Palmer Station Bathymetry Data Report
PRIMO Project

Gould / Palmer Station
April / May 2005
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Greg Packard and Keith von der Heydt, team members

1. Project Summary

Several projects being conducted in the Palmer Station area of the western Antarctic peninsula require high resolution bathymetric survey data for their success. These include The Palmer LTER program, which samples at least 10 inshore stations on a year round basis depending on ice cover, and the newly funded Southern Ocean Observatory project entitled: Establishing a Polar Remote Interactive Marine Observatory (PRIMO) near Palmer Station on the Western Antarctic Peninsula, Vernon Asper and Scott Gallager co-principal investigators. For the PRIMO project, it is critical that high resolution bathymetry data be obtained in order to locate the most efficient and safe path for the ground cable extending from the end of the Palmer Station pier out to the PRIMO site, along with the actual location of the Observatory base unit. Ice scour and grounding could pose serious problems with both the ground cable and the Observatory. The bathymetry just off the pier is highly variable with deep basins and rapidly rising pinnacles and good bathymetric data are required to find a path to lay the ground cable out of harm's way from scour.

Our objective was to complete a high resolution bathymetric survey of the Palmer area with priority given to the region from the pier out to the west south west about 3 km (LTER Station H), but with the potential to cover the entire inshore LTER sampling area if time and weather permit. To maximize the potential of success, we included, as back up to the REMUS survey approach, a conventional towed side scan sonar system, and a Furuno recording fathometer, both of which were configured for deployment from a Zodiac. We also brought a small video camera to acquire images of the seafloor to confirm and enhance the information derived from the sidescan sonars.

2. Methods

2.1 REMUS AUV Vehicle

The REMUS AUV is a small low cost autonomous underwater vehicle designed to perform hydrographic survey work within shallow water regions. The vehicle was developed by engineers of the Oceanographic Systems Lab at WHOI. REMUS has proven itself to be a productive tool for ocean sampling and survey work combining manageability, reliability, adaptability and ease of use. The unit is commonly handled by two personnel from a small boat platform. Over forty REMUS's are actively performing science and military tasks worldwide with over1500 accomplished individual vehicle missions. The vehicle's electrical and mechanical architecture allows for the integration of additional environmental sensors with minimum effort.
As part of a U.S. Navy evaluation program the REMUS has been undergone a full round of military specification environmental and safety screen testing. The schedule of testing includes shock and vibration testing, as well as, cold environmental testing. The vehicles Lithium Ion batteries have U.S. Navy fleet approval and U.S. Dept. of Transportation approval aboard cargo

1 REMUS vehicle in Palmer lab.

2 REMUS vehicle after completing survey in Arthur Harbor

REMUS AUV Specifications	
Vehicle Diameter	7 ½ Inches
Vehicle Length	63 Inches
Vehicle Weight (In Air)	~80 Lbs
Energy	1 kw-hr rechargeable Lithium Ion
Endurance	22 Hrs @ 3 Kts, 8 Hrs @ 5 Kts
Navigation	Acoustic LBL and USBL Navigation
	(2km transponder range)
	-WAAS GPS
	-Integrated Inertial Navigation Package
Tracking	-Acoustic Range Tracking (2 km range)
	-Underwater modem communications to a
	gateway buoy.
	-Iridium communications (worldwide)
Survey Instrumentation	-600 Khz MSTL Sidescan Sonar (60
	Meters Range)
	- 80 m swath coverage
	-Single point along track bathymetry with
	DVL.
	-Downward looking electronic video and
	still camera.
Additional Instrumentation	-YSI Conductivity/Temperature
	-Depth Sensor
	-Up/Down ADCP
	-SeaTech BB2F (Spectral
	Backscatter/Chlorophyll

2.2 Furuno Echosounders

In order to acquire general bathymetric data on a coarse (50-100m line spacing) resolution, we used two Furuno Echosounders. The first, a model Furuno model FCV582L internally recording, dual frequency (50 & 200 kHz) fathometer. This unit included a self-contained GPS receiver, allowing the operator to see the water depth, terrain tendencies, and location on one screen. These data were fed through a serial link to a Panasonic Toughbook computer where they were plotted in real time using color-coded dots on a Matlab-generated map. The transducer for this unit was a robust, brass and potted rubber unit that was mounted on a threaded aluminum pole and suspended about 0.5m below the surface. The second unit, an older model Furuno FL6600 had no internal GPS receiver, so a handheld Garmin model 12 was attached to send position strings to it. These data were combined with the depth information and sent through a serial connection to another Panasonic Toughbook using the same software although parsing the NEMA string was different. This unit used a relatively delicate, plastic transducer that incorporated a speed impeller and was attached to a steel pole using a single hose clamp and suspended about 0.5m below the surface. This unit was far more sensitive to speed than the newer one, requiring very slow (<5 knots) survey speeds and generating erroneous data if this speed was exceeded.

2.3 Towed Sidescan Sonar
A MarineSonic Inc. towed sidescan system was used to acquire data in areas where REMUS was inappropriate. This system includes a dedicated processor/display that was powered from a 24VDC pack fabricated from two marine batteries. It was towed using the davit and hand winch (figure 3) although this arrangement made maneuvering very difficult. The dynamic bathymetry once again made for some challenging data collecting with the constant need to adjust cable

3 Zodiac #44 showing the platform and davit that were used for the towed sidescan, Seacat, and video camera work.

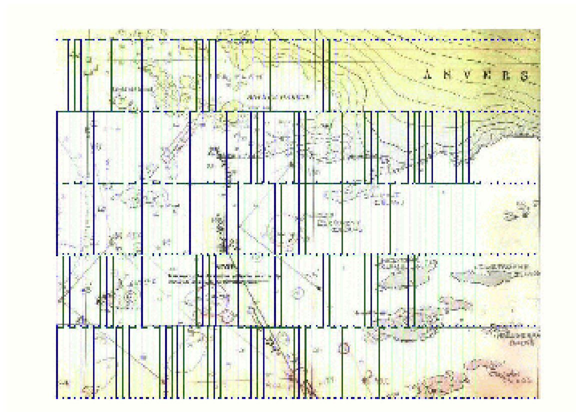
2.4 Video Camera
To evaluate the seafloor composition and to look for signs of iceberg scour, we used a Deep Sea Power and Light Mini Seacam. This small black and white video camera includes a ring of white LEDs for illumination but these produced too much particulate backscatter for our work. Instead, we mounted the camera and two dive lights on a “T” structure with the camera suspended below the lights and the lights aimed at a focal point about 1m below the camera. In the first deployments, the lights were used as supplied, but in later deployments, they were fitted with diffusers made from discarded

fluorescent light fixtures. Power from a 12V gel cell was supplied to the camera and the signal transmitted back to the surface through a 2 conductor, shielded cable spliced to a 4-conductor connector. The video was recorded using a Sony Digital 8 camcorder and another camcorder as a microphone. No external power was available for the camcorder, requiring a supply of rechargeable batteries to be taken along and limiting the daily endurance to about 3 hours.

3.0 Deployments and Results

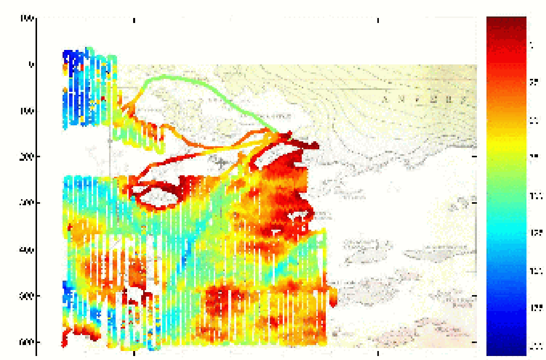
3.1 Furuno Bathymetry

To geolocate the depth data collected by the Furuno, we desired to plot the data on top of a standard chart or coastline data set for the area. Initially, the only chart available was that located on the bridge of the Gould. We scanned in the area around Palmer station, georeferenced the chart section using the Matlab mapping toolbox, and set up a routine to plot color coded depth as dots on the chart in realtime. (All Matlab routines and a readme file are located on a data CD).



