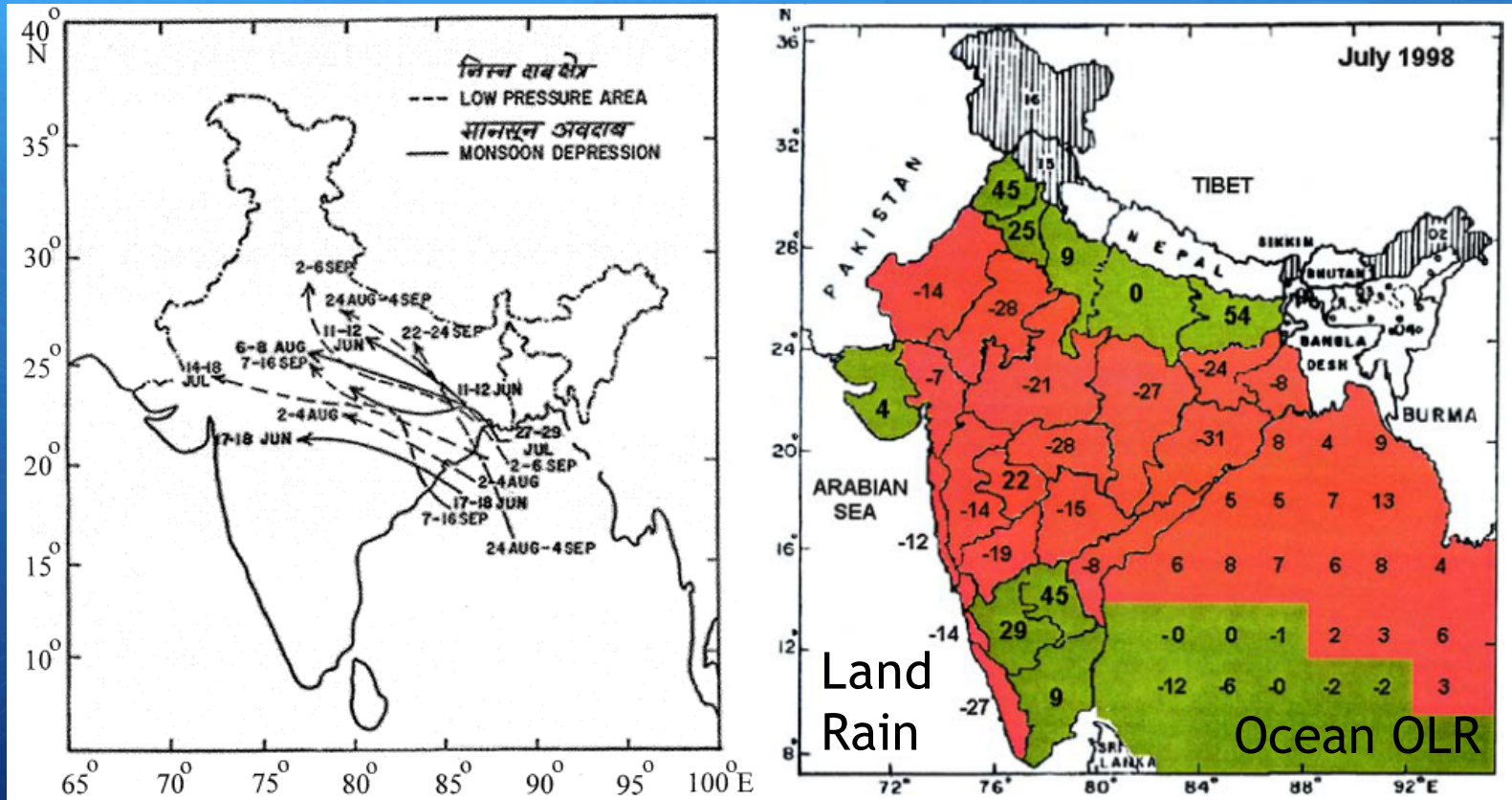




# Variability of the surface circulation and associated freshwater fluxes in the Bay of Bengal

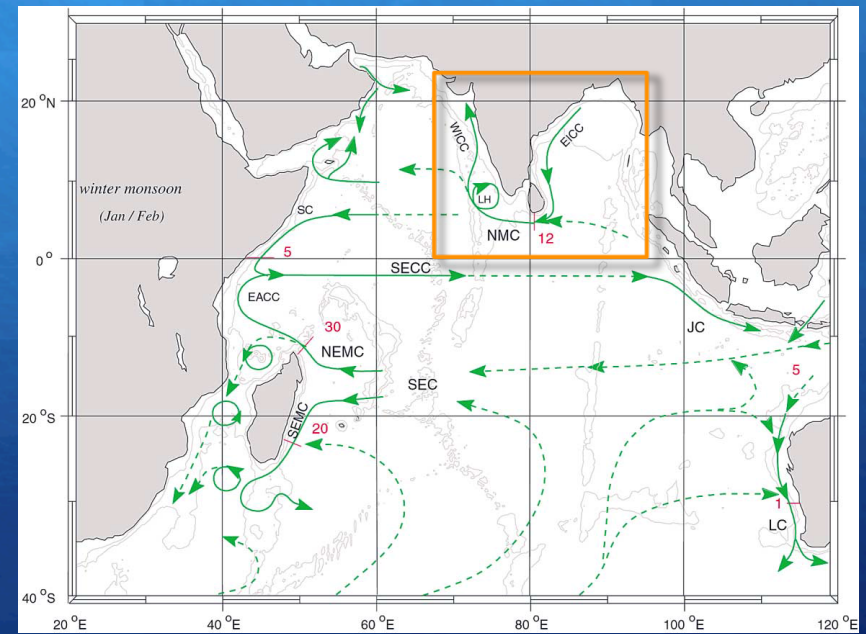
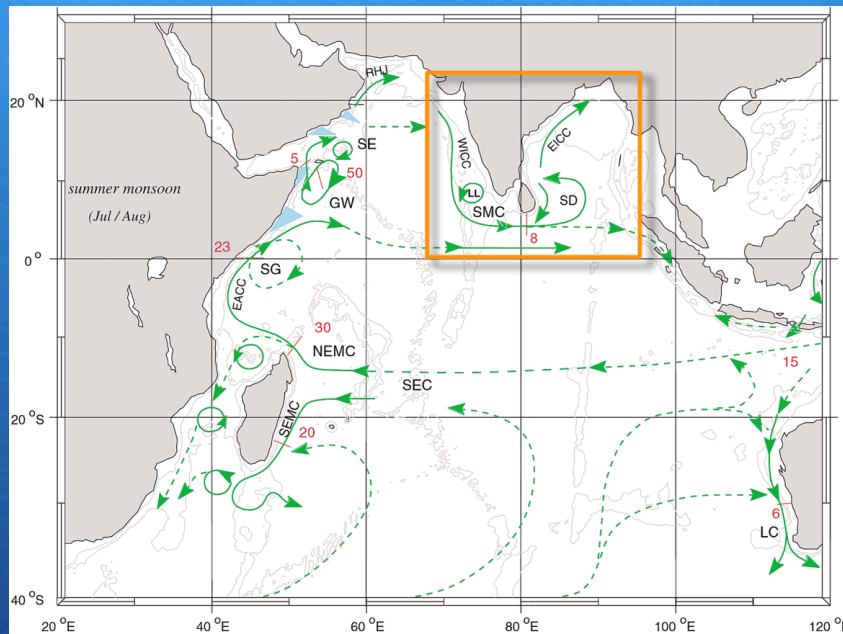
Verena Hormann & Luca R. Centurioni  
[vhormann@ucsd.edu](mailto:vhormann@ucsd.edu)

