The Extreme Wildfire, 17-19 July 2017 in Split (Croatia)

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Introduction

The summer months of 2017 were characterized by dry periods and extremely high air temperatures. In the Adriatic coastal area, such weather conditions were most pronounced across the southern part of the Croatian region of Dalmatia, There were 4 expressive heat waves in Dalmatia, and the most prolonged with the highest air temperatures began at the beginning of the third week of July and ended at the end of the first week of August. Thus, last summer, in Croatia, as in other areas of the Mediterranean, there was an increase in the number of forest fires. Some of them affected large areas of the Adriatic coast, and the most prominent was recorded near Split, the second largest city in Croatia and the centre of Dalmatia.

The wildfire in the Split area that occurred from 17 to 19 July 2017, according to the National protection and rescue directorate fire department, began on July 17, 2017 at 0042h in Central European Time at Tugare, about 10 km east of Split. On 17 July, the fire quickly spread from the east to north-east over the slopes of Mt. Mosor, as a result of a strong Bura wind and the local orography. Several houses, business premises and olive groves were burned, and the fire also reached the astronomical observatory at Mosor. Furthermore, the fire approached the Žrnovica missile launch facility, which was defended with a great effort by the firefighters and soldiers in attendance. The town of Split was endangered by the Bura from the northeast. The air force could not participate in the firefight until 1500h on July 17, because of the strong Bura. Three Canadair aircraft were involved in the fire extinguishing, as winds began weakening. The fire was placed under control on 18 July at about 0700h, localized on 19 July at about 1100h and was completely extinguished on 25 July 2017. Around 4300 ha of vegetation were burnt down in the fire and the fire front was occasionally 40-km long, making it one of the biggest fires in Croatia. Fortunately there were no human casualties.

This paper describes the course of the fire and the synoptic situation on 17 July 2017, when the fire was the most severe, as well as on 18 and 19 July, when it was placed under control and finally localized.

▲ *Figure 1. The area affected by the fire in Split (top) and NASA satelite imagery of the Split area on 17 July 2017 (bottom) (source: HUKM)*

Weather conditions from 17 to 19 July 2017

As mentioned, the summer months of last year were dry and extremely warm. Therefore, the hazard class derived from the meteorological hazard index for the 'fire emergence and spread' by the Canadian method was mostly 'large' or 'very large'. According to data from the Split-Marjan meteorological station, the highest danger class was recorded in the Split area on 25 June, and continued until 19 July 2017, when the fire was localized. A high danger class indicates the dryness of the canopy or the presence of dried vegetation, which is affected by high air temperature and lack of rain. Wind and low relative humidity are also contributing factors.

The meteorological index component, according to the Canadian method, which shows how the fire can spread is the Initial Spread Index (ISI). The Canadian forest fire weather system components have also been used, for example, by Carvalho et al. (2008) in Portugal, Tian et al. (2011) in China and also by Vu eti and Vu eti (2011) and Kozari and Mokori (2012) in Croatia. The details of the

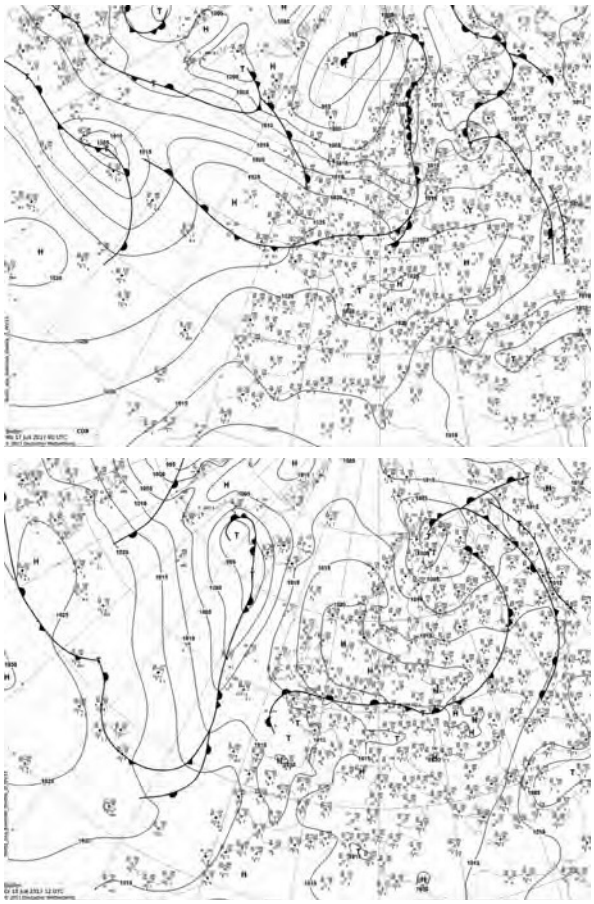
▲ *Figure 2. The mean and maximum wind velocities (a), mean wind direction (b), as well as the air temperatures at 2 m height (° C) and relative humidity (%) at the Split-Marjan station from 16 to 19 July 2017.*

