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Seasonal Variability of the Atlantic Marine ITCZ

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1. Introduction

The most notable variability in the tropical Atlantic is the migration of the Atlantic Marine ITCZ (Intertropical Convergence Zone, AMI). This controls the year round rainfall over the ocean and the adjacent land regions and its seasonal variability directly affects water resources, agriculture and health. We attempt to evaluate the link between the surface and near surface ocean circulation with the atmosphere on seasonal basis to assess possible impacts on land.

2. Bi-weekly oscillations of variability

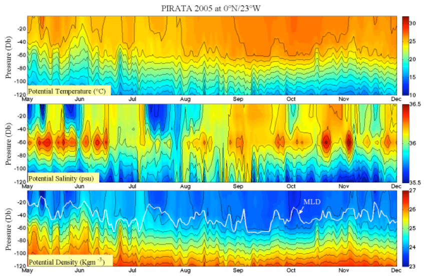

Figure 1: Pilot Research Moored Array in the Tropical Atlantic (PIRATA) mooring showing temperature, salinity, density profiles and Mixed Layer Depth (MLD -white contour) in 2005.

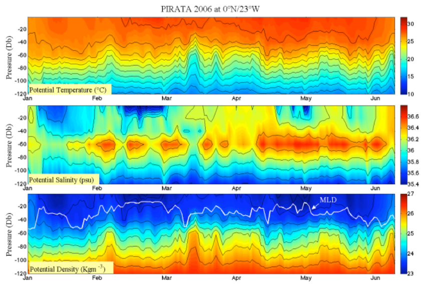

Figure 2: PIRATA mooring showing temperature, salinity, density profiles and MLD (white contour) in 2006.

Observed variability in the eastward-flowing Atlantic EUC (Equatorial Undercurrent) show quasi-biweekly oscillations of distinct features in both 2005 & 2006 data (figure 1 & 2). These are evident between 40 and 80m depth, and are in phase with the velocity components (figure 5).

Both temperature and salinity profiles show vertical fluctuations of the EUC core, due to intense periodic winds seen on satellite data (figure 4). The equatorial Atlantic cold tongue manifest in May of both years (figure 1 & 2), intensifies in June 2005, disappears and then reappears in Jan-Feb 2006. Near surface mixing as revealed by salinity shallows the thermocline, in which the Cold Tongue (developing from the coast of southern Africa toward the west along the equator) thwarts the EUC with its westward flow. Details of the Cold Tongue analysis is obtainable from Grodsky and Carton (2002).

The thick white contour line on the density plots is the Mixed Layer Depth (MLD), which is defined as the region between the surface and the depth, where density is almost the same as surface. Mixing due to turbulence and waves creates the MLD, thereby causing the density to be the same as the surface. It is shallower in Feb 2006 when the South East trade winds become weak (figure 4) and temperature rises. Earlier in Sep 2005 (figure 1), deeper MLD up to 70m depth corresponds to high mixing as evident in temperature & salinity profiles.

3. The AMI variability and Rainfall response

The Tropical Rainfall Measuring Mission (TRMM) data provides an insight into the influence of AMI migration on rainfall distribution. In figure 3, the period Jan-Mar has a band of maximum rainfall (~2.5mm/hr) at the central equatorial Atlantic with less than 1mm/hr on the lateral land areas of 2°S-7°N. This signifies dry conditions north of 7°N and south of 2°S. At this period, the AMI is at 1°S (figure 4), with stronger North East (NE) trade winds, and weaker South East (SE) trade winds. By convection, moisture is carried over South America, and the increase in strength of the SE trade winds allow rainfall over West Africa (WA) to increase (Apr-Jun). As the winds get stronger, rainfall retreats from South America and increases over WA from Jul-Sep. The process continues and maximum rain rate is found only in the central equatorial Atlantic during Oct-Dec period.