# Indian Ocean monsoon



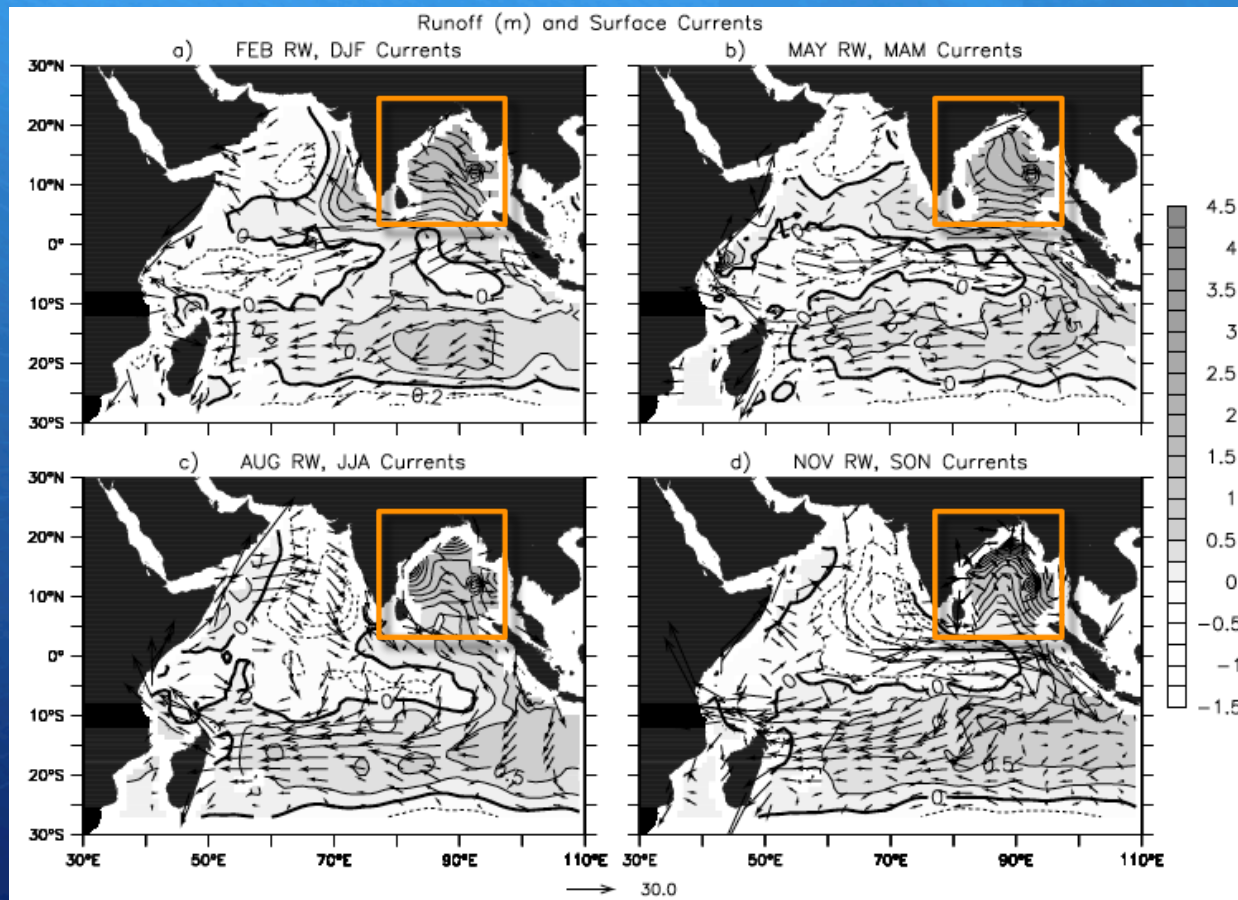
➤ Monsoon drastically affects life on Indian subcontinent, making its understanding and prediction of great importance

# Monsoon circulation



- Circulation of the Indian Ocean switches direction annually under the influence of the southwest/northeast monsoon during boreal summer/winter

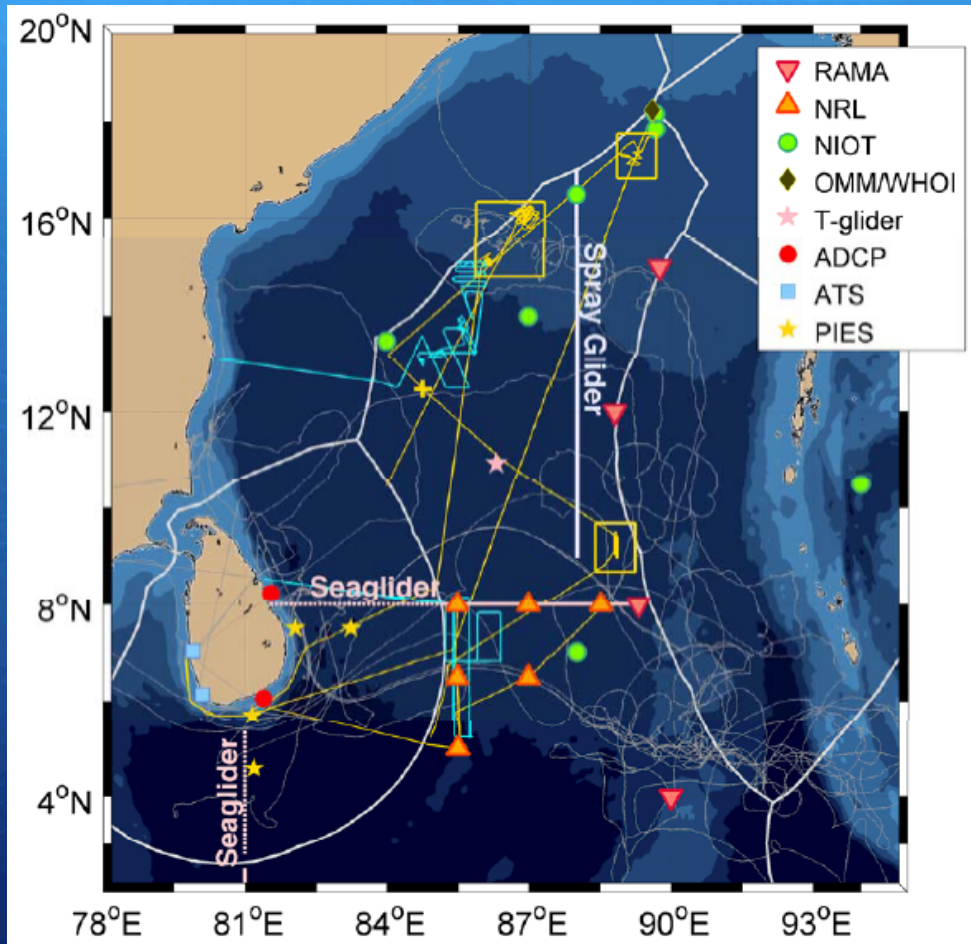
# Surface freshwater



15-m velocity vectors from drogued drifters

- Quantifying upper-ocean variability in the Bay of Bengal (BoB) challenged by large freshwater input from river runoffs and rainfall

# ASIRI initiative



Air-Sea Interactions in the Northern Indian Ocean observational program

- Monthly deployments of Surface Velocity Program (SVP) drifters off Sri Lanka between 05/2013 and 09/2015
- Deployment of 36 salinity drifters (SVP-S) during 2015 field campaign in Aug./Sep.

