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INVESTIGATION OF THUNDERSTORMS OVER ATATURK INTERNATIONAL AIRPORT (LTBA), ISTANBUL

A thunderstorm (TS), also known as an electrical storm, is a severe weather phenomenon characterised by lightning and its acoustic effect, extreme showers, updrafts and downdrafts and sometimes severe ice at higher levels produced by cumulonimbus cloud (NOAA, 2013). Well-developed TS may spread out over the tropopause level in some circumstances and it may produce wind shear, icing, turbulence, hail, lightning, windstorms, macroburst and microburst. This is really a matter for flight safety and it is needed to identify and predict the exact location of TS and its time. For TS to occur, the conditions below are required:

(*i*) Air parcel must have high amount of moisture,

(*ii*) Buoyancy to move air parcel upward (*i.e.*, convection, convergence, orographic ascent or frontal lifting),

(*iii*) Unstable atmosphere.

The climatological means of CAPE (Convective Available Potential Energy) increases with decreasing latitude and shows the largest values near the ITCZ (Inter Tropical Convergence Zone). The largest values of CIN (Convective Inhibition) do not occur around the ITCZ but between the Equator and the 30th parallel, revealing a bimodal zonal distribution, therefore resembling the ascending and descending parts of the Hadley Cell (Riemann-Campe *et al.*, 2009).

Sasse and Hauf (2003) investigated the effects of TS on landing aircrafts at Frankfurt Airport in Germany and Tafferner *et al.* (2010) compared TS locations measured by ground-based systems. Adams and Souza (2009) investigated CAPE and Convective Events in the Southwest America during the North American Monsoon and they found a moderate positive correlation, approaching 0.6 between precipitation and CAPE. Riemann-Campe *et al.* (2010) estimated the memory of convective precipitation via the analysis of the convective parameters CAPE and CIN. Kaltenböck *et al.* (2009) described environmental atmospheric characteristics in the vicinity of different types of severe convective storms in Europe during the warm seasons in 2006 and 2007.

Das *et al.* (2013) investigated severe thunderstorms that took place at Guwahati Airport on 5th April, 2010 using many meteorological observations (*i.e.*, pressure, temperature, humidity, rain and wind) and radar and satellite information; they found that moisture incursions at lower level, instability in the atmosphere (different stability indices) and linear organization of the convective system are responsible for squall and thunderstorm events. The study by Biswas and Dukare (2011) showed that SW Monsoon, depression, low pressure area, upper air cyclonic circulation and cyclonic storm are the main reasons for occurrence of thunderstorms at Aurangabad Airport in India between the years 1990 and 2009; also they found that one quarter of the all thunderstorms happened at the study area for the whole period in June, and that thunderstorm activities generally took less than 3 hours. Agnihotri *et al.* (2012) statistically studied thunderstorms for Bangalore between the years 1981 and 2010. 41% of thunderstorms happened in Pre-Monsoon and SW Monsoon seasons for this region, also 78% of thunderstorms took less than 3 hours, 20% of them took between 3-6 hours, 2% took more than 6 hours. 34% happened at 1500-1800 hours IST (India Standard Time), respectively. The long-term thunderstorm happened in May, taking 10.1 days. Finally, Laskar and Kotal (2013) studied Purnea, Araria and Kishanganj on 13th April, 2010, using synoptic charts, radar and satellite images, and WRF (Weather Research and Forecasting) Model with ECMWF (European Centre for Medium-Range Weather Forecasts) and GFS (The Global Forecast System) data products. According to them, though the WRF Model estimates many parameters well, rainfall could not be estimated by WRF with GFS data. However, WRF with ECMWF data can estimate only light rainfall.

In this study, thunderstorms at LTBA (Istanbul Atatürk International Airport) are analysed by the periods and using METAR (Aviation Routine Weather Report) and SPECI (Aviation Selected Special Weather Report) reports in the period 2008-2013. LTBA is the largest airport in Turkey and at south west of Istanbul. The airport is located at 40° 58′ 34″ N and 28° 48′ 50″ E and its altitude is 33 m. It was opened for service in 1953 and has a total area of 345270 m^2. According to the DHMI (2013) report, cumulative flights were 364322 total numbers of passengers were 45091962; total cargo handled was 1231503.50 tonnes including domestic and international traffic (cumulative totals of 2012 year).

