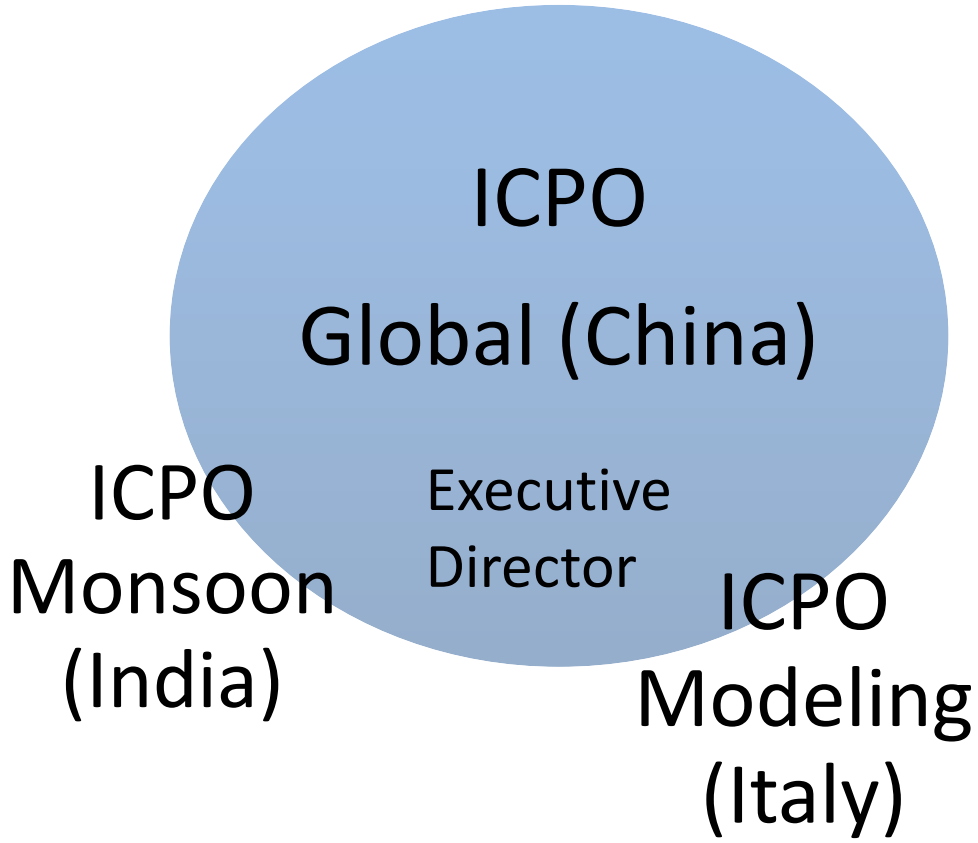
Report from IOP

Weidong Yu and M. Ravichandran
(Co-Chairs, IOP)
&
Members of IOP

Outline

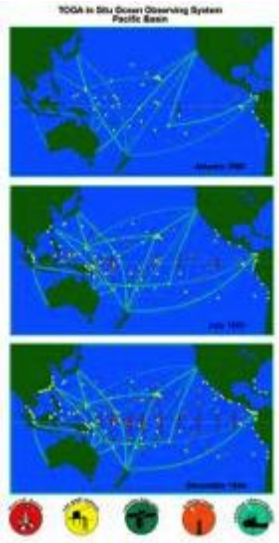
- CLIVAR & WCRP
- IndOOS status
- Research initiatives by IOP

Future Arrangements of (ICPO) to start early 2014



Current CLIVAR Research&Imperatives

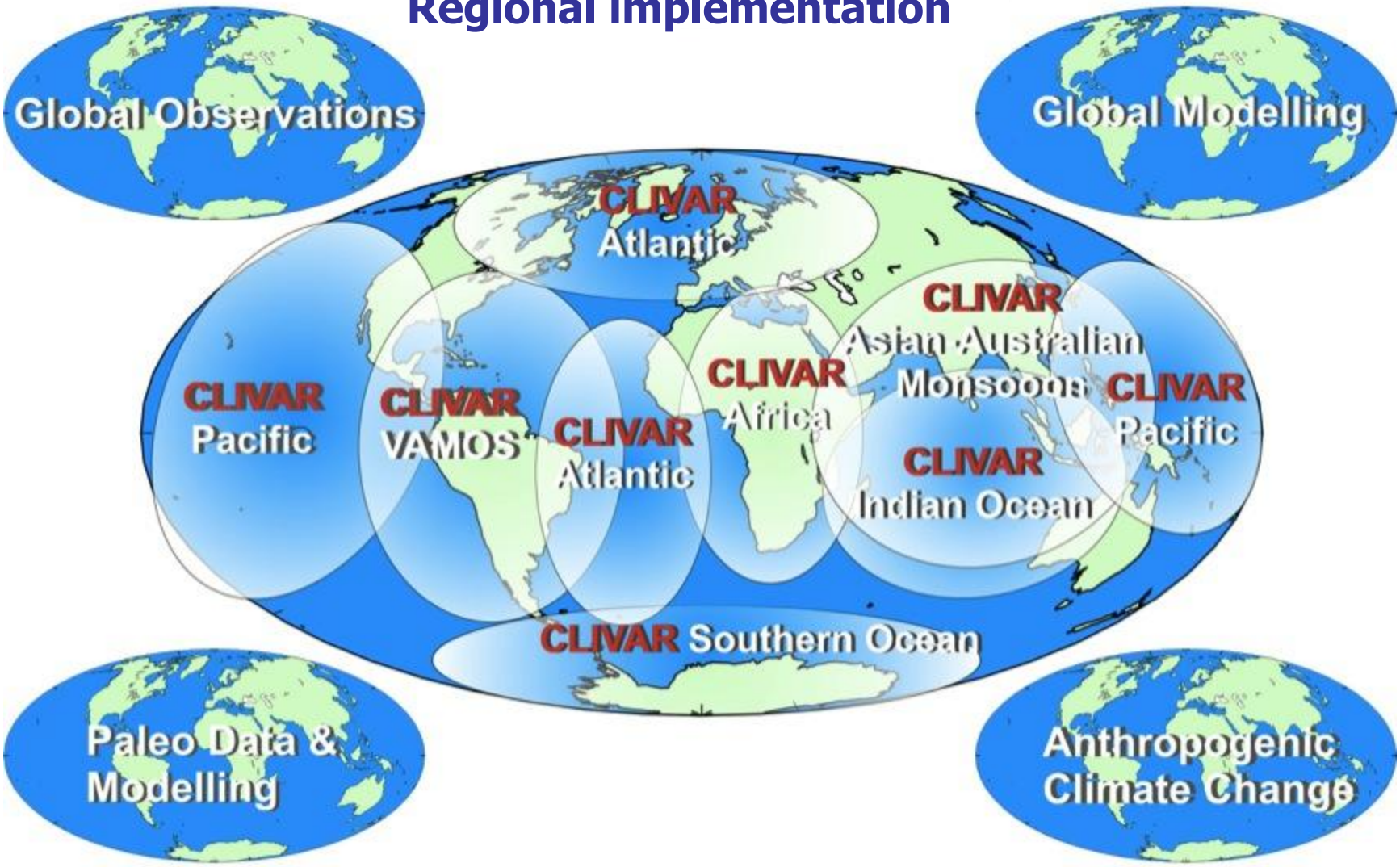
- Anthropogenic Climate Change
- Intra-to-Seasonal Variability, Predictability and Prediction
- Decadal Variability, Predictability and Prediction
- Improved Atmosphere and Ocean Components of ESMs
- Data Synthesis and Analysis
- Ocean Observing System
- Capacity Building



All Must Remain WCRP Priorities

CLIVAR – A Global View

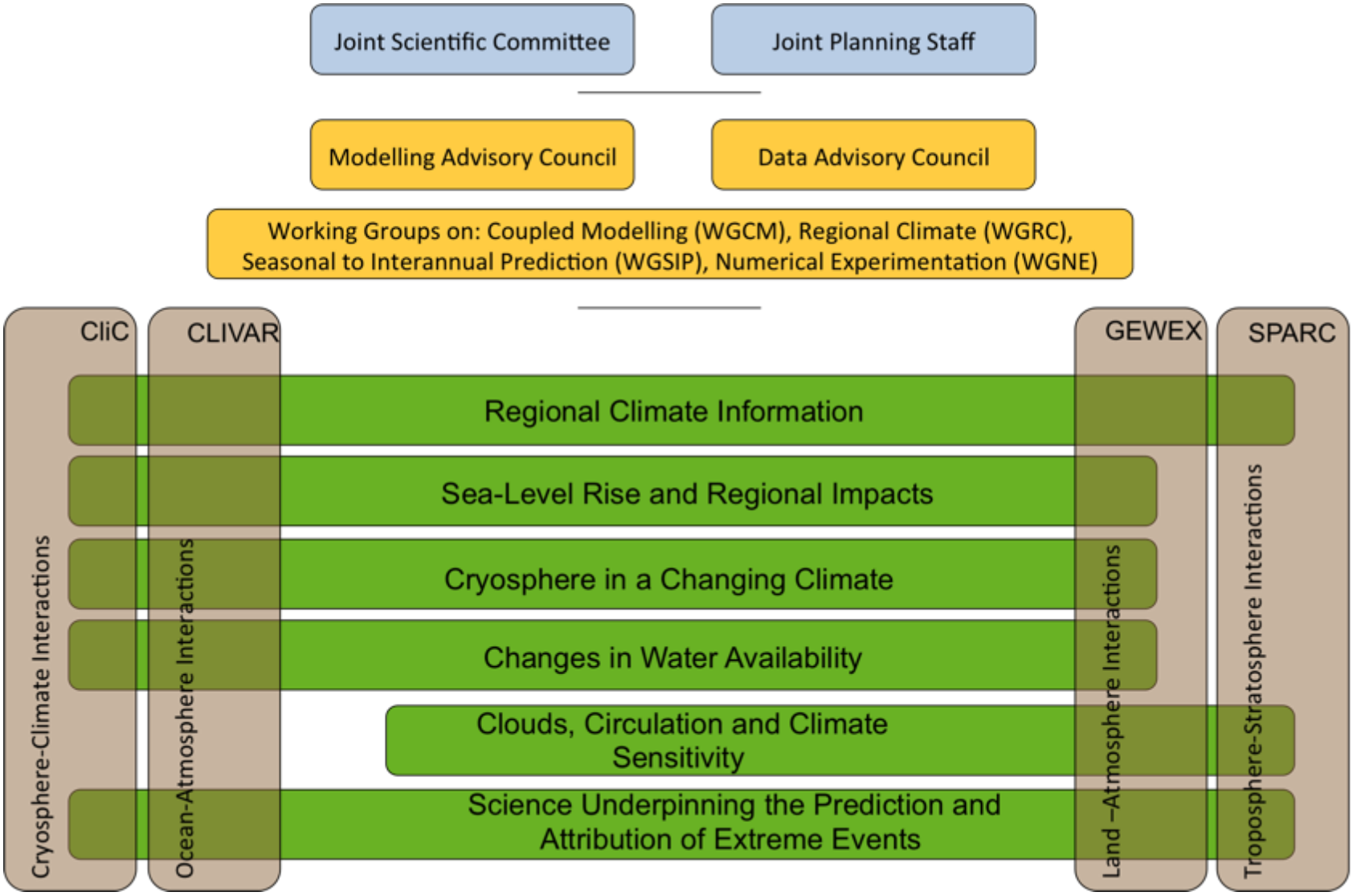
Regional implementation



CLIVAR Capabilities

- Improving the atmosphere and ocean component of Earth System Models.
- Implementing innovative process and sustained ocean observations.
- Facilitate free and open access to climate and ocean data, synthesis and information.
- Support Regional and global networks of climate and ocean scientist.
- Facilitate knowledge exchange and user feedback.
- Support education, capacity building and outreach.

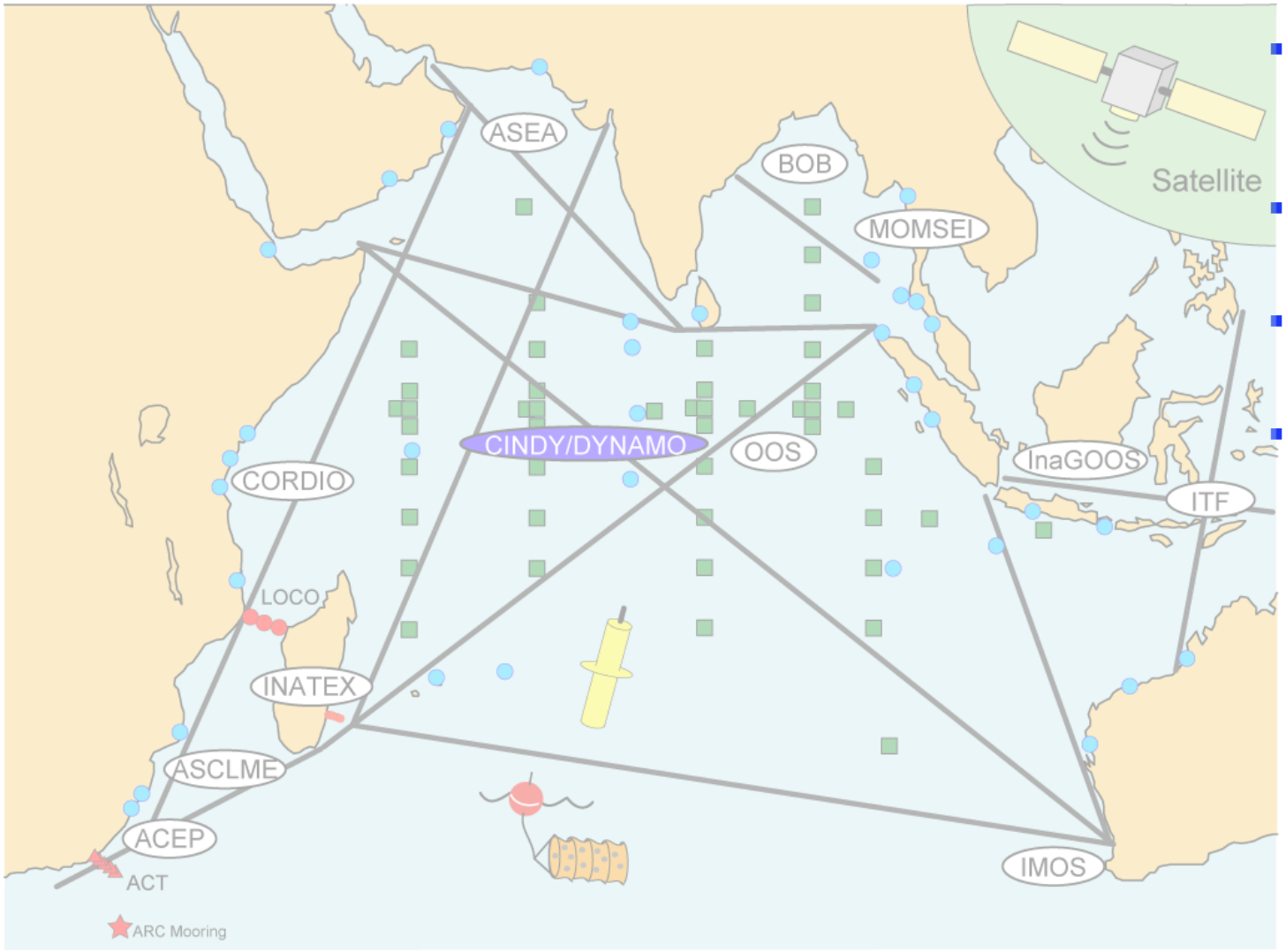
WCRP Grand Challenges



CLIVAR Research Opportunities

- Intraseasonal, seasonal and interannual variability and predictability of monsoon systems
- Decadal variability and predictability of ocean and climate variability
- Trends, nonlinearities and extreme events
- Marine biophysical interactions and dynamics of upwelling systems
- Dynamics of regional sea level variability
- Consistency between planetary heat balance and ocean heat storage
- ENSO in a warmer world

