Chapter 7: **Summary and Conclusions**

The information on sea state condition is essential for open ocean and coastal operations. In the present thesis an attempt was made to study the variability of wave parameters, in particular Significant Wave Height (SWH) over Tropical Indian Ocean (TIO) at spatio-temporal scale. Initially the spectral characteristics of waves and influence of southern winds were studied using buoy measurements at one location off east coast of India. The analysis showed that the average SWH during summer monsoon was highest (1.66 m) whereas the lowest (0.6) SWH occurs during winter monsoon. A wide range of swell groups observed from the spectrum data. The South-East (SE) trade winds over Tropical South Indian Ocean (TSIO) and westerly winds over southern Ocean were expected to be the responsible forcing for swells over Tropical North Indian Ocean (TNIO). From the lag correlation analysis between the measured swell (Hsw) and spatially averaged Extra Tropical South Indian Ocean (ETSIO) wind speed showed highest significant correlation in February 2010. Hence it was concluded that in the absence of strong wind forcing over entire Tropical Indian Ocean the variability of SWH and Extra Tropical South Indian Ocean wind were correlated with 7.12 days time lag.

To understand the variability of SWH for full spatial extent and its responsible forcing phenomena, the simulated SWH data using Wavewatch III model from NOAA was chosen. The model data over Tropical Indian Ocean was evaluated using *in-situ* and satellite measurements. The monthly mean data of model showed good agreement with *in-situ* as well as satellite data compared to 3 hr interval data. Hence the monthly mean data of model was used for further analysis.
The climatology of SWH over Tropical Indian Ocean was generated using 13 years of model data. The daily climatology of SWH for different sectors of Indian Ocean showed wider range of wave heights over Arabian Sea compared to Bay of Bengal and Tropical South Indian Ocean. Monthly climatology of SWH over Tropical North Indian Ocean show a strong seasonal signal with primary maximum during summer monsoon and secondary maximum during winter monsoon. The seasonal signal over Tropical South Indian Ocean consists of single maximum during summer monsoon. The highest sea state condition over entire Tropical Indian Ocean was observed during July and lowest during transition months (i.e., Mar and Nov). Another important observation was that the monthly mean SWH over Tropical South Indian Ocean was greater than that of Tropical North Indian Ocean for entire annual cycle due to strong sustained SE trade winds. A clear decreasing gradient of SWH towards north for all months except during July at 65°E was observed. The latitudinal and longitudinal transects showed a strong seasonality over Tropical North Indian Ocean.

Further, the analysis of major synoptic forcing phenomena responsible for the variability of SWH over Tropical Indian Ocean was carried out. Two major signals of variability were observed for Arabian Sea and Bay of Bengal; one seasonal and another annual. The seasonal signal was reduced and became insignificant towards south (ETSIO). The results from correlation and Empirical Orthogonal Function analysis revealed that the first major synoptic forcing phenomenon influence the variability of SWH over Tropical Indian Ocean was Southern Ocean Wind. The regions over western Arabian Sea and Tropical South Indian Ocean were more sensitive to Southern Ocean Wind variability. The
second major phenomenon was monsoon winds. The region over western and central parts of Arabian Sea was more sensitive to the monsoon winds. The third phenomena influencing the variability of SWH in inter-annual time scale were monsoon and IOD together. The occurrence of high positive IOD results in negative anomaly of SWH over SW sector of Tropical South Indian Ocean. The anomaly of SWH over TIO showed a significant increasing trend of 0.1 cm/month during the study period. The Southern Ocean Wind anomaly also showed an increasing trend (0.2 cm/s per month).

The significant conclusions drawn from the present study are as follows

- A significant contribution of swell from south to the sea state condition off East coast of India was observed from spectral measurements of wave. The observed swell groups were in wide distribution, where as seas were closely packed.

- A strong correlation (0.83) between the measured swell and Extra Tropical South Indian Ocean wind was observed with a time lag of 7.12 days.

- The range of wave heights was observed to be high over Arabian Sea compared to Bay of Bengal and Tropical South Indian Ocean.

- The seasonality of SWH climatology was high over Tropical North Indian Ocean compare to Tropical South Indian Ocean.

- The major synoptic forcing phenomenon influence the variability of SWH over Tropical Indian Ocean was Southern Ocean Wind, monsoon and Indian Ocean Dipole.
- The anomaly of SWH over Tropical Indian Ocean showed a significant increasing trend of 0.1 cm/month during the study period.

**Future Perspective**

The present work will be extended further to study the following aspects.

- The high positive anomalies observed in SWH data during the year 2007 need further investigation to identify the possible causes.
- The role of wind forcing over Tropical South Indian Ocean and Extra Tropical South Indian Ocean in predictability of waves over Tropical North Indian Ocean to be further studied with high resolution ocean-atmosphere coupled models.
- Validation of model data with *in-situ* measurements during extreme weather conditions will be further extended to other regions of Indian Ocean.
- The feasibility of estimating storm distance using available wave buoys in Indian Ocean region to be further investigated. Hence, it can be used for monitoring of cyclone tracks.