CATASTROPHIC FLOOD ON THE DANUBE RIVER IN AUGUST 2002

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Abstract: Formation and transformation of the catastrophic rainfall flood on the Danube River in August 2002, and preceding synoptic situation are considered. The main cause of heavy rains, resulted in the flood, was the sharp aggravation of a frontal zone with interaction of very cold Arctic and very warm Atlantic tropical air masses. The peak of the flood traveled along the Danube River from its upper part to the reservoir of Iron Gate-I in 15 days. Water levels near several towns exceeded the historical maximum and inundations took place. The flood converted into an artificial flush below the reservoir due to timely decrease of its storage. The flush rapidly sprawled along the Lower Danube and did not cause the inundation.
Keywords: Cyclone, front, rain, water level, flood, flush, gauging station.

KATASTROPHAL HOCHWASSER AM DONAUFLUSS IM JAHRE 2002

Schlüsselworte: Zyklone, Front, Regen, Wasserstand, Flut, Hochwasserableitung, Hydrologischer Posten

1. Synoptic conditions prectding the flood.

Intensive storms, heavy rains and floods, which followed them in the first half of August 2002, were caused by amplification of the meridional air masses movement during the penetration of cold Arctic air from the Northern Atlantic into Western Europe. As a result, a high-altitude frontal zone became aggravated here. There was an interaction of Atlantic wet tropical air with temperature of 28–35°C and Arctic air with maximal temperature of 18–23°C in a frontal zone. There were a heavy fall of rains in Southern France, Northern Italy and Switzerland on August 6, when a high cyclone vortex displaced here.

The process of cyclones formation was very active on August, 12–13. On the eve of August, 11 a polar front became active on periphery of a high cyclone. In the north of Italy, the cyclone with pressure of 997 mb at its centre was formed on a wave of this front. The centre of this cyclone already existed near Vienna on August, 12 (Figure 1). The catastrophic storms and heavy rains were connected with this cyclone. The total rainfall considerably exceeded monthly norm. Snow avalanches in mountain areas of Europe were a contributory factor for these processes.

In the first half of August 2002, a zone of rains covered the southern and eastern parts of Germany, Austria, Czech and Slovak Republics and adjacent territories. In the Upper Danube and in the upper part of the Elbe (Labe) River basin especially strong rains were observed on August, 6–7 and 11–12. The first wave of heavy rains led to floods on the rivers of Germany and in the southern and western parts of Czech Republic. The second wave of heavy rains followed, when soils were already saturated with water, and water levels in the rivers were enough high. Therefore, water levels in all rivers quickly rose and in specific cases reached the historical maximum.