Indian Ocean Observing System (IndOOS)



- Planned by CLIVAR/GOOS Indian Ocean Panel in 2004
- Basin scale with regional elements
- Supports short term process studies
- Design supported by numerical model observing system simulation studies

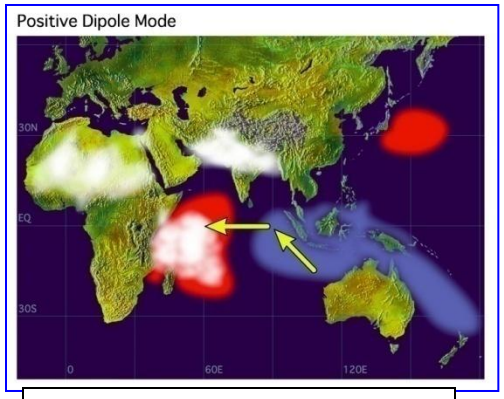
Multi-platform

Long-term

Observation

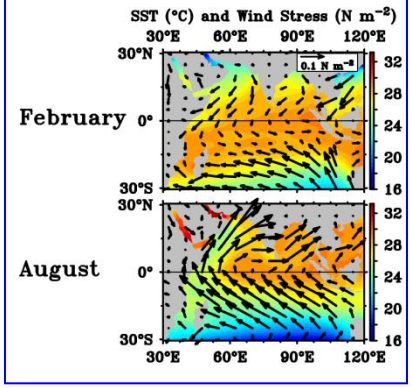
Network

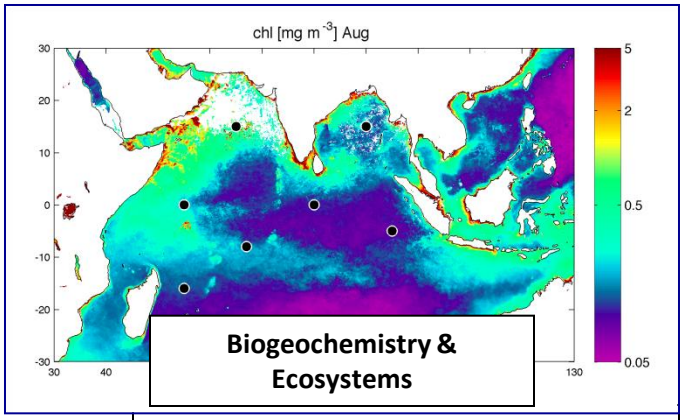
Interacting Variations in Time and Space



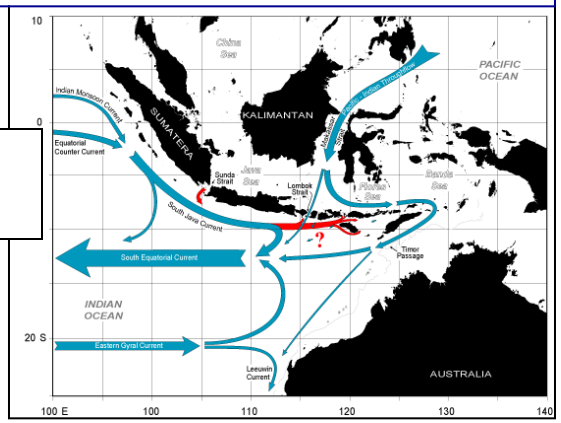
Indian Ocean Dipole

Monsoons

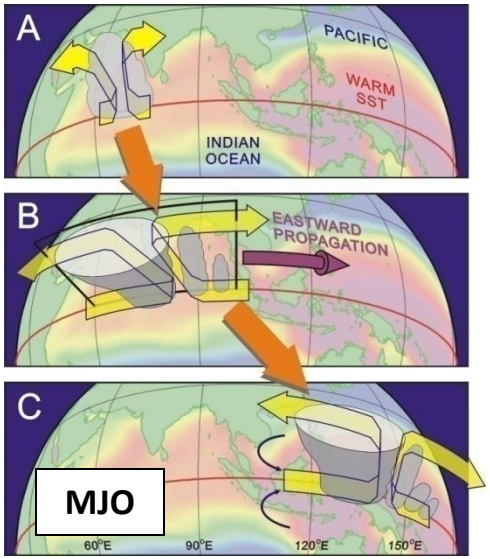




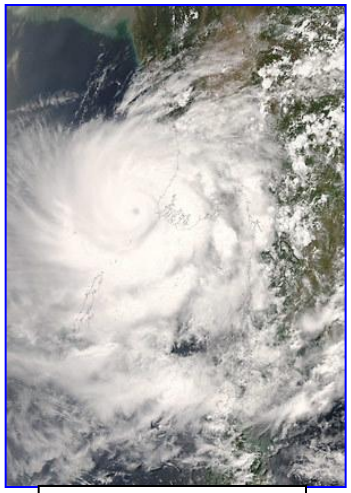
Biogeochemistry & Ecosystems



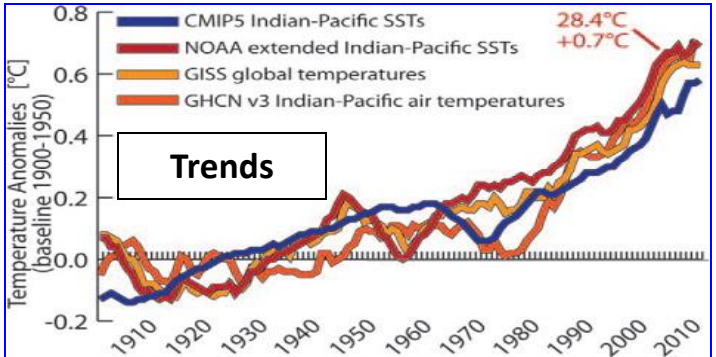
Ocean Circulation



MJO



Cyclones



Trends

RAMA

◆Surface Mooring ■Flux Reference Site ●ADCP ★Deep Ocean

Aug 2013
70% Complete

Japan (2000)
India (2000)
USA/India (2004)
USA/Indonesia (2006)
China/Indonesia (2007)
USA/ASCLME (2008)
USA/Australia (2012)

30°N
20°N
10°N
30°S
40°E
60°E
80°E
100°E

Solid=existing, open=planned

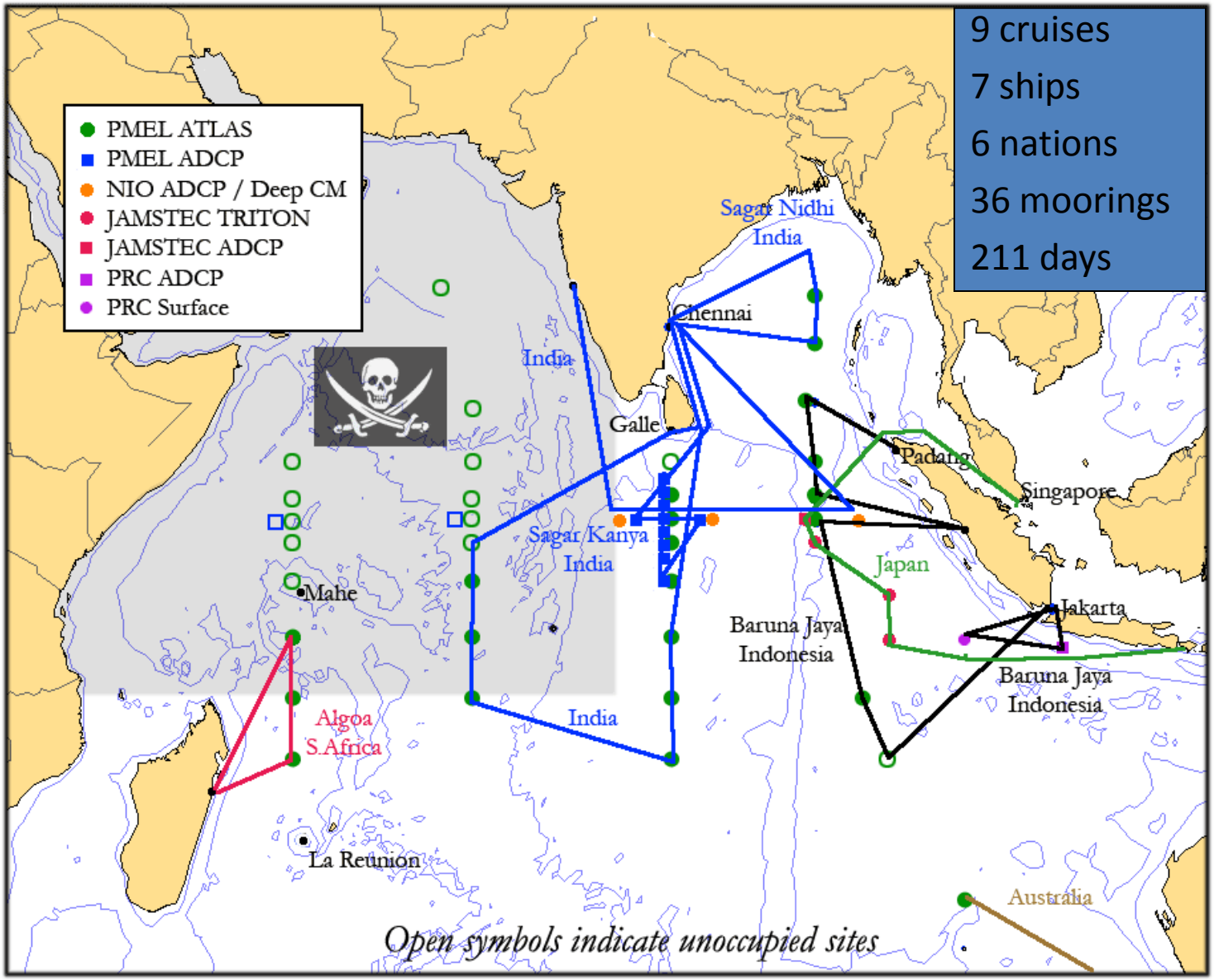
ORV Sagar Kanya deploys ATLAS mooring

Resource Formula:

- ✓ NOAA provides most equipment (+JAMSTEC, NIO, FIO)
- ✓ Regional partners provide ship time

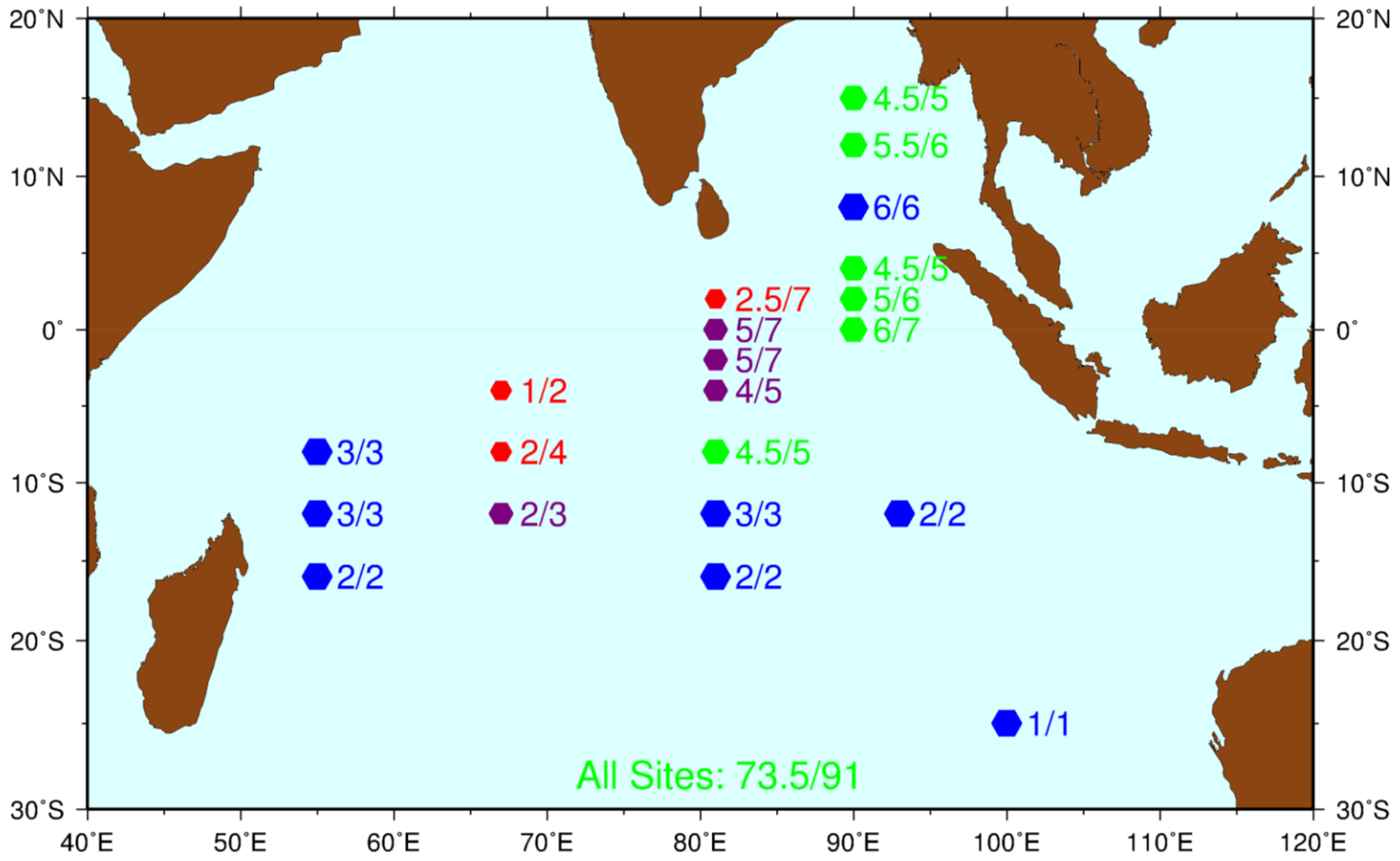
70 % of sites occupied at present (32 of 46)

