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# U.S. Law of the Sea Cruise to Map the Foot of the Slope and 2500-m Isobath of the U.S. Arctic Ocean Margin, Barrow to Barrow. Cruise Report

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# CRUISE REPORT

**USCGC Icebreaker *Healy* (WAGB-20)**

**U.S. Law of the Sea cruise to map the foot of the slope  
and 2500-m isobath of the US Arctic Ocean margin**

**CRUISES HE-0302**

**August 30 to September 11, 2003**

**Barrow, AK to Barrow, AK**

**Larry A. Mayer**

Center for Coastal and Ocean Mapping/Joint Hydrographic Center  
University of New Hampshire  
Durham, NH 03824



February 15, 2004

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## INTRODUCTION

The objective of HEALY-0302 was to test the feasibility of collecting high-resolution multibeam echo-sounder data in ice-covered areas of the Arctic Ocean which may potentially qualify for an extended continental shelf under Article 76 of the United Nations Convention on the Law of the Sea (UNCLOS).

Under Article 76 of UNCLOS, coastal states may, under certain circumstances gain sovereign rights over the resources of the seafloor and subsurface of “submerged extensions of their continental margin” beyond the recognized 200 nautical mile limit of their Exclusive Economic Zone. The United States has not yet acceded to the UNCLOS. However, increasing recognition that implementation of Article 76 could confer sovereign rights over large and potentially resource-rich areas of the seabed beyond its current 200 nautical mile (nmi) limit has renewed interest in the potential for accession to the treaty.

A detailed analysis of the relevance of current U.S. data holdings to a potential U.S. submission under Article 76 was conducted by Mayer, Jakobsson and Armstrong (2003). Included in this analysis is the identification of regions where the collection of new, modern multibeam sonar data would substantially improve the quality of a potential submission for an Extended Continental Shelf (ECS) under Article 76. Among the areas where new multibeam echo-sounder data would improve a submission, the Arctic is outstanding in that the existing database is far too sparse to support a well-defended submission. The data are especially sparse in areas where the perennial ice cover has prevented surface ships from operating. The collection of new high-resolution multibeam sonar data in these regions of the Arctic would also significantly add to data needed to support the growing recognition of the critical role that the Arctic Ocean plays in the climatic and tectonic history of the Earth. The new bathymetric data (as well as associated CTD measurements) will help define the nature of deep circulation in the Arctic Basin as well as the history and distribution of ice in the region, a key component of the global climate system.

The United Nations Convention on the Law of the Sea defines the conditions under which a coastal state may extend its continental shelf over regions beyond their current recognized 200 nmi limit (UN, 1982). These conditions involve the definition of a juridical or legal “continental shelf” that differs significantly from standard morphological descriptions of continental margins. A key element of this definition is the demonstration that the extended area is a “natural prolongation” of the nation’s landmass, known in legal parlance as the “test of appurtenance.” There are no explicit guidelines for demonstration of “natural prolongation” of a state’s land territory. The determination must be based on a general knowledge and interpretation of the bathymetry, geology, and nature of the seafloor in a region. For example, if a coastal state has a narrow physiographic shelf bounded by a seaward subduction zone (that clearly indicates the

transition from continental to oceanic crust) there is little chance for demonstration of a natural prolongation of the continental shelf.

Once a natural prolongation is demonstrated, a coastal state may extend their “continental shelf” beyond the 200 nmi limit based on either of two formulae. The distance formula allows an extension of the shelf to a line that is 60 nmi beyond the “foot of the continental slope” (defined to be the point of maximum change in gradient at its base). The sediment thickness formula allows the extension of the shelf to a point where the sediment thickness is 1 percent of the distance back to the foot of the slope. Whichever formula line is most advantageous to the coastal state may be used and they can be combined for the most advantageous extension. There are limits to the extension (limit lines) – the ECS shall not extend beyond 100 nmi from the 2500 m isobath or not beyond 350 nmi from the territorial baseline (the officially defined shoreline). Again these limit lines can be mixed in whatever way is most advantageous to the coastal state. Thus the definition of the extended continental shelf under UNCLOS Article 76 is based on a combination of bathymetric data (defining the 2500 m contour and the foot of the slope) and geophysical data (defining the thickness of sediment). When a nation accedes to the Law of the Sea Treaty, it has 10 years to submit all data and evidence supporting its submission to the United Nations Commission on the Limits of the Continental Shelf (CLCS) who evaluate the veracity of the submission and offer recommendations on it.