Canadian forest fire weather system can be found in Van Wagner and Pickett (1985). The ISI recorded at the Split-Marjan station at 1200 UTC on 16 July 2017, before the outbreak of fire, was very high (24). On 17 July at 1200 UTC, when the fire was uncontrollably spreading, the ISI value was 20. Then, on 18 July, the ISI decreased to 14. Rapid fire spread is associated with ISI values of more than 13, whilst values of more than 18 are associated with fire which is rapidly expanding. The estimated fire spread speed is 18.3m per minute when the fire occurs in the treetops and when multiple fire fronts appear. The high values of the initial spread index are due to the high wind speeds which were in the Adriatic region on 16 July 2017.

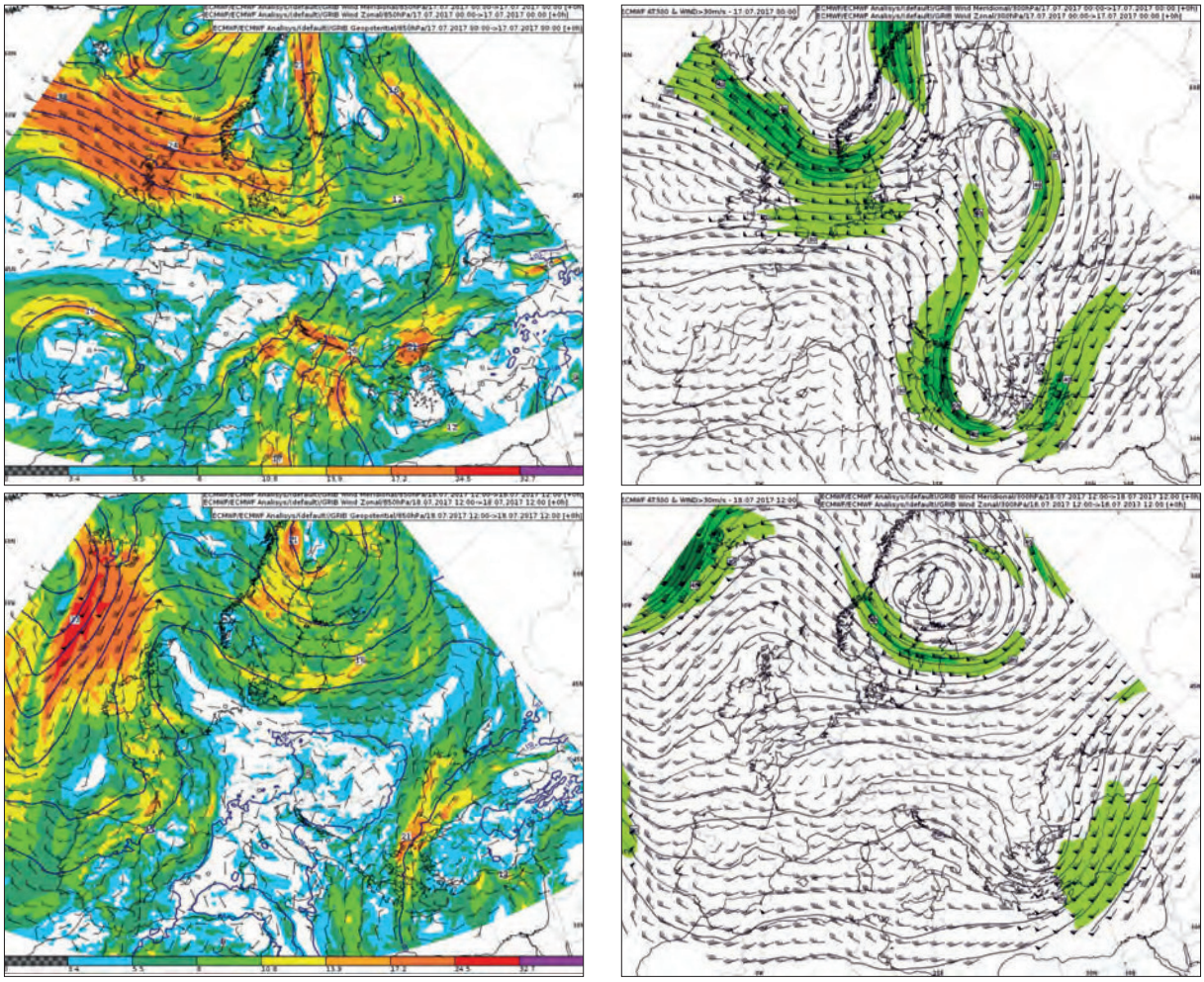
During the Bura on 17 July 2017 the relative humidity was between 20 and 30%, and when the Bura weakened on 18 July, the relative humidity was higher than 35%. Furthermore, according to the measurements from the Split-Marjan automatic station (see Figure 2) on 17 July, the Bura had weakened and was moderate to strong, whilst in the middle of the day the wind briefly turned to the east. On 18 July, the Bura weakened, such that in the morning the wind was mostly weak with an east to south-east direction. At midday and early in the afternoon, a moderate south-westerly wind was blowing. Then the wind was mostly weak, with the characteristics of a coastal circulation. Sharp changes in wind direction have been observed in the fire and made the behavior of the fire unpredictable, and the situation extremely dangerous.

