

SST Control by Subsurface Mixing during Indian Ocean Monsoons

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Award Number: N00014-14-1-0236

LONG-TERM GOALS

We seek to understand the detailed evolution of heat and freshwater distributions in the Bay of Bengal, given large-scale gradients associated with forcing (e.g., large source of freshwater input, heat fluxes, and wind forcing) and small-scale mixing processes. Since sea surface temperature variations are broad spatially and vary over long time scales, we are using extended time series at a variety of locations to directly measure and assess SST modification by turbulent mixing over the broad expanse of international waters in the Bay of Bengal on diurnal to seasonal time scales.

OBJECTIVES

Our specific objectives are to:

1. quantify the variability in upper ocean mixing associated with changes in barrier layer thickness and strength across the BoB and under different forcing conditions,
2. quantify the subsurface heat flux divergence across the thermocline and through the barrier layer that contributes to changes in SST, and
3. contrast barrier layer character (e.g., maintenance, turbulent mixing, strength) associated with relatively weak but uniform freshwater pools (e.g., originating from distant storms and/or riverine sources) to that of strong, patchy pools created through local precipitation.

These objectives directly target the fundamental role that upper ocean dynamics play in the complex air-sea interactions of the northern Indian Ocean.

APPROACH

In short, our approach has been to augment as many platforms as possible with additional turbulence sensors (*χpods*) for the purpose of acquiring long-term, spatially spread mixing measurements. Specifically, we have

- 1) deployed 10 *χpods* on NRL moorings in the BoB (to be recovered summer 2015),
- 2) augmented the 12N RAMA mooring with *χpods* at 15 and 30 m depth (to be recovered fall 2014),
- 3) equipped Revelle and Sagar Nidhi CTDs with self-contained *χpods* during survey work in winter 2013,
- 4) constructed and shipped 9 *χpods* for deployment at 15, 30, and 45 meters on each of the 8, 12, and 15 N RAMA moorings for deployment fall 2014 (to be recovered fall 2015), and
- 5) constructed and shipped 6 *χpods* for deployment on the WHOI air-sea interaction mooring at 18 N in fall 2014 (to be recovered fall 2015).

PI Shroyer has taken part in both shipboard field seasons. Analysis from these efforts is underway. We are eagerly awaiting the return of the first moored time series.

WORK COMPLETED

Construction of new *χpods* and refurbishment of existing units have now been completed. All *χpods* are either currently in the water (12 N RAMA and NRL systems) or en route to deployment sites (other RAMA and WHOI mooring systems). A map summarizing existing and upcoming mixing measurements is shown in Figure 1. Moored data should start to arrive this fall with the turn around of the 12 N RAMA mooring.

The PI has participated in two ASIRI field cruises— November-December 2013 and June 2014. She was the lead Chief Scientist for the winter cruise and assisted in the summer 2014 cruise. CTD-*χpod* measurements were acquired throughout the 2013 cruise; and *χpods* were added to wirewalkers for the summer 2014 work.

