The PIRATA Observing System in the Tropical Atlantic: Accomplishments and Perspectives

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PIRATA (PredIction and Research moored Array in the Tropical Atlantic) is a multinational program established to improve our knowledge and understanding of ocean-atmosphere variability in the tropical Atlantic. This oceanic region strongly influences the regional hydro-climates and, consequently, the economies of the adjacent land masses (e.g. West Africa, North-Eastern Brazil, the West Indies and the United States).

PIRATA is motivated by fundamental scientific issues but also by societal needs for improved prediction of climatic variability and its impacts on countries surrounding the basin.

PIRATA evolution:

PIRATA has been initiated via a partnership between National Oceanic and Atmospheric Administration/Pacific Marine Environmental Laboratory (USA), Institut de Recherche pour le Développement and Météo-France (France), and the Instituto Nacional de Pesquisas Espaciais and Diretoria de Hidrogafia e Navegacao (Brazil). PIRATA was originally launched as the "Pilot Research Moored Array in the Tropical Atlantic" in September 1997. The core array of 10 ATLAS moorings was installed by early 1999 and an ADCP mooring was added at 0°, 23°W in 2001. In 2005, INPE initiated a three mooring "Southwest Extension" in 2005. In 2006 the NOAA/Atlantic Oceanographic and Meteorological Laboratory initiated a four mooring "Northwest Extension" and South Africa sponsored a one year "Southeast Extension" in 2006-2007. The full present PIRATA array is presented in Figure 1. Along with TAO/TRITON in the Pacific and RAMA in the Indian Ocean, PIRATA is part of the Global Tropical Moored Buoy Array, as part of the Global Ocean Observing System (GOOS) and Global Climate Observing System (GCOS)

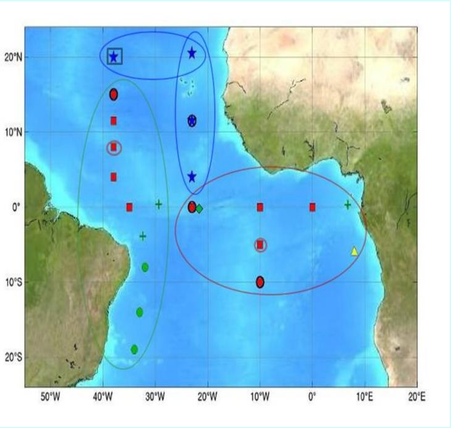

Figure 1: Present PIRATA array in October 2011:
red squares = backbone 10 ATLAS array; green dots = SE extension; blue stars = NE extension; yellow triangle = SW extension (2006-2007); green square = ADCP mooring; green crosses = island-based observation sites; buoys with barometers and the ability to estimate net heat flux are indicated with black circles.
"Piggyback" measurements:
Independent pCO2 instrumentations (PI: IRD/LOCEAN, France) are installed at buoys with red circles, and an atmospheric barometer (PI: Météo-France) is installed at the buoy with black rectangle.
Yearly cruises are organized to maintain the array:
i) by Brazil (INPE) is the area surrounded in green, ii) by France (IRD) in area surrounded in red and iii) by USA (NOAA/AOML) in area surrounded in blue.

PIRATA real time data:

All PIRATA data are freely available to the whole scientific community through internet web site: *http://www.pmel.noaa.gov/toga-tao/pirata/deliv/*.
Data are transmitted daily via service ARGOS system and also placed on GTS for distribution to operational centers.
PIRATA moorings data return is 82% (mean for the all sites and all sensors).

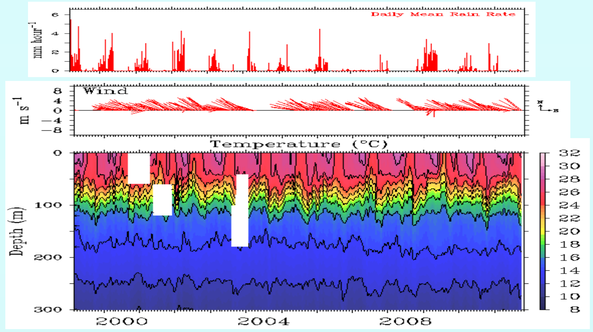

Figure 2: Example of PIRATA time series at 23°W-0°N of atmospheric (daily mean rain rate : top panel; wind: middle panel) and oceanic (vertical section of temperature: bottom panel) properties.
Gaps indicate missing data due to instrument failure or vandalism.

PIRATA accomplishments:

PIRATA data are used for different analysis, mainly: i) improve the description of the intra-seasonal to inter-annual variability in the atmospheric and oceanic boundary layers in the tropical Atlantic; ii) improve our understanding of the relative contributions of air-sea fluxes and ocean dynamics to variability in sea surface temperature (SST) and sub-surface heat content at intra-seasonal to inter-annual time scales; iii) provide a set of data useful for developing and improving the predictive models of the ocean-atmosphere coupled system; iv) document interactions between tropical Atlantic climate and variability outside the region, including the Pacific ENSO, the North Atlantic Oscillation, and the Southern Annular Mode.

Example 1 (Figure 3):
Studies using Pirata data have shown the dominant role of air-sea fluxes for the SST changes out of the equatorial band. Using net heat flux products (from OAFlux and ISCCP), high correlation coefficients (higher than 0.9) between the net heat flux (Qnet) and the SST change rate in the region outside of the equatorial band 5°S - 10°N, confirm the dominant role of air-sea flux (respectively ocean dynamics) out of (in) the equatorial band.

