Status report on HLY-03 153-kHz ADCP

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1. Introduction

The USCGC Healy contains two separate and independent hull-mounted acoustic Doppler current profiler systems. The systems are a 75 kHz phased array (Ocean Surveyor) and a regular 4-beam 153 kHz transducer (BroadBand). Each system is mounted in its own well that is filled with anti-freeze solution and is separated from the water by an acoustic window. The 75 kHz system performed exceptionally well, is fully operational, and requires minimal operator interference if it is setup and maintained correctly. The same cannot be said for the 153 kHz system which is not operational at the present time. Excessive mechanical and/or electromagnetic noise reduced water tracking range to less than 80-m and data quality below acceptable levels throughout the water column most of the time. The source of this "noise" is not known, however, I suspect that it is related to the "hash" reported earlier by Hummon and Firing (2000) who stated that *"…The most serious type of noise received by the ADCP has well-defined properties, but its source has not yet been identified. We refer to this noise as "hash" because of the way it looks on a correlation .... It shows up as high correlations and amplitudes in a single depth bin of all four beams simultaneously … Pings free of the interference occur at intervals of several seconds, but the interval was not constant from one instance to another …"* This status report summarizes 2003 findings that may aid trouble shooting of the instruments and its installation by its manufacturer RDI and UNOLS experts on vessel-mounted ADCP installations. I suspect that ship's vibrations overwhelm the signals that the acoustic receivers receive from the water column.

2. Data streams

The 153 kHz BroadBand (BB-153) was run via VMDAS under Windows-2000 Professional that controls input and output data streams. VMDAS receives

> BB153 single ping data via serial port COM7 (.ENR file on output),
> Gyro heading data via serial port COM7 (.ENR file on output),
> P-code (aft) GPS data via serial port COM8 (.N1R file on output), and
> Ashtech navigational and attitude data via serial port COM9 (.N2R file on output)

The aft P-code GPS system is distinct from the bridge P-code GPS system. VMDAS generates 10 different output files that merge and average data from the three input streams in varying ways. A .LOG file contains both direct commands send to the BB153 on start-up as well as all subsequent error messages. The most frequent, very intermittent error messages were

> [date,time]: NMEA [RPH] communication time out
> [date,time]: NMEA [RPH] Error writing to raw data file
> [date, time]: ADCPCOMMTMO:PrevPingTime=[19:15:00.659] EnsBufIndex=0 Hdr=[7f 7f c2 04]

indicating that VMDAS does not receive the Ashtech data. Generally, the Ashtech dropped out intermittently for a few minutes every day. Prior data recording problems were eliminated entirely when all data were recorded on the local machine ONLY. The last message is more serious as it indicates communication problems between the ADCP and its controlling software.

3. Performance

The BB-153 rarely penetrated more than 80-m of the water column for the water tracking pulse under a range of set-up parameters (2-m to 8-m vertical bins) and environmental conditions (0-kts to 18 kts ship speeds). This is much less than was reported for the 2002 (see Flagg's 2002 SBI-ADCP report) and 2000 (Hummon and Firing) deployments of this instrument. The above authors reported depth penetrations closer to 150-m or even 250-m. The bottom tracking pings does not appear to suffer the near-fatal fate of the water tracking ping as the BB-153 has no problem finding the bottom (and ship's speed over ground) correctly to about 450 to 500-m depths.

In order to illustrate the problem it is necessary to analyze single ping data. Figs. 4-10 show such data while the ship is on station (Oct.-3, 2003) in deep water (>1000-m) and while it steams at about 10 kts (Sept. 24/25, 2003) from deep (>400-m) into shallow (<200-m) water. The sea state was generally calm on both occasion with wind speeds <20 kts and wave heights <0.5-m. The details of the instrument set-up (direct commands) are described in section 5 below.

While the ship is on station in deep water, a small number of high echo-intensity, high correlation pings stand out (Fig. 4). These erroneous pings appear anywhere within the water column at semi-regular locations and times. It is possible to observe the situation in real time within VMDAS as the entire vertical profile of echo-intensity and correlation changes shape dramatically from ping to ping. The situation is very similar to that observed in 2000 by Hummon and Firing during the Healy sea trials in Baffin Bay and I most strongly agree with their conclusion that noise and/or vibrations internal to ship cause elevated signal strengths (echo intensity) where one would not expect it in the water column.

The semi-periodic nature of these perturbations ("hash") becomes most apparent when the single ping echo-intensity and correlation data are Fourier transformed. Fig,, 5 shows the log of spectral energy density with units of counts^2/(cycles/time-step) as a function of frequency and depth. The frequencies range from 1/2048 cycles/time-step to 0.5 cycles/time-step (Nyquist frequency) which for a time step of about 2.52 seconds between pings correspond to periods of about 1.5 hours to 5 seconds. Distinctly elevated peaks occur at about 9.6, 5.2, and 5.1 seconds. The frequencies of these perturbations vary. Fig. 6 shows a similar spectral energy density plot obtained from 2048 pings while the ship is steaming at about 10 kts. Pronounced peaks now occur a different frequencies. It may also be instructive to compare Figs. 5 and 6 from the BB-153 against similar data from the operational OS-75. No spectral peaks appear in Fourier transforms of single-ping correlation and echo intensity data (Fig. 7), that is, only the BB-153 is affected by the source of noise that originates from within the ship.

