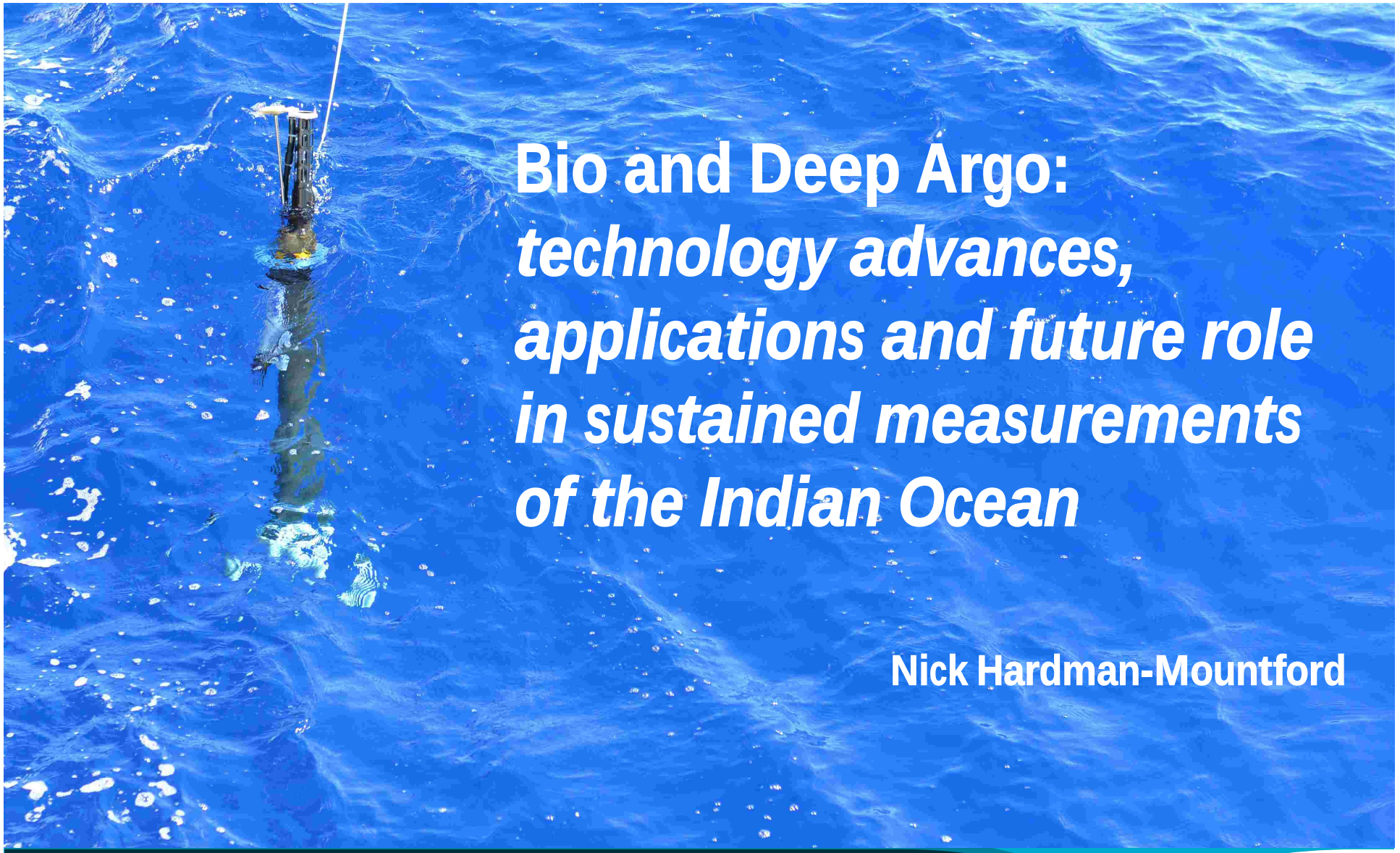


Bio and Deep Argo: *technology advances, applications and future role in sustained measurements of the Indian Ocean*

Nick Hardman-Mountford

https://research.csiro.au/iobioargo/

Why do we need a Bio-Argo network?

Courtesy of Ken Johnson

- Oceans are undergoing remarkable stresses: warming, acidification, nutrient supply, melting ice, circulation changes, deoxygenation….
- **Who's looking systematically?**

CHAPTER 4

THE ROLE OF MARINE BIOTA IN THE CO_2 BALANCE OF THE OCEAN-ATMOSPHERE SYSTEM

JORGE L. SARMIENTO[1], ANAND GNANADESIKAN[2], IRINA MARINOV[3] AND RICHARD D. SLATER[1]

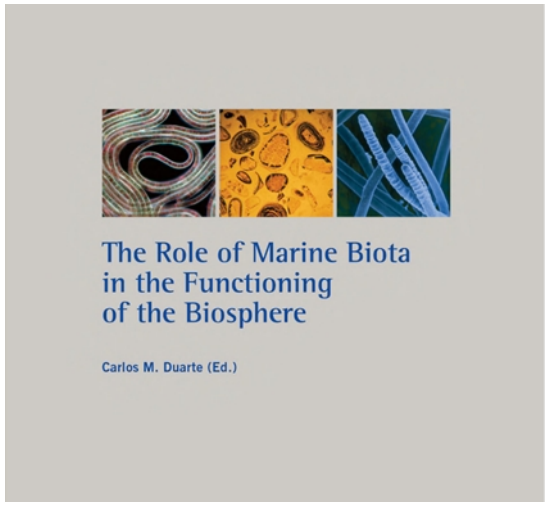
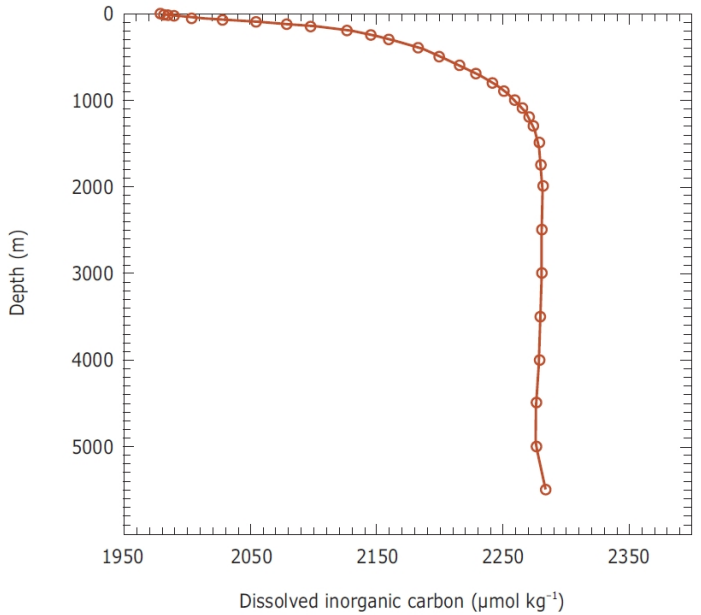


Figure 4.1: Vertical profile of horizontally averaged dissolved inorganic carbon in the ocean



Source: Based on the GLODAP data set of Key et al. 2004.

Simplified model studies show that shutting down the biological pump would release an amount of CO_2 to the atmosphere sufficient to increase its concentration from its pre-industrial value of 280 ppm to something in excess of 450 ppm. Marine biota thus play an important role in establishing the concentration of atmospheric carbon dioxide and therefore in the climate of the planet.

