

The background image shows a large white research vessel with a red hull, identified as the O.R.V. Sagar Nidhi, sailing on the open ocean. To the right of the vessel, a moored buoy with a white top and orange bottom is visible. The sky is clear and blue.

Annual Report of the  
**Tropical Moored Buoy  
Implementation Panel**  
to the  
**32nd Session of the  
Data Buoy Cooperation Panel**

**October 17-21, 2016  
La Jolla, CA  
USA**

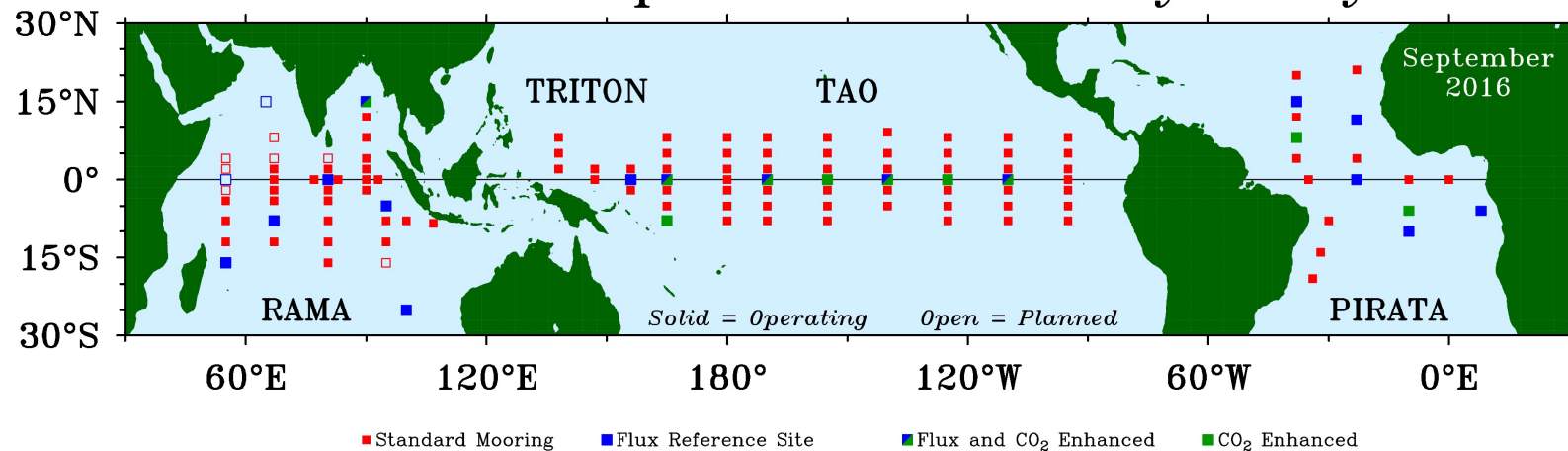
**Ken Connell, NOAA/PMEL**

**Ken Ando (JAMSTEC), Kathleen O'Neil (NOAA/NDBC), Weidong Yu (FIO), Vadlamani Murty (NIO),  
Mike McPhaden (NOAA/PMEL), Rick Lumpkin (NOAA/AOML), Paul Freitag (NOAA/PMEL)**

**Global Tropical Moored Buoy Array:**  
*A coordinated, sustained, multi-national effort to develop and implement moored buoy observing systems for climate research and forecasting throughout the global tropics*



## Global Tropical Moored Buoy Array



TAO Project Office, NOAA/PMEL

**A contribution to GOOS, GCOS, and GEOSS**

# Global Tropical Moored Buoy Array

## Moorings:

Surface and sub-surface met-ocean sensors measuring:

- **Surface:** wind, air temperature, relative humidity, SST, and SSS on all surface moorings. Air pressure, precipitation, short wave radiation, long wave radiation on some surface moorings.
- **Sub-surface:** temperature profiles down to 500m on all surface moorings. Salinity profiles down to 120m on some surface moorings. Current velocity on some moorings.

## Implementation:

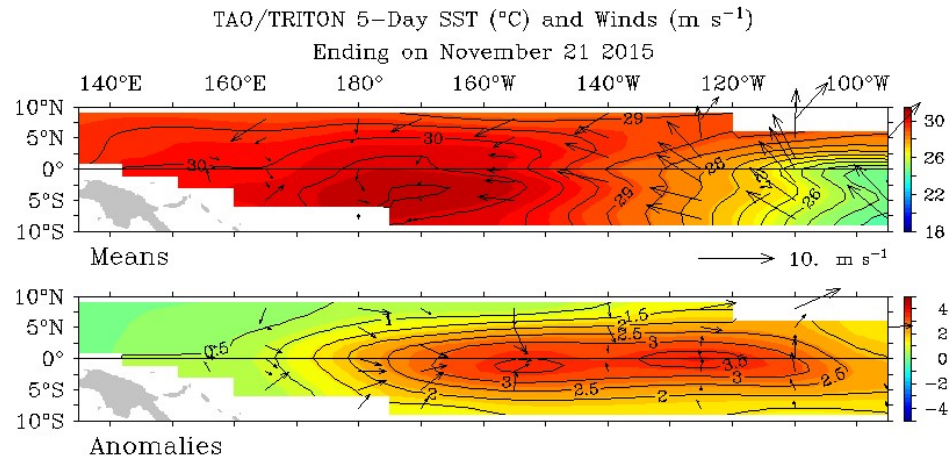
- **TAO/TRITON:** Tropical Pacific Ocean: 67 moorings (100% implemented)
- **PIRATA:** Tropical Atlantic Ocean: 19 moorings (100% implemented)
- **RAMA:** Tropical Indian Ocean: 46 moorings (78% implemented; 36 of 46)



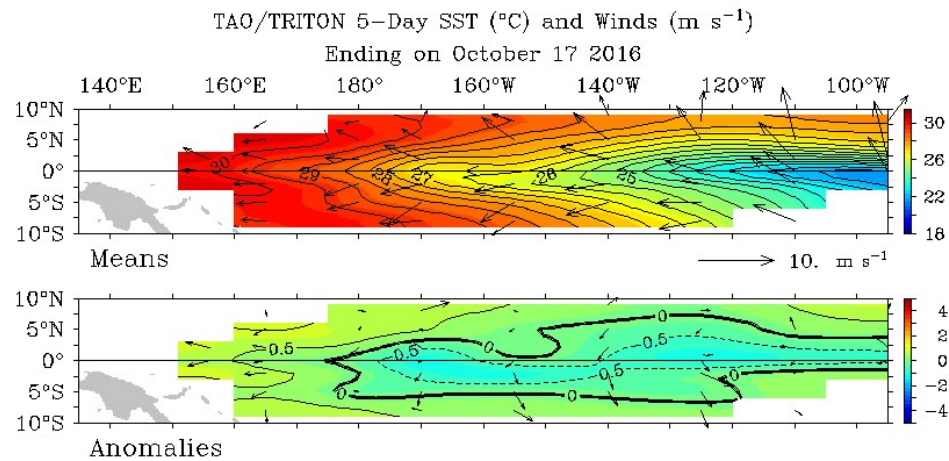
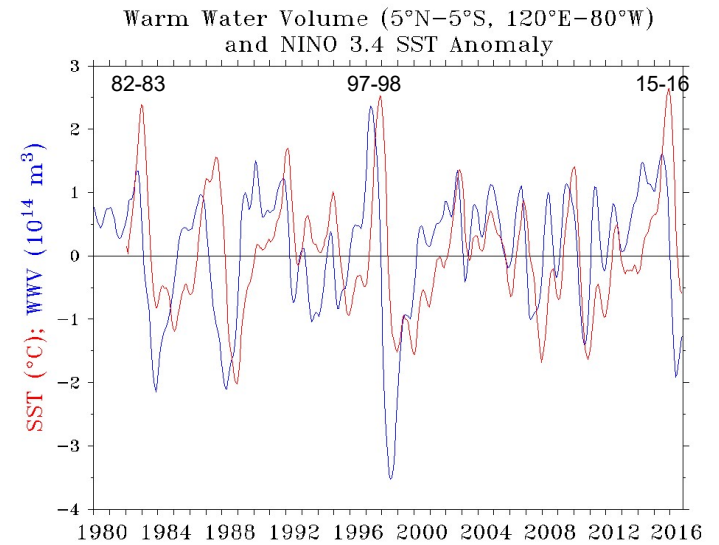


