Eddy and wave dynamics with TOPEX/POSEIDON and Jason-1 altimetry

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Several topics pertaining to the eddy and wave dynamics are under investigation using altimetry and model simulations. Diverse oceanic phenomena such as currents, mesoscale eddies and planetary wave propagation all contribute to the structure of sea surface height field. Oceanic eddies plays an important role in the energy transfer processes associated with the ocean circulation. Planetary waves play a fundamental role in redistributing and dispersing the large-scale time varying energy in the ocean interior far way from the energy sources. We study the eddy and wave dynamics in satellite observations and, derived fields, and numerical models.

Heat and Salt transports in the Indian Ocean

Heat transports in the Indian Ocean are derived using TOPEX/POSEIDON altimetry and MICOM simulations to examine the redistribution of heat in the Indian. We showed [Manganani et al., 2000] that T/P derived heat storage is weaker than that derived from the model but has similar spatial structure and temporal evolution. Complex Principal Component Analysis (CPCA) shows that there are two main modes of heat content redistribution in the Indian Ocean. The most dominant mode has an annual signal peaking in the boreal summer, and it depicts the response to strong southwest monsoon winds. This response involves offshore propagation of heat in the north Indian Ocean and southward propagation of heat across the equator (figure 1). The other main mode of heat content redistribution in the Indian Ocean results from westward propagating equatorial Rossby waves [Subrahmanyam et al., 2000; 2001]. This process is prominent in the boreal fall to spring, and represents the dynamic readjustment of the Indian Ocean to near-equatorial wind forcing. This mode indirectly relates to the Indian Ocean Dipole Mode.

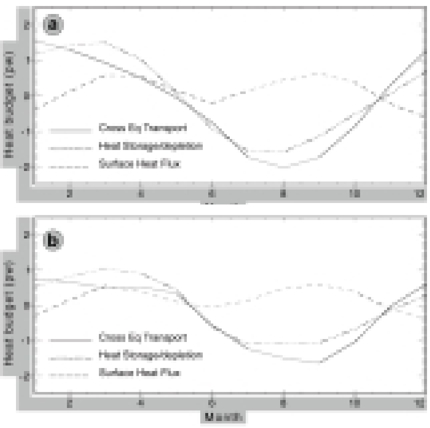

Figure 1: The mean annual cycle of the heat budget terms in the Indian Ocean derived from T/P altimetry (b) and MICOM simulations (a).

The Indian Ocean Dipole Mode is detectable in the T/P sea surface height anomalies along 4°S (figure 2a) during 97/98 El Niño. Negative sea surface height anomalies in the eastern basin and positive sea surface height anomalies showed the existence of the Dipole Mode. We calculated the Dipole Mode Index (DMI) in the equatorial Indian Ocean from the SST fields from MICOM model simulations (figure 2b). It is the difference between the average near equatorial temperature anomaly between the west (5°S-5°N, 55°E-75°E) and east (10°S - Equator, 85°E - 95°E) Indian Ocean. The minima of this time series coincide with the occurrence of the anomalous dipole structure in the equatorial Indian Ocean. We will continue examining the thermodynamic oceanic processes associated with the Dipole mode through the use of MICOM simulations and altimetric data (TOPEX/POSEIDON and Jason-1). We are developing synthesis of water mass, heat and salt budgets in the North Indian Ocean, with the goal to understand and characterize the physical processes that control the exchange and storage of water, heat and salt. This work will be carried out using the WOCE sections in the Indian Ocean and T/P and Jason-1 altimetric data.

Rossby-wave mixed-layer interactions

Large amplitude Rossby waves are generated in the mid-latitude Pacific Ocean during extremes of the El Niño/Southern Oscillation (ENSO). Rossby waves are detectable in both satellite altimetry and hydrographic data. At depths of 100 m the Rossby signal is about ± 1°C. This represents a significant perturbation of the mean temperature profile beneath the seasonal mixed-layer (ML). However, the perturbation is reversible except during the interaction with the winter ML. As the winter ML deepens it is strongly influenced by the underlying vertical structure. Both

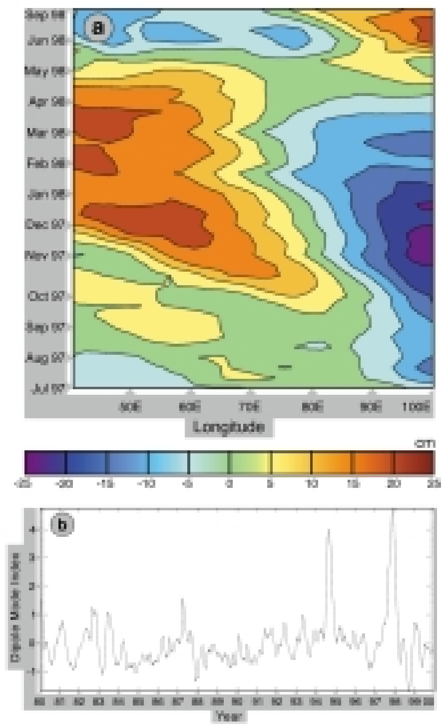

Figure 2: a) Sea surface height anomalies, relative to 1993-1996 mean from T/P altimetry, showing the Indian Ocean Dipole Mode during 1997/98 El Niño. b): The Dipole Mode Index in the equatorial Indian Ocean estimated from the SST fields in the MICOM model simulations.

