Okeanos Explorer: Aligning today's technology to a new paradigm of ocean exploration

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NOAA Okeanos Explorer Program

Larry Mayer and Andy Armstrong

Center for Coastal and Ocean Mapping

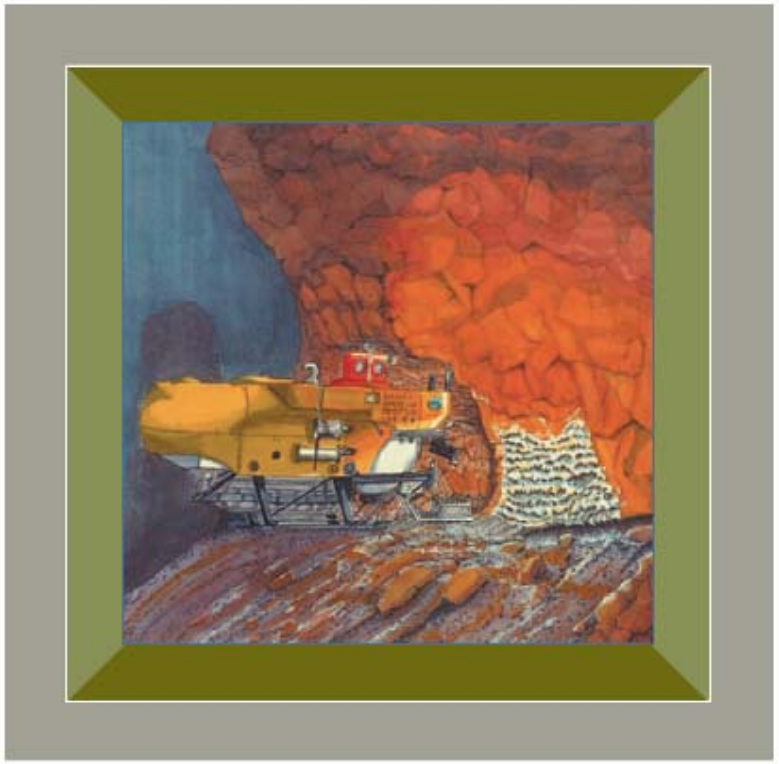
UNH

FEMME APRIL 2009

DISCOVERING

EARTH'S FINAL FRONTIER:

A U.S. STRATEGY FOR OCEAN EXPLORATION



The Report of the President's Panel for Ocean Exploration

President's Panel

- Systematic mapping of physical, geological, biological, chemical and archaeological aspects of the ocean
- Exploring ocean dynamics and interactions at new scales
- Developing new sensors and systems for ocean exploration
- Reaching out in new ways to stakeholders
- NOAA started the Ocean Exploration Program

EXPLORE

NOAA Ocean Exploration

- ***Mission***

  To support NOAA and national objectives by exploring the Earth's largely unknown oceans in all their dimensions for the purpose of discovery and the advancement of knowledge, using state-of-the-art technologies in evolutionary and revolutionary ways.

Ocean Exploration

Ocean Exploration is not traditional scientific investigation … it requires a different approach -- and a different mindset

RESEARCH --> ANALYSIS --> ANSWERS

EXPLORATION --> DISCOVERY --> QUESTIONS

Ocean Exploration

- We envisioned a program that expanded on the current proposal responsive system but integrates this with a newly REdiscovered paradigm for Ocean Exploration

A dedicated ship of discovery carrying out a systematic program of exploration linked through telepresence to the scientific community, the media and the general public

NOAA Ship
OKEANOS EXPLORER

America's Flagship for Exploration
Commissioned, August 2008

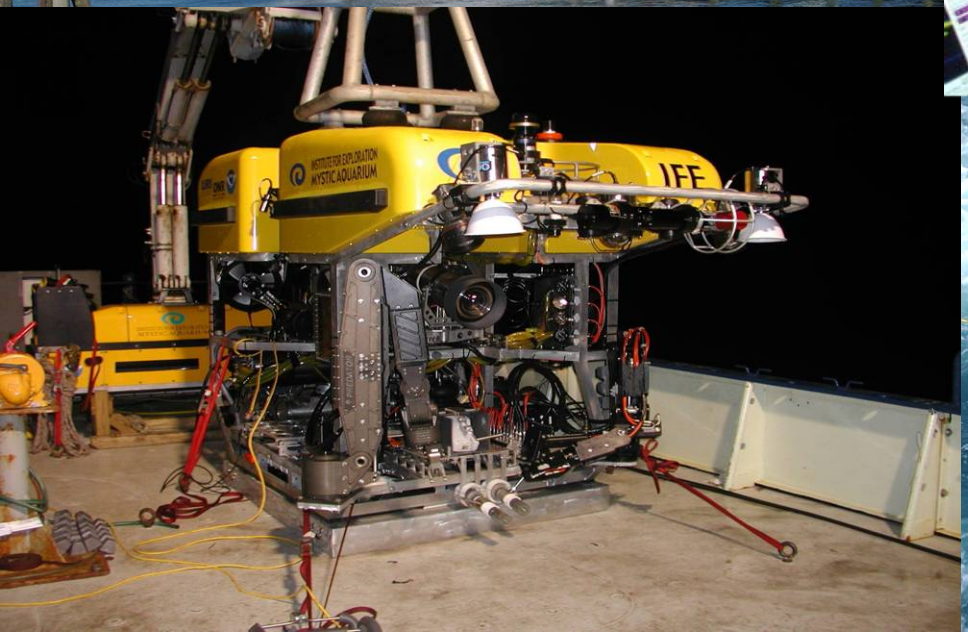
Primary operational capabilities:

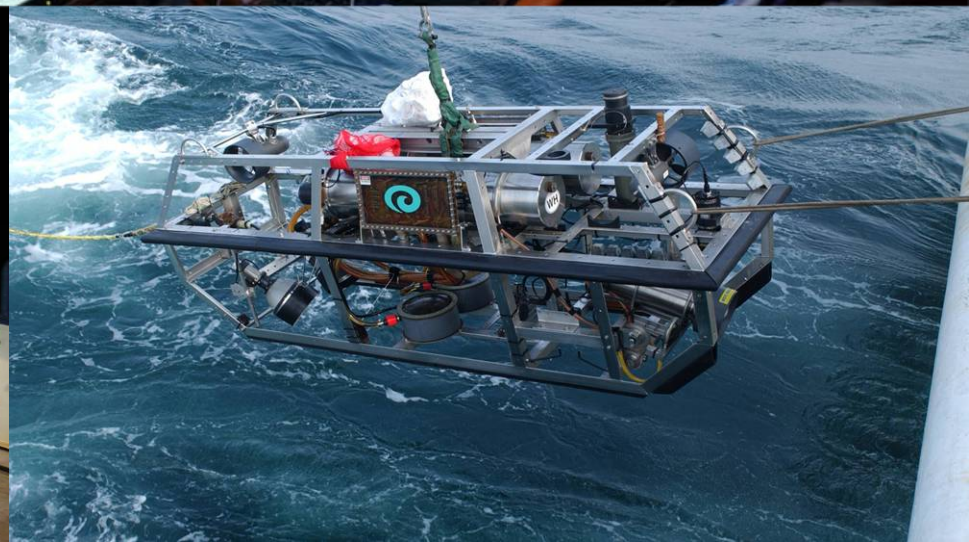
- ***State-of-the-art swath sonar***
- ***Dedicated 6000 m ROV***
- ***Telepresence system***

Status

- ***Mapping system initial tests successful***
- ***Telepresence system progressing***
- ***ROV system testing in April 2009***
- ***Field trials scheduled May - October***

OKEANOS EXPLORER





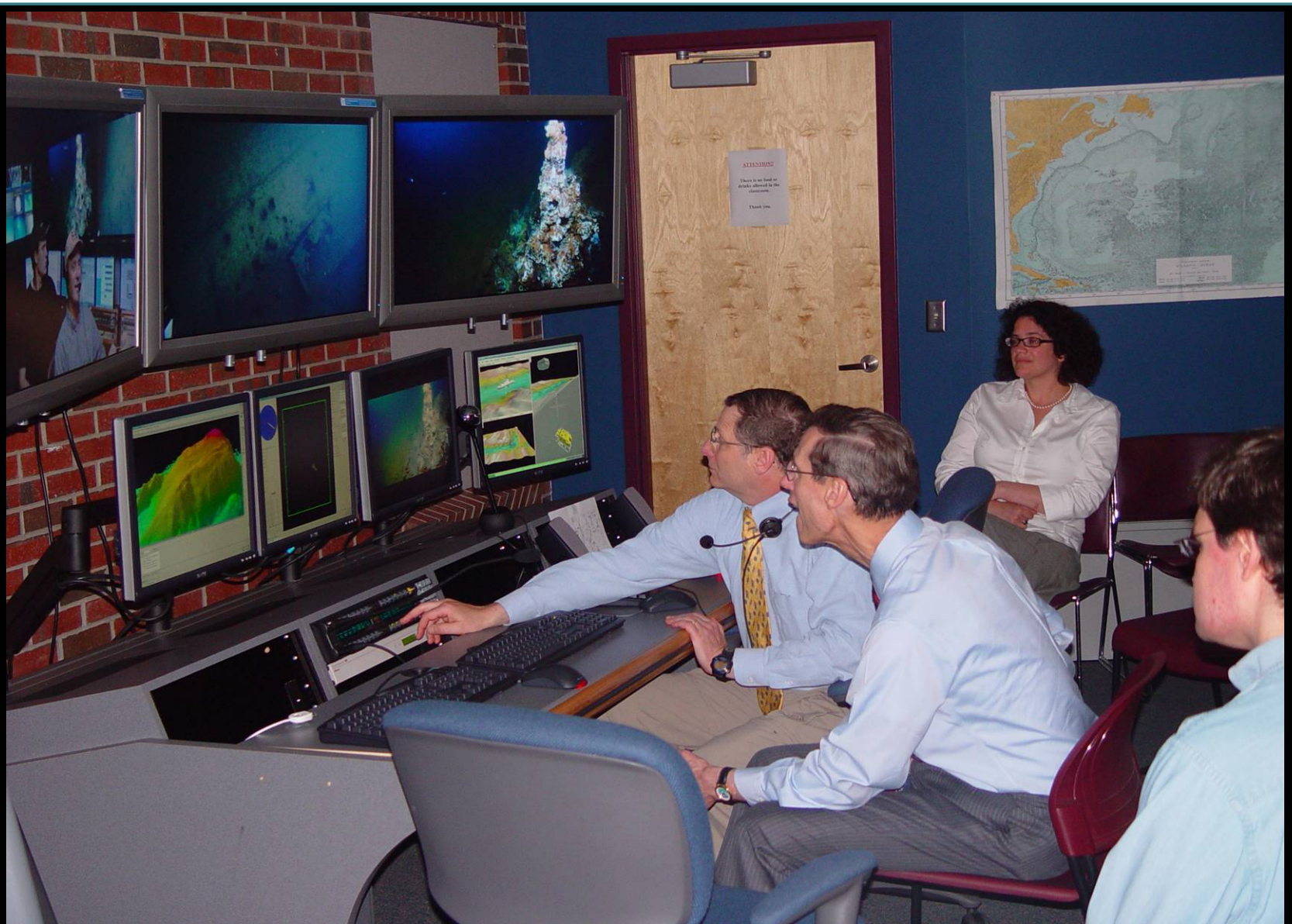
OKEANOS EXPLORER – CONTROL CENTER

INTEL
MAINE
MICHIGAN
Lamp High School
PIER, WISCONSIN
CT
RI
Washington DC
Research Facility
RI - Inner Space Center
Research Vessel
TEXAS • EDS
Sit-down
interactive theater
Walk through observatory
FLORIDA
Residence Watching
MSNBC
MYSTIC, CT
Institute For Exploration
Dedicated
Satellite
Channel and
Internet II
High-bandwidth 2-way comms

It's not a dream – its happening now

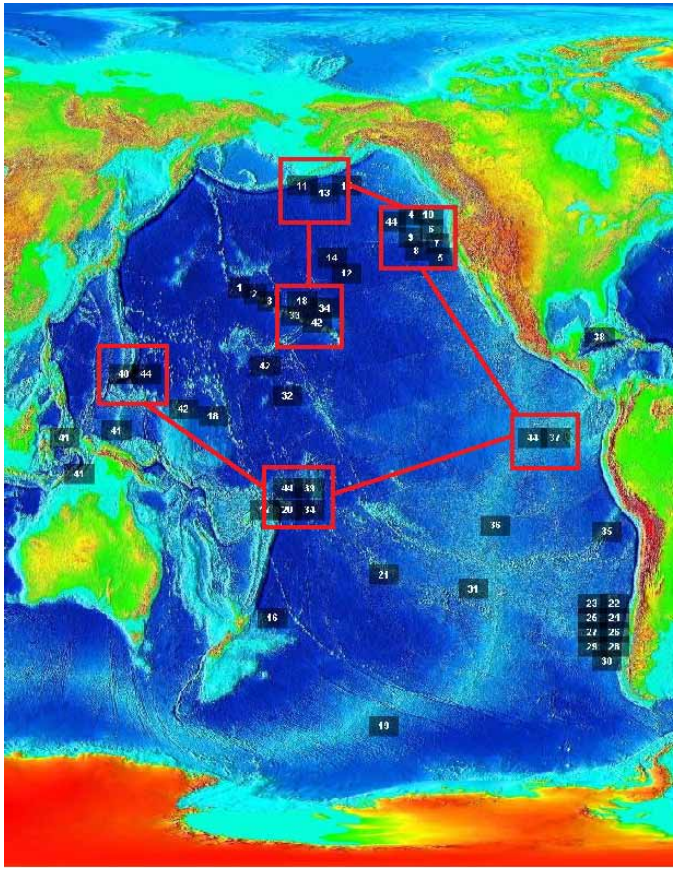
LOST CITY 2005

Archeology and Geology
Aegean and Black Seas



Expedition Planning Workshop

- "BOXES and STICKS" concept
  - BOXES – target regions of high interest (low hanging fruit) for focused exploration (but not full-blown research)
  - STICKS – transits through unknown, poorly studied regions where reconnaissance mapping and sampling would take place at transit speeds – leading to unpredictable discoveries



General Operating Area

Okeanos Explorer

- Name: *Okeanos Explorer*
  - » from the Greek "Okeanos," for ocean
  - » Named through a high school ship naming competition
- History: Former Naval surveillance T-AGOS Class ship
  - » USNS Capable
- Length: 67 m Breadth: 12 m Draft: 4.5 m
- Berthing: 46
- Commissioned: August 2008
- Run by OMAO; Mission equipment operated by OE

- Mission: Mapping, reconnaissance, site characterization, and education and outreach.

Exploration Modes Mapping Goals

Reconnaissance – searching unknown areas looking for anomalies that will initiate site characterization.

Large area coverage

Water Column Exploration : (1) characterize water masses during transits through poorly known areas; (2) search for anomalies that will initiate site characterization;

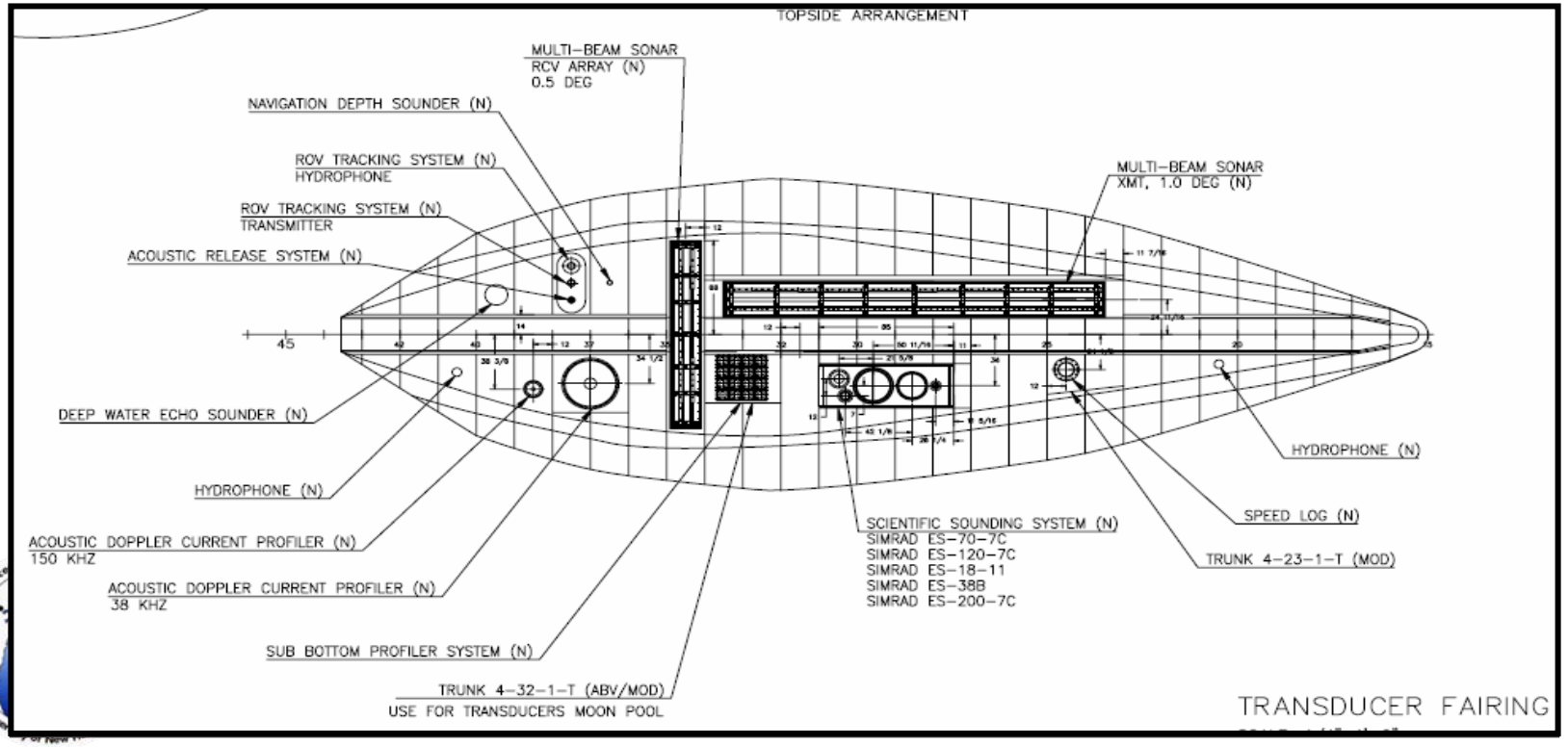
Water column mapping

Site Characterization – focused on a specific target with high discovery potential & utilizing all systems.