# TAO/TRITON

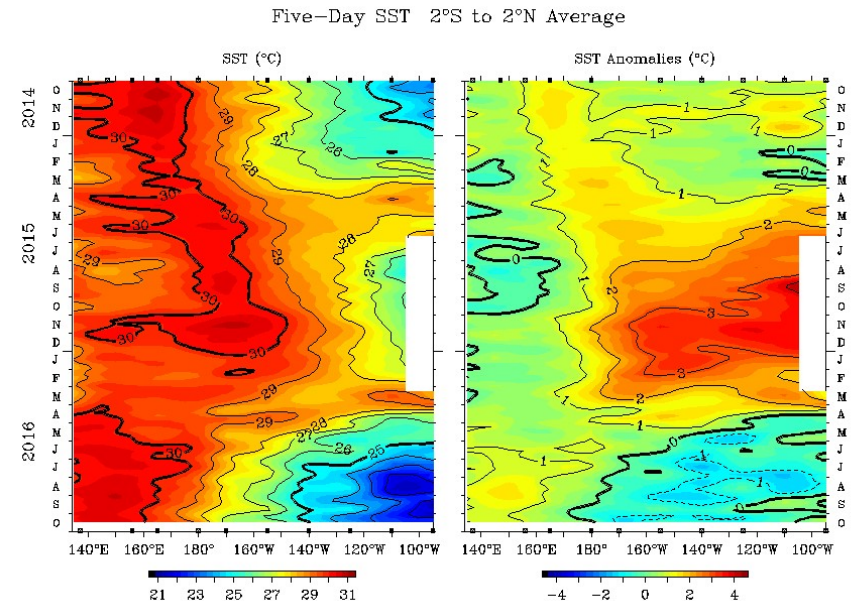
## 2015-16 Major El Niño



TAO Project Office/PMEL/NOAA



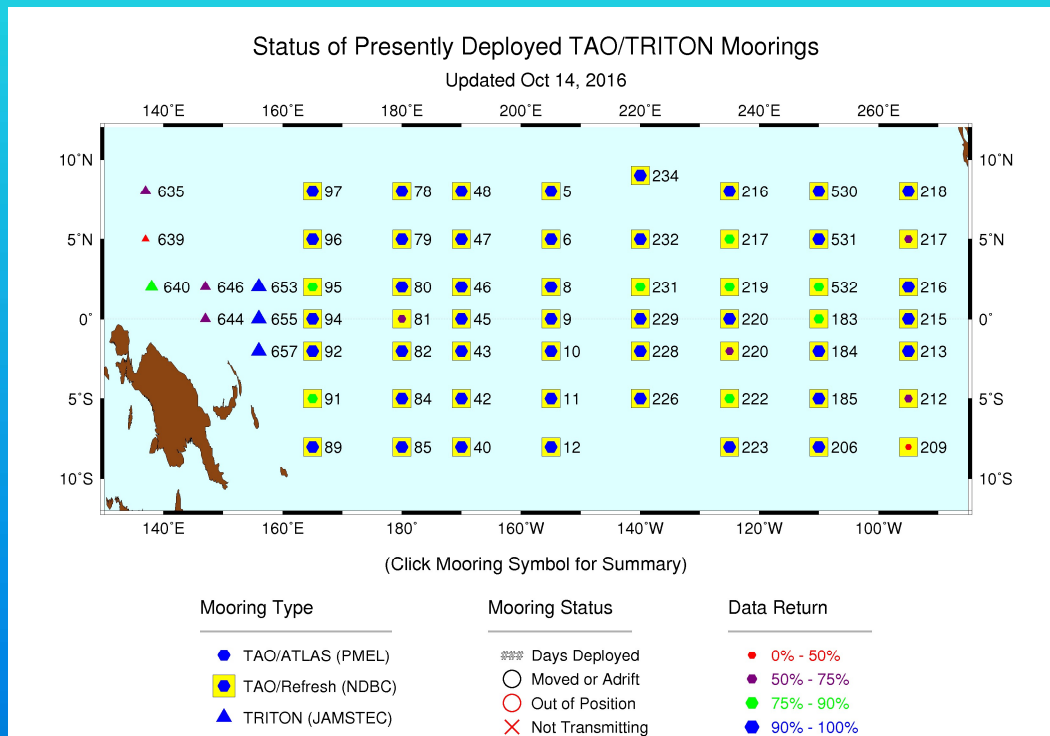
TAO Project Office/PMEL/NOAA



TAO Project Office/PMEL/NOAA

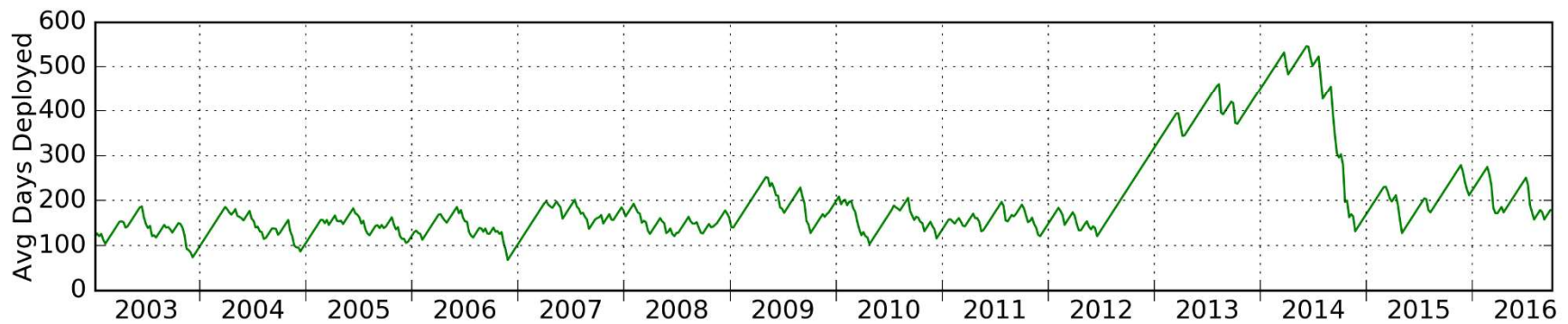
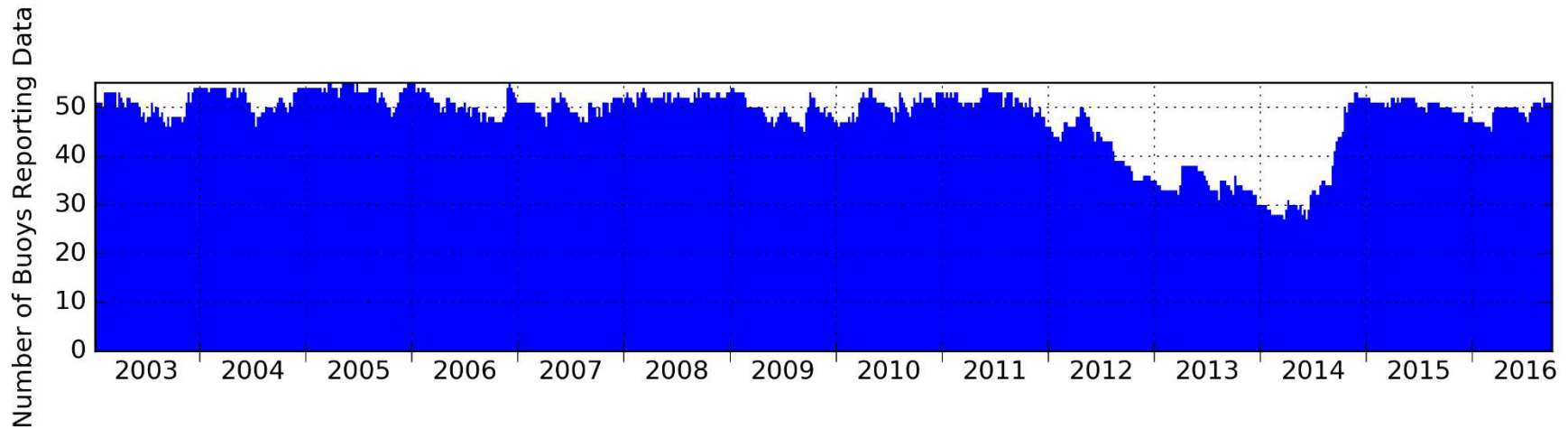
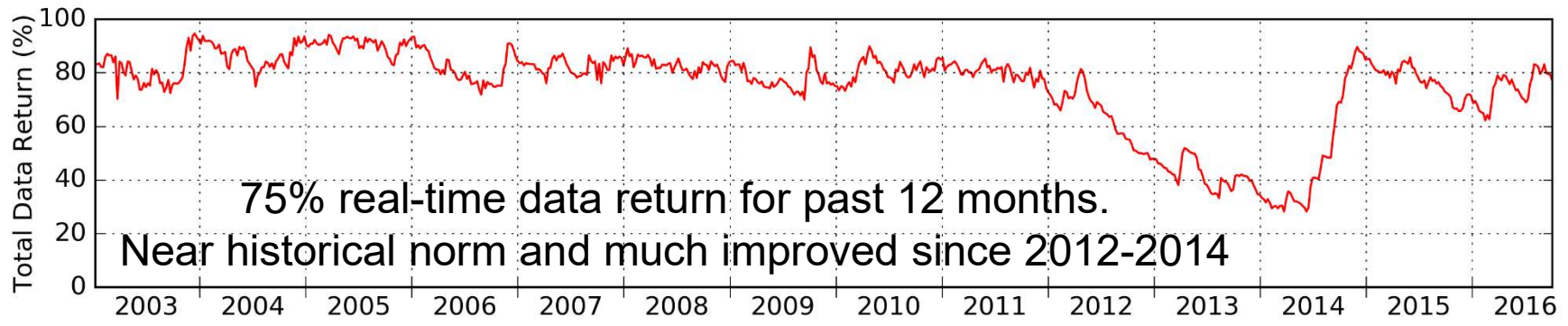
Oct 18 2016

