Bay of Bengal/Air-Sea Interaction Research Initiative (ASIRI)

- Air-Sea Interaction Research Initiatives
  -U.S. Office of Naval Research
- Integrated with Naval Research Laboratory program
- Coordinated with Sri Lanka
- Closely coordinated with India

Scientific Foci

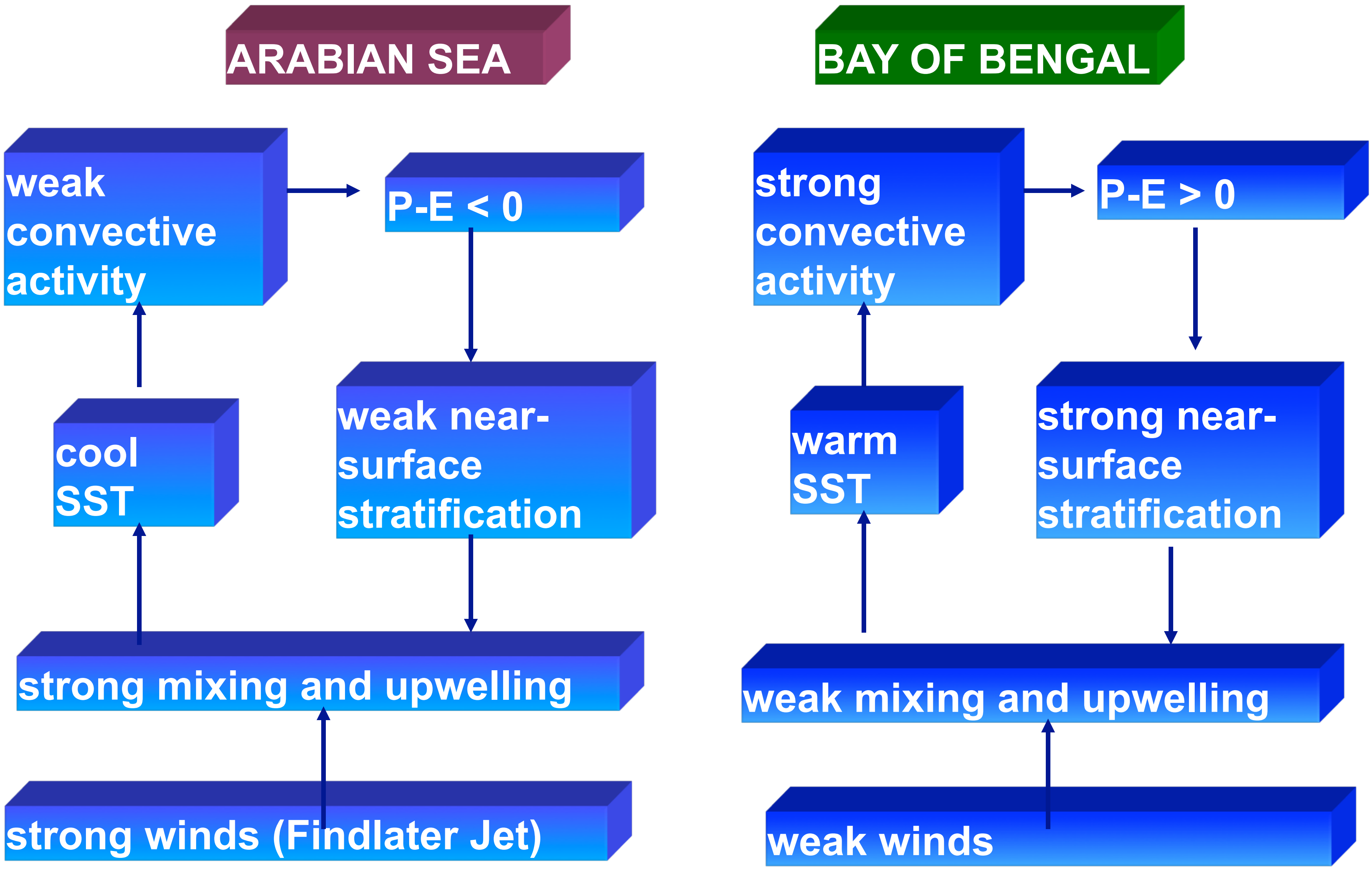
- **Understanding the processes that govern monsoon initiation**
- **Better understand the coupled physics involved in the monsoon so we might improve the predictive weather models**
- **Role of the ocean in determining monsoon strength**
- **Impact of the monsoon on the ocean**
- **Determine the important regions driving the ocean-atmosphere coupling (e.g. particular areas in the Bay of Bengal)**
- **Example Programs: Arabian Sea Study, JASMINE, DYNAMO, ITOP**

ASIRI-Bay of Bengal goals

- Exploring the conceptual, theoretical, dynamical constructs of air-sea interaction in the Bay of Bengal (BoB) // monsoonal regions
- Understanding the dynamics of the mixed layer
- Flux balances at different stages of the monsoon
- Role of the mesoscale in modifying monsoonal dynamics
- Improved process representation and coupling parameterizations in data assimilative models

Paluskiewicz

AS and BoB differences between the basins (Shenoi et al, 2002)

