CHAPTER 11

SUMMARY AND CONCLUSIONS

The ITCZ is a key component of the earth's climate system because it constitutes one of the most energetic circulations causing active convective activities in the troposphere. Climate variations in the tropics are strongly determined by the wide range of temporal time scales of the ITCZ system. Since almost all facets of societal and economic activities in the tropical countries are critically dependent on these climate variations, a better understanding of the climatology, variability, mechanisms, physical processes, and predictability of the ITCZ is of great importance.

In this research, statistical analyses are used to investigate the climatology and variability of the ITCZ, the relationship between SST, large-scale circulation, and deep convection, and the relationship between SSTs in the tropical Pacific Ocean during ENSO events and anomalous convection over Indonesia. The analysis from monthly OLR data for 1975-97 period suggests that there are a number of distinctly different ITCZ regimes in terms of their structure and dynamics. Over the Indian and western Pacific oceans, the ITCZ is characterized by a broad latitudinal band of cloudiness nearly symmetric about the equator. Over the central Pacific Ocean, two distinct peaks of convection are found at 7°N and at 9°S due to deep convection over the warm pool and an extending southeasterly direction of the South Pacific Convergence Zone (SPCZ). Over the eastern Pacific and Atlantic oceans, the ITCZ is characterized by a narrow well-defined structure of clouds occurring along 5°N to 9°N.

The migration of the ITCZ depends strongly on a wide range of temporal time scales. The power spectra density analysis shows that on interannual time scale (17-84 months), the most dominant feature is the eastward movement of the ITCZ from Indonesia to the central Pacific due to anomalous warm SSTs in the eastern-central Pacific Ocean. On the annual time scale (9.5-14 months), the north-south movement of the ITCZ follows the annual solar cycle and the zone maximum surface heating. This seasonal movement is generally greater over the lands than over the oceans. On the semiannual time scale (2-8.5 months), the migration of the ITCZ is dominated by the Madden-Julian oscillation between the Indian and western Pacific oceans.

Although convection tends to maximize at warm SSTs, increased deep convection is also determined by the divergence (DIV) associated with large-scale circulation. An analysis of the relationship between SST and deep convection shows that under subsidence and clear conditions, there is a decrease in convection (increase in OLR) at a maximum rate of 3.4 $Wm^{-2}\,°C^{-1}$. In the SST range of 25°C to 29.5°C, a large increase in deep convection (decrease in OLR) occurs in all domains. The OLR reduction is found to be a strong function of the large-scale circulation in the Indian and western Pacific oceans. Under a weak large-scale circulation, the rate of OLR reduction is about -3.5 $Wm^{-2}\,°C^{-1}$ to -8.1 $Wm^{-2}\,°C^{-1}$. Under the influence of strong rising motions, the rate can increase to about -12.5 $Wm^{-2}\,°C^{-1}$ for the same SST range. The overall relationship between large-scale circulation and deep convection is nearly linear. A maximum rate of OLR reduction with respect to DIV is -6.1 Wm^{-2} (10^{-6} s^{-1}) in the western Pacific Ocean. It is also found that the DIV-OLR relationship is less dependent on SST. For example, the rate of OLR reduction over the western Pacific Ocean for 26°C < SST ≤ 27°C is -4.2 Wm^{-2} (10^{-6} s^{-1}), while that for 28°C < SST ≤ 29°C is -5.1 Wm^{-2} (10^{-6} s^{-1}).

The ENSO event has a strong impact on the climate in Indonesia. The results from the EOF and CCA models show that warm (cool) SSTs over the eastern-central Pacific Ocean are associated with decreased (increased) deep convection over Indonesia. These correlations are seasonally dependent, which are strong during the boreal fall and winter months and weak during spring and summer months. Consequently, the predictive skills are generally high during winter months and much lower during summer months. The high predictability in the winter is at least partially due to the strongest El Niño signal during its mature phase. Meanwhile, the poor predictive skill in spring and summer may be from the weakest condition of the Southern Oscillation and from the so-called spring barrier in our predictive capabilities.

Numerical simulations are used as an additional tool to better understand the dynamics and the physics of the ITCZ system. The NRL/NCSU model and the PSU-NCAR MM5 are used to study the mean circulation and the associated convective activity over the Indian Ocean and Indonesia during two contrasting marine environments in 1997 and 1998. In general, both models are able to simulate low-level westerly winds during the 1997 northeast monsoon with well established ITCZ in the southern Indian Ocean up to 24 hours of integration. However, there are major shortcomings in the simulations at 48 hours of integration in maintaining and generating the westerly winds, particularly during the active period of the monsoon when the winds become stronger. In short-range simulations, the rapid deterioration of monsoon forecasts is attributed to the initial conditions, particularly moisture field. The impact of moisture initialization and also the establishment of appropriate thermodynamic and dynamic balance between temperature, moisture, and divergence fields and their compatibility with the parameterizations used in the models need to be explored.

When the synoptic-scale dynamic forcing of ENSO during the 1998 northeast monsoon dominates, the models can generally simulate mean wind flows characterized by the easterly winds over the Indian Ocean and weak westerly winds over the southeast Indian Ocean. Steady winds appear to assist in a better performance of the models.

Rainfall simulated from the NRL/NCSU model during the 1997 and 1998 northeast monsoons is more realistic than that from the PSU-NCAR MM5. Since the Kuo-Anthes scheme relies on grid-scale moisture convergence to determine whether convection can occur, an increased model resolution generally leads to greater moisture convergence, which in turn leads to the simulation of more convective rain. The NRL/NCSU model handles this condition quite reasonably. The PSU-NCAR MM5, on the other hand, needs a better PBL physics.

The distribution of rainfall during normal conditions in 1997 indicates strong relationships between low-level convergence, rising motion, and moisture content. While gradients of surface heat flux provide moisture near the surface, the low-level convergence is an important mechanism for moisture supply in the upper troposphere. During the ENSO event in 1998, a strong subsidence of the Walker circulation over the central-eastern Indian Ocean results in lack of surface kinetic energy and heat flux gradients, which in turn results in lower rainfall rates. In addition, diurnal variations of rainfall, vertical motion, and total surface heat flux over the Indian Ocean are prominent in the convective zone only during normal condition (non ENSO year).

Trajectories of air parcel during the 1997 forest fires in Kalimantan and the PBL structure and its diurnal variability during the INDOEX Intensive Field Phase 1999 are simulated by the PSU-NCAR MM5. A good agreement between the model results and analyses in simulating mesoscale wind circulations during the 1997 forest fires in Kalimantan would lead to improved trajectory analysis of the air pollutant's transport for research and operational purposes. Accordingly, the structure and diurnal variation of the PBL over the Indian Ocean which are simulated well by the PSU-NCAR MM5 would contribute to a better understanding of the connection between continental emission and the ITCZ during the northeast monsoon.