

Indian Ocean Science Workshop

*Scripps Institution of Oceanography, San Diego,
USA, September, 11-13, 2017*



2nd International
**Indian Ocean
Expedition**

 US Steering Committee



Introduction to the workshop and IIOE-2: Motivation, international science plan research themes and initiatives, and implementation strategy – Raleigh Hood

Outline:

- Motivation for this workshop.
- The IIOE-2 Science Plan Research Themes and initiatives.
- The IIOE-2 Implementation Strategy and Steering Committee.
- International Participation and Research Efforts.
- IIOE-2 Deep-Sea Research II Special Issues.

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Motivation for this Workshop:

The primary goal of this workshop is to generate a four-part workshop report that articulates potential U.S.-led contributions to the 2nd International Indian Ocean Expedition, highlighting new research activities, as well as existing and new observing assets and modeling tools that could motivate U.S. research in the Indian Ocean, prioritizing links to Indian Ocean phenomena and improved process understanding.

Reports will revolve around four themes:

Theme 1: Boundary fluxes, upwelling, ecosystem and atmospheric feedbacks

Theme 2: Monsoon dynamics and impacts on biogeochemistry

Theme 3: Ventilation, oxygen and carbon variability and change

Theme 4: Geological and deep-ocean biogeochemical processes

The real underlying goal is to motivate ideas, collaborations and ultimately PI-driven research proposals that can be submitted to US agencies in the coming months and years to get funding to participate in the IIOE-2 and do great science in the Indian Ocean.

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The IIOE-2 Science Plan:

- **Commissioned by SCOR.**
- The plan was developed by the SCOR IIOE-2 Science Plan Development Committee beginning in April/May 2014.
- The development was based on several IOC “Reference Group” planning meetings and national meetings.
- A progress report was delivered to SCOR in Bremen in September 2014.
- The first draft was completed in February 2015.
- The final peer-reviewed and revised draft was delivered to the IOC Interim Planning Committee in April, 2015 and accepted.
- **The plan was finalized and published for Goa Symposium in November, 2015.**

Available at:

<http://www.iioe-2.incois.gov.in/IIOE-2/Reports.jsp>

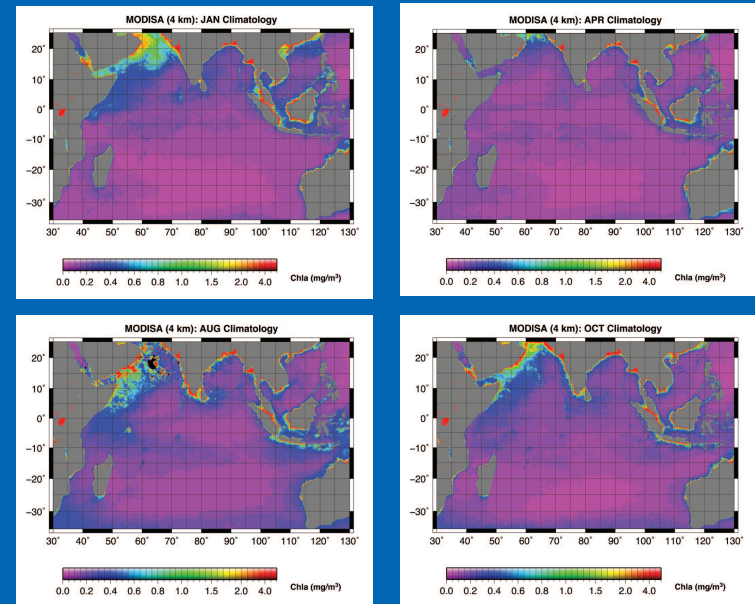
Or just google “IIOE-2” and go to reports

SECOND INTERNATIONAL INDIAN OCEAN EXPEDITION (IIOE-2)

A Basin-Wide Research Program



Science Plan



EDITED BY

R. R. Hood, H. W. Bange, L. Beal, L. E. Beckley, P. Burkill,
G. L. Cowie, N. D'Adamo, G. Ganssen, H. Hendon, J. Hermes,
M. Honda, M. McPhaden, M. Roberts, S. Singh, E. Urban, W. Yu

Overarching goal:

The overarching goal of IIOE-2 is to advance our understanding of interactions among geologic, oceanic and atmospheric processes that give rise to the complex physical dynamics of the Indian Ocean region, and determine how those dynamics affect climate, extreme events, marine biogeochemical cycles, ecosystems and human populations.

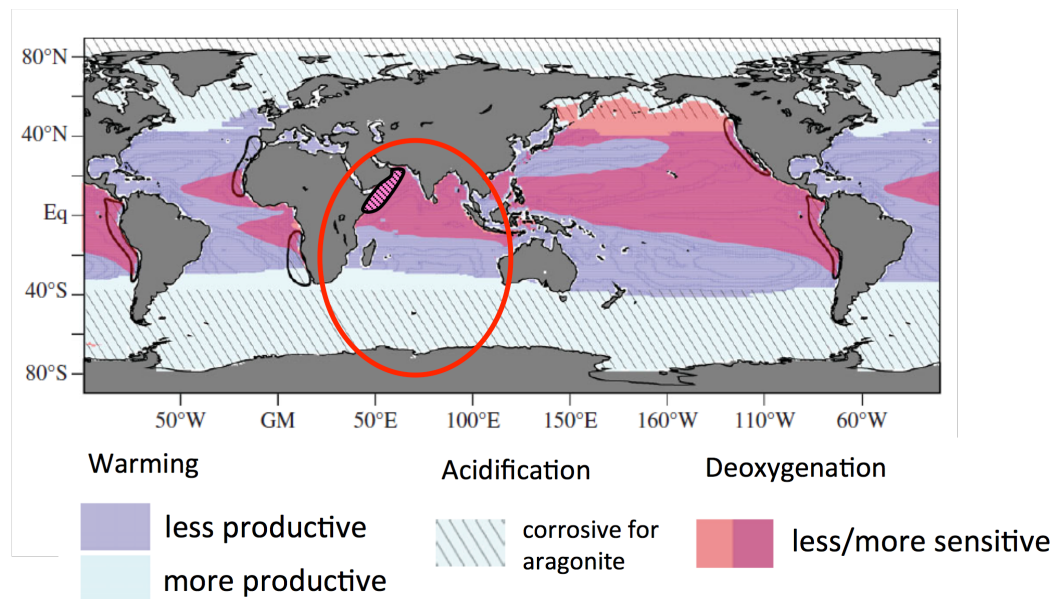
- The science plan is super broad and highly interdisciplinary.
- It includes coastal, open ocean and even deep sea environments.
- It is a “red carpet” to any individual, group, country or international coalition to participate.
- You can study anything you want.
- *It anticipates much more focused national priorities and plans.*

Scientific Themes

Theme 1: Human Impacts

Core questions:

- How are human-induced ocean stressors (for example, warming, sea-level rise, deoxygenation, acidification, eutrophication, atmospheric and plastic pollution, coastal erosion and overfishing) impacting the biogeochemistry and ecology of the Indian Ocean?
- How, in turn, are these impacts affecting human populations?