Planned RAMA Cruises Oct 2012 - Sept 2013



RAMA Mooring Survival

October 2004 - September 2012

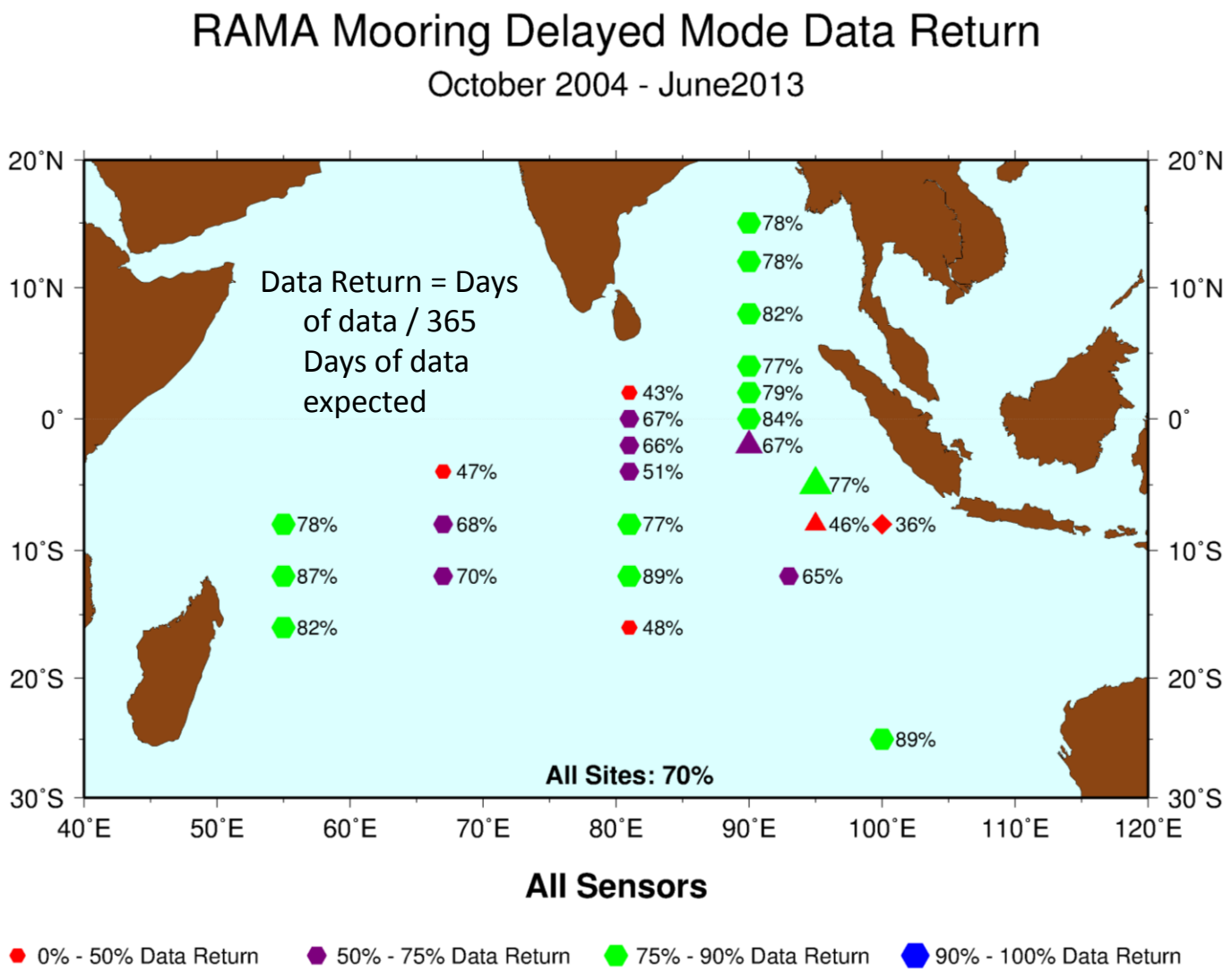


Moorings Intact / Moorings Deployed

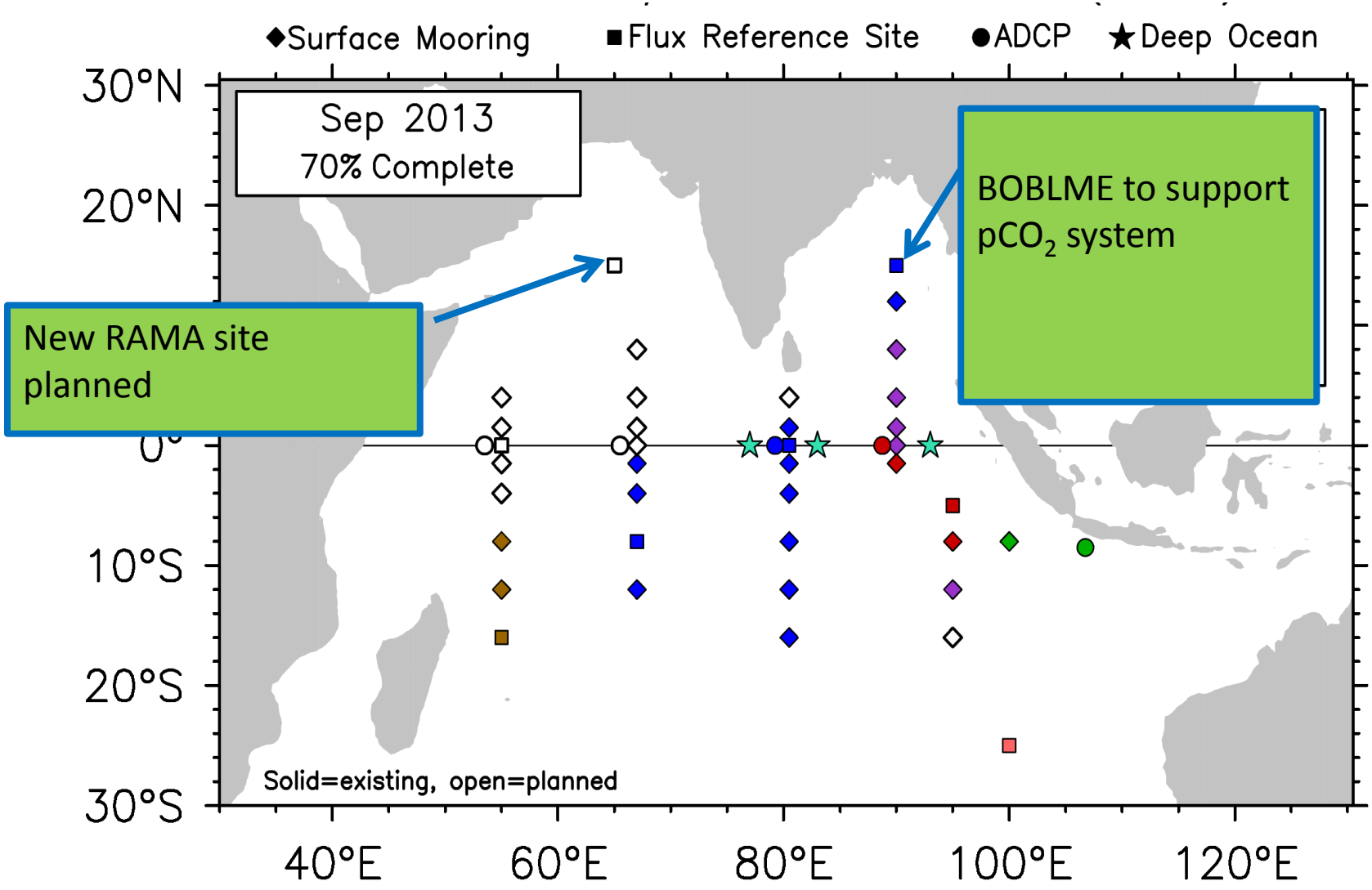
96% - 100% Intact **81% - 95% Intact** **51% - 80% Intact** **0% - 50% Intact**

(Intact: Not lost, significantly damaged, or impaired in any way)

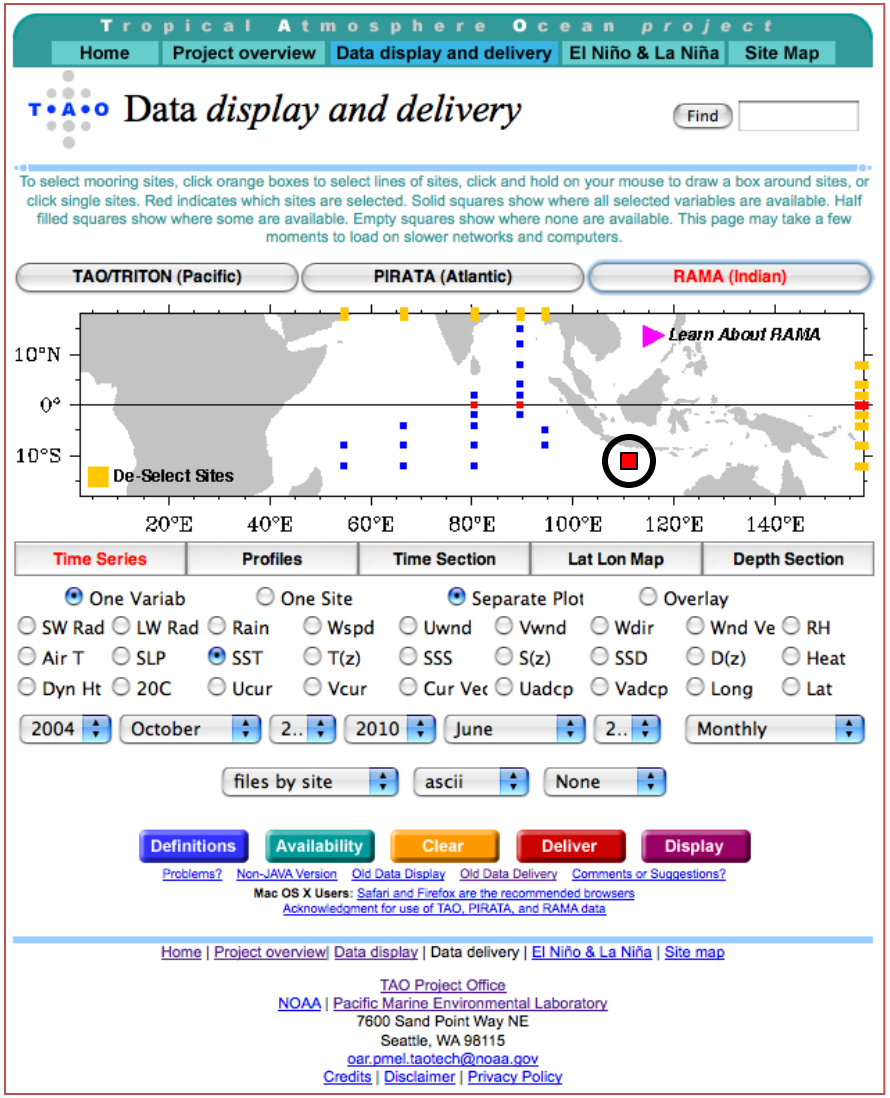
Hypothetical RAMA Data Return October 2004 – June 2013

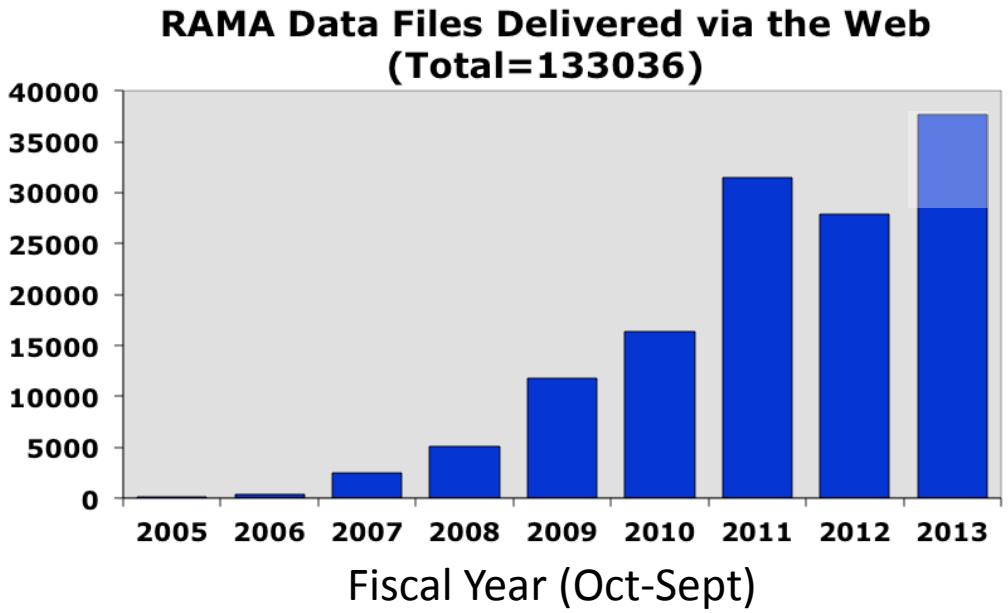


2013-2014 RAMA Plans

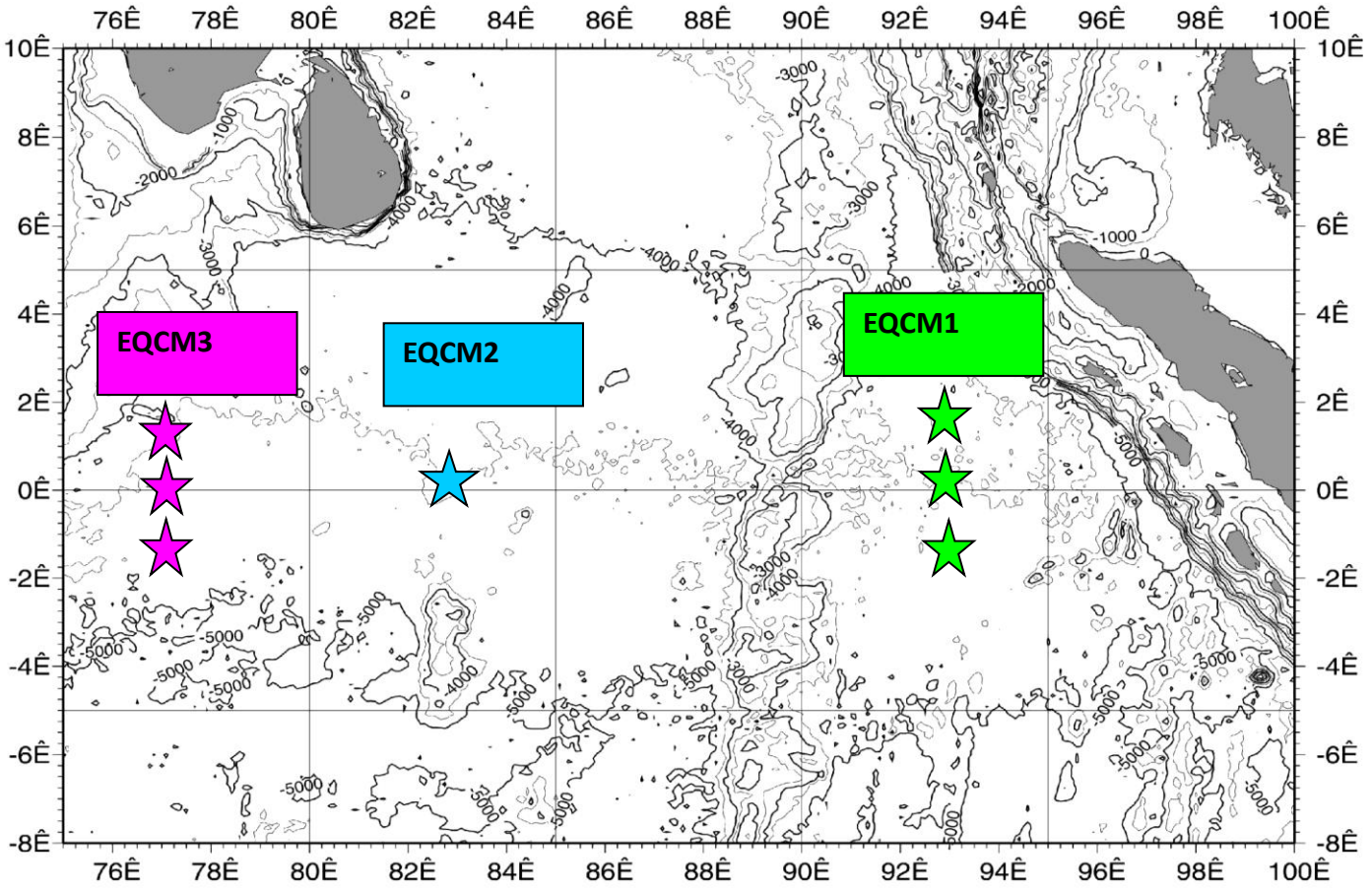


RAMA Data Access





Equatorial Indian Ocean Observational Array since 2000



The current meter moorings project is being executed since February 2000. Servicing of the moorings is being done regularly onboard *ORV Sagar Kanya and occasionally onboard Sagar Nidhi. The program is Extended till 2017.*

Research Moored Array for African-Asian-Australian Monsoon Analysis and Prediction (RAMA)

