Ocean Mixing and Monsoon (OMM): Seaglider Training at Seattle and Seaglider operations during summer 2015

By

M. S. Girishkumar, S. Shivaprasad and V. P. Thangaprakash

Modelling and Ocean Observations Group (MOG)

Earth System Sciences Organisation-Indian National Centre for Ocean Information Services (ESSO-INCOIS)

(Ministry of Earth Sciences, Government of India)

The Seaglider is an autonomous underwater vehicle, used to measure various oceanographic parameters along a desired track; the glider moves in a saw-tooth pattern from the surface to a target depth (typically 1000 m), and back to the surface along the track. The Seaglider was developed at the University of Washington and being manufactured commercially by Kongsberg Underwater Technology Inc. of Lynnwood, Washington, under a license agreement. The Seaglider is highly cost effective compared to profiling instruments deployed from research vessels; it provides quality data with high spatio-temporal resolution. Seagliders are specially effective for undisturbed measurements in the near-surface layer (where the presence of a ship can change temperature, salinity and current profiles).

The Seaglider uses small changes in buoyancy, and its wings to achieve forward motion; the system's pitch and roll are controlled using the vehicle battery. During a mission, the Seaglider surfaces often (at the end of each dive-and-climb phase) to determine its position and to transmit collected data and receive commands (e.g., command for sampling frequency of science sensors, waypoints and vehicle behavior) from the base-station via satellite telemetry. Navigation is accomplished using a combination of GPS fixes while on the surface and internal sensors (compass and pressure sensor) that monitor the vehicle heading, depth and attitude during dives.

Seaglider operation in the ocean is mainly achieved by coordination between the Pilot at the base-station and field team in the ocean. During the deployment phase, field team executes self tests and sea-launch test and associated data generated by glider is evaluated by the pilot to understand the vehicle overall performance. Based on the suggestion of the pilot, the field team deploys glider. After successful deployment of the glider, the pilot executes one or two shallow dives (45 m to 90 m) to ensure the flight performance and vehicle health. If the glider performance is satisfactory, the pilot releases the field team from the location. Then, the pilot monitors vehicle behavior continuously and does necessary adjustments (roll, pitch and buoyancy) to achieve movement along the desired track.

In order to improve the oceanographic observation in the Bay of Bengal, a Seaglider (SG615) has been acquired by the Indian National Center for Ocean Information services (INCOIS), Hyderabad under the "Ocean Mixing and Monsoon" (OMM) programme funded by MoES under the National Monsoon Mission (please see Table-1 and Table-2 for technical specification and sensors of SG615). Seaglider technology and operations are new to the Indian scientific community. Hence, it is imperative to get training on deployment, piloting and data processing from the glider developers and manufacturer in order to execute successful glider missions.

As part of capacity building, three training courses were planned. In the first phase, Dr. Girishkumar M. S. (Scientist-C, INCOIS), Mr. Shivaprasad S. (Scientist-B, INCOIS), Mr. V. P. Thangaprakash (Scientist-B, INCOIS) from INCOIS have been deputed for seaglider training at Kongsberg Underwater Technology inc., Lynnwood, Seattle, USA and Applied Physics Laboratory (APL), University of Washington, Seattle, USA during 19th June, 2015 to 5th July, 2015. In the second phase, Dr. Girishkumar M. S. (Scientist-C, INCOIS), has been deputed for seaglider training at APL, University of Washington, Seattle during 1st September, 2015 to 18th September, 2015. In the third phase, Mr. Shivaprasad S. (Scientist-B, INCOIS) has been deputed for seaglider refurbishment training at Kongsberg Underwater Technology inc., Lynnwood, Seattle, USA during 13 June 2016 to 16 June, 2016. All costs for training are met from OMM funds available with the Indian Institute of Science, Bangalore.

(i) Seaglider training: Phase-I

The primary jobs assigned to the team were to get operational training (basic principles, deployment and retrieval, piloting, processing and quality control of data) on the Seaglider, at Kongsberg Underwater Technology inc., Lynnwood, Washington, USA and Applied Physics Laboratory (APL), University of Washington, Seattle, USA during 19th June, 2015 to 5th July, 2015.

