Acoustic Seaglider Deployment Cruise Report
& Mid-Deployment Seaglider Status Update
Philippine Sea Experiment
N00014-10-1-0034

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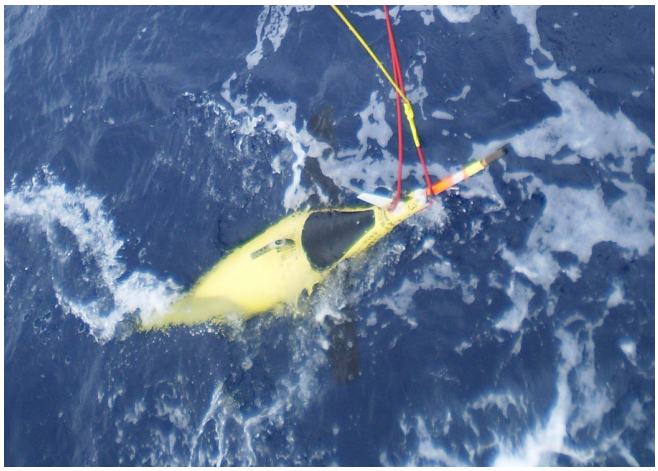
6-24 November, 2010
R/V Roger Revelle

in conjunction with
Impact of Typhoon on the Western Pacific Ocean (ITOP)
Barry Ma, University of Washington, co-chief scientist

January 26, 2011



Cruise Objectives

The objective of the University of Hawaii (UH) portion of this cruise was to deploy four acoustic seagliders in the vicinity of the acoustic tomography array in the Philippine Sea put in place in April 2010 by Peter Worcester at the Scripps Institution of Oceanography (SIO). All four seagliders (SG023, SG500, SG511, and SG513) were successfully deployed.

The gliders are measuring temperature and salinity in the upper 1000-m of the ocean between the tomography moorings, as well as recording transmissions from each of the 6 moored acoustic sources (T1-T6), serving as additional nodes in the tomography array and thereby enhancing the resolution of the tomography system. A major purpose of the experiment is to determine if this is possible, given the joint nature of the combined navigation/tomography problem. The gliders will continue to collect data until they are recovered during the mooring recovery cruise in March/April 2011.

Current Glider Status

The 500 series of acoustic seagliders, SG500, SG511, and SG513 are continuing to make acoustic and oceanographic measurements in the Philippine Sea. Current glider tracks are indicated in Figure 1. On 11 January, SG023 completed its last successful dive (final recorded position in Figure 1). Pitch errors sent the glider into recovery mode and it was not sent diving again for fear of losing the instrument. The glider drifted at the surface until it was recovered at approximately 21°30.42'N/119°46.95'E on 26 January 2011. Chen-Fen Huang at the National Taiwan University was extremely helpful in coordinating with a local fishing boat captain, Captain Chao, to recover SG023.