The largest potential for an extended continental shelf beyond the current 200 nmi limit of the U.S. EEZ is found in the area of the Chukchi Borderland, a tightly clustered group of generally high-standing, N-S-trending bathymetric elevations that form a natural prolongation from the Chukchi Shelf north of Alaska.

The Chukchi Borderland juts out between eastern Siberia and western Alaska into the deep Amerasia Basin north of the Chukchi Sea. The borderland occupies a rectangular area about 600 by 700 km, or some 4 percent of the Arctic Ocean. This area encompasses three, approximately north-south-trending segmented topographic highs: the Northwind Ridge, the Chukchi Cap and Rise, and the western (Arlis, Sargo, and T3) plateaus (which are located beyond the agreed boundary line with Russia). The plateau-like crests of the Chukchi Borderland rise, in some cases, as much as 3,400 m above their surroundings and they are relatively shallow (depths between 246 and 1,000 m). The ridges have steep flanks, which in some places exhibit remarkable linearity over hundreds of kilometers, especially along the east side of the Northwind Ridge. Between these ridges lie the Northwind, Chukchi, and Mendelejev “abyssal plains”. These lie at depths between 2,100 and 3,850 m

Congress (through NOAA) funded the University of New Hampshire’s Center for Coastal and Ocean Mapping/Joint Hydrographic Center (CCOM/JHC) to explore the feasibility of using a multibeam sonar-equipped ice breaker to collect the data needed to make a submission for an extended continental shelf in ice-covered regions of the Arctic. This was in recognition of the fact that a submission for an ECS under Article 76 must be substantiated by high-quality bathymetric and geophysical data, and that the existing bathymetric database in the Arctic is, in many areas, inadequate. The USCGC

*Healy* (WAGB-20), equipped with a SeaBeam 2112 (12 kHz, 120 beam) swath mapping system, was chosen for this task.

## **CRUISE OVERVIEW** (Figure 1)

HEALY Cruise 0302 was a 10 day, 3000 km long exploratory mission between departing from Barrow, Alaska, to the Chukchi Borderland to test the viability of using and icebreaker equipped to with a multibeam sonar to map in support of the requirements of a potential claim under the UNCLOS Article 76. The cruise began on 1 September in Barrow Alaska and returned to Barrow on 11 September. Data collection critical to a potential claim began at the US-Russian boundary line at 78°-30'N 168°-25'W and followed the 2500 m contour around to 78°-35'N 159°-07'W (Figure 1). In the course of this expedition, the cruise made several significant discoveries, that include:

- substantially changing the mapped position and complexity of the 2500-m isobath (a critical component of a Law of the Sea claim),
- found further evidence for pervasive ice and current erosion in deep water (flutes and scours),
- finding evidence for gas-related features (pock-marks), and
- discovering a previously unmapped seamount that rises more than 3000 m above the surrounding seafloor. This NE-SW trending feature, some 18 km wide and 40 km long with a slightly concave and northward tilted crest, has been officially named Healy Seamount.

