TOWARD SUSTAINED AND ENHANCED OBSERVATIONS IN THE EASTERN TROPICAL ATLANTIC BASED ON THE PIRATA NETWORK

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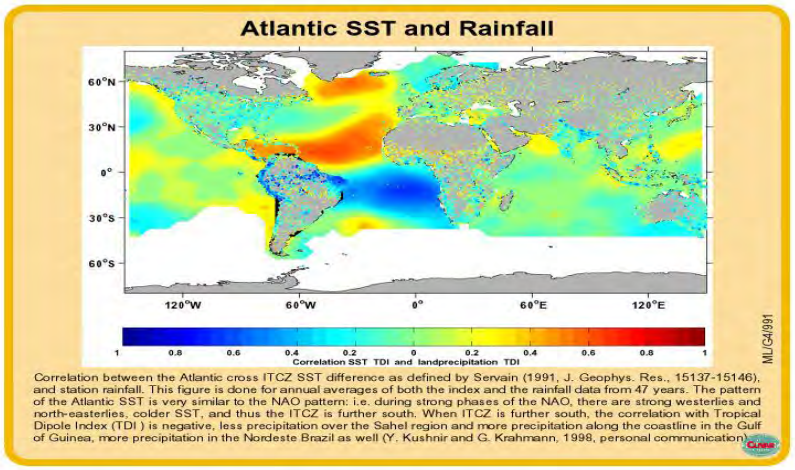
Photo: A.Kartavtseff

Institut de Recherche pour le Développement FRANCE

A Connected Ocean 2016, Brest, France 11-13 October, 2016

PIRATA in the Tropical Atlantic: why, what, who, how?

Why?



- fundamental scientific issues
- societal needs for improved prediction of the climatic variability and its impact on the regional hydro-climates.

⇒ MAJOR GOALS:

1) improve the description of the intra-seasonal to inter-annual variability in the atmospheric and oceanic boundary layers in the tropical Atlantic (air sea fluxes, SST, heat content…);

2) provide a set of data useful for developing and improving the predictive models of the ocean-atmosphere coupled system;

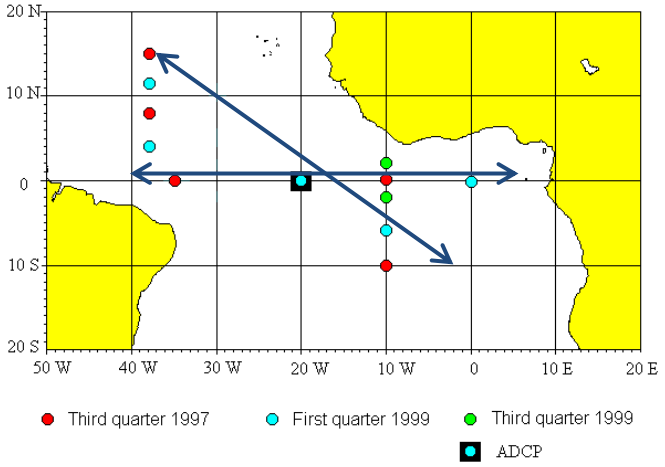
PIRATA in the Tropical Atlantic: : why, what, who, how?

What?

initially:

PIRATA = Pilot Research Moored Array in the tropical Atlantic

was initiated in order to establish an observation network
<u>to improve our knowledge and understanding</u>
<u>of ocean-atmosphere variability in the tropical Atlantic</u>.



First PIRATA network
as drawn in 1996
in order to monitor the two
main modes of variability (equatorial & meridional)
in the tropical Atlantic

PIRATA in the Tropical Atlantic: : what, why, who, how?

Who?

Initiated in 1996…. (by US, FR & BR colleagues)

PIRATA-1 Meeting
February 1996
Natal, Brazil

The Historic PIRATA' Birth...

10 years latter ...
Exactly at the same place

PIRATA 10 Years
Evaluation Workshop
February 2006
Natal, Brazil

PIRATA 1st buoy deployment:
September 10, 1997.

⇒ 2017: 20th anniversary of the PIRATA network

⇒ **Untill now, still a « tripartite » program sustained by:**

USA (NOAA), BRAZIL (INDP, UFPE,DHN) & France (IRD, Météo-France, Ifremer, CNRS…)

Also collaborations with Germany (GEOMAR) from 2005-2006.

PIRATA in the Tropical Atlantic: : what, why, who, how?

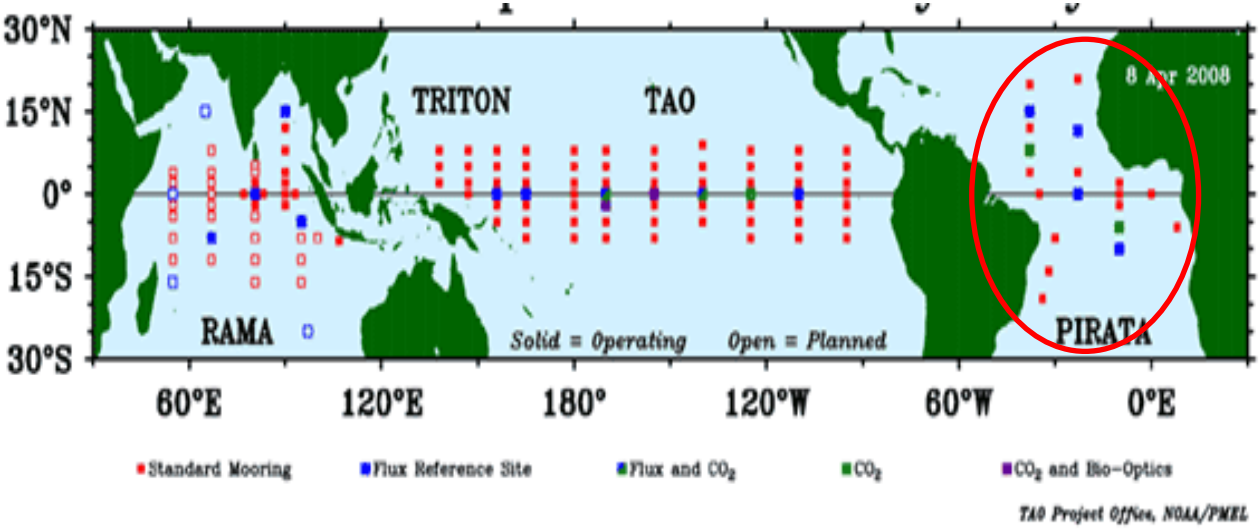
How?

to meet the scientific objectives:

=> design, deploy, and maintain an array of moored oceanic buoys
+ collect and transmit a set of oceanic and atmospheric data, via satellite in real-time.

=> PIRATA

= Atlantic contribution to the Global Tropical Moored Buoy Array



How?

PIRATA ATLAS buoys:

Measured Parameters :

Atmosphere:

- wind (direction, speed)
- relative humidity
- air temperature
- precipitation
- incident radiation

Ocean:

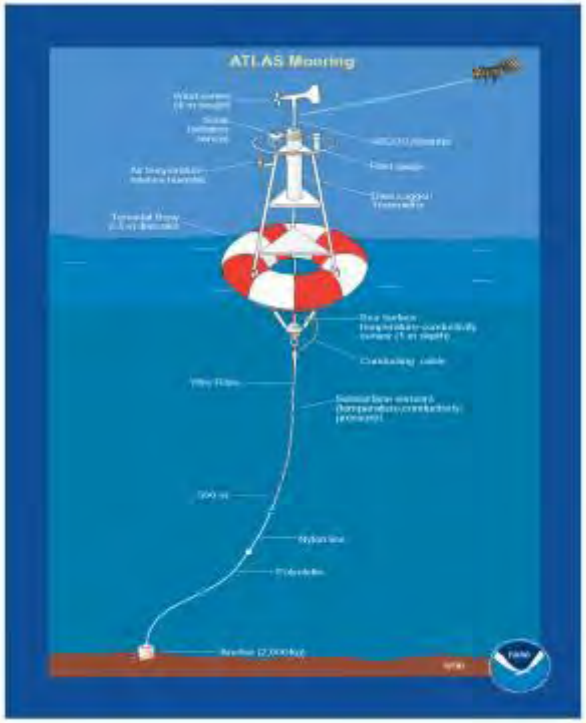
- temperature

(11 levels from surface to 500m)

- salinity

(4 to 9 levels between 0 & 120m)

- pressure (at 300 & 500m)
- surface currents at 4 sites



- Daily averaged data transmitted in real time by Argos;

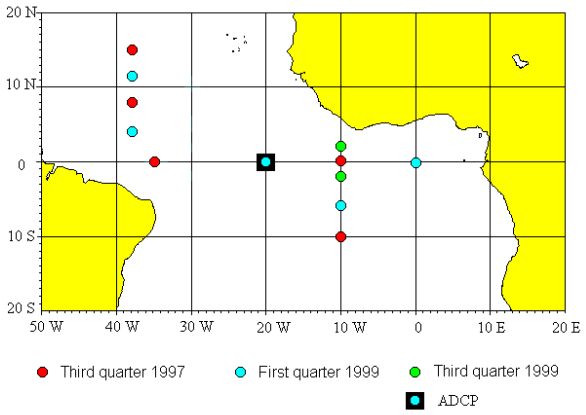
- High frequency data (10mn) available after servicing operations

How?

PIRATA network evolution until now

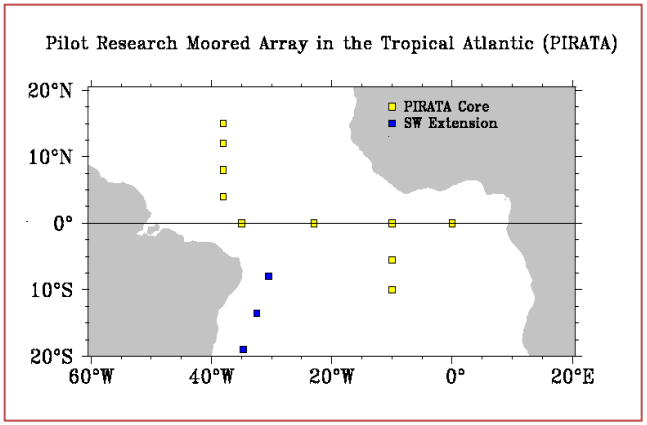
1) First PIRATA ATLAS buoys network in 1997

(10 buoys)

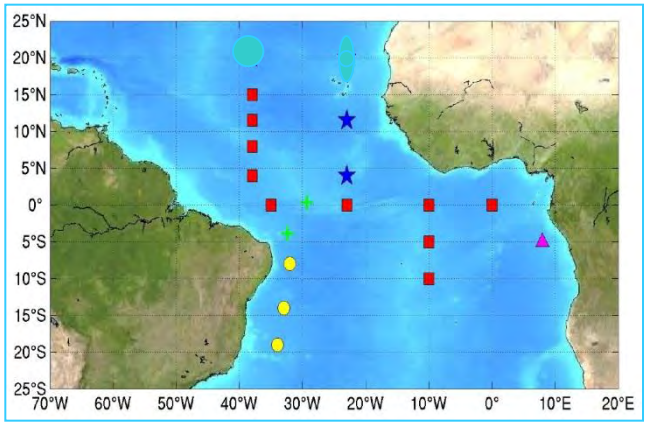


2) PIRATA ATLAS buoys network in October 2005

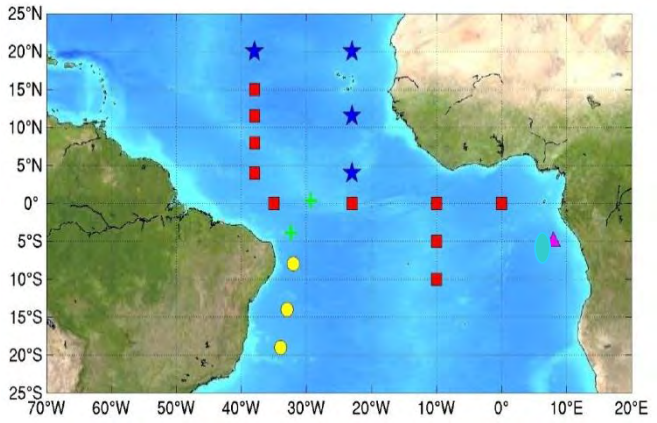
(Brazilian SW extension => 13 buoys)



