

**REPORT OF THE SIXTH MEETING OF
THE PILOT RESEARCH MOORED ARRAY IN THE TROPICAL ATLANTIC**

PIRATA-6

3-4 May 1999, Miami, FL, USA

(gathered by J. Servain)

SUMMARY

The sixth meeting of the PIRATA Steering Committee (PIRATA-6), hosted by NOAA/AOML and partially supported by IOC/GOOS, was held in Miami, FL, on May 3-4, 1999. The PIRATA-6 meeting was followed by the Climate Observation System in the Tropical Atlantic (COSTA) meeting. Most of participants to PIRATA-6 attended COSTA (see the list of the participants in Annex 3), with a total number of participants up to 30 for PIRATA-6 and up to 60 for COSTA. The local organizer for both meetings was NOAA/AOML, under the responsibility of Dr. Silvia Garzoli.

PIRATA-6 was mainly devoted to discuss the followings topics:

- Status of the national (Brazil, France, U.S.A.) past and present contributions to PIRATA, including mooring funding, ship-times, changes in cruises due to vandalism problems, refurbishment issues, shipping and customs problems...
- Evaluation of the first 18-month PIRATA data, and their contribution in our knowledge of the climate variability of the region
- Continuation of the deployment and maintenance of the PIRATA array until the end of the pilot phase (beginning 2001), including the associated instrumentation (tide-gauges, Met measurements)
- Proposition from the three countries (Brazil, France, USA) to maintain the original PIRATA array as a "back-bone" during 5 additional years (2001-2006) after the pilot phase, as a smoother transition to operational status, if warranted, under the GOOS auspices
- Possible "pilot" expansions of the PIRATA array with the collaborations of other nations and institutions interested by regional impacts of the climate variability, in synergy with a coherent sustained in-situ observing system on the region.

A resolution was prepared by the PIRATA-SC at the end of the meeting (see Annex 1).

A tentative agenda for the next PIRATA activities is proposed in Annex 2.

SESSION 1: Status of the PIRATA implementation and national participation's

(Notes recollected by P. Chang, partially written by P. Freitag and M. Vianna, arranged by J. Servain)

In the first session of the PIRATA-6, representatives from France, Brazil and U.S.A. summarized the participation of each country during the second phase of the PIRATA (1998-99) and the plan for the third phase of deployment/maintenance of buoys (1999-2001). Other issues concerning vandalism, data return, tide-gauges, meteorological buoy, ADCP and PIRATA web page were discussed.

A) National status

a1) Report of French participation and the status of the eastern array (J. Servain)

During 1997, France provided funding for three ATLAS buoys; two by ORSTOM and one by CNRS/Météo-France. Two moorings (Java at 0°N-10°W and Gavotte at 10°S-10°W) were deployed by French R/V Antéa during September 1997 (cruise PIRATA-FR1). In mid November 1997, Java was reported missing. In December 1997, French performed partial refurbishment of the Sao Tomé tide-gauge.

During January-February 1998, a new ATLAS mooring (Soul at 0°N-0°W) was deployed by R/V Antéa (cruise PIRATA-FR1-bis). Meanwhile, two new ATLAS mooring were purchased; one by ORSTOM/IRD and the other by CNRS/Météo-France. Another refurbishment of Sao Tomé tide-gauge Argos system was performed during August 1998. In mid-September 1998, Soul reported problem and then was reported missing by the end of October. In October-November 1998, Gavotte was replaced and a new mooring Soul was deployed (cruise PIRATA-FR2). Unfortunately, Soul reported problem again by the end of December 1998.

By early January 1999 Soul was reported missing. Luckily, it was recovered by a tuna fishing boat (Via Harmattan) on January 12, 1999 and was sent to Abidjan on February 2, 1999. The third French PIRATA cruise (PIRATA-FR3) with R/V Antéa was conducted in January-February 1999, during which two new moorings (Valse at 5°S-10°W and Java at 0°N-10°W) were deployed. France is also providing the funding for the refurbishment of two ATLAS moorings (one by IRD (ex. ORSTOM) and the other by PNEDC (via IRD). Therefore, by April 1999, France deployed ATLAS moorings in four sites (Java, Gavotte, Valse and Soul). Except Soul, all other moorings are broadcasting data. All the PIRATA real-time data set is available on <http://www.ifremer.fr/ird/pirata/piratafr.html> which is a mirror site of the PIRATA site from PMEL, with additional info about the PIRATA program (e.g. the present PIRATA-6 Meeting Report).

The French participation of PIRATA for the second half of 1999 and 2000 are scheduled as follows:

- Refurbishment of Sao Tomé Tide-Gauge Argos system is planned in June 1999. The real time data from this tide-gauge is scheduled to be available in the French PIRATA mirror Web page as soon as possible.

