MEMORANDUM OF UNDERSTANDING (MOU)

Between

Instituto Nacional de Pesquisas Espaciais
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 Observations

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, hereafter referred to as the "Participants", 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 Participants 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 Participants recall the long-standing history of the PIRATA program going back over 20 years and the critical nature of this array for collection of data which is assimilated into most operational weather and ocean centers worldwide.

The Participants 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 Participants have reached the following understanding:

SECTION 1
SCIENTIFIC OBJECTIVES OF THE PIRATA PROGRAM

The Tropical Atlantic is home to multiple coupled climate variations covering a wide range of timescales and impacting societally relevant phenomena such as continental rainfall, Atlantic hurricane activity, oceanic biological productivity, and coupled ocean-atmosphere processes in the global equatorial belt. Moreover, the Tropical Atlantic is a vital component of the earth system, being the only ocean with northward heat transport across the equator controlled by the Atlantic Meridional Overturning Circulation. Variations in biogeochemistry and responses to human influences (e.g., ocean acidification, deoxygenation, and marine plastics) are already evident.

The purpose of the PIRATA program is to study the ocean-atmosphere interactions in the Tropical Atlantic that are relevant to regional weather and climate variability and change on subseasonal-to-seasonal, interannual, and longer time scales; and to enable other communities to collaborate with PIRATA through sharing of PIRATA platforms for earth-system studies and monitoring of a wide array of environmental conditions. Along with the core ocean-atmosphere focus of the PIRATA array, the sampling of the full ocean column, when feasible, during PIRATA maintenance cruises is anticipated as an added benefit of PIRATA to long term climate variability and change research.

Specifically, the scientific goals of PIRATA are:

- To improve our understanding of the relative contributions of the different components of the surface heat flux, momentum flux, freshwater flux, CO_2 flux, coupled ocean-atmosphere dynamics, and the surface and upper ocean thermal and haline structures to subseasonal-to-seasonal, interannual, and longer time scale variability and change in the Tropical Atlantic;
- To provide a data set that can be used to develop and improve predictive models of the coupled ocean-land-atmosphere Atlantic climate system, and for seamless numerical predictions of the ocean and the atmosphere; and
- To provide an extensible network of platforms for enabling earth-system research and monitoring capabilities in the Tropical Atlantic region.

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 Participants will deploy and maintain an array of moored buoys in the Tropical Atlantic as part of the broader Global Tropical Moored Buoy Array (GTMBA) system. The mooring system technology is configured to send oceanographic and meteorological observations to ground stations in real time via satellite and on the internet via the World Meteorological Organization (WMO) Information System. These data can be assimilated in Earth System Models in order to improve weather and climate forecasts and other applications with direct benefit to the Participants 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
SUSTAINED PHASE OF PIRATA

PIRATA is a long-standing partnership between the Participants dating back to 1997, when a group of scientists engaged in CLIVAR (Climate and Ocean: Variability, Predictability, and Change) and other international fora began its implementation. PIRATA is the Atlantic

component of the GTMBA, which also includes the Research Moored Array for African-Asian-Australian Monsoon Analysis and Prediction (RAMA) array in the Indian Ocean and the Tropical Atmosphere Ocean Triangle Trans Ocean Buoy Network (TAO/TRITON) in the Pacific Ocean. The GTMBA and its separate components support research carried out under the auspices of the CLIVAR program; they also contribute sustained observations for the generation of products and services as part of the Global Climate Observing System (GCOS), the Global Ocean Observing System (GOOS), and the Global Earth Observation System of Systems (GEOSS).

Following the successful completion of the early PIRATA array and evaluation of the scientific results during the pilot phase, representatives of the Participants, in consultation with international CLIVAR, GCOS, and GOOS, resolved to maintain the array through a consolidation phase from 2001 through 2008 via the creation of the first MOU in 2002.

