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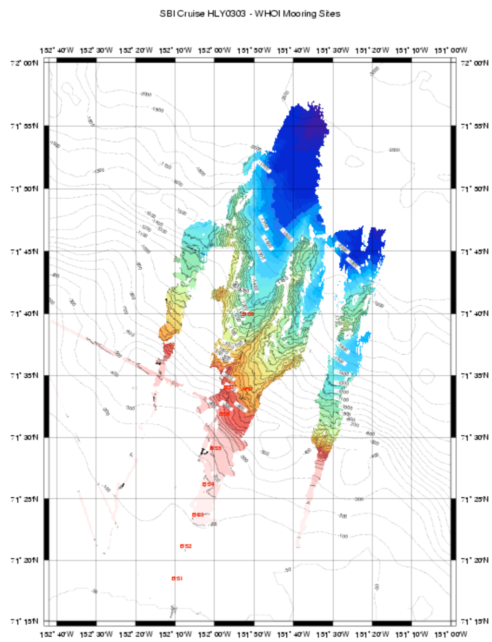

SBI Cruise: Healy-0303

Multi-Beam Sonar Ops

Abstract

This cruise report section documents the operation of multi-beam sonar aboard the USCGC HEALY during the fall 2003 SBI mission – leg 0303. Also included are other observations and recommendations regarding general shipboard and science operations.

Date

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1 About This Document

1.1 Purpose

The purpose of this text is to briefly describe the operational performance and of the SeaBeam multi-beam sonar during the HEALY's 2003 SBI cruise, leg 0303.

1.2 History

Version	Date	Author	Description
N/A			

1.3 Acknowledgements

Date	Contributor	Contribution

2 SeaBeam

2.1 Daily Operations

The SeaBeam 2112 sonar was operated continuously during the cruise. The following points describe the general philosophy for day to day operations.

Because multi-beam surveying was not of primary interest, the SeaBeam was operated without the benefit of continuous watchstanders. Every effort was made by the MSTs and myself to maintain a watchful eye over it.

Sound speed at the keel input was monitored closely from a newly-developed near-real time plot. Only a single event occurred during which the forward TSG data was found to be suspect. This was remedied immediately.

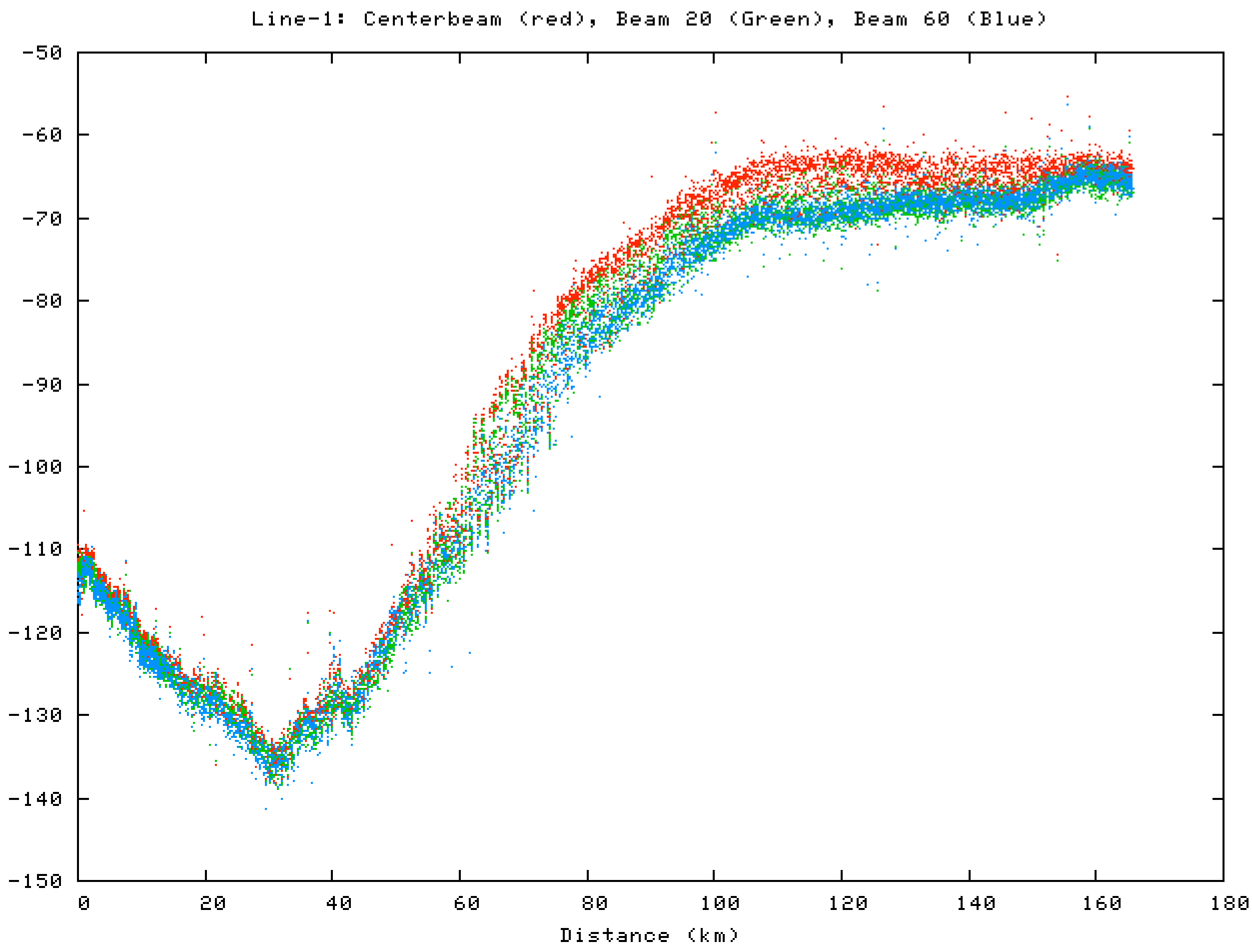
Sound speed profile analysis was conducted exclusively from CTD data, as some 320 CTD casts were made during the cruise. Generally new sound speed profiles were analyzed against recently collected bathymetry data using *mbvelocitytool* as the ship began new CTD lines, or when the ship began an extended operation in a new body of water. The exception to this rule was near the Alaska coast where the ship operated in a warm water current for brief, intermittent periods. Each time new sound speed profiles were applied, principal investigators were informed and comparisons with other sonar systems (after weighted average sound speeds were applied) showed good agreement.