3) PIRATA ATLAS buoys network in June 2006
(US NE -2-+ BCLME & S.Afr. SE -1- extensions => 16 buoys)



4) PIRATA ATLAS buoys network in July 2007
(US NE -4- extension => 17 buoys)



How PIRATA can work : different “phases”

=> From *Pilot Research moored Array in the Tropical Atlantic* **to** *Prediction and Research moored Array in the Tropical Atlantic*

CLIVAR-WCRP & OOPC endorsement

1995 1996 1997 — 1998 — 2000 — 2005 — 2006 2007 2008 — 2009 — 2014 — •••

Setup Planning Phase

Pilot Phase (MoU-1)

Consolidation Phase (MoU-2)

“Sustained” Phase

(MoU-3)

Commitments of partners through a MoU very important…

=> The PIRATA network at now :

Maintained by USA *: 4 Atlas buoys : PIRATA NEE from 2006*

18 meteo-oceanic buoys

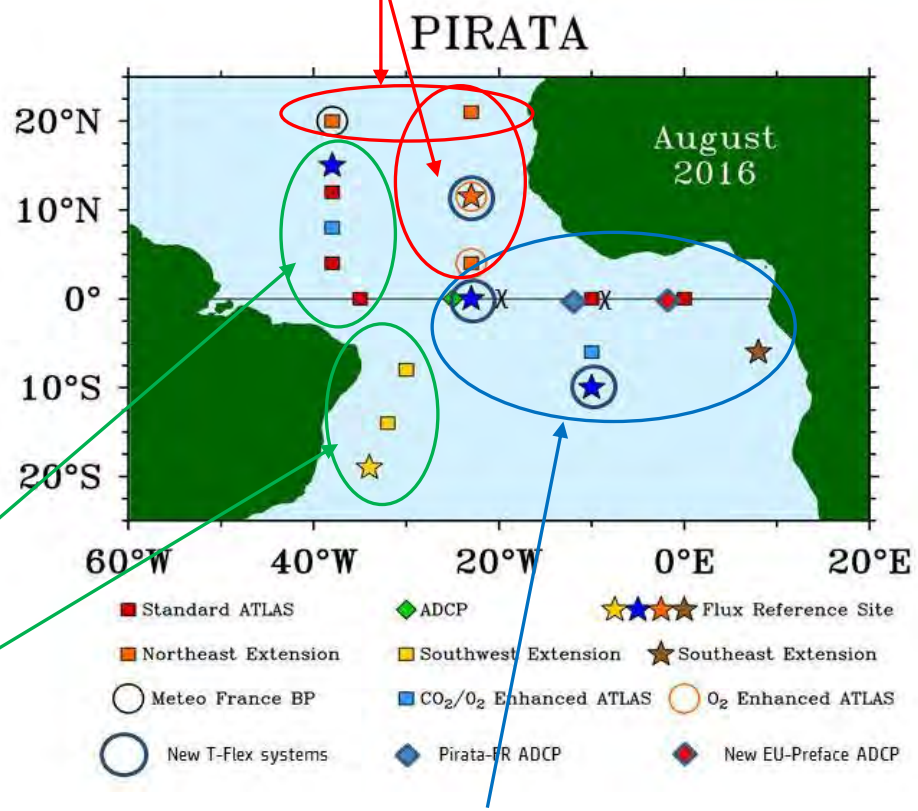
3 ADCP moorings (0-300m)

6 Flux Reference sites

2 with surface CO2 sensors

2 with 02 subsurface sensors

1 with P_{atm}



Maintained by Brazil:

8 Atlas buoys:

5 from 1998,

3 as the PIRATA SWE from 2005

Maintained by France *:*

6 Atlas buoys:

5 from 1997

+ PIRATA SEE at 6S-8E in 2006 – 2007 (by South Africa & BCLME)
then from 2013 (EU PREFACE programme)

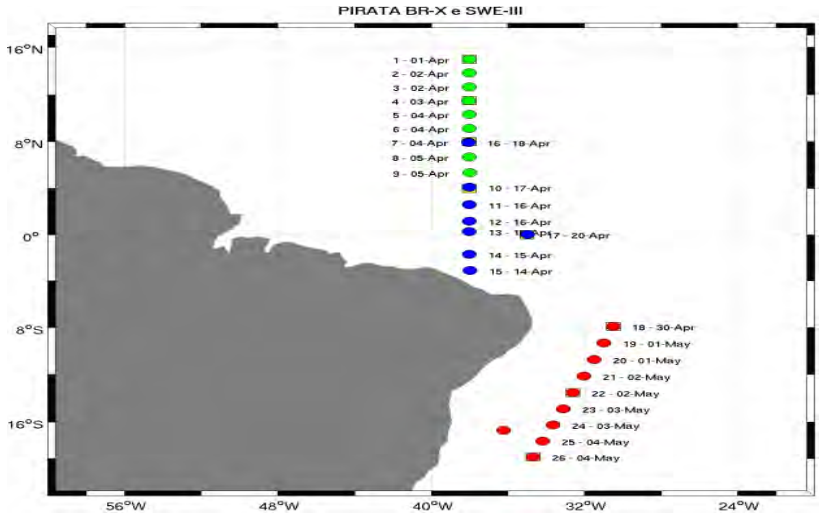
3 ADCP moorings (23°W, 10°W & 0°E along the equator);

Contribution by US & Germany for 23W-Eq site from 2006.

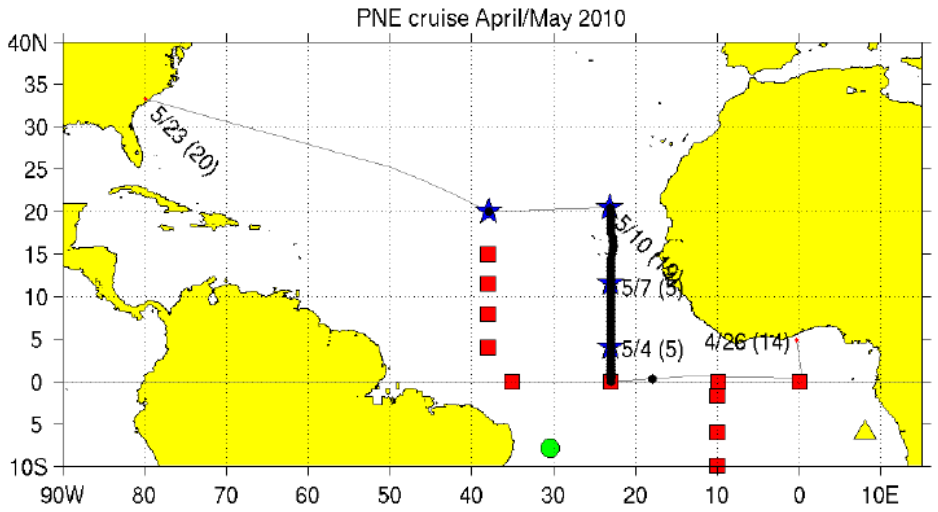
Network servicing:

YEARLY CRUISES => repeated sections with CTD profiles

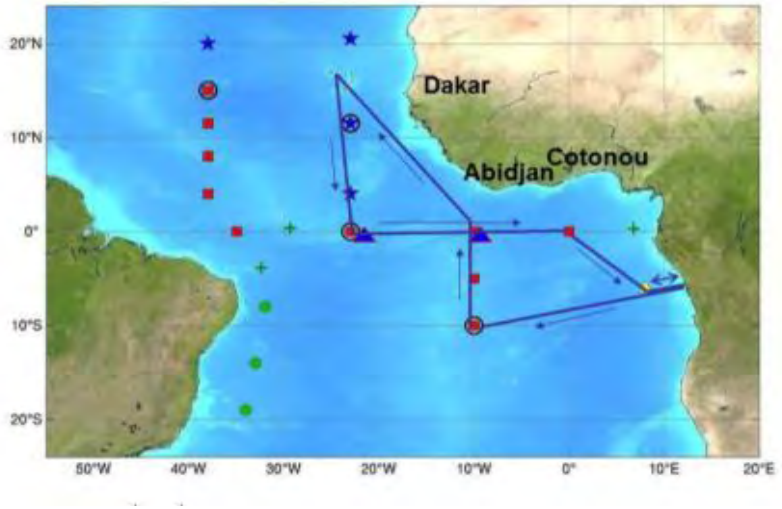
38°W section: Brazilian cruises



23°W section: US cruises



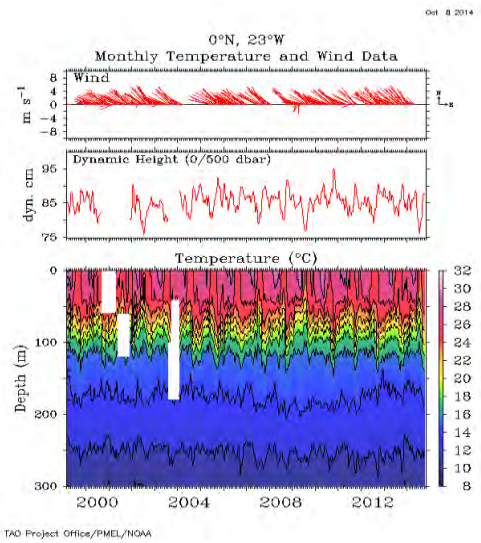
10°W section: French cruises



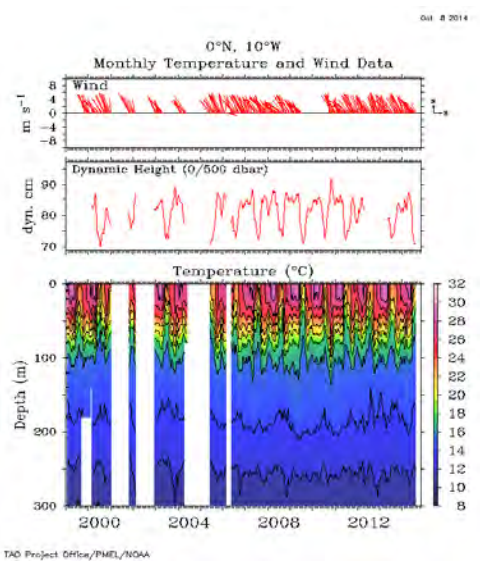
≥ 40 days each

Examples of PIRATA ATLAS time series (6 buoys east of 23° W)

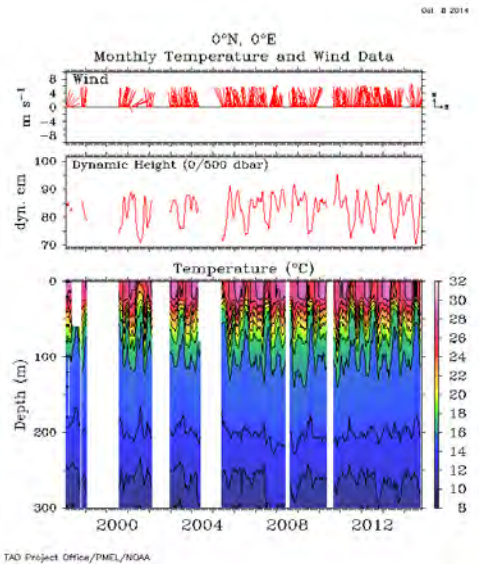
Eq-23° W



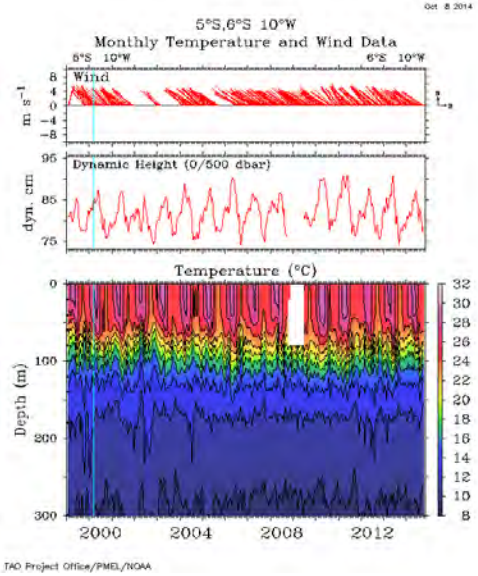
Eq-10° W



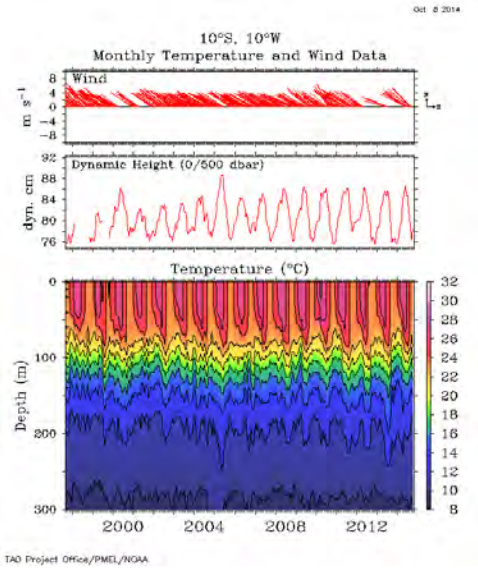
Eq-0° E:



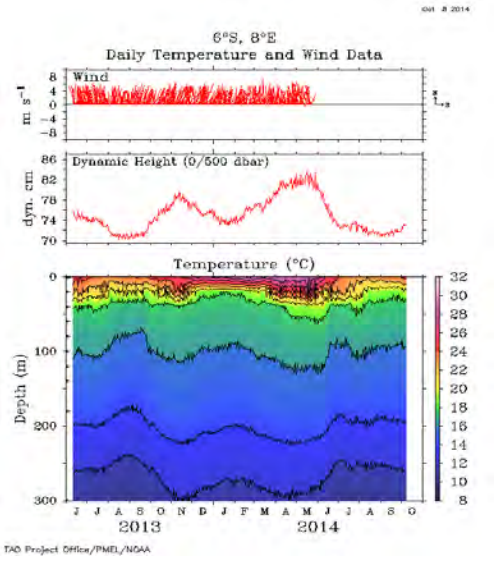
6° S-10° W



10° S-10° W



6° S-8° E:

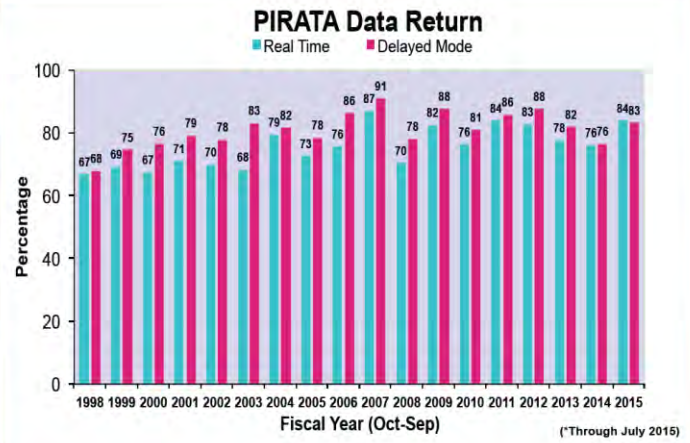


Gaps either due to piracy activities (mostly 0 and 10W-Eq; none from 2008) or sensors failure

ATLAS data => Real time & Delayed time:

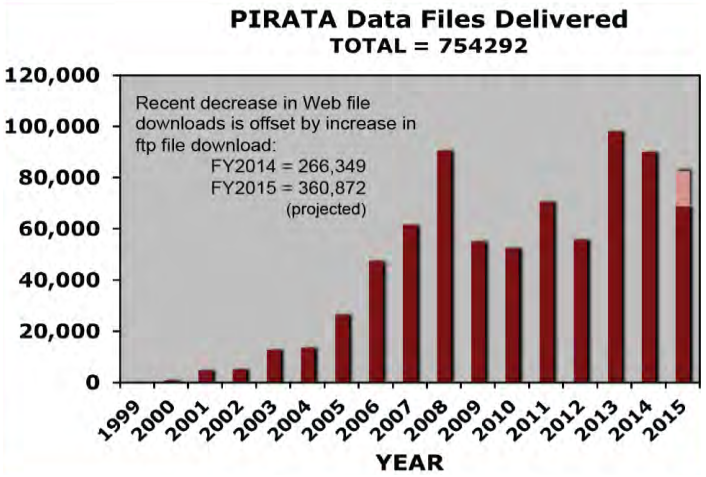
- PIRATA ATLAS data return over the period 1998-2015:

~>82% in average



- ***PIRATA files delivered over the period 1999-2015:***

Through website & ftp : important need/demand



Open Data Policy

http://www.pmel.noaa.gov/pirata

http://www.brest.ird.fr/pirata

http://www.pirata.ccst.inpe.br

http://www.aoml.noaa.gov/phod/pne/cruises.php

Progressive enhancement of measurements acquired thanks to PIRATA,

with focus in the Eastern tropical Atlantic during PIRATA-FR cruises

1) Essential Oceanic Variables (temperature, salinity, currents) measured from the first steps of PIRATA during the cruises & from the buoys (but current, only on a few ones)

2) Buoys & cruises = platforms to get more data sets & contribute to some other programs.

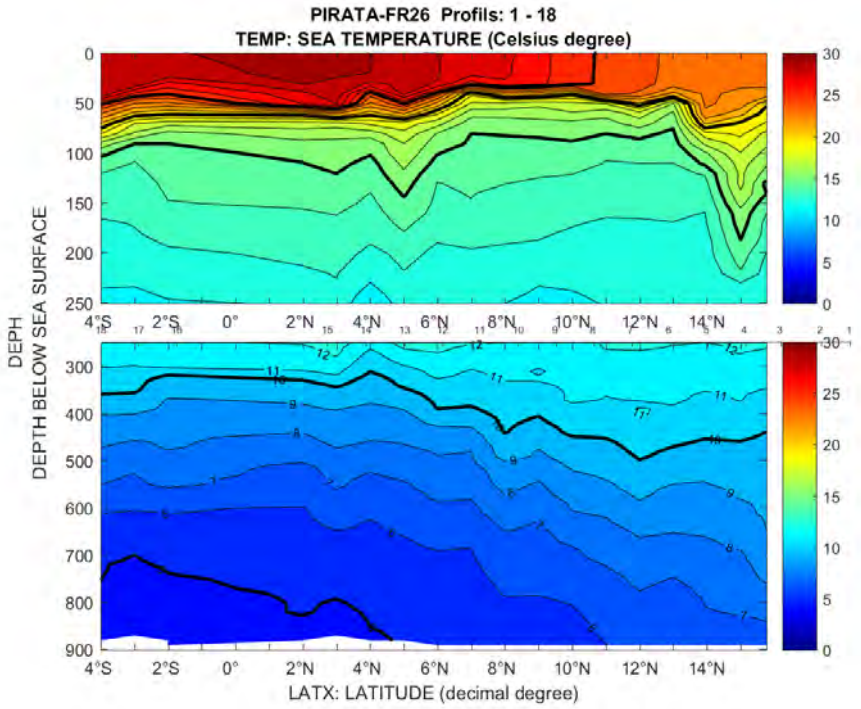
e.g.:
Quasi real time data (CTD, XBT) for operationnal services
ARGO profilers deployement
Biochemistry measurements
SVP-S deployement
Gliders experiments (Pirata-FR in 2011, with GEOMAR)
Atmospheric measurements (Radiosoudings…)
Etc…

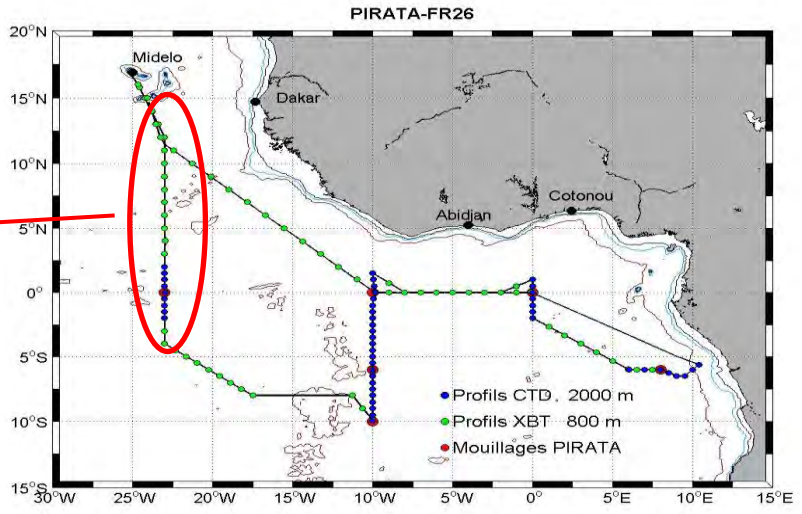
From 2003: deployment of XBT in the eastern Tropical Atlantic

Profiles transmitted in quasi-real time (daily) to CORIOLIS *(along with CTD profiles)*

Contribution to MERCATOR / GODAE

From 70 to 100 profiles during yearly French cruises.





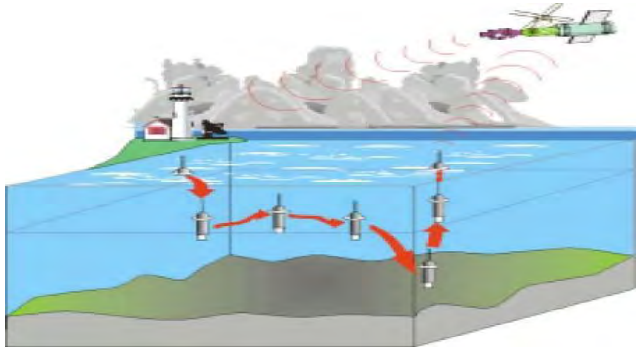
J.Grelet, IRD-Brest

From 2003 : deployment of ARGO profilers in the eastern Tropical Atlantic

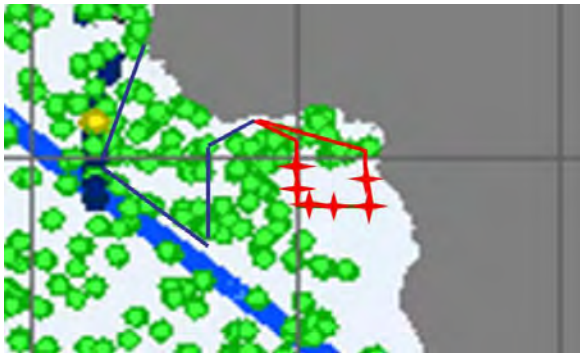
Contribution to ARGO, through CORIOLIS.

About 6-8 deployments during yearly French cruise.

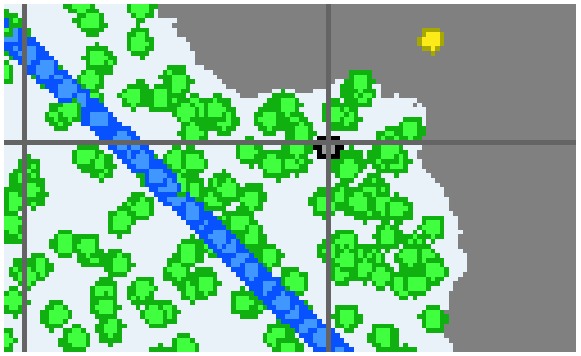
More than 80 profilers deployed from 2003



=> Data in poorly documented regions (Southeast)



April 2013



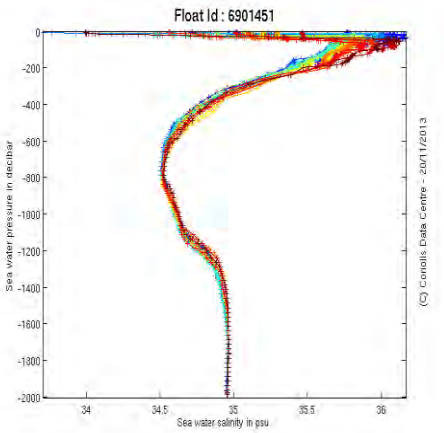
Sept 2013

Vertical resolution:

0-100m = 1m

100-200m = 5m

200-2000m = 25m

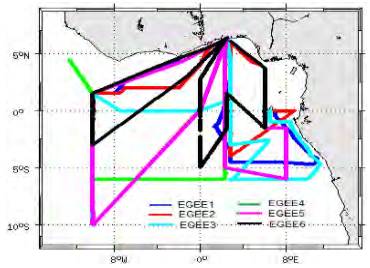


From 2013

<=> ARGO profilers with enhanced vertical resolution (1m)

