Védelem Tudomány 2023. 8. évfolyam 3. szám, 2023 október DOI: 10.61790/vt.2023.13136

The meteorological background of floods, and correlations between precipitation events: the 2013 Danube flood

Az árvizek meteorológiai háttere és a csapadékesemények összefüggései a 2013-as dunai árvíz tükrében

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Absztrakt:

A 2013 júniusi dunai árvíz kialakulásának előzménye a napok alatt lehullott, kiemelkedő mennyiségű csapadék. A hulló csapadék képződésének meteorológiai feltételeit vizsgálva a május 30. és június 2. közt lehullott, nagyjából két és fél hónapnyinak megfelelő eső játssza a főszerepet. A csapadék kialakulásának feltétele volt a Közép-Európa fölött kialakult ciklon, amelynek hőmérséklete ugyanakkor előnyt jelentett abban a tekintetben, hogy a hóban tárolt vízmennyiség nem indult olvadásnak.

Kulcsszavak: árvíz, csapadék, ciklon, Duna

Abstract:

The prelude to the Danube flood in June 2013 was an outstanding amount of precipitation that fell in only a few days' period. Examining the meteorological conditions for the formation of the falling precipitation, the rain falling between May 30th and June 2nd, corresponding to two and a half months' amount, plays the main role. The cause of the precipitation was the cyclone that formed over Central Europe, and its temperature was an advantage in that the amount of water stored in the snow did not start to melt.

Keywords: flood, precipitation, cyclone, Danube

1. INTRODUCTION

The basic prerequisite for the development of floods is an adequate amount of precipitation. Floods can also occur as a result of wind conditions (that's characteristic of seaside areas), but in this case, I am primarily dealing with precipitation conditions resulting in the formation of a notable flood of a single river, so wind waves and protection against them are not the subject of this thesis. The conditions for the formation of falling precipitation are the presence of sufficient water vapour content, aerosols (condensation seeds), and the cooling of the air to the dew point (mostly by updrafts). Factors that cause or promote upwelling: relief (orographic) barrier thermal movement due to warming of the earth's surface (hot air balloon), weather front.

The phase of precipitation can be liquid, solid, or a transition between them. The sudden melting of the solid precipitation after a significant temperature change has also caused significant floods in many cases. As we will see, this did not play any role in the development of the June 2013 Danube under study – even though a very large amount of snow fell a few months earlier. I also examine whether there are connections between the two weather events.

2. THE 2013 DANUBE FLOOD AND ITS CAUSES

The Water Management Act 1995 (1995 c. 57) [1] lays down that "the performance of tasks necessary for the protection against damage to waters – the construction, development, maintenance, operation, and protection of protection works – is the responsibility of the state, local governments, and those interested in the prevention or elimination of damage." Local water damage prevention is the protection against harmful waters that may occur due to the possible absence of protection works built for flood and inland water protection, and the return of water spread in the area due to flooding into watercourses and canals. Its technical tasks are: preparation for the defence, the defence, and the measures following its cessation. In this case, we can also conclude that – although the flood caused considerable damage and expenses – it was basically not the cause of the extensive natural conditions.

Hydrological studies show that during floods and falls, not only do water levels change, but also the water surface experiences fluctuation. When there is a flood, the drop in the water level is greater, while when it recedes, it is smaller than in a permanent state – which is what we consider water movement to be. Since the fall of the energy line is almost the same as the fall of the water surface, we can determine based on the Chezy formula (which is an empirical formula relating river discharge to channel dimensions and water surface slope) that, at the same water level, the water yield is higher in the flooding state, while in the falling state it is lower than in the permanent state.

