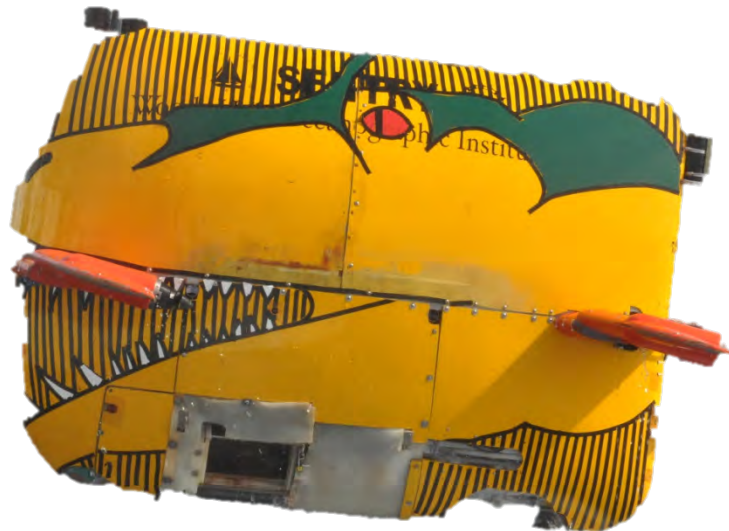## THE Jurassic QUIET ZONE (JQZ)

SKQ201402S Cruise Report

Dec. 16, 2014- Jan. 17, 2015

Honolulu, HI- Guam

A High Resolution Deep-AUV Magnetic Survey of the Hawaiian Jurassic Basin (OCE 1233000)

R/V Sikuliaq

Principal investigators:
M. Tominaga, M. TIVEY

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SKQ201402S Roster

Science Party

PIs

Masako Tominaga, Michigan State University (Chief Scientist)

Maurice Tivey, Woods Hole Oceanographic Institution (Co-chief Scientist)

Geophysics

Rachel Clark, Bryn Mawr College (Geophysics Watchstander)

John Greene, Michigan State University (Geophysics Watchstander)

Matt Karl, Michigan State University (Geophysics Watchstander)

Tyler Ruchala, Michigan State University (Geophysics Watchstander)

Tim Stadler, Michigan State University (Geophysics Watchstander)

Laura Stanley, Texas A&M University (Geophysics Watchstander)

Alex Stote, Harvard University (Geophysics Watchstander)

Cruise Archiving/Outreach

Aric Velbel, Johns Hopkins University

Sentry AUV

Dana Yoerger, NDSF, Woods Hole Oceanographic Institution, Sentry Expedition Leader

Zac Berkowitz, NDSF, Woods Hole Oceanographic Institution

Andrew Billings, NDSF, Woods Hole Oceanographic Institution

Dan Bogorff, NDSF, Woods Hole Oceanographic Institution

Alan Duester, NDSF, Woods Hole Oceanographic Institution

Marine Science Technicians

Bern McKiernan, University of Alaska, Fairbanks

Steve Roberts, University of Alaska, Fairbanks

Ethan Roth, University of Alaska, Fairbanks

Ship's Crew

Adam Seamans, Master

Mohammed Hossain, Chief Mate

Andrew Baer, 2nd Mate

John Hamill, 3rd Mate

Eric Danielson, Bosn AB

Steve Alicandri, AB

Elliott Sayler, AB

Scott Wilson, AB

Robert Worrad, AB

Terry Anderson, Chief Engineer

Rick Null, 1st Assistant Engineer

Randy Flannigan, 2nd Assistant Engineer

Joe Carr, 3rd Assistant Engineer

Patrick Bedard, QMED

Anton Costales, Oiler

Jim Hefferman, Oiler

Joel Rezendes, Oiler

Tony DePalma, Chief Steward

Matt Tocchini, Steward

Annie Kurek, Mess Attendant

SKQ201402S Cruise Objectives

The western Pacific Ocean has by far the largest extent of Jurassic ocean crust in the world and thereby forms an important repository of the oldest oceanic crustal recording of geomagnetic field behavior in the world – i.e. the Mesozoic M-series anomalies (pre-M29 to M44, Tominaga et al., 2008). This Jurassic-age (158-180 My) Pacific crust forms a triangle of three magnetic lineation sets: 1) the Japanese lineations to the north and west, 2) the Hawaiian lineations to the east and 3) the Phoenix lineations to the south (Fig. 1). The area encompassed by these three magnetic lineation sets is marked by low amplitude and relatively indistinct anomalies that together are called the Jurassic Quiet Zone (JQZ) (Fig. 1). The JQZ was originally thought to be a period of few, if any, polarity reversals, similar to the Cretaceous Quiet Zone (KQZ). However, subsequent near-bottom magnetic surveys of the Japanese lineations in 1992 and 2002/03 [Sager et al., 1998; Tivey et al., 2006; Tominaga et al., 2008] reveal that this region is marked by remarkably fast reversals and anomalies that are lineated and decrease in intensity over a period of time, which we have called the Low Amplitude Zone (LAZ) [Tivey et al., 2006; Tominaga et al., 2008] (Fig. 2). Prior to this LAZ period, the Japanese Jurassic magnetic anomalies recover in both amplitude and reversal activity. A geomagnetic polarity timescale (GPTS) was constructed from the Japanese anomaly sequence [Tominaga et al., 2008], but questions concerning the overall global significance of the reversal sequence and systematic field intensity changes require a confirmation of such a GPTS on crust created at different spreading centers. This then forms the central tenet of our originally proposed and funded research program, which is to answer the following overarching question:

Is the geomagnetic field behaving in a globally coherent way during the Mid-Jurassic?
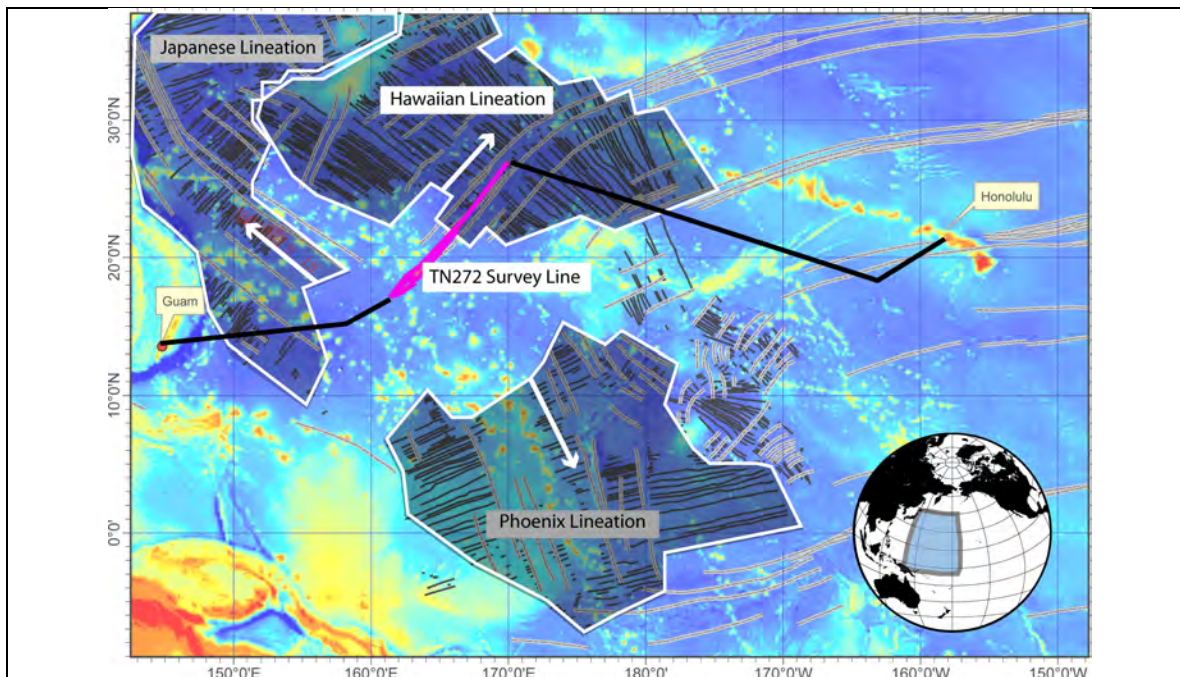
Figure 1. A map of the western Pacific Mesozoic lineations (modified from Nakanishi et al., 1992). White bounds indicate the Japanese, Hawaiian, and Phoenix lineation sets (black lines are lineations, gray lines are fracture zone traces). Black bold line is the 2011 cruise ship trackline and the purple lines indicate the detailed magnetic transects measured during the 2011 Thompson cruise. The white colored arrows indicate the approximate spreading direction of the Pacific-Farallon-Izanagi ridges. Red lines in the Japanese lineation indicate the pre-M27 anomaly sequence identified by 1992 (Sager et al., 1998) and 2002/2003 (Tivey et al., 2006; Tominaga et al., 2008) cruises.

A 2011 (TN272) cruise attempted to address this question using sea surface, deeptow and autonomous underwater vehicle (AUV) Sentry surveys. Unfortunately, technical problems with the Sentry operations during this cruise resulted in only two dives. AUV Sentry underwent a thorough engineering review and rebuild after problems were identified and subsequently solved and tested. We thus, proposed and were subsequently funded for this new project to redeploy Sentry and collect new magnetic data.

The basic premise of our project is to conduct a high-resolution, near-bottom magnetic survey of the Hawaiian lineations using the magnetically quiet, stable platform, AUV Sentry. This vehicle would collect the best quality data available without having to use deep-towed sensors in 6000-m deep water. The use of an AUV also allowed us to carry out an interleaved multichannel seismic program to image the shallow crustal structure and sediment thickness while the AUV's batteries were being recharged. In addition to the primary overarching question concerning geomagnetic field behavior in the Jurassic, we identified a series of related questions that arose from our analysis of the Japanese lineation data that we could address in our survey of Hawaiian crust. These questions include:

(1) *Is the M29-M38 anomaly sequence measured on the Japanese lineations characteristic of field behavior during this period*? The prior (1992 & 2002/2003) deep-tow results from the Japanese lineations [Tivey et al., 2006; Tominaga et al., 2008] reveal progressively decreasing anomaly intensity and substantial variations in reversal rate over the M29-M38 period (Fig. 2). A survey of the Hawaiian lineations would provide an independent record from another spreading ridge that could help verify the field behavior observed in the Japanese lineations.

(2) *What is nature and origin of the Low-Amplitude Zone (LAZ, M39 to M41 anomalies)?* Results from surveys of the Japanese lineations in 1992 & 2002/2003 [Tivey et al., 2006; Tominaga et al., 2008] reveal a period when magnetic anomalies are weak and apparently incoherent – the LAZ. It is important to identify whether the LAZ is a local phenomenon due to tectonic or crustal influences or if it truly is representative of geomagnetic field behavior. By measuring the magnetic record for this period at a different spreading center we will be able to either verify or eliminate any local tectonic or crustal variations as a source of the LAZ.

(3) *Does M44 mark the end of the marine magnetic Jurassic record?* We do not know if M44 is the oldest identifiable marine magnetic record based solely on the data from the Japanese Jurassic seafloor. In the Japanese sequence, M44 also marks the onset of rough-to-smooth basement topography [Abrams et al., 1993]. If the M42-M44 anomalies can be verified in the Hawaiian lineations, it may be possible to extend the magnetic record beyond the M44 chron. The older we extend our correlation of the marine magnetic record, the better we will constrain the birth of the Pacific plate in time and space.

(4) *Can we build a more robust Geomagnetic Polarity Time Scale (GPTS) based on the Hawaiian and Japanese lineation sets?* Obtaining high-quality, near-bottom data is imperative to unambiguously resolve anomalies that are only weakly observed at the sea surface due to the great ocean depths and diurnal noise that can mask the rapidly reversing signal we expect to find (Fig. 2A).
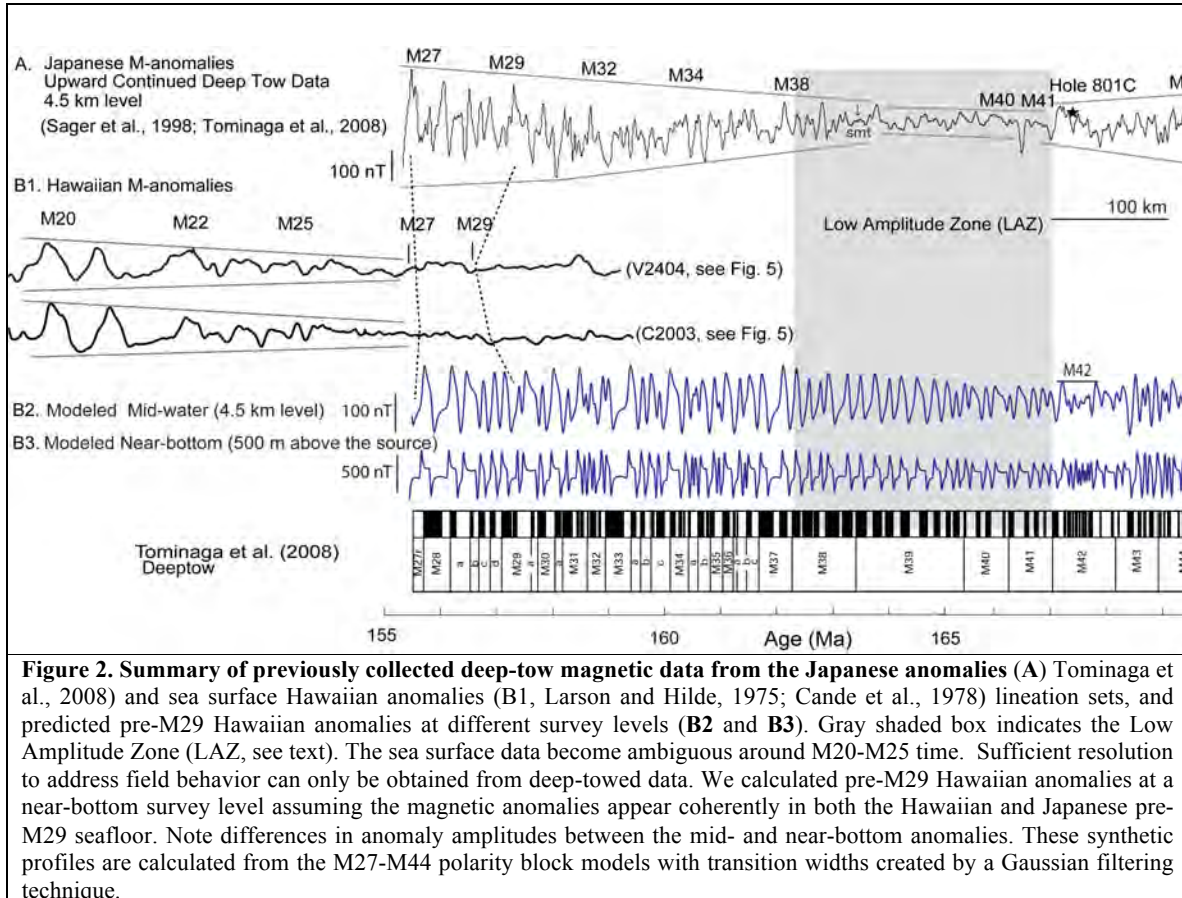
Figure 2. Summary of previously collected deep-tow magnetic data from the Japanese anomalies (**A**) Tominaga et al., 2008) and sea surface Hawaiian anomalies (B1, Larson and Hilde, 1975; Cande et al., 1978) lineation sets, and predicted pre-M29 Hawaiian anomalies at different survey levels (**B2** and **B3**). Gray shaded box indicates the Low Amplitude Zone (LAZ, see text). The sea surface data become ambiguous around M20-M25 time. Sufficient resolution to address field behavior can only be obtained from deep-towed data. We calculated pre-M29 Hawaiian anomalies at a near-bottom survey level assuming the magnetic anomalies appear coherently in both the Hawaiian and Japanese pre-M29 seafloor. Note differences in anomaly amplitudes between the mid- and near-bottom anomalies. These synthetic profiles are calculated from the M27-M44 polarity block models with transition widths created by a Gaussian filtering technique.

In addition to these scientific goals, **a key deliverable from this work is the development of a more robust and improved geomagnetic polarity time scale (GPTS) model for the Mid-Jurassic.** When one looks at a commonly available Geological Time Scale, such as the recently published Geological Society of America (GSA) Time Scale (Fig. 3; Walker and Geissmann et al., 2009), it is immediately obvious that the GPTS begins to break down in the Jurassic (145 to 201 My) period, typically around the M25-M29 chrons, the last presently accepted magnetic chron of the GPTS. There are two long-standing difficulties in improving the accuracy of the Late- to Mid Jurassic (M25-M44) geologic timescale. One is a dearth of reliable high-resolution radiometric dates and the other is a lack of a definitive Jurassic geomagnetic polarity time scale (GPTS) model that extends beyond M29. It has been an ongoing challenge for the International Commission on Stratigraphy (*www.stratigraphy.org*) and associated researchers [e.g. Pálfy, 2008; Przybylski et al., 2010a, 2010b; Ogg et al., 2010] to obtain data for this period because of the limited geologic exposure of well-preserved Late- to Mid-Jurassic sections across the globe. The duration of stages and the location of stage boundaries in the present Jurassic timescale are calculated from a simple interpolation of sparse data (see Ogg and Smith chapter *in* Gradstein et al., 2005). Absolute dates are difficult to obtain because fresh igneous rocks, which are amenable to precise radiometric dating and tied to the GPTS, are needed for dating. Usually such rocks come from ocean drilling [e.g. Ludden, 1992; Pringle et al., 2003; Koppers et al., 2003], so new dating will not provide an immediate solution for improving the Late- to Mid-Jurassic timescale in the near future. However, we can build a better GPTS model if we can measure a coherent sequence of marine magnetic anomalies in Late- to Mid-Jurassic time period. **Toward this goal, near-bottom magnetic profiles are imperative in providing unequivocal evidence of each anomaly peak and trough for this period in Earth's magnetic field history.**
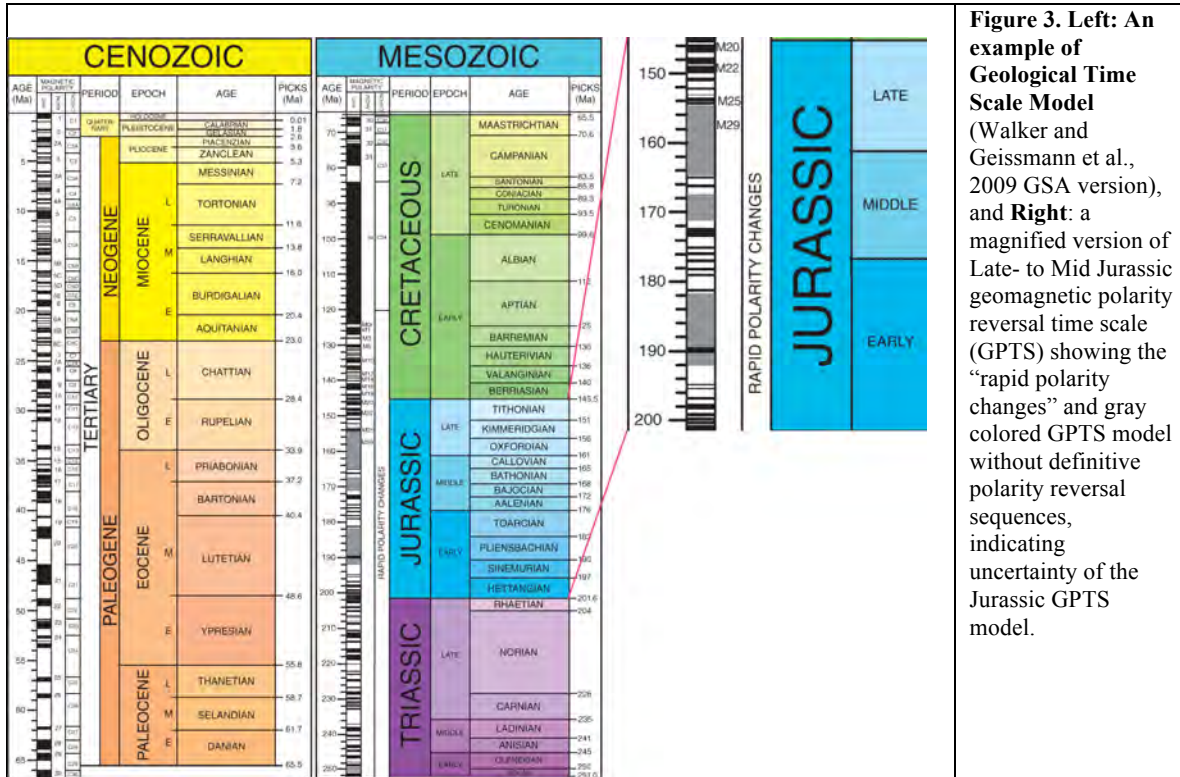
Figure 3. Left: An example of Geological Time Scale Model (Walker and Geissmann et al., 2009 GSA version), and **Right**: a magnified version of Late- to Mid Jurassic geomagnetic polarity reversal time scale (GPTS) showing the "rapid polarity changes" and gray colored GPTS model without definitive polarity reversal sequences, indicating uncertainty of the Jurassic GPTS model.

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Przybylski, P. A., J. G. Ogg, A. Wilerzbowski, A. L. Coe, M. W. Hounslow, J. K. Wright, F. Atrops, and Erlk Settles, 2010b, Magnetostratigraphic correlation of the Oxfordian-Kimmeridgian boundary, *Earth Planet. Sci. Lett*, 239, 256-272.

Sager, W. W., C. J. Weiss, M. A. Tivey, and H. P. Johnson, 1998, Geomagnetic polarity reversal model of deep-tow profiles from the Pacific Jurassic Quiet Zone, *Journ. Geophys. Res., 103*, 5269-5286.

Tivey, M. A., W. W. Sager, S. Lee, and M. Tominaga, 2006, Rapid magnetic field reversal and low amplitude as a cause of the Pacific Jurassic Quiet Zone, *Geology, 34, 9*, 789-792, doi:10.1130/G22849.

Tominaga, M., W. W. Sager, M. A. Tivey, and S. M. Lee, 2008, Deep-tow Profile Study of the Pacific Jurassic Quiet Zone and Inferences for the Geomagnetic Polarity Reversal Timescale and Jurassic Geomagnetic Field Behavior, *Journ. Geophys. Res, 113*, doi:10.1029/2007JB005527.

Walker, J. D., and Geissman, J. W., compilers, 2009, Geologic Time Scale, *Geol. Soc. Amer.*, doi:10.1130:2009.CTS2004R2C.

1. Shipboard Systems

Navigation Systems and Data Acquisition Systems

Science operations on the R/V Sikuliaq use three GPS receivers for the Data Acquisition System (DAQ). Kongsberg's Seapath 320+ is the primary positioning source for the DAQ, which has its own receiver separate from the bridge's navigation system. Seapath uses a differential GPS that has two antennae that provide a heading in addition to latitude and longitude coordinates. The GPS unit, C&C Technologies CNAV receiver, is the primary navigation source on the bridge and is used to improve the location data received from Seapath 320+ to the nearest half meter. As data is recorded, Seapath assigns location and time stamps to each of the Kongsberg systems: EM302, Topas PS18, ADCP OS75, ADCP OS150. All other data receive time stamps from the Network Time Protocol timeserver (NTP) as the data is collected in real time. This server uses two GPS receivers to assign exact UTC to the data in real time. See diagram below for GPS receiver locations:
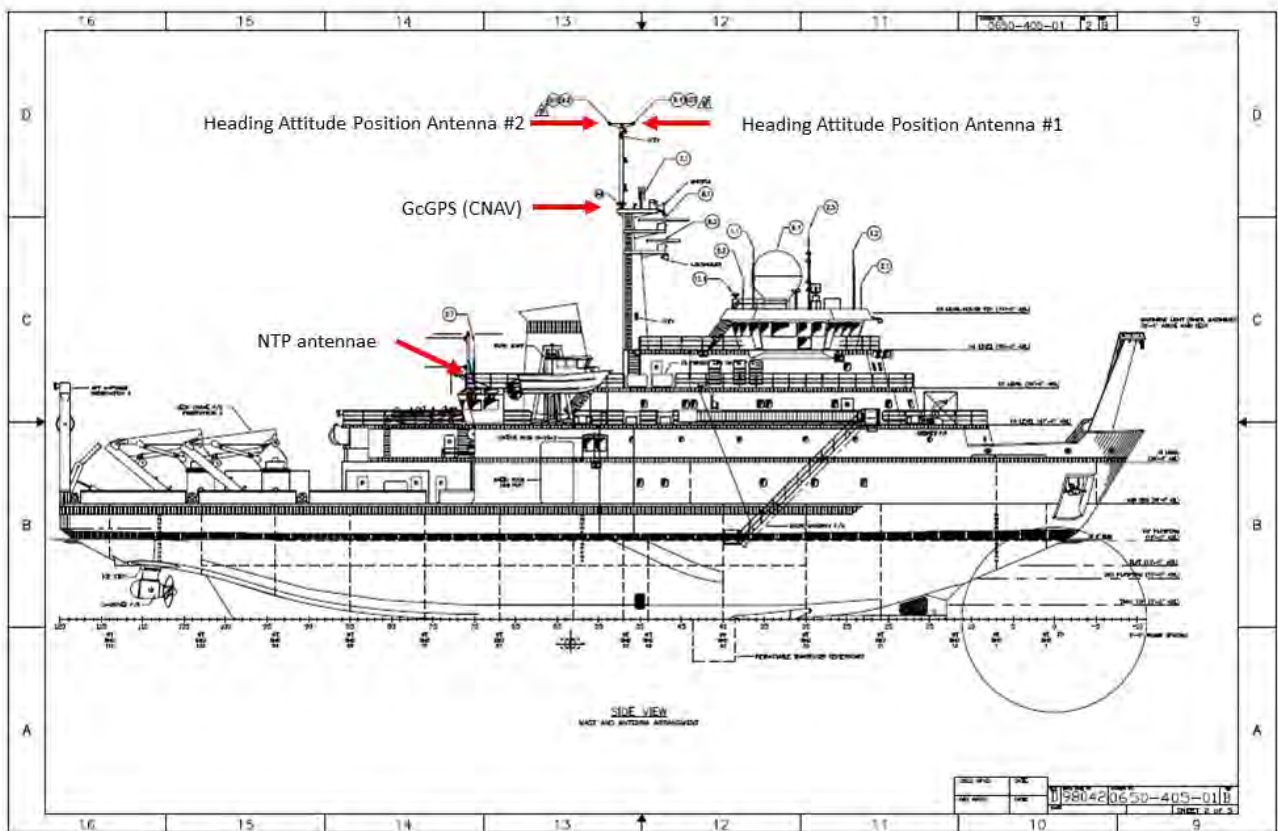
Figure 4. Diagram showing GPS antennae positions. Antennae locations with respect to the granite block in meters (x,y,z): GcGPS (CNAV): 14.131, 1.408, -26.671; Heading Attitude Position Antenna #1 (Seapath): 14.994, 2.079, -30.396; Heading Attitude Position Antenna #2 (Seapath): 13.171, 2.111, -30.396. NTP timeserver receivers were installed later; they are mounted on the railing on the aft side of the O3 deck.

DAQ (Data Acquisition System)

Raw data for science operations are copied from local data acquisition systems and compiled onto the Science Data Archive Repository (SDAR). The SDAR server is data.sikuliaq.alaska.edu/archive, and the raw and manually processed data are stored under the folder SKQ201402S. See table below for SKQ201402S index; notice that some folders are empty for this specific cruise. Each Kongsberg sonar system (EM302, Topas PS18, ADCP OS75, and ADCP OS150) has its own data acquisition system; these

data receive a timestamp generated from the ZDA clock in Seapath 320+ before being copied into the SDAR folder. There are periods on the cruise where some of these instruments are turned off during transit or Sentry operations. Most data from other sensors onboard are mined using raspberry pis (i.e. gravity measurements, surface temperature, etc.); this data is time stamped using the Network Time Protocol time server (NTP). All data mined from the raspberry pis are logged into the Lamont Doherty Logging System (LDS) once a second (1 Hz) before being copied into SDAR.

Table 1. SDAR: SKQ201402S index

Folder Name	Data Content
adcp/	OS75, OS150
ctd/	None collected
docs/	None collected
ek60/	None collected
em302/	Kongsberg multibeam echosounder data
em710/	None collected
knudsen/	None collected
lds/	Lamont Doherty Logging System (LDS) logs all ASCII serial data generated by onboard sensors such as GPS navigation, weather, and surface water properties. Refer to following table for data content within this folder.
lnxtestdas/	None collected
r2r/	R2R Event logger (Elog) entries logged by watchstanders
science/	None collected
soundguard/	None collected
topaz/	Kongsberg TOPAS PS18 parametric sub-bottom profiler data
wintestdas/	None collected
xbt/	Expendable bathythermograph probe data

Table 2. LDS folder index. See Appendix 2 for more details on file formats.

Subfolder name	Data Content
em302ctr2udp/	None collected
em710ctr2udp/	None collected
events/	Event logging for LDS sensors (i.e. start up); one file per sensor
flow_krohne_fwd/	OPTIFLUX 5000 Electromagnetic flowmeter data measuring the flow and electrical conductivity of fresh seawater in the forward seachest in the bow thruster room.
flow_omega_fwd/	Data from Omega high performance flow sensor, model FP 25-41, measuring flow of seawater being delivered from forward science seawater pump in the bow thruster room to science seawater system.
fluoro_turner-c6/	Data from Turner Designs C6 Multi-Sensor Platform with 5 Cyclops-7 submersible sensors located in the bow thruster room measuring the following seawater parameters: phycoerythrin, CDOM, chlorophyll a, crude oil, and turbidity.
gnss_cnav/	Navigational data from the C-Na3050 Globally Corrected Global Positioning System located on the main mast.
grav_bgm3_222/	Gravimeter BGM-3 data
gyro_1/	NAVIGAT 2100 Fiber-Optic Gyrocompass and Attitude Reference System data
gyro_2/	NAVIGAT 2100 Fiber-Optic Gyrocompass and Attitude Reference System data

ins_seapath_position/	Kongsberg Seapath 320+ heading, attitude, and positioning data using GPS and GLONASS satellites
mb_em302_centerbeam/	Nearest nadir centerbeam depth from multibeam EM302
mb_em710_centerbeam/	None collected
met_ptu307/	Vaisala combined pressure, humidity, and temperature transmitter model, model PTU307, data located on the forward mast.
pco2_ldeo_merge/	None collected
rad_psp-pir	Remote Measurements & Research Precision Spectral Pyranometer and Precision Infrared Radiometer data fromabove the science control room.
rain_org815ds_across/	Data from ORG-815-DS Optical Precipitation Sensor on port-starboard of flying bridge
rain_org815ds_forward/	Data from ORG-815-DS Optical Precipitation Sensor on fore-aft of flying bridge
sb_echosounder_1/	Data from bridge navigation echo sounder used for shallow depths
sb_echosounder_2/	None collected
speedlog/	Bridge navigation Doppler speed log
ssv_aml-svxchange_fwd/	Speed of sound through uncontaminated seawater as measured by the AML Oceanographic's SV•Xchange field swappable sound velocity sensor in the forward seachest in the bow thruster room.
thermo_pyrometer-ct15/	Seasurface skin temperature data as measured by the Heitronics infrared radiation pyrometer just forward of the science control room.
tsg_emssv/	Log of the Kongsberg external datagrams providing real-time input for seasurface sound velocity needed for these sonars
tsg_sbe45_fwd/	Surface seawater temperature and conductivity as measured by the Sea-Bird SBE 45 MicroTSG Conductivity and Temperature Monitor located in the forward seachest.
wind_gill_fwdmast/	Relative wind speed as measured by the WindObserver 70/75 Ultrasonic Anemometer located on the forward mast.
wind_gill_fwdmast_true/	True wind speed as measured by the WindObserver 70/75 Ultrasonic Anemometer on the foremast, using heading measurements from Seapath 320+.

2. Operations

Watchstanding schedule

00:00-17:00 Masako Tominaga
09:00-00:00 Maurice Tivey

08:00-12:00/20:00-24:00 John Greene, Laura Stanley
12:00-16:00/00:00-04:00 Tyler Ruchala, Matthew Karl, Alex Stote
04:00-08:00/16:00-20:00 Rachel Clark, Tim Stadler

(floating) Aric Velbel

Watchstanding duties

- Keeping an event log in E-log and logbook.
- Maintaining the data acquisition (quality check) of EM302, Topas, gravimeter, Seaspy surface magnetometer, deep-tow magnetometer (DTM), winch tension and wire-lengths, Sentry positions.
- Processing EM302 bathymetry and backscatter data, Topas reflection data, gravity and magnetic data.
- Tracking the ship position on charts.
- Helping deck operations for Seaspy surface magnetometer/DTM launch and recovery, and XBT deployment.
- Archiving the cruise through Daily Cruise Summaries and Outreach Blogs, both included in this final report.

Watchstanding stations

- Event logging and charting at R/V Sikuliaq computer lab.
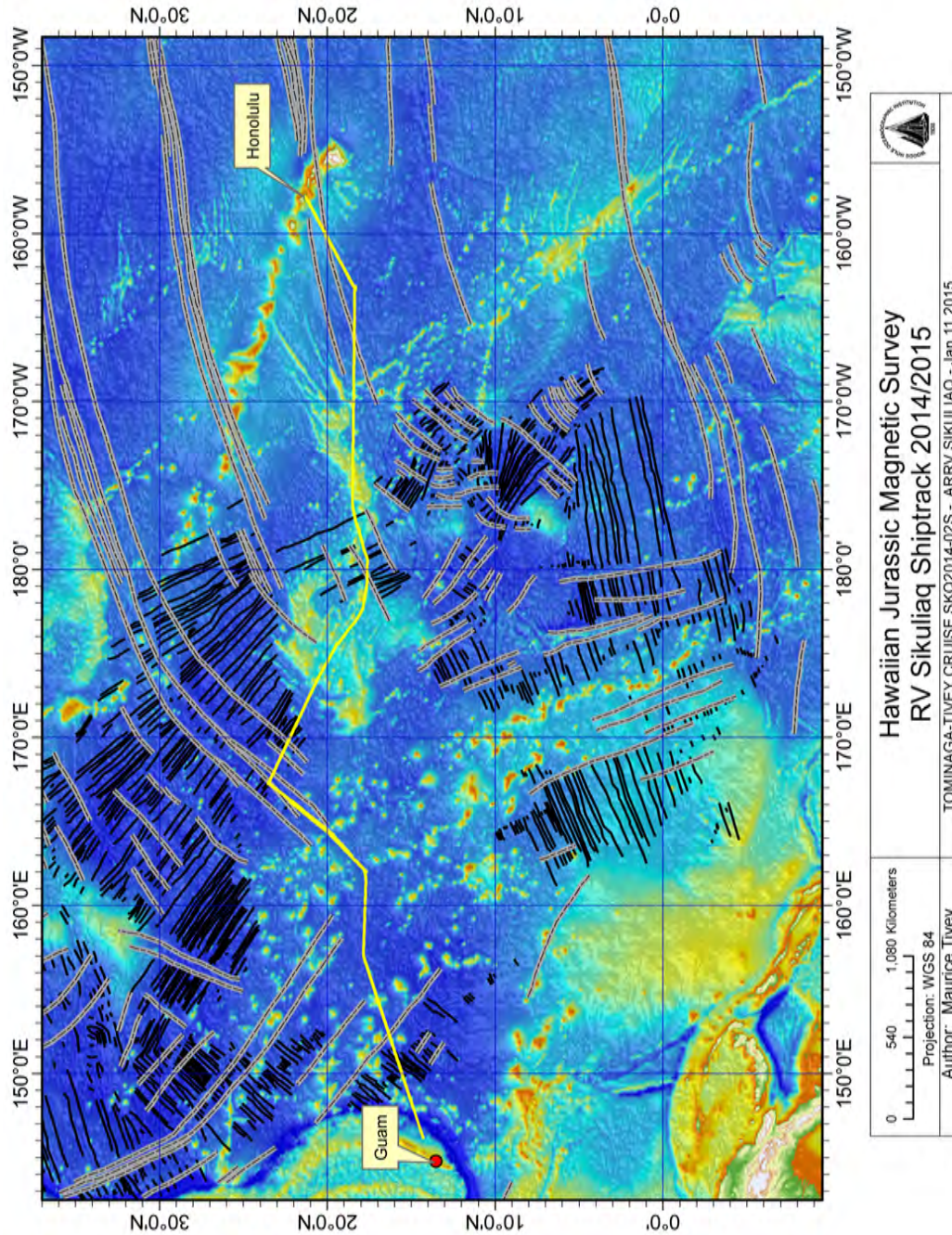- EM302 and Topas data processing at R/V Sikuliaq main lab (fore).

Figure 5. SKQ201402S-JQZ3.2 Completed Cruise Track (Honolulu, HI to Guam).

3. EM302 Multibeam Bathymetry (software version 4.1.3)

General Product Information:

The R/V Sikuliaq is equipped with a Kongsberg Simrad EM302 multibeam bathymetry echo sounder (see location, Fig. 6). The nominal sonar frequency is 30 kHz with an angular coverage sector of up to 150 degrees and 864 soundings per ping. The achievable swath width on a flat bottom is normally up to 5.5 times the water depth. The software used to acquire EM302 data was the Kongsberg Seafloor Information System version 4.1.3. Figure 7 shows an example of the application window and Figure 8 shows the geographical track that is generated from the data collected in real-time. The main feature manipulated by the watchstanders during data collection was the Depth Settings under the Sounder Main in the Runtime Parameters window. The minimum and maximum depths were manually adjusted by watch standers using depth information provided in the Cross Track window (located in the upper left of the application window). The "Force Depth (m)" was set according to the average depth displayed by the Cross track window. This option helps the echo sounder find the correct depth if there is acoustic interference or if the water is very aerated. The Ping Mode in the EM302 application window was adjusted according to the water depth and beam coverage in order to improve performance in varying bathymetry of the survey region. Auto Ping Mode was utilized in depths of less than 2500 m of water; Very Deep Ping Mode was used in water depths greater than 2500 m; Extra Deep Ping Mode was used in water depths greater than 4500 m. Watchstanders followed beam coverage to adjust ping mode accordingly. A combined total of ~105 degrees was used as an indication to move to shallower ping modes. It is important to note that when pinging in Very Deep and Extra Deep mode, Dual Swath is automatically turned off, even if it is selected in the Runtime Parameters menu. This is because of duty cycle limitations of the transmit transducer. However, at these depths the seabed coverage is usually narrow, giving a high relative ping rate even without Dual Swath.

XBT (eXpendable Bathy Thermocraft)

To obtain sound speed and temperature measurements with respect to depth measurements we deployed several model T7 XBTs (expendable bathy-thermocrafts) at various intervals throughout the cruise. Deployments were off the stern. Temperature and depth information was recorded using the WinMK221 Lockheed Martin Specicam software. No automatic processing was done to the data. Dual swath mode was turned off during XBT operations. Vertical reference units were used to help keep a reference position and increase angular resolution. The raw XBT data was edited by science technicians for use in the EM302 multibeam system using the SVPeditor software from the University of New Hampshire's Center for Coastal and Ocean Mapping. Table shows the XBT deployments for our research cruise:

Table 3. XBT deployment profiles.

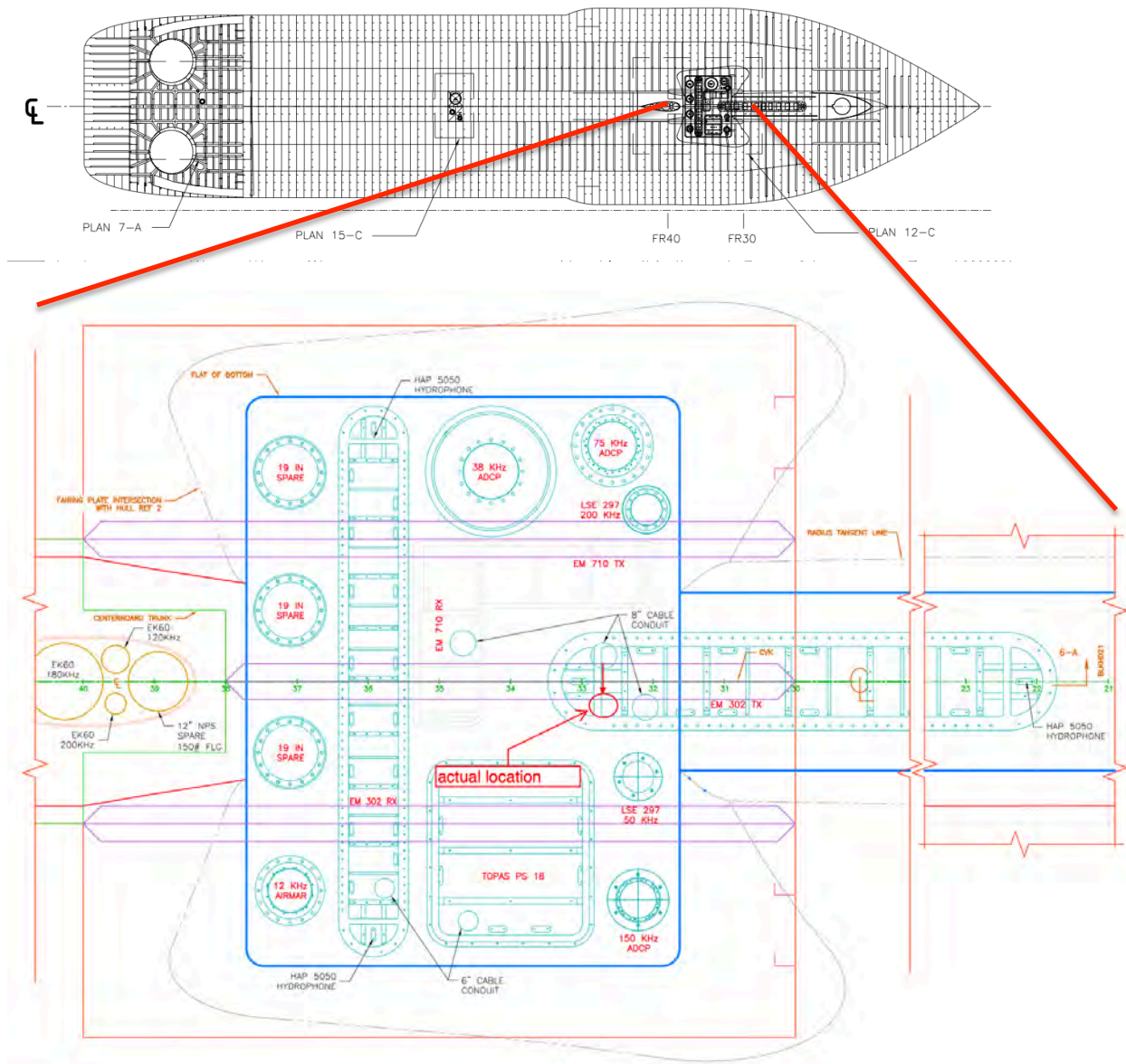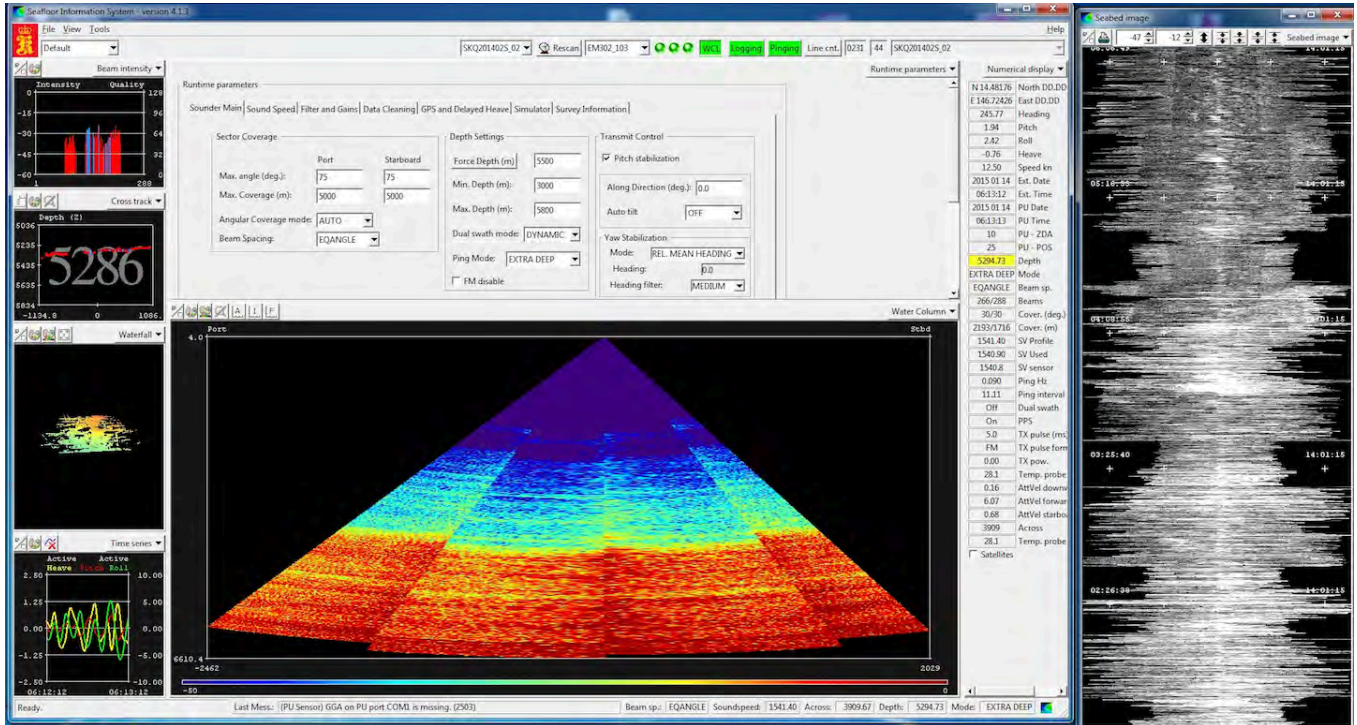| ID	Julian Day	Date m/d/y	Time h:m:s	Seq	Latitude (degrees N)	Longitude (degrees E/W)	Probe Type	Actual Depth (m)	Terminal-Depth (m)	PPT
T7_00045	354	12/20/2014	10:26:57 PM	45	18 27.29077N	171 15.24023W	T-7	367.00	760.06	30
T7_00046	354	12/20/2014	10:38:50 PM	46	18 27.30383N	171 17.55664W	T-7	365.06	760.06	30
T7_00047	357	12/23/2014	9:29:04 PM	47	19 14.2821N	175 43.54102E	T-7	431.80	760.06	30
T7_00048	359	12/25/2014	4:28:26 AM	48	21 59.44775N	170 29.88281E	T-7	760.06	760.06	30
T7_00049	360	12/26/2014	12:45:20 AM	49	23 19.67261N	167 8.08203E	T-7	494.25	760.06	30
T7_00050	362	12/28/2014	10:51:35 PM	50	19 0.58459N	163 28.56641E	T-7	760.06	760.06	30
T7_00051	002	01/02/15	1:50:51 AM	51	20 19.896N	164 46.00781E	T-7	760.06	760.06	30
T7_00052	004	01/04/15	4:25:19 AM	52	20 56.00073N	165 14.37305E	T-7	760.06	760.06	30
T7_00053	010	01/10/15	11:37:15 PM	53	17 47.12781N	162 5.94531E	T-7	760.06	760.06	30

Figure 6. Location of the EM302 multibeam system aboard the R/V Sikuliaq.

Beam intensity	Folder info; WCL, Logging, Pinging (Green on)		Numerical Display	Backscatter
	Runtime Parameters • Sounder main ○ Sector Coverage ○ Depth Settings ○ Transmit Control			
Cross track				
Real-time bathymetry interpretation	Swath Display			
Heave, Pitch, Roll vs. Time				

Figure 7. EM302 Seafloor Information System- version 4.1.3 (TOP) Example display window. (BOTTOM) Description of display window features.
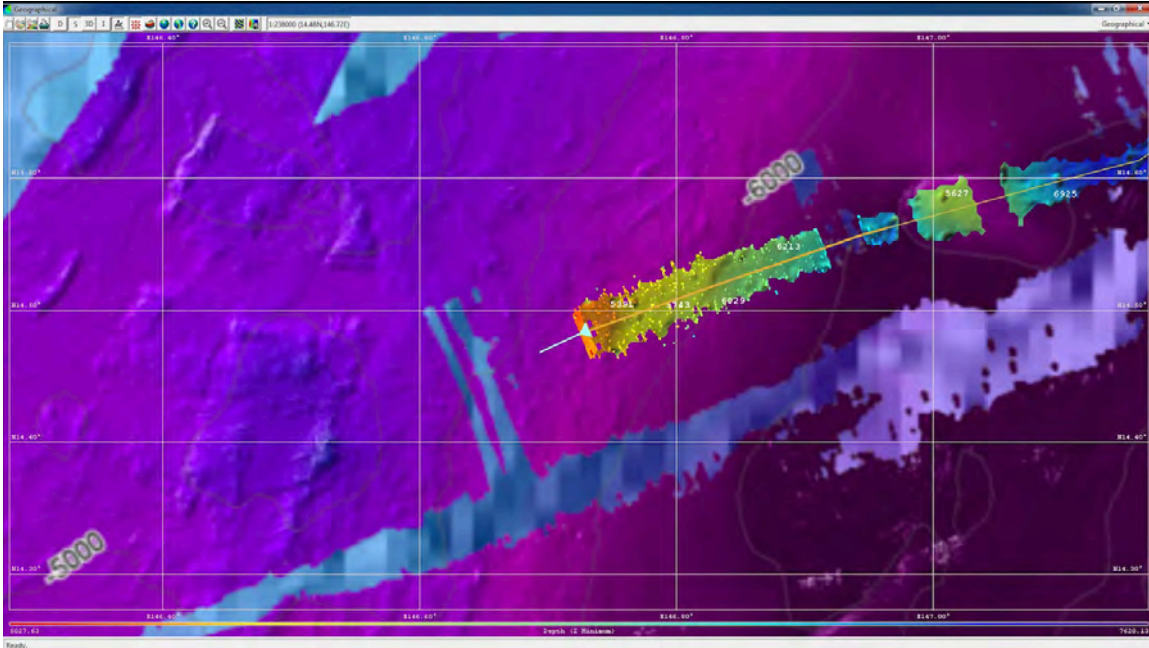
Figure 8. Example of geographical display of preliminary multibeam data track (plotted over geotiff grid collected from NGDC database).

Data Processing

MB-System software was used for data processing. Raw *.all data were converted to MB format *.mb59 for post processing using a script. Ping editing was done for each file and all files were saved as trackline swath grids by following these data processing steps:

1) Connect to the server "data.sikuliaq.alaska.edu/archive"
2) In "Archives"
   >Folder "SKQ201402S"
   >Folder "EM302"
   >Folder "raw"
   >Folder "SKQ201402S_01"
   >Folder "SKQ201402S_02"
3) Find *.all data files of interest in the folder "JQZ3.2_EM302P"
4) Make a new folder within "JQZ3.2_EM302P"
   >Copy *.all data files of interest (one at a time)
   >Name folder MBXXX where X is the number of the data sets
      [ex) MB0001 is the first data set, MB0003 is the third data set]
   >Do not begin working on new data until another file begins
      [ex) when MB0005 is created, work on MB0004]
5) Go to folder "MB_allfiles"
   >Copy "all2mb.txt" and "postedit_gridmaker.txt" into the folder you just created
6) In terminal run "all2mb.txt" which will create all aux folders (*.fbt, *.fnv, *.inf, and *.par) including *.mb59
7) In terminal window run "mbedit" [./mbedit]
   >File
   >Open
   >Select first *.mb59 file
8) Begin ping editing (erase, #pings shown, # pings to step, etc.)
   >Number of pings to step must equal number of pings shown

14

>Set vertical exaggeration to 1.00
>Erase pings individually by selecting erase or select "alongtrack view" to process the lines simultaneously by using the "grab" option
9) Select DONE (saves files automatically)
10) Select Quit
11) In terminal, run "gridmaker.sh"
>Other aux files appear in folder including *.grd
12) Open Fledermaus
>Import ".gridded data"
>Select *.grd file
>Keep all default settings (aka select next until prompted with the finish key)
>Make vertical exaggeration equal to 1.00
13) Change Color map
>Tools
>Edit CMap
>Fixed color range table
>Range used -6200 to -1000
>Apply
>Close
14) Save TWICE! In folder "MB_objectfiles"
>As object
>As scene
>Name = MBXXXX.sd and MBXXXX.scene
15) Open *.sd file in the "allmb.scene" and overwrite it once the *.sd file is imported
16) Fill out Excel spreadsheet "MB checklist" (saved in folder JQZ3.2_EM302P)
17) In order to retrieve header information for an .mb59 file
>navigate to the specified file folder
[ex) MB0001]
>ls and copy the .mb59 file for that file number
>Type "mbinfo –F59 –I[command+v to paste file name]"
>Hit
>Specified information should populate

5. PS18 Topas

The Kongsberg Topas PS18 Parametric Sub-Bottom Profiler is a narrow beam, high resolution, and full ocean depth sub-bottom profiler. The Topas PS18 is used for imaging sediment layers and to observe buried objects. The Topas PS18 uses a narrower beam width than most conventional sub-bottom profilers with a high bandwidth signal to obtain higher resolution and reduce reverberation levels. The low signal-to-reverberation levels allows for deeper penetration into bottom sediments. Figure 10 displays the location of the Topas transducer aboard the R/V Sikuliaq. The Topas PS18 Parametric Sub-Bottom Profiler was operated in conjunction with the EM-302 multibeam echosounder and configured to receive slope and depth datagrams from the multibeam system for beam control and bottom tracking.
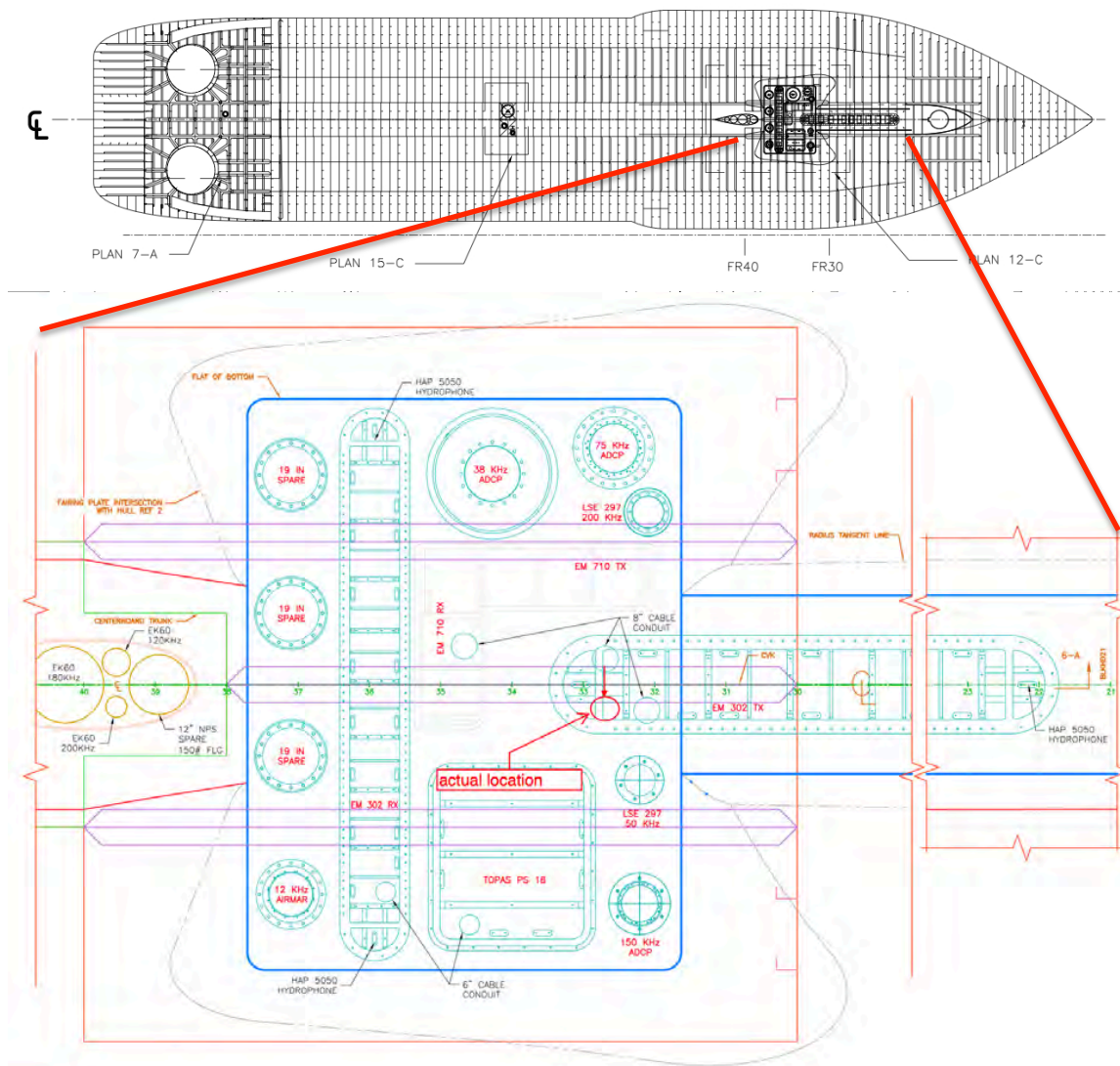

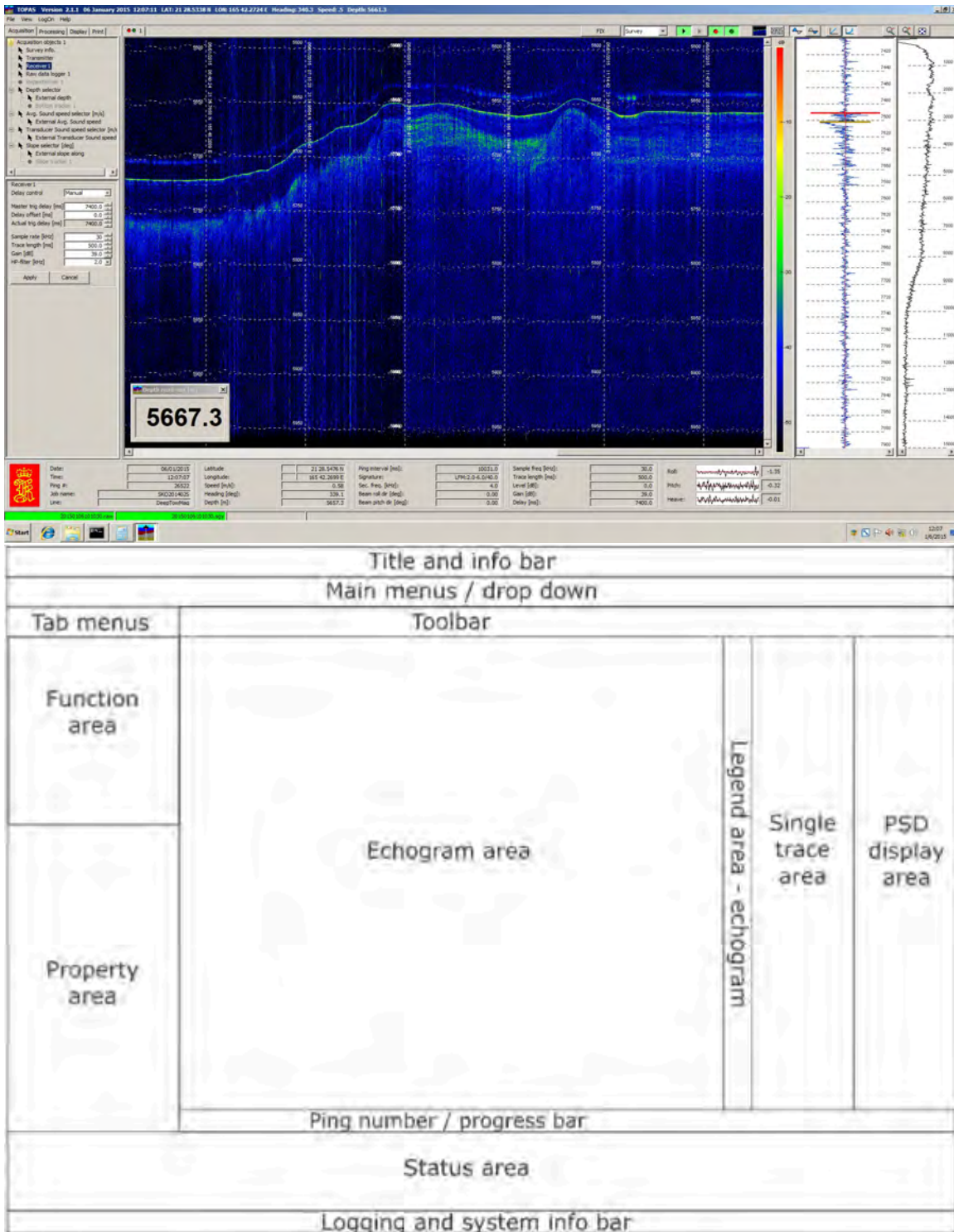**Figure 10. Location of Topas PS18 system aboard the R/V Sikuliaq.**

Figure 11. Top) TOPAS v.2.1.1 software display window. Bottom) Description of display window areas.

TOPAS Acquisition and Processing

The R/V Sikuliaq uses version 2.1.1 of the TOPAS MMI software for both acquisition and processing of the sub-bottom profiler data. The acquisition parameters were set for operating in

optimal capacity in deep water of the survey area (see Appendix 5 for further details). The transmitter for this cruise was a chirp LFM (linearly changing frequency) pulse form with a start frequency of 2.0 kHz, stop frequency of 6.0 kHz, and length of 40 ms for use in deep water survey areas. The receiver was set in manual mode due to the varying depth of the survey and the resultant jumps in trigger delay. The Master Trigger delay [ms] was set approximately to the actual depth divided by 0.75. The receiver sample rate was set to 30 kHz. The trace length was set to 500 ms due to the occasional slopes encountered in the survey area. A gain of 39.0 dB was applied due to the deep-water conditions of the survey area. A general high pass filter of 2.0 kHz was applied to all acquired data. During acquisition processing of the data a match filter was applied to increase the signal to noise ratio; the instantaneous amplitude module was enabled to increase resolution of the real parts of the signal. An example of the acquisition window application is displayed in Figure 11. See Appendix 5 for more information on the acquisition processing chain and display parameters. The data was logged as both Topas *.raw files and *.sgy files on the Sikuliaq's data archive:

smb://data.sikuliaq.alaska.edu/archive/SKQ201402S/topaz/raw.

In the format:

yyyymmddxxxx'-xxx'.raw or .sgy

Where:

yyyy = year
mm = month
dd = day
xxxx'-xxx' = additional unique number string

The shipboard data processing involved using the Topas software's replay function to reload the pre-processed *.sgy files from the Sikuliaq's data archive. Many of the processing features were kept the same from the pre-processing performed during the acquisition of the data, as they were the optimal settings for the survey area. Additional processing included adding a mute to zero the trace above the seabed reflector and time varying gain to add definition to the reflectors present. See Appendix 5 for more information on the post-acquisition processing chain. The processed data was saved on both external hard drives and was uploaded to the Sikuliaq's data archive in *.sgy file format:

smb://data.sikuliaq.alaska.edu/archive/SKQ201402S/topaz/proc.

In the format:

yyyymmddxxxx.raw or .sgy

Where:

yyyy = year
mm = month
dd = day
xxxx = additional unique number string

An explicit description of the processing steps undertaken by the cruise watchstanders is included below:

1. Open TOPAS v2.1.0 from the Desktop, open the TOPAS folder, and click on the TOPAS shortcut.

2. Press 'Start replay' button in the upper right hand corner. Go to Computer -> My Passport (E:) ->Topaz_segy and choose either SKQ201402S_01 or 02 (check/ fill out excel spreadsheet). Select a *.sgy file, making sure 'Files of type: File saved in segY format [*.sgy]' is selected.

3. Topas will then begin to replay the recorded *.sgy file.

4. Go under the Display tab, Legend bullet: (these are the display parameters we used during acquisition)

   • **View mode**   **Normal**

   • **Polarity**   **+**

   • **Scale**   **Logarithmic**

   Steps 5-10 Under the Processing Tab:

5. Enable the **PSD** (Power Spectral Density)

   • Enter a **Window start [ms]** value eg. 6000, *usually in this range, you just need a starting pt.*

   • Enter a **Window length [ms]** value eg. 500, *will adjust automatically.*

   • Choose a **PSD window** type use Welch; hit Apply.

6. Enable the **Bottom tracker**

   • Check **Show Master Depth**, *this brings up the brown bottom line in the single trace area.*

   • Check **Envelope detection**, *performs bottom detection on the signal envelope instead of the magnitude of the bottom return signal.*

   • Check **Auto search**, *if track is lost, the window will open up to allow for automatic re-establishing of the bottom track.*

7. Enable **Attribute processing** -> **Instantaneous amplitude**, *this is the magnitude of the analytical signal, which equals the envelope of the real signal.*

8. Apply **Time Variable Gain**, trying to capture the highest amplitudes in the Single Trace Window and **Mute** to attempt to remove signal above the seafloor reflector. *Try multiple combinations, in different areas, experiment and see what works!*

9. Enable **Data plotter 2**, select a different **plot color**, *this will show the effect of the filters/gains in the single trace area.* **REPEAT step 8 until satisfied with Data plotter 2/echogram output!**

10. Enable **Processed data logger**; change **max file size**: 100 [Mb]

11. Once you have the Time Variable Gain and Mute to your satisfaction, replay the data, see Step 2, and press the **Log processed data** circle button in the top right corner, and save in the 'Pro' directory as 'Files of type: File saved in segY format [*.sgy]'

Kingdom Processing

The processed data was then imported into the IHS Kingdom 8.8 (64-bit) software to view and perform preliminary interpretation of the data quality and contents of each profile. See Appendix 5 for an explicit description of the viewing parameters used in the Kingdom software and example figures of the processed data. An explicit description of the steps undertaken by the cruise watchstanders to import the processed *.sgy files into the Kingdom software is included below:

1. Open Kingdom 8.8 (64-bit) from Desktop
2. Open Project JQZ3.2
3. Under 'Surveys' toolbar select 'Import SEG Y…'
4. Select 'Import Multiple 2D SEG Y files with Coordinates'; Press 'Next >'
5. Press 'Browse…' under 'Import SEG Y files from: Disk'
6. Navigate to Computer > My Passport (\\psf)(Y:) > topas_pro > and select either the SKQ20142S_01_pro or SKQ20142S_02_pro folder
7. Select a *.sgy file and press 'Open'; press 'Next'
8. Specify Amplitude Format 32-Bit IEEE Floating Point, press 'OK'; press 'Next >'
9. Under Seismic Line Name in Row of the Text Header select 'Use disk file name as the line name'; press 'Next >'; press 'Next'; press 'Finish'
10. Under Surveys > All Surveys click on the file name to view the profile; note any characteristics/features of note present; record in Excel spreadsheet 'Topas Checklist.xlsx'

6. Shipboard Gravity

We collected shipboard gravity measurements for the entire transect covered during JQZ 3.2. The R/V Sikuliaq is equipped with a Bell BGM-3 Marine Gravimeter, Serial No. 222. The gravimeter is installed on the 00 deck in the marine tech workshop, as close to the center of the ship as possible. The gravimeter was installed in August 2014 at Woods Hole, before the Sikuliaq started its maiden voyage to the Gulf of Mexico and across the Pacific. The gravimeter worked well throughout the cruise; no shutdowns or reboots were necessary. Pre-cruise gravity measurements were conducted at Pier 30, Honolulu, HI, on land and in the ship during fueling before the ship went underway. A land tie was provided from the absolute gravity station at Snug Harbor, University of Hawaii Pier, Honolulu, HI. A post cruise land tie and gravity measurement was made upon arrival in Guam's Apra Harbor.

The gravimeter measures the acceleration due to gravity at a given location every 1 sec (1Hz sampling rate). A primary use of the gravity tie is to correlate the acceleration due to gravity measured aboard the ship to an absolute gravity measurement in a stable environment (ie. on land) [Hinze et al. 2013]. The gravimeter converts the acceleration at the location to an electric signal, outputting the raw data as a measurement in volts. The ship's gravity software outputs a raw data file every 24 hours to a shared drive. The raw data files (grav_bgm3_*data*) output 8 columns, from 1 to 8: the gravimeter model and serial number, month, day, hour, minute, second, gravity count (volts), and gravimeter status. We use the day, time, and raw gravity count to process the data into an interpretable form.

Figure 12. BGM-3 Marine Gravimeter on board the R/V Sikuliaq.

Marine gravity processing consists of a few scalar adjustments to the original measurement. First, we examined the gravity data for errors. Next, before processing the data, we obtained and examined all necessary information for processing, including the ships velocity (knots), heading, and latitude, longitude positions from the ship's navigation system. The first step in our

processing method was to filter the original raw gravity counts using a 6-minute Gaussian filter. Next, we applied a scale correction and instrument bias to the measured raw gravity to convert the voltage reading to milligals.

$$G_{obs} \ (mGal) = (G_{filt} \ x \ scale \ factor) + bias$$

The scale factor and bias were given by the gravimeter, with values of 4.949295 and 856837.06, respectively. G_{filt} is the Gaussian filtered raw gravity counts; G_{obs} are the observed gravity measurements in mGals.

The gravitational attraction of the Earth is not constant; it varies as the radius of the Earth changes. This radius change occurs as you go from the poles to the equator (~ 21 km), and results in a variation of about 5,000 mGals [Hinze et al. 2013]. In surveys that traverse different latitudes, a latitude correction (LATC) must be applied to correct for these changes. We use the international standard GRS80 ellipsoid values for the latitude correction.

$$LATC \ (mGal) = G_e \ x \ [1 + A \ sin^2(\theta) - B \ sin^2(2\theta)]$$

G_e is the value of gravity at the equator on the reference ellipsoid (geoid) and is approximately 978.03267715 gal. *A* and *B* are functions of the flattening of the earth and are constants, while θ is the latitude at a given observation location.

The next step we performed in processing is the Eotvos correction (EC). Since our gravimeter measures accelerations due to gravity, this correction is applied to negate any accelerations of the ship that could alter the gravimeter reading.

$$EC \ (mGal) = 7.487 \ x \ V \ x \ cos(\theta) \ x \ cos(\alpha) + 0.004 \ x \ V^2$$

Where V is ship velocity in knots, θ is latitude, and α is the ship's heading. Due to large variations in the ship's heading and velocities, we Gaussian filtered the Eotvos correction before adding it to the gravity measurement.

The final correction we applied accounts for the gravimeter height (h) above/below the geoid (nominally sea level). The gravimeter on the Sikuliaq is situated about 3 meters above sea level. This simple scalar correction is called the Free-Air correction (FAC) and has been constant for the entire expedition.

$$FAC \ (mGal) = 0.3086 \ x \ h$$

The free air correction assumes that all mass between the observation height and geoid have zero density, therefore it is assumed the measurement was taken in free air.

After performing the various corrections to our data, we calculated the final anomaly used to interpret the gravity data. Anomaly in this sense refers to the difference between the observed gravity measurement and its model-based theoretical value for any location on earth. We calculated the Free Air Anomaly (FAA) from the observed gravity measurement in mGals (G_{obs}), the filtered Eotvos correction (filtEC), latitude correction (LATC), and free air correction (FAC):

$$FAA \ (mGal) = G_{obs} - LATC + filtEC + FAC$$

The final free air anomaly was exported along with latitude and longitude values to plot in GMT

(Fig. 13). We exported daily text files of the data with the following headers; Date, time, longitude, latitude, ship heading (degrees), ship velocity (knots), gravimeter height (m), observed gravity measurement (mGals), Latitude correction (mGals), Eotvos correction (mGals), filtered Eotvos correction (mGals), Free – air correction (mGals), and the Free – air anomaly (mGals). All equations used for corrections were taken from Blakely, [1996] and Hinze et al. [2013].
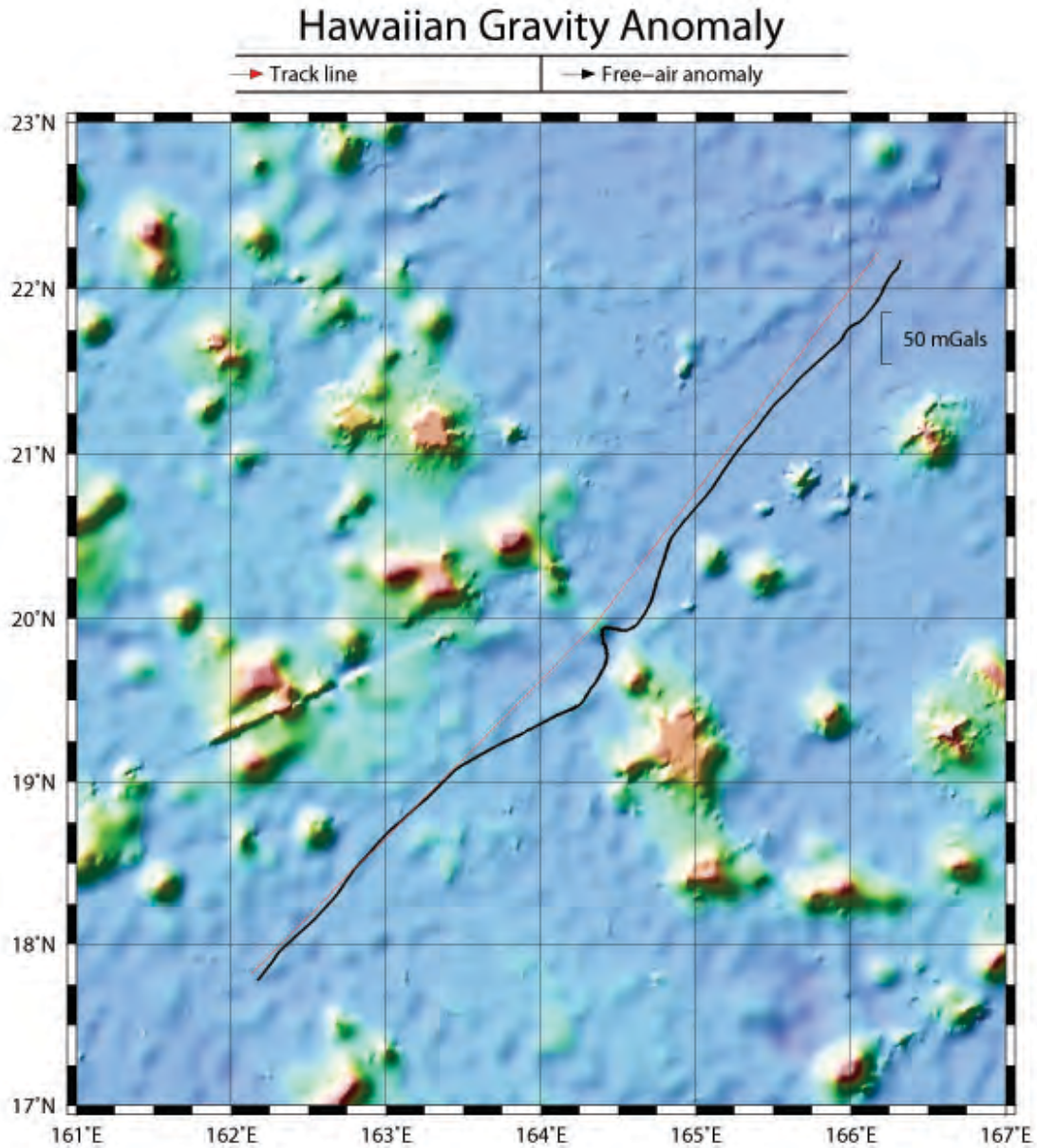

Figure 13. Free – air anomaly (mGals) over JQZ 3.2 track line. The track line (red) serves as the axis from which the anomaly (black) is plotted. Note: anomaly plots below track line meaning all values are negative, as in this case. Anomaly values compared to global grav.23.1.grd values from Sandwell and Smith [2014] shows near perfect match.

7. Sea Surface Magnetometer

A Marine Magnetics Seaspy marine magnetometer was used to collect sea surface magnetic measurements during the cruise. This Overhauser nuclear precession type of sensor collects total field data at a fast rate (for this cruise 1 sec rep. rate) with an accuracy of 0.1 nT. The magnetometer was deployed from a small special-purpose air-tugger winch on the port side of the fantail. Both the winch and magnetometer (Fig. 14) were supplied by the WHOI-MISO facility. The magnetometer cable was 200 m in length (approximately 5 m on deck with the remainder deployed over the rail). The fantail is 34 m from the GPS antenna location. A coaxial conductor deck cable ran to a patch panel at the Baltic Room bulkhead. Internal ship wiring provides a connection to the Sikuliaq Computer lab.
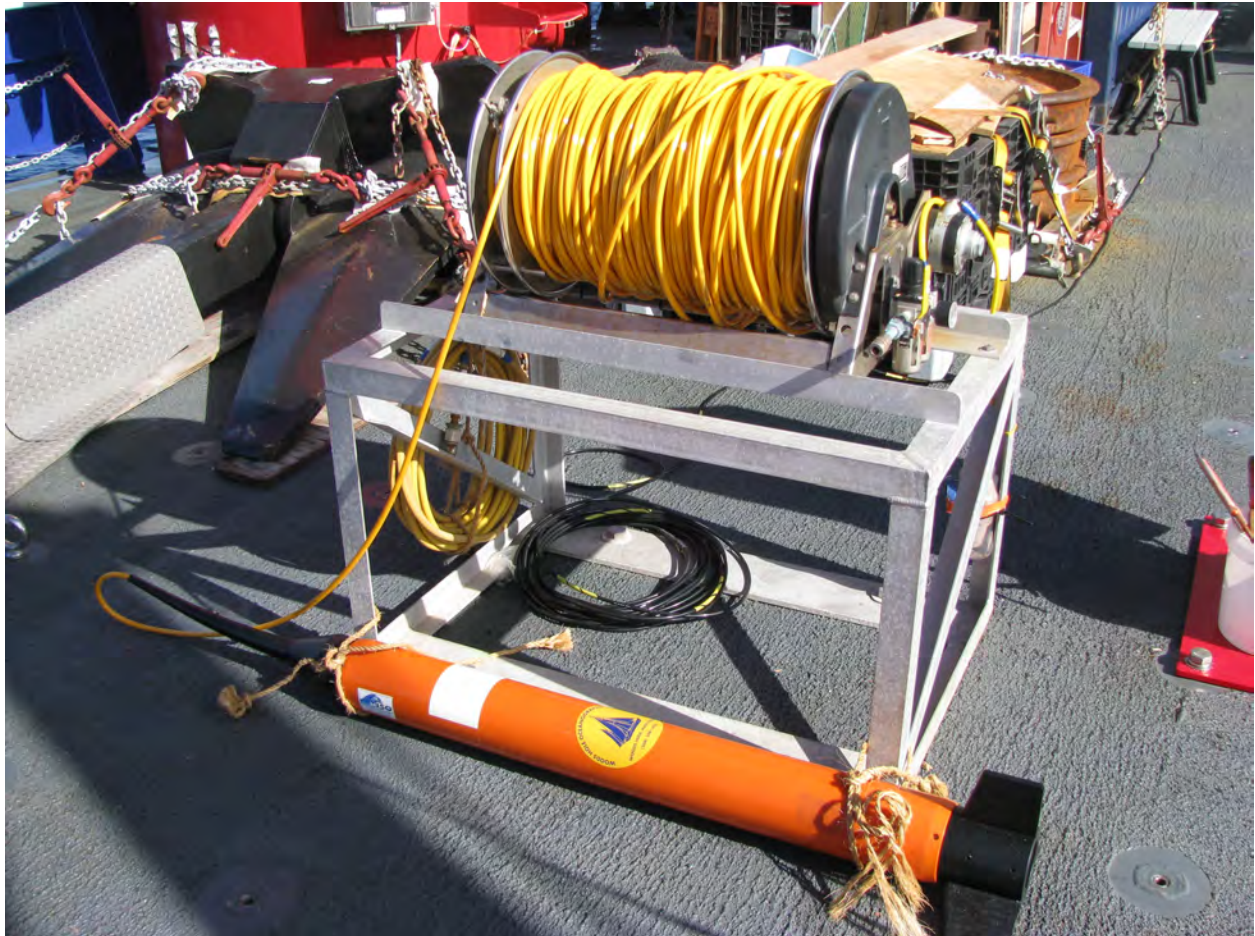

Figure 14. The Seaspy marine surface magnetometer and winch on board the R/V Sikuliaq.

Data from the magnetometer were logged by a PC-Win7 laptop running the Marine Magnetics BOB software. At first the laptop time was set manually to UTC time but after December 27 the laptop was hooked directly to the Sikuliaq's NTP timeserver (10.1.0.5) for more accurate and reliable timestamps. The magnetometer was used during all transits at speeds of up to 12.5 kts. Sea surface magnetic profile times are listed in Table 4. A map of tracks and the anomalies are shown in Figures 15 and 16A-D. Magnetic data were exported from the BOB software into ascii time-stamped files per survey line. These files were first parsed, corrected for time offsets if necessary, and merged with the ship's Seapath

navigation. The layback of the tow fish behind the ship was 234 meters and its position was calculated. Centerbeam depth from the EM302 was then interpolated onto the position of the towfish. The measured total field was median filtered for spikes. The International Geomagnetic Reference Field (IGRF-2010) was then calculated at the fish position and subtracted from the observed field. The resultant anomaly is saved in daily time-stamped ascii files with fish position, centerbeam depth and observed field.

Two sea surface magnetic survey lines (line 3 and line 4) were collected along the main study area transect. The remaining lines cover the transit to and from the survey site.

Table 4. Sea surface magnetic profile times

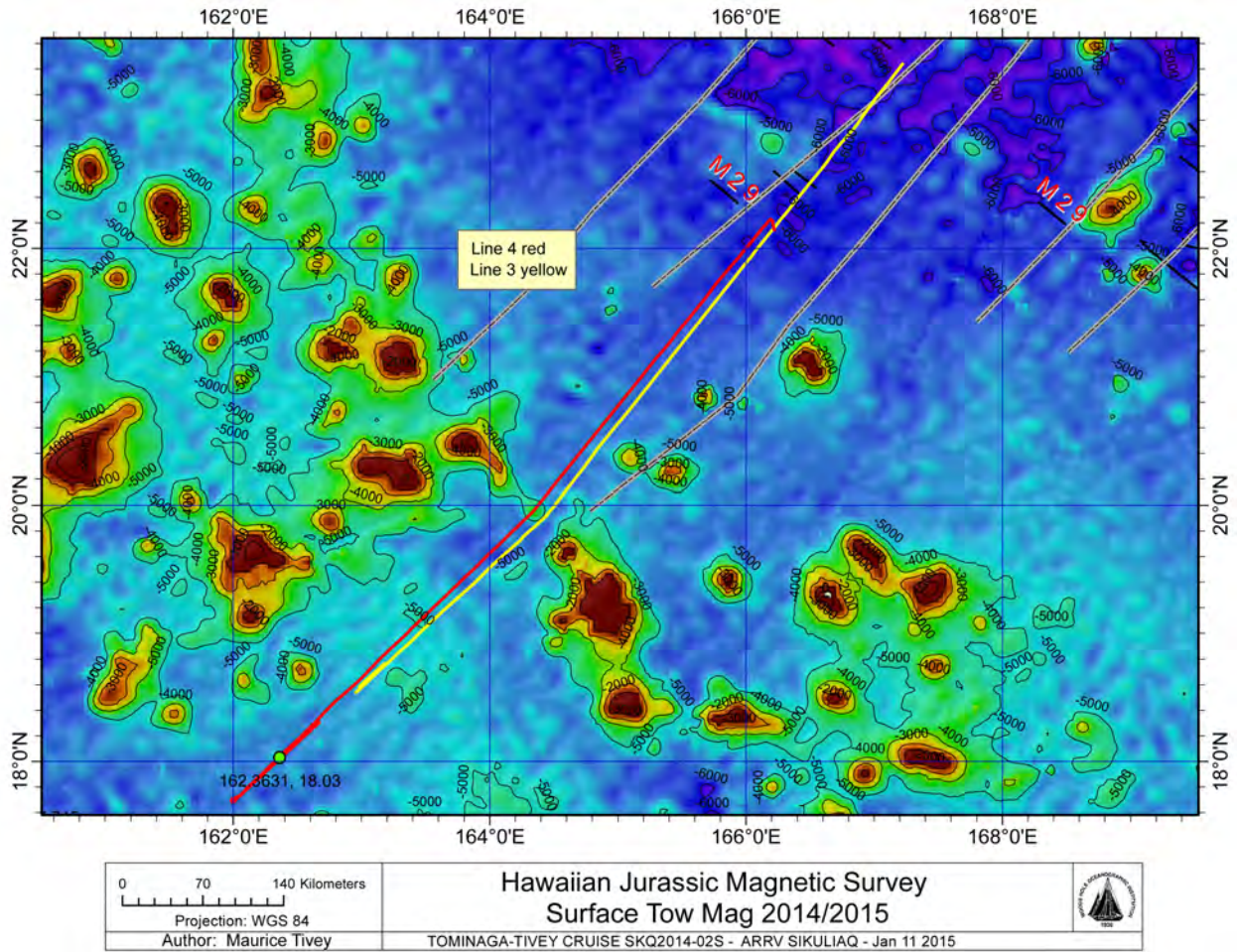| Start Time UTC (Date, JD)	End Time UTC (Date JD)	Line number	Length (km)	Comments
07:16 (12/17, 351)	13:29 (12/18, 352)	1	624	Transit to Sentry dunk site
07:10 (12/19, 353)	07:36 (12/25, 359)	2	3429	Transit west to start of survey
08:38 (12/25, 359)	09:23 (12/27, 361)	3	701	Transect survey
01:11 (01/08, 8)	13:30 (01/09, 9)	4	670	Transect survey
00:00 (01/11, 11)	03:45 (01/14, 14)	5	1991	Transit to Guam
TOTAL			7415 km	

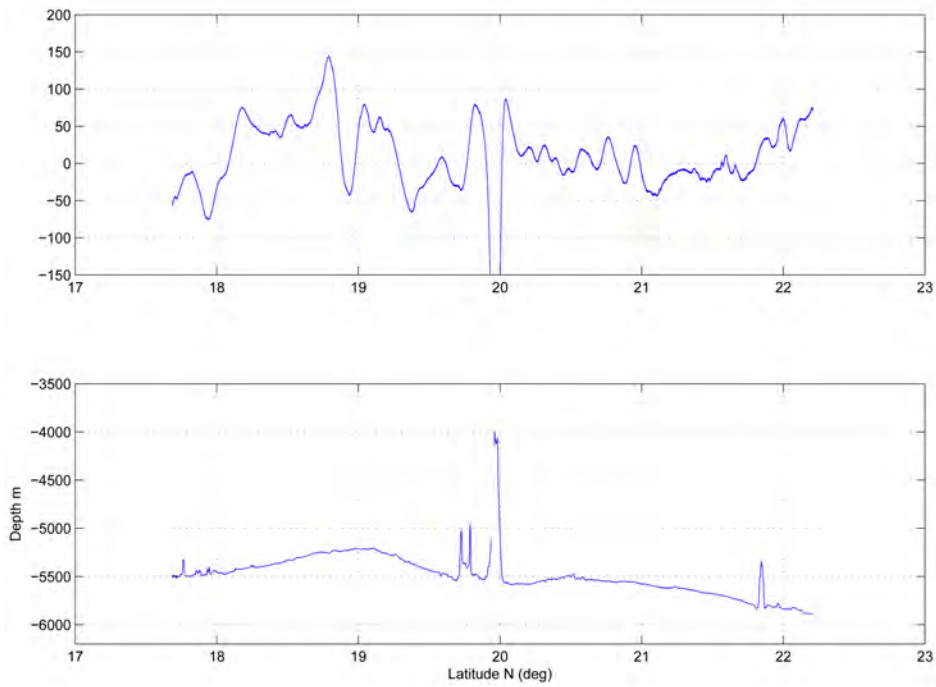**Figure 15. Map of Seaspy surface magnetometer tracks.**

JQZ2014 SSM Line 1
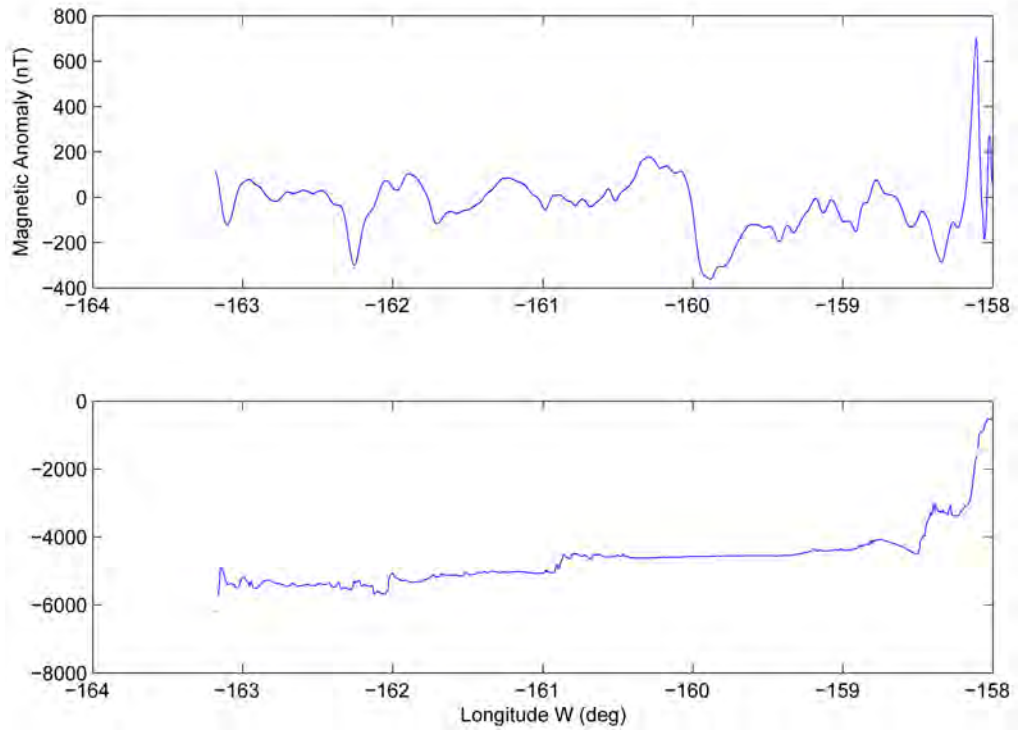
JQZ2014 SSM Line 2
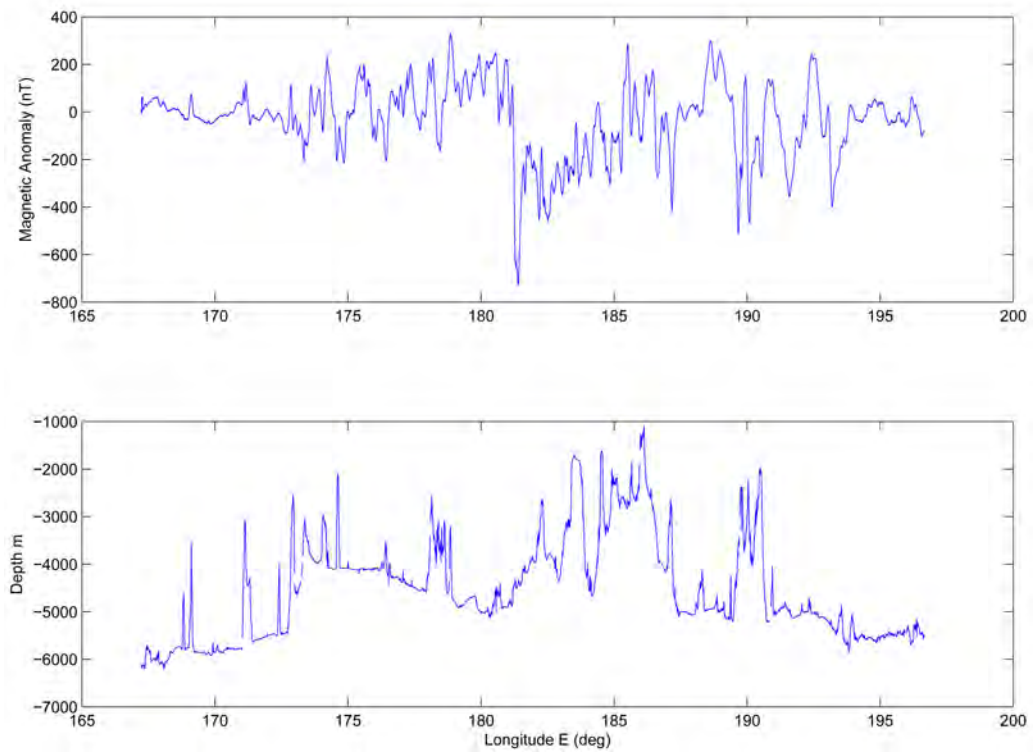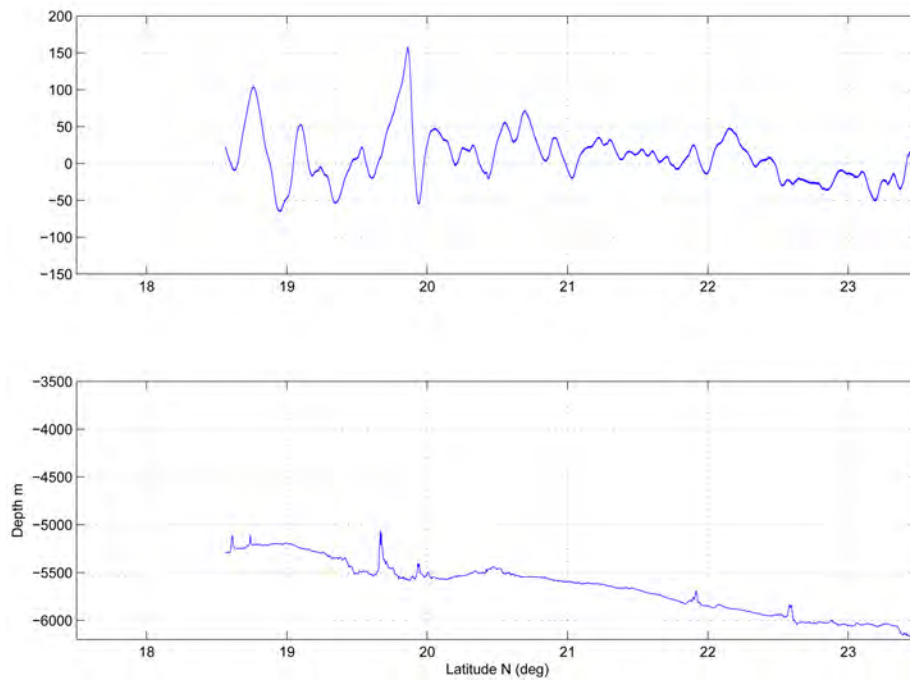
Figures 16A-D. Surface magnetic track lines and anomalies from survey transects 1-4.

8. Deep Tow Magnetometer Sled

A Deep Tow Magnetometer (DTM) sled (Fig. 17) was used to augment the AUV Sentry survey by providing a mid-water level tow with medium survey resolution as well as providing a backup in case of technical problems or weather delays with Sentry. The DTM sled, provided by WHOI-MISO facility, was similar to the configuration we used on the 2011 Thomas Thompson cruise (TN272). The DTM sled consisted of an aluminum frame with two magnetometer sensor systems, a Seabird SBE50 pressure depth sensor and a WHOI SDSL (Subsea Digital Subscriber Link) communication interface that provides real-time data up the CTD 0.322 conducting cable to the ship (ref. Swartz). Power was provided on the sled frame using two rechargeable 24V Deep Sea Power and Light (DSPL) deep sea lead acid gel batteries. The DTM sled weighed 708 lbs in water (1238 lbs in air) but we added more lead weight (424 lbs) to minimize the slack and snap loading of the wire. The Sikuliaq has a long wire run from the sheave to the block on the A-frame. To help reduce tension on the line and lift the line clear of the deck we used a block mid-way on the run, hung from the port crane (Fig. 18).

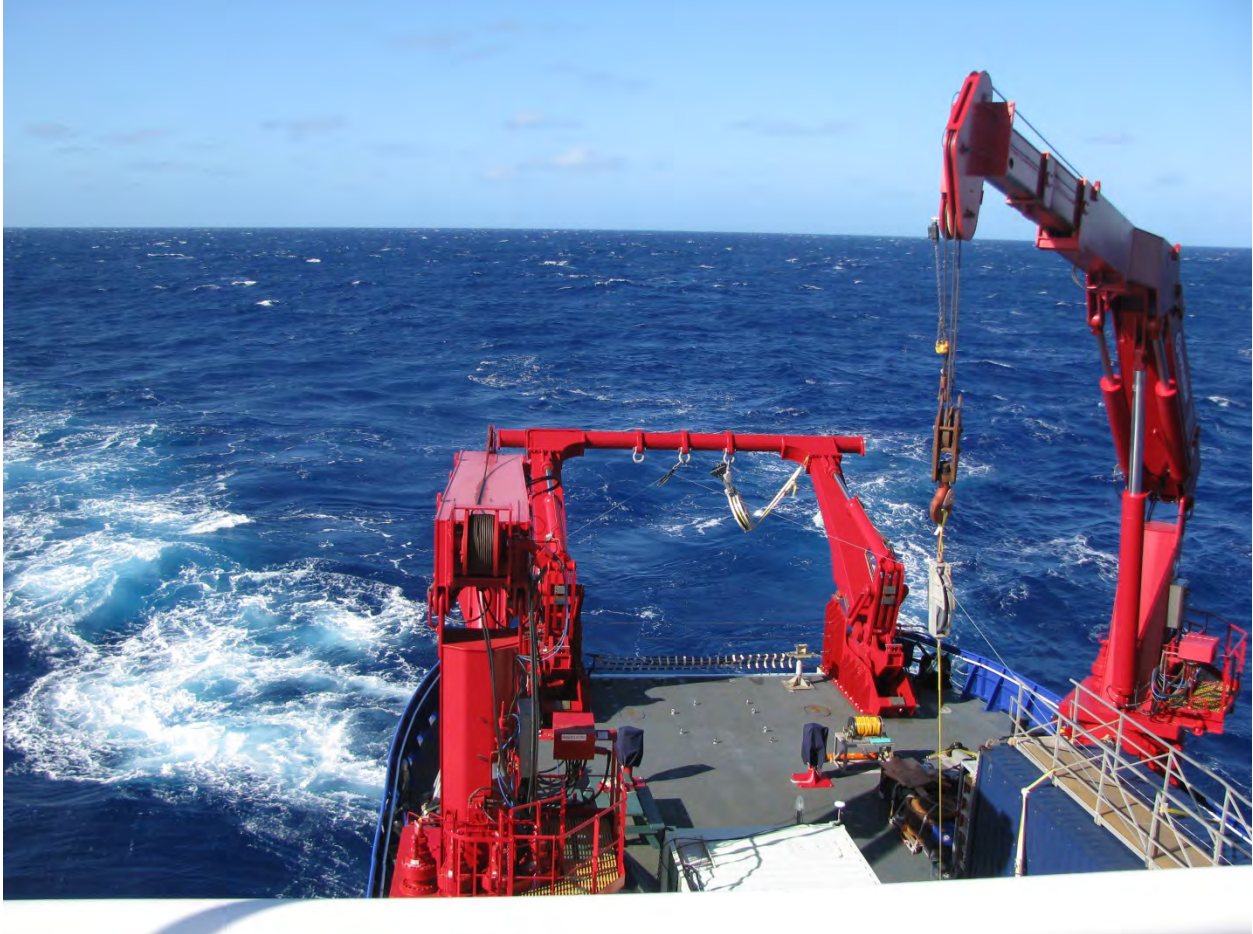**Figure 17. The Deep Tow Magnetometer (DTM) on board the R/V Sikuliaq**

Figure 18. The A-frame and port crane blocks used to support the Deep Tow.

We used two different magnetometer sensor systems on the tow sled. The first was the deep-sea Marine Magnetics Seaspy Overhauser magnetometer belonging to the University of Washington Shipboard Operations Group. This system is identical to surface towed Seaspy magnetometers but has a pressure housing that allows it to be used in a deep tow mode to 6000 m. The Seaspy magnetometer provides an absolute total field measurement of Earth's magnetic field and as such provides a reference value for the other magnetometer sensor (HMR) on the sled. We used a 1 Hz sampling rate for the Seaspy.

The second magnetic sensor was a small Honeywell HMR2300 digital magnetoresistor 3-axis magnetometer mounted on the sled fin. This magnetometer is similar to the magnetometer used on ROV Jason and in other configurations. The sensor measures the three components of Earth's magnetic field but needs to be calibrated to recover the appropriate field values. We use the Seaspy to provide this reference field value. The HMR runs at a data sample rate of 20 Hz.

Power was supplied by two rechargeable 24V 42 amp/hr DSPL lead-acid batteries mounted forward on the TowMag frame. The batteries were connected in parallel. They are secured on the frame with ratchet straps. Each of the sensors (Seaspy, HMR minimag and SeaBird depth sensor) provides an RS-232 data stream which is sent to a central SDSL bottle containing MOXA 5210 NPort convertors that translate these signals into Ethernet packets that are then transmitted up the CTD cable to the surface ship side using the SDSL protocol. The CTD wire termination at the sled used the green and white conductors only, which were connected to the SDSL output pigtail cable consisting of two wires (red and black). The

remaining CTD conductor was left unconnected to float with respect to armor (it cannot be paralleled with another conductor or tied to ground). No seawater return on the armor is used for the data link and no power is sent down the cable. The output of the SDSL Data Link is an AC signal with no polarity so wiring can be switched with no effect.

Topside, the two wires from the CTD wire come into the Sikuliaq Computer Lab to a terminal barrier block on a Black Box SDSL, which is then connected via Ethernet to a LAN port on a wireless router (MISO-Datalink-1).

> Summary of TowMag SDSL connections:
> J1 sea cable
> J2 power
> J3 Seaspy
> J4 HMR minimag
> J5 SBE50
>
> Serial Interfaces on J4-J6
> Moxa "J4" 192.168.1.101   UDP mode port 1 (4010)
> P1: HMR minimag 9600,n,8,1 (HMR configured to "spit data")
> P2: n/c
>
> Moxa "J5" 192.168.1.102   UDP mode port 2 (4002)
> P1: SBE50 9600,n,8,1
>
> P2 n/c
>
> Moxa "J6" 128.128.22.37
> P1: Seaspy deck unit inside SDSL, 9600,n,8,1
> P2: n/c
>
> Cables
> VMG4FS -> MCIL6F HMR minimag
> 1-1, 2-3, 3-6, 4-2, 4 n/c, 5 n/c

Logging was accomplished using two separate laptop computers for redundancy: a PC windows-7 (Dell Towcam-A) laptop and a Linux laptop (Lenovo: Stefano Suman WHOI). The PC windows laptop (Fornari Dell) used software "RunTowcamA" modified from MISO tow camera operations. Connection was made over a wireless link to the MISO-Datalink-1 wireless network router (SSID: MISO Datalink 1, pw: datalink). We ran the Marine Magnetics BOB software to log the Seaspy magnetometer output. An additional setting on the BOB software to send the output to a serial port was utilized to send the Seaspy output to the Linux laptop. The linux laptop ran the "gravlog" software (Stefano Suman – WHOI), which logged data with a timestamp. The linux laptop was linked by an ethernet cat-5 cable directly to a LAN port on the MISO-Datalink-1 wireless router. A serial cable from the PC-windows laptop provided the Seaspy data input.

On the linux laptop, the logging software time stamped the incoming data streams and flagged the data source as shown in the snippet below.

```
HMR 2014/12/28 23:35:04.727 SRC_HMR – 1,893  – 3,926  – 2,702
TSD 2014/12/28 23:35:04.796 SRC_TSD   0.45
```

```
HMR 2014/12/28 23:35:04.804 SRC_HMR - 1,896  - 3,925  - 2,704
MMD 2014/12/28 23:35:04.836 SRC_MMD *14.362/23:35:06.5 F:017814.100
S:072 D:-772.8m A:035.38m L0 0007ms Q:00  P G X:166021.4 Y:0.0 Z:31N
x:0.000000 y:0.000000

HMR 2014/12/28 23:35:04.881 SRC_HMR - 1,898  - 3,923  - 2,706
```

MMD indicates the Seaspy magnetic data and was generally setup to cycle at 1 Hz. HMR indicates the HMR minimag sensor output in raw millivolts and is at a 10 Hz rate. TSD indicates the SeaBird depth output in meters running at approx. 5 Hz. Log files are made every hour (20141228_2335.GEF) with a date string as filename. A perl script (read_towcam.plx) parses these files into time-stamped ascii files for input into MATLAB for further processing. The HMR minimag millivolt output is converted to nanotesla by multiplying by 6.667 nT per millivolt.

For the PC-Win7 laptop, the format of the HMR and depth sensor data is logged at a 1 Hz rate as shown below:

```
TOW  2014/12/29 04:00:04  0.00000  3055.2   - 3,602  - 3,299  -
1,872
TOW  2014/12/29 04:00:05  0.00000  3055 - 3,591  - 3,306  - 1,882
TOW  2014/12/29 04:00:06  0.00000  3054.8   - 3,579  - 3,318  -
1,879
TOW  2014/12/29 04:00:07  0.00000  3054.8   - 3,545  - 3,332  -
1,918
TOW  2014/12/29 04:00:08  0.00000  3054.8   - 3,533  - 3,359  -
1,894
```

Files are saved once an hour in ascii files with the date and time as filename (20141229_0100.tow). On the PC Win7 laptop the MMD data is recorded by the BOB software and then after the tow the data is exported to the standard csv export file format.

The time for both laptops was set to the ship's NTP time server (10.1.0.5). The PC-win7 laptop was directly wired via cat-5 cable to the Sikuliaq timeserver.

We successfully completed 10 mid-water tows during this cruise. The DTM was deployed during 5 of the 7 Sentry transects (Table 5). We did not deploy the DTM during the first Sentry dive (292) or the last Sentry dive (299). Additional DTM tows were undertaken during Sentry's 12 hr charging period on deck. These shorter tows were used to join the longer tows together (see Table 5 and Figure 19). The 10 tows covered approximately 454 km. Typical tow speeds varied between 1.5 and 1.9 kts averaging 1.7 kts. The average depth was about 2500 meters with a wire out of 4500 to 5000 m. Water depths averaged about 5500 m.

Processing involved parsing the deeptow data using the linux laptop data as that was sampled at the highest sample rate. A perl script (read_towcam.plx) is used to parse the DTM data into ascii files (tcm.hmr, tcm.mmd, tcm.tsd). These files are read into MATLAB (using read_towmagX.m) and saved as struct arrays (mmd, hmr, tsd) in binary MAT files. The start and end of the tows are determined and stored with the files as part of the struct arrays. The TSD depth is interpolated onto the HMR and MMD struct arrays and the ship's position is merged onto the various timebases of the HMR and MMD struct arrays. In the next step of processing (proc_towmagX.m), a simple wireout data array for each tow is entered and interpolated for the length of the tow. A simple geometric calculation is then used to calculate

the position of the tow fish behind the ship, which is then saved in binary MAT format. A plot of each tow is provide in Appendix 6.

