

**CLIMATE CHANGE IN THE UKRAINIAN CARPATHIANS AND
ITS POSSIBLE IMPACT ON RIVER RUNOFF**

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Based on the results of regular monitoring at 11 meteorological stations in the Ukrainian Carpathians, it was discovered a vivid tendency of air temperature increase. It was defined that thermal gradient in the mountains is much less than it is in the free troposphere; at the small altitude it is larger than it is on the tops of mountains. The largest gradient it is observed in period from March till July, the lowest one in period from November till January. It was revealed the cyclical fluctuations of precipitation, in particular the existence of a modern dry phase. There is a tendency of decrease in wind speed during all seasons, which is more evident in the second part of year. There is also the increase in snow cover depth at high altitude. In spite of climate change the river runoff has not changed essentially for the last decades. Like the precipitation the river runoff is of a cyclic nature too. During the last four decades the increase in evaporation, calculated on the base of water balance, has been observed. There is the tendency of runoff increase in a cold period at the large altitude. In turn the water runoff of rivers, located on low-mountain terrain, decreases in the summer period.

KEY WORDS: air temperature, precipitation, snow cover, river runoff, the Ukrainian Carpathians

Introduction

The impact of climate change on the river runoff is a very popular issue of scientific studies, which is considered in many scientific papers (Blöschl et al., 2017; Didovets et al., 2019; Duethmann and Blösch, 2018; Gorbachova et al., 2018; Halmová and Pekarová, 2020; Holko et al., 2020; Loboda and Kozlov, 2020; Kubiak-Wojcicka, 2020; Mostowik et al., 2019; Spinoni et al., 2015; Stagl and Hattermann, 2015; Szolgay et al., 2020). The changes of runoff are caused by many factors, i.e. air temperature, the amount of precipitation, evaporation, etc. The essential problem is to clarify the role of different factors, which impact is simultaneous and different by consequences. This problem is more difficult when it comes to the conditions in mountain areas due to the lack of observation at high altitudes. Under these conditions the obtained results are not often very clear and certain. In many cases the changes in meteorological and hydrological parameters are not statistically proved. Some authors consider (Gorbachova, 2015; Obodovskiy and Lukianets, 2017; Zabolotnia et al., 2019) that even having essential increase in air temperature the time series of annual runoff are stationary with long-term cyclical fluctuations. There is a point of view that the cyclical fluctuations are caused by solar activity and other factors, which refer the Earth in a whole (Fendekova et al., 2018).

So, the main goal of this study is to specify the changes

in river runoff in the Ukrainian Carpathians and the role of different factors influencing these changes.

The study area

The study area covers the territory of the Ukrainian Carpathians, which is the central part of the Carpathian Mountains. The total length of these mountains is about 240 km, the width is 50 km, the largest altitude is 2061 m a.s.l. (Hoverla Mountain). The characteristic feature of these mountains is the presence of ridges, which go almost parallel to each other. The highest ridge, where Hoverla Mountain is located, has the name of Chornohora or Chornohirskiy Ridge. The volumetric image of the Ukrainian Carpathians, created on the base of Shuttle Radar Topography Mission (SRTM) digital elevation model, is shown in Fig. 1.

Methodology and data

There is about a dozen meteorological stations in the Ukrainian Carpathians, located at the different altitudes. Among these stations only two ones are located at the rather high altitude. The first station Plai is located on the southwestern macroslope of the mountains; its altitude is 1331.5 m. The second station Pozhezhevska with the altitude of 1451 m is located on the northeastern macroslope. The other stations are located at low-mountain terrain; their altitudes range 432.1–762.5 m

(Table 1).

Among many variables measured at these stations, the main ones are air temperature, precipitation, wind speed and snow cover depth. The period of 1961–2019 was taken for the study. In many cases the data for the periods of 1961–1990 and 1991–2019 were analyzed separately. The same approach was carried out in the study (Rožnovský et al., 2020).

The factor that can impact on air temperature and other parameters, is the difference in geographical latitude and longitude of the meteorological stations. In both cases it exceeds 1° . Thus, the meteorological station Turka has the coordinates as $N49^\circ09'01''$ and $E23^\circ01'47''$, while the meteorological station Seliatyn – $N47^\circ52'36''$ and

$E25^\circ12'59''$. The significance of geographical latitude was studied on the base of regression analyze. It was found out that the impact of latitude on air temperature is very small. In most cases the correction is less than 0.1°C , i.e. it is equal to the measurement accuracy. That is why the actual data were operated without any correction. In our opinion such small impact of geographical latitude on air temperature can be explained the mountains extend from northwest to southeast. In case of their extend from southwest to northeast the impact of latitude would be obvious. It is well known that in a whole air temperature in Europe decreases when moving from southwest towards northeast.

