J. Ind. Geophys. Union (April 2016)
v.20, no.2, pp: 277-282

RESEARCH NOTE

Observational aspects of life cycle of a distinct squall line over Assam valley

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ABSTRACT
A squall line of about 180 km in length was observed on 24th April, 2007 over Assam valley with widespread heavy spells of rainfall and wind speed reaching 70 kmph. An attempt is made to analyze life cycle of squall line including genesis, growth and decay explained by synoptic and meso-scale features. The synoptic features like development of low pressure area with embedded cyclonic circulation at lower levels over Assam, adjoining Bangladesh, Gangetic West Bengal and north –south trough across Assam to northwest Bay of Bengal in mid-tropospheric level in the morning hours were found responsible for it. The thermodynamic parameters like LCL, CCL, and LFC were found as precursor for predicting the severe thunderstorm event well in advance on the contrary Showalter index, Total-Total index, SWEAT index, CAPE and CINE were not found use full as the precursor for occurrence of this particular squall line.

Key words: Assam valley, Thunderstorm, Squall line, Life cycle, IPWV, Radar, Synoptic .

PRESENT STUDY:

A detailed exposition of the topic is presented below to bring in to light importance of the study.

1. Squall: A Squall is defined in meteorological terms as sudden increase of wind speed by at least 3 stages on the Beaufort scale and the speed rising to force 6 (~39 km/hr) or more and lasting for at least one minute. Hamilton and Archbold (1945) first deduced that squall line is an organized structure of thunderstorms consisting of multi cell clusters from hundred to several hundred kilometers along its major axis. They also noted that the downdraft region is located under a precipitating trailing anvil clouds. India, lying in tropical region, is highly prone to convective activities, particularly during pre-monsoon (March –May) resulting in severe thunderstorms with high winds, squalls, heavy rain and occasionally hail storms causing damages to human life, property and standing crops. Many authors had studied the climatology, thermodynamics and synoptic aspects of thunderstorms and structure of squall lines in India. In the past a notable study at Calcutta was carried out by Cornford and Spavins (1973) using airborne radar, cameras and horizon gyroscopes besides the ground based radar of the meteorological department and established that pre-monsoon thunderstorms in northeast India extend up to 20 Km altitude or more and grow at a rate of 6 m/s. Bhattacharya and Barma (1981) studied pre-monsoon squalls from 1975 -79 over Dumdum with reference to radar echoes. Gambheer and Bhat (2000) have studied the life cycle characteristics and diurnal variation of 31 mesoscale convection systems (MCS)s over the Indian region and showed that in India the maximum number of MCSs had occurred over the northeast. Tyagi (2000) suggested forming mesoscale network of various observation methods to have reliable weather prediction of events like thunderstorm and squalls for Indian region. Choudhury and Chattopadhyay (2001) showed that convective inhibition energy (CINE) was relevant parameter for forecasting pre monsoon thunderstorms over Gangetic West Bengal. Basu and Mondal (2002) showed that occurrences of multiple squalls over Calcutta may be due to passage of jet streams at lower levels over Calcutta. Kumar and Mohapatra (2006) reported that on an average 5 squalls occur during pre-monsoon (March –May) mostly from northwesterly direction. Tyagi (2007) reported highest annual frequency of thunderstorms as 100-120 days over Assam and Sub Himalayan West Bengal and 80-100 days in Gangetic west Bengal and Bagladesh. Das et al. (2010) concluded that the most favourable time of occurrence of squall is during evening to early morning. The significant synoptic situations are sea level trough from east Uttar Pradesh/Bihar to north-east India and low level cyclonic circultion over Bihar and neighbourhood. Das et al. (2010) in an observational study of severe thunderstorm at Guwahati airport found the presence of a north-south trough at low levels running from Sub-Himalayan West Bengal to Orissa favorable for thunderstorm. Charan singh et al. (2011) reported that frequency and time of occurrence of thunderstorm, hail and squall shows large spatial variations. Pradhan et al. (2012) suggested nowcasting technique and evaluation of convective indices for thunderstorm prediction in Gangetic West Bengal (India) using Doppler Weather Radar and upper air data for 34 events of thunderstorm and proposed threshold values of CAPE and CINE for thunderstorm. Charan singh et al. (2014) in a study of thunderstorm accompanied with squalls over Agartala deduced that wind maxima at 150 hpa and trough in mid-tropospherical level, westerly's play an important role in development of thunderstorm activities over northeast region. Out of 13 indices 8 were found favorable for entire sounding.