Courtesy of Ken Johnson

Ocean Station Data (hydrocasts)

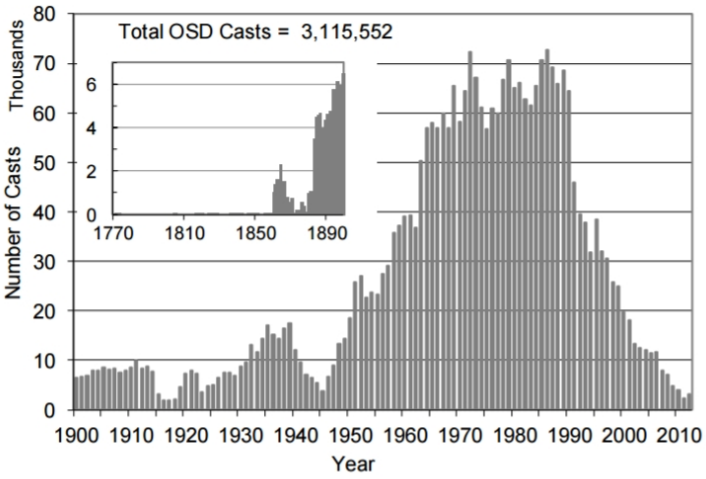


Figure 2.1. Time series of the number of OSD casts in WOD13

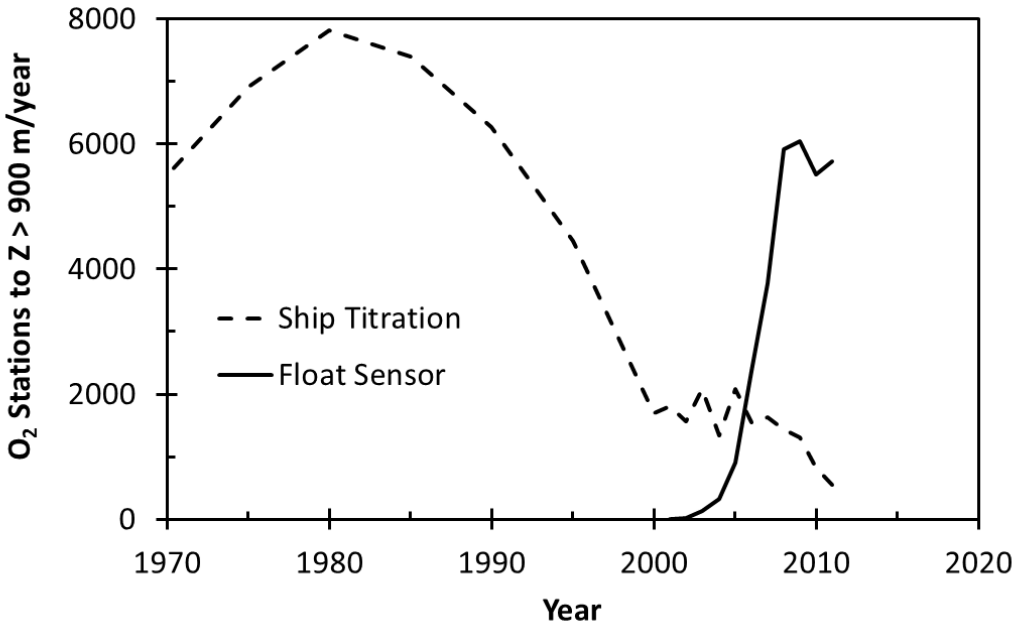
NOAA Atlas NESDIS 72

WORLD OCEAN DATABASE 2013

Timothy P. Boyer, John I. Antonov, Olga K. Baranova,
Carla Coleman, Hernan E. Garcia, Alexandra Grodsky,
Daphne R. Johnson, Ricardo A. Locarnini,
Alexey V. Mishonov, Todd D. O'Brien, Christopher R. Paver,
James R. Reagan, Dan Seidov, Igor V. Smolyar, Melissa M. Zweng

Courtesy of Ken Johnson

US NODC Data



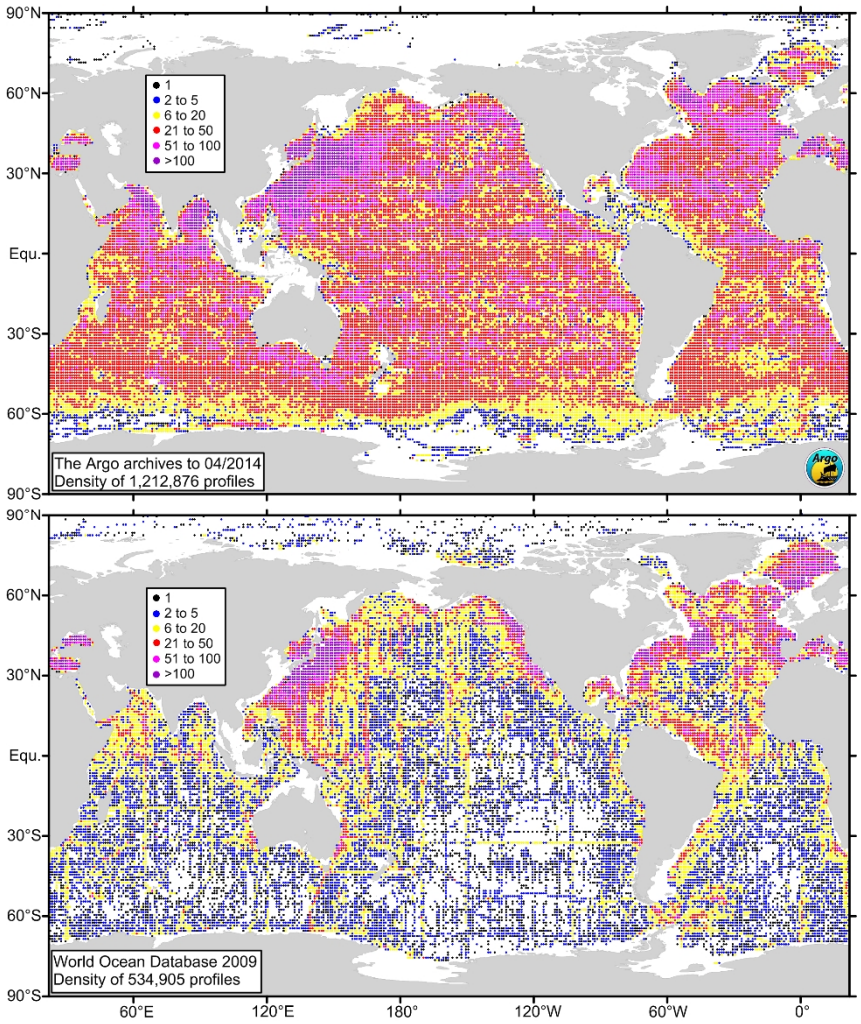
Johnson et al., 2015, *J. Atm. Oceanic Technol.*

Profiles to a depth of at least 900 m (through the core of the O_2 minimum)

Table 1.		
Sensor/Analysis	**Profiles/year Ships 2000-2010**	**Argo Profiles 2015**
Oxygen	1730	10555
Nitrate	1231	2671
pH direct	460	663

Argo transformed *global-scale* oceanography into *global* oceanography.

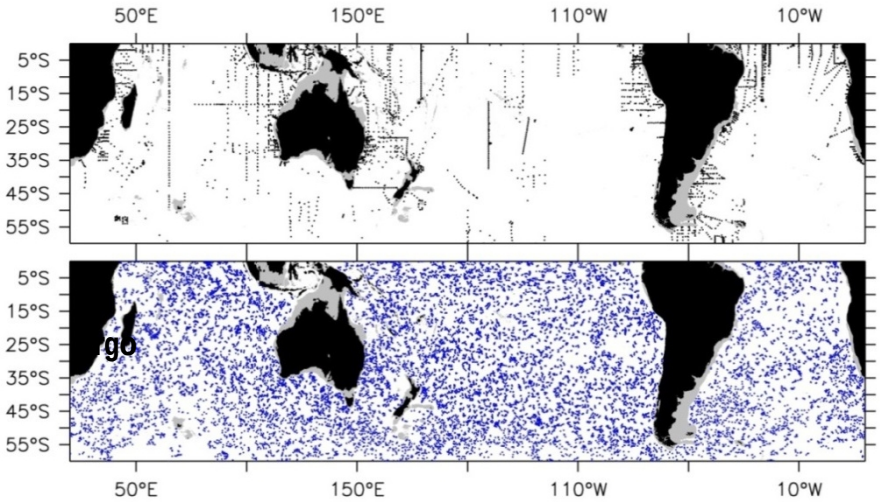
Argo: 1,000,000 T/S profiles milestone achieved in 2012.



