

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 scientific issues but also by societal needs for improved prediction of climatic variability and its impacts on surrounding countries.

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 Hidrografia e Navegacao (Brazil). PIRATA was originally launched as the “Pilot Research Moored Array in the Tropical Atlantic” with the deployment of two autonomous met-ocean measurements moorings in September 1997. The core array of 10 met-ocean moorings was installed by early 1999 (Figure 1a) and an ADCP mooring was added at 0°, 23°W in 2001. In 2005, INPE initiated a three mooring “Southwest Extension” in 2005 (Figure 1b).

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, and the EU PREFACE program funded a 2nd buoy in 2014 for the maintenance of this “Southeast Extension” (Figure 1c). Two ADCP moorings were also added at 0°, 10°W in 2006 and at 0°, 0°E in 2016. In 2018, the full PIRATA array consists in 18 met-ocean buoys and three ADCP moorings (at 23W, 10°W and 0°E along the equator); flux reference sites were established at 15°N, 38°W; 0°, 23°W; 10°S, 10°W and at 11.5°N, 23°W (Figure 1d). Along with TAO/TRITON in the Pacific and RAMA in the Indian Ocean, PIRATA is part of the Global Tropical Moored Buoy Array, implemented within the context of the Global Ocean Observing System (GOOS) and Global Climate Observing System (GCOS).

