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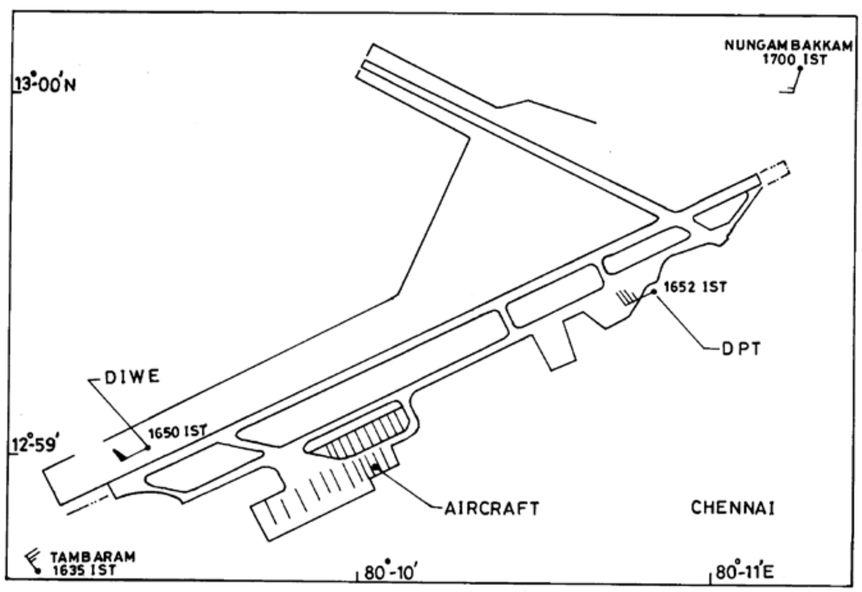
A DIAGNOSTIC STUDY OF STRENGTH OF DOWNDRAFTS IN A GUST FRONT AND THE ASSOCIATED DAMAGES TO AIRCRAFT AT PARKING BAY

1.1. Downbursts are one of the main causes of aircraft accidents. Downbursts are those violent winds rushing from mid troposphere down to the surface in a thunderstorm. The negative acceleration in a downburst is mainly due to evaporative cooling, melting and precipitation loading (Houze, 1993). Evaporative cooling dominates especially when the layer below the cloud base is deep and well mixed (Wakimotto, 1985). Entrainment below the downdraft base can further accelerate the downdraft if the ambient wet bulb temperature is lower than that of the downdraft parcel. However the entrainment rate generally decreases as the downdraft approaches the ground (Wakimotto, 1985). Foster (1958) estimated the effect of evaporative cooling, assuming that a downdraft starts from the 'level of free sinking' where the mean moist adiabat intersected the ambient temperature and the downdraft remained saturated upto ground. He found that the estimated values generally exceeded the observed one. Melting of hail may also be a significant energy source (Srivastava, 1987). Water loading accounts for about 20% of the observed downdraft acceleration in downbursts associated with a Colorado thunderstorm (Kessinger *et al*., 1988). Density current propagation and downward transfer of horizontal momentum occur in a convective downdraft. A cold pool building due to moist adiabatic descent and entrainment of mid troposphere low θe air. It spreads with a speed that is proportional to the square root of its temperature deficit and its depth. Deep intense cold pool generates waves that may cause strong gusts. Downdrafts do carry the ambient momentum from the incipient and entraining levels to the surface is a potentially large source of strong surface winds. The gust front is formed along the leading edges of large domes of rain cooled air that result from the amalgamation of cool downdrafts from individual thunderstorm cells and results from the denser cool air that piles up over the surface in a dome. At the edge of this dome, the horizontal surface gradients pushes the cool air outward into the warmer air as a density current (Charba, 1974, Hall *et al*., 1976). At the leading edge of this current, the gust front, there is a dynamic clash between the cool out flowing air and the warmer thunderstorm inflow that produces the characteristic wind shift, temperature drop and gusty wind that precede a thunderstorm (Caracena *et al*., 1989).

