Argo, Deep Argo and SOOP XBT Recent Activities and Results

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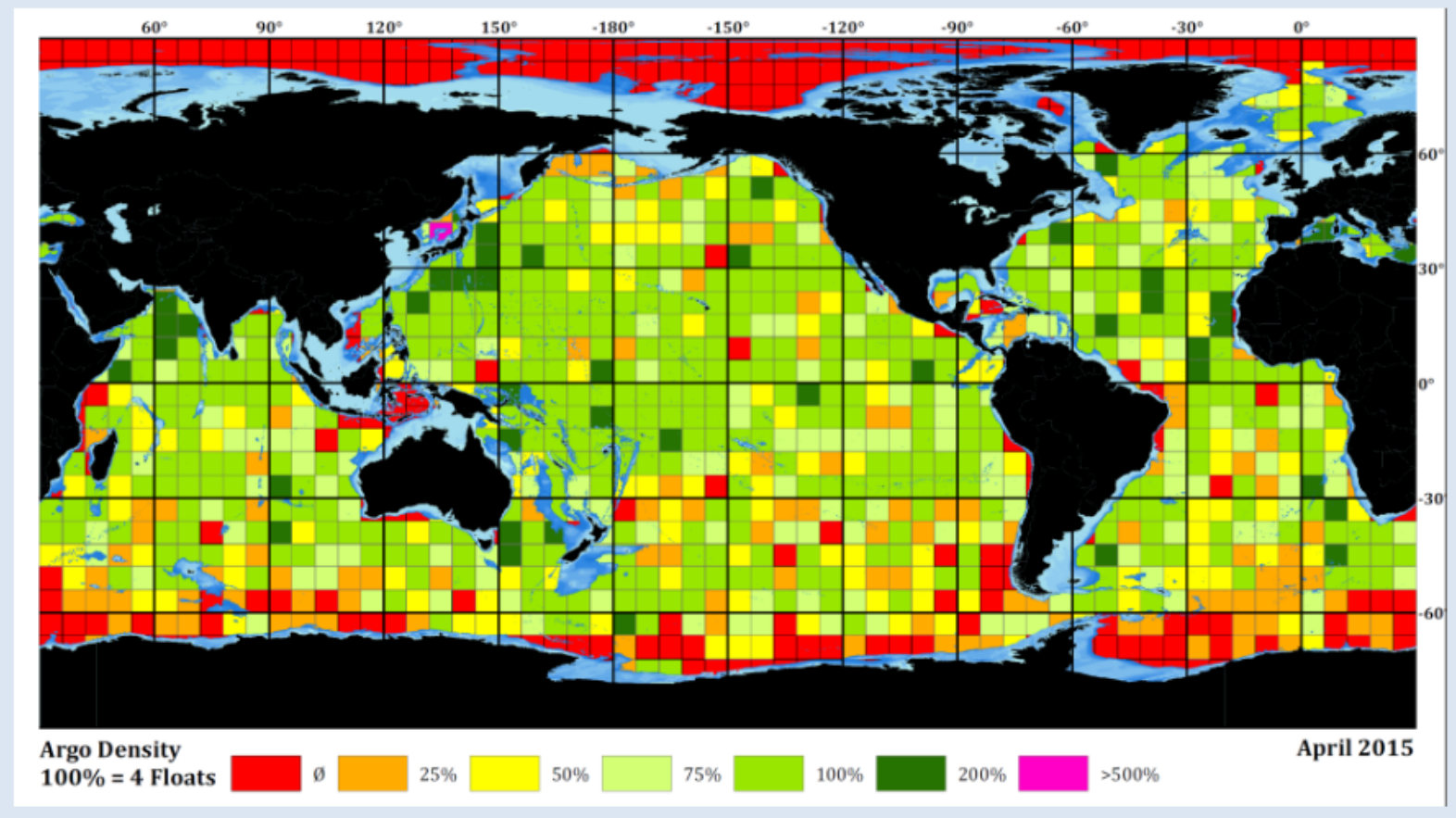
Information for this presentation obtained from D. Roemmich and G. Goni

Argo: Basic Facts

- US Argo supported by NOAA, includes a 5-institution consortium and a data assembly center
- US Argo activities include tech development, commercial acquisition, deployment and logistics, comms, data management, data analysis, international coordination and outreach
- US operates 1890 of 3854 currently deployed floats

Argo: Basic Facts

- Present coverage



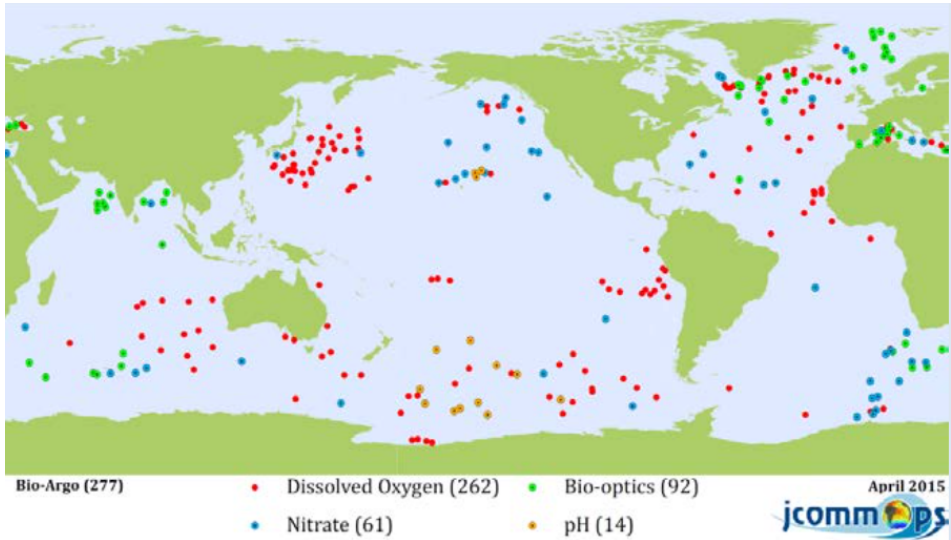
Argo: Recent Advances

- Development and early deployment of Deep Argo (more on this later)
- More biogeochemical sensors
- Major format change to Argo netCDF files to accommodate different types of sensors
- Several gridded Argo products are available (MOAA GPV, Roemmich and Gilson, MIMOC, etc.)
- More use of iridium communications (minimizes surface time, allows two-way control of float missions, higher vertical resolution)
- Deployment from non-traditional platforms (e.g. sailboats)

