Climate Variability in Under Sampled Regions: Tropical and Southern Atlantic

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U.S. DEPARTMENT OF COMMERCE

Improved understanding of the coupled ocean-climate system will depend on better knowledge of ocean dynamics and ocean-atmosphere exchanges in two historically under sampled regions:

1. South Atlantic → Meridional Overturning Circulation ("SAMOC")

2. Tropical Atlantic → Coupled ocean-atmospheric variability

US CLIVAR Summit, 8-11 Jul 2014
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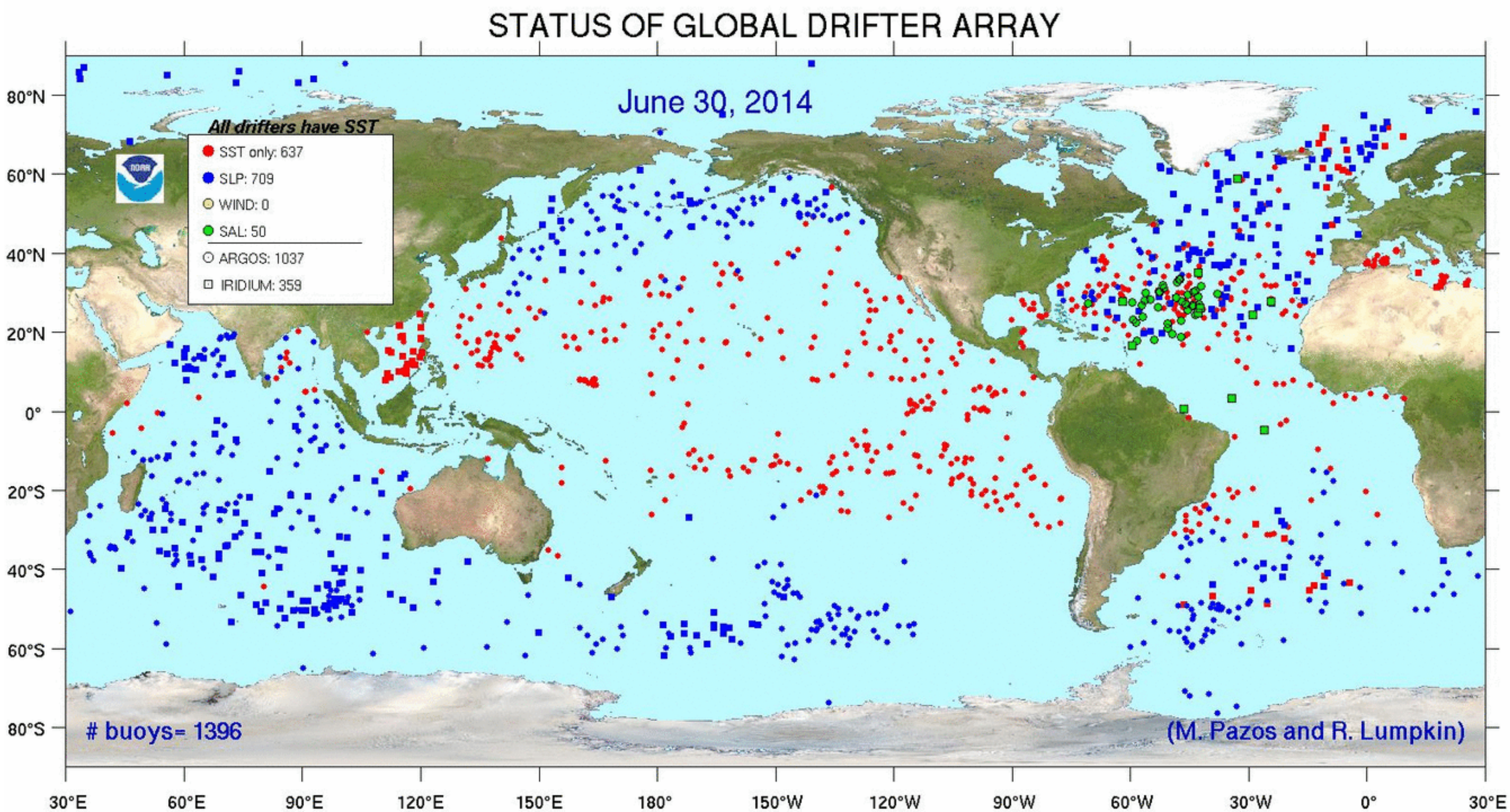
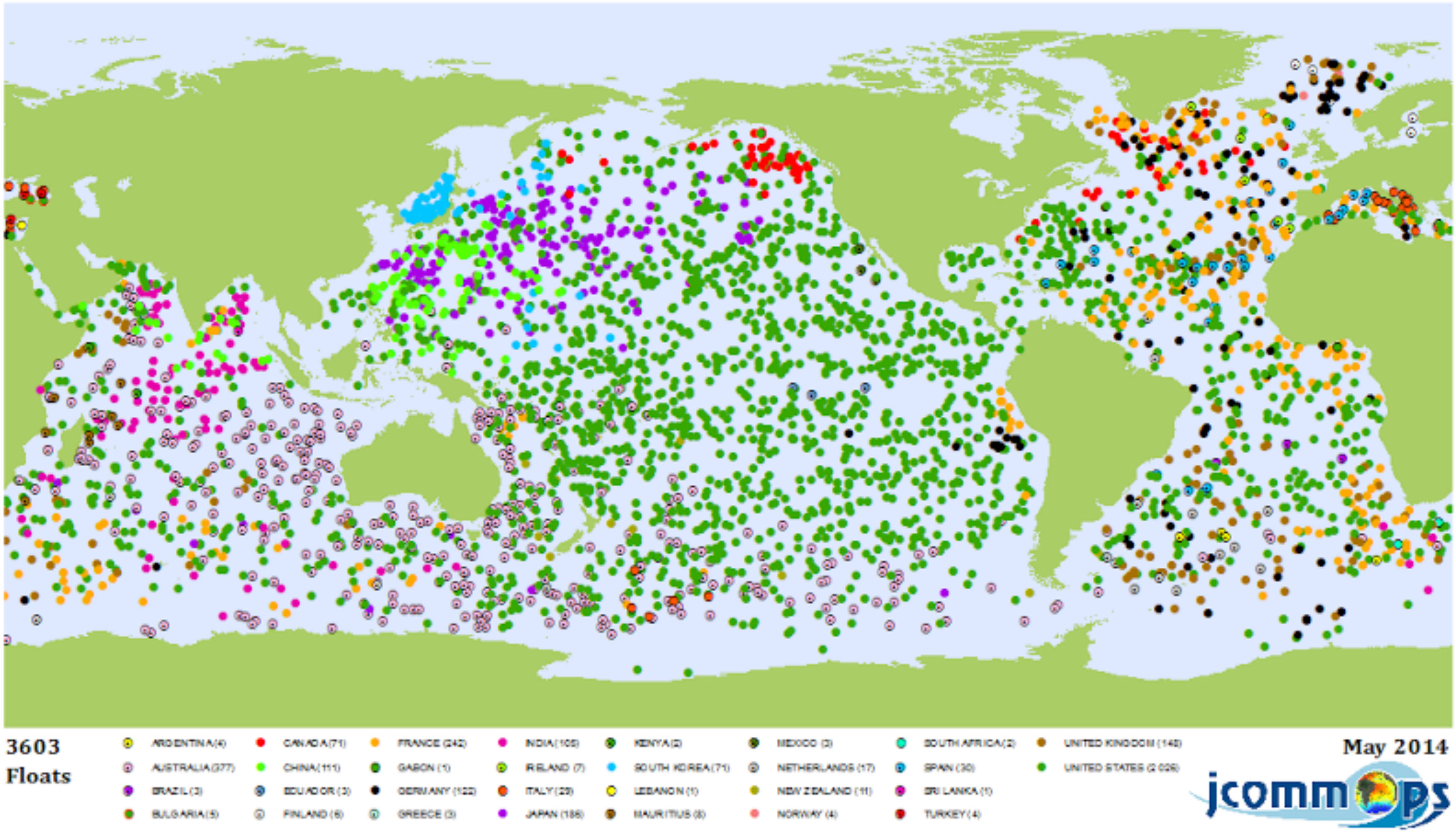
Basin-wide *in situ* measurements