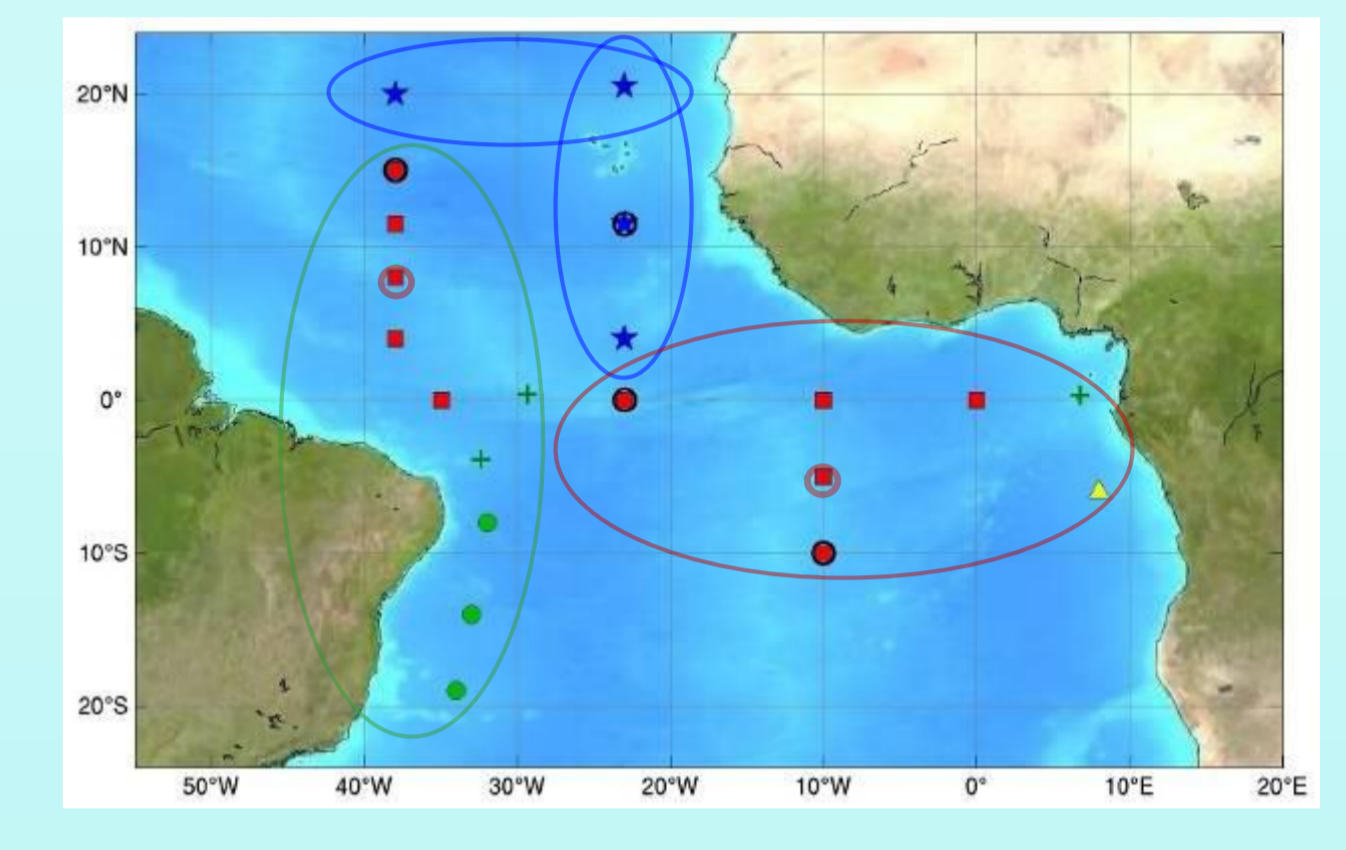