2. Squall Line: A 'Squall Line' of about 180 km was detected at 10:37:31 hrs UTC on 24^{th} April 2007 by C-band radar at Guwahati Airport. Observations from X- band storm detection radar at Guwahati Airport were used to analyze of squall line. The study is extended by analyzing the synoptic observations, autographic charts of rainfall, isohyetal analysis of rainfall and sounding data.

3. Life Cycle: Life cycle of squall line is documented in four stages viz., formation, advance, mature and decaying stage with the help of radar imageries scanned from 10:37:31 of UTC till 12:49:23 hrs UTC and other observations.

i) Initial stage of 'Squall Line'

Choudhury et al. (1976) described that the convective cells, which organize themselves into broken or solid lines, are initially observed as scattered or isolated oval shaped amorphous echoes. Figure 1 depicts similar echoes in the initial stage of formation of this phenomenon at 10:37:31 hrs UTC. Radar reflectivity shows the values around 10 dbz and hence the presence of weak cells. These weak cells formed 120 to 160 km away from Guwahati Airport towards west-northwest (between 270° and 300°) direction.

ii) Advance stage of 'Squall Line'

The advance stage at 11:42:13hrs UTC Figure 2 merging of cells and development of well organized convective clusters in the form of a squall line about 160 km long in north–south direction. It moved eastwards an average speed about 30 knots. The advance stage can be visualized by high reflectivity values of 45 to 50 dbz over a small region towards southwest (240°) about 100 km from Guwahati Airport near Tura, Meghalaya. Another small portion inside the cells with reflectivity of around 40 dbz was noticed towards west northwest (300°) at a distance of about 60 km.

iii) Mature Stage of 'Squall Line'

Figure 3 depicts the mature stage with the squall line extending upto 180 km in north–south direction at 12:12:27 hrs UTC about 20 km west of Guwahati Airport. Apart from formation of cloud clusters in a straight line, further intensification of convective clusters was noticed with maximum reflectivity of 55 dbz. Figure 4 shows (12:20:34 hrs UTC) vertical extent of CB clouds up to 12 km. Figure 6 scanned at 12:31:15 hrs UTC shows the persistence and eastward movement of squall line with a speed of 30 knots. The region covered by higher reflectivity reduced and was limited to the 20 km circle of radar centre. It means during the passage of squall line, the portion of land under its influence must have experienced high wind speed, due to downdraft and heavy rainfall (though no report is available) leading to weakening of the intense convective cells.

iv) Decaying Stage of 'Squall Line'

Figure 8 scanned at 12:49:23 hrs UTC further showed decaying stage of 'Squall Line' as the broken structure of organized cloud clusters in two parts viz., one extending up to 100 km from southeast to northeast of Guwahati and another over Tripura. The reflectivity values ranged from 10 dbz to 20 dbz indicating presence of weak precipitation cells.

4. Synoptic features

A trough of low-pressure was observed from West Bihar to coastal Gangetic West Bengal (GWB) at 0000 hrs UTC of 24^{th}. With advance of the day, southeastern end of the trough further extended eastwards to east Bangladesh at 0600 hrs UTC. An embedded feeble low-pressure area formed over central parts of West Bengal and adjoining Jharkhand at 0900 hrs UTC due to increase in afternoon insolation as observed by rise in maximum temperature up to 43°C over the region. The associated upper air embedded cyclonic circulation extended up to 1.5 km at 1200 UTC. Another cyclonic circulation which lay over northeast Assam and neighborhood extending up to 0.9 km. An upper air trough between 2.1 to 7.6 km extended from southeast Tibet to northwest Bay of Bengal across Arunachal Pradesh, Assam, Meghalaya and Bangladesh tilting westward with height at 0000 hrs UTC. Chakrabarti et al. (2008) and Das et al. (2010) have also described mostly similar type of synoptic condition favorable for severe thunderstorm event over Northeast India.