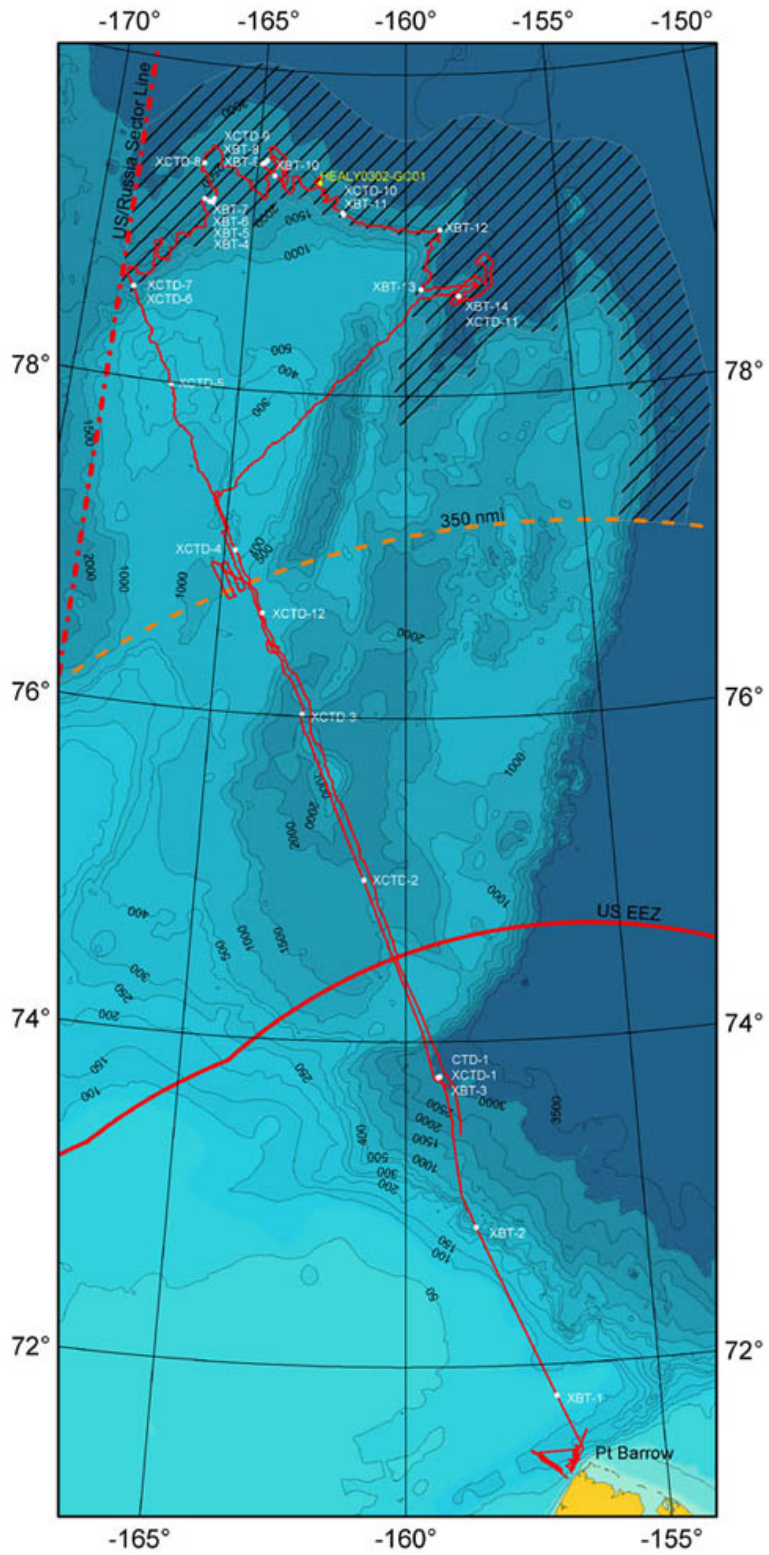


Figure 1. Cruise track for HEALY-0302

## SENSORS AND INSTRUMENTS

The data collected on HEALY-0302 is summarized below. For the most part these data are automatically logged by the ships SCS system. Only the multibeam and 3.5 kHz subbottom data (and appropriate navigation and water property data) were monitored during normal watch operations. Where appropriate – the SCS channel ID is also listed.

### UNDERWAY SENSORS

#### METEOROLOGY

Measurement	channel ID	Collect Status	Interval	Instrument
Air Temperature	079	Continuous	1 sec	R.M. YOUNG/Model 41372LC/LF
Dew Point	080	Continuous	1 sec	R.M. YOUNG/Model 41372LC/LF
Relative Humidity	081	Continuous	1 sec	R.M. YOUNG/Model 41372LC/LF
Barometer	082	Continuous	1 sec	R.M. YOUNG/Model 41372LC/LF
Relative Wind Speed	049	Continuous	1 sec	R.M. YOUNG/Model 09101-SE
Relative Wind Direction	050	Continuous	1 sec	R.M. YOUNG/Model 09101-SE
True Wind Speed	44	Continuous	1 sec	DERIVED
True Wind Direction	45	Continuous	1 sec	DERIVED

#### SONARS

Measurement	channel ID	Collect Status	Interval	Instrument
Bathymetry		continuous	varies	ODEC Bathy2000
Bathymetry		continuous	varies	SEABEAM 2112

#### OCEANOGRAPHY

Measurement	channel ID	Collect Status	Interval	Instrument
Conductivity	TSG fwd	Continuous	10 sec	Seabird 21
Salinity	TSG fwd	Continuous	10 sec	Calc from Primary Temp
Sea Surface Temp	TSG fwd	Continuous	10 sec	Seabird 21
Conductivity	TSG aft	Continuous	10 sec	Seabird 21
Salinity	TSG aft	Continuous	10 sec	Calc from Primary temp
Sea Surface Temp	TSG aft	Continuous	6 sec	SBE 911
ADCP 75khz		continuous	varies	RDI Instruments
ADCP 150khz		continuous	Varies	RDI Instruments
TEMP/Sound Velocity	XBT	As needed		Sippican MK21 Deck Unit



## NAVIGATIONAL INSTRUMENTS

Measurement	channel ID	Collect Status	Interval	Instrument
P-Code GPS (Fwd)		continuous	1 sec	Trimble
Attitude GPS		continuous	1 sec	Ashtech
Glonass GPS		continuous	1 sec	Glonass
Gyro		continuous	1 sec	Sperry
P-Code GPS (Aft)		continuous	1 sec	Trimble Centurion

## SCIENCE SYSTEMS:

The following sections address the state and usage of Healy's science systems during this leg.