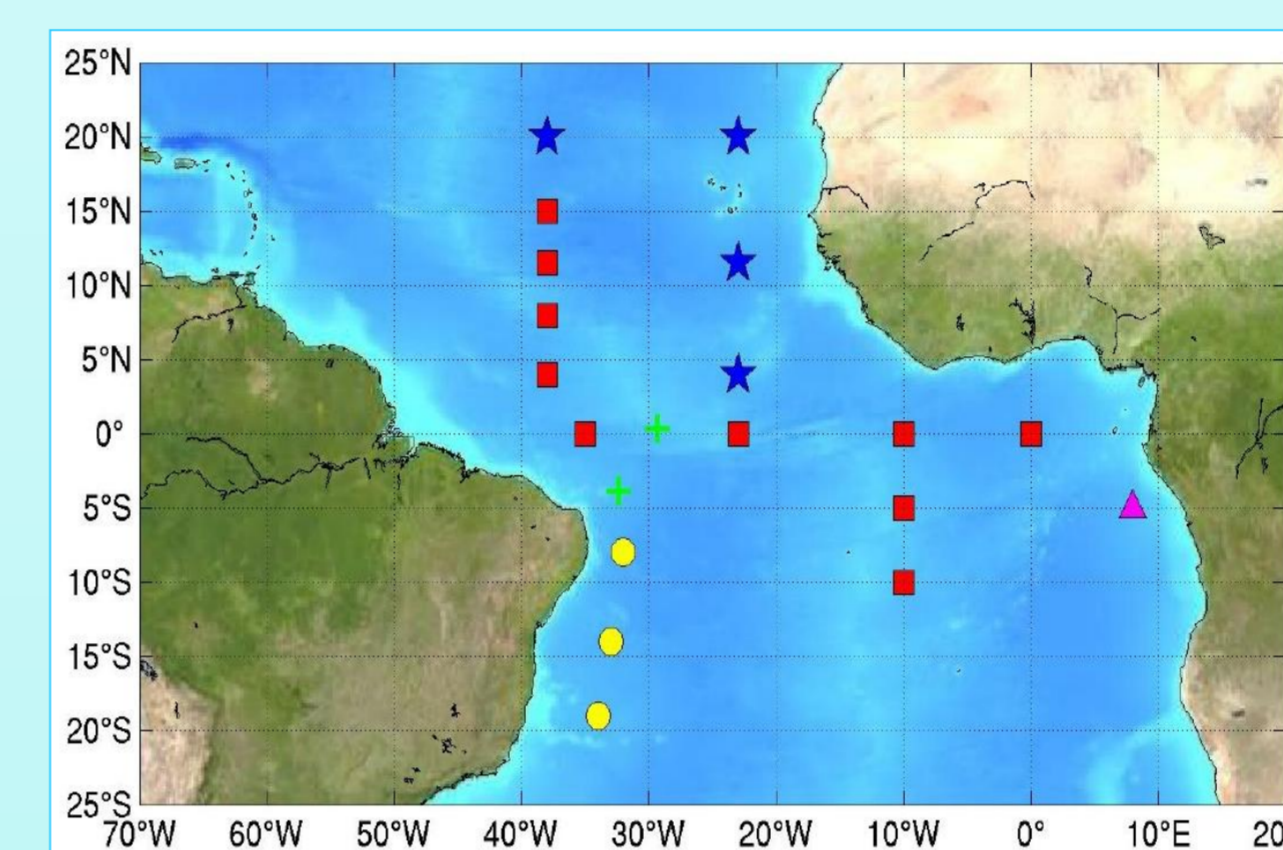
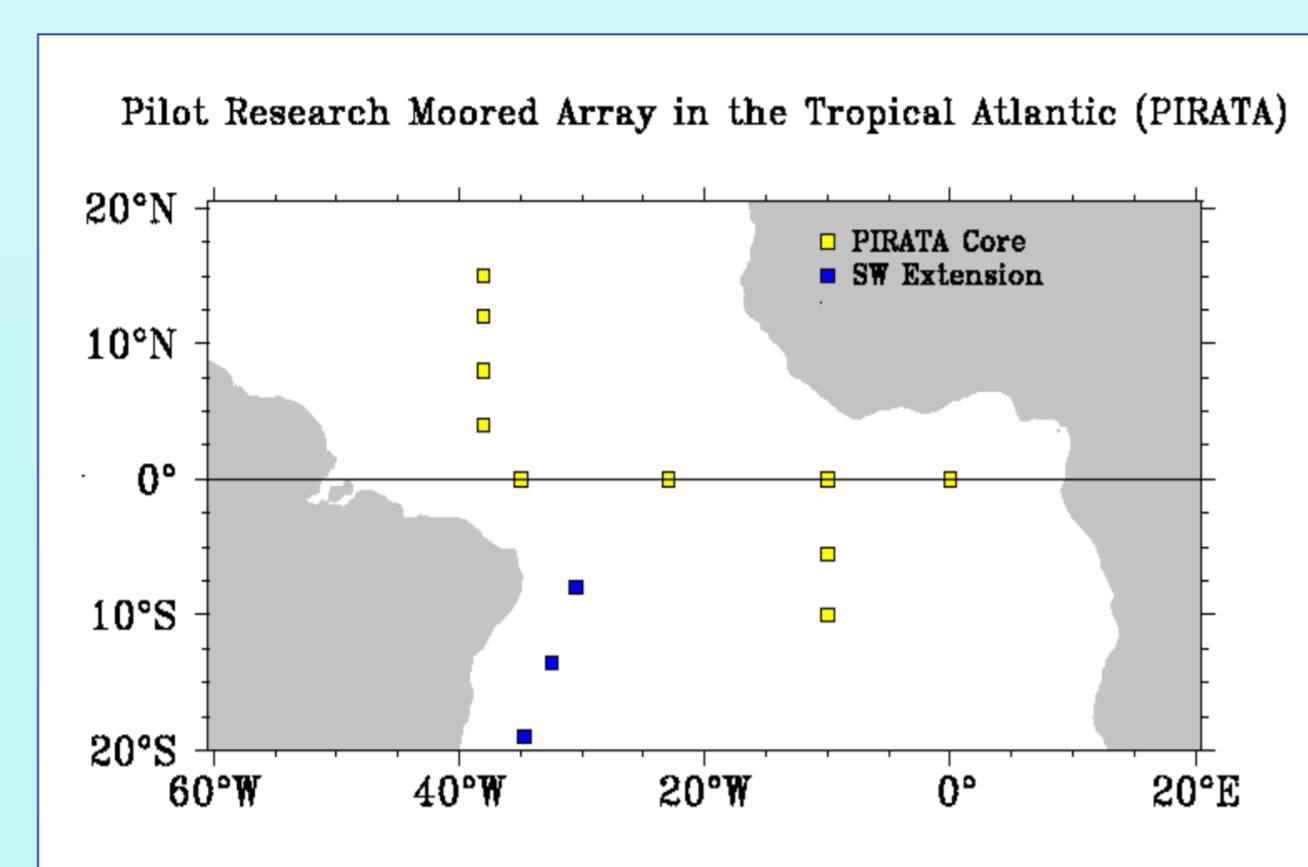