# TAO/TRITON Status and Data Return

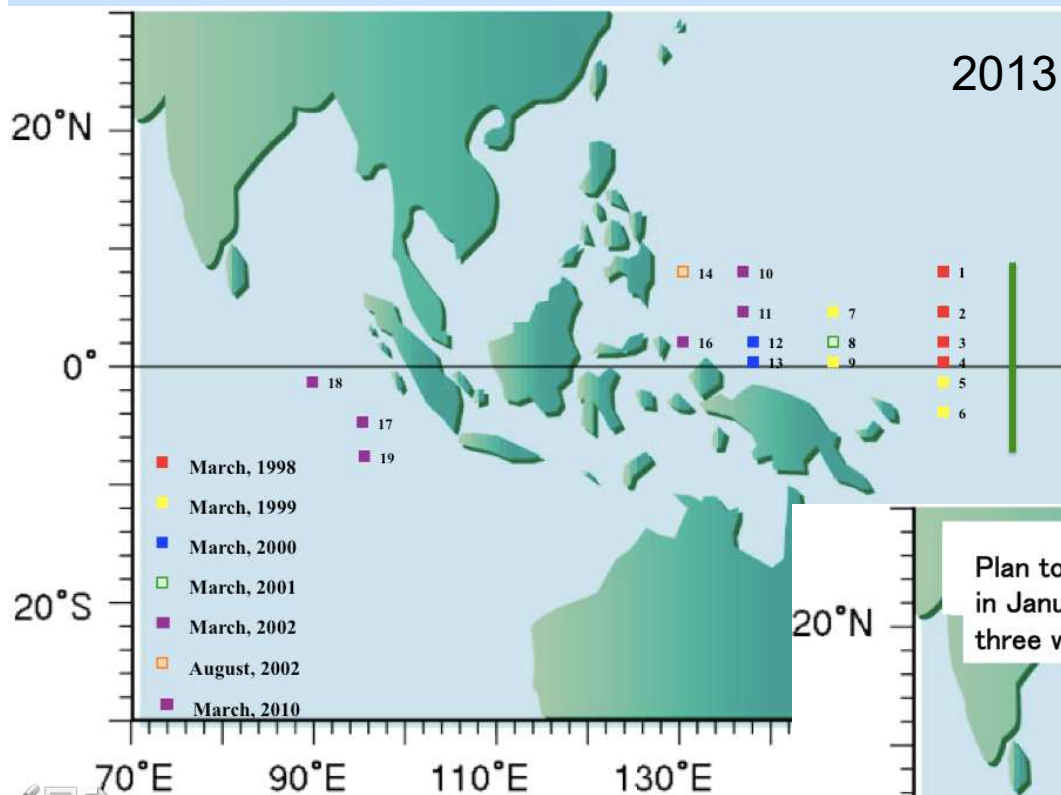


- 55 of 55 TAO moorings replaced in past year
- 54/55 sites returning data
- Data return from 28 TAO and 3 TRITON moorings  $\geq 80\%$  over past year.
- NDBC TAO Refresh systems occupy all TAO sites
- 4 of 12 TRITON sites retired
- 6 more (10 of 12) TRITON sites scheduled to be retired in 2017

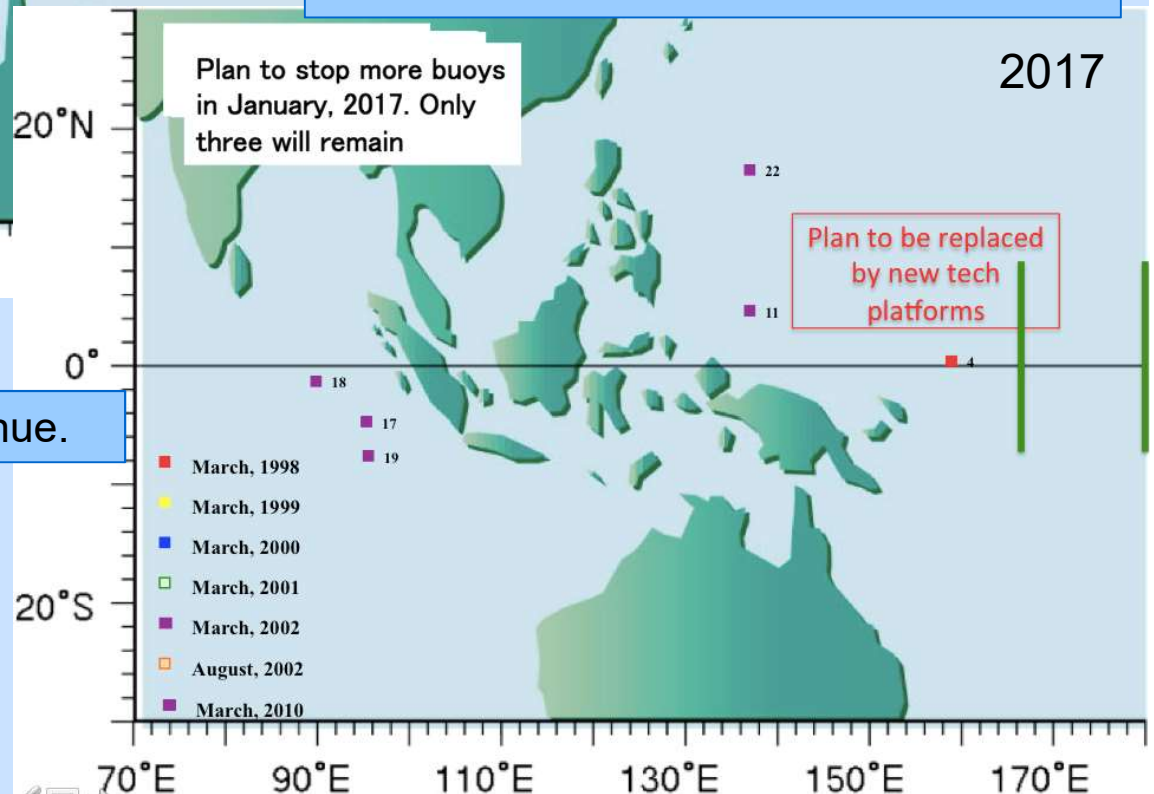
# TAO Status and Data Return



# Development and reduction of TRITON buoy array



- Retirement of Pacific TRITON sites, begun in 2013, will continue.
- By 2017 only 2 of original 12 TRITON sites will remain
- One new mooring planned north of TAO/TRITON Array
- Continue climate record with additional new technologies
- JAMSTEC is engaged in TPOS 2020 planning efforts



M-TRITON sites in RAMA will continue.



