PRACE GEOGRAFICZNE, zeszyt 108

Instytut Geografii UJ
Kraków 2000

Bolesław Osuch

VARIABILITY OF POTENTIAL WATER RESOURCES AGAINST THE BACKGROUND OF ANNUAL PRECIPITATION CHANGEABILITY

Abstract: The paper presents the variability of annual precipitation as a decisive factor influencing mean annual river discharge which characterizes surface water resources. The interpretation of variability trends and cyclicity in observed precipitation series for Cracow and Stróża are discussed. A comparison was made between mean annual river discharges' variability in Stróża and annual precipitation, considered as potential water resources in the Raba River drainage area.

Key words: precipitation and river discharge cyclicity, variability trends, water resources, the Raba River.

1. Introduction

The variability of climatic elements receives lots of researchers' attention, as the knowledge about the changes' trends, especially the cyclicity of the phenomena occurrence, would make the prediction of future climate, weather and extreme hydrometeorological phenomena much easier. Most publications deal with the fluctuations and tendencies in the course of meteorological elements in long-term periods and with seeking for the regular variability in their appearance. It concerns most often the atmospheric circulation, atmospheric pressure, insolation, precipitation and other elements together with the relations between them. This research domain has been widely developed and one of its main centers in Poland is the Department of Climatology, Institute of Geography, Jagiellonian University, Cracow, where the long traditions of climatic research established by Prof. Jan Śniadecki (1756-1830) are continued. Śniadecki was a mathematician and astronomer, also a founder and the first director of the Astronomical Observatory of Jagiellonian University. At the end of 18th century he started weather observations using the instruments for the measurements of atmospheric pressure, temperature, humidity, wind speed and directions, precipitation and snow cover (Trepińska 1993).

The paper's aim is to analyse the variability of potential resources of running waters and their relations with first of all the precipitation, as the precipitation itself consists potential water resources, but of higher level, causing the runoff from a river's drainage area. Potential water resources are defined here as the water circulating in natural terrestrial water cycle, limited only to precipitation reaching the drainage area and the runoff of surface running waters. The term "potential" suggests that we take under consideration the whole amount of water, from which only a part will be accessible for usage.

General analyses of runoff from surface running waters in a long-term period, for the Raba River drainage area (a Carpathian tributary of the Vistula River) are presented here. The observations of runoff were started everywhere much later than the observations of precipitation, therefore the research on precipitation variability might be very supportive for the analysis of runoff changeability, especially for short-time observational series. It should be only defined which characteristic river discharges are best correlated with precipitation.

2. Analysis of Hydrometeorological Observations Variability

Precipitation and runoff variability analyses are useful for hydrologists, mainly due to their significance for economy, especially for water management and protection against floods and droughts. It concerns hydrological predictions, for which the meteorological forecasts are of primary importance. The forecasts may be divided into three groups according to the time of prediction (short-term, medium-term and long-term ones) or according to the degree of precision (warnings, qualitative forecasts and quantitative forecasts). Professor Lambor in his 1962 work defined additionally predictions with the prediction time as long as one hundred years, the secular forecasts. Long-term trends together with variability cycles should be classified as long-term or secular forecasts and rather qualitative ones. For hundreds of years there have been many attempts to find trends or cyclicity, which in case of forecasts would be a very important achievement. Unfortunately, most of those attempts have been failures because we know very few basic, simple cycles, e.g. 11-year sun spots' cycle. Most meteorological elements are not characterised with any oscillations which discourages those researchers who find out with time that their predictions based on noticed regularities do not coincide with reality. However, as the observational series become longer, there are always enthusiasts who see a chance to discover certain regularities in the elements variability.

