Atmospheric Research 106 (2012) 120–138

Contents lists available at SciVerse ScienceDirect

Atmospheric Research

journal homepage: www.elsevier.com/locate/atmos

Organizational modes of squall-type Mesoscale Convective Systems during premonsoon season over eastern India

Shubho Dalal [a], Debasish Lohar [a,*], Sumana Sarkar [a], Indrajit Sadhukhan [b], Gokul Chandra Debnath [c]

[a] Atmospheric Science Research Group, Department of Physics, Jadavpur University, Kolkata-700032, India
[b] IERCEM Institute of Information Technology (IIIT), Banipur College Road, P.S. Banipur, 24 Parganas (N), West Bengal-743233, India
[c] Regional Meteorological Centre, India Meteorological Department, 4, Duel Avenue, Alipore, Kolkata-700027, India

ARTICLE INFO

Article history:
Received 16 June 2010
Received in revised form 5 December 2011
Accepted 5 December 2011

Keywords:
Premonsoon thunderstorms
Mesoscale Convective System
Nor'westers
Trailing stratiform
Leading stratiform
Parallel stratiform
Storm-relative wind and semi-arid region

ABSTRACT

Premonsoon thunderstorms, locally known as Nor'westers, were studied over the eastern part of India using routine observations and data acquired from STORM (Severe Thunderstorm Observation and Regional Modelling) program during the premonsoon season, i.e., March through May, of 2006–08. Doppler radar image analysis reveals that premonsoon convective activities on many occasions may be described as squall-type linear Mesoscale Convective Systems (MCSs) which are composed of three common organizational modes viz. Trailing Stratiform (TS), Leading Stratiform (LS) and Parallel Stratiform (PS). The most dominant and common mode of organization, in terms of frequency of occurrences, duration, mean speed and inter-conversion among the different modes, is the TS, contributing about 65% of the cases while LS and PS contribute only about 15% and 20% respectively. Examination of pre-storm environments indicates that line-perpendicular and line-parallel storm-relative winds possibly determine the modes of organization. Case studies, one from each class, were also carried out and the observed structures were found to be similar to that observed in warmer mid-latitudes with certain exceptions. Unlike mid-latitude MCSs, convective cells during the premonsoon season initiate over the region with the support of weak synoptic setting and in course of time, organize themselves to become an MCS under favorable mesoscale convective environment. However they are short-lived irrespective of the modes of organization.

1. Introduction

Premonsoon thunderstorms, locally known as Nor'westers (Kessler, 1982), over the eastern part of Indian sub-continent and Bangladesh, have been one of the subjects of great concern among the researchers in India for the past century (e.g., Normand, 1921; IMD, 1944; Mukhopadhyay et al., 2005). They are very severe in nature and are often associated with squall having speed as high as 22–28 m/s, causing considerable damage to crops and property. Loss of human lives as a result of collapsing of mud houses due to strong gust wind or lightning is also common over the area. Several aspects of premonsoon thunderstorms were studied (e.g., Sohoni, 1928; Koteswaram and Srinivasan, 1958; Weston, 1972; Chatterjee et al., 1995; Sadhukhan et al., 2000; Chaudhuri, 2008, etc.) though their spatial and temporal extent were not attempted, perhaps, due to lack of observations. Studies using radar observations were also carried out, although they were mainly restricted to frequency of occurrences (e.g., Srinivasan et al., 1973; Chatterjee et al., 1995; Sadhukhan and De, 1998), vertical extent of the cumulonimbus cloud (e.g., Mukherjee et al., 1972) and type of formation as scattered/isolated and/or in a line (e.g., Koteswaram and De, 1959). Use of satellite data in studying premonsoon thunderstorms (Ghosh et al., 2008) is also available in the literature where information was extracted

* Corresponding author. Tel.: +91 9748513630.
E-mail addresses: shubhodalal@gmail.com (S. Dalal), dlohar_atmos@yahoo.com (D. Lohar), i_sadhukhan@yahoo.com (I. Sadhukhan), gcdebnath@yahoo.com (G.C. Debnath).

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doi:10.1016/j.atmosres.2011.12.002

regarding their initiation by analyzing water vapor content in the lower and mid-upper levels. It was known since 1944 (IMD, 1944) that these storms initiate over Chotta Nagpur plateau and move south-eastwards. Following the description of IMD (1944), Ghosh et al. (2008) showed schematically the different types of thunderstorms (A, B, C and D type) with their initiating locations and subsequent movements. Type ‘A’ thunderstorm originates over the Chotta Nagpur plateau, presently in Jharkhand, and neighboring Gangetic West Bengal (GWB) at the daytime and moves eastward/south-eastward in the afternoon/late afternoon; type ‘B’ thunderstorm, on the other hand, occurs in the night or early morning in the foothills of the Himalayan region and moves southwards; type ‘C’ is a rare one, originates over the hills of the north-eastern states of India and moves westward; and type ‘D’ initiates over the Khasi and Garo hills in Meghalaya and moves southwards. But the exact spatial extent, structure and temporal characteristics of these thunderstorms were not known in the absence of adequate data. One Doppler Weather Radar (DWR) was installed in Kolkata (KOL) in 2004. Now it has become possible to study the development and structure of the premonsoon thunderstorms using the DWR data. It is seen that the A-type premonsoon thunderstorms initiate over a semi-arid region of Jharkhand (Ranchi: RNC; Dhanbad: DNB and Dumka: DMK) (Fig. 1) as discrete cells and move towards KOL/Bangladesh. Simultaneously few other cells also develop over a semi-arid part of Orissa, particularly near Chaibasa (CBS) and Baripada (BPD) (Fig. 1). These discrete cells either dissipate after attaining their maturity or get organized to a cluster of thunderstorms having horizontal dimension of hundreds of kilometers in one direction with a minimum life time of 2–3 h. Hence, they may be termed as Mesoscale Convective Systems (MCSs), following the definition of Zipser (1977) and Houze (1977).