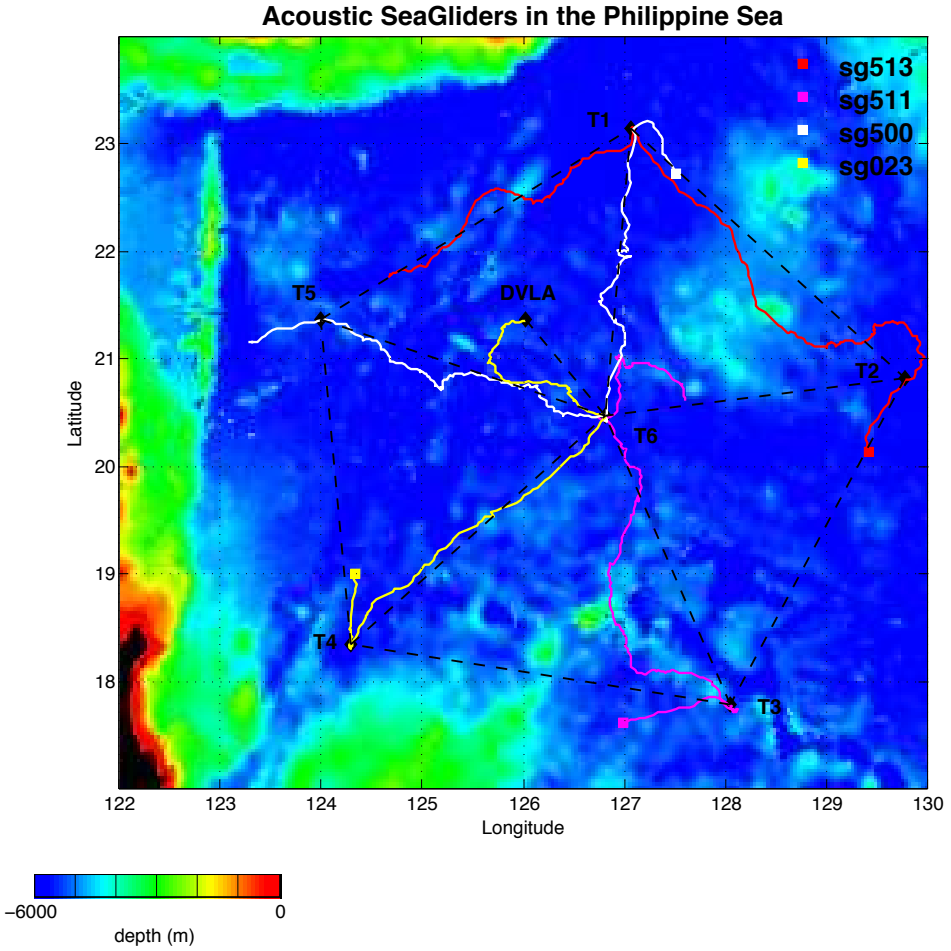


Figure 1: Acoustic seaglider tracks in the Philippine Sea from deployment to the time of this writing (indicated by square), overlaid on Smith-Sandwell bathymetry.

Cruise Narrative

The cruise departed from Kaohsiung, Taiwan on 6 November at 1600 and transited to the Luzon Strait. The first subsurface ADCP mooring, YJ, was recovered on 7 November over a four-hour period (Figure 2). Proceeding on to the SA2 mooring site on 8 November, we deployed SG500 and recovered the subsurface mooring. A rough sea state

early on 9 November prohibited any mooring work, so a hydrographic survey was conducted using shipboard instruments. The surface mooring A2 was recovered on 9 November as the sea state improved, and a bathymetry and hydrographic survey was conducted during the night. The SA4 and A4 moorings were recovered on 11 November. The second acoustic seaglider, SG513, was launched along the T1–T5 line on 12 November. We reached the DVLA site on 13 November and launched the third acoustic seaglider, SG511, but recovered it again approximately two hours later because it was not returning temperature and salinity data. Later in the afternoon we recovered six seagliders for Craig Lee at the University of Washington that had been deployed in September 2010.

The EASI-N buoy was serviced on 14 November, and we proceeded to recover mooring SA1 on 15 November. SG511 was re-launched on the morning of 16 November. Once all the recoverable moorings were onboard, we attempted to salvage mooring A1. The salvage effort failed due to the difficulty of dragging at 5,600 m water depth. A hydrographic study was then conducted using shipboard instruments on 17 November.

We returned to the DVLA site to launch the last seaglider, SG023, on 18 November. We transited to the northern Luzon Strait to conduct a 36-hr time series yo-yo CTD on 20–21 November. This was followed by XBT casts on a racetrack pattern that was repeated 36 times over the course of 36 hours on 22–23 November to survey the internal tide. The 19-day voyage was concluded by returning to Kaohsiung, Taiwan on 24 November at 0800 (Figure 2).

Timeline of ship operations during November 2010 cruise:

6 Set sail from Kaohsiung, Taiwan
7 Recover YJ subsurface ADCP mooring, CTD #1
8 Launch SG500, recover SA2 subsurface mooring, CTD #2
9 Glider deployment and mooring operations called off due to rough sea state
10 Recover A2 surface mooring, called off glider deployment due to iridium communication problems/approaching dusk.
11 Recover SA4 and A4 moorings, CTD #3 and #4. Glider deployment delayed due to ongoing iridium communication problems/piloting constraints.
12 Launch SG513, CTD #5
13 Launch and subsequently recover SG511, recover six UW Seagliders, CTD #6
14 Service EASI-N buoy, CTD #7
15 Recover SA1
16 Launch SG511, A1 mooring salvage attempt
17 Hydrographic survey, CTD #8
18 Launch SG023
19 36-hr yo-yo CTD
20 36-hr yo-yo CTD
21 36-hr yo-yo CTD
22 36-hr racetrack internal tide survey
23 36-hr racetrack internal tide survey
24 Return to Kaohsiung, Taiwan

