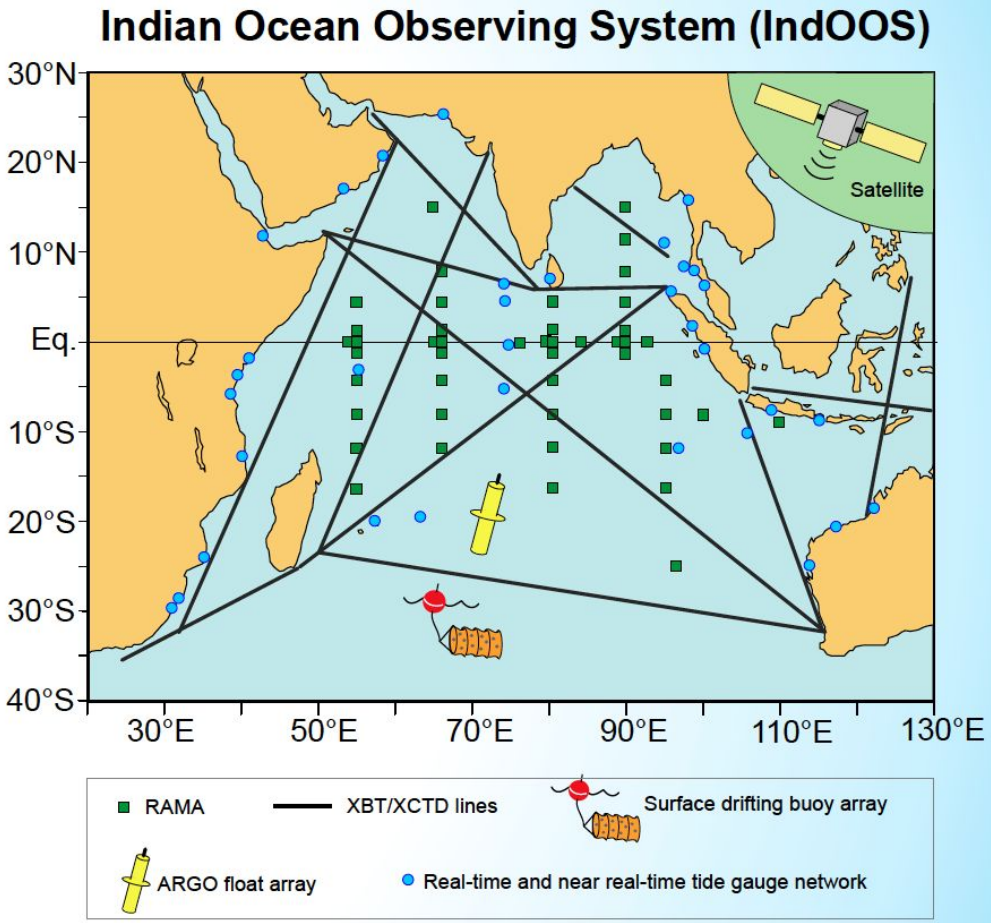
What is the Indian Ocean Observing System?

The mission of the IndOOS is to provide sustained, high-quality oceanographic and marine meteorological measurements that support knowledge-based decision-making through improved scientific understanding, and ultimately, through improved weather, ocean, and climate forecasts.

Juliet Hermes, Roxy Koll and Lisa Beal,
IORP members and IndOOS review authors

Why a review of IndOOS and roadmap to IndOOS-2?

- IndOOS design was established on the basis of an Implementation Plan drafted by the CLIVAR IORP in 2006.
- Since then, societal and scientific priorities and measurement technologies have evolved, many practicalities of implementation have been learned, and the pace of climatic and oceanic change has accelerated.
- The review findings provide a roadmap to address the clear and urgent need for expansion of the Indian Ocean observing system, designed to meet the requirements of a broad suite of users, as recognised in the GOOS 2030 Strategy.



Numbers of IndOOS-2

2000 +
EMAILS

60
AUTHORS

35
MONTHS

25
CHAPTERS

6
REVIEWERS

3
EDITORS

3
WORKSHOPS

= 

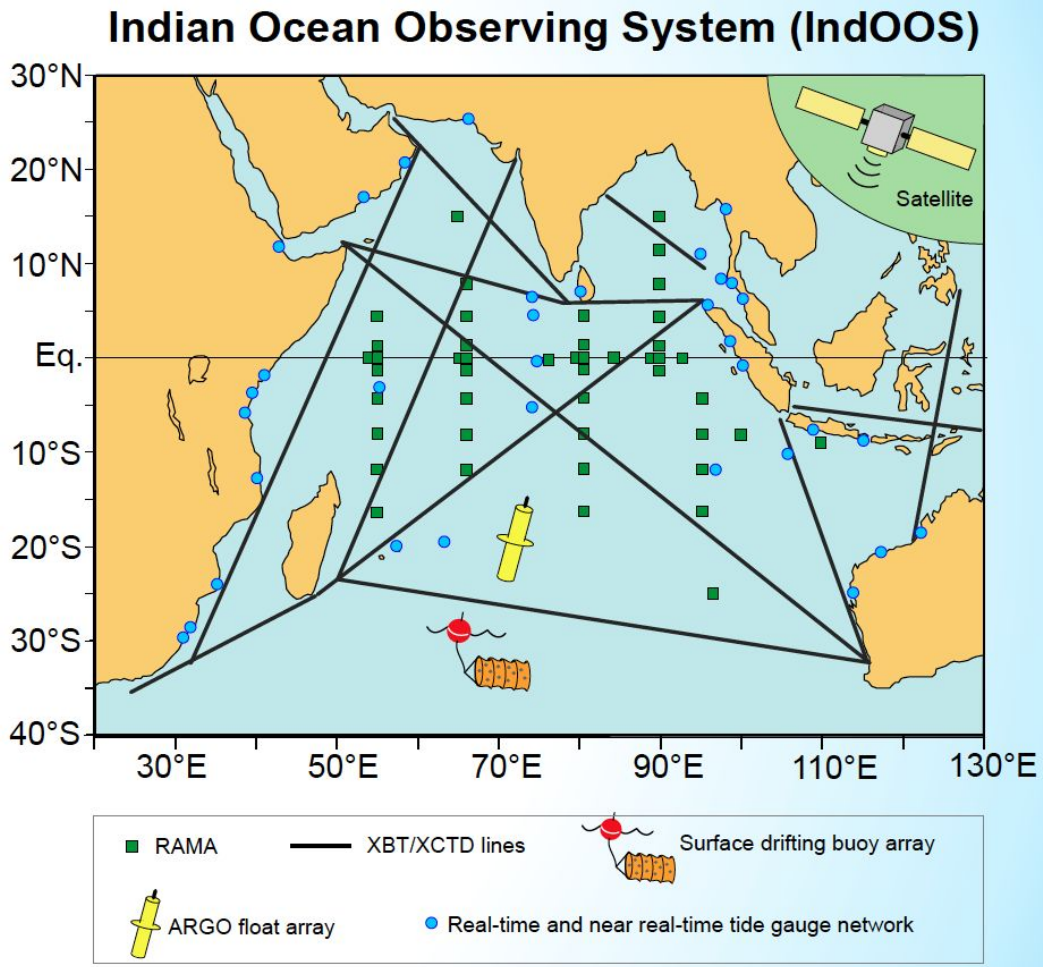
136
ACTIONABLE
RECOMMENDATIONS

GCOS • GOOS • WCRP
OOPC
IOGOOS
GLOBAL OCEAN OBSERVING SYSTEM FOR INDIAN OCEAN
United Nations Educational, Scientific and Cultural Organization
Intergovernmental Oceanographic Commission
The Global Ocean Observing System
IndOOS-2
CLIVAR
NOAA
IMBeR
WCRP World Climate Research Programme
IUGG
IAPSO International Association for the Physical Sciences of the Oceans

