Dynamical Response of Equatorial Indian Ocean to Intraseasonal Winds: Zonal Flow

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1 Background and models

Current observations show a broad, secondary energy peak centered at 40-60 day period for the zonal current at 200 m in the western (47°–62°E) and at 25 m in the central (80°30′E) equatorial Indian Ocean. In the east (near 90°E), a 50-day oscillation of zonal, near surface current was recently observed.

A nonlinear and linear $4\frac{1}{2}$-layer ocean models are used to investigate dynamics of the observed zonal flow. The former includes active thermodynamics and mixed layer physics, and the latter is purely dynamical and wind driven. Solutions are found in a basin resembles the actual Indian Ocean north of 29°S, and they are forced by NCEP/NCAR 5-day-mean reanalysis for a period of 20 years (1980–1999).

2 Solutions

Consistent with the observations, our nonlinear solution displays the 40-60 day relative spectral peaks of zonal currents in the western and central ocean, and there is a significant power of energy in the eastern basin (Figure 1).

These peaks almost vanish in the nonlinear solution forced by the winds with periods lower than 90 days being filtered out (Figure 2), suggesting that the 40-60 day zonal flow is primarily wind driven, although a small amount of energy still exists in the central ocean due to oceanic instabilities. The 40-60 day energy peaks of zonal currents are much stronger in the linear solution, and they result largely from direct wind forcing, with reflected waves strengthening the peaks somewhat (not shown). The linear solution forced only by the Madden-Julian Oscillation (MJO) associated wind suggests that the 40-60 zonal flow results largely from forcing by the MJO.

Interestingly, the strongest spectral peak of zonal current is at 90-day period, although the zonal wind peaks at 35 and 45-55 days. The 90-day peak passes the 95% significance level over the 20-year record, and it dominates the 40-60 day current. Our solutions suggest that the 90-day current, the dominant current at intraseasonal time scales, results from the near resonance response of the second baroclinic mode with the 90-day wind, which has a significant energy power that is not apparently associated with the MJO. The amplified response of the ocean to the 90-day wind is demonstrated by the resonance curve (Figure 3), which shows the surface current maxima from the solution to the linear, $4\frac{1}{2}$-layer model forced by an idealized wind patch with the same amplitude but varying frequencies. For the same spatial pattern and same strength of the wind, the ocean has a peak response near 90-day period, because of the lower frequency waves couple better with the large scale wind (directly forced response: thin solid line in Figure 3) and the reflected waves strengthening the directly forced part at 90-day period (dashed line).

Although the 90-day zonal flow does not appear in the a few available observations, a 7 year record (1993–1999) of TOPEX/POSEIDON altimetry data shows a dominant 90-day peak at intraseasonal time scales in the entire equatorial Indian Ocean (not shown). The near 90-day variability has a corresponding signal in thermocline depth and the sea surface temperature (SST) in the eastern equatorial ocean. Question of particular interest is how this SST signal feedbacks to the atmosphere to generate atmospheric variability.

