MAUSAM, **64**, 4 (October 2013), 721-746

L E T T E R S

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A STUDY OF SEVERE THUNDERSTORM IN THE DISTRICTS PURNEA, ARARIA AND KISHANGANJ OF BIHAR ON 13th APRIL 2010

1. A severe thunderstorm has occurred over Purnea, Araria and Kishanganj districts of Bihar at about 2305 hrs IST of 13th April 2010. Atmospheric conditions in association with the thunderstorm have been analyzed using satellite imageries, synoptic charts analysis, Weather Research and Forecasting (WRF) model, Global Forecast System (GFS) model products of India Meteorological Department (IMD) and European Centre for Medium Range Weather Forecasting (ECMWF) model products and discussed in this paper. It is inferred from this case study that continuous monitoring of satellite imageries and Radar products if available, during favourable atmospheric conditions could provide significant indication of thunderstorm activity to the operational forecasters.

Thunderstorms are atmosphere's most familiar dramatic events. Destructive off springs of thunderstorms are the hailstorms, lightning, high winds, heavy rains and most violent of all are the tornadoes. In India, theses thunderstorms reach severity when continental air meets warm moist air from Ocean. Essential conditions for the formation of a severe thunderstorm are (*i*) Conditional instability (*ii*) Availability of moist air at lower levels (*iii*) Insolation and orography for initial lifting of moist air at higher levels. (*iv*) Presence of high lapse rate of temperature, due to dry westerly at upper levels and moist southerly/southwesterly air at lower levels. (*v*) Presence of trough or cyclonic circulation in lower levels over the region. In addition, strong vertical wind shear is found to be one of the important factors for the occurrence of severe thunderstorm as the release of latent energy in an environment of strong vertical wind shear often leads to the development of severe convective storms (Stephen and Neil, 2000). Though each one of the conditions is considered favourable for convective development, their relative importance and the weightage to be given to each factor have not yet been clearly established. Thus, any discussion on this will have to be only qualitative and in general terms.

The eastern and northeastern parts of the country, *i.e*., Assam, Orissa, West Bengal, Jharkhand, Bihar and other parts of north eastern states are affected by higher frequency of severe thunderstorms locally known as Kal-baishaki or Nor'westers during pre-monsoon months. In northeast India, Thunderstorms (Nor'westers) are very common phenomenon during the period March to May. These thunderstorms are predominantly from northwest (NW) direction and hence called as Nor'westers (Desai 1950; Kessler 1982). These Nor'westers are not local heat storms. The warm, moist, southerly low-level flow from the Bay of Bengal and a cool, dry, westerly or northwesterly upper-level flow existing over the region gives rise to a favourable synoptic situation for the formation of Nor'westers. These have mesoscale structure with a very rapid development often associated with moderate/severe squalls achieving a speed in the range 130-150 kmph, which may even reach tornadic violence causing considerable damage to property and loss of life (Ghosh *et al*., 2008). Tyagi *et al.* (2011) assessed the skill of various indices and parameters and proposed suitable threshold values in forecasting the occurrence of thunderstorm activity at Kolkata.

The severe thunderstorms associated with thunder, squall lines, lightning and hail cause extensive losses in agriculture, damage to structure and also loss of life. Thus, the severe thunderstorms have significant impact in the socio-economy of eastern and northeastern parts of India. Early forecasting of thunderstorm is essential in order to safeguard the loss of life and prevent the damages of property resulting from these violent thunderstorms.

Data collected from different sources for this study are:

(a) Description of the thunderstorm and damages caused by the system collected from post thunderstorm survey report submitted by the touring officials of IMD Patna and the assessment report of Bihar Inter agency Group.

(b) Satellite imageries of KALPANA-I collected from Satellite Meteorology division of IMD, New Delhi.

(c) Synoptic weather charts and various products of NWP models have been collected respectively from RMC, Kolkata and NWP division of IMD New Delhi.

(d) Three hourly synoptic observations data for Purnea have been collected from Meteorological Centre, Patna.