1.2. At about 1702 IST on 31 July 1999, Strong downburst winds struck the parked Boeing 737-500 aircraft on the nose wheel practically lifting it into the air and swinging it to its right nearly seven metres away from

Fig. 1. The photograph of the damaged aircraft [Courtesy 'The Hindu']



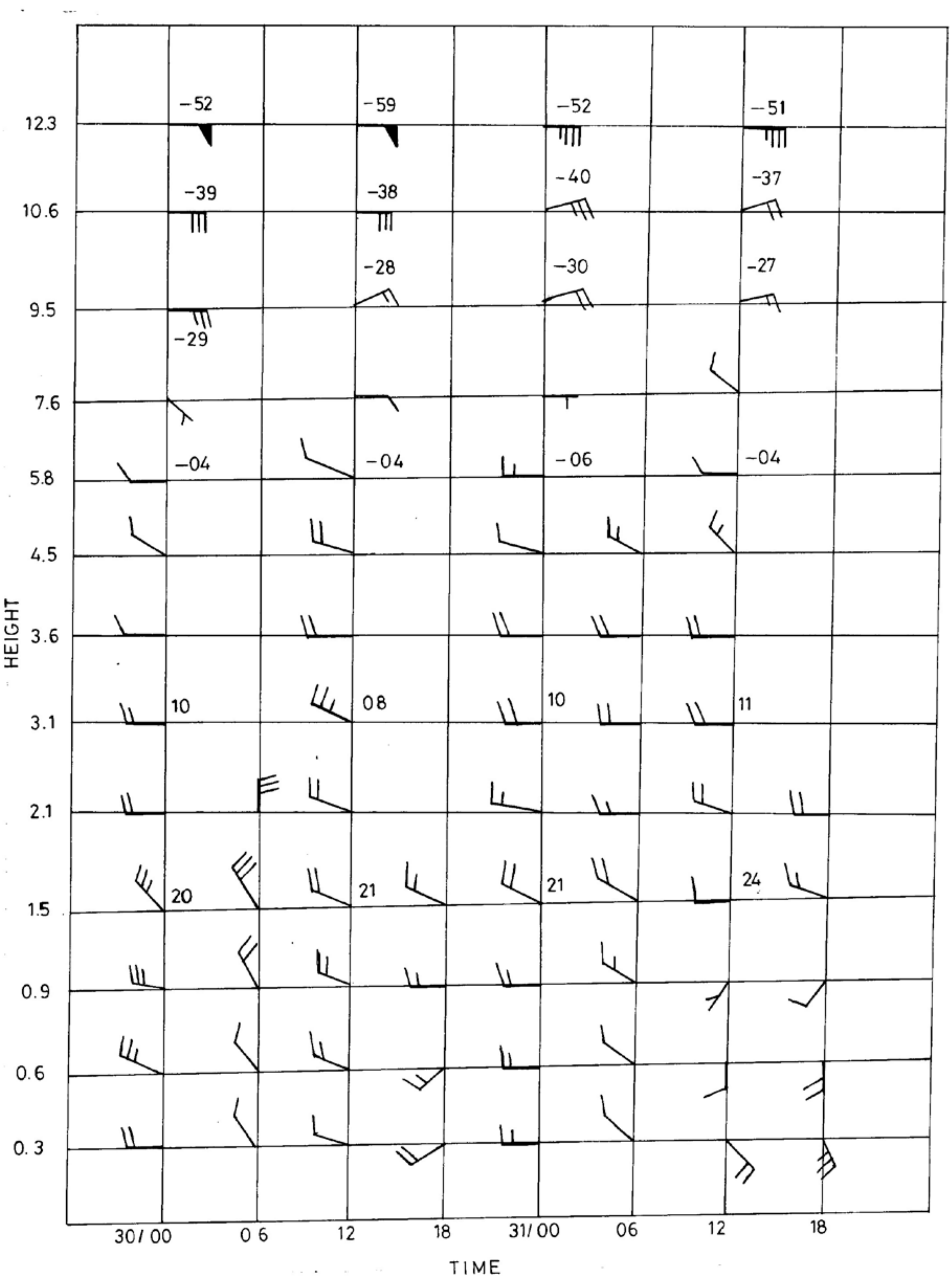


Fig. 3. Vertical time section of the winds over Chennai Airport from 0000 UTC of 30 July to 1800 UTC of 31 July 1999