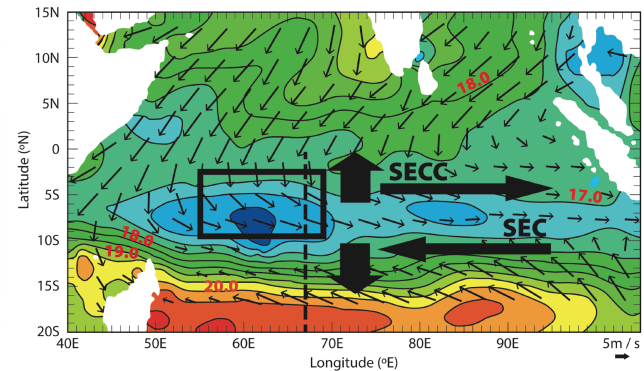
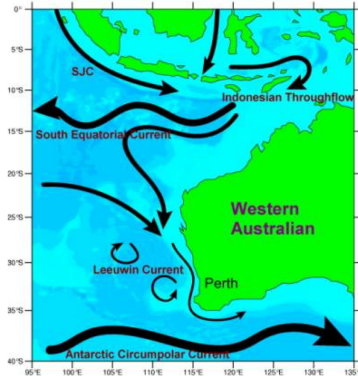
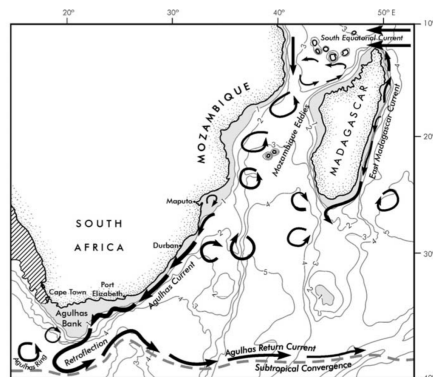
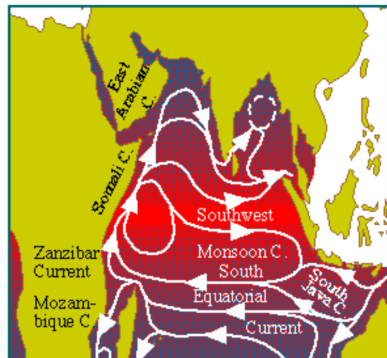


Scientific Themes

Theme 2: Boundary current dynamics, upwelling variability and ecosystem impacts (similar to our theme 1)

Core questions:

- How are marine biogeochemical cycles, ecosystem processes and fisheries in the Indian Ocean influenced by boundary currents, eddies and upwelling?
- How does the interaction between local and remote forcing influence these currents and upwelling variability in the Indian Ocean?
- How have these processes (and their influence on local weather and climate) changed in the past and how will they change in the future?

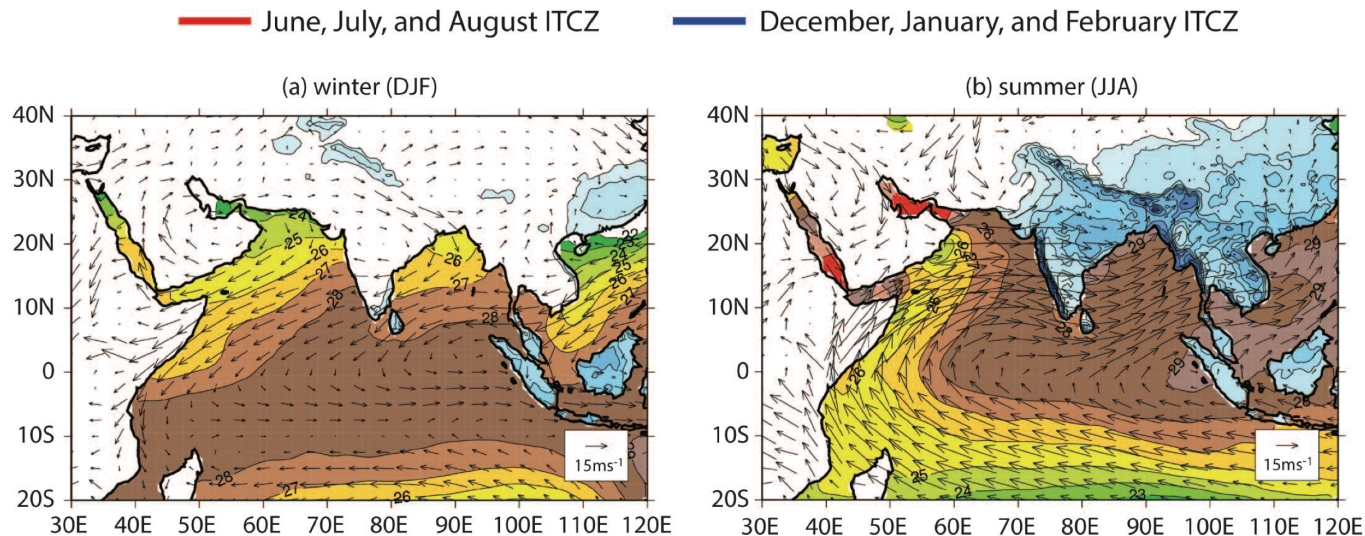


Scientific Themes

Theme 3: Monsoon variability and ecosystem response (similar to our theme 2)

Core questions:

- What factors control present, past and future monsoon variability?
- How does this variability impact ocean physics, chemistry and biogeochemistry in the Indian Ocean?
- What is the effect on ecosystem response, fisheries and human populations?

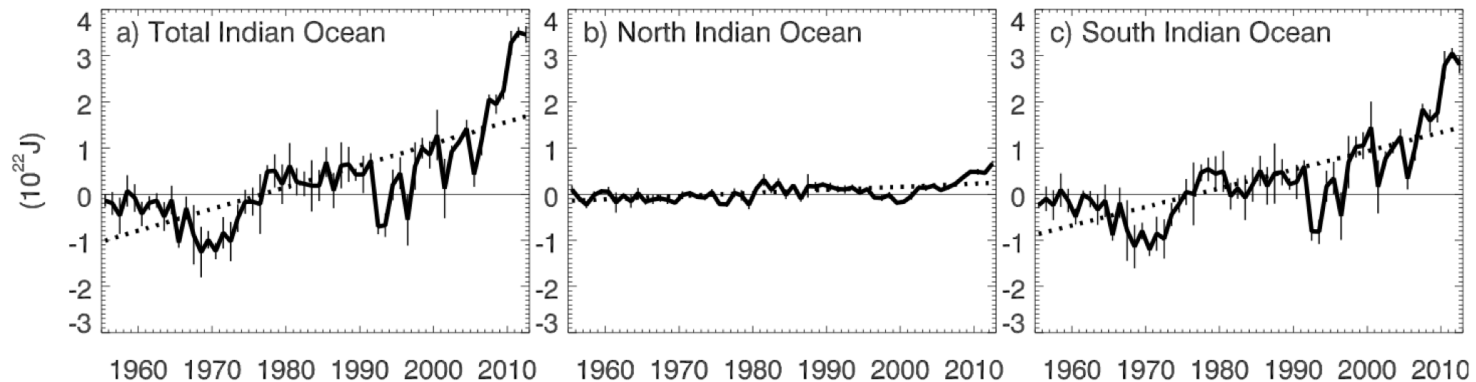


Scientific Themes

Theme 4: Circulation, climate variability and change (related to our theme 3)

Core questions:

- How has the atmospheric and ocean circulation of the Indian Ocean changed in the past and how will it change in the future?
- How do these changes relate to topography and connectivity with the Pacific, Atlantic and Southern Oceans?
- What impact does this have on biological productivity, carbon cycling and fisheries?

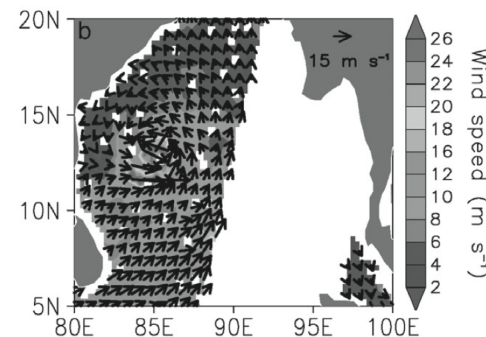
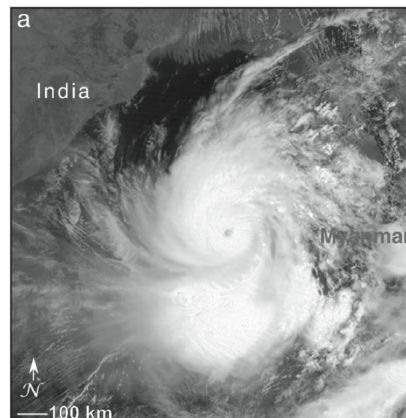
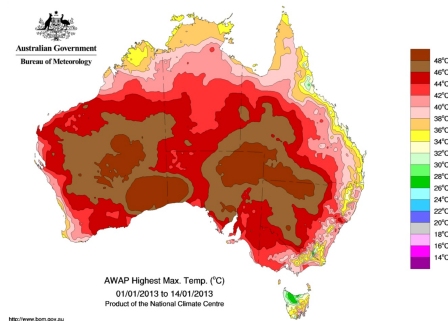


Scientific Themes

Theme 5: Extreme events and their impacts on ecosystems and human populations

Core questions:

- How will climate change impact the frequency and/or severity of extreme weather events, tropical cyclones and tsunamis in the Indian Ocean?
- How do extreme events in the Indian Ocean impact coastal and open ocean ecosystems?
- What are the threats of extreme weather events, volcanic eruptions, tsunamis, combined with sea level rise, to human populations in low-lying coastal zones and small island nations of the Indian Ocean region?

