On currents, upwelling and coastal trapped waves between Algoa Bay and Port Alfred

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Introduction

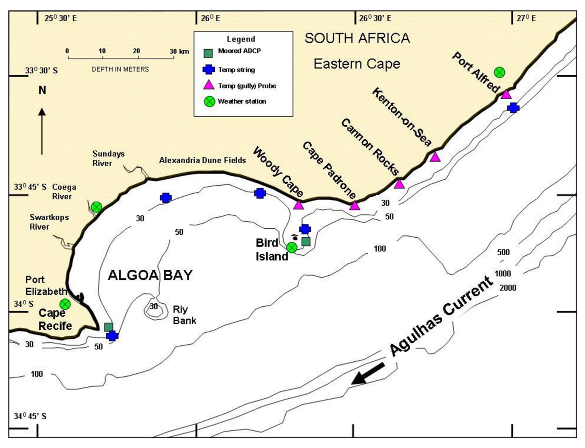


Fig. 1: Site of some of the measuring platforms deployed as part of the Algoa Bay LTMR programme. Weather stations belong to SAWS .

Algoa Bay is the easternmost and largest of several crenulated embayments on the southeast Cape coast of South Africa (Fig. 1). The mouth of its almost perfect clockwise logarithmic-spiral shape faces into the southwest Indian Ocean, making it vulnerable to large-scale ocean and weather influences. In this unique geographical location, the dynamics of the waters of Algoa Bay comprise interactions between nearshore, coastal and deep-water oceanographic processes, weather systems and local bathymetry and shoreline contours (Fig. 2).

These processes have been studied in the past by e.g., Goschen and Schumann (1994, 1995) and Schumann et al. (2005), and are well known. However, the study of the physical ocean in the northern area of Algoa Bay has received little scientific attention, due to its inaccessibility by boat-based scientists (except recently by Roberts, 2010). In October 2008, SAEON began deploying instruments measuring physical oceanographic variables in and around Algoa Bay as part of the Algoa Bay Long Term Monitoring and Research Programme (AMLMR). Physical data is collected for the following reasons: in order to gain knowledge of the long term trends in the physical ocean, to understand better the dynamics of the ocean in that region and to support the biological research underway in Algoa Bay. This paper presents some of the main results obtained from the first year of physical measurements.

Goschen W. S. and Schumann E. H. (1994). An Agulhas Current intrusion into Algoa Bay during August 1988. *South African Journal of Marine Science* **14**: 47-57.
Goschen W. S. and Schumann E. H. (1995). Upwelling and the occurrence of cold water around Cape Recife, Algoa Bay, South Africa. *South African Journal of Marine Science* **16**: 57-67.
Roberts M. J. (2010). Coastal currents and temperatures along the eastern region of Algoa Bay, South Africa, with implications for transport and shelf-bay water exchange. *African Journal of Science*, **32**(1):145-161.
Schumann E. H., Churchill J. R. S. and Zaayman H. J. (2005). Oceanic variability in the western sector of Algoa Bay, South Africa. *African Journal of Marine Science* **27**: 65-80.

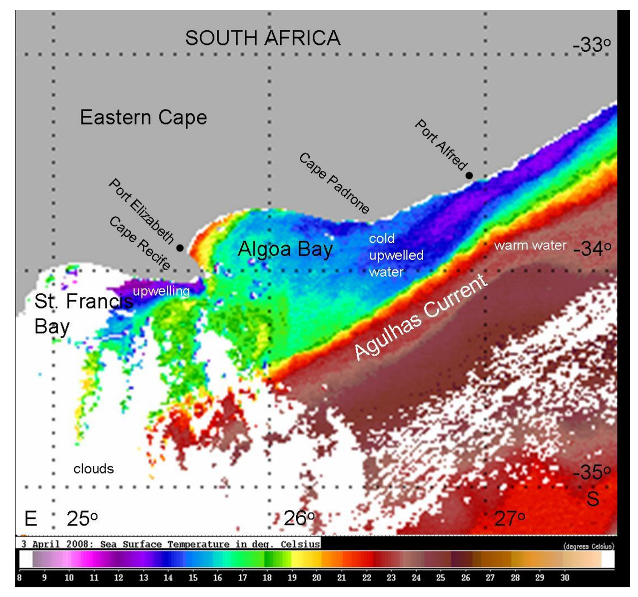


Fig. 2: The dynamic ocean in the region of Algoa Bay (image from UCT MRSU).