Schooner Lady Amber
>100 floats

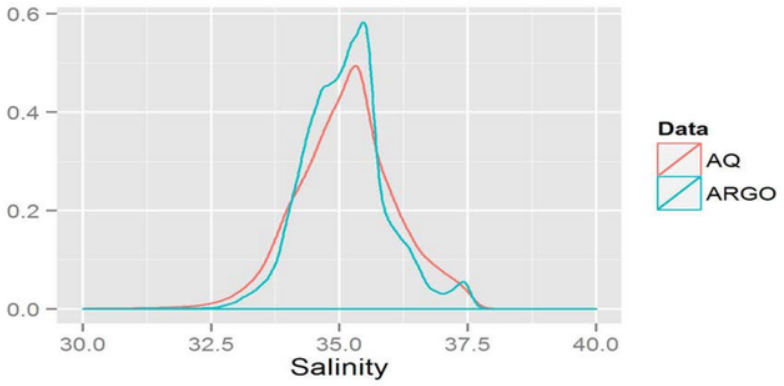
Argo: Future Plans

- Enhanced spatial coverage in marginal seas, WBCs, equatorial regions, high latitudes (~4135 floats)
- Implementation of Deep Argo
- Continued development and deployment of BGC sensors



Argo: Synergies between Argo and other observing system elements

- SSH and altimetry
- Repeat hydrography. Complementary sampling and cross-calibration
- Drifter network. Complementary estimates of dynamic topography
- Tropical moored array. Estimates of subsurface variability
- SSS – ground truth
- SST and OHC

