Synoptic analysis of the Catastrophic Floods in SE Europe, May 2014

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Introduction

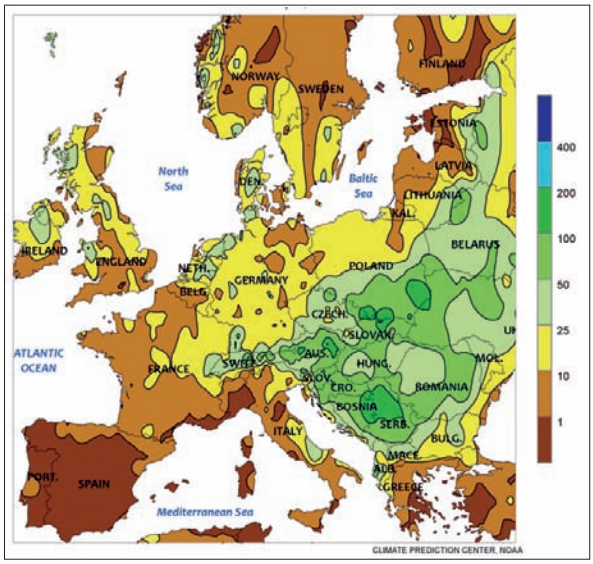
Over the past decade we have been witnessing increasingly frequent occurrence of catastrophic floods in Europe, caused by extreme precipitation events. One of these was the flood that occurred in east Croatia, north-west Bosnia and Herzegovina and central Serbia in mid-May 2014. It will most certainly be remembered as one of the most devastating events, as it was the worst flooding in the region in 120 years of record-keeping, with very large areas affected (Figure 1). More than 60 people died, over 100,000 homes and structures were destroyed and thousands of livestock animals were killed (Figure 2). The water caused 3000 landslides in the area, but also exposed or moved many landmines left from 1990s war. The situation urged the Croatian Government to proclaim the event as a catastrophe, the first since Croatia's independence. In the region, a state of emergency was declared in 18 towns and cities, including Belgrade in Serbia. The Serbian Prime Minister declared this the greatest flooding disaster ever.

▲ *Figure 1: Map of flooded areas during May 2014 flood (source: Wikipedia)*

◀ *Figure 2: Catastrophic consequences of May 2014 flood in SE Europe (Source: WWW)*

Analysis of the weather conditions

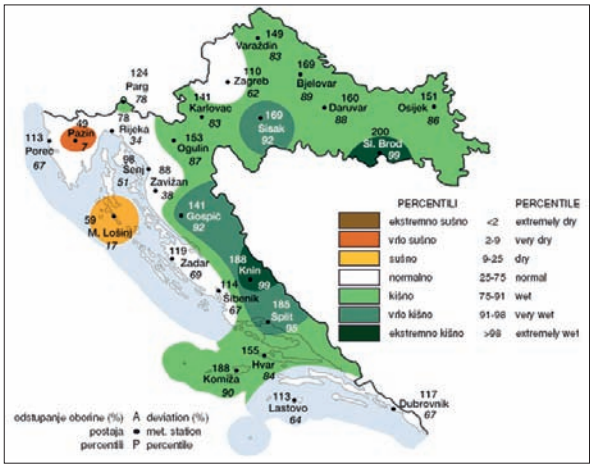
Heavy rainfall in the period between 11 and 17 May in east Croatia and neighbouring Bosnia and Herzegovina and Serbia exceeded the highest amounts ever recorded in some areas. In many places, rainfall amounts recorded during only 7 days (Figure 3) greatly exceeded average monthly precipitation for the entire month of May, and at some stations 3 month's worth of rain fell in these few days. The highest rainfall measured in east Croatia was 164 litres per square meter. At some stations in Bosnia and Herzegovina and Serbia total precipitation over this period exceeded 200 mm and in Bosnia even reached 300 mm.



