Water temperatures of the Danube and Tisza Rivers in Hungary

György LOVÁSZ[1]

Abstract

Based on a 60-year long hydrological observation series from the Hungarian Hydrological Service (between 1951 and 2010), the monthly mean water temperatures of both largest rivers in the Carpathian Basin, the Danube and the Tisza, important for a range of practical considerations, are studied. The monthly extremes in water temperatures are explained by the different climatic conditions in the drainage basins of the rivers: the Danube basin upstream its entrance to Hungarian territory with a marked Atlantic and the Tisza basin with a strong continental character. Changes are followed along the Hungarian stream sections. Trends in water temperature change are established and interpretations are sought with consideration to the climate change trends predicted by climatologists for Hungary. The trends are more clearly manifested for the Danube catchment than for the Tisza catchment. Within the outlined overall trends, positive and negative singularities are also identified for the coldest and hottest months and their occurrence is also analysed in regional contrast.

Keywords: water temperature, air masses, climate change, singularities

Introduction

In the Hungarian literature analyses of river water temperatures first appeared in the second half of the 19th century and included data from the observations on the Danube (Greguss, Gy. 1866). In the early 20th century observations on the water temperature of the Tisza River were also published (Pasteiner, D. 1905). In the mid-20th century a synthesis based on a 5-year time series of observations on the temperature conditions of standing waters and streams in Hungary (Lászlóffy, W. 1956).The observation network has significantly expanded since 1950: it has become ever denser and, in addition to major rivers, measures began on smaller watercourses too. 60-year series are available and allow analyses of broader thematics.

[1] Professor emeritus, Institute of Geography, University of Pécs, H-7624 Pécs, Ifjúság útja 6. E-mail: gyuresz@gamma.ttk.pte.hu

The present study is based on data from the observations of the Hungarian Hydrological Service for two stations on the two largest rivers: one at entering and another at leaving Hungarian territory. The Danube enters Hungary at Dunaremete and the Tisza near Tiszabecs, while the Danube leaves Hungary downstream of Mohács and the Tisza downstream of Szeged *(Figure 1).*

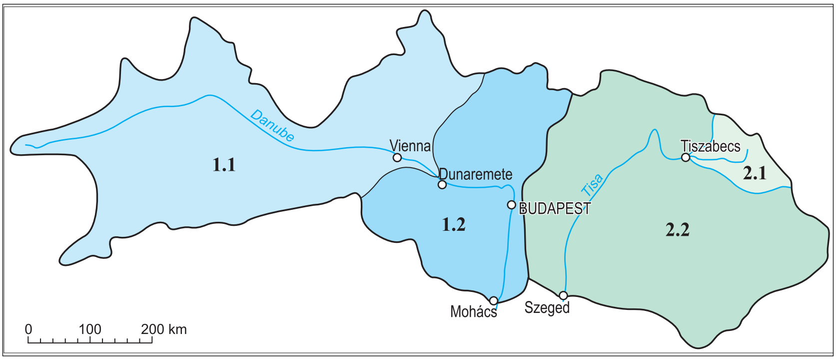


Fig. 1. The drainage basins of the Danube and the Tisza rivers. – 1.1 = the Danube catchment upstream of Dunaremete; 1.2 = the Danube catchment between Mohács and Dunaremete; 2.1 = the Tisza catchment above Tiszabecs; 2.2 = the Tisza catchment between Tiszabecs and Szeged

There is significant variation between the drainage basins of the two rivers. On the Danube catchment Alpine (high-mountain) climate, while in the northern Alpine foreland moist Atlantic climate is typical. Here the predominance of temperate maritime air masses deriving from the middle to high geographical latitudes of the Atlantic Ocean and of subtropical Atlantic maritime air masses is characteristic (Bacsó, N. 1959; Péczely, Gy. 1979). In the Tisza drainage basin, i.e. in the NE and E parts of the Carpathian Basin middle-mountain (dry continental) climate prevails. In the climate temperate continental air masses, primarily from Asia, and polar air masses are of significant importance. Thus, in the Alpine foreland the influence of maritime air masses, while in the NE and E parts of the Carpathian that of continental air masses are decisive. The paper investigates the impact of the climate of both catchments on the water temperature conditions. The 60-year observation series also allows the presentation of the hydrological impact of global warming.

