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# Lightning and convective rain over Indian peninsula and Indo-China peninsula

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**Abstract**

The impact of surface temperature, CAPE, convective cloud cover, outgoing long wave radiation and aerosol concentrations on lightning flashes and convective rainfall in the Indian peninsular and Indo-China peninsular regions are compared. Results showed that the observed relationships between lightning, precipitation and considered parameters are very complicated. An attempt is made to tie these observed results with physical considerations. For better understanding of involved processes, regional scale simulations to replicate the observed features are required.
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*Keywords:* Lightning; Convective rain; CAPE; Meteorological parameter; Aerosol optical depth

## 1. Introduction

Solar radiation heats the Earth's surface and air in the adjoining atmospheric boundary layer leading to formation of thunderstorm/convective clouds through the buoyancy forces. The surface temperature and its vertical gradient control development and intensity of convection, which affects lightning discharges and precipitation. In general, lightning discharges require deeper and stronger convection rate, whereas precipitation may occur even at weak and moderate convection. The regional distributions are ranked, from the most-to-the least, for thunderstorm activity as Africa, South America and Southeast Asia and that for rainfall activity as Southeast Asia, South America and Africa (Price, 2000, 2009; Christian et al., 2003; Singh et al., 2004; Siingh et al., 2007, 2008, 2011, 2012, 2013; Cecil et al., 2014).

Intense convection over tropical and sub-tropical regions impact global energy exchange and water substance reallocation (Chen et al., 2006). About 75% of water vapor supplied to the global tropical stratosphere in summer is from the South Asia monsoon region and Tibetan Plateau

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region (Zhou et al., 2002; Gettelman et al., 2004; Qie et al., 2003; Yuan and Qie, 2008; Qie, 2012). The land–sea distribution and thermal condition over Tibetan plateau terrain have profound impact on atmospheric circulation over South Asia and Southeast Asia. Romatschke et al. (2010) showed that deep convective system in South Asia move from the east coast of the Indian peninsula in the pre-monsoon season to western foothills of the Himalayan range in monsoon season. Heavy precipitation over India, China and Japan are reported which are influenced directly or indirectly by the Himalaya/Tibetan Plateau (Yihui and Chen, 2005; Fu et al., 2008; Qian et al., 2009; Takahashi et al., 2010; Qi and Wang, 2012; Siingh et al., 2013, 2014; Halder et al., 2014).

In it was believed that a mesoscale mountain imposes local and regional effects through the orographic lifting and windward rainfall and lee-ward rain shadow (Grossman and Durran, 1984; Jou, 1994; Colle and Mass, 1996; Ralph et al., 2003; Chen and Lin, 2005; Qie, 2012). However, the dynamical terrain effect could be seen up to 8000 km downstream in the central-western Pacific through the air–sea interaction under a stable trade-wind regime (Xie et al., 2001). The same group also reported that the terrain-forced convection from narrow mountains contributed significantly to the Asian Summer monsoon system through the Rossby wave response to the anomalous convective heating (Xie et al., 2006). The mesoscale convective system excited over Tibetan Plateau propagated eastward 3000 km downstream and leads to enhanced precipitation in the Yangtze River basin (Shi et al., 2008). Qi and Wang (2012) based on ensemble simulation showed that the Annam-Cordillera mountain (~900 m high) blocks/lifts the warm and moist air from the Bay of Bengal and forces upward motion and causes precipitation as far as 3000 km away over south and east China and western northwest Pacific.

Lightning and precipitation also depend on the aerosol concentration, surface temperature (land and ocean), convective available potential energy (CAPE), cloud cover area, outgoing longwave radiation (OLR), etc. (Massie et al., 2004; Cheng et al., 2007; Tinmaker et al., 2010; Yuan et al., 2011; Liu et al., 2011; Wang et al., 2011; Siingh et al., 2013, 2014; Kulkarni and Siingh, 2014). Aerosols present in the atmosphere scatter, reflect and absorb incident solar radiation and thus affect the solar radiation budget, surface temperature and outgoing long wave radiation. Indirectly aerosols also affect cloud droplet size (Twomey et al., 1984), cloud life time and cloud extent (Ackerman et al., 2000), precipitation process (Albrecht, 1989) and electrical properties of clouds (Westcott, 1995; Stallins and Rose, 2008; Kar et al., 2009; Siingh et al., 2008, 2011). CAPE and surface temperature are positively correlated with lightning flashes and convective rain (Penki and Kamra, 2012a,b, 2013; Siingh et al., 2013, 2014). The sea surface temperature (SST) is strongly related to atmospheric instability, significantly increases moisture advection and hence increases rain fall and lightning activity.

Reeve and Toumi (1999) suggested poor correlation between SST and lightning activity over sea, whereas Petersen et al. (1996) and Rivas Soriano et al. (2001) reported good positive correlation between lightning flashes and SST for the Arabian sea (correlation coefficient ~0.85) and Bay of Bengal (correlation coefficient ~0.92). Tinmaker et al. (2010) showed that SST of the Arabian sea and Bay of Bengal play a crucial role in the development of thunderstorm and lightning activity over the adjoining peninsular region of India. In order to understand this complex behavior, we decompose the relationships between SST and lightning into their components: (1) SST to rainfall amount, (2) lightning flashes and SST for a given rain fall amount.

Interaction of the mesoscale with the short-lived convection is a subject of great contemporary interest and mainly determines the precipitation and electrical properties of the resulting cloud systems in the area. Tropical regions are most suitable to study such interactions. In our area of investigations, the mesoscale convective activity embedded in the Asian monsoon system strongly interacts with continental, orographical and the sea/land breeze – induced convective activity (Romatschke et al., 2010; Medina et al., 2010). In this paper, we analyze lightning flashes and convective rain rate, SST, meteorological parameters, AOD and related parameters over the Indian peninsular (region $R_1$) and Indo-China peninsular (region $R_2$) regions and compare the results. The region $R_1$ lies between 8–18°N and 73–83°E; whereas the $R_2$ lies between 8–18°N; 98–108°E (Fig. 1). The selected regions belong to the same latitude range but different longitudes having different meteorological characteristics in different seasons. In $R_1$ region the Indian Summer Monsoon (ISM) operates, whereas $R_2$ region is an interface of the Indian Summer Monsoon and the Western North Pacific Summer Monsoon (WNPSM) (Wang and Lin, 2002). In both the ISM and WNPSM, the low level winds change from winter easterlies to summer westerlies.

## 2. Data analysis

The Indian peninsular region is bounded by the Arabian Sea on the west and the Bay of Bengal on the east, with an average elevation of 616 m. The mountain range of Western Ghats running along the western coast of India have mountain peak exceeding 2000 m in height with a gradual slope to sea level on the eastern side. Meteorological features in this region include development of an off-shore trough along the west coast of the southwest India during the monsoon season, a warm pool of air off-shore southern tip of India in the pre-monsoon month, and the north–east monsoon activity over south–east peninsular India during the post monsoon. These features influence and often cause development of thunderstorm with intense lightning activity. The Indo-China peninsula has an average elevation of 116 m and is bounded by the Bay of Bengal on its west and the South China Sea on the east. Moisture laden southwest

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