. The largest differences have been stated in the annual cycle of precipitation. In Lille the precipitation regime shows a higher stability that results from the oceanic climate. In Cracow the continental type of regime predominates which is determined by a strong concentration of the annual maximum precipitation.

Key words: pluvial oceanity, pluvial continentality, precipitation regime, Cracow, Lille.

1. Introduction

The purpose of this paper is to show the differences and similarities in the variability of the precipitation regime under conditions associated with the temperate and oceanic climates with a multi-annual series of precipitation records from Cracow ($\varphi = 50^0 04'N$, $\lambda = 19^0 58'E$, H=206 m a.s.l.) and Lille (Lesquin station; $\varphi = 50^0 34'N$, $\lambda = 03^0 06'E$, H=46.8 m a.s.l.) as examples. The basis of the paper are the monthly and annual precipitation totals of the 50-year long period of observations for 1950-1999. Both the stations are located close to the parallel of the latitude of 50^0N and both are at similar elevations a.s.l. Due to a significant meridional distance between Cracow and Lille, the influence of the atmospheric circulation on the climatic conditions is highly differentiated. The advection of the air masses of various geographic origins and of various properties is the major reason behind the given pluvial conditions. In Cracow,

the contrary to Lille, besides the circulation factors, the localization of the town in a concave landform (in the Vistula River valley), also has an essential influence on climate. Moreover, the presence of the Carpathian Mts. south of Cracow is very important because it has a significant impact on the appearance of very high precipitation due to the orographic effect during an advection of air masses from the northern sector. On the other hand, Lille is located in the area where relief is little diversified and is not an important geographical factor affecting climate.

According to the climate classification by W. Okołowicz (Martyn 1987), Cracow and Lille belong to the group of warm temperate climates. In Lille a maritime climate prevails while in Cracow – a transitional one. The climate of the western part of this zone is mild owing to the strong effects of the Atlantic air masses. In eastern part, the influence of the oceanic air masses is smaller, but the effects of the continental air masses and frequency of the advection of the arctic air are becoming more significant. Following the map of the world precipitation regions by J. Blüthgen (1966, after Martyn 1987), it is apparent that Cracow and Lille belong to the extra-tropical zone of cyclonic precipitation. The precipitation at these two stations is differentiated by its seasonal distribution. In Lille the maximum occurs in the autumn and winter while in Cracow in the summer.

2. Characteristics of the source materials

Weather observations were started at both stations many years ago. In Cracow, based on the notes about weather phenomena taken by Prof. M. Biem of the Cracow Academy (which then became the Jagiellonian University), the climatic conditions of the first half of the 16th century have been revealed (Limanówka 1996). In Lille, such notes taken by Vauban at the citadel come from the second half of the 17th century (Petit-Renaud 1980). The systematic measurements began in the 18th century. In Lille they were started in 1757 and in Cracow in 1792.

In the studies on the climate evolution, the numerical data from the old meteorological observations are not always sufficient to draw the correct conclusions. That quality of the data might have been influenced by the changes in location of the station and in its direct surroundings, which took place, as time passed, as well as the changes in the instruments and measuring methods used. Therefore, the additional information is necessary, the so called *metadata*, which could allow to elucidate certain ambiguities and would make possible some probable corrections of the data. The station in Cracow has fully documented *metadata* since the beginning of its operation. That is one of the longest series of the records in Central Europe, still taken at the same site. The series is used as a reference one for the studies on the evolution of climate in this part of Europe. In the case of the data from Lille, there are many gaps associated with breaks in the observations and with the disturbance in the homogeneity of the observation site. The continuous and homogenous data from this station comprise the period after the World War II. This period is taken for the comparative characteristics of the precipitation distribution at both the stations presented here.

3. Variability of the annual precipitation totals

General information about the pluviometric properties of the climate is provided by the analysis of the variability of the annual precipitation totals, which are the basic index for identifying years with an excess or deficit of precipitation. The course of precipitation in Cracow shows fluctuations, i.e. periods of increases and decreases in the totals occurring rather regularly, one after the other (Fig. 1). Certain cyclicity can be even noticed. In particular, that refers to very high precipitation (almost 1000 mm), which occurs, more or less, every 55 years (1855, 1912 and 1966). The precipitation in Lille shows fluctuations as well. At both the stations there is a large year-to-year variability in precipitation totals and the excesses and deficits in precipitation that appear are not synchronised over time. So, for example, a strong decline in precipitation in Cracow, which lasted throughout the 1980s and the first half of the 1990s, was accompanied by the large excesses in precipitation in Lille, which persisted particularly in the decade 1982-1991 (Dupuy 1998). At both the stations annual precipitation dispersion increases (Twardosz 1999, Petit-Renaud 1980).