Table 5. Completed deep tows

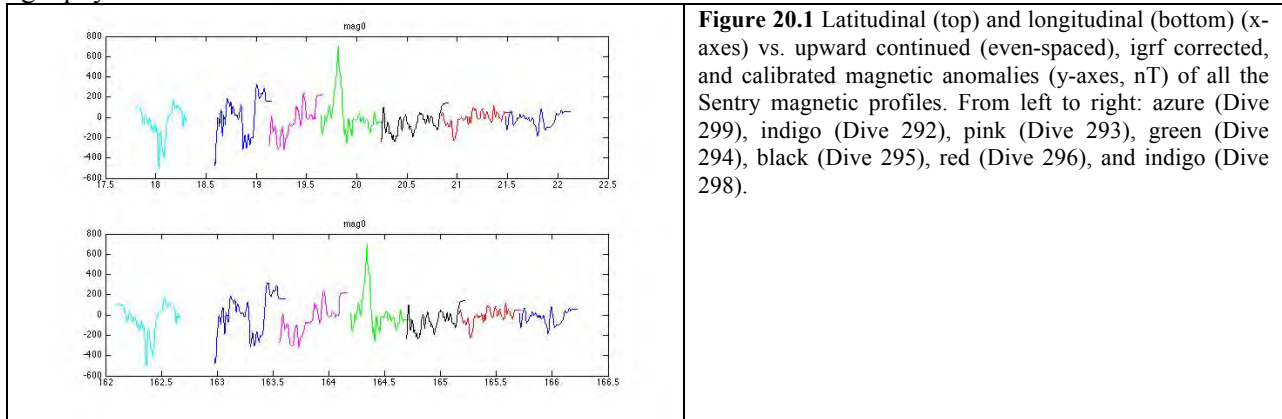| Start Time UTC, Date, JD	End Time UTC, Date, JD	Tow number	Duration	Starting Position (Lat/Lon)	Ending Position (Lat/Lon)	Comments
23:35 (12/28/14) 362	09:54 (12/29/14) 363	1	6.33 hrs	19 0.882'N 163 24.856'E	19 12.239'N 163 28.641'E	Solo
13:41 (12/29/14) 363	16:41 (12/30/14) 364	2	23.33 hrs	19 9.044'N 163 35.161'E	19 37.511'N 163 7.294'E	With Sentry Dive 293
19:50 (12/30/14) 364	11:22 (12/31/14) 365	3	7.17 hrs	19 39.740'N 164 12.897'E	19 48.900'N 164 20.440'E	Solo
11:22 (12/31/14) 365	14:34 (01/01/15) 1	4	23.77 hrs	19 39.744'N 164 12.725'E	20 10.783'N 164 39.319'E	With Sentry Dive 294
18:05 (01/01/15) 1	06:28 (01/02/15) 2	5	9.06 hrs	20 11.332'N 164 39.145'E	20 22.284'N 164 47.869'E	Solo
11:16 (01/02/15) 2	15:02 (01/03/15) 3	6	24.37 hrs	20 15.664'N 164 42.687'E	20 49.633'N 164 9.291'E	With Sentry Dive 295
19:16 (01/03/15) 3	06:46 (01/04/15) 4	7	8.08 hrs	20 47.130'N 165 7.635'E	20 55.311'N 165 13.878'E	Solo
10:56 (01/04/15) 4	16:43 (01/05/15) 5	8	26.25 hrs	20 51.498'N 165 11.052'E	21 26.960'N 165 39.107'E	With Sentry Dive 296
22:13 (01/05/15) 5	06:24 (01/06/15) 6	9	4.90 hrs	21 27.423'N 165 41.159'E	21 33.013'N 165 45.987'E	Solo
15:52 (01/06/15) 6	20:33 (01/07/15) 7	10	25.52 hrs	21 29.288'N 165 42.813'E	22 2.697'N 166 9.817'E	With Sentry Dive 298 (Sentry 297 aborted)
TOTAL			158.78 hrs	Length: 245 n.miles	Length: 454 km	
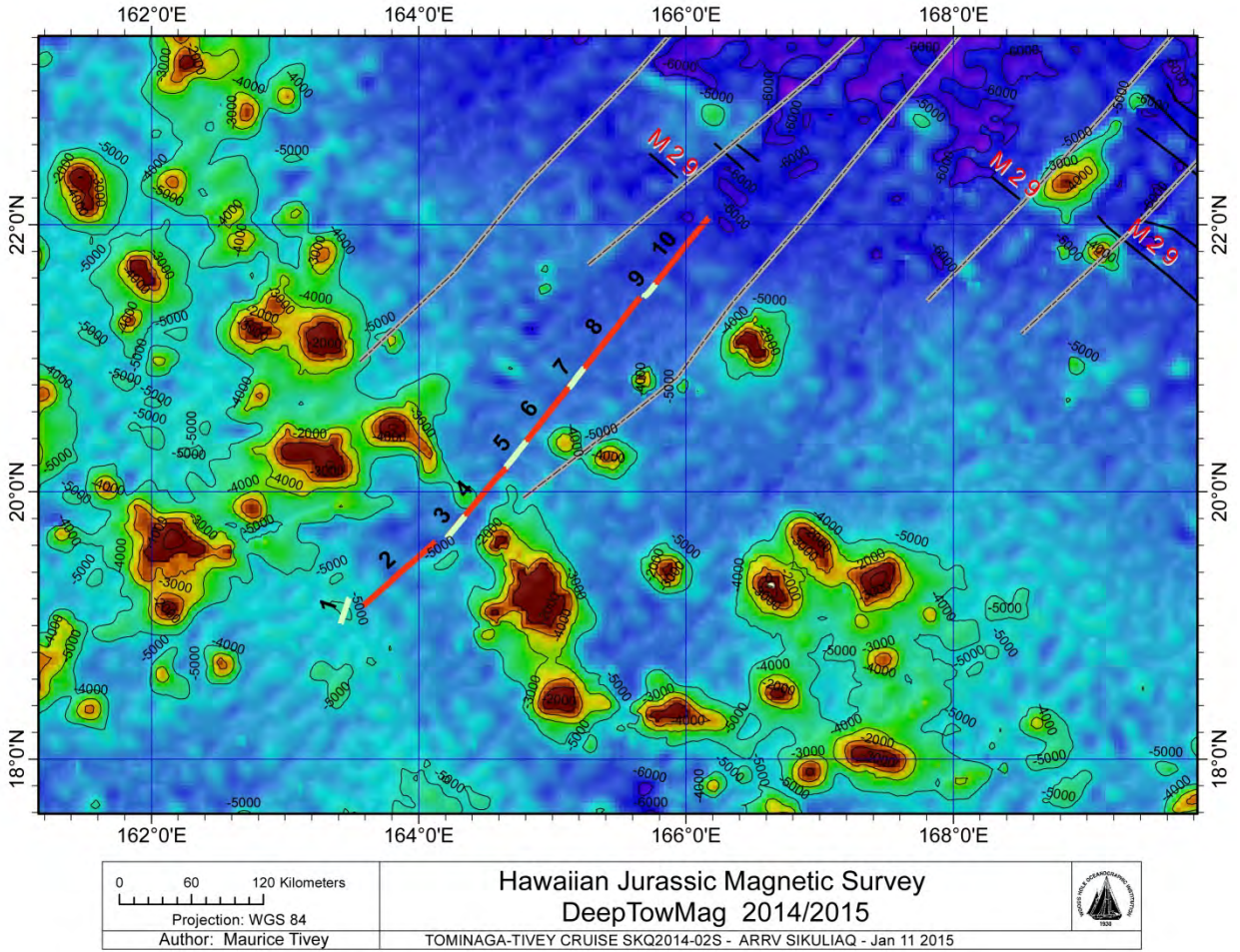
Figure 19. Map of Deep Tow Magnetometer Dives.

9. Near-bottom Sentry magnetics (in progress)

During the SKQ201402S cruise, a total of seven successful Sentry dives (Dives 292-296, and Dives 298-299) were conducted (Figures 20.1-20.15). In addition to these dives, the Sentry team aborted the first dive (Dive 290), accomplished one engineering dive (Dive 291), conducted three deck tests to assess magnetometer sensor configuration during transit, and aborted one dive (Dive 297). The detailed vehicle parameters for each dive program can be found in Appendix 1 ("Sentry Cruise Report").

Overall, the magnetic anomalies from all the sensors are extremely "clean" and coherent throughout this expedition, manifesting that Sentry magnetic data are one of the BEST available in the world of marine geophysics.

Figure 20.1 Latitudinal (top) and longitudinal (bottom) (x-axes) vs. upward continued (even-spaced), igrf corrected, and calibrated magnetic anomalies (y-axes, nT) of all the Sentry magnetic profiles. From left to right: azure (Dive 299), indigo (Dive 292), pink (Dive 293), green (Dive 294), black (Dive 295), red (Dive 296), and indigo (Dive 298).

Sensor Locations:

A total of three APS magnetic sensors were housed on the vehicle's upper central location in the float (mag2), starboard (mag1), and bottom right next to the weight holder (mag0) (Figure 20.2).

Figure 20.2 Sensor housing during the SKQ201402S cruise.

Engineering Dive (Dive 291)

This engineering dive was conducted with the sensor sampling configuration with 2 Hz sampling rate without (internal) filtering applied (Figure 20.3). Sensors mag-1 and mag-2 exhibited significant level of noises in each channel (e.g. Figure 20.4) despite of the effort to reduce the electrical noise of the vehicle in 2013.
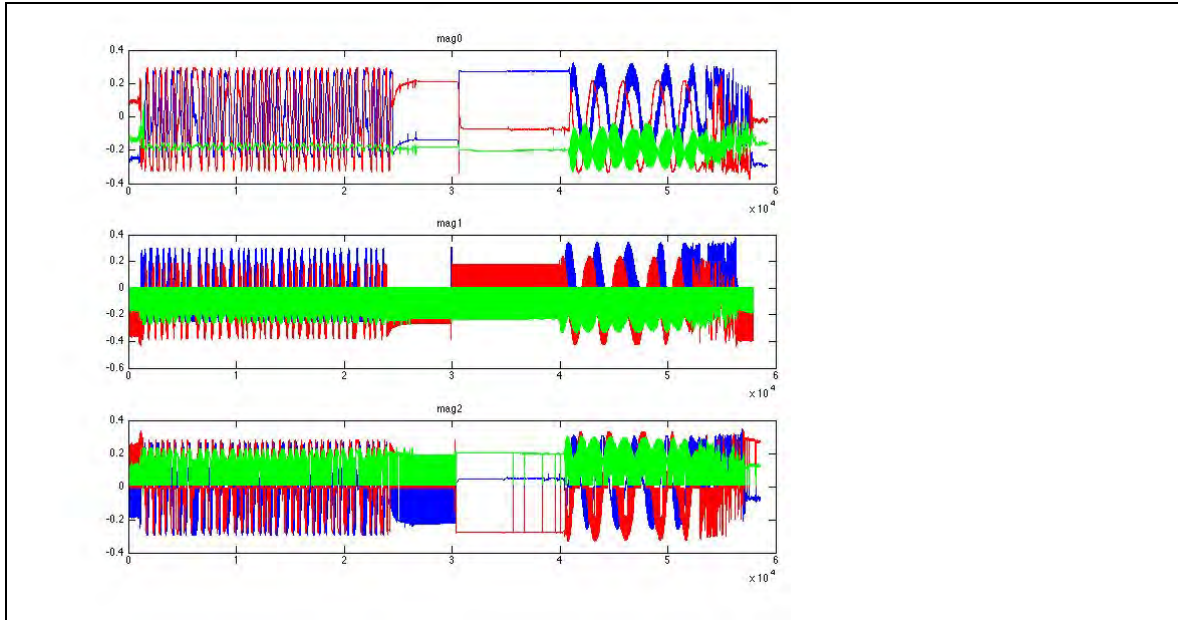

Figure 20.3 Magnetic sensor data. Blue (x-channel), red (y-channel), and green (z-channel). X and y-axes indicate magnetic anomalies (Gauss) and time (sec), respectively.
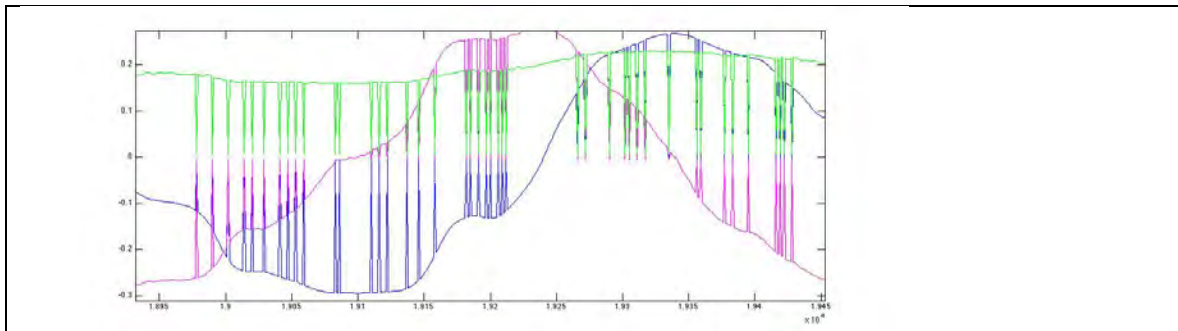
Figure 20.4 Noises observed in the data from Mag-2 sensor. Blue (x-channel), green (y-channel), and pink (z-channel). X and y-axes indicate magnetic anomalies (Gauss) and time (sec), respectively.

Magnetometer Deck Tests

Subsequent to Dive 291, Zachary Berkowitz and Alan Duester conducted deck test to optimize the noise reduction of each magnetometer.

Test 1

Duester changed the sampling and filtering rates of Mag1 and Mag2 sensors, resulted in reducing the noise in Mag1 sensor reasonable, but Mag2 sensor noises still remain significantly (Figure 20.5).
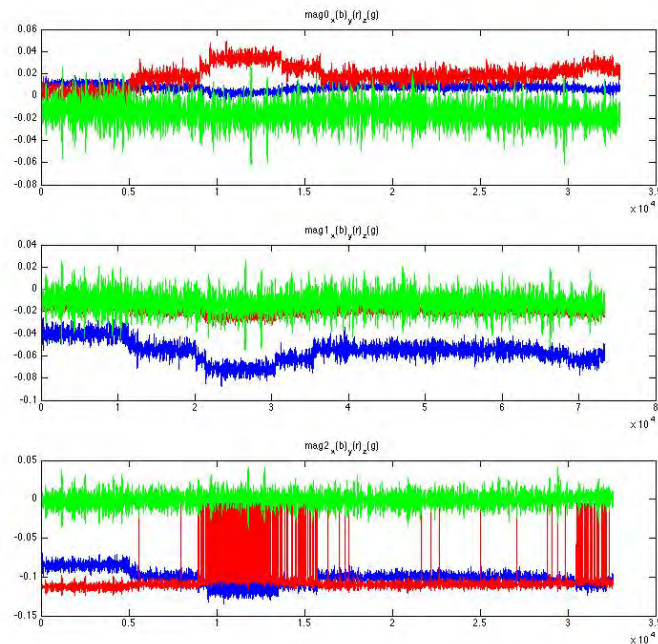
Figure 20.5 Blue (x-channel), green (y-channel), and pink (z-channel). X and y-axes indicate magnetic anomalies (Gauss) and time (sec), respectively.

Duester and Berkowitz conducted a bench-top test on a Sentry spare APS magnetometer sensor with the same sampling and filtering parameters. They discovered that there might have been a flaw in data output from the sensor (quote from e-mail correspondences, On 12/24/2014 7:50 PM, Al Duester wrote):

> "Two of our Sentry maggies are outputting a properly formatted string of garbage numbers (very low, but not zero), except for the temperature. This is at the end of the string and does seem to track. The strings are the same numbers every time they're issued, at least on a short time scale of under a minute. Not sure if it's the same between maggies. One does it every 6-8 samples, one about every 20. The third maggie appears to be working ok. I've duplicated the 6-8 with our spare maggie on the bench. All the same version number 3.85BD7716F
>
> Our settings are 00 for number of samples to average (0wc23b00), and 90h for the delay between sampling (0wc35b90).
>
> Best as I can tell, with averaging counts set lower and sample delay set higher, there is some threshold where the problem starts to occur. I assume it's different between units but we have not tried messing with the two better ones on the vehicle. It also appears to happen based on the difference between the two numbers. i.e., if I have the sample delay set to 90h, I can eliminate the garbage string by moving the averaging count to 04h. If I set the bench maggie to 02 avg., 60 delay, I can get two incorrect, changing, low strings every 9 secs. or so.
>
> I was also able to get the settings to a point where the data was be good for 30 seconds, but then would hammer in the bad string quite often for 5 seconds before returning to good data.
>
> In short, it's acting like there is something going on like two buffer loops, and the counters are getting confused, or there's a memory overlap issue."

Duester also directly contacted APS, and found that there is unwritten sampling vs. filtering rate configuration exists.

```
On 12/25/14 7:40 PM, Al Duester wrote:

OK folks, got a reply from one of the APS engineers, and the fix presented
appears to work on maggie 1. I'll be testing it on the other maggies before we
decide to/if implement it on the ones that were no exhibiting the problem as
much.

Right now we're looking at setting maggie 1 (stbd) per Maurice's request to no
averaging, and 4-5 samples per second, and leaving the other two alone at no
averaging and 2 samples per second.

- Al

On 12/24/2014 11:06 AM, David Holt wrote:

Hello Al,

I've been looking at the problem with the 1540.
It's a data rate issue between the ADC the averaging algorithm used by the send
data function.
In the error condition the function skips over this sample to catch up so you
get the carry over from the previous samples.

To correct this you need to set the sample clock frequency higher.
The default is 3.  You need to set it to 4. The maximum is 4.

By reading your message I can see that you know how to change configuration of
the 1540.
I'll not be too verbose about the commands.  I'm sure you'll understand.
Here is how to change the sample clock frequency.

0L
0wf4

The 1540 will respond,

Rebooting..

The sensor will restart and the problem will be gone.
```

Test 2

Duester applied the newly discovered sampling and filtering (averaging) setting to Mag1 and Mag2 sensors (Figure 20.6).
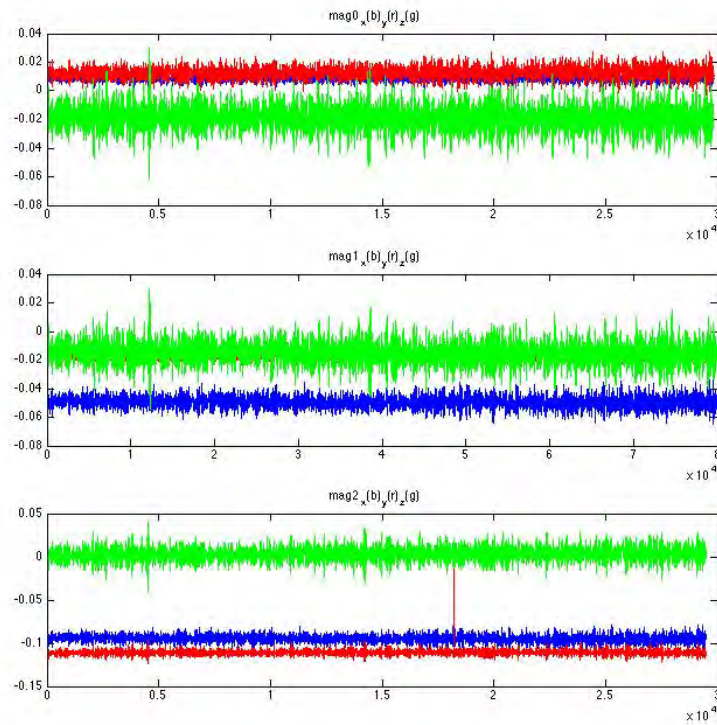
Figure 20.6 Blue (x-channel), green (y-channel), and pink (z-channel). X and y-axes indicate magnetic anomalies (Gauss) and time (sec), respectively.

The optimal sampling rates for Mag1 and Mag2 sensors were determined by Tominaga and Tivey:

> OK, both Maggie 1 (stbd) and Maggie 2 (top) have had the 0wf4 fix applied, and
> have now been set to 0wc23b08 for 8 averaging, and 0wc35b28 for just a bit over
> 4 Hz. I've also looked at them both at 0wc35b20 and 0wc35b40 and see no
> problems showing in the data stream.
>
> - Al
>
> On 12/25/2014 2:02 PM, Masako Tominaga wrote:
>
> Hi Al,
>
> Maurice and I suggest we change the averaging and data output rate for the
> Sentry APS mag1 and mag2 to the following:
>
> 4 Hz sampling rate with the number of averages of 8.
>
> Maurice and Masako

Test 3

The new sampling and filtering configurations were applied for Mag1 and Mag2 sensors. The sampling and filtering rates for Mag0 sensor remained the same (2 Hz, no averaging)(Figure 20.7).
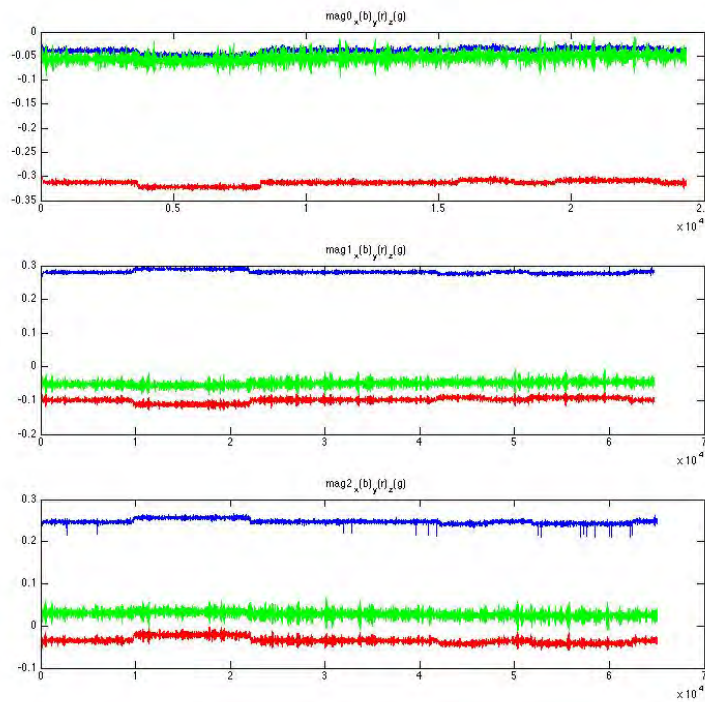
Figure 20.7 Blue (x-channel), green (y-channel), and pink (z-channel). X and y-axes indicate magnetic anomalies (Gauss) and time (sec), respectively.

Science Dives

Dive 292

For Dive 292, Mag-1 and Mag-2 sensors with new sampling/filtering configuration, and Mag-0 remains with 2Hz sampling rates with no filtering. This successful dive provided two significant insights on Sentry magnetic data: (1) although noise in each sensor has been drastically reduced, housing location makes a difference in the noise level (Figure 20.8). The data from Mag-2 sensor in the float, which is the most remote from electrical currents induced by the vehicle, represent the quietest among the three sensors. The Mag-1, located at the starboard midship position, provides intermediate data in respect to noise. The Mag-0, the sensor located at the bottom of the vehicle, was expected to be another quiet sensor due to the distance from the electronics, but has given the nosiest data (Figure 20.8); (2) Calibrated anomaly amplitudes and the mean values (DC-Shift) vary depending on the calibration coefficient based on vehicle rotations during descent and ascent (Figure 20.8).

In addition, at the beginning of the trackline, there is distinctive amplitude high observed, which does not match the adjacent profiles even after counting the DC_offset between one profile from another.
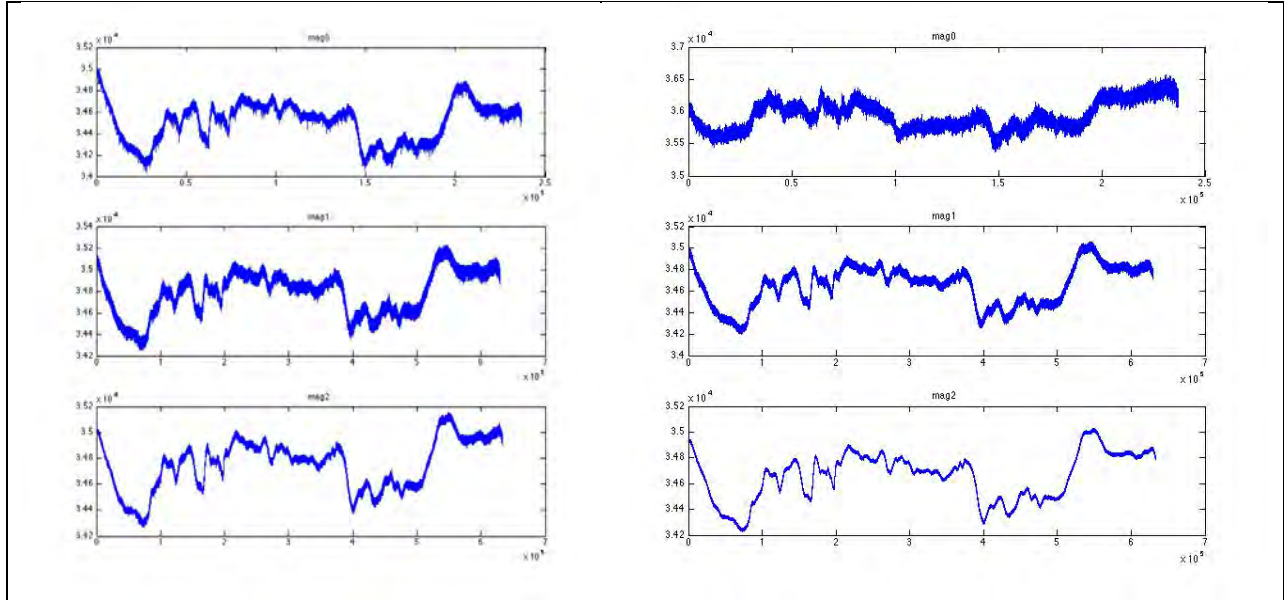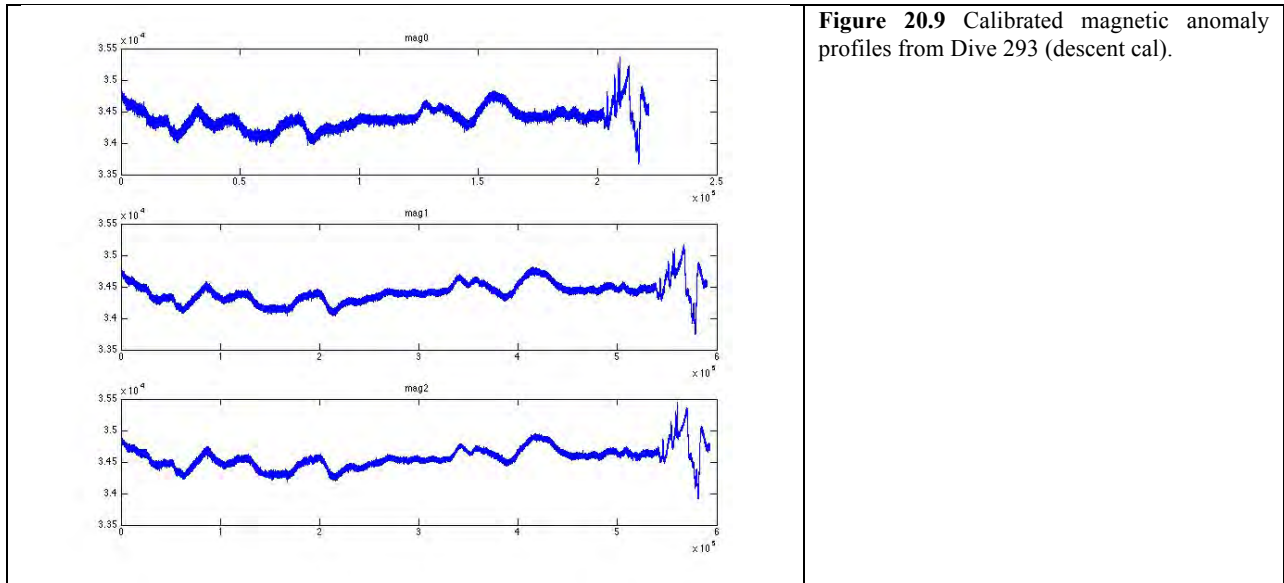
Figure 20.8 Calibrated magnetic anomaly profiles from Dive 292. Left: profile corrected with descent calibration loop; right: profile corrected with ascent calibration loop.

Dive 293

For Dive 293, Mag-1 and Mag-2 sensors with new sampling/filtering configuration, and Mag-0 remains with 2Hz sampling rates with no filtering. At the beginning of the trackline, there is distinctive amplitude high observed, which does not match the adjacent profiles even after counting the DC_offset between one profile from another.
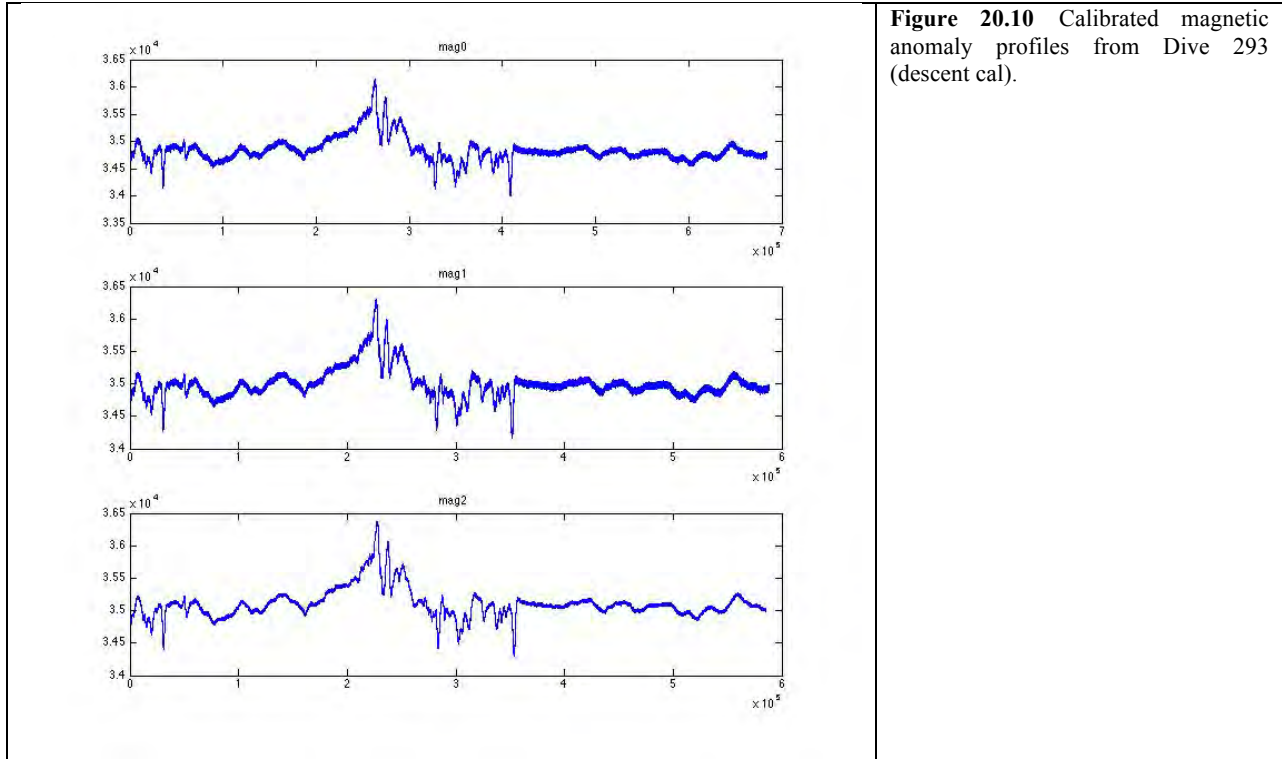

Figure 20.9 Calibrated magnetic anomaly profiles from Dive 293 (descent cal).

Dive 294

For Dive 294, Mag-0 configuration is adjusted to Mag-1 and Mag-2 (6-8 Hz sampling rates with filtering before write-out).

Figure 20.10 Calibrated magnetic anomaly profiles from Dive 293 (descent cal).

Dive 295

Berkowitz pointed out that the major discrepancy between descent, underway, and ascent noise may be due to the number of steel weights that Sentry carries (hereafter: "Berkowitz effect (TBD)")(Figure 20.10). This discrepancy explains the following observations: (i) differences in anomaly amplitudes and DC-shift depending on ascent and descent, and (ii) differences in noise level depending on ascent and descent calibration loops. Because Sentry carries two steel weights during her survey operation, we decided to use descent loops (where three steel weights) for calibration for all the dives during this expedition.
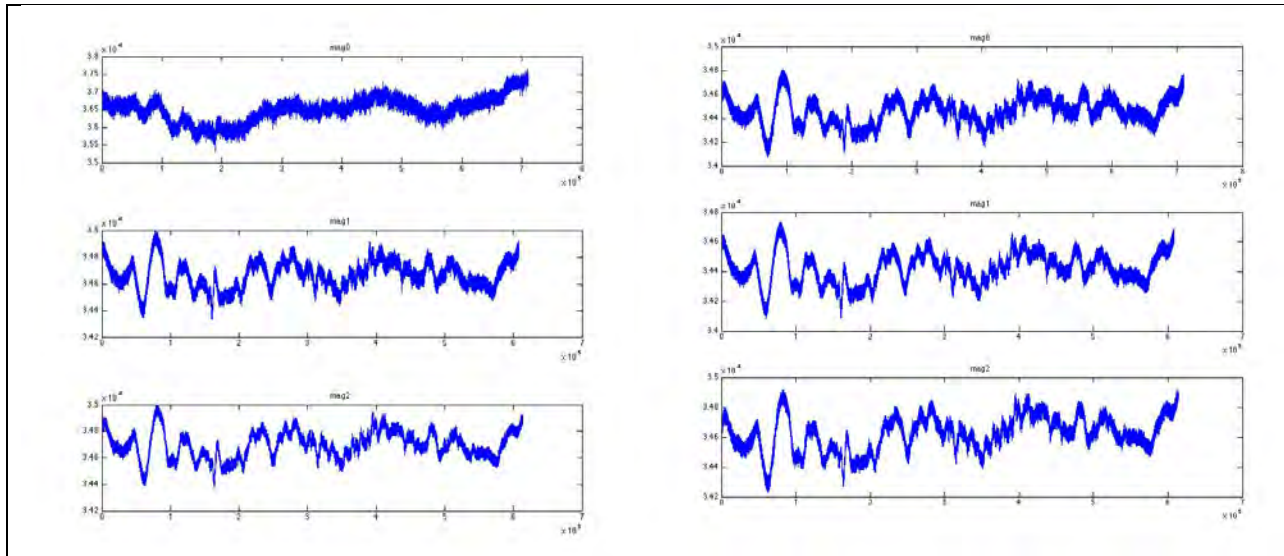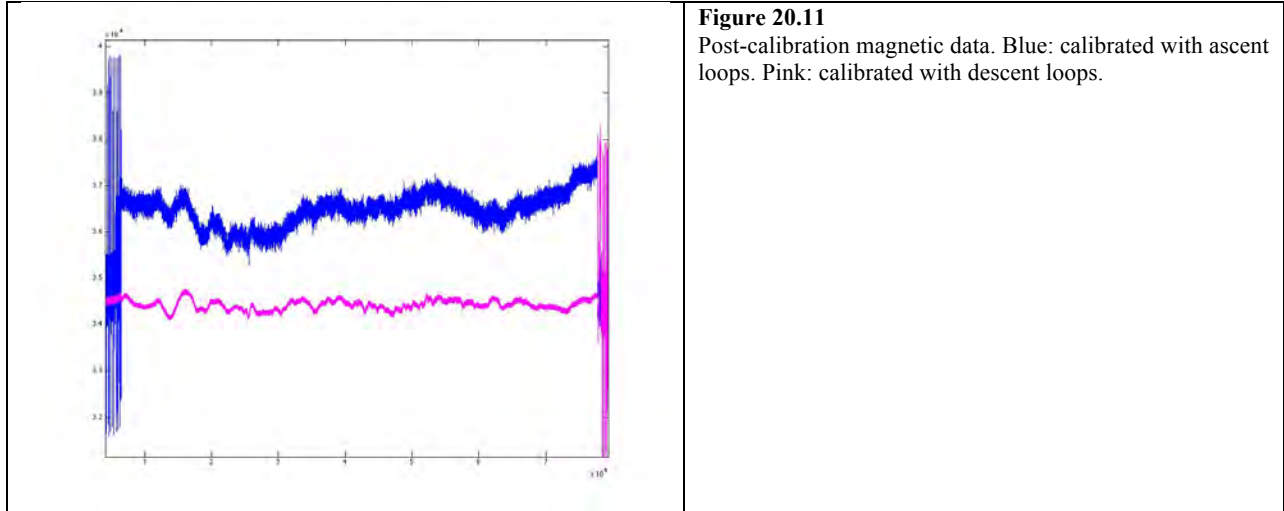
Figure 20.11
Post-calibration magnetic data. Blue: calibrated with ascent loops. Pink: calibrated with descent loops.

Figure 20.12 Differences in calibrated magnetic anomaly profiles depending on the locations of the calibration loops. Left: ascent cal; Right: descent cal.
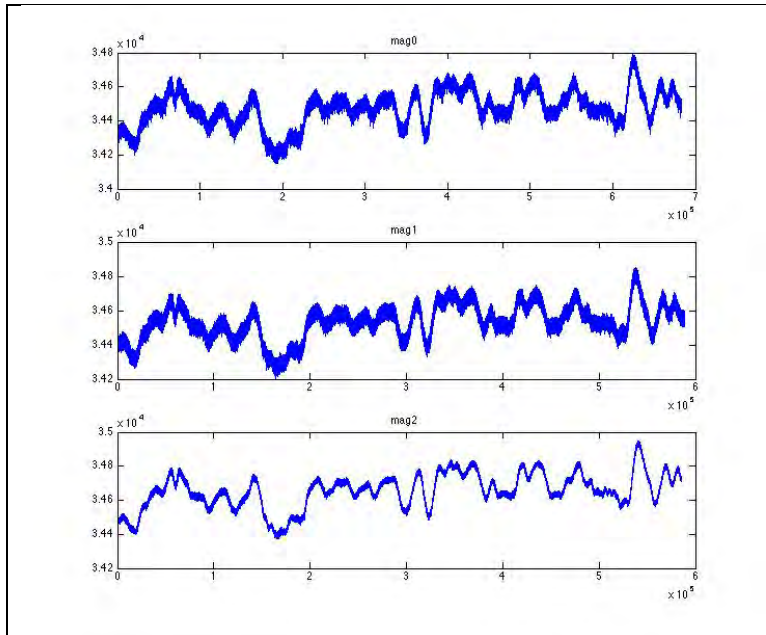
Dive 296

Figure 13.13 Calibrated magnetic anomaly profiles from three different sensors.

Dive 297

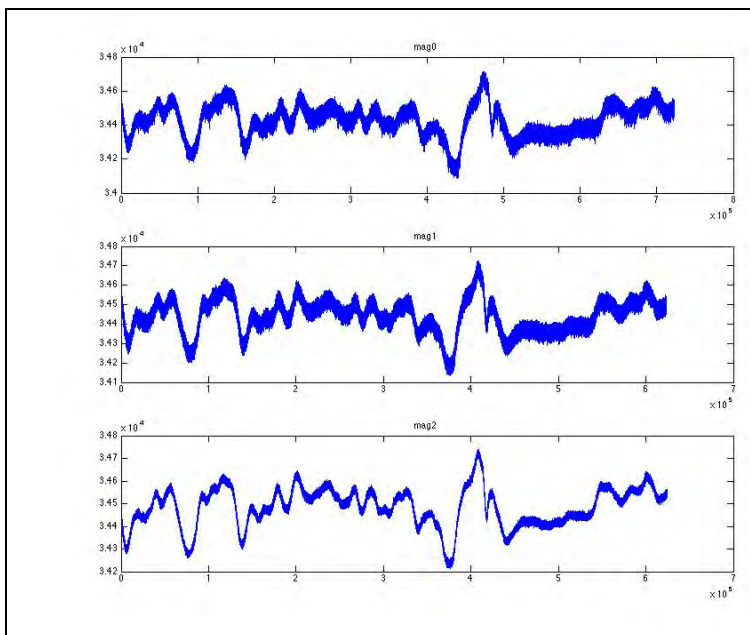No magnetic data due to the program abort (see Appendix 1).

Dive 298

Figure 20.14 Calibrated magnetic anomaly profiles from three different sensors.
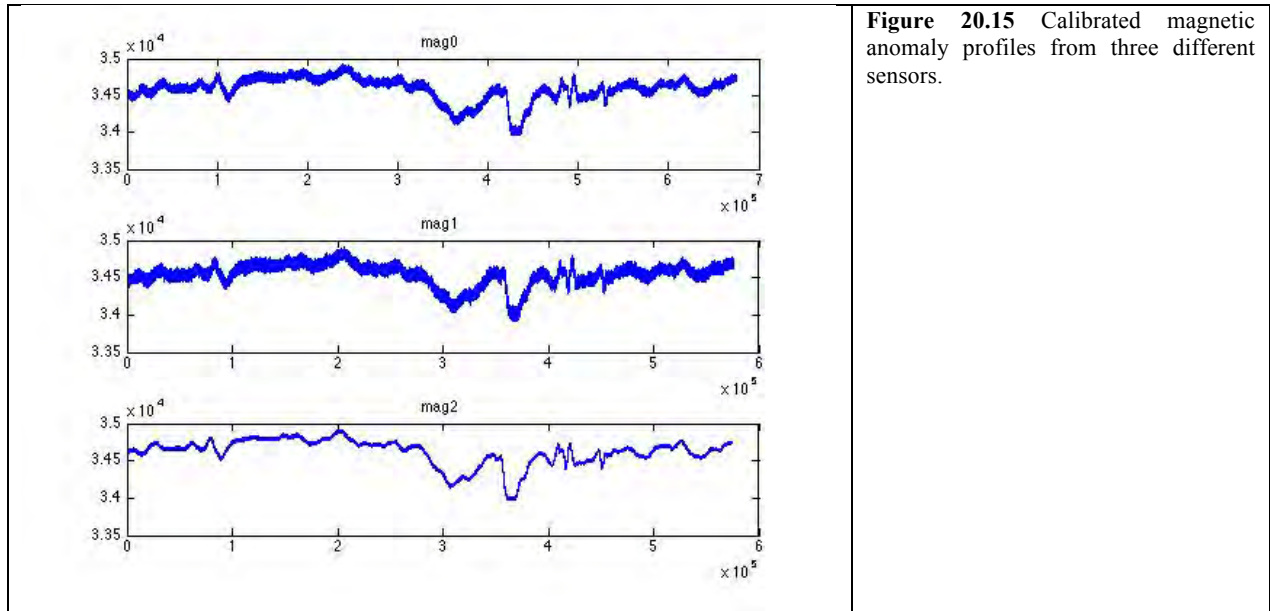
Dive 299

Figure 20.15 Calibrated magnetic anomaly profiles from three different sensors.

Daily Cruise Summaries

December 17, 2014- January 15, 2015

Reporter: Alex Stote

All daily report summaries are according to Julian date, all times are in UTC, and all coordinates are in degrees-minutes. Each summary begins with a narrative, is followed by a GMT map with the ship's track and, when applicable, Sentry's dive track, and concludes with an ADCP-75Hz map provided by the Sikuliaq. The narratives include the following details when applicable:

- The UTC times and coordinates for the launches and recoveries of Sentry AUV, the Seaspy surface Maggie, and the DeepTow Maggie
- Sentry AUV dive numbers, track length, and depths at the start and finish of track lines
- The wire length and depth of the DeepTow Maggie, and how the two vary over the duration of the tow
- The launch times and coordinates for XBTs and Argo floats
- Any issues with data collection, software logging, and/or dives, deployments and recoveries
- All waypoints established by the Chief Scientist
- Any changes to the dive plan and/or ship track
- Small anecdotes about life on the ship

The completed script for each GMT map is provided in Appendix 7.

Each report is saved in two locations:
> **Ship Archive:** Z:\SKQ201402S\SKQ201402S Cruise Report\14. Appendix\Daily Cruise Summaries
> **'Brendan Murphy' Computer:** C:\Users\Brendan Murphy\Documents\SKQ2014S Cruise Report docs\SKQ201402s Daily summaries
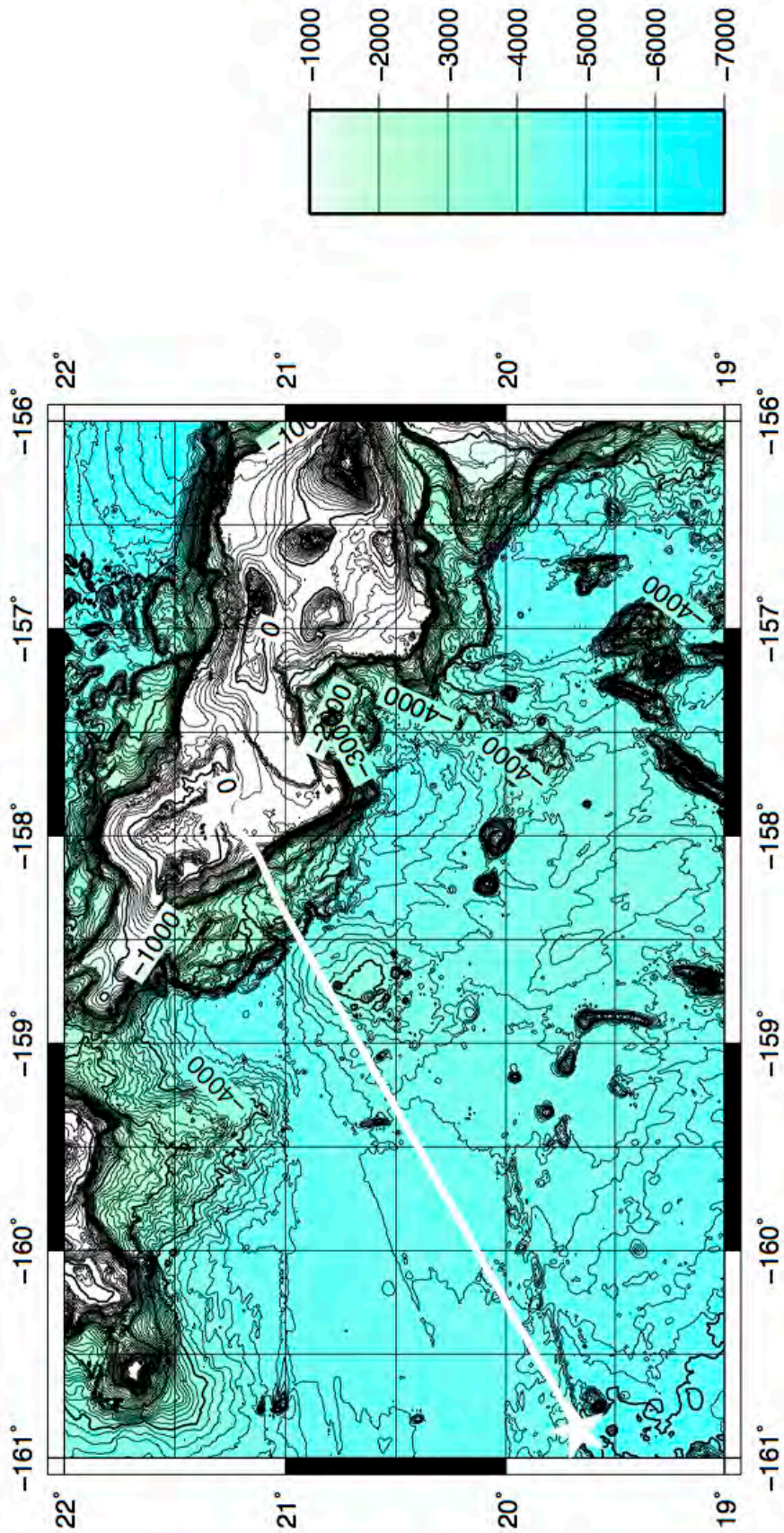
SKQ201402S

JD351 17 Dec 2014
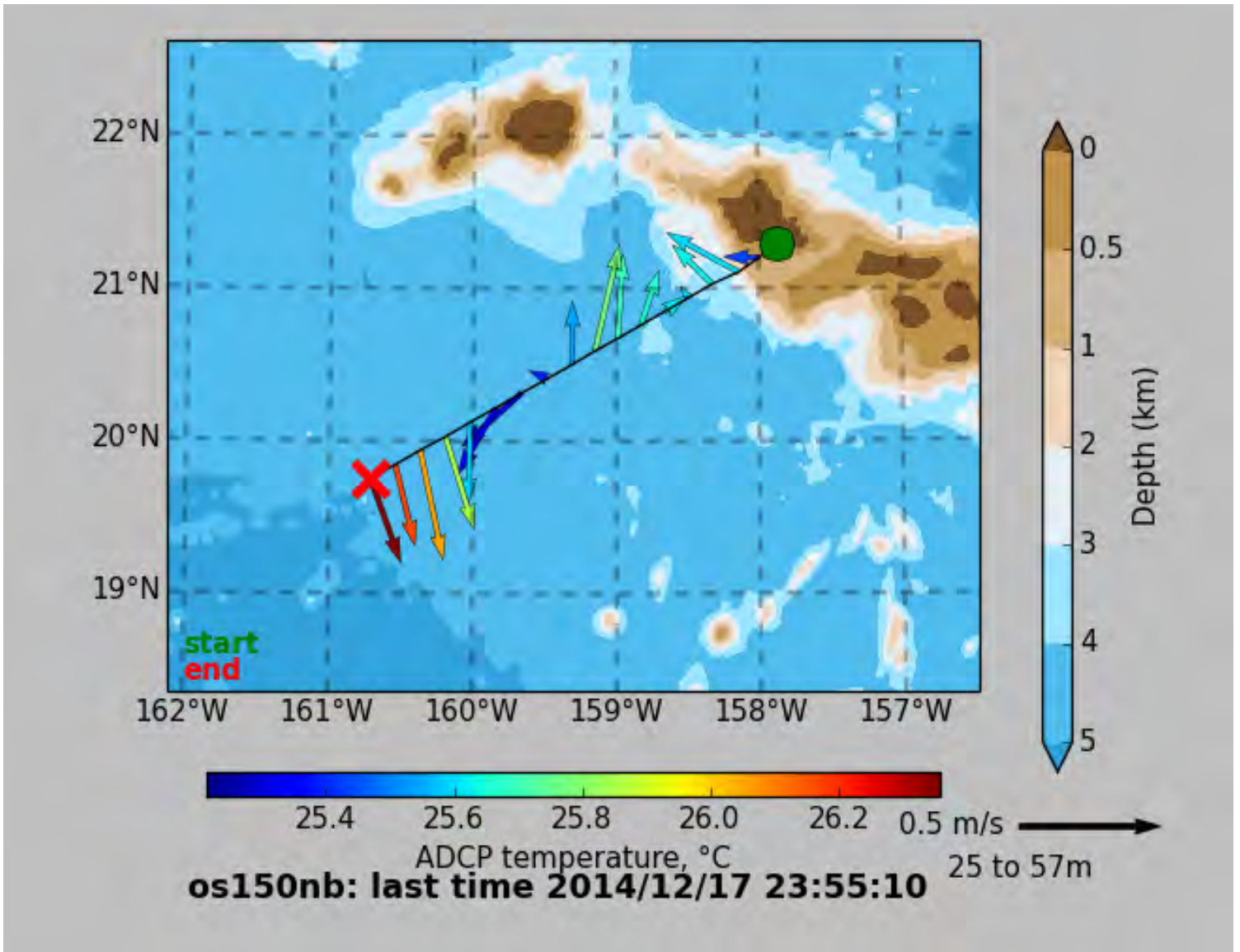Chief Scientists: M. Tominaga, M. Tivey

Daily Summary

R/V Sikuliaq departed the fuel pier at 05:46 UTC heading towards WP1 for our first Sentry test dive (starting point=21°18.65'N 157°52.50'W; WP1=18°24.90N 163°11.52W). Watchstanding duties began immediately after departure. We began multibeam sonar and data collection at 06:10 (instrument=EM302); Topas logging began at 06:43 (instrument=PS18). We successfully deployed the SeaSpy magnetometer at 07:00 and began collecting Maggie data at 07:20. At 10:10 we found the gravimeter malfunctioning, causing a pause in data collection until 10:15, when it successfully resumed function. Apart from an exhilarating fire drill and mandatory safety meeting between 18:30-19:15, all science carried on uneventfully. Boring = good science! No further problems with the gravimeter, and the multibeam, Topas, and Maggie data were all successfully recorded for the remainder of the day. We ended JD351 at 19°41.62'N 160°49.21W.

The wind reached speeds of 22 knots, setting the cruise off on a roll-y start. Almost as exciting as the science was everyone's adjustment to watchstanding duties. Poor Stadler could not hold anything down, a malady that began before we even took off. Soon enough Ruchala joined his ranks, christening the lab sink with his first night's dinner. This stirred debate between our marine techs: Bern, who instructed Tyler to use the sink at his disposal, and Ethan, who thought that the toilet bowl would have been a more suitable catchment. Continued excitement blessed the night shift when Karl's water bottle unexpectedly back-flipped off of the lab table, spewing liquid everywhere and resulting in his having to mop the entire lab floor. As clearly displayed by Day 351's events, the cruise is off to a smooth start, with everyone adjusting seamlessly!

JD350-1

Cruise Start Date: 16-12-14
Cruise End Date: 15-01-15

SKQ201402S

JD352 18 Dec 2014

Chief Scientists: M. Tominaga, M. Tivey

Daily Summary

Day 352 (ship's position= 19°39.66'N 160°52.81'W) continued with the SeaSpy Maggie underway and EM302, Topas and the gravimeter all successfully logging data. At 13:29 we slowed the ship and turned the SeaSpy Maggie off to begin its recovery at WP2 (18°18.00'N 163°11.52W). It was fully recovered and on deck by 13:51. We planned to do a multibeam survey over the proposed Sentry test dive site by way of WP2-WP6, but we were forced to change the course of the ship first to the north and then to the east in order to secure a better heading for the pre-dive multibeam survey.

After changing the course of the ship we prepared for a Sentry AUV test deployment (Dive 290). First the centerboard was fully deployed at 17:07. The ADCP (OS150 and OS75) and Topas were turned off at 17:45 for Sentry ops; EM302 was turned off at 17:58 for Sentry ops. After an impressive group effort by the Sentry and Sikuliaq crews, Sentry was deployed by 18:09 (18°22.25'N 163°17.22'W). Unfortunately the first test dive did not go as planned; the new Doppler software failed to detect the actual depth of Sentry, causing it to ascend before planned. A second complication arose when Sentry failed to remain neutrally buoyant, causing it to ascend a second time. We were forced to recover Sentry as a result of the complications, and by 18:39 (18°22.23'N 164°17.40'W) it was back on deck. We therefore did not conduct three east-west transects as planned. All sonar (EM302, OS150, OS75, PS18) was turned back on by 18:48.

We successfully held station (18°21.60'N 163°17.16'W) to deploy the Deeptow Maggie at 20:32. The Deeptow Maggie descended to the planned 500m depth, However, upon bringing in the Deeptow Maggie the ship's engineers discovered a hydraulic leak in the A-frame power units. The Deeptow was stopped at 100m for a few minutes until we switched over to another HPU to bring the remainder of the wire in. The Deeptow Maggie was successfully recovered on deck at 21:50. Quite the addition to an already exciting day!

Because we just can't get enough science, we prepared for a second Sentry test dive (Dive 291). We turned off all sonar (EM302, OS150, OS75, PS18) to prepare for Sentry ops, and launched Sentry at 23:10 (18°22.21N 163°17.16W). Meanwhile, Santa made a guest appearance in the galley, lifting the spirits of scientists and sailors alike.

That concludes Day 352, tune in next summary to learn of the fate of Sentry Dive 291!

JD352

os150nb: last time 2014/12/18 22:40:44
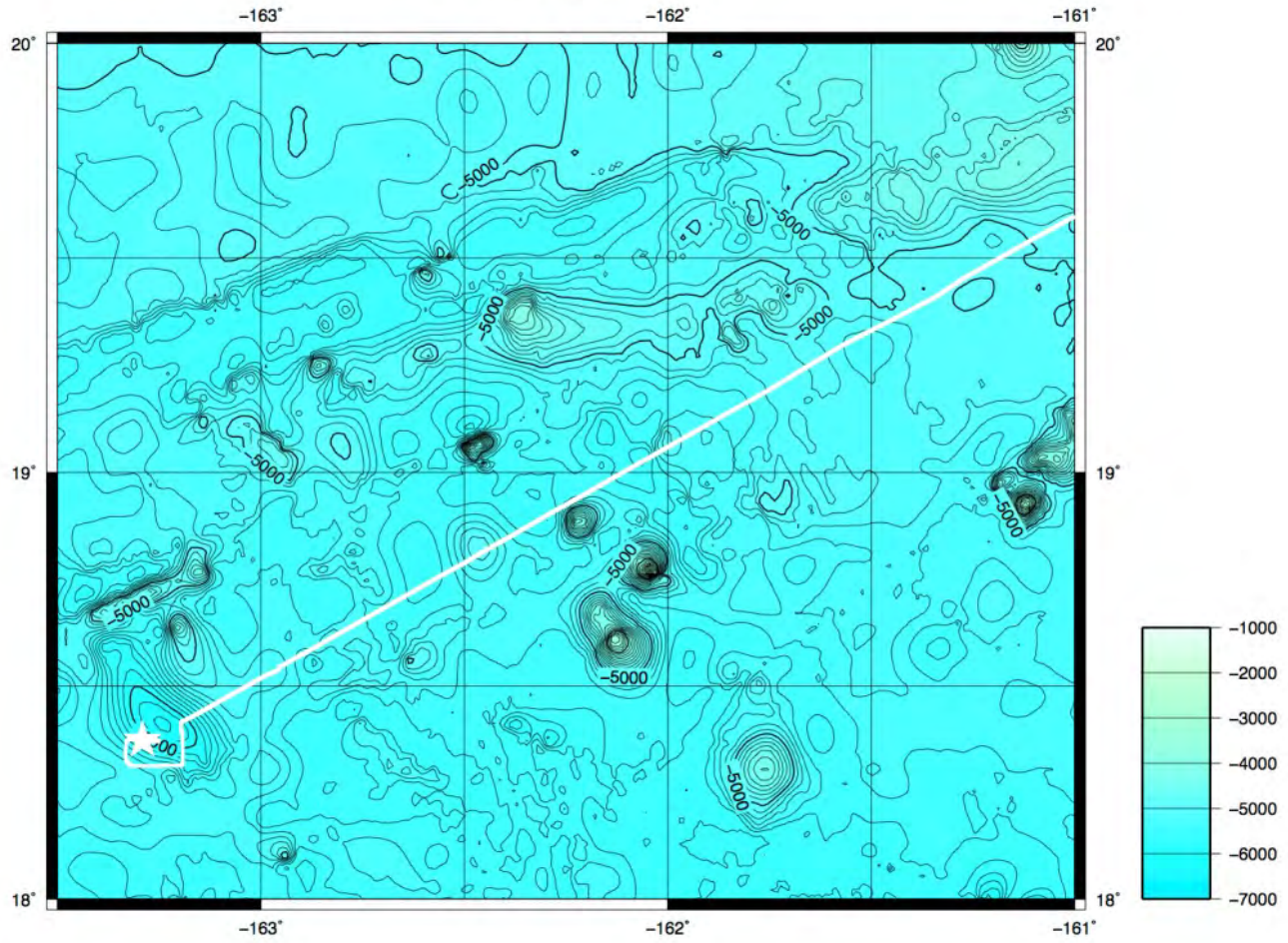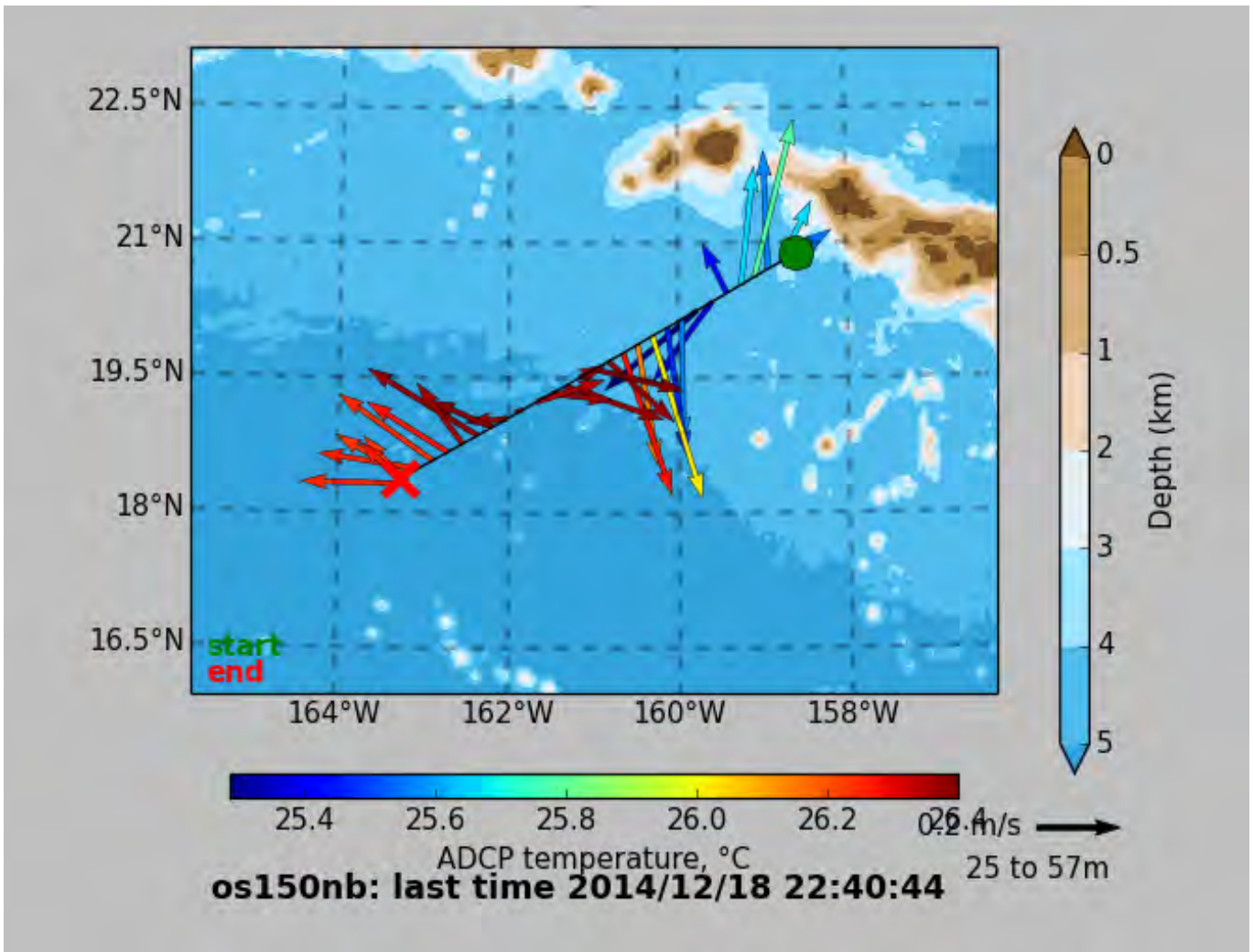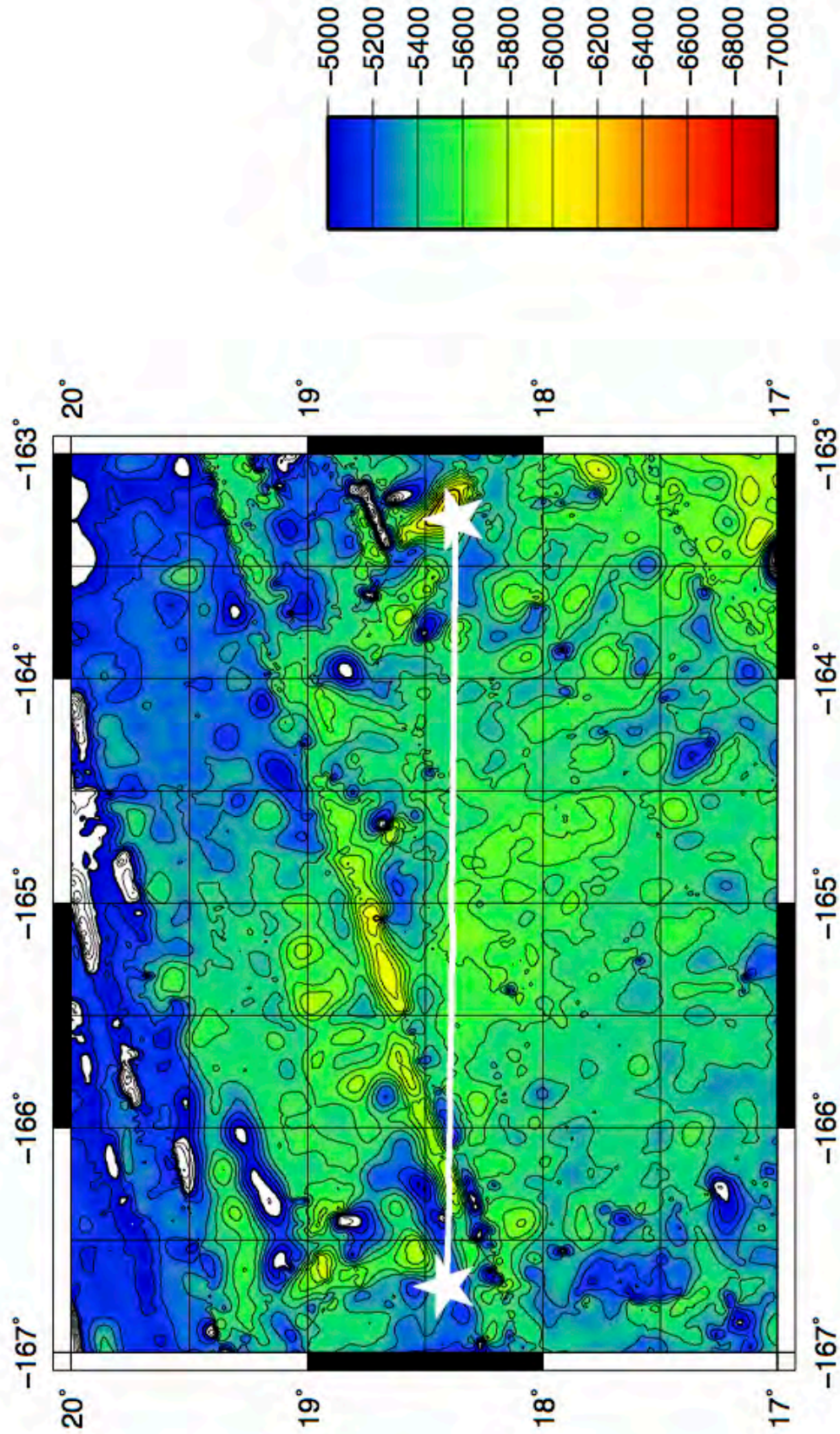
SKQ201402S

JD353 19 Dec 2014
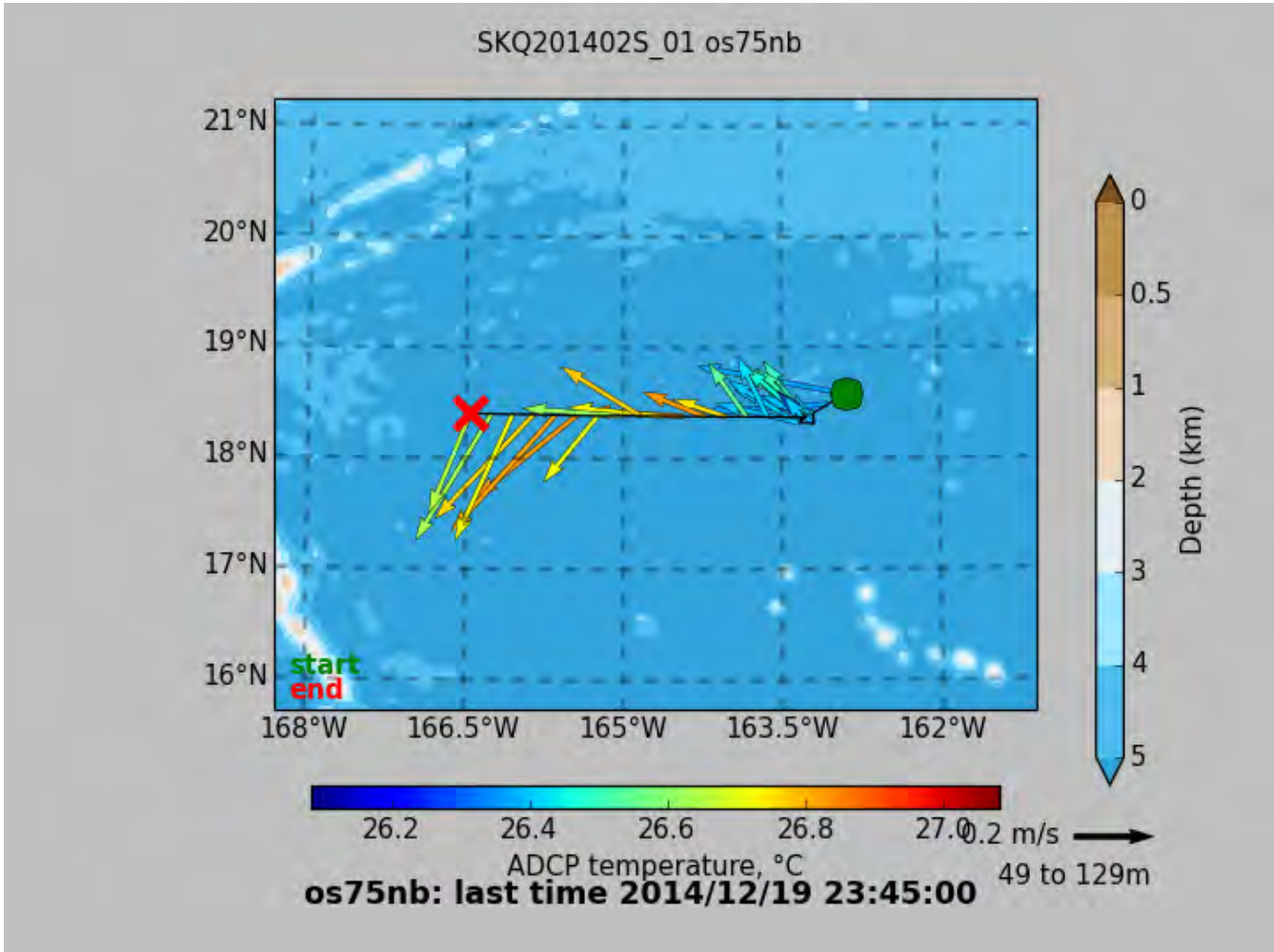Chief Scientists: M. Tominaga, M. Tivey

Daily Summary

Sentry was in the middle of its second test dive (Dive 291) as we began JD353 (18°22.366'N 163°17.447'W). It reached a max depth of 5639.8m at 03:10. After completing successful acoustic calibration and navigation test, we began to recover Sentry at 04:08. The AUV was fully recovered at 06:12 (18°22.320'N 163°17.520'W) and all sonars were turned back on to resume data collection (EM302, O75, PS18). The SeaSpy Maggie was deployed at 06:56 (18°22.320'N 163°19.578'W). The centerboard was returned to the safe position at 07:11, and we continued on our way to WP7 (18°38.228'N 170°29.136). All data collection was normal until around 21:30 when Topas was not producing good returns. Tominaga suggested that we may have been sweeping the shoulder of a fracture zone, which could have resulted in poor data. Topas eventually resumed normal activity around 22:20.

Highlights of the day included a successful Sentry test dive, pizza at lunch(!), golden sunshine and cerulean blue seas. Though we did not experience much weather today, we could be up for it this weekend.

SKQ201402S

JD 354 20 Dec 2014
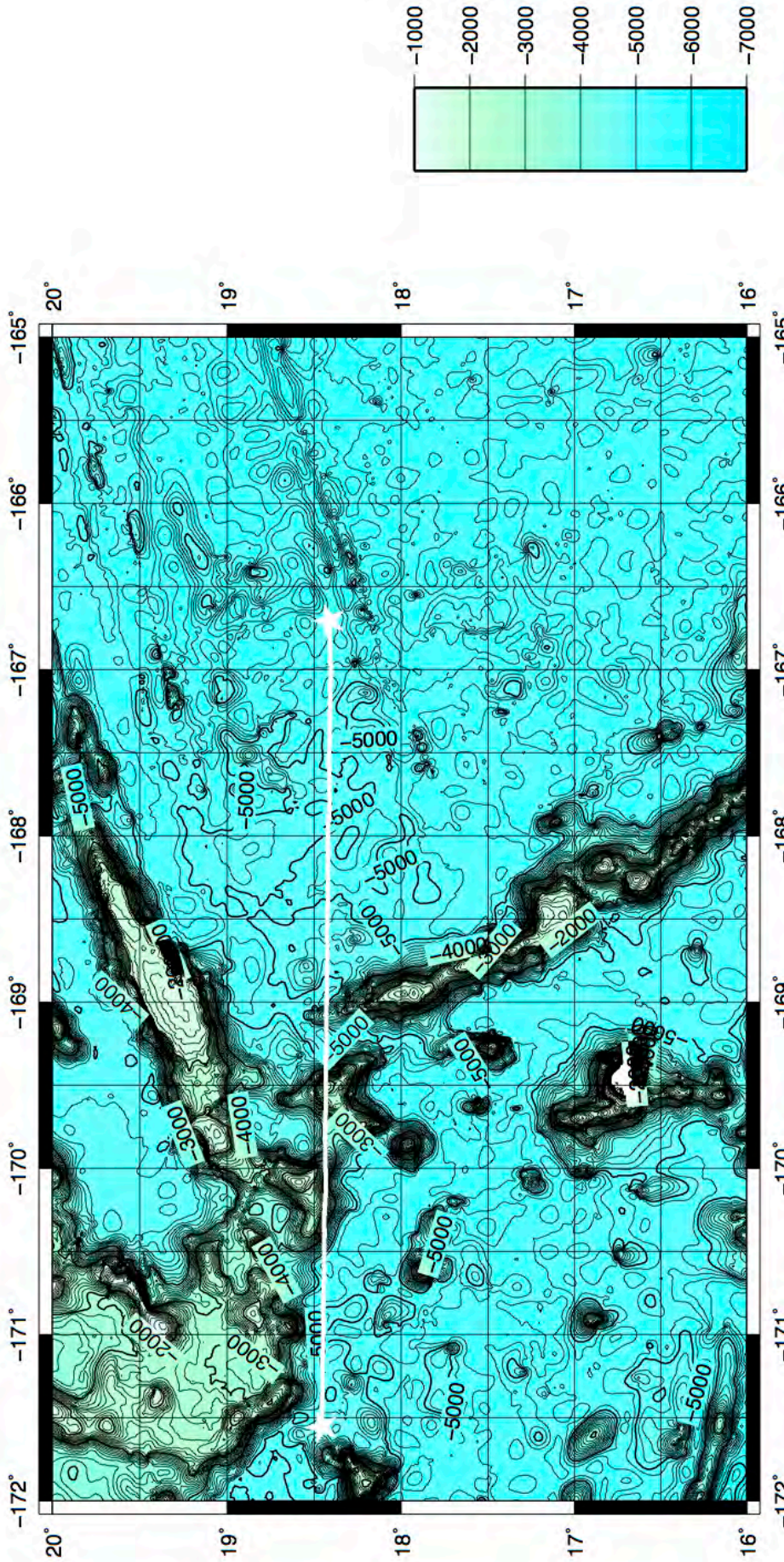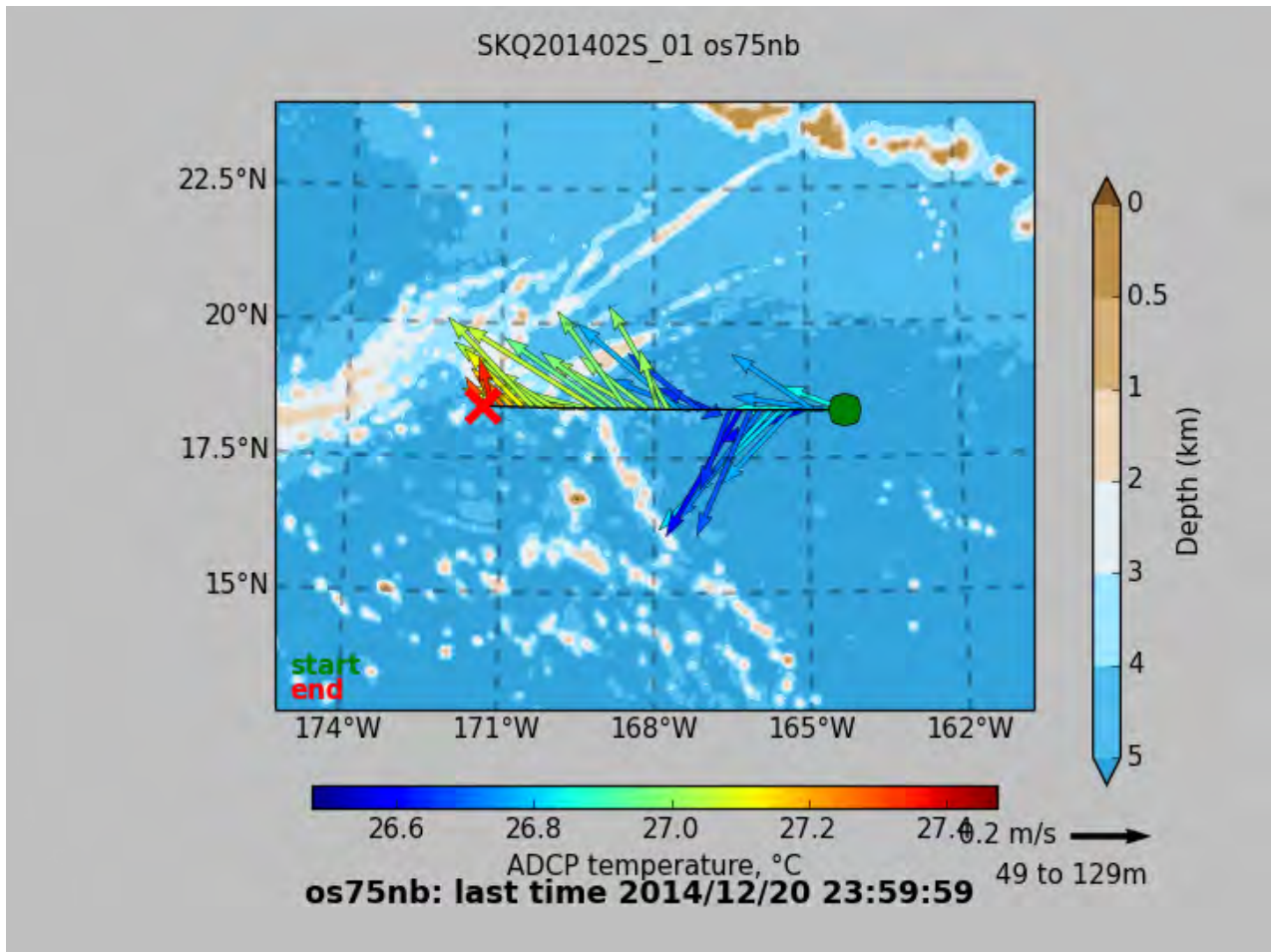Chief Scientists: M. Tominaga, M. Tivey

Daily Summary

Day 3 of transit to WP7 started at 18°24.75'N, 166°44.98'W and ended at 18°27.36'N, 171°30.24W. Our route was characterized by crossing various seamounts within the Mid-Pacific Mountains range. The varying range in depth as we cruised over the seamounts resulted in some spotty bathymetry data and Topas readings near the start of the day, but highly improved as the day went on. We are currently troubleshooting the ADCP 150, but the 75 is working fine.

At approximately 13:10 we sent out two XBTs; their release was anti-climactic for the two watchstanders who thought they were blasting canons into the deep ocean rather than simply dropping probes overboard, but it was a spectacle of entertainment for just about everyone else who seemed to be in on the joke. Both XBTs returned data up to only 300m due to interference with the surface SeaSpy Maggie. We are planning on sending out an XBT daily from here on out as we progress further away from Argo float readings, but will launch them from a different spot to avoid Maggie interference.

Maurice gave a science talk to the young scientists aboard around 15:30, and the rest of the day came to a quiet end.
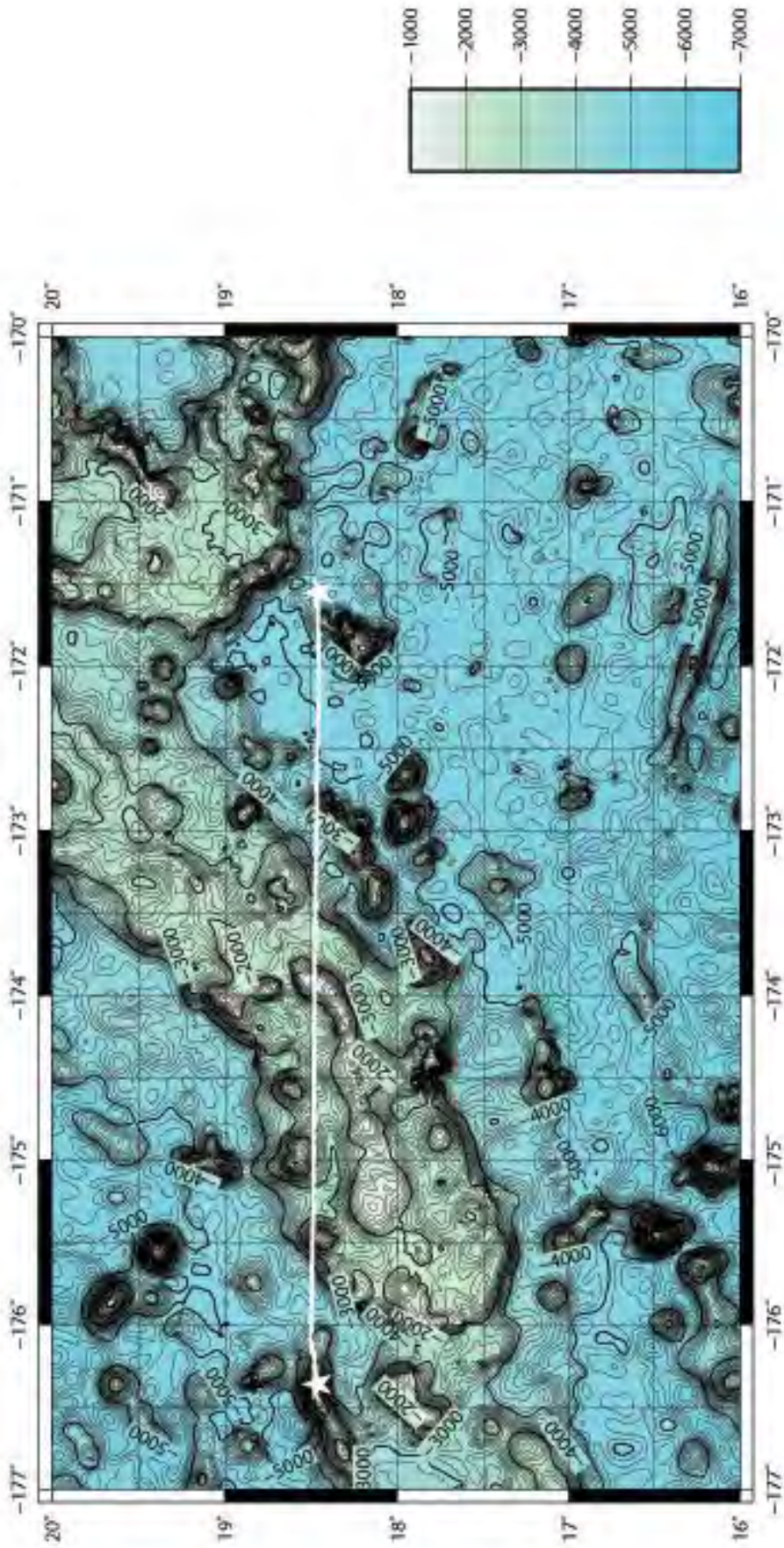
SKQ201402S

JD355 21 Dec 2014

Chief Scientists: M. Tominaga, M. Tivey

Daily Summary

Day 355 began at 18°27.48'N, 171°33.42'W. Another day in transit, not too much to report in the realm of science. Most notably we lost serial port connection to the surface SeaSPY Maggie logging computer due to large swells and steep ship rolls (reaching up to 22° at times). Temporary data gaps are at 09:44, 15:40, 18:05, and 19:20, but we regained readings shortly after each loss. Swells became so large that we changed our heading to try to minimize rolling: first at 22:40 from 271.35 to 245.95 and second at 23:20 from 245.90 to 260.30. We ended the day at 18°27.66'N, 176°22.56'W.

Internally, the ship is doing its best to adjust to the weather. The galley's had the worst luck, with full meals flying off tables, drinks tipping, and chairs toppling everywhere. On the brighter side, both the main lab and the computer lab have been decorated in the spirit of the holiday season. Ribbons and snowflakes adorn the ceilings, helping to alleviate the cranky moods watchstanders have been feeling lately due to lack of sleep. Things could be worse!

JD355

SKQ201402S_01 os75nb

start
end

27.0   27.2   27.4   27.6   27.8   0.2 m/s ➡
ADCP temperature, °C   49 to 129m
os75nb: last time 2014/12/21 23:53:27
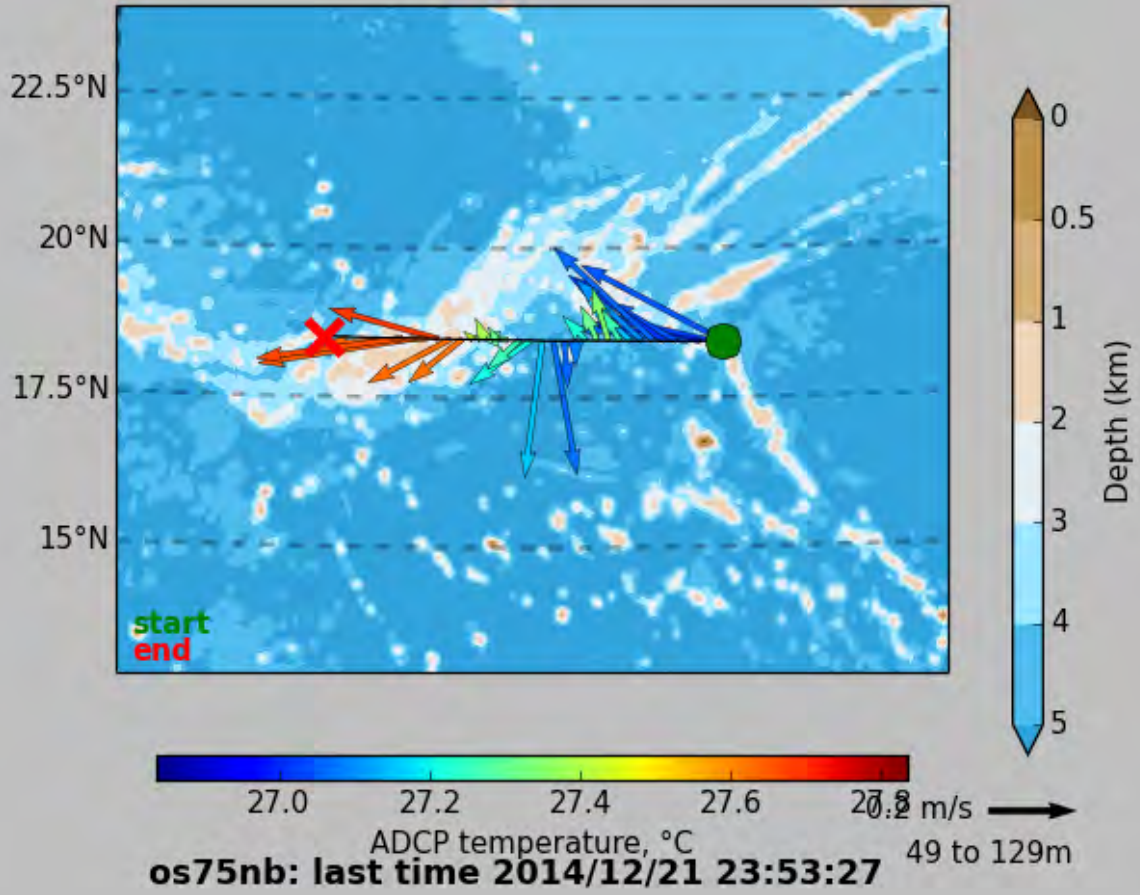
SKQ201402S

## JD356 22 Dec 2014
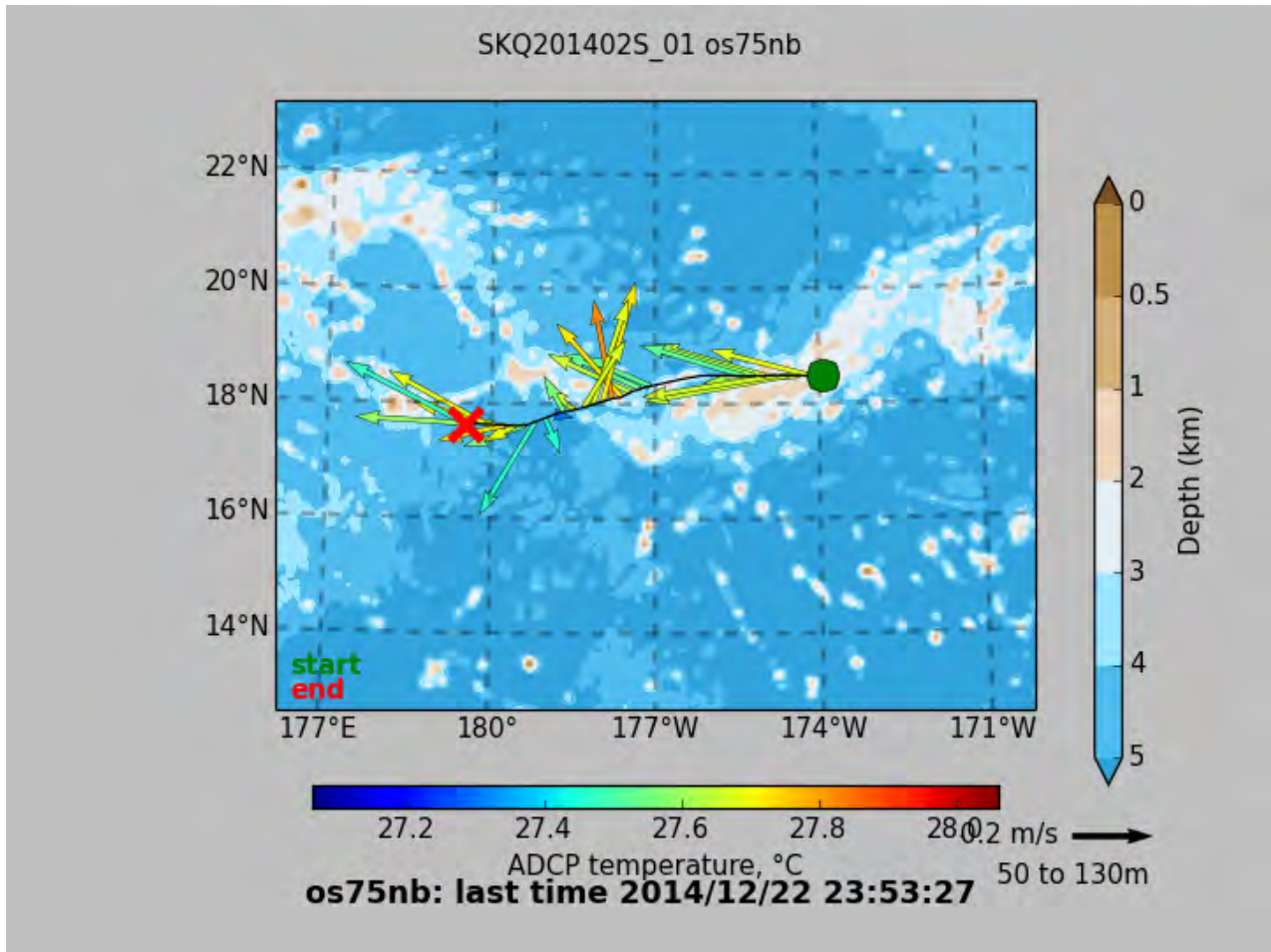Chief Scientists: M. Tominaga, M. Tivey

Daily Summary

We experienced our biggest rolls yet as the rough weather continued into JD 356 (starting point= 18°27.66'N, 176°22.56'W) which affected many areas of data collection. We lost connection to the surface SeaSpy Maggie at 01:28 but regained it shortly after. At 03:32 we restarted the EM302 bathy after also experiencing connectivity issues. It was fully functional several minutes later, after the reboot. At 13:20, reduced accuracy of the Seapath navigation data was recorded, again due to the poor weather conditions.

On a more exciting note, we had two interesting readings in the Topas, screenshots of which are provided at the end of this report. The first (18°25.52'N, 176°34.82'W) reveals a slope of almost 100m height deposited over the subsurface profile of the seafloor. The second (18°7.6'N, 177°38.31'W) is an interesting hilly subsurface profile different from most deposits we've seen so far. Really, they're both just pretty pictures that deserve inclusion in the daily report to break up the monotony that is transit reporting.

Though UTC time is unchanging and therefore unaffected by the crossing of time zones, we did indeed sail over the International Date Line today! We officially entered the eastern hemisphere at 20:17 (LAT= 17°37.98'N). We turned off all sonar as we crossed the date line and restarted it upon entering into the eastern hemisphere (20:20 UTC, 17°37.98'N, 179°59.34'E). The date and time of all logs and data will be kept in UTC, but ship time has officially jumped forward one full day.
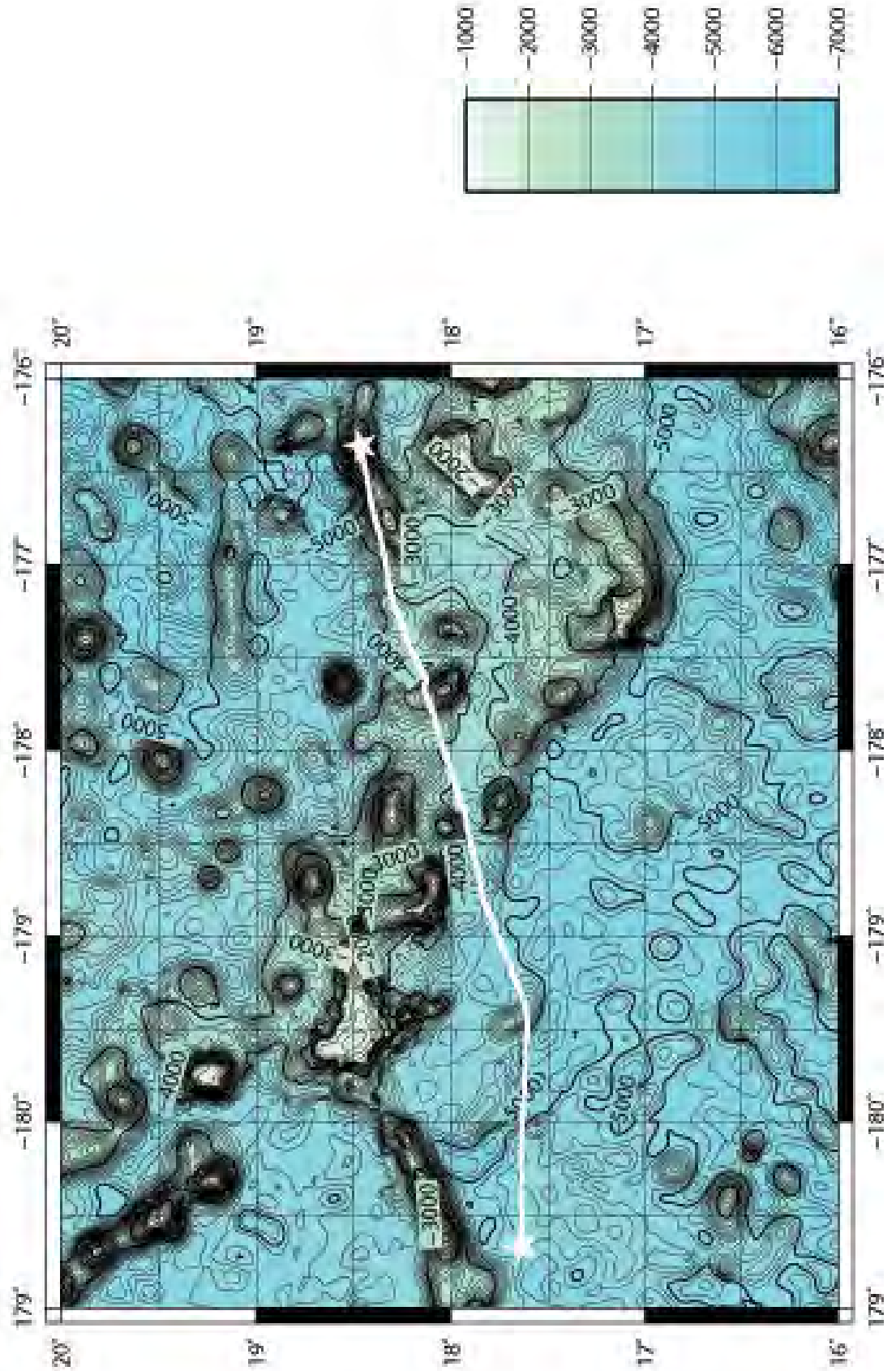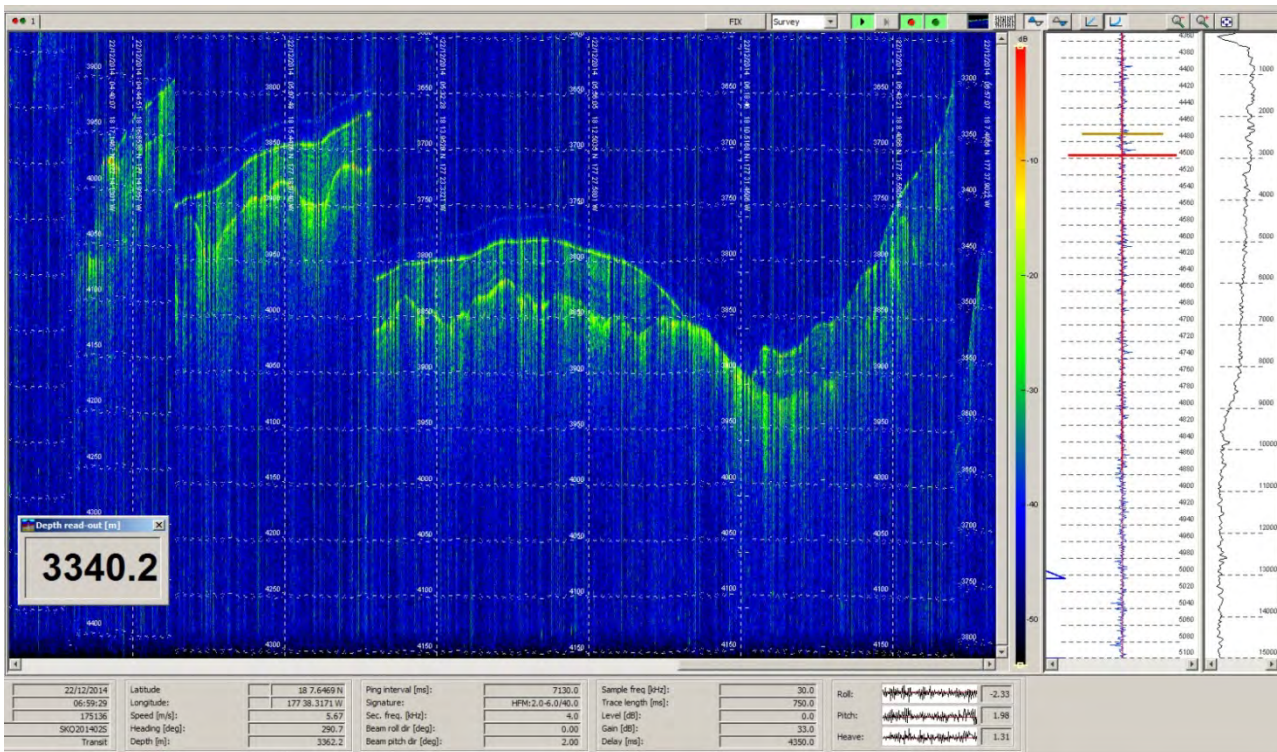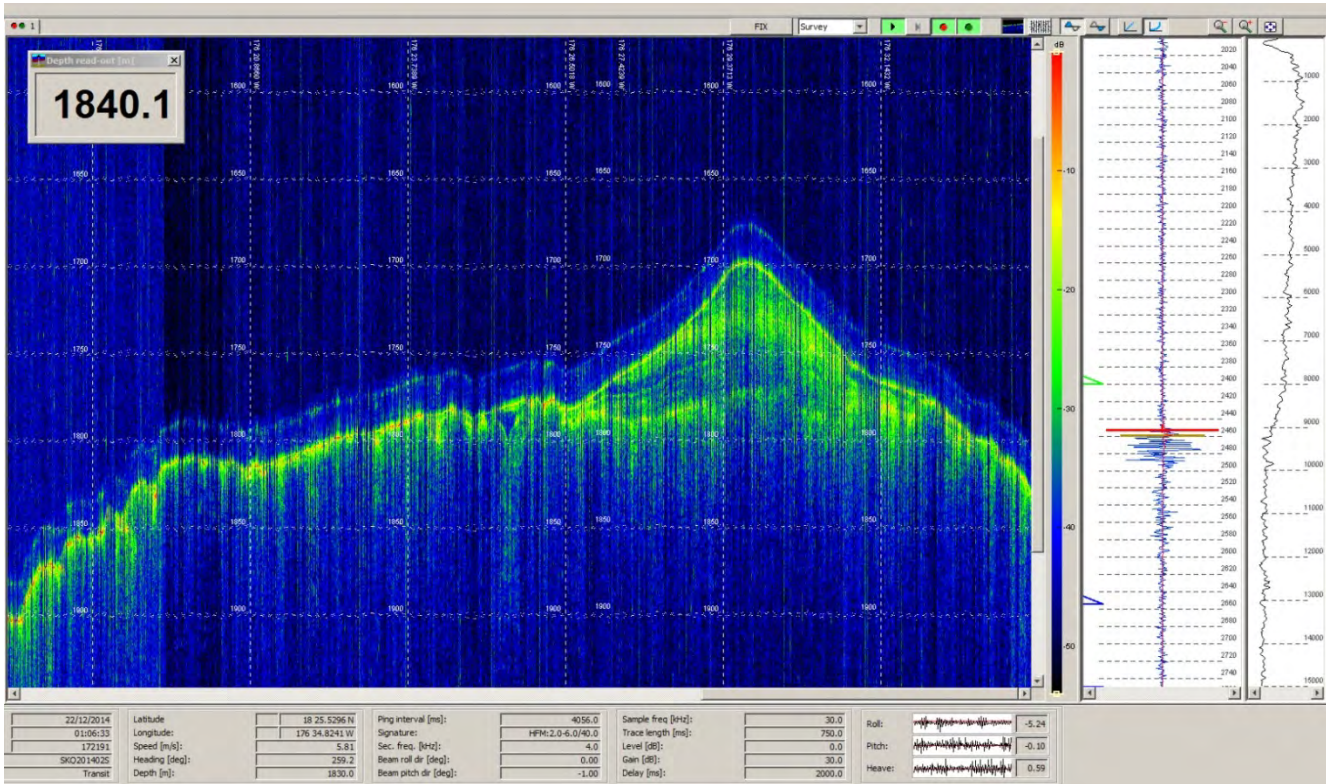
SKQ201402S

JD357 23 Dec 2014
Chief Scientists: M. Tominaga, M. Tivey

Daily Summary

The rough weather finally settled as we sailed in to JD357 (starting point= 17°38.16'N, 179°19.68'E). Today's transit looked similar to all others so far: underway with the SeaSpy surface Maggie, EM302 and PS18 all collecting good data. At around 18:24 (18°53.64'N, 176°11.88'E), we experienced connectivity issues with both the EM302 bathy and the PS18 Topas. Both were back up and collecting data by 18:36.

Weather forced us to change our heading several times over the last couple days, so our transit plan has now changed. Instead of transiting to WP7 (18°38.228'N 170°29.136), we are now transiting straight to WP8 (23°20N, 167°16E) in the interest of time. We therefore changed our heading today from 268.63 at our starting point to 300.16 by the end of JD 357. The nav map also reflects an abrupt change of ship track at 22:47 when we briefly deviated our course to avoid crossing paths with a nearby ship.

We deployed another XBT today at 21:29 from the starboard side but we had the same interference issues with the surface Maggie. We only recorded data up to about 400m.

Our ending point today was at 19°28.68'N, 175°28.32'E.