Ability to detect small features

OKEANOS EXPLORER: Primary Mapping Systems

- Kongsberg EM302 (30 kHz) multibeam sonar (0.5° x 1.0°)
- Kongsberg EA600 deepwater echosounder
- Knudsen Model Chirp 3260 sub-bottom profiler



EM 302 installation and testing

- An external fairing was added during refit

OKEANOS EXPLORER: Ancillary Gear

HARDWARE

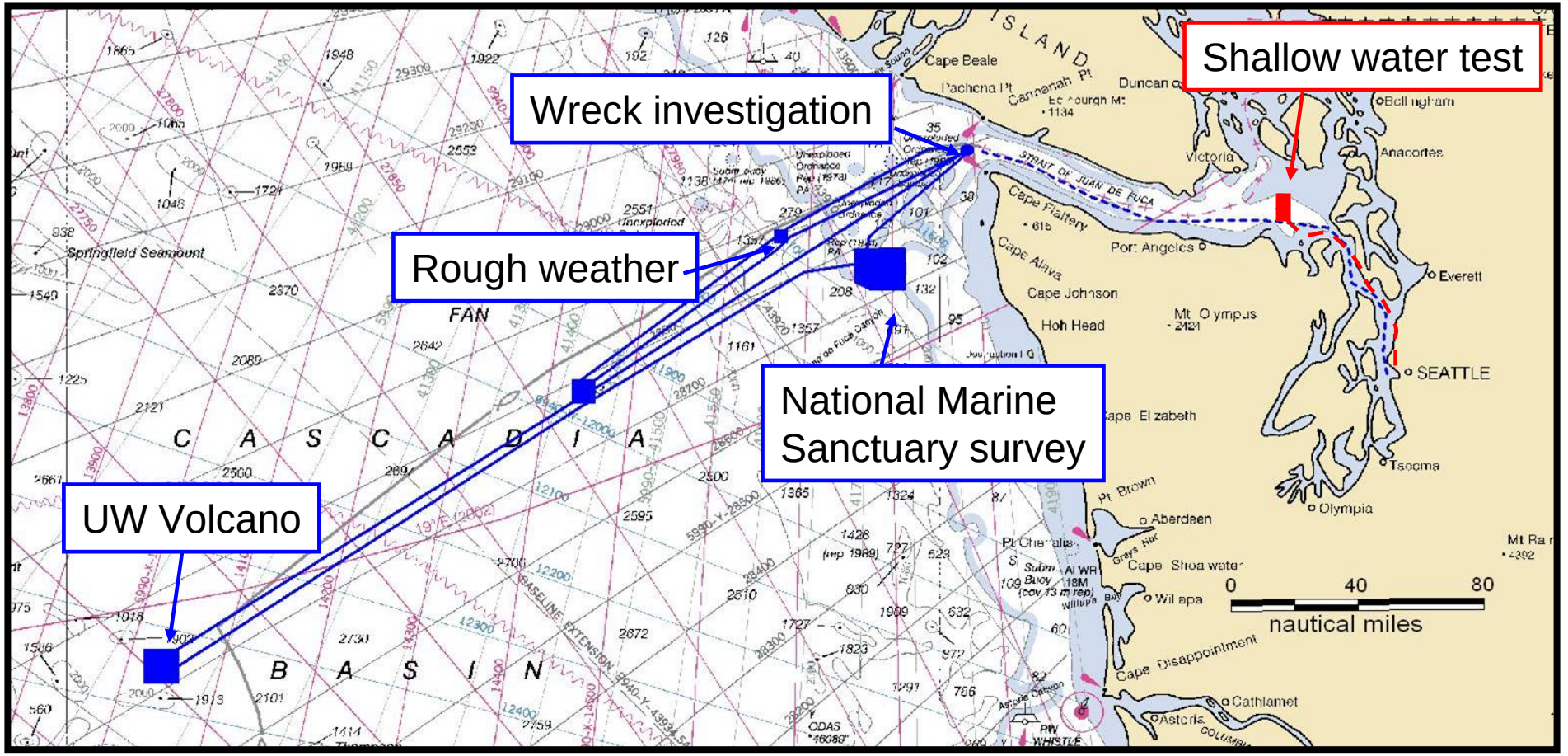
- C-Nav (global navigation system)
- POS/MV
- TSG
- XBT and CTD
- Netapps (data storage)

SOFTWARE

- SIS
- Hypack
- Caris
- Fledermaus
- Mapinfo
- ArcGIS
- *Geocoder*
- *SonarWiz*

OKEANOS EXPLORER: SAT and Shakedown

- **Sept 8 – 25, 2008 (Initial tests)**
  - **One-week of system acceptance w/ Kongsberg**
  - **Two-weeks of system shakedown testing**
- **March 31 – April 3, 2009 (New version of EM302 software / SIS / POS**



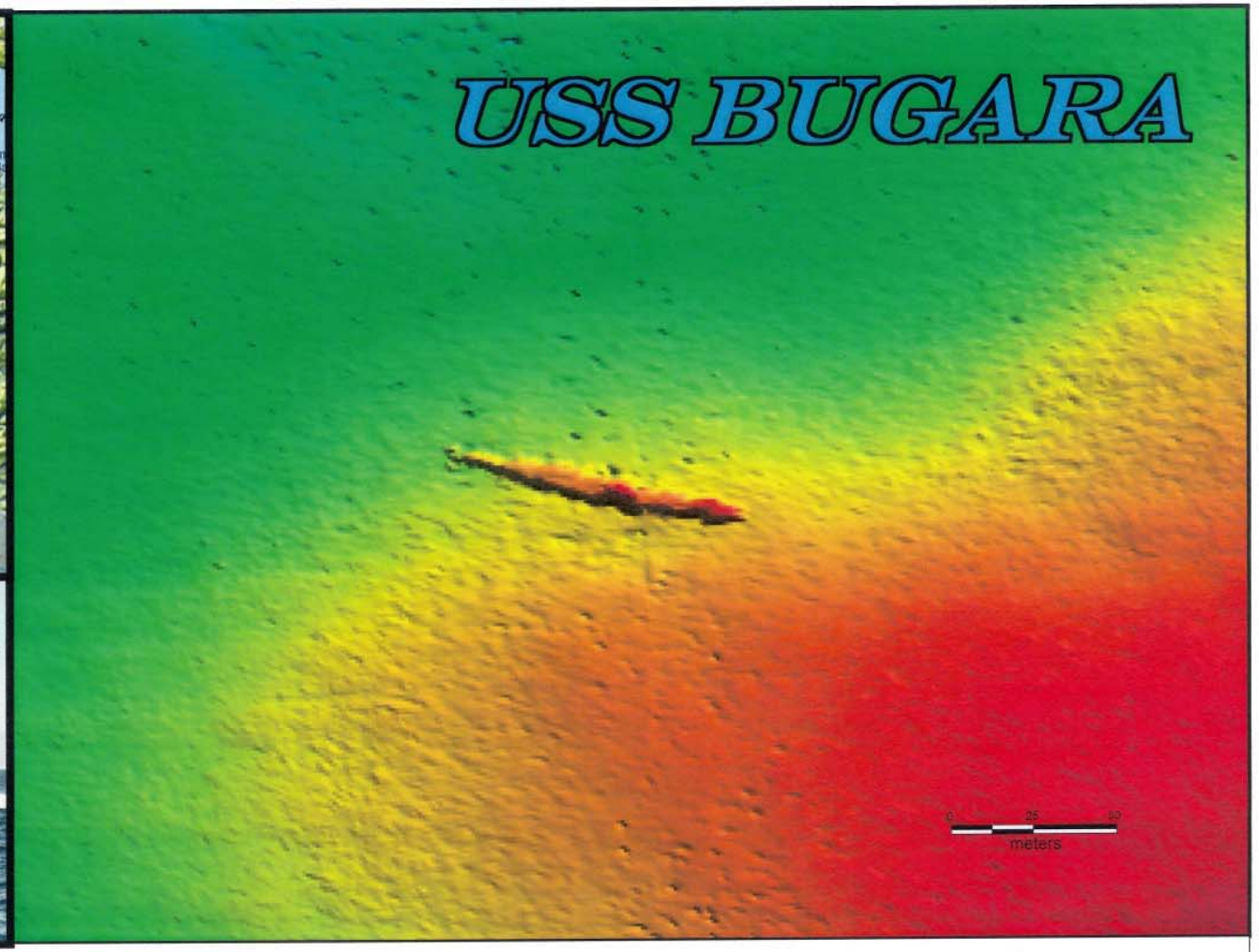
Test parameters

- **Unless noted otherwise:**
  - Vessel speed 8 kts
  - Opening angle 130 deg
  - 432 soundings per swath
  - Multiping mode

- **Sept 2008 tests**
  - POS MV V3
  - EM 302 software release 1.04 (September 2008)
  - SIS 3.5.1 (July 2008)

- **April 2009 tests**
  - POS MV V4 3.30
  - EM 302 software 1.05 (December 2008)
  - SIS 3.6.1 (Nov. 2008)

Wreck Investigation ~240 m water depth



Investigation of the USS Bugara, a decommissioned US Navy submarine lost off Cape Flattery in 1970 with no loss of life.
Wreck site surveyed using a Kongsberg EM302, 1° x 0.5° multibeam sonar system.

NOT FOR NAVIGATION

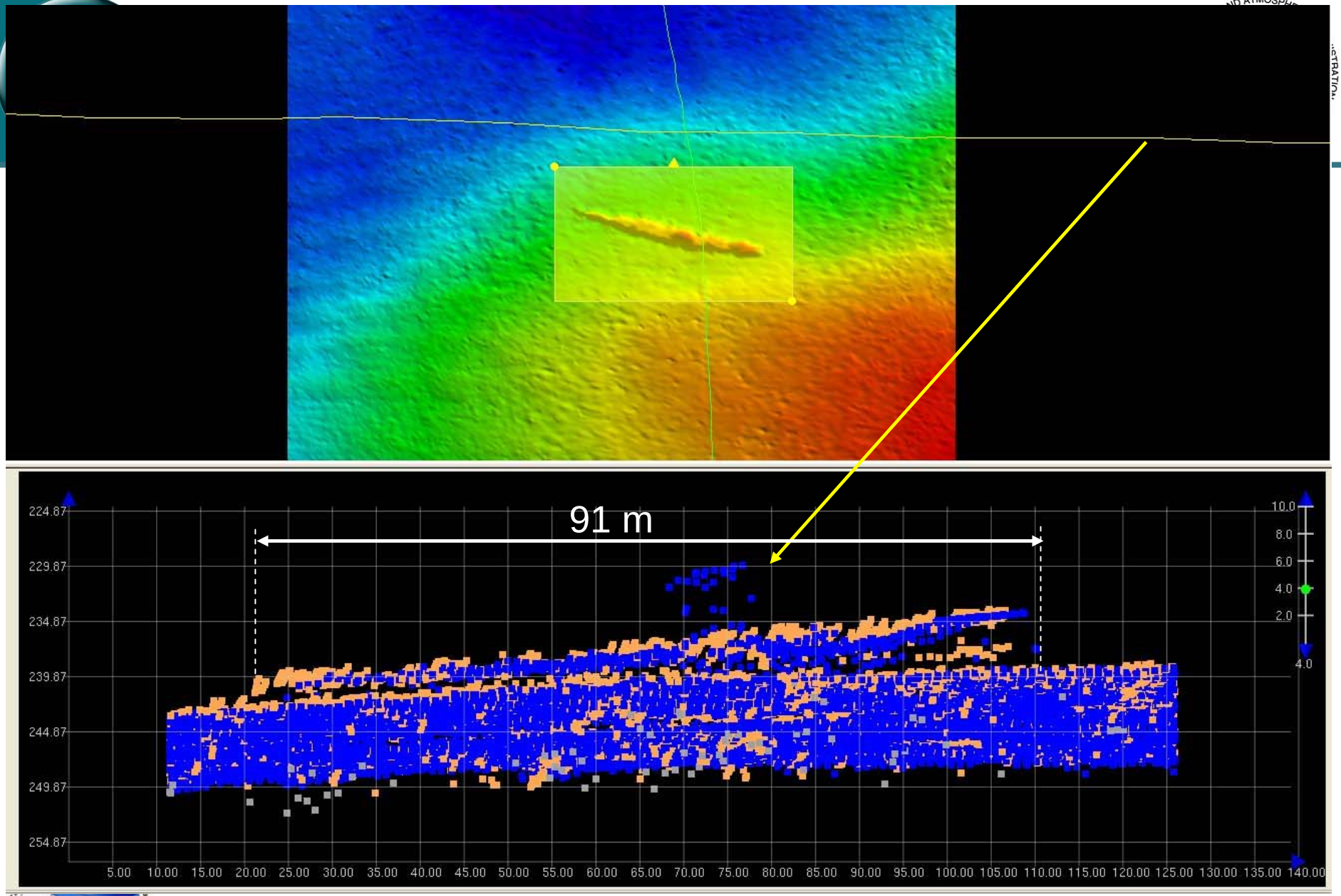
NOAA Ship Okeanos Explorer

CDR Joseph A. Pica
Commanding Officer

Project:	*EX Mapping Shakedown*
Survey:	*USS Bugara*
State:	*Washinton*
Locality:	*Olympic Coast NMS*
Sub-locality:	*Cape Flattery*
Survey Scale:	*1:10,000*

Date:	*22 Sept 08*
Sounding Units:	*Meters*
Horizontal Datum:	*NAD 83*
Projection:	*UTM 10*
Central Meridian:	*123° 00 00*
Scale Factor:	*0.9996*

OCEAN EXPLORATION & RESEARCH ON THE NOAA SHIP OKEANOS EXPLORER



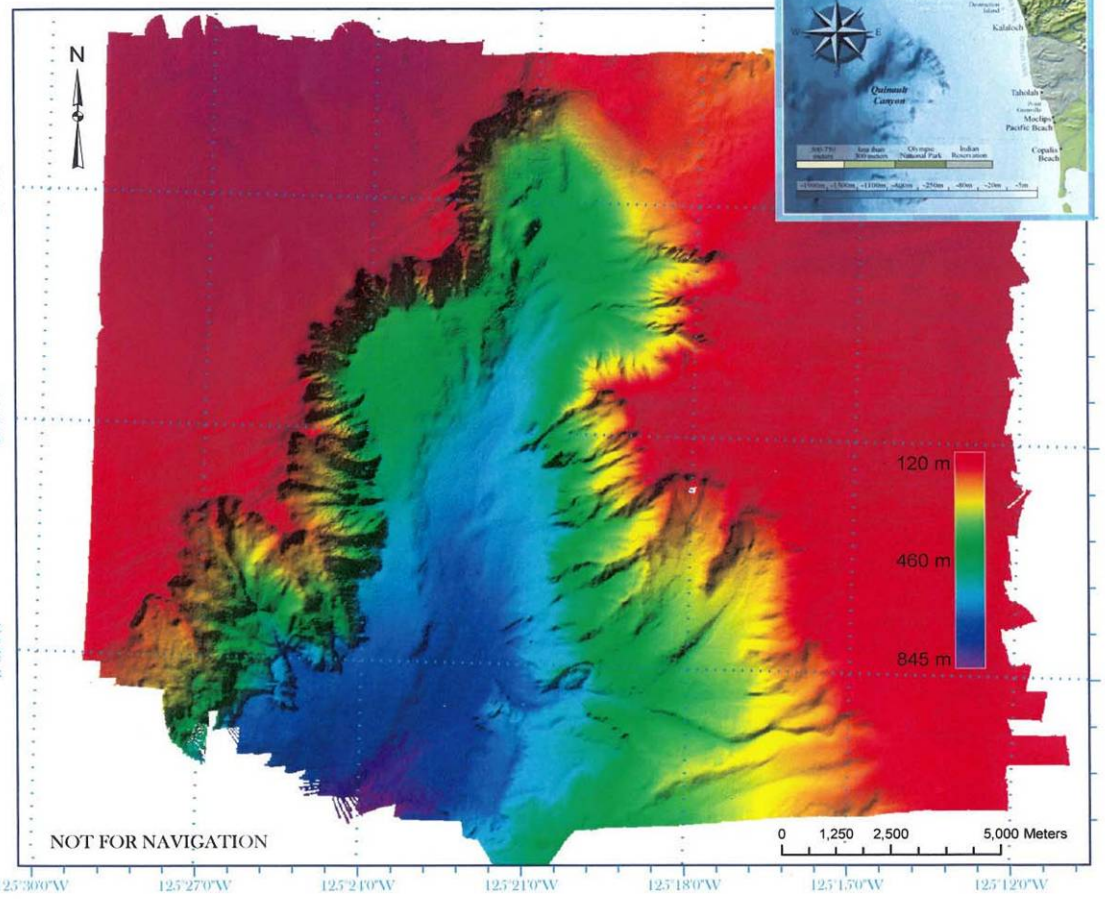
Dimensions:

Length 95 m; Beam 8.3 m (Dictionary of American Naval Fighting Ships);

Olympic Coast National Marine Sanctuary

Juan de Fuca Canyon

FIRST Exploration Survey by the NOAA Ship Okeanos Explorer
September 2008



OCEAN EXPLORATION & RESEARCH ON THE NOAA SHIP OKEANOS EXPLORER

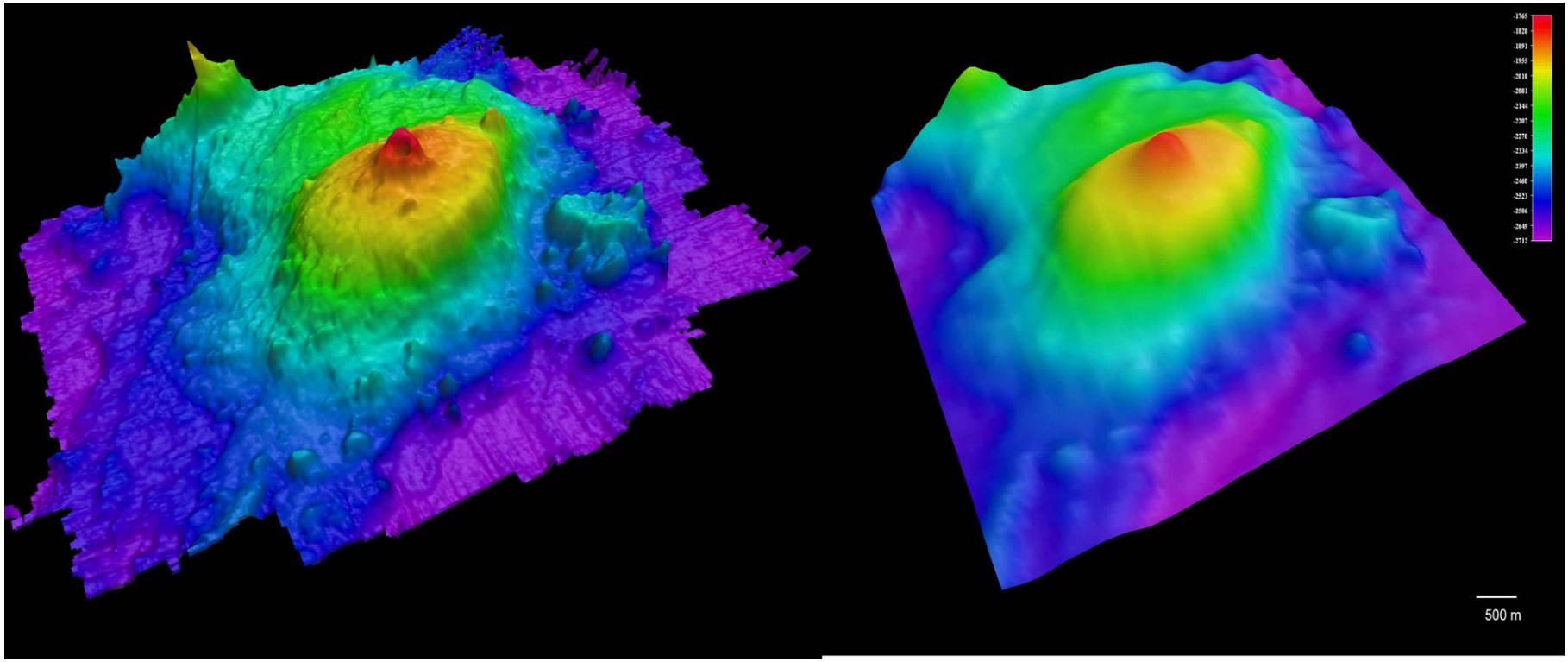
CDR Joseph Pica, Commanding Officer

Survey Stats

- Lines = 87
- LNM = 393 nm
- SQNM = 108
- # of Soundings = 174,950,496
- Time = 60 hrs
- Sea-state 2-4
- Water depth 120 – 845 m

