

Surface Currents in the Equatorial Indian Ocean during Spring and Fall – an Altimetry Based Analysis

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ABSTRACT

This communication presents the results of a study aimed at investigating the nature and variability of surface currents in the equatorial Indian Ocean between 5° N and 5° S during spring and fall seasons. Geostrophic surface currents were computed using 1° x 1° gridded sea surface height (SSH) anomalies derived from TOPEX-POSEIDON (T/P) altimeter data over the years, 1993 to 2000.

The results show that the spring Wyrcki jet derived between April and June is restricted to just south of the equator, whereas, the fall jet derived between October and December is almost symmetrical about the equator. These jets are found to be about 400 km wide with a speed of 70 – 80 cm/sec. Maximum duration of these wind-driven, eastward flows is about three months in both the seasons. The tendency of these jets to be either weak or totally absent during 1997-98 is attributed to the strong ENSO-IOD event of 1997.

KEYWORDS : Wyrcki jet, Equatorial Indian Ocean, Sea surface heights, Topex-Poseidon altimetry

INTRODUCTION

Indian Ocean experiences strong seasonal fluctuations in wind speed and direction mainly due to the reversing monsoons which is characteristic of this region. A major feature of these winds is the prolonged westerlies along a larger part of the equatorial Indian Ocean, except in the western region which is characterized by reversing NE and SW monsoonal winds. Associated with these westerlies are moderate east ward oceanic flows along the equator during spring and fall. These eastward flows were first pointed out by Wyrcki¹ and are generally referred to as equatorial (Wyrcki) jets(EJ).

An attempt is made to understand the nature of the EJs and to bring out the seasonal and inter-annual variations using T/P altimeter data. This study forms part of a larger investigation aimed at understanding the dynamics of the equatorial Indian Ocean based on long term observations on hydrography and moored current meters.

MATERIAL AND METHODS

Processed T/P altimeter data on sea level anomalies for the years, 1993-2000 during April-May-June and October-November-December along the equatorial Indian Ocean between latitudes, 5° N & 5° S and longitudes, 40° E & 100° E were extracted from the AVISO files². From the 0.5° x 0.5° gridded anomalies for each 10-day repeat cycles, 1° x 1° bin averages and thereby the monthly mean anomalies were obtained and these anomalies were used to compute the currents using geostrophic relationship. In the vicinity of the equator, however, a differential form of geostrophic relation was used for the current computations.

RESULTS

3.1 Spring Jet :

During spring (April-May-June) eastward currents (EJ) are noticed in the equatorial region (Fig. 1). The salient features of the observed spring EJ are : the eastward currents set-in by April and continue up to June during almost all the years under consideration. The currents are found to be stronger during June and weaker during April. Meandering tendency is also observed in the general flow pattern. It is not clear whether these meandering features are associated with any eddies present in this area. Another interesting feature observed is that the EJ is confined to the south of the equator during spring with no eastward flow north of the equator. The spring EJ has a width of about 400 km and a typical speed of about 70 cm/sec. However, EJ is not a continuous flow from west to east during this season but with discontinuities at certain longitudinal points along the equator.

It is found that the EJs are affected by the ENSO and Indian Ocean Dipole(IOD events of 1994 and 1997 (Fig. 2a and 2b). During the exceptionally strong ENSO/IOD event of 1997 it was noticed that moderate east ward currents were present during the spring of 1997 but very weak or no flows were seen during the subsequent spring of 1998 (Fig.2b) probably indicating the onset of ENSO event after the spring of 1997 thereby affecting the spring flow of 1998.

3.2 Fall Jet :

In fall (October-November-December), eastward flow is noticed along the equator (Fig. 3). This appears to

be stronger than the spring flow. The flow during November and December shows greater magnitudes than October in all the years. Unlike spring EJ, however, the fall EJ is almost symmetrical with respect to the equator. The width of the fall EJ is also about 400 km with speeds exceeding 80 cm/sec. During the ENSO-IOD event of 1994 a slight slow-down in the flow was noticed. During the event of 1997, the flow was almost negligible during the fall of 1997 (Fig. 2a). As mentioned earlier, when the 1997 ENSO event occurred, the spring jet in 1997 was not affected but it affected both the fall EJ of 1997 and the spring EJ of 1998. This indicates that the influence of ENSO, 1997 stretched from fall, 1997 to the spring of 1998.

The inter-annual variability of these jets are thus closely associated with the ENSO/IOD events as described above. Non-ENSO years had almost similar features except for differences in the duration of the EJs. During spring of 1993, 1995 and 1996 the jet had a duration of about three months but the jet prevailed for two months or less in 1999 and 2000. Similarly during fall the duration was three months in 1995 but in 1993, 1998, 1999 and 2000 the duration was limited to two months or less.

DISCUSSION

The present analyses show a weaker spring jet with a speed of about 70cm/sec and a stronger fall jet with speeds more than 80 cm/sec. The ship drift climatology also indicates a similar trend with a stronger fall jet and a weaker spring EJ³. The field experiments conducted by Reppin et.al⁴ however reveal a weaker fall jet with a speed of 50 cm/sec and a stronger spring jet with speeds exceeding 150 cm/sec. during 1993-94. These results found support in some of the model studies^{5,6,7} which used realistic winds to simulate the equatorial currents. However more observational data is needed to establish the actual situation.

