Prediction of IOD using altimetry and in-situ measurements

Irina V. Sakova[1,2], Richard Coleman[2,3,4], and Gary Meyers[5]

[1]Nansen Environmental and Remote Sensing Center, Bergen, Norway
[2]School of Geography & Environmental Studies, University of Tasmania, Hobart, Australia
[3]CSIRO Marine and Atmospheric Research, Hobart, Australia
[4]Antarctic Climate & Ecosystems CRC, Hobart, Australia
[5]Integrated Marine Observing System, University of Tasmania, Hobart, Australia

Background

In this work we extend the 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 strong positive Indian Ocean Dipole (IOD) of 2006 and propose to use this knowledge to improve the IOD forecast.

The previous analysis of the low-frequency SSH variability over the whole IO identifies several strong, well separated spectral bands carrying most of the signal. 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. 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: IX1- XBT temperature in the Java upwelling region (7.5S, 105.0E)

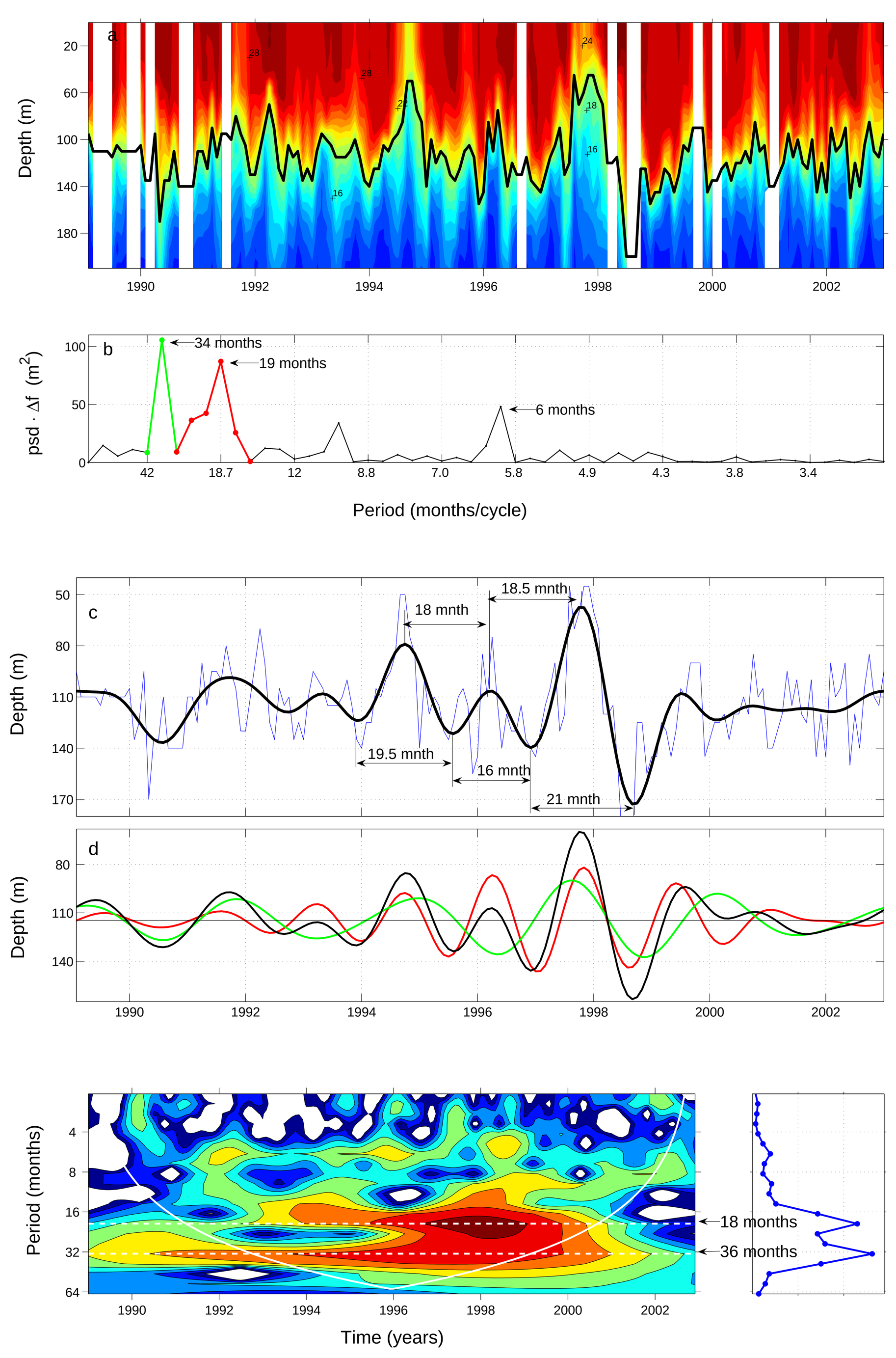


Fig. 1,a shows a typical temperature profile, where the black line marks the depth of the 20°C isotherm; Fig. 1,b shows a power spectrum of the depth of the 20°C isotherm; Fig. 1,c shows the low-pass filtered depth of 20°C with the cut-off frequency at 1/14 months; Fig. 1,d shows the 34-month signal (green line), 18-month signal (red line), and the sum of these signals (black line). Both of the signals in Fig. 1,d are strong between 1994 and 2000 (see the wavelet analysis in Fig. 1). The extremely shallow thermocline during IOD events of 1994 and 1997 as well as the negative IOD event in 1998 may be seen as caused by constructive interference of these two signals.