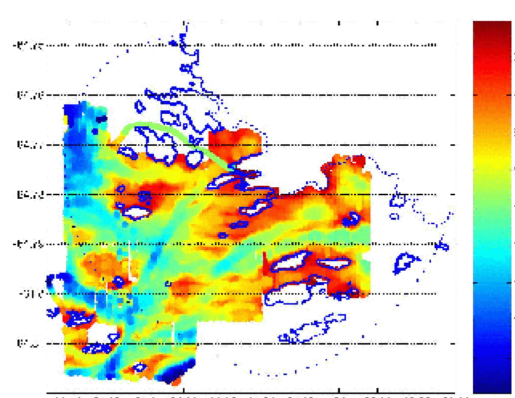
4 Original nautical chart showing normal Gould approach route and intended survey grid

The entire small boating area was covered with a series of grids consisting of 10 1 km long legs spaced at 100m. The realtime data allowed the zodiac driver to follow the grid lines as we “mowed the lawn”. In addition, a Matlab routine was developed to generate the grid and then a specific waypoint file that could be uploaded into the furuno to provide a navigational display for piloting purposes.



5 Nautical chart with first days’ results superimposed and showing offset.

This procedure worked well for a few days until we realized that the chart was significantly incorrect as we piloted over islands and through areas ‘un-navigable’ according to the chart. Subsequent calculations put the error in longitude at 1.5 miles. Latitude error was close to 0.25 mile. About the same time it was discovered that Jessie Walker, a GIS specialist in the Denver office, was the keeper of the coastline and island data or the small boating map. Upon request for the raw data, Jessie quickly sent us the arcview file saved out in ascii form on April 13. This was uploaded into Matlab and additional routines established to plot our bathy data on top of the coastline data. Amazingly, the two data sets merged nearly perfectly with only a few shoal markings

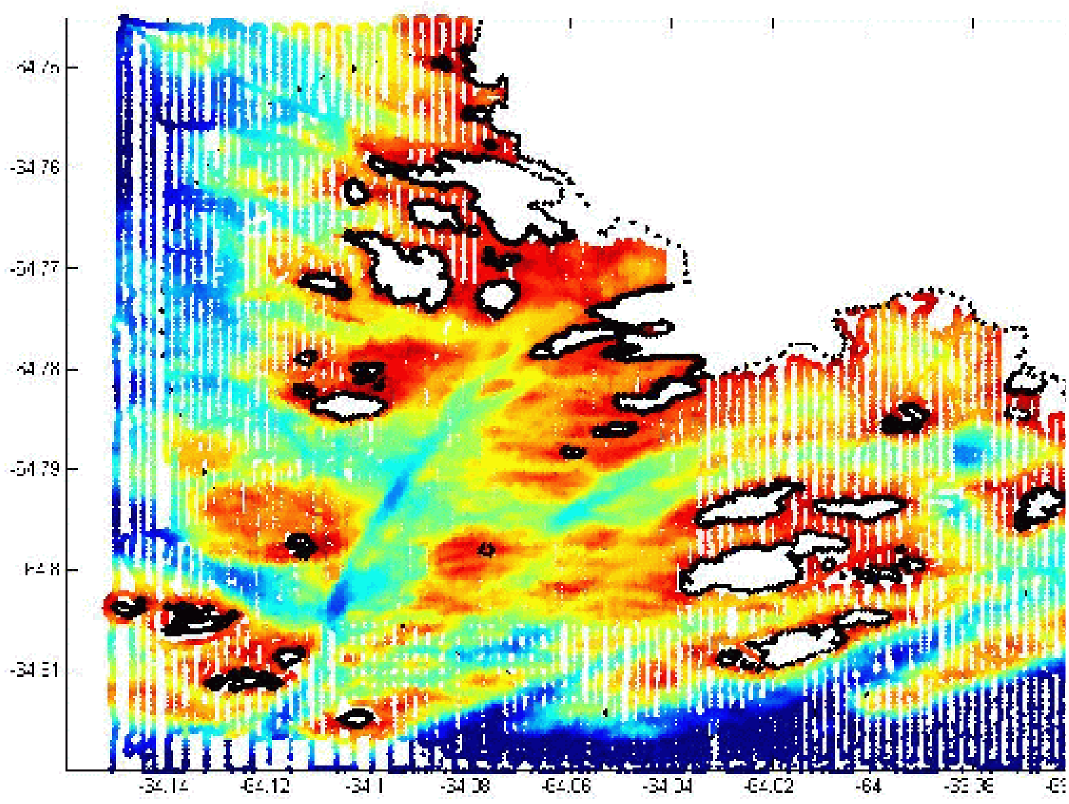


6 Chart of gridded depths following 3 days of work.

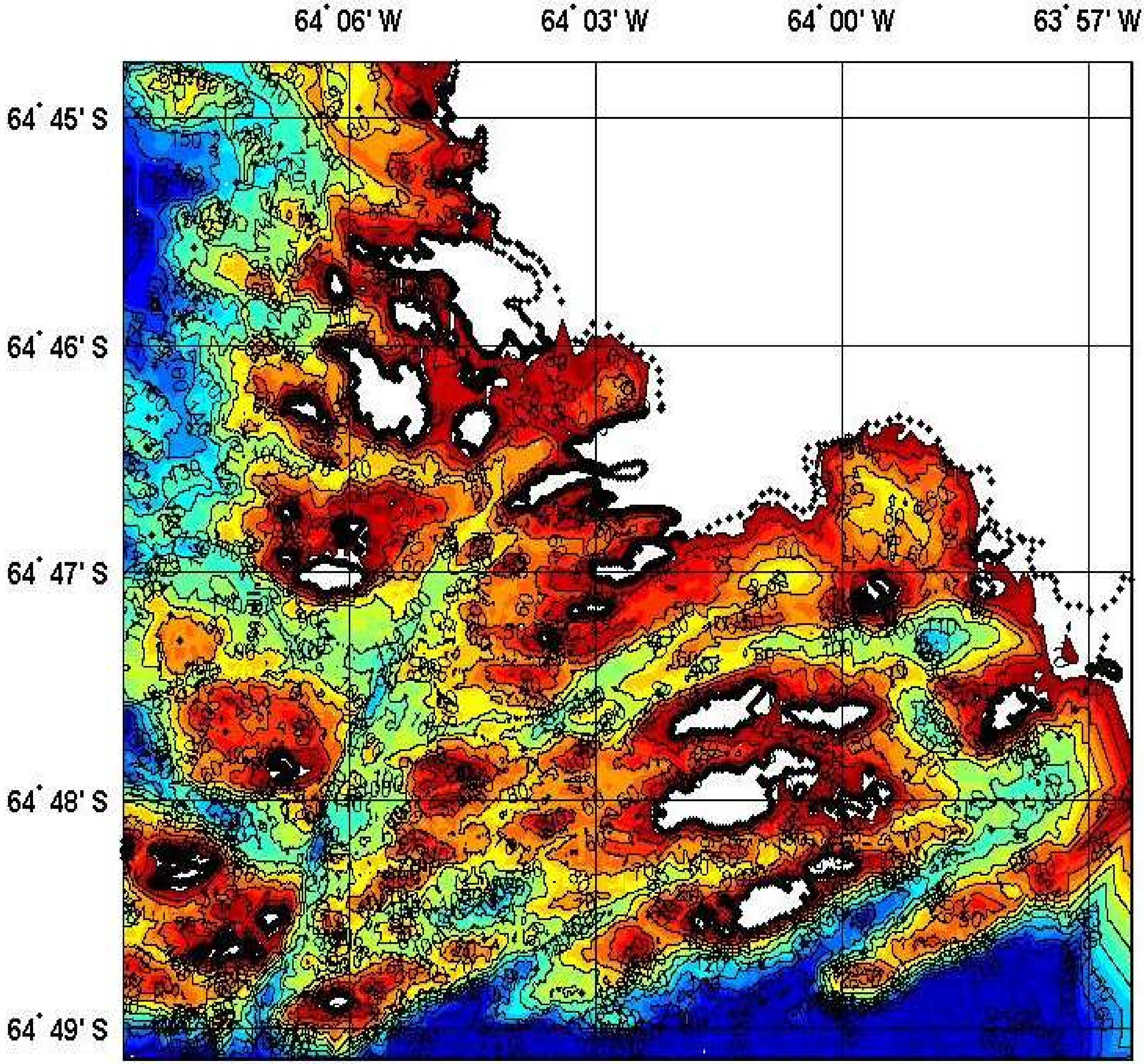
out of place, probably because these were taken off the original navigational chart now shown to be incorrect. The position of the shoals and pinnacle were corrected and we continued to collect bathy data using the new coastline data set superimposed with our survey grids.

By April 14 we had covered about 50% of the small boating area. We continued to collect data at 100 m intervals but went back to some locations where more detail was desired and reinvested some effort at 50 m leg spacing. By April 30 the entire small boating area was complete, but we continued to collect data primarily at 50 m spacing until May 6, the day before we left the Station. Using the routine ping_edit.m we cleaned up the raw data plot to remove bad data points which also revealed areas where more data was desired. In all, we collected over 100,000 data points of which 93,764 ended up in the final map. Total distance traveled was more than 600 km.