- The fourth French PIRATA cruise (PIRATA-FR4) with R/V Antéa is scheduled in two legs in July 1999. During the first leg (July 1-13), two new moorings, Rhythm (2°N-10°W) and Blues (2°S-10°W), will be deployed. Additionally, a third attempt of maintenance of Soul at 0°N-0°W will be made. At this time (early July 1999), the whole PIRATA array will be completed. During the second leg (July 15-22) a complex current measuring system will be deployed in the vicinity of Java (0°N-10°W) with an ADCP system (0-250 m) and a "Yoyo"

system (150-1000 m, daily profiles), and classical current measurements (1000-4000 m) at two sites along 10°W, 0°5N and 0°5S.

- Direct observations of turbulent air-sea flux are planned along zonal and meridional transects from Salvador de Bahia (Brazil) to Abidjan (Côte d'Ivoire), using a meteorological instrumented mast aboard the French R/V "La Thalassa" during the French cruise EQUALANT-99 (July-August 1999). During that cruise, three 36-hour intensive measurements (from surface air to bottom ocean) will be done in the vicinity of three PIRATA equatorial sites (Samba, Rhythm and Java). That will particularly provide useful calibration for the turbulent air-sea fluxes obtained by ATLAS mooring via the bulk formula.

- The fifth French PIRATA cruise (PIRATA-FR5) with R/V Antéa is scheduled in October 1999, during which Gavotte will be replaced.

- The sixth French PIRATA cruise (PIRATA-FR6) with another French R/V (probably "Le Suroît") is currently planned to take place in February 2000, during which Java and Valse will be replaced, and the "Yoyo" system will be visited (change of battery). It is also anticipated that France (IRD and PNEDC) will provide funding for refurbishment of 2-3 ATLAS moorings in 2000.

- PIRATA-FR7 is currently planned to take place in June-July 2000 with the servicing of Rhythm, Blues and ... (hope so!) Soul. That cruise will happen before the French EQUALANT-2000 (French R/V "Atalante"?) cruise (planned by September-October 2000?), during which the complex current measuring system close to 10°W-0°N will be removed. As a possibility, the Sao Tomé tide gauge could be also serviced during that cruise.

- PIRATA-FR8 is planned in October 2000, during which Gavotte will be serviced.

- The ninth French PIRATA cruise (PIRATA-FR9), the last one for the PIRATA pilot phase, is planned between January-March 2001, during which Java and Valse will be serviced.

Question (T. Busalacchi): Does France have specific commitment to fund PIRATA after its pilot phase 2001 ?

Answer (J. Merle): Although it is anticipated that France will provide continue support to PIRATA, there is no specific commitment made at this point.

Comment (M. McPhaden): The pilot phase of PIRATA is too short to examine how successful this observational program is. Perhaps, we should consider a 5-year transition phase after 2001.

Answer (J. Merle): We will support this idea (i.e. 5-year PIRATA transition phase).

a2) Report of Brazilian participation and the status of the western array (M. Vianna)

During the three legs of PIRATA-BR2 (January-March 1999), the Brazilian R/V Antares (DHN) serviced/recovered three buoys and deployed six new ones along 38°W (Reggae at 15°N, Forro at 11°30N, Lambada at 8°N and Frévo at 4°N) and along the equator (Samba at 35°W and Jazz at 23°W). Note that, due to the extreme roughness of the bottom (medio-Atlantic ridge) close to 20°W-0°N, the site of Jazz was shifted by 3 degrees longitude westward vs. its initial position. At the present time (May 1999), most instruments on the western Atlas mooring array are functioning normally. One conductivity sensor is missing at Forro. The wind sensor at Jazz - as well as the wind sensor and the rain-gauge at Valse (5°S-10°W) on the eastern array - have been lost (vandalism or simple failure?) only a few days after their deployments by early 1999. These three sensors will be replaced in July-August 1999 during the French cruise EQUALANT-99.

There has been a change in sampling strategy for salinity measurement during the last Brazilian PIRATA cruises. The salinity is presently being sampled at 1 m, 40 m, 80 m and 120 m. Sampling at 20 m was considered to redundant either with the measurements at 1 m or at 40 m. The sampling at both 20 m and 80 m, in addition to the other above-mentioned

depths, is being studied as an option to have 5 salinity measurements in an ATLAS mooring for PIRATA, instead of 4.

Brazil continues somehow the processing to install wind and sea level data collection platforms at St. Peter and St. Paul island (SPSP), Atol das Rocas, and at the coastal meteorological buoy 0°N-44°W. In the next few weeks, a new tide gauge will be installed by DHN at SPSP (one first instrument has already been installed in March 1999 but it does seem to work correctly). Currently, there is still a debate between INPE and DHN on which of the institutions will in fact install the meteorological station at SPSP, although INPE is booked already to complete this work. Deployment of a meteorological station by DHN at SPSP will depend on the feasibility of conversion of DHN's new MILOS station to PTT transmission by INPE. That will be determined soon. Meanwhile, INPE is looking into the fastest way possible to obtain at INPE-Natal in 1999 the necessary hardware to assemble 3 PTT-capable marine meteorological stations, to equip the 44°W-0°N coastal mooring, Atol das Rocas and (possibly) SPSP. The tide-gauge of Atol das Rocas is scheduled to be deployed by INPE in mid-1999. The real time data from the tide-gauge and meteorological stations are scheduled to be available in the Brazilian PIRATA mirror Web page which is currently operational (<http://www.cmcd.inpe.br/pirata>).

