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Nowcasting of a thunderstorm: The case study of 2 February, 2015 at Istanbul Ataturk International Airport

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सार – इस अध्ययन में; 2 फरवरी, 2015 को, इस्तांबुल अतातुर्क इंटरनेशनल एयरपोर्ट (ICAO: LTBA) पर आए गर्ज के साथ तूफान की जाँच की गई और पूर्वानुमान में “तात्कालिक पूर्वानुमान” के महत्व पर जोर दिया गया। इस अध्ययन में इस घटना के पहले दिए गए पूर्वानुमान की जाँच की गई। अनुसंधान के इस दायरे में, रेडार उत्पादों और तड़ित प्रेक्षणों का उपयोग तात्कालिक अनुमान के जरिए किया गया। इसके अलावा, मरमारा सागर में तुर्की राज्य की मौसम सेवा (TSMS) द्वारा मापे गए समुद्री सतह के तापमान का भी मूल्यांकन किया गया। इसका परिणाम यह है कि एक गर्ज और इसकी तीव्रता का अनुमान लगभग 42 मिनट से 57 मिनट पहले तक लगाया जा सकता है। हवाई अड्डे के मौसम विभाग द्वारा जारी किए जाने वाले पूर्वानुमान तैयार करते समय अधिक सुसंगत परिणाम प्रदान करने के लिए यह अध्ययन महत्वपूर्ण है।

ABSTRACT. In this study; on 2 February, 2015, a thunderstorm that took place at Istanbul Ataturk International Airport (ICAO: LTBA) was examined and the importance of “nowcasting” was emphasized. This study was performed in order to investigate earlier predictability of this phenomenon. Within the scope of the research, radar products and lightning observations were used as nowcasting tools. Also, the sea surface temperatures measured by the Turkish State Meteorological Service (TSMS) in the Marmara Sea were also evaluated. The result is that a thunderstorm and its intensity can be estimated from approximately 42 minutes to 57 minutes in advance. This is an important topic of study in order to provide more consistent results when preparing forecasts issued by airport meteorological office.

Key words – Istanbul Ataturk International Airport, Nowcasting, Sea surface temperature (SST), Lightning, Radar images.

1. Introduction

Nowcasting is performed in order to estimate the short-term future changes that may occur in the atmosphere for several hours (Mass and Mass, 2011). Such estimates are particularly important for commercial and general aviation, outdoor sport activities, construction, power plants and ground transportation (Wilson *et al.*, 1998). In particular, weather forecasting requires a lot of decision-making (Stuart *et al.*, 2007). Together with advances in technology, it is desirable that the forecasters be trained in the most current techniques of nowcasting (Stuart *et al.*, 2006). Convective nowcasting requires spatially (e.g., 1 km) and temporally (e.g., 10 min) high-resolution prediction products. Forecasters now have the use satellite and radar images, lightning observations and ground observations at their disposal. There is also a need for high-resolution model outputs and artificial intelligence products that can quickly auto-update and, for example, show the direction and intensity of the storm or cell that will be emerging (Sills, 2009). Wilson *et al.* (1998) have discussed thunderstorm nowcasting techniques as classified into three categories; extrapolation, convection initiation/dissipation and numerical prediction.

When an air mass passes over a warmer surface, the lower layer of the air mass (Meteorology, 2005; Türkeş, 2010; Ackerman and Knox, 2013) does the following: (*i*) becomes warmer, (*ii*) more unstable and (*iii*) the relative humidity decreases. For the opposite conditions, an air mass passing over a cold surface, it (*i*) becomes cooler, (*ii*) more stable and (*iii*) more humid.

An examination of the relationship between sea surface temperatures (SSTs) and thunderstorm occurrence

TABLE 1

Terminal Aerodrome Forecast (TAFs) that LTBA prepared on 2 February, 2015 at 1040 UTC and 1640 UTC

TAF
TAF LTBA 021040Z 0212/0318 20015KT 9999 SCT035 BKN100
TEMPO 0212/0216 –SHRA BKN030 BKN080
TEMPO 0222/0302 21015G25KT 4000 –TSRA FEW020CB BKN025
TEMPO 0303/0307 21017G27KT=
TAF LTBA 021640Z 0218/0324 22015KT 9999 SCT035 BKN100
BECMG 0218/0221 –SHRA BKN030 BKN080
TEMPO 0222/0302 23015G25KT 4000 –TSRA FEW020CB BKN025
TEMPO 0303/0307 21017G27KT
PROB30 TEMPO 0307/0310 4000 –TSRA FEW020CB BKN030=

TAF: Terminal aerodrome forecast; Z: Coordinated Universal Time; KT: knots; SCT: Scattered; BKN: Broken; TEMPO: Temporary; (-): Light; SHRA: Showers with rain; G: Gust; TSRA: Thunderstorm with rain; CB: Cumulonimbus; FEW: Few; PROB: Probability

TABLE 2

Amortized TAF (AMD-amended) that LTBA has issued on 2 February, 2015 at 1753 UTC

TAF
TAF AMD LTBA 021753Z 0218/0324 22015KT 9999 –SHRA SCT030 BKN080
TEMPO 0218/0222 4000 –TSRA FEW020CB BKN025
PROB30 TEMPO 0222/0301 23015G25KT –TSRA FEW020CB BKN030
TEMPO 0303/0307 21017G27KT
PROB40 TEMPO 0307/0310 4000 –TSRA FEW020CB BKN030=