Figs. 8 and 9 shows time-domain single ping echo-intensity, correlation, and percent good pings (either 0% or 100% for a single ping) for the underway data. The "hash" becomes most dramatic, both in its large amplitude and its distribution throughout the entire water column. Almost all pings below 80-m depth are flagged as bad, however, I suspect that many "good" pings within the surface 80-m are also impacted by "hash" (Fig.8). Nevertheless, the BB-153 bottom tracking pulse works well (Fig. 9), however, the character of the "hash" changes over time as indicated by Fig. 9. It now shows very regular single-ping patterns between 60-m and 120-m, however, groups of 4-6 pings with much elevated echo intensities and correlations now occur about every minute as

well. A histogram of the underway data emphasizes the skewed distribution of Echo intensity and correlation.

4. Recommendations

 Disassemble transducer unit (Fig. 1) and deckbox for testing, diagnostics, and refurbishment by the manufacturer RDI in San Diego;

 Replace the bent cable (Fig. 3), reterminate perhaps with a 90 degree adapters to accommodate the lid of the well;

 Insulate the mounting plate and bolts completely from the ship's hull;

 Inspect the acoustic window for perturbations such as scratches, fractures, or foreign material;

 Refurbish the inside of the well with sound-absorbing material to minimize ringing of the well and cavity of the velocimeter

5. Instrument Configuration (Direct Commands)

This report makes reference to two separate configurations while the ship was on station in water >1000-m deep (HLY-03-03bb024) and while it was steaming at about 10-kts from ~500-m deep water into <200-m deep water (HLY-03-03bb017).

5.1 The direct commands underway data (HLY-03-03bb017)

[2003/09/24, 03:51:48.743]:
Broadband ADCP Version 5.59
RD Instruments (c) 1991-2000
All rights reserved.
>[2003/09/24, 03:51:48.758]: -->Sending commands from ADCP command file...
[2003/09/24, 03:51:48.758]: cr1
[2003/09/24, 03:51:48.821]: cr1
[Parameters set to FACTORY defaults]
>[2003/09/24, 03:51:48.821]: WP0000
[2003/09/24, 03:51:48.836]: WP00001
>[2003/09/24, 03:51:48.836]: WM1
[2003/09/24, 03:51:48.852]: WM1
>[2003/09/24, 03:51:48.852]: WB0
[2003/09/24, 03:51:48.852]: WB0
>[2003/09/24, 03:51:48.852]: WS0400
[2003/09/24, 03:51:48.868]: WS0400
>[2003/09/24, 03:51:48.868]: WF0400
[2003/09/24, 03:51:48.899]: WF0400
>[2003/09/24, 03:51:48.899]: WN040
[2003/09/24, 03:51:48.915]: WN040
>[2003/09/24, 03:51:48.915]: WV650
[2003/09/24, 03:51:48.915]: WV650
>[2003/09/24, 03:51:48.930]: BA030
[2003/09/24, 03:51:48.930]: BA030
>[2003/09/24, 03:51:48.930]: BP001
[2003/09/24, 03:51:48.946]: BP001

>[2003/09/24, 03:51:48.946]: BX8000
[2003/09/24, 03:51:48.977]: BX8000
>[2003/09/24, 03:51:48.977]: WD111100000
[2003/09/24, 03:51:48.993]: WD111100000
>[2003/09/24, 03:51:48.993]: TP000150
[2003/09/24, 03:51:49.008]: TP000150
>[2003/09/24, 03:51:49.008]: TE00000300
[2003/09/24, 03:51:49.024]: TE00000300

5.2 The direct commands station data (HLY-03-03bb024)

[2003/10/03, 05:21:45.437]:
Broadband ADCP Version 5.59
RD Instruments (c) 1991-2000
All rights reserved.
>[2003/10/03, 05:21:45.453]: -->Sending commands from ADCP command file...
[2003/10/03, 05:21:45.453]: cr1
[2003/10/03, 05:21:45.515]: cr1
[Parameters set to FACTORY defaults]
>[2003/10/03, 05:21:45.515]: WP00001
[2003/10/03, 05:21:45.531]: WP00001
>[2003/10/03, 05:21:45.531]: WM1
[2003/10/03, 05:21:45.547]: WM1
>[2003/10/03, 05:21:45.547]: WB0
[2003/10/03, 05:21:45.562]: WB0
>[2003/10/03, 05:21:45.562]: WS0400
[2003/10/03, 05:21:45.578]: WS0400
>[2003/10/03, 05:21:45.578]: WF0400
[2003/10/03, 05:21:45.593]: WF0400
>[2003/10/03, 05:21:45.593]: WN040
[2003/10/03, 05:21:45.609]: WN040
>[2003/10/03, 05:21:45.609]: WV650
[2003/10/03, 05:21:45.625]: WV650
>[2003/10/03, 05:21:45.625]: BA030
[2003/10/03, 05:21:45.640]: BA030
>[2003/10/03, 05:21:45.640]: BP001
[2003/10/03, 05:21:45.656]: BP001
>[2003/10/03, 05:21:45.656]: BX8000
[2003/10/03, 05:21:45.672]: BX8000
>[2003/10/03, 05:21:45.672]: WD111100000
[2003/10/03, 05:21:45.687]: WD111100000
>[2003/10/03, 05:21:45.687]: TP000150
[2003/10/03, 05:21:45.703]: TP000150
>[2003/10/03, 05:21:45.703]: TE00000300
[2003/10/03, 05:21:45.718]: TE00000300

