Low-frequency variability in the INDIAN OCEAN and its connection with an Indian Ocean Dipole mode in 2006

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Background

In this work we extend our previous analysis of the low-frequency variability in the Indian Ocean (IO) using the latest available altimeter sea surface height (SSH) data. We show that the 18-month signal found in [1, 2] seems to be largely responsible for the latest SSH anomalies near the Java coast in autumn 2006

Previous analysis of the low-frequency SSH variability over the whole IO (based on Oct 1992 – Aug 2004 data) and in expendable bathythermograph (XBT) temperature profiles near the Sumatra-Java coast (based on Jan 1989 – Dec 2002 data) shows the existence of five strong, well separated spectral bands carrying most of the signal in the IO [1, 2]. The low-frequency part of the SSH spectra (corresponding to signals with periods from six months to six years) is predominantly concentrated in five frequency bands: semi-annual, annual, 18-20 months, 3 years, and 5-6 years. The existence of semi-annual, annual, 2-3-year and 4-6-year periodical signals is well known and described. Temporal and spatial characteristics of the 18-20-month signal as well as of the 3-year signal point to its relationship with the Indian Ocean dipole events [1,2].

Figure 1 represents the analysis of IX1- XBT temperature data in the Java upwelling region (~7.5°S, 105.0°E). Figure 1a shows a typical temperature profile, where the black line represents the depth of the 20°C isotherm. Figure 1b shows a power spectrum of the depth of the 20°C isotherm, where psd is the power spectral density (PSD), and Δf is the frequency resolution in cycles per month. The power spectrum shows three strong low-frequency maxima corresponding to periods of 6, 18.7, and 34 months.