The ADCP current mooring (with measurements all along 0-300 m) is scheduled to be deployed in the vicinity of Jazz (0°N-23°W) no later than January-February 2000. B. Johns from University of Miami will assist the mooring-deployment of this ADCP.

a3) Report of USA participation (M. McPhaden)

Between November 1998 and May 1999, NOAA/PMEL participated in two French cruises (PIRATA-FR2 and PIRATA-FR3) on the R/V Antéa, and in the three legs of the Brazilian cruise PIRATA-BR2 on the R/V Antares. In addition, PMEL built and delivered three ATLAS buoys to Brazil over the past six months. PMEL also built and delivered components for six ATLAS buoys to the IRD team in Côte d'Ivoire (Abidjan).

During the second phase of PIRATA, PMEL continued engineering development to improve next generation ATLAS sensor performance and reliability. PMEL also processed real-time data stream and maintained a Web page for data display and dissemination. The surface sensors of the PIRATA array captured well the large warming which occurred in the tropical Atlantic during 1997-1998, and which was contemporary with the 1997-1998 ENSO. Furthermore, some preliminary analyses support wind-evaporation-feedback hypothesis.

During the third phase of PIRATA (May 1999-April 2000), PMEL plans to participate in two Brazilian cruises with R/V Antares during February-March 2000, and three French cruises with R/V Antéa (or other French R/Vs) in July 1999, October 1999 and January-February 2000.

PMEL also anticipates building or refurbishing 12 buoys for PIRATA. PMEL will continue engineering development with a particular focus on rainfall measurement. PMEL will also continue to upgrade Web pages for display and dissemination. Finally, a systematic analysis of PIRATA data will begin during the third phase of PIRATA.

Our experience now indicates that 20 buoys in the buoy pool may not be sufficient to maintain all the 12 moorings in PIRATA, due to high vandalism, longer than expected lead time for shipping to Brazil and more frequent cruises. It is, therefore, recommended that the number of buoys in the buoy pool be increased to at least 23.

B) Data Return and Web sites (P. Freitag)

Sixteen moorings have been deployed at 10 sites since September 1997. At present (May 1999), there are 9 moorings deployed which are working. Previous moorings at two sites

(Java at 0°N-10°W, first deployment, and Soul at 0°N°W, first deployment) stopped transmitting after a few months and were not found during recovery cruises. A third mooring (Soul again, second deployment) was vandalized and the mooring cut near the surface. The surface buoy along with damaged instrumentation was recovered by a French tuna boat (Via Harmattan).

Raw data received at PMEL via Service Argos are processed, displayed and distributed on the Web from PMEL (<http://www.pmel.noaa.gov/pirata/>). Three Web sites are mirrors of this PMEL PIRATA Web site: one in France-Brest with extra information about PIRATA, another in Brazil-São José dos Campos, a third in Côte d'Ivoire-Abidjan. Data are also processed by Service Argos and submitted to the GTS.

For the one-year period ending April 15, 1999, overall real-time, daily-mean data return was 77%. The first year PIRATA data return is slightly below than our goal of 80% in real-time, but improvements in construction and design of components should result in a fully successful return in the future. The lowest data return per site was at Soul (0°N-0°W) due to vandalism. Data return at sites which were deployed for the entire year (Reggae, Forro, Samba, Gavotte) ranged between 80% and 89% (site averages for all sensors weighted equally). The sensor type with the lowest data return was sea surface conductivity (SSC), which had a data return of 60%. Problems with this sensor have been identified and corrected in newer version instruments. Overall return of wind data has been comparable to the mean of all sensors, but the spatial distribution of wind data return has a pattern of lowest return along the equator and in the east, presumable due to vandalism. The sensor type with the highest site-averaged data return was short-wave radiation (90%).

Other significant failure modes include:

- Real-time communication failures. In some cases data were available when the mooring was recovered. Improvements in mooring hardware and electronic design and construction are addressing this problem.

- Module electronic failures. PMEL has selected a new vendor for assembling circuit boards due to poor quality work from the original vendor. Boards are also being thermally stressed prior to check out to help identify marginal components. Test runs of the modules are also being extended.

- Failed or noisy rainfall sensors. PMEL is redesigning the electronic portion of the rain gauge. Tests to be performed soon will tell whether this redesign will improve the performance of the rain gauge. It is hoped that this redesign will also allow the addition of a second Argos transmitter on a buoy if desired.