Wind & Currents

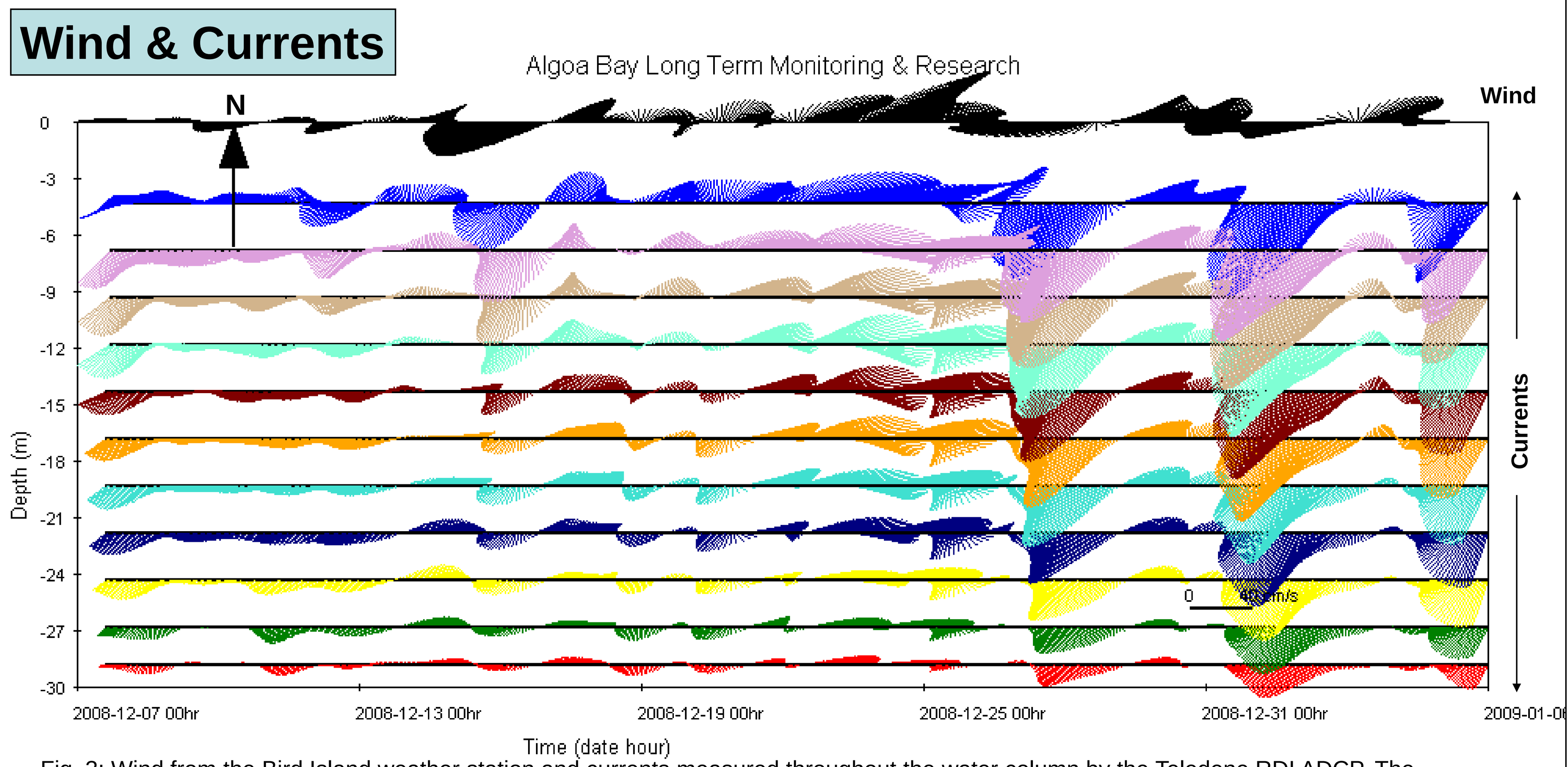


Fig. 3: Wind from the Bird Island weather station and currents measured throughout the water column by the Teledene RDI ADCP. The bottom is at about 30m. The series were filtered from 1hr to 12 hr by a Cosine-Lanczos filter.

