ENERGETIKA. 2015. T. 61. Nr. 2. P. 81–90

Present spatial changes of time and duration of spring flooding in the Prypiat River catchment (Ukrainian part)

Evgenia Vasylenko

Ukrainian Hydrometeorological Institute
of the National Academy
of Science of Ukraine and
of the State Emergency Service of Ukraine,
37 Nauki Prospect, Kyiv-28, 03028, Ukraine
E-mail evg_vasylenko@ukr.net

The research of changes of the maximum river runoff under the influence of climate change is one of the most urgent tasks of Ukrainian hydrologists. In this regard, spatial change research of the time and duration of spring flooding in the present climate conditions in the Ukrainian part of the Prypiat River catchment has been done.

The dates of the spring flood beginning and end, the dates of maximum water discharges and the spring flood duration in the rivers of the Ukrainian part of the Prypiat River catchment have been analysed. Changes of the above-mentioned characteristics have been detected after 1989 in the researched catchment territory. The maps of changes of the dates of maximum spring water discharges, dates of the beginning and end of the spring flood and its duration in the Prypiat River catchment (Ukrainian part) compared to the first rated period (up to 1989) have been constructed.

Key words: spring flood, time and duration of floods, spatial changes, Prypiat River

INTRODUCTION

Research of the spring flood characteristics is the most important section in the river runoff doctrine both in scientific and in practical ways.

The scientific sense of this issue is primarily explained by the fact that the spring flood identifies common features of the river runoff regime in any territory. The volume of spring flood runoff is the main part of the annual water runoff or the whole annual water runoff (for small streams, under certain conditions).

The practical side of spring flood research is important for hydraulic engineering. It is necessary to know the date and value of maximum water discharge of the spring flood. These characteristics affect the size of hydraulic structures, bridges across rivers and small streams, and the size of the spillway and the discharge conduit of the hydroelectric power centre.

The spring flood is a characteristic phase of the hydrological regime in the Prypiat River catchment. For normal functioning of industrial objects at the researched territory, it is important to know the main characteristics of this water content phase that were affected by climate changes [1].

The research of the influence of climate change on the hydrological regime of rivers, especially on maximum runoff changes, is carried out by scientists around the world, but most actively in Europe, North America and East Asia [2–8]. Some studies related to changes of spring floods are done by scientists of Baltic countries [9–11].

In Ukraine, researches of the impact of climate change on the hydrological regime of Ukrainian rivers are undertaken by scientists-hydrologists of National Taras Shevchenko University [12–14].

Estimation of probable changes of water resources in Ukraine in global warming conditions has been performed by the scientists of Odessa State Environmental University, E. Hopchenko and N. Loboda [15, 16].

The aim of the research is to analyse the spatial changes of the spring flood characteristics, namely, the dates of its beginning and end, the dates of maximum water discharge and the duration of spring flood in the modern climate conditions.

The research objects are the rivers of the Prypiat River catchment in the Ukrainian territory.

DATA AND METHODOLOGY

The Prypiat River is the largest right tributary of the first order of the Dnipro River by the basin area. The length of the river is 761 km, the catchment area is 121 thousand km^2. The greater right-bank part of the catchment with the total area of 68,300 km^2 or 56% of the river catchment area lies on the territory of Ukraine [17].

The source of the river is located near the Holiadyn Village of the Liuboml District of Volyn Region at the altitude of 165 m above the sea level. The river flows across Ukraine for about 200 km, after this, on the territory of Belarus for nearly 500 km. The last 70 km of the river are on the territory of Ukraine and the confluence to the Kiev storage reservoir (Dnipro River).

The main part of the right-bank of the Prypiat River catchment is in Ukrainian Polissia. The Ukrainian Polissia relief is generally flat; its monotony is broken by small loessial islands. Slovechansk-Ovruch and Ozeriansk Ridges are the largest among them [18].

The relief of the major part of the catchment is represented by Polissia Lowland with altitudes that rarely exceed 150–200 m. Only Slovechansk-Ovruch Ridge has the highest mark – 315 meters. The Volyn Range extends in the western part [12].

Volyn and Podilsk Uplands are in the southern part of the catchment. Its altitude is 320–350 meters.

The Prypiat River borders the Western Bug River to the south and west, Dnister and Southern Bug rivers to the south, the Dnipro River to the east and southeast on the territory of Ukraine.

4,429 streams flow in the Prypiat River catchment on the territory of Ukraine, 4,010 of which are rivers with the length less than 10 km. The total length of small rivers is 20,075 km, including rivers with the length less than 10 km – 11,304 km, which is 56% of the total length [17].

Density of the river network in the catchment ranges from 0.20–0.63 km/km^2, and an average for the catchment is 0.40 km/km^2.

Horyn, Styr and Uzh rivers are the largest right-bank tributaries of the Prypiat River. The largest part of these tributaries is entirely located on the territory of Ukraine, and only Styr, Horyn, Stvyha, Lva and Slovechna rivers have the status of transboundary waters.

The data of 25 water measurement stations with the duration of observations over 40 years have been used to study the changes of time and duration of spring flooding in the rivers of the Ukrainian part of the Prypiat River catchment. The layout of the location of hydrological stations in the researched catchment is shown in Fig. 1.

