MISO-BOB: An Air Sea interaction initiative *jointly* with NRL RIO-MISO

MISOBOB Steering Committee:
Amit Tandon,
Emily Shroyer, Hemantha Wijesekera(NRL), H. Joe Fernando, Eric D'Asaro, Amala Mahadevan, Drew Lucas, Jen Mackinnon, Tom Farrar

USA Institutions: UMass Dartmouth, WHOI, APL/UW, Scripps/UCSD, Oregon State Univ, University of Notre Dame, Columbia University, University of Alaska, University of Miami etc. **along with Naval Research Lab.(RIOMISO, EBOB)**

India: Ministry of Earth Sciences: Ocean Mixing and Monsoons (OMM) Indian Institute of Science Bangalore, National Institute of Ocean Technology, Indian National Center for Ocean Information Services, National Institute of Oceanography, Space Applications Centre, Indian Institute of Technology Madras, Indian Institute of Technology Delhi, ICTS Tata Institute for Fundamental Research

Sri Lanka: National Aquatic Resources and Research Agency (NARA**)**
Seychelles Meteorological Office
Maldives Hanimmadoo Climate Observatory, Singapore National University

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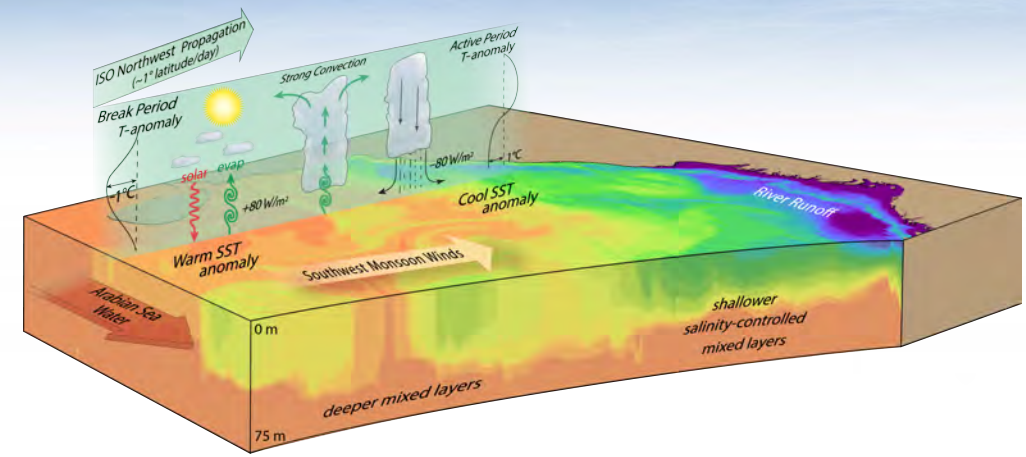
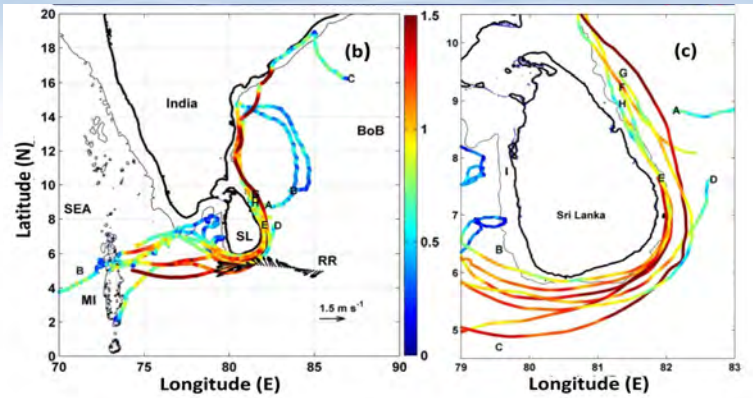
OBJECTIVES





- Understanding the ocean influence on the intensity and propagation speed (roughly 1 degree north per day) of the coupled ocean-atmosphere MISO signal.
- Determining how the large-scale upper ocean variability in the Bay of Bengal, which includes shallow salinity-driven mixed layers in the north and deeper mixed layers in the south, influences the MISO signal.
- Evaluating how the submesoscale and mesoscale perturbations affect the upper-ocean background state.
- Integrate data and models to determine the spatial and temporal scales at which atmospheric and oceanic signatures need to be coupled to accurately capture the MISO propagation.

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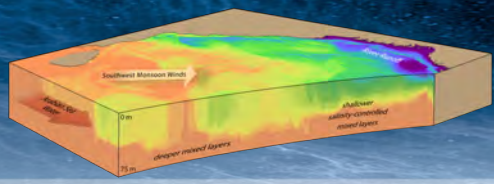
USA-India, USA-Sri Lanka Collaborative Research: History



Develop strong collaboration between countries by identifying common science interest. MISOBOB builds on ASIRI's success

First Meeting in New Delhi, 2011

Colombo, 2012

Improved Monsoon Forecasting:

- Ocean Mixing
- Air-sea Fluxes

Extreme weather event predictions

Indian interests:

- Science with Modern oceanographic instrumentation
- Capacity Building including glider training

Sri Lankan interests:

Fisheries; Capacity building for oceanographic research; Glider and buoy deployment training

USA interests:

- Improving Navy predictive capabilities
- Safety of ships at sea, navigation

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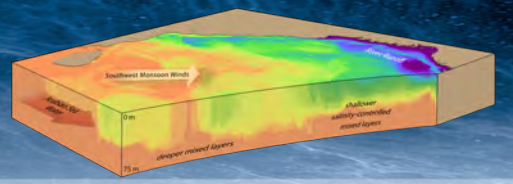
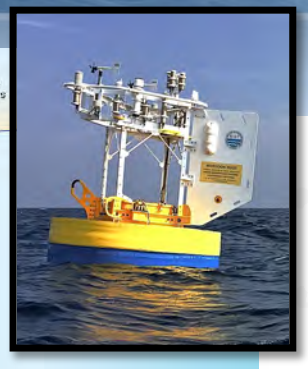
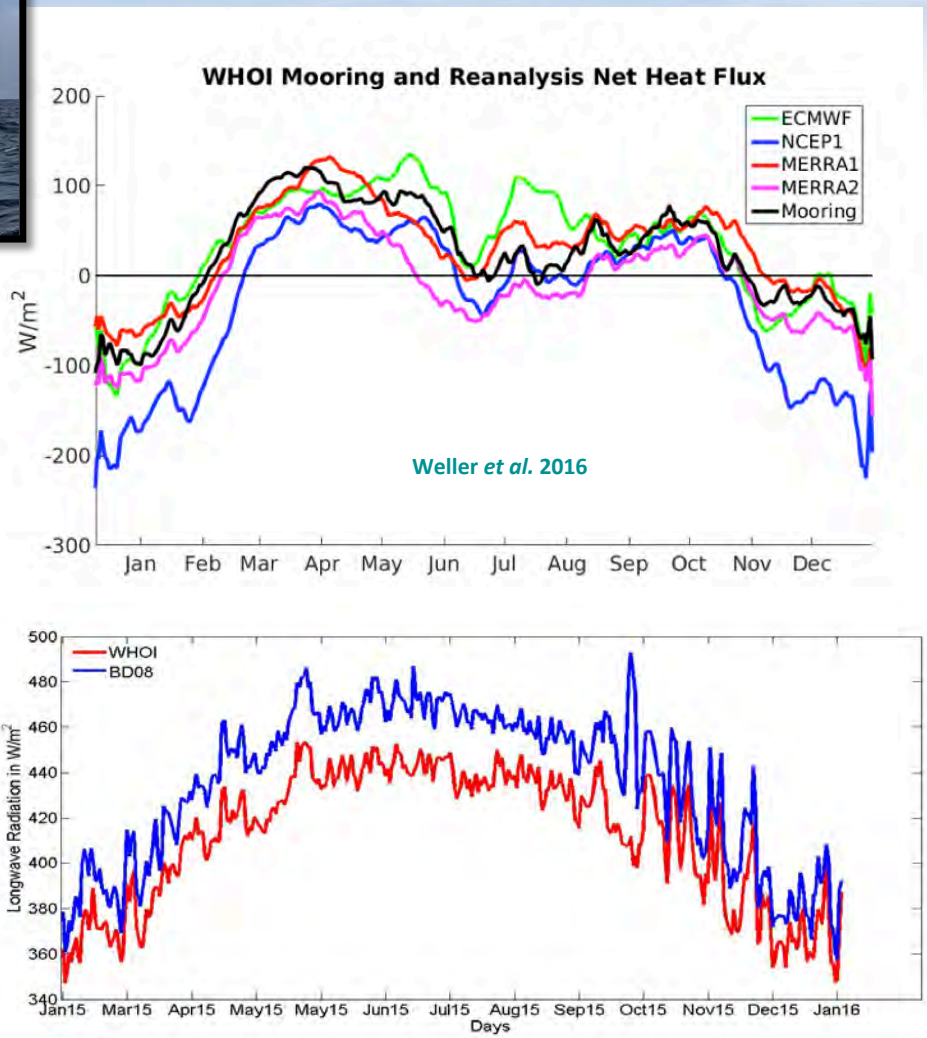
ASIRI -First Accurate annual cycle of air-sea flux (2015)







All products have large biases.

Reduce biases from Indian NIOT buoy compared to WHOI.

Led to improved flux measurements from Indian buoys

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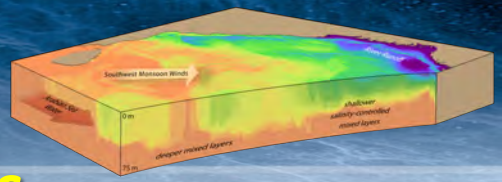
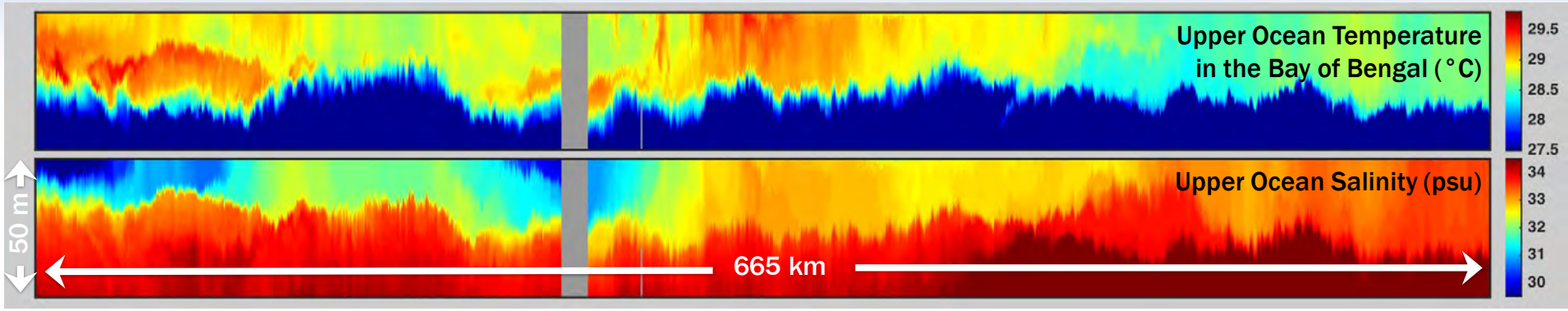
ASIRI