▲ *Figure3: Total precipitation between 11 and 17 May 2014, NOAA Climate Prediction Center (source: Wikipedia)*

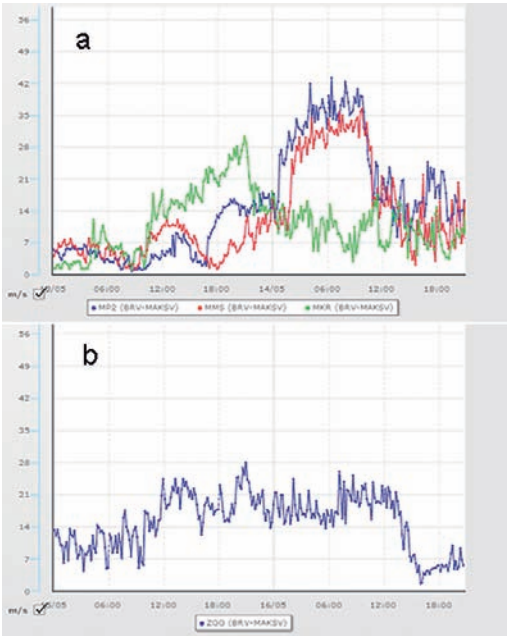
Besides the sudden and extremely heavy rainfall, the situation was additionally worsened by the fact that April 2014 was an extremely rainy month in most regions, and so was the beginning of May. Compared to climatology, April 2014 was wet or very wet across the area of east Croatia. The analysis of the precipitation amounts for April 2014, given in percentages (%)

of climatological average (1961 -1990) (figure 4), shows that monthly precipitation quantities at most of the analysed stations were above average.



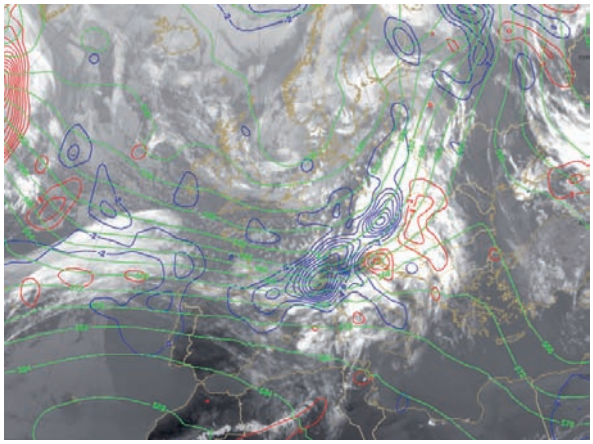
▲ *Figure 4: Deviation of precipitation from the climatological average in April 2014*

In Slavonski Brod, a station next to the Sava river, close to the area affected by floods, total monthly precipitation in April 2014 reached 200% of the climatological average and the rainy weather continued at the beginning of May. Therefore, large quantities of rain poured over the soil that was already saturated with water. Water levels in the rivers were extremely high and the Sava river, together with affluent rivers Vrbas, Bosna and Drina, flooded large areas of Bosnia and Herzegovina, Serbia and Croatia with catastrophic consequences.

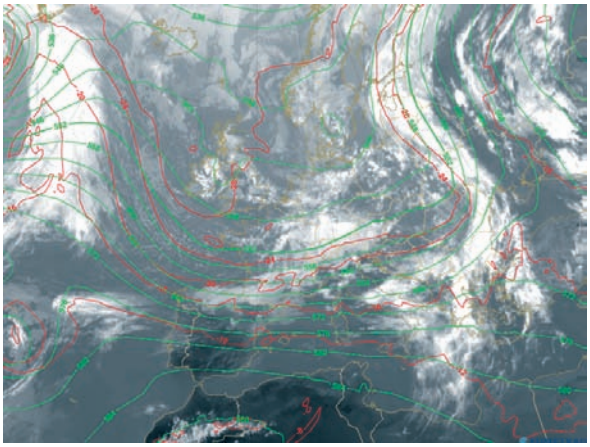


▲ *Figure 5: Maximum wind gusts measured by automatic stations in Croatia. a) for 13 and 14 May at Krk bridge (green), Pag bridge (blue) and Maslenica bridge (red) in the North Adriatic; b) for 15 and 16 May at the station Zagreb Grič*

Besides extreme precipitation, in most of the areas strong winds were also observed, with storm and even hurricane speed gusts. Windstorms caused damage along the Adriatic coast, but also in the continental areas. At the Croatian Adriatic coast wind gusts reached up to 42 m/s, whereas over the northern parts of Croatia very strong northerly winds, with constant gusts of 15 to 22 m/s and maximum gusts of 28 m/s, blew for 24 hours (Figure 5).