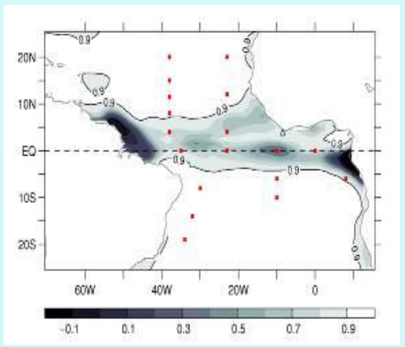

Figure 3: Correlation between Qnet and the rate of the SST change (adapted from Yu et al., 2006).

Example 2 (Figure 4):
Studies using data of PIRATA ATLAS buoys and PIRATA dedicated cruises (yearly repeated at 35/38°W, 23°W and 10°W) allow a better description of the eastward zonal currents at the equator, along with of dynamical processes responsible for their variability (e.g., equatorial waves, tropical instability waves…). The core depth and transport of the Equatorial Under Current decrease from West to East.

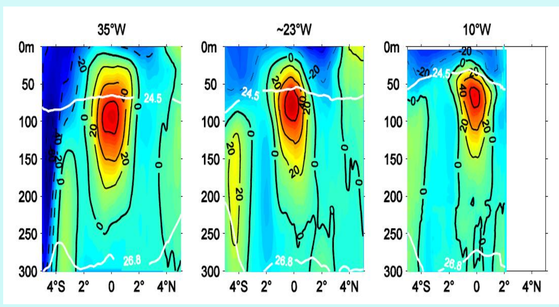

Figure 4 : Mean zonal velocity (color shading and black contours [cm/s]) and potential density surfaces 24.5 and 26.8 (white solid lines) along three meridional sections along 35°W, ~23°W, and 10°W (after Brandt et al., 2006; Hormann and Brandt, 2007; Kolodziejczyk et al. 2009).

Example 3 (Figure 5):
ADCP mooring at 23°W-0°N allows the description of the Equatorial Under Current variability and equatorial waves (see Brandt et al., JGR, 2008).

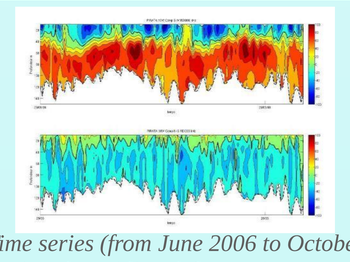

Figure 5: Time series (from June 2006 to October 2008) of the zonal (top) and meridional (bottom) components of the current at 23°W-0°N, from the surface down to 150m depth.

PIRATA contribution to other international programs:

- PIRATA is established as the main backbone of the Tropical Atlantic Observing System (by CLIVAR and OOPC); it is a major component of GOOS and GCOS.
- PIRATA data are assimilated into ocean operational forecasting system participating with Global Ocean Data Assimilation Experiment (GODAE), and at operational centers for seasonal forecasting (e.g.: ECMWF and NCEP).
- By deploying XBTs and autonomous profilers and by sending in real time CTD/XBT profiles during dedicated cruises, PIRATA contributes to the ARGO and CORIOLIS programs.
- PIRATA data are of particular value for the research field programs such as Tropical Atlantic Climate Experiment (TACE), African Monsoon Multidisciplinary Analysis (AMMA), and Variability of the American Monsoon System (VAMOS).
- PIRATA ATLAS buoys constitute platforms for CO2 measurements (contribution to CARBOOCEAN; Figure 6) and PIRATA cruises are opportunities to conduct seawater sampling for salinity, nutrients, O_2, CO_2, C13 and O18, and to carry out biogeochemical measurements in the framework of various national and international programs.

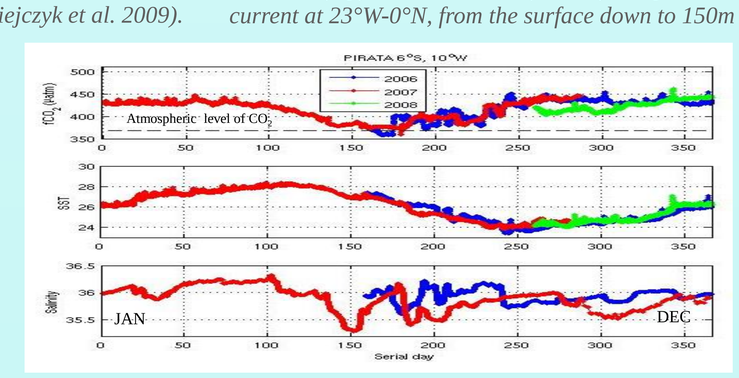

Figure 6: Time series of fCO2 (top), sea surface temperature (middle) and sea surface salinity (bottom) from June 2006 to December 2008 at the ATLAS buoy located at 6°S-10°W (courtesy Nathalie Lefevre).

PIRATA major issues:

- To get vessel time to maintain every year the ATLAS and ADCP moorings network is sometimes still a challenge.
- Vandalism (mainly) due to fishery activities induces a consequent loss of data (less from 2009)!

PIRATA major successes and perspectives:

- PIRATA has demonstrated that a multinational program with specific scientific goals and coordinated field operations can be carried out and maintained for the long term.
- To answer to new scientific demands, additional sensors (salinity, current, fluxes) begin to be installed.
- The addition of ATLAS buoys in the South East (off Angola) and South Atlantic is more and more needed!

Reference papers:

- Servain J., A. Busalacchi, M.J. McPhaden, A.D. Moura, G. Reverdin, M. Vianna and S. Zebiak, 1998: A Pilot Research Moored Array in the Tropical Atlantic (PIRATA). *Bull. Amer. Meteorol. Soc.*, **79**, 2019-2031
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