the ML depth and temperature are being examined in order to test the hypothesis that Rossby waves impact the winter sea surface temperature and are an important component in the quasi-decadal variability of the North Pacific Ocean. Altimetric data from GEOSAT and ERS are used in the early years under study and from the TOPEX/POSEIDON (T/P) and Jason-1 missions in later years. The hydrographic data is obtained from the World Ocean Database 1998 (WOD98) version 2.0. The analysis begins with a case study of the 1982/83 El Niño. Figure 3 shows the Rossby wave generated during the 1982/83 El Niño. The winter (Dec-Feb) average of ocean temperatures between 10 and 50 m depth in a bin ± 2° near the position of the Rossby wave are determined for several latitudes (20, 24, 28, 32, 36, 40, and 44°N). Most of the Rossby wave-related temperature anomalies are negative with an average of -0.2°C. Excluding the westernmost locations (west of 180°W) which are generally positive, the average ML temperature anomaly is -0.4°C. This result is consistent with the prediction of Meyers et al. [1996] that El Niño-generated Rossby waves in the North Pacific would generate negative temperature anomalies during the winter. Remaining to be investigated is the spatial extent of this change in SST and the effect of other ENSO-generated Rossby waves on the ML. Should these results hold for other ENSO events this would imply that near-decadal variability of ENSO is being propagated into the North Pacific Ocean via planetary waves [Meyers et al., 1996].

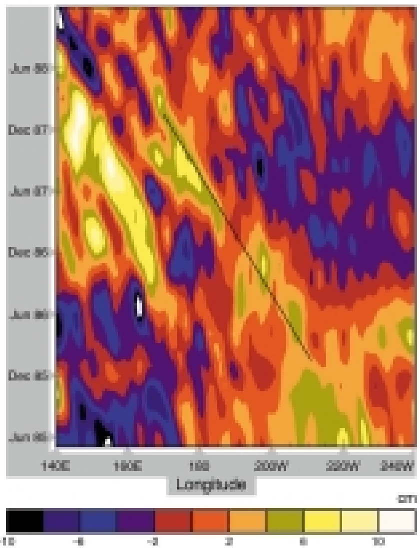

Figure 3: Sea surface height anomaly (cm) along 30°N from GEOSAT. The black line indicates the path of the Rossby wave generated during the 1982/83 El Niño. These locations were used to examine the temperature anomaly for the winter mixed-layer.

Dynamics of Agulhas rings and Brazil-Malvinas confluence

The South Atlantic is strongly effected by Agulhas rings, western boundary currents, and Rossby waves. We study the processes associated with the Agulhas rings, waves, Brazil current and Agulhas rings-Brazil current merging processes. We will also investigate the distribution of energy of propagating baroclinic Rossby waves through the south Atlantic.
This study is carried out with T/P and Jason-1 altimetric data, Tropical Rainfall Measuring Mission (TRMM) sea surface temperature data, and numerical models. The depth of the upper layer was calculated from hydrographic observations (using World Ocean Atlas, 1998) and altimeter derived sea surface height anomaly (figure 4). The size and intensity of the rings can be quantified in terms of ring volume anomaly relative to its surrounding water and ring energy content. Available potential energy, volume anomaly, and heat content anomaly are calculated for each ring.

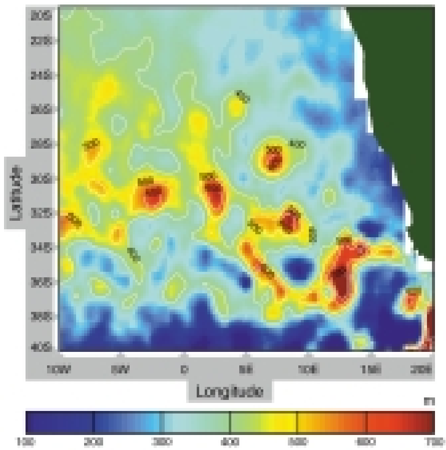

Figure 4: Agulhas rings depicted in the layer thickness (m) derived from altimeter data (T/P+ERS) and WOA98 hydrographic data during September 26, 1999.

Ongoing Research work

- Heat and salt budget of the Indian Ocean derived from the altimetry and Miami Isopycnal Coordinate Ocean Model (MICOM) simulations.
- Sesonal to interannual variability in the Indian Ocean using satellite observations and MICOM simulations.
- Rossby wave mixed layer interactions in the Pacific Ocean.
- Dynamics of Agulhas rings and Brazil-Malvinas confluence based on satellite altimetry and numerical model simulations.
- The generation and evolution of cyclonic eddies in the western edge of the Loop Current in the Gulf of Mexico. Use of altimetry data for the implementation of the boundary conditions of a high resolution numerical model of the Gulf of Mexico.
- Mesoscale variability along the southwest coast of Mexico using altimetry and Naval Research Laboratory Ocean Model (NLOM).
- Topical Pacific Ocean Bio-Physical variability derived from models forced and validated with multiple satellite observations.

References

Maghanani V., J. Morrison, L. Xie, B. Subrahmanyam, 2000: Heat Budget of the Indian Ocean using TOPEX/ POSEIDON altimetry and Model simulations, *Deep-Sea Res., (revised)*.

Meyers S.D., M.A. Johnson, M. Liu, J.J. O'Brien, 1996: Interdecadal variability in a numerical model of the northeast Pacific Ocean 1970-1989, *J. Phy. Oceanogr.*, 26, 2635-2652.

Subrahmanyam B., I.S. Robinson, 2000: Sea Surface Height variability in the Indian Ocean from TOPEX/ POSEIDON Altimetry and Model simulations, *Marine Geodesy*, 23, 167-195.

Subrahmanyam B., I.S. Robinson, J.R. Blundell, P.G. Challenor, 2001: Rossby waves in the Indian Ocean from TOPEX/POSEIDON altimeter and Model simulations, *Int. J. Remote Sensing*, 22, 141-167.

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