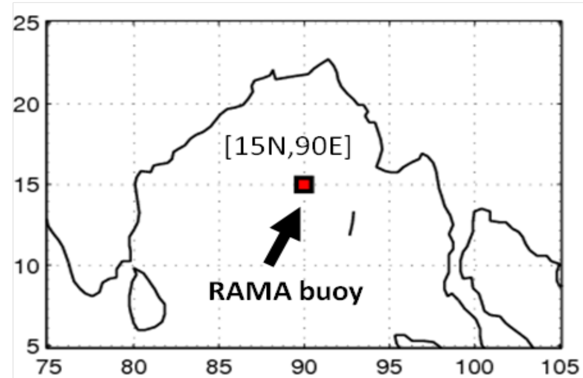


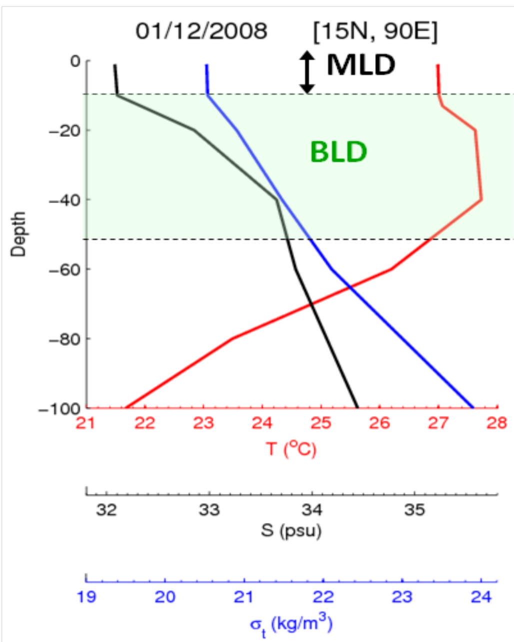
Paluskiewicz

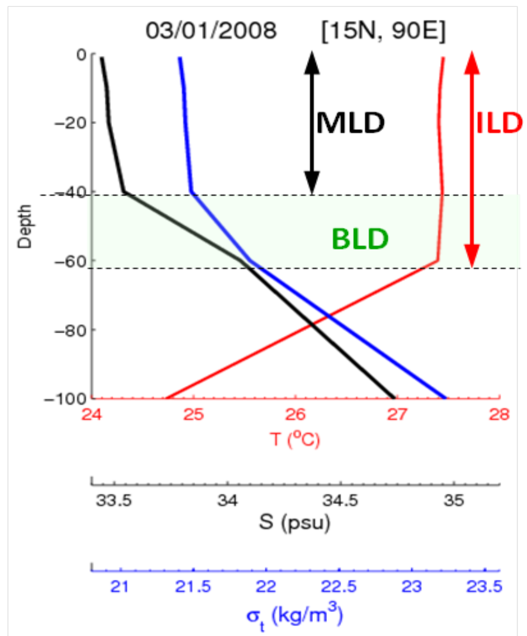
Paluskiewicz

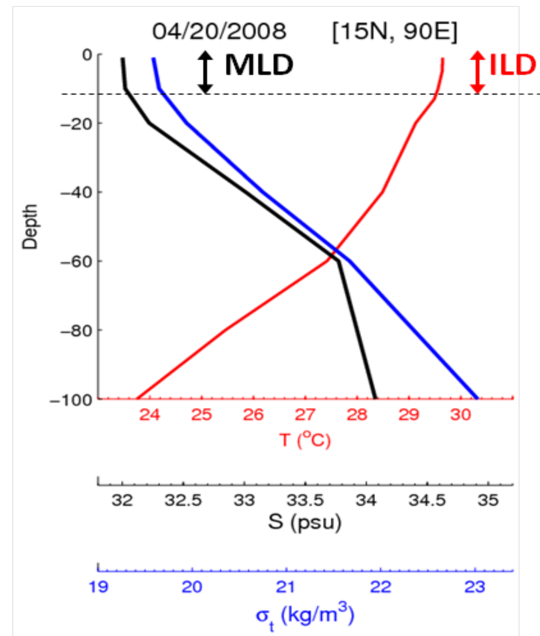
RAMA Observations at [15N,90E]

Mixed Layer Depth (MLD)
Isothermal Layer Depth (ILD)
Barrier Layer Depth (BLD)