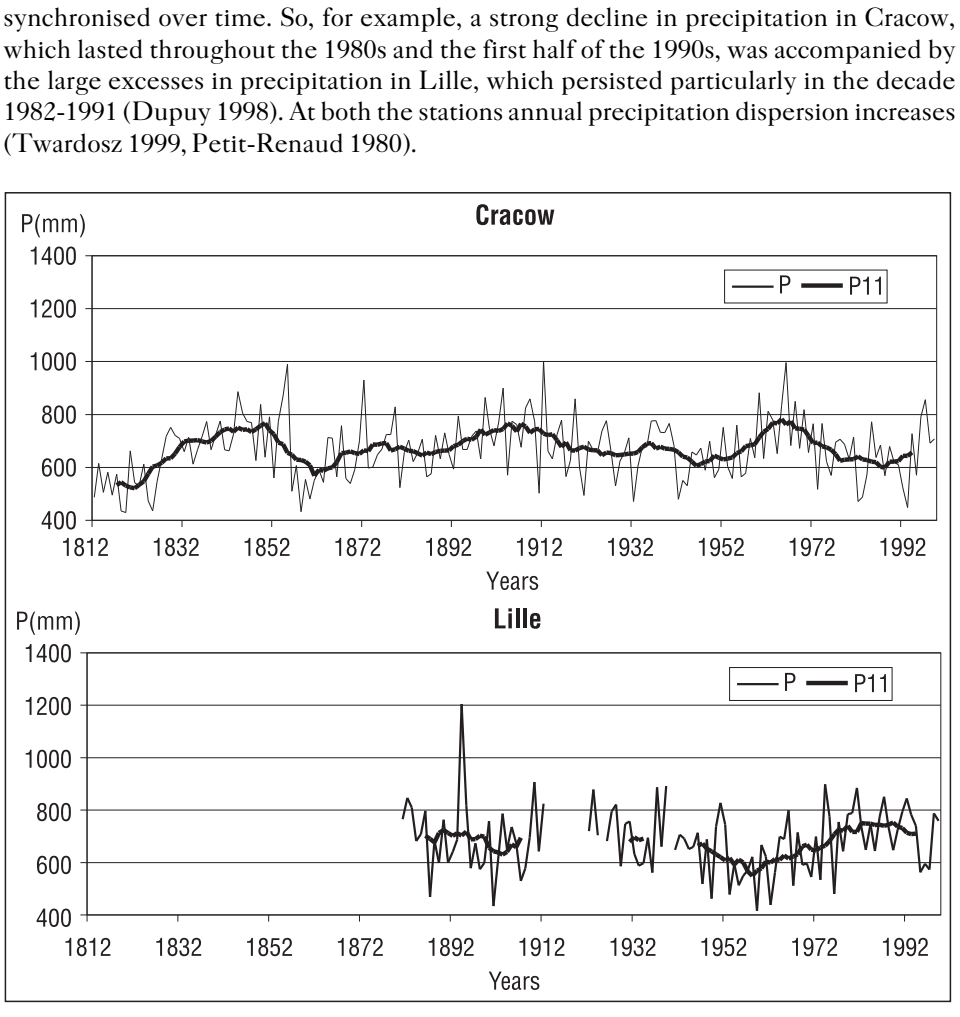

Fig. 1. Multi-annual course of the annual precipitation totals (P) and 11-years moving avarages

In the entire annual precipitation data series from Cracow, no trends were found (Twardosz 1999). This is a result of the counterbalancing effect of the high and low precipitation periods. On the other hand, Lille, following the studies by B. Dahlström (1994), is in the zone of an increasing tendency of precipitation. The reason behind the positive trend is attributed to an intensive transformation of the environment in the station's surroundings associated with a progressive urbanisation (Dupuy 1998).

4. Statistical distribution of precipitation totals (1950-1999)

The values of the selected statistical characteristics of the annual totals (Tab. 1) at the examined stations point to a similar precipitation variability. The mean totals at both the stations are close to the mean total in the zone delimited by the parallels of 50^0 and 55^0N. According to Jaeger (1976, after Kożuchowski 1985) that mean amounts to 794 mm. The range of the annual changes is large, from 448 mm in Cracow to 483 mm in Lille.