Last Updated: July 1, 2013

Journal Publications

Jump to year: 2013, 2012, 2011, 2010, 2009, 2008, 2007, 2005, 2004

2013

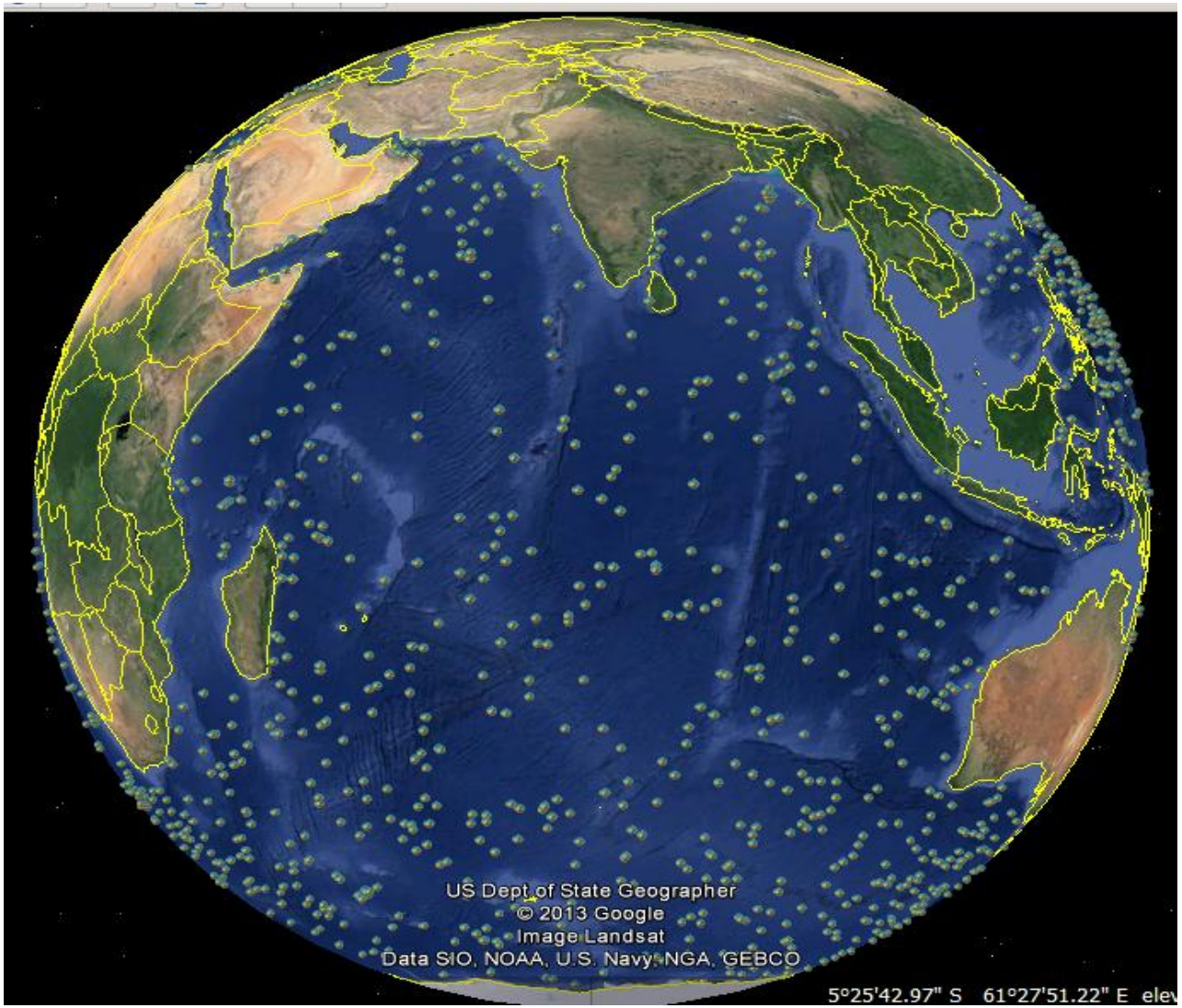
Cuypers, Y., X. Le Vaillant, P. Bouruet-Aubertot, J. Vialard and M. J. McPhaden, 2013: Tropical storm-induced near-inertial internal waves during the Cirene experiment: energy fluxes and impact on vertical mixing. *J. Geophys. Res., 118,* 358-380, doi: 10.1029/2012JC007881.in press.

Feng, M., M. J. McPhaden, S.-P. Xie, and J. Hafner, 2013: La Niña forces unprecedented Leeuwin Current warming in 2011. *Nature Sci. Repts., 3,* 1277, doi 10.1038/srep01277.

Girishkumar, M. S., M. Ravichandran and M. J. McPhaden, 2013: Temperature inversions and their influence on the mixed layer heat budget during the winters of 2006-07 and 2007-08 in the Bay of Bengal. *J. Geophys. Res., 118,* doi:10.1002/jgrc.20192.

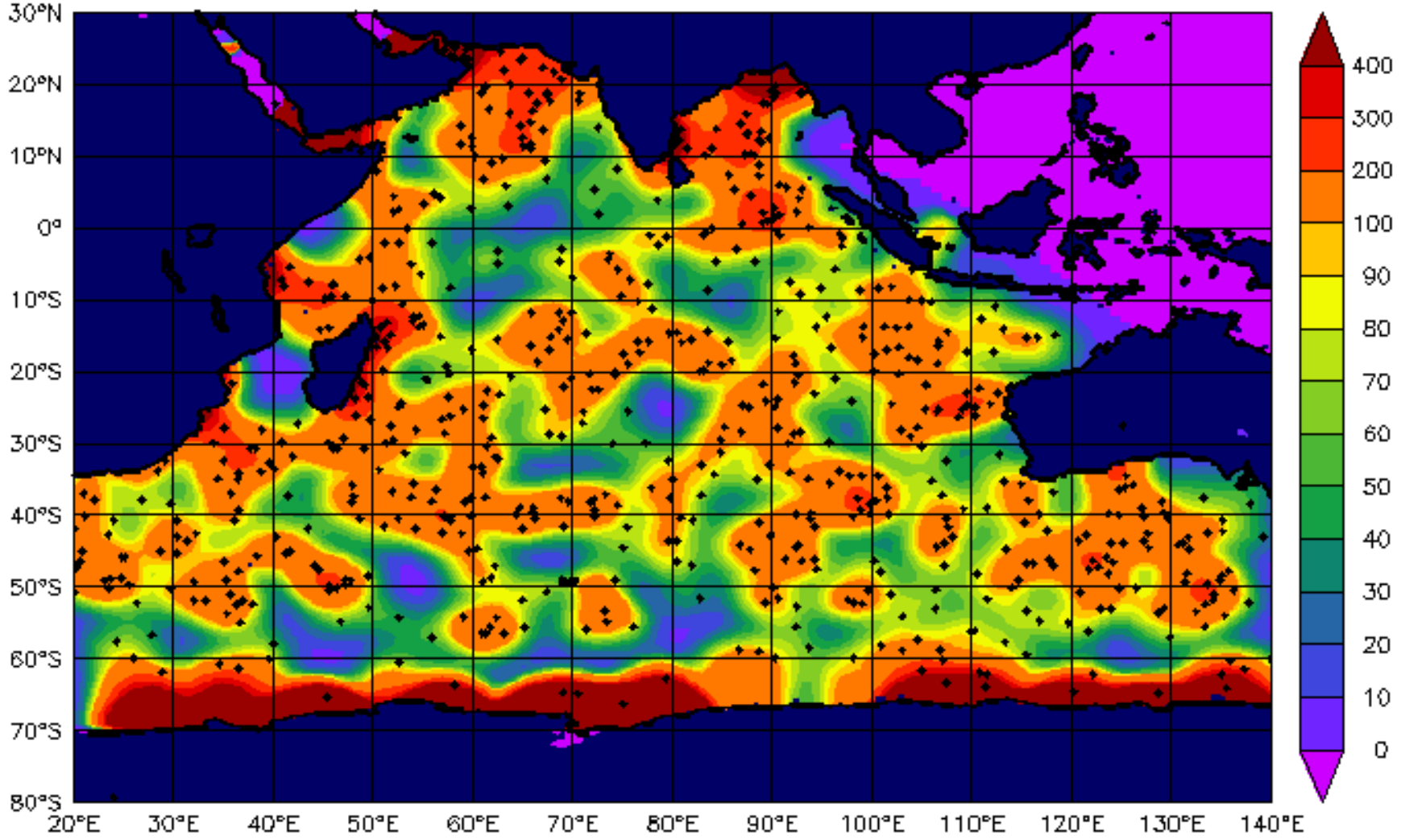
McPhaden, M. J., and G. R. Foltz, 2013: Intraseasonal variations in the surface layer heat balance of the central equatorial Indian Ocean: The importance of zonal advection and vertical mixing. *Geophys. Res. Lett., 40,* 1-5, doi:10.1029/GL056092.

Present status of Argo floats in the Indian Ocean

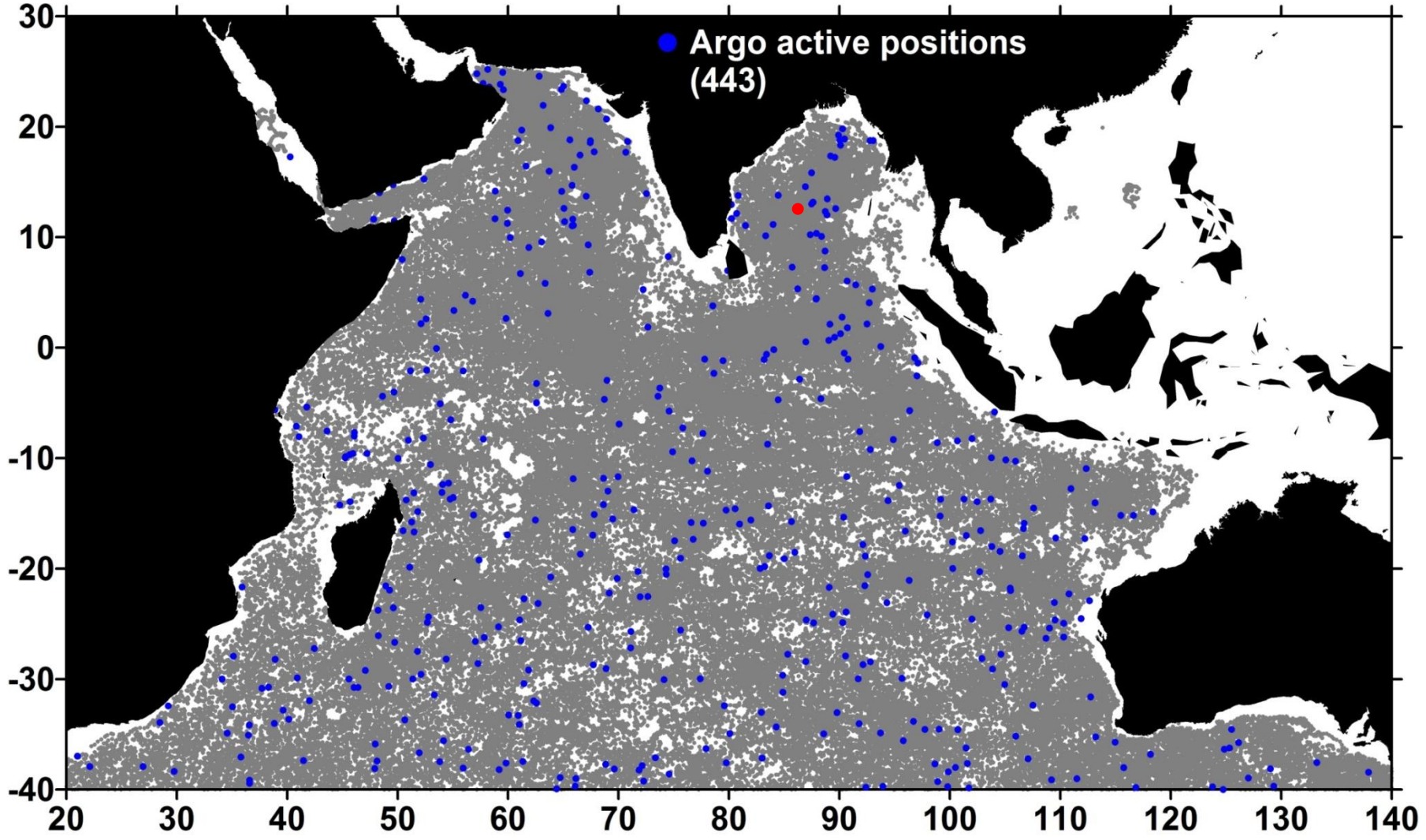


- 443 floats are active
- Only 67 floats deployed (175 last year)
- Most of the new floats are iridium communication (higher vertical resolution ~ 2m)
- Few floats with biogeochemical sensors, higher vertical resolution ~ 10 cm in the top 30 m)
- 71 % DMQC done