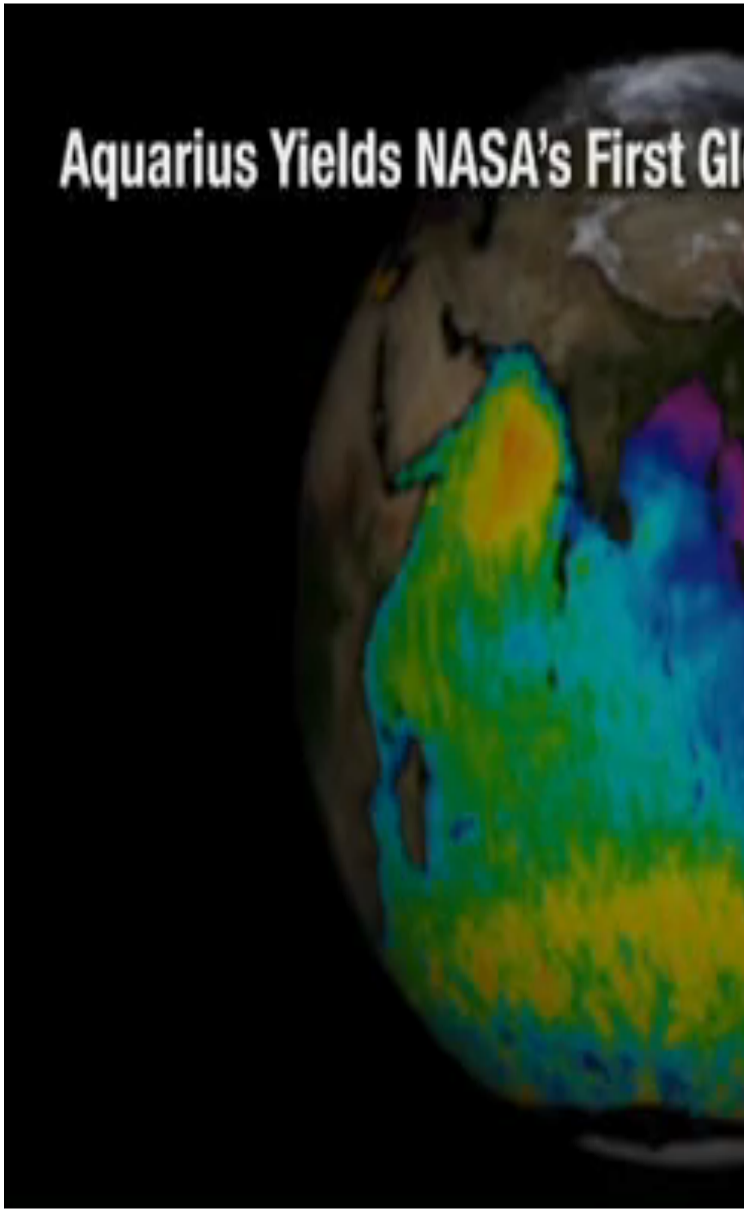


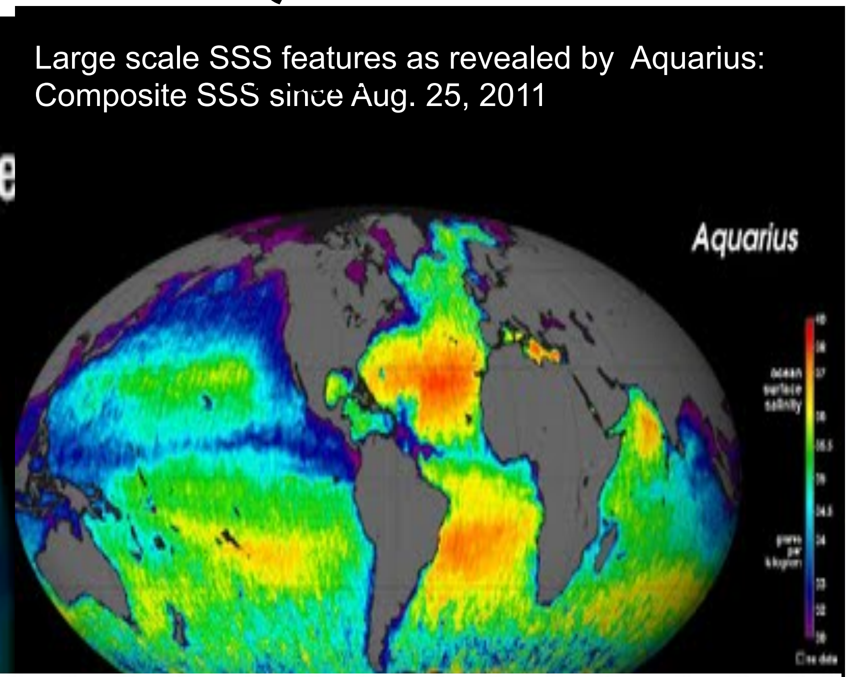


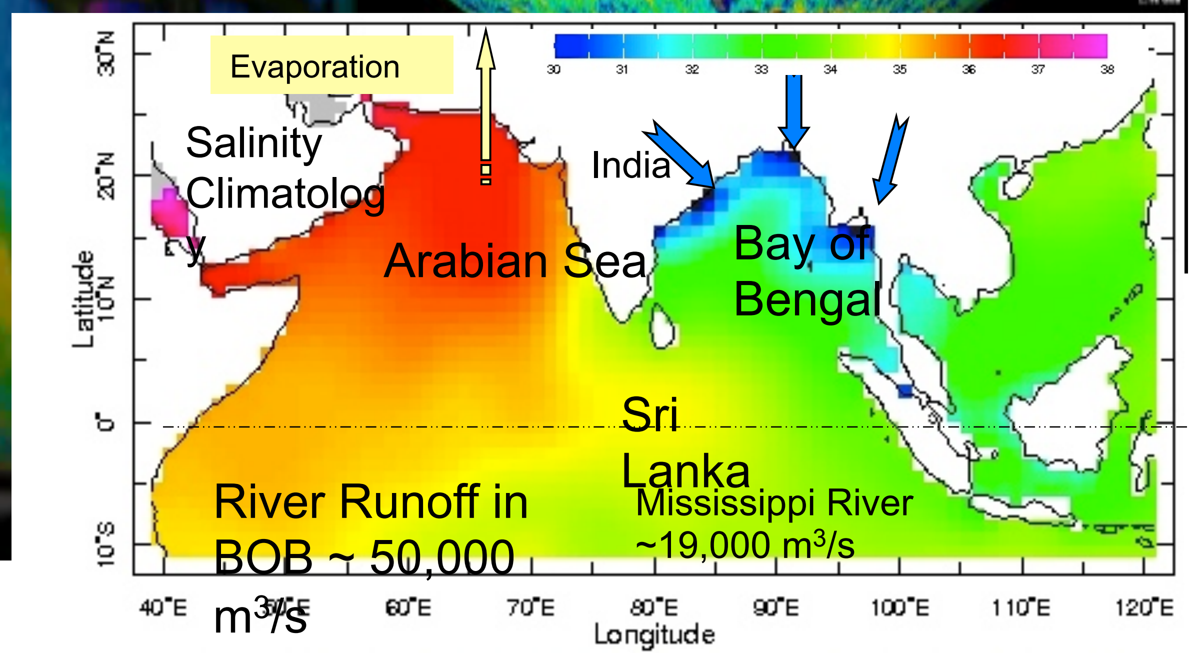


The MLD and BLD in the Bay have distinct seasonal variations.

