Study of seasonal-to-decadal variability in the Tropical Atlantic using altimetry, models and in-situ observations

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It is now well recognized that tropical oceanic regions have a big influence on the earth's climate variability. Of particular interest is the tropical Atlantic Ocean. Relative to the Pacific, the Atlantic extends to much higher northern latitudes and the cooling of relatively saline waters of southern origin leads to deep mixing in the vicinity of Greenland. Surface waters become increasingly saline as they flow in from the southern ocean, and are compensated by the outflow of deep relatively fresh water. This process has been dubbed the Atlantic conveyor belt [Gordon, 1982]. The thermohaline circulation of the Atlantic Ocean drives a pattern of warm upper layer flow northward from the subtropical South Atlantic into the North Atlantic. Cross-equatorial heat and salt flux is then required to produce this climatic Atlantic signal, which lasts over decades.

Low-frequency variability

If a general picture of the seasonal cycle of upper layer variability in the tropical Atlantic has been obtained in recent years, the low-frequency variability has been much less studied. It is often regarded as being dwarfed by the powerful influence of the annual cycle. Recently a number of studies have examined decadal tropical and midlatitude Atlantic climate variability [Rajagopolan et al., 1998; Tourre et al., 1999; Robertson et al., 2000; Ruiz Barradas et al., 2000] but the degree of correlation is not high. These studies are handicapped by the lack of a reliable time series over long period: in-situ data are not homogeneous and numerical coupled models are prone to significant bias. Integrated Sea Level Anomalies (SLAs) obtained by altimetry will provide a unique data set covering these long-period fluctuations at a global geographical scale. The nearly 10-year series of TOPEX/POSEIDON data already offers an insight into the year-to-year SLA variability in the tropical Atlantic domain (figure 1). Clear deviations from the seasonal cycle appear, peaking in boreal 1995 and 1996 winters, and during the 1998 summer.

It is therefore crucial that Jason and TOPEX/POSEIDON measurements be merged to obtain a homogeneous data set.

Western boundary dynamics

Numerical studies of the tropical Atlantic ocean also reveal that most of the complex mechanisms of these mass and heat transports should be concentrated on the western boundary, a complex area with eddies, current retroflection, undercurrents and through-flows. Early modeling studies indicated that the advection of South Atlantic waters into the subtropical gyre of the North Atlantic was the result of a considerable continuous western boundary transport [Philander et Pacanowski, 1986]. However, results from the WOCE community modeling effort do not show such a large direct transport along this route [Schott and Boning, 1991] and observations indicate that some transport occurs along the western boundary

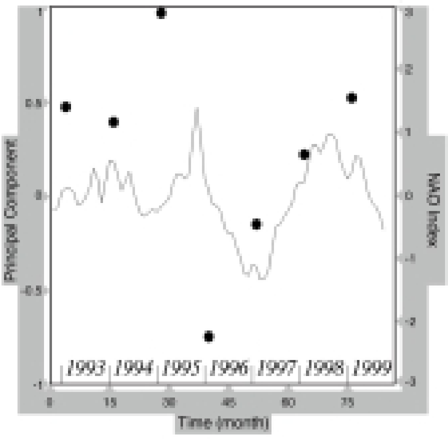

Figure 1: Low-frequency fluctuation of SLA over the tropical Atlantic as observed by TOPEX/POSEIDON. Dots indicate North Atlantic Oscillation (NAO) winter index.

