

## MEMORANDUM OF UNDERSTANDING (MOU)

between

Instituto Nacional de Pesquisas Espaciais  
and  
Institut de Recherche pour le Développement and Météo-France  
and  
National Oceanic and Atmospheric Administration

for

### **Implementation and Maintenance of the Prediction and Research moored Array in the Tropical Atlantic – PIRATA**

A Partnership in Climate Research and Ocean Observation

The Instituto Nacional de Pesquisas Espaciais (INPE) of Brazil, the Institut de Recherche pour le Développement (IRD) and Météo-France of France, and the National Oceanic and Atmospheric Administration (NOAA) of the United States of America, hereinafter referred to as the “Parties”, are interested in increasing the effectiveness of their activities in climate research and ocean observation through sustaining the Prediction and Research moored Array in the Tropical Atlantic (PIRATA);

The parties recognize that collaboration in sustaining PIRATA can be to their mutual benefit, the mutual benefit of their countries, and the benefit of many countries in Africa, the Americas, and Europe;

The parties believe that efforts such as sharing of tasks, cooperation on facilities utilization, exchange of scientific and technical information, and sharing of costs and human resources can result in the effective and efficient accomplishment of mutually beneficial objectives;

Therefore, the Parties have reached the following understanding:

#### SECTION 1 SCIENTIFIC OBJECTIVES OF THE PIRATA PROGRAM

The purpose of the PIRATA program is to study the ocean-atmosphere interactions in the tropical Atlantic that are relevant to regional climate variability on intra-seasonal, seasonal, interannual, and longer time scales.

Specifically, the scientific goals of PIRATA are:



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- To improve our understanding of the relative contributions of the different components of the surface heat flux, momentum flux, fresh water flux, ocean dynamics, and the surface and upper ocean thermal and haline structures to intra-seasonal, seasonal and longer time scale variability in the tropical Atlantic;
- To provide a data set that can be used to develop and improve predictive models of the coupled Atlantic climate system, and for numerical ocean and weather prediction.

A full description of the Scientific Objectives is contained in the PIRATA Science and Implementation Plan, Annex 1.

## SECTION 2 TECHNICAL OBJECTIVES OF PIRATA

To reach the scientific objectives of the PIRATA Program, the Parties will deploy and maintain an array of moored buoys in the tropical Atlantic. The ocean observations along with meteorological observations from the array will be transmitted to shore via satellite and will be available in near real-time on the Internet and via the World Meteorological Organization (WMO) Information System. These data can be assimilated in Ocean-Atmosphere Coupled General Circulation Models in order to implement weather, ocean, and climate forecasts and other applications with direct benefit to the Parties and other agencies in Brazil, France, the United States, and in other countries.

A full description of the Technical Objectives is contained in the PIRATA Science and Implementation Plan, Annex 1.

## SECTION 3 THE PILOT PHASE OF PIRATA

PIRATA was initially designed by a group of scientists involved in CLIVAR (Climatic Variability and Predictability) Program research, and implemented beginning in 1997 through this multi-national scientific collaboration. The project was built on the scientific success of the TOGA (Tropical Ocean and Global Atmosphere) Program and made use of the mooring technology established in the tropical Pacific where moored buoys make up the bulk of the TAO/TRITON array now being operated multi-nationally as a contribution to CLIVAR, the Global Climate Observing System (GCOS), and the Global Ocean Observing System (GOOS), all being now elements of the Global Earth Observation System of Systems (GEOSS).

PIRATA was originally conceived as a pilot study with a 3-year field phase (1997-2000) in support of CLIVAR, GCOS, and GOOS objectives. Technical, logistic and organizational issues associated with maintenance of the array were addressed within a research framework by the Brazil-France-United States scientific collaboration.



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SECTION 4  
THE CONSOLIDATION PHASE OF PIRATA

Following the successful completion of the PIRATA array and evaluation of the scientific results during the pilot phase, representatives of the Parties, in consultation with international CLIVAR, GCOS, and GOOS, resolved to maintain the array through a consolidation phase from 2001 through 2005. The consolidation phase is now completed and the accomplishments of the program have been acknowledged by the Global Ocean Data Assimilation Experiment (GODAE) and in the review document prepared for the CLIVAR Atlantic Panel and the Ocean Observations Panel for Climate (OOPC), highlighting the scientific achievements of the project and its operational potential as a component of GOOS within the GEOSS framework.

SECTION 5  
THE SUSTAINED PHASE OF PIRATA

The Parties now wish to establish this new MOU to extend and strengthen the collaboration beyond the consolidation phase and provide a stable framework under which PIRATA can continue into the future, within the perspective of operation of a long term sustainable system contributing to GCOS, GOOS, and GEOSS. This MOU documents the partnership between the Parties and their intentions to contribute the resources necessary to sustain such a multi-national effort including provision of ship time, scientific instruments, mooring systems, fabrication and maintenance, instrument calibration, logistics, delivery of data, training and technology transfer.

