551.515.4

THUNDER SQUALL OVER CHENNAI – A CASE STUDY

1. A squall is a strong wind that rises suddenly, generally lasts for some minutes and dies comparatively suddenly. WMO definition of squall is 'A sudden increase of wind speed by at least 8 m/s (16 knots) (28 kmph), speed rising to 11 m/s (22 knots) (40 kmph) or more lasting for at least one minute'. A two-minute squall of wind speed 99 kmph causing widespread damages in and around Nungambakkam area of Chennai city occurred on 2nd May 2005 at 0028 hrs IST. As per newspaper reports (The Hindu dated 3rd May 2005) it uprooted over 150 trees, twisted or brought down several advertisement hoardings and every other rusty or unstable structure. Damages were reported in most parts of the city, particularly close to the shoreline. Ten cars were damaged at Sangam cinema hall at Kilpak when a giant hoarding crashed on the automobiles parked there. A giant tree crashed on the compound wall of Presidency School at Egmore. Television cables were cut in several parts of the city. A cable TV dish antenna at Pudupet area of Chennai was ripped out of its stand and thrown several feet away.

Statistical studies of squall occurrences in cities like, Madras (Ramakrishnan and Ganapathiraman, 1953), Nagpur (Sharma 1966), Mumbai (Dekate and Bajaj, 1966), Ahmedabad (Saxena and Natarajan, 1966) etc. have been done in the past. Ramakrishnan and Ganapathiraman (ibid. 1953) have done statistical study on the occurrence of squalls at Chennai for the period from 1938 to 1950. They have utilized the records of Dines-Pressure Tube anemometer at Chennai-Nungambakkam and Chennai-Harbor. As per their studies, the number of squall days per year is 25. They occur during May to November only. Soundararajan and Raghavan (1962) have done a case study of a squall that has occurred at Madras (presently known as Chennai) Airport on 17 August 1961 with the data from the then newly installed storm detection radar. Basu and Mondal (2002) have analysed the forecasting aspect of thunder squall over Calcutta (Presently known as Kolkata) and its parameterization. Recent studies Suresh and Bhatnagar, 2004 & Suresh, 2005 show the usefulness of Doppler Weather Radar products in the study of meso-scale phenomena like squall.

In the present study the analysis of the severe squall that passed over Chennai (Nungambakkam) on the early morning hours of 2nd May 2005 causing extensive damage is reported. All the surface meteorological instruments have recorded sudden changes, which are of special kind. Also movement of the thunderstorm cell associated with the squall could be noticed well from the pictures of the Doppler Weather Radar, Chennai.

2. The autographic charts of temperature, pressure, relative humidity and rainfall and dines pressure tube record of wind speed and wind direction of Chennai on 2nd May 2005 were considered for the present study [Figs. 1(a-f)]. The Doppler weather radar pictures from CDR, Chennai during same period were also used for the present study.

3.1. *Synoptic situation on the day of the squall* - On 1st May 2005 morning at 0300 UTC a trough on sea level chart from Vidharbha to extreme south peninsula across Telengana and Rayalaseema was observed. Associated upper air cyclonic circulation extending up to 1.5 km above sea level was also seen [charts not shown]. On the 1200 UTC charts of the same day, the same trough on sea level chart [Fig. 2(a)] was running from Vidharbha to extreme south peninsula across Telengana and Rayalaseema with the associated upper air cyclonic circulation extending up to 0.9 kms above sea level [Figs. 2(b-d)]. The confluence between the moist air from the Bay of Bengal driven by the anticyclone and the warm dry air over land along the northern part of Tamilnadu coast resulted in release of convective instability through development of thunderstorm cells. This background setting of synoptic condition for the development of thunderstorm cells was seen to persist up to 1800 UTC of the same day [Figs. 2(e-g)].