Present changes in the time of spring flooding in the rivers of the Ukrainian part of the Prypiat River catchment have been researched in four homogeneous regions that stand out according to conditions of the spring flood formation: the first region includes the upper part of the Prypiat River catchment with Turia and Stokhid rivers, the second one includes the middle and lower reaches of Styr, Horyn and Sluch rivers in the Polissia Lowland, the third one consists of Lva, Ubort, Uzh rivers, the fourth one is the upper part of Styr, Horyn and Sluch rivers in the Volyn-Podilsk Upland (Fig. 1, Table 1) [19].

Two periods, the first one from early observations to 1989 and the second one from 1989 to 2009, have been selected to analyse the changes of the spring flood date and the duration in the rivers of the Ukrainian part of the Prypiat River catchment in the conditions of climate change. The year 1989 has been selected as

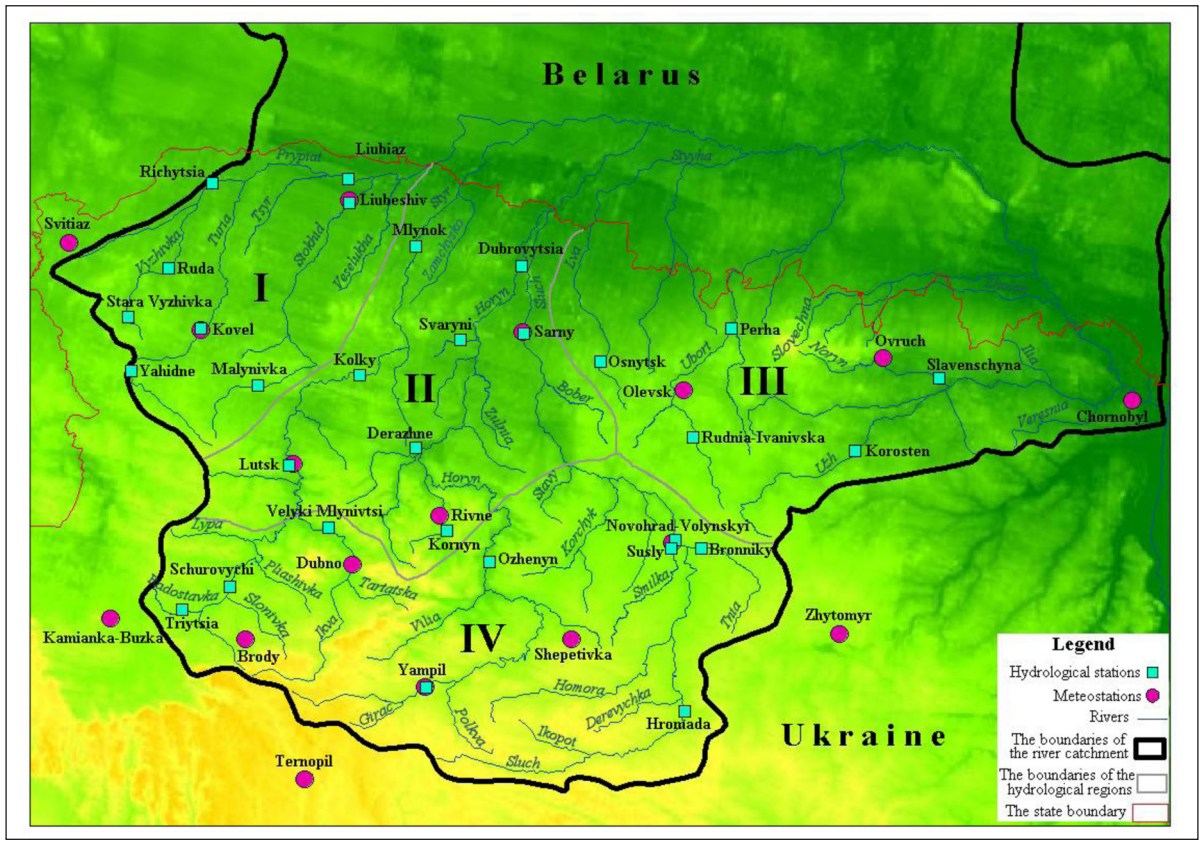

Fig. 1. The Prypiat River catchment and location of water measurement stations

Table 1. **Hydrological regionalization of the Prypiat River catchment (in Ukraine) under conditions of spring flood formation**

Region	Characteristics of main factors of the spring flood formation
I	The region is characterized by the smallest cultivated area (20–30%) in the Prypiat River catchment, the small values of water equivalents of the snow cover (25 mm), soil water storages (140–150 mm) and the depth of soil freezing (35–40 cm). The wetland area is 10–16%, the forests cover 20–26%.
II	The water equivalents of the snow cover (20–28 mm) at the beginning of spring flood on the region are smallest in the Prypiat River catchment. The soil water storages are fairly small (140–160 mm). The depth of soil freezing is big (50–55 cm) at the beginning of spring runoff formation. The smallest precipitation (90–100 mm) falls out during the spring flood on the region territory. This region is characterized by a large runoff regulation area (6–8%), a small forest cover and cultivated area, 15–25 and 30–40%, respectively.
III	The water equivalents of the snow cover (50 mm) and soil water storages (200–215 mm) at the beginning of the spring flood are biggest in the Prypiat River catchment. The biggest depths of soil freezing (on the average 55 cm) and the smallest areas of runoff regulation and wetlands (2–3%) in the catchment are observed. A fairly big amount of precipitation falls out during spring floods on the region (110–120 mm).
IV	The region is characterized by the biggest average heights of river basins (260–320 m), the biggest precipitations during spring floods (120–130 mm), the biggest soil water storages (200 mm) and big water equivalents of the snow cover (30–50 mm). The region has the largest cultivated area (60–70%) and the smallest forest cover (10–15%) in the Prypiat River catchment.

