Abstract

Tropical cyclones (TCs) are coupled atmosphere-ocean phenomenon where strong winds spiral around a low pressure centre at the surface. TC is one of the natural disasters which pose threat to infrastructure, biodiversity, and livelihood in the coastal regions. TC interacts thermodynamically with the ocean through the exchange of heat and momentum fluxes at the air-sea interface. The enhancement in latent heat flux and evaporation rate maintains the sustainability and intensification of TC in the high wind speed regime. An accurate calculation of heat fluxes is vital to understand the dynamics of TC. Therefore, understanding thermodynamic response of the upper oceanic layers is important for a better simulation of TC track and intensity. The Bay of Bengal (BoB), a semi-enclosed basin in northeastern Indian Ocean, witness severe cyclonic storms during the pre-monsoon and post-monsoon seasons every year. Nevertheless, the complex mechanism of air-sea interaction and its role in the TC evolution over the BoB is not well understood. The present thesis investigates the air-sea interaction and changes in the upper-ocean characteristics in response to the passage of tropical cyclones over the BoB. The study is based on the implementation of a coupled atmosphere-ocean-wave model. The coupled model is validated against in-situ and satellite measurements for the simulation of TCs of different intensities in the BoB. After a successful validation, the coupled model experiments are carried out to examine the upper-oceanic response to the TCs, impact of coupling on the air-sea fluxes, interaction of TC with mesoscale eddies, and the role of sea surface roughness and sea-spray on the TC characteristics.

Different configurations of the coupled model are applied to assess the impact of model coupling (among the atmosphere, ocean, and wave) on the simulations of air-sea fluxes, surface

currents, waves, and temperature profile during the passage of TC Phailin over the BoB. The uncoupled model simulated larger mean track error, positional error, and higher cold bias in sea surface temperature than the coupled model. An inter-comparison of coupled and uncoupled model experiments highlights the crucial role of correct air-sea fluxes of heat, moisture, and momentum for a better prediction of tropical cyclone. The thesis also examines the wave-current interaction and near-inertial mixing in the northern BoB utilizing more realistic vortex force (VF) method in the ocean model. To understand the effect of waves on hydrodynamics, the two dimensional (2D) depth integrated momentum balance with and without wave effect is analyzed. The effects of wave on current in leading terms of the momentum budget help to further our understanding of turbulent mixing in shallow coastal water. Further, the thesis examines the mixing in the upper-oceanic layers under the influence of TC over BoB. Model simulations highlight the prominent role of cyclone-induced near-inertial oscillations in subsurface mixing up to the thermocline depth. The inertial mixing introduced by the cyclone played a central role in the deepening of the thermocline and mixed layer depth. A detailed analysis of the generation, propagation, and dissipation of kinetic energy induced in the water column by inertial oscillations is carried out.

The study estimates the influence of sea surface roughness on the heat fluxes, track, and intensity of TC in a coupled modeling framework. Four different numerical experiments were performed with different parameterization schemes for surface roughness on the basis of (i) frictional velocity (Charnock) (ii) wave age (DGHQ), (iii) wave steepness (TY2001), and (iv) a combination of wave steepness and age (OOST). On the basis of model performance with these four parameterization schemes, another experiment is carried out with inclusion of sea-spray in the coupled model. The fifth experiment examines the impact of dynamic sea-spray on the surface heat fluxes and other parameters, which affects the cyclone. Inter-comparison of all five model experiments demonstrated differences in surface heat fluxes and its effect on the TC characteristics. It was found that the wave-age based roughness parameterization scheme along with sea-spray improves the track and intensity simulation of TC Vardah in the BoB.

The coupled model is utilized to examine the interaction of tropical cyclone (TC Vardah) with mesoscale cyclonic and anticyclonic eddies over the BoB. Three idealized numerical experiments are performed and results are inter-compared. It is found that the tropical cyclone interaction with an anticyclonic (warm-core) eddy provided an ancillary strength to the TC by raising the tropical cyclone heat potential (TCHP). The utilization of coupled ocean-atmosphere-wave model provided a better representation of ocean-atmosphere coupled feedback processes during TC interaction with different eddies. The analysis of feedback processes depicted that the TC interaction with an anticyclonic eddy raised the magnitude of its existing moist-static-energy comparative to the cyclonic (cold-core) eddy interaction case. The enhanced moist-static-energy lead to an increase in the intensity of TC in case of its interaction with anticyclonic eddy in the BoB. Therefore, the present thesis demonstrates that the better representation of air-sea fluxes in the fully coupled atmosphere-ocean-wave model overcomes the cold SST bias and improves the track and intensity simulation of a TC over the uncoupled model.