Airborne Bathymetric Lidar and Examples of NIOHC-type environment IHO Order 1 Specification Coastal Surveys

Don Ventura

NIOHC – Colombo, Sri Lanka – 23 March 2012

Resources

13,500 Employees

55 Vessels

75 CPT Trucks
CPT Towers

27 Laboratories

29 Jack-up Platforms

60 Aircraft

250 Land-based Drill Rigs
15 Offshore Drill Rigs

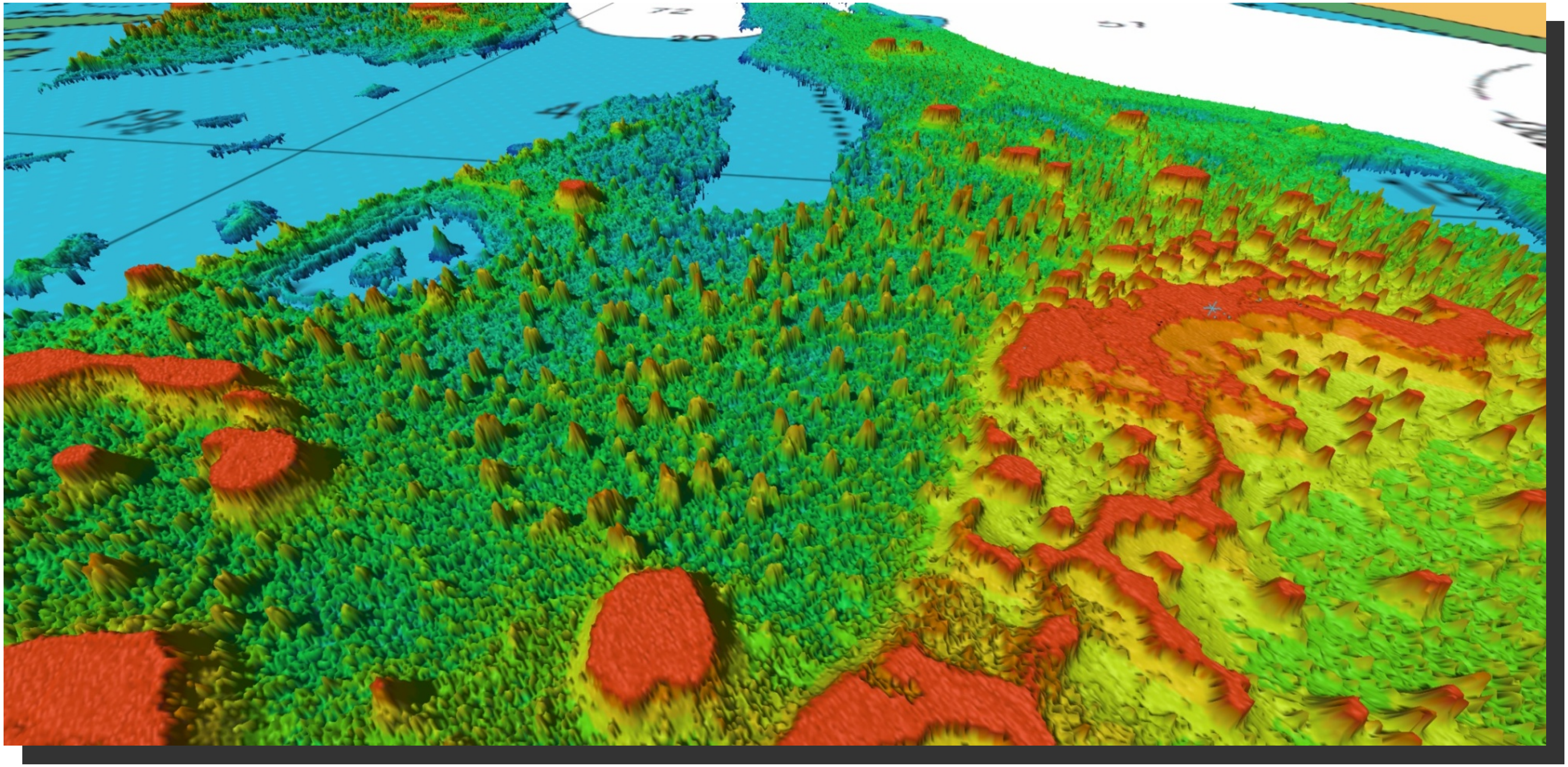
135 ROVs

8 AUVs

278 Offices

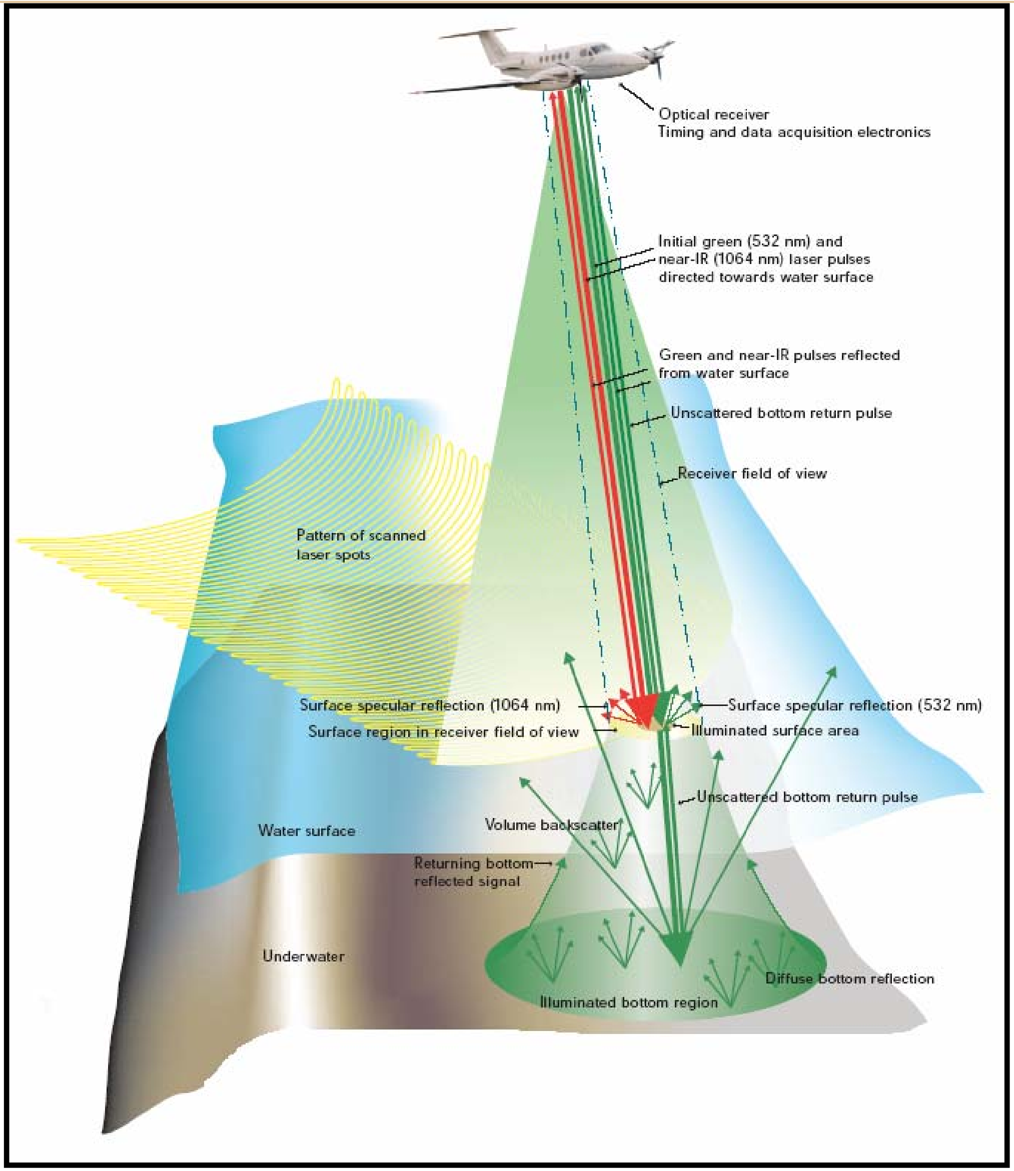
Fugro's people, vessels, equipment and facilities are continually growing in number and capability in order to meet the demand for continuous high quality services in ever-more challenging regions of the globe.