a critical point because it marks the beginning of present changes of the temperature regime in the researched catchment [12, 13].

Averaging of the dates of maximum spring water discharges, dates of the beginning and end of the spring flood and the flood duration in

selected hydrological areas has been done. The average values for the characteristic periods and their differences have been calculated for the above-mentioned characteristics. Comparative histograms for hydrological regions have been constructed for the rated period based on the average values of spring flood characteristics. Also, the maps of changes of the dates of maximum spring water discharges, dates of the beginning and end of the spring flood and its duration in the Prypiat River catchment (in Ukraine) compared to the first rated period (up to 1989) have been constructed.

RESULTS

Analysis of the dates of the spring flood beginning and end, the dates of maximum water discharges and the spring flood duration for the selected hydrological regions in the Ukrainian part of the Prypiat River catchment has been conducted. Analysis of the selected spring flood characteristics was performed for two characteristic periods (up to 1989 and 1989–2009) (Table 2).

The duration of the spring flood changed slightly (an increase of only 2 days) in the last two decades in the Prypiat River catchment (Ukrainian part). In general, the amplitude of changes of this indicator for the selected regions is insignificant comparing two selected periods (up to 1989 and from 1989 to 2009). Changes in the duration of spring flood have not been marked for the first and second regions after 1989 (Fig. 3).

The duration of the spring flood increased in recent decades by 3 and 2 days, respectively, for the third and fourth regions (Fig. 2). The maximum value of the mentioned characteristic (54 days) has been noted for the second region before and after 1989. The increased duration can be explained by spring flood wave flattering in the Polissia Lowlands [17].

The minimal value of the duration of the spring flood is observed in the third and fourth regions of the catchment in both characteristic periods.

The amplitude of fluctuation of the spring flood duration decreased by 5% after 1989 at the territories of the selected regions in the Prypiat River catchment.

The time of the spring flooding has also undergone some changes in the present period at the territory of the researched catchment.

Dates of the spring flood beginning shifted to the earlier periods – 6 days on average in the catchment. The earliest dates of spring flood beginning are characteristic for rivers of the fourth and second selected regions of the catchment (March 5 and 6 and February 28, respectively) for both calculated periods. The spring flood begins simultaneously in the territories of the first and third (on average, March 2) and the second and fourth (on average, February 28) regions in the period of 1989–2009 (Fig. 4). The dates of spring

Table 2. **Some spring flood characteristics in the rivers of the Ukrainian part of the Prypiat River catchment for two characteristic periods**

Region (for a more detailed description see Table 1)	Average for the period:								Difference, day			
	until 1989				1989–2009				Date of			
	Date of			spring flood duration, day	Date of			spring flood duration, day				
	spring flood beginning	passage of maximum water discharge	spring flood end		spring flood beginning	passage of maximum water discharge	spring flood end		spring flood beginning	passage of maximum water discharge	spring flood end	spring flood duration, day
I	08.03	23.03	28.04	51	02.03	17.03	20.04	51	–7	–6	–7	0
II	06.03	21.03	27.04	54	28.02	15.03	21.04	54	–6	–6	–6	0
III	09.03	22.03	17.04	41	02.03	11.03	13.04	43	–8	–11	–5	3
IV	05.03	17.03	16.04	42	28.02	11.03	12.04	44	–5	–7	–3	2
Average for the river catchment	**07.03**	**21.03**	**22.04**	**47**	**01.03**	**13.03**	**16.04**	**48**	**–6**	**–7**	**–5**	**1**