Professor Julian Lambor, a Polish hydrologist, engaged in hydrological predicting already forty years ago (1962) wrote a manual describing the forecasting methods. He states that there are cases of distinguished relation between the occurrence of sun spot number and water level, e.g. in Victoria Lake or Nile River. Most often, however, those relations are rather complex and there is no direct connection, although as far as we know the increase of Sun's activity causes the decrease of precipitation in Northern Hemisphere, as the result of higher atmospheric pressure and lower temperature. Professor Lambor also noticed that since 1920s mean annual air temperature had been increasing (especially in Warsaw), but he was very careful about concluding that there was a global warming. He also would not ascertain that there was any distinguished periodicity in the course of the meteorological and hydrological elements. On the other hand we cannot deny that some natural cycles exist, for example E. Brückner, a professor of geography in Vienna University, announced in 1890 theory about 35-year climatic oscillations. Similar theories were formulated already in 17th century and all of them have as many followers as opponents. Most probably the observed periodical oscillations of meteorological and hydrological phenomena occur as a result of different regular cycles' overlapping. If it was possible to transfer the curve showing the variability of a hydrological element into a few component periodograms of known cyclicity, then the prediction of the element future changes would be relatively simple. Usually the curves presenting the course of a hydrological element do not show any cyclicity, even though they might consist of regular cycles. The synthetic curve hardly reflects its genesis. The attempts of transferring the course of an element into periodograms have been known since 19th century but this method is rather complicated and was not widely used.

Many results obtained by 1950s were positively verified later and supported with new findings, also based on new computer calculating techniques. We should mention here some works of climatologists from Cracow, concerning climate change, atmospheric circulation variability (e.g. Cebulak et al. 1996; Niedźwiedź 1993; Ustrnul 1997), air temperature variability (e.g. Kożuchowski 1985; Trepińska 1983), relation between global and local climate against the background of global climatic change (Obrębska-Starklowa et al. 1994; Obrębska-Starklowa 1995).

The cyclicity of climatic elements is still being investigated by many researchers and new cycles of different periodicity are being found. Suryjak (1974) obtained 5- and 2-year cyclicity in precipitation course for northern and central Poland. A very interesting attempt of defining the cyclicity of yearly and monthly precipitation's changes in a multi-annual period in Cracow in relation to atmospheric circulation was presented by Kożuchowski and Trepińska (1986). Using the so-called Furich criterion they obtained the sinusoid components equations of 2 to 10-year periodicity for monthly precipitation and of about 27-year periodicity for annual precipitation.

Łaszewski (1986) analysed the changes of mean annual river discharge in a long-term period and he found out that dry and wet years occur in a-few-year cycles, while a dry year follows a wet one very rarely.

3. Variability of Mean Annual River Discharge in Stróża River Gauge at the Raba River in Relation to Annual Precipitation in the Drainage Area

The variability of mean river discharge against the background of annual precipitation is presented here as potential water resources. Taking under consideration that the precipitation series in Stróża is rather short (1916-1999), all precipitation analyses are compared with similar ones for Cracow. The series for Cracow was compiled using the data from Astronomical Observatory of the Jagiellonian University, from Institute of Meteorology and Water Management in Cracow and from the work of Rybczyński et al. (1933). The river discharges data for Stróża were taken from 1957 as earlier observations are highly doubtful.

Basic analyses of precipitation were carried using the 11-year moving averages as to follow the cycle of sun spots. This method is well known and tested but more attention should be paid to defining the trend of changes. The precipitation observational series shorter than 200 years are not long enough to obtain unmistakable results.

If we analyse the course of annual precipitation in Cracow from 1852 to 1997 (Fig. 1) we can only state that there is a large dispersion of observations and we can define extreme values. The lowest values in the long-term period tend to remain at the same level, while the highest ones seem to decrease with time. This statement might be controversial as the highest values are not precisely defined. Further we can calculate the mean value for the whole series and 11-year moving averages values (Fig. 2). Figure 3 shows linear trends for: 1. Annual precipitation series; 2. Logarithmic

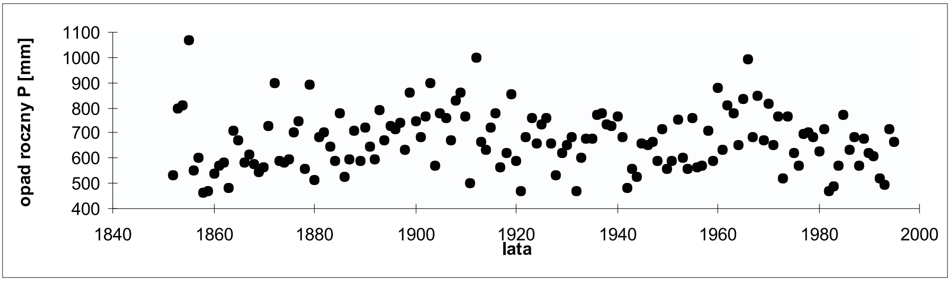

Fig. 1. Annual precipitation (P) course in Cracow in the years 1852-1997.