High temporal resolution data (10 min for most sensors, 2 min for short-wave radiation, 1 minute for rainfall) are recorded internally by the instruments and available after recovery of the moorings. To date, four moorings have been recovered after deployments of a year or more. Overall data return for this delayed mode data was 80%. In some cases, data not available in real time were recovered in delayed mode. In other cases, data which were transmitted in real time for a portion of the deployment were not recovered in delayed mode due to instrument failure or loss of equipment.

As mentioned above, small (within sensor specifications), sporadic, high-frequency noise is present in some 1-min rain time series. This noise can be eliminated using filtering techniques during post-processing, but, at present, on-board algorithms can not correctly process the noise, resulting in biased rainfall data in real-time. Design modifications to the sensor electronics and/or software modifications are being undertaken in order to reduce or eliminate this error.

The high-resolution delayed-mode data will be made available on the Web and via ftp. ASCII format files of the data compose about 35 Mbytes of data per mooring year. Transfer

of these data, especially via slow servers may present a problem. The final format of the data and method of transfer has not yet been determined.

SESSION 2: The present support of PIRATA

(Notes recollected by P. Nobre, partially written by M. Vianna, arranged by J. Servain)

A) Supports from France-Brazil-USA

a1) France/IRD (J. Merle), France/CNRS (G. Reverdin), France/Météo-France (S. Planton)

From the pessimistic point of view there is the fragility of the PIRATA system, mostly associated to vandalism, ship-time availability, people, ... (it was the same kind of problem with TAO at its beginning ...).

The optimistic perspective is an increased sensitivity from the French government to operational oceanography funding of the order of 10 M US\$ per year after 2001. That includes:

- IRD will continue to support PIRATA in the future, if possible at the same level as now ("if possible" means here that coming up conflicting strategy with other potential users of R/V Antéa in the western side of Atlantic could be resolved - see below);
- Programs CORIOLIS (in-situ data experiment in the Atlantic, = French participation of ARGO) and MERCATOR (data assimilation, = French participation of GODAE) are presently in development;
- PNEDC (National Program for Climate Study) supports PIRATA and contributes to the funding of climate studies like ECLAT (French participation of CLIVAR in the Tropical Atlantic, PATOM (process studies in the North Atlantic), MERCATOR;
- Validation of satellite products of SAF/O (SST, solar fluxes, ...); A FR-US space cooperation (T/P, Jason, ...) continues;
- Climate monitoring and studies (i.e. PIRATA is mentioned as one of the key elements for tropical operational oceanography on EuroCLIVAR discussions)
- Support for the Northern extension of the network for meteorological instrumentation of some mooring; Cyclone survey;
- A recent visit of French Research Minister to Brazil allows to foster scientific cooperation in climate domain.

Science programs in France are funded yearly, however operational oceanography is forever, and needs to secure the funding differently. It is presently under discussion.

Main problem: the strategy to maintain the R/V Antéa at its present base in Abidjan (Côte d'Ivoire) is not secured after 2000 (strong requests for others French oceanographic activities in the West Indies and along the French Guyana are coming up).

a2) Brazil/INPE (M. Vianna), Brazil/DHN (C. Hansen)

Funding for PIRATA in Brazil is controlled by INPE's Special Projects Coordination, an administrative unit under the direct control of INPE's Director. Allocation of funding from the federal budget happens yearly, and this is the case for INPE. Alternatives for funding PIRATA may be obtained by submittal of research proposals to State Funding Agencies, where projects are approved by a peer review system in a typical 90 day time frame. The basic PIRATA operations are supported through the INPE's Oceanography Program, which belongs to the Division of Remote Sensing, in the Coordination of Earth Observations. DHN, which provides the full ship-time for PIRATA operations under the Brazilian responsibility, has demonstrated its capacity building, and this is considered as an enormous success by that institution.

PIRATA is seen in Brazil as the first and essential part of an ocean observing system for climate predictability studies in the tropical Atlantic, and is widely recognized as a contribution to climate studies in the international level. It is presently seen as part of the GOOS-Brazil Pilot Project, under the sub-program called National Buoy Program, which is part of this pilot, and managed under the auspices of the Inter-ministerial Commission for Ocean Resources (CIRM). It is also endorsed as a contribution to CLIVAR-Brazil and can become very important to the climate forecasting activities of INPE/CPTEC.

Although there is presently a very difficult panorama for funding by the Federal Government in 1999, INPE and DHN will be able to assure the PIRATA objectives in 1999, 2000 (the third Brazilian PIRATA cruise in Feb-Mar 2000 is guaranteed with R/V Antares) and 2001. Beyond 2001, INPE and DHN will pursue the continuation of PIRATA, by assuring the maintenance of the "PIRATA array backbone" and the associated island instrumentation, with or without the help of other partners that may come in to help.