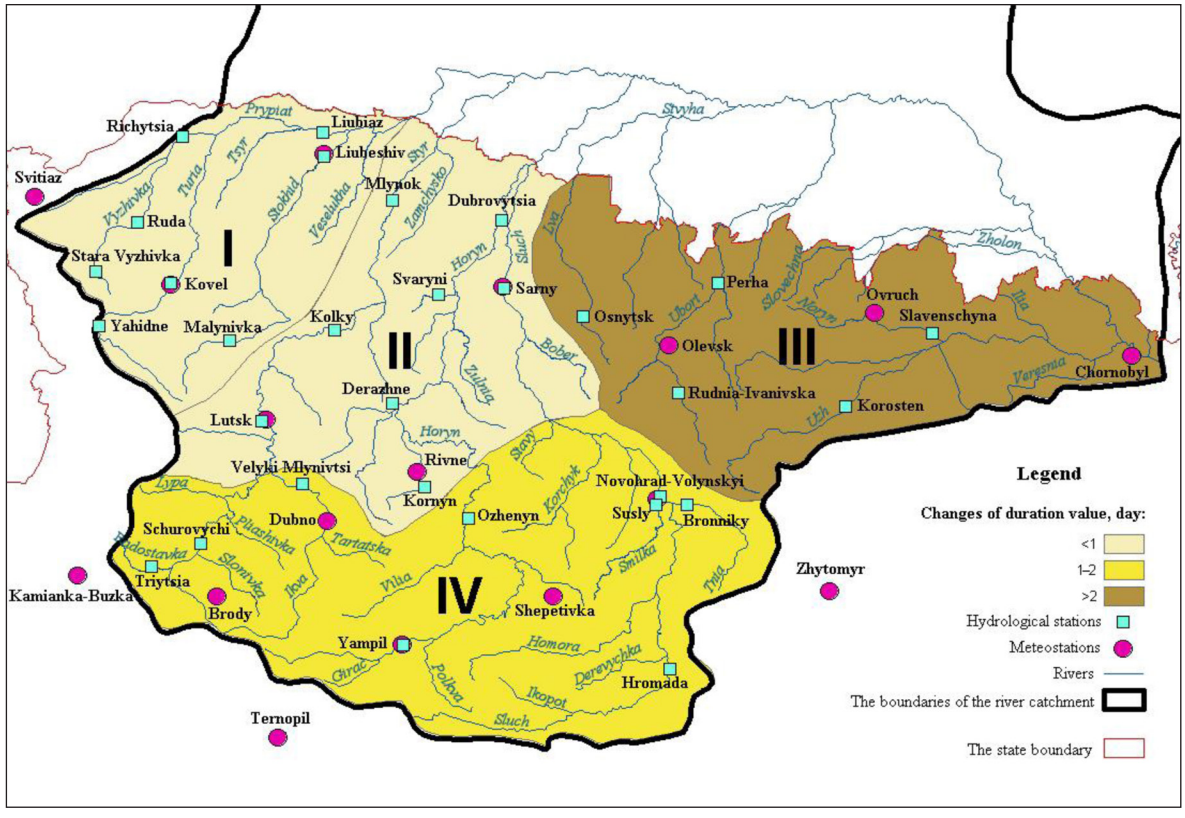

Fig. 2. Changes of the spring flood duration (*T*, day) in the Prypiat River catchment (Ukrainian part) compared to the first rated period

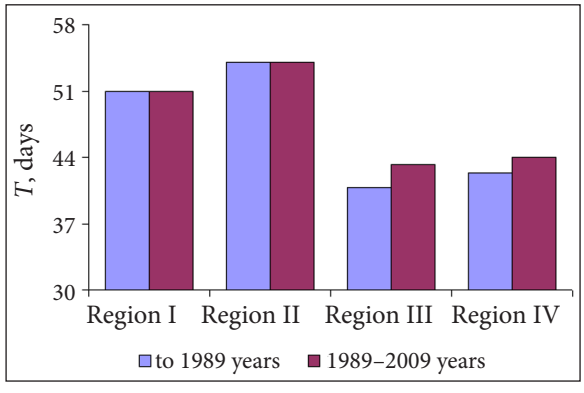

Fig. 3. Changes of the spring flood duration (*T*, day) for the selected areas of the Prypiat River catchment comparing two characteristic periods

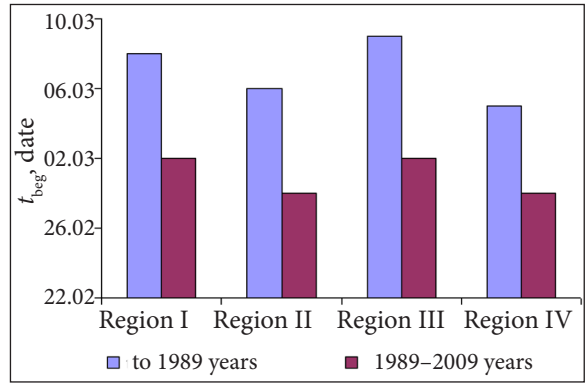

Fig. 4. Changes of dates of the spring flood beginning (t_{beg}, date) for the selected regions in the Prypiat River catchment comparing two characteristic periods

flood beginning in the third and first regions of the catchment have undergone the biggest changes in the present period (11 and 10%) (Fig. 5).

The greatest difference in the dates of spring flood beginning between the regions of the catchment were 4 days up to 1989, after 1989 it was only 2 days, i. e. the decrease in the amplitude of fluctuation of this characteristic happened in the current period.