The data on river runoff at the hydrological network were

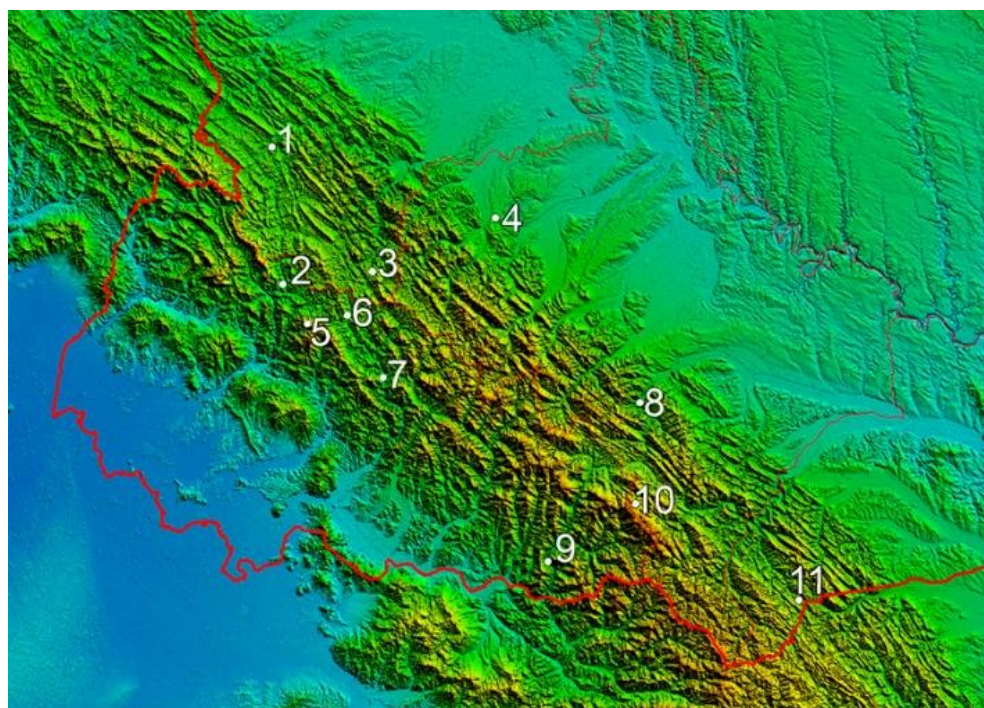


Fig. 1. Volumetric image of the Ukrainian Carpathians with the location of meteorological stations: 1 – Turka, 2 – Nyzhni Vorota, 3 – Slavske, 4 – Dolyna, 5 – Plai, 6 – Nyzhnii Studenyi, 7 – Mezhihiria, 8 – Yaremche, 9 – Rakhiv, 10 – Pozhezhavska, 11 – Seliatyn.

Table 1. Meteorological stations in the Ukrainian Carpathians and their altitudes

№	Name	Altitude [m a.s.l.]
1	Turka	592.4
2	Nyzhni Vorota	488.7
3	Slavske	593.6
4	Dolyna	467.6
5	Plai	1331.5
6	Nyzhnii Studenyi	611.4
7	Mezhihiria	455.4
8	Yaremche	531.3
9	Rakhiv	432.1
10	Pozhezhavska	1451
11	Seliatyn	762.5

analyzed as well. The hydrological parameters of rivers, which neither small no large, were processed. The features of water runoff of the rivers, located on the different macroslopes in the Ukrainian Carpathians were studied. An important issue, which was considered, is the differences in river basin altitude. The annual and monthly data were processed. The annual data was studied for the whole observation period, the monthly ones – for 1961–2019. In many cases the data for the periods of 1961–1990 and 1991–2019 were analyzed separately. Correlation and regression analysis were used in the study. To determine the spatio-temporal fluctuations of the precipitation and river runoff the residual mass curves were drawn.

Results and discussion

Air temperature

Air temperature is the main climatic parameter, which is paid the largest attention of scientists. Similar to many places in the world, in the Ukrainian Carpathians there is

a tendency to increase in air temperature. That refers to both low and high altitude stations (Fig. 2).

As can be seen on Fig. 2, the lowest temperature was observed in 1980, the highest one in 2019 (for most stations) and in 2014 for the two ones, located at the largest altitude. During the observed period, starting since 1961, the increase in mean air temperature is about 2 °C. The mean air temperature at all 11 meteorological stations during 1961–1990 was 5.6 °C, and during 1991–2019 it was 6.6 °C.

It is important to note that the increase in air temperature is registered in all seasons. The largest increase is observed in January and in August. In the last decades the mean air temperature in August has become almost the same as it is in July. The smallest increase is observed in autumn period (Fig. 3).

The similar results as to the seasonal features were described in many other papers (Grebin, 2010; Rangwalla and Miller, 2012; Spinoni et al., 2015). The study (Rangwalla and Miller, 2012) showed that in the Swiss Alps the rate of temperature rise in autumn period is less, than it is in other seasons. Possible

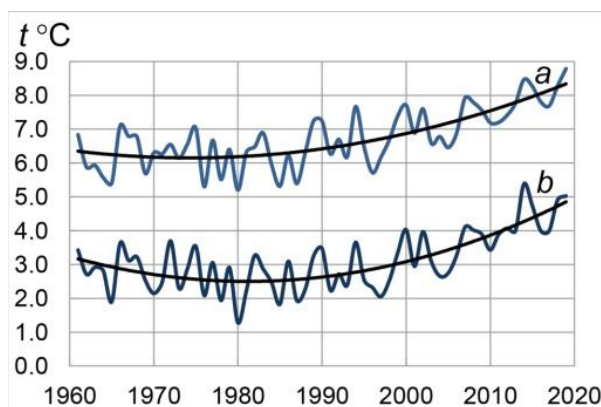


Fig. 2. The increase in mean annual air temperature in the Ukrainian Carpathians during 1961–2019: a) – at 9 meteorological stations, located at the low altitude, b) – at two ones, located at the high altitude.

