Chapter 7

Summary and Conclusions
7.1 Summary and Conclusions

Asian Summer Monsoon is a phenomenon occurring every year and is global in character. It affects a large portion of Asia and parts of Africa and the western Pacific Ocean. Its onset, its activity during the season, and its withdrawal are subject to variations that sometimes are large. Since early times, the term monsoon has been used to signify any annual climate cycle with a dominant seasonal wind reversal. Monsoon onset can be described as a part of the annual cycle of the large-scale circulation over the monsoon region. Monsoon is an important phenomenon of great significance both economically and meteorologically. A delay in the onset by 10 to 15 days would adversely affect the crop output and result in low water levels in hydroelectric reservoirs causing reduction in the generation of hydroelectricity.

The main aim of this study is to understand the onset of summer monsoon over south Asia with a special emphasis on the Monsoon Onset over Kerala (MOK). The thesis contains seven chapters. In the first chapter a very detailed literature review pertaining to the thesis is presented. This gives a broad description of regional monsoon systems and monsoon onsets over Asia and Australia. Asian monsoon includes two separate subsystems, Indian monsoon and East Asian monsoon. Mean onset of monsoon over Kerala (by IMD) during 1901-2004 is June with a standard deviation of 8 days. Extreme dates of onset are 11 May in 1918 and 18 June in 1972. Monsoon onset was more often in June than in May during the period 1901-1930, and the reverse occurred during 1931-1970. Chapter-2 gives a detailed description of the data sets and the atmospheric General Circulation Model used in this thesis.
In Chapter-3, which forms the core of this thesis, the main focus is to understand the Asian Summer Monsoon onset processes. The salient features brought out are:-

a) Two Intra Seasonal Oscillation (ISO) cycles (70 days totally in many years) are needed to complete the Asian Summer Monsoon onset process. During this period large scale organized convection occurs systematically at different locations of a big area (10S-20N, 50E-120E) in which the spatially averaged vertically Integrated Water Vapour increases steadily over the period and reaches very high values at MOK. Strong air-sea interaction over the north Indian Ocean is noted during this period. Warm pool SST reaches a peak in the Bay of Bengal first. Convection, which forms in association with this warm pool, cools it. The peak in SST over the Arabian Sea warm pool follows this cooling. After MOK Arabian Sea (SST) also cools.

b) In Indian and West Pacific Oceans, organized convection shifts from south to north of the equator, which completes the first ISO of 35 days (P-14 to P-8). The second ISO involves the shift of convection from P-7 when the center of convection lay over south of Bay of Bengal near the equator, to P-5 when convection has moved to southeast Asia and South China sea (onset of South China sea monsoon in many years). At P-3 an area of convection forms over the equatorial Arabian Sea, intensifies and moves to Kerala latitudes bringing about MOK.

c) Convection forms not near the center of the warm pool, but in the area to its south near the equator where the gradient of SST in the north-south direction is large. This is suggested to be as per the Lindzen and Nigam (1987) model.
d) The onset of monsoon over Kerala is caused by a large area of active convection from Southeast Arabian Sea to South China Sea through the Bay of Bengal which forces a cross equatorial Low Level Jetstream of the type described by Joseph and Raman (1966) and Findlater (1969), crossing the equator near the east African coast. Thus MOK is a planetary scale phenomenon and not just an increase of rainfall of Kerala.

A sustained increase in rainfall activity has been traditionally used to demarcate the onset of the monsoon. IMD has been declaring monsoon onset for the last more than 100 years using the data of daily rainfall of Kerala and Arabian Sea Islands and also factors like the strength and depth of monsoon westerlies of the lower troposphere and the depth of the moist layer. The method in use by IMD to determine the date of MOK is a subjective one. Definite threshold criteria for the factors used were not defined. Declaration of the date of monsoon onset depended heavily on the experience of the meteorologist. A method for the objective determination of the date of MOK has been developed in Chapter-4 for operational use. The parameters used are (1) the daily depth and strength of the monsoon westerlies just south of Kerala averaged between longitudes 70 and 85E and latitudes 5 and 10N, (2) the spatial pattern of the wind at 850 hPa and the spatial pattern of OLR (to distinguish between Pre-Monsoon Rain Peak (Joseph and Pillai, 1988, and MOK) and (3) the movement of convection from the equator to Kerala latitudes in a Hovmuller diagram of OLR averaged between longitudes 65E and 80E to ensure widespread rainfall over Kerala and southeast Arabian Sea at MOK). Using this method we have objectively determined the dates of MOK for each year of the period 1960 to 2003. The difficulties in defining monsoon onset objectively and unambiguously have been discussed in this chapter through several case studies. The method outlined in this chapter has given an objective form to what
IMD was doing all along in a subjective way as described in Chapter-1. The mean of the objectively derived date of MOK for the period 1960-2003 is 2June, with a standard deviation of ≈ 9 days. The linear correlation coefficient between this series and the series giving the IMD declared dates of MOK is 0.82.

In the ten-day period just prior to MOK there is strong positive feedback between convection and the low-level wind field as seen from the study described in Chapter-3. In Chapter-5, we examine qualitatively whether the T80 Global spectral model in use at the National Centre for Medium Range Weather Forecasting (NCMRWF), New Delhi, is able to reproduce this feed back between these two large-scale parameters. The initial conditions of atmosphere and SST of ten days prior to MOK were used as input to the model. SST was kept constant during the next 10 days. The model was found to simulate the positive feedback between convection and the low level wind. Simulation was done for the period 1995-2003 (9 years). We examined the individual years of this 9-year sample. In 7 out of these 9 years we could simulate the positive feed back process between convection and low-level monsoon winds over north Indian Ocean during the 10 days prior to MOK. A composite of these 7 years of the model output as well as the composite of the corresponding observations in OLR and 850hPa wind field when compared qualitatively showed clearly the positive feedback between convection and wind prior to MOK.

In Chapter-6, two methods (one an analogue method, using the systematic changes in OLR and 850hPa wind flow during the two ISO cycles prior to MOK as described in Chapter-3 and another using Monsoon Hadley Circulation Index) have been suggested for the prediction of the date of MOK on the medium range and slightly longer time scale. The slow and systematic evolution of convection (OLR) and 850hPa wind fields prior to MOK can be used for the prediction of the date of
MOK following an analogue method. Using this method it should be possible to predict monsoon onset 2 to 3 weeks prior to MOK. Using a Monsoon Hadley Circulation Index we may be able to predict the date of MOK about a week ahead. However we have to test the possibilities of these two methods for prediction in the hindcast mode using the data of 30 or 40 years.

7.2 Scope for future studies

(a). It is seen from this study that the duration of the different phases of the onset process are dependant on the period of ISO. We may be able to predict the date of MOK more than a month ahead, if we know the period of ISO. Following the pentad-to-pentad evolution of convection and wind prior to MOK, it may be possible to predict the monsoon onset more than ten days ahead even if we do not know the period. More work is needed on these two aspects.

(b). Based on the study of the monsoon onset process, presented in Chapter-3 modeling studies can be done for better understanding of the ocean- atmosphere interaction especially those associated with the warm pool in the Bay of Bengal and the Arabian Sea. We may also try to simulate the changes in deep convection and wind during a 60-day period prior to MOK.