6. Photos

Fig. 1: Top view of the 153-kHz ADCP transducer unit after the well is drained of most of its (light green) anti-freeze fluid. Note the rubber washers (black) below the rust-red mounting plate with 4 mounting bolts.

Fig. 2: Mounting of the transducer plate to the ship's hull. Note that this strip of rubber that is probably insufficient to acoustically insulate the ship's vibrations from the transducer heads.

Fig. 3: Bent cable providing power and data control to the transducer heads. Note the velocimeter in the background. The cavity was filled with hard styrofoam in St. John's July 19, 2003 to reduce resonance and ringing within the well.

7. Plots

I apologize for the generally poor quality of the figures as Microsoft Word does not easily accommodates high-resolution postscript graphics. I am forced to use this inferior product as my word-processing and desktop publishing software is still aboard the USCGC Healy. These high-resolution graphics can be found at

http://newark.cms.udel.edu/~muenchow/Healy-2003

along with this and supplemental reports on the ADCP data collections aboard the USCGC Healy in 2003.

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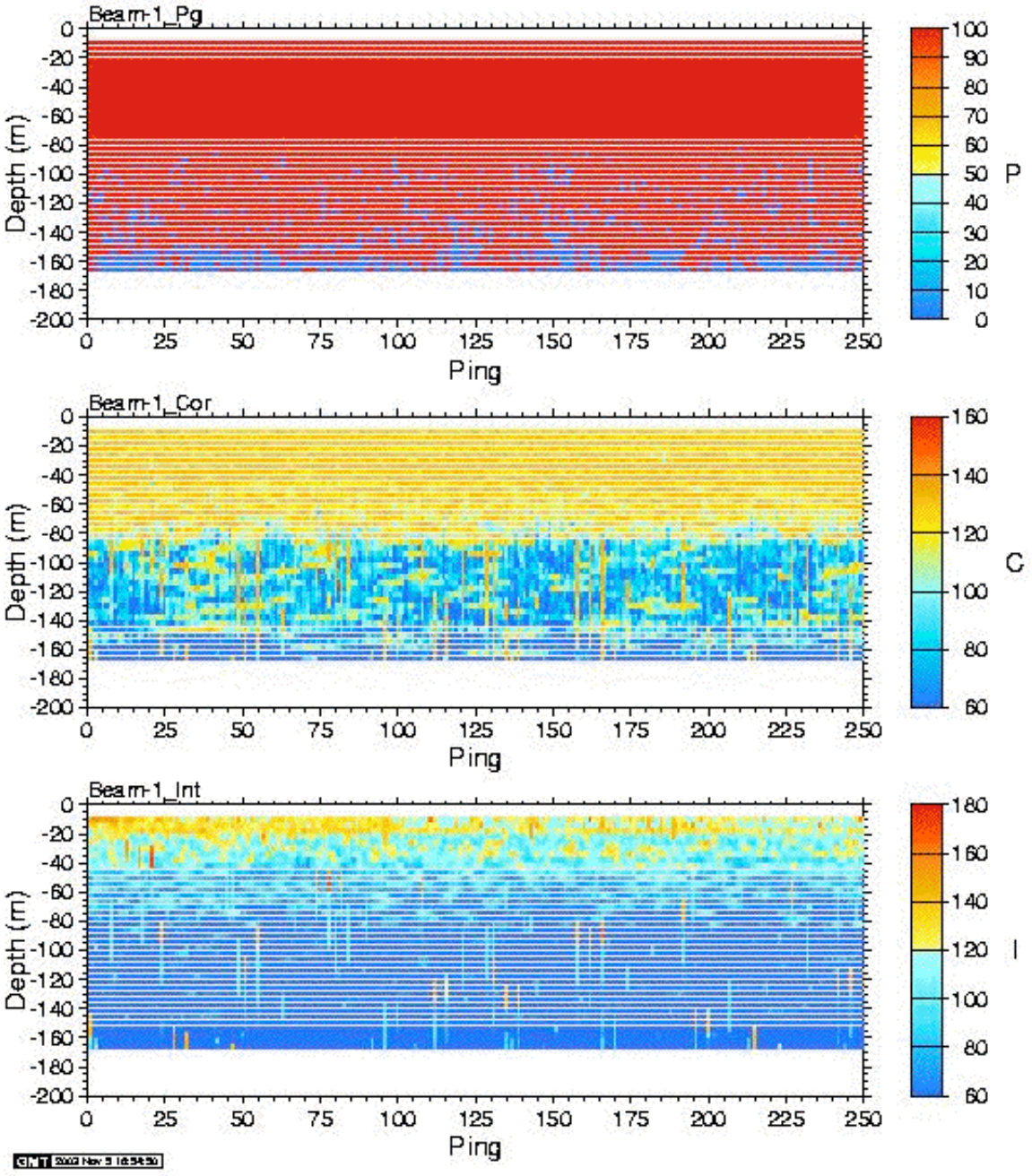

