*Research Article*
*https://doi.org/10.33904/ejfe.1288070*

*Eur J Forest Eng 2023, 9(1):10-25*

EJFE

# Using Meteorological Early Warning System (MEUS) and Meteorological Indices for Assessment of Manavgat Forest Fires Occurred in Turkiye July-August 2021

**Gülten Çamalan, Sercan Akıl, Muhammet Ali Pekin***

Turkish State Meteorology Service, Research Department, Ankara, Turkiye

## Abstract

Forest fires are one of the natural disasters that severely affect ecosystems, damage property and threat human life. An early warning system helps people respond to dangers promptly and appropriately. In the scope of this study, the forest fires occurred in Manavgat province of Antalya in Turkiye between 28 July 2021 and 6 August 2021 was analyzed using the meteorological early warning system (MEUS), which is developed by the Turkish State Meteorology Service. The performance of the model products was assessed and the association between the weather conditions in the region and the forest fire was evaluated. To examine the synoptic models, hourly meteorological data and MEUS warnings data were obtained two days before the Manavgat forest fire, and the probabilities generated by the meteorological variables that may be effective in the preparation of fire conditions in the region were evaluated in the study.

**Keywords:** Forest fires, Extreme temperature, Early warning, MEUS, Manavgat

## 1. Introduction

Forest fires are a global concern regarding their effects and consequences on ecosystems. Fires are an important threat that causes the burning of millions of hectares of forest areas worldwide every year, while causing loss of life and property (Grünig et al., 2023; Supriya and Gadekallu, 2023). Meteorological factors play an important role in the occurrence, severity, and duration of forest fires. Aegean and Mediterranean regions of Turkiye are closely interacting with forest fires, especially with the effect of regional features such as topography (adverse land conditions), climate, and vegetation consisting of fire-sensitive species such as Brutian pine (*Pinus brutia*) (Gao et al., 2023; Jo et al., 2023). Turkiye is under the threat of intense forest fires in the summer season; hence, a significant amount of forest area is damaged as a result of forest fires every year (Sağlam et al., 2023).

Forest fires are primarily controlled by the moisture content of the combustible material. The main factors affecting the moisture of combustible material are temperature, relative humidity, wind and precipitation. Since the daily and seasonal variation of the temperature is effective on the temperature and moisture content of the combustible material, it plays a vital role in increasing or decreasing the fire hazard. Especially drought periods should be monitored carefully. In Turkey, there has been an increase in the amount of area burned by forest fires due to drought in 2008, 2020, and 2021. Air temperature, relative humidity, and wind are the most effective meteorological factors in the initiation and development of forest fires. Initially, while the wind controls the relative humidity and temperature of the air, it affects the fire behavior with its direction and speed at the time of fire.

Depending on the geographical location, topography, and the origin of the effective air mass, the effect of the wind on forest fires also changes. The characteristic of the Mediterranean climate shows a dry summer season with high temperatures and relatively low humidity. In addition, the N, NE and NW directional winds, carrying the dry air masses of Central Anatolia during the fire season, increase the fire hazard by reducing the relative humidity and moisture content of flammable materials (both live vegetation cover and dead vegetation cover) in the Mediterranean region. Since the air mass that affects Turkiye the most in the summer season is the continental tropical (cT) air mass, which can be both very hot and poor in humidity. These air masses, called the Basra low pressure, are of hot tropical origin, and they lose their moisture well as they come by traversing large land surfaces. In Turkiye, 76% of the fires, 82% of the burned area and 65% of the fire days were observed when the continental tropical (cT) air mass was effective (Bekereci et al., 2010). The length of the Basra low pressure system, which is hot and poor in humidity, has a huge impact on the country in summer with a great risk for

*Corresponding Author: Tel: +90 312 3022624 E-mail: mapekin@tsms.gov.tr
Received: 28 April 2023; Accepted: 20 June 2023

forest fires, especially in the Mediterranean and Aegean Regions in Turkiye (Trucchia et al., 2023).

Real (actual) time conditions of the atmosphere are among the causes of all kinds of fires, natural or unnatural, in Turkey. Therefore, unless meteorological factors such as observed air temperature, relative humidity, wind speed and direction, atmospheric pressure, and stability-instability of the atmosphere are suitable for fire, a fire cannot break out or spread. For this reason, management systems, indices, or models developed for fighting fires can only be successful if they can be supported by sensitive meteorological measurements and records (Altan et al., 2011; Türkeş and Altan, 2012a, 2012b, 2012c).

MODIS (Moderate Resolution Imaging Spectroradiometer) is a satellite-based system detects and monitors forest fires. By analyzing data from the MODIS sensors, researchers can track the location, size, and severity of fires near-real-time, which can help with response efforts and fire management. MODIS data can also be used to monitor the impact of fires on the environment, such as changes in vegetation cover or air quality. Numerous studies have attempted to analyze forest fires by using MODIS (Ying et al., 2019; Tapan et al., 2023).

Turkiye faced the worst mega forest fires recently in July-August 2021, after a dry year without precipitation. Between 28 July and 12 August 2021, 8 people died in 299 forest fires that affected 54 provinces in Turkiye, thousands of animals died and hundreds of thousands of hectares of forest areas and settlements were damaged. In 2021, 60357 hectares of forest area was burnt as a result of 278 forest fires in Antalya Regional Directorate of Forestry. 91 of the fires and 40127 hectares of the burned area broke out in the Manavgat, Serik and Taşağıl Forest Management Directorates of the Manavgat district in Antalya. During that year, 104 forest fires damaged about 60000 hectares of the forest area in July and August. The year 2021 was reported as a year when the major forest fires were fought in Turkiye and resulted in a higher than targeted level in terms of area per fire (Akinci and Akinci, 2023; Aydin and Demir, 2023).

Forecasting and early warning of potential forest fire risk is critical in firefighting. For this purpose, the Forest Fires Meteorological Early Warning System (MEUS) is in use by the Turkish State Meteorology Service (TSMS) (Oğuz et al., 2021). This study aimed to evaluate Manavgat forest fires through a meteorological early warning system (MEUS) and meteorological indices.

## 2. Materials and Methods

### 2.1. Forest Fires Meteorological Early Warning System (MEUS)

With the Forest Fires Meteorological Early Warning System (MEUS), which is operationally prepared within the TSMS and shared with the General Directorate of Forestry (GDF) in order to take precautionary measures for forest fires, hourly "Forest Fire Hazard Maps" covering the next three days are generated for Turkiye. MEUS system uses 72-hour forecast data (2 m maximum temperature, 2 m average humidity, and 10 m wind vector components) of 00 GMT Alaro numerical weather forecast model with 4.5 km resolution. It generates data for 59356 grids covering Turkiye. MEUS and Angstrom produce hourly forest fire hazard maps, wind speed (km/h)-direction, temperature (ºC), and humidity (%) maps by using this data; thus, a total of 375 maps are produced every day. Along with the hour information of each day, the average values of that day can also be displayed. MEUS fire hazard ratios are determined by applying an algorithm to maximum temperature, humidity, wind speed-direction, and aspect analysis. The methodological flowchart of the MEUS model is shown in Figure 1 (Ozkan and Kilic, 2023).

The Foehn effect is a meteorological phenomenon that occurs when air masses move across a mountain range and warm up as they descend on the other side. This can increase the risk of forest fires in some areas, as the warm, dry air can quickly dry out vegetation and make it more susceptible to ignition (Pham, 2023). In this study, a meteorological situation assessment was made and the performance of the pre-fire warnings of the MEUS was evaluated by examining the synoptic models and observations of the forest fire took place on 28 July 2021 in the province of Manavgat in Antalya, Turkiye. Meteorological parameters dataset was obtained from the meteorological stations including Antalya-17302, Antalya Airport-17300, Manavgat Taşağıl Forest Field-17917, Manavgat Beşkonak Forest Field-18011, Manavgat-17954, and Manavgat Forest Field-18839, representing Antalya-Manavgat region.

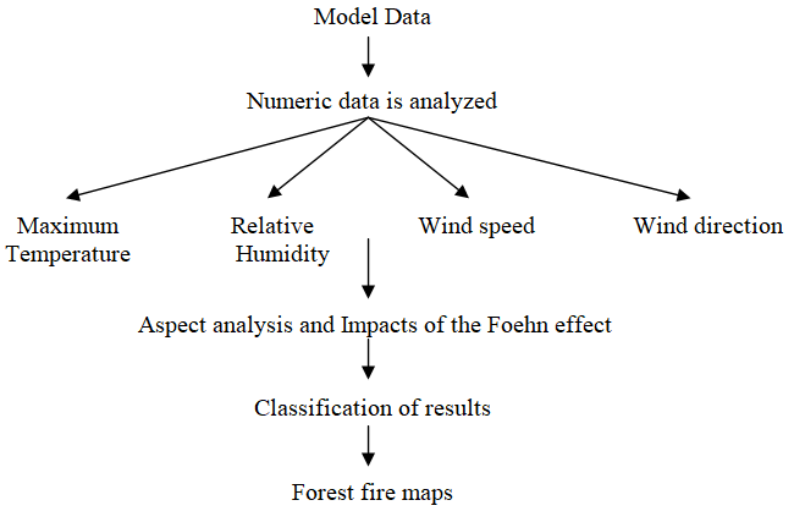


Figure 1. The flowchart of the MEUS model

## 2.2 Data of Study Area

Forest lands in the Mediterranean climate zone are among the areas adversely affected by forest fires in Turkiye, particularly within Antalya Regional Directorate of Forestry. Antalya region has a higher forest proportion in Turkiye, with 56% forest cover, and has a rough terrain, as seen in Figure 2 (Pekpostalci et al., 2023).