JD357
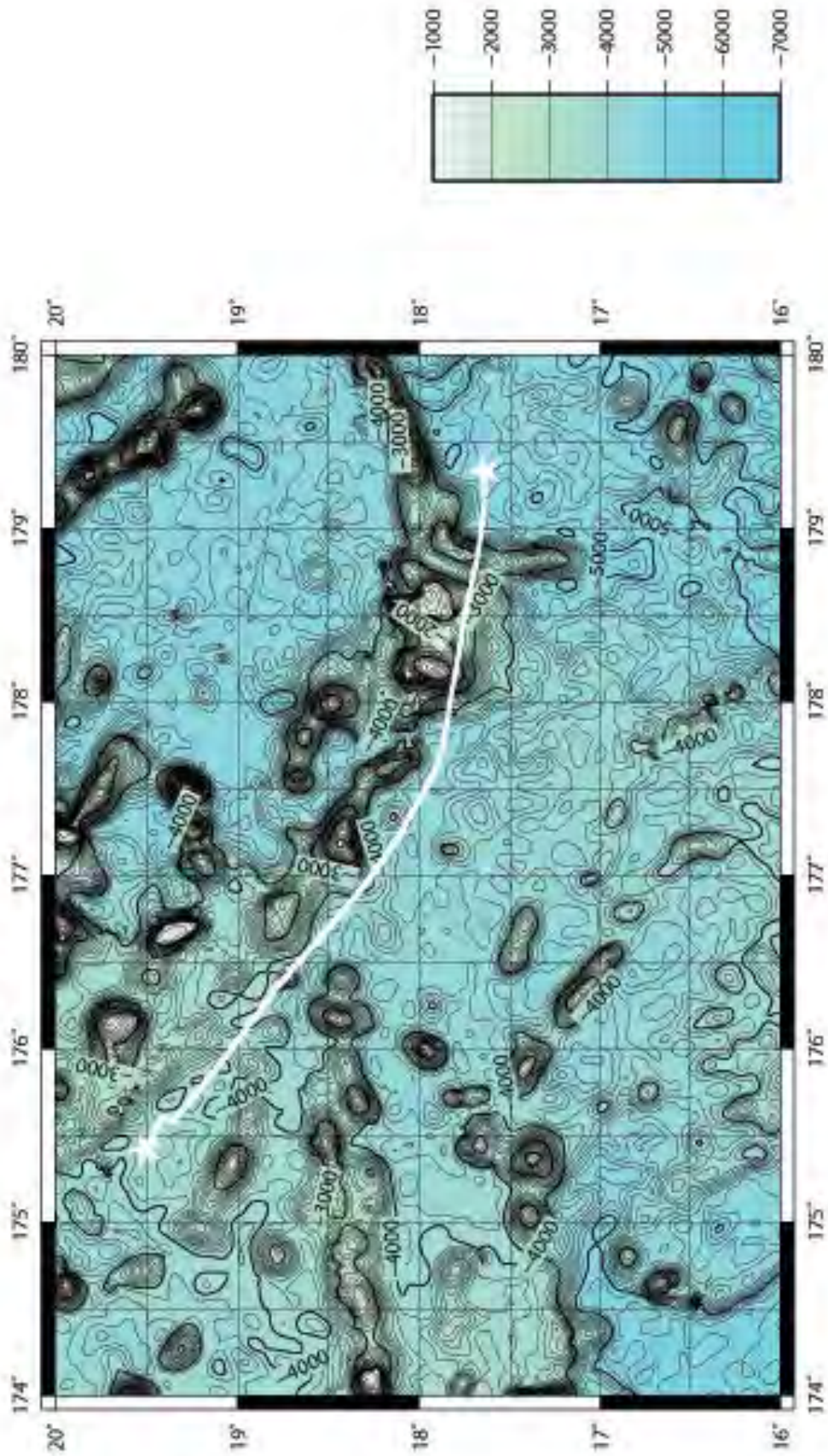
SKQ201402S
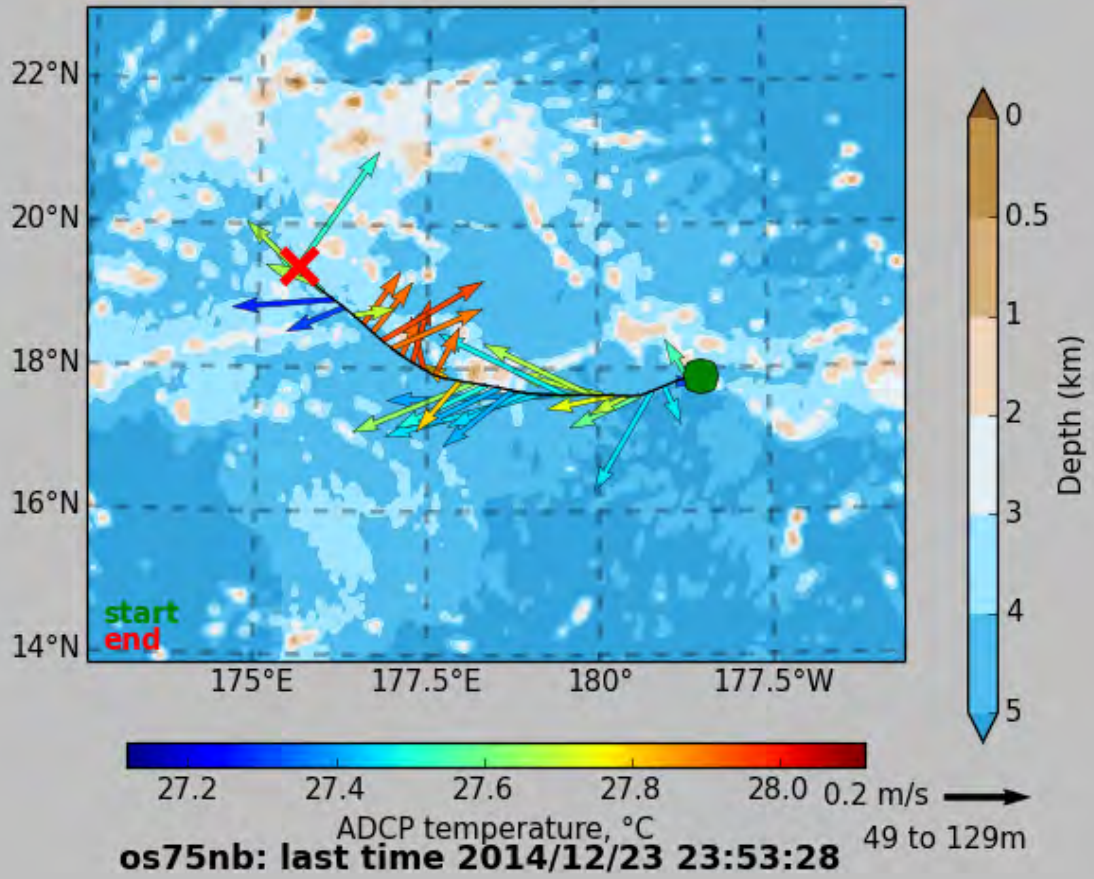
JD358 24 Dec 2014
Chief Scientists: M. Tominaga, M. Tivey

Daily Summary

Julian Day 358 and yep—you guessed it! Another day of transit. Today was perhaps the least exciting day of science yet (read: good science!). The EM302, Topas and SeaSpy surface Maggie each collected good data for the duration of the day. The only exception occurred around 12:40 when the Topas lost connection and was rebooted. It resumed data collection shortly after.

We continued on to WP 8 from our starting position of 19°30.300'N, 175°24.960E. We finished the day at 21°36.180'N, 171°23.673'E.

Ship morale is more than compensating for the lack of exciting science. Because ship time is now a full 12 hours ahead of UTC time, the stroke of midnight marked Christmas! The galley organized cookie decorating for anyone and everyone interested. The result: mounds of deliciously baked and festively decorated cookie men, cookie trees, and cookie Santas. An endless supply of sugar to carry us through all 12 days of Transit. It seemed that everyone celebrated in their own small ways; some broke Christmas crackers at midnight, some jaunted through the halls singing carols, and some were spotted sporting Santa socks (say that four times fast…) up past their ankles. Santa himself even made a stop on the boat! (See photo at end of summary). The official Christmas dinner will be held tomorrow, but the ship has proved so far that the holidays are really what you make them.

JD358
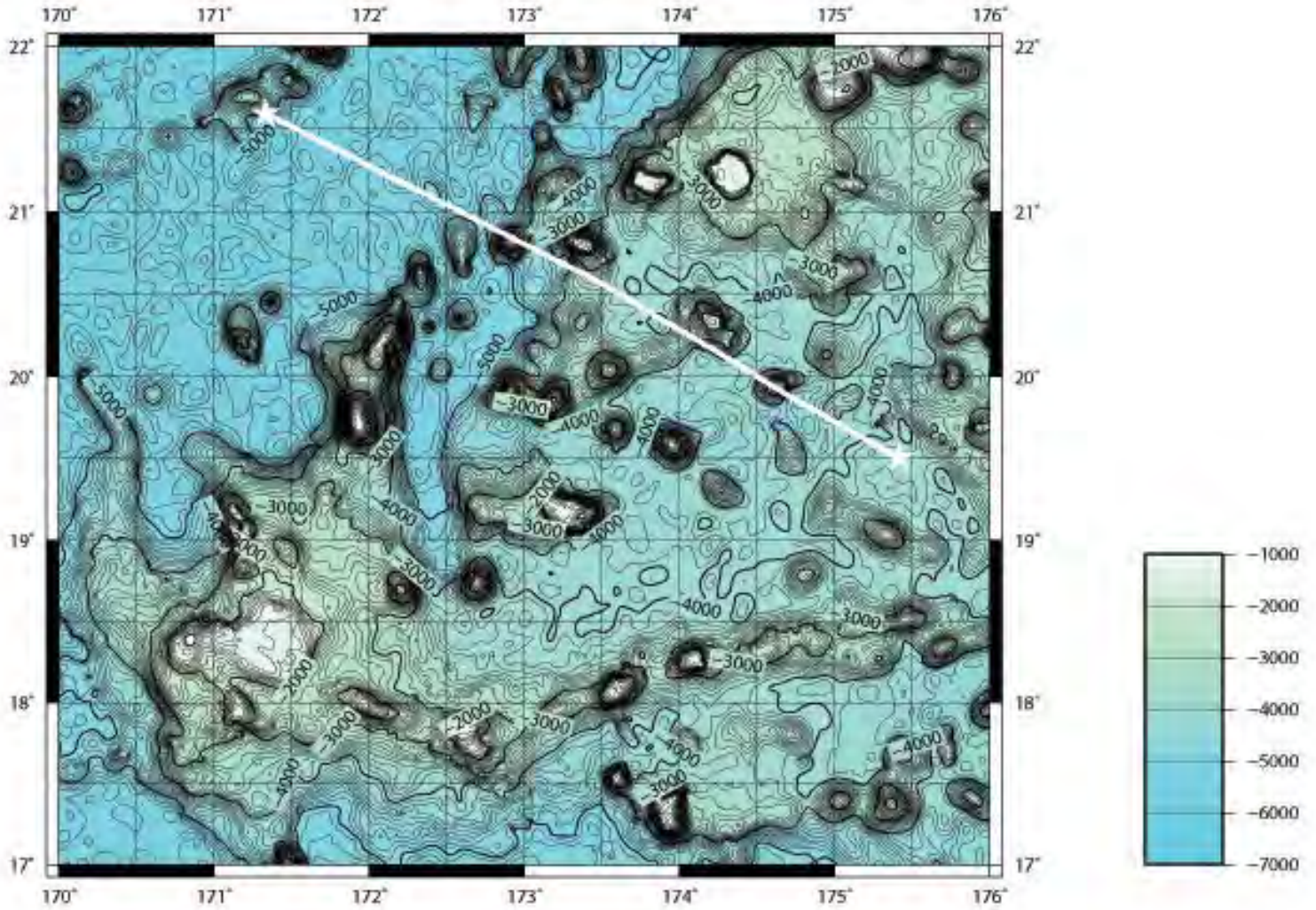
SKQ201402S_01 os75nb

os75nb: last time 2014/12/26 23:59:53

ADCP temperature, °C

49 to 129m
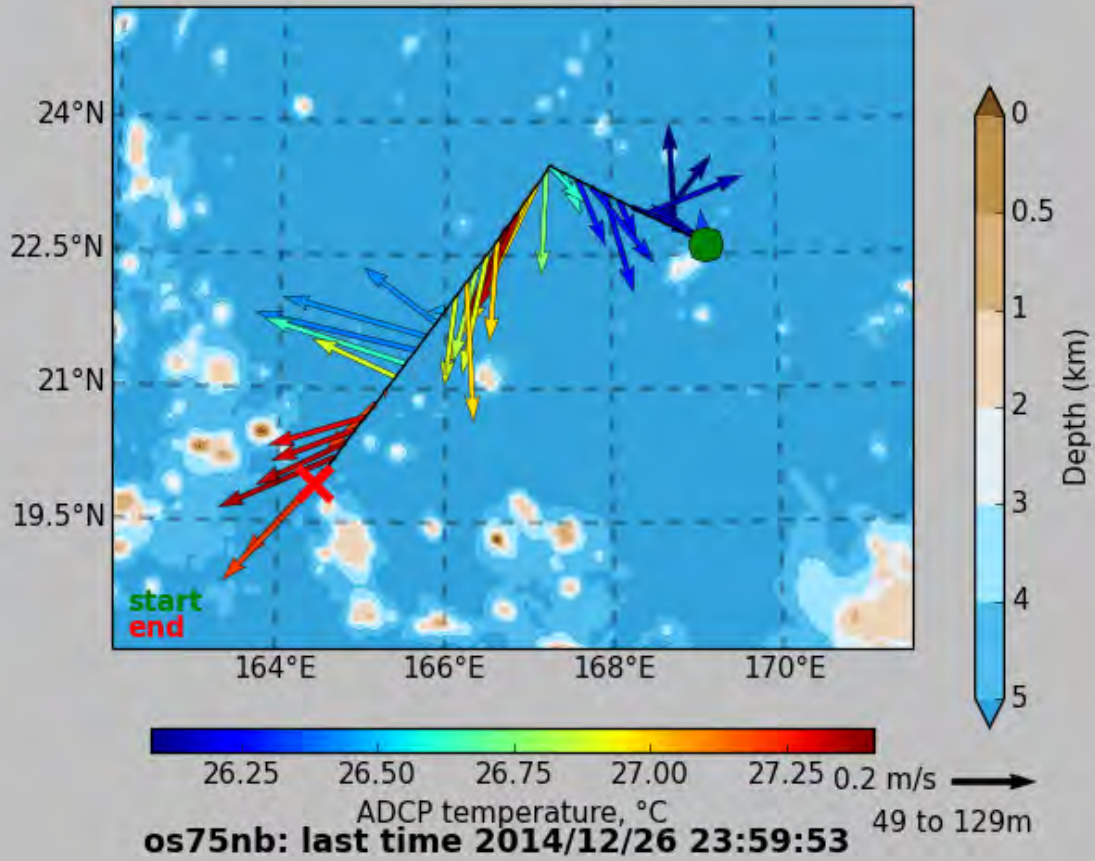
SKQ201402S

JD359 25 Dec 2014
Chief Scientists: M. Tominaga, M. Tivey

Daily Summary

JD 359 and more science a'happenin' than yesterday. Breaking it down into three parts: The SeaSpy Surface Maggie, The Plan, and The Day's Details.

The SeaSpy surface Maggie: we had our first connection issues at 00:20 (21°37.380'N, 171°15.780'E) but resumed collecting data at 00:25. Major connection issues began later around 14:00 (22°47.340'N, 168°47.340'E) when the Maggie could not connect to the GPS location. We troubleshot by creating a new line, "Line 3" but experienced a 2.7s offset in data recording time after doing so. The lag continued so we started a new line, "Line 4." At 21:00 we rebooted the Maggie entirely to resync the GPS and the mag system. Bob crashed twice in the process but by 21:21 the problem seemed to be alleviated. Again at 22:00 we turned off the Maggie, started it again 20 minutes later after checking the cables on the back deck.

The Plan: We reached WP 8 (23°30'N, 167°16'E) today at 23:10. From there, we started SeaSpy Maggie "Line 3" as the ship's course began on line 3. From WP8 we changed course to head towards WP9 (22°47.815'N,166°43.552'E); we will then head to WP10 (19°54.899'N,164°26.247'E) and finally WP11 (18°34.212'N,162°59.262'E). While transiting from WP8 to WP11, we will continue running the multibeam which will serve as a proxy for Sentry Dive 292, mapping the seafloor for the AUV's dive. We expect to arrive at WP11 at approximately 09:00 on JD 361. Once we arrive, we plan to deploy Sentry (Dive 292) and retrace our course back towards WP10 and WP9 with the vehicle. Until then, we will continue to run Topas, the ADCP, the gravimeter and the SeaSpy surface Maggie as usual.

The Day's Details: Starting and ending points were 21°36.180'N,171°23.673'E and 23°26.22'N,167°13.02'E respectively. We launched our first successful XBT today! Launched at 04:26 from the port side and achieved a max depth of 750m. Go Rachael! You Natural!

JD359
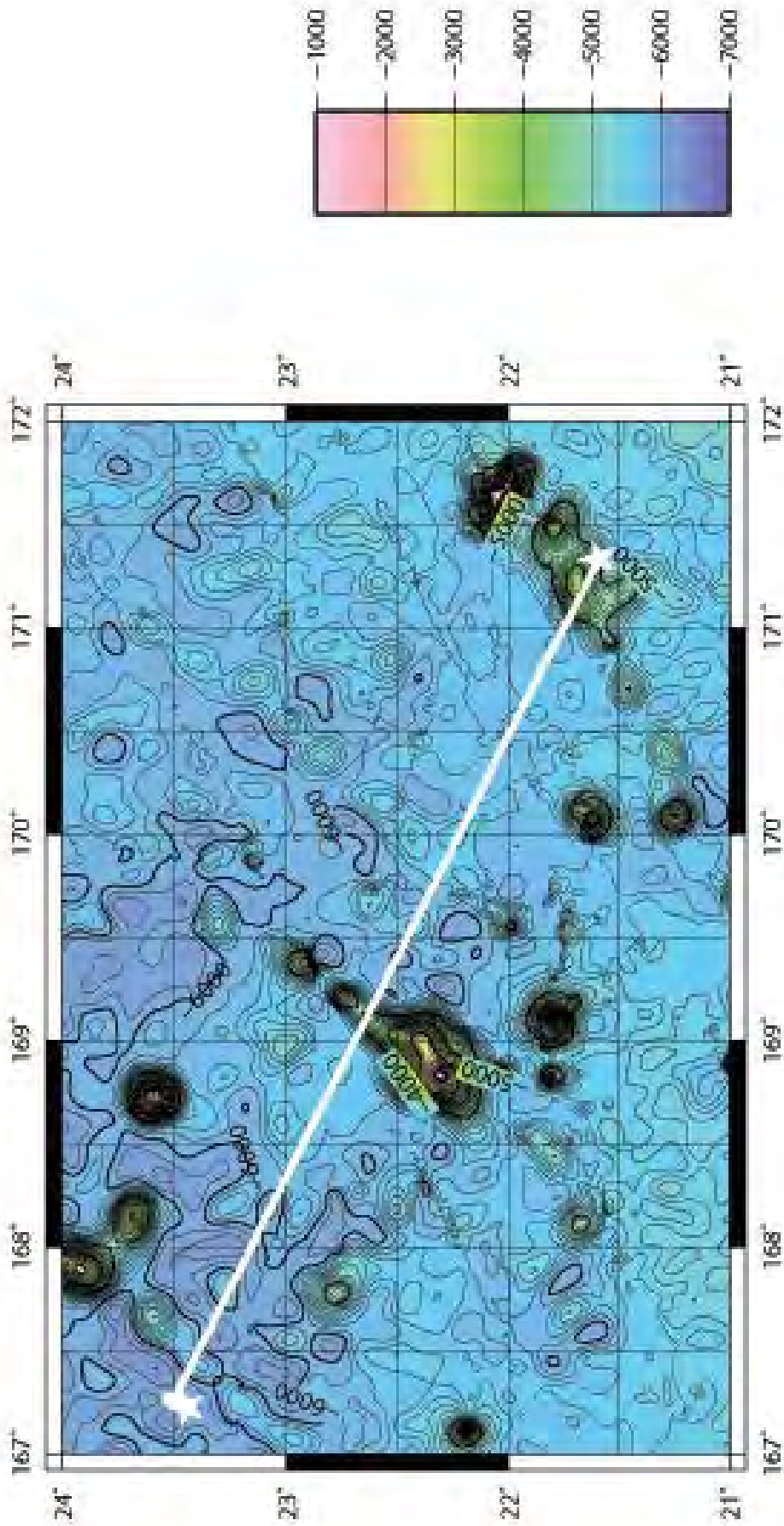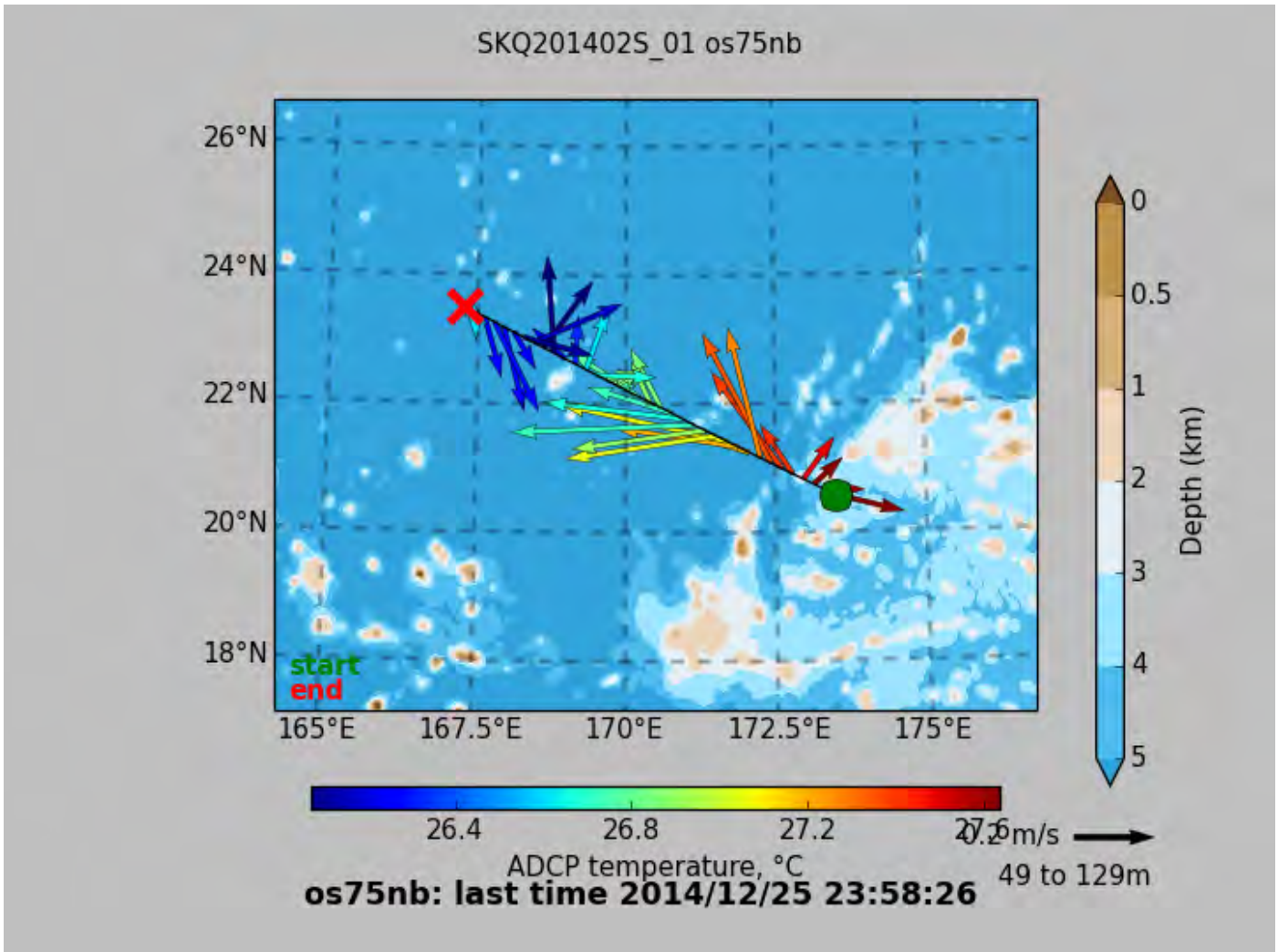
SKQ201402S

JD360 26 Dec 2014

Chief Scientists: M. Tominaga, M. Tivey

Daily Summary

Get ready for the most exhilarating narrative to come your way yet…

Started JD 360 (our final day of transit before deploying Sentry for Dive 292) at 23°26.22'N,167°13.02'E and ended at 19°47.64'N,164°18.19'E.

Deployed an (unsuccessful-ish) XBT from the starboard side at 00:45, reaching a terminal depth of 500m.

Continued underway.

The end.

Really, that's it. Not even the SeaSpy lost connection today. Let the reign of boring (read: great!) science begin! Hopefully we can ride this luck up through the end of the cruise.

JD360
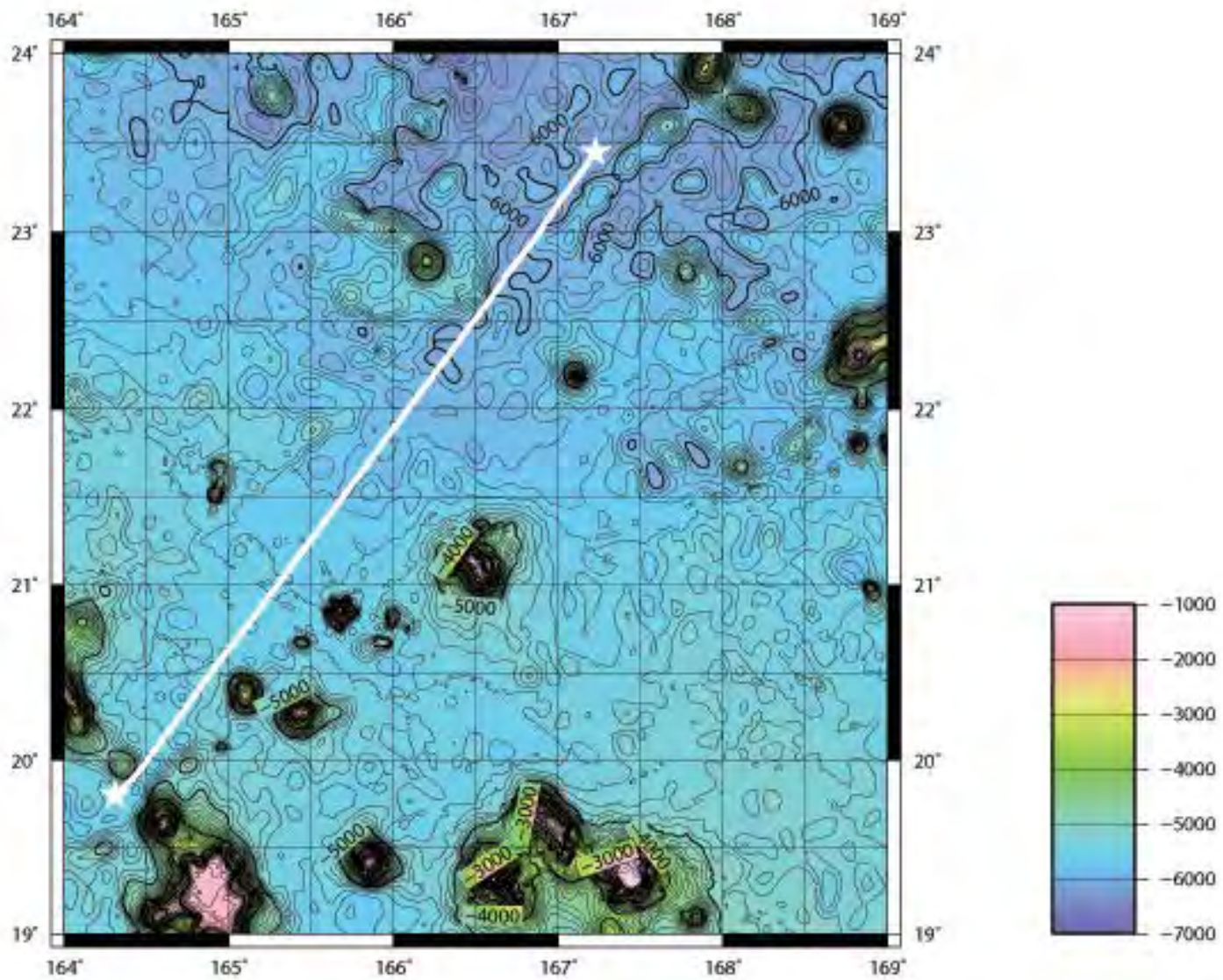
SKQ201402S
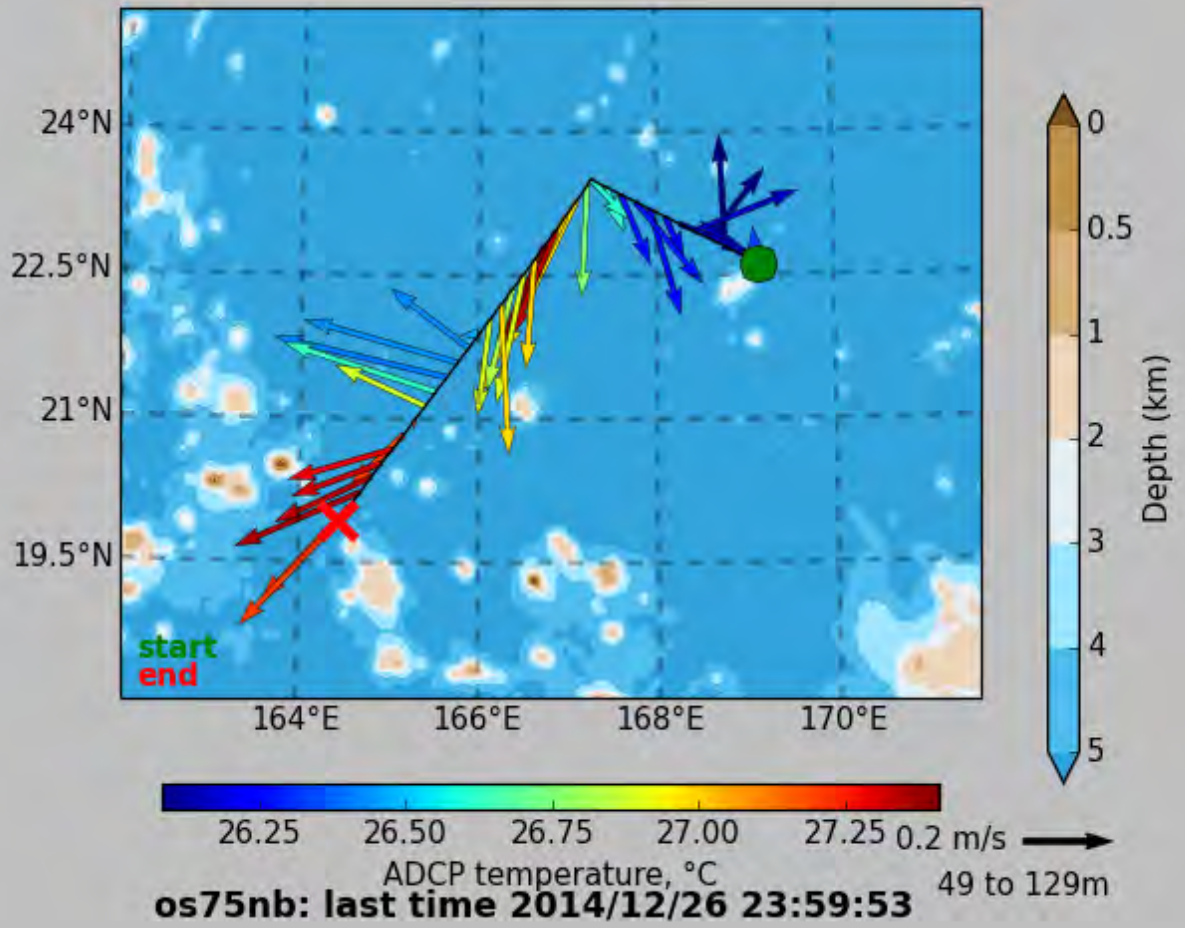
JD361 27 Dec 2014
Chief Scientists: M. Tominaga, M. Tivey

Daily Summary

JD 361, the day we've all been waiting for…

We reached WP11 (18°34.212'N,162°59.262'E) at 09:18 and prepared for Sentry launch (Dive 292). We slowed the ship and recovered the SeaSpy surface Maggie by 09:42; deployed the centerboard fully by 10:00; and finally secured the ADCP, PS18, and EM302 by 10:31. Talk about efficiency! We successfully deployed Sentry at 10:40 (ship's position= 18°34.25'N,162°59.29'E). The AUV descended for just over two hours, dropping its weight at 12:57 after achieving a depth of 5174.5m. Sentry's position at this time was recorded as 18°34.34'N,162°59.10'E. From here Sentry proceeded from WP11 to the start of the profile line to begin its first track line. It reached the track line and was underway by 13:20 (position= 18°34.55'N,162°58.70'E, depth= 5179.0m). It continued steadily on this track line through the end of JD 361 with an expected recovery time of approximately 19:00 on JD 362 (battery power will take us further than expected). At 22:20 we increased Sentry's speed to 0.8m/s. We ended JD 361 with Sentry's position recorded at 18°46.28'N,162°11.25'E and the ship close by holding dynamic position. The greatest depth recorded today was 5244.05, observed at 22:00 (18°44.01'N,162°8.70'E).

Moving forward, we're planning to recovery Sentry tomorrow, turn all sonars back on (ADCP, PS18, EM302) and deploy the deeptow Maggie while recharging Sentry and downloading the data from Dive 292.

JD361
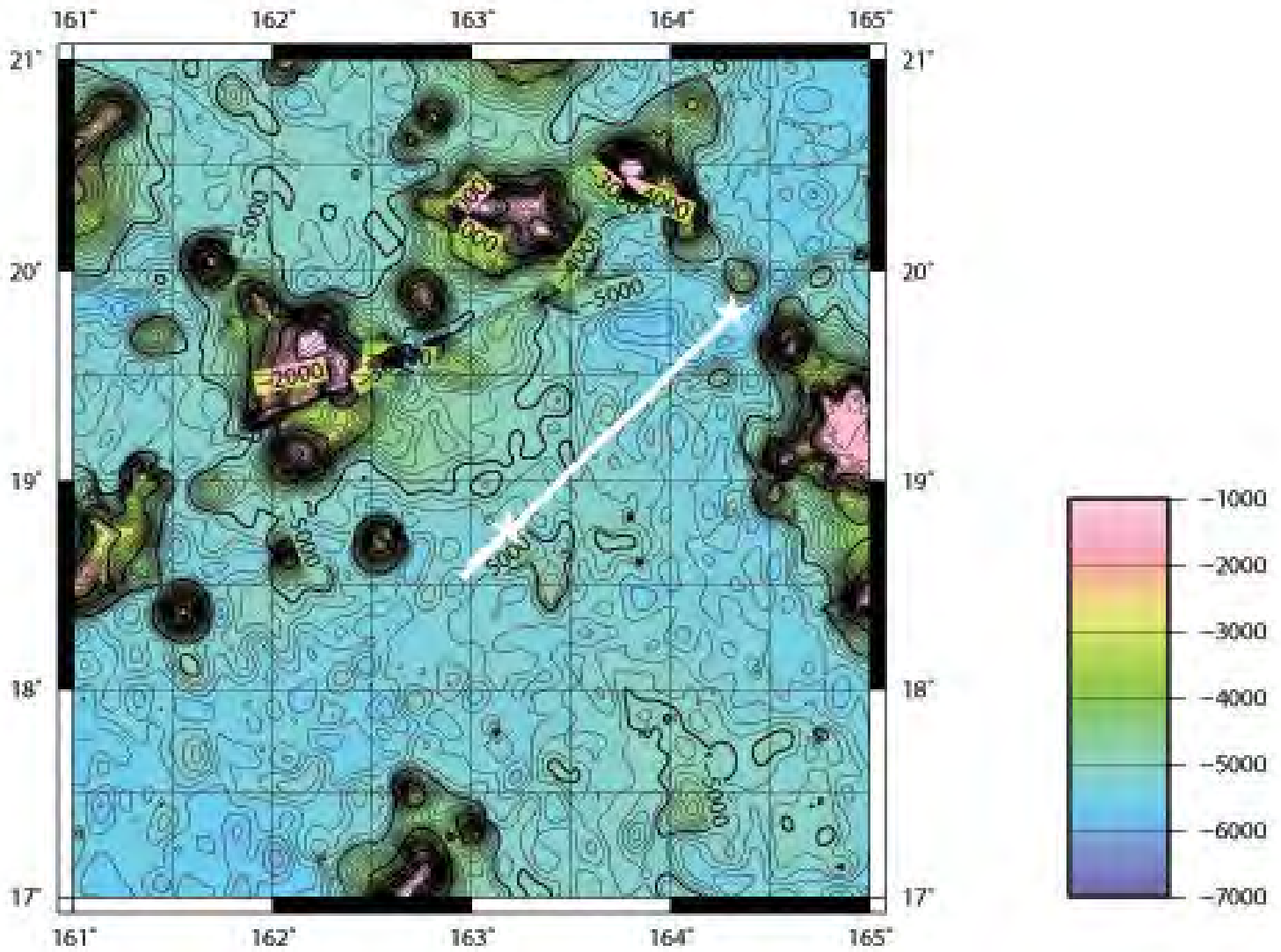
SKQ201402S
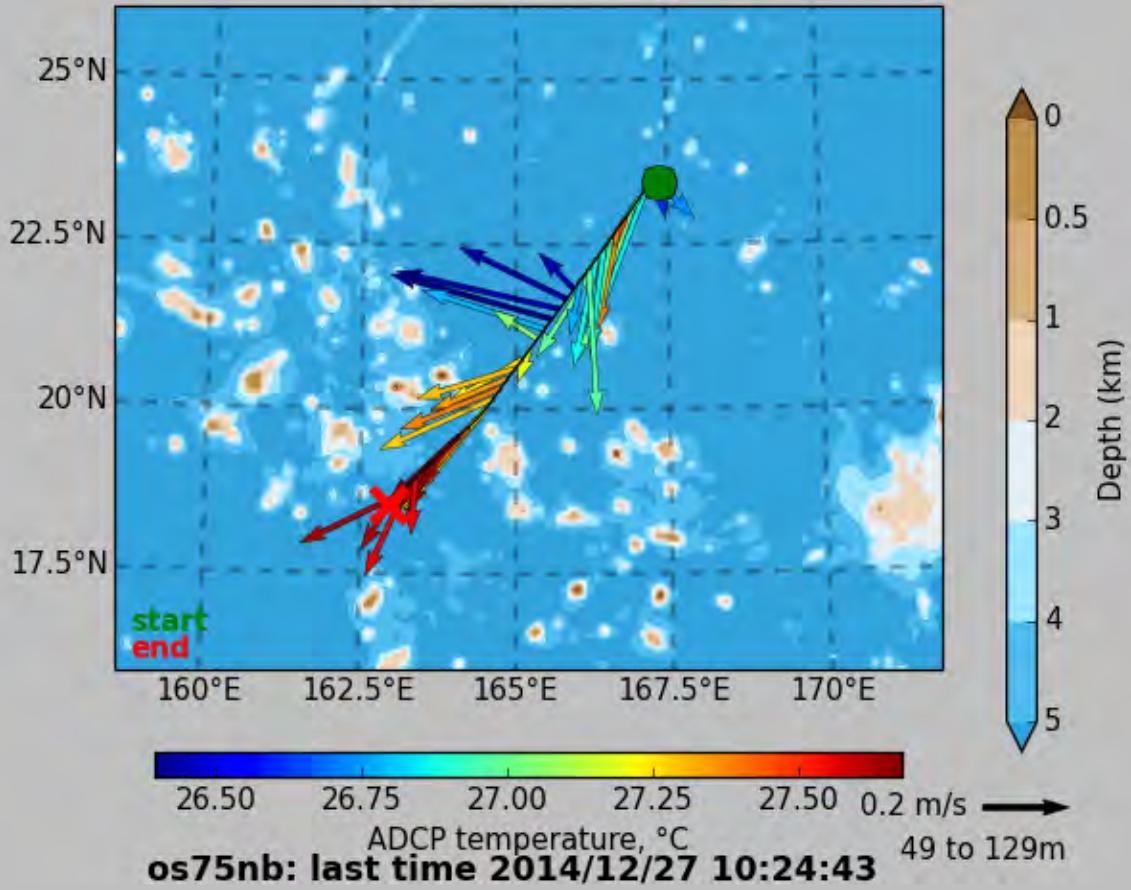
JD362 28 Dec 2014
Chief Scientists: M. Tominaga, M. Tivey

Daily Summary

JD 362 began with Sentry in the midst of Dive 292, precisely at 18°46.28'N,162°11.25'E, on track line 1 and at a depth of 5113.50m. Dive 292 continued smoothly through 19:00 (position= 19°9.12'N,163°36.84'E, depth= 5281.9), upon whence it completed its track line and prepared for recovery. The greatest depth achieved on track line 1 was recorded at the endpoint; 5281.9m deep.

Just over two hours later, at 21:12, Sentry was secured on deck after a successful recovery (ship's position= 19°9.00'N,163°9.732'E). The whole team was very happy with the battery efficiency of Sentry, the ease of recovery, and ultimately the precision of the data collected. Total dive length was recorded at 90km. Great dive!

Post-recovery, the routine steps occurred: the centerboard was raised (21:19); ADCP, EM302, and PS18 were turned back on (21:26); and we continued underway in the opposite direction of the completed track line towards WP13 (18°58.789'N,163°24.052'E). While underway, at 23:30, we deployed an Argo float (SN 9305) at the speed of 1.1kts, position= 18°68.31'N,163°23.66'E. Upon approaching WP13 (18°58.789'N,163°24.052'E), we prepared to launch the DeepTowMag. It was in the water by 23:48 at (18°58.54'N,163°23.988'E) and began to descend while the ship held a speed between 1.2-1.5kts. As the DTM (an acronym that will now affectionately be used for "DeepTowMag") began its descent, JD 362 became JD 363… what an action packed day all for the name of science! Check tomorrow's daily report for max depth and winch length details. [Spoiler alert: also prepare for the next Sentry dive, Dive 293].

JD362
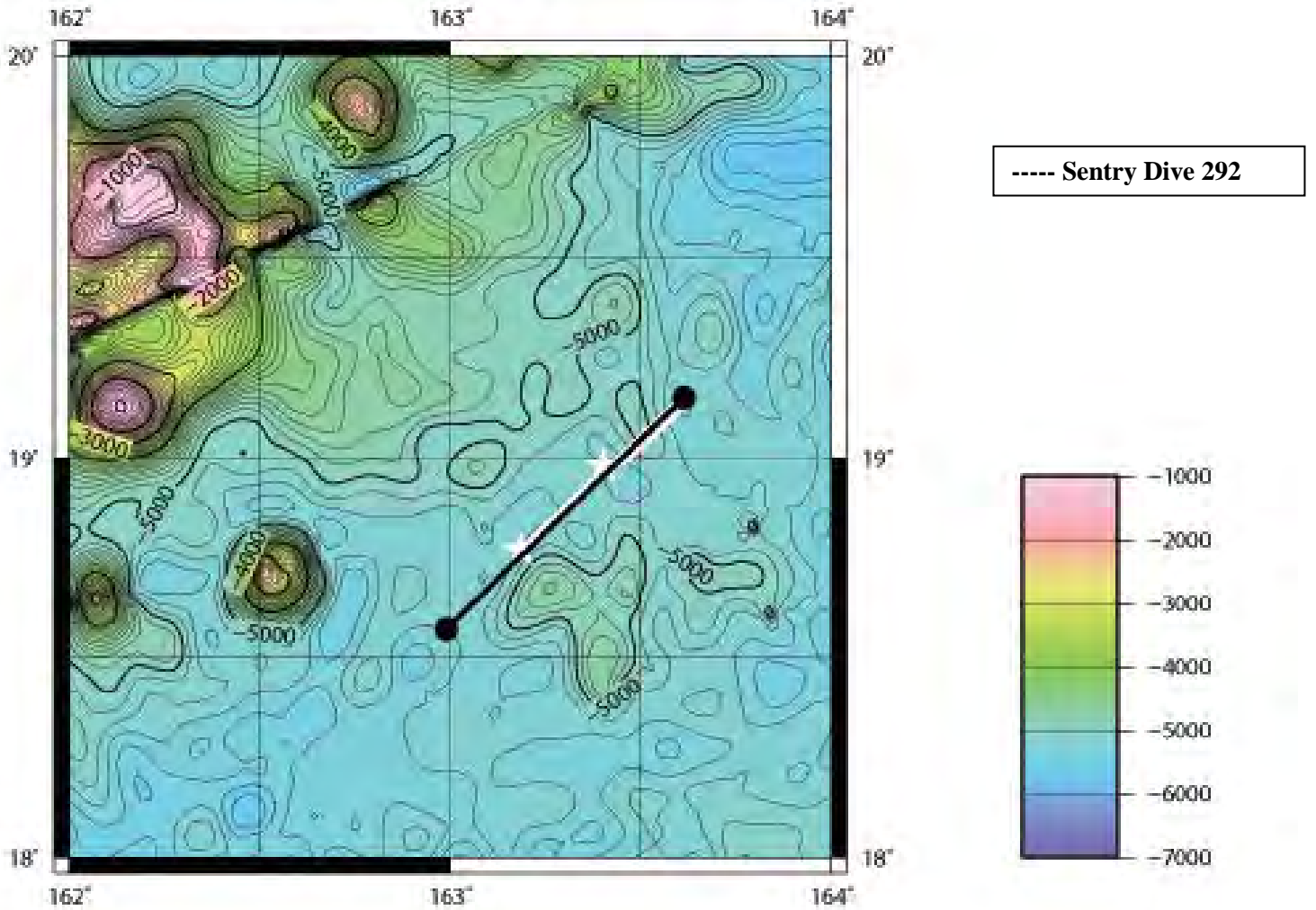
----- **Sentry Dive 292**
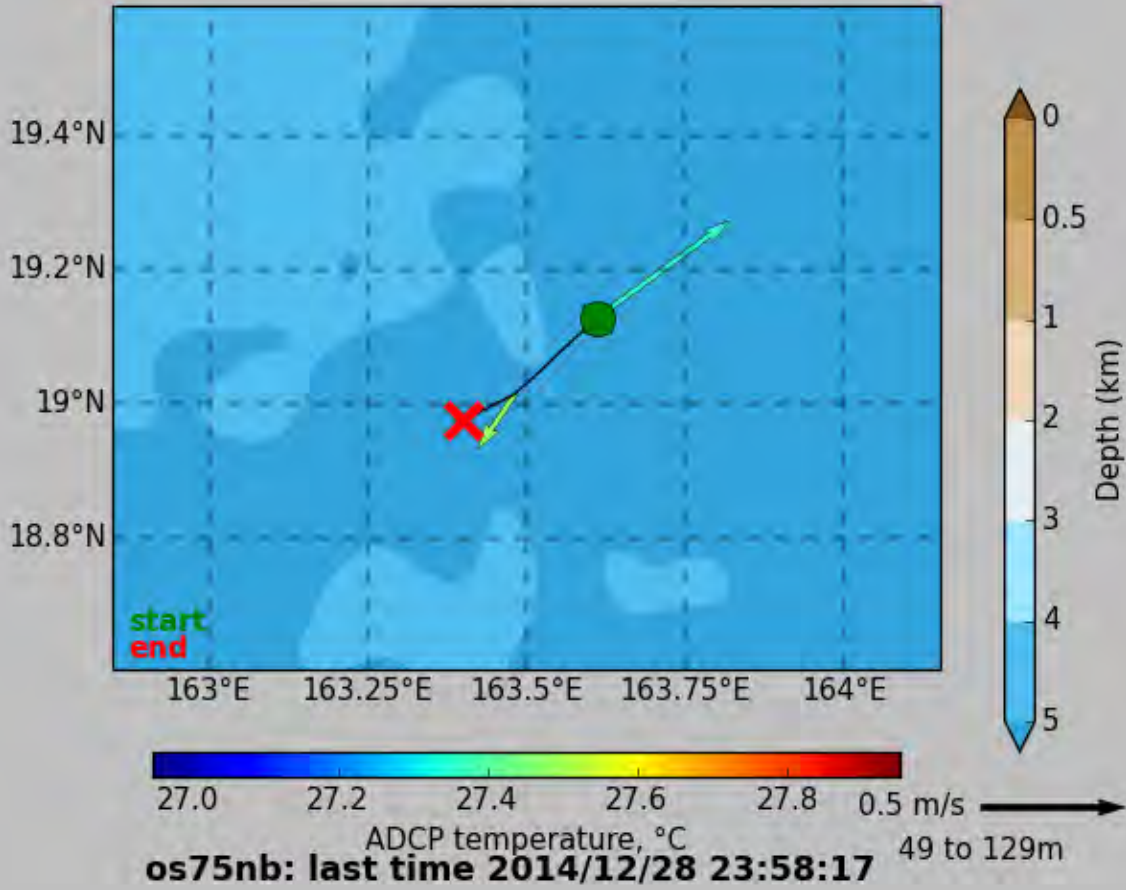
SKQ201402S

JD363 29 Dec 2014

Chief Scientists: M. Tominaga, M. Tivey

Daily Summary

The DTM had already been launched at WP13 (18°58.789'N,163°24.052'E) and was descending as we began JD 363. By 01:23 Maggie had reached a max depth of 3035m; we decided to hold wire length at 4198m to monitor the tension before extending further. After okaying the wire length, slack and tension, we increased the length to 4250m, thereby increasing the max depth of the DTM to 3040m (approx. 04:00). We also sped up to 1.7-1.9 kts, causing a slight decrease in DTM depth. We increased the wire length a final time to 4750m, achieving a max depth of 3111m (04:37).

We continued onto WP14 (19°7.594'N,163°33.590'E) with the DTM in tow. At 08:00 we slowed the ship to begin to haul in the Maggie at a rate of 50m/min to prepare for Sentry's launch. The DTM was on deck by 09:52 and we continued underway to begin Dive 293 with the beloved AUV.

Sentry was deployed for Dive 293 at 10:46 (position=19°7.584'N,163°35.304'E) after all necessary steps on board were taken (centerboard deployed, all other sonars switched off). The AUV dropped its weight at 13:03 (depth= 5135.5m) and proceeded to WP14 (19°7.594'N,163°33.590'E) reaching the destination at 13:19. From here, we continued underway to WP15 (19°39.725'N,164°9.832'E).

Things really started heating up when we again launched the DTM at 13:42. We held a terminal wire length of 4700m and reached a max depth of 2888m at approx. 16:00. We continued underway with Sentry and the DTM each healthily proceeding along the track line. A slight issue occurred at 15:48 when the DTM logging software crashed and was rebooted. Around 16:50 we increased ship speed to catch up with Sentry, again causing a slight decrease in DTM's depth. A few hours later, at 19:30, we extended the wire another 100m bringing it up to a total length of 4800m.

We closed out JD 363 with both Sentry and the DTM deployed and putting along the track towards WP15 (19°39.725'N,164°9.832'E). Our ending point for JD 363 was 19°21.162'N,163°48.834'E.

Lots of science today! Which can make for a thick and somewhat boring narrative. As a treat for making it this far, I'll leave you with this fun fish fact: Bluefin tuna (*Thunnus thunnus*) are able to hunt for food in deep waters as well as achieve remarkable swimming speeds because they are actually endothermic, a rare trait amongst teleost fishes. They owe this special adaptation primarily to an impressive thermoregulatory system whereby white and red muscle tissues interact to facilitate a countercurrent exchange system. So cool!

JD363

SKQ201402S_01 os75nb

ADCP temperature, °C
os75nb: last time 2014/12/29 10:28:19

49 to 129m
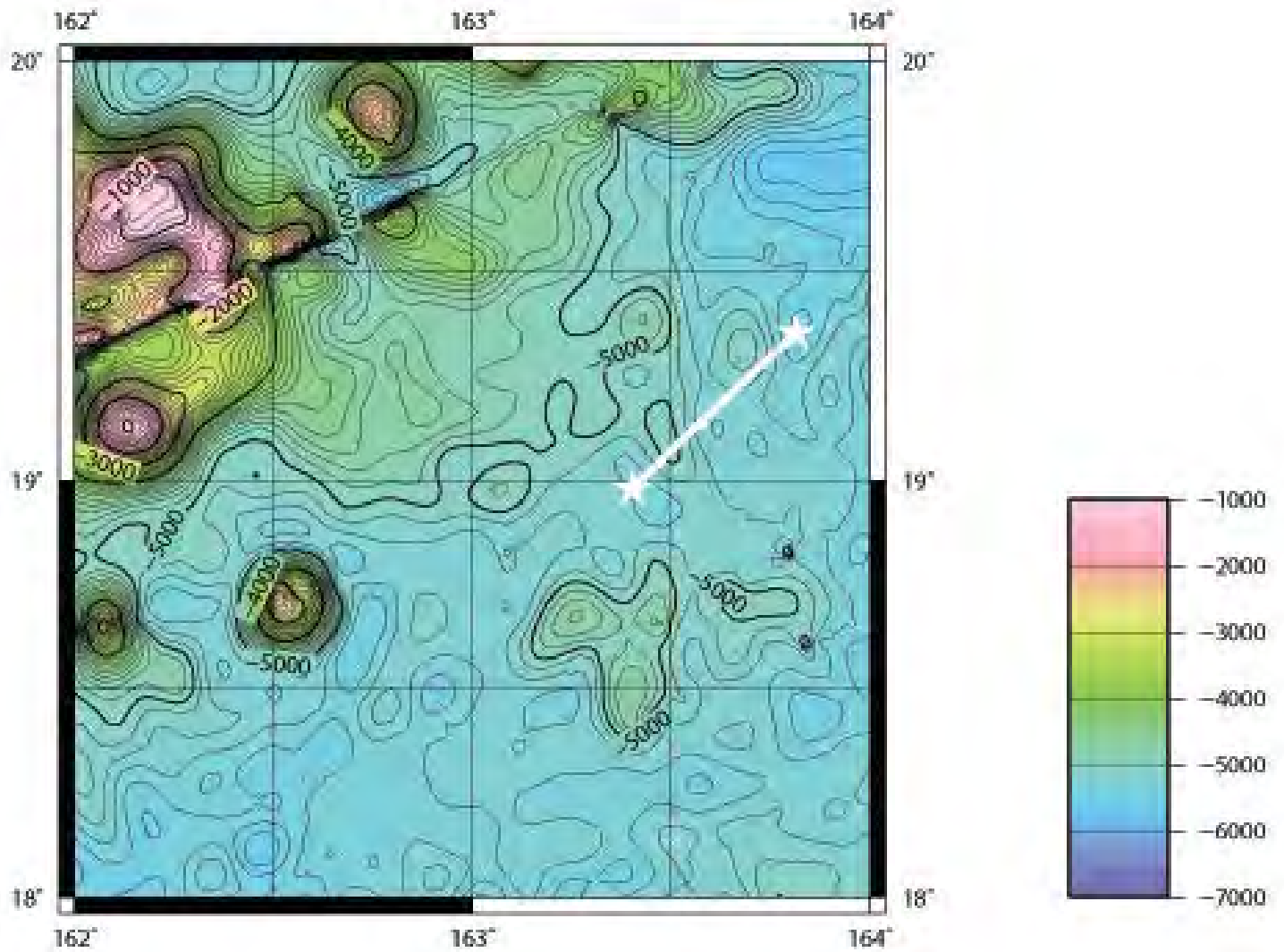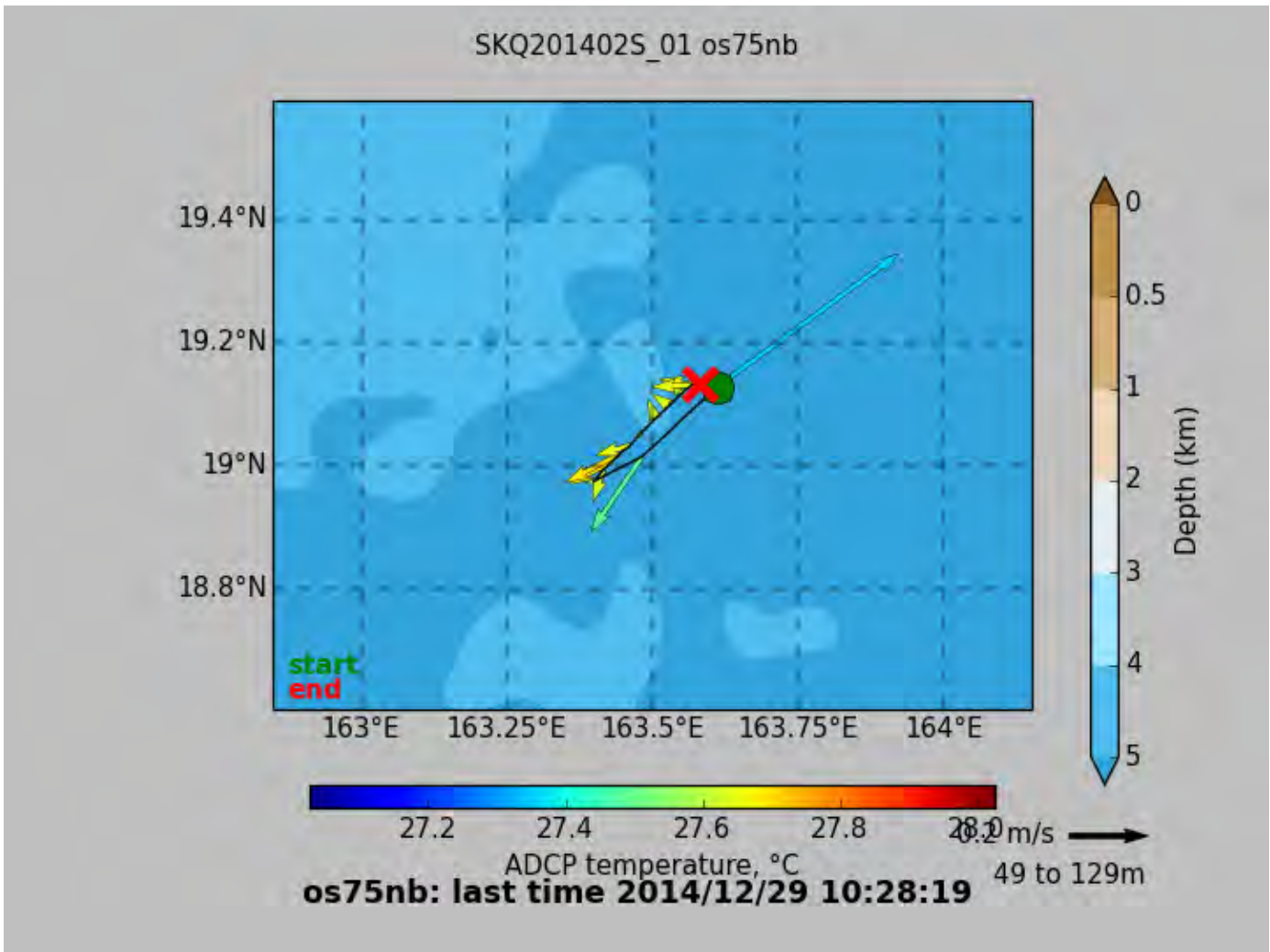
SKQ201402S

JD364 30 Dec 2014

Chief Scientists: M. Tominaga, M. Tivey

Daily Summary

The start of JD 364 saw both Sentry and DTM already in the water (ship position= 19°21.162'N,163°48.834'E) and approaching WP15 (19°39.725'N,164°9.832'E). The wire length remained constant between 4800-4820m over the entire time DTM was deployed (between 00:00-14:54). During this time the Maggie ranged from depths of 2323m-3709m. We dealt with two Maggie software reboots: one at 08:00 and another at 12:22.

We saw some action beginning around 14:50 as Sentry approached a seamount (Sentry's position= 19°38.957'N,164°8.994'E). Rather than navigating around the large mount we decided to fly over it, necessitating an earlier recovery of the DTM than previously planned. We started hauling up the lovely lady at 50m/min (winch speed) at 14:54 after Sentry began its ascension at 14:50. The sled was fully on deck and secured by 16:38 (last DTM position recorded=19°40.53'N,164°10.728'E).

Because we already passed our WP15 coordinates (which were slightly different than those of the Sentry groups'), and because Sentry's battery was waning, we decided to fully recover Sentry at 16:55 after successfully overcoming the sea mount (Sentry's position= 19°41.34'N,164°12.083'E). Another smooth recovery, all secured on deck at 18:51 (ship's position= 19°31.328'N,164°11.91'E). We proceeded to lift the centerboard and turn back on all sonars by 19:50. Dive 293 boasted a whopping track line of 92km—impressive!

We wasted no time in redeploying the DTM after Sentry was back on deck. We launched from WP16 (19°38.403'N,164°11.776'E) at 19:56 and began underway between 1.8-2.2 kts. We soon reduced our speed to 1.0-1.2 kts. to allow the wire length to reach 4500m, and by 21:47 DTM reached a depth of 2953m. We increased the wire length to 4800m at 22:12 which we held constant through the end of JD 364. Greatest depth achieved at this length was 2852m.

We ended JD 364 with Sentry on deck after completing Dive 293 and DTM redeployed from WP16 (19°38.403'N,164°11.776'E) with a heading goal of ~49. Our last recorded position for this day was 19°44.45'N,164°16.80'E).

Shipside, we celebrated Laura's birthday today with a yummy red velvet cake and inappropriate, albeit amusing jokes about blowing birthday candles vs. boyfriends… #nofilter.

JD364
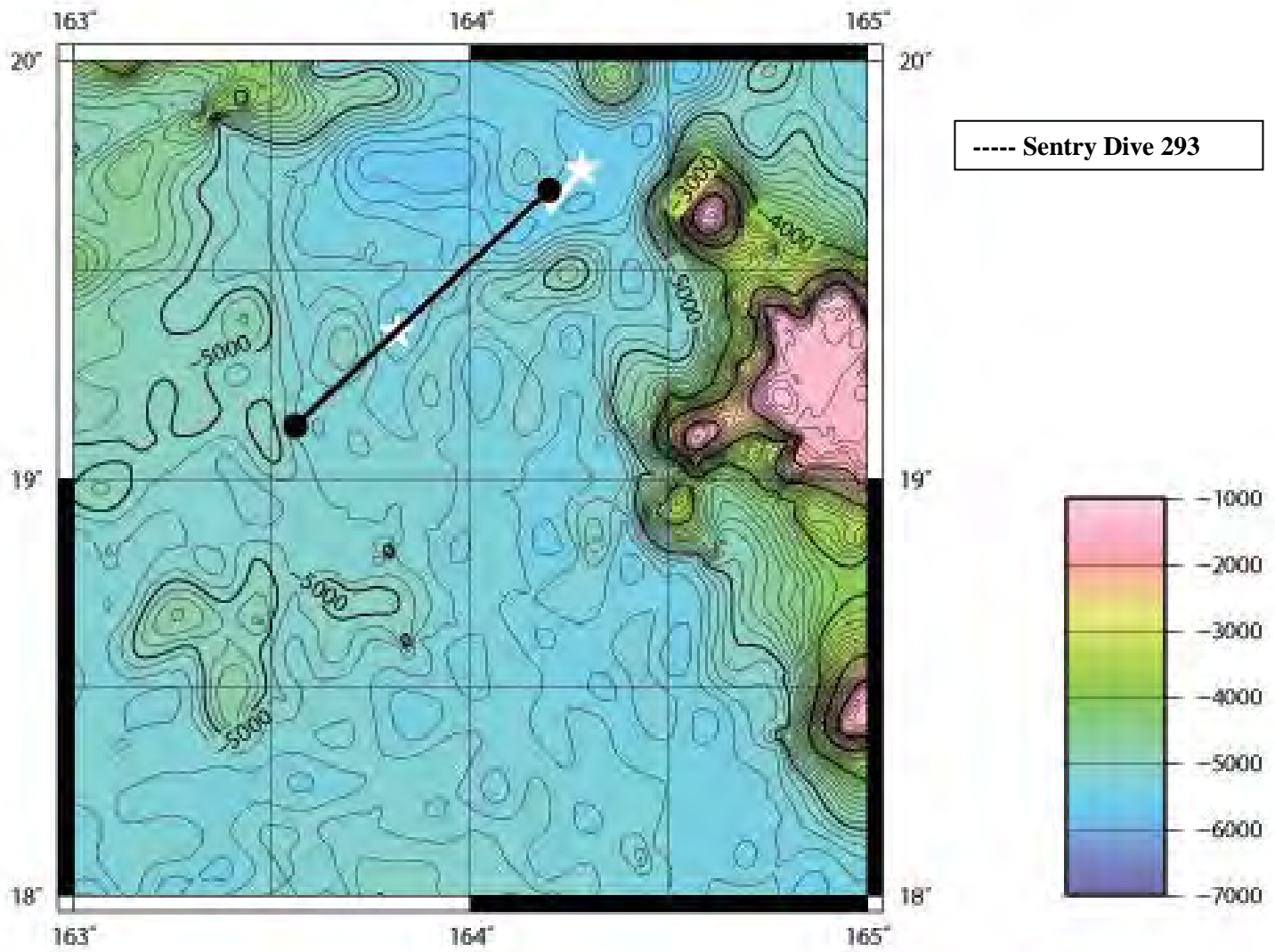
----- **Sentry Dive 293**
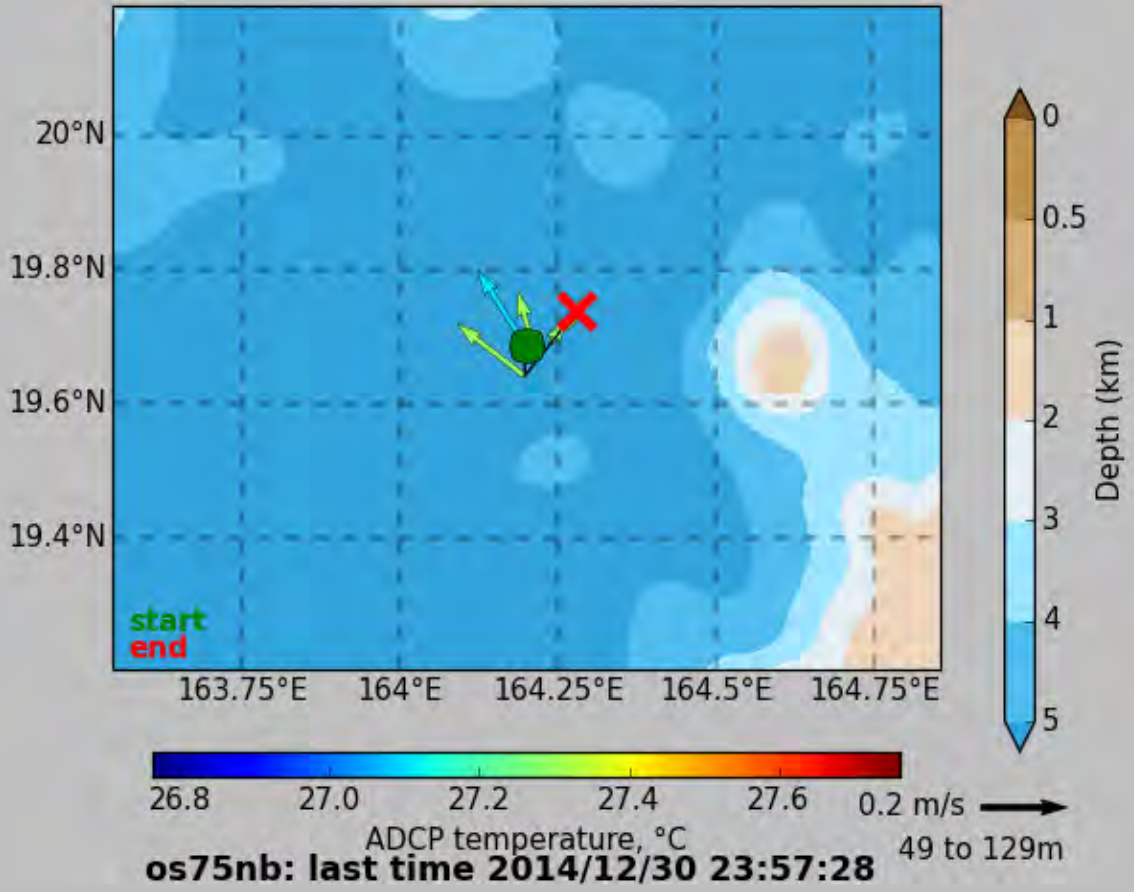
SKQ201402S

JD365 31 Dec 2014
Chief Scientists: M. Tominaga, M. Tivey

Daily Summary

JD Three-Six-Five. Officially hump day and the last day of 2014! Hard to believe we're exactly halfway through our venture. Here's what we closed out the year with:

The DTM was already in the water, starting the day off at 19°44.45'N,164°16.80'E, after being launched from WP16 (19°38.403'N,164°11.776'E) and keeping a constant heading of 49. At 02:40 we increased the wire length from 4800m to 5000m and held it constant for the duration of the tow, achieving a max depth of 3236m at 04:40. At 04:56 we started to reel in the sled to prepare for Sentry's launch (Dive 294). By 06:29, the DTM was fully recovered and on deck (ship position= 19°52.218'N,164°23.136'E). We then turned the ship around to return to WP16 (19°38.403'N,164°11.776'E), the launch position for Sentry's Dive 294.

At 08:15 we made all necessary preparations for the AUV launch: sonars off; centerboard down. By 08:39 Sentry was deployed from WP17 (which is the same as WP16, 19°38.403'N,164°11.776'E, renamed to avoid confusion) and began descending for Dive 294. At 11:00 we dropped the weights (depth= 5166.71m) and Sentry began its track line towards WP18 (20°16.286'N,164°43.247'E).

We redeployed the DTM at 11:28. At 13:20 we held the wire length constant at 4500m which put Maggie at a depth of 3143m. An hour later we released another 300m of wire and recorded the sled at a depth of 2774m. The rest of the day was quiet on the science end of things. We kept the deeptow at a wire length between 4800-4810m as we followed Sentry down the trackline. We ended the day (and the year!) at 19°56.04'N,164°26.412'E in the midst of Dive 294 heading towards WP18 (20°16.286'N,164°43.247'E).

On board the ship, things were less quiet than the science at sea. Talks about the golden dragon ceremony are officially in the works, cultivating an atmosphere of excitement, and maybe a tinge of anxiety, amongst those planning on participating. The celebration of the New Year has also manifested itself in quiet corners on the ship. Before the year changed over Karl's water bottle again rocketed off of the countertop in the computer lab causing an uproar reminiscent of that from the very first shift. One way to go out with a bang! At midnight local time, the changing over of watchstanders as well as the marine techs and chief sci's counted down to the New Year and created a mini celebration of their own. Certainly a unique place to be as the year changes over. Here's to 2015!

JD365
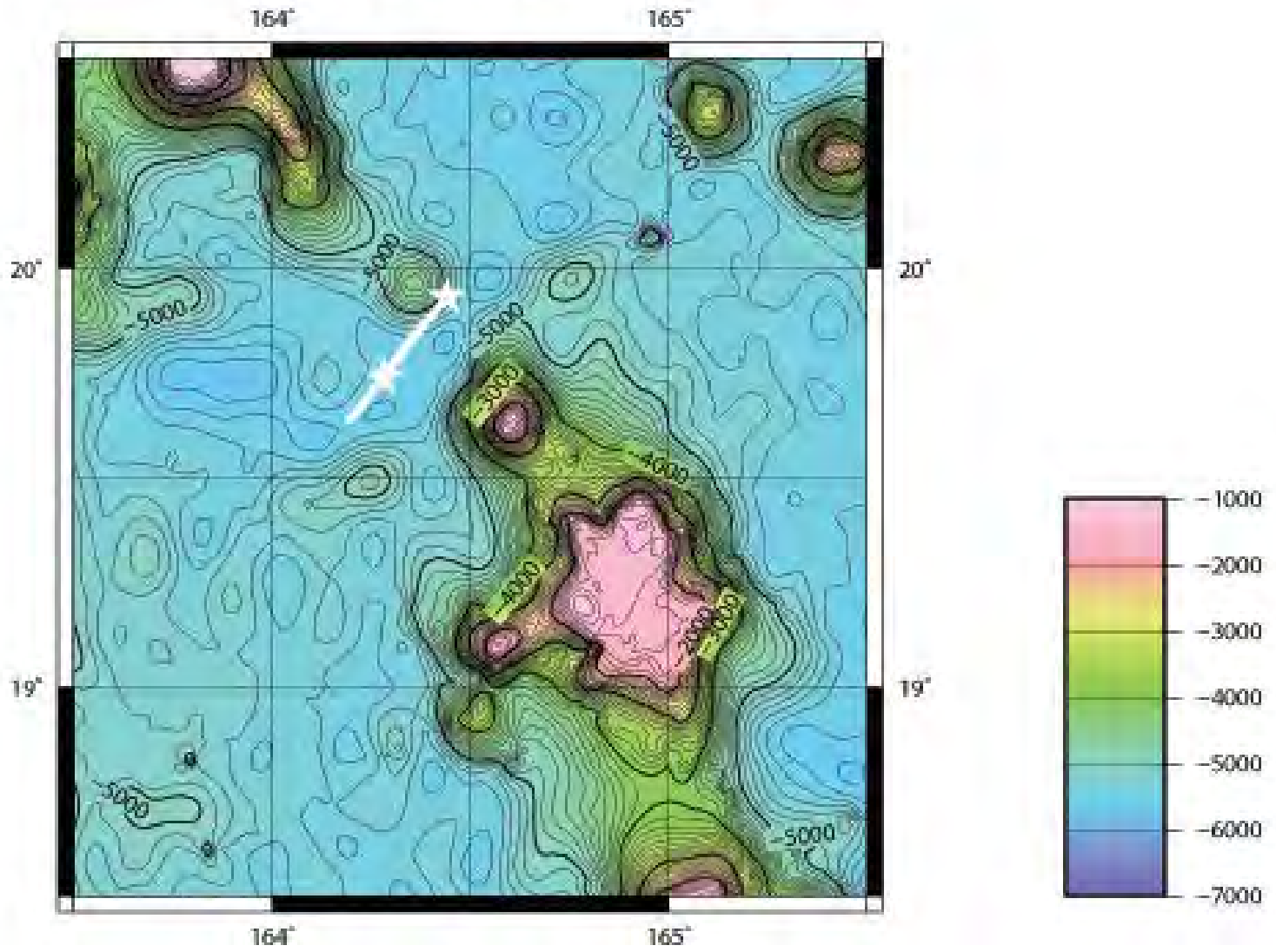
SKQ201402S
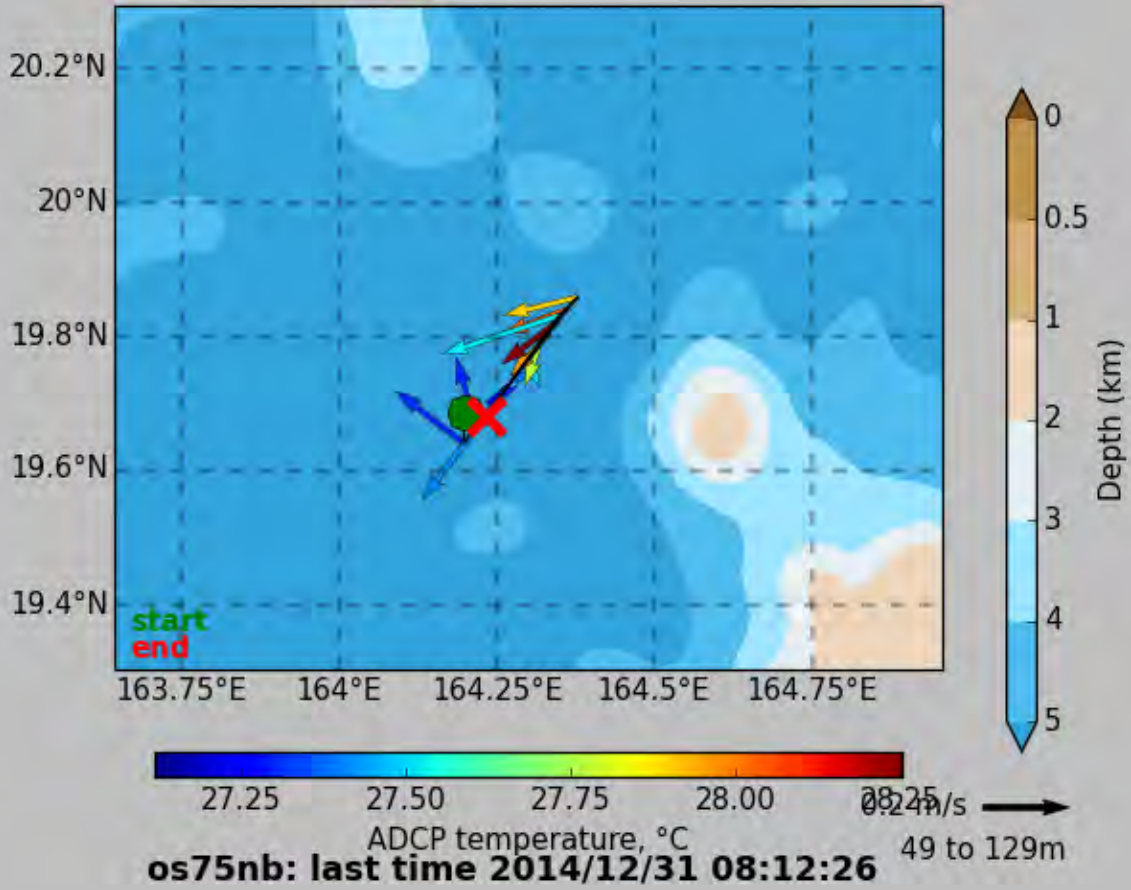
JD001 01 Jan 2015
Chief Scientists: M. Tominaga, M. Tivey

Daily Summary

We began with both the DTM and Sentry in the water with the ship's exact position at 19°56.04'N,164°26.412'E, in the midst of Sentry Dive 294 and heading towards WP18 (20°16.286'N,164°43.247'E). The wire length for the mag at this point was constant at 4810m; her depth was 2541m.

We continued underway with both instruments deployed until 13:02 when we began to haul in the DTM (ship's position= 20°13.98'N,164°41.34'E). We had steadily exercised the wire leading up to the recovery by 10m every few hours; by the time we recovered her we had reached a terminal wire length of 4906m and a depth of 2779m. While hauling up the DTM, the Towcam logging software crashed, requiring a reboot at 13:52. DTM was successfully on board by 14:34 and the software was turned off after recovery.

We continued underway following Sentry's track line until 14:51 when we initiated recovery after reaching WP18 (Sentry's position=20°16.609'N,164°43.605'E; Sentry's depth= 5086.5m). Two hours later, at 16:46, Sentry was recovered and on deck. The full track line of Dive 294 measured 90.07 km. Shortly after we turned on all sonars and retracted the centerboard (completed by 16:50). We then continued onward to WP19 (20°10.214'N,164°38.171'E) to redeploy the deeptow.

At 17:56 we deployed Argo float SN9294 (ship position= 20°10.394'N,164°38.431'E) en route to WP19. By 18:27 the DTM was redeployed at 20°10.696'N,164°38.381'E. We closed out the day with a total wire length of 4500m out and a mag depth of 2753m. Ship's position was 20°17.334'N,164°44.058'E.

On the ship, everyone was recovering from the highly debaucherous night out for New Years the evening before, so New Year's Day turned out to be a calm one. Worth mentioning is the pristine weather we've been having the last few days. Nothing but sunshine, glass seas, and happy sailors.

JD001

----- **Sentry Dive 294**

SKQ201402S_01 os75nb

os75nb: last time 2015/01/01 23:50:51
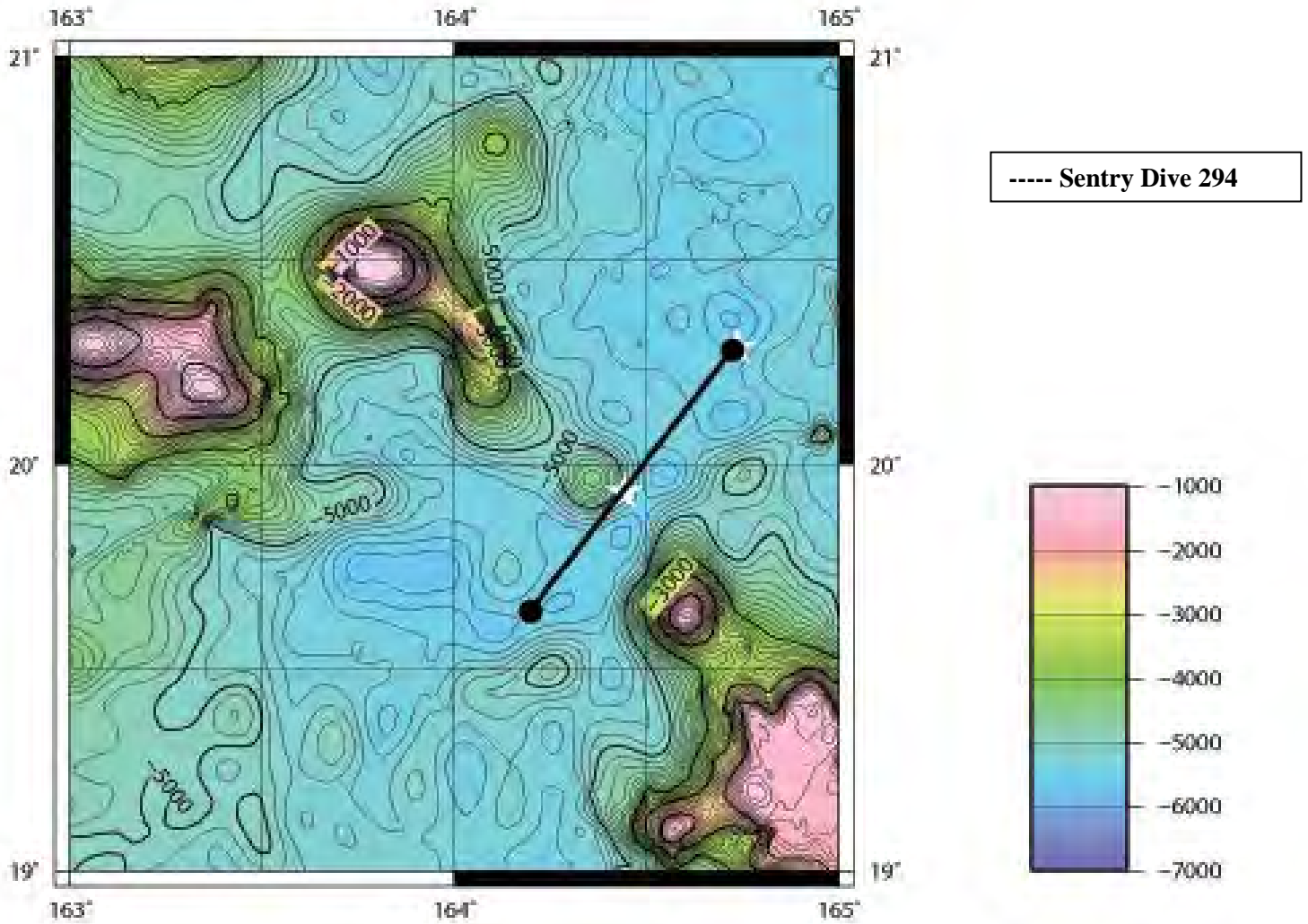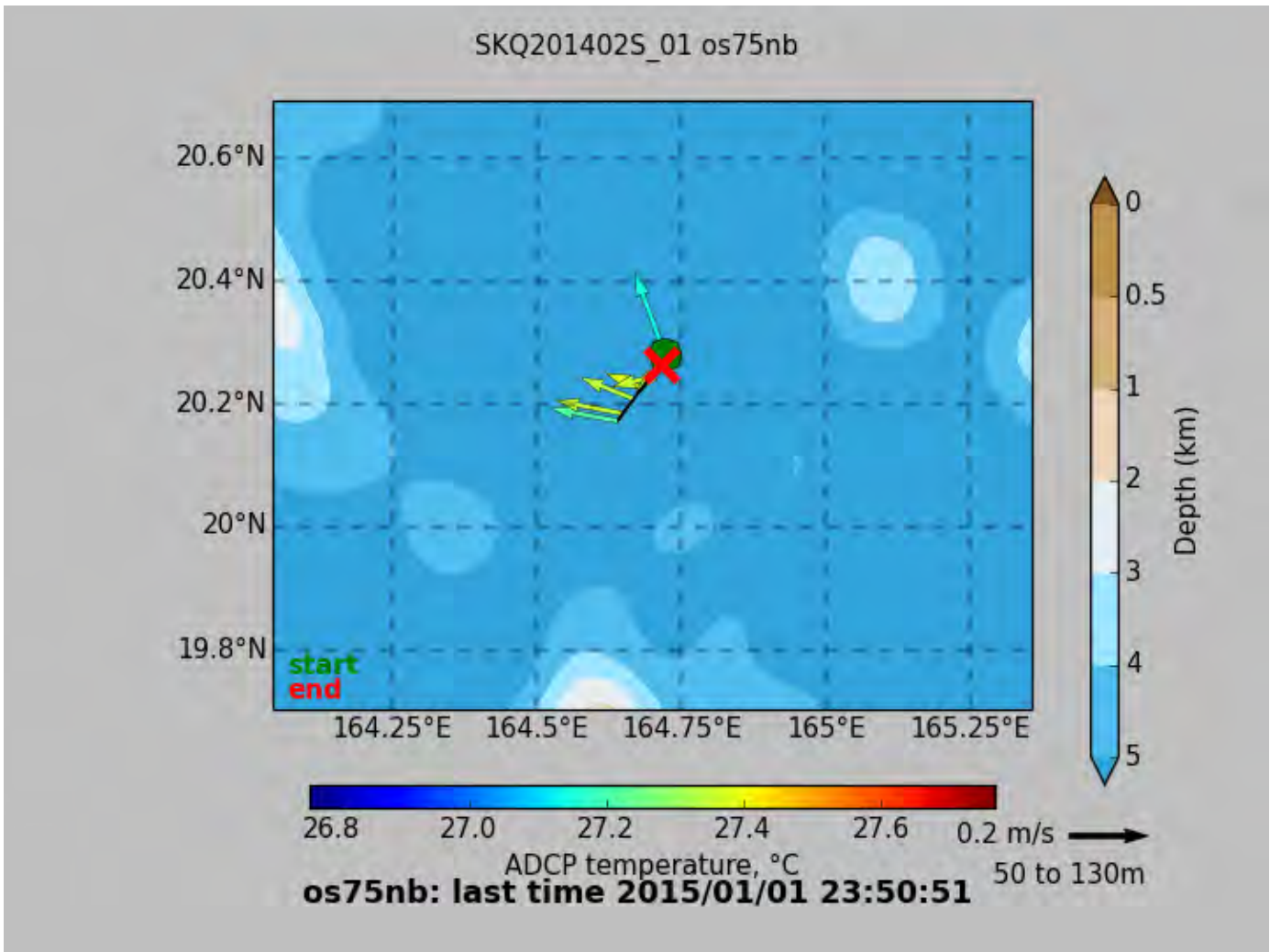
SKQ201402S

JD002 02 Jan 2015
Chief Scientists: M. Tominaga, M. Tivey

Daily Summary

JD002 began with the DTM at 2753m, wire length at 4500m, and the ship recorded at 20°17.334'N,164°44.058'E. At 01:20 we increased the wire length to 5000m, extending the depth of the deeptow to 2863m. We continued underway to complete the deeptow track at a heading of 49 and around 1.7 kts. At 01:50 we successfully deployed an XBT that reached the full 750 meters. By 05:03 we started hauling in the DTM (ship's position= 20°24.012'N,164°49.254'E) at a rate of 60m/min and from a depth of 2993m. She was fully recovered and on deck by 06:36 (ship's position= 20°26.124'N,164°51.09'E).

After recovery we changed the ship's position to heads towards WP20 (20°14.064'N,164°41.486'E) for Sentry launch, Dive 295. Sonars were on and functional while in transit. By 08:08 we deployed the centerboard to prepare for the launch and secured all sonars. At 08:37 we deployed Sentry (Dive 295) from WP20 (20°14.064'N,164°41.486'E). By 11:02 the AUV had reached the bottom (depth= 5575m) and dropped its weight to begin the track line.

We deployed the DTM shortly after, at 11:24. We reached a max wire length of 4500m by 13:20, putting Maggie at a depth of 3130m. We soon increased the wire length to 4800m at 14:00. We continued underway for the remainder of JD002 following Sentry along its track with the deeptow, well, in tow. Sentry's depth remained constant between 5350-5400m while the DTM wire length remained constant between 4800-4805m. Maggie herself fluctuated between 2540-2781 meters depth. We finished the day at 20°32.502'N,164°55.830'E.

We experienced two minor data logging issues while underway. We lost communication with Sentry's USBL at 12:37, but regained it after about 5 minutes. We also lost communication with the Towcam at 12:49, again rebooting the software with success.

And now, a quote of the day to leave you with, one I learned from someone very wise on this ship:

"If you saw a genius and an idiot arguing, would you be able to tell which one's the genius and which one's the idiot?" Hmmm… some food for thought.

JD002
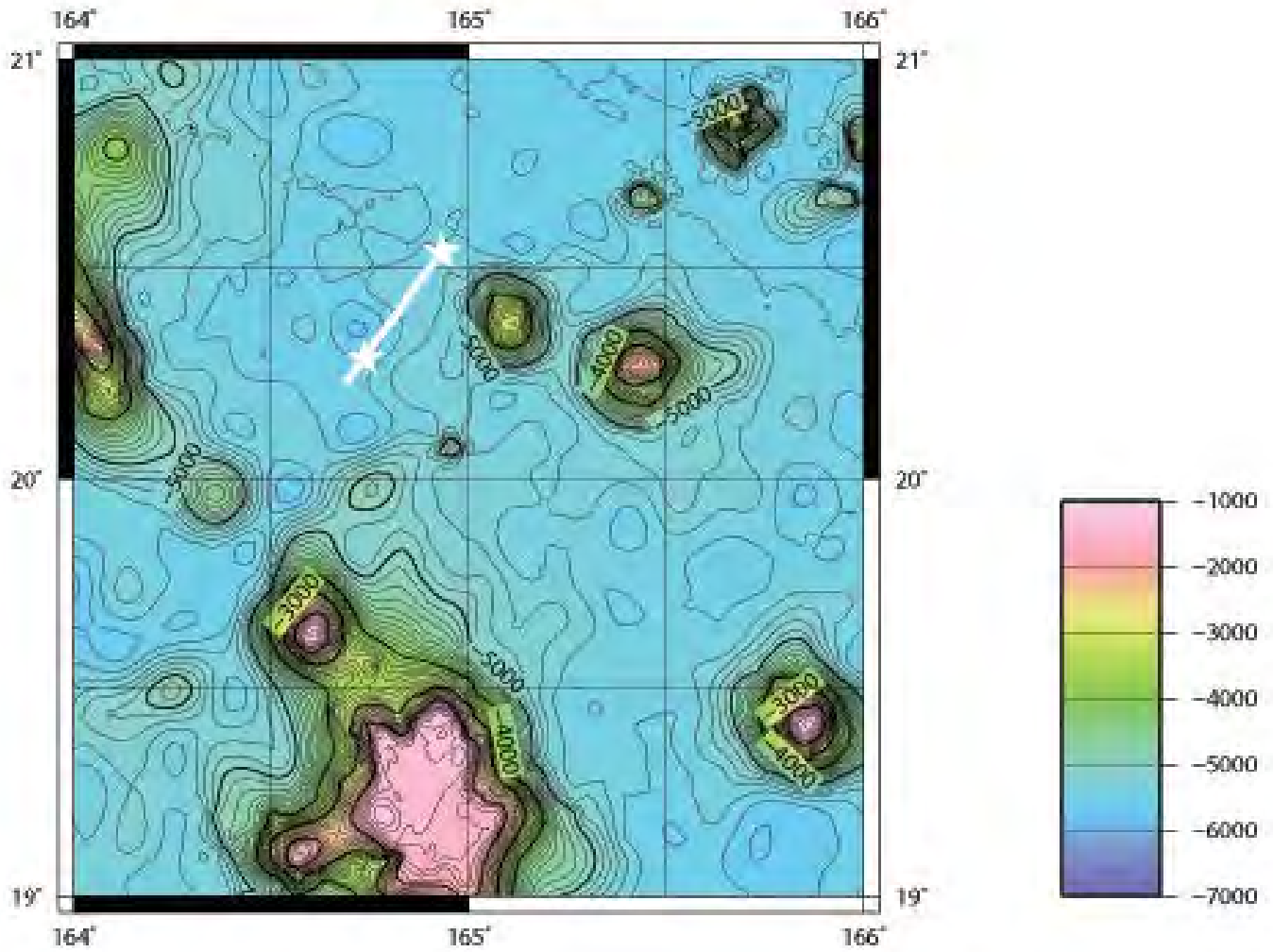
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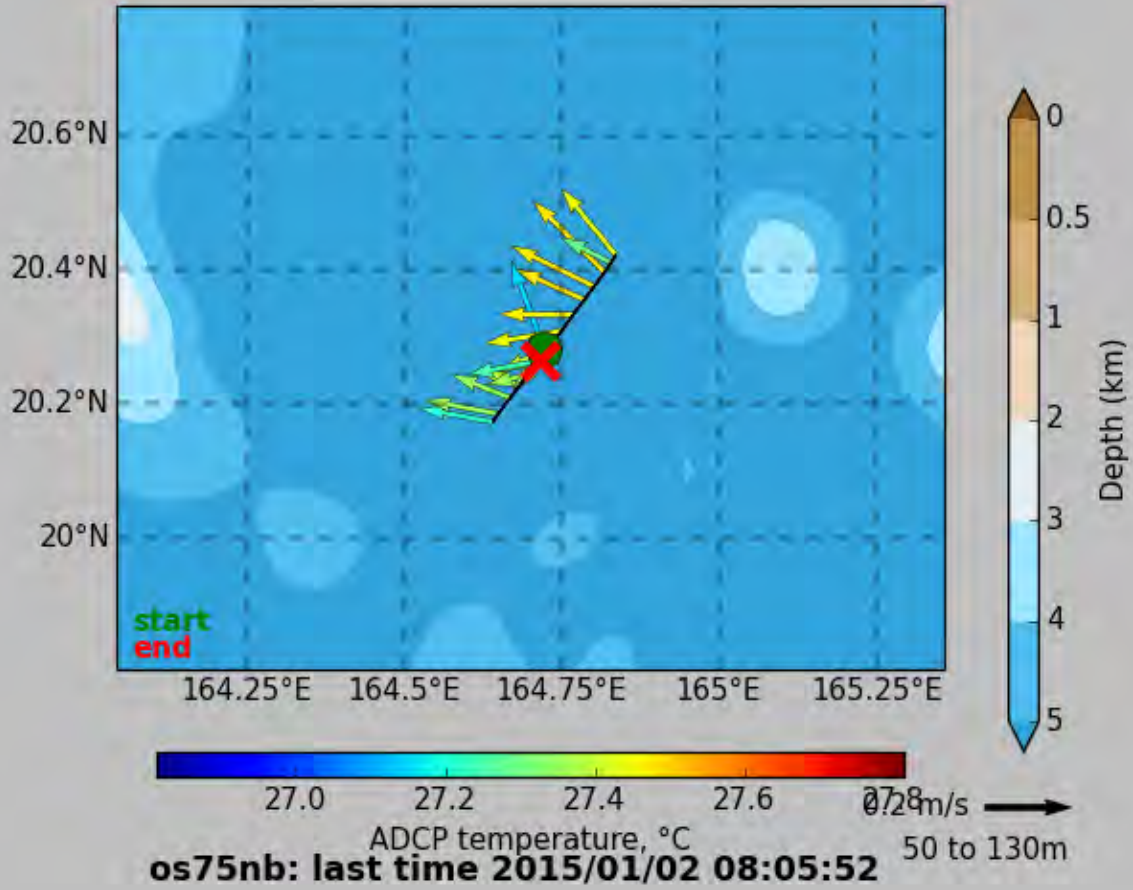
JD003 03 Jan 2015
Chief Scientists: M. Tominaga, M. Tivey

Daily Summary

Well hello JD003! We are just *cruising* through this cruise. Today's report brings you more of what you've already heard once or twice…

DTM+Sentry are in the water. *Swimming, swimming, swimming*. Then, out of the blue (literally), the deeptow comes up for the recovery first. It beats Sentry to the top, but the AUV is right behind for its own recovery. Because the two can't stand to be on the deck at the same time, the towsled was off the back deck almost as quick as Sentry was on! Sentry, glad to finally have some space of her own ('*what, the ocean isn't big enough for you Maggie..?*') stays on deck to recharge her batteries before heading back in for tomorrow's dive, Dive 296. See below for the scientific version.

Ship's position at the start of the day was 20°32.502'N,164°55.830'E with both Sentry (Dive 295) and the DTM in the water. Sentry's depth was 5392.0m; Maggie's wire length was 4805m and her depth was 2954m. Those numbers remained pretty consistent for the duration of the track line and the tow. At 13:30 we began the deeptow recovery at the ship position of 20°51.534'N,165°10.656'E and with a winch speed of 50m/min. She was safely on deck by 15:00. At 15:47, Sentry had surpassed its waypoint (WP21= 20°52. 355'N,165°11.541'E) and began recovery from its position at 20°54.402'N,165°13.02'E. The AUV surfaced at 17:27 and was on deck by 17:49 (ship's position= 20°55.63'N,165°12.17'E). The length of Dive 295 clocked in at 92.01km. We then transited to deploy the deeptow at 20°46.404'N,165°6.996'E. Our girl was in the water by 19:21 and reached our desired wire length (4500m) by 20:58. As we closed out the day, the wire length was out to 4503m and she was down to a depth of 3220m. The Sikuliaq's position as the day came to a close was 20°51.498'N,165°10.962'E. Tomorrow, Sentry will jump back in the water for Dive 296.

In world news, Our Chief lost and found her favorite silver ring all in one day and in quite the surprising fashion (sitting waiting for her on her breakfast bench…). Thank the power of Neptune!

JD003

----- Sentry Dive 295

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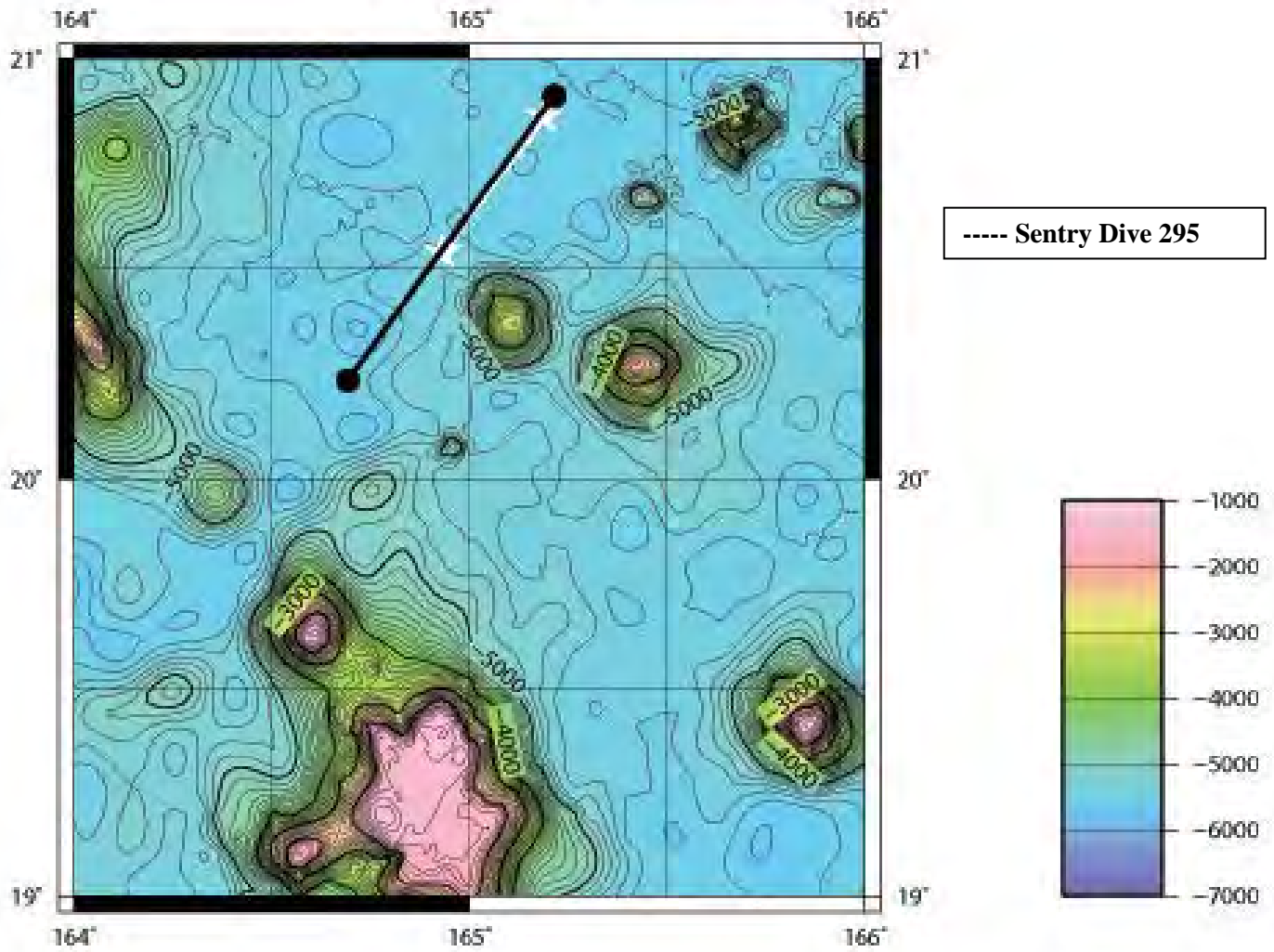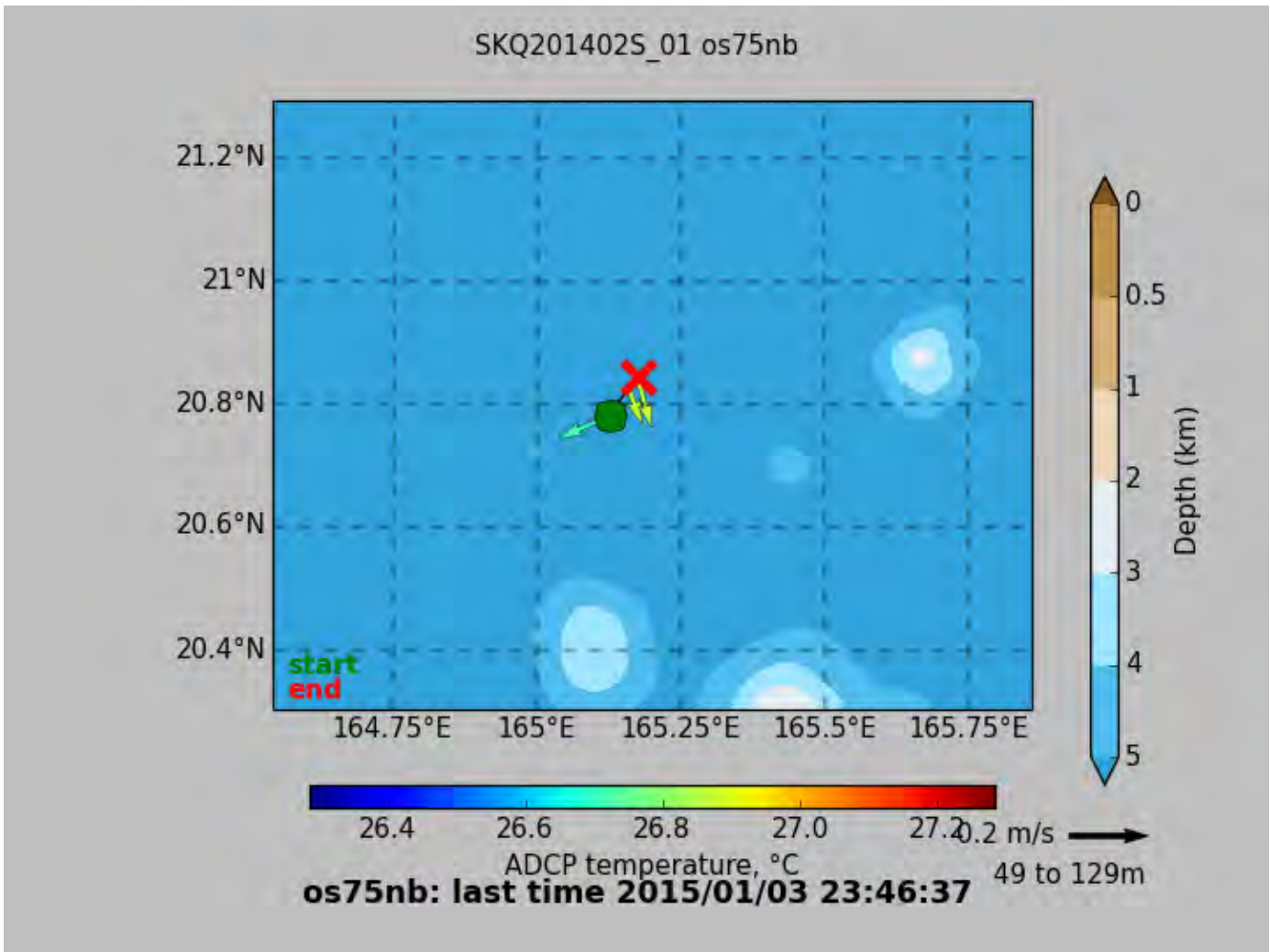
SKQ201402S

JD004 04 Jan 2015

Chief Scientists: M. Tominaga, M. Tivey

Daily Summary

JD004 began with the DTM in the water, Sentry on deck preparing for her next dive, and the ship's position recorded at 20°51.498'N,165°10.962'E. We began to haul in the deep tow beginning at 05:00 (ship's position= 20°56.923'N,165°14.802'E). At 05:27 we stopped hauling in the wire in order to grease up the center sheave, which we noticed had been periodically seizing. We began hauling out the wire again at 05:42 at a rate of 60m/min. She was fully recovered with the software turned off by 06:53 (position= 20°58.392'N,165°16.266'E).

At 07:04 we began underway to WP23 (20°50.172'N,165°10.011'E) for Sentry Dive 296. At 07:54, as we approached the waypoint, we slowed the ship to deploy the centerboard and turn off all sonars. Sentry was in the water by 08:19 at the recorded position of 20°50.214'N,165°9.924'E. Thus began Dive 296.

Sentry dropped its weight upon reaching the bottom at a depth of 5450.1m. The time was 10:40 and its position was 20°50.214'N,165°9.900'E. We continued underway at 1.4 kts, launching the DTM at 11:06. Wire length reached 4500m by 13:00 and depth was 2986m. We continued smoothly underway with both Sentry and the deeptow doing their thing. At 14:00 we increased Maggie's wire to 4800m and resulting in a depth of 2818m. Both instruments continued underway happily into JD005. Our last recorded position for the day was 21°8.304'N,165°23.916'E.