TAF: Terminal aerodrome forecast; Z: Coordinated Universal Time; KT: knots; SCT: Scattered; BKN: Broken; TEMPO: Temporary; (-): Light; SHRA: Showers with rain; G: Gust; TSRA: Thunderstorm with rain; CB: Cumulonimbus; FEW: Few; PROB: Probability

demonstrates that positive temperature anomalies leads to cloud formation because they contain a sufficient amount of latent heat. Studies have demonstrated that convective clouds (such as; cumulonimbus, cumulus) generally form or are enhanced. Ismail and Siadari (2015) have analyzed the relationship between daily SST by using model output for their case study about a thunderstorm. They found that increasing temperatures over the sea surface cause instability, formation of convective clouds and thunderstorms. SSTs also play an important role on the intensity of thunderstorm. Many computer-based model studies have indicated that small-scale changes in temperature also affected the wind patterns. It can lead to formation of the convective clouds by causing surface wind convergence (Hoyle, 2008). Das *et al.* (2014) tried to reveal the characteristics of a thunderstorm case study that was examined at the Guwahati Airport. The results show that warm and moist advection had progressed at low levels over the region and this generally happens in the pre-monsoon season. Additionally, there are many studies about thunderstorms in the scientific literature that examined the formation mechanisms and its effects on nearby airports (Young, 2007; Jebson, 2011; Pradhan *et al.*, 2012; Sibley, 2012; Singh, *et al.*, 2014; Özdemir and Deniz, 2016).

Thunderstorms at airports have caused flights to be cancelled or to be diverted because of turbulence, low visibility, heavy rain, etc. Although the consistency of meteorological forecasts is increasing today, there are still difficulties associated with the formation of convective systems. The use of radar products and lightning observations for nowcasting applications are increasingly important as well as the evaluation of model outputs.

The most common season for thunderstorms at Istanbul Ataturk International Airport is the boreal autumn for the period between 2008 and 2012. September and June are the months thunderstorms most frequently occur in general, while February and January are the months when the thunderstorms have occurred least. Regarding most frequent occurrence by time of day 42.16% of thunderstorms occurred between 1700 UTC (Coordinated Universal Time) and 2400 UTC; with 17.48% of storms occurring between 0900 UTC and 1300 UTC (Yazmuhammedov *et al.*, 2014; Özdemir *et al.*, 2017).

According to Terminal Aerodrome Forecast (TAF) reports prepared on 2 February, 2015 at 1040 UTC and 1640 UTC at LTBA, a thunderstorm with light rain (-TSRA) was expected between 2 February, 2015 at 2200 UTC and 3 February, 2015, at 0200 UTC (Table 1).

At LTBA, a thunderstorm with light rain began at 1757 UTC and ended at 1920 UTC (duration: 1 hour 23 minutes). The TAF previously prepared at 1640 UTC was republished as TAF AMD (Amended) (Table 2). The LTBA Meteorological Office changed the forecast at 1753 UTC. It was then expected that a thunderstorm with light rain showers would occur between 1800 UTC and 2200 UTC. In this study, the thunderstorm that took place on 2 February, 2015 at Istanbul Ataturk International Airport (LTBA) was examined and the importance of "nowcasting" was emphasized. The purpose of this study is to carry out a search for predictability (nowcasting) of thunderstorm beforehand from the expected time by using radar and lightning images from nowcasting applications.

Fig. 1. Locations of LTBA, Kartal (Istanbul Rawinsonde Station) and sea water measuring stations

2. Data and methodology

LTBA is located southwest of Istanbul and north of the Marmara Sea (Fig. 1). According to the 2014 annual flight statistics, LTBA is ranked 13th in the world for the number of air traffic operations (ACI, 2015). According to the statistics conducted for Turkey, LTBA ranks first in terms of total number of passengers (GDSAA, 2015).

The products used in this study to obtain data were the Aerodrome Routine Weather Reports (METAR) and Aerodrome Special Weather Reports (SPECI) prepared by Ataturk International Airport Meteorology Office, TAF reports, routine synoptic maps, Skew-T Log-P diagrams, radar images, lightning observations and SSTs (it measured by the Turkish State Meteorology Service at the stations on the Marmara Sea). SSTs are temperatures measured by TSMS and obtained from breakwaters and sea buoys located at points indicated in Fig. 1 and these were measured every minute. However, hourly mean values were used in this study.

The Max radar products (41°20′28″ N-28°21′24″ E; altitude: 378 m; tower: 41 m; distance to LTBA: ~56 km; C-band Doppler radar) were obtained from TSMS and also used for nowcasting. The Max product shows the maximum values measured by the radar between two defined horizontal levels using volumetric scanning data. It provides information about levels in which the events are more active and the condensation nuclei of air masses. Max radar images are products that are capable of displaying echo height and intensity on a single image and is used when weather conditions are severe. The lightning observations were evaluated also and these were obtained from the TSMS. Fig. 1 shows the locations of LTBA, Kartal (Istanbul Rawinsonde Station) and sea water measuring stations.

3. Analysis and nowcasting

3.1. *Synoptic condition*

On 2 February, 2015 at 1200 UTC, according to the Met Office synoptic charts, a cold front and low pressure with a minimum value of 996 hPa near the Romanian Black Sea coast, stretching east of Istanbul and Marmara Sea and reaching to Crete Island. At 1800 UTC, this cold front continued moving the northeast by passing through

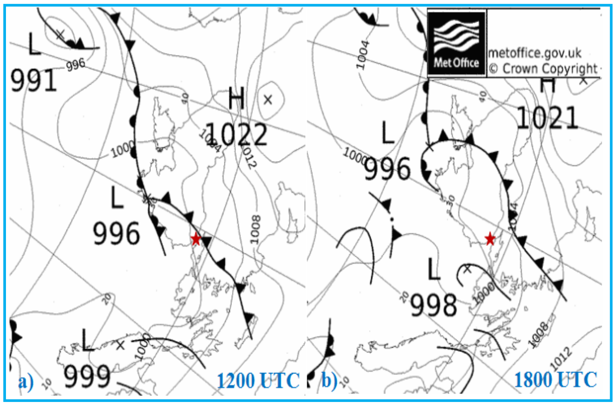


Fig. 2. Surface chart (lines, units in hPa) on 2 February, 2015 at 1200 UTC. A red star shows the location of Istanbul