From 2016

⇔ profilers with « double » programmation



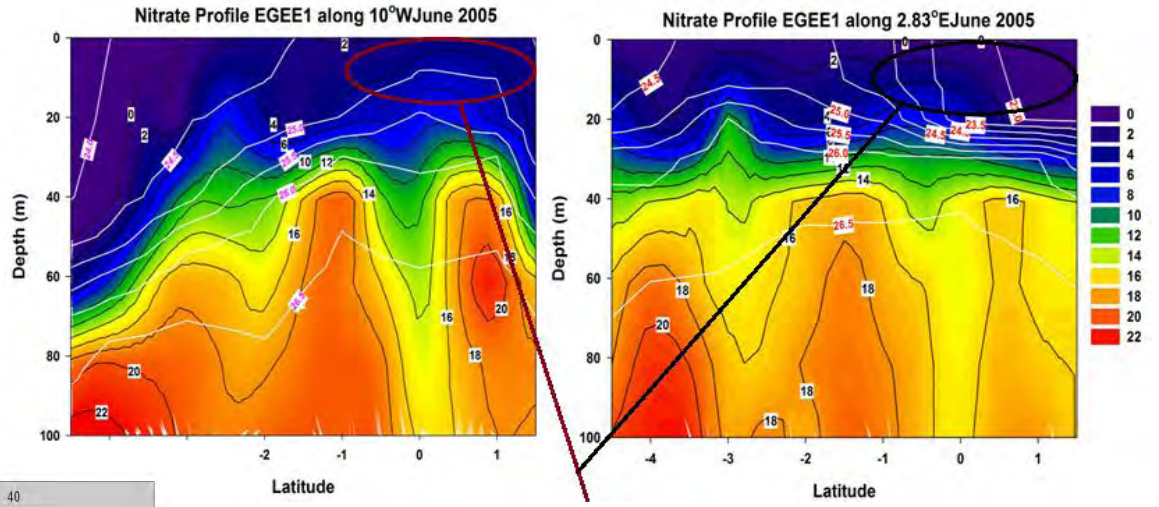
From 2004: measurement of nutrients in the eastern Tropical Atlantic

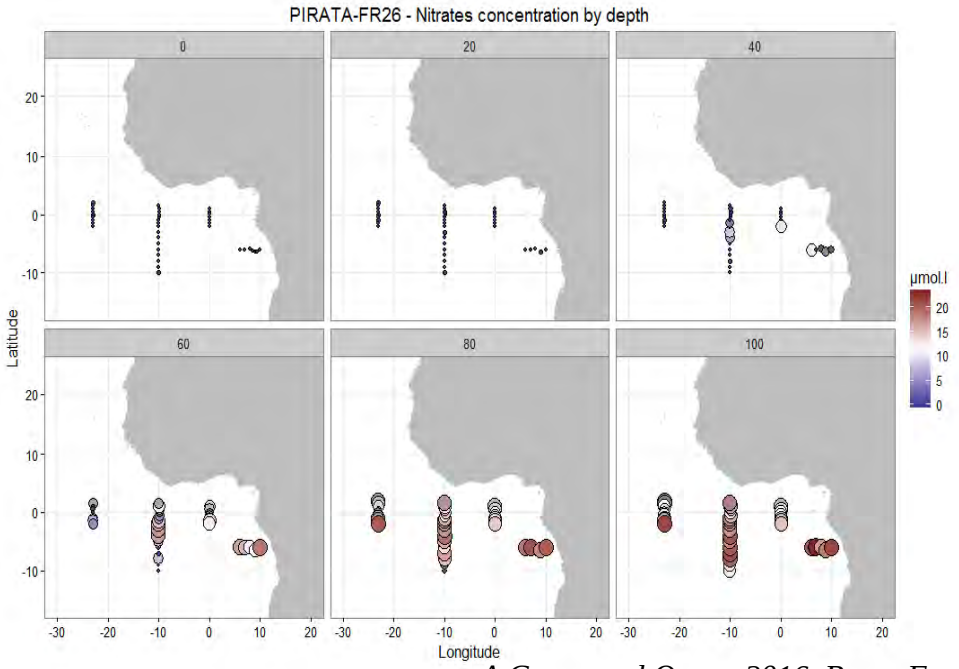
(Nitrates, Nitrites, Phosphates, Silicates)

Surface samplings along the trackline (every 1° - 2°)

Samplings along the vertical during CTDO2 casts

(F.Baurand, IRD-Brest)





Examples:

Up: Nitrate (µmol/kg) sections in June 2005 along 10°W and 3°E (from Nubi et al., 2016)

Down: Nitrate (µmol/kg) distribution at different depths In March-April 2016 (Habasque, IRD-Brest, pers. comm.)

Also: Fluorescence with Wetlab ECO FL sensor during CTD-O2 casts.

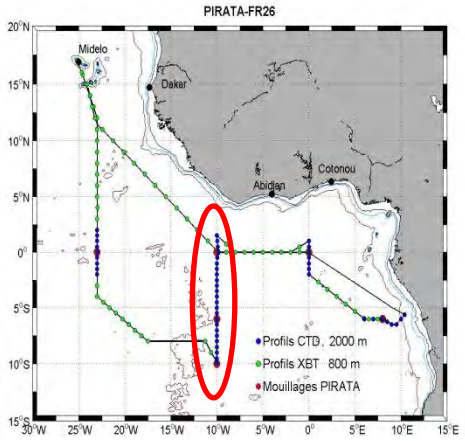
Surface salinity measurements along the trackline for Tsgraph data validation (CORIOLIS & GO-SHIP)

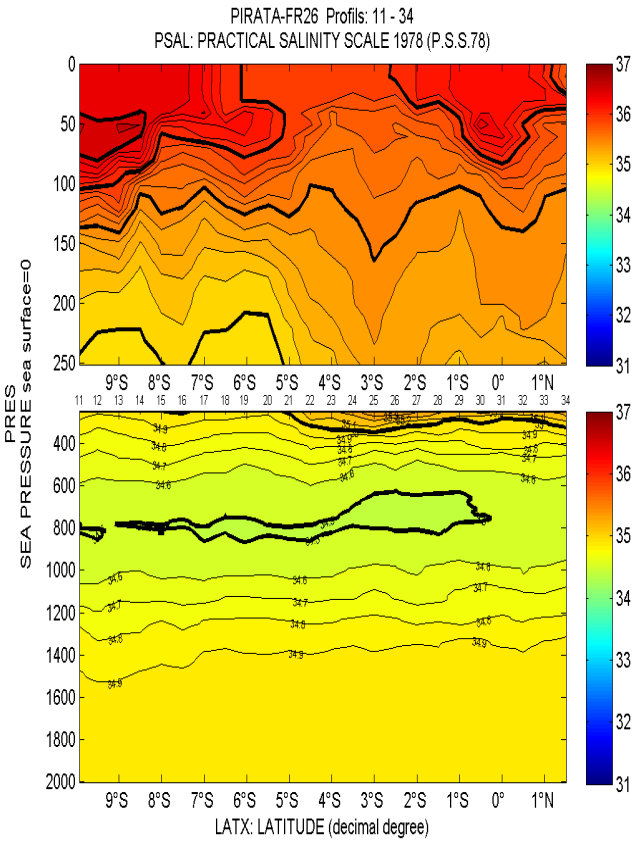
From 2005: acquisition of 0-2000m T/S & current profiles with CTD & Lowered ADCP in the eastern Tropical Atlantic

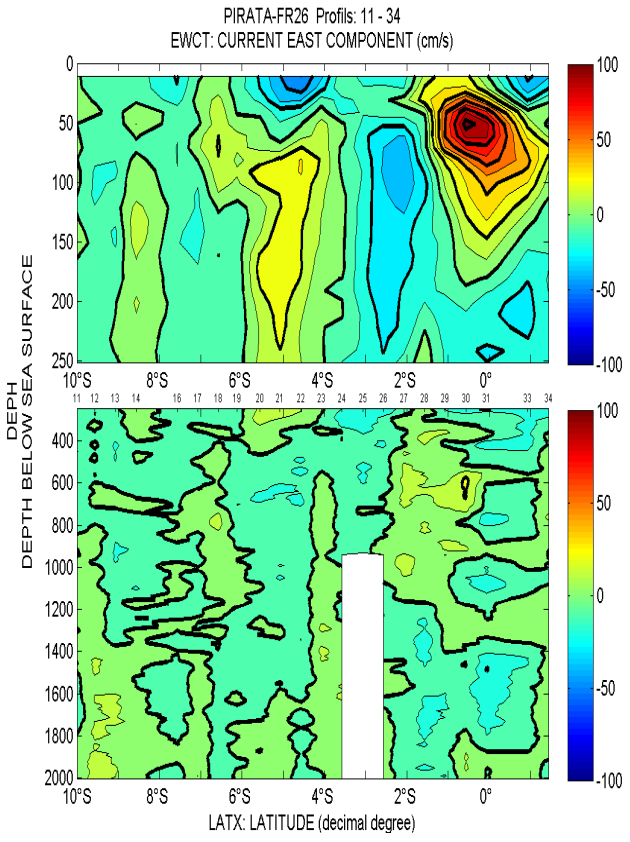
Goal: respond to the need of T/C measurements for ARGO profiles validation down to 2000m
$\Rightarrow$ 0-2000m CTD-O_2 and LADCP profiles along sections

Contribution to ARGO

Example:
10°W section in 2016:
S(z) & U(z)



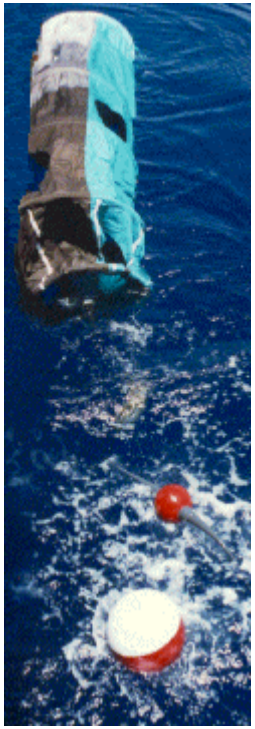




J.Grelet, IRD-Brest

From 2005: Deployment of surface profilers in the eastern Tropical Atlantic

(SVP, SVP-B, SVP-BS)



Contribution to Global Drifter Program (GOOS).

From 5 to 15 deployments per yearly French cruise.

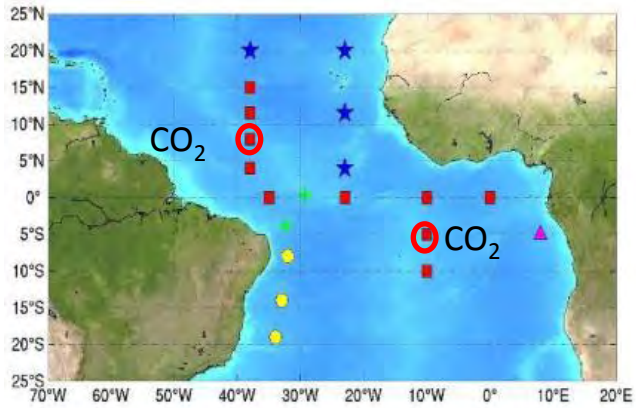
Through CNRS/INSU, Meteo-France, etc (& contribution to AtlantOS)

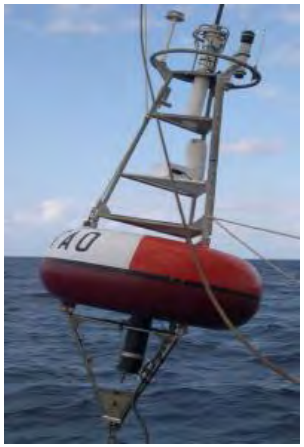
Example:
Trajectories of the 15
SVP-BS from their launch in March 2016
during PIRATA FR26,
as contribution to AtlantOS
(date: Sept 26, 2016; M. Le Garrec, pers. comm.)