The thermodynamic stability of the atmosphere represented by various indices such as Showalter's Stability Index (SHI), Galway's Lifted Index (GLI), George's K Index (GKI), Total-Total Index (TTI), Convective Available Potential Energy (CAPE), Precipitable water content, Severe Weather Threat (SWEAT) Index, Bulk Richardson Number calculated on the basis of RS-RW observation of Chennai (Meenambakkam) for 1st May 2005 (0000 & 1200 UTC) are given in Table 1. These indices generally indicate that the atmosphere was unstable and had favourable conditions for development of thunderstorm cells.

The variations of meteorological elements during the period of squall on 2 May 2005 as noticed from the autographic charts are discussed below.

3.2. *Relative humidity dip* - This is an interesting phenomenon seen in the present case of squall. Byers and Braham (1949) analysed the variation of relative humidity during occurrence of thunderstorm events and defined 'Relative Humidity Dip' as drop in relative humidity by about 8% or more during passage of a thunder squall followed by a return to the previous value within ten

TABLE 1

Table showing different stability indices calculated from the RS-RW data of Chennai (Meenambakkam) for 1st and 2nd May 2005 (Source: http://weather.uwyo.edu/upperair)

S. No.	Description of the index	01 May 2005 (0000 UTC)	01 May 2005 (1200 UTC)	02 May 2005 (0000 UTC)	02 May 2005 (1200 UTC)
1	Bulk Richardson Number	826.03	0.68	159.36	311.09
2	Showalter Index	-8.19	6.53	3.46	-2.10
3	George's K Index	44.10	9.10	27.30	36.80
4	Galway's Lifted Index	-9.50	0.85	-7.71	-10.06
5	Total Total Index	54.10	37.00	41.60	47.90
6	CAPE	5703.7 J/kg	0.0 J/kg	3951.23 J/kg	5679.65 J/kg
7	CAPE using virtual temperature	6045.09 J/kg	16.38 J/kg	4285.17 J/kg	6117.26 J/kg
8	Precipitable water content (PWC)	73.23 mm	21.07 mm	54.69 mm	53.86 mm
9	SWEAT index	401.41	92.20	154.99	211.99

TABLE 2

Changes observed at the time of passage of the squall on 02 May 2005 as observed from the autographic charts (all time in hours IST)

Time	Rainfall (mm)	Time	Temperature (°C)	Time	Pressure (hPa)	Time	Relative humidity
Up to 0000	Nil	2350	31.3	0000	1007.0	2350	79%
0000 to 0015	10	0000	28.0	0015	1009.4	0000	68%
0015 to 0030	22	0015	24.0	0030	1007.0	0010	65%
		0030	22.8	0045	1007.0	0015	89%
		0100	23.0	0100	1006.9		