Drifting buoy coverage



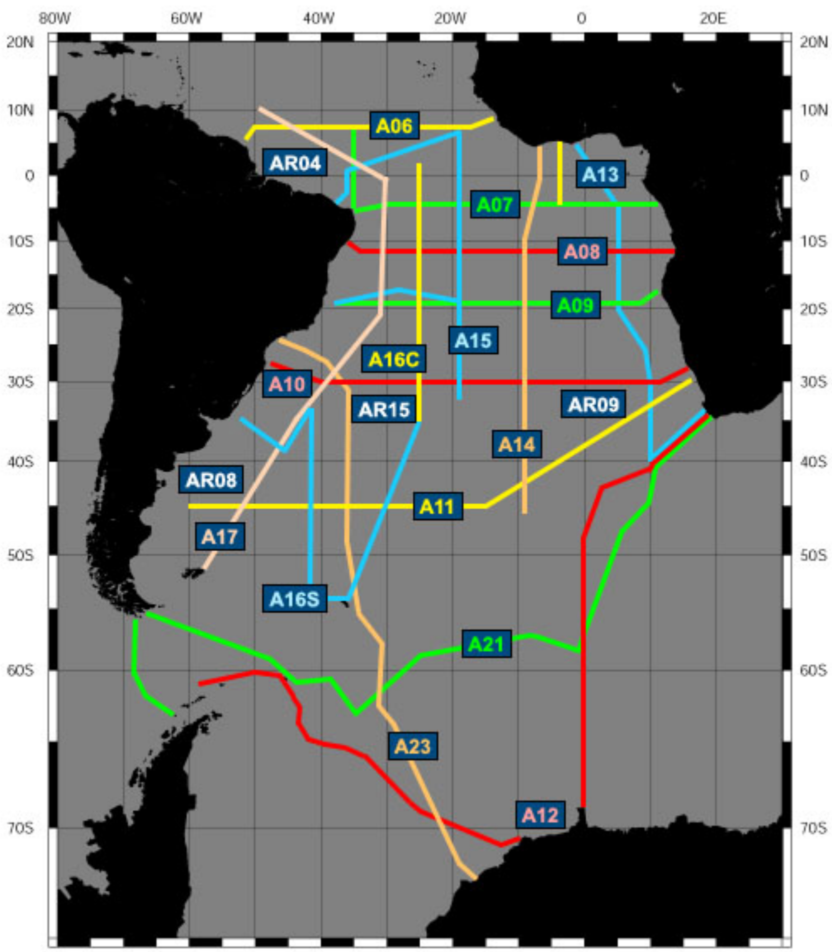
- Global drifter array status as of June 30, 2014 – Above 1250!
- Drifters deployed in tropical Atlantic diverge from equator or follow Guinea Current.

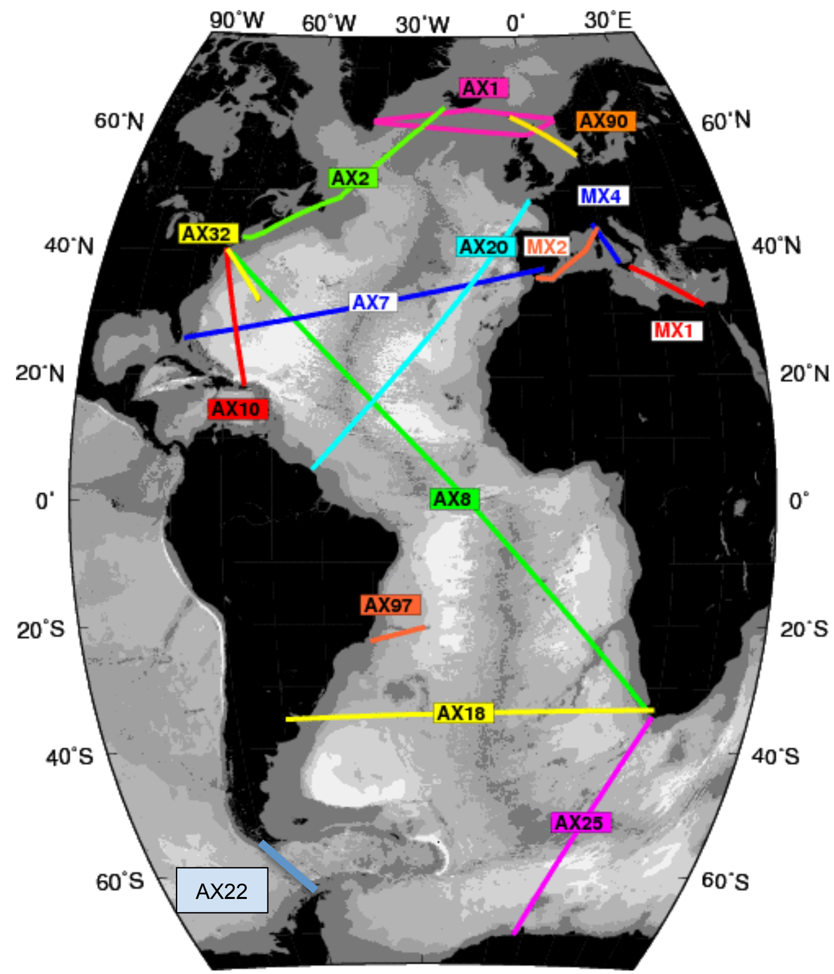
Argo float coverage



- Global Argo profiling float array status as of May 2014
- Fairly good coverage throughout tropical and Southern Atlantic

Repeat hydrographic lines





- Left: WOCE/CLIVAR/GO-SHIP surveys in tropical and Southern Atlantic
- Right: High-density quarterly XBT transects in the Atlantic

New and sustained field programs

Climate Variability and the South Atlantic Meridional Overturning Circulation (SAMOC)

