

Sustaining and Enhancing Argo for Observing the Global Ocean



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For the International Argo Steering Team

GOV Science Team Meeting

Bergen, November 2017



Outline

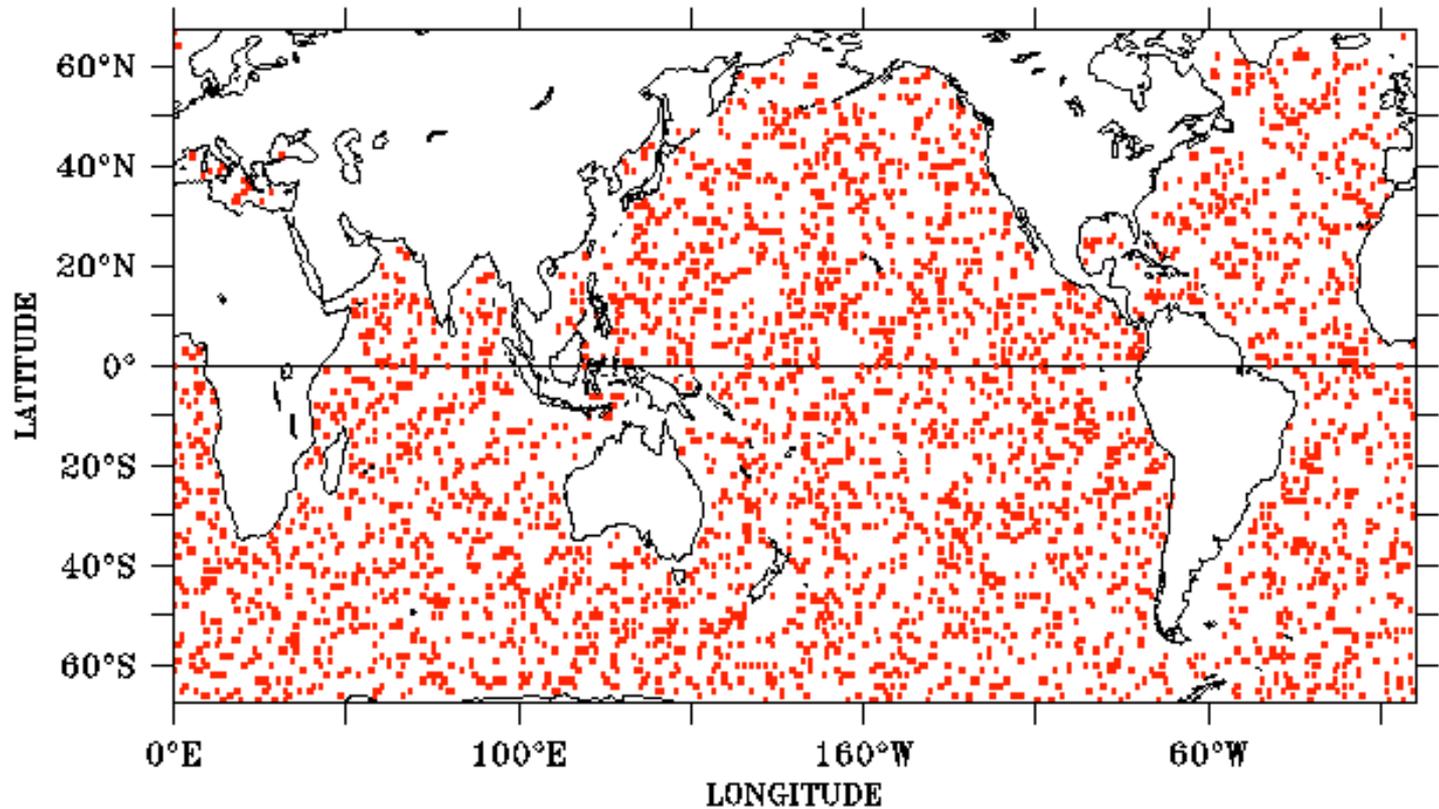
- The status of Argo
- Enhancements to Argo's upper ocean mission: sampling more of the global ocean area and sampling it more effectively.
 - Marginal seas
 - Equatorial variability
 - Seasonal ice zones
 - Western boundary current regions
- New Argo missions
 - Deep Argo
 - BGC Argo.
- Challenges
- Links Argo / GOV