▲ *Figure 6: AT 500 (green) and temperature advection at 700 hPa (red: warm, blue: cold) from the ECMWF model, overlaid on Meteosat 10 IR 10.8 µm image on 11th May 2014, 1800 UTC*

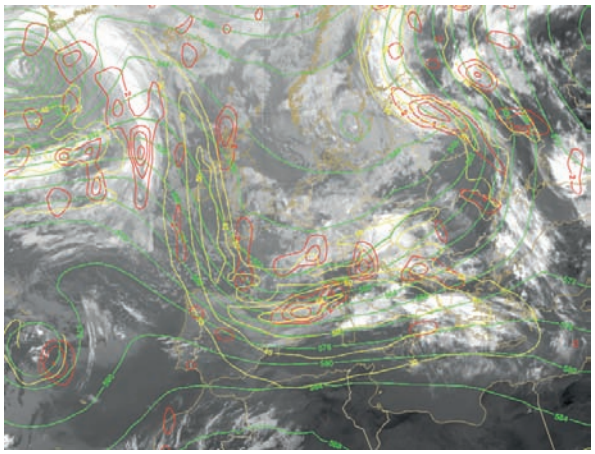


▲ *Figure 7: AT 500 (green) and temperature at 500 hPa (ECMWF), overlaid on Meteosat 10 IR 10.8 µm image on 12th May 2014, 1800 UTC*

Synoptic Situation

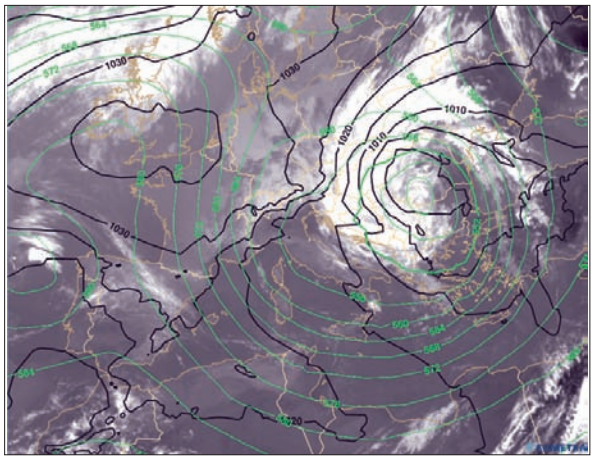
In the period between 12th and 15th May an upper-level pressure trough was moving from the west of Europe towards the southeast. The axis of the trough, and with it also the surface front, moved across central Europe and the Balkans during the night of 11th and the morning of 12th May. After the front passed over central Europe and the Balkan Peninsula, the cold air from the north of the continent arrived (Figure 6).

At the same time, in the strong westerly flow from the Atlantic, large quantities of humid air arrived (visible in figure 7 west of the Alps). By the end of the 12th May, a new upper-level trough formed west of the Bay of Biscay (figure 7). It moved very quickly eastwards with very strong westerly winds and was getting deeper during the 13th May (figure 8).



▲ *Figure 8: AT 500 (green), isotachs at 300 hPa (yellow) and cyclonic vorticity advection at 300 hPa (red) from ECMWF model, overlaid on Meteosat 10 IR 10.8 µm image on 13th May 2014, 0600 UTC*