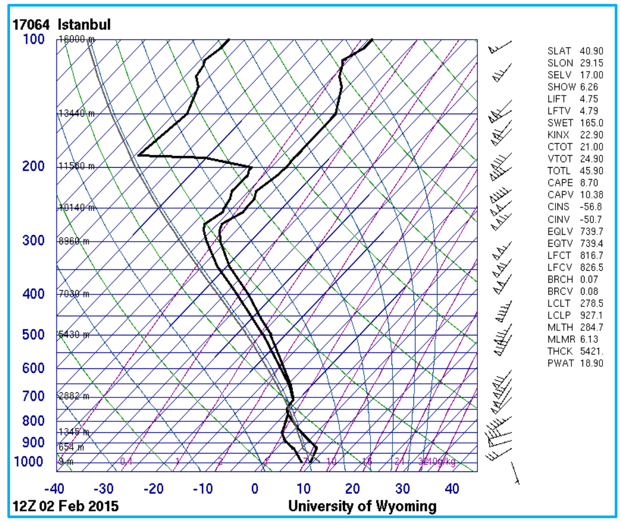


Fig. 3. Skew-T Log-P Diagram on 2 February, 2015 at 1200 UTC in Kartal (Istanbul)

Istanbul and reached the eastern parts of Turkey's western regions. At 1800 UTC, there was a trough from Bulgaria through Greece to the North Aegean (Fig. 2). At 1200 UTC and 1800 UTC, 90% relative humidity was observed at 700 hPa over the western and southwestern regions. At the 500 hPa level at 1200 UTC, a splayed trough entered into Turkey's western region. In particular, Istanbul is located at the left front side of the trough where positive vorticity values are high. Positive high vorticity values generally contributes to the lifting mechanism.

3.2. *Skew-T Log-P diagram of Kartal (Istanbul rawinsonde station)*

The distance between LTBA and Kartal (Istanbul) Rawinsonde Station is about 30 km. According to the 1200 UTC skew-T Log-P diagram (Fig. 3), K Index and Totals Totals Index values indicate that it may be a moderate thunderstorm (Table 3) (NOAA, 2015). The relative humidity in the layer between 825 hPa (1585 m) and 415 hPa (6769 m) is over 81%.

TABLE 3

Various instability values at 1200 UTC on 2 February, 2015

Index	Value	Interpretation
Showalter Stability Index (SSI)	6.26	SI ≥ 3, no significant activity expected
Lifted Index (LI)	4.75	LI ≥ 3, no significant activity expected
K Index (KI)	**22.90**	21 ≤ KI ≤ 25, 20%-40% probability of thunderstorm occurrence
Totals Totals Index (TTI)	**45.90**	45 ≤ TTI ≤ 47, partial/ moderate thunderstorm probability
Convective Available Potential Energy (CAPE)	8.70	CAPE < 1000, poor instability

3.3. *METAR and SPECI reports*

Then, METAR and SPECI reports obtained from TSMS were examined. On 2 February, 2015 at LTBA, a shower with rain started at 0420 UTC occasionally becoming of moderate intensity and continuing intermittently throughout the day. The thunderstorm with rain showers started at 1757 UTC and ended at 1920 UTC, continuing for 1 hour and 23 minutes (Table 4).

3.4. *Marmara Sea surface temperatures*

The hourly averaged SSTs obtained from measuring stations in the Marmara Sea and available through TSMS are shown in Table 5. In the table, the yellow shaded values indicate increases in sea surface temperature, while red boxes indicated the maximum temperatures. Between 1000 UTC and 1500 UTC, the increase in sea surface temperature is 0.30 °C at station 17424 (daytime maximum value is 10.63 °C at 1400 UTC) and 0.24 °C at station 17423 (daytime maximum value is 10.05 °C at 1400 UTC).

3.5. *Nowcasting*

3.5.1. *Radar images*

Max display images of Istanbul Radar for the period 1608 UTC to 1815 UTC on 2 February, 2015 obtained from TSMS are shown in Figs. 4(a-r). At 1608 UTC, a thunderstorm cell was seen in the southwest part of Istanbul's Anatolian side [Fig. 4(a)]. There was no

TABLE 4

METAR and SPECI reports at LTBA on 2 February, 2015 (1750 UTC to 1920 UTC)

