International Journal of Engineering and Geosciences
https://dergipark.org.tr/en/pub/ijeg
e-ISSN 2548-0960

Synoptic analysis of the January 2004 snowstorm: Example of Çanakkale

Mahmut Eşsiz [1], Zahide Acar [*1]

[1]Çanakkale Onsekiz Mart University, Department of Geography, Türkiye

Keywords
Radiosonde
Snowstorms
Synoptic Analysis

Research Article
DOI: 10.26833/ijeg.988115

Received: 28.08.2021
Accepted: 23.01.2022
Published: 13.04.2022

Abstract

Many natural disasters have occurred on the Earth we live in. Humans have always been in a struggle with these natural phenomena. Today, people are still struggling with atmospheric extreme events. One of the most important disasters like this is snowstorms that occur suddenly in winter. Especially countries in the middle belt (30-60 latitudes in the Northern Hemisphere) are constantly affected by snowstorms. Turkey, located in the Middle Belt, is also exposed to these storms during the winter season. From this perspective, the analysis of synoptic conditions and weather forecast is an important factor for risk analysis and take precautions for winter storms. Thus, the predictions made with the tracking of air masses and synoptic analysis make it easier to understand how the storm occurred. For this purpose, synoptic analyses were conducted to understand the development of the snowstorm that occurred in the high atmosphere in Çanakkale on January 20-30, 2004. This study examined how weather conditions change. Radiosonde data, surface maps, and daily bulletins provided from the Turkish State Meteorological Service were used in the study. Archival data were used to track air mass orbits using the Hysplit trajectory method. Stability and instability assessments of air masses were evaluated using the data from radiosonde stations using the K Index. Spatial analysis software was used to analyze the data and show the thematic distribution of topography. According to the findings, during the passage of a cold front of air masses coming from the north to Çanakkale on January 22, gusty winds began, suddenly dropped the temperatures, and began heavy snow events. Later, it turned into a blizzard and formed a type of snow.

1. Introduction

From the past to the present, finding solutions to environmental problems experienced by the destruction of nature along with the growing population is the greatest effort of humanity for a long time. Considering the relationship between man and space, the value of the interaction between them has emerged. Human-space interaction makes an inference through evaluations by developing different methods of its own.

Climate can be defined as the "synthesis of weather" over a long enough time period to determine its key statistical properties. More generally, it is the time-averaged state of the physical system that includes the atmosphere, hydrosphere, cryosphere, lithosphere, and biosphere and their interactions at many different time and space scales. The main areas that make up the climate system have a wide range of stabilization periods [1]. Turkey, a Mediterranean country, is a country located between three land continents such as Europe, Asia and Africa and surrounded by seas on three sides. The fact that the Black Sea, Aegean and Mediterranean basins are connected significantly affects the air masses and climate that come to the country. Turkey is under the influence of bipolar air mass, especially during the winter months. These are Maritime Polar (mP) and Continental Polar (Cp) air masses [2-8]. These polar air masses cause severe winters and snowstorms in the middle latitudes [9-12]. There is a high correlation between precipitation and storm intensity in the Mediterranean basin [13]. Stormy days display increasing trends in some regions where the wind is channeled by topographic effects such as Canakkale [14].

In January 2004, a severe snowstorm occurred in Çanakkale. Heavy snowfall and severe storms have turned northwestern Turkey into a disaster zone. Within

* **Corresponding Author**

(essizmahmut@gmail.com) ORCID ID 0000-0002-9219-7554
*(zacar@comu.edu.tr) ORCID ID 0000-0002-9174-0447

Cite this article

Eşsiz, M., & Acar, Z. (2023). Synoptic analysis of the January 2004 snowstorm: Example of Çanakkale. International Journal of Engineering and Geosciences, 8(1), 11-18

a day, temperatures of up to 15°C had dropped and heavy snowfall occurred. A strong winter storm formed along with strong winds. The problem of the study is to provide a good analysis and synthesis of the air masses available for blizzards. Previous studies have only assessed the catastrophic extent of the event [15]. The synoptic conditions that prepare the blizzard have never been studied, and there is a lack of knowledge in the literature. This study includes the climatology and effects of the blizzard that occurred in 2004 and affected the entire western Anatolia. It is believed that it will make a contribution to the literature with the scope of the study.

The snowstorm that occurred in January 2004 reached very effective dimensions in Çanakkale and the surrounding provinces. This severe snowstorm reached the size of a disaster and negatively affected the lives of the people of the region. In the Marmara Region, which is one of the most developed regions of Turkey, the snowstorm has reached the level of disaster. The January 2004 snow storm was felt very strongly in Çanakkale and the surrounding provinces. The purpose and scope of this study can be shown under the following headings.

• Determination of the effects of air masses in places where air masses pass by following the trajectory of the specified snowstorm, spatial distribution of the disaster,

• and the visual presentation of this with the map software program is the evaluation of the formation and development of the blizzard of January 20-30, 2004 by synoptic analysis.

2. Data and Method

Canakkale station was selected as the working area for the station scale assessment of the winter storm that was effective throughout western Anatolia (Figure 1).