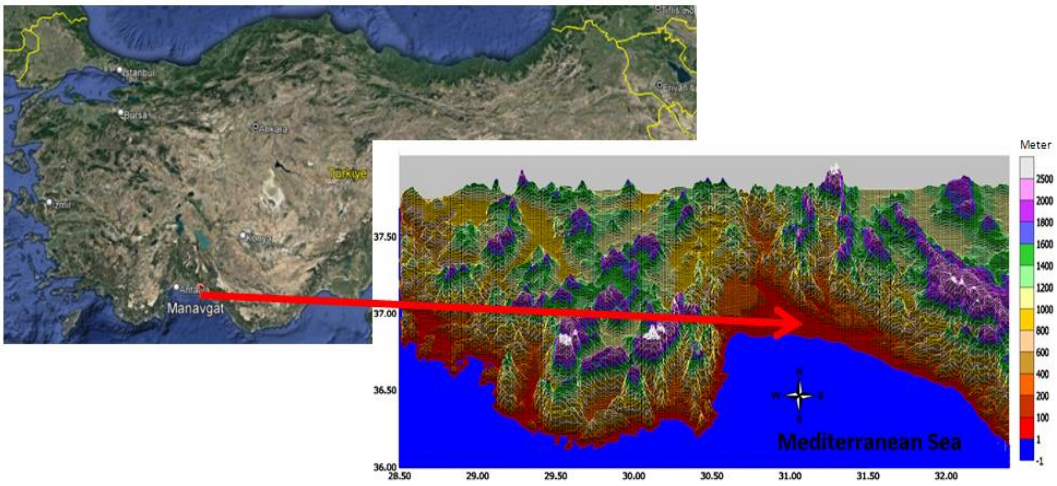


Figure 2. Topography of Antalya

Considering the annual average temperature and annual average total precipitation values, it is possible to divide Antalya and its surroundings into five characteristic sub-regions. Manavgat district, called hot rainy (annual average temperature 14-19 ºC, annual average total precipitation 950-1250 mm), is in group IV. In the coastal parts of the region, the first and second prevailing wind directions are North and South, respectively. In the inner parts of the region, the first prevailing wind direction is South, and the second prevailing wind direction is North. The region from the Kemer-Manavgat coastline to the inner parts is the region that receives the most wind in July. Also, the strongest wind blew 26.7 m/sec from the north in Manavgat and its surroundings in July (Figure 3a, b, c, d). Başaran et al. (2007) stated in their studies that these regions had received the most wind during the fire season (June-September) due to the topographic structure (broad valleys in the south-north direction).

As seen in Figure 3 (e, f, g, h), in accordance with the topographic structure, along the valleys up to the inner parts of Manavgat and its surroundings, where forest areas are dense, the spread of maximum temperatures exceeding 30 ° C and low humidity rates in July and August, create a dangerous situation in terms of forest fires (Çamalan and Çamalan, 2004; Çamalan et al., 2015; Çamalan et al., 2017).

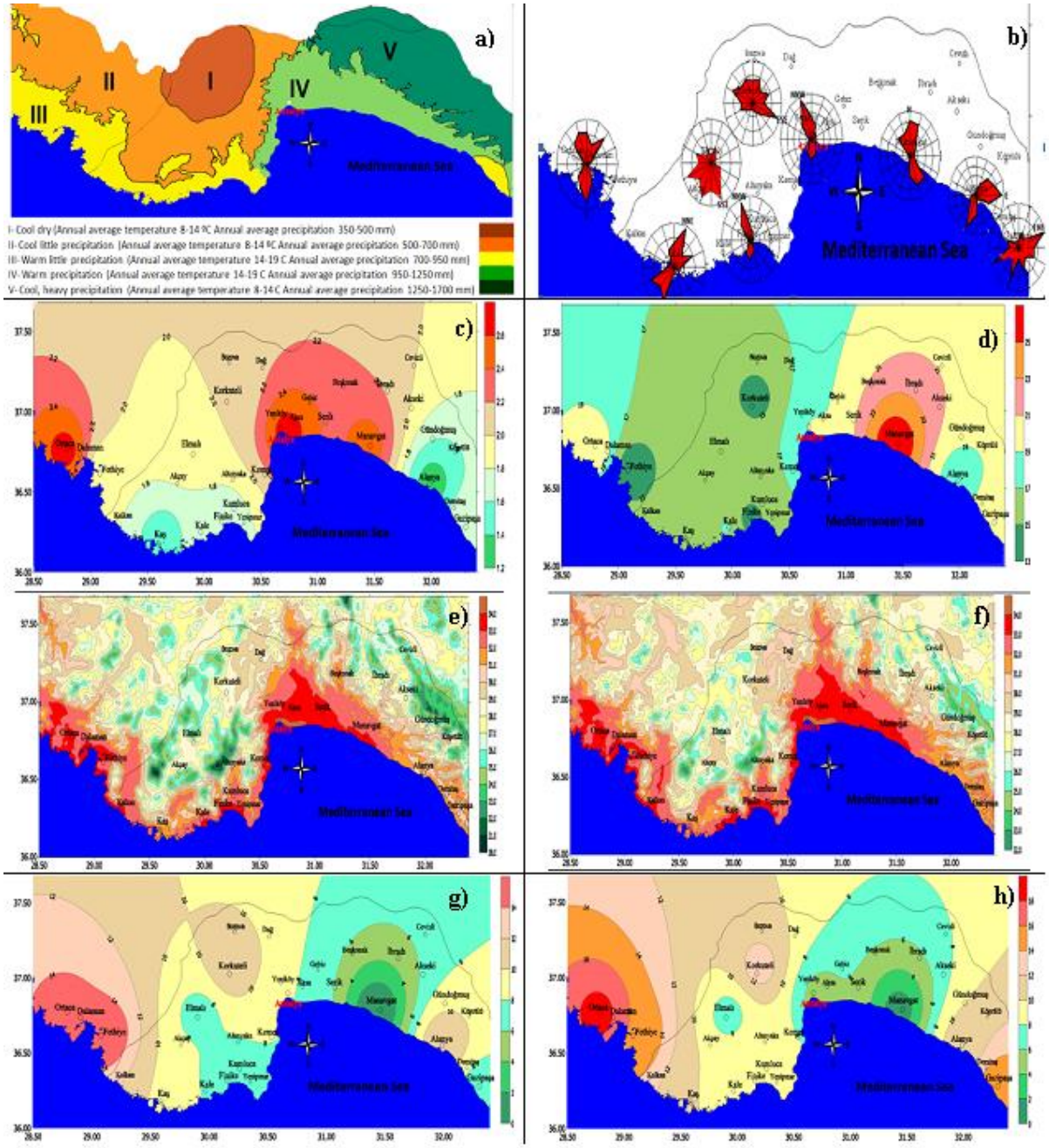


Figure 3. Climatologic characteristics of study area: a) Characteristics of precipitation and temperature in Antalya and surrounding area, b) Wind frequency in Antalya and its districts, c) Average distrubition of Wind (m/sec) in Antalya in July, d) July strongest wind (m/sec) distribution, e) Distribution of average max. temperature (°C) in Antalya in July, f) Distribution of average max. temperature (°C) in Antalya in August, g) Minimum relative humidity (%) distribution in Antalya in July, h) Minimum relative humidity (%) distribution in Antalya in August

## 3. Results and Discussion

In the Manavgat forest fire, which started on 28 July, 2021 and was took under control on 6 August, 2021, daily synoptic models, hourly meteorological data and daily MEUS warnings were examined, and the possibilities of meteorological variables that could be effective in the preparation of fire conditions on the region were evaluated. On 26 July 00:00 UTC surface card, it is seen that Antalya and its surroundings were under the influence of the Basra low pressure system, the contour trophy crosses the region at the upper levels of the atmosphere (00:00 UTC 500 hpa) and the conditions behind the trophy (west north-west) began to prevail with the effect of the isotherm trophy (Figure 4).

Figure 4. Surface Card and 500 hPa on 26 July 2021 at 00:00 UTC

For this reason, it is seen that the normal daily circulation in Antalya and its surroundings, from the ground level, was low from the north until noon, and moderate from the south in the afternoon, changing from the north to moderately strong winds from time to time throughout the day. In the meantime, it is seen that the maximum temperature rises from the usual range of 29-32°C to 38-40°C, and the minimum humidity drops to 15-20%. At the 17954-Manavgat station, the highest maximum temperature was 39.1°C at 11:00 UTC, and 40.9°C at 13:00 UTC at 18011-Manavgat Beşkonak Forest Field station. At the 17954-Manavgat station, the highest maximum wind blew from North-Northeast at 01:00 UTC and from South-Southwest at 10:00 UTC as 21 km/h (Figure 5).

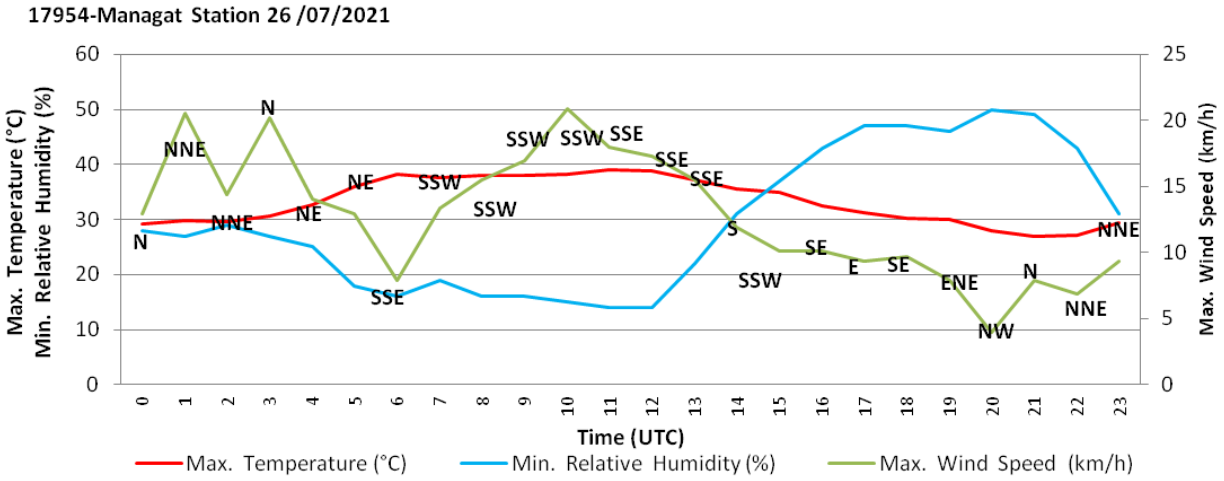


Figure 5. 17954-Manavgat station Hourly Max. Temperature, Min. Relative Humidity and Max. Wind Speed and Direction on 26 July 2021

It is seen that on 27 July 2021, at the upper levels of the atmosphere (500 hPa), with the movement of the contour trophy to the east of the region, the conditions behind the contour strengthened. The flows became strong from the northwest, and the effects of the blow-dry event that started to occur in the Taurus Mountains increased (Figure 6).