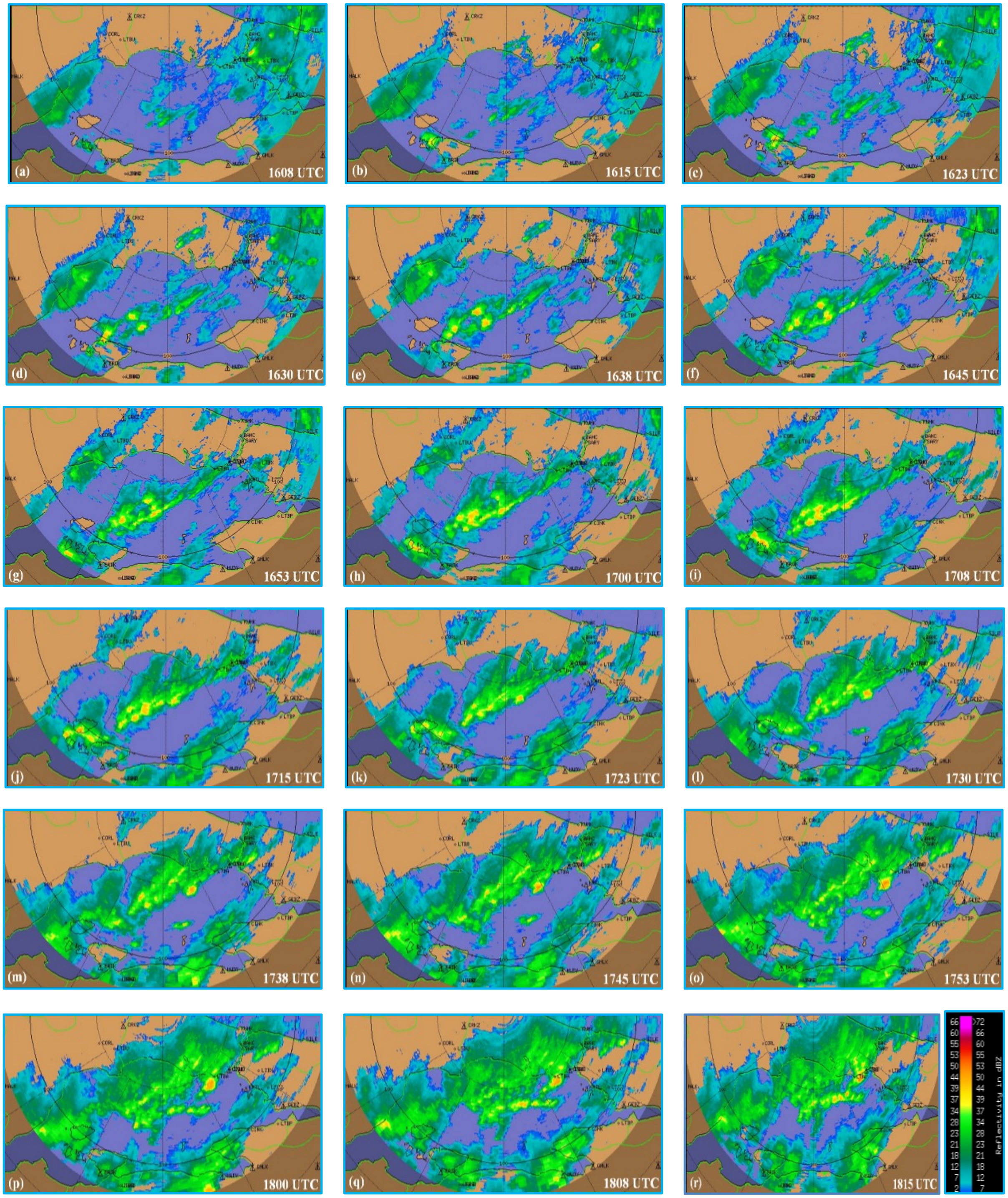
Time (UTC)	Wind direction (°)	Wind speed (knots)	Phenomena	Prevailing visibility (m)	Cloudiness	Temp. & dew temp. (°C)	Pressure (hPa)
14:50	180	8	(-) SHRA	10,000	SCT030 BKN080	11-08	1000
15:20	190	10	(-) SHRA	10,000	SCT030 BKN080	11-08	1000
15:50	180	11	-	10,000	SCT030 BKN080	11-08	1000
16:20	190	10	-	10,000	SCT030 BKN080	11-07	1001
16:50	180	10	-	10,000	SCT030 BKN080	11-08	1001
17:15	170	12	(-) SHRA	10,000	SCT030 BKN080	11-08	1000
17:20	170	14	(-) SHRA	10,000	SCT030 BKN080	10-08	1001
17:50	190	10	(-) SHRA	10,000	FEW020CB BKN030 BKN080	11-07	1001
17:57	200	8	(-) TSRA	8,000	FEW020CB BKN025	11-07	1001
18:20	200 / 180V240	11	(-) TSRA	8,000	FEW020CB BKN025	10-07	1001
18:50	220 / 190V270	10	(-) TSRA	4,000	FEW020CB BKN030	10-07	1002
19:20	280 / 220V340	4	(-) SHRA	8,000	FEW020CB BKN030	09-07	1002
19:50	150 / 100V200	3	(-) SHRA	8,000	FEW020CB BKN030	09-07	1002
20:20	140 / 030V180	3	(-) SHRA	8,000	FEW020CB BKN035	09-07	1002
20:50	150 / 100V180	6	(-) SHRA	7,000	FEW017CB BKN030	09-07	1002

Temp: temperature; Dew Temp: dewpoint temperature; (-): light; SCT: scattered; BKN: broken; CB: cumulonimbus; TSRA: thunderstorm with rain; FEW: few; SHRA: heavy rain showers