The Brazilian strategy in term of climate studies consists of supplying data for short and long term seasonal forecasts led by INPE/CPTEC. In order to satisfy these objectives, it is perceived that more ATLAS moorings in the South Atlantic off the Brazilian coast are needed. Moreover, it is serving to inspire the making of other complementary large "process studies" in Brazil, as the BISEC Proposal, and a change of the emerging Brazilian oceanography into the concept of "operational oceanography". That will serves also the objectives of DHN who gives the support with ship-time.

For all these reasons, INPE is developing a special facility at its Natal Regional Center (CRN) with the objective of serving as a base for refurbishment of PIRATA ATLAS moorings, as well as maintenance of meteorological stations and tide gauges. Furthermore, development of ATLAS-like mooring systems in INPE/Natal, could be constructed in parallel with the PIRATA activities in collaboration with PMEL/NOAA. The testing of these moorings should be done by deployment of these ATLAS-like systems near standard PIRATA moorings, for better comparison of the data sets produced. DHN needs also further cooperation (technological transfer) with the USA and France, to learn more about the technical issues associated with mooring operations and ATLAS systems engineering.

Some problems: Due to varied economic and strategic reasons, most of the instrumentation's which would have been normally deployed during the first two phases of the PIRATA program (ADCP at Jazz, tide-gauge at Atol das Rocas, meteorological stations at 44°W-0°N, Atol das Rocas and SPSP) have been delayed until now. DHN has installed a tide gauge in the SPSP rocks, which is not operational at this time. Support for travel and personnel engaged in deployment operations have been limited during the previous PIRATA period. Possible funding problems could come from federal administrative recent changes in both the executive and political levels and from the present instability of the Real.

a3) USA/NOAA/OGP (M. Johnson)

Distinctions between observations for research and observations for operations are fading away in the USA. PIRATA 1999-2000 is a top priority within NOAA. The next steps for the years 2001 and on are towards the establishment of a sustained observational system, along the lines of the Framework Convention on Climate Change (FCCC) for the establishment of a climate observing system (decisions are being made during the week of the PIRATA-6 meeting and next weeks).

The observing system must be international. PIRATA is a good example of three countries united toward a common goal. The non-requirement of ship time from the USA made the participation of NOAA in PIRATA a much simpler matter (however, it is possible that the USA can contribute with ship time to PIRATA missions, in case the program is extended).

B) The institutional support (and program's recommendations)

b1) IOC/GOOS (J. Trotte)

GOOS components: African, Euro, Caribbean, TAO...

GOOS operational activities (e.g. data collection networks...).

Five phases of implementation (e.g. design and planning...) with the following time table:

- 1990-2000 Develop tools; system trials
- 2000-2010 Progress implementation
- 2003-2005 GODAE full scale experiment
- 2010 System fully operational
- 2010+ Progressive refinements

Some application examples: Malaria vs. ENSO on Colombia, maize vs. rain and ENSO on Zimbabwe, grains vs. rain over Nordeste Brazil (for Nordeste, 2-3 months lead-time seasonal climate forecast can impact harvests).

IOC has hosted a Partnership for Observation of the Global Oceans (POGO)...

Integrated Global Observing Strategy (IGOS) links GOOS, GCOS, GTOS programs under one umbrella. The strategy is to make the three global observation systems to work together.

IOC/GOOS encourages that more countries get involved in PIRATA, assists in running PIRATA meetings (especially from 2000), facilitates the development of plans that are in alignment with the GOOS agenda, facilitates commitment to expand PIRATA into its permanent mode.

The XXXI session of IOC executive council approved a resolution on vandalism, on November 1998 (initially proposed during the PIRATA-5 meeting, see The PIRATA-5 Report). Follow up discussions will occur at the UN level during 1999-2000.

Recommendations: PIRATA is considered as a building block to future ocean observation system in the Tropical Atlantic. More government support is yet to be pointed out. IOC/GOOS facilitates interactive process to get more support from other countries.

b2) International CLIVAR (T. Bussalacchi)

The CLIVAR SSG-8 shall convene in Southampton, UK, during May 10-14, 1999. Among other topics, the following topics on the Atlantic will be discussed: Atlantic BECS; EuroCLIVAR (the Nov/98 issue brought an article about PIRATA, "a moored buoy array that needs to be continued"); Implementation status; Identification of gaps; Actions to be taken; VAMOS; Africa climate variability, ...

b3) VAMOS (J. Picaut)

There are two types of monsoon systems on the Americas: The North America Monsoon, encompassing mostly Mexico and the USA, and the South America Monsoon, over Brazil and Guyana's.

The VAMOS panel tries to bring scientists from the North and the South to study: Amazon basin atmosphere-biosphere interactions, low level jet along the east side of the Andes between Brazil and Argentina, stratus clouds along Peru coast, warm pool off Costa Rica, ... VAMOS represents the first time that scientists from South and Central Americas come together to study the American Monsoon system. LBA experiment in the Amazon region is being brought into the VAMOS "concept"... Until now, VAMOS was more met-oriented. There is need to make VAMOS more climate-oriented, by including ocean and surface interactions research.