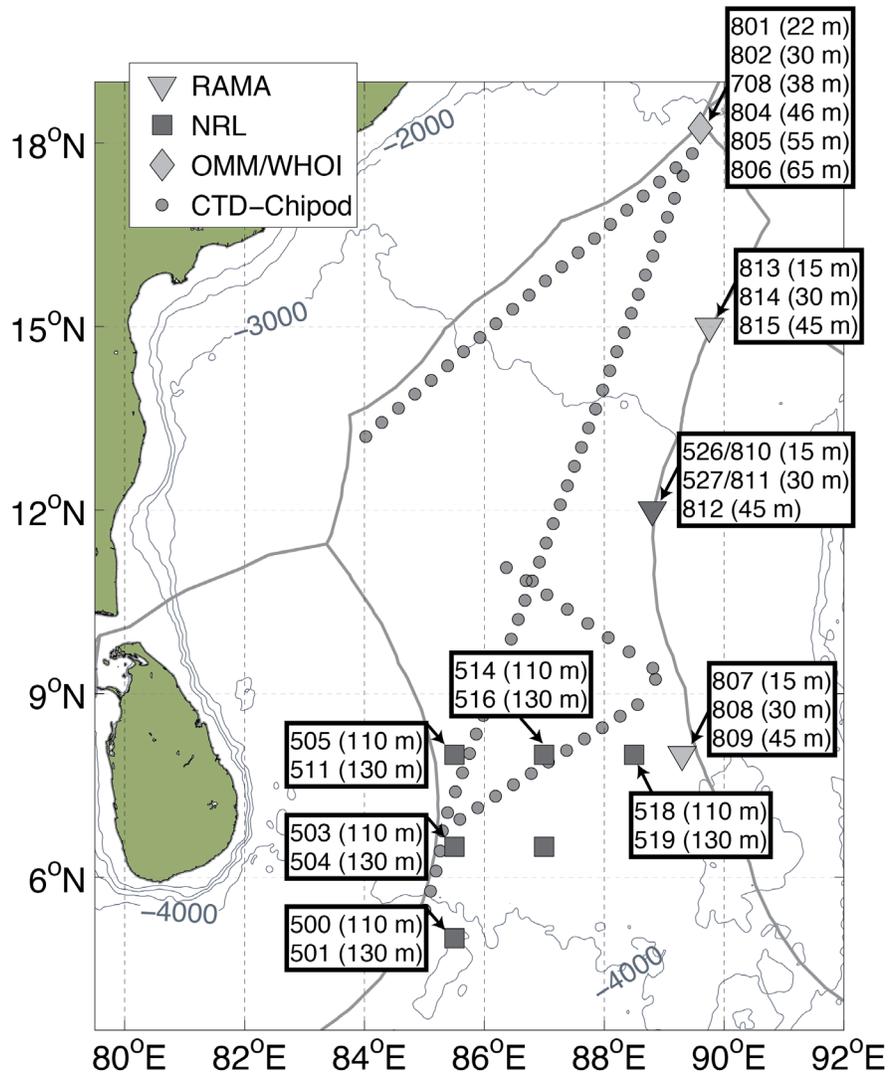


Figure 1: Map of existing (dark grey) and upcoming (light grey) χ pod deployments on moorings (RAMA-triangles, NRL-squares, and WHOI/OMM-diamond). CTD- χ pod stations that were collected during the 2013 pilot are indicated by circles. The RAMA mooring at 12N will collect a two-year data record with turn-around this fall. All other locations will span periods of 12-18 months.

