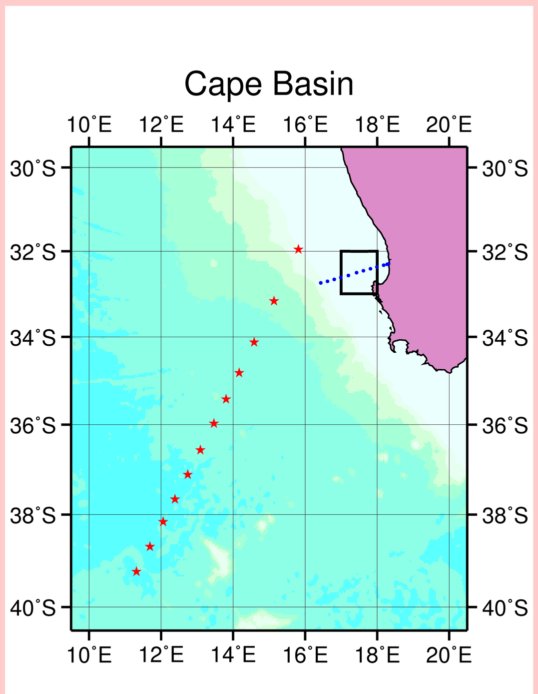
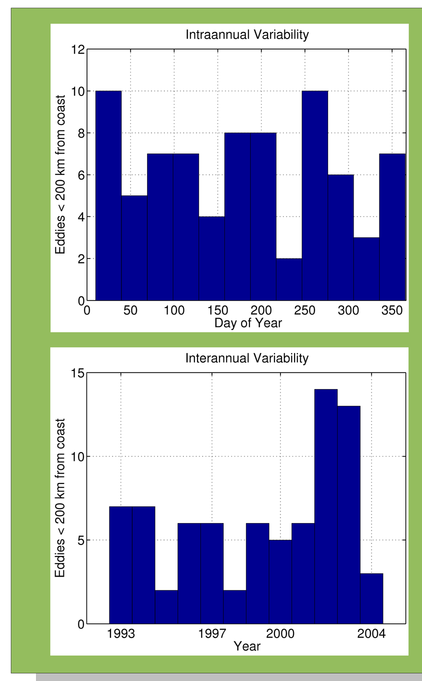
A Statistical Consideration of the Interaction of Oceanic Mesoscale Variability with the Benguela Upwelling System

Christopher M. Duncombe Rae[1], Deirdre A. Byrne[1] and Sheekela Baker-Yeboah[2]
1. School of Marine Sciences, Univ. of Maine, Orono, ME 04469, U.S.A. 2. M. I. T., Cambridge, MA 02139, U.S.A.

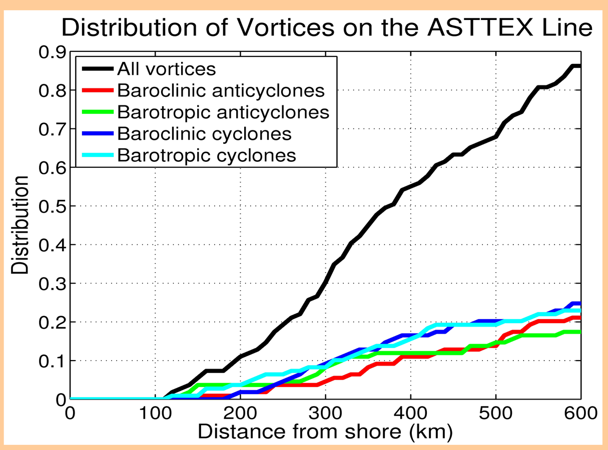
The Agulhas Leakage provides the bulk of the return flow of the global meridional overturning circulation (MOC). Agulhas rings and eddies shed from the retroflection (AREs) enter the Cape Basin interacting with each other and topography, splitting and merging. The AREs occasionally impinge on the Benguela upwelling system (BUS), draw surface water from the upwelling front, and affect the ecosystem of the southwest African shelf. New data show that other mesoscale features affect shelf circulation; baroclinic and barotropic cyclones and anticyclones have been observed in the vicinity of the shelf and slope and our hypothesis is that all of these types of features may significantly influence the upwelling system.

We use satellite-derived sea-surface height (SSH) and an upwelling index (UI) in the BUS (in the area designated by the box) to examine the interaction between mesoscale features observable in the satellite SSH record and the upwelling system. We discuss the implications for the upwelling response and the possible effect on the Agulhas-derived features in terms of their contribution to the global MOC. Together with field data from a mooring array deployed from 2003–2005 (ASTTEX project, red stars) and cruise data from the St Helena Bay Monitoring Line (SHBML, blue dots), we assess the contribution of the mesoscale variability in the Cape Basin to the shelf/ocean exchange.