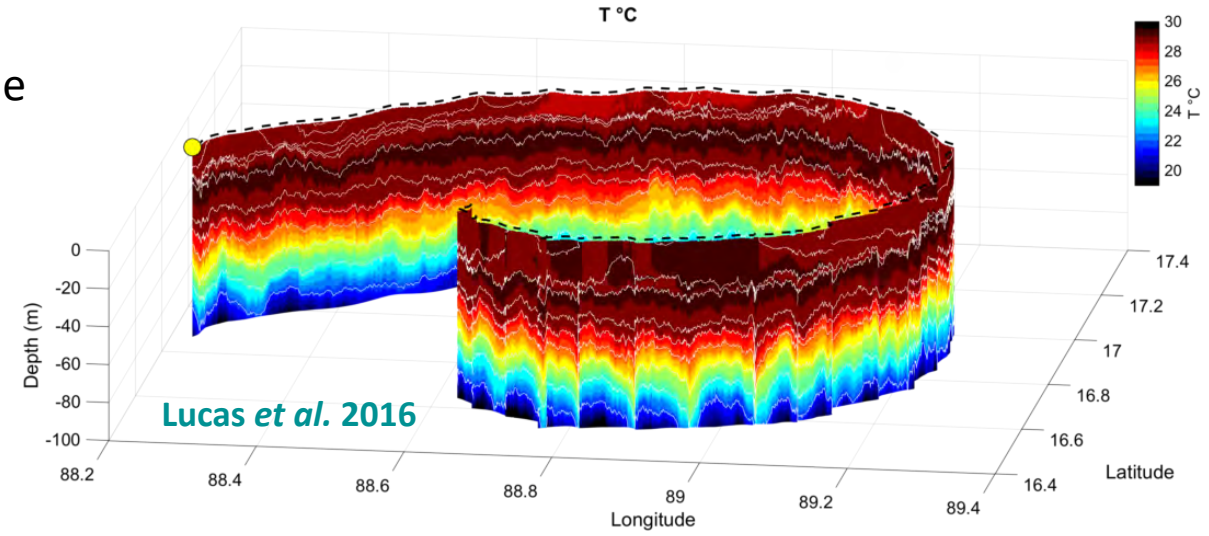
Scales of intense stratification & sub-surface warm barrier layers





Shallow salinity stratification with very weak mixing below the halocline enhances air-sea interaction.

Trapped heat has important implications for cyclone development and Monsoon forecasts.



