PIRATA: Recent results and future perspectives

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PIRATA has initiated the installation and maintenance operations of an ocean observing system for climate studies in the Tropical Atlantic based on an initial array of 12 moored PMEL/NOAA Next Generation ATLAS moorings (which extends the capability of the previous ATLAS technology), meteorological and tide stations with satellite transmitting capability on two Brazilian oceanic islands, one coastal meteorological buoy near the Brazilian coast, one tide station in one island in the Gulf of Guinea, and one internally recording ADCP current meter mooring on the Equator (Figure 1). The principal objective is to monitor atmospheric-oceanic surface variables and upper ocean thermal structure at optimal locations in the Tropical Atlantic, where the most important regional large scale ocean-atmosphere interaction processes take place. The measurements are transmitted daily via satellite, and are available to all interested users in the research or operational communities. In addition, the original data are recorded internally every 10 minutes for most of sensors in the acquisition system, to be retrieved one year later during mooring substitution and refurbishment operations. Presently, PIRATA is concentrating on the operational side of the initiative and very broad themes related to the future expansion of the array, and the main scientific findings will be the subject of discussions next year.

The choice of the "optimal locations" was made based on past but recent knowledge of the areas where the most critical ocean-atmosphere interaction processes seem to take place. The two main processes which guided the design of the array geometry were: (1) the "equatorial mode of variability", of "El Niño type", which is known to be important in the description of the annual cycle, but also seem to play a role in Atlantic Warm Events at interannual scales; (2) a "dipole mode", which refers to the decadal variability of the interhermispheric sea surface temperature (SST) gradient, which correlates well with land climate variability at these scales.

Implementation started with the first deployment in September 1997. The initial scheduling anticipated an end of the "Pilot Phase" in March 2001, but extension of this phase up to 2006 is presently being agreed upon by the partners.

Three years of measurements will give a good start on the issues of seasonal to interannual variations in the tropical Atlantic, but will not be enough to relate directly to decadal scale variability. However, these observations will make it possible to understand a few key processes thought important for forcing variability on this long time scale. PIRATA also has the potential to establish the foundation for a longer term monitoring network that will address more completely some important scientific problems, under the auspices of CLIVAR, GOOS and GCOS.

Scientific questions of interest

Of the main "socio-economic" drivers for the establishment of PIRATA, two are noteworthy: (a) the strong long term correlation between seasonal precipitation anomalies in the semi-arid north-northeastern Brazil and the African Sahel, and off-equatorial Atlantic SST anomalies (correlation has an inter-hemispheric dipolar distribution), which reveal variability peaking on a decadal (12-13 years) scale, as compared to a smaller correlation with El Niño/ La Niña in the Pacific at this scale, and (b) an "Atlantic El Niño", the El Niño-like warm event in the Eastern Atlantic, which modulates and also disturbs fisheries ecosystems from the Gulf of Guinea down to Namibia, and equally influences the terrestrial climate, this process having a seasonal to decadal variability.

The scientific questions of interest in PIRATA may therefore be formulated thus:

- what processes are responsible for changes in the off-equatorial meridional SST gradient vs. those changes in SST along the equator, and the related problem of variability of the excursions of the Inter-tropical Convergence Zone (ITCZ)?
- to what degree does the tropical Atlantic upper ocean variability affect the coupled ocean-atmosphere-land system of the region and its predictability?

- to what extent is the predictability of the equatorial effects affected by the meridional off-equatorial variability?
- to what degree is the predictability of the coupled system within the tropical Atlantic basin determined by local interactions vs. external influences such as connections with the El Niño-Southern Oscillation (ENSO) and extra-tropical Atlantic processes (North Atlantic Oscillation - NAO, the South Atlantic Convergence Zone-SACZ, the northward propagation of cold fronts)?
- how do anomalous changes in the oceanic transports of mass, heat and freshwater in the region affect SST within the tropical Atlantic basin and via exchanges to higher latitudes?