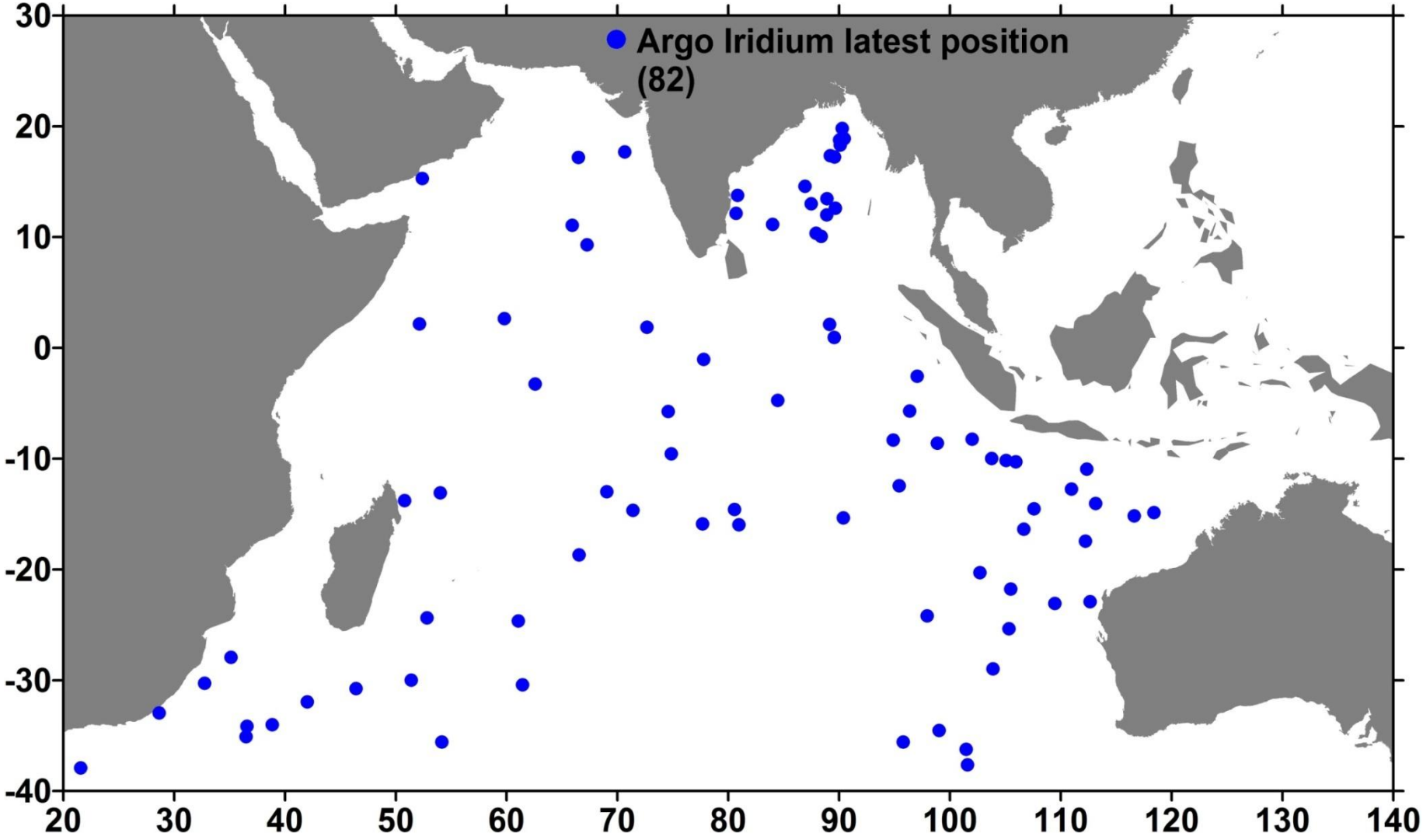
Argo float density as on Aug 2013

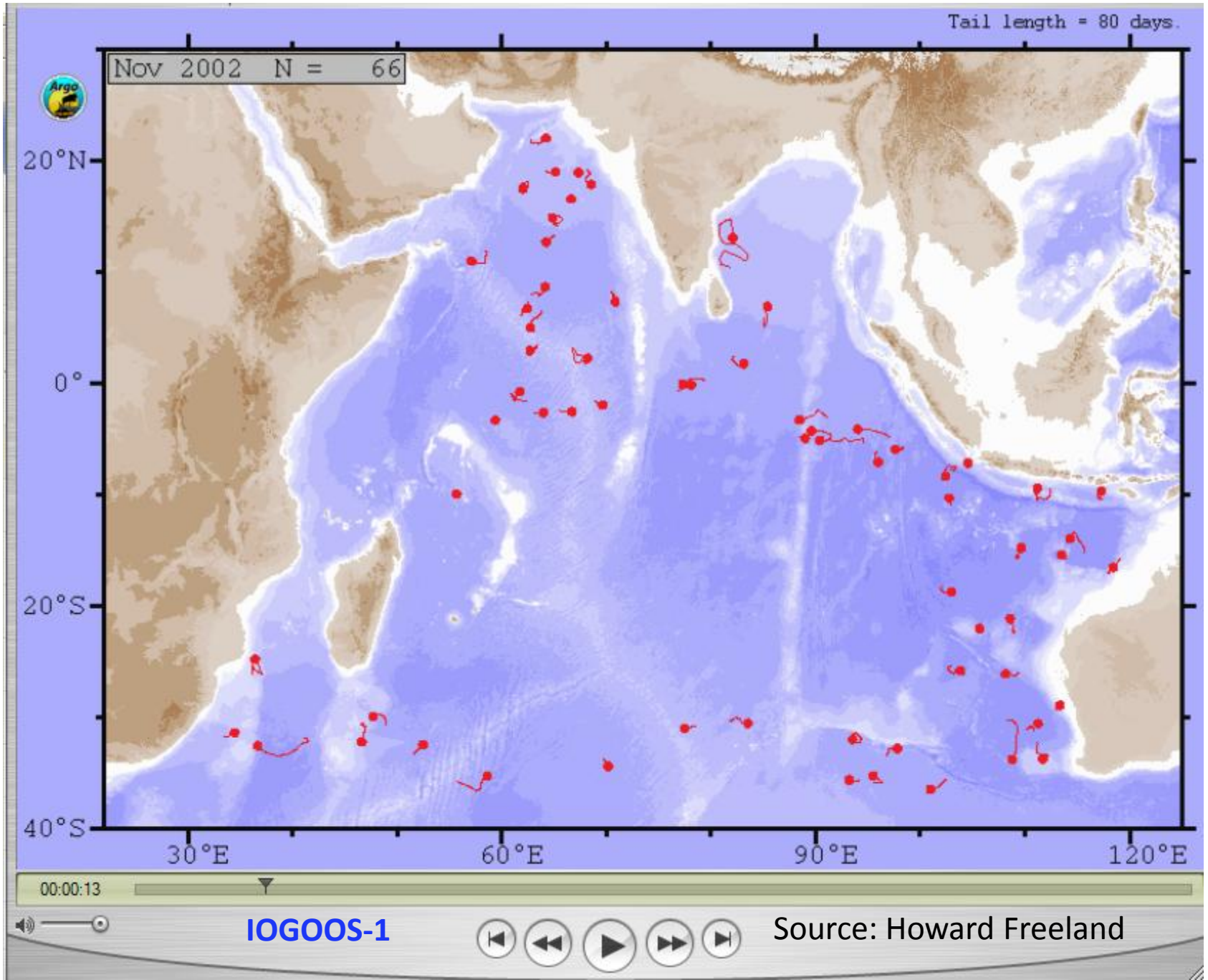


Present Status of Argo float locations



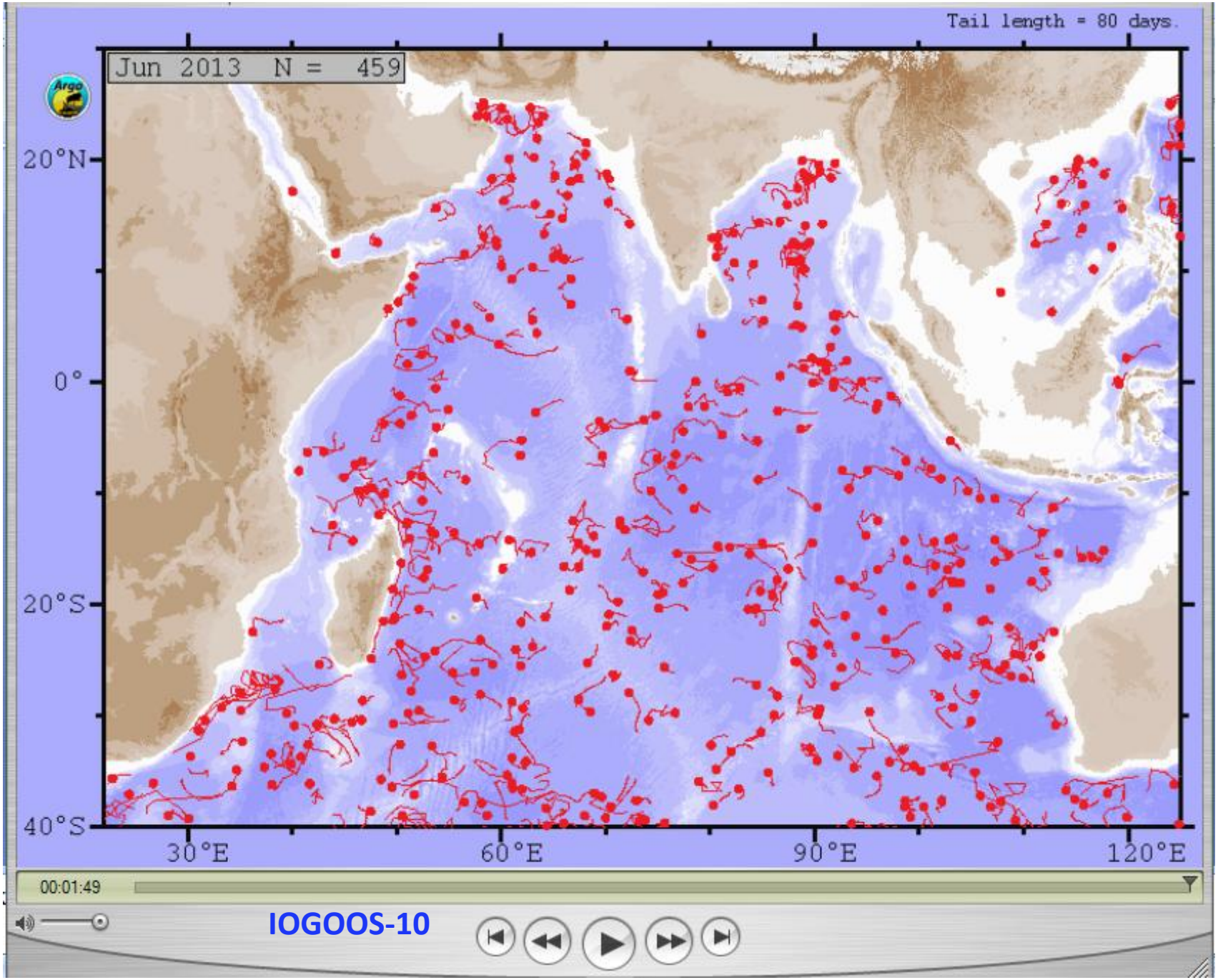
High vertical resolution (2 m)



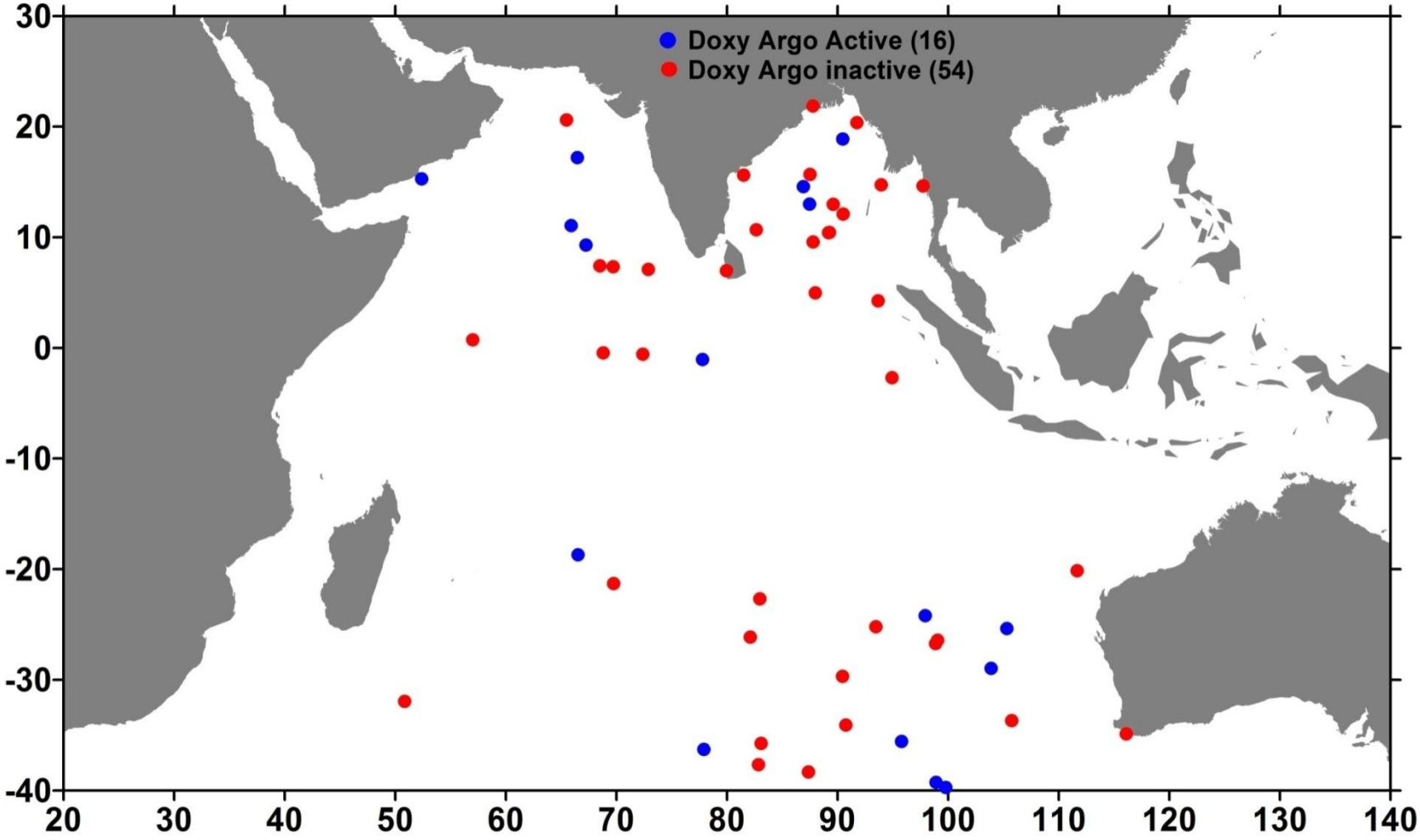


IOGOOS-1

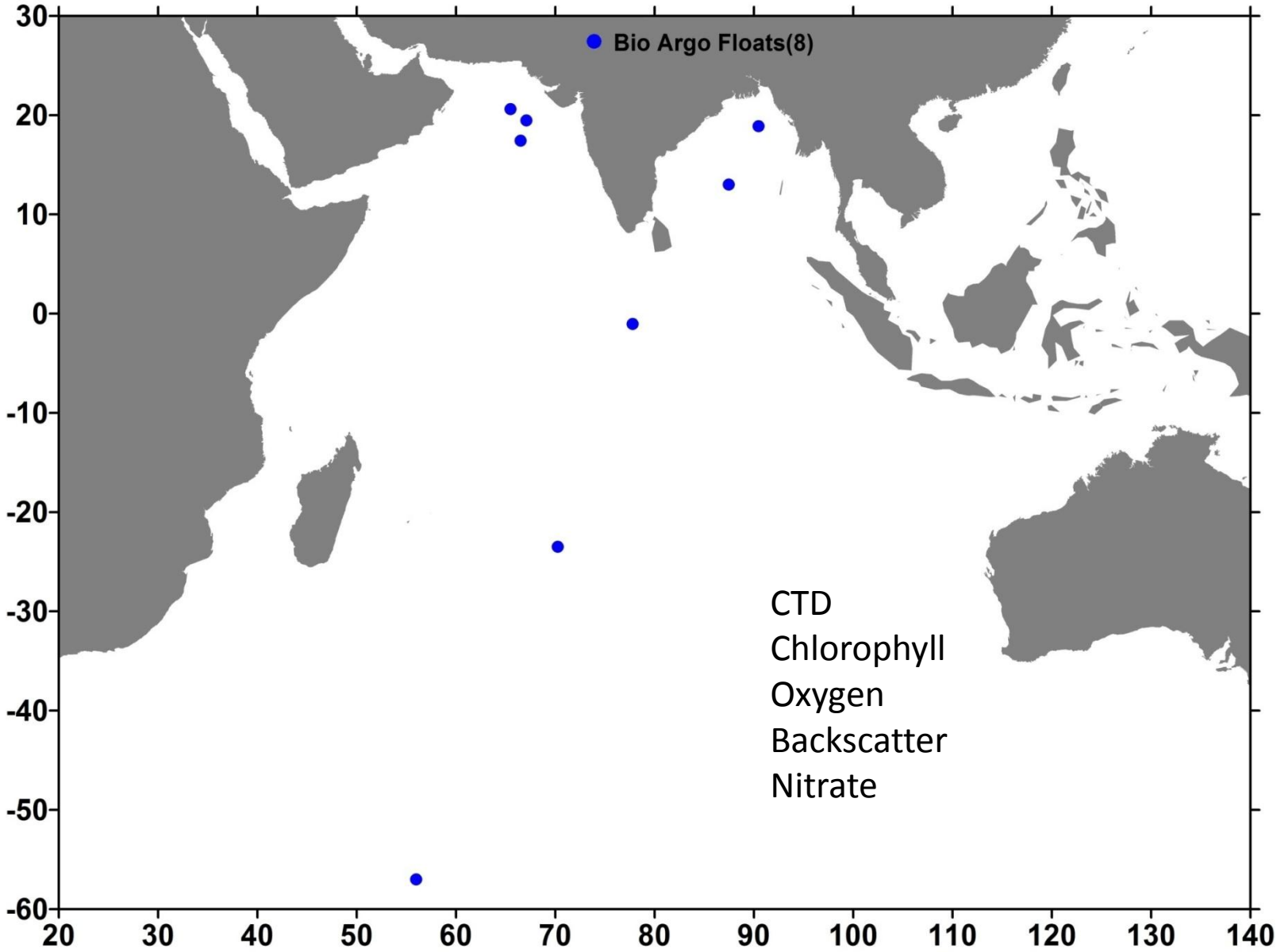
Source: Howard Freeland


Tail length = 80 days.
Jun 2013 N = 459
20°N
0°
20°S
40°S
30°E
60°E
90°E
120°E
00:01:49
IOGOOS-10