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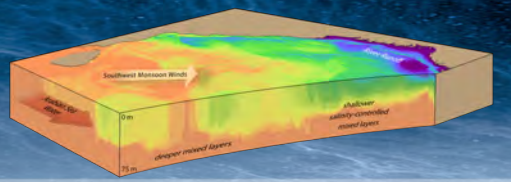
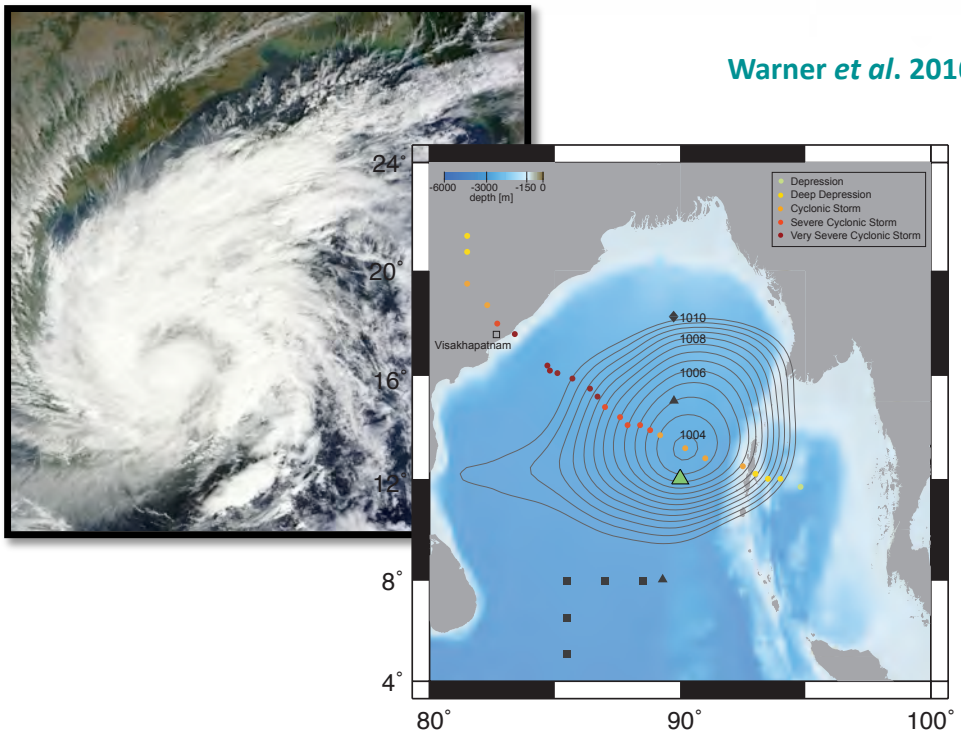
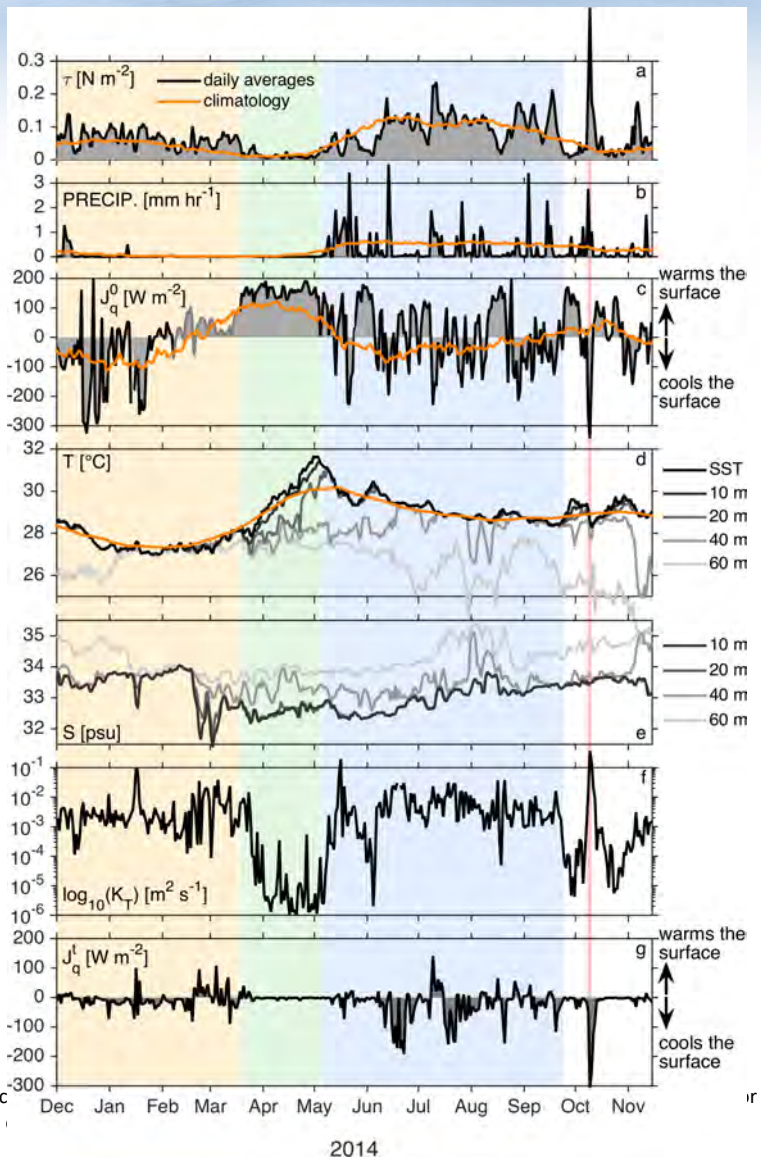
ASIRI
Mixing in the Bay of Bengal from annual cycles to cyclones



- Anomalous Bay: High freshwater prevalence leads to minimal vertical mixing.
- Driver for Mixing required to be consistent with BoB circulation: Cyclones!
- As captured by ChiPods deployed during ASIRI



Warner *et al*. 2016



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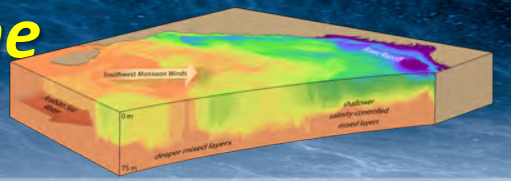
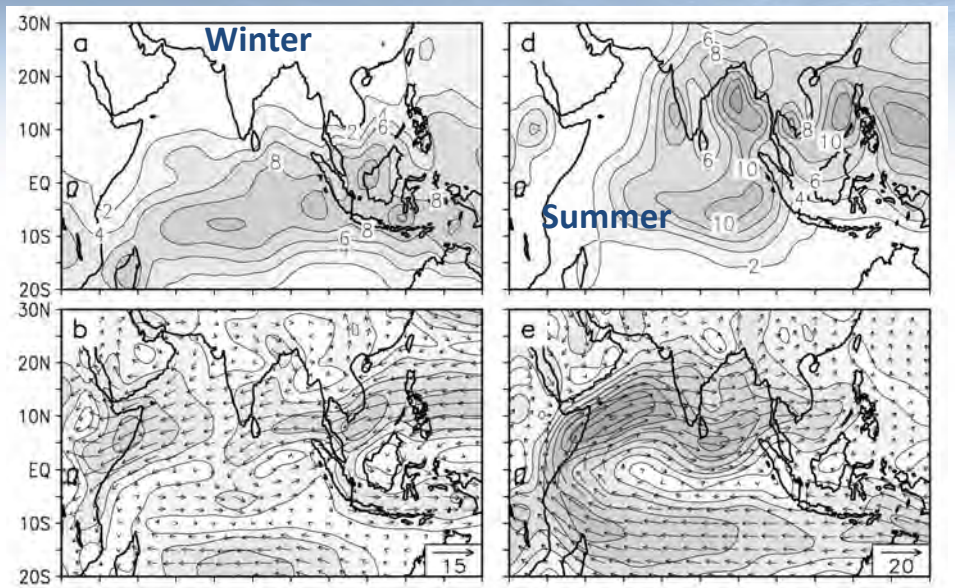
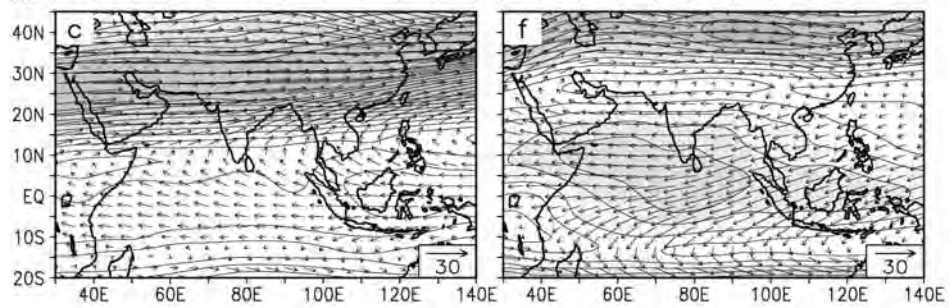
Intraseasonal Variability in the Monsoons