20th Century: 500,000 T/S **profiles > 1000 m**

Argo Floats Do Not Mind Bad Weather

All August T/S profiles (> 1000 m, 1951 - 2000).

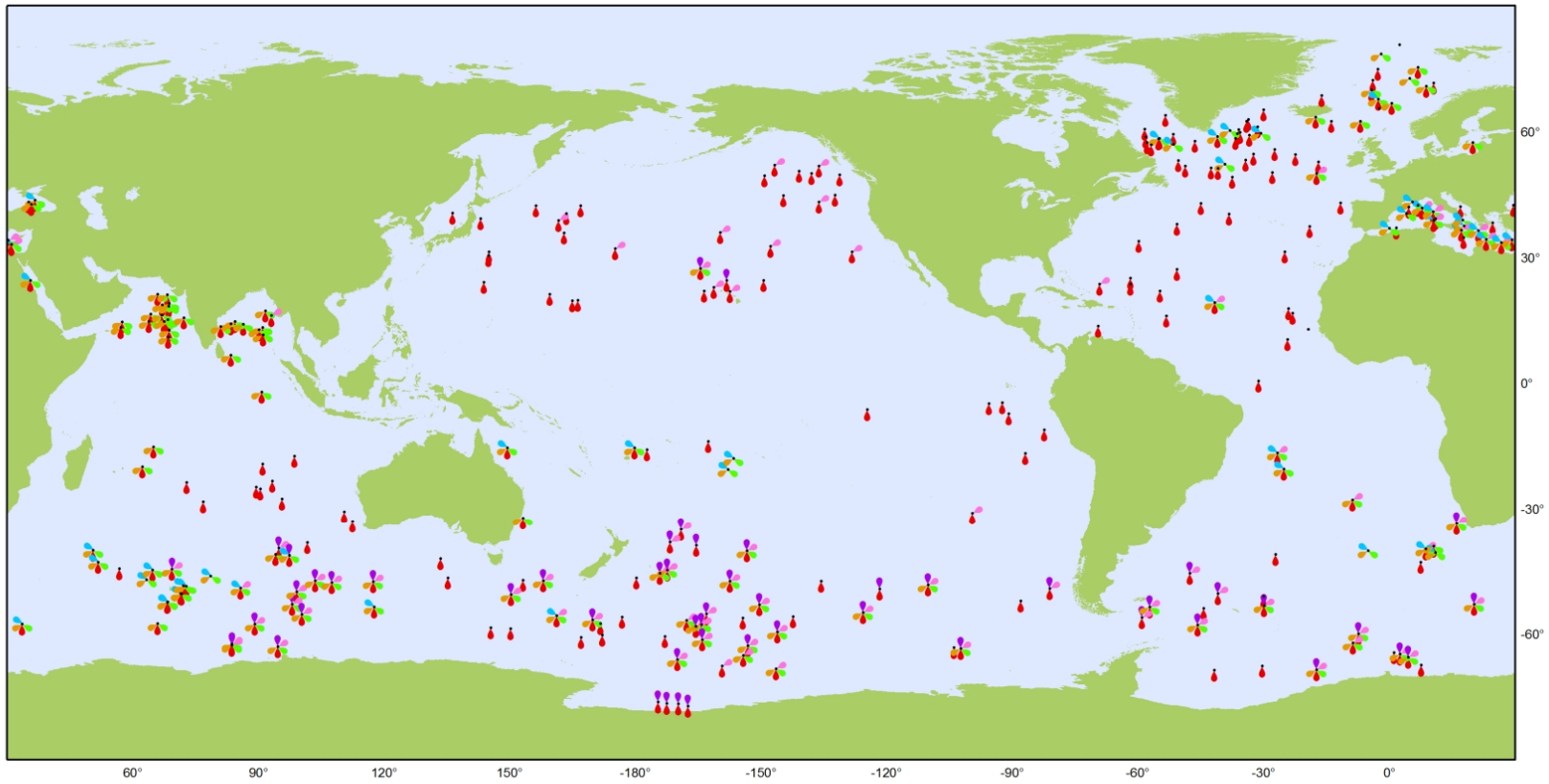


5 years of August Argo T/S profiles (2008-2012).

- The World Ocean Circulation Experiment (WOCE) was a global survey of 8,000 T/S profiles in 7 years (1991-1997).
- **Argo is a global survey of 12,000 T/S profiles every month.**

Courtesy S. Piotrowicz

We can now do the same for ocean biogeochemistry and carbon cycling!



Biogeochemical Argo

Sensor Types

Latest location of operational floats (data distributed within the last 30 days)

November 2016

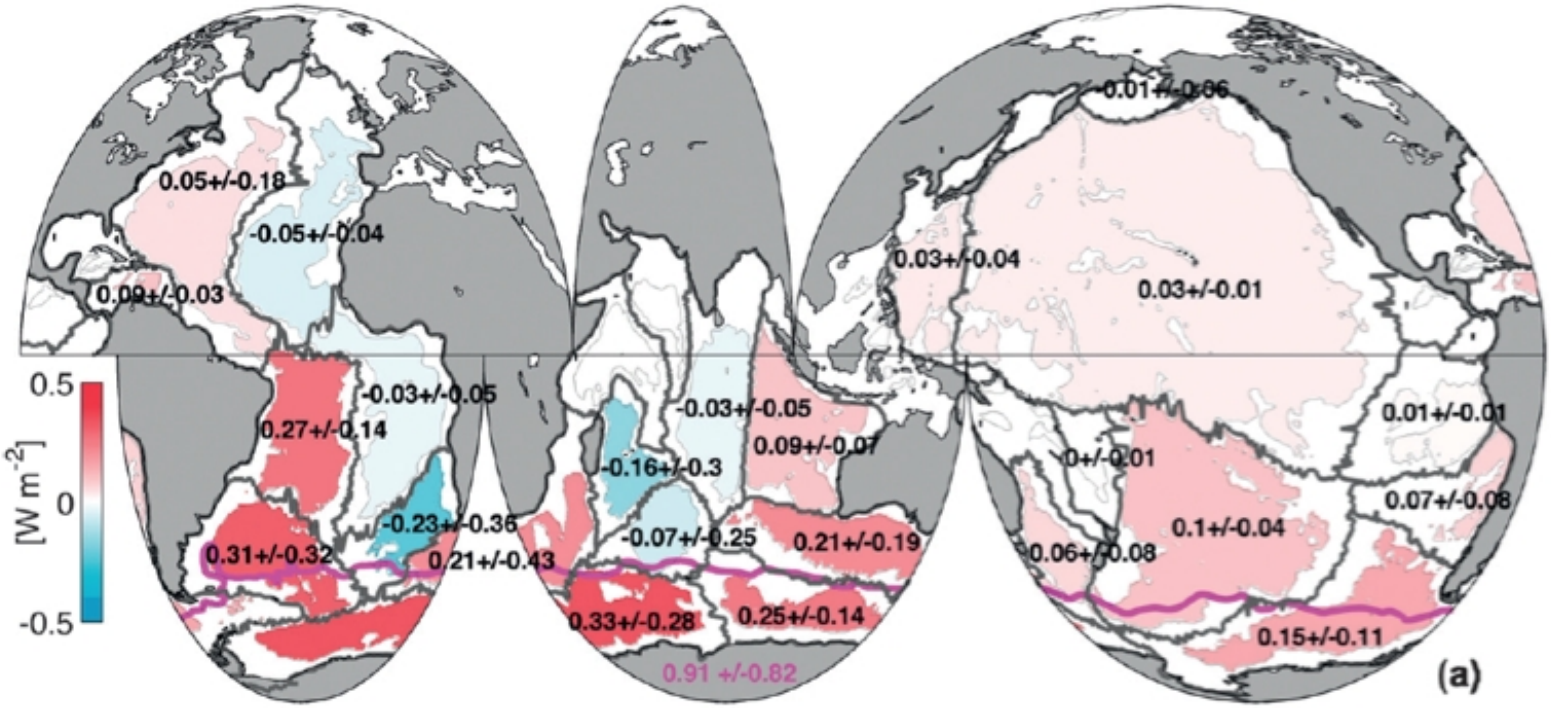
- Operational Floats (290)
- SCATTEROMETER_BBP/TURBIDITY (135)
- RADIOMETER (DOWN_IRR, PAR) (50)
- TRANSISTOR_PH (54)
- SPECTROPHOTOMETER_NITRATE/BISULFIDE (81)
- FLUOROMETER_CHLA/CDOM (135)
- DOXY (270)

Courtesy of Ken Johnson

Generated by www.jcommops.org, 05/12/2016

Deep Ocean

- Sparse repeat ship data show that the ocean below Argo is warming consistently, particularly in the Southern Hemisphere.
- This matters for sea level rise and the Earth's energy budget.
- Model initialization/assimilation requires data below 2000 m.