After a positive scientific evaluation of the PIRATA program by CLIVAR and the Ocean Observations Panel for Climate (OOPC), a new MoU was drafted during 2006 to 2008 which was signed in February 2, 2009, by the four institutions INPE (Brazil), IRD and Météo-France (France) and NOAA (USA), during the PIRATA 14 meeting organized in Toulouse (2009). Following the consolidation phase (2001 – 2008), the second formal MOU initiated the ongoing sustained phase from 2009 to the present, which will now be continued through this MOU. The Participants now wish to continue this long-standing partnership through this MOU which reflects technological advances and expanded partnerships since 2009. This MOU provides a stable framework under which PIRATA can continue into the future. This MOU therefore documents the partnership between the Participants 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 4
ORGANIZATION AND MANAGEMENT OF PIRATA

PIRATA Resources Board: A PIRATA Resources Board (PRB) is established with Terms of Reference (TOR) (Annex 2). The initial members of the PRB are managers representing INPE, IRD, Météo-France, and NOAA. Although the PRB is presently comprised of representatives from institutions only in Brazil, France, and the United States, the PRB may welcome other institutions and other nations if they wish to contribute with resources (financial, material, etc.) to the PIRATA Program. The Chairperson 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 could be applied to the Program;
- To encourage scientific and technological initiatives in the participating countries to meet the objectives of PIRATA; and
- To report on its activities to the Heads of institutions providing resources. The PRB is guided by the scientific objectives and research strategy formulated by the PIRATA

Scientific Steering Group (SSG), which is regarded as the main scientific and operational body to advise the PRB.

PIRATA Scientific Steering Group:

The SSG is formed by researchers, managers, and representatives of operational agencies of the Participants and academic institutions. Members are recognized as scientific and operational experts in the areas of meteorology, climatology, oceanography, and others linked to Tropical Atlantic Ocean research. Members are nominated by the SSG and are approved by the PRB. The Chairperson(s) of the SSG is(are) designated by the SSG members. The principal tasks of the SSG are:

- To ensure accomplishment of the scientific and technical objectives as described in the PIRATA Science and Implementation Plan, and as accepted by the Participants;
- To coordinate the technical and logistic support necessary to maintain the array;
- To ensure the rapid dissemination of PIRATA data (in real time when possible) to serve both research and operational applications;
- To promote the utilization of PIRATA data in national and international research and operational weather, ocean, and climate prediction programs;
- To evaluate, encourage, and promote associated pilot extension projects, new process studies, and technological advances that could build upon and/or enhance the 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 programs and organizations as mentioned in Section 7 to ensure an integrated approach to observing the climate system;
- To report regularly on the status of the PIRATA array and scientific results to the PRB and to international stakeholders; and
- To prioritize the order of replacements, in case more than two buoys are missing in one particular year.

PIRATA National Coordinators:

INPE serves as the coordinator of PIRATA in Brazil. A national coordinator is indicated by INPE to be the representative of PIRATA-Brazil. The national coordinator is a member of the 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 SSG. NOAA serves as the coordinator of PIRATA in the 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 SSG. The coordination between the Participants is ensured jointly through the PRB and the SSG, especially through the Chairpersons of these two committees and the national coordinators.

SECTION 5
NATIONAL COMMITMENTS OF THE PARTICIPANTS IN PIRATA

In planning for future resources in support of the PIRATA Program, it is recognized that the Participants are dependent upon year-to-year funding allocations from their governments and other funding agencies, and thus commitments for long-term funding and logistical support cannot be guaranteed. Given this proviso, the Participants 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:

The Participants (NOAA, INPE (in cooperation with the Brazilian Navy/DHN), IRD, and Météo-France) will maintain the PIRATA array of eighteen mooring sites as the array is presently configured (Annex 3). Should the array design be modified, it must be done under the best scientific evidence made available, as agreed upon by the SSG and the PRB in order to meet its scientific and operational requirements, and preferably via endorsement made by international programs with which PIRATA interacts, as defined in Section 7. In particular:

NOAA will:

- Provide essential surface mooring equipment and sensors to maintain the array based on mooring array design articulated in Annex 3 and sensor configurations as agreed to by the Participants;
- Provide ship time, shipping costs, and logistics support to maintain the U.S. moorings in the PIRATA array as described in Annex 3;
- Refurbish moorings necessary to maintain the present PIRATA array until facilities in Brazil, France, or new partner countries are prepared to take over refurbishment tasks.
- Supply up to two replacement mooring systems each year, if required, because of damage or loss;
- Provide technical training for French and Brazilian technicians and/or scientists, or technicians and/or scientists from new partner countries, as necessary, to learn new techniques and procedures, to observe developmental work, and to obtain a copy of the latest available documentation. Travel costs related to these visits are the responsibility of France, Brazil, and/or new partner countries, respectively;
- Be responsible for providing data processing, quality control, and delivery of essential surface mooring measurements;
- Provide and maintain a PIRATA website for PIRATA moorings data display and dissemination;
- Cover costs for satellite data telemetry of the mooring system measurements and ensure that the data are distributed in real time; and
- Be responsible for quality control, dissemination, and archival of PIRATA shipboard data, including Acoustic Doppler Current Profiler (ADCP) and Conductivity, Temperature, and Depth (CTD) data, collected during NOAA cruises.

INPE will:

- Provide ship time to maintain the Brazilian moorings of the PIRATA array according to the design in Annex 3;
- Be responsible for shipping costs, customs, and logistics required to transport PIRATA equipment to and from U.S. and Brazilian-designated ports; and
- Be responsible for quality control, dissemination, and archival of shipboard data, including ADCP and CTD data, collected during Brazilian cruises.

IRD in coordination with Météo-France will:

- Provide ship time to maintain the French moorings of the PIRATA array including ADCP moorings according to the design in Annex 3;
- Be responsible for shipping costs, customs, and logistics required to transport PIRATA equipment to and from the U.S. and French-designated ports;
- Maintain a French PIRATA website with additional national contributions and information; and
- Be responsible for quality control, dissemination, and archival of shipboard data, including ADCP and CTD data, collected during French cruises.

It is recognized that successful climate observation requires continuity in measurements for many years. The Participants are committed to sustaining the ocean observing system in the Tropical Atlantic Ocean over the long term and will work together and with other institutions to plan for the future, including the consideration and testing of new technologies for data collection. The Participants may 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.
The commitments of the Participants will depend on their budget availability and compliance with the respective national legislation.

SECTION 6
THE RELATIONSHIP BETWEEN THE PARTICIPANTS AND FUTURE PIRATA EXTENSION PROJECTS

The commitments of the Participants described in this MOU do not apply to future PIRATA extension projects that may be implemented by countries other than Brazil, France, and the United States. Amendment Terms to this MOU can be signed between the Participants, or with new partners, to coordinate the activities related to the implementation and operation of extension projects which have been recommended by the SSG and approved by the PRB.

SECTION 7
COOPERATION WITH INTERNATIONAL ORGANIZATIONS AND PROGRAMS

The Participants will as far as possible:

- Remain connected to the relevant international science initiatives and implementation panels and efficiently meet our scientific and operational goals by staying current with

international organizations, United Nations programs, and other multilateral agreements and regional alliances; in particular, research activities under the World Meteorological Organization (WMO), the Intergovernmental Oceanographic Commission (IOC), and the International Science Council (ISC), such as those participating in the World Climate Research Program (WCRP). Among them, maintain cooperation with the CLIVAR Atlantic Panel;

- Take an integrated approach to observing the earth climate system in the tropics, recognizing the complimentary nature of PIRATA moored buoy and shipboard measurements with other *in situ* and satellite measurements. As part of GEOSS, PIRATA contributes to the GCOS framework, in particular by cooperating and working to strengthen GOOS in the tropics;
- Contribute to bilateral and multilateral cooperation; for example, by coordinating with the All-Atlantic Research Alliance partners, including the Galway Statement on Atlantic Cooperation (Canada, the U.S. and the European Union) and the Belém Statement on Atlantic Innovation and Cooperation (Brazil, South Africa, and the European Union), including the creation of an integrated and interoperable All-Atlantic Ocean Observing System through the Optimizing and Enhancing the Integrated Atlantic Ocean Observing Systems (AtlantOS) Program; and
- Collaborate with initiatives such as the United Nations Decade of Ocean Science for Sustainable Development (2021 – 2030), to the extent possible.

SECTION 8
EXCHANGE OF INFORMATION

The activities specified under this MOU involve the collection and exchange of (public) environmental data which are not intended to be protected. The Participants 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 Participants or developed jointly under this MOU is accurate to the best knowledge of the Participants. The Participants do not assure the suitability of the information transmitted for any particular use or application by the receiving Participant or by any third party.