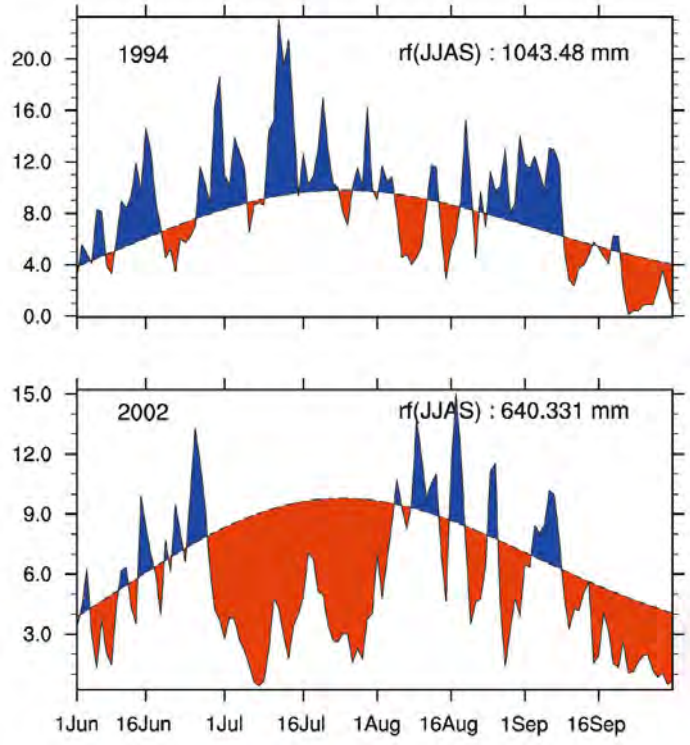
Winter(DJF) and summer(JJAS) climatology for rain and winds at 850hPa above and at 200hPa (below)

Goswami book chapter (2012)



Active and Break Periods in the Monsoon precipitation

Flood year (1994) and Drought year (2002)



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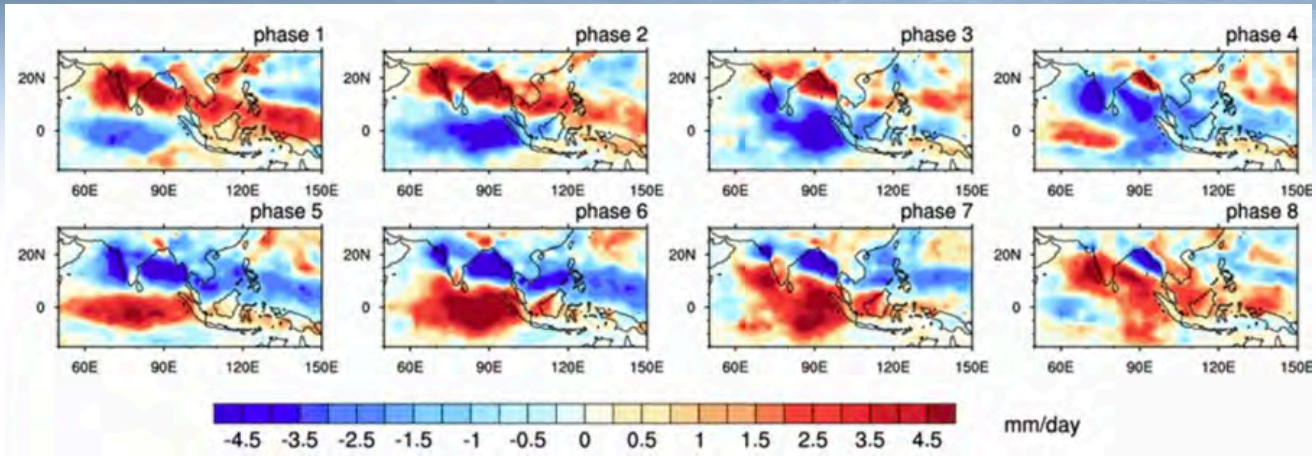
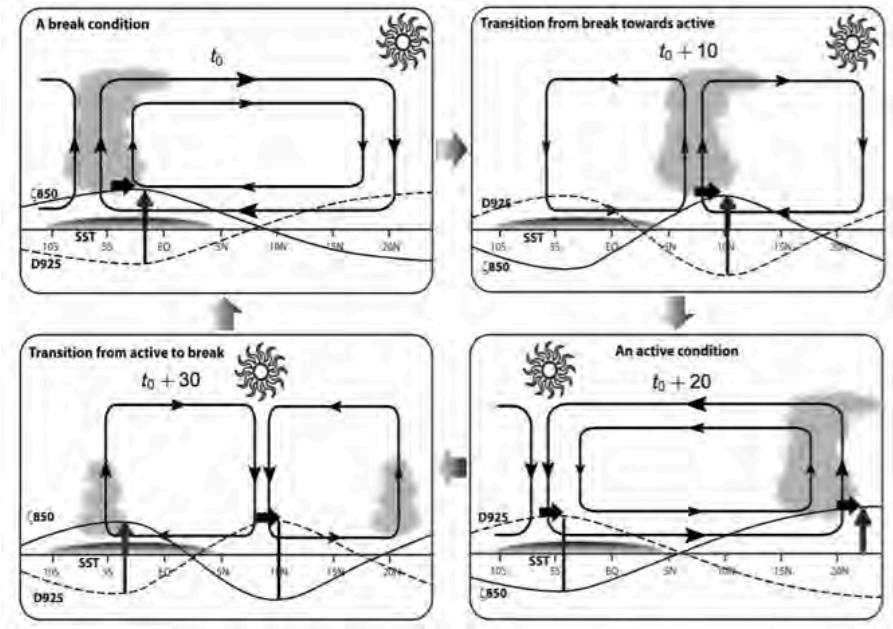
MISO propogates northward 30-40 day mode