The ITCZ is a region of low mean wind, less solar heating due to cloud cover accompanied by deep atmospheric convection (figure 4). This results in rainfall. See Grodsky and Carton (2001).

The AMI (indicated by black lines) induces oceanic downwelling and suppresses the thermocline, thereby enhancing lateral upwelling and mixing. As a consequence, other dynamical processes such as vertical transport counteraction of current follows. The periodic shifts of these regions of wind convergence and their asymmetry could lead to the development of barotropic instability in the current system. This may generate Tropical Instability Waves (TIWs), and/or enhance the equatorial Cold Tongue.

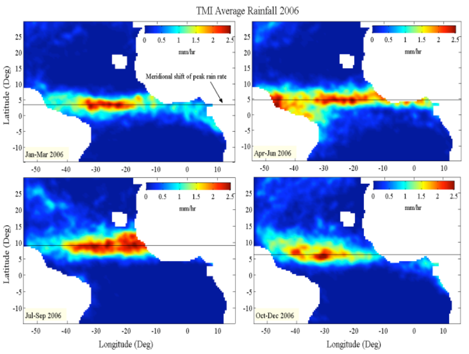

Figure 3: TMI three-monthly mean marine rainfall 2006 smoothed by a Gaussian filter. The black line shows a view of zonal shift of rainfall. Black lines indicate the meridional shift of peak rain rate.

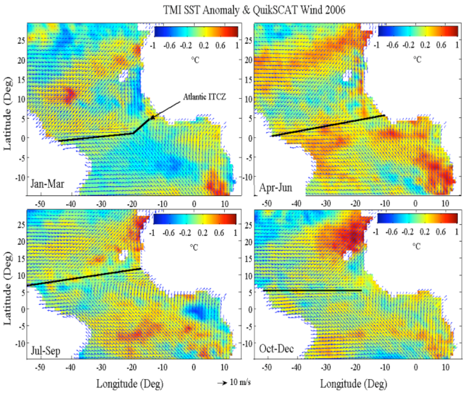

Figure 4: TMI Sea Surface Temperature anomaly was obtained by removing seasonal cycles for 9 years (1999-2007) before averaging. Overlaid are QuikScat wind vectors for the corresponding months. Black lines indicate the meridional displacement of the Atlantic Marine ITCZ. In Oct-Dec, it is almost symmetrical with the equator.

4. Zonal and meridional velocities

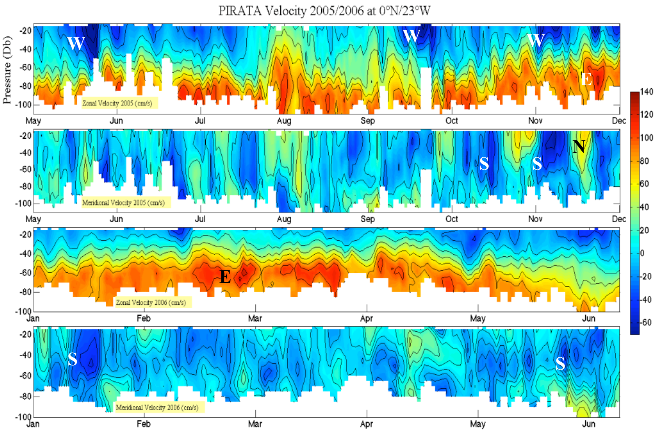

Figure 5: Daily running mean of zonal and meridional velocities from May 2005-Jun 2006 at 0°N/23°W. This position of PIRATA ADCP is appropriate for the understanding of equatorial dynamics not influenced by the coasts. Direction of flow is indicated by N, E, S, and W alphabets.

Zonal velocities of the EUC reaches maximum (~110 cm/s) at 70-100m depth notably Jul, Aug, Oct-Dec 2005 and Feb-Apr 2006. The EUC core oscillates both laterally and vertically on a quasi-biweekly basis, interacting with seasonal winds and accompanying westward flowing South Equatorial Current (SEC). This produces a see-sawing flow regime as seen from figures 1, 2 and 5. Intense wind burst results in strong surface westward flow in late May, Sep and Nov 2005. In a similar vein, strong surface southward flows are also observed in meridional velocities in October and November 2005, as well as in Jan and Jun 2006.