As Zsuffa points out in his book, "in free-surface, permanent water movements – including rivers in general – according to theories, the water flow and the water level in any section are clearly related to each other. This […] is also widely used in hydrological practice when determining the time series of water flows from water levels. However, in the history of the Tisza river at the end of the 19th century, the experience of measurements showed the opposite regarding the clarity of this connection." [2, p. 93] In the case of our present investigation, however, it is not the direction of the flood loop curve that is unusual, but the meteorological and weather factors that determine the development of the flood itself. In addition to the factors detailed below, hydrological aspects also contributed to its development, such as, for example, the flooding at the same time.
The notable event already mentioned is the tidal wave that descended on the Danube in the first days of June 2013, which in a few days broke many previous flood records. As summarized in the table of Homikiné's study [4], the greatest increase (by 35–43 cm) was observed at the Nagybajcs, Komárom and Esztergom water gauges compared to the previous highest waters measured in 2013, namely in these cases compared to 2002, at the Nagymaros and Budapest water gauges. There were

also increases of over 30 cm, compared to the previous highest volume in 2006. In our other water gauges, the highest values in 1965 were typically lower by 10-20 cm, in the case of Baja, fell from 976 cm to 989 cm.

A particularly narrow period of one and a half days and quite intense rain at the same time directly caused the Danube flood, which exceeded the standard levels for decades. Bavarian cities along the Danube suffered extensive damage, flooding hundreds of square kilometres in Eastern Germany. The flooding also hit Slovakia, Hungary, and Serbia, among other countries. In a few days of June 2013, an extremely large amount of precipitation fell in the Danube's Bavarian-Austrian river basin. In the border region of Germany and Austria, more than 150 mm of rain fell in several places in 36 hours until eight in the morning on June 2. (Although the flood followed weeks of heavy rainfall, it was the intense precipitation that fell between May 30 and June 2 that caused the flooding. The precipitation sums for the period for Bavaria and that of June 2 for Austria can be seen in figure no. 1.) The fundamental reason for this, as we shall see shortly, is to be found in the meridional global atmospheric circulation, as shown by Horvath et al. [6]. Before we get to that, let's examine the chronology of the events.

As Horvath and his co-authors state, the 15-20 mm of rain that fell in a large area between Linz and Győr was the starting point of the rather rainy period that started on May 30, which caused the flood. [6] Rainfall continued heavily during the night, mainly in the upper catchment area, and then the following day also resulted in heavy rain, mainly around Vienna: amounts of around 15-20 mm fell.
The next 24 hours also showed significant precipitation activity in the upper section – adding, however, that the daily rainfall exceeded 100 mm at some measuring points in the mountains.According to the point of view of Horvath and his co-authors, the reason for the intense rainfall that continued to fall in the first few days of June (Linz and Passau area, June 1-2: 70 mm; on the 2nd mainly in the river basins of the Inn, the Isar and the Traun, about 40 mm on average) was that the flood wave was so strong – because if these quantities did not appear in the mentioned catchment areas, the Danube flooding would have been significantly smaller. [6]

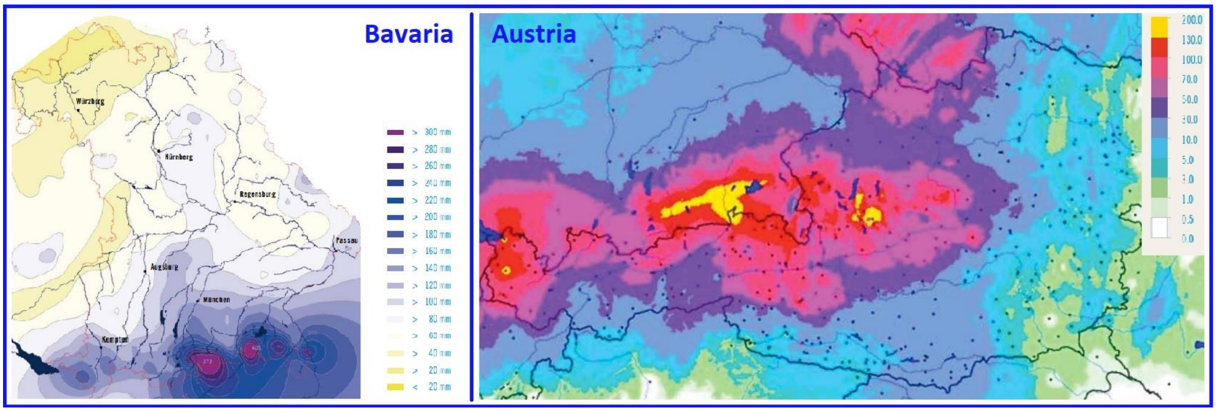

Figure 1: Rainfall totals for the four-day period between May 30 and June 2 in Bavaria and June 2 in Austria. Source: [8]