Review: Achievements of the IndOOS

IndOOS has provided unprecedented knowledge of weather, ocean, and climate phenomena, among them:

- Observations and forecasts of tropical cyclones and marine heatwaves
- Improved understanding of coupled convective modes (MJO and MISO) and their influence on global hydro-climate
- Mapping of the equatorial and monsoon circulations and variability of the Indonesian Throughflow
- Elucidated year-to-year climate variations in the tropical Indian Ocean (IOD) and their relationship to tropical Pacific climate variations (ENSO)



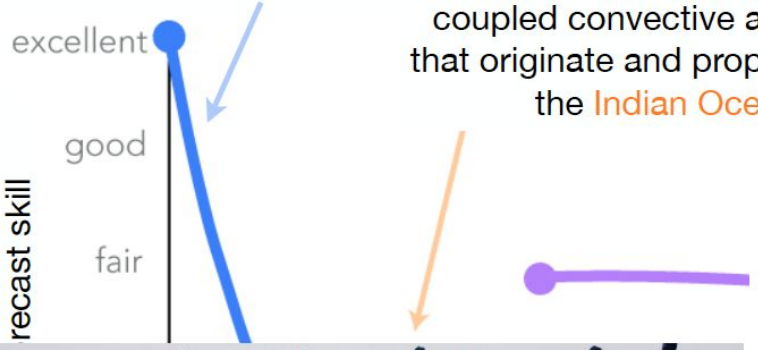
Review: Remaining gaps

- Low prediction skill of sub-seasonal to seasonal forecasts
- Large discrepancies in climatologies of heat exchange at the air-sea interface
- Lack of observations in western equatorial Indian Ocean (piracy and vandalism) and of boundary currents
- No sustained ecosystem measures

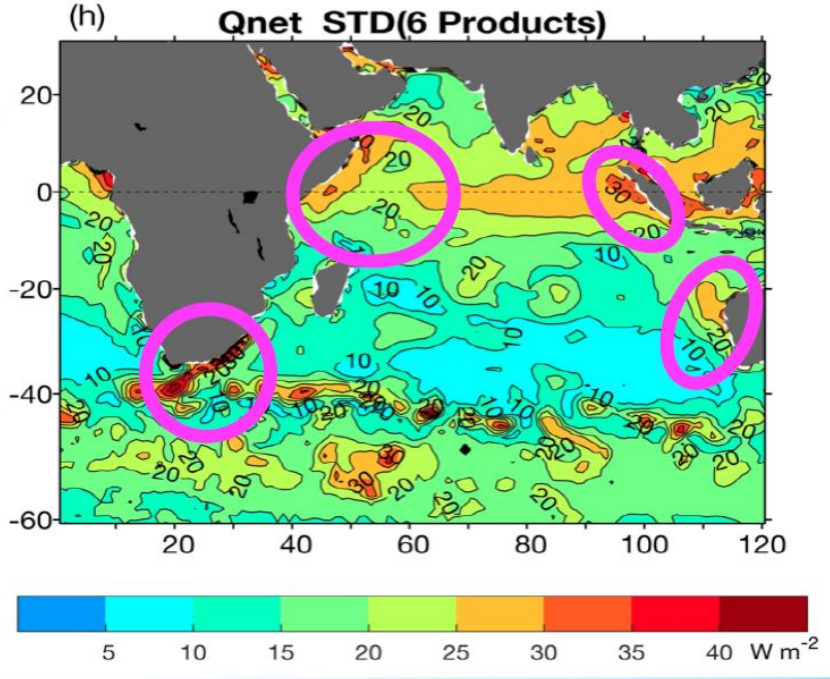
Weather forecasts
predictability from initial atmospheric and oceanic conditions

Sub-seasonal forecasts
predictability from Madden Julian Oscillation and the Monsoon Intra-seasonal Oscillation, coupled convective anomalies that originate and propagate over the Indian Ocean

Seasonal forecasts
predictability from ENSO and IOD state, modes of ocean-atmosphere interaction related to the