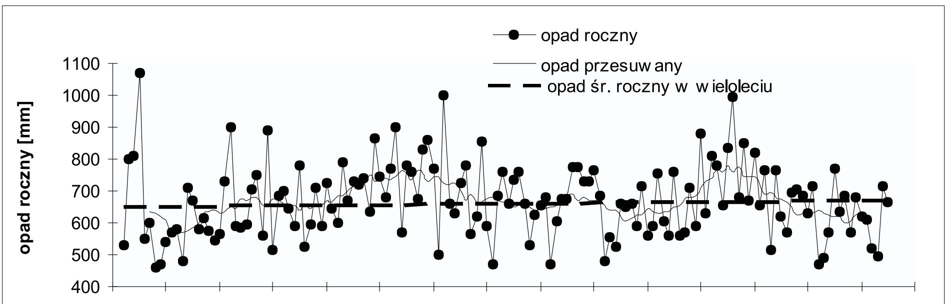

Fig. 2. The 11-year moving average of precipitation (thick line) in Cracow against the background of annual precipitation course (P) (dotted line) and the long-term mean value for the period 1852-1997 (dashed line).

values of annual precipitation series; 3. The trend according to multinomial curve for annual precipitation series in Cracow in 1852-1995. Linear trends "a" and "b" show the increase of annual precipitation of 30 mm per 143 years, while multinomial trend "c" shows the increase of water resources from 1852 up to 1930s and then their decrease up to the end of the analysed period. In a way it was proved by the flood of 1934 which was the largest one in the 20th century in the Carpathian part of the Vistula River's basin. We know, however, that such trend can hardly be accepted.

The linear trends might be further analysed by eliminating from the observational series the first 10 elements (Fig. 4). In all cases we obtain decreasing trends. The more elements are eliminated the more distinguished the trends are. However, if we eliminate the last 10 elements the trends become increasing and also they are the more significant the more elements are eliminated (Fig. 5). This proves the importance of basic assumptions accepted for such analyses: the series length and the values of the first and last elements. The longer the series the less sensitive it is to the trend deviations (due to accidental extreme values) from the general tendency. To reduce those deviations, the changes of tendencies should be analysed for the cycle starting and ending with the elements for which the moving average curve crosses the mean arithmetic value for all elements of the series, as presented in Figure 6. The trend line shows slight increase comparing to the mean long-term value.

The analysis of the moving average curve for annual precipitation in Cracow in the period 1852-1995 reveals the following features:
1. Major oscillations are separated by minor ones.
2. Maximum values of the oscillations appear every 30 years.
3. Minimum values of the oscillations occur every 20, then 40, then again 20 and 40 years.

4. The course of moving averages for annual precipitation in Cracow is similar to the periodogram obtained by Lambor

At present, it is not possible to determine the rules of annual precipitation prediction in Cracow, but we may not exclude the possibility of finding the basic cycles contributing to the annual precipitation course. It would enable to prepare qualitative and maybe even quantitative predictions of wet and dry years.

Comparing the precipitation observational series for Stróża with the one for Cracow (Fig. 7), especially their moving average curves, it can be stated that the precipitation variability in both places is very similar. Therefore we can assume that also in those years when there were no observations in Stróża the similarity for both sites was the same.

The analysis of the course of potential water resources in the Raba River in Stróża river gauge includes mean annual river discharges. The relation between the maximum annual river discharge and annual precipitation is of no importance and therefore is not analysed here.

Comparing mean annual and moving averages of river discharges in Stróża (Fig. 8) with the annual precipitation moving averages for Stróża (Fig. 7) and Cracow (Fig.