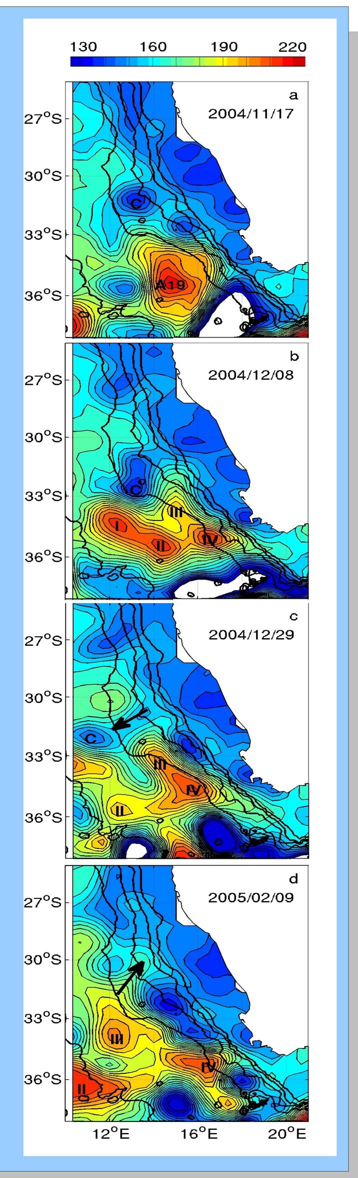
Intraannual variability of the presence of eddies in the Cape Basin within 1000km of the coast was not pronounced. There appeared to be a slightly more eddies in January but this does not appear to be a significant difference. Interannual variability was more pronounced and a maximum in the presence of eddies was observed in the Basin during 2002 and 2003. The upwelling signal was strongly seasonal, dependent on the wind forcing, as expected showing a maximum in the summer months (not shown).



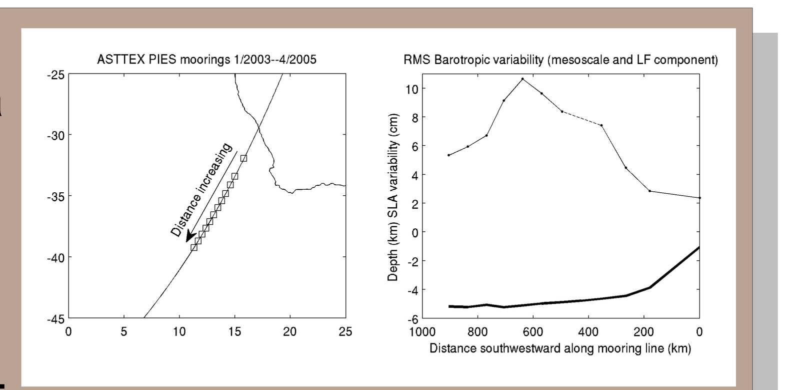
Vortices detected by the pressure sensor equipped inverted echo sounders (PIES) on the ASTTEX line were fairly evenly distributed among baroclinic cyclones and anticyclones, and barotropic cyclones and anticyclones.

Case Study

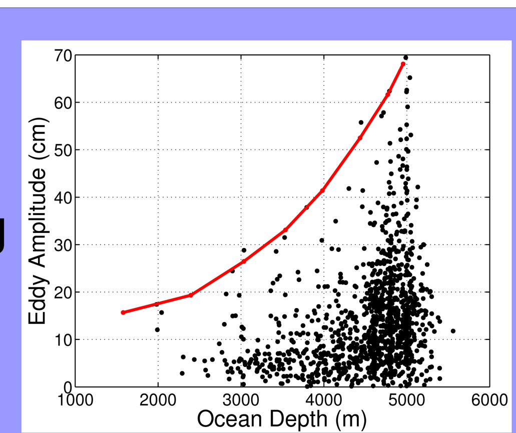
Four snapshots of AVISO delayed-time maps of absolute dynamic topography (DT-MADT) over a period of 3 months are shown.
(a) An Agulhas ring (A19) encounters the shelf/slope environment. It is 400 km in diameter and 35 cm SSH relief above surrounding waters).
(b) Within 15 days of encountering the slope, A19 splits into four parts (I, II, III & IV). I and II propagate rapidly west away from the shelf region; III and IV remain close to the shelf with low translation velocities.
(c) While III and IV remain in close proximity to the shelf, cyclonic eddies are generated at the shelf edge and propagate away from it (cyclone "C") and upwelled water is removed from the shelf environment (arrow).
(d) at the same time, incursions of water from the remnants of A19 into the shelf environment occur.
This feature is described in detail by Baker-Yeboah (2008).