One of the objectives of this study is to examine critically the different stages of thunderstorm

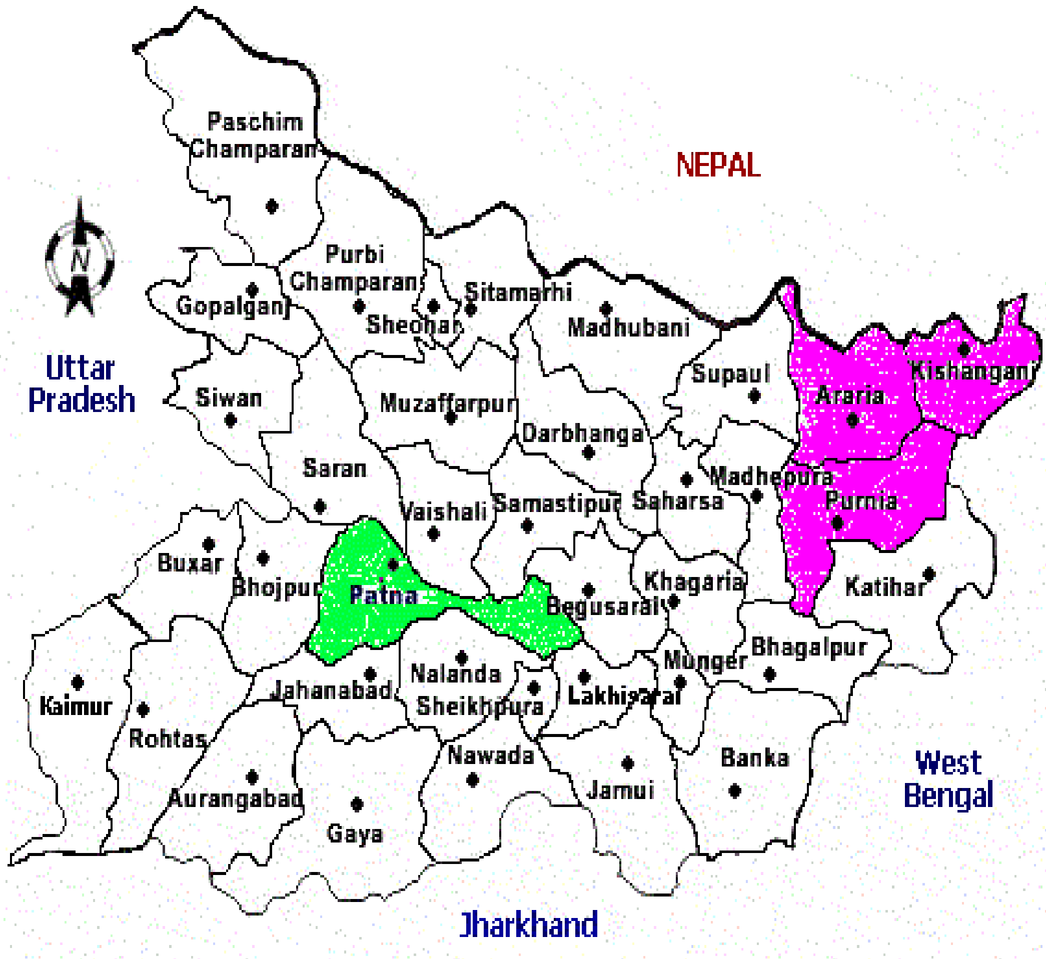


Fig. 1. Map of Bihar showing the districts Purnea, Araria, Kishanganj and Patna

development and its special characteristics or signatures in satellite cloud imagery, which may be considered to be indicative of such development well in advance. Secondly, we have analyzed different synoptic situations and various products of numerical weather prediction model and tried to find out probable dynamic aspects of such widespread severe weather situations.