# Tropical Pacific Observing System 2020 (TPOS 2020)

- Redesign and refine the TPOS to observe ENSO and advance scientific understanding of its causes
- Determine the most efficient and effective observational solutions to support prediction systems for ocean, weather and climate services
- Advance understanding of tropical Pacific physical and biogeochemical variability and predictability

TPOS 2020 will provide evidence-based, vetted advice pointing to an intelligent evolution of the observing system.



# TPOS 2020 ORGANIZATION

TPOS 2020 is an international project under GOOS

## Steering Committee:

15 members from 6 nations

Co-chairs: Billy Kessler (NOAA) and Neville Smith (BOM, Australia)

## Task Teams:

- Planetary Boundary Layers
- Models and data assimilation
- Biogeochemistry
- Eastern and Western Pacific

The draft of the First Report on the TPOS 2020 posted to:

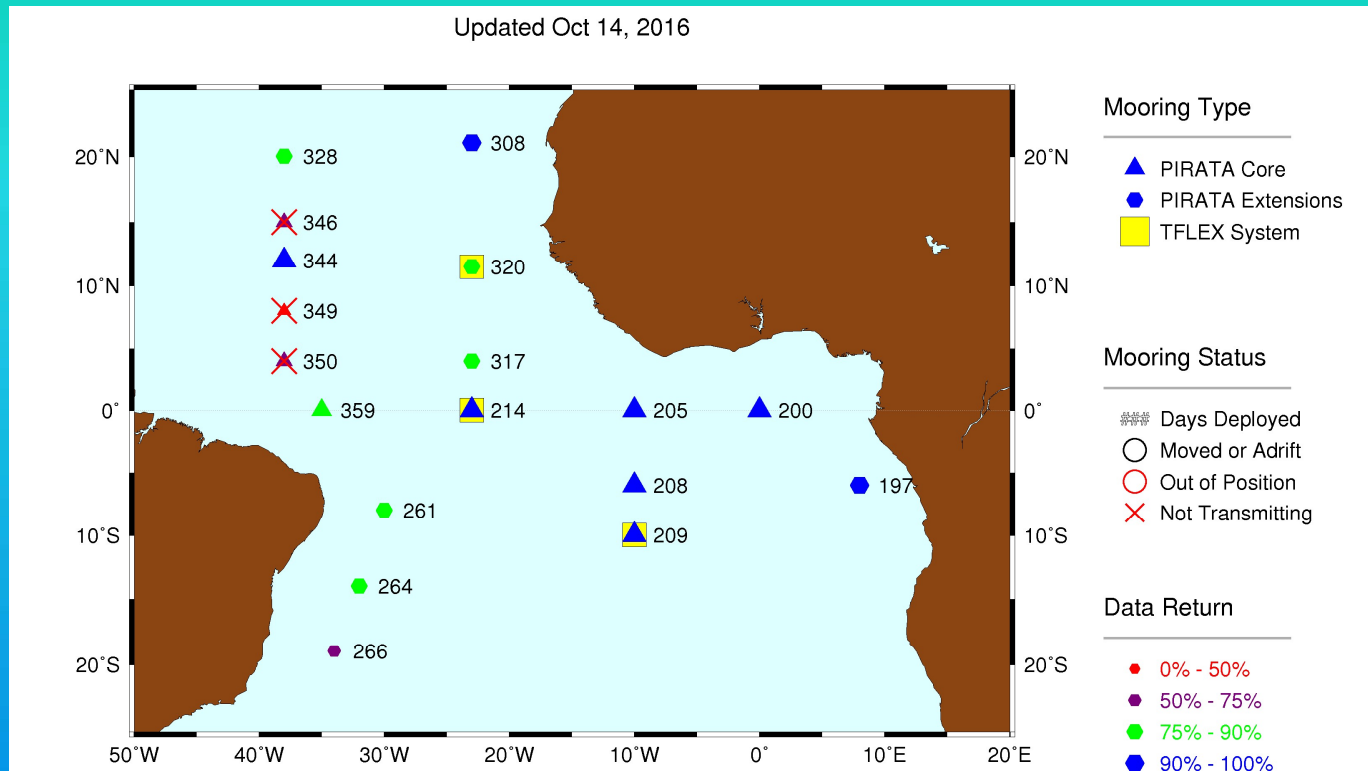
<http://www.tpos2020.org>

# TPOS 2020 EXPERIMENTS

Four TPOS 2020 experiments to be conducted over a four-year period have been funded by NOAA:

- Enhanced ocean boundary layer observations on the TAO moorings
- Profiling Rainfall, Wind Speed, and Biogeochemical Sensors for Use in the Tropical Pacific Observing System
- Autonomous Surface Vessels (Saildrone) as Low-Cost TPOS Platforms for Observing the Planetary Boundary Layer and Surface Biogeochemistry
- Development and Testing of Direct (Eddy Covariance) Turbulent Flux Measurements for NDBC TAO Buoys

# PIRATA Status and Data Return



- 86% Annual Real Time Data Return (Oct 2015 – Sep 2016)
- 15 of 18 sites presently transmitting
- All 18 sites maintained in past year
- PIRATA Scientific Steering Group meeting: Paris, 2 Dec 2016 to discuss planning an international review of PIRATA in 2017
- PIRATA last reviewed (by CLIVAR and OOPC) in 2006;
- Review published in Bulletin of the American Met. Soc. (2008)