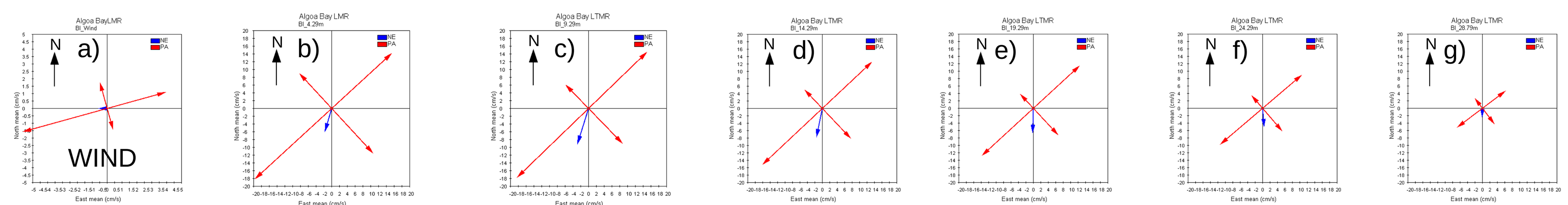


Fig. 4: Principal axes for a) wind measured at Bird Island and currents measured at approx. b) 5m, c) 10m, d) 15m, e) 20m, f) 25m and g) 30m depth. Notice the alignment of the major and minor axes (red arrows). Net currents (blue arrows) rotate slightly anti-clockwise with depth.

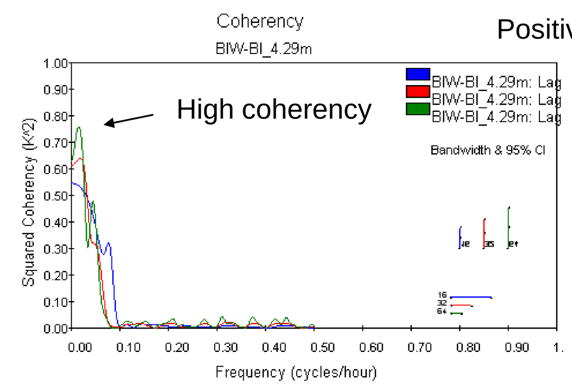


Fig. 5: The coherency spectra of the major axes of winds and currents at 4.29m at lags of 16, 32 and 64. Notice the high coherency at the lower frequencies. Data were from 1hr measurements.

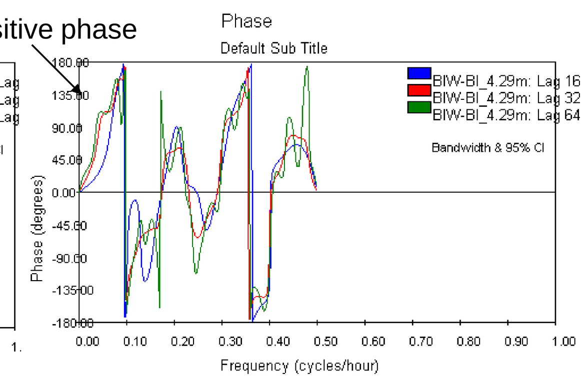
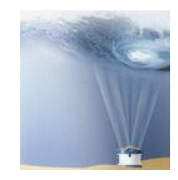


Fig. 6: The phase spectra of winds and currents at 4.29m at lags of 16, 32 and 64. A positive phase in the lower frequencies mean wind lead currents. Same dataset as Fig. 5.

The Teledene RDI ADCP.



The ADCP (acoustic Doppler current profiler) deployment at Bird Island is taken to be representative of the currents in the mid-depth areas of northern Algoa Bay, beyond the influence of both nearshore dynamics and the Agulhas Current .