SECTION 6  
ORGANIZATION AND MANAGEMENT OF PIRATA

PIRATA Resources Board:

A PIRATA Resources Board (PRB) is established with Terms of Reference (TOR) (see Annex 2). The initial members of the PRB are managers representing INPE, IRD, Meteo-France, and NOAA. Although the PRB is presently comprised of representatives from institutions only in Brazil, France, and the United States, the PRB will welcome other institutions and other nations if they wish to contribute to the PIRATA Program. The Chairman of the PRB is designated by the PRB members.

The principal tasks of the PRB are:

- To review the requirements for the implementation of PIRATA;
- To coordinate resources that may be applied to the Program;
- To encourage scientific and technological initiatives in the participating countries to meet the objectives of PIRATA;
- To report on its activities to the Heads of the institutions providing resources.



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The PRB is guided by the scientific objectives and research strategy formulated by the PIRATA Scientific Steering Group (PIRATA-SSG), which is regarded as the main scientific and operational body to advise the PRB.

#### PIRATA Scientific Steering Group:

A PIRATA Scientific Steering Group (PIRATA-SSG) is formed by researchers, managers, and representatives of operational agencies of the Parties or other institutions who are recognized as scientific and operational experts in the area of the tropical Atlantic climate. Members are nominated by the PIRATA-SSG in consultation with appropriate international sponsoring bodies participating in GOOS, GCOS, and CLIVAR, and are approved by the PRB. The Chairman of the PIRATA-SSG is designated by the SSG members.

The principal tasks of the PIRATA-SSG are:

- To ensure accomplishment of the scientific and technical objectives as described in the PIRATA Scientific and Implementation Plan, and as accepted by the Parties;
- To coordinate the technical and logistic support necessary to maintain the array;
- To ensure the rapid dissemination of PIRATA data (in real-time where possible) to serve both research and operational applications;
- To promote the utilization of PIRATA data in national and international climate research and operational prediction programs;
- To evaluate, encourage, and promote pilot extension projects that could build upon jointly with the original PIRATA array;
- To coordinate with other ongoing and planned observational efforts in the tropical Atlantic region;
- To invite collaborations with other nations and institutions interested in implementing a sustained climate observing system in the tropical Atlantic;
- To cooperate with international organizations such as the CLIVAR Atlantic Panel, the GOOS/GCOS/WCRP Ocean Observations Panel for Climate (OOPC), and the Joint WMO/IOC Technical Commission for Oceanography and Marine Meteorology (JCOMM) to ensure an integrated approach to observing the climate system in the tropics;
- To report regularly on the status of the PIRATA array and scientific results to the PRB, GCOS, GOOS, JCOMM and CLIVAR.

#### PIRATA National Coordinators:

INPE serves as the coordinator of PIRATA in Brazil. The support of the Diretoria de Hidrografia e Navegação (DHN) is critical to the success of PIRATA. The support of DHN is arranged through INPE. A national coordinator is indicated by INPE to be the representative of PIRATA-Brazil. The national coordinator is a member of the PIRATA-SSG.

IRD serves as the coordinator of PIRATA in France, in association with Météo-France. A national coordinator is indicated by IRD to be the representative of PIRATA-France. The national coordinator is a member of the PIRATA-SSG.



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NOAA serves as the coordinator of PIRATA in United States. A national coordinator is indicated by NOAA to be the representative of PIRATA-United States. The national coordinator is a member of the PIRATA-SSG.

The coordination between the Parties is ensured jointly through the PRB and the PIRATA-SSG, especially through the Chairmen of these two committees and the national coordinators.

## SECTION 7 NATIONAL COMMITMENTS OF THE PARTIES IN PIRATA

In planning for future resources in support of the PIRATA Program, it is recognized that the Parties are dependent upon year-to-year funding allocations from their governments, and thus commitments for future funding and logistical support can not be guaranteed. Given this proviso, the Parties affirm that PIRATA is a high priority for Brazil, France, and the United States, and that the institutions are making plans for continued support as follows:

INPE (in cooperation with DHN), IRD, Météo-France, and NOAA will maintain the PIRATA array as it is presently configured (Annex 3) or as the array may be modified by agreement of the PIRATA-SSG and the PRB in order to meet scientific or operational requirements. In particular:

- NOAA will refurbish moorings until facilities in Brazil and/or France/African countries are prepared to take over refurbishment tasks.
- NOAA will supply up to two replacement mooring systems each year if required because of damage or loss (these replacements will be utilized in the backbone array and PIRATA Extensions as specified below).
- NOAA will provide ship time for maintenance of four moorings in the North East Extension.
- NOAA will provide existing plans and specifications to INPE and IRD for mooring systems and instrumentation in order for Brazil and France to develop refurbishment and construction capabilities in-country. It is noted that the mooring systems are constantly being improved as technology advances. INPE and IRD are invited to send regularly PIRATA technicians to the United States in order to observe and learn new techniques, procedures, and developmental work, and to obtain a copy of the latest available documentation. Travel costs related to these visits are the responsibility of INPE and IRD.
- NOAA will provide primary data delivery and processing of the mooring system instrument measurements.
- NOAA will pay Argos data processing costs for the mooring system measurements. NOAA will provide a PIRATA web site.
  