Figure 1

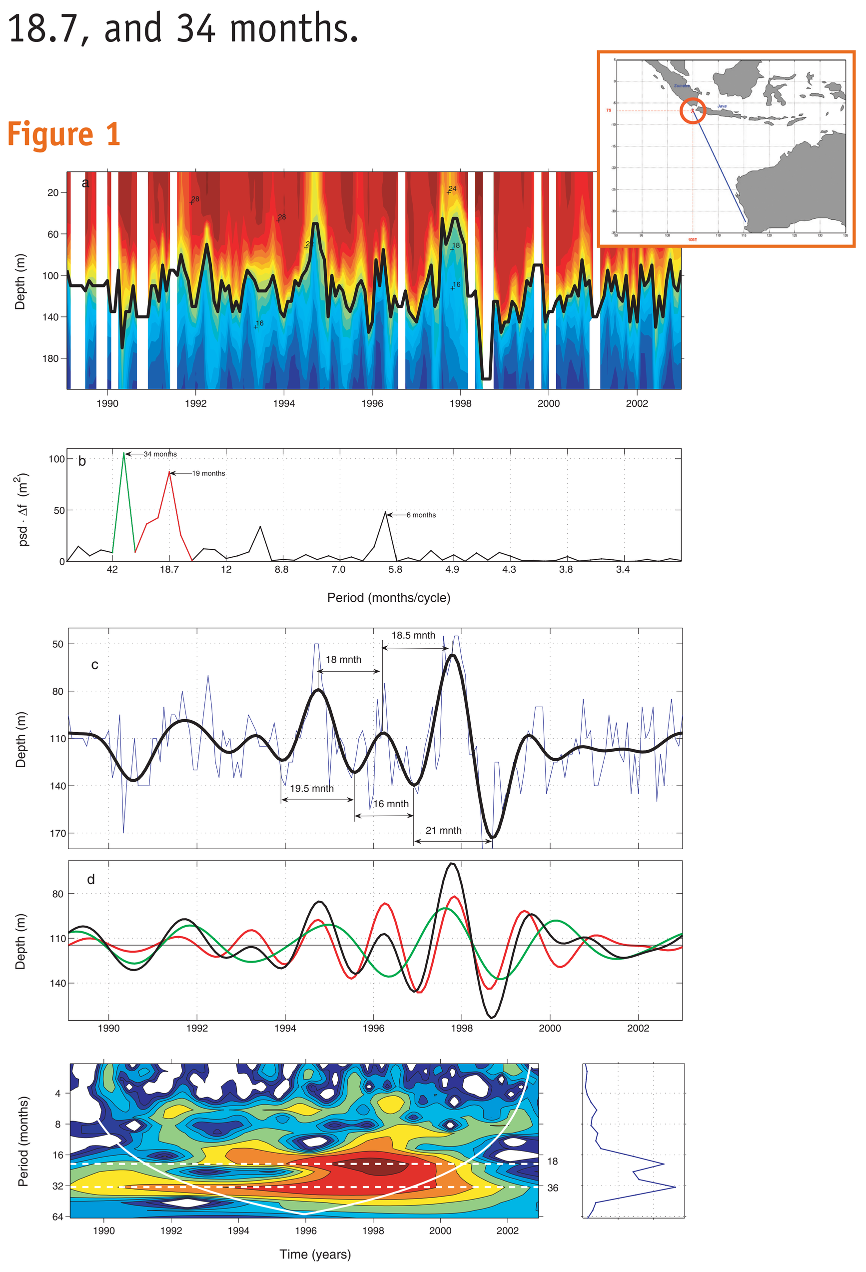


Figure 1c shows the low-pass filtered depth of 20°C isotherm (D20) with the cut-off frequency at ~1/14 months. Between 1994 and 1999, the low-passed D20 oscillates with a period close to 18 months; it has minimum depth during recognised IOD events (1994, 1997) and maximum depth during recognised negative IOD events (1996, 1998). Figure 1d shows separately the 34-month signal (green line) and 18-month signal (red line), as well as the sum of these signals (black line). Both of these signals exist between 1994 and 2000 (Figure 1e – wavelet analysis). The extremely shallow thermocline during IOD events of 1994 and 1997 may be seen as caused by constructive interference of these two signals, as well as the negative IOD event in 1998.

Data and methods

- Satellite altimetry SSH data (Oct 1992 to Oct 2006) collected by the ERS/Envisat/TOPEX/Jason-1.
- Discrete Fourier Transform (DFT) methods.
- Wavelet (Morlet) software was provided by *C. Torrence and G. Compo* (http://paos.colorado.edu/research/wavelets).

Analysis of SSH data

Analysis of the SSH variability over the whole IO shows the existence of five well separated frequency bands that carry most of the low-frequency signal. This is demonstrated by Figures 2a-2c, which show the PSD of SSH in a number of different locations in the IO: 7.7°S, 105°E (a); 24°S, 75.0°E (b); 7.7°S, 75.0°E (c); and Figure 3, which presents the maps of the spatial spectral density of SSH for each individual frequencies. In this picture one can clearly see strong signals with periods of 6- and 12-months as well as the well 18-21-month band at 18.6 and 21 months. There is little energy at 12.9-, 14-, 15.2-, and 6.7- month signal separated 12 and 18-21 months frequency bands. The different spatial distribution makes it possible to distinguish between a 2.3-3.5 year and 4.6-7 year frequency bands. Interestingly, despite the previous research investigating on the quasi-biennial (24-month) mode, there is no major signal associated with the bi-annual period.

