Cruise Report

R/V Marcus G. Langseth

MGL1803
South Island Subduction Initiation Experiment (SISIE)
Dunedin, New Zealand to Dunedin, New Zealand
Feb. 17, 2018 to March 22, 2018

Michael Gurnis, Chief Scientist

Cover Caption: Photograph taken during the morning of Feb., 2018, when the R/V Marcus G. Langseth sought refuge from heavy seas to the lee of Auckland Island to the south east of our study region. Photo taken from just beyond twelve miles from shore. (Photo courtesy Steffen Saustrup, University of Texas)

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1. Cruise Overview

MGL1803 was an active source seismic survey using ocean-bottom seismometers (OBS) and the multichannel seismic streamer from the *R/V Marcus G. Langseth*, in the Southwestern Pacific, off the south coast of the South Island of New Zealand. The survey off New Zealand occurred within the area ~163–168°E, and the south coast of the South Island to 50°S (Figure 1.1). The principal investigators (PIs) and funded NSF project objectives drove this cruise on the *R/V Langseth* with the coordination and advisement of the technical staff headed by the Office of Marine Operations (OMO) at Lamont Doherty Earth Observatory (LDEO).

The procedures used for the marine geophysical surveys were similar to those used during previous surveys by using conventional seismic methods. The surveys involved only one source vessel, the *R/V Langseth*. The *R/V Langseth* deployed an array of 36 Bolt Source Elements as an energy source with a total volume of ~6600 in^3. Four hot spares were present within the arrays which could be brought online in case of a failure of one of the Source Elements. The receiving system consisted of 28 University of Texas Institute of Geophysics (UTIG) OBSs for 43 deployments on two refraction lines and a single hydrophone streamer either 4.05 or 12.6 km in length towed by the *Langseth*. The longer streamer provided opportunities to suppress unwanted energy that interferes with the geophysical targets, allowed for accurate measurements of seismic velocities, recorded refracted arrivals at longer offsets, and provided a large amount of data redundancy for enhancing seismic images during data processing. As the source array is towed along the survey lines, the OBSs received and stored the returned acoustic signals internally for later analysis, and the hydrophone streamer transferred the data to the onboard processing system.

During the survey, using both reflection and refraction data, the science party imaged the Puysegur margin and improved their understanding of the formation of new subduction zones. The OBSs deployed sequentially in two east-west profiles were shot with an interval of 150 m or ~60 s. The streamer was then deployed and used to collect 2-D profiles with a shot interval of 50 m or ~22s for deep crustal MCS acquisition.

Other supporting equipment consisted of a Kongsberg EM122 Multibeam echosounder with a median frequency of 12 kHz, Knudsen 3260 chirp Sub-bottom Profiler operated from 2-6 kHz, Bell Aerospace BGM-3 gravimeter, the RDI 75 kHz Acoustic Doppler Current Profiler (ADCP), and Geometrics 882 magnetometer. LDEO ensured that the equipment in use meet the manufacturer’s specifications, while also meeting their internal quality requirements. The technicians onboard were proficient in the operations of standard systems. The science party led the pre-deployment programming and post-deployment data download of the OBS. The science party also led the ship board processing of the MCS, multibeam, gravity and magnetometer data. In addition to the operations of the acoustic source array, a Multi-beam echo sounder (MBES) and a Sub-Bottom Profiler (SBP) were also operated from the Langseth.

Seismic data were obtained from 39 of the 42 recovered OBS. One of the deployed OBS was not recovered. We acquired 717.35 km of MCS data using a 12.6 km streamer and 534.75 km using a 4 km streamer for a total of 1252.1 km of reflection data. We also successfully recovered about extensive bathymetry, chirp SBP data, gravity and magnetometer data. The onboard analysis and interpretation of the geophysical data allowed all of the science questions proposed in the PIs NSF proposal to be addressed. A number of fundamental scientific discoveries on the initiation of subduction were made and will be discussed by the PIs and the science party in papers to be submitted to peer-reviewed journals.

The principal investigator (PI) was Michael Gurnis (Caltech). He was onboard for the survey, along with 17 other scientists/students (total of 18 scientists), 9 LDEO/contract technicians and 5 Protected Species Observers (PSOs).

The cruise took (34) days to complete; mobilization started on Feb 17, 2018 and completion of demobilization occurred March 22, 2018. The ship sailed on Feb 19 from Victoria Pier in central Dunedin, New Zealand. The ship returned to port on March 20, 2018. A day by day summary, in UTC, is provided in Table 1.1. So as to avoid confusion and make the seismic data easier to understand in scientific publications post cruise, we have renamed the OBS and MCS lines starting with SISIE-1. A simple cross-referencing table is included as Table 1.2.

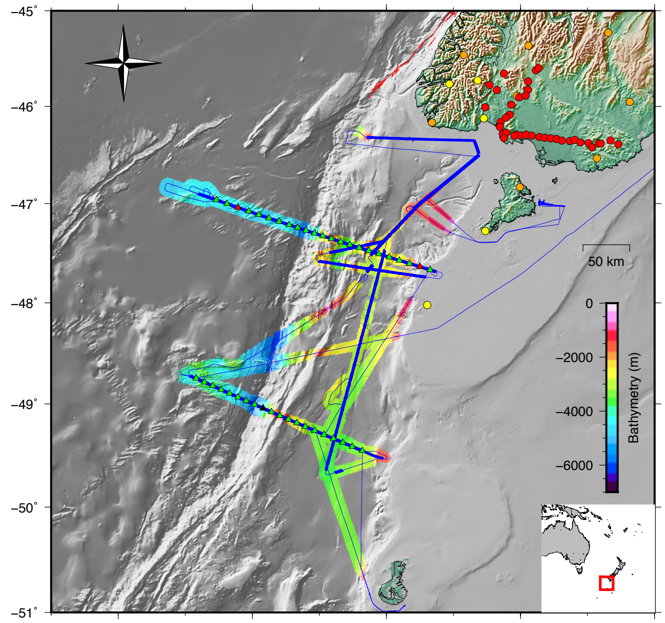


Figure 1.1. Summary of the South Island Subduction Initiation Experiment (SISIE) cruise of the R/V Marcus G. Langseth (MGL1803) Feb. 17, 2018 to March 22, 2018. In the background as a grey scale is the NIWA bathymetry of the region. Overlain is shown: the ship track with underway geophysics (thin black line), MCS lines (thick blue line), multi-beam bathymetry (color coded raster), and OBS locations (as triangles, green successful, back not recovered, and red data not recoverable). Seismometers deployed by Victoria University and GNS Sciences shown as circles: short period (red), broadband (yellow), and GeoNet broadband (orange).

Table 1.1 Day by Day Summary of MGL1803

JD	date(UTC)	Description
48	17-Feb	Dockside Dunedin; MOB
49	18-Feb	Dockside Dunedin; MOB
50	19-Feb	Depart Dunedin. Transit to Survey Region
51	20-Feb	Deploy OBS 101 to 113
52	21-Feb	Deploy OBS 114 to 120. Start shooting OBS Line 1
53	22-Feb	Finish shooting OBS Line 1. Recover OBS 101 to 104
54	23-Feb	Recover OBS 105 to OBS 114
55	24-Feb	Recover OBS 115. Transit SE to Auckland Island. Gravity malfunction
56	25-Feb	Auckland Island. Return to OBS Line 1. Gravity On. Recover OBS 120-119
57	26-Feb	Recovery OBS 118 to 116. Transit to OBS Line 2. Deploy OBS 223 to 215
58	27-Feb	Deploy OBS 214 to 201. Start shooting OBS line 2
59	28-Feb	Complete shooting OBS line 2. Recover OBS 223
60	1-Mar	Recover OBS 222 to 211
61	2-Mar	Recover OBS 210 to 201
62	3-Mar	Deploy 12.6 km streamer. Start shooting MCS01
63	4-Mar	MCS01
64	5-Mar	Finish MCS01. Start shooting MCS03a
65	6-Mar	Finish MCS03a. Shoot MCS T01 Start MCS23a
66	7-Mar	Finish MCS23a. Failed T02, streamer surfaced. Circled back missing segment. Started MCS23b
67	8-Mar	Finish MCS 23b. No shooting on transit. Started MCS14
68	9-Mar	Finish MCS14
69	10-Mar	Recover source and streamer. Transit North. Deploy guns and streamer
70	11-Mar	Shoot MCS17a. Shoot MCS17b. Weather Evasion
71	12-Mar	Down for weather near Stewart Island
72	13-Mar	Down for weather near Stewart Island
73	14-Mar	Down for weather near Stewart Island
74	15-Feb	Down for weather near Stewart Island
75	16-Mar	Waiting on weather Steward Island.
76	17-Mar	MCS17c. T02 and start MCS19c
77	18-Mar	Complete MCS19a. Transit to Dunedin
78	19-Mar	Transit to Dunedin
79	20-Mar	Transit to Dunedin. DeMOB
80	21-Mar	Dockside Dunedin; DeMOB
81	22-Mar	Dockside Dunedin; DeMOB complete

Table 1.2 Summary of SISIE Seismic Lines for Post-cruise publications

New Reference	OBS Line	MGL1803 MSC Lines
SISIE-1	1	MCS14
SISIE-2	2	MCS01
SISIE-3	--	MCS23a, MCS23b
SISIE-4	--	MCS03a
SISIE-5	--	T01
SISIE-6a	--	MCS17a
SISIE-6b	--	MCS17b
SISIE-6c	--	MCS17c
SISIE-7	--	T03
SISIE-8	--	MCS19a

2. Science objectives

The experiment tested models for the formation of new subduction zones. Subduction zones are those places where the tectonic plates dive back into the mantle and are the locus for most of the driving forces of plate tectonics. Initiation of subduction is one of the last unsolved puzzles of plate tectonics because of the lack of good, present days sites. The Puysegur margin is a globally unique place where the causes and consequences initiating a new subduction zone can be seen. SISIE aimed to measure several fundamental aspects of this poorly understood process. The science party aimed to measure the angle of the new fault which forms the new plate boundary and test ideas of how the faults form. They aimed to measure the thickness of the oceanic crust at the Puysegur ridge and test models of how the force from the nascent slab is transmitted into the plate. They aimed to measure the nature of the faults, especially the thrust faults, on the over-riding plate and test models for how the forces on the over-riding plate change with geological time. Finally, they aimed to use the acoustic source array to produce seismic waves that would be recorded onshore of the South Island and use these to test models for the tectonic evolution and nature of the shallow mantle directly below the plates.

3. Cruise Participants

Survey operations were based on a 24-hour day and the following personnel were utilized for this cruise:

Table 3.1 Technical personnel

Participant	Group/Affiliation	Position
Robert Steinhaus	L-DEO OMO	Chief Science Officer
Todd Jensvold	L-DEO OMO	Science Officer - Acq
Tom Spoto	L-DEO OMO	Chief Source Mechanic
Alan Thompson	L-DEO OMO	Marine Science Technician (Nav)
Clive Dugdale	Atlas Personnel	Marine Science Technician (Acq)
Andrew Davey	Atlas Personnel	Source Mechanic
Dean Addison	Atlas Personnel	Source Mechanic
Graham Goddard	Atlas Personnel	Source and Compressor Mech

Table 3.2 Protected species mitigation personnel

Participant	Group/Affiliation	Position
Amanda Dubuque	RPS	Lead PSO
Sara Davis	RPS	PAM operator / PSO
Aletta Busssenschutt	RPS	PSO
Gail Begbie	RPS	PSO
Brooke Stanford	RPS	PSO

The following science party participants were granted access to R/V *Langseth*. They all completed Next-of-Kin (NOK) forms that were returned to the OMO Manager before sailing. During operations, 2 members of the science party were available in the main lab console for online data monitoring, log keeping, and other operational needs that arose (i.e. SVP casts, deployment, etc). These participants provided their undivided attention during their time assigned. The PI assigned each to a shift so that 24 hour coverage was maintained. The science party also participated in OBS deployment and recovery and streamer deployment and recovery.

Table 3.3 Science party members

Participant	Affiliation	Function	Email Address
Gurnis, Mike	Caltech	PI & Chief Scientist	gurnis@gps.caltech.edu
Stock, Joann	Caltech	Co-PI	jstock@gps.caltech.edu
Van Avendonk, Harm	UT	Co-PI	harm@ig.utexas.edu
Gulick, Sean	UT	Co-PI	sean@ig.utexas.edu
Sutherland, Rupert	Victoria U	Scientist	Rupert.Sutherland@vuw.ac.nz
Saustrup, Steffen	UT	OBS Tech. 1	steffen@ig.utexas.edu
Duncan, Dan	UT	OBS Tech. 2	dduncan@ig.utexas.edu
Davis, Marcy	UT	OBS Tech. 3	marcy@ig.utexas.edu
Hightower, Erin	Caltech	PhD student	ehightow@caltech.edu
Williams, Ethan	Caltech	PhD student	efwillia@gps.caltech.edu
Shuck, Brandon	UT	PhD student	brandon.shuck@utexas.edu
Kardell, Dominik	UT	PhD student	dkardell@utexas.edu
Patel, Jiten	Victoria U	MSc student	pateljiten93@gmail.com
Herzig, Erich	Caltech	BS student	eherzig@caltech.edu
Idini, Benjamin	Caltech	PhD student	bidiniza@gps.caltech.edu
Graham, Kenny	Victoria U	PhD student	Kenny.Graham@vuw.ac.nz
Estep, Justin	TAMU	PhD student	jdestep@tamu.edu
Carrington, Luke	U Otago	MSc student	carlu665@student.otago.ac.nz

The science party consisted of three female and 15 male participants, for a total of 18 scientists. Four graduate students (Hightower, Williams, Shuck, and Patel) participated as part of their thesis research supervised by one or more of the five principal scientists, while the remaining students participated to obtain valuable experience on a seismic research vessel.

4.0 Data sets acquired

4.1 Multi-beam

4.1.1 Method and instrumentation

The bathymetry data was acquired using a Kongsberg EM122 multibeam echosounder (MBES) that was run with FM (Frequency Modulation) enabled and automatic parameter adjustments enabled where possible. This configuration provided good coverage (swath width), but did not necessarily provide optimal coverage under all conditions. These settings did not necessarily provide the best data quality.

The EM122 sound velocity profile (SVP) was processed with Expendable Bathythermograph (XBT) data that were uploaded to the EM122 system by the *Langseth* technical staff. The updates occurred about once per day, coincident with XBT deployment (see Section 4.7 XBT).

The data were processed with Caris HIPS and SIPS hydrographic software. Data were ping-edited using the Swath and Subset editors. Base surface grids were then exported in 10m and 100m xyz grids for plotting in other visual software programs. Edited data points were exported in daily files (xyz). We also created a geotiff of NIWA 250 m bathymetry data overlaid with MGL1803 bathymetry data gridded at 100 m for use as a background image in other processing software.

We encountered two multibeam issues. The EM122 system randomly produced an artifact that decreased/increased the depth of near nadir beams up to 200m.This was apparently a problem on the previous cruise as well. . The issue was reported to the MAC; on MAC request we turned the penetration filter strength to OFF in waters greater than 300m deep. It was not apparent if this eliminated the artifacts, but they were reduced. The filter was applied in waters less than 300m deep and this improved the shallow water bathymetry.
The other issue was related to the -processing software (Caris). The first two pings of some files did not have motion applied. This resulted in the pings appearing as a sinusoidal pattern. We increased the time overlap of adjacent lines during batch conversion to solve this issue.

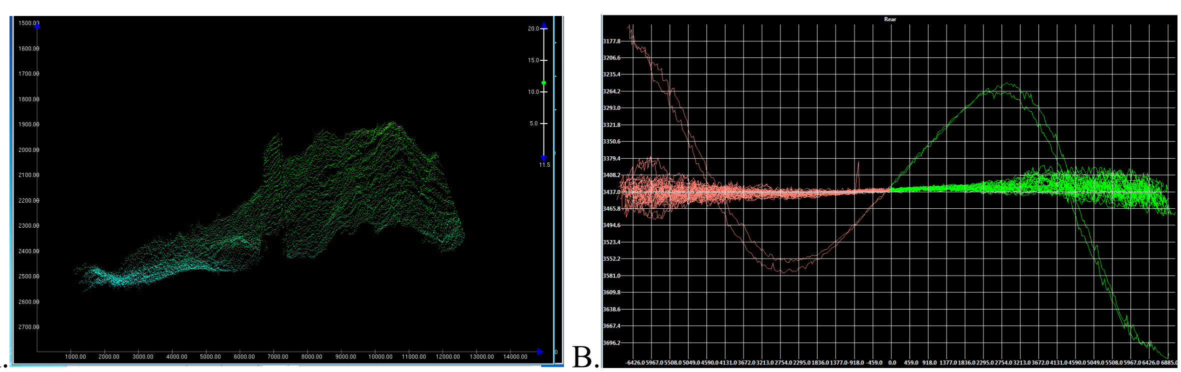

A. B.

Figure 4.1.1 Examples of two multibeam issues during MGL1803. A. EM122 spreading of near-nadir beams as seen in the Subset Editor and B. Image shows converted data files in which motion data were not applied to the first two pings.

4.1.2 Examples

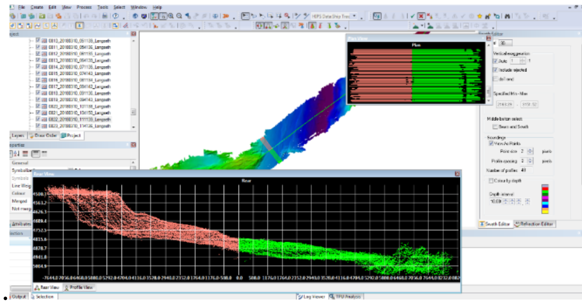


Figure 4.1.2 Screenshot showing an example of Caris Swath Editor module showing an example of edited data file.

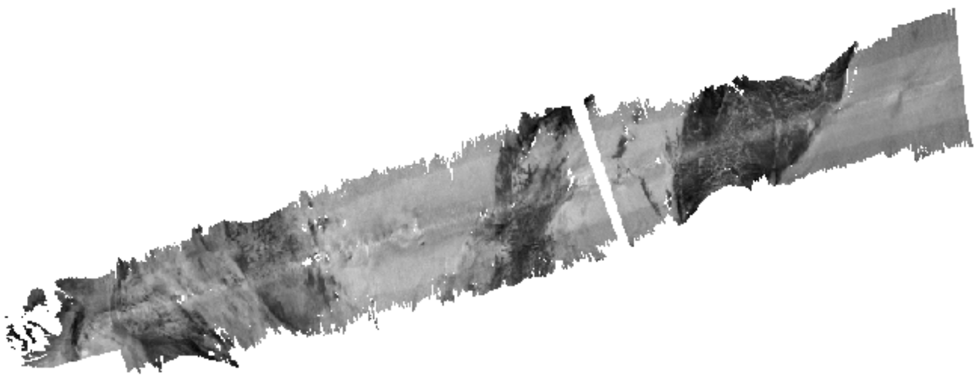


Figure 4.1.3 100m backscatter of line T01.

4.1.3 Summary

Raw data were stored in daily folders in files that represented approximately a half hour of recording time. Files are named sequentially beginning with 0000_YYYYMMDD_hhmmss.all. Files were then copied to the processing computer and converted to Caris HIPS and SIPS v. 10.2.1 format for editing. Spurious data points were removed using the Swath and Subset editing modules.

Daily base surface grids (10 m and 100 m, xyz ascii) were made from edited data and exported for use in other software packages. Files are named MMDD_*x*m.txt. Backscatter mosaics were also produced from multibeam data. One hundred meter mosaics (xyz ascii) of single lines were exported. File names roughly correspond to MCS and Transit line names or days where complete coverage exists (i.e. not days where OBS were deployed or recovered) and exported for specific areas of interest. A compilation of all of the bathymetry at a 100 m resolution and regridded and displayed with the GMT software is shown in Figure 4.1.3

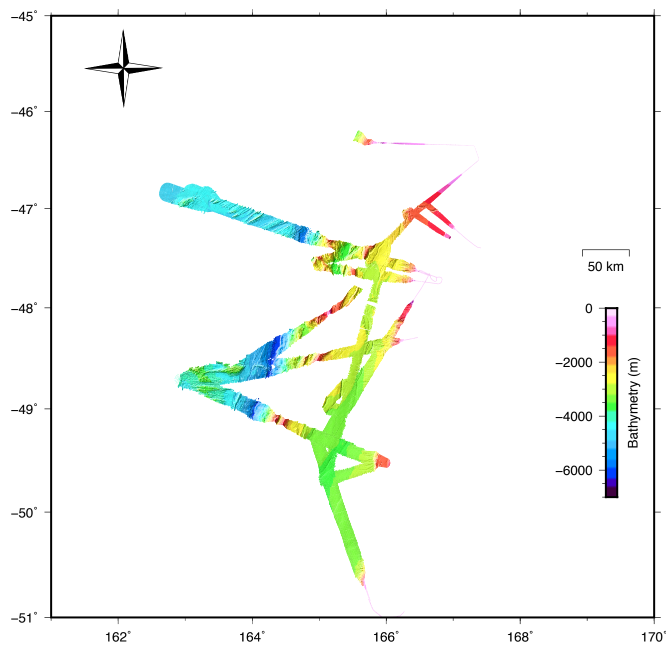


Figure 4.1.3. Summary of the multibeam data at 100 m resolution regridded and displayed with the GMT software.

Table 4.1.1 Summary of multibeam data (Note: Data is not tide corrected)

Date	Exported file name (daily)	Initial line name	Final line name	Project trackline
20-Feb	022018_10m.txt	0054_20180220_000551_Langseth	0105_20180220_235844_Langseth	Transit to OBS1 and OBS1 deploy
21-Feb	022118_10m.txt	0106_20180221_002836_Langseth	0157_20180221_235958_Langseth	OBS1 deploy and shoot OBS1
22-Feb	022218_10m.txt	0158_20180222_002953_Langseth	0195_20180222_233511_Langseth	shoot OBS1 and recovery OBS1
23-Feb	022318_10m.txt	0196_20180223_013501_Langseth	0218_20180223_235118_Langseth	recovery OBS1
24-Feb	022418_10m.txt	0219_20180224_011632_Langseth	0246_20180224_144613_Langseth	Transit to Auckland Island
25-Feb	022518_10m.txt	0247_20180225_080050_Langseth	0257_20180225_230227_Langseth	recovery OBS1
26-Feb	022618_10m.txt	0258_20180226_003925_Langseth	0301_20180226_233933_Langseth	recvy OBS1 trans OBS2 deply OBS2

27-Feb	**022718_10m.txt**	**0302_20180227_000935_Langseth**	**0355_20180227_235049_Langseth**	**deploy OBS2 shoot OBS2**
28-Feb	**022818_10m.txt**	**0356_20180228_002055_Langseth**	**0402_20180228_235528_Langseth**	**shoot OBS2**
1-Mar	**030118_10m.txt**	**0403_20180301_003618_Langseth**	**0427_20180301_221720_Langseth**	**recovery OBS2**
2-Mar	**030218_10m.txt**	**0428_20180302_002220_Langseth**	**0451_20180302_234648_Langseth**	**recovery OBS2**
3-Mar	**030318_10m.txt**	**0452_20180303_001638_Langseth**	**0508_20180303_234355_Langseth**	**recovery OBS2**
4-Mar	**030418_10m.txt**	**0509_20180304_001349_Langseth**	**0556_20180304_234347_Langseth**	**shoot MCS over MCS01 (OBS2 line)**
5-Mar	**030518_10m.txt**	**0557_20180305_001346_Langseth**	**0605_20180305_235406_Langseth**	**shoot MCS over MCS01 and MCS03a**
6-Mar	**030618_10m.txt**	**0606_20180306_002409_Langseth**	**0653_20180306_233726_Langseth**	**shoot T01 and MCS23a**
7-Mar	**030718_10m.txt**	**0654_20180307_000729_Langseth**	**0702_20180307_233937_Langseth**	**shoot MCS23a and MCS23b**
8-Mar	**030818_10m.txt**	**0703_20180308_000936_Langseth**	**0751_20180308_235425_Langseth**	**shoot MCS23b, T02 and MCS14 (OBS1 line)**
9-Mar	**030918_10m.txt**	**0752_20180309_002425_Langseth**	**0799_20180309_234142_Langseth**	**shoot MCS14**
10-Mar	**031018_10m.txt**	**0800_20180310_001133_Langseth**	**0847_20180310_234135_Langseth**	**transit to MCS17a**
11-Mar	**031118_10m.txt**	**0848_20180311_001145_Langseth**	**0892_20180311_212325_Langseth**	**shoot MCS17a, MCS17b trans to Stewart Island**
12-Mar	**no data**	**-**	**-**	**weather delay Stewart Island**
13-	**no data**	**-**	**-**	**weather delay Stewart Island**

Mar				
14-Mar	**no data**	**-**	**-**	**weather delay Stewart Island**
15-Mar	**no data**	**-**	**-**	**weather delay Stewart Island**
16-Mar	**031618_10m.txt**	**0893_20180316_174727_Langseth**	**0011_20180316_233628_Langseth**	**MCS17c, note: A new folder was started when the multibeam was restarted this morning. It was not r-synced, so another was started. This resulted in insequential numbering as each project meant that line naming began again at 0000**
17-Mar	**031718_10m.txt**	**0012_20180317_000625_Langseth**	**0041_20180317_235558_Langseth**	**Shoot MCS17C, T03, and MCS19A**
18-Mar	**031818_10m.txt**	**0042_20180318_002600_Langseth**	**0051_20180318_043931_Langseth**	**Shoot MCS19A Sonars off 16:50 local**

4.2. Gravity

4.2.1 Method and Instrumentation

The Langseth is equipped with a Bell Aerospace BGM-3 gravimeter. To convert meter units to mGal requires scaling by a factor of 4.99017410 and addition of a bias of 855011.630. Gravity data will be adjusted and reduced by the R2R data archive group at LDEO. However, for immediate use by the science party we also reduced and analysed gravity data during the cruise.

Ship-based gravity data were processed as a function of time and position as follows. Using a Lacoste-Romberg gravimeter, a tie was made on 16 February 2018 between the Victoria pier in Dunedin and the absolute gravity station in the Old Geology Building of the University of Otago (Stagpoole et al. 2015). During this process, the elevation of the dock was measured and used to apply an altitude correction to the ship's gravity meter. No consideration was made for vertical changes associated with tides, air pressure, or changes in ship's draught during the voyage. The Eötvös correction was made to gravity values using GPS-measured latitude, heading, and speed of the vessel. These values were then corrected for latitude using the International Gravity Formula 1967 (IAG 1971) and filtered in the time domain to remove wave noise by convolution with a 5-minute Gaussian window. During the voyage, meter drift was analyzed through comparison of repeat data and by comparison with altimetry-derived gravity grids (Smith & Sandwell). At the end of the cruise, another tie was made between the pier and Old Geology Building. The final instrument drift was approximated as a linear rate (method described below) and subtracted from measured values. The resulting values are reported as Free Air gravity anomalies in this report.

On Feb. 24, 2018, starting at 14:35 UTC the gravity meter was showing inconsistent and abnormally high readings and troubleshooting commenced and continued throughout the day. On Feb 25, 2018, more trouble shooting of the Bell gravimeter took place and at 14:26 UTC readings returned to a reasonable range and remained so throughout the rest of the cruise. It appears the issue was a stuck sensor. Following this equipment malfunction, it was not immediately clear if our tie with the pre-cruise gravity station was maintained, and consequent analyses were undertaken to quantify the effect of the failure on recorded data. Gravity was measured across OBS line 1 three times (during deployment, wide-angle acquisition, and recovery) before the instrument failure, which occurred during transit to Auckland Island for weather evasion at the end of recovery. Following the re-stabilization of the instrument, gravity was measured across OBS line 2 four times (during deployment, wide-angle acquisition, recovery, and MCS acquisition) and again across OBS line 1 one further time (during MCS acquisition). Measurements made during OBS deployment and recovery were excluded from this analysis because of large acceleration errors and significant deviations from the line associated with starting and stopping at each OBS drop-point.

Pre-malfunction instrument drift (from here $\mathbf{m_1}$) was estimated from gravity measurements made on JD46 through JD49 while sitting in port by performing a linear regression after applying a band-stop filter between 8 and 30 hr periods in order to remove the diurnal and semi-diurnal tidal signals, yielding $\mathbf{m_1}$ = -0.41 Gal/day. Post-malfunction instrument drift ($\mathbf{m_2}$) and static offset associated with the equipment malfunction (**d**) were then estimated by several approaches and the results compared. First (see Fig. 4.2.1), before and after measurements across OBS line 1 (wide-angle acquisition before, MCS acquisition after) were compared. The “before” values were corrected for drift ($\mathbf{m_1}$ ***** t) and then subtracted from the “after” values, and the difference was then fit by a linear regression yielding $\mathbf{m_2}$ = -1.03 mGal/day and **d** = 32.86 mGal. Second, $\mathbf{m_2}$ was estimated independently by regressing the difference between the two acquisition passes of OBS line 2, yielding $\mathbf{m_2}$ = -3.23 mGal/day. Then, the static offset **d** was estimated as the difference between the final gravity tie value minus $\mathbf{m_2}$ times the period since the gravimeter corrected itself and the initial gravity tie value plus $\mathbf{m_1}$ times the period before the gravimeter malfunctioned, yielding **d** = 52.68 mGal. Finally, we explored the possibility that the gravimeter experienced the same drift before and after the offset by setting $\mathbf{m_2} = \mathbf{m_1}$ = -0.41 mGal/day then extrapolating the static offset **d** from the gravity ties, yielding **d** = -12.26 mGal. Of the three methods attempted, the first correction method resulted in by far the greatest reduction of misfit between repeat passes of both OBS line 1 (mean residual 0 mGal) and OBS line 2 (mean residual 3 mGal), though the corrected data exhibited a mean misfit from Smith and Sandwell gravity values of 10 mGal. The Second correction reduced the mean line 2 residual to -0.7 mGal but yielded a poor estimate of the instrument shift associated with the error which resulted in a mean line 1 residual of 36 mGal and mean Smith and Sandwell misfit of -47 mGal. The third method performed even less well, yielding mean line 1 and line 2 residuals of -17 and -12.7 mGal respectively and a mean Smith and Sandwell misft if ~7 mGal. Consequently, we correct gravity data shown in this report using the first correction method described above. An inaccurate initial and/or final gravity tie is most likely to blame for the failure of the second and third methods, while residuals resulting from the first method are likely due to the fact that the repeat pass of line 1 includes spatially correlated error as a function of time in addition to the temporally correlated error we attempt to fit.

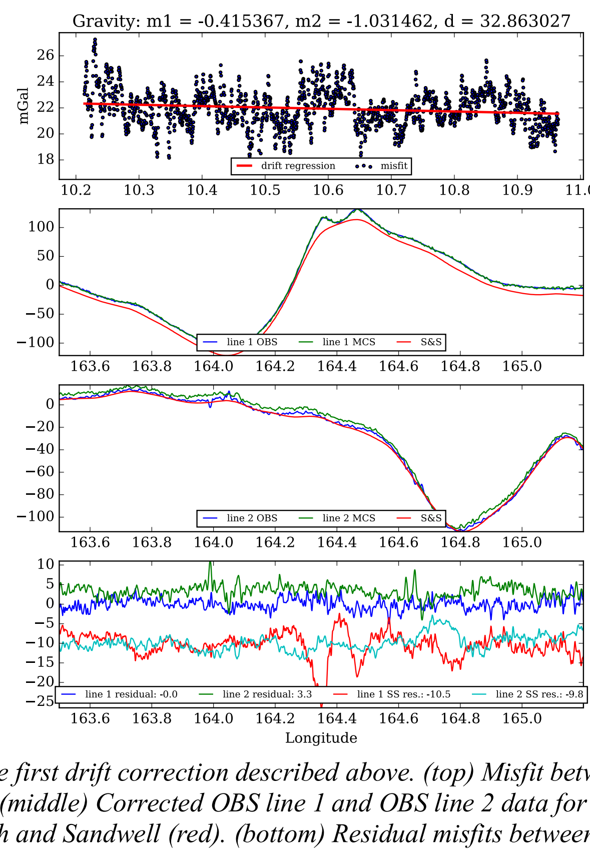


Figure 4.2.1. Validation of the first drift correction described above. (top) Misfit between repeat passes of OBS line 1 (black) and linear fit (red). (middle) Corrected OBS line 1 and OBS line 2 data for each pass (blue and green) plotted with values from Smith and Sandwell (red). (bottom) Residual misfits between the two passes of corrected gravity data for line 1 (blue), line 2 (green), and each line with Smith and Sandwell (blue and red).

4.2.2 Examples

Daily plots for all of the gravity acquired is shown in the figures in Appendix F.

4.2.3 Summary Table

Raw serial files for gravimeter readings can be found under ~/MGL1803/raw/serial/ on the ship's local server. Files exist for each day of the cruise and each include a full 24 hours of data with sub-second sample rate.

4.3. Magnetics
4.3.1 Method and instrumentation

The *Langseth* carries two Geometrics 882 Cesium-vapor total field (scalar) magnetometers, one of which we deployed. The magnetometer was only deployed in the survey area when the sea conditions permitted and when it would not interfere or be harmed by other instrumentation or when ship was maneuvering during OBS deployment and recovery. The magnetometer was towed 142.5 meters behind the Navigation Reference Point (NRP) of the ship (which corresponds to the Marine Mammal Observing Tower). This was 113 m beyond the stern of the ship, off the starboard corner. This magnetometer position was between the stern and the seismic source array when the array was deployed.

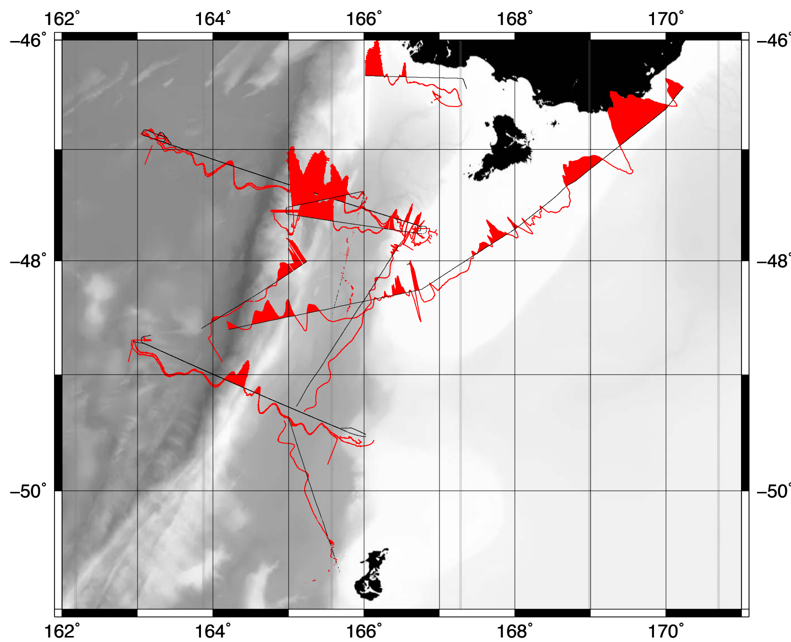


Figure 4.3.1. Magnetometer collected during MGL1803.