Climatic character and water temperature

There is no significant difference between the *annual mean water temperature* of the two rivers when they enter Hungary: the Danube at Dunaremete has a value of 10.4 °C and the Tisza at Tiszabecs 10.0 °C. The annual and monthly curve of water temperature for the rivers arriving from the 131,543 km² basin W of the Carpathian Basin and from the 9,707 km² basin in the NE-Carpathians reflects climatic variations less directly.

Minimum monthly water temperature is observed for both rivers in January: on the average the Danube at Dunaremete is warmer (2.3 °C) than the Tisza at Tiszabecs (0.7 °C). The values are influenced by mild Atlantic winters as opposed to longer continental winters *(Table 1).*

Table 1. Monthly and annual water temperatures of both rivers at the entrance to Hungary, 1951–2010, °C

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
The Danube at Dunaremete, 131,543 km²												
2.3	3.0	5.6	9.6	13.5	16.7	17.9	18.1	15.7	11.8	7.3	3.7	10.4
The Tisza at Tiszabecs, 9,707 km²												
0.7	1.0	3.8	8.5	14.2	18.1	20.0	19.7	15.7	10.4	5.2	1.9	10.0

In the NE-Carpathians, to the influence of cold continental air masses, warming is more gradual than on the catchment to the W of the Carpathian Basin. As a consequence, *until April the water temperature of the Tisza is lower than that of the Danube*. In the summer period (from May to September) the warmer continental summer also contributes to the higher water temperature of the Tisza.

The *maximum monthly water temperatures* reflect the summer temperature conditions W and E of the Carpathian Basin, respectively., as the Danube at Dunaremete peaks 18.1 °C (in August) and the Tisza at Tiszabecs 20.0 °C (in July).

The range of the monthly mean temperatures is higher for the Tisza (19.3 °C) than for the Danube (15.8 °C). The differences in discharge are also influential in this respect (*Figure 2)*. Heat energy arrives in similar amounts but the lower water mass of the Tisza warms up more rapidly and to greater extent.

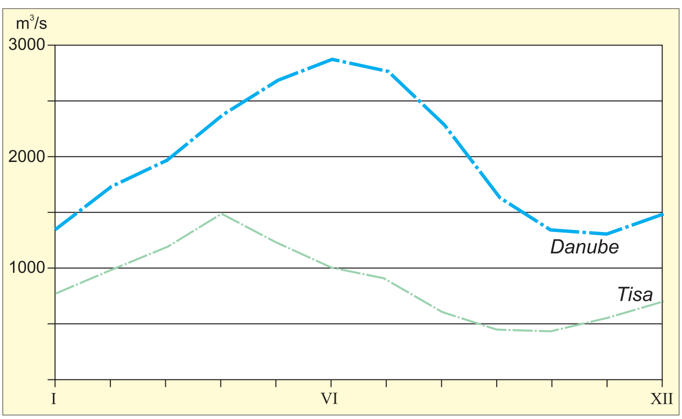


Fig. 2. The mean monthly discharges of the Danube and the Tisza, 1951–1980, m³/sec

Changes along the longitudinal profile of the Hungarian section

The length of the Hungarian section of the Danube is 378.6 km, while the Tisza is 51% longer (572.3 km). The growth of the Danube catchment area from Dunaremete to Mohács in the W margin of the Carpathian Basin is 77,521 km^2, while for the Tisza from Tiszabecs to Szeged in the NE and E part of the Carpathian Basin is 128,701 km^2 (*Figure 1*).