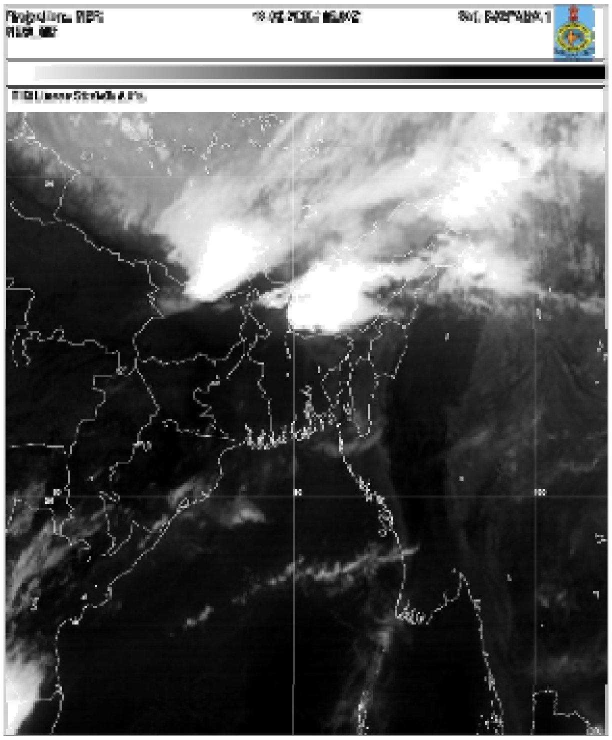
2. *Case description of Severe Thunderstorm of 13th April 2010* - On 13th April 2010 a severe thunderstorm accompanied with rain and hailstorm was reported at about midnight in the districts of Araria, Kishanganj and Purnea of north Bihar. The distance of the districts of Purnea, Araria and Kishanganj from the state capital Patna is about 300 km. The geographical locations of Patna and Purnea, Araria and Kishanganj districts have been shown in Fig. 1. As per the information collected by the officials of India Meteorological Department, Patna during the post thunderstorm survey, the thunderstorm started at about 1735 UTC of 13th April 2010 and lasted for about an hour with mostly northwesterly wind of speed about 88 to 177 kmph. During the thunderstorm moderate rainfall occurred with light (3 to 5 cm) hailstorm intensity and significant fall in temperature.

As per report of the touring officers, the destructive paths of the thunderstorm appeared random. One house flattened while its neighbour remains untouched, trees were uprooted and electric poles were twisted and fallen in different directions presumably due to localized heavy winds in circulation.

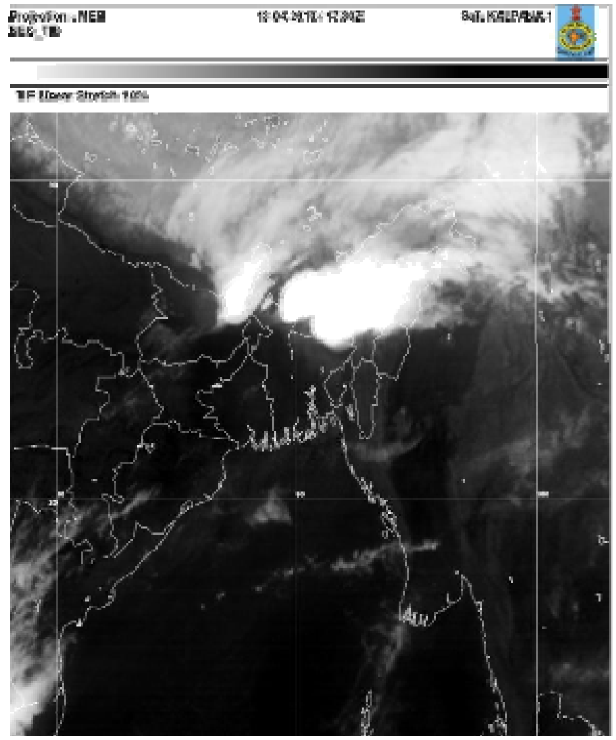
As per official report of the Government of Bihar which is available online in the assessment report of Bihar Inter agency Group, 30 Blocks, 368 Panchayats, 412 villages, 197005 family, 985025 persons and 1288.80 hectare of Agricultural Area affected. Moreover, due to this devastating thunderstorm 90 persons died and 99040 houses damaged partially or fully.