Argo in 1998: an idea

On The Design and Implementation of Argo

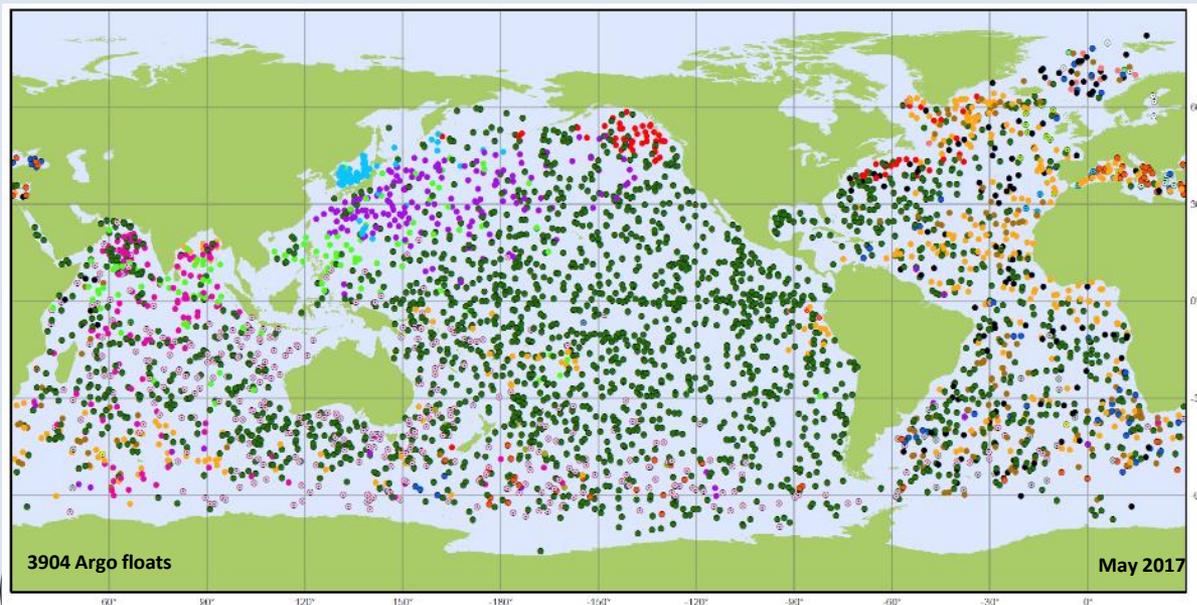
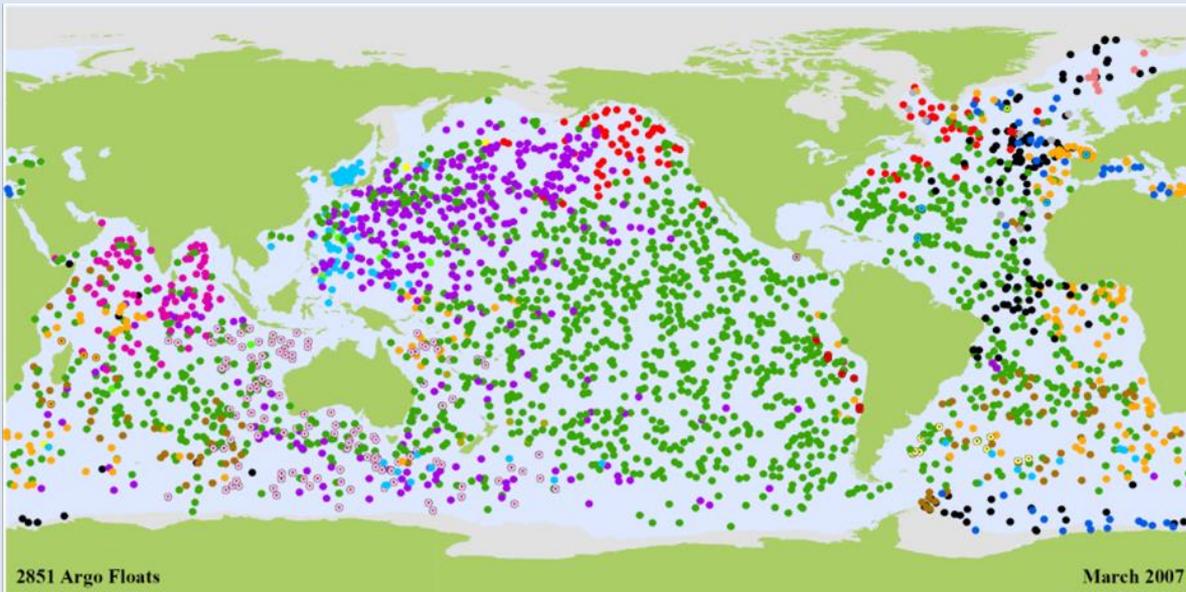
A Global Array of Profiling Floats



From the 1998 Argo Design document: See <http://www.argo.ucsd.edu/argo-design.pdf>



Argo in 2007 to 2017

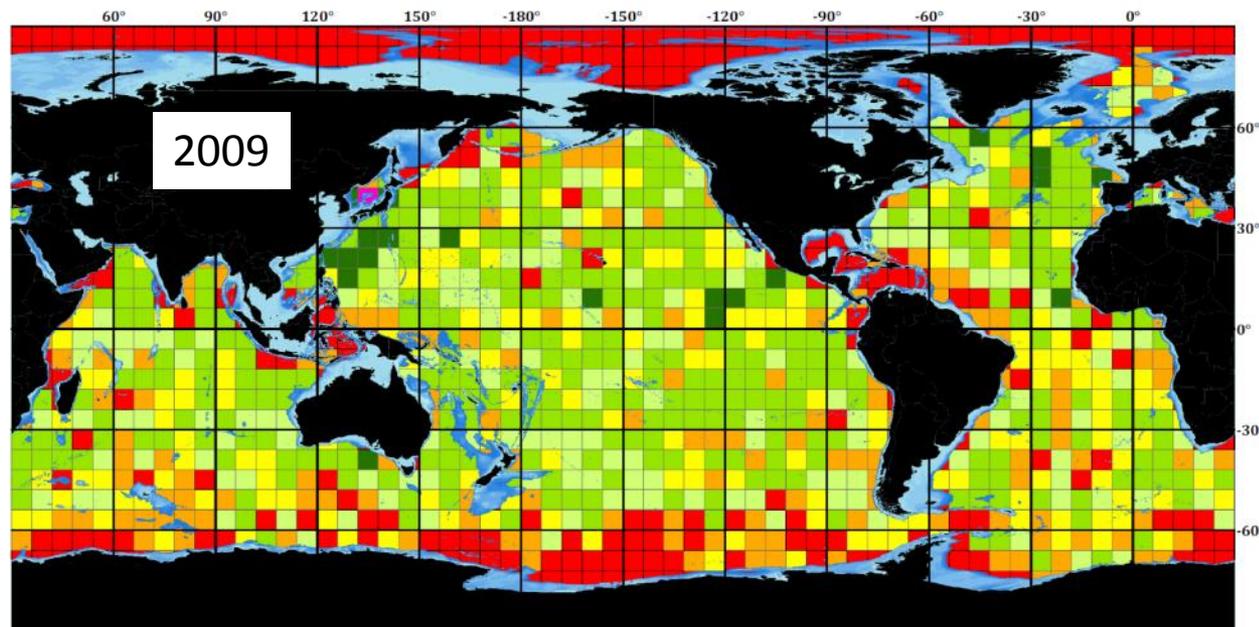


- The Argo array is remarkably similar to the original 1998 design, with contributions from over 28 nations.
- More than 1.6 million T/S profiles and trajectories have been acquired, presently > 10,000 per month.
- Argo profile data quality is better than originally expected, thanks to SeaBird, the Argo Data Management Team, and users.
- Since the 3000-float mark in 2007, further gains have been made in coverage and data quality.

Density of coverage:

Floats per 6° square
2009 and 2017

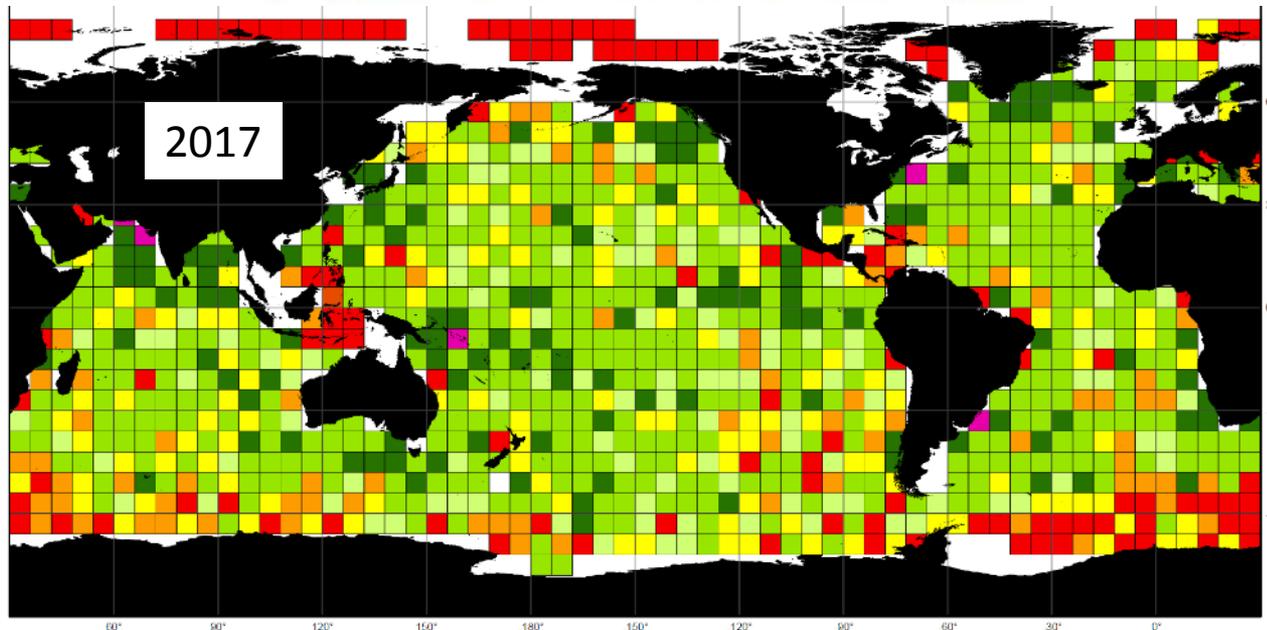
Improvements:
South of 60°S
Eq. Pacific
Gulf of Mexico/Caribbean
Mediterranean
S. Atlantic
Some coastal regions



Density (good floats only)
100% = 4 Floats

Red	Orange	Yellow	Light Green	Green	Dark Green	Magenta
0	25%	50%	75%	100%	200%	>500%

November 2009



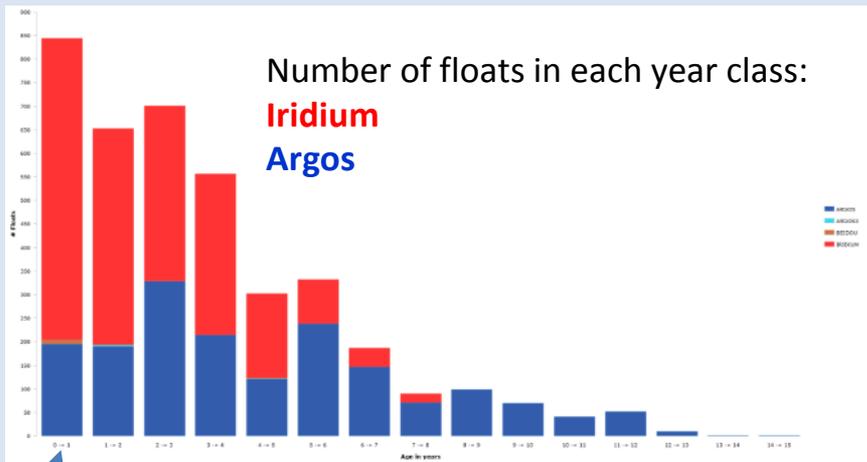
Argo Density - simple March 2017



Bi-directional comms.

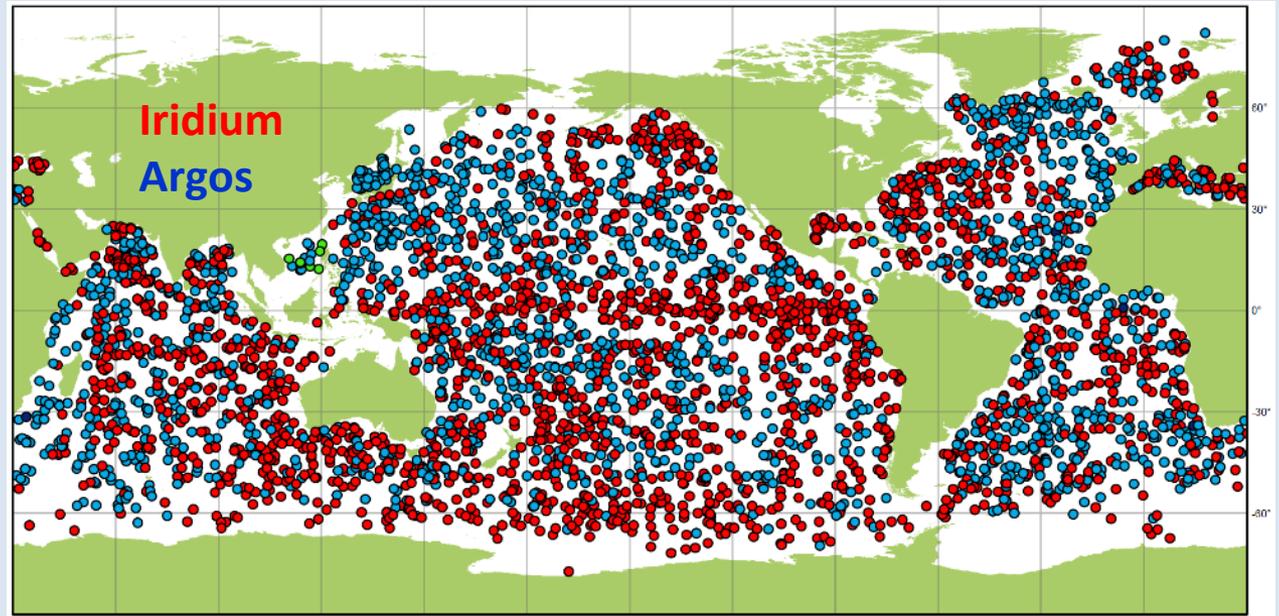
Today, over half of operational Argo floats use Iridium, including 80% of those deployed in the past year.

Below: Note the Equatorial Pacific, high southern latitudes, and some marginal seas.



0 - 1 year old

- Bi-directional communication is having major impacts on Argo:
- Minimizing sea surface hazards and
 - Enabling mission changes.