Dates of the maximum water discharge of the spring flood. The latest dates of the maximum flood discharges are inherent to the first region for both periods, but they are 6 days earlier in the second period. The earliest dates of

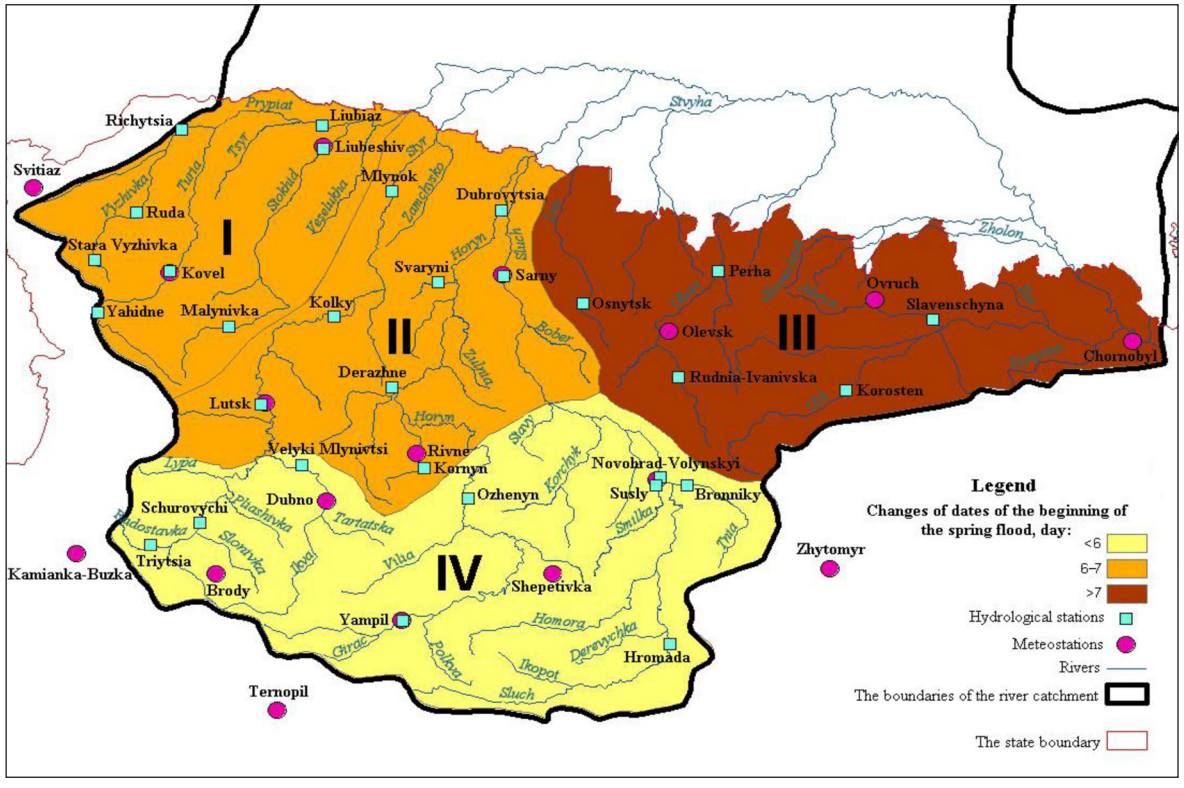

Fig. 5. Changes of dates of the spring flood beginning (t_{beg}, date) in the Prypiat River catchment (Ukrainian part) compared to the first rated period

the maximum discharges are characteristic of the fourth region (March 17) up to 1989, and after 1989 of the third and fourth regions, when the maximum spring flood discharges were fixed simultaneously in the territory of two regions (on average, March 11) (Fig. 6). The dates of the maximum discharges of the spring flood shifted on average by 7 days to the beginning of the year in the Prypiat River catchment (Fig. 7).

The amplitude of the fluctuation of this characteristic has been registered 6 days earlier and 2 days later after 1989 in the territory of the regions of the Prypiat River catchment (Ukrainian part).

In the present period, the dates of the maximum discharges of the spring flood have changed from the southeast and east to the west of the catchment. This fact can be explained by different direction of the river flow in the eastern and western part of the catchment. Rivers of the central and eastern part of the catchment mainly flow from the south and south-east to the north (except the Uzh River, which flows from the south-west to the east) and the rivers of the western part flow in the direction to the southwest–north (Fig. 7).

This characteristic varies insignificantly over the selected regions (up to 1 day) compared to other characteristics of the spring flood.

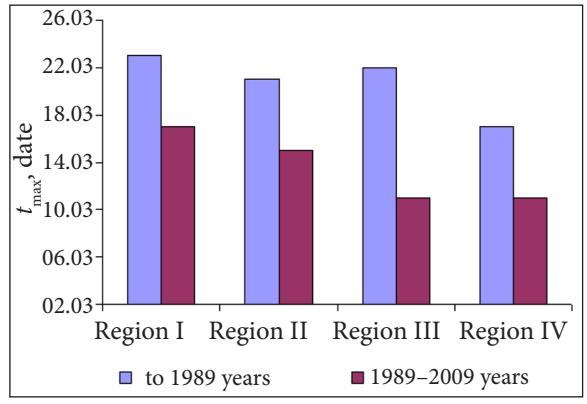

Fig. 6. Changes of dates of the maximum spring flood discharges (t_{max}, date) for the selected regions in the Prypiat River catchment comparing two characteristic periods