Fig. 4: Time-series of "%-good-pings" (top), "correlation" (middle), and "echo intensity" (bottom) for 250 single pings of beam-1 while the ship is on station in water >1000-m deep in the Beaufort Sea (Oct.-03, 2003, ~05:30 UTC).

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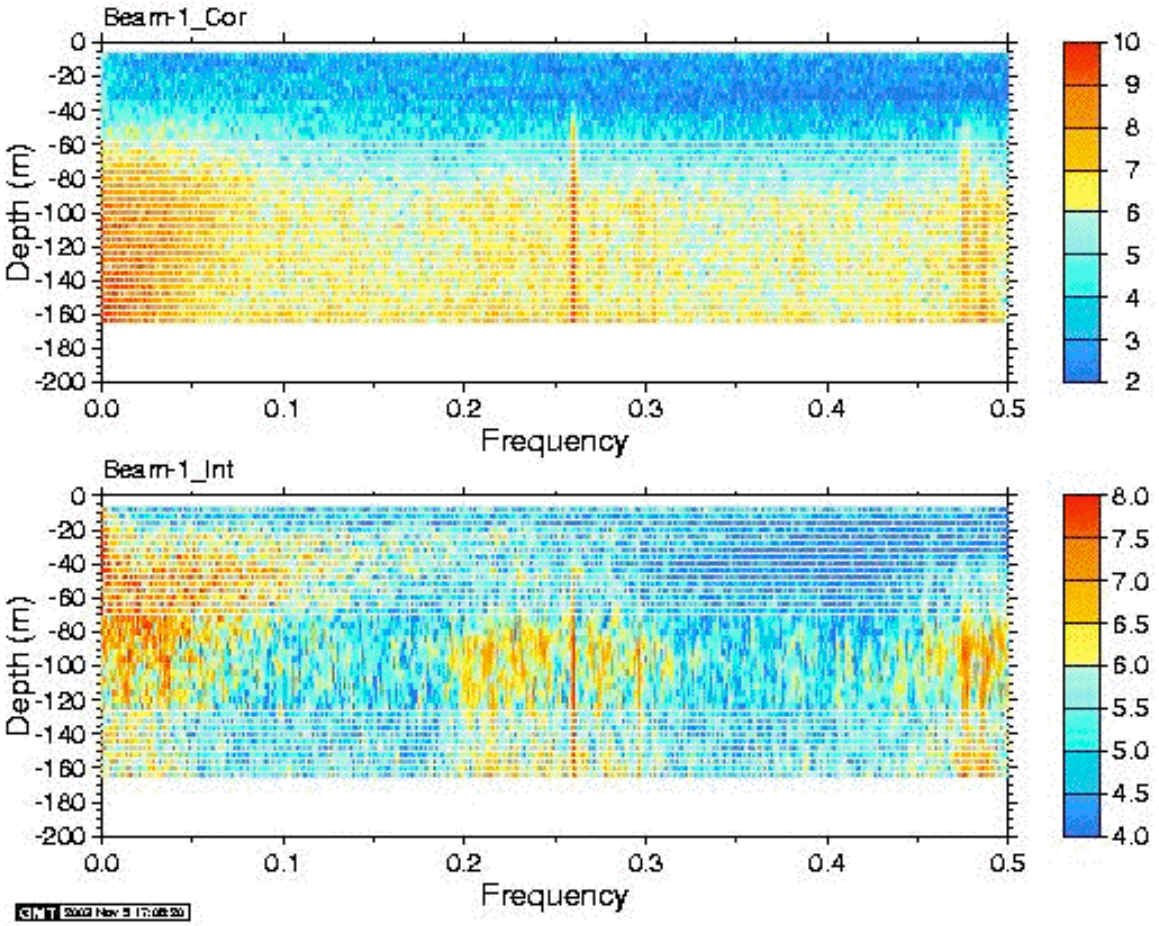

Fig. 5: Power spectra of “correlation” (top) and “echo-intensity” (bottom) for 2048 pings while the ship is on station in water >1000-m deep in the Beaufort Sea (Oct.-3, 2003 ~05:30 UTC). Frequency is in cycles/time-step where the time step between pings is about 2.5 seconds. Note the large peaks near 0.26, 0.48, and 0.49 cycles/time-step that correspond to periods of about 9.6, 5.2, and 5.1 seconds, respectively. Color coding indicates the logarithm of the power spectral density with units (counts^2/(cycles/time-step).