Argo

Telecom. Types

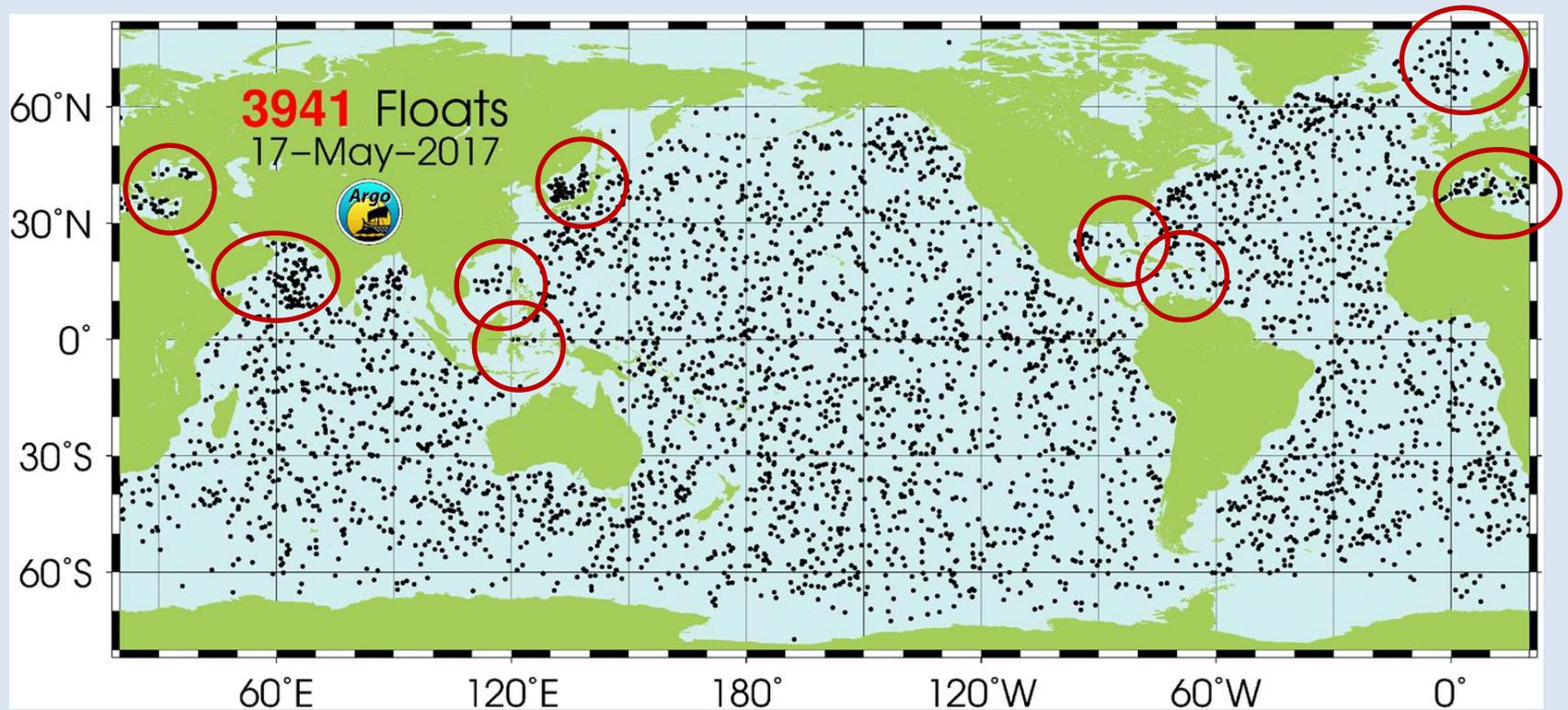
May 2017



Figures: JCOMMOPS

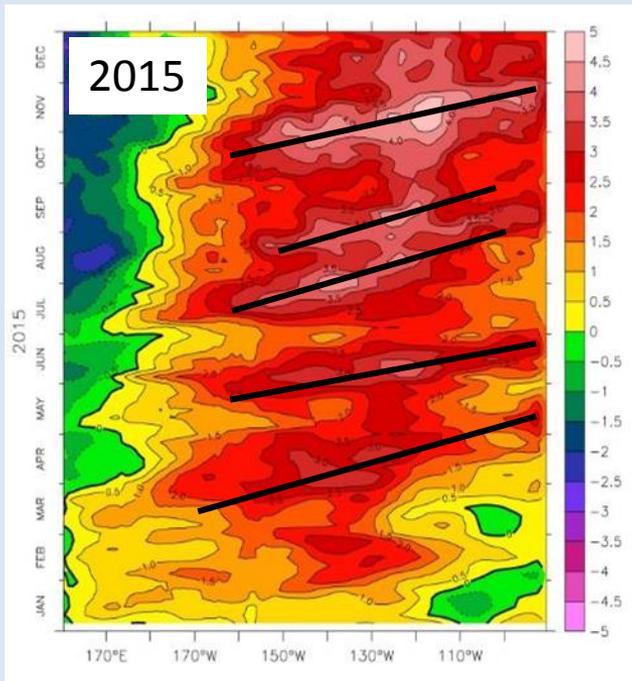
Marginal Seas

- Target density 2 x global design = 2 floats every 3° x 3°
- Demand for biogeochemistry and optics is high
- Present coverage is uneven, with about 200 active floats.
- Implementation can only happen within strong functioning GOOS regional alliances which are able to overcome EEZ sensitivities



Equatorial Enhancement

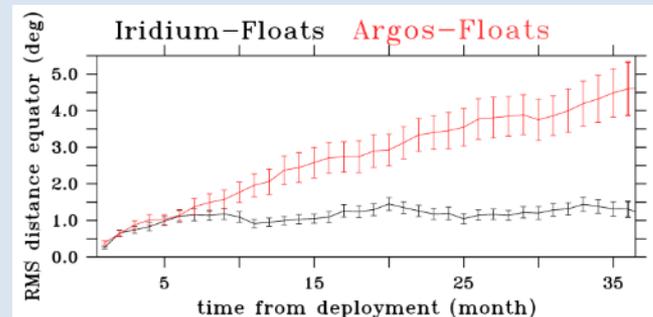
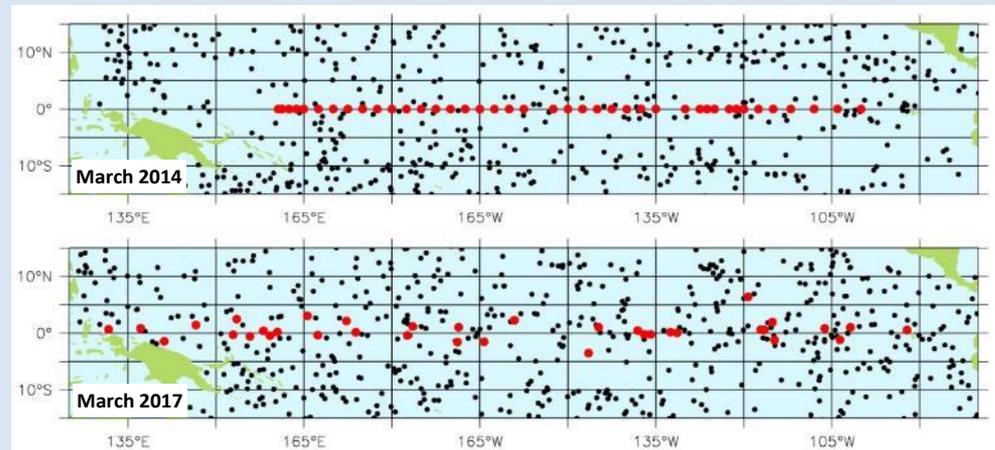
- *TPOS 2020 First Report* recommends doubled Argo coverage in the Pacific from 10°S to 10°N, beginning with the western Pacific and along the equator.
- Improved spatial resolution of intraseasonal to interannual variability is important for observation of ENSO/monsoon/IOD



0-200m vertically-averaged temperature anomaly along the Equator in 2015, showing the sequence of Equatorial Kelvin waves.