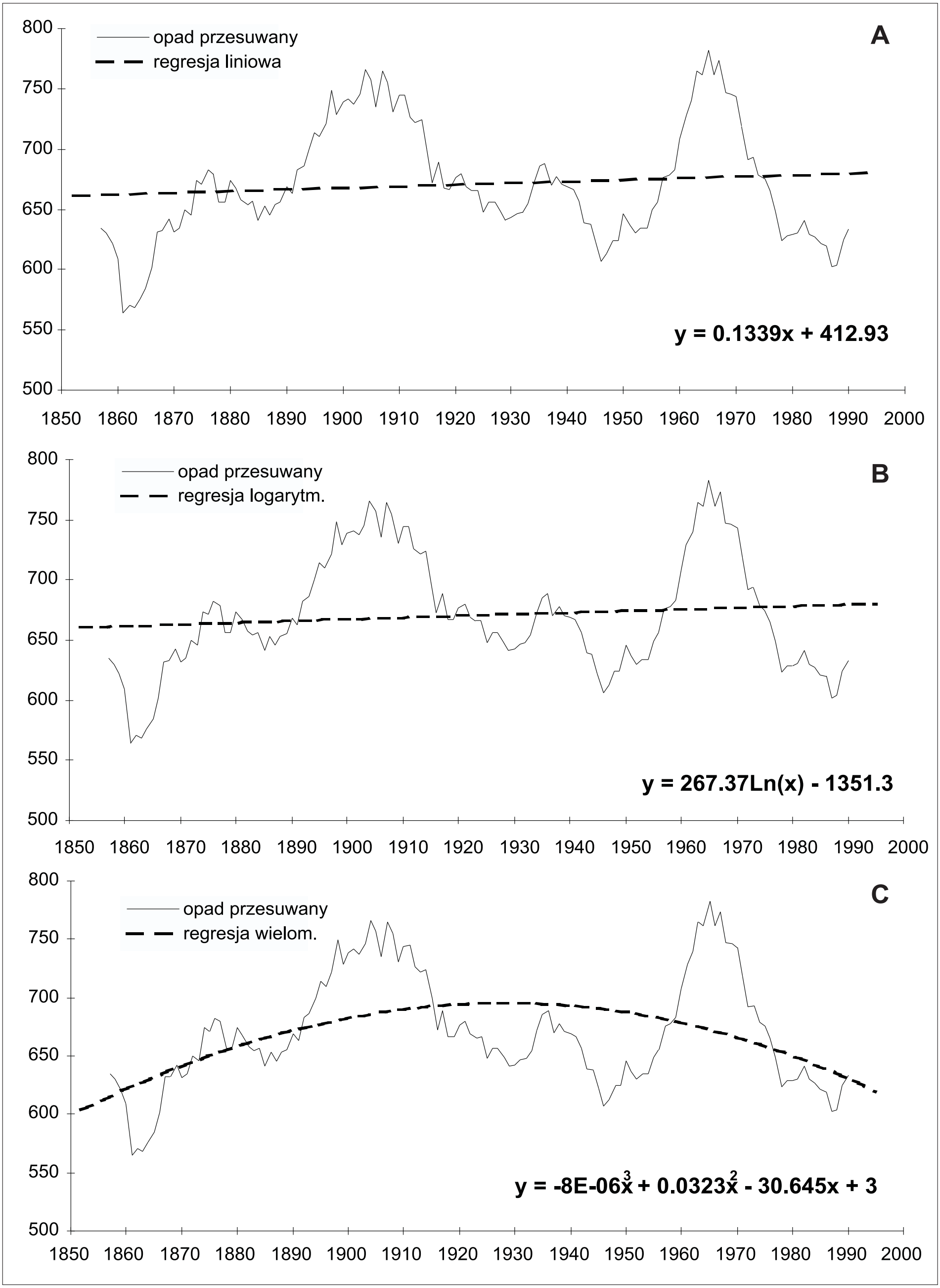

Fig. 3. Chosen trends of annual precipitation changes in Cracow in the period 1852-1997. Solid line: 11-year moving average; dashed line: a) linear regression, b) logarithmic regression, c) multinomial regression.