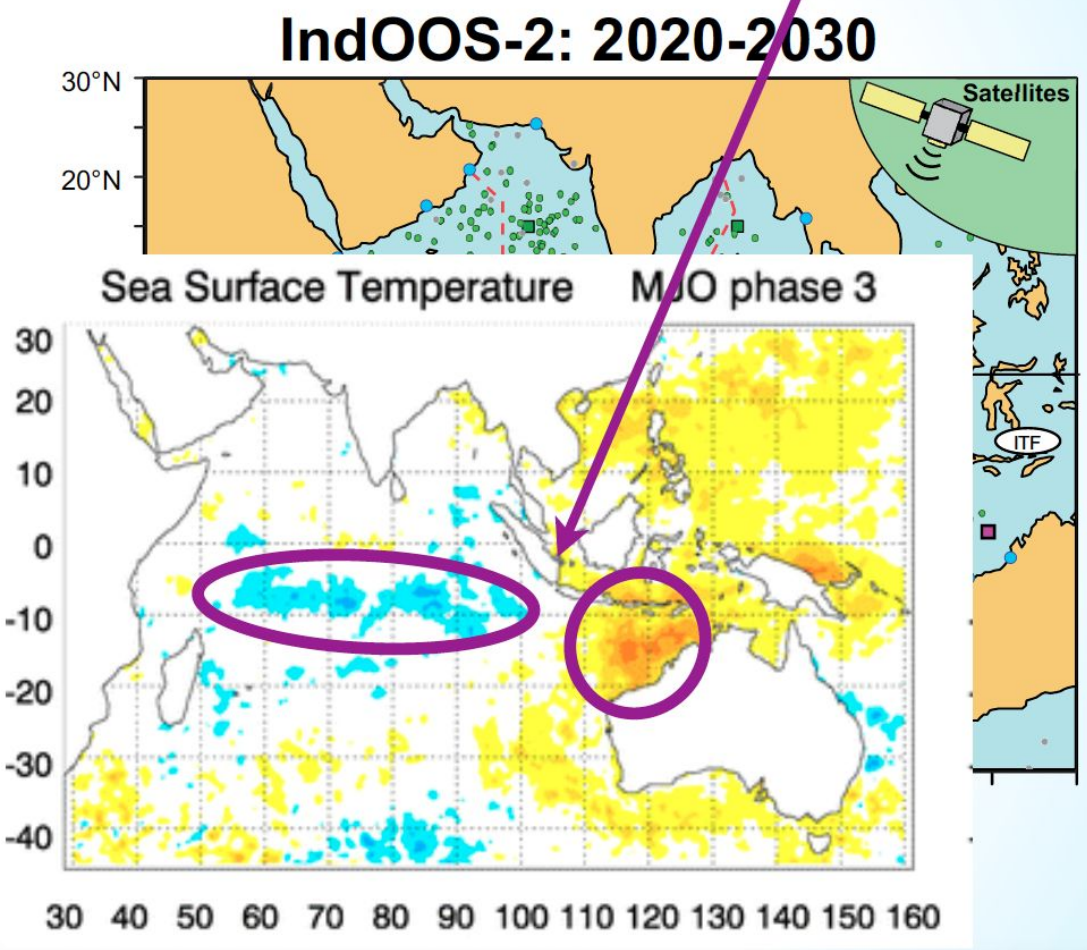
Fish mortality event in Arabian Sea



Roadmap for IndOOS-2: Core Findings

- Coverage of the **western equatorial Indian Ocean** needs to be completed.
- **Biogeochemical measurements must be collected alongside physical parameters**, initially targeted to regions of high variability and change, such as the OMZs and upwelling systems.
- **Enhanced vertical and temporal resolution of upper-ocean measurements** are needed in tropical regions strongly coupled to MJO and MISO development.

EOVs: T, S, u(z), surface stress, surface heat flux



ARGO
+ Bio-Argo
+ Deep-Argo

RAMA 2.0
Occupied
To occupy
New site
Standard
Flux ref.
ADCP

XBT lines
Enhanced

Tide gauges
+ Vertical land motion
+ more Island sites

Surface drifters
+ surface pressure

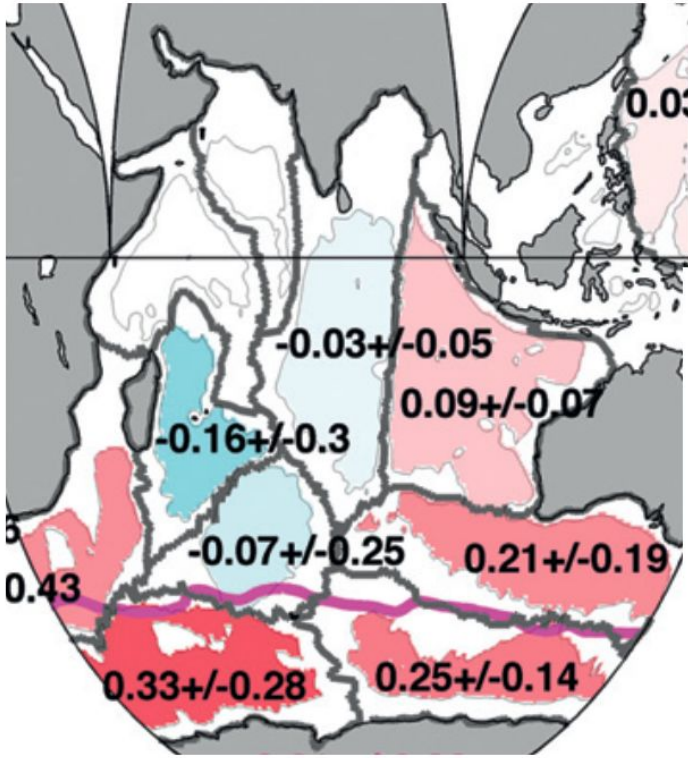
+ Boundary current array

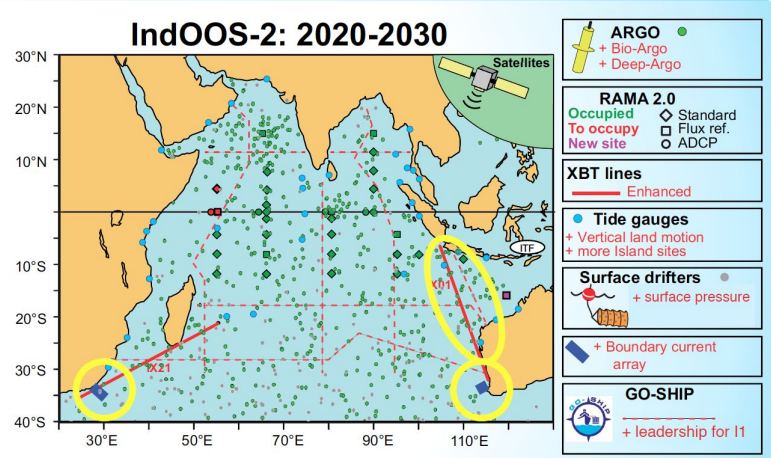
GO-SHIP
+ leadership for I1

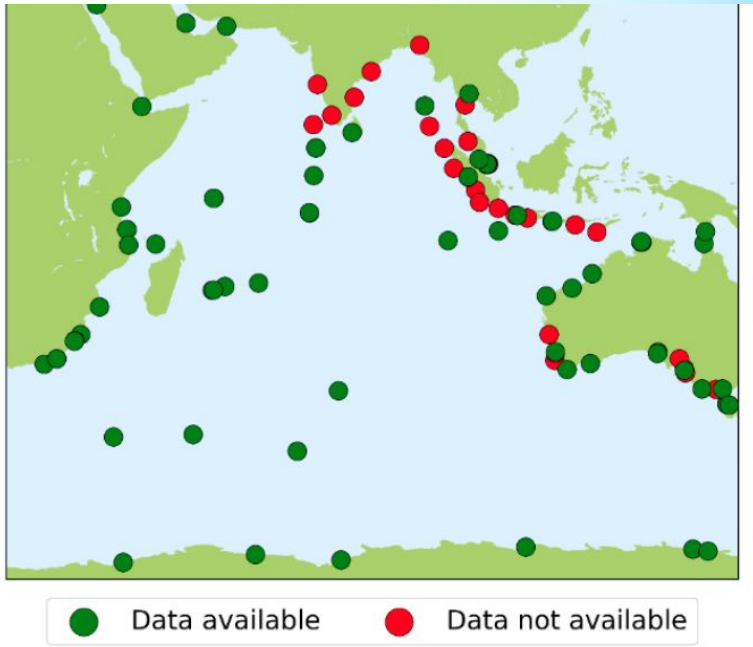
Roadmap for IndOOS-2: Core Findings

- **Boundary flux arrays** in the Agulhas and Leeuwin Currents are needed alongside an **enhancement of Indonesian Throughflow monitoring.**
- More **observations of the deep ocean below 2000 m** are needed to capture circulation, heat content, and sea level change. Initially targeted to subtropics.
- More land motion sites are needed alongside tide gauges, as well as additional island sites.

