

First Results of Indian - Current Meter Moorings Along The Equator: Vertical Current Structure Variability At Equator, 93°E during February – December, 2000

V.S.N. MURTY, A. SURYANARAYANA, M.S.S. SARMA, V. TILVI, VIJAYAN FERNANDO,
G. NAMPOOTHIRI, AREEF SARDAR, D. GRACIAS AND SADASHIV KHALAP

Physical Oceanography Division, National Institute of Oceanography, Dona Paula, Goa – 403 004, India.
e-mail: vsnmurty@darya.nio.org and vsnmurty@csnio.ren.nic.in

ABSTRACT

The first results of time-series currents data obtained from 6 levels at equator, 93°E in the eastern equatorial Indian Ocean during February-December 2000 are analyzed. The top RCM was located at 135m. The mean currents at each depth are weak while the low pass filtered (49-hour) current data show considerable meso-scale variability, comprising of Intraseasonal Oscillations (ISO) of period 10-20 day and 40.5 day. The 10-20 day ISO is associated with similar variability in surface wind forcing while the 30-50 day ISO with Madden-Julian Oscillations. The energy spectrum at 280 m shows relatively higher energy than that at 135 m at 10-20 day ISO, while cross-spectra of kinetic energy at these depths reveal high coherence and upward phase propagation at 10-20 day ISO.

Key words: Indian Ocean Observing System, Eastern Equatorial Indian Ocean, variability of currents, low frequency oscillations.

INTRODUCTION

The Indian National Program of Ocean Observing System (OOS) has been launched by the Department of Ocean Development (DOD), Government of India and is executed at the National Institute of Oceanography, Goa, India since 1998. Among its four sub-programs, one sub-program is the *Current meter moorings along the equator*. Under this sub-program, deployment of three deep-sea current meter moorings at 93°E, 83°E and 76°E (Fig. 1) in the Eastern Equatorial Indian Ocean (EEIO) has been planned. The main objective is to collect long-term time-series currents data at different depths covering the upper ocean, intermediate, deep and near-bottom depth regimes. Under this project, three current moorings were deployed – one at equator, 93°E in February 2000, December 2000 and March 2002, the second mooring at equator, 83°E in December 2000 and March 2002 and the third mooring at equator, 76°E in March 2002. These currents data will enhance our knowledge on the seasonal and interannual variation of currents in the EEIO region and their relation to the basin scale processes of the tropical Indian Ocean. These data would also be useful for validating the Ocean General Circulation Model (OGCM) simulations for the equatorial Indian Ocean. For the first time, the nature of variability of equatorial currents is described¹ from time-series data at Gan Islands in the Central Equatorial Indian Ocean, based on long-term time-series measurements of currents. Recently, upper ocean currents variability in the EEIO is documented²⁻³. Modeling studies⁴⁻⁶ indicate that the equatorial Indian Ocean plays a

dominant role for the variability of currents along the coast of India through propagation of long period Kelvin Waves along the equator through the EEIO and coastally trapped waves along the eastern rim of the Bay. The eastward flowing equatorial jets (EJ) of the monsoon-transition periods appear to intensify in the EEIO^{2,7}. Based on the drifting buoy data, the EJs are identified during April-May and November⁸ and higher eddy kinetic energy of the surface currents in the EEIO is reported⁸. While the information on the variability of currents through direct measurements is relatively better for the western equatorial Indian Ocean, the same is only recent for the EEIO^{2,9}. It is in this context, the Indian OOS program launched the direct current measurements along the equator beginning at equator, 93°E. In this paper, the authors present the variability of currents at 6 depths at the equator, 93°E location utilizing the first time-series currents data and discuss the kinetic energy variability of the upper ocean currents.

DATA AND METHODS

Rotor-type Recording Current Meters (RCMs) from Aanderaa Instruments, Norway were used to record time-series of currents. In the latest deployments, Acoustic Doppler Current meters (RCM9/11) were also used at near-bottom depths. Sensors for temperature, conductivity and pressure were also fixed to the RCMs. At equator, 93°E location the RCMs were placed at 106m, 259m, 461m, 964m, 1972m and 3975m depths at the water depth of 4482m. At 461m depth the RCM lost the rotor after one month of deployment. The recording interval was one hour and the mooring duration was for 11 months

(13 February - 23 December 2000). The length of data recording for the upper two RCMs was only 10 months, because of early battery drain at warmer temperatures.