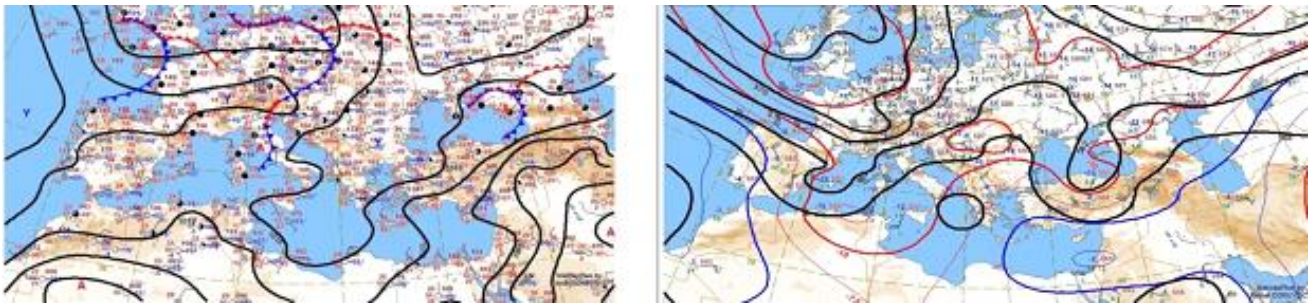

Figure 6. Surface Card and 500 hPa on 27 July 2021 at 00:00 UTC

With the effect of this event, the winds at ground level blew from the north-north-east with moderate strength from time to time. Maximum temperatures increased (38-42ºC) and minimum humidity decreased (10-20%) with the blow dryer effect. At the 17954-Manavgat station, the highest maximum temperature was 40.7 ºC at 12:00 UTC, and the highest maximum wind was 43 km/h from north directions at 08:00 UTC (Figure 7).

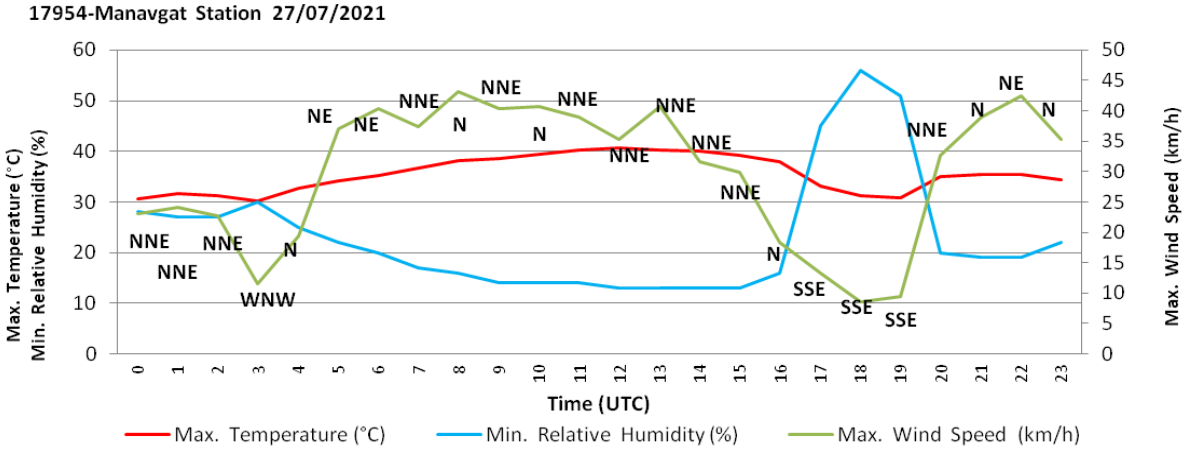


Figure 7. 17954-Manavgat station Hourly Max. Temperature, Min. Relative Humidity and Max. Wind Speed and Direction on 27 July 2021

As of 28 July, the strong northern winds and high maximum temperatures, and low relative humidity conditions prevailed in the region. It was observed that the foehn winds continue to increase in the region, the maximum temperatures increase to 40-42ºC, the minimum humidity decreases to 5-15% (Figure 8). The risk of fire on such a day is much higher than on days when it is under the influence of normal circulation, and it is much more challenging to control a forest fire that occurs for any reason than on days when it is under the influence of normal circulation. The highest maximum temperature was 41.4 ºC at 12:00 UTC at the 17954-Manavgat station, 41.7 ºC at 12:00-13:00 UTC at the 17917- Manavgat Taşağıl Forest Field station, and 41.8 ºC at 12:00-13:00 UTC at the 17302-Antalya station. At the 17954-Manavgat station, the highest maximum wind blew 50 km/h from the North-Northeast at 08:00 UTC.

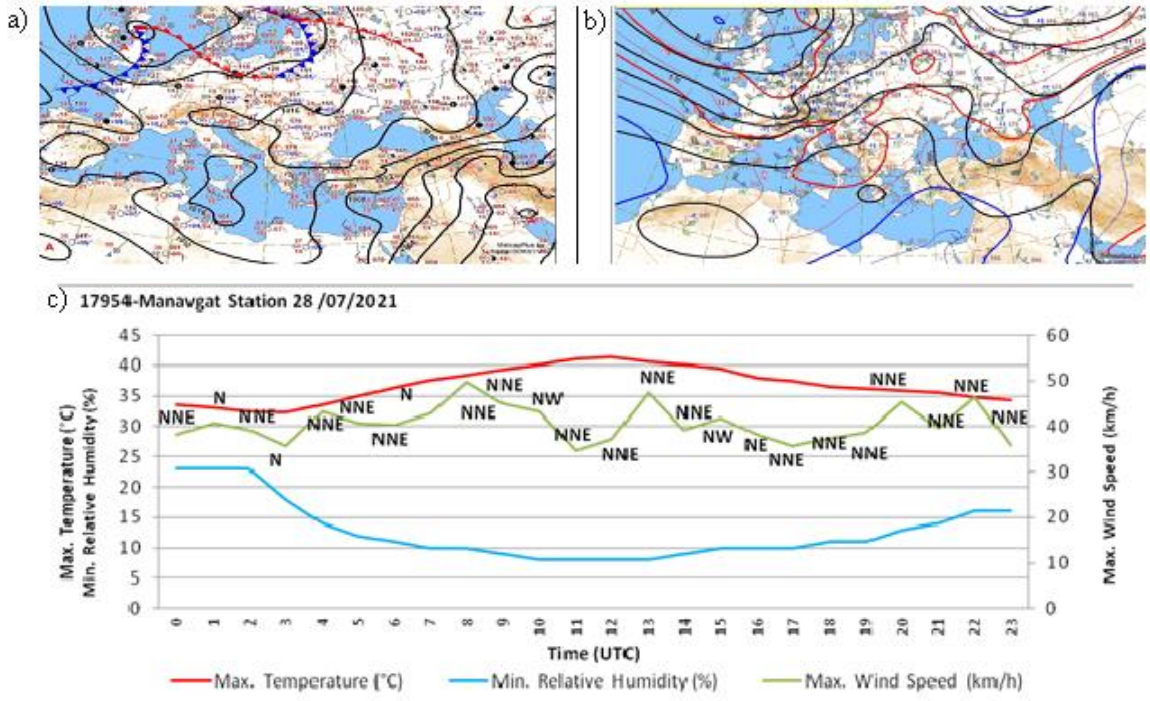


Figure 8. 28 July 2021 00:00 UTC Surface Card (a) and 500 hPa (b), 17954-Manavgat station Hourly Max. Temperature, Min. Relative Humidity and Max. Wind Speed (c)

It was found that the Basra low-pressure system, which also affected Antalya and its surroundings on July 29, 2021, at 00:00 UTC, deepened and increased its area of influence, and as a result, the pressure gradient force increased significantly as a result of the increasing isobaric compaction, further increasing the strength of the northerly winds prevailing in the region (Figure 9).

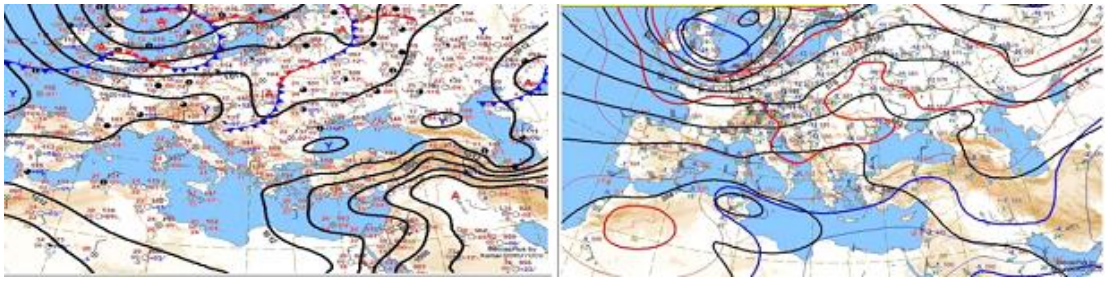

Figure 9. 29 July 2021 00:00 UTC Surface Card and 500 hPa

For most of the day, ground level surface winds are strong winds from the North-Northeast, blowing as a storm in places. At the 17954-Manavgat station, the highest maximum wind blew 48 km/h from the North-Northeast at 07:00 and 09:00 UTC, while at 02:00 UTC at 18839-Manavgat Forest Field station, it blew at a range of 75 km/h from the North-Northeast. Meanwhile, the maximum temperatures in Antalya and its surroundings have increased to 42-44 ºC, and the minimum humidity has decreased to 5-10% (Figure 10). The highest maximum temperature at 17954-Manavgat station was 38.8 ºC at 10:00-11:0 UTC, 41.3 ºC at 14:00 UTC at 17917- Manavgat Taşağıl Forest Field station, and 42.4 ºC at 12:00 UTC at 17302- Antalya station.