The climate of the E part of the Carpathian Basin is strongly influenced by the Carpathian ranges, which in winter moderate the effect of cold air masses generated over N-Asia, often modifying the direction of air currents (Péczely, Gy. 1979). The water temperature of the Tisza is remarkably influenced by the heat input from the tributaries on Hungarian territory and the temperature of inflow of communal and industrial sewage since the river transports only 36% (855 m^3/s) of the discharge of the Danube. These kinds of effects are less significant for the Danube. On the territory of Hungary the long-term mean temperature of the Danube rises by 1.2 °C and of the Tisza by 2.0 °C (*Table 2).*

Table 2. Changes in the monthly and annual mean temperatures of the Danube and Tisza in Hungary, 1951–2010, °C

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
The Danube between Dunaremete and Mohács, 378.6 km												
-0.3	-0.1	0.1	1.0	2.0	12.1	2.7	2.7	1.9	1.2	0.5	-0.2	1.2
The Tisza between Tiszabecs and Szeged, 572.3 km												
0.2	0.5	0.8	2.1	2.5	2.9	3.0	3.2	3.1	3.0	2.0	0.7	2.0

In the winter months (from December to February), arriving from the Atlantic regions with mild winters to the continental Carpathian Basin, the Danube loses from its temperature. The same phenomenon does not apply for the Tisza as in the NE-Carpathians the continental winters are colder than in the E parts of the Carpathian Basin, where *the Carpathian Mountains often prevent the penetration of cold continental air masses from the direction of Siberia* (Péczely, Gy. 1979). As a result of the protective effect of the Carpathians the left-bank tributaries bring warmer water than those coming from the NE-Carpathians. The temperature difference between the two rivers is most pronounced in the summer and early autumn (between June and October). To the influence of the cold air masses arriving from easterly direction, after November the water of the Tisza cools more rapidly than the Danube *(Table 3).*

As a consequence of the temperature conditions of the Carpathian Basin, the Danube, which was warmer, when reached Hungary, is colder, when leaving the country, than the Tisza *(Table 1*).

Table 3. Monthly and annual water temperatures of both rivers leaving Hungary at the S border, 1951–2010, °C

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
The Danube at Mohács, 209,064 km²												
2.0	2.9	5.7	10.6	15.5	18.8	20.6	*20.8*	17.6	13.0	7.8	3.5	11.6
The Tisza at Szeged, 138,408 km²												
0.9	1.5	4.6	10.6	16.7	21.0	*23.0*	22.9	18.8	13.4	7.2	2.6	12.0

The trends of water temperature change between 1951 and 2010

The trend of mean water temperature changes of both rivers is related to global warming (Mika, J. 1988, 1989, 1991; Bartholy, J. *et al.* 2007 and others). The temperature of waters flowing in from catchments lying W from the Carpathian Basin rises more rapidly than that of waters deriving from the E parts of the Basin *(Table 4)*.

Table 4. Trend of change in annual mean temperature, 1951–2010, °C

Station	Area, km²	Y[1]	Trend, °C/60 years
Mohács (Danube)	209,064	0.0243	1.46
Szeged (Tisza)	138,408	0.0149	0.89

[1] Coefficient of the regression equation

The general rising trends of variable extent are interrupted by short spells of positive and negative fluctuations, which primarily depend on winter and summer air temperatures *(Figure 3)*. The trends of mean annual minimum (winter) and annual maximum (summer) temperatures represent most faithfully the impact of winters and summers on water temperature. Climate change is most remarkably manifested in the temperature and precipitation conditions of these seasons. The *waters in the coldest month of the year* arrive from the catchment of 131,543 km² area W of the Carpathian Basin with a positive trend of 2.31 °C/60 years, while waters from the NE-Carpathians show a very weak negative trend *(Table 5)*.

The tendency of water temperature changes indicates that the impact of ever milder winters is not observed in the mountainous NE parts of the Carpathian Basin.

Table 5. Trend of changes in minimum monthly mean temperatures, 1951–2010, °C

Station	Area, km²	Y[1]	Trend, °C/60 years
Dunaremete (Danube)	131,543	0.0385	2.31
Tiszabecs (Tisza)	9,707	-0.0042	-0.25

[1] Coefficient of the regression equation

In the hottest summer month the positive trend (1.28 °C/60 years) of waters from the Danube catchment W of the Carpathian Basin points to summers getting warmer at a slower pace than winters are getting milder (*Table 6).* In the NE-Carpathians summer temperatures virtually remain the same (trend: -0.03 °C/60 years).