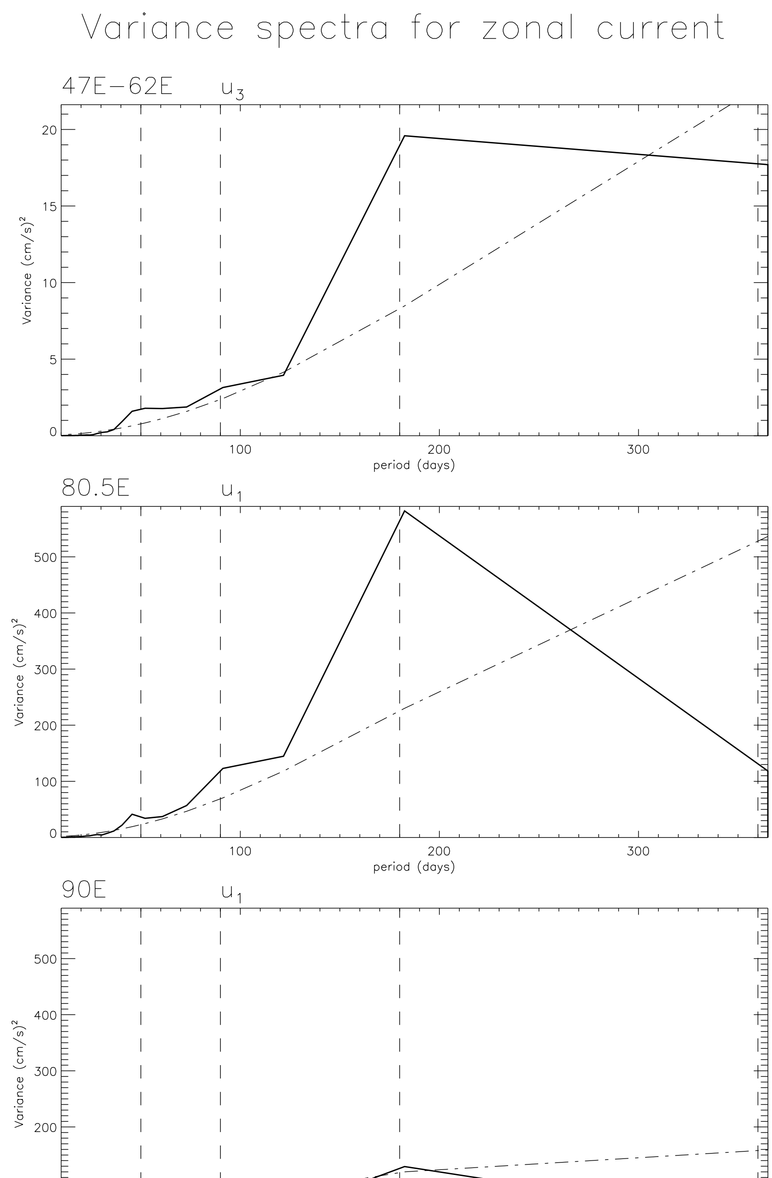

Figure 1: Variance spectra for the zonal surface current from the model in the western ocean in the thermocline layer (top), central ocean in the surface mixed layer (middle), and eastern ocean in the surface mixed layer (bottom). The three locations correspond to the three observations discussed in the text.