Magnetometer readings were archived with a GPS location of the Seapath GPS (on the stern of the ship) and a time string that was converted to decimal years. These values were then converted to an input string that could be read by the Geomag7.0 program (https://www.ngdc.noaa.gov/geomag/data/geomag/geomag70_linux.tar.gz), which was used to calculate the corresponding magnitude of the expected total field from the IGRF12 Magnetic Field Model. The marine magnetic anomaly was determined by subtracting the magnitude of the IGRF12 from the observed magnitude of the Total Field Magnetic measurement from the magnetometer. No adjustment was made for the towed position of the magnetometer behind the ship.

4.3.2 Examples

The processed magnetometer data is shown in Figure 4.3.1 with a wiggle diagram in map view showing the data we acquired in our survey region. In addition, all of the magnetometer data is shown in the figures in Appendix F. Daily Plots of Underway Data.

Notable features included: crossings of South Tasman Oceanic Crust magnetic anomalies C13 to C17, on Days 58 and 62-63, with amplitudes of 250 nT or less; and recording of a longer wavelength >300 nT amplitude magnetic anomaly associated with the Puysegur Ridge complex. Shorter wavelength anomalies of +/- 200 nT were sometimes also recorded over the Campbell Plateau (Days 59 and 64).

Table 4.3.1. Summary of Magnetometer Data

File Number	date on	time on	date off	time off
1	50	3:06	51	9:07
2	52	6:24	53	13:52
3	55	1:50	55	9:59
4	57	4:48	57	14:33
5	58	10:25	59	22:10
6	62	12:52	66	9:53
7	67	19:03	69	0:28
8	69	10:24	69	16:57
9	69	20:52	69	22:55
10	76	12:45	77	2:45

4.3.3 Summary Table

The data is summarized in Table 4.3.1. Magnetometer data were recorded during part or all of Days 50-53, 55, 57-59, 62-69, and 76-77. Data gaps resulted from instrument noise as well as from avoiding other back deck operations as noted above.

4.4. Chirp Subbottom Profiler
4.4.1. Method and Instrumentation

The Knudsen chirp Sub-bottom Profiler (SBP) was operated at 2-6 kHz and run synchronously with the EM122 MBES, operated at a median frequency of 12 kHz. This sometimes results in a reduction in the Knudsen sampling rate but minimizes any potential cross-talk with the EM122. When the multibeam was not in use, the Knudsen was run in internal sync mode. The Knudsen data were recorded in KEA and KEB formats and were converted to SEG-Y using the Knudsen Convert Program. Due to the slow ping rate and default instrument setup, the files contain the envelope versions of the returned signal but not the full waveform versions. An error was observed during the intervals of multibeam being synced with Knudsen. Consequently, for the final three MCS lines the system was run in Manual mode as a test and full waveform SEGY was output. Result of this test was that in Manual mode the inconsistent sampling interval problem disappeared. Additionally, we discovered that writing our SEGY (filtered) does preserve the full waveform dataset in both KEB and SEGY formats but does not actually write out the envelope version. This may still be preferable as envelope versions can be generated from full waveform but not visa versa. We recommend a new operating procedure be developed for the Knudsen 3260 that results in the correct types of data being output (full waveform and/or envelope) for each science party. We also recommend that the settings be changed so that a new file is written whenever a major change occurs to the data as opposed to have 3 day long files with multiple different record lengths.

4.4.2 Examples

A sample file from the South Tasman Oceanic Crust shows a profile of Knudsen data west of the Puysegur Trench (Figure 4.4.1) LINE-SMALLFAULTS-2). Small faults or oceanographic features are observed to affect the top of the sedimentary layers on this profile in several locations, including apparent offset of some of these layers suggestive of faulting.

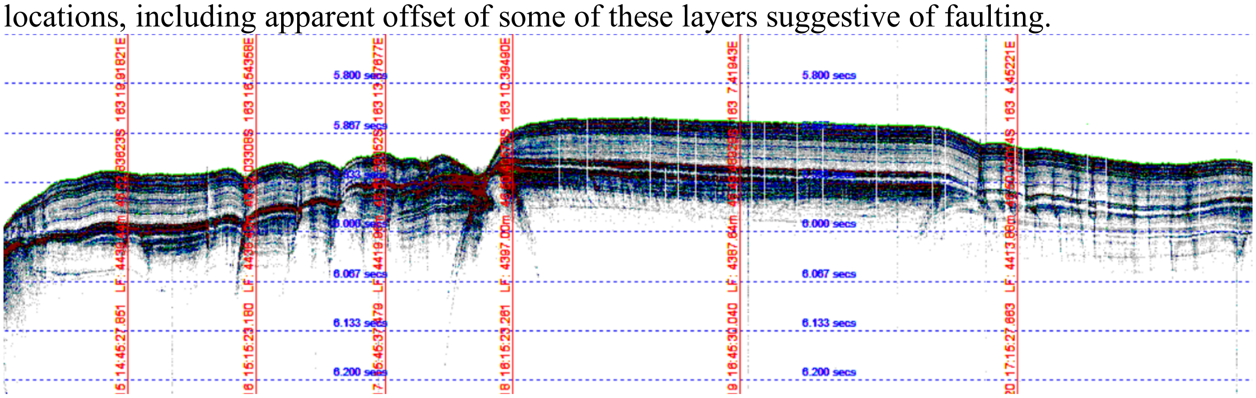


Figure 4.4.1. Example of chirp data west of the Puysegur trench. (Date and time UTC)

4.5 Ocean Bottom Seismometers (OBS)

4.5.1 UTIG OBS Description

The UTIG ocean-bottom seismometer is an instrument designed for active-source seismic studies, manufactured by GeoPro GmbH. The package consists of a data logger, an acoustic release, a three-component geophone, and alkaline battery packs, all inside a glass sphere rated to 6000 m depth. The glass sphere is housed in a plastic shell and mounted on a 50 lbs steel anchor frame for deployment. A hydrophone, placed on the plastic housing, is connected to one of the external ports on the glass sphere. Programming the instrument requires GPS synchronization of the internal clock, setting gain and recording sample rates and time windows, and a backup release time. The OBS communicates with an acoustic deck unit on the vessel through a transducer mounted on the glass sphere. To release the instrument, the science party can thus enable the OBS, release it, and obtain acoustic ranges through the transducer. During the MGL1803 cruise, both the ship's hull transducer and a portable transducer were used to release OBSs. An acoustic release command will trigger a current through a burn wire. The glass sphere rises at approximately 60 meters per minute. For sighting and retrieval, the instrument has a light inside the glass sphere, and an external flag and radio antenna. After recovery, a second clock synchronization provides an estimate of clock drift, and the data are downloaded.

Two OBS lines were deployed, Line 1 with 20 OBS (Figure 4.5.1) and Line 2 with 23 OBS (Figure 4.5.2). For reference, OBS Line 1 was reshot as MCS14 while OBS Line 2 as MSC01 (see section 4.6 below). Of the 20 instruments on OBS Line 1, 17 were recovered with data (Table 4.5.1). All OBSs of Line 1 that recorded data show interesting crustal and mantle seismic refractions that will help to constrain the crustal structure along the transect. The deployment of 23 OBSs on Line 2 yielded 21 good record sections (Table 4.5.2). Further details of the OBS operations, including OBS deployment, recovery and data recovery for both lines is give in Appendix B. OBS Operations Log.

Table 4.5.1 OBS deployment time and location during MGL1803.

OBS			Deployment				
Station	Instrument	type	Date	Time	Lat.	Lon.	Depth (m)
101	38	sedis6	02/20/18	13:31	-48˚44.852	163˚09.663	4126
102	9	sedis5	02/20/18	14:26	-48˚47.148	163˚17.104	3628
103	42	sedis6	02/20/18	15:29	-48˚49.362	163˚24.545	3924
104	69	sedis6	02/20/18	16:23	-48˚51.556	163˚32.043	4152
105	54	sedis6	02/20/18	17:19	-48˚53.789	163˚39.564	4431
106	68	sedis6	02/20/18	18:11	-48˚55.987	163˚47.027	4469
107	51	sedis6	02/20/18	19:03	-48˚58.174	163˚54.546	4994
108	72	sedis6	02/20/18	19:49	-49˚00.370	164˚02.078	5901
109	62	sedis6	02/20/18	20:41	-49˚02.503	164˚09.593	4221
110	13	sedis5	02/20/18	21:29	-49˚04.709	164˚17.103	2305
111	6	sedis5	02/20/18	22:16	-49˚06.891	164˚24.667	2209
112	45	sedis6	02/20/18	23:06	-49˚09.058	164˚32.227	2198
113	47	sedis6	02/20/18	23:53	-49˚11.171	164˚39.803	2572
114	41	sedis6	02/21/18	0:42	-49˚13.324	164˚47.393	2904
115	46	sedis6	02/21/18	1:33	-49˚15.649	164˚55.769	3436
116	70	sedis6	02/21/18	2:28	-49˚17.992	165˚04.150	3420
117	40	sedis6	02/21/18	3:13	-49˚20.305	165˚12.516	3442
118	64	sedis6	02/21/18	4:04	-49˚22.611	165˚20.893	3550
119	60	sedis6	02/21/18	4:57	-49˚24.922	165˚29.313	3408
120	53	sedis6	02/21/18	5:55	-49˚27.419	165˚38.515	3149
201	64	sedis6	2/27/18	10:14	-46˚57.757	163˚27.646	4471
202	60	sedis6	2/27/18	9:24	-47˚00.080	163˚37.360	4432
203	13	sedis5	2/27/18	8:33	-47˚02.359	163˚47.092	4365
204	53	sedis6	2/27/18	7:41	-47˚04.629	163˚56.852	4423
205	6	sedis5	2/27/18	6:53	-47˚06.728	164˚05.826	4532
206	46	sedis6	2/27/18	6:04	-47˚08.809	164˚14.842	4462
207	41	sedis6	2/27/18	5:14	-47˚10.918	164˚23.812	4706
208	47	sedis6	2/27/18	4:24	-47˚12.986	164˚32.877	4376
209	42	sedis6	2/27/18	3:41	-47˚14.681	164˚40.411	5057
210	72	sedis6	2/27/18	3:00	-47˚16.354	164˚47.433	5638
211	51	sedis6	2/27/18	2:15	-47˚18.030	164˚55.553	4110
212	68	sedis6	2/27/18	1:40	-47˚19.705	165˚03.233	2716
213	6	sedis5	2/27/18	1:01	-47˚21.385	164˚10.695	2081
214	54	sedis6	2/27/18	0:17	-47˚23.212	165˚19.002	3094
215	49	sedis6	2/26/18	23:37	-47˚25.043	165˚27.182	3300
216	7	sedis5	2/26/18	22:54	-47˚26.875	165˚35.664	2656
217	5	sedis5	2/26/18	22:10	-47˚28.659	165˚44.052	2473
218	2	sedis5	2/26/18	20:42	-47˚30.612	165˚53.228	2746
219	38	sedis6	2/26/18	19:53	-47˚32.523	166˚02.410	2371
220	40	sedis6	2/26/18	19:02	-47˚34.440	166˚11.568	2589
221	71	sedis6	2/26/18	18:06	-47˚36.355	166˚20.708	2074
222	8	sedis5	2/26/18	17:04	-47˚38.258	166˚29.885	2589
223	44	sedis6	2/26/18	16:02	-47˚40.159	166˚39.087	176

Table 4.5.2. OBS recovery characteristics during MGL1803.

OBS	Recovery				Data	
Station	Date	Time	Lat.	Lon.	Raw	SEGY
101	2/22/18	16:27	-48˚45.013	163˚10.292	Yes	Yes
102	2/22/18	18:45	-48˚47.355	163˚17.424	Yes	Coming
103	2/22/18	20:47	-48˚49.446	163˚25.092	Yes	Yes
104	2/22/18	22:58	-48˚51.784	163˚32.421	Yes	Timing error
105	2/23/18	1:32	-48˚53.528	163˚39.758	Yes	Yes
106	2/23/18	3:43	-48˚56.112	163˚47.143	Yes	Yes
107	2/23/18	6:02	-48˚58.307	163˚54.723	Yes	Yes
108	2/23/18	8:32	-49˚00.510	164˚02.245	Yes	Yes
109	2/23/18	Lost			No	No
110	2/23/18	15:03	-49˚05.120	164˚16.751	Yes	Coming
111	2/23/18	19:34	-49˚06.838	164˚24.822	Yes	Coming
112	2/23/18	17:13	-49˚09.228	164˚32.224	Yes	Yes
113	2/23/18	21:39	-49˚11.263	164˚39.699	Yes	Yes
114	2/23/18	23:16	-49˚13.501	164˚47.453	Yes	No
115	2/23/18	1:33	-49˚15.808	164˚56.241	Yes	Yes
116	2/26/18	4:33	-49˚17.925	165˚04.666	Yes	Yes
117	2/26/18	2:40	-49˚20.184	165˚13.214	Yes	Yes
118	2/26/18	0:38	-49˚22.414	165˚22.0364	Yes	Yes
119	2/25/18	22:26	-49˚24.925	165˚29.668	Yes	Yes
120	2/25/18	20:34	-49˚27.217	165˚38.711	Yes	Yes
201	3/2/18	23:06	-46˚58.125	163˚27.563	Yes	Yes
202	3/2/18	20:38	-47˚00.263	163˚37.210	Yes	Yes
203	3/2/18	18:15	-47˚02.588	163˚47.048	No	No
204	3/2/18	15:34	-47˚04.834	163˚56.064	Yes	Yes
205	3/2/18	12:27	-47˚07.335	164˚05.865	Yes	Coming
206	3/2/18	9:31	-47˚08.989	164˚14.804	Yes	Yes
207	3/2/18	7:27	-47˚10.827	164˚24.001	Yes	Yes
208	3/2/18	4:55	-47˚13.114	164˚33.029	Yes	Yes
209	3/2/18	2:42	-47˚14.874	164˚40.575	Yes	Yes
210	3/2/18	0:20	-47˚16.454	164˚47.802	Yes	Yes
211	3/1/18	21:45	-47˚17.826	164˚55.513	Yes	Yes
212	3/1/18	19:35	-47˚19.284	165˚32.833	Yes	Yes
213	3/1/18	17:47	-47˚21.171	164˚10.388	Yes	Coming
214	3/1/18	16:07	-47˚23.218	165˚18.753	Yes	Yes
215	3/1/18	14:18	-47˚25.344	165˚26.186	Yes	Yes
216	3/1/18	12:03	-47˚26.826	165˚35.650	Yes	Coming
217	3/1/18	10:11	-47˚28.865	165˚44.118	Yes	Coming
218	3/1/18	7:55	-47˚30.810	165˚53.021	Yes	Coming
219	3/1/18	6:17	-47˚32.558	166˚02.151	Yes	Yes
220	3/1/18	4:39	-47˚34.303	166˚11.415	Yes	Yes
221	3/1/18	2:30	-47˚36.149	166˚20.713	Yes	Yes
222	3/1/18	0:36	-47˚38.371	166˚130.022	No	No
223	2/28/18	23:19	-47˚40.564	166˚39.221	Yes	Yes

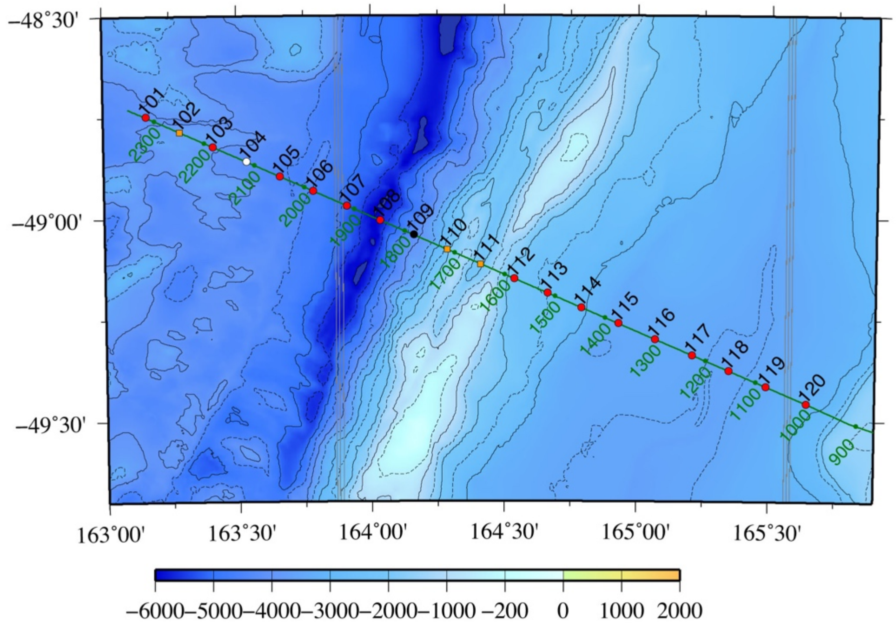


Fig 4.5.1. OBS deployment sites on Line 1 on an elevation map. In red are all OBSs for which SEGY data files have been produced. OBSs in orange recorded data, but these have not yet been converted to SEGY format. OBS 109, in black, was not recovered. OBSs in white were recovered, but did not have useful data. The Langseth shot line with annotated shots in green.

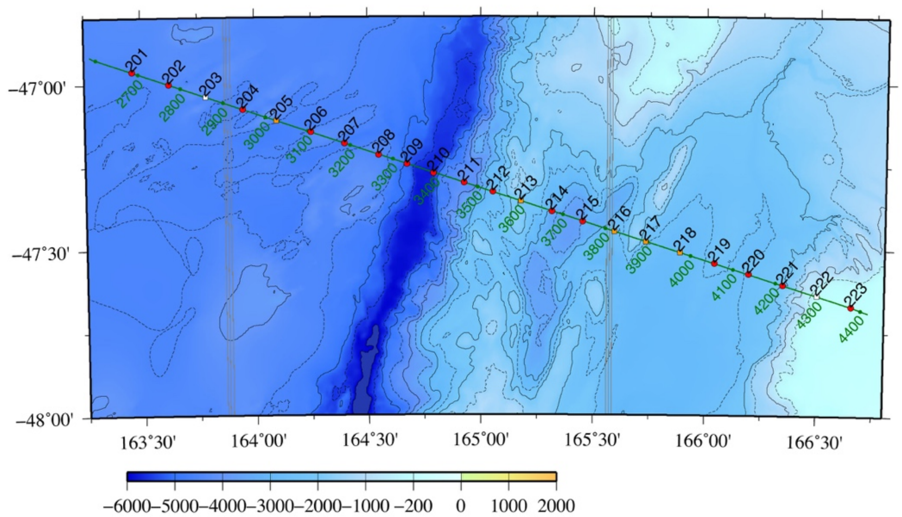


Fig 4.5.2. OBS deployment sites on Line 2 on an elevation map. In red are all OBSs for which SEGY data files have been produced. OBSs in orange recorded data, but these have not yet been converted to SEGY format. OBSs in white were recovered, but did not have useful data. The Langseth shot line with annotated shots in green.

4.5.4 Data examples

The OBS records on SISIE Line 1 and Line 2 show seismic reflections and reflections to offsets between 25 km and 80 km. These seismic phases will help constrain the crustal seismic velocity structure along both profiles, and determine the thickness of crust. In general, the hydrophone channel appears to be best in signal/noise ratio, followed by the vertical geophone and the two horizontal geophone channels. We have gaps in the data where the acoustic array was shut down after a marine mammal sighting. The first water multiple appears to be roughly twice as strong as the primary arrival, which is quite common in OBS data. In the example OBS records for stations from Line 1 and Line 2 we therefore show both the primary and multiple arrival with a reduction velocity of 7 km./s (Figure 4.5.3). Some records show shear-waves, though these phases are weaker than the equivalent compressional wave arrivals. Include a map of the OBS stations

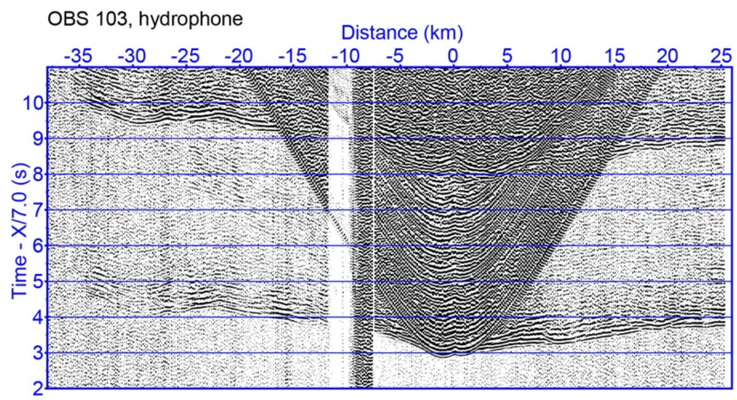


Figure 4.5.3a. Record section for OBS 103. Positive distances on Line 1 are measured westward. Note a data gap due to fur seal sighting at -10 km.

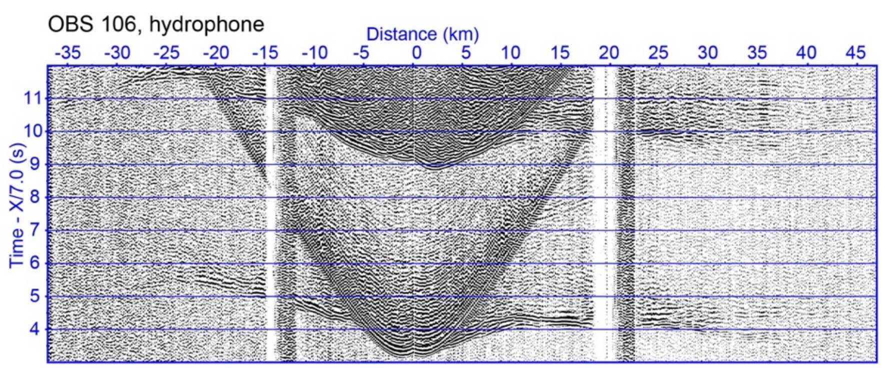


Figure 4.5.3b. Hydrophone data record for OBS 106.

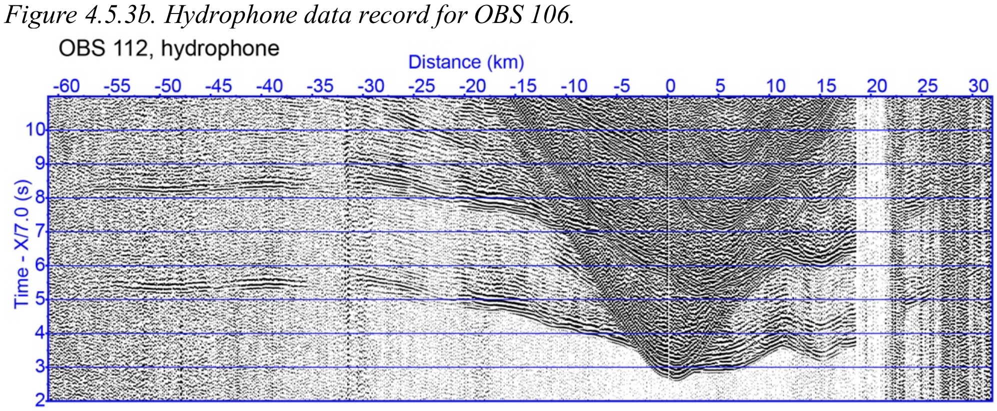


Figure 4.5.3c. Hydrophone data record for OBS 112.

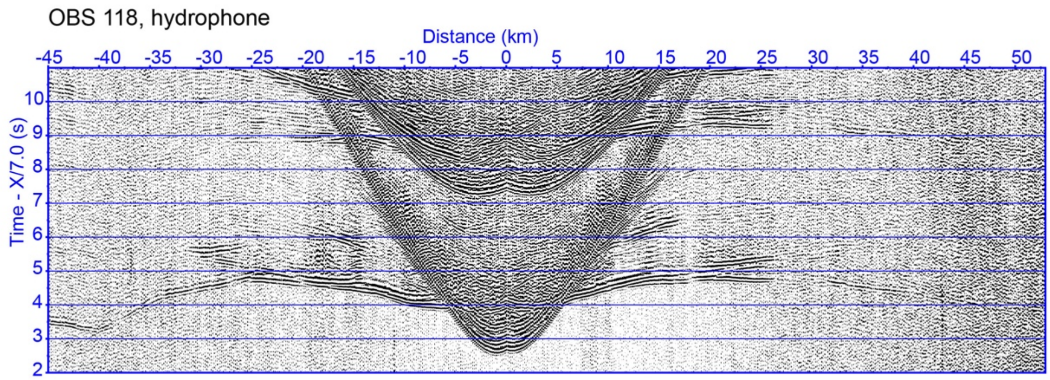


Figure 4.5.3d. Hydrophone data record for OBS 118.

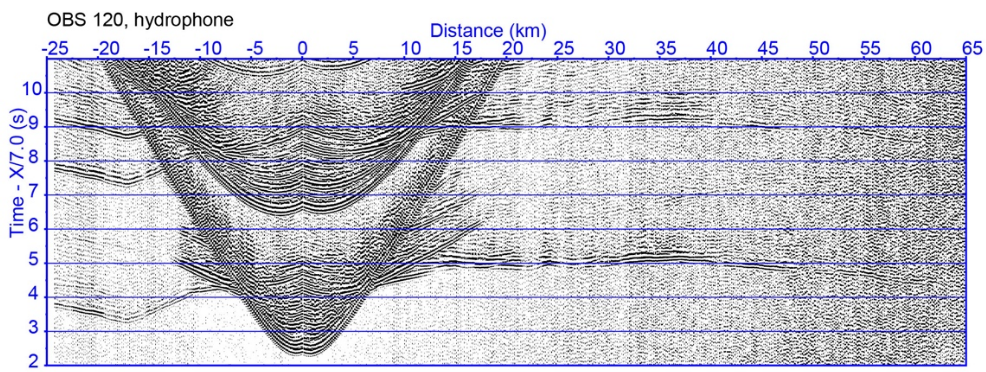


Figure 4.5.3e. Hydrophone data record for OBS 120.

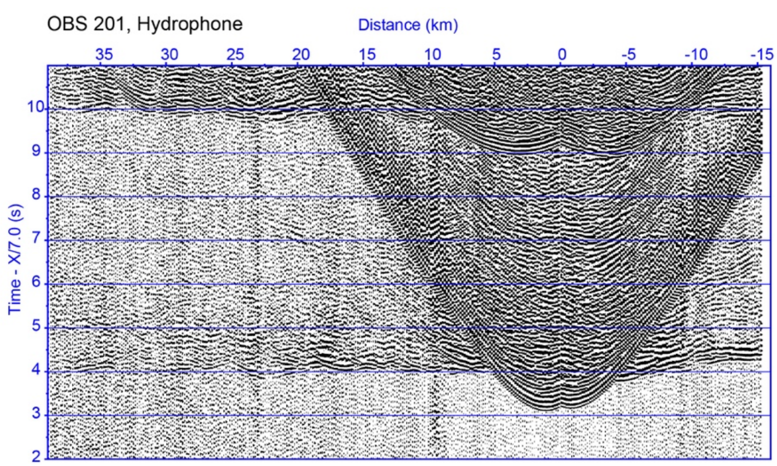


Figure 4.5.3f. Hydrophone data record for OBS 201.

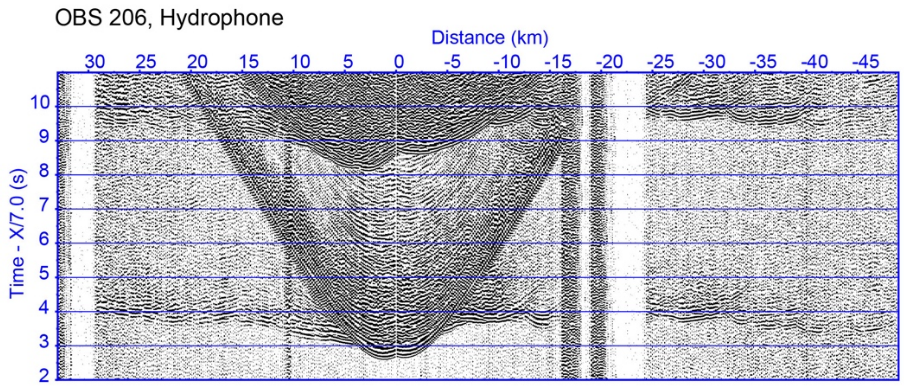


Figure 4.5.3g. Hydrophone data record for OBS 206.

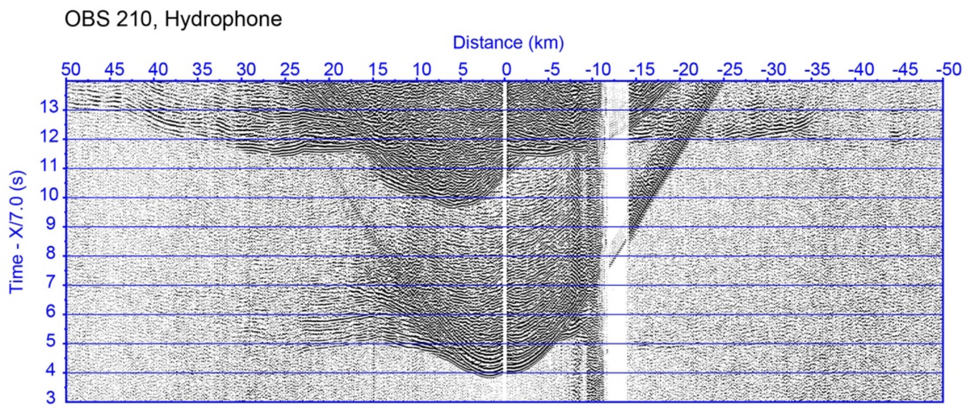


Figure 4.5.3h. Hydrophone data record for OBS 210.

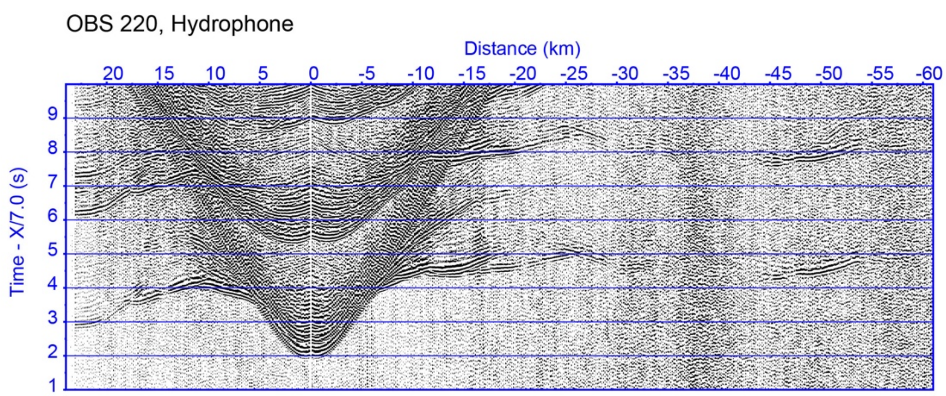


Figure 4.5.3i. Hydrophone data record for OBS 220.

4.5.5 Status of OBS refraction data

The seismic data records of all Sedis VI instruments have been converted to SEGY format. We have used the drop location (Table 4.5.1) to measure the distance to air-gun shots. This version of the data set is preserved in SEGY files "with nav", and the files have extension *.sr.segy. We also have a filtered version of these OBS records at present. To bring out the long-offset refractions we applied a bandpass filter between 6 Hz and 14 Hz with 48 dB per octave dropoff.

Next we applied a predictive deconvolution filter with 0.16 sec prediction length to sharpen the seisimic refractions. These filtered data are archived with the extension *.filt.segy.

Future processing steps to prepare the OBS data set are 1) conversion of the Sedis V OBS data in SEGY format, and 2) a relocation for all instruments using the direct wave in water to relocate the instruments.

4.6 Multi-channel seismic lines
4.6.1 Method and instrumentation

4.6.1.1 Source. The Source portion of this survey were made up with 4 sound-source subarrays, consisting each of 10 Bolt source elements with 9 being active for a total of 1,650 cubic inches (in3) per subarray; yielding a total of 6600 cubic inches (in^3). Each array consisted of a mixture of Bolt 1500LL and Bolt 1900LLX Elements and were configured as four identical linear arrays or "strings" (Figure 6.5.1). Each sub-array had ten elements; the first and last elements in the sub-array are spaced 6 m apart. Nine elements in each sub-array were fired simultaneously for a total volume of approximately 6,600 in^3, whereas the tenth element was kept in reserve to be enabled in case of failure of another element. The array was towed approximately 200 m behind the vessel. Discharge intervals depend on both the ship's speed and Two-Way Travel Time (TWTT) recording intervals. The sound sources were discharged every 150 meters during OBS, and 50 meters during MCS operations using a Spectra navigation system (so-called firing on distance mode). The nominal firing pressure of each array is 2,000 pounds per square inch (psi). During firing, a brief (~0.1 s) pulse of sound is emitted. The sound sources were silent during the intervening periods.

The tow depth of the sound source arrays was 9 m. Because the actual source is a distributed sound source (36 sound sources) rather than a single point source, the highest sound levels measurable at any location in the water will be less than the nominal single point source level. In addition, the effective (perceived) source level for sound propagating in near-horizontal directions could be substantially lower than the nominal omni-directional source level because of the directional nature of the sound from the source array (i.e. sound is directed downward).