- INPE will assume responsibility for the logistics required to transport PIRATA equipment between United States and Brazilian depots.
- INPE will take the necessary actions so that adequate ship time is available to maintain the PIRATA array on the Brazilian side (INPE works with DHN to provide the ship time). The Brazilian side includes the five backbone moorings in the western tropical Atlantic, from 15°N to the equator along 35°-38°W, and three moorings in the South West Extension.



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- Shipboard ADCP and CTD data collected during PIRATA operations on the Brazilian side will be archived and disseminated by INPE.
- INPE will provide for the deployment, maintenance, and the real-time delivery of the data (including the Argos costs) of one tide-gauge located at Fernando de Noronha archipelago, and of a meteorological station located at St. Peter & St. Paul archipelago.
- A mirror PIRATA web site will be maintained by INPE with additional national contributions and information.
- IRD and Météo-France will assume responsibility for shipping costs and the logistics required to transport PIRATA equipment between Seattle and French/African country depots.
- IRD will ensure that adequate ship time is available to maintain the PIRATA array on the African side. The African side includes the five backbone moorings in the eastern tropical Atlantic, in the region 0° to 10°S, and 0° to 23°W, the ADCP mooring close to 0°, 23°W, and possible new sites in the South East Extension.
- Shipboard ADCP and CTD data collected during PIRATA operations on the African side will be archived and disseminated by IRD.
- IRD will provide for the deployment, maintenance, and the real-time delivery of the data (including the Argos costs) of one tide-gauge station and one meteorological station located at São Tomé Island.
- A mirror PIRATA web site will be maintained by IRD with additional national contributions and information.

The two NOAA-supplied replacement mooring systems will be utilized in the following priority order:

1. The backbone array.
2. The South West Extension.
3. The North East Extension.
4. Other Extensions.

Replacements will be coordinated by the PIRATA National Coordinators. If more than two replacement systems are required in any year, then any of the Parties shall have the option of providing additional funding to NOAA for fabrication of additional systems, or of providing replacement systems in-kind as approved by the PIRATA-SSG. Future other extensions will be agreed by the PRB.

It is recognized that successful climate observation requires continuity in measurement programs for many years. The Parties are committed to sustaining the ocean observing system in the Atlantic Ocean over the long term and will work together and with other institutions to plan for the future. The Parties will consider options for making PIRATA operations more efficient and effective, such as further consolidation of facilities, services, and ship support as experience and capabilities advance. Possibilities might include unification of the PIRATA operational depots and a dedicated ship to service the entire tropical Atlantic domain, besides the participation of other countries/institutions that could provide ship time necessary for a complete functioning of the enhanced PIRATA array.

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## ANNEX 3

### PIRATA Array Configuration November, 2008

1. Backbone mooring systems:
  - a) Along 38° W:
    - 4° N
    - 8° N
    - 11.5° N
    - 15° N
  - b) Along the equator:
    - 0° E
    - 10° W
    - 23° W
    - 35° W
  - c) Along 10° W:
    - 6° S
    - 10° S
2. ADCP mooring close to 0°, 23°W
3. Island Tide Gauge Stations:
  - St. Peter & St. Paul Archipelago
  - São Tomé Island
4. Meteorological Stations:
  - Fernando de Noronha Island
  - St. Peter & St. Paul Archipelago
  - São Tomé Island
5. South West Extension mooring systems:
  - 8° S, 30° W
  - 14° S, 32° W
  - 19° S, 34° W
6. North East Extension mooring systems:
  - 4° N, 23° W
  - 11°30' N, 23° W
  - 20°30' N, 23° W
  - 20° N, 38° W
7. South East Extension mooring system (experimental):
  - 06° S, 08° E

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SECTION 8  
THE RELATIONSHIP BETWEEN THE PARTIES AND  
FUTURE PIRATA EXTENSION PROJECTS

The commitments of the Parties described in this MOU do not apply to PIRATA extension projects that may be implemented by countries other than Brazil, France and the United States. However, the Parties are supportive of scientifically sound extension projects and look forward to working with other institutions and countries as they seek to develop their plans. Amendment Terms to this MOU can be signed between the parties, or with new partners, to coordinate the activities related to the implementation and operation of Extension Projects which have been approved and recommended by the PIRATA-SSG to the PRB.