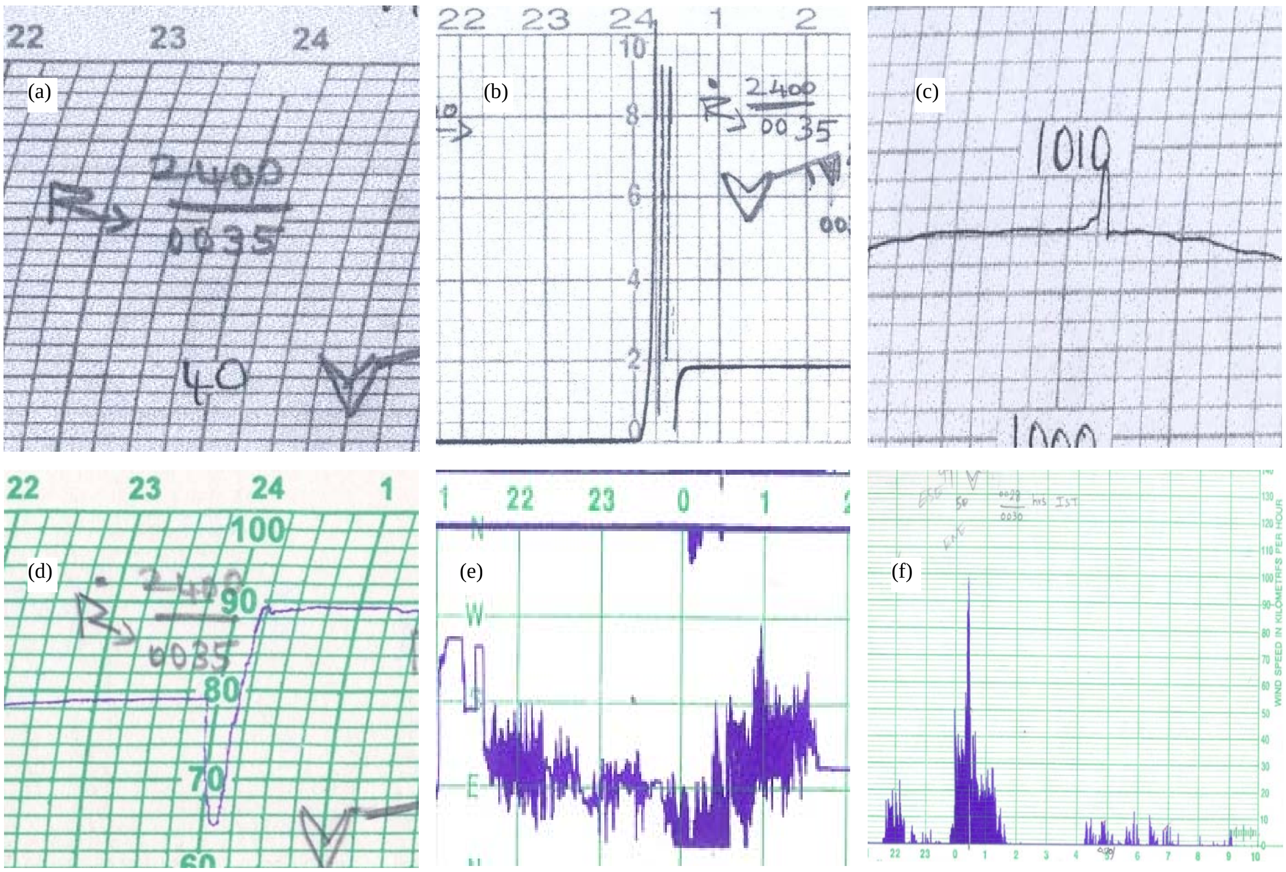
TABLE 3

Minimum temperatures recorded at Chennai. Note the sudden change in minimum temperature due to squall on 02 May 2005. However the squall on 3rd did not have any effect in minimum temperature

Date	Minimum temperature in °C		Remarks
	Nungambakkam	Meenambakkam	
30 Apr 2005	29	29	
01 May 2005	26	27	
02 May 2005	22	23	Squall at 0028 hr (IST)
03 May 2005	27	27	Squall at 1615 hr (IST)
04 May 2005	26	24	

minutes. In the present case just before the occurrence of squall at 0028 hrs (IST), the rain commenced at 0000 hrs (IST). At that time the relative humidity was 82%. Though the rain continued, the relative humidity suddenly fell to 65% and within five minutes it has risen to 81%. A very sharp dip has been recorded in the hygrograph of the day [Fig. 1(d)] (Table 2).

3.3. *Pressure jump* - When a thunderstorm cell accompanied by a squall passes over a station the pressure



Figs. 1(a-f). Portion of Autographic charts of Chennai (Nungambakkam) of 1/2 May 2005 showing features of the squall that passed over the station at 0028 hours IST on 2nd May 2005. (a) Thermograph of 1/2 May 2005 showing a sudden drop of temperature 9 degrees C, (b) Hyetograph showing the intense, sharp shower between 0000-0030 hours, (c) Pressure Dip: the sharp rise and fall of pressure during the passage of squall, (d) Relative Humidity Dip: The sudden fall and sharp rise of humidity. The RH fell in spite of rainfall at that time, (e) Wind direction at the time of squall and (f) Squall at 0028 hrs (IST) : Wind speed rising to 99 kmph

values traced by the station barograph may show (Asnani, 2005)