Tab. 1. Statistical characterictics of annual totals of the precipitation (1950-1999) in Cracow and Lille

Characteristic	Cracow	Lille
Average (mm)	673	674
Min (mm)	448	416
Max (mm)	996	899
Standard deviation (mm)	115	120
Variability coefficient (%)	17	18
Skewness	0.4	-0.2
Kurtosis	0.1	-0.8

The frequency distribution of precipitation at both the stations is close to the normal one (Fig. 2). H. Panofsky and G Brier (1958, after Kożuchowski 1985) are of the opinion that the normal distributions of the precipitation totals are typical features of wet climates. Table 1 shows that precipitation distribution in Cracow is slightly positively skewed and that it is leptokurtic distribution. On the other hand, precipitation distribution in Lille is slightly negatively skewed and it is a platykurtic distribution.

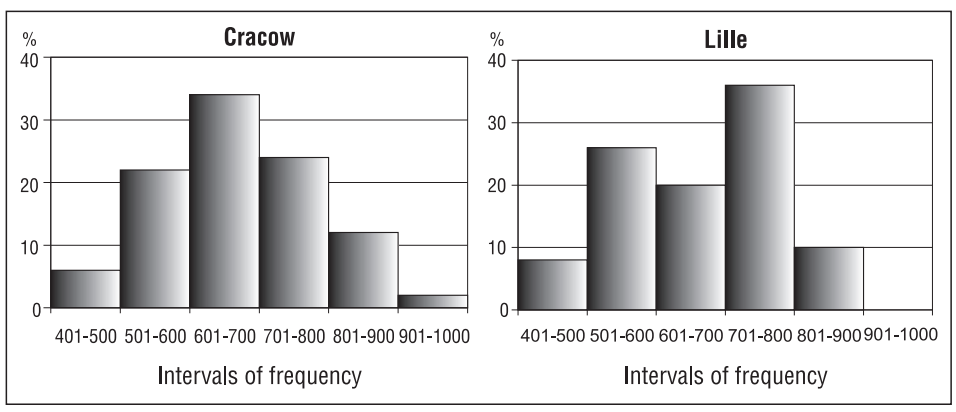

Fig. 2. Distribution of the frequency of annual precipitation totals

Large differences in the distribution of precipitation refer to the monthly totals (Fig. 3). In Lille there is a steady course of precipitation during a year, which is characteristic of an oceanic climate. The highest mean monthly total (66 mm) occurs in November, and the lowest in February (44 mm). The month-to-month changes in the precipitation totals are very small. The course of the monthly totals in Cracow is characterised by a much higher differentiation. The highest precipitation is concentrated in the summer months with the maximum (95 mm) in June, which is typical of a continental climate. The month-to-month changes in precipitation are significant and are of a systematic nature, i.e. their values increase from February to June, and then decrease from July to January.

When considering the variability coefficient, it is evident that the monthly precipitation at both the stations has a similar degree of dispersion. In Lille, the precipitation variability is slightly larger than in Cracow in 9 months. The largest dispersion of precipitation at this station occurs in July while in Cracow it is in October (Fig. 4). Large dispersion is characteristic for the extreme monthly totals (Fig. 5). In Cracow, the highest totals can even exceed the multi-annual mean value three times in July and February. However, there are also the months when there was no precipitation,