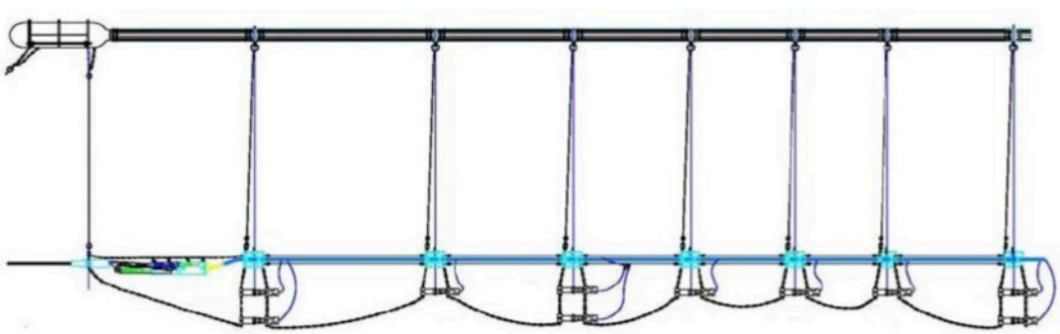


Figure 4.6.1: Typical Seismic Array Diagram

Flotation was used to keep the sound sources at a depth of 9 m and the vessel speed during data collection ranged from 4 to 5 nautical miles per hour [knots]. Depth indicators were located on each string to verify the depth of the sources during acquisition.

Acoustic transponders were also present along both streamers utilized during this survey and on the tail-buoy, and each sub-arrays. A head and tail network was configured in the system to aid in the accurate positioning of the in-water equipment to navigate locations of each source and receiver to within ~1 m.

4.6.1.2. Streamer.

Seismic Parameters

Table 4.6.1 Seismic Recording Systems

Recording type	Sercel SEAL 408xl
Sample rate	2ms
Recording length	14-16 seconds w/ no Deep Sea Delay
Low Cut Filter	3.0 Hz Digital Filter / 12 dB/OCT
High Cut Filter	200 Hz Digital Filter /276 dB/OCT w/ linear phase
Data format	SEG-D 8058 Rev1 demultiplexed with External Header.
Media	Data recorded directly to disk

Table 4.6.2 Seismic Streamer

Streamer type	Sercel Sentinel SSAS
No of streamers	1
Streamer length	12.6 km (4 km)
No of groups	1008 Channels (324 for the 4 km)
Group Interval	12.5m
Group length	12.5m
Streamer depth	TBD mTBD m10, 12, 14, and 18 m depending on sea stateTBD m
Near offset	~188 m
Spacing of birds	~300meters300meters300 m300meters with extra redundancy at head and tail of streamer

Table 4.6.3 Seismic Source

Source type	Bolt Air-Sound Source
Shot interval	OBS Component: 150m150m150 m150m - Towed Streamer Component: 50 m
Number Sources	111 (36 source elements)1
Source depth	9m9m9 m9m
Volume	6600 in3
Air pressure	1900 +/- 100 psi
Source separation	0 m
Max timing error	+/- 2 ms

A Tail-buoy was deployed at the tail of a streamer for positioning. Each Tail-buoy was fitted with a GPS unit, a radar reflector, a strobe light, and a DigiCourse Acoustic transponder for ranging to the transponders on the tail of each streamer. Each Sub-Array float had a Posnet rGPS Pod installed along with each sub-array having a DigiCourse acoustic pod. Streamers were positioned using a DigiCourse 5011 compass birds and DigiCourse acoustic transponders. The compasses and birds were mounted at 300 m intervals on the streamer. The depth controllers/compasses were DigiCourse model 5011. Extra compass birds were mounted in the front and tail of the streamer for redundancy. DigiCourse DigiRange Acoustic Pods were mounted at the head and tail of the streamer cable. The units mounted at the head of the Streamer ranged to the Acoustic Transponder Pods co-located with the rGPS units on the Sub-Array Floats. Units mounted at the tail of the streamer ranged to the tail-buoy transponder co-located with the rGPS unit. Because of the sea state during the cruise, the streamer was often kept at much greater depth (up to 18 meters), A summary of the depths use is found in Table 4.6.4.

Table 4.6.4. Summary of MCS Lines

MCS Line	Shot Strt	Shot End	File Strt	File End	Tape Strt	Tape End	Smpl (ms)	Rec Lgth (s)	Strm (km)	Strm Dpth (m)	Src Vol (cu in)	Dist (km)
MCS01	4832	10464	1	5623	1	10	2	16	12.6	10, 12	6600	281.6
MCS03a	10983	13408	5625	8087	11	15	2	16	12.6	12	6600	121.25
T01	14278	15545	8088	9357	16	18	2	16	12.6	12	6600	63.35
MCS23a	15873	19370	9358	12882	19	24	2	16	12.6	12, 18	6600	174.85
MCS23 b	19359	20885	12883	14428	25	27	2	16	12.6	18	6600	76.3
T02	21236	21396	14330	14590	28	28	2	16	12.6	18	6600	Aborte d
MCS14	21956	26080	14592	18751	29	36	2	16	12.6	18,14	6600	206.2
MCS17a	26971	27171	18753	18953	37	37	2	16	4.0	14	6600	10
MCS17 b	28039	29718	18954	20632	38	38	2	16	4.0	14, 18	6600 3120	83.95
MCS17c	30910	32830	20633	22553	39	39	2	14	4.0	14, 18	6600 4590	96
T03	33017	33332	22554	22868	40	41	2	14	4.0	14	6600 6600	15.75
MCS19a	34013	36470	22870	25327	42	43	2	14	4.0	14	6600	122.85
TOTAL												1252.1

4.6.2. Examples

This section shows a map summarizing the MCS Lines (Figure 4.6.2) and several example plots (Figure 4.6.3 to Figure 4.6.5) of un-migrated and migrated full and zoom in plots of the MCS lines.

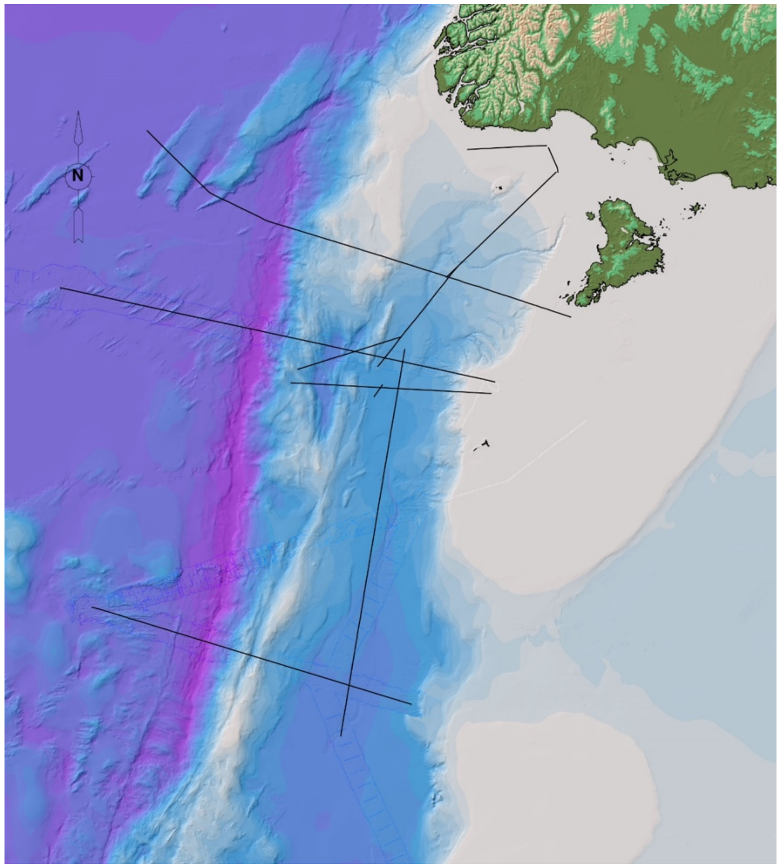


Figure 4.6.2. Map of MCS Acquisition Lines.

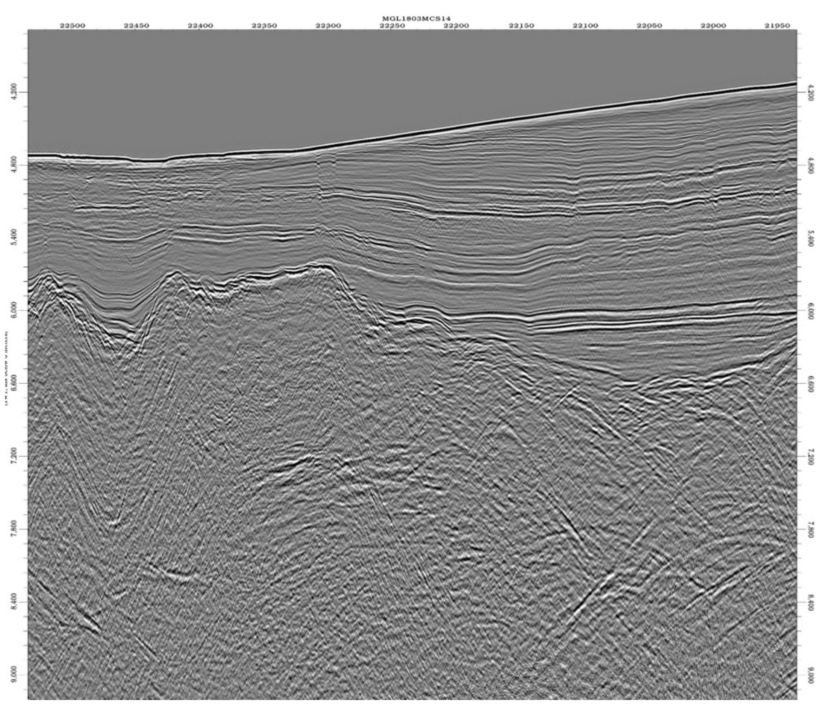


Figure 4.6.3: Eastern end of MCS14 showing basement blocks and crustal reflectivity.

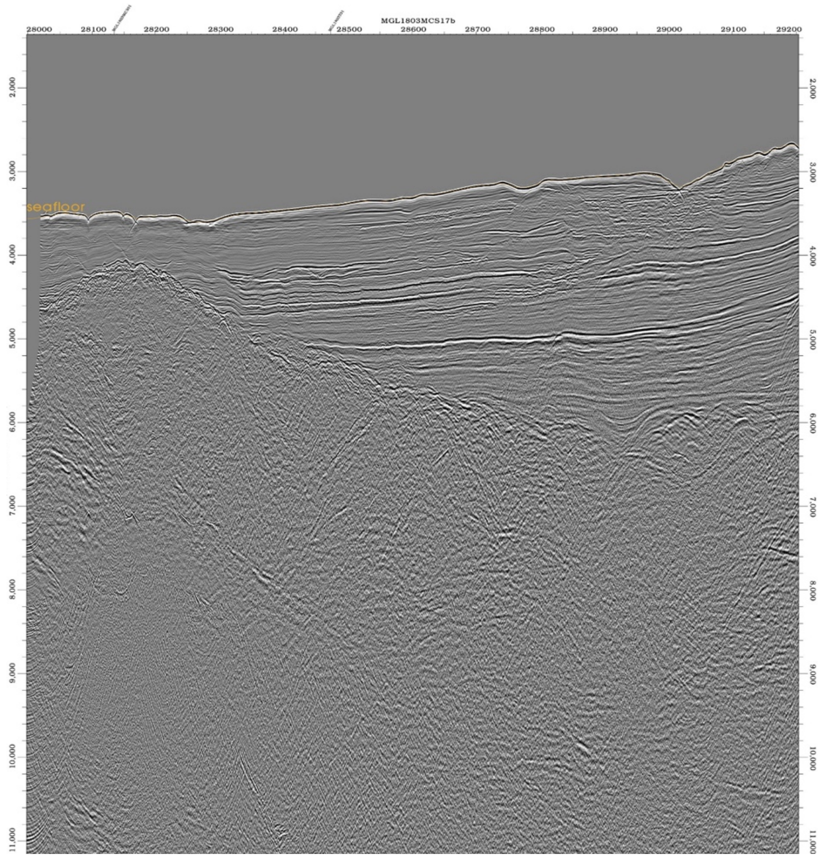


Figure 4.6.4. MCS17a showing deep dipping reflector

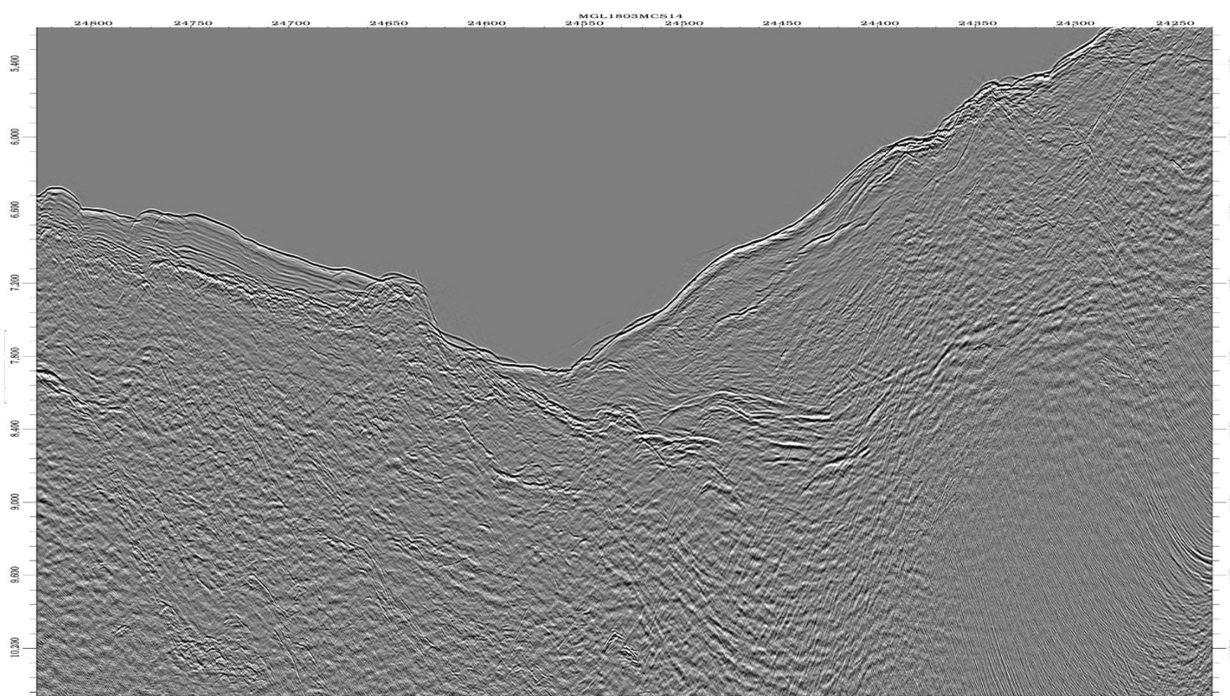


Figure 4.6.5. MCS14 showing trench and sediment under thrusting beneath a crystalline margin.

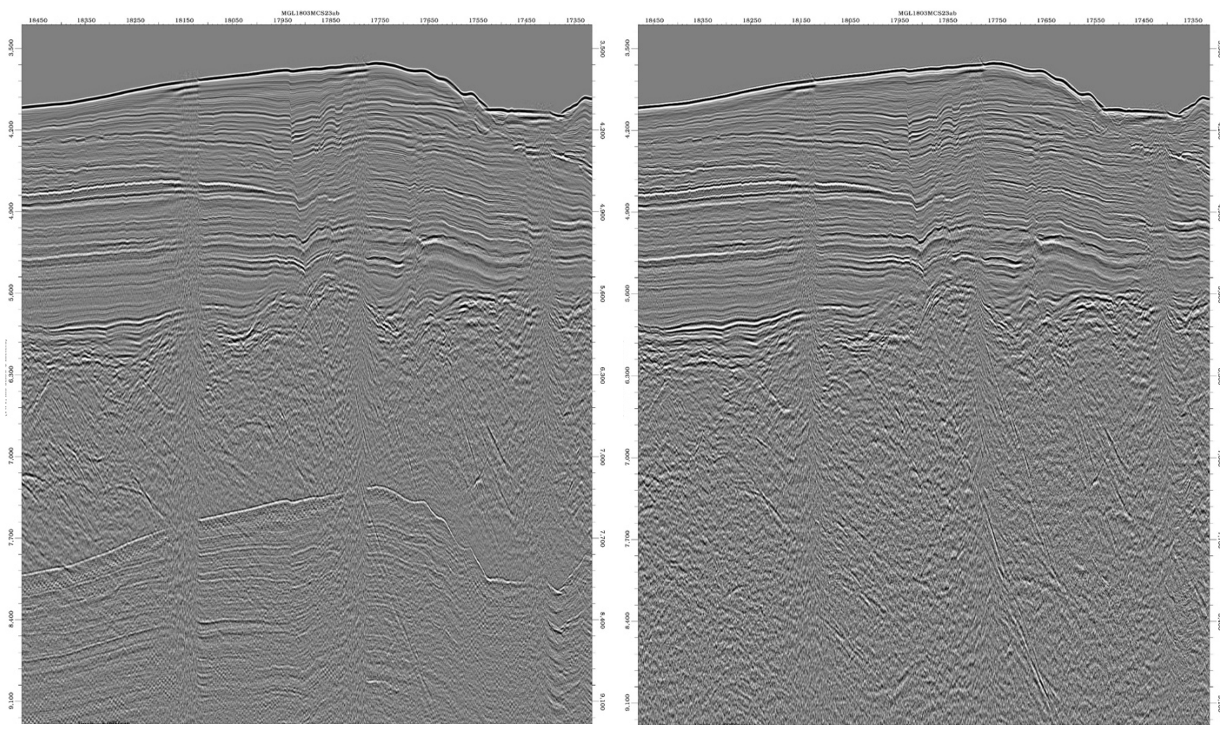


Figure 4.6.5. MCS23 before and after Radon multiple attenuation. Three PSO power-downs are visible in this section as vertical distortions.

4.6.3 Protected Species Observing and Mitigation

To comply with our permit to gather seismic reflection and refraction data offshore New Zealand, we had a team of five marine mammal observers on board the R/V *Marcus Langseth*. The PSO team monitored for wildlife from the observation deck and from the bridge. During seismic data acquisition they also deployed the Passive Acoustic Monitoring (PAM) system, a short streamer, to record marine mammal vocalizations. Each observation of a marine mammal within or approaching the prescribed safety radius, led us to shut down the acoustic array. We would ramp up the source volume again after 20 minutes, or if we observed that the animal was leaving the vicinity of the acoustic source. Powerdowns were implemented for dolphins, and one for a whale, but also for pinnipeds (such as fur seals).

During the cruise we had a total of fifteen acoustic shutdowns for marine mammals (Table 4.6.5). To shorten the data gaps we would slow down the vessel to 3.5 knots. Nonetheless, a gap in our airgun shot record of 3 kilometers or more would be inevitable due to staged ramp-up procedure. The ramp-up shots were fired on time (17 seconds), so they were less useful to our survey, which was shot on distance. This short time interval of ramp-up shots should be revisited especially for OBS data. For MCS data the time interval results in shots that increment in File # but sometimes have duplicate Shot #s; a problem that has workarounds but should be noted for processing.

Table 4.6.5. Summary of seismic shutdowns due to marine mammals.

Line	Cause	Shot Strt	Ramp Strt	Ramp End	Distance (km)
OBS01	Pinniped	1706	1723	1739	4.95
OBS01	Pinniped	1883	1889	1904	3.15
OBS01	Pinniped	2106	2118	2133	4.05
OBS201	Pinniped	2946	2965	2980	5.1
OBS201	Pinniped	2981	2986	3000	2.85
OBS201	Pinniped	3305	3319	3335	4.5
OBS201	Pinniped	4294	4315	4327	4.95
MCS03a	Dolphin	11449	11587	11639	9.5
MCS03a	Dolphin	11705	11775	11828	6.15
MCS23a	Pinniped	17362	17409	17465	5.15
MCS23a	Pinniped	17728	17773	17831	5.15
MCS23a	Pinniped	18062	18116	18173	5.55
MCS23b	Pinniped	20435	20482	20529	4.7
MCS14	Whale	22913	22991	23040	6.35
MCS14	Pinniped	23457	23493	23542	4.25
TOTAL					76.35

4.7 XBT measurements

4.7.1 Method and instrumentation

Expendable Bathythermograph (XBT) probe is an instrument that is launched from the surface to more than a thousand meters depth in the ocean to measure the salinity, temperature, and inferred acoustic wave speed. These measurements are a valuable tool for multibeam mapping of the seafloor and for reflection and refraction seismology. During the cruise, the *Langseth* carried Sippican T-5 and T-7 XBT probes. During the cruise we deployed about one probe daily when possible. The actual details of the XBT probes launched is given in Table 4.7.1. The science party often assisted the LDEO technicians for the routine probe launch. The standard cut-off limit for XBT probes will be used unless otherwise specified (Probe T-5 to 1850 m and Probe T-7 to 700 m).

Approximately one XBT was launed each day (see Table 4.7.1). Many of these probes reached a maximum depth of 1827 meters, though some fell short. Given that this depth is well below the thermocline, we can reasonably well estimate the average acoustic wave speed at these sites, by assuming that the deepest recorded velocity is representative for all greater depths to the seafloor. The drop locations are shown in Figure 4.7.1 and other data summarized in Table 4.7.1.

Table 4.7.1 XBT Launch results.

Launch	Date	Time	Longitude	Latitude	Seafloor (m)	Probed (m)	Avg. speed (m/s)
T7_00001	2/19/18	3:48	170.1445	-46.5066	117	119	1498
T7_00002	2/20/18	2:42	165.7837	-48.3870	3175	756	1486
T7_00006	2/24/18	4:21	165.1982	-49.7743	3499	756	1485
T7_00009	2/27/18	4:46	164.4634	-47.1966	4454	756	1487
T5_00003	2/21/18	3:13	165.2087	-49.3390	3459	1827	1484
T5_00004	2/22/18	14:24	163.0310	-48.7247	4198	1380	1481
T5_00005	2/22/18	21:45	163.5387	-48.8614	4145	1827	1484
T5_00007	2/25/18	8:20	165.6400	-49.4550	3132	1827	1483
T5_00008	2/26/18	2:06	165.2178	-49.3437	3468	1827	1484
T5_00010	3/1/18	5:28	166.0375	-47.5465	2381	1827	1485
T5_00011	3/2/18	3:37	164.5492	-47.2157	4395	1075	1484
T5_00012	3/2/18	3:42	164.5488	-47.2156	4394	1827	1485
T5_00013	3/4/18	6:02	164.3697	-47.1754	4647	1827	1485
T5_00014	3/5/18	11:57	166.2122	-47.7064	2372	308	1492
T5_00015	3/5/18	23:14	165.0954	-47.5930	2205	440	1487
T5_00016	3/8/18	2:30	165.2532	-49.2718	3432	1827	1484
T5_00017	3/9/18	1:24	165.0881	-49.3050	3400	1827	1483

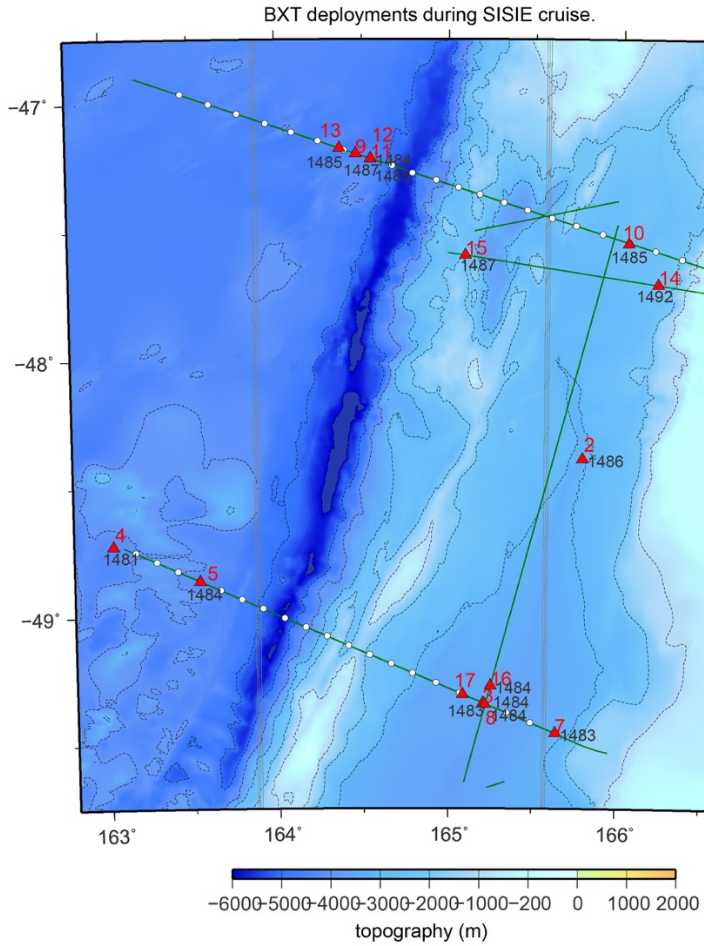


Fig. 4.7.1. Map of XBT locations (in red) and average acoustic wave speeds annotated in black).

4.7.2 Data Files.

1-D XBT profiles are stored in text files with the extension *.EDF. The header of these files marked the time and location of the probe. It is followed by a table that logged the depth, temperature, resistivity, and acoustic wave speed as the instrument descended.

5. Education and Outreach

During the cruise, the scientists organized a formal class for the students. This was overseen jointly by Joann Stock and Sean Gulick. The purpose of the class was primarily to provide an overview of the methods and techniques of marine geophysical research and an overview of the scientific motivation for the cruise. The Caltech students were enrolled in GE 211 and received course credit for their participation. The list of topics covered is given in Appendix C.

From their student perspective, NSF supported GRAs Erin Hightower and Brandon Shuck were invited and wrote an article concerning SISIE and MGL1803 for the *GeoPrisms Newsletter*.

The science party and the LDEO techs lead three tours during demobilization in Dunedin on March 20 for about 45 university students from the University of Otago. The course GEOL263 and GEOL363, entitled "Fossils, Strata and Hydrocarbon Basins" given by Ewan Fordyce and Andrew Gorman. There also were a few postgrads students from the university's Geology Department as well.

On March 21, the Chief Scientist and the Chief Science Officer meet with a group from the Otago Daily Times, which resulted in a story in the local news paper, a web posting and news story in the local TV station the next day. See https://www.odt.co.nz/news/dunedin/visiting-us-research-ship-weathered-storms-science

6. Recommendations

The collection of the marine geophysical data went extremely well and all of the science objectives will be addressable with the data post cruise. In particular, the Science Party was truly impressed with the capabilities of the marine technicians responsible for the seismic acquisition. Nevertheless, the Science Party offers the following recommendations so as to make future expeditions using the *R/V Langseth* reach their full potential.

1. The sonar systems were shut down when transiting to and from the survey area and during the weather evasions, but were kept on when transiting between seismic lines. Sonar shut downs during transiting for weather or operational reasons but while still within the survey area made no logical sense. This causes a loss of potentially key observations given that this cruise was proposed as a combined seismic and underway geophysics cruise. These shutdowns of the sonars when seismic was not operating occurred even though the overall acoustic take or amount of insonification that has occurred during the cruise was far below that within our environmental permit. We need to point out that the New Zealand regulatory authority had no issues with sonars being left on during the entire time we were in the survey area and would integrate our data into national grids. We need to emphasize that this shutdown led us not to acquire important scientific data on faults and new sea mounts during the final transit back to Dunedin across our survey area.
2. The ramp up of the acoustic source following shutdowns due to protected species followed the same for procedure for OBS as they did for MCS. This means that the ramp up for the sources was 17 s between shots making the data un-usable for imaging with the OBS. It would be far more logical to use a 60 s shot spacing for the ramp up. We recommend that the new protocols be developed for the *Langseth* for seismic ramp ups during OBS operations.
3. The off-ship internet on the *Langseth* was far too slow and far too unreliable for us to fully achieve our outreach goals. For example, SISIE specifically was not able do the daily blog that had been planned, because the internet was so unreliable and slow.
4. The Knudsen 3260 operations could use a new protocol being developed. The automatic mode of syncing it with the multibeam resulted in spurious changes in sampling interval and deep water delay errors. Therefore use of the manual mode is recommended. Also the KEB files written if the SEGY option is turned off are only the envelope data preventing any further processing of these data using seismic or signal processing techniques. Checking the box for SEGY (filtered) resulted in the full waveform version of the data being recorded for both SEGY and KEB. While this option works for our Science Party, some experimentation of the system is recommend so that a cook book of options can be created to allow science parties to use the system as is most beneficial to their needs (e.g. envelope only but in manual mode if no processing is planned vs full waveform in SEGY in manual mode if later improvements to the data are planned). Also the Knudsen conversion software should be installed on a ship computer.
5. Given the range of seagoing experience within and between science parties, we recommend tool box talks being routine for deck operations (e.g., OBS and MCS).
6. We suggest that a set of processing scripts for the underway data be available on board ship so that the science party can use the raw serial data files and convert them to

MGD77 or tab-separated text file formats for the science party to use during the cruise. We ended up spending significant science party time re-creating scripts to work with the serial data strings because nothing suitable was present on board.

7. We suggest that a cookbook be prepared from the Information Technology side to explain to the science participants how to optimize the setups of their computers on the internal ship network and subnetworks.

7. References

Stagpoole, V.M., Dando, D., Caratori Tontini, F., Black, J., Amos, M., 2015. Absolute gravity observations at principal New Zealand stations 2015. GNS Science Report 2015/46. 48 p.

Appendix A. Geodetic Parameters and Positioning

All survey calculations will use the World Geodetic System 1984 datum (WGS84) UTM Zone (TBD at sea) projection. The Global Positioning System (GPS) operates on the WGS84 datum. The vessel's Differential GPS (dGPS) Reference Stations are defined in the WGS84 datum.

In order to obtain optimized navigation, waypoints need to be in decimal degrees (DD) to five (5) decimal points. Decimal degrees express latitude and longitude geographic coordinates as decimal fractions and are used in many Geographic Information Systems (GIS), web mapping applications such as Google Maps, and GPS devices. Negative numbers represent latitudes south of the equator and longitudes west of the Prime Meridian.
Example: 38.88972, -77.00888

A.1 Geodetic and Projection Parameters

The geodetic and projection parameters are detailed in Table A.1.

Table A.1. Project geodetic and projection parameters

<table>
<tr><td colspan="3">Global Positioning System Geodetic Parameters</td></tr>
<tr><td>Datum</td><td colspan="2">World Geodetic System 1984 (WGS84)</td></tr>
<tr><td>Reference Ellipsoid</td><td colspan="2">WGS84</td></tr>
<tr><td>Semi Major Axis (a)</td><td colspan="2">6378137.0 m</td></tr>
<tr><td>Inverse Flattening (1/f)</td><td colspan="2">298.257224</td></tr>
<tr><td colspan="3">Survey (local) Geodetic Parameters</td></tr>
<tr><td>Datum</td><td colspan="2">World Geodetic System 1984 (WGS84)</td></tr>
<tr><td>Reference Ellipsoid</td><td colspan="2">WGS84</td></tr>
<tr><td>Semi Major Axis (a)</td><td colspan="2">6378137.0 m</td></tr>
<tr><td>Inverse Flattening (1/f)</td><td colspan="2">298.257224</td></tr>
<tr><td colspan="3">Datum Transform Parameters: Global to Survey Datum</td></tr>
<tr><td>X shift: 0.0 m</td><td>X-axis Rotation: 0.0 arcsec</td><td>Scale correction: 0.0 ppm</td></tr>
<tr><td>Y shift: 0.0 m</td><td>Y-axis Rotation: 0.0 arcsec</td><td></td></tr>
<tr><td>Z shift: 0.0 m</td><td>Z-axis Rotation: 0.0 arcsec</td><td></td></tr>
<tr><td colspan="3">Map Projection (Project Projection Parameters)</td></tr>
<tr><td>Grid</td><td colspan="2">Universal Transverse Mercator (UTM)</td></tr>
<tr><td>Projection Type</td><td colspan="2">Universal Transverse Mercator (UTM), Southern Hemisphere</td></tr>
<tr><td>Projection Zone</td><td colspan="2">58 South</td></tr>
<tr><td>Latitude at Origin</td><td colspan="2"></td></tr>
<tr><td>Longitude at Origin (Central Meridian)</td><td colspan="2"></td></tr>
<tr><td>False Easting</td><td colspan="2"></td></tr>
<tr><td>False Nothing</td><td colspan="2"></td></tr>
<tr><td>Scale Factor at Central Meridian</td><td colspan="2"></td></tr>
<tr><td>Grid Units</td><td colspan="2">Meters</td></tr>
</table>

A.2. Positioning Reference System

Two independent standard multi-station dGPS systems are required for the survey.

Table A.2. Vessel Positioning Reference Systems

System	Equipment
Primary Nav system	C-Nav 3050 dGPS
Secondary Nav system	Seapath dGPS (on stern)
Tailbuoy navigation	PosNet rGPS
Source navigation	PosNet rGPS (1 unit per subarray)
Acoustics	DigiCourse
Navigation processing	Concept Sprint 4.3.9
Bird Controller	DigiCourse
Survey-Gyro (Primary)	Simrad GC-80
Ships-Gyro (secondary)	Sperry MK-27
Speed Log	Furuno DS-50
Multibeam	Kongsberg EM-122

Appendix B. OBS Operations Log

When we arrived at the dock in Dunedin at 10:00 am on February 17 (local time), the crew of the Langseth had already placed the UTIG OBSs in the wet lab of the Langseth, after the gear came on board on February 9 in Napier. We started to set up the OBS assembly line in the adjacent dry lab. We installed two GPS antennas on the deck above us for clock synchronization. The next morning we started to prepare ocean-bottom seismometers for deployment on the first SISIE seismic refraction line. To save space in the lab, finished instruments were placed back in their box in the wet lab. As the Langseth left Dunedin on February 19th, the seas were relatively calm, which made it easy to continue the OBS check-out. In the late afternoon of February 20th we finished programming all OBS. During the southward transit, we took ten of the programmed instruments and mounted them on anchor frames, and secured with straps and bolts on the deck next to the A frame.

A.1 OBS Line 1:

We started with the deployment of OBS 101 shortly after midnight on February 21st. The seas were rough at this time, and waves swept across the starboard deck. One of these waves was powerful enough to separate one of the OBS on deck from its anchor. We therefore decided that we would stage the remaining OBSs from the wet lab. Given the space constraints, no more than two instruments would be ready at any time during our operation OBS Line 1 (Fig. 4.5.1). In the course of the day the weather improved, and in the late afternoon we were finished with all 20 instruments. In the late evening, the marine mammal observers cleared us to start shooting the first OBS refraction line for SISIE. The gunners started a soft ramp-up of the airgun array. At about 1:00 am on February 22nd we started shooting the full Langseth airgun to the array of 20 OBSs on SISIE Line 1. On three occasions the marine mammal observers sighted fur seals near the Langseth, which led to a fast shutdown of the acoustic array, and a slow ramp-up. These events caused gaps of 3-5 km in our shotline record.