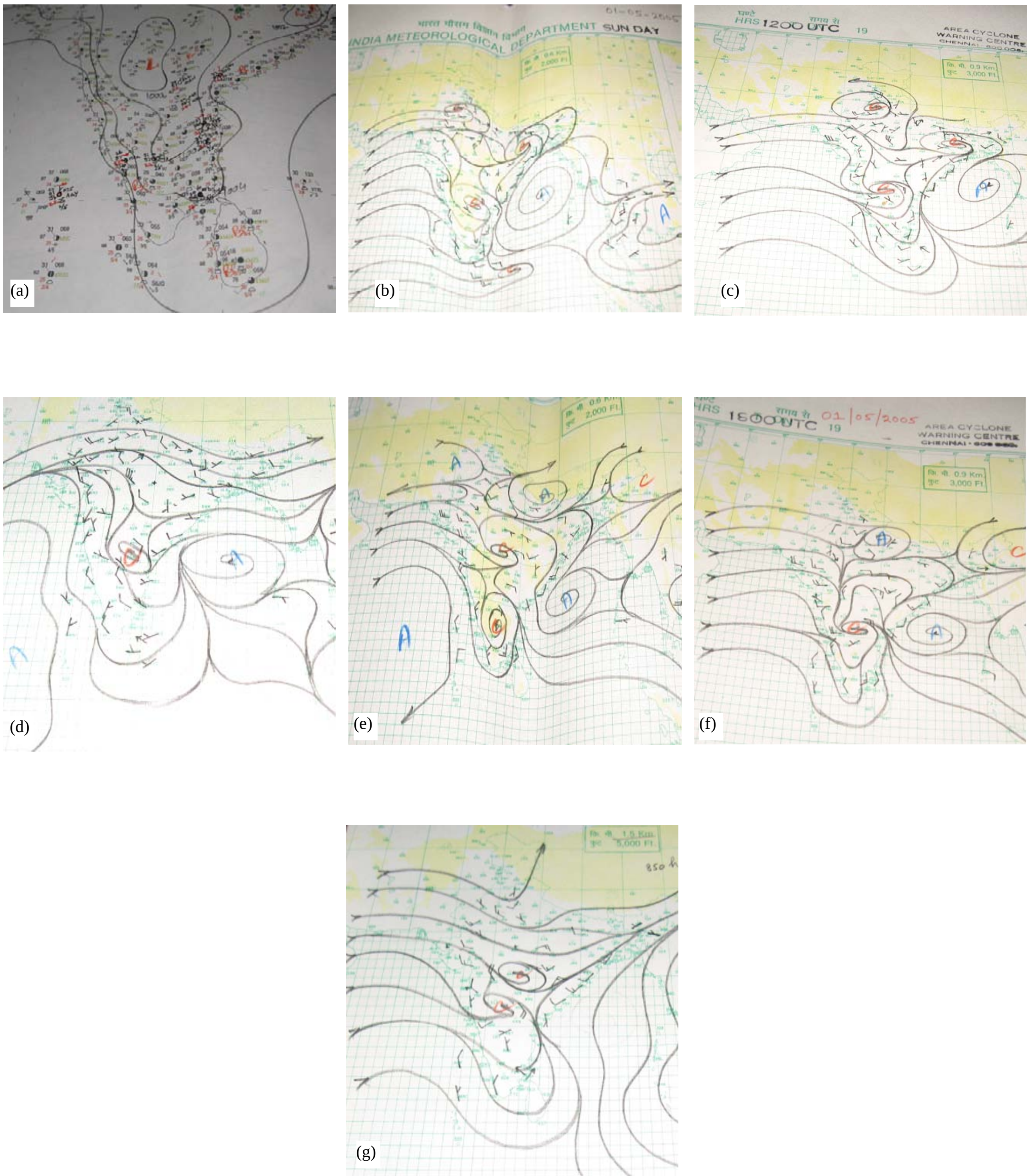
(*i*) a cup type pressure curve

(*ii*) a 'dip' – *i.e*., first by a fall of pressure and then by a rise of pressure

(*iii*) a pressure jump line curve

The large quantity of cold air released by a thunderstorm cell provides an 'extensive dome of cold air' which creates a ridge of high pressure. This contributes to the sudden rise of surface pressure. In the present case thunder with rain commenced at 0000 hrs (IST) of 2nd and continued up to 0035 hrs. The squall occurred at 0028 hrs (IST). Pressure started rising gradually at first from 0005 hrs and then at 0015 hrs abruptly rose to 1010 hPa (from 1007.0 hPa) and then fell back to 1007.0 hPa within five minutes [Fig. 1(c)].