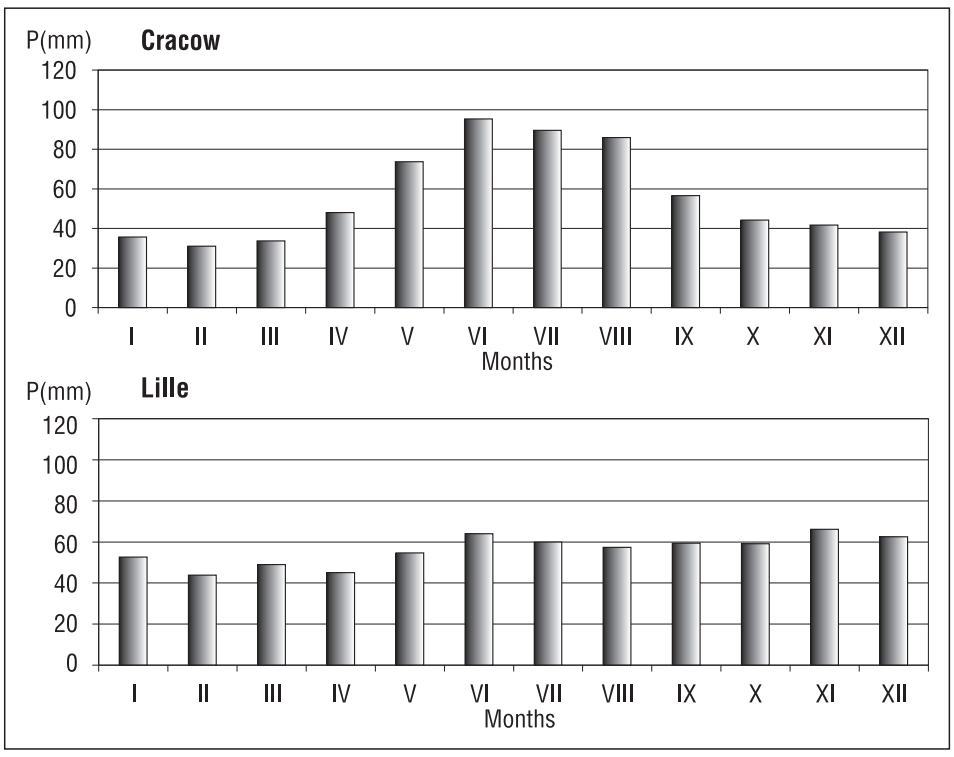

Fig. 3. Annual course of the mean monthly precipitation totals

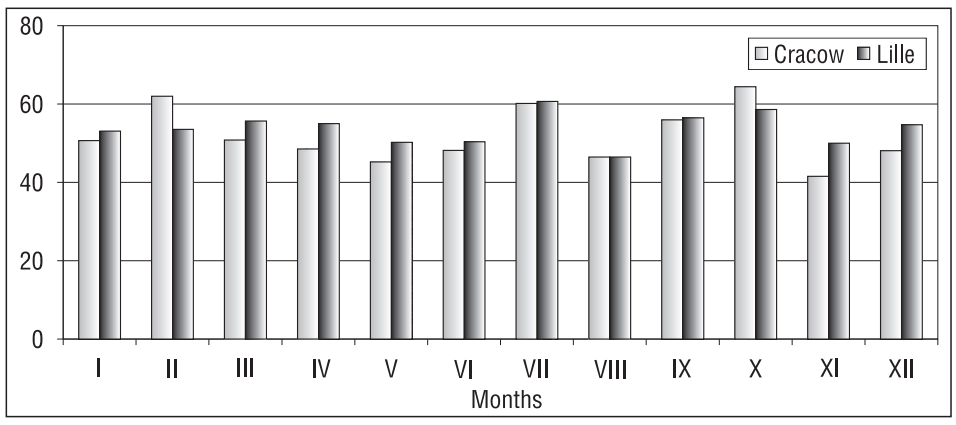

Fig.4. Annual course of the variability coefficient of monthly precipitation totals