3.1. *Analysis of satellite cloud imagery* - Satellite imagery of 1600 UTC on 13th April 2010 showed deep

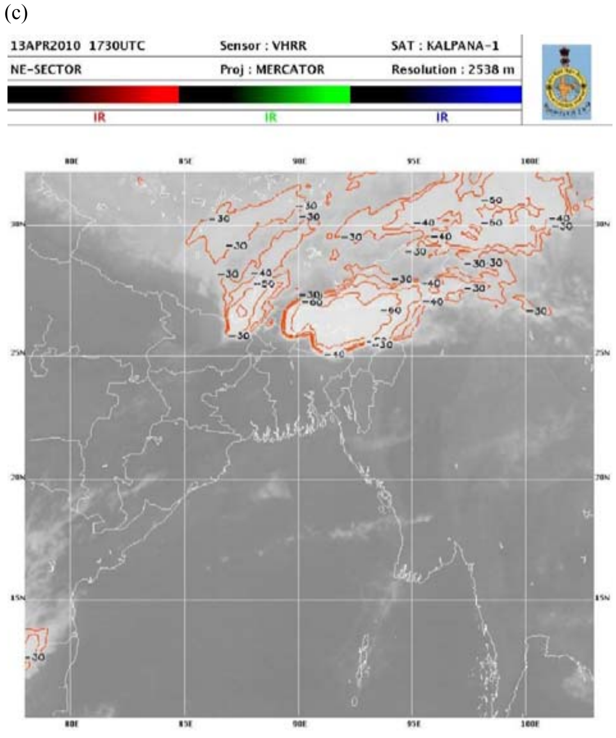
(a)



(b)



(c)



Figs. 2(a-c). Satellite imagery (KALPANA-1) at (a**)** 1600 UTC, (b) 1730 UTC and (c) 1730 UTC showing CTT of 13th April, 2010