TABLE 5

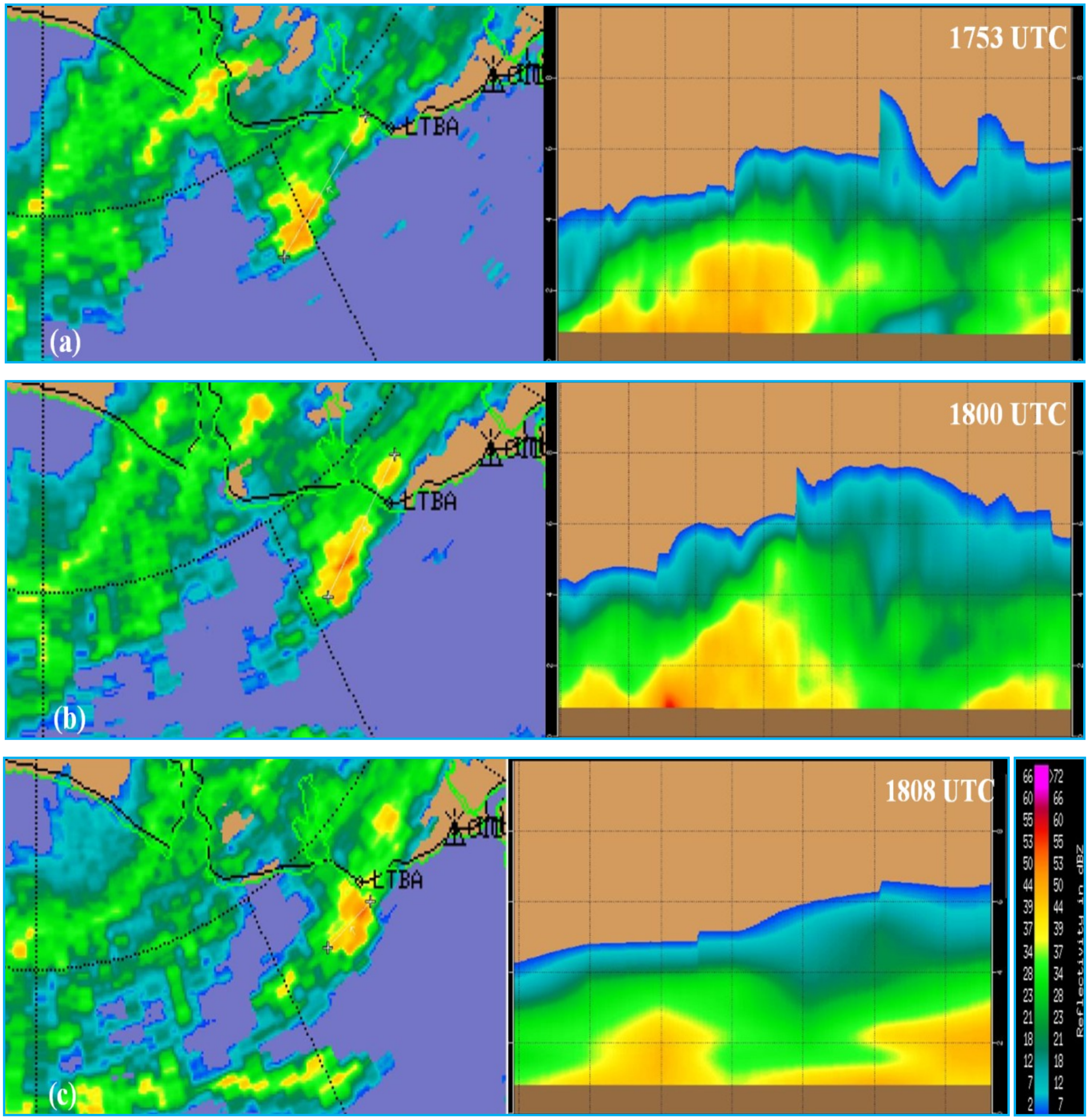
Sea surface temperatures of the Marmara Sea on 2 February, 2015

Station numbers & time (UTC)	17382	17388	17422	17423	17424	17431	17437	17438	17448	17451
0100	9.99	9.54	**10.58**	9.64	9.53	11.20	9.28	8.14	9.72	8.38
0200	9.90	9.60	**10.59**	**9.73**	9.45	11.19	**9.30**	8.10	9.70	8.37
0300	9.83	9.60	10.43	**9.74**	9.40	11.11	**9.31**	8.10	9.70	**8.38**
0400	**9.90**	9.60	9.85	**9.81**	**9.73**	11.07	9.30	8.09	**9.77**	8.36
0500	9.85	9.60	9.80	**9.85**	**10.24**	**11.09**	9.30	8.08	**9.79**	8.33
0600	9.50	9.60	**9.82**	**9.90**	**10.40**	**10.92**	9.30	8.06	**9.80**	8.31
0700	9.50	9.60	9.78	**9.90**	**10.52**	10.53	9.30	8.01	9.78	8.29
0800	9.47	9.60	9.41	**9.90**	**10.61**	10.34	9.30	8.00	9.78	8.29
0900	**9.57**	9.60	9.20	9.82	10.53	**10.47**	9.25	**8.07**	**9.80**	8.29
1000	**9.60**	**9.68**	9.12	9.79	10.21	**10.55**	9.25	8.03	9.79	8.28
1100	**9.62**	**9.70**	8.96	**9.81**	**10.39**	**10.59**	9.29	7.96	**9.79**	**8.37**
1200	**9.68**	**9.71**	8.94	**9.93**	**10.40**	**10.66**	**9.28**	**7.99**	**9.80**	**8.37**
1300	**9.81**	**9.77**	**9.02**	**10.03**	**10.60**	**10.69**	**9.30**	**7.99**	**9.80**	8.32
1400	**9.94**	**9.79**	8.96	**10.05**	**10.63**	**10.70**	**9.30**	**8.00**	9.79	**8.35**
1500	**9.98**	**9.79**	8.90	9.93	10.60	10.58	**9.31**	7.95	9.77	8.22
1600	9.88	9.71	8.90	9.92	10.40	10.49	9.29	7.90	**9.79**	8.09
1700	**9.90**	9.70	8.90	9.86	10.31	**10.57**	**9.31**	7.90	**9.80**	8.06
1800	**9.99**	9.70	8.90	9.84	**10.39**	**10.65**	9.30	7.90	9.74	**8.08**
1900	9.98	9.70	8.83	9.81	**10.45**	**10.73**	9.30	7.90	**9.76**	8.05
2000	9.86	9.70	8.82	9.80	**10.50**	10.69	**9.31**	**7.98**	**9.70**	**8.11**
2100	9.83	9.70	8.82	9.79	**10.52**	**10.72**	9.30	7.94	**9.70**	**8.19**
2200	9.80	9.68	**8.91**	**9.80**	10.49	10.71	9.28	7.96	**9.70**	**8.22**
2300	9.67	9.60	8.90	**9.80**	10.45	10.56	**9.29**	7.90	**9.71**	**8.28**
0000	9.53	9.60	8.90	9.78	10.39	10.27	**9.30**	7.90	9.70	8.19



Figs. 4(a-r). Max display images of Istanbul radar

convective activity over the Marmara Sea and at LTBA. At 1615 UTC, cloudiness [Fig. 4(b)] on Pasalimani Island moved northeast and convectively developed, reaching a vertical height of approximately 10 km [Fig. 4(c)]. At 1638 UTC, two more thunderstorm cells appeared on the Marmara Sea over the northeast part of the Kapidag Peninsula [Fig. 4(e)]. At 1708 UTC, large thunderstorm cells were observed over the middle and southwest parts of the Marmara Sea [Fig. 4(i)]. At 1738 UTC, the thunderstorm cell, which was spread over a large portion