From 2006: acquisition of CO2 parameters in the eastern Tropical Atlantic

1) CARIOCA systems added at the Buoys localed at 6°S-10°W (and at 8°N-38°W from 2008)

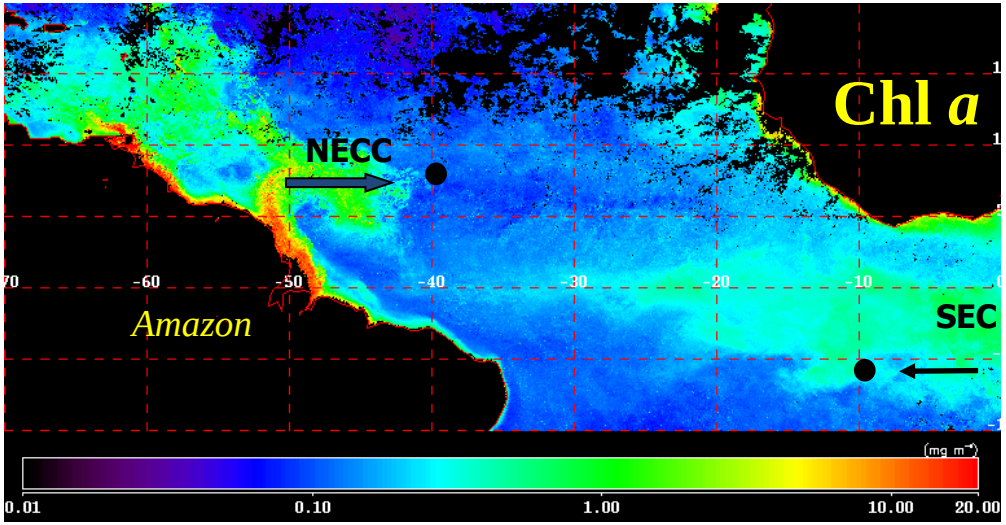
2) Surface samplings along the tracklines (every 1°- 2°) for TCO_2, TA





Samplings along the vertical (0-100m) during CTDO2 casts at the buoys

=> Amazon & Congo influences?



PI: N.Lefevre (IRD, Paris)

As part of PIRATA.

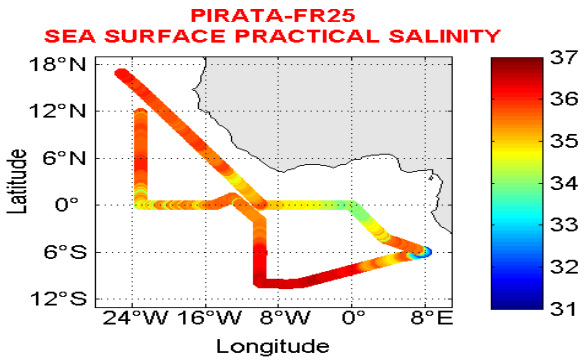
Contribution to CARBOOCEAN & CARBOCHANGE

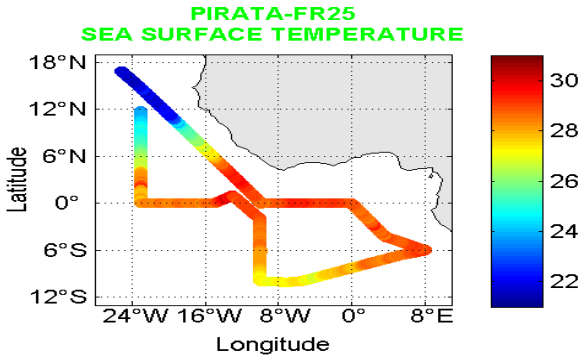
From 2011: Acquisition of Chl pigments in the eastern Tropical Atlantic

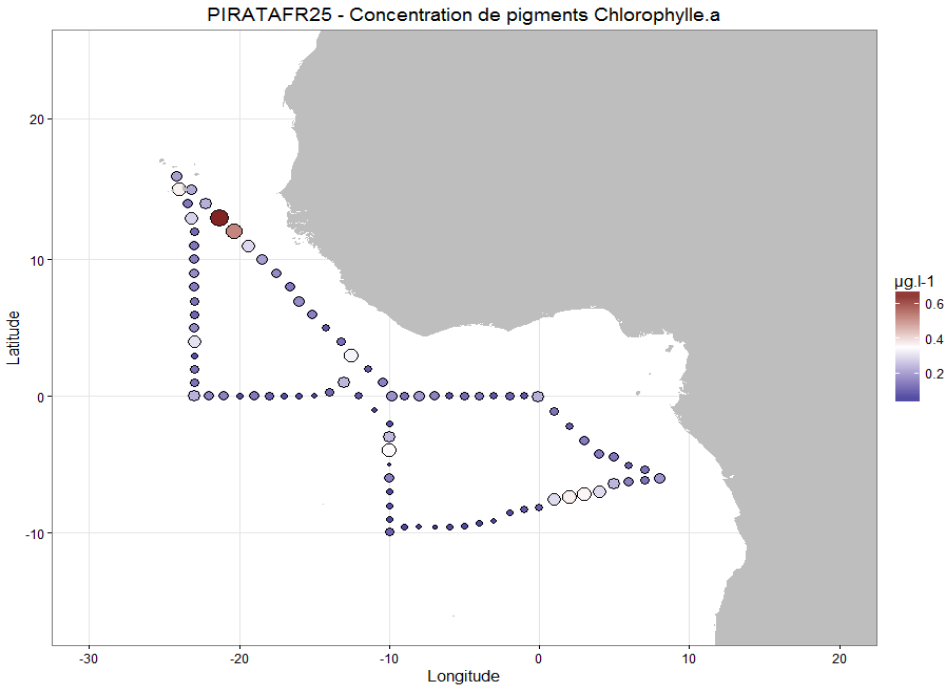
Surface samplings along the trackline (every 2°)

Samplings along the vertical during $CTDO_2$ casts

(S. Hillion, IRD-Brest)







Examples:

Up: Surface Chl pigments concentation during the PIRATA FR25 cruise -March/April 2015- (J.Habasque, IRD-Brest)

Left: surface SSS & SST along the PIRATA FR25 trackline (J.Grelet, IRD-Brest)

Occasional operations carried out in collaboration & thanks to PIRATA-Fr in the GG:

2005-2006 PIRATA & EGEE cruises : Helium measurements (PI: M.Rhein, Univ. Bremen)

=> mixing & upwelling vertical velocity.

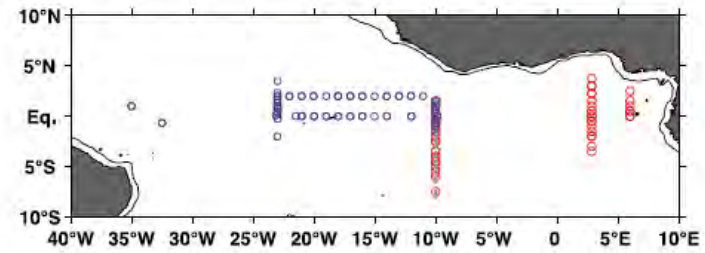


Figure 1. Conductivity temperature and depth stations with helium samples in the mixed layer: (red circles) cruise EGEE2, September 2005; (gray dots) cruise EGEE3, June 2006; and (blue circles) cruise M68/2, June 2006.

He isotopes ratio in the mixed layer
=> estimate of *w*

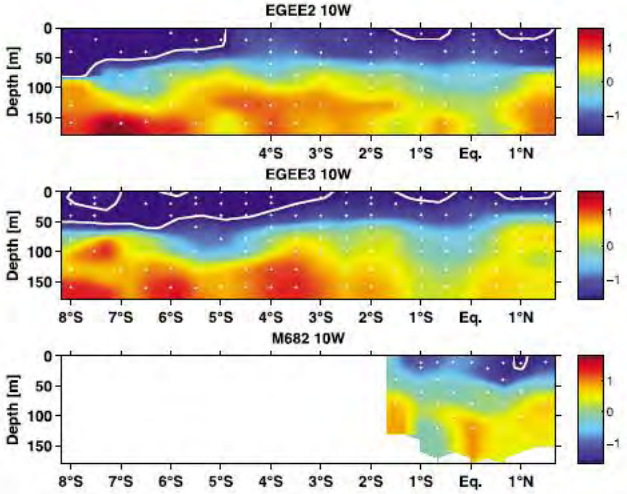


Figure 2. δ^3He (%) distributions at 10°W: (top) EGEE2, September 2005; (middle) EGEE3, June 2006; (bottom) M68/2, June 2006. The white lines follow δ^3He (%)= −1.6%, the equilibrium ratio in surface water for tropical temperatures.

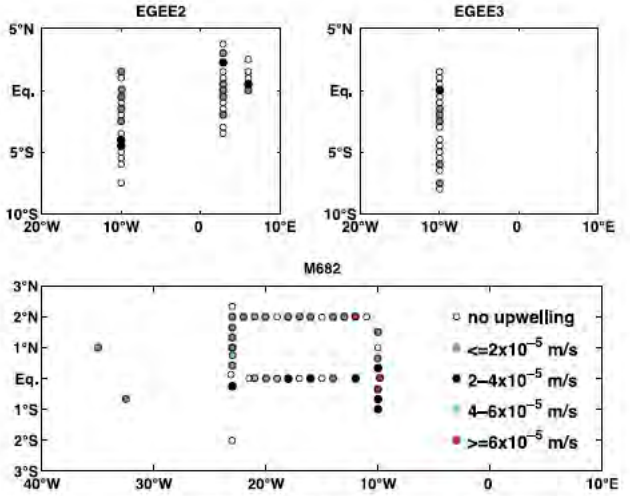


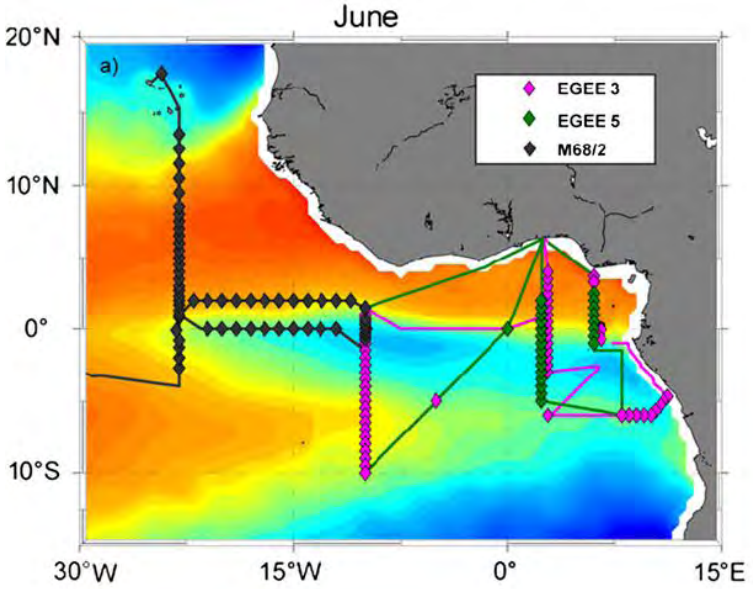
Figure 7. Upwelling velocity *w* for (left) cruise EGEE2, September 2005, (right) cruise EGEE3, June 2006, and (bottom) cruise M68/2, June 2006.

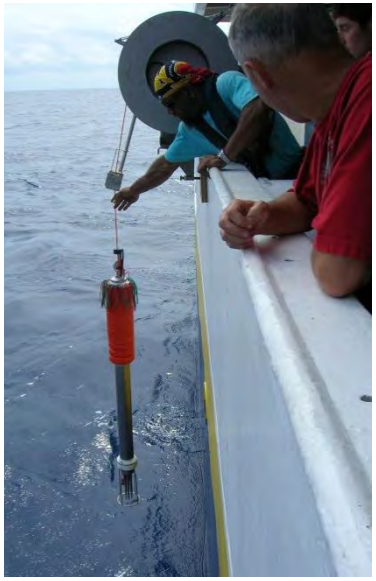
(from Rhein et al., 2010)

Occasional operations carried out in collaboration & thanks to PIRATA-Fr in the GG:

2005-2007 PIRATA & EGEE cruises : MSS microstructure profiles (PI: GEOMAR)

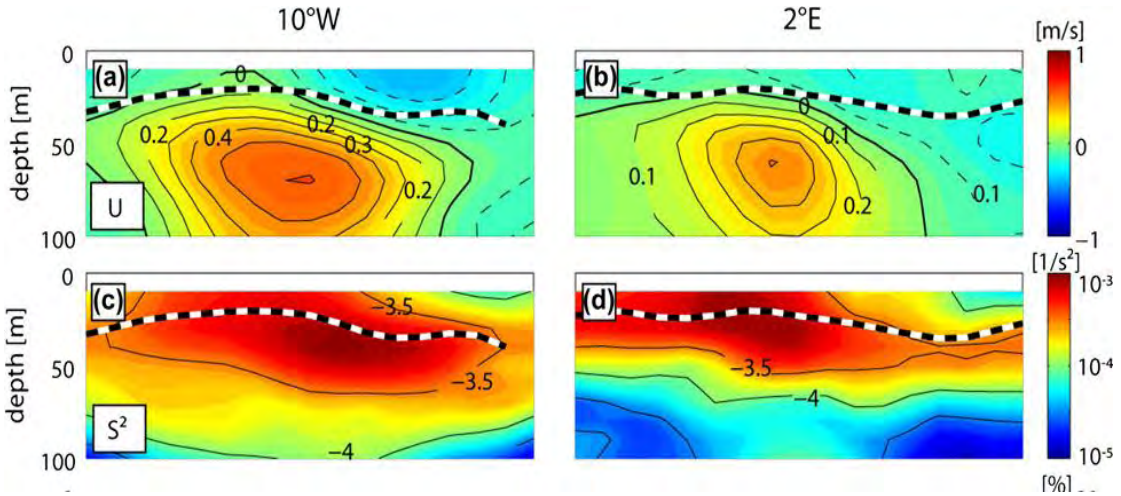
=> turbulence & mixing processes.