The recovery of OBSs on Line 1 started at 3:00 am on February 23rd, and progressed from west to east. We used a Bentos acoustic deck unit and transducer on a cable over the side of the ship to a depth of 8 meters. With this arrangement we were able to release the instruments from the seafloor. However, we did not get an adequate acoustic response back from the OBS as they released. OBS 108 was the deepest OBS at 5901 m, and it was recovered without a problem. At this time we managed to connect our newer Teledyne acoustic deck unit to the Langseth's hull transducer, which gave us clear responses from the OBS array. Unfortunately, OBS 109 was not able to release from the seafloor. This instrument acknowledged the ship's release request, but did not rise from the seafloor. After attempting to release OBS 109 for three hours, we concluded that the instrument is likely trapped, either due to rough terrain, sticky mud, or debris flows at the Pacific trench wall. The OBS recoveries progressed smoothly through February 24th. Some of the Sedis V instruments did not come upright to the surface, which made them difficult to see in the dark. Fortunately, the radio signal from the instrument guided us in the right direction. After we recovered OBS 115, the wind and waves started to increase. The weather forecast also showed that a storm was going to hit us in the next 24 hours, so we suspended the OBS recovery, and started a course towards Auckland Island, to be sheltered from the storm. The Langseth spent much of February 25th on the south side of Auckland Island, while our study area experienced seas higher than 6 meters. At night we started planning our return to the margin of Campbell

Plateau. At 8:30am on February 26th, winds had subsided enough, so we were able to able to get OBS 120. By 3:30pm we had all instruments on board. Besides data downloads we had installed new batteries and re-programmed OBSs for the next deployment on SISIE Line 2.

B.2. OBS Line 2

After a 12-hour transit, we arrived at Line 2 at 5:00am on February 27th for the deployment of 23 OBSs (Fig. 4.5.2). The deck operations mostly went smoothly, except for site 217, where the OBS fell off the hook on the deck as we prepared to lift it over the side of the ship. The instrument was not damaged, but we used a spare OBS at this site. Around noon the weather became sunny and calm. The deployments went well, though OBS 209 did not hold vacuum, so it was replaced as well. At 21:00 the last instrument, OBS 201, was deployed. After a short transit to the west end of the line, the gunners brought out the acoustic source. At 2:30am on February 28th we started shooting SISIE Line 2 OBS from west to east, with a shooting speed around 4.9 knots. Later in the morning, we had two interruptions from fur seal sightings, during which we reduced speed to 3.5 knots. One of these gaps was just 5 km long, while the other was 8.2 km, due to the fact that two seals were observed in short succession. In the early morning of March 1st the shooting of Line 2 was finished.

OBS 223 was retrieved by 12:20pm on March 1st, and six more instruments came on board that day. The weather was calm at first, but the wind increased during the night of March 2nd. As we were concerned for the visibility of the Sedis V OBS at night, we had added 4.5 lbs in lead at the base of the sphere in two of these instruments. The extra weight slowed the ascent of this OBS by 15 minutes, but it surfaced more upright than some other Sedis V instruments, because the center of gravity was now lower. The last four OBS's of Line 2 were recovered by noon on March 3rd. Two of the23 OBS did not appear to have recorded seismic data. Otherwise, we were content to have gathered two marine seismic refraction lines in the first two weeks of the project, without major problems.

B.3 OBS Instrument performance

The science party brought 28 UTIG OBSs on the SISIE cruise. Eight of these instruments are of an older Sedis V type, and the 20 other OBSs are of the newer Sedis VI type. There are differences between these instruments in the data logger, programming software, and the strobe light for instrument recovery. All instruments were programmed to record for the duration of deployment with a 4 msec sample interval. A total of 20 instruments were dropped on OBS Line 1, and 23 on OBS Line 2.

After the instruments from Line 1 were recovered, many of them were reprogrammed and equipped with new batteries for the second deployment. Of the 20 instruments on Line 1, 17 were recovered with data (Table 4.5.1). We communicated with OBS 109 and sent a release command, but it did not rise from the seafloor. OBS 104 recorded data, but there appears to be a large timing error that may make the data unusable. Last, OBS 114 did not record data. All OBSs of Line 1 that recorded data show interesting crustal and mantle seismic refractions that will help to constrain the crustal structure along the transect. The deployment of 23 OBSs on Line 2 yielded 21 good record sections (Table 4.5.2). Instruments 203 and 222 were retrieved without data.

Appendix C. Shipboard MCS Processing

Shipboard processing was performed by students using Echos software by Paradigm Geophysical, installed on 2 Dell workstations. The general processing sequence included these steps:

SEGD trace input 14-16 s @ 2 ms, 1008 channels
Resample to 4 ms Nyquist filter applied
Output shots to SEGY and Echos PDS Format
Trace Edit ~10 traces removed
Band-pass Filter 7-85 Hz
Debias
Geometry Application 50m shot spacing; 12.5m receivers
Trace Interpolation Interpolation to fill edited traces
Time-varying Gain *t**1.5 function*
CMP Sort 6.25m CMP's
Output CMP's in Echos PDS format
Output CMP's in SEGY format
Perform Brute Stack with near 200 channels, nominal velocities and mutes
Pick seafloor from brute stack
Velocity Analysis
Parabolic Radon Multiple Attenuation
NMO Correction
Offset Mute
Internal Mute
CMP Stack 42-126 fold nominal
Time-varying Filter
Seafloor Mute
Output Stack in Echos PDS format
Output Stack in SEGY format
F/K Migration Water Velocity
Output Migration in Echos PDS format
Output Migration in SEGY format

Processing was performed using shell scripts which built and then ran Echos jobs in batch mode, with some steps run manually. For each line, an initial processing sequence was performed in near-real time, followed a second iteration including deconvolution and radon multiple reduction. Echos jobs used were:

(Line#)segd.dat Reads SEGD data, resamples to 4 ms, outputs Echos shotgathers and SEGY
shotgathers.
(Line#)geometry.dat Creates database geometry. Creates nominal brute stack velocity function. Creates nominal brute stack mute function.
(Line#)cdpsort.dat Trace edit. Stores trace header water depth (m) as WBTIME. Noise

	Suppression, debias, geometry application, interpolation of edited traces. CMP sort. Creation of brute stack. Output of CMP gathers.
(Line#)veldef.dat	Interactive stacking velocity picking.
(Line#)velstack.dat	Spherical divergence correction, NMO correction, offset muting, cmp stack, seafloor mute, output of stack section, F/K migration, output of migrated section.

Shell scripts used, and their corresponding Echos jobs, were:

segd_rsync.csh	Copies raw SEGD files from the Langseth shipboard network.
Flist_script	Defines input "tape" lists for SEGD input.
segdinSISIE.csh	Builds and runs segd.dat
geometrySISIE.csh	Builds and runs cdpsort.dat
sortSISIE.csh	Calls Flist_script, segdinSHIRE.csh, and geometrySHIRE.csh in turn to produce
	cmp sort and brute stack.
stackSHIRE.csh	Builds and runs velstack.dat

Migration

Migration was generally performed using F/K Migration with Water Velicity (1500 m/s). For selected lines Fast 2D Kirchhoff Migration was performed using stacking velocities.

Scripts sequence was:

1) Run segd_rsync.csh to copy over most recent SEGD files.
2) Run geometrySISIE.csh to define geometry and perform a brute stack.
3) Pick the seafloor time from the brute stack (horizon called "SF.TIME")
4) Run sortSISIE.csh to apply geometry, preprocess, and CMP sort.
5) Interactively run veldef.dat to pick stacking velocities and mutes.
6) Run stackSISIE.csh to perform a velocity stack and F/K migration.

Multiple Attenuation

Multiple attenuation testing was performed on selected lines using Radon and/or internal muting.

Interpretation

Migrated SEGY data were imported into Landmark's OpenWorks, preliminary interpretation was performed using DecisionSpace interpretation software. Shotpoint locations were imported from the shipboard-produced real-time (unprocessed) OBSIP shotlog files.

Disk Organization

All data were stored on a 32-terrabyte RAID (23-terrabyte available) external filesystem mounted as /sisie1. Directory organization within /sisie1 was:

/sisie1/

Steffen/	*Steffen test processing*
Landmark/	*Landmark installation backups*
direct/	*Echos database seismic etc*
SEGD/	Raw field data in SEGD format
SEGY/	*All SEGY types*
RAWSEGY/	Field data in SEGY format
CDPSEGY/	*CDP gathers in SEGY format*
PROCSEGY/	*Field-processed stacks and migrations*

SISIE/	
PROGS/	*Processing scripts*
PRODUCTION/	*Production-level scripts*
TESTING/	*Test scripts*
FLIST/	*FLIST tape lists for process SEGD*
NAV/	*P190 files*
VELOCITIES/	*Text velocity vertical functions and mute functions*
JOBS/	*Field Echos job decks for all lines*
PRODUCTION/	*Production Echos jobs*
TESTING/	*Test and beta Echos jobs*
obsip/	*Shotpoint navigation files*
EW9601	*Data and processing jobs for line EW9601_p1*
FOCUS/	Files used by Echos processing
FLIST/	Flist files used by Echos process SEGD

Backups

Backups were made to USB drives /SISIE3 and /SISIE4 of raw SEGD data, SEGY shotgathers, Processed lines, Velocities, Mute files, and navigation files.

Appendix D. MCS Daily Log

All times local

March 3rd
Last OBS picked up ~12:30 allowing transition to MCS acquisition. From ~12:30 until 23:00, tail buoy and 12 km of Sercel hydrophone streamer were deployed. An issue arose with one of the bird communications channels which turned out to be within the armored tow leader. It was decided as this was a backup to turn off that communication channel and proceed.

March 4th
Airguns strings were deployed from 00:30 to 02:30, but not ramped up due to fog. A lessening of the fog occurred around 06:00 to allow for PSO clearance and ramp up started ~06:30. Line MCS01 acquisition then commenced starting at 08:00. First SP4832 but first good SP with streamer straight was 4900. By midnight still acquiring MCS01 with no problems.

March 5th
Line MCS01 acquisition continued however due to swell direction streamer deepened to 12 m at 05:07 @SP8376 to reduce noise. Line MCS01 continued until 18:10 @SP10464. Started starboard turn on Line MCS03a. Turn ended around 20:15 waiting for streamer to straighten before starting line. SOL MCS03a at 20:31 @SP10983 although streamer only ~1/3 straight. Watchstanders recorded when streamer was fully straight. By midnight acquiring MCS03a with no problems.

March 6th
Line MCS03a continued throughout the midnight to noon shift. There were two power downs due to dolphins (one fairly long) near the edge of the Campbell Plateau. Power downs were from 00:15 (SP11448) to 01:32 (SP11639) with a partial ramp up in the middle, and from 01:58 (SP11704) to 02:44 (SP11828). Now further issues on this line and EOL MCS03a was at 13:18, SP13408, with a starboard turn start towards next line, T01. SOL T01 was at 15:34, SP14276, with streamer still straightening out. In a head current starting around 19:00 so SOW < 4knts. Slow improvement later in the evening but head current still present. 23:29 EOL T01, SP15545. Starting starboard turn onto MCS23a and continued in turn until midnight.

March 7th
Line MCS23a was started at 00:52, SP15873 as a strike line down the Solander Basin. Due to increased sea state and noise on the streamer, the tow depth was increased to 18 m at 08:10, SP17020. Three power downs occurred due to pinnipeds from 10:17-10:54 (17362-17466), 12:27-13:03 (17728-17831), and 14:28-15:08 (18062-18173). Discovered that shots during ramp ups are on time and within those shots several will have duplicate SP #s and odd time stamps. Guns became tangled with tow leader and between strings due to ocean conditions and a change in streamer feathering required EOL. EOL MCS23a 23:50, SP19370. Guns were being untangled and brought on board a bit at a time at midnight.

March 8th
Took a starboard turn bring guns on board and repairing. Returned to line and re-started with

overlap as MCS23b at SP19359 10:11 local time. One power down due to a pinniped occurred at 18:33, SP20435 and ramp up after was complete at 19:13, SP20529. EOL at 21:42, SP20885. Port turn onto T02.

March 9th
SOL T02 at 00:38, SP21236, however due to following heavy seas streamer surfaced by 00:54, SP21271. No control was possible once completely on the surface given the seastate. Line ended at 01:48, SP21396. Line will not be considered as part of the cruise given only 160 shots with much of it on the surface. At the end of the transit line turned to port onto MCS14 which is collocated with OBS01. SOL 08:23, SP21956. Power down at 14:47, SP22915 due to dwarf minke whale and end of ramp up after at 15:40, SP23040. As sea state had improved, raised streamer to 14m at 20:59, SP23845. Still shooting MCS14 at midnight.

March 10th
Continued shooting MCS14 until EOL at 11:35, SP26080. Due to weather coming decided to pull all gear and transit to north area of survey to redeploy a shorter streamer (4 km). All MCS gear recovered and desk secured by 23:15. Starting transit to northern study area.

March 11th
Streamer and sources re-deployed around 06:00 and completed by 11:30. Turned the ship around to start line south of previously MCS lines 03a and 01. SOL MCS 17a 13:20, SP26971. 14:21 noted that the Passive Acoustic Monitoring cable (PAM) was wrapped around the lead to String #4 and decided to end line to turn into rough seas and unfoul it. After proceeding ~8km into the seas to northwest (330°) PAM was disentangled and ship turned to starboard heading towards the northern end of Line 17 waypoint but from this new starting location. Line was called MCS 17b and SOL was at 16:07, SP28040. Streamer was at 14 m for 17a and 17b but deepened to 18m at 20:31, SP28295 due to worsening seas. Gun1 String 4 failed at 23:23 and was hot swapped with Gun 5 on the same string lowering source volume to 6420 cu in at SP29379. At 23:52 sea state was viewed as too rough to continue. Two strings were pulled before EOL and turning towards shelter of Stewart Island. This last SP at full volume was 23:52, SP29466 but line continued at 3120 cu in (two strings) and we were shooting along MCS 17b at half volume at midnight while recovering the 2 starboard strings.

March 12th
Continued recovering two strings until 01:11 at which point EOL, SP29718. Turned to the SE and continued downwind until we reach shelter behind Stewart Island. There we recovered the remaining two strings and 4 km streamer by 11:30. Waiting on weather remainder of the day.

March 13-16th
Waited on weather behind Stewart Island and caught up on processing all data.

March 17th
Steaming back towards field area. Deployed guns and streamer in somewhat rough conditions resulting in overshooting line crossing. So turned to port to come on line with a 4 km overlap. SOL MCS 17c at 15:12, SP30910 with streamer at 14 m. Streamer showed low frequency noise and so lowered to 18 m from 15:38 to 15:51 when we decided it did not improve the noise

enough given the following sea and thus returned the streamer to 14 m. One gun tow point failed and thus at 19:26, SP31701 had to recover string 3; during repairs guns were operating at 4950 cubic inches (3 strings). By 19:50, string 3 had redeployed and full volume resumed at SP31780. At midnight near end of MCS17c.

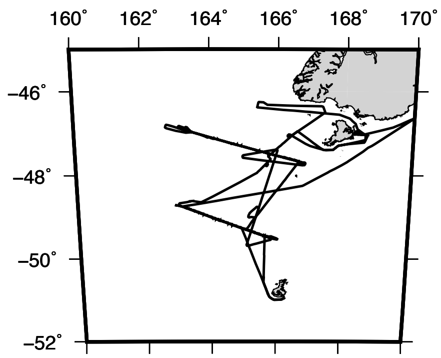
March 18th

Completed MCS17c at 01:09, SP32830 and turned to port. Shot a connecting line called T03 with SOL at 02:16, SP33017. EOL T03 at 04:49, SP33332. Turned to port onto line MCS19a. SOL MCS19a at 04:54, SP34013. String 1, Gun 1 had a few timing errors but otherwise clean line acquired into somewhat worsening weather. Due to oncoming storm call was made to end the line at 16:00, with official EOL at SP 36470. Guns and PAM were recovered by 17:30 going into the seas and then after a port turn to create a following sea, streamer and tail buoy were recovered from 19:00 and completed by 21:00. Final data QC, processing, and backups continued through the end of the day.

Appendix E. Topics for Marine Geophysics Course

Date	Topic	Discussion Leader
2/20	Science project orientation	GURNIS
2/21	Data collection	ROBERT Steinhaus
2/22	Plate Tectonic history movies of SW Pacific	Joann Stock
2/23	No class because of instrument turnover in OBS lab	N/A
2/24	Multibeam DEPTHS	SG & JMS
2/25	Multibeam SIDESCAN (BACKSCATTER)	SG & JMS
2/26	Chirp	SG
2/27	Magnetics	Stock
2/28	REFRACTION	HVA
3/01	Intro to SEISMIC reflection	SG
3/02	Protected Species	PSO TEAM
3/03	MCS Data processing (1)	SG
3/04	MCS Data processing (2)	SG
3/05	Scripts in Echoes (1)	SG
3/06	Scripts in Echoes (2)	SG
3/07	Regional Geology	RS
3/08	Local Geology	RS
3/09	Resolution (horizontal and vertical)	SG
3/10	ADCP	JMS
3/11	Analog data: compressional margjns	SG
3/12	Analog data, Gulf of California	JMS
3/13	Discussion of research themes	All
3/14	Analog data: Iberian margin	HVA
3/15	Gravity data	All
3/16	Safety training	All
3/17	Geology near the wells	RS
3/19	Review of major science results	MG, All

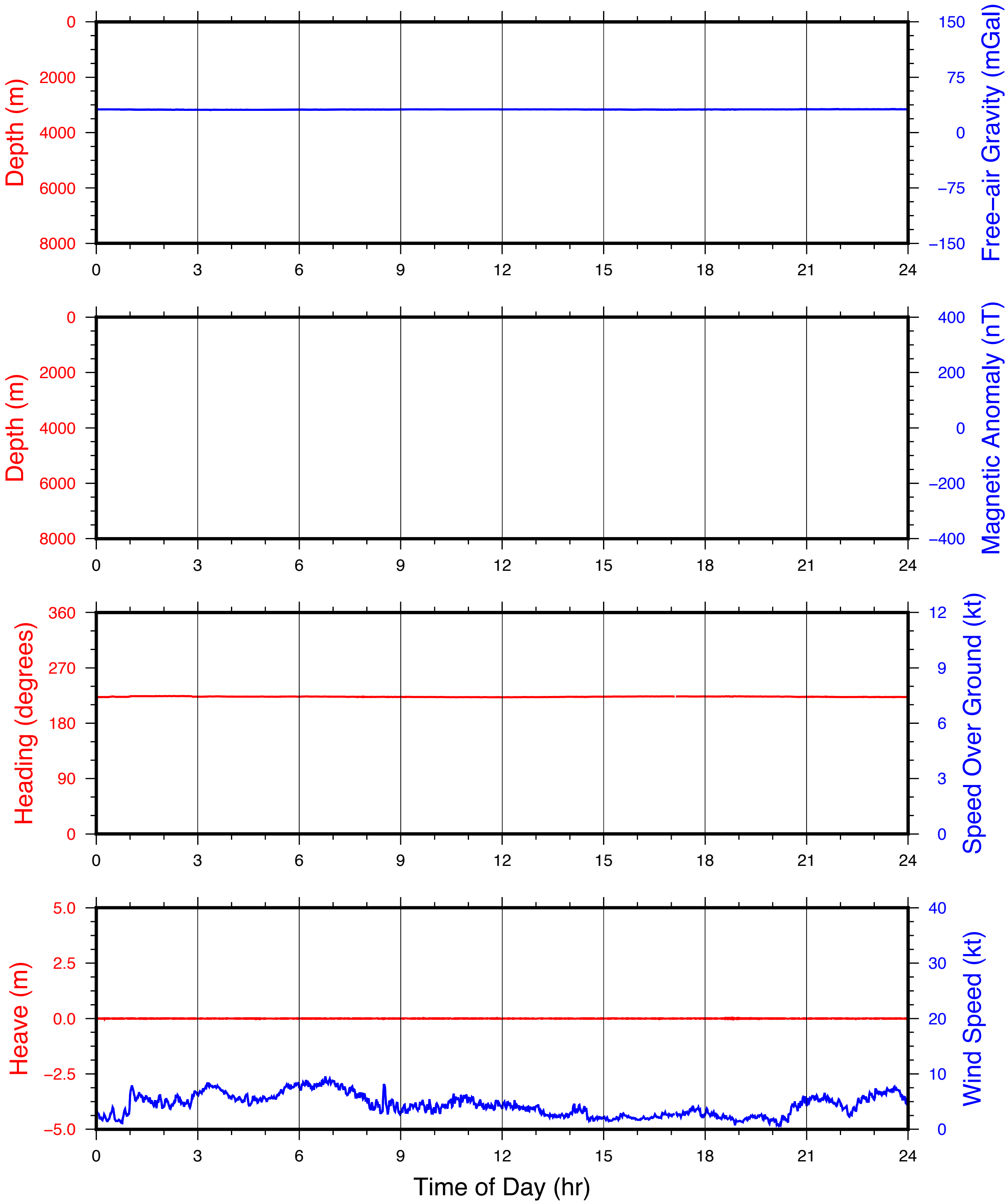
Appendix F. Daily Plots of Underway Data

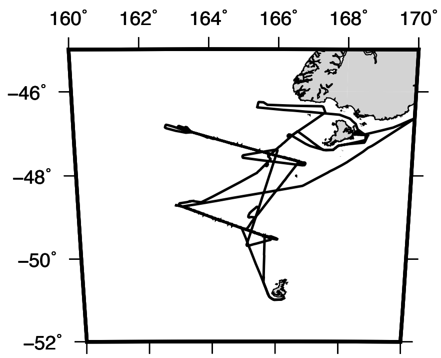


MGL1803

JD48
17 Feb 2018
UTC 00:00:00 – 23:59:59

Dockside Dunedin
MOB





MGL1803

JD49
18 Feb 2018
UTC 00:00:00 – 23:59:59

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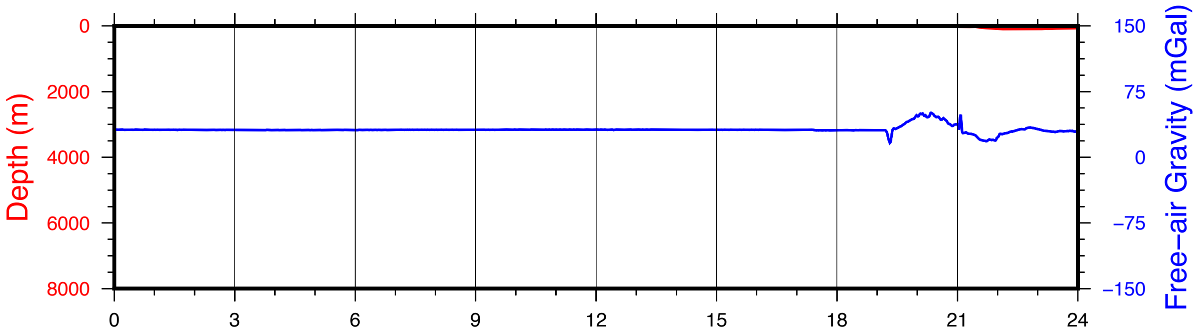
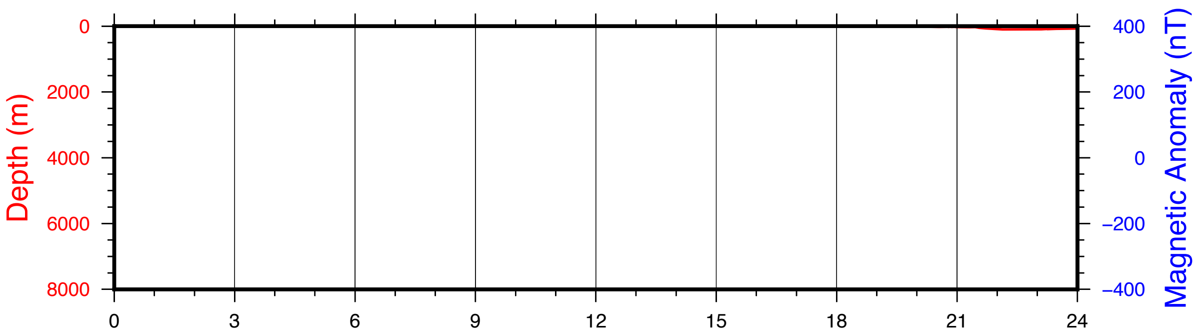
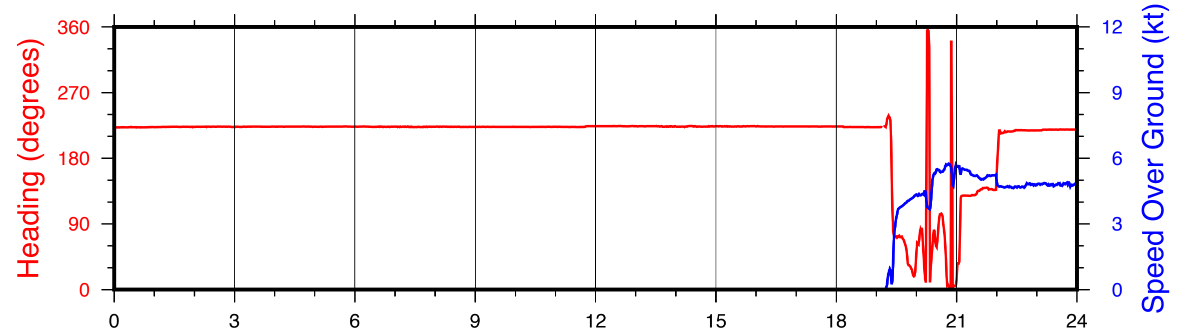
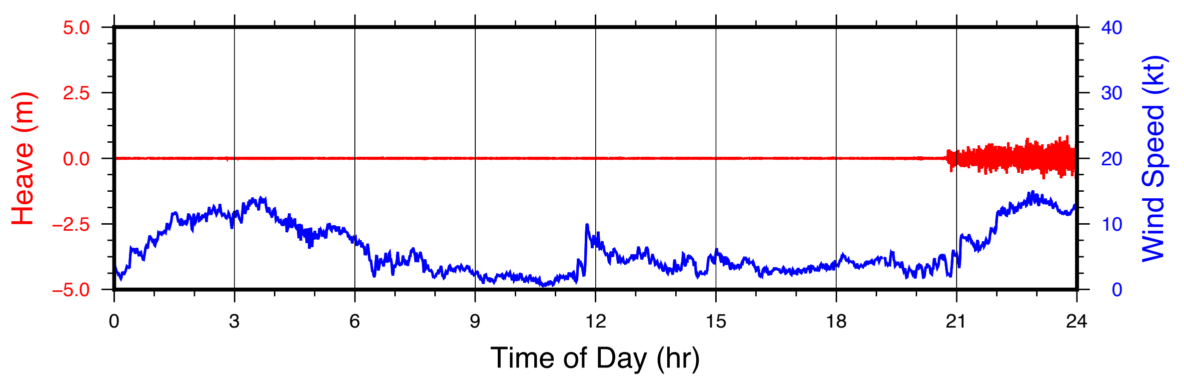
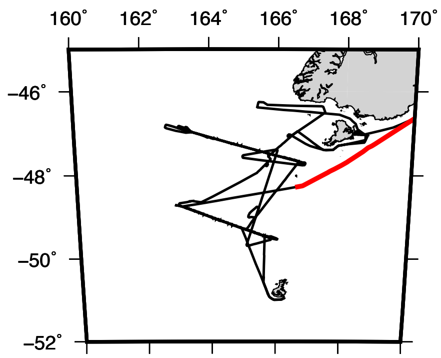






