Environmental Conditions and Dryline Influence on the Occurrence of Severe Local Convective Storms in Bangladesh during the Pre-Monsoon Season

Abstract

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Chapter 1 Introduction

Among the worst ten historical tornadoes in the world in terms of casualties six cases were reported in Bangladesh. These tornadoes were brought by severe local convective storms (SLCS). Nevertheless, studies on SLCS are very few due to the scarcity of observation data in Bangladesh. This chapter describes a comprehensive overview of devastating SLCS that occur during the pre-monsoon months, i.e. March, April and May, in Bangladesh. The general features of pre-monsoon meteorological fields are illustrated in relation to the occurrence of SLCS. Review of existing literatures also suggests that the initiation mechanism of individual storm has not been well investigated. In the present study the importance of dryline which forms between maritime moist air mass and continental dry air mass is proposed with reference to the studies of SLCS in the United States.

Chapter 2 Data and Methodology

JRA-55 reanalysis data that cover 55 years (1958-2012) from the Japan Meteorological Agency (JMA) are used in the analysis of synoptic meteorological fields. In this chapter, JRA-55 data are described in detail and the adequacy of the use in the study region is validated by comparing with existing upper sounding data. Then, analysis tools and methods are introduced here. The procedure for the calculation of various environmental parameters diagnosing kinematic features and thermal stability are described. JRA-55 reanalysis data used here are based on the model grids at horizontal resolution of 0.5625 degrees. The data are converted to standard pressure level data for the calculation of some parameters defined with reference to standard pressure levels. To examine environmental stability conditions several stability indices such as K Index (*KI*), Total-Total Index (*TT*), Showalter Stability Index (*SSI*), Lifted Index (*LI*), Precipitable Water (*PW*) (Kg/m^2),

Convective Available Potential Energy (*CAPE*) (J/kg), and Convective Inhibition (*CIN*) (J/kg), Mean Shear (*MS*), Storm Relative Environmental Helicity (*SREH*), Vorticity Generation Parameter (*VGP*), Energy Helicity Index (*EHI*), and Bulk Richardson Number (*BRN*) are computed.

Chapter 3 Synoptic Features and Environmental Conditions of a Tornado

This chapter describes the synoptic features and environmental conditions for a devastating tornado outbreak on 22 March 2013 at Brahmanbaria in the east-central region of Bangladesh. Various factors for the initiation of the terrific event are investigated using JRA-55 data, surface data and satellite data. A clear boundary was found between moist air and dry air in this case. Detailed synoptic analysis showed that increase of surface temperature was smaller on the moist side of the dryline than the dry side by few degrees. The mean sea-level pressure was high over the Bay of Bengal and on the east side of dryline over Bangladesh territory. Surface winds turned towards the dryline and resulted in enhancement of surface convergence at the position of dryline. Surface convergence induced upward motion near dryline. As day advances *CAPE* increased due to enhanced moisture incursions in the lower level from the Bay of Bengal on the east side of the dryline. The elevated warm mixed layer laying above the moist region, however, acted as a cap or a lid over the moist region and protected the release of *CAPE* for a while. The dryline advanced gradually eastward and moisture gradient squeezed, then localized convergence became stronger and lifted moist air aloft. Eventually, it forced air parcels to break the lid and reached their LFC (Level of Free Convection) to trigger deep convection.

It is also shown that the upper westerly wind and the strong wind shear maintained and enhanced the triggered convection. The westerly wind also conveyed the whole convective system eastward. During its eastward migration the convective system intensified and matured enough to spawn a tornado at Brahmanbaria. In the current case, the low level wind convergence coupled with the strong vertical wind shear lifted moist air aloft to trigger deep convections which initiate the severe storm. Various environmental stability parameters were computed, among which the *EHI* was confirmed to be the best predictive environmental parameter for this specific event.

Chapter 4 Pre-Monsoon Dryline Position and Risk Zone of Tornado Occurrence

This chapter highlights dryline in view of a triggering mechanism of historical deadliest tornadoes in Bangladesh. Twenty five violent tornado cases in Bangladesh were first chosen between 1961 and 2013. The methodology of identifying dryline was developed based on the way applied in the Great Plains environment with some modification. Using this, dryline was identified for each of the 25 cases. These twenty-five cases drylines were, then, classified as Type-A (13 cases), Type-B (8 cases), and Type-C (4 cases) according to their positions. Type-A drylines correlated to the tornado occurrence in central regions of Bangladesh, and Type-B in northwestern, northern-central and sometimes central regions. For Type-C tornado occurrence sites were scattered in northwestern and central regions. The relation of dryline and the initiation of convection was also investigated for specific cases when satellite images are available. In all Type-A and some Type-B cases, surface convergence was enhanced along drylines, which promoted upward motion. Eventually updraft penetrated LFC and a convection was initiated. The convective system continued to develop on their eastward migration and brought severest events at a distance from dryline. For other Type-B and Type-C cases, though convections were initiated near the dryline, they did not developed to the SLCS of tornado events. In severe cases with Type-C dryline, storms were initiated at the southern slope of the Himalayan range and migrated southeastward to West-Bengal of India and Bangladesh territory.

Chapter 5 Discussion

The characteristics of dryline in the study region, Bangladesh and West Bengal of India, are compared with those in the Great Plain in United States. Both drylines are similar in that they are formed between warm-moist southerly wind and hot-dry continental westerly wind. However, the orientation is slightly different. The difference was explained by the different topographic circumstances.

In order to find the frequency and preferable position of dryline, a simple dryline climatology was explored for pre-monsoon months between 1958 and 2013. The frequency of strong specific humidity gradient, exceeding 3g/kg per 100 km, was counted at each grid point over the region between 84˚E and 91˚E in longitudes and 18˚N and 26˚N in latitudes.

The frequencies were quite high, for example 4070 days (79%) at 1200 UTC (1800 Bangladesh Standard Time), over the total of 5152 days. It is evident that the dryline exists many days in the pre-monsoon season. Thus, dryline is just a necessary condition but not the sufficient condition for the occurrence of SLCS. The background conditions indicated by *CAPE* and *EHI* etc. also need to have preferable values for the occurrence of SLCS.

Chapter 6 Conclusion

A recent violent tornadic storm was closely investigated in chapter 3. It was found that low level convergence along dryline lifted the lower atmosphere up to the level of free convection in a significantly unstable environment, where the initial convection was triggered. It was also demonstrated that the *EHI* is a good predictor to identify SLCS occurrence place among various stability parameters.

Twenty five violent tornado cases in Bangladesh between 1961 and 2013 were investigated in their relation to the dryline features and the environmental stability parameters. Drylines specified for individual cases were classified into three types according to their position. A specific correlation between the dryline types and hazard prone regions was found. For the initiation of convection Type-A drylines were found to be responsible for triggering initial convection of SLCSs that produced tornado, but the Type-C drylines were not. Type-B drylines had an intermediate feature. The drylines in this region are basically similar to those found in the Great Plains, but has some different natures derived from different topography.

A climatological investigation showed that the dryline exists very frequently in pre-Monsoon months in the study region