Another boring narrative = another great day of science

JD004
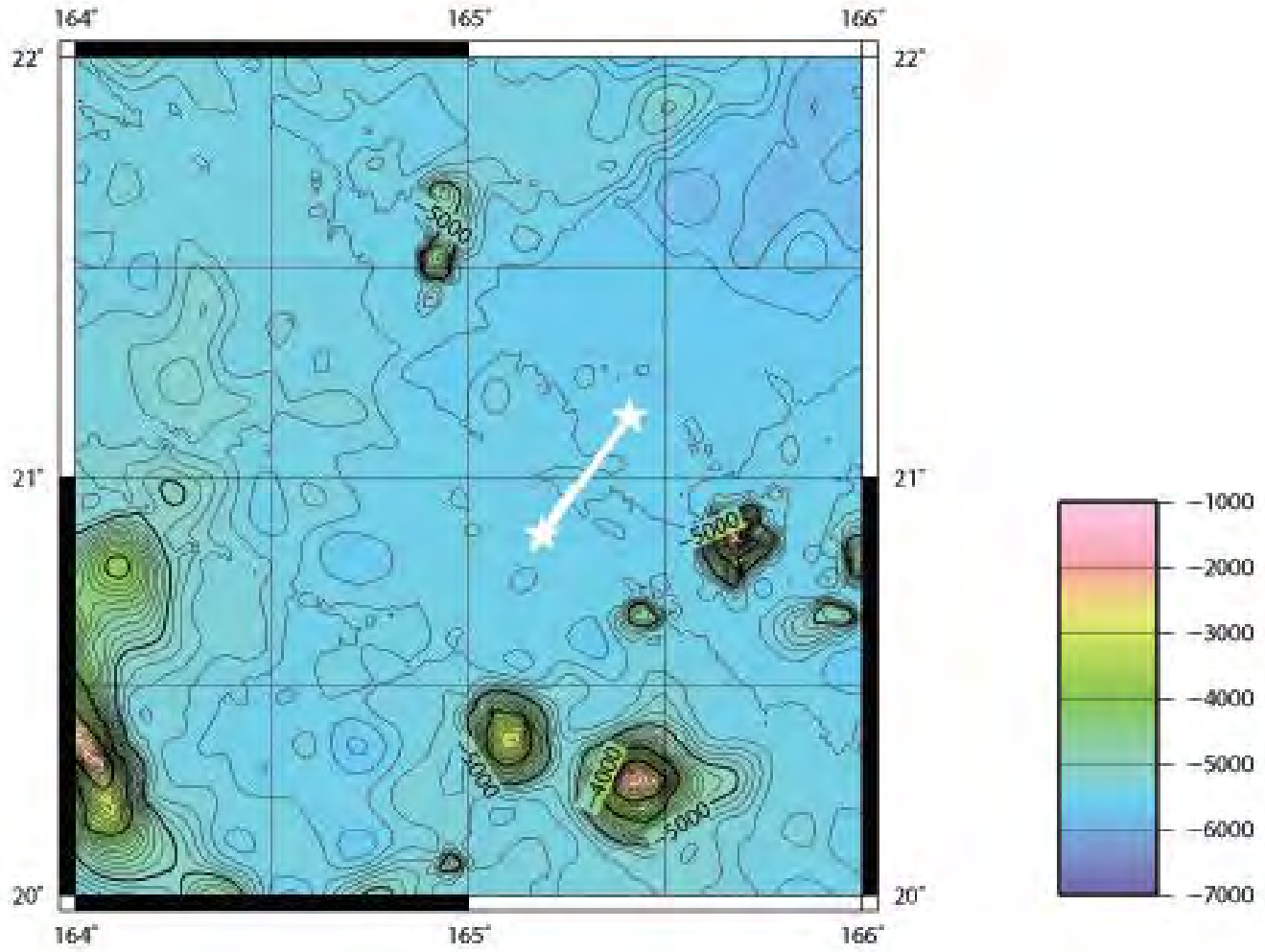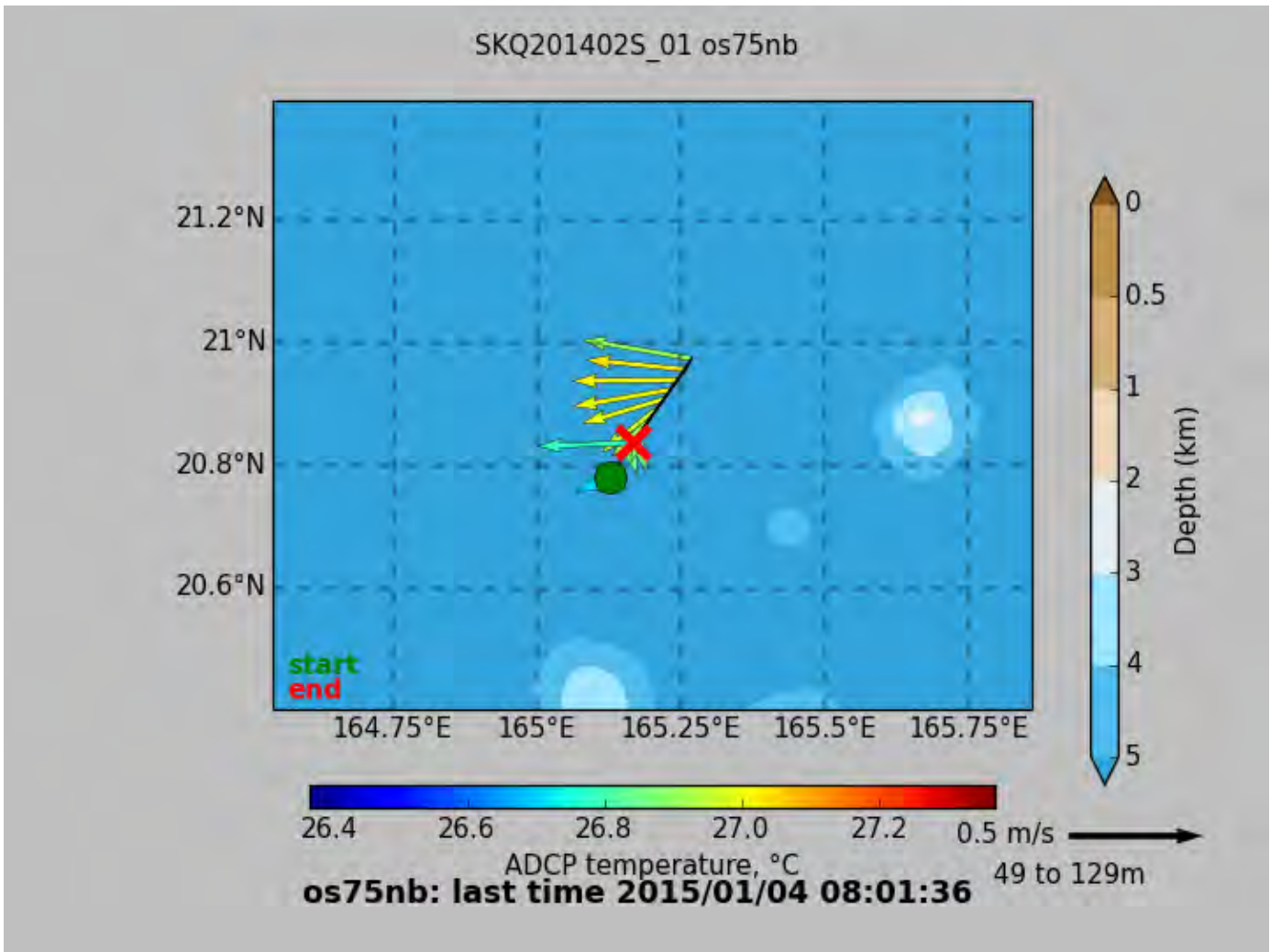
SKQ201402S

JD005 05 Jan 2015
Chief Scientists: M. Tominaga, M. Tivey

Daily Summary

JD005 saw a little more action than yesterday. Ship's position started at 21°8.304'N,165°23.916'E with both Sentry and Maggie in the water. Wire length was 4805m; Maggie's depth 2735m; Sentry's depth 5495.0m. At 03:20 we increased the wire length to 5000m. We held it there for about 12 hours until we started recovering the deeptow (50-60m/min) at 15:00 (ship's position= 21°28.692'N,165°40.482'E). By 16:40 we had the tow sled on deck (ship's position= 21°31.038'N,165°42.348'E). While hauling her in, we rebooted the software at 15:20.

After securing Maggie on the back deck, we prepared for Sentry's ascension at 17:16. Dive 296 ended at WP24 (21°27.681'N,165°39.472'E). The AUV surfaced at 18:59 and was securely on deck by 19:20 (ship's position= 21°32.117'N,165°42.972'E). This was our longest dive yet, measuring 95.38m. The centerboard was retracted and all sonars were turned on again by 19:34. After recovery, we began transit to WP25 (21°26.604'N,165°40.998'E) to redeploy the DTM.

We reached WP25 for deeptow launch by 20:35. Because the wind was blowing SW, the deeptow wire was cast close to the block hanging from the A-frame. Because of this proximity, we decided to halt deployment of the deeptow, haul it back in, and take the block off the A-frame to avoid any interference with the wire. We stopped the winch at 21:04 and began to haul the deeptow back in. We removed the block by 22:00, then turned the ship around to head back towards WP25 (21°26.604'N,165°40.998'E). We reached the waypoint and deployed the DTM at 22:25. This time the deeptow descended completely. At the end of JD005 the wire length was around 4100m and continuing to cast. Maggie's depth at this point was around 3000m, deeper than we've been seeing at this wire length due to the slower SOG of the boat.

Thus ended JD005; Maggie in the water and Sentry on deck recharging. Ship's final position was recorded at 21°28.074'N,165°41.772'E. Shipside, we had our third and perhaps final fire drill of the cruise (say goodbye to those awful lifejackets!) and it seems like the days to Guam are creeping closer and closer.

JD005
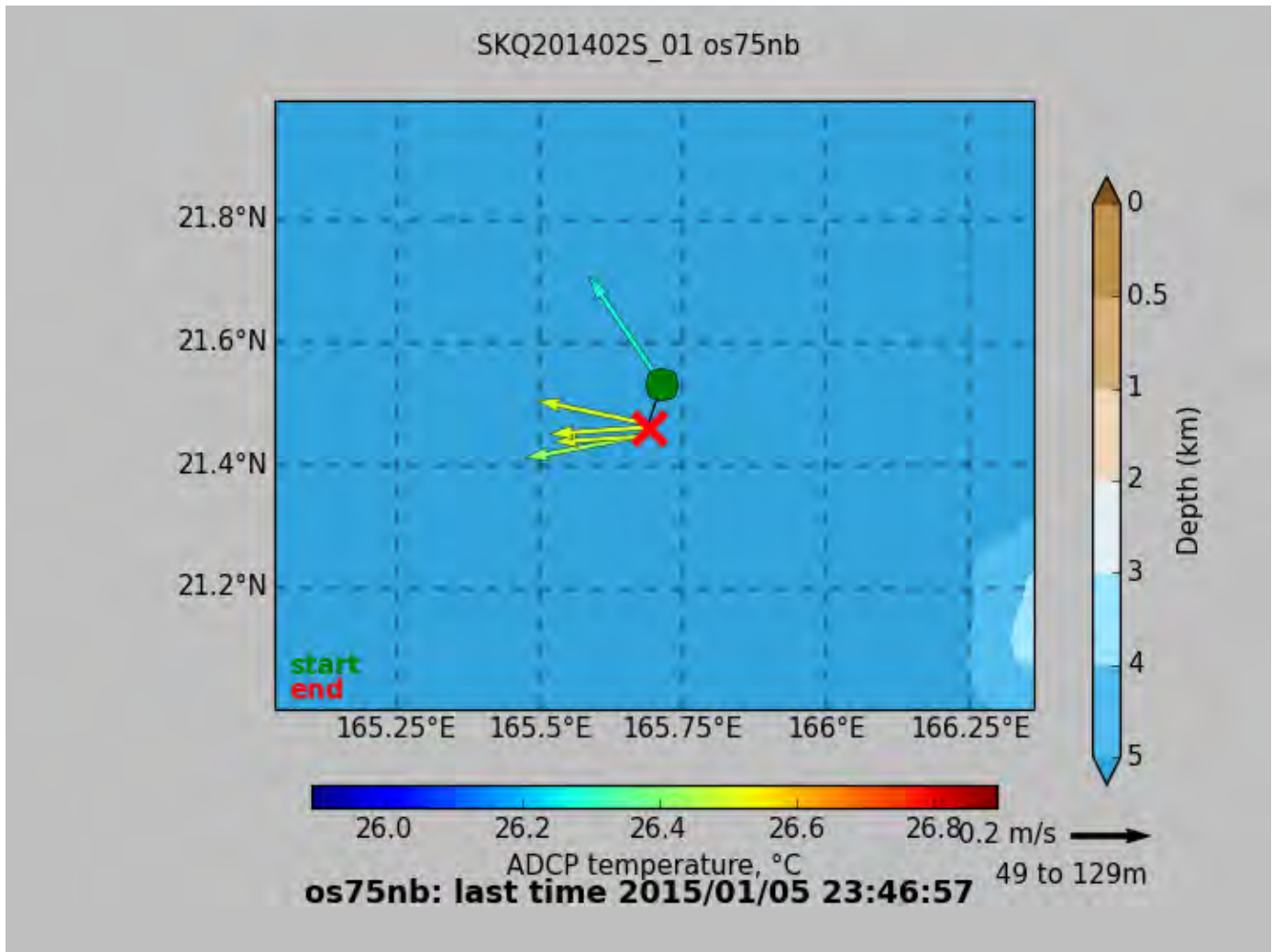
----- **Sentry Dive 296**

SKQ201402S

JD006 06 Jan 2015
Chief Scientists: M. Tominaga, M. Tivey

Daily Summary

The R/V Sikuliaq sailed into JD006 at 21°28.074'N,165°41.772'E with Sentry on deck after having completed Dive 296 and the DTM in the water descending to its max depth. At the start of the day the wire length measured 4229m and Maggie's depth was 3881m. We reached the desired wire length of 4500m at 00:20 and continued towing until 05:00. We initiated recovery at 60m/min from 21°34.488'N,165°47.262'E. By 06:28 the deeptow logging system was turned off and the DTM was safely secured on the back deck (ship's position= 21°35.904'N,165°48.360'E). We then sped up the ship in transit to WP26 (21°28.567'N,165°42.258'E) for Sentry Dive 297. As we reached our waypoint, we deployed the centerboard and turned off all sonars (which, as a reminder, are the PS18 Topas, EM302 bathy, and the ADCP).

We deployed Sentry for Dive 297 at 08:16 from WP26 (21°28.567'N,165°42.258'E). As the AUV descended, the DVL software was experiencing communication problems so we decided to abort Dive 297 at 09:03. All sonars were turned on by 10:00, and Sentry was fully recovered by 10:08. The Sentry team worked on troubleshooting the software problems and had Sentry ready for redeployment for Dive 298 before long. After turning off the sonars a second time, Sentry was re-launched at 13:17 and reached a max depth of 5449.5m by 15:40 (Sentry's position= 21°28.482'N,165°42.21'E). At 15:57 the deeptow was in the water with the logging software turned on (ship's position= 21°28.482'N,165°42.21'E). She reached the desired depth of 4500m at 17:30. At 21:10 we increased the wire length to 4800m.

We closed out JD006 with Maggie in tow, her depth at 3734m and wire length at 4800m, and Sentry in the midst of Dive 298, it's depth at 5621.0m. Our last recorded position was at 21°39.54'N,165°51.078'E as we continued underway to WP27 (22°10.563'N,166°15.561'E) to finish the dive.

JD006
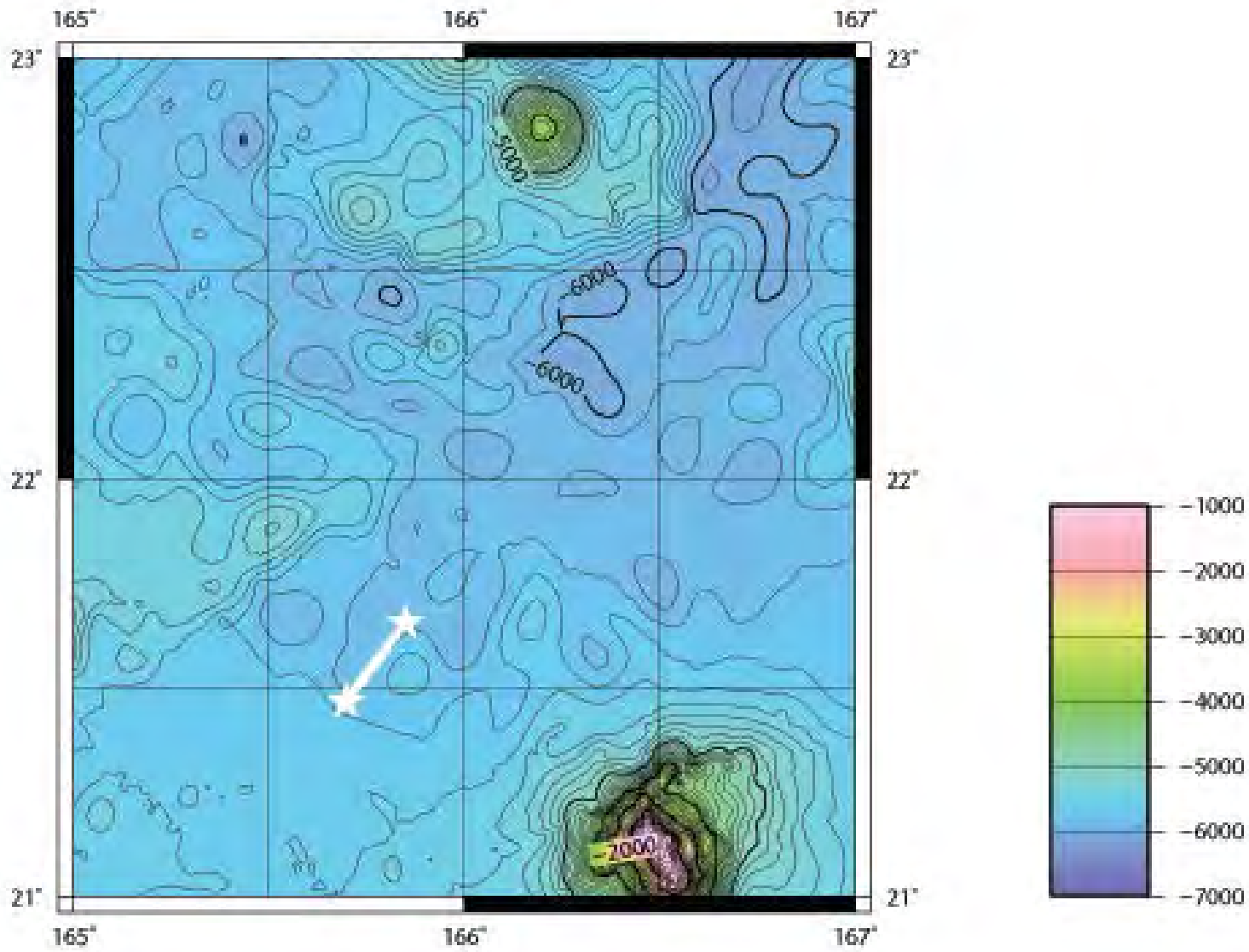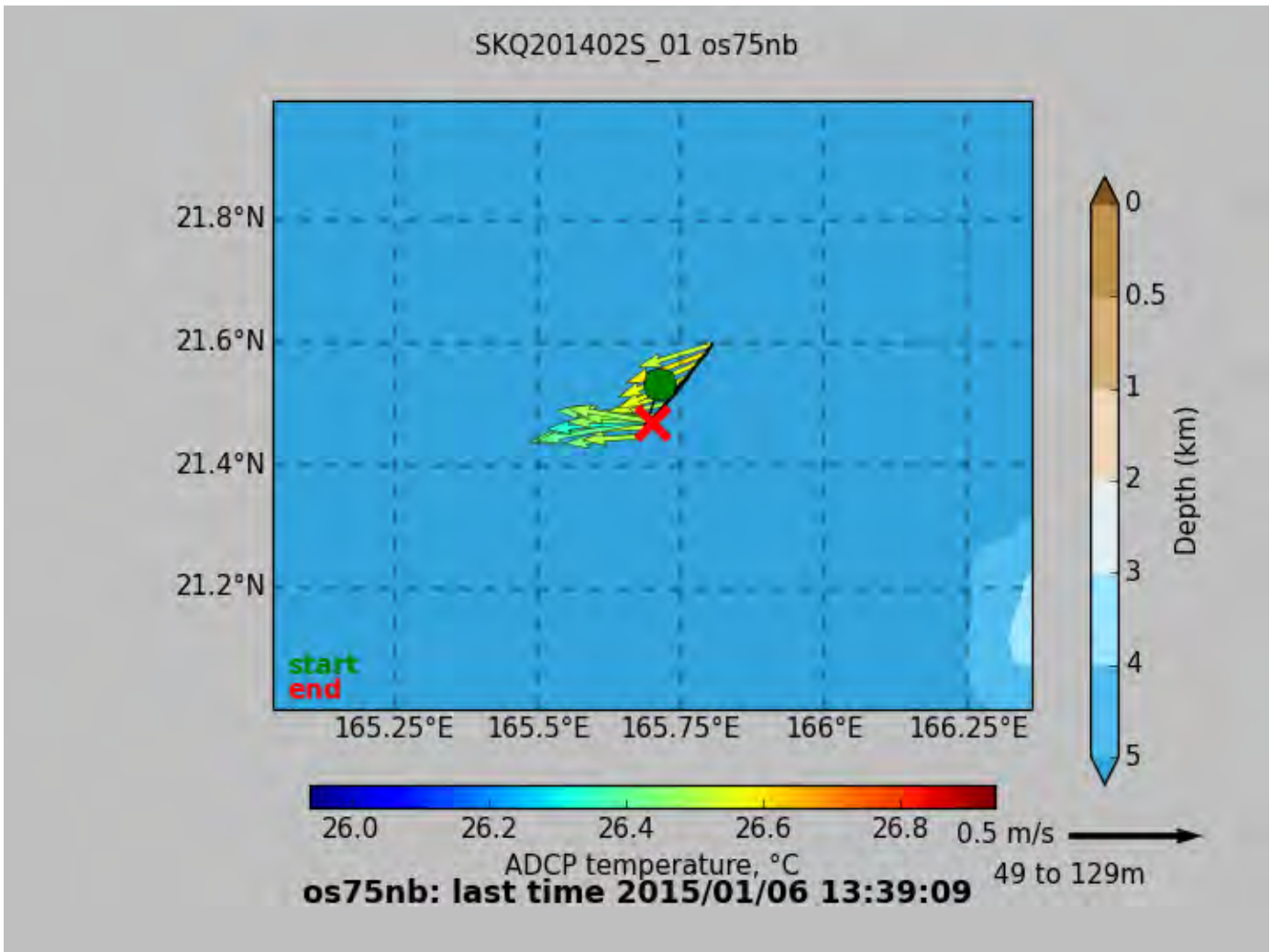
SKQ201402S

JD007 07 Jan 2015
Chief Scientists: M. Tominaga, M. Tivey

Daily Summary

JD double-oh-seven. A day almost as cool as Bond, James Bond, himself. Highlights of 007: the DTM is (tentatively) retired for the remainder of the cruise after finishing its last dive today. Sentry finished it's second-to-last dive (Dive 298). Details below.

We began the day with both the deeptow and Sentry in the water with the ship's position recorded as 21°39.54'N,165°51.078'E. Wire length was out to 4802m, Maggie was down to 2853m depth, and Sentry hovered around 5621m depth. We continued along our track line towards WP27 (22°10.563'N,166°15.561'E) for a while. At 09:09 we increased the wire length to a max of 5100m, putting Mags down at a depth of 2976m. Everything continued smoothly until 15:04 when we temporarily lost connection to the deeptow. We rebooted the software and were back collecting data by 15:07. Ship's position at the time of data loss was 21°59.500'N,166°7.075'E. We started the hauling in the DTM at 60m/min at 19:00 (ship's position= 21°4.651'N,166°11.220'E). We experienced another deeptow software issue while hauling in the DTM at 19:33; this time the clock calibration was off. We had the sled fully recovered and on deck by 20:30 (ship's position= 21°6.570'N,166°12.71'E). While the DTM was recovering, we ran the freshwater wash in the winch room over the wire since this was the final cast of the deeptow.

Sentry continued on its track line until 21:01 when it finished its profile and began ascension (Sentry's position= 22°7.338'N,166°13.374'E). The AUV was recovered and on deck, completing Dive 298, by 23:14. The dive measured a total length of 89.0km. We turned all of the sonars back on and recovered the centerboard by 23:29. From there we continued to WP28 (22°13.693'N,166°11.358'E) to launch the Argo float. The day ended in transit at the final position recorded as 22°8.238'N,166°13.344'E.

JD007

----- **Sentry Dive 298**

SKQ201402S_01 os75nb

os75nb: last time 2015/01/07 23:59:57

SKQ201402S

Cruise Start Date: 16-12-14
Cruise End Date: 15-01-15

JD008 08 Jan 2015
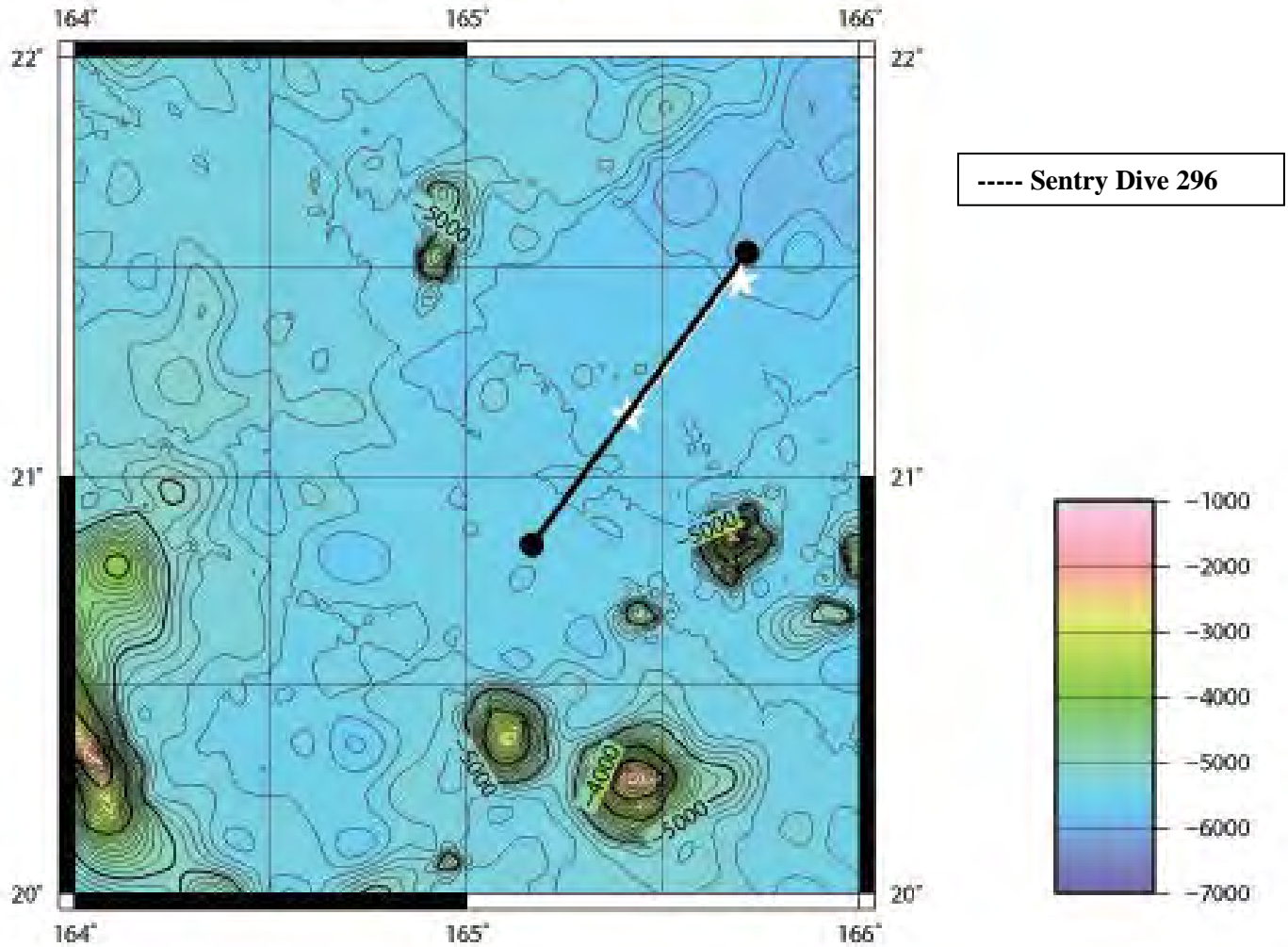
Chief Scientists: M. Tominaga, M. Tivey

Daily Summary

We started JD008 at 22°8.238'N,166°13.344'E en route to deploy the Argo float, serial number 9303. We reached our deployment site at 00:40 and launched the float from 22°13.56'N,166°11.34'E. We then sped up to 4 kts to deploy the SeaSpy Surface Maggie. We completed deploying the instrument at 00:57, position 22°12.48'N,166°10.2'E.

After Argo deployment we continued our track SE with all sonars turned on and collecting data, namely Topas, multibeam, and ADCP. The EM302 software crashed majorly, once at 03:30 and again at 03:32. We rebooted the system completely after the second crash. It was on and working again by 03:40.

We continued underway towards our next Sentry launch point, WP32 (18°18.186'N,162°39.963'E), for our final Sentry dive, Dive 299. In the midst of our transit we started a multibeam survey line at WP 29 (22°11.799'N,166°9.438'E) which will be finished tomorrow at W31 (17°41.271'N,162°0.042'E), before the final Sentry launch.

We will be in transit for the next day and a half or so because our waypoints are far southwest from our current position. We ended the day in transit at 18°57.744'N,163°18.774'E.

JD008
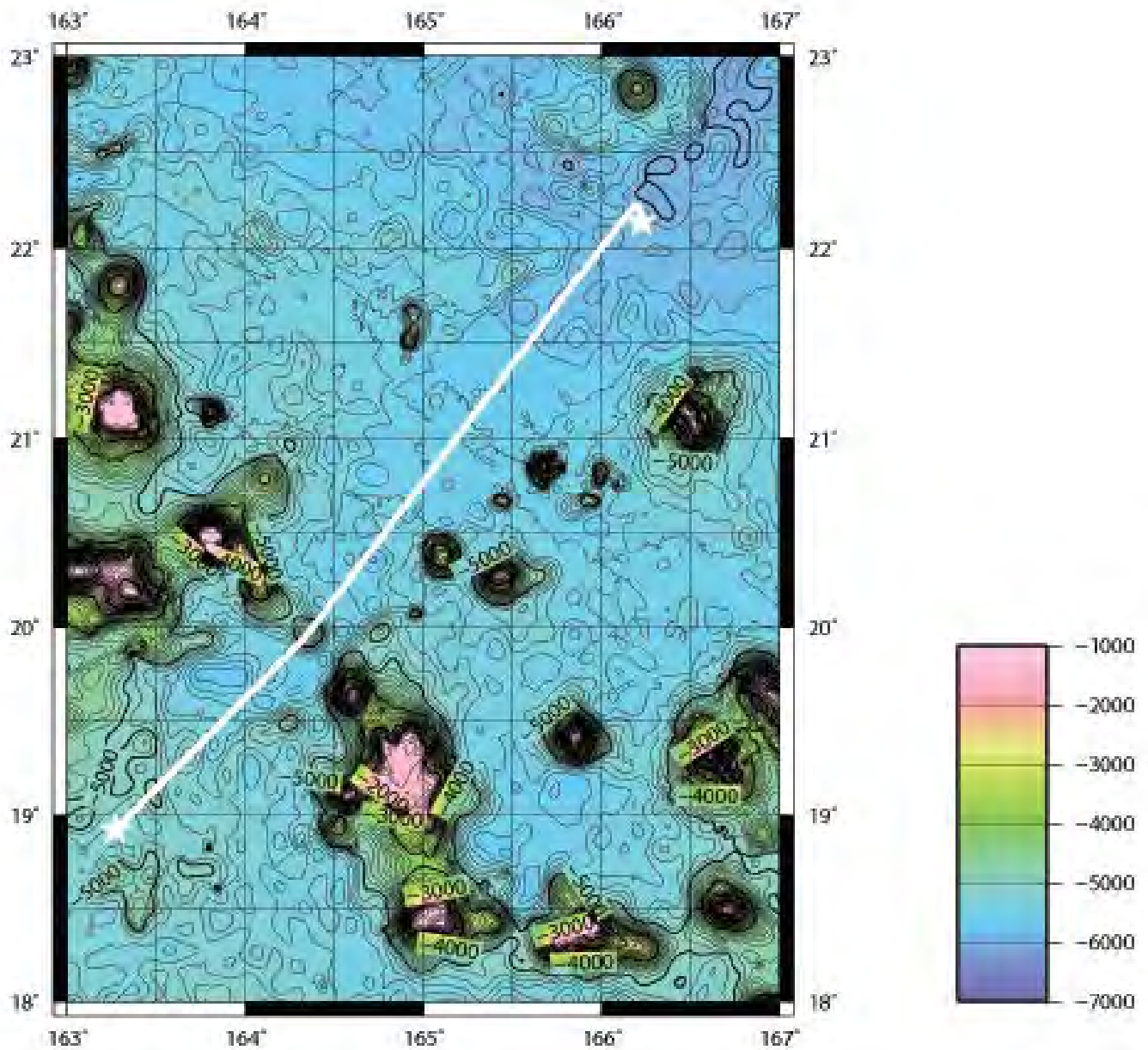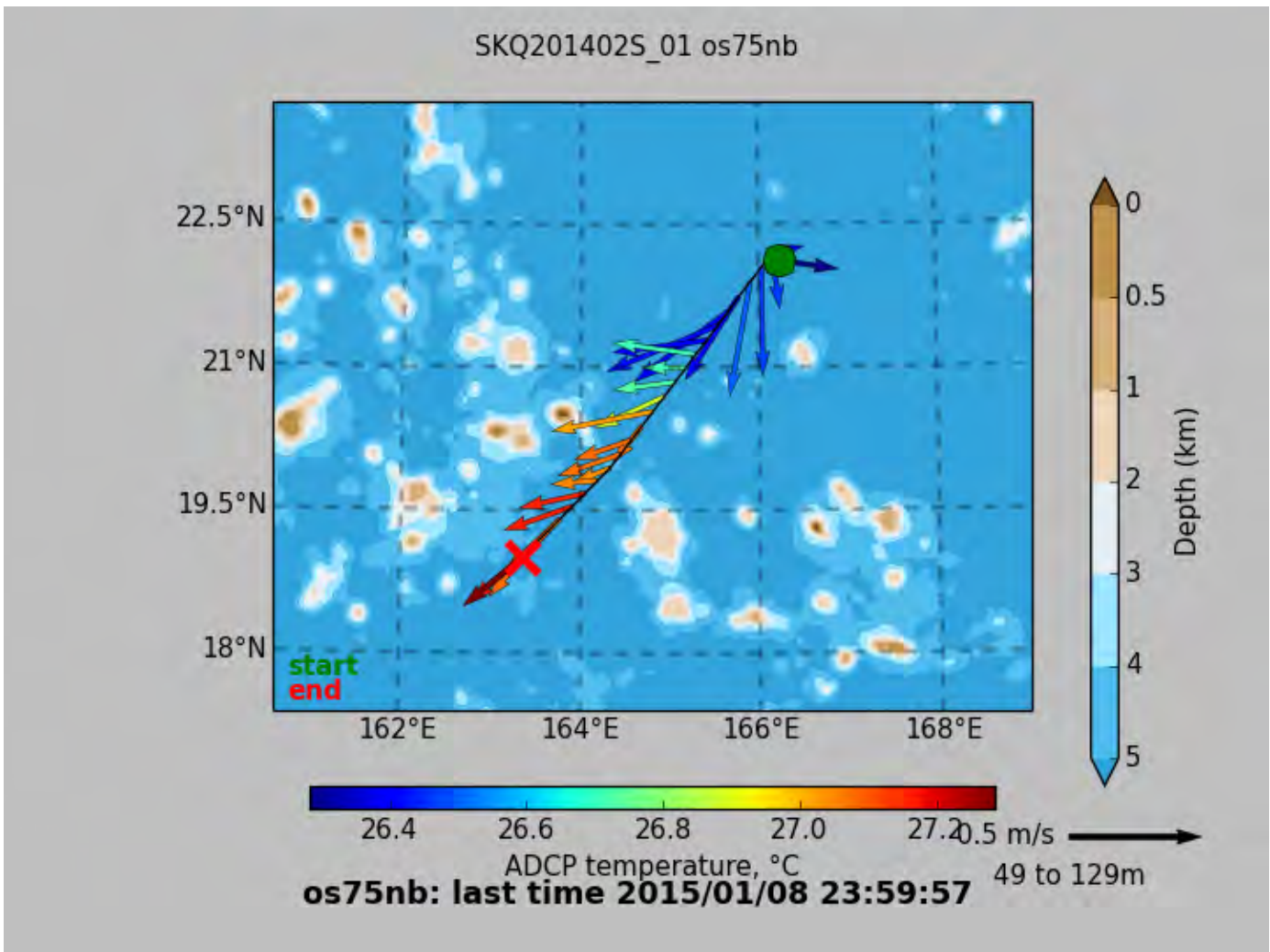
SKQ201402S

JD009 09 Jan 2015
Chief Scientists: M. Tominaga, M. Tivey

Daily Summary

JD009 and all is good in the world of ocean science. A brief narrative for today:

We started in transit with the surface Maggie in tow (ship's position=18°57.744'N,163°18.774'E) heading towards WP32 (18°18.186'N,162°39.963'E) for our final Sentry launch, Dive 299. En route we passed through WP31 (17°41.271'N,162°0.042'E), our "end of survey line" for the multibeam swath.

We neared WP32 around 13:40 and began recovering the surface Maggie in preparation for Sentry deployment. The surface Maggie was fully recovered by 13:55 (ship's position= 18°11.622'N,162°32.859'E). We continued underway to our launch site for about an hour, then turned off all sonar and deployed the centerboard at 15:06 as we reached WP32. Sentry was successfully deployed for Dive 299 at 15:15 from a recorded position of 18°18.15'N,162°18.774'E. Sentry reached the bottom at 17:40, dropped its weight and started underway (depth= 5271.5m, Sentry's position= 18°18.164'N,162°40.08'E). We closed the day underway with Sentry's last position recorded as 18°11.257'N,162°32.856'E.

JD009

SKQ201402S_01 os75nb

ADCP temperature, °C

os75nb: last time 2015/01/09 14:59:57

49 to 129m
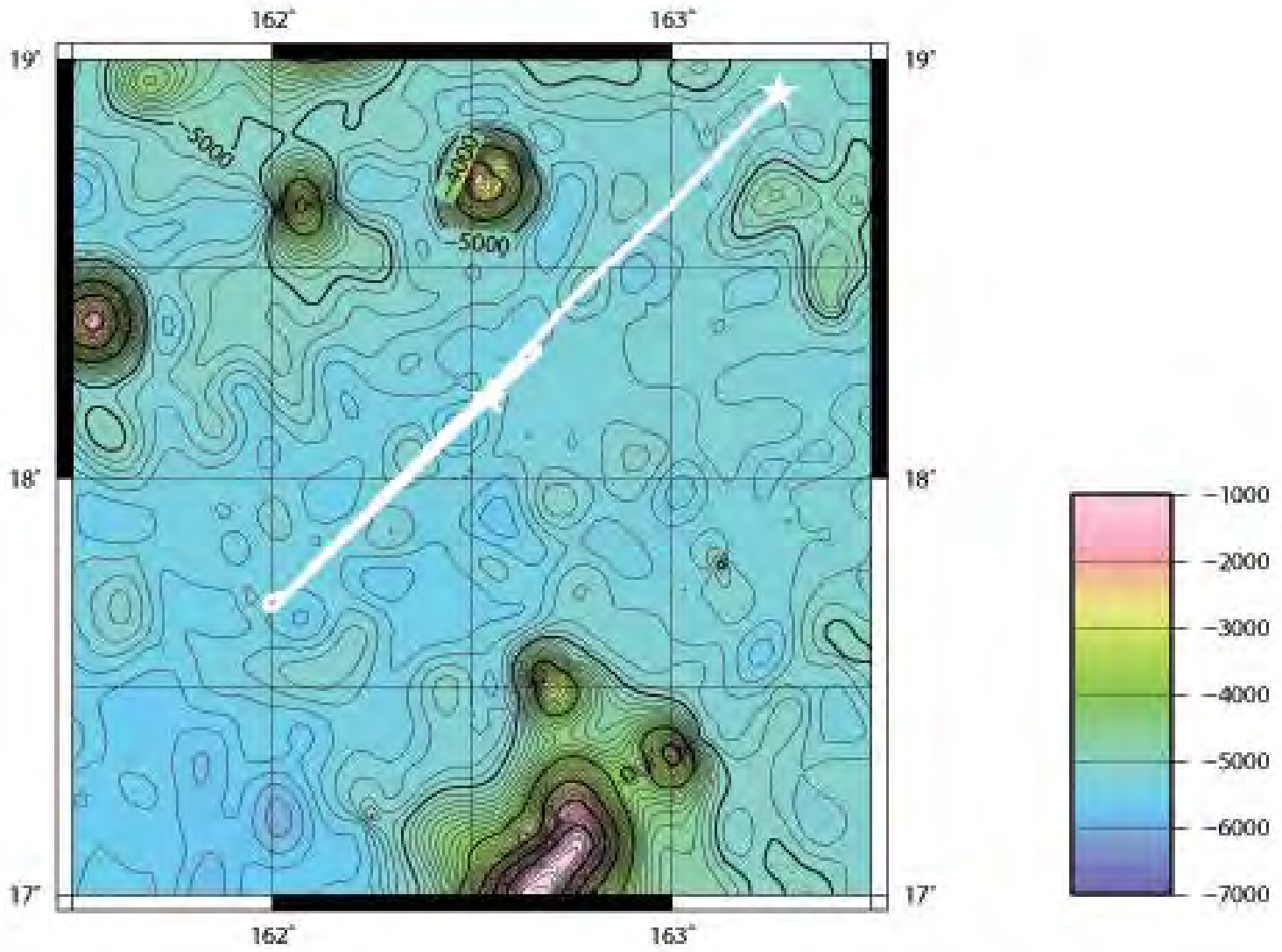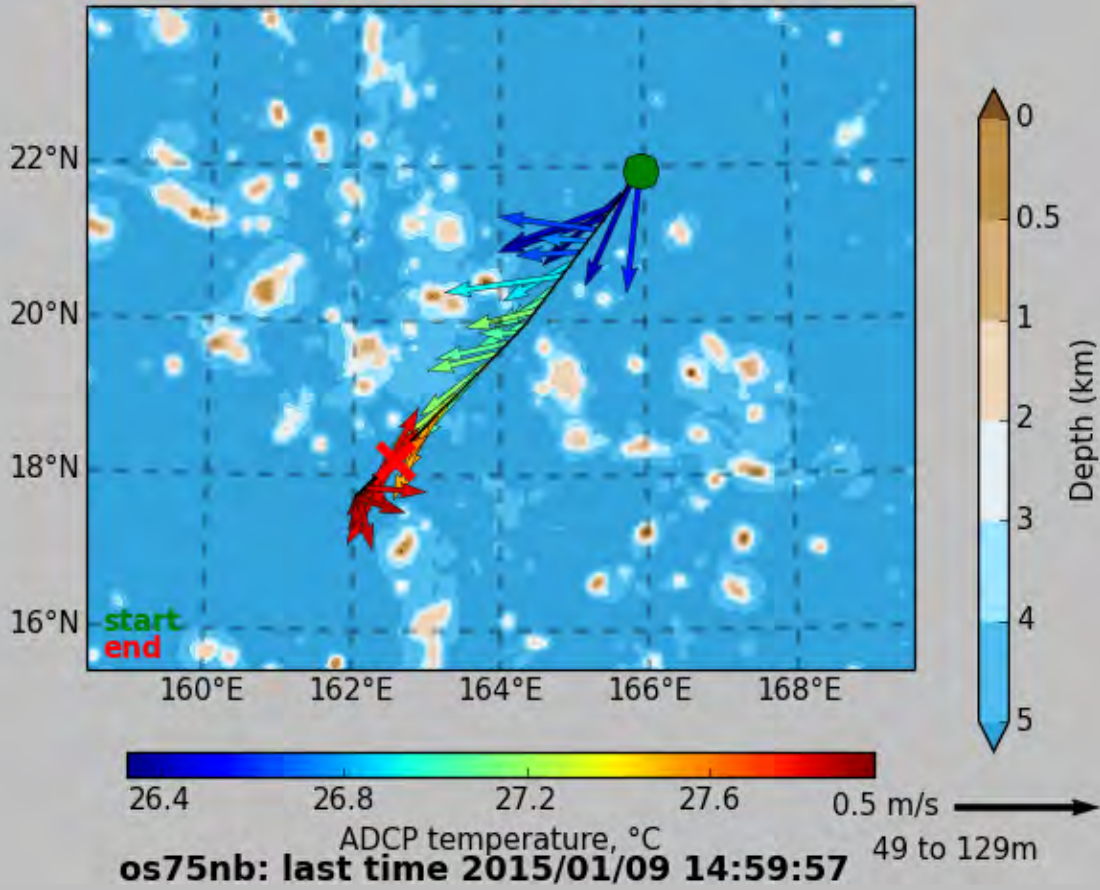
SKQ201402S

Cruise Start Date: 16-12-14
Cruise End Date: 15-01-15

JD010 10 Jan 2015
Chief Scientists: M. Tominaga, M. Tivey

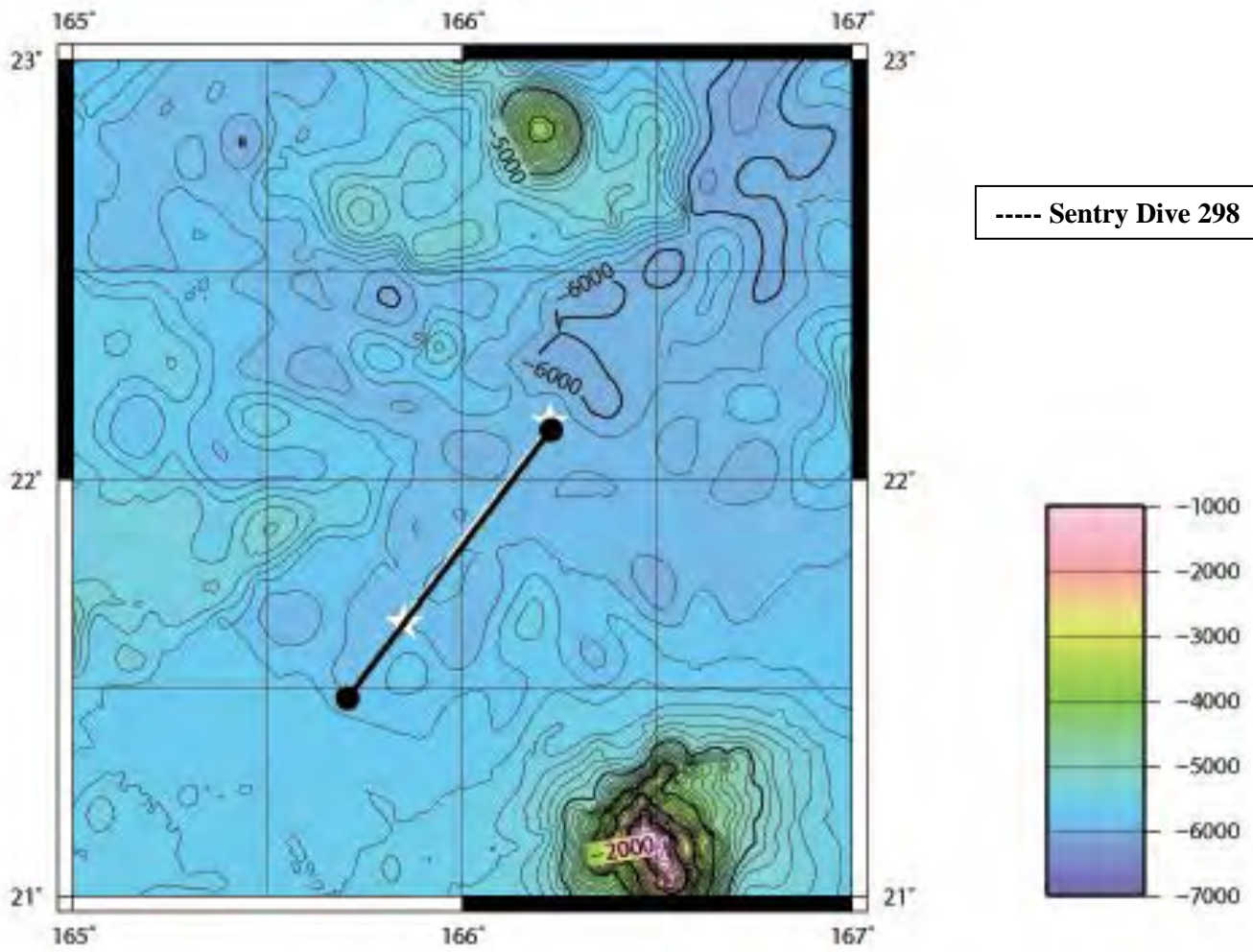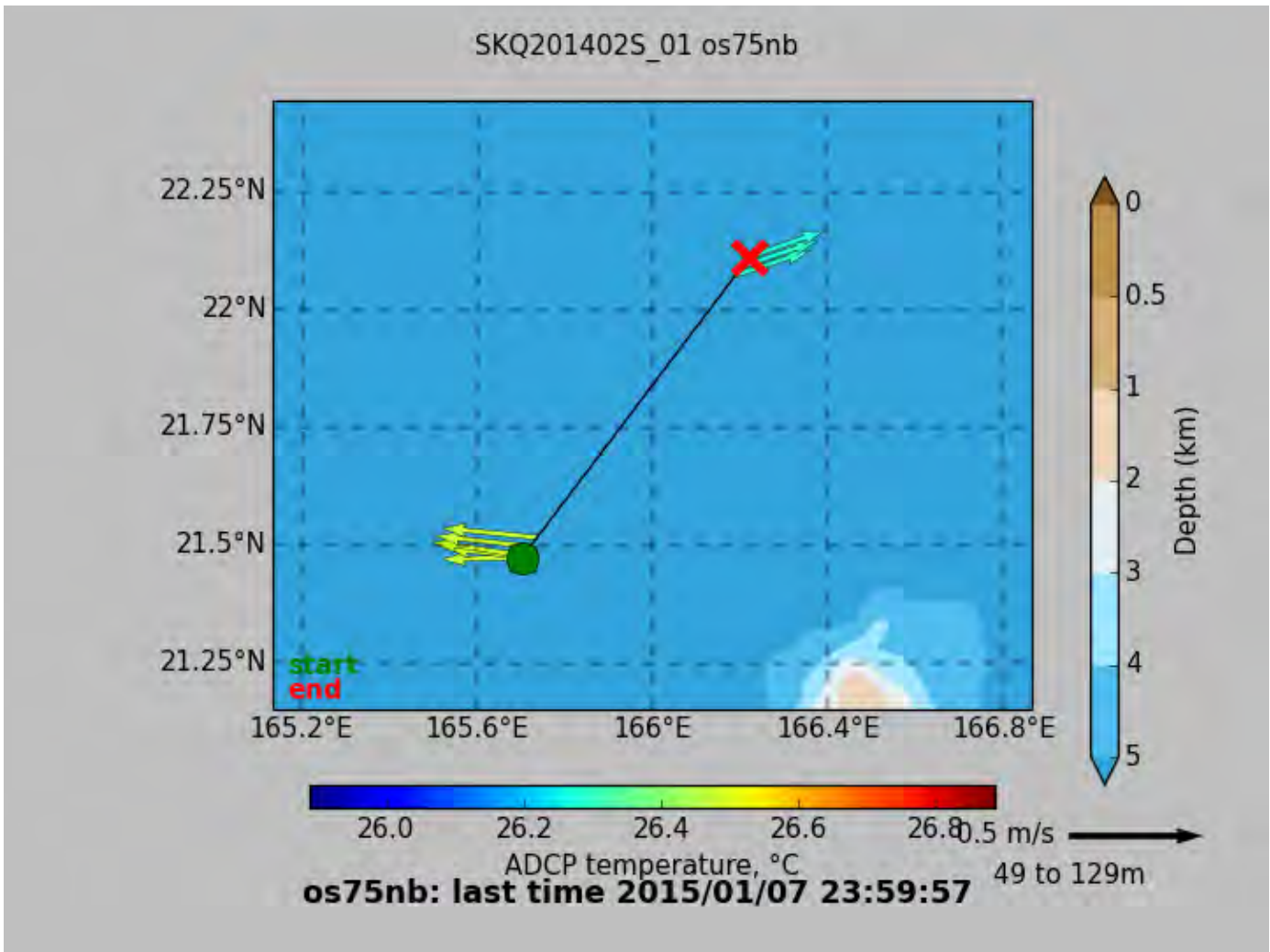## Daily Summary

We started JD010 with Sentry in the midst of its final dive, Dive 299, at the recorded position of 18°11.257'N,162°32.856'E. We couldn't have asked for a smoother dive to finish off the cruise. Sentry flew along until 21:13 when it finished its track line and dropped its weight to begin ascension (Sentry's position= 17°47.461'N,162°5.932'E; Sentry's final depth=5197.3m). Sentry surfaced, was brought aboard, and was secured by 23:17 (ship's position= 17°47.208'N,162°6.036'E). Dive 299 measured in at a total distance of 83.08km. Not bad for a final dive!

We recovered the centerboard and restarted all sonar systems once Sentry was on board, then had a series of mini launches: At 23:37 we launched an XBT (ship's position= 17°47.112'N,162°5.931'E), at 23:43 we launched Argo float SN9306 (ship's position= 17°47.256'N,162°5.796'E), and at 00:00 (JD 011, technically) we deployed the SeaSpy Surface Maggie (17°47.466'N,162°5.148'E). The surface Maggie launch point was our last recorded position of the day. We are currently heading towards WP34 (17°51.284'N,157°0.000'E), our final waypoint before Guam, which is at the crux of the Japanese lineation.

Our plan going forward is to continue towing the surface Maggie through WP34 and to continue towing almost all the way to Guam after passing the waypoint. We will be collecting Topas and multibeam data along the way as well. There's no doubt that the end of the cruise is tangible. Cruise report tasks have long been assigned, as have tasks for the virtuous ceremony of the Golden Dragon, which is almost upon us. As the science dwindles down over these final days, excitement penetrates the air as people speculate about the upcoming ceremony, compare plans for Guam, and fantasize about travels, either home or abroad, after reaching our destination.

JD010

----- **Sentry Dive 299**

SKQ201402S_01 os75nb

os75nb: last time 2015/01/10 23:50:22

ADCP temperature, °C

49 to 129m
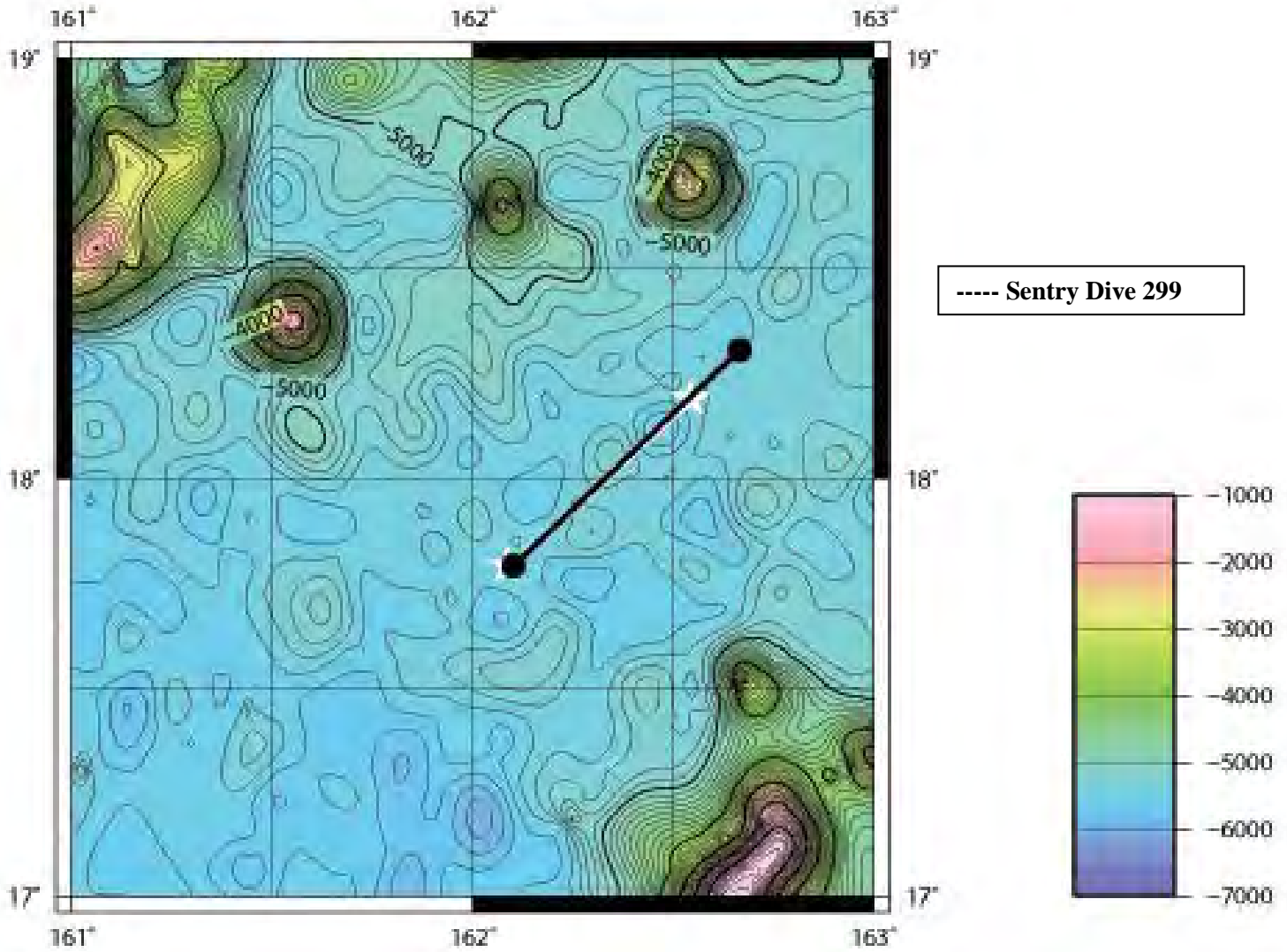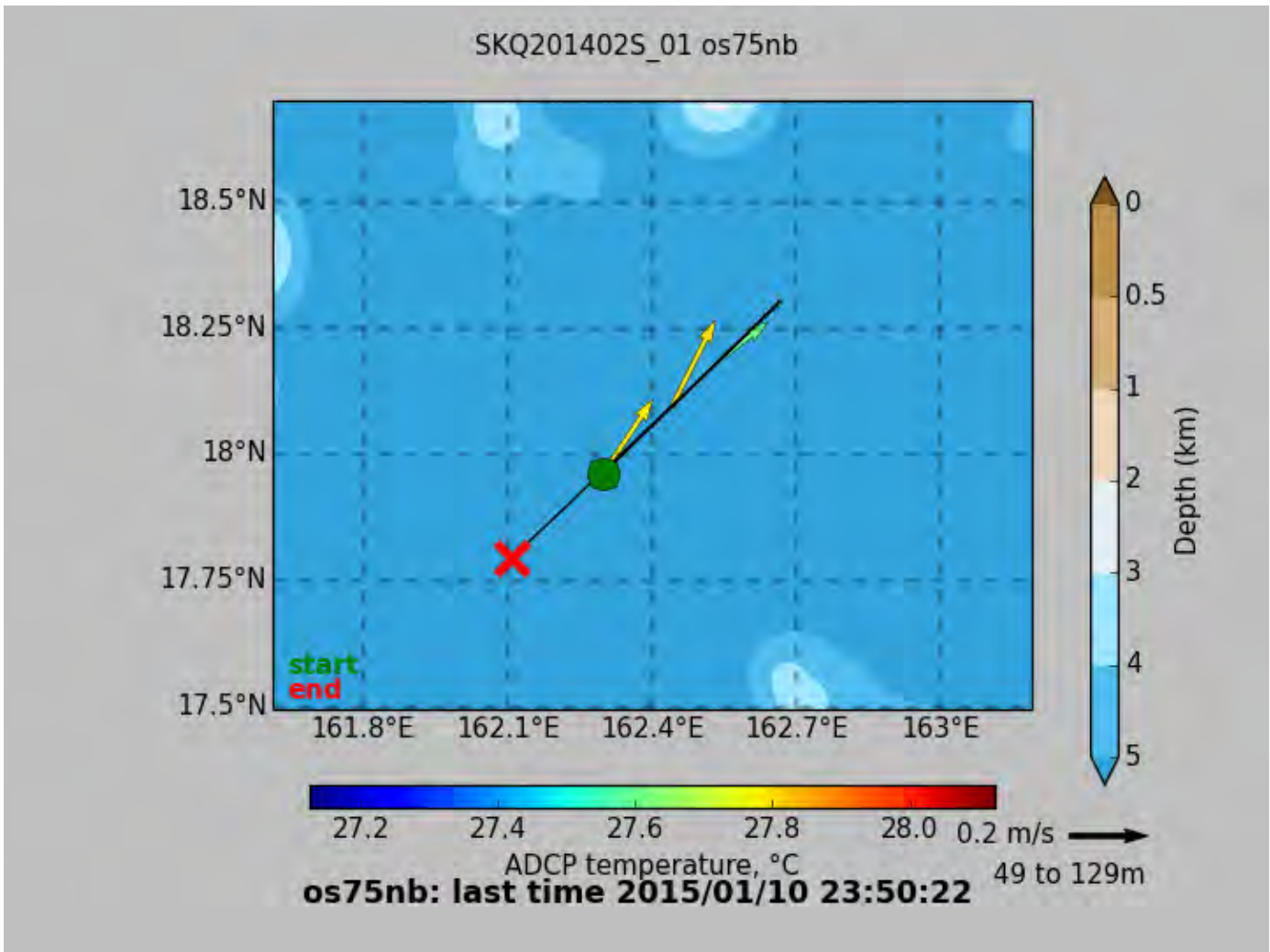
SKQ201402S

JD011 11 Jan 2015
Chief Scientists: M. Tominaga, M. Tivey

Daily Summary

We began JD011 with the deployment of the SeaSpy Surface Maggie at exactly 00:00 from a position of 17°47.466'N,162°5.148'E and at a speed of 5.6 knots. We continued towing the Maggie at speeds between 10-12.5 knots through the end of the day. No problems with the logging software. We ended the day at a recorded position of 17°51.066'N,157°7.092'E. Great day of science!

Shipside, the ritualistic ceremony of the Golden Dragon officially commenced today. Crazy hats, costumes, accessories and face "painting" donned the wogs participating. The fun continued into the afternoon with an enthusiastically and thoroughly entertaining talent show at the expense of the wogs on the lido deck of the Sikuliaq. The Golden Dragons received them with plenty of coffee beans, water balloons, spit balls, and minimal applause. It was an energetic and highly enjoyable day to say the least. Everyone is excited to see what Day 2 will bring…
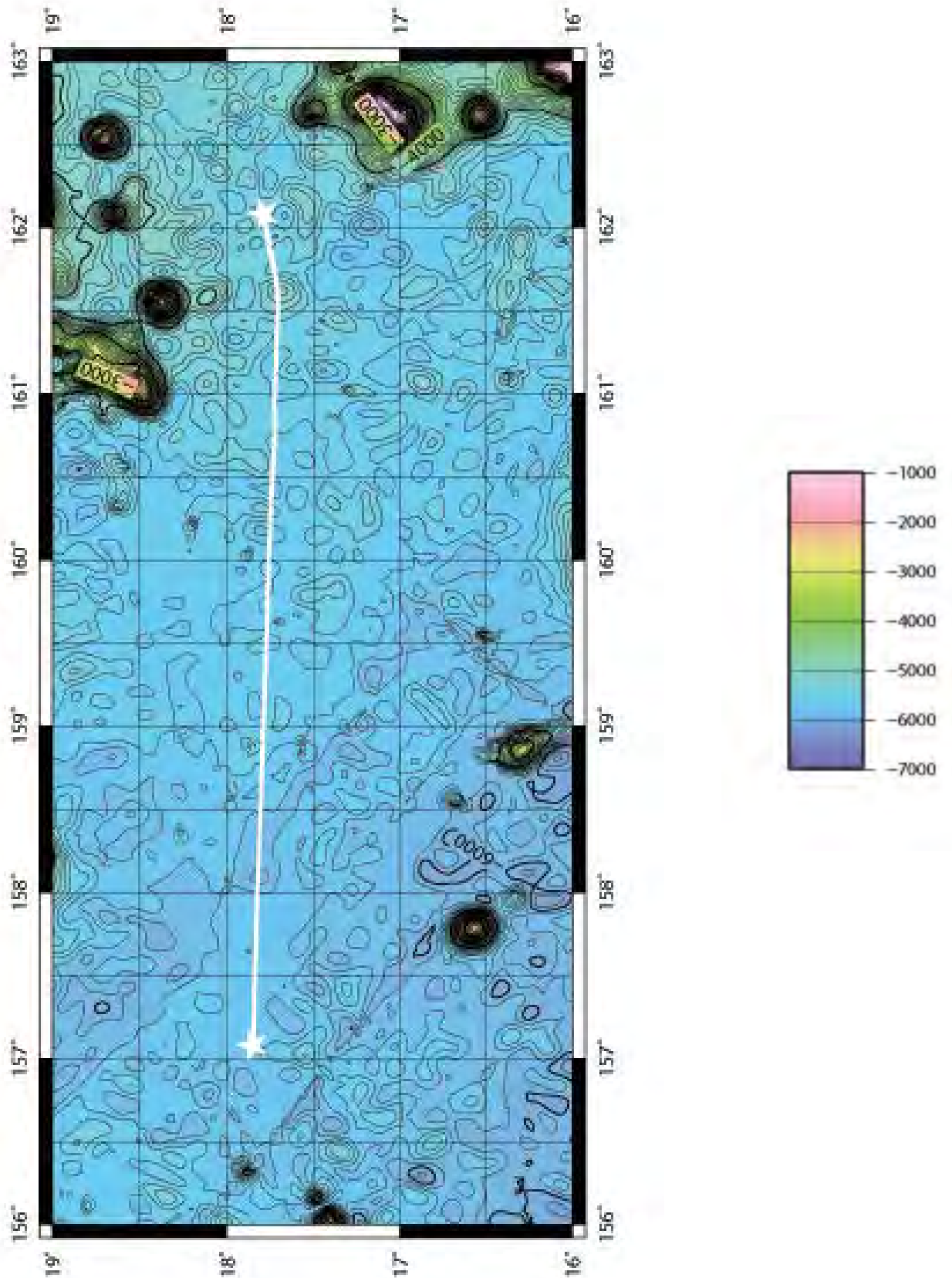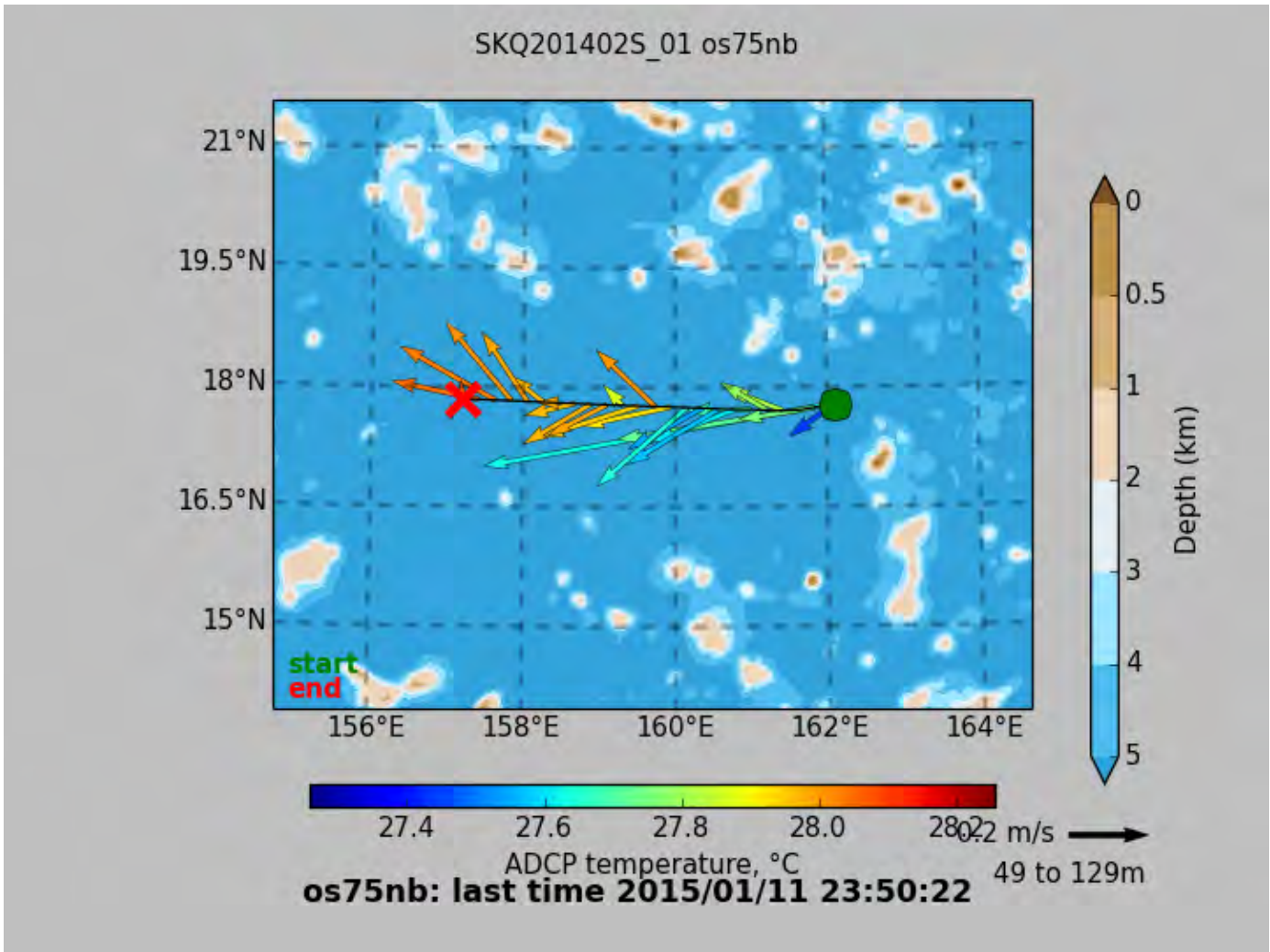
SKQ201402S

JD012 12 Jan 2015
Chief Scientists: M. Tominaga, M. Tivey

Daily Summary

Day JD012 started at 17°51.066'N,157°7.092'E underway with the surface Maggie in tow and heading towards our final waypoint, WP34 (17°51.283'N,157°.000'E). We reached our final waypoint around 00:20, after which we changed our course to head southeast towards Guam. We kept our transit speed between 12-13 knots as we sailed through the day. Two notable events: We cruised over the Vlinder guyot between ~14:30-15:30. We collected really beautiful bathymetry and topaz data from that, worth checking out. Second, we accidentally turned off the EM302 for a bit between ~16:00-16:05, so there is a gap in the bathy data during that time stamp.

We ended the day in transit with the surface Maggie still working great. Final recorded position for the day was 16°17.592'N,152°17.952'E.

Shipside, today concluded the Golden Dragon Ceremony! Without delving too much into detail, activities included sunrise warm-ups, four-limbed fish crawls, diving for dogs, relinquishing transgressions against Neptune, swimming in the belly of a whale, stopping for a quick cut at the barber, kissing the Royal Baby, and, to conclude it all, being knighted by King Neptune himself. Today, 13 worthy wogs were duly welcomed into Neptune's Court after the whole ceremony, which turned out to be a swash-buckling, knee slapping, mustard throwing, fun-filled shenanigan for all involved. The day will for sure live on in everyone's memories as a rite of passage and well-forged connection with the sea and all her sailors. What a truly special capstone to the cruise as it nears its end.

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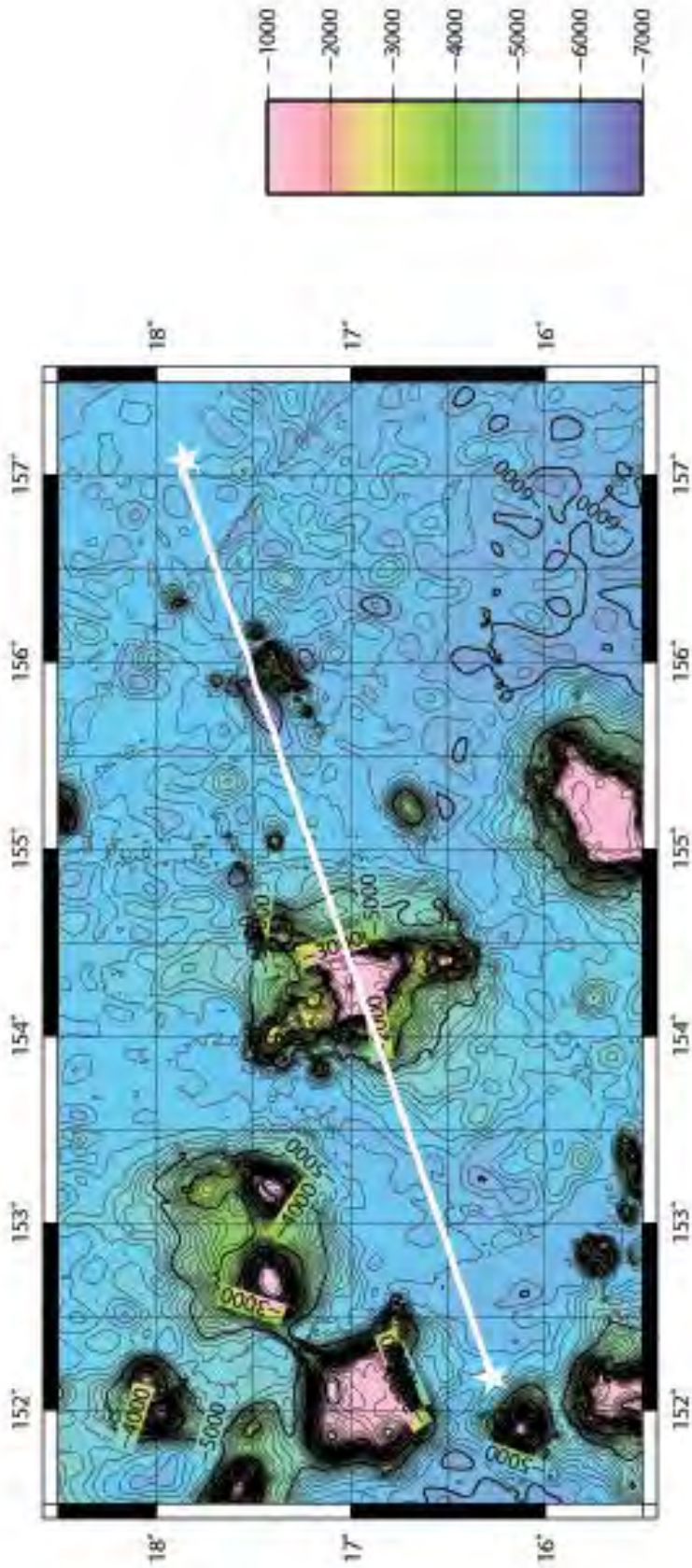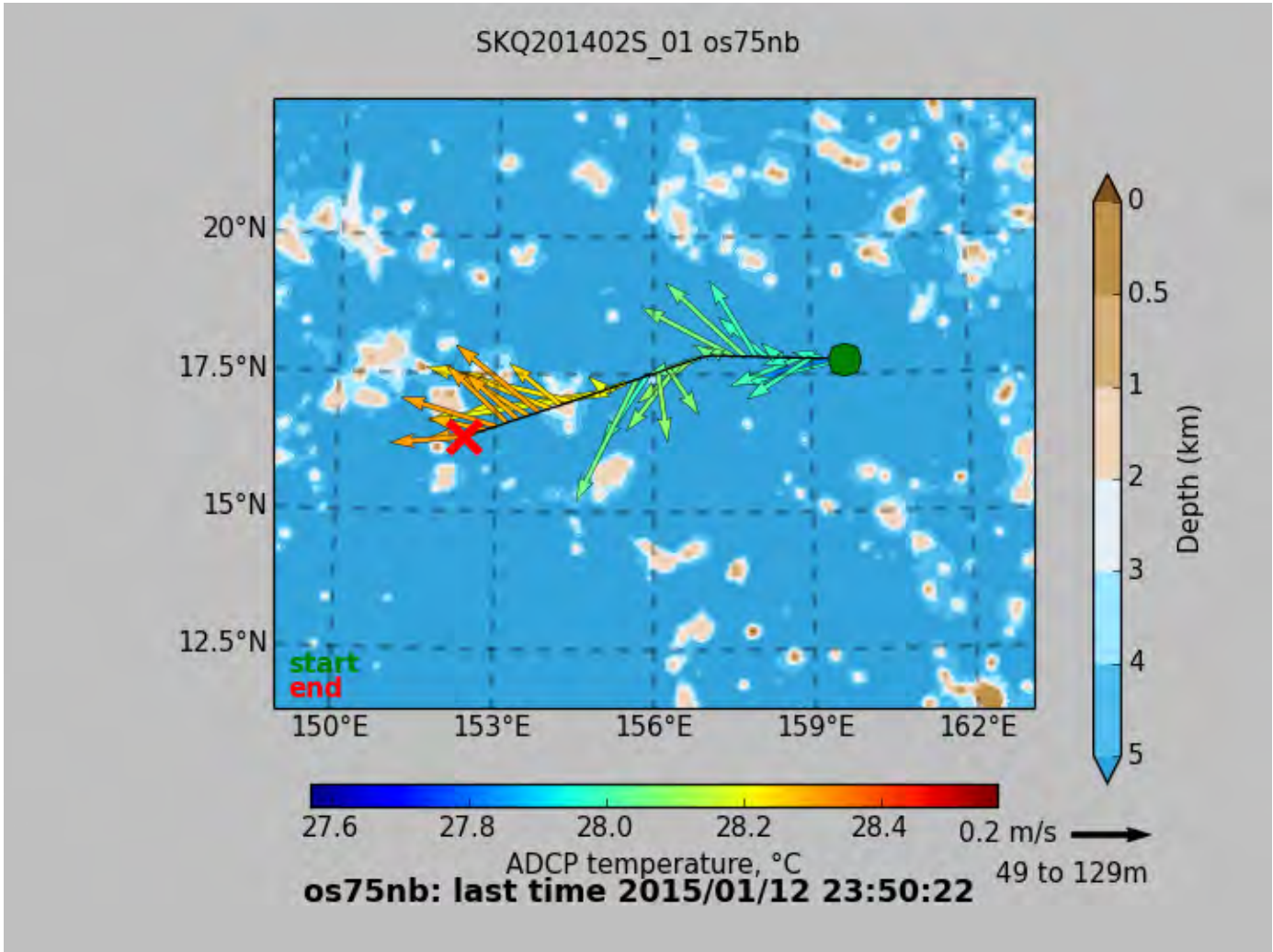
SKQ201402S

JD013-14 13-15 Jan 2015
Chief Scientists: M. Tominaga, M. Tivey

Daily Summary

The last final days of the cruise were slow on the science end with little to report, so in the interest of saving space the events will be recorded together:

Day JD013 started at 16°17.592'N,152°17.952'E underway with the surface Maggie in tow for the final stretch of the cruise. All was well with the logging software; no crashes or issues in data collection. The day ended with Maggie still in tow at 14°51.69'N,147°52.98'E, which means that we crossed the Tropic of Cancer! Covering so much on this cruise. Over the course of the day, our ship speed slowed from just over 12 kts to 9.6-10kts.

Day JD014 started right where 013 left off, 14°51.69'N,147°52.98'E. As the official last day of the cruise (by the JD calendar) the highlights of the day included cruising over the Mariana's Trench, pulling in the surface Maggie one final time, the end of watchstanding shifts and the whirlwind pressure of cleaning, packing and wrapping up an incredible 35-day excursion at sea. We approached the Mariana's Trench around 02:00. As we sailed over the deepest part of the earth, three lucky watchstanders "accidentally dropped" a decorative steel plate to commemorate the special moment. After the passing, we reeled in the surface Maggie for the final recovery. Software was off and the magnetometer was on board by 04:00. Watchstanding officially ended once the Maggie was recovered and the rest of our time on board was dedicated to cleaning and archiving. We arrived in Apra Habor, Guam around 22:00 as sharper scientists and enriched individuals. Amazing what some time at sea can do for you!
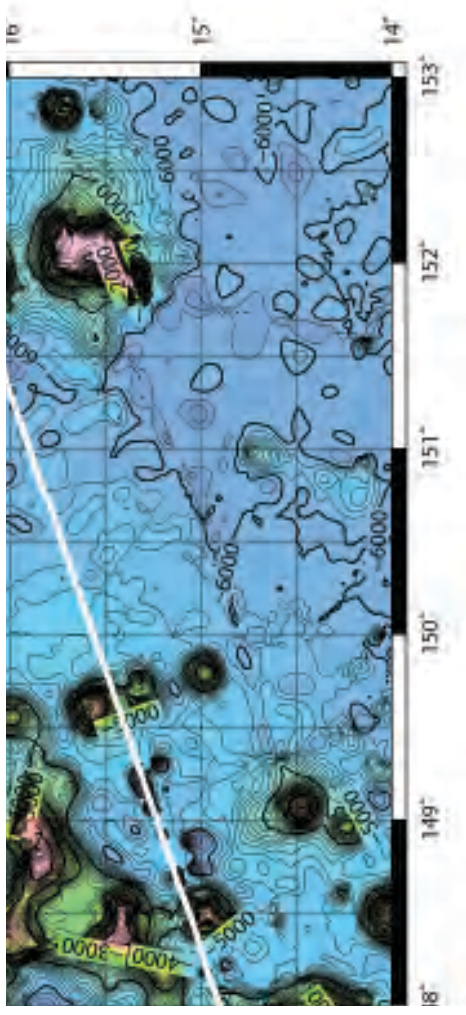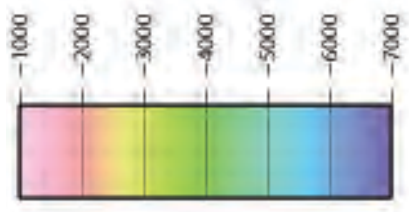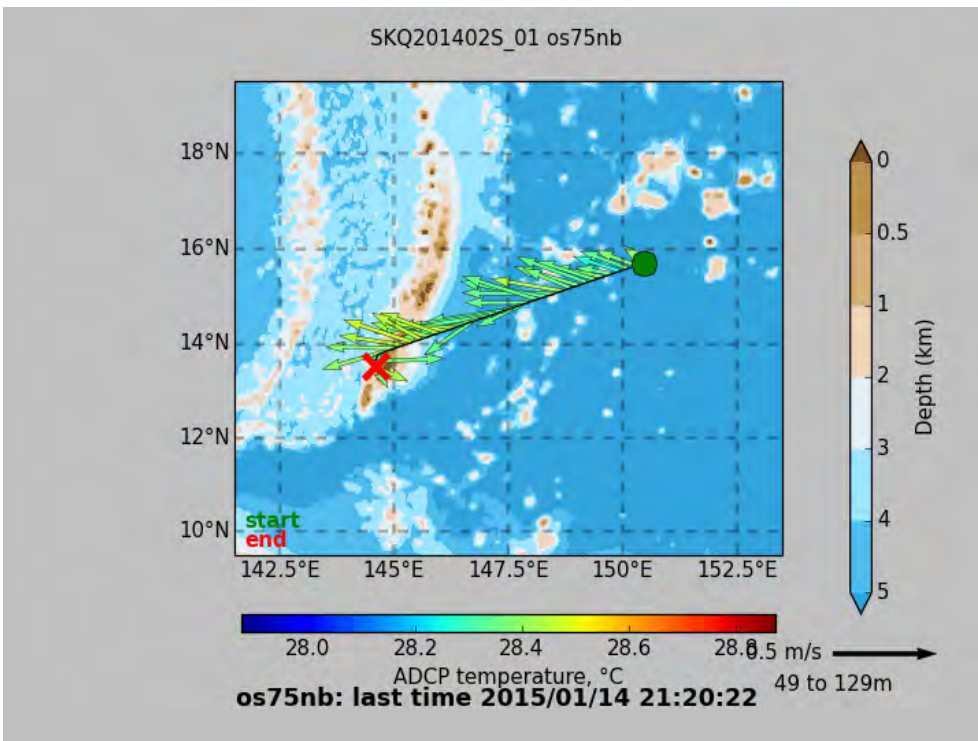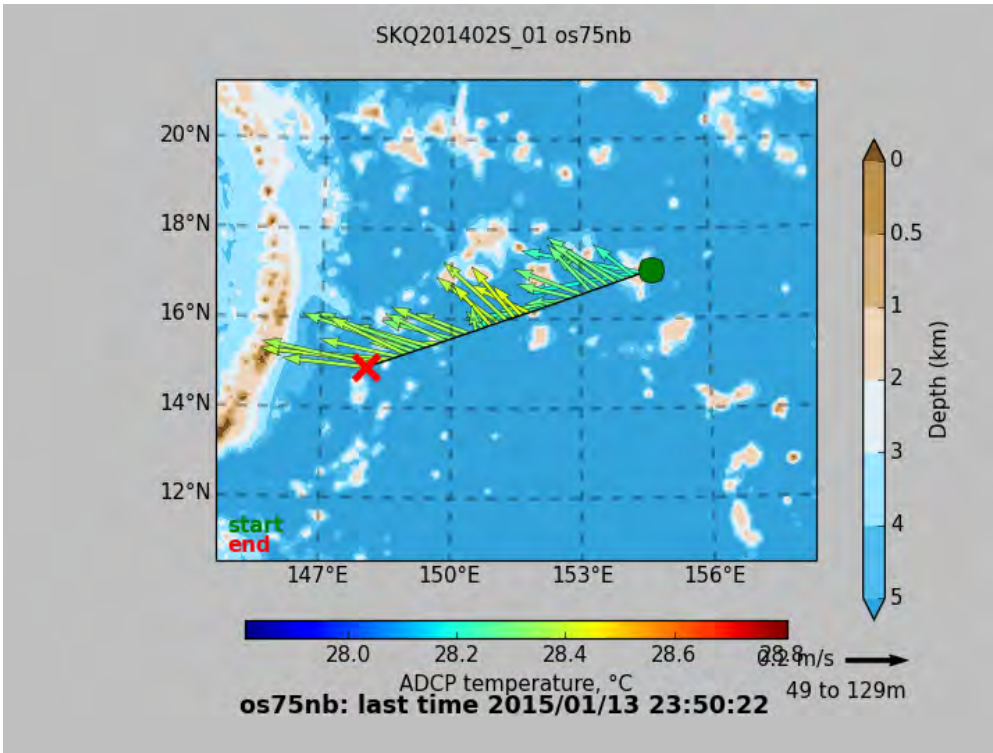
SKQ201402S Cruise Report Appendix

December 17, 2014- January 15, 2015

Includes:
- Appendix 1. Sentry Report
- Appendix 2. Shipboard systems setting
- Appendix 3. EM302 Multibeam settings
- Appendix 4. Backscatter script and preliminary interpretations
- Appendix 5. Topas settings and processing information
- Appendix 6. Deep tow dive plots
- Appendix 7. Navigation and bathymetry map scripts (from Daily Cruise Summaries)
- Appendix 8. List of archived data (from R/V Sikuliaq)
- Appendix 9. Cruise T-shirt design
- Outreach (Blog)

Sentry Operations Report for the Tominaga-Tivey 2014 Cruise DRAFT

WHOI Sentry Operations Group

Dr. Dana Yoerger, Alan Duester, Andrew Billings, Zachary Berkowitz, Daniel Bogorff

Sentry Expedition Leader: Dr. Dana Yoerger

Chief Scientist: Masako Tominaga, Michigan State University
Co-PI: Maurice Tivey, WHOI

ARRV Sikuliaq — Dec 16, 2014 to Jan 15, 2015

Publication Date: January 15, 2015

1   Summary

This document summarizes operations with the *Sentry* autonomous underwater vehicle (AUV) during the 2014 Tominaga-Tivey cruise. Included in this report is the vehicle configuration; basic vehicle and sensor performance; and post-dive reports (with summary statistics and narratives). This report does not attempt to describe the scientific results or conclusions. A detailed description of the data files resulting from this cruise is provided in a separate document. Individual dive summaries for Sentry dives 290 - 299 follow — each of these is a free-standing document summarizing the dive. High level objectives of each dive were to run long, straight magnetometer lines. The biggest challenge was the great depth (5200-5900m) but the vehicle performed well and our acoustic systems (Sonardyne USBL, WHOI acoustic modem, and WHOI ranging) all worked well. The Sonardyne SMS capability was not useful beyond about 3800m. The general operations for the cruise are shown in the cruise track summary plot.

Our overall approach to following the vehicle worked very well. The vessel used our navG display to follow the vehicle. We knew the location of the vehicle at all times. The biggest gaps in tracking occured due to frequent software problems with the Sonardyne USBL system. It simply stops working every few hours and we needed to restart the software. In any case we continued to receive and plot the dead-reckoned update through WHOI acomms along with data for vehicle speed, heading, altitude, depth, etc. So these gaps were annoying but did not jeapordize vehicle safety.

Sikuliaq worked well for us and communication with the bridge was very good. Our experience with Capt Adam Seamans on Knorr and Atlantis was very helpful, as he was very familiar with our operations. Deck operations went well even in some challenging conditions. The hospitality on the ship was excellent
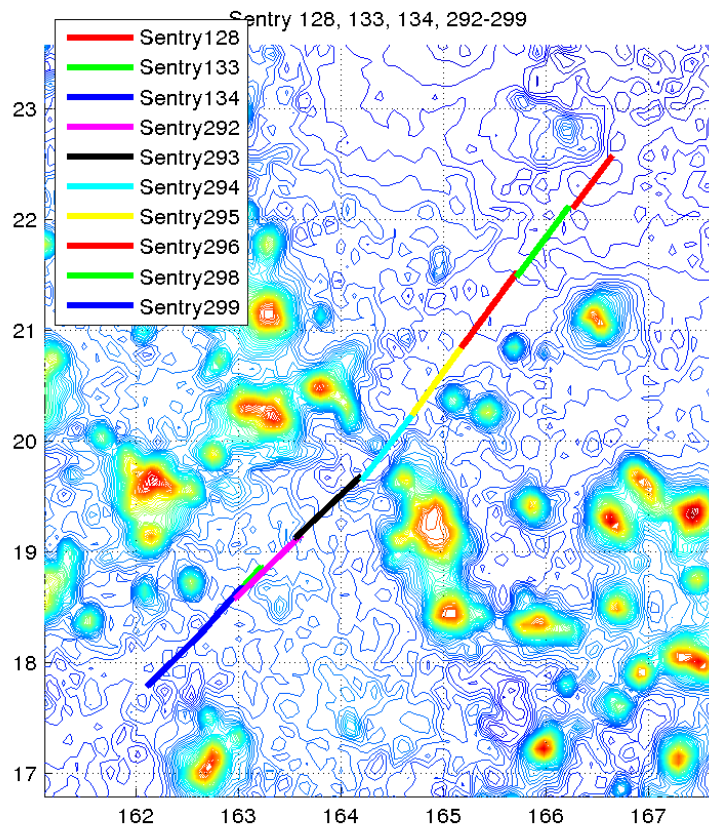
Figure 1: This plot shows tracklines from 2011 and 2014-15. Total trackline length is 700km.

2 Cruise Log

This section provides a brief chronological summary of *Sentry* activities during the cruise. Additional information on specific dives is available in the dive reports.

A note about times: we crossed the International Dateline on this cruise, which can lead to some confusion about dates. In all cases, we use UTC date and time. For our main operations, we were in a time zone 12 hours ahead of UTC.

Dec 16 Vessel sailed on time after fueling

Dec 18 First engineering dive, Sentry290, at deep test site. This dive ended soon after launch due to a bug in our new depth processing routines

Dec 19 Sentry291, our second engineering dive. On this dive Sentry never got bottom lock with its Doppler Velocity Log (DVL). The DVL detected a "false bottom" about 200 meters above the actual bottom, so it exited the descent process. We had some success forcing the vehicle down but not enough to continue the dive. We got good deep tests of the USBL and WHOI acomms.

Dec 19-Dec 26 Transit to to main work site. Crossed the International Date Line, adding a day

Dec 26-27 EM302 multibeam survey from the vessel of the entire work site from NE to SW

Dec 27-Dec 28 Sentry292, first operational science dive at the SW end of the survey line heading to the NE. The vehicle covered about 93km at about 5200m depth. Data quality appears to be as good as expected.

Dec 29-Dec 30 Sentry293, second operational science dive. The vehicle covered 91.6 km of tracks with excellent data quality. The vehicle flew over a seamount 550m high toward the end of the run.

Dec 31-Jan 01 Sentry294, third operational science dive. The vehicle covered 90.1 km of tracks with excellent data quality. Energy use slightly higher than expected.

Jan 02-Jan 03 Sentry295, fourth operational science dive. The vehicle covered 92.0 km of tracks with excellent data quality.

Jan 04-Jan 05 Sentry296, fifth operational science dive. The vehicle covered 95.3 km of tracks with excellent data quality.

Jan 06 Sentry297 was a failed dive. We noticed on descent that the DVL was not reporting properly and we aborted the dive. On recovery, we found a startup problem with the nav software.

Jan 06-Jan 07 Sentry298, sixth operational science dive. The vehicle covered 89.0 km of tracks with excellent data quality.

Jan 07-Jan 09 Transit to SW end of the entire survey line for the final dive

Jan 9-Jan 10 Sentry299, seventh operational science dive. The vehicle covered 83.0 km of tracks with excellent data quality.

Jan 15 Arrive Guam, begin offload

3 Vehicle Configuration

Table 1 lists the science sensors installed on *Sentry* on this cruise.

Table 1: Sentry Sensor Configuration

Sensor
APS 1540 Magnetometers (3)
Seabird SBE49 Conductivity-Temperature-Depth (CTD)
Seapoint optical backscatter sensor (OBS)
Anderaa optode model 4330
300kHz RDI Doppler Velocity Log (DVL)
IXEA PHINS
Reson Sound Velocity Probe

4 Navigation

All dives were navigated using realtime DVL velocity inertial measurement unit (IMU) attitude measurements. External aiding during descent was performed with Ultra-Short Baseline (USBL) throughout the cruise. Dive specific notes on navigation are included in the dive reports. All final navigation consists of a track where the DVL/IMU track was fused with the USBL fixes in post-processing.

We used the older (name?) Sonardyne system on this cruise as the newer system installed in the van could not be used due to a cable length issue. Many of our software issues were related to the use of the old software, no doubt.

The basic acoustic performance of the Sonardyne was very good. On our last dive, the mean time between fixes during the survey was 26 seconds for a 13 sec update rate. Some of those lost fixes were due to software outages.

The acoustic installation on Sikuliaq peformed very well for us. Tracking was better than on Falkor at similar depths.

4.1 Coordinate origins

The vehicle's control system uses simple equidistant coordinates. This system uses an origin, defined in terms of latitude and longitude with the World Geodetic System 1984 (WGS84) datum, and a fixed scaling between meters displacement from the origin. We use the identical routines that have been used by the National Deep Submergence Facility (NDSF) assets Alvin and Jason for decades. Likewise we always used the same origin for Sentry and Alvin at each site. These simple coordinates have several advantages for realtime control of a vehicle. Unlike Universal Transverse Mercator (UTM) grid coordinates, the x and y axes intersect at right angles and align with true east and north respectively at the origin. These coordinates distort quickly as one moves away from the origin, but we solve that problem by putting the origin close to the operating area. We almost always report our results in latitude/longitude, so most users need not be aware of these details.

4.2   USBL Calibration and Performance Notes

A CASIUS calibration of the USBL system was conducted during the trials cruise before the 2014-baco-taylor leg. A copy of the USBL calibration report is included in the appendices of this document

5 Items of Note

This section summarized details which are worthy of note or mention for future reference but which do not constitute problems:

N.1: We followed launch and recovery procedures worked out on the previous cruise (Baco-Taylor, also on Sikuliaq)

N.2: Launches and recoveries were performed on the stbd side of the vessel as far forward as possible with the deck layout.

N.3: The data set was small by Sentry standards, as we recorded no images or sonar data.

6 Technical Issues

This section summarizes technical issues encountered by the *Sentry* operations group on the cruise. Issues which affected primarily individual dives are listed in the individual dive reports.

T.1: we benefited greatly from the experience of the ship's crew with Sentry on the previous leg and had no systematic problems with launch and recovery

T.2: we learned that the vessel HPU for the cranes and Aframe had lost its spare. While this was of no real consequence, we had to plan for hydraulic issues and lengthened the amount of battery reserve accordingly.

7 Sentry Operations Team

The *Sentry* team was comprised of 5 members on this cruise — Dr. Dana Yoerger, Alan Duester, Andrew Billings, Zachary Berkowitz, and Daniel Bogorff. Dana Yoerger was the Expedition Leader and principal author of this report.

8 Acknowledgments

1. Thank you to the crew of the R/V Sikuliaq for going out of their way to make this science cruise for the vessel a success.

Sentry 290 Dive Report
DRAFT

WHOI Sentry Operations Group
Dr. Dana Yoerger, Alan Duester, Andrew Billings, Zachary Berkowitz, Daniel Bogorff

Sentry Expedition Leader: Dr. Dana Yoerger

Chief Scientist: Masako Tominaga, Michigan State University
Co-PI: Maurice Tivey, WHOI

Summary

Weather: At recovery, winds were steady at 15 knots with confused seas with moderate swells.

Reason for end of dive: A software bug in our new depth processing routine returned zero for depth rate, which caused the descent process to end shortly after the vehicle reached 50 meters depth.

Vehicle Configuration

The science sensing suite for this dive was:

Table 2: Sentry Sensor Configuration

Sensor
APS 1540 Magnetometers (3)
Seabird SBE49 CTD
Seapoint OBS
Anderaa optode model 4330
300kHz RDI DVL
IXEA PHINS
Reson Sound Velocity Probe

This dive was navigated using the DVL/INS system in real time. USBL provided post-dive corrections.

Important Positions

Dive Origin: 18 21.273 -163 -16.755

Launch Position: sentry290 launch position: 18 22.080'N 163 17.106'W

Narrative

This was an engineering dive and we were testing a lot of new software. Launch was normal, but the descent process failed at less than 100meters. The vehicle had not aborted, the descent process terminated as designed because it received data that the depth rate was zero. This was caused by a bug in the new depth processing routine.

We had an anomalous recovery. We dropped the main lift line after it was attached to the vehicle. In manuevering close enough to pick up the lift line, the vehicle hit the side of the vessel and the port fwd wing broke off at the flange bolts as designed. The safety line held and the cables were not damaged.

1   Issues and Proposed Solutions

Chief Scientist Comments

The Chief scientist is requested to include any desired comments.

Dive Statistics

Sentry290 Summary Launch: 2014/12/18 18:03:35
Survey start: 2014/12/18 18:05:56
Latitude: 18.349090 Longitude -163.285314
Depth: 84.80
Survey end: 2014/12/18 18:06:10
Latitude: 18.349092 Longitude -163.285316
Depth: 84.19
Ascent begins: 2014/12/18 18:06:10
On the surface: 2014/12/18 18:11:12
On deck: 2014/12/18 18:36:05
descent rate: 35.9 m/min
ascent rate: 16.7 m/min
survey time: 0.0 hours
deck-to-deck time 0.5 hours
Mean survey depth: 85m
Mean survey height: 3m
distance travelled: 0.05km
average speed; 0.00m/s
average speed during photo runs: 0.08 m/s over 0.18 km
average speed during multibeam runs: NaN m/s over NaN km
total vertical during survey: 0m
Battery energy at launch: 13.5 kwhr
Battery energy at survey end: 13.5 kwhr
Battery energy on deck: 13.3 kwhr
Battery energy used for survey: 0.0 kwhr
Average power during survey: 134.7 watts

Sentry 291 Dive Report
DRAFT

WHOI Sentry Operations Group

Dr. Dana Yoerger, Alan Duester, Andrew Billings, Zachary Berkowitz, Daniel Bogorff

Sentry Expedition Leader: Dr. Dana Yoerger

Chief Scientist: Masako Tominaga, Michigan State University
Co-PI: Maurice Tivey, WHOI

Summary

Weather: On recovery winds were at 18 knots, steady. Moderate confused swells.

Reason for end of dive: We ended the dive as the vehicle had not reached the seafloor and we could not make it drive down. The descent process had ended early on a "false bottom" as seen by the DVL. In addition, the vehicle was ballasted light. We were able to make the vehicle drive down when it was running at 0.8m/s, but when the program slowed it to 0.6, the vehicle was not able to descend.

Vehicle Configuration

The science sensing suite for this dive was:

Table 3: Sentry Sensor Configuration

Sensor
APS 1540 Magnetometers (3)
Seabird SBE49 CTD
Seapoint OBS
Anderaa optode model 4330
300kHz RDI DVL
IXEA PHINS
Reson Sound Velocity Probe

This dive was not renavigated as the DVL never got bottom-lock

Important Positions

Dive Origin: 18 21.273 -163 -16.755

Launch Position: sentry291 launch position: 18 22.080'N 163 17.106'W

Narrative

Launch was normal, but the descent process ended early when the DVL detected a "false bottom" when it was still out of range of the seafloor. We drove the vehicle down with an acoustic command and made some slow progress until the program switched the fwd speed from 0.8 to 0.6 m/s. Then the vehicle was unable to descend as it was ballasted quite light. When we were unable to force the vehicle down (we did not understand the ballast issue at the time), we aborted the dive. Had we increased the fwd speed to at least 0.8m/s, we probably could have forced the vehicle down and saved the dive.

1   Issues and Proposed Solutions

Tighten up the depth window for the descent process to accept DVL data.

Chief Scientist Comments

The Chief scientist is requested to include any desired comments.

Dive Statistics

Sentry291 Summary Launch: 2014/12/18 23:10:25
Survey start: 2014/12/19 02:01:44
Latitude: 18.348628 Longitude -163.286060
Depth: 5582.03
Survey end: 2014/12/19 04:04:50
Latitude: 18.357762 Longitude -163.301890
Depth: 5038.20
Ascent begins: 2014/12/19 04:04:50
On the surface: 2014/12/19 05:38:40
On deck: 2014/12/19 06:09:46
descent rate: 32.6 m/min
ascent rate: 53.7 m/min
survey time: 2.1 hours
deck-to-deck time 7.0 hours
Mean survey depth: 5379m
Mean survey height: 512m
distance travelled: 6.81km
average speed; 0.63m/s
average speed during photo runs: 0.02 m/s over 0.16 km
average speed during multibeam runs: 0.70 m/s over 4.46 km
total vertical during survey: 1183m
Battery energy at launch: 13.2 kwhr
Battery energy at survey end: 11.9 kwhr
Battery energy on deck: 11.4 kwhr
Battery energy used for survey: 0.6 kwhr
Average power during survey: 312.0 watts

Plots and Images

This section contains selected images of data products and plots of vehicle navigation and selected sensors.
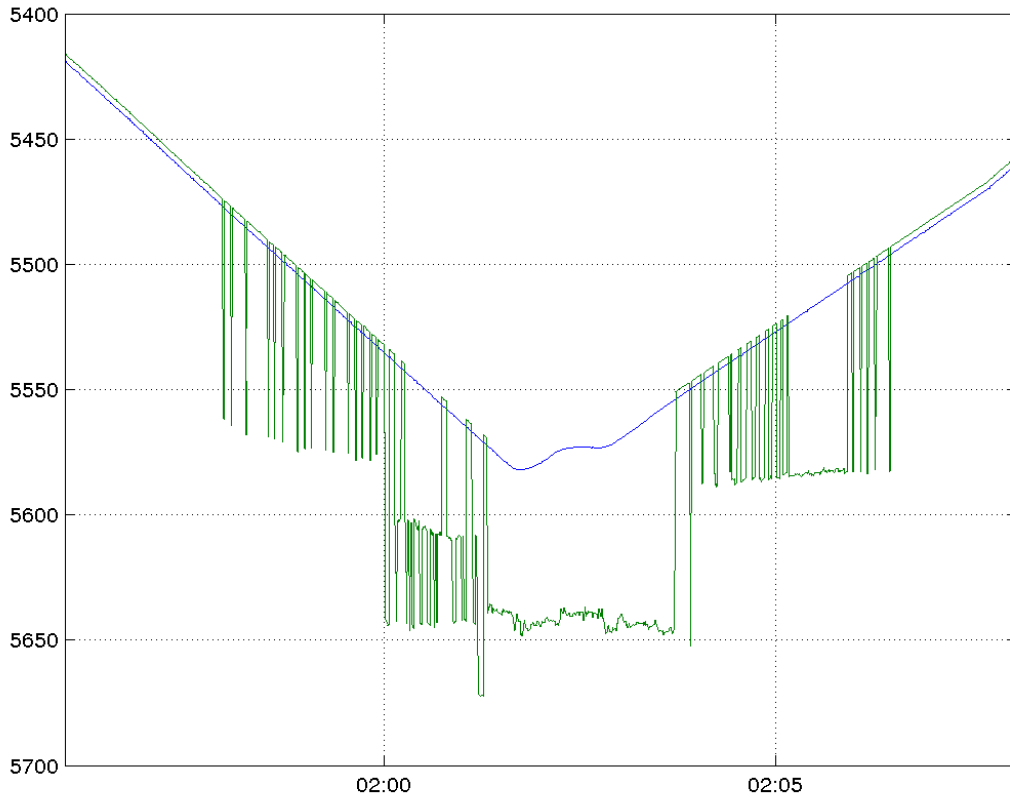
Figure 2: This plot shows why the descent process ended too early, as about 02:01:30. While the vehicle was still about 300m above the seafloor, it saw a false bottom at 5650 when in fact the bottom was at 5850 (this is based on data from Sentry127 in 2011). The dvl readings for about 2.5 minutes met all the criteria. The vehicle was deeper than the depth at which the dvl was enabled (5570), the altitude was below the minimum (80m), and the altitude was decreasing (at least until the weight was released). After a number of such readings, the hit counter reached the needed value and the descent process ended. We can see two other stretches with such false bottoms, the last one running for nearly a minute without a missed return. The dvl readings during those times appeared solid. The DVL got 3 or 4 beam solutions on the false bottoms. I think there was some sort of layer there, which the DVL detected as the bottom.
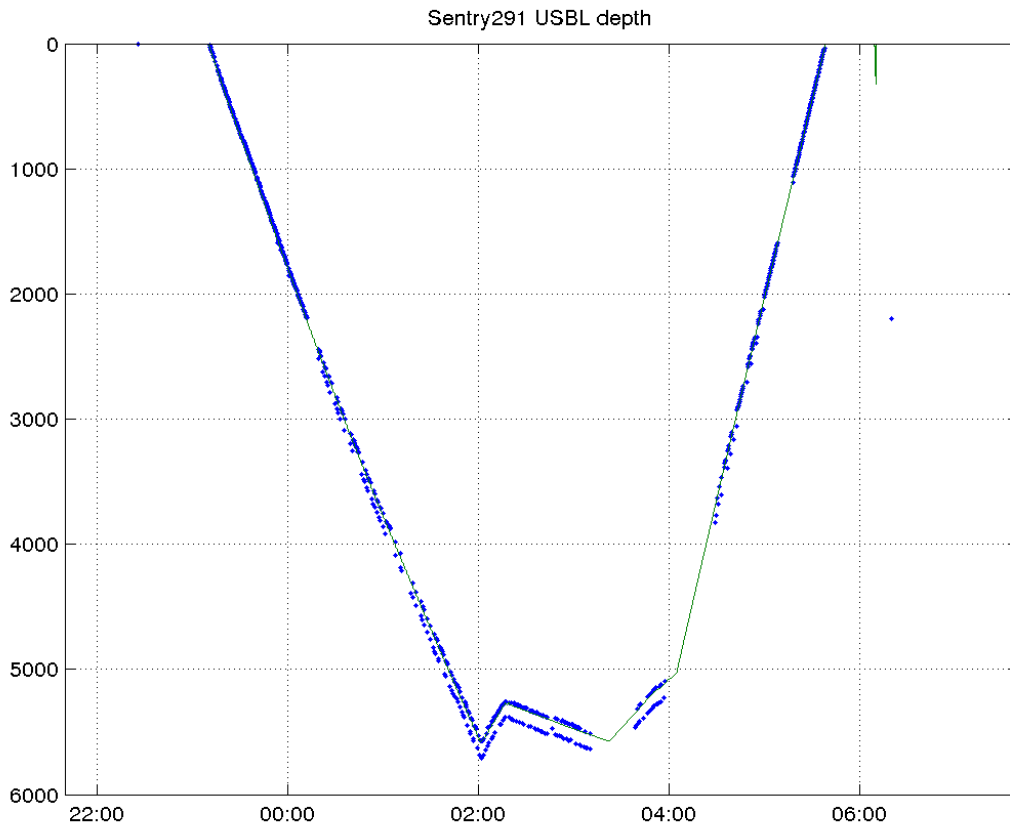
Figure 3: This plot shows the USBL depth for Sentry291 along with the measured depth (green trace). Overall, performance is good with a few concerns. We had several sonardyne vacations when the topside ranger program stopped working. The double trace represents both avtrak transponders, although their IDs are the same (we will fix that). They report consistently different depths below about 2200m, but report the same depth above. This is a mystery. A problem with the turn-around time (mismatch between what's in the transponder and how the Ranger program is setup) would explain a difference but would not explain why the depths match much better above 2200m. Was something reset during the first vacation as the vehicle descended through 2400m? How could that have been reset on the way up? The difference seems to get larger with depth. Could the two avtraks be using different sound velocity profiles? That seems impossible, I don't know how two svps could be active.
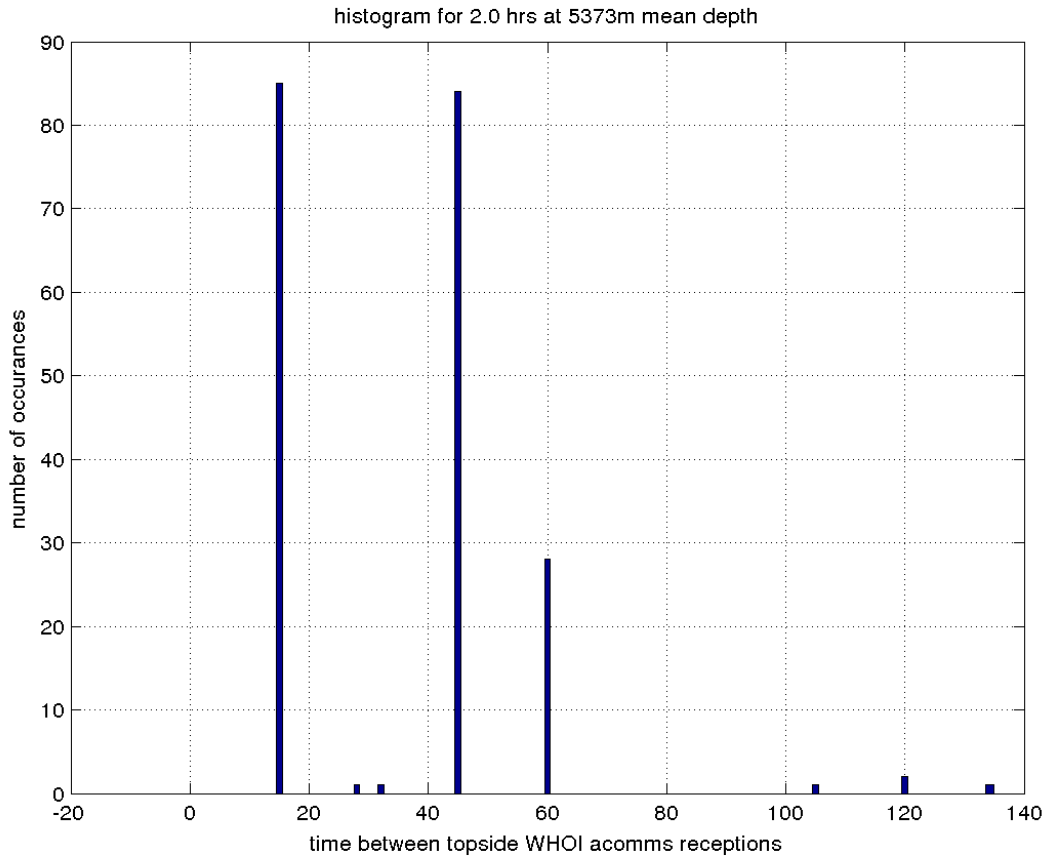
Figure 4: This plot shows a histogram of the time between receptions for the WHOI acomms when the vehicle was at depth. We setup the WHOI acomms to send a message at the top of the minute and at 15 seconds after the minute. If we never missed a message, only the 15 and 45 sec intervals would be populated. The 60 second bin corresponds to instances where one reception was missed but the previous and following messages were received. Together, that constitutes very good performance and we would be functional with considerably less performance. We had an average SNR of 8 topside. While this might drop at longer ranges, we should have acomms to ranges over 6000m.