From the pressure sensor data, it was found that the top RCM was at a mean depth of 135m, while the other RCMs were at mean depths of 280m, 487m, 983m, 1996m and 3995m. The hourly currents data were subjected to low-pass filtering with 49 hours moving average to filter out the semi-diurnal and diurnal tidal oscillations¹⁰. These filtered data (zonal (U) and meridional (V)- components) were used for preparation of vector plots, computation of total kinetic energy and eddy kinetic energy per unit mass and for spectral analysis¹¹⁻¹² with 6 degrees of freedom and 3 ensembles of length 81 days each. The cross-spectral estimates of kinetic energy, correlation and phase relationship of the currents have been studied and presented only for the upper ocean currents at 135 and 280 m depths.

RESULTS AND DISCUSSION

The temporal variation of daily averaged current vectors at 135, 280, 983, 1996 and 3995 m (Fig. 2) show considerable variation of currents at all the depths. At 135m strong currents of speed up to 50 cm/s can be seen from the last week of May to end of June. Subsurface flow reversals are noticeable at 135 m and 280 m. At 135m, while there is a westward flow during February – mid-April, eastward flow occurs during mid-May – first week of July. The weaker (20cm/s) southeastward currents during mid-April – mid-May may represent the part of the flow associated with the Spring Equatorial Jet. In general, the Equatorial Jet attains 100 cm/s velocity at sea surface². The currents were irregular from the 2nd week of July to 3rd week of September. Weaker (20 cm/s) eastward flow in October might be associated with the Fall Equatorial Jet. At 280 m, westward flow occurs from mid-February to mid-May and currents are variable and attain higher speeds (>50 cm/s) in August-September. At 983 m, 1996m and 3995m the currents show a regular, periodic variation. The monthly mean currents at each depth during February-November 2000 are also examined. At 135m the mean currents also indicate westward flow during February – April and eastward flow from May through October, barring minimum currents in July. From this, one can visualize the annual variation in the subsurface currents (at 135m) in the EEIO. Interestingly, this annual variation of currents is also noticed at 280m and 983m depths. At 1996m, the mean currents are weak and show the west / southwestward flow. At 3995m the mean currents during July–October (southwest monsoon) are relatively higher than those at 1996m with a 60 day periodicity. It is to be studied whether this increase is

due to the near-bottom intensification of currents during southwest monsoon.

Spectral analysis: The spectral analysis of zonal component (U) and meridional component (V) of velocity at 135 m and 280 m depths are presented in Fig. 3. It is noticed that at 135 m depth spectral energy for zonal component is less than the meridional component (Fig. 3) for frequencies between 0.0988 and 0.0494 cpd (10.13 to 20.25 days), whereas at 280 m depth, spectral energy for meridional component is generally higher for frequencies (<0.25 cpd), except at 0.037 cpd (27.0 day). At all the depths (except at 280 m), the spectral energy is higher for the meridional component at the frequency of 0.0494 (20.25 day). However, for the low frequency period of 40.5 day, zonal component contains higher spectral energy at 135 m and 1996m, while the meridional component has higher spectral energy at 280 m and 983 m. This analysis suggests the presence of high frequency Intraseasonal Oscillation (ISO) of period between 10 and 20 day and a low frequency ISO between 30 and 50 day (associated with the Madden - Julian oscillation¹³). However, the high frequency ISO represents the north-south meandering current, particularly during February-April and mid-May – June. At 280 m, the north-south meandering motion of the flow is intense during mid-July – October. This also gives rise to higher spectral energy at ISO of 40.5 days in the meridional component at this depth.

Good coherence (>0.6) between zonal and meridional component velocities is noticed at both the ISOs. Recently, Sengupta *et al*¹⁴ through OGCM simulations, also reported the presence of ISO of 10-15 day and 30-50 day. They opined that the former ISO is originated due to similar ISO in the local wind forcing and the latter ISO due to reflected Rossby waves from the eastern boundary of the Indian Ocean. Our study supports these OGCM simulations and thus the equatorial mooring at 93°E captured the ISO signals.

The spectral estimates of kinetic energy (KE) per unit mass of the currents at 135 and 280 m, their cross-spectral estimates of coherence and phase (obtained from February 15 (46 Julian day), the beginning of the time-series data) are presented in Figures 4a-c. For ISO of 40.5 day, the spectral energy is nearly the same both at 135 m and 280 m depths. However, the spectral energy is slightly more at 280 m depth for the period of 11.57, 13.5 and 16.2 days. The energy spectra at 135 m and 280 m are well coherent (Fig. 4b) at 0.037, 0.049 and also at 0.074 cpd (corresponding periods 27, 20 and 13.5 days). This suggests that the impact of 10-20 day intra-seasonal oscillation up to 280 m layer. The negative phases at these periods (Fig. 4c) indicate the downward transfer of energy to deeper layers. The good coherence at 13.5 day in the energy spectra is close to that reported (14 days) in the NCEP/NCAR wind stress data for the

Gulf of Mannar¹⁵ which is closer to the equatorial region.