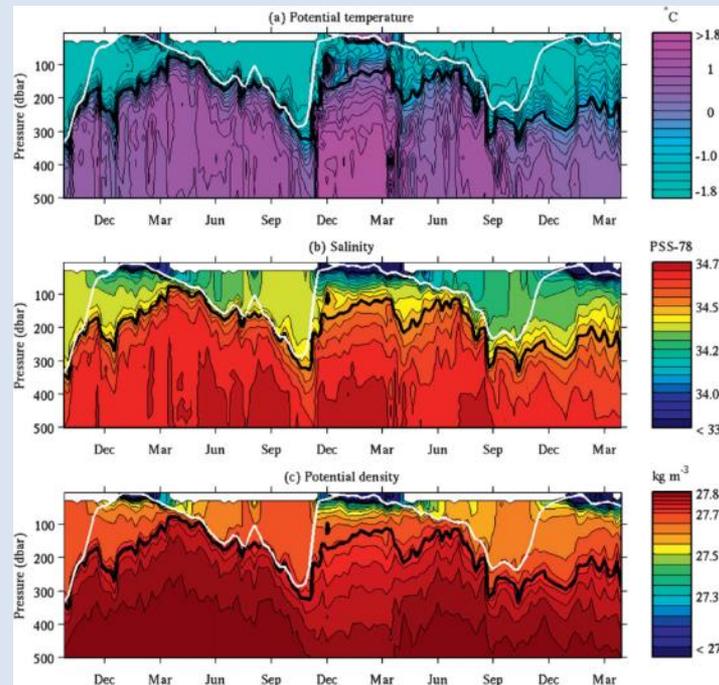
Mapping improvements: Gasparin et al (2015, JAOT)

2014 pilot deployment of 41 Argo floats (red)

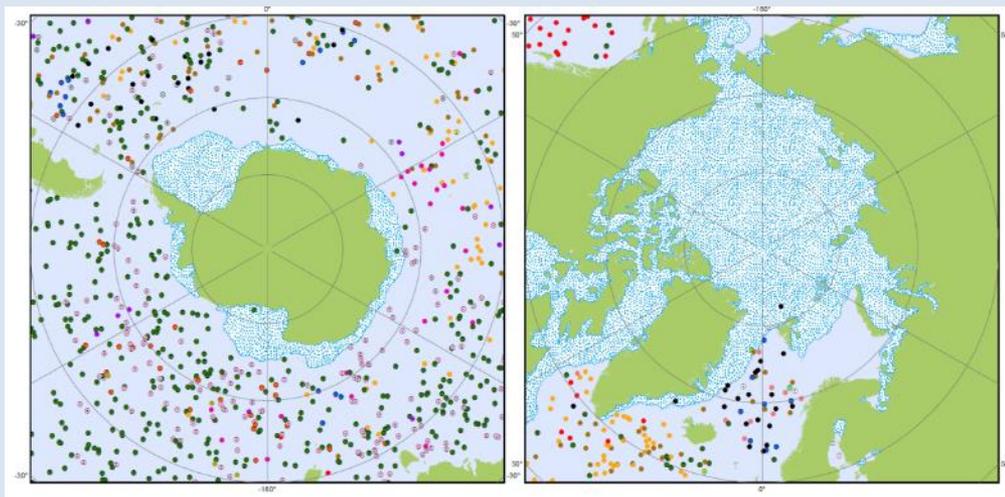


Seasonal Sea-Ice Zone

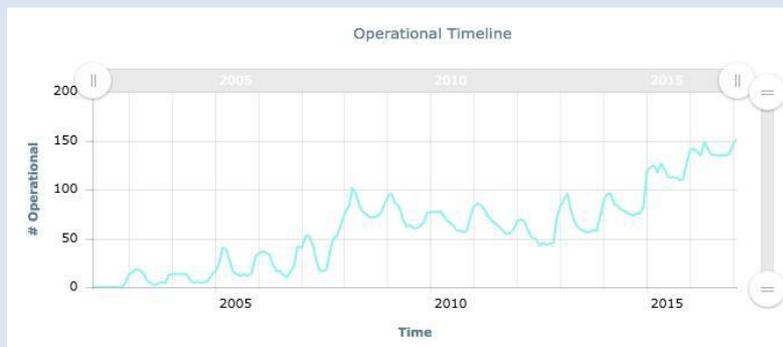
- A blind spot in the GOOS – needs to be urgently addressed due to links between ocean warming – ice sheet loss – future sea level rise.
- Arctic- 86 active floats north of 60°N.
- Antarctic- 154 active floats south of 60°S. Deployment opportunities are limiting.
- Floats use an “Ice-avoiding” algorithm to remain below ice during winter.



Modification of surface waters in the ice zone (Wong and Riser, JPO 2011)