In the present study, higher speeds are noticed in the western sector during spring where as during fall, the maximum is shifted towards the central Indian Ocean. In their model, Han et. al⁷ had shown that the semi annual wind forced component is considerably stronger than the annual component and that the two semiannual components interfere to enhance the amplitudes in the central Indian Ocean. Most of these models however indicative of the proposition that the annual component of the winds drives a response that tends to strengthen the spring EJ and weaken the fall EJ.

The present study indicates that the duration of the jets is about three months and that the jets extend into the months of June(spring) and December (fall). However, the direct observations of Reppin et.al.⁴

showed a more prolonged jets during spring (about 6 months) and fall (about 5 months) during 1993-94. Some of the more recent observations have also shown the eastward equatorial currents extending up to December⁸.

As mentioned earlier, the ENSO/IOD events of 1994 and 1997 are found to influence the jets. During 1997, when the ENSO/IOD events were much stronger, the spring jet showed moderate currents during 1997 but practically no appreciable flow was noticeable during the spring of 1998. During fall, however, the effect of the 1997 ENSO event was felt in the fall EJ of the same year. Thus it is interesting to note that ENSO 1997 forced both the 1997 fall jet and 1998 spring jet to disappear demonstrating the year-long influence of the ENSO event. During these events, one would expect the reflected Rossby waves to interfere either to weaken these directly forced jets or enhance them depending up on the frequency spectrum of the wind forcing.

The forcing for the EJs appears to be the equatorial westerlies in between the SW and NE monsoons. Han et.al⁷ had found that the semiannual component of the wind is the dominant forcing for the jets. It appears that when the wind is periodic resonance takes place at certain points and there can be areas along the equator where discontinuity in the flow occurs as seen in the present study.

Though the NCEP/ENCAR re-analyses wind showed strong westerlies from April, the ocean response is seen only in May and June probably indicating a lag in the currents. Similarly during fall, the winds are stronger during October and November but the currents attain the peak only during November and December providing further evidence to the lag of the currents.

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Legend to Figures

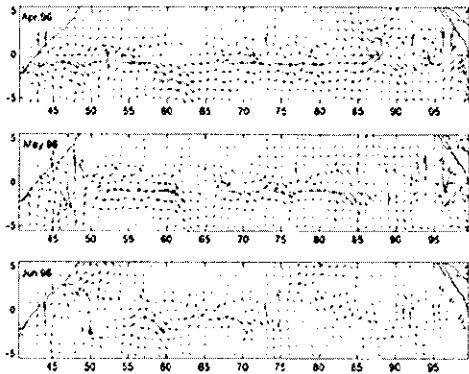


Fig. 1. T/P SSH anomaly-derived equatorial jet during spring, 1996

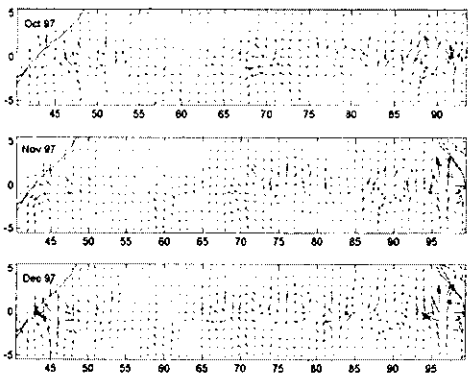


Fig. 2a. As in Fig. 1 but for fall, 1997 (influence of ENSO/IOD event, 1997)

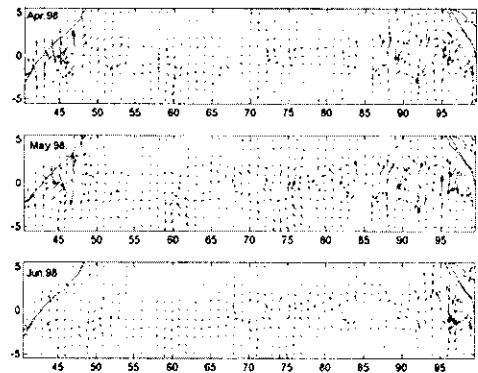


Fig. 2b. As in Fig. 2a but for spring, 1998 (influence of ENSO/IOD event, 1997)

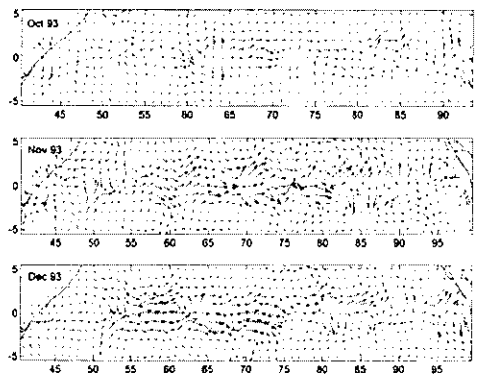


Fig. 3. As in Fig. 1 except for fall, 1993