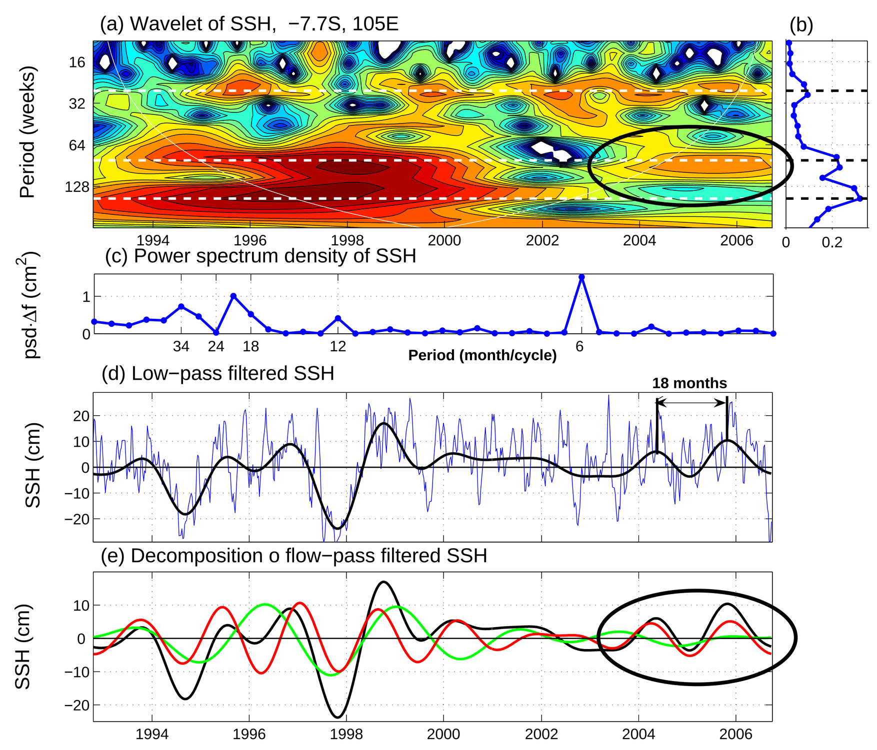
Data and methods

- Gridded (1 degree) satellite altimetry SSH data (Oct 1992 to Jan 2008) collected by ERS/Envisat/TOPEX/Jason-1.
- Subsurface temperature data set from IOTA (Indian Ocean Thermal Archive) for the period from Jan 1989 to Dec 2002.
- Frequency analysis methods.
- Wavelet analysis (Morlet) using software provided by C. Torrence and G. Compo.

2006 Indian Ocean Dipole

In fall 2006 a very strong Indian Ocean Dipole has occurred. Presented below is the analysis of SSH in the Java upwelling region (8S, 105E).

Figure 2: Analysis of altimetry SSH in the Java upwelling region



One can see from the wavelet analysis in Fig. 2,a that the signals with periods of 18-22 months and 3 years have existed in 1992-2000, but subsided after 2000. At the end of 2003 the signal with period of 18-22 months starts to develop, and continues to increase till October 2006. Figs. 2d,e (black line) show the low-pass filtered SSH signal with the cut-off frequency set at approximately 1/14 months. Since 2003 it has had two maxima, in June 2004 and December 2005 (with the interval of about 18 months), and two minima, in March 2005 and October 2006 (with the interval of 19 months). Fig. 2e 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.