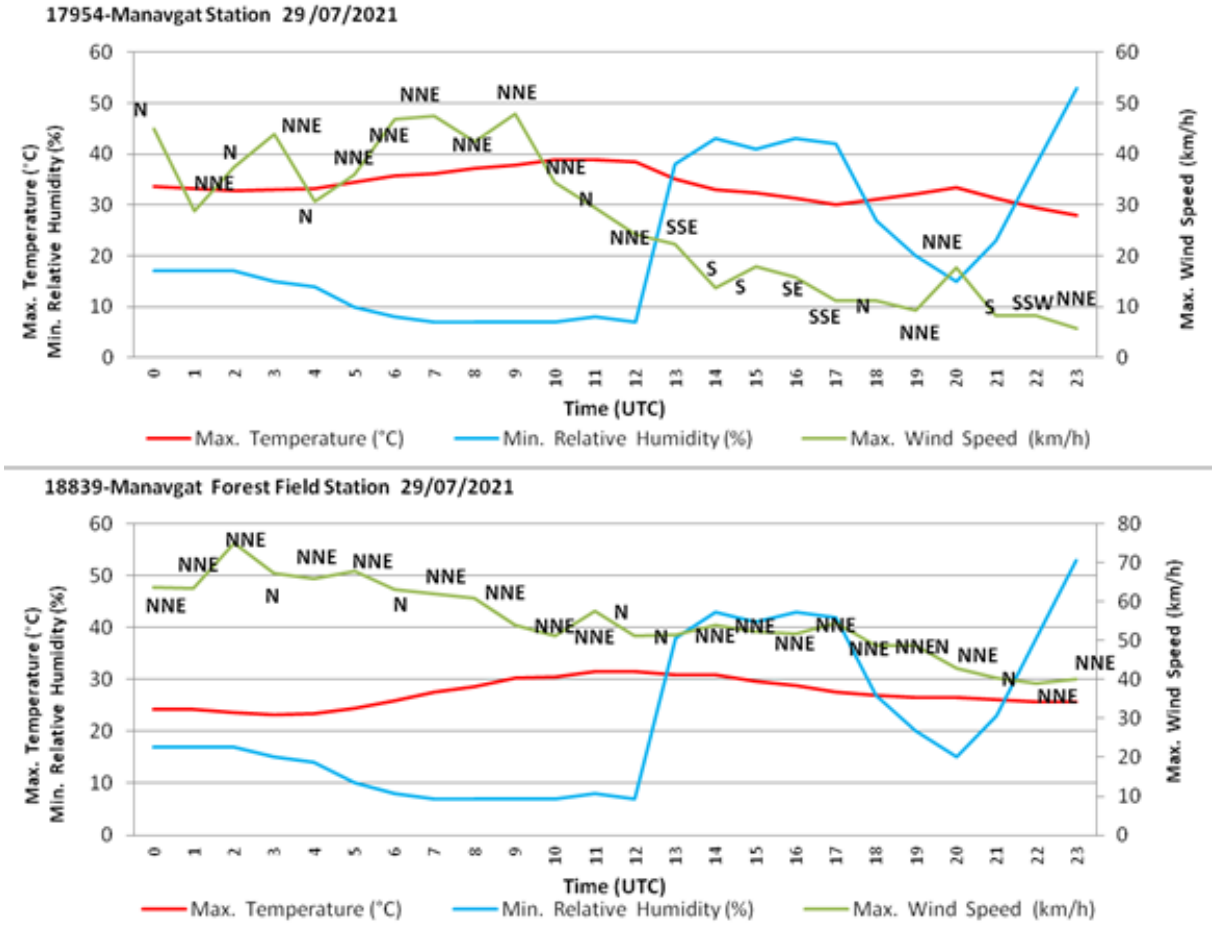


Figure 10. 17954-Manavgat station and 18839-Manavgat Forest Field Hourly Max. Temperature, Min. Relative Humidity and Max. Wind Speed and Direction on 29 July 2021

On the third day of the fire, on 30 July at 00:00 UTC, on the 500 hpa map, it was seen that isotherm compression at the upper levels of the atmosphere and related northern currents continue. It was also observed that high maximum temperatures continue to affect the region with the effect of the strong northerly winds (Figure 11). The highest maximum temperature was recorded as 42.3 ºC at 11:00 UTC at the 17954-Manavgat station, 41.6 ºC at 13:00 UTC at 18011-Manavgat Beşkonak Forest Field station, 41.8 ºC at 13:00 UTC at 17917-Manavgat Taşağıl Forest Field station, and 42.8 ºC at 11:00 UTC at 17302-Antalya station. The maximum wind at the 18839-Manavgat Forest Field station was 68 km/h from the North-Northeast at 18:00 UTC.

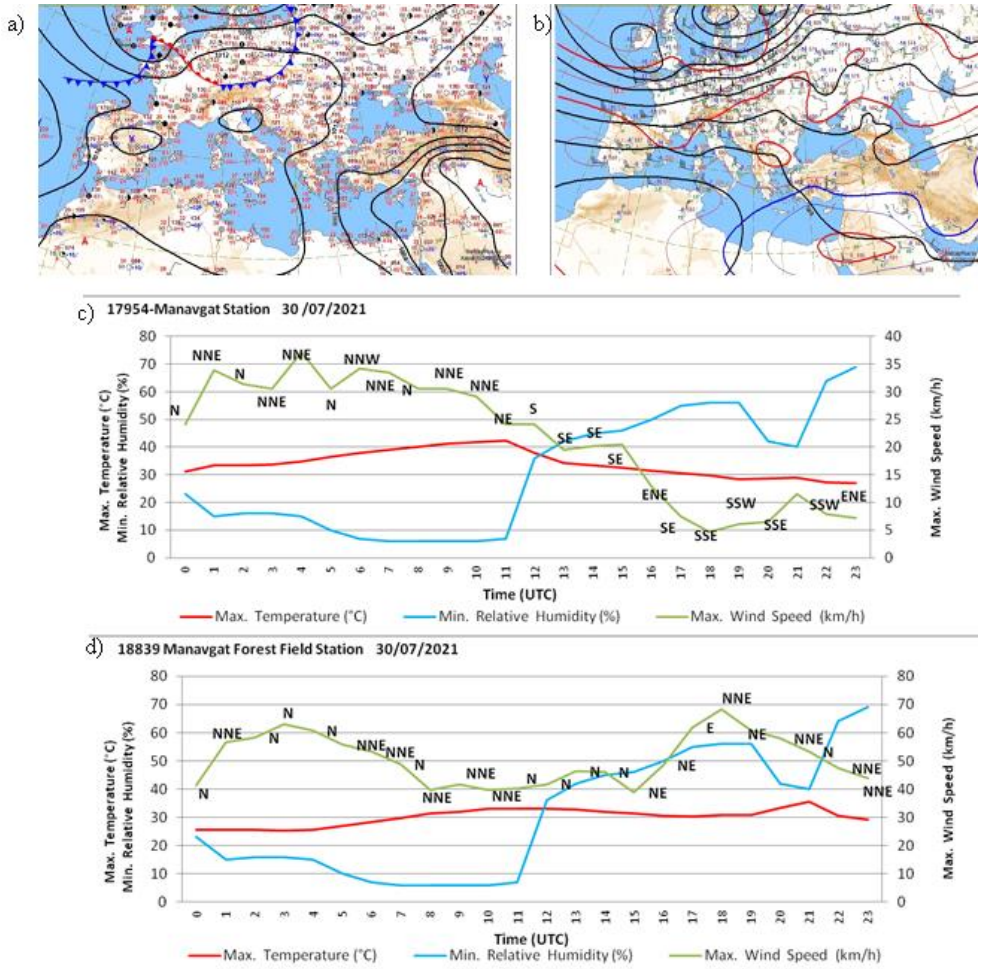


Figure 11. Surface Card (a) and 500 hPa (b), 17954-Manavgat (c) and 18839-Manavgat (d) Forest Field stations Hourly Max. Temperature, Min. Relative Humidity and Max. Wind Speed and Direction 30 July 2021 00:00 UTC

Although a weakening trend was observed in the Basra low-pressure system and in the conditions that caused the formation of high northerly winds and high maximum temperatures compared to the previous days of 31 July and 1 August 2021. Thus, the conditions resulted in a high fire risk continuously. Meanwhile, the maximum temperatures in Antalya and its surroundings have increased to the range of 42-43 ºC, and the minimum humidity has decreased to the range of 5-20% (Figure 12).

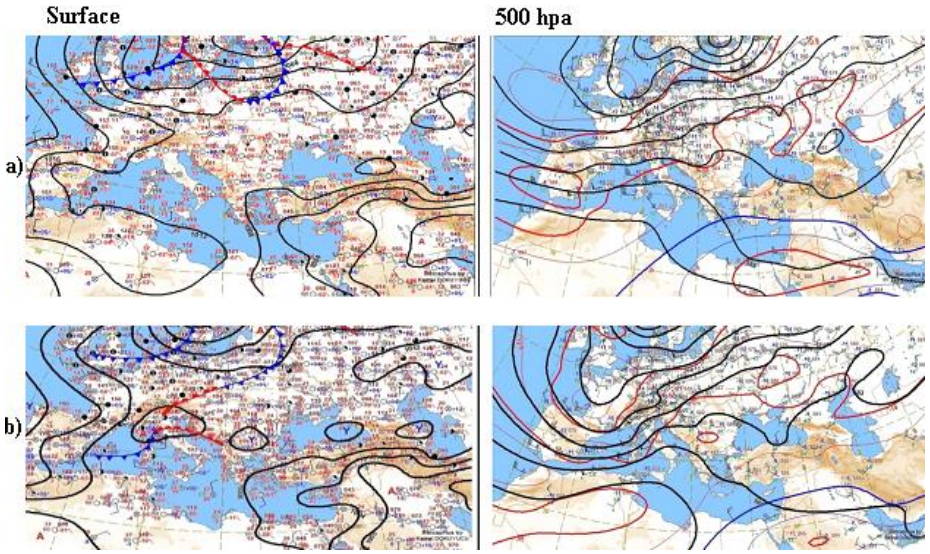


Figure 12. 31 Surface Card and 500 hPa on July (a) and 01 August (b) 2021at 00:00 UTC

On July 31, the highest maximum temperature at the 17954-Manavgat station was 41.3 ºC at 10:00 UTC, 41.3 ºC at 13:00 UTC at the 18011-Manavgat Beşkonak Forest Field station, 42.2 ºC at 11:00 UTC at the 17917-Manavgat Taşağıl Forest Field station, 42.3 ºC at the 17302-Antalya station, and 42.9 ºC was recorded at the

17300-Antalya Airport station. While the maximum wind at the 17954-Manavgat station was 43 km/h from the North at 06:00 UTC, it blew 61 km/h from the North-Northeast at 03:00 UTC at the 18839-Manavgat Forest Field station (Figure 13).