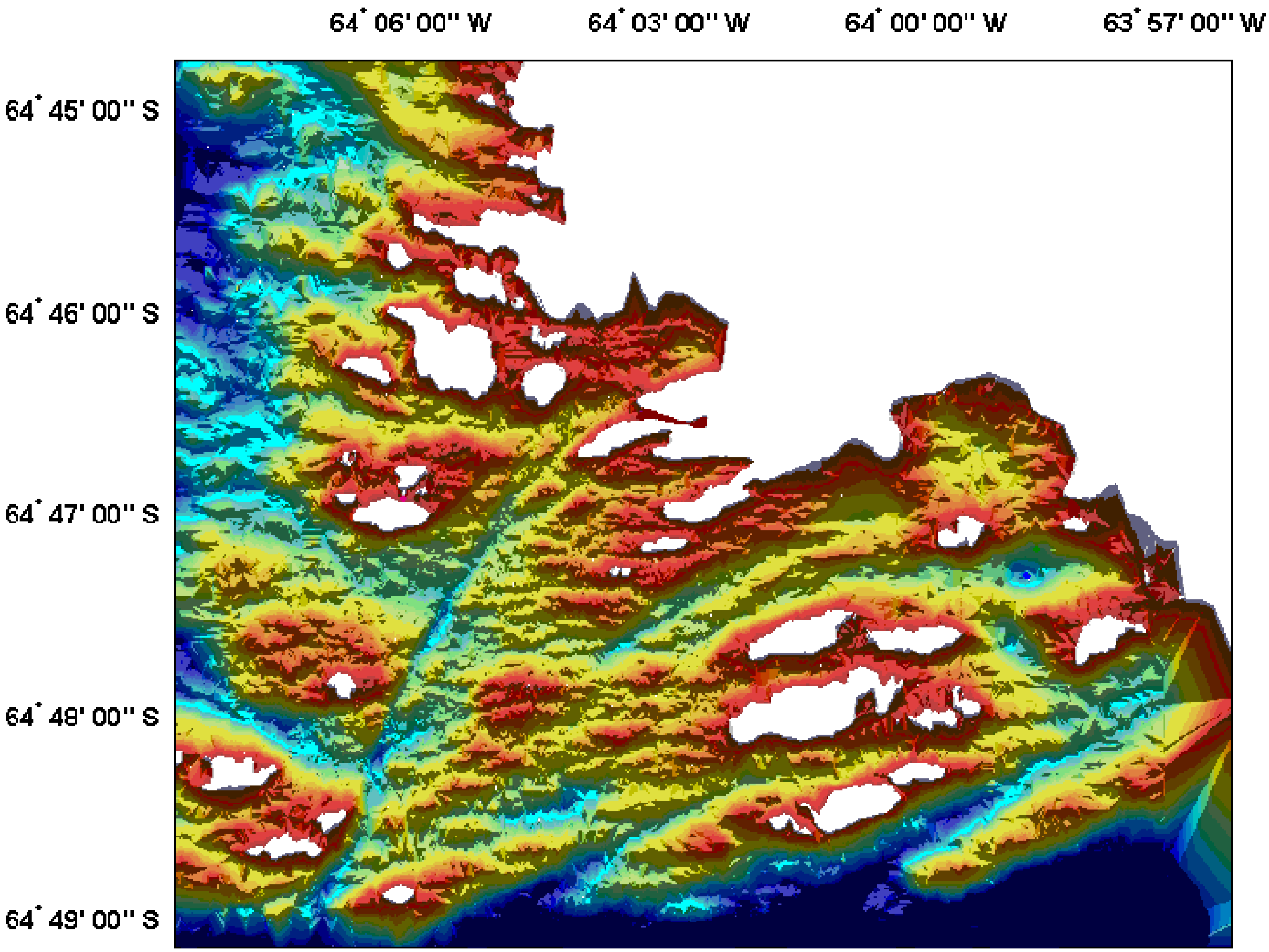
The raw data file was then linearly interpolated to a standard grid of 750 x 2120 rows by columns at a spatial resolution of 0.001 degrees. The grid file was used to generate both mesh plots and contour plots (see readme_Matlab_furuno.txt for details on Matlab routines). Grid_furuno.m produced the grid file and the mesh_furuno.m, and contour_furuno.m produced standard plots. Chart_mesh.m and chart_conrour.m use commands in the mapping toolbox so they are very specific to the need to re-grid the data into a UTM format. All that is done in either of the chart_mesh or chart_contour mfiles.