CAPE and CIN values are also statistically analysed according to weak, moderate, strong and extreme convection thresholds. CAPE and CIN values are obtained from sounding observations performed at Kartal Meteorology Station. Sounding observations are implemented in 8 stations in Turkey and twice a day at 0000 UTC and 1200 UTC. Kartal Meteorology station is where sounding observations started on 1st December, 2007. The altitude of Kartal Meteorology Station is 16 m

Fig. 1. The location of LTBA and Kartal Station (*Source* : Google Earth, 2015)

TABLE 1

Classified CAPE values

Index	Value (J/kg)	Interpretation
Convective Available Potential Energy (CAPE)	0 < CAPE < 1000	weak convection
	1000 < CAPE < 2500	moderate convection
	2500 < CAPE < 4000	strong convection
	4000 < CAPE	extreme convection

TABLE 2

METAR and SPECI reports, 2008-2013

Year	Day number	METARs	SPECIs	Total
2008	366	17556	107	17663
2009	365	17519	134	17653
2010	365	17517	118	17635
2011	365	17520	129	17649
2012	366	17516	157	17673
Total	1827	87628	645	88273

and it is located at 40° 54′ 40″ N, 29° 09′ 20″ E. The distance between LTBA and Kartal is 29.77 km and Kartal is 103° degrees east according to LTBA. The locations of Istanbul Ataturk Airport and Kartal Meteorology Station are shown in Fig. 1.

2. METAR observations are performed twice an hour at HH:20 and HH:50 and also SPECI observations are performed between the METAR observations as per criteria stipulated in ICAO (International Civil Aviation Organization) ANNEX 3 (ICAO, 2013).

TS events are detected by investigating METAR and SPECI codes from LTBA in the period of 2008-2013. Different categories of TS such as TSSN (Thunderstorm & Snow), TSRA (Thunderstorm & Rain) events, moderate TS, VCTS (Thunderstorm in the Vicinity of the aerodrome) events. VCTS is reported if a TS is in the range of 16 km from the airport but not greater than that range (MGM, 2010). It is widely accepted that thunderstorms exist if TS and one of its combinations with

TABLE 3

Monthly and seasonal distribution of TS days over LTBA, 2008 - 2013

Year	Winter				Spring				Summer				Autumn				Total
	Dec	Jan	Feb	Total	Mar	Apr	May	Total	Jun	Jul	Aug	Total	Sep	Oct	Nov	Total	
2008	0	0	2	2	3	0	2	5	3	3	1	7	3	1	2	6	20
2009	4	0	0	4	6	2	0	8	2	4	2	8	8	3	3	14	34
2010	1	3	2	6	2	1	1	4	9	4	1	14	4	3	1	8	32
2011	0	0	0	0	0	1	0	1	4	1	0	5	2	3	0	5	11
2012	5	0	0	5	1	5	5	11	1	0	3	4	5	4	1	10	30
Total	10	3	4	17	12	9	8	24	19	12	7	38	22	14	7	43	127

TABLES 4(a-f)

The mean of CAPE, CAPE (max) and corresponding CIN values of TS days during 2008 - 2013

(a)

2008	CAPE	CIN	CAPE(max)	CIN
Spring	62.55	-33.33	109.79	-15.46
Summer	434.00	-36.73	633.22	-24.69
Autumn	112.31	-35.59	378.70	-47.26
Winter	0.00	0.00	6.61	0.00

(b)

2009	CAPE	CIN	CAPE(max)	CIN
Spring	4.14	-6.35	10.21	-11.71
Summer	1018.21	-54.70	1058.91	-52.88
Autumn	245.46	-54.27	279.82	-50.54
Winter	3.13	-21.48	5.92	-75.48

(c)

2010	CAPE	CIN	CAPE(max)	CIN
Spring	28.04	-123.50	28.09	-123.71
Summer	540.04	-62.26	659.07	-59.89
Autumn	254.99	-71.39	266.45	-73.06
Winter	30.63	-18.88	44.67	-30.46

(d)

2011	CAPE	CIN	CAPE(max)	CIN
Spring	0.00	0.00	0.08	-119.92
Summer	462.73	-15.46	557.89	-146.03
Autumn	193.47	-112.50	202.51	-110.25
Winter	-	-	-	-

(e)

2012	CAPE	CIN	CAPE(max)	CIN
Spring	189.18	-36.65	214.54	-60.01
Summer	617.15	-118.40	807.04	-45.02
Autumn	373.68	-73.34	429.20	-33.31
Winter	14.01	-28.37	89.39	-10.82

(f)

5 Years Avg.	CAPE	CIN	CAPE(max)	CIN
Spring	56.78	-39.97	72.54	-66.16
Summer	614.42	-57.51	743.22	-65.70
Autumn	235.98	-69.42	311.34	-62.89
Winter	11.94	-17.18	29.32	-29.19

TABLE 5

Classification of CAPE and CAPE (max) values

CAPE J/kg	CAPE			CAPE (Maximum)		
	DAYS	Mean CAPE	Mean CIN	DAYS	Mean CAPE (max)	Mean CIN
0 < CAPE < 1000	117	199.34	-49.26	113	234.67	-53.70
1000 < CAPE < 2500	9	1259.30	-72.18	13	1275.52	-55.45
2500 < CAPE < 4000	1	2529.12	-0.18	1	2529.12	-0.18
4000 < CAPE	-	-	-	-	-	-

other events is reported at least in one report. The duration of TS is based on RE (recent) past weather group in METAR and SPECI reports. But the duration of VC events is still determined by consecutive reports because it does not have a past weather identifier. It is considered as one-minute duration if the VC event is reported only in one METAR or SPECI report.