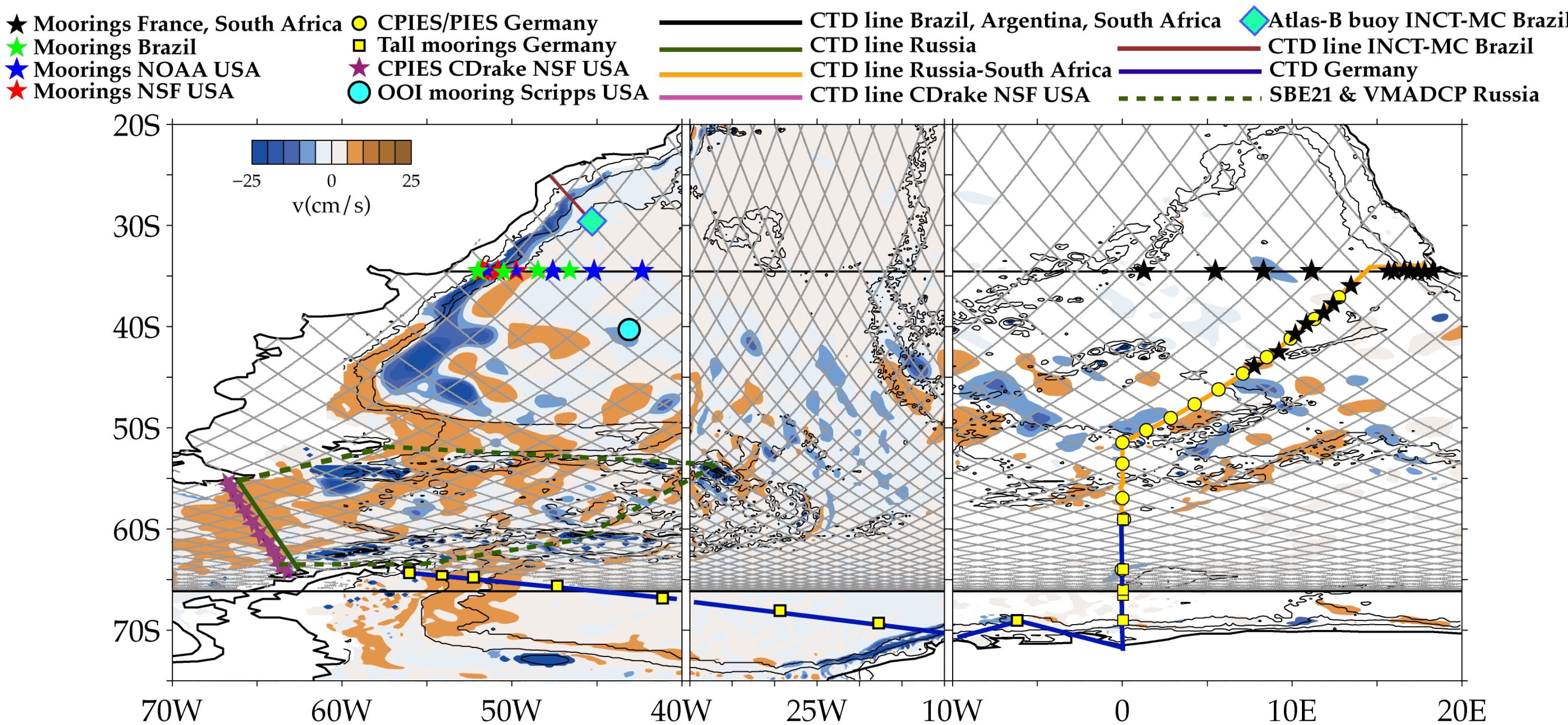
Variations in AMOC have been shown to be correlated to changes in important climate signals including surface air temperatures, precipitation, and hurricane intensity in the northern hemisphere.

Given complex nature of the AMOC system, achieving a more complete understanding of its behavior requires a comprehensive observing system that spans entire Atlantic.

Challenges:

1. Far fewer observations and model analyses available
2. Intense mesoscale variability (WMT, eddy-mean interactions)
3. Inter-ocean exchanges connect to other basins

SAMOC observational network

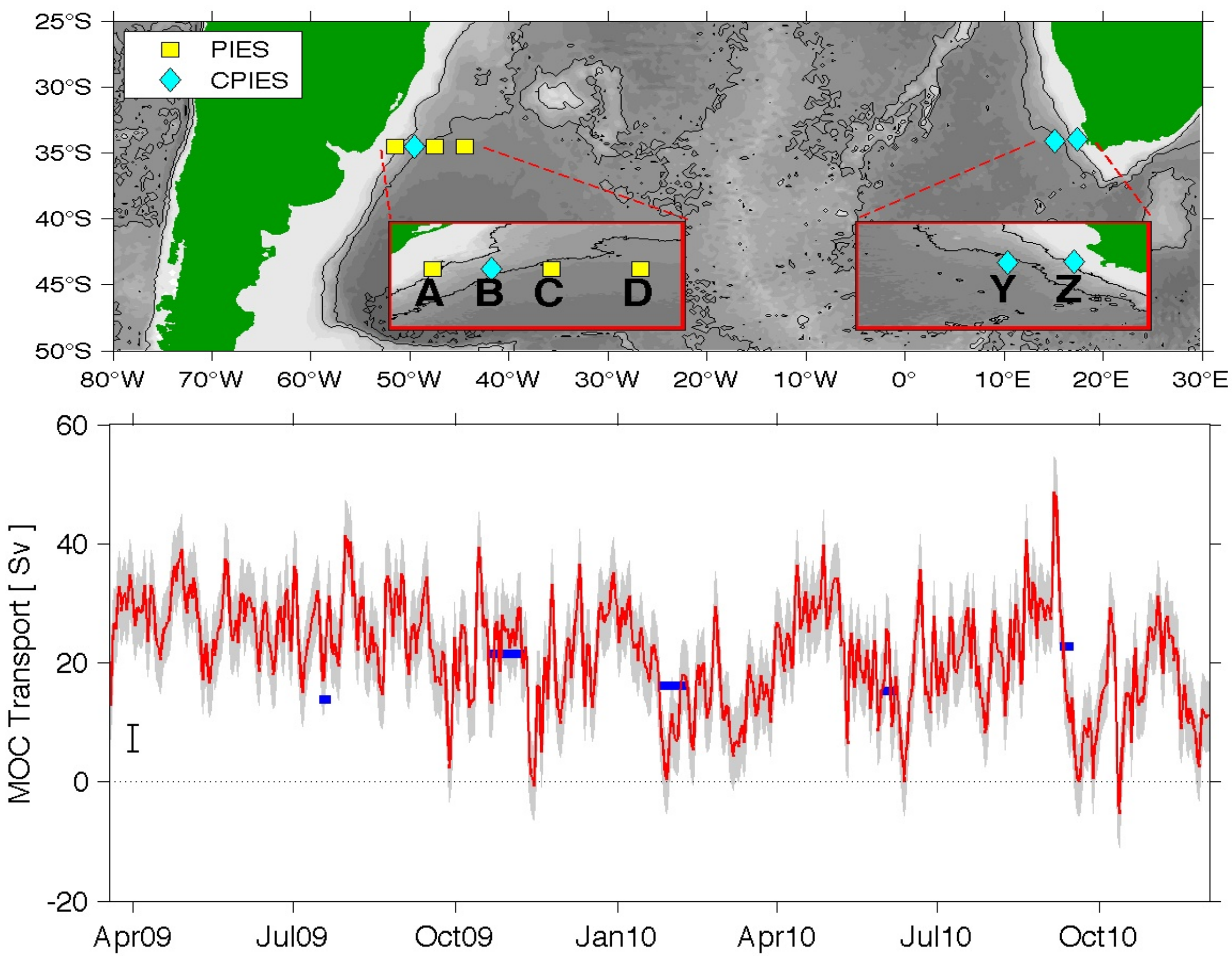


- Schematic of the SAMOC observing network ("the vision")
- SAMoc Basin-wide Array (SAMBA) along 34.5°S
- Eastern boundary short/tall moorings, oblique Goodhope transect by end 2014
- Seeking funding for short/tall moorings on western boundary, interior PIES-datapods
- Color shading: mean OFES simulation meridional velocity at 200 m depth
- JASON ground-tracks are overlaid as light gray lines