5. Thermo dynamical factors

Table.1 shows various thermodynamic indices values over Guwahati on 24^{th} April 2007. CAPE (convective available potential energy) the indicator of instability was 1020 J/Kg over Guwahati with weak CINE at 1200 hrs UTC. However CAPE values observation before 1200UTC of 24^{th} April were low. Hence CAPE and CINE had not been seen favorable for (Tyagi et al. 2011 and Foroozan Arkian and Karimkhani, 2014) occurrence of thunder squall. Chakrabarti et al. (2008) also described occurrence of severe thunderstorm events over Assam and adjoining states in very low CAPE. The values of stability indices viz., SI, LI, TTI and SWEAT index became favourable only at 1200 hrs UTC. However CCL, LCL and LFC over Guwahati were lowest at 0600 hrs UTC and were favorable conditions for the occurrence of severe thunderstorm. Hence these parameters may be considered as precursor

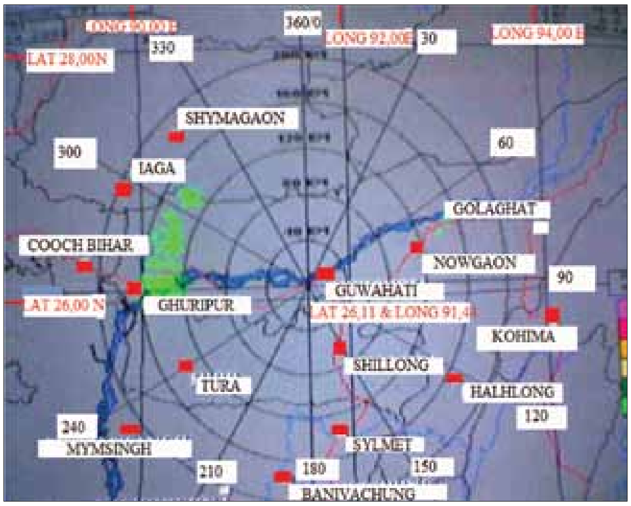

Figure 1. Initial Stage