Bottom Water warming from 1990's to 2000's

Purkey and Johnson (2010)

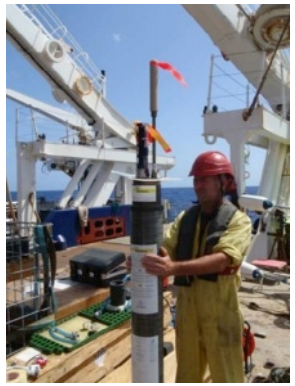
Courtesy of Susan Wijffels

Deep Argo: Argo to 4000-6000m

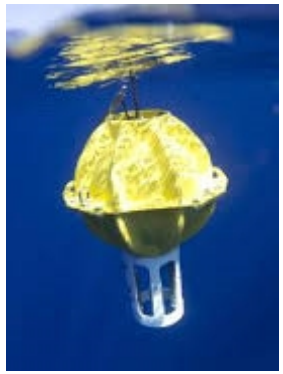
Status

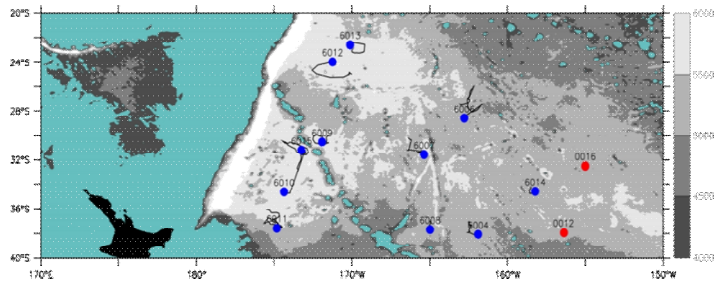
- Four Deep Argo float models have been developed and tested.
- A new CTD sensor (SBE-61) is under parallel development with improved stability and accuracy.
- A Deep Argo Workshop was held to develop a science and implementation prospectus, global design, and costing - to feed into the **GOOS Deep Ocean Observing Strategy**
- 3 coordinated regional Deep Argo pilots are being deployed in the N. Atlantic, S. Pacific, and Southern Ocean

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



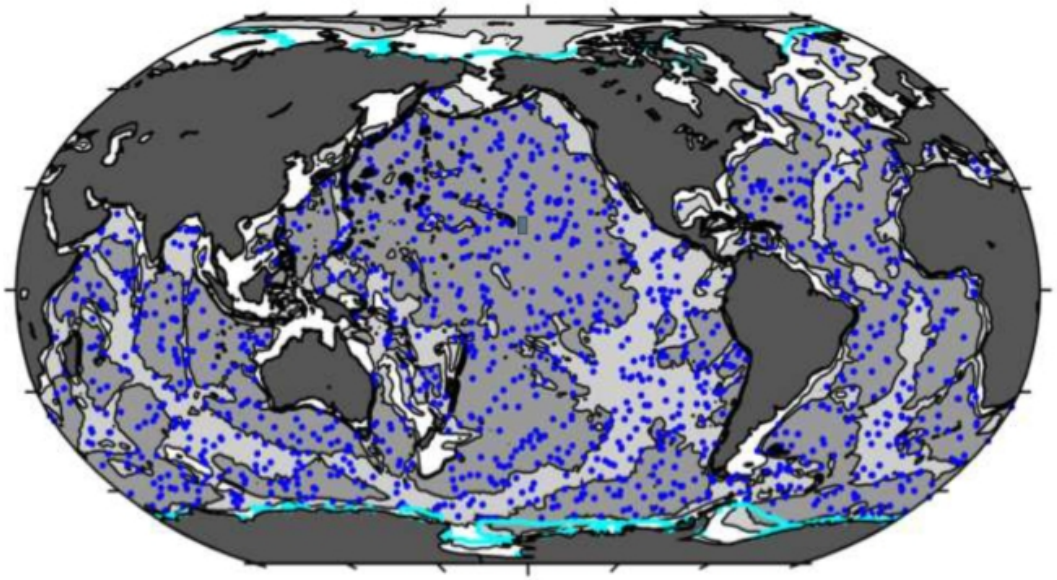
Deep APEX (below left) and Deep SOLO (below center) 6000 m floats. Location of 13 active Deep SOLO (blue) and Deep APEX (red) floats (below right) in the SW Pacific Basin





Courtesy of Susan Wijffels

Deep Argo Implementation Plan



Strawplan for 1228 Deep Argo floats at nominal 5° x 5° spacing (Johnson et al, JAOT, 2015) over the global ocean where depth exceeds 2000 m.

Report of the Deep Argo Implementation Workshop
http://www.argo.ucsd.edu/DAIW1report.pdf