7 Chart showing location of all raw data points (soundings).

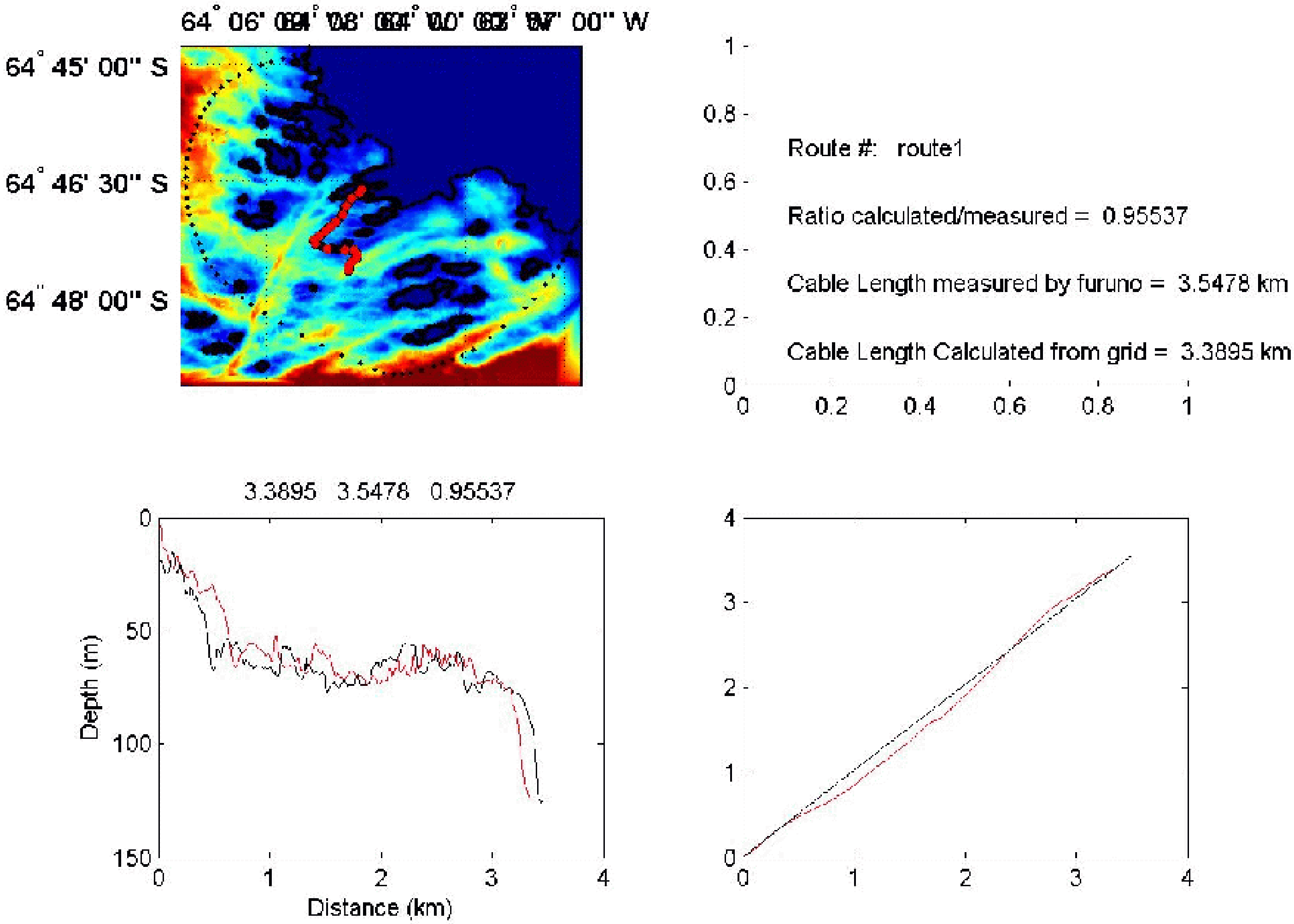


8 Contour chart with shading and contour lines.

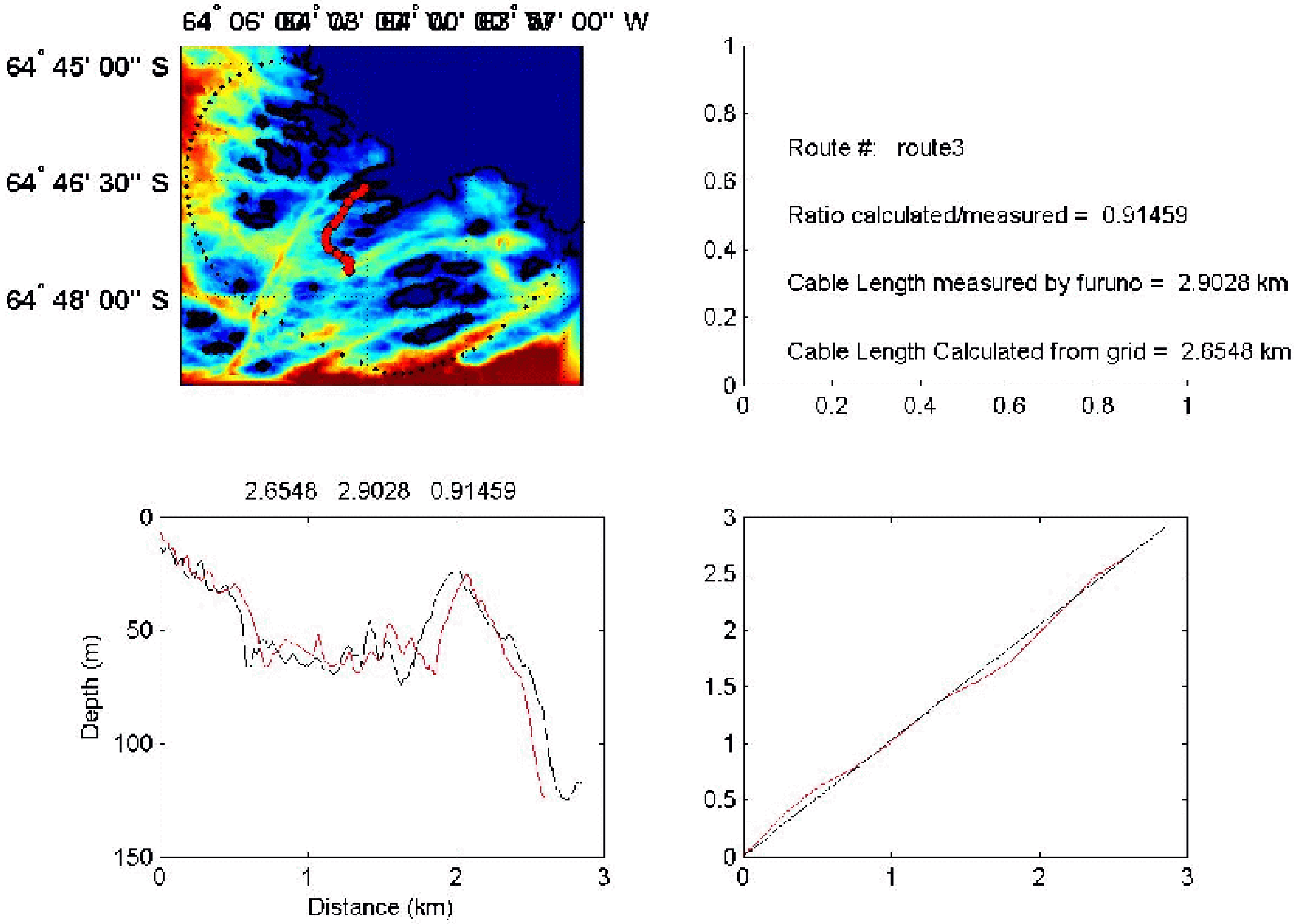


9 Shadow_chart.bmp produced with the meshlsrm.m command.

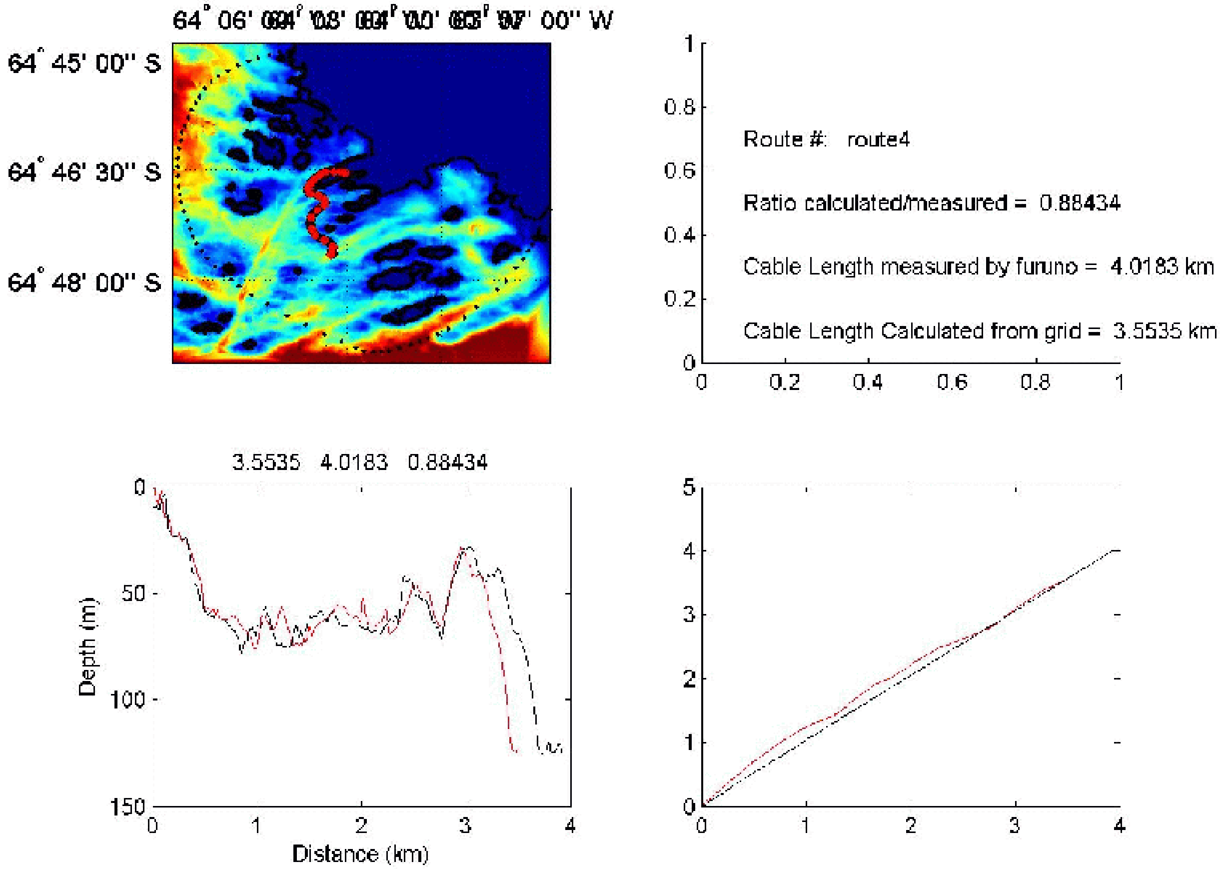
Exploring required cable lengths and routing locations
To evaluate the actual length of the cable necessary to run form the IMS building and to the proposed PRIMO sites, a routine was developed using the get_profile command in the mapping toolbox. First a plot is produced using mesh_chart.m then profile.m s run. A query asks how many waypoints you would like to enter for the length of the cable route. The output is a multiplot display of the meshed bathymetry and cable location, and the depth profile and cumulative cable length. To determine the accuracy of using this approach on gridded data, 10 track lines were established and the waypoints sent to a file to be uploaded into the furuno for subsequent track following.



Potential Cable Route #1 is the optimal run for the purposes of protection form ice scour. This runs from the IMS building, across Hero Inlet, across Bonaparte Pt, out into Kristie Cove and then snakes its way through the troughs between humps to the south then to the east. The most significant trough is just south (about 0.5 mi) of surge rock at a depth of 60 m. The cable would run from the end of the trough southeast into a 125 m hole equidistant from surge rock (PRIMO site #1), the tip of Christine Island, and THE pinnacle. Total cable length estimated by the interpolated grid is 3.389 km and by direct measure 3.548 km for a difference of 159 m. The ratio of estimates is 0.95. The difference in measurements and offset seen in the depth profiles is due to a slight difference in the beginning and end points of the transects; otherwise, the two techniques agree quite well.