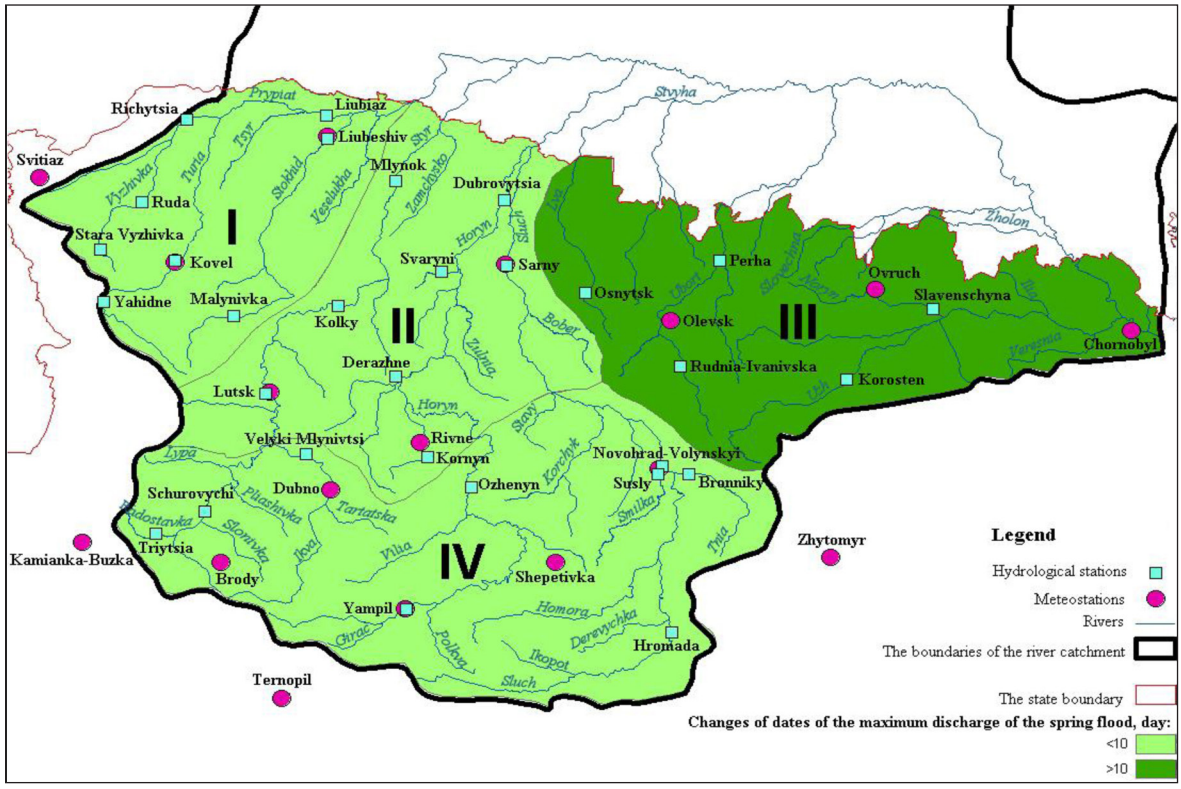

Fig. 7. Changes of dates of the maximum spring flood discharges (t_{max}, date) in the Prypiat River catchment (Ukrainian part) compared to the first rated period

Dates of the end of the spring flood in rivers of the Ukrainian part of the Prypiat River catchment shifted to the earlier period in the last two decades – on average by 5 days to the beginning of the year. The end of the spring flood begins from the east and southeast to the west in the river catchment. Thus, up to 1989, the latest dates of the end (April 28) were observed in the territory of the first region, the earliest (April 16) dates were observed in the fourth region. The spring floods finished almost at the same time in the territories of the third and fourth (April 12 and 13, respectively) and the first and second (April 20 and 21, respectively) hydrological regions of the researched catchment after the 1989 year (Fig. 8).

In the current period, the dates of the spring flood end changed the most in the first region – shifted by 7 days closer to the beginning of the year, changed the least for the territory of the fourth region (by 3 days) (Fig. 9).

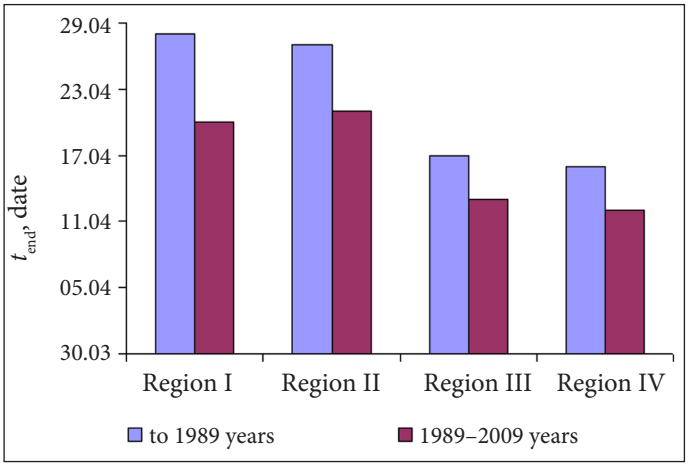

Fig. 8. Changes of dates of the end of the spring flood (t_{end}, date) for the selected regions in the Prypiat River catchment comparing two characteristic periods

