

Chapter-1

Introduction

South Asia experiences two monsoons, Southwest monsoon or summer monsoon during June to September and the Northeast (NE) Monsoon or winter monsoon during October to December. While the boreal summer monsoon (June to Sept) is responsible for a major portion of annual rainfall over India, rainfall received during the NE monsoon season (Oct-Dec) is also important, especially for the south peninsula, Sri Lanka and Maldives. During the southwest monsoon season, the southeastern parts of India remain in the rain-shadow region and receive moderate rains.

NE monsoon is associated with the seasonal reversal of surface and lower tropospheric winds, which starts by October. During the southwest monsoon season, surface pressure gradient is directed from the Indian ocean to land with southwesterly monsoon winds in the lower troposphere. During the NE monsoon season, the pressure gradient reverses (from land to the Indian ocean) resulting in northeasterly trade winds, which is the basic state of the system. This change in surface pressure gradient and lower tropospheric winds is associated with the southward movement of the continental tropical convergence zone (CTCZ) and the subtropical anticyclone in the upper troposphere. Therefore, the NE monsoon is often described as the retreating phase of the southwest monsoon.

In a broader perspective, it is also associated with the northern hemispheric winter circulation dominated by a strong surface high pressure region over Siberia, a primary low over eastern equatorial Pacific region and secondary shallow lows over the north Indian ocean (Geetha, 2011, Raj 2012). A salient feature of the seasonal circulation during the winter monsoon is the low-level northeasterly flow over the Indian subcontinent and southeast Asia. There are similarities in circulation and rainfall patterns of southeastern peninsular India and other South / Southeast Asian regions and also the established roles of Siberian High, sub-tropical westerly jet stream and the

teleconnection influences of global parameters such as ENSO on the NE Monsoon rainfall (Geetha 2011). There is an asynchronicity in the establishment of northeasterlies over the Bay of Bengal and the South China Sea; the northeasterlies appear over the Bay of Bengal in late October, a month later than over the South China Sea (Sengupta and Nigam, 2019).

NE monsoon is relatively dry, stable and has less vertical extend compared to the southwest monsoon. The India Meteorological Department (IMD) refers to the October to December period as the northeast monsoon, which is a part of the northeast trades (Dhar et al., 1982, Dhar and Rakhecha, 1983). Dhar and Rakhecha (1983) studied monthly rainfall data for a 100-yr period (1877-1976) to investigate the association between the northeast and southwest monsoons over Tamil Nadu, and concluded that summer rainfall is negatively correlated with NEM rainfall.

NE monsoon rainfall exhibits variability from diurnal to synoptic, intra-seasonal and inter-annual time scales. The inter-annual variability of the NE monsoon rainfall influences agricultural production and water resources over south peninsular India. The NEMR affects the productivity of rice and maize in the provinces of Tamil Nadu and Andhra Pradesh (Krishna Kumar et al., 2004). During the years when the NE monsoon is deficient it has been noted that there is a considerable decrease in agricultural production over the region. The NE monsoon rainfall is highly variable both spatially and temporally. The coefficient of variation (inter-annual) of the NEMR averaged over the five subdivisions is 25%, which is more than that of the southwest monsoon rainfall averaged over the country as a whole (10%). South peninsula is well known for large year to year variability. In 2015, the city of Chennai experienced deluge in 2015, which resulted significant loss of life and property. Four years later, in 2019, Chennai city experienced severe water shortage and crisis. During the NE monsoon season, south Asia also experiences many extreme weather events like heavy precipitation, strong

winds and floods. Some of these extreme events are associated with the passage of tropical cyclones forming over the Bay of Bengal.