Based on EEOF analysis of precipitation in the tropics
Neena *et al.* 2017

- 30-40 day mode, Low-level convergence of moisture and SST gradients play a key role in the northward propagating systems



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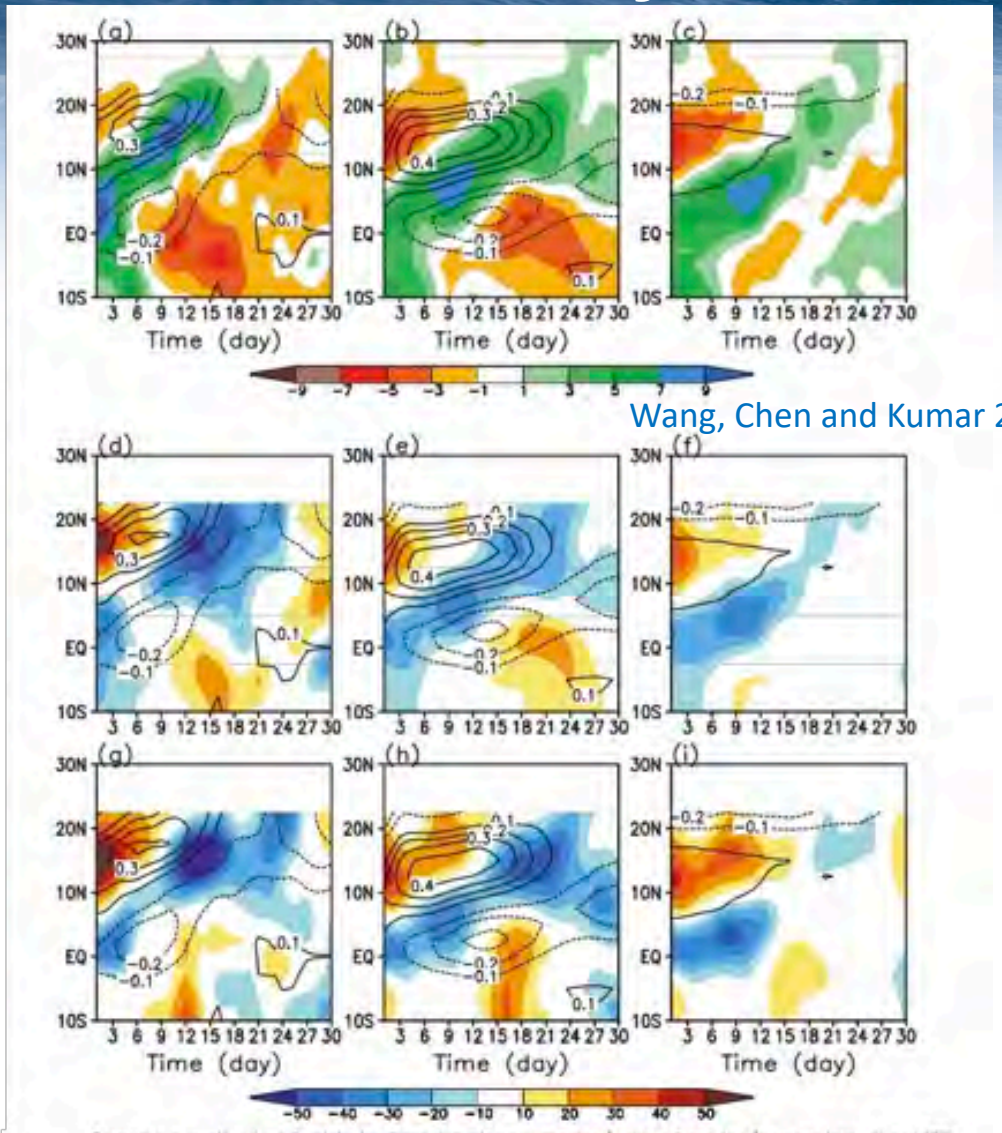
Air-Sea interactions are key to MISO

- Higher vertical resolution in the upper ocean and resolving the diurnal cycle in coupling helps improve the representation of MISO.(Klingaman et al., 2010)
- Coupled forecasts show right phase relation between latent heat flux, SST and SW radiation with the MISO propagation (Wang et al. 2009)
- **Scales of atmospheric-ocean coupling remain unexplored**.