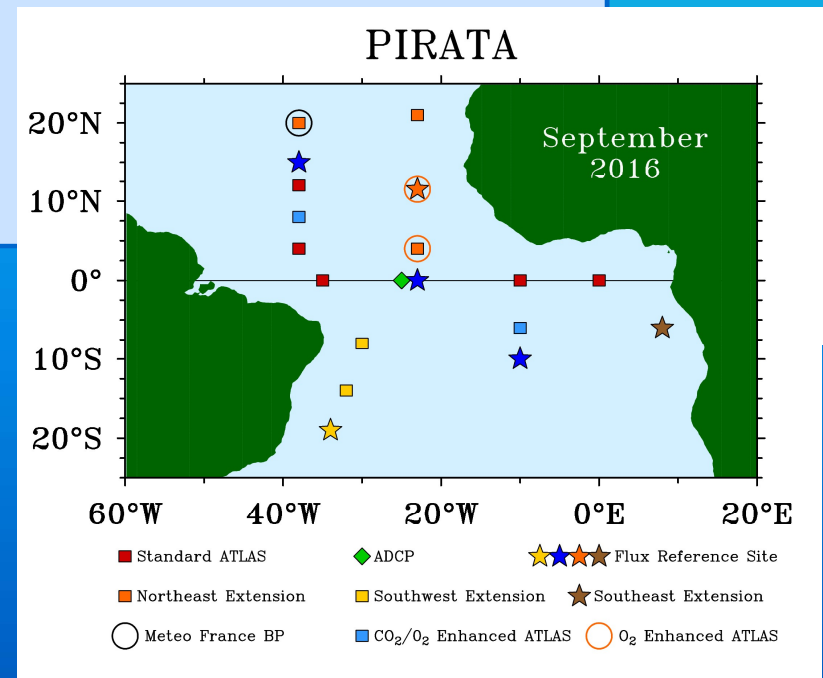
# PIRATA

## Enhancements/Collaborations

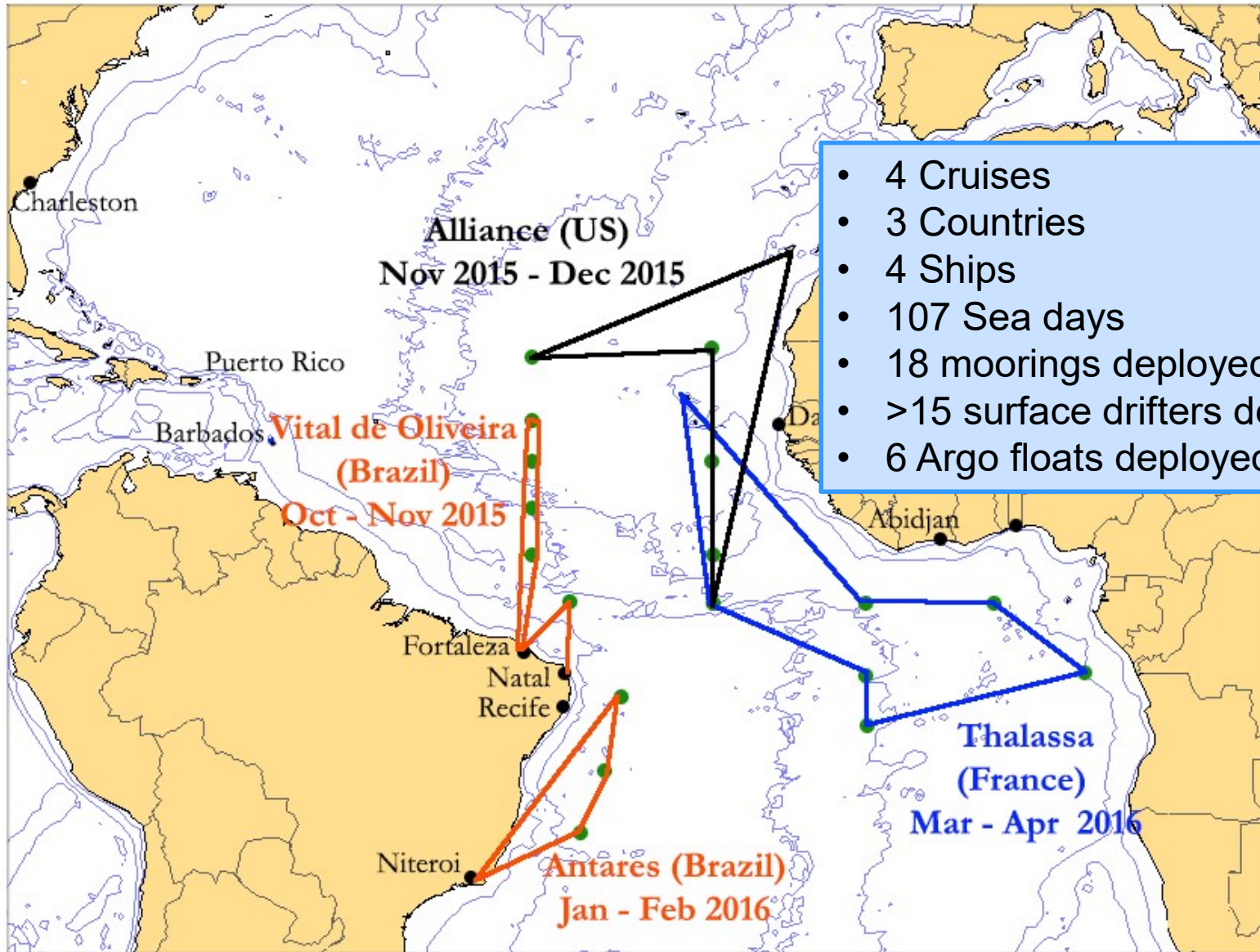
- 6 Flux Reference Sites (longwave radiation, surface pressure and currents, additional subsurface temperature and salinity)
- 2 Surface CO<sub>2</sub>/O<sub>2</sub> (LOCEAN)
- 2 Subsurface O<sub>2</sub> (IFM/GEOMAR); 8 more planned for 2017
- 1 Surface Pressure (Meteo France)
- 2 Thermal microstructure (ChiPods, Oregon State University)
- 17 Acoustic monitors (OTN, Dalhousie University)
- AEROSE (Aerosols and Ocean Science Expeditions, NCAS)

### Future Enhancements

- EU AtlantOS to add T/C and V
- FUNCEME to add T/C

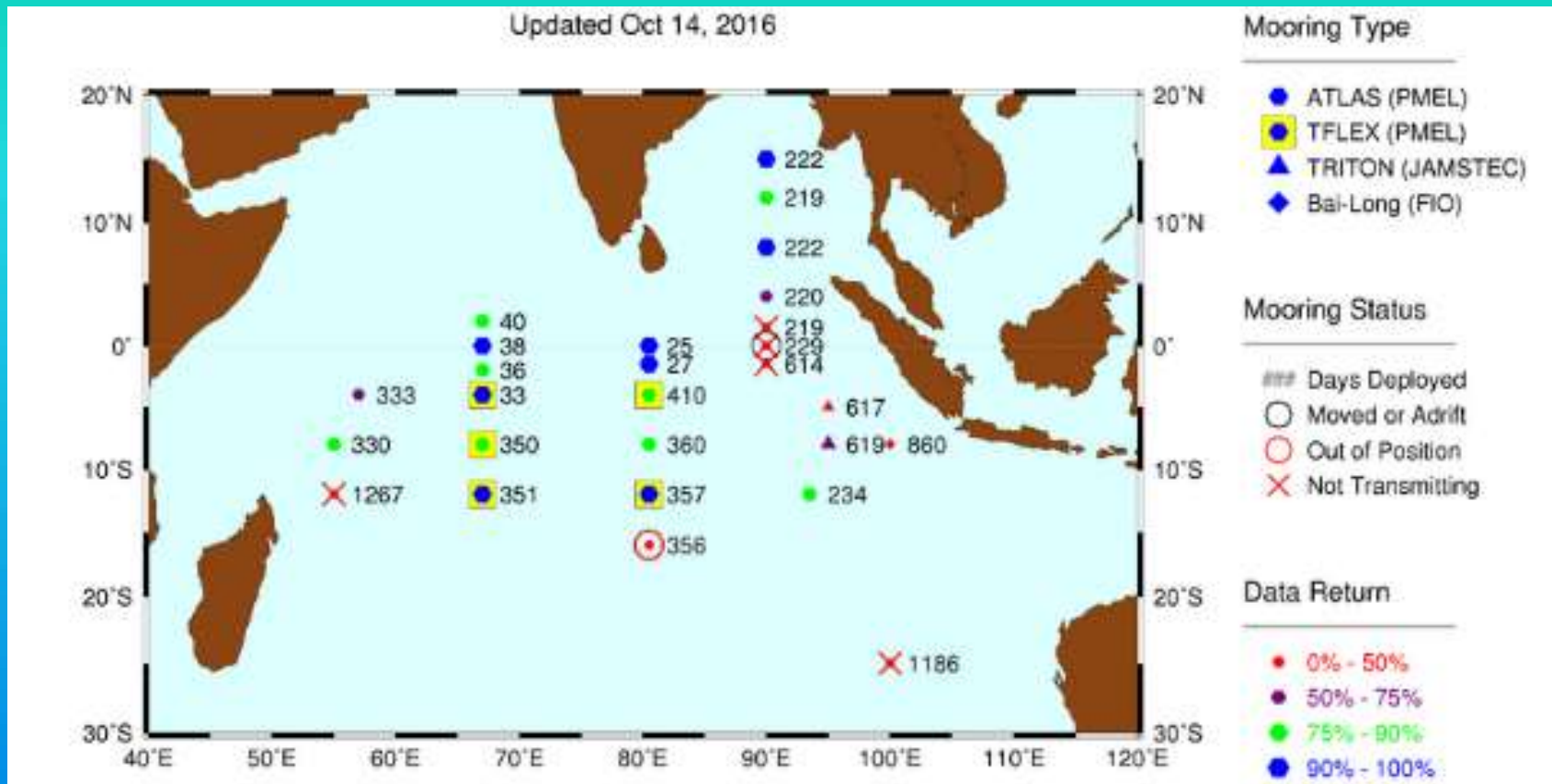


## PIRATA Cruises Oct 2015 - Sep 2016



- 4 Cruises
- 3 Countries
- 4 Ships
- 107 Sea days
- 18 moorings deployed
- >15 surface drifters deployed
- 6 Argo floats deployed