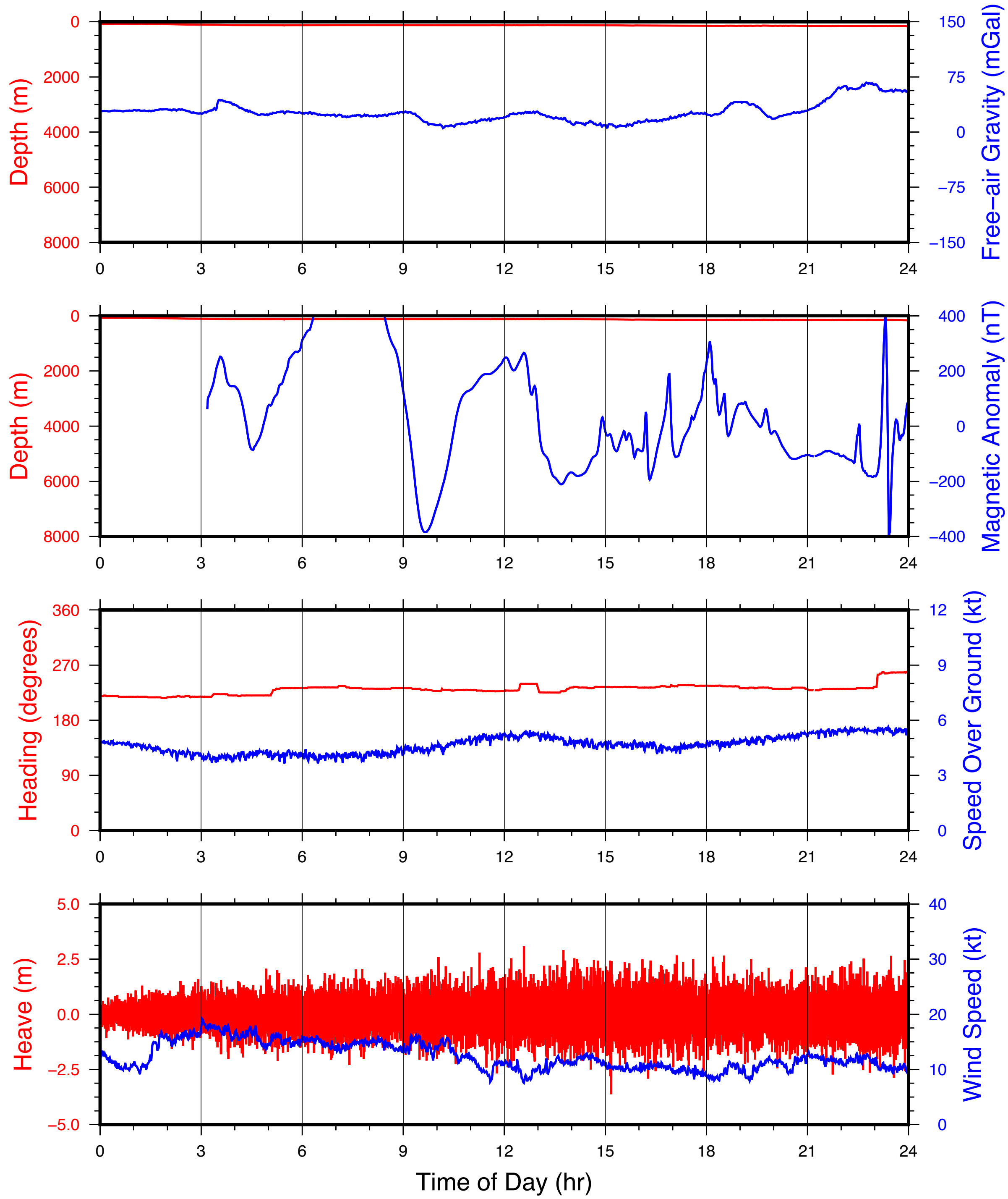


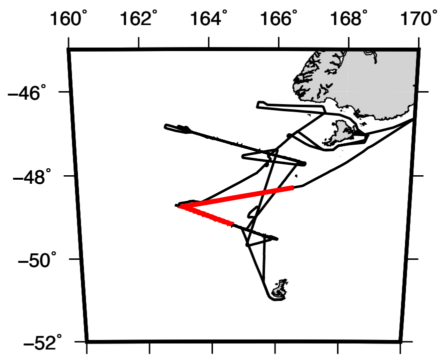


MGL1803

JD50
19 Feb 2018
UTC 00:00:00 – 23:59:59

Depart Dunedin
Transit to Survey Region

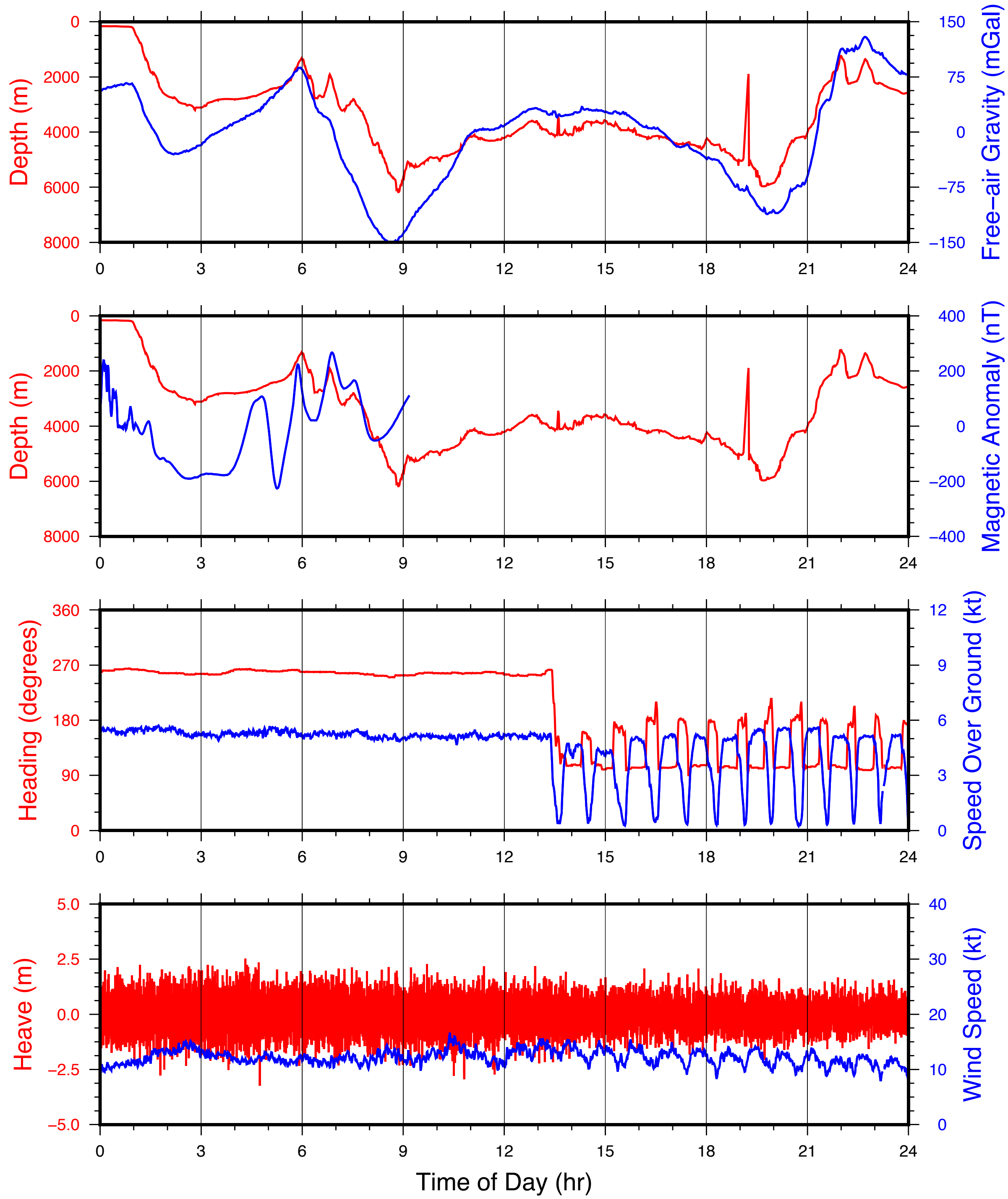


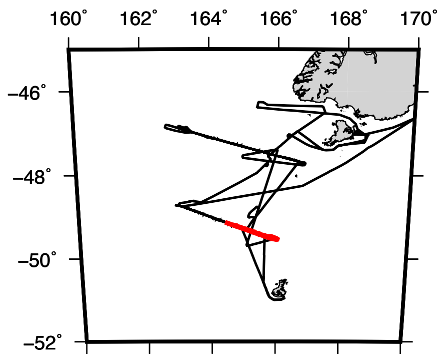


MGL1803

JD51
20 Feb 2018
UTC 00:00:00 – 23:59:59

Deploy OBS 101 to 113

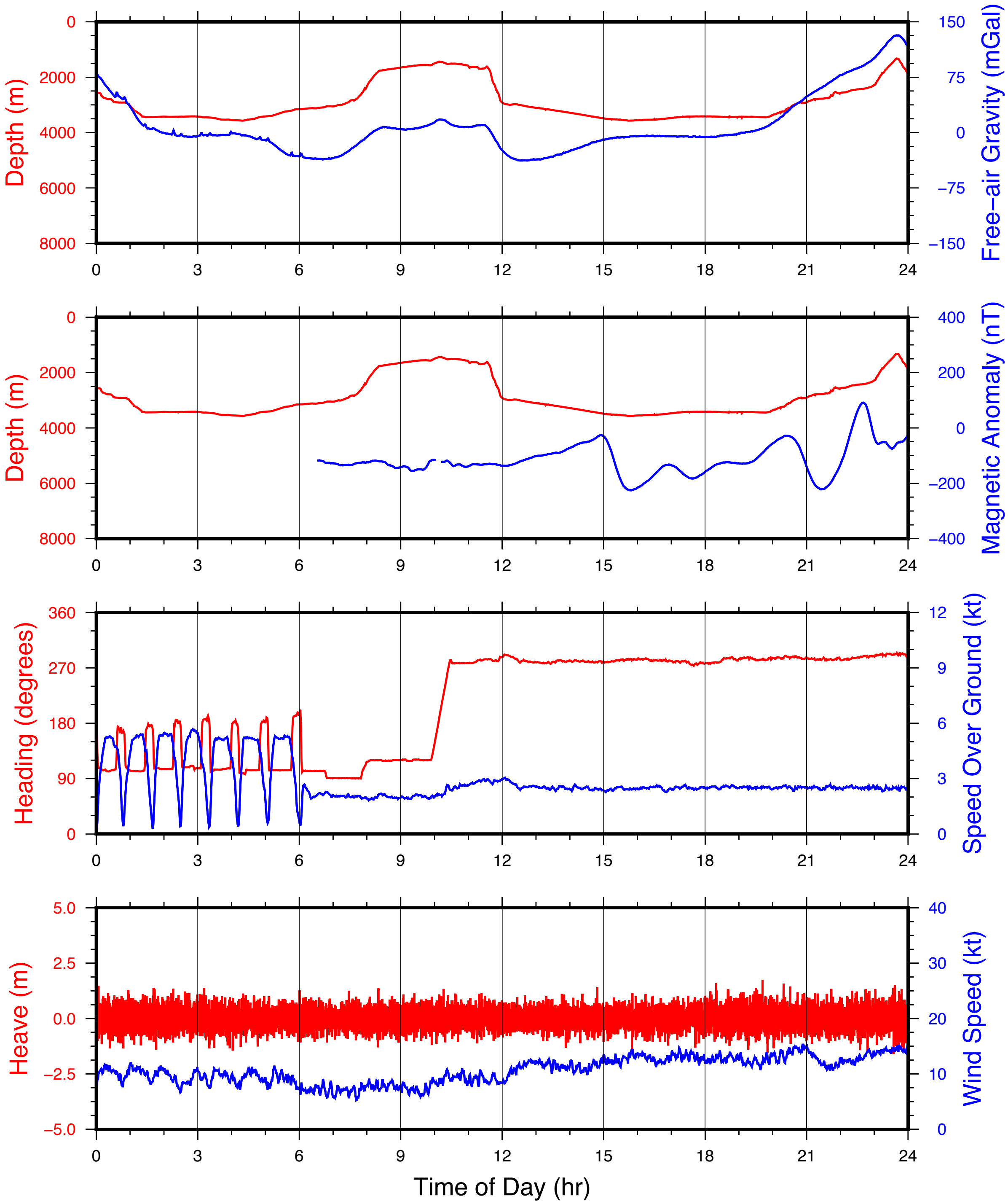


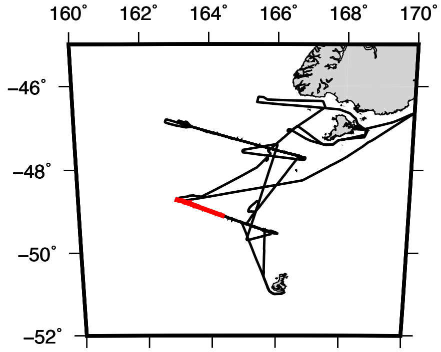


MGL1803

JD52
21 Feb 2018
UTC 00:00:00 – 23:59:59

Deploy OBS 114 to 120
Start shooting OBS Line 1

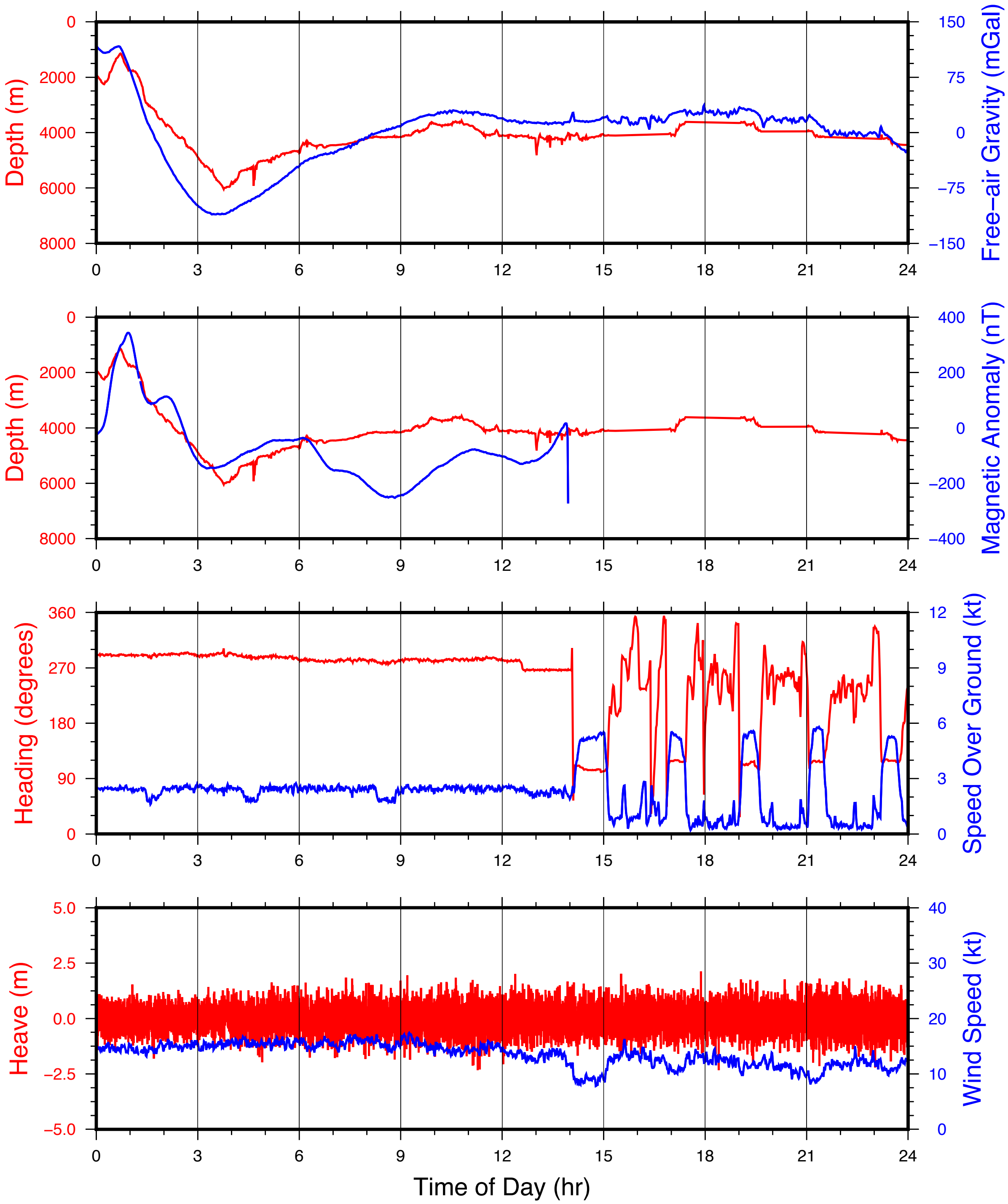


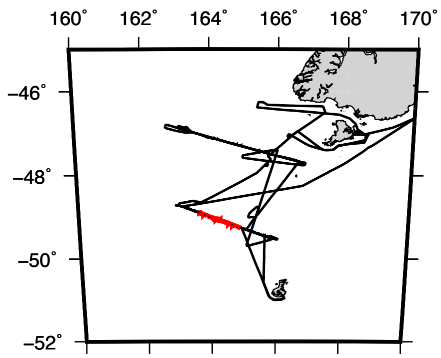


MGL1803

JD53
22 Feb 2018
UTC 00:00:00 – 23:59:59

Finish shooting OBS Line 1
Recover OBS 101 to 104

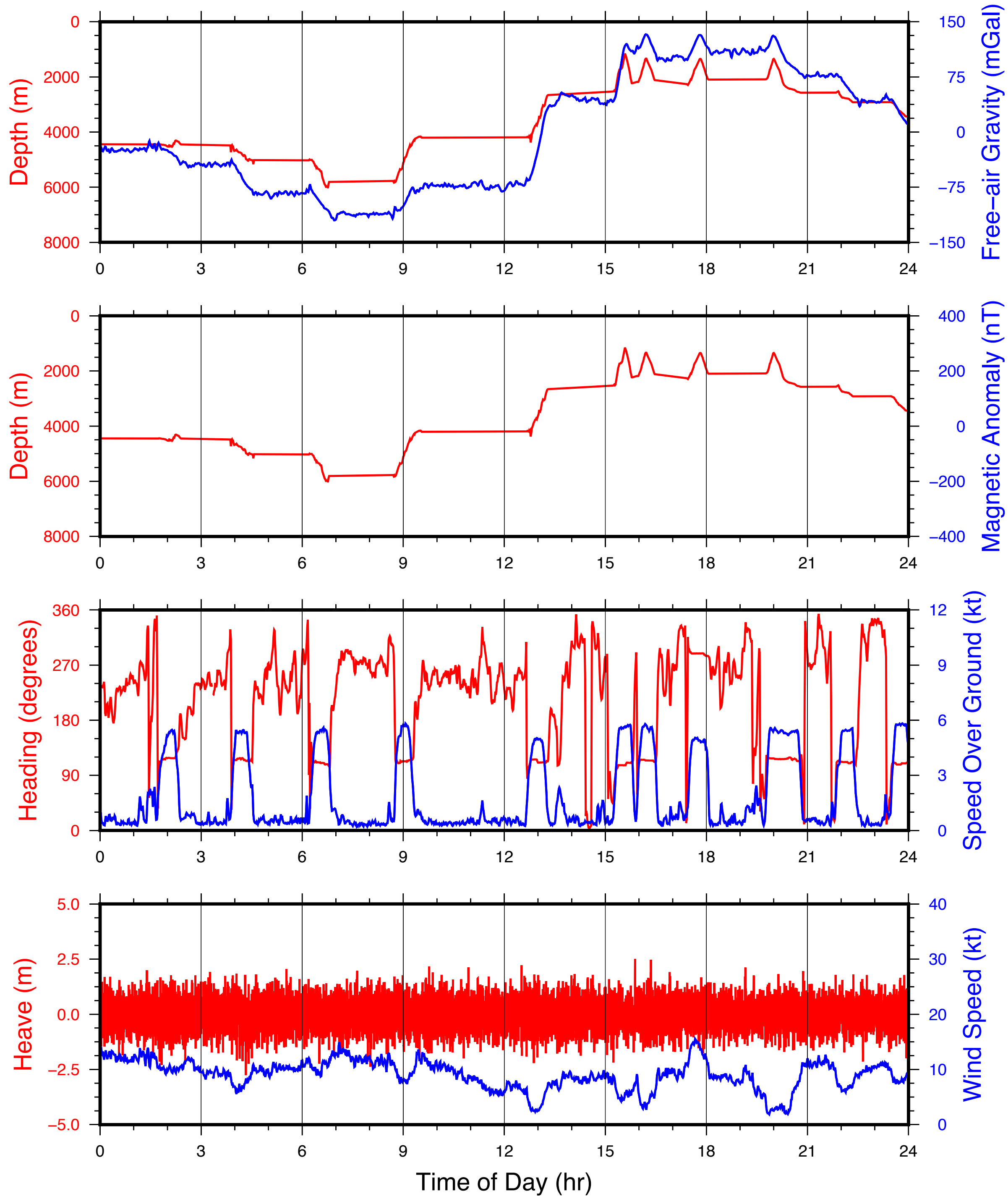


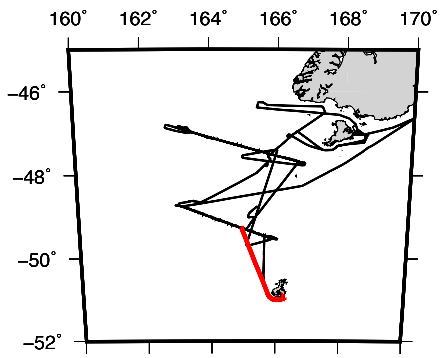


MGL1803

JD54
23 Feb 2018
UTC 00:00:00 – 23:59:59

Recover OBS 105 to OBS 114

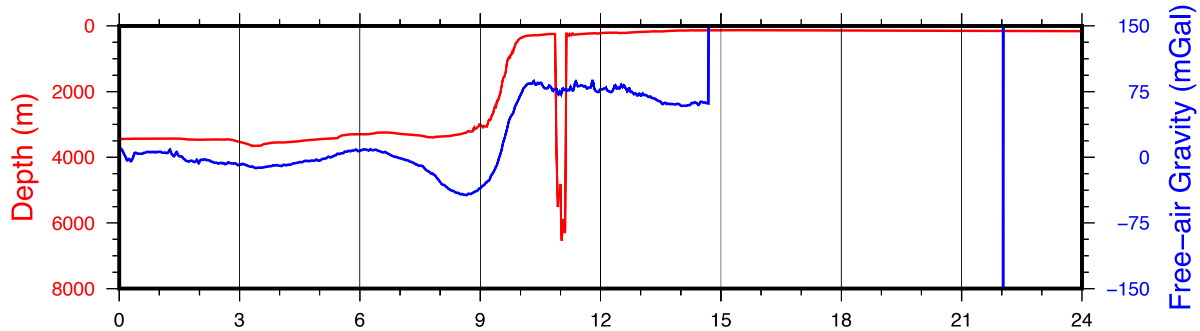


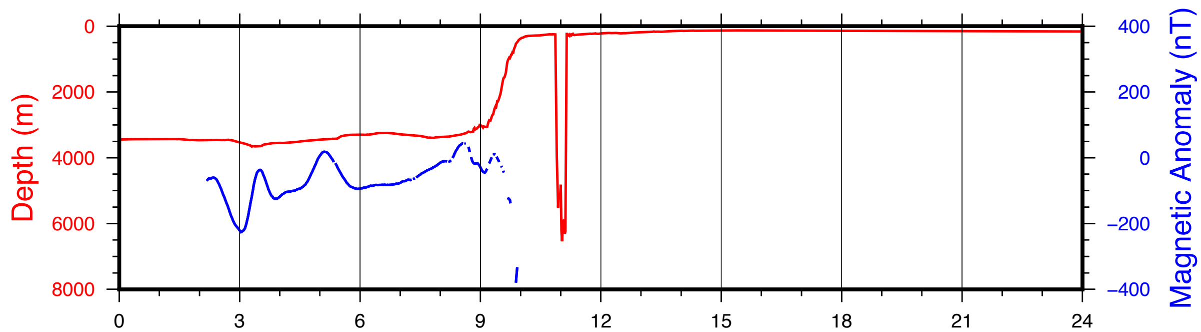


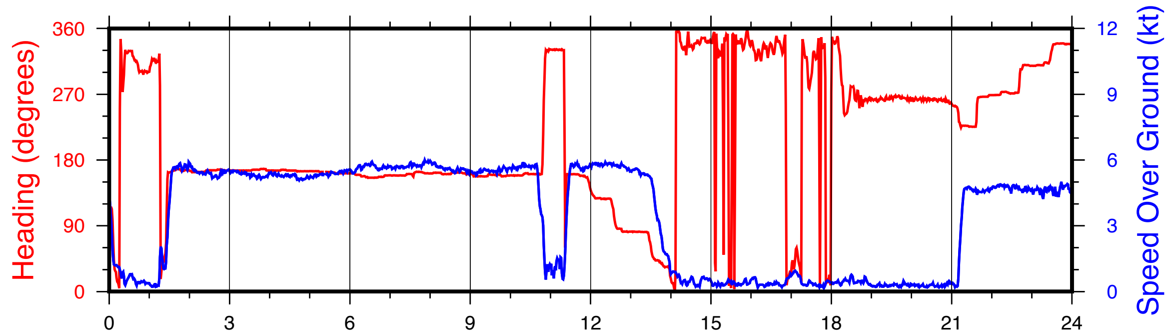
MGL1803

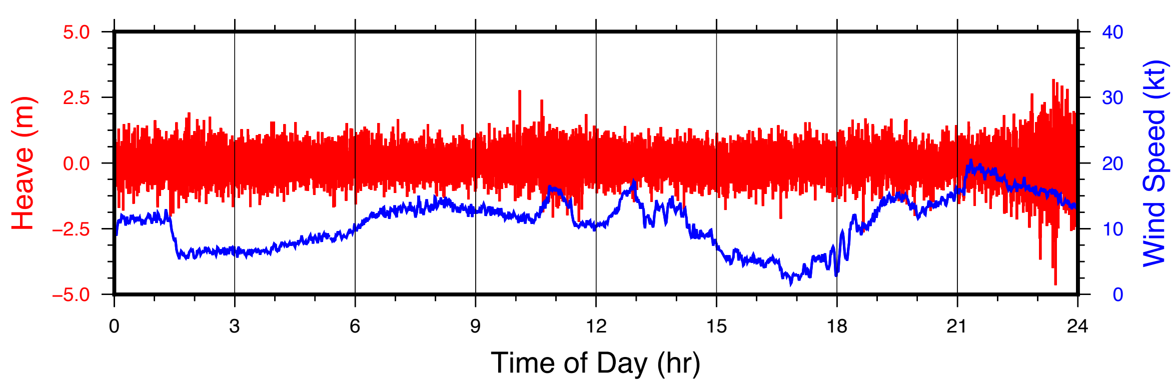
JD55
24 Feb 2018
UTC 00:00:00 – 23:59:59

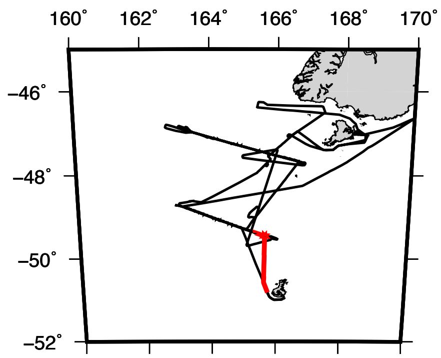
Recover OBS 115
Transit SE to Auckland Island
Gravity malfunction







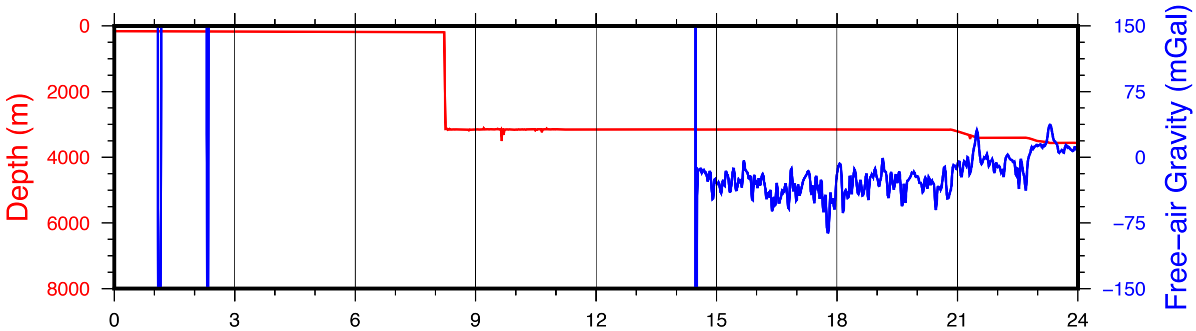


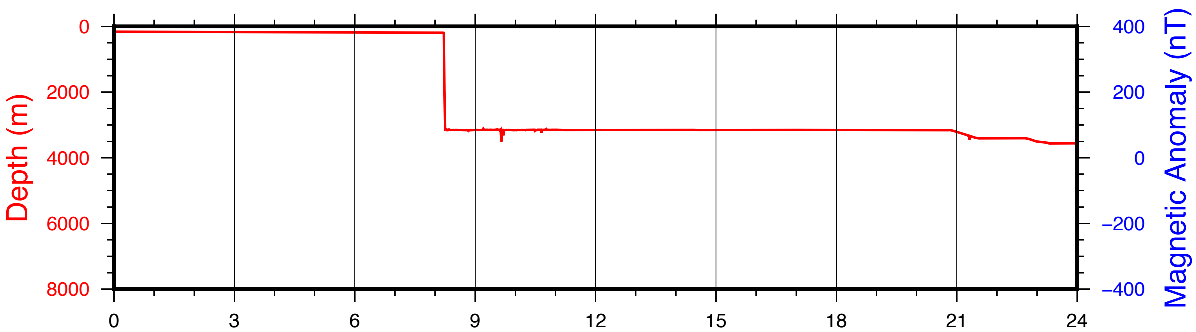


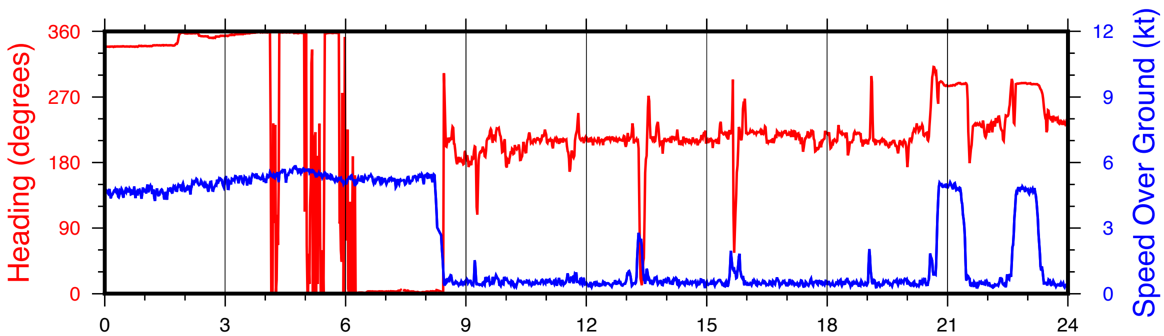
MGL1803

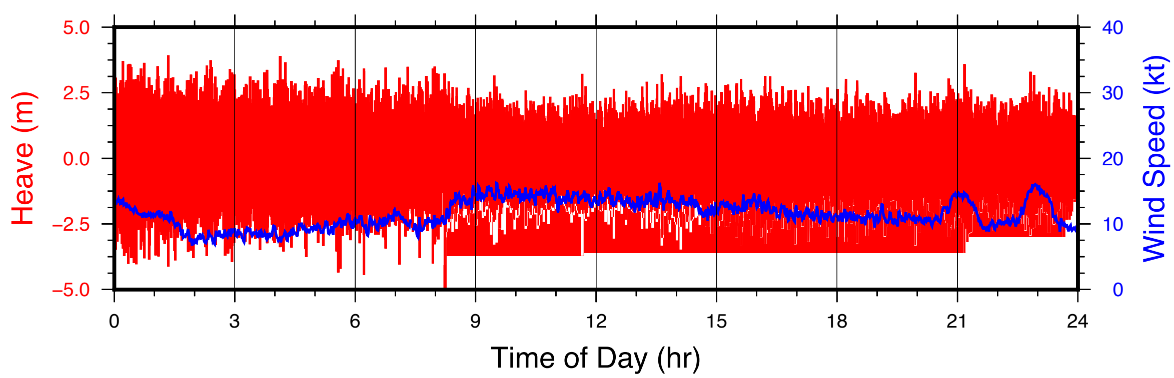
JD56
25 Feb 2018
UTC 00:00:00 – 23:59:59

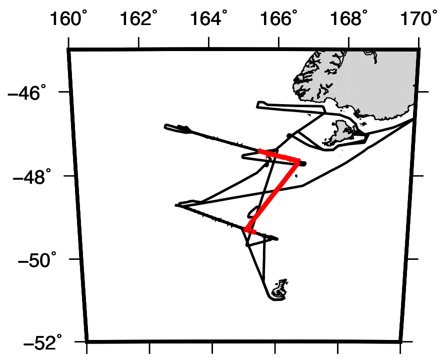
Auckland Island
Return OBS Line 1
Gravity On
Recover OBS 120−119