If the 18-20 months signal can be associated with IOD, as we assume, its development can be used for improving prediction of IOD. The development of the this signal can be best detected by analysing the subsurface temperature (T) in the Java upwelling region.

Figure 3: Subsurface temperature anomaly at 7-8S, 104-106E

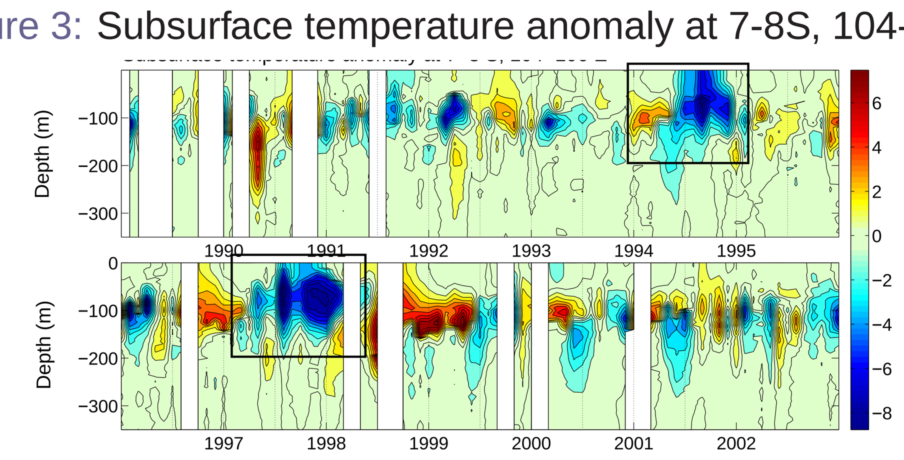


Fig. 3 shows that the highest variability of the subsurface T in the Java upwelling region is located at depth of about 100m, close to the depth of the 20°C isotherm. T anomalies on that depth have a clear oscillatory character, especially during 1994/1995 and 1997/1998 IOD events. The negative anomaly of 1994 was followed by the positive anomaly of 1995; the negative anomaly at the beginning of 1996 - by positive one at the end of 1996; the negative anomaly of 1997 - by positive of 1998/1999. This agrees with the SSH behaviour in Fig. 2,d. For both positive IOD events in 1994 and 1997 the negative T anomaly first appears at the depth of thermocline, and only 2 months after that manifests itself at the surface. Fig. 4 shows the behaviour of variance of the subsurface T signals with periods of 18 months and 3 years. The maximum variability of the 18-month signal is at about 100m, and the signal quickly reduces with distance from the Java coast.