In the literature, there is a controversy about using the term “Northeast” monsoon (IMD, 1973). As per the classifications given by the India Meteorological Department (IMD), the October-December period constitutes the “Post-monsoon season”. It is also known as “the Retreating Southwest Monsoon Season”, as the monsoon convergence zone shifts to lower latitudes during this season. Mr Blanford, who was the first Director General of the India Meteorological Department (IMD) in his Memoirs on “Rainfall of India” raised the question about the term “Northeast Monsoon Rains” (IMD, 1973). IMD discussed this aspect on many occasions and the IMD decided to retain the term. IMD recommends that “the term Northeast Monsoon should continue to be used for rainfall season over south peninsula during October to December”. Subbaramayya (1976) had examined meridional sea-level pressure profiles over India, the Atlantic and Pacific and of winter rainfall over India and Sri Lanka and suggested that that the so-called north-east monsoon over south-east India differs little, either in wind in weather, from the generality of the northern-hemisphere trade winds.

Compared to the southwest monsoon, adequate attention was not given to address various aspects of the NE monsoon. There are only a few research papers addressing NE monsoon over south Asia. After the classic work by Srinivasan and Ramamurthy (IMD 1973), a few papers have been published on different aspects of NE Monsoon. The review article by Raj (2012) in the Monsoon Monograph edited by Ajit Tyagi et al. is an excellent documentation of various aspects of NE Monsoon season over India. The papers by Sreekala et al. (2012) and Rajeevan et al. (2012) also are good reviews on the variability of NE monsoon rainfall and its prediction aspects. Amudha (2016) using modern meteorological data analyzed the characteristics of Indian Northeast monsoon and cyclonic storms of the North Indian Ocean. The study revealed

many interesting aspects of the movement of clouds and other rainfall regimes associated with the NE monsoon.

These publications contain all relevant references of research papers on NE monsoon published till 2012. Since then, there is growing research interest on NE Monsoon with much more papers are getting published in the recent years (Satyanarayana et al., (2020), Raj and Amudha (2022), Raj and Geetha (2008), Balachandran et al., (2006), Nair et al., (2013), Dash et al., (2019), Naidu et al., (2012), Maharana et al., (2022), Prasanna et al., (2019), Mondal and Choudhari (2022), Suneetha et al., (2018), Prasanna et al., (2021), Geetha and Balachandran (2021), Saikranthi and Chiranjeevi (2022), Mishra and Nagaraju (2021), Geetha and Raj (2014), Amudha et al., (2016), Prasanna et al., (2020), Prakash and Gairola (2013), Kiran Kumar and Singh (2021), Pattanaik and Mohapatra (2017), Parvathi et al. (2017), Sengupta and Nigam (2019), Mishra and Bharadwaj (2019)). The paleoclimate aspects of NE monsoon are recently discussed in Achyuthan (2021) and the references therein.

In spite of the growing research interest, there is a lot of scope for an exhaustive compilation of research results based on recent data products and forecasting tools on different aspects of NE monsoon over south Asia. During the last one decade, our understanding on diurnal, intra-seasonal, seasonal variability, monsoon onset, synoptic weather systems during the NE monsoon season has improved substantially. At the same time, our capability to make more accurate forecasts also has improved by using the state-of-the-art dynamical models or Numerical Weather Prediction (NWP) models. The present monograph is designed accordingly to include more recent research results, which have resulted in better understanding of NE monsoon and its variability in all time scales and their prediction aspects. Such a compilation would be very useful for forecasters as reference material and also students, young researchers venturing into NE monsoon research.

In this monograph, the climatological features of NE monsoon are discussed using long term and updated climate data sets. Discussions on mean temperatures, sea level pressure, upper air circulation features, monthly and seasonal rainfall, heavy rainfall, extreme winds, characteristics of monsoon clouds, thunderstorm and lightning are included. The variability of NE monsoon from diurnal, synoptic, intra-seasonal and seasonal time scales is also discussed in detail with a few case studies. The details of synoptic systems affecting south peninsula and Sri Lanka during the season and forecasting aspects of these weather systems are also discussed. A brief summary of the verification of forecasts of NE monsoon rainfall over India using two different weather prediction systems is included as reference material for forecasters. A separate section of NE monsoon season over Sri Lanka is also provided to widen the scope of this book. The grey areas where more research is required are identified and discussed.