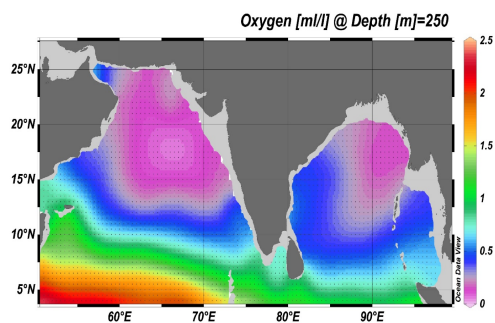


Scientific Themes

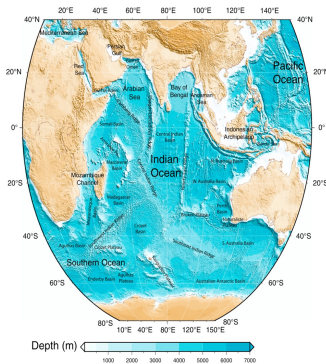
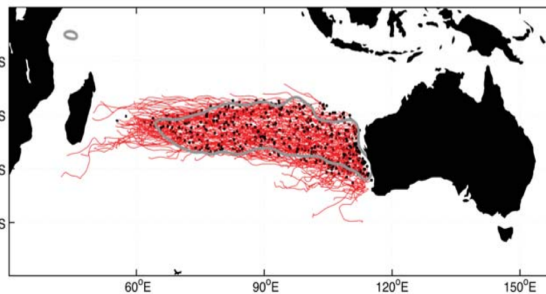
Theme 6: Unique geological, physical, biogeochemical and ecological features of the Indian Ocean (related to our themes 3 and 4)

Core questions:

- What processes control the present, past, and future carbon and oxygen dynamics of the Indian Ocean and how do they impact biogeochemical cycles and ecosystem dynamics?
- How do the physical characteristics of the southern Indian Ocean gyre system influence the biogeochemistry and ecology of the Indian Ocean?
- How do the complex tectonic and geologic processes, and topography of the Indian Ocean influence circulation, mixing and chemistry and therefore also biogeochemical and ecological processes?



a) Trajectories of Anticyclones



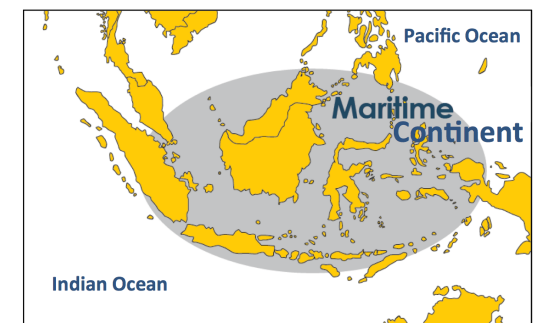
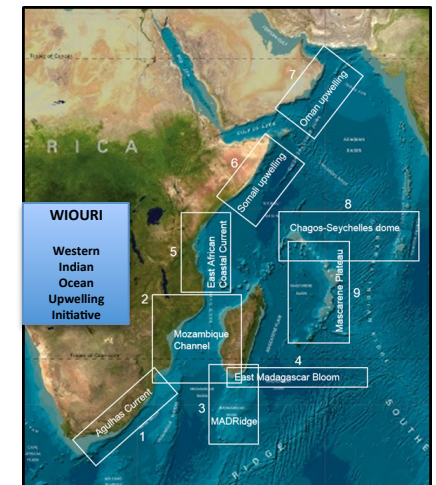
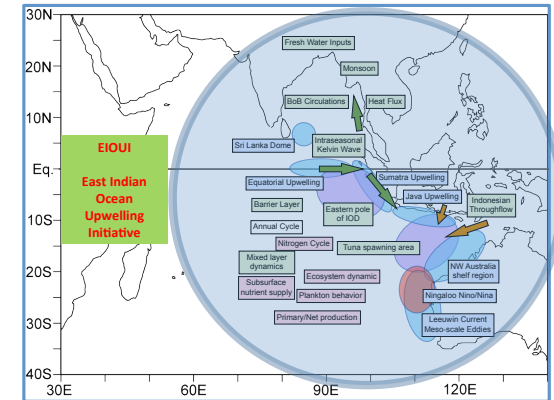
IIOE-2 Research Initiatives

The Eastern Indian Ocean Upwelling Research Initiative:

Planning for an Eastern Indian Ocean Upwelling Research Initiative (EIOURI) is complete and it happening now. The main foci of this initiative is on the upwelling regions that develop seasonally off Java, Sumatra, and northwestern Australia.

The Western Indian Ocean Upwelling Research Initiative: In addition to EIOURI, planning efforts are underway to develop a complementary upwelling research initiative on the western side of the basin: A Western Indian Ocean Upwelling Research Initiative (WIOURI).

The Year of the Maritime Continent: In addition to these research initiatives, the IIOE-2 is coinciding with and embracing the Year of the Maritime Continent (YMC) as a major IIOE-2 field champagne in 2017-2018. This is spinning up now.



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The IIOE-2 Implementation Strategy:

- **Commissioned by IOC.**
- In June/July 2014 the IOC decided to establish (through Resolution EC-XLVII.1) the IOC IIOE-2 Interim Planning Committee (IPC).
- The IPC was tasked to propose to the IIOE-2 sponsoring organizations (IOC, SCOR and IOGOOS) the establishment of committees to oversee the planning and implementation of IIOE-2.
- The IOC Executive Secretary coordinated the establishment of the IPC (through a call via IOC Circular Letter No. 2541, in September 2014).
- The IPC met four times by teleconference and twice in person in 2015 to undertake these assigned tasks.
- **The strategy was finalized and published for Goa Symposium in November, 2015.**

Available at:

<http://www.iioe-2.incois.gov.in/IIOE-2/Reports.jsp>

Or just google “IIOE-2” and go to reports

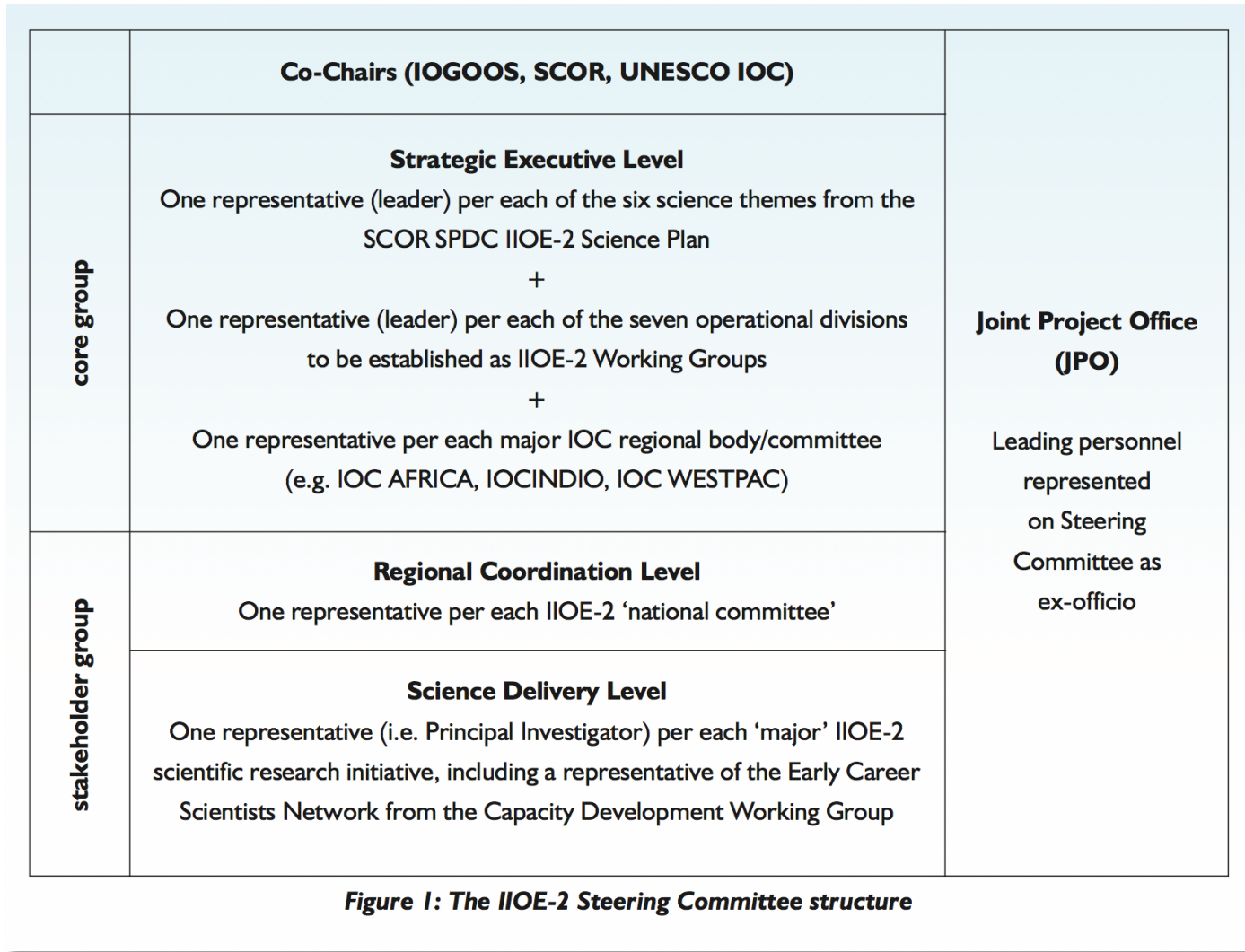


IMPLEMENTATION STRATEGY
FOR THE
SECOND INTERNATIONAL
INDIAN OCEAN EXPEDITION
2015-20

4 December 2015



Governance Structure:



IIOE-2 Steering Committee

IIOE-2 SC members & focal points

SC Co-Chairs

Vladimir Ryabinin France / UNESCO IOC
 Peter Burkill UK / SCOR
 Satheesh Shenoi India / IOGOOS

SC Strategic Executive Level

Ben Milligan UK
 P N Vinayachandran India
 Yukio Masumoto Japan
 Adrian Matthews UK
 Joaquim Goes USA
 Jerome Vialard France
 Amit Tandon USA
 Charitha Pattiaratchi Australia
 Jerome Dymnt France
 Hermann Bange Germany
 Cynthia Chandler USA
 Harrison Ong'anda Kenya
 Nasser Zaker Iran
 Zainal Arifin Indonesia
 Shailesh Nayak India
 Faiza Al-Yamani Kuwait
 Rezah Badal Mauritius
 M Atmanand India
 Somkiat Khokiattiwong Thailand
 Kentaro Ando Japan
 Johnson Kazungu Kenya

SC Regional Coordination Level

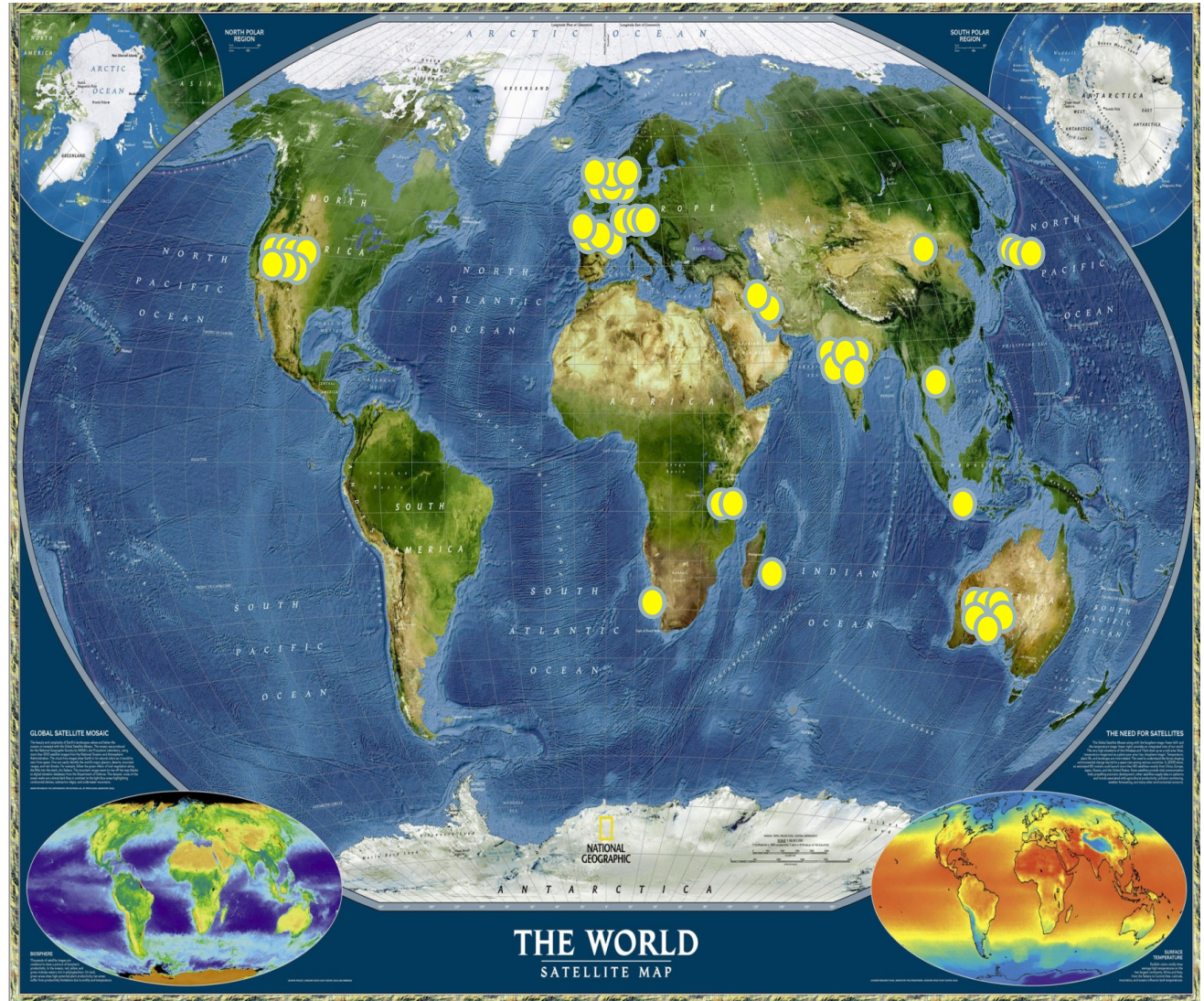
Shailesh Nayak India
 Ashley Johnson South Africa
 Raleigh Hood USA
 Lynnath Beckley Australia
 Hermann Bange Germany
 Greg Cowie UK

SC Science Delivery Level

Danielle Su Australia
 Weidong Yu China
 Yukio Masumoto Japan
 Mike Roberts UK
 Raleigh Hood USA
 Jerome Vialard France
 Lisa Beal USA
 Charitha Pattiaratchi Australia
 Boris Kelly-Gerrey Australia
 Hermann Bange Germany
 Greg Cowie UK

IIOE-2 Joint Project Office

Rajan Sivaramkrishnan India Node
 Nick D'Adamo Australia Node



There are 52 people involved in the governance structure from many countries. 18

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Summary of National IIOE-2 Efforts:

- **India:** IIOE-2 National Organizing Committee formed and active, hosting JPO in Hyderabad / INCOIS, hosting website, multiple cruises undertaken and planned 2016 and beyond including GEOTRACES (Shenoi, Rajan, Singh, Prakash et al.)
- **Japan:** Hosted and convened first EIOURI workshop, co-leading EIOURI, research cruises undertaken and planned (Masumoto, Honda, JAMSTEC)
- **Germany:** IIOE-2 Organizational Meeting Convened, National Committee formed and active, science plan published, multiple cruises planned (Visbeck, Bange, Gaye, et al.)
- **Indonesia:** Delegation sent to the USA with strong emphasis on IIOE-2, LIPI ship support committed to the effort, hosting 2nd IIOE-2 SC meeting, leading IIOE-2 capacity development efforts, hosting 2nd IIOE-2 SC meeting (Arifin, Susanto, et al.)
- **China:** Hosted and Convened RG-2 meeting, and leading EIOURI effort, research cruises undertaken and planned (Weidong Yu, SOA)
- **Australia:** IOC Perth Office hosting JPO secretariate (D'Adamo), National Committee formed and active, science priorities developed and published, 110E repeat line proposal funded (Beckley), EIOURI cruise funded (Wijffels), strong backing from UWA/IOMRC, hosted first IIOE-2 SC meeting and symposium
- **Mauritius:** Hosted and Convened RG-3 meeting with strong SWIO representation including South Africa (Badal, Roberts, D'Adamo)
- **USA:** OSB/NAS informed and updated, US National Committee formed and active, science plan development workshop funded (September 11-13, 2017 at SIO), *RV Ron Brown* cruise confirmed for early 2018, leading YMC activities
- **UK:** IIOE-2 Organizational meeting convened and proto-national committee formed, proposals submitted and funded, Joint UK and South Africa Agulhas Bank study on *RV Discovery* planned (Burkill, Cowie, Roberts, et al.)
- **Thailand:** Hosted EIOURI science plan writing workshop and fully engaged in IIOE-2 through SIBER (Khokiattiwong, Yu, et al.)
- **South Africa:** WIOURI under development, strong engagement by Dept. of Environmental Affairs, Agulhas II ship time allocated, Huggett appointed SA IIOE-2 lead (Beal, Huggett, Roberts et al.).
- **Kenya and other eastern African countries:** Engaged through IOC, expressed strong desire to participate, promotion video developed, hope to motivate capacity development and equip/deploy a new research vessel (M. Odido and IOC Africa)
- **Saudi Arabia:** Initiated discussions to develop a Red Sea Research Initiative (RSRI) under IIOE-2, glider missions through Bab-el-Mandeb also discussed (Jones, Hood et al.)
- **Pakistan:** Engaged through IOC and have expressed strong desire to participate. Submissions to DSR II Special Issue on IIOE-2 planned (Kidwai et al., NIO Pakistan)
- **South Korea:** Engaged through NOAA, especially related to supporting RAMA / IndOOS, science planning workshop to set South Korean science priorities for participating in IIOE-2 will be convened in November, 2017 (McPhaden, Hood, Wiggert, and South Korean counterparts)
- **Russia:** Engaged through IOC, geophysical and repeat hydrographic surveys planned
- **Iran:** Engaged through IOC, planning research in the northern Arabian Sea with new vessel
- **France:** Engaged through IOC and IORP, cruises ongoing and planned in the northwestern Indian Ocean and in the southern hemisphere
- **Norway:** Cruises undertaken and planned, EAF-Nansen, Mauritius Workshop, 21-13 Aug 2017, Negotiations with FAO and Norway research leaders for EAF-Nansen / IIOE-2 linkages and collaboration are underway (T. Stromme, N. D'Adamo)

**All planning outputs, current and prospective activity details available at
the IIOE-2 dedicated website**

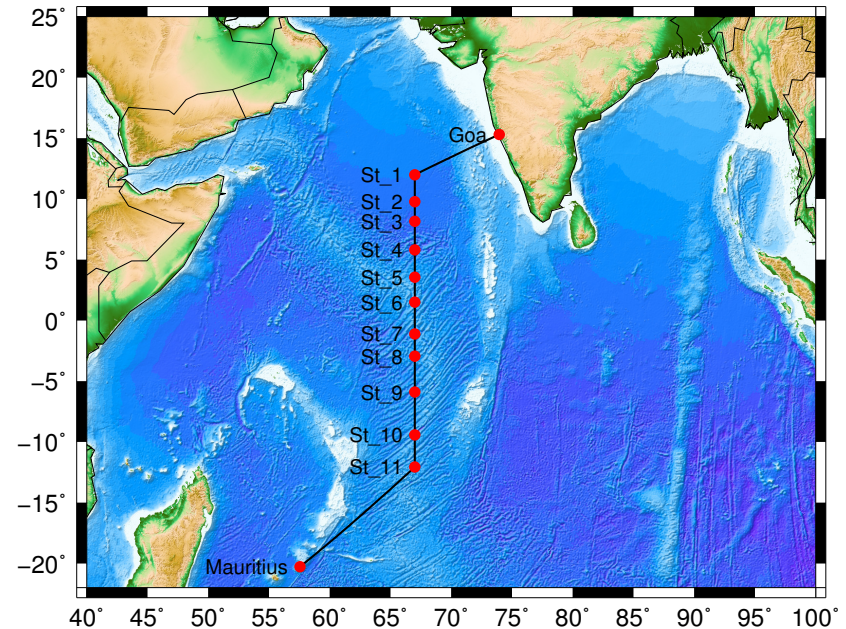
www.iioe-2.incois.gov.in

The screenshot shows a web browser window displaying the IIOE-2 website. The browser's address bar shows the URL <http://www.iioe-2.incois.gov.in/>. The website header includes the text "Principal Enquiries: JPO Perth Office" and a "Contact Us" link. The main content area features the "2nd International Indian Ocean Expedition 2015-2020" logo, along with logos for IO-GOOS, United Nations Educational, Scientific and Cultural Organization, Intergovernmental Oceanographic Commission, and SCOR. A navigation menu lists: HOME, ABOUT US, GOVERNANCE, NATIONAL COMMITTEES / PLANS, COLLABORATORS, IO BUBBLE 2, REPORTS, PUBLICATIONS, and MEETINGS. The main banner image shows a research vessel at sea, with the text "IIOE-2 Cruise#1, Goa-Mauritius December 4-22, 2015" and a "Read more" link. The browser window is overlaid on a PowerPoint slide, with the slide number "41" and "SLIDE 39 OF 52" visible at the bottom.

Or just google "IIOE-2"

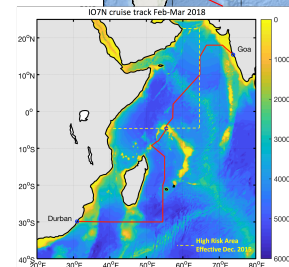
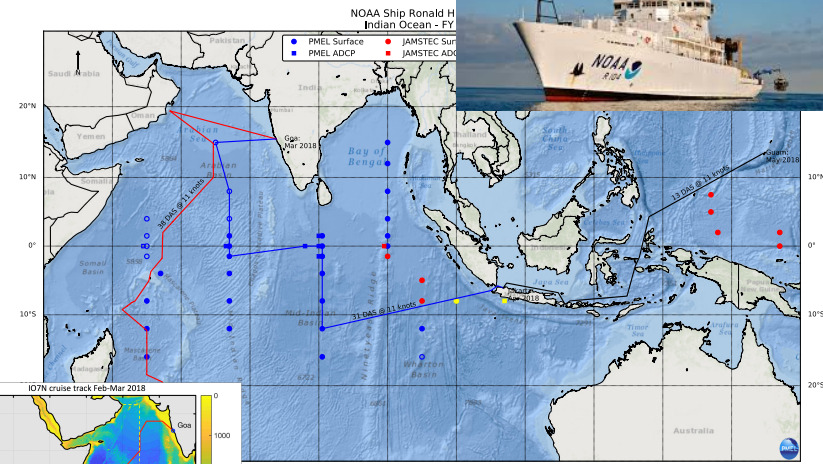
First Official Cruise of IIOE-2 Completed in 2016:

- Goa to Mauritius on the new NIO vessel RV Sagar Nidhi
- Departed December 5, 2015 following the IIOE 50th anniversary symposium in Goa
- Repeat line of IIOE
- For cruise report see: <http://www.iioe-2.incois.gov.in/IIOE-2/Reports.jsp>
- Many more Indian-Motivated cruises are happening



YMC, EIOURI and RAMA Cruises update:

- An Australian proposal to involve the R/V *Investigator* in the Years of the Maritime Continent (YMC) received good reviews (funded?). Chief scientist will be Susan Wijffels.
- The cruise will focus on waters off the west coast of Sumatra or in Timor Sea.
- The *RV Ron Brown* has been approved to work in the Indian Ocean in early 2018 to occupy GO-SHIP line (IO-7N), deploy and service RAMA mornings, and continue with work to contribute to IIOE-2 and YMC.
- *Ron Brown* cruise track finalized.
- Basin-wide South Korean Expedition planned and funded. Will support RAMA and IIOE-2.
- IIOE 110°E Repeat Line Cruise funded, a coupled bio-physical, ecosystem-scale examination of Australia's International Indian Ocean Expedition line (Lynnath Beckley et al., will bring R/V *Investigator* to the Indian Ocean in 2018 / 2019).