Sentry 292 Dive Report
DRAFT

WHOI Sentry Operations Group
Dr. Dana Yoerger, Alan Duester, Andrew Billings, Zachary Berkowitz, Daniel Bogorff

Sentry Expedition Leader: Dr. Dana Yoerger

Chief Scientist: Masako Tominaga, Michigan State University
Co-PI: Maurice Tivey, WHOI

Summary

Weather: The weather was within the operating window. winds were steady at 20 knots with moderate, confused swells.

Reason for end of dive: We terminated the dive to maintain our 48 hour schedule using an acoustic command. we had 11% remaining at the time, the limit was set to 8%.

Vehicle Configuration

The science sensing suite for this dive was:

Table 4: Sentry Sensor Configuration

Sensor
APS 1540 Magnetometers (3)
Seabird SBE49 CTD
Seapoint OBS
Anderaa optode model 4330
300kHz RDI DVL
IXEA PHINS
Reson Sound Velocity Probe

This dive was navigated using the DVL/INS system in real time. USBL provided post-dive corrections.

Important Positions

Dive Origin: 18 34.212 162 59.262

Launch Position: sentry292 launch position: 18 34.212'N 162 59.262'E

Narrative

This was our first operational science dive. The launch, descent, survey, ascent, and recovery went substantially as planned. We increased the speed from 0.80m/s to 1.0m/s over the course of the dive. We were pleased that the vehicle covered 93.4 km over 30.1 hours of seafloor survey.

1 Issues and Proposed Solutions

numerous display changes for navG

improve resolution of battery data on WHOI acomms

Chief Scientist Comments

The Chief scientist is requested to include any desired comments.

Dive Statistics

1.1 sentry292 Summary

sentry292 Summary
Origin: 18.570200 162.987700
Origin: 18 34.212'N 162 59.262'E
Launch: 2014/12/27 10:40:30
Survey start: 2014/12/27 12:56:14
Survey start: Lat:18.572584 Lon:162.985670
Survey start: Lat:18 34.355'N Lon:162 59.140'E
Survey end: 2014/12/28 19:00:48
Survey end: Lat:19.152237 Lon:163.613144
Survey end: Lat:19 9.134'N Lon:163 36.789'E
Ascent begins: 2014/12/28 19:00:48
On the surface: 2014/12/28 20:35:14
On deck: 2014/12/28 21:10:11
descent rate: 38.2 m/min
ascent rate: 54.4 m/min
survey time: 30.1 hours
deck-to-deck time 34.5 hours
Mean survey depth: 5114m
Mean survey height: 100m
distance travelled: 93.43km
average speed; 0.86m/s
average speed during photo runs: NaN m/s over 0.00 km
average speed during multibeam runs: 0.84 m/s over 93.43 km
total vertical during survey: 6194m
Battery energy at launch: 13.6 kwhr
Battery energy at survey end: 1.3 kwhr
Battery energy on deck: 1.0 kwhr

Plots and Images

This section contains selected images of data products and plots of vehicle navigation and selected sensors.
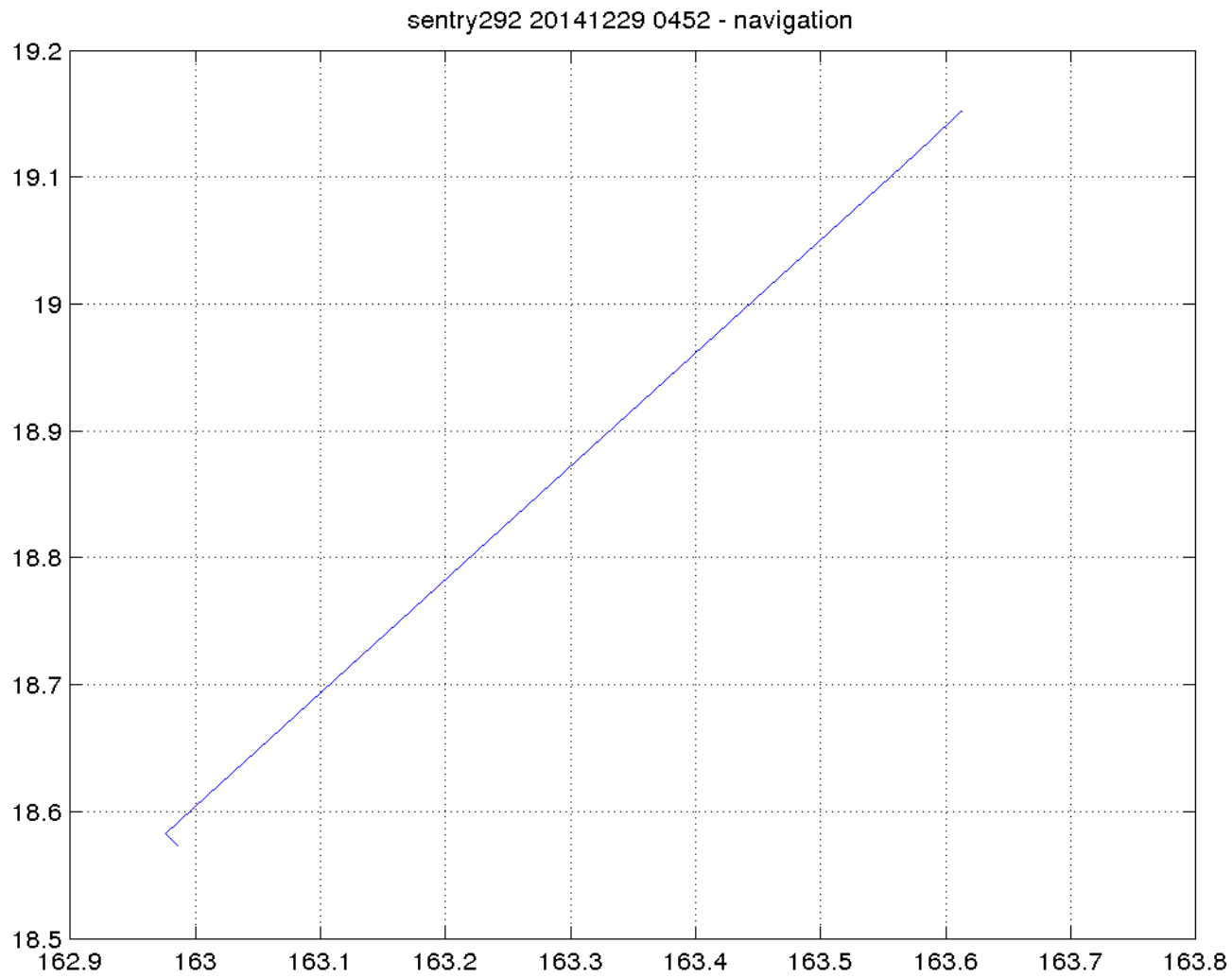
Figure 5: Latitude/Longitude plot of Sentry dive 292 based on post-processed navigation.
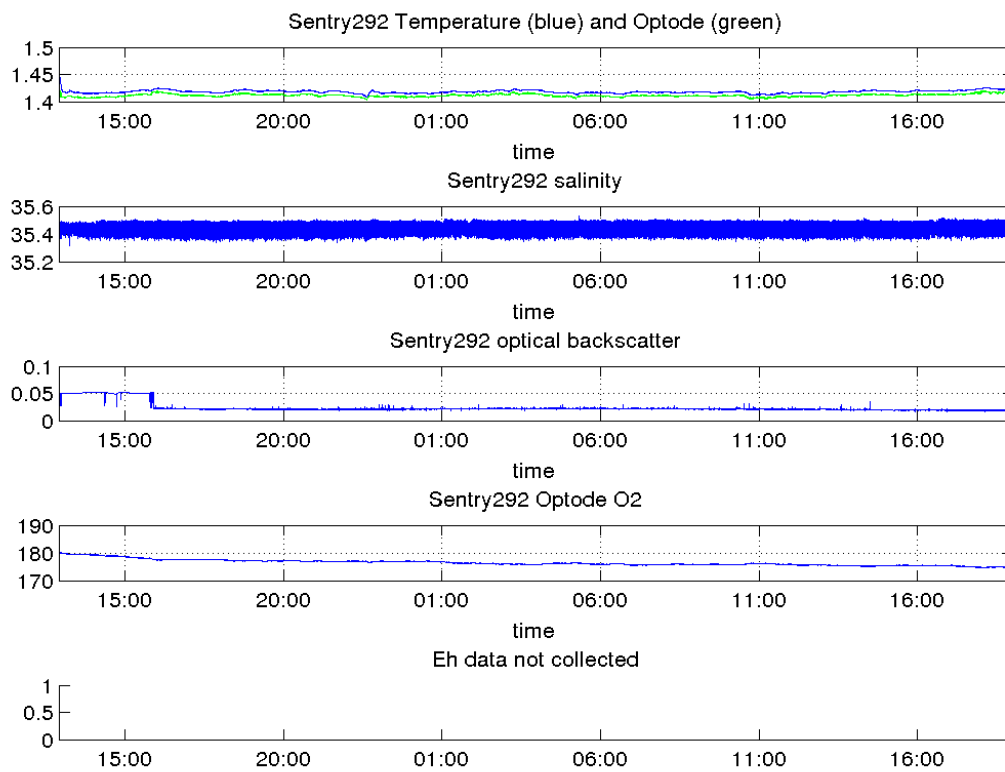
Figure 6: Time series plot of five of the basic sensors on Sentry, from top to bottom, temperature, salinity, optical backscatter, and dissolved Oxygen.

Figure 7: Depth and Altitude of Sentry during dive 292.
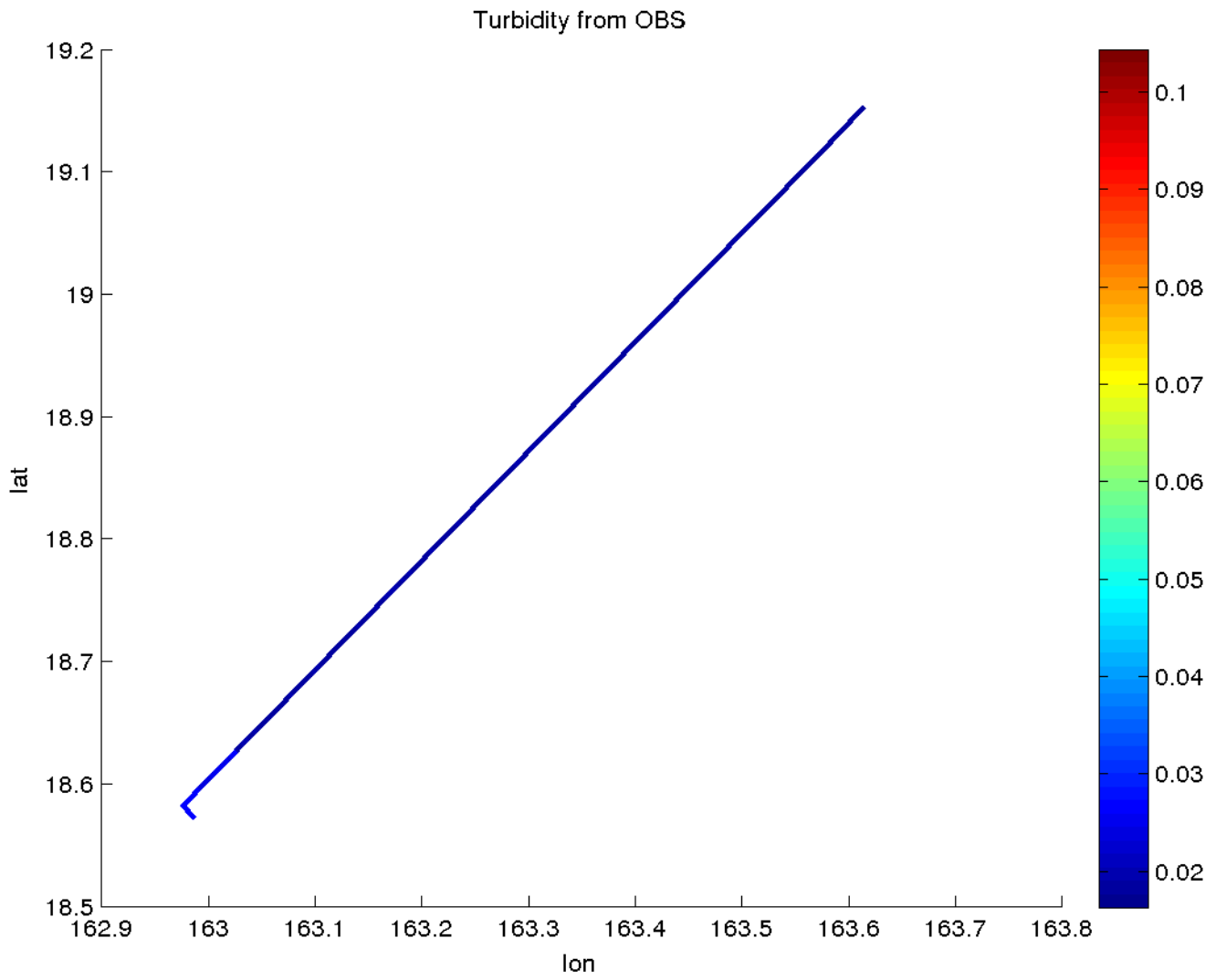
Figure 8: Optical backscatter on dive 292.

Sentry 293 Dive Report
DRAFT

WHOI Sentry Operations Group
Dr. Dana Yoerger, Alan Duester, Andrew Billings, Zachary Berkowitz, Daniel Bogorff

Sentry Expedition Leader: Dr. Dana Yoerger

Chief Scientist: Masako Tominaga, Michigan State University
Co-PI: Maurice Tivey, WHOI

Summary

Weather: The weather was well within the operating window. On recovery, winds were at 10 knots and dropping. Moderate, confused swells.

Reason for end of dive: We terminated the dive to maintain our 48 hour schedule using an acoustic command. we had 11% remaining at the time, the limit was set to 8%.

Vehicle Configuration

The science sensing suite for this dive was:

Table 5: Sentry Sensor Configuration

Sensor
APS 1540 Magnetometers (3)
Seabird SBE49 CTD
Seapoint OBS
Anderaa optode model 4330
300kHz RDI DVL
IXEA PHINS
Reson Sound Velocity Probe

This dive was navigated using the DVL/INS system in real time. USBL provided post-dive corrections.

Important Positions

Dive Origin: 19 7.594 163 33.590

Launch Position: sentry293 launch position: 19 7.594'N 163 33.590'E

Narrative

This was our second science dive. The launch, descent, survey, ascent, and recovery went substantially as planned. We began the dive at 0.95 m/s based on the projections from sentry292 for 30 hours of bottom time. Energy consumption was higher on this dive. We slowed the vehicle to 0.90 m/s but still ended two hours early when we reached the battery limit of 8%.

1 Issues and Proposed Solutions

numerous display changes for navG

improve resolution of battery data on WHOI acomms

stay on top of power consumption to maximize distance covered for each dive while keeping to a 48 hr cycle.

Chief Scientist Comments

The Chief scientist is requested to include any desired comments.

Dive Statistics

1.1 sentry293 Summary

sentry293 Summary
Origin: 19.126567 163.559833
Origin: 19 7.594'N 163 33.590'E
Launch: 2014/12/29 10:46:47
Survey start: 2014/12/29 13:03:44
Survey start: Lat:19.126899 Lon:163.559603
Survey start: Lat:19 7.614'N Lon:163 33.576'E
Survey end: 2014/12/30 16:55:45
Survey end: Lat:19.686732 Lon:164.199469
Survey end: Lat:19 41.204'N Lon:164 11.968'E
Ascent begins: 2014/12/30 16:55:45
On the surface: 2014/12/30 18:31:38
On deck: 2014/12/30 18:49:52
descent rate: 37.6 m/min
ascent rate: 54.4 m/min
survey time: 27.9 hours
deck-to-deck time 32.1 hours
Mean survey depth: 5258m
Mean survey height: 100m
distance travelled: 91.98km
average speed; 0.91m/s
average speed during photo runs: NaN m/s over 0.00 km
average speed during multibeam runs: 0.89 m/s over 91.98 km
total vertical during survey: 6364m
Battery energy at launch: 13.5 kwhr
Battery energy at survey end: 1.0 kwhr
Battery energy on deck: 0.7 kwhr

Plots and Images

This section contains selected images of data products and plots of vehicle navigation and selected sensors.

Figure 9: Latitude/Longitude plot of Sentry dive 293 based on post-processed navigation.
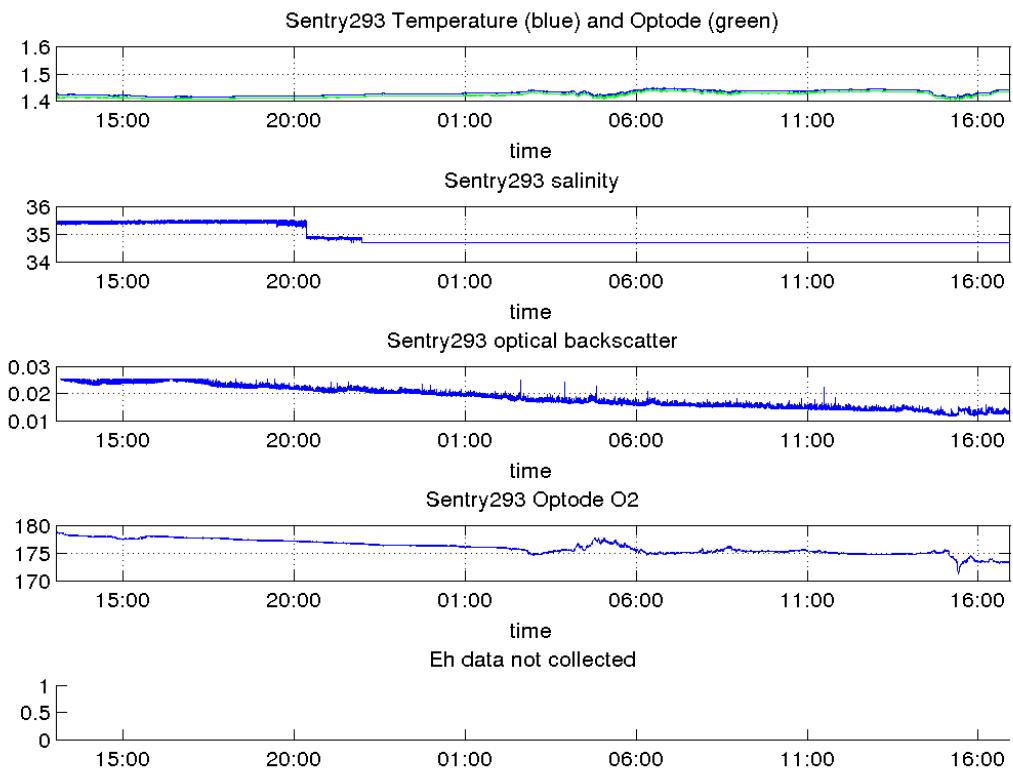
Figure 10: Time series plot of five of the basic sensors on Sentry, from top to bottom, temperature, salinity, optical backscatter, and dissolved Oxygen.

Figure 11: Depth and Altitude of Sentry during dive 293. The vehicle negotiated a seamount 500m high at the end of the dive without incident
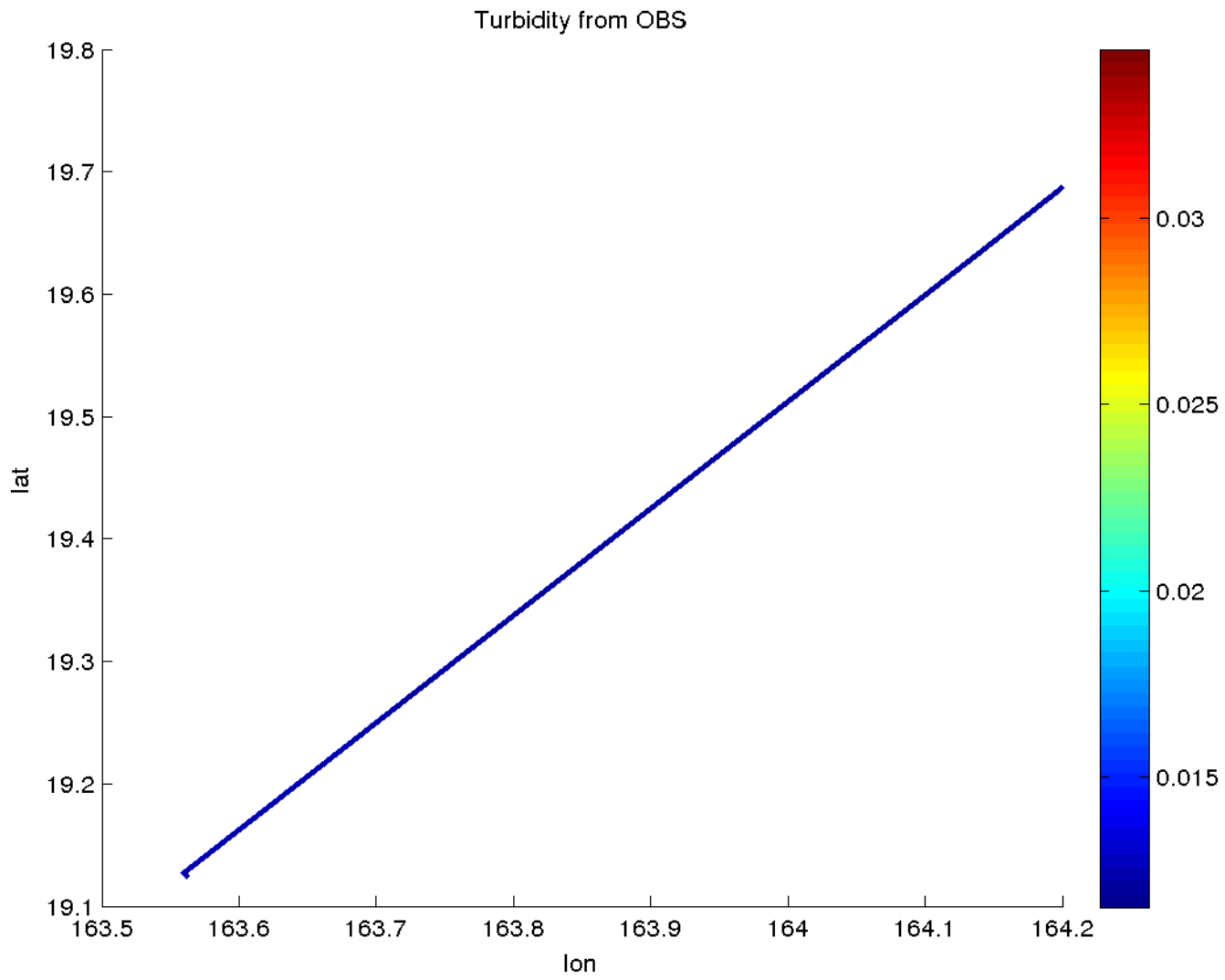
Figure 12: Optical backscatter on dive 293.

Sentry 294 Dive Report
DRAFT

WHOI Sentry Operations Group
Dr. Dana Yoerger, Alan Duester, Andrew Billings, Zachary Berkowitz, Daniel Bogorff

Sentry Expedition Leader: Dr. Dana Yoerger

Chief Scientist: Masako Tominaga, Michigan State University
Co-PI: Maurice Tivey, WHOI

Summary

Weather: The weather was well within the operating window. On recovery winds were at 13 knots and rising, moderate confused swells.

Reason for end of dive: the dive ended on low battery when programmed level of 8% was reached.

Vehicle Configuration

The science sensing suite for this dive was:

Table 6: Sentry Sensor Configuration

Sensor
APS 1540 Magnetometers (3)
Seabird SBE49 CTD
Seapoint OBS
Anderaa optode model 4330
300kHz RDI DVL
IXEA PHINS
Reson Sound Velocity Probe

This dive was navigated using the DVL/INS system in real time. USBL provided post-dive corrections.

Important Positions

Dive Origin: 19 38.403 164 11.776

Launch Position: sentry294 launch position: 19 38.403'N 164 11.776'E

Narrative

This was our 3rd science dive. The launch, descent, survey, ascent, and recovery went substantially as planned. We began the dive at 0.95 m/s based on the projections from sentry292 but immediately dropped that to 0.90 m/s. Energy consumption was again higher on this dive than on 292. The dive ended two hours early when we reached the battery limit of 8%.

1   Issues and Proposed Solutions

numerous display changes for navG were resolved

improve resolution of battery data on WHOI acomms

stay on top of power consumption to maximize distance covered for each dive while keeping to a 48 hr cycle.

Chief Scientist Comments

The Chief scientist is requested to include any desired comments.

Dive Statistics

1.1   sentry294 Summary

sentry294 Summary
Origin: 19.640050 164.196267
Origin: 19 38.403'N 164 11.776'E
Launch: 2014/12/31 08:39:47
Survey start: 2014/12/31 11:00:25
Survey start: Lat:19.640695 Lon:164.195677
Survey start: Lat:19 38.442'N Lon:164 11.741'E
Survey end: 2015/01/01 14:47:20
Survey end: Lat:20.274879 Lon:164.725340
Survey end: Lat:20 16.493'N Lon:164 43.520'E
Ascent begins: 2015/01/01 14:47:20
On the surface: 2015/01/01 16:26:46
On deck: 2015/01/01 16:43:25
descent rate: 36.7 m/min
ascent rate: 54.4 m/min
survey time: 27.8 hours
deck-to-deck time 32.1 hours
Mean survey depth: 5402m
Mean survey height: 100m
distance travelled: 90.07km
average speed; 0.90m/s
average speed during photo runs: NaN m/s over 0.00 km
average speed during multibeam runs: 0.87 m/s over 90.07 km
total vertical during survey: 5894m
Battery energy at launch: 13.7 kwhr
Battery energy at survey end: 1.0 kwhr
Battery energy on deck: 0.6 kwhr

Plots and Images

This section contains selected images of data products and plots of vehicle navigation and selected sensors.

Figure 13: Latitude/Longitude plot of Sentry dive 294 based on post-processed navigation.
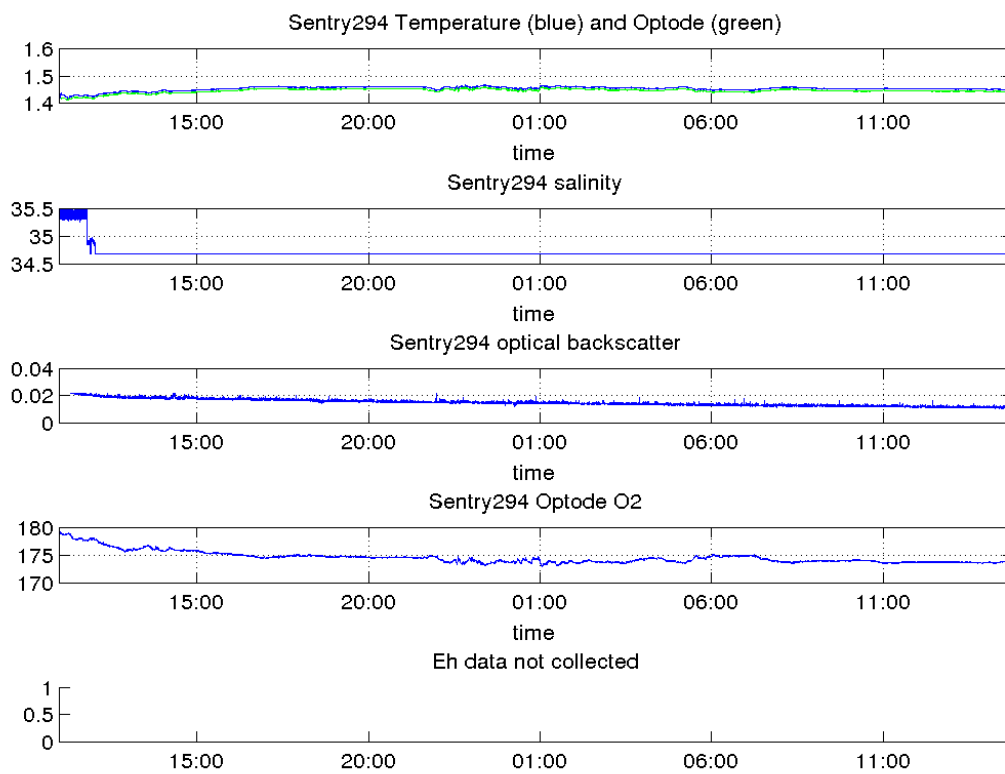
Figure 14: Time series plot of five of the basic sensors on Sentry, from top to bottom, temperature, salinity, optical backscatter, and dissolved Oxygen.
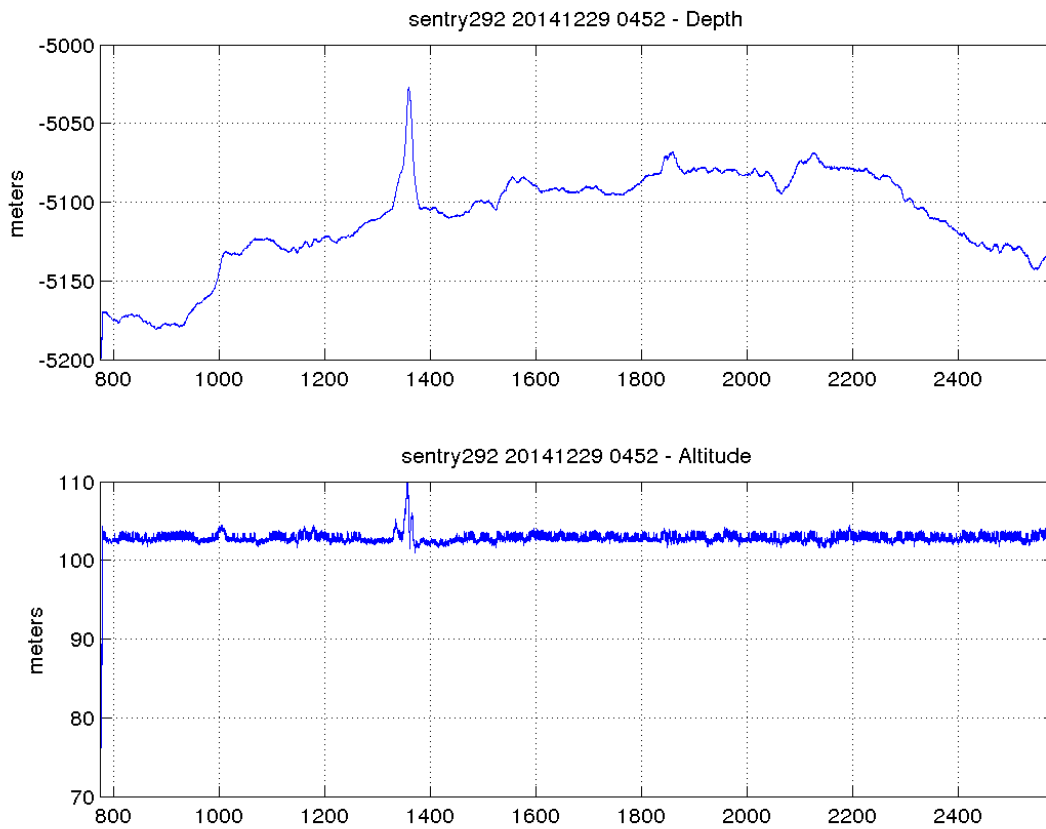
Figure 15: Depth and Altitude of Sentry during dive 294. The vehicle negotiated a seamount 500m high at the end of the dive without incident

Figure 16: Optical backscatter on dive 294.

Sentry 295 Dive Report
DRAFT

WHOI Sentry Operations Group

Dr. Dana Yoerger, Alan Duester, Andrew Billings, Zachary Berkowitz, Daniel Bogorff

Sentry Expedition Leader: Dr. Dana Yoerger

Chief Scientist: Masako Tominaga, Michigan State University
Co-PI: Maurice Tivey, WHOI

Summary

Weather: The weather was well within the operating window. On recovery, winds were at 10 knots and dropping, moderate confused sea.

Reason for end of dive: the dive ended on low battery when programmed level of 8% was reached.

Vehicle Configuration

The science sensing suite for this dive was:

Table 7: Sentry Sensor Configuration

Sensor
APS 1540 Magnetometers (3)
Seabird SBE49 CTD
Seapoint OBS
Anderaa optode model 4330
300kHz RDI DVL
IXEA PHINS
Reson Sound Velocity Probe

This dive was navigated using the DVL/INS system in real time. USBL provided post-dive corrections.

Important Positions

Dive Origin: 20 14.064 164 41.486

Launch Position: sentry295 launch position: 20 14.064'N 164 41.486'E

Narrative

This was our 4th operational science dive. The launch, descent, survey, ascent, and recovery went substantially as planned. We began the dive at 0.90 m/s based on the projections from sentry293 but dropped that to 0.85 m/s with about 6 hrs left in the dive. Energy consumption was again higher on this dive than on 292. The dive ended about one hour early when we reached the battery limit of 8%. On recovery, we had over 5% battery remaining.

1 Issues and Proposed Solutions

numerous display changes for navG were resolved

improve resolution of battery data on WHOI acomms (resolved)

stay on top of power consumption to maximize distance covered for each dive while keeping to a 48 hr cycle.

Chief Scientist Comments

The Chief scientist is requested to include any desired comments.

Dive Statistics

1.1 sentry295 Summary

sentry295 Summary
Origin: 20.234400 164.691433
Origin: 20 14.064'N 164 41.486'E
Launch: 2015/01/02 08:37:39
Survey start: 2015/01/02 11:04:26
Survey start: Lat:20.237942 Lon:164.690680
Survey start: Lat:20 14.277'N Lon:164 41.441'E
Survey end: 2015/01/03 15:45:24
Survey end: Lat:20.906606 Lon:165.217761
Survey end: Lat:20 54.396'N Lon:165 13.066'E
Ascent begins: 2015/01/03 15:45:24
On the surface: 2015/01/03 17:25:28
On deck: 2015/01/03 17:45:54
descent rate: 36.9 m/min
ascent rate: 54.6 m/min
survey time: 28.7 hours
deck-to-deck time 33.1 hours
Mean survey depth: 5400m
Mean survey height: 100m
distance travelled: 92.01km
average speed; 0.89m/s
average speed during photo runs: NaN m/s over 0.00 km
average speed during multibeam runs: 0.86 m/s over 92.01 km
total vertical during survey: 4953m
Battery energy at launch: 13.6 kwhr
Battery energy at survey end: 1.0 kwhr
Battery energy on deck: 0.6 kwhr

Plots and Images

This section contains selected images of data products and plots of vehicle navigation and selected sensors.
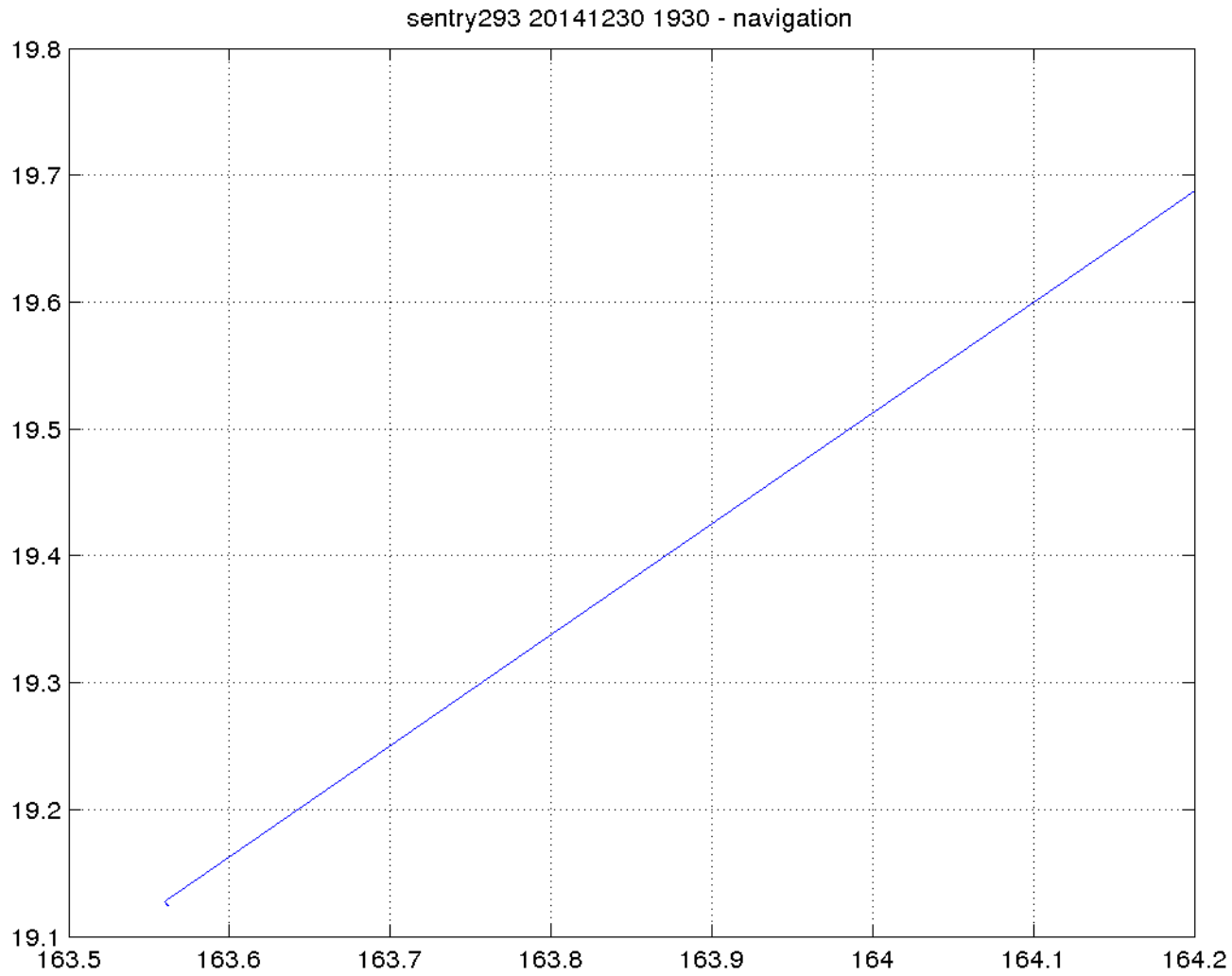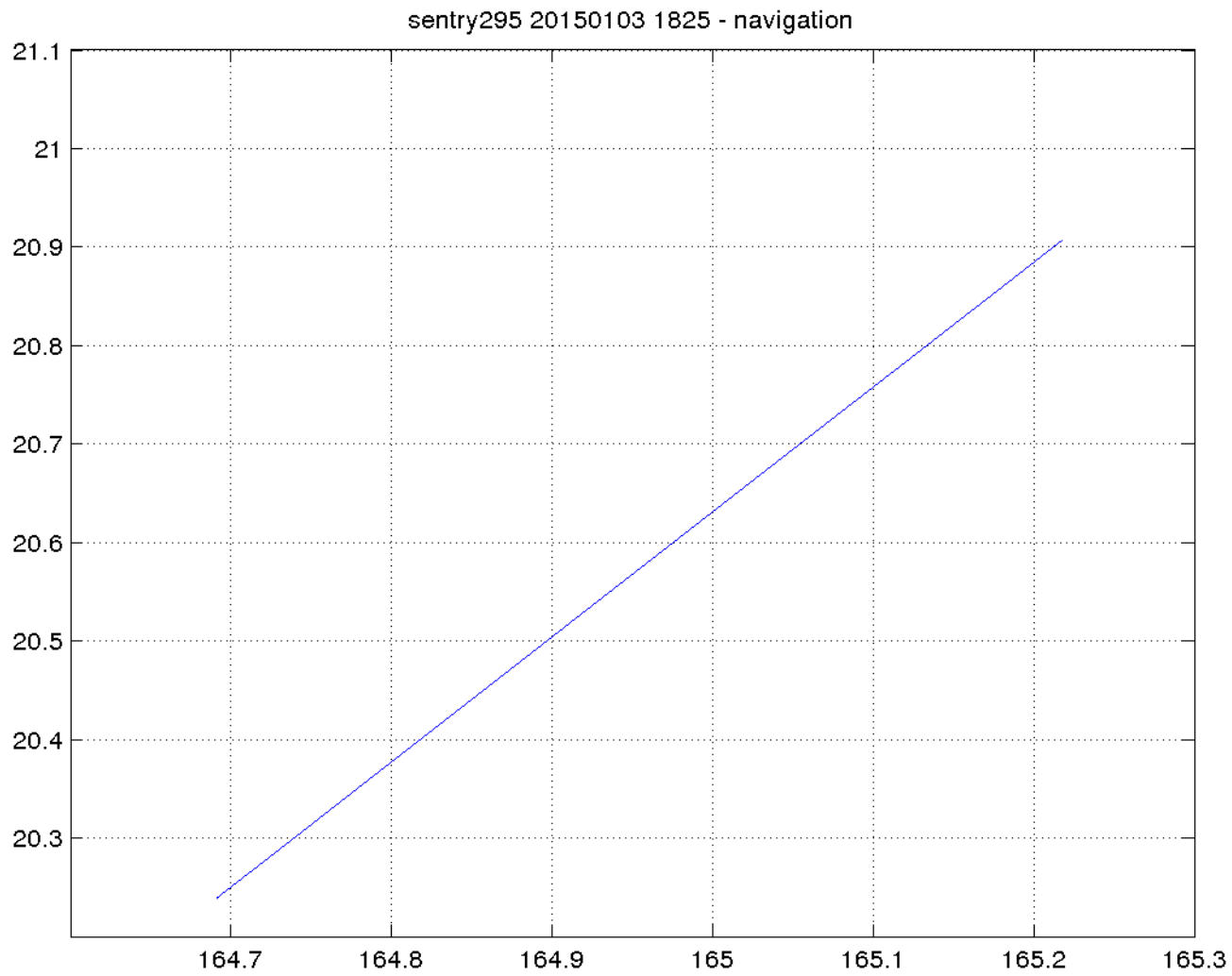

Figure 17: Latitude/Longitude plot of Sentry dive 295 based on post-processed navigation.
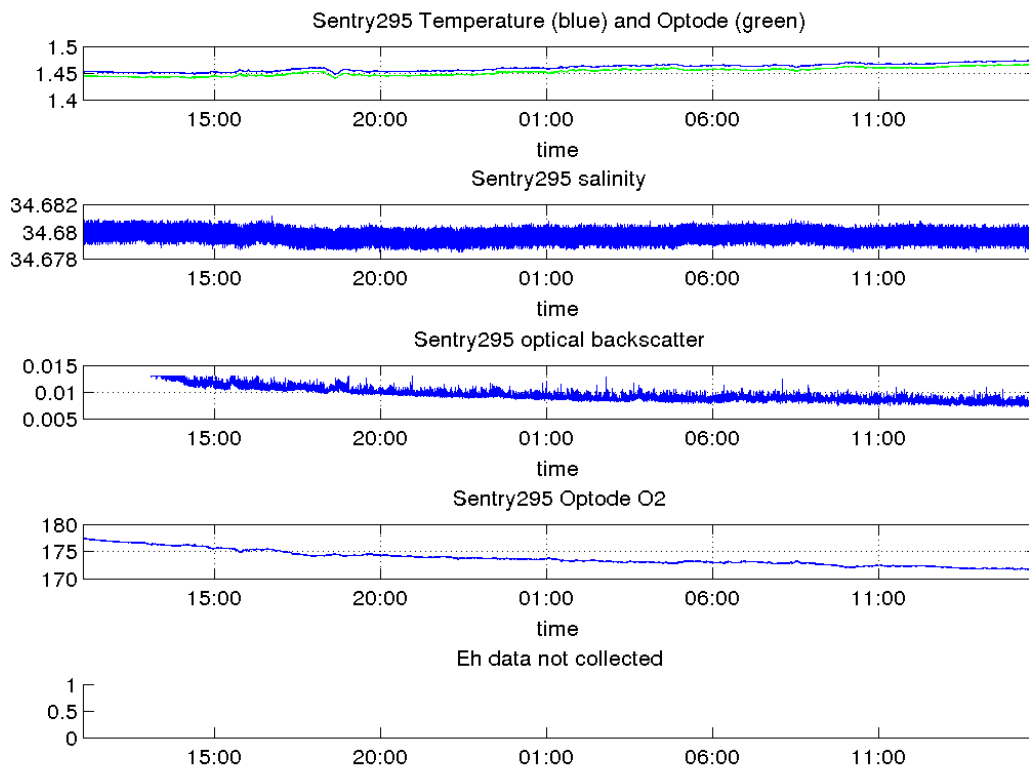
Figure 18: Time series plot of five of the basic sensors on Sentry, from top to bottom, temperature, salinity, optical backscatter, and dissolved Oxygen.
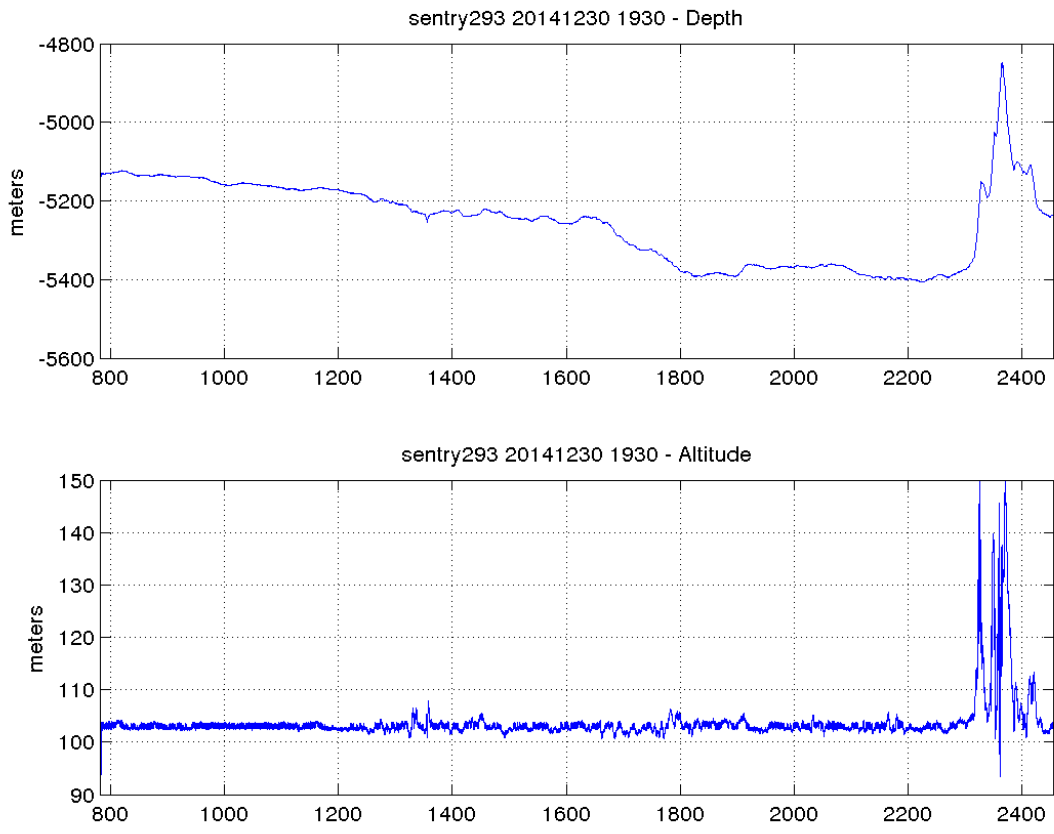
Figure 19: Depth and Altitude of Sentry during dive 295. The vehicle negotiated a seamount 500m high at the end of the dive without incident

Figure 20: Optical backscatter on dive 295.

Sentry 296 Dive Report
DRAFT

WHOI Sentry Operations Group

Dr. Dana Yoerger, Alan Duester, Andrew Billings, Zachary Berkowitz, Daniel Bogorff

Sentry Expedition Leader: Dr. Dana Yoerger

Chief Scientist: Masako Tominaga, Michigan State University
Co-PI: Maurice Tivey, WHOI

Summary

Weather: The weather was within the operating window. Winds were at 18 knots and rising with a moderate, confused swell.

Reason for end of dive: the dive ended on low battery when programmed level of 8% was reached.

Vehicle Configuration

The science sensing suite for this dive was:

Table 8: Sentry Sensor Configuration

Sensor
APS 1540 Magnetometers (3)
Seabird SBE49 CTD
Seapoint OBS
Anderaa optode model 4330
300kHz RDI DVL
IXEA PHINS
Reson Sound Velocity Probe

This dive was navigated using the DVL/INS system in real time. USBL provided post-dive corrections.

Important Positions

Dive Origin: 20. 50.172 165 10.011

Launch Position: sentry296 launch position: 20 50.175'N 165 10.011'E

Narrative

This was our 5th operational science dive. The launch, descent, survey, ascent, and recovery went substantially as planned. We began the dive at 0.90 m/s based on the projections from sentry293 but dropped that to 0.85 m/s after about 6 hrs of survey. Energy consumption was again higher on this dive than on 292. The dive ended at 30.5 hrs of survey time when we reached the battery limit of 8%. On recovery, we had over 5% battery remaining.

1 Issues and Proposed Solutions

stay on top of power consumption to maximize distance covered for each dive while keeping to a 48 hr cycle.

Chief Scientist Comments

The Chief scientist is requested to include any desired comments.

Dive Statistics

1.1 sentry296 Summary

sentry296 Summary
Origin: 20.836200 165.166850
Origin: 20 50.172'N 165 10.011'E
Launch: 2015/01/04 08:19:12
Survey start: 2015/01/04 10:45:14
Survey start: Lat:20.837486 Lon:165.165636
Survey start: Lat:20 50.249'N Lon:165 9.938'E
Survey end: 2015/01/05 17:15:44
Survey end: Lat:21.530405 Lon:165.716819
Survey end: Lat:21 31.824'N Lon:165 43.009'E
Ascent begins: 2015/01/05 17:15:44
On the surface: 2015/01/05 18:58:20
On deck: 2015/01/05 19:19:07
descent rate: 37.2 m/min
ascent rate: 54.4 m/min
survey time: 30.5 hours
deck-to-deck time 35.0 hours
Mean survey depth: 5508m
Mean survey height: 100m
distance travelled: 95.38km
average speed; 0.87m/s
average speed during photo runs: NaN m/s over 0.00 km
average speed during multibeam runs: 0.84 m/s over 95.38 km
total vertical during survey: 4854m
Battery energy at launch: 13.5 kwhr
Battery energy at survey end: 1.0 kwhr
Battery energy on deck: 0.5 kwhr

Plots and Images

This section contains selected images of data products and plots of vehicle navigation and selected sensors.
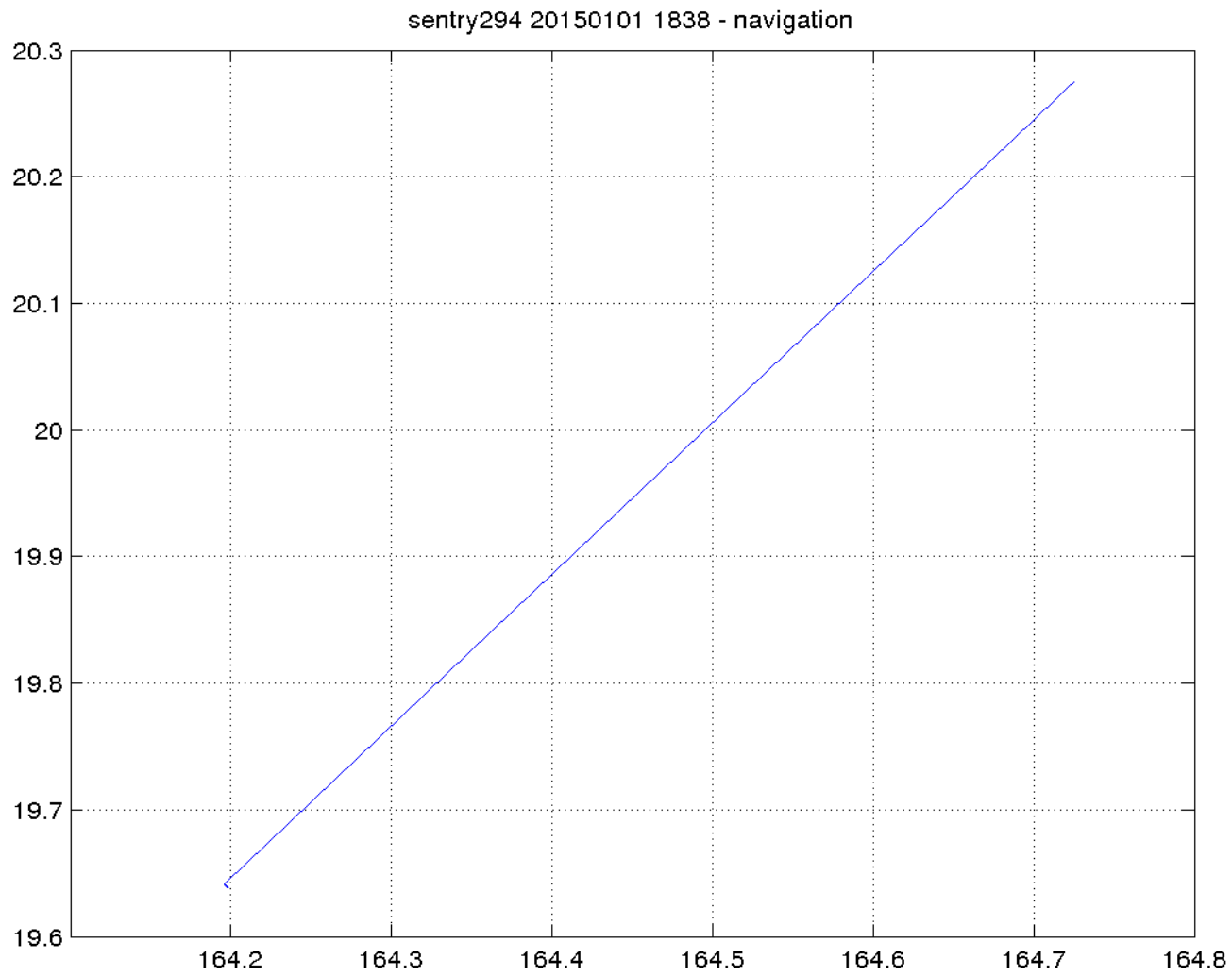

Figure 21: Latitude/Longitude plot of Sentry dive 296 based on post-processed navigation.
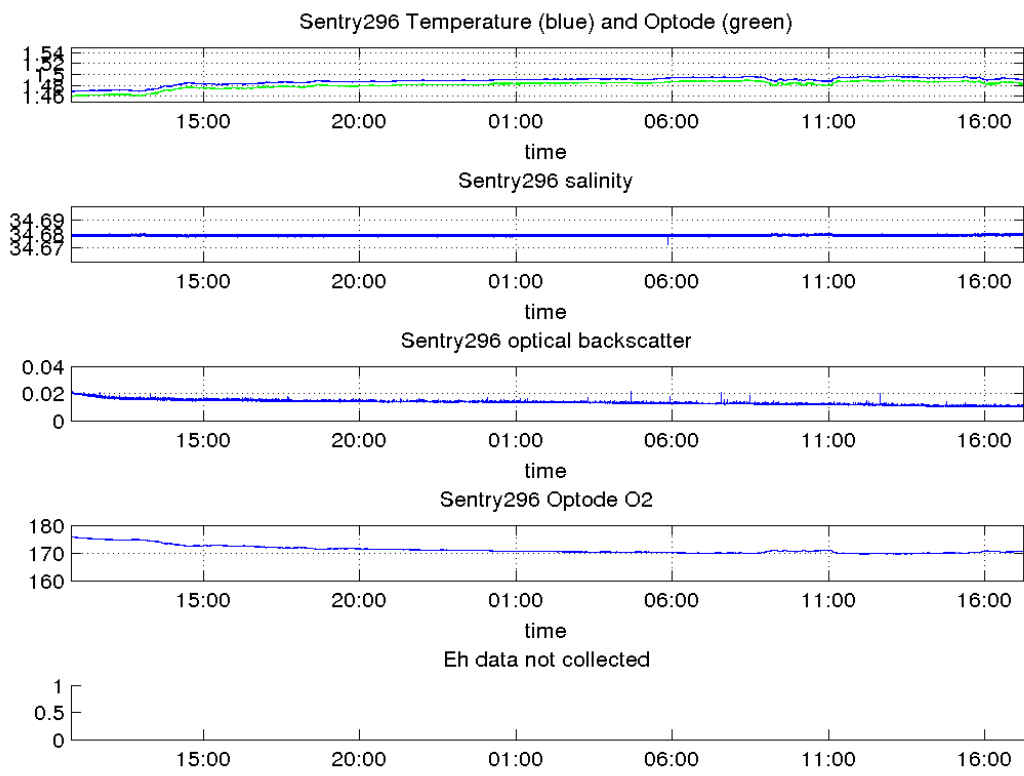
Figure 22: Time series plot of five of the basic sensors on Sentry, from top to bottom, temperature, salinity, optical backscatter, and dissolved Oxygen.
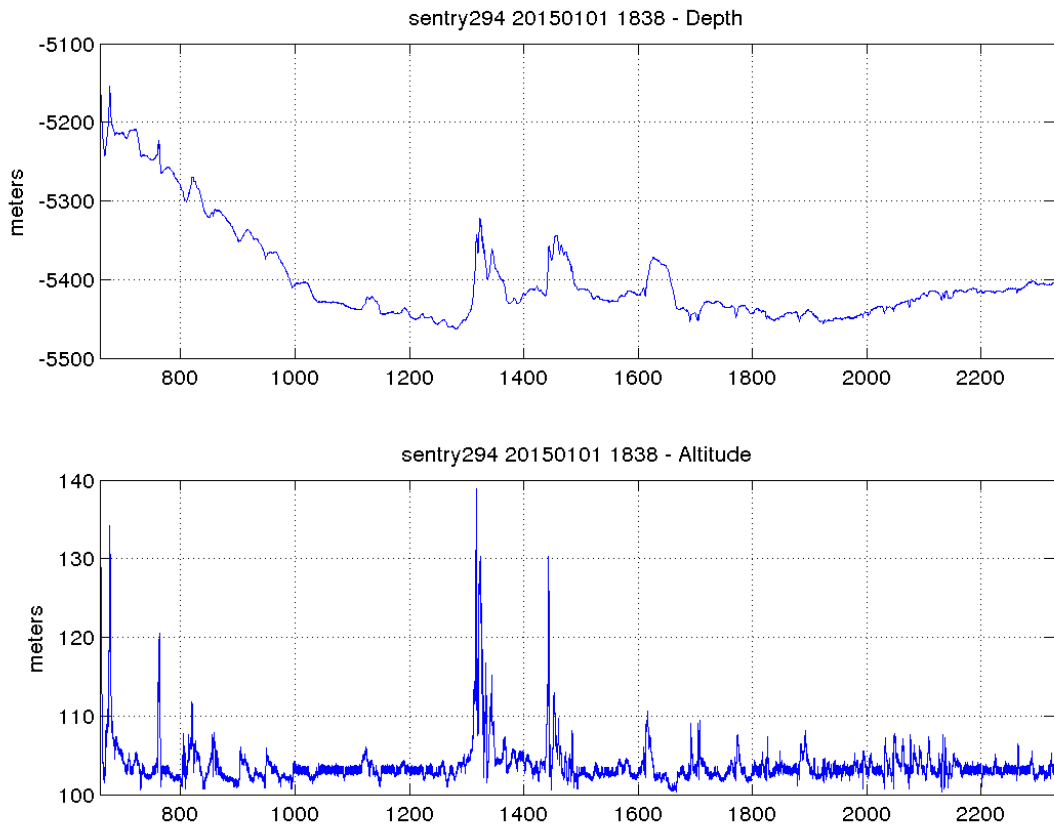
Figure 23: Depth and Altitude of Sentry during dive 296. The vehicle negotiated a seamount 500m high at the end of the dive without incident
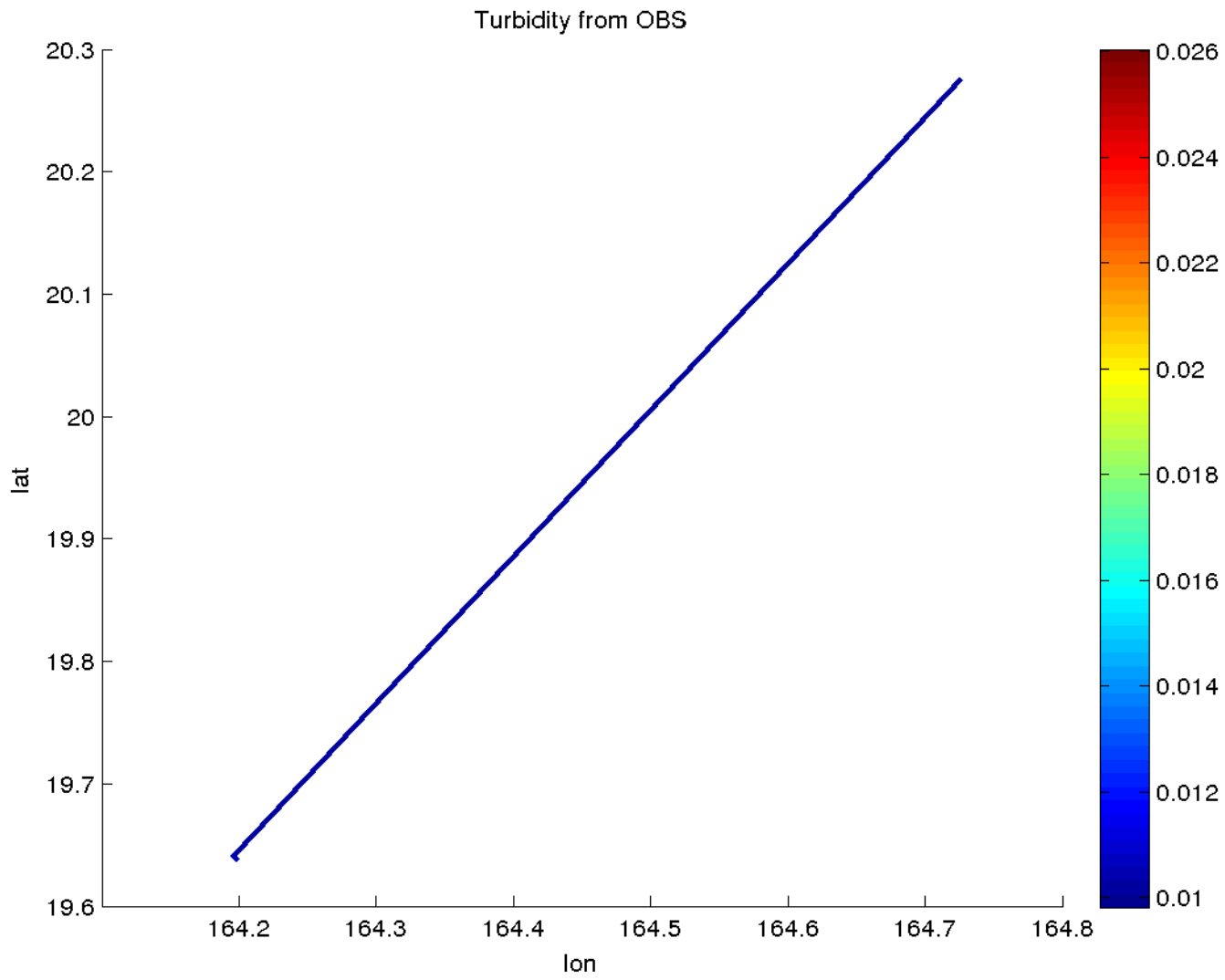
Figure 24: Optical backscatter on dive 296.

Sentry 297 Dive Report
DRAFT

WHOI Sentry Operations Group

Dr. Dana Yoerger, Alan Duester, Andrew Billings, Zachary Berkowitz, Daniel Bogorff

Sentry Expedition Leader: Dr. Dana Yoerger

Chief Scientist: Masako Tominaga, Michigan State University
Co-PI: Maurice Tivey, WHOI

Summary

Weather: The weather was up a bit, the winds had peaked at just of 25 knots in the hour before launch but then settled down well below 20 knots. We specifically discussed the weather with the bosn. We decided we could do a recovery should the dive fail. The dive did fail and we recovered without incident under challenging conditions.

Reason for end of dive: We ended the dive at 1500 m when we recognized that the DVL was not returning proper values.

Vehicle Configuration

The science sensing suite for this dive was:

Table 9: Sentry Sensor Configuration

Sensor
APS 1540 Magnetometers (3)
Seabird SBE49 CTD
Seapoint OBS
Anderaa optode model 4330
300kHz RDI DVL
IXEA PHINS
Reson Sound Velocity Probe

This dive was navigated using the DVL/INS system in real time. USBL provided post-dive corrections.

Important Positions

Dive Origin: 21 28.567 165 42.258

Launch Position: sentry297 launch position: 21 28.567'N 165 42.258'E

Narrative

This was meant to be our 6th operational science dive. This dive had a failure of the on-vehicle navigation due to an improper software startup. On descent, we noticed that the DVL was reporting a bad value. Normally the DVL returns a range of -3 (indeterminant) when the vehicle is in the water column. Instead, we were receiving a code of -1, which is the same code that is returned when the vehicle is on deck. We were certain that the DVL was not in a working condition, so rather than risk impact with the seafloor we aborted the dive at about 1500m depth. In hindsight, this was the right call, the problem was not fixable from the surface.

On careful inspection of the state of the software when the vehicle was on deck, we could see that we did not have a clean shutdown from the deck test. The decktest version of the real-time navigation software, navest, was running. So the real version of navest did not have access to all the proper ports, and both versions were sending data to the other programs.

1   Issues and Proposed Solutions

Revise startup procedure to be certain we have a clean and complete shutdown from the decktest.

We also noted that we expect the DVL to return an altitude of -1 on deck, but that value should change to -3 when the vehicle enters the water.

We should consider adding an automatic abort for the altitude=-1 condition as that indicates that the dvl is not returning expected data even when in mid-water. That check must not be applied on deck.

Chief Scientist Comments

The Chief scientist is requested to include any desired comments.

Dive Statistics

1.1 sentry297 Summary

sentry297 Summary
Origin: 21.476117 165.704300
Origin: 21 28.567'N 165 42.258'E
Launch: 2015/01/06 08:16:31
Survey start: 2015/01/06 09:02:00
Survey start: Lat:21.476162 Lon:165.704339
Survey start: Lat:21 28.570'N Lon:165 42.260'E
Survey end: 2015/01/06 09:02:50
Survey end: Lat:21.476162 Lon:165.704339
Survey end: Lat:21 28.570'N Lon:165 42.260'E
Ascent begins: 2015/01/06 09:02:50
On the surface: 2015/01/06 09:37:36
On deck: 2015/01/06 10:07:55
descent rate: 41.3 m/min
ascent rate: 53.5 m/min
survey time: 0.0 hours
deck-to-deck time 1.9 hours
Mean survey depth: 1876m
Mean survey height: 1m
distance travelled: 0.00km
average speed; 0.00m/s
average speed during photo runs: NaN m/s over 0.00 km
average speed during multibeam runs: NaN m/s over 0.00 km
total vertical during survey: 30m
Battery energy at launch: 13.4 kwhr
Battery energy at survey end: 13.2 kwhr
Battery energy on deck: 13.0 kwhr

Plots and Images

This section contains selected images of data products and plots of vehicle navigation and selected sensors.
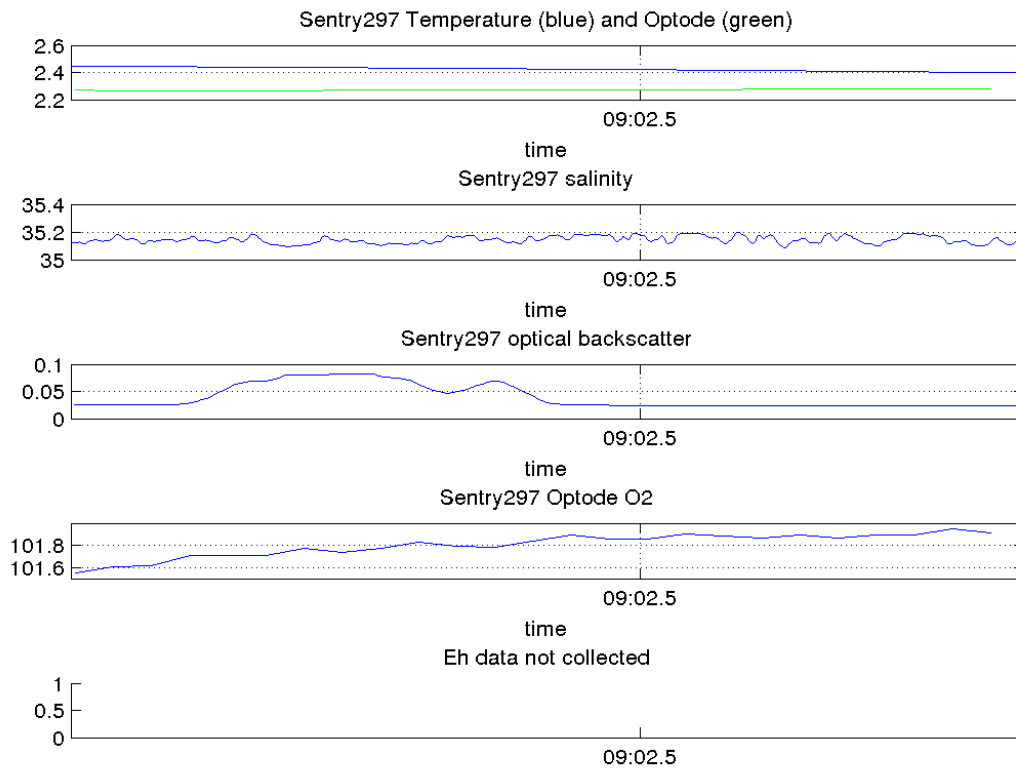
Figure 25: Time series plot of five of the basic sensors on Sentry, from top to bottom, temperature, salinity, optical backscatter, and dissolved Oxygen.
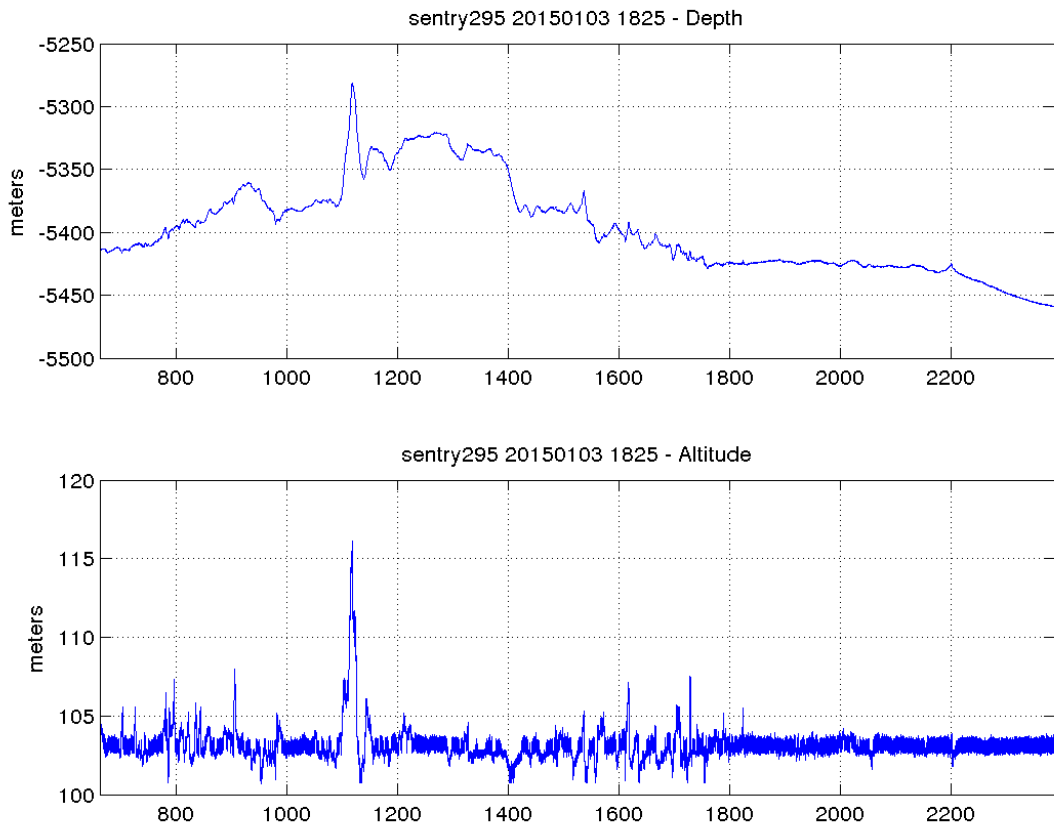
Figure 26: Depth and Altitude of Sentry during dive 296. The vehicle negotiated a seamount 500m high at the end of the dive without incident
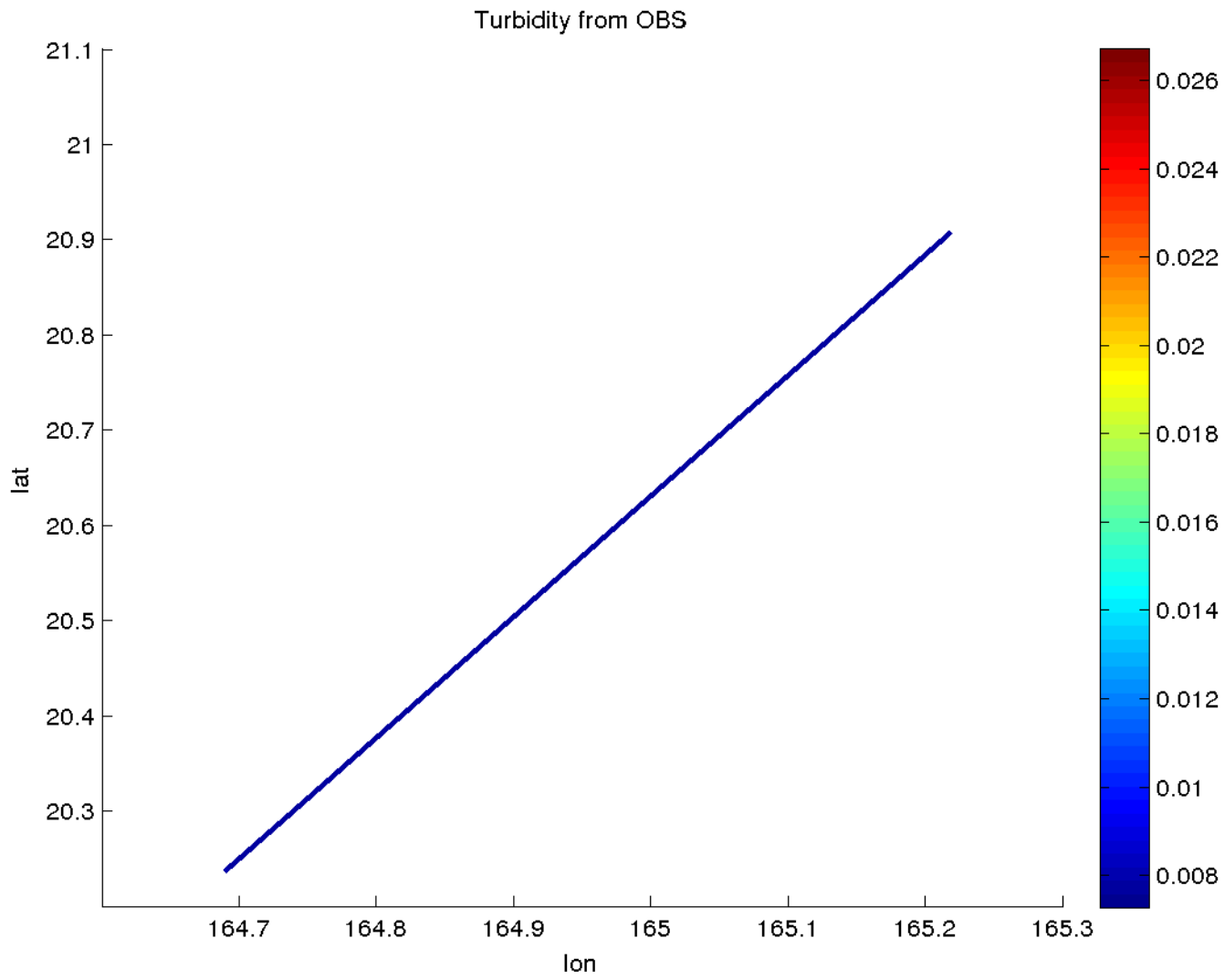
Figure 27: Optical backscatter on dive 296.

Sentry 298 Dive Report
DRAFT

WHOI Sentry Operations Group
Dr. Dana Yoerger, Alan Duester, Andrew Billings, Zachary Berkowitz, Daniel Bogorff

Sentry Expedition Leader: Dr. Dana Yoerger

Chief Scientist: Masako Tominaga, Michigan State University
Co-PI: Maurice Tivey, WHOI

Summary

Weather: The weather was well within the operating window. On recovery winds were at 10 knots and steady. Moderate confused seas.

Reason for end of dive: the dive ended on low battery when programmed level of 8% was reached.

Vehicle Configuration

The science sensing suite for this dive was:

Table 10: Sentry Sensor Configuration

Sensor
APS 1540 Magnetometers (3)
Seabird SBE49 CTD
Seapoint OBS
Anderaa optode model 4330
300kHz RDI DVL
IXEA PHINS
Reson Sound Velocity Probe

This dive was navigated using the DVL/INS system in real time. USBL provided post-dive corrections.

Important Positions

Dive Origin: 21 28.567 165 42.258

Launch Position: sentry298 launch position: 21 28.567'N 165 42.258'E

Narrative

This was our 6th operational science dive. The launch, descent, survey, ascent, and recovery went substantially as planned. We ran the entire dive at 0.85 m/s to maximize our range. The dive ended at 29.2 hrs of survey time when we reached the battery limit of 8%. On recovery, we had over 5% battery remaining.

1 Issues and Proposed Solutions

stay on top of power consumption to maximize distance covered for each dive while keeping to a 48 hr cycle.

Chief Scientist Comments

The Chief scientist is requested to include any desired comments.

Dive Statistics

1.1   sentry298 Summary

sentry298 Summary
Origin: 21.476117 165.704300
Origin: 21 28.567'N 165 42.258'E
Launch: 2015/01/06 13:17:32
Survey start: 2015/01/06 15:46:54
Survey start: Lat:21.475361 Lon:165.703827
Survey start: Lat:21 28.522'N Lon:165 42.230'E
Survey end: 2015/01/07 21:00:35
Survey end: Lat:22.121082 Lon:166.221712
Survey end: Lat:22 7.265'N Lon:166 13.303'E
Ascent begins: 2015/01/07 21:00:35
On the surface: 2015/01/07 22:45:10
On deck: 2015/01/07 23:11:42
descent rate: 37.2 m/min
ascent rate: 55.0 m/min
survey time: 29.2 hours
deck-to-deck time 33.9 hours
Mean survey depth: 5675m
Mean survey height: 100m
distance travelled: 89.01km
average speed; 0.84m/s
average speed during photo runs: NaN m/s over 0.00 km
average speed during multibeam runs: 0.82 m/s over 89.01 km
total vertical during survey: 4662m
Battery energy at launch: 13.3 kwhr
Battery energy at survey end: 1.0 kwhr
Battery energy on deck: 0.6 kwhr

Plots and Images

This section contains selected images of data products and plots of vehicle navigation and selected sensors.
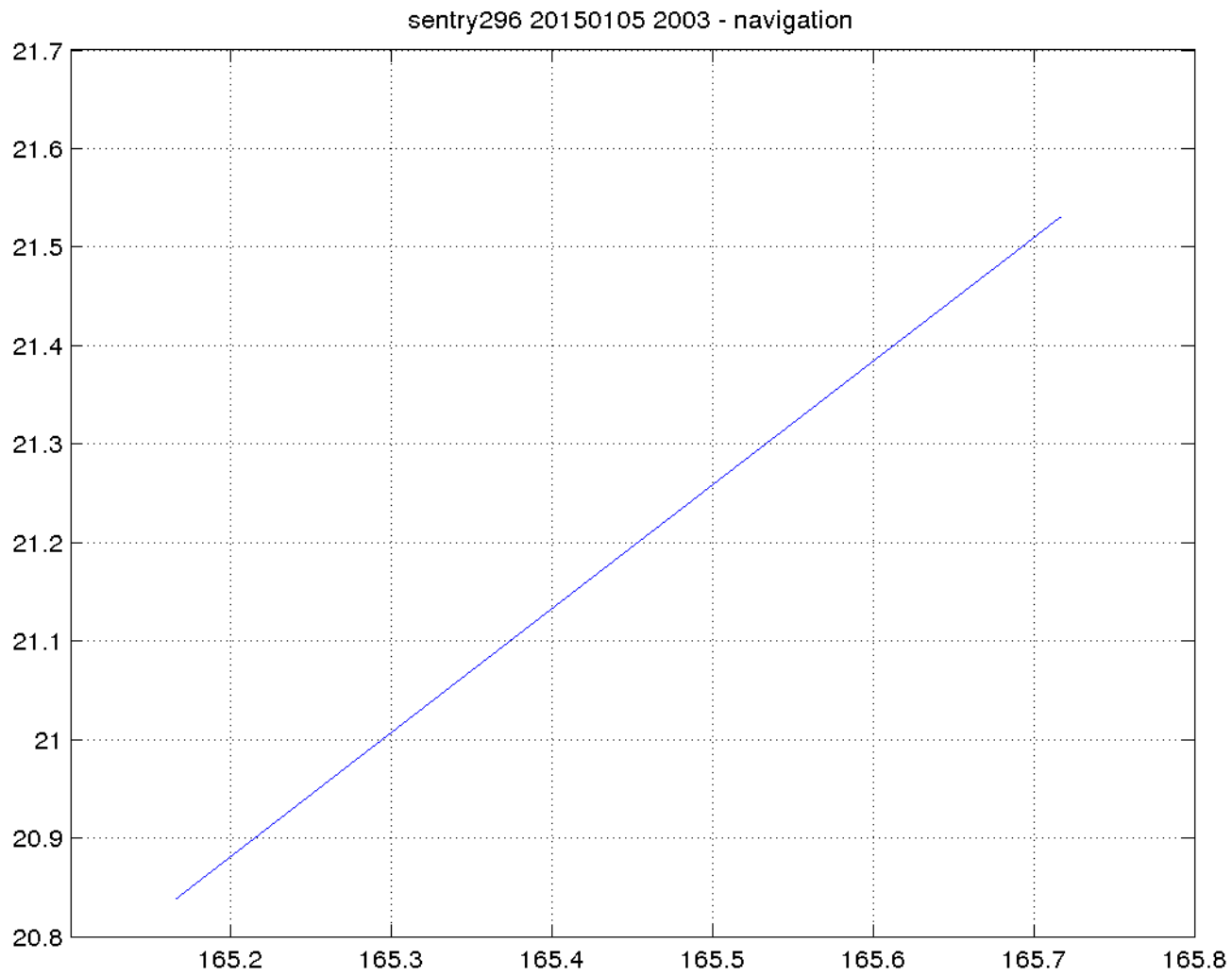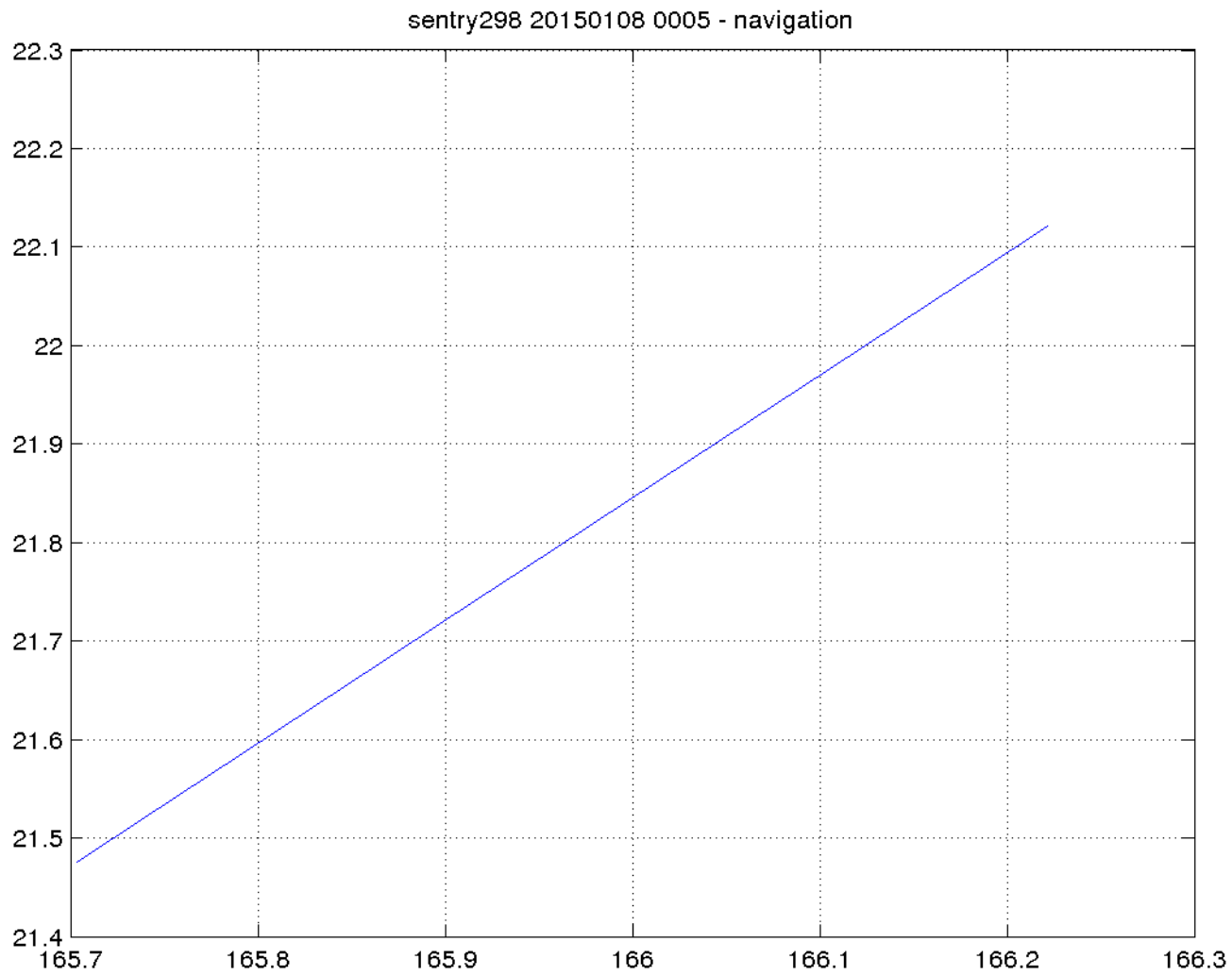

Figure 28: Latitude/Longitude plot of Sentry dive 298 based on post-processed navigation.
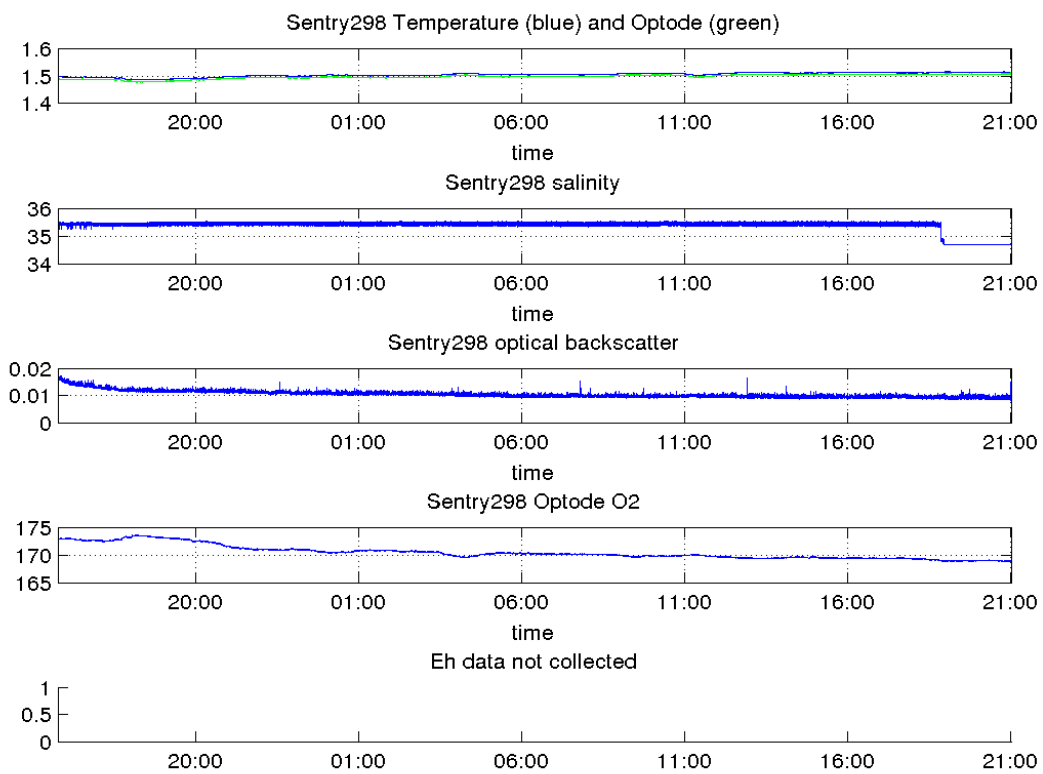
Figure 29: Time series plot of five of the basic sensors on Sentry, from top to bottom, temperature, salinity, optical backscatter, and dissolved Oxygen.
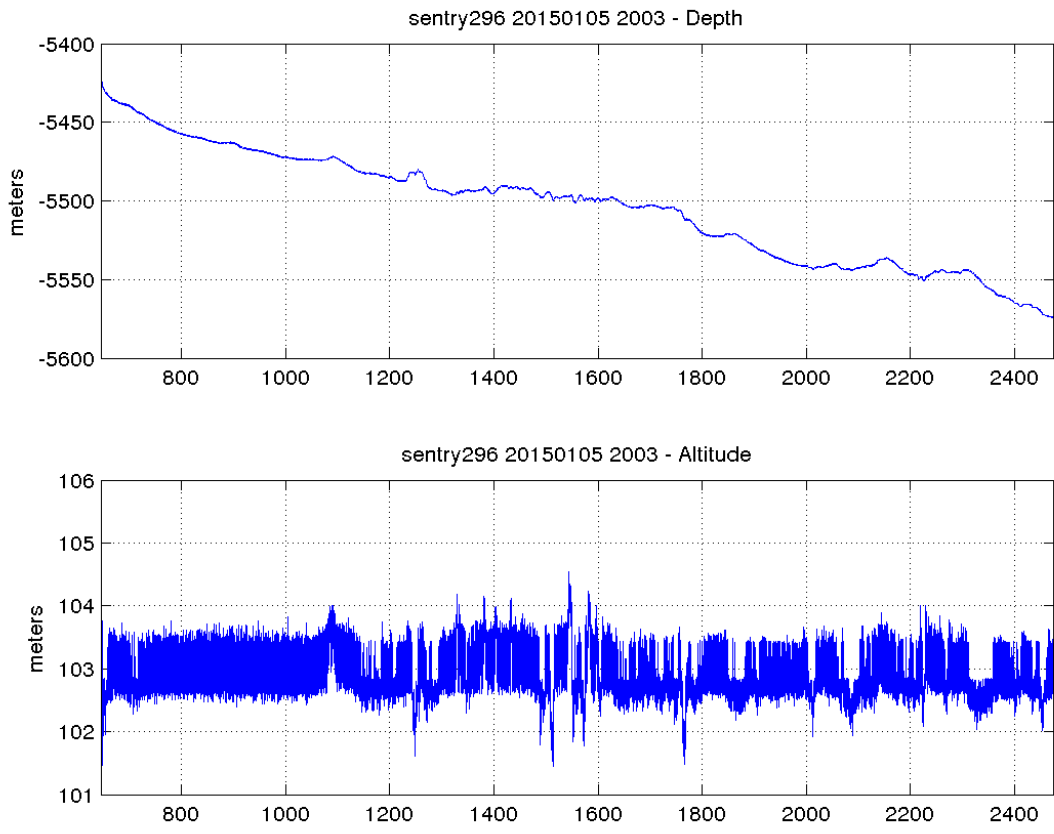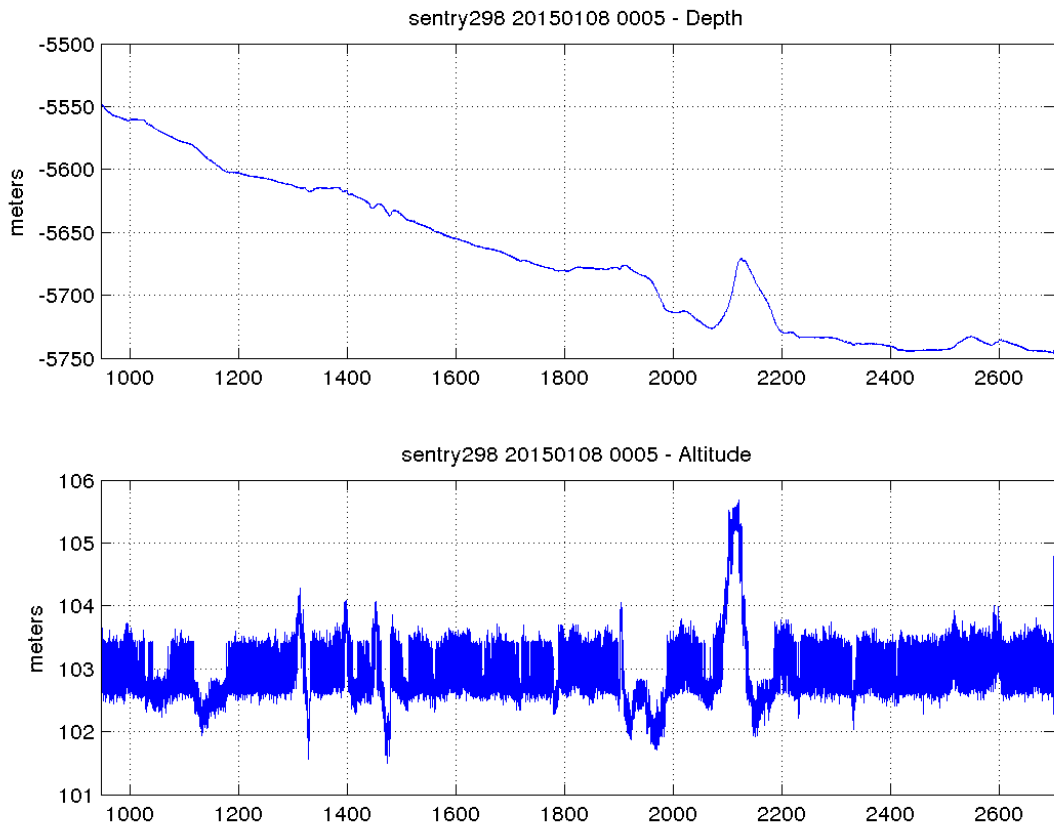
Figure 30: Depth and Altitude of Sentry during dive 298. The vehicle negotiated a seamount 500m high at the end of the dive without incident
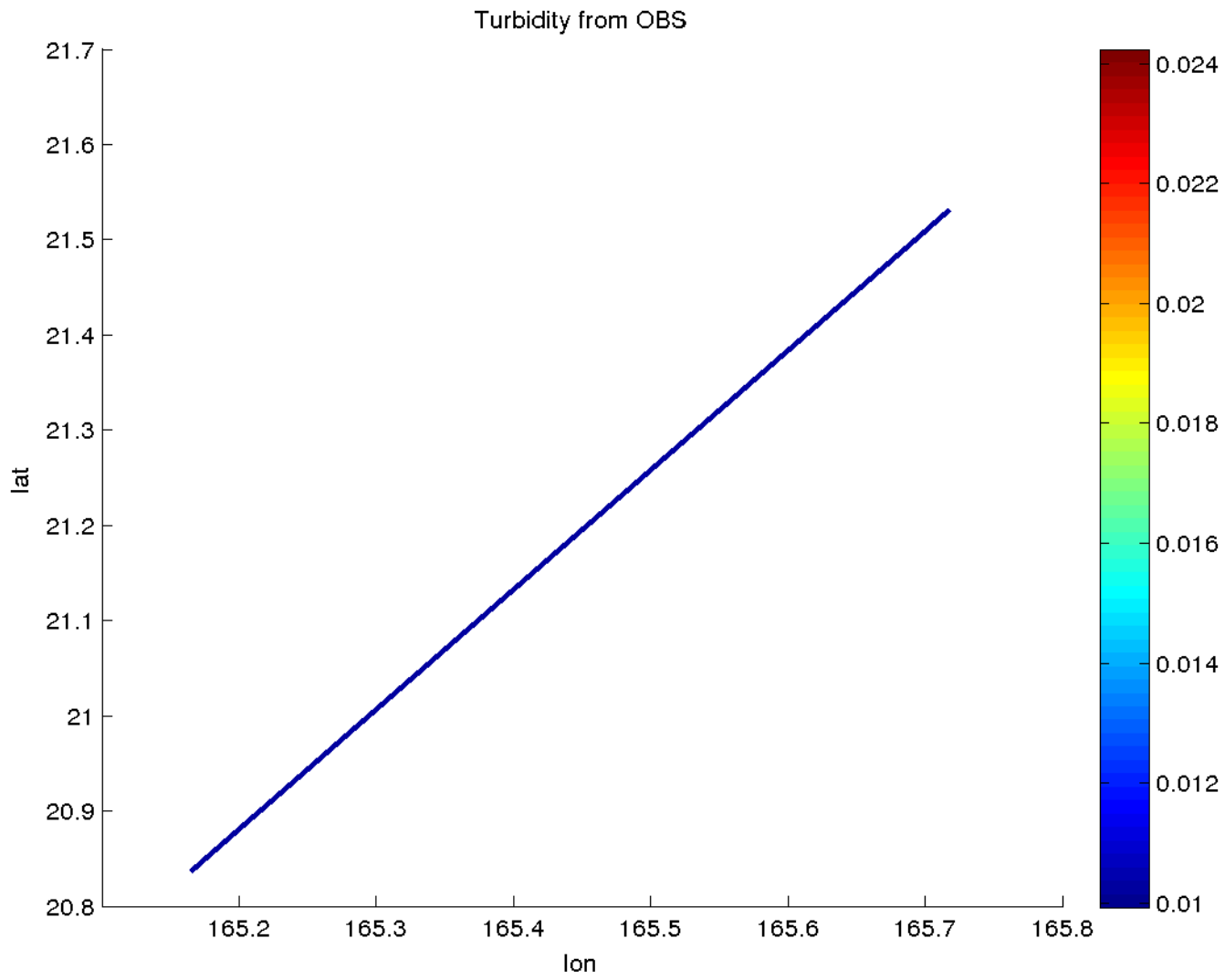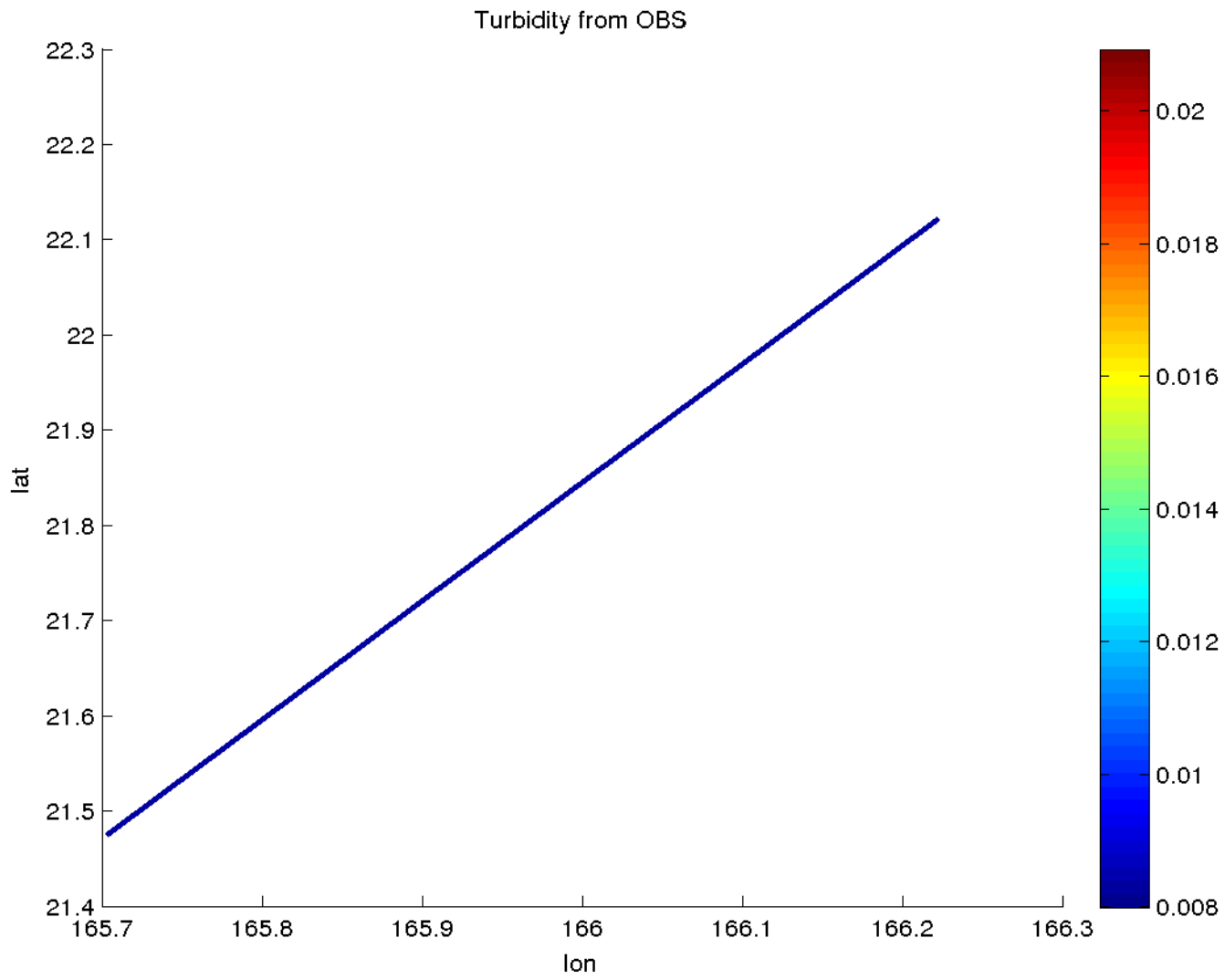
Figure 31: Optical backscatter on dive 296.

Sentry 299 Dive Report
DRAFT

WHOI Sentry Operations Group

Dr. Dana Yoerger, Alan Duester, Andrew Billings, Zachary Berkowitz, Daniel Bogorff

Sentry Expedition Leader: Dr. Dana Yoerger

Chief Scientist: Masako Tominaga, Michigan State University
Co-PI: Maurice Tivey, WHOI

Summary

Weather: The weather was well within the operating window. On recovery we had mild, confused, winds just under 20 knots.

Reason for end of dive: the dive ended on low battery when programmed level of 8% was reached.

Vehicle Configuration

The science sensing suite for this dive was:

Table 11: Sentry Sensor Configuration

Sensor
APS 1540 Magnetometers (3)
Seabird SBE49 CTD
Seapoint OBS
Anderaa optode model 4330
300kHz RDI DVL
IXEA PHINS
Reson Sound Velocity Probe

This dive was navigated using the DVL/INS system in real time. USBL provided post-dive corrections.

Important Positions

Dive Origin: 18 18.186 162 39.963

Launch Position: sentry299 launch position: 18 18.186'N 162 39.963'E

Narrative

This was our 7th operational science dive. The launch, descent, survey, ascent, and recovery went substantially as planned. We added a short dogleg followed by spins to help calibrate the magnetometers at the start. We ran the entire dive at 0.85 m/s to maximize our range. The dive ended at 27.6 hrs of survey time when we reached the battery limit of 8%. We think the vehicle was driving into a current, so the power consumption was higher than for previous runs. On recovery, we had over 5% battery remaining.

1 Issues and Proposed Solutions

Chief Scientist Comments

The Chief scientist is requested to include any desired comments.