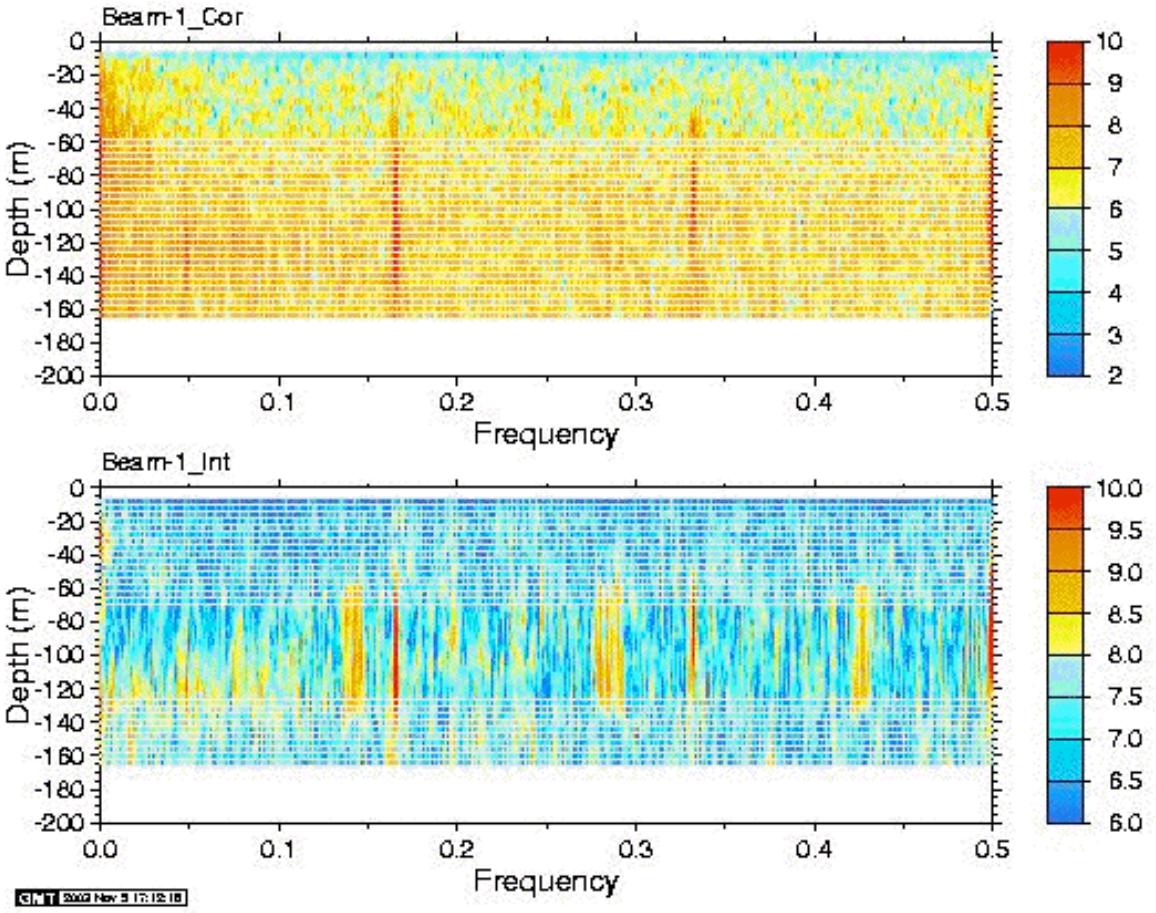

Fig. 6: As Fig. 5, but for data from the 153-kHz ADCP while the ship is steaming at 10 kts. Note the spectral peaks below 40-m near frequencies of 0.16, 0.32, and 0.5 cycles/time-step in the beam-1 correlation (top panel) that also occur in echo intensity (bottom panel).