# Scientific objectives

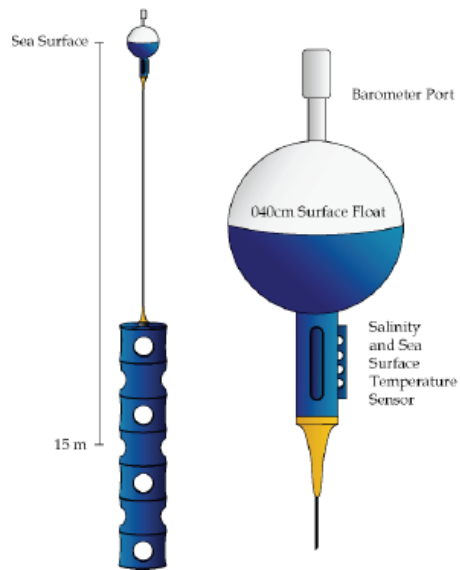
- Identify unknown/constrain known circulation patterns in the BoB, particularly along the east coast of India and around Sri Lanka
- Quantify horizontal salt fluxes
  - Terms related to the horizontal advection of salt can be directly measured with drifters
  - Comparison of drifter-derived and satellite-/model-based mean and eddy salt flux divergences
  - Question: Is  $\langle U'S' \rangle$  reproduced realistically by models?

$$\underbrace{\left\langle \frac{DS}{Dt} \right\rangle}_{\text{drifter}} = \underbrace{\left\langle \vec{U} \right\rangle \cdot \nabla \langle S \rangle + \left\langle \vec{U}' \cdot \nabla S' \right\rangle}_{\text{satellite/model}}$$

# SVP/SVP-S specifications

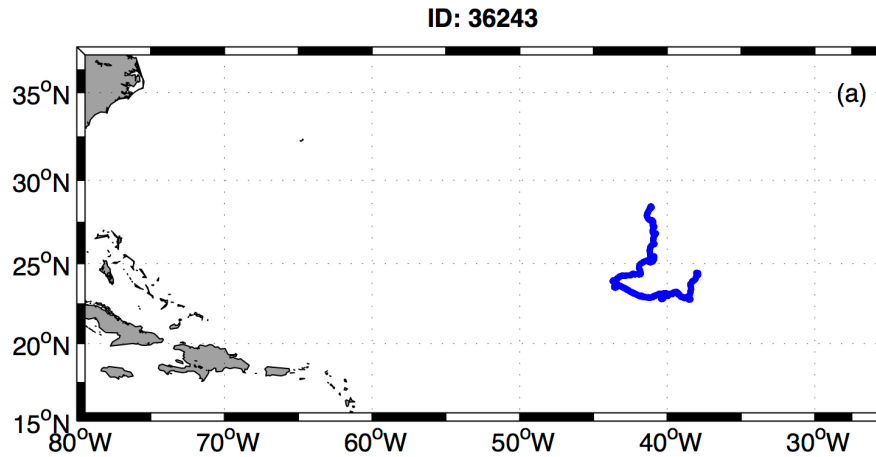


Salinity Drifter

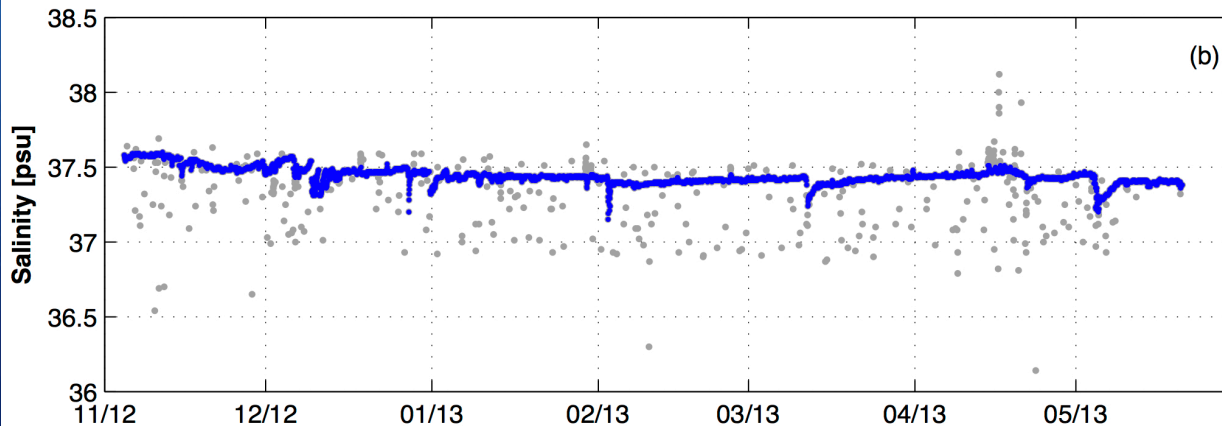


- Argos telemetry and fixing (acc.: 150-1000 m) or Iridium with GPS (acc.:  $\pm 50$  m)
- Drogue on/off sensor: strain gauge
- Lagrangian currents at 15 m
- Sea Surface Temperature (SST)
  - Thermistor:  $\pm 0.05-0.1$  °C
- Salinity (S) at 0.5 m
  - Standard sampling: every 30 min.
- SBE37-SI (unpumped, poisoned cell)
  - Conductivity:  $\pm 0.0003$  S/m
  - Temperature (T):  $\pm 0.002$  °C
- Air pressure (optional):  $\pm 0.5$  hPa
- Endurance: ~ 1-2 yrs

# SVP-S issues



Salinity Processes in the Upper Ocean Regional Study (SPURS)



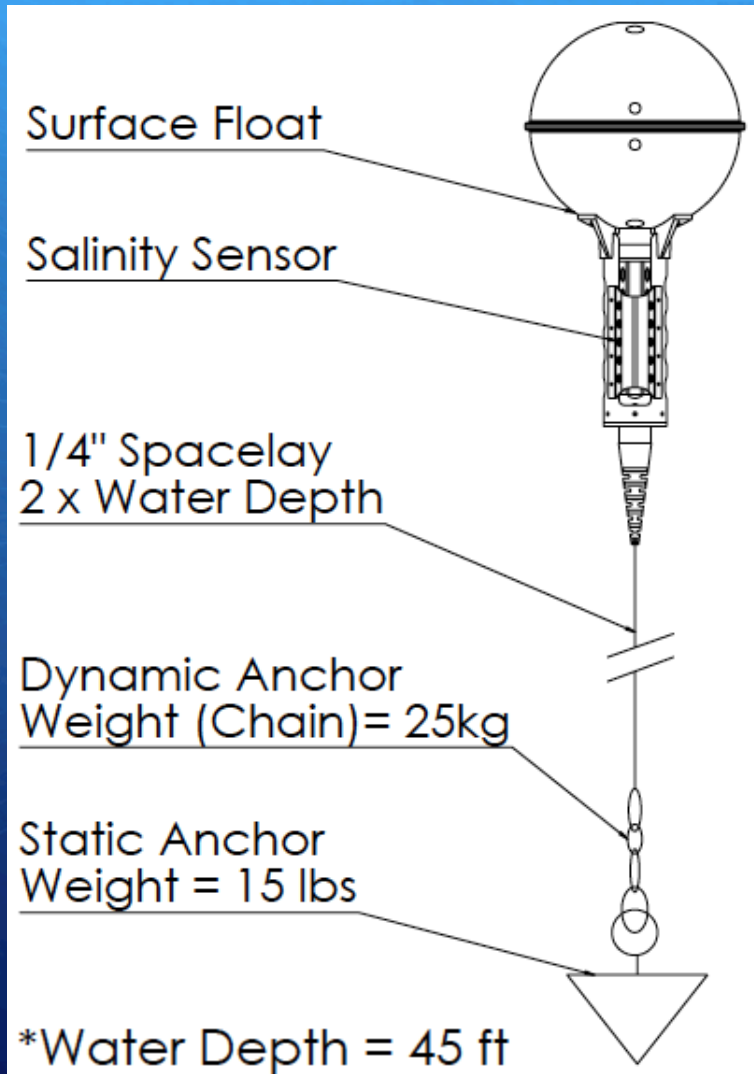
➤ Averaging sampling mode introduces fresh bias in the salinity noise level

