Brief Report on *ORV Sagar Nidhi* Cruise SN82
15 November - 2 December 2013, North Bay of Bengal

Summary

During the Ocean Mixing and Monsoon (OMM)-Air-Sea Interaction Research Initiative (ASIRI) pilot cruise to the Bay of Bengal in November 2013, the Indian research ship Sagar Nidhi (Cruise SN82) worked with the US ship Roger Revelle to study lateral and vertical gradients of temperature, salinity and density in the upper ocean. The Sagar Nidhi obtained somewhat limited but very useful observations, and the onboard training of Indian personnel was an unqualified success. The positive outcome of the overall observational and training effort was due to the close interaction of Eric D'Asaro and Michael Allen with young engineers and students from several Indian research universities and institutes on the Sagar Nidhi.

Objectives

Summer monsoon rainfall and monsoonal rivers supply a large amount of fresh water to the northern Bay of Bengal. North of 14 degrees, net annual fresh water input (total rainfall plus river runoff minus evaporation) is nearly 4 metres. Near-surface salinity stratification is highest in the post-monsoon season (October-November), with one or more sharp haloclines in the upper 5-40 metres. The lowest salinity water is found along the eastern and western boundaries; climatological salinity gradient in the central longitudes is oriented north-south. Low-salinity water is carried south along the western

boundary of the Bay of Bengal by the basin-scale circulation in October-December. Climatological winds are from the northeast. The north Bay of Bengal begins to cool in November, because the total flux of latent heat and longwave radiation exceeds shortwave radiation. Circulation in the north Bay is influenced by eddies moving off the eastern boundary (the coast of Myanmar).

During the OMM cruise, the research vessels *Sagar Nidhi* and *Roger Revelle* worked together in international waters of the northern and central Bay of Bengal during the second half of November 2013. The common objectives were to: (I) Map upper ocean temperature and salinity from *in situ* and satellite observations (II) Identify regions of large lateral surface salinity gradients or salinity fronts (III) Obtain data on surface meteorology, upper ocean current profiles, subsurface radiation and vertical and lateral gradients of temperature, salinity and density, and (IV) Train Ph. D. students and young engineers from Indian research institutes and universities on instruments, observing techniques and data interpretation on both ships.

Eric D'Asaro and Michael Allen from the Applied Physics Laboratory (APL), University of Washington, Seattle, were on the *Sagar Nidhi*. There were several young participants on the *Roger Revelle* from the Indian National Centre for Ocean Information Systems (INCOIS) Hyderabad, National Institute of Ocean technology (NIOT) Chennai and Indian Institute of Technology (IIT) Bhubaneswar. One of the primary goals was to begin the

training of Indian participants on data acquisition and interpretation using instruments for upper ocean measurements at high resolution.

Operations

The November 2013 *Sagar Nidhi* cruise was allocated for recovery and deployment of an INCOIS mooring at 18 degrees north, 89.5 east, and two RAMA moorings at 15 and 12 degrees north. We used the opportunity to conduct the OMM work. The *Roger Revelle* sailed from Colombo on 10 November, and *Sagar Nidhi* sailed from Chennai on 15 November. We effectively had two-three days' time for joint operations with the *Roger Revelle* at 16 north, 85-87 east in international waters; when we arrived, the *Revelle* had already surveyed the vicinity for a few days and located a promising salinity front. In addition, we had about three days for a survey closer to the 18 north mooring. We finished joint operations with the *Revelle* on 19 November, and the mooring operations at 18 and 15 degrees north, by 24 November.

The mooring operations at 15 north had to work around tropical cyclone *"Helen"*, which lay south of the *Sagar Nidhi* location on 20 November. When the 15 north mooring operations were done, a new storm was brewing near the Andaman islands. The India Meteorology Department (IMD) forecast track of very severe cyclonic storm *"Lehar"* lay directly on the 12 north mooring location. *"Lehar"* was the second tropical cyclone to develop in the Andaman Sea within a week; both *"Helen"* and *"Lehar"* intensified during the convectively active phase of a Madden-Julian Oscillation passing over the

Indian Ocean. *Sagar Nidhi* sailed north and east of “Lehar”, and started towards the 12 north mooring location on 27 November.

Observations

Using the *Nidhi’s* (somewhat slow) internet connection, we obtained useful satellite data prior to the start of the cruise, and near real-time data on surface winds from the scatterometer onboard ISRO’s Oceansat-2, sea surface height, SST, Aquarius surface salinity from ftp sites set up at the Indian Space Research Organisation’s (ISRO) Space Applications Centre (SAC), Ahmedabad, and INCOIS. Aquarius salinity, 12.5 km scatterometer wind analyses from SAC, and analyses of AVHRR SST fronts provided by INCOIS were very useful in planning the operations of the Revelle and Nidhi. On the *Sagar Nidhi*, scientists at SAC sent us some (delayed mode) radar imagery from ISRO’s RISAT; other satellite data and imagery were regularly obtained from IMD and data centres in the US.