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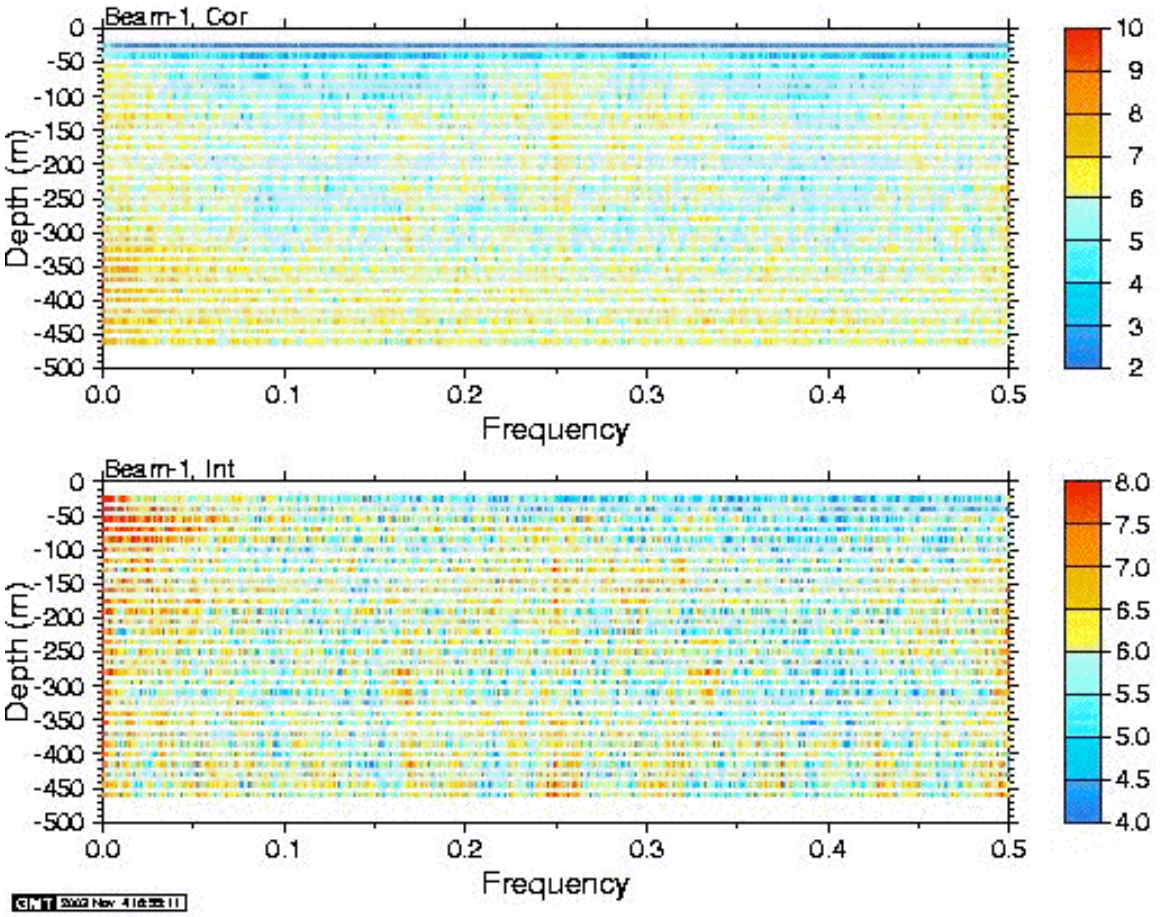

Fig. 7: As Fig. 5, but for data from the operational 75 kHz Ocean Surveyor ADCP. Note the absence of any spectral peaks.