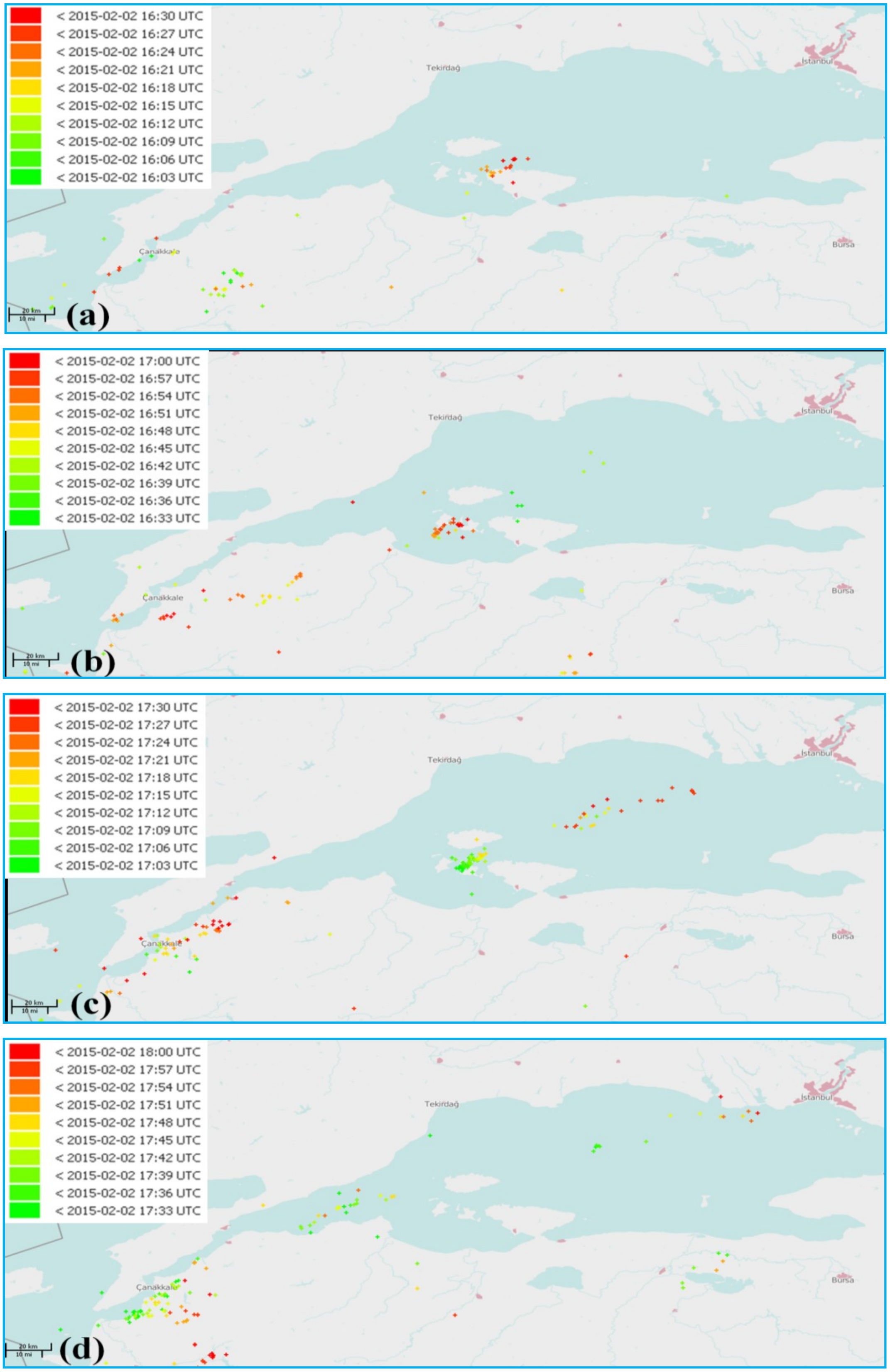
Figs. 5(a-c). Max display images from Istanbul radar, the vertical sections of the max radar images for (a) at 1753 UTC, (b) 1800 UTC and (c) 1808 UTC

of the middle Marmara Sea region, moved a northeast direction parallel to the movement of the cold front [Fig. 4(m)]. At 1808 UTC, the thunderstorm cell was close to LTBA [Fig. 4(q)]. By 1816 UTC, the northern parts of the thunderstorm cell was on the LTBA [Fig. 4(r)].

Figs. 5(a-c) shows vertical sections of Max display radar products for the time period between 1753 UTC and 1808 UTC. Examining the vertical cross-section of the Max radar product at 1800 UTC, it is demonstrated that the thunderstorm cell reached a maximum reflectivity value of 53.5 dBZ [Fig. 5(b)].

3.5.2. *Lightning observations*

The lightning observations in the Marmara Sea between 1600 UTC and 1800 UTC are shown in Figs. 6(a-d) (the position of LTBA is shown using the red circle). Between 1600 UTC and 1630 UTC, lightning was observed over and around Kapidag Peninsula [Fig. 6(a)].



Figs. 6(a-d). Lightning observations in the Marmara Sea region for (a) 1600 UTC-1630 UTC, (b) 1630 UTC-1700 UTC, (c) 1700 UTC-1730 UTC and (d) 1730 UTC-1800 UTC

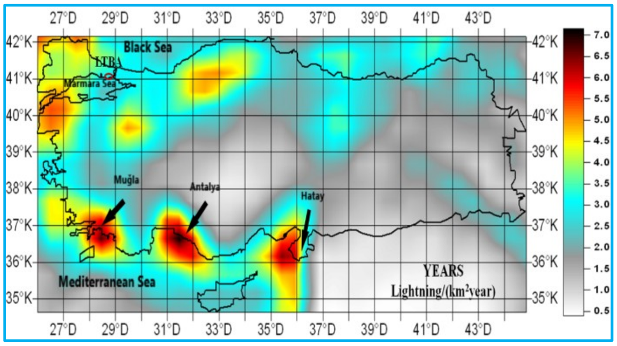


Fig. 7. Temporal and spatial distribution of lightning events in Turkey, 2010-2014 (*Source*: Oztopal, 2017)