5. Recirculation and mixing

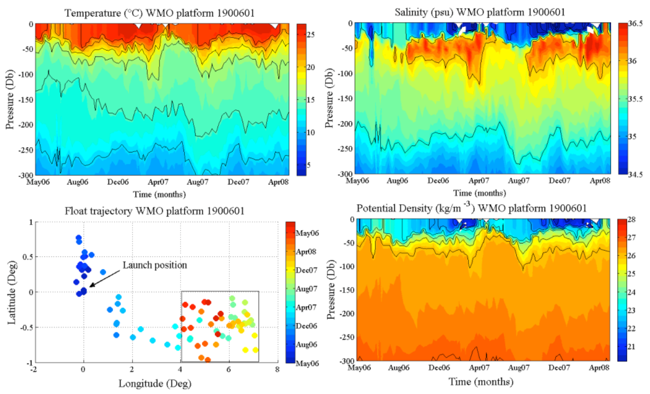

Figure 6: Argo float, lunched at 0°N/0°S in May 2006, sampled between ±1°N/2°W-7°E from May 2006-Apr 2008. The float remained in a recirculation cell around 1°S-0°N/4-7°E from Apr 2007-May 2008.

Evidence of mixing is seen from all the plots. Water masses are directly influenced by mixing resulting from the interaction of westward South Equatorial Current (SEC - 25°S to 4°N, depth ~100m) and the eastward flowing Guinea Current (3°N, depth ~200m) close to the coast. This recirculation around the continental shelf acts on the bathymetry and advects cold water westward. This is intensified further by coastal upwelling induced by SE trade winds which remained reasonably strong throughout the year (figure 4).

Below 250m (figure 7), the water mass is stratified, having no further influence of near surface circulation. The Antarctic Intermediate Water (AAIW) is evident with salinity minimum (34.5 psu) between 600-950m depth. The temperature (not shown) is 6°C.

Near surface mixing intensifies from Apr-Aug 2007 around 6°E, and accompanying bathymetry, the AAIW now narrows (figures 6 & 7) as it approaches land. See Tomczak and Godfrey (1994) for detailed analysis of AAIW.

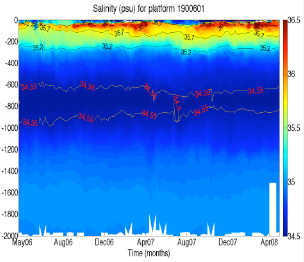

Figure 7: Argo salinity profile, showing the Antarctic Intermediate Water (AAIW) between 600-950m depth.

6. Summary

Satellite data of wind, SST and rainfall were used in conjunction with in situ data of velocity fields, temperature, salinity. We observed a marked correlation between AMI variability and rainfall over adjoining land areas. Surface and near surface fluxes contribute immensely in the distribution of salinity and temperature across the basin. High evaporation occurs at higher temperatures which results in precipitation due to convection. Further work will focus on the migration of AMI in response to the Atlantic Thermal Equator.

We would like to thank the Petroleum Technology Development Fund of Nigeria for funding this project, the US/GODAE for providing Argo data on the GDAC portal (http://www.usgodae.org/) and the Pacific Marine Environment Laboratory (PMEL) for PIRATA datasets made available at (http://www.pmel.noaa.gov/tao/jsdisplay/). We are also grateful to PODAAC for the QuikScat wind data sets made available at (http://poet.jpl.nasa.gov/) and Remote Sensing Systems (http://www.remss.com) for processing and providing TMI data.

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Tomczak, M., Godfrey, J. S., (1994). Regional oceanography: an introduction. *Pergamon press*. 261 pp.