The currents are predominantly barotropic (flow in the same direction throughout the water column) with the strength in current speed decreasing towards the bottom (Fig. 3 & 4).

There is a high coherency between winds and currents (Fig. 5), with wind leading currents (wind is forcing the currents, Fig. 6).

The rotary spectra show the M2 tidal constituent to be a strong component of currents, although it seems to be less linearly polarized with depth. Inertial currents are evident but not strongly so (Fig. 7).

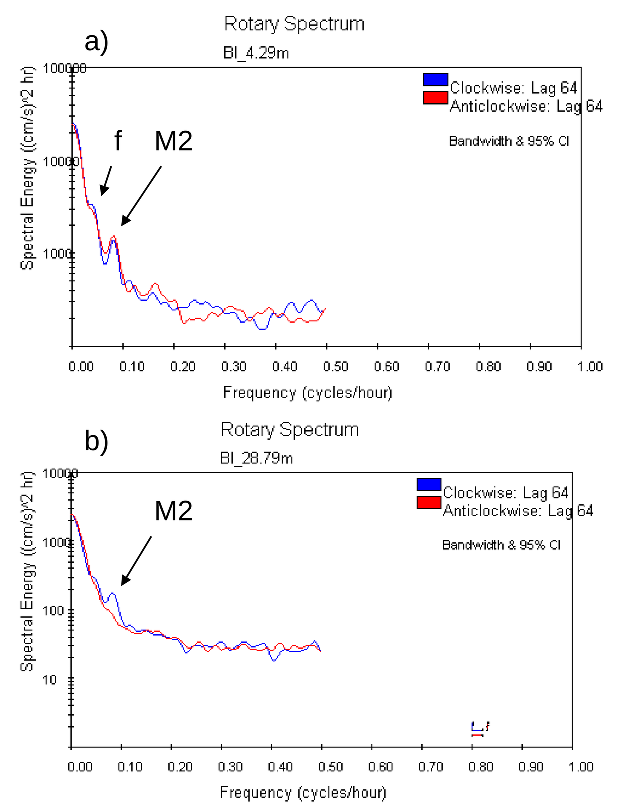
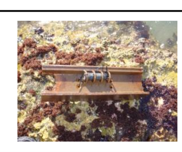


Fig. 7: The rotary spectra of currents at approx.a) 4m and b) 28m. A peak at the M2 tidal frequency at 0.0805 cph (12.42 h) is clearly visibility at lower frequencies while inertial currents (f) at 0.0467 cph (21.4 h) were weak.

Wind & Upwelling – Gully Probes



A Gully Probe (single temperature sensor) before deployment in a gully.

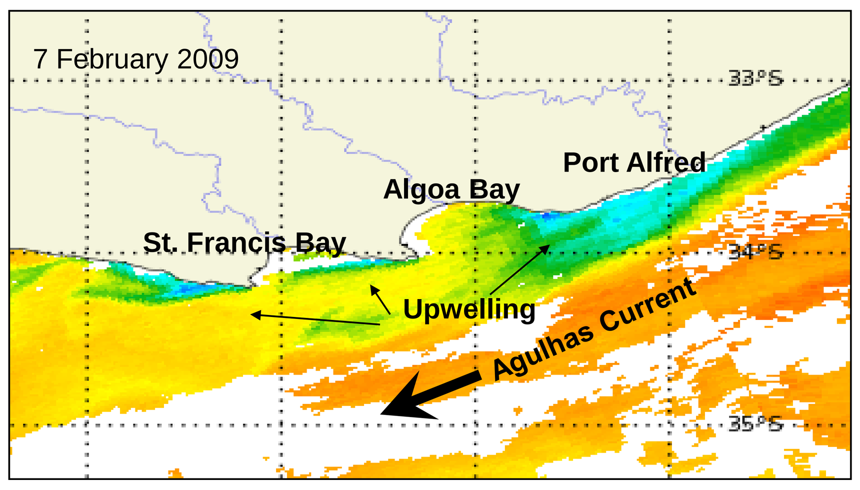


Fig. 8: A satellite image taken on 2009-02-07 showing upwelling (blue areas) off the Capes, extending northward to Port Alfred and beyond. The Agulhas Current (orange colour) was in its “normal” position at the shelf break during this period.