Although the full explanation for the tropical Atlantic variability should involve the coupling of possibly unknown processes, the PIRATA proposal included, from the outset, the suggestion that one attribute, the so-called "dipole mode", referring to a model of a coherent inter-hemispheric tropical SST anomaly field (SSTa) of opposite signs in each hemisphere, should be important for predictability. Presently, there is a debate in the scientific community as to whether this interhemispheric gradient in SST may be related to a physical mode or it is just a statistical artifact explaining part of the variance. One of the possible hypotheses for such a process is now well stated in the literature, involving a wind-induced evaporation-SST positive feedback, such that the SST anomalies maintain the anomalous wind field, via surface latent heat flux, while low frequency ocean motions should set the restoring force for the oscillation with a period of 12-13 years to be sustained (see, e.g., Chang et al., 1997). Other processes may emerge from future studies based on new data, to explain why the net SSTa variance seem to involve a sort of "symmetry breaking" from the "dipole mode". Is has been shown by several authors that most of the variance of the tropical Atlantic SSTa interhemispheric gradient seem to be related to possibly independent oscillations of the north and the south portions of the "dipole" in the decadal scale (see, e.g., Mehta, 1998), but so far no alternative ocean-atmosphere processes have been proposed to explain the "symmetry braking" of the proposed "dipole process". That is to say that the final explanation for the SSTa variances should possibly include the coupling of the dipole mode with other still unknown processes yet to be proposed. The main issue in PIRATA is, however, the relationship of the ocean to the land climate, and presently the "SST dipole" is still quite appealing a process, as related to the observed correlations of SSTa and precipitation anomalies on land.

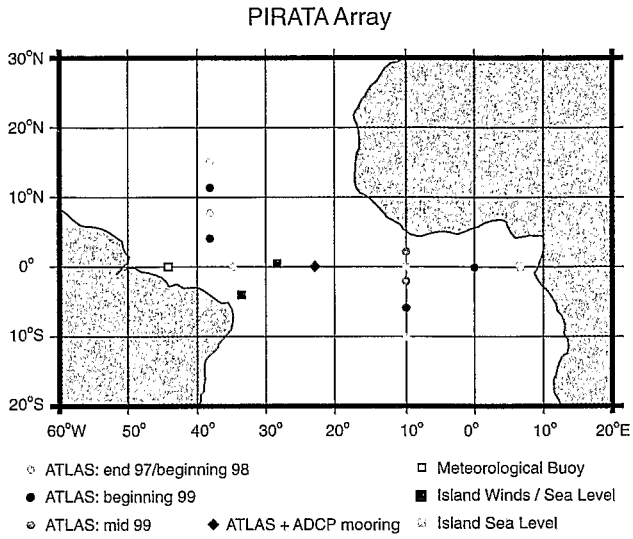

Figure 1: The PIRATA ocean observing system geometry in the tropical Atlantic.

Scientific and technical goals of PIRATA

These goals are multiple:

- to provide an improved description of the seasonal-to-interannual variability in the upper ocean and at the air-sea interface in the tropical Atlantic,
- to improve our understanding of the relative contributions of the different components of the surface heat and freshwater fluxes, and ocean dynamics, in the formation of the oceanic and atmospheric mixed layer, to be able to understand the seasonal and interannual variability of SST within the tropical Atlantic basin, via predictive models of the coupled Atlantic climate system
- to provide a data set that can be used to develop and improve this detailed understanding of how basic mass, momentum, heat and freshwater fluxes couple in the oceanic and atmospheric mixed layer,
- to design, deploy, operate and maintain a pilot array of moored buoys and island stations, similar to the ones used during the TOGA programme in the tropical Pacific,
- to collect high resolution (10 minute time steps) data, and transmit via satellite in real-time a set of quality controlled oceanic and atmospheric daily average data to observe and study the upper ocean and the ocean-atmosphere interface of the tropical Atlantic.

High resolution data from three Brazilian moorings and one French mooring are now available in the PIRATA web page. This data set is very important in support of flux and local air-sea interaction process studies.