SECTION 9  
COOPERATION WITH INTERNATIONAL IMPLEMENTATION PANELS

The Parties are committed to working cooperatively with the international implementation panels that are working to implement GCOS and GOOS, in particular the panels coordinated under the Observations Programme Area of the Joint WMO/IOC Technical Commission for Oceanography and Marine Meteorology (JCOMM), including the Data Buoy Cooperation Panel, the Ship Observations Team, the Global Sea Level Observing System Group of Experts, the Argo Steering Team, the OceanSITES program, and the International Ocean Carbon Coordination Project.

SECTION 10  
EXCHANGE OF INFORMATION

The activities specified under this MOU involve the collection and exchange of environmental data which are not intended to be protected. The Parties support the widest possible dissemination of the information resulting from the PIRATA Program. Each participant should have the right to use, disclose, publish, or disseminate such information for any and all purposes. Information transmitted between Parties or developed jointly under this MOU will be accurate to the best knowledge of the Parties. The Parties do not assure the suitability of the information transmitted for any particular use or application by the receiving Party or by any third party.

SECTION 11  
GENERAL PROVISIONS

This MOU is between institutions – the Parties – and is not intended to, and does not, obligate the governments of the countries of Brazil, France, or the United States. This MOU is not intended to, and does not, create any binding obligations under international law. Nothing in this MOU is intended to affect other cooperation or collaboration between the Parties. All activities under this MOU will be in accordance with the applicable laws of the respective countries, including technology export regulations.

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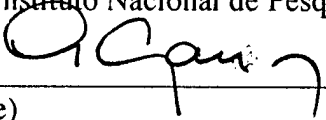


All questions related to the MOU arising during its term will be settled by the Parties by mutual agreement.

This MOU will enter into effect upon the signature by all Parties and remain in effect for five years, renewable for another term if agreed by the parties. The MOU may be amended or extended by mutual written agreement and may be terminated at any time by any of the Parties upon six months written notice to the other Parties.

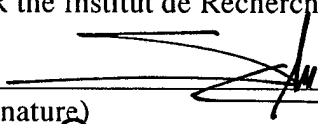
This MOU may be referenced as the "PIRATA MOU."

FOR the Instituto Nacional de Pesquisas Espaciais

  
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DR. GILBERTO CÂMARA  
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(Printed Name)

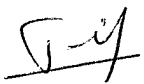
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(Title) **Gilberto Câmara**  
Diretor

FOR the Institut de Recherche pour le Développement

  
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Dr. Pierre SOLER  
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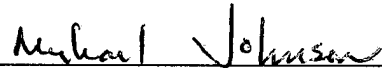
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(Title) **Pierre SOLER**  
Director, Department Earth  
& Environmental Sciences

FOR Météo-France

  
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Dr Joël PSITEVIN  
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(Title) on behalf of the Deputy Director  
general -  
the Deputy Director of the  
research Branch

FOR the National Oceanic and Atmospheric Administration

  
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(Signature)  
MICHAEL JOHNSON  
\_\_\_\_\_  
(Printed Name)

2 FEBRUARY 2009  
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(Date)  
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(Title) **CHIEF, CLIMATE OBSERVATION DIVISION**



## ANNEX 1

### **PIRATA, Pilot Research Moored Array in the Tropical Atlantic Science and Implementation Plan**

November 2006

#### **Introduction to PIRATA**

PIRATA (Pilot Research Moored Array in the Tropical Atlantic), is a multinational program (tripartite between Brazil, France and United States of America) established to monitor the ocean-atmosphere system in the Tropical Atlantic in order to improve our knowledge and understanding of the Ocean-Atmosphere variability in this particular world region. Actually, the variability of the ocean-atmosphere system in the Tropical Atlantic, from the seasonal to the multi-decade scale, strongly influences the regional hydro-climates (*ie* variations in rainfall) and, consequently, the economies of the adjacent continental regions (principally West Africa and North-East Brazil). PIRATA is motivated by fundamental scientific issues but also by the societal needs for improved prediction of the Tropical Atlantic climatic system (mostly the Intertropical Convergence Zone -ITCZ- displacement) and its impacts on surrounding countries. It has been observed that the long term variability of the Tropical Atlantic can be described principally into two modes: an equatorial mode associated principally with sea surface temperature (SST) anomalies in the eastern equatorial Atlantic (this mode is in some aspects analogous to the El Niño - Southern Oscillation mode over the equatorial Pacific), and a meridional mode, associated essentially with SST anomalies on either side of the ITCZ. Also, the north of the Tropical Atlantic is the main development region for hurricanes affecting the West Indies and the United States of America.