Figure 2

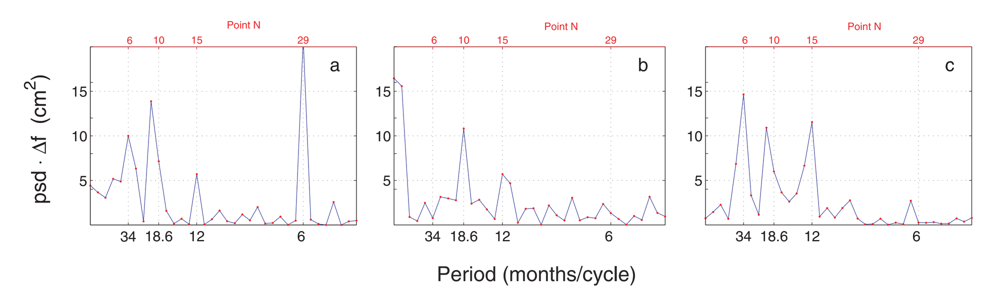
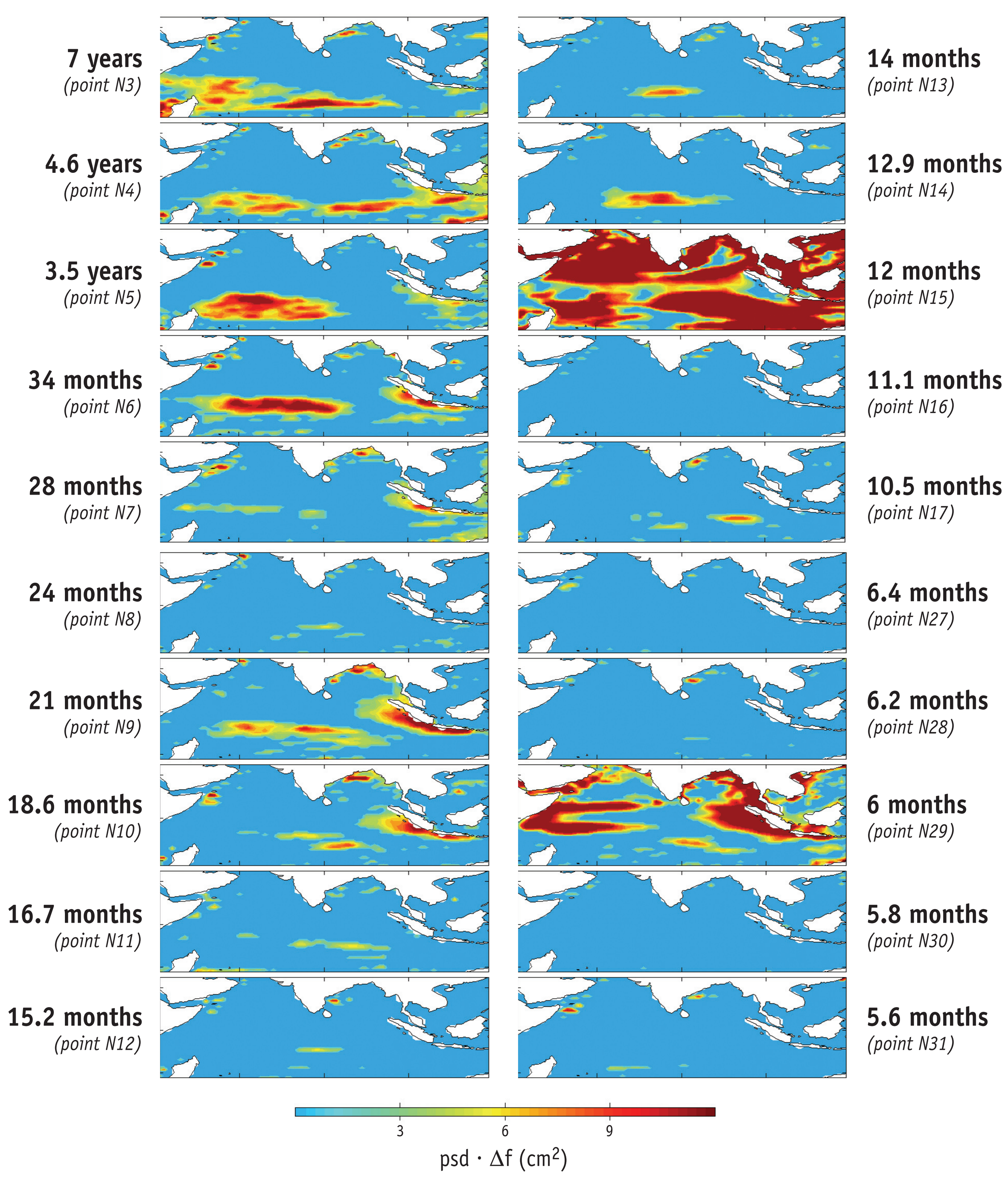