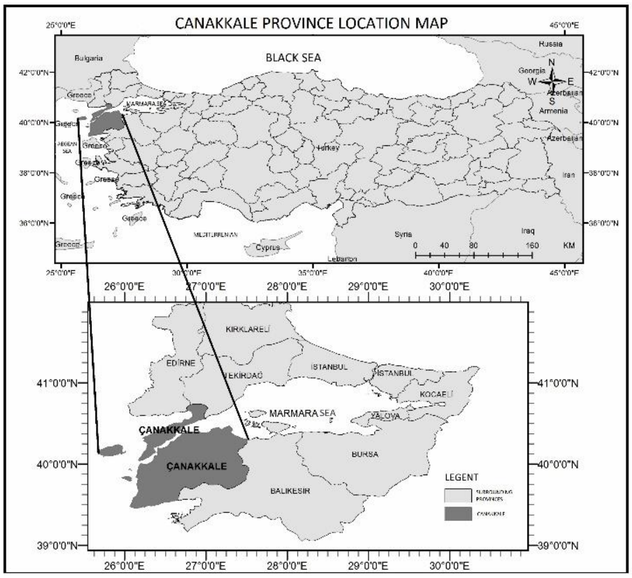

Figure 1. Çanakkale location map study area

The data used in the study are listed below. Daily and hourly data provided by Turkish State Meteorological Service. Hourly sea level pressure, temperatures, humidity, wind speed and wind direction, cloud amount and cloud base height data.

Daily Kadıköy/Istanbul radiosonde (rawinsonde) data. Daily bulletins (surface card and 500 hpa) and the HYSPLIT Reanalysis retro-orbit data model developed by NOAA (National Oceanic and Atmospheric Administration), and SKEW T LOG-P diagram sounding data of all stations in the World, shared publicly by the University of Wyoming [16]. In addition, 500 hpa geopotential altitude pressure distribution maps using Era5 satellite data from the European Center for medium-term weather forecasts (ECMWF) [17]. Synoptic analysis is based on radiosonde data and daily synoptic weather maps. Wind is the movement of air on the earth's surface. Winds play an important role in determining and controlling climate and weather [18].

Wind direction and speed maps [19], and 500 hpa geopotential elevation maps of the Global Forecast System (Gfs) numerical weather forecast model were used [20].

Graphs were created using hourly data (temperature, pressure, humidity, wind speed and direction, cloud base level, amount of cloud). The formation and development of air masses and the developmental stages of blizzards were analyzed and evaluated.

The Hybrid Single Particle Lagrange Integrated Orbit (HYSPLIT) instrument, developed by the National Oceanic and Atmospheric Administration (NOAA) Air Resources Laboratory, was used in this study to calculate retrograde trajectories to understand the development of intense blizzards. Trajectory analysis is a method used to determine the direction of arrival of air masses affecting a snowstorm and its path.

Trajectory analysis represents a method and framework used to analyze the physical processes that cause heavy winter precipitation. Therefore, this research effectively linked the varying concentration of components, the posterior trajectories identified using the HYSPLIT tool, to the physical processes that contribute to winter precipitation, as well as to the evolving large-scale circulation regimes. The origin of air masses was analyzed by calculating three-dimensional posterior orbits (or inverse orbits) using the HYSPLIT (Hybrid Single Particle Lagrangian Integrated Orbit) model from the Air Resources Laboratory (ARL). This model was chosen because it is widely used in international scientific research. For this study, reanalysis data for archival trajectories of the online version of HYSPLIT were used and run hourly, twice a day, during 15-30 January 2004 was determined as 48 hours. The isentropic considered, representing the transport by the air mass, are in surface, the 850 hPa and 500 hPa levels [21].

Within the scope of the study, the Skew T log P diagram data sets and graphics of all stations where the air masses pass, and the changes experienced by the air masses as they pass from one station to another station were evaluated. Calculations were made using the K index to determine the stability and unstability of the air. The calculation formula used for the index is as follows;

$$K= (T850-T500) + Td850 - (T700-Td700)$$

T 850: 850 mb dry bulb temperature,
Td850: 850 mb dew point temperature,
T700: 700 mb dry bulb temperature,
Td700: 700 mb dew point temperature,
T500: 500 mb is the dry chamber temperature.

The K index is among the most preferred indexes for determining the intensity of thunderstorms and storms in air masses. A temperature gradient of 850-500 mb, a dew point temperature of 850 mb for humidity in the lower troposphere, and a moisture distribution of 700 mb were presented together. The K index was constructed using data collected from radiosondes. With the addition of the dew point, it allows the determination of unstable air masses from the moisture in the lower levels to the upper level. The probability of occurrence of storm-thunderstorm for the K index is given in Table 1 [22-23].

Table 1. K Index Values

Values	Thunderstorm probability (%)
K<15	0
18-19	20% unlikely
20-25	20-40% isolated thunderstorm
26-29	50% widely scattered thunderstorms
30-35	85% numerous thunderstorms
K>36	100% chance for thunderstorms

3. Results

3.1. Change of Air Masses Due to Topography

Temperatures on land and sea change according to the seasons. Turkey has high windiness due to its location in the subtropical zone. Northwest Anatolia is one of the places where windiness is high in Turkey [3, 24-26]. In this section, the change experienced by the air masses that caused the January 2004 snowstorm is evaluated. The arrival paths of the air masses affecting the study area in Northwest Anatolia were determined using the Hyplit orbit model. The data obtained from the stations where the air masses pass was graphed by extracting the K index to determine the stability and instability situations. Radiosonde stations are homogeneously distributed in Turkey as in Europe. The spatial distribution of the radiosonde stations used in the study is shown in Figure 2. Stability and instability conditions are determined with the data obtained from the stations where the air masses pass. The change experienced by the air masses that were effective in the snowstorm that occurred in Çanakkale in January 2004 is presented visually.

January 20, 2004, according to the heights of the green air masses (red 0m, blue 1500m, green 5500m), their arrival trajectories to Çanakkale and the instability at the station they pass through are as in Figure 3. It is 16.5 at LGIR (Iraklion, Crete, Greece) station and 10.7 at Izmir station.