SECTION 9
GENERAL PROVISIONS

This MOU is between institutions - the Participants - 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 Participants. All activities under this MOU will be in accordance with the applicable laws of the respective countries, including technology export regulations.

Nothing in this MOU is intended to be arranged as granting or implying any rights to, or interest in, patents or inventions of the Participants, institutions acting on pursuant to this MOU. In the event of joint undertakings conducted pursuant to this MOU that result in inventions or patents,

the Participants intend to conclude separate arrangements to provide for appropriate and equitable protection for the intellectual property rights.

Any changes in the MOU must be unanimously approved by the PIRATA National Coordinators and it must be presented written to the other PIRATA National Coordinators for deliberation and eventual approval. All questions related to the MOU arising during its term will be settled by the Participants by mutual agreement and shall not seek recourse before national courts. The English version of the MOU shall be used to solve translations conflicts.

This MOU will enter into effect at the date of expiration of the previous MOU, and remain in effect for five years, renewable for successive five-year terms if agreed by the Participants. The MOU may be amended or extended by mutual written agreement and may be terminated at any time by any of the Participants upon six months written notice to the other Participants.

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

FOR the Instituto Nacional de Pesquisas Espaciais

(Signature) 21/01/2022 (Date)

CLÉZIO MARCOS DE NARDIN (Printed Name) DIRECTOR (Title)

FOR the Institut de Recherche pour le Développement

Florence MORINEAU
Déléguée Régionale
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FLORENCE MORINEAU (Printed Name) DÉLÉGUÉE RÉGIONALE IRD (Title)

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(Title)

LIST OF ACRONYMS

ADCP	Acoustic Doppler Current Profiler
AtlantOS	All-Atlantic Ocean Observing System Programme
CLIVAR	Climate and Ocean: Variability, Predictability and Change
CTD	Conductivity, Temperature, and Depth
DHN	Diretoria de Hidrografia e Navegação
ENSO	El Niño Southern Oscillation
GCOS	Global Climate Observing System
GEOSS	Global Earth Observation System of Systems
GOMO	Global Ocean Monitoring and Observing
GOOS	Global Ocean Observing System
GTMBA	Global Tropical Moored Buoy Array
INPE	Instituto Nacional de Pesquisas Espaciais
IOC	Intergovernmental Oceanographic Commission
IRD	Institut de Recherche pour le Développement
ISC	International Science Council
ITCZ	Intertropical Convergence Zone
MCTI	Ministry of Science, Technology and Innovations
MOU	Memorandum of Understanding
NOAA	National Oceanic and Atmospheric Administration
OOPC	Ocean Observations Panel for Climate
PIRATA	Prediction and Research moored Array in the Tropical Atlantic
PNE	PIRATA Northeast Extension
PRB	PIRATA Resources Board
RAMA	Research Moored Array for African-Asian-Australian Monsoon Analysis and Prediction
SSG	PIRATA Scientific Steering Group
SST	Sea Surface Temperature
TAO/TRITON	Tropical Atmosphere Ocean Triangle Trans Ocean Buoy Network
TAOS	Tropical Atlantic Observing System
TOR	Terms of Reference
WCRP	World Climate Research Program
WMO	World Meteorological Organization

ANNEX 1

Prediction and Research Moored Array in the Tropical Atlantic (PIRATA)
Science and Implementation Plan
December 2020

1. INTRODUCTION TO PIRATA

PIRATA is motivated by the societal need for improved prediction of the Tropical Atlantic climatic system (notably the Intertropical Convergence Zone (ITCZ) displacement), its impacts on surrounding countries, and the advancements in ocean science that result from this endeavor. Long term variability of the Tropical Atlantic can be described by two modes: 1) an equatorial mode, associated with sea surface temperature (SST) anomalies in the eastern equatorial Atlantic (this mode is in some aspects analogous to the El Niño Southern Oscillation (ENSO) mode over the equatorial Pacific), and 2) a meridional mode, associated with SST anomalies on either side of the ITCZ. Additionally, the northern portion of the Tropical Atlantic is the main development region for Atlantic hurricanes affecting the Caribbean, Central America, and the United States of America, while the southern portion of the Tropical Atlantic is linked with interannual droughts over the Nordeste region of Brazil and the Sahel in Africa. Impacts on the global climate system through teleconnections to the Pacific Ocean, the Indian Ocean, other ocean basins and the higher latitudes.