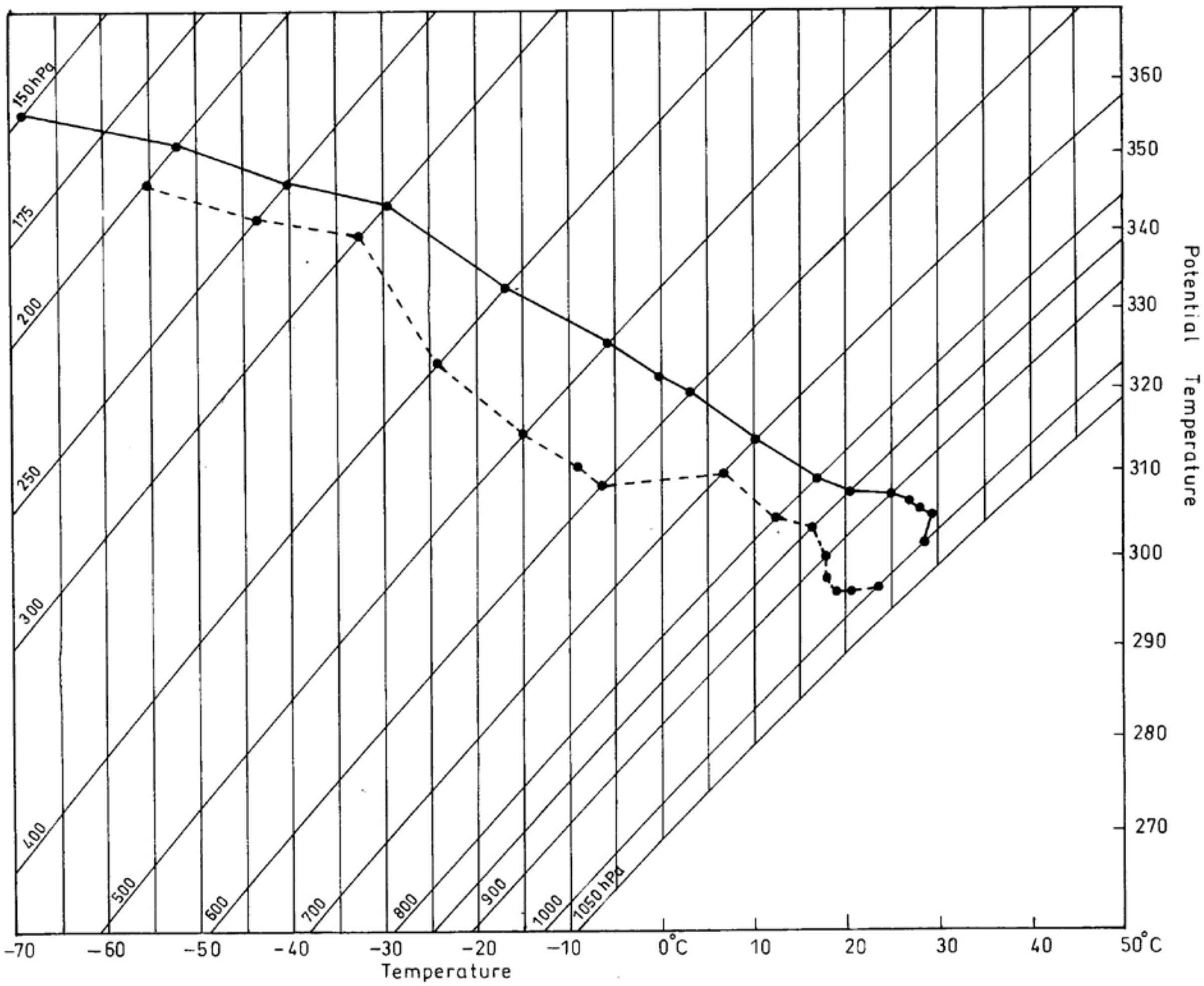


Fig. 4. T-ϕ Gram of Chennai airport at 0000 UTC on 31 July 1999

the central line of the parking Bay No 22. The photograph of the damaged aircraft can be seen in Fig. 1 (courtesy 'Hindu' daily). The aircraft suffered extensive damage to its tail portion, where a nearly two feet deep 'gash' was opened as well as to the nose wheel and to the screw jack compartment. The position of the aircraft with respect to the wind instruments is shown in the Fig. 2. At Chennai airport, Dines Pressure Tube (DPT) anemograph is located at the technical building and the sensor of Distance Wind Indicating Equipment (DIWE) is located near the runway 07, which is about 3 kilometres from DPT. The other DPT IS located at Nungambakkam (about 8 km from Chennai airport DPT). Also another DPT is located at Tambram Air force station (about 7 km from DIWE at runway 07). It is proposed to study the synoptic and the thermodynamic environment, which was favourable for the development of this damaging downburst.

2. On 31 July 1999, around 1652 IST, the wind changed from 170 degrees to 250 degrees and the speed started increasing from 06 knots and the maximum gust of 37 knots was reached at DPT located at the technical building at Chennai airport. The temperature fell by 0.6 degrees centigrade in association with the drizzle first and then a sudden fall of 5.5 degree within 6 minutes was recorded in association with a thunderstorm and rain. The centre of the meso high associated with the downburst passed the station at 1653 IST with a pressure increase of 1.4 hPa. The relative humidity increased from 57% to 85 %. The whole event was over within 10 minutes.

However the maximum gust of 52 knots was recorded at 1702 IST by the DIWE located at runway 07. There the wind had changed from 180 degree to 240 degree. The event persisted for about 12 minutes.

TABLE 1