INCOIS acquired a high-frequency ADCP for upper ocean currents and an underway CTD for this cruise. The ADCP could not be installed on the *Sagar Nidhi’s* drop keel, as we had initially hoped. It was mounted on a 12 m long, heavy swivelled pole over the side. When the pole was deployed in the vertical position, the ADCP was about 6 m below the water surface and 1.3 m below the ship’s hull. The pole was secured to the ship at one point along its length; it formed a cantilever that vibrated at about 2 Hz at ship speeds beyond 1.5 knots during testing; ship’s navigation data was not integrated with the ADCP. We acquired very limited ADCP data, including about two and

a half hours steaming alongside the Revelle. We hope the limited data will prove to be useful for science, but it has been very effectively used by Eric D'Asaro for training purposes (see below).

We obtained useful observations with the underway CTD, but a couple of manufacturing defects in the spool and brake meant that we had to mostly work in tow-yo mode. The spool and brake defects were rectified with Michael Allen's help. We collected a fair amount of data (several hundred profiles), including the time the *Nidhi* was working with the *Revelle* during 17-19 November. After that we got occasional but useful UCTD data, before the stiff motor compelled us to stop regular operations. The Chi-pod from Jim Moum and Emily Shroyer's group at Oregon State University was strapped to the ship's CTD. The ship CTD with the attached Chi-Pod and sampling bottles, and the SBE CTD, were operated regularly; most casts were to 250 metre depth. A multispectral radiometer was used to measure downwelling and upwelling subsurface radiation on several casts. The Lagrangian floats from Eric D'Asaro's group at APL did not arrive at Chennai in time for the cruise. We are keen to use the floats on a subsequent OMM cruise.

Continuous data from the Nidhi's automatic weather station (AWS) and thermosalinograph (TS graph) covers a wide region as we wandered across the northern Bay of Bengal (Figure 1a) as per the cruise plan, as well as to skirt the cyclones. The range of surface salinity values encountered was nearly 23 psu close to 17 north 93 east, to 34.5 psu at 12 and 15 north. Preliminary comparison with CTD suggests that the TS graph surface salinity

is reliable (we have CTD casts to validate surface salinity over nearly full range). We should be able to obtain reliable statistics of along-track gradients of surface salinity and density from the 10 second TS graph data. Comparison with Aquarius and SMOS satellite salinity, and the detailed observations carried out by the *Revelle* in the viscinity of the *Nidhi* (Figure 1b), should be instructive.

