Abstract

Exchange of mass (water vapor), momentum, and energy between atmosphere and ocean has profound influence on weather and climate. This exchange takes place at the air-sea interface, which is part of the marine atmospheric boundary layer. Various empirical relations are being used for estimating these fluxes, being used in numerical models but their accuracy not sufficiently verified or tested over the Indian Ocean. The main difficulty is vast areas of open oceans are not easily accessible. The marine environment is very corrosive and unattended long term and accurate measurements are extremely expensive. India has research ships that spend most of their time over the seas around India but that opportunity is yet to be exploited. To address this, a air-sea flux measurement system for operation on board research ships was planned. The system was tested on board Indian Research Vessels ORV Sagar Kanya during its cruise SK-296 in the Bay of Bengal (BoB) in July-August 2012, and NIO ship Sindhu Sadhana in June-July 2016. The set included instruments for measuring wind velocity, wind speed and direction, air and water temperature, humidity, pressure, all components of radiation and rainfall. In addition, ship motion was recorded at required sampling rate to correct for wind velocity. The set up facilitates the direct computation of sensible and latent heat fluxes using the eddy covariance method.

In this thesis, design and installation of meteorological and ship motion sensors onboard research ships, data collection and quality control, computation of fluxes of heat, moisture and momentum using eddy covariance method and their comparison with those derived from bulk method are described. A set of sensors (hereafter, flux measuring system) were mounted on a retractable boom, ~7 m long forward of the bow to minimize the flow disturbance caused by the ship superstructures. The wind observed in the ship frame was corrected for ship motion contaminations. During the cruise period true mean wind speed was over 10 m/s and true wind direction was South/South-Westerly. True wind speed computed from the anemometer using the compass on AWS and the GPS, speed over ground/course over ground; is interpreted as the speed relative to the fixed Earth. Turbulent fluxes were computed from motion-corrected time-series high frequency velocity, water vapor, and air temperature data. Covariance latent heat flux, sensible heat flux, and stress were obtained by cross-correlating the motion-corrected vertical velocity with fast humidity fluctuations from an IR hygrometer, temperate fluctuation from sonic and motion-corrected horizontal wind fluctuation from sonic anemometer respectively.

During the first attempt made in July-August 2012 as part of a cruise of CTCZ monsoon research program, observations were mainly taken in the North Bay of Bengal. The mean air-temperature and surface pressure were ~28 Deg C and ~998 hPa, respectively. Relative humidity was ~80%. Average wind speed varied in the range 4-12 m/s. The mean latent heat flux was ~145 W/m^2, sensible heat flux was ~3 W/m^2 and average sea-air temperature difference was ~ 0.7°C.

The Bay of Bengal boundary layer experiment (BoBBLE) was conducted during June-July 2016. Same suites of sensors were used during BoBBLE. During daytime, peaks of hourly net heat flux into the sea (Q_{net}) were around 600 Wm^{-2} whereas during night time values were around -250 Wm^{-2}. During the experimental period the mean Q_{net} was about -24 Wm^{-2} for both eddy covariance and conventional bulk methods. Sea surface temperature was always >28°C and maximum air temperature exceeded 29°C.

Keywords: wind components, ship motion correction, direct covariance method of flux observation, latent heat flux, sensible heat flux, momentum flux.