One thing to be considered is the extension of PIRATA to the south, bringing in the participation of Argentina.

b4) IRI (A. D. Moura)

Assessment: Works on the interannual framework.

Applications: Justification of information comes from climate interfaces to agriculture, water resources, and public health.

Modeling: Will work also with data assimilation, and will start with the tropical oceans. There is a special interest over the tropical Atlantic, to be studied in cooperation with COLA and CPTEC.

Comment: It is important that analyses fields are generated and offered to PIRATA researchers, in order to evaluate the impact of PIRATA data on model simulations and forecasts.

SESSION 3: The transition through an operational PIRATA program (open discussion)

(Notes recollected by I. Wainer and M. Jury, arranged by G. Reverdin and J. Servain)

A) Questions related to the management of the present array

a1) Constructions of the moorings

Construction of moorings in the three partner countries is discussed. That is possible (example of TRITON made in Japan), but is likely to be at a higher cost than what is currently available (due to the size of the array that PMEL/Seattle takes in charge). M. Vianna suggests that some technology exchange could take place by forming personal paid by Brazil at PMEL (*see also the section a2 of Session 2 reported above*). J. Merle suggests that in Europe the issue of a greater commercial value might to some extent reflect the subsidies that in some sense NOAA attributes to the operation. M. McPhaden comments that commercial alternatives to the ATLAS moorings already exist.

a2) Management of the present array

M. McPhaden comments the issue of flexibility of the equipment in a multi-partner project (inventories are spread out and intervals between cruises are short, so that more moorings are required to maintain the array that if it was maintained by one institute). The consensus arising from following discussion (M. Vianna, K. Mooney) is that it would be interesting to increase calibration capacity in the partner countries (i.e. in Natal, Abidjan...) in addition to the elements of refurbishing already taking place there. This requires technology transfer as well as significant up-front investment. D. Moura recalls that ship-time costs currently more than the moorings, and that the future strategy between INPE, DHN, IRD, PMEL... should include all the elements.

a3) Stabilization of the original array

The main message originating from the PIRATA group (in particular T. Busalacchi and M. McPhaden) is that the initial design ("backbone") for the array has worked, and that we should try to show that we can maintain this array in a cooperative project between the three initial participating countries. This will also leave some time for a user community to develop. R. Molinari comments that one should in particular target the operational agencies (NCEP, ECMWF, CPTEC...). The organizational basis is already in place, but we are still demonstrating the feasibility (for example, issue of losses in the Gulf of Guinea... in particular

for the wind measurements). This calls for a transition phase for 5 years between the present pilot phase and a future permanent array.

There appears to be a support for this transition phase by IRD for France, by NOAA/OGP for USA, and by both DHN and INPE for Brazil. K. Mooney comments that NOAA views PIRATA as a success that has proven its feasibility and would like to commit resources.

B) Questions related to possible extensions of the array

In parallel to the evolution of the project through an operational status, it is important to leave the door open to important extensions of the array. D. Enfield, for instance, recalls that the relation between fluxes and SST seems to have a complicated pattern with four different and potentially important regions in the tropical Atlantic (25°N-25°S). These extensions should be managed as pilot projects, which are justified by science objectives on their own, and which will be evaluated differently to decide whether they should be part of the permanent array. Thus, this second part of the session focus on the extensions to which other partners (other than the three original ones) could contribute:

- J. Servain insists on the eastern Atlantic signal, in particular in the Southeast region, near the Angola dome and the Angola front where SST presents its largest standard deviation.

- D. Enfield comments on the Northeast Atlantic anomalies, and their specific role in the heat flux-SST relationship. He suggests that a flux station near the Cabo Verde Islands might be an interesting complement to the PIRATA array.

- M. Vianna comments that the salinity-fresh water fluxes and circulation patterns would suggest moorings off Brazil near 10-15°S. C. Nobre comments on the sensitivity of climate in Southeast South America to short-lived SST anomalies. What causes these anomalies and how they are maintained would justify placing a mooring in this area. K. Mooney comments that this would be complemented by drifting buoy data.

- A. Orbi (Morocco) presents the activities of INRH (Casablanca). Five weather buoys will be placed this year in key areas of the coastal zone, in order to monitor the relation between upwelling circulation, wind and fisheries. Their research vessel (41 m, 3 K\$/day) can be used to deploy one or two ATLAS moorings in the region. Furthermore, an agreement with Mauritania and Senegal is being signed with Morocco which will be a framework for joint oceanic work.

- M. Jury (South Africa) presents the climate justifications for South Africa and the African CLIVAR. Climate variability over the African continent is strongly influenced by the Atlantic SSTs. A recommendation would be to extend the PIRATA array towards the Southeast, in particular along 10°S. Interest on this project is growing among the South African scientific community (possibility of ship-time) [*see after the special add from M. Rouault*].