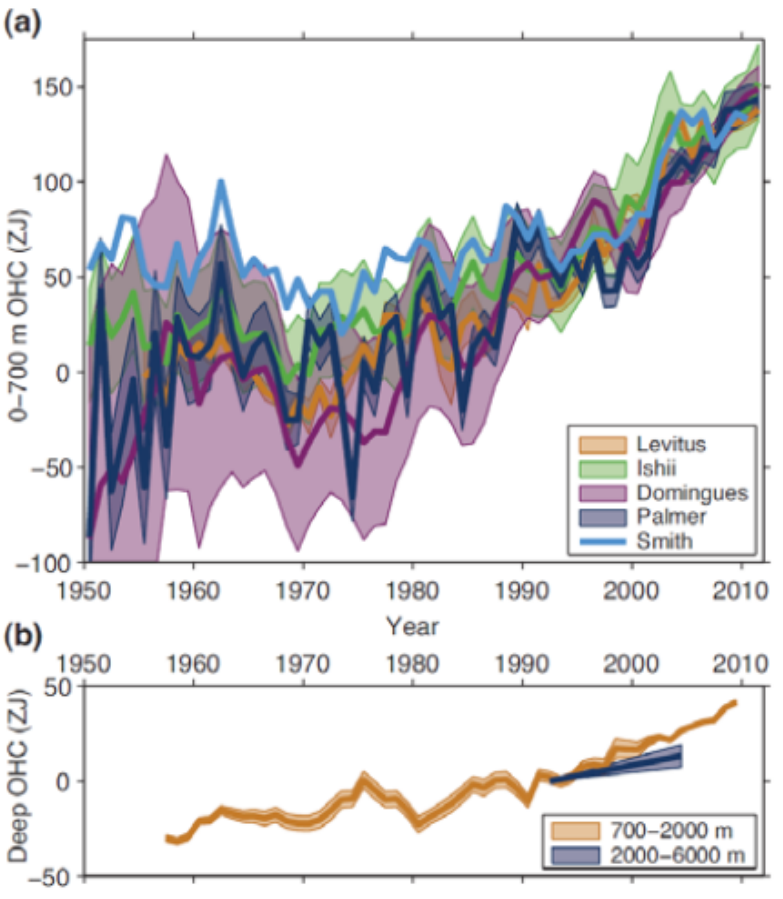


Mannshardt et al., 2015

FIG. 1. Argo and Aquarius Worldwide Comparison

Argo: Accomplishments

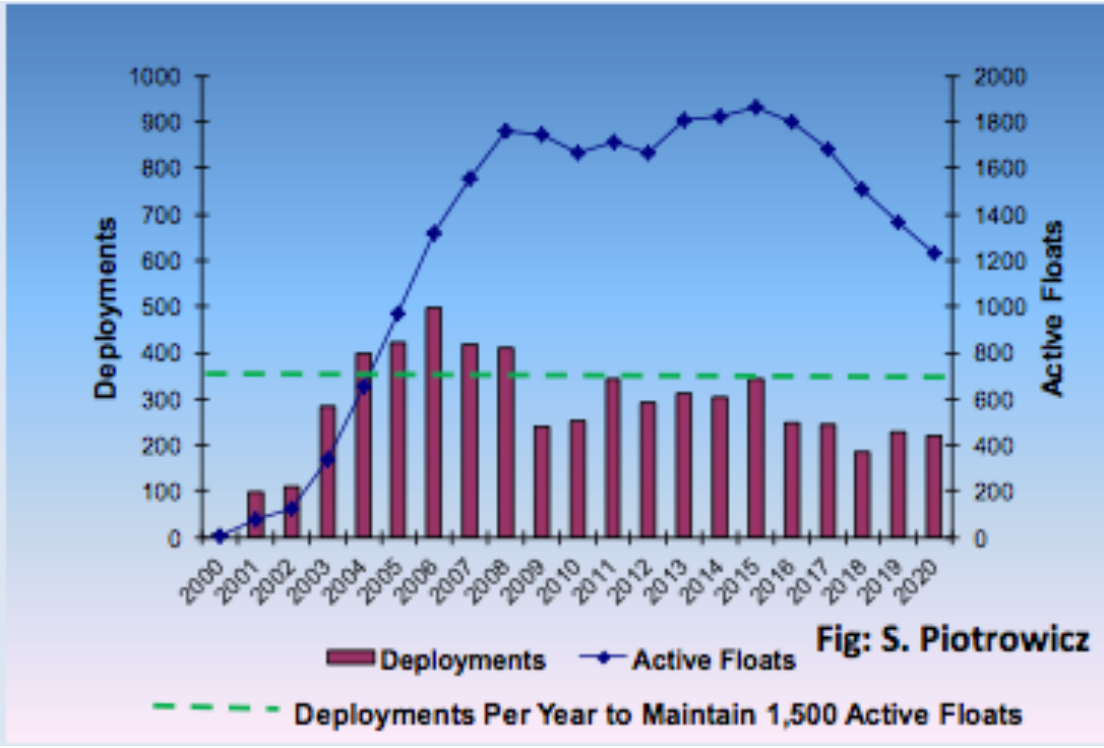
- 2038 Research papers based on Argo
- Global change assessment
- Use in data assimilation models
- Education



IPCC AR5 WG1 Fig 3.2 Observations-based estimates of global mean ocean heat content

Argo: Challenges

- Sustaining core array under level or decreasing budgets
- Deployment inside EEZs and other restricted areas



Deployment priorities. Polar oceans? Regional seas?

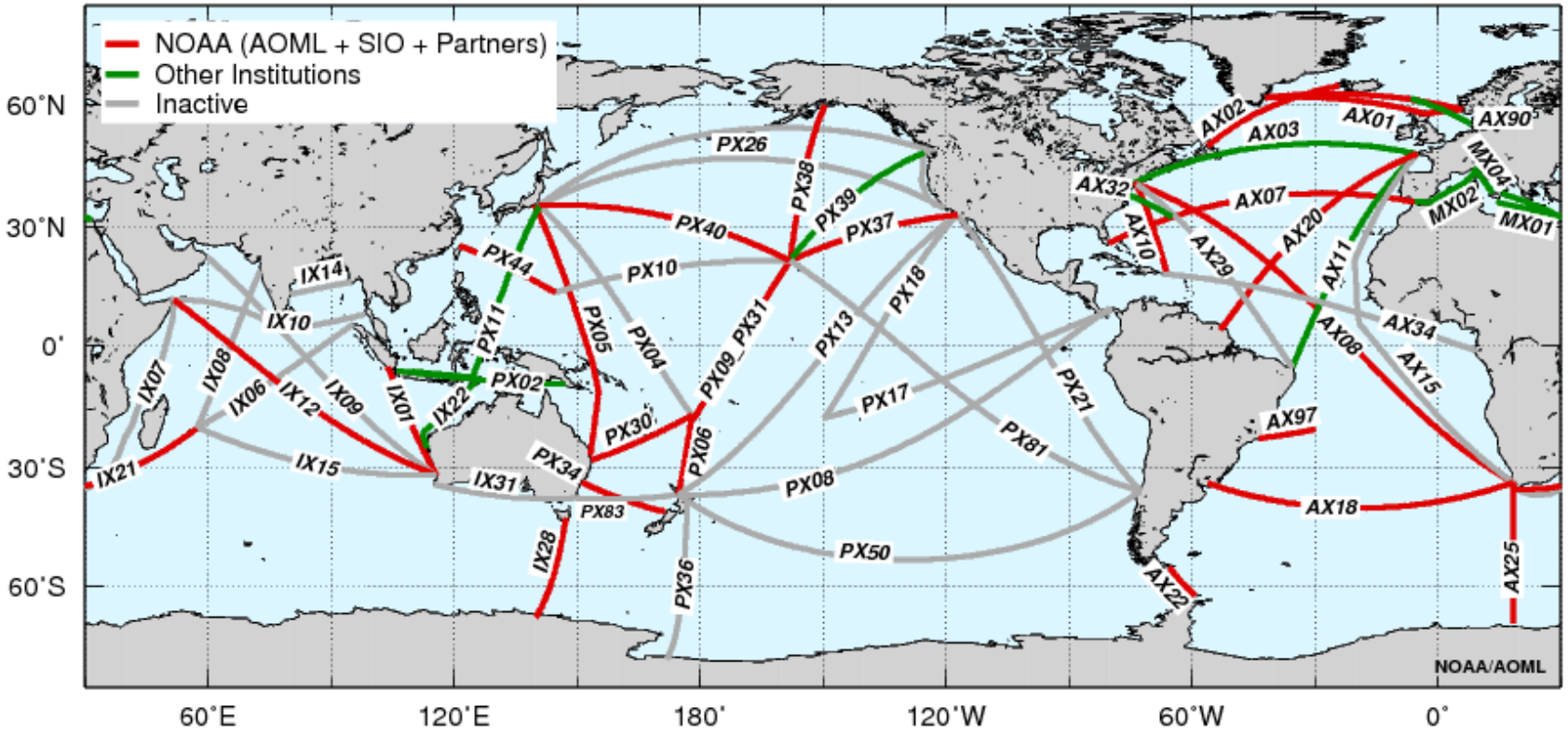
XBT Network: Basic Facts

- **The XBT Network is an international program dedicated to the implementation, maintenance, enhancement, and data management of upper ocean measurements from XBTs**
- Science objectives: meridional heat transport, current variability (esp. WBCs), upper ocean heat content, model initialization and validation