The nearshore waters respond rapidly to wind forcing along the coastline between Woody Cape and Port Alfred (Fig. 9). Water is upwelled at all sites during a northeasterly wind, with lag towards the north, and often penetrates through to the surface layers further offshore (Fig. 11). Upwelling is predominantly a summer occurrence (Fig. 10).

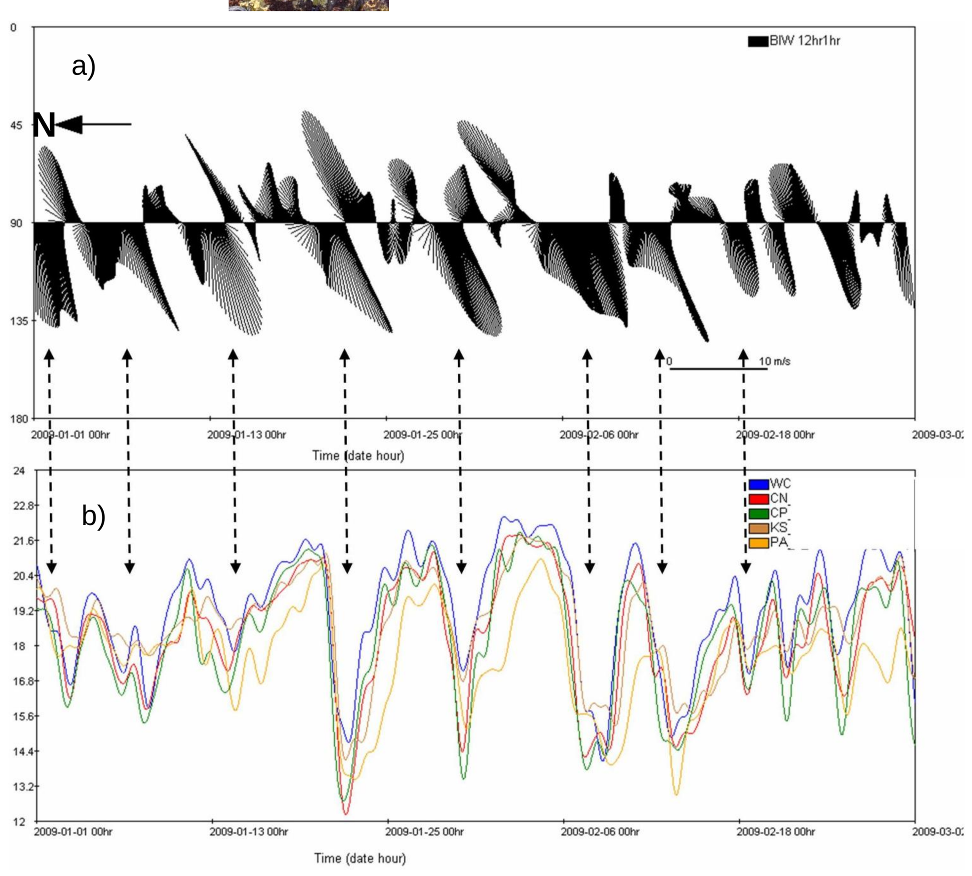
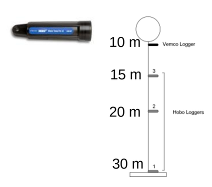


Fig. 9: a) Wind from the Bird Island weather station and b) temperatures measured at Port Alfred (PA), Cannon Rocks (CN), Kenton-on-Sea (KS), Cape Padrone (CP) and Woody Cape (WC) over a two month period.

Upwelling – UTR strings



A Hobo underwater temperature data logger and the UTR (underwater temperature recorder) string configuration.

