

Project	AtlantOS – 633211
Deliverable number	D3.3
Deliverable title	PIRATA network improvement report
Description	Report on new (physical, meteorological and biogeochemical) sensor implementation and derived time series.
Work Package number	WP 3
Work Package title	Enhancement of autonomous observing networks
Lead beneficiary	IRD
Lead authors	Bernard BOURLÈS
Contributors	Peter BRANDT, Nathalie LEFEVRE
Submission data	
Due date	31 March 2017
Comments	



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement n° 633211.

Executive summary:

The Prediction and Research Mooring Array in the Tropical Atlantic (PIRATA), initiated in 1997, is now recognized as the reference network of oceanic and atmospheric observations in the Tropical Atlantic, as for climate dedicated research and for operational climate and ocean prediction. The PIRATA network was initiated in the framework of a multinational cooperation and is maintained on the long-term thanks to close collaborations and a Memorandum of Understanding between US, Brazil and France organizations and now comprises 18 permanent ATLAS buoys along with one ADCP mooring (at 23°W-Equator). As part of AtlantOS, the main objective is to make PIRATA more efficient and relevant in terms of filling observational gaps- essentially by implementing and operationally maintain additional sensors to existing ATLAS moorings and demonstrating a preview of what could be the “future PIRATA network”.

After a recall of the existing PIRATA network in early 2015 (i.e. before AtlantOS), the different steps of the network evolution from this date are detailed in the following. Enhancements have been, and will be, made possible through i) new meteo-oceanographic buoys, ii) deploying one new ADCP mooring, iii) purchasing additional sensors through AtlantOS or thanks to other programs/partners.

PIRATA network status in early 2015:

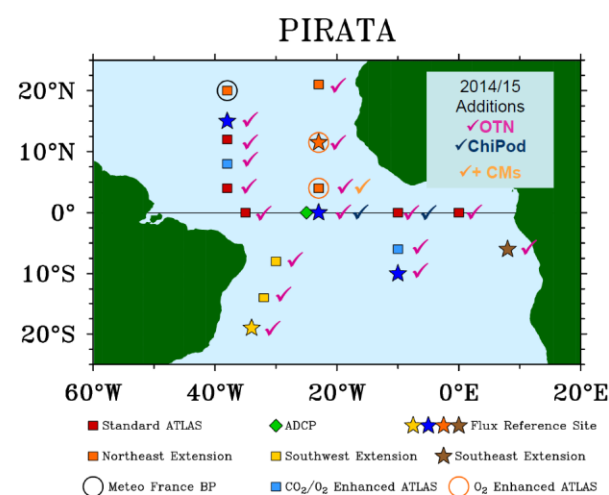
18 meteo-oceanographic buoys constitute the main component of the PIRATA network. These buoys are of ATLAS type, and located at (from west to east and north to south): 20°N-38°W, 15°N-38°W, 12°N-38°W, 8°N-38°W, 4°N-38°W, 0°N-35°W, 8°S-30°W, 14°S-32°W, 19°S-35°W, 21°N-23°W, 12°N-23°W, 4°N-23°W, 0°N-23°W, 0°N-10°W, 6°S-10°W, 10°S-10°W, 0°N-0°E, 6°S-8°E (see map).

These ATLAS buoys are initially designed to measure surface meteorological variables (wind direction and speed, air temperature and humidity, rainfall and SW solar radiation) and hydrographic EOVS (Essential Ocean Variables) 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).

Six of these PIRATA buoys (see map) are “flux reference sites”, i.e. also equipped with LW radiation, atmospheric pressure, one currentmeter (at 10m depth), and 8 T/C (temperature/conductivity) sensors (instead of four T/C at other sites), i.e. at 0, 5, 10, 20, 40, 60, 80, 120m. One atmospheric pressure sensor is also maintained at 20°N-38°W from 2012.

Two buoys are equipped with CO₂ sensors (CARIOCA systems) at 6°S-10°W (from 2006) and 8°N-38°W (from 2008; PI: IRD/LOCEAN, France).

O₂ sensors are also maintained from 2008 at 12°N-23°W and 4°N-23°W at 300 & 500m depth to monitor the Oxygen Minimum Zone (PI: GEOMAR, Germany).



All data (but O₂ and CO₂) are transmitted in real time through GTS and made available for free to the whole scientific community (operational climate and research).

CO₂ are transmitted in real time independently, O₂ is only available after buoy service.

All buoys are replaced on the yearly schedule, and, data are made available in Delayed Mode once sensors are calibrated and data quality controlled.

From 2014, PIRATA buoys are platforms for other measurements. All buoys are equipped with acoustic receivers at 200m depth for the « Ocean Tracking Network » program (PI: Dalhousie University). Also, χ pods (turbulence sensors) are installed at 0°N-23°W and 0°N-10°W (5 χ pods on each, between 20m and 82m depth; PI: Oregon State University, USA).