Airborne Lidar Bathymetry (ALB)

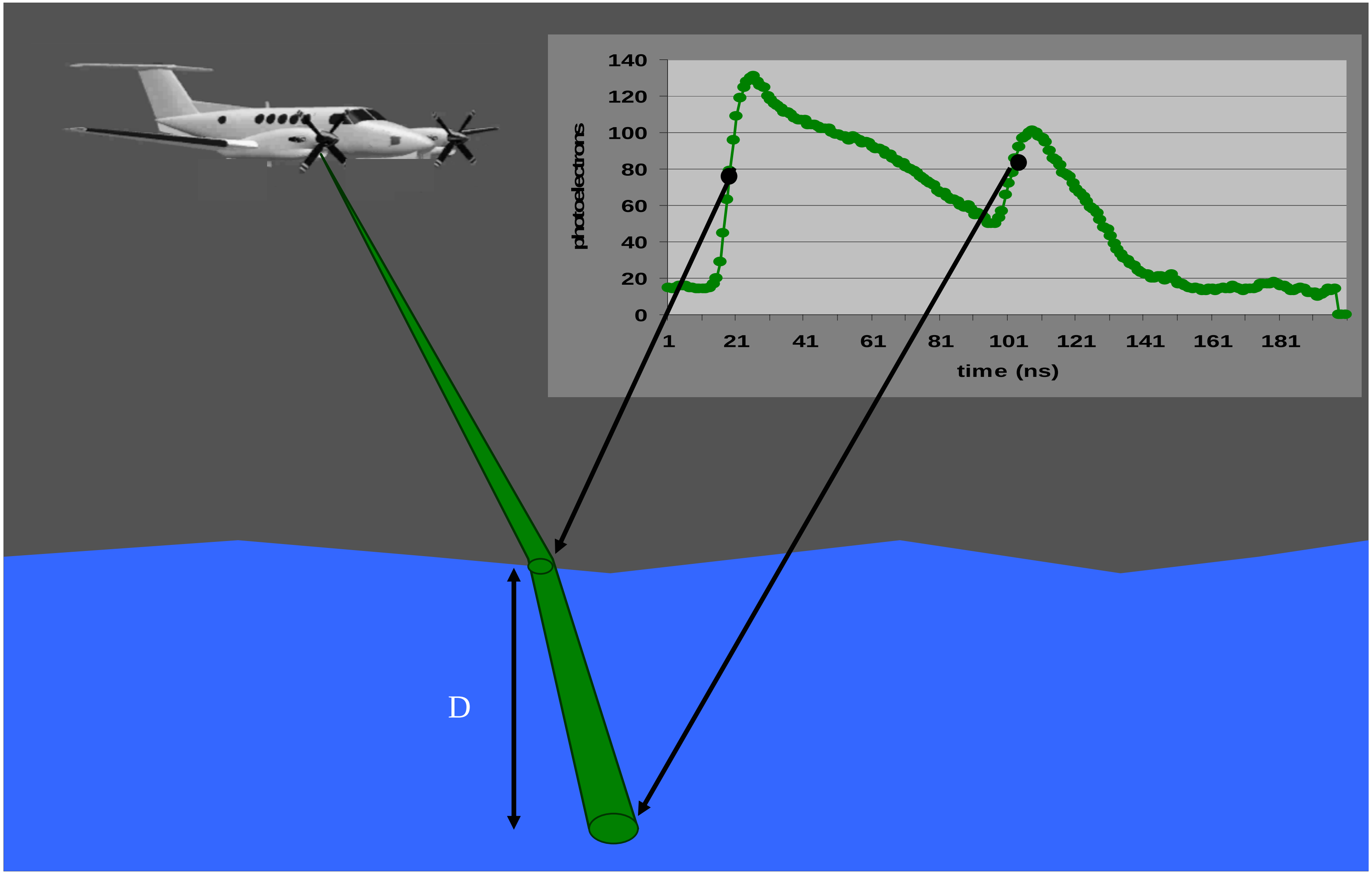


Hydrographic LiDAR Technology – The Basics

- Laser light source projects 2 beams onto spinning mirror
  - IR
  - Green
- Mirror rotates at a very fast rate
  - Directs two beams per pulse to water surface
  - Creates a swath of points within field of view
- Green beam penetrates water and detects seabed
- Infrared beam penetrates little: detects land and sea surface
- Red energy from Raman backscatter can also detect surface



Hydrographic LiDAR Technology – The Basics



Why Hydrographic LiDAR?