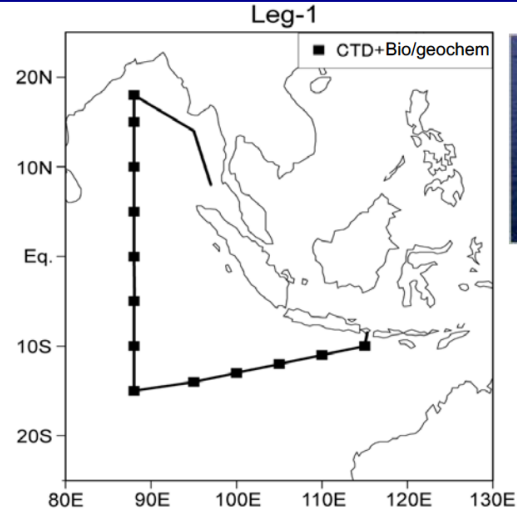
Open symbols indicate yet to be established sites.
 In FY18, Indian partners will provide ship time to establish sites between 0°-4°N, 55°E, Seychelles site at 13°S, 55°E, and Indonesia site at 18°S, 90°E.

Japan / EIOURI

Integrated eastern Indian Ocean Expedition for Physical, Biogeochemical and Ecosystem Researches (2018 Fall – 2018/19 Winter)

(Leg. 1) Bay of Bengal, 88°E section

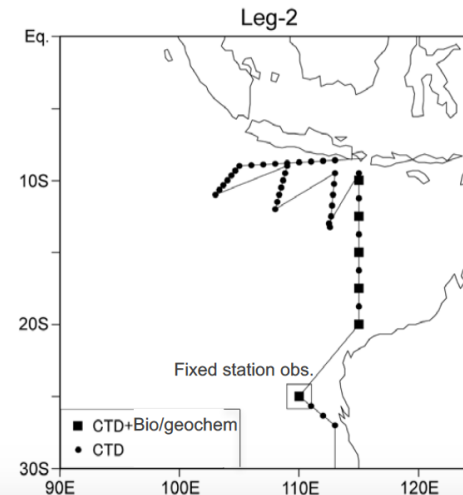
- ◎ Air-Sea interaction and Nitrogen Cycle
Monsoon, Eolian dust, Fe, N₂ fixation, de-nitrification, N₂O production
- ◎ Mapping of biogeography and biogeochemistry
Bioelements, Trace elements, phyto / zoo plankton, bacteria
- ◎ Upper-layer circulations



R/V Hakuho-maru

(Leg.2) off Sumatra / Java and NW Australia

- ◎ Upwelling and biogeochemistry
Seasonal variation and IOD upwelling
- ◎ Indonesian Through Flow and its impact on biogeochemistry
- ◎ Ningaloo Niño/Niña



Makio Honda - funded

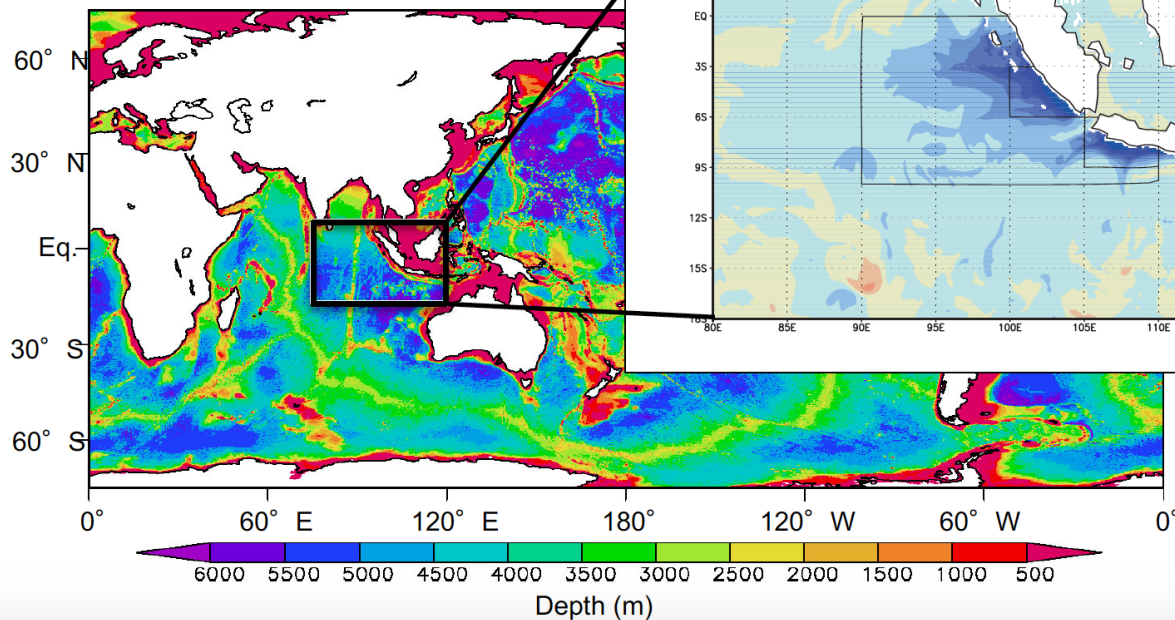
High-resolution modeling

OGCM for the Earth Simulator (OFES)