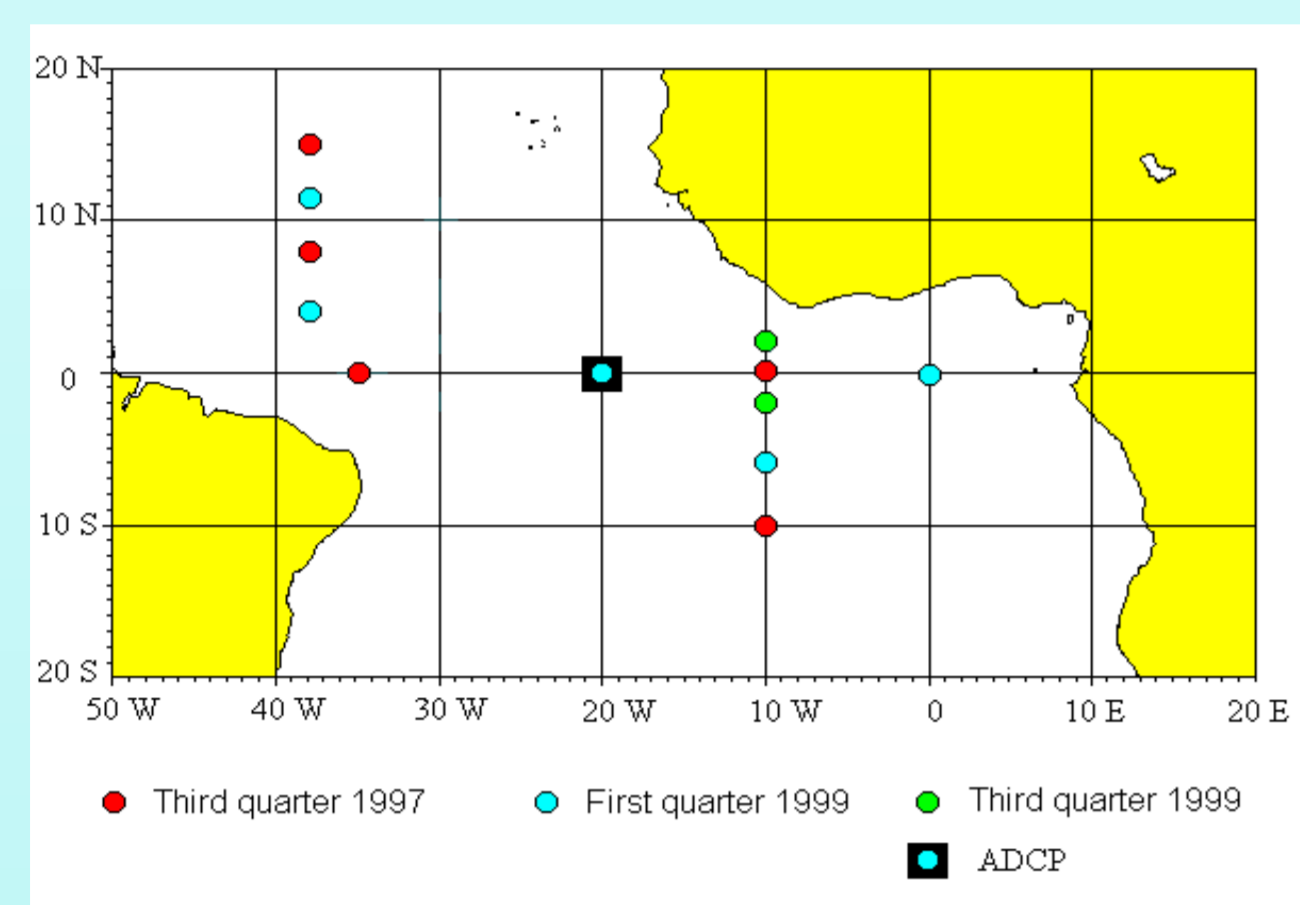