Although the snow in the higher areas did not start to melt in the cold of the cyclone, the flood wave occurred almost immediately due to this intensive rainfall. For this reason, I stated above that this event has nothing to do with the amount of water otherwise present in the snow reserve. It is questionable whether there could have been a scenario that would have resulted in the combination of the mentioned two events as a result of the temperature change, but it appears below that this was actually impossible.

The planetary wave is called so because a particularly large amount of moisture has accumulated in its low-pressure system - above all, we have to mention the Mediterranean basin here. The air stagnant and repeatedly forming vortices were forced to undergo an unusual transformation. As Horvath and his co-authors point out, instead of the "usual cold and warm front structure, spirally twisted arms, so-called moisture was concentrated in wet conveyor belts. Several of such conveyor belts were created in the cyclone that caused heavy rainfall" [6]. As it turns out, the particularly intense rainfall that began to fall on June 1st was caused by a strengthening anticyclone approaching from the Atlantic and distorting the western flank of the cyclone, forcing the conveyor belts to crowd into each other on the northwest side of the cyclone, and on the south to turn in the direction of the Alps, "which brought the rest as good extras for the sake of the film." [6]

The rainfall was caused by a cyclone – the effects of which had already been seen in the region long before. A relatively motionless, low-pressure, cold planetary wave had been hovering over the central and western parts of Europe for several weeks, as Horvath and his co-authors point out. [6] They also point out that the low-pressure cyclones of deepened waves result in precipitation, while the high-pressure anticyclones result in dry weather.

"The cyclone that directly caused the Danube flood was formed in the low-pressure part of such a stationary planetary wave that remained for weeks. The centre of the cyclone was located over the Czech Republic on May 31, and on its eastern side, warm air flowed over Russia, the Baltic, and Scandinavia, causing unusually warm summer weather there. On the backside of the cyclone, the cool air mass caused unusually cold weather in the French, German and Alpine regions." [6] All this can be clearly seen in fig. no. 2.