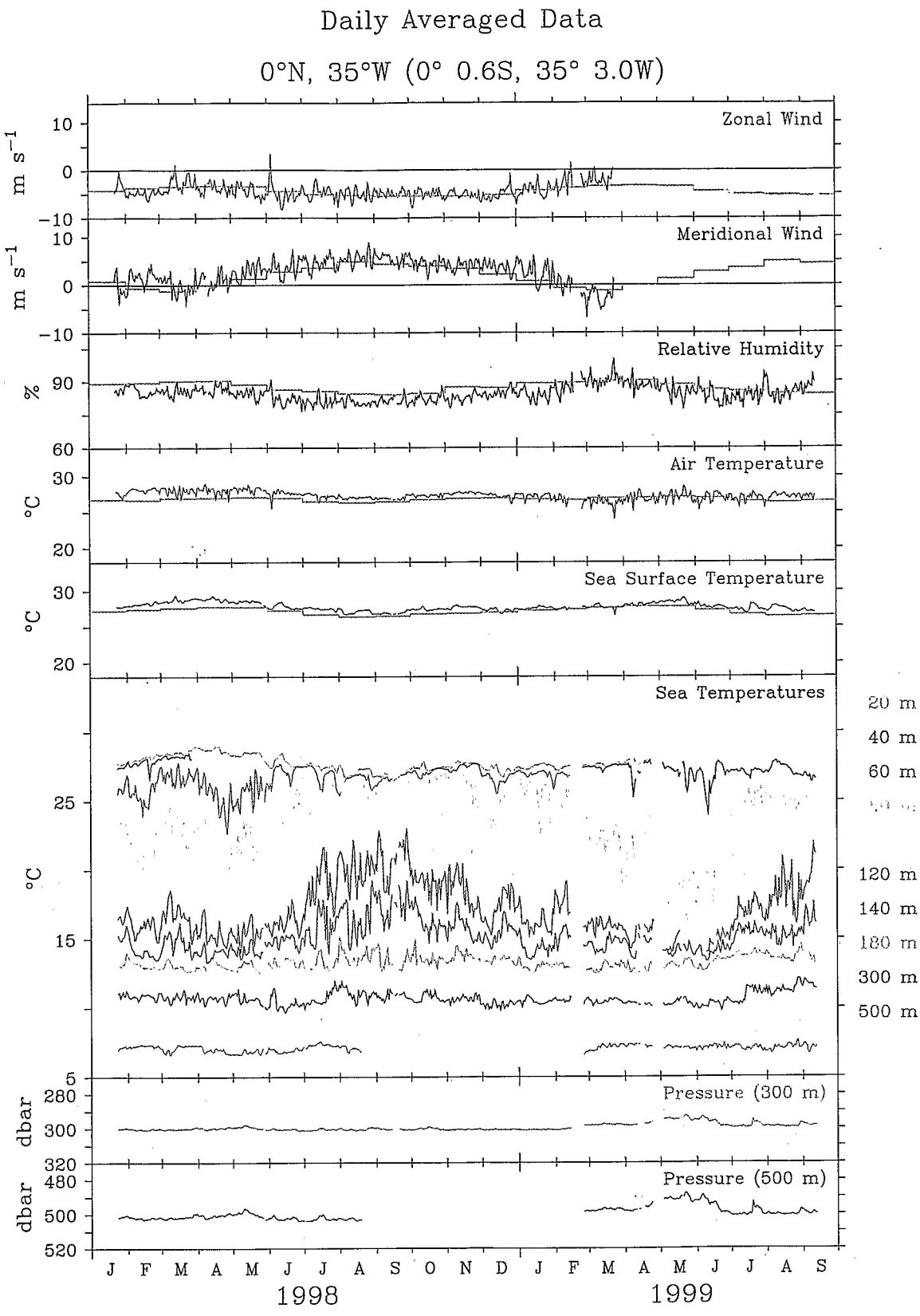

Figure 2a: Surface and subsurface measurements of a PIRATA buoy at the equator, 35°W