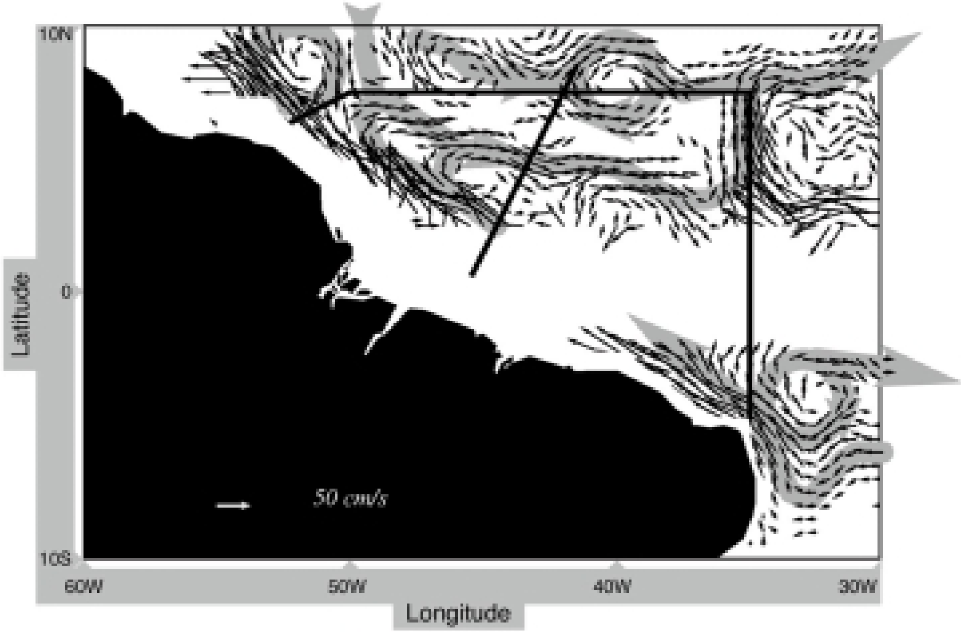

Figure 2: Surface currents in the western tropical Atlantic area from TOPEX/ POSEIDON in September 1995 [From Arnault et al., 1999].

via intermittent shallow boundary currents and eddies that peak off from the North Brazil Current (NBC) retroflection [Richardson et al., 1994]. Recently, a joint investigation involving in-situ measurements and TOPEX/ POSEIDON altimetry during the ETAMBOT experiment has improved our understanding of the surface circulation in that area [Arnault et al., 1999]. For instance, altimetry has evidenced the presence in September 1995 of a large eddy structure at about 51°30'W, 8°30'N, that was only partly sampled during the campaign (figure 2). It also showed the NBC retroflecting between 45 and 50°W, 4 and 8°N towards the North Equatorial CounterCurrent (NECC). But the NBC was not the only current feeding the NECC at that period, as the North Equatorial Current also contributed. Southward, around 3-4°S, the NBC also retroflected eastwards. Altimetry thus gave an explanation for in-situ measurements showing a surface eastward flow in that area during boreal falls [Schott et al, 1998; Bourlès et al., 1999].

These results imply a high degree of accuracy, attained thanks to high-quality altimetric measurements.

Subsurface dynamics

Looking at subsurface dynamics from altimetry is more challenging, because satellite data only concern the ocean surface. Assimilation of satellite data in numerical models is a way to project the 2D-altimetric information in deeper oceanic layers. In the tropical Pacific, Carton et al. [1996] have demonstrated that altimetric data assimilation has a greater impact than temperature profile or mooring assimilation on the SLA and surface current variability. We conducted several Geosat and TOPEX/POSEIDON data assimilation experiments in the tropical Atlantic using a variational approach [Greiner et al., 1998a et b; Greiner and Arnault, 2000; Arnault and Greiner, 2001]. The results emphasized the impact of assimilation not only on the SLA but also on the current structure, and not only at the surface.

For instance, figure 3 reveals that assimilation plays an important role in terms of kinetic energy for the oceanic currents located at about a depth of 50 meters along the Equator and along the western American coast. This is the mean location for the eastward South Equatorial Current, a key factor influencing heat and mass redistribution in the Tropical Atlantic basin.

In conclusion, high-quality satellite missions such as TOPEX/POSEIDON and in future Jason to obtain measurements spanning several years, combined with modeling and in-situ data collection, will provide a unique tool to learn more about the oceanic contribution to climate variability.

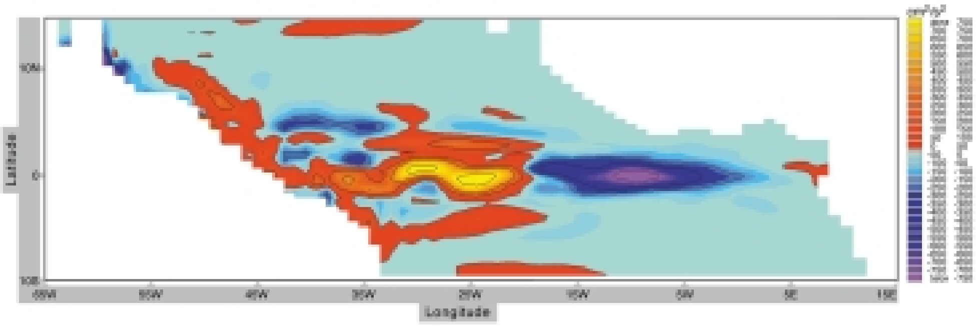

Figure 3: Difference in terms of mean kinetic energy between a numerical experiment using a general circulation model with (ASSIM) or without (REF) assimilation of TOPEX/POSEIDON data in 1993-1994 [From Arnault and Greiner, 2001].

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