During their visit to Kongsberg, 22nd-26thJune, 2015, the INCOIS team was introduced to the basic working principles of the instrument, glider piloting, compass calibration and tank demonstration in detail (Figure 1). The team moved to APL on 29th June, 2015 for four days of intensive training. During their training at APL, they were introduced to glider hardware and software, analysis of glider generated files, seaglider piloting software and interpretation glider generated data and a field campaign on deployment and retrieval of glider in the Puget Sound, a small estuary in the Seattle. During the field campaign, Mr. S. Shivaprasad and Mr. V. P. Thangaprakash went out on Puget Sound in a boat along with Mr. Benjamin Jokinen, engineer from APL. They successfully executed pre-deployment glider tests and deployed the glider in the water. At the same time, Dr. Girishkumar did the piloting with the help of Mr. Geoff Schilling at APL. After successful completion of four dives, the field team retrieved the glider from water. The detailed analysis of pre-deployment tests and glider generated data were explained to the Indian team by APL technicians. The team returned back to INCOIS on 07th July, 2015.

(ii) **Seaglider training: Phase-II**

In order to understand the near surface thermohaline structure and mixed layer salt and temperature balance in the northern Bay of Bengal, a repeated hydrographic survey was planned, deploying Seaglider SG615 in a 30-km butterfly pattern centered around a Woods Hole Oceanographic Institute (WHOI) surface mooring at 18.01°N, 89.45°E (Figure 2). The proposed glider track is consistent with the proposed OMM science objectives.

Since it was the very first glider operation, Dr. Girishkumar was deputed to APL for Seaglider piloting under the supervision of APL scientist. On 3rd September, 2015, a team consisting of Mr. Shivaprasad and Mr. Thangaprakash of INCOIS and Mr. Michael Ohmart of APL, successfully deployed the Seaglider in the northern Bay of Bengal (17.52°N, 89.78°E) from a small boat during the OMM Sagar Nidhi cruise (SN100) (Figure 3). At the same time, Dr. Girishkumar did piloting under the supervision of APL technicians using the Seaglider base-station already setup at INCOIS, Hyderabad (Figure 4).

The Seaglider was moved from its deployment location to desired waypoints provided by the pilot, butterfly pattern near the surface mooring. During this training Dr. Girishkumar learned various aspect of Seaglider piloting with close interactions with Mr. Geoff Schilling. Seaglider is a fixed-mass, variable-volume device such that it moves without using propellers. For vertical motion, they change their buoyancy by changing their displaced volume while keeping their total mass fixed. Typically, this is done by moving hydraulic oil from a reservoir inside a pressure hull to inflate or deflate an external rubber bladder. As per the manufacturer configuration, SG615 can communicate to the satellite only if the surface density is higher than 15.8 σ_t. After the 40th dive, on 10th September, 2015, when SG615 was heading towards northwest from south west target (Figure 2), the background salinity in the glider path dropped below 15.8 σ_t due to the presence of extremely low salinity water in the near surface layer (~23.5 PSU; as per WHOI mooring record). Hence, SG615 could not communicate to base-station through satellite and it keeps continued its northward journey (Figure 2; marked as pink line). On 14 September 2015, after 59th dive (at 18.06°N and 89.52°E), the density in the near surface layer increased above 16σ_t and seaglider communicated to basestation through satellite and it successfully received pilot command to move southward. Then seaglider continued its mission in its prescribed butterfly path. The files which were not transferred to the basestation during the dive 41-59 were successfully transferred in the successive dives. So far (5th October, 2015), the Seaglider has successfully completed more than 150 dives and provided real time data (300 profiles) to the INCOIS base-station (Figure 5**).** The current mission will continue up to mid-December, 2015. Dr. Girishkumar returned to INCOIS on 21th September, 2015 and the team is continuously evaluating the ongoing glider mission.