Synoptic analysis from 17 to 19 July 2017

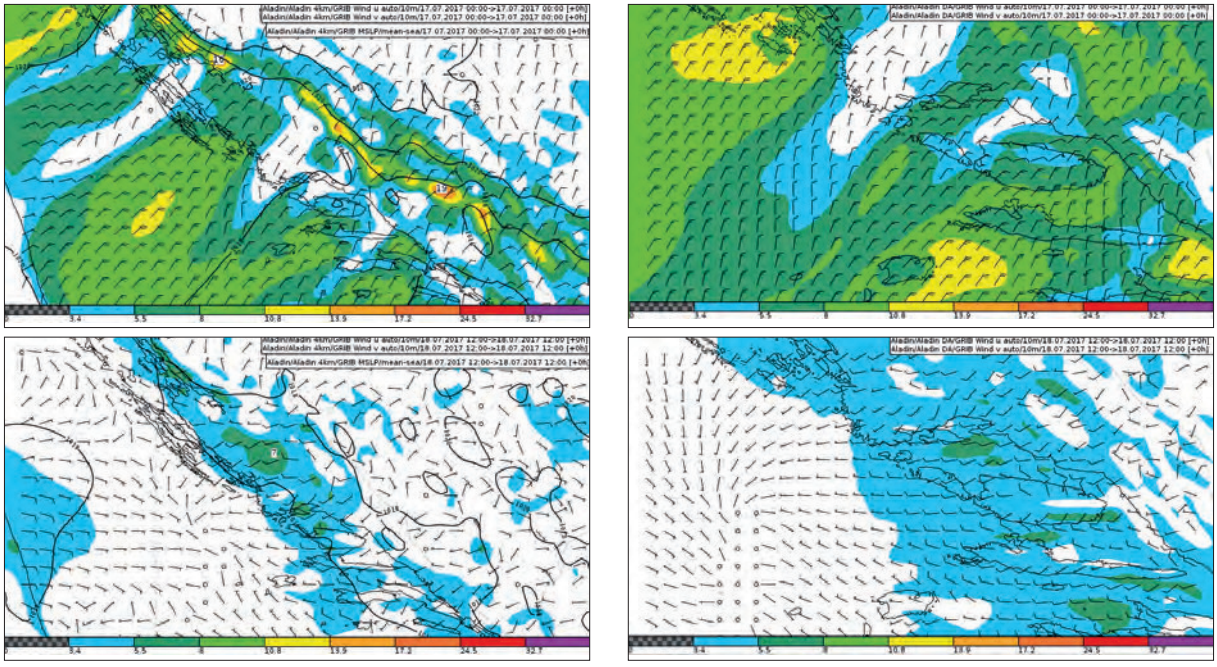
The surface analysis based on the synoptic maps (from DWD and the reanalysis from ECMWF) show that on 17 July anticyclonic conditions extended from north-western Europe towards Croatia (see Figures 3 and 4). At the same time, over south-east Europe, there was an area of low pressure, whose centre was over Asia Minor. Therefore, there was a large surface pressure gradient over the Adriatic. In the upper atmospheric layers (isobaric surfaces 850, 500 and 300 hPa) on 17 July at 0000 UTC, central and south-western parts of Europe were under the influence of an upper level low. Along with this, the separation of the upper level cyclone with a cold air core over the south-eastern part of Europe is visible, so that the upper level cyclone is placed over the southern Adriatic. The jet stream stretched from eastern Europe across the central Adriatic and southern Italy, and turned toward the Ionian Sea at 300 hPa. Such synoptic conditions caused a deep Bura which blew on 17 July 2017. In the middle of 17 July, the anticyclonic ridge over north-west Europe spread over the western Balkans, and cyclonic conditions moved over south-east Europe. The jet flow was still visible at 