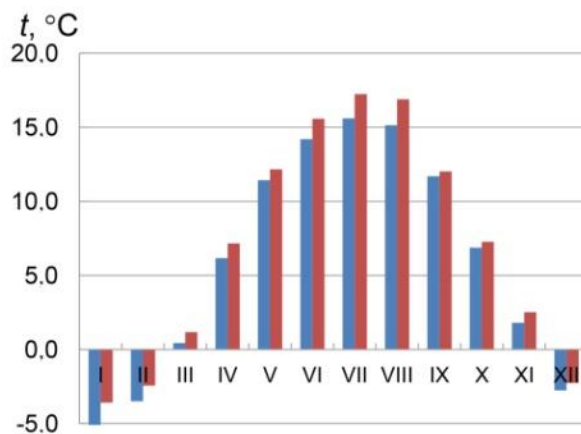


Fig. 3. The mean monthly temperature at 11 meteorological stations in the Ukrainian Carpathians: left columns – during 1961–1990, right columns – during 1991–2019.

differences in our and others' findings can be explained by the different observation periods taken for the studies. The last years in Europe were much warmer than there were at the beginning of observations.

The seasonal increase in air temperature depends on altitude of the meteorological stations. The increase in temperature in January (the coldest month of the year) at the stations, located at a rather small altitude, in most cases was in the range of $0.5\text{--}0.6^\circ\text{C}$ per decade. In turn at the highest stations Plai and Pozhezhevskaya the increase is much less – $0.15\text{--}0.2^\circ\text{C}$ per decade. Taking into account the essential variability of air temperature in January it is possible to say, that at high altitude the temperature has not changed. The increase in air temperature in August at the studied meteorological stations has a range of $0.5\text{--}0.6^\circ\text{C}$ per decade.

The changes in mean temperature by altitude are uneven as well. At low altitude the decrease is more essential, than at a higher one (Fig. 4).

During the period 1961–1990 the mean air temperature at the altitudes 500, 1000 and 1500 and 2000 m was the following: 6.4, 3.8, 2.4 and 1.4°C . During 1991–2019 the mean air temperature became higher. At the above mentioned altitudes it was 7.5, 4.7, 3.3 and 2.2°C .

The gradient of mean air temperature at the altitudes

500–1000 m, 1000–1500 and 1500–2000 m during the first period was 0.52, 0.28, and 0.20°C per 100 m, during the second one it was 0.56, 0.28 and 0.22°C per 100 m. The obtained result essentially differs from those ones, which are based on the aerological study. It is well known that a thermal gradient in the troposphere is about 0.6°C per 100 m and it is almost stable along the first kilometers from the earth surface. In particular, such results of the aerological study were obtained in the Western Ukraine (Kablak, 2007). In the mentioned study it was also clarified that thermal gradient in winter is slightly smaller than it is in summer time.

Based on the available data the mean air temperature during 1991–2019 was calculated for each month and at different altitude (Fig. 5).

Fig. 5 indicates that at high altitude, i.e. on the tops of the mountains, the warmest month is August. During the year, the gradient of air temperature by altitude is uneven. The largest thermal gradient is observed in period of March–July, when the difference in air temperature at the altitudes 1000 and 2000 m is equal to $0.33\text{--}0.36^\circ\text{C}$ per 100 m. The lowest gradient ($0.15\text{--}0.18^\circ\text{C}$ per 100 m) is observed in the period of November–January.

It is worth noting that, according to the obtained data,

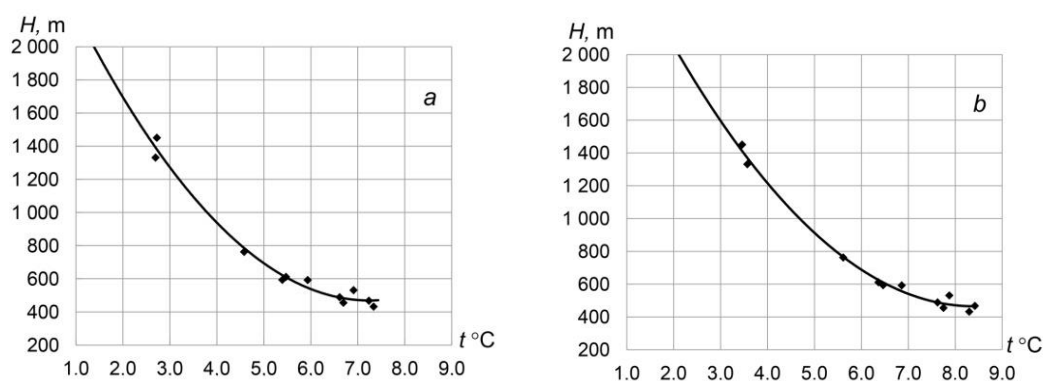


Fig. 4. The dependence of mean air temperature in the Ukrainian Carpathians on altitude: a) – during 1961–1990, b) – during 1991–2019.

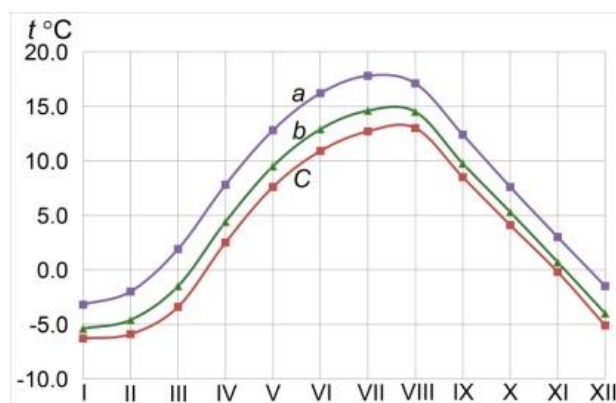


Fig. 5. The monthly mean air temperature in the Ukrainian Carpathians during 1991–2019 at different altitudes: a) – 500 m, b) – 1000 m, c) – 1500 m.

the gradient of air temperature by altitude in the Ukrainian Carpathians is smaller than it is in many studies in other regions (Rangwala and Miller, 2012; Rolland, 2003; Wang et al., 2017). To some extent it can be explained by the relief of the studied region, characterized by rather gentle slopes.

