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Thunderstorm characteristics in Nepal during the pre-monsoon season 2012

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ABSTRACT

A training period of lightning location data usage has been carried out in Nepal during the pre-monsoon season April–June 2012. The training was one part of a Finnish–Nepalese Project (FNEP) between the Department of Hydrology and Meteorology of Nepal (DHM) and the Finnish Meteorological Institute (FMI). FNEP aimed for the development of operational meteorological readiness in a developing country such as Nepal. The lightning location training included the introduction to lightning location techniques and principles and the actual hands-on training for the operational DHM forecasters. The lightning location system used was the Vaisala long range Global Lightning Dataset 360 (GLD360), which has practically a global coverage. During the three months of training, a dataset of Nepalese lightning was also collected, indicating the pre-monsoon thunderstorm characteristics of Nepal.

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1. Introduction

Global statistics of thunderstorms (Christian et al., 2003) indicate that the most abundant regions of lightning are the tropical continental areas in Africa, South America and Indonesia, where thunderstorms occur almost on daily basis. Outside the tropics, thunderstorms have a seasonal cycle: the thunderstorm season is shorter, and therefore also less lightning occurs during the year. However, despite the shorter season, *individual* storms at higher latitudes may reach extreme intensity. A good example is the thunderstorms in the central parts of the United States (Christian et al., 2003; Mäkelä et al., 2011).

In the Himalayan region, the local climate is influenced by the summer monsoon which brings large amounts of moisture and precipitation from the Indian Ocean towards the north (Robinson and Henderson-Sellers, 1999; Malla, 2008). Before the monsoon, the atmosphere changes into highly unstable and intense convection occurs. Thunderstorms during this pre-monsoon season have also been noted to reach extreme intensity, and they have a great impact to the densely populated countries such as Sri Lanka, India, Bhutan, Bangladesh, and Nepal. According to Christian et al. (2003), extremely high flash rates occur in the northern Pakistan in the Himalayas. Unfortunately, there are not many studies concerning the thunderstorm climate of these areas.

Nepal is without a doubt one of the most intriguing countries in the world (Fig. 1); the Himalayan mountains lie in the northern parts of the country, with eight of the ten tallest mountain tops in the world situated in Nepal. The elevation changes rapidly in the South–North direction; the lowest areas in the South are only some hundreds of meters above the sea level, while the Mount Everest only about 200 km to the North peaks at almost 9000 m. The climate of the lowest areas is moist and warm, while in the mountains the air is dry and cold (Robinson and Henderson-Sellers, 1999).

Nepal is divided into five development regions (shown in Fig. 1 with thick solid line): Far West, Midwest, West, Central, and East. The development areas are further subdivided into a total of 14 zones, which are numbered in Fig. 1 and explained in Fig. 1 caption.

Several kinds of meteorological studies have been made in the Himalayan region during the years. Many of them have

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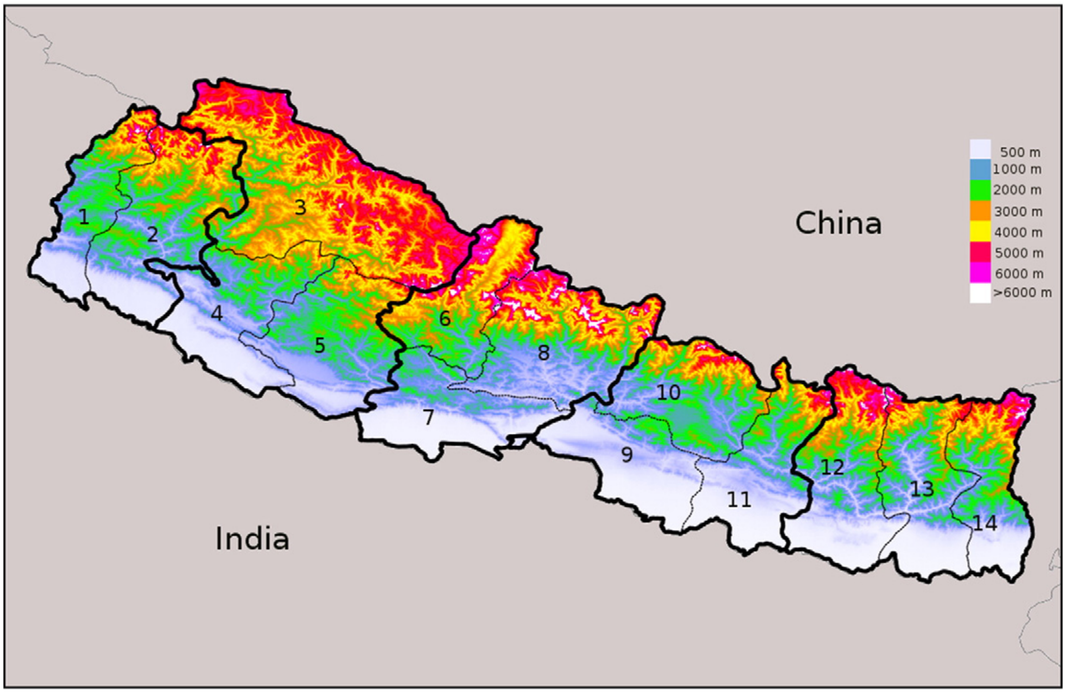

