South Atlantic Ocean and Southern Ocean

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Contrary to the North Atlantic, the South Atlantic is largely open to the influence of the southern ocean and other oceans. The Antarctic Circumpolar Current (ACC) allows for inter-ocean transport of heat and freshwater anomalies, permitting ocean route telecommunication of climate anomalies to regions remote from the southern ocean at various timescales. The ACC link drives a global thermohaline circulation that is responsible for much of the meridional heat transport in the Atlantic and for shaping the distribution of intermediate and deep water masses. The South Atlantic thermocline exchanges with the Indian Ocean thermocline, and the injection of Pacific-Ocean-derived Antarctic Intermediate and mode water masses in Drake Passage are part of the "warm route, cold route" debate. It is still unknown to what extent the ratio between the cold and warm water route changes across a range of timescales and which processes could determine such a variability.

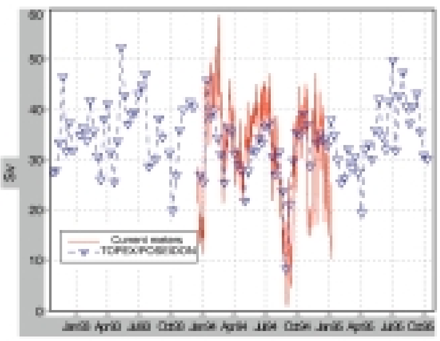

Figure 1: Malvinas Current transport at 42°W in the upper 1500 metres (in red from the currentmeter array, in blue from TOPEX). The Correlation is 0.8 and TOPEX/POSEIDON captures 60% of the variance of the flow at periods beyond 20 days.

The exchanges between the southern ocean and the Atlantic occur mostly in two very energetic frontal regions, namely the Brazil/Malvinas Confluence, and the Agulhas Current and its retroflection along with the upwelling area of the Benguela Current. Remote sensing data are powerful tools to investigate and monitor system variability at various spatial and temporal scales in these highly dynamic, energetic, and complex regions.

Monitoring the cold route of the thermohaline circulation

Monitoring the Malvinas Current and its relationship to the ACC

We have demonstrated that the TOPEX/POSEIDON altimeter, combined with the statistical information on the vertical structure of the current provided by current metre data gathered within the WOCE-funded Confluence program can provide estimates of the Malvinas transport at 42°S (with a correlation of 0.8) (figure 1). [Vivier and Provost, 1999].

The transport time series was extended throughout the TOPEX/ POSEIDON lifetime and used to study the variation of the Malvinas Current transport at timescales less than one year, and the mechanisms responsible for those variations. Dominant periods are 50-80 days and close to 180 days. Interannual variations are large. Comparatively, little energy is found at the annual period, suggesting that the Malvinas Current has only a small impact on the annual migrations on the confluence. The near 70 day period corresponds to a shelf wave propagating along the continental margin [Vivier et al., 2001]. Similar intraseasonal coastal variability has been evidenced propagating along most of the western coast of South America at a phase speed of 2-3 m/s [Clarke and Ahmed, 1999], originating from incoming Kelvin waves in the equatorial Pacific.

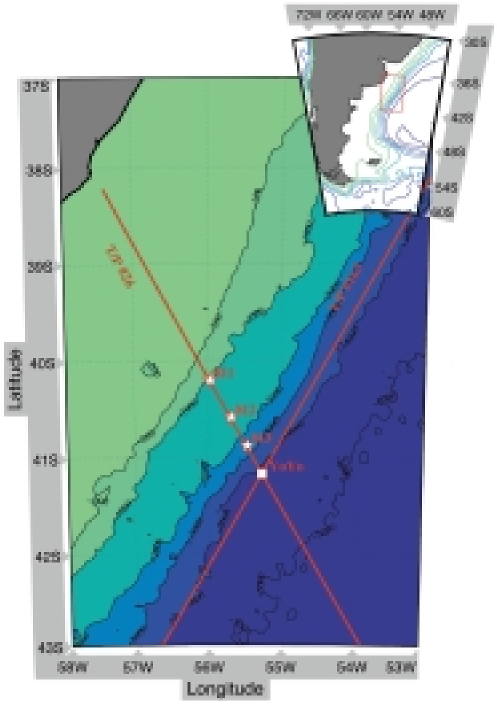

Figure 2: Location of the array of currentmeter moorings (M1, M2 and M3) and Yoyo profiler to be deployed in 2001 with respect to T/P (Jason) tracks.

At the 100-200-day period, the ACC and Malvinas current have opposite phases with an increasing Malvinas transport corresponding to a decreasing ACC transport and vice versa. Both currents respond to the wind, the ACC responding to the wind stress along its path, whereas the Malvinas Current responds to a barotropic adjustment to changes in the wind stress curl to the north of 50°S, mostly in the Pacific sector [Vivier et al., 2001]. This suggests that two distinct regimes occur at Drake Passage: while barotropic fluctuations to the south are driven by the zonal wind stress, changes to the north seem to be driven by the wind stress curl over subtropical regions of the Pacific as speculated by Hughes et al. [1999].

As the estimated mean value of the current was obtained with one year of in-situ data, we have to be very cautious in using this time series for estimating interannual variations. In order to examine the low-frequency variability of the Malvinas Current transport, we need to improve upon the mean estimate. Therefore a minimal array of three current metre moorings is to be deployed in 2001 across the Malvinas Current below the same track (T/P 26) (figure 2).