Bear Seamount: *Old vs New*

1700-2700 m



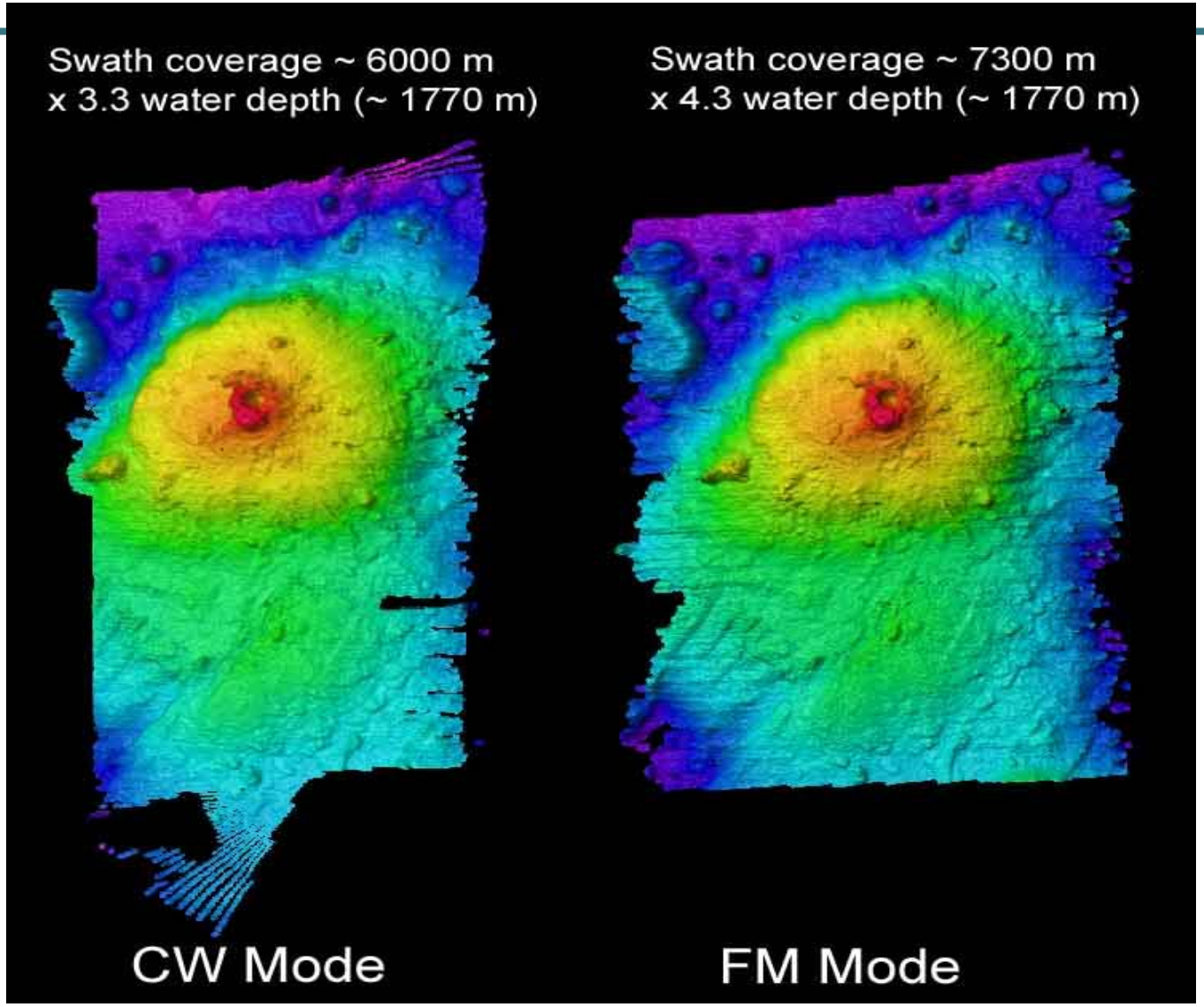
EM302 Data

20m bin size

Previous NGDC Multibeam Data

SeaBeam Classic (1981)

Underwater Volcano: *Testing CW and FM*



EM 302 bathymetric quality checks

Along track depth variations

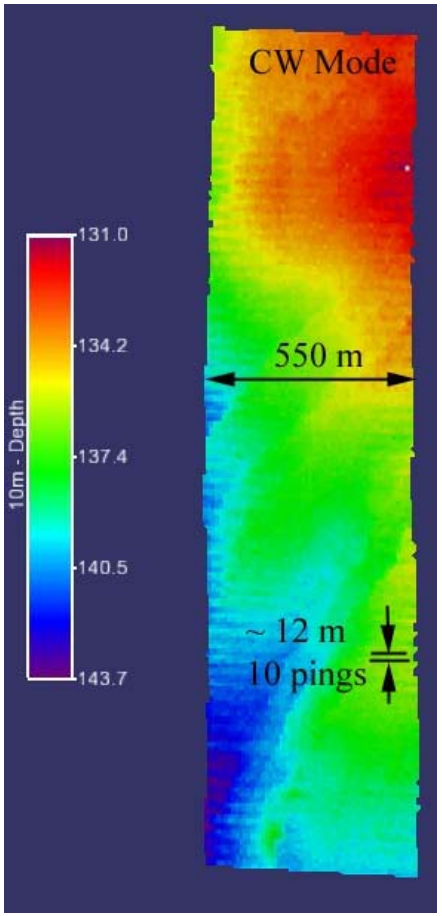
Assume no depth variation
With in 10 pings window