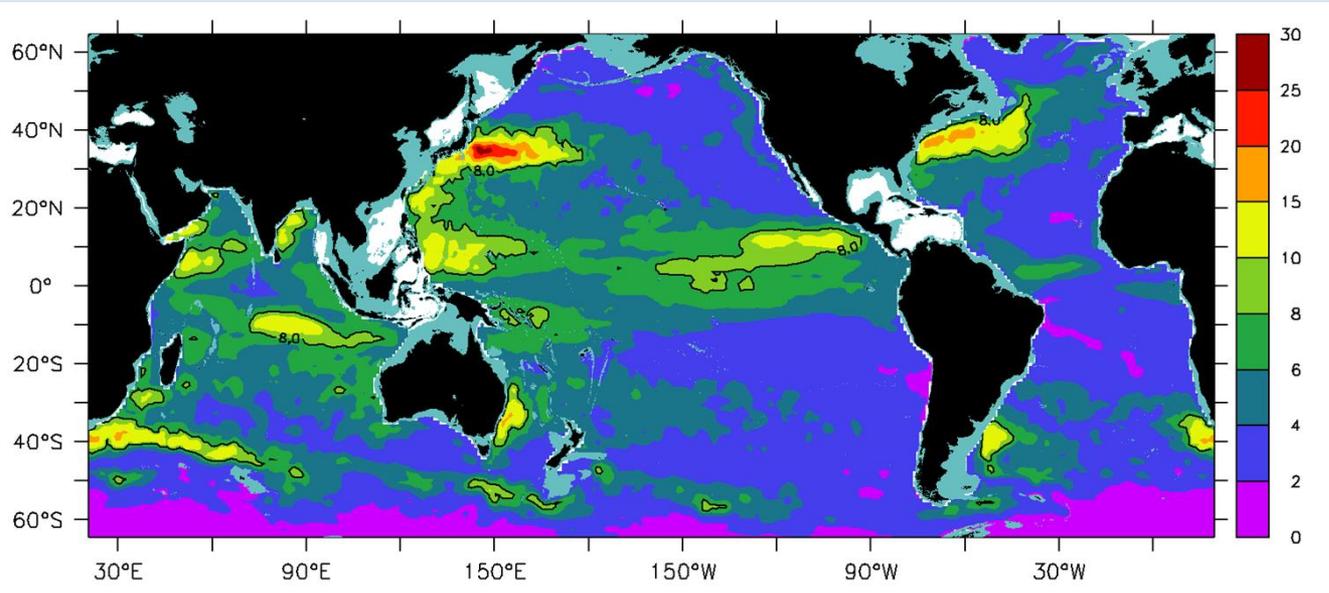
Active Southern Ocean and Arctic floats, 5/2017



Timeline of active Southern Ocean floats

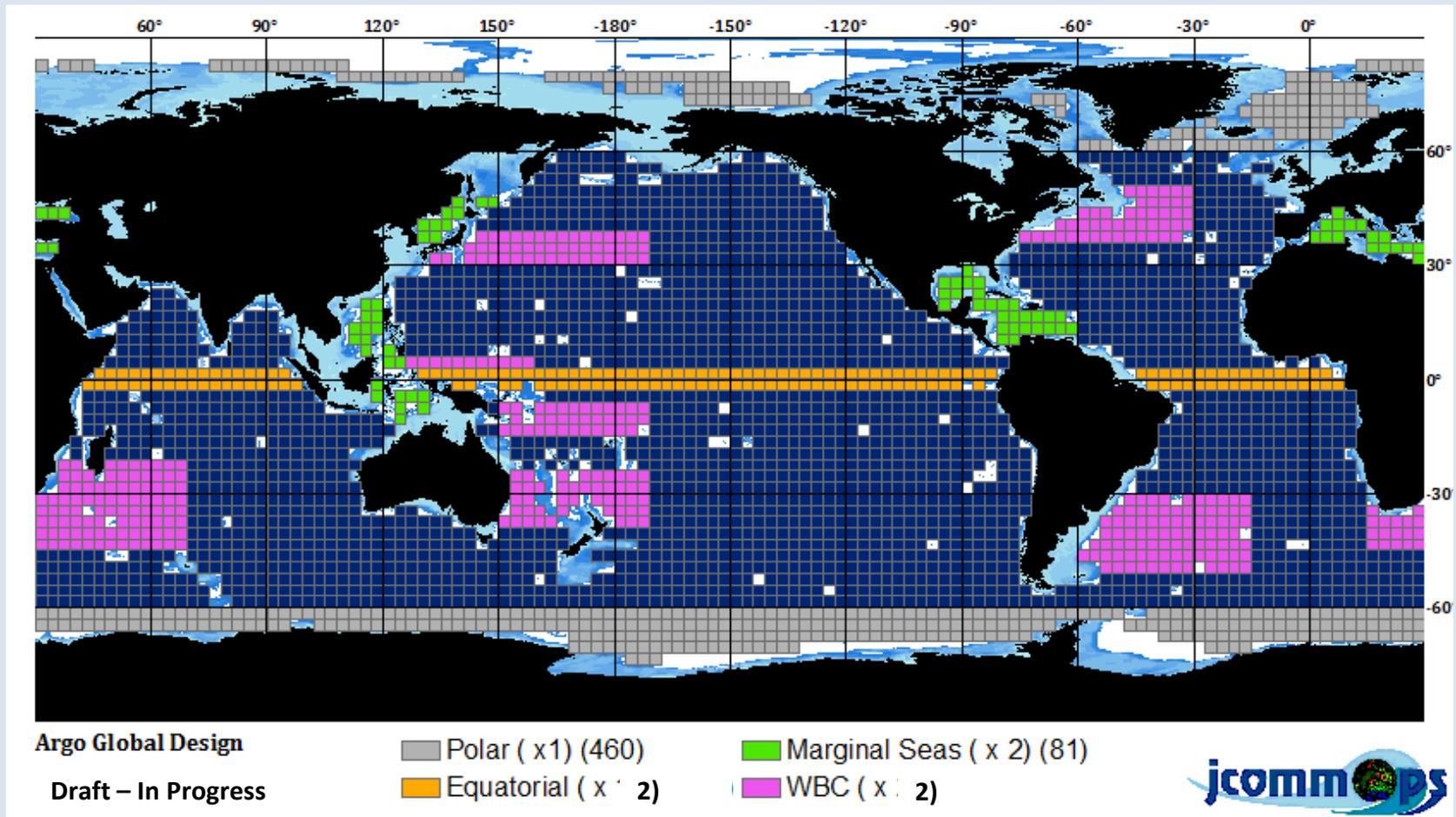
Western Boundary Regional Enhancements

- High eddy activity drives a lower signal/noise ratio for Argo's target space/time scales. Enhanced resolution needed.
- Target density 2 x global design = 2 floats every $3^\circ \times 3^\circ$ in high energy regions.
- Due to process studies and regional interest, the Kuroshio/Oyashio system has been a pilot of this coverage enhancement.
- Engagement with OSE/OSSE activities useful to clarify benefits from and to obtain further guidance for this enhancement.