An MCS, a combination of convective clouds and stratiform clouds, is one of the severe weather events in tropics and in the warmer mid-latitudes producing hail, gusty wind and intense rainfall leading to flash flood and damage to property (Parker and Johnson, 2000; Rigo and Llasat, 2007 etc.). The convective region of an MCS contains several deep cells while the stratiform part is the outer spreading portion of the convective region. Among the MCSs, the leading-line trailing stratiform structure is a common pattern, where the stratiform part trails behind the convective region as identified by Zipser (1969, 1977) and Houze (1977) in tropical region and later in mid-latitudes (Smull and Houze, 1985; Houze et al., 1989). Considering about 63 mesoscale precipitation systems, it was identified that the observed precipitation systems were mostly the leading-line trailing-stratiform type of MCSs (Houze et al., 1990). Schiesser et al. (1995) noted the existence of leading-stratiform trailing-line MCS while Parker and Johnson (2000) identified two modes of organization for linear MCSs in the mid-latitudes other than the leading-line trailing-stratiform structure: a convective line with a leading stratiform region and a convective line with parallel stratiform regions. Simulations of these modes of organization were carried out (e.g., Parker and Johnson, 2004; Parker, 2007a) to investigate the dynamics of such organizations. Even more complex convective episodes with number of different systems were also studied in the eastern Kansas (French and Parker, 2008).

In Indian region, Mesoscale Convective Complexes (MCCs) were identified during the monsoon season (June through September) by Maddox (1980). Laing and Fritsch (1997) reported formation of MCCs over the Indian subcontinent during the same season using Indian National Satellite System (INSAT) imageries. Later on, Johnson et al. (2005) reported the MCS

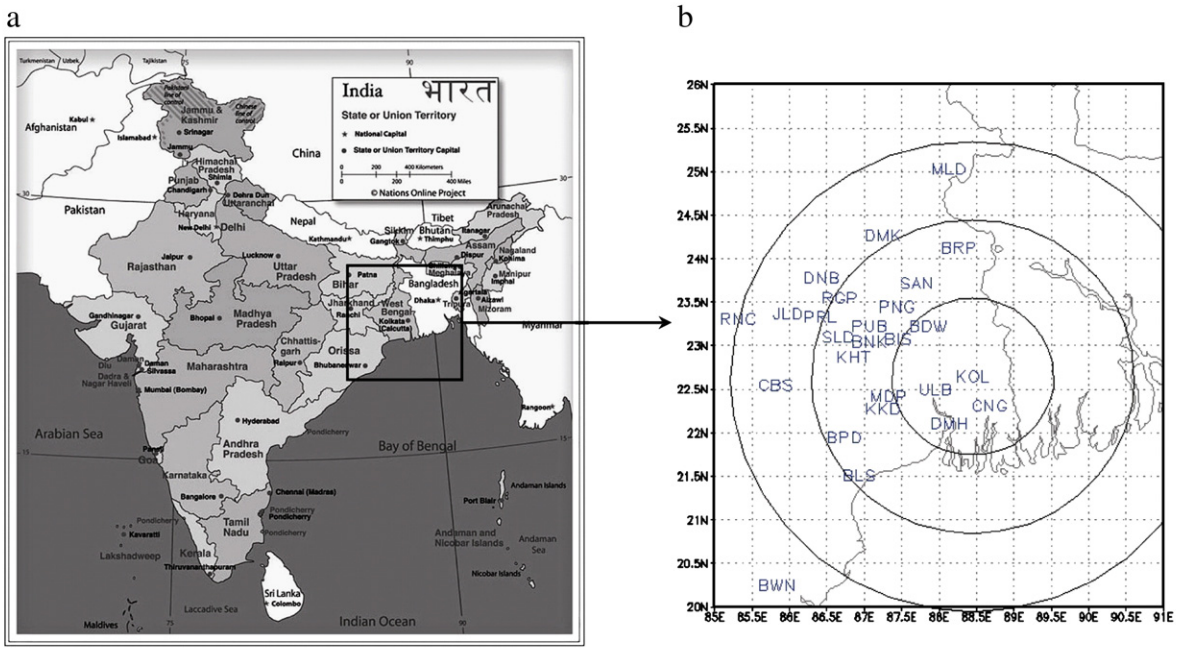

Fig. 1. Map shows the different states of India and the right panel displays the study area (b). The concentric circles with radii 100 km, 200 km and 300 km show the area covered by a Doppler weather radar located at the center, KOL. The upper air observation stations are located at RNC, PNG, KKD and KOL while the AWSs are at JLD, PRL, RGP, SLD, PUB, KHT, SAN and BIS. The details of the stations (shown as abbreviated form) are given in Table 3.