**Agulhas Current-driven hydrographic variability on the southeast coast of South Africa**

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**Background**

Similar to the other western boundary currents (WBCs) of the world, the Agulhas Current, the largest WBC in the southern hemisphere, strongly influences the oceanographic conditions of its adjacent shelf system. As a result of limited societal drivers, such as large-scale fisheries and marine mining, the southeast African shelf is one of the least studied and under-sampled shelf systems in South Africa. As a result of this *in situ* sample deficit, the majority of previous studies conducted in the region have used satellite data and model output. Few studies, using limited *in situ* data, have been carried out at either a bay-scale, which fall short of accurately identifying the larger surrounding oceanographic features, or they have been conducted at a larger scale with a coarser resolution, which unsuccessfully captured the finer detail of the shelf circulation. Understanding hydrographic variability on the shelf, as well as the processes influencing it, is crucially important for understanding the functioning of the numerous Marine Protected Areas (MPAs) along this coast, and is essential for their effective management. In order to address the lack of *in situ* data in the region, a collaborative venture between the South African Department of Environmental Affairs (DEA) and the African Coelacanth Ecosystem Programme (ACEP) Phakisa Ocean Cruises Initiative funded two shelf-wide multi-disciplinary research cruises which were conducted during January/February (austral summer) and July/August (austral winter) 2017, to establish a baseline of shelf-wide environmental conditions.

**Methods**

In order to identify and characterise the physical oceanographic processes modifying hydrographic conditions on the shelf, this study used a combination of satellite data and high-resolution *in situ* data, acquired during the two hydrographic surveys. Vertical profiles of temperature, salinity, dissolved oxygen and fluorescence were collected, between the surface and 1000 m depth, using a Conductivity, Temperature and Depth (CTD) Sea-Bird Electronics (SBE) 911+ instrument. Conservative Temperature and Absolute Salinity, calculated according to TEOS-10, were used to map surface and bottom distributions of these parameters. Water masses were identified using Temperature-Salinity (TS) plots in combination with neutral density criteria. Discrete seawater samples were collected at selected depths for the analysis of chlorophyll *a* and macro-nutrients. Chlorophyll *a* samples were analysed using the flourometric technique and used to calibrate vertical fluorescence profiles. Nutrient samples were analysed either manually (phosphate, nitrite) or using a Lachat Autoanalyzer (nitrate, silicate) and used to map surface and bottom distributions of the macro-nutrient concentrations. Satellite altimetry was obtained from the Copernicus

Marine Environment Monitoring Service, and daily maps of delayed-time merged sea level anomaly, overlaid with geostrophic velocity anomaly vectors were used to identify the general circulation on the shelf, as well as identify any mesoscale variability.

## Results

The same five water masses, Tropical Surface Water (TSW), Subtropical Surface Water (STSW), South Indian Central Water (SICW), Red Sea Water (RSW) as well as Antarctic Intermediate Water (AAIW), were observed throughout the upper 1000 m of the water column during each survey. TSW and STSW occupied the upper 200 m of the water column, while SICW was generally found between 400 m and 800 m, and RSW and AAIW usually occurred below 700 m. Indications of seasonality in temperature and salinity were observed across the shelf, within the upper waters (TSW and STSW) but not within the deeper water masses (SICW, RSW and AAIW). There was a ~4 °C difference in maximum surface temperatures between the two surveys, with higher temperatures in January/February than in July/August. In January/February, the surface salinity observations were frequently below 35.22 g $kg^{-1}$, contrasting with July/August when they exceeded that value. The low salinity values across the shelf, as well as those located in close proximity to the Mzimvubu river mouth during austral summer, were observed as a result of the influence of higher rainfall and the subsequently stronger river outflow.

The Agulhas Current, as well as cyclonic mesoscale eddies along the inshore edge of the Current, were observed to strongly drive conditions on the shelf region during each survey. Several upwelling mechanisms, which uplifted colder, nutrient-rich water from deeper layers onto the shelf, were identified during each survey. Divergence-induced upwelling, driven by the offshore deflection of the Current from the coast as a result of the widening shelf, was observed in the southern part of the region. Ekman veering in the bottom boundary layer, driven by the interaction of the Current with the slope topography, was observed at some locations, and was found to essentially prime the lower levels of the shelf with cold nutrient-rich water. Ekman pumping associated with the cores of cyclonic eddies, also introduced nutrient-rich water onto the shelf. Wind-driven upwelling, induced by offshore Ekman transport and vertical mixing, was responsible for the surfacing of this cold (10-15 °C) nutrient-rich water from below at several inshore sites. These upwelling mechanisms, which introduce cold nutrient-rich water into an essentially mesotrophic shelf-environment, strongly impact ecosystem functioning, as evidenced by substantially higher chlorophyll *a* maxima (5.00 mg $m^{-3}$) during January/February 2017 as opposed to much lower values in July/August (3.00 mg.$m^{-3}$). The shelf-wide dissolved oxygen levels (> 3 ml $l^{-1}$) during both surveys suggested that oxygen availability adequately facilitates the survival of the existing shelf biology.

## Conclusion

This study described hydrographic conditions from the first two shelf-wide high-resolution surveys of the southeast shelf of South Africa, providing a baseline of environmental conditions across the shelf, and the processes affecting it. This baseline environmental information is crucial for understanding the functioning, and for effective management, of the numerous Marine Protected Areas along this coast. Although further research is needed to determine the relative importance of these processes, it is necessary that their temporal variations be monitored to understand if and how they may change in the context of a changing climate.