Precipitation

The precipitation in the Ukrainian Carpathians is uneven in space and in time. It depends on altitude and location of the meteorological stations as to the mountains ridges. The largest precipitation is observed at meteorological stations Plai and Pozhezhevskya, which altitudes are the highest. The mean precipitation during the period of 1991–2019 at Plai station was 1456 mm, at Pozhezhevskya one – 1525 mm. At the same time the lowest precipitation is observed at the meteorological stations Dolyna (901 mm) and Seliatyn (853 mm) located on the northeastern macroslope of the mountains. There is a dependency of precipitation on altitude, but not very close – the precipitation increases by about 1 mm per meter of altitude.

The lowest precipitation (the mean value is 828 mm) at all 11 meteorological stations was observed in 1961, the highest one (1579 mm) was in 1998.

During 1961–2019 the amount of precipitation did not change significantly. In our view, these changes are in the form of two cyclic fluctuations with the period of about 30 years having wet and dry phases. The last cycle started in the beginning of the 1990s and it is likely will finish in 2022–2025. Nowadays it is observed the dry phase, which started in 2011 (Fig. 6).

The mean annual precipitation at all 11 meteorological stations in 1961–1990 was 1101 mm, and in 1991–2019 it was 1124 mm. It can be assumed that when the dry phase will finish, the amount of precipitation in both periods will be the same. The comparison of data for 1961–1990 and 1991–2019 shows a small tendency in increasing the precipitation in the cold period from September till March. During the last three decades it is observed the decrease in precipitation in summer time, primarily in June. This feature refers both low-mountain terrain and a rather large altitude where the meteorological stations Plai and Pozhezhevskya are located (Fig. 7).

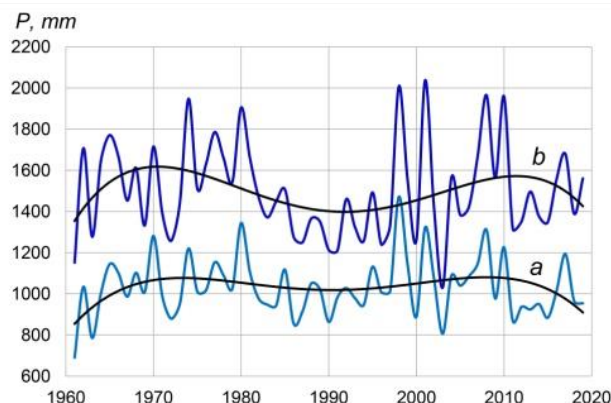


Fig. 6. The changes in mean annual precipitation in the Ukrainian Carpathians: a) – at 9 meteorological stations, located at low attitude, b) – at two ones, located at high attitude.

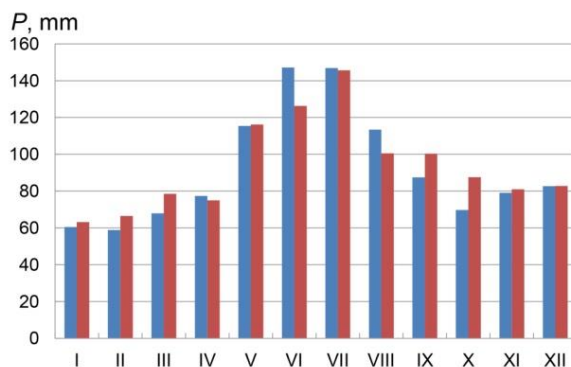


Fig. 7. The intra-annual distribution of precipitation at 11 meteorological stations in the Ukrainian Carpathians: left columns – during 1961–1990, right columns – during 1991–2019.

The similar results for the studied region and the periods from the beginning of observation till 1988 and for the period of 1989–2008 were obtained in the paper (Grebin 2010). The tendency of increasing winter precipitation is observed in the Bieszczady Mountains, located to the northwest from the Ukrainian Carpathians (Mostowik et al., 2019).

Relative humidity

The mean relative humidity at the meteorological stations, located in the Ukrainian Carpathians, is about 80 %. The largest value is observed in December, the lowest one in April and May. The similar results were obtained for the adjacent areas of the Carpathian Mountains (Marin et al 2014, Spinoni et al 2015). During the observation period there is a small tendency of decreasing relative humidity at about 0.15 % per decade. This decrease can be considered as a consequence of air temperature increasing.

Wind speed (WS)

During the observation period there was a tendency of decreasing wind speed. In 1961–1990 its mean value at 11 meteorological stations was 2.5 m/sec, in 1961–2019 it was 2.1 m/sec. The mean annual decrease in wind speed is about 0.14 m/sec per decade. It means that during the analyzed period the mean wind speed decreased in a whole at about 0.8 m/sec (Fig. 8).

The similar results as to the decrease in wind speed were obtained in many other regions of the world including the Carpathian Mountains (Guo et al., 2011; Marin et al., 2014; Spinoni et al., 2015). It is likely this decrease is considered to be a global tendency.