### **ADCP (150khz)**

The ADCP 1050 was run routinely during this leg.

### **ADCP (75khz)**

The ADCP 750 was run routinely during this leg. It locked up and was rebooted many times.

### **Aft P-Code (Trimble Centurion)**

Data was collected and logged but not used. There were no known problems.

### **Ashtech 3DGPS (ADU2)**

The ADU2 operated routinely during this leg.

### **CCTV**

A small black and white monitor was installed on the shelf above the multibeam displays so that the science underway watch could the forward looking camera mounted in Aloft Conn.

### **CTD**

The MSTs took two CTD stations during this leg to provide accurate sound speed profiles for use in the multibeam. These stations went well.

### **DI/RO Pure Water Systems**

There was no need for DI water on this leg.

### **Forward P-Code (Rockwell Collins)**

Data was collected and logged but not used. There were no known problems.

### **General Purpose Data Processing Computers**

No problems.

### **General Purpose Science Workstations**

The science party made casual use of the public workstations in the lab and the conference room.

The CTD data was processed into sound speed profiles on one of the public workstations using SeaBird's software.

No known problems

### **Gravity Coring Equipment**

One 2 m long gravity core was taken – HEALY0302-GC01

### **Gyro Compasses**

Data was collected and logged but not used. There were no known problems.

### **Integrated Bridge System**

IBS provided position, heading and time of day data to the SB2112 in real-time during this leg. No known problems.

### **Map & Map-2 & Pproc Auxiliary Computers**

*Pproc* was not used during this leg

*Map* was used as an X-terminal.

*Map-2* was used for processing and analysis of gravity data and for automatic quality checking, plot generation, etc.

*Map-2* was also the host for a number of server processes described elsewhere.

### **Multibeam Router**

The multibeam router performed normally during this leg.

### **Piston Coring Equipment**

Not used.

### **Science Data Network (general)**

Compared to earlier legs, there were very few significant perturbations in the science network during this leg.

### **Science Hoist/A-Frames/Capstans & Cranes**

Limited use on this leg. No problems to report.

### **Science Uncontaminated Seawater System**

The seawater system was used when in open water but only to provide flow to the forward TSG

### **Science Reefer/Freezer/Climate Control Chambers**

Not used.

### **SDN Time Servers**

The starboard timeserver was used during this leg. The port server was not turned on because we do not have an antenna mounted to support it.

### **SeaBeam 2112 Multibeam Sonar**

#### **Sippican Mk21 XBT System**

Several expendable XBT and one XCDT probe were launched to document the sound speed profile. A number of probes failed to reach the expected depth.

There appears to be no spare hand-held launcher or deck cable.

#### **Sperry Speed Log (SRD-5000)**

Data was logged but not used for science. No known problems.

### **Sub-Bottom Profiler (Bathy 2000)**

The Bathy 2000 did not work for most of the leg. After many hours of trouble shooting it was found that that well had no fluid in it despite the fact that the fluid level gauge outside the well showed that it was full. The Bathy was restarted about nine times to recover from various failure modes including but not limited to lock-ups.

### **Winches/Wires/Displays**

Two CTD stations were taken specifically to get accurate sound speed profiles. No problems were reported with the winches, wires or displays.

## **CHIEF SCIENTIST'S DAILY LOG:**

### **30 August 2003 - JD242 – All times local unless otherwise noted**

Arrive Barrow 0925L– picked up by Andy A. – brought to helo pad – hang around most of morning and afternoon as small groups shuttled to and from HEALY. Finally got on board at about 1400L. Last scientist on board (Kathy Crane) at about 1600L.

“INBRIEF” meeting with ship’s company at 1630L –

While this is happening, Dale is continuing to have ship run lines over Barrow Canyon – we will use these data for testing processing flow. Processing flow will be tested tomorrow when we hook our own PC’s to the ship’s network. Brian and Martin are working hard to figure out how to make Caris work with Polar Stereographic projections – if now we will export data to Geomedia and do transformation there.

1830 – First science meeting – introductions and general overview of program.