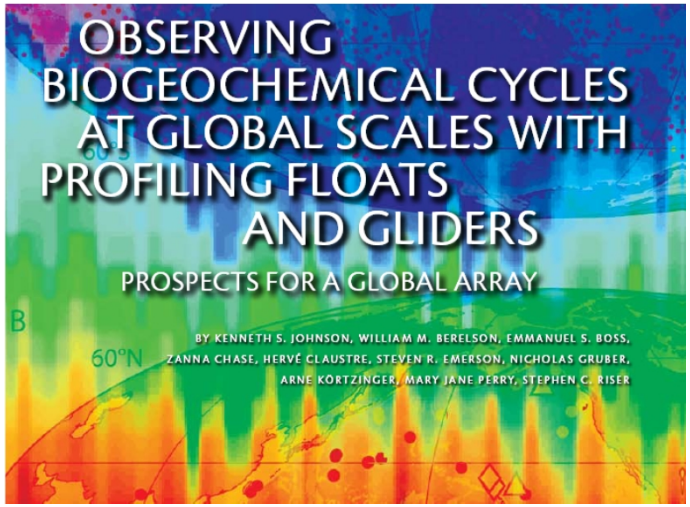
Courtesy of Susan Wijffels

Bio-Argo origins and planning

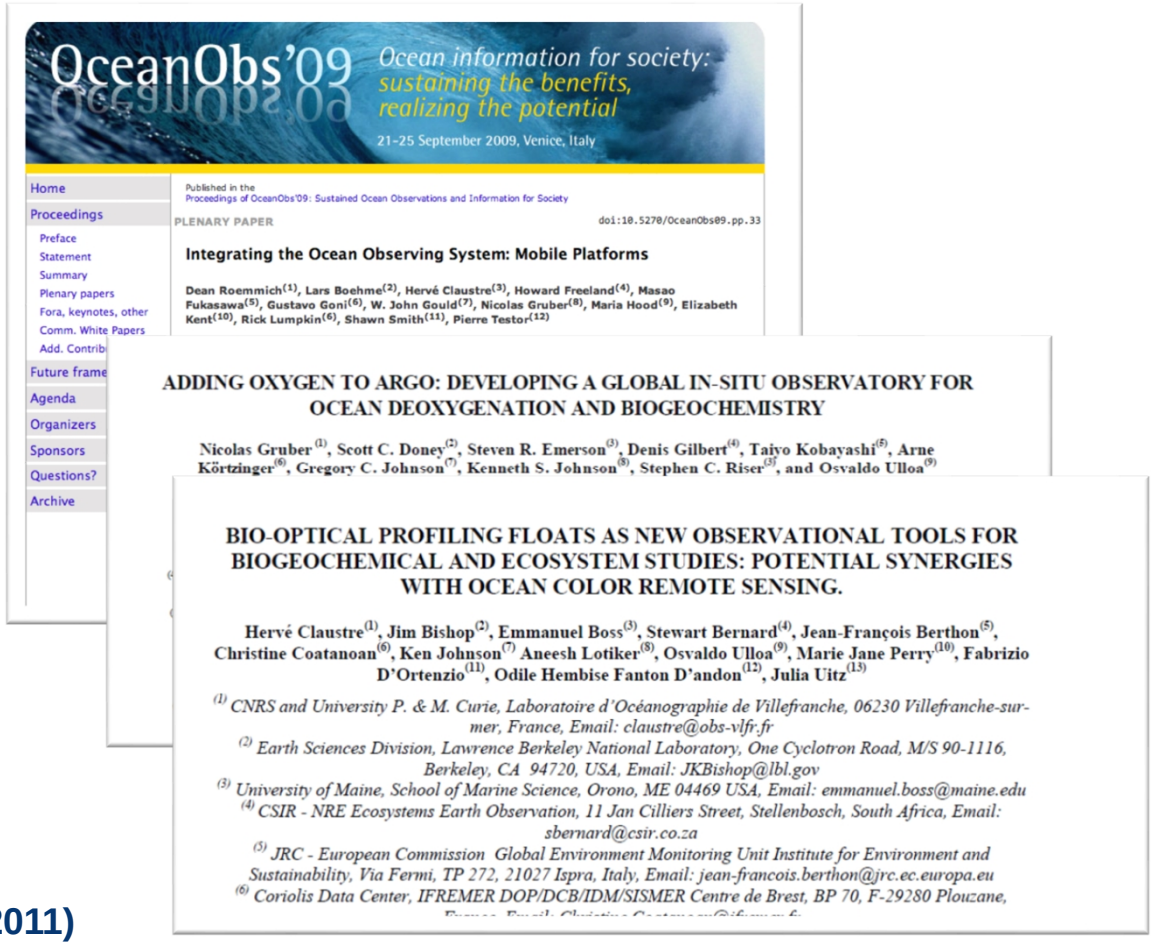
US Ocean Carbon & Biogeochemistry Scoping Workshop

Observing biogeochemical cycles at global scales with floats and gliders

28-30 April 2009, Moss Landing, CA http://www.whoi.edu/sites/OCBfloatsgliders



Sept. 2009 issue of *Oceanography*



IOCCG Report 11 (2011)

Bio-Optical Sensors on Argo Floats

Edited by Hervé Claustre

Planning for a global network has begun

Biogeochemical-Argo Network - Group photo

First meeting in Villefranche-sur-Mer, 11-13 January 2016.

Draft implementation plan out for comment.

Data available through Argo data centers.

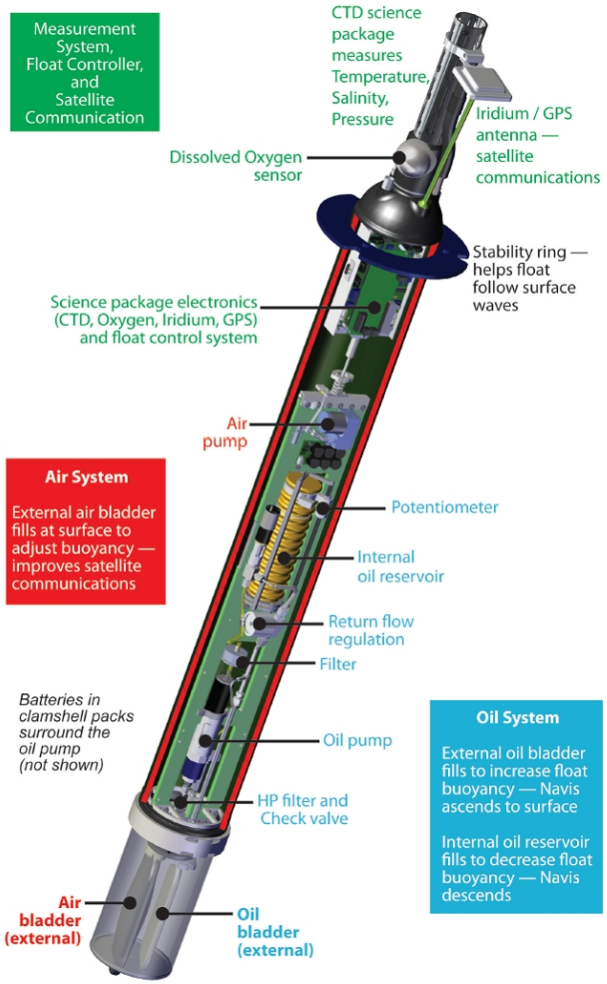
Grand Science Challenges:

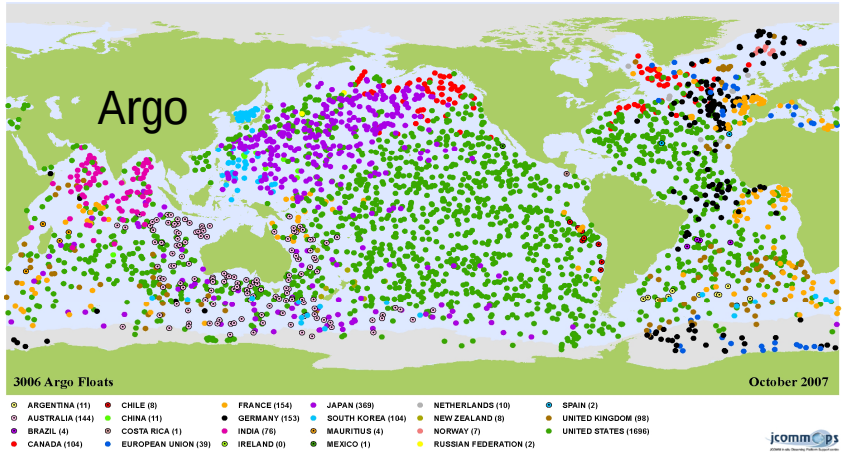
- Will ocean carbon uptake continue at the same relative rate as the ocean warms?
- What are the interannual variations in the biological carbon pump? Will its strength be reduced in a warmer ocean?
- How does the volume of Oxygen Minimum Zones change in time? How does this affect the cycling of nitrate?
- What is the variability and trend in ocean pH? How does the changing carbonate saturation state affect biogeochemical processes?
- How do biogeochemical properties shape open-ocean ecological niches?

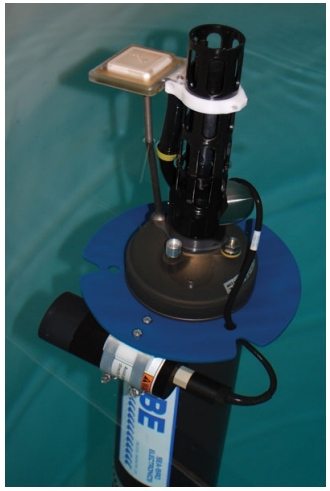
Grand Societal Challenges:

- Can synoptic and real-time data on ecological niche variability improve management of living marine resources?
- Carbon treaty verification: Does an improved ocean carbon budget lead to greater constraints on terrestrial carbon fluxes and a better understanding of global actions to reduce atmospheric CO2?

What is Bio(geochemical)-Argo?