(iii) **Seaglider training: Phase-II**

After the successful recovery of seaglider after a mission, each vehicle has to undergo refurbishment, which involves calibration of sensors and mechanical and electronic component replacements. The primary objective of this training was to get refurbishment training on Seaglider, at Kongsberg Underwater Technology inc., Lynnwood, Washington, USA. During his visit from 13 June 2016 to 16 June 2016, Mr. Shivaprasad was introduced to various topics of seaglider ballasting, which included inspection and disassembly of vehicle, removal of batteries and sensors, and preparation for shipment to the factory for recalibration, installation of batteries, installation of sensors, reassembly of vehicle, Bench testing, compass calibration, communications tests, and trim sheets preparation. The primary purpose of this training was to develop a national glider refurbishment facility at INCOIS, and it will help prepare the vehicle for the next mission as quickly as possible after the recovery.

Tables

Body size	2.0 m long and 0.3 m maximum diameter
Lift surfaces	Wing span 1 m
Weight	52 kg (dry)
Batteries	Two 15V Lithium sulfuryl chloride batteries
RF data telemetry	Iridium satellite data telemetry
Operating depth range	45-1000 m
Maximum travel rage/Duration	6000 km (650 dives to 1 km depth)
Typical speed	25 cm/sec
Glide angle	16-45°

Table-1. Seaglider (SG615) specifications

Sensors	Accuracy

SBE CT sail (free flow)	Conductivity: ± 0.0003 S/m Temperature : ± 0.002 °C
Dissolved Oxygen (Aanderaa Optode AA4831)	< 8μm
Chlorophyll fluorescence (470/695 nm)	0.015mg m^{-3}
Optical Backscatter (700 nm)	0.0015m^{-1}
Colored Dissolved Organic Matter (CDOM) (460 nm)	0.28ppb
Photosynthetically active radiation (PAR-QSP2150) (400-700 nm)	±5% (<0.003μEM-2 sec-1)
Table-2. Seaglider sensor specifications	

Figures

Figure 1. INCOIS scientists during their training at Kongsberg Underwater Technology Inc.