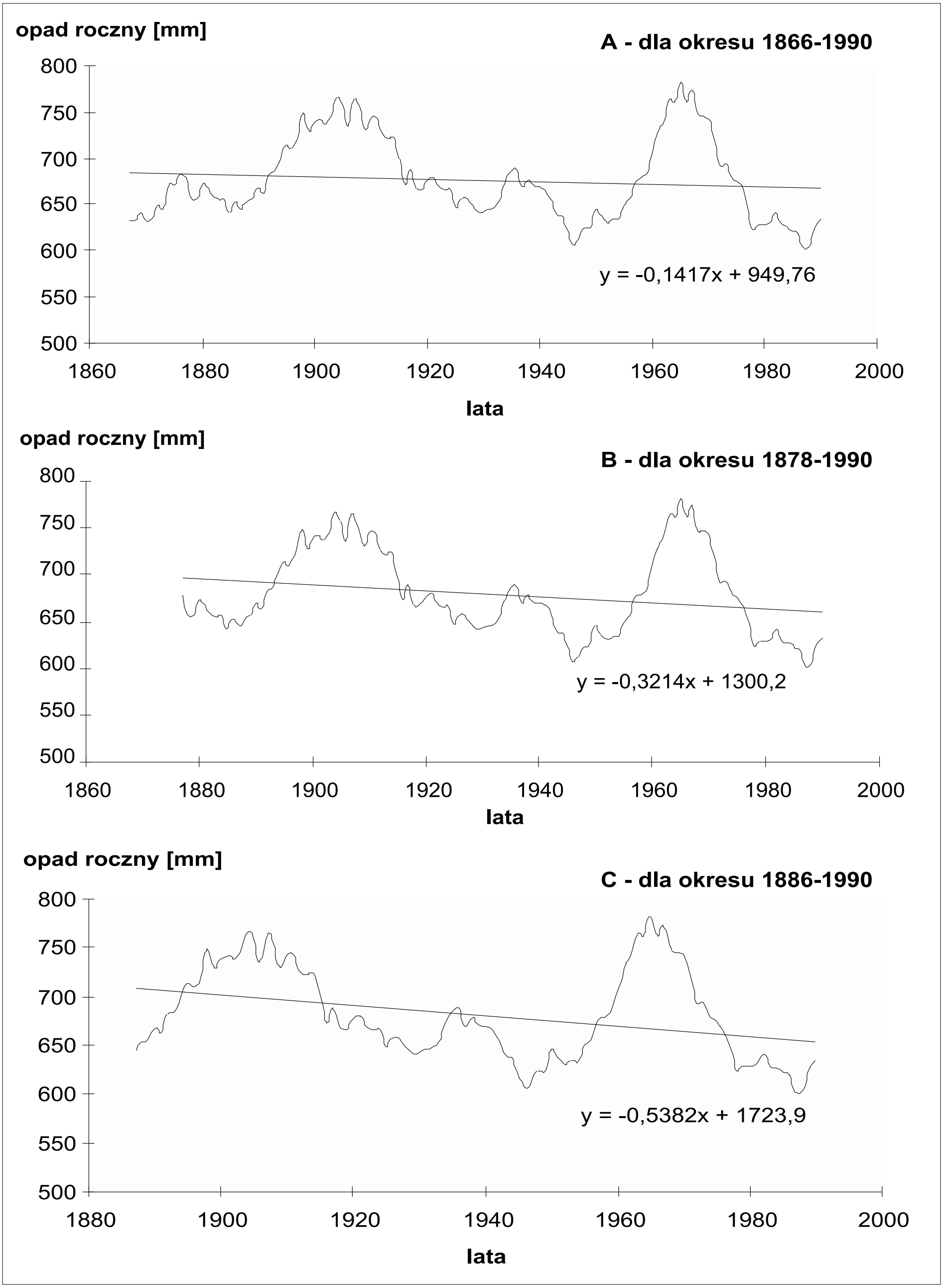

Fig. 4. Linear trends of annual precipitation changes in Cracow in the period 1852-1997 for the observational series with eliminated 10 (a), 20 (b) and 30 (c) first elements against the background of moving averages curve.