Significant events in operation including Integrated Bridge System outages, system lockups, changes to operating parameters (gain, power levels, pulse-width, etc.) and application of new sound speed profiles were logged in the ship's Underway Logbook database. These entries have been extracted for this cruise and are part of the data package.

2.2 Data Quality

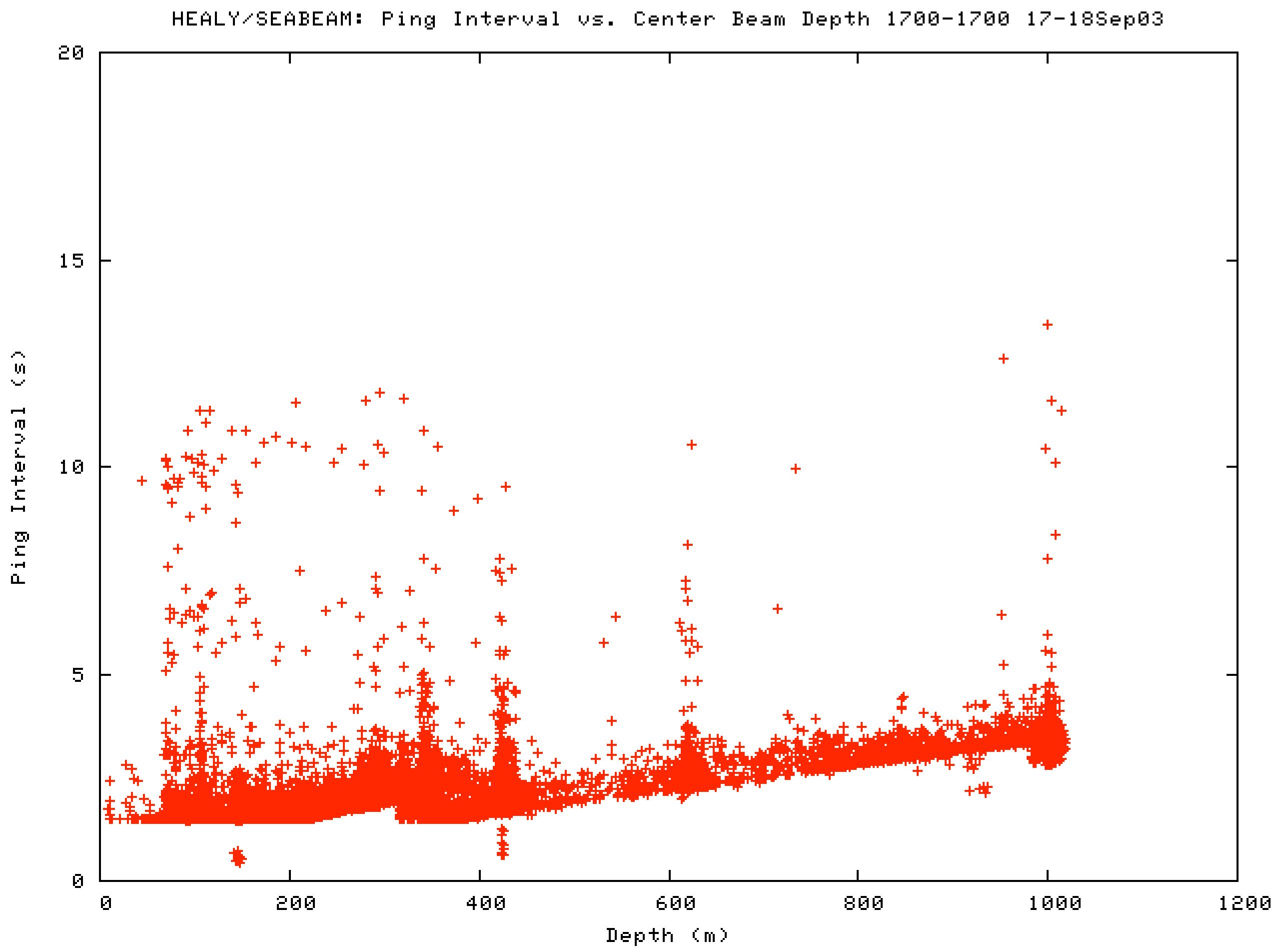
2.2.1 Variance and Bottom Tracking in Shallow Water