PIRATA also maintains ADCP moorings at 23°W-0°N (from 2001) and 10°W-0°N (from 2006). These ADCPs allow monitoring the Equatorial Undercurrent from near the surface down to about 300m depth. The mooring at 23°W-0°N (from 2001) includes additionally deep velocity measurements (partly top to bottom; PI GEOMAR, Germany).

This network is maintained thanks to yearly cruises ensured by Brazil (western part), USA (north-eastern part) and France (eastern part). These cruises allow ensuring a large number of measurements (mostly CTD casts along systematically repeated sections at 38°W, 23°W and 10°W) and to contribute to several other programs (e.g., by deploying Argo profilers and SVP drifters). All operations are summarized in the table below, depending upon the country.

	FR cruises	BR cruises	US cruises	
Vertical profiles	CTD or CTDO2 / depth / quasi real time data transmission (qrttd)	CTDO2; 0-2000m; qrttd	CTD; 0-1500m; qrttd	CTDO2; 0-1500m; qrttd
	L-ADCP	Yes; 0-2000m	Yes; 0-1500m	Yes; 0-1500m
	Bottles S analysis	Yes; 0-2000m	Yes; 0-1500m	Yes; 0-1500m
	Bottles O2 analysis	Yes; 0-2000m	No	Yes; 0-1500m
	Bottles nutrients analysis	Yes; Nitrates, Nitrites, Phosphates, Silicates 0-2000m	No	No
	Bottles Chl pigments analysis	Yes ; 0-100m only at CO2 equipped buoys ; 0-100m	No only at CO2 equipped buoys ; 0-100m	No
	Bottle CO2 parameters			No
Continuous measurements along trackline	XBT or XCTD; depth? quasi real time data transmission (qrttd)?	XBT; 0-800m; qrttd	XBT; 0-800m; qrttd	XBT; 0-800m; qrttd
	SST&SSS (Tsgraph)	Yes	Yes	Yes
	S-ADCP	Yes	Yes	Yes
	pCO2	No	Yes	Yes (usually; not always)
	Acoustic EK60	Yes (from 2015; RV Thalassa)	Yes, (only with RV Vital de Oliveira)	Kongsberg EM122, Bathy 2010, CHIRP 3260 / Furuno FE-700
	Meteo	Yes	Yes	Yes
	U-CTD	No	Yes	No
Opportunity operations	ARGO profilers	Yes (about 7 per cruise)	No	Yes
	Surface drifters	Yes; SVP or SVP-S & BS (number depending of years)	Yes; SVP (number depending of years)	Yes
	Radiosoundings	No	Yes (number depending of years)	Yes (usually; not always)
	Aerosols	No	No	Yes
	O3 (ozonesondes)	No	No	Yes (usually; not always)

Enhancements status in early 2017:

NOAA/PMEL developed a new type of meteo-oceanographic buoys, already tested in the Indian and Atlantic oceans, the T-Flex systems. These buoys are with new modular design and off-the-shelf electronics, and ensure data transmission through Iridium instead of Argos. They allow the potential implementation of more sensors with high frequency data transmission in real time. All the ATLAS buoys will be progressively replaced by T-Flex, beginning at “Flux reference sites”.

Three T-Flex systems were installed in late 2015 and early 2016 at 12°N-23°W, 0°N-23°W and 10°S-10°W. In March 2017, 4 T-Flex systems have also been installed at 6°S-8°E (FR cruise), 4°N-23°W, 21°N-23°W and 20°N-38°W (US cruise). 3 T-Flex are expected to be implemented in April-May 2017 at 0°N-35°W, 4°N-38°W and 15°N-38°W (BR cruise).

Since 2015, underway acoustic backscatter measurements have been carried out during French PIRATA cruises, thanks to the scientific echo sounder mounted on the *R/V Thalassa*. Such measurements will be continued when this R/V used.

A new currentmeter mooring (with ADCP installed at 300m depth looking upward) has been deployed at 0°N-0°E in March 2016. This mooring, also deployed in contribution to the FP7 PREFACE programme, should be maintained in the framework of PIRATA in the future.