Figure 2. Geographical distribution of radiosonde stations in Turkey and surrounding countries [27].

The arrival trajectories to Çanakkale according to the altitudes of the air masses (red 0m, blue 1500m, green 5500m) on January 21, 2004, and the instability at the station it passes through are as shown in Figure 4. Instability changed to 5.5 at HEMM station (Mersa Matruh, Egypt), 26.3 at LGIR station (Iraklion, Crete, Greece), and 22.5 at IZMIR (Turkey) station.

The arrival trajectories of Çanakkale on 22 January 2004 according to the heights of the air masses (red 0m, blue 1500m, green 5500m) and the instability at the Istanbul station it passes through are as shown in figure 5. The air mass came from the north and the instability changed as 47.83 at Istanbul station (-3.9 at Poprad-Ganovce (Slovakia) station, -13.3 at LRBS (Bucharest, Romania) station).

According to the altitudes of the air masses (red 0m, blue 1500m, green 5500m) on January 23, 2004 and the instability of the station they passed, the trajectories of their arrival in Çanakkale are as in Figure 6. The air mass coming from the north (red 0m) changed to -8.7 at Budapest station, -11.6 when arriving at LHUD station (Szeged, Hungary), and -9.1 when passing through LRBS (Bucharest, Romania) station.

It is very important to evaluate the synoptic maps in order to see the conditions that created the January 2004 snowstorm and to reveal its effects. Global Forecast System (Gfs) Digital Weather Forecast Models and ECMWF (European Medium Term Weather Forecasts 507 Center) Era 5 satellite models were examined. On January 20, 2004, when viewed at 500 hPa level in Figure 7., a cold core trough path began to form towards Tunisia and Algeria, passing through Italy, where the EU region is formed, in the north of Turkey. The high-pressure ridge in the west also affects Turkey.

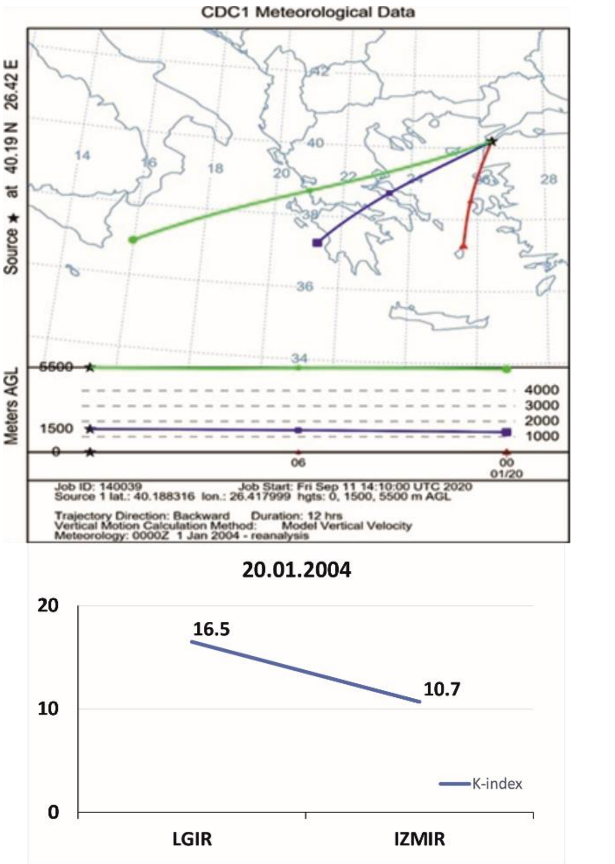

Figure 3. HYSPLIT Reanalysis Back trajectory analysis of 48 hours dated 20 January 2004 and k index analysis at stations where air masses pass

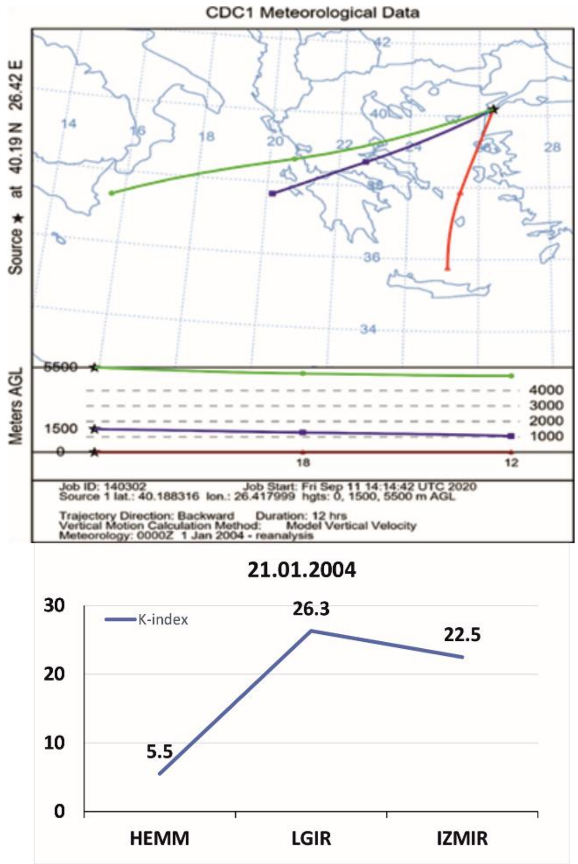

Figure 4. HYSPLIT Reanalysis Back trajectory analysis of 48 hours dated 21 January 2004 and k index analysis at stations where air masses pass