Most of the ship's operations during this cruise have been in ocean depths less than 150 meters, with considerable operation less than 80 meters. In these depths the SeaBeam operates in its "near field" where traditional deep water processing assumptions no longer apply. Moreover, noise from the ship and the sonar itself are reflected from the sea floor and can saturate the system producing very low Signal to Noise ratios and subsequently, noisier sonar data. The following plot of beams 20, nadir and 60 vs cumulative along track distance illustrates the point.



In the plot above, the variance of the data is smaller at depth – perhaps 5%, and larger in the shallow water, perhaps 10%. The larger spread of data during the slope illustrates the fact that the sonar has difficulty tracking the bottom, through even a moderate depth change in such conditions. None-the-less, a reasonable approximation of the bottom depth can be had from this data.

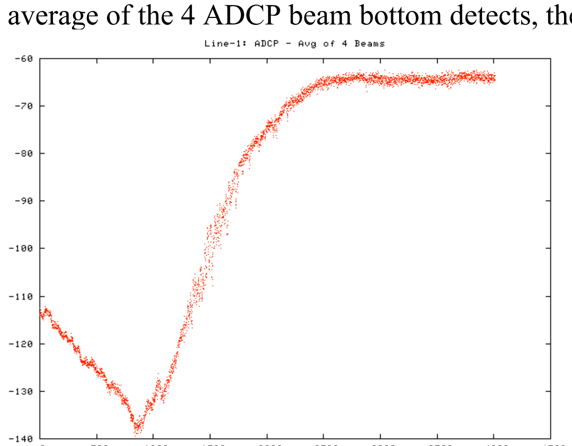
Another measure of sonar bottom tracking ability is to plot the ping interval vs. bottom depth for a portion of the data. For the SeaBeam 2112, this can only be done in water deeper than ~ 400 meters when the sonar will adjust its ping rate off the 1.5 second peg. An excursion to deeper water on September 17th afforded us this opportunity; the resulting plot is below:

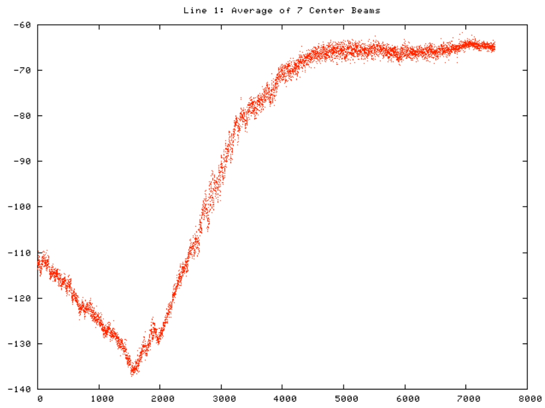


Here the scatter in the plot at water depths shallower than 400 meters illustrates the sonar's inability to track the bottom. In these areas the sonar operates in an analogous way to that of a person when looking at an object that is just closer to his eye than one can focus. Vertical "lines" of scatter in deeper water (400, 600 and 1000 meters) coincide with CTD stations. Deeper than 400 meters, the relationship between ping interval and depth is quite clear which illustrates the sonar's improved tracking ability at these depths.