Thus, the more specific goals of the PIRATA program are:

- To improve the description of the seasonal to inter-annual variability in the surface layer (from the surface to a depth of 500 m) in the Tropical Atlantic;
- To improve our understanding of the relative contributions of surface fluxes and oceanic dynamics in the variability of the SST and the sub-surface heat content at seasonal and interannual scale;
- To provide a set of data that could be used to develop and improve the predictive models of the ocean-atmosphere coupled system.

In this way, PIRATA main objectives are to largely contribute or answer to the principal scientific questions in need of answers pertaining to tropical Atlantic Variability, that are:

- What are the forcing and coupling mechanisms between the atmospheric and oceanic components on the Tropical Atlantic? In particular, what are the SST's control mechanisms and what are those of heat fluxes?
- What are the influences of these heat fluxes (and of quantities of movement: the wind) on the variability (position and intensity) of the ITCZ and on the convective systems of the Gulf of Guinea (which is of interest to the West African monsoon),

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and on those of the western region of the basin (which is of interest to rainfall over South America and to hurricanes over West Indies)?

- What is the relationship between the variability of the SST and that of the heat content of the Tropical Atlantic, and what is its influence on the various variability modes in this region? In particular, what is the dynamic link between the north and south poles of the meridian variability mode of the Atlantic and between it and the equatorial mode?
- What are the teleconnections and their mechanisms between the variability in the Tropical Atlantic region and that in other regions (El Niño Southern Oscillation - ENSO-, North Atlantic Oscillation -NAO-, South Atlantic variability etc.)?

In addition to these scientific objectives, PIRATA also has important technical goals: to design, deploy, and maintain a pilot array of moored oceanic buoys and to collect and transmit via satellite in real time a set of oceanic and atmospheric data to monitor and study the upper ocean and atmosphere of the tropical Atlantic. PIRATA is principally endorsed by CLIVAR (CLImatic VARIability and predictability), and OOPC (Ocean Observations Panel for Climate) international programmes.

### The PIRATA Programme

#### 1) PIRATA implementation:

The PIRATA experimental program has developed from 1997 an array of meteo-oceanic (ATLAS type) buoys in the Atlantic, similar to the Tropical Atmosphere–Ocean (TAO) array used to study ENSO variability in the equatorial Pacific. PIRATA commits to provide high resolution time series measurements of surface heat and moisture fluxes, sea surface temperature and salinity, and subsurface temperature and salinity in the upper 500m. PIRATA so contributes to considerably increase the oceanic *in situ* data base in the Atlantic, that was mostly limited before PIRATA to, along with some synoptic oceanographic cruises, measurements from volunteer observing ship (VOS) programs, coastal and island tide gauge stations, a small number of drifting buoys and a few disparate time series of some parameters (e.g. wind, currents...) acquired during particular programs (e.g. FOCAL-SEQUAL in 1982-84).

PIRATA also includes two automatic meteorological stations at Fernando de Noronha Island and St. Peter & St. Paul Rocks, along with one current meter (ADCP) mooring at 23°W-0°N and a tide gauge at São Tome Island.

Furthermore, while each ATLAS buoy has to be changed at least once a year, a large number of measurements (temperature and salinity profiles, upper layer currents, sea surface temperature and salinity...) are carried out during all the PIRATA cruises, imposed for the ATLAS moorings monitoring. At now, a total of 23 cruises have been dedicated to PIRATA, done by Brazil (responsible for the maintenance of the 5 buoys located in the west of the basin, 8 from August 2005 due to the Southwest extension) and France (responsible for the maintenance of the 5 buoys located in the east and of the current meter mooring at 23°W-0°N).

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Thus, the PIRATA program provides to the scientific community a free access to many data, summarized as follows:

1) Real time data:

- **Meteo-oceanic measurements using ATLAS buoys:** The ATLAS buoys are designed to measure surface meteorological variables (wind direction and speed, air temperature and humidity, rainfall and solar radiation) and hydrological sensors between the surface and 500m, namely 2 pressure sensors (at 300m and 500m), 11 temperature sensors (at the surface, 20m, 40m, 60m, 80m, 100m, 120m, 140m, 180m, 300m and 500m) and 4 conductivity sensors (at the surface, 20m, 40m and 120m). The mean daily observations are transmitted by satellite via Argos and are available in near real-time via Internet.
- **Meteorological measurements from meteorological stations:** data from the two automatic meteorological stations located at Fernando de Noronha Island and St. Peter & St. Paul Rocks, are transmitted by Brazil's SCD satellites at 3-hourly interval, and data available in near real time via internet.
- **Sea level measurements:** At São Tomé (6°30'E-0°N), a tide gauge station transmits daily via Argos hourly measurements of sea level, sea surface salinity and temperature along with atmospheric pressure.