300 hPa, from Sicily to the Ionian Sea. The Bura then weakened, and along the coast and the open sea, it turned to the north-west. Then, during the night and in the morning of 18 July most of Croatia, including the Mid-Adriatic, was influenced by an anticyclonic ridge. With the shifting of the upper level trough axis to the east of Croatian territory and the strengthening of the anticyclonic branch from the north-west of Europe on 18 July, the air pressure gradients decreased and the Bura weakened. The South Adriatic was affected by the forward side of the upper ridge, and the rearward side of an upper trough, which was then centred over the Ionian Sea, having tracked slowly east. The jet stream had moved away from the Mediterranean area. Then, on 19 July, the anticyclonic ridge weakened leading to an elevated pressure field over Croatia, and from the middle of the day equalized pressure field reduced to mean sea level. At upper levels, the ridge in geopotential height was spread across the Balkans, whilst the upper low was still over the area of Asia Minor.



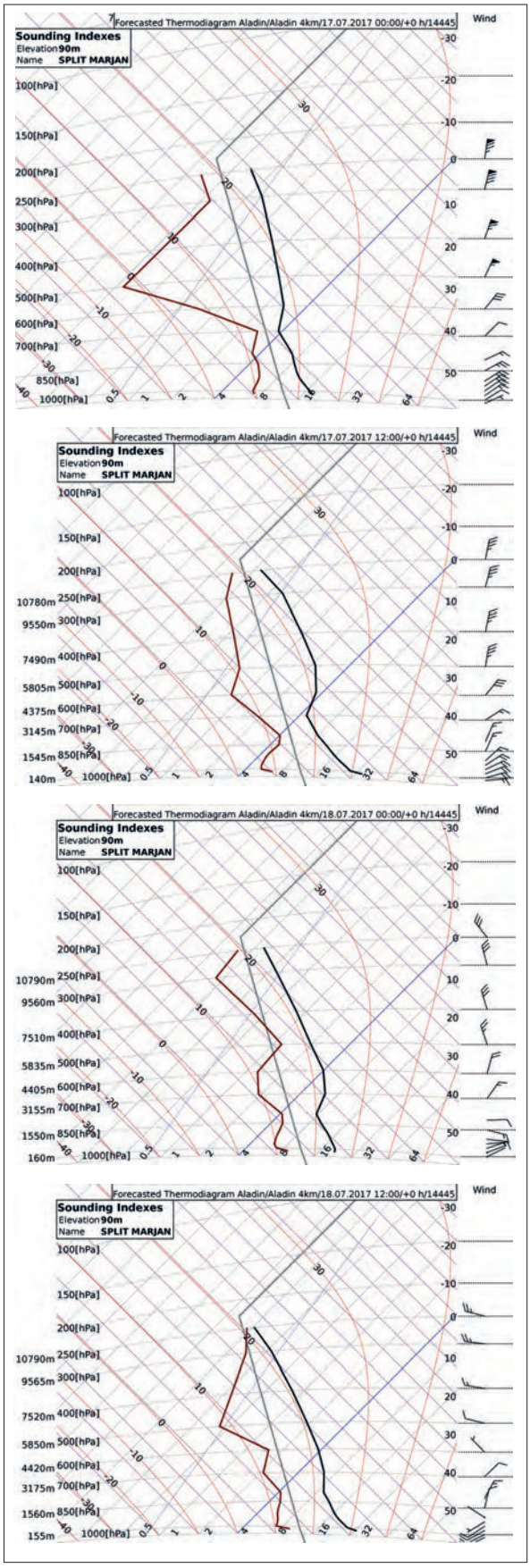
▲ *Figure 3. Synoptic situation on 17 July 2017 at 0000 UTC (a) and on 18 July 2017 at 1200 UTC (b) (source: German Meteorological Service, DWD)*