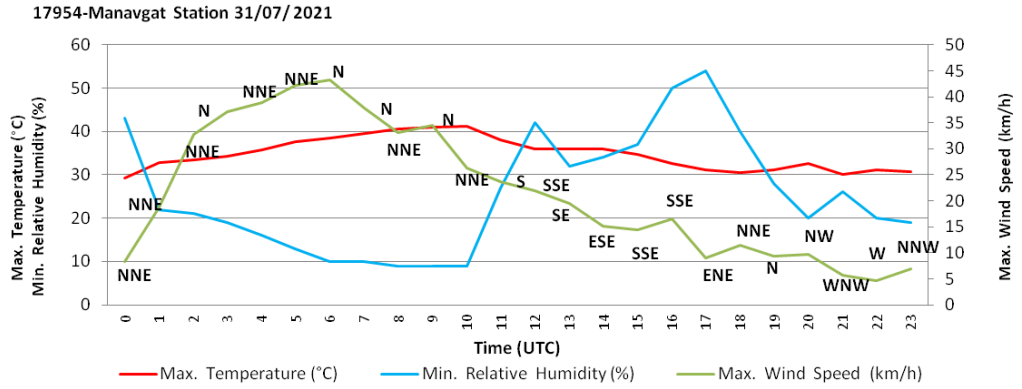


Figure 13. 17954-Manavgat station Hourly Max. Temperature, Min. Relative Humidity and Max. Wind Speed on 31 July 2021

On August 1, the highest maximum temperature was recorded at the 17954-Manavgat station was 42.5 ºC at 08:00 UTC, 42.3 ºC at 12:00 UTC at the 18011-Manavgat Beşkonak Forest Field station, 42.8 ºC at 11:00 UTC at the 17302-Antalya station, and 43 ºC at 07:00 UTC at the 17300-Antalya Airport station. While the highest maximum wind blew from the North-Northeast at 07:00 UTC, it was at 53 km/h from the North-Northwest at 10:00 UTC at the 17954-Manavgat Forest Field station (Figure 14). Increases in the maximum temperatures in the range of 42-45 ºC and decreases in the relative humidity in the range of 10-20% were observed with the increase of the effect of northwest flows at the upper levels of the atmosphere (500 hPa) in Antalya and its surroundings on 2-3 August 2021 (Figure 15).

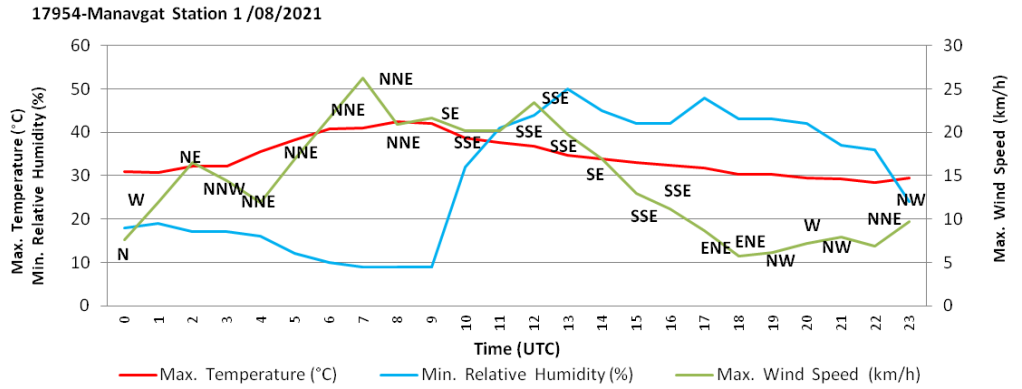


Figure 14. 17954-Manavgat station Hourly Max. Temperature, Min. Relative Humidity and Max. Wind Speed on 01 August 2021

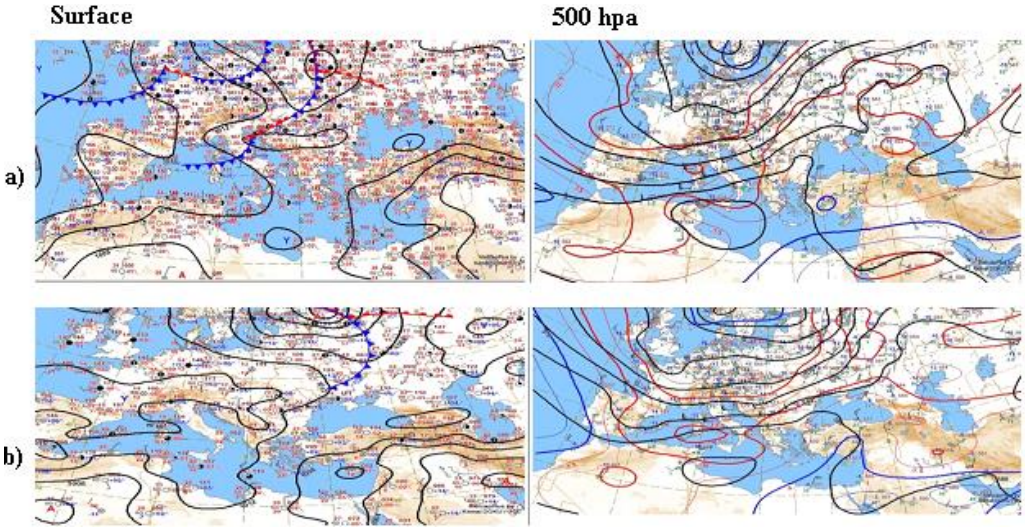


Figure 15. 02 August (a) and 03 August (b) 2021 00:00 UTC Surface Card and 500 hPa

On August 2, the maximum temperature was recorded as 43.3 ºC at 09:00 UTC at the 17954-Manavgat station, 43.3 ºC at 10:00 UTC at the 17917-Manavgat Taşağıl Forest Field station, 42.5 ºC at 10:00 UTC at the 17302-Antalya station, and 43.4 ºC at the 17300-Antalya Airport station. While the maximum wind blew from North-Northeast at 30 km/h at the 17954-Manavgat station at 06:00 and 08:00 UTC, it blew 58 km/h from North directions at the 18839-Manavgat Forest Field station at 22:00 UTC. On August 3, the highest temperature was recorded as 43.9 ºC at 08:00 UTC at the 17954-Manavgat station, 44.6 ºC at 11:00 UTC at the 17917-Manavgat Taşağıl Forest Field station, 43.4 ºC at 09:00 UTC at the 17302-Antalya station, and 44.8 ºC at the 17300-Antalya station. The maximum temperature (44.8 ºC) recorded on August 3 in the province of Antalya was the highest temperature recorded between 1930 and 2021. The highest wind blew at the 18839-Manavgat Forest Field station from the Northeast at 55 km/h at 03:00 UTC (Figure 16).

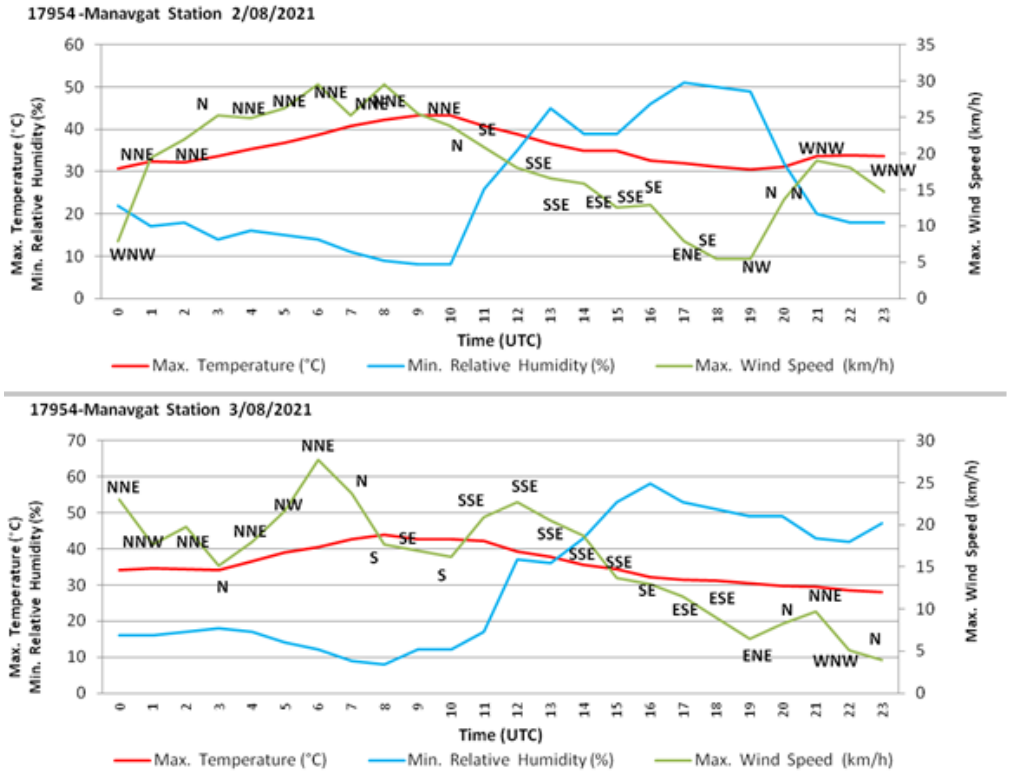


Figure 16. 017954-Manavgat station Hourly Max. Temperature, Min. Relative Humidity and Max. Wind Speed on 2 and 03 August 2021

It can be seen that the conditions that led to strong northern flows in the region on 4-5-6 August 2021 weakened (Figure 17). Normal circulation in the region has begun to be effective. However, there has been no significant decrease in maximum temperatures with the effect of the great fire since continued as of July 28, 2021 (Figure 18).