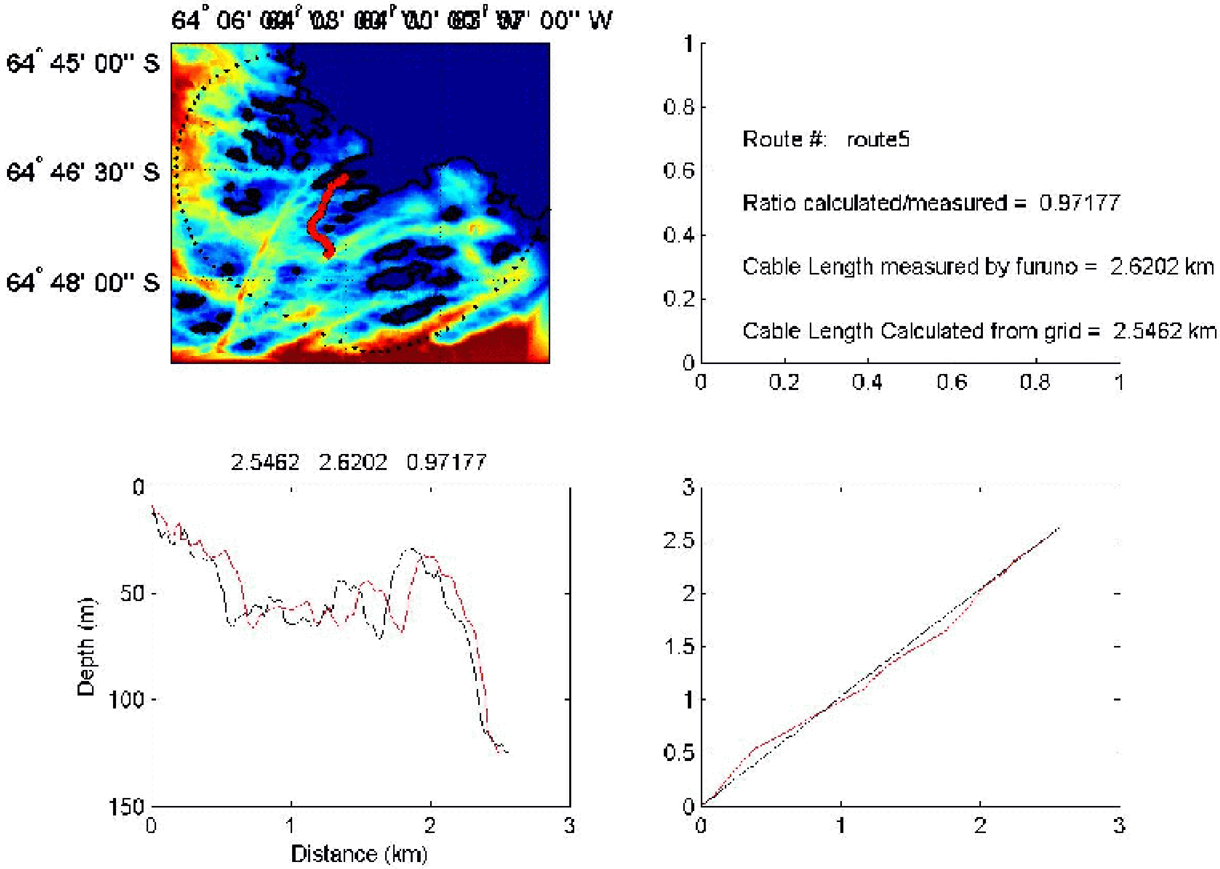


Potential Cable Route #3 is similar to #1 with the exception of the run south
of surge rock, which in this case runs over the ridge instead of through it. This location would allow the ship some breathing room between it and surge rock, but it does open possibilities for ice damage as the cable transverses the front face of the ridge. Total cable length is 2.654 and 2.903 km, respectively.

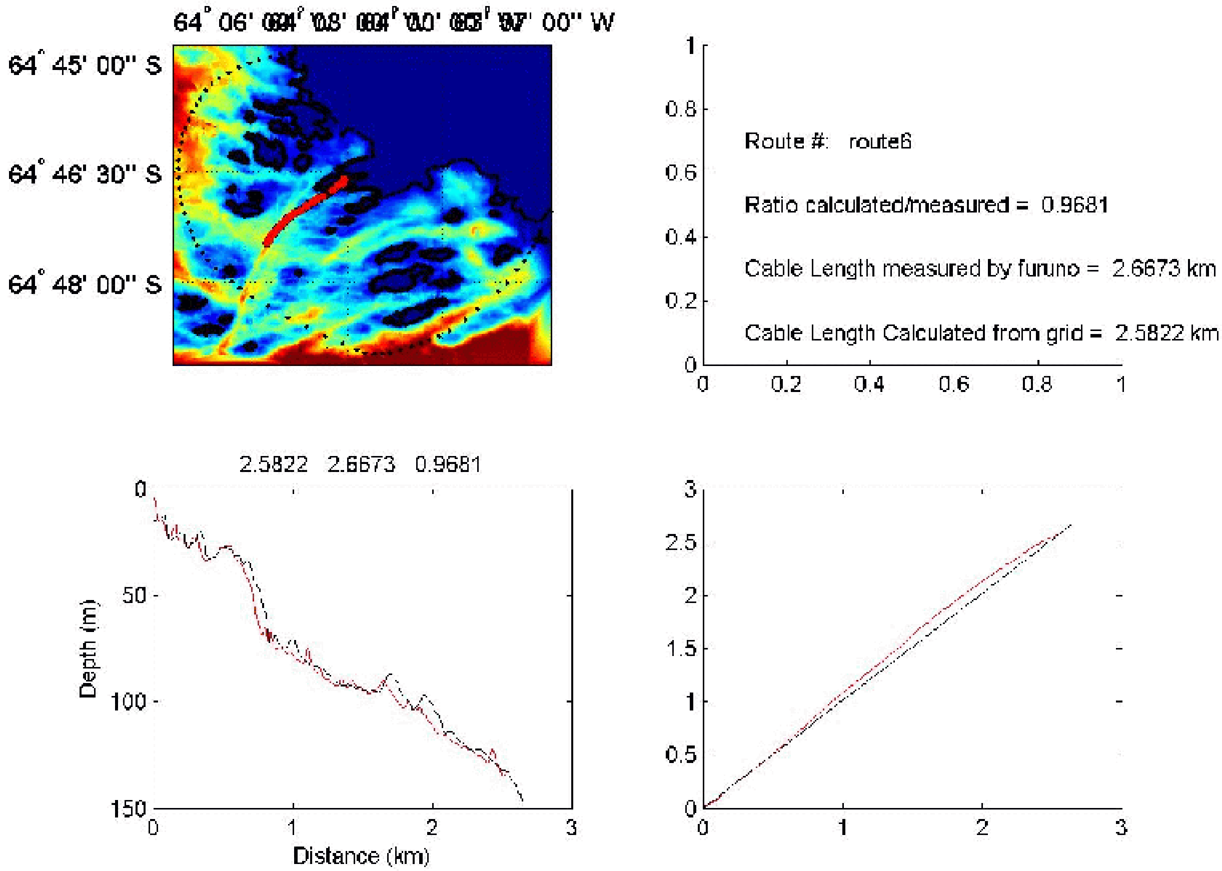


Potential Cable Route #4 is similar to Route #3 but its origin is on the north side of Bonaparte Pt rather than the south. The cable would enter Hero Inlet to the east of the trolley and run along the north side of Bonaparte Pt at a depth of about 30 m approximately 100 m from the rocky edge. There exists a ledge or sill 20 m to the west of the trolley rising from 30m to 4 m and then back to 12 m, but only along the northern side of the Inlet. The south side of the inlet is about 12 m deep so bergy bits can and do enter the Inlet through this passage. The cable running through this passage would be exposed to ice damage. In addition, it is well known at the Station that various cruise ships and private yachts come into the Station unannounced and anchor just north of Bonaparte Pt. This could expose the cable to damage by hooking and dragging by an anchor.