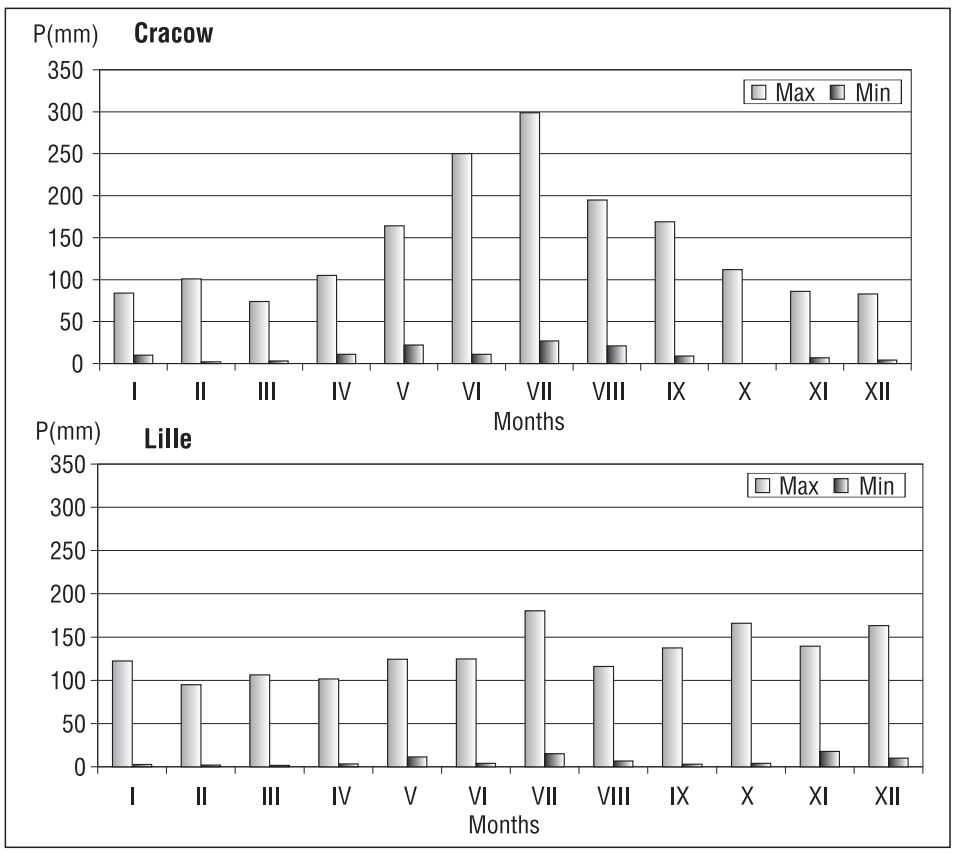

Fig. 5. Annual course of the maximum and minimum monthly precipitation totals

e.g. in October 1951. In the examined period, the highest monthly precipitation occurred in July 1997 (299 mm). It was ranked as a second one after the even wetter July of 1903 with the total of 313 mm. So high precipitation, which amounted, in this case, to over 40% of the multi-annual mean of the annual precipitation total, trigger catastrophic floods in southern Poland (Niedźwiedź 1999). The high monthly precipitation totals, close to 100 mm, can occur also in winter months. They occur rather rarely and belong to the group of phenomena that are considered an anomaly. On the other hand, very low precipitation can be recorded in the summer months, e.g. the monthly total in June 1992 was as low as 11 mm. In Lille, the differentiation in the extreme precipitation is much smaller. The largest monthly total (180 mm) was noted in July 1968. From October to April, the maximum totals exceed 100 mm and are higher than the analogous totals in Cracow. However, the lowest monthly totals (2 mm) occur at the turn of the winter and spring (e.g. February 1959, March 1993).

The range of the monthly precipitation totals, i.e. the difference between the maximum and minimum precipitation, emphasises the degree of precipitation differentiation during a year (Fig. 6). In Cracow, the years might happen when this range of precipitation is very high, e.g. in 1997 it was up to 282 mm. In Lille, the year-to-year changes of this parameter are much lower, but there were years when a range higher than in Cracow was recorded.

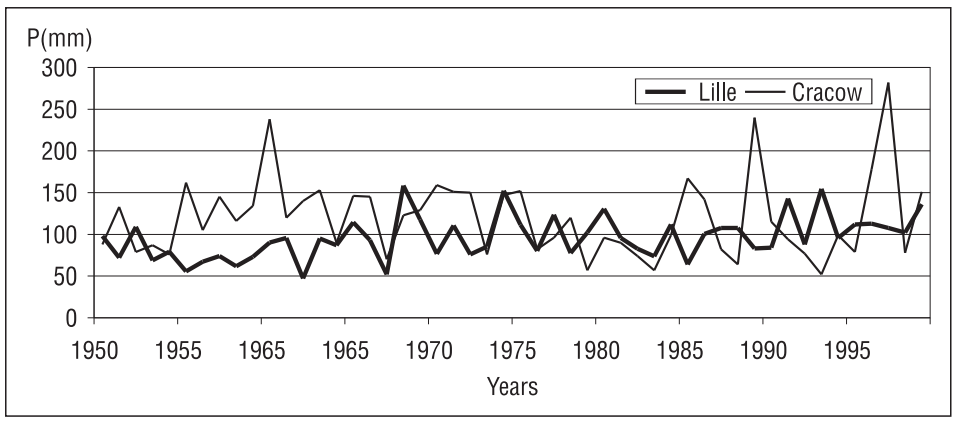

Fig. 6. Multi-annual course of the range (maximum - minimum) of monthly precipitation

5. Variability in the annual course of precipitation

The continentality, and the opposite to it - oceanity are the traditional field of interest of climatology, especially of Polish one, which can result from the transitional nature of the climate in Poland. However, with respect to precipitation, a significant part of Poland is more continental than the "mean continentality" of Eurasia between the parallels of 50^0 and 55^0N (Kożuchowski, Wibig 1988). The pluvial continentality of

Poland can be defined as a medium one, compared with the scale whose ends are determined by the indices calculated for Thorshavn and Verhoyansk. The fluctuations in the precipitation regime are associated mainly with the changes in atmospheric circulation. A particular role is played here by the intensity of the zonal circulation. The advection precipitation, which forms at such circulation, determine, according to W. Okołowicz (1969) the oceanic regime of precipitation.