The h maximum temperature on August 4 was 43.9 ºC at the 17954-Manavgat and the 17917-Manavgat Taşağıl Forest Field stations, 44.2 ºC at 09:00 UTC at the 17302-Antalya station, 44.7 ºC at 12:00 UTC at 18011-Manavgat Beşkonak Forest Field station, 44.4 ºC at 17300-Antalya Airport station. The maximum wind blew from the South-Southeast at 10:00 UTC at 17954-Manavgat station was 30 km/h, and it was 45 km/h from the Northeast at 01:00 UTC at the 18839-Manavgat Forest Field station.

The highest temperature on August 5 was recorded as 38.3 ºC at 17954-Manavgat station, 39.7 ºC at the 17917-Manavgat Taşağıl Forest Field station, 42.7 ºC at 17302-Antalya station, 45.7 ºC at the 18011-Manavgat Beşkonak Forest Field station, and 42.6 ºC at 17300-Antalya Airport station. The highest wind blew was 26 km/h at 09:00 UTC from the South-Southeast at 17954-Manavgat station, and it was 45 km/h at 01:00 UTC from the Northeast at 18839-Manavgat Forest Field station.

The maximum temperature on August 6 was recorded as 35.7 ºC at the 17954-Manavgat station, 34.2 ºC at the 17917-Manavgat Taşağıl Forest Field station, 32.4 ºC at the 17302-Antalya station, 41.5 ºC at 18011-Manavgat Beşkonak Forest Field station, and 37.0 ºC at the 17300-Antalya Airport station. The maximum wind blew was 22 km/h at 07:00 UTC from South directions at the 17954-Manavgat station, and it was 24 km/h at 09:00 UTC from Southwest at 18839-Manavgat Forest Field station (Figure 18).

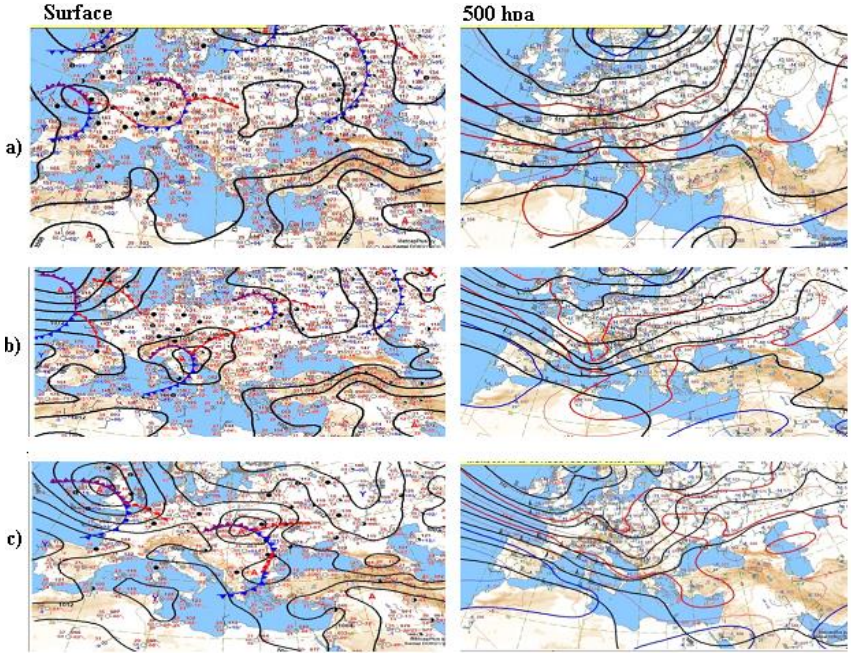


Figure 17. Surface Card and 500 hPa at 04 August 2021 (a), 05 August (b), and 6 August (c) at 00:00 UTC

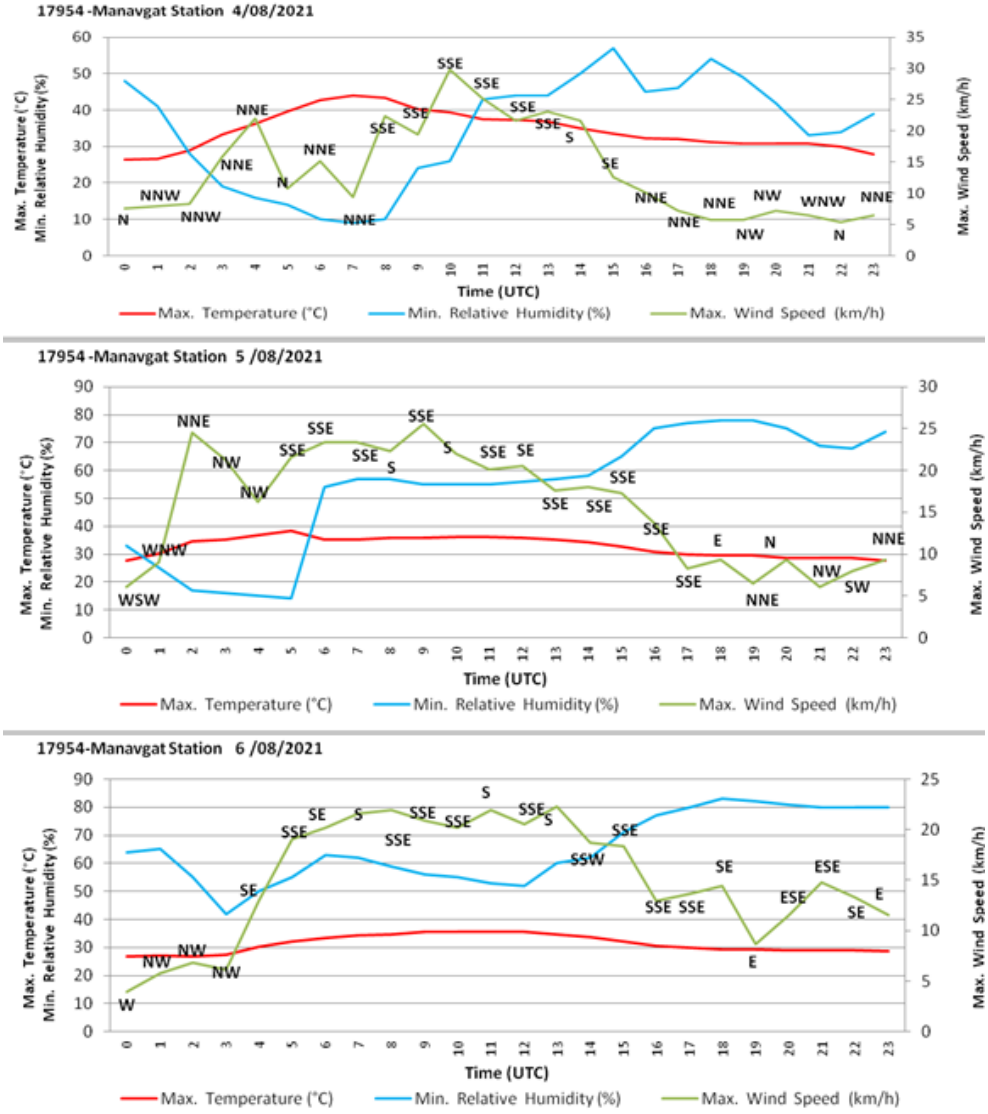


Figure 18. 17954-Manavgat station Hourly Max. Temperature, Min. Relative Humidity and Max. Wind Speed on 04-05-06 August 2021

The dangerous situation in terms of fires disappeared with the emergence of suitable conditions that caused the formation of instability precipitation in the region on the ground map with the effect of the significant cooling that

occurred at the upper levels of the atmosphere and the trophy formed on the 00:00 UTC 500 hpa map on August 7 in Antalya and its surroundings (Figure 19). The maximum temperature was 35.2 ºC at the 17954-Manavgat station 32.7 ºC at the 17300-Antalya Airport station. The highest wind blew was 51 km/h at 14:00 UTC from West-Northwest directions at the 17954-Manavgat station, and it was 56 km/h at 18:00 UTC from North-Northeast at the 18839-Manavgat Forest Field station. When the hourly precipitation around Antalya on August 7, 2021 was examined, it was calculated as 44.4 mm between 05:00-09:00 UTC at 17302-Antalya station, 16.7 mm at 14:00 UTC at the 17954-Manavgat station, 3.4 mm between 12:00-14:00 UTC at the 18839-Manavgat Forest Field station, 2.2 mm between 17:00-23:00 UTC at the 17917-Manavgat Taşağıl Forest Field station, and 21 mm of precipitation between 6:00 UTC and 13:00 UTC at 18011-Manavgat Beşkonak Forest Field station.

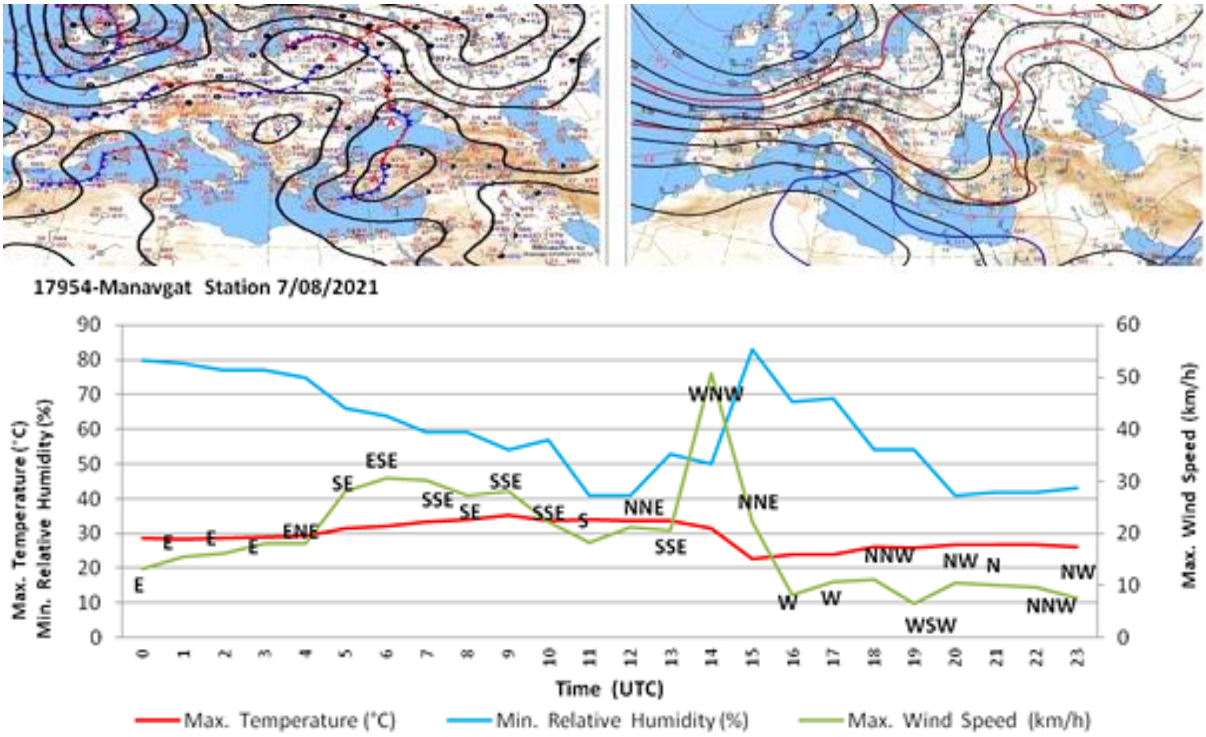


Figure 19. Surface Card and 500 hPa, 17954-Manavgat station Hourly Max. Temperature, Min. Relative Humidity and Max. Wind Speed and Direction on 07 August 2021 00:00 UTC