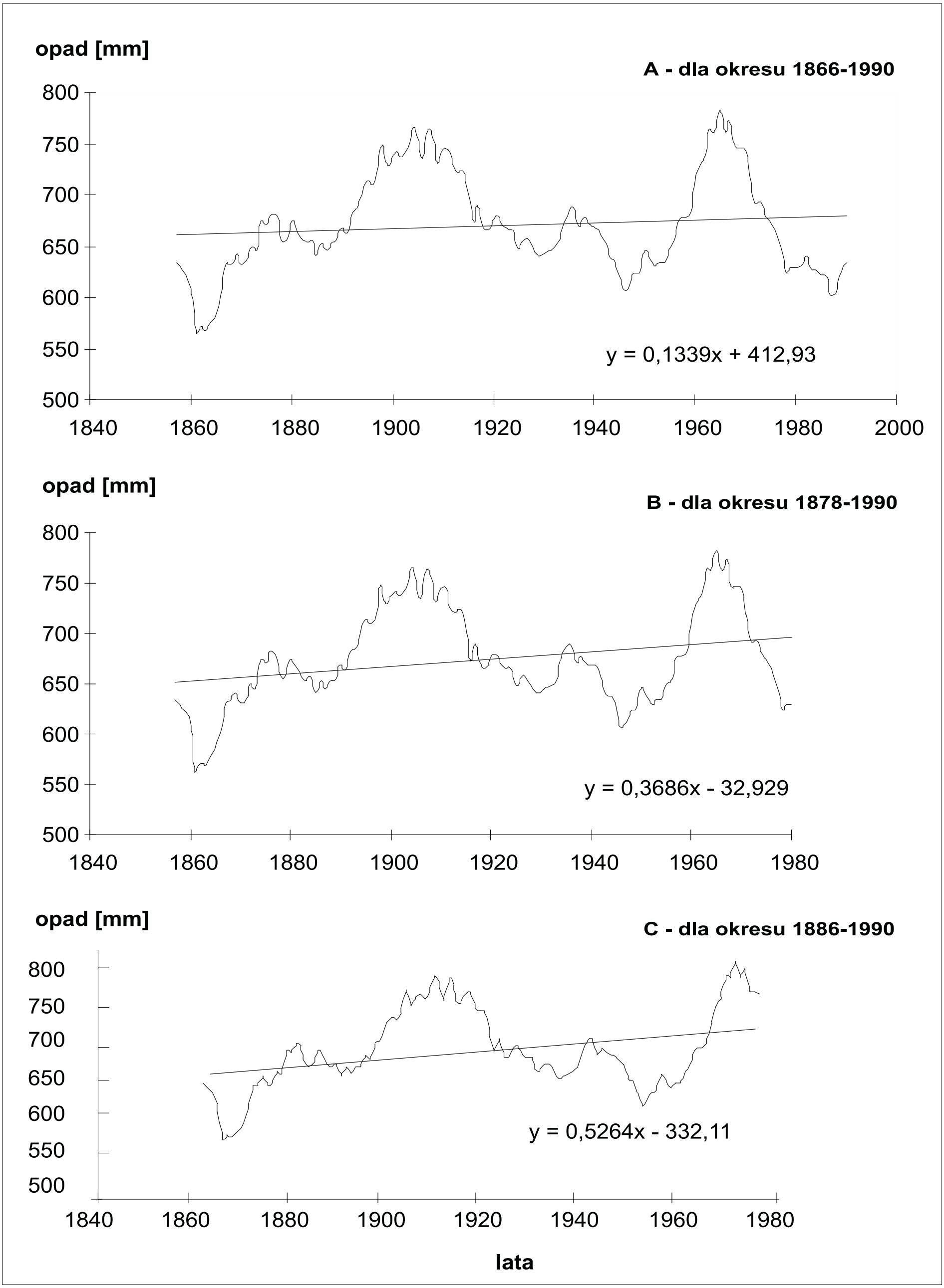

Fig. 5. Linear trends of annual precipitation changes in Cracow in the period 1852-1997 for the observational series with eliminated 10 (a), 20 (b) and 30 (c) last elements against the background of moving averages curve.

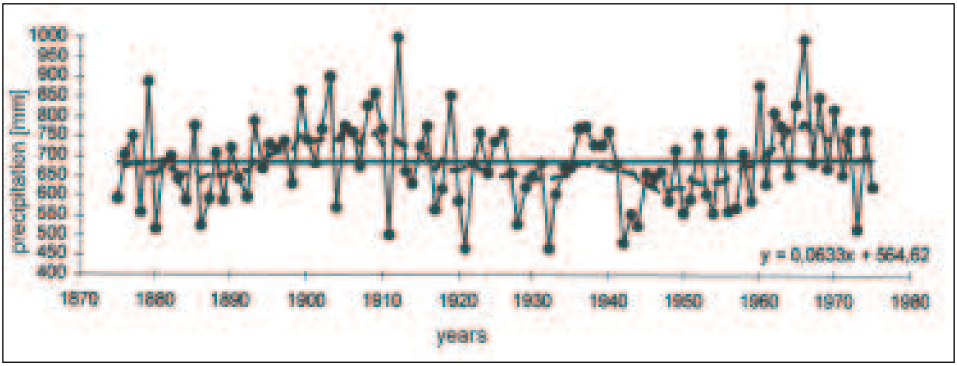

Fig. 6. Trend line of annual precipitation in Cracow in the period 1875-1975 with the moving averages curve (dashed line), starting and ending with the value of mean annual precipitation sum for long-term period.