Table 6. Trend of changes in maximum monthly mean temperatures, 1951–2010, °C

Station	Area, km²	Y[1]	Trend, °C/60 years
Dunaremete (Danube)	131,543	0.0213	1.28
Tiszabecs (Tisza)	9,707	-0.0005	-0.03

[1] Coefficient of the regression equation

The tendencies confirm that *the rise of winter temperatures in the catchment W of the Carpathian Basin is remarkable, while no change is observed in summer temperatures*. The trends observable along the Hungarian sections of both rivers also reflect the modifying effect of the climate of drainage basins to which the Carpathian Basin was added *(Figure 3).* The effect is manifested in the variation of the Y coefficient values.

In winter the most pronounced changes are found in the water temperature of the Tisza River. The 1.24 °C/60 years positive trend along the Hungarian section of 572.3 km length, between Tiszabecs and Szeged, indicates significant warming during winter in the E parts of the Carpathian Basin *(Table 7).* The Tisza arrives from a catchment of severe climate upstream of Tiszabecs into the Carpathian Basin, where winters are milder and river water temperature rises. The water temperature of the Danube reduces along its Hungarian section of 378.6 km length because the river flows from a W region of mild Atlantic winters into the relatively colder Carpathian Basin.

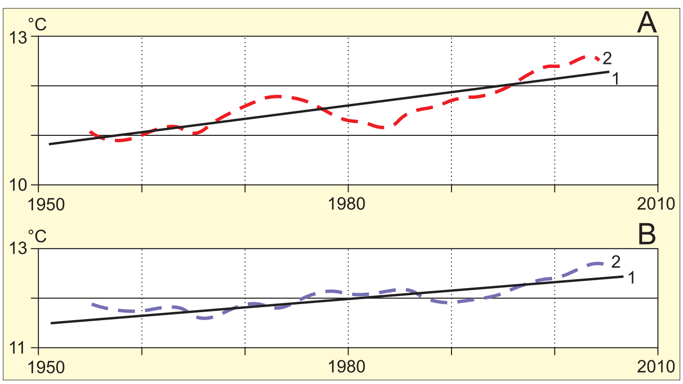


Fig. 3. Changes in the water temperatures of the Danube and the Tisza, 1951–2010, °C. – 1 = linear trend (regression line); 2 = moving trend (means for 10 values)

Table 7. Trend of changes in minimum monthly mean temperatures for the Hungarian sections of the Danube and the Tisza rivers, 1951–2010, °C

Station	Area, km²	Y[1]	Trend, °C/60 years
Dunaremete (Danube)	131,543	0.0385	2.31
Mohács (Danube)	209,064	0.0208	1.25
Tiszabecs (Tisza)	9,707	-0.0042	-0.25
Szeged (Tisza)	138,408	0.0098	0.59

[1] Coefficient of the regression equation

The summer water temperatures show a much moderate rising trend (0.08 °C/60 years) for the Hungarian Danube section (378.6 km) between 1951 and 2010 than for the Hungarian Tisza section of 572.3 km length (1.1 °C/60 years) *(Table 8)*.

Table 8. Trend of changes in maximum monthly mean temperatures for the Hungarian sections of the Danube and the Tisza rivers, 1951–2010, °C

Station	Area, km²	Y[1]	Trend, °C/60 years
Dunaremete (Danube)	131,543	0.0385	2.31
Mohács (Mohács)	209,064	0.0398	2.39
Tiszabecs (Tisza)	9,707	-0.0005	-0.03
Szeged (Tisza)	138,408	0.0179	1.07

[1] Coefficient of the regression equation

The more remarkable warming trend of the Tisza River is influenced by its course 192.7 km longer than that of the Danube and the fact that in summer the Tisza has 26 and 22% lower discharges than the Danube. The identical amount of heat warms the lower amount of water more efficiently.

The *singular positive and negative fluctuations* within the above outlined trends (*Figure 4*) are remarkable in the monthly changes of water temperatures for the Danube catchment upstream of Mohács (209,064 km² area) and for the Tisza catchment upstream of Szeged (138,048 km² area).