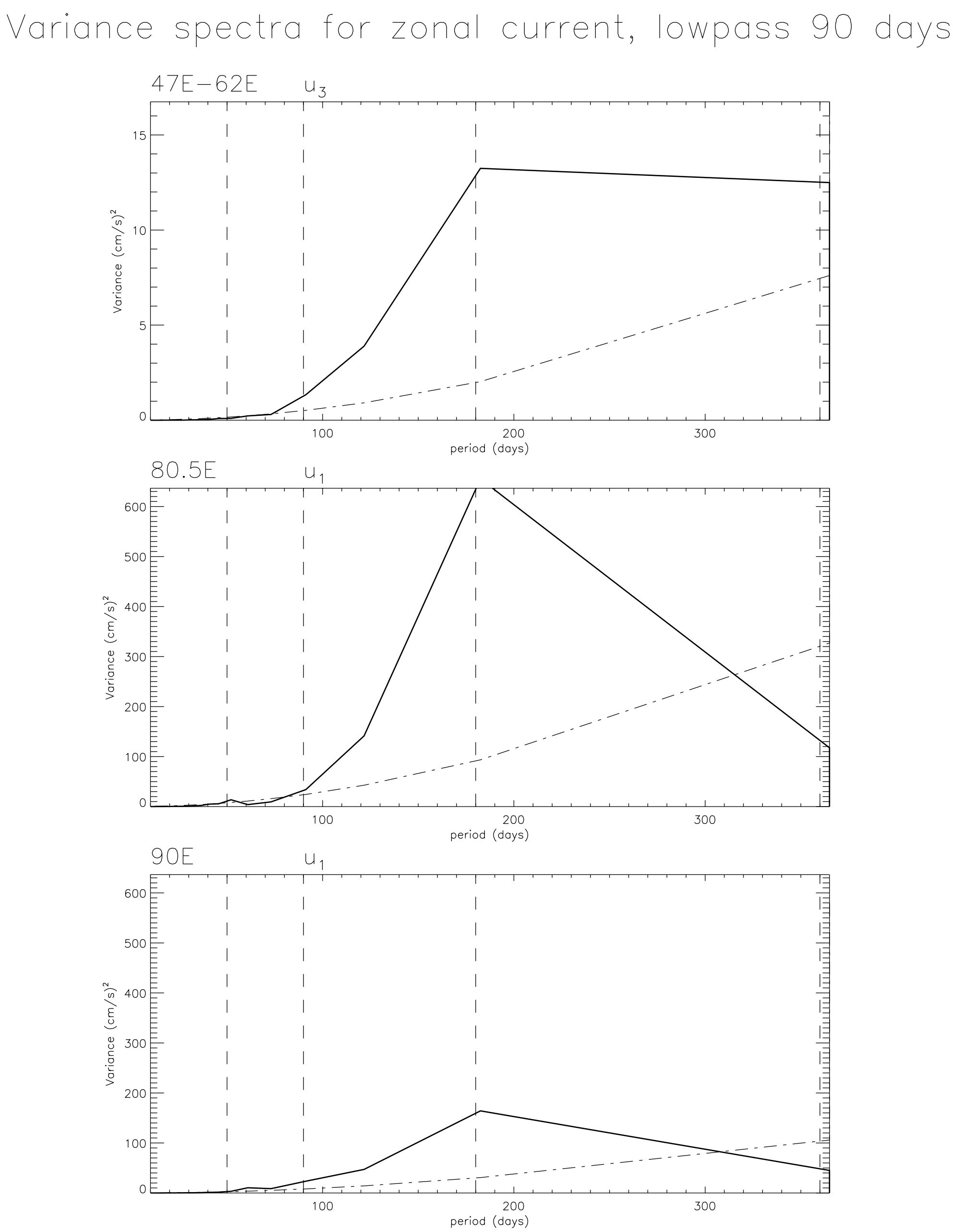

Figure 2: The same as Figure 1 except for the solution forced by the low pass wind (with periods of shorter than 90 days being filtered out).

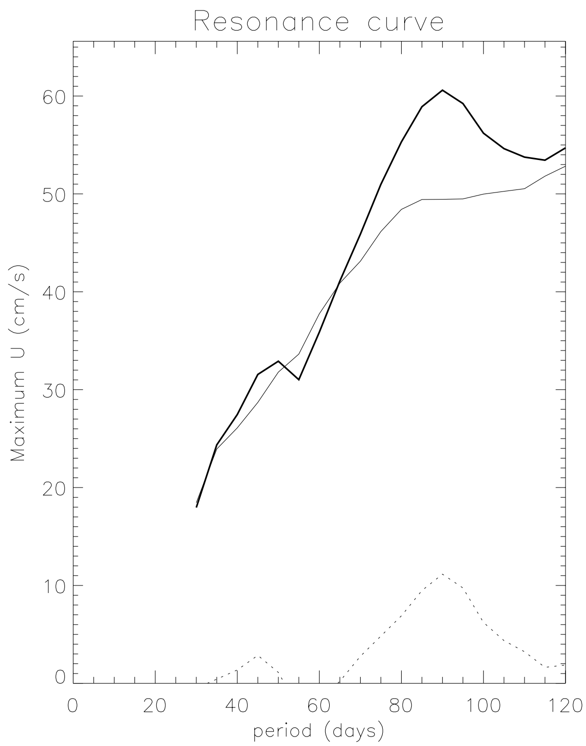

Figure 3: Resonance curve from the solution to the linear, $4\frac{1}{2}$-layer model. Maximum current versus period of the forcing wind: thick solid line (total current), thin solid line (directly forced current), and dashed line (current due to reflected waves).