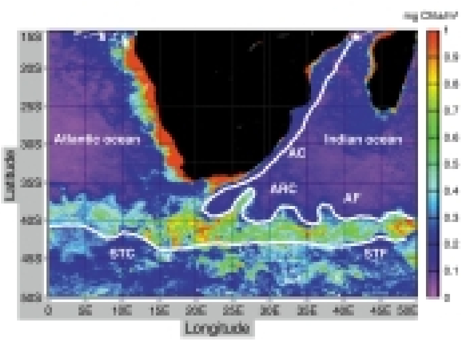

Figure 3: Schematic of the surface circulation in the Agulhas Current system. AC: Agulhas Current; ARC: Agulhas Return Current; AF: Agulhas Front, STC: Subtropical Convergence; STF: Subtropical Front.

Monitoring the water mass properties of the cold water route in the Argentine basin

Determining the thermohaline circulation variability implies monitoring currents and the changes of water mass characteristics.
A eulerian Yoyo profiler [Provost and du Chaffaut, 1996], able to profile between 1,000 and 50 metres, equipped with CTD and a nitrate analyzer ANAIS, will be moored further offshore below the crossover of track 26 and track 163 to monitor the characteristics and transformation of the Subantarctic Mode water and Antarctic Intermediate water in the Argentine Basin. This will initiate a time series station at a key location for monitoring water mass variability of the thermohaline circulation.

Spatio-temporal variability of the phytoplanktonic distribution from SeaWIFS data in the Agulhas Current system

The Agulhas system plays an important role in two ways: first, as the inter-ocean conduit for warm Indian Ocean water into the Atlantic Ocean (the warm water route), thus maintaining the global thermohaline circulation; second, as a key active region in the carbon cycle. Indeed, the frontal system formed by the Agulhas Return Current and the Subtropical Convergence is a region of intense mesoscale activity exhibiting intense levels of biological production and chlorophyll a (as seen in figure 3 below for the Southern

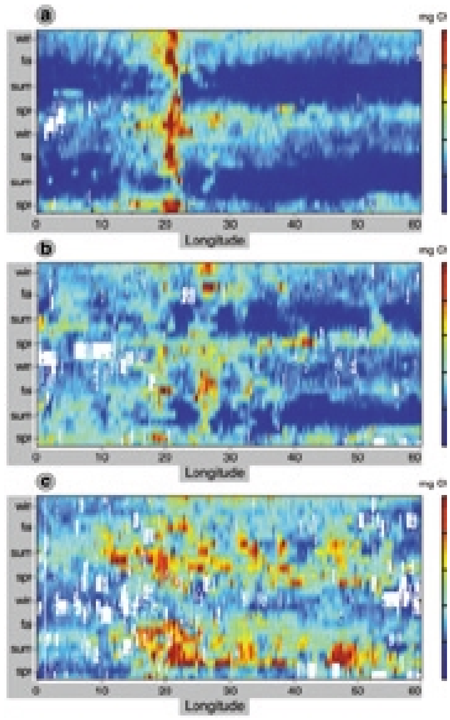

Figure 4: Time-longitude diagrams of SeaWIFS chlorophyll a at a) 36, b) 38 and c) 41°S for the period October 1997-September 1999.

Hemisphere Summer-monthly SeaWIFS February 1998 composite).

These time-longitude diagrams of SeaWIFS chlorophyll concentrations (mg Chla/m^3) at 36, 38, and 41°S for two years of data (October 1997-September 1999) (figure 4) show:

- a marked seasonality of the phytoplanktonic distribution in the Agulhas region: within the AF and STF frontal system, an extended maximum in chlorophyll a concentration is observed in spring-summer-fall, and a pronounced minimum occurs in winter,
- a clear phase opposition between the oligotrophic gyre of the southwest Indian ocean and the double frontal system formed by the Agulhas Front (AF) and the Subtropical Front (STF) [Machu and Garçon, 2001].

The seasonal average variances (figure 5) for the ocean colour, sea level anomalies, and SST data, as a function of latitude resulting from a meridional average (15-45°E) of the 2D power Hovmöller of the wavelet analysis show:

• during spring and summer, a biological front present between the AF and STF associated with high levels of variance,

• fall season with the highest variance within the dynamical AF and lowest variances in winter,

• for the STF, steady decrease in chlorophyll variance from spring until winter,

• the area between the AF and STF fronts exhibits a chlorophyll a enrichment except during winter.

An understanding of the respective roles of physical and biogeochemical processes in initiating and modulating this chlorophyll spatio-temporal variability requires a coupled physical-biological model of the Agulhas system, work which is in progress.

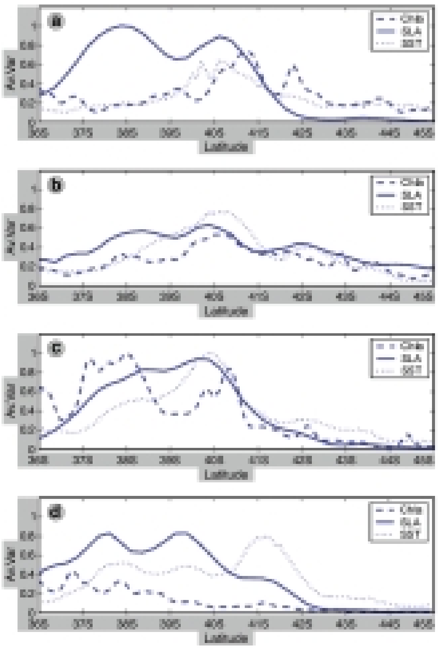

Figure 5: Seasonal average variances for the SLA (sea level anomalies, full line), SST (sea surface temperature, dotted line) and ocean color (dashed line) data as a function of latitude resulting from a meridional average (between 15-45°E) of the two-dimensional power Hovmöller. a) Spring, b) Summer, c) Fall and d) Winter. Variances are normalized by the maximum variance achieved for each signal over one year, October 1997-September 1998, and between 36°S and 45°S.

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