More details @ http://www.aoml.noaa.gov/phod/SAMOC_international/

Pilot array to continuously measure South Atlantic MOC

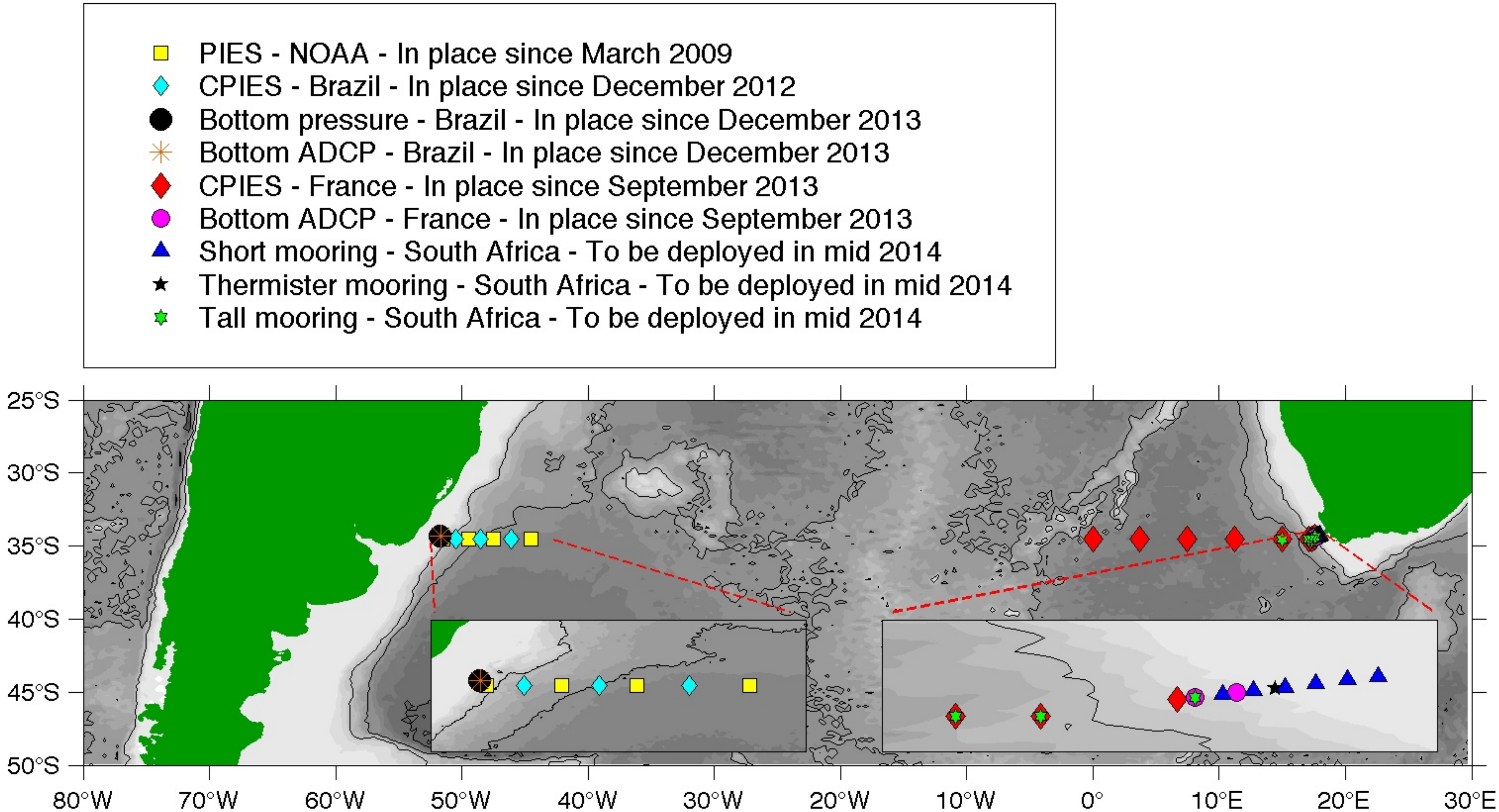
MOC estimated from a daily time series of dynamic height from inverted echo sounders (PIES/CPIES)



- An ~20 month long pilot array and a novel technique using model output and Argo data helps determine the daily MOC strength at 35°S.
- MOC time series compares favorably with XBT derived time series.
- MOC variability is as large at that at 26N, with both eastern and western boundary flows contributing equally to the variance.
- The full array was reestablished in the fall of 2013 in collaboration with France, Brazil, Argentina and South Africa.

Meinen et al. (2013)

Update on SAMOC/SAMBA



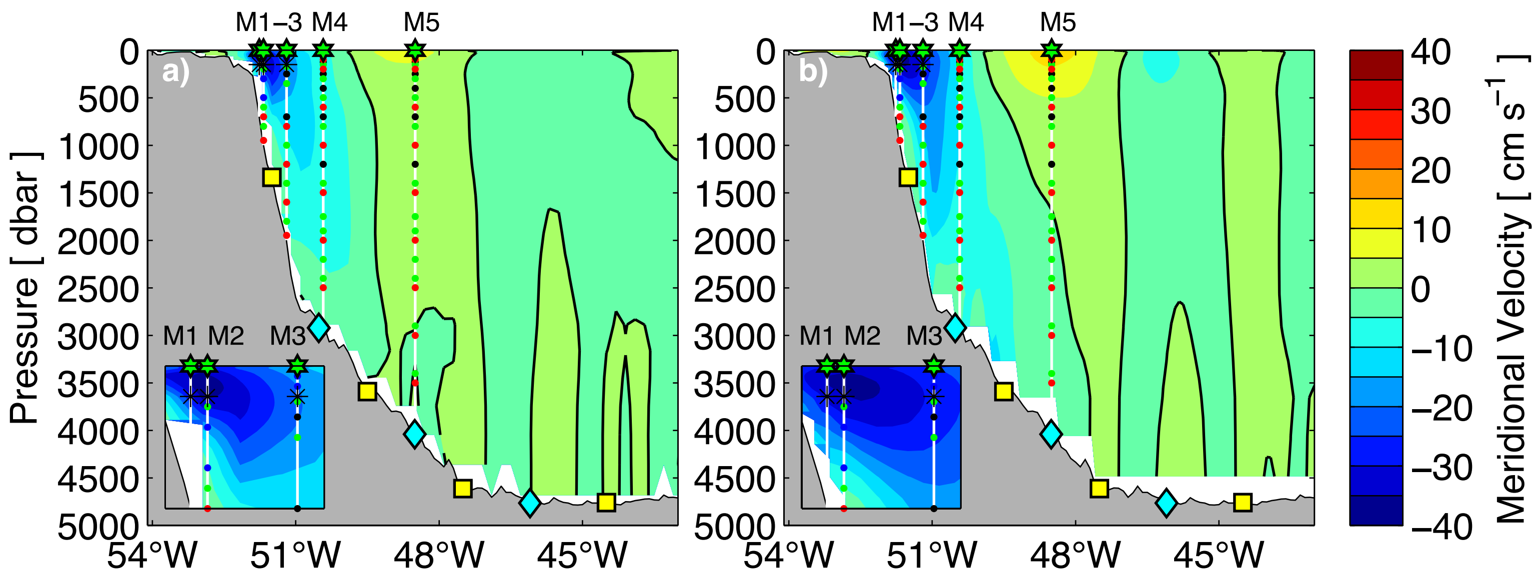
- In both 2012 and 2013, array doubled in size!
- Eastern boundary short/tall moorings to be deployed by the end of 2014
- Seeking funding for short/tall moorings on western boundary, interior PIES-datapods
- Ship time concerns: Cruises done by int'l partners (Argentina, Brazil, South Africa)