RESULTS

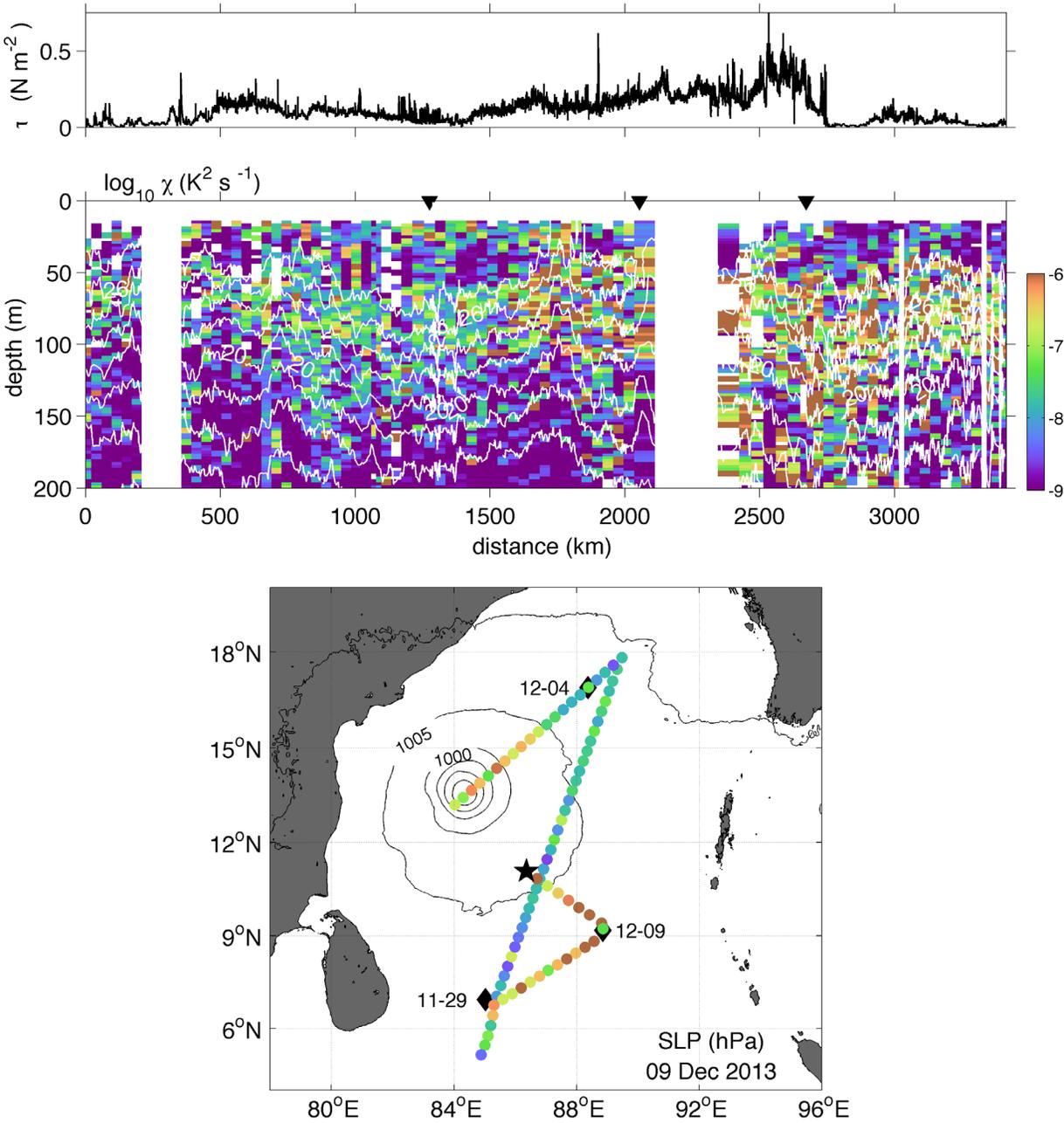


Figure 2: Wind stress as measured from the ship (upper panel), temperature variance dissipation rate (lower panel), and sea level pressure (courtesy Rashmi Sharma and Prashant Kumar) with average temperature variance dissipation in color (map).

CTD- χ pod data and turbulence glider measurements (Louis St. Laurent, WHOI) are being used to assess the mixing footprint of Cyclone Madi, a storm that developed and intensified during the 2013 cruise (Fig. 2). Mixing within the thermocline was relatively weak during the northward transit, and began to intensify (along with winds) during the southwest transit outside the Indian EEZ.

Wind and wave conditions over the northern portion of the southeast leg along with increasing urgency to recover a turbulence glider (star, Fig. 2), prohibited additional CTD profiling during the first portion of the southeast leg. The maximum mixing was observed more than 500 km from the center of the storm during its peak intensity. We are in the process of analyzing the inertial wave response using shipboard ADCP data and the local mixing response using turbulence glider data in conjunction with Louis St. Laurent (WHOI).

Upon return of the moored data we plan on assessing the monsoonal mixing signals and implication for upper ocean heat budget/air-sea fluxes. We will also look at the higher wavenumber and frequency mixing signals using χ pods deployed on the NRL mooring array, (e.g., internal wave signals and dynamics associated with the Sri Lankan dome).

IMPACT/APPLICATIONS

Within the Bay of Bengal high freshwater input creates salt-stratification that can form a barrier layer, dynamically isolating the thermocline from the surface mixed layer and trapping atmospheric heat and momentum fluxes near the surface. This buoyancy flux further stabilizes near-surface layers, thereby requiring an increase in the energy needed to mix cool fluid up from the thermocline. Our work seeks to understand the time-evolving contribution of mixing to the upper ocean heat budget and sea surface temperature under the influence of strong freshwater buoyancy forcing and monsoonal winds.

PUBLICATIONS

A. J. Lucas and E. L. Shroyer and H. W. Wijesekera and H. J. S. Fernando and E. D'Asaro and M. Ravichandran and S. U. P. Jinadasa and J. A. MacKinnon and J. D. Nash and R. Sharma and L. Centurioni and J. T. Farrar and R. Weller and R. Pinkel and A. Mahadevan and D. Sengupta and A. Tandon, *Eos, Transactions American Geophysical Union* 95 269--270 (2014)

RELATED PROJECTS

N00014-13-1-0357 funded the pilot work for this project.