# RAMA Status and Data Return

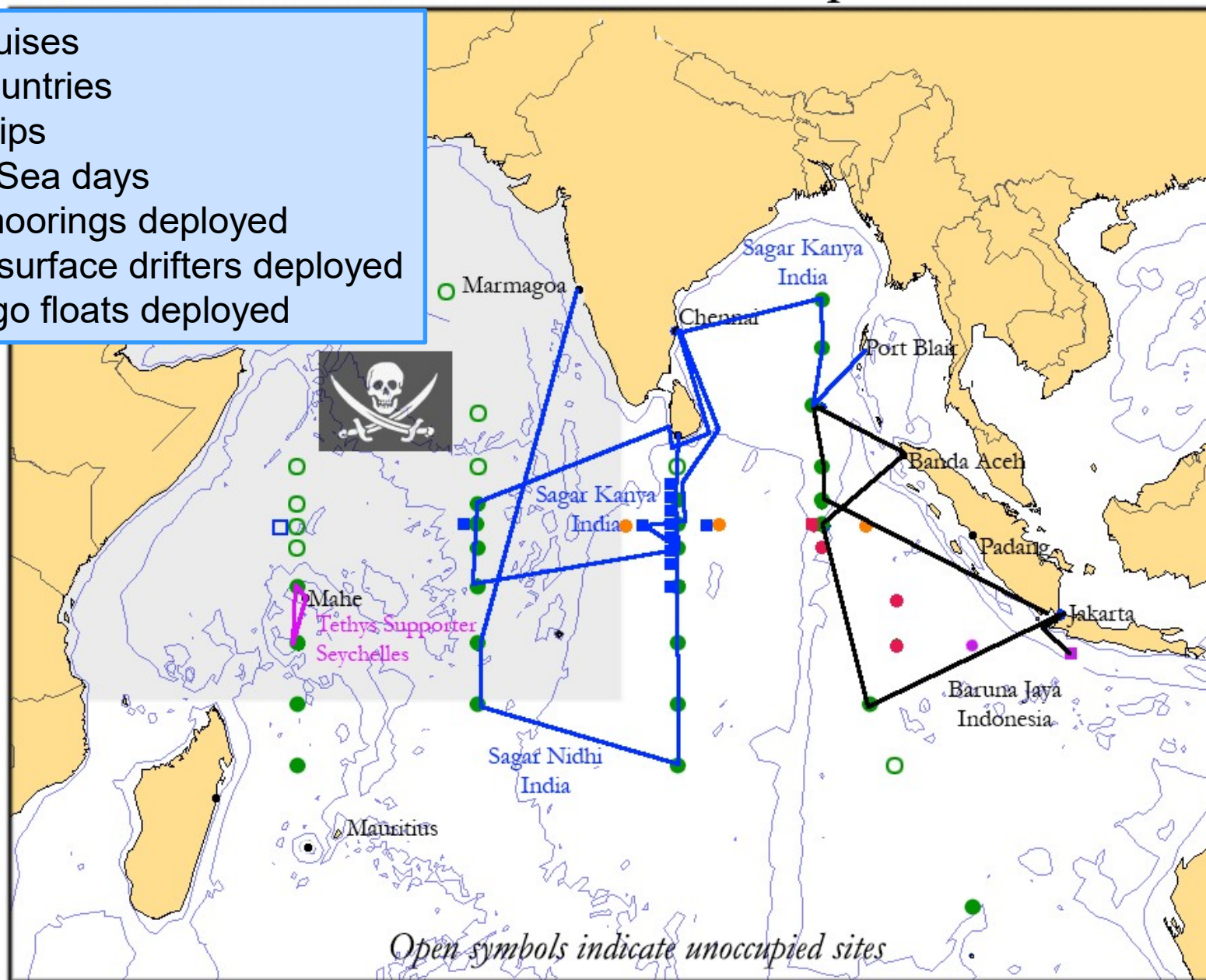


- 7 surface mooring sites not serviced for more than 1 year due to lack of ship time
- Most maintained sites are providing good data.
- Australian proposals for 25°S, 100°E support not funded
- 12°S,55°E & 16°S,55°E sites not maintained due to completion of ASCMLE program.
- Review of the IndOOS on 30 Jan-3 Feb 2017 convened by the CLIVAR/GOOS Indian Ocean Panel and sponsored by the CLIVAR, OOPC, and IMBER programs.

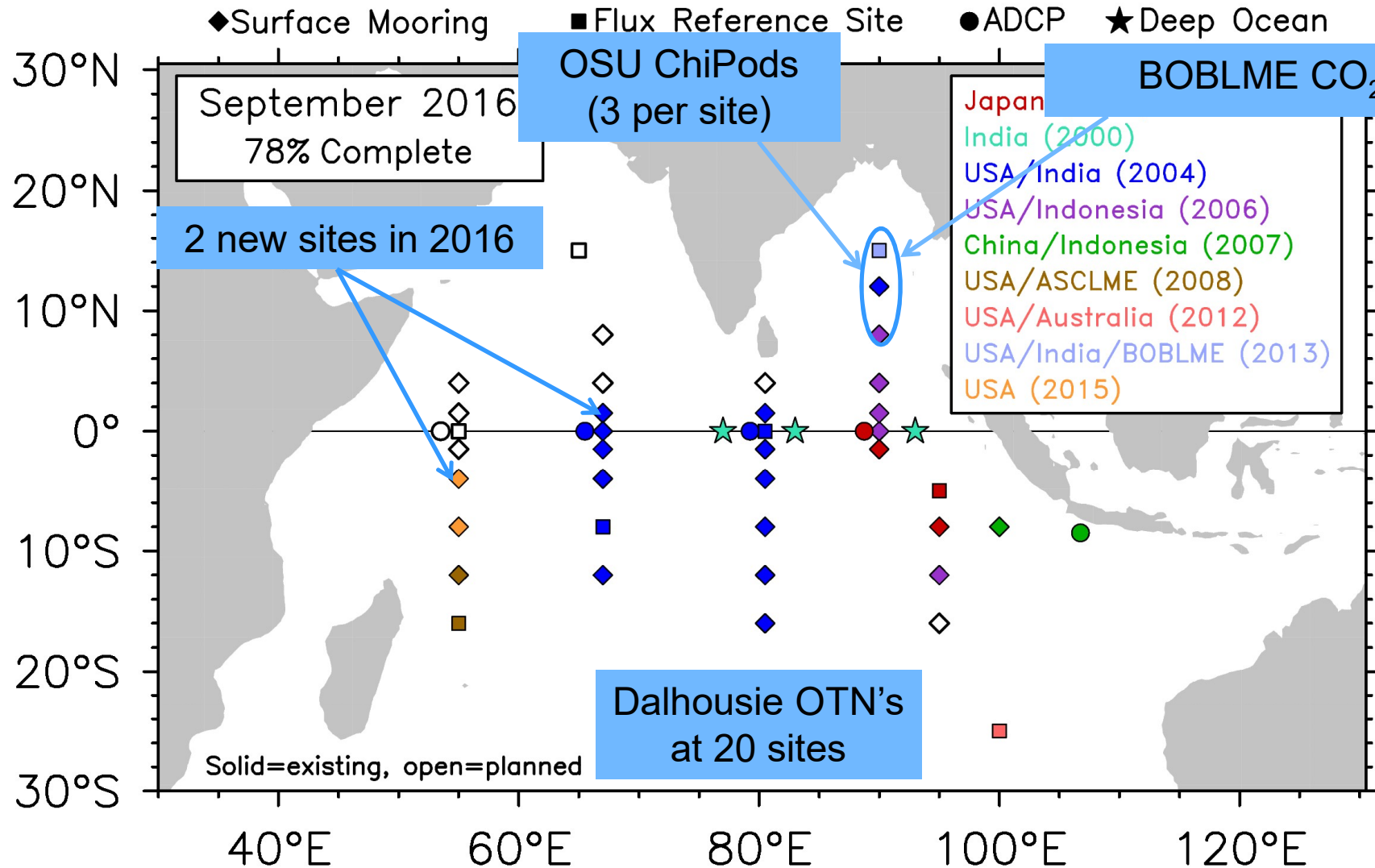


## RAMA Cruises Oct 2015 - Sep 2016

- 5 Cruises
- 3 Countries
- 4 Ships
- 126 Sea days
- 23 moorings deployed
- >25 surface drifters deployed
- 6 Argo floats deployed



# RAMA Implementation and Collaborations



# Research Partnerships under development



## *Blue Ocean Initiative* *KOREA-U.S. Cooperation Project*



- KIOST has new RV: Isabu
- Planned activities in 2017:
  - Pilot cruise on RV Isabu to service 3 RAMA moorings along 67E
  - International workshop in Korea to design a multi-year joint Korea-U.S. Indian Ocean contribution to IIOE-2