Figure 1: a) Original PIRATA array (backbone) with 10 ATLAS buoys. The two ones at 10°W-2°N and 10°W-2°S have been suppressed due to vandalism. b) PIRATA array in 2005. c) PIRATA array in 2006-2007. d) Present PIRATA array: red squares = backbone ATLAS array, green dots = SW extension, blue stars = NE extension, yellow triangle = SE extension (2006-2007 and from 2013); green crosses indicate the island-based observation sites (stopped at São Tomé in 2010). Buoys with barometers and the ability to estimate net heat flux are indicated with black circles. Three ADCP moorings are also maintained at 23°W-0°N, 10°W-0°N and 0°E-0°N. Yearly cruises are organized to maintain the array: i) by Brazil (INPE) in 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. “piggyback” measurements: Independent pCO₂ instrumentations (PI: IRD/LOCEAN, France) have been installed at 10°W-6°S in 2006 and 38°W-8°N in 2009 (buoys with red circles).

PIRATA accomplishments:

All PIRATA data are freely available to the whole scientific community through internet web site:

<http://www.pmel.noaa.gov/pirata/> (Fig.2). 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, from 1997).

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 interannual 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.

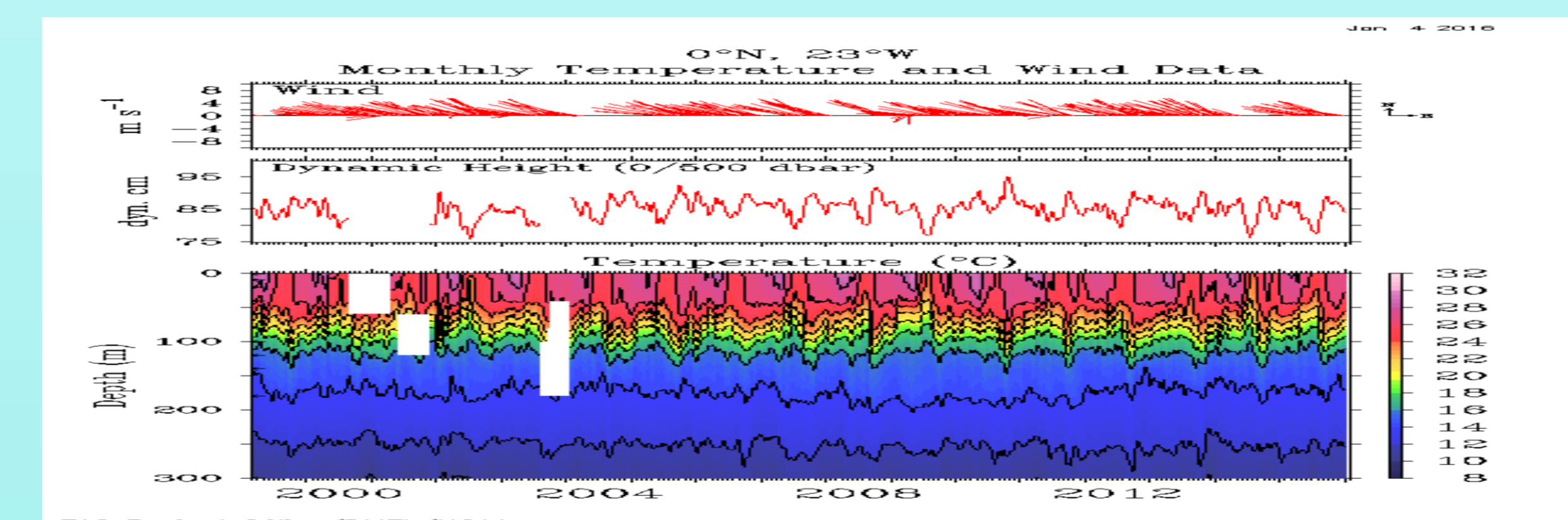


Figure 2: Example of PIRATA time series at 23°W-0°N of atmospheric (daily mean wind: top panel) and oceanic (dynamic height: middle panel, and vertical section of temperature: bottom panel) properties. Gaps indicate missing data due to instrument failure or vandalism.

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 OAFflux 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.