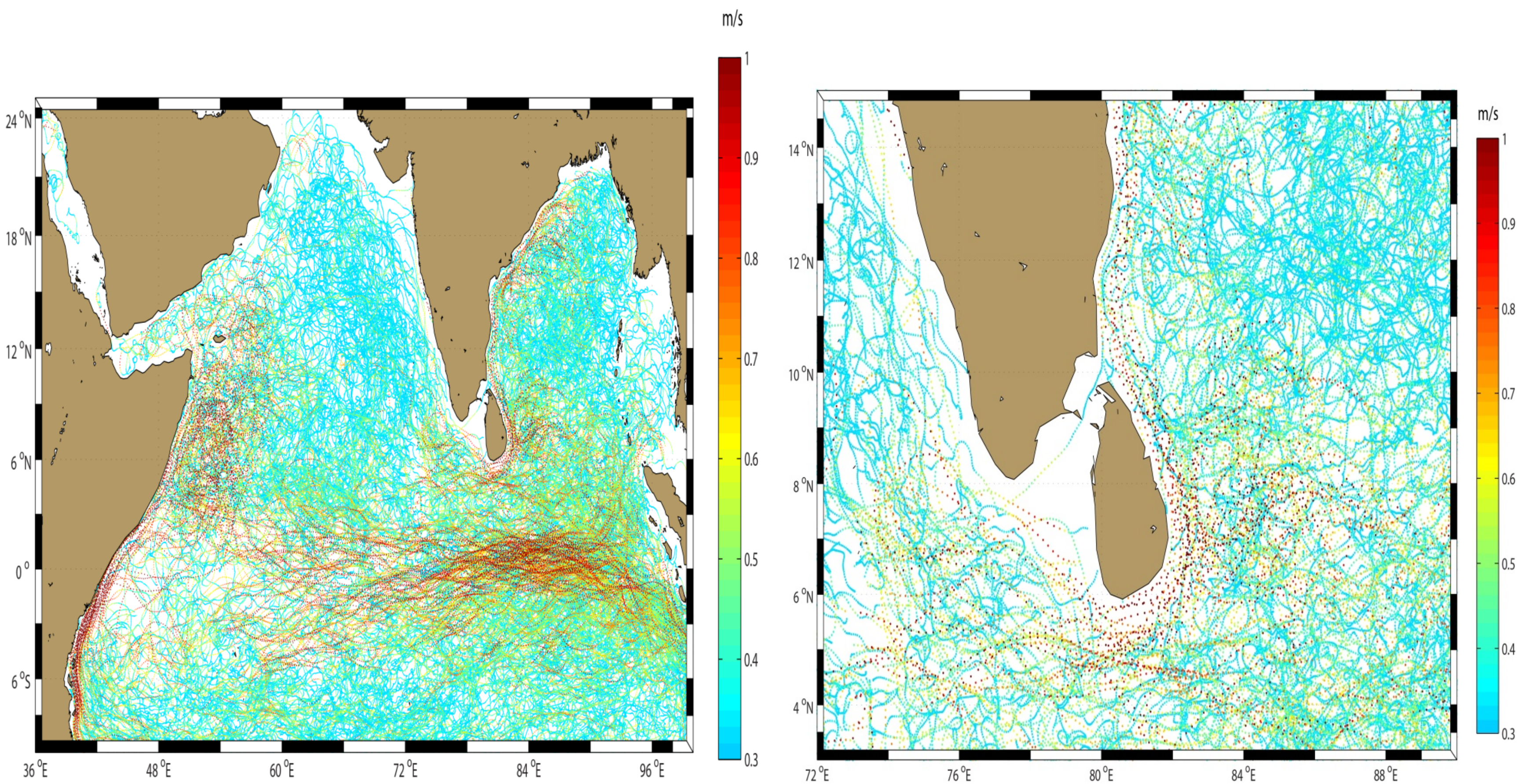
Surface Salinity from AQUARIUS







Surface Currents in the Region

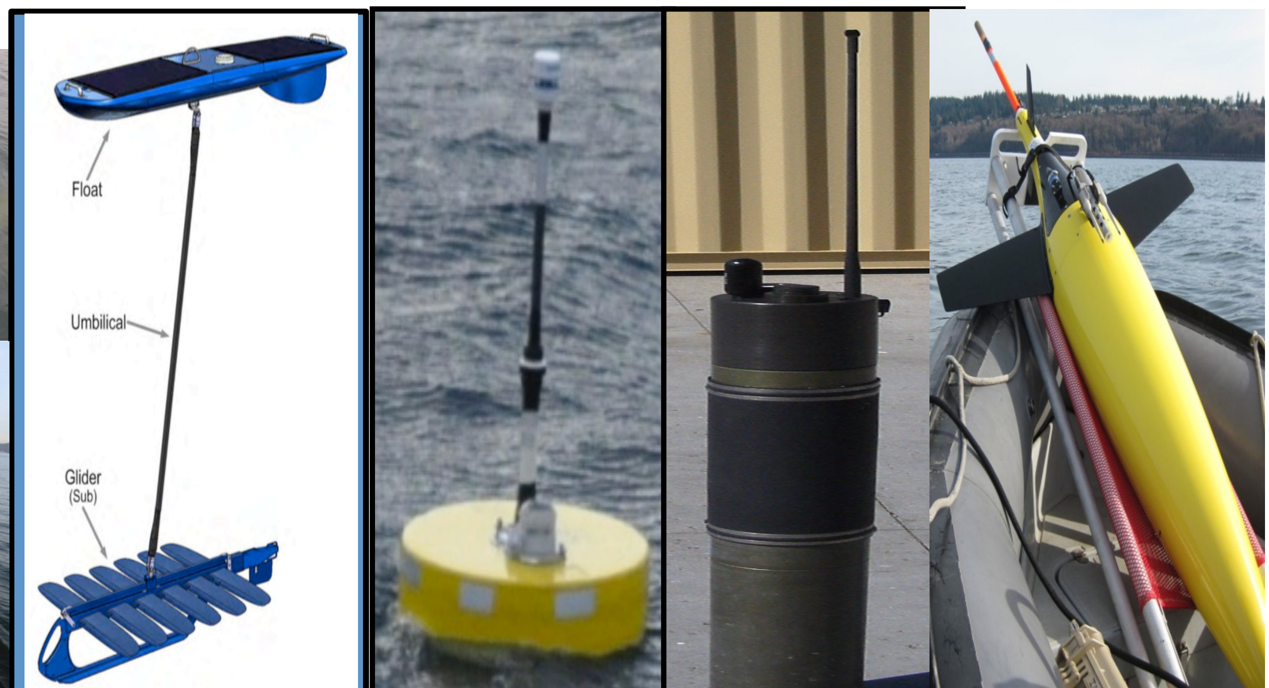


Field Program

Conduct a field experiment in the international waters of the Bay of Bengal; utilize model studies to determine critical areas of air-sea interaction .
- Structure these model-deployments as hypothesis tests
- Structure the process model – sensor choices as hypothesis tests
- Develop cooperative cruises to build a multi-stage sample set of the monsoon