Compute mean of 10 pings

Compute difference between
Soundings and 10 ping mean

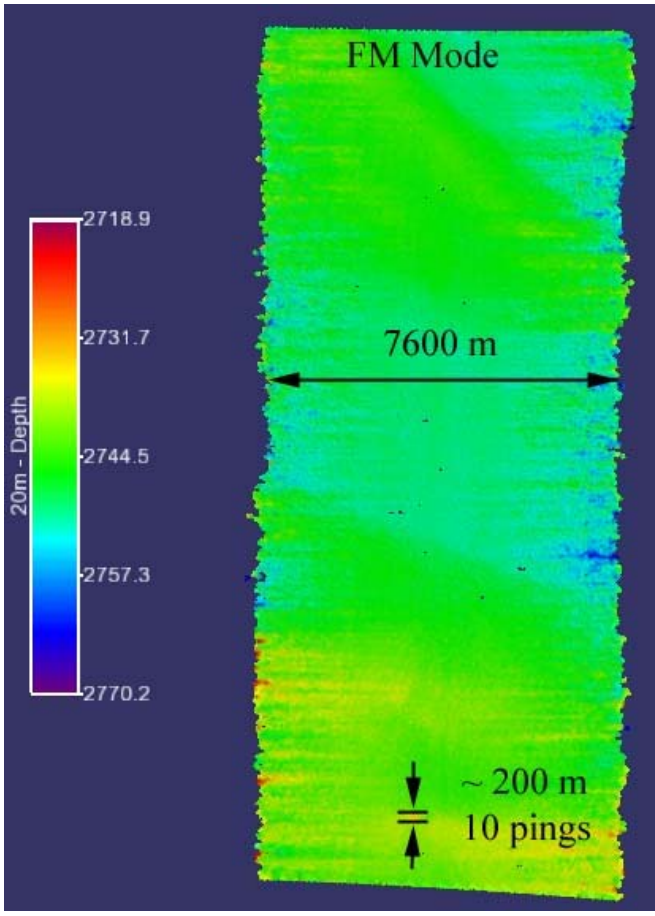
Compute statistics of these
differences

CW mode



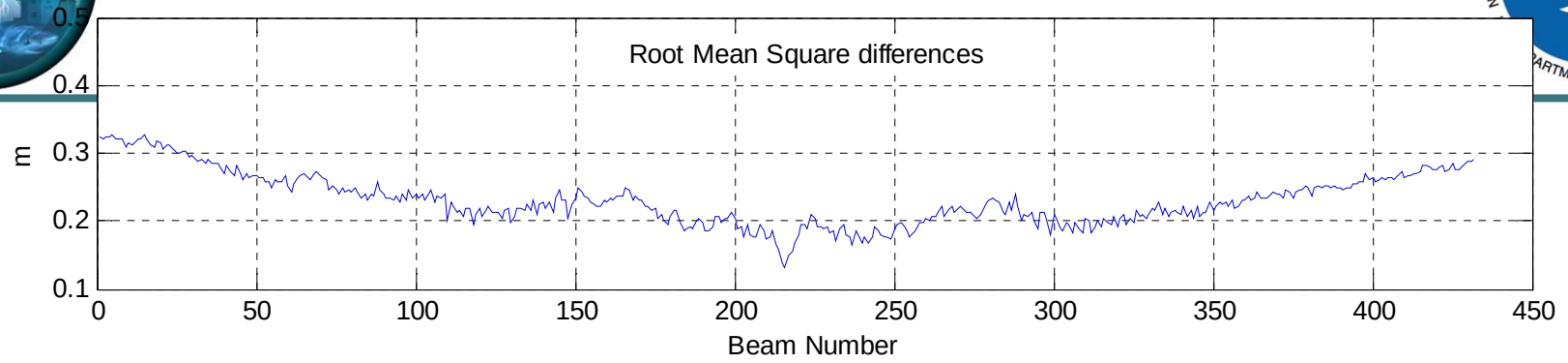
Depth ~ 150 m

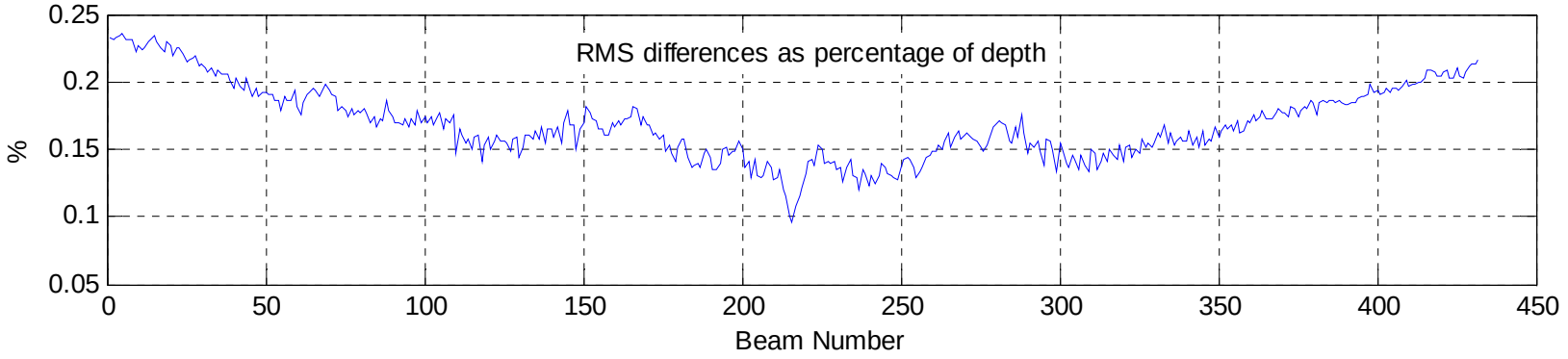
FM mode

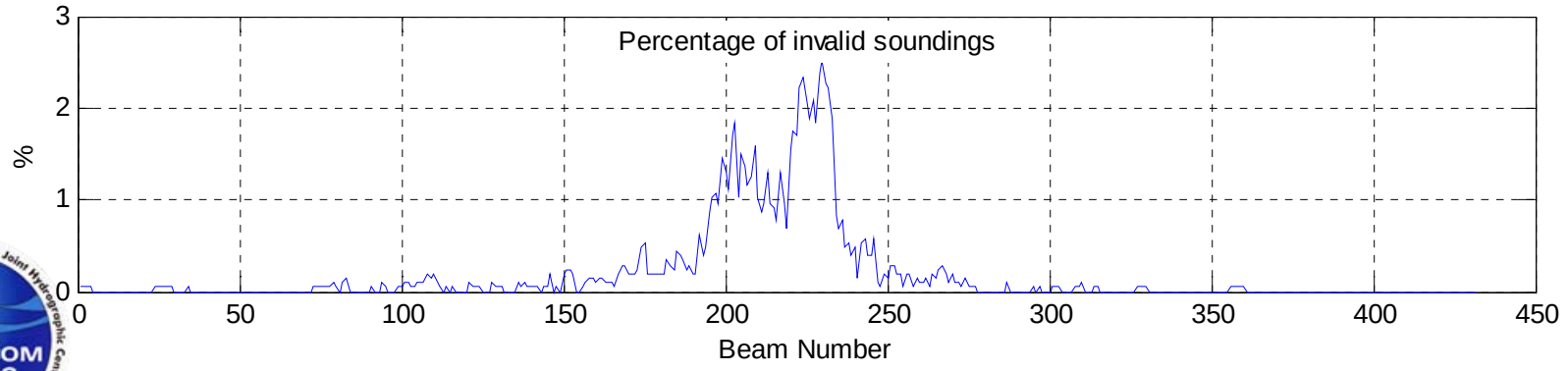


Depth ~ 2750 m

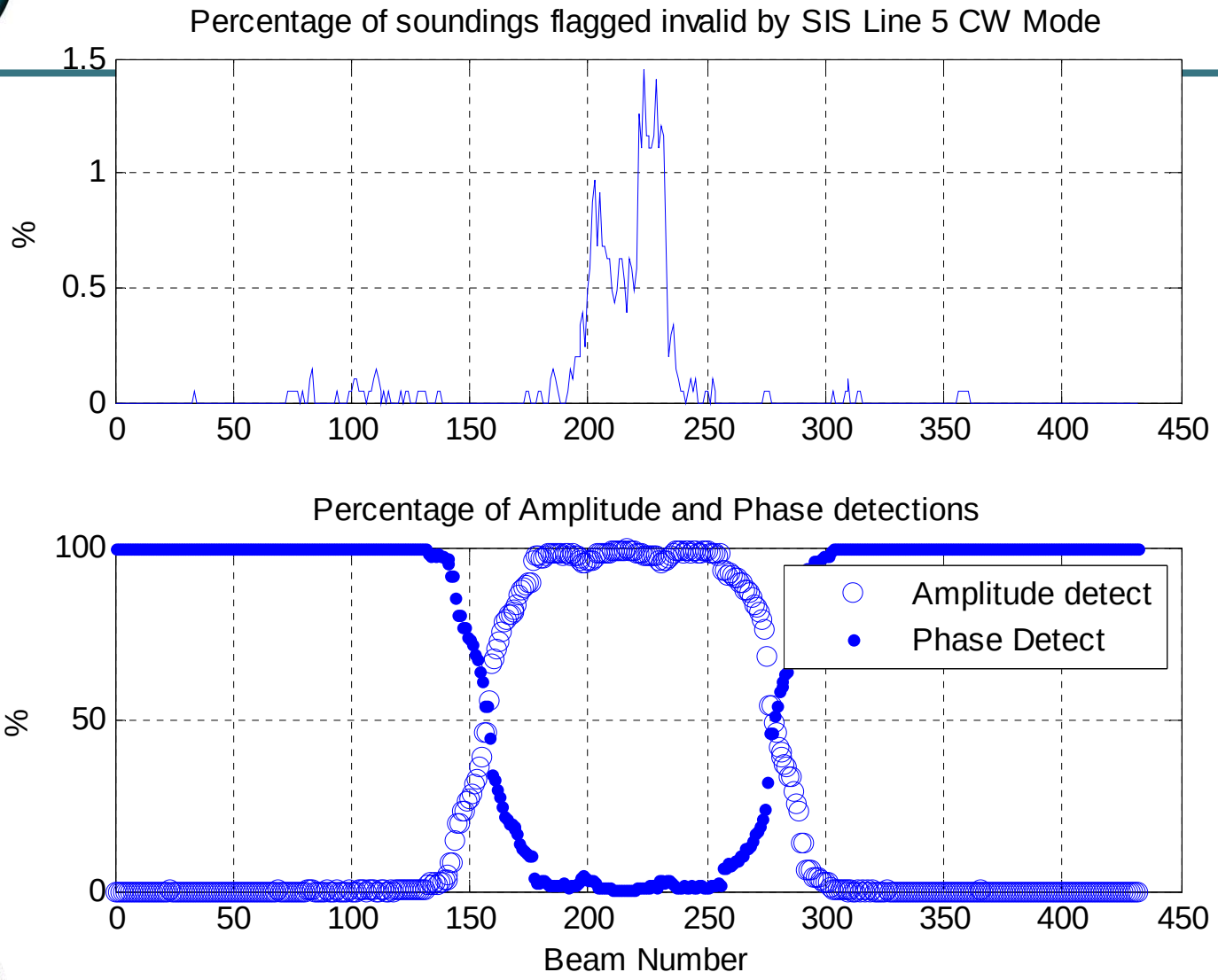
CW mode depth ~ 150 m



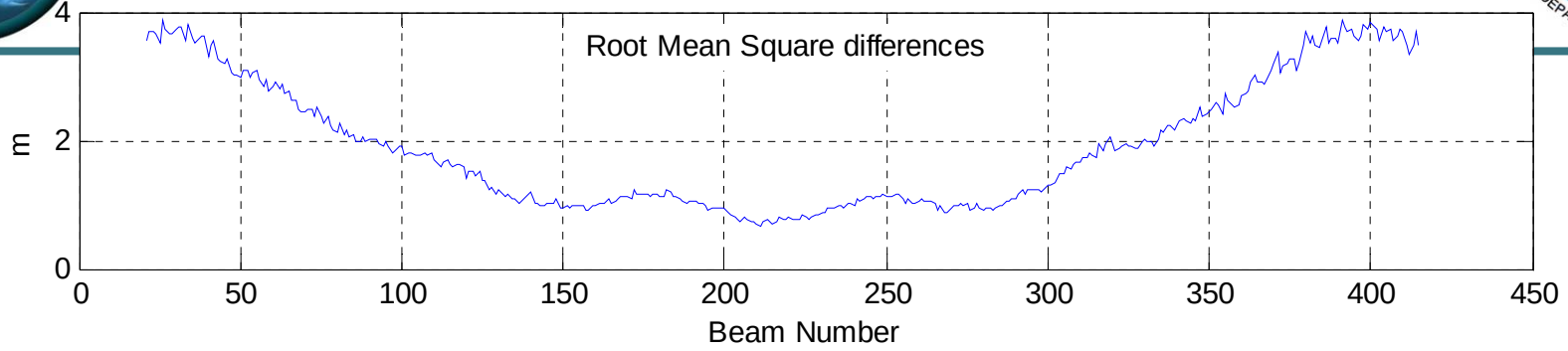


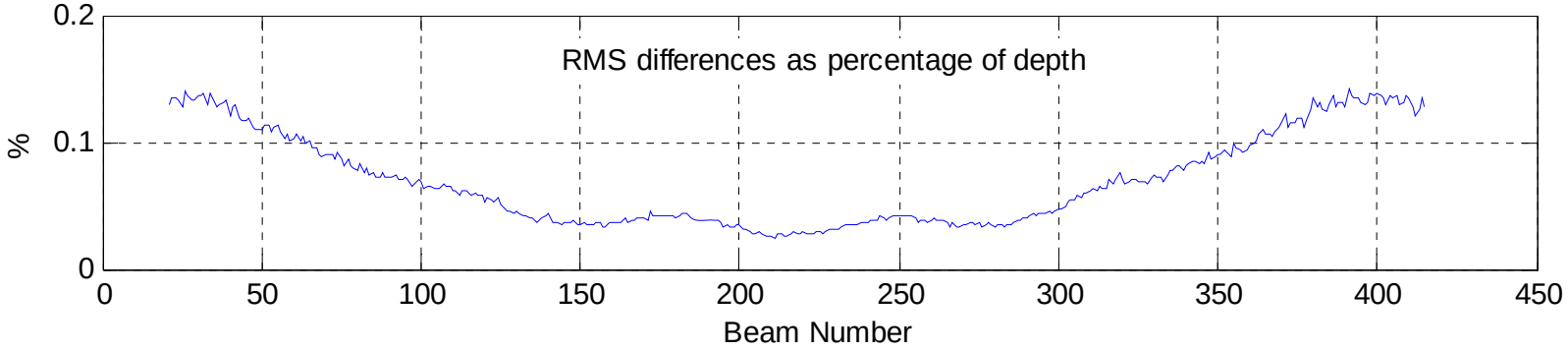


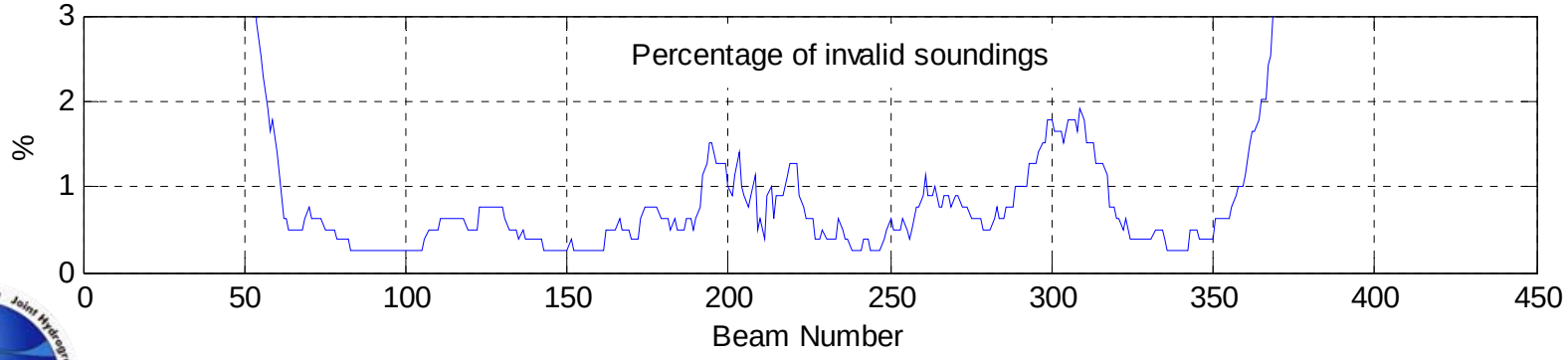
CW mode depth ~ 150 m



FM mode depth ~ 2750 m

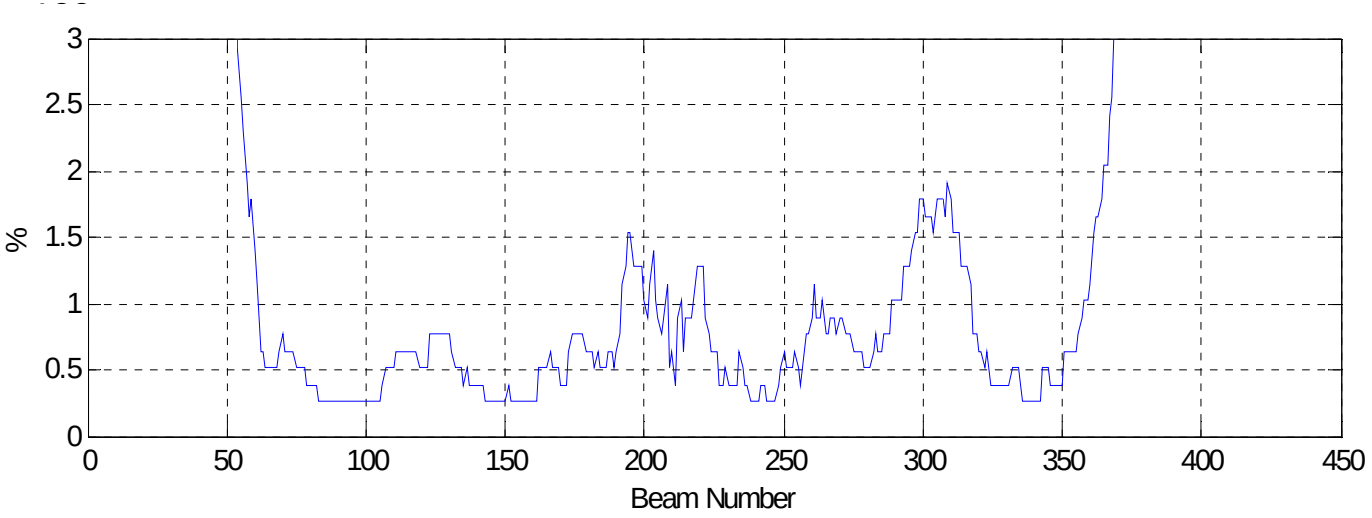


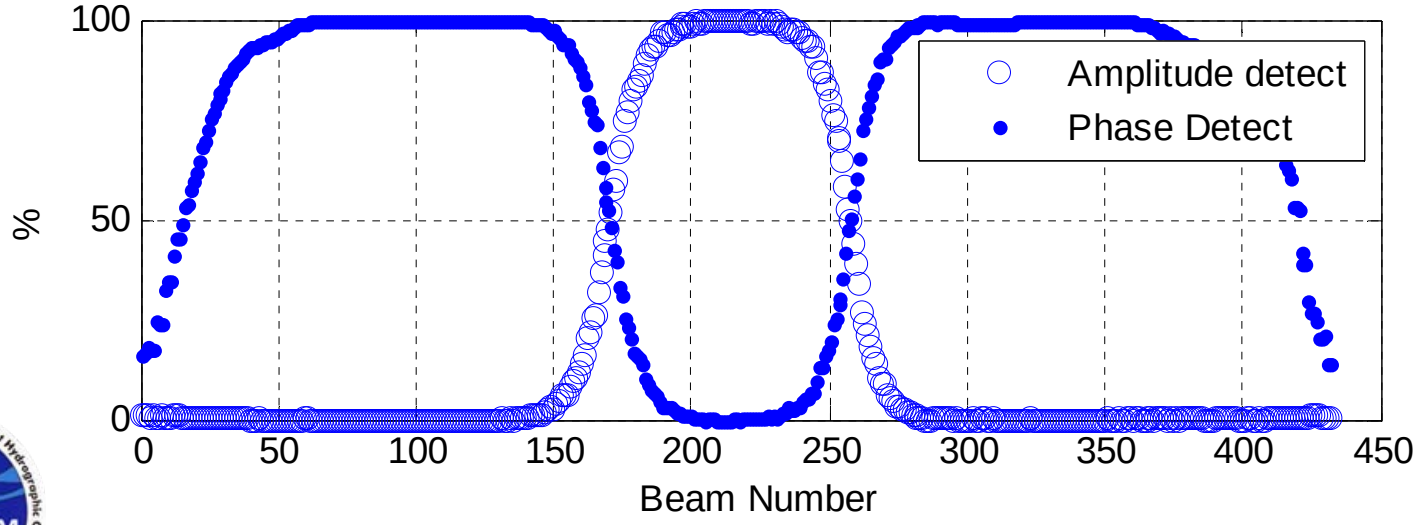




FM mode depth ~ 2750 m

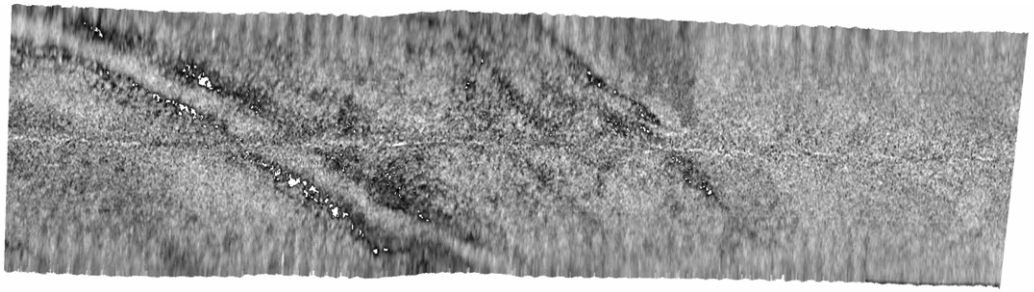
Percentage of soundings flagged invalid by SIS Line 8 FM mode





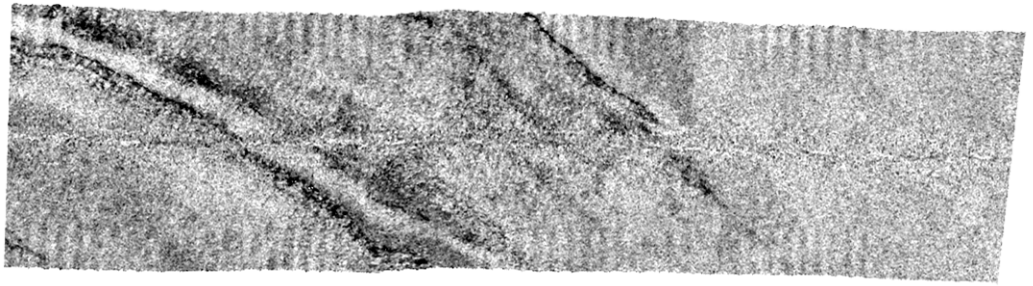
Preliminary Backscatter

2008 Tests (Depth ~ 120 m)



Beam Averaged

Time Series

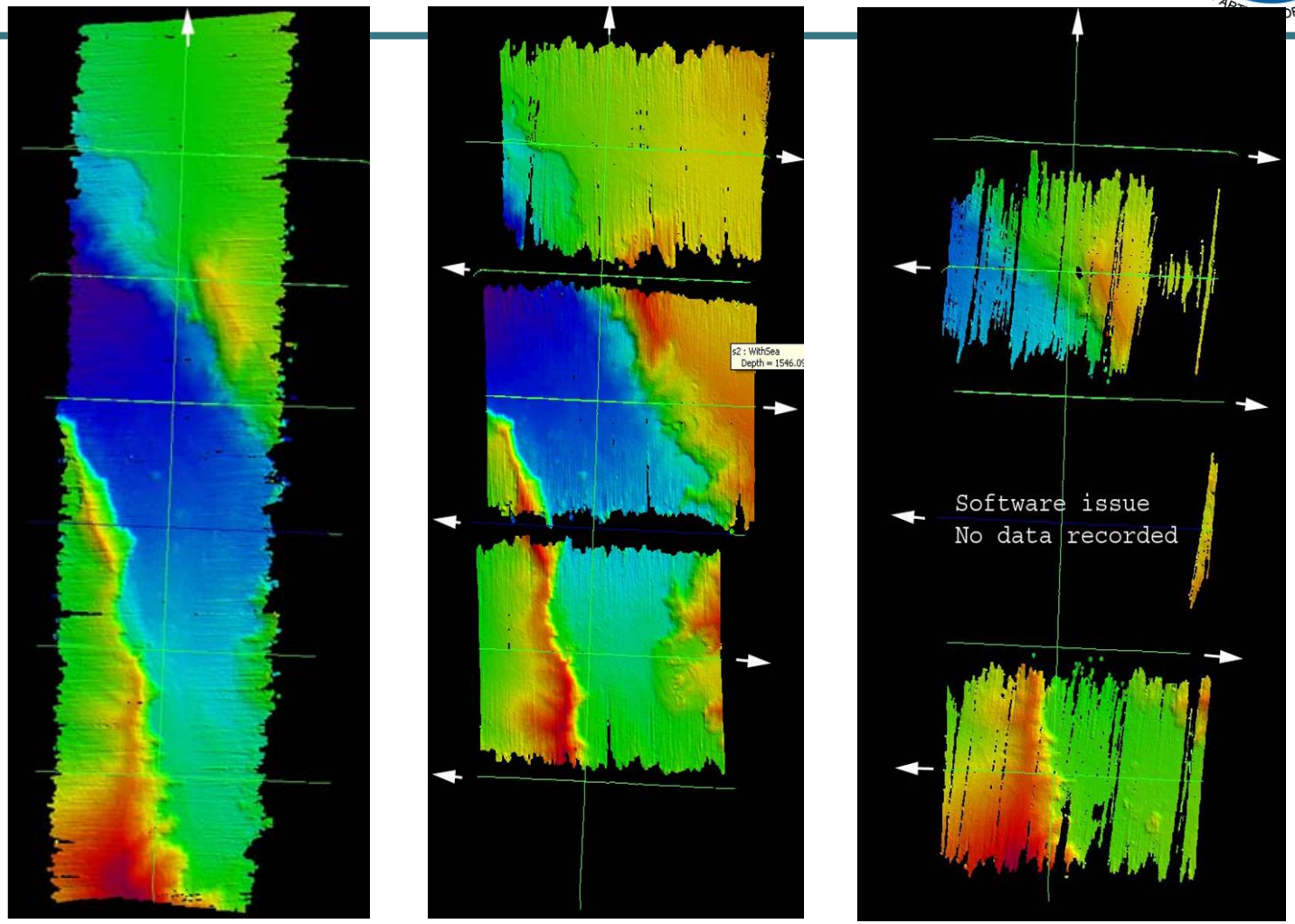


Bubble sweep down

Sea state ~5?

Swell

Roll	+/- 7°
Pitch	+/- 4°
Heave	+/- 2 m

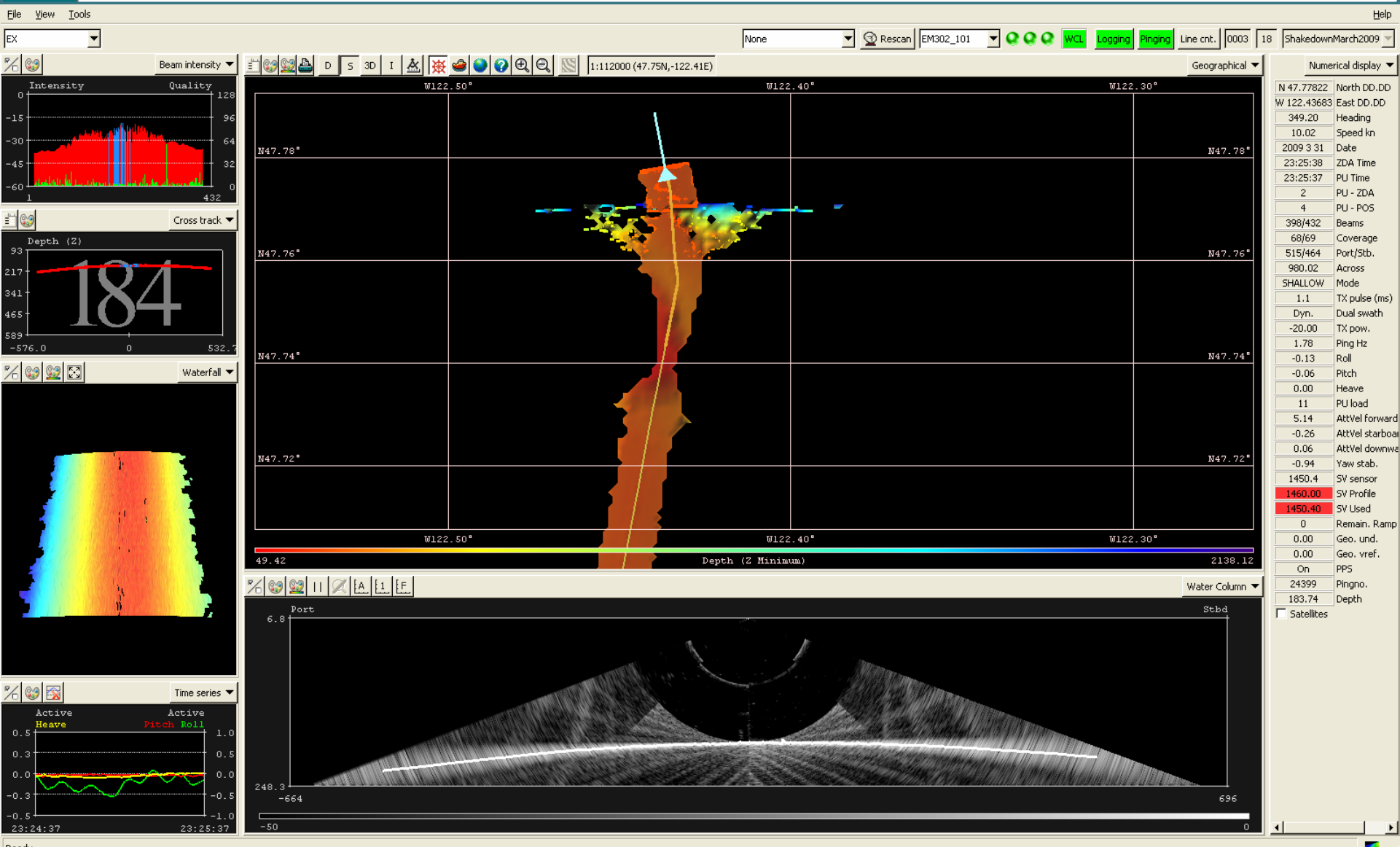


Sea broadside | With swell | Against swell

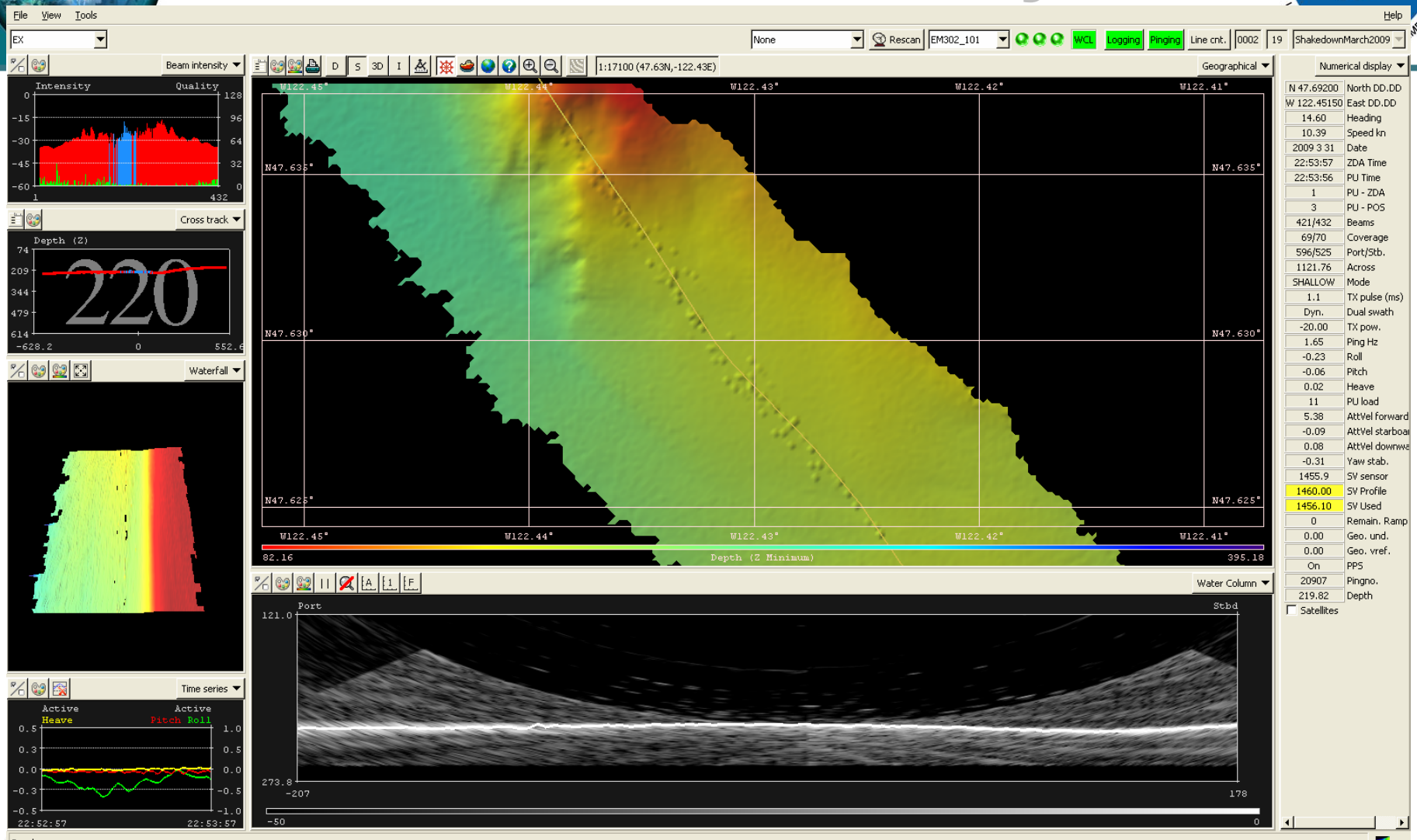
March/April 2009 Results

- **New versions of SIS, EM302 software, POS MV**
- Brought Knudsen Chirp 3260 online
  - interference
- Near-nadir "anomaly"
- Cross lines checks
- Backscatter calibration implementation and issues?