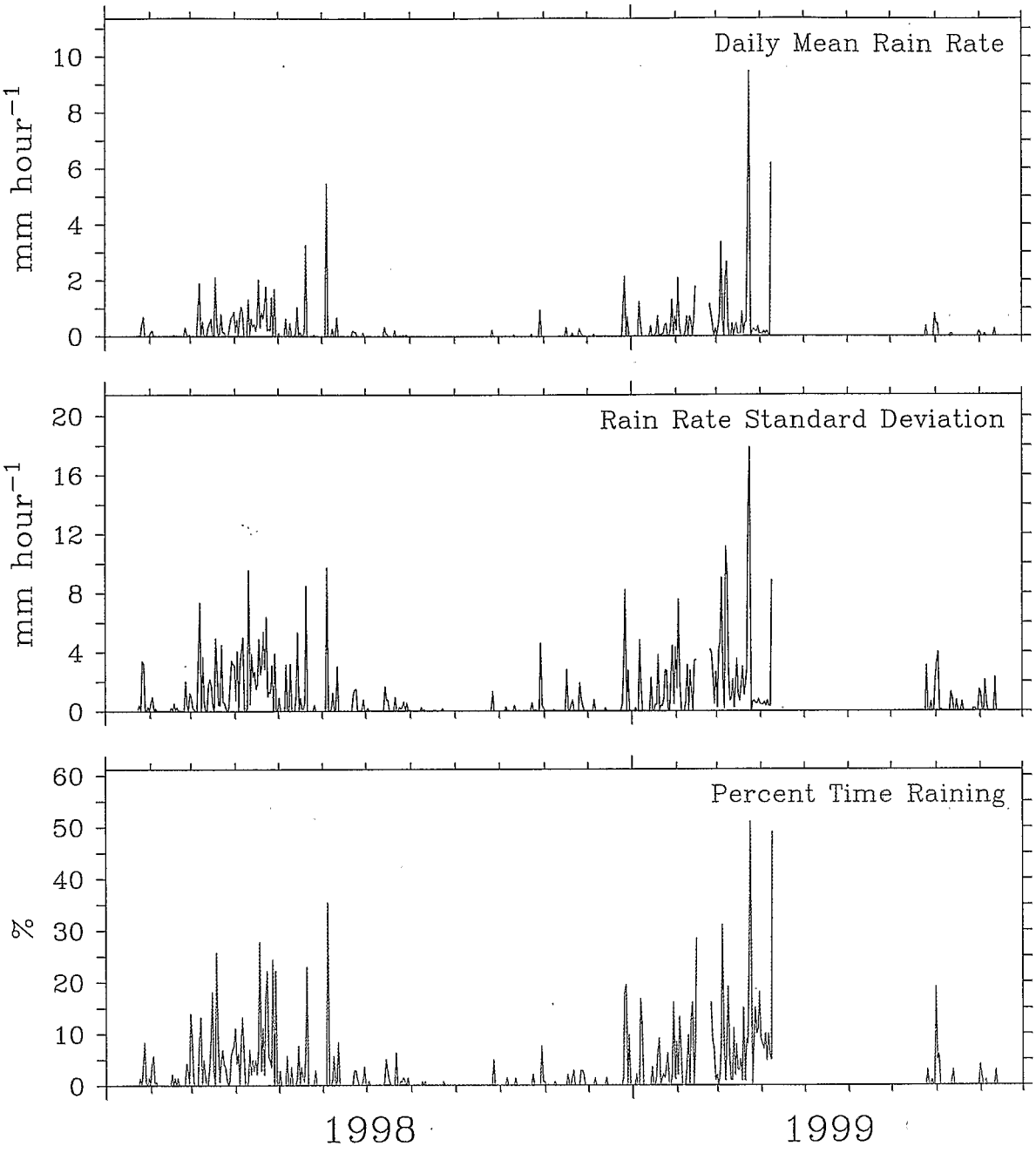

Figure 2b: Rainfall parameters for the PIRATA buoy at 0°, 35°W

The PIRATA Array

PIRATA consists of 12 ATLAS moorings, 4 spanning along the equator, and 8 spanning two meridional lines (Fig.1). This specific configuration has been chosen to provide coverage along the equator of regions of strong wind forcing in the western basin and significant seasonal-to-interannual variability in SST in the central and eastern basin. The meridional arrays cover the regions of high SST variability associated with the SSTa dipole mode, with the northwestern meridional line cutting across the ITCZ during most of the year. The variables measured are surface winds, SST, sea surface conductivity (salinity), air temperature, relative humidity, incoming short-wave radiation, rainfall, subsurface temperature (10 depths in the upper 500 m), subsurface conductivity (presently 3 depths in the upper 150 m, 4 depths in future moorings), and subsurface pressure (at 300 m and 500 m). Examples for some PIRATA measurements are given in Figs. 2-4. An acoustic Doppler current profiler mooring is proposed for 0°N-23°W to monitor the vertical current profile variations in the central Atlantic where high zonal current variability occurs, close to the ATLAS mooring sited at 0°N-23°W (the 20°W mooring position had to be displaced to the west due to difficulties with local bottom topography).

The present importance of obtaining good subsurface temperature and salinity data, especially in the upper 150m, is driven by the need to monitor the influence of shallow mixed layers (30m) occurring with waters of different temperature and salinity stratifications (causing what is known as a "Barrier Layer"), which have impacts on the vertical heat transfer in the ocean, affecting SST. Mixed layer parameterisations for predictive models should take into account such salinity effects, which will be even better monitored once the ATLAS moorings to be deployed in the year 2000 will carry conductivity sensors at five depths (1m, 20m, 40m, 80m and 120m). The demand for these five depths is the result of the observation of "barrier layers" in the vertical profiling with CTD's, which form a necessary part in the data collection made during the deployment cruises.

The initial ATLAS deployments were made during 1997-1999 (Fig.1). In addition to the ATLAS mooring observations, wind measurements and tide-gauge data are scheduled to be available in real-time from a few equatorial sites: Brazil will deploy systems at St. Peter and St. Paul Rocks Archipelago (0.7°N-29.2°W) and Atol das Rocas (3.9°S-33.5°W), while France will maintain the tide gauge at São Tomé island (0.5°N-6.5°E). Brazil must also deploy a coastal meteorological buoy at 0°N-44°W, offshore the State of Maranhão.