Thus, the scientific goals of the PIRATA program are:

- To improve our understanding of the relative contributions of the different components of the surface heat flux, momentum flux, freshwater flux, CO_2 flux, coupled ocean-atmosphere dynamics, and the surface and upper ocean thermal and haline structures to subseasonal-to-seasonal, interannual, and longer time scale variability and change in the Tropical Atlantic;
- To provide a data set that can be used to develop and improve predictive models of the coupled ocean-land-atmosphere Atlantic climate system, and for seamless numerical predictions of the ocean and the atmosphere; and
- To provide an extensible network of platforms for enabling earth-system research and monitoring capabilities in the Tropical Atlantic region.

The main objectives of PIRATA are to contribute to the scientific understanding of Tropical Atlantic variability, which includes but is not limited to questions such as:

- What are the forcing and coupling mechanisms between the ocean and atmosphere in the Tropical Atlantic? In particular, what are the mechanisms controlling the evolution of SST and heat flux in the Tropical Atlantic?
- What are the influences of heat fluxes and wind on the position and intensity of the ITCZ, the convective systems of the Gulf of Guinea, and over the western region of the basin?

- What is the relationship between the variability of SST, the variability of heat content, and sea-level rise? What is the influence of SST variability on the various variability modes in this region? In particular, what is the dynamic link between the meridional mode variability of the Atlantic and the equatorial mode?
- What are the teleconnections and their mechanisms between the variability in the Tropical Atlantic region and that in other regions (ENSO, North Atlantic Oscillation, South Atlantic variability, Atlantic meridional overturning circulation variability, etc.)?
- What are the influences of Tropical Atlantic SST, sea level pressure, and wind variability on precipitation and Atlantic hurricane intensity forecasts and outlooks in the main hurricane development region?
- What is the role of the Tropical Atlantic on oxygen, nutrients, and pH variability and how do these factors affect marine ecosystems and fisheries in this region?

In addition to these scientific objectives, PIRATA also has important technical goals: to design, deploy, and maintain an array of moored oceanic buoys and to collect and transmit via satellite, in near real time, a set of oceanic and atmospheric data to monitor and study the upper ocean and atmosphere of the Tropical Atlantic.

The motivation for PIRATA and vision for the Tropical Atlantic Observing System array is further described in:

Bourlès, B., et al. (2019): PIRATA: A sustained observing system for tropical Atlantic climate research and forecasting. https://doi.org/10.1029/2018EA000428; and

Foltz, G.R., et al. (2019): The Tropical Atlantic Observing System. https://doi.org/10.3389/fmars.2019.00206.

2. THE PIRATA PROGRAM

A) PIRATA Implementation:

PIRATA provides high temporal resolution time series measurements of surface heat and moisture fluxes, sea surface temperature and salinity, subsurface temperature and salinity in the upper 500m, and near-surface ocean velocity from PIRATA moored buoys. Since its inception, the PIRATA program has considerably increased the oceanic *in situ* database in the Atlantic. PIRATA also includes three Acoustic Doppler Current Profiler (ADCP) moorings. Furthermore, while each PIRATA buoy (ATLAS and T-FLEX) has to be changed at least once a year, a large number of measurements (temperature and salinity profiles, upper layer currents, SST and sea surface salinity, and winds, etc.) are carried out during all the annual PIRATA cruises.

The PIRATA program provides to the scientific community free access to a variety of data, summarized as follows:

1) Real time data:

- The PIRATA buoys are designed to measure surface meteorological variables (at minimum wind direction and speed, air temperature and humidity, rainfall and solar radiation) and hydrological variables between the surface and 500m using at least 2 pressure sensors, 11 temperature sensors, and 6 conductivity sensors, all at varying depths. The mean hourly or daily observations are transmitted by satellite and are available in near real time.
- At minimum, 12 PIRATA mooring sites bear a current meter at 10m or 12m depth.

2) Delayed data:

- PIRATA includes three ADCP moorings which continuously measure the two horizontal components of the current, from the surface to approximately 300m. The *in situ* measurements are available every 4m from a depth of 16m.
- Meteo-oceanic measurements are carried out during each oceanographic campaign dedicated to PIRATA.
- All of the variables that are delivered in real time are also available at higher temporal resolution in delayed mode with additional quality control applied.