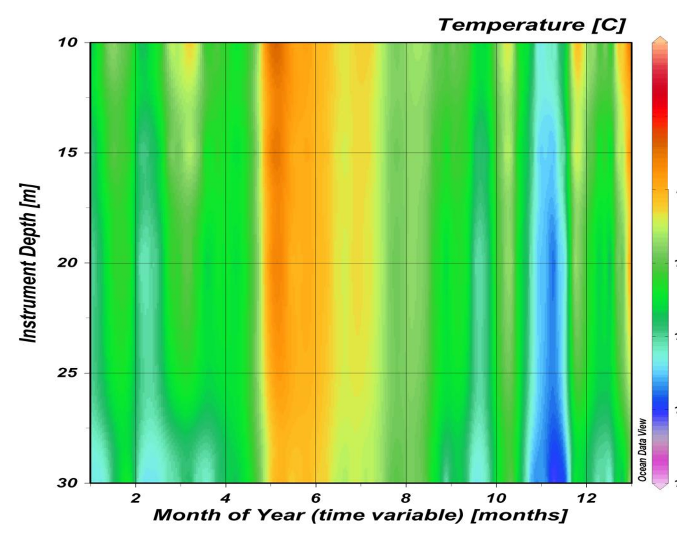


Fig. 10: Time-evolution plots from the temperature string off Bird Island over an annual period. Shown is the absence of upwelling (warmer mixed water column, shown by orange colour) during the winter months (May to August).