- B. Bourlès (France) presents the French EQUALANT-99 project and the possibility to continue regularly a monitoring in the Gulf of Guinea. Current plans for EQUALANT-2000 call for surface to bottom hydrography along 10°W and to the African coast along 10°S, as well as deployment of surface float, XBT, XCTDs, ADCP measurements, PCO₂, nutrients,... The following cruises (from 2001, and so on) would be with reduced hydrography 0-1000m, deployment of surface floats, XBT, XCTDs, SST, SSS, ADCP measurements, PCO₂... and are discussed in relation with a possible float investigation of the intermediate and deep circulation off Africa (program EQUEST with floats at 800 m and 2000 m led by IFREMER/LPO, Brest). These cruises could be used to contribute to the logistics of PIRATA in the east during the phase of "consolidation" of the array (2001-2006).

- I. Rojas (Venezuela) discusses the interest for Venezuela to better understand the evolution of SST in the northern tropical Atlantic which have a strong impact on rainfall in northern South America.

- J. Fisher (Germany) presents the IFM-Kiel programs in the tropical Atlantic. The focus is on tropical-subtropical cell and on monitoring the transports in and out of the tropics near the western boundary. An initial deployment of a current-meter mooring array along 7.5°S will take place in March 2000 during a Meteor cruise in the equatorial Atlantic. A cruise is proposed in fall-2000 along the northern coast of South America, during which a mooring array will be installed near 15-16°N. These arrays should last at least four years and are intended for long time monitoring.

- M. McCartney (USA) presents the GAGE experiment in the western Atlantic (15-16°N) in cooperation between IFM-Kiel and WHOI (duration, at least four years). The proposed array (full water column moored profiling CTDs and other dynamic height moorings together with inverted echo-sounders) will monitor the deep water limb of the meridional overturning circulation. It would be very valuable if the easternmost element of the array was coupled with a PIRATA buoy to investigate the air-sea fluxes in this region of potential positive feedback between the ocean and the atmosphere. The program could provide ship-time to install/retrieve it.

- S. Garzoli (USA) presents AOML programs in the tropical Atlantic. 80 surface drifters have been committed to the tropical Atlantic for each year. This should allow to cover the gap in coverage with drifter that currently extends between 20°N and 20°S. AOML will deploy 11 PALACE floats (temperature only) in early 2000, and expects to be part of ARGO for part of the tropical Atlantic. A study of North Brazil Current rings (NBC) is taking place (total duration 2 years) (IES, current meter moorings, hydrographic cruises). The early cruise results suggest different vertical structure in different rings. AOML is also involved in the Inter-American Seas Program (Caribbean), and in particular with the monitoring of the transport across the Antilles.

- This following additional info for South Africa participation in PIRATA was given by M. Rouault (who could not attend PIRATA-6, but who sent us an E-mail just after the meeting): There is increasing support for the extension of the PIRATA array towards Angola, Namibia and South Africa. A good chance to get funding and finding ship time is more and more realistic. Very positive discussion with high level decision makers (WRCP, World Bank) are underway. South Africa-Namibia-Angola are key players in oceanography and are extremely interested.

SESSION 4: Recommendations (*summarized by Group PIRATA*)

- Retain PIRATA identity, i.e. momentum
- Don't jeopardize PIRATA "back bone" but consider building up
- Develop long-term strategy and commitment to continue the transition of PIRATA through an operational issue
- Coordination with GOOS and CLIVAR for logistics
- Provide focus for COSTA mooring consortium
- Written communiqué by PIRATA partners (Resource Board with Terms of Reference)
- Consider enhancements/expansion as pilot/process experiments (needs additional partners) - Develop scientific rationale for expansion
- Base of operations for PIRATA in Natal (Brazil) and related capacity building in neighboring regions

Annex 1

RESOLUTION BY THE PIRATA STEERING GROUP

PIRATA-6 meeting
Miami, Florida, 5 May 1999

Progress in implementation of the Pilot Research Moored Array in the Tropical Pacific (PIRATA) was reviewed at PIRATA-6 in Miami, Florida on 3-4 May 1999. Deployment of the moored buoy array began in late 1997, and by early May 1999 nine sites were occupied and successfully transmitting data in real-time. Implementation is on schedule and nearly complete. The full array of 12 moorings will be in place for one year before the field phase is scheduled to end in early 2001.

The first phase of PIRATA implementation coincided with a warm event which occurred in the whole tropical Atlantic. That dramatic event developed during the end of the largest ENSO event ever registered and was concomitant with one of the five worst droughts in NE Brazil this century. The buoy array captured the development of the upper ocean thermal anomalies, and the seasonal evolution of oceanic and atmospheric variability on which they were superimposed. Real-time PIRATA data available on the GTS were used in operational oceanic and atmospheric analyses and forecasts during this period. Preliminary diagnosis of the data also supports hypotheses concerning ocean-atmosphere coupling in the region.