Wang, Chen and Kumar 2009

Composite anomalies. (top) Precipitation (shaded starting at 1 mm day^{-1}, with a 2 mm day^{-1} contour interval) and SST (contours starting at ±0.1 K, with a 0.1-K contour interval, negative values dashed) averaged between 65° and 95°E. (middle) Same as the top row, except that the shading is for downward surface solar radiation (starting at ±10 W m^{-2}, with a 10 W m^{-2} contour interval). (bottom) Same as the middle row, except that shading is for downward latent heat flux. (left) Observation, (middle) CFS forecast, and (right) GFS forecast.

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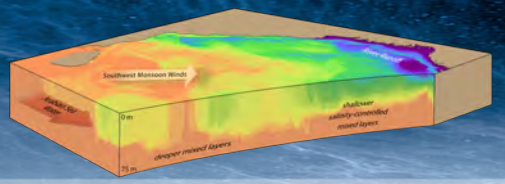
MISOBOB & RIO-MISO

Spanning the air & sea

ONR / NRL / India / Sri Lanka



Ocean Observations

- Long-term Indian moorings collaborative with US
- Long-term Glider observations with Sri Lanka
- US and Indian Cruises supported by autonomous platforms

Atmospheric Observations

- Indian & Sri Lankan operational networks
- Network upgrades
- C-130 flights from Sri Lanka
- Flux and boundary layer observations on cruises

Improved Process Understanding

- Strong modelling component compared to ASIRI
- Process / Regional / Coupled models
- Indian and US oceanographers and atmospheric scientists
- Analysis of ASIRI and MISOBoB data

Operational Models

- NRL COAMPS
- Strong collaboration with Indian Operational and modelling centers

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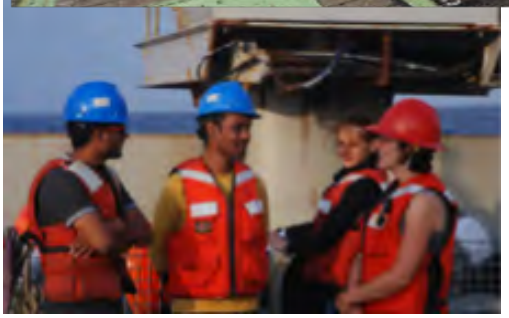
Scientific Exchange
(ongoing)

- Three formal summer and winter training workshops in India. 4th one concluded yesterday!
- Workshops in the US (Oregon State)
- Many individual training activities, with students visiting US institutions
- Multiple US PI visits to multiple Indian institutions
- About 10 joint science meetings with US/India/SL PIs in India, Sri Lanka and in USA. 11th one today!

Technical Exchange
(ongoing)

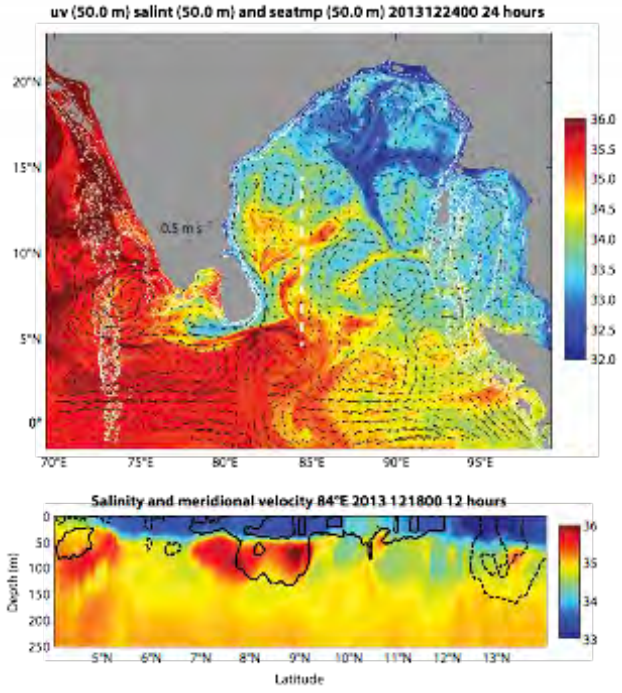


- Collaborations onboard US and Indian vessels
- Indian scientists on US vessels (>50 overall)
- US scientists on Indian vessels
- Lagrangian float training and deployments.
- Glider training and deployments
- 18N INCOIS flux mooring and training
- Junior scientist visits to WHOI, APL/UW, UMass, Scripps, Oregon State etc.

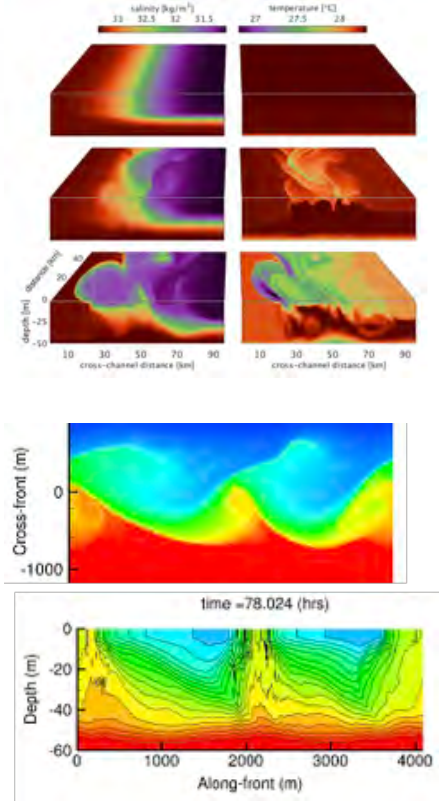
Such activities are building new indigenous capability in India, and in Sri Lanka, training a new cadre of US scientists well versed in monsoon air-sea interaction, and forging strong links between US and Indian and US and SL oceanographic institutions.