3.4. *Temperature and rainfall* - The thermograph record shows that the temperature started falling from 2350 hrs (IST) of 1st May 2005 before the commencement of rains. When the wind speed increased from calm situation to a mean wind speed of 25 kmph temperature fell from 31.7° C to 22.7° C (a fall of nine deg C) and then started rising gradually [Fig. 1(a)]. The sharp fall in temperature is quiet significant, which can be seen from Table 3 wherein the minimum temperatures recorded from 30th April to 4th May 2005 is shown. A squall has been recorded on 3rd May at 1615 hrs (IST) also, but the temperature fall is not as significant as in the present case.



Figs. 2(a-g). Analysed charts showing the synoptic conditions at 1200 UTC of 1st May 2005 in (a-d) and 1800 UTC of 1st May 2005 in (e-f). (a) 01 May 2005/1200 UTC surface chart showing the trough across CAP and NTN, (b) 01 May 2005/1200 UTC Upper Air chart 0.6 kms level showing CYCIR over south peninsula, (c) 01 May 2005/1200 UTC Upper Air chart 0.9 kms level showing CYCIR over south peninsula, (d) 01 May 2005/1200 UTC Upper Air chart 1.5 kms level showing CYCIR over south peninsula, (e) 01 May 2005/1800 UTC Upper Air chart 0.6 kms level showing CYCIR over south peninsula, (f) 01 May 2005/1800 UTC Upper Air chart 0.9 kms level showing CYCIR over south peninsula and (g) 01 May 2005/1800 UTC Upper Air chart 1.5 kms level showing CYCIR over south peninsula