XBT Network: Distribution

- **28 active transects**

Red = Active US

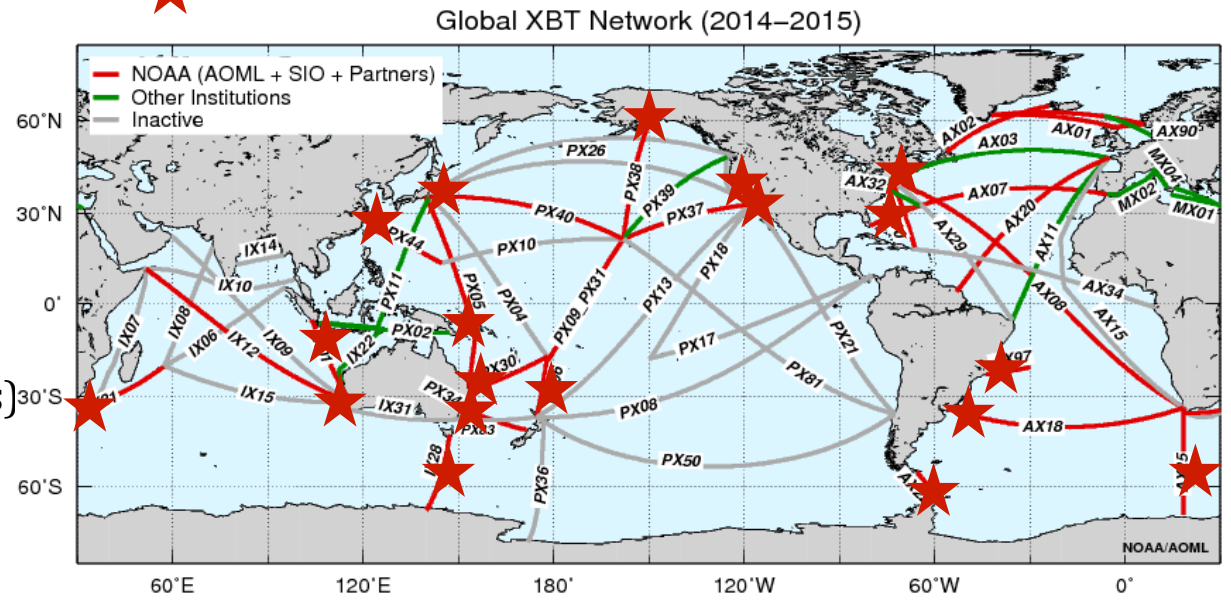


XBT Network: Boundary, surface and subsurface currents

XBT transects are sampling:

Western Boundary Currents:
Kuroshio (3 transects)
Gulf Stream (3 transects)
Agulhas Current, rings
Brazil Current, rings (2 transects)
East Australian Current (2 transects)
East Auckland Current and Tasman Outflow

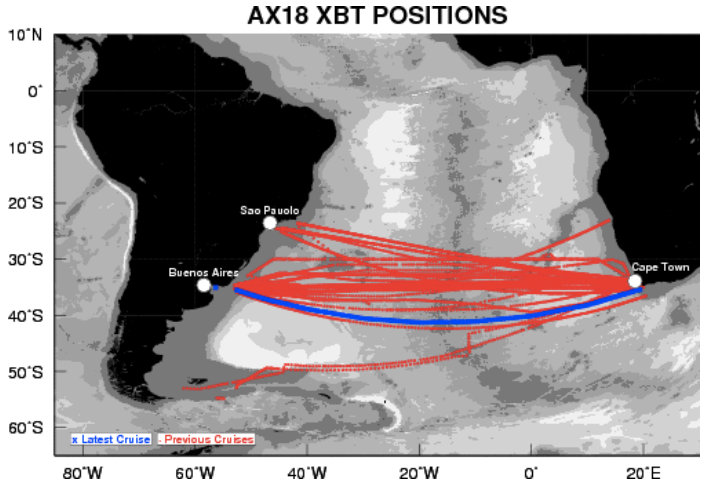
★: Boundary currents sampled by the XBT Network

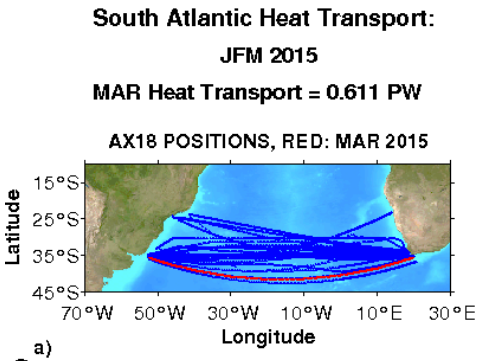


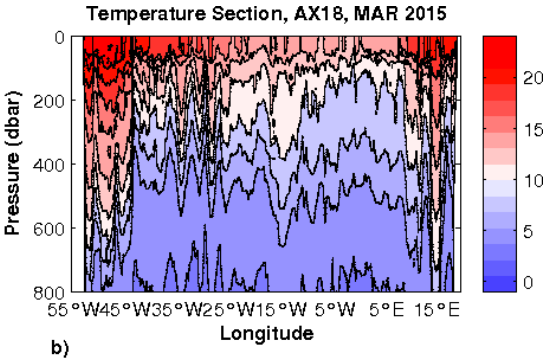
Eastern boundary currents: California Current, Alaska Current, Leeuwin Current, …
Low latitude WBCs: Solomon Sea, Indonesian Throughflow
Equatorial System: NECC, NEUC (2 transects)
High latitude: Antarctic Circumpolar Current (3 transects)