2.2.2 Comparison of Shallow Water Sonar Data with Other Systems

Although the Sea Beam performance in shallow water pales in comparison to that in deeper water, a reasonable estimate of the bottom contour can still be made. Below are two plots to compare the SeaBeam data with that from the ADCP to illustrate the point. The first is an average of the 4 ADCP beam bottom detects, the second an average of the 7 center multi-beam sonar beams.





The two plots are in quite good alignment, offset somewhat by the fact that the ADCP uses only a single nominal 1500 m/s sound speed. A weighted average sound speed of 1466 m/s applied to the ADCP data brings the curves to within a half meter.

2.2.3 Data Coverage

The maximum ping interval for the SeaBeam 2112 is roughly 1.5 seconds. In water depths of less than a few hundred meters, the sonar pings at this maximum interval. Therefore, to get good bottom coverage in shallow water, the ship must operate at speeds below 5 knots. Multi-beam sonar operations were not of primary interest for this cruise, therefore speeds this slow were not common.

2.2.4 Watchstanding

Because multi-beam data was not of primary concern for the Principle Investigators on this cruise, there were no watchstanders designated to provide 24x7 monitoring of the system. Every reasonable effort was made by myself and the MSTs to keep a watchful eye on the SeaBeam, however we did not catch every operational mishap in as timely a manner as one would normally like. Early on the in the cruise, prolonged operation in shallow water frequently caused the system to lock up, loose bottom track, or simply stop pinging. We found that operating the system with manual depth gates seemed to reduce the number of these system problems. The negative effect of this method of operation was that without dedicated watchstanders the system would occasionally wander outside the depth gates and lose the “real” bottom producing little or no usable data.

2.2.5 General Data Quality

To get a rough idea of the quality of the data provided by the Sea Beam, one can run an automated flagging algorithm over a representative portion of the data. Then, keeping in mind the operational issues described above and the range of water depths and time operating at each, the percent of beams not reported (zero beams) and beams flagged by the algorithm will provide some nominal measure of the sonar’s performance.

Some 240 hours of data were collected and processed to create the composite gridded image on the cover of this document. The range of water depths was between 40 and 2500 meters, with a roughly equal amount of time spent in waters of depth above and below 500 meters. An automated flagging algorithm from MB-System was run on the resulting data. [mbclean –F-1 –I data-list –G.97/1.03 –C1 –M2]. This algorithm flagged beams greater than 3% of the local median and those with or near a slope greater than 1 (45 degrees). These parameters were chosen to provide reasonable cleaning of the data without throwing out the proverbial *baby-with-the- bathwater* through a trial and error process.

```
Data Totals:
Number of Records:           307171
Bathymetry Data (151 beams):
  Number of Beams:         34164149
  Number of Good Beams:    11125786     32.57%
  Number of Zero Beams:    18221372     53.33%
  Number of Flagged Beams:  4816991     14.10%
```

Here we see that after applying the automated flagging routine the nominal percentage of acceptable data is 32%. While not as high as one might nominally expect from a mult-beam sonar, this value is consistent with other data collected during the cruise. The largest attrition of beam values is due to “zero” beams. These occur when the sonar system cannot resolve the bottom due to any of many causes, most notably, operation in shallow water, improperly set depth gates, excessive noise from the bow thruster, bubbles under the hull in rough seas, etc.

2.3 Challenges to Continuous Operation

2.3.1 SeaBeam Stability

This sonar is particularly unstable when operating in water depths shallower than for which it is designed, resulting in all kinds of odd behavior that are extremely difficult to troubleshoot. For example, occasionally the sonar stops pinging for no apparent reason. Error messages from the vertical reference unit occur when there has been no discernable loss of information from it. When moderate changes in the sea floor depth occur (~500 meters) over a relatively short distance the sonar frequently has a difficult time tracking. Sometimes the system reaches an internal state in which no amount of manual intervention to restore bottom track can correct. In most of these cases the only recourse is a complete power down and restoration of the system – a 15-20 minute process. While all of these phenomena have been witnessed in deep water operation, their frequency of occurrence increased dramatically when operating in shallow water. The result was an abnormally high number of system outages.