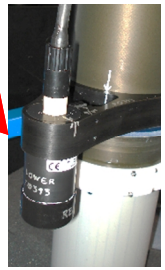


- Modelled on Argo
- Network of profiling floats equipped with biogeochemical sensors
- Configured to contribute towards a global program of ocean biogeochemical observations
- Data is freely available in near real-time without restriction

Sensors on Bio-Argo floats

MCOMS
- Chl Fl
- *CD Fl*
- BB

OCR504I/*R*
- Ed x 4
- *Lu x 4*



Iridium

SBE41 Pumped CTD

MCOMS
- Chl Fl
- BB *x 2*

SBE63 O_2 Optode

ECO BB3

CRV Trans-missometer

Deep SUNA NO_3

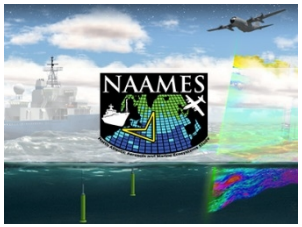
Aanderaa O_2 Optode

SeaFET pH

Wetlabs FLBB

Regionally-focused projects

Atlantic Polar / Sub-Polar



Indian

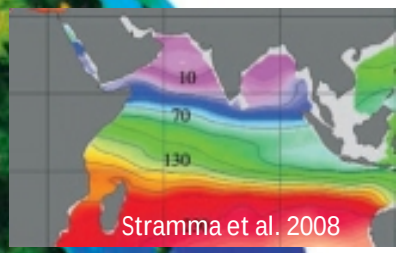
Pacific

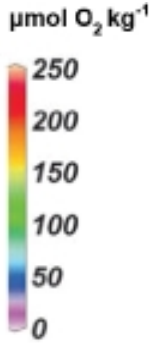
Atlantic / Mediterranean / Red Sea

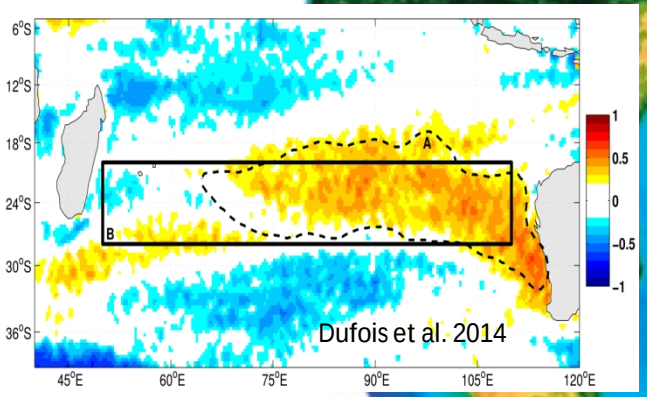
Southern Ocean

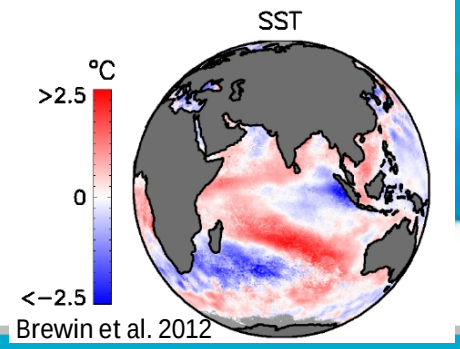
CSIRO

Indian Ocean biogeochemistry

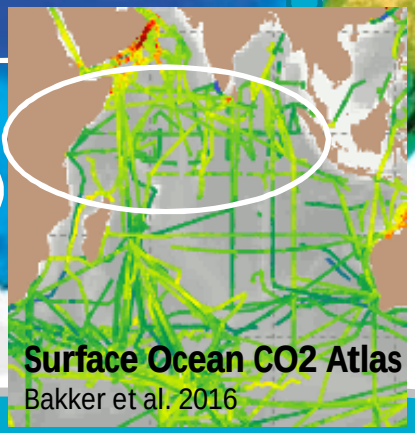


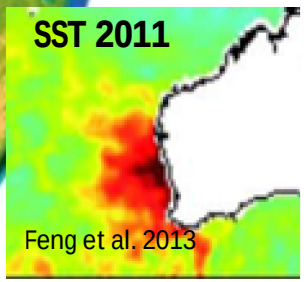




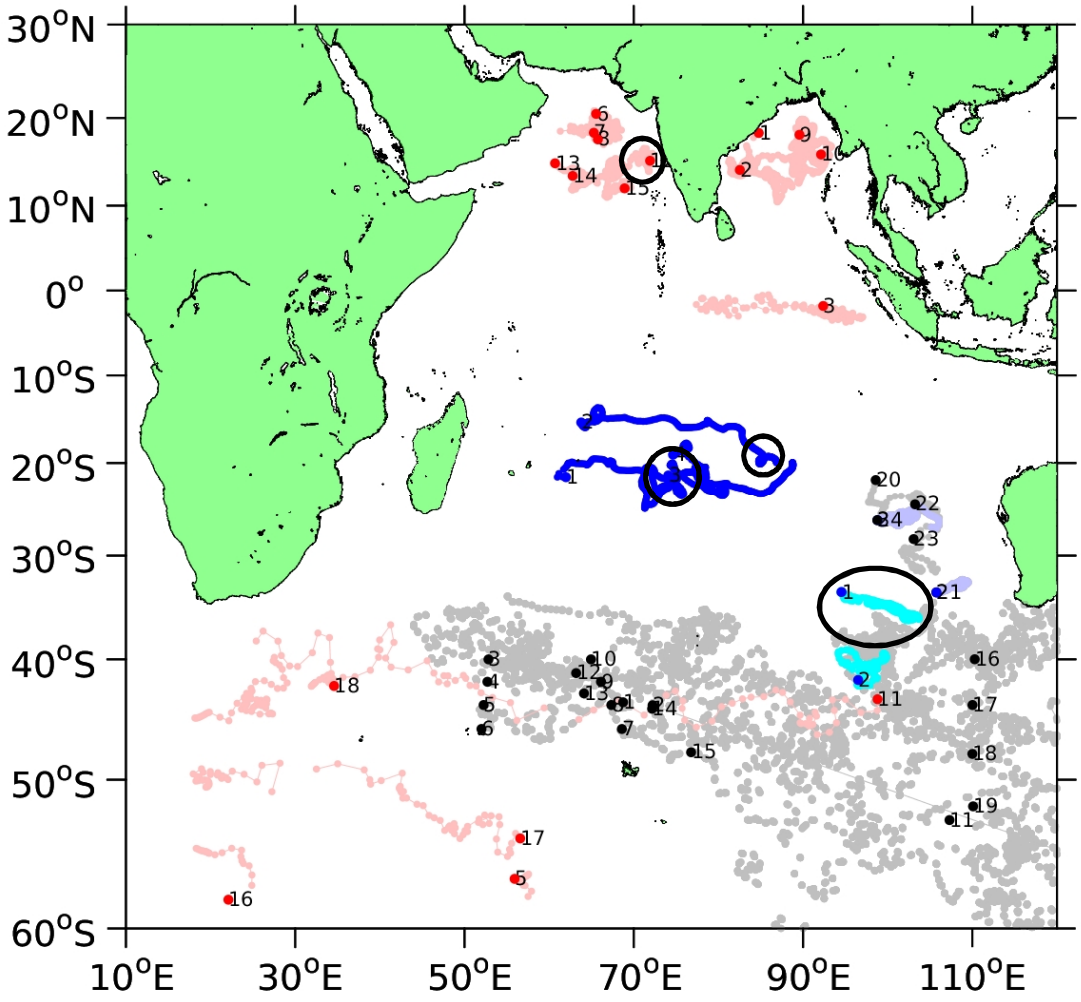


NASA: SeaWiFS





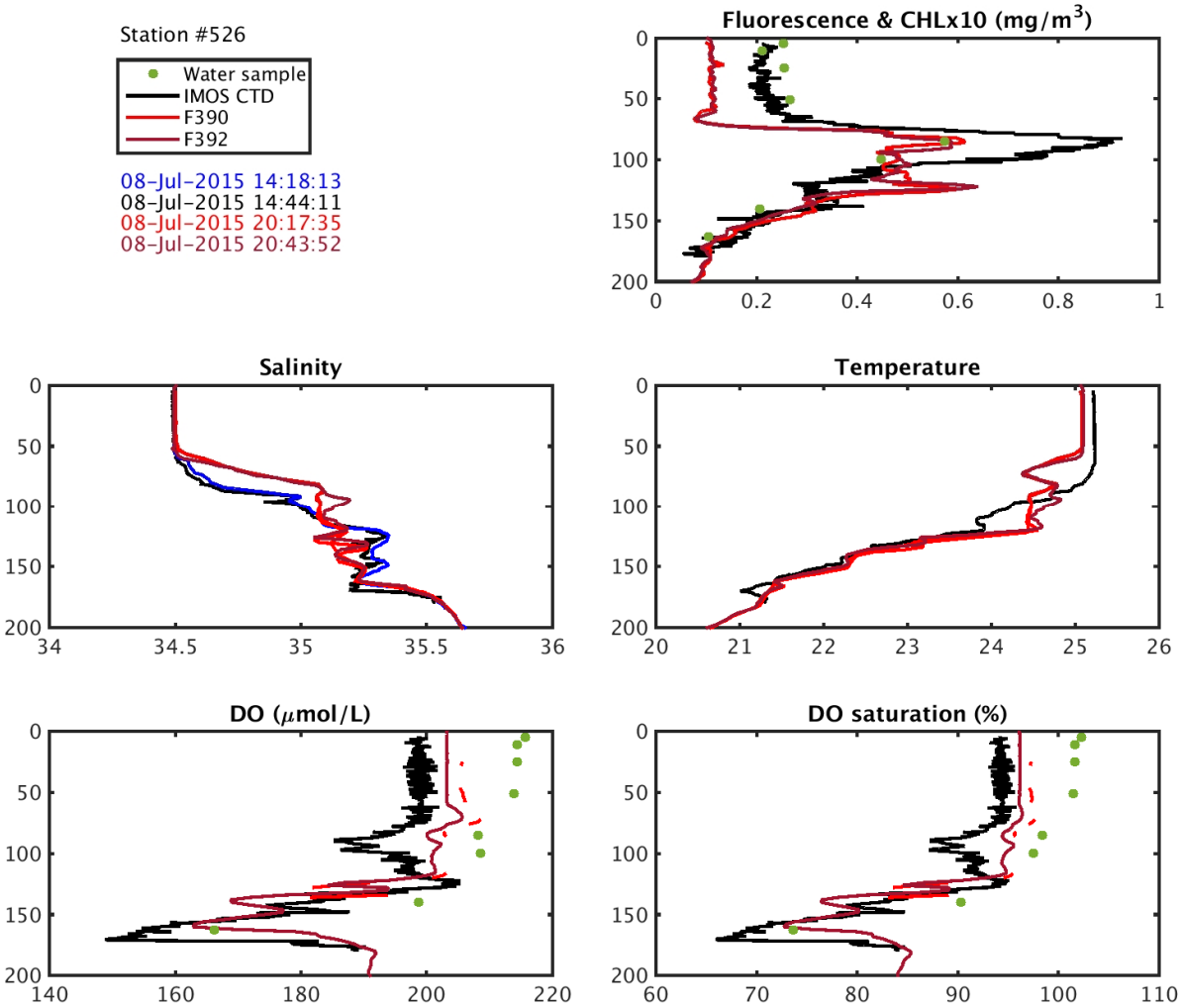
Biogeochemical floats in the Indian Ocean



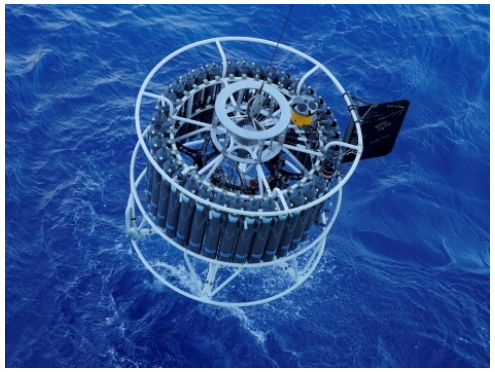
Bio-Argo is a mature technology

- Core sensors are all available off-the-shelf
- Core sensor suite has expected life of 3-4 years (~250 profiles)
- Significant numbers of float-years testing for all core sensors:
  - Oxygen = >600 floats
  - Fluoresence, backscatter >200 floats