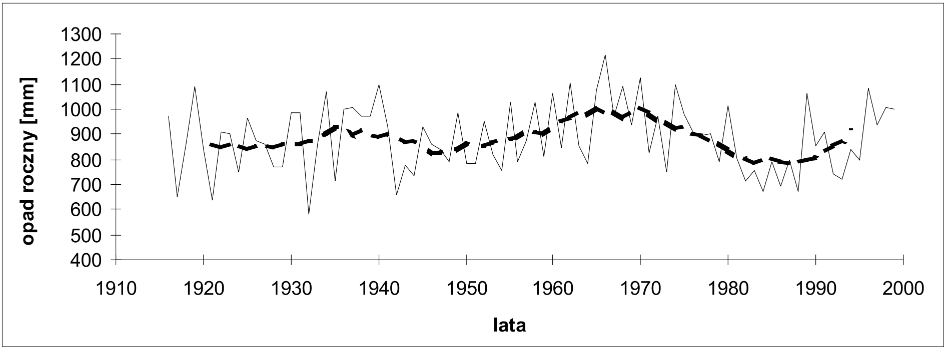

Fig. 7. Annual precipitation (solid line) course in Stróża in the period 1916-1999 and the 11-year moving averages (dashed line).

2) it can be stated that the cyclicity is similar. However, the moving average curve for river discharges is slightly shifted to the right, which suggests that the drainage area retention delays the occurrence of runoff in relation to the precipitation causing it. Figure 9 proves that there is a strong connection between the annual precipitation and mean annual river discharge. Including additional factors, e.g. the influence of ground water retention would undoubtedly make the connection stronger.

Mean annual river discharge variability trends are similar to annual precipitation's trends. We may also expect that the cyclicity of annual river discharges and annual precipitation is similar.

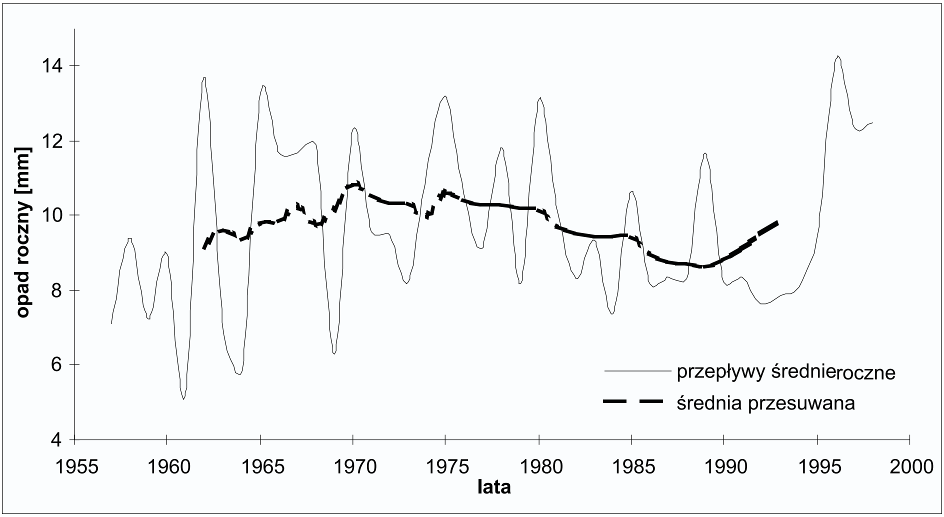

Fig. 8. Variability of annual river discharges (SQ) and their 11-year moving averages (dashed line) in Stróża in the period 1957-1998.

