Chapter I

INTRODUCTION
EXPLORING THE ROLE OF REGIONAL PARAMETERS

1.1 Introduction

'I seek the blessings of Lord Indra to bestow on us timely and bountiful monsoons'

This opening remark by the finance minister, Pranab Mukherjee, in his presentation of the budget for 2011-12 in the Lok Sabha, drives home the point that the monsoon continues to have a substantial impact on the Indian agricultural production and the economy, even after six decades of development [Gadgil and Gadgil, 2006]. Thus, understanding and prediction of the variability of the monsoon rainfall over the Indian region is extremely important. With the exception of Jammu and Kashmir in the extreme north and in Tamil Nadu in the south, 80-90% of the annual rainfall over the country occurs mostly during the summer monsoon season. The summer monsoon is an affair, which is preceded by several months of working up a thirst so that when the waters come they are drunk deep and with relish. With the monsoon the tempo of life increases. Since time immemorial, monsoon rains have been the bedrock of India’s food security and of the very survival of land and its people. Farmers have learnt to time their crop-seasons in order to get the best out of the monsoon rains. Moreover, when the Indian agriculture suffers, it will also affect a lot of secondary agro-based industries. Any adverse effect on farming will affect the purchasing power of the people as well. Taking these factors into consideration, the monsoon is aptly called the ‘real finance minister’ of India.

In the Indian context, the monsoon is a priceless input to a country’s economy. A large part of India’s energy production is dependent on monsoon rains because a great deal of India’s electricity is generated by hydel power provided by the monsoon rains. Forests, ecosystems and vegetation are highly dependent on the monsoon rains. A good monsoon is also essential to protect and propagate the biodiversity, not only flora but fauna as well. Additionally, the monsoon affects a very large coastline of India, which harbours a very large population. There are large coastal mega cities like Mumbai and Kolkata, which serve as the crux of the commercial and economic activities of the country. The monsoon is literally the central point around which life in India keeps revolving. Thus, a reasonably correct prediction of monsoon has become a significant stabilizing factor in a socio-economic milieu of large population.

The vulnerability of the Indian economy to the vagaries of the monsoon has reduced over recent years because of the emergence of new growth drivers such as
software, telecom, pharmaceuticals and other sectors. Even then, it cannot be emphatically said that the monsoon is no longer of any consequence. Variations of Indian summer monsoon on wide range of space and time scales are well known and still extensively documented. This raises the question, “How much do we understand about the monsoon?” In fact, the unique attribute of the monsoon is the large variation of the winds with season. However, for Indians, it is not the winds, but the rains that they bring along with them, that assume a far greater importance. The dominant characteristics of the monsoon systems, the annual cycle itself, has led the inhabitants to divide their lives, customs and economies into two distinct phases “the wet” and “the dry.” It is important to note that year-to-year variation of rainfall averaged over the Indian region during the southwest monsoon is characterized by a standard deviation, which is only about 10% of the long time averaged rainfall of about 85 cm. Yet, this meagre inter-annual variation can lead to the occurrence of widespread droughts and floods that imparts long-lasting economic and social impacts. The effect of droughts is accentuated by the higher coefficient of variability over regions of lower seasonal rainfall (Parthasarathy, 1984).

It is obvious that the Indian southwest monsoon, being such a large component of the global weather and climate system, will have positive and negative associations with other entities. The weakening of global linkages in the recent period led to a spurt of studies of the sea surface temperatures over regions of the globe to discover afresh their relationships with the monsoon that had been hitherto neglected.

Predicting the likely physical behaviour of the monsoon system and the resulting distribution of rainfall over different parts of India in different phases of the monsoon season is an extremely challenging task. What people ideally want is a calendar of rainfall events to be drawn up well in advance of the arrival of the monsoon so that they can plan and organize their activities during the monsoon season accordingly.

Monsoon prediction is, therefore, of great value in any efforts aimed at minimizing the agricultural risks and maximizing the crop yields. However, a single common prediction cannot serve all purposes. Different types of predictions of the behaviour of the monsoon are required to be generated on appropriate time and space scales, to suit applications ranging from national and state level policy making, to managing crops in farmers’ fields. People are not therefore satisfied with just one All-India seasonal rainfall figure and they desire to have forecasts for smaller space and time...
scales appropriate to practical applications particularly agriculture. The following section deals with the various research studies directed to understand the monsoon mechanism.

