Gateways to the west: understanding ocean circulation at the Mascarene Plateau

Oceanographic studies are revealing important information about the marine ecosystems of the western Indian Ocean. In this, the second of two articles on the research voyages of the Dr Fridtjof Nansen, Isabelle Ansorge and Claire Attwood look at the oceanographic research that is being carried out in a remote part of the western Indian Ocean.

Last year, over a period of three months, 33 South African scientists had the opportunity of conducting oceanographic and fisheries research from the decks of the Dr Fridtjof Nansen, one of the most advanced research ships in the world. Working with their colleagues from four other African countries, as well as from Europe and the USA, the scientists surveyed a wide swath of the western Indian Ocean, paying particular attention to the physical, chemical and biological oceanography of the remote Mascarene Plateau.

The Mascarene Plateau
The Mascarene Plateau is a submerged volcanic plateau extending over 2,200 km between the Seychelles Bank at 4°S to Mauritius at 20°S (Figure 1). The Mascarene Plateau is a complex bathymetric feature characterised by a series of islands, banks and shoals, which are separated by deep channels. Covering an area of over 115,000 km², the Mascarene Plateau is orientated roughly north-south, in a crescent shape. The main banks are known as the Seychelles Plateau, the Saya de Malha Bank, the Nazareth Bank and the Cargados-Carajos Bank (Figure 2).

These are typically 20 m to 100 m deep and topped with coral. On either side of the plateau, steep slopes plunge to abyssal depths of 4,000 m. The general circulation in this region is dominated by the South Equatorial Current (SEC), a broad current between 10° and 16°S sweeping westwards at velocities less than 0.3 m/s (Figure 3). The SEC is directly driven by the trade wind belt and forms the westward limb of the large-scale subtropical Indian ocean gyre (spiral current) feeding into both the Agulhas Current system and the East African coastal current (Figure 3).

What makes this plateau so interesting?
The plateau’s islands, banks and shoals form a barrier that modifies the predominantly westward passage of the SEC. Recent studies have shown that as the SEC approaches the Mascarene Plateau, it branches into a number of tributaries, the largest occurring between the Saya de Malha and Nazareth Banks at 12 to 13°S. Here, approximately 50% of the SEC flow is forced through the narrow channel separating the Saya de Malha and Nazareth Banks, with the remainder of the flow passing in roughly equal volumes around the northern edge of the Saya de Malha Bank (8° to 9°S) and between Mauritius and the Cargados-Carajos Bank (18° to 20°S). The modifying influence of this barrier provides a rare example of an extensive shallow-
Buoy overboard!

by Michael McPhaden

The 2008 voyage of the Dr Fridtjof Nansen provided the Pacific Marine Environmental Laboratory (PMEL) of the USA’s National Oceanic and Atmospheric Administration (NOAA) with an opportunity to deploy two ATLAS moorings in the western Indian Ocean. ATLAS moorings were developed at PMEL in the early 1980s to measure surface wind speed and direction, air temperature, relative humidity, solar radiation, rain rate, sea surface temperature and conductivity at several depths in the upper 500 m and ocean velocity at 10 m depth.

The two moorings deployed from the Dr Fridtjof Nansen bring to 22 the number of moorings that have been deployed in the Indian Ocean through a multi-national effort called RAMA (the Research Moored Array for African-Asian-Australian Monsoon Analysis and Prediction). Eventually a total of 46 ATLAS moorings will span the Indian Ocean between 15ºN and 25ºS and provide a key oceanographic and marine meteorological data set for monsoon research and forecasting.

The first mooring was installed at a location of 8ºS, 55ºE and the second was at 12ºS, 55ºE. The aim of these moorings is to study how shifts in the Intertropical Convergence Zone (ITCZ) as a result of the changing monsoon influence the ocean conditions of this region. For instance, changes in surface conditions occur during periods when the ITCZ is well developed, i.e. during January to March. Then, as the ITCZ migrates northwards and winds become stronger the thermocline deepens. The thermocline is also deeper on average at 12ºS than at 8ºS, which is consistent with the presence of a the westward flowing South Equatorial Current (SEC) at these latitudes. The SEC is seen in the 10 m velocity data and is weaker and more variable at 8ºS than at 12ºS (where unfortunately real-time transmissions from the current meter stopped in early January). Monthly time scale eddy activity in both temperatures and currents is apparent at both sites.

Top right: Isabelle Ansorge, an oceanographer at the University of Cape Town, is dwarfed by an ATLAS mooring prior to its deployment from the Dr Fridtjof Nansen. Image: Isabelle Ansorge.

Right: Daily averaged atmospheric and oceanic data at 8ºS and 12ºS along 55ºE. Shown from top to bottom are shortwave radiation, rain rate, surface wind, ocean currents measured at 10 m depth in the mixed layer and temperature in the upper 300 m. Small arrows on the left axis of the temperature plot indicate the depths of temperature sensors. Image: Mike McPhaden

shelf sea completely detached from land boundaries, and remains an isolated and almost completely unexplored marine ecosystem.

Why the need to investigate this region?