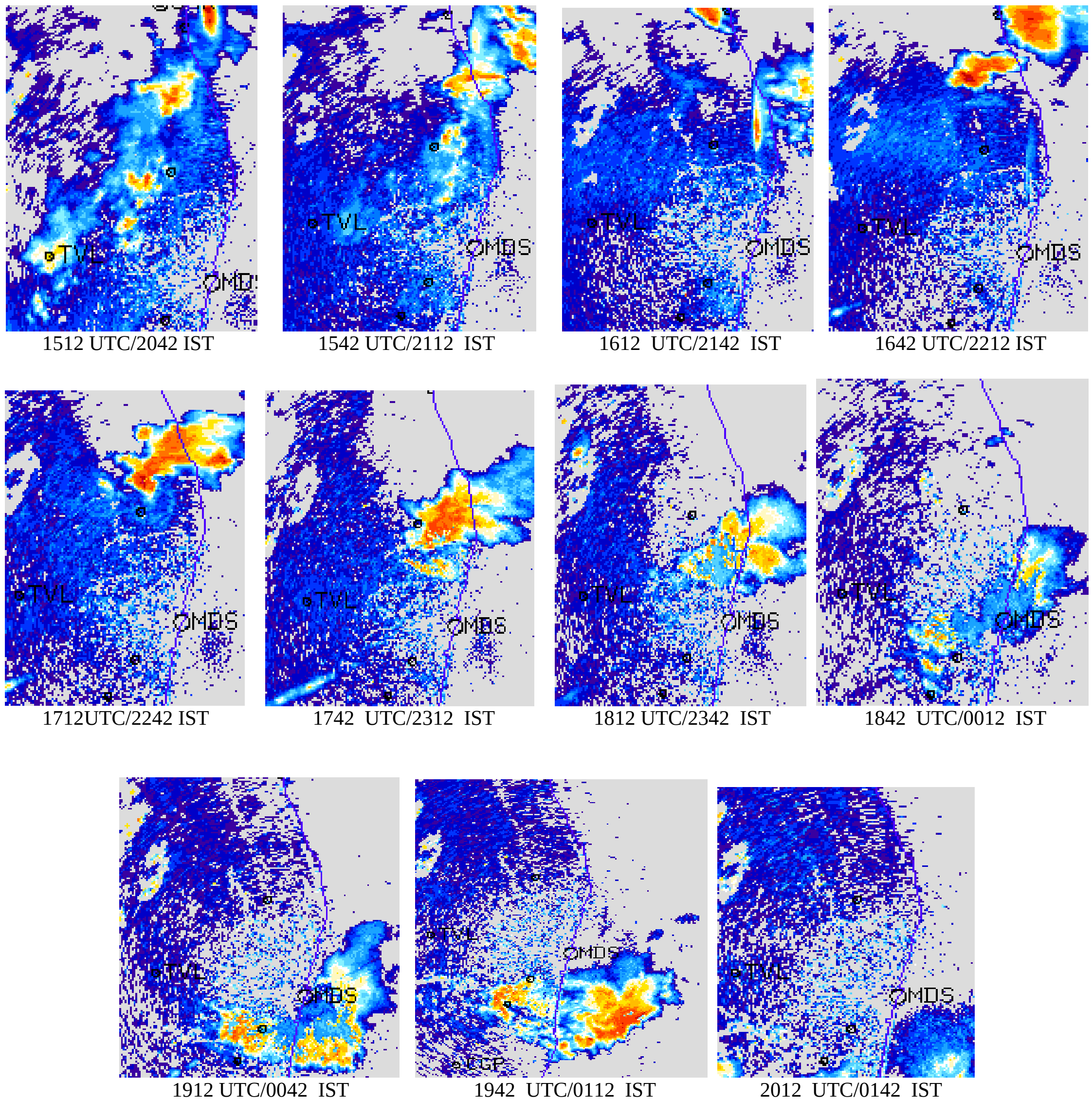


Fig. 3. DWR pictures PPI (Z) from 1512 UTC to 2012 UTC showing the approach of the thunderstorm cells from north of Chennai