Argo – Oxygen floats



Bio – Argo floats



Acknowledging Argo data
▼ Media Center
Movies
Photos
▼ Documents
Argo bibliography
Complete float bibliography
Argo research in press
Newsletter: Argonautics
Argo user group reports
Argo brochures
Argo design papers
News archive
▼ Argo Steering Team
Argo Steering Team
Members
Meeting reports
▶ Meetings
▶ Links
▶ Google Earth Layer
▶ FAQ
▶ Contact
▶ Site Map

2013 2012 2011 2010 2009 2008 2007 2006 2005 2004 2003 2002 2001 2000 1999 1998 1997 1996 1995 1992 1991

2013 (100)

Abe, H., K. Hanawa, and N. Ebuchi, 2013: Interannual variations in the Hawaiian Lee Countercurrent. *Journal of Oceanography*, **69,** 191-202, **http://dx.doi.org/10.1007/s10872-012-0166-0**

Aoyama, M., M. Uematsu, D. Tsumune, and Y. Hamajima, 2013: Surface pathway of radioactive plume of TEPCO Fukushima NPP1 released 134Cs and 137Cs. *Biogeosciences*, **10,** 3067-3078, **http://www.biogeosciences.net/10/3067/2013/**

Bashmachnikov, I., D. Boutov, and J. Dias, 2013: Manifestation of two meddies in altimetry and sea-surface temperature. *Ocean Science*, **9,** 249-259, **http://www.ocean-sci.net/9/249/2013/**

Bostock, H. C., P. J. Sutton, M. J. M. Williams, and B. N. Opdyke, 2013: Reviewing the circulation and mixing of Antarctic Intermediate Water in the South Pacific using evidence from geochemical tracers and Argo float trajectories. *Deep Sea Research Part I: Oceanographic Research Papers*, **73,** 84-98, **http://www.sciencedirect.com/science/article/pii/S0967063712002270**

Boutin, J., N. Martin, G. Reverdin, X. Yin, and F. Gaillard, 2013: Sea surface freshening inferred from SMOS and ARGO salinity: impact of rain. *Ocean Science*, **9,** 183-192, **http://www.ocean-sci.net/9/183/2013/**

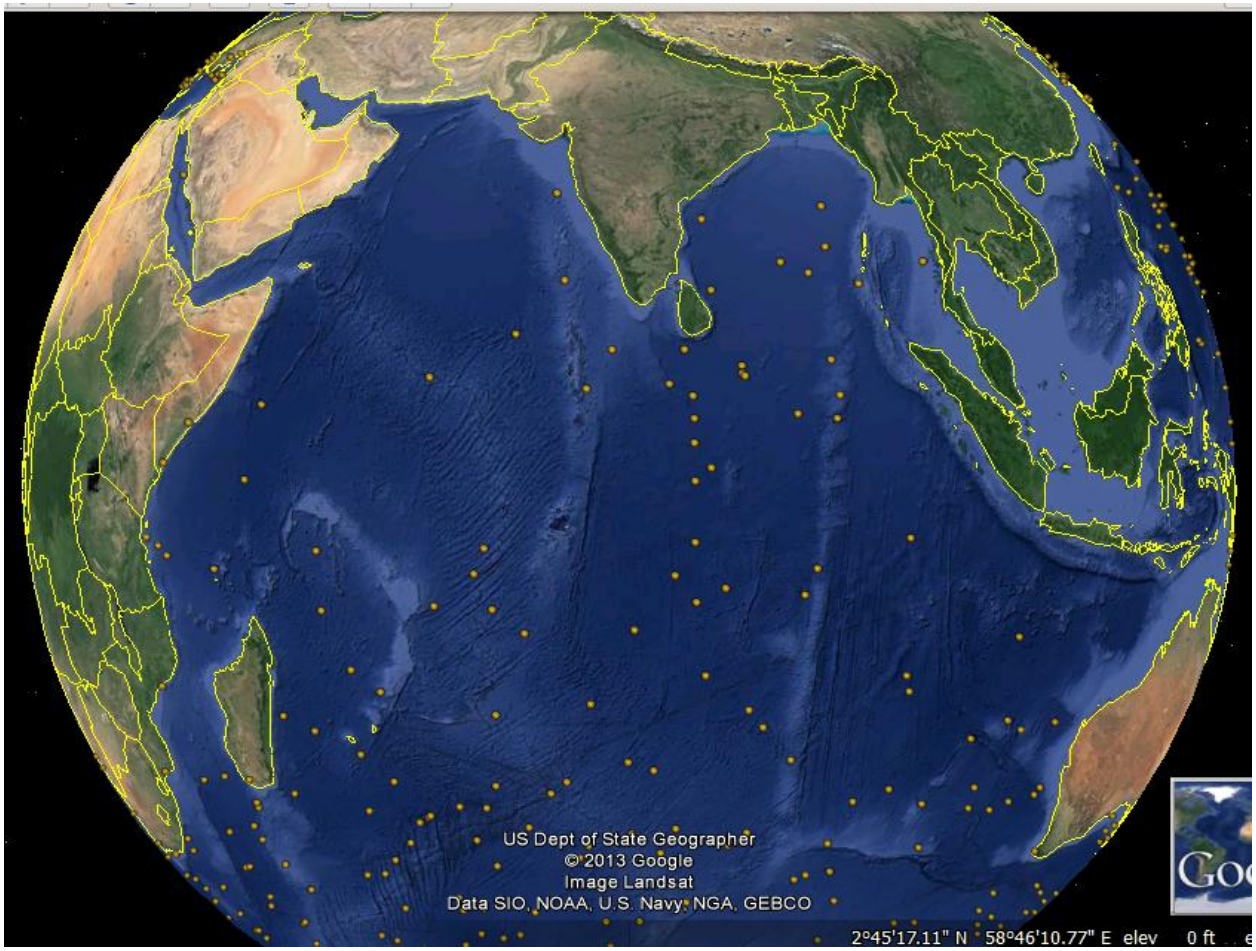
Buckingham, C. E. and P. C. Cornillon, 2013: The contribution of eddies to striations in absolute dynamic topography. *Journal of Geophysical Research: Oceans*, **118,** 448-461, **http://dx.doi.org/10.1029/2012JC008231**

Cabanes, C., A. Grouazel, K. von Schuckmann, M. Hamon, V. Turpin, C. Coatanoan, F. Paris, S. Guinehut, C. Boone, N. Ferry, C. de Boyer Montégut, T. Carval, G. Reverdin, S. Pouliquen, and P. Y. Le Traon, 2013: The CORA dataset: validation and diagnostics of in-situ ocean temperature and salinity measurements. *Ocean Science*, **9,** 1-18, **http://www.ocean-sci.net/9/1/2013/**

Cai, W. and Y. Qiu, 2013: An Observation-Based Assessment of Nonlinear Feedback Processes Associated with the Indian Ocean Dipole. *Journal of Climate*, **26,** 2880-2890, **http://dx.doi.org/10.1175/JCLI-D-12-00483.1**

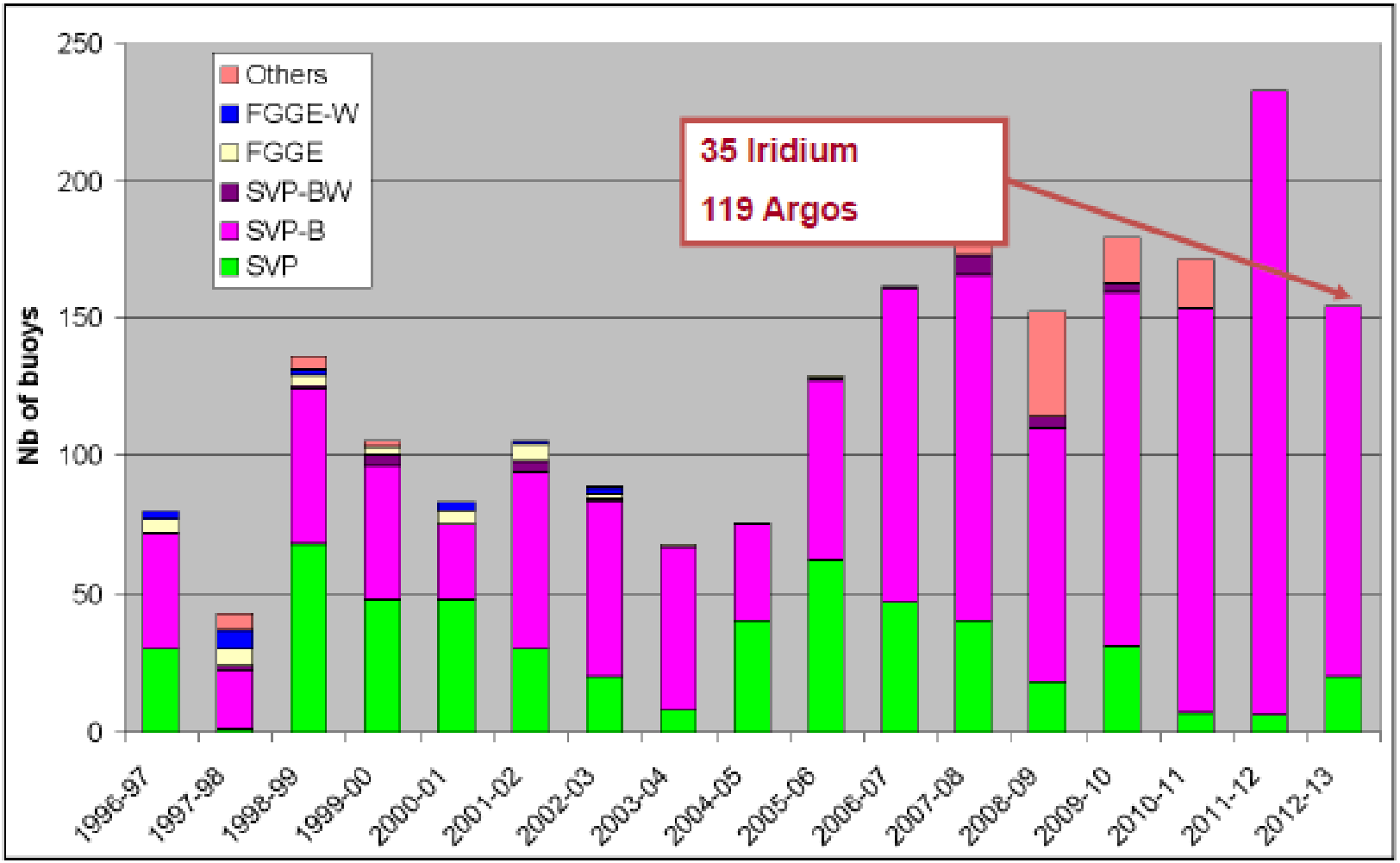
Carton, X., B. Le Cann, A. Serpette, and J. Dubert, 2013: Interactions of surface and deep anticyclonic eddies in the Bay of Biscay. *Journal of Marine Systems*, **109–110, Supplement,** S45-S59, **http://www.sciencedirect.com/science/article/pii/S0924796311002272**