Interference with Knudsen Chirp SBP

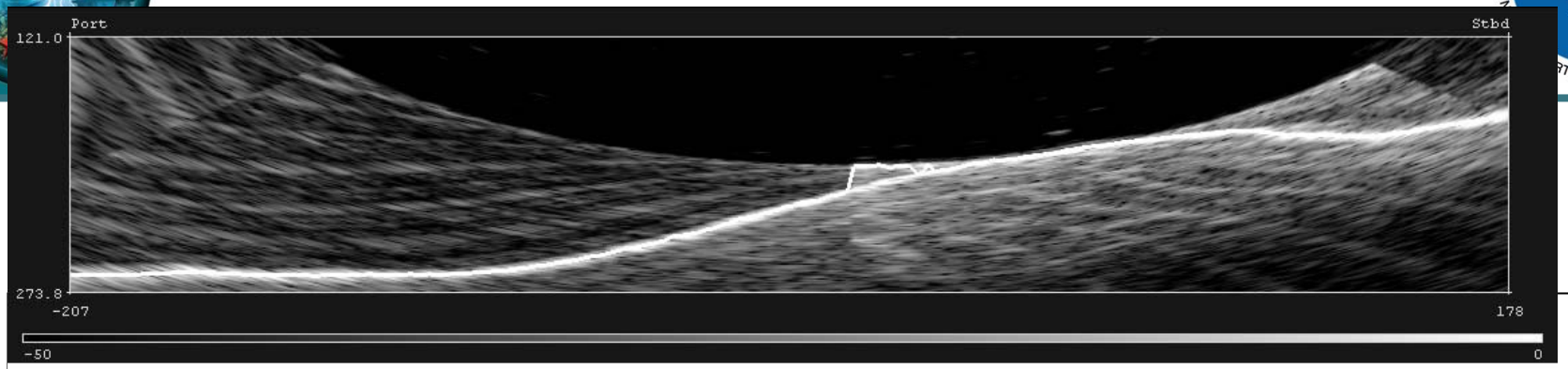


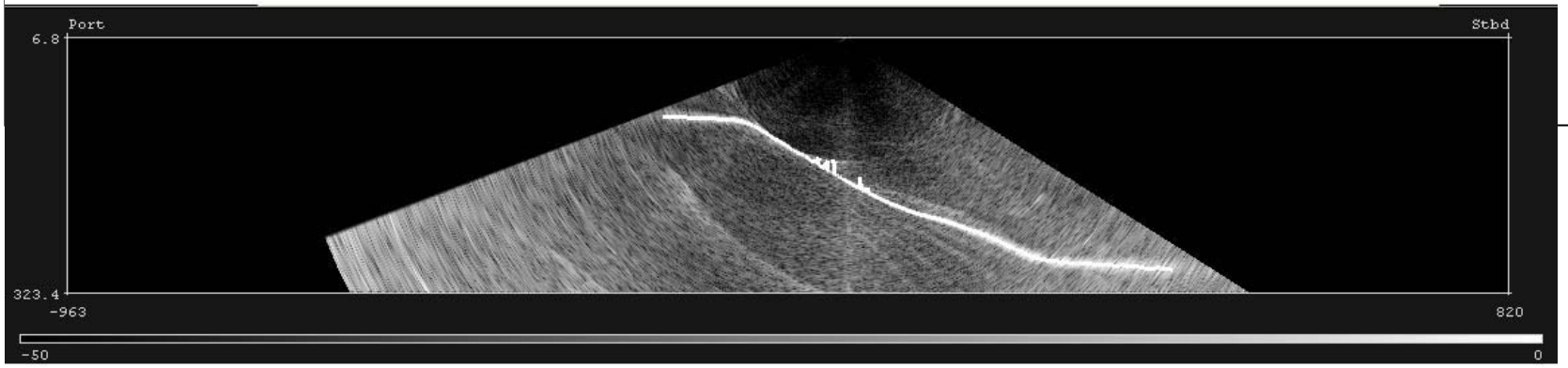
Near nadir anomaly

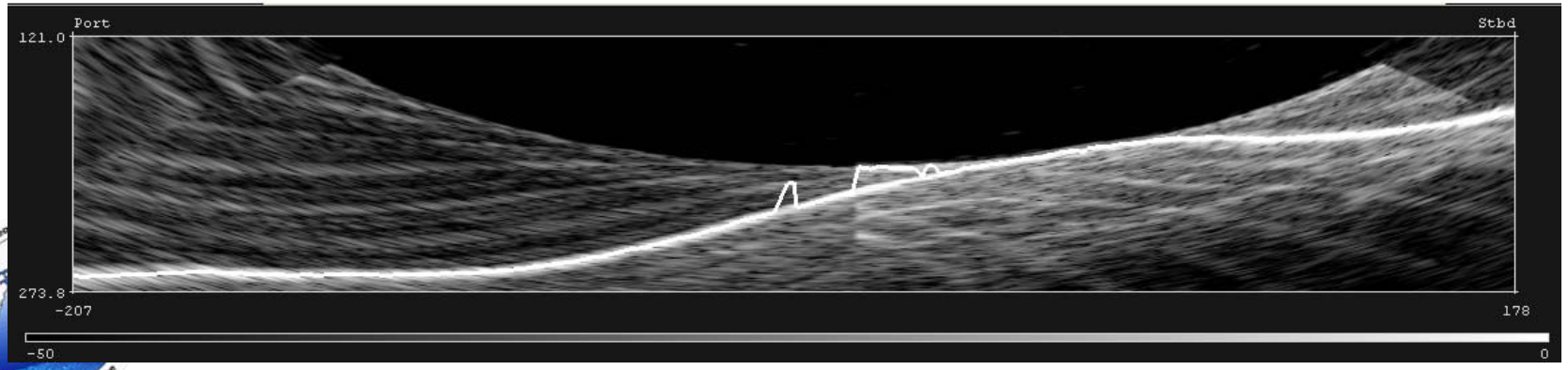


Independent of Knudsen and other sensors
More pronounced in hard bottom areas

UNIHORNS????







Water column data examples showing near nadir artifacts

Cross Line Checks (April 2009)

(removing “near-nadir anomalies”)

CrossCheck Application

File Help

Selected Data Sets for Analysis

File Name

- ALL_DATA_SUMMARY
- W:\DepthTest2\After_FridayHarborTide\line14_cline.txt
- W:\DepthTest2\After_FridayHarborTide\cline1.txt
- W:\DepthTest2\After_FridayHarborTide\cline2.txt
- W:\DepthTest2\After_FridayHarborTide\line10_cline.txt

Add Vertical Bias (m) 0.0 Clear Lines

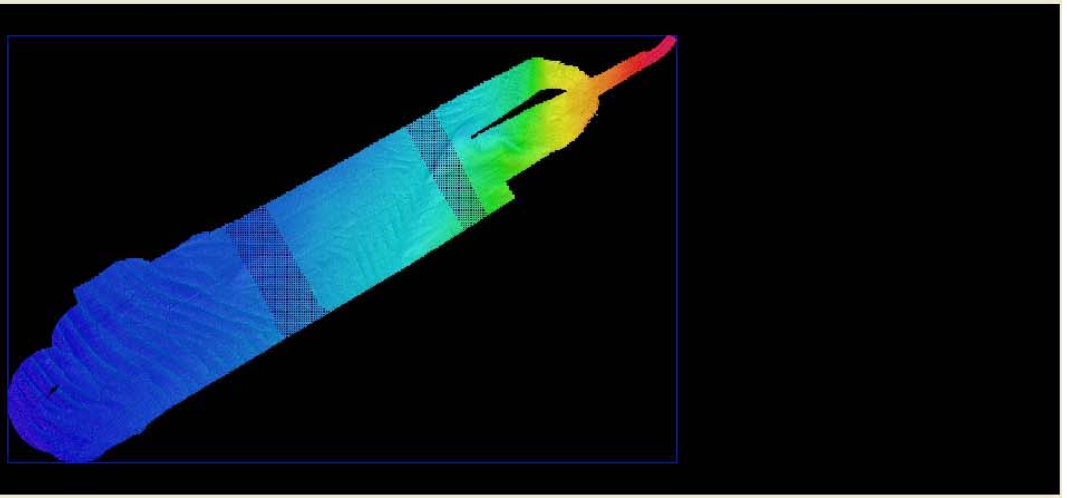
Run Analysis Run Status: Finished

Difference Range

-2.8074 3.7686

Force Diff Range

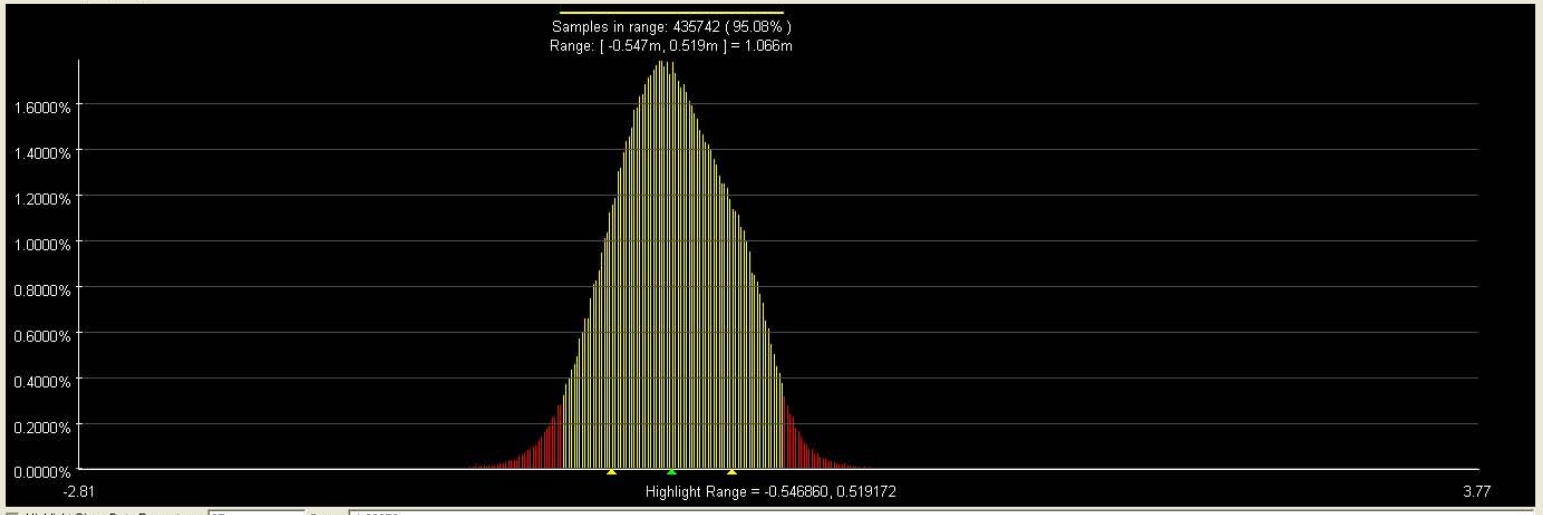
Point Size 176.471 (0 – 500)



Difference Statistics Information

	Statistic	Value
1	# of Points	458294
2	Difference Mean	-0.0085
3	Difference Median	-0.013875
4	Difference Std. Dev	0.283550
5	Difference Range	[-2.81, 3.77]
6	Mean + 2*Stddev	0.58
7	Median + 2*Stddev	0.58
8	Data Mean	-99.32
9	Reference Mean	-99.32
10	Data Z-Range	[-110.49, -75.88]
11	Reference Z-Range	[-97.56, -99.56]
12	Order 1 Error Limit	1.38
13	Order 1 # Rejected	216
14	Order 1 P-Statistic	0.000
15	Order 1 Test	ACCEPTED
16	Order 2 Error Limit	2.49
17	Order 2 # Rejected	10
18	Order 2 P-Statistic	0.000
19	Order 2 Test	ACCEPTED
20	Special Order Error Limit	0.79
21	Special Order # Rejected	5086
22	Special Order P-Statistic	0.011
23	Special Order Test	ACCEPTED

Difference Frequency Analysis



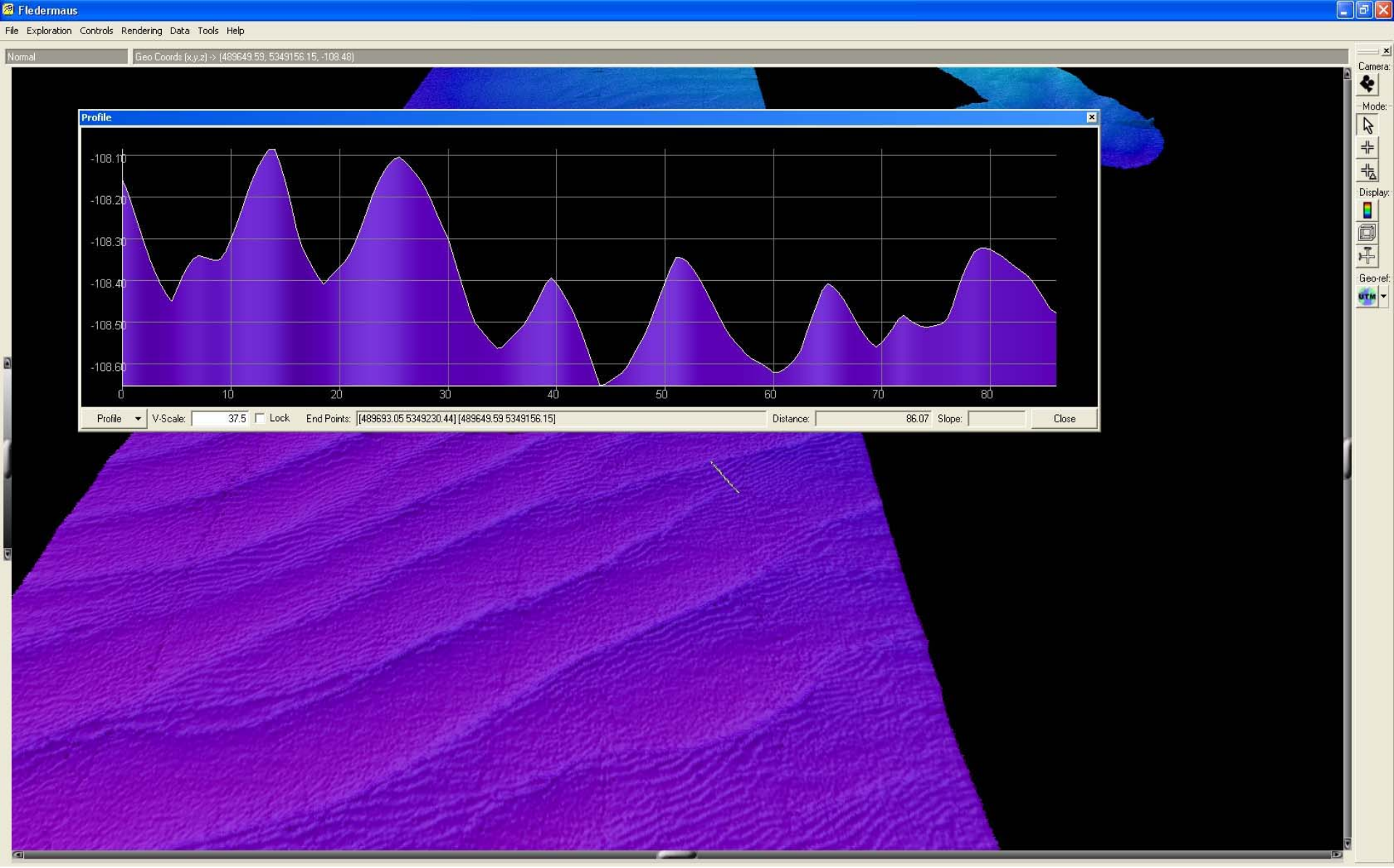
Highlight Given Data Percentage 95 Cursor: -1.68353