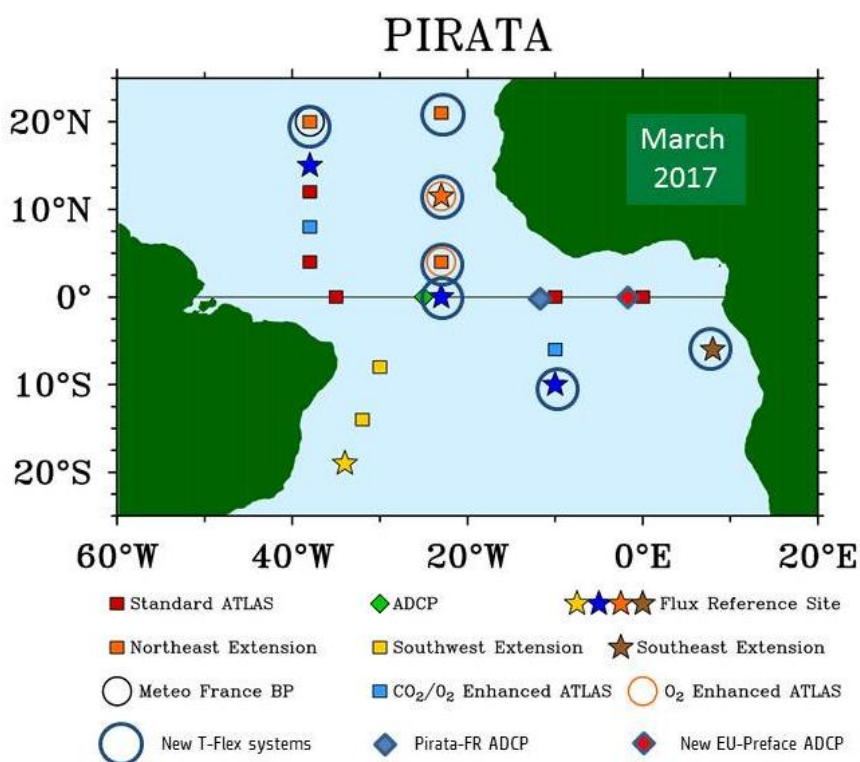
PIRATA proposed several enhancements in the framework of the AtlantOS program, mostly through the purchase and implementation of additional sensors and through the real time transmission for new O₂ and CO₂ sensors. Thus:

- i) 16 inductive O₂ loggers sensors have been assembled (GEOMAR), part of the material (sensors, modems, electronics) were purchased thanks to AtlantOS fundings. GEOMAR ensured the development and the construction of oxygen logger software and hardware for online moored observations, along with the development for processing of online data. 8 inductive oxygen loggers have been prepared for deployment along 23°W during the US cruise in February 2017 at the 21°N-23°W (at 80m, 150m and 300m depth), 12°N-23°W (at 80m, 300m and 500m depth) and 4°N-23°W (at 300m and 500m depth) sites. In spite of some initial problems with the data transfer, first online oxygen data are now operational from the 6 O₂ loggers installed at 21°N-23°W and 12°N-23°W.
- i) One CO₂ (Carioca system) has been purchased (IRD/LOCEAN) in order to be added on the buoy at 6°S-8°E. As a T-Flex system had to be installed there, the first issue was to change the size of the Carioca and its installation on the buoy (T-Flex are full buoys, contrary to ATLAS ones). This CO₂ sensor has been successfully implemented on a T-Flex at 6°S-8°E during the FR cruise in March 2017.
- ii) 4 T/C sensors have been purchased in 2016 (IRD/LEGOS), in order to increase the vertical sampling in the mixed layer. These sensors were delivered to NOAA/PMEL in October 2016 and will be deployed on T-Flex systems at 0°N-10°W (in the area where the equatorial upwelling signature is maximum) at 5m and 10m depth. This site is expected to be occupied with a T-Flex system in 2018, but T/C sensors have however been added in March 2017 during the PIRATA FR cruise on a classical ATLAS system, even without data transmission in real time.
- iii) 6 currentmeters (Aquadopp) have been purchased in 2016 (IRD/LEGOS), in order to monitor the current in the mixed layer (10m depth) at 0°N-10°W, 0°N-35°W and 8°N-38°W. These currentmeters were delivered to NOAA/PMEL in December 2016, but with a wrong configuration, and processes are going on for exchanging them. As mentioned just above, the 0°N-10°W site is with an ATLAS system so the currentmeter will be installed in 2018 at this

location. However, a classical currentmeter (Sontek) has been added in March 2017 during the PIRATA FR cruise without data transmission. At 0°N - 35°W and 8°N - 38°W , the currentmeters will also be installed in 2018.

Brazilian partners (FUNCEME, LOFEC/UFPE) proposed to extend the T/C vertical sampling in the mixed layer in the west, namely at the sites 0°N - 35°W , 4°N - 38°W and 8°N - 38°W , where Amazon plumes and associated low salinity are present along with the subsurface central waters salinity maximum. 9 additional T/C sensors will be deployed (instead 4) at these sites between the surface to 140m depth and FUNCEME is purchasing 54 T/C sensors. These sensors will be deployed on T-Flex systems (progressively replacing ATLAS ones from April-May 2017) from 2018.

To conclude, the figure below shows the present status of the PIRATA network, with 7 T-Flex buoys (and still 11 ATLAS), 3 ADCP moorings, 3 CO_2 sensors (3rd one at 6°S - 8°E , not clearly illustrated on the map), O_2 sensors along 23°W , OTN on each buoy, Xpods at 23°W and 10°W at the equator.



Time series are available on:

Realtime Data from PIRATA ATLAS Systems (with links to other sites with cruises data sets):

<https://www.pmel.noaa.gov/gtmba/pirata>

Realtime Data from PIRATA TFLEX Systems (including O_2 data):

<http://www.pmel.noaa.gov/tao/pirata/tflex/>

Delayed mode quality controlled CO_2 data sets:

<http://cdiac.ornl.gov/oceans/Moorings/PIRATA6S10W.html>

<http://cdiac.ornl.gov/oceans/Moorings/PIRATA8N38W.html>