Figure 3



Analysis of SSH in the Java upwelling region is represented in Figures 4 and 5 (8°S, 105°E). Figure 4 shows that the signals with periods of 19 months and 3 years exist during 1992-2000. It also shows that the signal with a period of 19 months starts to develop in 2004 and continues to increase till October 2006. Figures 5a and 5b (black line) show the low-passed filtered SSH signal with the cut-off frequency set at approximately 1/14 months. This signal starts to oscillate in 2004 with the two maxima in May 2004 and November 2005 and the interval between them of about 18 months. Figure 5b shows separately the signals for each low-frequency band. It can be seen that the biggest contribution comes from the 18-month signal.

Figure 4

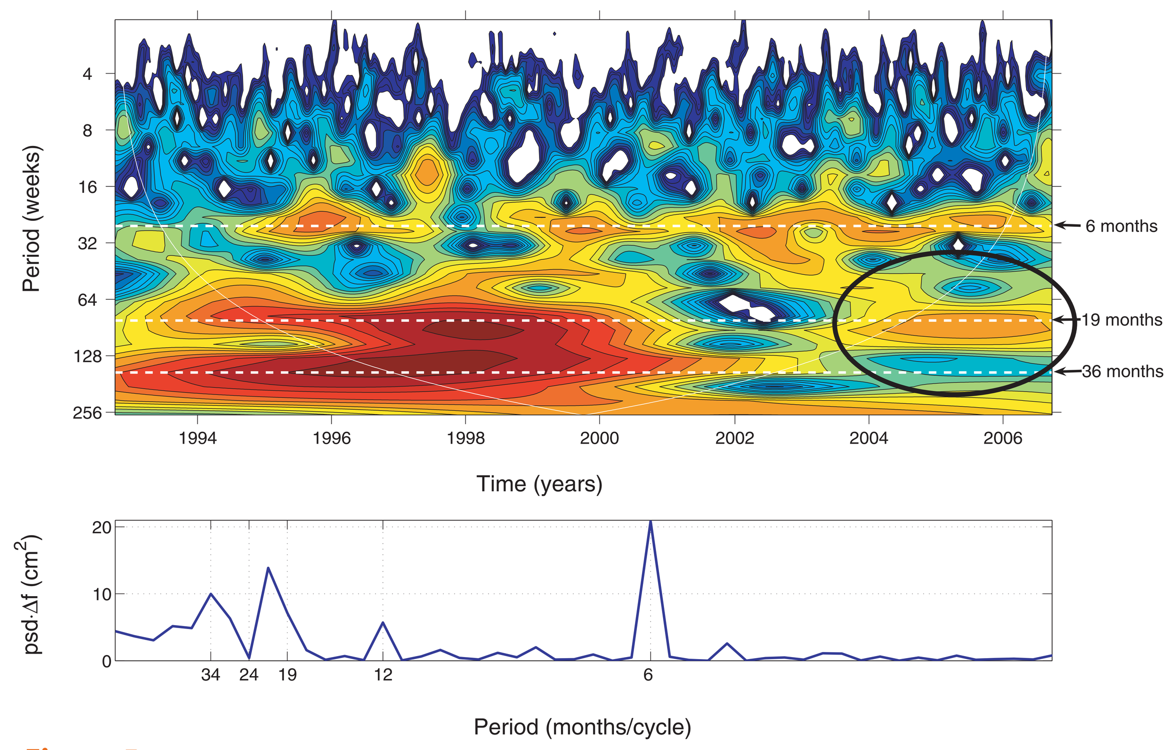


Figure 5

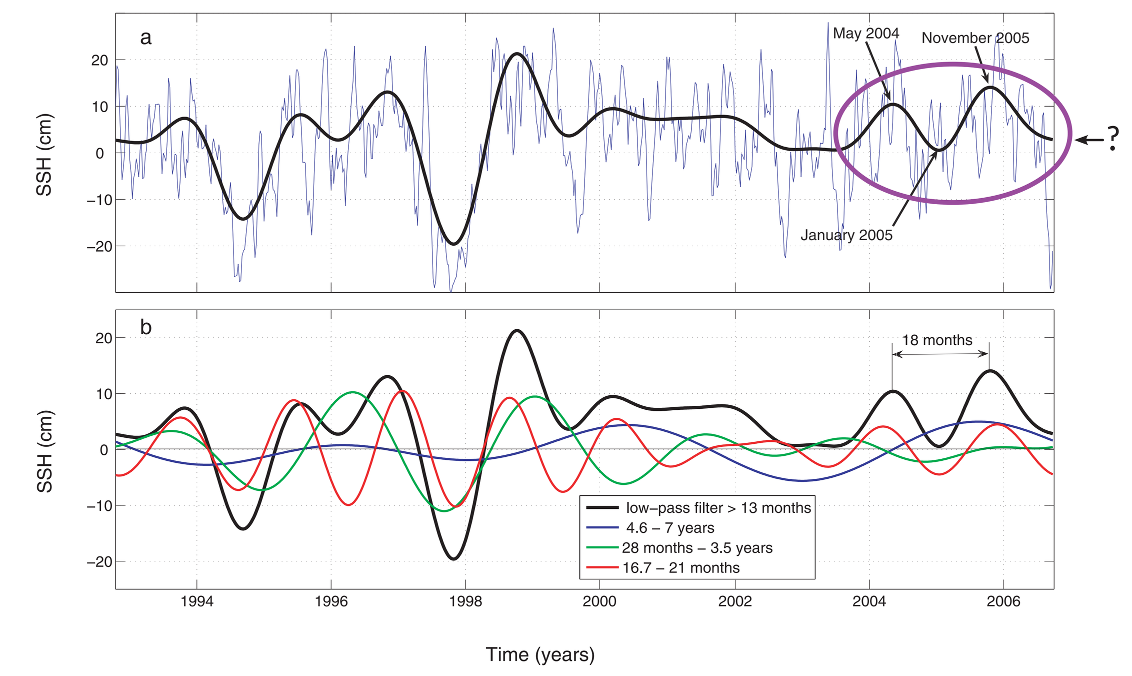
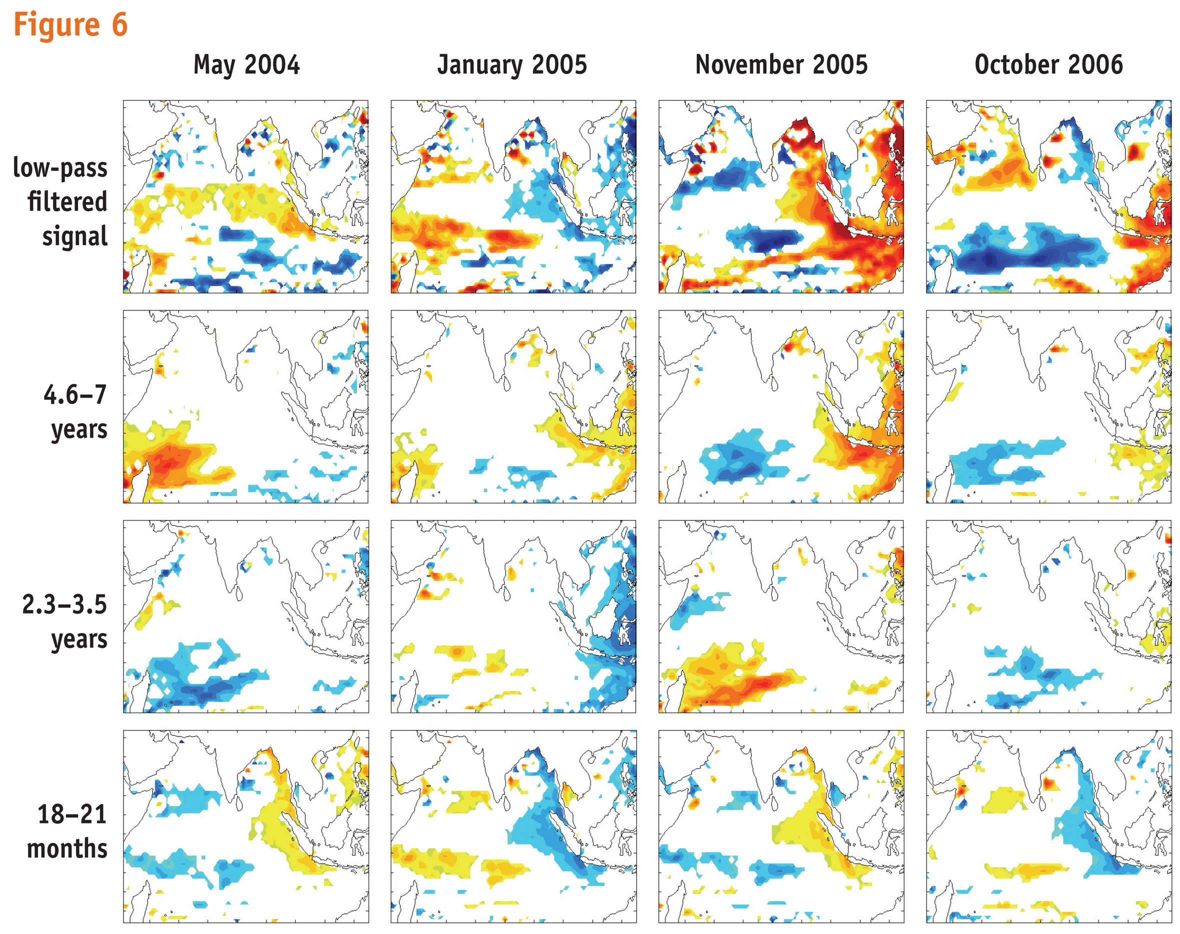