Mean sections of zonal velocity (a and b), shear variance (c and d), along 10W(left panels) and 2E (right panels). The average section at 10Wis compiled from 13 cruises, whereas the 2E average was compiled from 4 cruises (Table 1). The black and white line denotes average MLDs.

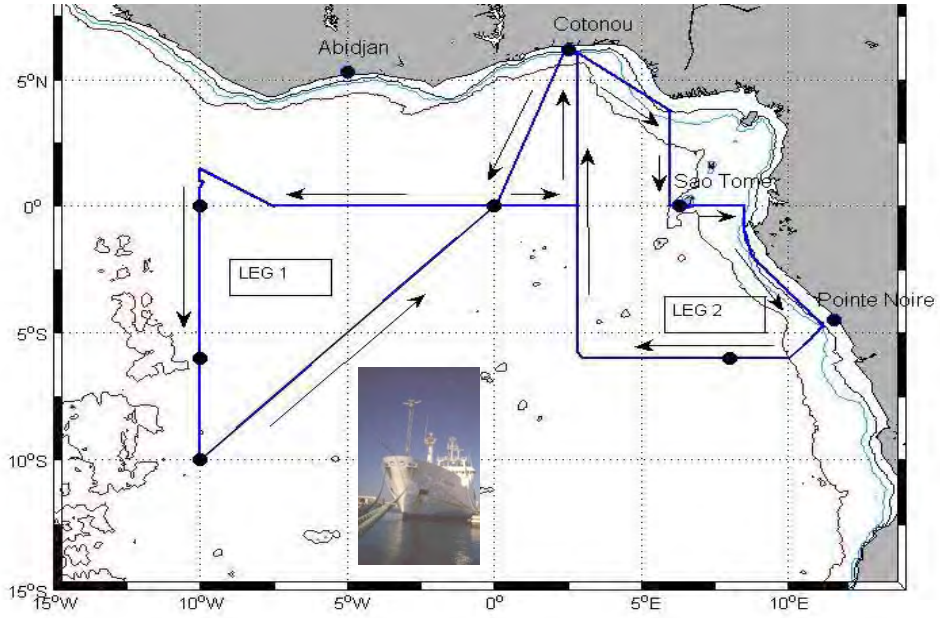
(from Hummels et al., 2013)



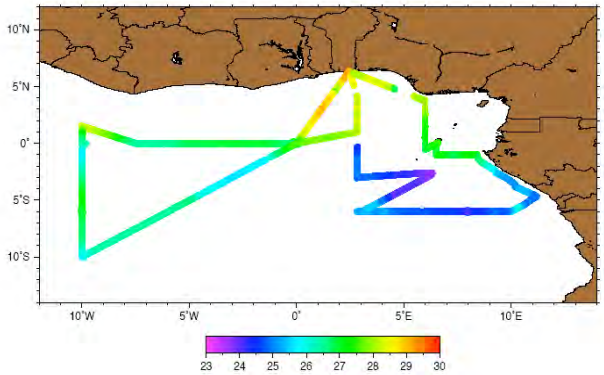
Occasional operations carried out in collaboration & thanks to PIRATA-Fr in the GG:

2006: the PIRATA-FR15 / EGEE3-AMMA cruise *(May-July)*:

atmospheric measurements, biochemistry, skin SST, light penetration, plancton…



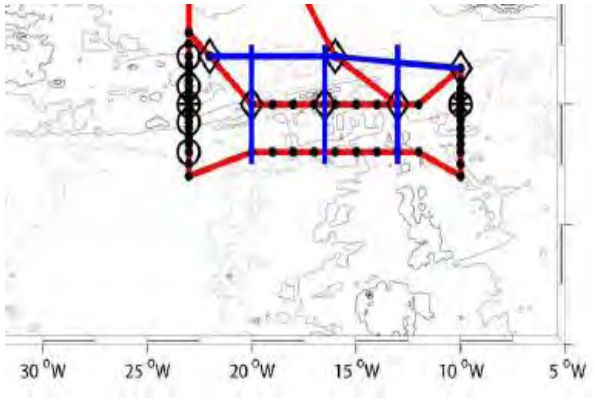
MAERI-3 Skin Temperature
(26.05.2006 - 02.07.2006)



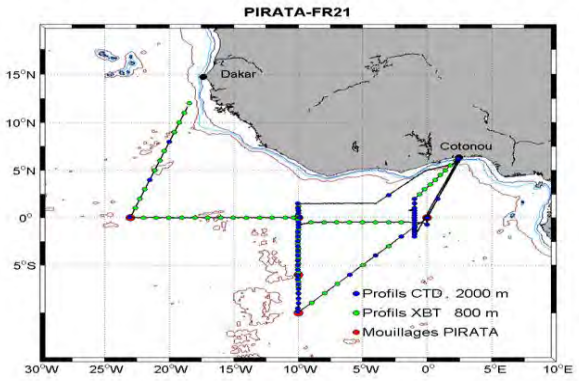
Occasional operations carried out in collaboration & thanks to PIRATA-Fr in the GG :

PIRATA FR21 (Ma-June 2011) : Gliders operations (coll. with GEOMAR)

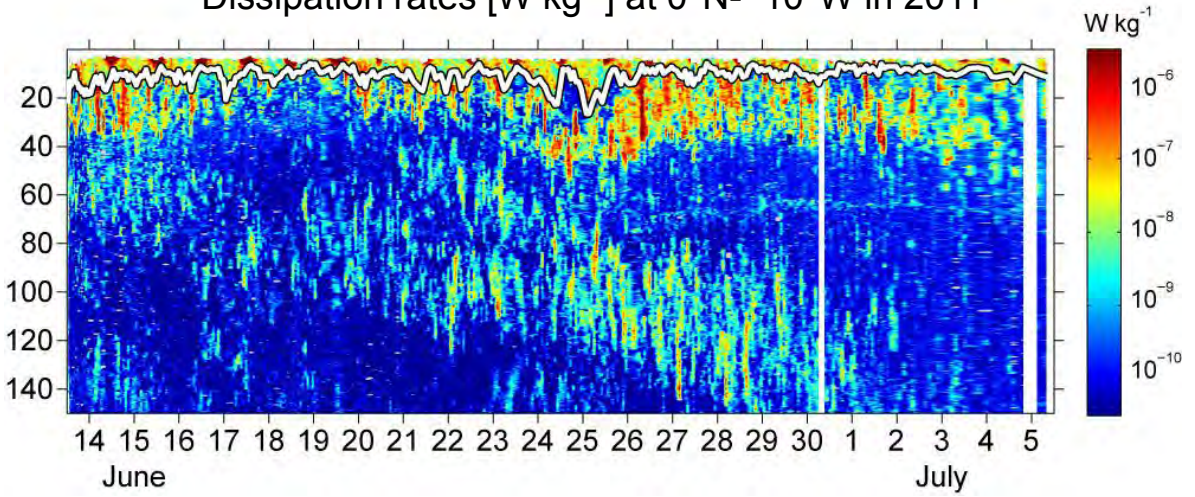
IFM-GEOMAR cruise : May 11-June 19, 2011



PIRATA FR 21 cruise : May 1-June 16, 2011



Dissipation rates [W kg^{-1}] at 0°N- 10°W in 2011

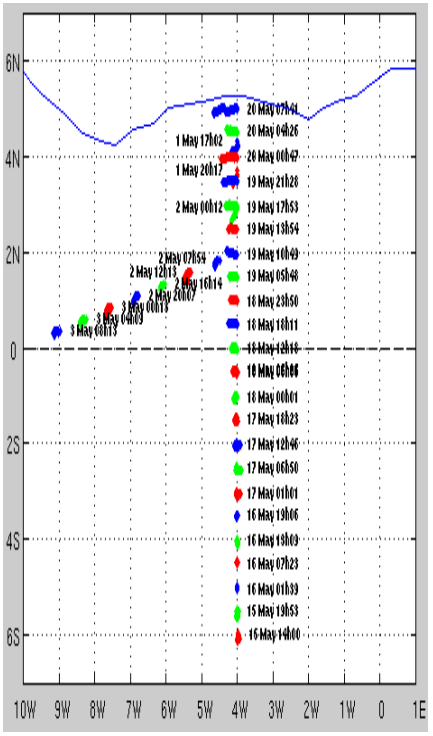


Courtesy P.Brandt & M.Dengler

Occasional operations carried out in collaboration & thanks to PIRATA-Fr in the GG :

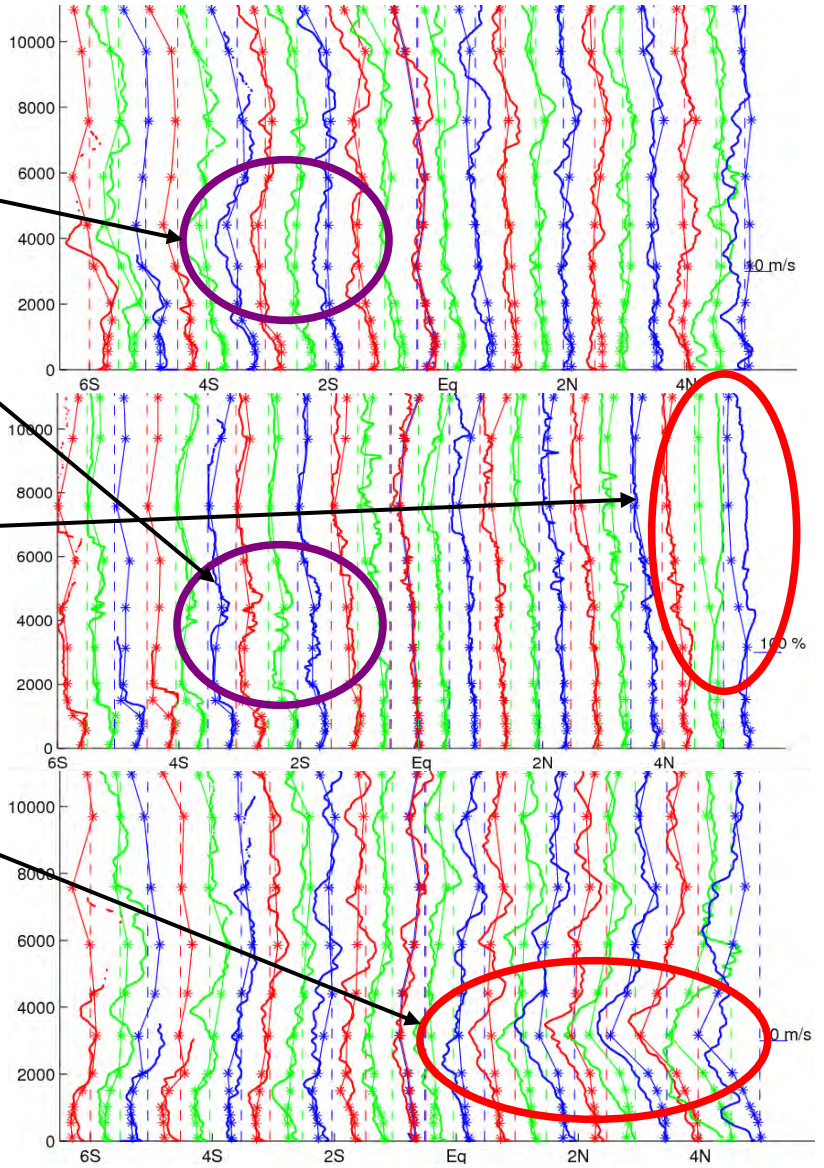
PIRATA FR24 (May 2014) : 34 radiosondes (2014 LEFE-INSU; PI: *G. de Coetlogon, Latmos/FR*)

RS confirm a low-level northerly flow (~4000 m) largely underestimated in the op. analysis, with corresponding increased RH.