Water depth ~ 100 m

Difference Mean = -0.0085 m

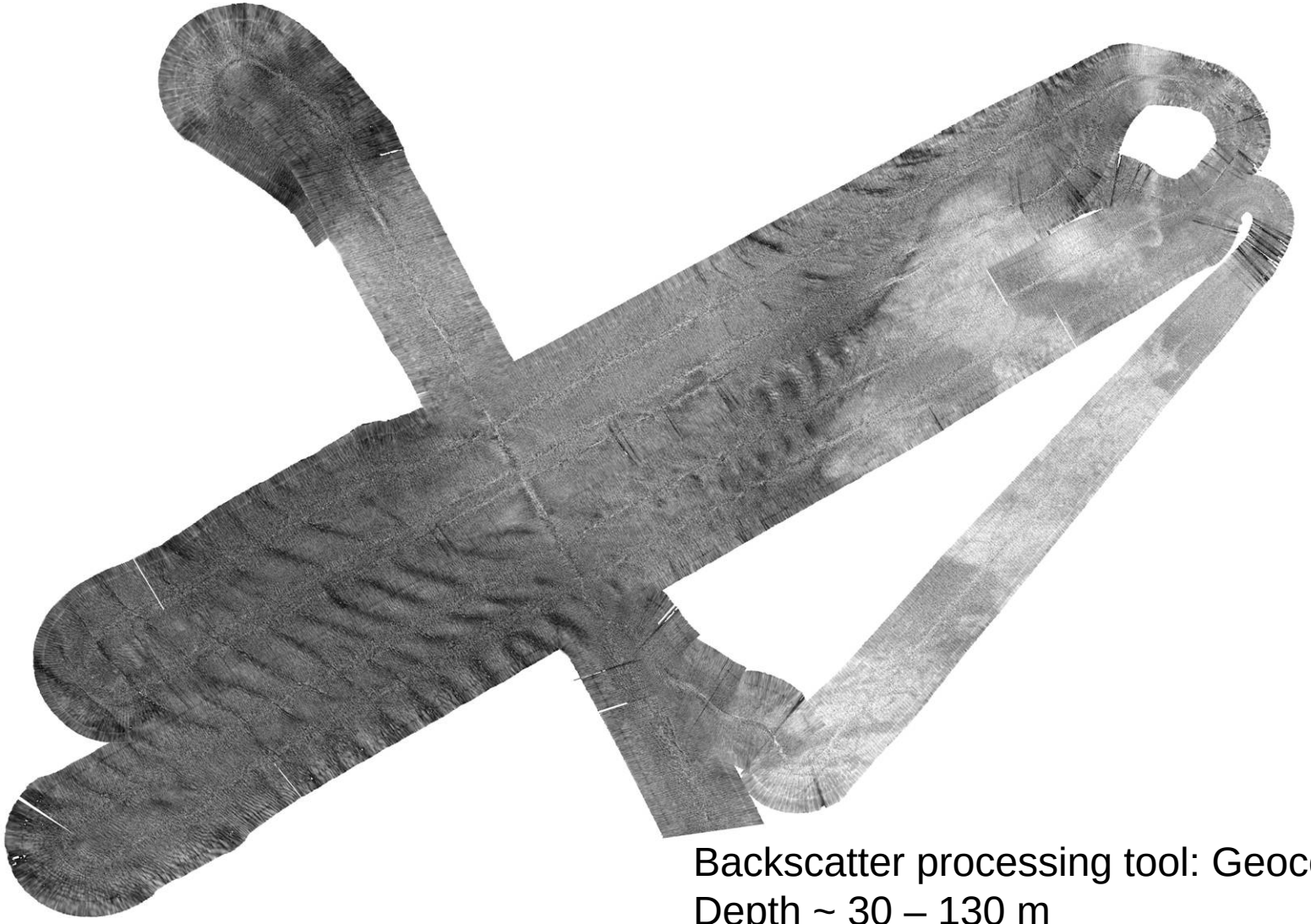
Data passed Special Order test

Mean + 2*std dev. = 0.58 m



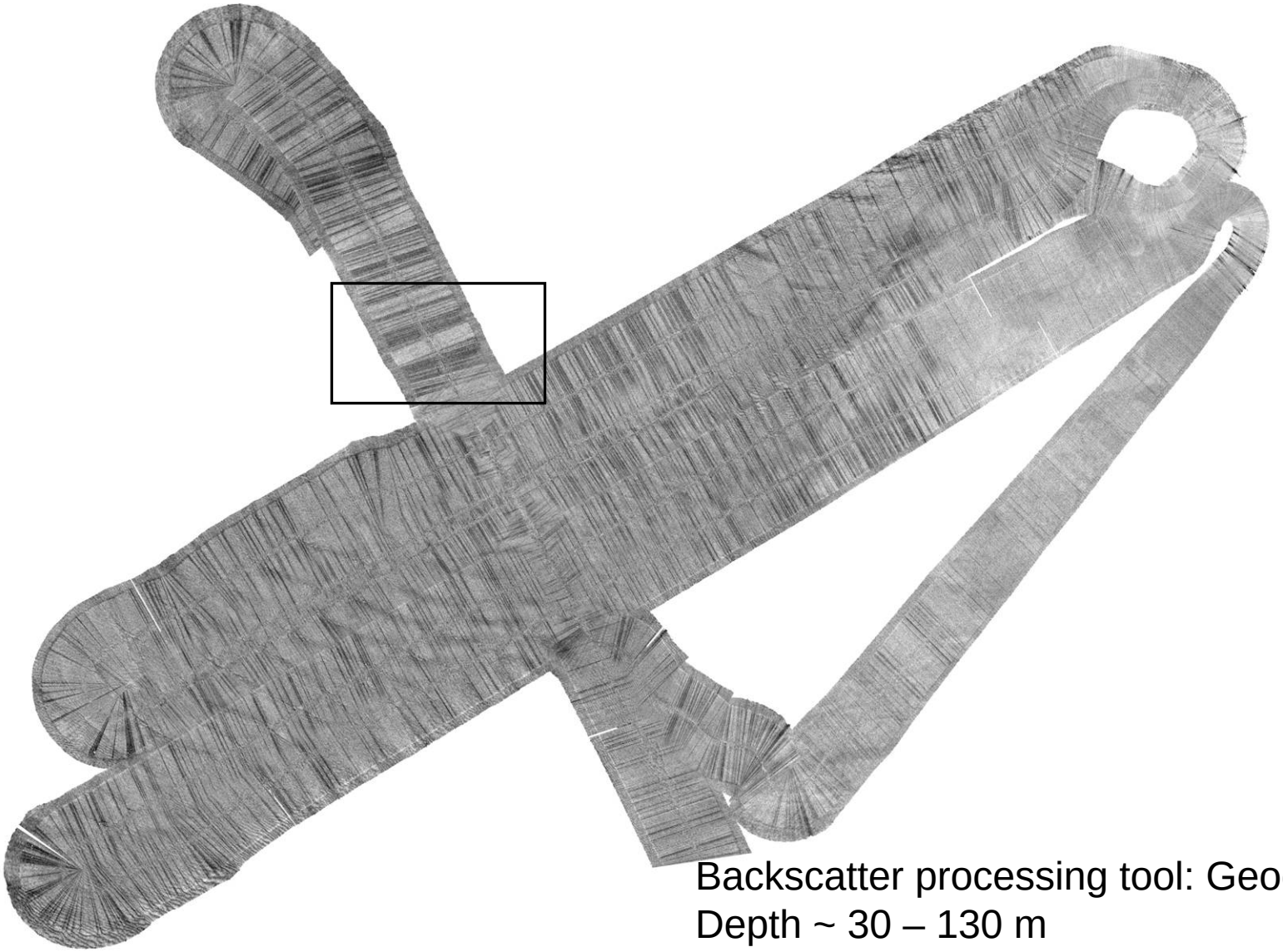
EM 302 bathymetry differentiated sand ripples as small as 15-30 cm in 100m of water ("near-nadir anomalies" removed).

Beam Averaged Backscatter (April 2009)



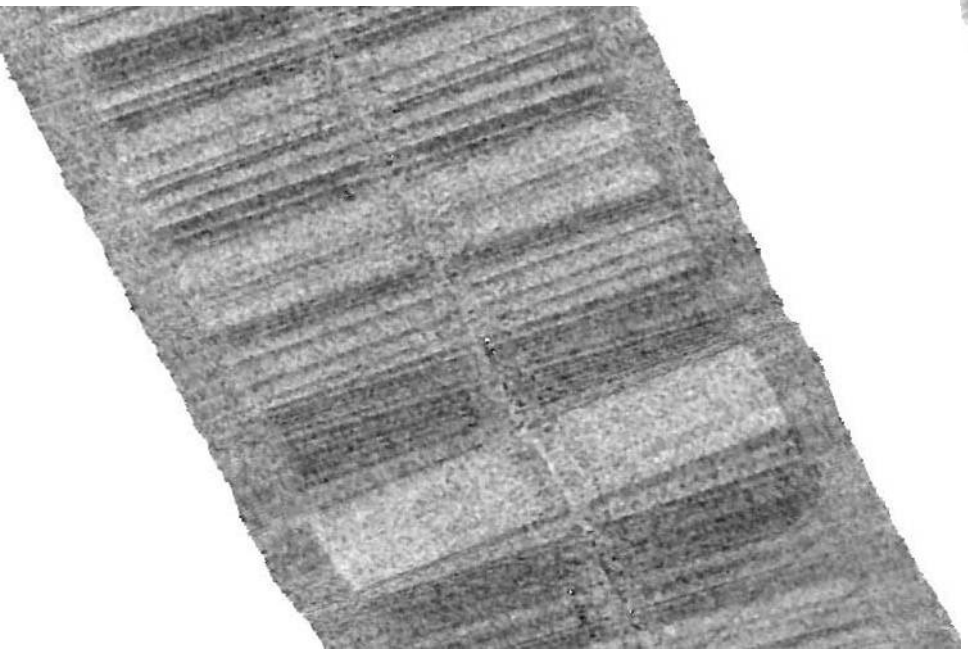
Backscatter processing tool: Geocoder
Depth ~ 30 – 130 m

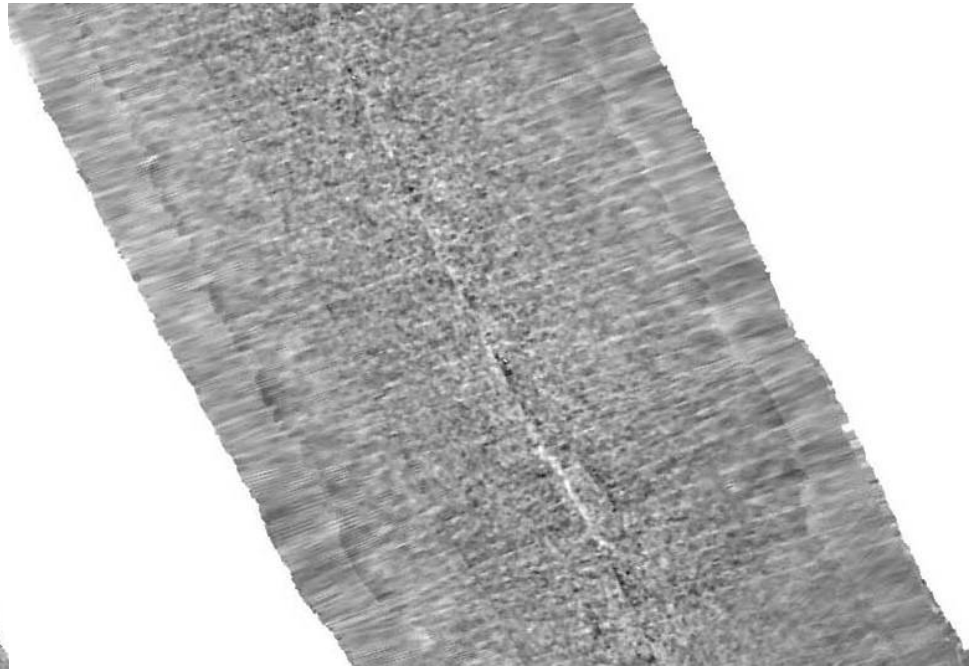
Full Time Series Backscatter (April 2009)



Backscatter processing tool: Geocoder
Depth ~ 30 – 130 m

Hmmm…….????