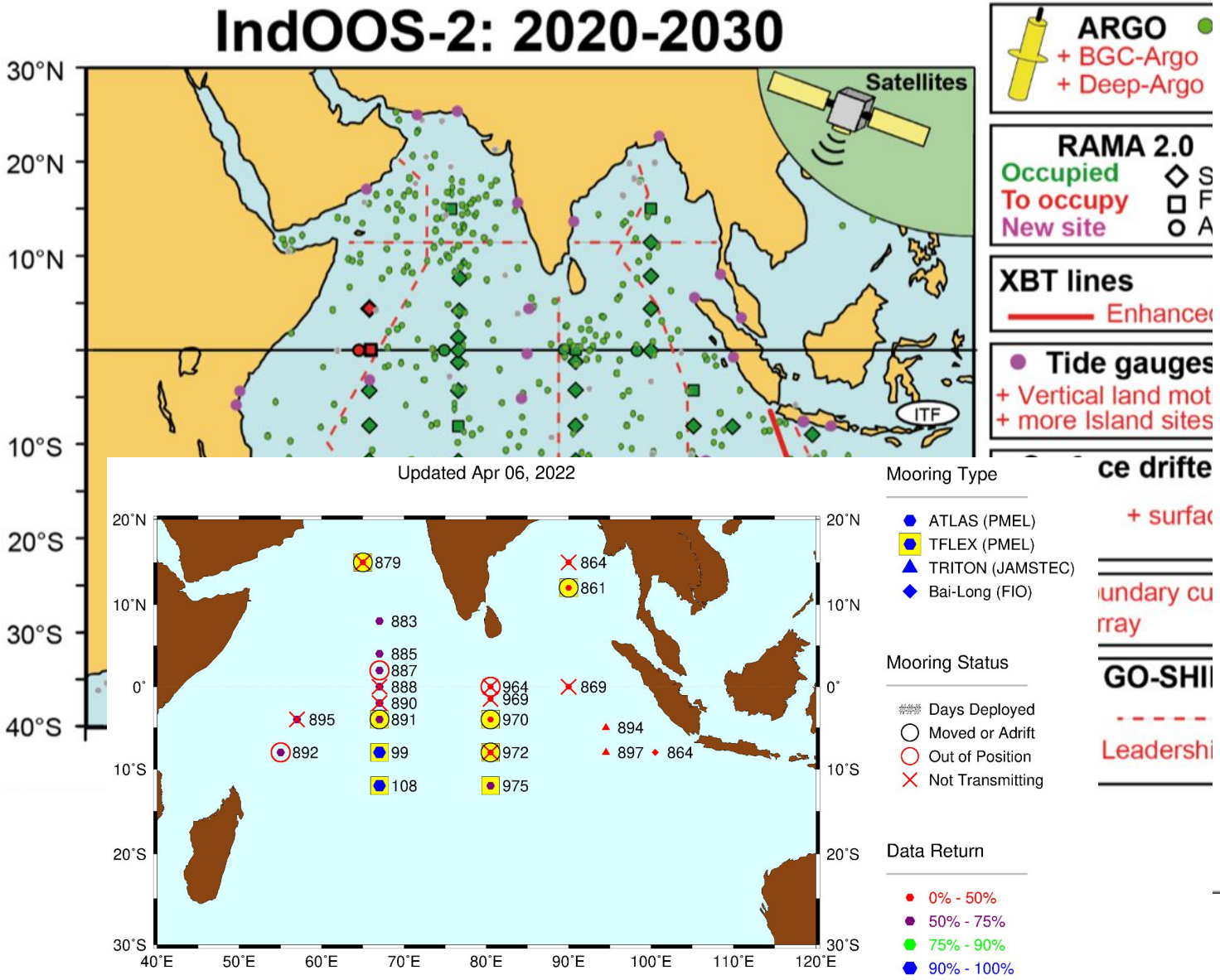
Warming below 4000 m, W/m2,
Purkey & Johnson (2010).