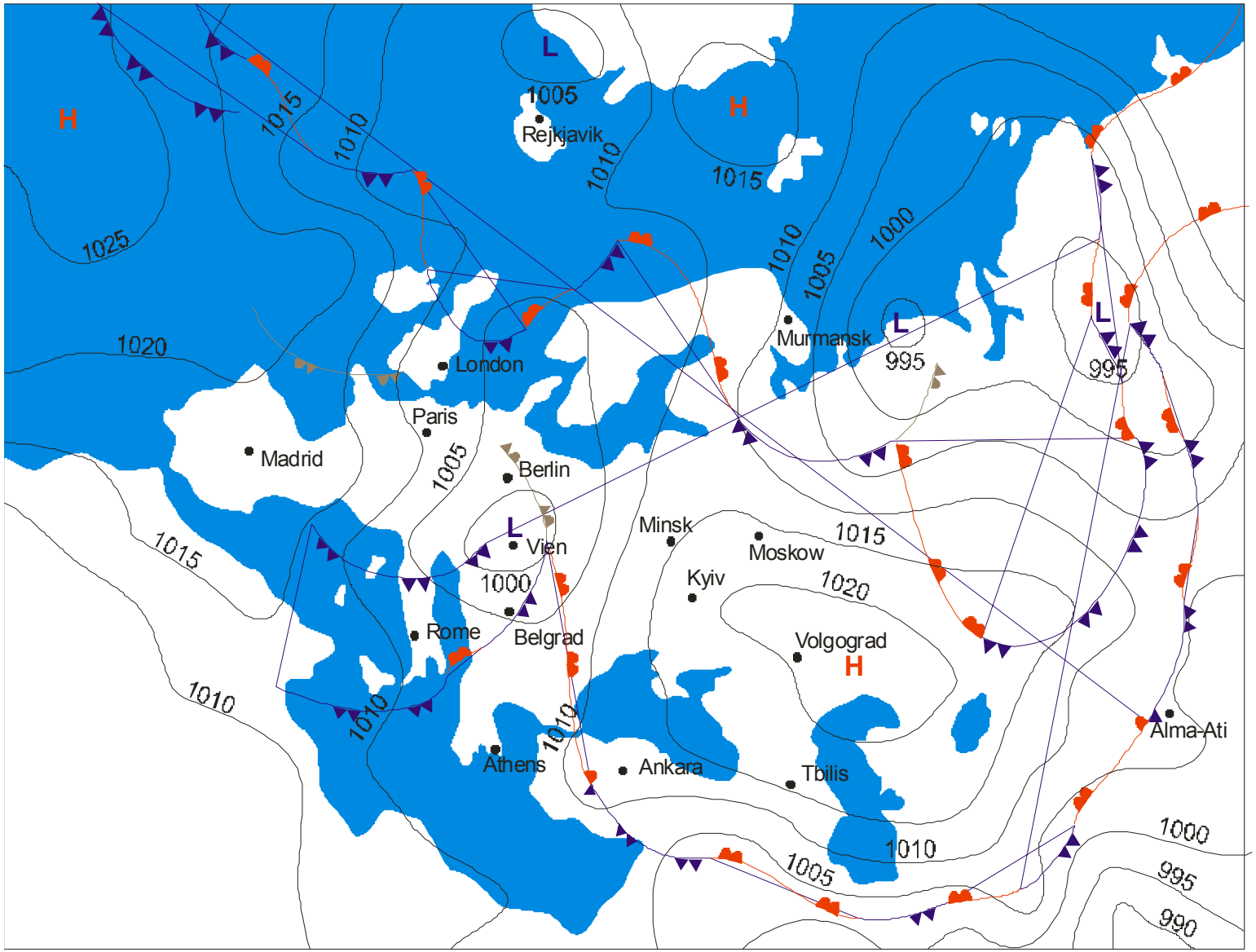


Figure 1. Synoptic conditions in Western Europe on 12th of Auguct 2002.

2. Development and transformation of the flood along the Danube river.
For the analysis of occurrence and movement of the flood in August 2002, we used the data on daily water levels on 25 gauging stations from the Upper Danube to the river mouth (Figure. 2, Table 1). On the base of data on water levels measured each day at 8 o'clock, we plotted the graphs, which allowed us to follow the evolution of the flood practically from the source to the mouth of the Danube River (Figure 3a-h). For comparison of water levels observed in August 2002 with historical maxima, we used the data of the Danube Hydrometeorological Observatory and reference sources of hydrological data on the Danube River [1–3].

The very first wave of the flood on the *Upper Danube* (on the reach from the source to the inflow of the Morava River) began to form on August, 6. The first peak of the flood at the gauges in Ingolstadt, Regensburg, Passau, Linz, Kienstock and Bratislava came on August, 8–9. The excesses of the water levels above an average level in the beginning of month at these gauges were approximately 100, 70, 270, 260, 480 and 370 cm, respectively. By August, 10–11, the water level decreased here to a monthly average mark. The first wave of the flood did not extended downstream Bratislava.