Time 10:37:31 hrs UTC

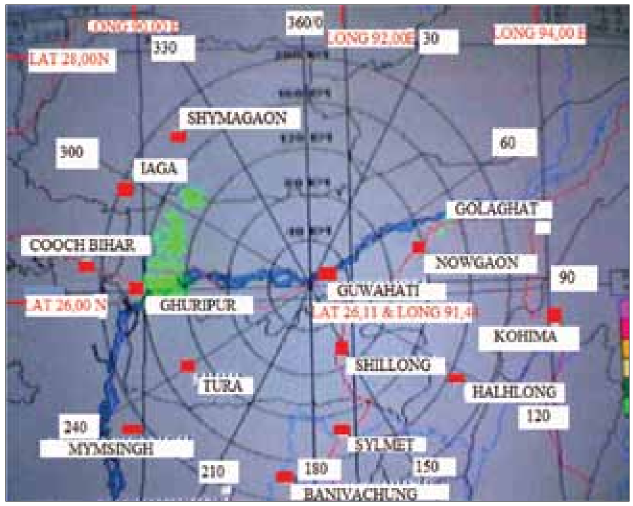

Figure 2. Advance Stage
Time 11:42:13 hrs UTC

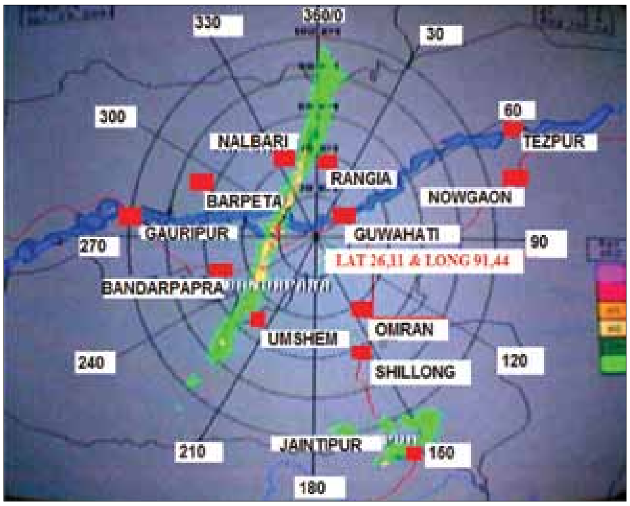

Figure 3. Matured stage
Time 12:12:27 hrs UTC

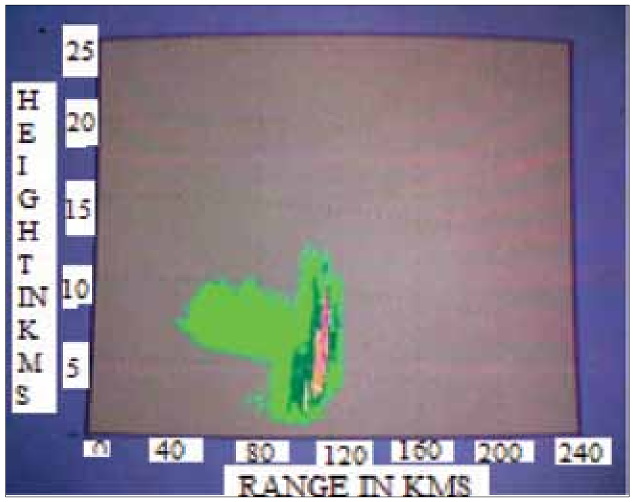

Figure 4. Vertical extent of Cb Clouds
Time 12:20:34 hrs UTC

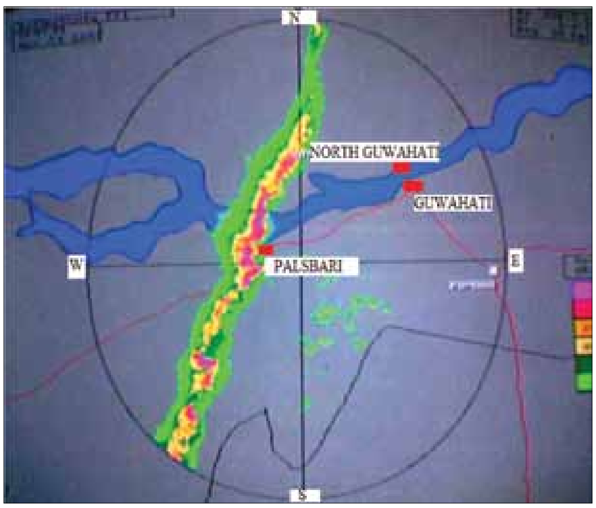

Figure 5. Matured stage
Time 12:31:15 hrs UTC

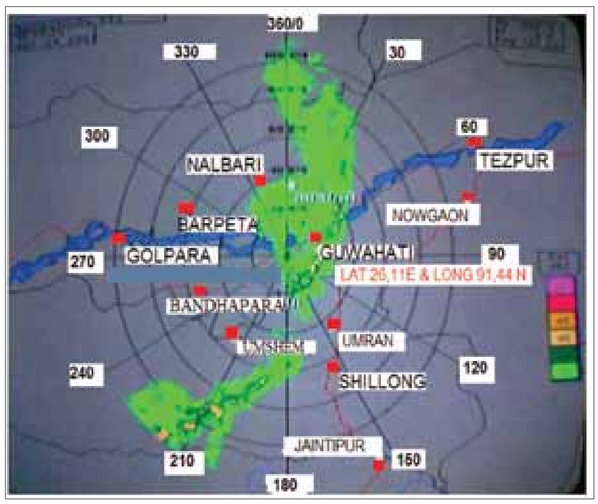

Figure 6. Decaying stage
Time 12:49:23 hrs UTC

Table 1. Values of different thermodynamic parameters stability indices over Guwahati and Agartala at different time of observations of 24th April, 2007.

Parameters/Index	Values over Guwahati at different time hrs UTC			
	00	06	12	18
LCL(hPa)	998	942	942	973
CCL(hPa)	997	891	904	978
LFC(hPa)	997	635	817	973
CAPE(J/Kg)	428	138	1020	402
CINE	0	-180	-28	-80
Showalter Index	3.1	5.4	-3.8	-1.0
SWEAT	225.8	150.8	442.4	194.2
Total Total Index	41.4	38.0	52.1	49.0
Lifted Index	-1.3	-0.5	-5.7	-3.1