Dive Statistics

1.1 sentry299 Summary

sentry299 Summary
Origin: 18.303100 162.666050
Origin: 18 18.186'N 162 39.963'E
Launch: 2015/01/09 15:15:26
Survey start: 2015/01/09 17:37:05
Survey start: Lat:18.302615 Lon:162.666882
Survey start: Lat:18 18.157'N Lon:162 40.013'E
Survey end: 2015/01/10 21:13:06
Survey end: Lat:17.791738 Lon:162.101113
Survey end: Lat:17 47.504'N Lon:162 6.067'E
Ascent begins: 2015/01/10 21:13:06
On the surface: 2015/01/10 22:53:21
On deck: 2015/01/10 23:13:50
descent rate: 37.2 m/min
ascent rate: 53.7 m/min
survey time: 27.6 hours
deck-to-deck time 32.0 hours
Mean survey depth: 5325m
Mean survey height: 100m
distance travelled: 83.08km
average speed; 0.83m/s
average speed during photo runs: NaN m/s over 0.00 km
average speed during multibeam runs: 0.81 m/s over 83.08 km
total vertical during survey: 4801m
Battery energy at launch: 13.7 kwhr
Battery energy at survey end: 1.0 kwhr
Battery energy on deck: 0.6 kwhr

Plots and Images

This section contains selected images of data products and plots of vehicle navigation and selected sensors.
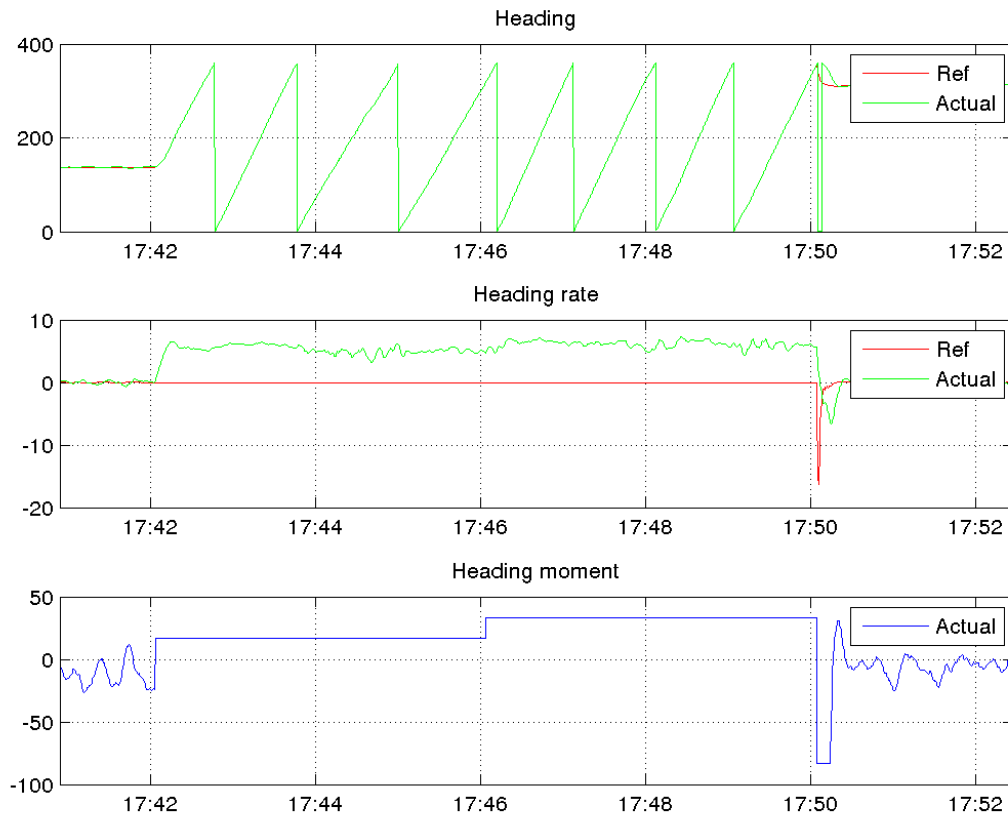
Figure 32: This figure summarizes the results of the magnetometer spin, used for calibration. These were run with joystick values of 0.1 and 0.2 and resulted in turn rates of about 5 deg/s and 6 deg/s
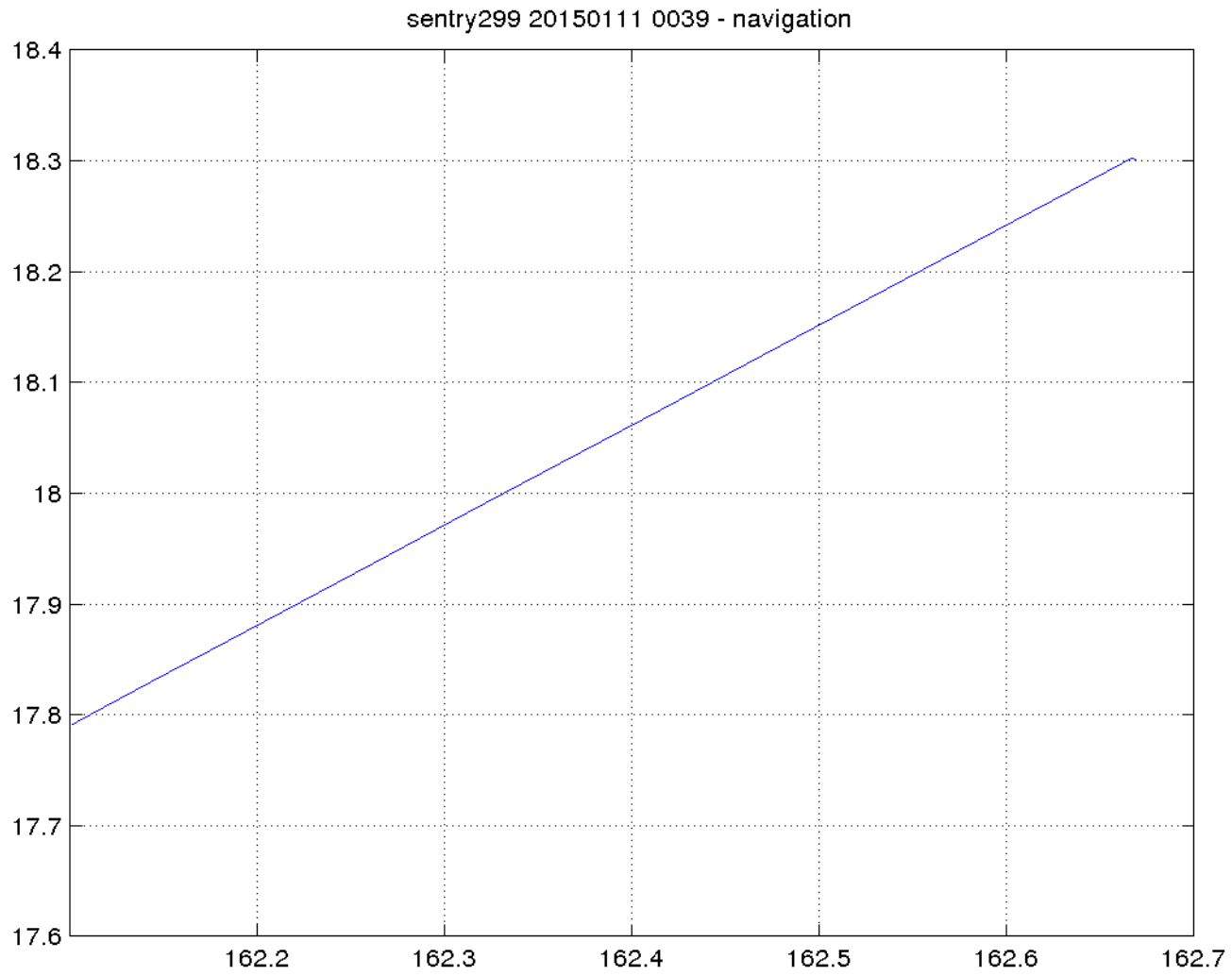
Figure 33: Latitude/Longitude plot of Sentry dive 299 based on post-processed navigation.
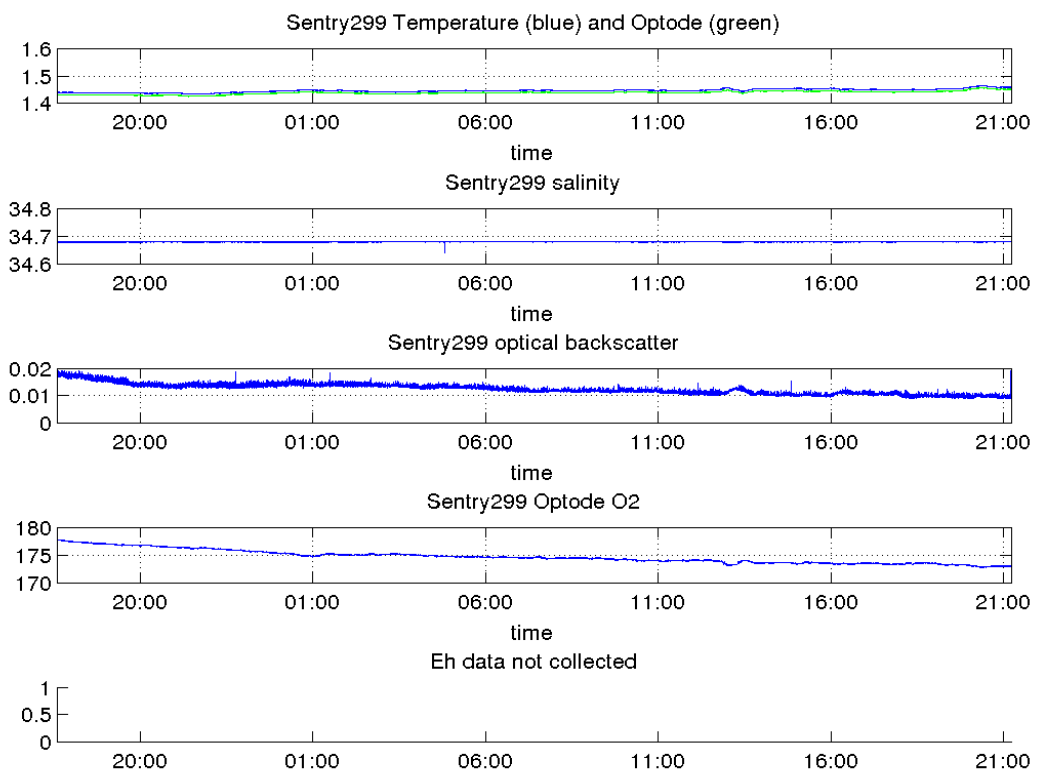
Figure 34: Time series plot of five of the basic sensors on Sentry, from top to bottom, temperature, salinity, optical backscatter, and dissolved Oxygen.
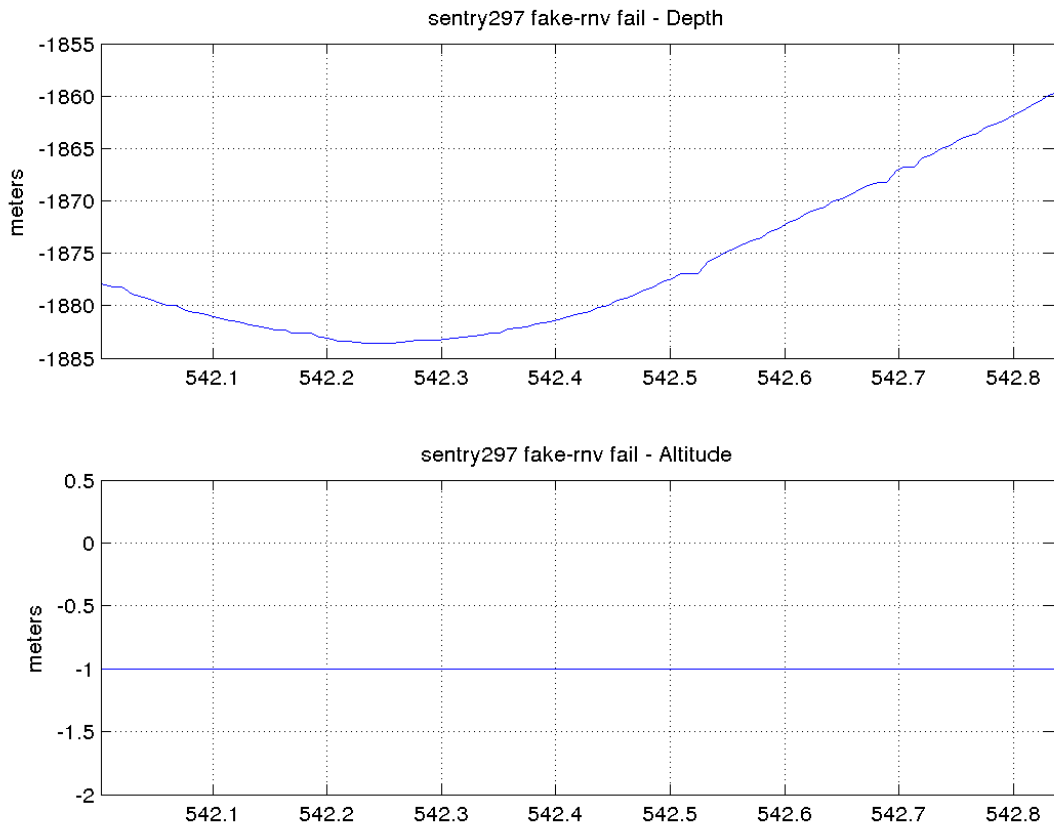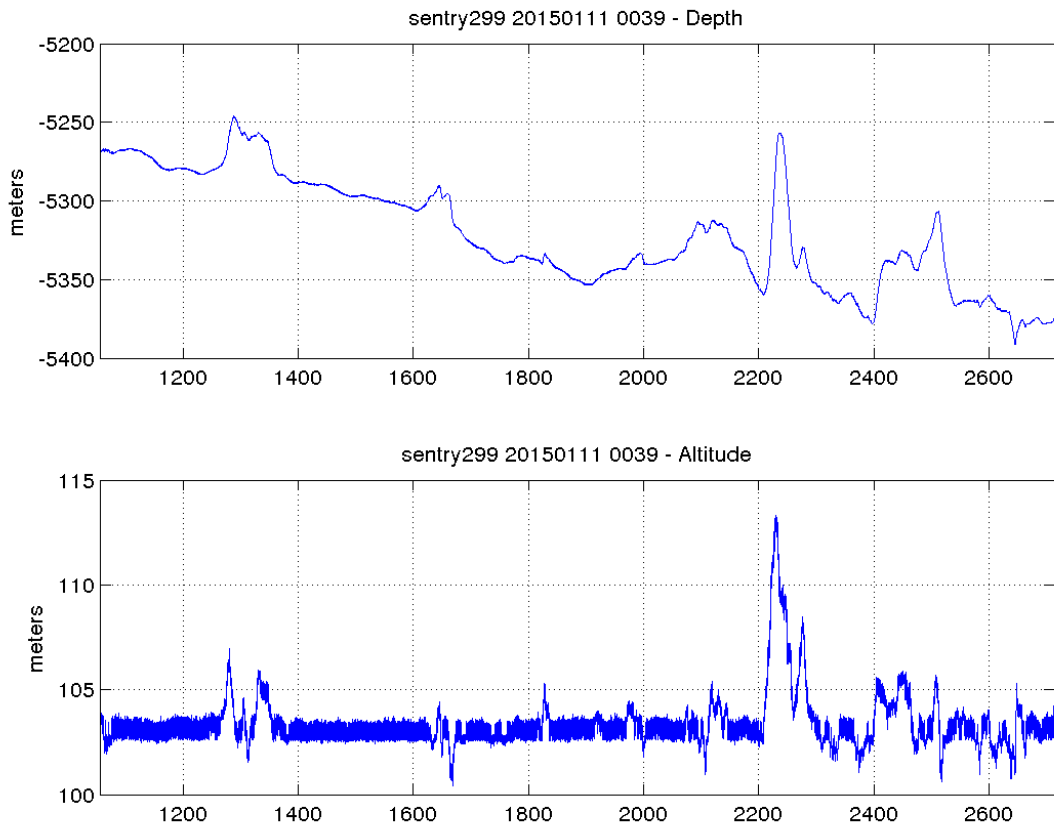
Figure 35: Depth and Altitude of Sentry during dive 299. The vehicle negotiated a seamount 500m high at the end of the dive without incident
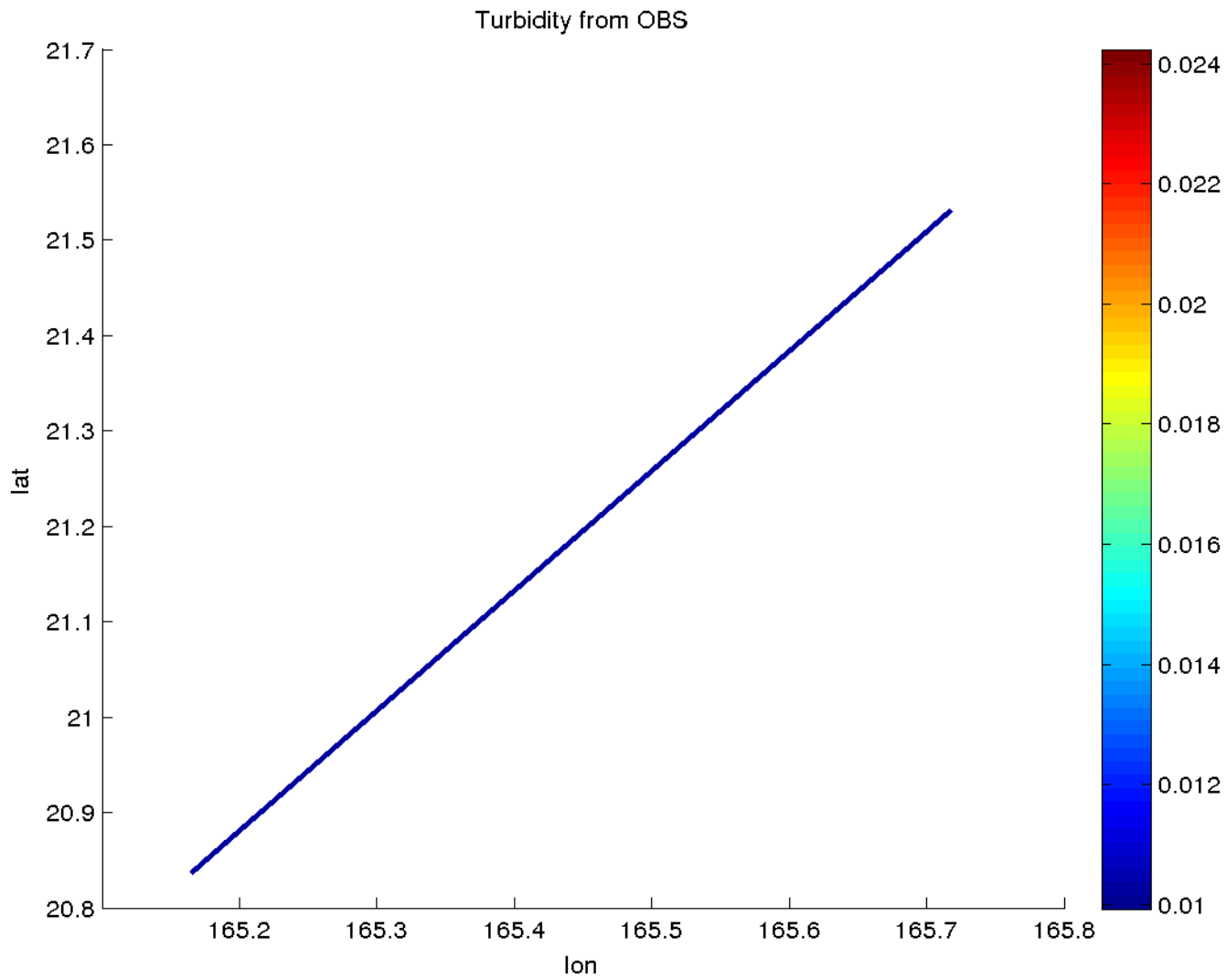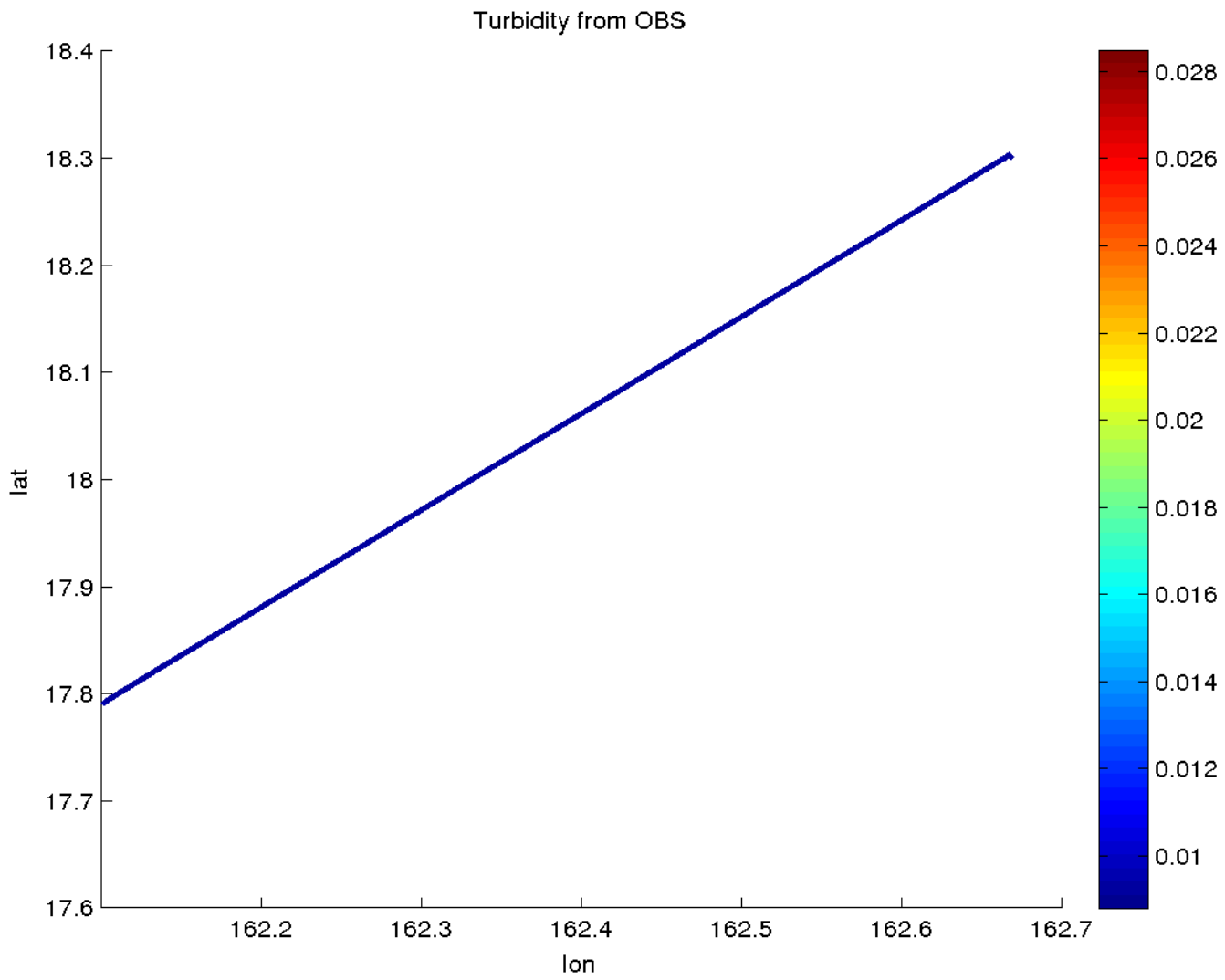
Figure 36: Optical backscatter on dive 296.

CASIUS Calibration Report

Sonardyne
SOUND IN DEPTH

Vessel: R/V Sikuliaq   **Device No:** 1009   **Date/Time:** 08 November 2014 10:01:58
Used UH avtrack Beacon for survey.

Settings:

Initial Estimates for BoxIn	
Transceiver depth offset	0.480m
Transceiver depth	0.480m
Antenna starboard offset	1.530m
Antenna forward offset	-34.340m
Antenna height offset	14.345m

Error Estimates for BoxIn	
DGPS lags USBL	0.00s
Range measurement	0.2m
Range gate	1.0m
DGPS position	2.0m
Beacon position	30.0m
Beacon depth	5.0m
Sound velocity	15.0m/s
Transceiver depth	0.5m
Transceiver offset	1.0m

Transceiver & Beacon	
Transceiver Index	11
Beacon Name	1001
Turn Around Time	320.0ms

Depth Aiding	
Boresight Angle Limit	22.0º
Depth Difference Limit	1.0m

Transceiver Attitude Calculation Inputs	
Angle Gate	2.0º
Known Heading Correction	n/a

Values Used During Data Collection	
Transceiver Pitch Correction	-0.25º
Transceiver Roll Correction	-0.20º
Transceiver Heading Correction	-0.32º
Sound Velocity	1490.4m/s

Results:

Beacon BoxIn	Beacon Eastings	Beacon Northings	Beacon Depth	Sound Velocity	Transceiver Starboard Offset	Transceiver Forward Offset
Before	590908.80m	2328637.20m	2768.20m	1490.35m/s	1.82m	-0.54m
Calculated	590900.93m	2328637.01m	2767.57m	1490.08m/s	1.49m	0.18m
Calculated Accuracy	0.11m	0.11m	0.55m	0.19m/s	0.08m	0.09m

Transceiver Attitude	Pitch Correction	Roll Correction	Heading Correction
Before	-0.25º	-0.20º	-0.32º
Calculated	**-0.30º**	**-0.15º**	**-0.06º**
Calculated Accuracy	0.00º	0.00º	0.03º

Statistics:

	Before CASIUS (distance)	After CASIUS (distance)	Before CASIUS (% depth)	After CASIUS (% depth)
39.4% Beacon Positions (1 sigma)	10.0m	9.9m	0.36	0.36
50.0% Beacon Positions (CEP)	11.9m	11.6m	0.43	0.42
63.2% Beacon Positions (1 Drms)	14.3m	14.1m	0.52	0.51
86.5% Beacon Positions (2 sigma)	21.7m	22.2m	0.78	0.80
98.2% Beacon Positions (2 Drms)	37.4m	37.7m	1.35	1.36

General:

	Beacon BoxIn	Transceiver Attitude
Number of Iterations	3	2
Number of Fixes Used	2702	2702
Number Depth Aided		0
Average weighted residuals	0.020	0.822

Vessel Track

	CASIUS10 11081756
✕	CASIUS11 11081849
✕	CASIUS12 11081956
✕	CASIUS13 11082045
✕	CASIUS14 11082126
✕	CASIUS2 11081001
✕	CASIUS3 11081022
✕	CASIUS4 11081115
✕	CASIUS5 11081219
✕	CASIUS6 11081320
✕	CASIUS7 11081450
✕	CASIUS8 11081543
✕	CASIUS9 11081654
—	Beacon
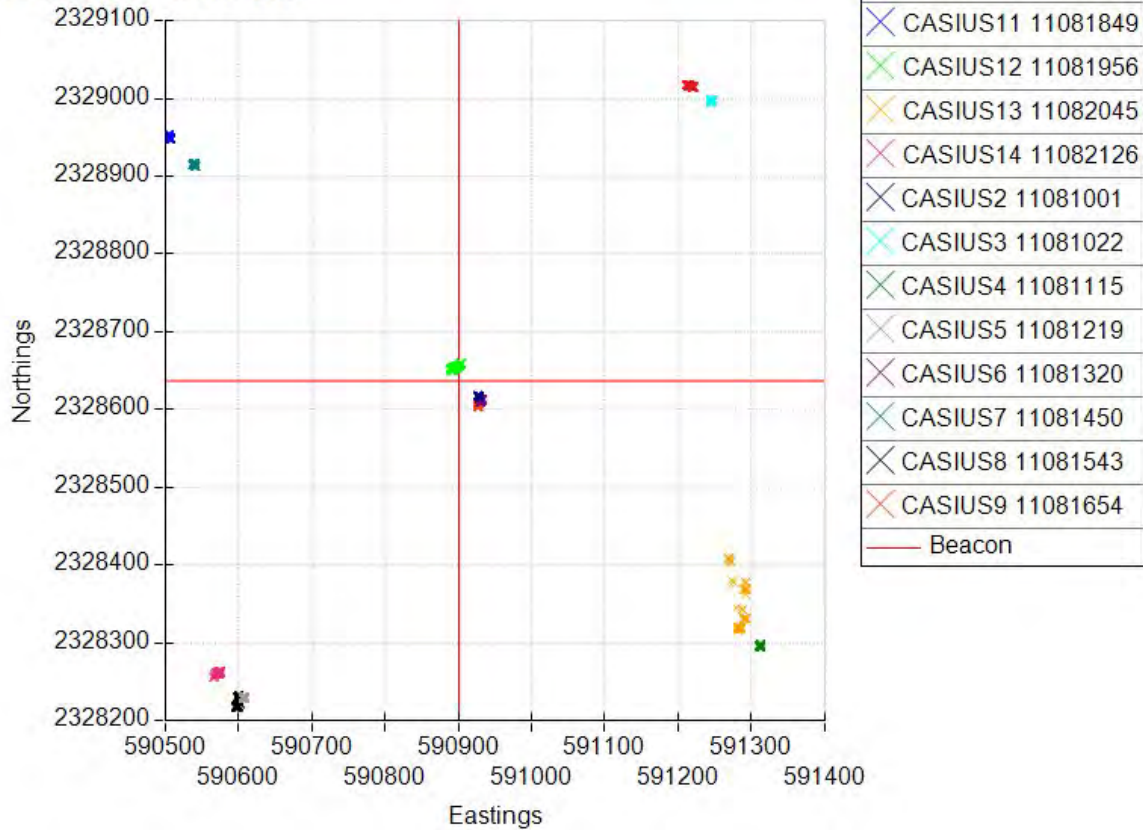
Data used:

Name	Filename	Start	End	#Acoustic	#Position
CASIUS10 11081756	C:\Ranger Files\CASIUS\CASIUS10 11081756.csv	08/11/2014 18:32:24	08/11/2014 18:49:00	200	1003
CASIUS11 11081849	C:\Ranger Files\CASIUS\CASIUS11 11081849.csv	08/11/2014 19:39:03	08/11/2014 19:56:39	212	1061
CASIUS12 11081956	C:\Ranger Files\CASIUS\CASIUS12 11081956.csv	08/11/2014 20:28:49	08/11/2014 20:45:40	203	1016
CASIUS13 11082045	C:\Ranger Files\CASIUS\CASIUS13 11082045.csv	08/11/2014 21:09:56	08/11/2014 21:26:37	201	1006
CASIUS14 11082126	C:\Ranger Files\CASIUS\CASIUS14 11082126.csv	08/11/2014 21:58:09	08/11/2014 22:15:00	203	1016
CASIUS2 11081001	C:\Ranger Files\CASIUS\CASIUS2 11081001.csv	08/11/2014 10:01:58	08/11/2014 10:22:48	209	1257
CASIUS3 11081022	C:\Ranger Files\CASIUS\CASIUS3 11081022.csv	08/11/2014 10:52:43	08/11/2014 11:15:19	227	1359
CASIUS4 11081115	C:\Ranger Files\CASIUS\CASIUS4 11081115.csv	08/11/2014 11:59:16	08/11/2014 12:19:39	205	1225
CASIUS5 11081219	C:\Ranger Files\CASIUS\CASIUS5 11081219.csv	08/11/2014 13:00:35	08/11/2014 13:20:35	201	1203
CASIUS6 11081320	C:\Ranger Files\CASIUS\CASIUS6 11081320.csv	08/11/2014 14:29:36	08/11/2014 14:50:43	212	1276
CASIUS7 11081450	C:\Ranger Files\CASIUS\CASIUS7 11081450.csv	08/11/2014 15:22:09	08/11/2014 15:43:16	212	1273
CASIUS8 11081543	C:\Ranger Files\CASIUS\CASIUS8 11081543.csv	08/11/2014 16:32:43	08/11/2014 16:54:49	222	1328
CASIUS9 11081654	C:\Ranger Files\CASIUS\CASIUS9 11081654.csv	08/11/2014 17:39:57	08/11/2014 17:56:41	201	1013

2D Scatter - Before CASIUS

Legend:
- × CASIUS10 11081756
- × CASIUS11 11081849
- × CASIUS12 11081956
- × CASIUS13 11082045
- × CASIUS14 11082126
- × CASIUS2 11081001
- × CASIUS3 11081022
- × CASIUS4 11081115
- × CASIUS5 11081219
- × CASIUS6 11081320
- × CASIUS7 11081450
- × CASIUS8 11081543
- × CASIUS9 11081654
- ----- 1 Drms
- —— 2 Drms
- —— Beacon
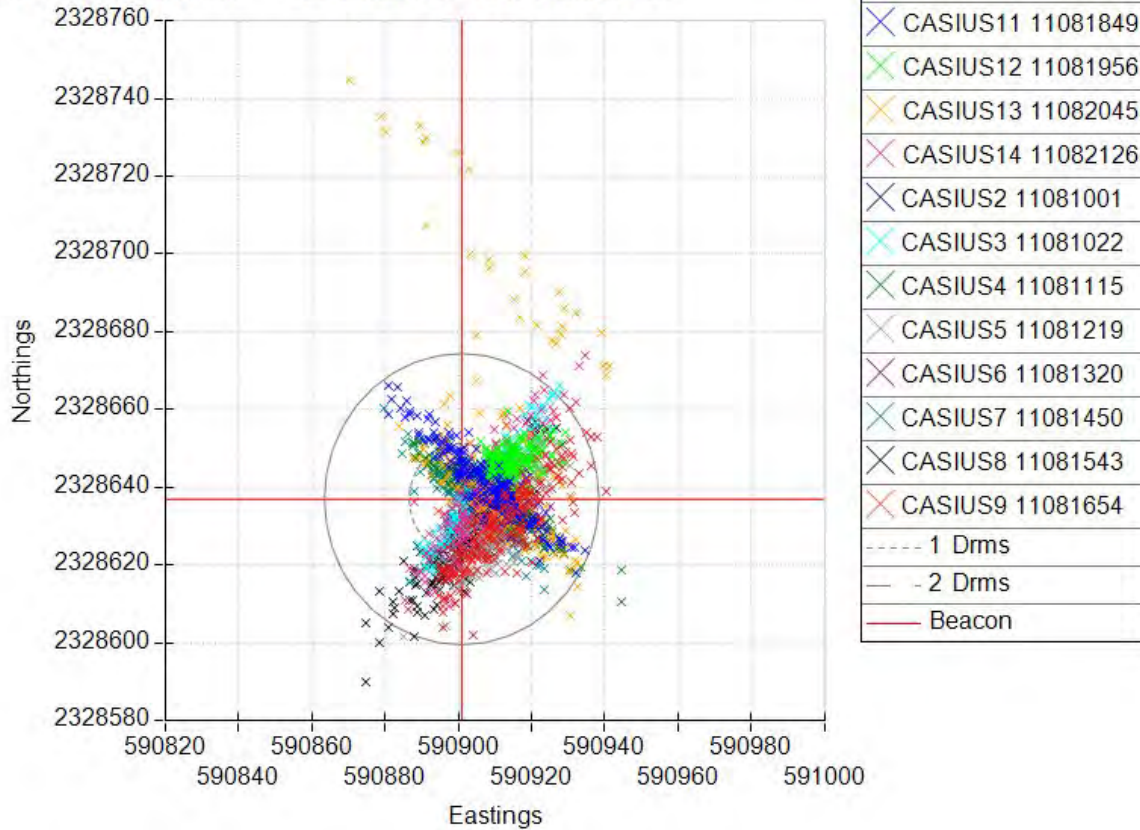
3D Histogram - Before CASIUS

Legend:
- 11 - 12
- 10 - 11
- 9 - 10
- 8 - 9
- 7 - 8
- 6 - 7
- 5 - 6
- 4 - 5
- 3 - 4
- 2 - 3
- 1 - 2
- 0 - 1

2D Scatter - After CASIUS

Legend:
- CASIUS10 11081756
- CASIUS11 11081849
- CASIUS12 11081956
- CASIUS13 11082045
- CASIUS14 11082126
- CASIUS2 11081001
- CASIUS3 11081022
- CASIUS4 11081115
- CASIUS5 11081219
- CASIUS6 11081320
- CASIUS7 11081450
- CASIUS8 11081543
- CASIUS9 11081654
- 1 Drms
- 2 Drms
- Beacon
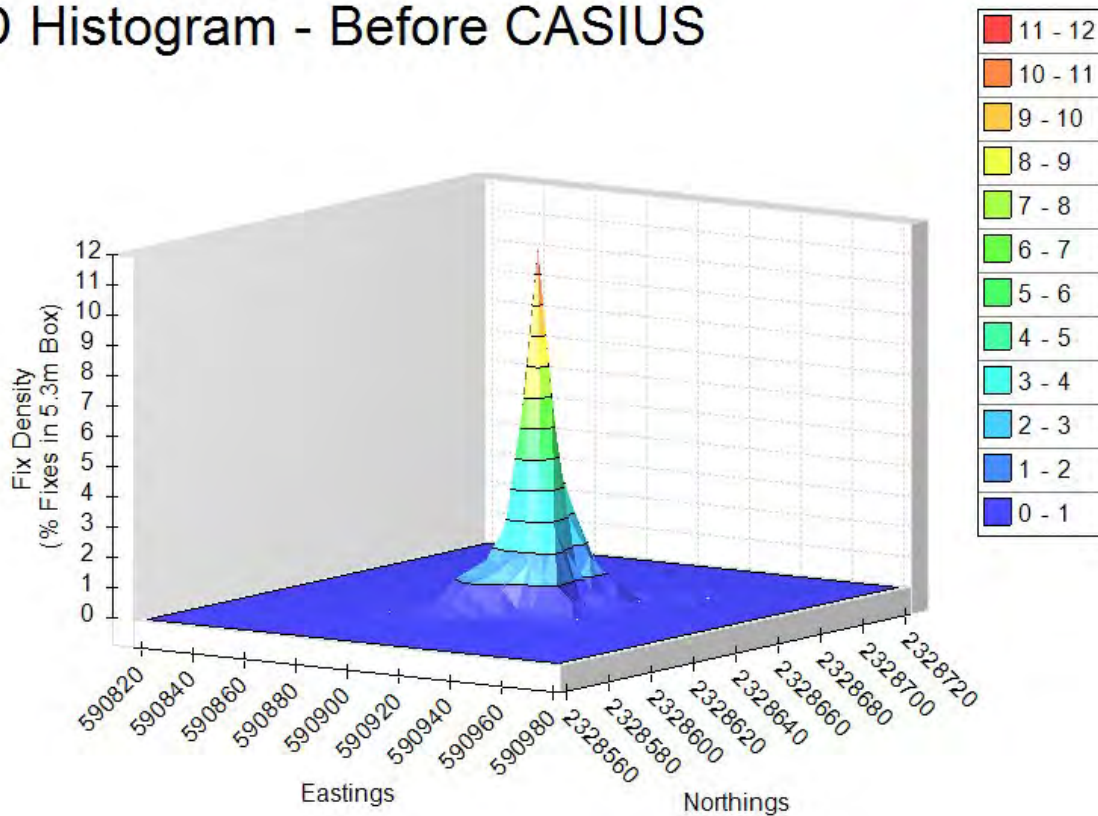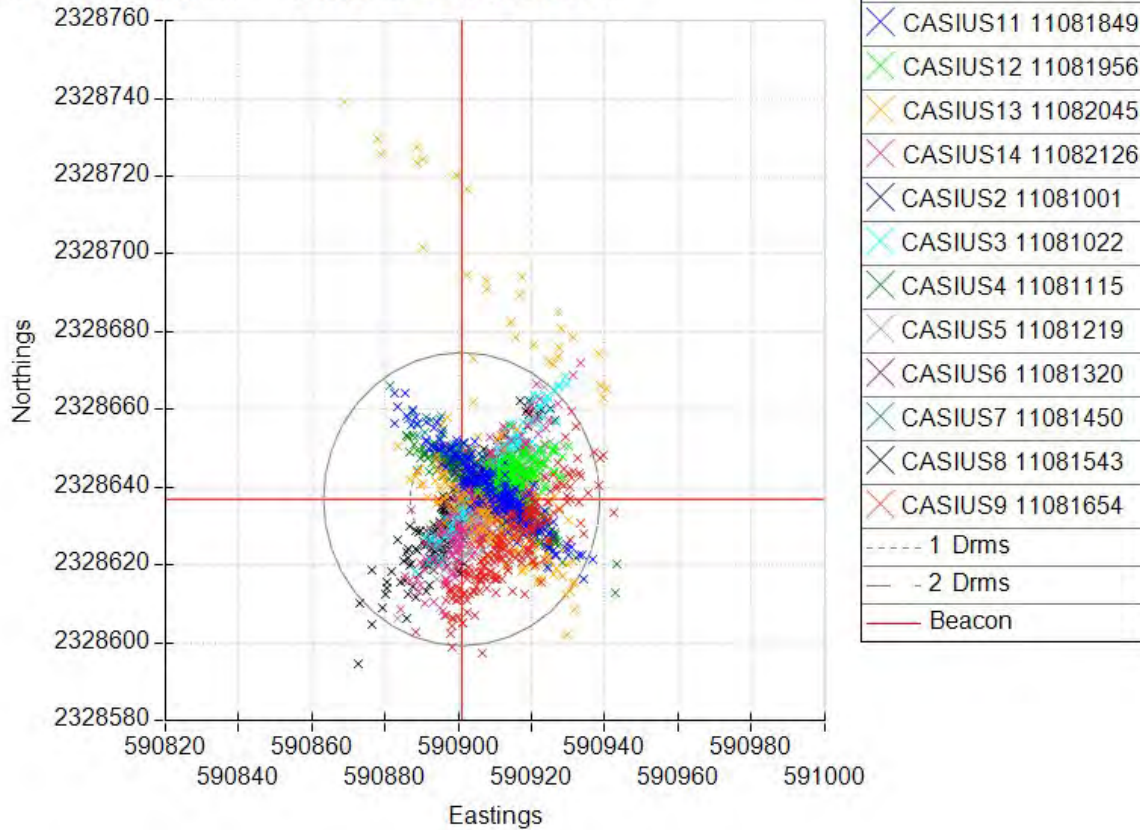
3D Histogram - After CASIUS

Legend:
- 11 - 12
- 10 - 11
- 9 - 10
- 8 - 9
- 7 - 8
- 6 - 7
- 5 - 6
- 4 - 5
- 3 - 4
- 2 - 3
- 1 - 2
- 0 - 1
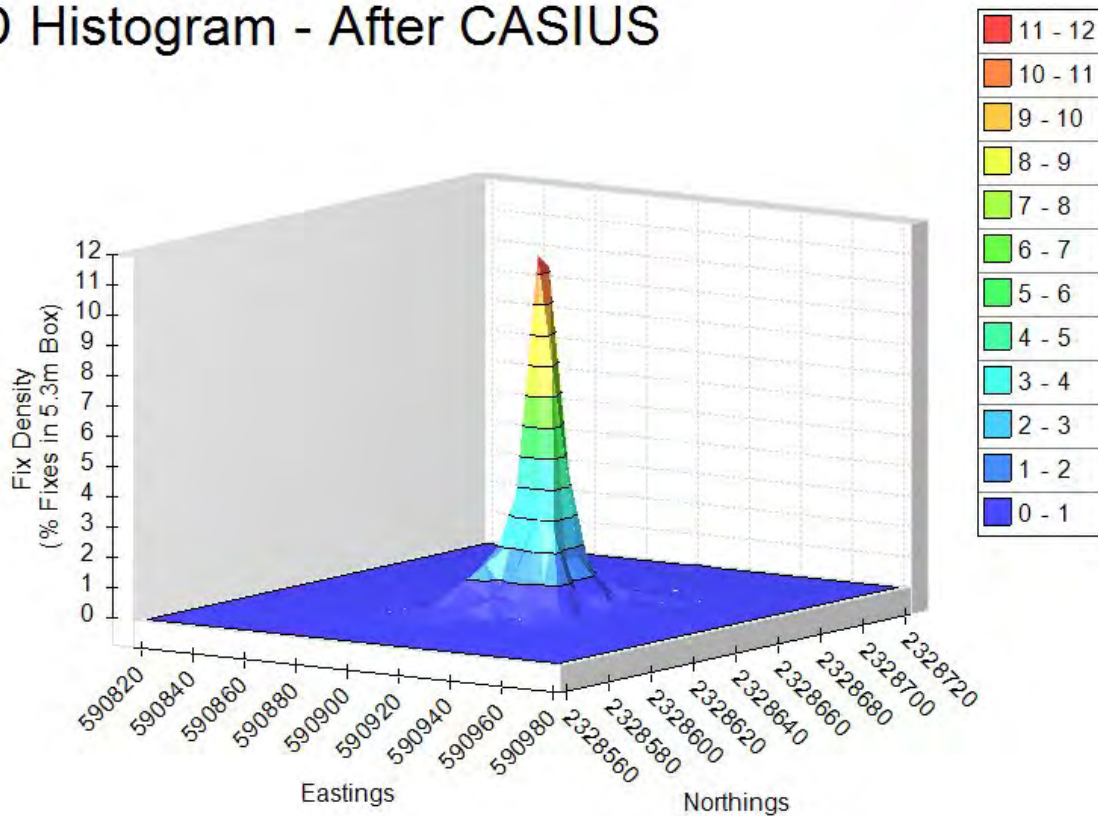
Appendix 2: File format for LDS sensor data (Adapted from previous cruise's file format descriptions document)

----

flow_krohne_fwd:
KROHNE OPTIFLUX 5000 Electromagnetic flowmeter measuring surface seawater flow being delivered to forward TSG, SVP probe and Turner C6 in bow thruster room. These electromagnetic flowmeters are designed exclusively to measure the flow and conductivity of electrically conductive, liquid media.
Location: Forward sea-chest in bow thruster room
Sample rate: 1 per second

Example data line:
flow_krohne_fwd 2014-12-11T20:19:01.7029Z 0.558,5.93,27.38,0.65940

Field Descriptions:
   Logger ID
   Time Stamp [UTC]
   flow speed [m/s]
   volume flow [l/min]
   coil temperature [C]
   conductivity [S/m]

----

flow_omega_fwd:
Omega High performance flow sensor, model FP-2541. Measures flow being delivered from forward science seawater pump in bow thruster room to science seawater system.
Location: Forward sea-chest in bow thruster room
Sample rate: variable

Example data line:
flow_omega_fwd 2014-12-11T21:01:29.0588Z   22.6

Field Descriptions:
   Logger ID
   Time Stamp [UTC]
   Flow alarm [single character, H = High Alarm, L = Low Alarm, B = Both High and Low Alarms or Space = Neither High nor Low Alarms.]
   flow [?]

----

fluoro_turner-c6:
Turner Designs C6 Multi-Sensor Platform with 5 Cyclops-7 submersible sensors located forward in bow thruster room. Measures the following parameters in surface seawater from forward seachest in bow thruster room:
  Phycoerythrin, Serial Number: 2102973
  CDOM, Serial Number: 2102975
  Chlorophyll a, Serial Number: 2102977
  Crude Oil, Serial Number: 2102979
  Turbidity, Serial Number: 2102981
  Platform Serial Number: 220223
Location: Forward sea-chest in bow thruster room
Sample rate: 1 per second

Example data line:
fluoro_turner-c6 2014-11-29T00:00:00.8851Z 11/29/14 0:00:01   79.88   20.60   101.32   44.32
7.28 9.38 21.05

Field Descriptions:
   Logger ID
   Time Stamp [UTC]
   C6 Date
   C6 Time
   Phycoeryth(RFU)
   CDOM(RFU)
   Chlorophyll_a(RFU)
   Crude Oil(RFU)
   Turbidity(RFU)
   Depth(m)
   Temp(C)

----

gnss_cnav:
C-Nav3050 Globally Corrected Global Positioning System (GcGPS). Antenna located on main mast. C-Nav Subscription Services were active for this entire cruise.
Sample rate: 1 per second

Example data lines:
   gnss_cnav 2014-12-11T00:00:01.0020Z $GNZDA,000001.00,11,12,2014,00,00*7D
   gnss_cnav 2014-12-11T00:00:01.0811Z
$GNRMC,000001.00,A,2304.167961,N,16553.836924,W,7.87,100.6,111214,0,E,D*17
   gnss_cnav 2014-12-11T00:00:01.1226Z $GNVTG,100.6,T,,M,7.87,N,14.57,K,D*2E
   gnss_cnav 2014-12-11T00:00:01.1630Z $PNCTR,NAVQ,000001.00,3D,SBAS,DUAL*38
   gnss_cnav 2014-12-11T00:00:01.2517Z
$GNGGA,000001.00,2304.167961,N,16553.836924,W,2,11,1.0,44.542,M,0.000,M,2.0,0103*43
   gnss_cnav 2014-12-11T00:00:01.3251Z
$GNGST,000001.00,2.0309,3.5667,3.1000,89.3421,3.1001,3.5666,7.2710*46
   gnss_cnav 2014-12-11T00:00:01.3611Z $PNCTR,RXQ,000001,N,0.00,0,100*50

Field Descriptions:
   Logger ID
   Time Stamp [UTC]
   NMEA ASCII message

----

grav_bgm3_222:
  Gravimeter BGM-3, Serial Number: 222
Sample rate: 1 per second

Example data lines:
   grav_bgm3_222   2014-11-17T20:18:10.3194Z   04:024671 00

Field Descriptions:
   Logger ID
   Time Stamp [UTC]
   Interface_Counter_period:Raw_Counts

Status
Status:
    00 = all good(data valid)
    01 = platform not valid(e.g. gyro)
    02 = sensor not valid
    03 = both platform and sensor not valid

----
gyro_1:
NAVIGAT 2100 Fiber-Optic Gyrocompass and Attitude Reference System. Primary. Sample rate: 10 per second. Downsampled to 2 per second in log files.

Example data lines:
    gyro_1 2014-12-11T00:16:03.5470Z $HEHDT,107.38,T*12
    gyro_1 2014-12-11T00:16:03.5984Z $TIROT,-0000.6,A*20
    gyro_1 2014-12-11T00:16:03.8972Z $PPLAN,,,,,,,,2*71

Field Descriptions:
    Logger ID
    Time Stamp [UTC]
    NMEA ASCII message
----
gyro_2:
NAVIGAT 2100 Fiber-Optic Gyrocompass and Attitude Reference System. Secondary. Sample rate: 10 per second. Downsampled to 2 per second in log files.

Example data lines:
    gyro_2 2014-12-11T22:05:38.7155Z $PPLAN,,,,,,,,1*72
    gyro_2 2014-12-11T22:05:39.0194Z $TIROT,-0039.0,A*2C
    gyro_2 2014-12-11T22:05:39.0669Z $HEHDT,106.27,T*1D

Field Descriptions:
    Logger ID
    Time Stamp [UTC]
    NMEA ASCII message
----
ins_seapath_position:
Kongsberg Seapth 320+ Precise Heading, Attitude and Positioning Sensor. The product combines inertial technology together with GPS and GLONASS satellite signals. Core components in the product are the MRU 5+ inertial sensor, the two combined GPS/GLONASS receivers, the Processing and HMI Unit.
RTCM corrections provided by the C-Nav3050.
Sample rate: 1 per second

Example data lines:
    ins_seapath_position 2014-12-11T22:09:32.4715Z $GPZDA,220932.45,11,12,2014,,*6B
    ins_seapath_position 2014-12-11T22:09:32.5563Z
$GPGGA,220932.45,2207.733438,N,16242.262661,W,2,09,1.1,7.25,M,4.62,M,1.2,0001*6A
    ins_seapath_position 2014-12-11T22:09:32.6020Z $GPVTG,111.01,T,101.59,M,8.5,N,15.7,K,D*14
    ins_seapath_position 2014-12-11T22:09:32.6841Z
$GPRMC,220932.45,A,2207.733438,N,16242.262661,W,8.5,111.01,111214,9.4,E,D*16

   ins_seapath_position 2014-12-11T22:09:32.7451Z
$GPGST,220932.45,0.49,0.206,0.193,32,0.202,0.197,0.439*42
   ins_seapath_position 2014-12-11T22:09:32.8020Z $GPGBS,220932.45,0.06,-
0.03,0.44,19,0.00,0.46,0.51*40
   ins_seapath_position 2014-12-11T22:09:32.8229Z $GPHDT,104.68,T*0E
   ins_seapath_position 2014-12-11T22:09:32.8450Z $PSXN,20,0,0,0,0*3B
   ins_seapath_position 2014-12-11T22:09:32.8825Z $PSXN,23,1.28,1.93,104.68,-0.24*18

Field Descriptions:
   Logger ID
   Time Stamp [UTC]
   NMEA ASCII message
----
mb_em302_centerbeam:
Nearest nadir centerbeam depth from multibeam EM302.
Sample rate: variable

Example data lines:
   mb_em302_centerbeam 2014-12-11T22:47:00.4684Z
$EMCTR,2014,12,11,22:46:48.730,22.101408,-162.613610,4567.00,288*56

Field Descriptions:
   Logger ID
   Time Stamp [UTC]
   ID [$EMCTR]
   Year,Month,Day,Hour:Min:Sec
   Latitude [Decimal Degrees]
   Longitude [Decimal Degrees]
   Depth [Meters]
   Number of Beams
   CheckSum
----
mb_em710_centerbeam:
Nearest nadir centerbeam depth from multibeam EM710.
Sample rate: variable

Example data lines:
   mb_em710_centerbeam 2014-12-09T00:42:29.8146Z
$EMCTR,2014,12,09,00:42:28.954,25.616626,-172.513725,111.31,350*6B

Field Descriptions:
   Logger ID
   Time Stamp [UTC]
   ID [$EMCTR]
   Year,Month,Day,Hour:Min:Sec
   Latitude [Decimal Degees]
   Longitude [Decimal Degees]
   Depth [Meters]
   Number of beams in ping
   CheckSum
----

met_ptu307:
Vaisala Combined Pressure, Humidity, and Temperature Transmitter
 Model: PTU307
 Serial Number: J1620011
 Location: forward mast

Example data lines:
   met_ptu307 2014-12-11T22:57:50.4649Z N   0 P= 1016.8 hPa   T= 24.5 'C RH= 68.0 %RH

Field Descriptions:
   Logger ID
   Time Stamp [UTC]
   Transmitter status [7 character field, for example:
     N   0   no heating
     h   115   probe heating active, power 115/255
     H 159.0   purge heating active, temperature 159C
     S 115.0   purge cooling active, temperature 115C
     X 95.0   sensor heating active, temperature 95C]
   Atmospheric pressure[hPa]
   Air Temperature[C]
   Relative Humidity[%]
----
pco2_ldeo_merge:
Sensor was not run during this cruise.
----
rad_psp-pir:
Remote Measurements & Research PSP (Precision Spectral Pyranometer) and PIR (Precision Infrared
Radiometer)
 PSP Serial Number: 37668F3
 PIR Serial Number: 37684F3
 Location: top of science control room
 Sample rate: 1 every 10 seconds

Example data line:
rad_psp-pir 2014-12-12T01:29:38.2952Z $WIR20,14/12/12,01:46:30, 175, -418.5, 265.53, 26.31,
26.15, 278.59, 27.9, 10.8

Field Descriptions:
   Logger ID
   Time Stamp [UTC]
   ID [NMEA-style tag]
   DATE TIME [yy/MM/dd,hh:mm:ss(Note: this time is not synced with external time server so do not
use)]
   # [the number of samples that went into the averages]
   PIR [the average voltage from the PIR thermopile,millivolts]
   LW [the computed longwave downwelling irradiance,Wm**2]
   TCASE [the PIR case temperature,C]
   TDOME [the PIR dome temperature,C]
   SW [the computed shortwave downwelling irradiance,Wm**2]
   T-AVR [the computed shortwave downwelling irradiance,C]
   BATT [the battery voltage after the input diode drop,volts]

----
rain_org815ds_across:
ORG-815-DS OPTICAL PRECIPITATION SENSOR
  Model: ORG-815-DS
  Serial Number: 1304383
  Location: Flying Bridge, mounted port-starboard**
  Sample rate: 1 per minute

Example data line:
rain_org815ds_forward 2014-12-12T05:06:01.9937Z R- .118 000.709 01** 4999 0044 0062 +25

Field Descriptions:
   Logger ID
   Time Stamp [UTC]
   40 character long ASCII data string *.
* See section 4.1.3 "C" Poll Response in included document "ORG815DS User Guide 110114.pdf". The
"C" poll is used to obtain routine data in NWS weather code format and detailed system diagnostic data.
The accumulation is zero-out every 24hours at 0 UTC. While underway this sensor always indicates that
it is raining regardless of the weather conditions. So usefulness of this data is probably rather limited
until this issue is resolved.
 ** Sometime after sensors were mounted it appears they rotated about 45 degrees rendering the
   concept of "across" and "forward" meaningless.
----
rain_org815ds_forward:
ORG-815-DS OPTICAL PRECIPITATION SENSOR
  Model: ORG-815-DS
  Serial Number: 13040382
  Location: Flying Bridge, mounted fore-aft**
  Sample rate: 1 per minute

Example data line:
rain_org815ds_across 2014-12-12T04:20:02.5143Z R- 2.04 017.917 01** 4999 0353 0063 +26

Field Descriptions:
   Logger ID
   Time Stamp [UTC]
   40 character long ASCII data string*.
* See section 4.1.3 "C" Poll Response in included document "ORG815DS User Guide 110114.pdf". The
"C" poll is used to obtain routine data in NWS weather code format and detailed system diagnostic data.
The accumulation is zeroed-out once every 24hours at 0 UTC.   While underway this sensor always
indicates that it is raining regardless of the weather   conditions. So usefulness of this data is probably
rather limited until this issue is resolved.
 ** Sometime after sensors were mounted it appears they rotated about 45 degrees rendering the
concept of "across" and "forward" meaningless.
----
sb_echosounder_1:
  Bridge navigation echo sounder, port console
  Model: LAZ 5100
  Sample rate: variable

Example data lines:

    sb_echosounder_1 2014-11-19T02:52:42.7943Z $SDDPT,0005.9,-0.0,0010*6B
    sb_echosounder_1 2014-11-19T02:52:42.8741Z $SDDBT,0019.3,f,0005.9,M,0003.2,F*30

Field Descriptions:
  Logger ID
  Time Stamp [UTC]
  NMEA ASCII message
----
sb_echosounder_2:
Bridge navigation echo sounder, chart table fiddle board
  Model: LAZ 5100
  Sample rate: variable

Example data lines:
    sb_echosounder_2 2014-11-19T02:48:28.9308Z $SDDPT,0005.7,-0.0,0010*65
    sb_echosounder_2 2014-11-19T02:48:29.0106Z $SDDBT,0018.6,f,0005.7,M,0003.1,F*39

Field Descriptions:
  Logger ID
  Time Stamp [UTC]
  NMEA ASCII message
----
speedlog:
Bridge navigation Doppler Speed Log
  Sample rate: variable

Example data lines:
    speedlog 2014-12-12T06:02:42.8523Z $VDVLW,14566.6,N,4566.64,N*5A
    speedlog 2014-12-12T06:02:43.7550Z $VDVBW,5.5,0.2,A,,,V,,V,,V*44

Field Descriptions:
  Logger ID
  Time Stamp [UTC]
  NMEA ASCII message
----
ssv_aml-svxchang_fwd:
AML Oceanographic's SV•Xchange field swappable sound velocity sensor. Measures speed of sound in surface seawater from forward seachest in bow thruster room.
  Model: SV•Xchange Calibrated Sensor
  Serial Number: 203298
  Location: Forward seachest in bow thruster room
  Sample rate: 1 every 5 seconds

Example data line:
    ssv_aml-svxchang_fwd 2014-12-12T06:08:43.7092Z 1537.965

Field Descriptions:
  Logger ID
  Time Stamp [UTC]
  Speed of Sound [m/s]
----

thermo_pyrometer-ct15:
Heitronics infrared radiation pyrometer. Measures seasurface skin temperature.
  Model: CT15.10
  Serial Number: 10975
  Location: Just forward of science control room
  Sample rate: 1 per second

Example data line:
    thermo_pyrometer-ct15 2014-12-12T06:26:14.2312Z   25.51 C

Field Descriptions:
    Logger ID
    Time Stamp [UTC]
    Temperature [C]
----
tsg_emssv:
Log of the Kongsberg external datagrams(C+T format) sent to the Kongsberg multibeams(EM302 and EM710). These provide the real-time input for surface sound velocity needed by these sonars.
  Sample rate: 1 every 5 seconds

Example data line:
    tsg_emssv 2014-12-12T06:51:13.1575Z $KSSIS,80,1537.39,26.44,

Field Descriptions:
    Logger ID
    Time Stamp [UTC]
    Kongsberg external datagram(C+T format)*
  * Note:
  $KSSIS,80,c.c,t.t,\n\r
  where
  • $KSSIS specifies that this is a Kongsberg proprietary datagram format
  • 80 is the datagram number indicating that this is an external soundspeed sample
  • c.c is the sound speed at transducer represented as an ASCII text string e.g. 1460.95
  • t.t is the temperature at transducer represented as an ASCII text string e.g. 19.25
----
tsg_sbe45_fwd:
Sea-Bird SBE 45 MicroTSG Conductivity and Temperature Monitor. Measures surface seawater temperature and conductivity from forward seachest.
  Model: SBE45
  Serial Number: 0455
  Location: Forward seachest in bow thruster room
  Sample rate: 1 every 5 seconds

Example data line:
    tsg_sbe45_fwd 2014-12-12T06:34:03.1647Z   26.4679, 5.44818, 34.9076, 1537.771

Field Descriptions:
    Logger ID
    Time Stamp [UTC]
    Temperature [C]
    Conductivity [S/m]

Salinity [psu]
Speed of Sound [m/s]
----

wind_gill_fwdmast:
WindObserver 70/75 Ultrasonic Anemometer. Relative wind speed only.
 Model: 1390-75-B-313
 Serial Number: 1351005 - WC45
 Location: Forward mast
 Sample rate: 1 per second

Example data line:
   wind_gill_fwdmast 2014-12-12T07:08:16.3849Z A,356,006.00,M,60,0E

Field Descriptions:
   Logger ID
   Time Stamp [UTC]
   Unit ID
   Wind direction [In degrees relative to bow of ship (DDD)]
   Wind speed [In increments of 0.01 units (+-MMM.MM)]
   Units [M Metres per second (m/s)]
   Status [0   : OK
       60 or 66   : Heating enabled and OK if enabled
       Any other value: Warning or fault condition]
   Checksum
----

wind_gill_fwdmast_true:
WindObserver 70/75 Ultrasonic Anemometer. Computed true wind speed. Uses SeaPath 320+ for
reference heading source.
 Model: 1390-75-B-313
 Serial Number: 1351005 - WC45
 Location: Forward mast
 Sample rate: 1 per second

Example data line:
   wind_gill_fwdmast_true 2014-12-12T07:25:11.4542Z $WIMWD,81.4,T,,M,6.9,N,3.6,M*43

Field Descriptions:
   Logger ID
   Time Stamp [UTC]
   NMEA ID
   Wind direction, 0 to 359 degrees,T[True]
   Wind direction, 0 to 359 degrees,M[Magnetic]
   Wind speed, N[knots]
   Wind speed, M[meters/second]
   Checksum

Appendix 3. EM302 Multibeam Settings

Sounder Main

Sector Coverage	Port	Starboard
Max. Angle (deg.)	75	75
Max Coverage (m)	5000	5000
Angular Coverage Mode	Auto	---
Beam Spacing	HD EQDST	---

Depth Settings

Force Depth	4800
Min. Depth (m)	200
Max. Depth (m)	Changed as needed (ex.5750)
Dual Swath Mode	DYNAMIC
Ping Mode	Changed based on Max. Depth
FM Disable	Unchecked

Transmit Control

Pitch Stabilization	On
Along Direction (deg.)	---
Auto Tilt	2 deg.

Yaw Stabilization

Mode	Rel. Mean Heading
Heading	0.0
Heading Filter	Medium

Sound Speed

Sound Speed at Transducer

Source	Sensor

Sound Speed (m/sec.)	1536.5
Sensor Offset (m/sec.)	0.0
Filter (sec.)	60

Filter and Gains

Filtering

Spike Filter Strength	Medium
Range Gate	Normal
Phase Ramp	Normal
Penetration Filter Strength	OFF
Slope	Checked
Aeration	Checked
Sector Tracking	Unchecked

Absorption Coefficient

Source	CTD Profile
Salinity (ppt)	35
31.5 kHz	5.455

Mammal Protection

TX power level (dB)	Max
Soft Startup Ramp Time (min.)	0

Water Column

30	Log R
20	dB Offset

Special Mode

Sonar	Unchecked
Passive	Unchecked

Data Cleaning

Real Time Data Cleaning

Rule Set	Automatic1

GPS and Delayed Heave

Java and Trimble setup

Start Javad/Trimble logging	Unchecked
Height On	Unchecked

ATH log parameters

Start Applanix PosMV TrueHeave Log.	Unchecked
Interval for new line (min.)	30
Source Port for ATH data	5602

RTCM log parameters

Start Seapath RTCM Log.	Unchecked
Interval for new line (min.)	30
Source port for Seapath RTCM data	31103

PPP log parameters

Start Applanix PosMV PPP	Unchecked
Interval for new line (min.)	30
Source Port for ATH data	5602

SRH log parameters

Start Seapath Real Heave Log.	Unchecked
Interval for new line (min.)	30
Source Port for SRH data	31102

Simulator

Simulation Setup

Simulator min. depth (m)	390
Simulator max. depth (m)	390
Enable Simulation	Unchecked
Step along (%)	0
Slant Across (deg.)	0

Parameters for Scope Display

Beam No.	400
Swath No.	1

Survey Information

Survey Information

Time Created	2014-12-22 20:19:16
User	SIS User
Grid Cell Size (m)	50.00
Number of Cells in Processing Grid	128
Projection	MERCATOR_WGS84
From Template	Default
Survey Comment	---

Ping Modes (Single Swath/Double Swath)

- FM pulse form is used if pulselength > 15 ms.
    - The typical coverage is given for a 1*1 deg. system.

- Deep' is same as Deep, but uses FM instead of CW in outer sectors
    - Very Deep and Extra Deep does not have dual swath

- If FM is disabled by the operator:
    - Deep and Very Deep mode have 5 ms CW in all sectors. Extra Deep has 15 ms CW in all sectors. The frequencies are the same.

Table 1. Single swath mode

Mode	Depth	Typical total coverage Deg	Meter	TX pulse (ms) Frequency (kHz) Port				Starboard			
Shallow	10-250	140		0.7 ms 26.5 kHz		0.7 30.5		0.7 32.5		0.7 28.5	
Medium	250-750	140		2 27		2 30		2 31.5		2 28.5	
Deep1	750	140	3750	5 26.5	5 27.5	5 28.5	5 29.5	5 30	5 29	5 28	5 27
	1000	140	5500								
Deep2	1000	140	5500	100 26.5	60 27.5	5 28.5	5 29.5	5 30	5 29	60 28	100 27
	3300	104	8500								
Very Deep	3300	104	8500		100 26.5	60 27.5	40 28.5	40 29	60 28	100 27	
	5000	70	7000								
Extra Deep1	5000	70	7000			100 26.5	100 27.5	100 28	100 27		
	7000	36	4500								
Extra Deep2	7000	36	4500				200 26.5	200 27			

Table 2. Dual swath mode

Mode	Depth	Typical total coverage Deg	Meter	TX pulse (ms) Dual swath #1 frequency (kHz) Dual swath #2 frequency (kHz) Port				Starboard			
Shallow	10-250	140		1.1 ms 26.5 kHz 29.1 kHz		1.1 27.7 31.7		1.1 30.4 33		1.1 26.5 29.1	
Medium	250-750	140		2 26.5 27.7		2 28.9 30.1		2 27.1 31.3		2 29.5 28.3	
Deep	750	140	3750	5 28.1 28.9	5 26.5 27.3	5 31.3 32.1	5 29.7 30.5	5 31.7 32.5	5 30.1 30.9	5 28.5 29.3	5 26.9 27.7
	1000	140	5500								
Deep'	1000	140	5500	50 28.1 28.9	30 26.5 27.3	5 31.3 32.1	5 29.7 30.5	5 31.7 32.5	5 30.1 30.9	30 28.5 29.3	50 26.9 27.7
	3300	104	8500								
Very Deep	3300	104	8500		100 26.5	60 27.5	40 28.5	40 29	60 28	100 27	
	5000	70	7000								
Extra Deep	5000	70	7000			100 26.5	100 27.5	100 28	100 27		
	7000	36	4500								

Extra Deep'	7000	36	4500				200 26.5	200 27	

Table 3. Pulse lengths and coverage if FM is disabled:

Mode	Depth	Typical total coverage		TX pulse (ms)							
		Deg	Meter	Port			Center		Starboard		
Deep	750	140	3750	5	5	5	5	5	5	5	5
	1000	140	5500								
	2200	104	5500								
Very Deep	2200	104	5500		5	5	5	5	5	5	
	3500	70	4900								
Extra Deep	3500	70	4900			15	15	15	15		
	5000	22	2000								

Appendix 4. Backscatter script and preliminary interpretations

"sidescan.sh" script

```csh
#!/bin/csh

###### --
# post-editing process
# written by MT for TN272 cruise/EM302 system
# Sidescan added by John Greene for JQZ3.2 cruise
###### Compile all .mb59 files into datalist--
ls -1 | grep mb59$ > tmplist
mbdatalist -F-1 -I tmplist > datalist

#create plotter file "ssplot.cmd". Run "ssplot.cmd" to produce sidescan plot
mbm_plot -F-1 -Idatalist -G5 -Ossplot

stop
```

mbm_plot: Creates a shellscript that can be executed to produce a GMT plot displaying swath sonar data.
- -F: Data format of the input file (-1)
- -I: Input file name (datalist)
- -G: Mode. Use option "5" for grayscale fill of sidescan data
- -O: Sets root used to create the output shellscript filename (ssplot)

Interpretations:

Interpretations were made in conjunction with the bathymetry data. Much of the seafloor was observed to be fairly homogeneous, light in tone (indicating soft or smooth), and mostly featureless. Files listed in the table below displayed significant contrast or features. The unlisted files were unclear or featureless.

Folder	Observations	Interpretation
MB0001	Patches of strong backscatter.	Volcanic features surrounded by sediment.
MB0002	Few, faint patches of strong backscatter.	Minor outcrops over a mostly sediment track.
MB0007	Semi-linear patches of strong backscatter.	Outcrops of volcanics within sediments.
MB0008	Patches of strong backscatter.	Outcrops of volcanics within sediments.
MB0009	Patches of strong backscatter.	Outcrops of volcanics within sediments.
MB0012	Large patch of strong backscatter.	Sediments changing abruptly to exposed rock.
MB0014	Bands and patches of weak backscatter within dark.	Sediment channels over exposed rock. No major bathymetric change so fairly flat lying.
MB0015	Strong backscatter patch.	Volcanic feature surrounded by sediment.
MB0027	Patches of strong backscatter.	Two volcanic features.
MB0035	Patches of strong backscatter.	Seamounts and volcanic cones grouped together.
MB0036	Weak backscatter moving abruptly to very strong.	Sediment moving abruptly to seamount. Large bathymetric change.
MB0037	Band of strong backscatter perpendicular	Deep channel of exposed rock, with some volcanic cones and

	to track.	seamount.
MB0038	Patch of weak backscatter surrounded by strong.	Large cliff of exposed rock topped by sediment.
MB0041	Ripple marks.	10-20 meters tall in bathymetry. Possibly volcanic flows. Some volcanic cones and seamounts.
MB0046	Patches of strong and weak backscatter.	Moving upslope to a volcanic feature with some volcanic flows.
MB0047	Transition between weaker and stronger corresponding with lineation on bathymetry.	Transition from sediment to exposed rock.
MB0048	Strong backscatter transitioning to weak.	Volcanic cones surrounded by sediments. Abrupt change in depth creating exposed cliff.
MB0049	Variable spots of strong backscatter.	Volcanic features.
MB0050	Predominantly weak with some strong backscatter.	Sediment surrounding volcanics.
MB0051	Predominantly weak with some strong backscatter.	Sediment surrounding volcanics. Curved channel present.
MB0062	Patch of strong backscatter surrounded by weak.	Volcanic features.
MB0087	Strong with patch of weak transitioning to only weak.	Exposed rock plateau with a sediment patch followed by sediment.
MB0088	Mostly strong backscatter with patches of weak.	Rock with sediment patches
MB0089	Weak with interspersed strong backscatter.	Sediment with a few, flat lying rock outcrops.
MB0100	Band of strong backscatter.	Volcanic ridge.
MB0106	Small patches of strong backscatter.	Volcanic cones surrounded by sediments.
MB0111	Small patch of strong backscatter.	Small, raised feature.
MB0113	Small patches of strong backscatter.	Volcanic cone surrounded by sediments.
MB0121	Mounds of strong backscatter within weak backscatter.	Volcanic cones surrounded by sediments.
MB0172	Various sized patches of strong backscatter surrounded by weak.	Seamount and volcanic cones surrounded by sediment.
MB0173	Mounds of strong backscatter within weak backscatter (adjacent to MB0121).	Volcanic cones surrounded by sediments (adjacent to MB0121).
MB0176	Small patches of strong backscatter.	Volcanic cones.
MB0185	Small patches of strong backscatter.	Volcanic features.
MB0200	Rough backscatter pattern to smooth pattern.	Transition from sediment to edge of seamount.
MB0203	Patch of strong backscatter surrounded by weak.	Seamount surrounded by sediment.
MB0204	Strong Backscatter abruptly changing to weak backscatter.	Boundary between seamount slope and sediment covered plateau
MB0205	Strong Backscatter abruptly changing to weak backscatter.	Boundary between sediment covered plateau and seamount slope.
MB0216	Rough backscatter pattern to smooth pattern.	Transition from sediment to edge of seamount.

Appendix 5

The processing chain used during acquisition of the Topas data contained modules described below in order of priority. All of the settings used during data acquisition are included in Table 1.

A matched filter was applied to increase the signal to noise ratio and resolution. The filter was implemented by de-convolving the chirp signal using a complex conjugated Fourier transform. The corner frequency was set to low sidelobe which automatically matched to the start and stop frequency of the chirp and gave the filter a $\cos^2$ window shape. Replica shaping was initialized to multiply the filter by a Hanning window.

The bottom tracker module was always enabled and was set to display the master depth. The envelope detection feature was checked so that the Topas software performed bottom detection based on signal envelope instead of bottom return signal. Auto search for the bottom was also checked so that if the bottom signal was lost, the search window used to find the bottom signal was increased. The threshold in percent of the peak value in the trace, which is normally the seabed, was set to 70%.

The attribute processing module was always enabled with the instantaneous amplitude attribute selected. The instantaneous amplitude represents the magnitude of the analytical signal which is equal to the envelope of the real signal. It is achieved by taking the Fourier transform of the input signal, removing the imaginary part of the signal, and then performing the inverse Fourier transform to return the signal to the time domain.

The display parameters for the Topas data acquisition for the echogram included a trace width of 1 pixel, with the echogram window set to adjust to the current trace length. The downsampling was set to RMS (root mean square) which used the root mean square number of samples per pixel in the display. The echogram legend was set to display the positive polarity of the trace on a logarithmic scale. The JET color map was found to be the most aesthetically pleasing way to display data.

For post-processing of the data many of the processing features were kept the same from the pre-processing performed during data acquisition since they were the optimal settings for the survey area. Additional processing included mute and time varying gain to the Topas processing chain. All of the settings used during the post-acquisition processing of the data are included in Table 2.

The mute was set to zero all trace values located from the start of the trace to a specified offset from the seabed position. The mute offset was adjusted in real time during the processing of each file to include the seabed layer in the echogram. This removed noise above the seabed in post-processing *.sgy files.

The time variable gain (TVG) was enabled to compensate for propagation attenuation and spreading losses in the signal. The TVG was set to auto mode which meant that it followed the bottom tracker with a specified offset, which was set to zero during our processing. The TVG was adjusted in real time during the processing of each file to match the highest amplitudes observed in the single trace area. This brightened the reflectors observed in the echogram and the post-processed *.sgy files.

Table 1. Topas Acquisition Parameters

Acquisition Objects	
Transmitter	
Transmit mode:	Normal
Trigger Mode:	External
Pulse Form:	Chirp (LFM)
Start frequency:	2.0 kHz
Stop frequency:	6.0 kHz
Chirp length:	40 ms
Output level:	0 dB (100%)
HRP Stabilization:	☑
Beam control:	Manual
Receiver	
Delay Control:	Manual
Master trigger delay [ms]	~= (actual depth)/(0.75)
Sample rate:	30 kHz
Trace length:	500 ms
Gain:	39 dB
HP-filter:	2.0 kHz
Selectors	
Depth Selector:	*External depth*
Avg. Sound speed selector:	*External Avg. Sound speed*
Transducer Sound speed selector:	*External Transducer Sound speed*
Slope selector:	*External slope along*
Processing Chain	
Filters	☑ Enabled
Filter type:	*Matched*
Corner frequencies:	*Low sidelobe*
Replica Shaping	☑
Bottom tracker	☑ Enabled
Show master depth:	☑
Envelope detection:	☑
Window start:	automatically adjusts if *auto search* is enabled
Window length:	8 ms
Threshold:	70%
Auto search:	☑
Attribute processing	☑ Enabled
Attributes:	*Inst. Amplitude*
Display Images	
Echogram	
Trace width:	1 pixel
Adjust to current trace length:	☑
Downsampling:	RMS
Legend	
View Mode:	Normal
Polarity:	+
Scale:	Logarithmic
Color map:	JET

Table 1. Topas Post-Acquisition Processing Parameters

Acquisition Objects		
Replay Rate:	200 ms	
Processing Chain		
Data plotter 1	☑ Enabled	
PSD plotter	☑ Enabled	
Cursor readout for this plotter	☑	
Window start:	7600 ms	
Window length:	50 ms	
PSD window type:	Welch	
Filters	☑ Enabled	
Filter type:	*Matched*	
Corner frequencies:	*Hi Res*	
Replica Shaping	☑	
Bottom tracker	☑ Enabled	
Show master depth:	☑	
Envelope detection:	☑	
Window start:	automatically adjusts if *auto search* is enabled	
Window length:	10 ms	
Threshold:	70%	
Auto search:	☑	
Mute	☑ Enabled	
Mute:	10-40 *ms depending on strength of seabed reflector*	
Time variable gain	☑ Enabled	
TVG control:	Tracking	
Offset:	*negative for above seabed reflector, depends on profile*	
	Length [ms]	*Slope [db/ms]*
Section A-B	1	10
Section B-C	20-70, *depends on profile*	0
Section C-D	1	-10
Attribute processing	☑ Enabled	
Attributes:	*Inst. Amplitude*	
Processed data logger		
Maximum file size:	100 MB	
Data plotter 2	☑ Enabled	
Display Images		
Echogram		
Trace width:	1 pixel	
Adjust to current trace length:	☑	
Grid enabled	☑	
Grid depth unit:	ms	
Ping tick spacing:	200	
Depth tick spacing:	10	
Downsampling:	Sample	
Legend		
View Mode:	Normal	
Polarity:	+	
Scale:	Logarithmic	
Color map:	JET	
PSD trace		
Grid enabled	☑	
Logarithmic scale:	☑	
Grid tick spacing:	1000 Hz	
Min PSD value:	-175 dB	
Max PSD value:	50 dB	

Table 2. Kingdom Software Display Parameters

Set Scales	
Horiz. Scale	
☑ Use Traces/cm	
Traces per cm:	19.35
☑ Label Increment	Shotpoint 200
☑ Adjust Trace Scale to Nearest Pixel	
Vert. Scale	
cm per s:	37.8211
Time Label Increment	0.1
☑ Use Data	
Display Options	
☑ Line Overlays	
☑ Auto Update	
☑ Auto Update Horizon Map	
☑ Display intersection of this line with displayed surveys	
Seismic	
Line Skip Increment:	10 traces
Plot Gain:	☑ Normalize each Trace
Type of plot for seismic display:	☑ Hi Res Color Raster

The processed data was then imported into the IHS Kingdom 8.8 (64-bit) software to view and perform preliminary interpretation of the data quality and contents of the profile. The parameters used to view the data in the Kingdom software are contained in Table 3. Examples of the processed data observed in the Kingdom software are included in Figures 1-4.
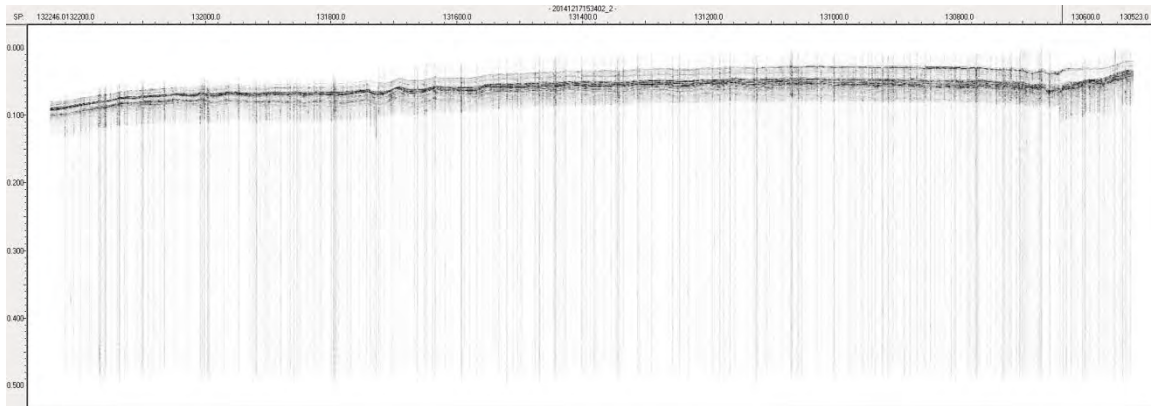

Figure 1. Example of post-processed data record 2014/12/17. Axes: X -axis is shot point; Y-axis is travel time (s). Interpretation: Strong seabed reflector and underlying sediment reflectors
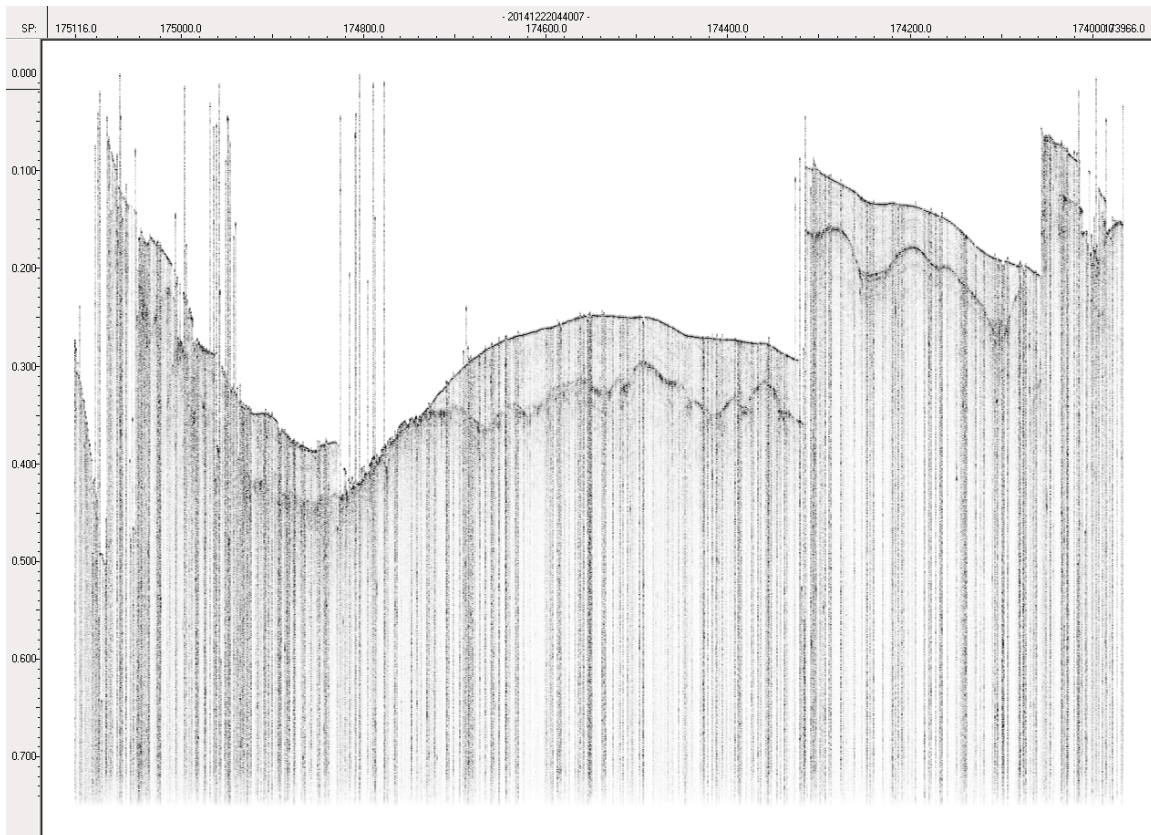

Figure 2. Example of post-processed data record 2014/12/20. Axes: X -axis is shot point; Y-axis is travel time (s). Interpretation: Strong seabed reflector and underlying sediment reflectors, possibly cross-cutting
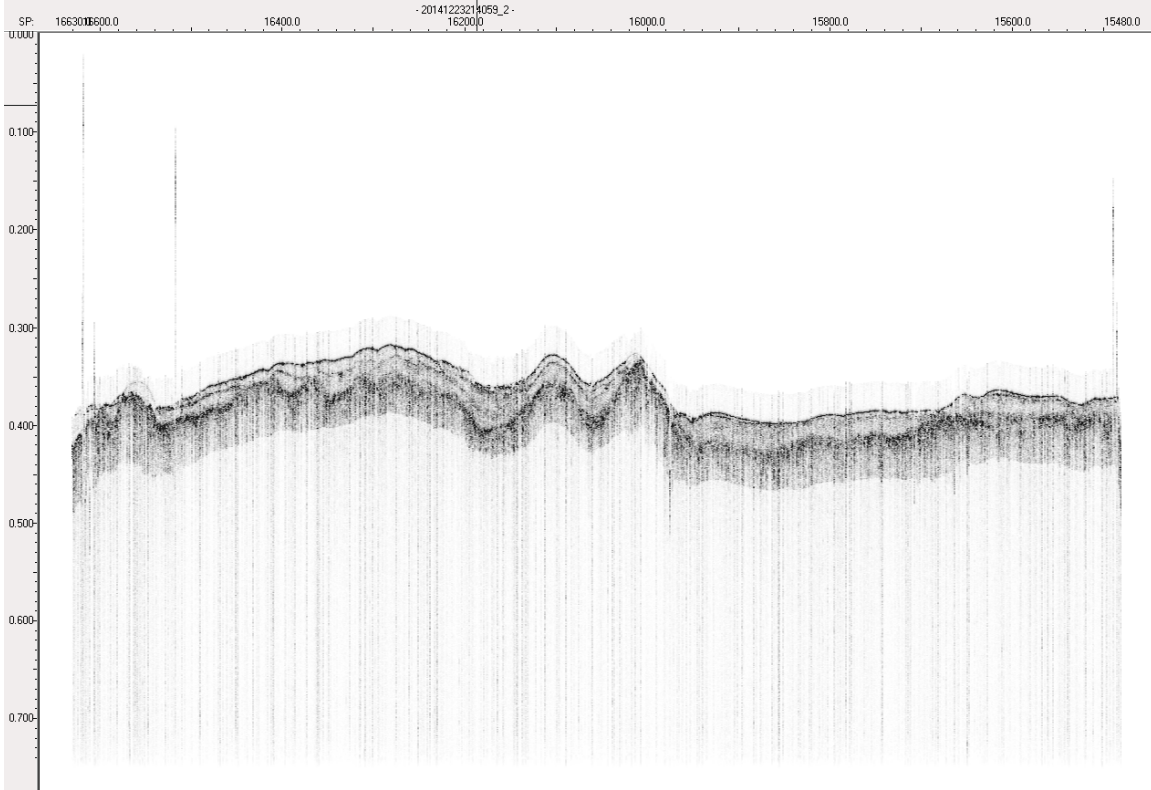
**Figure 3. Example of post-processed data record 2014/12/23. Axes: X -axis is shot point; Y-axis is travel time (s).
Interpretation: Strong seabed reflector and underlying sediment reflectors**

**Figure 4. Example of post-processed data record 2014/12/23. Axes: X -axis is shot point; Y-axis is travel time (s).
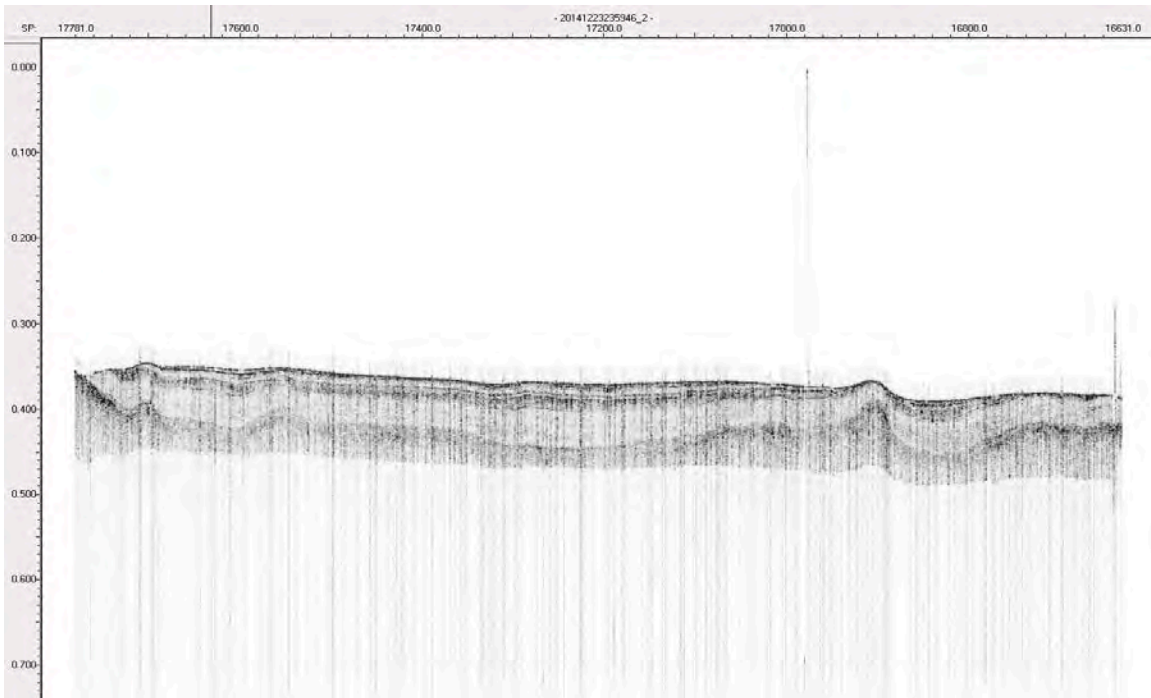Interpretation: Strong seabed reflector and underlying sediment reflectors**
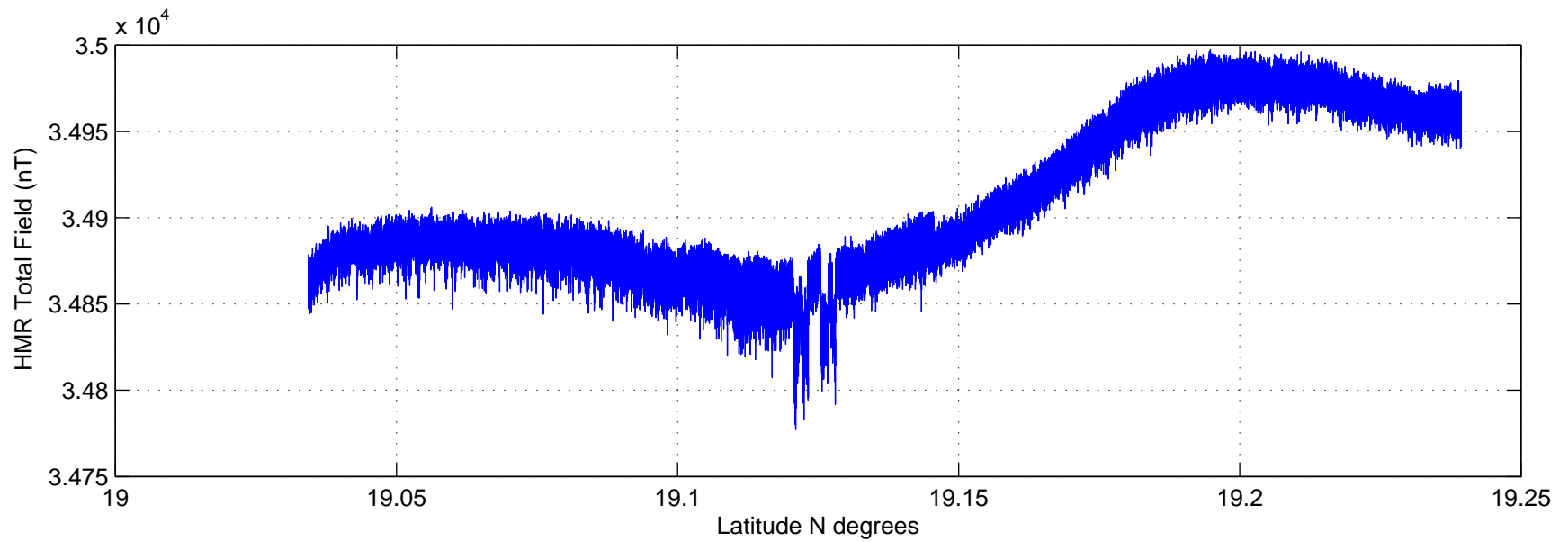
Hawaiian JQZ DEEPTOWMAG Line 1
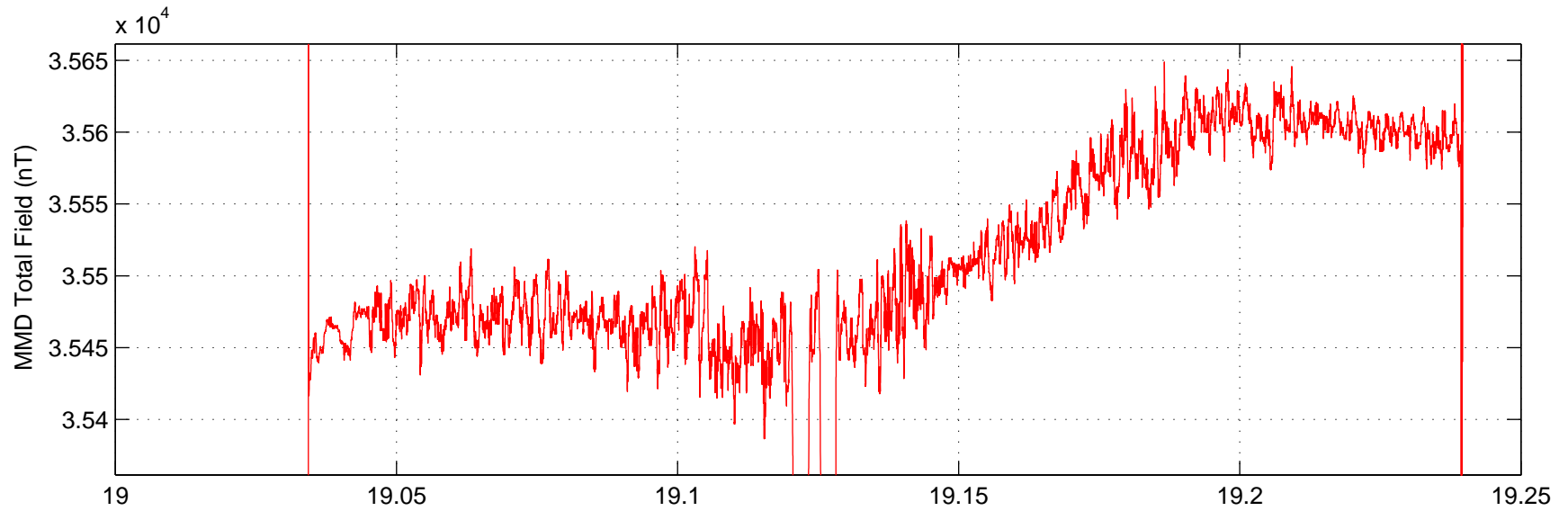
Hawaiian JQZ DEEPTOWMAG Line 2
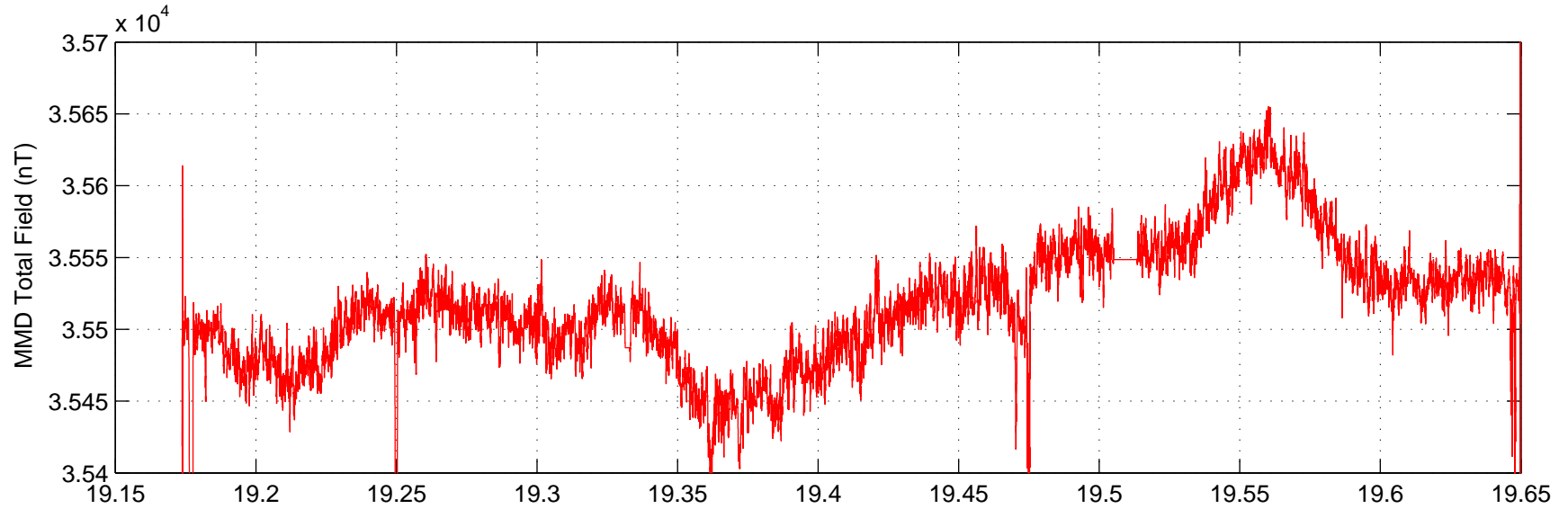
Hawaiian JQZ DEEPTOWMAG Line 3