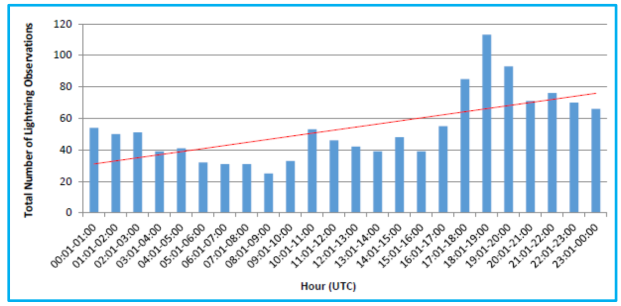


Fig. 8. Hourly lightning observations at LTBA, 2001-2015 (*Source*: Yavuz, 2016)

It is seen that the lightning observations spread along the northeast-southwest direction in the middle of Marmara Sea between 1700 UTC and 1730 UTC [Fig. 6(c)]. In Fig. 6(d), increased lightning activity is approaching LTBA from the southwest between 1730 UTC and 1800 UTC.

4. Discussions

Oztopal (2017) has examined the temporal and spatial distribution of thunder and lightning events for the period 2010-2014 within Turkey, using the Arrival Time Differencing Network (Atdnet) observation data operated by the UK Meteorological Office (Fig. 7). The highest value shown for lightning activity in Turkey is about 7.1 strokes $km^{-2}year^{-1}$. The shores of the Hatay province, Gulf of Iskenderun, many districts of Antalya and Muğla provinces (Belek, Side, Alanya, Dalaman, Fethiye and Marmaris) and coastlines of Marmaris especially observed the highest density of lightning activity 5.0-7.1 strokes $km^{-2}year^{-1}$. When we look at the frequency of lightning activity in the LTBA region, it was not observed to be as intense as the regions mentioned above. The value is approximately between 2.5 and 3.5 strokes $km^{-2}year^{-1}$. These results show that the LTBA and its surroundings were not the place where the convection was initiated and intensifying, but that the thunderstorm was entering the mature stage and then the disintegration phase.

Yavuz (2016) reviewed the METAR and SPECI reports that were prepared by LTBA over a period of 15 years from 2001 and 2015 inclusive. Lightning events were observed mainly between 1700 UTC and 2200 UTC (Fig. 8). Over that period, there was an increasing trend towards 1700 UTC to 2200 UTC occurrences. Also in the same study, the author examined ATDnet lightning strike data for the seven year period covering 2008 and 2014 (Fig. 9). A total of 623 lightning events per hour were detected within a 25 km radius for the selected period in LTBA. Also, in this region, the maximum number of lightning events for one particular hour was 44 (7% - 1000 UTC and 1100 UTC); and then 38 (6% - between 1700 UTC and 1800 UTC).

High SST values are directly related to water vapor in the lower atmosphere (lower troposphere). Similarly, changes and trends in water vapor have a direct correlation with SST anomalies. Theoretically and observed in the model studies, the observed increase in SST and associated with water vapor in the case of constant relative humidity conditions has a positive effect on atmospheric convection (such as the development of thunderstorms and tropical cyclones, see Trenberth, 2005). The increase in the insolation that occurs on a daily basis causes SST values to increase. Therefore, changes in surface fluxes are observed in association with shortwave length radiation. Even increases on the order of a few degrees Centigrade can lead to high variations in the net surface flux. This can lead to an instability effect in the lower atmosphere (Kawai and Wada, 2007).

Due to the location of LTBA (the Black Sea to the north, the Marmara Sea to the south and the Bosphorus to the north-east), it constitutes a transit zone for thunderstorm and lightning activities because there are large water sources around it (three sides) to provide the moisture required for convective movements. The surface circulation of the Marmara Sea, which was constructed and synthesized here using data from March 1992 to October 1999 is shown in Fig. 10. The circulation of the Marmara Sea surface waters (Fig. 10) can be described as a current circulating from the Black Seas through the Bosphorus and into the Mediterranean establishing a clockwise gyre within a large portion of the basin. This general structure may vary due to the wind and/or the amount of water coming from the Black Sea (Besiktepe *et al.*, 2000). In the southern part of the Marmara Sea, the relatively warm sea surface currents move to the north part of the Marmara Sea and it causes increasing instability in the atmosphere to the north of the Marmara Sea. Conversely, these same surface currents increases the stability of the atmosphere to the south by causing the

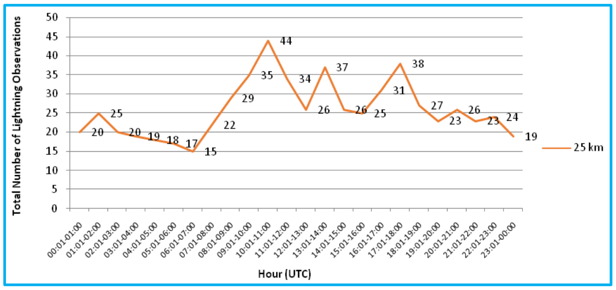


Fig. 9. Total number of hourly lightning observations at LTBA within the 25 km radius, 2008-2014 (*Source*: Yavuz, 2016)

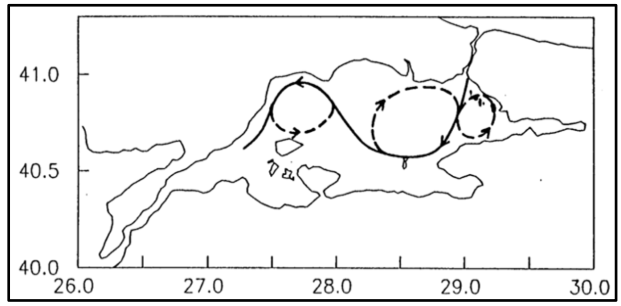


Fig. 10. Sea surface circulation of the Marmara Sea (*Source*: Beşiktepe *et al.*, 2000)

surface temperature to decrease in the Marmara Sea (which is located just south of LTBA). The authors note that most thunderstormsthat took place at LTBA have occured between 1700 UTC and 2200 UTC (Yavuz, 2016) and between 1700 UTC and 2400 UTC (Özdemir *et al.*, 2015). Moreover, it is postulated that there was a contribution by the sea surface currents and the location and timing of thunderstorms. These issues have been raised in this study by the authors for the first time in Turkey. Future work should be done investigating this topic as it would influence nowcasting for these regions.