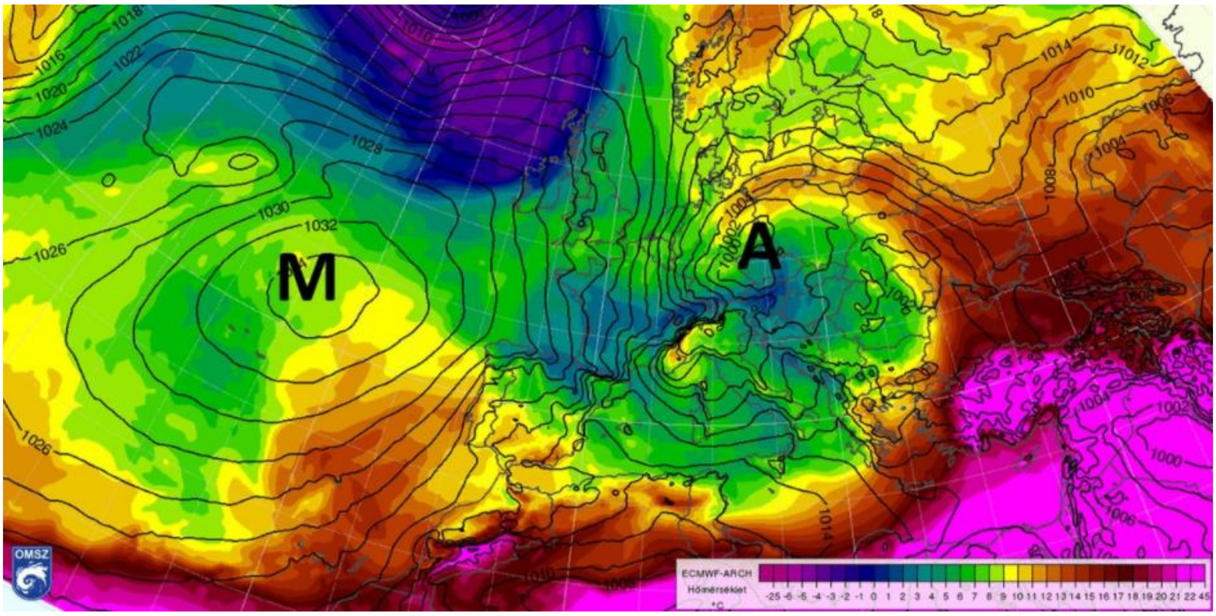

Figure 2: Warm air flowed on the eastern side of the cyclone over Central Europe, the Baltic, and Scandinavia, while in the western part it was flooded with unusually cold air in the region of the Alps and Western Europe in 2013. May 31st at 2 p.m.
(Air pressure at sea level and temperature at 850 hPa) Source: [6]

Fortunately, the cyclone moved and filled up, Horvath and his co-authors state, which resulted in the end of the rainy season for the area of this study. [6] At the same time, I am indebted to mention what Homokine [4], Horvath [5], and Hodobacs [3] also mention: and this is none other than the snowstorm that occurred in our country on March 14th.

"The blizzard, then the cool spring, and the frequent Mediterranean cyclones are ultimately the indirect consequences of the previously mentioned meridional type of global circulation. The polar cold pole is surrounded by a belt of westerly winds. As the temperature of the pole decreases, the strength of the surrounding east-west flow increases. In the zonal circulation type that occurs at this time, the weather in the temperate zone is more balanced, and air masses from the oceans are warmer in winter and cooler in summer, moving into the interior of the continents. At the same time, the zonal flow does not favour the heat exchange in the north-south direction, and as a result, the temperature difference in the north-south direction will be large. Mainly because of this difference, the flow becomes unstable, waves are formed, and, becoming meridional, it transports cold from the north and heat from the south." [4]

This kind of formation of the meridional type is particularly rare in the Carpathian basin; at the same time, the abovementioned example shows perhaps the most relevant fact that it is not impossible at all. The snowstorm in March was generated by this situation, as well as the Danube flood in June a few weeks later. "If these kinds of cold fronts reach the Carpathian basin from the northwest, then in our country it usually takes the form of a fast-moving cold front, which passes over us, causing much less trouble than at present. This time, however, the cold air first rushed into the Mediterranean basin, where it created a large-scale Mediterranean cyclone." [4] As stated, in this case, an additional influence played a role in the formation and course of the mentioned events, namely the so-called jet-stream, which is a wind channel that surrounds the entire Northern Hemisphere.

We can therefore conclude that the meridional type, which has increased in recent years and entails an increase in the frequency of extremes, also played a significant role in the development of the unusually intense flood (but already previous weather characteristics) – as Horvath highlights. [5]

The National Meteorological Service (Hungarian abbreviation: OMSZ) is certainly also researching the topic, which, as Hadobacs points out, is at the forefront of accurate forecasting of extreme snowfall and floods [3], and the following statement is made for the not-too-distant future: "The OMSZ based on three model simulations, more intense precipitation events are expected in all seasons except spring for 2021–2050, while the length of dry periods in the spring-summer period also increases. All this predicts a more uneven distribution of precipitation." [7] The extreme events of 2013 already emphasize to prepare carefully for everything that our forecasts call our attention to.

3. CONCLUSION

An extreme amount of precipitation led to the Danube flood in June 2013. The rain occurred over a period of only four days. The meteorological conditions for the formation of the falling precipitation are examined. The rain falling between May 30th and June 2nd, corresponding to two and a half months' amount, played a crucial role. The condition for the formation of the extreme rainfall was the cyclone that formed above Central Europe, and its temperature was an advantage in that the amount of water stored in the snow did not start to melt.

4. REFERENCES

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