PIRATA Status (August 1999)

Since November 1998 nine deployments have been made, giving an initial data return statistics around 90%, up to last May. By the end of August some sensor problems, vandalism, and delays in the deployment schedule are showing up, a fact that is considered normal in this kind of "Pilot Project", as has been anticipated in the Implementation Plan. Details may be obtained directly from the PIRATA web page.

The final phase of the PIRATA experiment (spring 2000 - early 2001) will be hopefully dedicated to the yearly maintenance of the ATLAS sites and the other components of the in-situ observing system. Thus, an integrated ocean observing system (full PIRATA array + equatorial current measurements + equatorial sea level data + equatorial Met observations) is expected to be operational during (at least) one year.

Other nations are being stimulated to join in the maintenance and possible expansion of PIRATA (and other type of in-situ oceanic observations) to constitute a tropical Atlantic Ocean "fixed" in-situ observing system after 2001. A dedicated meeting to discuss all of the oceanographic projects and proposals within the Tropical Atlantic (Climate Observing System in the Tropical Atlantic, COSTA) was hosted by Dr. Sylvia Garzoli at AOML/NOAA in Miami (May 3-7 1999) where these discussions took place, at the same time of the sixth meeting of PIRATA (PIRATA-6, Miami, 2-3 1999) where practical and strategic questions about the final phases of the PIRATA project have been discussed. To facilitate the management of this increasingly complex implementation, a PIRATA Resources Committee (PRC) is being formed by the major sponsors of the Project, to establish a long-term strategy for funding, logistics, training, and national priorities and interests regarding the future of PIRATA (where the P will then stand for "Permanent").

One of the main issues facing PIRATA now is the feasibility of participation of other countries in PIRATA, as it will continue post- 2001, after the first "pilot phase" ends. Presently there are statements from both Brazil and France assuring ship time to the end of this first phase, but discussions will continue regarding the extension of the project up to 2006, including geographical extensions of the array. Some extensions are only possible with the entrainment of other countries, but some are also being proposed by the present partners. This issue is also dependent on capacity building in the region in the form of an efficient training and technology transfer programme needed to help alleviate the