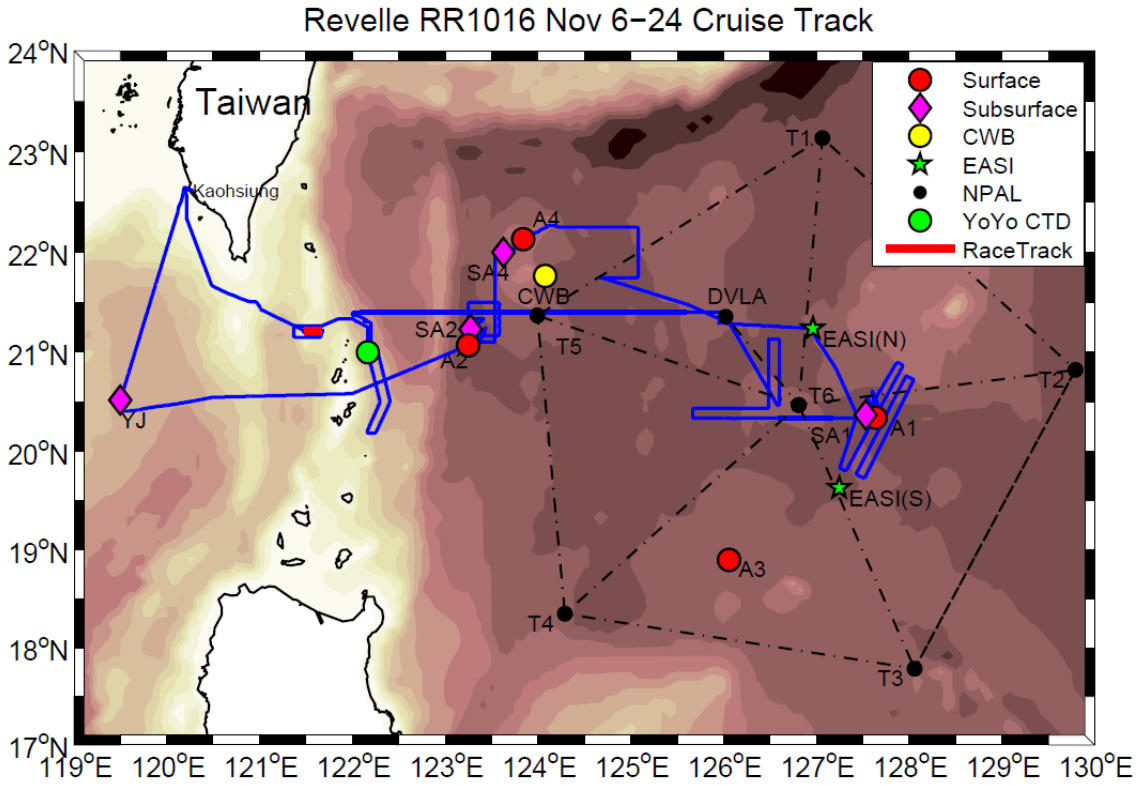


Figure 2: Ship track of RR1016 *R/V Revelle* cruise 6–24 November 2010 (blue line). Red dots mark the positions of surface moorings. Magenta diamonds mark the positions of subsurface moorings. The green circle marks the 36-hr yo-yo CTD location. The red line indicates the 36-hr racetrack internal tide study route (Figure courtesy of Barry Ma).

Seaglider Deployment Operations

Glider operations were allotted 4 days of ship time during the cruise. The initial plan was to deploy all four gliders at once at the location of the DVLA mooring, fly them to T6, spread them out to T1, T2, T3, and T4, and then fly them clockwise around the pentagon until recovery. During the cruise, it was decided to deploy them at varying locations to obtain different sampling tracks as well as to spread the deployments out in time, allowing the onshore glider pilot to focus on one glider at a time. The current glider positions at the time of writing are indicated in Figure 1.

The preferred method of glider deployment is via small-boat. The weather in the Philippine Sea was not always conducive to this type of deployment, so several deployment methods were employed with varying degrees of success.

The first glider to be deployed, SG500, was lowered by hand over the aft starboard quarter. This deployment was successful, although it put the glider at risk of hitting the side of the ship.

The second glider, SG513, was deployed from the aft port quarter crane using a line with loops around each side of the rudder. The loops became tangled on the glider during the release, but it eventually became loosened. Although the launch was successful, it was not an optimal method of deployment.