This decrease is observed throughout the year, but in the second part of the year it is the most essential (Fig. 9). The data referring air temperature, precipitation and wind speed show that the most suitable month for tourism activities in the Ukrainian Carpathians is August. In this

time the air temperature is the highest and the wind speed is the lowest. August is also characterized by a relatively small amount of precipitation.

Snow depth

This parameter, like precipitation, has the essential impact on the river runoff. Snow depth depends on altitude of the meteorological stations, their location as to the mountain ridges, precipitation in cold period and to some extent on geographical latitude and longitude.

The largest snow depth is observed at the meteorological stations Plai and Pozhezhevsk, which altitudes are the highest. During 1991–2019 the mean snow depth at the meteorological station Plai in the third decade of February, when it is the largest, is 46 cm. In turn the mean snow depth at the meteorological station Pozhezhevsk in the third decade of March, when it is the largest, reaches 42 cm. The mean snow depth among the largest measured values at these meteorological stations is 73 and 78 cm respectively.

During 1991–2019 the largest snow depth was registered at the end of the cold and snowy winter of 1998/1999. That winter the mean snow depth among the largest measured ones at 11 stations was 106 cm. The lowest value was observed in winter 2015/2016, when it was 20 cm.

The available data show that despite the increase in air temperature (primarily at small altitudes), the snow depth increases as well. The most essential increase is observed in February, March and the first half of April. During 1961–1990 the mean snow depth at 9 meteorological stations in low-mountain terrain, when it is the largest, was 17 cm, during 1991–2019 it was 18 cm. The more essential changes are observed at the meteorological stations Plai and Pozhezhevsk, located at the highest altitudes, – correspondingly 33 and 42 cm (Fig. 10).

Nowadays the largest snow cover is observed some later, than it was before. In our view the increase in snow depth at two meteorological stations, located at the highest

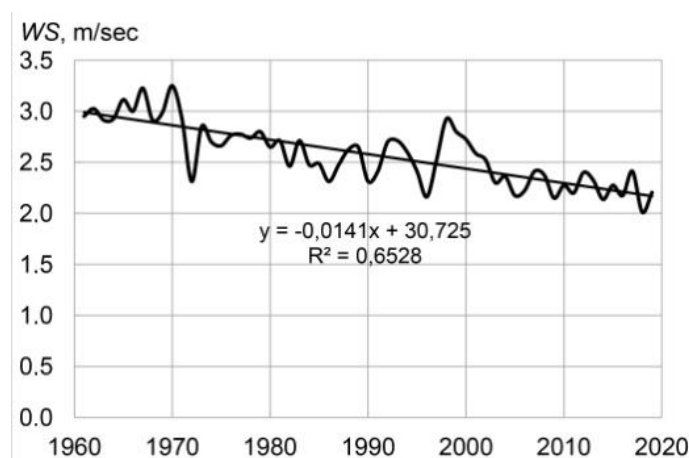


Fig. 8. The changes in mean wind speed at 11 meteorological stations in the Ukrainian Carpathians.

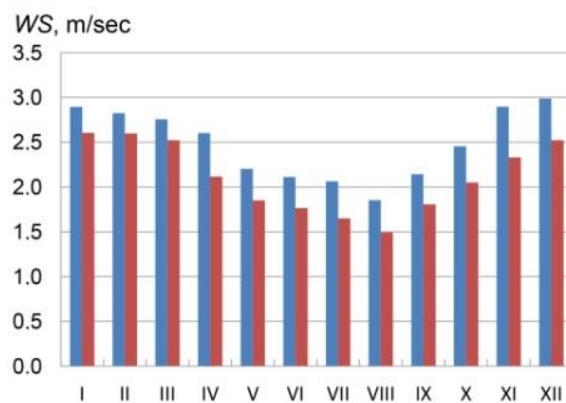


Fig. 9. Wind speed at 11 meteorological stations in the Ukrainian Carpathians: left columns – during 1961–1990, right columns – during 1991–2019.

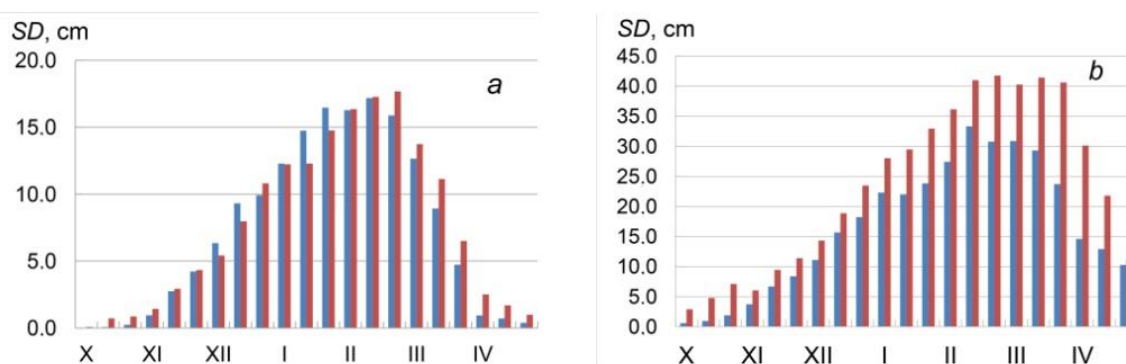


Fig. 10. The mean snow depth in the Ukrainian Carpathians: a) – at 9 meteorological stations in low-mountain terrain, b) – at highest Plai and Pozhezhevskaya stations; left columns – during 1961–1990, right columns – during 1991–2019.

altitudes, is caused by the precipitation increase in cold period. It should be noted that at these meteorological stations the changes in air temperature in winter are not significant and are statistically unreliable.