➤ Bias most likely due to air bubbles within the measuring cell



# SVP-S revision

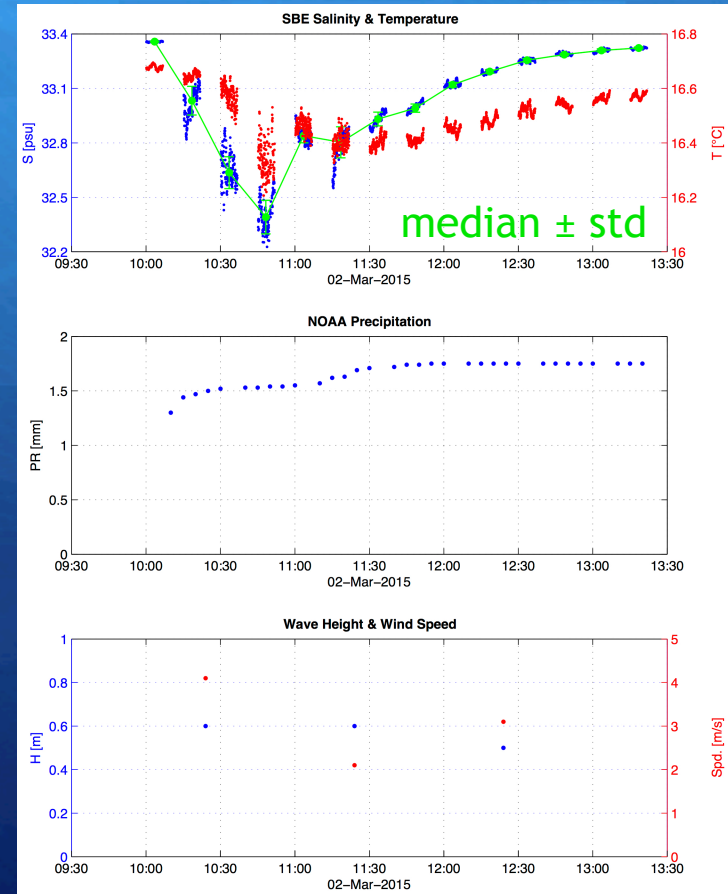
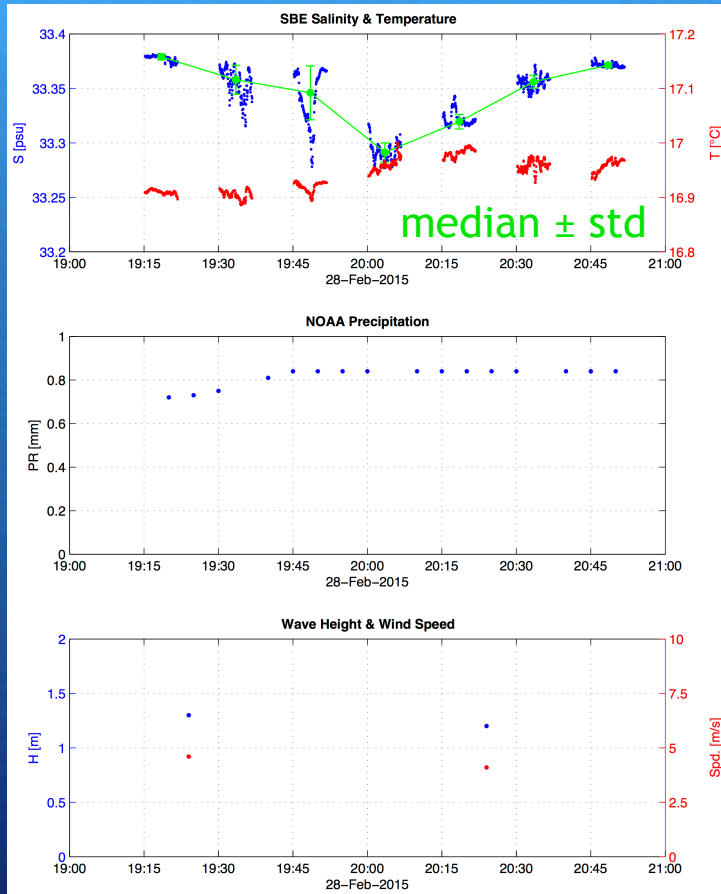
- Revision of SVP-S sampling algorithm needed to enable onboard filtering of incorrect salinity measurements



# Test mooring

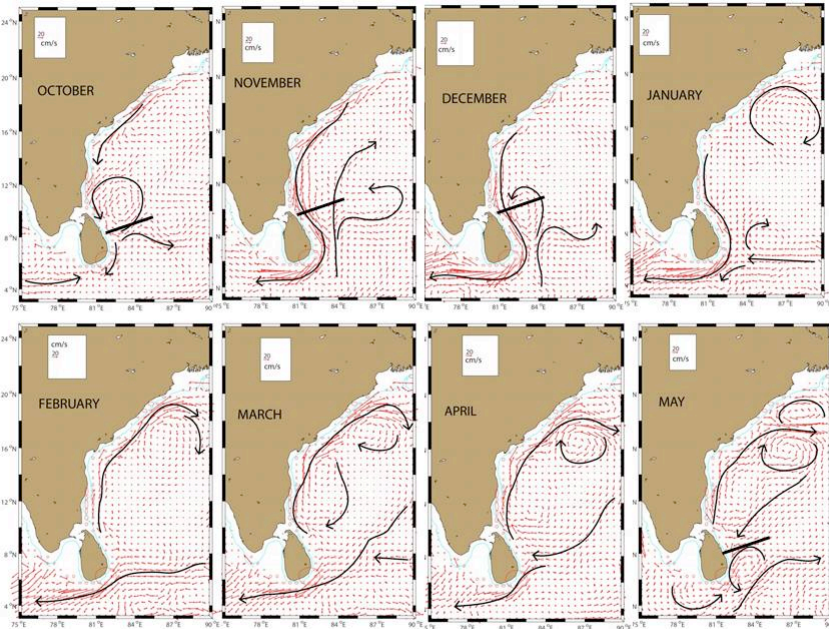
WaveNet

WaveNet

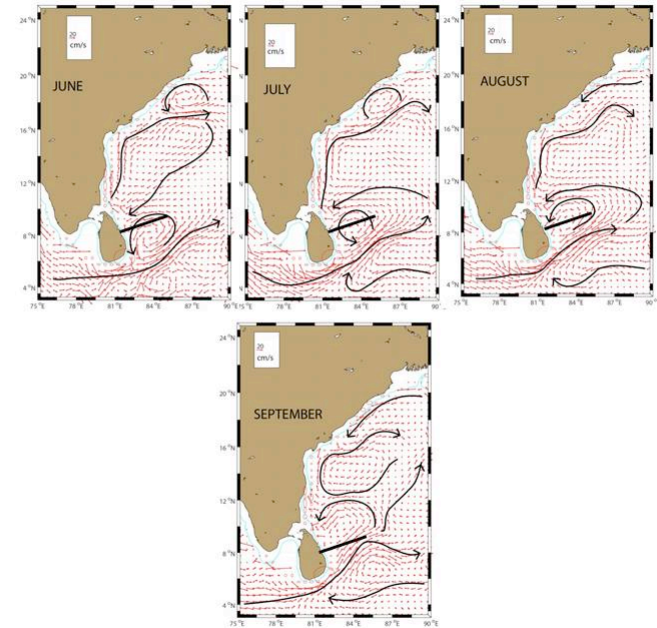


➤ Note the high-frequency interval sampling (161 vs. 5 in SPURS) and air-bubble noise

# Surface circulation



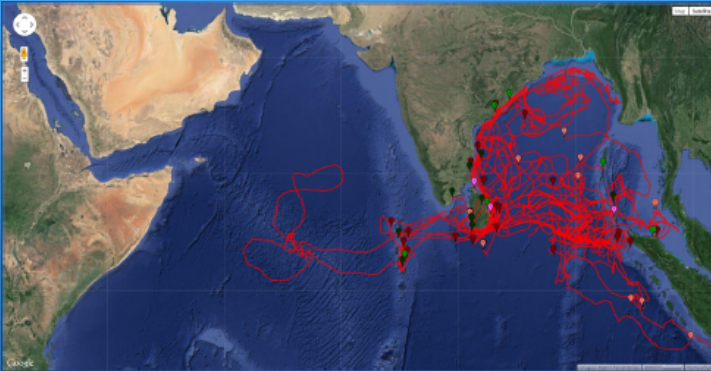
Surface circulation (drifters+altimetry). Monthly average. 1992-2012.