(A) Autonomous platforms

Disposable Wave Buoys

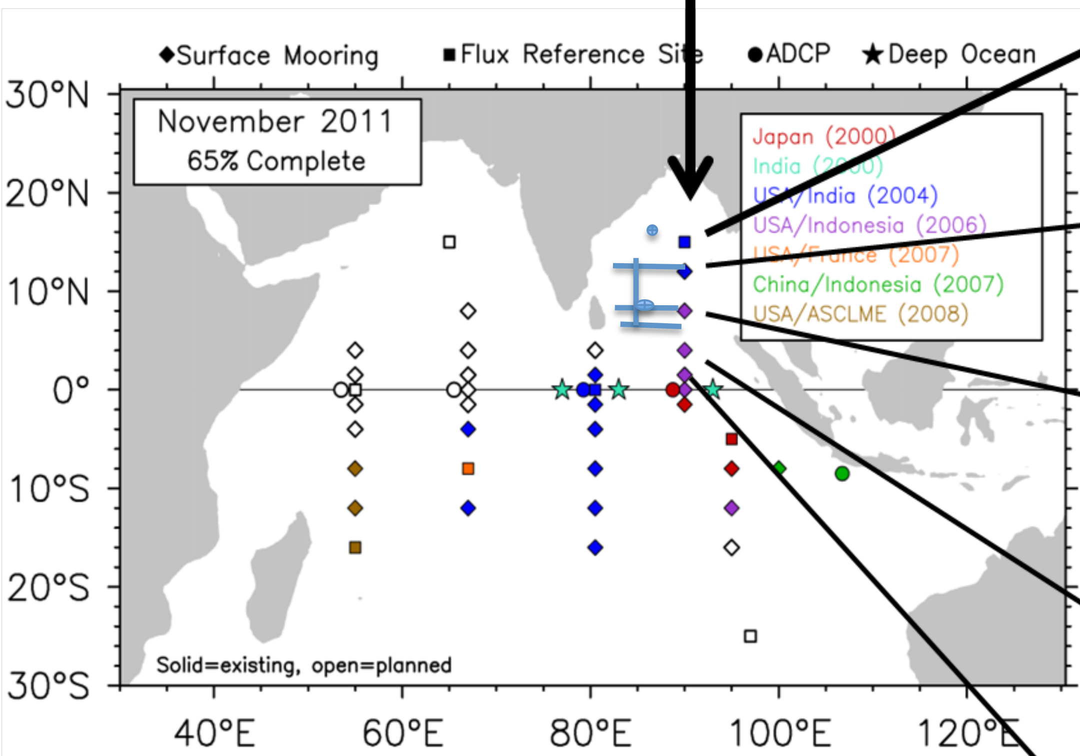


Wave Glider | **Deployable met buoy** | **Air-Sea Interaction Profiler** | **Glider**

Air-Sea Interaction Buoys

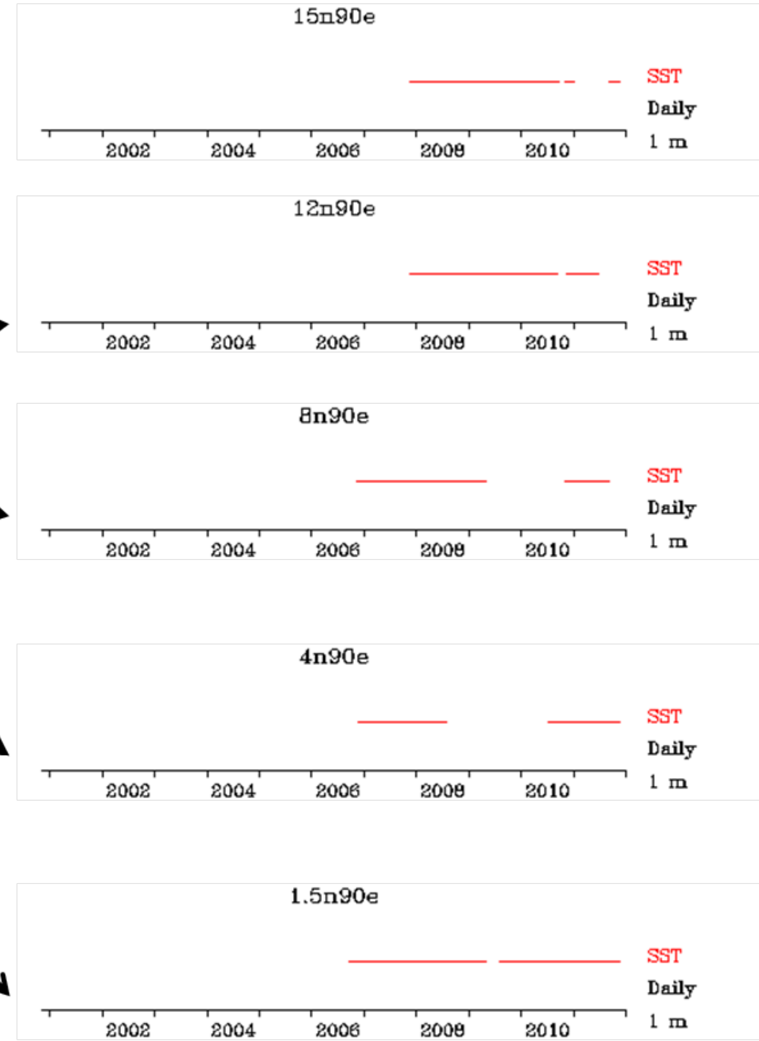
OMM/ASIRI Glider Lines

Add Chi pod sensors Flux reference site [15N,90E]



Availability

Daily SST measurements



Pilot Cruise: 8 Nov-15 Dec 13

Coupled Physical Processes in the Bay of Bengal and Monsoon Air-Sea Interaction

"Ocean Mixing and Monsoons (OMM)"

IISc. INCOIS NIOT IITM NIO Goa NIO Vizag SAC TIFR Hyderabad IIT Madras IIT Bhubaneswar IIT Bombay IIT Delhi

Debasis Sengupta

- **River-dominated north BoB: Shallow, fresh layer over deep, warm layer; coupled monsoon subseasonal oscillations (ISO), tropical cyclones, *diurnal cycle, monsoon disturbances …***
- **Present ocean and coupled models deficient : *Incorrect fluxes, missing physics in ocean and atmosphere boundary layers***

OMM: A four-year (2013-2016) programme (A) Observations of ocean and atmospheric boundary layers; (B) Fine-scale models; (C) Regional ocean/coupled models, and (D) OGCM development.

Pilot experiment: November 2013 and May 2014
18-24 month IOP: October 2014-October 2016

Goals: (A) Legacy datasets (B) Model-based syntheses of multi-scale observations (C) Parameterise upper ocean physics, surface fluxes, atmospheric mixed-layer physics (D) Capacity development.

Debasis Sengupta

Hypotheses:

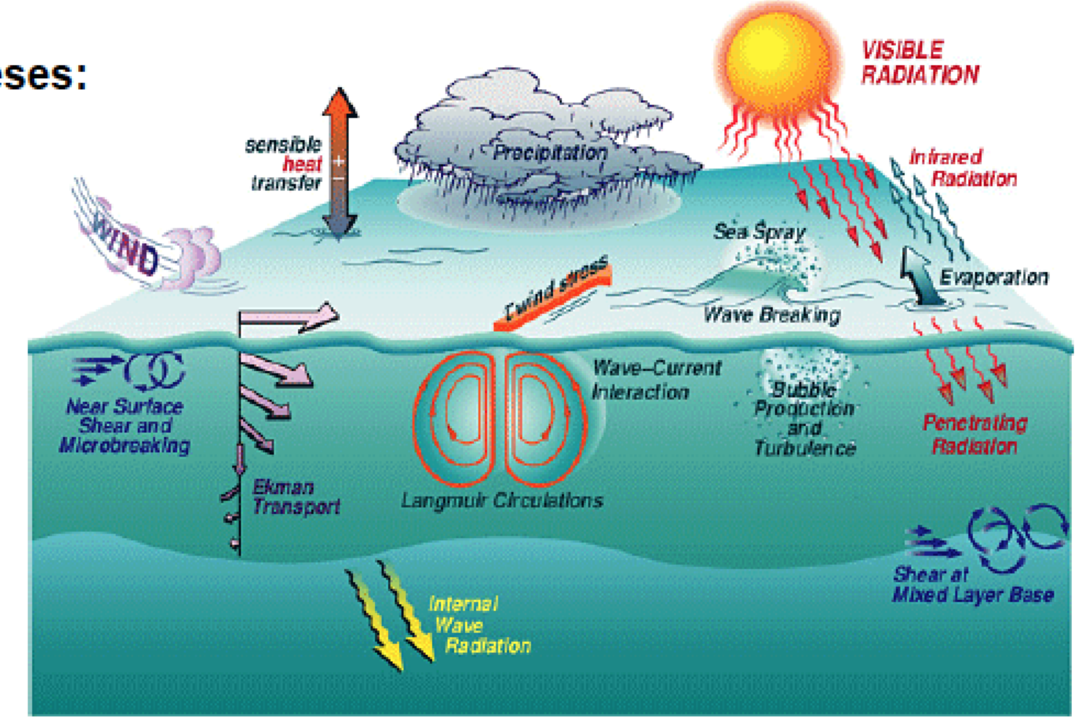


Figure: WHOI

Surface fresh layer in the north Bay is shallow due to tilting, slumping of multi-scale salinity fronts, barrier layer warmed by solar penetration

Air-sea gradients & fluxes depend on 3-d processes in atmos./ocean mixed layer; shallow ocean surface layer & atmos. stability determine transition from shallow to deep convection north of monsoon ITCZ.

Debasis Sengupta

- ***Main Science Issues/Questions:***
- **Pathways, persistence, balance of freshwater**
- **Physics of thin, fresh upper layer, salinity fronts**
- **Key processes of upper ocean stratification/mixing and balances**
- ***Consequences of shallow, fresh upper layer and deep, warm subsurface layer for air-sea coupling***

- **Causes of unique near-surface air-sea gradients**
- **Surface flux algorithms/parameterisation**
- **Local atmospheric mixed layer/ABL properties and stability, shallow-deep transition of monsoon convection**
- ***Coupling of ABL to upper ocean on synoptic to intraseasonal scales***

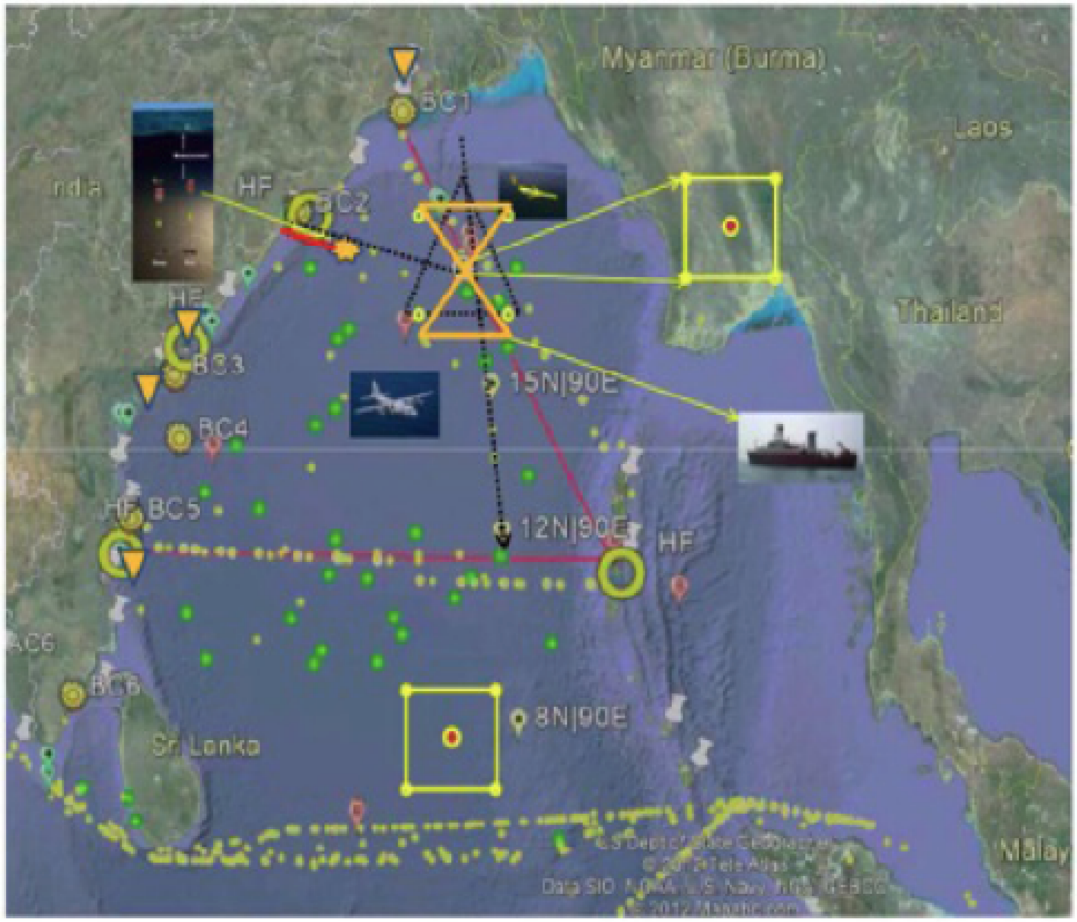
Approach:

Synthesis of multi-scale 3-d observations with process models

Large-scale air-sea interaction with regional models

Parameterise fine-scale near-surface processes in GCM's

Debasis Sengupta



OMM Observations 2013-2016

Ships, Moorings, UCTD, Upto-Surface Argo Floats, Drifters, Gliders, Lagrangian floats, Wirewalker, Turbulence probe, Possibly Aircraft & Radar

Debasis Sengupta

OMM: is now approved for funding!

18-month focus: Equipment acquisition, first deployments, Training of personnel in India (travel and local hospitality for US trainers will be covered by MoES) and US (150 man-months of training time in the US for the project). Pilot cruises 2013/2014 Laboratory for autonomous instruments

IOP (2015-16): Ship time 5-6 cruises 15-20 days each, smaller craft for coastal/EEZ work.