2.3.2 Peripheral System Stability

Multi-beam sonar systems rely on several peripheral inputs, many of which must be received in real-time. These include measurements of sound speed at the keel, a standard time source, navigation information, and vertical reference input. A loss of any of these inputs effectively puts the system out of service, and so the mean time between failures of the sonar can only be as good as any of these peripheral items.

The quality of these inputs is also extremely important – for sound speed at the keel, it is unrecoverable. Because keel sound speed is used in sonar beam forming, and the raw time series data used by the sonar in this process is not available to the operator, incorrect data from this device results in a complete loss of useful data. Real-time input from one of two possible thermo-salinographs is provided to meet this need, however the sonar system is plagued by the fact that it defaults, on reboot, to a manually entered value rather than external input from the TSG. In the past, freezing pipes in cold weather and ice operations have clogged the forward TSG sea water suction and resulted in poor sound speed values until noticed and the aft TSG placed in operation. Fortunately, on this trip, reduced ice conditions and lower latitude operations freed us of this hassle. It was also noticed that the TSG occasionally resets itself which results in a line of text in the serial output and at least once, subsequent data was of dubious quality. An excerpt from the log of this instance follows.

```
09/15/2003,05:50:10.223,      57517         0.385         2.530        29.70        -0.080      1443.837
09/15/2003,05:50:16.223,      57518         0.386         2.530        29.70        -0.080      1443.845
09/15/2003,05:50:22.285,      57519         0.385         2.530        29.70        -0.079      1443.837
09/15/2003,06:02:44.289,C:\DATA\HLY-03-03-1.hex  Sep 15 2003 06:02:44  SEASOFT V 5.27c
09/15/2003,06:02:44.383,       scan         t068m         c0S/m        sal00         t190m          svC
09/15/2003,06:02:44.446,          1         0.793         2.578        29.92         0.335      1446.000
09/15/2003,06:02:44.524,          2        20.344         0.080         0.43        98.976      1483.897
09/15/2003,06:02:49.821,          3         0.795         2.578        29.91         0.334      1446.002
```

In this instance, a reboot of the TSG computer resulted in a resumption of normal operation.

Navigation from the Integrated Bridge System (IBS) comes with just two decimal places of precision, and yet has an extraordinary amount of noise. Moreover, since we have been keeping close records this summer, the IBS has failed in some manner (either loss of nav data or time synch) no less than once a week, and sometimes as many as three or four times in a day. Most of these failures have not lasted more than an hour, yet they have occasionally required a full system reboot of the sonar. It is of no little concern that the IBS component computers (9 of them) operate on Windows NT. The stability of this operating system and the complexity of the IBS are likely contributors to the outages. At least three times during this cruise the science system administrator has asked the entire science party with Windows based computers to conduct full virus scans because of some recent threat. While the IBS IP data network is physically isolated from the other networks on board, it is likely just a matter of time before these systems become infected from floppies or other means. Such an infection would likely render the system inoperable until return to port.

2.4 Summary and Recommendations

The Sea Beam has not operated significantly different on this leg of the SBI cruise than any of those earlier this year. Differences in data quality can be largely attributed to dedicated watchstanders, quick to take action when the sonar looses bottom or otherwise malfunctions. The stability of the Integrated Bridge System, thermo-salinograph, and other peripheral systems remain a significant source of down time for the system. An automatically generated plot, visible to any web browser has been created to help watchstanders and MSTs monitor the thermo-salinograph. The replacement of the IBS inputs to the Sea Beam with a high stability GPS-aided inertial navigation system should be of the highest priority.

Of course, damage to the transducers and transducer windows should be repaired during the coming shipyard period. These repairs should include a complete survey of the transducers with respect to the ship's reference, a full set of impedance measurements on the repaired transducers for the ship's records, rewiring of the transducers to remove the shorts that have been inserted removing damaged transducers from the circuit, and two to three days of dedicated sea time with reasonable weather to conduct roll, pitch and heading biases and otherwise groom the system.

In the long term, the Coast Guard should begin considering an upgrade to the Sea Beam. Upgraded versions of the current model are available with greatly increased system stability and additional operational features that would both increase the data quality and quantity provided to the scientific community.