1.2 Summary of some important studies

The importance of Indian monsoon rainfall to the county’s economy and also as a major circulation parameter has motivated many studies during the last century, pertaining to its characteristics, variability, teleconnections with regional/global circulation features and long range predictions. Efforts are being made during the last one century about the long-range forecast of Indian monsoon rainfall. No discussion about the prediction of the Indian South-west monsoon can be regarded as complete without reference to the pioneering efforts of Henry Blanford, John Eliot and Gilbert Walker. Amongst all British meteorologists who worked in India, the name of Sir Gilbert Walker ranks high by any standard. He had the longest tenure of 20 years as the Director General of IMD. Walker’s work in the field of monsoon meteorology was so robust that eighty years after he left India, his statistical approach continues to be used for long range forecasting of the Indian southwest monsoon rainfall. After the pioneering work of Walker, several workers in India as well as outside India have added new large-scale components of the SW monsoon in different years since 1950. The prominent amongst them are:

- Upper Tropospheric Tropical Easterly Jet Stream (Koteswaram 1958a)
- Global Scale East-West divergent circulation in the upper troposphere (Krishnamurti 1971) with wave number two structure with two divergent centres over Tibetan and Mexican highs and two convergent centres over the mid-Atlantic and mid Pacific troughs
- Low Level Jet (LLJ) off Somalia Coast (Findlater 1969) and its extension over Peninsular India (Joseph & Raman 1966) which is the artery for moisture supply for monsoon in the lower troposphere.
- Maintenance of mean monsoon trough over India (Keshvamurthy 1968, Keshvamurthy and Awade 1970), heat and moisture budget of the monsoon trough (Anjaneylu 1969) and dynamics of tropospheric circulation during
contrasting monsoon seasons (Kanamistu and Krishnamurti 1978, Awade et al 1984 and others)

- Marcarene High (Krishnamurti and Bhalme, 1976)
- Presence of temperature inversions in the lower troposphere over the Arabian Sea, which were, for the first time, discovered from the aircraft reconnaissance during the IIOE period (Colon 1964). They were also studied with SMONEX aircraft data. Recently, during ARMEX – 2002, their role for widespread subsidence over the Arabian Sea and even inside northern and central India have been discussed by Bhat ( 2006) and Rao & Sikka (2005)
- Role of double equatorial trough, the so called northern hemisphere near equatorial trough and the southern hemisphere near equatorial trough over the Indian Ocean (Raman and Dixit 1964)
- Energetics of the northern hemisphere and summer circulation over the tropics and regional South West Monsoon regions were diagnosed in several studies during 1970s to 1990s (Murakami 1978, Kanamitsu and Krishnamurti 1978, Mohanty et al 1983, 2005, Awade et al, 1984, and Rao et al 1999). These studies brought out the interactions between the planetary-scale waves, medium-scale waves and short-scale waves in the maintenance of circulations and differences in good and deficit monsoon years.
- Heat sources and moisture sinks fluctuations (Bhide et al 1998)

From the times of Blanford, Eliot and Walker, until 1960, a variety of predictors including snowfall, sunspot numbers and river discharges were tried by IMD in its long-range forecasting schemes (Jagannathan, 1960). Recently, Parthasarathy et al. (1998) and Gowariker et al,(1989, 1991) have made a comprehensive study of many parameters related to the Indian monsoon rainfall and developed regression equations. However, the search for new parameters continues, as no forecasting scheme is as yet consistently successful over a period of time. In the sixteen-parameter model developed by Gowariker et al. (1991), the SST’s over Indian region have not been considered. There is sufficient evidence both on empirical and theoretical basis to believe that sea surface temperatures exert significant control over the atmosphere. Many workers viz. Ranjit Singh (1983), Joseph and Pillai (1984), Vinayachandran and Shetye (1991), Sadhuram et al. (1991) have brought out the importance of SST over Arabian sea as an input parameter for the
Indian monsoon rainfall. In addition, the parametric model of Gowariker et al. gave only a qualitative indication of whether the AISMR was likely to be normal, deficient or excess. The model did not make use of the actual values of the correlation coefficients of the 16 parameters, but only their positive/negative signs.

This model, which had been providing correct prediction of normal monsoon since its introduction until 2001, failed in 2002, when the monsoon failed badly. This resulted in the formulation of two new power regression models for long range forecasting of monsoon, based on 8 and 10 parameters respectively. It is also desirable that statistical and empirical techniques for long-range forecasting on monthly and seasonal scales be developed and continuously refined to produce operational long range forecasts.

Sometimes, the necessity of producing long-range forecasts has compelled investigators to develop empirical relationships between different facets of the coupled atmosphere-ocean land system, even if a plausible physical basis for such a relationship is not understood. However, such empirical attempts have sometimes led to the discovery of important processes in the atmosphere. It therefore seems appropriate, and perhaps even desirable, that the existence of significant empirical relationships among different components of the atmosphere-ocean-land system be documented and discussed because it might provide some insight into the underlying physical and dynamical processes. It is in this spirit that this research presents some empirical evidence of relationships between monsoon rainfall and other features of the planetary scale circulation.