The second wave of the flood began to form after August, 11. As heavy rains simultaneously covered the basin of the Upper Danube and its tributaries, the peaks of the second wave of the flood on the reach from Ingolstadt to Kienstock (80 km upstream Vienna) were observed practically simultaneously: on August, 13-15. Only downstream Kienstock, the flood was characterized by well-expressed wave moving downwards the river. Excesses of the water levels above preceding average levels at the gauges in Ingolstadt, Regensburg and Passau were about 390, 280 and 550 cm, respectively. Some areas of Regensburg were flooded. Passau was damaged by water most of all. On the Austrian reach of the Danube River, the maximum of the water levels came on August, 13–14. These days, levels at the gauges in Linz and Kienstock increased by 420 and 780 cm in comparison with average levels in the beginning of this month. And the water level at Kienstock reached 1085 cm above datum and exceeded the historical maximum (896 cm above datum in July 1954). Many settlements between Vienna and Austrian-Hungarian boundary were flooded. However, Vienna was slightly suffered from the flood: the protective dams retarded a pressure of water.

On the upper border of the *Middle Danube*, the water level in Bratislava since August, 12 promptly rose, from a mark of 466 cm above datum. On August, 13 the water level reached 674 cm, and on August, 14 it achieved 839 cm, on August, 15 it equaled 961 cm. Because of a sharp rise of the water level, the urgent evacuation of the inhabitants of Devin (suburb of Bratislava) began. The maximum water level in Bratislava was observed by August, 16. It equaled 986 cm above datum. It was higher by 2 cm than the historical maximum in July 1954 and by 659 cm than an average level in the beginning of August 2002. Such sharp rise of the water level of the Danube River near Bratislava can be explained as well as by the inflow of the Morava River (a large left tributary of the Danube River), where the rainfall flood was already generated.

The peak of the flood wave passed from Kienstock to Bratislava (146 km) during 2 days with the speed of 73 km/day, or 0.84 m/s.

On the Hungarian reach of the Danube River, the flood threatened to historical monuments and large resort zones. Near Budapest, the water level began to rise approximately on August, 8. The second wave of the flood spread from Bratislava to Budapest (222 km) in 3 days (with the speed of 74 km/day, or 0.86 m/s). The low part of Pest on the left bank of the river suffered from the flood. The peak of the flood was fixed on August, 19. The level rose up to a mark of 844 cm above datum (only by 1 cm below the historical maximum and approximately higher by 630 cm than an average level in the beginning of August).