Figure 4: Variance of the subsurface T in the Java upwelling region

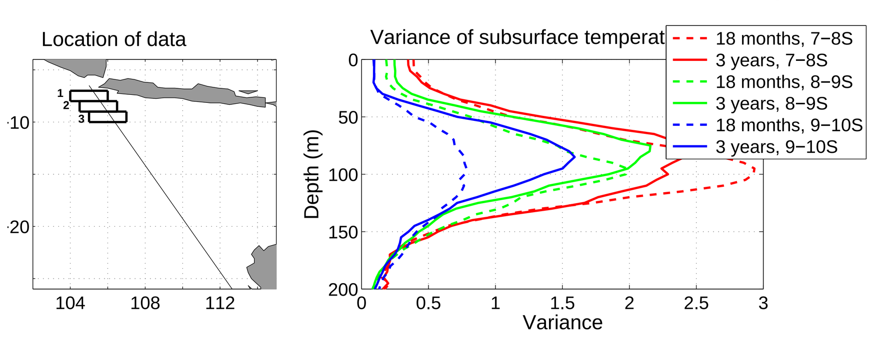


Figure 5: SSH, as in Fig. 2, for the period ending January 2008

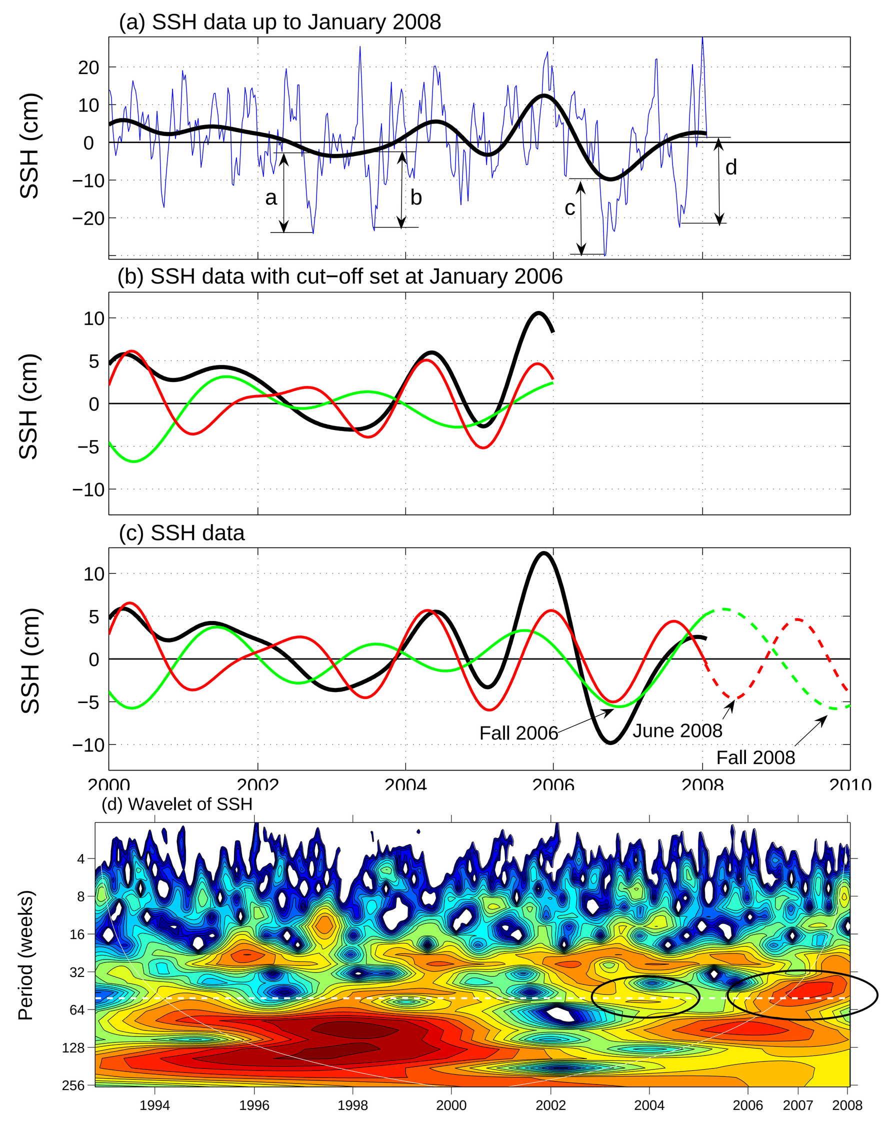


Fig. 5 shows altimetry SSH variability in the Java upwelling region until January 2008. There are strong negative yearly anomalies in 2002, 2003, 2006, and 2007 (marked by a, b, c, and d in Fig. 5,a; see also Fig. 5,d); however, a strong positive IOD happened in only 2006, while a weak negative IOD happened in 2007. This occurred due to the interference with the low-frequency signal.

The main question is how far in advance one can detect the development of the low-frequency signal? Fig. 5,b shows the SSH signal on January 2006, 9 months prior to IOD. The 18-month signal already passed 1.5 periods and was quite noticeable. Fig. 5,c shows a possible extension of the low-frequency signals up to 2010. The 18-month and 3-year signals will interfere constructively in 2009 and, if they will not decay to that date, will create conditions for IOD in 2009.

Conclusions

- The analysis of the low-frequency variability of the IO shows the existence of 18-month signal that can be connected with the IOD events of 1994 and 1997.
- The 18-month signal starts to develop in 2004 and continues until the end of SSH data set (January 2008) and seems to be largely responsible for the latest positive IOD of 2006.
- We suggest that IOD has oscillatory, rather than triggered nature.
- We suggest monitoring of the 18-month signal in the Java upwelling region for better IOD prediction.

Literature

[1] Irina V. Sakova, Gary Meyers, and Richard Coleman. 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, 2006.

[2] Irina V. Sakova, Gary Meyers, and Richard Coleman. On the low frequency variability in the Indian Ocean. pages 47–50. Springer-Verlag, 2006.

Acknowledgements

This research was supported by a joint CSIRO and University of Tasmania PhD scholarship in Quantitative Marine Science (QMS) with additional support from the Wealth from Oceans National Research Flagship.

http://nersc.no
irina.sakova@nersc.no