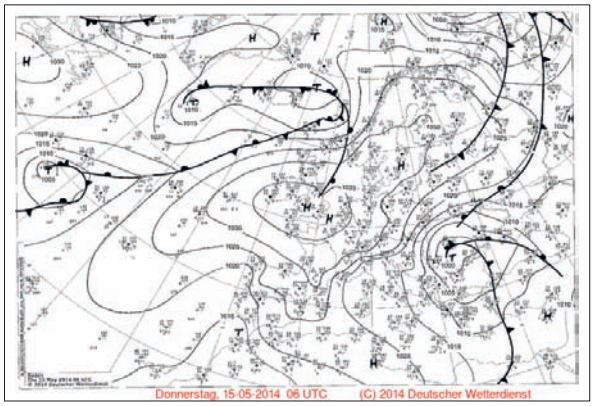
The process intensified when the upper-level trough crossed over the Alps. A surface low formed over northern Italy and the Adriatic on the 13th May, moving slowly towards NE. During the 14th May, the trough closed into a deep cyclonic vortex, stretching almost through the entire troposphere, with the cyclone axis being placed almost vertically, so that the centre of the upper-level low in the highest layers was almost exactly above the centre of the surface cyclone. This contributed to the intensity and stationarity of the entire system. The cyclone reached its maximum on 15th and 16th May, while its centre shifted only slightly towards northeast (Figure 9).



▲ *Figure 9: AT 500 (green) and MSLP (black) from ECMWF model overlaid on METEOSAT 10 10.8 µm image on 15th May 2014, 0600 UTC.*

The system was receiving humidity from the Mediterranean and the Black Sea, while pulling cold air from the north. During 15 May, the centre of the surface low was over the central parts of the Balkan peninsula. The cyclone remained quasi-stationary for more than 3 days over SE Europe. Precipitation was additionally enhanced by the orography of the Bosnian mountains with many thunderstorms embedded in the cyclonic cloud system.

Because of the northeasterly flow in the upper levels, the cyclonic vortex slowly returned westwards, while at the same time the anticyclone ridge (Figure 10) grew stronger.

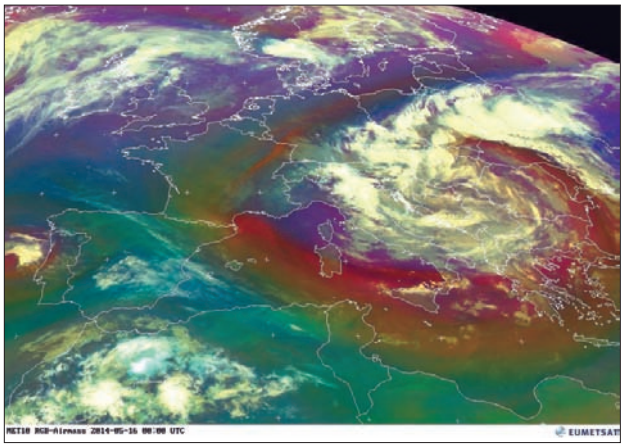


▲ *Figure 10: Surface air pressure analysis and the position of frontal systems on 15th May 2014, 0600 UTC (Source: DWD)*