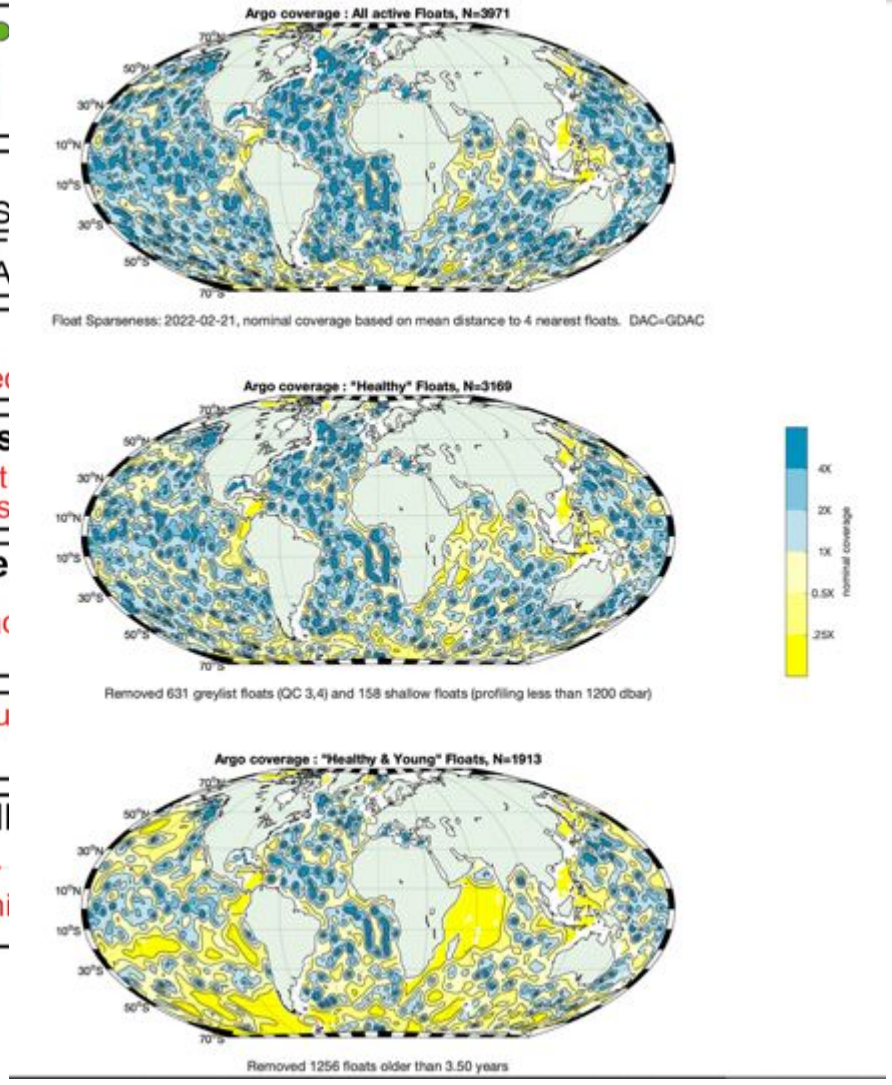






Sustained observations in the Indian Ocean

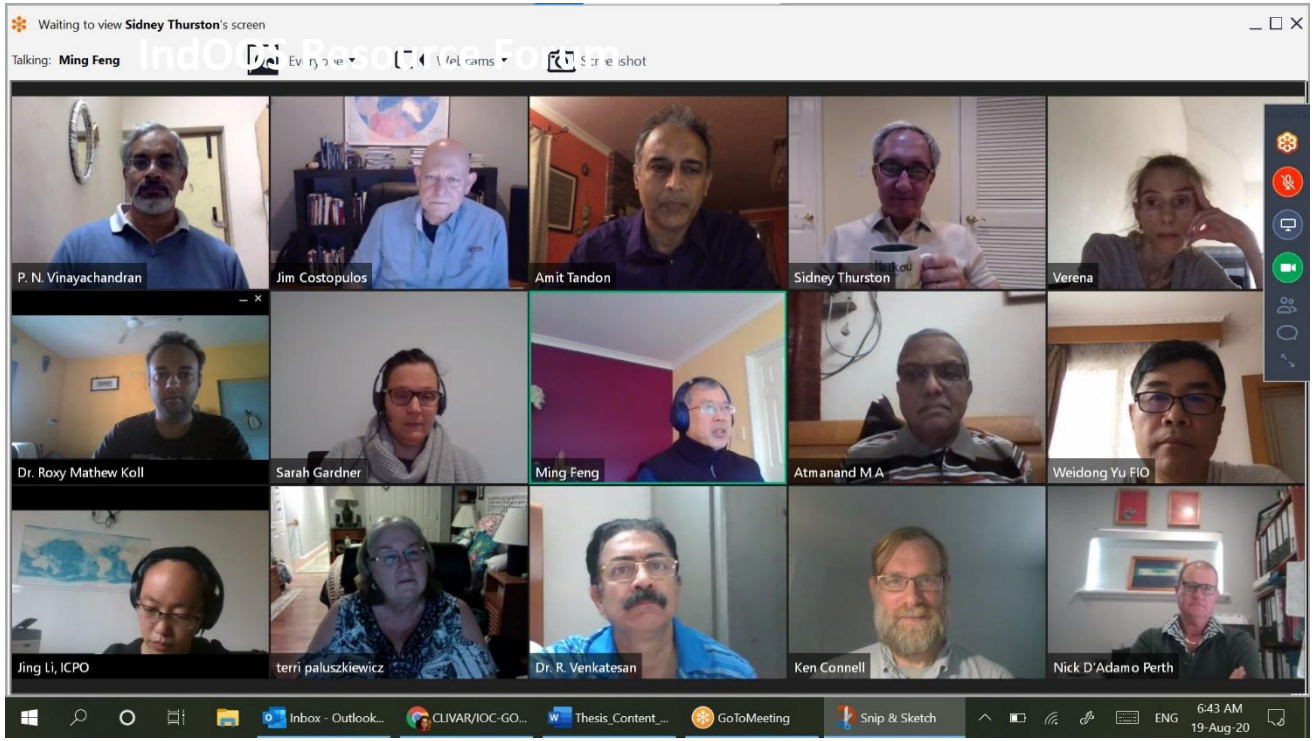




Beal et al. *BAMS* 2020; Hermes et al. *Frontiers in Marine Science*

IndOOS Resource Forum, for implementing IndOOS-2

IndOOS Resource Forum (IRF) and IIOE2 can facilitate the implementation of IndOOS-2 recommendations, and maximize the use of the existing resources



Coordination across platforms and regional basin scale programs has remained a priority of IORP and IndOOS and the IRF has helped achieve this, we continue to ensure that IORP has active regional scientist membership.

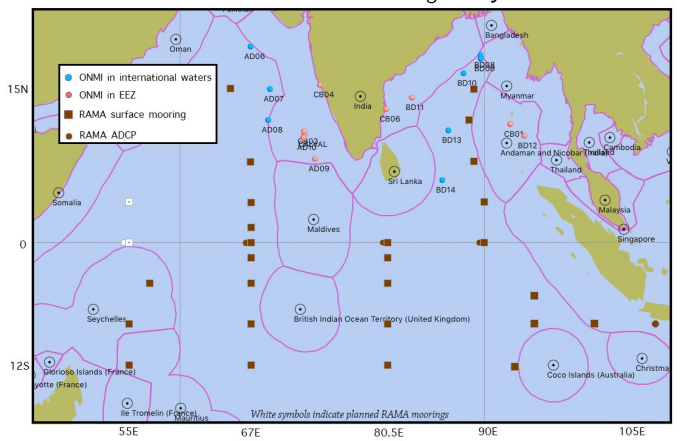
WCRP World Climate Research Programme
CLIVAR
UNESCO United Nations Educational, Scientific and Cultural Organization
Intergovernmental Oceanographic Commission
The Global Ocean Observing System GOOS

Core Findings: Beyond *in situ* Observations

- Continuous, overlapping **satellite measurements are central** to the IndOOS.
- There is urgent need for **advancements in data assemblage and coupled data assimilation** techniques
- There is a need for increased investment and **stronger partnerships with Indian Ocean rim countries and end-users,** along with improved data sharing and commitments to best practices.

INDIAN OCEAN RIM ASSOCIATION

RAMA-OMNI Mooring Array



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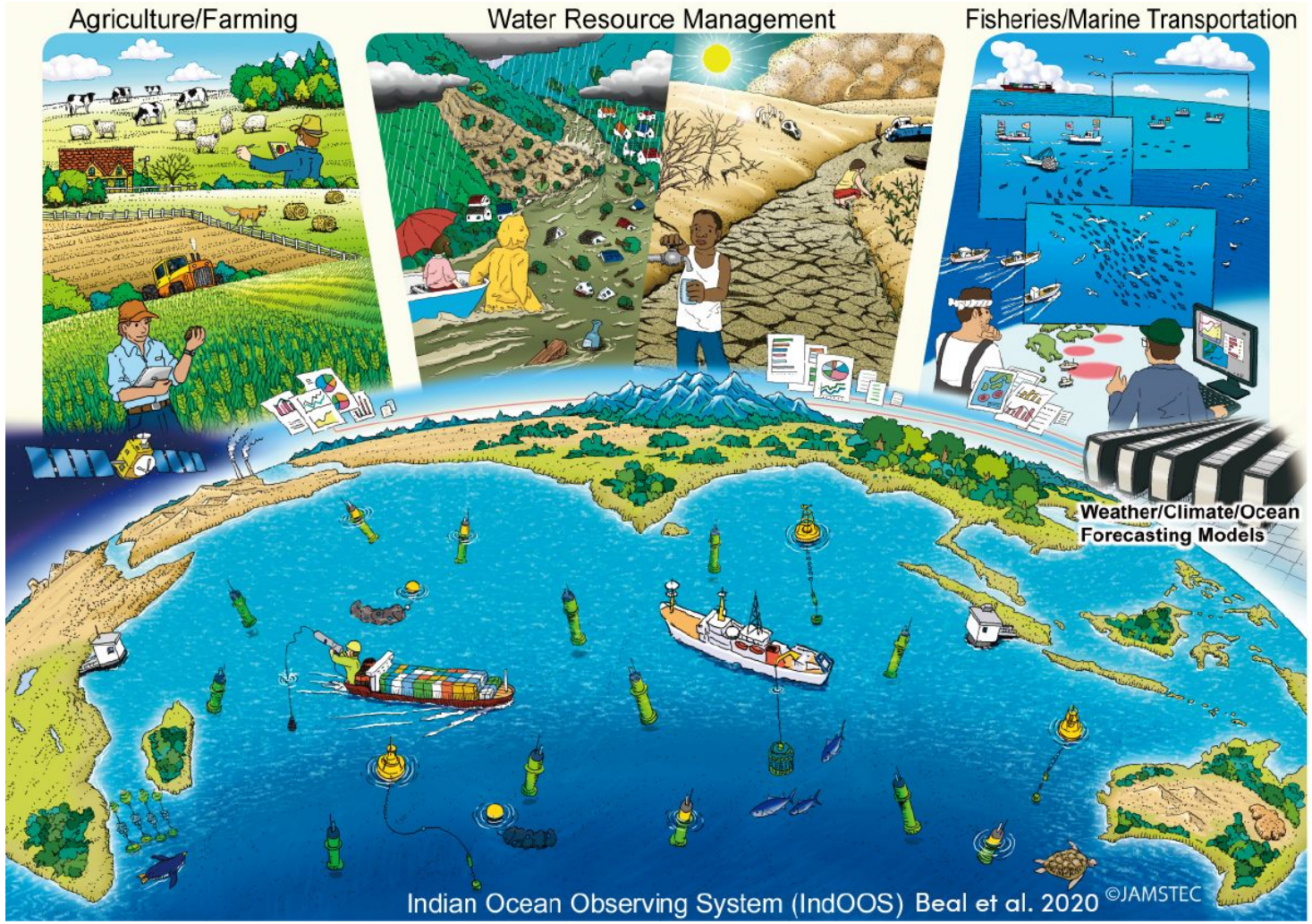
Why do we monitor and forecast these changes?