  - Nitrate >100 floats
  - pH >50 floats
  - Radiometry >50 floats
- Bio-optical fouling is main control on mission length, mitigated by deep parking and profiling
- Long-term drift characterisation available for oxygen, underway for nitrate and pH – reference deep sections and climatology, surface pCO_2
- Chl, backscatter and radiometry reference satellite ocean colour
- Strongest sensor drifts are in air so initial correction is most important

Ship-board data essential for vicarious calibration



- Differences in sensor scaling
- Need bottle measurements for calibration of Chl, O_2, NO_3
- Corrections to first profiles can be used to update NRT processing for rest of mission



Global Biogeochemical Argo is the glue that brings these programs together

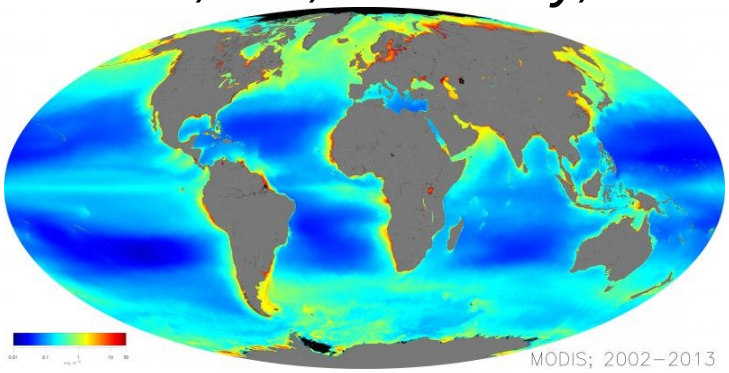
GO - SHIP

TOWARDS A SUSTAINED GLOBAL SURVEY OF THE OCEAN INTERIOR

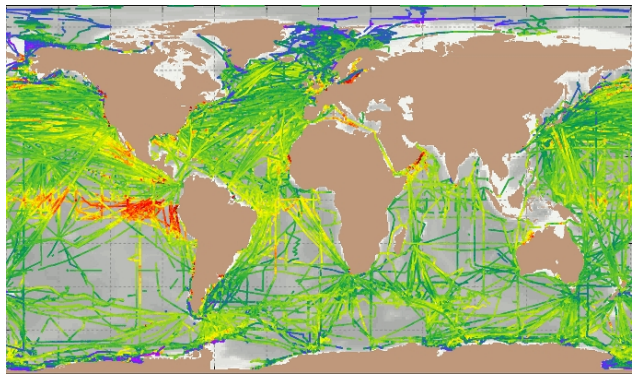
GO-SHIP brings together scientists with interests in physical oceanography, the carbon cycle, marine biogeochemistry and ecosystems, and other users and collectors of hydrographic data to develop a globally coordinated network of sustained hydrographic sections as part of the global ocean/climate observing system.

GO-SHIP is a major contributor to WCRP's Climate Variability and Predictability Experiment (CLIVAR) and International Ocean Carbon Coordination Project. GO-SHIP is part of the Global Climate Observing System / Global Ocean Observing System (GCOS / GOOS).