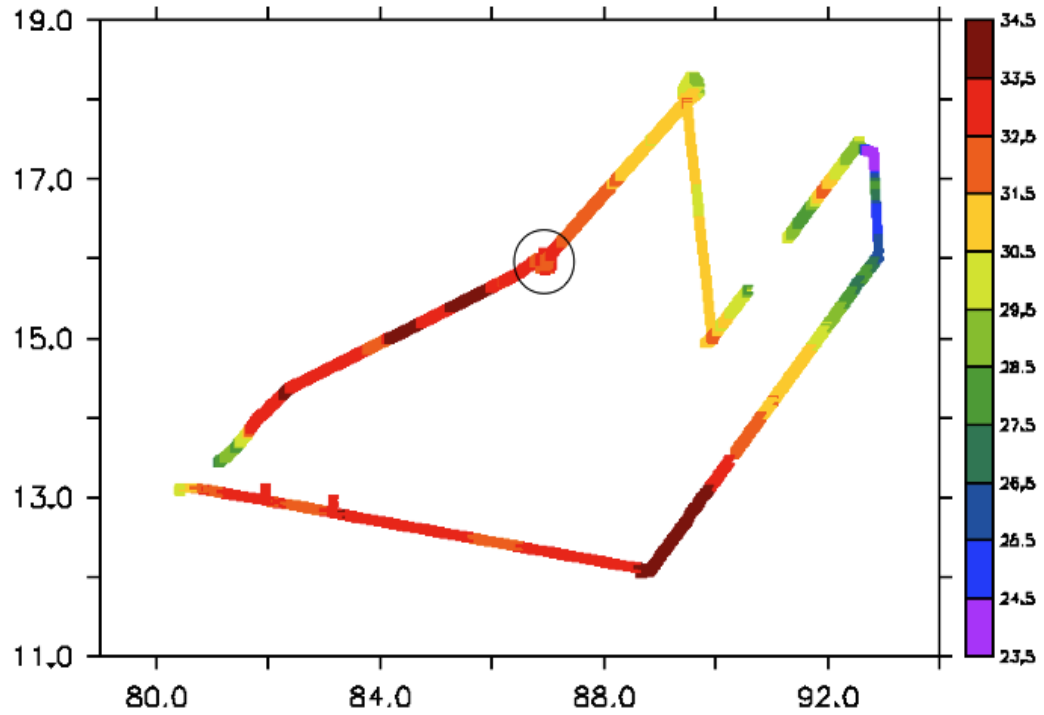

Figure 1a: *Sea surface salinity (psu) measured by the thermosalinograph along the track of the Sagar Nidhi, 15 November to 2 December 2013.*

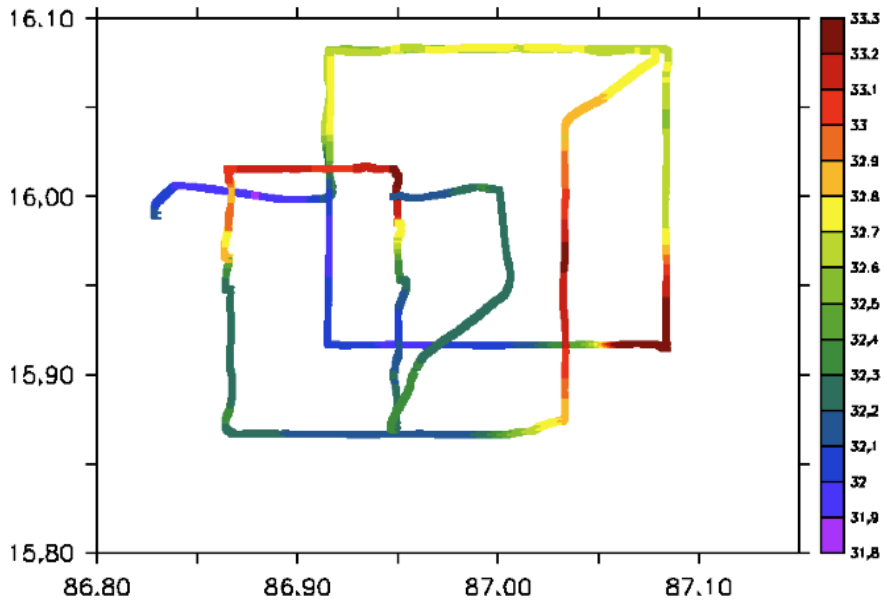

Figure 1b: Expanded view (circle in Figure 1a) of *sea surface salinity (psu),17 to 19 November 2013*

Onboard Training and Science Discussions

On the Nidhi, experienced scientists and engineers had regular discussions with younger participants; Eric and Mike worked alongside other participants during collection of data, specially ADCP and UCTD operations. We had evening meetings in the conference room, or on the aft deck, covering various aspects of instrumentation, satellite observations, physical oceanography, air-sea interaction and oxygen isotopes in tropical rainfall and water vapour.

The teaching talks/discussions on the analysis of moored data, and the *in situ* data being collected live, were specially stimulating and useful. Eric D'Asaro taught a whole range of topics from ADCP's and Lagrangian floats to tides, inertial oscillations, fronts and upper ocean mixing. In addition, we had teaching talks on the remote sensing of sea level and salinity, cyclones, surface fluxes and intraseasonal oscillations. The young participants enjoyed the talks, and showed results of their previous work, as well as analysis and calculations related to the cruise data. We learn that the exposure and training of Indian participants on the Revelle Leg-I cruise (continuing on Leg-II) was very useful.

Participants on the Sagar Nidhi

1. M. Ravichandran INCOIS Hyderabad Chief Scientist
2 Eric D'Asaro APL, University of Washington, Seattle
3 Michael Allen APL
4 Debasis Sengupta IISc. Bangalore
5 Rashmi Sharma SAC Ahmedabad
6 R. Shivaprasad INCOIS
7 Aneesh Lotliker INCOIS
8 Dinesh Kumar INCOIS
9 Hari Kumar INCOIS
10 Dipanjan Choudhuri IISc.
11 J. Sreelekha IISc.
12 Midhun Madhavan PRL, Ahmedabad
13 Lekshmi Ravishankar PRL
14 R. Kumaraswami Mangalore University
15 Kesava Kumar NIOT, Chennai
16 Vivek NIOT
17 Sheik Meeran NIOT
18 Ismail NORINCO
19 Madhan Kumar NORINCO
20 Pursothaman NORINCO
21 David Zimmerman NOAA/PMLE Seattle
22 Patrick Lawrence NOAA/PMEL

Acknowledgements

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