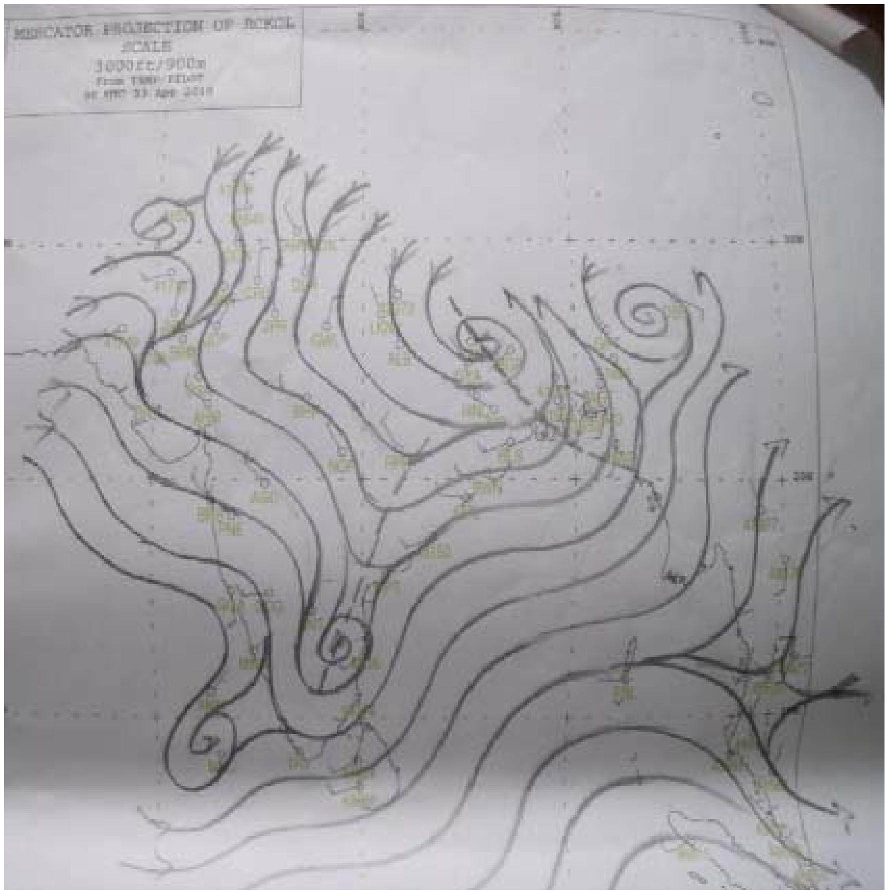


Fig. 3. Analyzed chart of 0000 UTC 0.9 km above sea level of 13th April, 2010

convective clouds over northeast Bihar [Fig. 2(a)]. These convective cloud mass intensified and moved in east to southeastward direction. The cloud system further intensified to look like a mesoscale convective complex around 1730 UTC and moved over Purnea, Araria and Kishanganj districts in Bihar and adjoining north Bengal region [Fig. 2(b)]. A detailed enquiry from local people revealed that at about 1800 UTC the intensity of the system was maximum and this was the probable time of devastation due to strong downdrafts with wind speed might be exceeding 100 kmph. Thereafter the system moved away and entered Bangladesh and gradually weakened. From satellite imagery of 1730 UTC [Fig. 2(c)] it is seen that cloud top temperature was as far as –50 °C, which indicates that the cloud top might have reached a height of 12 km.

3.2. *Synoptic situation*- Although thunderstorm is a mesoscale phenomenon, the realization of the instability mostly depends on large scale synoptic situation, particularly the vorticity of motion in atmosphere. Significant thunderstorm activity is generally associated with some synoptic system or the other of the cyclonic type. However, many of these systems are generally weak. These necessitates a careful analysis of the charts, great need to maintain space and time continuity in the analysis and also the need for the forecaster to be well aware of the diurnal variations and local peculiarities of the area.

The records of the meteorological observatory at Purnea, which records observations at synoptic hours from 0000 to 1200 UTC, indicate that the sky was generally cloudy with stratocumulus and cumulus clouds till 0600 UTC, partly cloudy at 0900 UTC with stratocumulus cloud but at 1200 UTC sky became clear with no cloud reported. The surface wind was light and mainly easterly to southeasterly till 0900 UTC but surface wind was calm as reported in the 1200 UTC observation. Relative humidity was reported as 65% at 1200 UTC. The dew point temperature increases gradually from 24.5 °C at 0300 UTC to 25.4 °C at 1200 UTC. There was 6 hPa fall of pressure from 1007 hPa at 0300 UTC to 1001 hPa at 1200 UTC. The maximum temperature on that day was reported as 35.5 °C.