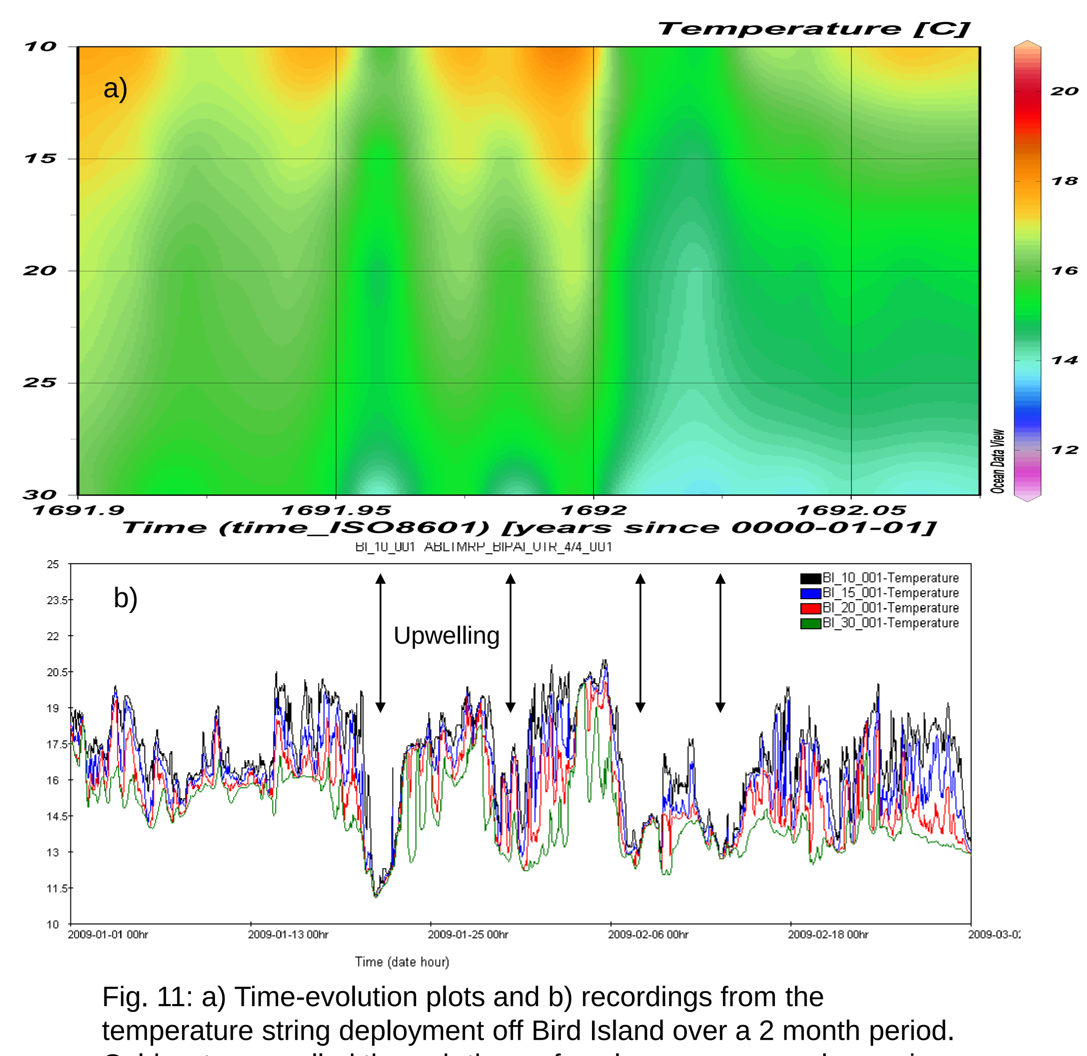


Fig. 11: a) Time-evolution plots and b) recordings from the temperature string deployment off Bird Island over a 2 month period. Cold water upwelled through the surface layers on several occasions.

Coastal Trapped Waves

Coastal trapped waves (CTWs) propagate with the coast on the left in the southern hemisphere, and cause changes in sea level over periods of days within the Rossby radius of the coast (approx. 30 km). They have characteristics of Kelvin waves (which require a vertical coastline and flat bottom) and continental shelf waves (which require a sloping bottom). The associated longshore current at the coast is in the direction of wave propagation as the wave peak propagates through, and reverses with the trough. CTWs with substantial amplitudes (> 50 cm) have been found off SA, and are attributed to the waves travelling in resonance with the wind systems (Schumann & Brink, 1990). Such CTWs are generated by a regular succession of weather systems.

In the Algoa Bay LTMR area large disturbances in sea level were occasionally recorded at all moorings, although clearly more evident in the exposed regions at the capes of Algoa Bay as well as Port Alfred (Fig. 12). Further investigation at the Bird Island site (Fig. 14) suggested that these were CTWs that propagated through the area during severe weather conditions (Fig. 13). In particular, during the first event on 22 January Hunter (2008) reported that storm conditions and large swells were responsible for sinking of boats and loss of life.

Hunter (2008). Two severe December Storms: Heavy seas take their toll. Society of Master Mariners SA.
Schumann & Brink (1990). Coastal-trapped waves off the coast of South Africa: generation, propagation and current structures. Journal of Physical Oceanography, 20: 1206-1218.

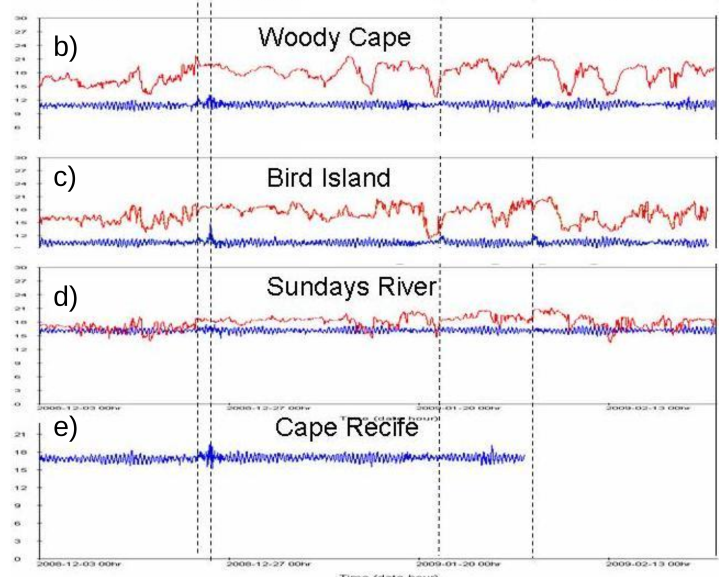


Fig.12: Water level (blue line) recorded at the UTR string deployments between Port Alfred and Cape Recife. The red line is the sea temperature. Large sea level disturbance were recorded at all sites, but clearly more evident in the exposed regions at the capes of Algoa Bay as well as Port Alfred.