Hawaiian JQZ DEEPTOWMAG Line 4

Hawaiian JQZ DEEPTOWMAG Line 5
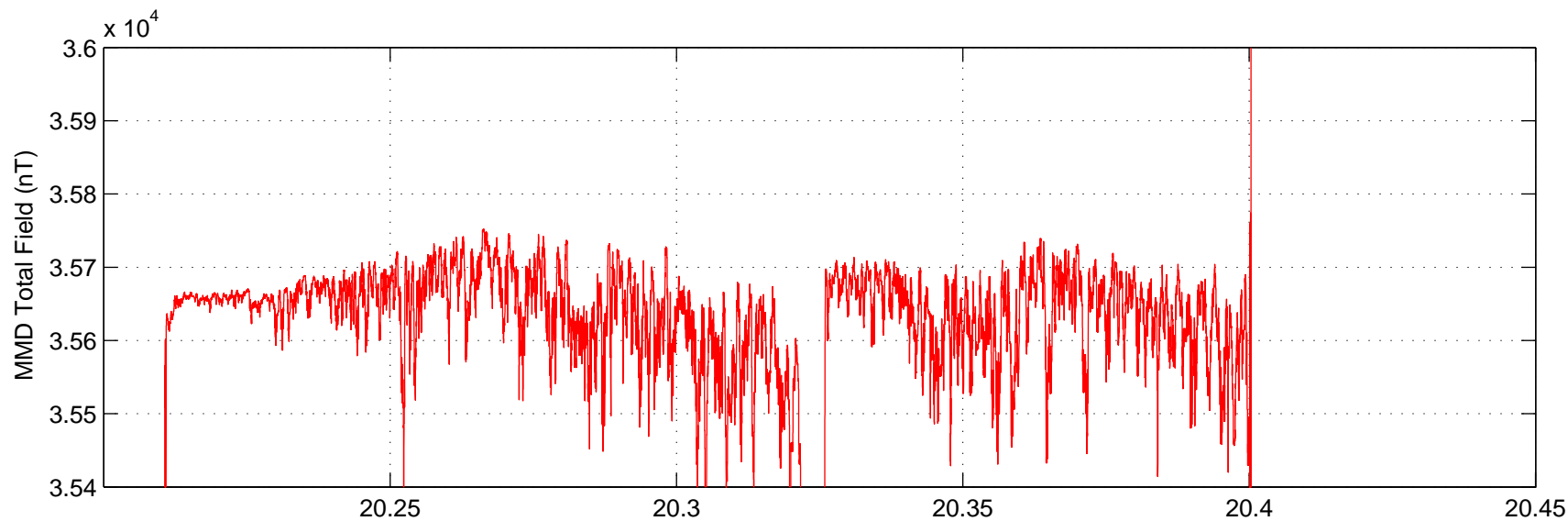
Hawaiian JQZ DEEPTOWMAG Line 6
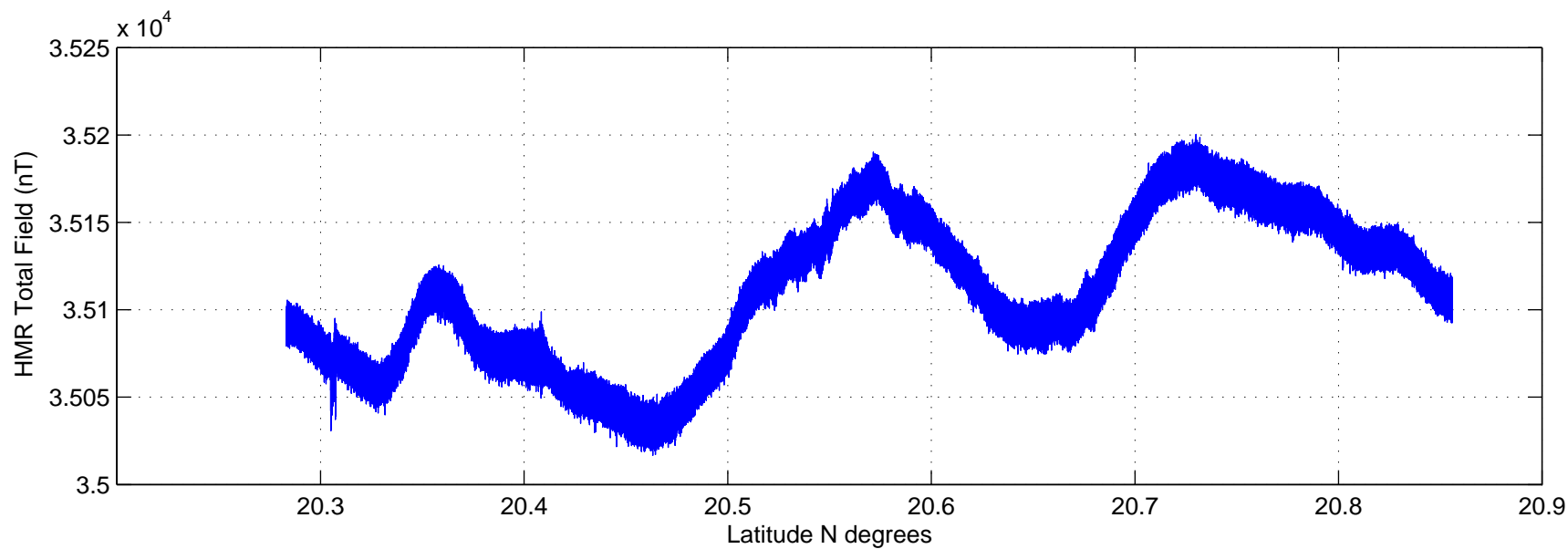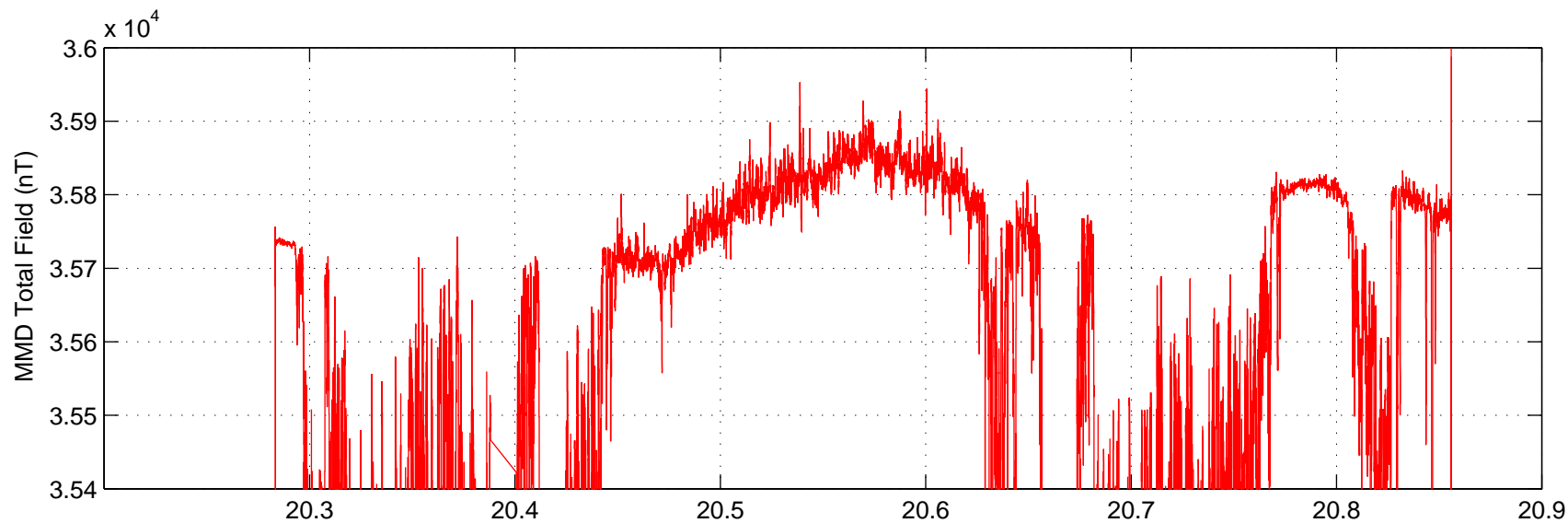
Hawaiian JQZ DEEPTOWMAG Line 7
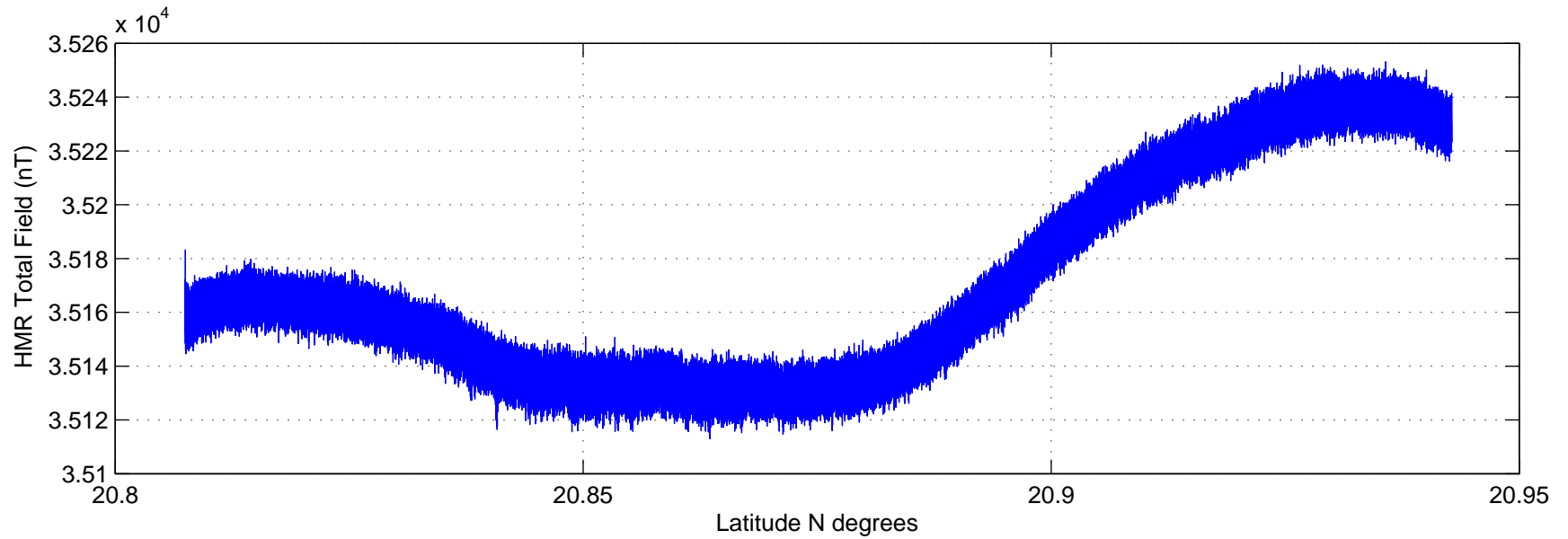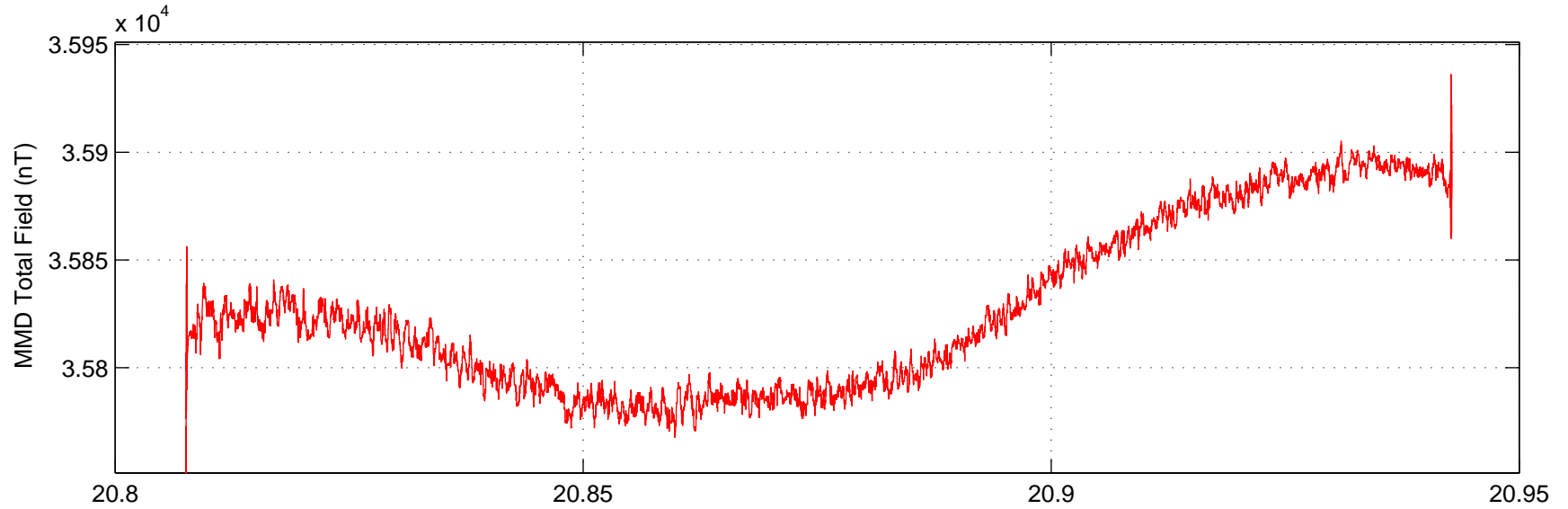
Hawaiian JQZ DEEPTOWMAG Line 8
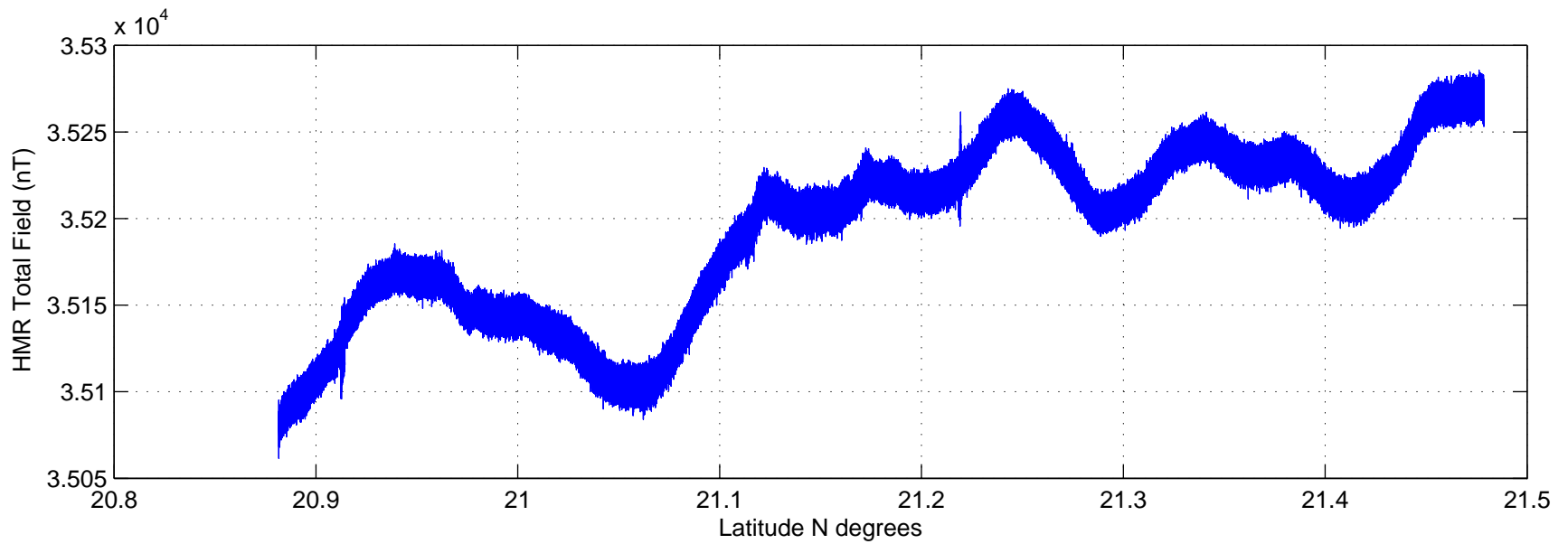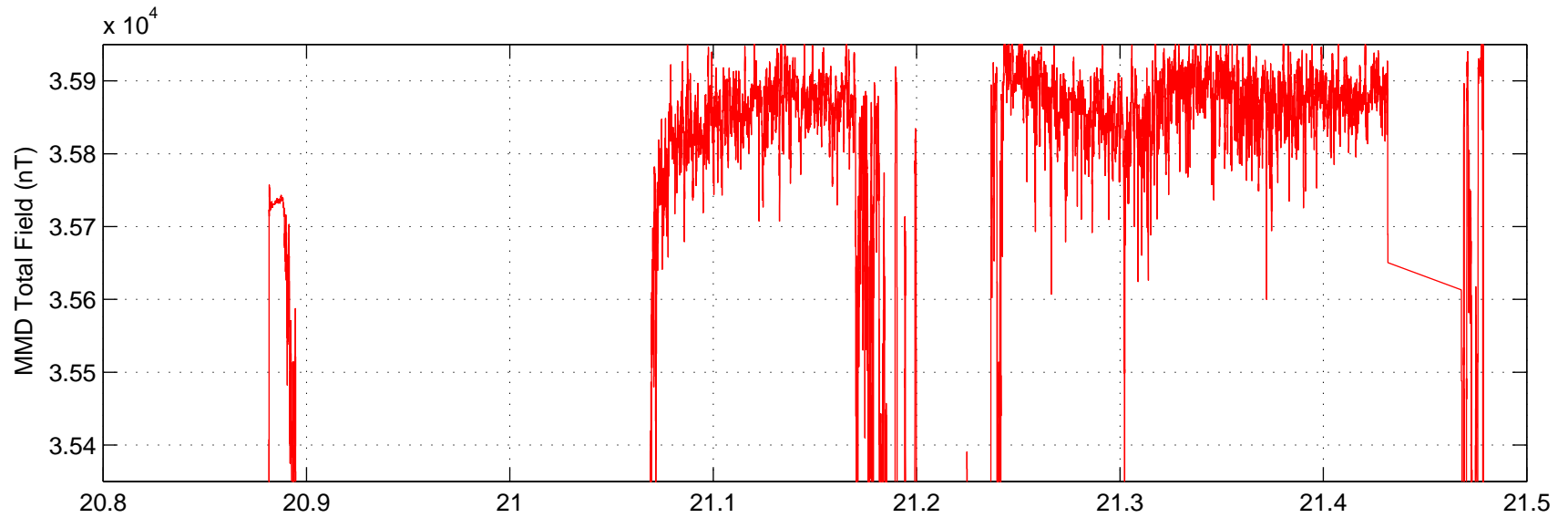
Hawaiian JQZ DEEPTOWMAG Line 9
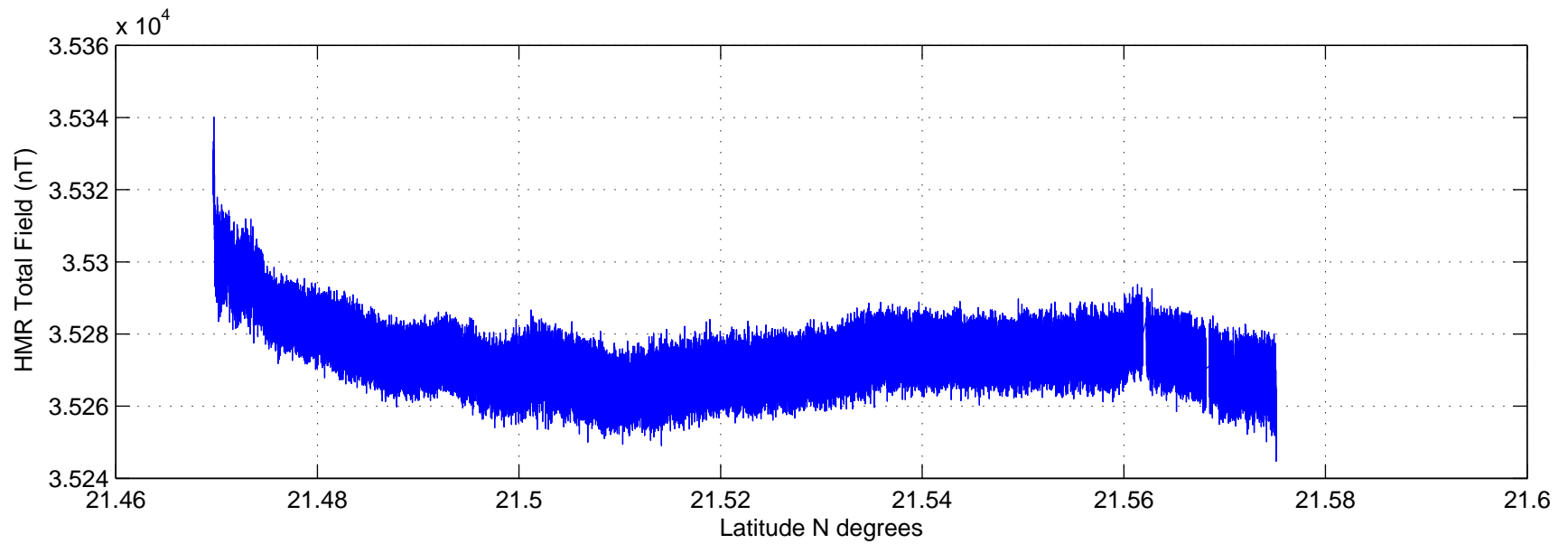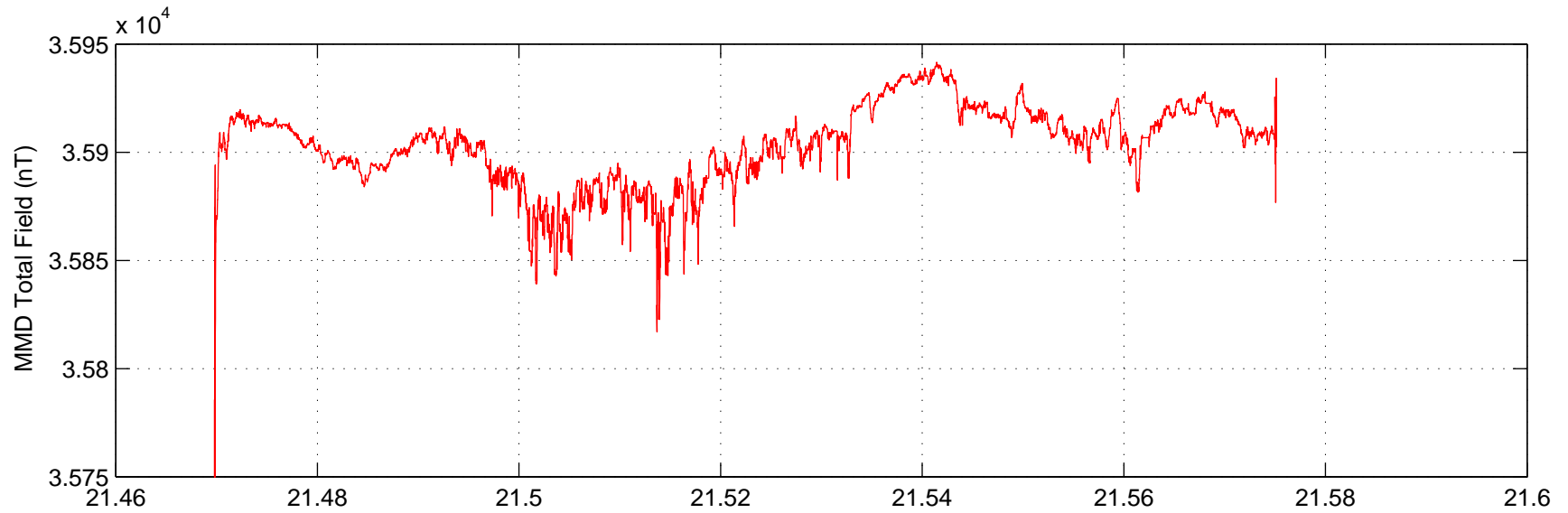
Hawaiian JQZ DEEPTOWMAG Line 10
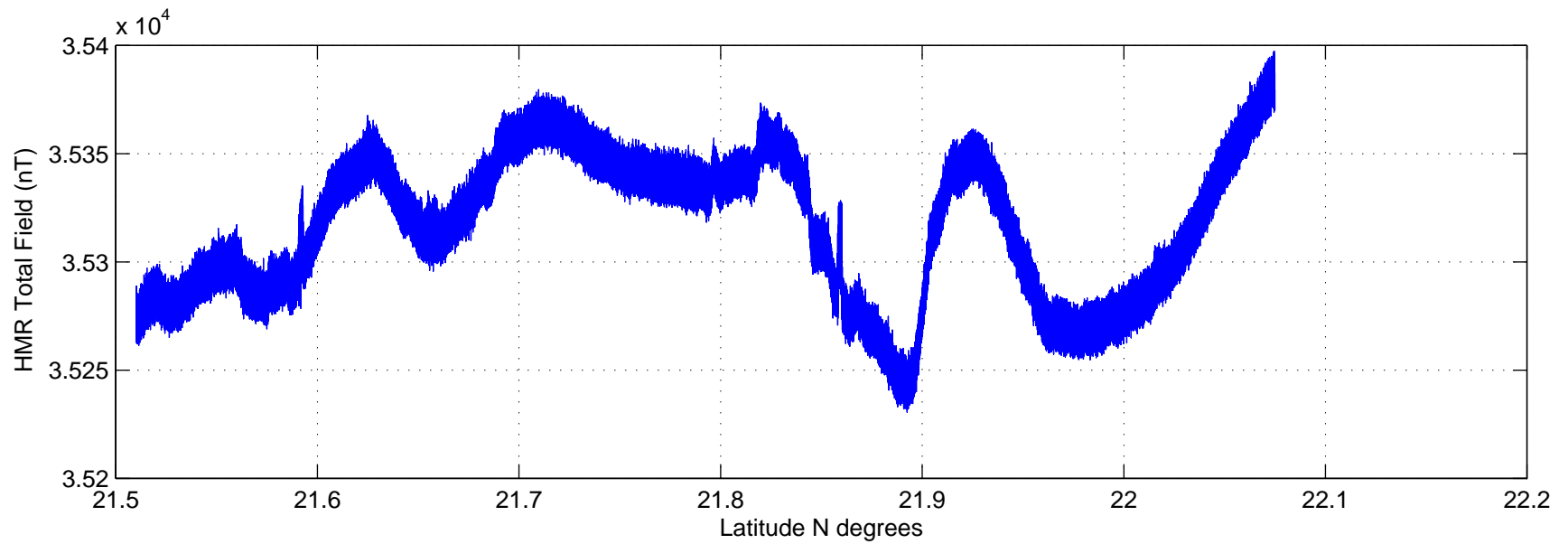
PEARL Script for processing seapath files

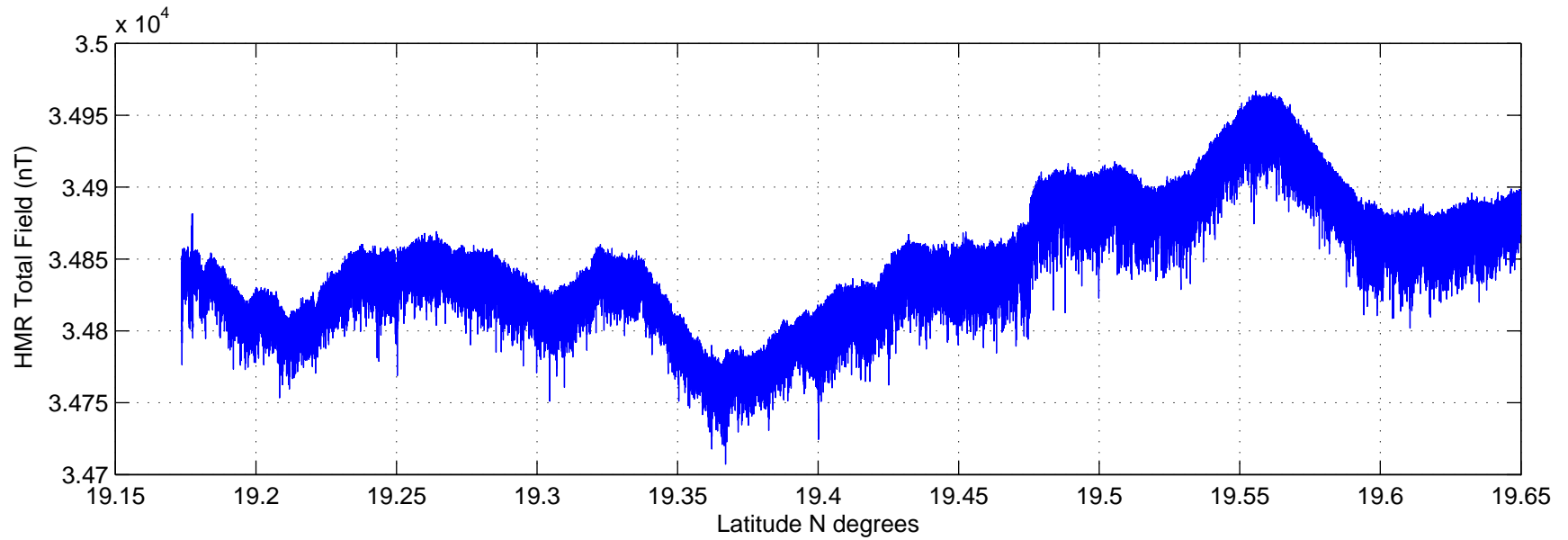-The ship's coordinates are saved in one seapath file that is updated daily. In order to select the coordinates for a given day to then later plot the ship's track, these coordinates must be separated by day. To separate, run this pearl script ("seapath_splitter.pl") in terminal.

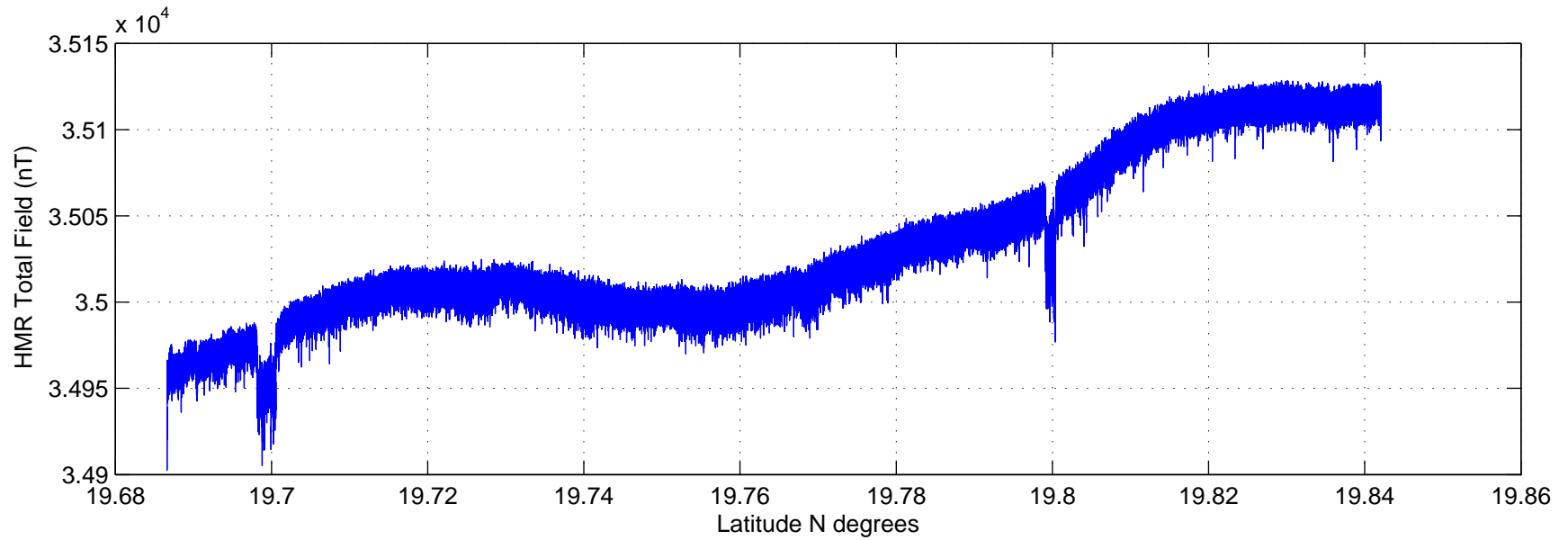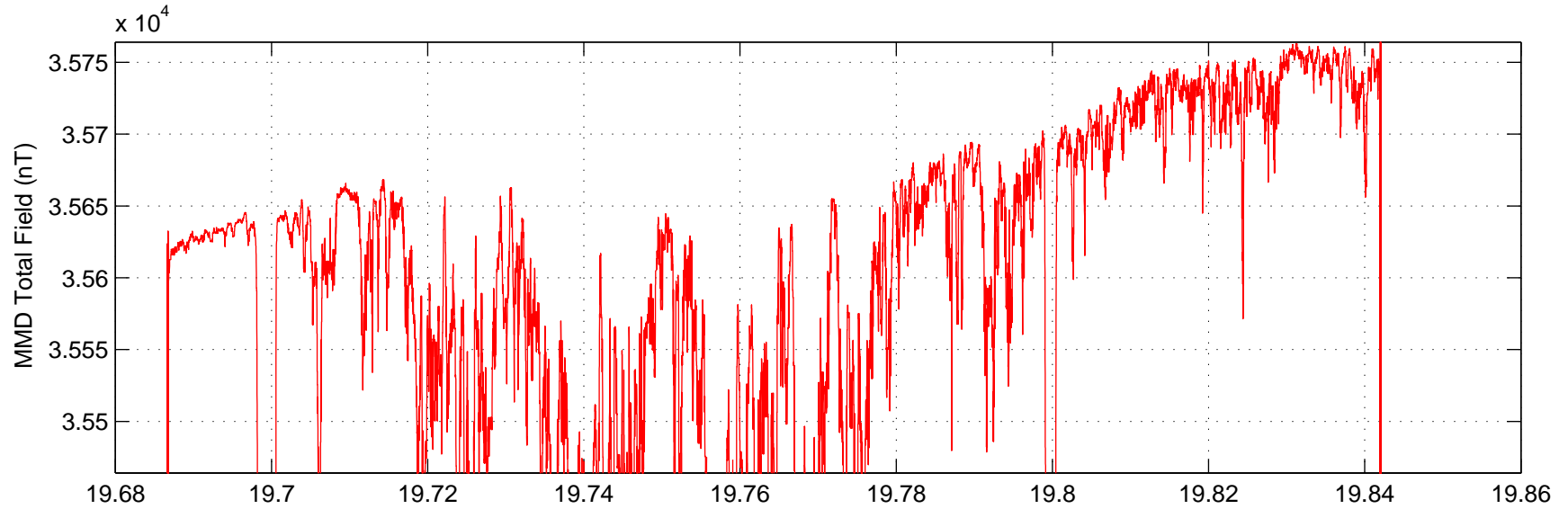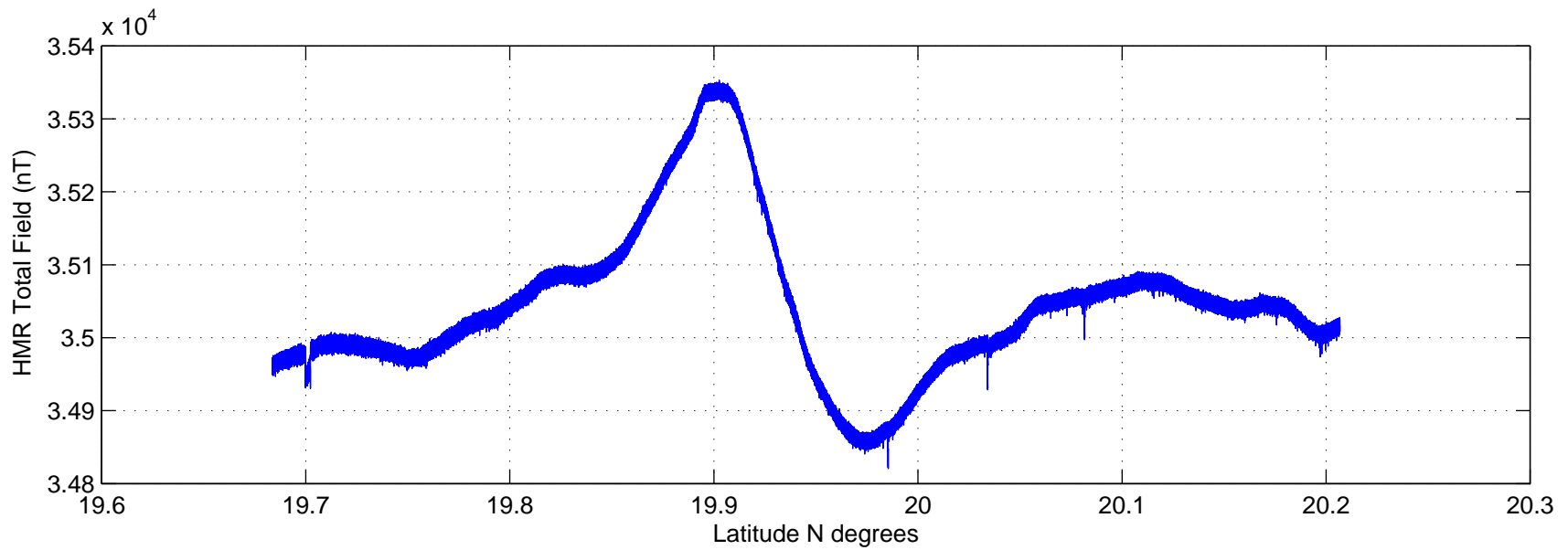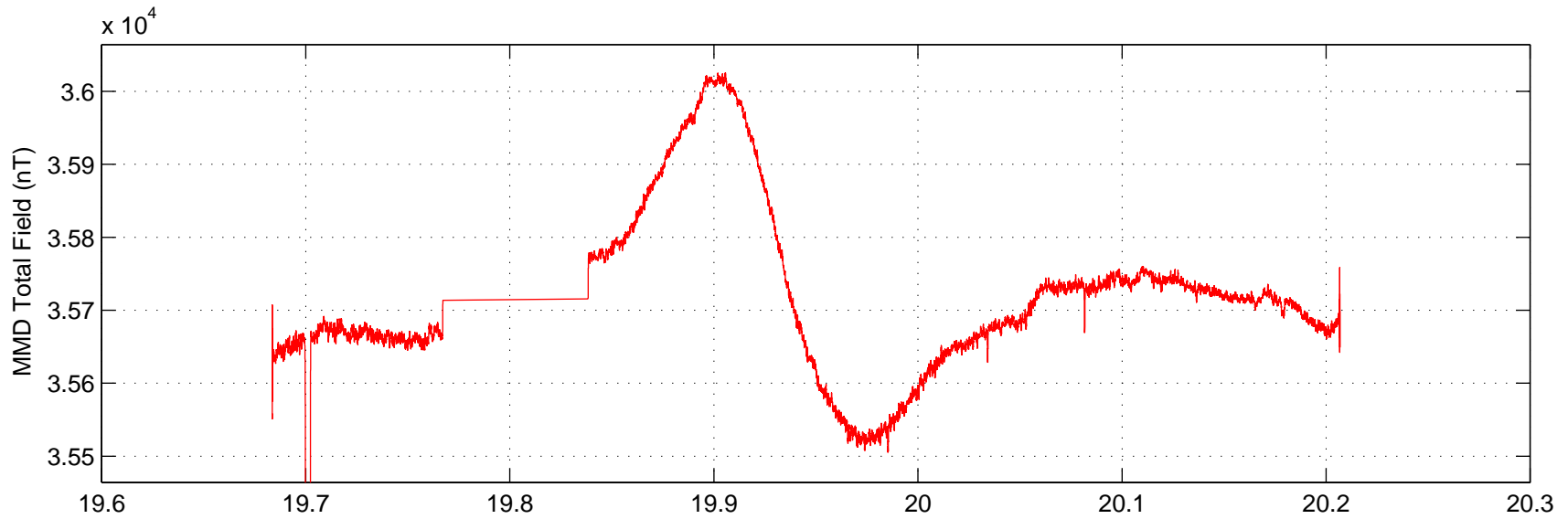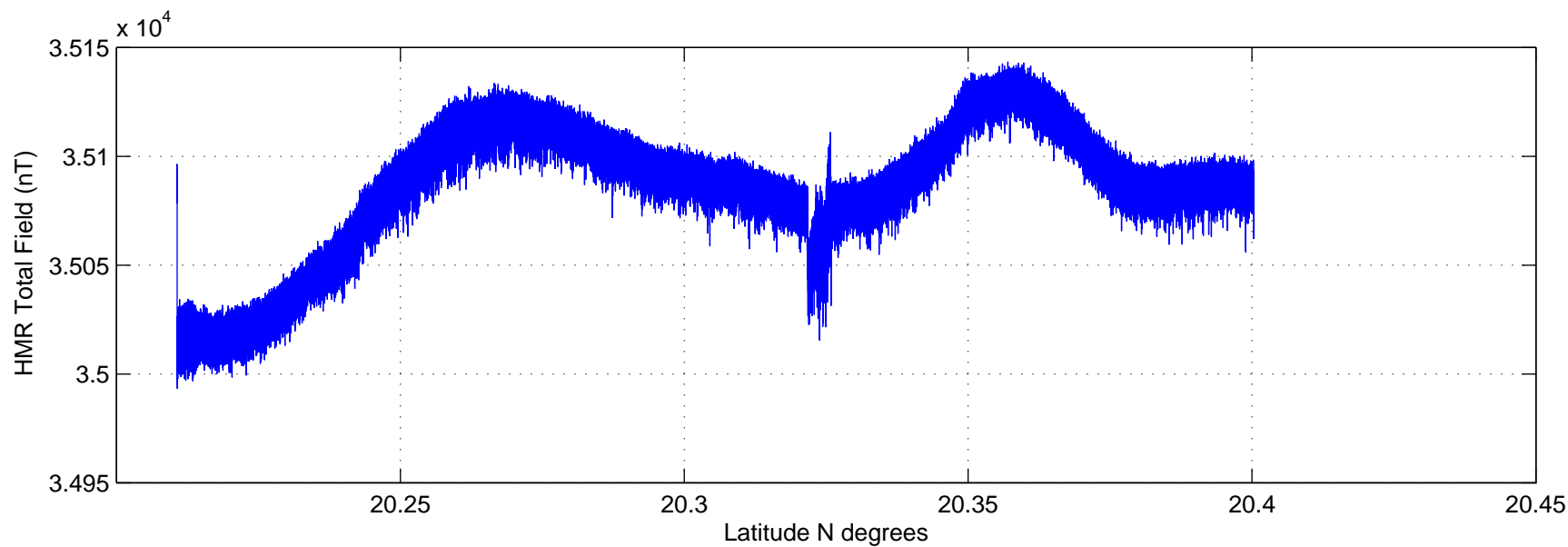-Before running, make sure the seapath file with the raw data is saved in the directory listed in the first line of the script. In this case, it was '/Users/johngreene/Desktop/report_nav'.

```perl
#!/usr/bin/perl

my $dir = "/Users/johngreene/Desktop/report_nav";
foreach my $fh (glob("$dir/*")) {
    if ($fh =~ m/seapath/g) {
    open my $fx, '+<', $fh or die $!;
    while (<$fx>) {
    if ($_ =~ m/GPGGA/g) {
      $_ =~ s/,/ /g;
      $_ =~ s/-/ /g;
      $_ =~ s/T/ /g;
      $_ =~ s/:/ /g;
      $_ =~ s/Z/ /g;

      my @inf = split(" ", $_);
      my $day = $inf[3];
      my $hr = $inf[4];
      my $min = $inf[5];
      my $sec = $inf[6];
      my $latitude = $inf[9];
      my $longitude = $inf[11];

      $latdeg=int($inf[9]/100);
    $londeg=int($inf[11]/100);
    $lat=$latdeg+($inf[9]-$latdeg*100)/60;
    $lon=$londeg+($inf[11]-$londeg*100)/60;
    if ($inf[12] == "W") {
    $lon=-$lon;
    }

    open(my $fs, '>>', 'navdata.txt');
      printf $fs "%s %s %s %2.4f %3.8f %2.8f\n", $day, $hr, $min, $sec, $lon, $lat;
      close $fs;
      }
  if ($_ =~ m/GPVTG/g) {
    $_ =~ s/,/ /g;
      $_ =~ s/-/ /g;
      $_ =~ s/T/ /g;
      $_ =~ s/:/ /g;
      $_ =~ s/Z/ /g;

      my @dat = split(" ", $_);
```

```perl
        my $dd = $dat[3];
        my $hh = $dat[4];
        my $mm = $dat[5];
        my $ss = $dat[6];
        my $heading = $dat[9];
        my $knot = $dat[12];

        open(my $fn, '>>', 'headspeed.txt');
        printf $fn "%s %s %s %2.4f %3.2f %s \n", $dd, $hh, $mm, $ss, $heading, $knot;
        close $fn
        }
    }
}
close $fx;
}
close $fh;
```

Running this script will create a .txt file named 'navdata.txt.' this file will then be loaded into the following script in MATAB.

MATLAB Navigation Processing Script

       -After creating the navdata.txt file, run this script in MATLAB to create two .txt files: 'navXXX.txt' and 'endpointXXX.txt.' 'navXXX.txt' contains all of the ship's coordinates for the given day which will ultimately be plotted as the trackline. 'endpointXXX.txt' contains the first and last coordinates of the day, which are used to create endpoints on the track line. XXX= the Julian day number (ex- nav365.txt = the ship's coordinates for Dec 31).

       -In the command lines defining the variables 'ind1' and 'ind2,' 'days==XX' should be replaced by the numerical date (ex- days==31 would be used for Dec 31).

       -In the command line 'lonXXX=longitude(ind1:ind2)*-1;' the coordinates are multiplied by -1 to be plotted as positive points. In the navdata.txt file, these values are negative, which results in their being plotted as western coordinates rather than eastern coordinates. If you're plotting western coordinates, eliminate the '*-1' in the command line.

```matlab
clear all;
format long;
load('navdata.txt');
days = navdata(:,1);
longitude = navdata(:,5);
latitude = navdata(:,6);

ind1=find(days==XX,1,'first');
ind2=find(days==XX,1,'last');

lonXXX=longitude(ind1:ind2)*-1;
latXXX=latitude(ind1:ind2);

endpoint = [lonXXX(1) latXXX(1); lonXXX(end) latXXX(end)];
```

dlmwrite('navXXX.txt',[lonXXX latXXX], 'delimiter', '\t', 'precision', '%5.4f');
dlmwrite('endpointXXX.txt',endpoint, 'delimiter', '\t', 'precision', '%5.4f');

Running this script will create two .txt files named 'navXXX.txt' and 'endpointXXX.txt.' Make sure these files are saved in the directory from which you will run the following BASH script.

BASH Script for plotting the ship's track on a GMT map
    -This script will create a .ps document with the ship's track line plotted over a GMT map. Each command line is explained with the #description above it.
    -XXX again represents the Julian Date.
    -Make sure the .txt files you created in the previous step are saved in the directory you're accessing from the terminal.
    -An example of a completed script is provided after the following outline.

#Document title: JDXXX
#!/bin/bash

#creating the color palate and range of the bathymetry map
gmt makecpt –C[choose color palate] -T-[max depth]/[min depth]/[depth scale] -Z >
bath.cpt

#to load the GMT map, specify the range, and set the X-Y coordinate scale
gmt grdimage gebco_[map file name] –Jm[degree length in inches]i –
R[Xmin]/[Xmax]/[Ymin]/[Ymax] –Ba[make grid lines every how many degrees]g[make
grid lines every how many minutes]m:.JDXXX\
: -Cbath.cpt -K > JDXXX.ps

#to create grid contours
gmt grdcontour gebco_[map file name] -C100 –A[draw contour lines every how many
meters depth] -J -R -O -K >> JDXXX.ps

#to create the ship's track line
gmt psxy navXXX.txt -J -R –W[line weight]p,[line color desired] -O -K >> JDXXX.ps

#to create the ship's endpoints
gmt psxy endpointXXX.txt -J -R –S[endpoint shape].[endpoint weight] –W[endpoint color]
–G[endpoint color] -O -K >> JDXXX.ps

#to create the legend
gmt psscale –D[location on the page, measured in inches from the left]i/1i/2i/.5i -Ac -
Cbath.cpt -O >> JDXXX.ps

EXAMPLE for Jan 6:
#JD006
#!/bin/bash
gmt makecpt -Csealand -T-7000/-1000/1000 -Z > bath.cpt
gmt grdimage gebco_08_160_0_170_25.nc -Jm2i -R165/167/21/23 -Ba1g30m:.JD006\
: -Cbath.cpt -K > JD006.ps
gmt grdcontour gebco_08_160_0_170_25.nc -C100 -A1000 -J -R -O -K >> JD006.ps

gmt psxy nav006.txt -J -R -W2p,white -O -K >> JD006.ps
gmt psxy endpoint006.txt -J -R -Sa.5 -Wwhite -Gwhite -O -K >> JD006.ps
gmt psscale -D5i/1i/2i/.5i -Ac -Cbath.cpt -O >> JD006.ps

Running this script will create a .ps document with the ship's track and endpoints plotted over a GMT map. To append Sentry's track on the same map, see below.

BASH Script for plotting Sentry's track on the same GMT map
　　　　-This script will append Sentry's track line to the same .ps document with the ship's track line plotted over a GMT map.
　　　　-Make sure the .csv file you create is saved in the directory you're accessing from the terminal.
　　　　-An example of a completed script is provided after the following outline.

Before running this script, you must first create a .csv file (Windows comma separated format) containing the Sentry dive endpoints, Y-coordinates first, X-coordinates second:

　　165.165　　　20.8369
　　165.712　　　21.5352

Save the file as 'SentryZZZcsv' where ZZZ= Sentry's dive number. After saving this is the same directory as the other files, append the following command lines **(in bold)** to the previous script you used, after the 'gmt psxy' command lines. A complete example is given after the descriptions below.

...
gmt psxy navXXX.txt -J -R -W2p,white -O -K >> JDXXX.ps
gmt psxy endpointXXX.txt -J -R -Sa.5 -Wwhite -Gwhite -O -K >> JDXXX.ps
gmt psxy SentryZZZ.csv -J -R –W[line weight]p,[line color] -O -K >> JD005.ps
gmt psxy Sentry296.csv -J -R –S[endpoint shape].[endpoint weight] –W[endpoint color] –G[endpoint color] -O -K >> JDXXX.ps
...

EXAMPLE for Jan 5:
#JD005, SENTRY DIVE 296
#!/bin/bash
gmt makecpt -Csealand -T-7000/-1000/1000 -Z > bath.cpt
gmt grdimage gebco_08_160_0_170_25.nc -Jm2i -R164/166/20/22 -Ba1g30m:.JD005\
: -Cbath.cpt -K > JD005.ps
gmt grdcontour gebco_08_160_0_170_25.nc -C100 -A1000 -J -R -O -K >> JD005.ps
gmt psxy nav005.txt -J -R -W2p,white -O -K >> JD005.ps
gmt psxy endpoint005.txt -J -R -Sa.5 -Wwhite -Gwhite -O -K >> JD005.ps
gmt psxy Sentry296.csv -J -R -W2p,black -O -K >> JD005.ps
gmt psxy Sentry296.csv -J -R -Sc.3 -Wblack -Gblack -O -K >> JD005.ps
gmt psscale -D5i/1i/2i/.5i -Ac -Cbath.cpt -O >> JD005.ps

All of the scripts used to create the maps begin on the following page.

```bash
#!/bin/bash
# Purpose: The purpose of this script is to plot bathymetry data and the
# seapath navigation data
# GMT functions:gmtset, grdimage, psxy, pscoast, psscale
#control-X, control-S, control-X control-Z to exit window
#fg to get back to script (to make changes)
#emacs filename.sh
#chmod +x filename to make script executable
#./filename.sh (enter to run, check directory for map)


#JD350-351
gmt gmtset PS_MEDIA = a4
gmt makecpt -Cbathy -T-7000/-1000/1000 -Z > bath.cpt
gmt grdimage gebco_08_-175_-15_-155_25.nc -Jm2i -R-160/-157/19/22 -Ba1g1 -
B+t"JQZ JDAY350-351" -Cbath.cpt -K > firstmap.ps
gmt psxy navdata_lonlat.txt -Jm2i -R-160/-157/19/22 -Ba1g1 -W2p,255/255/255 -O -K
>> firstmap.ps
gmt pscoast -Jm2i -R-160/-157/19/22 -Df -FUS.HI -G169/169/169 -O -K >> firstmap.ps
gmt psscale -D7i/1i/2i/.5i -Ac -Cbath.cpt -O >> firstmap.ps


#JD352
gmt grdimage gebco_08_-175_-15_-155_25.nc -Jm3i -R-163.5/-161/18/20 -Ba1g1 -
B+t"JQZ 352" -Cbath.cpt -K > JQZday2.ps
gmt psxy lonlat.txt -Jm3i -R-163.5/-161/18/20 -Ba1g1 -W2p,255/255/255 -O -K >>
JQZday2.ps
gmt psscale -D8i/1i/2i/.5i -Ac -Cbath.cpt -O >> JQZday2.ps


#JD353
gmt grdimage gebco_08_-175_-15_-155_25.nc -Jm2i -R-166.75/-163.25/17/19 -Ba1g1 -
B+t"JQZ 353" -Cbath.cpt -K > JQZday3.ps
gmt psxy lonlat.txt -Jm2i -R-166.75/-163.25/17/19 -Ba1g1 -W2p,255/255/255 -O -K >>
JQZday3.ps
gmt psscale -D8i/1i/2i/.5i -Ac -Cbath.cpt -O >> JQZday3.ps


# JD354
#!/bin/bash
gmt makecpt -Cgebco -T-7000/-1000/1000 -Z > bath.cpt
gmt grdimage gebco_08_-175_-15_-155_25.nc -Jm1i -R-172/-165/16/20 -
Ba1g30m:.JD354: -Cbath.cpt -K > JD354.ps
gmt grdcontour gebco_08_-175_-15_-155_25.nc -C100 -A1000 -J -R -O -K >> JD354.p\
s
gmt psxy nav20.txt -J -R -W2p,white -O -K >> JD354.ps
gmt psxy endpoint20.txt -J -R -Sa.5 -Wwhite -Gwhite -O -K >> JD354.ps
gmt psscale -D8i/1i/2i/.5i -Ac -Cbath.cpt -O >> JD354.ps


#JD355
#!/bin/bash
gmt makecpt -Cgebco -T-7000/-1000/1000 -Z > bath.cpt
gmt grdimage gebco_08_-180_10_180_25.nc -Jm1i -R-177/-170/16/20 -
Ba1g30m:.JD355\
: -Cbath.cpt -K > JD355.ps
```

```
gmt grdcontour gebco_08_-180_10_180_25.nc -C100 -A1000 -J -R -O -K >> JD355.ps
gmt psxy nav21.txt -J -R -W2p,white -O -K >> JD355.ps
gmt psxy endpoint21.txt -J -R -Sa.5 -Wwhite -Gwhite -O -K >> JD355.ps
gmt psscale -D8i/1i/2i/.5i -Ac -Cbath.cpt -O >> JD355.ps

#JD356: SPLIT MAPS/DATELINE CROSSING
#!/bin/bash
gmt makecpt -Cgebco -T-7000/-1000/1000 -Z > bath.cpt
gmt grdimage gebco_08_-180_10_180_25.nc -Jm1i -R-181/-176/16/20 -
Ba1g30m:.JD356\
\
: -Cbath.cpt -K > JD356.ps
gmt grdimage gebco_08_168_15_180_25.nc -Jm1i -R-181/-176/16/20 -
Ba1g30m:.JD356\
: -Cbath.cpt -K -O >> JD356.ps
gmt grdcontour gebco_08_-180_10_180_25.nc -C100 -A1000 -J -R -O -K >> JD356.ps
gmt grdcontour gebco_08_168_15_180_25.nc -C100 -A1000 -J -R -O -K >> JD356.ps
gmt psxy nav22.txt -J -R -W2p,white -O -K >> JD356.ps
gmt psxy endpoint22.txt -J -R -Sa.5 -Wwhite -Gwhite -O -K >> JD356.ps
gmt psscale -D6i/1i/2i/.5i -Ac -Cbath.cpt -O >> JD356.ps

#JD357
#!/bin/bash
gmt makecpt -Cgebco -T-7000/-1000/1000 -Z > bath.cpt
gmt grdimage gebco_08_168_15_180_25.nc -Jm1i -R174/180/16/20 -Ba1g30m:.JD357\
: -Cbath.cpt -K > JD357.ps
gmt grdcontour gebco_08_168_15_180_25.nc -C100 -A1000 -J -R -O -K >> JD357.ps
gmt psxy nav23.txt -J -R -W2p,white -O -K >> JD357.ps
gmt psxy endpoint23.txt -J -R -Sa.5 -Wwhite -Gwhite -O -K >> JD357.ps
gmt psscale -D7i/1i/2i/.5i -Ac -Cbath.cpt -O >> JD357.ps

#JD358
#!/bin/bash
gmt makecpt -Cgebco -T-7000/-1000/1000 -Z > bath.cpt
gmt grdimage gebco_08_168_15_180_25.nc -Jm1i -R170/176/17/22 -Ba1g30m:.JD358\
: -Cbath.cpt -K > JD358.ps
gmt grdcontour gebco_08_168_15_180_25.nc -C100 -A1000 -J -R -O -K >> JD358.ps
gmt psxy nav24.txt -J -R -W2p,white -O -K >> JD358.ps
gmt psxy endpoint24.txt -J -R -Sa.5 -Wwhite -Gwhite -O -K >> JD358.ps
gmt psscale -D7i/1i/2i/.5i -Ac -Cbath.cpt -O >> JD358.ps

#JD359: SPLIT MAPS
#!/bin/bash
gmt makecpt -Csealand -T-7000/-1000/1000 -Z > bath.cpt
gmt grdimage gebco_08_168_15_180_25.nc -Jm1i -R167/172/21/24 -Ba1g30m:.JD359\
: -Cbath.cpt -K > JD359.ps
gmt grdimage gebco_08_160_0_170_25.nc -Jm1i -R167/172/21/24 -Ba1g30m:.JD359\
: -Cbath.cpt -K -O >> JD359.ps
gmt grdcontour gebco_08_168_15_180_25.nc -C100 -A1000 -J -R -O -K >> JD359.ps
gmt grdcontour gebco_08_160_0_170_25.nc -C100 -A1000 -J -R -O -K >> JD359.ps
gmt psxy nav25.txt -J -R -W2p,white -O -K >> JD359.ps
```

```
gmt psxy endpoint25.txt -J -R -Sa.5 -Wwhite -Gwhite -O -K >> JD359.ps
gmt psscale -D6i/1i/2i/.5i -Ac -Cbath.cpt -O >> JD359.ps


#JD360 = "bath36.sh" <<-- TYPO!
#!/bin/bash
gmt makecpt -Csealand -T-7000/-1000/1000 -Z > bath.cpt
gmt grdimage gebco_08_160_0_170_25.nc -Jm1i -R164/169/19/24 -Ba1g30m:.JD360\
: -Cbath.cpt -K > JD360.ps
gmt grdcontour gebco_08_160_0_170_25.nc -C100 -A1000 -J -R -O -K >> JD360.ps
gmt psxy nav360.txt -J -R -W2p,white -O -K >> JD360.ps
gmt psxy endpoint360.txt -J -R -Sa.5 -Wwhite -Gwhite -O -K >> JD360.ps
gmt psscale -D6i/1i/2i/.5i -Ac -Cbath.cpt -O >> JD360.ps


#JD361
#!/bin/bash
gmt makecpt -Csealand -T-7000/-1000/1000 -Z > bath.cpt
gmt grdimage gebco_08_160_0_170_25.nc -Jm1i -R161/165/17/21 -Ba1g30m:.JD361\
: -Cbath.cpt -K > JD361.ps
gmt grdcontour gebco_08_160_0_170_25.nc -C100 -A1000 -J -R -O -K >> JD361.ps
gmt psxy nav361.txt -J -R -W2p,white -O -K >> JD361.ps
gmt psxy endpoint361.txt -J -R -Sa.5 -Wwhite -Gwhite -O -K >> JD361.ps
gmt psscale -D5i/1i/2i/.5i -Ac -Cbath.cpt -O >> JD361.ps


#JD362*** SENTRY DIVE 292
#!/bin/bash
gmt makecpt -Csealand -T-7000/-1000/1000 -Z > bath.cpt
gmt grdimage gebco_08_160_0_170_25.nc -Jm2i -R162/164/18/20 -Ba1g30m:.JD362\
: -Cbath.cpt -K > JD362.ps
gmt grdcontour gebco_08_160_0_170_25.nc -C100 -A1000 -J -R -O -K >> JD362.ps
gmt psxy nav362.txt -J -R -W2p,white -O -K >> JD362.ps
gmt psxy endpoint362.txt -J -R -Sa.5 -Wwhite -Gwhite -O -K >> JD362.ps
gmt psxy Sentry362.txt -J -R -W2p,red -O -K >> JD362.ps
gmt psxy Sentry362.txt -J -R -Sc.3 -Wred -Gred -O -K >> JD362.ps
gmt psscale -D5i/1i/2i/.5i -Ac -Cbath.cpt -O >> JD362.ps


#JD363
#!/bin/bash
gmt makecpt -Csealand -T-7000/-1000/1000 -Z > bath.cpt
gmt grdimage gebco_08_160_0_170_25.nc -Jm2i -R162/164/18/20 -Ba1g30m:.JD363\
: -Cbath.cpt -K > JD363.ps
gmt grdcontour gebco_08_160_0_170_25.nc -C100 -A1000 -J -R -O -K >> JD363.ps
gmt psxy nav363.txt -J -R -W2p,white -O -K >> JD363.ps
gmt psxy endpoint363.txt -J -R -Sa.5 -Wwhite -Gwhite -O -K >> JD363.ps
gmt psscale -D5i/1i/2i/.5i -Ac -Cbath.cpt -O >> JD363.ps


#JD364*** SENTRY DIVE 293
#!/bin/bash
gmt makecpt -Csealand -T-7000/-1000/1000 -Z > bath.cpt
gmt grdimage gebco_08_160_0_170_25.nc -Jm2i -R163/165/18/20 -Ba1g30m:.JD364\
: -Cbath.cpt -K > JD364.ps
gmt grdcontour gebco_08_160_0_170_25.nc -C100 -A1000 -J -R -O -K >> JD364.ps
```

```
gmt psxy nav364.txt -J -R -W2p,white -O -K >> JD364.ps
gmt psxy endpoint364.txt -J -R -Sa.5 -Wwhite -Gwhite -O -K >> JD364.ps
gmt psxy Sentry364.csv -J -R -W2p,red -O -K >> JD364.ps
gmt psxy Sentry364.csv -J -R -Sc.3 -Wred -Gred -O -K >> JD364.ps
gmt psscale -D5i/1i/2i/.5i -Ac -Cbath.cpt -O >> JD364.ps
```

```
#JD365
#!/bin/bash
gmt makecpt -Csealand -T-7000/-1000/1000 -Z > bath.cpt
gmt grdimage gebco_08_160_0_170_25.nc -Jm2i -R163/165/18/20 -Ba1g30m:.JD365\
: -Cbath.cpt -K > JD365.ps
gmt grdcontour gebco_08_160_0_170_25.nc -C100 -A1000 -J -R -O -K >> JD365.ps
gmt psxy nav365.txt -J -R -W2p,white -O -K >> JD365.ps
gmt psxy endpoint365.txt -J -R -Sa.5 -Wwhite -Gwhite -O -K >> JD365.ps
gmt psscale -D5i/1i/2i/.5i -Ac -Cbath.cpt -O >> JD365.ps
```

```
#JD001*** SENTRY DIVE 294 (do not use as template, missing nav data!)
#!/bin/bash
gmt makecpt -Csealand -T-7000/-1000/1000 -Z > bath.cpt
gmt grdimage gebco_08_160_0_170_25.nc -Jm2i -R163/165/19/22 -Ba1g30m:.JD001\
: -Cbath.cpt -K > JD001.ps
gmt grdcontour gebco_08_160_0_170_25.nc -C100 -A1000 -J -R -O -K >> JD001.ps
gmt psxy endpoint001.txt -J -R -Sa.5 -Wwhite -Gwhite -O -K >> JD001.ps
gmt psxy Sentry294.csv -J -R -W2p,black -O -K >> JD001.ps
gmt psxy Sentry294.csv -J -R -Sc.3 -Wblack -Gblack -O -K >> JD001.ps
gmt psscale -D5i/1i/2i/.5i -Ac -Cbath.cpt -O >> JD001.ps
```

```
#JD002
#!/bin/bash
gmt makecpt -Csealand -T-7000/-1000/1000 -Z > bath.cpt
gmt grdimage gebco_08_160_0_170_25.nc -Jm2i -R164/166/19/21 -Ba1g30m:.JD002\
: -Cbath.cpt -K > JD002.ps
gmt grdcontour gebco_08_160_0_170_25.nc -C100 -A1000 -J -R -O -K >> JD002.ps
gmt psxy nav002.txt -J -R -W2p,white -O -K >> JD002.ps
gmt psxy endpoint002.txt -J -R -Sa.5 -Wwhite -Gwhite -O -K >> JD002.ps
gmt psscale -D5i/1i/2i/.5i -Ac -Cbath.cpt -O >> JD002.ps
```

```
#JD003*** SENTRY DIVE 295, USE AS TEMPLATE
#!/bin/bash
gmt makecpt -Csealand -T-7000/-1000/1000 -Z > bath.cpt
gmt grdimage gebco_08_160_0_170_25.nc -Jm2i -R164/166/19/21 -Ba1g30m:.JD003\
: -Cbath.cpt -K > JD003.ps
gmt grdcontour gebco_08_160_0_170_25.nc -C100 -A1000 -J -R -O -K >> JD003.ps
gmt psxy nav003.txt -J -R -W2p,white -O -K >> JD003.ps
gmt psxy endpoint003.txt -J -R -Sa.5 -Wwhite -Gwhite -O -K >> JD003.ps
gmt psxy Sentry295.csv -J -R -W2p,black -O -K >> JD003.ps
gmt psxy Sentry295.csv -J -R -Sc.3 -Wblack -Gblack -O -K >> JD003.ps
gmt psscale -D5i/1i/2i/.5i -Ac -Cbath.cpt -O >> JD003.ps
```

```
#JD004
#!/bin/bash
```

```
gmt makecpt -Csealand -T-7000/-1000/1000 -Z > bath.cpt
gmt grdimage gebco_08_160_0_170_25.nc -Jm2i -R164/166/20/22 -Ba1g30m:.JD004\
: -Cbath.cpt -K > JD004.ps
gmt grdcontour gebco_08_160_0_170_25.nc -C100 -A1000 -J -R -O -K >> JD004.ps
gmt psxy nav004.txt -J -R -W2p,white -O -K >> JD004.ps
gmt psxy endpoint004.txt -J -R -Sa.5 -Wwhite -Gwhite -O -K >> JD004.ps
gmt psscale -D5i/1i/2i/.5i -Ac -Cbath.cpt -O >> JD004.ps

#JD005*** SENTRY DIVE 296, USE AS TEMPLATE
#!/bin/bash
gmt makecpt -Csealand -T-7000/-1000/1000 -Z > bath.cpt
gmt grdimage gebco_08_160_0_170_25.nc -Jm2i -R164/166/20/22 -Ba1g30m:.JD005\
: -Cbath.cpt -K > JD005.ps
gmt grdcontour gebco_08_160_0_170_25.nc -C100 -A1000 -J -R -O -K >> JD005.ps
gmt psxy nav005.txt -J -R -W2p,white -O -K >> JD005.ps
gmt psxy endpoint005.txt -J -R -Sa.5 -Wwhite -Gwhite -O -K >> JD005.ps
gmt psxy Sentry296.csv -J -R -W2p,black -O -K >> JD005.ps
gmt psxy Sentry296.csv -J -R -Sc.3 -Wblack -Gblack -O -K >> JD005.ps
gmt psscale -D5i/1i/2i/.5i -Ac -Cbath.cpt -O >> JD005.ps

#JD006
#!/bin/bash
gmt makecpt -Csealand -T-7000/-1000/1000 -Z > bath.cpt
gmt grdimage gebco_08_160_0_170_25.nc -Jm2i -R165/167/21/23 -Ba1g30m:.JD006\
: -Cbath.cpt -K > JD006.ps
gmt grdcontour gebco_08_160_0_170_25.nc -C100 -A1000 -J -R -O -K >> JD006.ps
gmt psxy nav006.txt -J -R -W2p,white -O -K >> JD006.ps
gmt psxy endpoint006.txt -J -R -Sa.5 -Wwhite -Gwhite -O -K >> JD006.ps
gmt psscale -D5i/1i/2i/.5i -Ac -Cbath.cpt -O >> JD006.ps

#JD007*** SENTRY DIVE 298, USE AS TEMPLATE
#!/bin/bash
gmt makecpt -Csealand -T-7000/-1000/1000 -Z > bath.cpt
gmt grdimage gebco_08_160_0_170_25.nc -Jm2i -R165/167/21/23 -Ba1g30m:.JD007\
: -Cbath.cpt -K > JD007.ps
gmt grdcontour gebco_08_160_0_170_25.nc -C100 -A1000 -J -R -O -K >> JD007.ps
gmt psxy nav007.txt -J -R -W2p,white -O -K >> JD007.ps
gmt psxy endpoint007.txt -J -R -Sa.5 -Wwhite -Gwhite -O -K >> JD007.ps
gmt psxy Sentry298.csv -J -R -W2p,black -O -K >> JD007.ps
gmt psxy Sentry298.csv -J -R -Sc.3 -Wblack -Gblack -O -K >> JD007.ps
gmt psscale -D5i/1i/2i/.5i -Ac -Cbath.cpt -O >> JD007.ps

#JD008
#!/bin/bash
gmt makecpt -Csealand -T-7000/-1000/1000 -Z > bath.cpt
gmt grdimage gebco_08_160_0_170_25.nc -Jm1i -R163/167/18/23 -Ba1g30m:.JD008\
: -Cbath.cpt -K > JD008.ps
gmt grdcontour gebco_08_160_0_170_25.nc -C100 -A1000 -J -R -O -K >> JD008.ps
gmt psxy nav008.txt -J -R -W2p,white -O -K >> JD008.ps
gmt psxy endpoint008.txt -J -R -Sa.5 -Wwhite -Gwhite -O -K >> JD008.ps
gmt psscale -D5i/1i/2i/.5i -Ac -Cbath.cpt -O >> JD008.ps
```

```
#JD009
#!/bin/bash
gmt makecpt -Csealand -T-7000/-1000/1000 -Z > bath.cpt
gmt grdimage gebco_08_160_0_170_25.nc -Jm2i -R162/164/17/19 -Ba1g30m:.JD009\
: -Cbath.cpt -K > JD009.ps
gmt grdcontour gebco_08_160_0_170_25.nc -C100 -A1000 -J -R -O -K >> JD009.ps
gmt psxy nav009.txt -J -R -W2p,white -O -K >> JD009.ps
gmt psxy endpoint009.txt -J -R -Sa.5 -Wwhite -Gwhite -O -K >> JD009.ps
gmt psscale -D5i/1i/2i/.5i -Ac -Cbath.cpt -O >> JD009.ps

#JD010*** SENTRY DIVE 298, USE AS TEMPLATE
#!/bin/bash
gmt makecpt -Csealand -T-7000/-1000/1000 -Z > bath.cpt
gmt grdimage gebco_08_160_0_170_25.nc -Jm2i -R161/163/17/19 -Ba1g30m:.JD010\
: -Cbath.cpt -K > JD010.ps
gmt grdcontour gebco_08_160_0_170_25.nc -C100 -A1000 -J -R -O -K >> JD010.ps
gmt psxy nav010.txt -J -R -W2p,white -O -K >> JD010.ps
gmt psxy endpoint010.txt -J -R -Sa.5 -Wwhite -Gwhite -O -K >> JD010.ps
gmt psxy Sentry299.csv -J -R -W2p,black -O -K >> JD010.ps
gmt psxy Sentry299.csv -J -R -Sc.3 -Wblack -Gblack -O -K >> JD010.ps
gmt psscale -D5i/1i/2i/.5i -Ac -Cbath.cpt -O >> JD010.ps

#JD011
#!/bin/bash
gmt makecpt -Csealand -T-7000/-1000/1000 -Z > bath.cpt
gmt grdimage gebco_08_160_0_170_25.nc -Jm1i -R156/163/16/19 -Ba1g30m:.JD011\:
-\
Cbath.cpt -K > JD011.ps
gmt grdimage gebco_08_142_10_162_25.nc -Jm1i -R156/163/16/19 -Ba1g30m:.JD011\:
\
-Cbath.cpt -K -O >> JD011.ps
gmt grdcontour gebco_08_160_0_170_25.nc -C100 -A1000 -J -R -O -K >> JD011.ps
gmt grdcontour gebco_08_142_10_162_25.nc -C100 -A1000 -J -R -O -K >> JD011.ps
gmt psxy nav011.txt -J -R -W2p,white -O -K >> JD011.ps
gmt psxy endpoint011.txt -J -R -Sa.5 -Wwhite -Gwhite -O -K >> JD011.ps
gmt psscale -D9i/1i/2i/.5i -Ac -Cbath.cpt -O >> JD011.ps

#JD012
#!/bin/bash
gmt makecpt -Csealand -T-7000/-1000/1000 -Z > bath.cpt
gmt grdimage gebco_08_142_10_162_25.nc -Jm1i -R151.5/157.5/15.5/18.5 -
Ba1g30m:.\
JD012\: -Cbath.cpt -K > JD012.ps
gmt grdcontour gebco_08_142_10_162_25.nc -C100 -A1000 -J -R -O -K >> JD012.ps
gmt psxy nav012.txt -J -R -W2p,white -O -K >> JD012.ps
gmt psxy endpoint012.txt -J -R -Sa.5 -Wwhite -Gwhite -O -K >> JD012.ps
gmt psscale -D7i/1i/2i/.5i -Ac -Cbath.cpt -O >> JD012.ps

#JD013
#!/bin/bash
```

```
gmt makecpt -Csealand -T-7000/-1000/1000 -Z > bath.cpt
gmt grdimage gebco_08_142_10_162_25.nc -Jm1i -R146/153/14/17 -Ba1g30m:.\
JD013\: -Cbath.cpt -K > JD013.ps
gmt grdcontour gebco_08_142_10_162_25.nc -C100 -A1000 -J -R -O -K >> JD013.ps
gmt psxy nav013.txt -J -R -W2p,white -O -K >> JD013.ps
gmt psxy endpoint013.txt -J -R -Sa.5 -Wwhite -Gwhite -O -K >> JD013.ps
gmt psscale -D8i/1i/2i/.5i -Ac -Cbath.cpt -O >> JD013.ps
```

Appendix 8. Ship Data Archive

The raw data (and processed data in the case of ADCP materials) is available from two sources from the ship: an external hard drive provided at the end of the cruise and an archive depository, Rolling Deck-to-Depository (R2R), to which the ship submits the raw cruise data. Both contain data in the following folders:

>adcp
>raw
>SKQ201402S_1
>gbin
>heading
>os75
>0s150
>processed
>os75bb (or os75nb, os150bb, os150nb)
>adcpb
>cal
>botmtrk
>heading
>rotate
>watertrk
>config
>contour
>edit
>grid
>load
>nav
>ping
>png_archive
>quality
>scan
>stick
>vector
>raw
>cnav
>config
>gyro1
>gyro2
>os75
>os150
>seapath

>rbin
>cnav
>gyro1
>gyro2
>seapath

>em302
>raw

>SKQ201402S_01
>SKQ201402S_02
>lds
>raw

>events
>flow_krohne_fwd
>flow_omega_fwd
>fluoro_turner-c6
>gnss_cnav
>grav_bgm3_222
>gyro1
>gyro2
>ins_seapath_position
>mb_em302_centerbeam
>met_ptu307
>rad_psp-pir
>rad_qsr2150a
>rad_qsr2150a
>rain_org815ds_across
>rain_org815ds_forward
>rain_rmy50202
>sb_echosounder_1
>speedlog
>ssv_aml-svxchang_fwd
>thermo_pyrometer-ct15
>tsg_emssv
>tsg_sbe45_fwd
>wind_gill_fwdmast
>wind_gill_fwdmast_true
>topaz
>raw

>SKQ201402S
>SKQ201402S_01
>SKQ201402S_02
>xbt
>raw

>SKQ201402S

Appendix 9. Cruise T-shirt logo

JQZ 3.2 Blog

An outreach-oriented, informal cruise journal and collection of short informative essays targeting the general reader and emphasizing the day-to-day experience from a student watchstander's perspective

Online blog:

http://web.whoi.edu/jurassicmagnetism/

Shipside blog:

\\share\public\Cruises\SKQ201402S\blog

Sikuliaq Shipside network photo repository:

\\share\public\Cruises\SKQ201402S\SKQ201402S Cruise Report\Shared Photos

This blog was posted from the Sikuliaq during the JQZ 3.2 cruise. All copy was written by Aric Velbel unless otherwise noted. Editorial oversight was provided by Maurice Tivey; all errors, omissions, and inaccuracies are the sole responsibility of Aric Velbel. Photographs and screenshots were taken by Aric Velbel unless otherwise noted. Other images are attributed to their sources. Posts are categorized as "Cruise Journal" (short summaries of a few days' events), "Science at Sea" (essays on the scientific instruments, techniques, and concepts employed during the cruise), and "Life on Board" (relaying aspects of the shipboard experience persisting throughout the cruise).

The blog consists of approximately 18,000 words over 26 posts.

Part I. Cruise journal

Welcome to the Jurassic Quiet Zone

JQZ

The "Jurassic Quiet Zone" is the name of a portion of the Earth's crust which formed in the period around 180 million years ago and now constitutes the seafloor under part of the Pacific ocean. It is called "quiet" because unlike the rest of the crust, the geomagnetic record here is weak and difficult to analyze. This record, which consists of the measurable patterns in magnetic properties of the crust resulting from the gradual and continual oscillation in the Earth's magnetic field, is of crucial importance to geophysicists who want to establish a timeline of reference points against which the age of various of the Earth's structural features can be compared. Because the JQZ is the oldest and most difficult area to understand magnetically, it is of particular interest to scientists including us.

The cruise

is a collaboration between scientists and students from Michigan State University, Woods Hole Oceanographic Institution, University of Houston, and more. We will spend 35 days at sea collecting magnetic, bathymetric, and gravimetric data to significantly improve the state of the scientific record of the magnetic history of the JQZ. The science mission will be enabled by the crew and facilities provided by the R/V Sikuliaq, a National Science Foundation research vessel that was built this year for operations like this one. Funded by NSF, our cruise will produce data that will appear in scientific journals and serve as valuable resources for geophysicists conducting further research.

In the meantime,

This Blog

will serve as our conversation with you. As professional scientists and science students, we want to communicate what it's like, day-to-day, to be involved in marine geophysics research. These cruises are exciting opportunities for undergraduate students, graduate students, and established scientists to experience operating state-of-the-art instruments and gathering and processing lots of important data. More than that, this mission is a chance to spend a month getting used to life at sea for the first time (for some of us), return to one of our favorite places on Earth (for the veterans), and share for a short time the daily experience of the crew of professional sailors who will return to the sea while the rest of us are coming back to our classrooms, labs, and offices.

Later, you can read about our scientific results in peer-reviewed publications. For now, we hope you can join us in this experience by following this blog, which will feature the science, sailing, and socialization of our foray into marine geophysics. Stay tuned for more about our ship, the Sikuliaq, who we are and where we're from, and what it's like to spend a month doing science at sea.

Last Night on Shore

[Cruise Journal: December 14]

For the science team, tonight is our last on shore before over a month at sea. Of all the places we could have spent these last hours of land-bound indulgence, we have decided that Honolulu is really not too bad a choice at all.

That's Waikiki Beach behind the palm trees across the street from our hotel. (A. Stote)

After convening at the baggage claim at Honolulu International Airport and becoming acquainted during the short taxi ride to our hotel, the four undergraduate (or recently graduated -- congratulations, Alex!) and three graduate student members of our expedition's science group spent the evening soaking in the ambience of Honolulu in December. Northern hemisphere winter is a good time to be in Hawaii, and we were far from the only mainlanders to be found.

In fact, we were in the midst of such a well-honed tourism destination that the first-time Hawaiian visitors among our party were taken aback by the extent of the city's modern urban appearance, and we all wondered at the appeal of travelling so many miles to the tropics in order to find a

Tiffany's next to a Chanel. Later our taxi driver would recount the old days when the waterfront was clear of skyscrapers, and in lazy endless nights people would gather in restaurants along the beach to talk and watch the water.

Honolulu for the holidays (A. Stote)

Today's Honolulu is of course not without its own considerable charms. Following a fine dinner, swapping excellent seafood and stories around a turntable in an establishment seconds away from our hotel, we set out to browse the beachfront district. (There are many upscale clothes and accessories to choose from. There is also a Ferrari store.) Our mainland-acclimated senses were treated to the kind of December evening we can usually only wistfully imagine, and we eventually returned to a hotel whose open-air lobby is comfortable at any time of day.

The last sunset silhouette that isn't the Sikuliaq that we'll be seeing for a while (T. Ruchala)

Tomorrow, we provision and board.

When in Hawaii, get some Hawaiian shave ice -- John, 2014 (J. Greene)

Preparations and departure

[Cruise Journal: December 15-16]

Two busy days in which: we go shopping for last minute supplies and snacks, move into our quarters and spend our first night aboard the Sikuliaq in port, acquire some important control data (on-shore gravimetrics), meet our AUV, cast off from Pier 34, travel a very short distance to the fueling station, wait a very long time to take on a very large amount of diesel fuel, and ultimately depart from Honolulu Harbor.

A the gas station

The first order of business for the cleverest among us on Monday was to get out into the Hawaiian surf. That left the few of us remaining on shopping duty: procuring the last minute forgotten essentials, air travel-unfriendly items and comfort snacks required to complete our preparations for boarding the ship and leaving the safety net of retail behind us. Laden with copious (we mean, sufficient) quantities of floss, shampoo, sunscreen, coffee beans, nuts and dried fruit, pretzels, cookies, Monster and Mountain Dew, and probably several other things (ah; forgot the whiteboard -- unfortunate), we navigated the surprisingly opaque taxi system back to the hotel where we stashed our conspicuously generous pile of groceries until a generously extended checkout time.

We managed a leisurely lunch, becoming familiar with the intricacies of competitive surfing courtesy of the open-air restaurant's a giant array of wall screens which showed exclusively competitive surfing, and with just a bit more taxi-wrangling arrived at our destination: Honolulu Harbor's Pier 34, current berth of the R/V Sikuliaq.
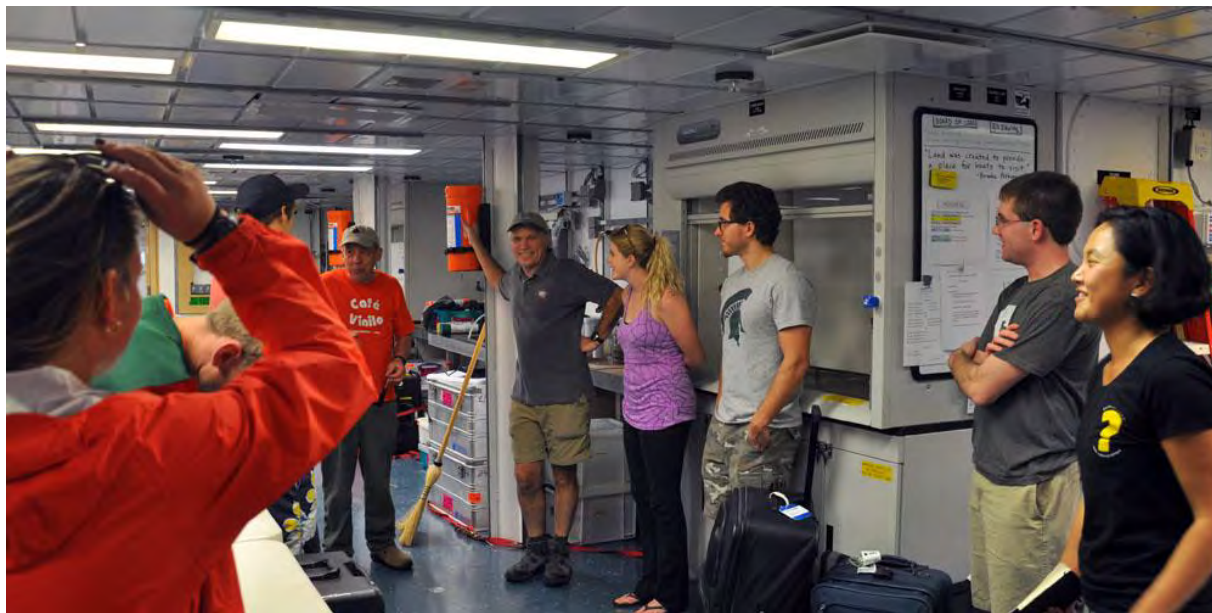
The Main Lab looks just like any other lab, especially right now while the floor is parallel to the horizon

A brief overview of the areas of the ship between the gangway and our rooms was followed by a period of unpacking, exploring the main deck, and getting used to looking at the world over a railing. We were given leave to make our own use of the time until tomorrow 0800 (join us as we adapt to using 24-hour time in all things) at which point all hands must be on board in advance of casting off at 0900.

* * *

The science team spent the morning before 0900 variously enjoying breakfast (in the mess daily 0720-0830), taking one last early morning run, sleeping in, and preparing data and tools for the cruise. We have been advised that, even more than one might be ready to expect, our vessel for this excursion likes to roll --a lot. This means that one has to be careful. To paraphrase the third mate, who is in charge of safety, if you have anything you don't like, leave it on a tabletop; if there's anything you wouldn't mind getting tossed around, don't secure it. Rolling is imminent, and that means books, pens, coffee cups, and everything else are going to need to be watched carefully or stowed. Some things, like the several computers we will be using to process and analyze the data collected on the cruise, are not so easy to put in a drawer. Fortunately, the ship's workshop is more than adequate to supply the drills, nuts, and bolts needed to affix these top-heavy and tip-prone displays to the table.

Day 1: we give Matt power tools

While our computers might have been ready to cruise at 0900, the ship itself was not. Pier 34 is only a short jaunt away from the harbor's fueling station, so the first leg of our journey was quite quickly over. Fueling this ship is a time-consuming process, but fortunately there is always science to be done. Before departing for the open ocean, we needed to collect a reference point gravitometric reading. This instrument and its readings are going to be useful throughout the cruise, so we'll tell you a lot more about it soon.

Tyler, our undergrad gravitometer veteran

Taking gravity readings does not take as long as fueling the Sikuliaq, so we also had time to get a little bit more information about Sentry, the Autonomous Underwater Vehicle that will be collecting the most prized magnetism data on our agenda. (Sentry is so important that it deserves a post all to itself. Stay tuned.)

Finally, the fuel line was disconnected and the ship took on the pilot who would guide us out of the harbor. (Ordinarily the ship is helmed by its own bridge crew, but in a busy and vital harbor, a local expert up to date with the latest charts and steeped in experience and practice in this particular location is used to pilot the ship out to sea.) Once we reached the sea buoys and his job was done, the pilot disembarked onto a waiting boat and we were on our way.

Honolulu Harbor, farewell (A. Stote)

Tomorrow, our regular schedule of data collection and watch standing begins as we set out for the first dive site for Sentry.

Safety drill, first watches

[Cruise Journal: 17 December]

The difference between rooming in a hotel and rooming on the ship is minimal. This is a fair assessment of a comparison of our last night on shore to our first night on board. However, something changed between our first night on board and our second: we set sail. We are now able to verify from firsthand experience that the first and most frequent thing we've heard from the crew is true: that the Sikuliaq does indeed roll. Quite a bit. In fact sometimes it seems that, even though the swells are modest or even barely discernable to the untrained eye, the ship will roll gleefully and wantonly simply because that is how it derives joy for itself.

Walking is no longer straight-forward. Doors acquire and abandon preferences for which way they will swing from a neutral position. Cups slide. Chairs shift. Motion is an inescapable facet of life now. Among science team, the race to adjust is just beginning, and to declare a winner now would be premature.

Into this context comes the 0830 fire and boat drill.

In the event of an emergency (or this drill), all personnel are required to report to designated muster stations with their survival equipment: PFD (personal flotation device) and immersion suit. The science team musters in the Main Lab. At the 3rd Mate's instructions, we donned (we mean, modeled) in turn the vests and suits and practiced moving from the Main Lab to the alternate

muster station on the aft deck where, in the best-case response to what would have to be a very un-best-case situation, the lifeboats would be tied waiting to receive evacuees.

Laura and the co-chief scientist, mustered in the Main Lab. Hats are mandatory.

(Many more details about shipboard safety and procedures will fill another post.)

Following the drill, we had a thorough tour of the ship from one of the techs. Rather than simply recapitulate that here, we'll introduce you to the various areas of the Sikuliaq gradually as we inhabit and use them over the next several weeks.

It takes up most of the deck for everyone to lay out, unfurl, and put on their immersion suits

Today's other major event was the commencing of watchstanding. (By the end of the cruise, we will have a lot to say about watchstanding. Watch this space). Because the instruments are constantly recording data, someone needs to be monitoring and logging the status at all times. Covering the whole 24 hour clock means that some people are going to have interesting and unfamiliar schedules. It also means, unfortunately, that the cruise archivist cannot be present to document everything that happens on watch. There may have occurred an eventuality in the first round of watches earlier today. Mops may have been employed. I'm afraid that's as much as I know.

Laura and John are the first to get Masako's watchstanding tutorial

Data is being collected, watchstanders are actively monitoring their stations, and the ship is steaming at 11.9 knots toward Waypoint 1, where our AUV Sentry will have its first deep dive test of the cruise.

Waypoint 1: test dives

[Cruise Journal 18-19 December]

For those of us on the science team who have never seen the AUV Sentry deployed from the deck of a research vessel before, today was a bounty: *two* launches for the price of one
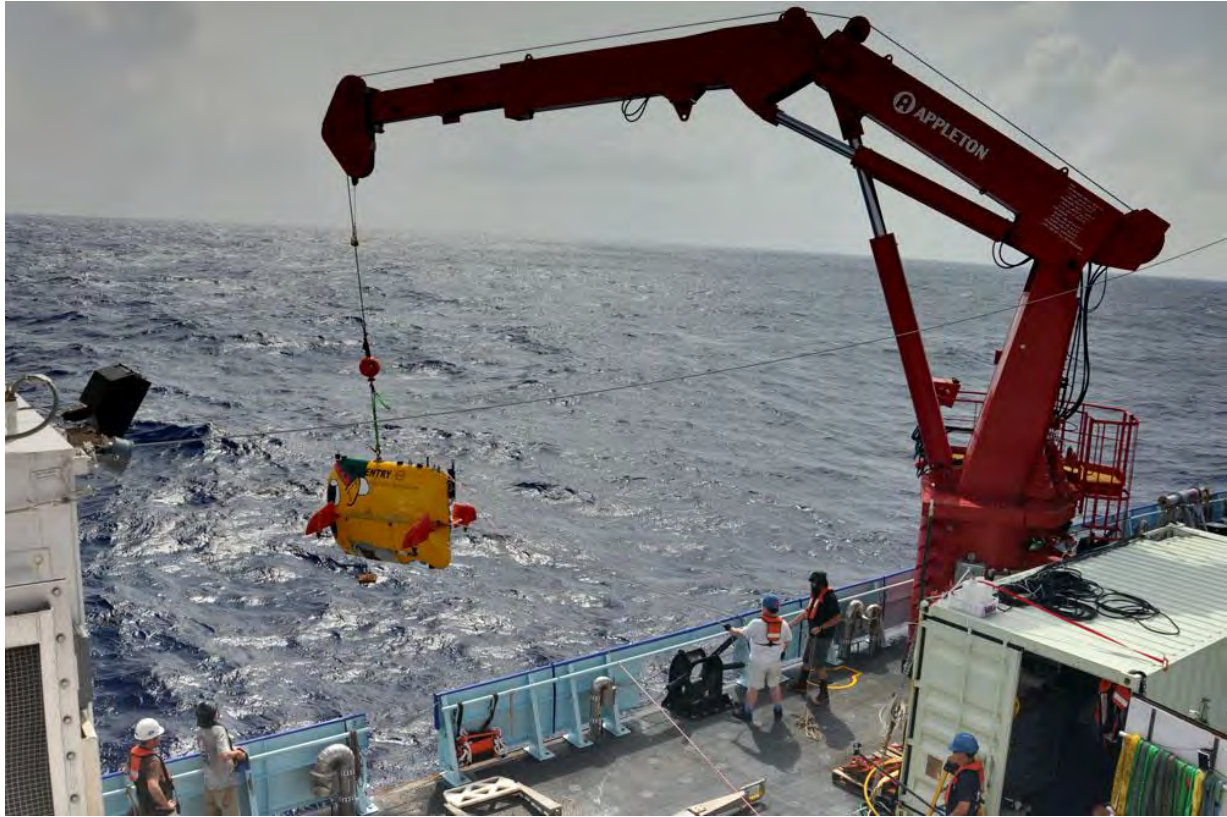
Sentry on the crane

Waypoint 1 is the point in the Pacific Ocean closest to our port of departure in Hawaii that reaches a depth comparable to the bulk of our area of interest in the Jurassic Quiet Zone. That's why it's the best place to perform the first Sentry dive of the cruise.

Here's what happened, according Sentry Expedition Leader Dana Yoerger:

"This was an Engineering test day for Sentry. That's a day specifically dedicated to testing improvements on the vehicle. Of course it's also a chance to test our readiness for the upcoming science dives. These days give us to chance to try big changes to software and hardware that would not be prudent in the midst of intense science operations.

We had two dives, both revealed important aspects of some changes we had made in the vehicle's hardware and software. We test all our changes as carefully as we can before we launch the vehicle. We do simulations, which test the higher level aspects of our software. And we do tests on the vehicle on deck to look at the interfaces between our software and the vehicle's hardware. Nevertheless, until we actually run the vehicle in deep water we can't be sure our changes are good.

Our first dive ended very early, when the vehicle reached about 100m. We had revised our code that handles the vehicle's depth sensor, but that code had a bug in it. So Sentry ended its descent early (very early). As soon as we got the vehicle on deck and the data offloaded, the problem was obvious and the code repaired and tested in a few hours. The science team took advantage of the time to test the deep tow magnetometer, we try to never let the vessel be idle.

On our second dive, Sentry got quite deep (about 5600m) but never started surveying. After launch, Sentry's descent weight forces it to go down without using much energy. Normally, Sentry descends until it senses it's close to seafloor (within 80 meters) using its Doppler Velocity Log (DVL). Then Sentry drops its descent weight and starts its programmed mission. In this case, Sentry "thought" it saw the seafloor within 80 meters but in fact it was sensing some sort of "false bottom". Sentry's software applies a series of tests to judge if the readings are genuine. Sentry was very deep (over 5500 meters). The bottom appeared to be close enough (within 80 meters) and the distance to the seafloor was decreasing. When the software sees a series of readings in a row meeting those criteria, it drops the descent weight and starts the survey. All this worked as expected. Except the sensor was giving us erroneous readings, it was sensing something other than the seafloor. The readings were consistent, sensible, but wrong! Some sort of deep layer? We don't know.

Bon voyage, Sentry

We were able to command the vehicle to continue its mission using acoustic commands to force it to drive deeper. But in the end, we had another problem: the vehicle was too light and it simply couldn't fight its positive buoyancy. So we decided to end the dive and bring the vehicle home.

We're always disappointed when a dive does not go as planned. But despite the problems, we were able to check most of the changes to Sentry's software and hardware. We'll be working on solutions to the "false bottom" problem. We have a 9-day transit, so we'll have time to solve the problem."

With the engineering test dives completed, we are now under way toward the first area of the JQZ on our survey agenda. While we're transiting, we'll have some time to tell you more about the ship and the scientific instruments on board.
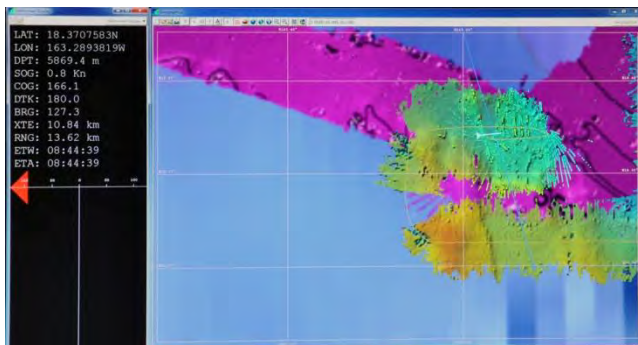
Sentry has been here before. The pink track is depth data from a previous cruise; the multicolored track is our current survey of the test dive site

In transit: Cake, XBT, Science Briefing

[cruise journal 20 December]

Several days of travelling from the test dive site to the first survey area provide us some time to review the scientific fundamentals of our mission and the history of the twenty-year-plus research program we're part of, as well as a chance for the crew to make us feel at home on board.

Alex celebrates our first science party birthday aboard

First order of business: the galley surprised Alex with a post-watch birthday celebration including rousing song led by mess attendant (and chief morale officer) Annie and a cake from chief steward Tony. And if that weren't consolation enough for an 0000-0400 birthday watch, the crew are happy to bestow another honor on the celebrant: the dangerous but mission-critical deployment of the XBT, an instrument with a crucial role in calibrating the ship's many sonar-based sensor systems.

Marine technician Bern instructs Alex in the procedures and gear necessary for safe deployment of the XBT

Making our way from the computer lab to the aft deck, numerous members of the crew stuck their heads out of various hatches to double check the full complement of safety gear equipped by our student XBT-launcher. The deployment of this instrument is one of the very rare exceptions to the "science party has no reason to be near the transom" rule (the transom is the very back of the ship, and on the Sikuliaq forms a sheer drop to the water separated from the aft deck by just a cargo netting). Fortunately, the science party puts a great deal of trust in the abilities of the marine techs like Bern to help us conduct operations safely and efficiently. This means we also are naturally inclined to give credence to the solemn warnings Bern and company issued to us regarding the firing of the XBT.

Left: ready to fire. Right: XBT deployed. Alex was fortunately not injured during the launch, nor dragged overboard by the probe's wire. Did you miss it? Not to worry. We launched another one...
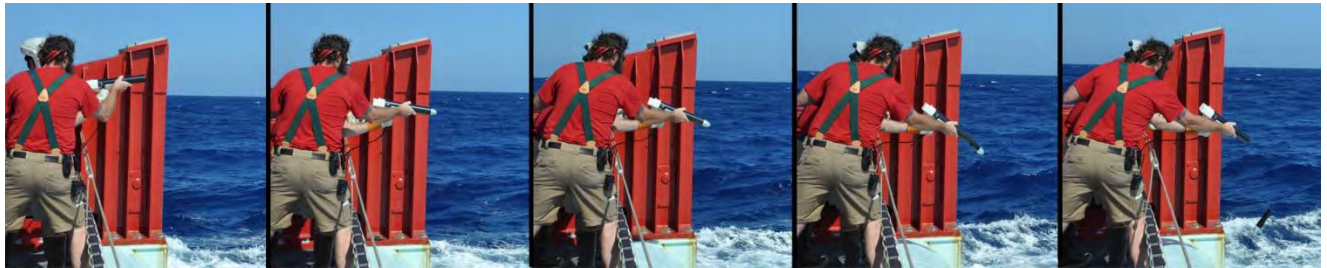
Bern, assisting John with this very, very explosive and perilous task

Of course, it wouldn't feel much like home if we weren't being masterfully, expertly, and mercilessly led on through a ritual of grave warnings and dire insinuations about the capacity for bodily harm inherent in throwing a small torpedo-shaped temperature probe over the side of the ship. Happy birthday, Alex! with fondest regards from the Sikuliaq's thoroughly entertained crew. (There's a lot more to say about the XBT. Read about it here)

Next on the agenda: co-chief scientist Dr. Maurice Tivey delivers the science briefing to our team and Sentry's, and we share this history and background with you.

Rolling intensifies; engine room tour

[Cruise Journal 21 December]

Today at 1530, a tour of the engine room. But first things first: after gradually becoming accustomed to swells in the area of 5-8 feet, this morning we were greeted with what the forecast we received estimated to be swells of 6-10 with maximum combined seas of around 15 feet. Difficulty level has increased from novice to moderate. The Sentry team, who need to account for the orientation of the ship to correctly communicate with the vehicle, reported that today the Sikuliaq has been undergoing rolls of up to 20 degrees, spiking in one chair-slinging episode at 24. Third

Mate Hamill has seen plenty of rolling in his time, and has his own opinions about how far we are going to see the Sikuliaq go on that score. But first, let's check out the engine room.

Thanks to Chief Engineer Terry Anderson, First Engineer Rich Null, and QMED Anton Costales for letting us into their work space and giving us an overview of Engineering

Chief Engineer Terry Anderson shows science team around the lower decks

Multiple members of the engineering department separately likened their responsibilities to those of the municipal services in a self-contained city. Any amenities we enjoy, like running hot water, cold fresh water and plumbing, air conditioning, and lights -- not to mention the power to actually move the ship -- ultimately come from Engineering. Chief Engineer Terry leads the three assistant engineers and three QMED's (Qualified Members of the Engineering Department, or engineers training for their certifications) in the operation of the ship's systems which power and cool the engines, analyze and desalinate seawater, adaptively coordinate the efforts of all the drive systems, and much more.

Matt inspects the desalinators, which rapidly boil and condense seawater to produce clean fresh water for use on board

This ship has four generators which can scale their collective output up or down as power demands vary. The main transiting thrust is provided by a pair of electric motors at the stern, which use a contemporary design, only recently gaining prevalence among research and cruise ships, whereby the water is "pulled" in from the front of the propeller, instead of "pushed away from the back as in conventional props. Finer directional control is provided by a single "z-drive" (so called because of the gearing containing two right angles in sequence, reminiscent of the shape of a Z) in the bow. The entire drive system can be computer controlled to keep the ship steady at a given point or follow a course plotted by GPS; this is called "dynamic positioning" and we'll use it when we follow Sentry as it performs its science dives in the coming weeks.

From this station, Rich and Anton can monitor thousands of electrical connections and a state of the art fire detection/suppression system. The ship can even be controlled form here using the joysticks to the left side of the console

All of this maneuvering, as well as the demands of the rest of the ship's systems, comes at a cost. The Sikuliaq holds around 180,000 gallons of fuel, and depending on the amount and rate of travel, can burn between 5,500 and 6,600 gallons per day. According to Engineering, the ship's infrastructure is nominally rated to support a voyage of up to fifty days; of course this is heavily dependent on the drain put on the fuel reserves by transiting. Our current condition, making around 10 knots in modest to moderate seas, is not near the boundary of the ship's capabilities. Nevertheless, as we finished our tour of the engine room and prepared to ascend back to the main deck, a digital thermometer near one of the four generators read 95 degrees Fahrenheit.

This is one of the two smaller 12 cylinder engines. The other pair have 16; each is attached to a generator and can be called upon as needed to supply power to the ship

After our first big twenty-plus degree roll, which sent chairs and their occupants skittering across the crowded mess, the Third Mate, who along with much of the crew will continue with the Sikuliaq toward its eventual home in Alaska after the science party has completed our mission and disembarked in Guam, gave his assessment.

"By the time we get to Ketchikan, I expect to see some boot prints on the bulkheads."

Transiting: Christmas

[Cruise Journal 22-25 December]

In which: we skip a day, create some culinary art, fire more XBT's, and the seas mellow in time for Christmas.

The chief scientist is not to be outdone by Sentry's festive headgear

As we are reinforcing our sea legs, the bridge is keeping us on course toward the next waypoint and the crew are working hard to ensure we all enjoy a safe and happy holiday. When the swells reach a certain magnitude, the Captain orders the weather deck ("outside") be sealed off. This involves the closing and dogging (securely latching) of the numerous watertight doors (WTD's) that separate the climate controlled interior spaces of the ship (remember, thanks to engineering for this comfortable air conditioning -- it's about 80 degrees F outside, not bad for December) and the open air decks.

This is about as big as the swells got -- before the Captain sealed off the weather deck.

Transiting in heavier swells means lots of rolling, which in turn means keeping an eye on wireless mice, retrieving wayward chairs, and tying up books and crates with bungee cords and straps.

DEAR SANTA,
FOR CHRISTMAS I'D REALLY LIKE
A KEEL. THANKS
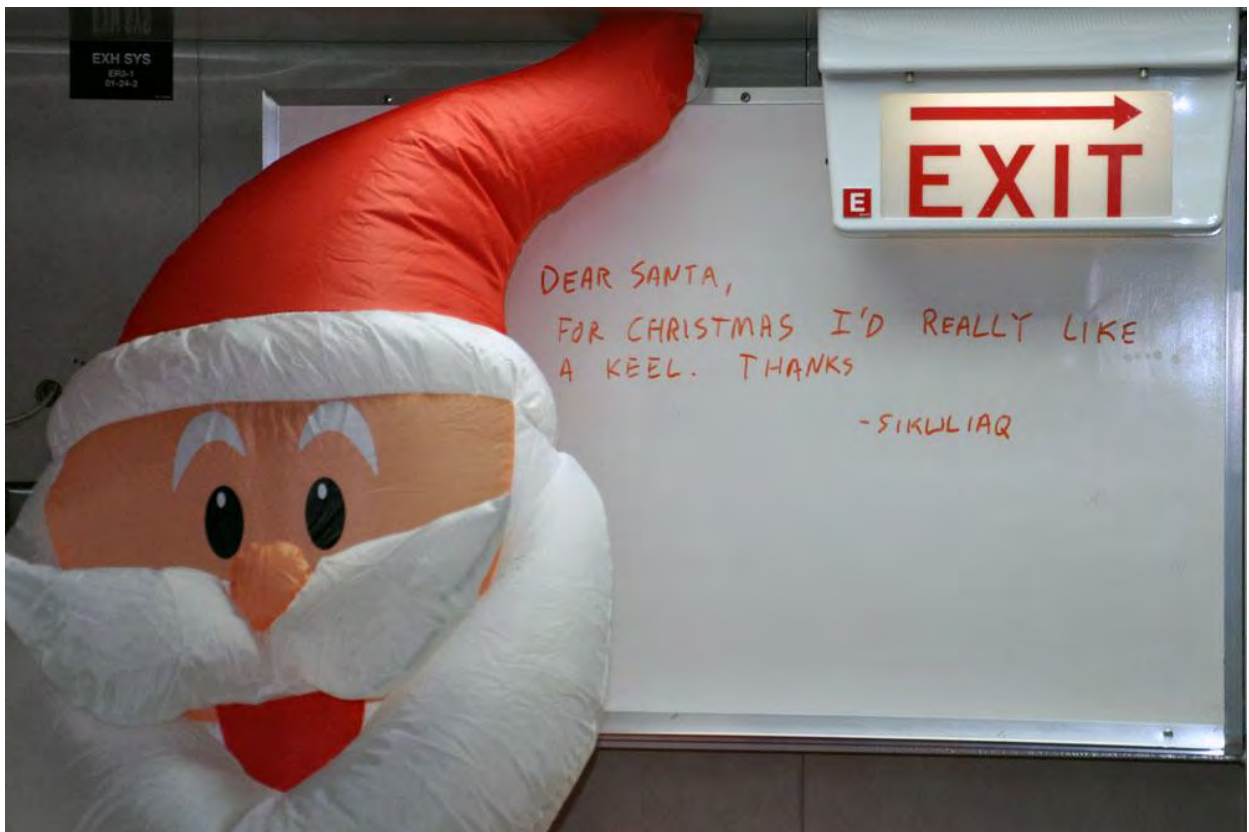
-SIKULIAQ

Sikuliaq's Christmas list is considerate and to the point, unlike its hull

Of course, veteran seagoing folk are not fazed by some waves (this isn't even a storm), and the celebratory spirit won't be deterred in the science or Sentry crews either. Candy canes have appeared around the computer lab; homemade sugar cookies have been decorated (members of the Sentry team showed great precision and zeal in this endeavor). Our festive inclination was so strong that in our eagerness we were able to forgo December 23 entirely -- by crossing the International Date Line from east to west, we advanced the clocks and effectively skipped a day. (We'll make up for it by going through the same day twice on our easterly return flights next month.)

Zac applies a custom heuristic for sprinkle placement

Even if Santa didn't come through with a keel for our ship, we were at least gifted with a calming of the seas in time for December 25. After a few uneventful days inside, we were able to get out in the sun; Laura had her turn firing the bathythermograph; the ship's tech group provided a Voice Over Internet Protocol (VOIP) phone for holiday correspondence; and the next couple days of transiting toward the first survey site will look like this:

Starting science dives

[Cruise Journal 26-29 December]

In this edition: we arrive at the first science dive site, make a small adjustment to Sentry's planned survey track, and watch Sentry successfully complete Dive 292 of its career.

Sentry is ready to do some science

After quite some time at "cruising" speed of around 11 knots, we finally arrived at the location of our first science dive, number 292 for the Sentry vehicle. While surveying the intended track with shipboard sensors prior to launching Sentry, we noticed a conspicuous sea mount directly along the planned course of the AUV. Since the most consistent magnetic data can be obtained by closely following a level tract of ocean floor, and to make the vehicle's navigation task as simple as possible, Sentry and science teams decided to adjust the course to bypass the sea mount.
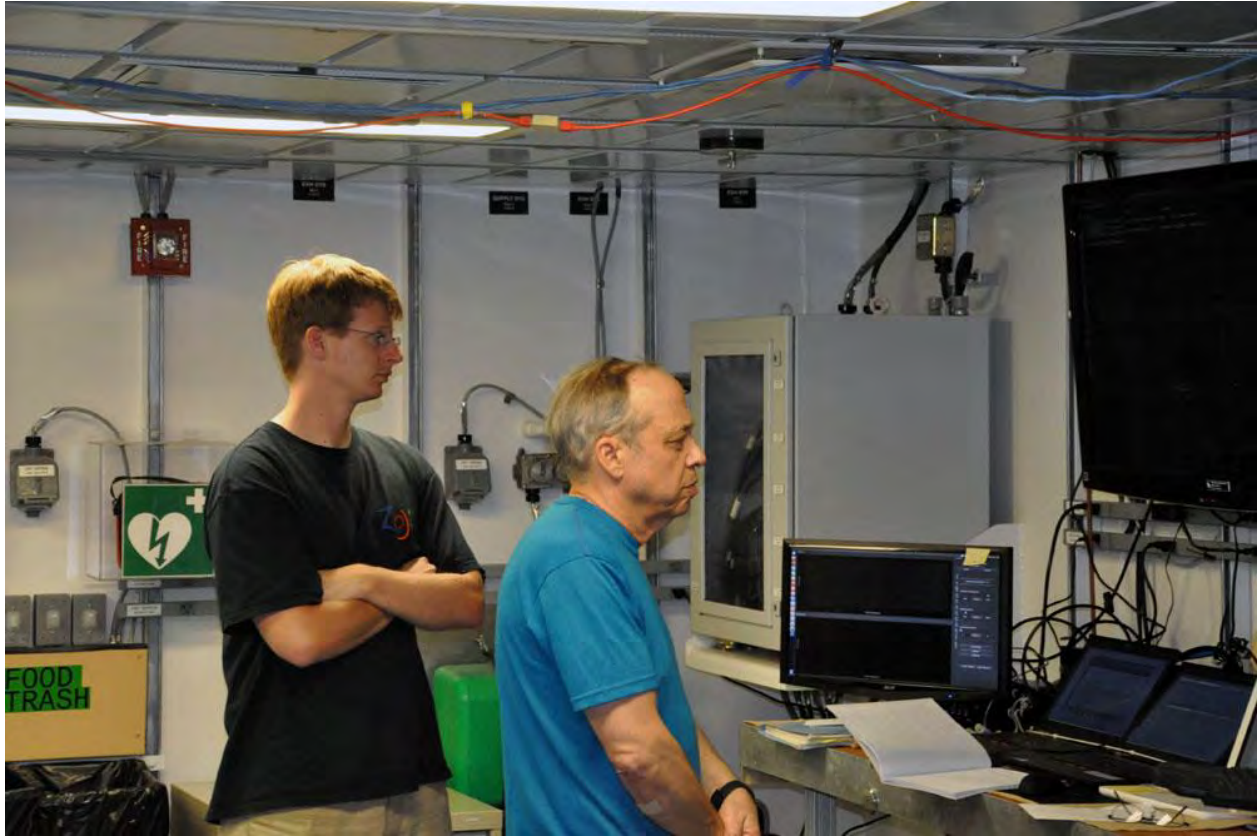
Zac and Dana watch the vehicle's descent just after deployment

The evening watch and anyone else who was still awake watched the Sentry team and Sikuliaq crew crane the vehicle into the water, and it descended out of view everyone returned to their duties. As the night wore on, everyone on board was pleased to follow Sentry's progress as the first data collection dive exceeded expectations. As the dive progressed, the Sentry team noticed that the vehicle's battery was lasting longer than expected, and were able to extend the range of the survey track by increasing the vehicle's speed slightly.
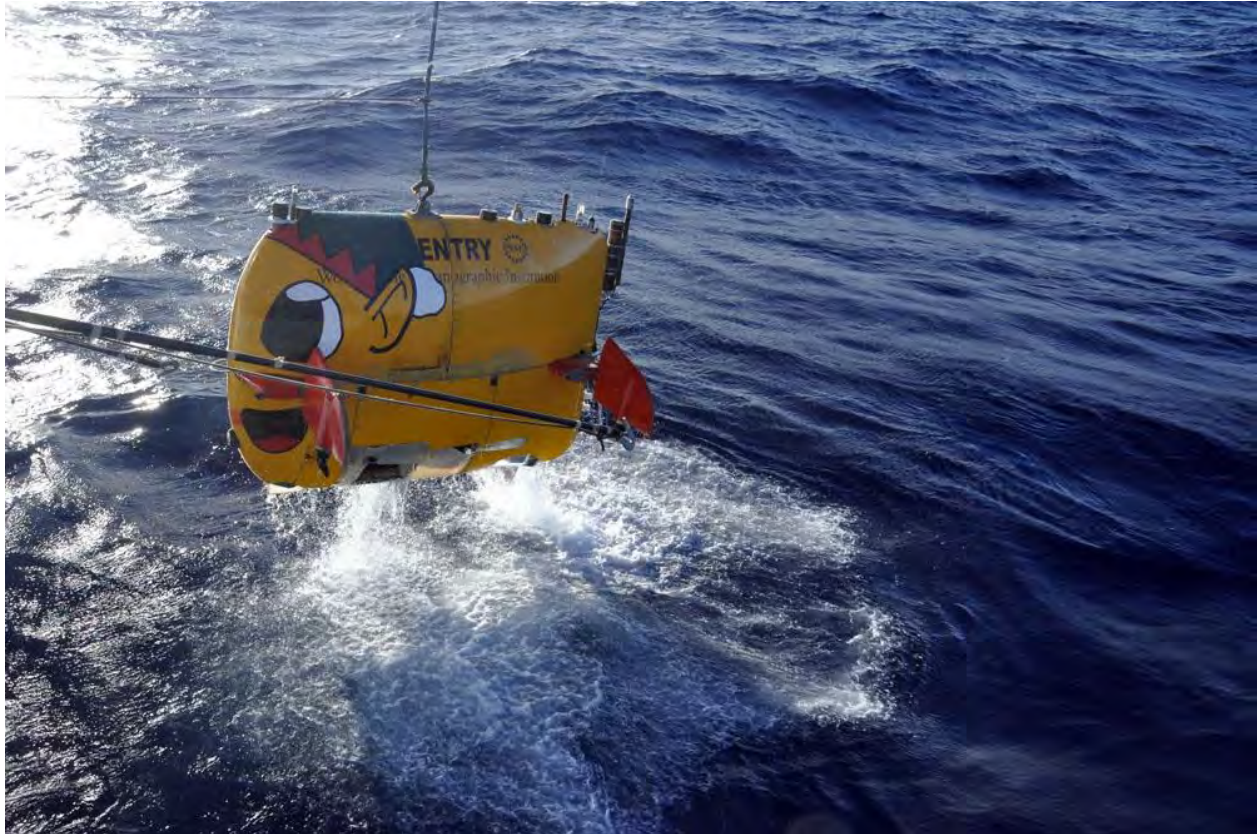
Sentry resurfaces after an excellent performance

Given how smoothly this dive went, the Sentry team are looking forward to gradually raising the survey speed of the vehicle in subsequent dives to further extend the amount of seafloor we can survey within each 48-hour turnaround-launch-descent-survey-ascent-retrieval cycle. This is great news for the science mission of the cruise, as longer tracks provide glimpses of more of the magnetic record of the JQZ.

Now, while the AUV's batteries recharge, we're towing the DeepTow magnetometer sled to the next dive site, and the Sentry team are preparing to turn the vehicle around for its dive 293.