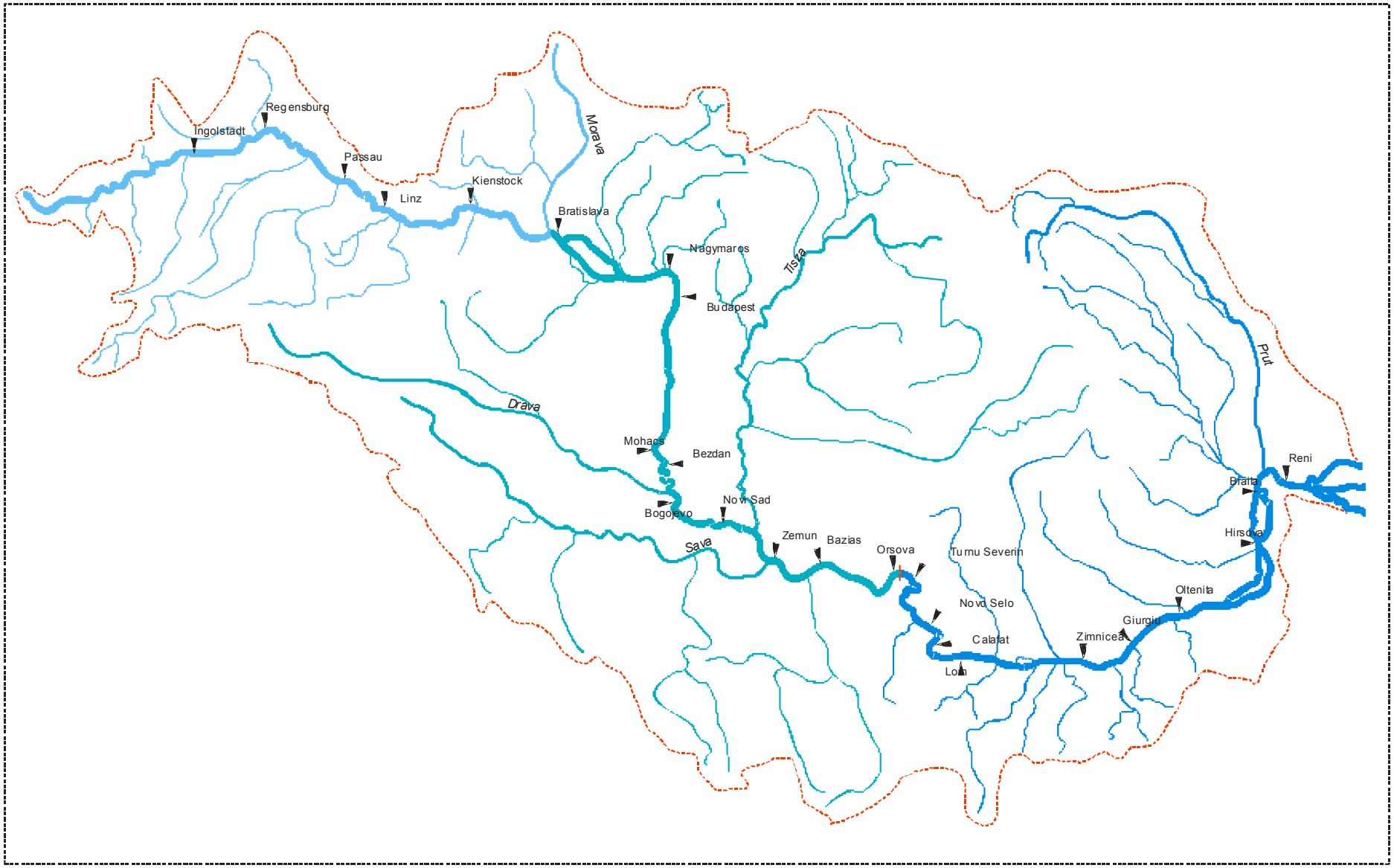
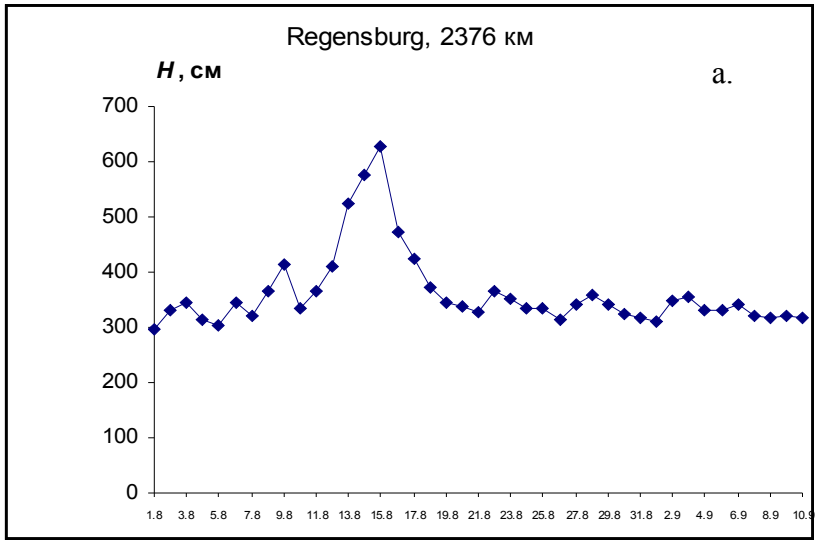


Figure 2. Danube river basin and location of gauging stations

Table 1. Highest water levels during the flood in august-september 2002 and their historical maximums on a gauging stations along the Danube river.