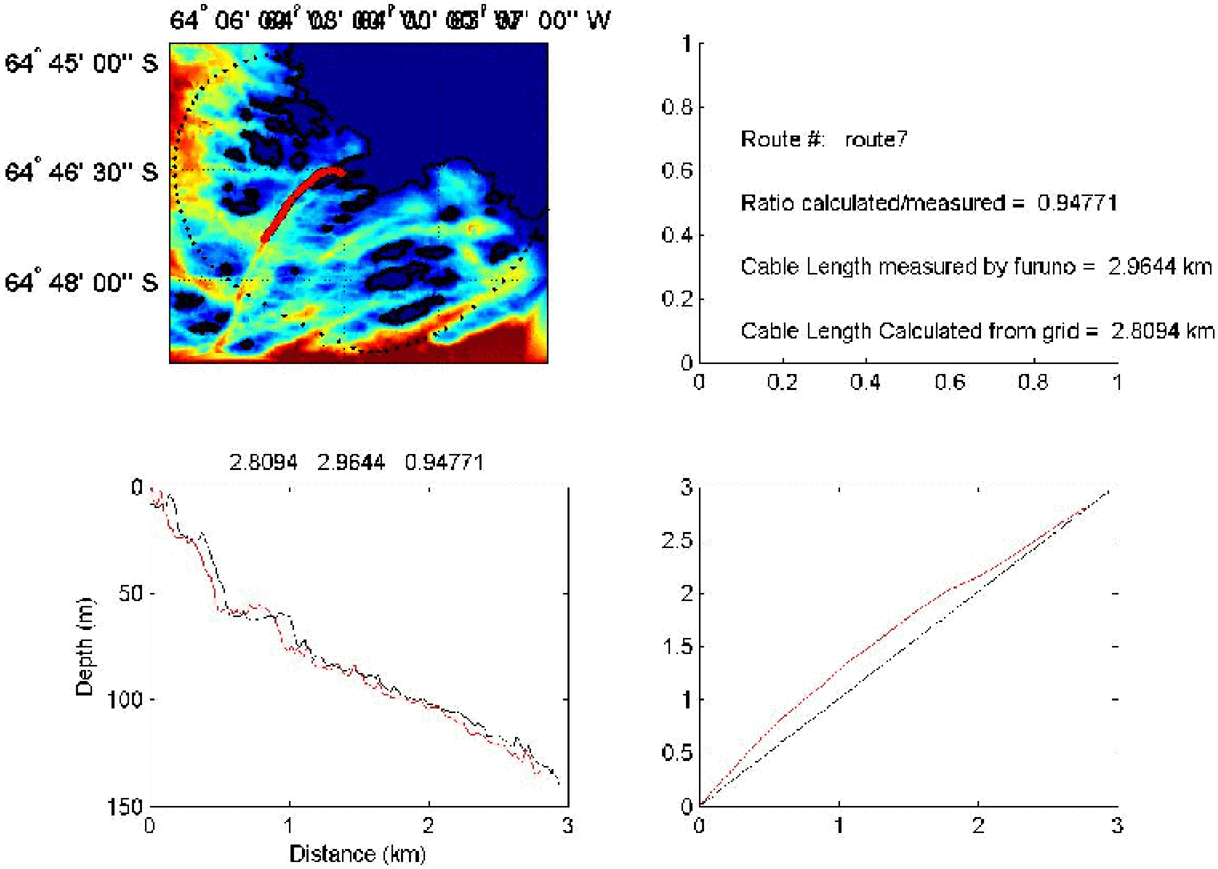
For these reasons, any of the routes requiring a run through Hero Inlet and along the north edge of Bonaparte Pt. is deemed of lower priority relative to running across Bonaparte Pt. to the east of the trolley. (see section on shore cable routes) Note also that the total cable length is 3.553 and 4.018 km nearly 1 km longer than the routes extending across Bonaparte Pt.



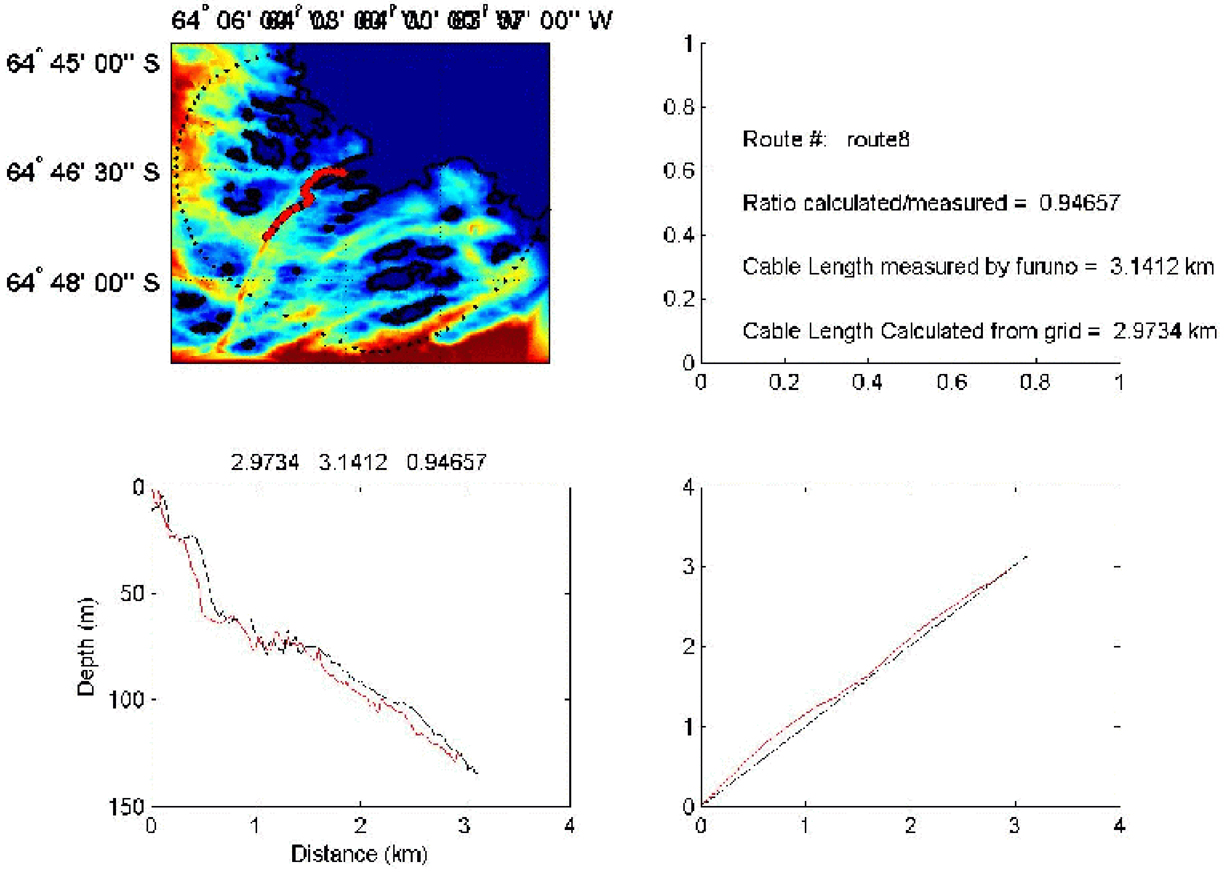
Potential Cable Route #5 is similar to Route #3, but tends to be a bit more circuitous following troughs and valleys more directly.



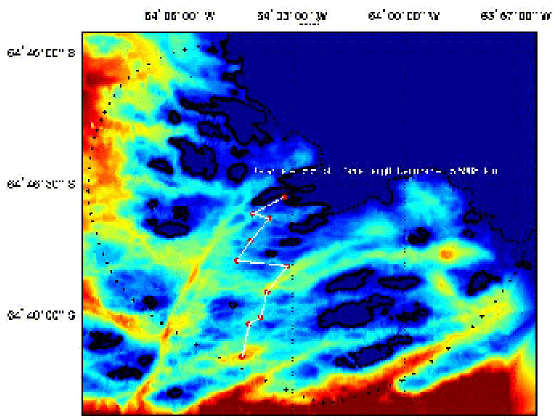
Potential Cable Route #6 runs out of Kristie Cove but then travels directly down "Main Street", the trough extending to the southwest of Bonaparte Pt. and into a hole at a depth of 130 m. The hole is actually 140 m at its greatest depth so this site is on the eastern slope. This site is PRIMO #2 and could be useful if PRIMO #1 is deemed unworkable in the future. The advantage of PRIMO #2 is its direct cable route with the lest length necessary (2.582 and 2.667 km), its main disadvantage being its direct exposure to deep burgs with keel depths between 70 and 100 m coming in from the west and south.

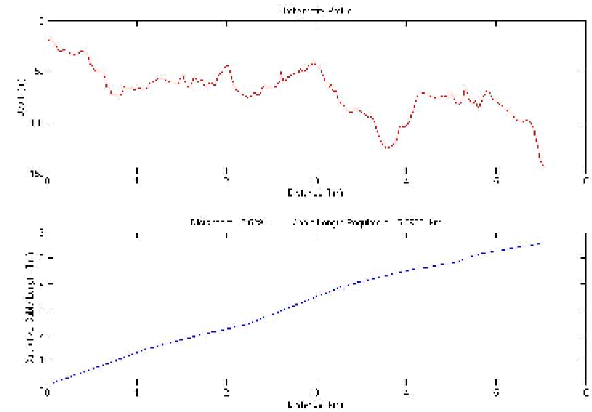


Potential Cable Route #7 runs out the north side of Bonaparte Pt. and travels directly down "Main Street" and into a hole at a depth of 130 m. Note that the total length is 2.809 and 2.964 km or about 200 m longer than the route taken out of Kristie Cove.