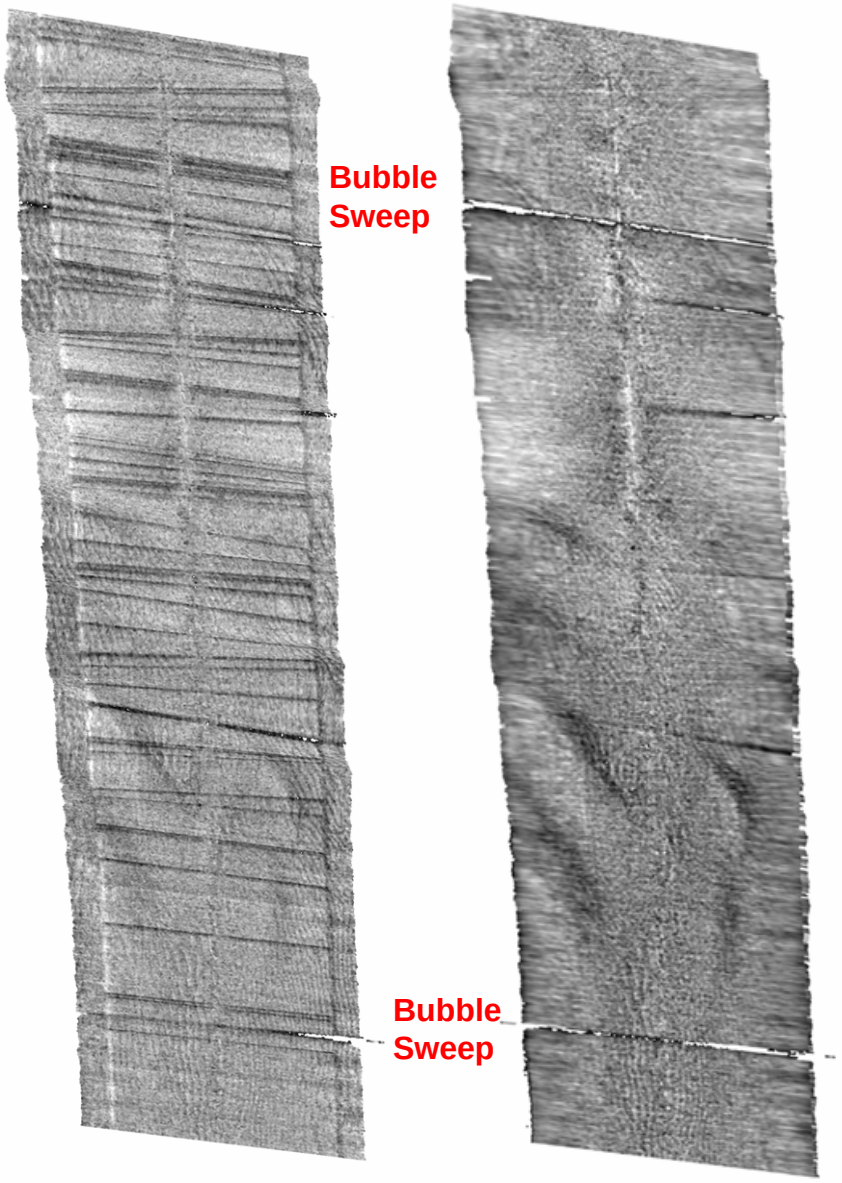




Full Time Series

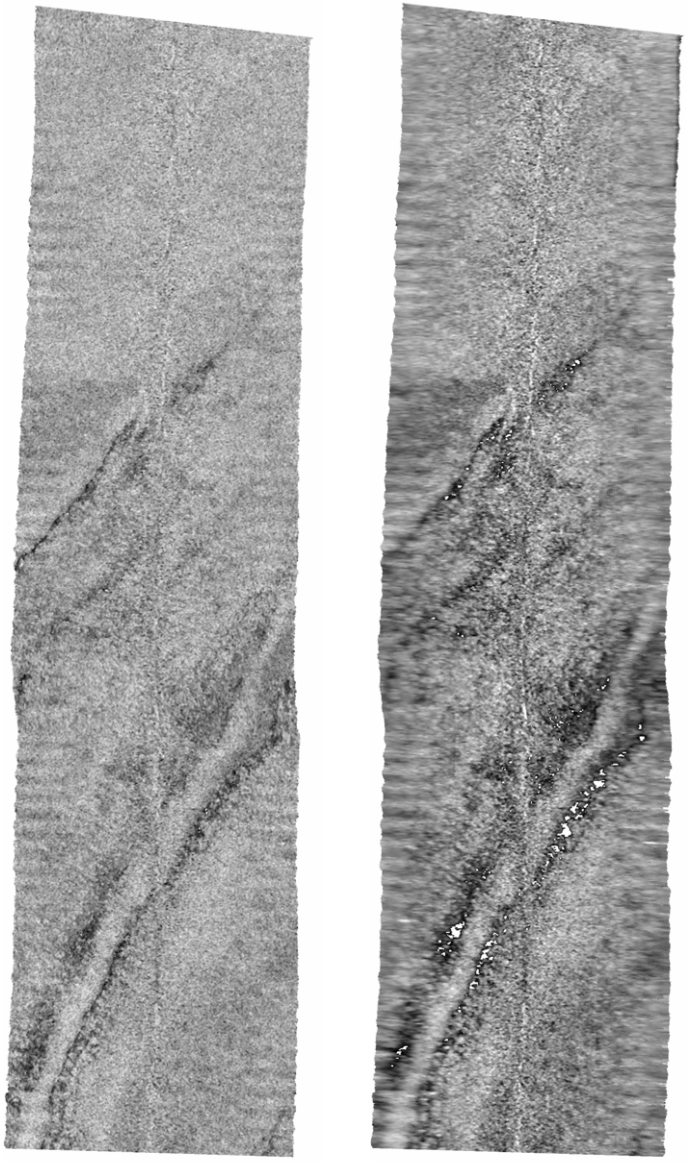
Beam averaged

2009 Tests (Depth ~ 90 m)

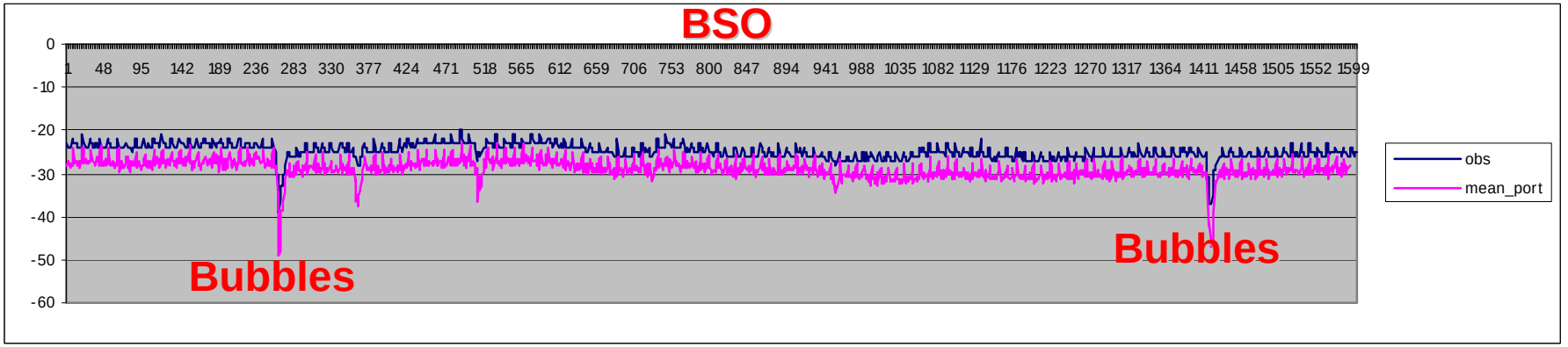


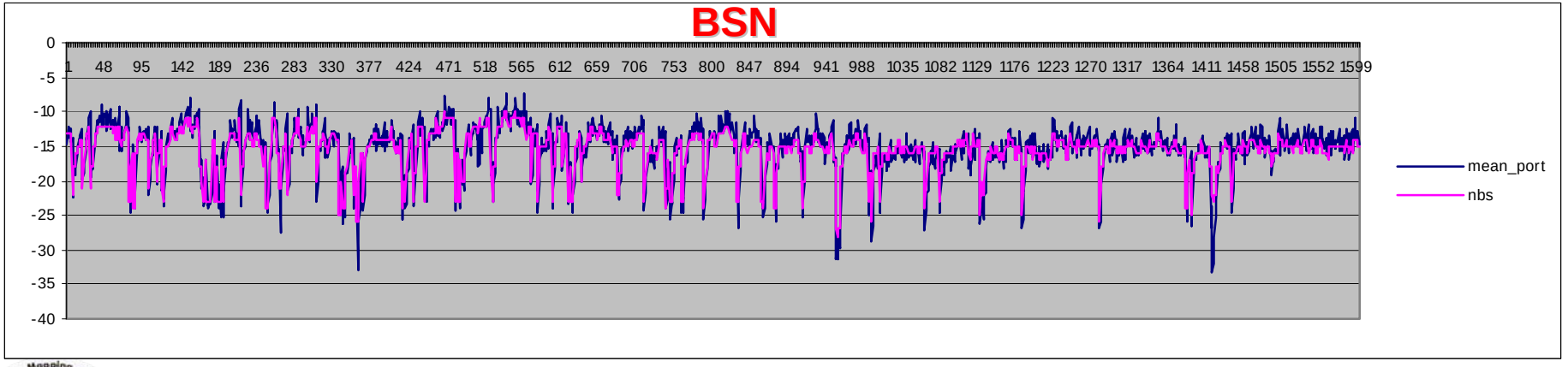
Time Series Beam Averaged

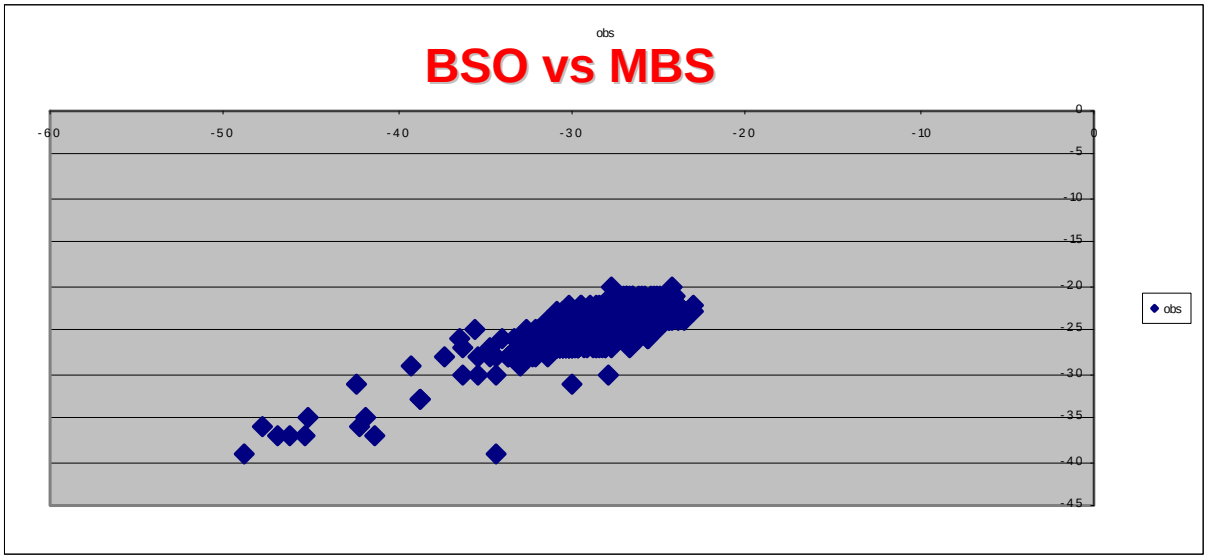
2008 Tests (Depth ~ 120 m)

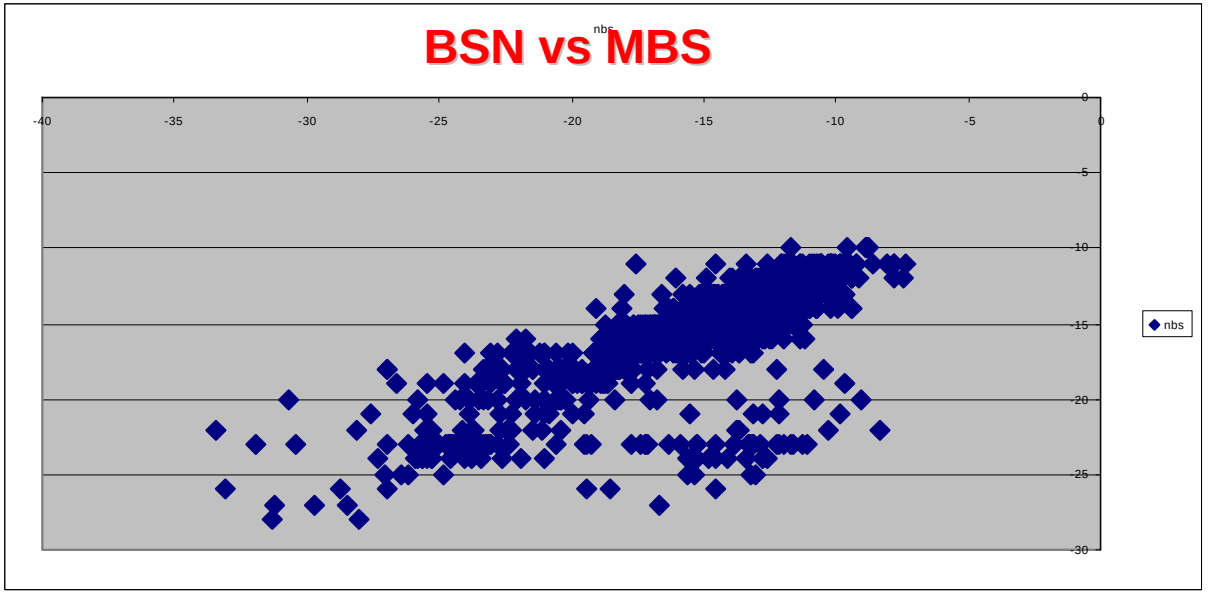


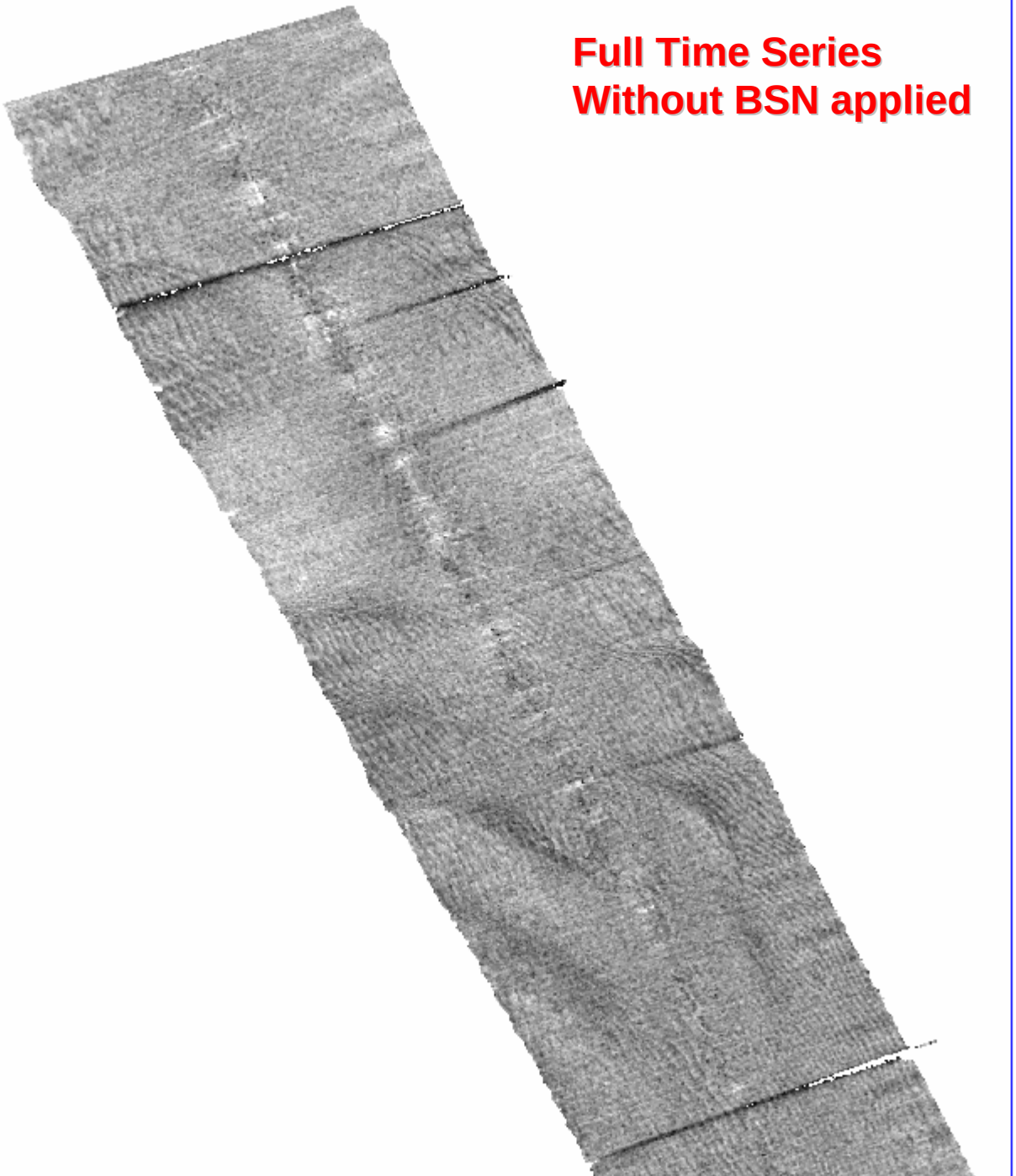
Time Series Beam Averaged


BSO
0
-10
-20
-30
-40
-50
-60
1 48 95 142 189 236 283 330 377 424 471 518 565 612 659 706 753 800 847 894 941 988 1035 1082 1129 1176 1223 1270 1317 1364 1411 1458 1505 1552 1599
Bubbles
Bubbles
obs
mean_port


BSN
0
-5
-10
-15
-20
-25
-30
-35
-40
1 48 95 142 189 236 283 330 377 424 471 518 565 612 659 706 753 800 847 894 941 988 1035 1082 1129 1176 1223 1270 1317 1364 1411 1458 1505 1552 1599
mean_port
nbs


obs
BSO vs MBS
-60
-50
-40
-30
-20
-10
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
obs