Thermodynamic parameters/indices based on upper air data at Chennai airport on 31 July 1999

Thermodynamic parameters/indices	0000 UTC	1200 UTC
Lifted index	-5.6° C	-4.2° C
Total total index	48.9° C	48.7°C
Sweat index	134.5° C	309.5°C
George 'K' index	39	43
PBE	2587 J/K	1601 J/K
$\Delta\theta_e$	21° C	22°C
Windex	40 kts	46 kts
Gustex	32 kts	35 kts

At Tambram air force station, the maximum gust recorded was 24 knots accompanied with direction change from 120 degree to 315 degree and the duration of the wind change was about 10 minutes.

At Chennai city, wind changed from 140° to 200° had occurred on 31 July but rain occurred for five minutes duration at 1700 IST. The Pressure change of 0.3 hPa and temperature fall of 2° centigrade were recorded at the time of rain.

3. All autographic charts of Chennai airport and Chennai city as well as wind charts of DIWE at runway 07 of Chennai airport and Tambram airport are used for this study. The vertical time section of the winds over Chennai airport is plotted for the period 30 July to 1 August 1999 and is used for the analysis of the system responsible for the development of the downburst. All the surface and upper air charts of 30 July and 31 July are used to see the synoptic situation of the atmosphere over Chennai. T-ϕ grams of Chennai airport of 31 July are also utilised to see the thermodynamic status of the atmosphere over Chennai.

4.1. Fig. 3 shows the vertical time section of the winds over Chennai airport from 30 July 1999 to 1 August 1999. From the figure, it is seen that on 31 July 1999 a trough in the lower level westerlies passing over Chennai airport between 0600 and 1200 UTC, which triggered the convection and provided the necessary lifting of moisture upto the level of free convection. The trough was extending up to 2.1 km a.s.l. Also from the analysis of upper air charts it is seen that velocity convergence was also available for lifting the moisture upto the level of free convection.