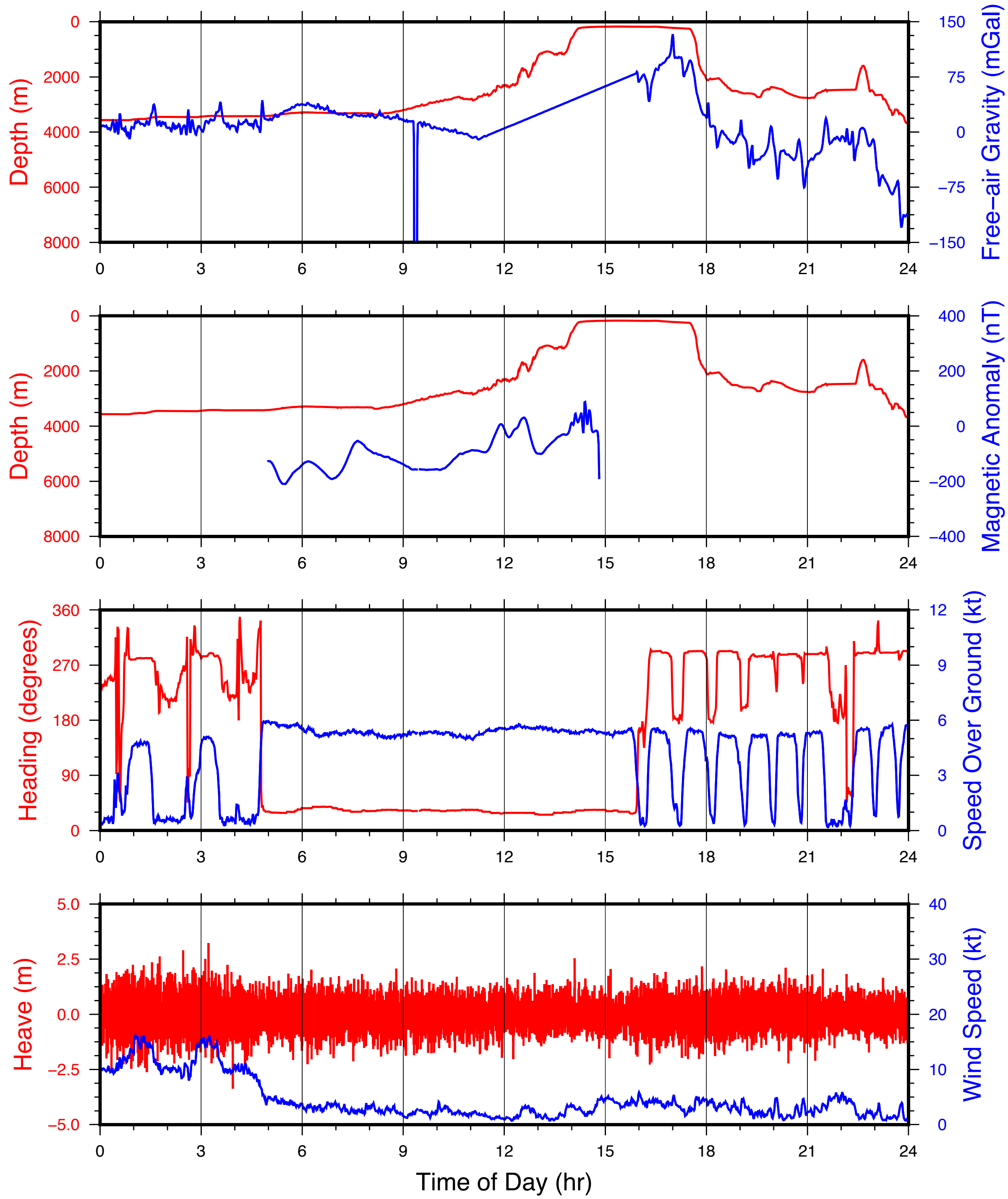


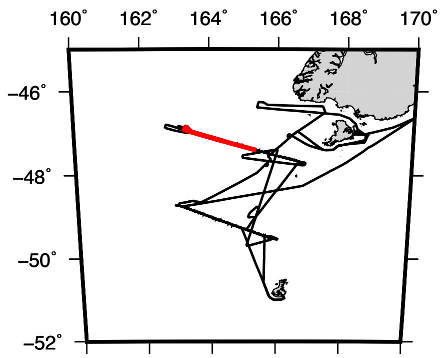


MGL1803

JD57
26 Feb 2018
UTC 00:00:00 – 23:59:59

Recover OBS 118 to 116
Transit to OBS Line 2
Deploy OBS 223 to 215

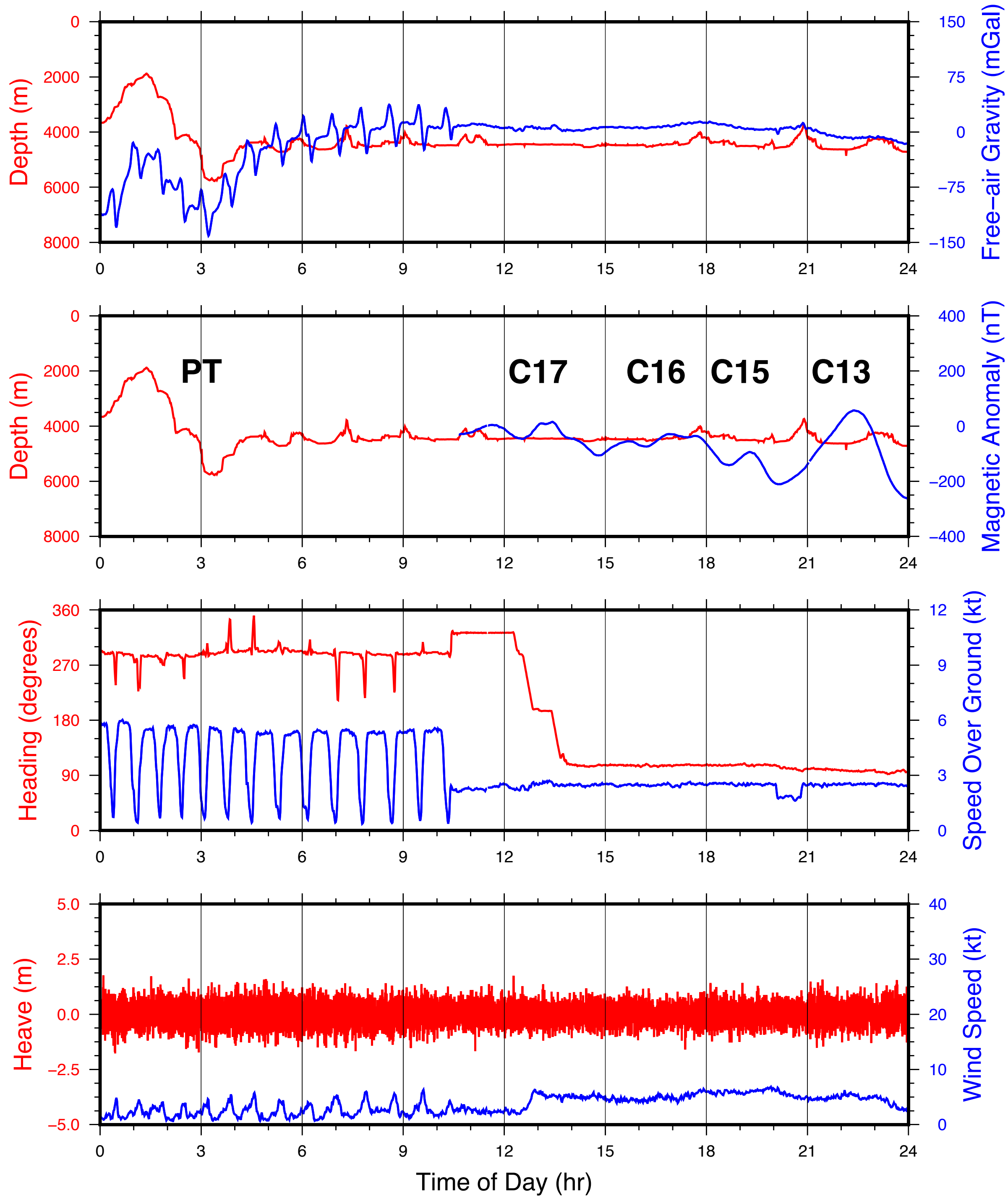


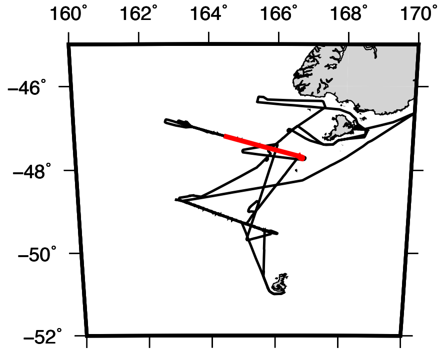


MGL1803

JD58
27 Feb 2018
UTC 00:00:00 – 23:59:59

Deploy OBS 214 to 201
Start shooting OBS line 2

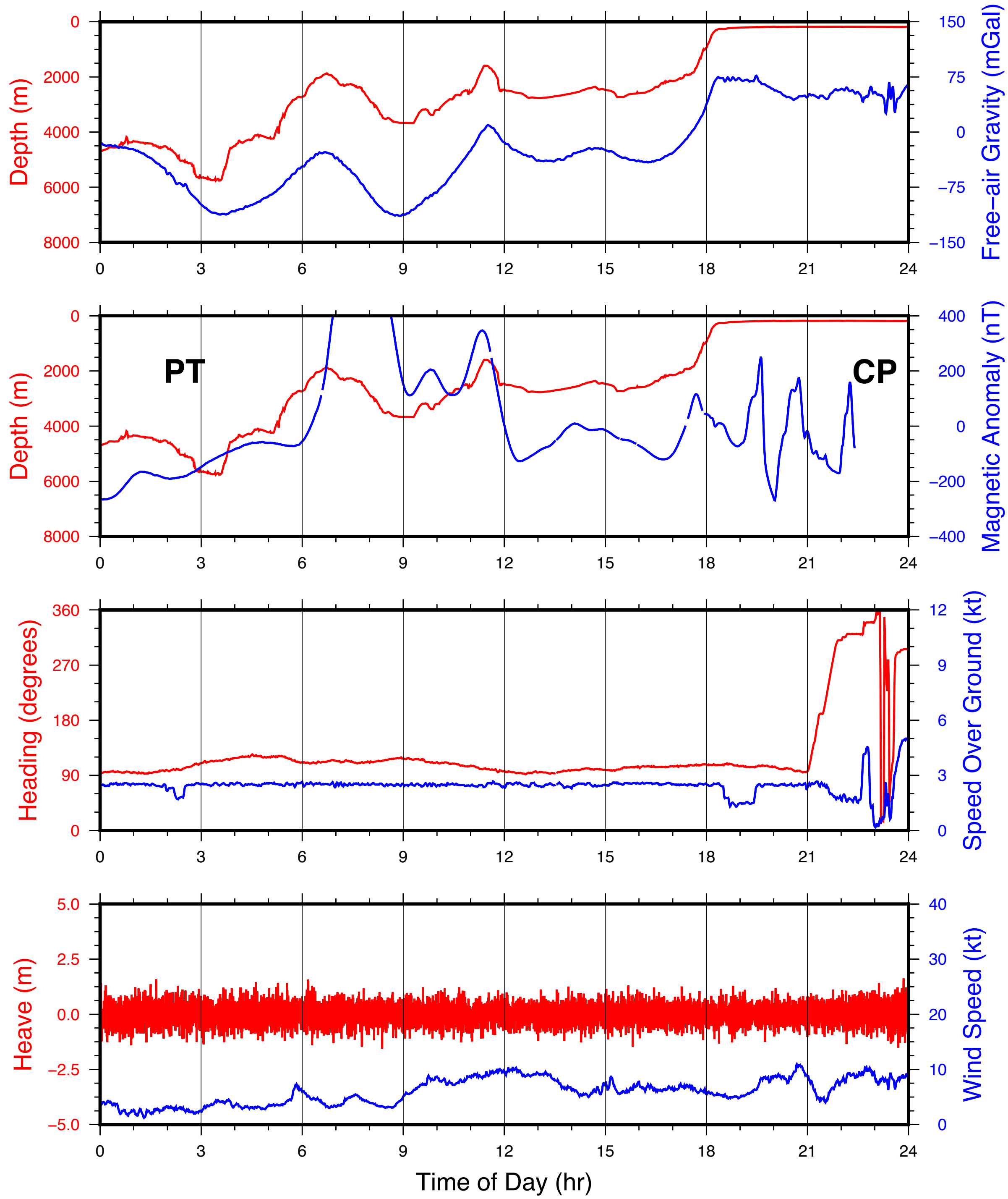


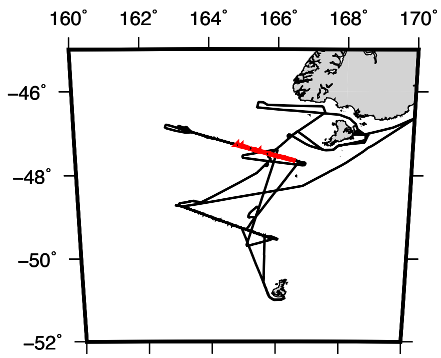


MGL1803

JD59
28 Feb 2018
UTC 00:00:00 – 23:59:59

Complete shooting OBS line 2
Recover OBS 223

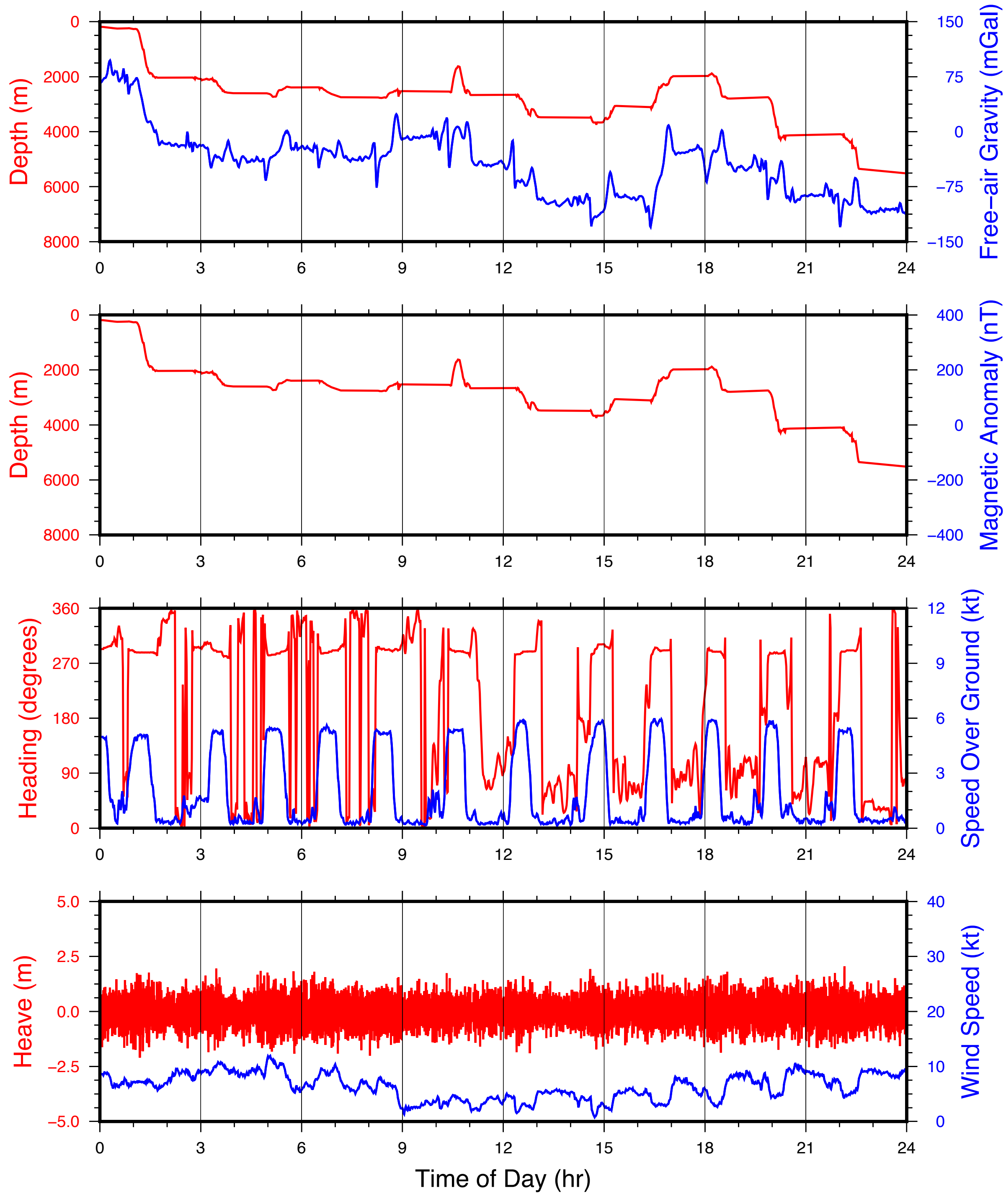


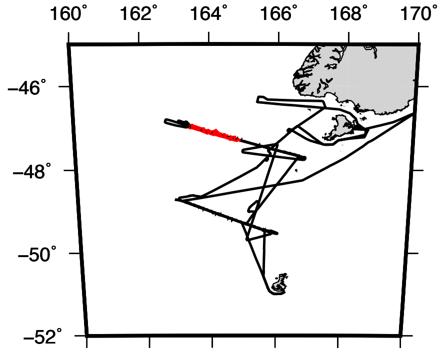


MGL1803

JD60
01 Mar 2018
UTC 00:00:00 – 23:59:59

Recover OBS 222 to 211

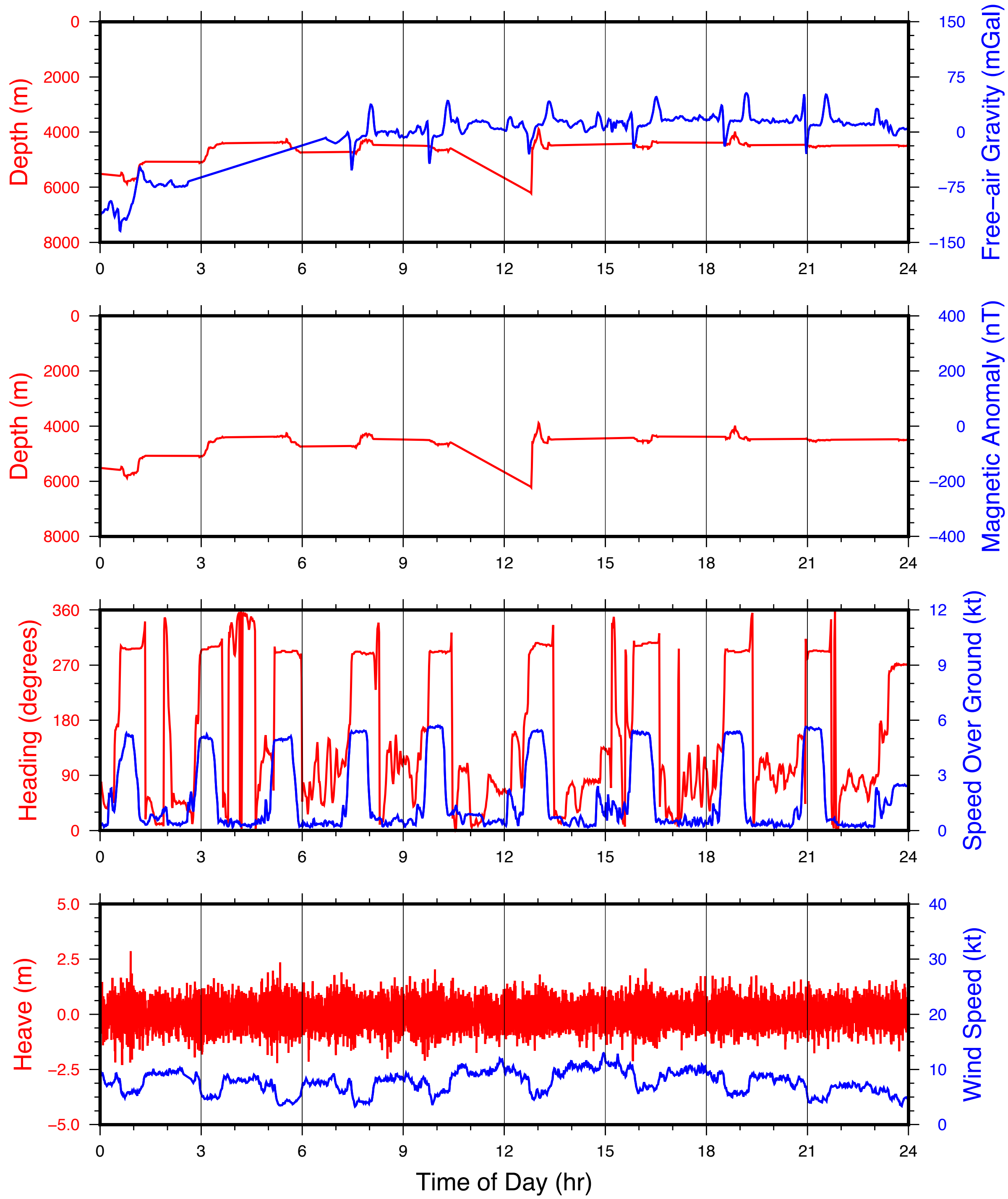


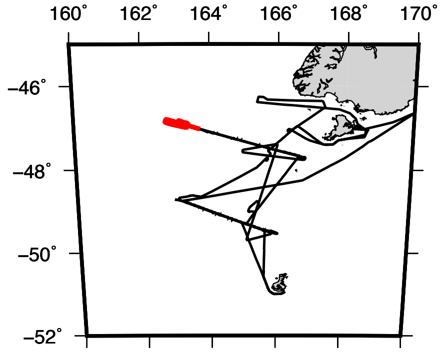


MGL1803

JD61
02 Mar 2018
UTC 00:00:00 − 23:59:59

Recover OBS 210 to 201

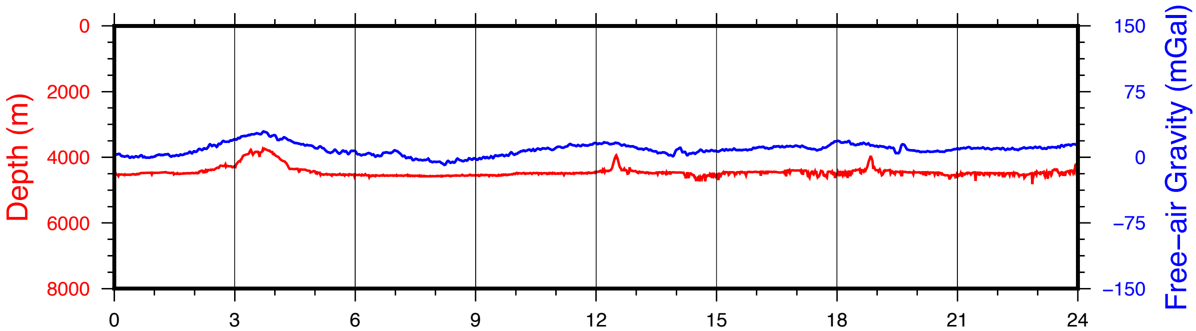


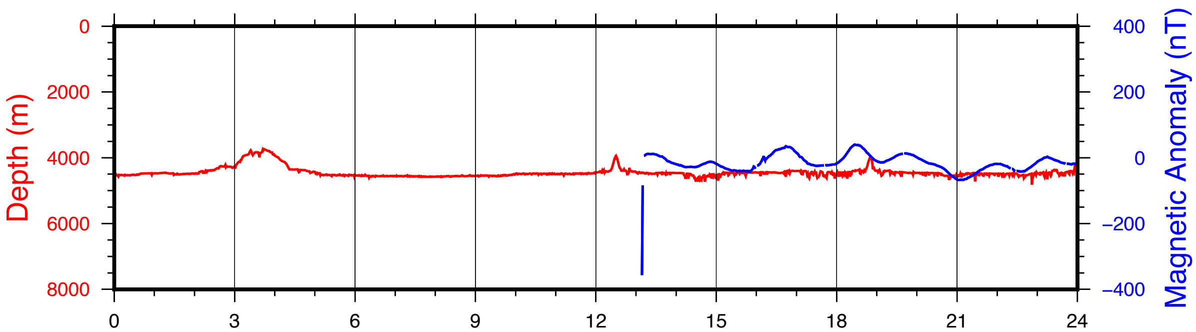


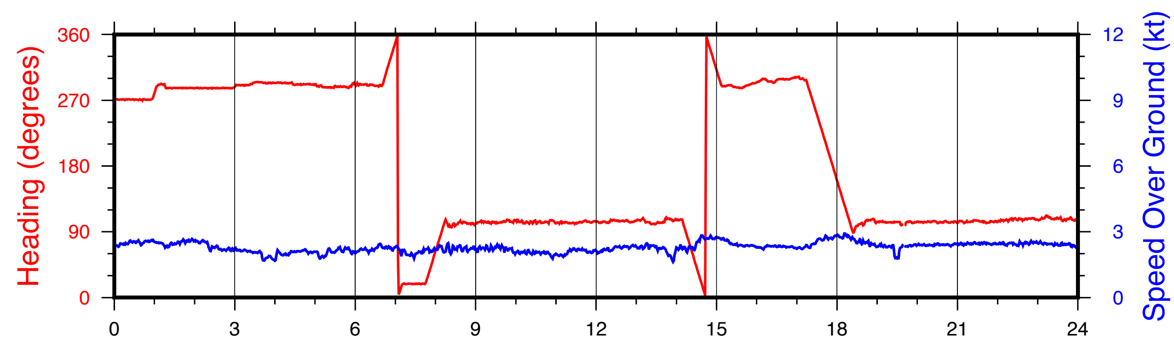
MGL1803

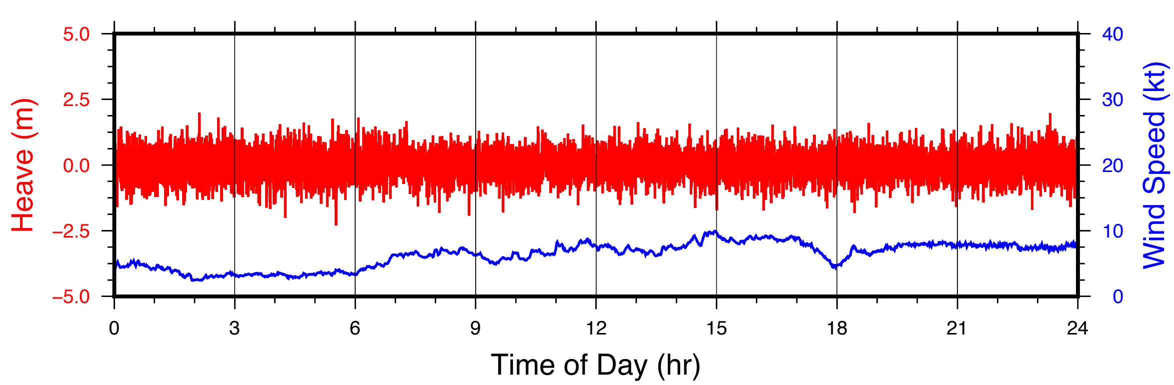
JD62
03 Mar 2018
UTC 00:00:00 – 23:59:59

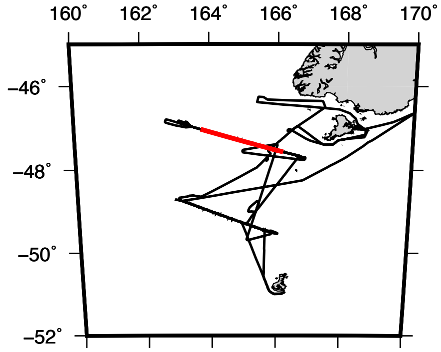
Deploy 12.6 km streamer
Start shooting MC01







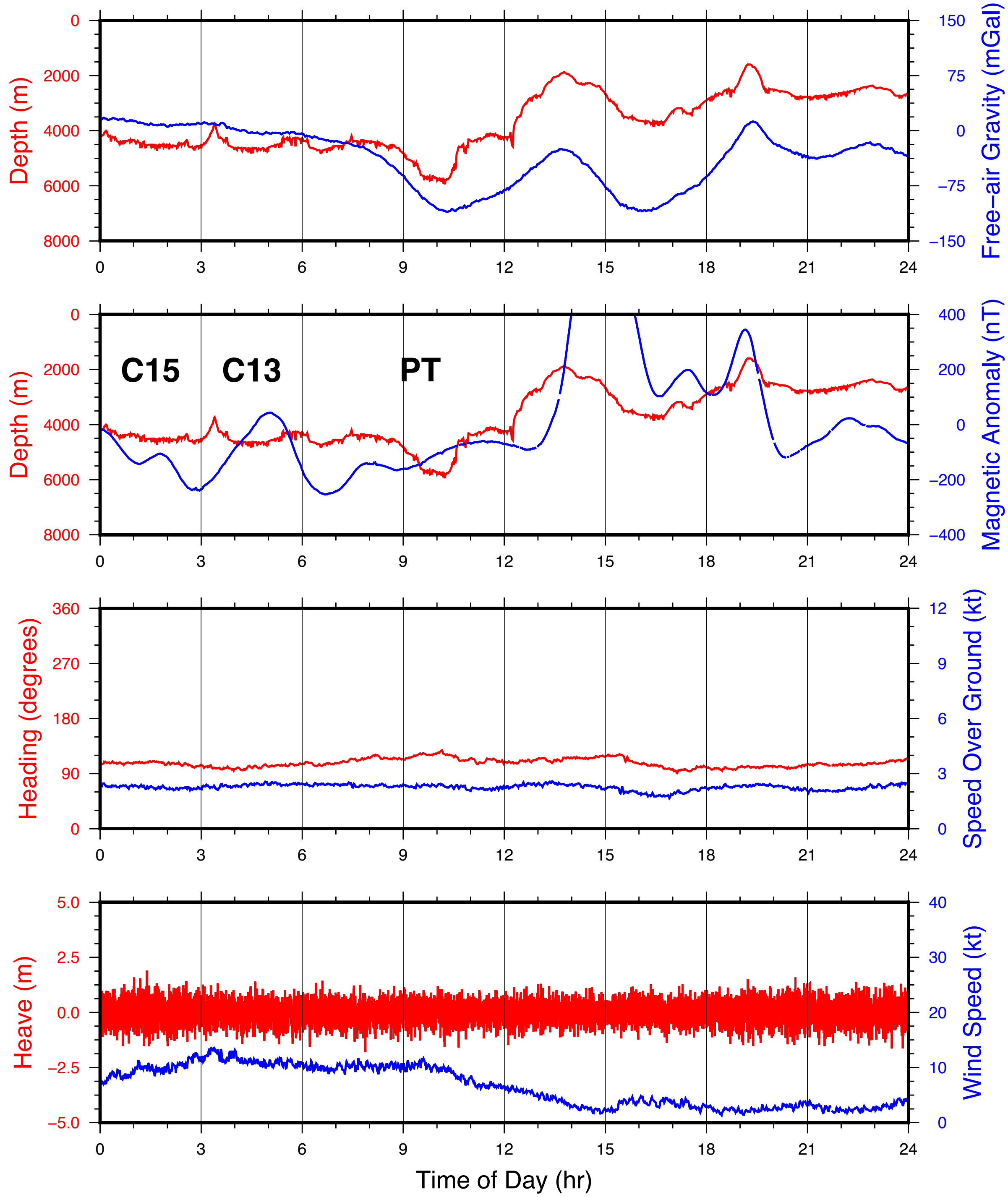


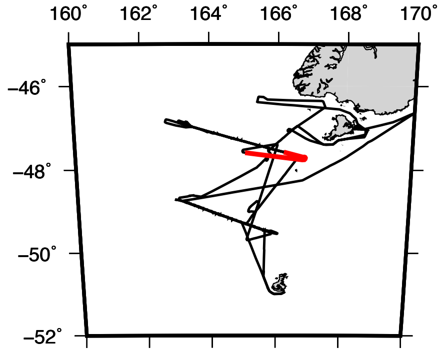


MGL1803

JD63
04 Mar 2018
UTC 00:00:00 – 23:59:59

MCS01

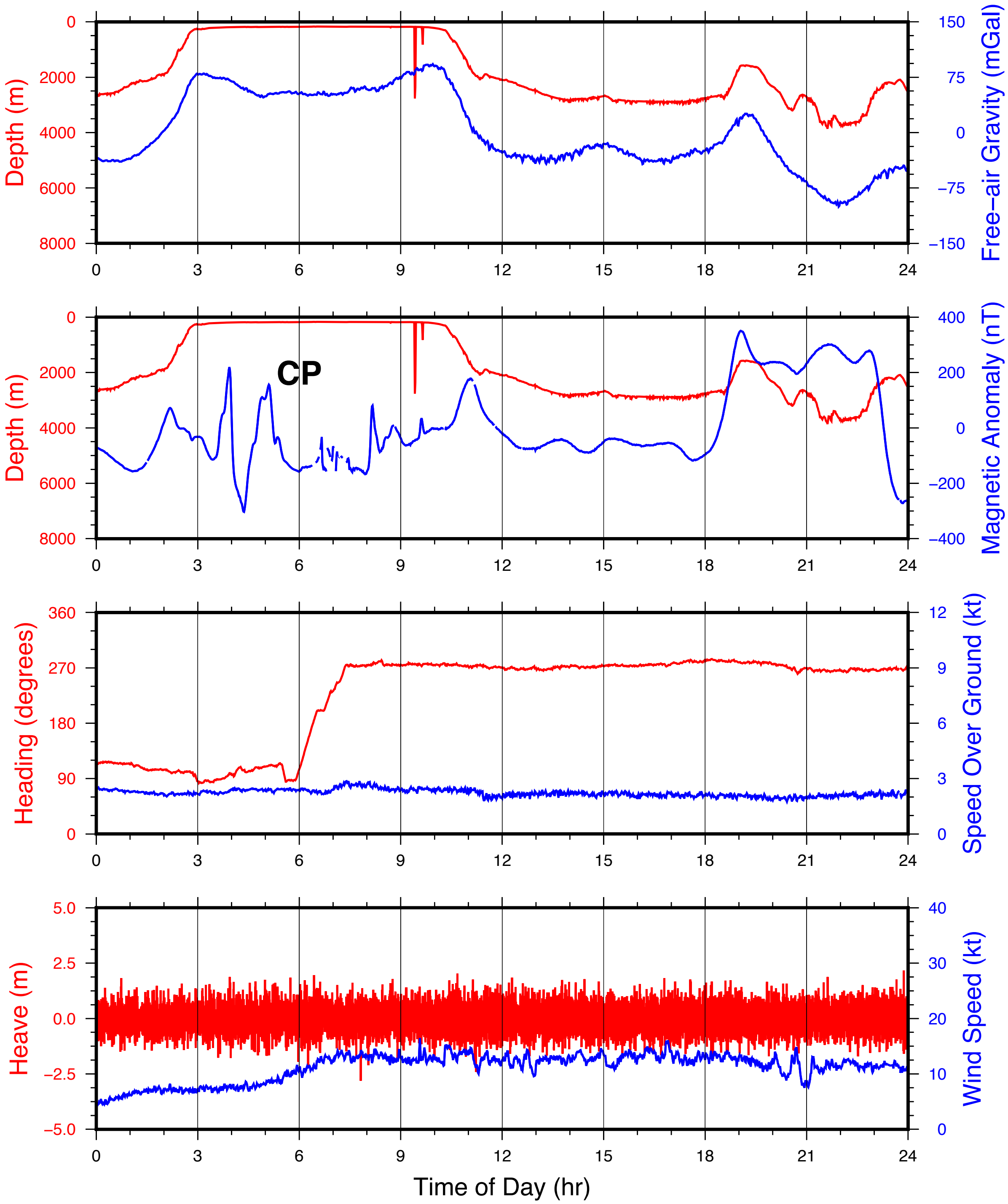


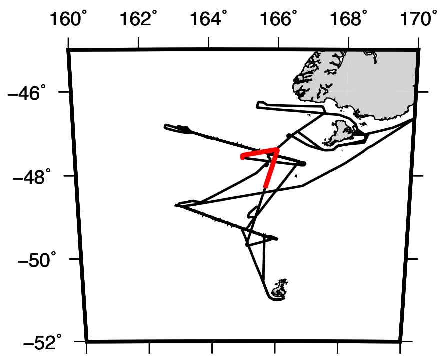


MGL1803

JD64
05 Mar 2018
UTC 00:00:00 – 23:59:59

Shooting MCS03a

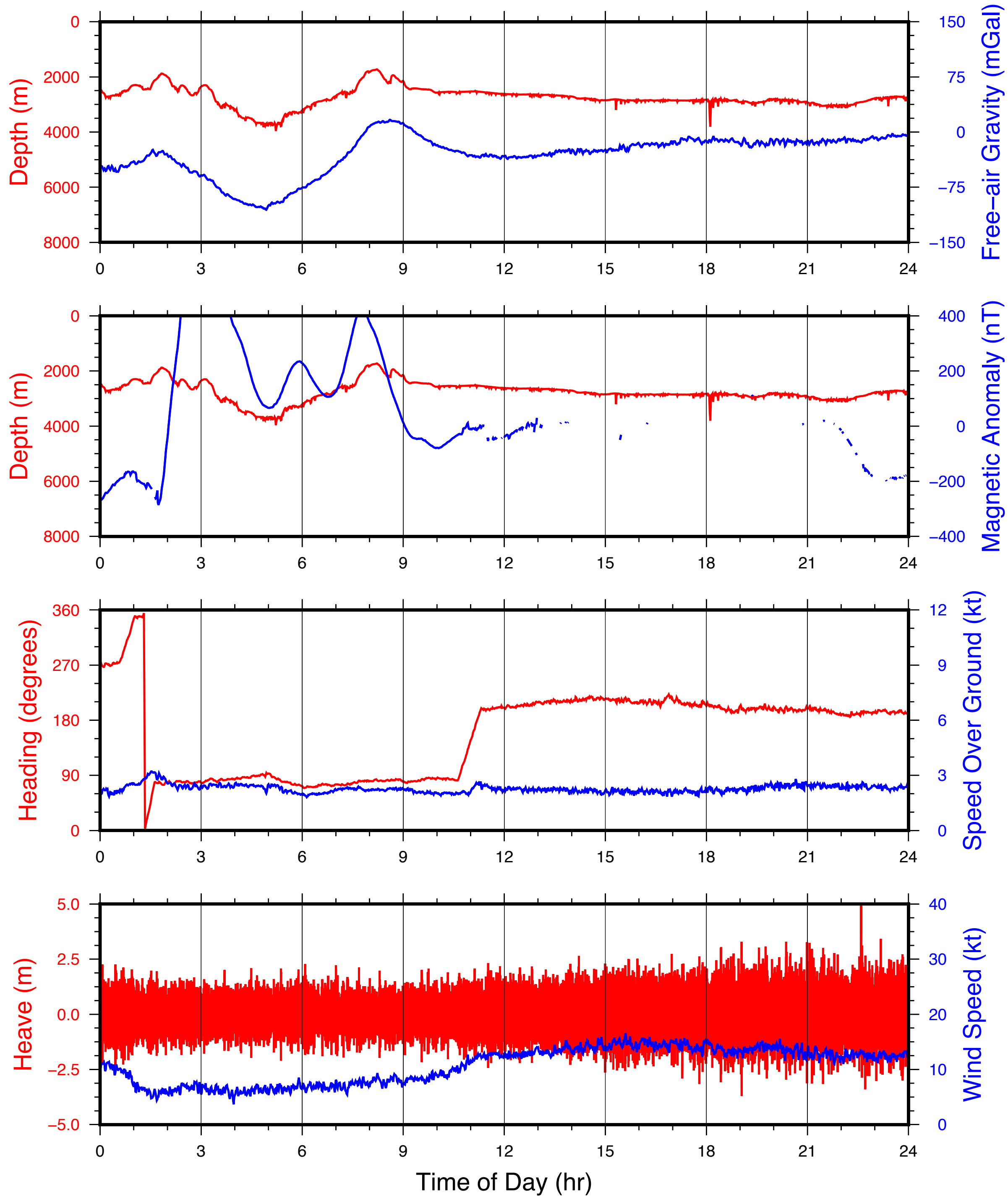


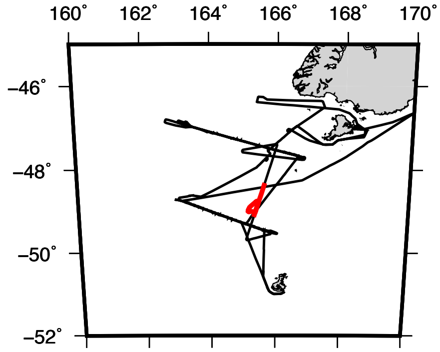


MGL1803

JD65
06 Mar 2018
UTC 00:00:00 – 23:59:59

MCS T01 Start MCS23a





MGL1803

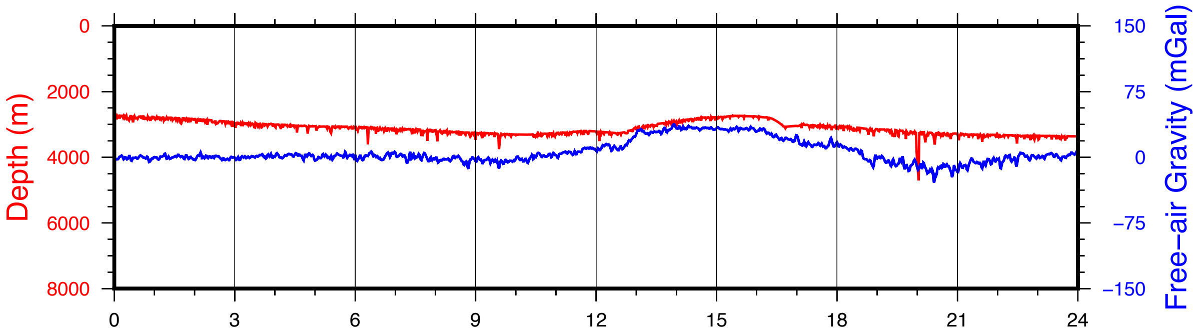
JD66
07 Mar 2018
UTC 00:00:00 – 23:59:59