### **31 August 2003 – JD243**

0000 – 0600L – Dale and Larry standing first watch – joined by Kevin Kelly, John Hall, Jan Backman, and Rick Brennan. Basically running lines back and forth over Barrow Canyon watching poor performance of SeaBeam in shallow (~60-150m) water. Not official start of cruise until we leave from Barrow.

In looking at data already collected, Brian found that the nav jumped back and forth about 40-60 m between pings – appears the “Integrated Bridge System” which provides the sole source of navigation to the SeaBeam is not blending solutions properly – appears to be jumping back and forth between sensors. Dale says this is common and there is no way to change this (Sperry black box) and no way to force SeaBeam to accept another nav input.

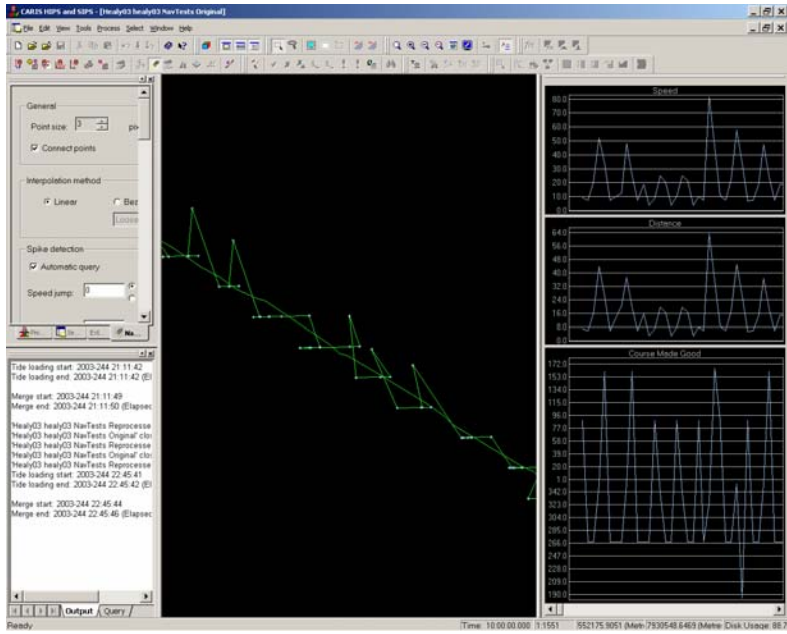


Figure 1 – Original Navigation as coming from IBS – jumps are 40 – 60m

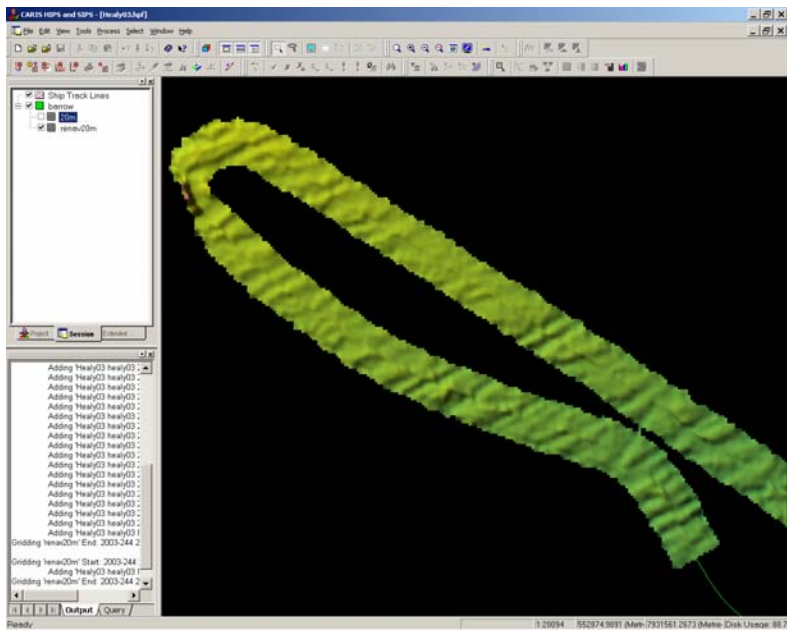
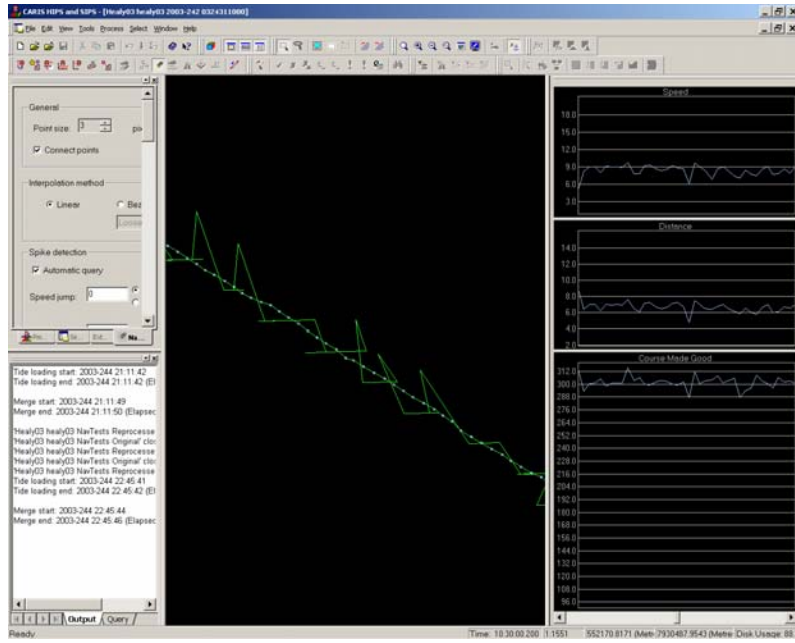
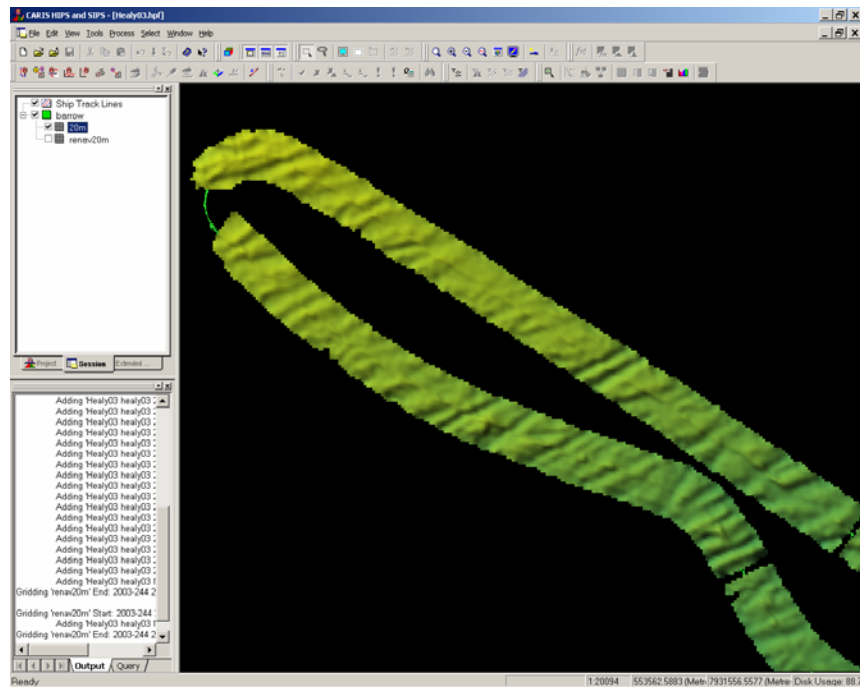


Figure 2 – bathymetry using original navigation



**Figure 3. Smoothed navigator (using XXX point centered moving average) compared to original bathymetry. This was temporary fix – real solution is to use single P-code nav string and Ashtech dual antenna DGPS for heading.**



**Figure 4- Bathymetry using smoothed navigation**

Brian will look at Caris to ensure that we have a path that can take one of the P-code nav strings and process using this instead of the nav coming with the SeaBeam data

Brian also built a moving filter for the SeaBeam nav which greatly improved the result.

0600 – stop survey for fueling

1800L: Seminar – Larry describing LoS and cruise background

### **1 Sept 2003 – JD 244**

0100L – begin pulling anchor – anchor finally free at 0245L – underway and begin lab watches – on watch Team B – Calder, Crane, Gardner, Solvsten. Dale and Larry in the lab too. SB started, but Bathy 2000 having problems – called Roger – looking into it. Switched to Knudsen – trying to get that up – steaming at 15 knts. Verified first way point – bridge had 73 47 N 159 57 W – right latitude but too far west – went up to bridge to revise – first way point should be: 73 47N 159 14 16W. Make sure we verify each way point with the bridge!