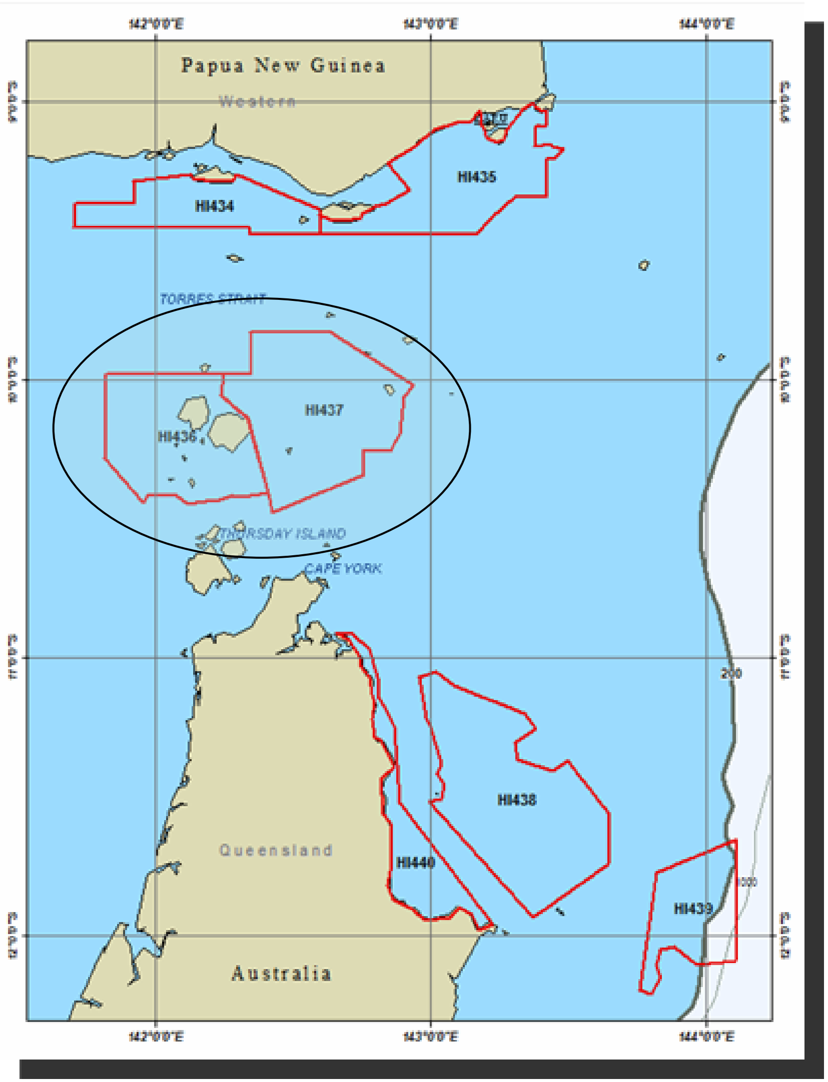
- Significantly greater production rates than MBES
- Consistent and predictable swath widths
- Elimination of shallow water boat work
  - Speed
  - Cost
  - Safety
- Mobility and flexibility of an airborne system
  - Respond to brief favorable weather windows
  - Respond to evolving condition / urgent requirements
- Reduction in survey time and cost
- Enhanced data quality
  - Density
  - Uniformity
- Combine with MBES for optimal efficiency and safety

NIOHC Case 1: Torres Strait – Queensland, Australia

- Opportunity to conduct a very large Lidar survey to IHO Order 1b for the RAN/AHO
- Same positional accuracies as for Order 1a but with relaxed target detection
- Over 6000Km^2
- 100% coverage; 3m x 3m spot spacing; 30% overlap
- Drying soundings down to 33 metres (not charted!)
- Highly complex bathymetry:
  - Lots of islands with lots of rocks
  - Lots of reefs
  - Lots of uncharted features