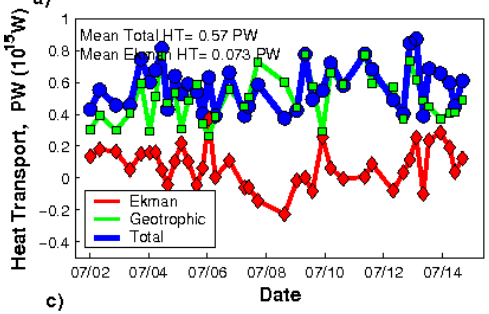
Multiple transects across one current provide critical information on spatial changes in the structure

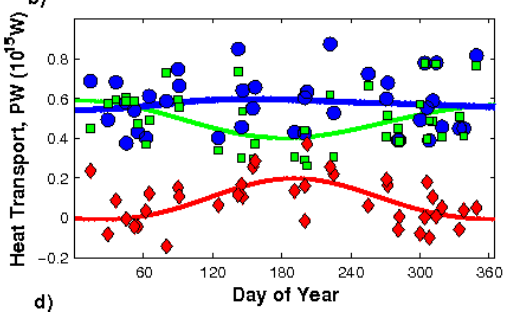
South and North Atlantic Meridional Overturning and Meridional Heat Transport











AX07 (North Atlantic): Started in 1994 (21 years)
AX18 (South Atlantic): Started in 2002 (13 years):

- 42 Realizations
- 11,000 XBTs deployed
- First sustained observations in the South Atlantic to monitor MOC/MHT, and Brazil-Agulhas Currents
- Quarterly reports of MOC/MHT
- Carried out ocean experiments to determine optimal sampling

http://www.aoml.noaa.gov/phod/soto/mht/reports

XBT Network: Recent Developments

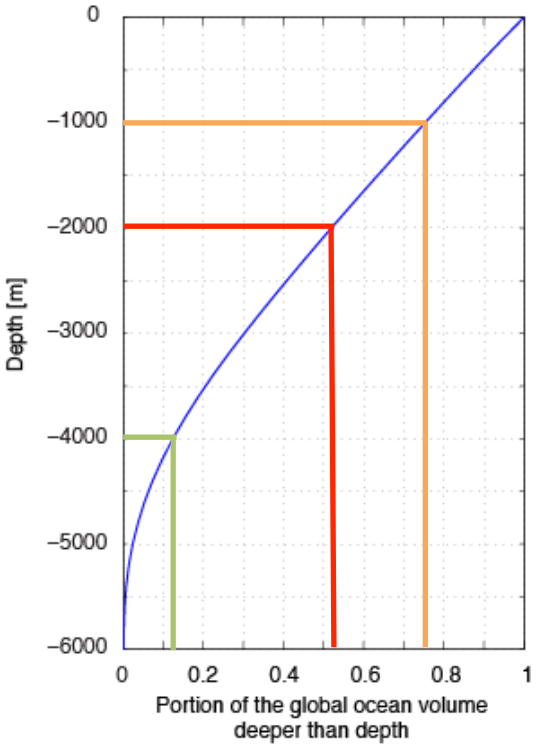
- Transition to Iridium communications
- Redesign of autolaunchers, new data acquisition software
- Program managed with international cooperation (US, Germany, France, Japan, …) by the SOOPIP
- Important long-term datasets (10+ years)
- Are the current transects the best ones to do?

Deep Argo: Basic Facts

- Systematic ocean observations > 2000 m are limited to ship-borne measurements sparse in time and deep moored arrays of confine spatial coverage
- Coverage is not sufficient to describe the mean ocean circulation in many regions or the decadal property variations
- Deep Argo Workshop
  - May 5-7th, 2015 in Hobart, Tasmania
  - 30 participants, 6 countries
  - U.S., France, U.K., Australia, New Zealand, Japan

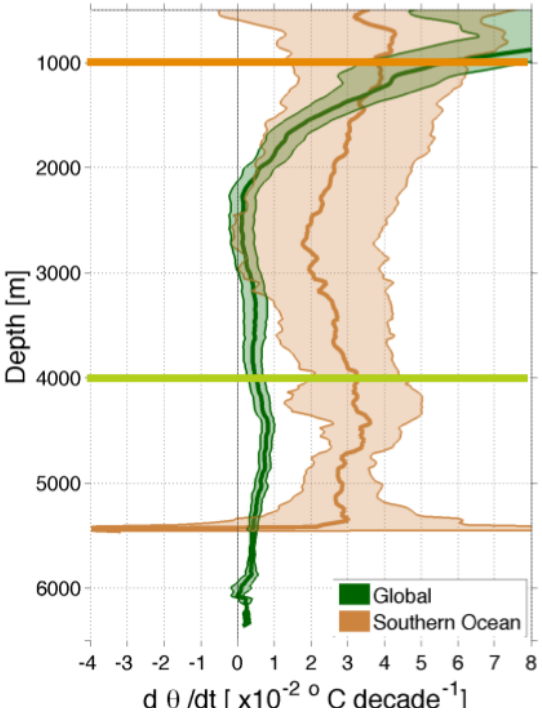
Information for this presentation obtained from N. Zilbermann and the Deep Argo workshop steering committee (Dean Roemmich, Susan Wijffels, Nathalie Zilberman, Guillaume Maze, Steve Riser, Toshio Suga, Katsuro Katsumata, Breck Owens, Greg Johnson, Brian King, Bernadette Sloyan)