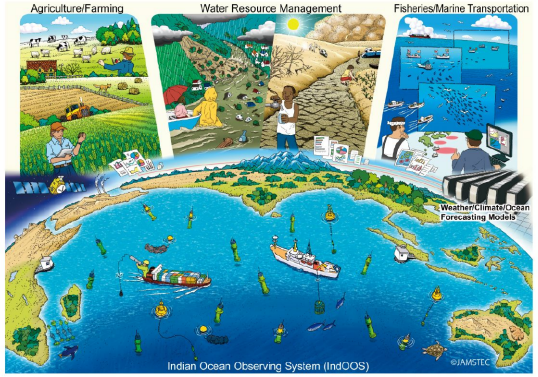


Full Report

CLIVAR GOOS

IndOOS-2

A roadmap to sustained observations of the Indian Ocean for 2020-2030



Coordinating lead authors
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December 2019

Sponsored by

WCRP IMBeR GCOS·GOOS·WCRP OOPC IOGOOS UNESCO IOC NOAA IUGG IAPSO

doi.org/10.36071/clivar.rp.4.2019

What counts in life is not the mere fact that we have lived. It is what difference we have made to the lives of others that will determine the significance of the life we lead, Mandela

Beal et al. *BAMS* 2020; Hermes et al. *Frontiers in Marine Science* 2019

Dissemination of the Impacts through Media

THE HINDU
TUESDAY, FEBRUARY 8, 2022

Marine heatwaves on the rise around India, says study

These events are linked to coral bleaching, seagrass destruction, and loss of kelp forests; they also affect fisheries sector

JACOB KOSHY
NEW DELHI

Heatwaves on the land are well known. But marine heatwaves – or the ones that form on oceans – have been on the rise in the waters around India, says a study.

Marine heatwaves are periods of extremely high temperatures in the ocean. These events are linked to coral bleaching, seagrass destruction, and loss of kelp forests, af
ies sector
derwater s

85% of the corals in the Gulf of Mannar near the Tamil Nadu coast got bleached after the marine heatwave in May 2020. Emerging studies have reported their occurrence and impacts in the global oceans, but are little understood in the tropical Indian Ocean. The study appears in the journal *JGR Oceans*.

The Western Indian Ocean region experienced the largest increase in marine heat-

Hot topic: 85% of the corals in the Gulf of Mannar got bleached after the marine heatwave in May 2020.

a rate of 0.5 events per de-
tes.

Bay of Bengal had 94 events,

ne heatwaves in
n Indian Ocean

and the Bay of Bengal increased drying conditions over the central Indian subcontinent. Correspondingly, there is a significant increase in the rainfall over south peninsular India in response to the heatwaves in the north Bay of Bengal.

" This is the first time that a study has demonstrated a close link between marine heatwaves and atmospheric circulation and rainfall," the authors note.

"Climate model projections suggest further warming of the Indian Ocean in the future, which will very likely intensify the marine heatwaves and their impact on the monsoon rainfall," Roxy Mathew Koll, among the authors of the study and a scientist at the Indian Institute of Tropical Meteorology, Pune, said in a statement.

Dr. Koll conducted the research in collaboration with – Saranya J.S. (Kerala Agriculture University), Panini Dasgupta (IITM), and Ajay Anand (Cochin University of Science and Technology).

Heatwaves in IOR may be affecting monsoon: Study

Vaishnavi Chandrashekhar | TNN

Indian Institute of Tropical Meteorology's study found that marine heatwaves caused less rain in central India and more in the south

Mumbai: Marine heatwaves in the Indian Ocean have risen in frequency and size since the 1980s, with the largest increases seen in the western Indian Ocean and the Bay of Bengal, as per a new study.

The trend has implications not only for the region's fisheries but also, potentially, the monsoon —the study found marine heatwaves reduced rainfall over central India and increased rain over the southern peninsula.

The rise is due to rising ocean temperatures and El Nino events, as well as local factors, the study said, and is in line with global trends.

The western Indian Ocean saw a four-fold increase in heatwaves between 1982 and 2018 for a total of 66 events, the study found.

ne heatwaves only recently.

Indian Ocean heatwaves are among the least understood despite the ocean being among the fastest warming in the world, says Roxy Mathew Koll of the Indian Institute of Tropical Meteorology in Pune who led the study. Surface temperature in these waters rose by 1°C on average from 1951-2015, compared to the global average of 0.7°C.

both regions led to less rain over central India, while heatwaves in the northern Bay of Bengal appeared to drive more rain to south India.

How can a heatwave in the ocean control rainfall in the sky? "The distribution of heat can influence the course of winds," explains Koll. Strong heating over the western Indian Ocean, for instance, can cause winds to converge to-

तापमानवाढीचा भारतीय मॉन्सूनवर परिणाम

हिंदी महासागरात वाढलेल्या उष्णतेच्या लाटांचा प्रभाव; 'आयआयटीएम'चा निष्कर्ष

पुणे, ता. ५ : लांबलेला पाऊस, काही ठिकाणी पावसाची कमतरता, तर काही भागात धुवाधार पावसाच्या सरी. सातत्याने होत असलेले हवामान बदल, त्यात पावसाचे चक्रदेखील बदलले आहे. हिंदी महासागरात उष्णतेच्या लाटांचे (मराईन हिटव्हेव) वाढत असलेले प्रमाण व सागरी तापमानवाढ याचा प्रभाव भारतीय मॉन्सूनवर प्रामुख्याने होत असल्याची बाब नुकतीच एका अभ्यासातून समोर आली आहे. पुण्यातील भारतीय उष्णकटिबंधीय हवामानशास्त्र संस्थेच्या (आयआयटीएम) वतीने हा अभ्यास करण्यात आला आहे.