PIRATA was originally conceived as a pilot study with a 3-year field phase in support of CLIVAR, GCOS, and GOOS objectives. It is becoming clear that a complete array for one year will provide insufficient time to evaluate whether PIRATA should be part of a permanent climate observing system. On the other hand, it is also clear that PIRATA data are already providing valuable new information for climate studies of relevance to the Americas and Africa.

Therefore, based on the initial successes of the program, the PIRATA Steering Group recommends a transitional phase towards the development of a sustained climate observing system for an additional five years, to 2006. This extension will allow for a full demonstration of the utility of PIRATA data, and a smoother transition to operational status, if warranted.

In addition, recognising that this extension will require a sustained level of support in terms of funding, ship-time, and equipment, the PIRATA Steering Group recommends that a PIRATA Resource Board, with terms of reference, be established to ensure that adequate resources will be available for the duration of the program. This Resource Board would initially consist of representatives from the institutions in Brazil, France and the United States that presently provide support for the array.

Finally, in recognition of the widespread interest in developing a sustained observing system in the tropical Atlantic for climate studies, as evident from the international participation at the Climate Observing System for the Tropical Atlantic (COSTA) workshop that followed the PIRATA-6 in Miami, the PIRATA Steering Group resolves to coordinate with ongoing and planned observational efforts in the region. Furthermore, building upon recommendations put forward at the COSTA workshop, the Steering Group encourages consideration of scientifically sound pilot expansion projects that build upon the original PIRATA array. Moreover, the Steering Group invites collaborations with other nations and institutions interested in implementing a sustained climate observing system in the tropical Atlantic.

Annex 2

AGENDA FOR PIRATA COMING UP ACTIVITIES

(mid 1999-mid 2001)

- June 1999: Visit of the PIRATA chairman to INPE and DHN directors. Proposal for members of the PIRATA Resource Board: Directors of INPE and DHN for Brazil, J. Merle for France/IRD, M. Johnson for USA/OGP/NOAA
- June-December 1999: elaboration of Terms of Reference by the PIRATA Resource Board for the 5-year (2001-2006) consolidation of PIRATA "back bone". One possibility discussed at PIRATA-6 by the Steering Group would be that USA/NOAA/PMEL furnish additional ATLAS systems and be responsible for refurbishing the pool of moorings (+ associated shipping/engineering services) for the full PIRATA array, while Brazil (INPE-DHN) and France (mainly IRD) service with their R/Vs the western (6 sites) and eastern (6 sites) parts of the original array, respectively. These Terms of Reference should clearly relate the capacity building developed by the partners, especially in the domain of the base(s) of operations and capability of maintenance for part of the ATLAS material
- July 1-22, 1999: PIRATA-FR4 cruise in two legs (deployment of Rhythm, Blues and Soul, July 1-13; + deployment of complex current measurements in the vicinity of Java, July 15-22)
- Meeting at St Raphael, France, 18-22 October 1999: The Ocean Observing System for Climate meeting. Informal (short) PIRATA meeting in parallel of the OOSC meeting
- October 18-31, 1999: PIRATA-FR5 cruise (recovery and new deployment of Gavotte)
- End of November 1999: Possibility of a first PIRATA-Extension meeting at Cape Town (South Africa) in coordination with M. Rouault (Univ. Cape Town) with the participation of scientific/managers from South Africa, Namibia, Angola and representatives of PIRATA-SC. Writing a scientific rationale and (if possible) an international agreement for the PIRATA extension array (1 to 2 sites) through the Southeast (i.e. Dome/Front of Angola)
- December 1999: Proposed date line for the "Terms of References" prepared by the PIRATA Resource Board
- February 2000: PIRATA-FR6 cruise
- February-March 2000: PIRATA-BR3 cruise
- April/May 2000: Possibility of a second PIRATA-Extension meeting at Casablanca (Morocco) in coordination with A. Orbi (INRH, Casablanca) with the participation of scientific/managers from Morocco, Mauritania, Sénégal and representatives of PIRATA-SC. Writing a scientific rationale and (if possible) an international agreement for the PIRATA extension array (1 to 2 sites) through the Northeast (i.e. Mauritania/Sénégal upwelling region)

- May/June 2000: Extended PIRATA-7 SC meeting, somewhere in Brazil (Porto Seguro? Natal? Fortaleza? São Paulo? São José dos Campos? Other?)
- July/August 2000: PIRATA-FR7 cruise
- October 2000: PIRATA-FR8 cruise
- January/February 2001: PIRATA-FR9 cruise
- March/April 2001: PIRATA-BR4 cruise
- April/May 2001: Second COSTA meeting at Marrakech (Morocco)
- June/September 2001: 2-3 week PIRATA workshop somewhere in Brazil, France or USA (*what did PIRATA 1997-2000 bring us in the improvement of our knowledge of the climatic variability in the Tropical Atlantic?*)

Annex 3

LIST OF PARTICIPANTS

OF CLIMATE OBSERVING SYSTEM FOR THE TROPICAL ATLANTIC (COSTA)

May 4-7, 1999;

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