Deep Argo: Motivation



50% of the ocean volume is at depth > 2000 m

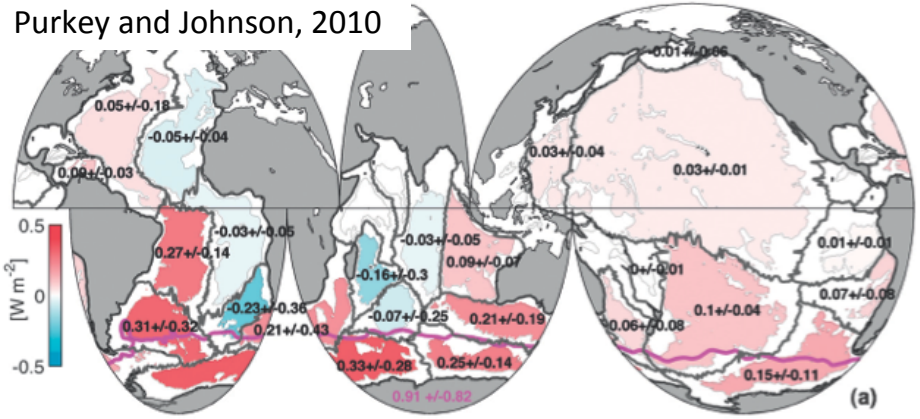
12% of the ocean volume is at depth > 4000 m



Deep ocean warming > 2000 m intensified below 4000 m

Purkey and Johnson, 2010

Purkey and Johnson, 2010



Deep ocean > 4000 m heat uptake equivalent to 0.027 Wm^{-2} (~5 ZJ $decade^{-1}$), about half of the ocean below 2000 m

Regional signals > 4000 m are much larger

Deep Argo: Value

1. **Operational application**

Improve global ocean reanalysis and coupled ocean-atmosphere forecasting systems below 2000 m (assimilation, constraint, OSSEs, removal of deep bias)

2. Basic research

- ❑ Significant progress in global heat budget and freshwater storage
- ❑ Improve knowledge of regional distribution of regional sea level budget, and quantification of the causes of sea level change
- ❑ Provide basin coverage of deep ocean circulation
- ❑ Resolve abyssal decadal signal changes locally not just globally
- ❑ Many other research topics (mixing, ice melting, TS structure, ...)

3. Mutidecadal climate change assessment

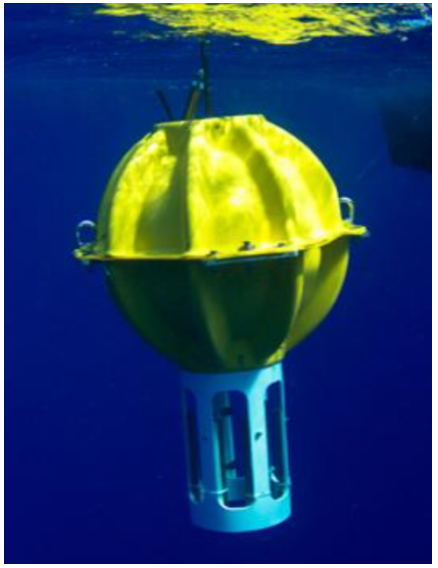
IPCC AR5, BAMS state of the climate reports, ...

4. Education (as demonstrated for Argo)

Deep Argo: Float models

Deep NINJA
TSK Co LTD, JAMSTEC
0 – 4000 m
SBE-41 CTD
50 kg
15 deployed so far

Deep APEX
TWR, UW
0 – 6000 m
SBE-61 CTD
43 cm glass sphere
2 Prototypes deployed



Deep ARVOR
NKE, CNRS, IFREMER
0 – 4000 m
SBE-41 CTD
26 kg
4 Prototypes deployed

Deep SOLO
SIO
0 – 6000 m
SBE-61 CTD
25 kg
33 cm glass sphere
3 Prototypes deployed