Figure 6 shows the spatial spectral density of the SSH for the total low-pass filtered signal the cut-off frequency at ~1/13 months, 4.6-7-year, 2.3-3.5-year and 18-21-month signals for May 2004, Jan 2005, Nov 2005, and Oct 2006. It shows that the 18-month signal makes the strongest contribution to the low SSH in October 2006 and can be responsible for the anomalous sea surface cooling at the end of 2006.

Figure 6



Conclusions

- The spectral analysis of the low-frequency variability using SSH satellite observations in the IO exhibits five strong, well separated, low-frequency bands: semi-annual, annual, 18-20 months, 2.4-3.5 years, and 5-7 years.
- The 18-month signal starts to develop in 2003 and continues until the end of the data set – Oct 2006.
- The 18-month signal seems to be largely responsible for the latest SSH anomalies near the Java coast in autumn 2006.

Acknowledgments:

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References:

1. Sakova, I. V., G. Meyers, and R. Coleman (2006), Interannual variability in the Indian Ocean using altimeter and IX1-expendable bathy-thermograph (XBT) data: Does the 18-month signal exist?, Geophys. Res. Lett., 33, L20603, doi:10.1029/2006GL027117.
2. Sakova, I., G. Meyers, and R. Coleman (2006). On the low frequency variability in the Indian Ocean, (In) Dynamic Planet - Monitoring and Understanding a Dynamic Planet with Geodetic and Oceanographic Tools, IAG Symposia Series, Vol.130, Springer-Verlag, P. Tregoning and C. Rizos (Eds), pp47-50.

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