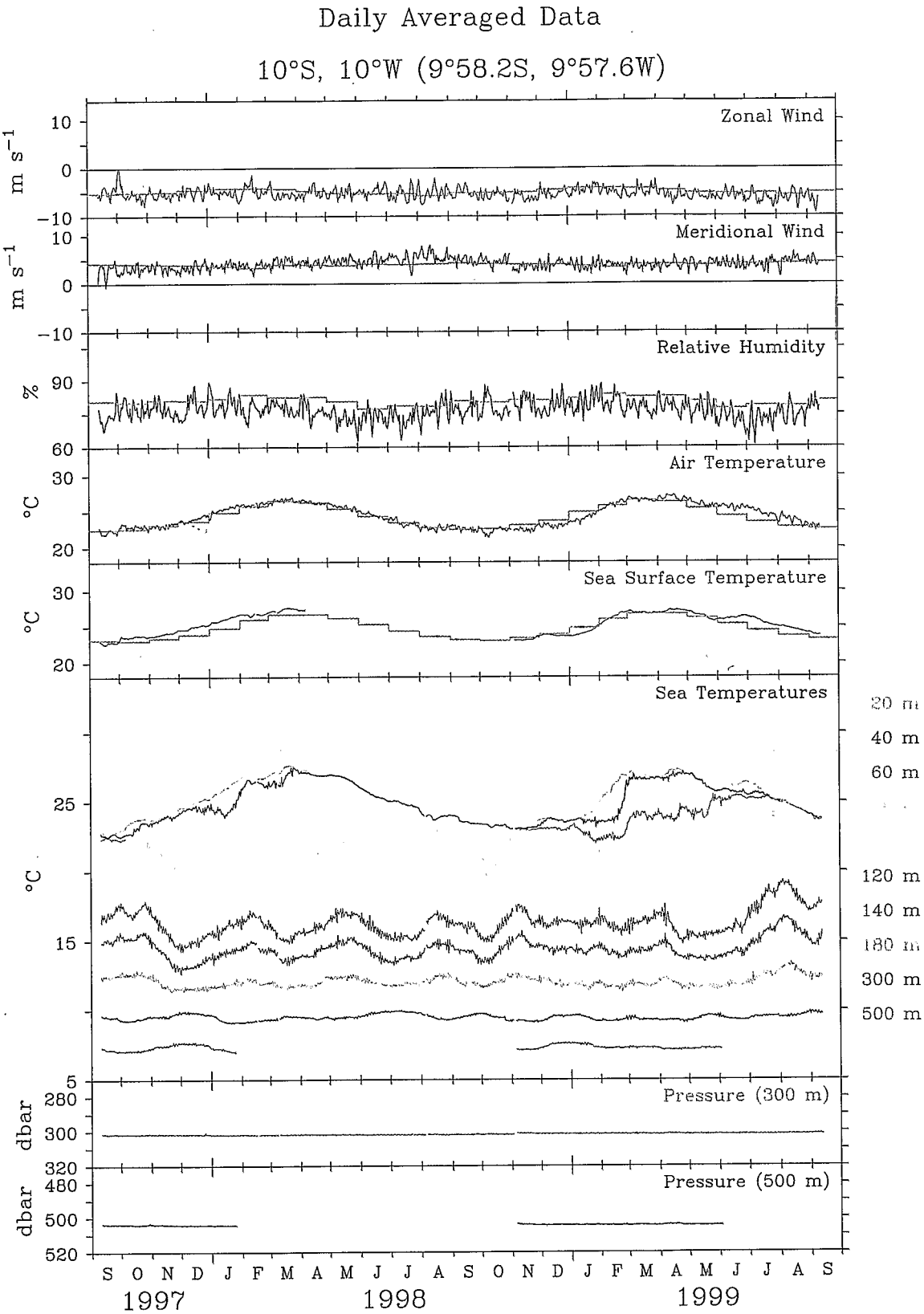

Fig. 3: as for Fig. 2, for the mooring at 10°S, 10°W

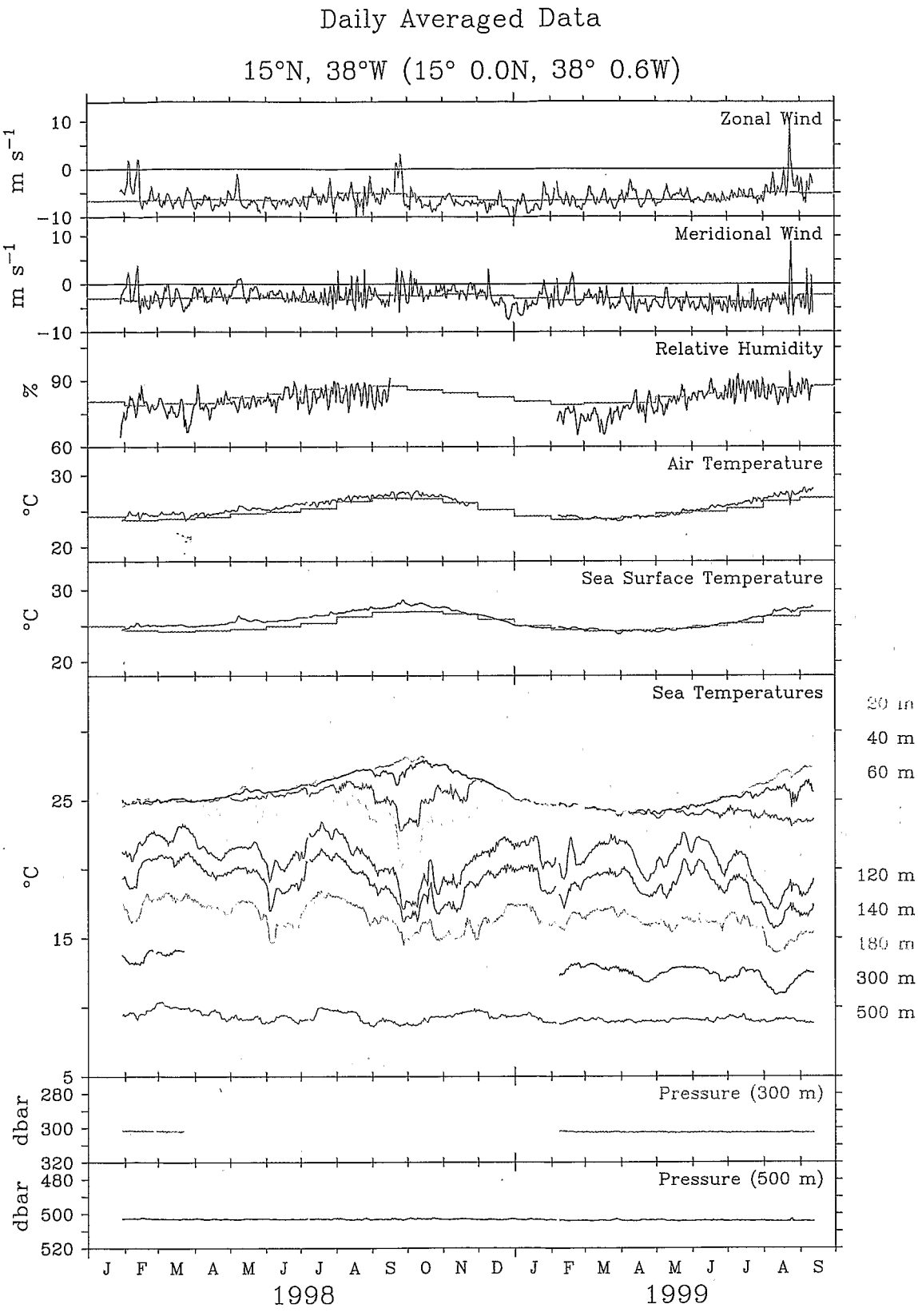

Fig. 4: as for Fig. 2, for the mooring at 15°N, 38°W

burden being placed on PMEL.

The COSTA Meeting (summary see this issue) was very successful in producing a first synthesis of all of the scientific issues contemplated by ongoing large scale oceanographic projects in the region, underlying the complementarity between these initiatives. The report of this important meeting may be obtained at the AOML website http://www.aoml.noaa.gov/phod/COSTA/report/

International resource commitments

PIRATA is realised as part of a multi-national effort involving Brazil, with INPE responsible for the national coordination, funding and technical work, and the ship time furnished by the Directory of Hydrography and Navigation (DHN) of the Brazilian Navy (which collaborates with the most extensive civil oceanographic programmes in Brazil); France, involves IRD in both the coordination, funding and ship time, and Météo-France and CNRS/INSU) with funding; and the US through the Pacific Marine Environmental Laboratory (NOAA/PMEL), being responsible for mooring construction, maintenance of systems and support in deployment operations, quality control and distribution of data through the Internet, construction and maintenance of the main PIRATA web page, as well as funding via NOAA/OGP.

During the pilot study (1997-2001) all the ATLAS mooring systems are being built by NOAA/PMEL at Seattle. NOAA/PMEL also funds and coordinates shipping to and from the theatre of operations, and participates in deployment as well recovery of mooring systems at sea. It is responsible for all calibration, laboratory check outs and instrument refurbishment. It maintains a data base of real-time and research quality delayed mode data (10 minute data) for all variables, which become available in the PIRATA web pages as soon as they are processed. However, Brazil has plans to develop a dedicated laboratory in the coastal city of Natal, northeast Brazil, to facilitate this complex logistics, and at the same time develop a better partnership with PMEL which will involve full refurbishments of moorings near the theatre of operations.