Gauging station		*State*	*Distance from Black Sea (Sulina), km*	*Flood in august – september 2002*			*Historical maximum*		
№	*Name*			*highest level (from zero of gauge), cm*	*data*	*Excess under the flood preceding level, cm*	*period of measure-ments*	*level, cm*	*data*
1	Ingolstadt	Germany	2458	642	14 VIII	390	1827-1970	778	18.06.1910
2	Regensburg	>>	2376	627	15 VIII	280	1884-2001	666	28.03.1988
3	Passau	>>	2225	1083	13 VIII	550	1877-2001	1230	10.07.1954
4	Linz	Austria	2135	799	13 VIII	420	1893-2001	963	11.07.1954
5	Kienstok	>>	2015	1085	14 VIII	780	1830-2001	896	13.07.1954
6	Bratislava	Slovakia	1869	986	16 VIII	650	1823-2001	984	15.07.1954
7	Nagumarosh	Hungary	1695	707	18 VIII	600	1876-2001	682	17.06.1965
8	Budapest	>>	1647	844	19 VIII	630	1876-2001	845	17.06.1965
9	Mohach	>>	1447	924	22 VIII	650	1876-2001	984	19.06.1965
10	Bezdan	Croatia	1425	712	22 VIII	600	1876-2001	776	24.06.1965
11	Bogojevo	>>	1367	727	23 VIII	600	1890-2001	817	15.06.1965
12	Novi Sad	Serbia	1255	602	25 VIII	460	1888-2001	778	30.06.1965
13	Zemun	>>	1173	470	27 VIII	240	1876-2001	757	26.03.1981
14	Bazias	Romania	1072	628	28 VIII	50	1874-1970	795	06.04.1942
15	Orsova	>>	955	2540	1 VIII	-	1888-2001	2568	17.10.1994
16	Turnu-Severin	>>	931	831	27 VIII	150	1879-2001	906	28.03.1981
17	Novo Selo	Bulgary	834	513	28 VIII	360	1941-2001	900	28.03.1981
18	Calafat	Romania	795	415	22,28 VIII	360	1879-2001	801	29.03.1981
19	Lom	Bulgary	743	558	28,29 VIII	360	1921-2001	934	29.03.1981
20	Zimnicea	Romania	554	411	30 VIII	310	1879-2001	800	02.06.1970
21	Giurgiu	>>	493	376	24,30 VIII	320	1879-2001	795	02.03.1970
22	Oltenita	>>	430	393	31 VIII	320	1879-2001	784	1897
23	Hirsova	>>	253	413	2-3 IX	320	1898-2001	727	04.06.1970
24	Braila	>>	170	431	2-3.IX	270	1874-2001	639	28.05.1970
25	Reni	Ukraine	127	350	2.IX	320	1921-2001	555	28.05.1970