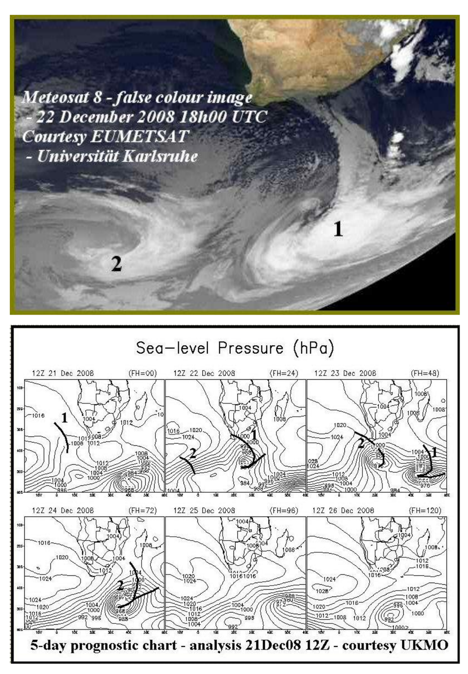


Fig.13: “The wind on the FA gas production Platform (western Agulhas Bank) peaked at 15h30 SAST – SW'ly 53 kts gusting 61. As would be expected wave conditions peaked after the wind, at 6.30 pm - significant wave height 7.2m. Sadly, one of the victims of this 1st storm was a chokka boat off Oyster Bay (west of Cape St Francis)”. From Hunter (2008: Two severe December Storms: Heavy seas take their toll).

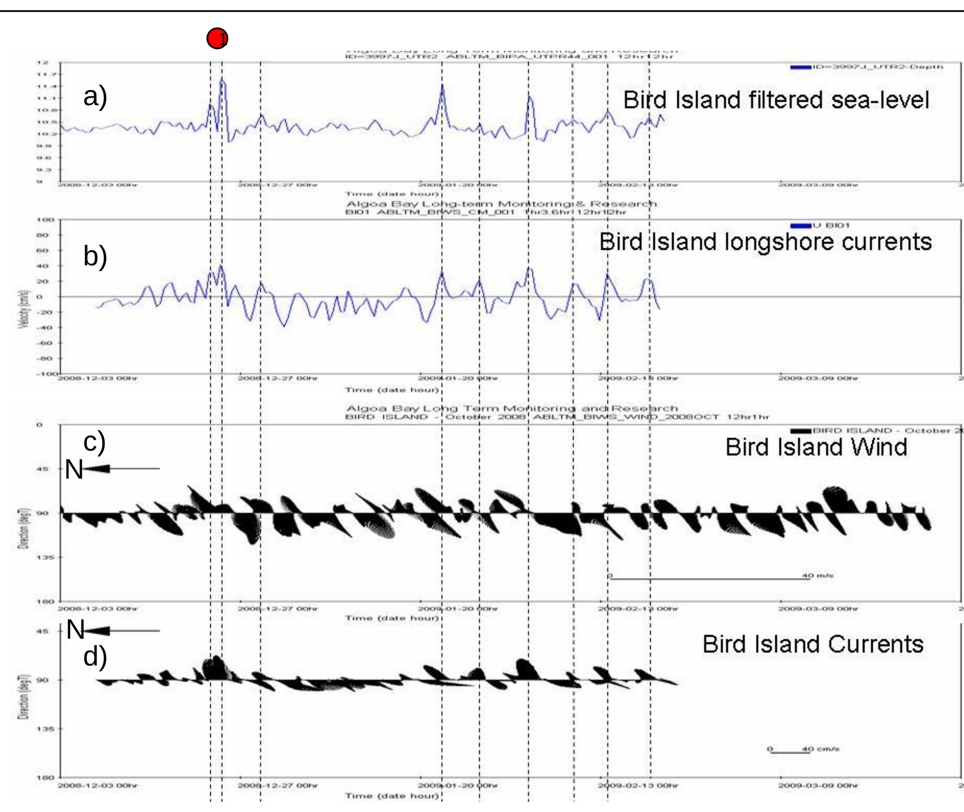


Fig. 14: The a) sea level (compensated for atmospheric pressure) and b) the longshore current measured at Bird Island. The bottom figures show stick-vectors for wind and currents at Bird Island. Notice how a rise in sea level is accompanied by an increase in strength of the longshore (approx. NE) component of current and while a strong SW'ly wind was blowing.