▲ *Figure 4. Distribution of geopotential height (dam), wind speed and direction (shades of colour) at 850 hPa (left) and 300 hPa which are filled marking the wind speed above 30 m s^{-1} (right), on 17 July 2017 at 0000 UTC with shades of green (a and b), and on 18 July 2017 at 1200 UTC (c and d) (according to the ECMWF analysis).*



▲ *Figure 5. Wind speed and wind direction at 10 m height (shaded in color) and pressure reduced to mean sea level (right) to ALADIN/ALARO HR analytical fields at 4 km (left), and wind speed and direction at 10 m height (shaded in colors) to analytical fields ALADIN/ALARO DADA model, dynamic adaptation at 2 km (right), 17 July 2017 at 0000 UTC (a and b) and 18 July 2017 at 1200 UTC (c and d).*



▲ *Figure 6. Pseudotemp from the mesoscale numerical model ALADIN/ALARO HR analysis for the Split-Marjan station, on 17 July at 0000 UTC (a) and 1200 UTC (b), and 18 July at 0000 UTC (c) and 1200 UTC (d).*

Regarding the change in speed and direction of the wind on 17 and 18 July, the wind field was analyzed in more detail from the reanalysis of the mesoscale numerical prognostic model ALADIN/ALARO Croatia. At 0000 UTC on 17 July, the strongest pressure gradient was in the northern part of the Mid-Adriatic. On 18 July, the wind was light along most of the Adriatic coast, and even in the Split area. Trošić and Trošić (2010) have also shown the strong influence the local orography and synoptic situation has on wind rotation during summer Bura, at its onset in the Northern Adriatic.