Scope

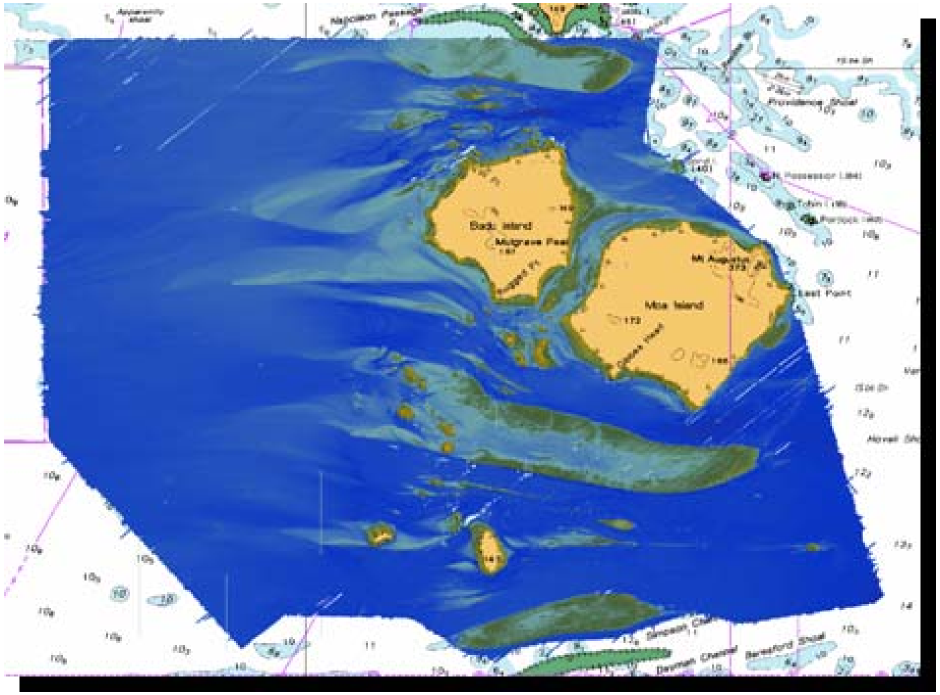
- Contracted by RAN – AHS
- Expand the area of surveyed waters within the Torres Strait and northern Great Barrier Reef
- To facilitate safe navigation and freedom of manoeuvre
- Two areas to be surveyed over two years, totaling ≈ 6,000 km^2
- Four phases:
  - Mobilization
  - Surveying
  - Tidal and Levelling Observations
  - Final Report of Survey