Multi-scale Ocean and Coupled Modeling

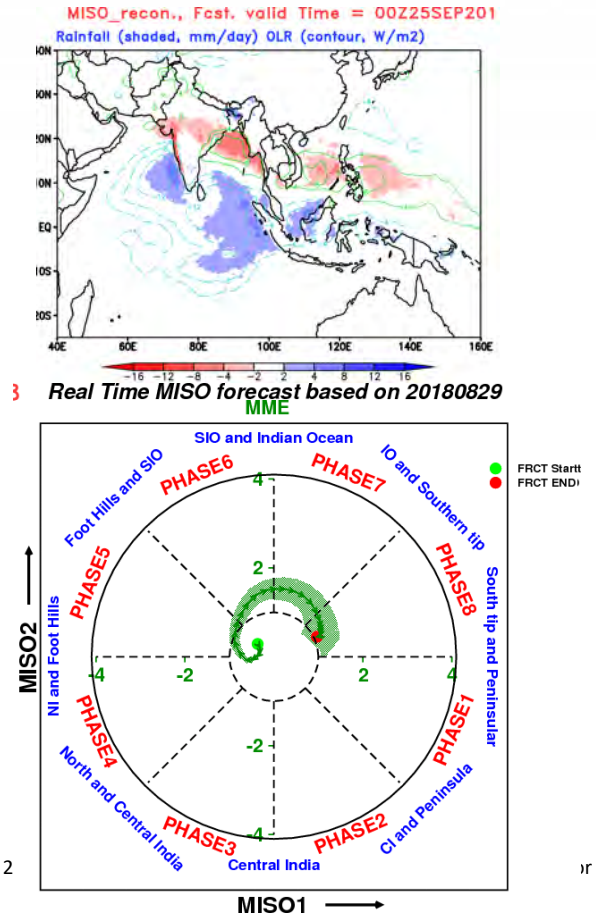
Large scale models (NRL, U of Alaska)



Process models and Large Eddy Simulations



Indian and other forecast models



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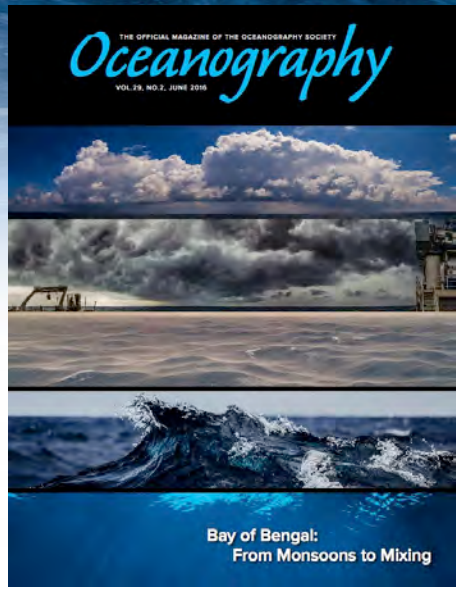
RECENT PUBLICATIONS

- ASIRI/EBOB/OMM/MISOBOB related publications in a special TOS issue (June 2016); BAMS, Eos. Detailed analyses are published and being published in journals (Journal of Physical Oceanography, Geophysical Research Letters, Journal Of Geophysical Research-Oceans).
- Special Deep Sea Research issue on Atmosphere-Ocean Dynamics of Bay of Bengal (eds. A. Gordon, J. Fernando, U. Jinadasa, M. Mathur, E. Shroyer and A. Tandon) **SUBMIT YOUR PAPERS NOW!**
- IIOE-2 synthesis review, 2009-2019 (Amit/Emily)
- First Intl Operational SatOce. Symposium, abstracts due March 29, 2019 (Gad Levy)



Nature, June 28, 2018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The Indian monsoon can bring damaging floods, but also has a crucial role in ensuring an adequate water supply for people and crops.

ATMOSPHERIC SCIENCE

Mysteries of Indian monsoon probed

Research plane and ships aim to gather the most detailed data yet on rainfall variations.

BY ALEXANDRA WITZE

Heavy rains and seven-metre-high waves pummelled the research vessel *Thomas G. Thompson* in the Bay of Bengal this month, routinely drenching the oceanographers on deck. But that was just fine with the scientists. Their entire plan involved getting as wet as possible, in order to directly measure what happens where the air and the sea meet in a summer storm.

The team is part of a multinational group of researchers who are descending on the Indian Ocean this summer to study its seasonal monsoon. They intend to gather the most detailed observations yet on the wet and dry periods that alternate roughly every 30–50 days during the monsoon season, which lasts from June to September.

If modellers could better predict these varying patterns — called monsoon intraseasonal oscillations, or MISOs — then officials could better prepare for the monsoon each year. That includes timing the planting of crops in concert with the rains, storing water behind dams for hydropower, and preparing for floods and other natural disasters.

"One billion people on the Indian subcontinent depend on planning for water resources," says Harindra Fernando, a mechanical engineer at the University of Notre Dame in Indiana and one of the project's leaders. "When people are waiting for rain, it's important to know when you will get it and when you won't."

MISOs represent the monsoon's 'active' and 'break' periods, in which weeks of heavy rainfall give way to brilliant sunshine before starting all over again. The patterns of rainfall generally track northwards over the Bay ▸

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