Sounding data and CAPE / CIN values from University of Wyoming website (http://weather.uwyo.edu/upperair/sounding.html) in respect of Istanbul have been used to calculate the CAPE and CIN values (downloaded CAPE / CIN values and sounding data). Furthermore, sounding data closest to the observation time of TS in METAR and SPECI reports and maximum CAPE and matched CIN values in the event day are taken into account.

For weak convection CAPE is usually less than 1000 J/kg, while for strong convection CAPE can be 2500-4000 J/kg. In this paper, CAPE values are classified according to Table 1 (Wallace and Hobbs, 2006; http://www.srh.noaa.gov/ffc/?n=gloss2).

3. A total of 88273 reports belonging to LTBA are examined in the period 2008-2013. In the study period of 1827 days, 87628 reports are METAR and 645 are SPECI (Table 2). Unfortunately, 12 in 2008, 1 in 2009, 3 in 2010, 52 in 2012 and in total 68 METAR reports are missing. Monthly and seasonal distribution of TS days over LTBA have been tabulated in Table 3. Autumn season has the highest TS frequency of 43 days of which September accounted 22 days in the 5 year period of study. Winter season has the lowest frequency of TS days. The year 2011 had the smallest number of TS days (11 days) while the year 2009 had the maximum TS occurrence (34 days).

Further analysis revealed that the highest frequency of TS occurred between 1800 UTC and 1859 UTC followed by 2100 - 2159 UTC and 1700 - 1759 UTC. The lowest frequency of TS events was observed between 0600 UTC and 0659 UTC. The maximum duration is 52 hours 15 minutes in September and the minimum duration is 4 hours 46 minutes in February.

The CAPE and CIN values have been collected from the University of Wyoming website and analysed for closest TS events. Also the maximum CAPE value of TS day has been analysed. The mean of the CAPE value closest to the TS time is 292.80 J/kg and the mean of corresponding CIN values is -50.50 J/kg. The mean of maximum CAPE values in 127 days is 359.28 J/kg and the mean of corresponding CIN values is -53.46 J/kg. The highest CAPE of 2529.12 J/kg was observed on 7th August, 2009. Such low values of CAPE suggest that, CAPE may be necessary condition for the occurrence of thunderstorms but not sufficient since large scale flow pattern may also trigger convection with these low CAPE (Bhat *et al*., 1996).

Non-TS days average CAPE is 83.17 J/kg and average CIN is -43.49 J/kg during 2008-2013.

Yearly and seasonal distribution of CAPE, CIN and their maximum values closest to TS events in the day occurred at LTBA in the period 2008-2013 are shown in Tables 4(a-f). It can be seen that the maximum CAPE values are observed during summer and minimum CAPE values during winter. The summer mean of CAPE values in 2009 is 1018.21 J/kg and the mean CAPE (max) (*i.e.*, CAPE (max) value is the highest CAPE value seen in the day) is 1058.91 J/kg. This is the maximum value over the entire 5-year period [Table 4(b)].

CAPE and CAPE (max) values are classified in Table 5. The number of days with moderate convection (CAPE and CAPE (mean) between 1000 J/kg and 2500 J/kg) is 9 and 13 days. As more than 113 out of 127 TS days were observed to be associated with a meagre mean CAPE and mean CAPE (Max) of about 200-235 J/kg, it appears that CAPE may be necessary but not sufficient condition for triggering convection which supports earlier findings by Bhat *et al*. (1996) and Suresh and Bhatnagar (2005).

4. Ataturk International Airport (LTBA) recorded 127 TS days during 2008-2013 with Autumn having maximum frequency of 43 TS days [September (22 days) and June (19 days)] and winter with a minimum frequency 17 TS days [February (4 days) and January (3 days)] . It is seen further that the duration of TS in Autumn season is the highest during the study period.

42.16% of TS events are between 1700 UTC and 2400 UTC and 17.48% are between 0900 UTC and 1300 UTC.

The longest TS were on 8 and 9 September, 2009 and June 23, 2010 in the 5-year period and its duration is 7 hours 30 minutes. The other long-lasting TS is on October 23, 2012 (5 hours 40 minutes), 22nd November, 2008 and 23 November, 2010 (5 hours 30 minutes). These TS events continued without break.

The mean of the CAPE close to the occurrence of TS timing was 292.80 J/kg during 2008-2013. The mean of maximum CAPE values in 127 days was 359.28 J/kg. Such low values of CAPE suggest that, CAPE may be necessary condition for the occurrence of thunderstorms but not sufficient since large scale flow pattern may also trigger convection with these low CAPE. The mean value of CAPE during non-TS days was 83.17 J/kg.

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