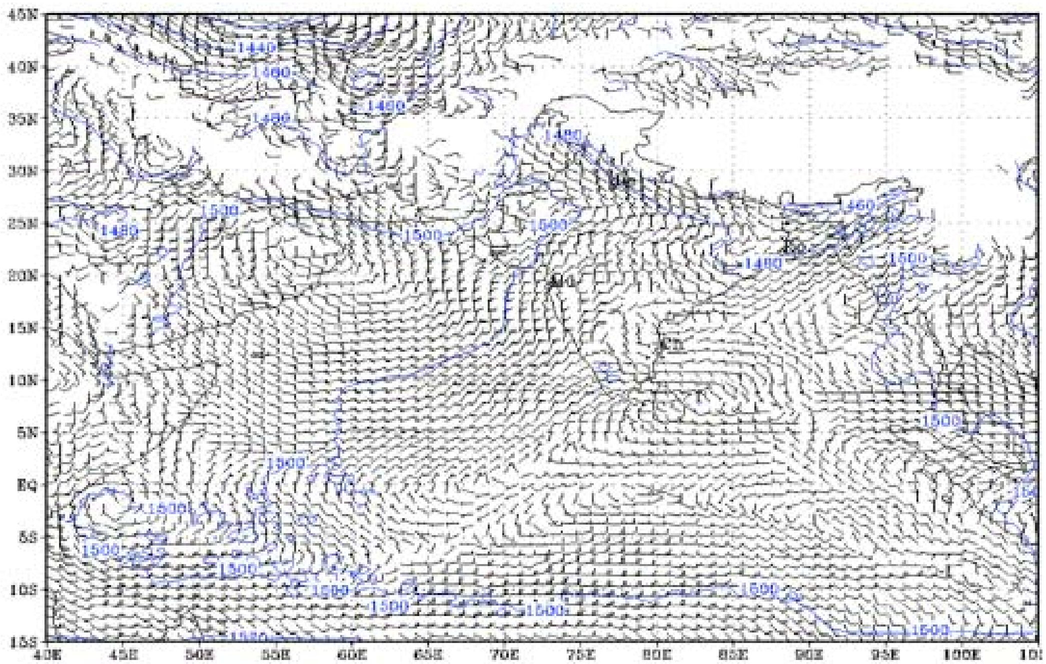
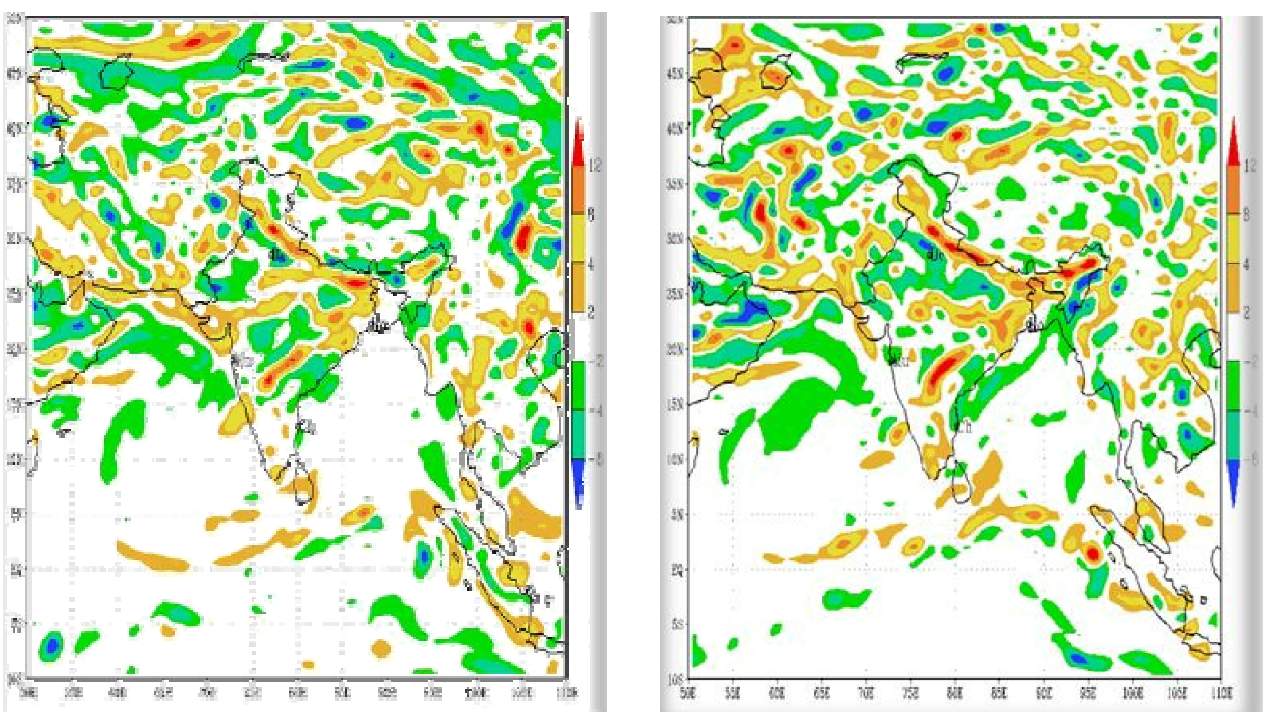


Fig. 4. IMD WRF-VAR (27 km) model 850 hPa wind forecast based on 0000 UTC of 13th April, 2010



Figs. 5(a&b). GFS model 850 hPa vorticity (a) 0000 UTC of 13-04-2010.analysis and (b) forecast valid at 0000 UTC of 14 April 2010

The analysis of 0300 UTC sea level weather chart of 13th April 2010 and 0000 UTC upper air chart of same date indicate that a trough of low pressure was extending from east Uttar Pradesh to interior Orissa across Bihar and Jharkhand and a cyclonic circulation was lying over Bihar and adjoining Sub-Himalayan West Bengal extending up to 1.5 km above sea level. Fig. 3 shows the upper wind analysis at 0.9 km. The analysis also indicates that there was trough/wind discontinuity line from Bihar and adjoining Sub Himalayan West Bengal to North West Bay of Bengal across Bangladesh at 1.5 km above sea level causing sufficient moisture incursions from Bay of Bengal for development of convective system over the region. Thus the synoptic system was very much favourable for occurrence of severe thunderstorm over the area.