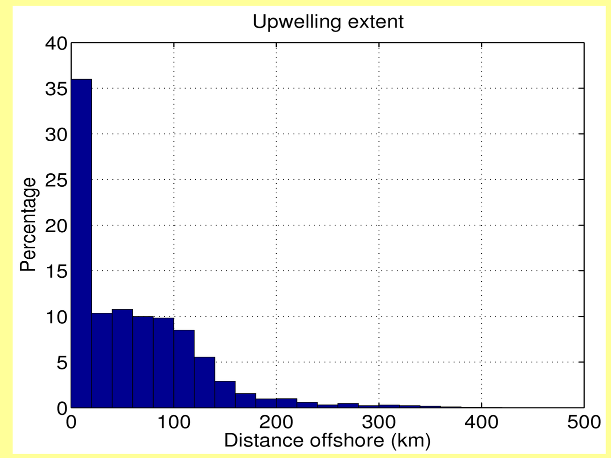
I and II crossed the ASTTEX moorings. The barotopic component of the RMS sea level anomaly (SLA) was determined from the bottom pressure recorders.16% of the SLA of I was barotropic; 30% of the SLA of II was barotropic. II was smaller than I, and the barotropic component contributed 60% of the EKE. A full analysis of A19 was not possible as other compenents did not reach the mooring line.However analysis of RMS barotropic variability shows that it decreases rapidly with proximity to the coast.



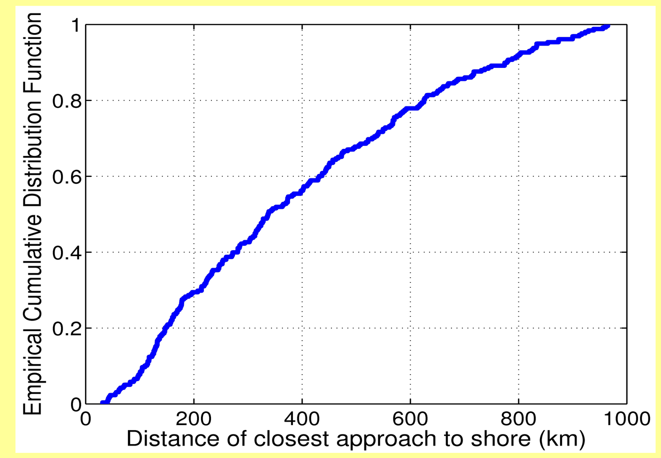
The amplitudes of all anticyclonic (Agulhas) eddies west of 10°E occuring in 1993–2005 were identified from Jason-1 and Topex/POSEIDON along-track altimetry using an automated tracking procedure (D. Witter, Kent State U.). Amplitudes are plotted versus the depth of the ocean under the eddy center. Lower amplitudes of rings close to the shelf may indicate reduced volumes from splitting due to eddy/shelf interaction. Since the altimeter data will under-represent ARE amplitudes when the center of the feature is not directly along a ground-track, it is the upper bound of the amplitude data (shown in red) that is significant. The upper bound clearly shows a dearth of high-amplitude Agulhas eddies at shallow depths in the Cape Basin. The lack of high-amplitude eddies cannot simply be ascribed to the positioning of the Agulhas eddy corridor further to the west, as approximately 15% of AREs encounter the shelf/slope.



An UI was obtained for the SHBML area from NOAA/PFEL/ERD. The UI provides the Ekman transport in units of m^3s^{-1}/ 100 m of coastline. To relate this upwelling intensity to the distance offshore and the potential for interaction with mesoscale oceanic vortices, the upwelling index was scaled by the Mixed Layer Depth (climatic monthly average from WOD98 data), and the mean distance of the upwelling front from the coast obtained from hydrographic data (St Helena Bay Monitoring Line).



The distribution of the extent of the upwelling front suggests that ~7% of the time the upwelling front extends more than 150km from the coast.



The distribution of vortices found within 500km of the coast suggest that ~30% approach to within 150km of the coast.

The upwelling front of the BUS extends more than 150 km offshore ~7% of the time. This is a mean estimate, and does not consider extentions of the front, such as excursions of the frontal jet unrelated to wind forcing, or filaments which may extend the zone of influence of the upwelling front more than 700 km offshore.
15% of Agulhas retroflection eddies interact with the shelf and slope while 30% of all vortices approach within 150 km of the coast. The proportion of all vortices that might influence the BUS by interacting with the mean upwelling front is thus ~2%.
15% of Agulhas eddies may undergo interactions of the type described in the case study, losing mass and energy in the interaction.

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References: Baker-Yeboah, 2008. *Sea Surface Height Variability and the Structure of Eddies in the South Atlantic Cape Basin*. PhD Thesis, Univ. of Rhode Island.

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