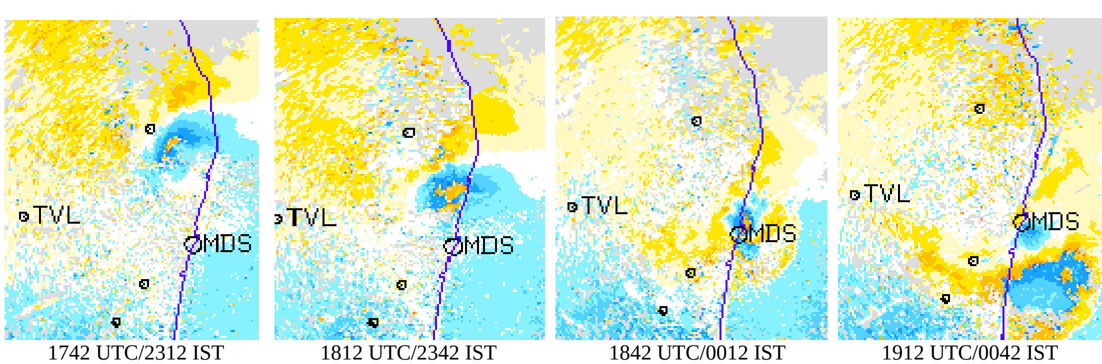
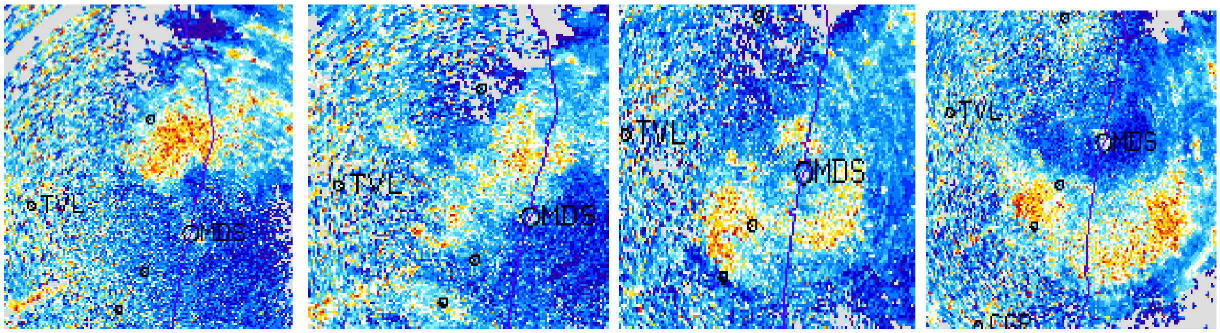
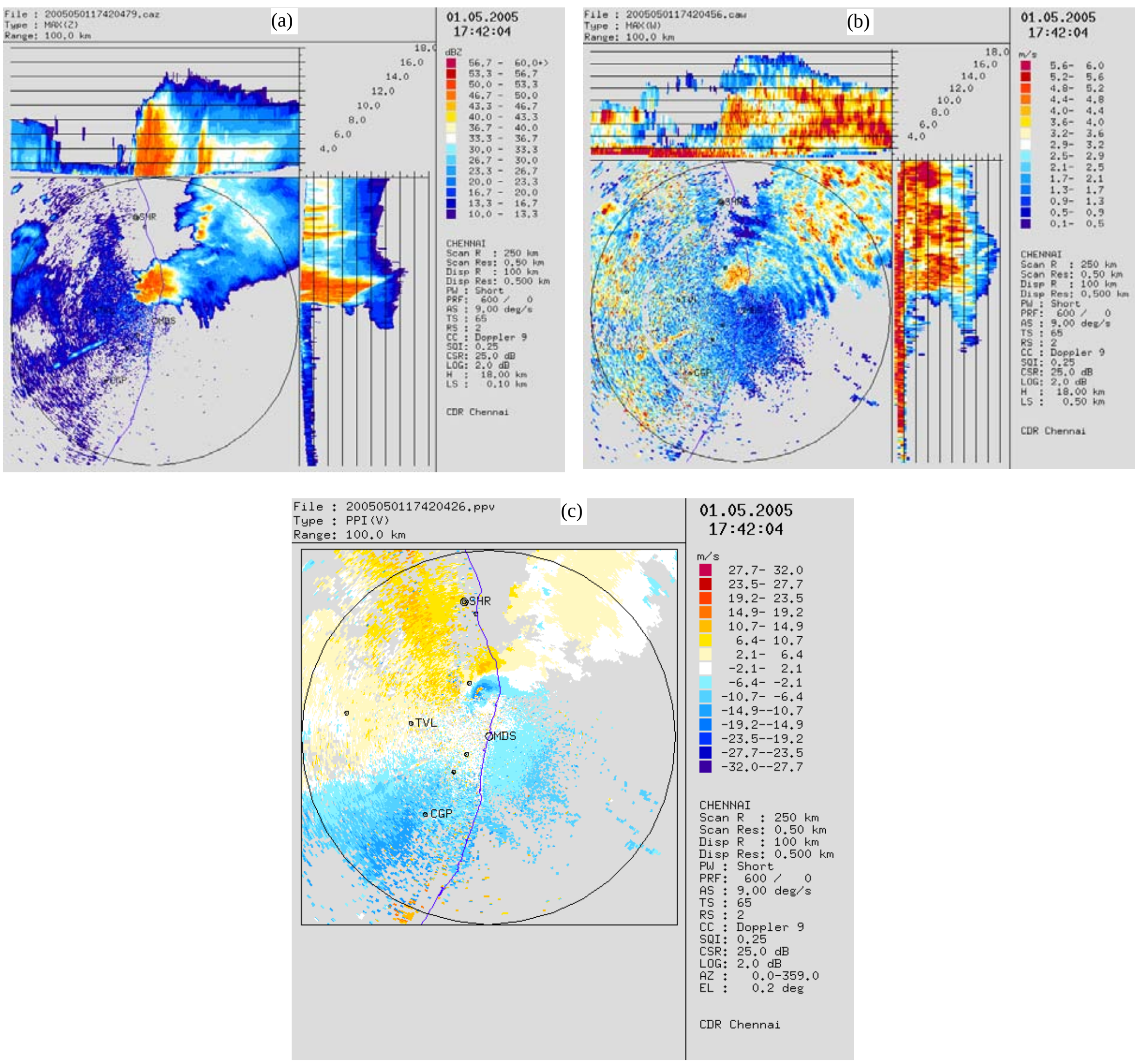