Instrumented aircraft time for atmospheric boundary layer

International collaboration outside EEZ: US Partners WHOI, Scripps, U. Washington, U. Massachussetts .... to train and work with young Indian scientists/PhD students

Co-ordination with other Bay of Bengal nations under IIOE (?)

Debasis Sengupta

Pilot: Things We Know

Dates

Leg 1:

November 8	Mobilization
November 12	Embark
November 29	Disembark/Offload

Leg 2:

December 1	Embark
December 13	Disembark
December 14	Demobilization

Components

Survey
Process
Training-Exchange

Resources

Turbulence Gliders
Spray and Seagliders
Shipboard Assets: uCTD, CTD, HDSS, ADCP
Wire-walkers, Spar buoy
Other: Argo, RAMA, etc.

Coordination with Sri Lankan and Indian Efforts

Pilot: Survey Leg 2

November 28	Embark
December 13	Disembark
December 14	Demobilization

How do we best use the available resources to differentiate small-scale mixing processes that contribute to the flux of heat and freshwater in the Bay of Bengal?

Motivation

We would like to understand the heat and freshwater distribution in the Bay of Bengal at small-spatial scales, given large-scale gradients associated with forcing (e.g., large source of freshwater input, heat fluxes, and wind forcing) and small-scale mixing processes (both lateral and vertical).

Specific Goals

- measure NS variability in atmospheric conditions, upper layer properties, and vertical mixing
- resolve sub-mesoscale and larger features using Doppler sonar, uCTD & chipod CTD
- training-exchange with Sri Lankan/Indian colleagues
- include a “southern” process study to compliment first leg
- marine mammal observations

Technique

- NS survey line using uCTD (4 km resolution)
- Underway systems (x-band, met sensors, flow through, Doppler, echosounder, etc.)
- CTD stations (to roughly 200 m), repeat with optics and chipod CTD
- Small Process Study ('Southern' Turbulence Glider Station, 12N)
    - Drifters (5, 15 m drogue) (small scale grid deployment)
    - Thermistor Chains (?)
    - Rapid small-scale survey with shipboard resources (tow-yo CTD or VMP)

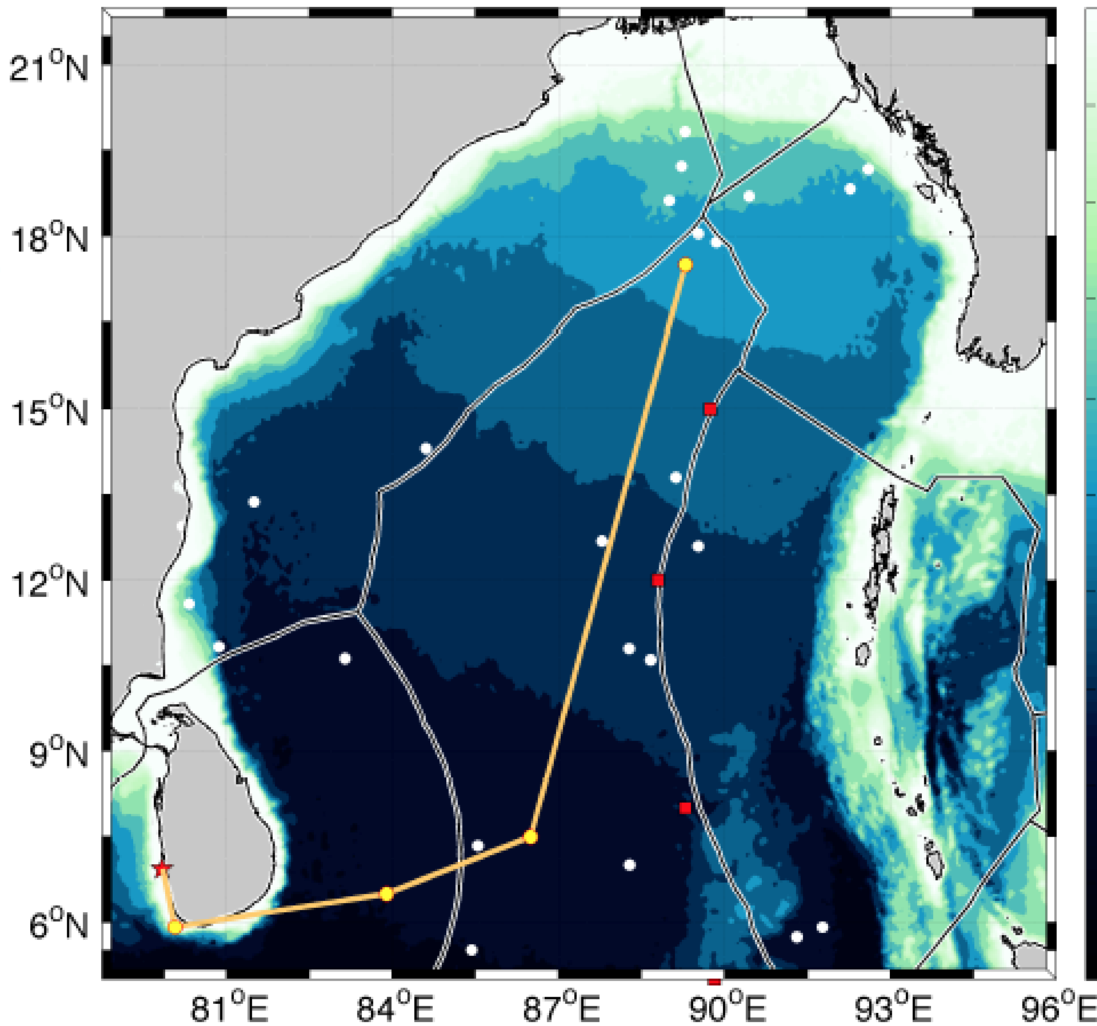
What we can expect to get

- wavenumber content in the NS direction
- variability in mixed layer and barrier layer properties
- high resolution sampling over the large scale gradient
- variability in vertical mixing as a function of ML/BL properties
- comparison point to the northern process study

Survey Component (15 days at Sea)

This is not the actual transect line, but is representative of distance we can cover!!!!

3.25 day RT commute to Colombo
2.5 days for CTD (60-80 stations)
2.5 days for southern process leg
6 days of uCTD (1300 nm)
0.75 days Recovery of Glider



Process cruise planning

co-Chief Sci: D. Lucas and J. MacKinnon

Current UNOLS ship schedule dates, leg I:

Mobilization (Colombo): 8 November
Depart: 12 November
Demob. (Trincomallee, tentative): 27 November

Process cruise motivation:

Investigate small vertical and lateral scales, temporal evolution of salt, heat, buoyancy fluxes, vorticity from combination of drifting WW array and ship survey (Impact of submesoscale on lateral and vertical FW/buoyancy exchange).