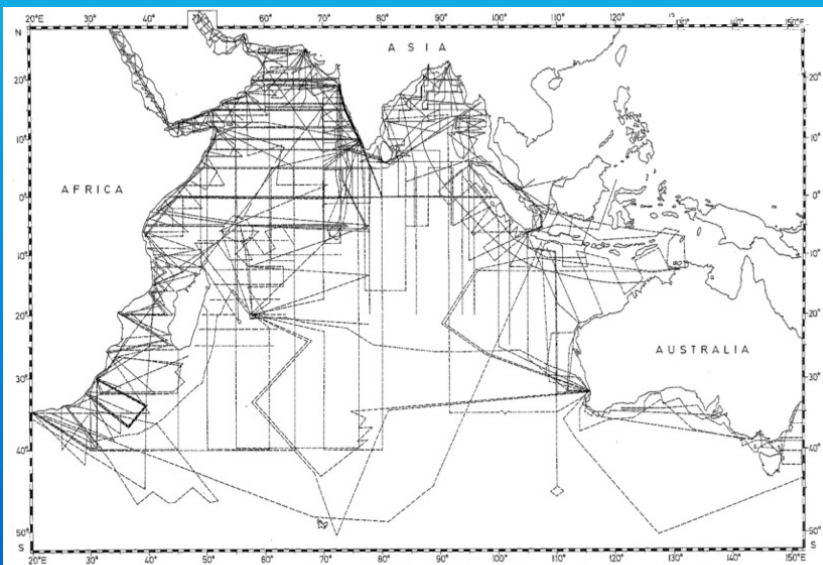
<http://www.kookje.co.kr>



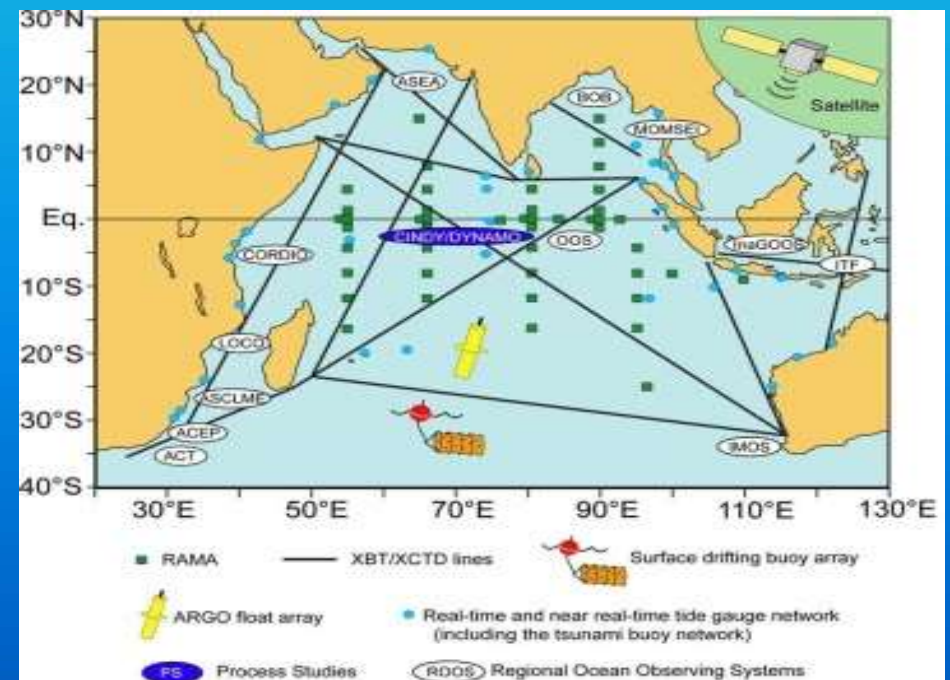
# Research Partnerships under development

## 2<sup>nd</sup> International Indian Ocean Expedition (IIOE-2) 2015-2020

**Vision:** to advance our understanding of the dynamical interactions between the ocean and atmosphere that give rise to the complex physical variability that is observed in the Indian Ocean region, and determine how this variability affects climate, marine biogeochemical cycles, ecosystems and fisheries.



International Indian Ocean Expedition  
1959-1965



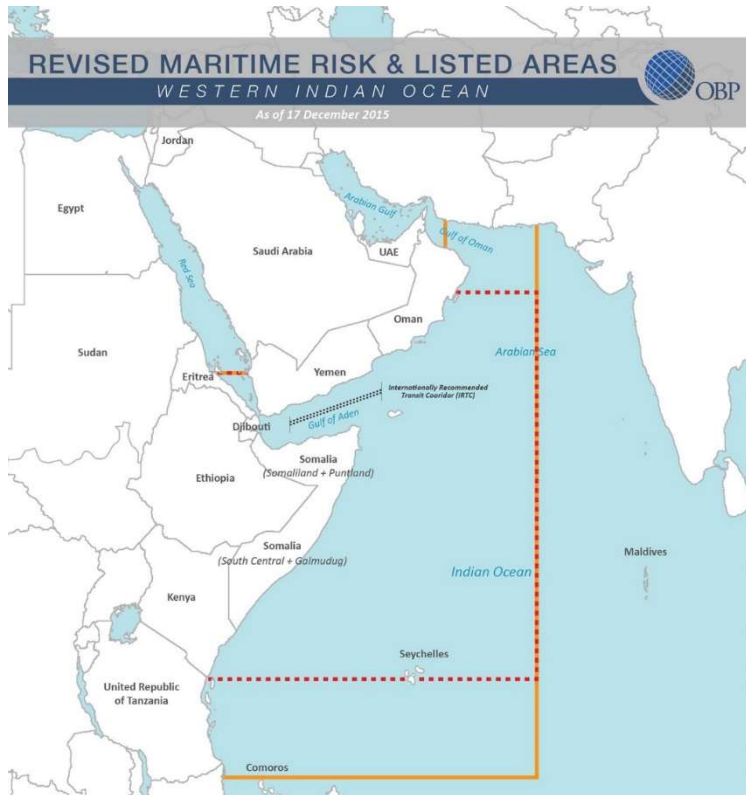
# Strategies for Implementing IIOE-2

1) **Leverage off and coordinate existing international programs** that have research ongoing or planned in the Indian Ocean during this time:

- Sustained Indian Ocean Biogeochemistry and Ecosystem Research (SIBER) which is a part of the IMBER project
- Climate Variability and Predictability (CLIVAR), which is part of the WCRP
- The Indian Ocean component of the Global Ocean Observing System (IOGOOS)
  - Presents an opportunity to complete and enhance RAMA.
- GEOTRACES (a global survey of trace elements and isotopes in the ocean)
- The Global Ocean Ship-Based Hydrographic Investigations Program (GO-SHIP)
- Year of the Maritime Continent (2017-18)



2) Develop and coordinate new initiatives. The first of these is the Eastern Indian Ocean Upwelling Research Initiative (EIOURI)