SAMOC-related research

1. Model analysis and observing system experiments
2. Mean and intraseasonal-to-interannual variability of the MOC and heat and salt transport by the MOC
3. Meridional coherence (or lack thereof) of MOC
4. Why models don't get the MOC seasonal cycle right?
5. Intraseasonal-to-interannual variability/secular changes of Agulhas leakage and impact on the MOC
6. Intraseasonal-to-interannual variability/secular changes of boundary currents (BC, DWBC…) and impact on the MOC
7. Mean and intraseasonal-to-interannual variability of ACC transport through Drake Passage
8. SAMOC water mass pathways (e.g., fate of NADW)
9. Study of water mass properties on the boundaries (T, S, O2)
10. Water mass transformations
11. Eddy-mean flow interactions
12. Bistability of the MOC ("MOV")
13. … and many more

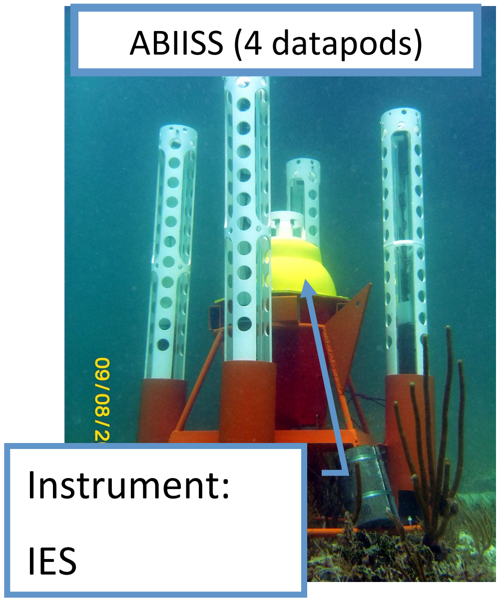
Directions for future expansion/augmentation

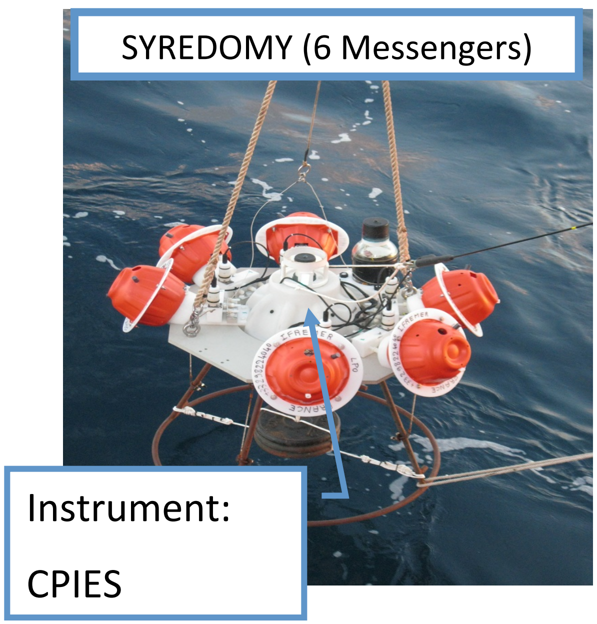
- New sites/moorings:
  - Short/tall moorings (T, S, p, v) on the western boundary to better measure transport (BC, DWBC) and water mass (NADW) changes
  - PIES in the interior (i.e., either side of the MAR)
  - Drake Passage moorings for ACC transport
- Trans-basin hydrographic/SADCP/tracer cruise
- Challenges: Funding, Ship time (cruises by international partners)



- Proposed locations of tall moorings on the western boundary
- Shading: Mean OFES (left) and NEMO (right) meridional velocity along 34.5°S

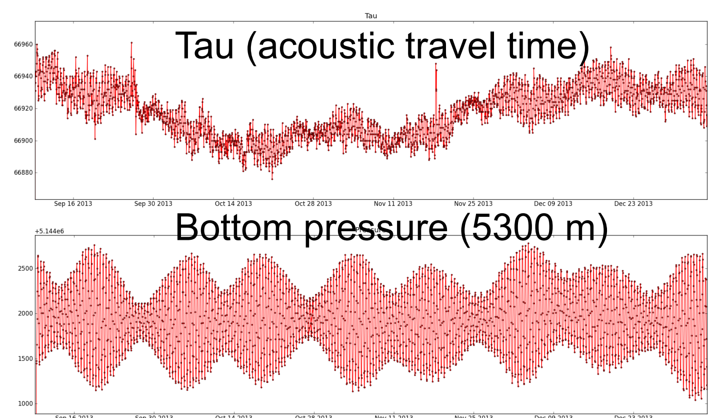
Datapod technology: ABIISS(US)/SYREDOMY (France)





- Successful launch of two data pods and data transmission via satellite from US ABIISS
- 6 month test deployment in the Florida Straits (800 m)
- Instrument recovery in August 2014

- Successful data transmission via satellite from first set of French SYREDOMY messengers (example: SAMOC/SAMBA CPIES, 5300 m)



Climate Variability and the Tropical Atlantic

Climate variability in the Tropical Atlantic drives floods, droughts, hurricane activity, etc., affects the evolution of SST anomalies in other ocean basins, and is a fingerprint for large-scale climate change.

Challenges:

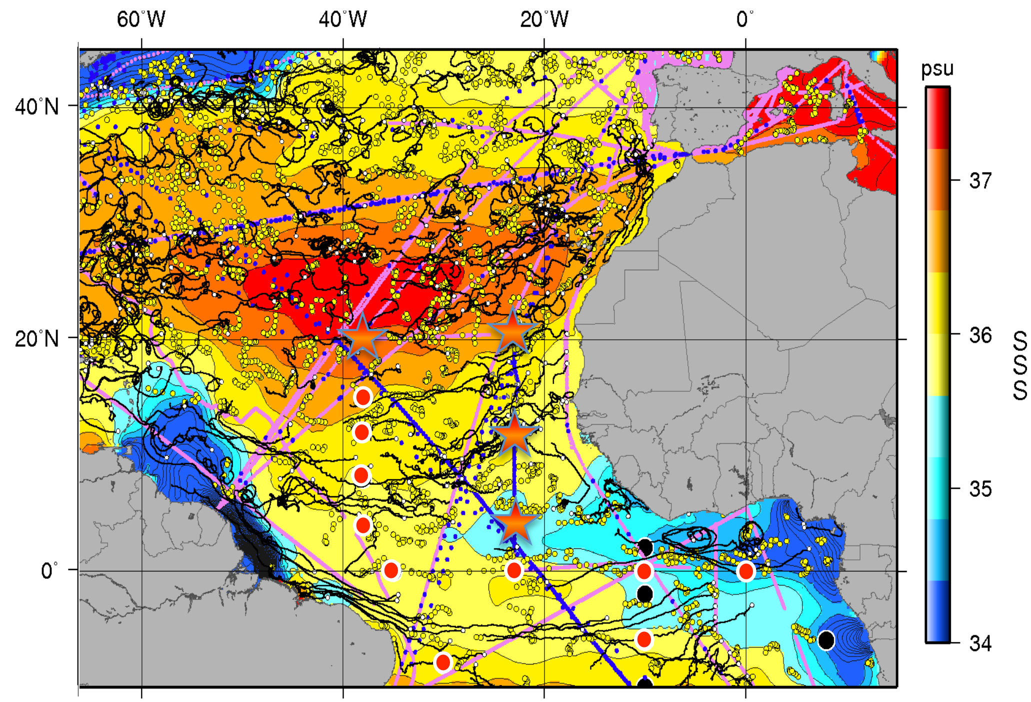
1. Biases in coupled models limit predictability
2. Biases in synthesis velocity products
3. Intense variability at intraseasonal to seasonal scales, modulated at interannual and longer time scales
4. Teleconnections to other regions