Birthday II; flying colors; distance record

[Cruise Journal 30 December - 1 January]

Sentry continues to impress, breaking its all-time single dive distance record; the second science party birthday is celebrated with another cake from steward Tony; and the Michigan State flag is flown over the Jurassic Quiet Zone.

Tim and John ensure that the green and white will be flying in time for the bowl game

After a brilliant first science dive setting a personal best 93.17 kilometers, Sentry showed up again for Dive 293 and coaxed some extra survey time out of its battery to tally 91.64 more. At this rate, things are looking good for challenging this pace on Dive 294, in progress now, and henceforth during the remaining science dives of the cruise.

The jovial crew joins Laura for her birthday celebration in the mess

In the meantime, life on board involves much less rolling than we've become accustomed to, as the Pacific has been more placid. With a lower SOG (that's "speed over ground," the absolute travel velocity calculated by GPS), we're feeling less of a breeze and more of the 79.88 degrees Fahrenheit currently reported by the ship's instruments. It's not the typical northern hemisphere New Year's climate, but we're doing our best to stay positive. Laura was gifted with an excellent cake and particularly spirited round of song for her birthday, and the Michigan State contingent received the blessing of the Chief Mate to raise their banner on the main mast: Spartans Will.

Conclusions

[Cruise Journal: the rest of the cruise]

A busy time in which: Sentry successfully completes the remainder of its science dives; watchstanding and data processing continue apace; we begin sharing our already limited satellite internet with several other research vessels in the region; we wrap up our science mission and begin transiting to Guam; and all of the various books, computers, notes, devices, containers, coffee, and other accoutrements of marine geophysics in the field begin to be packed away for shipping back to their home labs.

As the surface towed maggie is retrieved for the last time, we can take stock of the status of the science mission and reflect on our time onboard during the few brief hours that remain.

With this last surface maggie recovery, science operations of JQZ cruise 3.2 are complete

The scientific highlight of the cruise has inarguably been the exemplary performance of the AUV Sentry in collecting magnetic data in close proximity to the Pacific JQZ ocean crust. Pushing the envelope of the vehicle's operating depth and dive duration, the Sentry team have gone beyond the call of duty in enabling longer than expected survey tracks, squeezing the most out of the battery, and turning the vehicle around swiftly between dives.

In all, Sentry covered a total horizontal distance of 635 km over seven science dives. That near-bottom data is supplemented by 545 km of DeepTow track (197.9 hours of wire time, with 158.8 of that at data-collecting depth, and a maximum wire length of 5424 meters) and 7415 km of surface towed magnetometer data (that's 4607 miles).

Being able to collect so much accurate data on the reversals and strength of the Earth's magnetic field during this oldest portion of the Jurassic period for which ocean crust remains is a privilege. Past cruises in this research program have yielded data that are used in the canonical text on the geologic time scale (The Geologic Time Scale; Gradstein et al, 2012, Elsevier), and hopefully the data from this cruise will extend that tradition.

Moving a lab to and from the Sikuliaq involves seven of these pelican cases

In the meantime, the watchstanding may have ended but a student's duties are never done. Before arriving in Guam, remaining tasks include: packing personal effects; inventorying, packing, and triple checking lab equipment; making final data dumps and backups; returning linens to the designated repository; returning your stateroom to the spotless condition you found it in (brand new ship, remember); taking one last turn around the upper decks outside; and anything else you want to do on board before returning to shore.

In keeping with tradition, a steel plate painted with school emblems and initials is cast into the Marianas Trench, some 9000 meters below.

All too soon after these things are completed, we'll disembark from the Sikuliaq, which has become a comfortable and familiar second home, and say goodbye to the crew, who've been the consummate stewards, tutors, and travelling companions these past thirty days. With a vastly improved knowledge of marine magnetics, the shape and character of the Pacific Jurassic ocean crust, shipboard conduct and safety, echo-sounding sonars, Java archives for driving parametric sub-bottom profilers, euchre, and the tropical night sky, we'll make our way toward further studies and travels. Sometime in the future, this program of exploratory research will return to the JQZ to

finish up surveying the polarity reversals in the third side of that triangle of the world's most ancient ocean crust -- the Phoenix lineations to the south. Maybe we'll see you there.

Thank you for joining us.

Part II. Life on board

Standing watch

When the students of the science party were invited to participate in this cruise, we were told that our major responsibility would be serving as "watchstanders". What exactly does that entail?

Hint: there's a reason it's called "watch"

The Sikuliaq is a very new research vessel equipped with many means of analyzing the ocean and seafloor. It also sports a sophisticated and comprehensive shipboard computer network which archives all the data coming in from each of the various instruments. Each of these instruments is controlled by its own software, all of which can be viewed over the network. Still, they are not

completely autonomous. Making sure that the instruments are calibrated correctly, not interfering with one another, properly accounting for the changing course and position of the ship itself, and turning in data that make sense is a full time responsibility. These duties are the constituents of watchstanding.

In order to give these tasks the round-the-clock coverage they require, the day is broken up into three watches. They are named by the "on watch" hours in each twelve-hour period: 12-4, 4-8, and 8-12. Each of these corresponds to a 24-hour schedule consisting of four hours of watch followed by eight hours off, followed by another four hour watch then another eight hour break.
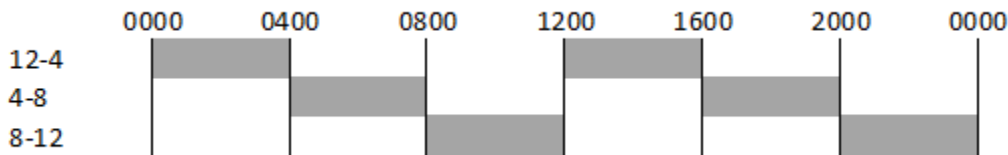
Everyone has two shifts (gray) and two breaks per day, and the whole 24 hour period is covered

Punctuality is paramount, and the further your shift is from your normal schedule, the more of an interesting and fun challenge this becomes. One way or another though, you're up and ready to report to the computer lab ten minutes before your watch begins; you're briefed by the previous shift's watchstanders about the current conditions; and then it's your turn to keep track of the ship's course, instrument readouts, and other important events. The repository for this record keeping is the ship's electronic logging system (E-log). Each time an instrument is turned on or off, or the ship changes course, or data collection is interrupted for any reason, it's up to one of the watchstanders to create an E-log entry. The computer fills in the time and ship's position (GPS coordinates), and the log entry is completed by selecting the relevant instrument and event type from a pair of menus, followed by a brief explanatory comment.

Event	dateTimeUTC	GPS_Time	Instrument	Action	Transect	Station	Cast	Latitude	Longitude	Seafloor	Author	Comment
20141223.1832.001	20141223.1832	2014/12/23 18:32:40	EM302	other	NaN	NaN	NaN	18.908265	176.178022		Rachael	Full complete shutdown of 302
20141223.1833.001	20141223.1833	2014/12/23 18:33:23	PS18	other	NaN	NaN	NaN	18.909539	176.176181		Rachael	Internal trigger
20141223.1837.001	20141223.1837	2014/12/23 18:37:53	EM302	other	NaN	NaN	NaN	18.917839	176.164403		Rachael	MB302 rebooted and functioning
20141223.1838.001	20141223.1838	2014/12/23 18:38:26	PS18	other	NaN	NaN	NaN	18.918876	176.162921		Rachael	External trigger
20141223.2249.001	20141223.2249	2014/12/23 22:49:57	Ship	other	NaN	NaN	NaN	19.400018	175.602405		Laura	Deviated course to avoid contact
20141224.0002.001	20141223.2130	2014/12/23 21:29:53	XBT	release	NaN	NaN	NaN	19.240170	175.722958		Ethan	
20141224.1240.001	20141224.1240	2014/12/24 12:40:46	PS18	stop	NaN	NaN	NaN	20.632604	173.360437		Tyler	Topas crashed
20141224.1243.001	20141224.1243	2014/12/24 12:43:51	PS18	start	NaN	NaN	NaN	20.636525	173.351804		Tyler	Topas is back up and working. Thanks Ethan!
20141225.0027.001	20141225.0028	2014/12/25 00:28:01	SeaSPY magnetometer	stop	NaN	NaN	NaN	21.632614	171.242679		Alex	connection lost
20141225.0028.001	20141225.0028	2014/12/25 00:28:48	SeaSPY magnetometer	start	NaN	NaN	NaN	21.633760	171.240243		Alex	restarted; connection regained
20141225.0429.001	20141225.0429	2014/12/25 04:29:55	XBT	release	unch XBTNaN	NaN	NaN	21.993409	170.492565	5774 m	Tim	launch XBT
20141225.1415.001	20141225.1430	NaN	SeaSPY magnetometer	start	Mag survey Line 3	NaN	NaN	NaN	NaN		Matthew	Navigation crashed ,readjusted setup, started new line
20141225.1428.001	20141225.1428	NaN	SeaSPY magnetometer	other	Mag survey Line 3	NaN	NaN	NaN	NaN		Matthew	Sea surface magnetometer not logging while fixing navigation
20141225.1445.001	20141225.1445	2014/12/25 14:45:37	SeaSPY magnetometer	start	Resumed logging line 3	NaN	NaN	22.852170	168.653122		Matthew	Resdumed logging, with 2.7s offset from gps
20141225.1601.001	20141225.1601	2014/12/25 16:01:57	SeaSPY magnetometer	stop	Line 3	NaN	NaN	22.955298	168.434425		Matthew	Stopped logging to switch laptops
20141225.1623.001	20141225.1623	2014/12/25 16:23:32	SeaSPY magnetometer	start	NaN	NaN	NaN	22.983207	168.373591	5873 m	Tim	started to log on line 4 - up and running again
20141225.2103.001	20141225.2103	2014/12/25 21:03:11	SeaSPY magnetometer	other	NaN	NaN	NaN	23.341452	167.601697		John	Reboot Magnetometer

Electronic logging: Since the ship crosses timezones (and the International Date Line), all events are logged in UTC (Coordinated Universal Time) for consistency

Watchstanding is not simply passive observation, however. Despite the sophistication of the instruments on board, some of them still require close supervision and occasional assistance. Most of this has to do with the depth of the ocean: the distance between the various sonars and the seafloor. The EM-302 (or "multibeam") sonar can be given a maximum depth within which it should expect to find the bottom, as well as a more coarse-grained "ping mode" that ranges from

auto (for waters up to 2500m) through "very deep" (2500-4500m) to "extra deep" (for depths >4500m). Similarly, the TOPAS sub-bottom profiler has a configurable trigger delay -- the time between sending out a sonic pulse and beginning to listen for the return signal -- which must be set so that, given the speed of sound through the water column and current the water depth, the instrument will be listening for the returning sound waves at the appropriate time.

Sometimes an entire watch will pass without requiring any adjustments. This is likely to happen when the ocean floor beneath the ship is flat, and the depth remains relatively consistent. Other times, we will pass over more varied topography and more attentiveness is required. The extreme case is passing directly over a sea mount (a submarine volcano): both instruments have to be gradually guided from a steady 5000-6000m up to a much shallower depth (depending on the particular mountain, up to a couple thousand meters above the surrounding seafloor) and back down.

Old school logging: Every twenty minutes, we record the time, location, heading, speed, and magnetometer reading in a paper logbook

Once per watch, usually near the end, we add our current position to this chart

The amount of hands-on assistance required by the instruments during a watch can be somewhat predicted by looking ahead on our course to see what the upcoming depth profile looks like. Other events, like rebooting instruments or unscheduled course corrections, are less predictable. By the end of each watch, there is at least one thing that is certain: next watch starts in eight hours. Time to go get some sleep; get some fresh air; work on your thesis? Probably get some sleep.

Safety

The occasion of the second fire and boat drill of our cruise is a good time for a refresher on the safety procedures on board the Sikuliaq. The gist of shipboard safety is: "follow directions". Still, preparedness involves more than just confidence in your ability to listen.

As in many contexts, safety begins with a video

Each type of emergency has a unique signal on the general alarm. For example, the abandon ship order is signaled by more than 6 short blasts followed by a single long blast

There are two broad responsibilities for all hands in the event of an emergency. The first of these is being in right place. Every person on board is assigned a station for each of the three categories of emergencies that could be signaled by the ship's general alarm. For the crew, these stations correspond to the areas of the ship that would need attention in an emergency: the site of a potential fire; the port and starboard life rafts in the event of an abandon ship order; various

lookout positions on all decks for man overboard stations, and so on. For the science party, there is a single muster station for all emergency alarms: the main lab.

Science Party – FE #38	ARRV Sikuliaq
Fire/Collision: Main Lab Prolonged blast of General Alarm or Ships whistle 10 Sec or greater	Standby to assist as directed. Alternate muster station: starboard hanger.
Abandon Ship: LR #2&4 More than 6 short blasts followed by one prolonged blast of General Alarm or ships whistle	Upper bunks, PORT Liferafts.
Man Overboard Three prolonged blasts of the General Alarm and or Ships whistle.	Report to Main Lab; Assist as directed.

A convenient reference is attached to each bunk including a summary of muster stations and emergency duties

The second responsibility in case of emergency is communication. The cardinal rule of reporting on an emergency is "what, where" -- what exactly do you see (e.g. "flames black smoke") and where exactly it's happening ("main deck passage outside the tech lab"). There are many ways of passing along the word of an emergency. In addition to a local phone network, the ship is equipped with squawk boxes (don't lean on that switch), a voice operated telephone system that can function without external power, and of course a crew carrying portable radios connecting with each other and the bridge.

"Abandon ship" is the most involved emergency, and it requires a bit more explanation. The Sikuliaq is equipped with four inflatable 25-person lifeboats which can be automatically or manually deployed and self-inflate upon contact with the water. This is more than enough capacity to accommodate every person aboard our cruise twice over, so the crew is able to keep half of the lifeboats in reserve in case of a deployment problem or any other unforeseen circumstance which might require some similar flexibility.

The port-side life rafts, stored very compactly and unobtrusively on the exterior of the ship

After launch, these lifeboats would be tied at the port and starboard sides of the aft deck. If possible, a Jacob's ladder on each side of the deck can be used to get down to the lifeboat. In the more likely emergency scenario requiring getting to the boats by way of the water (and therefore use of the immersion suits) there are a few things to remember. If you're going into the water, step; don't jump. Form a knife-shape with your hand and slip it inside the hood of the suit to allow air to escape through somewhere other than your eardrums when your impact with the surface creates a moment of high pressure throughout the interior of the suit. If you're first into the boat, as soon as you're in, you are looking to help the next person in. Take turns manually activating the 12-18 hour battery operated lights on the suits. At this point, if you've followed the instructions of the chief mate and the rest of the crew, you've done your job, and can await rescue with a clean conscience.
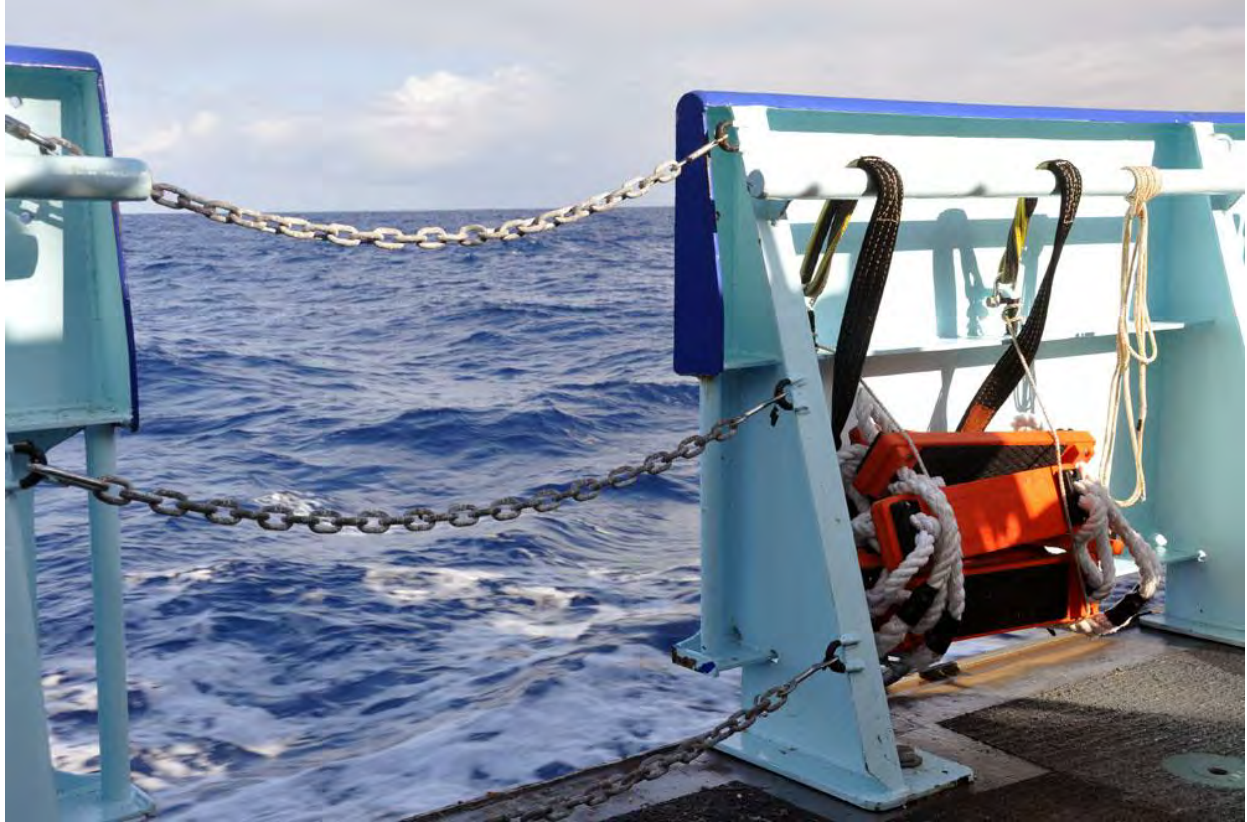
The Jacob's ladder can be easily thrown over the side to allow access to the lifeboats, if the seas allow for it

Of course, shipboard safety isn't restricted to emergency situations. In addition to securing stray items for the pitching and rolling of the ship, there is one type of component on board that demands particular respect: doors. Even an ordinary door becomes a hazard in heavy rolling, and the very robust and heavy watertight doors can range from cumbersome to dangerous even in port. The best way to keep your fingers attached in the right places is to only ever touch a door by its designated handle. Even then, you are sometimes taking your chances if you fail to notice the posted warnings:

Life on board: Staterooms

Several reasonably well-founded preconceived notions of life aboard a ship involve dark cramped crowded living spaces, spare amenities, and crude approximations of the comforts of civilization. Fortunately, the designers of the very modern and almost brand new Sikuliaq made a great effort to throw these notions out the window.

Few of us have lived in university dorm rooms any newer or much bigger than this (J. Greene)

As any of the crew or science party veterans with several sea voyages under their belts will tell you, being assigned living quarters above the waterline is a privilege not to be taken for granted. Those of us for whom this is the first prolonged experience at sea are going to come back spoiled by a spacious, carpeted, climate controlled cabin with a view of the water (in just about every case).

Port, through the porthole. Almost every stateroom has one of these. Bad luck, Tyler

Although the rooms are provisioned very comfortably (pillows and linens provided; a full laundry on board means you are responsible for maintaining your own), it's actually rare that the opportunity to linger there arises. Because of the watchstanding schedule, politeness dictates that the room be available (and dark and quiet) for whichever of the two occupants is trying to rest up in time for their next watch. Depending on the synchronization of schedules between any given pair of roommates, this can range from trivial to "some consideration required". Good manners breed good science.

Each pair of rooms shares a "head," with a toilet and shower cubicle aligned perpendicular to the ship's direction of travel. This enclosed space is one of the worst for having the sensory context required to anticipate and compensate for rolling. We've been told of unlucky sailors caroming through unsuspecting shower curtains, and shattered porcelain of hapless, non-weight-bearing sinks. On this boat, the sinks are out in the staterooms and so far no one has admitted to taking down a curtain.

Even with a cooperative roommate, you're not guaranteed a peaceful night's sleep unless you've been careful to secure the entire room for sea. A stray quarter in a desk drawer; a slightly loose cabinet latch; anything that can rock or swing or slide is an invitation for irritation. After chasing all of these down, it's a simple matter to settle in for a couple of hours before your next watch ...

One level up from the main deck, the 01 deck passage gives access to all of the science party staterooms and the mess

There is an immersion suit and personal flotation device for each bunk, as well as some closet space for personal effects, in these lockers

Life on board: Working spaces

The Sikuliaq is a relatively large ship with a great variety of deck, passage, and lab areas. Even on a vessel dedicated to supporting scientific expeditions, however, much of the volume on board is dedicated to stores, propulsion, and the various other systems within the purview of the Engineering department. There is also ample living and working space, but in the course of settling into your routine onboard, it's likely that as a student watchstander, your on-duty hours will be primarily spent in two rooms: the computer lab and the main lab.
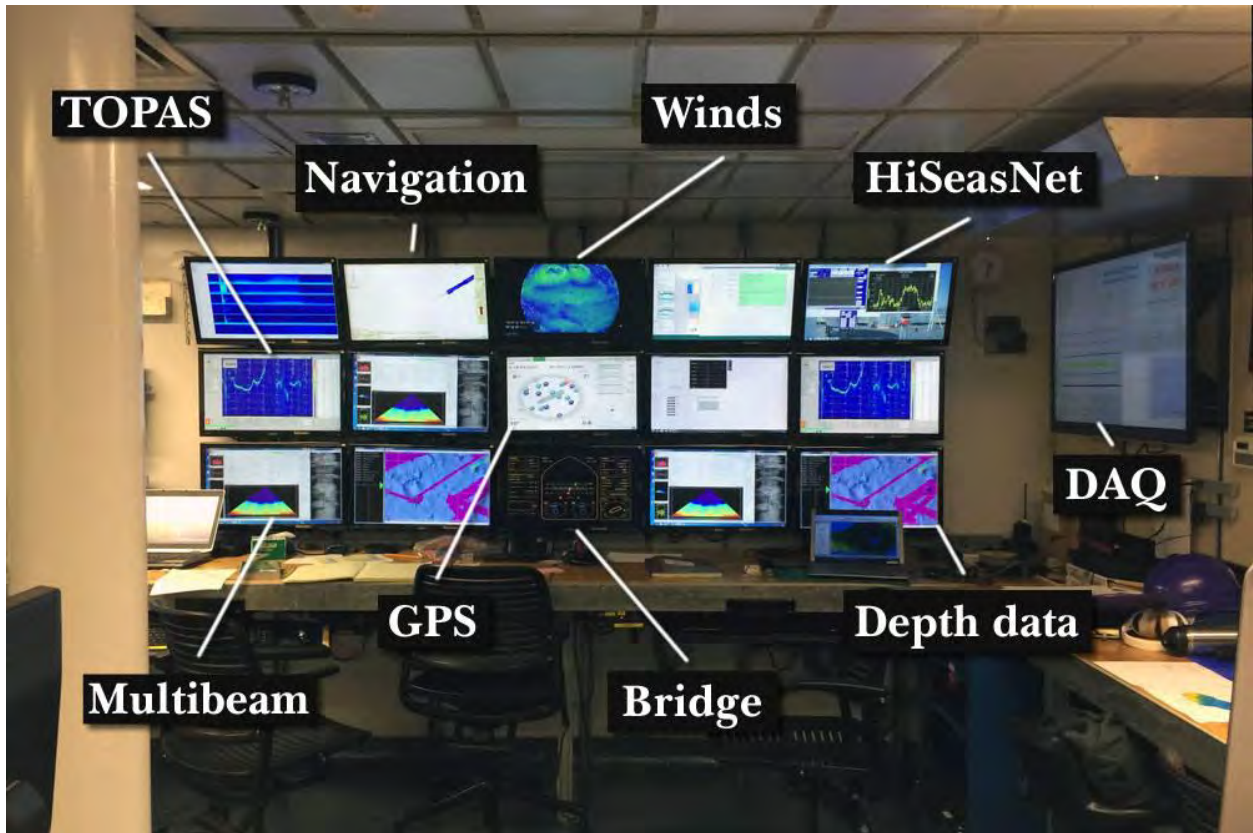
Some of the displays available for watchstanders' edification and entertainment in the computer lab. Read on to find what they show

Occupying much of the starboard side of the main deck, the main lab is outfitted to support a variety of types of science missions. There is a large expanse of lab bench space punctuated regularly with sinks, compressed air lines, power and LAN drops as well as a large area of open floor that for our cruise is configured with tables and chairs to provide an office-like setting for data processing and Sentry monitoring. The lab also sports two fume hoods and a couple of ultra-low temperature freezers (none of which will be necessary on our cruise).

For our purposes, the main lab serves as a central location for data processing tasks which are shared among watchstanders as well as the place where individual students (and co-chief scientists) can sit down and put some time into their own projects. As such, it's usually the more reserved of the two work environments, where everyone agrees that for the most part, leaving one another to their own tasks results in the ideal combination of productivity and peace of mind.
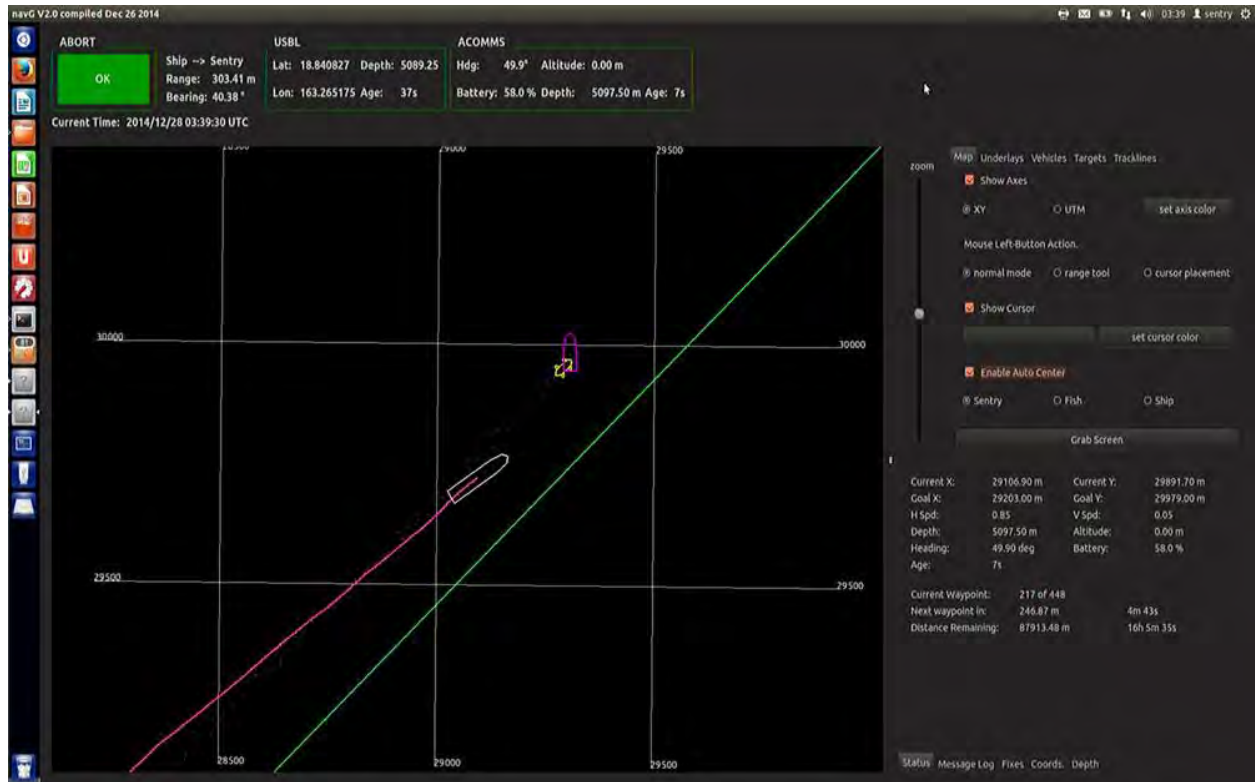
Provided by the Sentry team, this screen, which can be shown on any of the TVs in the labs, mess, or elsewhere, shows the positions and tracks of both the boat and the AUV, Sentry's depth heading and speed, as well as some of the depth data Sentry is using to navigate its way through the current survey track

Science is a collaborative effort. Tyler, Aric, Matt and John sort out some GMT in the main lab (L. Stanley)

By contrast, the computer lab, across the main passage on the port side, is a moderately more social place. The long hours of watch can become an exercise in endurance, and the more eyes on the clock, the more likely every 20-minute log entry will be accurate and on time. So it's not uncommon to find, in addition to the shift's designated watchstander and marine tech, a co-chief scientist or two as well as a couple of off-duty watchstanders floating in an out of the computer lab to catch up on Sentry's current progress, check the ship's course and heading, sample the current watch leader's music choices, or just pass the minutes talking over this or that until the next shift change.

The computer lab certainly has no shortage of conversation starters. Each of the many monitors can be switched to one of a vast number of displays, each showing the current status of some aspect of the ship or science mission. Several are shown in the picture, and even more are available:

TOPAS

Readout and control for the sub-bottom profiler

Multibeam

Readout and control for the EM-302 echo sounder

GPS

An overview of the number and position of GPS satellites currently being used to track our position, including the quality of the positional fix

DAQ

The "Data AcQuisition" view shows a summary of the ship's instruments and includes information about the seawater like salinity and temperature as well as ambient temperature, pressure, and the ship's speed, heading, and position

Bridge display

This shows the orientation and speed of both main propellers, the ship's orientation and rate of rotation, Speed Over Ground (absolute speed), Speed Through Water (relative speed), and other figure of interest to the bridge

Topo

A topographical view of the seafloor incorporating data from our own cruise as well as previous missions and other sources

Winds

An animated schematic of the wind direction and speed for our area of the ocean

Nav

This screen shows our position and current survey track as well as the next waypoint and our ETA

HiSeasNet

A readout of the up- and download bandwidth usage for the ship over the HiSeasNet satellite internet
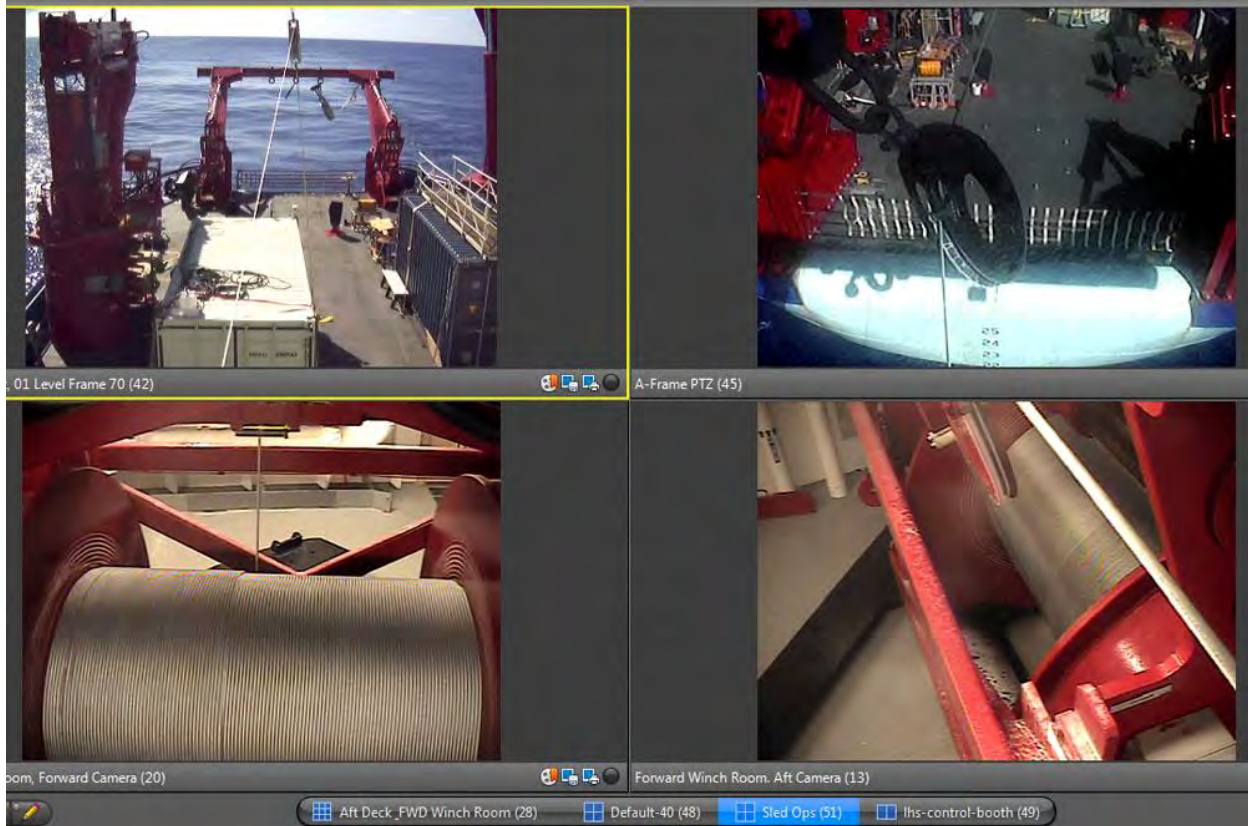
CCTV

The Sikuliaq has a large number of CCTV cameras, many of which support remote PTZ (pan-tilt-zoom) from this console or others around the ship. It's an easy way to keep track of the progress of a Sentry launch or DeepTow deployment from the comfort of the computer lab.

Life on board: Mess/galley

Over twenty sailors covering a round-the-clock watchstanding schedule; a couple dozen scientists and engineers pulling fieldwork-level hours -- making sure all these people have a variety of hearty healthy food available when they need it is the challenge facing, and admirably met by, the galley.

Chief steward Tony, in his element

Thanks to chief steward Matt for a generous overview of the role of the galley

"Galley" (referring to the kitchen) is a term used to name a particular space onboard the ship, along with "mess" (the dining area), and "scullery" (the area devoted to cleaning dishes and disposing of food scraps. The word "galley" is also used to refer, collectively, to the chief steward, steward, and mess attendant who operate these areas.

The galley is responsible, before departing port, for provisioning the ship. This entails, essentially, grocery shopping. The ship's stores are not totally emptied and preplaced from scratch at the end of each voyage; rather, a permanent stock of supplies is maintained on board and is supplemented as needed at each port of call. This means a steward's job can include some fairly long-term planning: for example, the favorable midwestern meat and poultry prices encouraged stocking up on these items in Marinette following the ship's launch, rather than in subsequent, more pricey ports like Puerto Rico or Honolulu. No matter where it happens, "filling the box" involves acquiring a lot of food. According to Matt, this is by far the most difficult aspect of the steward's role. Depending on the port, logistical support for obtaining produce, dairy, dry goods, fish, and meat can range from a dedicated procurer per category to one big solo trip to Costco. In the end, this shopping trip has to top off a store capable of feeding thirty or more people for up to as many days.

For our leg of the Sikuliaq's journey, the stores were augmented, in part, by eleven 15-dozen egg crates (as well as two 40-lb boxes of liquid eggs), several hundred pounds of fish, and enough steak that after twenty-plus days underway there is about 1000 lbs remaining. We've also been struck by the continual availability of fresh fruit, including of course an ample supply of excellent Hawaiian pineapple.

Keeping this fully-stocked pantry makes it possible to indulge in a great deal of variety and innovation. Every galley is different; on the Sikuliaq, the steward and cook prefer, instead of planning out each meal in advance of departing, to choose menus on the fly, and peruse a couple of huge comprehensive cookbooks to expand their repertoires and our palates throughout the cruise. The result is a vast and varied slate of favorites punctuated by expert experiments and deft first tries. (What none of science party could have suspected was this galley's first ever beef stroganoff was widely regarded by all to be a great beef stroganoff).

Depending on the geography and velocity of a particular cruise, a ship's galley may have the option of preparing fresh fish caught from the deck. Alas, thus far, the JQZ has been quiet in this regard as well: the deep, open waters above the world's most ancient ocean crust are not widely inhabited, and the Sikuliaq's comfortable 11-knot cruising speed isn't quite enough to attract the attention of the adventuresome mahi and ahi who can sometimes be found biting on lines moving at 12 to 14. Nevertheless, we've been treated to an extensive range of seafood as well as meat and poultry in the course of the cruise. Marlin, lamb, salmon, steak, shrimp stir fry, veal, chicken, lasagna, macaroni, casseroles, quiches, baked potatoes, mashed potatoes, squash and cucumbers, asparagus, cheeseburgers, turkey burgers, barbeque wings, pulled-pork sandwiches, grilled chicken sandwiches, all manner of entrees atop rice, couscous, or noodles, pizza, or chili; each followed by a full salad bar, with dinner rolls, several varieties of cheese, and usually some fruit as well. This is after a morning of eggs to order, French toast or pancakes, sausage and bacon, fruit, yogurt, and granola, and a big hit, almond butter, for breakfast.

To partake of this bounty, all that is required is that you show up to the mess at one of the three daily hour-long mealtimes. Of course, running a ship or a science dive sometimes takes priority, and this is just one of the ways the galley shows us all a great deal of accommodation: any person who will be on shift, sleeping, or otherwise engaged during a meal can alert the galley in advance and have a plate of their choosing prepared and saved in the fridge for later. (The galley is also sensitive to and prepared for all dietary restrictions, and will work within these constraints when producing at least a portion of the day's fare).

For everyone else, the dining experience begins at the aft entrance to the mess, where we glance at the whiteboard listing the meal's menu and make our way through the short cafeteria-window line and, with a possible diversion for juice, water, coffee, or tea, arrive at one of the six tables. As we have found especially useful on this particular vessel, the mess tables are equipped with slip-resistant placemats, which can be the difference between a peaceful meal and an orange-juice-based calamity in the presence of unpredictable swells.

After eating and enjoying the conversation with your tablemates and the respite from watch or work, politeness dictates you vacate your seat to make way for the next wave of diners. It's your responsibility to bus your table and appropriately dispose of all refuse: recycling to be saved for processing on shore in the blue can, incinerator-bound burnables in the black, and food slops in the designated bucket. The handling of food waste on board is the final stage in the galley's management of all edible materials onboard. Within a twelve miles of shore, food slops are stored for later disposal. Outside this limit, with permission of the bridge, the scullery dumps the slops overboard to be dispersed with minimal impact by the ocean currents.

All in all, the dining experience on board the Sikuliaq is not conspicuously ocean-bound in any way -- aside for the consideration that must be given to rolling of course. The variety and quality of food, the depth and endurance of fresh produce stores, and amicable personal investment shown by the galley in the crew and science party alike make for an extremely agreeable experience. As the menu whiteboard recommended a few days into the cruise,

Tip your cooks.

Down time

How do you fill the eight hours between watches, besides sleeping and catching whichever meals are served in the mess during your off time? No matter what you choose, you'll not be able to get too far away from where you started, but that's just another way to say that there's plenty to do on board practically within arm's reach. After stopping by the computer lab to keep the current watch entertained, putting some time into your own work in the main lab, or resting up a bit, you can indulge in the ship's library or gym, catch up with your fellow watchstanders over a game or snack, learn a bit about the routine and responsibilities of the professional sailors on duty, or just take in the view and air on deck.

It's like this every day (A. Stote)

The tropical Pacific sun is quite the attraction in December and January, and it's easy to enjoy in any number of ways. In the absence of a wire under tension (a scenario which means no one is allowed on this portion of the deck without a hardhat and work vest), the aft deck provides the closest view of the ship's wake and spray. Depending on the current roll, pitch, and heave, this spot can be anywhere from ten to just one or two feet above the water. Eleven knots looks and feels faster the closer you are to the surface, and from here it's possible to hear the electric drives adjusting their output on the fly to keep the ship on a steady course.

Further up, the 02 and 03 decks wrap around the entire ship, providing a nice walking circuit as well as long unobstructed views of the sky and sea. At the bow, noise from the drives fades and all that can be heard is the sound of wind and water against the hull, loud in proportion to the agitation of the weather. On calm days, it is nearly perfectly still. In the center of the ship, the 03 deck is equipped with a couple of sturdy chairs which nearly never slide across the rough non-slip deck surface. Grab a book; have a chat; or just sit in the sun.

The view from 02 on a calm day

When you've had enough of loafing about, it's no trouble to head down to the lower deck and hit the gym, which is distributed across two locations on the engineering level. In the aft, and coincidently therefore closer to the very warm engine room, a treadmill and elliptical constitute the cardio portion of the gym. Forward, inside the sloping port-side bow can be found the well-outfitted weight room.
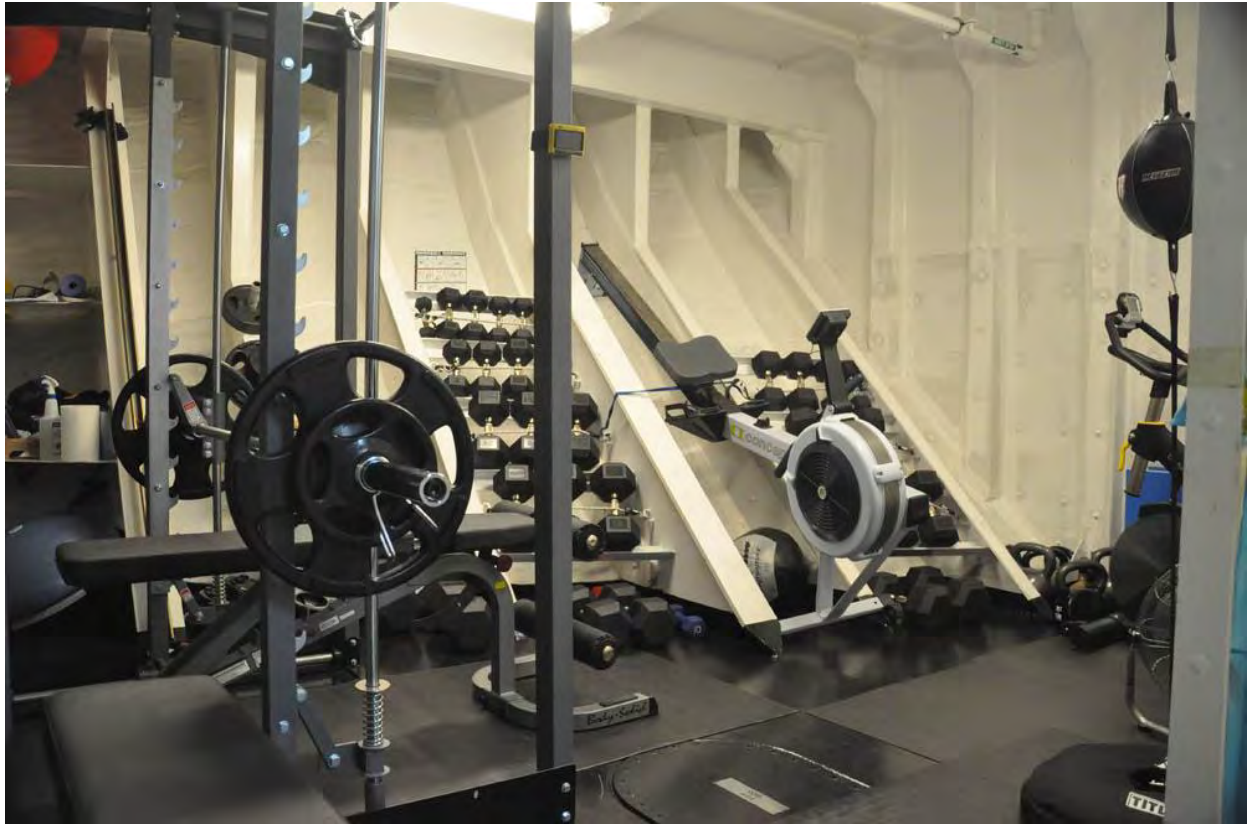
The weight room: something for everyone

After your workout, you can rely on the galley to have a good stock of everything from bagels, fruit, crackers, and cereal to a particularly resilient reserve of ice cream to fill the gaps between mealtimes. If you're feeling like housekeeping, you can avail yourself of the full-service laundry (be sure to use the detergent provided, as it's designed to cooperate with ship's water-treatment system). If you're feeling recreational, you can probably get a game of cards going (we find cribbage has wide adoption in this region, and the Michigan contingent is always up for supplementing the population of euchre players).

In the evenings, it's not unheard of to find the main lab converted to an impromptu theater for a film brought by one of the science party or Sentry team, or from the shipboard network's own expansive collection. If you've kept up with the longitude of the current course, you can be outside in time for sunset, which can be well worth seeing (and if you're lost amidst time changes and course corrections, the bridge can give you sunset to the second in a pinch). Later, depending on cloud cover, the dark working deck can be an excellent place to take in the night sky.

Evening twilight with Venus and Mercury just visible (and Mars is just a few degrees out of frame)

Part III. Science at sea

Cruise science fundamentals

Three phenomena from geology and geophysics form the foundation of the science mission of our cruise:

1. the formation of new ocean crust at the accretionary boundaries between tectonic plates

2. the magnetic field of the Earth, which fluctuates in strength and flips direction

3. the interaction of this field with newly forming crust to create a record of the field's strength and orientation through time

These phenomena in combination allow us to make detailed accounts of the magnetic history of the Earth's surface, and provide reference data to other scientists who will be dealing with rocks of the same age. Since so many parts of the Earth are involved in eventually creating the records we will be observing, let's start from the very center and work our way outward.
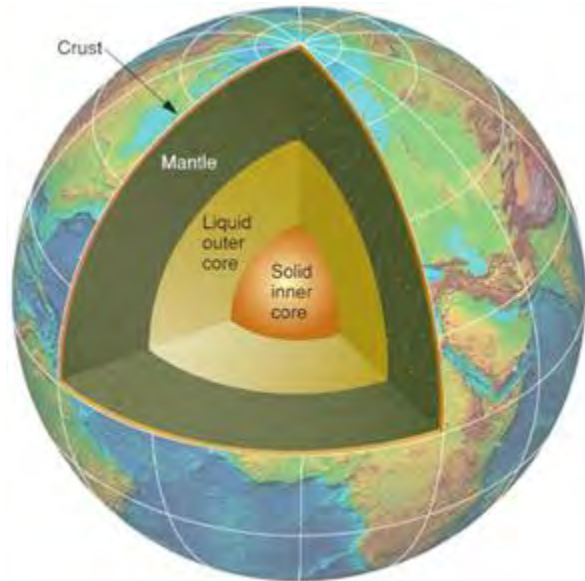
Motion in the outer core leads to magnetic fields which get recorded in ocean crust (From a presentation by M. Tivey)

The solid inner core is both beyond the reach of our instruments and largely distinct from the geodynamic system that produces the magnetic anomalies that are our objects if interest. However, the next layer outward, the liquid outer core, provides the source for the Earth's magnetic field and is thereby the origin of our observations. The Earth's spin and thermal convection within the outer core generate electric currents, which in turn generate a magnetic field much like a dynamo does; in fact, we call this process the" geodynamo". Only recently has computing power become sufficient for geophysicists to begin to realistically simulate the behavior of the geodynamo in detail; it is immensely complex and difficult to predict. In fact it is so chaotic that the magnetic poles of the earth have wandered and even switched places many times in the planet's past, and the field continues to change its direction and strength even now. (The geographic location of magnetic north, where your magnetic compass will point, is always moving. A nice overview of its recent history can be [found at Woods Hole's website](#).)

Subtle short term variations in the field's orientation can be observed and recorded during a single lifetime or even, with the right equipment, over the span of hours to minutes. However, different techniques are required to analyze its behavior over the overwhelmingly more vast scale of geologic time. Fortunately, the Earth itself provides us the means. The next layer out from the inner core, the mantle, which consists of rock at extremely high temperature and pressure, experiences its own solid convection motion. In places where these solid convection currents drive molten magma up through rifts in the crust (called mid-ocean ridges, or spreading centers), this material erupts as

volcanic lava and gradually cools and solidifies, becoming brand new ocean. Eventually, like a conveyor belt, the aging crust will be dragged further and further from the rift where it originated to be finally consumed by sinking back into the mantle at deep ocean trenches called subduction zones.

As new ocean crust is being created, it cools and solidifies into rock under the influence of the Earths' magnetic. As the material cools, the magnetic mineral crystals will align their magnetism to the direction of the Earth's field, eventually freezing that direction in place. Depending on the rate of cooling, the new rock may consist of small crystals (fast cooling, leading to strongly magnetic material) or large ones (slower cooling and weaker magnetic material). Ocean crust is very much analogous to a magnetic tape, slowly created at the spreading center -- the area where the magnetic record is written into the rock. When the field is pointing the way it is today (so called "normal polarity" -- with magnetic north pointing generally to the geographic north pole), the newly formed rocks' own magnetic field will be "set" in the same alignment. During periods of "reverse polarity" the planet's field is oriented in the opposite direction (the magnetic north pole has switched to the south geographic pole), and the rocks will similarly lock in this reversed direction. These fluctuations, written regularly over distance and time in the crust itself, are a record of the Earth's magnetic history and in our case we are seeking to reveal this history for the Jurassic period.
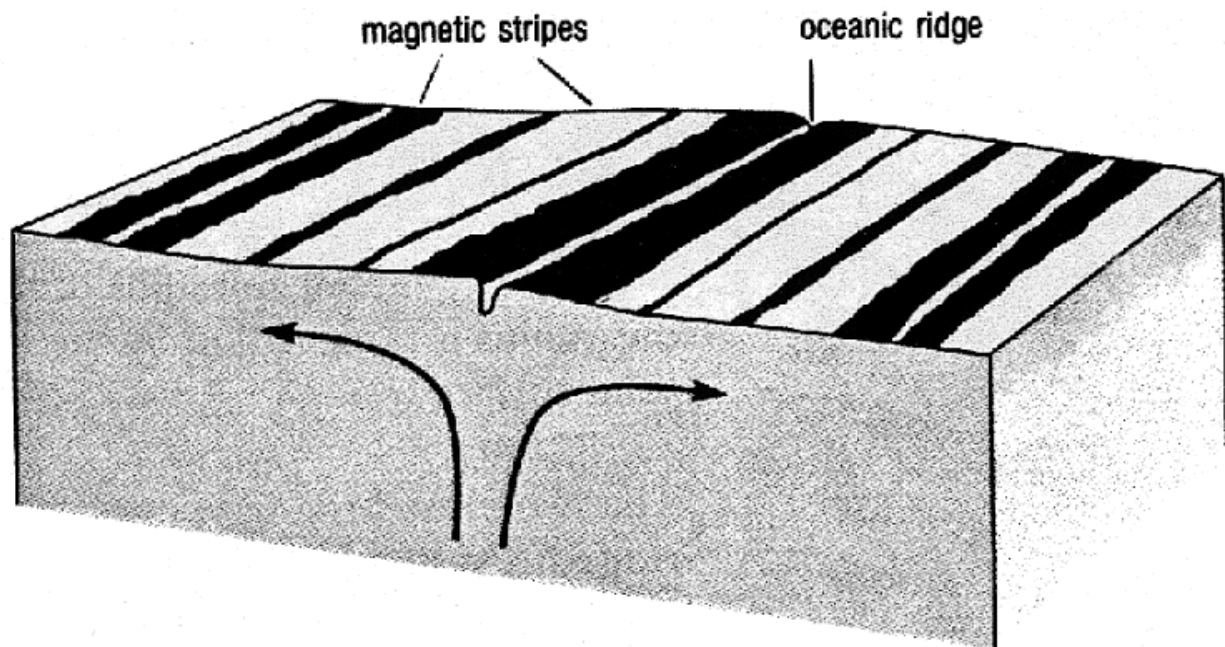
As the ocean crust spreads from the midocean ridge, the polarity of the Earth's magnetic field is recorded in stripes (deeptow.whoi.edu)

Making our conceptual way outward from the center of the planet, we've almost made it to the surface, but there's still one thing separating us from the magnetic record we're after: the Pacific Ocean. The oldest ocean crust remaining in the world -- the rock from the Jurassic period containing the last unmapped magnetic record -- is also the crust nearest the end of its life, closest

to the subduction zone where it will eventually be returned to the mantle. A few areas on Earth fit this profile: on either side of the Atlantic ocean, where the Jurassic crust is obscured by kilometers of sedimentary rock constituting the continental shelves of North America and Africa; a portion of the southern African coast near Madagascar, and a triangular region in the western Pacific.
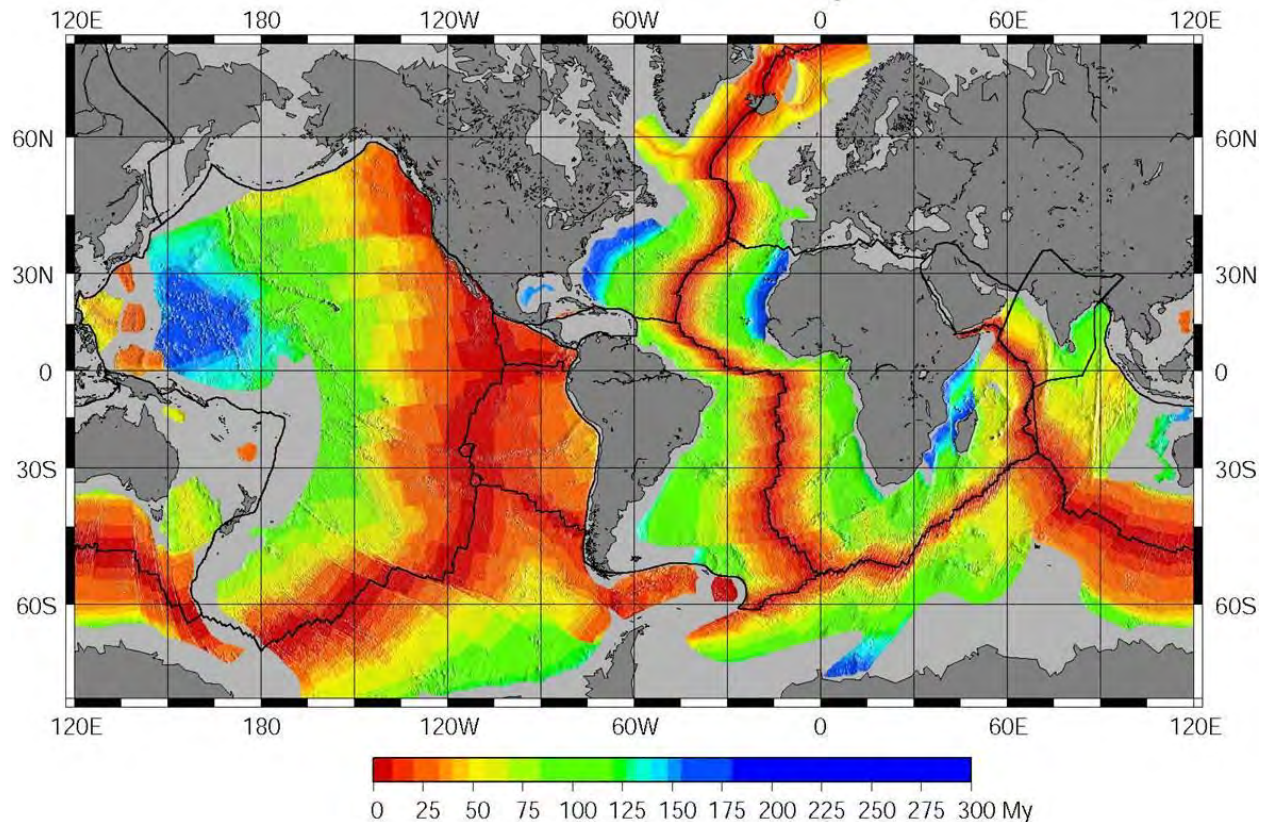
Red denotes newer crust; the blue areas are the oldest oceanic crust (from the work of Müller et al; see more)

Each side of the triangular area in the Pacific represents crust originating from a different spreading center. For this reason, it's a uniquely useful area for magnetic surveying. By taking readings from each side of the triangle and cross-referencing them, we can hope to construct a comprehensive profile of the history of polarity reversals in the magnetic field during the Jurassic period. This is the overarching goal of a research program that our co-chief scientist Dr. Maurice Tivey has been involved in since 1992. On a series of cruises like this one, Dr. Tivey and colleagues began collecting data on the magnetic anomalies in the Japanese lineations (the west side of the triangle) with a deeptow magnetometer. Since then, each successive cruise has employed more sophisticated sensors and contributed another piece of the whole picture of the magnetic history of the Jurassic Pacific crust. On this cruise and the last (which are mapping the Hawaiian lineations, on the east side of the JQZ triangle), the opportunities provided by the Sentry vehicle to make close up observations of these rocks at depths greater than 5000 meters are essential to retrieving high-resolution records of the subtle and faint magnetic fluctuations that occurred during that period.
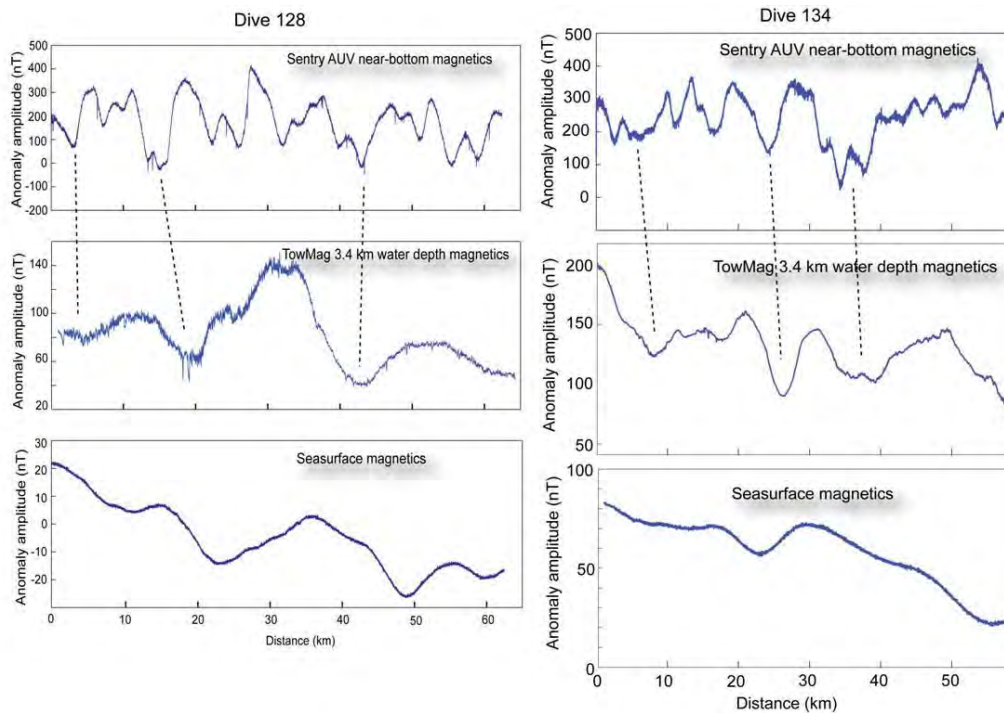
The deeper you go, the more details you see: Sentry (the top of each column) provides by far the most detailed magnetic profile compared to the surface towed and even the deep tow magnetometers

This definitive record at the frontier of magnetic crustal surveying will help resolve questions about what exactly the Earth's magnetic field was actually doing during the Jurassic period, and will provide an authoritative benchmark against which other magnetic observations from the same time can be calibrated.

Instruments: Expendable Bathythermograph

Although the research priority of our cruise is magnetic data, we are not passing up any opportunity to use the state of the art sonar-based instruments on the Sikuliaq to conduct surveys of the ocean floor under our path. Because these instruments rely on the sending, receiving, and timing of sound waves through sea water, we must be sure to be able to account for all the factors which can affect the speed of sound in the water between the ship and the topography below.

Thanks to marine technician Ethan for a great briefing on the XBT

Enter the expendable bathythermograph (or XBT) : a disposable probe that profiles the temperature of the water column below the vessel

The speed of sound through seawater is a function of, in order of decreasingly powerful influence: pressure (and therefore depth), temperature, and salinity. Sonar is a ranging technology whose expertise is depth: determining the point at which the signals it emits bounce off a hard boundary and begin the return journey to the receiver; but by itself it can't know anything about temperature or salinity. Making a bad assumption of the water conditions can lead to inaccurate ranging results, so it's important to know these values. Since temperature has the larger effect, we start there.

It isn't enough to take a single temperature reading of the water under the ship. Sonar signals have to travel through as much as 6000 meters of water to reach the bottom and that means we need an entire temperature profile -- a curve plotting the temperature versus depth from the surface all the way down. The XBT is essentially a thermometer that is lowered down to about 750 meters and continually sends back a temperature reading up a length of copper wire.

Preparing to guide new members of the science party through launching an XBT is a time honored, and much valued, tradition among the crew

While for our purposes there is a whole lot of ocean left below 750 meters, most of that deeper region stays relatively static in temperature. However, a lot can change closer to the surface. Depending on the location, temperatures near the surface may begin to fall off immediately, or they may remain steady for a few hundred meters in a so-called mixed layer of homogenized, similarly heated waters. At a certain point, we find a thermocline: the depth at which the water temperature begins to drop very rapidly. Finding the thermocline is vital to calibrating sonar to work correctly in the waters we're surveying at any given moment.

Below 750 meters, we use data collected in the World Ocean Atlas, combined with our XBT readings, to extrapolate the temperature profile for the rest of the water column.

An example plot showing the speed of sound, temperature, and salinity versus depth. On the middle chart, the small vertical blue segment is shows the steady temperature of the mixed layer as seen by the XBT; the thermocline is the point where the temperature takes a dive to the left, the lower values. (Ethan Roth)

Since we're collecting sonar data while transiting at a decent speed, the convenience of the XBT is a big asset. The ship doesn't need to slow down at all, and the instrument doesn't need to be retrieved. Other cruises with different goals collect even more detailed water column profiles with a bigger instrument called a CTD, which must be deployed from a stationary vessel. We are trading off this precision for expedience, as the site of our magnetometric survey is still some days off.

Instruments: EM-302 (the multibeam)

The multibeam echo-sounder is one of the two main instruments built into the ship for the purposes of mapping the seafloor. When standing watch, it's one of the systems that must be monitored to ensure it's constantly able to track the bottom. It's also the source of the second half of a watchstander's duties: processing.
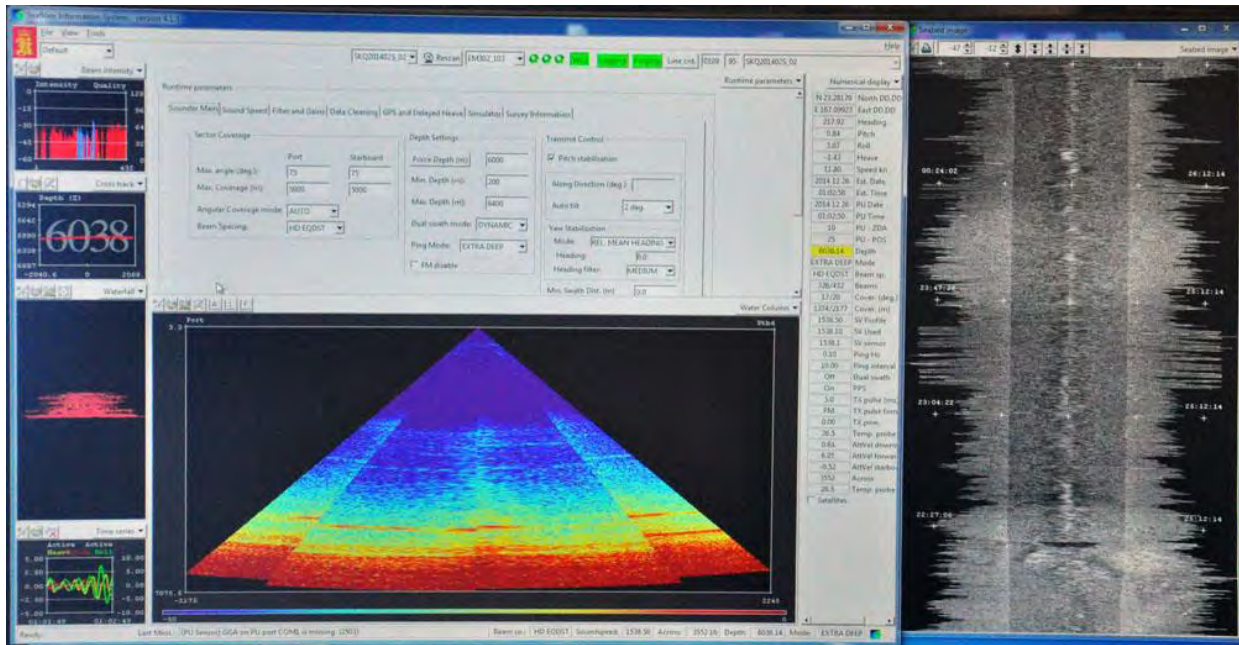
The EM-302 interface

Thanks to Ethan for a thorough review of the EM-302

In the picture above, the current depth directly below the ship is displayed in large numbers at left. Below that, a 3D schematic of the local seafloor. The colorful triangle represents the returning sonar pings from the whole survey swath, and the white line shows a slice of the bottom perpendicular to the ship's direction of travel. The grayscale column at right is a trace of the backscatter -- more on that later.

Depth sounding, the process of determining the depth of the ocean beneath a vessel, has always been of critical importance among the nautical pursuits. Formerly the province of a lead-weighted line, graduated with knots or markings at regular intervals, this task has routinely been, since about the 1920's, accomplished by precisely measuring the travel time of directed sound pulses. By knowing the speed of sound in water and timing the trip taken by a sound pulse from a transmitter aboard a ship down to the bottom and back, the total distance travelled by the pulse and therefore the depth of water (half that distance) can be easily calculated.
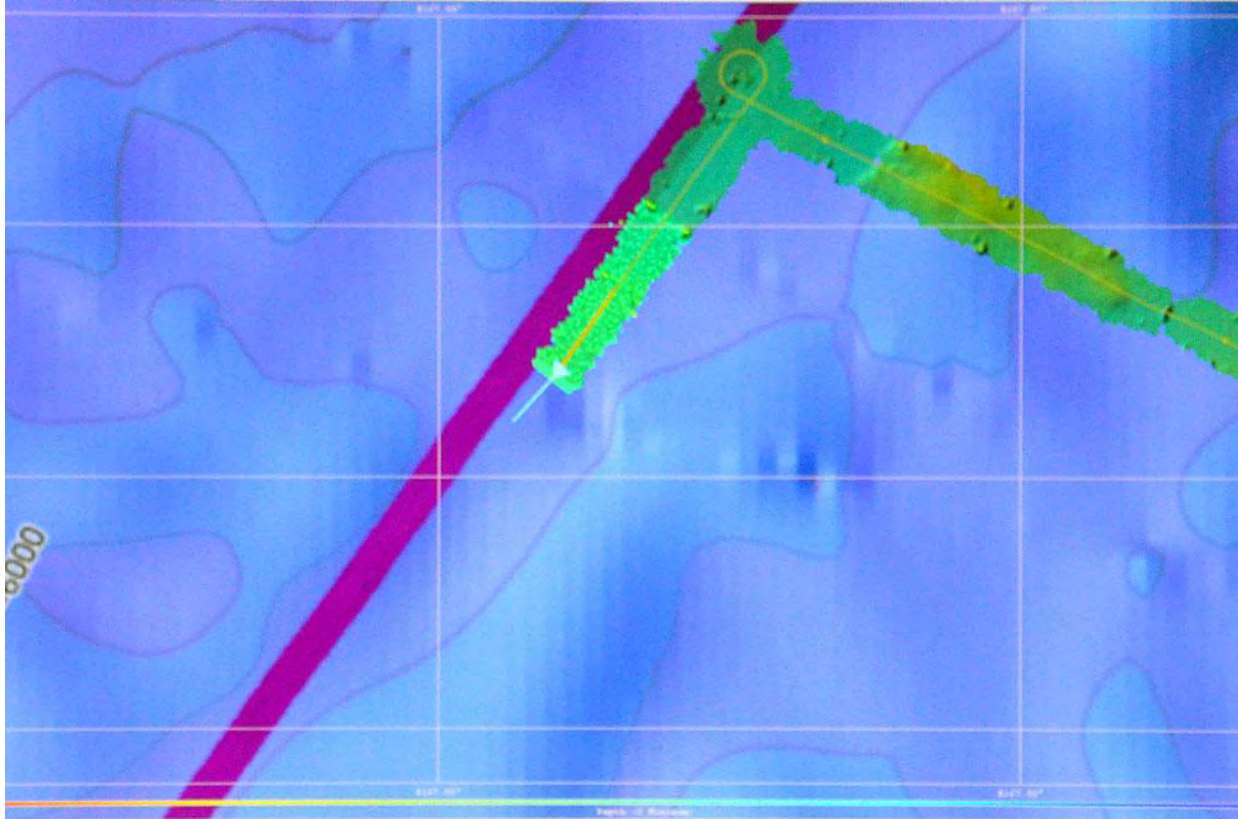
Mapping output of the multibeam. Pink track: a previous cruise. Green track: our cruise. The looping turn increases coverage of that part of the map; turn too quickly, and some of the seafloor would be missed between pulses.

A conventional echo-sounder (or a lead plumb-line for that matter) provides a single sample: the depth at exactly one point on the ocean floor. As you may have guessed, multibeam systems like the EM-302 take simultaneous depth readings at many points which can be combined to form a line of readings across a portion of the seafloor. Taking many lines, or slices, in succession and stacking them together provides a 3D map of the bottom.

 The EM-302 receives 432 individual return beams per ping, each of which consists of a pulse of sound at 30 kilohertz (that's a considerably higher frequency than the maximum extreme of human hearing). This is in contrast to other echo-sounders, who operate at lower frequencies e.g. 12khz. Higher frequency requires more power, and means the pulses are still decipherable after returning from greater depths.

The multibeam has another capability that makes it unique from other echo-sounding sonar. Any time a wave crosses a so-called density gradient, that is, a boundary between a medium in which it has a higher speed and another medium in which it travels slower, part of the wave will bounce or reflect off the boundary while the rest will continue into the new medium at the new speed. Mapping the ocean bottom, we are most interested in the most noticeable, very stark density gradient: the bottom itself, the boundary between the water, where sound moves at around 1500 meters per second, and the sediment and rock of the seafloor, through which acoustic waves travel

much faster. This boundary is the clearest to observe in the timings of returning sonic pulses, and the software that drives multibeam shows it as a white line in the main display window. But the multibeam is recording the returning pulses from *every* density gradient, not just the seafloor. That's why the main triangular view shows a range of colors: each blob shows a place in the water column where the sound waves changed in speed, which the multibeam noticed as a change in return time. It is possible to see, for example, schools of fish and other features of the water column in addition to the depth to bottom with this instrument.

Since the EM-302, a large device which consists a transmitter array along with a receiver array, is built into the ship's hull, it is susceptible to the motion of the vessel. Making sure that each swath of depth readings from the sonar corresponds to the correct location on the map relative to all the other readings requires accounting for the precise attitude, or orientation, at the moment of each observation. Unfortunately, between the motion of the ship in heavier seas and the bubbles produced along the hull by the ship's drives, there is sometimes plenty of interference causing the multibeam to return noisy data. This is where the student watchstander who isn't monitoring the max depth and ping mode steps in.

Rachel is looking forward to the multibeam processing shift after the heaviest rolling we've experienced so far

We'll talk more about cleaning up multibeam data soon.

Instruments: TOPAS (the sub-bottom profiler)

Whereas the multibeam echo sounder returns information about the depth and shape of the seafloor, the TOPAS system is designed to provide information about the density of the material *below* the water-seafloor boundary, hence its designation as the "sub-bottom" profiler.
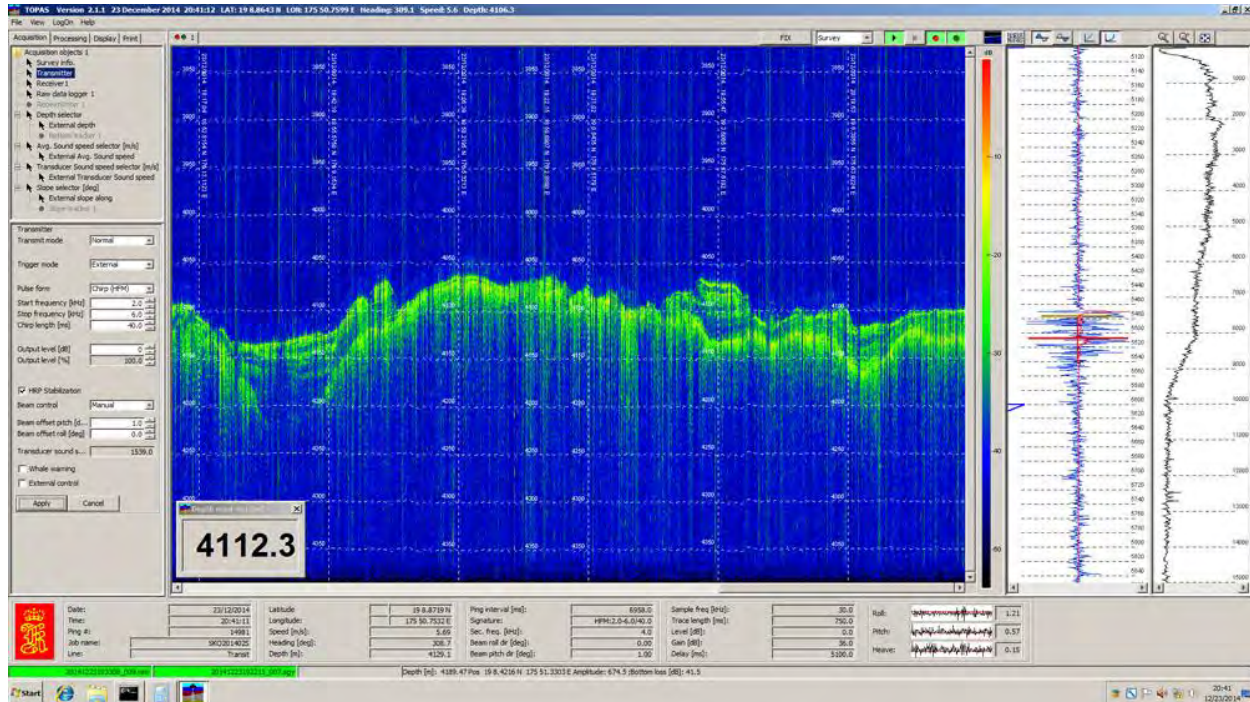
The interface for the TOPAS

The TOPAS system provides observations penetrating up to 100 meters into the ocean bottom. It accomplishes this by using a "parametric" array which combines two independent 15-21 kHz signals whose interaction creates a frequency-modulated sweep of a much lower frequency than for example the multibeam or other echo-sounders. These resulting lower-frequency sound waves are not interfered with as much by the bubbles surrounding the ship's hull or other density fluctuations in the water column, and interact primarily with the much denser material constituting the bottom and sub-bottom. The technique of creating a low frequency pulse by combining two higher frequency signals is used in order to allow a physically smaller array transceiver array, requiring less power, than would be required to generate the same signal from a single transmitter. This allows a the construction of a more compact instrument which can deployed on more ships.

Just as the sound waves emitted from the multibeam bounce partially off density gradients in the water column and the bottom, those sent out from the TOPAS bounce mostly off the seafloor and then some of them partially penetrate deeper into the ocean crust before bouncing back off density boundaries in the underlying sediment and rock. These return pings are timed and the return time of each of these signals makes up the main green and blue plot in the TOPAS interface.

An important distinction when comparing the multibeam output to that of the TOPAS: because the speed of sound through water is fairly predictable (especially when you have the data from an XBT and the World Ocean Atlas), it's possible to read the depth-to-bottom directly from the multibeam output. By contrast, since the TOPAS is dealing with sound that has spent time travelling through a sub-bottom medium of unknown density, it is not possible to read the *depth* of the various sub-bottom features observed by the TOPAS directly in its readout. All TOPAS reports are the time delays between sending and receiving its modulated sonic pulses.

These time delays depend on the density of the sub-bottom material, but also on the distance the sound must travel through water before and after interacting with the bottom. This is the reason that when standing watch it is important to make sure the "trigger delay" -- the time between emitting a sweep and beginning to listen for echoes -- is set so that the TOPAS will be listening when its own signals are returning to it.

Even though the sub-bottom density data gathered by TOPAS is mostly unrelated to the magnetic survey we are conducting of the JQZ, it is still a very valuable resource for a number of reasons. This sub-bottom profiling technology is relatively new, and demonstrating its success, particularly in a region of the Pacific for which even ordinary depth mapping data is sparse or nonexistent, is good progress for the oceanographic community as a whole. It also gives us a chance to help NSF show off the state of the art capabilities of the Sikuliaq, and hopefully inspire and encourage other researches to use this ship as a platform for explorations of their own.

Instruments: Argo

An opportunity to contribute to the collective global effort to understand the world's oceans: we've had the chance to deploy one of the Argo program's autonomous floating temperature and salinity probes. These devices are part of a network around the world and periodically traverse the top layers of ocean by pumping water into and out of a reservoir to gradually alter their buoyancy. During these trips through the water column, they record the temperature and salinity as these values vary with depth and ultimately report their findings via satellite phone.

More information on the Argo project can be found at their website http://www.argo.ucsd.edu/How_Argo_floats.html

Bern and the bosun prepare to drop the Argo into the water

Gravimetry

Gravity is the force of attraction between any two masses; the study of this force is gravimetry; the instruments used to perform this study are gravimeters (or sometimes gravitometers). In the context of the Earth, when we measure the acceleration due to gravity, the Earth is so massive compared to everything else in the picture that there is little room for variance: we must be able to detect small variations on the scale of 1/1000th of a "gal" (the unit of gravitational acceleration named for Galileo, and equaling 1cm/s^2). Variations in density -- the amount of mass per unit of volume -- in the Earth lead to subtle variations in the gravitational acceleration at different points around the globe (higher density -> more mass -> more gravity and vice versa). These density variations arise from the composition and structure of the Earth, which are of interest to geologists and geophysicists. Therefore, data on the "gravity anomaly" (the difference between the mathematically expected and actually observed gravitational acceleration) at each location we visit is one of the staples of any marine geophysics cruise.

The portable gravimeter. Taking a reading involves manually moving a needle to the correct spot using the silver dial

Most gravimeters cannot report the absolute acceleration due to gravity; instead, they display the difference in gravitational acceleration at their location compared to a reference point. This value is calculated by observing the change in the length of a very sensitive, specially prepared spring. Known reference points, where a more bulky and expensive "absolute" gravimeter has been used to take a definitive reading somewhere that the gravity anomaly is likely to remain constant, are known as "gravity ties". We took a reading with our portable gravimeter at one such tie in Honolulu. This reading, and another taken a few miles away at the pier where the Sikuliaq was fueled, can be used to calibrate the shipboard gravimeter and calculate the absolute gravity anomaly as we travel.

The gravity tie in Snug Harbor

The ship's gravimeter takes a reading every second. These data are susceptible to many sources of noise, such as the movement of the ship, and other factors which cause the gravimeter to report accelerations including influences that we would prefer to isolate. These corrections can be applied using some simple formulas which yield coefficients that when multiplied by the raw gravity reading, account for these various effects. For example: the Earth is not a perfect sphere, but rather an "oblate spheroid" (almost spherical, but wider around the equator than it is tall along its axis). This means that when travelling north or south, changing latitude, you are drawing slightly closer to or further away from the center of the Earth and consequently changing your distance from its gravitational center. The distance separating two masses affects acceleration due to gravity, and therefore this must be accounted for in the "latitude correction".

The gravimeter aboard the Sikuliaq is located in the tech shop

For a ship moving about the globe, the east-west direction also influences the observed gravity. When traveling with the direction of the Earth's rotation (east), you experience a greater centrifugal acceleration than normal, which if uncorrected would make the gravity reading appear too low (and conversely, going west inflates the observed value for the same reason) . This is called the "Eötvös effect" and can be corrected with a little trigonometry. Yet another adjustment, the "free air correction," accounts for the additional vertical distance between the gravimeter and the radius used in the latitude correction.

In practice, applying these corrections involves taking the text files dumped by the instrument to the shipside network and running some FORTRAN or MatLab code to produce the fully corrected result. Finally, these processed data can be used to plot the gravity anomaly on maps.

Magnetometry

Any time you use a conventional compass to check which way is north from where you're standing, you are taking advantage of magnetism, specifically the tendency of a magnetic material to align itself, if its motion is appropriately unconstrained, to the direction of the surrounding magnetic field. Imagine a line extending outward from the north and south points of your compass needle; this line will coincide with one of the field lines which designate the direction of the magnetic field

of the Earth. These lines all extend outward from the magnetic north pole and loop out and around (one of them going right through your compass needle, another going through every other magnetic compass needle anywhere around the globe) to dive back in at the magnetic south pole.

Because of what we know of the changing nature of the Earth's magnetic field, it is possible to imagine that if you had very, very acute senses, you would be able to observe, over the course of several years, the direction to magnetic north from your current spot shifting slightly as the Earth's field gradually oscillates and reorients itself. You could also observe, if you walked along the surface of the Earth, tiny fluctuations in the direction of the needle as local influences -- magnetic fields from magnetic material within the rocks constituting the Earth's crust -- momentarily jostled with the global field for control of your compass' direction.

This observable variation in the magnetic field as we move over different parts of the Earth is exactly the reason why we are in the Pacific Jurassic Quiet Zon; only instead of a compass and impossibly sensitive eyes, we rely on instruments developed for this specific task: magnetometers.
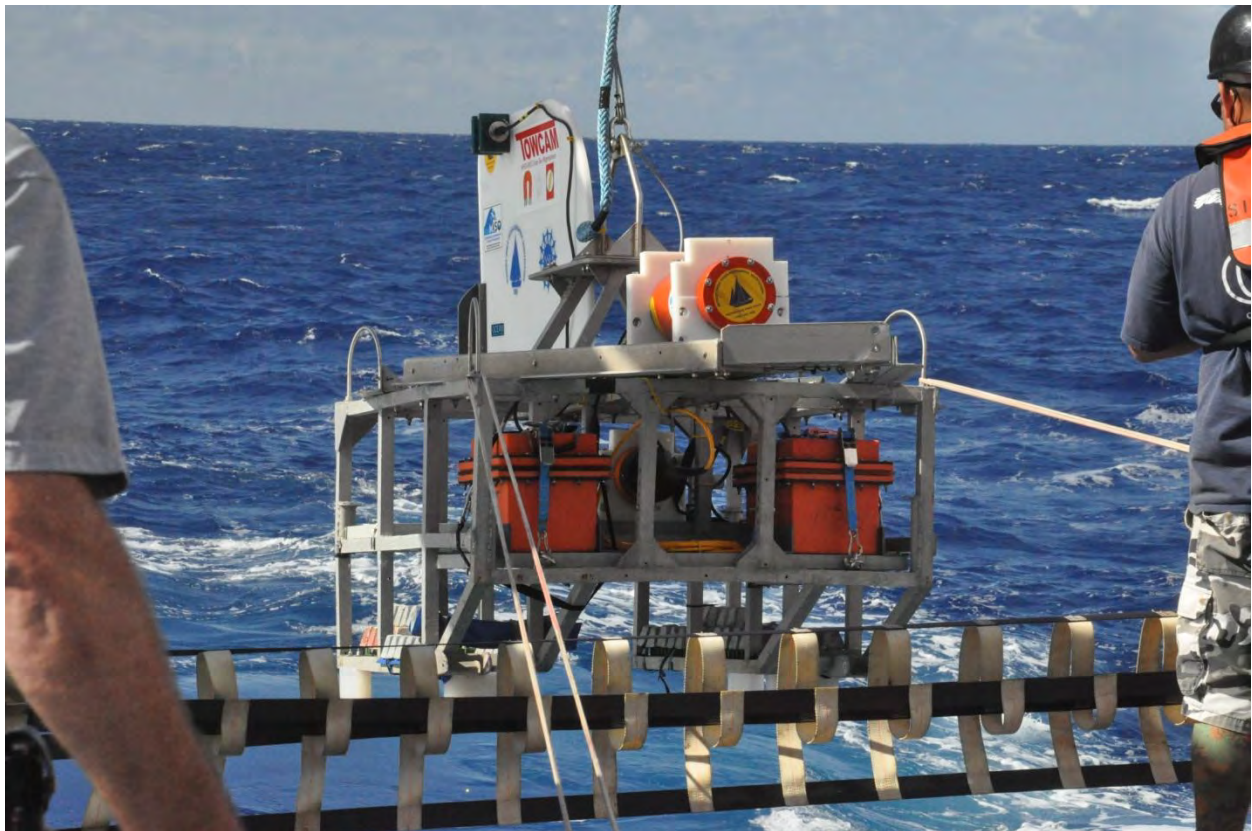
The DeepTow sled, carrying two magnetometers, is deployed overboard off the a-frame

The magnetic field at any given point in space has a magnitude (the strength of the field), combined with a direction (the line along which an imaginary compass needle would align itself if it were placed at that exact spot). It is possible, or rather inevitable, that this value can be thought of as the *sum* of a variety of magnetic fields from an assortment of sources. Move a bar magnet

gradually near your compass and observe how the direction it points is first totally dictated by the Earth's magnetic north; then it splits between the two, pointing to neither yet influenced by both; until finally the bar magnet exerts such a strong local pull that the Earth's field is ineffectual at moving the needle at all. This is important: the strength of the force a magnetic field exerts on magnetic material decreases roughly with the square of the distance. Furthermore, the field at any point is the combined result of multiple influences. It follows that it is easier to notice, and therefore measure, the magnetic field associated with a particular object of interest the closer you are to it.

This leads us to the range of magnetometers used on this cruise to the JQZ. In order to get a good magnetic "picture" of the magnetic anomalies here, we are using several different magnetometers. Each operates at a different depth, resolution, and sensitivity, and together they can help to provide a comprehensive analysis of both general magnetic trends in the crust as well as specific details in the record of the Earth's magnetic field's polarity reversals during the period when this crust was formed. From shallowest to deepest (and therefore general to specific, lower to higher resolution) , they are:

Surface tow magnetometer. The "surface maggie" consists of a single "Overhauser" nuclear precession magnetometer towed behind the ship by a single cable, which it uses to relay data in real time back to the lab on the ship. These devices are the state of the art in magnetometer technology, taking advantage of the Nuclear Overhauser Effect to provide amazingly accurate, absolute readings of the magnetic field strength. Overhausers are new and improved over older proton precession maggies in that they need lower power but can sample at a faster rate. Old proton mags could only sample at a 6 second rate for the most part, whereas the Overhausers can sample at up to four times per second.

The surface maggie is portable enough to be deployed and recovered by hand, and resilient enough to be usable at cruising speeds. This means it can basically always be in the water, gathering a "wide-angle" view of the magnetic field several kilometers above the ocean crust.

Maurice connects the surface maggie to its tow and data cable

DeepTow magnetometer sled. About half way between the surface and the bottom, giving a medium-resolution, medium-area degree of coverage, the DeepTow sled actually carries two magnetometers: another Overhauser (this one rated for greater depth and pressure), and a 3-axis magnetoresister magnetometer. "3-axis" means the device takes readings along three perpendicular directions, making it possible to recover not only the field strength but 3-dimensional direction as well. "Magnetoresister" means this one uses a material whose resistance changes in response to a magnetic field; measuring this change can yield directional but relative magnetic field readings (requiring a calibration value to recover absolute field strength).

The DeepTow sled consists of an aluminum frame housing both magnetometers, batteries, and a configurable amount of lead ballast weights used to give the sled the appropriate weight on the wire for its target depth. Towed by a long cable from one of the ship's main winches, the sled operates at a depth of around 2500-3000m. This system is also realtime and sends data up the cable using an ethernet connection similar to a regular home TV/cable internet cable.

Sentry's magnetometers. Yet another variety of magnetometer rides in Sentry: three 3-axis fluxgate magnetometers, arrayed in a vertical line along the vehicle's central axis. This type of magnetometer is both durable and compact, and can tolerate nearby magnetic sources, making it the ideal choice for deployment on the AUV.

There is a clear tradeoff between ease of use and quality of data. Each successive apparatus operates deeper, takes readings closer to the ocean crust, and is increasingly complex and time-consuming to deploy. Managing this tradeoff is part of the art of this branch of marine geophysics, and choreographing the timings of deployment and turnaround to synchronize coverage, maximize survey range, and facilitate safe launch and recovery of all these devices to make optimal use of the limited ship time available is a full time task. Fortunately, with numerous cruises under the belts of our chief scientists, instruments that have improved markedly in the twenty-plus years since this research area was first explored, and with a brand new ship and a well-versed technical crew, this particular challenge is, so to speak, down to a science.

Processing data

If you're feeling like you've had enough of keeping an eye on instruments and making regular log entries for a bit while on watch, you're in luck because whenever they are on (which is most of the time that Sentry isn't in the water -- its own acoustic communications would be hindered by the other sonars' simultaneous operation), the TOPAS and multibeam are outputting megabytes upon megabytes of raw data which need to processed to correct for things like the unpredictable rolling of the Sikuliaq, noise from the bubbles from the ship's drive, and other irregularities.

John, creating 3d topographic maps of the seafloor from multibeam data

Data processing takes place on the computers in the main lab, and consists of operating a few specialized software programs depending on the instrument of interest. Depth data from the multibeam echo-sounder is processed in several phases. Raw sonar timing data from the multibeam is courteously converted by the software driving the instrument to a series of depth profile "slices" tracing contours along the surface of the ocean floor. These slices appear as lines -- cross sections of a portion of the bottom perpendicular to the direction of the ship's travel.

In an ideal world, the ship would traverse a steady, straight course through still water with a completely known temperature profile, the drives would produce no bubbles or extraneous energy of any kind, and waves would be an imaginary abstraction. In the real world, the drives produce bubbles, the ship pitches (tilting forward and backward), rolls (tilting side-to-side), and heaves (bobbing up and down relative to the plane of the ocean's surface), making even the most accurately calculated ping timings produce noisy, messy depth data that does not reflect the true shape of the bottom.
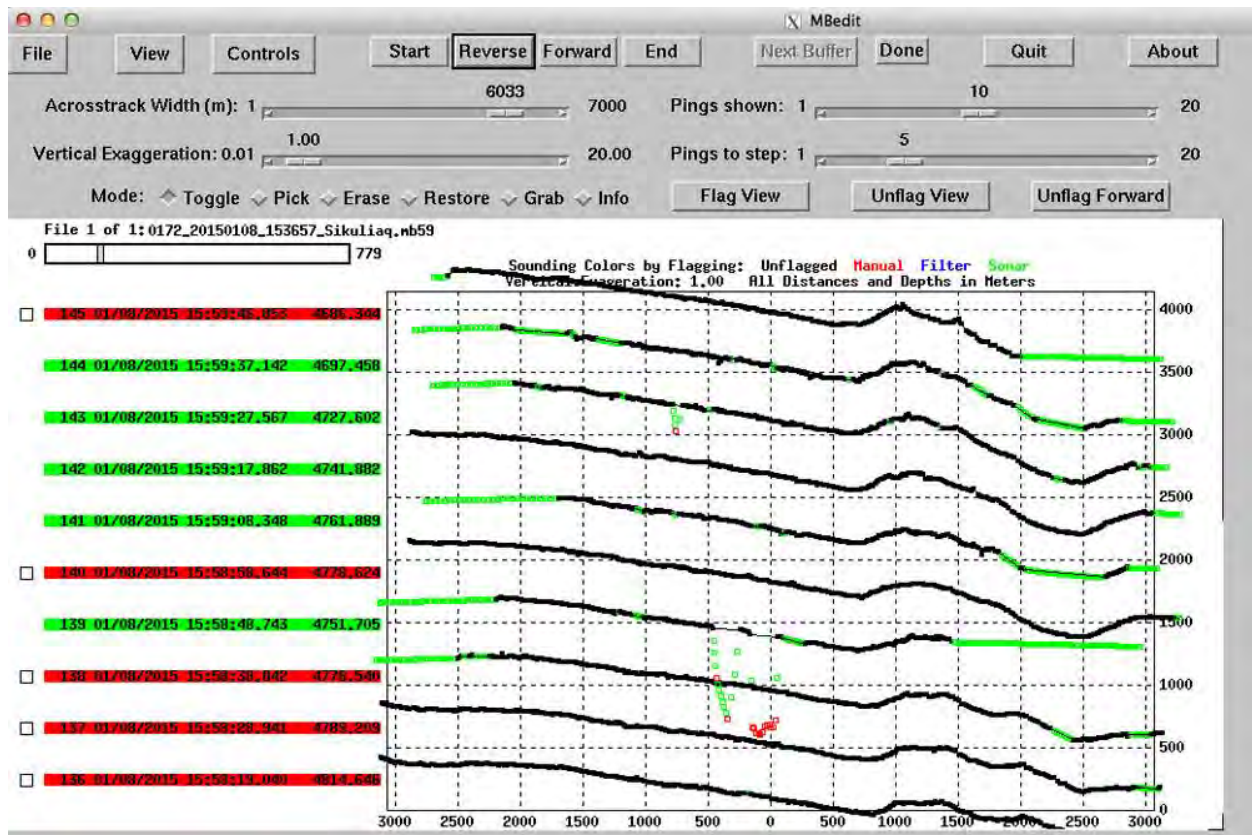
Editing interface for multibeam data. Each line is a swath showing the depth perpendicular to the ship's course

It is a simple, if somewhat involved and time-consuming matter, to manually inspect each slice or beam swath for noticeably anomalous points and eliminate them, allowing the software to make mathematical interpolation of that particular depth reading rather than letting a noisy point contaminate the shape of the depth profile. In practice, this task consists of scrolling through screens of "waterfall" view sequences of slices and clicking on individual points or groups of points to flag them as anomalous.
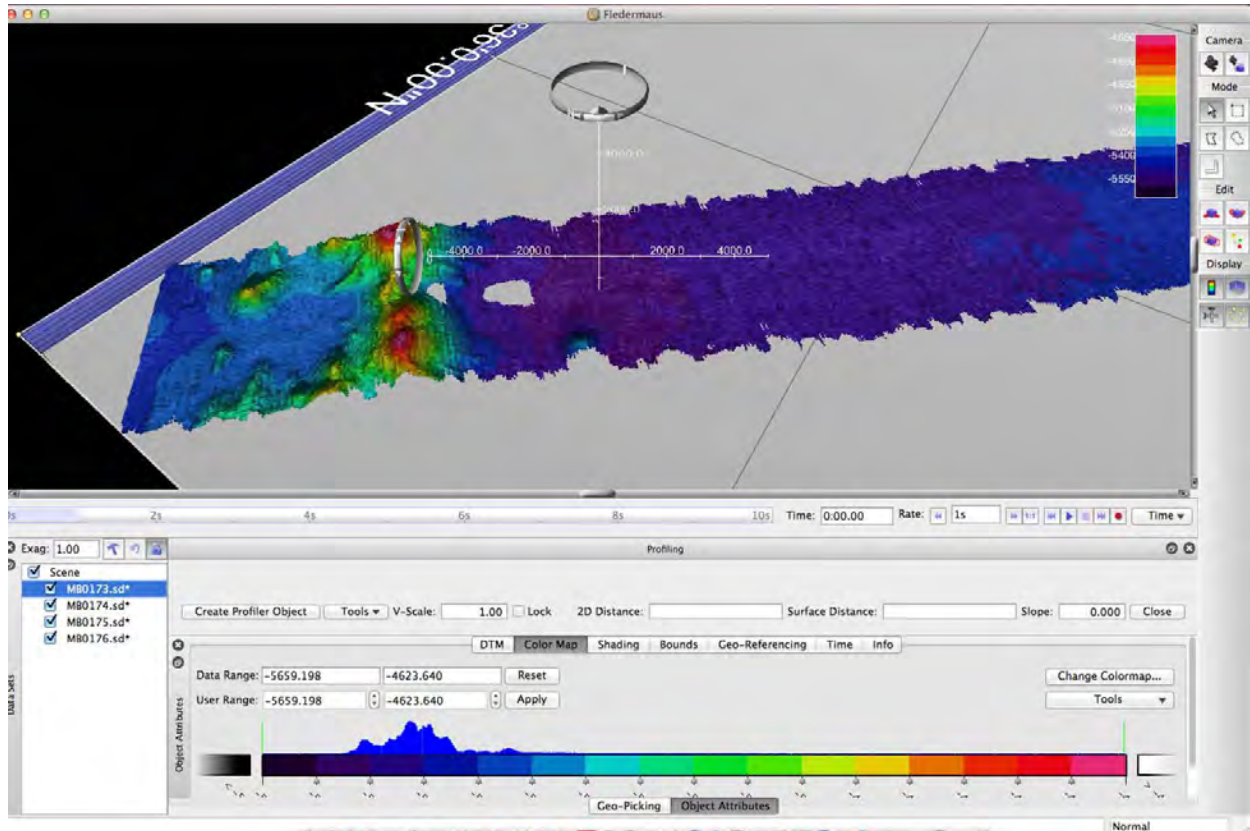
Multibeam data are combined and interpolated to create 3d depth maps in Fledermaus

The payoff for this work is a clean set of depth data for the day's multibeam surveying that can be fed through another program to produce three dimensional topographic representations of the ocean floor. The student's job at this step is simply to verify that all the segments of a survey fit together properly, and to edit the color gradient used to show variations in depth to maximize the visibility and contrast of the features of the bottom. In some cases, these will be the first 3D maps of a given section of ocean floor ever to be acquired.

* * *

The TOPAS parametric sub-bottom sonar also produces data that requires some supervision in order to maximize its utility. Being concerned with the sub-bottom density and structure, TOPAS

is dealing with targets further away and therefore more difficult to analyze than the multibeam. Therefore, under identical circumstances, it's usually safe to expect slightly less noisy data from the multibeam than the TOPAS. Fortunately, the TOPAS software provides a deep suite of signal processing tools to help the operator pick out the range from each frequency-modulated pulse most useful to the task at hand.

For a student watchstander, processing TOPAS data means: loading up a series of data files, running through the file at a slightly higher than realtime speed to get a feel for the peculiarities of this particular track, applying a matched filter (to ideally improve the signal-to-noise ratio) or passband filter (in the case of an overwhelming need to attenuate all non-interesting frequencies), adjusting the mute timing to ignore all echoes returning too early to have come from the bottom or sub-bottom, possibly tweaking the time-variable gain to emphasize echoes in a certain time range and hopefully therefore a well-known spatial range in the sub-bottom, and then having arrived at a satisfactory configuration, replaying the file in logging mode to produce a processed output file.

Because the sub-bottom profiler of this design is such a new instrument, and it is so rare to have one on a research vessel of this size, it's an exciting privilege to be among the first to feel out the capabilities of this instrument in the deep-ocean environments of the JQZ.

Meet Sentry

The Sikuliaq has several powerful instruments and sensors on board, and we brought along a few of our own in addition to those, but the up-close and personal magnetic data from the oldest Jurassic crust in the Pacific -- our main goal -- just can't be gathered from the surface. For that, we need the help of the Autonomous Underwater Vehicle Sentry and the team of engineers from Woods Hole Oceanographic Institution who run it.

For our cruise, Sentry has gotten into the spirit of the season

Sentry is an **AUV** -- an autonomous underwater vehicle. This puts it in contrast with many other oceanographic research vehicles which are often manned submersibles or **ROV's** -- remote-operated vehicles. Autonomy provides a variety of benefits: there are no passengers to take up weight and volume that could be used for batteries or instruments, and the lack of an operator controlling each move means there is no latency between new data and navigation decisions.

Even among AUV's, Sentry's design gives it several advantages as a platform for deep sea science. For one thing, the vehicle's shape and vertical orientation make for easier and more flexible navigation. Sentry has about a forty-five degree field of view and is capable of avoiding obstacles if it sees them. Similar to the way a helicopter exceeds the maneuverability of a plane, Sentry's four props on movable fins give it much finer control over its motion than typical torpedo-shaped vehicles whose propulsion is much more directional.

Andy introduces science party to Sentry

Each of these propellers is made of carbon fiber, and they actually come from a specialized Czech model airplane vendor. In combination, they can drive the vehicle at speeds of up to about 2 nautical miles per hour. In practice, stability of Sentry's travel decreases as speed increases, and the limiting factor for all considerations is the finite resource on board: battery life. It takes more power to maintain a stable trajectory at a higher speed. The tradeoff is that much of what Sentry does -- including collecting data with a magnetometer for us -- involves traveling over large spans of the ocean floor, so speed and distance count for a lot. As the vehicle continues to accumulate data from each dive, the Sentry engineers are always analyzing the speed/power tradeoff, including factors like water temperature and currents, to coax even better performance from the vehicle. So far on this cruise, we've seen Sentry break its all time distance record and resurface with battery power to spare on a number of occasions, indicating that the most impressive dives are still ahead.

Sentry is constructed of syntactic foam with a ceramic housing. It is reconfigurable depending on the needs of each individual science assignment; different instruments can be replaced or added to suit the particular type of data being collected. Fully outfitted with the magnetometer and other instruments for our cruise, Sentry weighs about 3000 pounds. After dropping its expendable steel ballast (not recovered, but environmentally harmless), it is neutrally buoyant and can use its unique propulsion configuration to navigate, ascend, and descend with ease.

Night launch: Sentry going overboard for another dive

On our cruise, Sentry has been operating, roughly, on a 48 hour cycle with about 30 hours of dive time bookended by ascent, recovery, recharging, launch, and descent. While on deck here in tropical latitudes, Sentry's interior computers and instruments are protected from the heat by a water cooling system which pumps 48 degree F water through the AUV to remove waste heat. When submerged, the ocean itself keeps the components cool.

Sentry's capabilities are crucial to our mission: without it, we would be unable to get a magnetometer close enough to the seafloor to get the high-resolution readings of the magnetic record in the ocean crust that we need to complete the survey of the history of field reversals during the Jurassic. As the vehicle continues to exceed expectations, we're looking forward to returning with even more of this record. After this cruise, as we return to the lab to process and interpret these data, Sentry will continue its own mission of enabling unprecedented oceanographic science.

You can read a lot more about Sentry at its own page on Woods Hole's website

http://www.whoi.edu/main/sentry

R/V Sikuliaq

Conceived of to fill the need for an ice-capable research vessel in the Alaskan region, designed to provide a state-of-the-art platform for all manner of oceanographic research including the effect of climate change in that area, and already embarked on her second science mission en route from construction in the Great Lakes to her home port in Seward, AK, the R/V Sikuliaq is our lodging, transport, base of operations, and laboratory for the duration of our mission to the Pacific Jurassic Quiet Zone.

R/V Sikuliaq at Pier 30 in Honolulu Harbor (A. Stote)

Oceanographic research vessels in the United States are coordinated by the University-National Oceanographic Laboratory System. The UNOLS fleet consists of ships owned by various organizations, two of the most prominent of which are the Navy and the National Science Foundation (NSF), and operated by partners of the UNOLS group of universities and US National Labs. This organizational structure facilitates the process by which ship time is allocated to researcher of all stripes, who typically apply to NSF for project funding (as in the norm among all sciences) and then, upon approval, enter a subsequent process through which they may be assigned a research vessel capable of accommodating their scientific, geographic, and scheduling needs.

The newest member of the UNOLS fleet, the R/V Sikuliaq is owned by NSF and operated by the University of Alaska Fairbanks. This means that the ship is potentially available to all oceanographic researches affiliated with the UNOLS system, and is crewed by UAF employees.

These sailors comprise a diverse group of research ship veterans, crewmen moving on from recently-retired ships, merchant mariners and more. The ship spends more time at sea than any individual member of her crew, and this means that positions on the ship rotate through regulars and relief. Each time the ship departs port, she sails with a complement of her total pool of crew depending on each individual's opting-in to the contract for that trip. On our cruise, much of the first, original crew of "plank-owners" (who, upon the ship's eventual decommissioning, will be entitled to take away a piece) are still aboard, with a few positions occupied by relief.

A brand new vessel whose construction was finished earlier this year in Marinette, Wisconsin, the Sikuliaq is still in the process of making her way to her home port, which will be Seward, Alaska. A new ship is required to undergo a rigorous and ongoing certification, verification, and testing process including "sea trials" some of which have been already completed, as well as "ice trials" which will begin once the ship reaches her home waters around Alaska. The Sikuliaq is designed for this region of arctic seas, and is capable of breaking up to three feet of seasonal ice at a speed of two knots. As a consequence of this design, which includes a tapering hull that narrows toward the rear of the ship in order to reduce friction with the ice, the underside of the hull is curved in a way uncommon to most open-ocean vessels. This lack of a pronounced keel is a major contributing factor in the incessant rolling -- even in what we now must necessarily think of as *deceptively* calm seas -- that we may have already mentioned once or twice.

A view from one of the upper decks over the foremast at the front of the ship; it's rare to see the foremast perpendicular to the horizon like this (J. Greene)

The Sikuliaq is 261 feet in length, 52 feet wide (in the "beam") at her widest point, and draws about 19 feet of water (the size of the "draft" is the vertical distance from the lowest point of the hull to the water line). She is driven by two "azimuth thrusters," so called because each can independently rotate through a full 360 degrees of azimuth (in the horizontal plane), obviating entirely the need for a rudder to steer the ship, benefiting from the flexible output of a diesel-electric power train managed by the engineering department. The ship is rated for a maximum calm-water speed of 14.2 knots; we have been used to travelling at around 11 in most manageable seas but at the time of this writing (beginning the final transit to Guam) our speed over ground (that's SOG for short) is hovering around 12.2.

When precision is called for in preference to raw power, the Sikuliaq's "dynamic positioning" system -- a combination of GPS guidance and computer control -- allows the ship to automatically hold station over a given point or follow precisely a course specified by the bridge. This is essential in following the Sentry AUV during its dives, as maintaining communication with the vehicle depends on staying close enough to hear it.

Another advantageous feature of the Sikuliaq for our purposes is the somewhat rare "centerboard." This is a deployable segment of the lower hull which can be raised and lowered to extend or retract instruments and sensors below the rest of the ship. Although it requires a low SOG when lowered, the centerboard is capable of putting sonars and other sensors below the bubbles that often can cause interference, and having this ability has made for very smooth sailing as far as communicating with AUV Sentry goes.

Bern lowers the centerboard from the main deck passage

The ship is equipped with numerous cranes and winches -- the so-called "overboard capability" -- which allow deployment and recovery of instruments and vehicles over the side of the ship. For this cruise, Sentry has been deployed and recovered on the starboard side using one of the large cranes and the DeepTow sled is towed by a cable running through a block mounted on the A-frame, which is a mobile structure at the very aft end of the ship. Smaller, movable pneumatic winches can be stationed at critical positions on the deck to provide additional stability for moving loads during deck operations.

The winch control room overlooks the working deck

Inside (within the watertight doors, off the exposed "weather deck"), in addition to the working areas and living quarters we've already described, the ship is equipped with numerous other vital spaces: science stores, with ample reserves of everything office necessities to cleaning supplies; the tech shop, with a workbench, drill press, and comprehensive assortment of tools and hardware; the "Baltic room," a temperature-controlled staging area for overboard equipment; the wet lab, a transitional space between the Baltic room and the main lab; the analytical lab, for additional lab space, and many other rooms dedicated to the marine techs and crew tasked with maintaining a science-conducive environment on board.

On a modern ship like the Sikuliaq, one component of this environment is fast fiber-optic local area network (LAN) and shipwide local wireless network. This serves as a convenient central repository for the copious amounts of sensor data gathered by the ship's suite of instruments, a sort of one-stop-shop for all of the location, course, heading, and attitude (that's spatial orientation) data that are necessary to put other instruments' observations in their appropriate context. It's also the definitive source for settling bets on just how many degrees that last terrific roll really was.

Named with the Alaskan native Iñupiat word for "young sea ice," the Sikuliaq is still making her way toward the seas that will ultimately be her primary home and research area. Nevertheless, by providing this cruise a platform and processing environment for our several various magnetometric

instruments, she is already hard at work proving her versatility and excellence as a facilitator of a great variety of marine research.