Ocean color, SST, Altimetry, LIDAR



SOCAT
SURFACE OCEAN CO2 ATLAS



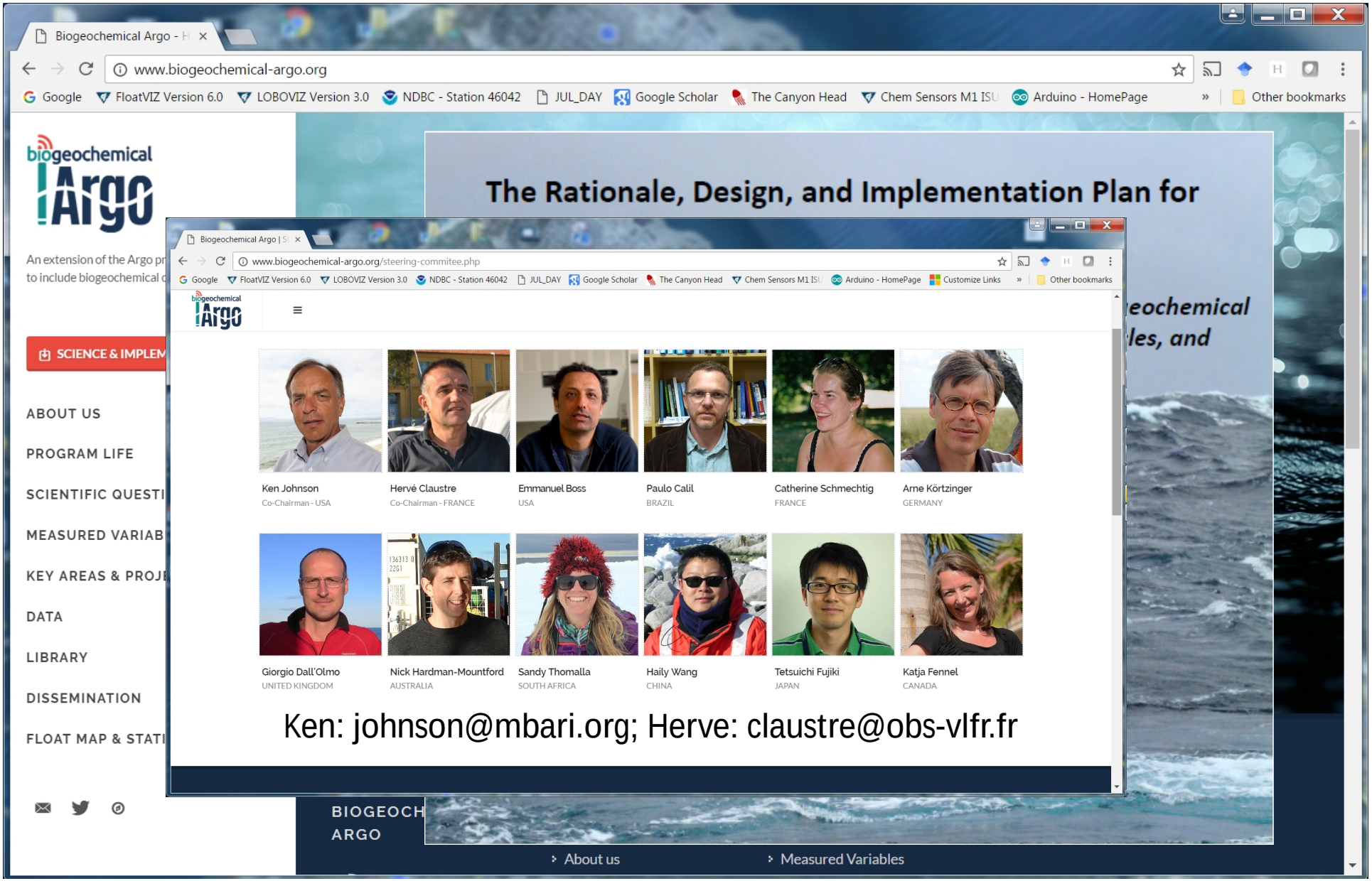
How many floats do we need globally?

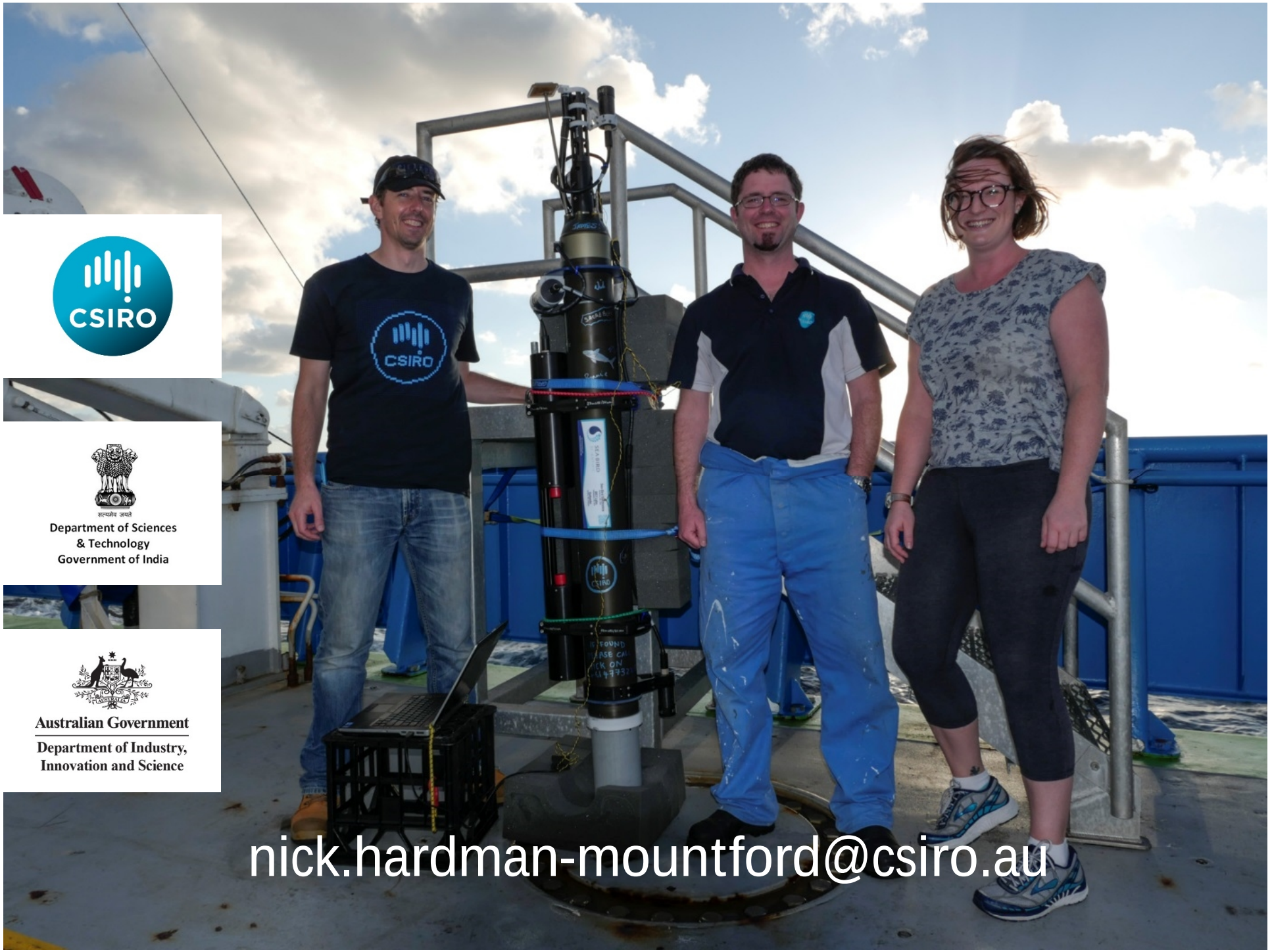
Assessment	Global Array Size
Southern Ocean OSSE extrapolated to global scale	700
Global OSSE of air-sea CO2 flux	1000
Satellite chlorophyll reconstruction	1000
pCO_2/nutrient decorrelation length scales	1800
Mean of all assessments	1000

Sustaining a 1000 float array will require ~250 floats/year

Courtesy of Ken Johnson

www.biogeochemical-argo.org

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CSIRO
सत्यमेव जयते
Department of Sciences
& Technology
Government of India
Australian Government
Department of Industry,
Innovation and Science
nick.hardman-mountford@csiro.au


Australia's
innovation
catalyst
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