There are many different nowcasting systems that are in use today. Some of the most commonly used are; Thunderstorm Identification Tracking Analysis and Nowcasting (TITAN) (Dixon and Wiener, 1993), McGill Algorithm for Precipitation Nowcasting by Lagrangian Extrapolation (MAPLE)(Germann and Zawadzki, 2002), Short-Term Ensemble Prediction System (STEPS) (Bowler *et al.*, 2006) and the Short-range Warnings of Intense Rainstorm in Localized Systems (SWIRLS) (Li and Lai, 2004). In Turkey, TSMS operates the meteorological radars of which there are a total of 18 of them including 17 C-band and 1 X-band in Turkey. The C-band radars are mountain radars (These radars are located on the high hills, not on the airport plain). Including LTBA, the nowcasting systems mentioned above are not used in Turkey. As with many countries using radar, Turkey has also performed nowcasting based on human prediction.

The modification of a predictive TAF report that thunderstorm cells observed over the Marmara Sea are being monitored by radar products should not mean that definitely there will be a thunderstorm at LTBA. On 23 September, 2015, LTBA Meteorological Office surveyed convective activity over the Marmara Sea by evaluating radar products. The TAF published at 1640 UTC was corrected at 1957 UTC and a thunderstorm was expected between 2000 UTC and 2200 UTC. However, the thunderstorm cell collapsed and only a shower with rain occurred at LTBA. The authors believe that local SST anomalies (10-20 km) in the proximity of LTBA over the Marmara Sea contribute to sea surface water flow, which will either increase or decrease the effect of warm water or relatively cold water from runoff due to thunderstorms. Air masses undergo thermodynamic changes as they pass through relatively warm or cold surfaces. As a result, the stability of the lower layer of air mass is changing (Meteorology, 2005; Türkeş, 2010; Ackerman and Knox, 2013).

5. Conclusions

In this study, a thunderstorm accompanied by rain showers at LTBA on 2 February, 2015 was investigated for its predictability by using radar and lightning images (nowcasting) before it occurred.

On 2 February, 2015 at 1200 UTC, a cold front passed over LTBA and the airport was behind the cold front by the afternoon and evening. After evaluation of meteorological model outputs and actual maps, the thunderstorm incident is expected due to the passage of the trough behind the cold front between 2200 UTC and 0200 UTC (February 2 to 3, 2015). According to the 1200 UTC sounding data, important activity was not expected or the probability of precipitation associated with the trough was expected to be very low due to solar heating. According to the sea surface temperature data obtained from Marmara Sea water measuring stations, there was an increase in the temperature anomaly to a maximum value of +0.30 °C between 0900 UTC and 1500 UTC. The increase in sea surface temperature caused the increase in the instability on the Marmara Sea. Depending on this instability, thunderstorm cells formed in different parts of the Marmara Sea. Between 1615 UTC and 1630 UTC, the thunderstorm cells began to form over the southwestern part of the Marmara Sea, particularly; Marmara Island, Avsa Island and the Kapidag Peninsula. These thunderstorm cells formed and then moved parallel to the movement of the cold front to the northeast of Istanbul and the system continued to move towards the northeast. At 1700 UTC, there was a wide range of thunderstorm cells over the Marmara Sea. Small increases in Marmara Sea SSTs between 1700 UTC and 2100 UTC, have increased the activity of the thunderstorm cells. These small increases in SSTs (maximum of +0.16 °C) are due to the changes in the flow of sea surface waters. At 1723 UTC, the thunderstorm cell that would affect LTBA continued to evolve by ingesting enough humidity from the sea. At 1808 UTC, the northern parts of these cells were located at LTBA. The thunderstorm with shower activity was reported commencing at 1757 UTC by LTBA and ended at 1920 UTC. Thus, the thunderstorm continued at the airport for 1 hour and 23 minutes.

This thunderstorm activity, which was expected by the LTBA Meteorology Office at 1753 UTC, could have been estimated sooner by using Max radar images and lightning observations. If the thunderstorm cell observed on Pasalimanı Island and Kapidag Peninsula at 1615 UTC was tracked and then later the distribution and direction of movement of this cell over the Marmara Sea were also monitored, the TAF estimate could have been corrected by LTBA Meteorological Office between 1700 UTC and 1715 UTC. Revising the TAF forecasts by monitoring thunderstorm cells from the Marmara Sea using radar products and lightning observations, should not mean that will be automatically a thunderstorm observed at LTBA. On 23 September, 2015, the LTBA Meteorological Office assessed the radar products to track convective activity over the Marmara Sea. The TAF published at 1640 UTC was revised at 1957 UTC and a thunderstorm was expected to occur between 2000 UTC and 2000 UTC. However, the thunderstorm cell decayed and it only caused shower with rain at LTBA.

The work done by Özdemir *et al.* (2017) for the period 2008-2012 included the fact that 42.2% of the thunderstorms that took place at LTBA occurred between 1700 UTC and 2400 UTC. On 2 February, 2015 the timing of the thunderstorm activity at LTBA and the Özdemir's results are consistent with each other. The occurrence of the thunderstorm activities should be observed normally at about noon when convective activity is greatest. However, these activities occurred between 1700 UTC and 2400 UTC at LTBA.

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