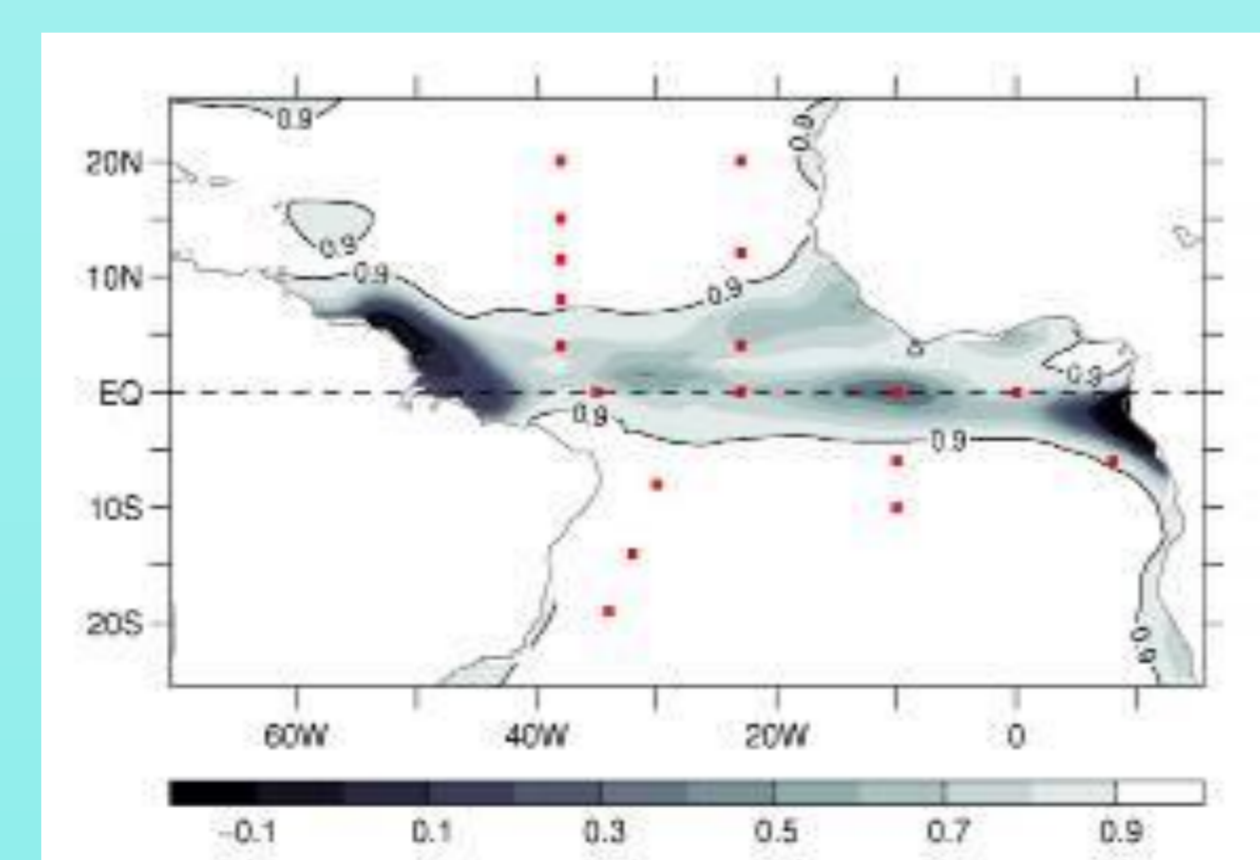


Figure 3: Correlation between Qnet and the rate of the SST change (adapted from Yu et al., 2006).

Example 2 (Figures 4):

Studies using data of PIRATA 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.