Despite the success of previous investigations under the Sheds of Capricorn Marine Programme in 2002, surprisingly little is known of the role the Mascarene Plateau and the effect its channels and surrounding waters have on the biodiversity of the western Indian Ocean. A key aim of the five-year Agulhas and Somali Current Large Marine Ecosystems (ASCLME) Project is to develop a series of well coordinated oceanographic research cruises aimed at gathering essential information about the oceanography and its interaction with and influence on the biodiversity and economies of the western Indian Ocean region.

What have we found?

Having surveyed the entire Mascarene Plateau (Figure 4) we have a better understanding of its influence on the surrounding marine environment. What have we learnt?

1. It appears that the SEC is displaced southwards from its mean position of 10ºE to 10ºS by the obstruction caused by the shallow bathymetry of the Mascarene Plateau. Upstream of this plateau, the SEC exists as a p-

Figure 4: Cruise map showing all oceanographic stations occupied during the Mascarene Plateau survey.
Argo floats – robots of the sea – how do they work?

Four Argo floats were deployed from the Dr Fridtjof Nansen as she traveled west, from Seychelles to Pemba, Mozambique.

Argo is an international collaboration that collects high-quality temperature and salinity profiles from the upper 2,000 m of the ice-free global ocean, and currents from intermediate depths. The data come from battery-powered autonomous floats that spend most of their life drifting at a predetermined depth (commonly about 1,000 m). This is known as the ‘parking depth’.

At 10-day intervals, the floats pump fluid into a bladder, which inflates, causing the float to rise to the surface over about six hours. During this ascent the float sensors measure temperature and salinity. Satellites determine the position of the floats when they surface, and receive the data transmitted by the floats. The bladder then deflates and the float returns to its original parking depth, drifting along until the cycle is repeated. Floats are designed to make about 150 such cycles.

Steve Kunze and Mike McPhaden deploy one of four Argo floats released from the deck of the Dr Fridtjof Nansen last year. Image: Tommy Bormann.

Dr Fridtjof Nansen

Dr Fridtjof Nansen is owned by the Norwegian Directorate for Foreign Aid (NORAD) and staffed by the Norwegian Institute of Marine Research (IMR). It is working in the western Indian Ocean through a partnership between two United Nations projects: the Agulhas and Somali Current Large Marine Ecosystems (ASCLME) Project and the Ecosystem Approach to Fisheries (EAF)–Nansen Project. The latter project is supported by the UN’s Food and Agriculture Organisation (FAO).

The ASCLME Project is based in Grahamstown at the world-renowned South African Institute for Aquatic Biodiversity (SAIAB). Its role is to assist the nine countries that share the resources of the western Indian Ocean to document the environmental problems — such as pollution, over-fishing and climate change — that are faced by the region and develop a strategic action programme to tackle these problems. Although the ASCLME Project focuses on the Agulhas and Somali Current ecosystems, it was decided that a detailed survey of the Mascarene Plateau would be required to study the complex nature of the South Equatorial Current, an ‘upstream’ current that influences both the Agulhas and Somali Currents and their ecosystems.

broad (~650 km in width) shallow (~1,000 m in depth) current with speeds averaging 0.30 m/s. On approaching the Mascarene Plateau the SEC splits into separate cores centred near 18°, 12° and 8°S and correlated with the location of the deep channels (Figures 2 and 6). Once passed the Plateau it seems likely that these cores continue westwards towards the Madagascar coast at 50°E and there form the North East and South East Madagascar Currents.

2. The SE trade wind field results in a gradual shoaling of water masses between 15° to 5°S. The thermocline depth changed from 250 m close to Mauritius to just under 30 m on the Seychelles Bank (Figure 5). Since nutrients increase with depth, it would be expected that nutrient levels would gradually increase with distance north, thus influencing the biological productivity of the surrounding region. This probably explains improved fish catches as we moved closer to the Seychelles.

3. Finally, the presence of an eastward flow between 6° and 2°S (Figure 6 – blue box) can be related to the position of the eastward flowing South Equatorial Counter Current. This current lies north of the SEC and flows in the opposite direction. This proved to be extremely interesting with salty warm water being swept into the Seychelles region from as far away as the Arabian Sea!

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Oceanographers to track our journey into a new, warmer future

Long-term oceanographic studies could help African countries to better understand the impacts of climate change and to plan for a warmer future.

Within the next 10 to 20 years, global climate change is expected to have a significant effect on marine ecosystems and the coastal communities that depend on them. Scientists believe that sea level rise alone will cause increased flood frequency, accelerated erosion, rising water tables, increased saltwater intrusion and a number of associated ecological changes. These biophysical changes will have significant socioeconomic implications as a result of coastal land loss and changes in coastal resources. Such changes will inevitably lead to a loss of livelihoods, reduction in food security and a general decline in the quality of life, health and well-being of coastal communities. Such impacts will also be felt far inland, as climate patterns that are...driven by the sea, change.