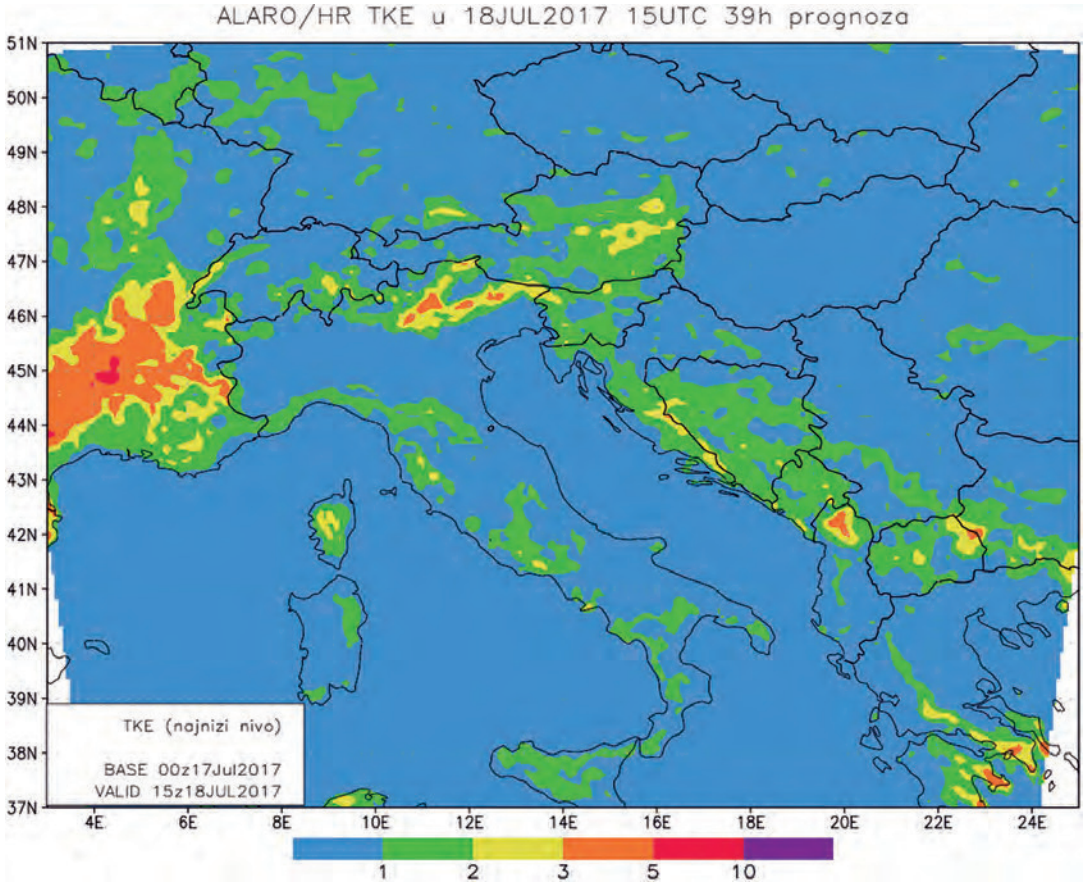
However, at midday and through the early afternoon on 18 July in the Split area, there was occasionally either a moderate south-westerly or moderate north-westerly wind at 850 hPa (see Figure 4c). The circulation at 850 hPa over south-eastern Europe was possibly causing the north-western "synoptic wind" with a wind speed of up to 6 m s^{-1} over the Split area that then supported the development of the south-western sea breeze, with wind speeds of up to 8 m s^{-1} (see Figures 5c and 5d).

The vertical wind profile from the pseudotemp of the ALADIN/ALARO mesoscale numerical forecast model shows wind shear on 18 July for the Split-Marjan station at 1200 UTC (Figure 6d). Analysis of the vertical atmospheric structure was shown to be important by Byram (1954) for the examples of the big fires on the Croatian islands Kornati and Brač, by Vučetić et al. (2007) and Mifka and Vučetić (2012), respectively.

The turbulent kinetic energy model forecast for midday and the early afternoon on 18 July for the area around Split also shows wind shear in the near-surface level of the atmosphere, with instability present in the dry air. Figure 7 shows the ALADIN/ALARO model of turbulent kinetic energy at 4 km on 18 July at 1500 UTC. Along with the equalized air pressure reduced to mean sea level over Croatia, and with the weakening and further shift of the upper level cyclone to the east on 19 July, the wind weakened and there was no turbulence, although there was still instability in the dry air. On 19 July, the wildfire was localized.

Conclusion

The behaviour of the front of the fire on 17 July was dominated by a strong or very strong Bura due to the influence of the local orography, such that it was called "a fire carried by the wind". The next day, on 18 July, when the main synoptic systems moved, the Bura weakened to moderate and turned south-westerly, after which the fire was mostly affected by the coastal circulation. Therefore, it can be concluded that the behaviour of the fire was conditioned not only by the wind



▲ *Figure 7. ALADIN/ALARO model turbulent kinetic energy forecast at 4km on 18 July at 1500 UTC, model run from 17 July at 0000 UTC.*

speed, but also by the combination of wind shear (wind direction and wind speed change by height), i.e. turbulence in the near-surface layer of the atmosphere, instability in the dry air, and the thermodynamic processes that were caused by the extreme fire itself. The meteorological parameter pointing to the possible occurrence of wind shear and the influence of orography was the prognostic field of the turbulent kinetic energy of the numerical mesoscale model of ALADIN/ALARO Croatia.

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