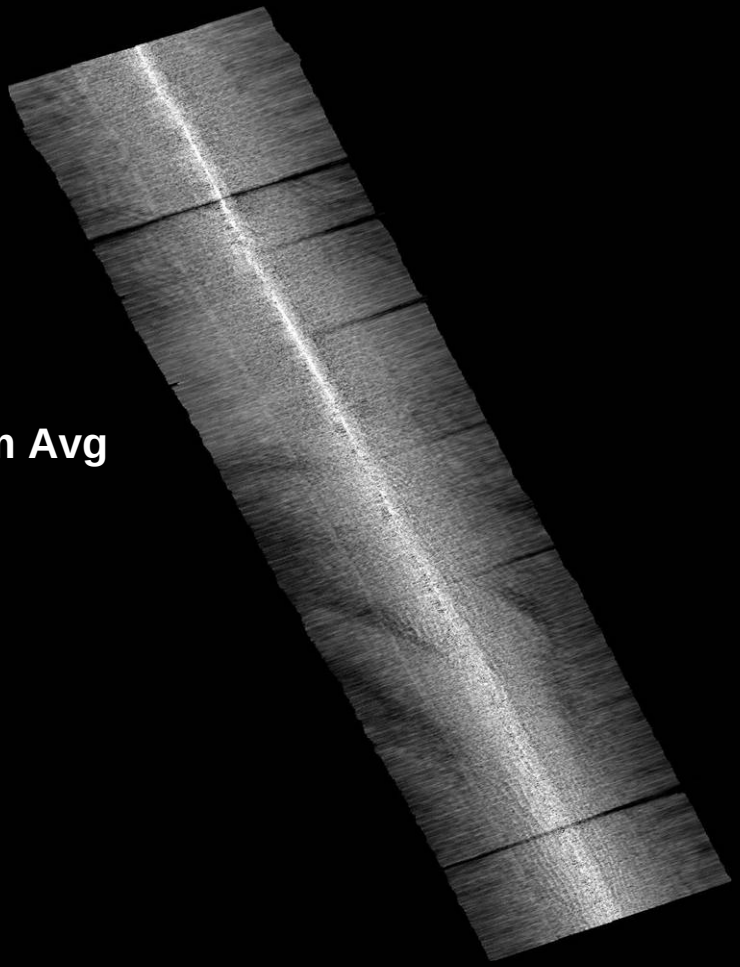

nbs
BSN vs MBS
-40
-35
-30
-25
-20
-15
-10
-5
0
5
10
15
20
25
30
nbs



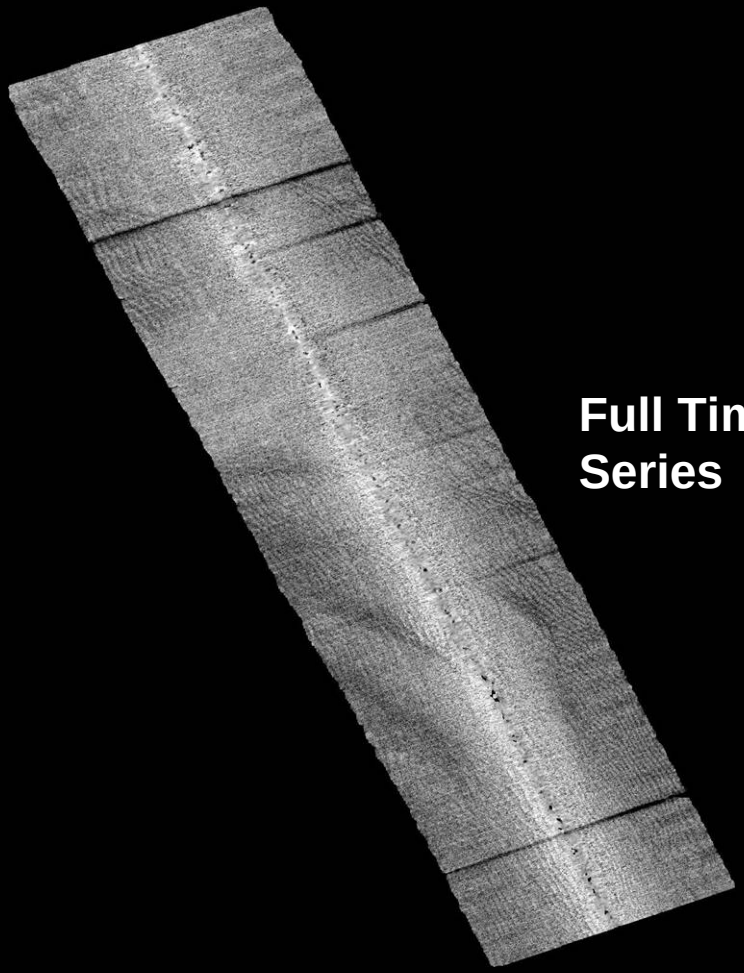
Full Time Series
Without BSN applied

IFREMER SONARSCOPE

Beam Avg

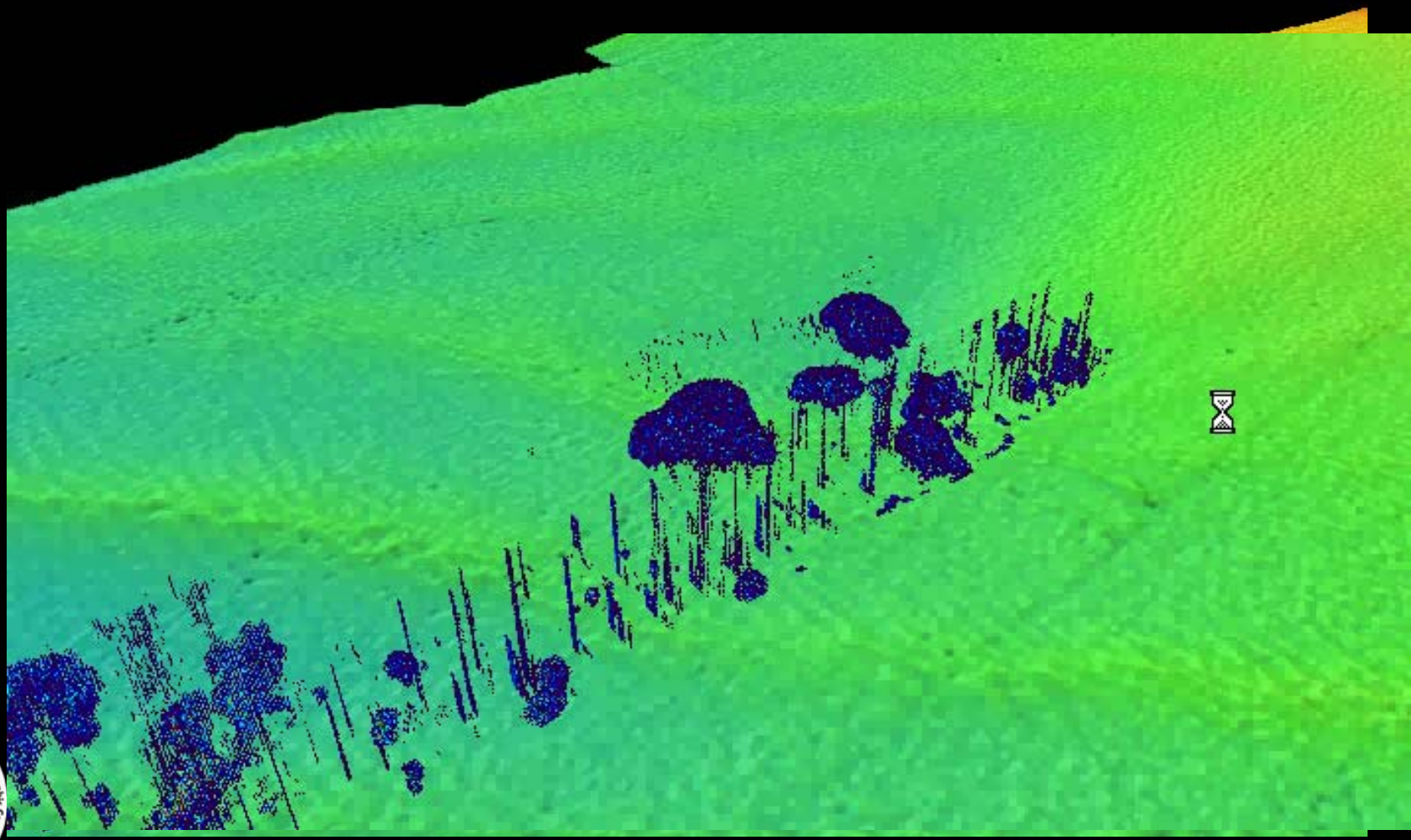


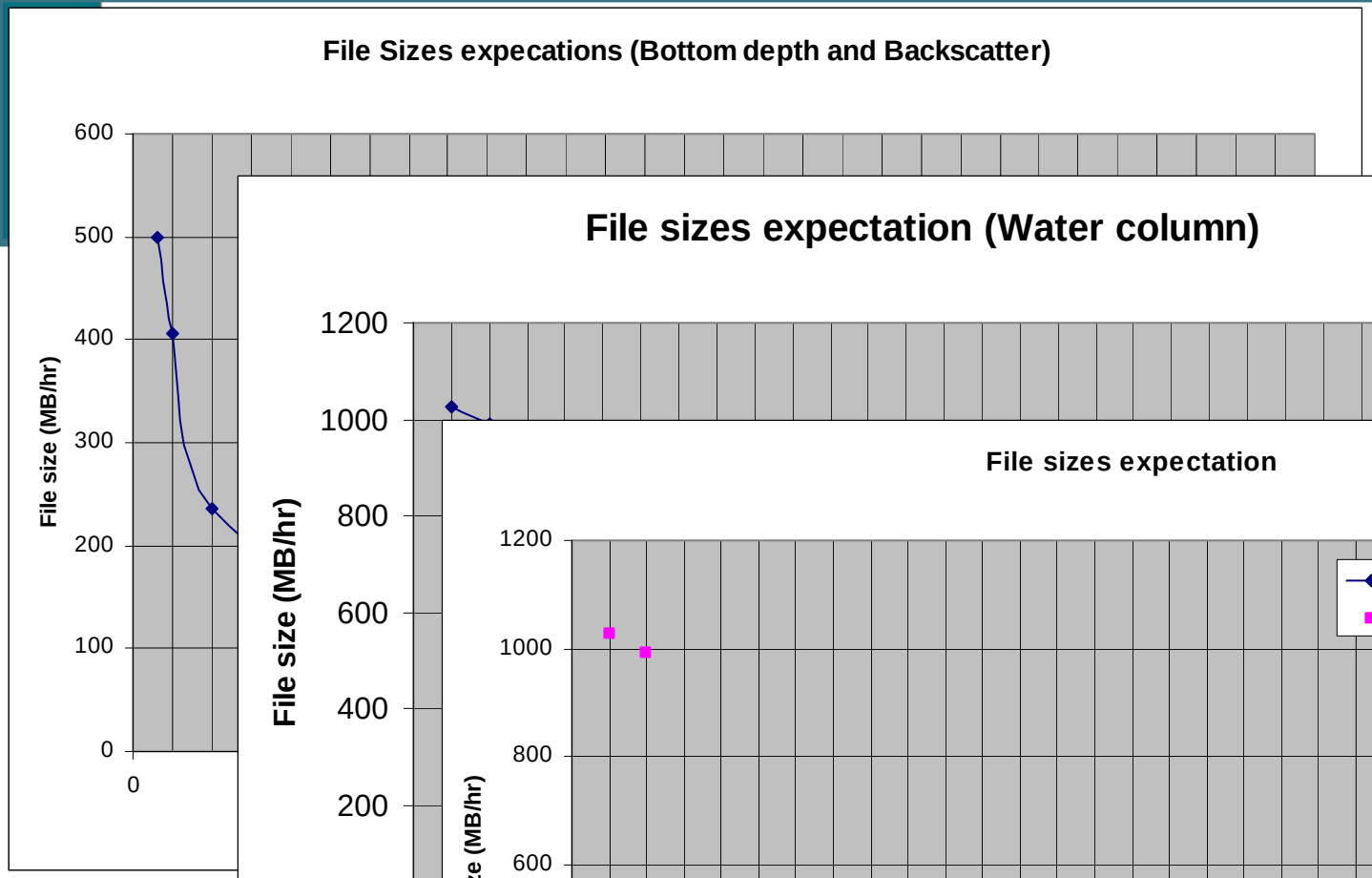
Full Time Series



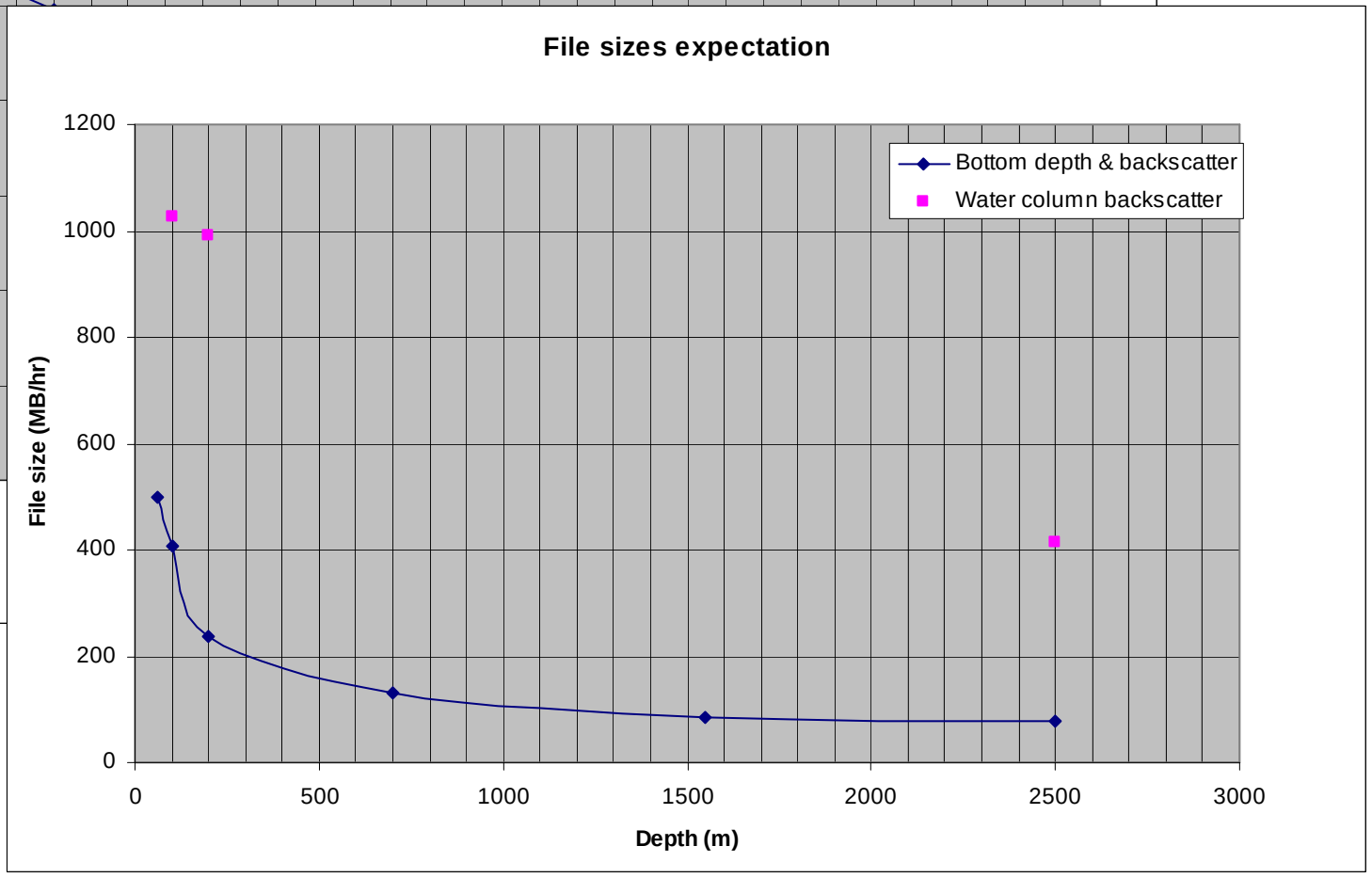
Merci Jean-Marie Augustin

EM 302 Water Column Data




File Sizes expecations (Bottom depth and Backscatter)
File size (MB/hr)
600
500
400
300
200
100
0
0

File sizes expectation (Water column)
File size (MB/hr)
1200
1000
800
600
400
200
0
0


File sizes expectation
File size (MB/hr)
1200
1000
800
600
400
200
0
0
500
1000
1500
2000
2500
3000
Depth (m)
Bottom depth & backscatter
Water column backscatter

WCD ~ 5 times

Outstanding issues

KONGSBERG:

Needed:

- Understand near-nadir anomalies
- Questions about full-time series BS as well as seafloor and water column BS calibration
- EM 302 integration with helmsman display and DP system

Desired:

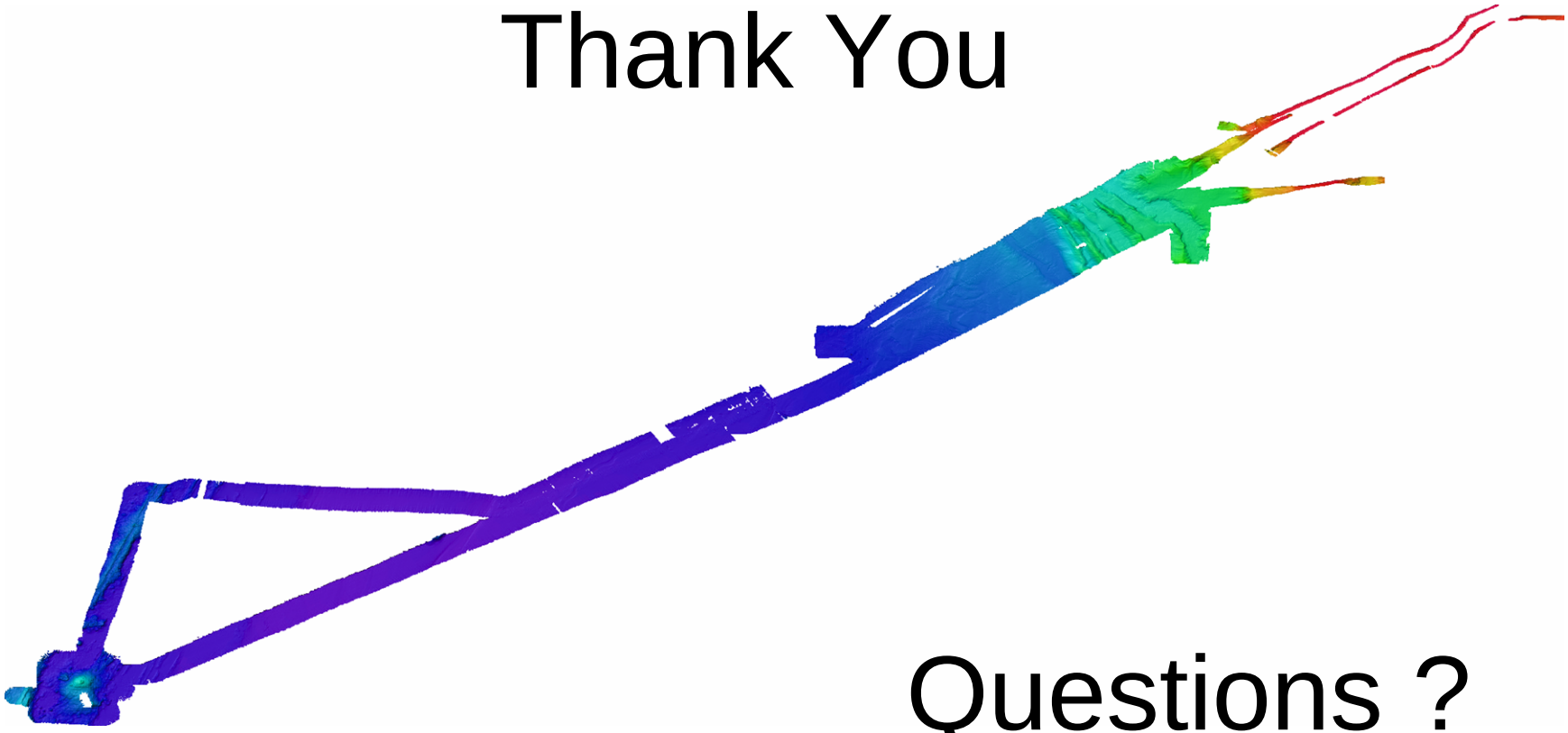
- EM 302 error model

Outstanding issues

NOAA needs to:

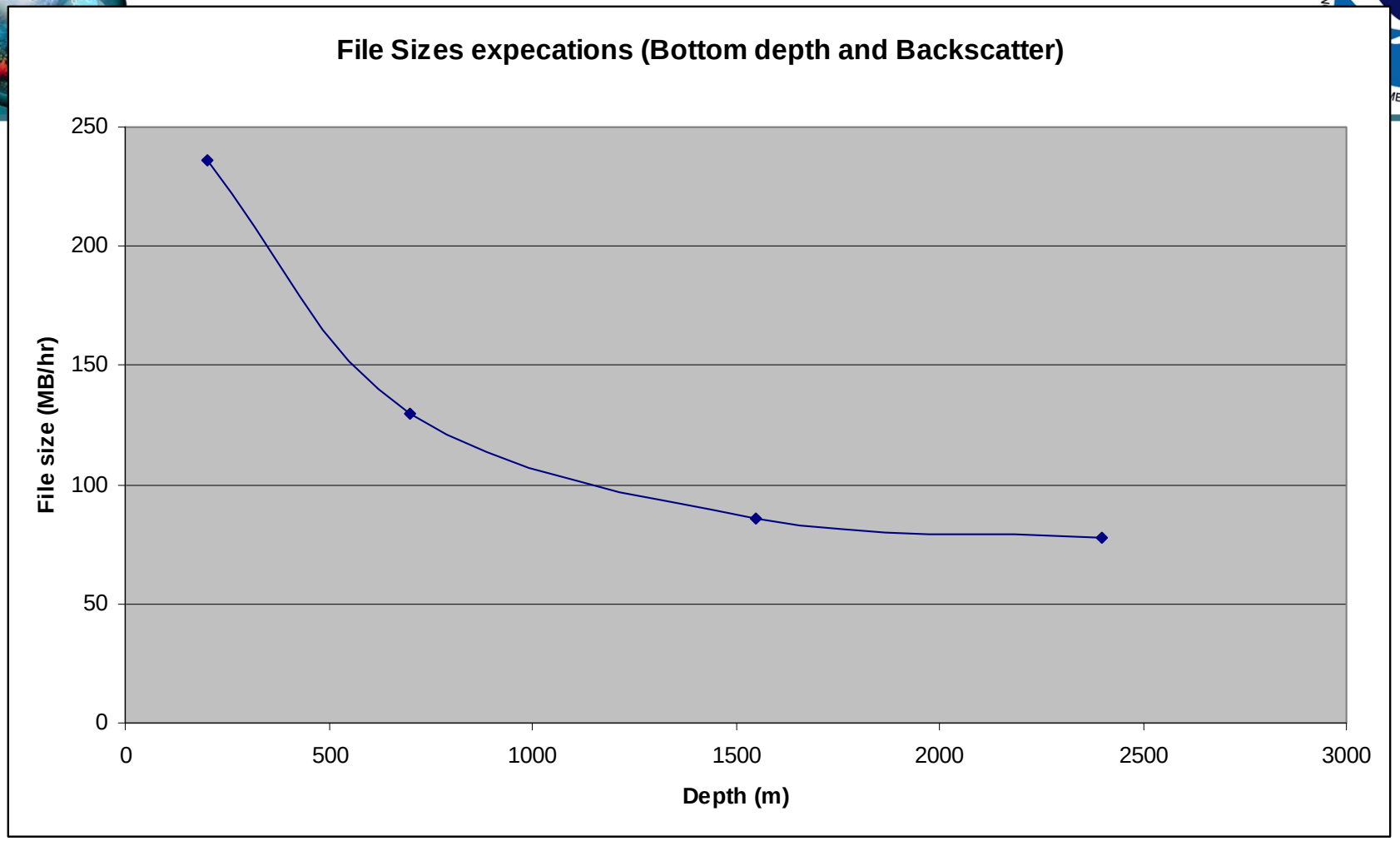
- Further establish accuracy and resolution achievable
  - Depth, Backscatter, water column mapping
- Understand system limits (deep and shallow water)
- Work on elimination of interference with other sensors (SBP etc.)
- Address bubble sweep issues

Thank You



Questions ?

Multibeam EM 302 file size expectations



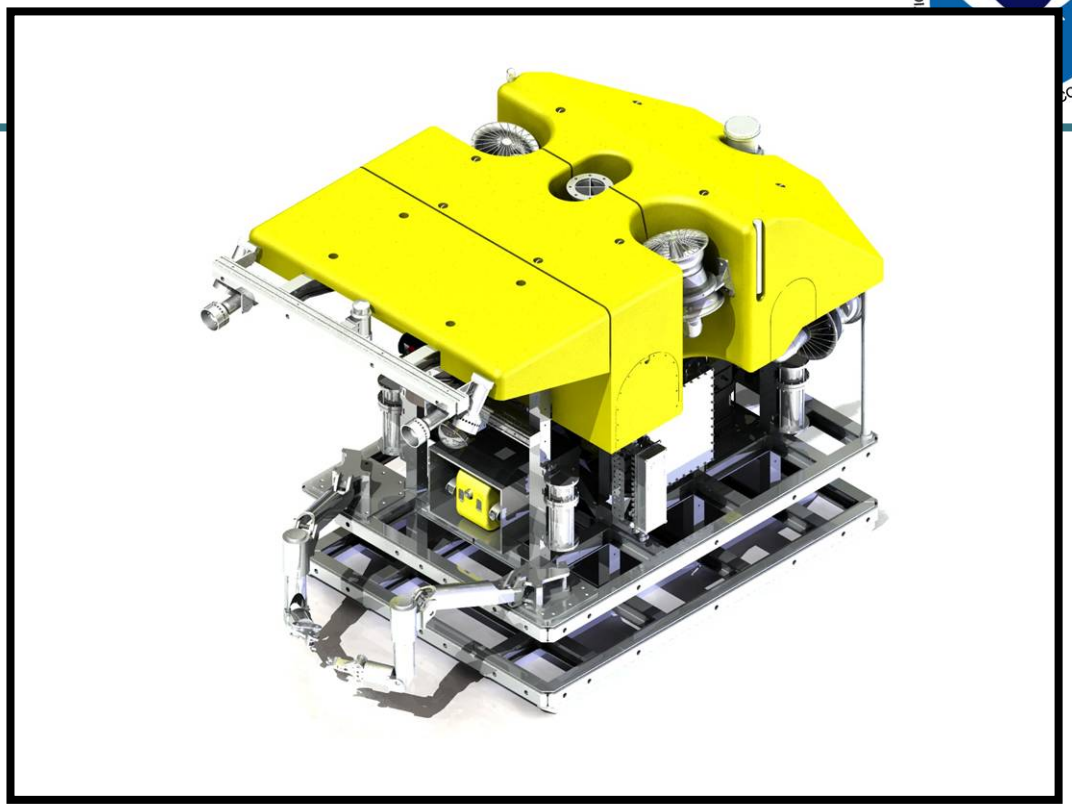
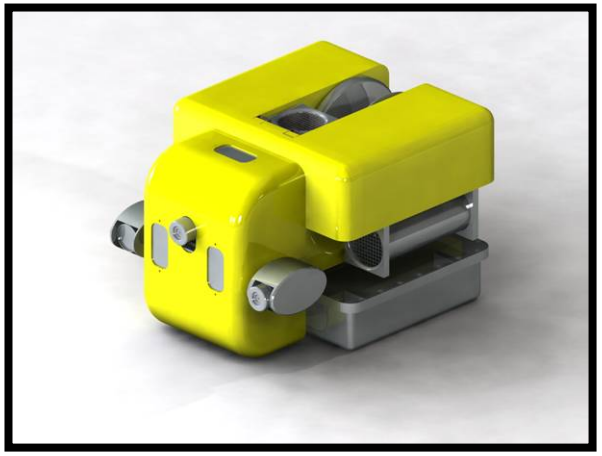
WCD data files ~ 5.3 times (at 2550 m depth)
~ 4.2 times (at 150 m depth)

Agenda

- Introduction
- Re-thinking Ocean Exploration
- Ocean Exploration mapping goals
- EM 302 installation and testing
- EM 302 outstanding issues
- Conclusion

NOAA Ship OKEANOS EXPLORER:

America's vessel for ocean exploration

State of art sensors
Tele-presence equipped
A new concept of operations

Okeanos Explorer ROV's