2) Delayed data:

- **Current-meter measurements from moorings:** Since late 2001, a mooring located at 23°W-0°N ATLAS is equipped with an ADCP (Acoustic Doppler Current Profiler) which continuously measures the two horizontal components of the current, from the surface to approximately 130m. The *in situ* measurements are available at a rate of one measurement every 4m from a depth of 16m.
- **Oceanographic measurements obtained from ships:** During each oceanographic campaign dedicated to PIRATA, meteo-oceanic measurements are carried out, which are principally : Current measurements (from 0 to 700m max.) using VM-ADCP acoustic Doppler current profilers; Surface temperature and salinity measurements using a thermosalinograph; Meteorological and navigational measurements using data acquisition units; Hydrological measurements with CTD profiles (continuous pressure, temperature and salinity measurements between the surface and 500m or 1000m); Temperature measurements between the surface and approximately 800m with XBT probes.

**2) Scientific contribution:**

According to the main initial scientific goals of PIRATA, the number of studies (and papers) done in the framework of, or using data obtained thanks to, PIRATA indicates to what extent it

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is clear that PIRATA largely contributes and answers to the comprehension of the climate system in the Tropical Atlantic.

Thus, PIRATA contributes to:

- a) Provide an improved description of the seasonal-to-interannual variability in the upper ocean and at the air-sea interface:
  - According to the state of the art knowledge accumulated during the last decades PIRATA was then established with the early purpose to provide a description of the two main (meridional and equatorial) modes of climate variability in the tropical Atlantic. Thus, PIRATA first allows increasing our description and interpretation on the meridional and equatorial modes of variability.
  - PIRATA is providing data to validate and to initialize models of air-sea interaction in the Tropical Atlantic. The PIRATA buoy data are extensively used by both academic and operational communities to validate satellite based surface flux estimates.
  - PIRATA data, along with data from PIRATA dedicated yearly cruises (ADCP currents along the same meridional sections, namely 35/38°W and 10°W), allow studies focusing on equatorial currents and equatorial processes.
- b) Estimate the relative contributions of the different components of the surface heat flux and ocean dynamics to the seasonal and interannual variations of SST;
- c) The development and improvement of predictive models of the coupled Atlantic climate system:
  - Ocean state estimation: Over the time period that PIRATA buoys have been deployed, ocean state estimation has progressed from a research activity to the operational generation of ocean products initiated under the framework of GODAE. For many years, PIRATA has been a major source of tropical Atlantic observations to research assimilation schemes for the global ocean. The French MERCATOR operational oceanography project is routinely using PIRATA data processed in real time. Such product generation of operational oceanography for the tropical Atlantic is now possible because the oceanic data from the Atlas buoys are made available in near real-time.
  - Forecasting:
    - Weather: the surface meteorological fields from the PIRATA Atlas buoys are assimilated in near real-time into predictive atmospheric models. PIRATA data have significant potential for improving the initial analysis of weather forecasting in the region.
    - Seasonal Climate Forecasts: PIRATA data are used in operational seasonal forecasts via data assimilated into oceanic models that provide ocean initial conditions using coupled ocean-atmosphere models.

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d) Unanticipated advances: PIRATA contributes to advances in areas not fully anticipated at the start of the program. For example, utility and accuracy of rain and salinity sensors from PIRATA Atlas buoys are now well established, and it is now proven that such data are of fundamental importance for the mixed layer heat budget and air-sea exchanges. In the same way, it was not appreciated how strongly the pull from the operational community would be for PIRATA data. The many activities that demand these data for development of ocean assimilation systems and for constraining ocean model analysis in the tropical Atlantic attest to the value that the operational community has assigned to PIRATA data. The ready availability of the data via the GTS and the web in real-time have helped to create this demand, which continues to grow as operational oceanography itself develops and matures.

Furthermore, mostly thanks to the dedicated cruises, PIRATA also contributes to training to implicate scientists from developing African countries in oceanographic and climate research.

Finally, PIRATA is also a contribution for the realization of other programs, for which PIRATA dedicated cruises and Atlas buoys are opportunities for buoys, drifters, XBT probes or profilers deployments (*e.g.* for CLIVAR, ARGO and CORIOLIS), or sea water samplings (*e.g.* for IGBP/SOLAS programs), or biogeochemical measurements. PIRATA also contributes, through the data transmission in real-time from vessels during dedicated cruises, to GODAE and MERCATOR projects.

### 3) Extensions and prospective:

PIRATA encourages consideration of scientifically sound pilot expansion projects that build upon the original PIRATA array. Extensions are supposed to contribute to fill out the PIRATA array in order to provide better definition of the two key climate modes of variability in the Tropical Atlantic Ocean. After a scientific evaluation, extensions of the array have been initiated, with more planned and funded, greatly magnifying the scope of scientific issues and operational value addressed by PIRATA.