Interaction with Sagar Nidhi in northern region (~17-18N) of strong FW lateral gradients. Inter-comparison of shipboard instrumentation (met/ radiometers, uCTD, underway systems), LatMix style two ship operations

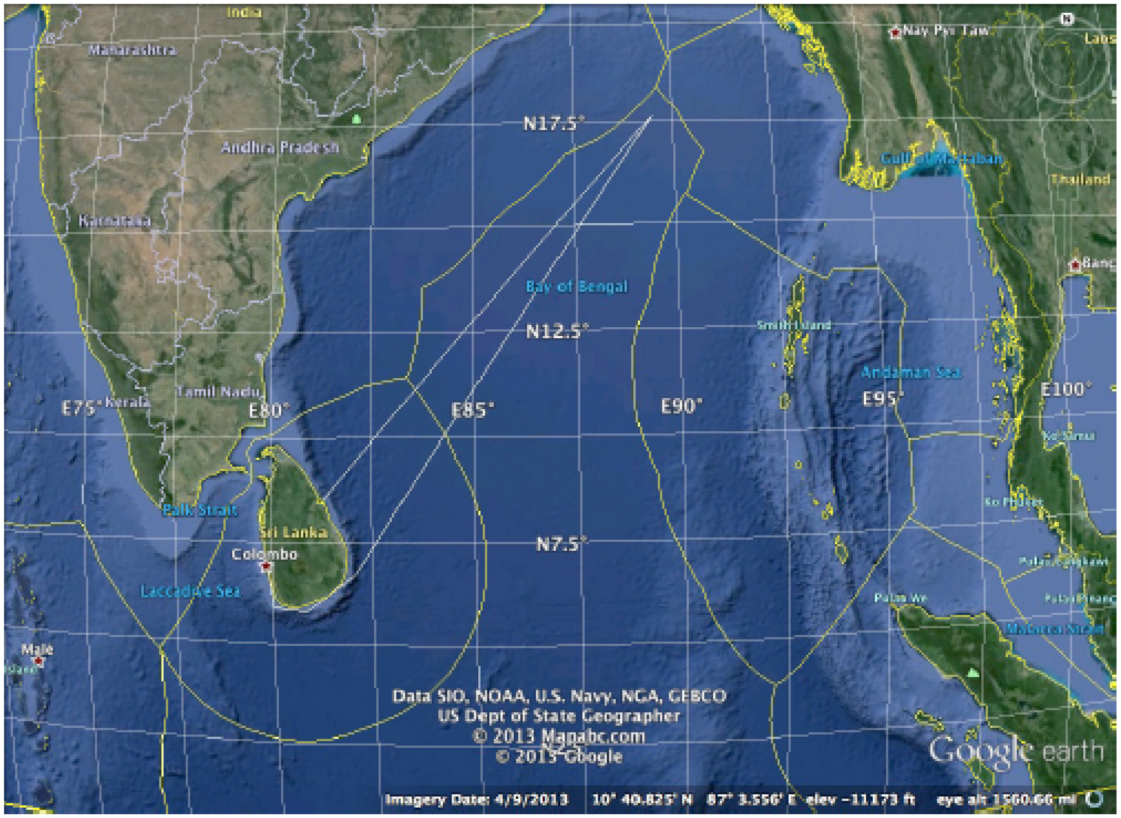
Training opportunities for students/colleagues.

Refine drifting array management/reseeding techniques.

Maximize science time given long transits to international waters/ water of interest.

Process cruise planning

co-Chief Sci: D. Lucas and J. MacKinnon



15d leg I: 7 days transit Colombo to 18N to Trinco = 8 science days

Approximate break-down: 2-3d for Seaglider, Spray, Slocum, ASIS deployment/recovery. 5-6d for “active-phase” process study

Nominal tasks: Process cruise

Pre-cruise: Utilize remote sensing (Aquarius, MODIS, Indian platform, SAR), models (NRL, Harper?), Sagar Nadhi schedule, identify likely region of strong small-scale lateral gradients (far north international waters).

Transit (4 d) to ~17-18N, deploy autonomous assets:

1) Long-range gliders (Spray, Sea Glider)
2) "Vertical time-series" Slocum turbulence glider (~12 N, to be recovered end of leg II, approx. 28d deployment, Lou: thoughts?)

Process study location (8 d): uCTD survey (Revelle X-band?) to identify gradient of interest.

Deploy Slocum turbulence
Deploy ~5 Luca drifters (15m drogue)
Deploy WW/spar array
Deploy ASIS
Commence uCTD sampling around array (10km box, nominal)
Tend array, re-seed as necessary (~1d^-1)
VMP (?)
Nested survey with Sagar Nidhi
Recover ASIS

Steam to port (3d)

Process cruise: Toolkit

co-Chief Sci: D. Lucas and J. MacKinnon

name	**variables**	**cast freq.**	**nominal depth**	**vertical res.**	**horiz res.**	**notes**
uCTD	S,T, P	10 min	200m	1m (??)	1 km	(at 3.2 knots, nominal)
WW 1	S, T, P, Fl, χ, dO2, PAR, u, v, w, ζ^z	15 min	150m	10cm	2km	Line of sight real time data transmission. Horizontal res. and ζ^z refer to the vort. array.
WW 2	S, T, P, Fl, χ, u, v, w, ζ^z	15 min	150m	10cm	2km	Horizontal res. and ζ^z refer to the vort. array
Spar buoy	T, u, v, w, ζ^z	N/A	100m	1m (300 kHz), 0.25m (1200 kHz)	2km	1200 kHz upward looking ADCP deployed at 20m, 300 kHz upward looking deployed at 100m. Horizontal res. and ζ^z refer to the vort. array
Slocum glider (2x)	S, T, P, microstructure, ?	?	150m	<1m	?	Need Lou's input
Shipboard CTD/rosette	S, T, P, Fl, χ, dO2, nitrate (?), optical	Irregular	200m	<0.5m	N/A	Irregular casts as needed for water sampling (dO2 calibration, nutrients, etc.)
HDSS	u, v, w	1 min	0-250 m, 0-1000 m	6 m 20 m	300m-1000m	
WW 3	T, P	N/A	30m	10cm	N/A	Training WW unit for collaborators, students.