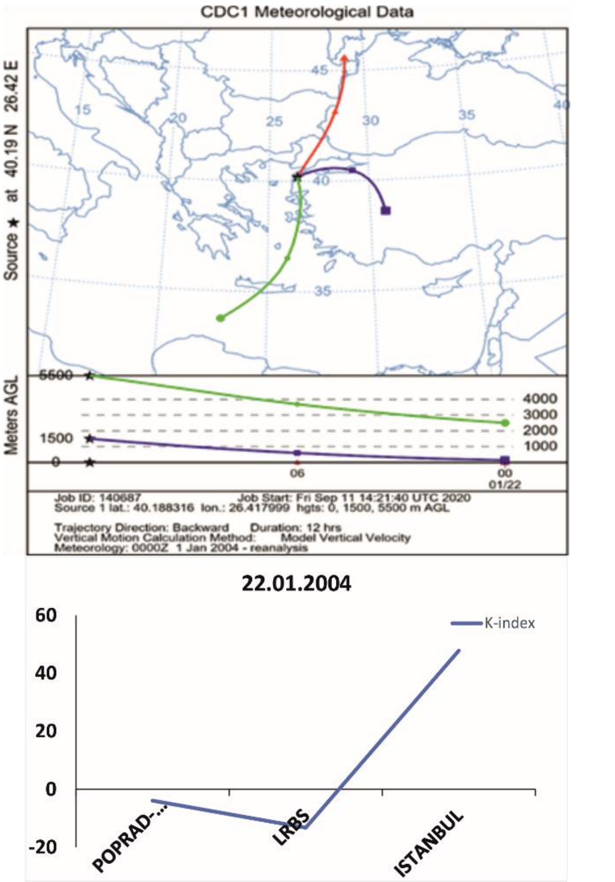

Figure 5. HYSPLIT Reanalysis Back trajectory analysis of 48 hours dated 22 January 2004 and k index analysis at stations where air masses pass

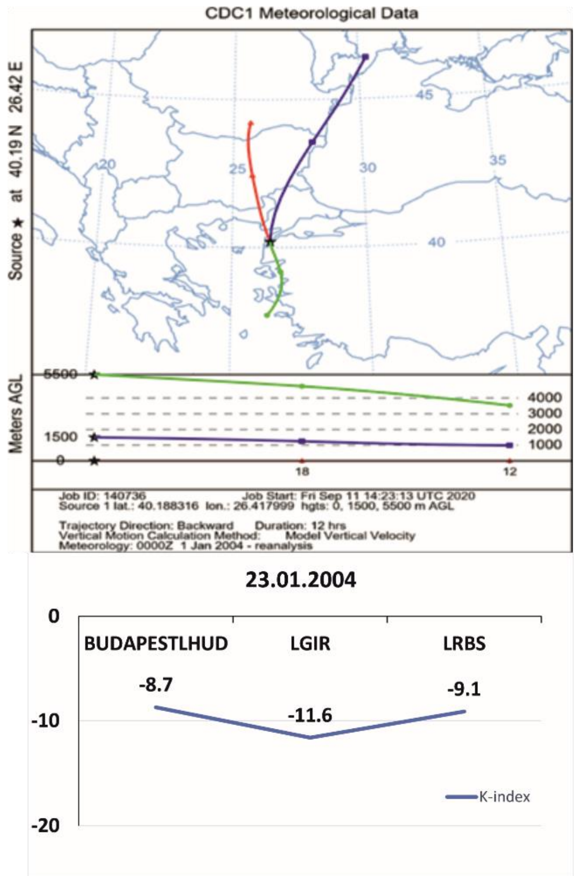

Figure 6. HYSPLIT Reanalysis Back trajectory analysis of 48 hours dated 22 January 2004 and k index analysis at stations where air masses pass

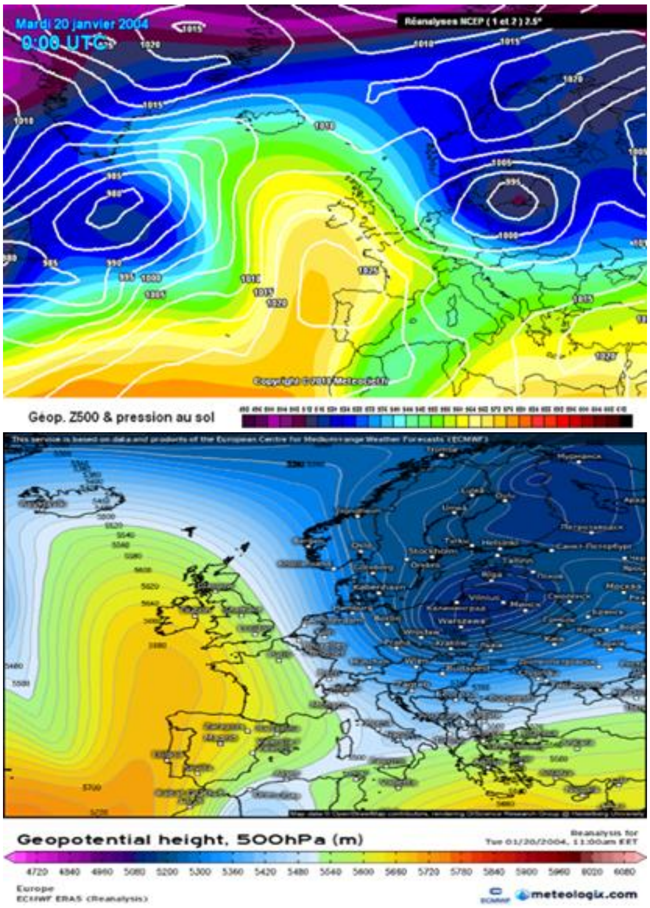

Figure 7. 20.01.2004 Global Forecast System (Gfs) 500 hPa Synoptic Map of the European Continent of the Digital Weather Forecast Model and ECMWF Era5 Satellite model 500 hPa geopotential elevation map

On January 20, 2004, the biggest effect on the transport of air masses was the wind. As indicated in the ECMWF Era5 Satellite model figure 8, the wind blows from south to north at a speed of 40-50 km/h towards the northwest of Turkey.