Predictions such as these are particularly serious for the western Indian Ocean, a region that is shared by nine developing nations, including South Africa, Mozambique, Kenya, Tanzania, Madagascar, Mauritius, Seychelles, Comoros and Somalia. There are an estimated 55 million people living in the coastal zone of the western Indian Ocean and poverty levels in the region are among the highest in the world. All nine nations rely on the sea as a source of food security, subsistence livelihoods and employment, and their coastal populations are considered to be extremely vulnerable to the impacts of climate change. Low-lying island nations are particularly concerned with sea level rise associated with climate change.

The potential for the countries of the western Indian Ocean to benefit from long-term oceanographic monitoring was highlighted in a paper entitled *Long-term monitoring and early warning mechanisms for predicting ecosystem variability and managing climate change*, which was presented at the Ocean Observation Conference in Venice in September 2009. Authored by David Vousden and Magnus Ngoile of the multilateral

![Diagram of ocean currents and ecosystems in the western Indian Ocean.](image)

*Figure 1: ASCLME System boundary as defined by currents in the western Indian Ocean.*
and Mauritius to the edge of the Mascarene Plateau (Figure 1). The objective of the Project is to clearly define the ecosystem boundaries, understand the major transboundary environmental impacts that occur within the ecosystems and develop Strategic Action Programmes for their effective management. A major focus of the ASCLME Project is the collection of baseline data within the western Indian Ocean marine environment that will identify the transboundary impacts on human societies, vulnerable species and habitats. A critical component of the project is the translation of scientific information into management and policy briefings that will guide the countries and the region in the overall sustainable management of vital important marine resources. Community involvement is an important component of this science-to-governance process. It is envisaged that baseline studies will act as a foundation for long-term monitoring, which is considered to be essential for the sustainable management of the ecosystems.

According to Vosden and Nguie, very little is known about the links between ocean and atmosphere in the western Indian Ocean, which is one of the least studied ocean regions in the world. It is against this backdrop that the ASCLME Project is establishing a system for inshore and offshore data collection and monitoring. Figure 1 also shows the planned distribution of oceanographic equipment that will monitor ecosystem variability in real-time and provide the foundation for a western Indian Ocean ‘early warning system’ for climate change impact and ecosystem variability. The offshore system consists of underwater temperature recorders (UTRs), Autonomous Temperature Line Acquisition System (ATLAS) moorings and Acoustic Doppler Current Profilers (ADCPs). They provide permanent recordings of atmospheric parameters (wind speed, air temperature, humidity, precipitation) and sea surface and seabed temperatures, salinities, carbon flux, seawater acidity, and current direction and velocities. Many of these instruments are already in place, with further deployment and maintenance planned for 2010 and beyond. It is envisaged that inshore coastal studies will supplement the information generated by oceanographic equipment, so as to better predict long-term impacts and management needs. For example, the authors suggest that monitoring trends in inshore fisheries and the livelihoods of coastal people will reveal the impacts of climate change on coastal communities, along with an inshore monitoring programme covering basic oceanographic parameters such as water temperature and salinity. The monitoring system is likely to expand with the addition of remote sensing satellite imagery, specifically in terms of collecting data on ocean colour (for productivity and photosynthesis), sea surface temperature and sea level altimetry. This will be an integral part of the eventual climate and ecosystem variability modelling process at the regional and sub-regional level, which will then lead to the guidelines and policy briefs at a national level. According to the authors, the development of this comprehensive monitoring network has been made possible through a number of partnerships. In particular, the United States’ National Oceanic and Atmospheric Administration (NOAA) has provided the ATLAS moorings as part of the organisation’s contribution to the Research Moored Array for African-Asian-Australian Monsoon Analysis and Prediction (RAMA) network, as well as a number of floating data collection systems. Meanwhile, the countries of the western Indian Ocean are each engaged in developing a Marine Ecosystem Diagnostic Analysis in an effort to record baseline ecosystem conditions – including the socioeconomic status of coastal people – in order to record any changes induced by climate change. This is seen as a priority source of information about the impact of climate change on the ecosystems. National efforts will feed into an overall regional Transboundary Diagnostic Analysis.

Vosden and Nguie propose that the long-term monitoring network has the potential to become one of the most sophisticated long-term monitoring and early-warning systems outside the developed world. As such, it can act as a pilot system for regional and sub-regional modelling, prediction and effective, adaptable governance. With the ultimate goal of better preparing African governments for the impacts that climate change will have on their people, the long-term monitoring network is at the cutting edge of global efforts to improve the link between science and governance, says the authors. 

This year the South African Institute of Aquatic Biodiversity celebrates 10 years as one of the National Research Foundation’s family of research facilities. Situated in Grahamstown in the Eastern Cape, SAIB houses world-famous collections of marine and freshwater fishes from African inland water systems and surrounding seas. Recognised internationally as a hub for the study of aquatic biodiversity, SAIB research involves:

- **Discovery** – Exploring African Aquatic Biodiversity
- **Systematics and Taxonomy, Phylogenetics, Phylogeography**
- **Conservation Biology** – Coastal and freshwater conservation biology and invasion biology
- **Ocean Exploration** – African Coelacanth Ecosystem Programme – SAIB’s flagship programme
- **Biodiversity Informatics** and the National Fish Collection