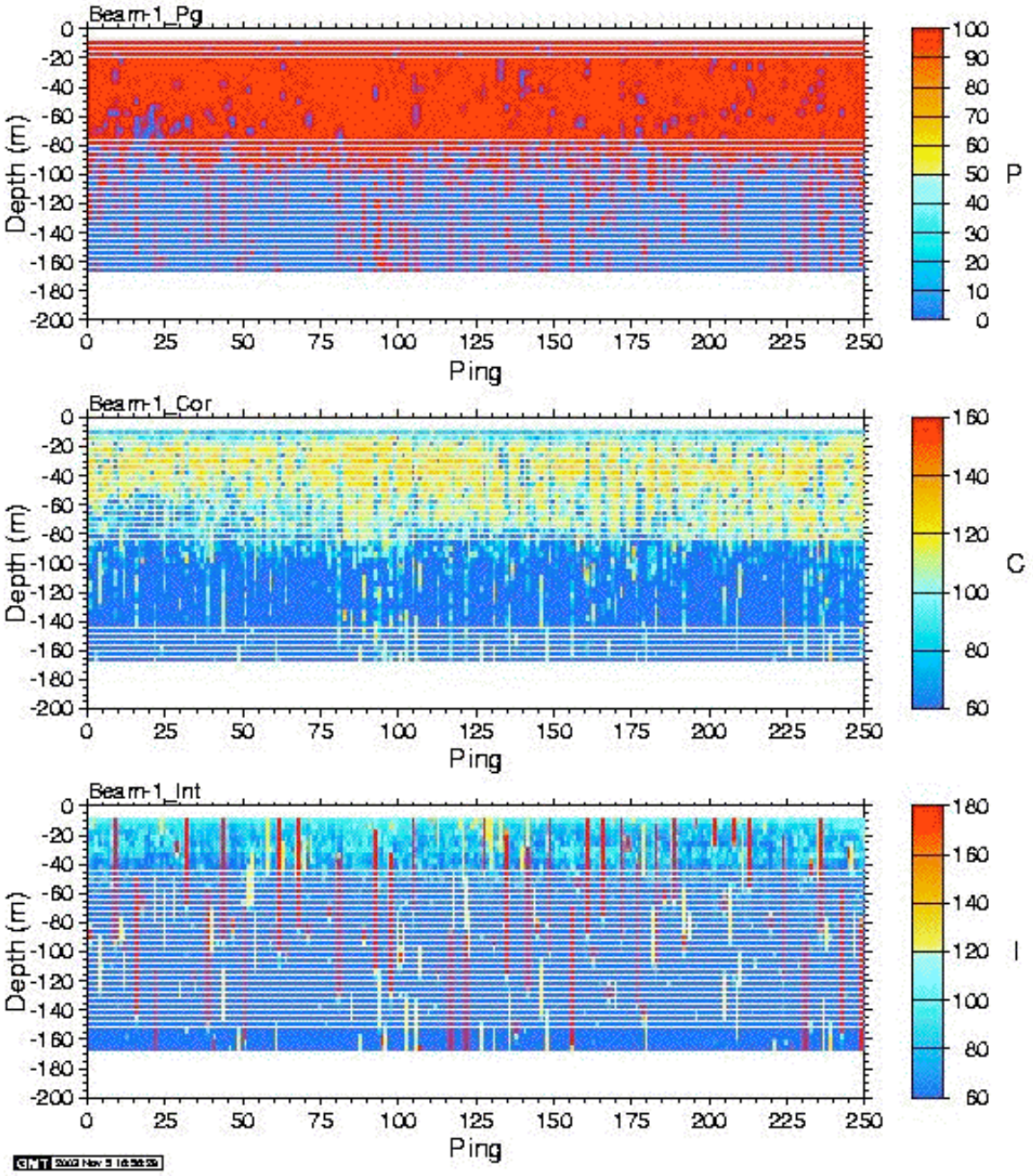

Fig. 8: As Fig. 4, but while the ship is steaming at ~10 kts in water >300-m (Sept.-24, 2003, ~03:55 UTC). Note the large echo intensity (bottom panel) that occurs intermittently throughout the entire water column. It corresponds to low correlation (middle panel) and often is flagged falsely as a good ping (top panel). This erroneous signal originates from within the ship.