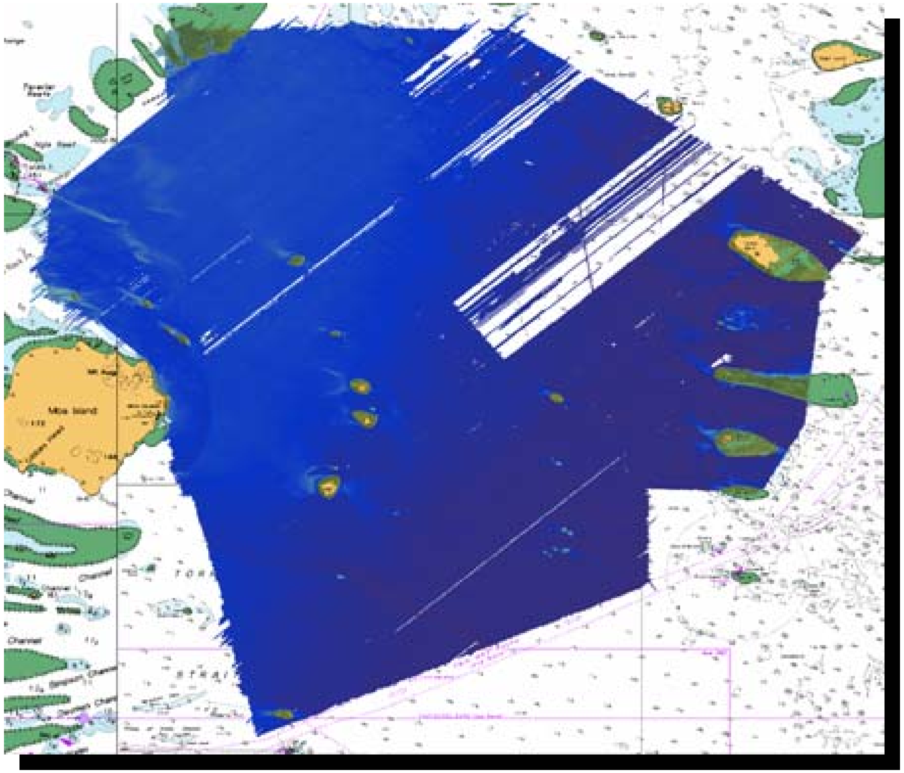
System Description

- Optech SHOALS 1000T
  - 1000Hz
  - Nd:YAG pulsed dual frequency laser
  - 532, 1064nm (green and near-IR)
  - IR reflects from seasurface; green from seabed
  - Orientation and navigation through Applanix POS AV410 IMU
  - Includes 4mp digital camera firing at 1Hz; resolution 20-30cm