0400L Switched back to Bathy2000 – still trying to get subbottom going --

0650L – take fist XTB – T7-00065-- no problem – just 70 m of water – ridiculous process to get xtb data into seabeam – have to get access to xtb file, strip off extra info – put into mbvelocitytool, interpolate, strip off header info and then send back to seabeam – all for only 30 values – easier to manually type in.

Ops Officer came down to lab to discuss why his way points are different from ours (by as much as 8 nm!!! – reason is that they plotted our track from Barrow Pt to the 2500 m contour on a mercator chart. They then entered the extra way points (the xCTD stations) by just picking the latitude on the track rather than plotting the positions (which we derived from polarstereographic projection).

Also learned that bridge really wants positions in deg, min.xxxx

Other issues – need better feedback in lab of ship's heading, and position – a repeater of bridge ENC would be helpful.

Need whiteboard in main lab for notices, wakeup calls, etc.

1027L – XBT 66 @ 250 m as we come over shelf break -- update sound speed profile by hand for upper 250 m – leave original profile for deeper section. – heading over shelf break enroute to 3000 m depth and CTD station.

Noticed several small ridges paralleling Northwind trend – not on charts.

SeaBeam performing reasonably

1430 – start CTD-001 in 3003 m of water at about 73 57N, no problems –

1640 – finish CTD

XCTD – 67 for calibration

XBT – 68 – for calibration

1730 – start roll bias test -- run about 40 minutes at 8 knots parallel to contours (118) and then do Williamson turn.

1820 – finish line one

1903 – conclude roll bias tests

1908 – resume surveying – 15 knots heading north

2000 - Martin seminar on Ice scours

2300 – approaching ice edge – beautiful

2330 – switch to aft TSG

## **2 September 2003 – JD 245**

Entering ice – quite variable – from 1 – 6-7/10 cover – speed 6-7 kts in ice 12 –15 when clear – SeaBeam still reasonable

0309L – XCTD 69 at 75N

smooth sailing, reasonable data all day -- **still no subbottom system**

1200L – xCTD 00070 at 76 N

2000L – hitting first heavy ice – large (many km) flow about 1-2m thick – SeaBeam not doing well but still functioning.

2051L – x CTD 00071 at 77 N

2051L – x CTD 00071 at 77 N

## **3 September 2003 – JD 246**

Continuing north – intermittent heavy and light ice. SeaBeam still doing as well as can be expected.

1500 – approaching 2500 m contour – SB system is degrading – thought it was from shallow water but is getting worse – ice moderate to heavy – 9/10 –2-3 m thick.

1600 – SB system stops pinging – Dale rebooting

1745 – SB system back on line – much better but ice thickening – beginning search for 2500 m contour.

1930 – tracking 2500 m contour – Al and Martin following on SB console – Larry in loftcon –

2130 – looks like we are tracking an embayment of the 2500 m contour – will continue on.

#### **4 September 2003 – JD 247**

Continue to follow the 2500 m contour with reasonable success – Andy relieves Larry in loftcon

0330L – Larry back in loftcon – 8-9/10 ice moderate thickness – breaking fine – SB working intermittently (due to ice) but able to follow contour – some discrepancies with existing chart

0800L Davey Jones arrives on board to call out all WOGS – the festivities have begun.

1200L - continuing to follow the 2500 m contour – with some success. Ice variable thickness 9/10 moderate flows, about 4-6ft thick

#### **5 September 2003 – JD 248**

Continuing to survey along a very convoluted 2500 m contour – much more complex than in existing database.

0109L – XCTD - 080

0500 – wogs awakened for festivities – COLD COLD COLD

1400L – come into flow for ice liberty and gravity core

1800L end ice liberty

1900L – maneuvering to free transducers of ice.

2000L – begin gravity core HLY0304-GC01

2200L – core secured on deck - good core – full penetration – 4.21 m -- Naja and Jan curating – will probably send to Stockholm for MST and permanent curation.

2215L – underway to continue mapping



## **6 Sept 2003 – JD 249**

Mapping going well – continuing along 2500 m contour – have crossed the original end of track indicative of the higher speeds we have been able to make – data continues to be fine – but still no subbottom profiler.

Discussions with Captain indicate that we should only expect these kind of conditions in late August/September. He suggests we not consider doing this sort of work in other times of the year.

0450 – attempted XCTD but broke – use XTB instead – XTB-085 – good – have adjusted XTB sound velocity by 4.3m (added) to have it match XCTD 80 at about 700 m depth.

1230L – polar bear sighted – came right up to ship – there should be some amazing photos.

1300L – back on track mapping 2500 m contour – we will follow contour south till it parallels the seamount that is in the embayment on the IBCAO map. We will then head due east and cross the seamount, map it and take a CTD for Kathy.