Another reason for the increase in snow depth at the Plai and Pozhezhevskaya meteorological stations, located on the mountain tops, may be the decrease in wind speed. At high wind speeds snow mainly accumulates in the lower parts of the area. Now that the wind speed has decreased, its depth has become more uniform.

The meteorological stations Plai and Pozhezhevskaya are characterized not only by the largest snow cover, but also by its longest duration. For example, in the first decade of October, the presence of snow has a probability of 28–30%.

River runoff

There are some dozens of gauging stations on the rivers of the Ukrainian Carpathians. In most cases the observation of river runoff was started in the middle of 20th century. For analyzing of water runoff the data of 8 rivers, which are not small and not large, were analyzed. The studied rivers are located evenly by territory. Four rivers basins are located on

the southeastern macroslope of the mountains (Bila Tysa – Luhi, Teresva – Ust-Chorna, Rika – Mezhihiria, Latoritsa – Pidpolozzia) and four ones (Stryi – Matkiv, Limnitsa – Osmoloda, Prut – Yaremche, Chorna Tysa – Verkhovyna) – on the northeastern macroslope. It is important that the data of all selected rivers practically do not have the observation gaps. The catchment areas of the selected rivers range from 106 km² (Stryi – Matkiv) to 657 km² (Chorna Tysa – Verkhovyna). The range of altitudes of the river basins is 720–1200 m with a mean value of 1009 m. The range of runoff depth is 666–1050 mm with a mean value of 842 mm (Table 2). The river runoff at all studied gauging stations is characterized with the essential variability, both annual and seasonal. There is no tendency in increasing or decreasing in annual values of water discharge or runoff depth during the observation period. At the same time it can be observed two cycles similar to precipitation (Fig. 11).

As it can be seen, the Fig. 6 and Fig. 11 are rather similar. It means that precipitation plays an essential role in river runoff formation. The correlation coefficient between the mean annual runoff depth (RD) of 8 studied rivers and the mean annual precipitation reaches 0.90 (Fig. 12). This result was confirmed by the use of correlation and

regression analyses. The effect of air temperature on river runoff is reverse and rather small. Nevertheless taking into consideration this factor this dependence becomes closer with a correlation coefficient of 0.95.

Comparing the available precipitation and runoff depth data, one should take into account the essential differences in mean altitude of meteorological stations

(702 m) and studied river basins (1009 m). It means that actual precipitation in the studied river basins is larger, than average values of measured data. Based on the dependence of precipitation on altitude, it can be considered that it is 1.1–1.2 times larger than the mean values at the studied meteorological stations.

Many authors (Gorbachova, 2015; Obodovskyi and

Table 2. The main hydrological parameters of the selected rivers in the Ukrainian Carpathians

River	Gauging station	Area of river basin [km ²]	Average altitude of river basin [m a.s.l.]	Average discharge 1961–2019 [m ³ ·s ⁻¹]	Runoff depth [mm]
Bila Tysa	Luhi	189	1200	5.09	849
Teresva	Ust-Chorna	572	1100	18.3	1009
Rika	Mezhihiria	550	800	13.6	780
Latoritsa	Pidpolozzia	324	720	9.25	900
Stryi	Matkiv	106	860	2.69	800
Limnitsa	Osmoloda	203	1200	6.76	1050
Prut	Yaremche	597	990	12.6	666
Chorna Tysa	Verkhovyna	657	1200	14.2	682

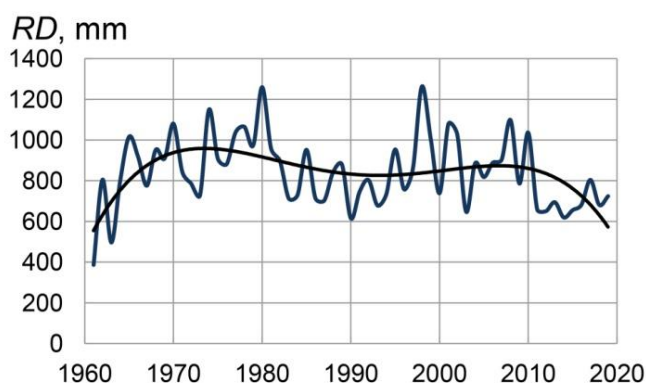


Fig. 11. The changes in annual runoff depth at 11 gauging stations.

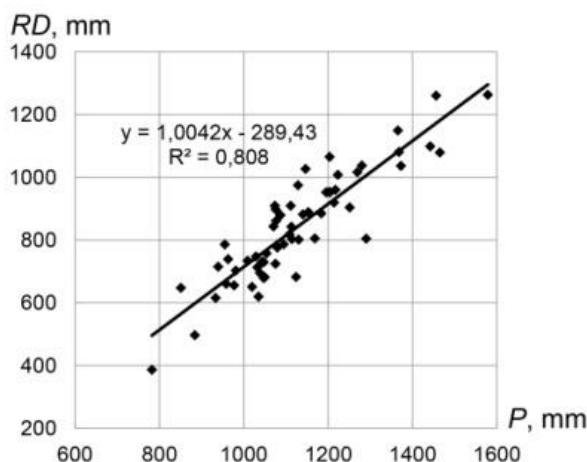


Fig. 12. The dependence of mean runoff depth of 8 studied rivers (Bila Tysa – Luhi, Rika – Mezhihiria, Teresva – Ust-Chorna, Latoritsa – Pidpolozzia, Stryi – Matkiv, Limnitsa – Osmoloda, Prut – Yaremche, Chorna Tysa – Verkhovyna) in the Ukrainian Carpathians on mean annual precipitation at 11 meteorological stations.