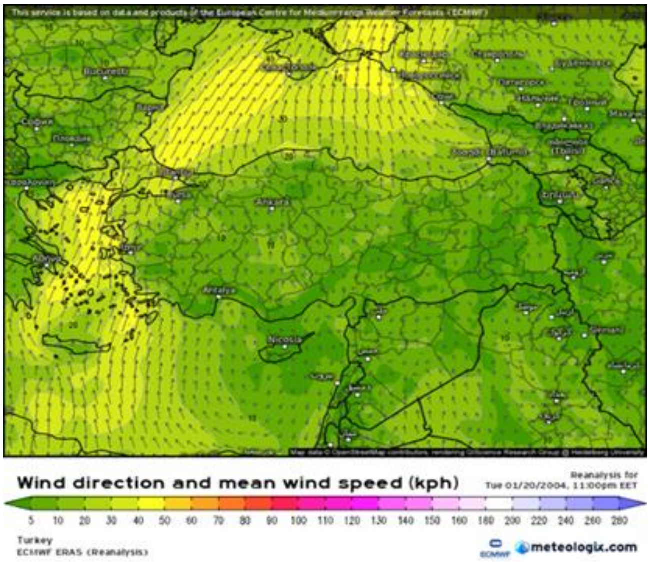

Figure 8. 20.01.2004 ECMWF Era5 Satellite model wind speed and wind direction map

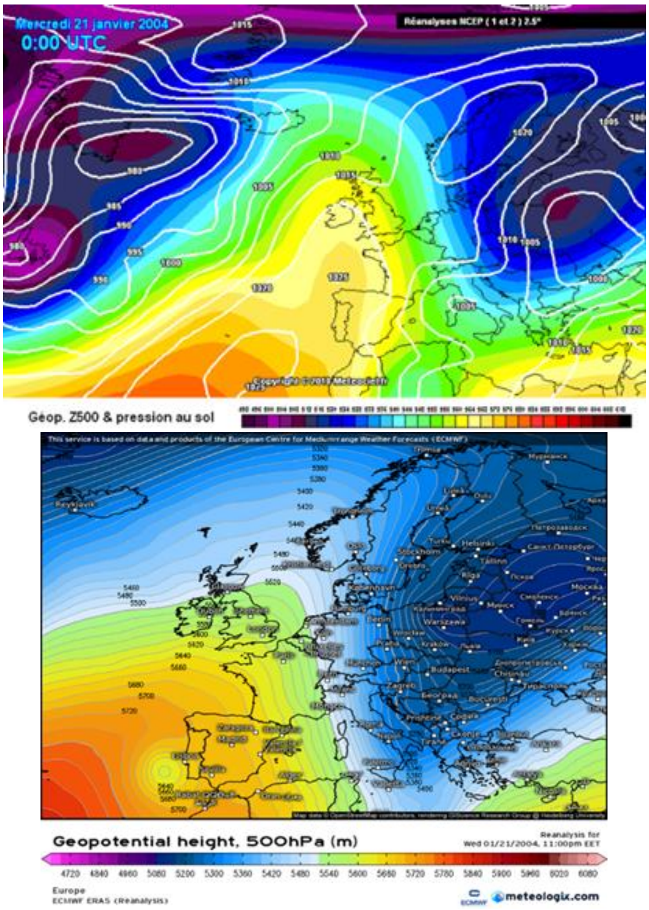

Figure 9. 21.01.2004 Global Forecast System (Gfs) 500 hPa Synoptic Map of the European Continent of the Digital Weather Forecast Model and ECMWF Era5 Satellite model 500 hPa geopotential elevation map

On January 21, 2004, the temperature in the Balkans dropped to -30 degrees, and a deep and cold trough extends to Italy. A frontal system was formed in the Mediterranean. The temperature and pressure gradient in the atmosphere is very strong. The cold-fronted mid-latitude cyclone in the north passes through Thrace and encounters the warm-fronted mid-latitude cyclone in the west. With the presence of a low-pressure system, a cold, rainy and stormy weather is effective on Turkey. With the entry of the cold front from the Balkans, snow in Thrace, Çanakkale region and northern Anatolia, heavy rain in the south and thunderstorms in Marmara are effective. During the passage of the cold front in the northwest of Turkey, the south-westerly wind became northerly (Figure 9 and 10).

On January 22, 2004, a very cold and deep trough deepened in northern Russia (Figure 11). The northern polar air mass affected the whole of Europe and a part of the Mediterranean basin, causing snowfall to begin in Thrace and northwestern Anatolia. With its intrusion towards the south, a pressure center of approximately 990 hpa was formed over Greece and the Aegean Sea, and a mid-latitude frontal area was formed.