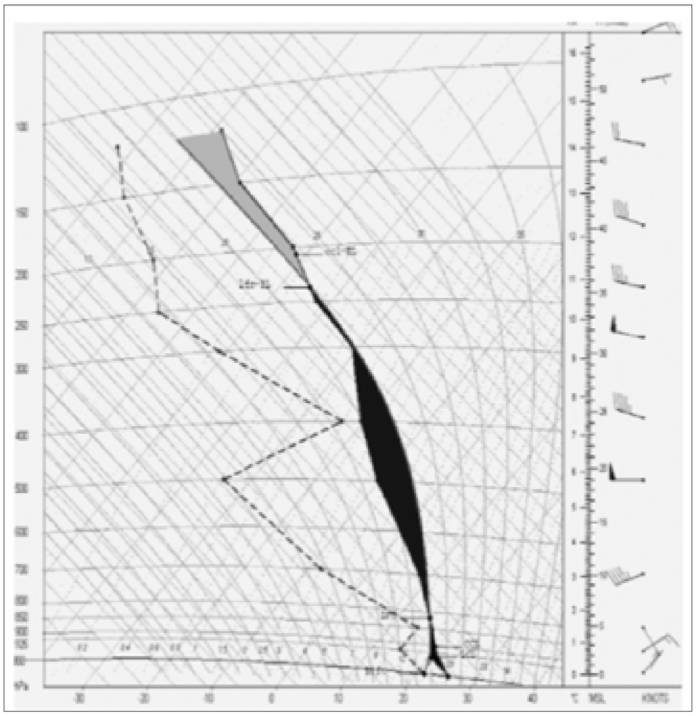

Figure 7. T-ϕ gram of Guwahati at 12:00 hrs UTC

of severe thunderstorm about 6 hours in advance. The T-ϕ gram of Guwahati for 1200 hrs UTC of 24th April Figure 6 shows a relatively dry layer above 850hPa over the warm moist lower tropospheric levels near the surface and a moist layer at mid-tropospheric levels over ran the dry layers. Veering of winds with height upto 700hPa level and considerably high wind shear about 30 knots were observed between surface and mid-tropospheric level (500 hPa). Also the winds at mid/upper tropospheric levels were westerly 40 -50 knots which was mainly relatively colder continental air. So cold air advection prevailed at middle and higher levels. It contributed to the increase in evaporation process by the presence of liquid moisture condensed from vertical motions and resulted further cooling. Continuation of this process may be a cause of formation of a group of convective cells with strong gusty winds.

6. Surface Signatures of 'Squall Line'

Figure 7 shows the rainfall recorded over different stations under influence of this system. During the formation stage, Dhubri (DHB) in west Assam reported 23 mm rainfall. The rainfall maxima extended from west-southwest to east-northeast across Assam. The central and eastern part of Assam experienced higher rainfall seen in matured stage of the squall line. Relatively less rainfall with isohyetal line of 10-20 mm was realized over Meghalaya and South Assam

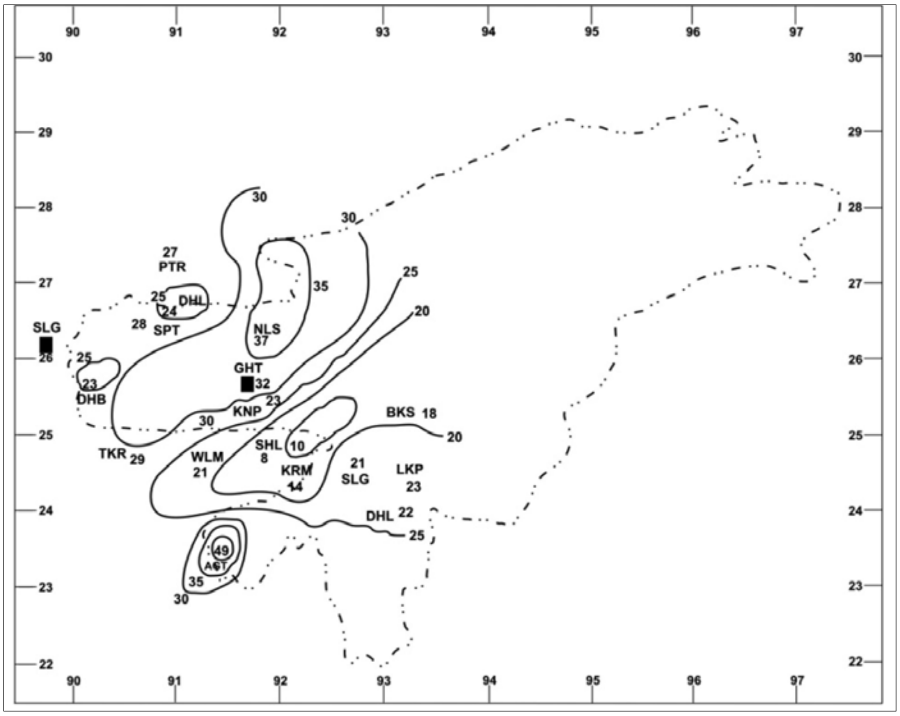

Figure 8. Isohyetal analysis of rainfall (mm) recorded over different stations in the vicinity of the squall line.