Lukianets, 2017) found out that the river runoff in this region is of a cycle nature. The duration of the cycles determined in the paper (Obodovskyi and Lukianets, 2017) is 29 years, which is practically equal to our findings.

There is a point of view (Duethmann and Blösch, 2018) that during four last decades the tendency of evaporation increase is observed. This result is based on the calculation of water balance made for the territory of Austria, mainly covered by mountains. The available data, collected for the Ukrainian Carpathians, enable to evaluate these changes as well. The calculations were carried out in two ways. The first one was based on precipitation data at 11 studied meteorological stations and water discharge of 8 studied rivers. It was found out that the calculated evaporation at the beginning of the observation had the tendency to decrease and during the last decades – to increase.

The more reliable result was obtained with the use of the data from the Prut River basin within which two meteorological stations Pozhezhevska and Yaremche are located. It is important that average altitude of this river basin (990 m) coincides with the mean altitude of these stations (991 m). During 1961–2019 the actual precipitation at these stations was 1473 and 968 mm respectively. The mean precipitation value for these two stations was 1220 mm, the mean runoff depth was 666 mm. It means that mean evaporation in this river basin was 554 mm and runoff coefficient was 0.55.

During the observation period the calculated evaporation in the Prut River basin was characterized with essential fluctuations. The first reason of these fluctuations is insufficient data on the precipitation within the river basin. Another important factor is the use of the data of a calendar year, but not of the hydrological one. For example, the essential precipitation in the end of 2001 had an effect on the water storage and river runoff formed next year. In any cases the calculated evaporation at the beginning of the observation period in a whole had the tendency to decrease and during the last four decades – to increase. This result is similar to the one obtained for the territory of Austria (Duethmann and Blösch, 2018), (Fig. 13).

The important issue is the seasonal changes in river runoff. These changes were analyzed by division of available runoff data on two periods: 1961–1990 and 1991–2019, as it was carried out in other cases. It turned out that these changes are not very essential. With a certain level of probability, we can state that these changes only in separate months.

The common feature of the rivers, located at high altitude, is the increase in water runoff in cold period from September till April. This feature can be explained by the increase in precipitation during this period of year and melting of snow cover in March and April. The common feature of the rivers, primarily located in low-mountain terrain, is the decrease in water runoff from May till August. In our view it is caused by the decrease in precipitation during this period along with the simultaneous increase in air temperature and evaporation (Fig. 14).

The differences in seasonal distribution of river runoff become more evident for high-water and low-water phases of the obtained cycles. The common feature of the seasonal distribution during the last wet (1998–2010) and dry (2011–2019) phases is the similar runoff in January–February. In contrast to that in the rest months the water runoff in low-water phase is much less than in high-water one. It means that the main role in the river runoff formation in the mountains plays the precipitation in warm period.

In our view the result of study referring to the changes in precipitation, river runoff and evaporation, essentially depends on the observation period. If we operate with the data during a high-water phase, the findings are essentially different than in case of low-water phase or the whole cycle of river runoff.

Our results and the results of many other scientists (Duethmann and Blösch, 2018; Lukianets et al., 2019; Obodovskyi and Lukianets, 2017; Zabolotnia et al., 2019) show that nowadays the period of lower than usual water runoff is observed. The presence of the strong correlation between river runoff and precipitation proves that last one is the main influencing factor in the observed changes. Air temperature increase, which intensifies evaporation, causes the additional effect.

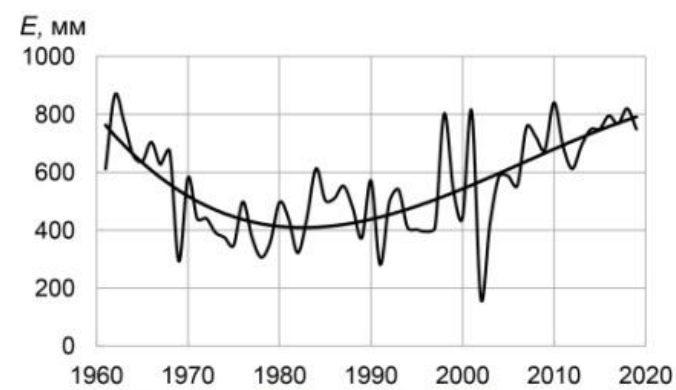


Fig. 13. The changes in calculated evaporation in the Prut River basin upstream Yaremche gauging station.