Present status of Drifters in the Indian Ocean

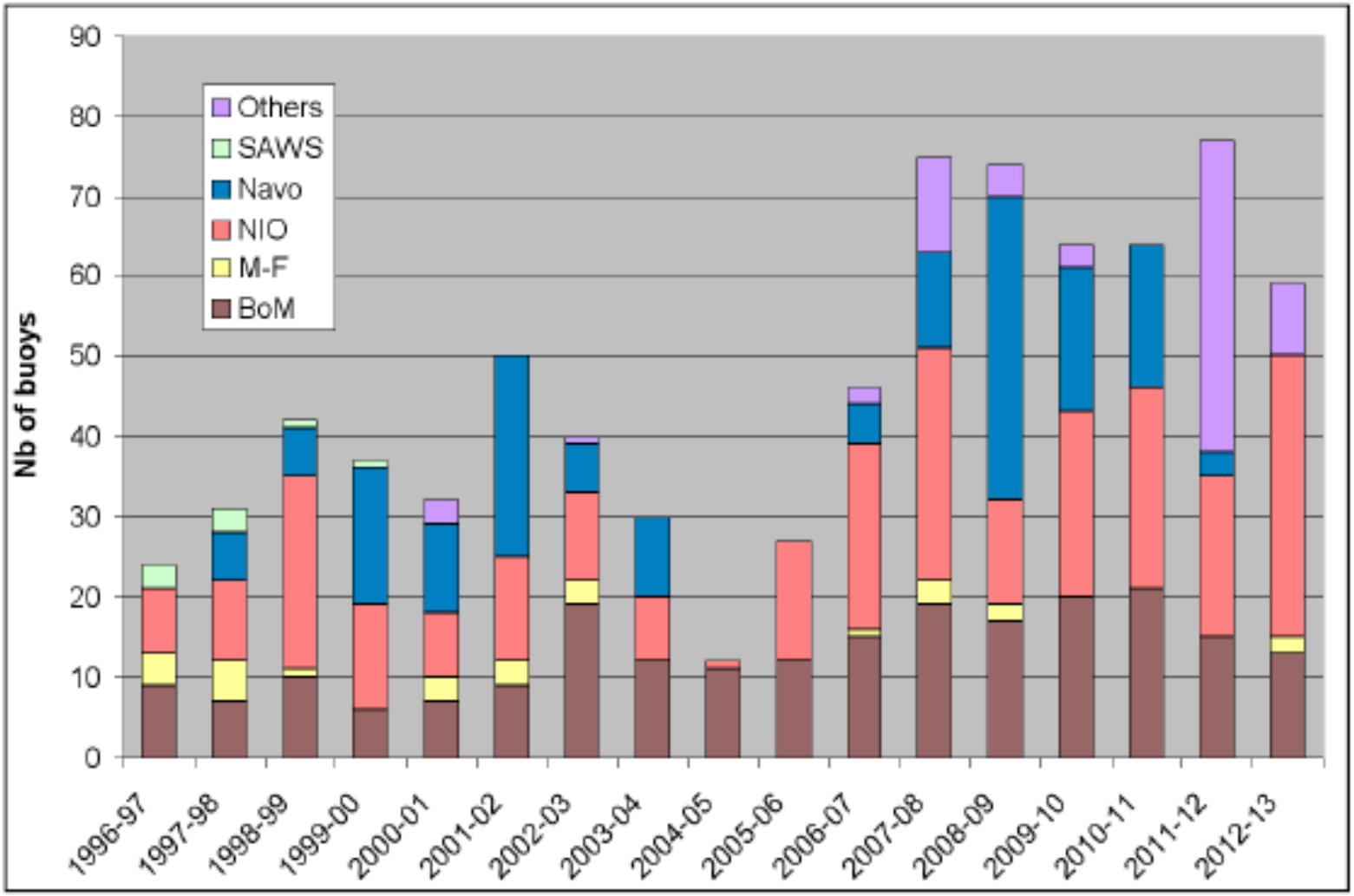


- Slight improvement compared to last year, but need more

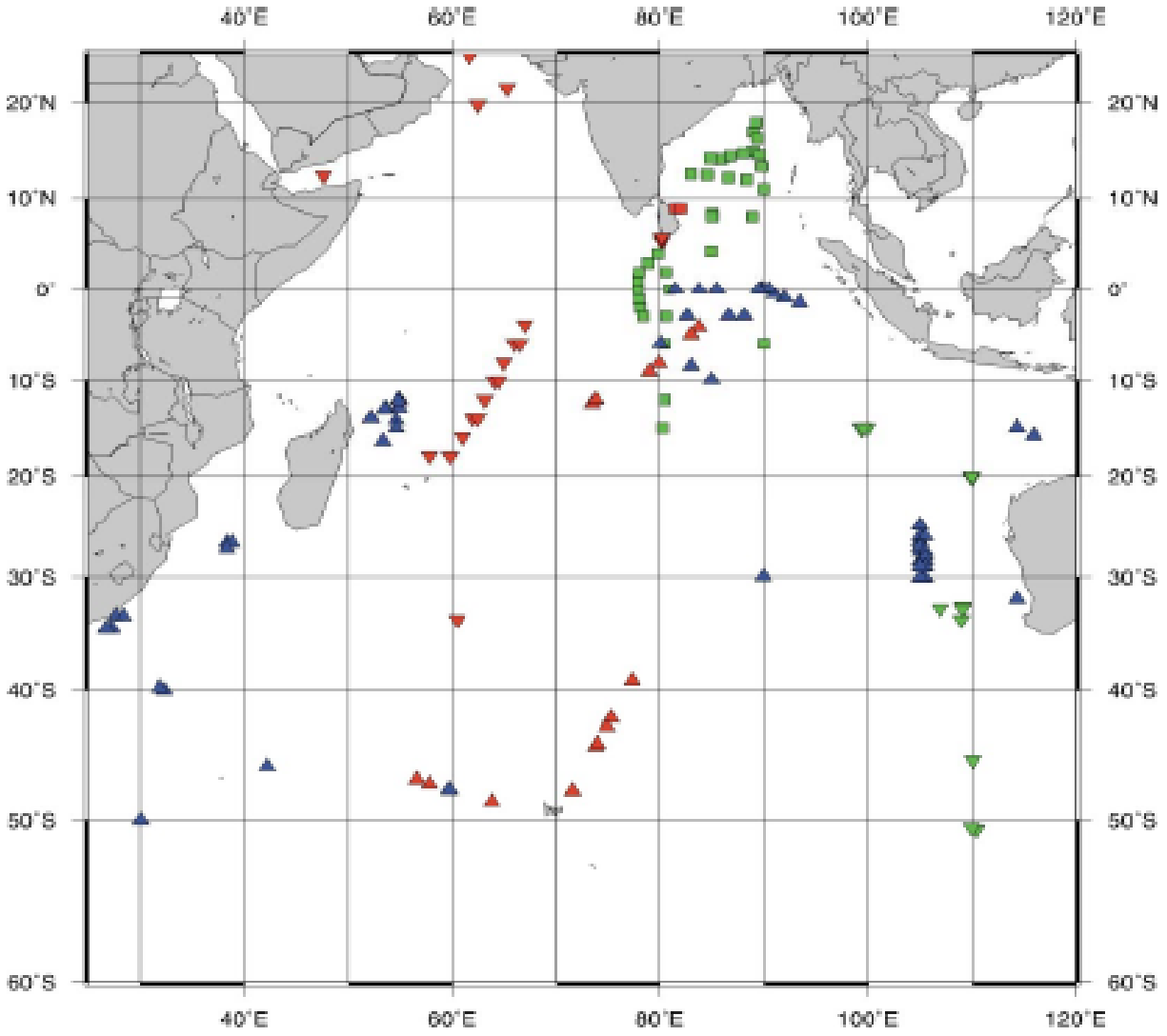
Drifting buoys - types



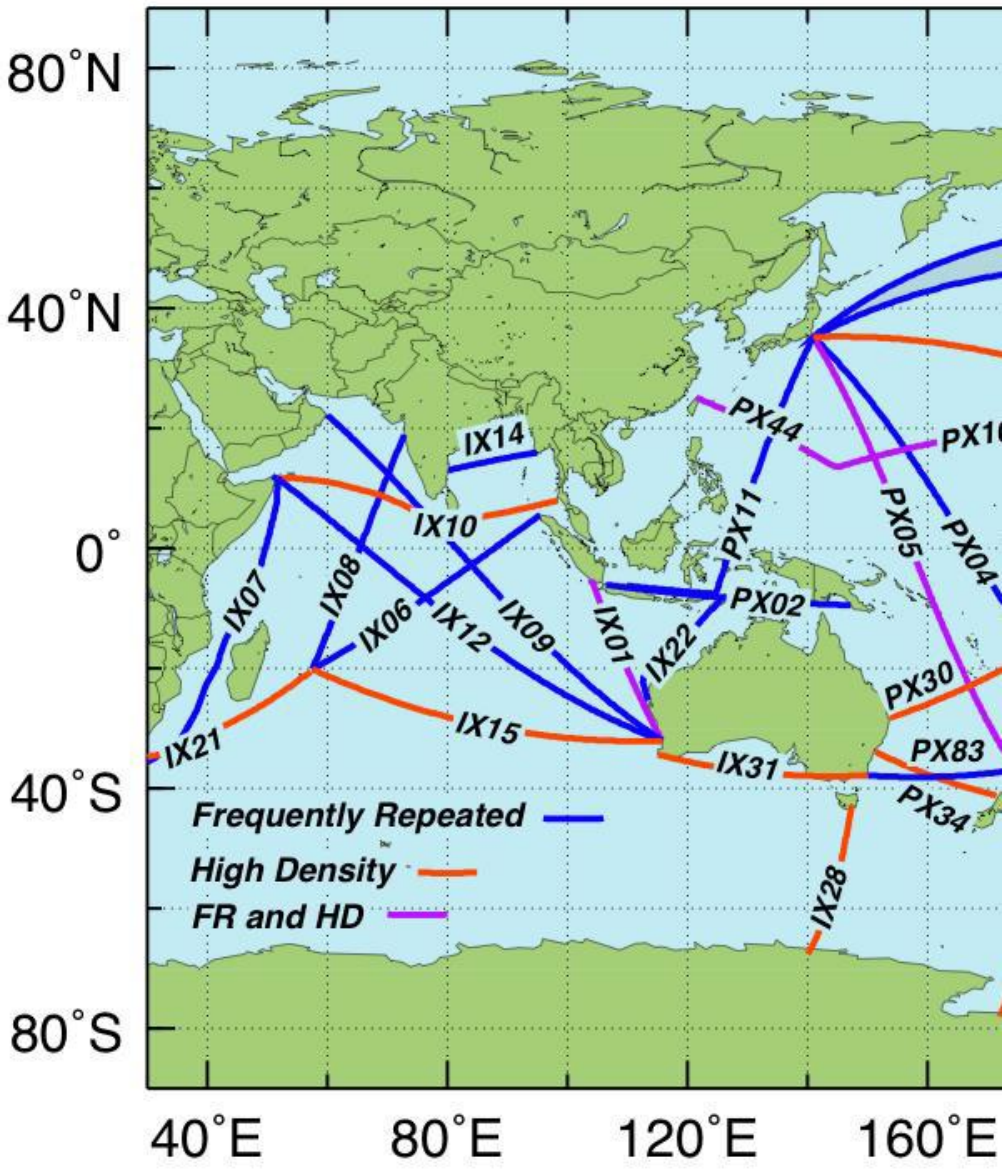
Drifting buoys - contribution



Deployment during last one year



OceanObs09 XBT Transect recommendation



High Density (**HD**) – mesoscale resolving (25 km), 4 times per year

Frequently Repeated (FR) – interannua/decadal resolving, 12-18 times per year, 100-150 km spacing (6 drops per day)

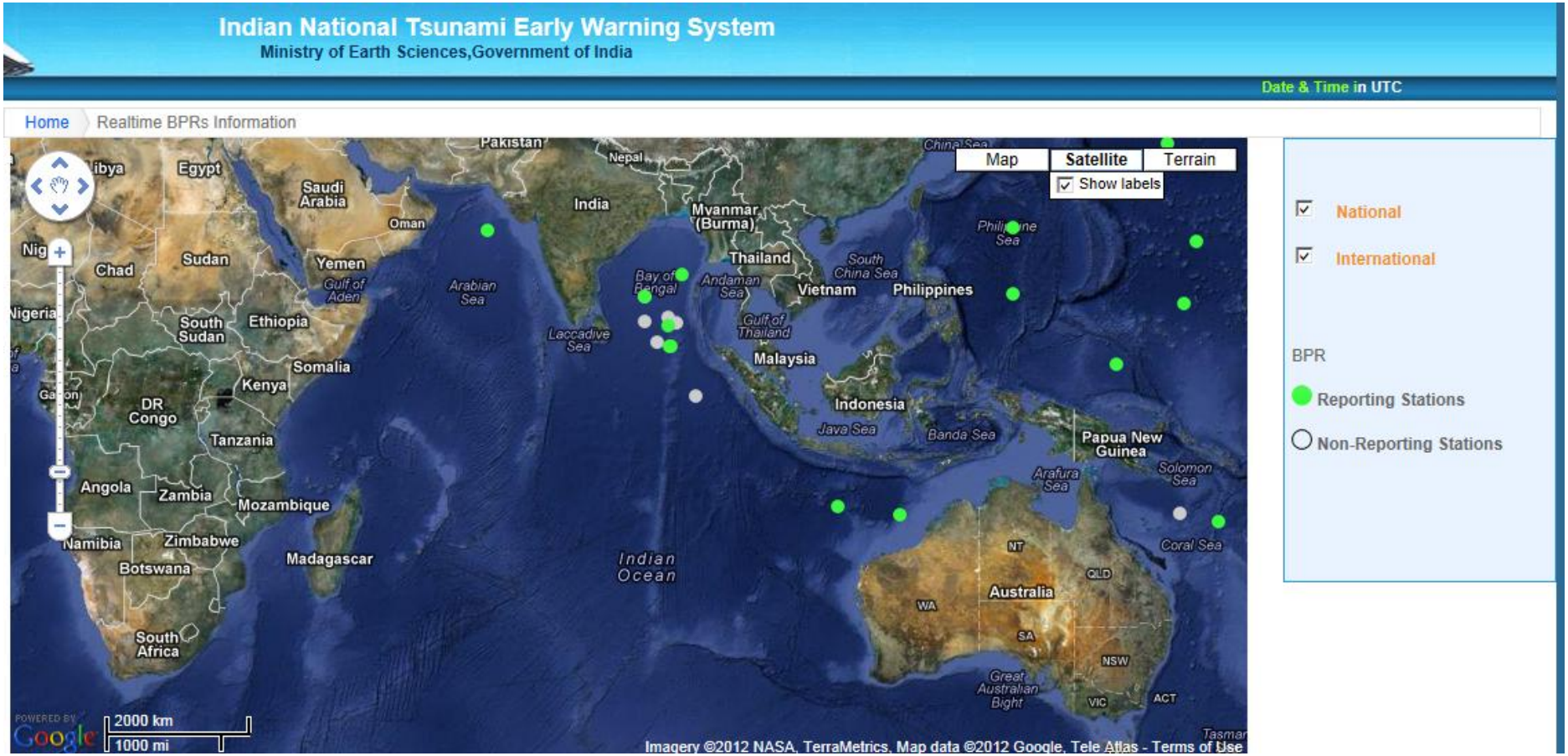
– abandoned in Atlantic due to budget restriction (NOAA AOML)

Low Density – no longer recommended

Tide gauge locations

67 Tide gauges are active in the Indian Ocean

Tsunami - BPR


Indian National Tsunami Early Warning System
Ministry of Earth Sciences,Government of India
Date & Time in UTC
Home
Realtime BPRs Information
Map
Satellite
Terrain
Show labels
National
International
BPR
Reporting Stations
Non-Reporting Stations
Pakistan
Nepal
India
Myanmar (Burma)
Thailand
Vietnam
Philippines
Malaysia
Indonesia
Papua New Guinea
Australia
Egypt
Saudi Arabia
Oman
Yemen
Sudan
Chad
Ethiopia
South Sudan
Somalia
Kenya
DR Congo
Tanzania
Angola
Zambia
Mozambique
Zimbabwe
Namibia
Botswana
Madagascar
South Africa
Arabian Sea
Bay of Bengal
Andaman Sea
Laccadive Sea
Gulf of Aden
Gulf of Thailand
South China Sea
Java Sea
Banda Sea
Arafura Sea
Solomon Sea
Coral Sea
Indian Ocean
Great Australian Bight
NT
QLD
WA
SA
NSW
VIC
ACT
2000 km
1000 mi
Imagery ©2012 NASA, TerraMetrics, Map data ©2012 Google, Tele Atlas - Terms of Use

Science - Highlights

- Prediction and attribution of extreme events (cyclones)
- Intra-seasonal, inter-annual and decadal variability
- Warming event in the southwest Indian Ocean
- Simulation of atmospheric and ocean variables from regional ocean-atmosphere coupled model
- Marine biophysical interactions and dynamics of upwelling systems.

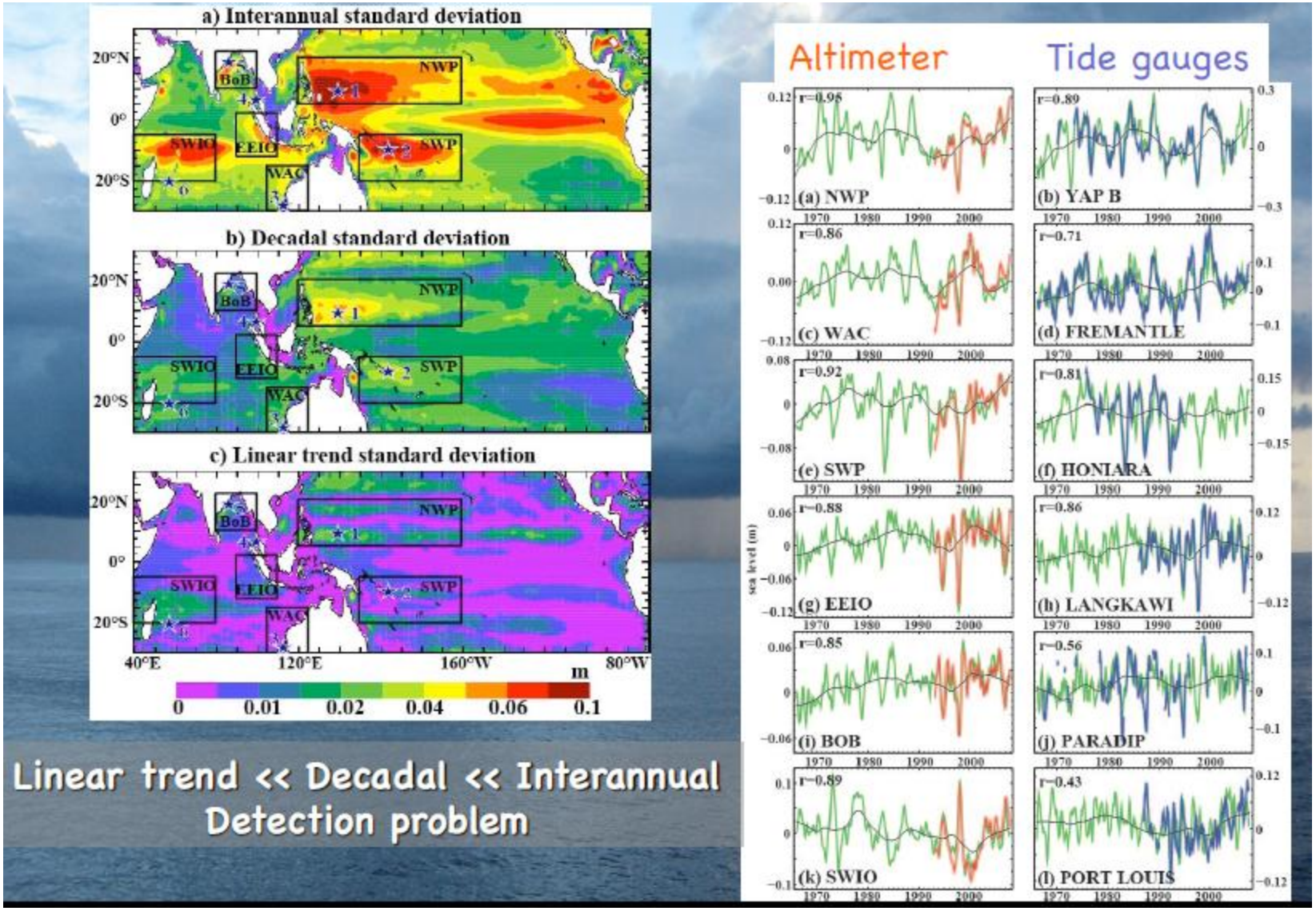
Bay of Bengal Cyclones

- The influences of ENSO on TC activity in the BoB during post monsoon cyclones (Girishkumar and Ravichandran, JGR, 2012)
  - During La Nina conditions, the number of cyclones and the intensity of the TC are enhanced in the BoB
- Influence of upper-ocean stratification on tropical cyclone-induced surface cooling in the Bay of Bengal (Neetu et.al, JGR, 2012)
  - During the postmonsoon season, a deeper thermal stratification combined with a considerable upper-ocean freshening strongly inhibits surface cooling induced by vertical mixing underneath TCs. On average, thermal stratification accounts for ~60% of this cooling reduction during postmonsoon season, while haline stratification accounts for the remaining 40%.
- Bimodal Character of Cyclone Climatology in the Bay of Bengal Modulated by Monsoon Seasonal Cycle (Zhi Li, et.al, J. of climate, 2013)
  - Monsoon seasonal cycle leads to the bi-model feature of BoB Cyclone behaviour and favours the occurrence of super cyclone during the summer monsoon onset phase.
- The impacts of TCs on the BoB heat budget were examined using HYCOM: TC winds may significantly alter the ISO BOB heat budget through ocean heat transport and surface heat fluxes (Jih-Wang Wang, et.al, JGR, 2012)