Surface circulation (drifters+altimetry). Monthly average. 1992-2012.

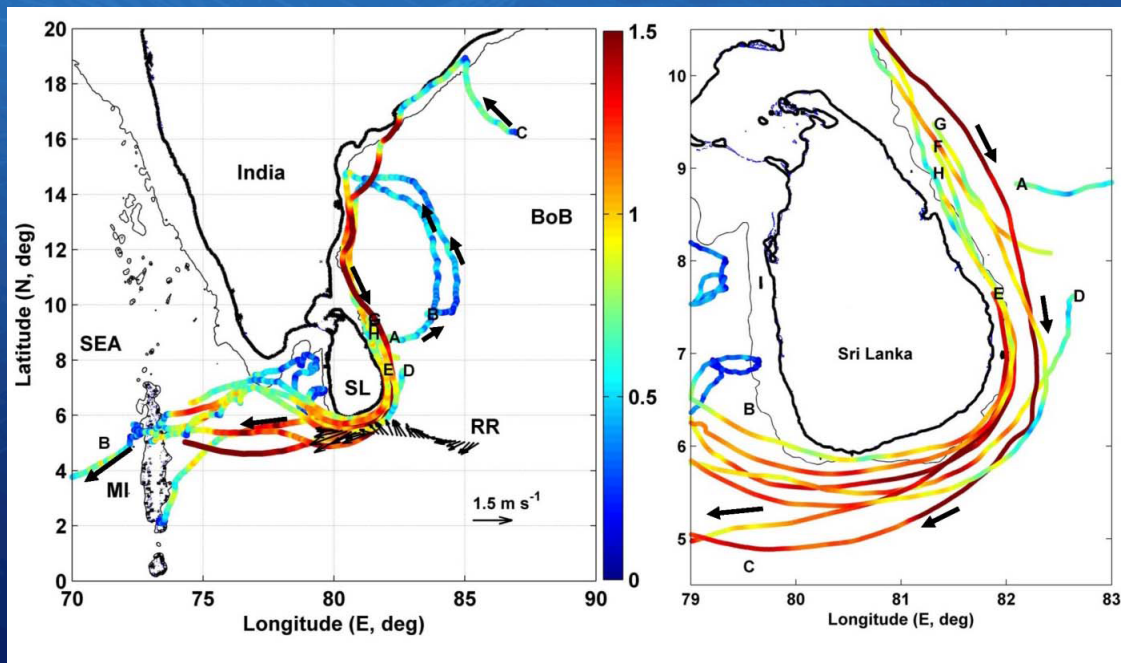
- Seasonally reversing pattern of near-surface currents in the southern Bay of Bengal, with the East India Coastal Current (EICC) flowing southward during boreal winter

# Sri-Lanka deployments

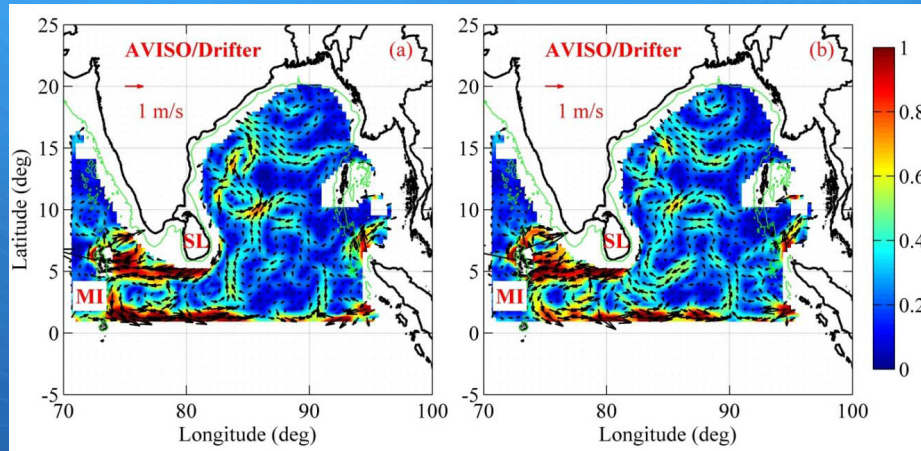


Tracks of 64 SVP drifters deployed in 2013-14

- Drifters can be quickly injected into the EICC and exported out of the BoB indicating a possible pathway for interior freshwater export during the northeast monsoon