Stand-alone ocean
GCM based on MOM3

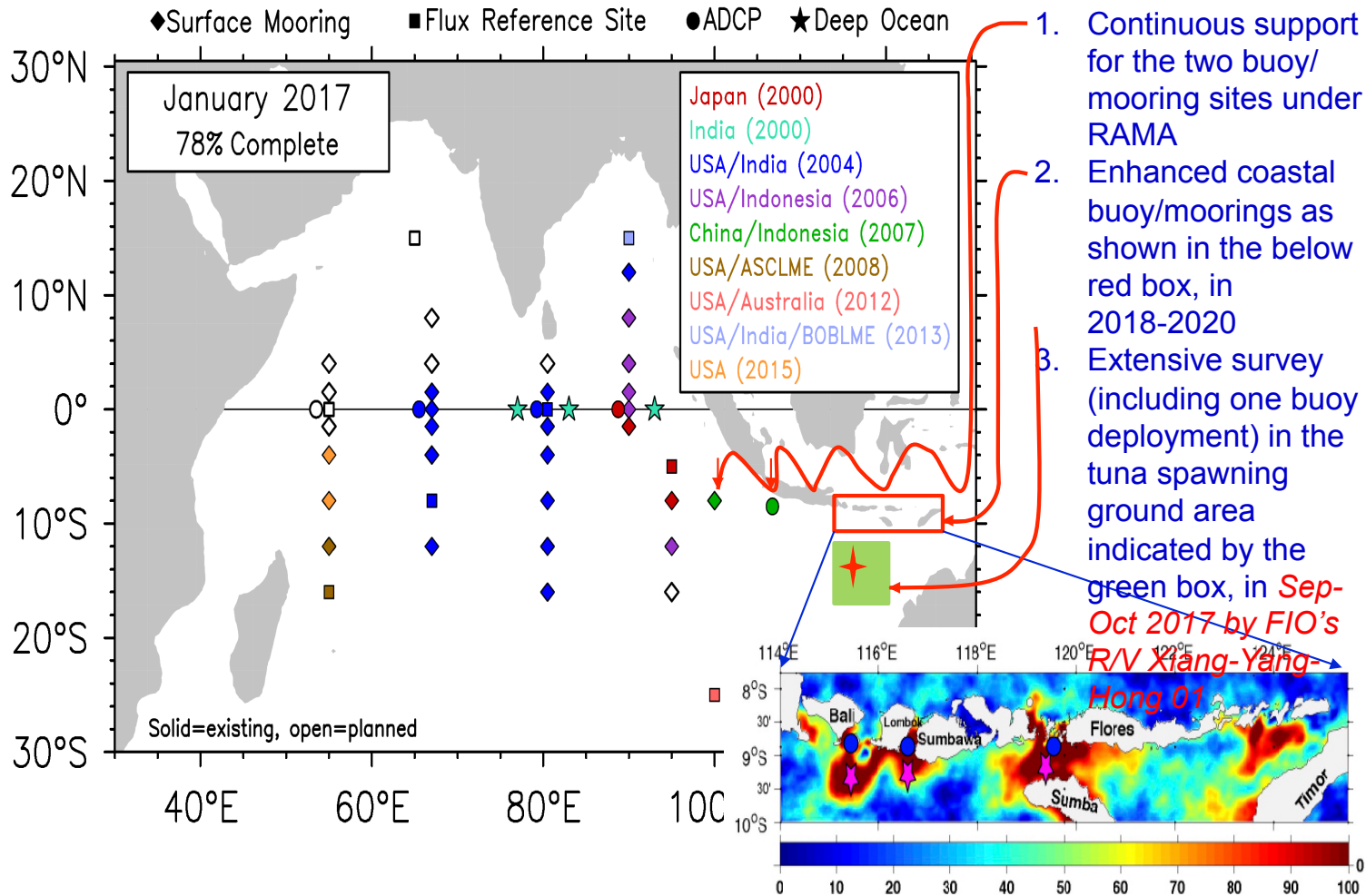
Domain
Grid spa
Vertical l
Bathyme

75° E - 75° W
Simulated SST anomaly during Sep.2006 (pIOD year)



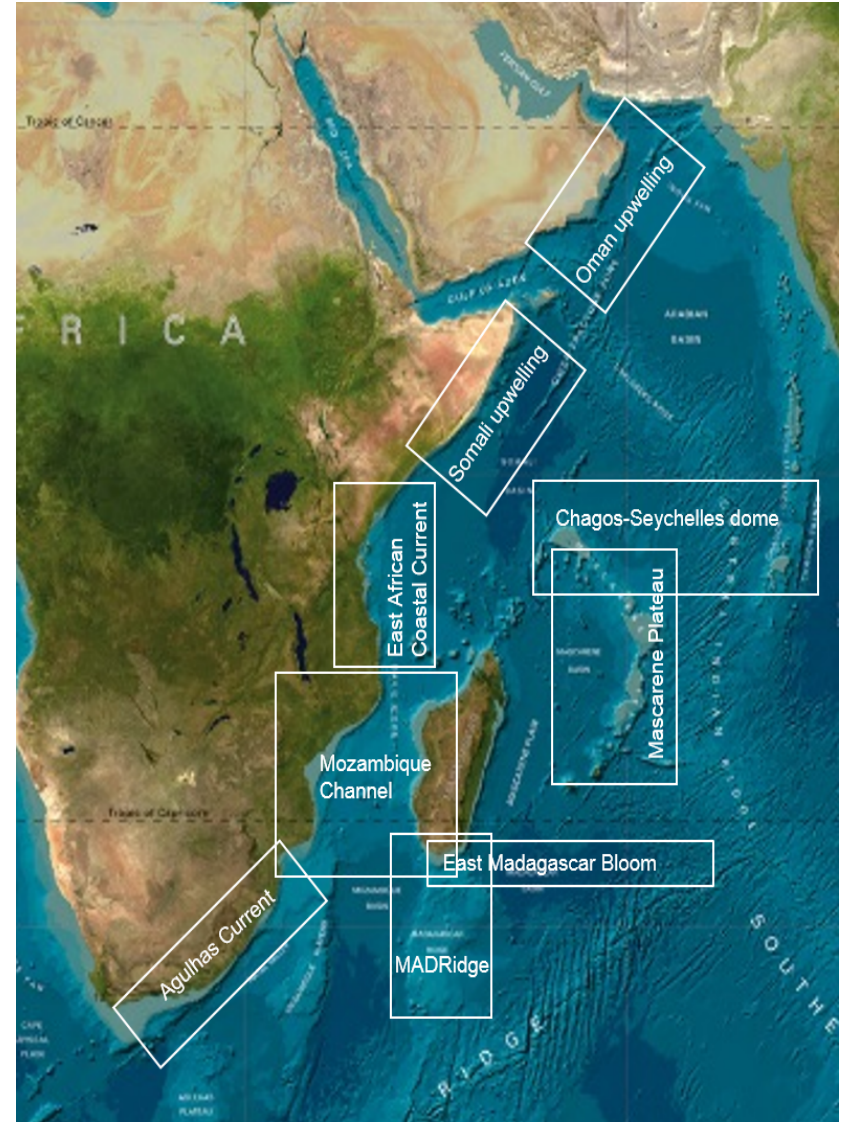
China / EIOURI

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



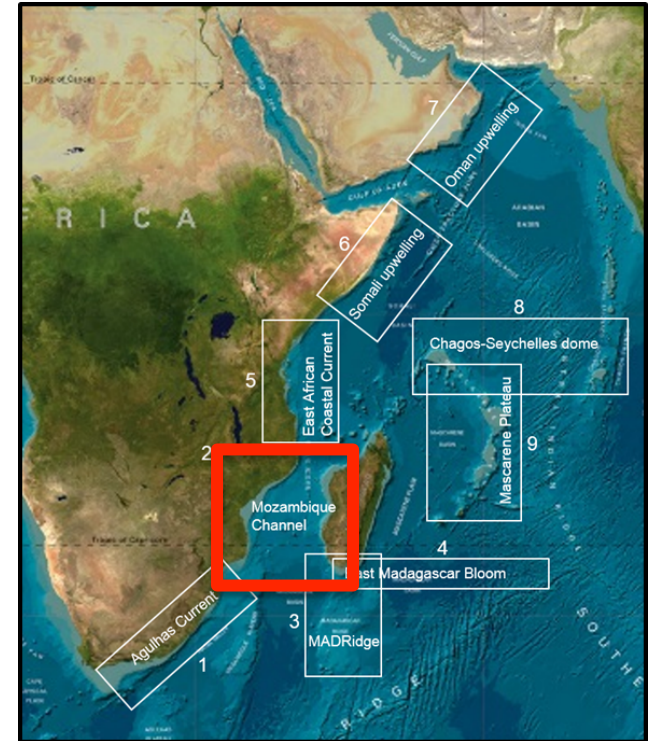
China / WIOURI

- ✓ 1. Agulhas Current driven upwelling
FIO is discussing with South Africa Depart. Environmental Affairs to jointly conduct the Agulhas current survey, with FIO's R/V Xiang-Yang-Hong 01, around Dec. 2017
- ✓ 2. Upwelling in the Mozambique Channel
FIO is discussing with SEMer on the possible collaboration on the Mozambique Channel study
3. Madagascar Ridge and seamounts
- ✓ 4. Southeast Madagascar shelf and SICC chlorophyll bloom
FIO is discussing with SEMer on the possible collaboration on Southeast Madagascar upwelling
- ✓ 5. Upwelling in the East African Coastal Current (EACC) and influence of major islands
FIO is discussing with Kenya on the coastal current study
6. Upwelling Somalia Current system
7. Oman/Arabian Sea upwelling system
8. Chagos-Seychelles upwelling dome and Chagos Ridge
9. Mascarene Plateau induced upwelling



South Africa / WIOURI

- SA Agulhas II will leave Cape Town on about 14th of October, 2017.
- She will occupy hydrographic stations on the Mozambican and Tanzanian shelf, between 25m and 2000m depth, including CTD, plankton net-tows, and benthic grab.
- ***The science focus is shelf-ocean interaction and shelf upwelling.***
- There will be bird and cetacean observations and possibly attempts at tagging larger mammals.