Regensburg, 2376 км
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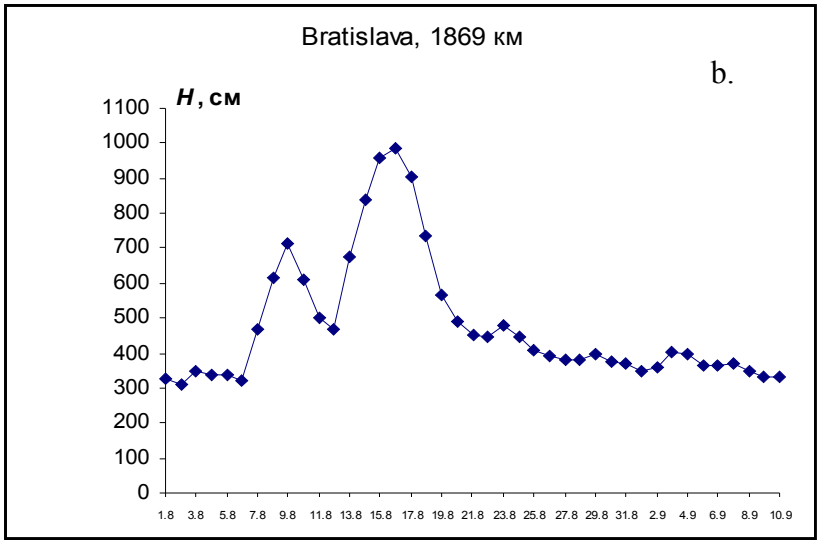
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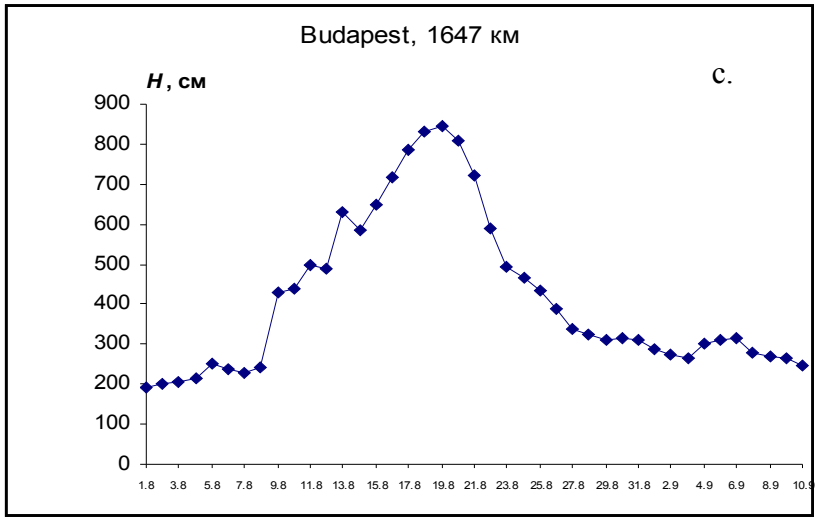