The logistical support in terms of ship time for developing and maintaining the PIRATA moored array is under the responsibility of Brazil and France (about 90 days per year of ship time for servicing the entire array). The Brazilian R/V Antares (DHN) services the western half of the array and the mid basin mooring at the Equator, departing from Fortaleza or Natal. Brazil will install wind and sea level data collection platforms at St. Peter and St. Paul Archipelago, Atol das Rocas, and at the coastal meteorological buoy (0°N-44°W). The French R/V Antéa (IRD) services the eastern half of the array from Abidjan, Côte d'Ivoire. France maintains a sea level data collection platform at São Tomé island (0.5°N-6.5°E).

All the PIRATA daily data are available at PMEL/NOAA-Seattle via the World-Wide-Web at http://www.pmel.noaa.gov/pirata, with an electronic link with IRD-Brest at http://www.ifremer.fr/orstom/pirata/piratafr.html, and INPE at http://www.cmcd.inpe.br/pirata.

Interactions with other programmes

As with the TAO programme in the Pacific, the PIRATA programme is not conceived as a self-sufficient programme. The main role of PIRATA is to offer high quality geographically fixed time series of ocean surface and subsurface measurements, to complement existing Lagrangian measurements offered by other projects in the tropical Atlantic, and to give verifiable elements to future model experiments. Consequently, many scientific interactions take place between PIRATA and other climate change programmes which are being developed in the tropical Atlantic region (see a partial list below). Such interactions are of mutual benefit to PIRATA and these other programmes.