CONCLUSIONS

The first results of analysis of time-series of currents data at the equator, 93°E are presented. The daily averaged currents at 135 m and 280 m depths clearly depicted the intraseasonal variability with 10-20 day and 40.5 day periods. This is in conformity with the OGCM simulations of the equatorial Indian Ocean driven by daily surface wind forcing. The ISO of 10-20 day oscillation has higher spectral energy in the meridional component, suggesting the Yanai waves propagation. Cross-spectra of kinetic energy at 135 m and 280 m depths indicated good coherence and upward propagation of phase at 0.074 cpd frequency (corresponding 13.5 day period).

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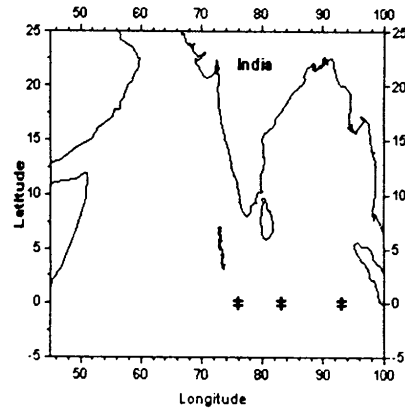


Fig.1 shows the OOS-Current meter mooring locations in the Eastern Equatorial Indian Ocean.

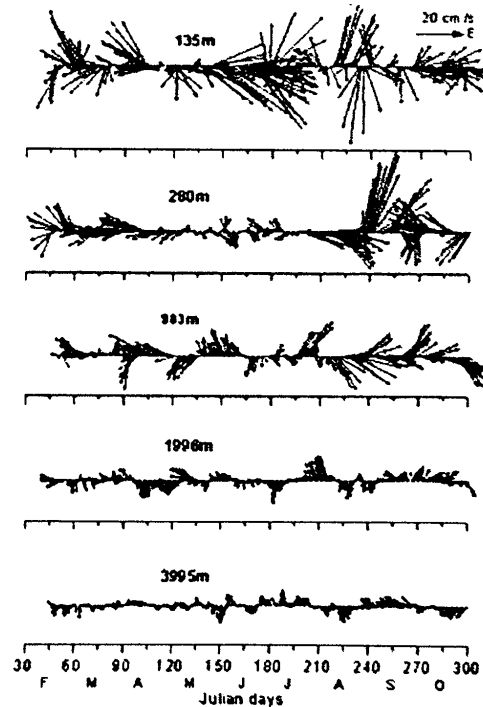


Fig 2. Time variation of daily averaged current vectors at equator, 93°E location at the RCM mean depths during February - November 2000.

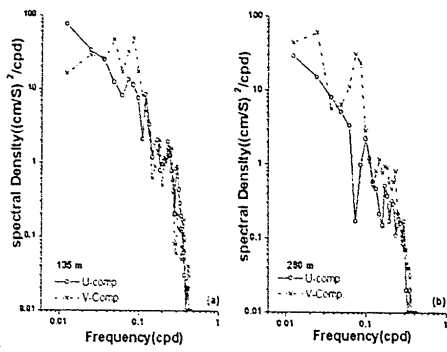


Fig 3. Spectral estimates of U- component (solid line) and V-component (dashed line) of velocity at (a) 135 m and (b) 280 m depth.

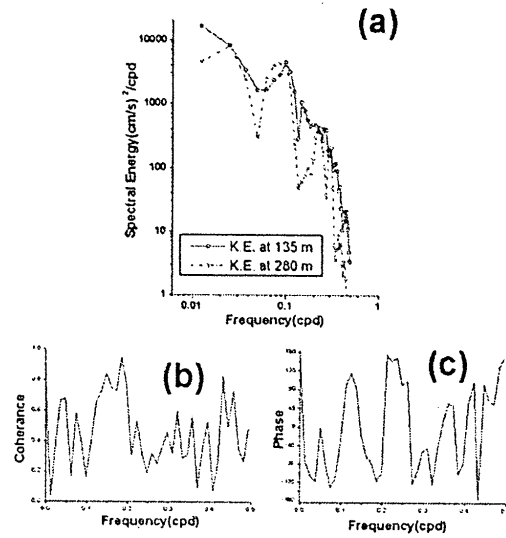


Fig. 4. (a) Spectral estimates of Kinetic energy at 135m & 280m and (b) coherence and (c) phase variations between these two levels.