Past 2-3 decades of tropical Atlantic research

1. Model evaluation (e.g., examining biases in coupled models)
2. Intraseasonal-to-interannual variability of zonal currents (SEC, NECC, EUC)
3. Intraseasonal-to-interannual variability of temperature, salinity, surface heat/salt budgets
4. Variability of ventilation in the Oxygen Minimum Zone
5. Atlantic Niños, Benguela Niños
6. Zonal and meridional mode dynamics
7. Forcing of Decadal SST variability by African dust aerosols
8. Salinity barrier layers
9. Tropical instability waves and tropical/subtropical cells
10. Turbulent mixing
11. Connections to AMO/AMOC
12. Impact of Atlantic warm pool on US weather and climate
13. Impact of tropical Atlantic variability on Pacific and Indian Ocean and vice versa
14. … and many more

Tropical Atlantic sustained observations

A flavor of sustained observations in the region, US partners with researchers around the world (Brazil, France, Germany) to better understand climate fluctuations.



Shading: SSS during spring 2010.
Markers: In-situ ocean observations during spring 2010.

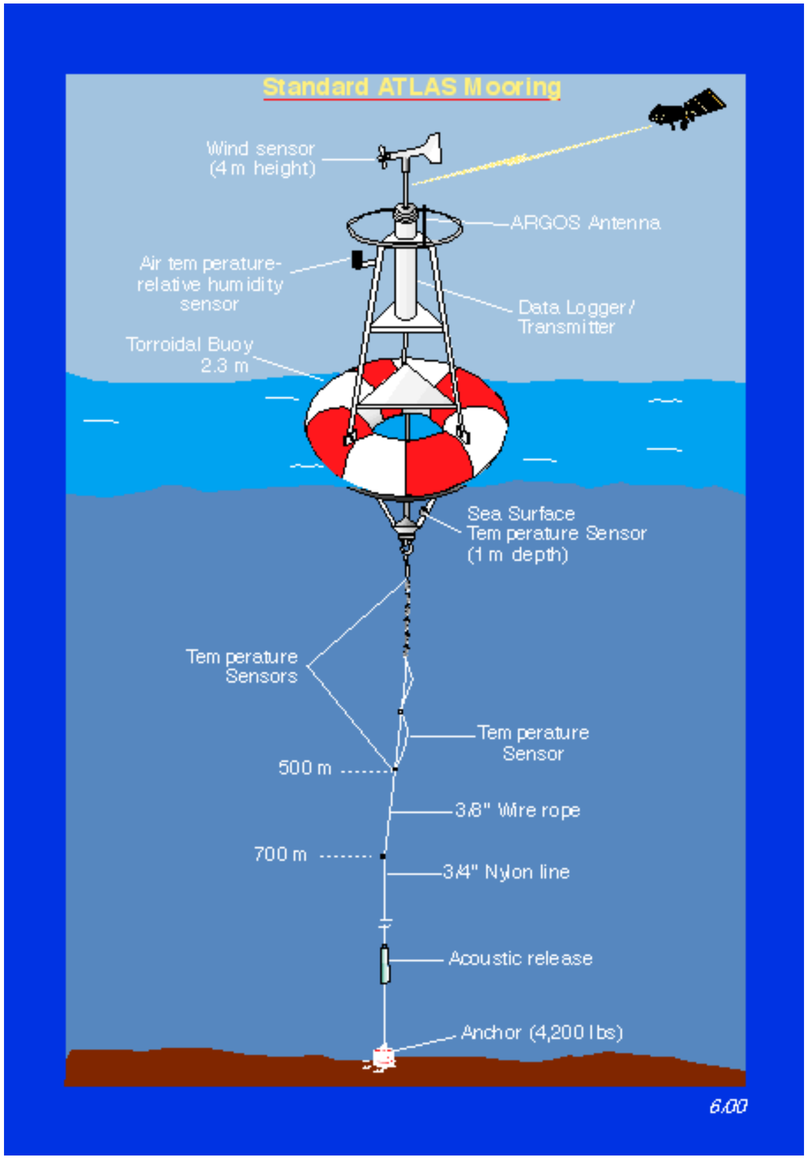
Blue: XBT profiles
Yellow: Argo float profiles
Black: surface drifter trajectories
Purple: TSG transects
Red: PIRATA moorings (upper 500m)

= NOAA-maintained PIRATA Northeast Extension (AOML/PMEL partnership)

Map does not include non-PIRATA moorings deployed by US, Germany, France for tropical Atlantic studies

Slide content courtesy of Rick Lumpkin

PIRATA ATLAS moorings



Standard ocean measurements:

Temp: 1, 20, 40, 60, 80, 100, 120, 140, 180, 300, 500 m

Salinity: 1, 10, 20, 40, 120 m

Pressure: 300, 500 m

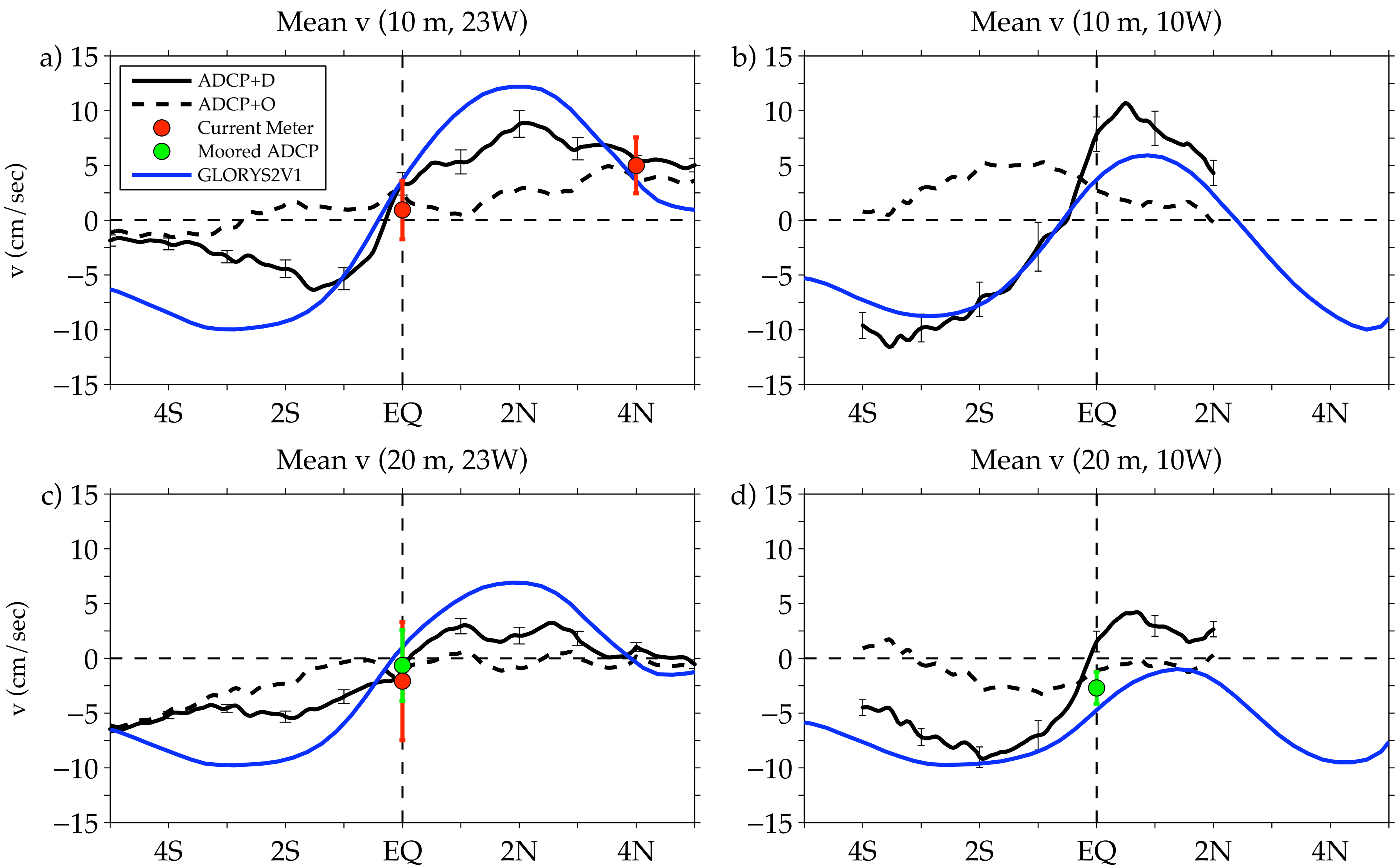
PNE moorings:

Current meter: 10 m

Other moorings:

ADCPs: typically resolving between 30 m and intermediate depth

Few moored velocity measurements near surface



Perez et al. (2013)

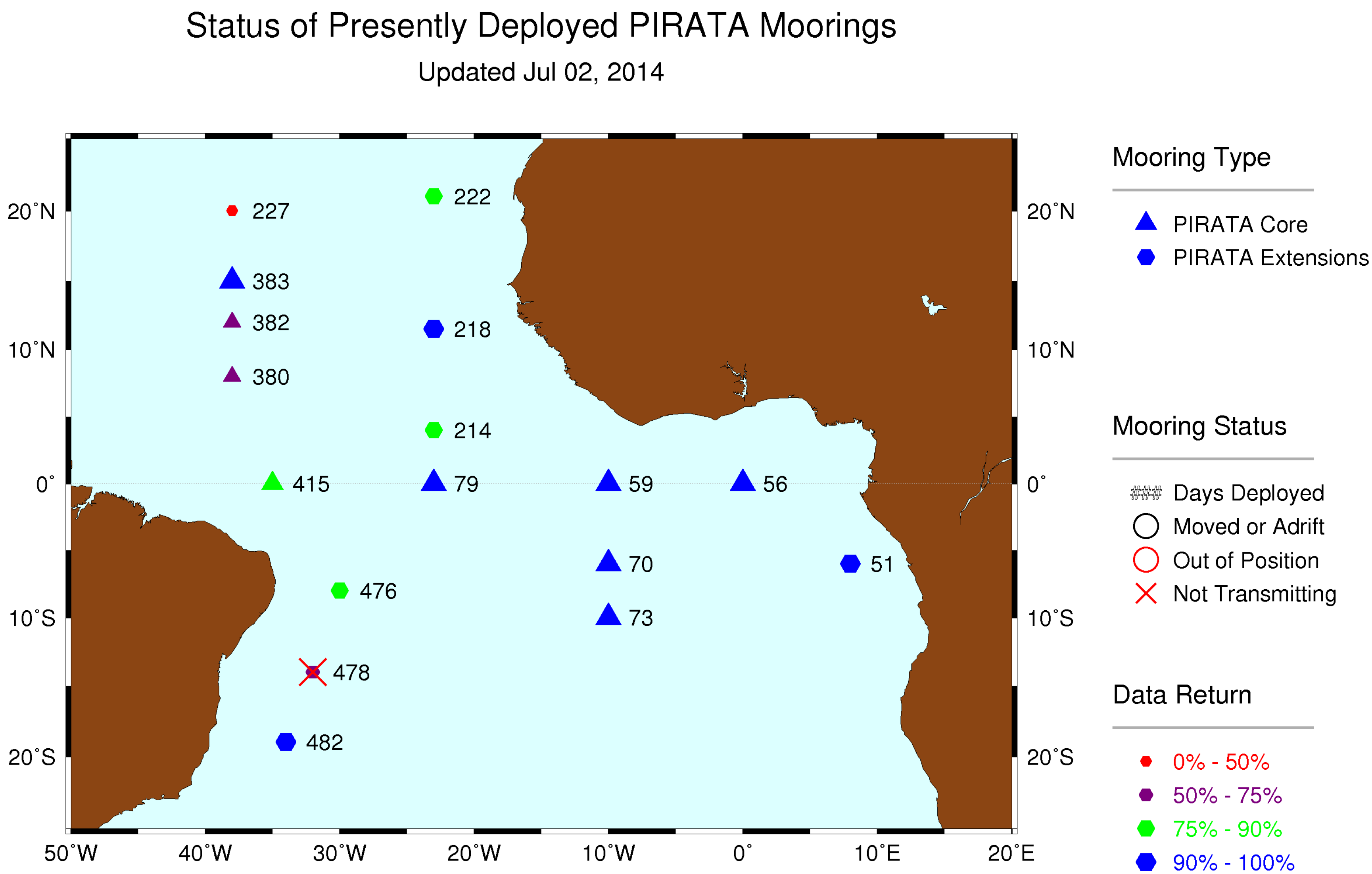
Directions for future expansion/augmentation

- New sites/moorings:
    - More off-equatorial sites
    - Along African coast in Benguela region, where coupled model biases are largest
    - In biologically active coastal zone/river discharge regions
    - Dust deposition moorings at 12N, 23W and 38W

- Instrumentation on existing moorings:
    - Minimum of one current meter at 10 m
    - More velocity shear estimates in surface mixed layer
    - More salinity measurements in upper 100 m
    - More biogeochemical observations (O_2, CO_2, DIC, …)
    - Self-cleaning radiometers

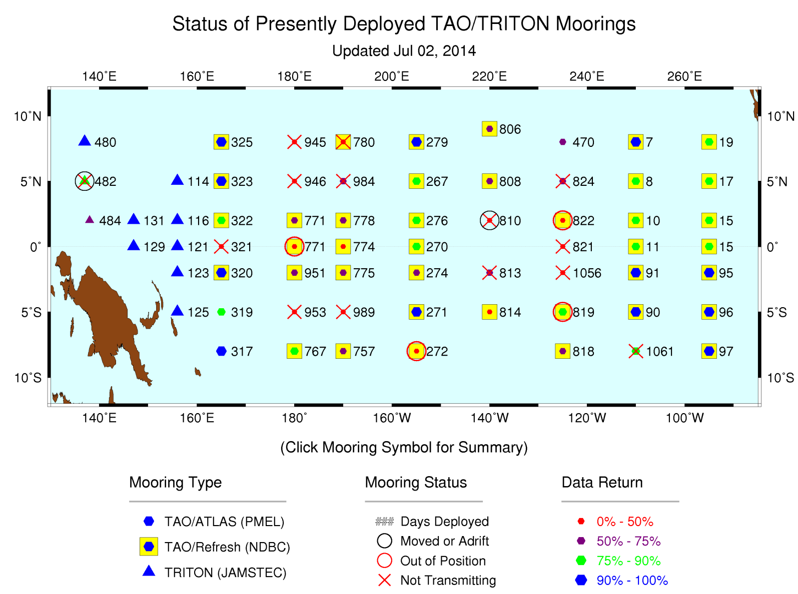
- More international meteo-oceanographic cruises to study the stratus deck formation-upwelling system in eastern Atlantic