B) Scientific Contribution:

According to the main scientific goals of PIRATA, the number of publications written in the framework of, or using data obtained thanks to, PIRATA indicates to what extent PIRATA contributes to the comprehension of the climate system in the Tropical Atlantic.

In addition to the scientific objectives outlined in Section 1 of this Annex, PIRATA also contributes to:

- Providing data to validate and to initialize earth system models in the Tropical Atlantic. The PIRATA buoy data are extensively used by both academic and operational communities to validate satellite-based surface flux estimates;
- Studies focusing on equatorial and cross-equatorial currents and processes. The repeat full column transects along 38W since 2017 shall prove invaluable to monitor temporal AMOC variations;
- Estimation of the relative contributions of the different components of the surface heat flux and ocean dynamics to the seasonal and interannual variations of SST;
- Providing data to monitor changing oxygen, chlorophyl, nutrients, pH, CO_2, plastics, and Sargassum distributions;
- Development and improvement of predictive models of the coupled air-sea interactions in the Atlantic:

    1. Ocean state estimation and forecast: 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, legacy of the Global Ocean Data Assimilation Experiment (GODAE), now under the framework of the Ocean Predict panel that brings together research initiatives by the

operational oceanography community worldwide. For many years, PIRATA has been a major source of Tropical Atlantic observations to research assimilation schemes for the global ocean. Hence, the generation of operational products and development of end-to-end ocean services for the Tropical Atlantic by ocean forecasting centers worldwide, like the French Mercator Océan, is strengthened and continuously improved because the oceanic data from the PIRATA buoys are made available in near real time.

2. Forecasting climate and weather: The surface meteorological fields from PIRATA buoys are assimilated in near real time into predictive atmospheric models. PIRATA data significantly improve the initial analysis of weather and hurricane forecasting in the region. PIRATA data are used in operational seasonal forecasts via data assimilated into oceanic models that provide ocean initial conditions using coupled ocean-atmosphere models. Also, PIRATA data are readily utilized in Coupled Data Assimilation systems for NWP using Earth System Models.
3. 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 moorings 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 both ocean and coupled ocean-atmosphere 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 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 engages in capacity building and trains scientists from France, Brazil, the US, and other countries in oceanographic, meteorological, and climate research.

PIRATA also contributes to the goals of other programs for which PIRATA dedicated cruises and moorings are opportunities for buoys, profiling floats, underwater gliders, drifters, XBT probes, radiosondes, ozonesondes, surface meteorological measurements, and other deployments.

Finally, the UN Decade of Ocean Science for Sustainable Development will take place from 2021-2030 with the aim of generating The Science We Need For The Ocean We Want. The Decade is embracing a participative and transformative process so that scientists, policy makers, managers, and service users can work together to ensure that ocean science delivers greater benefits for both the ocean ecosystem and society. The continuity of PIRATA can offer an opportunity for the Participants to contribute to the Ocean Decade, and beyond, to give us The Science We Need For The Ocean We Want.

3) PIRATA EXTENSIONS

PIRATA encourages consideration of scientifically sound pilot expansion projects that build upon the consolidated PIRATA array. Extensions could 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. 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, supported by Brazil, was inaugurated in August 2005. This extension allows monitoring the South Equatorial Current bifurcation into the Brazil Current and the North Brazil Current, and the interactions between the Southwest Tropical Atlantic SSTs and the South Atlantic Convergence Zone (Nobre et al., 2012).

Nobre, P., R. A. F. De Almeida, M. Malagutti, and Emanuel Giarolla, 2012: Coupled ocean-atmosphere variations over the South Atlantic ocean. *J Clim.*, **25**, 6349–6358, https://doi:10.1175/JCLI-D-11-00444.1.

The PIRATA Southeast Extension, supported by South Africa, was implemented for a one-year test period from boreal summer 2006 to boreal summer 2007 and further from 2013 to 2019. If continued, observations in this region could be used to monitor the Benguela Niños, and the potential linkage between the equatorial mode and the Benguela Niños (Rouault et al., 2009).