The weather permitted a successful small-boat deployment for SG511. After roughly 2 hours, it was determined that the glider was not reporting temperature and salinity data so it was recovered. The problem was resolved by changing the port configurations for the conductivity/temperature sensor. SG511 was then deployed from the aft port quarter crane using a quick-release, which was by far the easiest way to deploy without the possibility of small-boat deployment.

The final glider, SG023, was an older model, which meant the ballasting was a concern. Because of this, it was deployed via small-boat. The glider remained tethered to the boat for 5 minutes to ensure that the ballasting was okay before it was released to dive.

After each deployment, the ship remained on station for approximately one hour to ensure that the glider successfully completed its first dive and transmitted data.

Table 1: Seaglider Deployment Times and Positions

Seaglider	Time of Deployment	Latitude	Longitude
SG500	8Nov10 02:06:26 UTC	21°09.667'N	123°16.603'E
SG513	12Nov10 03:52:02 UTC	21°45.221'N	124°40.007'E
SG511	16Nov10 00:29:01 UTC	20°36.341'N	127°35.979'E
SG023	18Nov10 05:35:50 UTC	21°21.440'N	126°01.074'E

Conductivity/Temperature Data

Conductivity and temperature sensors on the glider take measurements every 10 seconds above 200m, every 20 seconds from 200 to 300m, and every 40 seconds below 300m. Cross sections of temperature and salinity data from the gliders are shown in Figure 3. Data shown are unfiltered and unedited. Outliers in salinity measurements on some gliders are likely due to stalling.