Technical aspects of Deep Argo floats under discussion

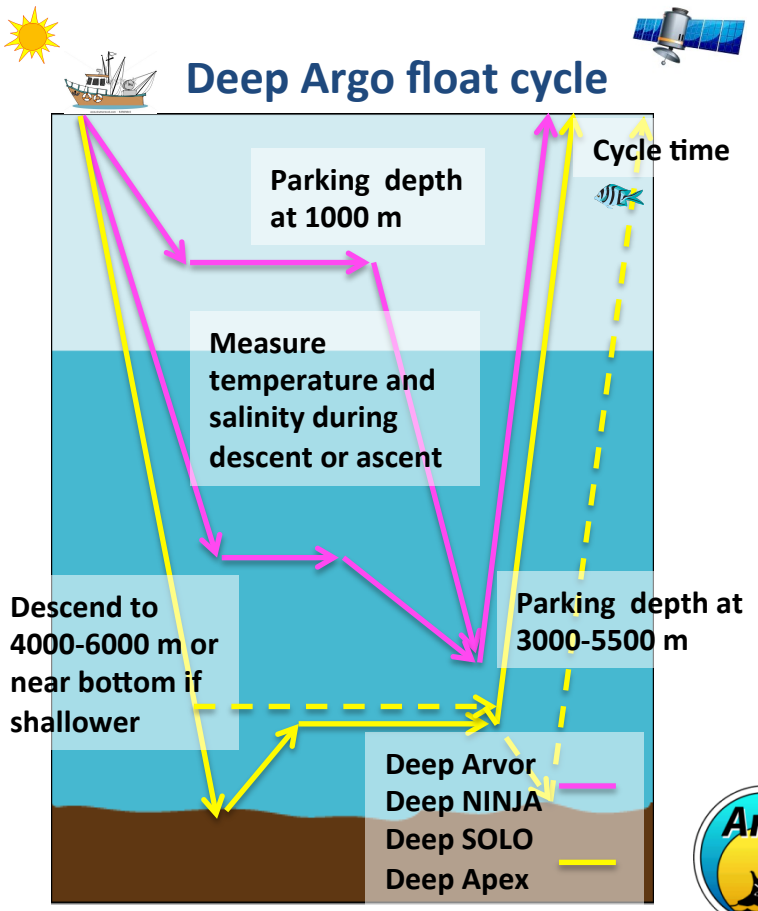
Deep NINJA

Deep Apex

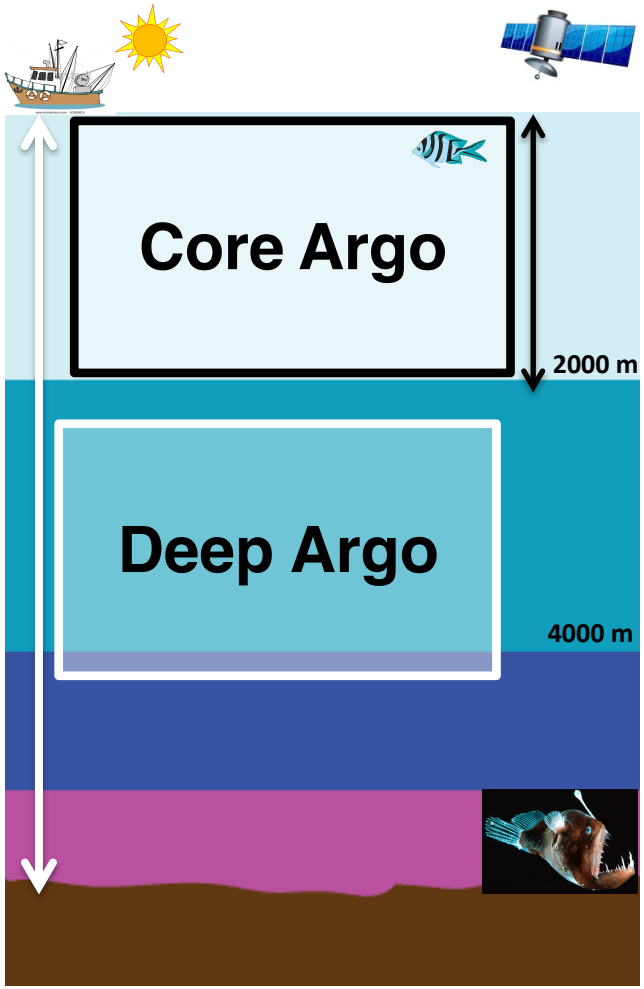
Deep SOLO

Deep Arvor

- Cycle time – aim for array refresh time of 5 years (15-day cycle)
- Collect data during ascent or descent
- Parking depth. Bottom landing
- Vertical resolution of profile
- CTD accuracy requirements: ±0.001°C, ±0.002 salinity, ±3 dbar)
- Meeting temperature accuracy goal, working towards salinity and pressure goal.

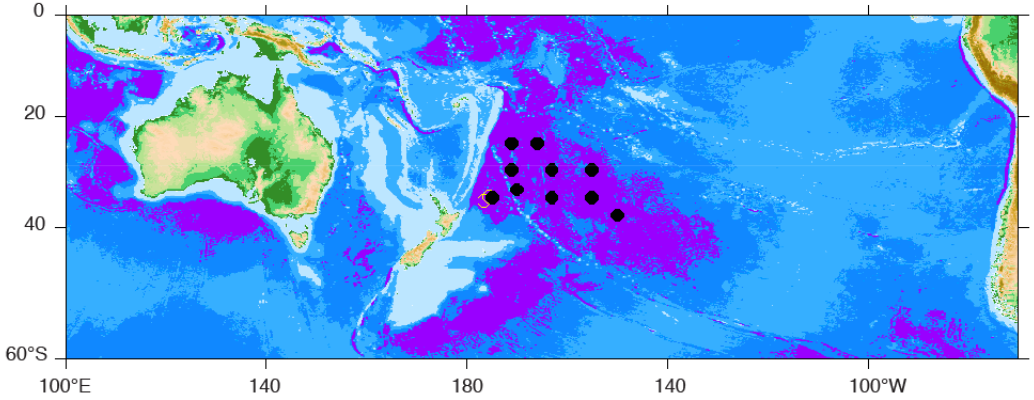


Deep Argo: Recent Developments



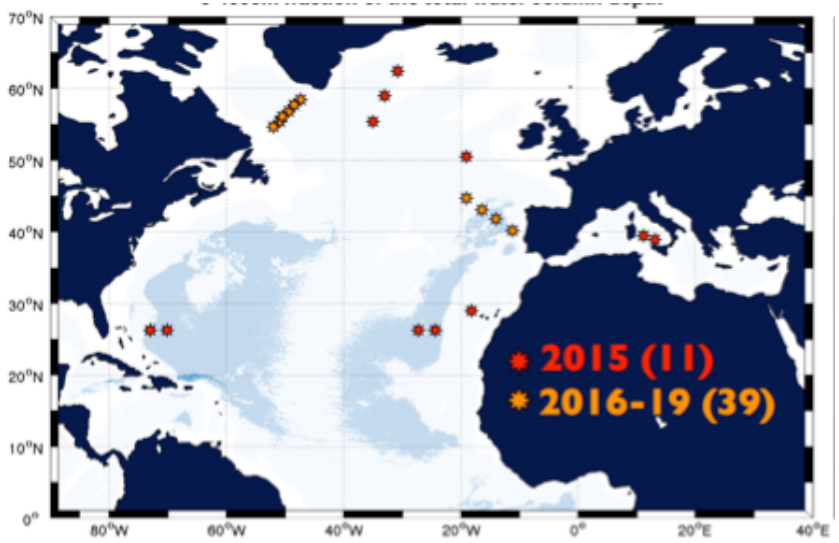
- A Workshop was held to discuss technology developments for Deep Argo, scientific and operational rationales, and plans for future work
- 4 designs of Deep Argo floats have been developed and tested with depth ranges of 4000 m and 6000 m
- A Deep Argo CTD has been developed by SBE in collaboration with NZ/US/Aus. Argo and deployed in shipboard casts and float profiling, with encouraging results.
- Regional pilot arrays of Deep Argo floats have begun and will continue in 2015-2016 in the Southern Ocean, SW Pacific, and North Atlantic