3 Other Comments and Suggestions

Let it be said that the science support of the HEALY and her crew has been wonderful. The "can-do" attitude and friendliness of the crew as well as living accommodations and food have made this a completely enjoyable trip.

There are a few details that would increase the productivity of scientists at sea and as well as the general livability of the ship. These are listed below:

1. The ship desperately needs a technical reference library, for scientists, crew and system administration staff. It should be located in the "science spaces" in the aft portion of the ship (perhaps the Futures lab). I have taken a poll of the current science party to create an impromptu list of references that should be included in the library. Where specific titles could not be listed, a general description is provided. I think the references listed below are largely representative of such a poll taken of any science party likely to board the HEALY. :
    - Recently published undergraduate textbooks for Chemistry, Biology and Physics.
    - *Data Analysis Methods in Physical Oceanography* - Emery and Thomson. 1997.
    - *The CRC Handbook of Chemistry and Physics*
    - Several Matlab references.
    - A large collection of computer science texts from the O'Reilly Publishing group (known as the "animal books"). Topics should include Perl, Visual Basic, C, HMTL, Unix System Administration, Window System Administration, Mac System Administration, DocBook, Shell Scripting, Sendmail, IMAP
    - The Practical Navigator – any recent edition.
    - A guide to serial communications and devices.
    - *Numerical Recipes in C* and *Numerical Recipes in C++*
    - *Principles of Underwater Sound,* Ulrick
    - *Handbook of Ocean and Underwater Engineering*. Myers, Holm, McAllister
    - *Fundamentals of Acoustics.* Kinsler and Frey
    - *The Visual Display of Quantitative Information.* Tufte.
    - *Advanced Mathematics for Engineers.* Kreizig
    - *Polar Oceans (Vol I and II)* W. O Smith.
    - The 'Open University Series' books on Oceanography.

2. It would be very helpful to have navigation/chart software with a real time GPS feed operating continuously that could be remotely monitored from any computer on the ship. The idea is to provide instant "where are we?" without the need to find a chart and plot our position from the most recently logged data. Displays could be created in the main lab, science lounge and perhaps the mess. An alternative to this is simply an increase in the number of ship's video system viewing stations. Composite displays of multiple "channels" would be helpful.
3. A Linux computer called "map" is used primarily for processing of multi-beam sonar data for troubleshooting and diagnostic purposes. A second computer, "pproc" is used for the processing of sonar data for science. This kind of computing and display of multi-beam data sets is extremely cpu and memory intensive. These machines each have just a 700MHz cpu and 375 MB of RAM. Both of these machines should be upgraded to systems with a minimum 2 GHz cpu and 1 Gigabyte of onboard RAM.

4. The ship's policy of two hours of internet connectivity to shore each day seems reasonably adequate for science needs. However, it would be extraordinarily helpful to augment the current two hours of internet time with at least one other time during the day when the science email system is allowed to connect to shore to send and receive mail. General internet access would not be necessary during this time. The extra email transfer time would allow one to send an email to a colleague one evening, receive their response the next morning, and confirm any details before their work day is out. [In the final days of HLY0303 this suggestion was put into practice. It would be nice for it to become the norm.]
5. It has become clear, that the shore support personnel for the Iridium system have taken to regularly reading the email correspondence sent by the science party. On several occasions personnel have received replies from the shore support regarding content in email to colleagues, friends and family ashore, that is not in any way related to email operation. I have helped in troubleshooting the Iridium system on occasion and have built a relationship with some of these people. At times they have intervened when I have inadvertently sent attachments of inappropriate size. For this I am thankful. However I think it is generally inappropriate for other members of the ship's science party to have their email read and commented on by the Coast Guard support staff. Some modicum of privacy is expected.
6. It is a wonder that the ship could have ever operated without a dedicated system administrator, as it seems Joe does so much and provides so much help to the science operation. Indeed, he is overburdened by the scope of his responsibilities and the length of the cruise. A second system administrator should be assigned to the ship to both assist Joe and provide him some much needed relief.

7. Final Notes

In closing, the HLY0303 leg of the SBI cruise has been quite successful, due in no small part to the professional and dedicated work of the Healy's crew and pleasing disposition of the science party. Despite the challenges of shallow water operation and peripheral system stability, SeaBeam multi-beam sonar provided good coverage of the mooring positions and single line bottom depths for CTD runs. Many thanks to the principle investigators for their understanding, patience and support during these past six weeks.