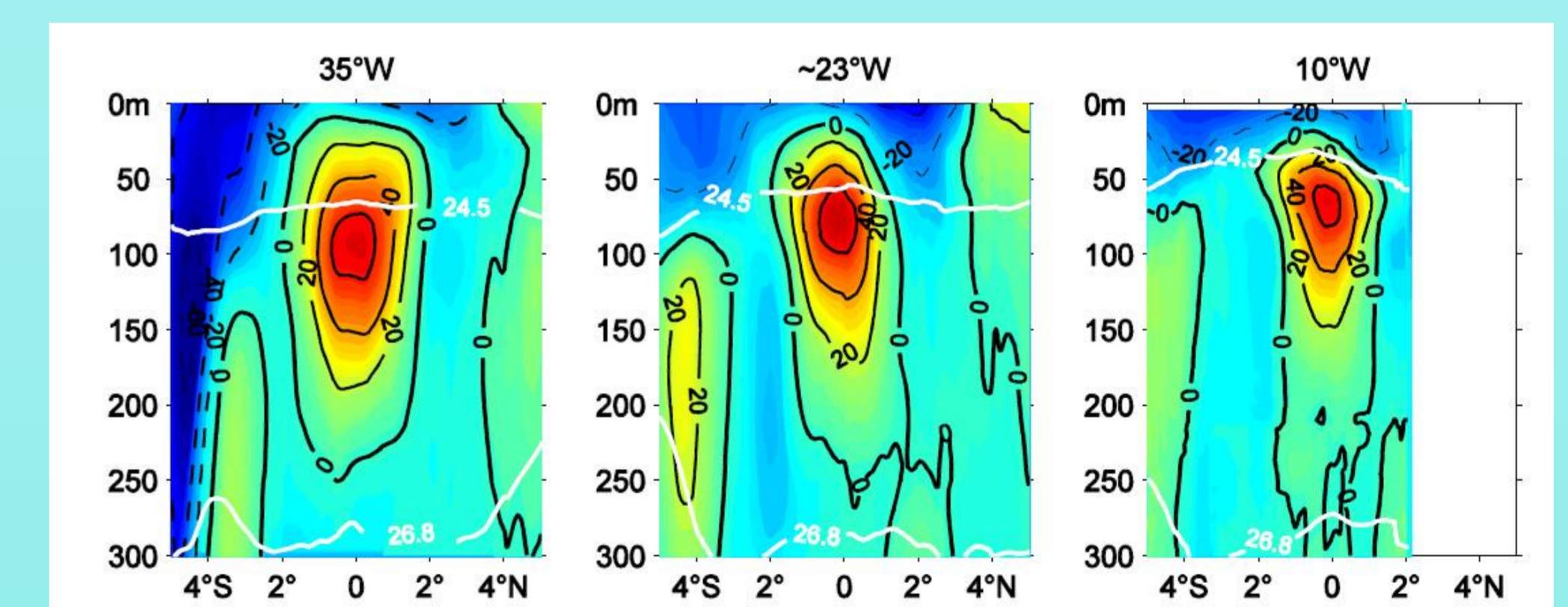


Figure 4: Mean zonal velocity (color shading and black contours [cm/s]) and potential density surfaces 24.5 and 26.8 (white solid lines) along three meridional sections along 35°W, ~23°W, and 10°W (after Brandt et al., 2006; Hormann and Brandt, 2007; Kolodziejczyk et al. 2009).

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) such as Mercator for short-term forecasting, and at the European Centers for Medium-Range Weather Forecasting (ECMWF) and the National Centers for Environmental Prediction (NCEP) operational centers for seasonal forecasting.
- By deploying XBTs and ARGO autonomous profilers, and by sending in real time CTD/XBT profiles during PIRATA 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), “Variability of the American Monsoon System” (VAMOS), “Enhancing prediction of Tropical Atlantic climate and its impacts” (PREFACE) and “Optimizing and Enhancing the Integrated Atlantic Ocean Observing Systems” (AtlantOS) in which it is involved. It is also implied in 2018-2019 EU H2020 projects.
- PIRATA met-ocean buoys constitute platforms for CO₂ measurements (contribution to CARBOOCEAN) and PIRATA cruises are opportunities to conduct seawater sampling for salinity, nutrients, O₂, CO₂, C¹³ and ¹⁸O, and to carry out biogeochemical measurements in the framework of other national and international programs.

PIRATA major successes and perspectives:

- Now going on from more than 20 years, PIRATA demonstrates that a multinational program with 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,...) are regularly installed, and new met-ocean T-Flex systems progressively replace ATLAS systems from 2015.
- The addition of met-ocean buoys in the South East (off Angola) and South Atlantic is more and more needed to improve climatic predictions.

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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