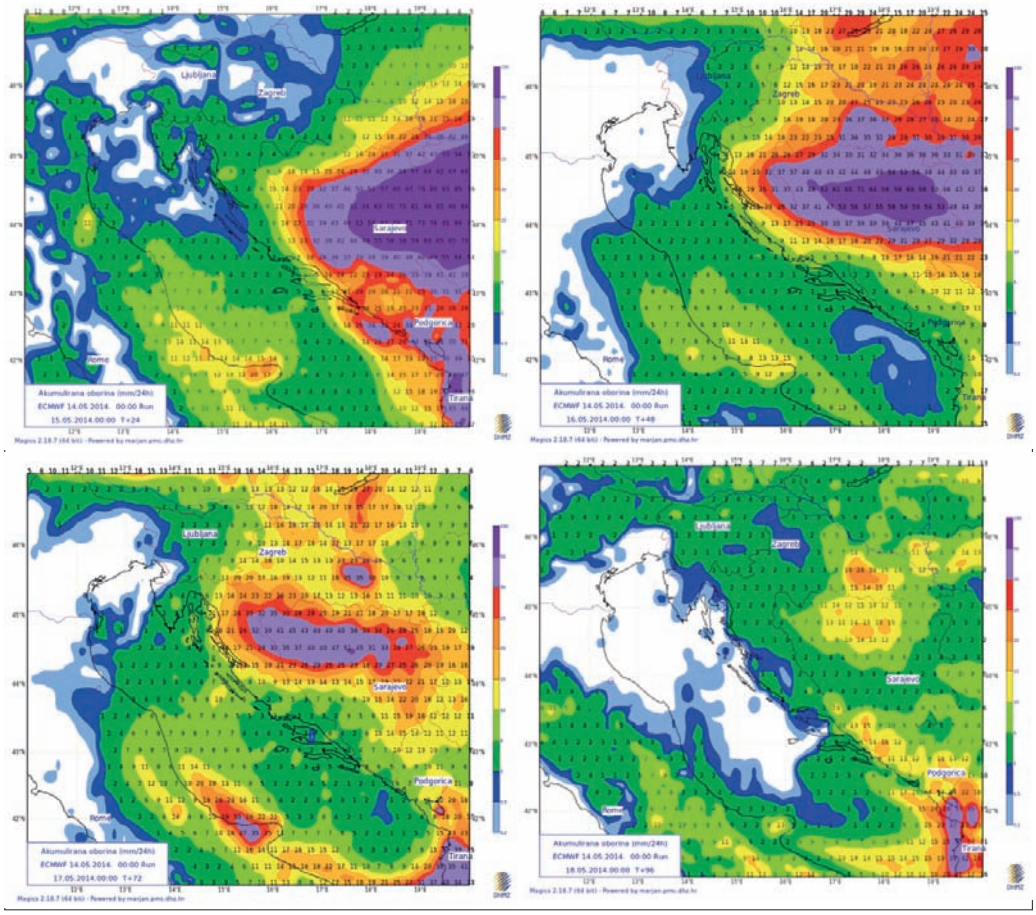
Under such circumstances, large differences in the surface air pressure developed, causing, besides heavy rainfall, very strong winds in many regions, with gusts locally reaching hurricane force. Very intense development in the cyclone led to formation of a thick cloud layer and heavy precipitation in the area of northern Croatia, but also extremely heavy and long-lasting precipitation in most of Bosnia and Herzegovina and Serbia. This was mostly rain, but snow also fell in the mountains. In some places in Bosnia and Herzegovina, the snowfall was quite heavy. During the 16th May, the centre of the upper-level cyclone was located over Serbia (figure 11), weakening towards the end of the day.

Forecasts and warnings

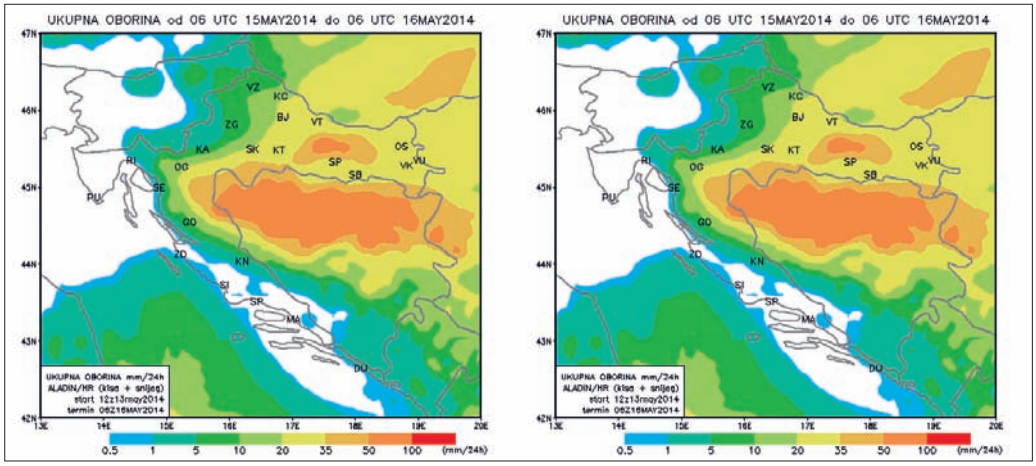
The Meteorological and Hydrological Service of Croatia (DHMZ) and corresponding meteorological services of Bosnia and Herzegovina and Serbia warned about the extreme weather conditions to the best of their abilities. The damage and casualties caused by floods would have been even worse had the event not been forecast on time.