Pluvial oceanity or continentality is determined by the concentration of precipitation in its annual course. For its evaluation several indices are used (Kożuchowski, Wibig 1988). The most often used index is the quotient of the precipitation totals for winter and summer. The values of this quotient are almost three times higher in Lille (1.1) than in Cracow (0.42). In Lille, in the multi-annual course of this index there are large oscillations from 0.3 in 1964 to 3.4 in 1995 (Fig. 7), which can evidence the instability of the precipitation regime also under the conditions of an oceanic climate. A particularly strong pluvial oceanity appeared in 1983-1995. In Cracow, in all the analysed years of the 50-year long period, the precipitation for winter was lower than for summer, i.e. it matched the continental regime. Nevertheless, in 1963, 1987 and 1992, the precipitation regime in Cracow was characterised with a higher precipitation oceanity than in Lille. When considering the values of the quotient of January and July totals in particular years, the significant deviations from the average precipitation distribution during a year can be shown better (Fig. 8). In Cracow, higher precipitation totals have been stated in January than in July (the quotient higher than 1) in up to 20% of the cases. In 1994, precipitation in July was fifty percent lower than in January. On the other hand, in Lille there is a similar probability of occurrence of both the higher and the lower total in January than in July. The relationship between the precipitation in these months at this station are highly variable, especially in the last years of the examined period, which confirms the instability of the annual course of precipitation.

The next index of oceanity presents the relationship between precipitation in autumn and spring (Fig. 9). In Cracow, the precipitation in autumn is slightly lower than in spring, which is a characteristic feature of continental climates (the quotient is equal to 0.996). In Lille, under the conditions of oceanic climate, precipitation in autumn is higher than in spring (the quotient is equal to 1.39). In the years 1973-1977, the pluvial oceanity was marked at both stations.

Despite a large distance between the discussed stations, it has been stated that in some years the annual courses of precipitation show a similarity. For example, the coincidence in the annual course of precipitation occurred in 1969 (Fig. 10). However, in the majority of years, both in Cracow and Lille, there are significant deviations from the average course of precipitation. It results from the large temporal and spatial dispersion of this climatic element. This finding is confirmed by the analysis of the occurrence of the annual maximum and minimum precipitation, which are treated as basic indicators for evaluation of the type of precipitation distribution. In Cracow, the lowest monthly precipitation total can occur with an equal probability from December until March and in October (Fig. 11). It is also probable that the minimum occurs in April or in June. This is due to the transitional character of the climate in Poland, meaning that the oceanic and continental properties of climate occur at the same time or change

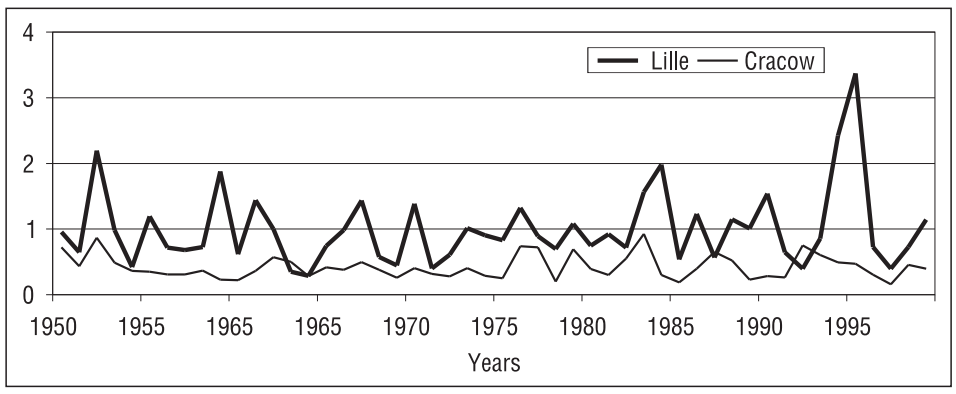

Fig. 7. Multi-annual course of the quotient of winter and summer precipitation totals

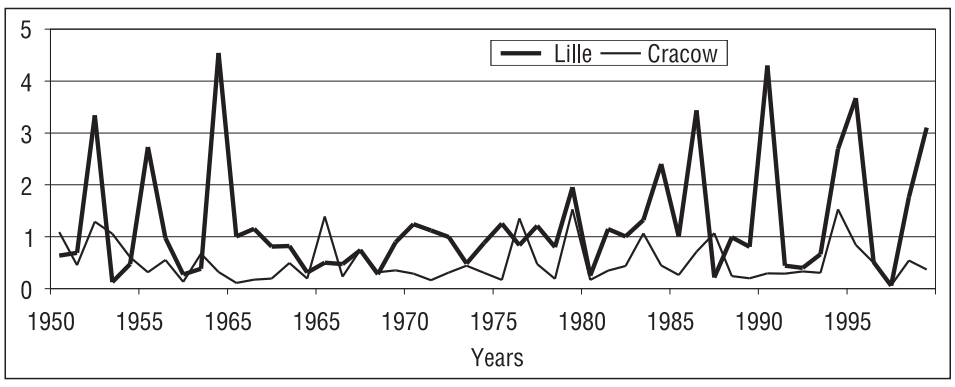

Fig. 8. Multi-annual course of the quotient of January and July precipitation totals