हवामान बदल, मॉन्सूनचे बदलते स्वरूप, यामुळे होणारा परिणाम यामागे नेमकी कोणती कारणे आहेत, याचे संशोधन केले आहे. या संशोधनाची माहिती नुकतीच 'जेजीआर ओशन्स जर्नल'मध्ये प्रकाशित झाली आहे. या अभ्यासात 'आयआयटीएम'चे शास्त्रज्ञ रॉक्सी मॅथ्यू कोल यांच्यासह पाणिनी दासगुप्ता, केरळ कृषी विद्यापीठाच्या सरन्या जे. एस. आणि कोची विज्ञान व तंत्रज्ञान विद्यापीठाचे अजय आनंद या शास्त्रज्ञांनी सहभाग घेतला होता. यामध्ये सागरी उष्णता घटनांमध्ये लक्षणीय वाढ नोंदली गेली आहे. वेगाने झालेल्या हिंदी महासागरातील तापमानात वाढ आणि त्यात 'एल निनो' यामुळे उष्ण लाटांचे प्रमाण वाढत आहे. परिणामी, मध्य भारतात पावसाचे प्रमाण कमी, तर दक्षिण द्वीपकल्पातील पावसाचे प्रमाण जास्त झाल्याचे दिसून येत आहे. सागरी उष्णतेच्या लाटा, पर्जन्यमान आणि वातावरणीय परिसंचार यांच्यातील संबंध असल्याचे प्रथमच या अभ्यासातून समजले आहे. यासाठी 'बोयस' या प्रणालीच्या माध्यमातून डेटा गोळा केला असून, पहिल्यांदा सागरी उष्ण लाटांचा अभ्यास झाला आहे.

> **हवामान मॉडेलच्या अंदाजानुसार भविष्यात हिंद महासागरात आणखी तापमानवाढीची शक्यता आहे. यामुळे सागरी उष्णतेच्या घटना आणि मॉन्सूनवर याचा परिणाम होऊ शकतो. महासागरात उष्णतेच्या लाटांची वारंवारता, तीव्रता आणि त्याचे क्षेत्र वाढत असल्यामुळे या घटनांचे अचूक निरीक्षण करण्यासाठी आपल्याला महासागर निरीक्षण व्यापी वाढवणे आवश्यक आहे. त्याचबरोबर तापमानवाढीबाबत जगाने मांडलेल्या आव्हानांचा कुशलतेने अंदाज लावण्यासाठी हवामानविषयक मॉडेल अद्ययावत करणे आवश्यक आहे.**
> – रॉक्सी मॅथ्यू कोल, शास्त्रज्ञ, आयआयटीएम

- हिंदी महासागराचे तापमान वेगाने वाढत आहे
- यामुळे सागरी गवत नष्ट होणे, प्रवाळांचे रंग बदलणे
- सागरी जैवविविधतेचे नैसर्गिक अधिवास नष्ट होतात
- सागरी जैवविविधतेवर परिणाम
- मत्स्यपालन क्षेत्रावर प्रतिकूल परिणाम

अभ्यासातील निष्कर्ष

१. सागरी भागात केलेल्या सर्वेक्षणानुसार मे २०२० मधील उष्ण लाटेच्या घटनेनंतर तमिळनाडू किनाऱ्याजवळील मन्नारच्या आखातातील ८५ टक्के प्रवाळाचा रंग बदलला
२. उष्णकटिबंधीय हिंदी महासागरात अशा उष्णतेच्या लाटांचे घटनांचे प्रमाण पूर्वी दुर्मिळ होते, आता दरवर्षी आढळतात
३. मागील चार दशकांमध्ये पश्चिम हिंदी महासागरात उष्णतेच्या लाटांच्या घटना चार पटीने वाढल्या
४. बंगालच्या उत्तरेकडील उपसागरात त्या २ ते ३ पटींनी वाढल्या
५. १९८२ ते २०१८ या कालावधीत बंगालच्या उपसागरात ९४, तर पश्चिमी हिंदी महासागरात एकूण ६६ वेळा असे घडले

''याबाबत रॉक्सी म्हणाले, ''साधारणपणे हिंदी महासागराचे सरासरी तापमान २८ अंश सेल्सिअस इतके आहे. मात्र, गेल्या काही दशकांमध्ये सरासरीपेक्षा तापमानात वाढ होत ३० ते ३२ अंशापर्यंत पोचले आहे. त्यामुळे पश्चिम हिंद महासागर आणि बंगालच्या उपसागरातील उष्णतेच्या लाटांच्या घटना वाढल्या असून मध्य भारतातील उपखंडात कोरडेपणा जाणवतो. त्याचबरोबर उष्णतेच्या लाटांमुळे उत्तर बंगालच्या उपसागरातील दक्षिण द्वीपकल्पीय भागात पावसाच्या प्रमाणात लक्षणीय वाढ झाली आहे. उष्णतेच्या लाटांमुळे मॉन्सूनच्या वाऱ्यांमध्ये ही बदल झाले आहेत.''

Pune, Pune-Today
06/02/2022 Page No. 10

കടലിൽ ചൂടുയരുന്നു

തെക്കേയിന്ത്യയിൽ മഴ കൂടുമെന്നു പഠനം

പവിഴപ്പുറ്റുകളെ ഇല്ലാതാക്കും

എം.എസ്. ഗോപകുമാർ
ആലപ്പുഴ

▸ ഇന്ത്യൻ മഹാസമുദ്രത്തിലും ബംഗാൾ ഉൾക്കടലിലും താപതരംഗങ്ങൾ വർധിക്കുകയാണെന്നും ഇത് ഇന്ത്യയിലെ കാലവർഷത്തെ സ്വാധീനിക്കുമെന്നും പഠനം. തെക്കേയിന്ത്യയിൽ മഴക്കൂടുതലിനും മധ്യേന്ത്യയിൽ മഴക്കുറവിനും വരാം ച്ചുള്ളും ചുഴലിക്കാറ്റുകളുടെ വ്യതിയാനത്തിനും ഇതുകാരണമാകും. പെട്ടെന്നു തീവ്രമാകുന്ന ചുഴലിക്കാറ്റുകൾ രൂപപ്പെടാനും ഇടയാക്കും. പുണെയിലെ ഇന്ത്യൻ ഇൻസ്റ്റിറ്റ്യൂട്ട് ഓഫ് ട്രോപ്പിക്കൽ മെറ്റിയറോളജിയിലെ കാലാവസ്ഥാ വ്യതിയാന ഗവേഷണകേന്ദ്രത്തിൻറെതാണു പഠനം.

വേഗത്തിലുള്ള താപനവും ശക്തമായ എൽനിനോകളുംമൂലം ഉഷ്ണമേഖലാ ഇന്ത്യൻ മഹാസമുദ്രത്തിൽ താപതരംഗങ്ങൾ നാലിരട്ടിയായി വർധിച്ചു. ഇതു പവിഴപ്പുറ്റുകളുടെയും കടൽച്ചെടികളുടെയും നാശത്തിന് ഇടയാക്കുമെന്ന് ജേണൽ ഓഫ് ജിയോഫിസിക്കൽ റിസർച്ച് (ജെ.ജി.ആർ. ഓഷൻസ്) എന്ന ശാസ്ത്ര ജേണലിൽ പ്രസിദ്ധീകരിച്ച പഠനത്തിലുണ്ട്.