Southwest Pacific Ocean



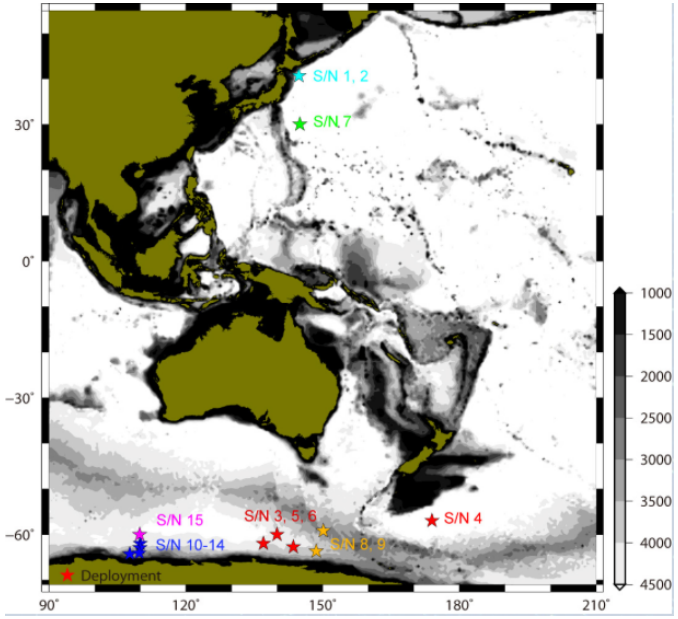
2 Deep SOLO in 2014
8 Deep SOLO, 2 Deep Apex in 2015
Deployment opportunity in 2016
(R/V Investigator, CSIRO, P15S)
Flat abyssal plain w/ substantial deep warming, limited eddy activity

North Atlantic Ocean



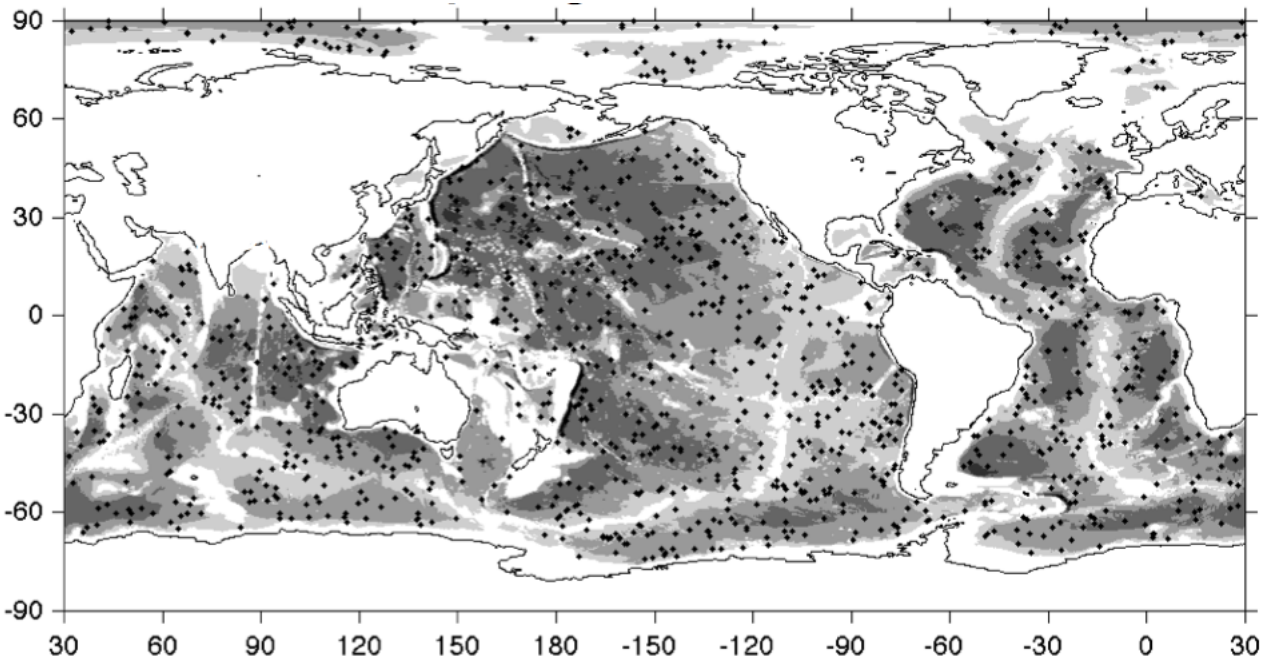
2 early (3500m) Deep Arvor in 2012-2013
2 Deep Arvor prototypes (4000 m) in 2014
9 Deep Arvor in 2015
North Atlantic deep water formation rates and characteristics

North Pacific Ocean and Southern Ocean



15 Deep NINJA deployed in 2012-2014
3 Deep NINJA in 2015
Engineering test (3,Pacific Ocean), water mass formation and deep MOC (12,Southern Ocean)

Deep Argo: Straw Plan



Greg Johnson

- Plan: 2-3 year pilot arrays before global implementation
- Sample to the ocean bottom (up to 6000 m)
- 5° x 5° spacing: ~1200 floats, based on decorrelation statistics
- Start at high latitudes (deep-ocean warming signal) -> equator -> global
- Challenges: Funding, CTD technical challenges, float endurance, leverage international collaboration between partners