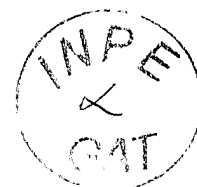
The PIRATA Southwest Extension (3 buoys off Brazil), supported by Brazil, was inaugurated in August 2005. This extension will notably allow monitoring the South Equatorial Current bifurcation into the Brazilian Current and the Northern Brazilian Current, and the interactions between the South West tropical Atlantic SSTs and the South Atlantic Convergence Zone.

The PIRATA Southeast Extension (1 buoy off Congo and Angola), supported by South Africa, has been implemented for an one year test period from boreal summer 2006 to boreal summer 2007. Observations in this region will be used to monitor the Benguela Niños, and the potential linkage between the equatorial mode and the Benguela Niños.

The PIRATA Northeast extension (4 buoys along 20°N and 23°W), supported by USA has been fully implemented in boreal summer 2006 and spring 2007. Observations in this region will allow capturing processes impacting interannual variations in the seasonal migration of the eastern ITCZ.

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Also, NOAA has funded enhancement of three sites (15°N-38°W; 0°N-23°W and 10S°-10°W) for full surface flux capability, as part of the OceanSITES program.

Ultimately, the PIRATA array will transition to an operational, international, sustained observing system for weather and climate prediction spanning the widely varying dynamical regimes of the tropical and low-latitude subtropical Atlantic Ocean and providing invaluable opportunities for deployment of Argo floats, surface drifting buoys, and platforms for conducting process studies and future research efforts.

#### **4) Program Management and Support:**

An International Scientific Steering Group (SSG) heads the PIRATA Program. Presently, three scientists of the three countries involved in, *i.e.* Brazil, France and USA compose this PIRATA-SSG.

A PIRATA Resources Board (PRB) was set up in 1999 in order to meet the objectives of the undertakings of each of the principal institutes that are partners in the PIRATA program, and to ensure that the program would be fully supported by the three countries.

#### **Final comments:**

After a "Pilot phase" from 1997 to 2001, during which the array has been fully implemented, institutions in the three supporting countries decided to extend the program for a 5-year "Consolidation phase" (2001-2005) to allow for a meaningful demonstration that the data would contribute significantly to both scientific research and operational applications.

In 2006, PIRATA was at a key point of its evolution, and conditions of its continuation had to be defined by different parties, after the endorsement of international CLIVAR and OOPC programs. The PIRATA continuation till 2008 has been decided by the supporting Brazilian, French and US organisms, in the same conditions as until now.

Actually, there is a sound scientific basis for the PIRATA continuation as a permanent component of GOOS and GCOS. Anyway, the fixed time series measurements from the PIRATA moorings together with observations from the regular deployment and service cruises has since become the backbone of the tropical Atlantic observing system. The addition of ARGO floats has served to complement the unique, high temporal sampling and limited spatial extent of the original set of PIRATA buoys. The federation of complementary observational platforms provided thanks to PIRATA has become, *de facto*, the Tropical Atlantic Ocean Observing System. From its beginning, PIRATA has also cooperated and communicated on a frequent basis with the CLIVAR Atlantic Panel, OOPC, GOOS, GCOS, GLOSS, GEOSS, JCOMM, and CORIOLIS. Actually, through the concerted efforts of those participating nations and institutions, PIRATA has become a worldwide recognized GOOS and GCOS pilot-project in the region. By way of membership in the PIRATA-SSG, organizations such as INPE, IRD, NOAA, CPTEC, FUNCEME, Météo-France, CNRS, and MERCATOR/GODAE have all been regularly

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informed and have had input to the direction of PIRATA. In addition, the PIRATA-SSG has been actively involved in the development of new programs as, *e.g.*, TACE and AMMA. With the onset of AMMA in 2001, more than 25 institutions in Africa, Europe, and the United States developed a plan to improve prediction of the West African Monsoon and Atlantic hurricanes. AMMA has been endorsed by CLIVAR and the Global Energy and Water Cycle Experiment (GEWEX). AMMA and TACE require long-term observations in the Atlantic Ocean through at least 2010, and PIRATA is obviously for these programs a key observation system and a closely associated program.

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## ANNEX 2

### PIRATA Resources Board Terms of Reference 24 March 2008 (as amended)

#### 1. Establishment

The PIRATA Resources Board (PRB) has been established by the Resolution adopted by the institutions from Brazil, France, and the United States of America that are currently committing resources to the PIRATA Program.