ഉഷ്ണതരംഗങ്ങളുടെ സമയത്തു കടലിലെ ചൂട് 90 ശതമാനത്തിനുമേൽ കൂടുന്നുണ്ട്. 2020 മേയിലുണ്ടായ താപതരംഗത്തെത്തുടർന്ന് തമിഴ്നാട് തീരത്തിനടുത്തുള്ള മന്നാർ ഉൾക്കടലിലെ പവിഴപ്പുറ്റുകളിൽ 85 ശതമാനവും നശിച്ചു. 1982–2018 കാലയളവിൽ പടിഞ്ഞാറൻ ഇന്ത്യൻ മഹാസമുദ്രത്തിൽ 66–ഉം ബംഗാൾ ഉൾക്കടലിൽ 94–ഉം തവണ ഉഷ്ണതരംഗങ്ങളുണ്ടായി.

ദുരന്തനിവാരണ സംവിധാനങ്ങൾക്കു വെല്ലുവിളി

ഉഷ്ണതരംഗങ്ങളുടെ സ്വാധീനം ഭാവിയിൽ അറബിക്കടൽ ഉൾപ്പെടെയുള്ള സമുദ്രങ്ങളിലുണ്ടാകും. ഈ നൂറ്റാണ്ടിൻറെ അവസാനത്തോടെ ഇന്ത്യൻ മഹാസമുദ്രത്തെ മുഴുവൻ ഇതു ബാധിക്കും. പ്രവചിക്കാനുള്ള സമയംപോലും കിട്ടുന്നതിനുമുൻപ് തീവ്രമാകുന്ന ചുഴലിക്കാറ്റുകൾ ദുരന്തനിവാരണ സംവിധാനങ്ങൾക്കു വെല്ലുവിളിയാകും.

ഡോ. റോക്സി മാത്യു കോൾ
ശാസ്ത്രജ്ഞൻ, കാലാവസ്ഥാ വ്യതിയാന ഗവേഷണകേന്ദ്രം, ഇൻസ്റ്റിറ്റ്യൂട്ട് ഓഫ് ട്രോപ്പിക്കൽ മെറ്റിയറോളജി, പുണെ

06/02/2022 CHENGANNUR,MAVELIKKARA Pg 12

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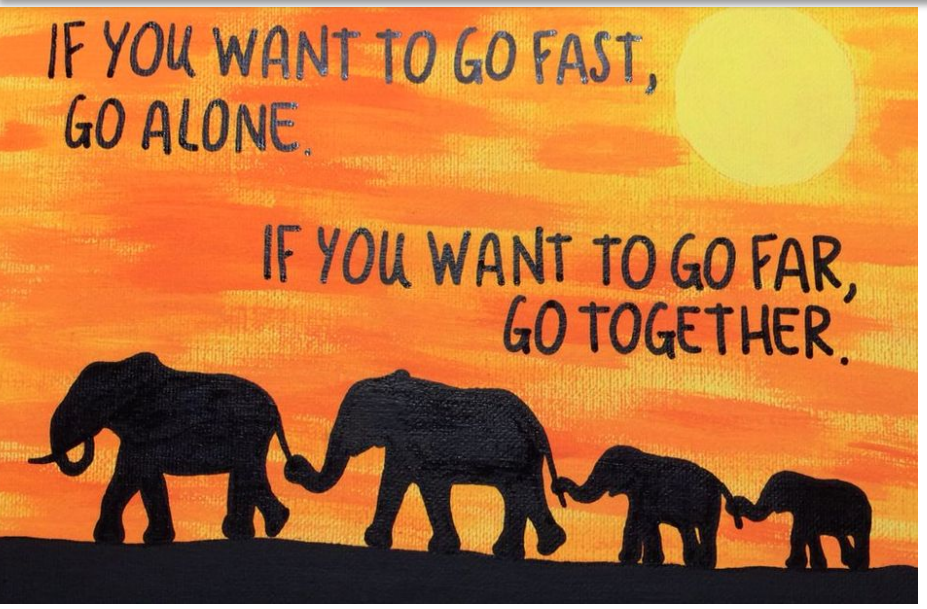
The Global Ocean Observing System GOOS

Growing the network and the impact



Co-design - To change the concept of making decisions **for** people with lived experience to making decisions **with** people with lived experience; seeing marginalised people as a burden to seeing marginalised people as resilient, creative and capable

COLaB

GEM-in-a-BOX

A Global Eutrophication Monitoring Program in Partnership with Commonwealth Member States

CLIVAR/IOC-GOOS Indian Ocean Region Panel

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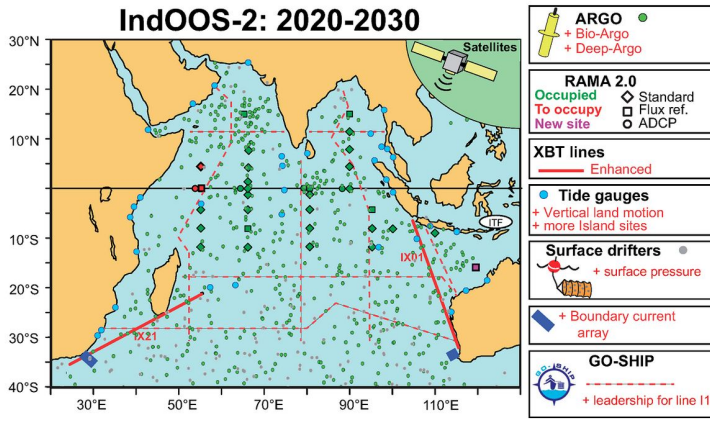


Pacific Region Panel

About Us

The Abdus Salam International Centre for Theoretical Physics

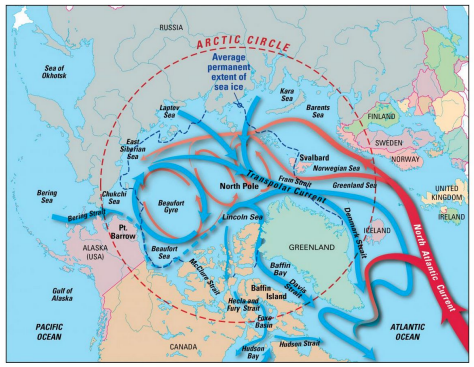
Individually we are a drop, together we are a *fit-for-purpose* ocean *observing system*

CLIVAR/CliC/SCAR Southern Ocean Region Panel

About Us

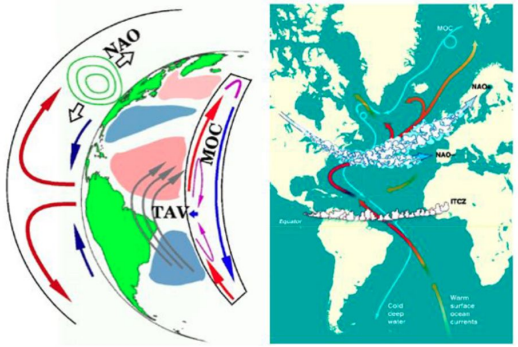
CLIVAR /CliC Northern Oceans Region P

About Us



Atlantic Region Panel

About Us



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