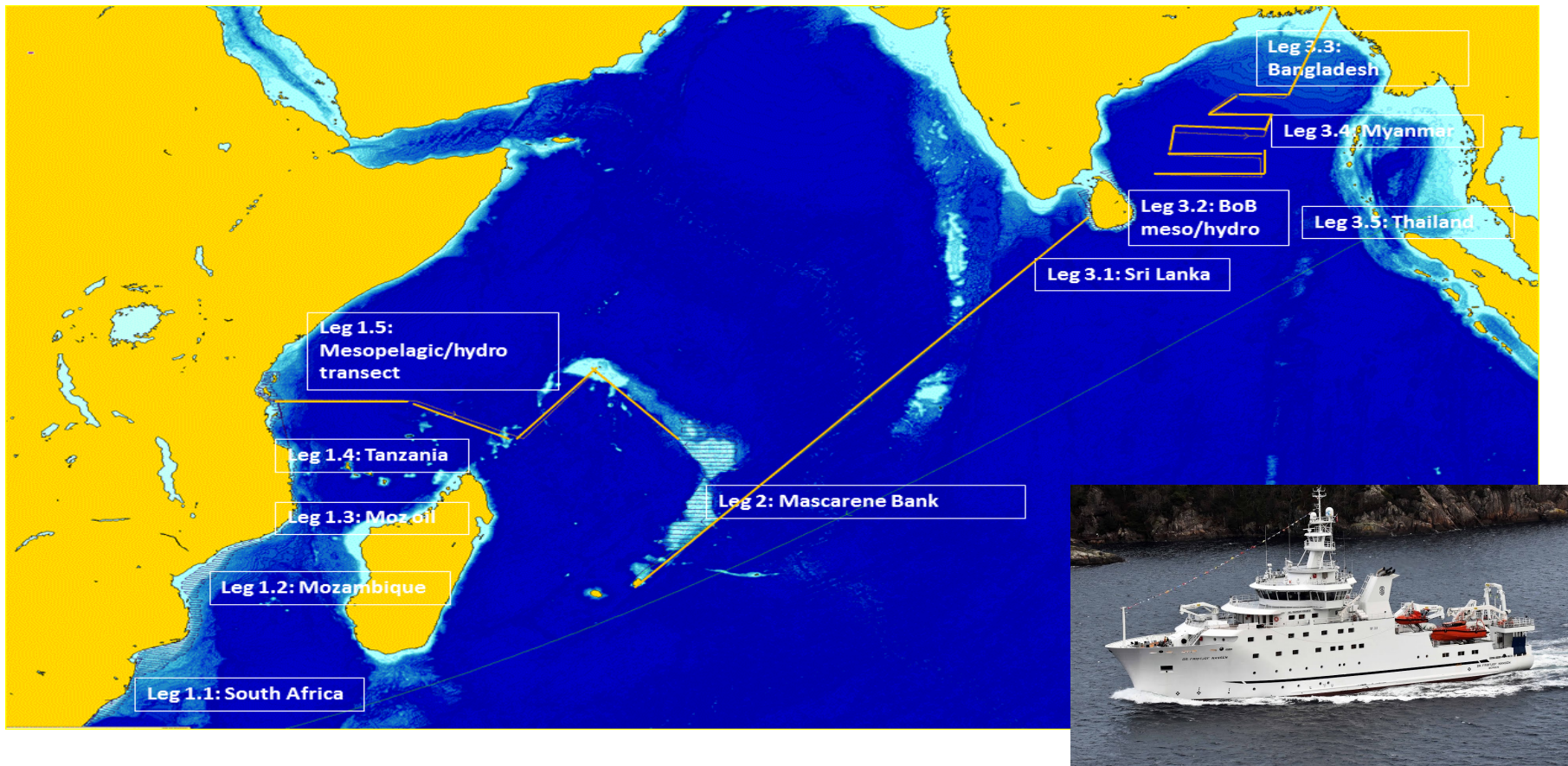


Norway

Survey programme for the RV *Dr Fridtjof Nansen* in the Indian Ocean, 2018

(EAF-Nansen, Mauritius Workshop, 21-13 Aug 2017)

Negotiations with FAO and Norway research leaders for EAF-Nansen / IIOE-2 linkages and collaboration are underway



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- **IIOE-2 Deep-Sea Research II Special Issues.**

Deep-Sea Research Special Issues on IIOE-2

- We have been invited to put together the first special issue on IIOE-2 for publication in DSR II.
- Guest editor team:
 1. Raleigh Hood (rhood@umces.edu)
 2. Jerry Wiggert
 3. Lynnath Beckley
 4. Birgit Gaye
 5. Jerome Vialard
 6. Sunil Singh
- Tentative title: “The 2nd International Indian Ocean Expedition (IIOE-2): Motivating New Exploration in a Poorly Understood Basin. Volume 1”
- Deadlines:

Submission: November 1, 2017
Acceptance: June 1, 2018
Publication: August 15, 2018
- 52 contributions already identified
- **Multiple volumes planned**
- Dedicated to Gary Meyers

Volume 54 Numbers 11–13 2007 ISSN 0967-0645

DEEP-SEA RESEARCH

PART II

Editor:
John D. Milliman

Guest Editors:
**Raleigh Hood
Jerry Wiggert
Lynnath Beckley
Birgit Gaye
Jerome Vialard
Sunil Singh**

The The 2nd International Indian Ocean Expedition (IIOE-2): Motivating New Exploration in a Poorly Understood Basin Volume 1

IIOE-2 2nd International Indian Ocean Expedition

www.elsevier.com/locate/dsr2

Indian Ocean Science Workshop

*Scripps Institution of Oceanography, San Diego,
USA, September, 11-13, 2017*



2nd International
**Indian Ocean
Expedition**

 US Steering Committee



Workshop Research Themes

Theme 1: Boundary fluxes, upwelling, ecosystem and atmospheric feedbacks (leaders: Hood, Beal, McPhaden)

Theme 2: Monsoon dynamics and impacts on biogeochemistry (Leaders: Zhang, Murtugudde, Bulusu)

Theme 3: Ventilation, oxygen and carbon variability and change (Leaders: Talley, Coles, Cutter)

Theme 4: Geological and deep-ocean biogeochemical processes (Leaders: Humphris, Dick, Lloyd)

- *We want to generate a report for each of these themes that articulate U.S.-led contributions to the 2nd International Indian Ocean Expedition.*
- *Imagine generating something that could lead to an NSF, NOAA or NASA RFP. Perhaps something as large as a multi-cruise process study over multiple years..*
- *These reports need to be “focused”. What do we want to study and how do we want to study it?*
- *Keep in mind that the funding model is based upon GEOTRACES, i.e., it is unlikely that there will be dedicated funding from the agencies. Funding will likely have to come from PI-driven proposals submitted to “core” programs.*

Three Breakout Sessions

Breakout Session 1 (Tuesday morning) objective:

Devise and prioritize potential U.S.-led projects/ regions/topics related to the research theme.



Define science questions and regional studies

Breakout Session 2 (Tuesday afternoon) objective:

Discuss technical implementation of potential new projects and associated collaborations (both disciplinary and international)



Develop implementation strategy (when, where and how)

Breakout Session 3 (Wednesday Morning) objective:

Identify funding opportunities and existing observational infrastructure that could contribute to the implementation of new projects.



Identify where to submit proposals, where needed assets are available (ships? Satellites? Moorings?)

SCIENCE THEME LEADERS (Science Plan)

| ST 1 Human impacts | ST 2 Boundary current dynamics, upwelling variability and ecosystem impacts | ST 3 Monsoon variability and ecosystem response | ST 4 Circulation, climate variability and change | ST 5 Extreme events and their impacts on ecosystems and human populations | ST 6 Unique geological, physical, biogeochemical, and ecological features of the IO |
|-----------------------|--|--|---|--|--|
| Ben Milligan | Vinayachandran & Yukio Masumoto | Adrian Matthews & Joaquim Goes | Jerome Vialard & Amit Tandon | Chari Pattiaratchi | Jérôme Dymont |

WORKING GROUP LEADERS (Implementation Strategy)

| WG 1 Science & Research | WG2 Data & Information Management | WG 3 Capacity Development | WG 4 Operational Coordination | WG5 Outreach & Communication | WG6 Translating Science for Society | WG7 Resources & Sponsorship |
|----------------------------|--------------------------------------|------------------------------|----------------------------------|---------------------------------|--|--------------------------------|
| Hermann Bange | Cynthia Chandler & Harrison Ong'Anda | Nasser Zaker & Zainal Arifin | Shailesh Nayak | Faiza Al-Yamani | Rezah Badal | JPO Perth & Hyderabad |