The fact that the temperatures were higher than 39 ºC, the humidity was lower than 20%, and the wind was around 45 km/h from the north-northeast when the forest fire is experienced in the region. These values indicate that there was a very risky situation in terms of forest fires. The risky situation generated by the synoptic model, which occurred on July 28, 2021, and where the risk of forest fire formation and control is quite high, was predicted as a high-risk day in the 26 July 2021 D+3, and 28 July 2021 D+1 MEUS index outputs produced by the MEUS model (Figure 20). In addition, high-risk areas are seen in the 26 July 2021 D+3 and 28 July 2021 D+1 hourly maximum temperature, relative humidity and wind forecast outputs (Figure 20). The risky situation caused by synoptic models from 29 July 2021 to 6 August 2021 was predicted as high-risk day in MEUS D+1 index in Figure 21.

Manavgat forest fire can be also analyzed in the Figure 22 obtained by the Moderate Resolution Imaging Spectroradiometer (MODIS) on NASA's Aqua satellite in 2021. It is seen that the smoke density completely covers the Mediterranean sea and the size of the burned area is clearly visible.

## Conclusion

Due to its topographic structure, Manavgat and its surroundings are located in an area that is directly open to drying north winds. In accordance with the topographic structure, the spread of maximum temperatures exceeds 30 °C in July and August along the valleys of Manavgat and its surroundings, where the forest areas are dense, and the low humidity rates in July and August create a dangerous situation in terms of forest fires. Başaran et al. (2007) stated in their study that the fire hazard in Manavgat and its surroundings will reach the highest level during the fire season between June and September. In Manavgat and its surroundings, where the Mediterranean climate is observed, the abundance of young and damaged Brutian pine lands in terms of combustible material types makes the forest areas vulnerable to fires. The highest maximum temperature (44.8 ºC) recorded on August 3, 2021, in the province of Antalya was the highest temperature recorded in last 90 years (1930-2021).

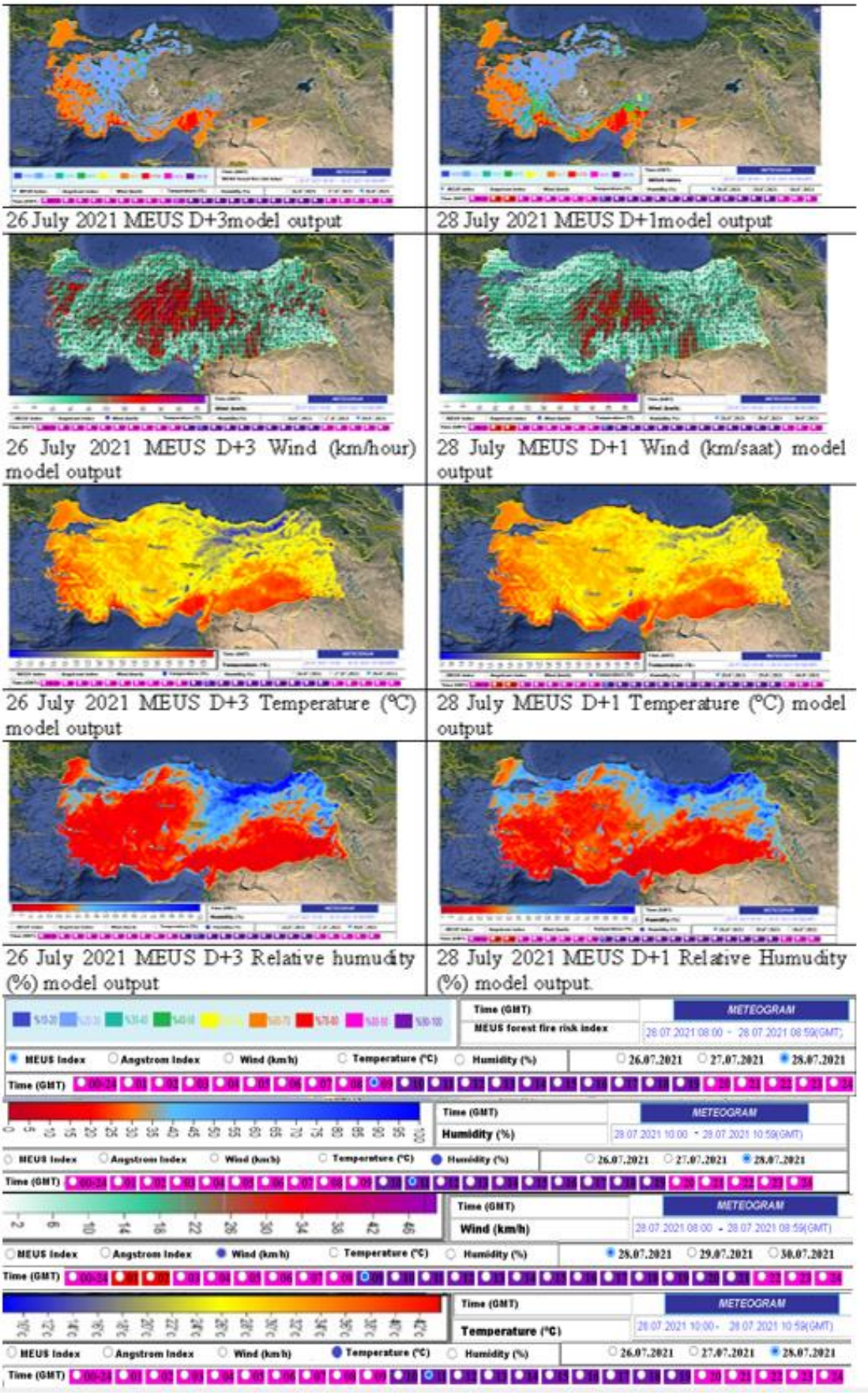


Figure 20. MEUS D+3 and D+1 output

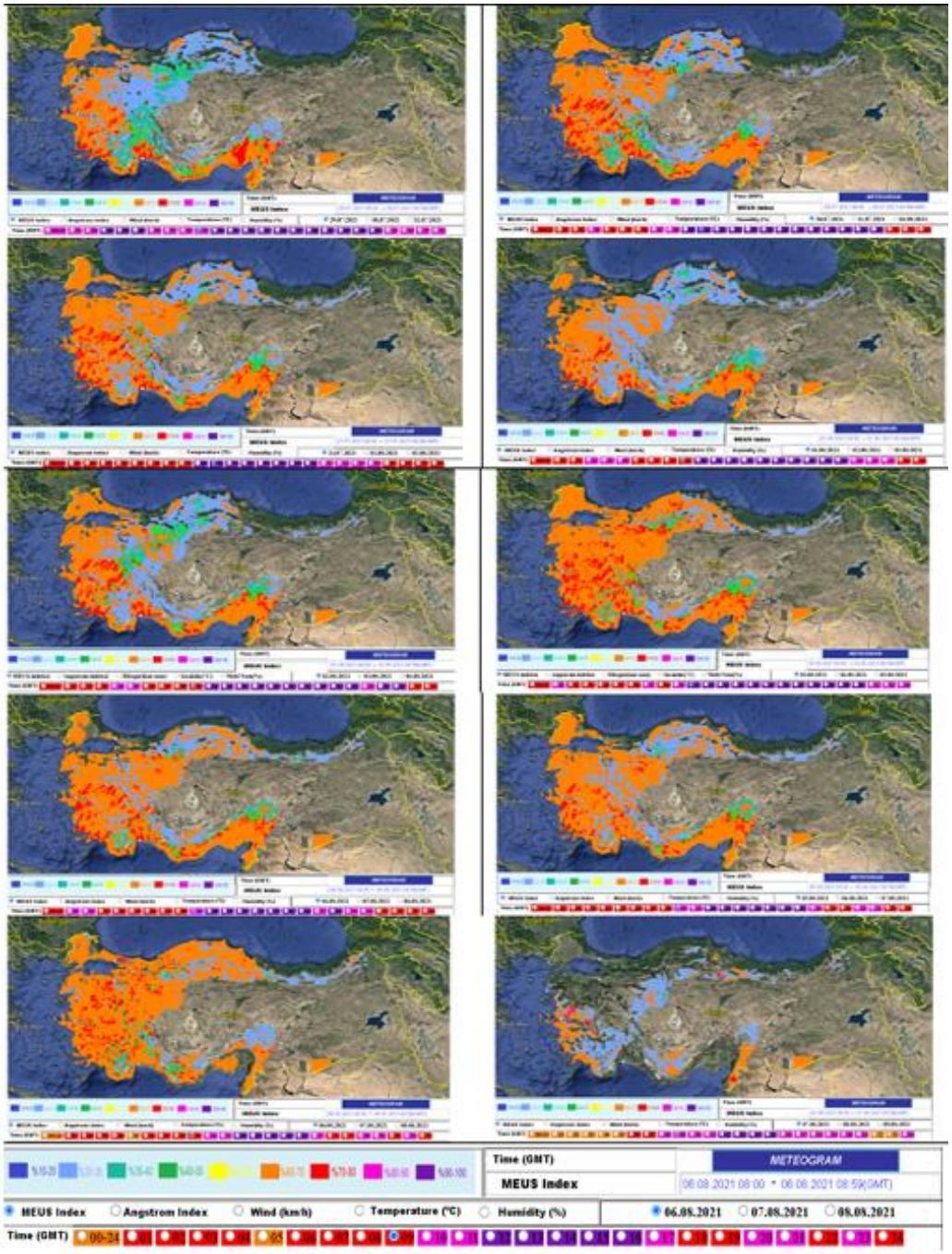


Figure 21. 29-30-31 July 2021 and 01-02-03-04-05-06-07 August 2021 MEUS D+1model output