▶ *Figure 11: Meteosat 10 Airmass RGB image on 16th May 2014, 00 UTC, showing a deep low system over SE Europe*



▶ *Figure 12: The ECMWF forecast of 24-hour precipitation for 14th, 15th, 16th and 17th May*



▶ *Figure 13: a) Aladin forecast of 24-hour precipitation for the period from 06 UTC 15th till 06 UTC 16th May; b) interpolated measured precipitation for the period from 06 UTC 15th till 06 UTC 16th May*

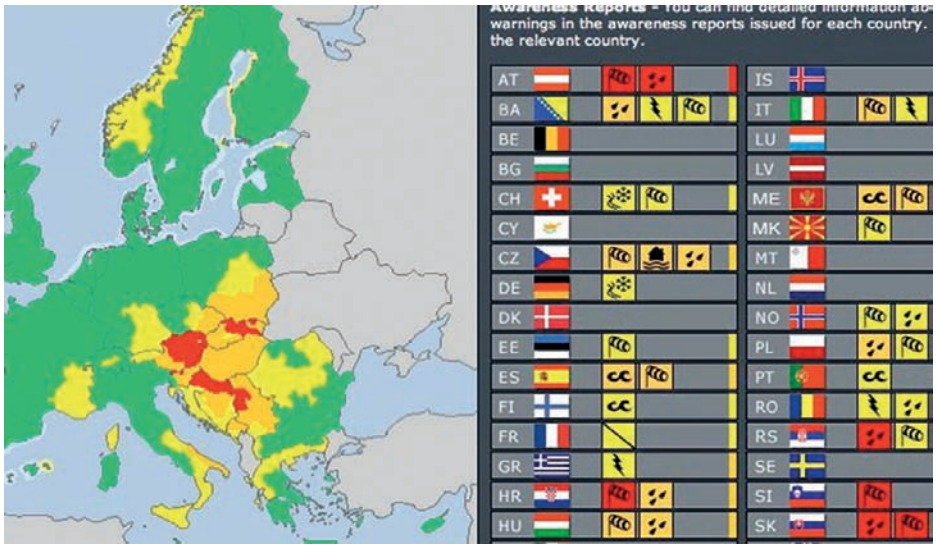
Numerical models captured the process correctly in space and time but slightly underestimated the precipitation intensity. The ECMWF model forecast well the precipitation quantity in the period from the 14th to 17th May (Figure 12), dark violet areas denoting amounts 50-100 mm.

Similarly, for the Croatian region, the Aladin LAM run locally at DHMZ forecast 24-hour precipitation of between 20 and 100 mm for the area of east Croatia over the period from 0600 UTC on 15 till 0600 UTC on the 16th May (figure 13a), which was very close to the actual precipitation measured (Figure 13b).

On the 14th May, a yellow precipitation alert for east Croatia was issued by DHMZ through the METEOALARM system, followed by an orange precipitation alert and a red wind alert on the 15th May. The weather forecasters of Bosnia and Herzegovina also issued an orange precipitation alert, and the Serbian meteorologists a red alert for precipitation (Figure 14).

Conclusion

The flood that occurred in the lower Sava river basin was a consequence of increased precipitation between the 11th and 17th May 2014, especially in the areas of east Croatia, north-west Bosnia and central Serbia. The cause of the increased precipitation was a strong and stationary cyclone, with a centre located over the southeast Europe. The flood was also preceded by a very wet period, so that the soil was saturated with water in the area of the Sava river basin. The event was correctly forecast and all forecasting services issued alerts for high precipitation. However, due to abnormal intensity and stationarity of the cyclone that brought extreme rainfall (in some places exceeding the average monthly precipitation amounts by several times), the large-scale flood was inevitable.



▲ *Figure 14: METEOALARM alerts for 15th May 2014.*