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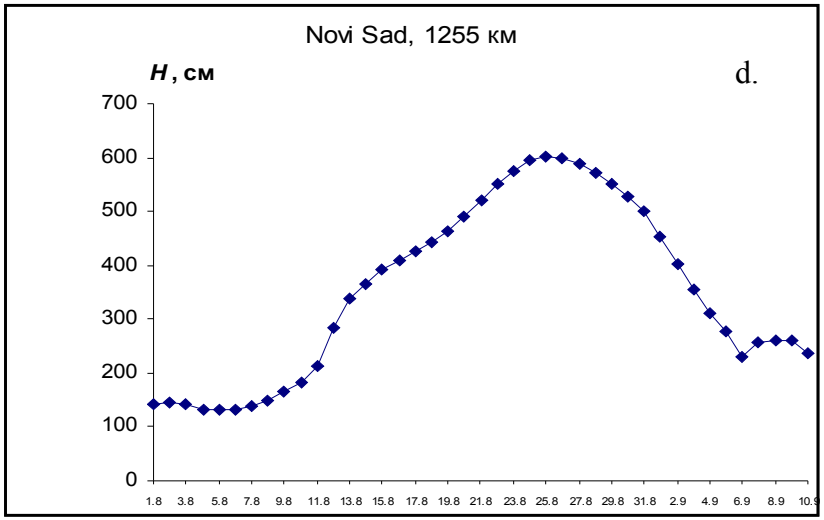
Novi Sad, 1255 км
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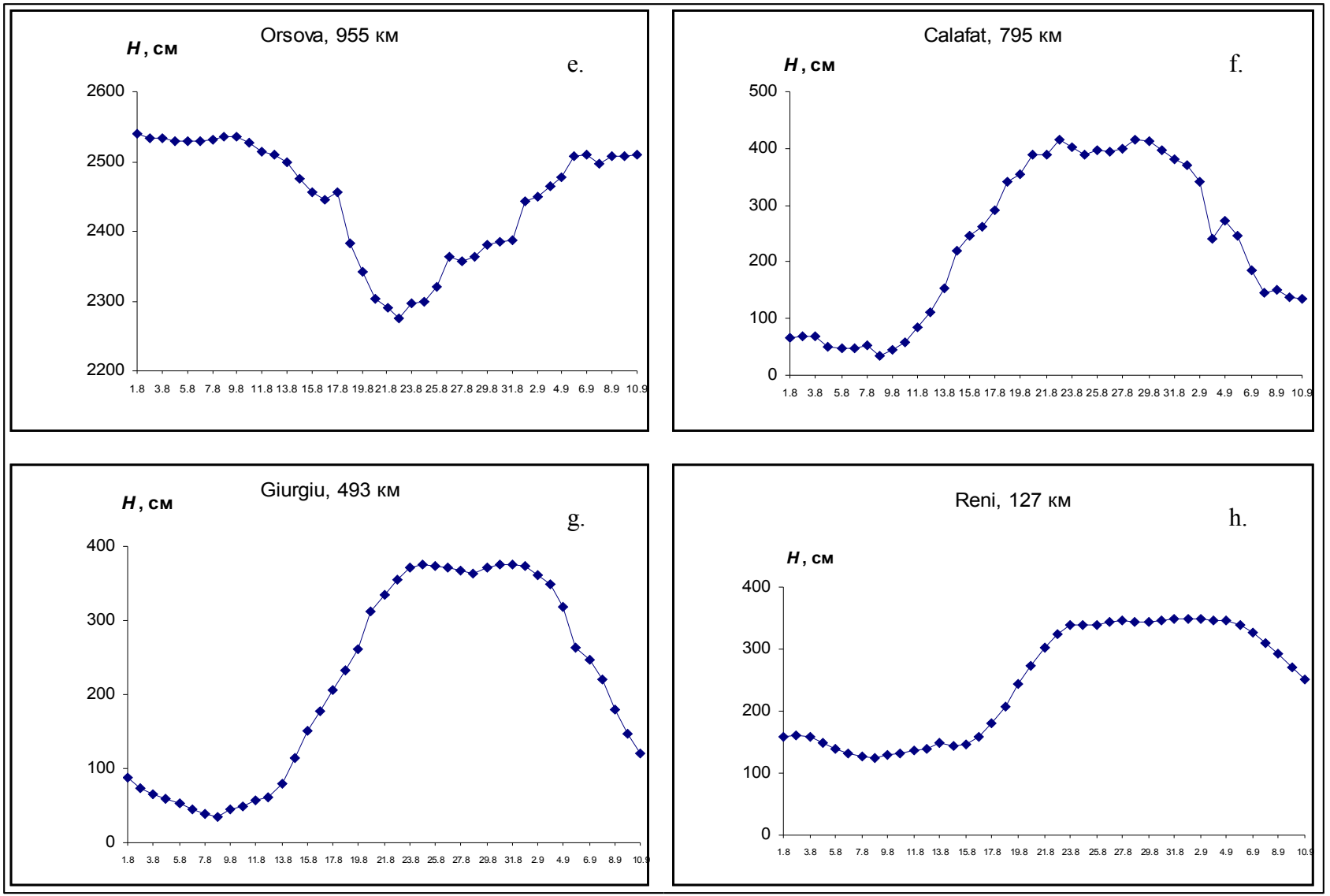