Standard deviation of monthly Argo dynamic height (cm, 0/2000)

Going Forward - Revising Global Argo Design



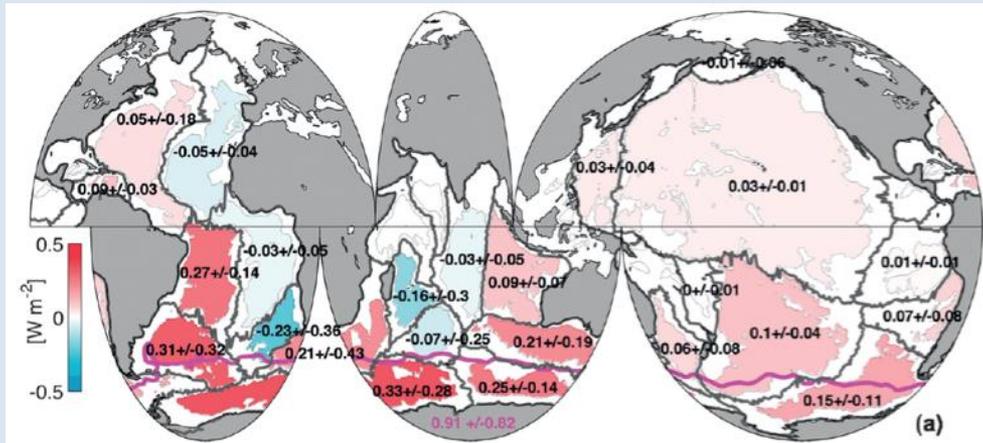
- Same mission – but more spatially complete and better signal to noise ratio. The total requirement is 4400 floats
- Double coverage in WBCs and equatorial regions
- Marginal Seas: enhanced sampling - determined by regional partnerships
- Seasonal Ice zone: normal sampling



New Missions: Deep Argo

Why?

- Sparse repeat hydrographic data show that the ocean below Argo-depth is warming consistently, particularly in the Southern Hemisphere.
- This matters for sea level rise and the Earth's energy budget.
- Important elements of deep circulation and MOCs are below 2000 m .
- Model initialization/assimilation requires data below 2000 m.



Bottom Water warming from 1990's to 2000's

Purkey and Johnson (2010)

Deep Argo Implementation Workshop 5-7th May 2015



**Report on the
Deep Argo Implementation Workshop**

Hobart, May 5-7th 2015



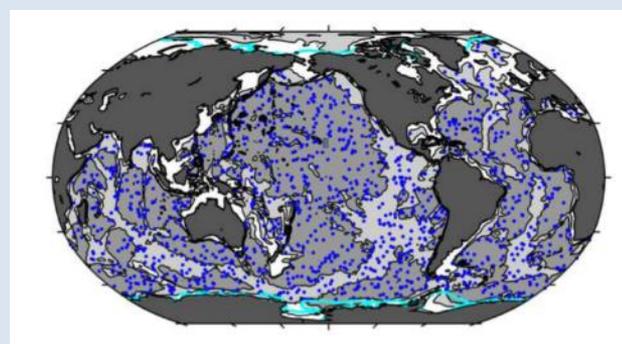
Nathalie Zilberman and Guillaume Maze



Report of the Deep Argo Implementation Workshop

<http://www.argo.ucsd.edu/DAIW1report.pdf>

Deep Argo



Left: Strawplan for 1228 Deep Argo floats at nominal $5^\circ \times 5^\circ$ spacing (Johnson et al, JAOT, 2015) over the global ocean where depth exceeds 2000 m. (Based on decorrelation statistics from GO-SHIP decadal repeat hydrography.

Status

- Four Deep Argo float models have been developed and tested.
- New CTDs (6000 m SBE-61, plus 4000 m version of SBE-41) are under assessment for stability and accuracy.
- Coordinated regional Deep Argo pilots are being deployed in the N. and S. Atlantic, S. Pacific, and Southern Ocean

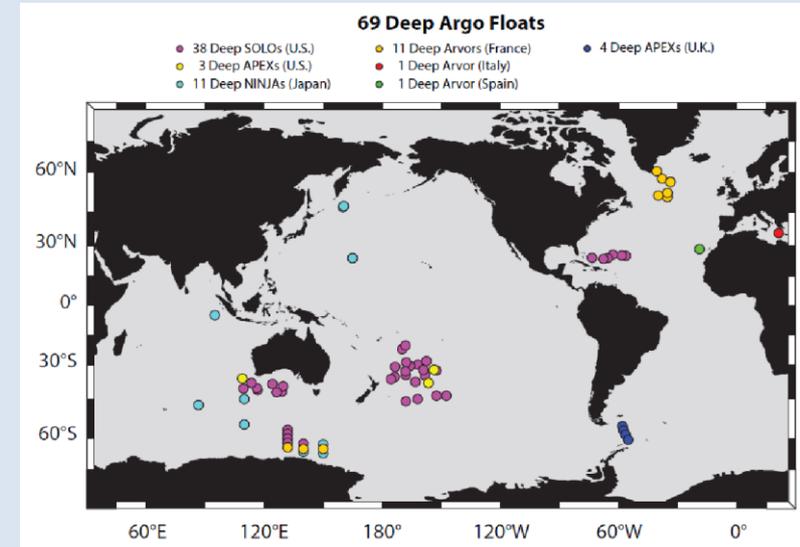
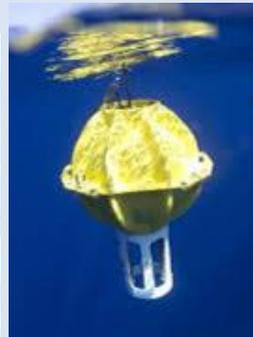
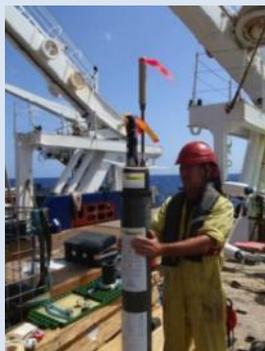


Figure: N. Zilberman



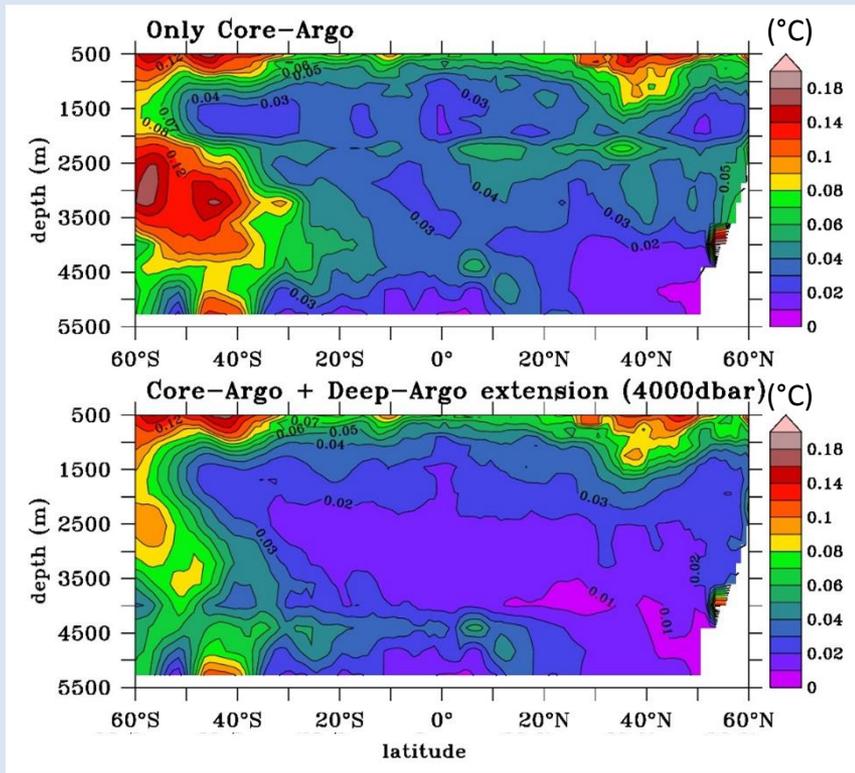
Deep NINJA (left) and Deep PROVOR (below) 4000 m floats.