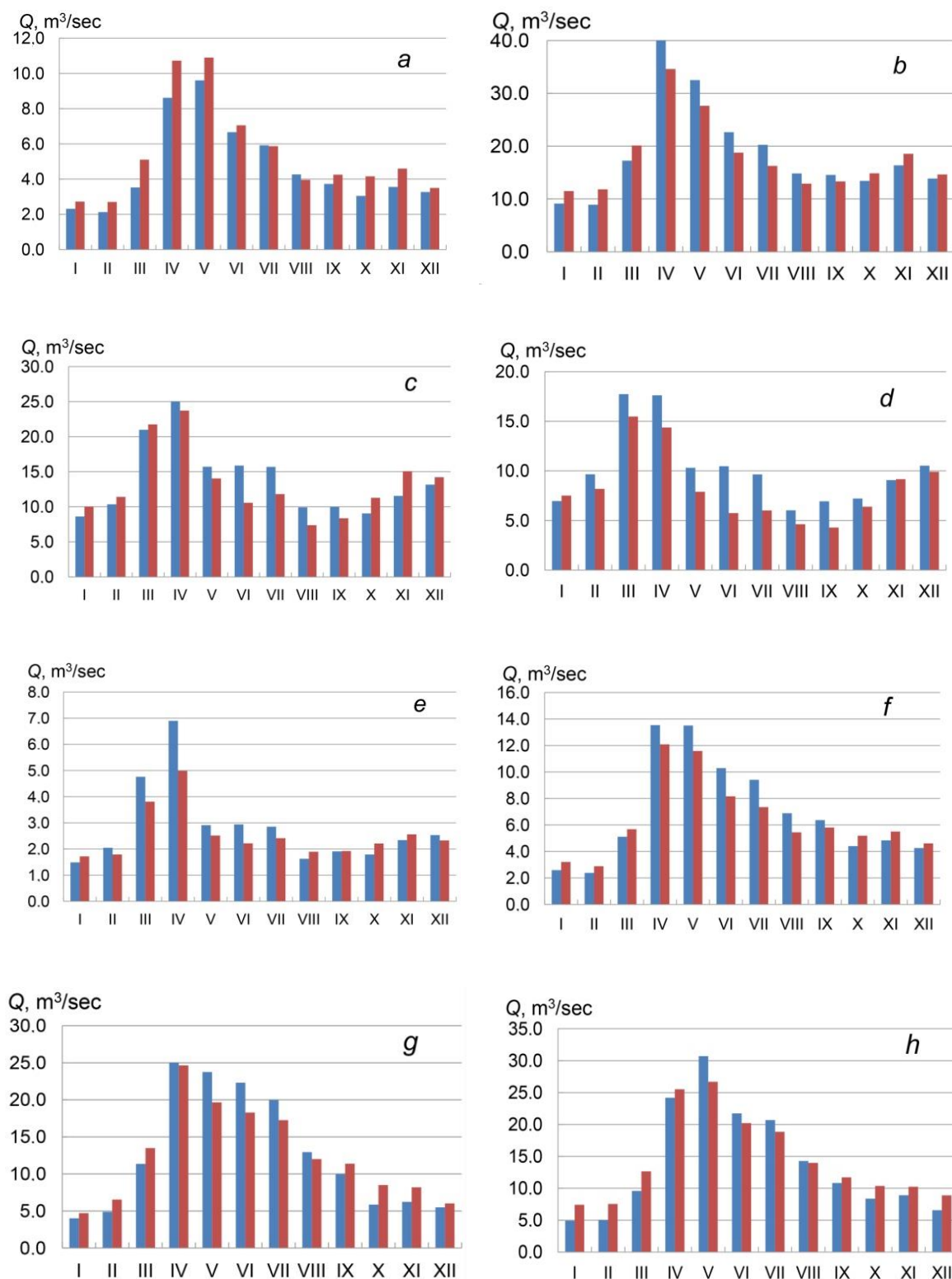


Fig. 14. The intra-annual distribution of water discharge in the Ukrainian Carpathians rivers: a) – Bila Tysa – Luhy, b) – Teresva – Ust-Chorna, c) – Rika – Mezhihiria, d) – Latoritsa – Pidpolozzia, e) – Stryi – Matkiv, f) – Limnitsa – Osmoloda, g) – Prut – Yaremche, h) – Chornyi Cheremosh – Verkhovyna (left columns – during 1961–1990, right columns – during 1991–2019), (a) – d) – south-western macroslope, e) – h) – north-eastern macroslope).

Conclusions

The available data obtained from 11 meteorological stations in the Ukrainian Carpathians show the presence of vivid tendency of air temperature increase. During 1961–2019 the increase in air temperature is about 2°C. The thermal gradient in the mountains is much less than it is in free troposphere. At the low altitude it is larger than on the tops of the mountains. The largest gradient is observed in the period from March till July, when the difference in air temperature at the altitude of 1000 and 2000 m is equal to 0.33–0.36°C per 100 m. The lowest gradient (0.15–0.18°C per 100 m) is observed at these altitudes in the period from November till January. The changes in annual precipitation in the Ukrainian Carpathians are not essential. These changes are of a cycle nature with the period of about 30 years. It is likely that modern dry phase will continue till the mid-2020s. The seasonal changes in the precipitation are rather small. Probably there is a small increase in cold period from September till March. In turn the precipitation in summer time is characterized with a tendency to decrease, primarily in June. Nowadays it is observed the increase of snow cover depth on the tops of the mountains. There is a vivid tendency of wind speed decrease, which is the most obvious in the second part of a year.

In spite of some changes in the climatic parameters the annual river runoff has not changed essentially for some last decades. Similar to the changes in precipitation, it is of a cyclic nature. Nowadays the phase of relative small water runoff, which started in 2011, is observed. The calculated evaporation, based on the water balance, shows up the cyclic nature of this phenomenon, but the duration of the cycles is larger, than for precipitation and river runoff. The available data indicate that the increase in evaporation has been lasting for about 40 years.

The water runoff of the rivers, located at high altitudes, has the tendency to increase in cold period. In turn the common feature of the rivers, primarily located in low-mountain terrain, is the decrease in water discharge in the period from May till August.

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