Rouault, M., Servain, J., Reason, C. J. R., Bourlès, B., Rouault, M., & Fauchereau, N., 2009: Extension of PIRATA in the tropical South East Atlantic: an initial one year experiment. African Journal of Marine Science, 31(1), 63–71, https://doi.org/10.2989/AJMS.2009.31.1.5.776.

The PIRATA Northeast Extension (PNE), supported by USA was inaugurated in boreal summer 2006 and spring 2007. Observations in this region allow capturing processes impacting interannual variations in the seasonal migration of the eastern ITCZ, study of cross-equatorial currents and tropical instability waves, and data collection in the main hurricane development region and oxygen minimum zone (Foltz et al., 2013).

Foltz, G. R., C. Schmid and R. Lumpkin, 2013: Seasonal cycle of the mixed layer heat budget in the northeastern tropical Atlantic Ocean. J. Climate, 26, 8169-1811, https://doi.org/10.1175/JCLI-D-13-00037.1.

Also, the US, Brazil, and Europe have funded enhancement of multiple sites for full surface flux capability and higher vertical resolution for other processes.

Ultimately, the PIRATA array should transition to an operational, international, sustained observing system for ocean, weather and climate prediction spanning the widely varying dynamical regimes of the tropical and subtropical Atlantic Ocean and providing invaluable opportunities for deployment of other oceanographic and meteorological instruments and platforms for conducting process studies and future research efforts.

4) PROGRAM MANAGEMENT AND SUPPORT

An International Scientific Steering Group (SSG) heads the PIRATA science program. Presently, four scientists of the three MOU signatories compose this 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.

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 (TAOS). The addition of platforms like global surface drifters and Argo profiling floats complement the limited spatial extent of the PIRATA buoys, but cannot provide the unique coverage of the air-sea interface and high temporal sampling offered by the moorings across the Tropical Atlantic.

The federation of complementary observational platforms provided thanks to PIRATA has become the TAOS. From its beginning, PIRATA has also cooperated and communicated on a frequent basis with other international science organizations. Through the concerted efforts of those participating nations and institutions, PIRATA has become a world-renowned core Atlantic component of GOOS and GCOS.

ANNEX 2

PIRATA Resources Board Terms of Reference

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 composed of representatives of institutions allocating resources to accomplish the overall goals of the PIRATA Program. The initial composition of the PRB may include representatives of the following institutions:

- Brazil:
  - Instituto Nacional de Pesquisas Espaciais (INPE);
- France :
  - Institut de Recherche pour le Développement (IRD);
  - Météo-France;
- United States:
  - National Oceanic and Atmospheric Administration (NOAA)/Global Ocean Monitoring and Observing (GOMO);

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

In discharging its tasks, the PRB should be guided by the scientific objectives and research strategy formulated by the PIRATA Scientific Steering Group (SSG), 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 may hold sessions at dates and places, to be decided in the previous session, which should be communicated by the Chair of the Board. Invitations to attend the sessions may be sent to:

- All PRB members; and
- Experts invited as Observers by the Chair of the PRB, including firstly the Co-Chairs of the PIRATA SSG, as necessary for the deliberations in that specific session of the PRB.

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

5.3 Sessions may 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.

ANNEX 3
PIRATA Array Configuration

PIRATA Array Configuration as of July 2021

1. Ocean-atmosphere interaction moorings (the countries responsible for maintaining these moorings are shown in parentheses):
   - 4° N, 38° W (Brazil)
   - 8° N, 38° W (Brazil)
   - 11.5° N, 38° W (Brazil)
   - 15° N, 38° W (Brazil)
   - 8° S, 30° W (Brazil)
   - 14° S, 32° W (Brazil)
   - 19° S, 34° W (Brazil)
   - 0°, 35° W (Brazil)
   - 6° S, 10° W (France)
   - 10° S, 10° W (France)
   - 20°S, 10° W (France)
   - 0°, 0° E (France)
   - 0°, 10° W (France)
   - 0°, 23° W (France)
   - 20°N, 38° W (US)
   - 4°N, 23°W (US)
   - 11°30'N, 23°W (US)
   - 20°30' N, 23°W (US)

2. Equatorial ADCP moorings:
   - 0°N, 23°W (France)
   - 0°N, 10°W (France)
   - 0°N, 0°E (France)