CHAPTER 1
INTRODUCTION

The Intertropical Convergence Zone (ITCZ) is a zone of low-pressure near the equator where two easterly trade winds originating from the Northern and Southern hemispheres converge. This zone of enhanced convection, cloudiness, and rainfall constitutes the rising branch of the meridional Hadley circulation (Fig. 1.1). The non-uniform distribution of land and sea introduces zonal asymmetries in heating, which drive an east-west overturning, known as the Walker circulation, wherein air rises at longitudes of the heating and sinks at the other longitudes. The three-quasi permanent centers of the rising branch of the Walker circulation are located over Indonesia, central Africa, and the Amazon basin (Fig. 1.2). From satellite data, the ITCZ can be identified as a meandering band of cold infrared effective temperature and high albedo located over the warmest equatorial region.

The ITCZ plays an important role on the atmospheric energy balance (Waliser and Gautier 1993) and the earth’s climate (Zhang 1993). The excessive heat absorbed at the surface over the tropical oceans is transferred to the lower troposphere through evaporation then transported to higher altitudes through convection and latent heat release and to higher latitudes through the Hadley circulation. The convective latent heat release plays a vital role in driving low-latitude circulations and in supplying energy to balance the radiative heat losses and ‘fuel’ the wind systems of middle and high latitudes. Furthermore, the enhanced cloudiness associated with convective cloud systems contributes significantly to the planetary albedo, absorptivity, and transmisivity of the
incident solar radiation. Inside and outside the ITCZ, the fluxes of heat, moisture, and momentum and radiation through the ocean surface and in the atmosphere differ dramatically. Therefore, the structure, position, and migration of the ITCZ are important in defining and analyzing the earth’s climate on a global scale. Accordingly, the strength and character of the air-sea coupling are important in determining the earth’s climate on a local scale.

Figure 1.1. Schematic diagram of the Hadley circulation over the tropics which consists of rising air near the equator and sinking air at subtropical latitudes.
Nearly 45% of the world’s population live in the tropics (World Bank Atlas, 1992). Almost all facets of societal and economic activities in the tropical countries are critically dependent on the climate variations in the regions. For example, the major agriculture productions in Asian countries can be accounted for by the fluctuation of the monsoon rainfall (World Market Atlas, 1992). Because of the strong linkage of the tropical climate to the rest of the world through coupling with the global climate and economic systems, variability in tropical climate affecting economic productivity will have major global impacts. Through the implications mentioned above, it is obvious that advanced understanding and better predictions of the tropical climate will greatly benefit the social and economic aspects not only for the population in the tropical region, but also for the whole world.

A considerable number of observational and theoretical studies on many aspects concerning the ITCZ have been undertaken over the last few decades. The emergence of satellite era with its broad spatial coverage and long period of records has produced the
capability to estimate tropical convection with a variety of spatial and temporal scales (Winston and Krueger 1977; Heddinghaus and Krueger 1981; Waliser and Gautier 1993; Waliser et al. 1993). Therefore, rain estimation based on satellite-derived infra red and visible data appears to be the only way to obtain for a long continuous period over tropical oceans and inaccessible parts of land masses, though it is recognized that additional information derived from passive and active microwave sensors must be added to improve quantitative measurement of tropical rainfall (Simpson et al. 1988).

On the theoretical side, the understanding gained from analytical and numerical modeling approaches have considerably advanced the knowledge of the physical processes of the tropical convection (Pike 1972; Ramage 1974; Helfand 1979; Rind and Rossow 1984; Lipps and Hemler 1986; Xie and Philander 1994; Xie 1996; Oort and Yienger 1996; Liu 1997). However, the complex interactions between the atmosphere, oceans, and land masses remain an outstanding challenging problem for the understanding of the tropical climate. Observations readily verify this complexity. It appears that there is a distinct mode preference in response to the large-scale structure of the tropical atmosphere. Such preference scale would be described by the simple and linear dynamic methods. But, the tropical convection composes a wide spectrum of phenomenon that spans spatial scales ranging from planetary to mesoscale and time scales ranging from interannual to diurnal.

The most dramatic, most energetic, and best-defined pattern of interannual variability in the tropics is the global set of climate anomalies referred to as El Niño/Southern Oscillation (ENSO). The ENSO-related changes in precipitation, temperature, and other environmental variables have both direct effects (through drought,
flood, and extreme weather events) and indirect effects (through changes in transmission and outbreaks of infectious diseases) on human life as well as economic activities. Based on research achievements over the past fifteen years, scientists can now offer skillful experimental forecast of ENSO. Improved climate predictions related with ENSO, furthermore, will provide early warning of extreme climate events, and thereby, reduce both societal and economic vulnerability.

In view of the above considerations, the results of this study may have some practical implications. Based on improved analyses and modeling methods, the climate variations associated with the ITCZ in the tropics could be predicted, tested, and adjusted. The results could be made available as input information for the government, private organizations, and the public at large so as to adapt their plans and activities accordingly and to the best interest of the people. More specifically, this research aims to address six different tasks:

1. fundamental characteristics of the global ITCZ, such as the climatology, the standard deviation, the coefficient of variation, the meridional profiles, and the spatial and temporal variability.
2. the role of large-scale atmospheric circulation and sea surface temperature on tropical convection over the tropical Indian, western Pacific, central Pacific, eastern Pacific, and Atlantic oceans.
3. the relationships between sea surface temperature anomalies over the Pacific Ocean and convective anomalies over Indonesia during ENSO events and their long-term prediction.
4. the physical processes and dynamical interpretations of the ITCZ over the Indian Ocean and Indonesia during a normal and during an ENSO event.

5. the importance of meteorological processes associated with transport of air masses during forest fires in Indonesia.

6. the planetary boundary structure over the Indian Ocean and its role on the connection between continental emissions and impacts over the ITCZ.

To achieve these objectives, a hierarchy of methodologies from simple statistical analysis to intermediate numerical simulation is utilized. The statistical analysis including its key objectives - data reduction, inference, and the identification of relationships - is performed to provide a basic representation of observations. Meanwhile, the numerical simulation is used when the complexity and non-linearity of the air-sea-land interactions pose great difficulties if simple models are used.

In Chapter 2, previous relevant studies are reviewed as background references. The statistical analysis and numerical models used in this study are presented in Chapter 3 and Chapter 4, respectively. The extensive results and discussion are given in Chapter 5 to Chapter 10. Summary and conclusions are presented in Chapter 11.