The tendency of ever milder winters is not continuous. Since the mid-1960s it is evident for approximately 10 years but then it is followed by almost stagnation (*Figure 4,* A). In the E part of the Carpathian Basin the weak negative trend is replaced by a weak positive trend of ca 15-year duration from the mid-1960s (*Figure 4*, B). Since the early 1980s there has been a very moderate rise to the present. *The singular changes in monthly mean water temperatures for the coldest winter months in the period 1951 to 2010 confirms that winters started to become ever milder in the region W of the Carpathian Basin in the early 1960s.*

Summer warming in the Danube catchment W of the Carpathian Basin only began in the beginning of the 1980s (*Figure 4*, C). A marked rise in temperatures has been continuing to our days. In the E part of the Carpathian Basin the remarkable positive trend also dates back to the beginning of the 1980s, but this process is significantly slowing down since the early 1990s (*Figure 4*, D). *The singular changes in monthly mean water temperatures for the hottest summer months indicate that summers started to become hotter only in the early 1980s and in the region W of the Carpathian Basin this process has been more marked than in the E part of the Carpathian Basin*.

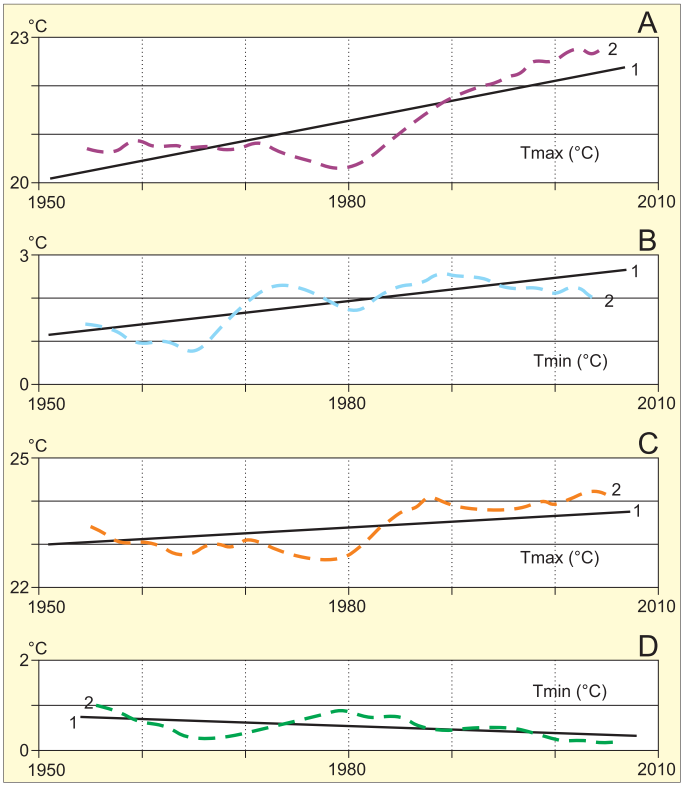


Fig. 4. Trend of changes of the coldest winter months (Tmin, °C) and of the warmest summer months (Tmax, °C), 1951–2010. – 1 = linear trend (regression line); 2 = moving trend (means for 10 values)

Conclusions

From the analyses of the 60-year long observation series the following conclusions can be drawn. In function of climate on the upstream catchment, the water of the Danube is generally warmer at the entrance to the Carpathian Basin than that of the Tisza, but in summer the Tisza water reaches higher temperatures and also its annual temperature range is higher. After November the water of the Tisza cools more rapidly than the Danube.

The overall rising trend in the monthly mean temperatures of Danube water indicate remarkable climate change, winters getting milder in the catchment section upstream of Dunaremete, while a similar trend cannot be pointed out for the Tisza catchment in the NE-Carpathians. These trends does not show steady warming but are interrupted by short spells of positive and negative fluctuations, which primarily depend on winter and summer air temperatures.

REFERENCES

Bacsó, N. 1959. *Magyarország éghajlata* (Climate of Hungary). Budapest, Akadémiai Kiadó, 302 p.

Bartholy, J., Pongrácz, R. and Pattantyús-Ábrahám, M. 2007. A cirkulációs viszonyok változásának elemzése az atlanti-európai térségben (Analysis of changes in air circulation in Atlantic Europe). *Légkör* 52. 18–24.

Greguss, Gy. 1866. A Dunavíz hőmérséklete vonatkozólag a hazai viszonyokra (Water temperature of the Danube in Hungary). *Matematikai és Természettudományi Közlemények* 4. Budapest, MTA, 472. p.