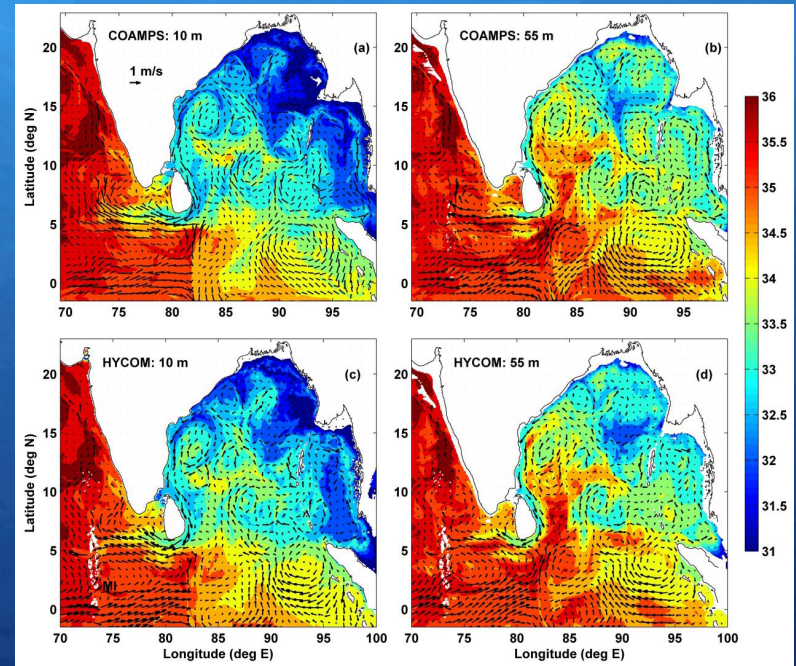


# Freshwater export



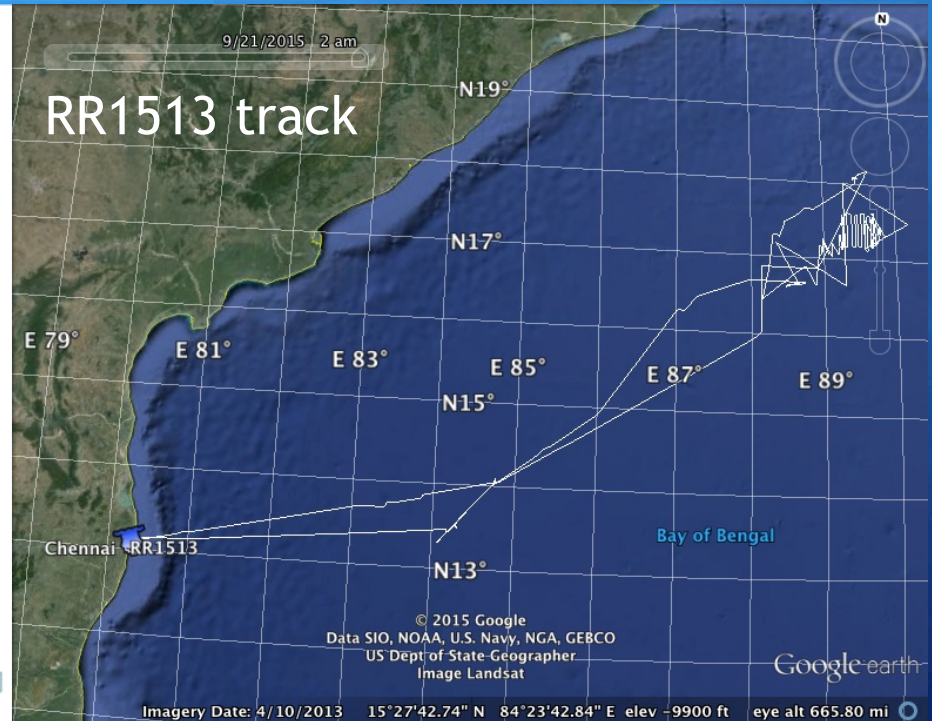
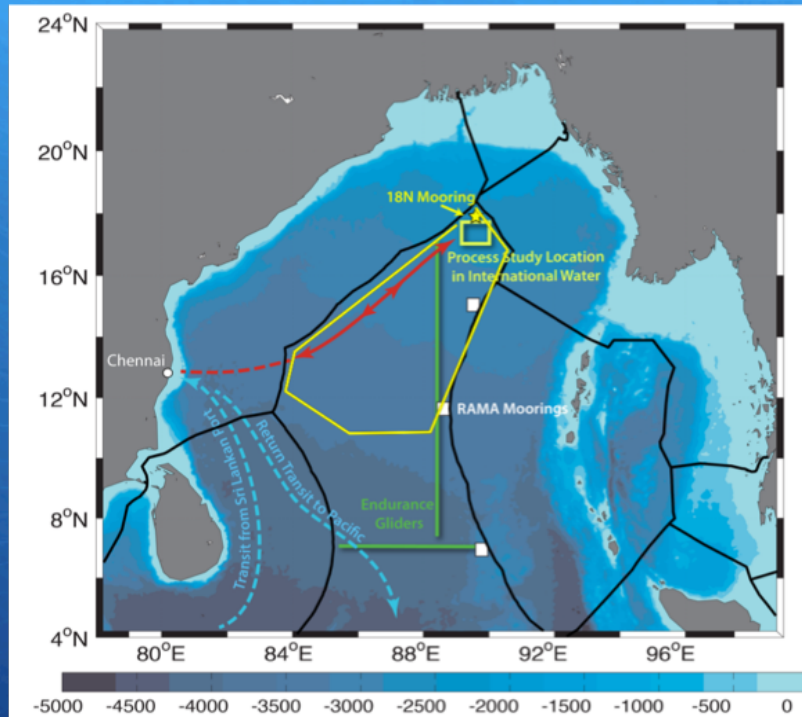
(Left) 15-m current vectors and magnitude

(Right) Model velocities and salinity [psu]



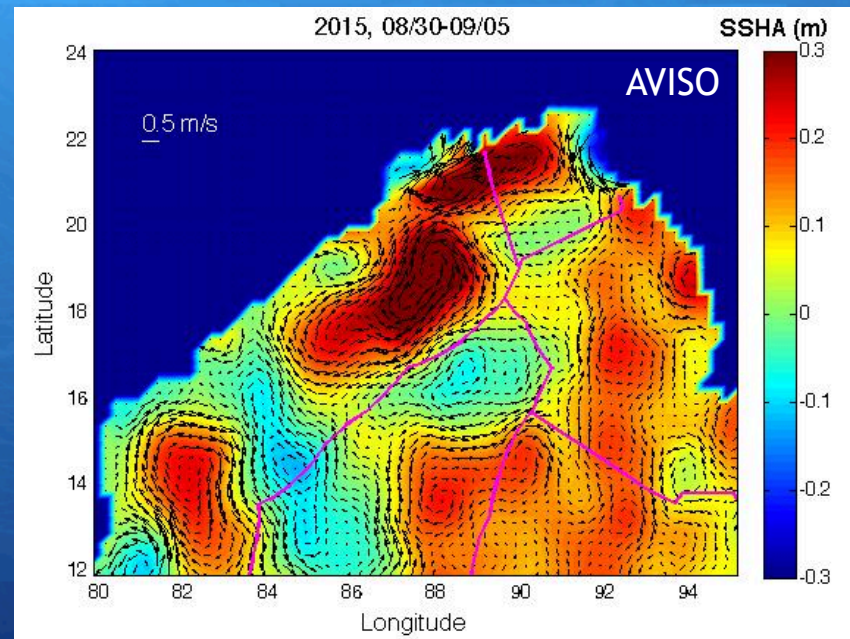
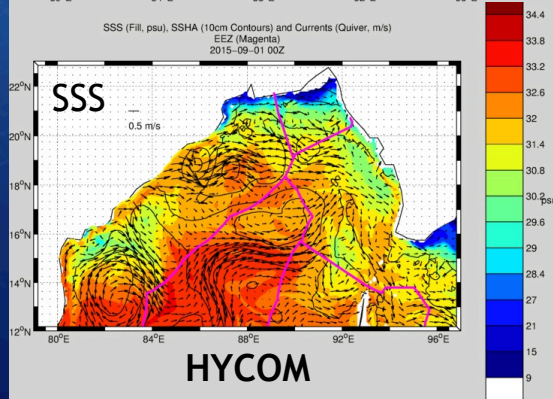
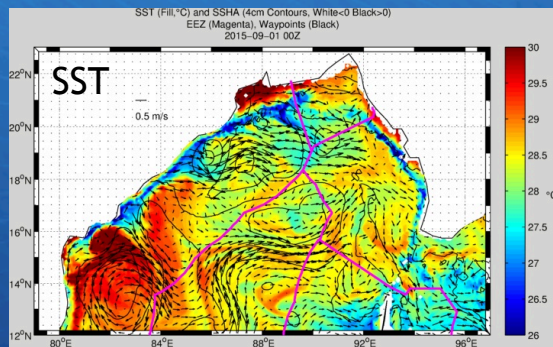
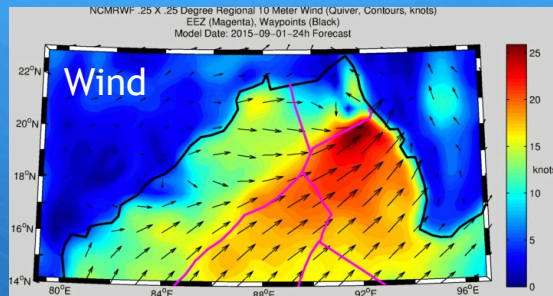
- Verification of plausible near-surface export pathways with satellite products (i.e., geostrophic plus Ekman velocity)
- Model results reproduce EICC freshwater export and suggest a northward subsurface salt transport to the east

# R/V Roger Revelle 2015



- Area of operations: International BoB waters from 23 Aug. to 21 Sep. 2015 during the waning southwest monsoon
- Experimental objectives: To capture the dynamics of freshwater and heat dispersion via submesoscale processes