International programmes:

CLIVAR (Climate Variability and Predictability), and its sub-programmes; CLIVAR-Africa, EuroCLIVAR, VAMOS (Variability of American Monsoon Systems);
GCOS (Global Climate Observing System), GOOS (Global Ocean Observing System);
Brazilian programmes:
GOOS-Brazil and its sub-programmes (e.g., National Drifter Program-PNBoia);
French programmes:
ECLAT (Etudes Climatiques dans l'Atlantique Tropical), Clipper-MERCATOR-CORIOLIS (Operational Oceanography);
USA programmes:
ACVE (Atlantic Climate Variability Experiment), PACS (Pan American Climate Studies), ACCE (Atlantic Climate and Circulation Experiment);

References

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The PIRATA Executive Committee

It was during the 4th TAO Implementation Panel Meeting in 12-14 September, 1995, that a decision was made to prepare a proposal for a TAO array extension into the Tropical Atlantic. The first ad-hoc committee was formed with the task of preparing a proposal, and involving those parties that could make possible the funding and the ship time required, with the first meeting scheduled for February 1996, in Natal. The components of this first "PIRATA Executive Committee-PEC" were the present authors, plus Drs. Mike McPhaden (PMEL/NOAA), Antonio Divino Moura (INPE-in the move-to IRI/NOAA), Gilles Reverdin (LEGOS/GRGS) and Steve Zebiak (LDEO/Columbia University), with Drs. Moura and Servain as co-chairs. The first version of the "PIRATA-Science and Implementation Plan for an Observing System to Support Tropical Atlantic Climate Studies" was discussed in the PIRATA-1 Meeting in Natal, where feasibility issues for initiating implementation in 1997 were first examined. Subsequent meetings (in Brest-1996, Seattle, March 1997, Rio de Janeiro, November 1997, Abidjan, November 1998) have been important to discuss the logistic and implementation issues of PIRATA. Last year, in the PIRATA-5 Meeting in November 1998 in Abidjan, Dr. Zebiak, who gave much of his time with ideas that made possible the materialization of PIRATA, rotated off the PEC. The PEC is now enlarged by Drs. Serge Planton (IRD), Ping Chang (Department of Oceanography, Texas A&M University) and Ilana Wainer (Instituto Oceanografico, Universidade de S. Paulo), with Dr. Servain now acting as Chairman.

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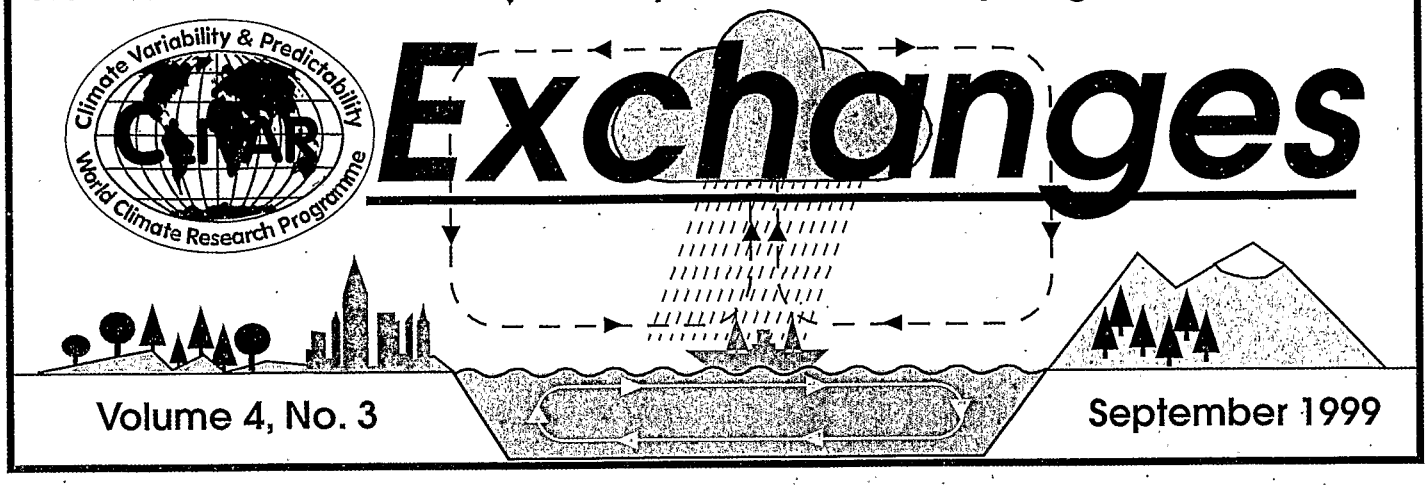
Newsletter of the Climate Variability and Predictability Programme (CLIVAR)

Exchanges



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OceanObs'99 Special Edition

Call for Contributions

In the next issue of Exchanges, which will be published in December, we would like to highlight the accomplishments and future challenges in climate modelling. If you would like to contribute, please send your manuscripts which should not exceed 4 pages of text (single spaced) plus 2 figures electronically (text either in Word, RTF or ASCII, figures in postscript, eps or high resolution tiff format) to the editor of CLIVAR Exchanges: andreas.villwock@clivar.dkrz.de.

Please note, that your contribution has to be submitted by November 12th, 1999.