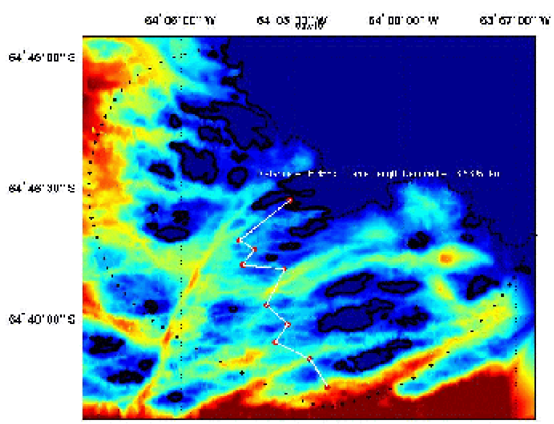


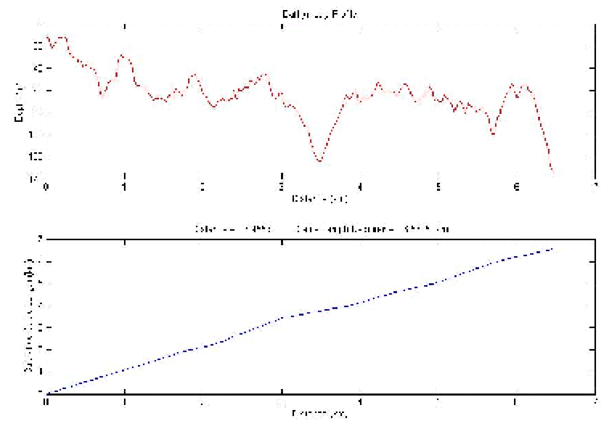
Potential Cable Route #8 runs out the north side of Bonaparte Pt. and travels directly down "Main Street" and into a hole at a depth of 130 m. During its run, however, the route takes several doglegs to remain in the troughs rather than transverse any exposed face. Total length is 2.973 and 3.141 km.



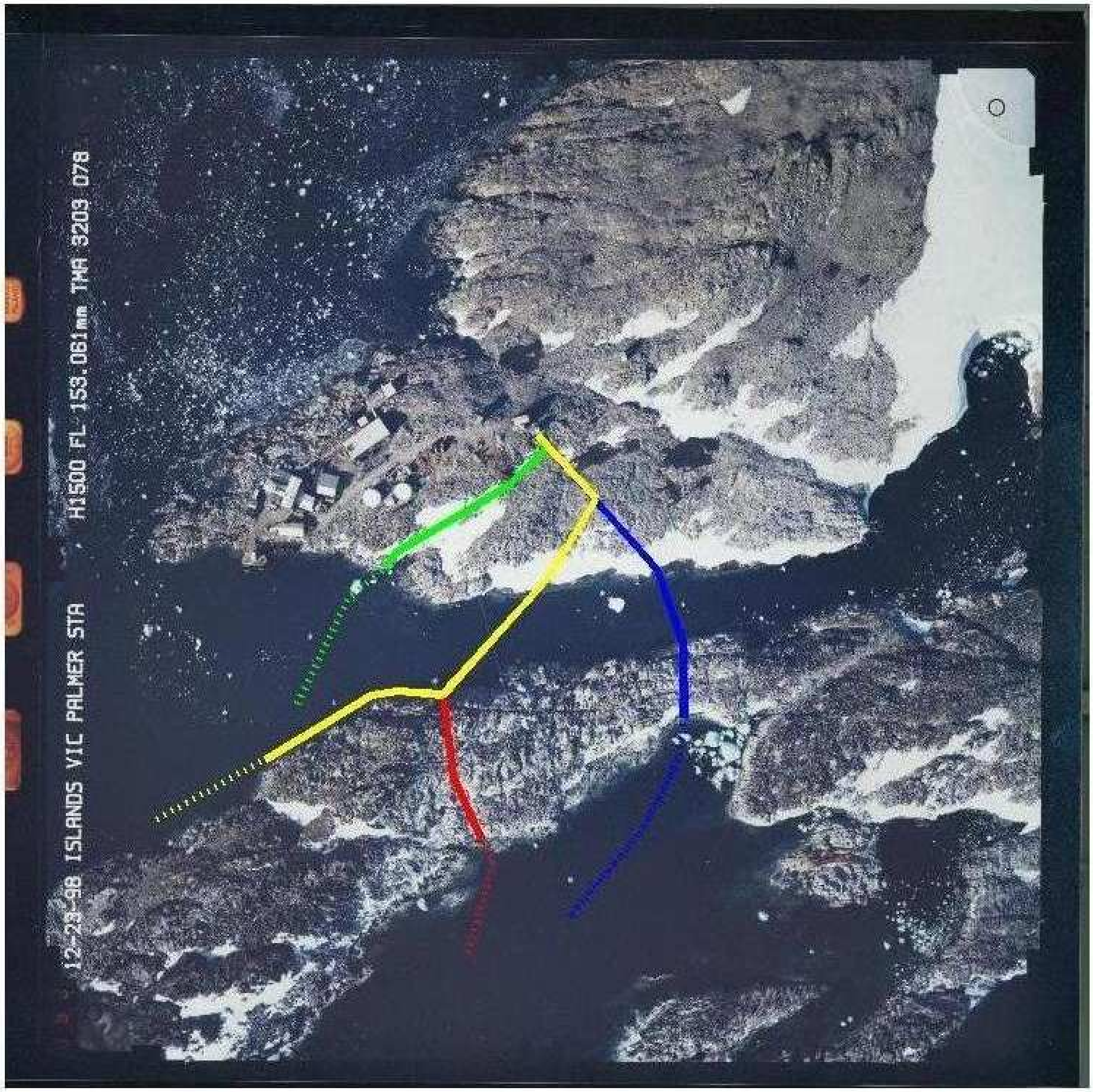


Potential Cable Route #9 runs out of Kristie Cove taking a protective but circuitous route past the PRIMO #1 site and into a basin at a depth of 130 m (PRIMO #3 site). This is close to LTER station F. Total cable length is 5.590 km. No Furuno data available.





Potential Cable Route #10 runs out of Kristie Cove taking a similar protective, but circuitous route past the PRIMO #1 site and into a basin southwest of Laggard Island at a depth of 140 m (PRIMO #4 site). This is close to LTER station E. Total cable length is 6.539 km. No Furuno data available.



Potential locations for cable routes from the IMS building

3.2 Camera Casts.

The camera was generally deployed as closely to the bottom as possible and the course traveled recorded using a combination of trackpoints and marks (waypoints) using a Garmin GPS 12. Following are the courses traveled as well as the dates and times (most in local time):