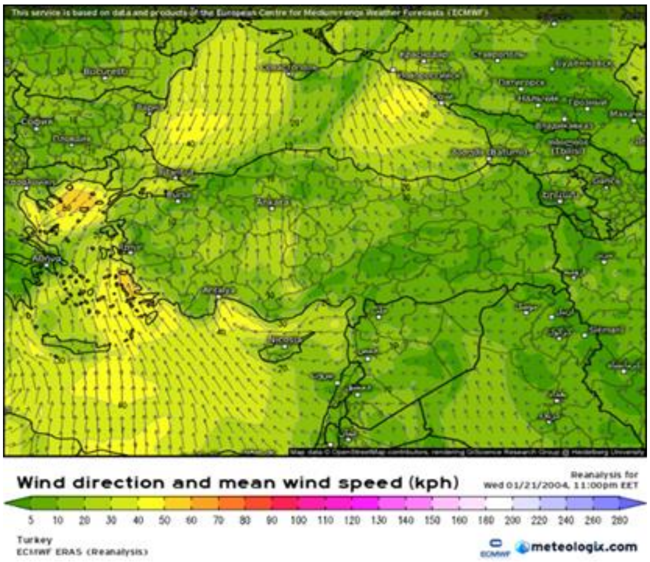

Figure 10. 21.01.2004 ECMWF Era5 Satellite model wind speed and wind direction map

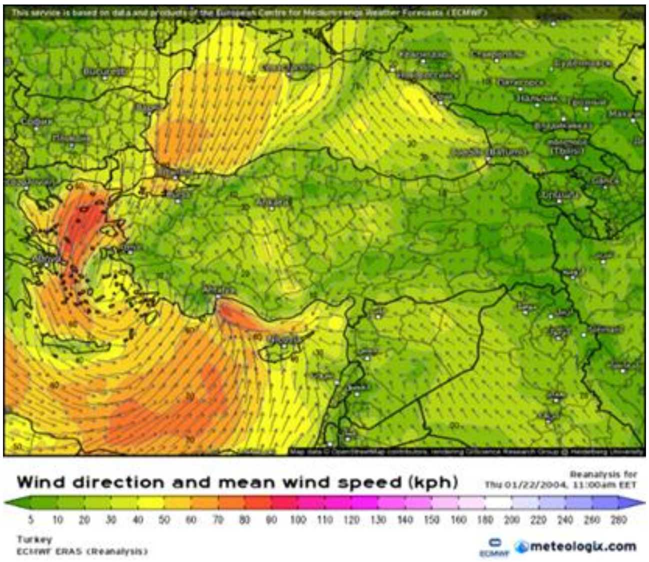

Figure 12. 22.01.2004 ECMWF Era5 Satellite model wind speed and wind direction map

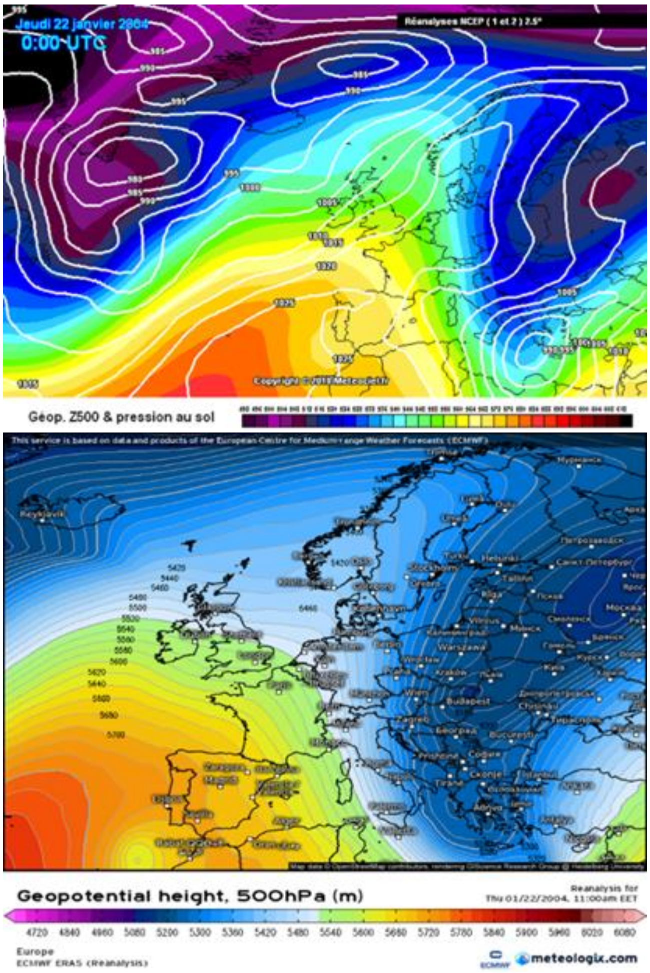

Figure 11. 22.01.2004 Global Forecast System (Gfs) 500 hPa Synoptic Map of the European Continent of the Digital Weather Forecast Model and ECMWF Era5 Satellite model 500 hPa geopotential elevation map