Intra-seasonal and Inter-annual

- Observed ISO variability (30 -120 days) of thermocline in the Bay of Bengal (Girishkumar et.al, 2013)
- Intraseasonal variations in the surface layer heat balance of the central equatorial Indian Ocean (McPhaden et.al)
- Indian Ocean Dipole interpreted in terms of Recharge Ocsillator theory. (*McPhaden et.al, climate dynamics, accepted)*
- Temperature inversions and their influence on the mixed layer heat budget during the winters of 2006-07 and 2007-08 in the Bay of Bengal (Girish kumar, et. al, JGR, 2013)
- Impact of Indian Ocean Dipole and El Niño/Southern Oscillation forcing on the Wyrtki jets (Gnanaseelan, et.al, JGR, 2012)
- Interannual variability of the Tropical Indian Ocean mixed layer depth (Keerthi, et.al, Clim. Dynamics, 2012)

Decadal and long-term sea level variability in the tropical Indo-Pacific Ocean



Nidheesh, et. al, Clim. Dynamics, 2012

Indian Ocean decadal variability: a review

Han, W., J. Vialard, M.J. McPhaden, T. Lee,
M. Feng, Y. Masumoto, and W. de Ruijter

BAMS

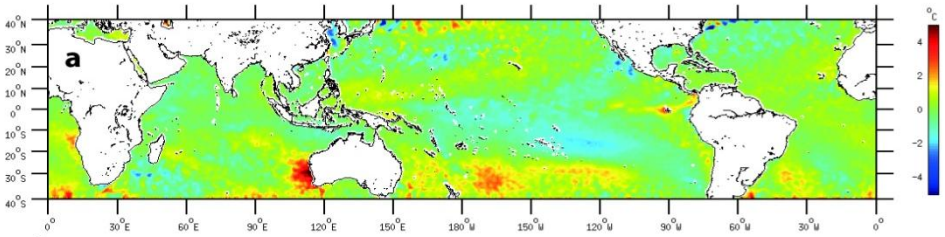
1. Climatic and Societal impacts

2. Decadal variability signals and causes

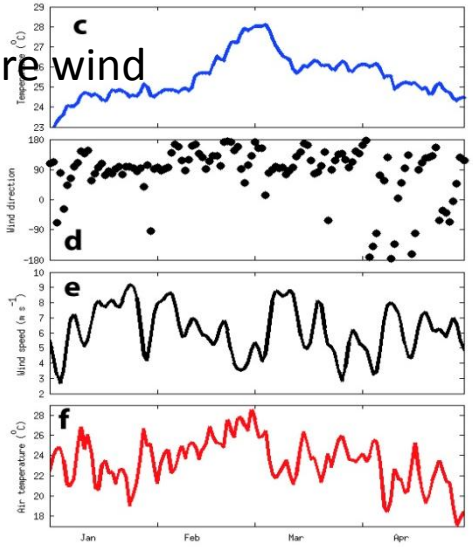
- ***a) Warming trend since the 1950s, structure and decadal variation***
- **b) Air-sea coupling: SST, SLP & surface wind**
- ***c) Indian Ocean dipole***
- ***d) Salinity***
- ***e) Sea Level and thermocline***
- ***f) Ocean circulation & inter-basin exchange***
- ***g) Prediction & predictability***

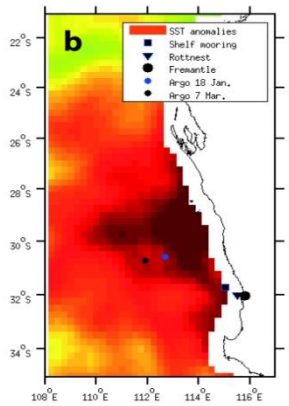
3. Summary, Science issues and Challenges

Warming event in the Southeast Indian Ocean

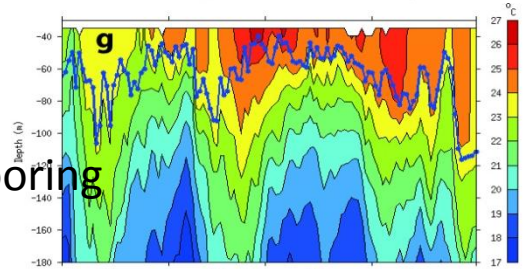


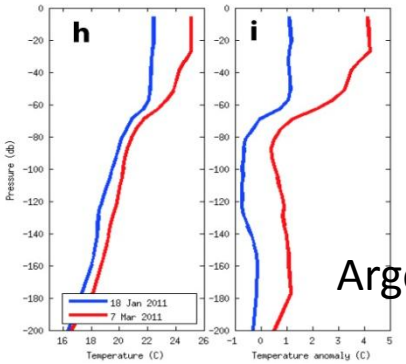
Alongshore wind



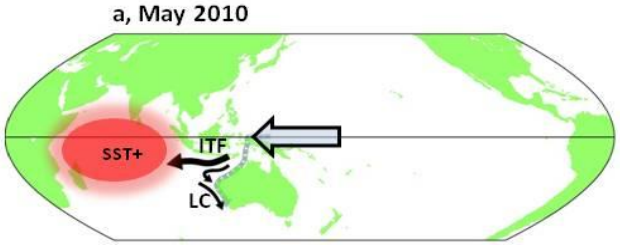


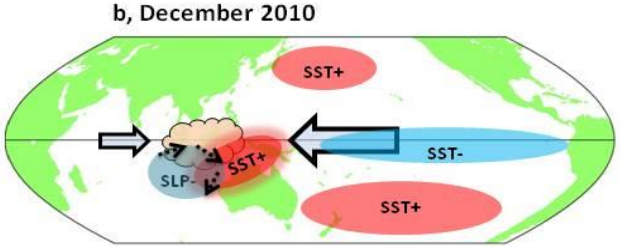
Shelf mooring

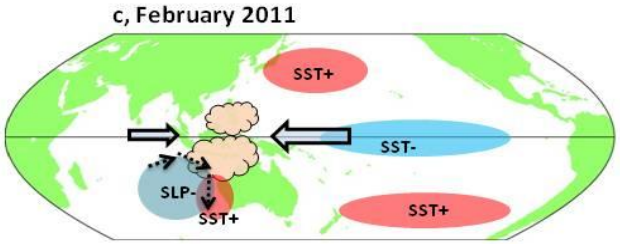




Argo profiles





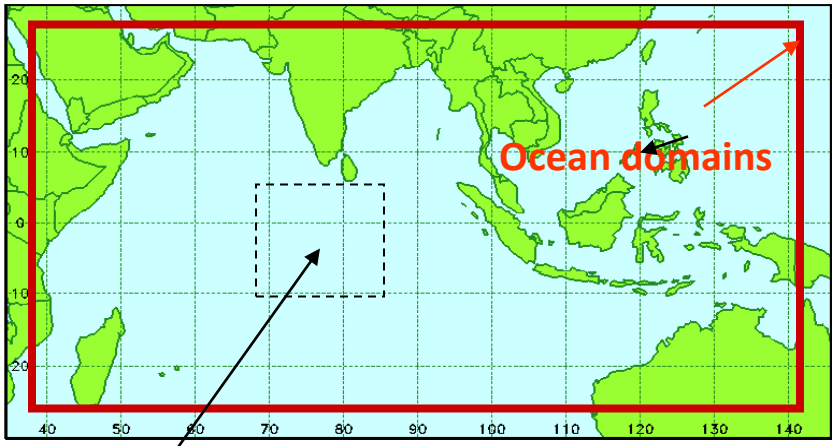


Ming Feng, et. al., Nature

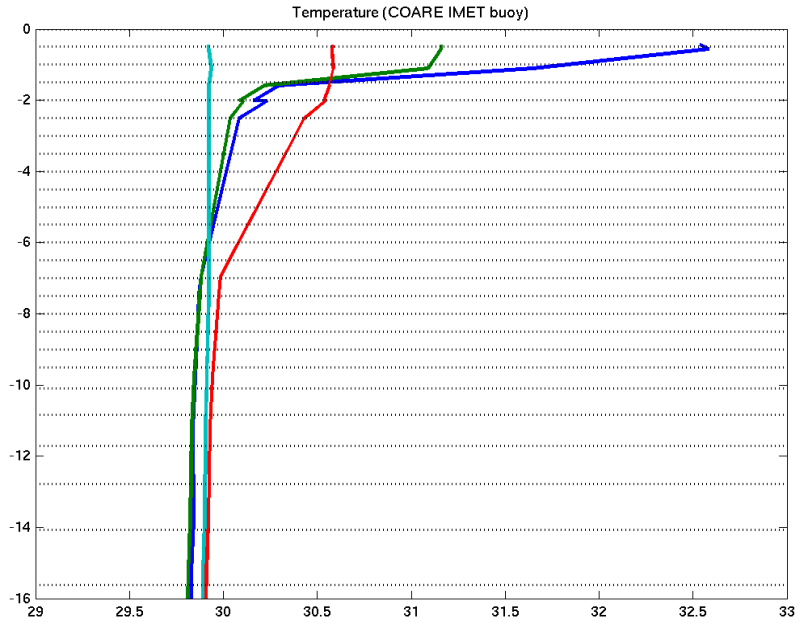
Oceanic variability associated with the MJO simulated by a regional coupled model (COAMPS)

High vertical resolution of ocean component

60 levels (45 sigma + 15 z-levels)



High resolution (9km) and explicit clouds covering DYNAMO area (10S-5N, 68-84E)



Atmosphere:
452x252x40
(27 km grid)
12 h data assimilation cycle

2-way

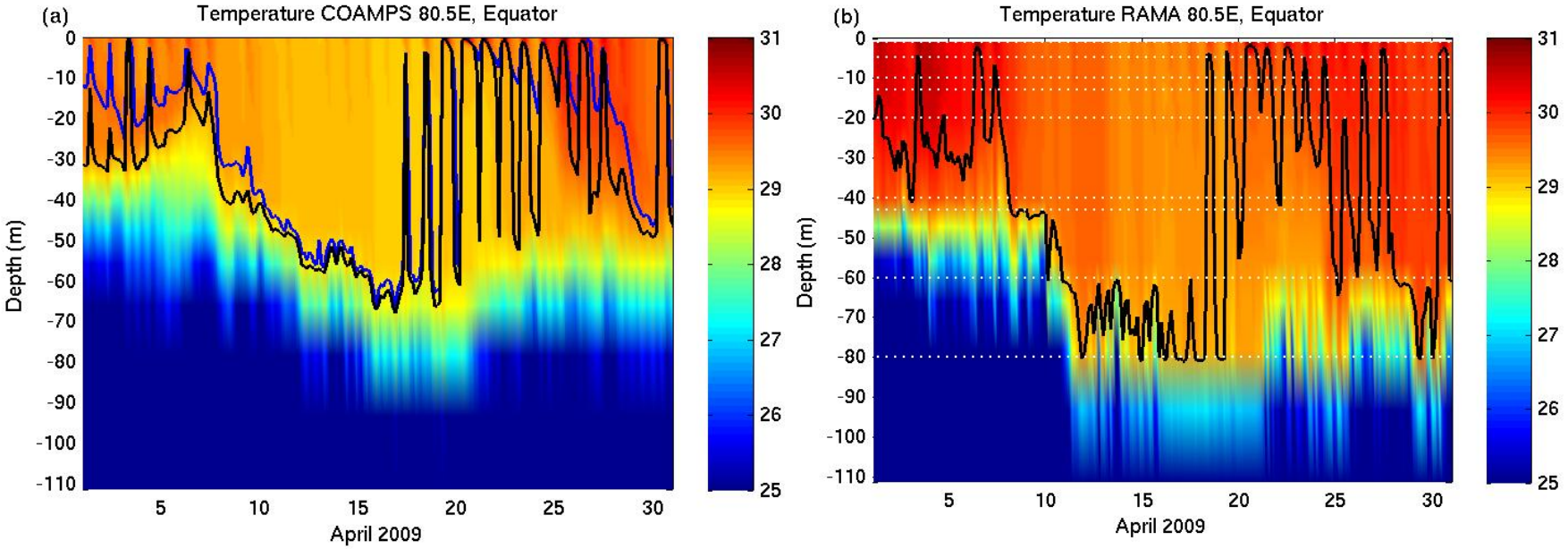
Ocean :
811x433x60
(1/8 °)
no data assimilation

Toshi Shinoda, et. al.,

Mixed layer evolution

COAMPS

RAMA



Mixed layer depth calculated by the density criteria

Top of the thermocline depth calculated by the temperature criteria

COAMPS is able to generate SST diurnal variability with the amplitude similar to observations.

Marine biophysical interactions

- Closely working with SIBER in
  - Defining and understanding biogeochemical variability
  - Developing models of ocean-atmosphere-biosphere interactions
  - Assessing the impacts of climate change on ocean primary productivity and air-sea CO2 exchange
- Efforts are underway to incorporate biogeochemical sensors to RAMA flux sites
- Three workshops are planned during 2013 and 2014 related to "Eastern Indian Ocean Upwelling Research Initiative"
- Deployed many Argo floats with biogeochemical sensors (Oxygen, chlorophyll, light, nitrate..) in the Indian Ocean
- Observed variability of chlorophyll-*a* using Argo profiling floats in the southeastern Arabian Sea, (Ravichandran et.al, DSR, 2012) – to demonstrate the value of Bio-Argo

Capacity building activities

- IOP members are engaged in many CB activities in the Indian Ocean rim countries
  - WMO/IOC DBCP sponsored In-region western Indian Ocean capacity building workshop (Mauritius, 2011, Kenya, 2012 and Tanzania -2013)
- Bi-lateral capacity building programs related to IndOOS
  - NOAA/USA and MoES/India – Monsoon mission (model and observations)
  - JAMSTEC/Japan and BPPT/Indonesia
  - FIO/China and BRKP/Indonesia
  - MOMSEI workshop and summer schools
- IOC / Perth Office: Modeling for ocean forecasting and process studies
- Efforts are underway to hold An IOP-SIBER summer school as part of the 50th IIOE anniversary celebrations? during 2015
  - Capacity building in physical and biogeochemical oceanography
  - targeting PhD students and early-career scientists from around the rim of the Indian Ocean

Thank you for your attention