Figure 3. Graphs of changing of water levels on some gauging stations along the Danube river.

By August, 21, the flood wave reached Baja. And by August, 22, it came to Mohacs (on the boundary between Hungary and Croatia). From Budapest to Mohacs (200 km) the flood wave extended in 3 days with the speed of 66.7 km/day, or 0.77 m/s.

On Croatian reach of the river, the maximum water levels were observed in Bezdan by August 22, and in Bogojevo by August 23; they equaled 712 and 727 cm above datum respectively, almost higher by 600 cm than an average level in the beginning of August.

From Hungarian Mohacs to Novi Sad in Serbia (192 km) the flood wave spread in 3 days with the speed of 64 km/day, or 0.74 m/s, and from Novi Sad to Zemun (82 km) – in 2 days with the speed of 41 km/day, or 0.47 m/s. Here maximum water levels were fixed on August, 25–27. They equaled 602 and 470 cm above datum, respectively, that approximately higher by 460 and 240 cm than an average level before the beginning of the flood.

Near Bazias in Romania, the peak of the flood was observed on August, 28. Thus, on the Middle Danube (from Bratislava to the reservoir of the Iron Gate) the flood wave traveled approximately during 12 days.

On the *Lower Danube,* the water levels increase began on August, 9 with the beginning of the artificial flush from the reservoirs of Iron Gate-I and II (on the boundary between Serbia and Romania). The artificial flush was carried out beforehand to accept waters of the flood and to extinguish it on a reach downstream the reservoirs. Since August, 9 until August, 16 the water level in headwater of the reservoir dropped by 90 cm, and since August, 17 until August, 22 by 170 cm. When the flood reached the Iron Gate (August, 26–27), the level in reservoir dropped by 260 cm. This permitted to accumulate the volume of the flood in the reservoir and to prevent the further increase of water levels on the Lower Danube.

On the Lower Danube (from Turnu Severin to the Black Sea) any rainfall flood did not generate, and the artificial flush from the reservoirs of Iron Gate-I (the dam is in 943 km from the Black Sea) and Iron Gate-II (863 km from the sea) occurred.

On the Romanian reach of the Danube River near Calafat, the water levels began to rise on August, 9 (with the beginning of the flush from the reservoir). By August, 22 the water level reached the maximum (415 cm above datum) and exceeded an average level before the beginning of the flush approximately by 360 cm. Then the level dropped by 20 cm and again reached the maximum on August, 28. Near Zimnicea, Giurgiu and Oltenita changes in the water levels were similar. The water levels at the first two gauges began to rise on August, 9, reached the maximum on August, 30 and were equal to 411 and 376 cm, respectively. In Oltenita, the highest water level was on August, 31 (393 cm above datum). The excesses of maximum levels above an average level of water before the flush on these three gauges were 310, 320 and 320 cm, respectively. At the Romanian gauges in Hirsova, Braila and at the Ukrainian gauge in Reni, the rise of the water level began on August, 10–11. The maxima were achieved by September, 2 (413, 431 and 350 cm above datum respectively). The excess of the maximum water level above an average level before the beginning of the flush from the reservoir at these gauges were 320, 270 and 230 cm accordingly, that testifies that the flood wave along the Lower Danube gradually flattened out.

Thus, on the Lower Danube the catastrophic flood did not take place due to a regulating role of the reservoirs. The maximum levels during the flush (in the end of August and in the beginning of September) were much lower than historical maxima.

The flood wave from Calafat to Reni (668 km) propagated in 11 days with the speed of 60.7 km/day, or 0.70 m/s.

3. Conclusions

Formation and transformation of the rainfall flood along the Danube River in August, 2002 and preceding synoptic conditions are considered. It is established, that as the basic reasons of the flood there were two extraordinary strong intrusions of cold air in the south of Western Europe. The heavy rains took place in a zone of interaction of warm Atlantic and cold Arctic air masses. As a result, the total rainfall much more exceeded monthly norms. Because of heavy rains on the Upper and Middle Danube, two waves of the catastrophic rainfall flood were generated. At a number of gauges on the Danube (Bratislava, Budapest, etc.) water levels exceeded historical maxima and caused inundation. The basic features of movement of the flood along the Danube are revealed. Because of decrease of storage of the reservoir of the Iron Gate, the flood «was extinguished» and converted into the artificial flush on the Lower Danube River. On the Ukrainian reach of the Danube, this did not cause a significant rise of water levels.

4. References

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