1.3 Aims and objectives

Keeping these aspects in the background, the present study aims at identifying regional and global meteorological parameters, which have more influence on inter-annual variability of Indian monsoon rainfall. To achieve this aim, the following objectives are proposed:

- Assessment of some regional meteorological parameters, namely sea surface temperature (SST) and wind stress
- Evaluation of global meteorological indices such as El Nino, Southern Oscillation Index (SOI) and North Atlantic Oscillation Index (NAOI)
- Exploring the relationship between the above parameters and the rainfall over the Central India and Peninsular India.
• Examining the relationships between the regional and global meteorological parameters at micro-spatial units

1.4 Data sources

The following data were considered for the period of 1951 – 2012:

a) Summer monsoon rainfall data over the entire country were collected from India Meteorological Department (IMD).

b) Monthly rainfall datasets were obtained from IMD for the homogeneous regions (HR) of Central India and South Peninsula, along with their meteorological subdivisions.

c) Monthly SST data over the Indian Ocean bounded by latitudes 30°N to 30°S and longitudes 40°E to 120°E were acquired from National Centers for Environmental Prediction (NCEP) reanalysis data.

d) Monthly mean zonal (u - component) and meridional (v - component) winds at 850 hPa were procured from the above-mentioned NCEP reanalysis dataset (This dataset was available from 1958 – 2012).

e) Monthly data related to El Nino, SOI and NAOI were obtained from www.cpc.ncep.noaa.gov. In addition, ENSO indices were also procured from the same website.

1.5 Methodology

Monthly and seasonal climatology maps for SST and wind fields were prepared over the study area. Based on the criteria of annual deviation of 4° - 6°C in SST anomalies along with wind stress varying between 20 to 40 m²/s², four pockets were identified over the Indian Ocean to find out their predictive skills, if any, with the monsoon rainfall. The relationships between the SSTs of the pockets and summer monsoon rainfall were examined from large to finer spatial scales.

The associations within and between the global regional meteorological parameters and monsoon rainfall was assessed to understand the changing global relationships. For this purpose, correlation coefficients were computed between each of the parameters discussed above and the summer monsoon rainfall.

Emphasis of the study was given to the changes occurring in the circulation patterns in the recent period. Thus, the spatial variability of rainfall over various
subdivisions was studied by analysing the CCs obtained in the recent period. The detailed methodology considered for the analysis is given in the respective chapters.

1.6 Study area

Traditionally, India has been divided into what are known as meteorological subdivisions (MS), which have a common weather and rainfall pattern within themselves, and are administratively convenient as they are drawn along state and internal boundaries. These MS are grouped under four homogeneous regions (HR), namely Northwest India, Northeast India, Central India and South Peninsula. Out of these, the HR of Central India and South Peninsula are taken as the study area (Fig. 1.1), because they depict the true character of the southwest monsoon system originating in the tropical waters. However, the rainfall of other two HRs is influenced by the mid-latitudinal systems, and hence forms another topic for research.

1.7 Arrangement of the text

The entire work has been organized in five chapters:

First chapter deals with the introduction of the subject and discusses the aims and objectives of the study. The chapter also enumerates the data obtained from different agencies and government publications and explains the methodology adopted for executing the present work. In addition, the chapter deals with the scope of the present study.

Second Chapter gives an overview of the climatological features of the summer monsoon circulation. The spatial distribution and temporal variability of various climatic elements over the region forms an important aspect for this chapter.

The all-India summer monsoon rainfall is dominated by a high inter-annual variability. The assessment of various regional meteorological parameters such as SST and wind patterns was carried out in the third chapter to get more insights to this inter-annual variability. Based on SST and wind stress, four pockets were identified over the Indian Ocean. The chapter also discusses the climatology over the same. In addition, the CCs worked out between the SSTs of different pockets and monsoon rainfall over various spatial units are discussed in this chapter.

As next step, possible connections of this inter-annual variability with several global circulation parameters, such as El Nino, SOI and NAO were examined in the
Fig. 1.1 Study area with its meteorological subdivisions
fourth chapter. The chapter also includes the regression equations worked out for different pockets over the Indian Ocean governing the rainfall of some MS.

Based on the results obtained, the conclusions and major findings are discussed in the fifth chapter.

1.8 Scope of the study

For the millions inhabiting monsoon regions, the seasonal as well as interannual variation of rainfall associated with the monsoon system is of far greater importance than the seasonal variation of winds. The space-time variation of rainfall has such a large impact on the resources of the region that it has been said that the Indian economy is a gamble on the monsoon rains. This necessitates search for suitable parameters that can predict the monsoon rainfall. Monsoon prediction studies have utilized indicators of atmospheric circulation, land surface conditions, and Indian and Pacific Oceans SSTs (summarized in Webster et al. 1999). The predictive relationship between Indian Ocean SST and monsoon rainfall remains especially poorly characterized, particularly at lead times greater than 1–2 months before the boreal summer monsoon season. This study assesses the relationship between SST variations in the tropical Indian Ocean and Indian monsoon rainfall, including the temporal stability of these linkages in the recent period

This study explores the annual cycle of SST–Indian monsoon rainfall relationships and reveals that Indian Ocean SST is significantly correlated with the all-India rainfall index several months preceding the onset of the monsoon. We extend these studies by examining the relationship with global parameters also, noting especially the change of the character of the correlations in the recent period.