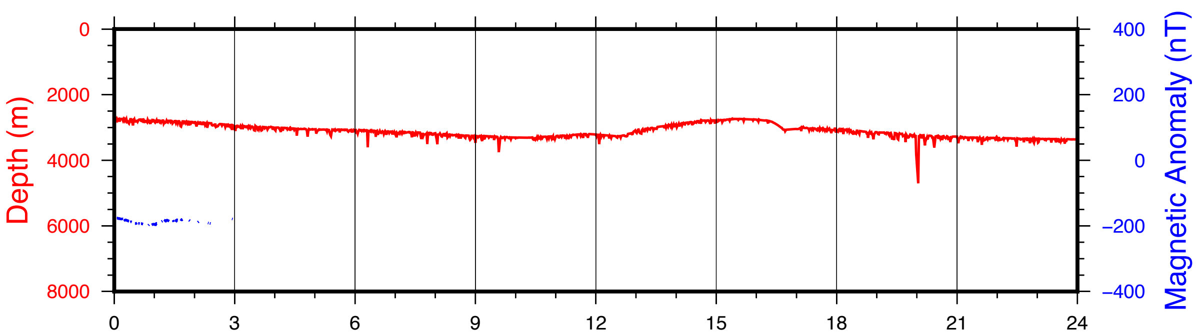
MCS23a

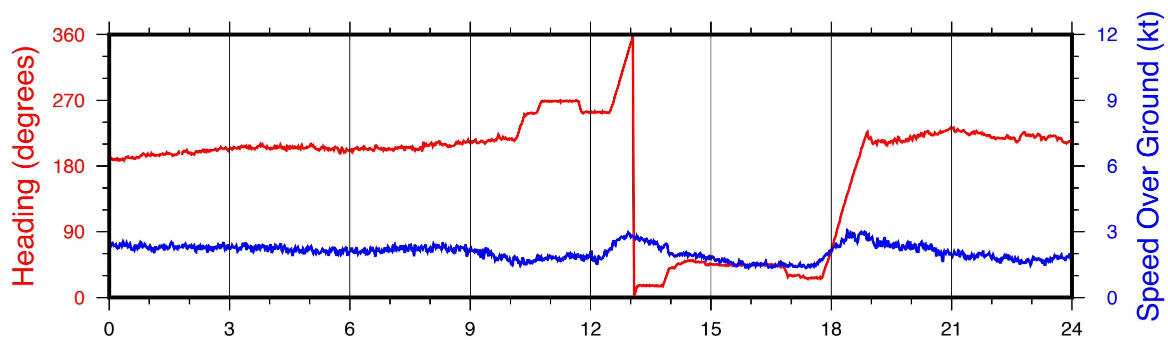
Array Tangled

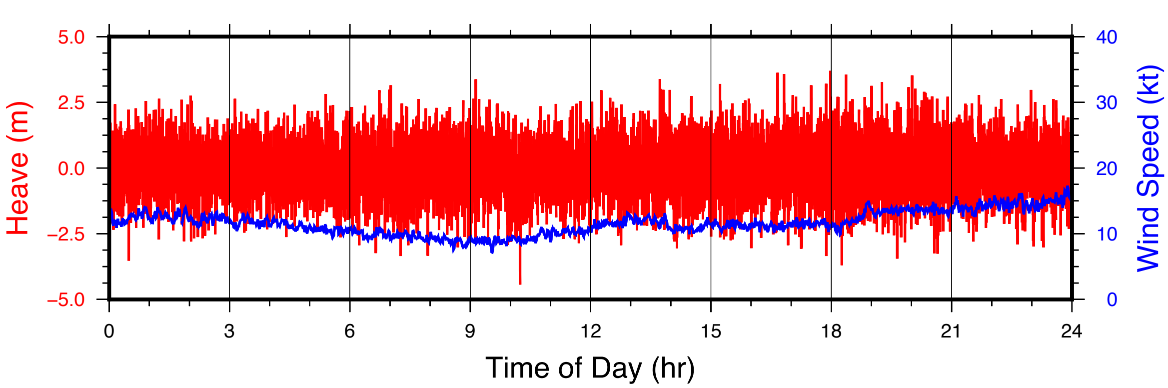
Circled back missing segment

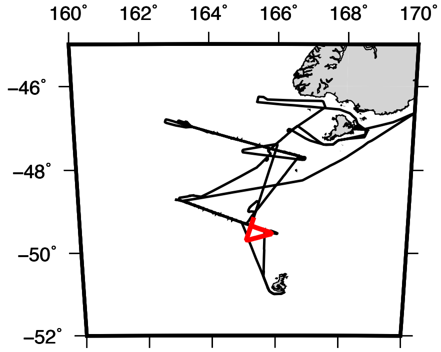
Started MCS23b







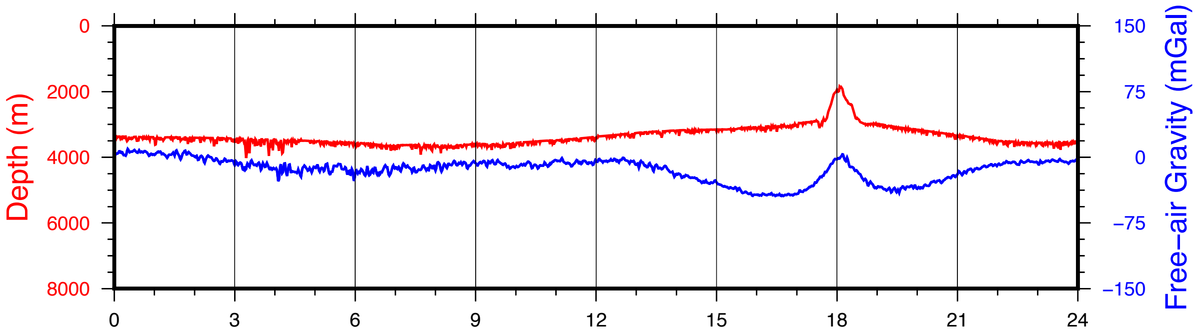


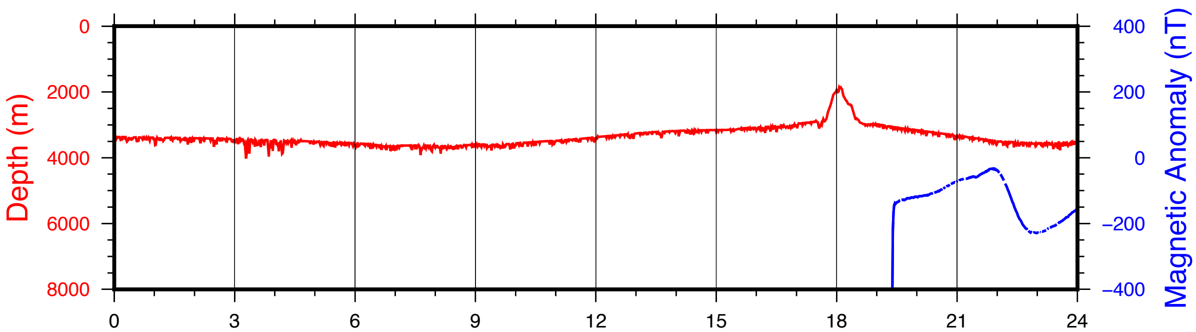


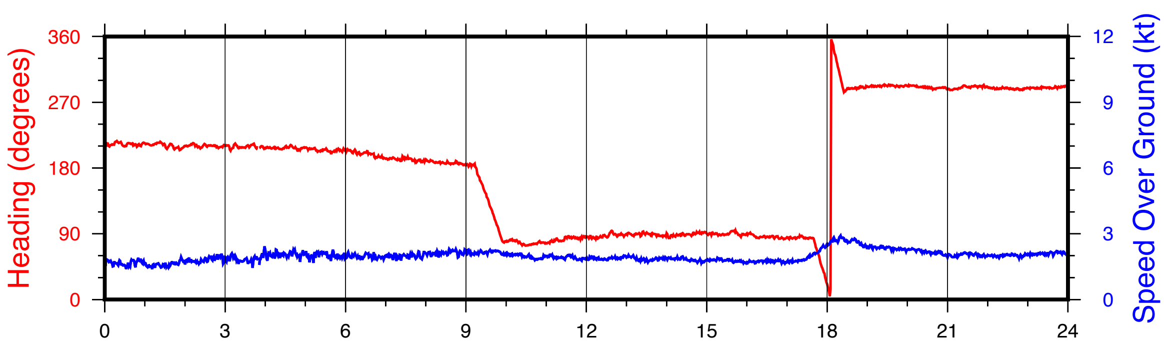
MGL1803

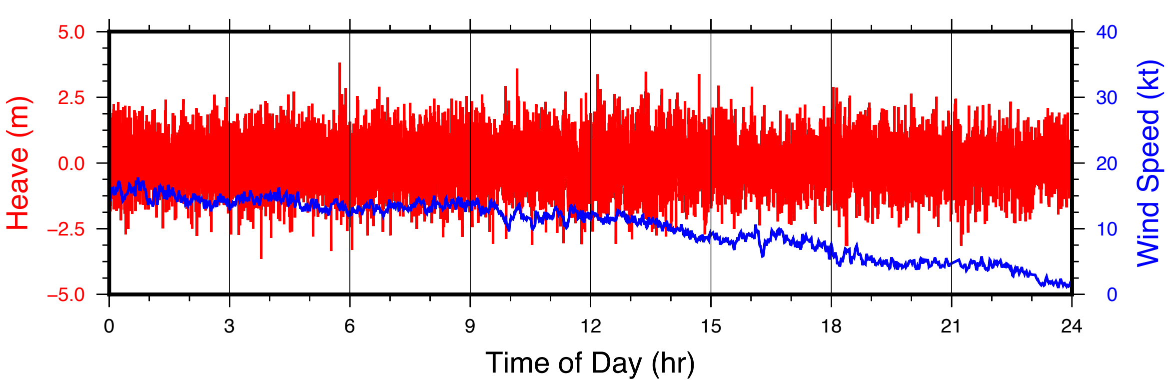
JD67
08 Mar 2018
UTC 00:00:00 – 23:59:59

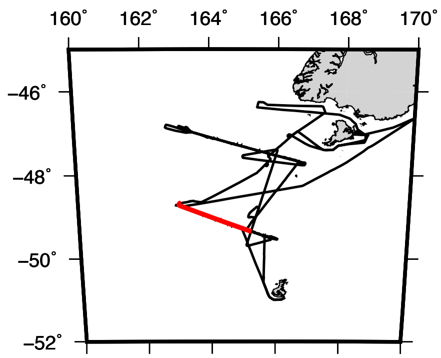
Finish MCS 23b
No shooting on transit
Started MCS14