3.3. *Numerical Weather Prediction Model products* - To study the characteristics of severe thunderstorm dynamically, we have considered some of the analysis and forecast products of GFS, WRF-VAR (27 km) of IMD, New Delhi and ECMWF models.

Wind analysis of 13^{th} April, 2010 by all the three models showed that there was a cyclonic circulation over Bihar and neighbourhood extending up to 1.5 km above sea level. The forecast of wind by all the three models showed that the cyclonic circulation became less marked on 14^{th} and westerly to northwesterly wind over the region in the lower level. ECMWF model showed very weak divergence at 500 hPa level over the region on 13^{th} April with slight increase of divergence at 500 hPa level over some areas of north Bihar and Sub Himalayan West Bengal during next 24 hours from 0000 UTC of 13^{th} April. The wind shear between 850 and 200 hPa level was strong over the region on 13^{th} and 14^{th} April as shown by ECMWF model. The 24 hour forecast of wind by WRF-VAR model based on 0000 UTC of 13^{th} April valid for 0000 UTC of 14^{th} April reveals wind discontinuity at 850 hPa level over the affected area and its surroundings (Fig. 4.). The ECMWF model showed moderate positive vorticity ($\sim 4*10^{-5}\ s^{-1}$) at 850 hPa level whereas GFS model showed high positive vorticity ($\sim 12*10^{-5}\ s^{-1}$) [Fig. 5(a)] over north east Bihar and neighbourhood on 13^{th} April, 2010. Both the model forecasts show almost similar vorticity as of 13^{th} for next 24 hours [Fig. 5(b)]. The values of CAPE ($\leq$750 J/kg) over the region were under-estimated by GFS model on 13^{th} April 2010. Neither GFS nor WRF could capture rainfall for this particular convective system whereas ECMWF predicted light rainfall over the affected districts.

4. *Discussion and conclusions* - The severe thunderstorm might have been triggered by a cyclonic circulation over Bihar and adjoining Sub-Himalayan West Bengal extending up to 1.5 km above sea level and a trough/wind discontinuity line from the cyclonic circulation extended up to North West Bay of Bengal at 1.5 km above sea level.

Thunderstorm development could be spotted only from satellite images by continuous monitoring since no Doppler Weather Radar was available in the affected districts of Bihar, the system could not be noticed from the nearby Doppler Weather Radar located at Kolkata which is at a distance of about 500 km from the affected districts of Bihar.

NWP models could predict some of the favourable parameters for thunderstorm development such as high vorticity as well as the synoptic system but could not predict the rainfall in association with this thunderstorm.

Doppler Weather Radar is a very important tool for monitoring the development and movement of the thunderstorm. The variation of meteorological elements during the period of severe weather could also not be analyzed from the autographic charts due to absence of the same.

Fine network of surface and upper air observing systems are needed to understand the mesoscale systems and to augment our prediction capability.

Acknowledgement

Authors are grateful to the Director General of Meteorology, India Meteorological Department, New Delhi for his interest and encouragement in this research work. Authors are also thankful to Deputy Director General of Meteorology (NWP) for his guidance to improve the quality of the paper. Authors acknowledge the use of ECMWF data in this research work.

References

Desai, B. N., 1950, "Mechanism of Nor'wester of Bengal", *Indian J. Meteorol. Geophys.,* **1**, 74-76.

Ghosh, A., Lohar, D. and Das, J., 2008, "Initiation of Nor'wester in relation to mid-upper and low-level water vapor patterns on METEOSAT-5 images", *Atmos. Res.*, **87**,116-135.

Kessler, E., 1982, "Thunderstorm morphology and dynamics", U.S. Department of commerce. National Oceanic and Atmospheric Administration, Environmental Research Laboratories, Vol. **2**.

Stephen, R. J. Knott and Neil, M. Taylor, 2000, "Operational aspects of the Alberta severe weather outbreak of 29 July 1993, *Natl. Wea. Dig.*, **24**, 4, 11-23.

Tyagi, Bhishma, Naresh, Krishna, V. and Satyanarayan, A. N. V., 2011, "Study of thermodynamic indices in forecasting pre-monsoon thunderstorms over Kolkata during STORM pilot phase 2006-2008", *Nat Hazards*, **56**, 681-698.

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