4.2. Table 1 summarizes the stability parameters/ indices of the atmosphere based on the 0000 & 1200 UTC

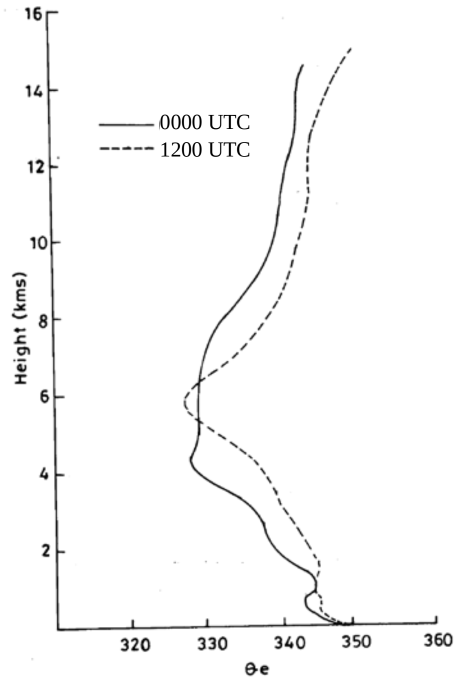


Fig. 5. θe profile on 31 July 1999

radiosonde ascents on 31 July 1999 at Chennai airport. All the stability indices *viz*. Lifted index, Total index, George 'K' index indicate the chance of formation of severe weather (Kessler 1982, WMO 1992). Severe weather threat index (SWEAT Index) which is used to predict. Thunderstorm and tornado (WMO, 1992) also indicate the formation of severe thunderstorm. Potential Buoyant Energy (PBE), which measures the updraft potential and indirectly the downdraft, is also favourable for the formation of severe downburst. Fig. 4 shows the T-ϕ gram of 0000 UTC on 31 July 1999. It is an inverted V type ascent characterizing less low level moisture / and more middle level moisture which is favourable for the formation of severe down burst provided convection occurred. The windex, which is the estimate of maximum potential wind gust in knots, adjacent to the microburst (McCann 1994) at the surface is defined as

$$WI - 5\left[H_m R_q \left(\Gamma^2 - 30 + Q_1 - 2Q_m\right)\right]^{0.5}$$

Where,

H_m = the height of the melting level in kilometers above the ground.

Rq = Q_1 / 12 but greater than 1.

Γ = lapse rate in degree Celsius per kilometre from the surface to the melting level.

Q_1 = the mixing ratio in the lowest one kilometre above the surface (g/kg).

Q_m = the mixing ratio at the melting level (g/kg).

The windex is calculated for the 0000 and 1200 UTC soundings of Chennai airport and is shown in the Table 1. This windex is designed to forecast gust speeds in wet or dry microbursts. Greets (2001) defines Gustex to estimate maximum wind gust in any kind of thunderstorm by combining downburst spreading with the vertical transfer of horizontal momentum. It is defined as,

$$\mathrm{Gu} = \alpha\,\mathrm{WI} + 0.5\,\mathrm{U}_{500}$$

where α is a constant, 0 <α< 1. WI is the Windex in knots. U_{500} magnitude of the 500 hPa wind Vector (knots). Taking α as 0.6 (as in Greets, 2001), Gustex is calculated for morning and evening radiosonde ascent of Chennai airport and is given in Table 1. Here Gustex underestimate the actual wind gust. Fig. 5 shows the profile, which is the difference between maximum and minimum in excess of 20, is favourable for the formation of severe microburst (Atkins and Wakimoto 1991). Hence all thermo dynamical parameters/indices predicts strong downburst.

4.3. The equivalent potential temperature is used as a tracer to determine the source region of downburst under adiabatic process (Desai and Mull 1938). The downdraft originated near 770 hPa and evaporational cooling occurred throughout the sub cloud layers and accelerated the descending air along the moist adiabatic path. The precipitation driven downdraft at the surface is estimated as per the equation given below :

$$\mathrm{d}W / \mathrm{d}t - \mathrm{g}\Delta T / T \qquad (1)$$

Where W is the vertical velocity, t is time, g is acceleration due to gravity, T is the average temperature, ΔT is the virtual temperature difference between environmental and the parcel temperature (Kessler 1982). The down draft at the surface estimated to be as 22.3 mps (45 knots) as calculated using equation (1).

5. The direction of the maximum wind gust recorded by the 4 different locations are from 200 to 315 and as such does not indicate the wind gust is associated with the microburst. The strong gusts, which damaged the aircraft, seem to be the part of the gust front associated with the strong downburst. Also the turbulence associated with the wind shift at the leading edge of the gust front could have aggravated the damages as have occurred in the present case.

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