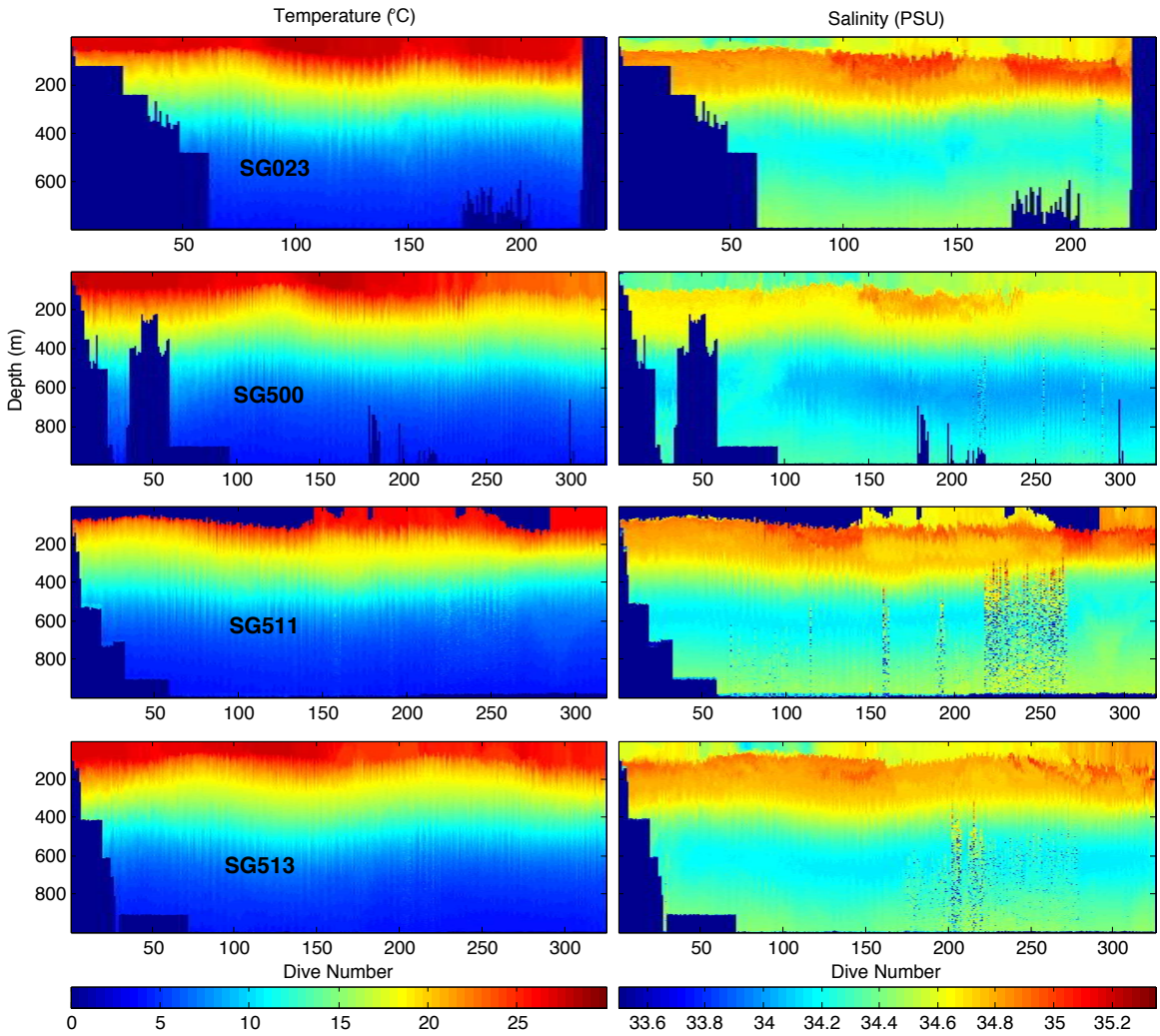


Figure 3: Seaglider temperature (left) and salinity (right) data

Acoustic Data

The acoustic sampling schedules were designed to receive transmissions from the 6 moored tomography sources. The sources transmit for 135 sec, every three hours on odd-numbered year days at nominally 0000Z, 0300Z, 0600Z, ... 2100Z (+ Xmit time seconds given in Table 2). (From NPAL Philippine Sea Experiment: PhilSea10 SIO Experiment Plan, Version 1.5, P.F. Worcester).

The Acoustic Recorder System (ARS) collects data at a sampling rate of 4kHz for approximately 54 minutes beginning at the transmit time for the T1 mooring so as to receive transmissions for all six moored sources. The 500-series of seagliders were initially set to record daily (including even-numbered, i.e. non-transmission, yeardays), but on 10 Jan the schedule was modified to record on tomography transmission days only to conserve battery. Based on the projected battery life of the older glider model, SG023 was set to record every 4th day, or every other mooring transmission day.

Table 2: Moored Source Transmission Schedule and surveyed positions

Mooring	Xmit Time (sec)	Latitude	Longitude
T1	0	23.138°	127.063°
T2	540	20.823°	129.789°
T3	1080	17.788°	128.058°
T4	1620	18.351°	124.290°
T5	2160	21.366°	123.992°
T6	2700	20.468°	126.812°
DVLA	--	21.360°	126.020°

It appears from the PSD reports for SG023 that the ARS system was not functioning properly. PSD plots for SG513 are also suspect, but the data from gliders SG500 and SG511 appear to be healthy (Figure 4).