Fig. 1. The elevation, development areas and zones of Nepal. Development areas are (solid thick lines from West to East) Far West, Midwest, West, Central, and East. The zones are (dashed lines): 1 = Mahakali, 2 = Seti, 3 = Karnali, 4 = Bheri, 5 = Rapti, 6 = Dhawalakiri, 7 = Lumbini, 8 = Gandaki, 9 = Narayani, 10 = Bagmati, 11 = Janakpur, 12 = Sagarmatha, 13 = Kosi, and 14 = Mechi.

dealt with the characteristics and effects of the summer monsoon (He et al., 1987; Barros et al., 2000; Krishnamurti and Kishtawal, 2000; Shrestha, 2000; Lang and Barros, 2002; Barros and Lang, 2003), winds (Egger et al., 2000; Zängl et al., 2001), mountain effects (e.g. Kuo and Qian, 1981), precipitation (e.g. Shrestha et al., 2000), and weather conditions in general (Ye, 1981; Bollasina et al., 2002). However, although some studies of Nepalese thunderstorms exist (e.g. Rosoff and Hindman, 2002) the thunderstorm characteristics of Nepal have not been studied deeply.

One of the most detailed investigations of Nepalese lightning is by Baral and Mackerras (1992). They studied the lightning occurrence characteristics with a flash counter network for a total of 21 months (March 1987–November 1988) in the Kathmandu Valley. Their results indicate that when the lightning activity starts in March, it intensifies quickly reaching its peak in May, while in June the activity decreases rapidly as the monsoon season starts. Similar findings have been found by Kayastha and Regmi (2008).

The pre-monsoon season thunderstorms usually approach from Northwest and hence are called Nor'westers. Nor'westers are mesoscale convective systems, which can develop under large scale envelope of the seasonal low-level trough with a possible embedded low pressure area.

The upper air flow over Gangetic West-Bengal and the adjoining areas has a shallow layer of moist southerlies/southwesterlies from the Bay of Bengal near the ground and dry westerlies aloft. Although this type of situation prevails almost daily during April–May, thunderstorms do not occur every day. The atmospheric instability is released through the action of large scale flow and the associated synoptic and sub-synoptic systems. In the lower troposphere, pressure troughs, low pressure areas, and wind convergence are important. In the upper troposphere, divergent flow can cause the moist and unstable lower level air to be drawn upward leading to convective cloud formation and hence thunderstorms. The divergent flow is usually associated with the upper tropospheric trough in the westerlies. Areas of upper tropospheric positive vorticity advection in association of large scale vertical upward motion help triggering thunderstorms. Towards mid May, anticyclonic flow starts in the middle and upper troposphere, prior to the onset of monsoon. The anticyclonic circulation also provides upper level divergent field, mainly near the Gangetic West Bengal and neighborhood which favors development of convection.

Nowadays, thunderstorm characteristics can be examined accurately with lightning location systems (LLS), which provide lightning location data practically in real time. Many types of LLSs exist (Cummins and Murphy, 2009): short-range systems utilizing Very High Frequencies (VHF) are intended for detailed detection of practically all discharges occurring in the thundercloud (Richard et al., 1986), while long-range systems monitoring Very Low Frequency (VLF) and Low Frequency (LF) electromagnetic signals emitted by lightning return strokes are designed to cover large areas with only a handful of sensors (Cummins and Murphy, 2009). This is possible because VLF pulses travel long distances reflecting back and forth between the ground and ionosphere. The latter types of LLSs are especially useful because they can monitor areas which are difficult to cover otherwise (e.g., oceans). Also, a long range

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