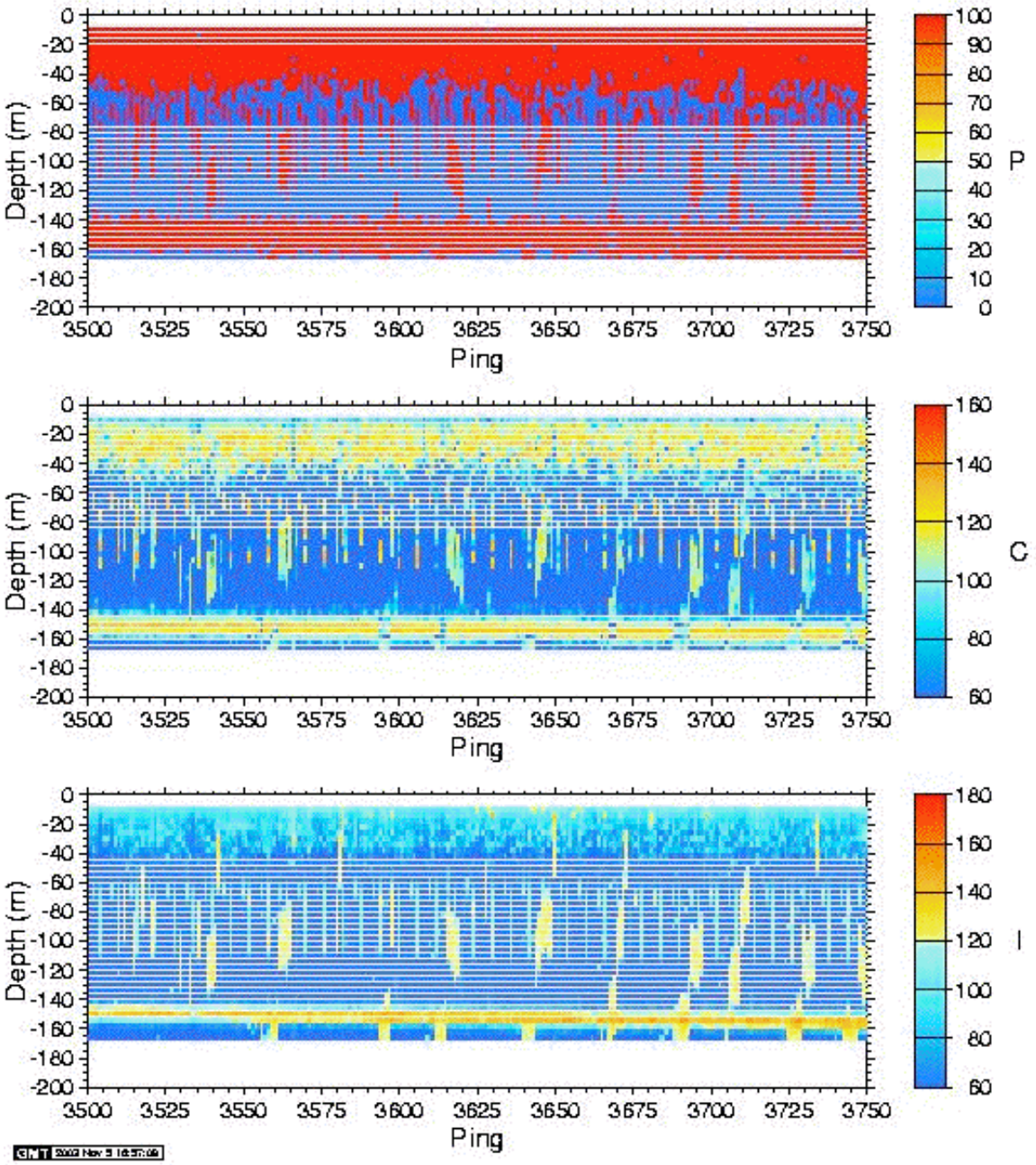

Fig. 9: As Fig. 8, but while the ship is tracking the bottom correctly at about 150-m. Note the large amount of very periodic “hash” between 50-m and 120-m water depth. This erroneous signal originates from within the ship.

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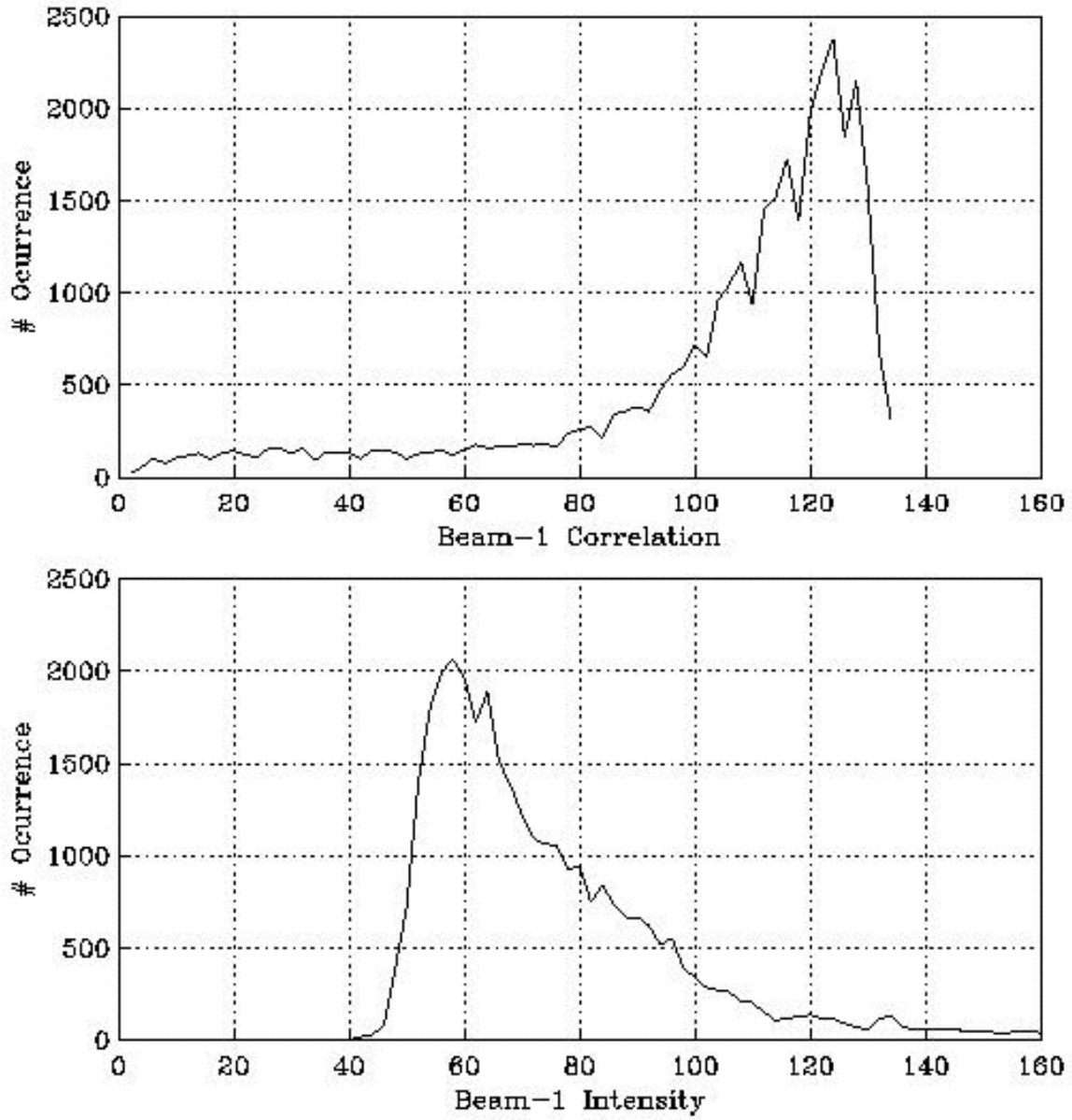

Fig. 10: Histogram of “correlation” (top) and “echo-intensity” (bottom) for beam-1, bin-30 (~130-m depth) for data collected Sept.-24, 2003, 03:51 UTC to Sept.-25, 2003, 04:05 UTC. Note the highly skewed distribution for both echo intensity and correlation.