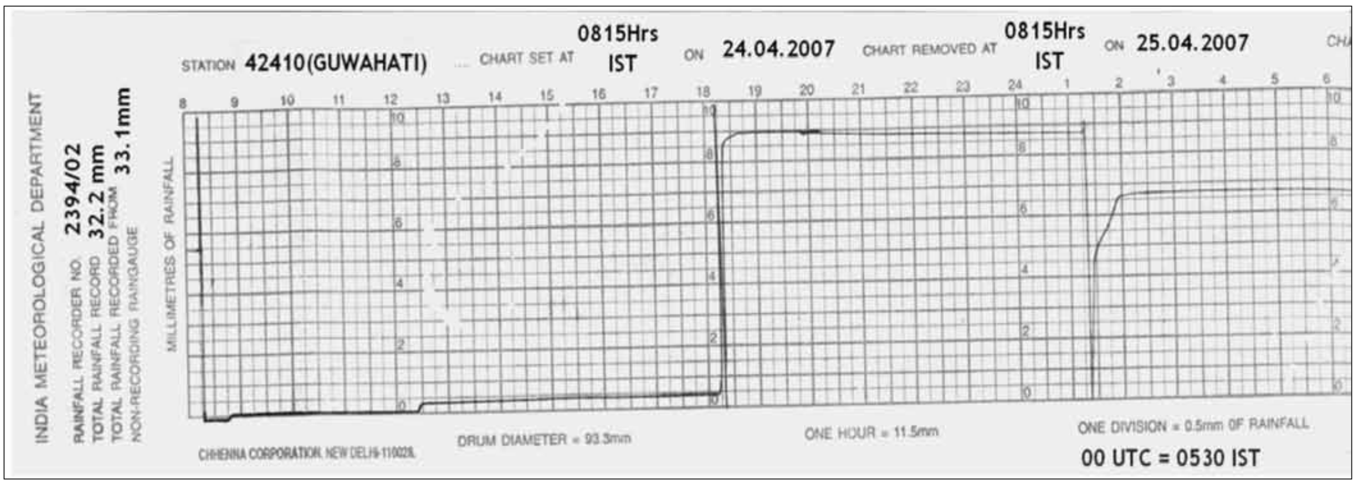

Figure 9. Hyetograph

as these places experienced the squall line in decaying stage. Isohyetal analysis also shows the breaking of the squall line into two parts as there was another rainfall maxima of 40- 50 mm over Tripura.

The overall analysis divulges the variation of precipitation with the formation and movement of the squall line. The squally weather with wind speed exceeding 70 kmph was observed in many parts of west Assam and Meghalaya. It was reported that many dwelling houses were destroyed, trees uprooted and electric pole fallen over this region. The influx of squall line over Guwahati was marked by rapid changes in wind speed and direction, drop in temperature, rise in pressure and intense rainfall as expected in association with a severe thunderstorm. Figure 8 shows that during 15 minutes period between 23:40:00 hrs UTC to 23:45:00 hrs UTC a rainfall of 19 mm with an intensity of 76.2 mm/hour has been recorded.

CONCLUSIONS

(i) The development of surface low pressure area with embedded cyclonic circulation in lower tropospheric levels over the region and adjoining GWB and Bangladesh along with a trough in middle tropospheric level running in north south direction across the region to the northwest Bay of Bengal in the morning hours was found responsible for occurrence of thunder squall. Veering of wind upto 700 hPa and considerably high wind shear favors the occurrence of squall line.

(ii) The thermodynamic parameters like LCL, CCL, and LFC predicted the severe thunderstorm event well in advance. However, the Showlter index, Total-total index, SWEAT index, CAPE and CINE could not found to be useful as the precursor for the occurrence of this particular squall line.

ACKNOWLEDGEMENTS

The authors are thankful to Director General of Meteorology, India Meteorological Department for encouragement and support for this study. The authors are also thankful to Dr.M.Mohapatra, Scientist –F, Cyclone Warning Centre, India Meteorological Department, New Delhi.

Critical and useful review by an anonymous reviewer has improved quality of the manuscript substantially. They are grateful to the Chief Editor of the journal for constructive suggestions and organized editing.

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