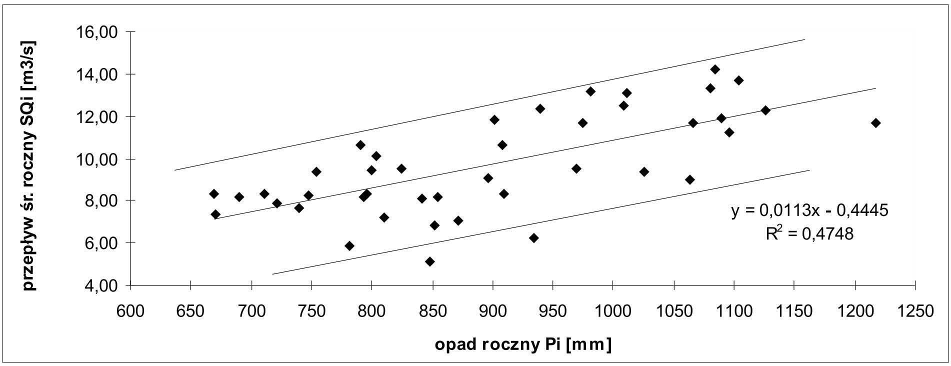

Fig. 9. Relation between the mean annual river discharge, SQ_i, and precipitation, Pi, for Stróża in the period of 1957-1998.

4. Conclusions

The analysis of the course of potential water resources, defined as annual precipitation and river discharge, for Stróża in the Raba River drainage area, against the background of annual precipitation course in Cracow, indicates that it is possible to define the variability of the mentioned elements:

1. The tendencies of long-term changes should be evaluated taking under consideration the observational series beginning and ending at the crossing point of moving average curve and mean long-term value of precipitation. It is of great significance for short-period series.

2. There is a certain cyclicity in the course of analysed elements but it probably consists of a few overlapped sinusoidal cycles and one of the cycles is alike to be linked with sun spots number changes.

3. The research on the variability and cyclicity of analysed elements should be continued as it may enable at least qualitative predicting of potential water resources which is of great economic importance.

References

Cebulak E., Czekierda D., Falarz M., Niedźwiedź T., Ustrnul Z., 1996, *Climate Variability in Poland During Last 45 Years*, [in:] *Proceedings of the International Conference on Climate Dynamics and the Global Change Perspective*, October 17-20 1995, Zesz. Nauk. UJ, Prace Geogr., 102, 395-402.

Kożuchowski K., 1985, *Zmienność opadów atmosferycznych w Polsce w stuleciu 1881-1980*, Acta Geogr. Lodz., 48.

Kożuchowski K., Trepińska J., 1986, *Fluktuacje opadów atmosferycznych w Krakowie w okresie 1881-1980*, Zesz. Nauk. UJ, Prace Geogr., 64, 7-20.

Lambor J., 1962, *Metody prognoz hydrologicznych*, WKiŁ, Warszawa.

Łaszewski J., 1986, *Kilkuletnie cykle lat suchych i mokrych*, Gosp. Wodna, 2 (449), 38-39.

Niedźwiedź T., 1993, *Changes of Atmospheric Circulation (Using the P, S, C, M Indices) in the Winter Season and their Influence on Air Temperature in Cracow*, [in:] *Early Meteorological Records in Europe: Methods and Results*, Zesz. Nauk. UJ, Prace Geogr., 95, 107-114.

Obrębska-Starklowa B., 1995, *Differentiation of Topoclimatic Conditions in Carpathian Foreland Valley Based on Multi-Annual Observations*, Zesz. Nauk. UJ, Prace Geogr., 101.

Obrębska-Starklowa B., Olecki Z., Trepińska J., 1994, *The Diagnosis of Climate Change in Cracow against a Background of Circulation and Local Conditions*, Geogr. Polon., 63, 51-62.

Rybczyński M., Pomianowski K., Wóycicki K., 1933, *Hydrologja cz. I*, Komisja Tow. Bratniej Pomocy Studentów Politechniki Warszawskiej, Warszawa.

Suryjak W., 1974, *Wystąpienie cykliczności pięcioletniej i quasidwuletniej w przebiegu sum opadów dla Polski północnej i środkowej*, Wiad. IMGW, 2-3, 75-87.

Trepińska J., 1983, *Climatic Fluctuation in Cracow City 1926-1975*, Geog. Pol., 45, 59-70.

Trepińska J., 1993, *Meteorological Observations Carried out by Jan Śniadecki at the Astronomical Observatory of Jagiellonian University*, [in:] *Early Meteorological Records in Europe: Methods and Results*, Zesz. Nauk. UJ, Prace Geogr., 95, 35-40.

Ustrnul Z., 1997, *Zmienność cyrkulacji atmosfery na półkuli północnej w XX wieku*, Mat. Bad. IMGW, seria Meteorologia, 27, Warszawa.

Bolesław Osuch
Institute of Water Engineering
Cracow University of Technology
Cracow
Poland