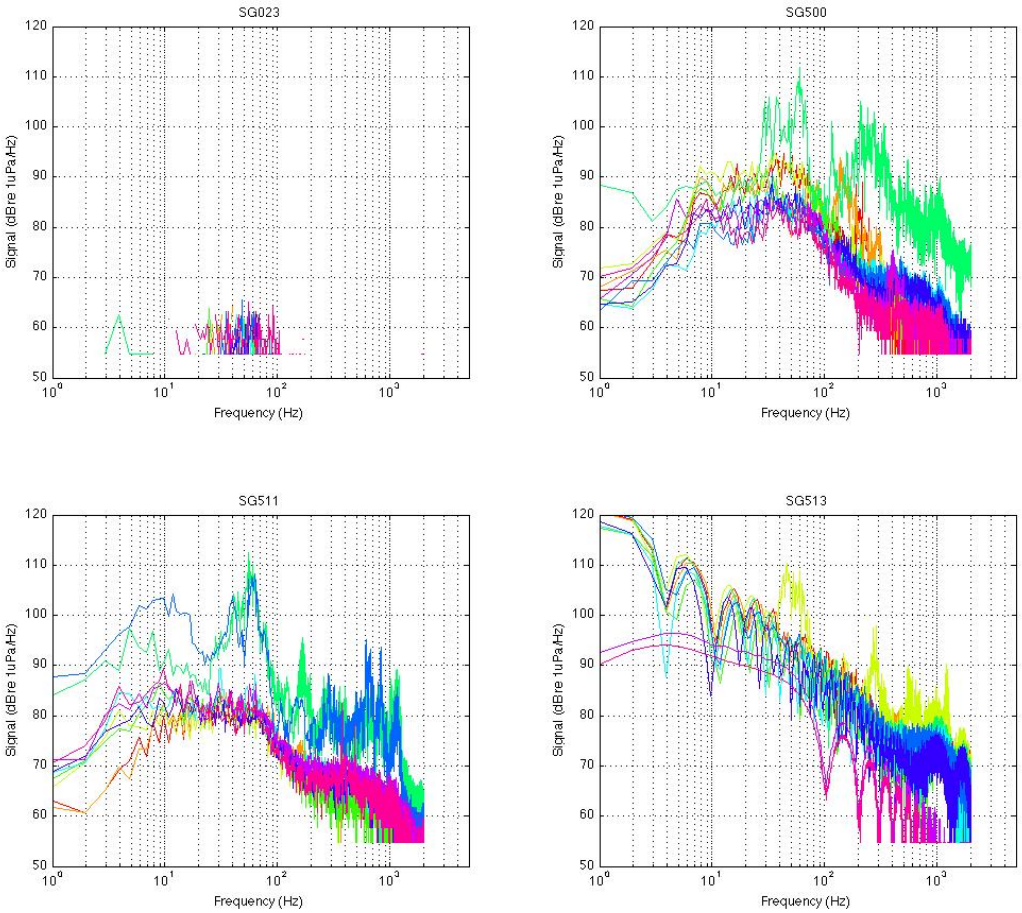


Figure 4: Power Spectral Density for 10 most recent dives for each Seaglider.

Shipboard Data

Throughout the cruise, the ship collected multibeam (EM122) bathymetry, Knudsen bathymetry, underway meteorology data, underway sea surface temperature and salinity data and shipboard ADCP data. CTD casts were performed at 8 locations during the cruise in addition to the 36-hour yo-yo CTD at the locations shown in Table 3. Expendable bathy-thermograph (XBT) measurements were also made in a racetrack pattern as indicated in Figure 2.

Table 3: CTD Locations

CTD	Latitude	Longitude
1	20°26.17' N	119°28.54' E
2	21°09.69'N	123°16.34'E
3	22°00.26'N	123°32.38'E
4	22°07.47'N	123°47.89'E
5	21°20.63'N	125°55.89'E
6	21°18.58'N	126°01.13'E
7	20°22.67'N	127°26.47'E
8	20°25.97'N	126°28.95'E
Yo-Yo	20°59.99'N	122°09.97'E

Science Party

The gliders were deployed by Jennie Mowatt (glider technician) and Lora Van Uffelen (co-chief scientist) from UH. Meghan Donohue (*R/V Revelle* resident marine technician) assisted with glider deployment and Capt. Tom Desjardins, along with the rest of the crew of the *R/V Roger Revelle*, were extremely helpful with the deployment and small-boat operations.

Bruce Howe (UH) assisted with loading, seaglider testing, and ground-support. Steve Poulos (UH) piloted gliders remotely from UH. The ground team communicated with the team on the *R/V Revelle* via Iridium phone and online chat. Kevin Heaney provided daily surface current predictions from the Naval Oceanographic Office's Naval Coastal Ocean Model (NCOM) to assist with planning glider deployment positions, and with SG023 recovery.

The mooring operations group consisted of Barry Ma, Yih Yang, Wen-Hwa Her, Jr-Hau Chang, Chi-Kai Hu, Fang-Hsu Kuo, Chao-Tsung Chiu, Yu-Hung Hsiao, Chun-Chieh Huang. Two observers from the Philippines, Glenn Jandayan and Rocky Dejan were also onboard.

Ongoing and Future PhilSea10 Seaglider Operations

The three remaining gliders are continuing in a clockwise pattern around the tomography pentagon. Glider pilots are monitoring the instruments on a daily basis and continue to adjust the trim for optimal flight performance.

Glider data are available in near-real time at http://hahana.soest.hawaii.edu/seagliders/. The temperature and salinity data are being assimilated into NAVO ocean models (facilitated by Kevin Heaney).

An underwater navigation study is planned for a single glider for a single dive in the near future. The study will be performed at one of the tomography mooring locations within short range of the bottom-mounted acoustic transponder network. During the dive, the glider altimeter will interrogate the transponders at 9kHz and record their replies to track the glider position underwater. The ARS sample rate will be increased to 64 kHz to receive the transponder replies at 11.0, 11.5, and 12.0 kHz.

Seagliders SG500, SG511, and SG513 will be recovered by Lora Van Uffelen during Peter Worcester's mooring recovery cruise planned for 25 March-15 April, 2011.