Lászlóffy, W. 1956. *Folyóink és tavaink hőmérsékleti viszonyai* (Temperature conditions of lakes and rivers in Hungary). Beszámoló a VITUKI 1955. évi kutatásairól. Budapest, VITUKI, 131–146.

Mika, J. 1988. A globális felmelegedés regionális hatásai a Kárpát-medencében (Regional impact of global warming in the Carpathian Basin). *Időjárás* 92. 178–189.

Mika, J. 1989. A globális felmelegedés és magyarországi hatásai (Impacts of global warming in Hungary). *Vízügyi Közlemények* 71. 542–599.

Mika, J. 1991. A nagyobb globális felmelegedés várható magyarországi sajátosságai (Predictable characteristics of major global warming in Hungary). *Időjárás* 95. 265–278.

Pasteiner, D. 1905. A Tisza folyó hőfoka (Temperature of the Tisza River). *Vízrajzi Évkönyv* 13. Budapest, Országos Vízépítési Igazgatóság, 141–150.

Péczely, Gy. 1979. *Éghajlattan* (Climatology). Budapest, Tankönyvkiadó, 336 p.

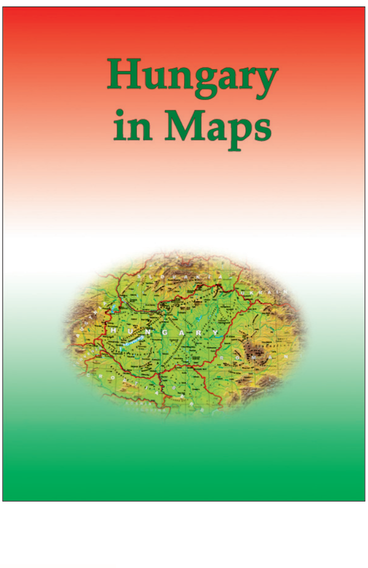
Hungary in Maps

Edited by
Károly Kocsis and Ferenc Schweitzer

Geographical Research Institute Hungarian Academy of Sciences
Budapest, 2009. 212 p.

'Hungary in Maps' is the latest volume in a series of atlases published by the Geographical Research Institute of the Hungarian Academy of Sciences. A unique publication, it combines the best features of the books and atlases that have been published in Hungary during the last decades. This work provides a clear, masterly and comprehensive overview of present-day Hungary by a distinguished team of contributors, presenting the results of research in the fields of geography, demography, economics, history, geophysics, geology, hydrology, meteorology, pedology and other earth sciences. The 172 lavish, full-colour maps and diagrams, along with 52 tables are complemented by clear, authoritative explanatory notes, revealing a fresh perspective on the anatomy of modern day Hungary. Although the emphasis is largely placed on contemporary Hungary, important sections are devoted to the historical development of the natural and human environment as well.

In its concentration and focus, this atlas was intended to act as Hungary's 'business card', as the country's résumé, to serve as an information resource for the sophisticated general reader and to inform the international scientific community about the foremost challenges facing Hungary today, both in a European context and on a global scale. Examples of such intriguing topics are: stability and change in the ethnic and state territory, natural hazards, earthquakes, urgent flood control and water management tasks, land degradation, the state of nature conservation, international environmental conflicts, the general population decline, ageing, the increase in unemployment, the Roma population at home and the situation of Hungarian minorities abroad, new trends in urban development, controversial economic and social consequences as a result of the transition to a market economy, privatisation, the massive influx of foreign direct investment, perspectives on the exploitation of mineral resources, problems in the energy supply and electricity generation, increasing spatial concentration focused on Budapest in the field of services (e.g. in banking, retail, transport and telecommunications networks), and finally the shaping of an internationally competitive tourism industry, thus making Hungary more attractive to visit.



This project serves as a preliminary study for the new, 3rd edition of the National Atlas of Hungary, that is to be co-ordinated by the Geographical Research Institute of the Hungarian Academy of Sciences.

Price: EUR 20.00
Order: Geographical Institute RCAES HAS Library
H-1112 Budapest, Budaörsi út 45.
E-mail: magyar.arpad@csfk.mta.hu