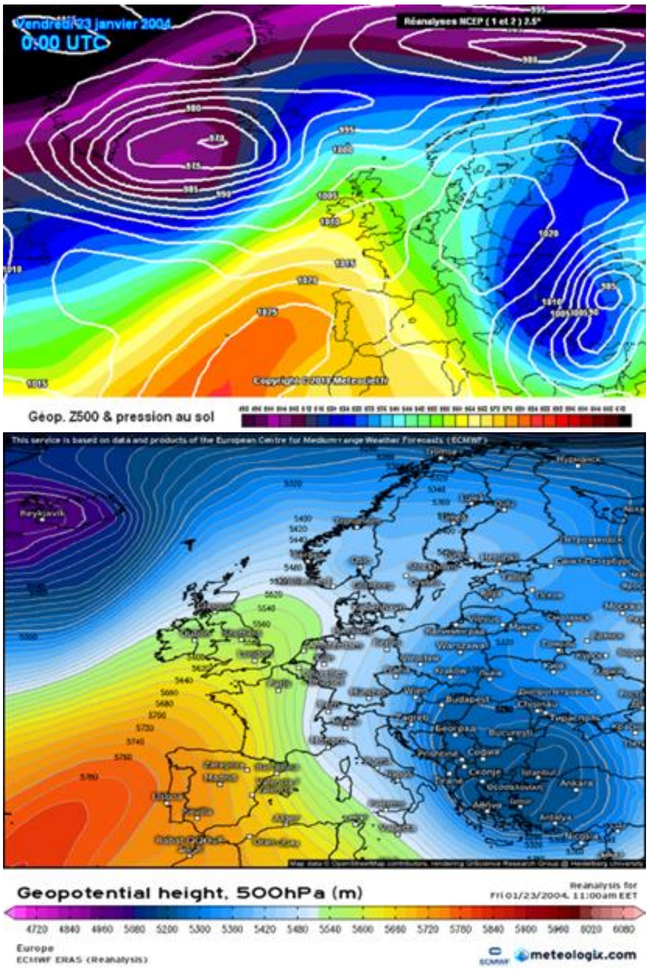

Figure 13. 23.01.2004 Global Forecast System (Gfs) 500 hPa Synoptic Map of the European Continent of the Digital Weather Forecast Model and ECMWF Era5 Satellite model 500 hPa geopotential elevation map

Snowfall, which started with the effect of northern sector air currents in Northwest Anatolia, increased the intensity of the wind together with the strong pressure gradient and turned into a snowstorm (Figure 12).

On January 23, 2004, the cold core, which expanded its influence in the Russian plains and settled in the Balkans and northwest of Turkey, formed a very cold and deep center. From this point of view, the low air temperature along with the mid-latitude cyclone has increased the possibility of snowfall. When we look at Turkey in general, it has been under the influence of cold advection. It was very cold and rainy in most of Turkey. As of January 23, 2004, the cold weather in the northwest of Turkey is effective from the north and northeast sectors, but the wind speed has gradually weakened (Figure 13 and Figure 14).

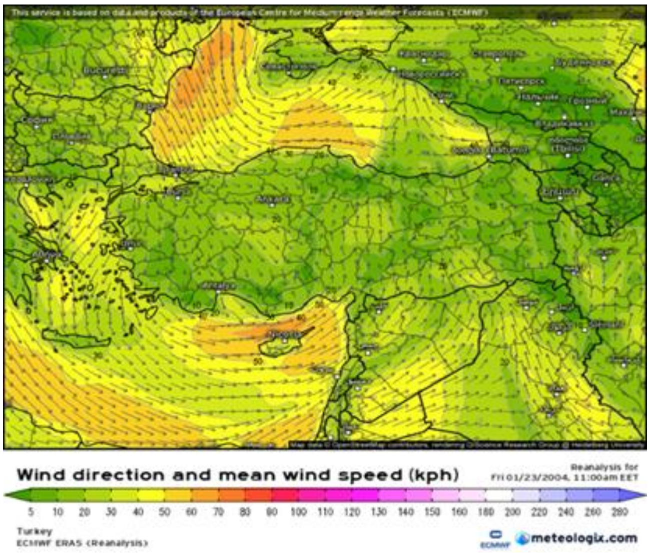

Figure 14. 23.01.2004 ECMWF Era5 Satellite model wind speed and wind direction map

The impact of the blizzard that occurred in January 2004 in the northwest of Turkey was materialized and evaluated with synoptic analyses. In figure 15, the hourly temperature, pressure and wind speed changes of the snowstorm and the effects of the snowstorm are visualized. 20-23 January are examined for storm details.

When the figures are examined, the snowstorm started on the morning of January 22 with the increase in wind speed with the temperature falling below 0 degrees on the night of January 21 and the pressure falling below 1000 hPa. Temperature Until January 26, the temperature is below 0 degrees. As the wind speed has fallen to 23 January (Figure 15).

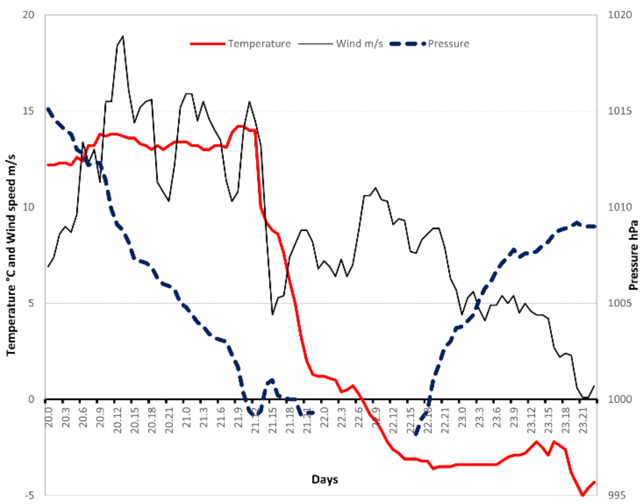

Figure 15. Analysis of hourly temperature, pressure and wind speed of 20-23 January 2004 Çanakkale snowstorm

4. Conclusion

Disasters are the results that occur according to the characteristics of the natural and social environment. There is an increase in disasters worldwide and in Turkey. The unavoidable increase in disasters causes more loss of life and property.

The snowstorm occurred in January 2004 in the Marmara region. However, many provinces in the Marmara region, especially Çanakkale, were affected by the snowstorm and experienced a disaster. The synoptic evaluation of the formation and development of the January 2004 snowstorm in Çanakkale is as follows:

Mid-latitude depressions are effective at an annual rate of 45% in the northwestern part of Turkey [8, 28]. Due to the displacement of the polar front to the south during the cold period, the effective rate of mid-latitude depressions increases in this period. The intensity and duration of the winter storm was strengthened by the presence of cold air introduced into the middle latitudes by the trough in the upper atmosphere.