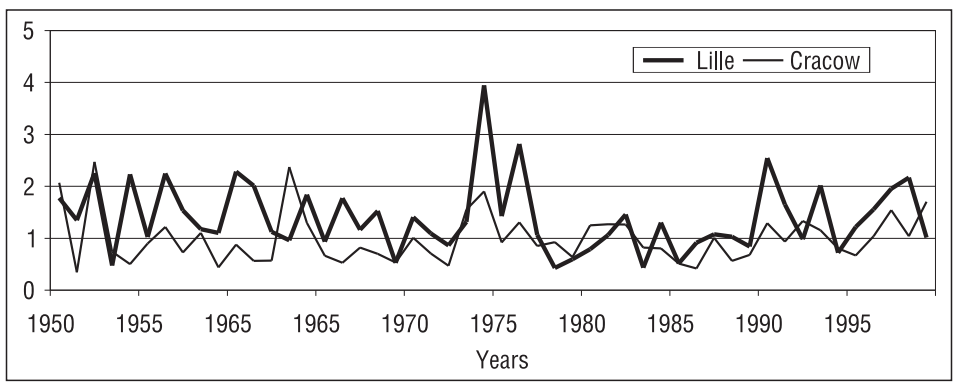

Fig. 9. Multi-annual course of the quotient of autumn and spring precipitation totals