Small rainy episodes in the end not « seen » in op. analyses.

Speed of the Eastern African Jet also largely underestimated !

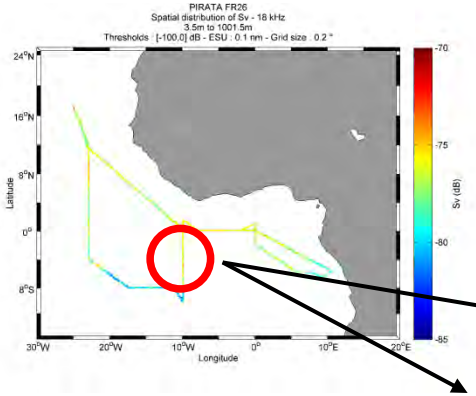


Stars mark profiles found in op. analysis. RS not assimilated

Occasional operations carried out during PIRATA-Fr in the GG :

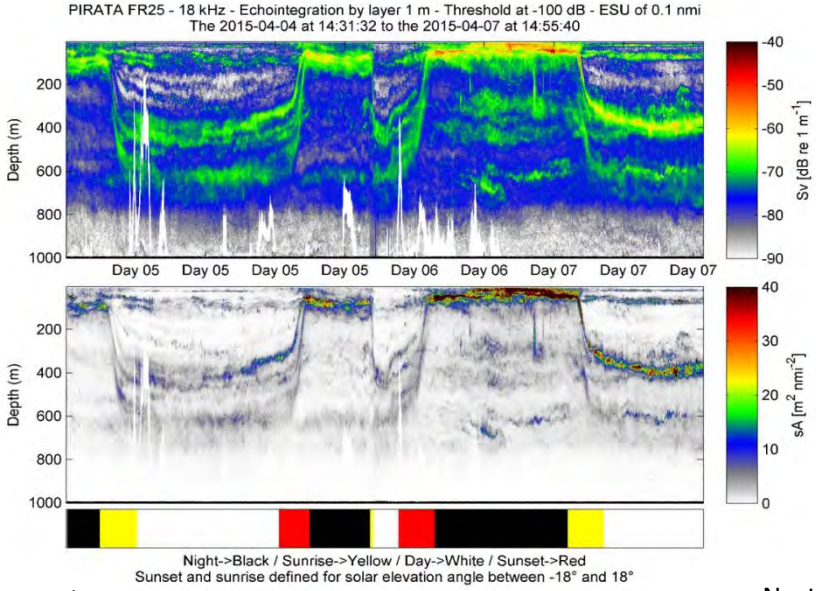
From 2015 *(but depending upon the research vessel equipment)*: Acoustic measurements

R/V Thalassa => Multifrequency acoustic data (18, 38, 70, 120, 200 and 333 kHz)
=> information on biotic and abiotic ecosystem components.

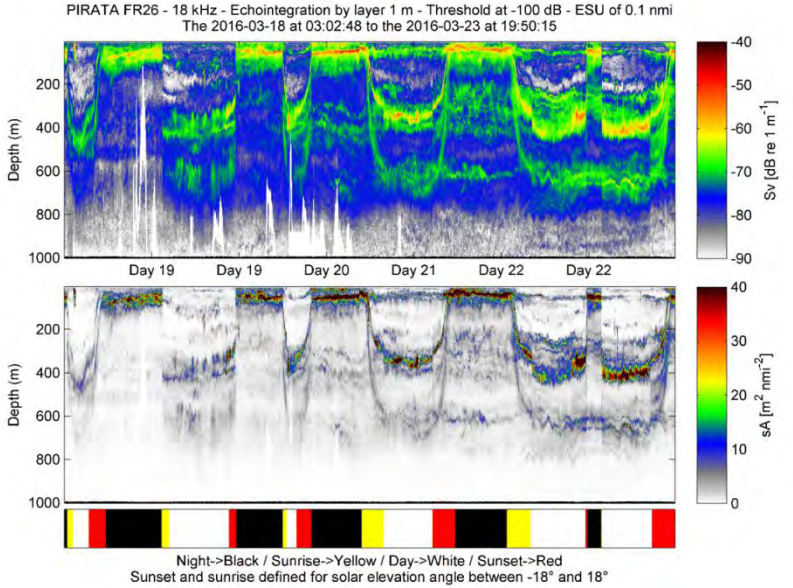


⇒ Analysis of the pelagic organism spatial organization, the planktonic biodiversity, as well as upper trophic level marine organisms in relation with ocean conditions in contrasted regions (fronts, upwellings, currents shear…) + diel vertical migration.

2015



2016



South → North

(J.Habasque, IRD-Brest)

reinforce and maintain needed observations in the Gulf of Guinea

Following PIRATA, CLIVAR and PREFACE scientific requirements/recommendations

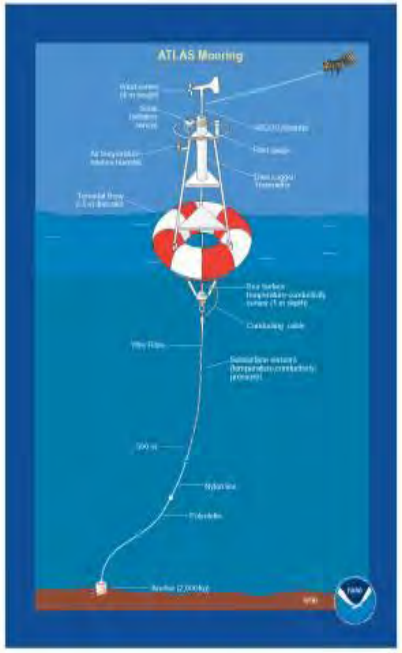
PIRATA met-ocean observation:

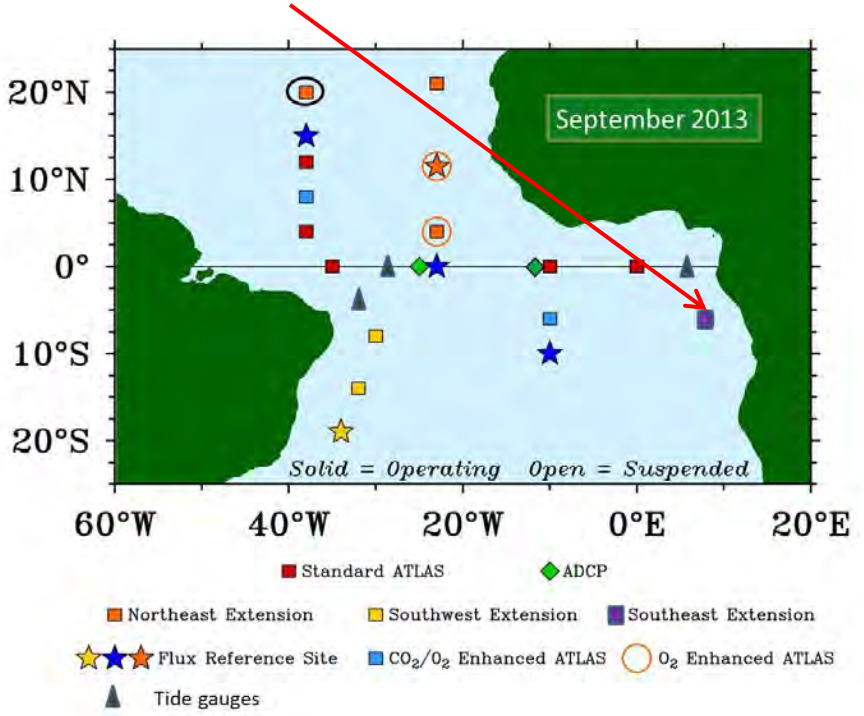
=> the PIRATA South-Eastern Extension (2006-2007 & from 2013)

2nde needed buoy funded by PREFACE (EU FP7)

Deploiement done on June 13, 2013

This PIRATA SEE is now maintained, as part of the PIRATA network.





reinforce and maintain needed observations in the Gulf of Guinea

Following PIRATA & CLIVAR (TACE) scientific requirements/recommendations

Upper layer equatorial currents:

From 2001: 1 ADCP mooring already maintained at 23°W-0°N

⇒ From 2005: a 2nde ADCP mooring maintained at 10°W-0°N (by IRD)

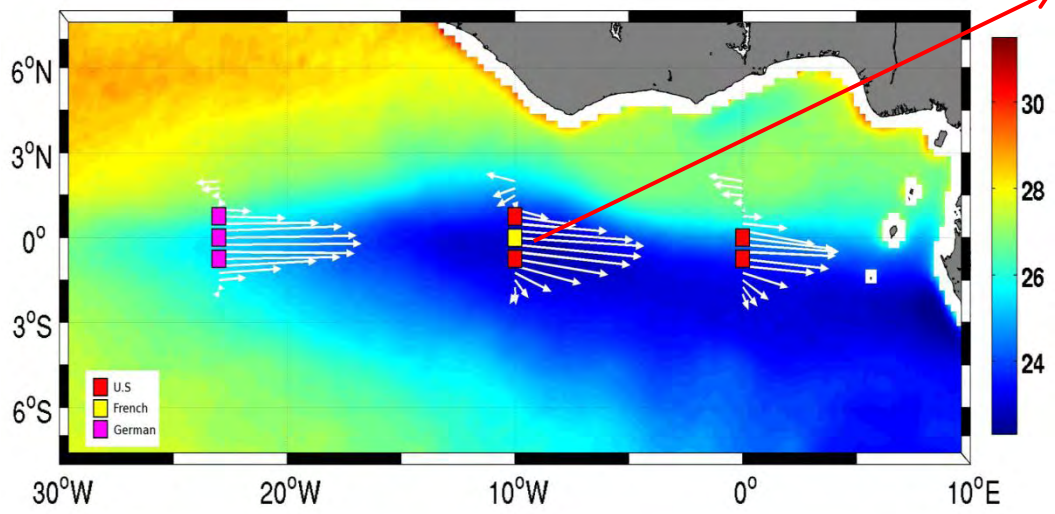
in the frame of EGEE/AMMA then PIRATA-Fr

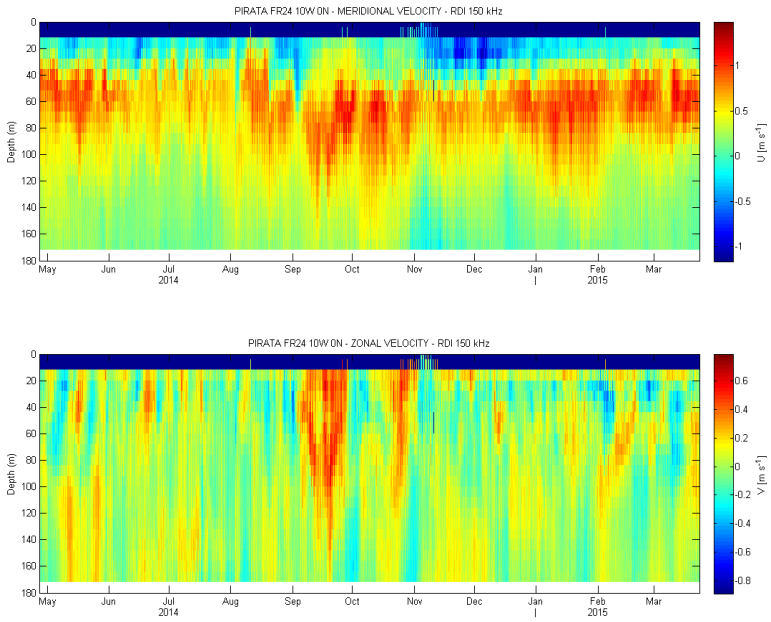
=> From 2016: a 3rd ADCP mooring at 0°E-0°N

in the frame of PREFACE & PIRATA-Fr

⇒ 3 equatorial ADCP moorings:

⇒ 23°W-10°W-0°E => EUC monitoring,
SEC/EUC vertical shear, waves,…





J.Grelet, J.Jouanno, J.Habasque, IRD

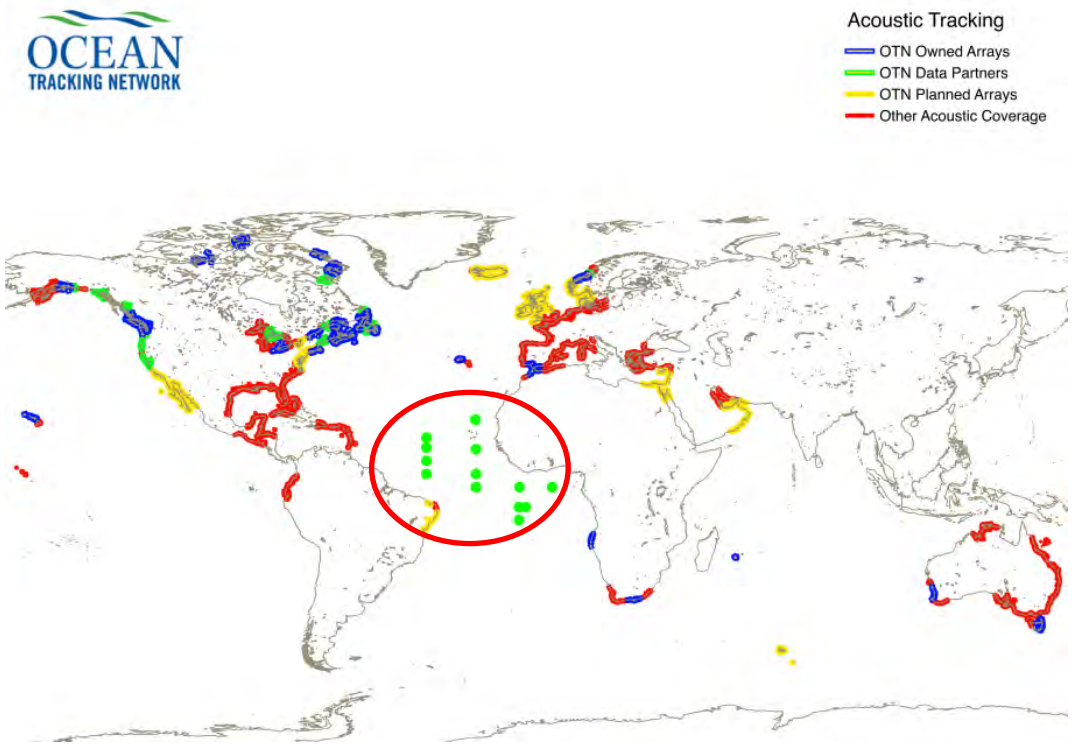
(Kolodziejczyk et al., 2009; Johns et al., 2013; Perez et al., 2014…)

reinforce and maintain needed observations in tropical Atlantic:

PIRATA as a platform for other international programs

From 2014: contribution to Ocean Tracking Network (OTN; *PI: F. G. Whoriskey*)

=> placement & maintenance of acoustic receiver units on the 18 buoys at 200m depth for tracking the movements and survival of tagged marine animals

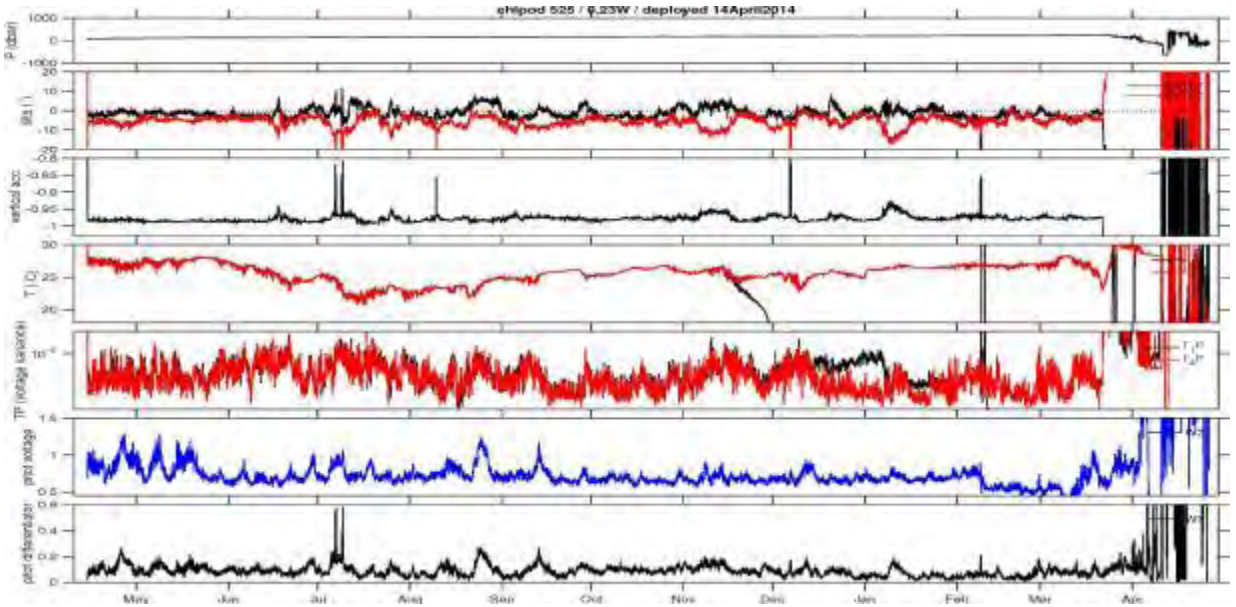


reinforce and maintain needed observations in tropical Atlantic:

PIRATA as a platform for other international programs

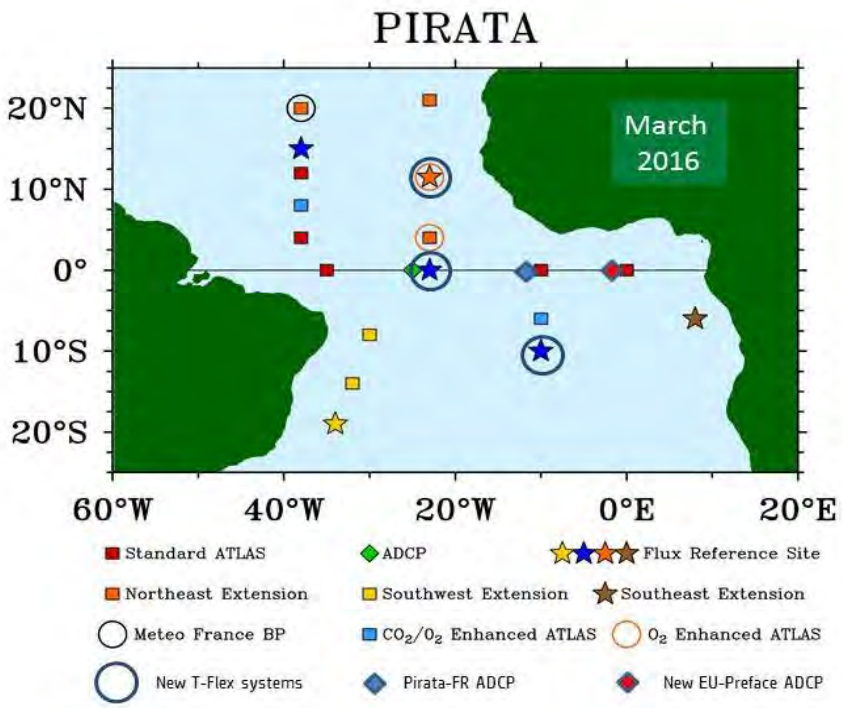
From 2014: contribution to a 5-years program (*USA/NSF)*
of oceanic turbulence measurements (*χpods*; *PI: J.Moum*)

=> placement & maintenance of 10 *χ*pods on 2 buoys at 23°W & 10°W-Equator
(at 21, 35, 50, 65 & 81m depth on each)



Some first « Pirata » time series from χpods, at 23°W-0°N April 2014- April 2015.

PIRATA present & short term enhancements



From 2015:

Progressive replacement of ATLAS system
By T-FLEX systems:

⇒ More real-time data (Iridium transmission)
⇒ Potentially more sensors

- 3 new T-FLEX systems installed in late 2015 and 2016 at 12N-23W, 0N-23W & 10S-10W

Data available on:
http://www.pmel.noaa.gov/pirata/tflex/

In the frame of the AtlantOS : enhancements expected from 2017

- 3 currentmeters at 10W-0N, 38W-8N & 35W-0N (at 10m) (IRD/LEGOS)
- 2 T/C at 10W-0N (at 5m & 10m) (IRD/LEGOS)
- O2 at 23W-4N and 23W/11.5N with RT data transmission (GEOMAR)
- CO2 at 8E-6S (IRD/LOCEAN)

Concluding remarks *(before thinking to the future of PIRATA…)*:

- PIRATA achieved a considerable work from its early steps…
  and is recognized as "*the backbone for observations in the Tropical Atlantic for both climate research and operational climate and ocean prediction*" *(CLIVAR)*

Increasing enhancement demands (AtlantOS, CLIVAR…):

e.g. biochemistry sensors, aerosols, O_2, CO_2, currents, fluxes, time series in the South…

To keep in mind :

- vessel time, funding resources & human power limited (*some are decreasing!*...)
- data still « sleeping »… or not validated yet (*human power!*...).

⇒ **Before extensions/enhancements *(ref. AtlantOS D3.19 deliverable)*, think to:**

- PIRATA (or non PIRATA) data scientific use :
  are existing data until now already well used & valorized?
  (⇔ additional sensors have to be fully justified!).

⇒ Additional sensors/buoys have to be conditioned by
needed related funding resources & human power support
(at sea & before/after!).

=> PIRATA long term sustainability (from feasibility to some issues…)

PIRATA present network sustainable:

- PIRATA partners (USA, Brazil, France) committed through a MoU (-> 2019)
- No sign for stopping it after 2019, but MoU to be rewritten/modified by 2019 with PIRATA commitments for potential enhancements and extensions…

PIRATA actual enhancements that could be maintained without major issues:

- Additional classical sensors (EOVs: T, S, currents, atmospheric param.)
- OTN
- Turbulence (Xpods); at now, until 2019 (US/NSF supported program).
- classical CTDO2/LADCP profiles, XBT, ARGO and sea water samplings (*e.g.* for French PIRATA-FR cruises: S, O2, nutrients, CO2, ChL pigments)
- ADCP moorings (at least 23W-0N, 10W-0N; the 0E-0N is questionable…).

- **Main issues for the long term enhancements:**
  - Vessel time (if additional buoys…)
  - Human power (key issue; data treatment & validation; operations at sea)
  - National fundings (key issue; costs are growing up!)

MERCI / THANKS / OBRIGADO

PIRATA data management

ATLAS meteo-oceanic buoys:

- transmission and available in real time (24h averaged & transmission every 24h)
- validated data, a few months after yearly servicing (high frequency data)

http://www.pmel.noaa.gov/pirata/

& New T-FLEX buoys at 3 PIRATA sites (1h averaged & transmission every 6h)

http://www.pmel.noaa.gov/pirata/tflex/

YEARLY CRUISES data:

French site: http://www.brest.ird.fr/pirata/

US site: http://www.aoml.noaa.gov/phod/pne/

Brazil site: http://pirata.ccst.inpe.br/en/home/ *(all raw data sets; data treatment expected by 2017, INPE & UFPE involved)*

CO2 data : through SOCAT database (WP7) ; international CO_2 community protocol.

O2 data : in "quasi" real time is planed at term at GEOMAR.

Additionnal info about PIRATA French cruises & data:

- All PIRATA cruises have a D.O.I.; *http://dx.doi.org/10.18142/14*
- S-ADCP data have a D.O.I. (2007-2016); *http://doi.org/10.17882/44635*

How works PIRATA ?

PIRATA structure & responsabilities sharing:

1) **PIRATA Resources Board**: => committee with one representative of each organism
⇒ 1 from NOAA/USA ; 1 from INPE ; 1 from IRD/France & 1 from Meteo-France/France

=> Major tasks:

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.

2) **PIRATA Steering Scientific Group**: *3 members of each initial country (Br, Fr, USA) + 1 of Germany (GEOMAR, from 2008).*

=> Major tasks :

To ensure accomplishment of the scientific and technical objectives ;
To coordinate the technical and logistic support necessary to maintain the array;
To invite collaborations with other nations and institutions…;
To cooperate with international organizations ;

Good & efficient collaborations & cooperation => possible enhancements!