The mid-latitude cyclone observed over the northern Aegean on 20-23 January 2004. The continuity and effectiveness of snowstorm and heavy snowfalls are related to the trough in the upper atmosphere. The trough is deepened by cold advection from the north. The k-index data from the skew t log p diagram vary across at stations. The values of the K index showed the stability and instability of the air masses. Accordingly, the instabilities of the air masses that caused the snow disaster are quite high in January 2004. According to the K-index of stations, there is a high probability of thunderstorms in northwest Turkey on January 21, 2004. On January 21-22, the air temperature dropped by about 10 degrees, and the storm was effective in the northwest of Turkey. Strong instability of the air mass was experienced snowfall and snowstorm in surrounding the northwestern part of Turkey.

Author contributions

Mahmut Eşsiz: Methodology, Writing-Original draft preparation, **Zahide Acar:** Conceptualization, Data curation, investigation, writing-reviewing and Editing.

Conflicts of interest

The authors declare no conflicts of interest.

References

1. Barry, R. G., & Carleton, A. M. (2001). Synoptic and Dynamic Climatology. Boca Raton: Taylor & Francis.
2. Şensoy, S. (2004). On the Flood Forecasting at the Bulgarian Part of. Ohrid, FY Republic of Macedonia, 1–10.
3. Gönençgil, B. (2008). Doğal süreçler açısından iklim değişikliği ve insan. İstanbul: Çantay Yayınevi.

4. Yılmaz, E., & Çiçek, İhsan. (2016). Thornthwaite climate classification of Turkey, Journal of Human Sciences, 13(3), 3973–3994.
5. Yılmaz, E., & Çiçek, İhsan. (2018). Detailed Köppen-Geiger climate regions of Turkey<p>Türkiye’nin detaylandırılmış Köppen-Geiger iklim bölgeleri. Journal of Human Sciences, 15(1), 225–242.
6. Acar Deniz, Z. Gönençgil, B., & Korucu Gümüşoğlu, N. (2017). Long-Term Changes in Hot and Cold Extremes in Turkey. *Istanbul University Journal of Geography, 37*, 57-67.
7. Acar Deniz, Z., & Gönençgil B. (2019). Extreme precipitation events in Turkey. Meteorological Journal, 2(22), 87-94.
8. Koç, T., (2001). Climate and Environment in Northwest Anatolia with Synoptic, Statistics and Application Dimensions. Istanbul: Çantay Bookstore.
9. Goree, P.A. & Younkin, R.S. (1966). Synoptic climatology of heavy snowfall over the central and eastern United States, Montly Weather Review, 94(11), 663-668.
10. Suriano, Z, & Leathers, D. J. (2017). Synoptic climatology of lake-effect snowfall conditions in the eastern Great Lakes region: synoptic climatology of lake-effect snowfall conditions. International Journal of Climatology, 37, 37: 4377-4389.
11. Mote, T., Gamble, D.W., Underwood, S.J., Bentley, M.L. (1997). Synoptic-Scale Features Common to Heavy Snowstorms in the Southeast United States, Weather and Forecasting, 12(1), 5-23.
12. Topuz, M., & Karabulut, M. (2016). Interrelation of Extreme Climatic Events with Air Masses in Antakya (Hatay, Turkey). International Journal of Humanities and Social Science Invention, 12;61-73.
13. Galanaki, E., Lagouvardos, K., Kotroni, V., Flaounas, E., & Argiriou, A. (2018). Thunderstorm climatology in the Mediterranean using cloud-to-ground lightning observations. Atmospheric Research, 207, 136–144.
14. Kurtulus, Y. F., & Acar, Z. (2021). Interannual variability of stormy day over Turkey. Journal of Geography, 42, 19-31.
15. Acar, Z , Gönençgil, B. (2022) Investigation of Extreme Precipitation indices in Turkey. Theorical and Applied Climatology, 147 (3-4). https://doi.org/10.1007/s00704-022-03971-3.
16. http://weather.uwyo.edu /upperair/sounding.html
17. https://meteologix.com/tr/reanalysis/ecmwf-era5
18. Britannica, T. Editors of Encyclopaedia (2020, March 28). wind. Encyclopedia Britannica. https://www.britannica.com/science/wind.
19. https://meteologix.com/tr/reanalysis/ecmwfera5/turkey/wind-mean-direction/20171113-1800z.html
20. https://www.meteociel.fr/modeles /archives/archives.php?day=13
21. https://www.ready.noaa.gov/ hypub-bin/trajasrc.pl
22. George, J.J. (1960). Weather Forecasting for Aeronautics. Academic Press, 410-415.
23. Stutevant, J.S. (1995). The Severe Local Storm Forecasting, Weather Scratch Meteorological Services; 1st edition. 978-096050408200.
24. Erinç, S. (1996). Klimatoloji ve Metodları, Alfa Yayınevi. İstanbul.
25. Erol, O. (1999). Genel klimatoloji (5. bs). İstanbul Üniversitesi yayınları no: Vol. 9. İstanbul: Çetinkaya Kitabevi.
26. Koçman, A. (1993). Türkiye İklimi, Ege Üniversitesi Edebiyat Fakültesi Yayınları: 72. İzmir.
27. http://weather.uwyo.edu/upperair
28. Flocas, H. A., Karacostas, Th. (2007). Cyclogenesis over the Aegean Sea: Identification and synoptic categories, Meteorological Applications, 3(1), 53-61.