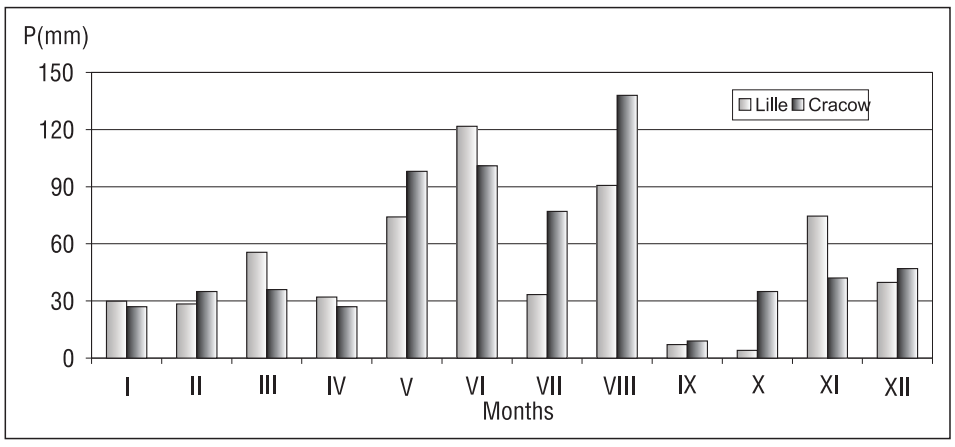

Fig. 10. Annual course of precipitation in 1969

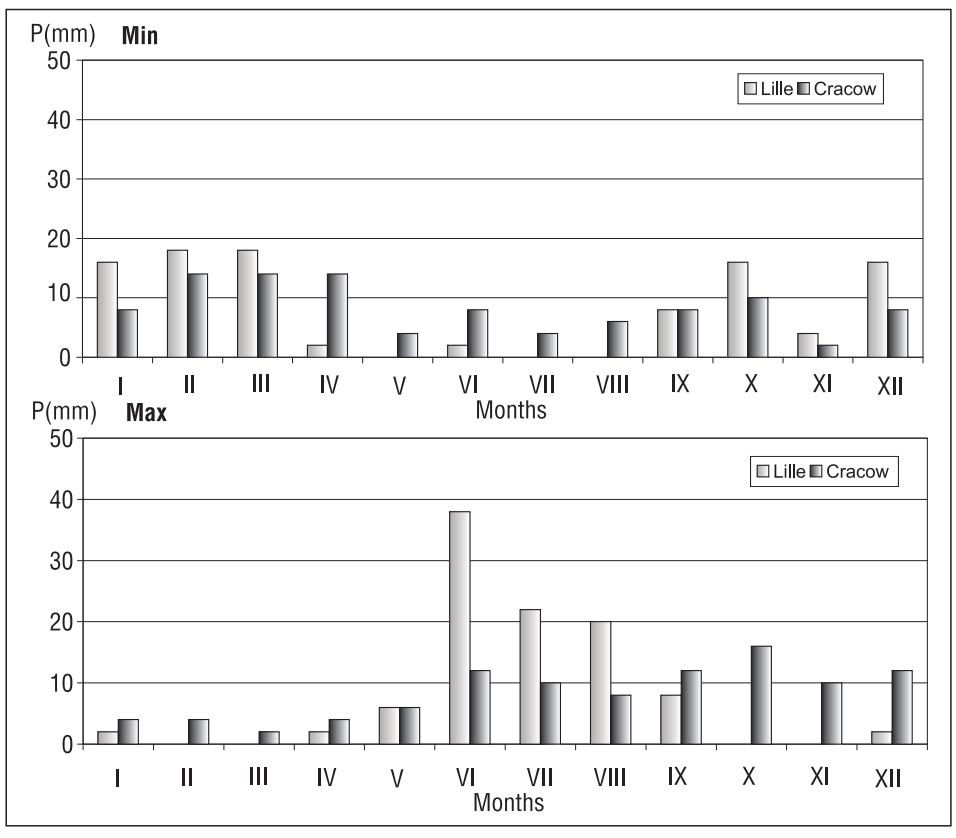

Fig. 11. Annual course of the probability of the minimum and maximum monthly precipitation totals occurrence

rapidly. In the case of precipitation in Cracow, the regime more often shows the continental properties than the oceanic ones. The maximum of the annual course of precipitation has a high concentration. The probability of its occurrence is the largest in summer (80%), mainly in June (38%) (Fig. 11). The lower variability in the precipitation regime occurs in Lille, which results from the oceanic nature of the climate. Both the maximum and minimum precipitation may appear in any month at this station. The large variability in the occurrence of the extreme totals brings about the steady course of the annual precipitation.

6. Closing remarks

The analysis of the precipitation course based on the examples of two stations belonging to the same temperate climate zone, showed different aspects of the precipitation variability. Despite the large distance between Cracow and Lille, the annual precipitation has several common features, e.g. the value of the total and degree of dispersion. In the multi-annual course there are certain differences in the timing of the excesses and deficits of precipitation, which results from the spatial variability of precipitation.

The largest differences between precipitation are in the annual cycle. They occur in the mean values, and especially in the extreme monthly precipitation totals. In Lille, the precipitation regime is characterised by a higher stability, which results from the oceanic character of the climate. The location of Cracow in the zone of both maritime and continental air masses influences causes strong contrasts in the annual course of the precipitation. In Cracow, however, the continental type of regime predominates as determined by the high concentration of the maximum in the annual course of precipitation.

At both the stations significant deviation from the average course of precipitation can occur but high accordance of the regimes is also possible. It seems, however, that the intensity of oceanity may not be treated as the reverse of continentality. In both the cases, the features of both types can occur.

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Fluktuacje reżimu opadów w warunkach klimatu przejściowego i oceanicznego na przykładzie Krakowa i Lille

Streszczenie

W pracy ukazano różnice i podobieństwa w zmienności reżimu opadowego w warunkach klimatu przejściowego i oceanicznego na przykładzie serii pomiarów opadów atmosferycznych w Krakowie i Lille. Podstawę opracowania stanowią miesięczne i roczne sumy opadów z lat 1950-1999. Obie stacje położone są w pobliżu równoleżnika 50^0 szerokości geograficznej północnej i na zbliżonej wysokości nad poziomem morza. Na podstawie wybranych charakterystyk statystycznych ukazano różne aspekty zmienności opadów na obu stacjach. Przedstawiono zmienność czasową występowania miesięcy z najwyższymi i najniższymi opadami oraz wybranych wskaźników kontynentalizmu i oceanizmu pluwialnego.

Wykazano, że mimo znacznej odległości między Krakowem a Lille, roczne opady odznaczają się wieloma cechami wspólnymi, tj. wysokością sumy i stopniem dyspersji. W przebiegu wieloletnim pojawiają się niezgodności w czasie wystąpienia nadmiarów i niedoborów opadów. Największe różnice między opadami istnieją w rocznym cyklu. Występują one głównie w ekstremalnych miesięcznych sumach. W Lille reżim opadów odznacza się większą stabilnością, co wynika z oceanicznego charakteru klimatu. Położenie Krakowa w strefie oddziaływania morskich i kontynentalnych mas powietrza wywołuje silne kontrasty w rocznym przebiegu opadów. W Krakowie zdecydowanie dominuje jednak kontynentalny typ reżimu, o którym decyduje silna koncentracja

maksimum rocznego przebiegu opadów. Na obu stacjach mogą wystąpić znaczne odchylenia od przeciętnego przebiegu opadów. Możliwa jest również duża zgodność reżimu opadów na obu stacjach.

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