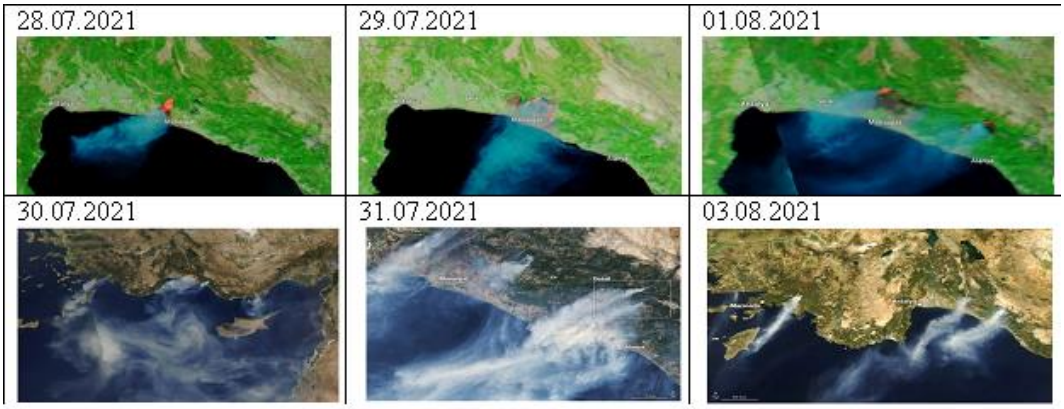


Figure 22. Manavgat forest fires analyzing through MODIS

The transformation of the fires that occured in July and August 2021 classified as a mega fire in Turkiye was not only related to extreme meteorological conditions. Since forest fires lead to in different parts of the country and the fires threatened settlement areas and some facilities, giving priority to such areas in the intervention hindered the extinguishing efforts. It is also possible to say that GDF was caught unprepared for mega fires in terms of vehicles, equipment, air fleet and number of personnel (Ministry of Environment and Urbanization, 2022).

Fighting forest fires requires very systematic approach with many components such as early warning systems, firefighting teams, forest villagers, aircraft, helicopters, sprayers, dozers, fire towers, radio communication system, fire safety roads and lanes, etc. The essential issue in the fight against fires is early intervention. Using the meteorological information correctly in line with this main rule increases the effectiveness of the fight against forest fires and minimizes the damage that will occur. The MEUS model run at TSMS showed high temperatures, low humidity and strong winds in the region. These conditions are very favorable conditions for the spread of forest fires.

The risky situations created by the synoptic model, which occurred in Manavgat on 28 July 2021 and where the risk of forest fire formation and control is quite high, was predicted as a high-risk day in the outputs produced by MEUS, and the outputs were shared with the GDF day by day. With the MEUS fire hazard maps prepared by the TSMS, the decision makers in the GDF actively use this system to fight possible fires more effectively by taking interregional logistic measures according to the danger situation. Lack of precipitation, drought and high temperatures are factors that facilitate forest fires, as well as inadequate air systems in the country, fires at different points at the same time, which affect the distribution of personnel and cause early intervention to be delayed and the success of forest fires to decrease.

**Ethics Committee Approval:** N/A.

**Peer-review:** Externally peer-reviewed.

**Author Contributions:** Concept: G.Ç. and S.A.; Design: G.Ç. and S.A.; Supervision: G.Ç. and S.A.; Resources: G.Ç. and S.A.; Data Collection: G.Ç. and S.A.; Analysis: G.Ç. and S.A.; Literature Search: G.Ç. and S.A.; Writing Manuscript: G.Ç. and S.A.; Critical Review: M.A.P.

**Conflict of Interest:** The authors have no conflicts of interest to declare.

**Financial Disclosure:** The authors declared that this study has received no financial support

**Cite this paper as:** Çamalan, G., Akıl, S., Pekin, M.A. 2023. Assessment of Using UAV Photogrammetry Based DEM and Ground-Measurement Based DEM in Computer-Assisted Forest Road Design. *European Journal of Forest Engineering*, 9(1):10-25.

**References**

Akıncı, H.A., Akıncı, H., 2023. Machine learning based forest fire susceptibility assessment of Manavgat district (Antalya), Turkiye. *Earth Science Informatics*, 16(1): 397-414.

Altan, G., Türkeş, M., Tatlı, H., 2011. Climatological and meteorological analysis of forest fires for the year of 2009 in Çanakkale and Muğla with the Keetch-Byram Drought Index, In: 5th Atmospheric ScienceSymposium Proceedings Book, Istanbul Technical University, 27-29 April, İstanbul. Turkiye, pp:263-274.

Aydin-Kandemir, F., Demir, N. 2023. 2021 Turkey Mega Forest Fires: Biodiversity measurements of the IUCN Red List wildlife mammals in Sentinel-2 based burned areas. *Advances in Space Research*, 7(1): 3060-3075.

Başaran, M.A., Sarıbaşak, H., Çamalan, İ. 2009. Using Geographic Information System Technique in Determining Fire Risk and Hazard Classes. 12thWorld Forestry Congress, 17-19 October, İstanbul, pp:3-15.

Bekereci, A., Küçük, Ö., Çamalan, G. 2010. The blow-dry effect of air masses affecting Turkey in forest fires. In: 1. Meteorology Symposium, 27-28 May, Ankara, pp:83-93.

Çamalan, G., Çamalan, İ., Cevri, H. 2017. Greenhouse design based on climate parameters in order to prevent from meteorological disaster risks in Western Mediterranean Region, VII. Atmospheric Sciences Symposium with International Participation, İstanbul.

Çamalan, İ., Çamalan, G. 2004. Distribution of climate elements in Antalya province and its surroundings and meteorological risk maps, TSMS, Antalya.

Earth observatory NASA. 2022. https://earthobservatory.nasa.gov/images/148650/fires-rage-inTurkiye (Accessed: 10 January 2022)

Gao, C., Lin, H., Hu, H. 2023. Forest-Fire-Risk Prediction Based on Random Forest and Backpropagation Neural Network of Heihe Area in Heilongjiang Province, China. *Forests*, 14(2): 170.

Grünig, M., Seidl, R., Senf, C. 2023. Increasing aridity causes larger and more severe forest fires across Europe. Global Change Biology, 29(6): 1648-1659.

Jo, H.W., Krasovskiy, A., Hong, M., Corning, S., Kim, W., Kraxner, F., Lee, W.K. 2023. Modeling Historical and Future Forest Fires in South Korea: The FLAM Optimization Approach. *Remote Sensing*, 15(5): 1446.

Ministry of Environment and Urbanization, 2022. Turkiye Sectoral Vulnerability and Risk Analysis, Strengthening Climate Change Adaptation Action in Turkey Project (TR2017 ESOP MI A3 04).

Moderate Resolution Imaging Spectroradiometer (MODIS). 2022. https://modis.gsfc.nasa.gov/gallery/individual.php?db_date=2021-07-31 (Accessed: 10 January 2022)

Oğuz, K., Oğuz, E., Çamalan, G. 2021. Analysis of İzmir-Tırazlı Forest Fire with Satellite and Model Data. *UCBAD*, 4(1):1-12.

Ozkan, O., Kilic, S. 2023. UAV routing by simulation-based optimization approaches for forest fire risk mitigation. *Annals of Operations Research*, 320(2):937-973.

Pekpostalci, D. S., Tur, R., Danandeh Mehr, A., Vazifekhah Ghaffari, M. A., Dąbrowska, D., Nourani, V. 2023. Drought Monitoring and Forecasting across Turkiye: A Contemporary Review. *Sustainability*, 15(7): 6080.

Pham, T.T. 2023. Forest fire in the tropical montane forests of northern Vietnam. Doctoral dissertation, Murdoch University. 190 p.

Sağlam, B., Boyatan, M., Sivrikaya, F. 2023. An innovative tool for mapping forest fire risk and danger: case studies from eastern Mediterranean. *Scottish Geographical Journal*, 1-21.

Supriya, Y., Gadekallu, T.R. 2023. Particle Swarm-Based Federated Learning Approach for Early Detection of Forest Fires. *Sustainability*, 15(2): 964.

Tapan Dhar, Basudeb Bhatta, S. Aravindan, 2023. Forest fire occurrence, distribution and risk mapping using geoinformation technology: A case study in the sub-tropical forest of the Meghalaya, India, Remote Sensing Applications: Society and Environment, Volume 29, 100883, ISSN 2352-9385, https://doi.org/10.1016/j.rsase.2022.100883.

Trucchia, A., Meschi, G., Fiorucci, P., Provenzale, A., Tonini, M., Pernice, U. 2023. Wildfire hazard mapping in the eastern Mediterranean landscape. *International Journal of Wildland Fire*. 32-3.

Türkeş, M. Altan, G. 2012a. Meteorological and hydro-climatological analysis of large forest fires of Çanakkale in the year of 2008. Coğrafi Bilimler Dergisi, 10(2): 195-218.

Türkeş, M., Altan, G. 2012b. Analysis of the year 2008 fires in the forest lands of the Muğla Regional Forest Service by using drought indices. *International Journal of Human Sciences*, 9(1): 912-931.

Türkeş, M., Altan, G. 2012c. Analysis of forest fires in Kaz Mountain Region with drought index and their relationship with climate changes, Kazdağları 3rd National Symposium with International Participation Proceedings, 24-26 May, Balıkesir, pp:83-109.

Ying L, Shen Z, Yang M, Piao S. 2019. Wildfire Detection Probability of MODIS Fire Products under the Constraint of Environmental Factors: A Study Based on Confirmed Ground Wildfire Records. Remote Sensing, 11(24):3031.