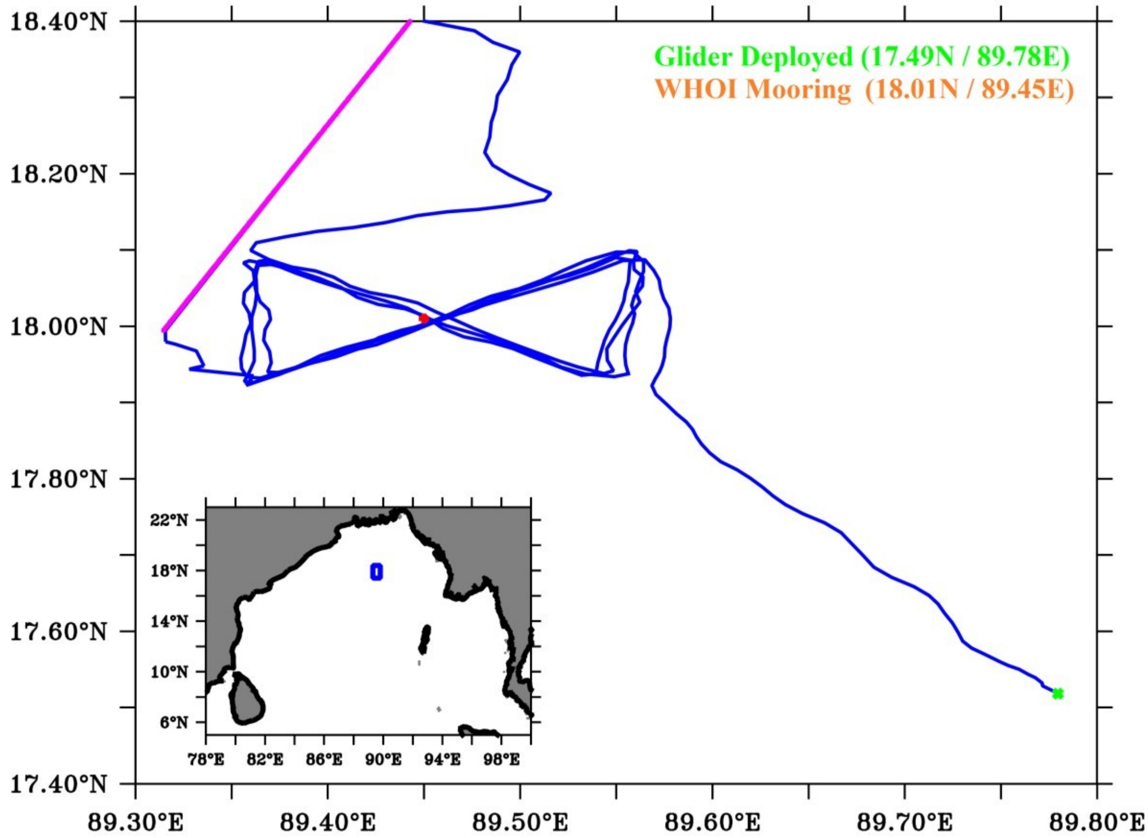

Figure 2. Deployment location (green circle) and track (blue line) of SG615 around WHOI (18.01°N, 89.45°E) mooring (Red circle). The approximate track of dive 41-59 is marked in pink color.

Figure 3. Seaglider (SG615) deployments by INCOIS team during SN100 cruise.

Figure 4. Seaglider (SG615) piloting at INCOIS basestation by INCOIS scientist.

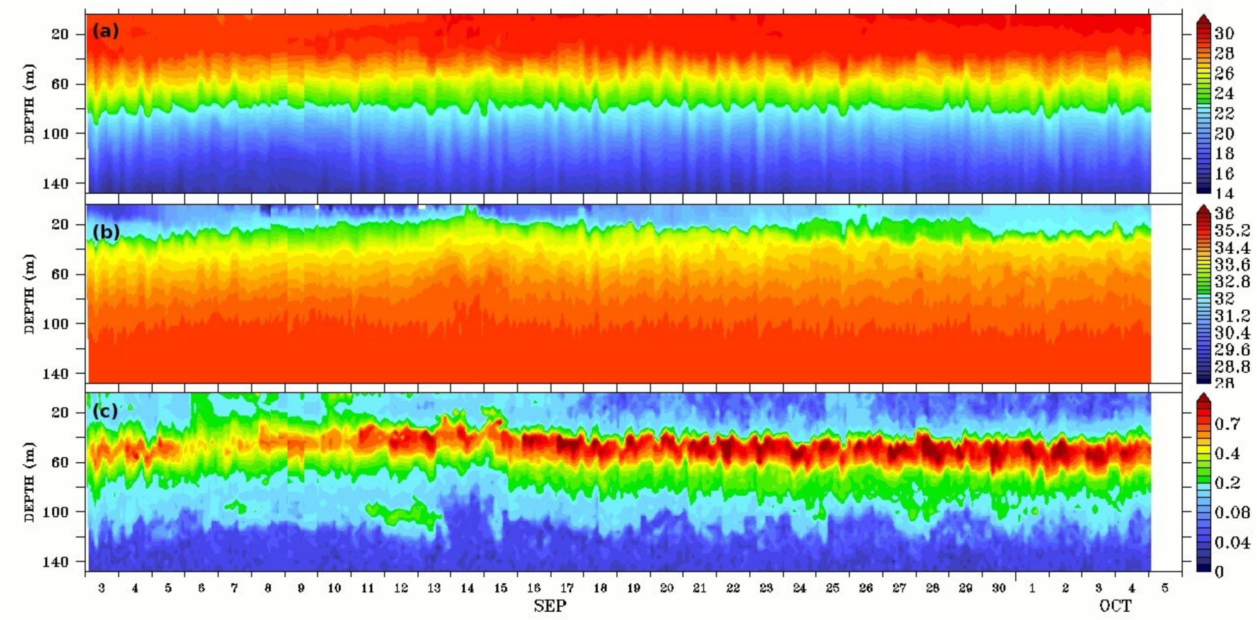

Figure 5. Temporal evolution of (a) temperature (°C) (b) salinity and (c) chlorophyll (mg m^{-3}) measured by seaglider (SG615).