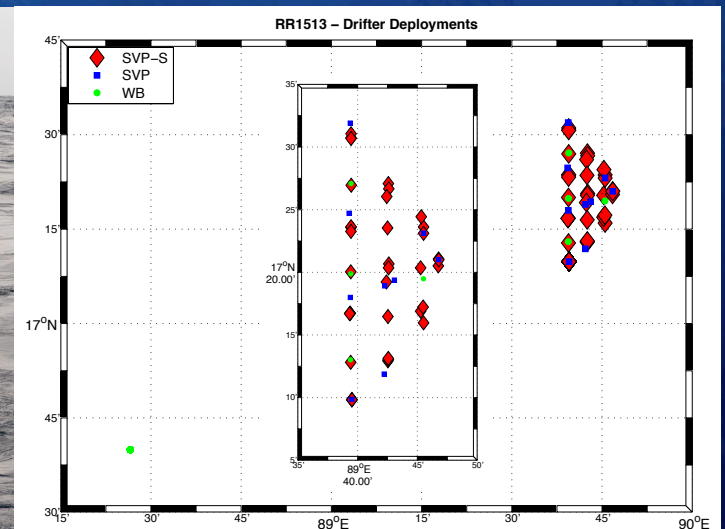
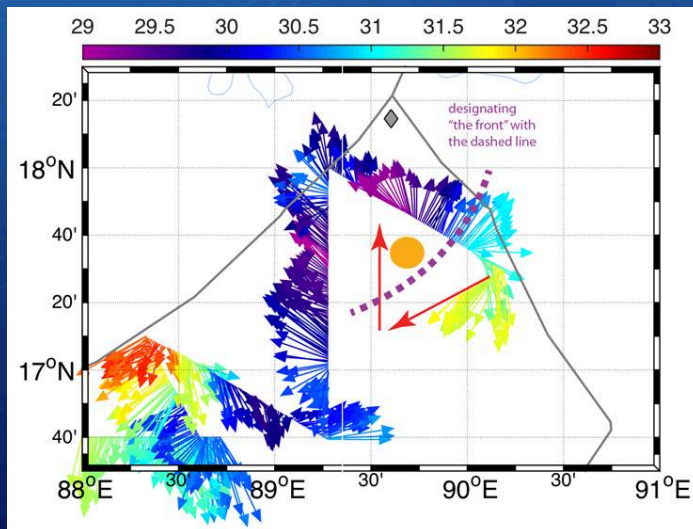
# Background fields



- Surface conditions prior to drifter deployments on 2-3 Sep. 2015
- Note the mesoscale feature and associated Sea Surface Salinity (SSS) between about 15-18°N

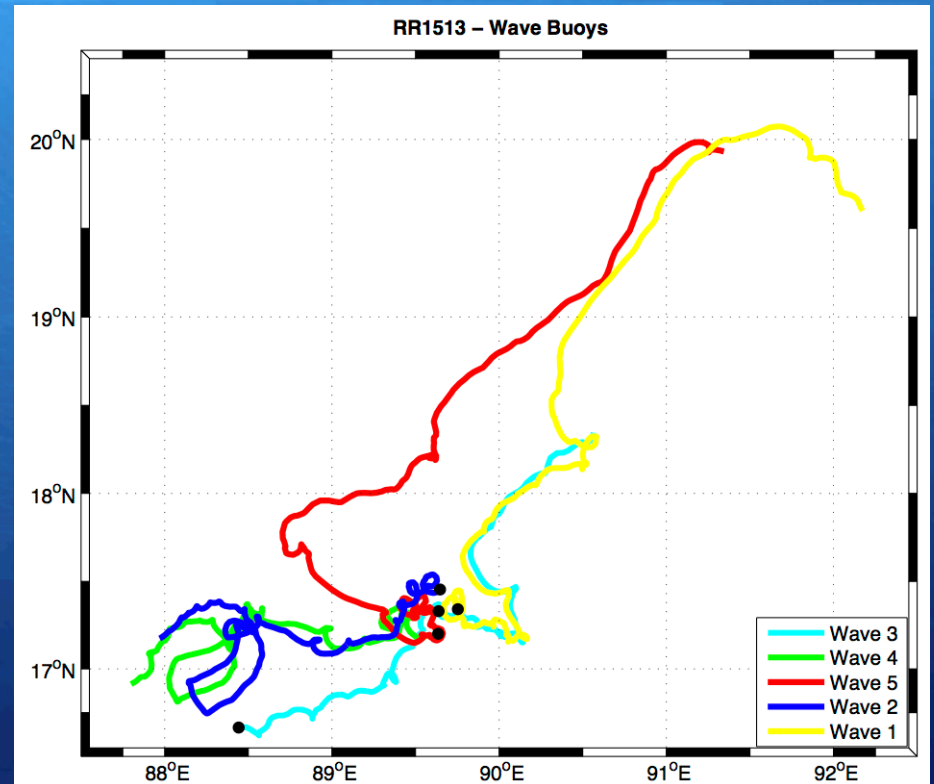
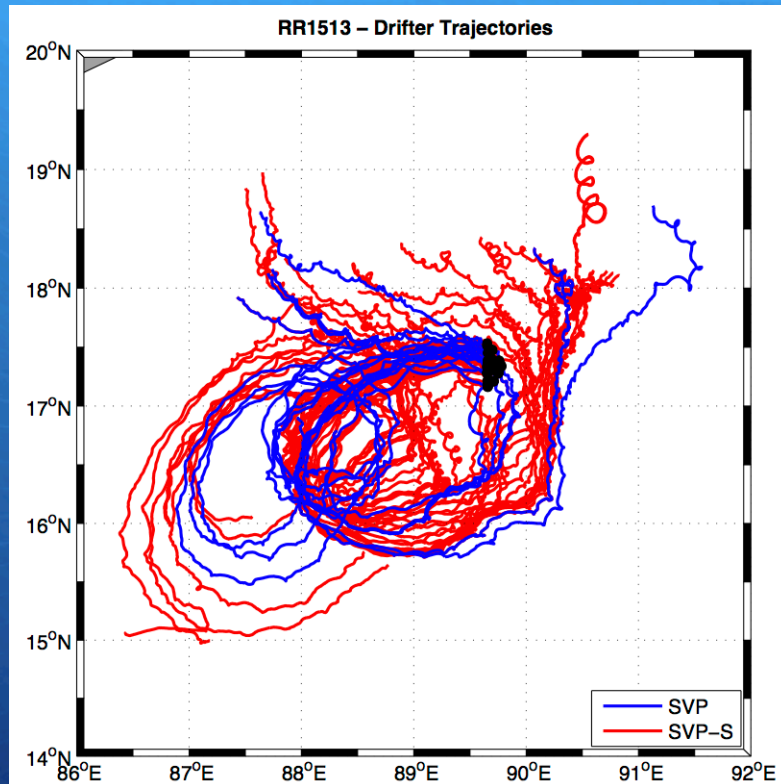
# RR1513 deployments

- Total deployment of 51 satellite-tracked drifting buoys (i.e., 36 SVP-S, 10 SVP, and 5 experimental wave buoys)
- Tight SVP-S/SVP array to sample a variety of spatiotemporal scales - particularly the lateral spreading of the freshwater - as the drifters disperse, with 5-min temporal resolution for the first month