Camera Cast in upper Arthur Harbor

Start W 007 S64E 46.3854' W064E 03.6137' Waypoint I E 13-APR-05 14:08

End W 008 S64E 46.2865' W064E 03.3575' Waypoint I E 13-APR-05 14:21

Camera Cast in lower Arthur Harbor

Start W 009 S64E 46.7256' W064E 04.4418' Waypoint I E 13-APR-05 14:40

End W 010 S64E 46.5019' W064E 04.0823' Waypoint I E 13-APR-05 15:06

Camera cast near Christie cove

Start W 011 S64E 46.9689' W064E 03.5522' Waypoint I E 13-APR-05 15:18

End W 012 S64E 46.8376' W064E 03.2892' Waypoint I E 13-APR-05 15:37

Camera cast near proposed PRIMO site

Start W FLTSPT S64E 47.6538' W064E 03.4392' Waypoint I E 15-APR-05 14:32

Int W ONBTM S64E 47.6464' W064E 03.4186' Waypoint I E 15-APR-05 14:46

End W 013 S64E 47.7102' W064E 03.4856' Waypoint I E 15-APR-05 15:36

Camera cast near proposed PRIMO site

Start W 014 S64E 47.2937' W064E 08.1352' Waypoint I E 19-APR-05 14:36

Int W 015 S64E 47.3397' W064E 05.2629' Waypoint I E 19-APR-05 15:22

Int W 016 S64E 47.3790' W064E 05.5861' Waypoint I E 19-APR-05 16:02

End W MOB S64E 47.3455' W064E 05.7612' Waypoint I E 19-APR-05 16:11

Camera cast

Start W 017 S64E 47.8199' W064E 07.8401' Waypoint I E 20-APR-05 13:18

End W 018 S64E 47.8476' W064E 08.2270' Waypoint I E 20-APR-05 14:10

Camera Cast

Start W 019 S64E 48.7771' W064E 02.1804' Waypoint I E 20-APR-05 15:18

End W 020 S64E 48.5808' W064E 01.9606' Waypoint I E 20-APR-05 16:23

Camera Cast

Start W 021 S64E 47.4955' W064E 04.8825' Waypoint I E 21-APR-05 18:33

Int T S64E 47.5788' W064E 04.4805' 04/21/2005 13:43:37 0 0:00:16 0.009 2.1

End W 022 S64E 47.9055' W064E 04.4364' Waypoint I E 21-APR-05 19:51

Camera Tow from Hero inlet to Bonaparte Point and Back

Start T S64.775975 W064.048523 04/22/2005 13:02:30 0 0:06:52 0.196 1.3

Int W 001 S64.776737 W064.063543 Waypoint I E 22-APR-05 18:27

ENCOUNTER WITH ALGAE; BROUGHT TO SURFACE

Int W 002 S64.778379 W064.068350 Waypoint I E 22-APR-05 18:39

ROUNDING BONAPARTE POINT

Int W 003 S64.780229 W064.064611 Waypoint I E 22-APR-05 18:53

Int W 004 S64.779216 W064.071729 Waypoint I E 22-APR-05 19:09

Int W 005 S64.776056 W064.069251 Waypoint I E 22-APR-05 19:25

Int W 006 S64.775337 W064.068146 Waypoint I E 22-APR-05 19:29

Int W 007 S64.774801 W064.066971 Waypoint I E 22-APR-05 19:31

Int W 008 S64.774967 W064.060137 Waypoint I E 22-APR-05 19:47

End W 009 S64.775809 W064.049928 Waypoint I E 22-APR-05 20:01

CTD and camera cast in depression south of the Pinnacle

Start W 028 S64.808114 W064.074830 Waypoint I E 27-APR-05 17:59

Int W 029 S64.807963 W064.073939 Waypoint I E 27-APR-05 18:02\

Int W 030 S64.807926 W064.073875 Waypoint I E 27-APR-05 18:04

End W 031 S64.808457 W064.074288 Waypoint I E 27-APR-05 18:36

Camera tow with Chris on the winch, out the proposed cable track to site “PRIMO” and back via “main street”

Start: these data need to be downloaded from the Furuno system

A complete description of the epibenthic community in the regions covered by the drop camera will be included in a manuscript describing the bathymetry and bottom conditions. Briefly, in areas where the bottom formed depressions such as in the troughs between rocks and sea mounts, a fine silty sediment has accumulated to varying depths. Where surfaces rise at a rate of more than about 45 degrees, hard rock is exposed with silt-filled crevasses. Attached broad-leaf macrophytes are extremely abundant from near surface to 60 m, but were observed even at depths of 100m. On rock surfaces, starfish, sunstars, crinoids, and tunicates are fairly abundant. On soft surfaces, tunicates, crinoids, sea cucumbers, and brittle stars dominated the epifaunal community. One particularly interesting area was just off Gamage Point where the number of brittle stars exceeded 100/m3. Given the location of this dense, mono-specific population, it is possible that the brittle stars are feeding on the organic-rich sediment resulting from the Palmer Station outfall pipe.

Appendix A:

Readme file for data and m files
PRIMO Bathymetry project
Palmer Station, Antarctica
April 7 - May 12 2005

Depth data were collected by a furuno depth sounder mounted on a vertical pole extending approximately 0.5 meter below the surface. Transect were run on a 50-100 m grid extending north-south.

NEMA strings of GPRMC and GPDBT and were parsed in realtime using matlab scripts on a tough book laptop and position and depth color coded on the display. Grids were generated to provide 10 vertical north-south legs and overlayed on the small boating map obtained form Jessie Walker in Denver. The zodiacs drove down each leg sampling at approximately once per 3 seconds. The Matlab routine furuno3.m was set up with lat and lon limits to display the chart in realtime.

Set Up

Go to the directory c:\matlab701\ and copy from the CD the folders bathy_data, bathy_grids, and Gould_realtime.

Run matlab and change the directory to bathy_data. All data and mfiles should reside in the current directory.

Plotting mfiles

Plot_all_data2.m
Calls catall.m which makes a list of all the raw files and then reads them in using textread. Catall.m also removes bad data previously identified using ping_edit.m (see below). The file generated is catdata.mat

Then plot_all_data2.m creates variable vectors for time, lat, lon, depth, resets any depth > 200 to 200 so that we can expand the color scale, and plots each individual data point as a color mapped to the color map, in this case jet. It then loads coast_islands_fixed.mat which is the coastline provided by Jessie Walker but the position of THE pinnacle and several shoals have been corrected, and plots the coastline and islands as black dots. The final task is to write out a text file containing all the raw, but ping-corrected data into a file called latlon.txt. This file is used by grid_furuno in the next step.

Grid_furuno.m
This mfile loads latlon.txt created by plot_all_data2.m, sets up a grid of the appropriate size based on the data limits and then interpolates the raw data to fit within the grid dimensions using linear interpolation. Output is furuno_grid.mat which is used by all subsequent plotting routines.

Mesh_furuno.m
Loads furuno_grid.mat and performs a mesh plot using a user-selected view angle
(default is view(-10, 80))[azimuth, angle].

Contour_furuno.m
Loads furuno_grid.mat and performs a contourf which fills the contours will the colormarp and then plots contours at 10 m intervals overlain in black. Units are in decimal degrees.

Chart_contour.m
Produces chart provided to the captain of the Gould. This plot most similar to standard nautical charts. Loads furuno_grid.mat and produces either a contourfm (filled) or contourm (no fill) contour chart at 10 m intervals. Units are in degrees, minutes, seconds.

Chart_mesh.m
Produces chart given to Palmer Station using the function meshm, which allows user selected azimuth and angle of sun light illumination. This produces shadows on the opposite edge providing a sensation of depth. Default light angle is (0,45) but can be changed by the user.

Some useful Tools

Ping_edit.m
User must first run plot_all_data2.m to generate the raw data plot. Then enlarge plot to full screen and zoom in to the area you would like to edit. Now run ping_edit.m, which produces a cross hair on the plot. You can click on any data point (be very precise)which then turns black indicating it has been added to the bad_data.txt list. After you finish editing any given area, right click the mouse to exit ping_edit.m. You can immediately move the plot by the grab icon or re-zoom to a new location where ping_edit is envoked again. Each time you right click, the bad_data.txt file is written with indicies into the raw data file catdata.mat which will be ignored the next time you run plot_all_data2.m.

To complete an editing operation, invoke plot_all_data2.m once again to generate new catdata.mat and latlon.txt file.

Get_depths.m
Allows user to click on the plot generated by mesh_furuno.m to get [lat,lon,depth] along with a dot at that location. Right click to exit the script. Must generate much_furuno plot first.

Profile.m
Allows user the generate a multi-plot with the meshed chart, the depth-distance contour along a trackline, and the cumulative distance traveled both linearly and along the track length (i.e., actual cable length) in 3D. Profile uses furuno_grid.m to generate a mesh plot then asks the user for hoe many data points they would like to enter. Try 2 at first but you can use an infinite number if you like. Right click to get out of the pointing routine and complete the profile generation.

Realtime Plotting utilities

Furuno3.m (or similar mfile call by name of location where mapping to take place).
Opens and closes a text file every time a data line is assembled and written to the file. The line contains GPS time (in Decimal day), location, bottom depth. The filename is established as the current date and time every time the mfile is called.

The procedure was used to record the file on the laptop in the field and then transfer it to the desk top "tunnel" under c:\matlab701\bathy_data\'dayfolder'\filename. The data files for that day were also added to a parallel file structure under \bathy_data\all_grid_data which contained all the raw files.
Example raw file: \bathy_data\all_grid_data\200505T1234 each file containing four columns time lat lon depth.

Contour_gould_realtime.m
Change directory to \Gould_realtime
Loads latlondepth.txt generated by plot_all_data2 and then grids and generates a contour plot of the bathy data. This will take many minutes particularly on a slow machine with low memory. Following the generation of a plot, you must manually run get_gps_plot.m which sets up a com port object and starts parsing the com1 buffer looking for GPGGA which was the most useful string coming from the ashtek gps on the bridge. Get_gps_plot.m calls plot_gould_realtime.m.