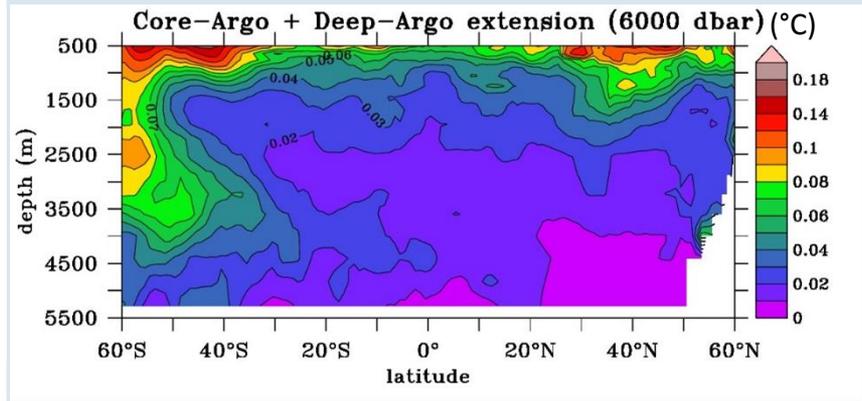
Deep APEX (above left) and Deep SOLO (above right) 6000 m floats.



Deep Argo OSSE - Mercator Ocean (Gasparin et al.) (Atlantos H2020 project)



Temperature zonal RMS diff. compared with the realistic simulation for representing a 2-yr mean for only core-Argo (0-2000dbar, top panel), for core-Argo + deep-Argo extension (0-4000dbar, bottom left panel), for core-Argo + deep Argo extension (0-6000dbar, bottom right panel)



Large potential impact of Deep Argo for GOV systems



New Missions: BGC-Argo

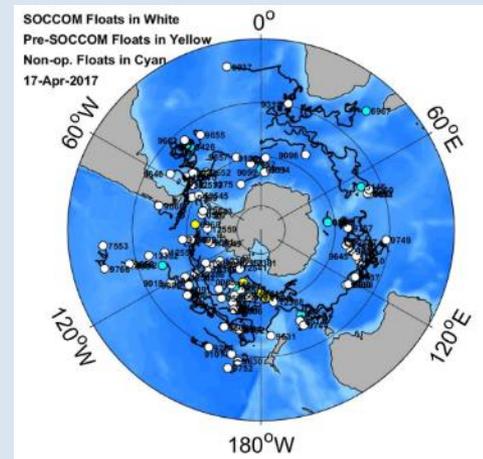
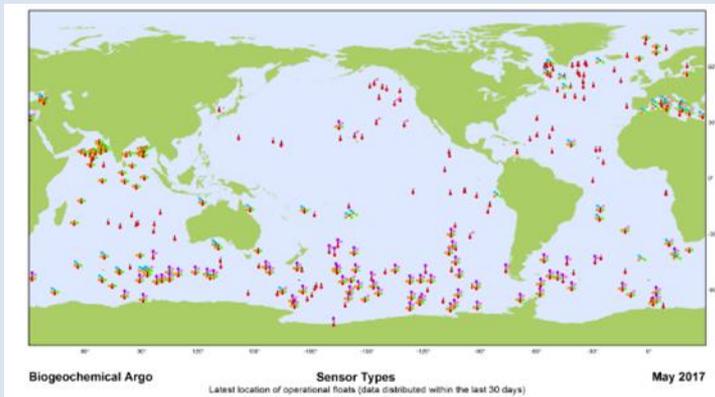
Why

- Understand the fundamental bio-geochemical cycling in the oceans, and thus the foundation of biological productivity patterns and carbon uptake
- To track any long term trends – e.g there is already evidence of significant ocean oxygen changes

Status

- > 200 floats already carry oxygen – QC and sensor stability work is progressing well
- Nitrate, pH (acidity), and bio-optical sensors have been developed and now deployed on a subset of Argo floats
- Regional pilot arrays (Atlantic, Southern Ocean, Med Sea) are rolling out, including SOCCOM
- Progress on data handling and QC via partnership with the Argo Data System
- Strong links to **GOSHIP/IOCCP/GOOS**.

Location of 284 active floats carrying one or more BGC sensors.



SOCCOM float locations: 68 active (JCOMMOPS)



Summary and Challenges

GOOD NEWS

- The Core Argo array is in a healthy state.
- Argo enhancements are valuable and practical, and developing as part of the integrated GOOS.
- Research and operational uptake of Argo data continues to grow.
- Argo's future will fulfill the vision of comprehensive global ocean observation.

CHALLENGES: SHORT AND LONG-TERM

- National Argo budgets have not kept up with inflation. Can the inflationary loss continue to be offset by increasing float lifetimes?
- New initiatives generate excitement and sometimes new funding, but Argo's first priority is to sustain the original Argo mission.
- Argo enhancements and extensions pose new challenges for data management and for synthesis/analysis
- Deployment inside EEZs remains an issue.
- The AST is considering these and other issues for sustaining Argo over the coming decades (see draft document on AST-18 web page). Comments are invited.



Past/present/future links between Argo and GOV

Very strong at the start of GODAE (Argo was a pilot projet of GODAE and CLIVAR).

Still strong but interactions could be improved. Argo is the main source of in-situ data to constrain GOV systems. Feedback on the array design, impact of Argo, data system (real time/delayed mode).

Need active participation of Argo teams in GOV and its task teams and vice versa. Topics of direct joint interest :

- ✓ Core Argo – monitoring/documenting impact, feedback on QC (e.g. black list), float recovery (trajectory forecast), deployment plans (longer run).
- ✓ Design of Argo extensions, advocating for Argo extensions and monitoring/documenting impact.

GOV centers need to advocate for the sustainability of Argo and the development of Argo extensions (BGC, Deep Argo, polar seas, marginal seas).