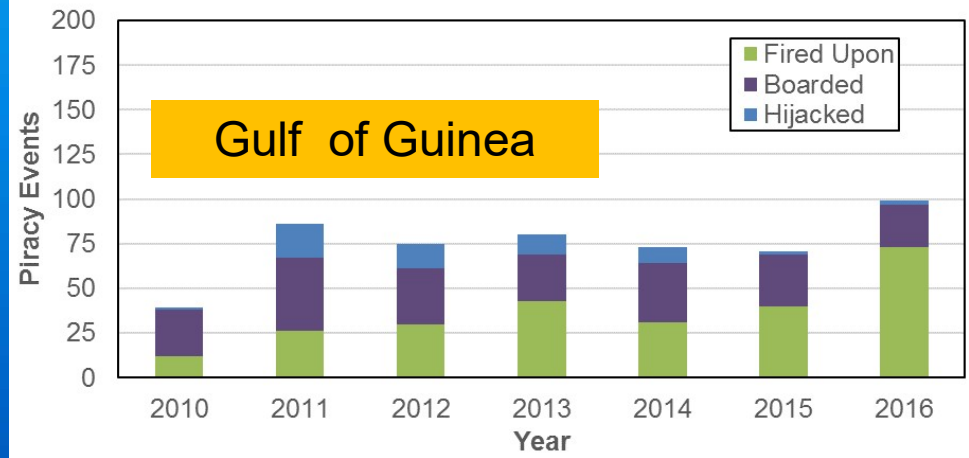
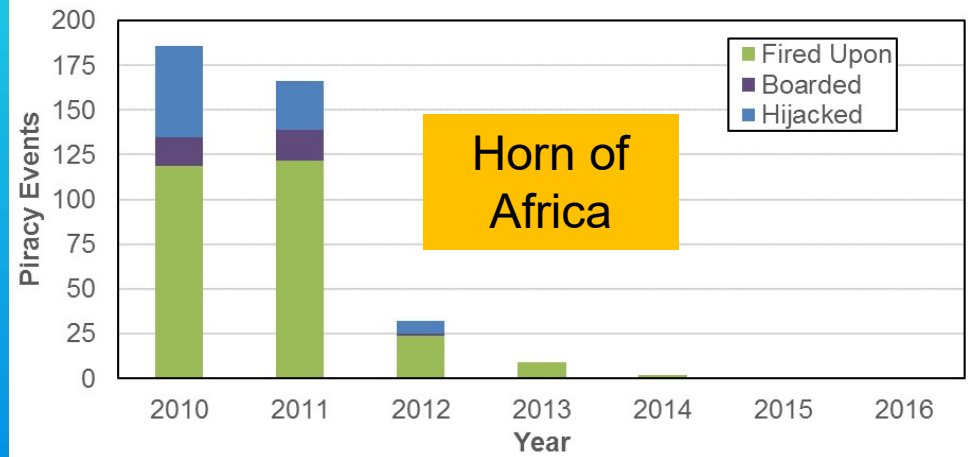


📍 = Attempted Attack  
 📍 = Boarded  
 📍 = Fired upon  
 📍 = Hijacked  
 📍 = Suspicious vessel

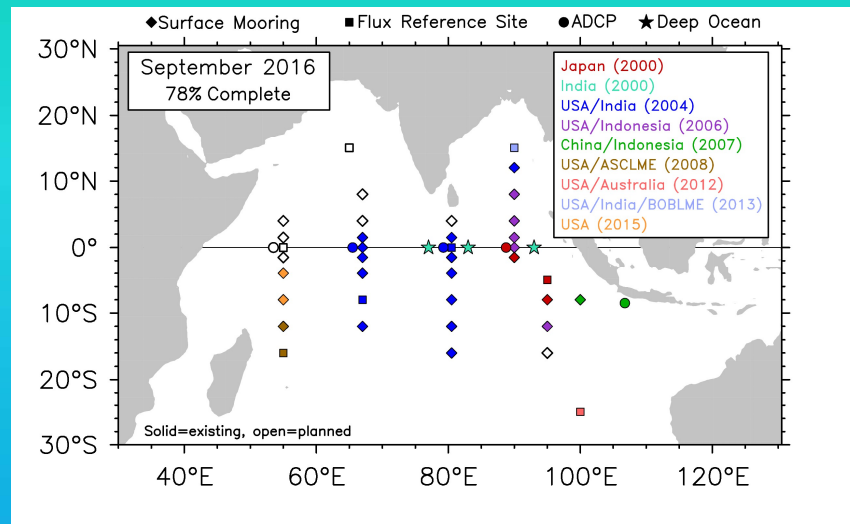


# PIRACY

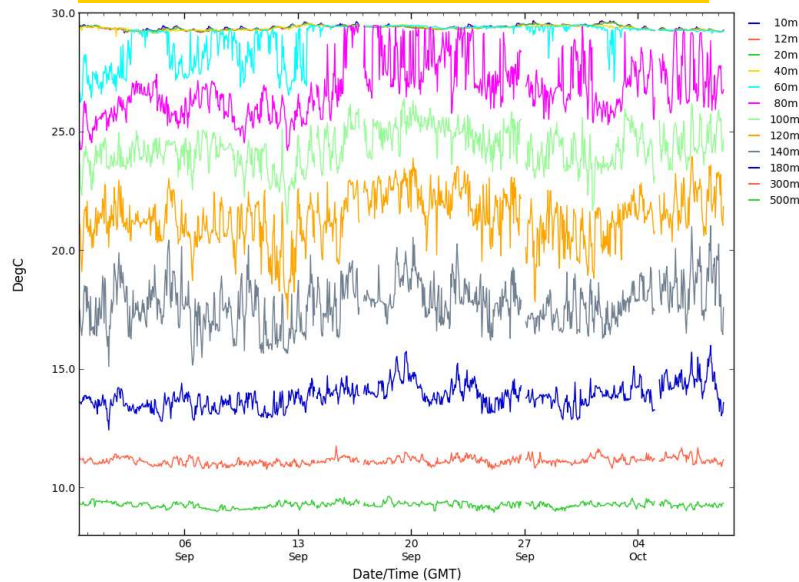
- IO pirate activity resulted in zero incidents for 2015 & 2016
- Lloyds of London Exclusion Zone Reduced in Dec 2015 to 65°E (from 78°E)
- African ports off-limits for PIRATA in response to increasing risk of piracy in Gulf of Guinea.



# T-Flex Implementation



## Hourly subsurface temperature

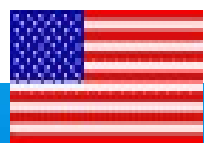
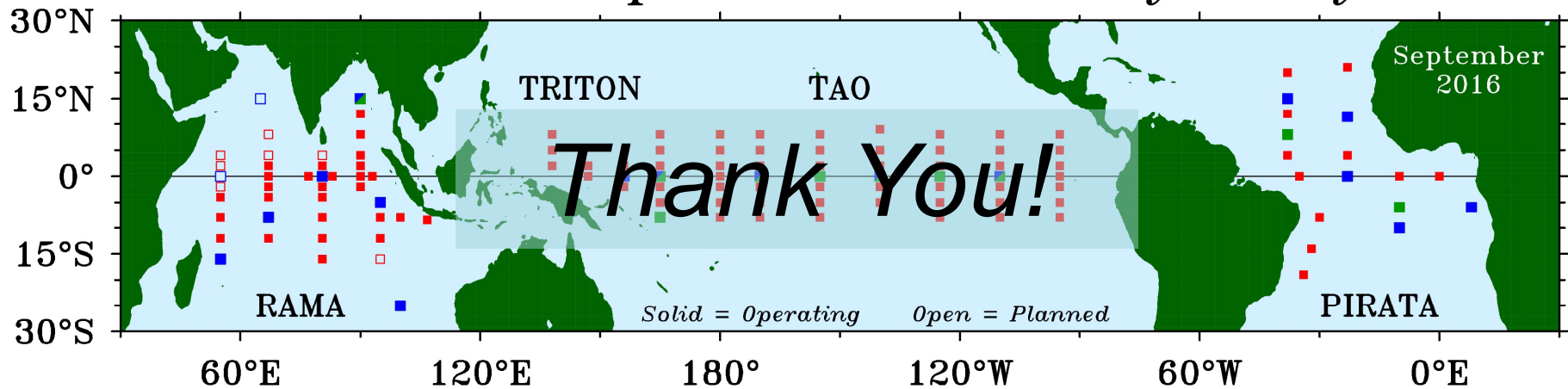


- 8 standalone T-Flex moorings currently implemented in PIRATA/RAMA:
  - 5 in RAMA
  - 3 in PIRATA
- ATLAS/T-Flex/BaiLong met sensors compared at PMEL
- T-Flex pilot study data shown to be comparable to ATLAS
- NOAA Tech Memos on mooring comparisons available or in prep.
- Provides hourly time series in real time
- Capable of higher vertical resolution in real time
- On GTS. Bulletin Header IOBX08 KPML in BUFR
- WMO numbers for T-Flex moorings take the 7-digit analog of 5-digit ATLAS code
- Plan to convert ~8 additional PIRATA/RAMA sites to T-Flex in coming year.



# Tropical Moored Buoy Implementation Panel

## Global Tropical Moored Buoy Array



PMEL  
NDBC  
AOML



JAMSTEC



IRD  
MeteoFrance



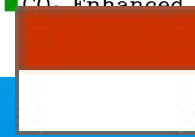
INPE  
DHN



INCOIS  
NIO  
NIOT



FIO



BPPT  
BMKG



CSIRO  
UTAS  
BOM

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