1600L – scientific party making dinner for the crew tonight – pizza –

1830L – turn east to find seamount

Dale and crew found the problem with the 3.5 system – it seems the transducer well was devoid of fluid so transducers were firing into air. Filling the chambers and we'll see what happens.

2000L – Odec 3.5 up and running

2200L – begin surveying of seamount

## **7 September 2003 – JD 250**

0240L – SeaBeam went down – almost finished with survey of seamount.

0400L – 2500m contour took a turn to the north at northern end of the seamount – watch decided to follow to the north – where 2500m contour splits into two closed promitories. Given the time it took to do this we decide its probably not worth steaming 6 hours to Northwind as we would only have enough time for a few hours of survey. Instead we decide to finish up on Chukchi and head to the scour area for a more detailed survey on the way back to Barrow. Kathy wants one more xCTD on top of seamount.

0719L IBS on bridge down – and back up

1453 – Engines down briefly

1800L – xCTD on top of seamount – broke at 355m – took XBT too

1930L – head to 2500m contour on eastern edge of Chukchi back to where we came from.

2100L – reached 2500 m contour – heading to waypoint M – which meets up with survey line coming up here and then we will parallel old survey line until we get to scour area to begin scour survey.

### **8 September 2003 – JD 251**

Enroute to waypoint M – 7/10<sup>th</sup> s ice about 6 feet thick

1200L – reached waypoint M

1600L – reached waypoint N – begin scour survey

1623 – reached waypoint O

1800L Surveying in scour region continuing – large scours apparent on both SeaBeam and subbottom.

2230 – crossing large depression that shows channel like fill on 3.5 at waypoint S

### **9 September 2003 – JD 252**

Continuing scour survey will maintain original plan of waypoints M through W – bridge says not enough time for extra work though we may have time for another small survey after we are out of ice.

1100L – entering pock mark area – take xCTD –

paralleling old line, nothing convincing on subbottom in pockmark area but we are not crossing directly over them. Have decided to double back and cross directly over several big pockmarks we crossed on way up.

1400-1500L – crossing over pockmarks show clear disruption on subbottom – well worth the detour.

1830L – Bridge informs us that there is no more time for diversions – we must forge on directly to Barrow – plan is to parallel northward track.

2200L – Crossing a series of small seamounts

### **10 September 2003 – JD 253**

Continuing south – still in ice but much less – steady snow for last 10 hours

2145L – crossing the 100m contour – official ending of data logging for this segment of cruise.

Other issues --

    Need improved comms with bridge –

    Midnight rations are fine but there is virtually nothing to eat for scientists who continue watches throughout night – would be nice to have small refer with sandwich stuff.

## Appendix I. Cruise Personnel:

### Science Party

Name	Position	Institution	Email
Larry Mayer	Chief Scientist	U of New Hampshire, CCOM/JHC	<a href="mailto:lmayer@unh.edu">lmayer@unh.edu</a>
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Brian Calder	Research Professor	U of New Hampshire, CCOM/JHC	<a href="mailto:brc@ccom.unh.edu">brc@ccom.unh.edu</a>
Jessica Abrams - NOAA	Physical Scientist	NOAA	Jessica.abrams@noaa.gov
Jan Backman – Univ of Stockholm	Professor	Univ. of Stockholm	backman@geo.stockholm.se
Diane (DeDe) Bentley –	Analyst	Arctic Submarine Lab San Diego	
Rick Brennan	LT	CCOM/JHC NOAA	Richard.D.Brennan@NOAA.gov
Dale Chayes	Multibeam	Dale Chayes	dale@ldeo.columbia.edu
Kathy Crane	Scientist	NOAA OE/Arctic Program	Kathy.crane@noaa.gov
Joan Gardner	Scientist	Naval Research Lab	Joan.gardner@nrl.navy.mil
John Hall	Scientist	Geol Survey of Israel/CCOM	Jhk1@012.net.il
Al Hayashida	Analyst	Arctic Submarine Lab – San Diego	
Kevin Kelley	Photographer	San Francisco	
Martin Jakobsson	Scientist	CCOM/JHC	Martin.jakobsson@unh.edu
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Naja Mikkelsen	Scientist	Geological Survey of Denmark	
Chris Szorc	Ice Observer	National Ice Center	
Morten Solvsten	Hydrographer	Danish Hydrographic Service	
Peter Vogt	Scientist	Naval Research Lab	
Jeremy Weirich	Lt.	NOAA Corps	Jeremy.weirich@noaa.gov