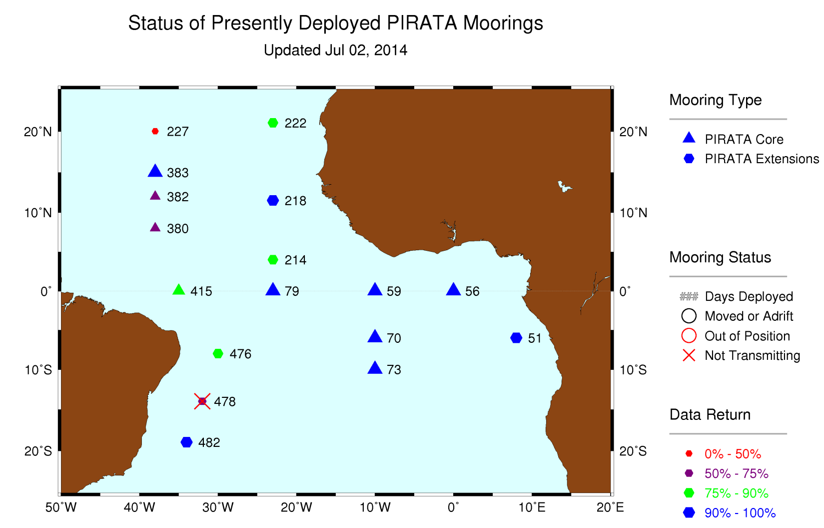
PIRATA


Status of Presently Deployed PIRATA Moorings
Updated Jul 02, 2014
227
222
383
382
218
380
214
415
79
59
56
70
51
476
73
478
482
20˚N
10˚N
0˚
10˚S
20˚S
50˚W
40˚W
30˚W
20˚W
10˚W
0˚
10˚E
20˚E
Mooring Type
PIRATA Core
PIRATA Extensions
Mooring Status
Days Deployed
Moved or Adrift
Out of Position
Not Transmitting
Data Return
0% - 50%
50% - 75%
75% - 90%
90% - 100%

Ship-time concerns

- NOAA ship time shortages led to significant outages of the TAO network.
- NOAA's Class 1 research ship (*Ronald H. Brown*) was diverted to Pacific.
- Through 2016-2017, NOAA-led PIRATA Northeast Extension cruises will be dependent on existing charter options
- Limited ship availability and use of smaller ships leads to reductions in missions during cruises
- Difficulty getting ship-time is endemic, decline of US fleet impacts ability to make sustained observations
- New ships are coming on-line, but not quickly enough

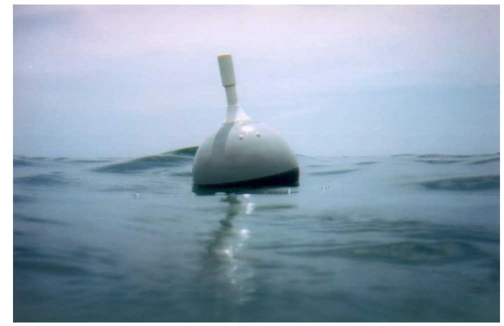


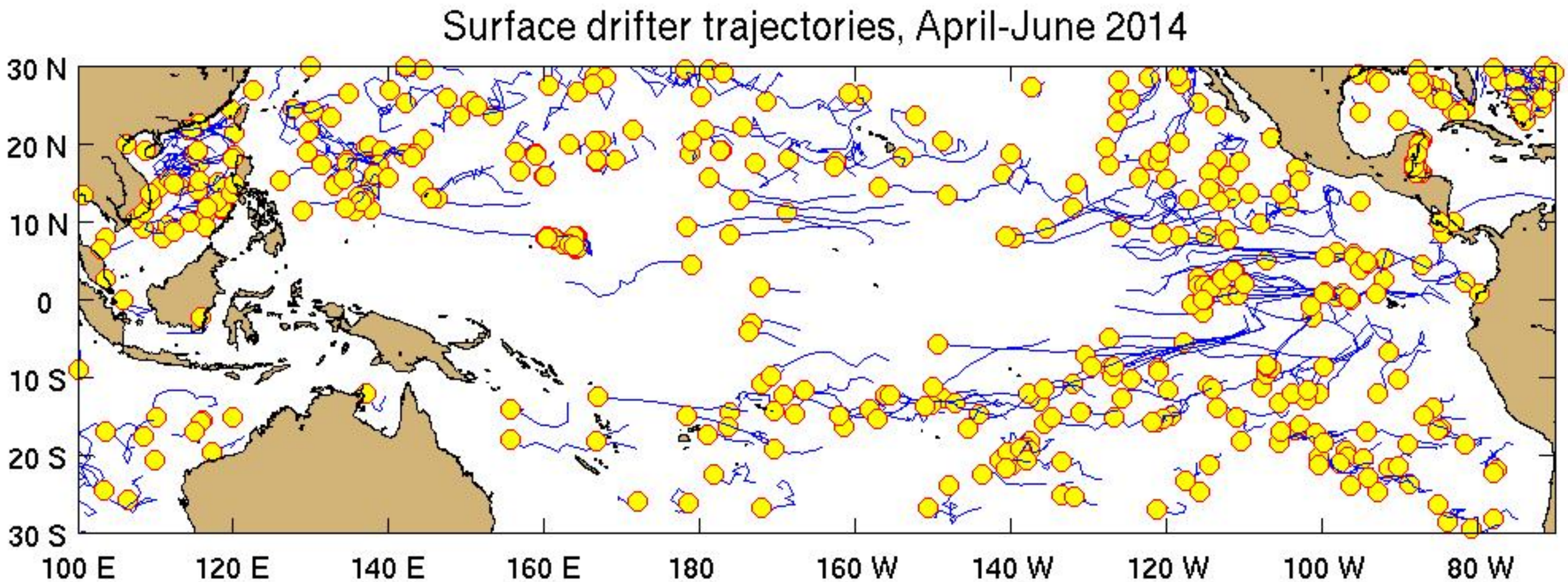


Surface Drifter Observations in the Eastern and Central Tropical Pacific

Surface Currents, Sea Surface Temperature, Winds, Atmospheric Pressure and Surface Salinity

www.aoml.noaa.gov/phod/dac/gdp.html





The Global Drifter Program mainly uses cargo ships and TAO servicing ships to deploy drifters in the central and eastern tropical Pacific.

Cargo ships: transits between Panama Canal, US west coast to/from Australia, New Zealand. Limited longitudes in region. Drifters rapidly diverge from equator (except in strong El Niños).

TAO servicing: with several ships experiencing problems in 2013-2014, a number of deployments were canceled or altered. Recent examples include the 95W/110W lines in August 2013 and again in April 2014. As a result of engine problems on those two cruises, both servicing lines were aborted and 30 drifters had to be reallocated to deployments elsewhere.

The GDP has increased deployments from cargo ships in the region, and will be collaborating with NOAA/NWS on upcoming TAO cruises for additional deployments.