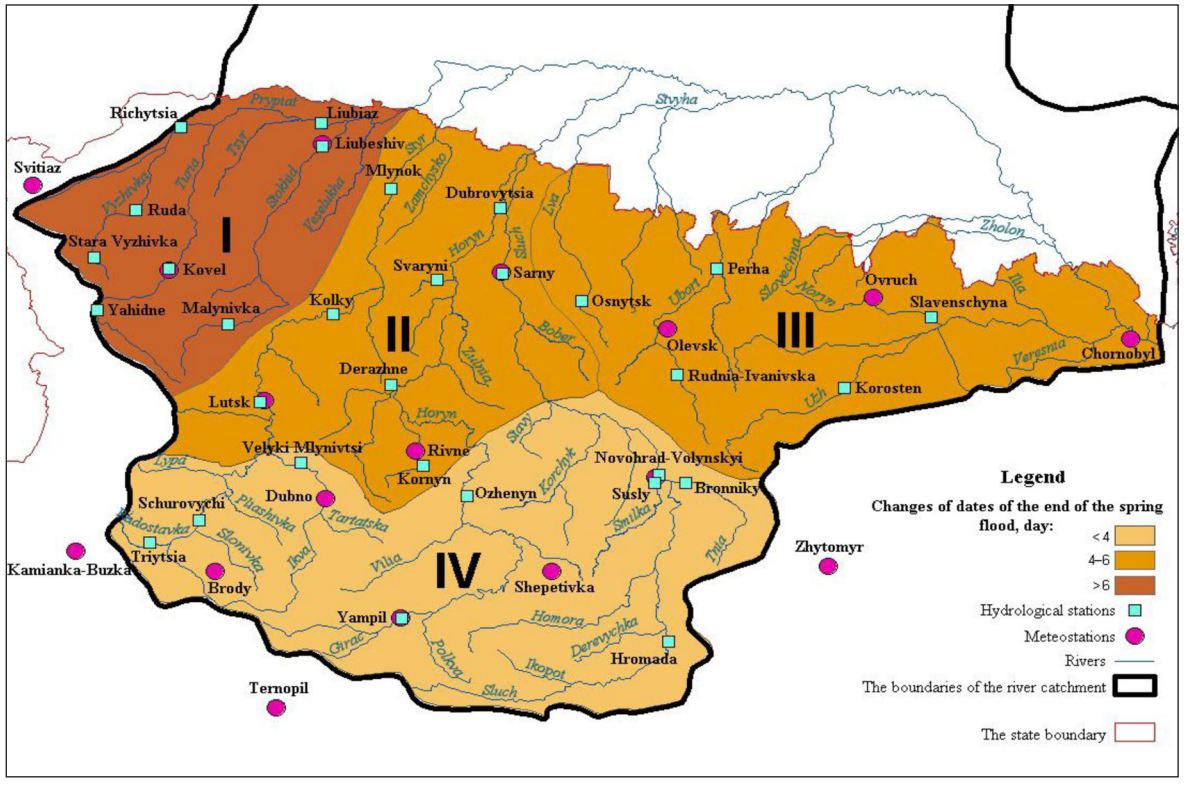

Fig. 9. Changes of dates of the end of the spring flood (t_{end}, date) in the Prypiat River catchment (Ukrainian part) compared to the first rated period

CONCLUSIONS

Climate change that has taken place over the past decades influenced the characteristics of the spring flood in the Prypiat River catchment (Ukrainian part). First of all, it concerns the time and duration of flooding.

The dates of the spring fluid beginning shifted to earlier dates on average by 6 days in the catchment comparing the last two decades with the previous period. This characteristic in the third region of the catchment has undergone the maximum changes in the present period (8 days). The minimum changes in the dates of the spring flood beginning are observed in the fourth region (5 days).

The dates of the maximum discharge of the spring flood shifted by 7 days to the year beginning. Similar changes in dates of the maximum discharges are found out almost for the whole territory of catchment (6 days). The maximum change of these dates is observed in the third region (11 days).

In the last two decades, the dates of the spring flood end in the rivers of the Ukrainian part of the Prypiat River catchment shifted by 5 days to the beginning of the year. These dates have undergone the maximum change in the first region (7 days) and the minimum change in the fourth region (3 days).

In the last two decades, the duration of the spring flood changed slightly (an increase of only 2 days) in the catchment. The maximum change of this characteristic is observed in the third region (increasing by 3 days). Changes in the duration of the spring flood have not been marked for the first and second regions after 1989.

The fluctuation amplitude of the spring fluid timing in the regions of the Prypiat River catchment decreased in the current period. Such changes varied from 50% (dates of the beginning of the spring flood) to 15% (duration of the spring flood).