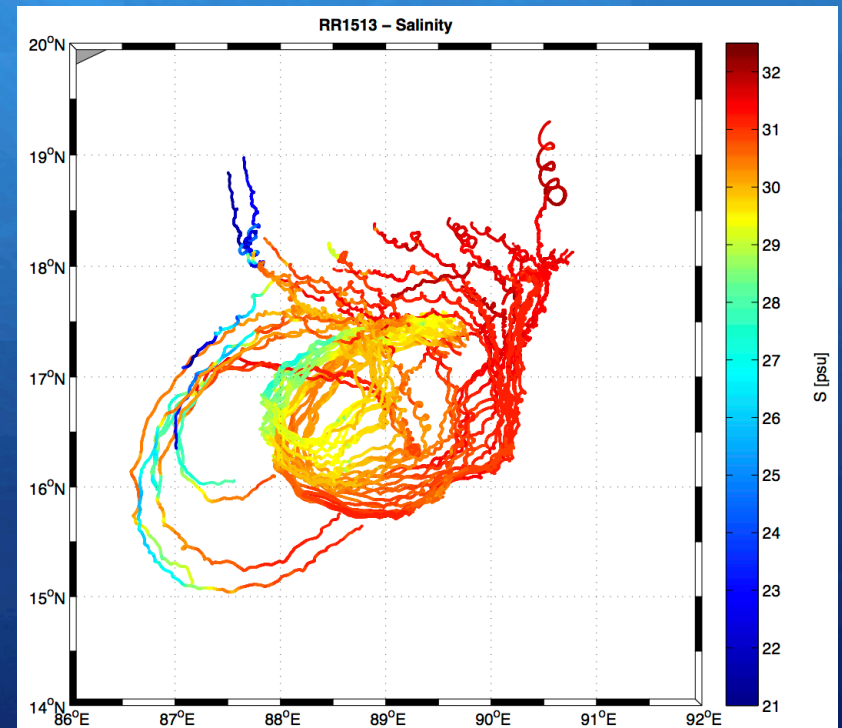
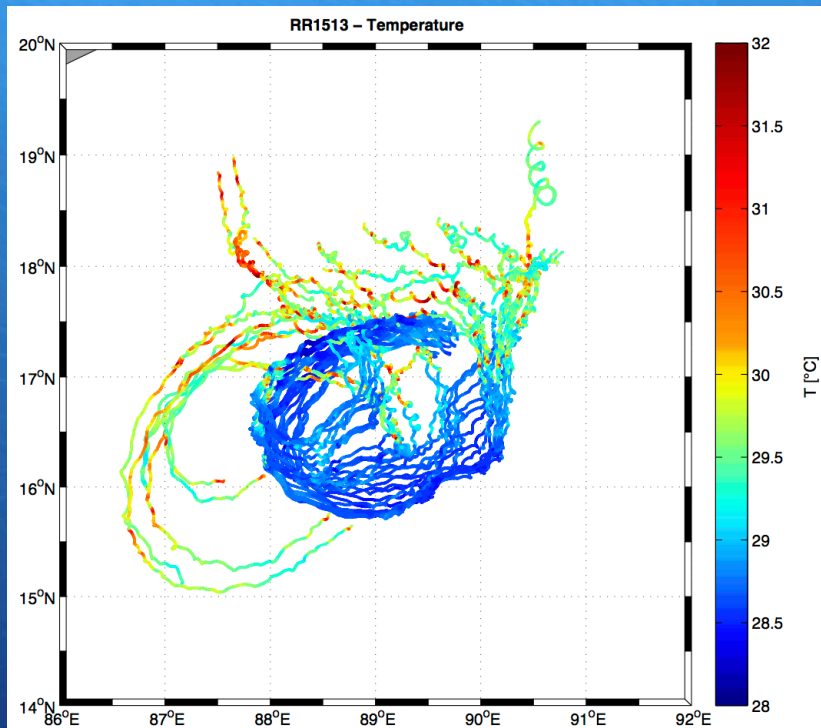


# Drifter trajectories



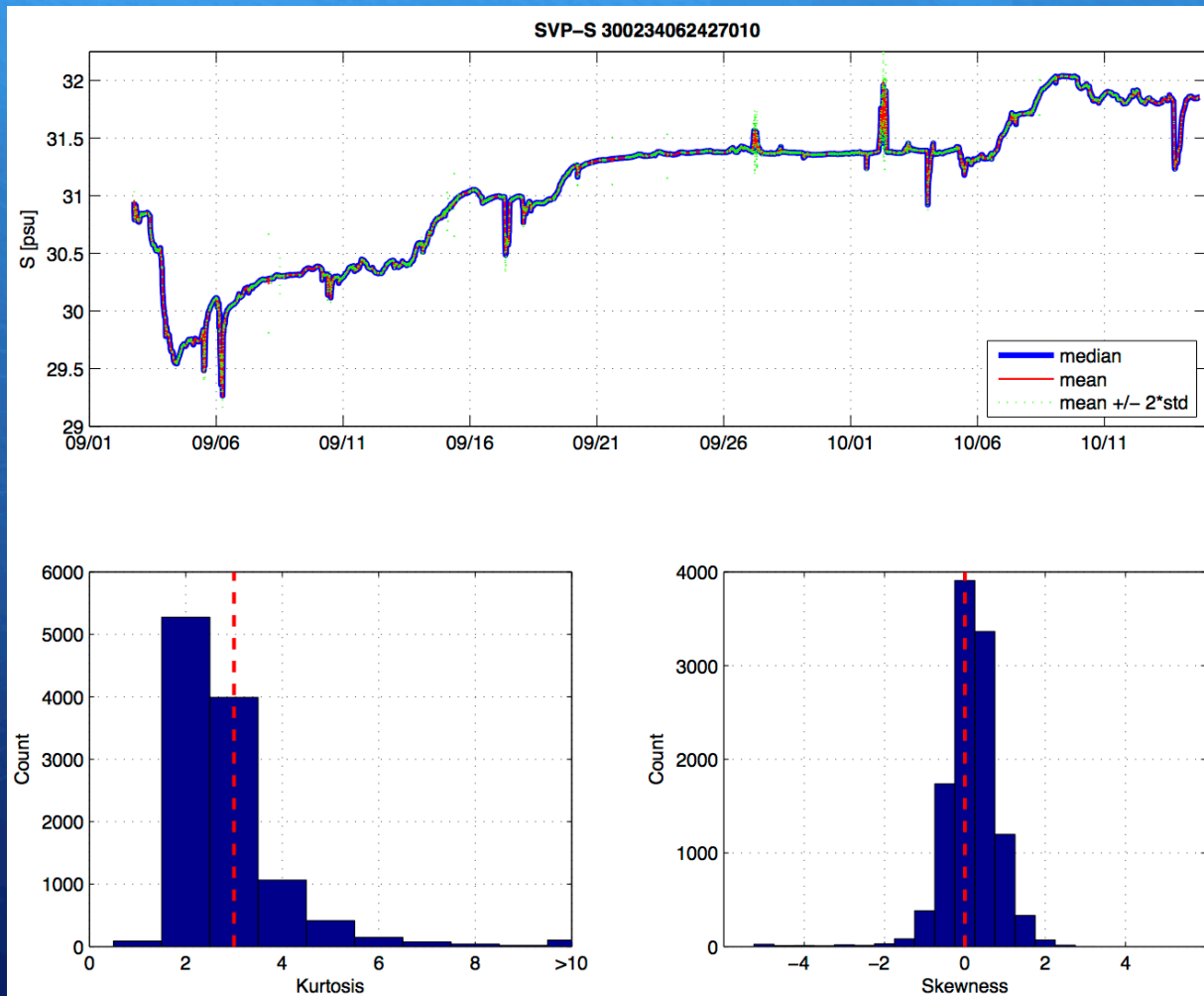
- SVP-S/SVP drifters largely follow a mesoscale feature during the first month, with indications of near-inertial oscillations
- Wave buoys are subject to wind-driven Ekman drift

# T/S measurements



- SVP-S drifters show large variability in temperature and salinity, particularly outside of the cyclonic eddy

# Data quality



- Transmission of statistical parameters (i.e., mean, std, kurtosis, skewness) as performance measure for the median salinity

# Summary

- First drifter deployments off Sri Lanka confirm a surface freshwater export out of the BoB by the EICC
- Model simulations indicate a northward subsurface salt transport into the BoB
- Promising new drifter dataset from 2015 field campaign to address near-surface salt flux divergences in the BoB (e.g., for data/model comparisons)