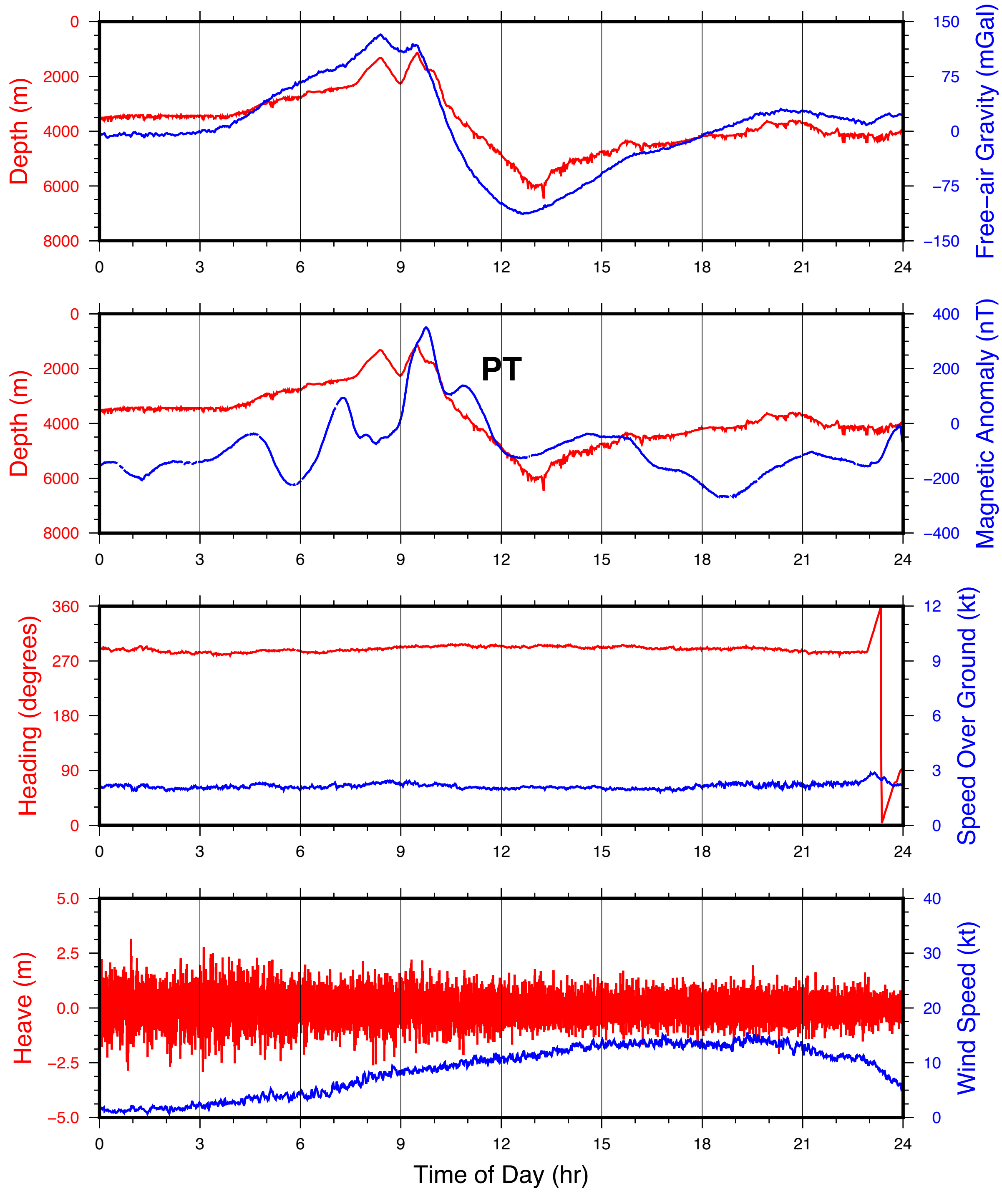


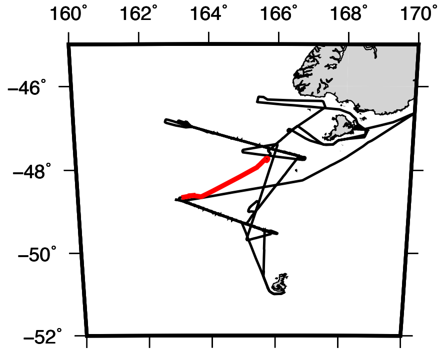


MGL1803

JD68
09 Mar 2018
UTC 00:00:00 – 23:59:59

MCS14

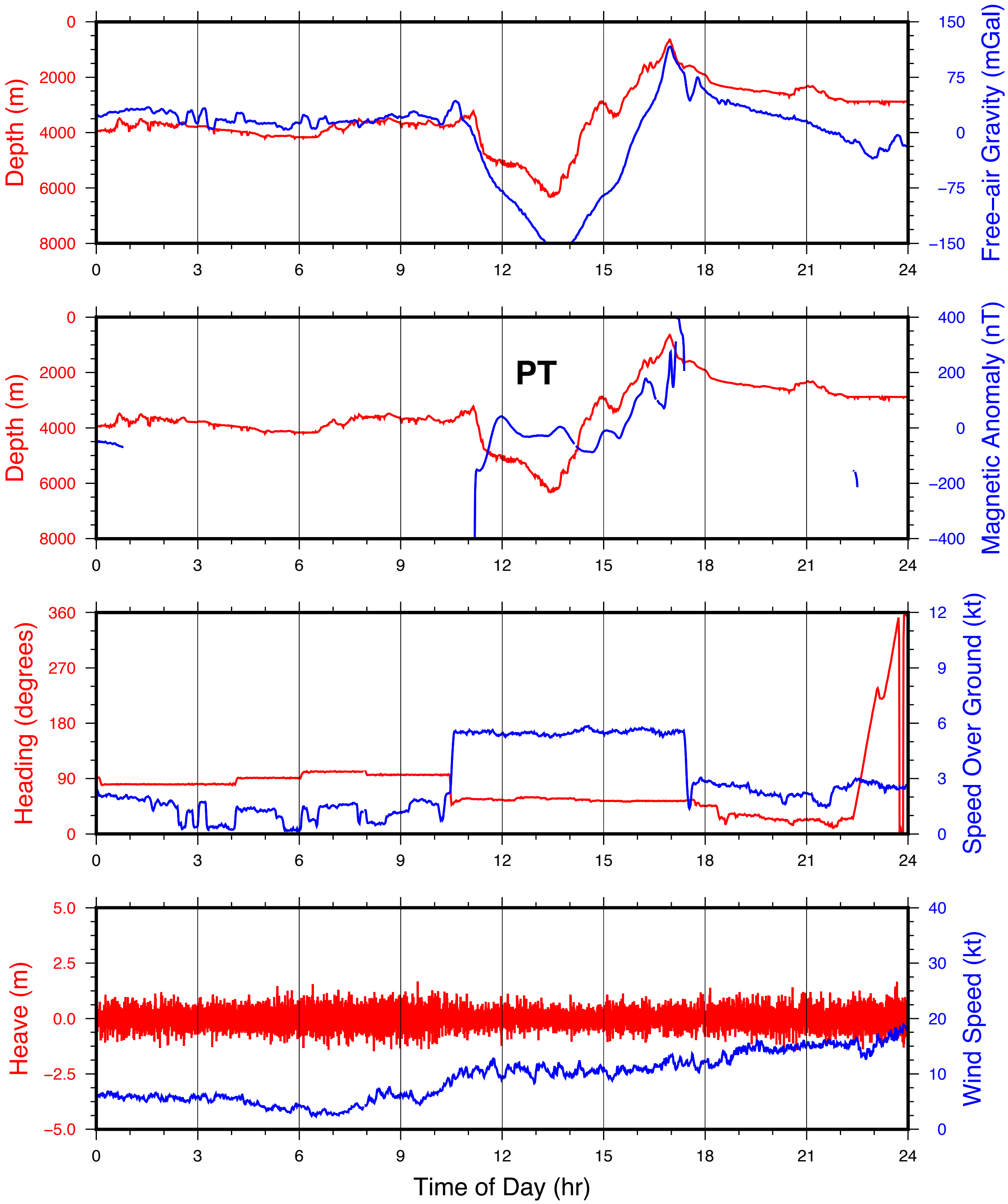


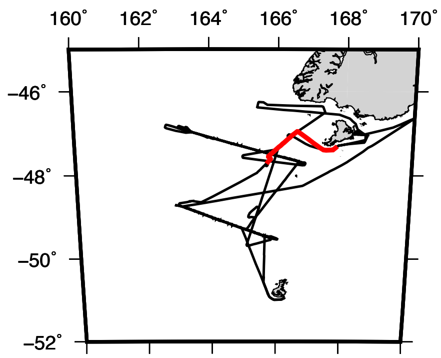


MGL1803

JD69
10 Mar 2018
UTC 00:00:00 – 23:59:59

Recover source and stremer
Transit North
Deploy guns and streamer

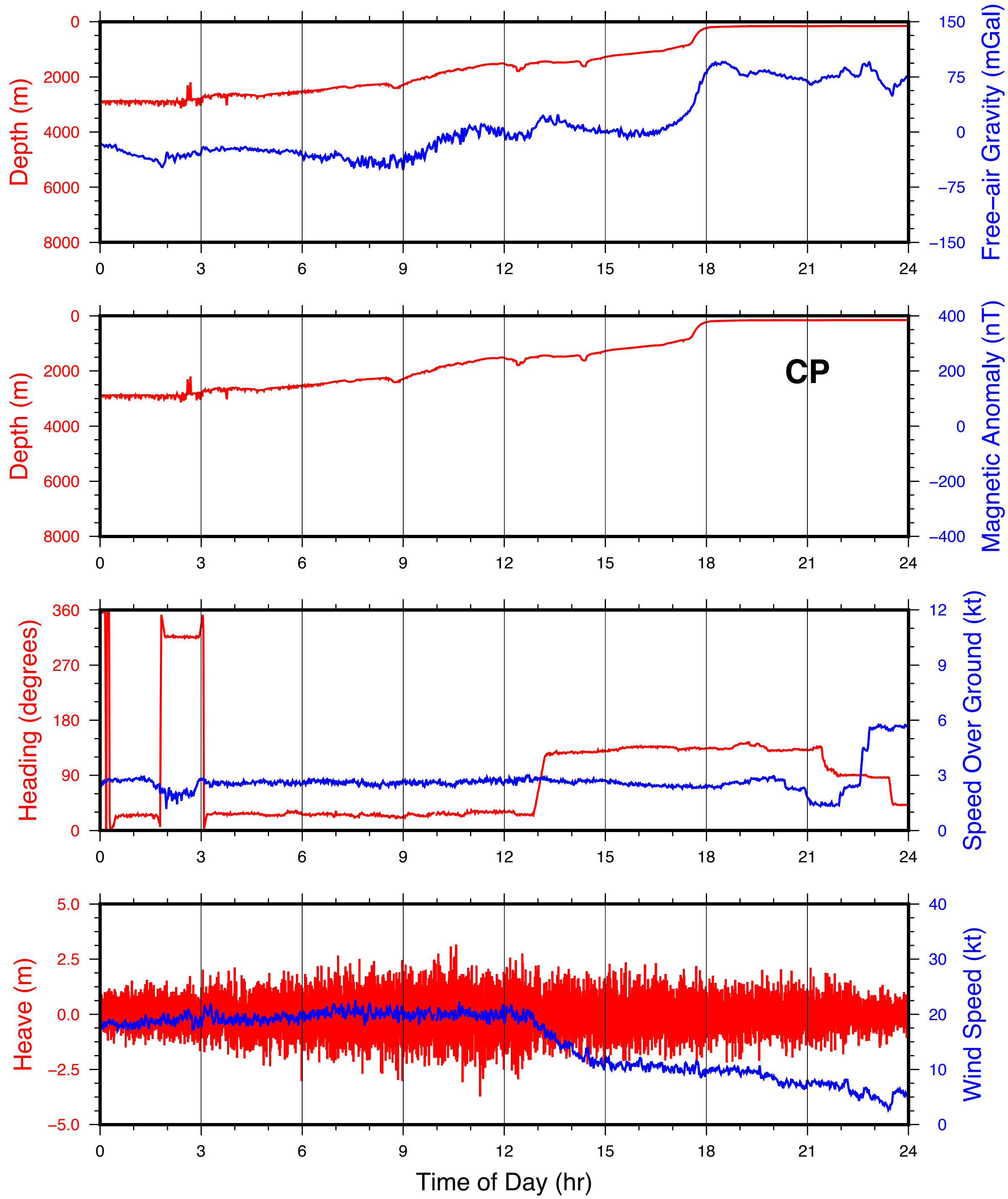


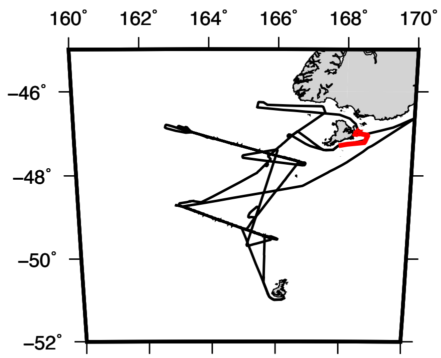


MGL1803

JD70
11 Mar 2018
UTC 00:00:00 – 23:59:59

Shoot MCS17a
Shoot MCS17b
Weather Evasion

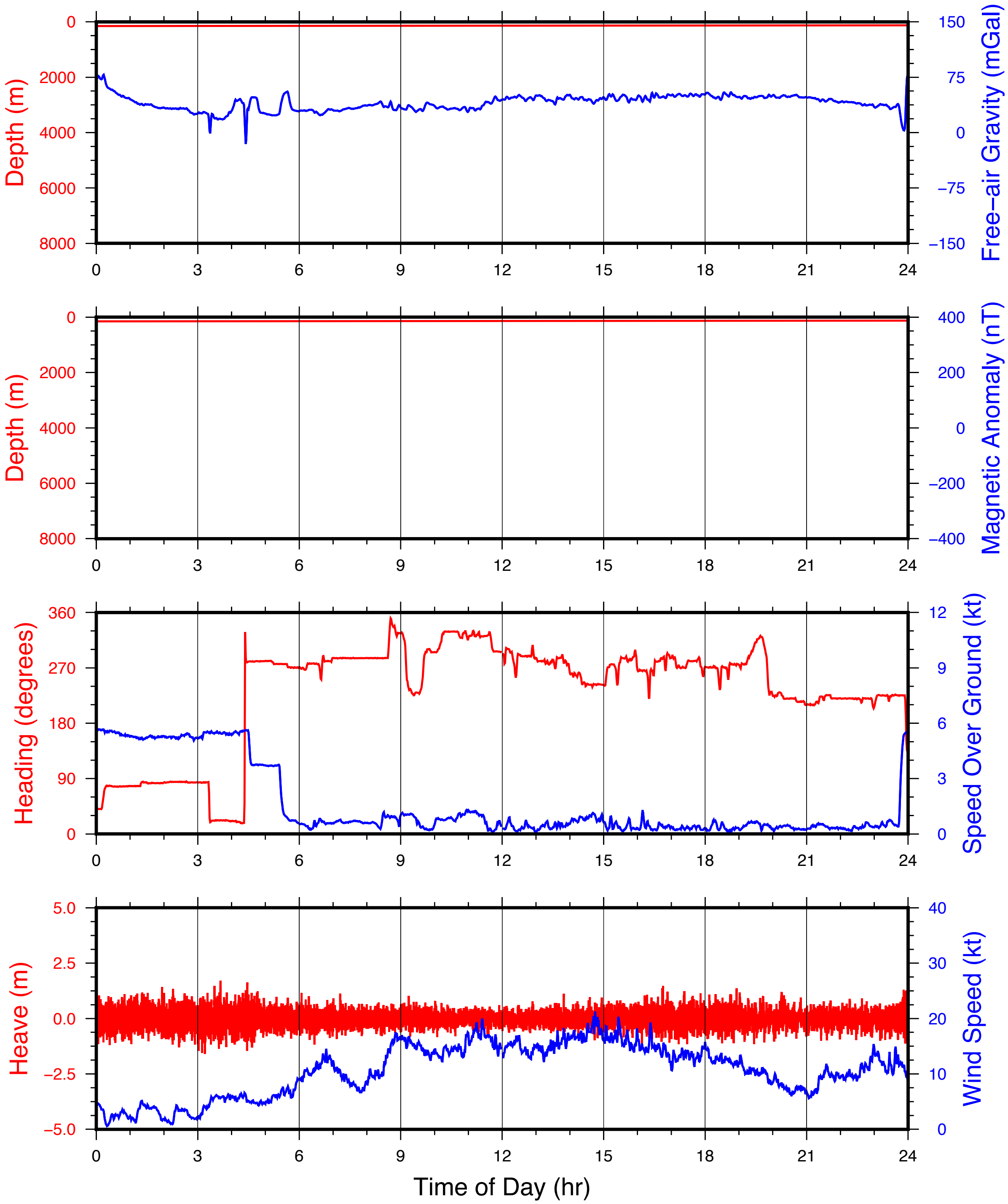


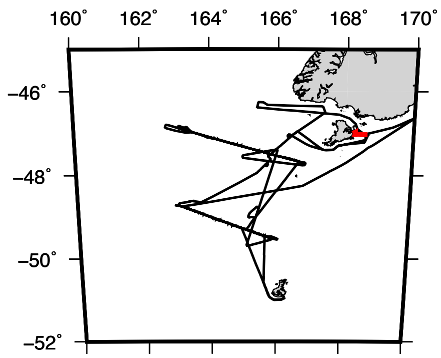


MGL1803

JD71
12 Mar 2018
UTC 00:00:00 – 23:59:59

Down for weather near Stewart Island

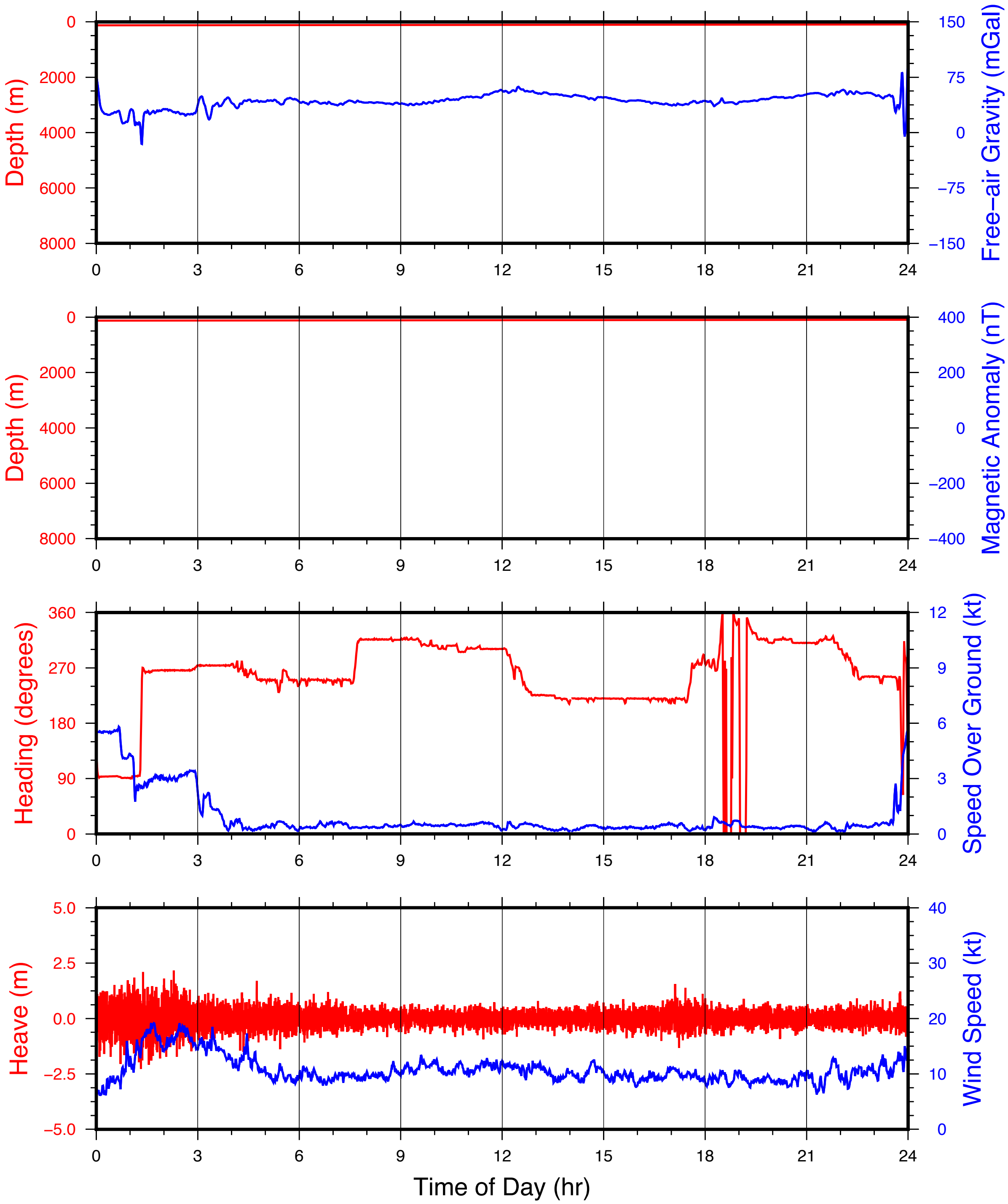


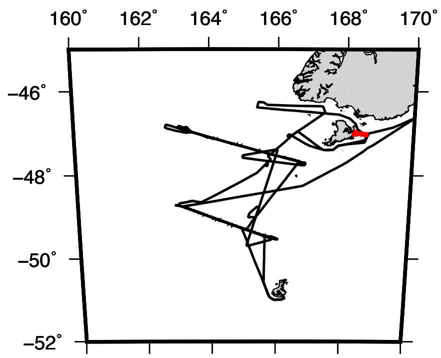


MGL1803

JD72
13 Mar 2018
UTC 00:00:00 – 23:59:59

Down for weather near Stewart Island

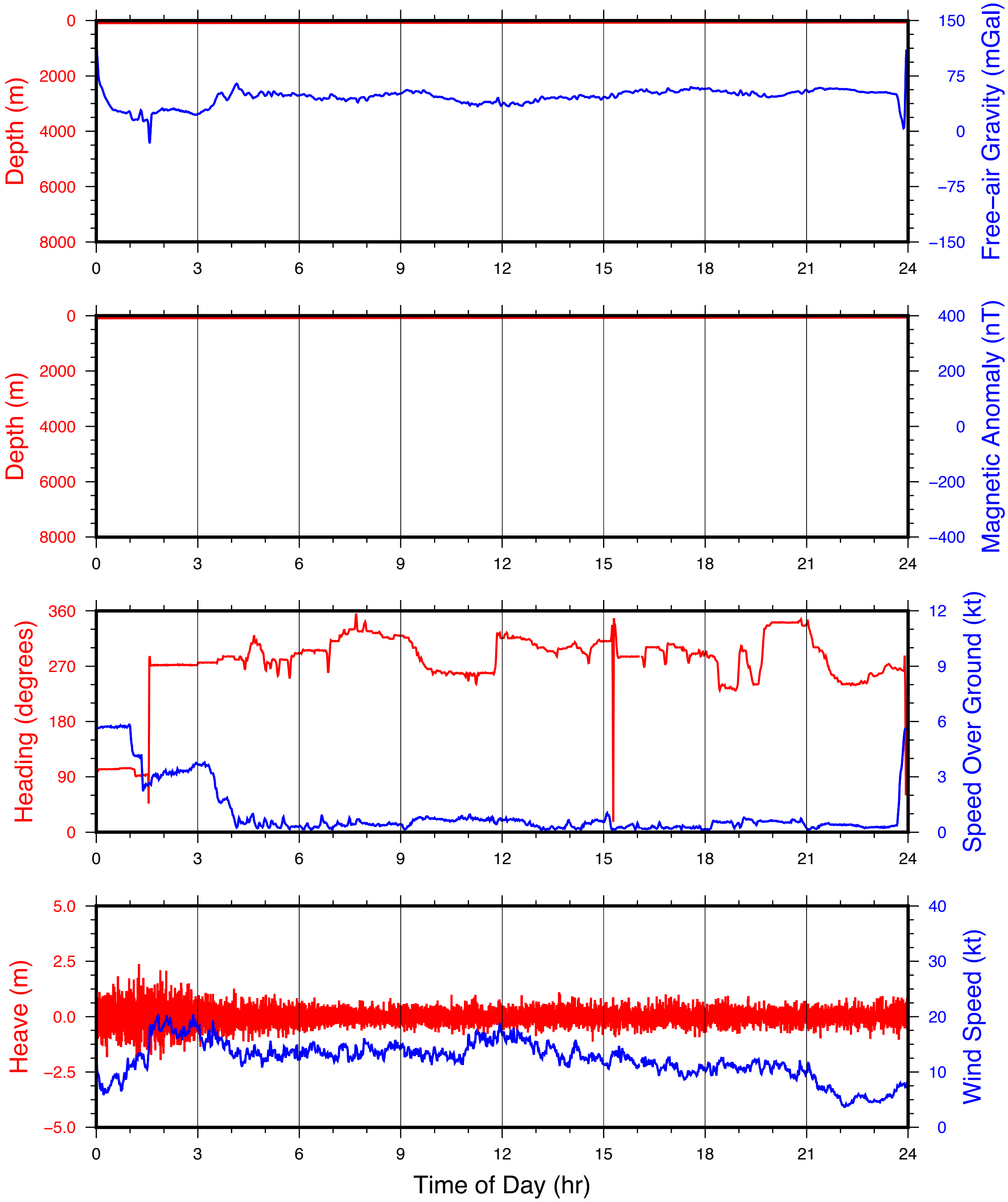


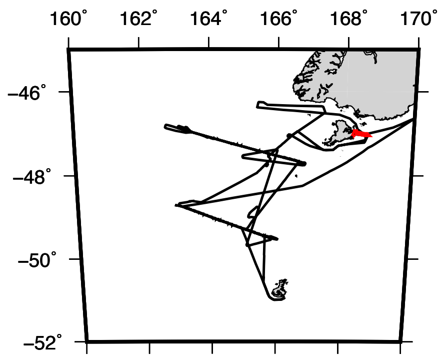


MGL1803

JD73
14 Mar 2018
UTC 00:00:00 − 23:59:59

Down for weather near Stewart Island

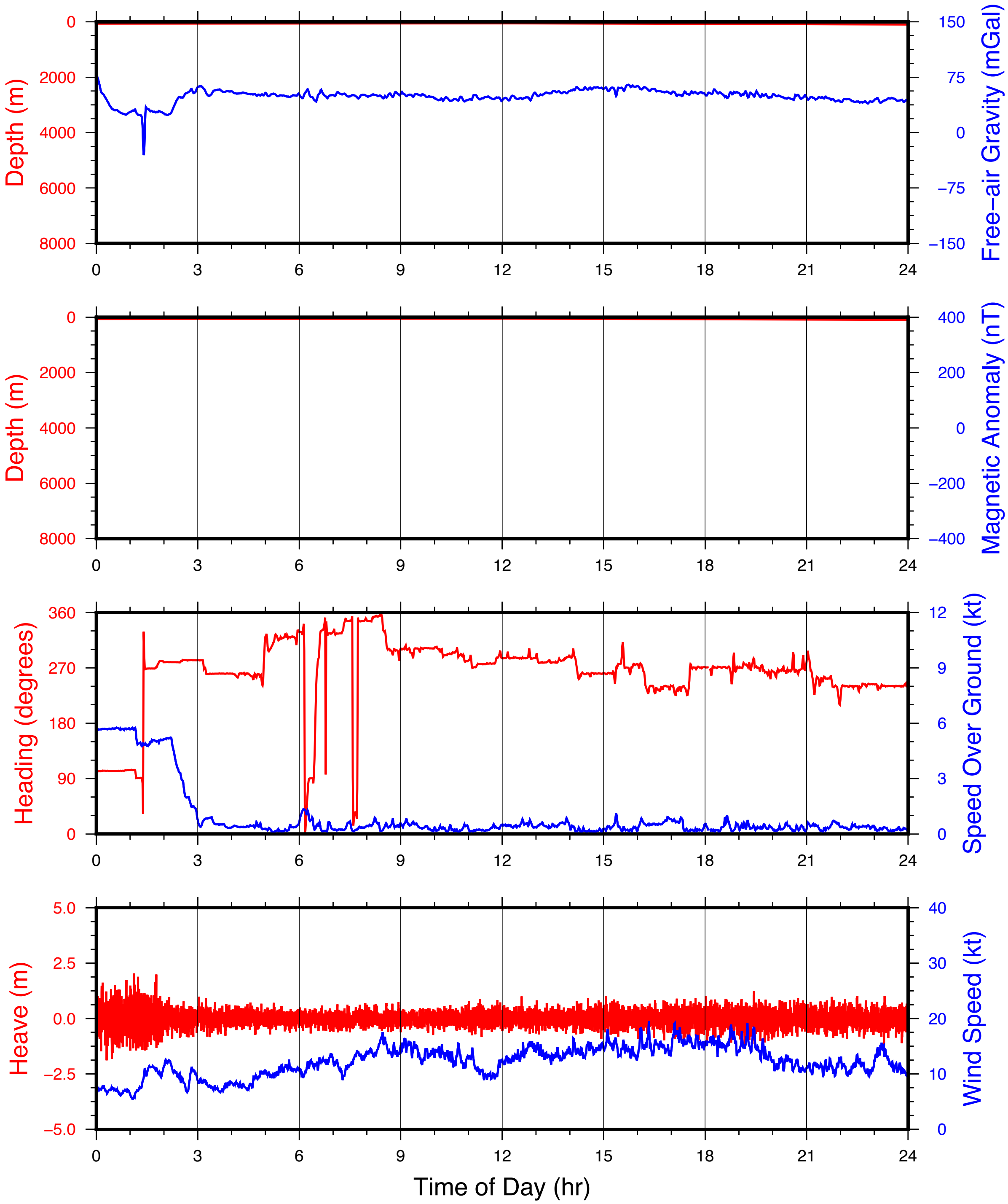


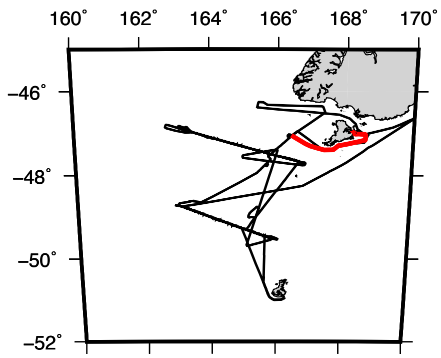


MGL1803

JD74
15 Feb 2018
UTC 00:00:00 – 23:59:59

Down for weather near Stewart Island

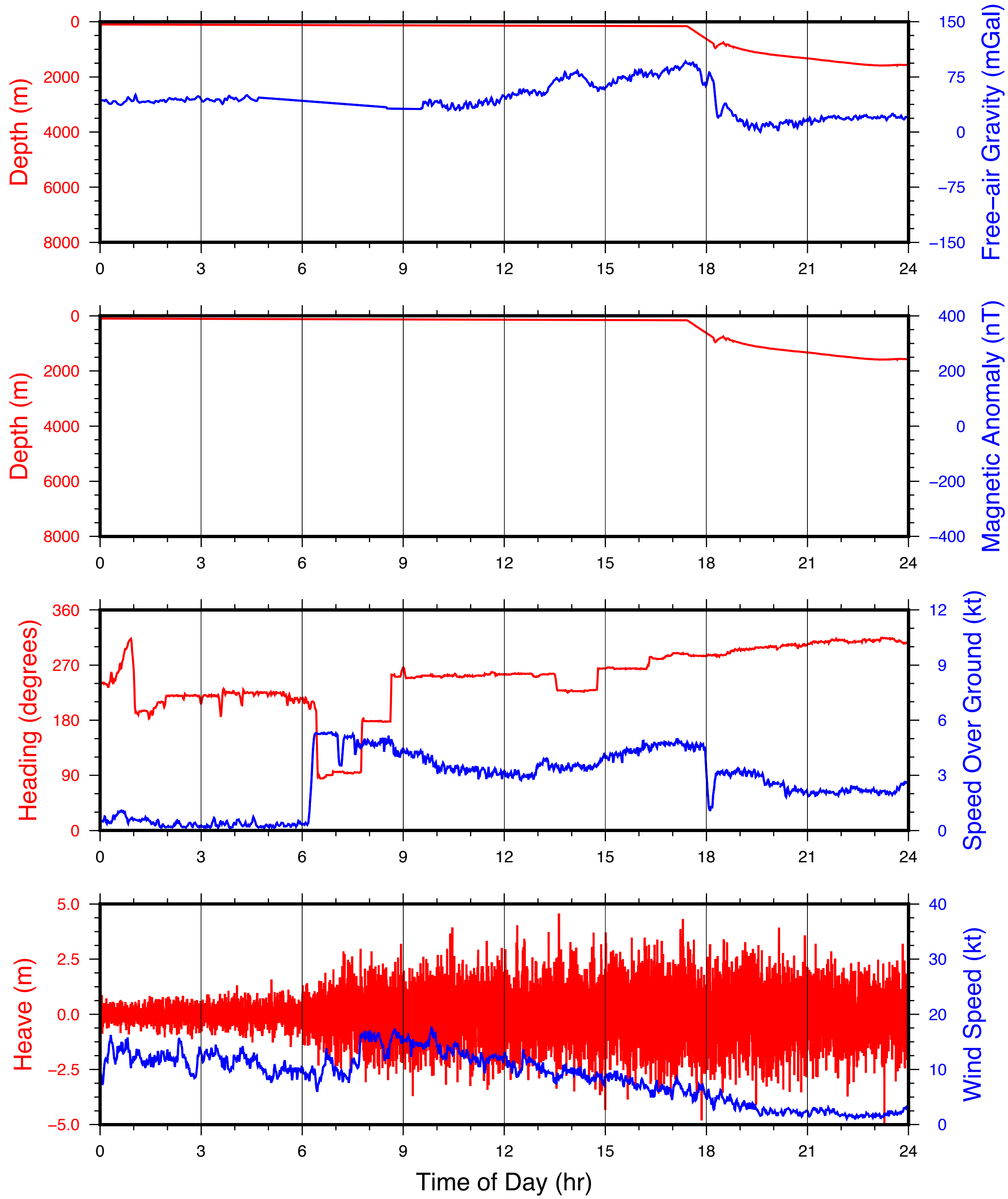


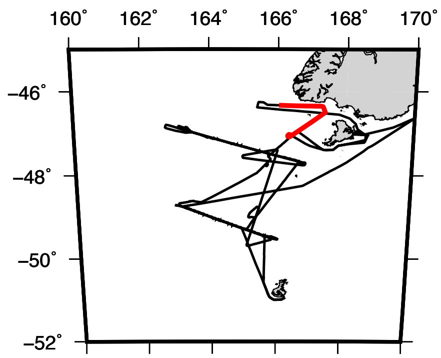


MGL1803

JD75
16 Mar 2018
UTC 00:00:00 – 23:59:59

Waiting on weather Stewart Island

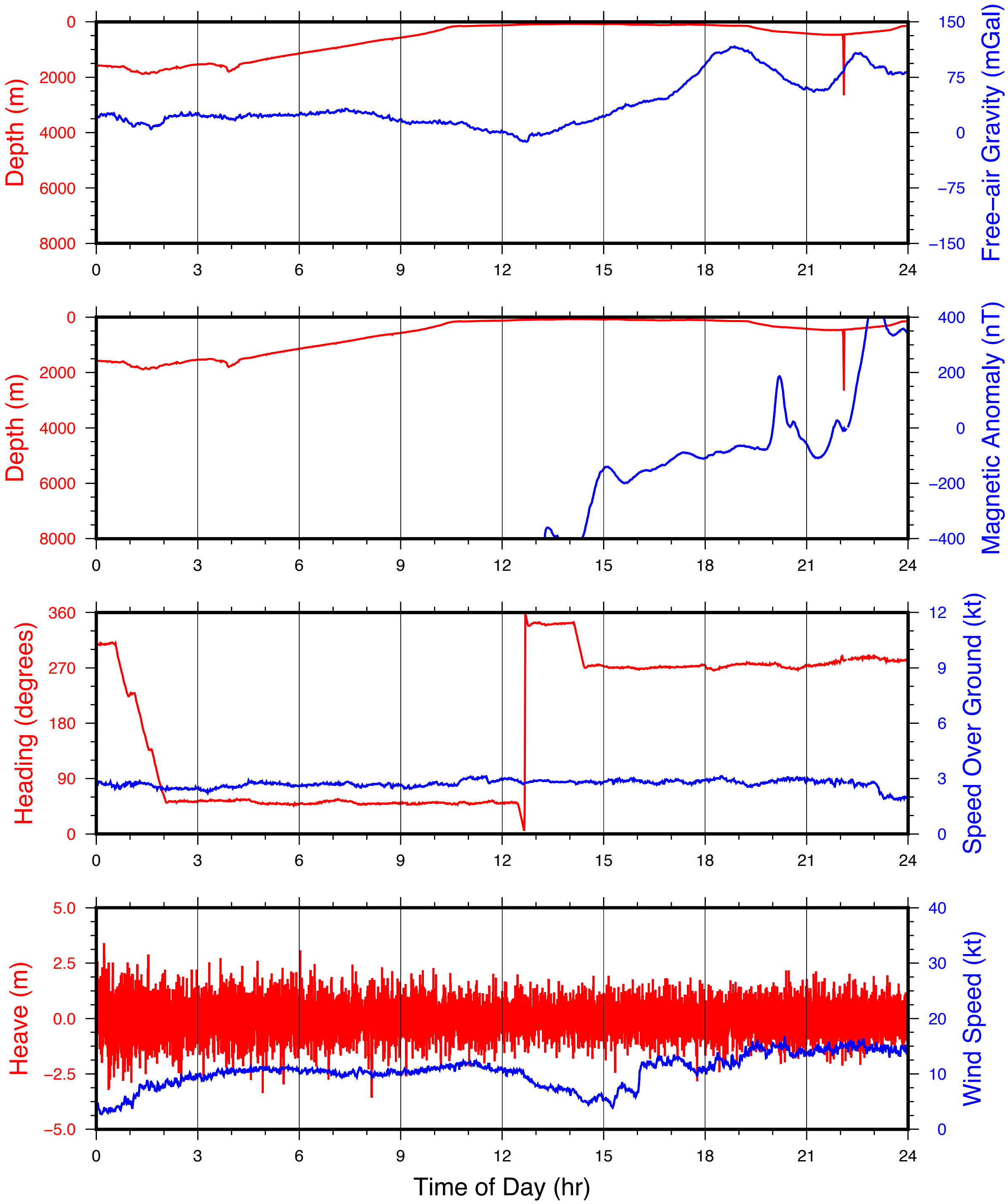


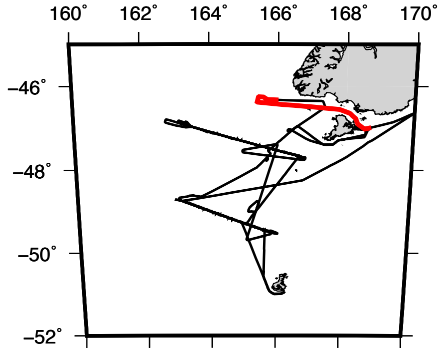


MGL1803

JD76
17 Mar 2018
UTC 00:00:00 – 23:59:59

MCS17c and T02
Start MCS19c

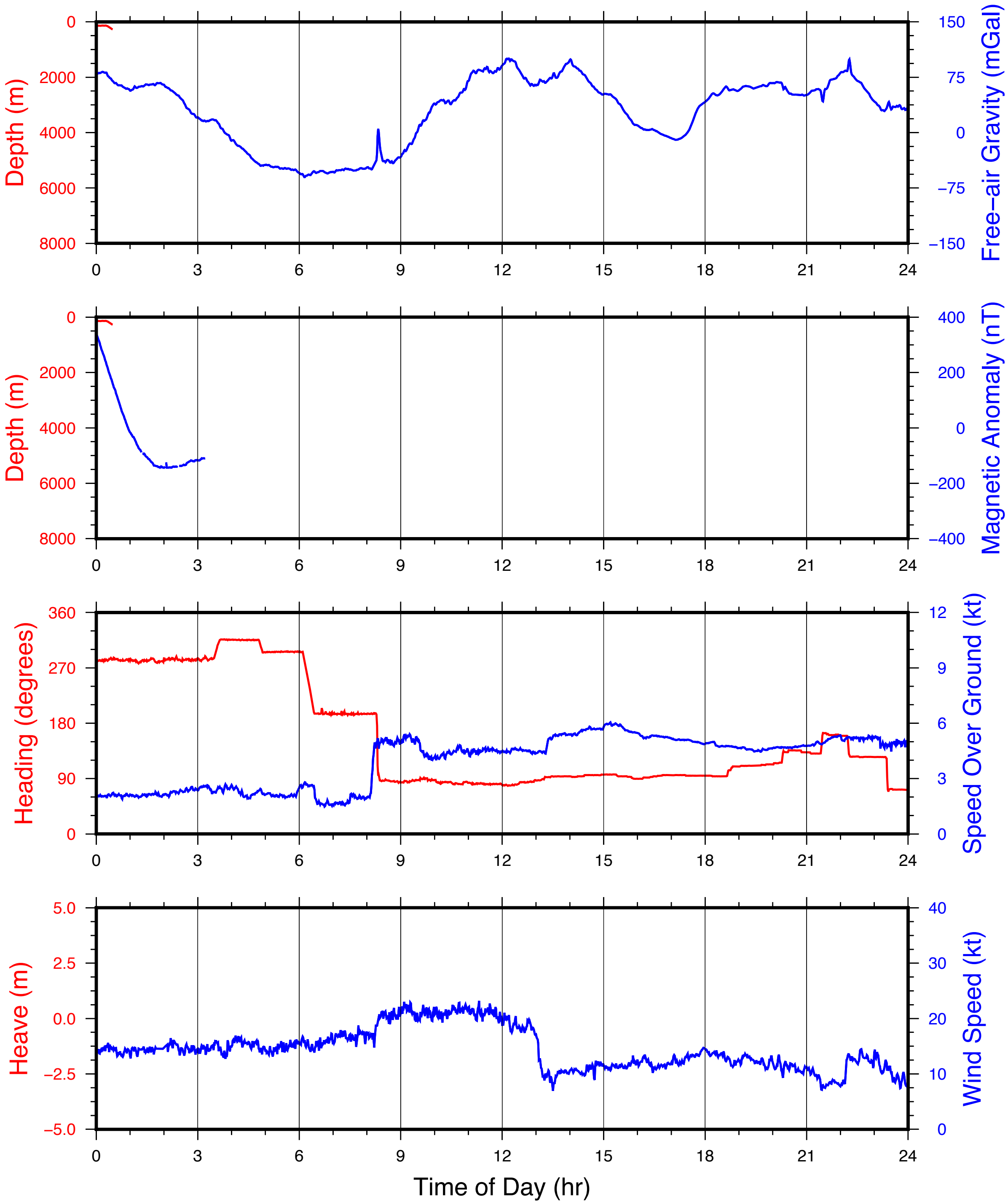


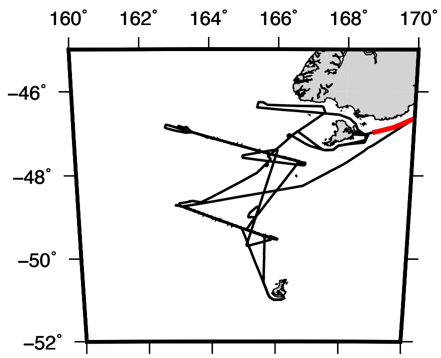


MGL1803

JD77
18 Mar 2018
UTC 00:00:00 – 23:59:59

Complete MCS19a
Transit to Dunedin

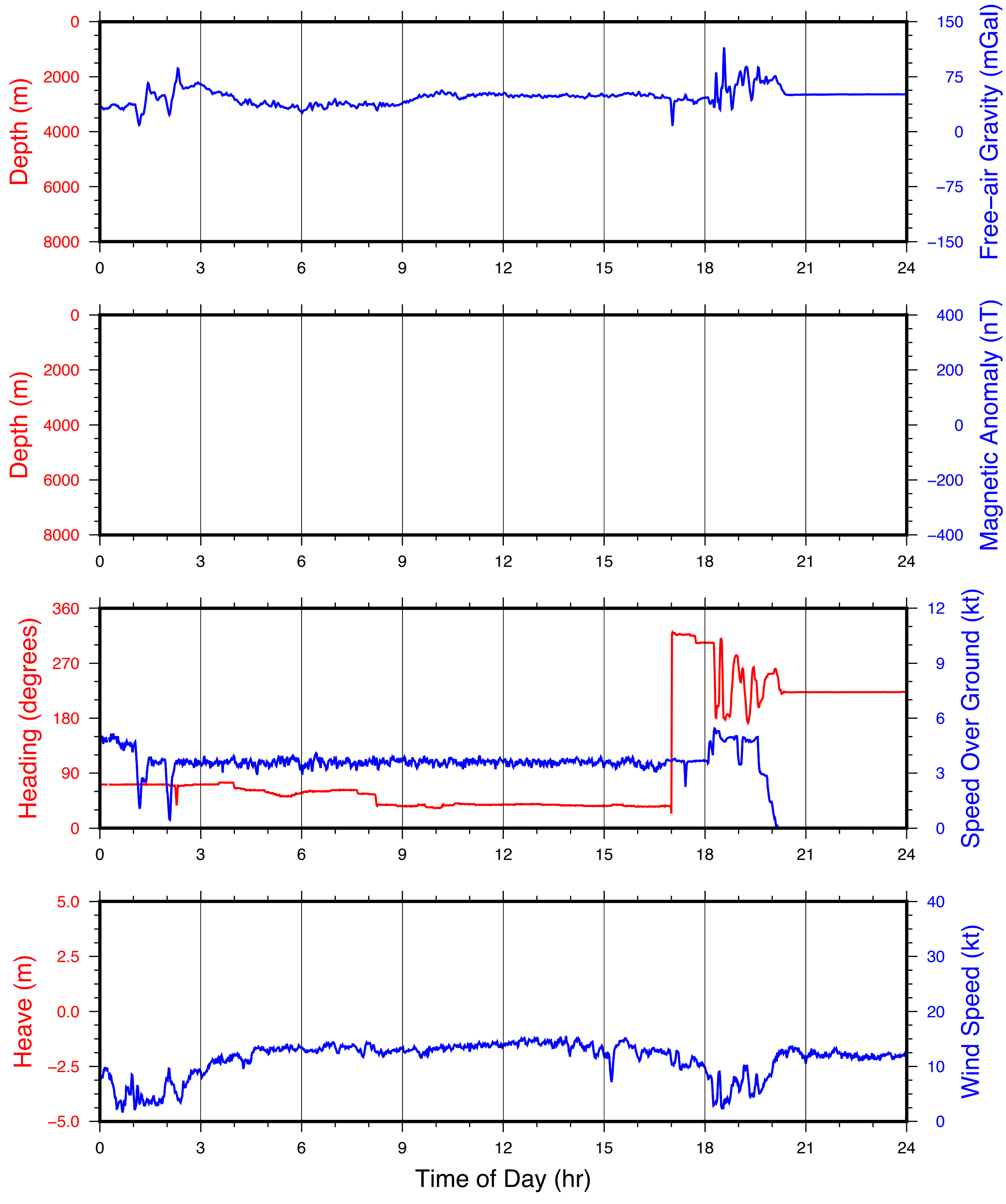


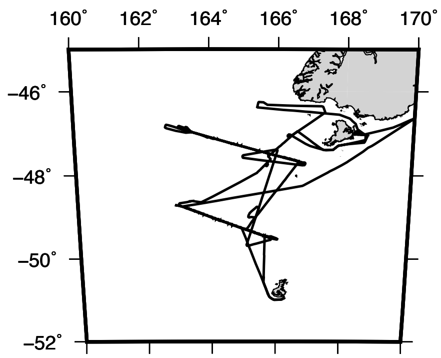


MGL1803

JD78
19 Mar 2018
UTC 00:00:00 – 23:59:59

Transit to Dunedin



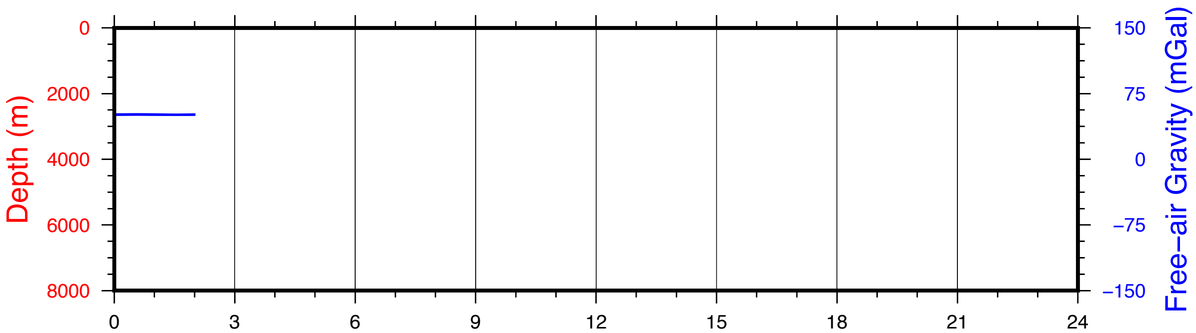


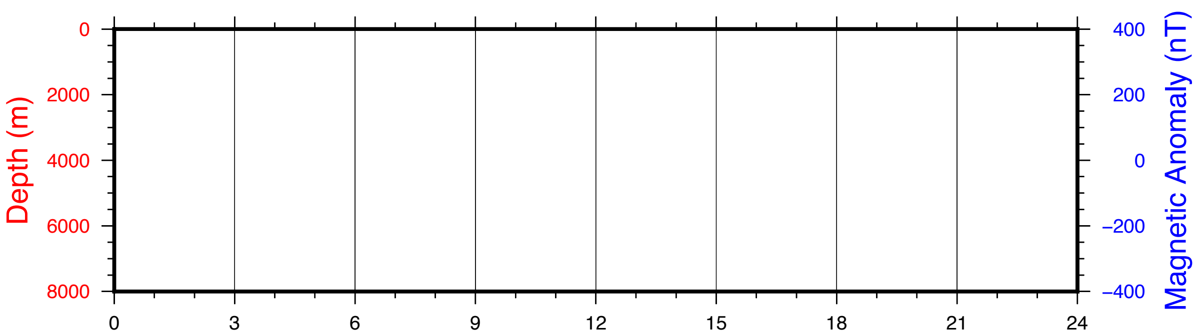
MGL1803

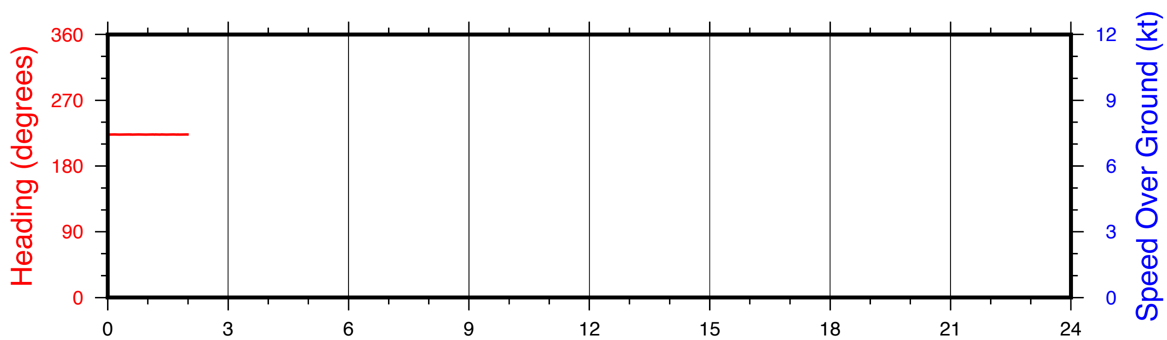
JD79
20 Mar 2018
UTC 00:00:00 – 23:59:59

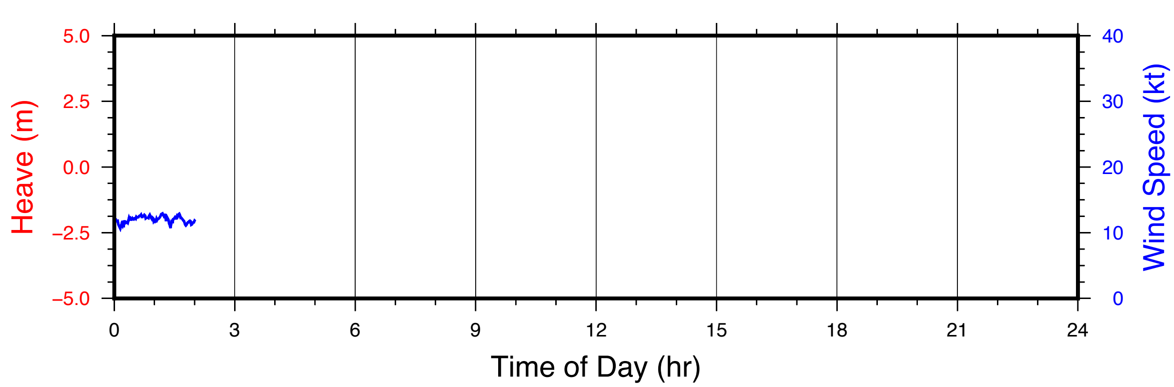
Transit to Dunedin

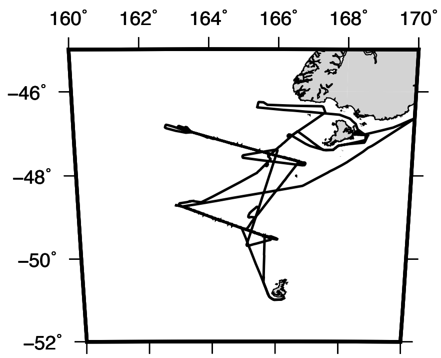
DeMOB







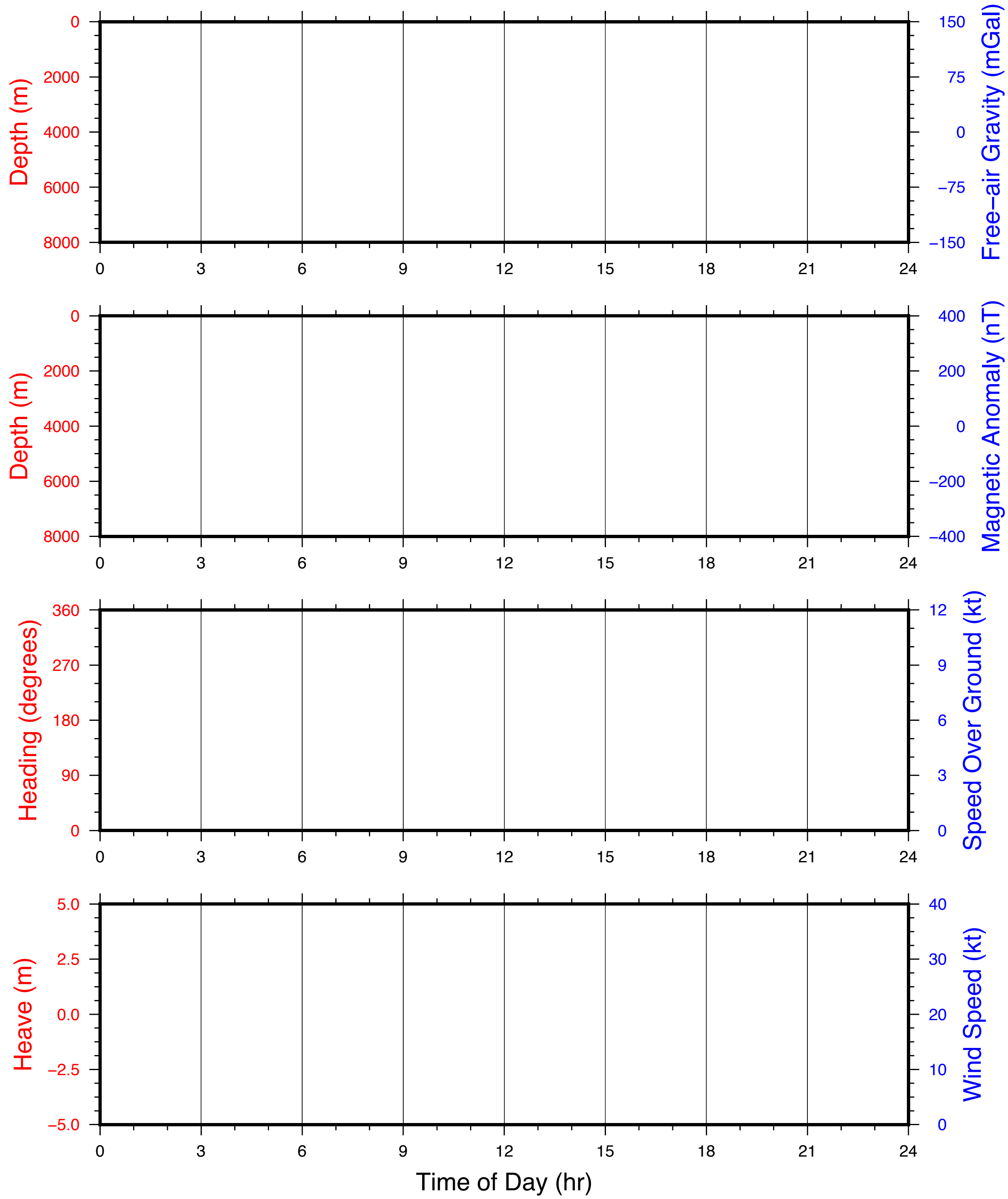


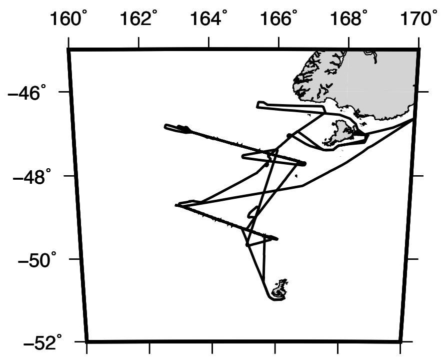


MGL1803

JD80
21 Mar 2018
UTC 00:00:00 – 23:59:59

Dockside Dunedin
DeMOB





MGL1803

JD81
22 Mar 2018
UTC 00:00:00 – 23:59:59

Dockside Dunedin
DeMOB complete