#### 2. Composition

The membership of the PRB is comprised of representatives of institutions allocating resources to accomplish the overall goals of the PIRATA Program. The initial composition of the PRB shall include representatives of the following institutions:

Brazil: INPE -- Instituto Nacional de Pesquisas Espaciais;  
DHN -- Diretoria de Hidrografia e Navegação;

France: IRD - Institute de Recherche pour le Developpement;  
Meteo-France;

United States: NOAA/CPO - National Oceanic and Atmospheric Administration /  
Climate Program Office;

And the Chair of the PIRATA Scientific Steering Group, as Observer.

#### 3. Functions

The main function of the PRB is to provide a multi-institutional Forum for the coordination of resources for implementation of the PIRATA Program, including the following:

- 3.1 To review the requirements for the implementation of PIRATA;
- 3.2 To coordinate resources that may be applied to the Program;
- 3.3 To encourage scientific and technological initiatives, in the participating countries, to meet the objectives of PIRATA;
- 3.4 To report on its activities to the Heads of the institutions providing resources.

#### 4. Scientific and Technical Advisory Bodies

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In discharging its tasks, the PRB should be guided by the scientific objectives and research strategy formulated by the PIRATA Scientific Steering Group, which is regarded as the main scientific body to advise the PRB, and by the CLIVAR Scientific Steering Group in its general strategy to implement an international climate research program.

## 5. Organization of Sessions

5.1 The PRB shall hold sessions at dates and places, to be decided in the previous session, which will be communicated by the Chair of the Board and arranged by the secretariat. Invitations to attend the sessions shall be sent to:

- All PRB members;
- Experts invited as Observers by the Chair of the PRB, including firstly the Chair of the PIRATA Scientific Steering Group, as necessary for the deliberations in that specific session of the PRB.

5.2 At the close of each session, the PRB will elect from its members a Chair who will serve in that capacity until the close of the next session. An individual shall serve no more than two consecutive years as Chair.

5.3 Sessions will be conducted in English and reports published in that language. Translations of reports into French and Portuguese are the responsibility of institutions in France and Brazil, respectively.

5.4 Secretariat support for the Board will be arranged by the PRB as appropriate.

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**LETTER OF INTENT  
TO EXTEND THE PIRATA MOU**

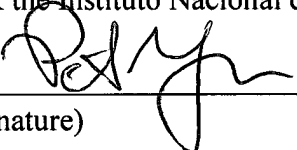
The Instituto Nacional de Pesquisas Espaciais (INPE) of Brazil, the Institut de Recherche pour le Développement (IRD) and Météo-France of France, and the National Oceanic and Atmospheric Administration (NOAA) of the United States of America, hereinafter referred to as the "Parties",

**Recognizing** the fruitful collaboration that the Parties have conducted pursuant to the Memorandum of Understanding between the Parties for Implementation and Maintenance of the Prediction and Research moored Array in the Tropical Atlantic - PIRATA, signed on 28 July 2014 (hereinafter referred to as "the MOU"), expired by its terms on 28 July 2019,

**Decided** to begin working on a new MOU for the purpose of sustaining the array into the future and to enhance the array according to scientific justification, and as resources permit, bearing in mind new findings of the Tropical Atlantic Observing System (TAOS) Review as well as the OceanObs19 Conference, to be held in September 2019, towards future potential development of PIRATA as part of an integrated global ocean observing system,

**Have agreed** that in order to continue PIRATA operations uninterrupted, the Parties express, by mutual agreement, their willingness to extend the validity of the present PIRATA MOU for an additional two-year term, effective from 28 July, 2019 through 27 July, 2021.

FOR the Instituto Nacional de Pesquisas Espaciais

  
(Signature)

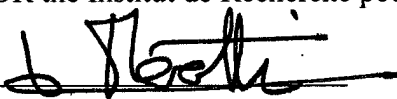
25 July 2019  
(Date)

PETRONIO NORONHA DE SOUZA

(Printed Name)  
Petronio Noronha de Souza  
Diretor Substituto  
SIAPE 664598  
Portaria nº3.313-19/07/2019

Deputy Director  
(Title)

FOR the Institut de Recherche pour le Développement

  
(Signature)

25 juillet 2019  
(Date)

Jean-Paul MOATTI  
Président-directeur général

Jean-Paul MOATTI  
(Printed Name)

Cheminier and Executive officer  
(Title)

FOR Météo-France



(Signature)



73, Avenue de Paris  
94165 SAINT MANDÉ CEDEX

24 June 2018

(Date)

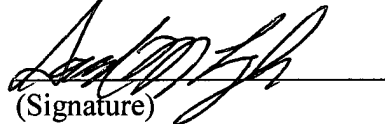
ANNE DEBAR

(Printed Name)

Deputy director general

(Title)

FOR the National Oceanic and Atmospheric Administration



(Signature)

15 July 2019

(Date)

David M. Legler

(Printed Name)

Director, Ocean Observing & Monitoring Division

(Title)