Fig. 4. DWR PPI (V) pictures showing the characteristics of the thunderstorm cell which is very prominent in the first two pictures



1742 UTC/2312 IST 1812 UTC/2342 IST 1842 UTC/0012 IST 1912 UTC/0042 IST

Fig. 5. DWR pictures MAX (W) from 1712 UTC of 1st May 2005 showing strong turbulence (values more than 4.0 m/s)



Figs. 6(a-c). The above three pictures are showing the characteristics of the thunderstorm cell at 1742 UTC of 1st May, 2005 (a) DWR MAX (Z) picture with reflectivity more than 53 dBz, (b) DWR MAX (W) showing the spectral width values more than 5.3 m/s and (c) DWR PPI (V) showing the wind speed equal to more that 54 kmph

The self-recording rain gauge has recorded rain from 0000 hrs to 0035 hrs (IST) of 2nd May. An amount of 31.8 mm rainfall has been recorded in 35 minutes, which is at a very heavy rate of approximately 6 cm/hour [Fig. 1(b)].

3.5. *Wind speed and direction* - Practically 'CALM' winds were there from 2240 hrs (IST) and winds from northeasterly direction started strengthening from 2345 hrs (IST). The squall with maximum gust of 99 kmph was observed for two minutes from 0028 to 0030 hrs (IST). The direction of the wind changed from northeast to southeast direction after the passage of the thunderstorm cell. [Figs. 1(e&f)].

3.6. *Other weather elements* - Lightening was observed by Numgambakkam observatory from 2000 hrs (IST) and rain with thunder commenced at 2400 hrs (IST). While rain stopped at 0030 hrs (IST), thunder continued till 0400 hrs (IST) of 2nd May and lightening was observed up to sunrise [0600 hrs (IST)].

4. *Movement of the thunderstorm cells from Doppler Weather Radar data* - A line of thunderstorm cells accompanied with the squall was also tracked by the Doppler Weather Radar (DWR). A cluster of echoes with reflectivity more than 50 dBz was first observed at 1512 UTC [2042 hrs (IST) of 1st May 2005] about 100 kms north of Chennai near Sriharikota. The cells moved in a near southerly direction, crossed Sriharikota and split into two groups by 1642 UTC. One patch continued to move in a southerly direction while the other patch moved into the sea area and gradually weakened. At 1742 UTC the cell was noticed at 30 kms north-northwestwards of the DWR with intensity about 50 dBZ. It slightly weakened from 1812 UTC onwards but improved its strength at the time of passing over Nungambakkam observatory (Fig. 3).

In the PPI (Velocity) pictures (Fig. 4), velocity values associated with the thunderstorm cells were of the order of 20 mps (72 kmph). The spectral width associated with the thunderstorm cells was more than 4.0 m/s (Fig. 5) indicating the presence of strong turbulence associated with the squall (Suresh, 2006). The MAX (Z), PPI (V) and MAX (W) [Figs. 6(a-c)] pictures depicts the feature of meso scale circulation in the thunderstorm field.

5. To the best knowledge of the authors this is first squall to pass exactly over the station for which both Doppler weather data and surface autographic instruments data is available. Analysis of the data of this squall that occurred over Chennai using autographic charts and Doppler products highlight the need of integration of all inputs such as synoptic charts and DWR products in the understanding of such meso-scale phenomena.

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K. V. BALASUBRAMANIAN
S. BALACHANDRAN

Regional Meteorological Center, *Chennai*, *India*
(*Received 22 May 2008*, *Modified 17 July 2008*)
e mail : kvbmanian@yahoo.com