Received 2 March 2015
Accepted 26 June 2015

References

1. Lukianetz O. I., Susidko M. M. The rivers of the right bank of the Prypiat River in the high water content period: repeatedness of the rain floods and features of hydrological regime. *Proceedings of UHMI*. 1999. Vol. 247. P. 136–143 (in Ukrainian).
2. Shiklomanov I. A., Georgievskyi V. Yu. Impact of climate changes on hydrological regime and water resources of rivers in Russia. *Proceedings of the International British-Russian Conference on Hydrological Impacts of Climate Change, June 13–15, 2007, Novosibirsk*. P. 192–204 (in Russian).
3. Andréasson J., Bergström S., Carlsson B., Phil Graham L., Lindström G. Hydrological change – climate change: impact simulations for Sweden. *Ambio*. 2004. Vol. 33. No. 4–5. P. 228–234.
4. Diemann J., Eltahir E. Sensitivity of regional hydrology to climate changes, with application to the Illinois River basin. *Water Resources Research*. 2005. Vol. 41, No. 7. C. W07014/1–W07014/15.
5. Javelle P., Taha B., Ouarda M. J., Bobée B. Spring flood analysis using the flood-duration-frequency approach: application to the provinces of Quebec and Ontario, Canada. *Hydrological Processes*. 2002. Vol. 17. Issue 18. P. 3717–3736.
6. Krasovskaja I., Gottschalk L. River flow regimes in a changing climate. *Hydrological Sciences Journal*. 2002. Vol. 47. No. 4. P. 597–609.
7. Rodhe A. Spring flood: meltwater or groundwater? *Nordic Hydrology*. 1981. Vol. 12. P. 21–30.
8. Sen-Loran D., Mesyui M., Ewen G. Hydroclimatic variability and the floods (South Quebec, Canada). *Journal of the Russian Academy of Sciences "Water Resources"*. 2009. Vol. 36. No. 1. P. 46–60 (in Russian).
9. Reihan A., Kriaučiūnienė J., Meilutyte-Barauskienė D., Kolcova T. Temporal variation of spring flood in rivers of the Baltic States. *Hydrology Research*. 2012. Vol. 43. No. 4. P. 301–314.
10. Šarauskienė D., Kriaučiūnienė J., Reihan A., Klavis M. Flood pattern changes in the rivers of the Baltic countries. *Journal of Environmental Engineering and Landscape Management*. 2015. Vol. 23. Issue 2. P. 28–38. http://dx.doi.org/10.3846/16486897.2014.937438
11. Meilutytė-Barauskienė D., Kovalenkovienė M. Change of spring flood parameters in Lithuanian rivers. *Energetika*. 2007. Vol. 53. No. 2. P. 26–33.
12. Grebin V. V. *The Modern Water Regime of Rivers in Ukraine (Landscape-Hydrologic Analysis)*. Kyiv: Nika-Centr, 2010. P. 316 (in Ukrainian).
13. Strutynska V. M. Dynamics of the ice regime characteristics in rivers of the Dnipro River Basin on the background of modern climate changes. *Hydrology, Hydrochemistry and Hydroecology*. 2008. Vol. 14. P. 116–122 (in Ukrainian).
14. Chornomoretz Yu. O., Grebin V. V. Intrayearly distribution of individual elements of the water balance of the Desna River basin (within Ukraine and their long-term fluctuations). *Hydrology, Hydrochemistry and Hydroecology*. 2010. Vol. 18. P. 98–106 (in Ukrainian).
15. Gopchenko E. D., Ovcharuk V. A., Shakirzanova J. R. The researches of the influence of modern climate changes on the characteristics of maximum spring flood runoff in the Prypiat River Basin. *Hydrology, Hydrochemistry and Hydroecology*. 2010. Vol. 3(20). P. 50–59 (in Ukrainian).
16. Loboda N. S. *Calculations and Generalization of the Annual Runoff Characteristics of the Rivers in Ukraine in the Conditions of Anthropogenic Influence*. Odessa: Ekologia, 2005. P. 208 (in Russian).
17. Kalinin M. Yu., Obodovskyi A. G. (ed.). *Monitoring, Use and Management of Water Resources in Prypiat River Basin*. Minsk: Belsens, 2003. P. 269 (in Russian).
18. Zastavnyi F. D. *Geography of Ukraine*. Lviv: Svit, 1994. 472 p. (in Ukrainian).
19. Vasylenko E. V. Spatial structure of the spring flood formation factors in the Prypiat River basin (within Ukraine). *Proceedings of UHMI*. 2013. Vol. 265. P. 22–27 (in Ukrainian).

Evgenia Vasylenko

DABARTINIAI PAVASARIO POTVYNIŲ DATŲ IR TRUKMĖS POKYČIAI PRIPETĖS UPĖS BASEINE (UKRAINOS TERITORIJA)

Santrauka

Upių maksimalaus nuotėkio pokyčių tyrimas dėl klimato kaitos poveikio yra vienas aktualiausių Ukrainos hidrologų uždavinių. Atliktas Pripetės upės baseino upių (Ukrainos teritorija) pavasario potvynių datų ir trukmės pokyčių dabartinėmis klimato sąlygomis tyrimas.

Ištirta Pripetės upės baseino (Ukrainos teritorija) upių pavasario potvynio pradžios ir pabaigos bei maksimalaus vandens debito datos ir pavasario potvynio trukmė. Minėtų charakteristikų pokyčiai tiriamojoje baseino teritorijoje buvo nustatyti nuo 1989 metų. Sudaryti Pripetės upės baseino (Ukrainos teritorija) pavasario potvynio maksimalaus vandens debito, potvynio pradžios ir pabaigos datų bei potvynio trukmės pokyčių žemėlapiai, palyginti laikotarpiai iki ir po 1989 metų.

Raktažodžiai: pavasario potvynis, potvynio datos ir trukmė, pokyčiai, Pripetės upės baseinas