Survey Estimate

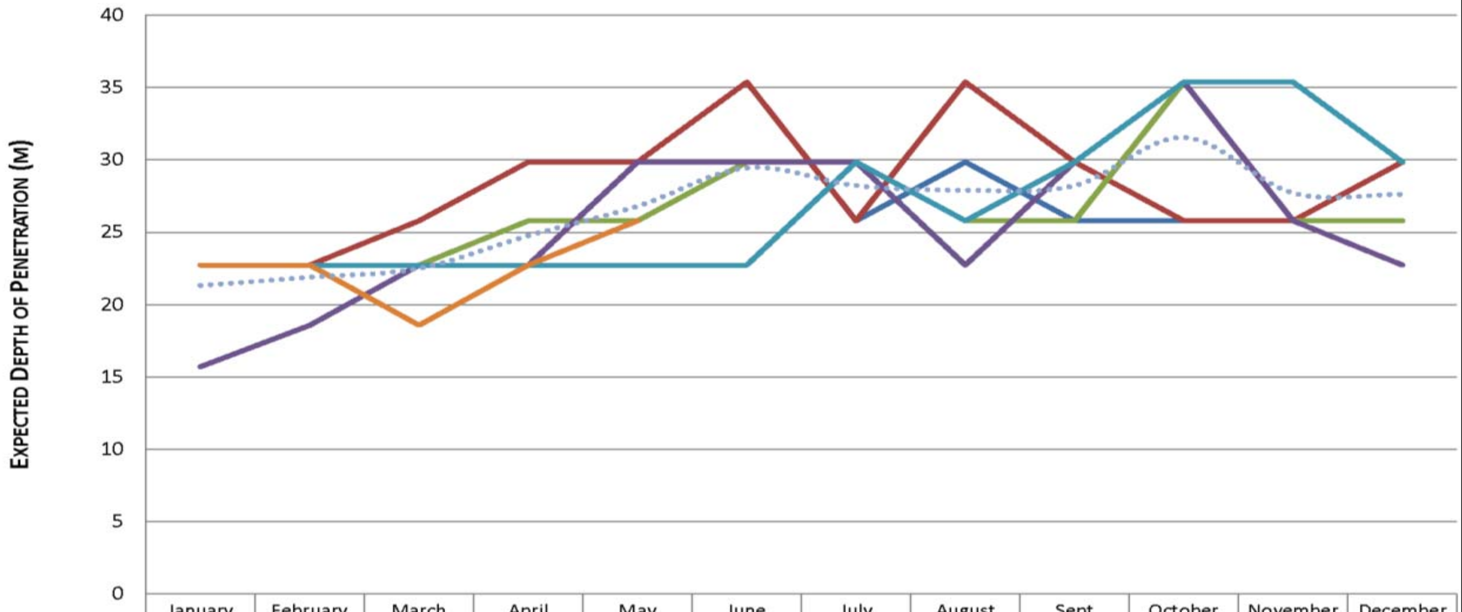


- HI 436 was approximately 55km x 48km and covered an area of 2706km^2



- HI 437 was approximately 60km x 65km, and covered an area of 3445km^2

Survey Estimate



	January	February	March	April	May	June	July	August	Sept	October	November	December
2002							25.8	29.9	25.8	25.8	25.8	29.9
2003	22.7	22.7	25.8	29.9	29.9	35.4	25.8	35.4	29.9	25.8	25.8	29.9
2004	22.7	22.7	22.7	25.8	25.8	29.9	29.9	25.8	25.8	35.4	25.8	25.8
2005	15.7	18.6	22.7	22.7	29.9	29.9	29.9	22.7	29.9	35.4	25.8	22.7
2006	22.7	22.7	22.7	22.7	22.7	22.7	29.9	25.8	29.9	35.4	35.4	29.9
2007	22.7	22.7	18.6	22.7	25.8							
Average	21.3	21.9	22.5	24.8	26.8	29.5	28.2	27.9	28.2	31.5	27.7	27.6

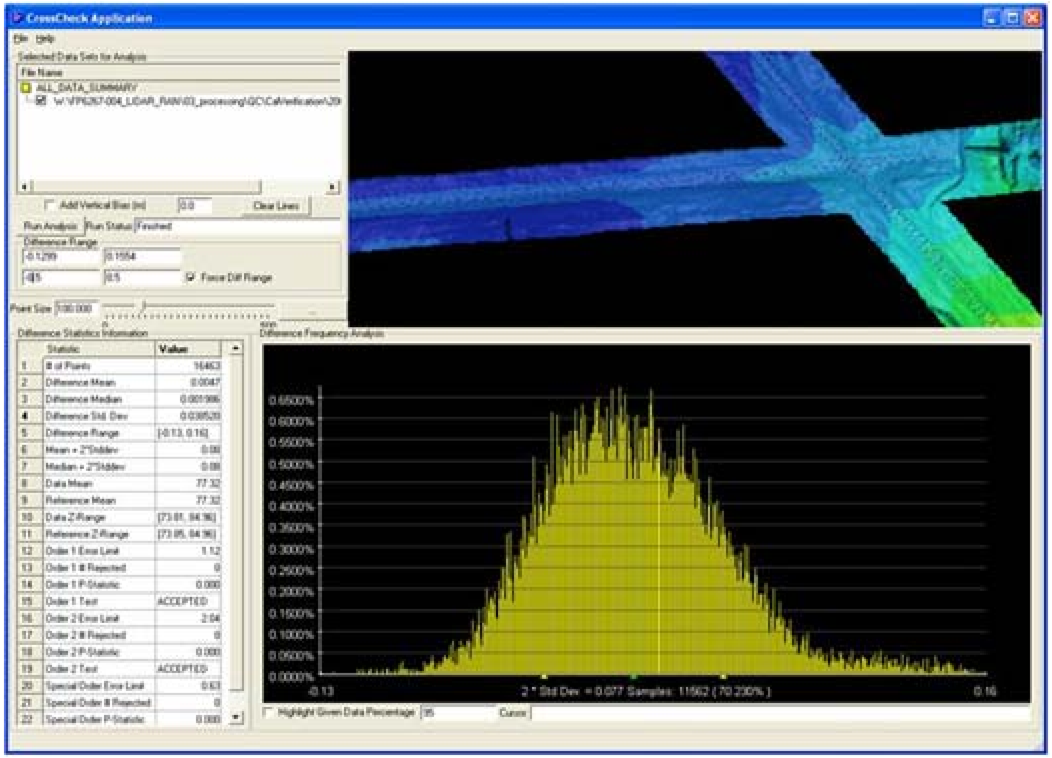
- This output of historical data shows the pattern over several years of water clarity at 450 – 520 nm wavelengths
- From this we can determine the likely Lidar penetration depth and the optimum season for data collection in a region

Ground Truthing

- Ground truthing Lidar requires:
  - Terrestrial survey support
  - Acoustic bathy support (MBES)
  - Accessible sites
  - Overflight permissions
  - A stable seabed
  - Appropriate features to prove target detection
  - Locations either in or close to the survey area

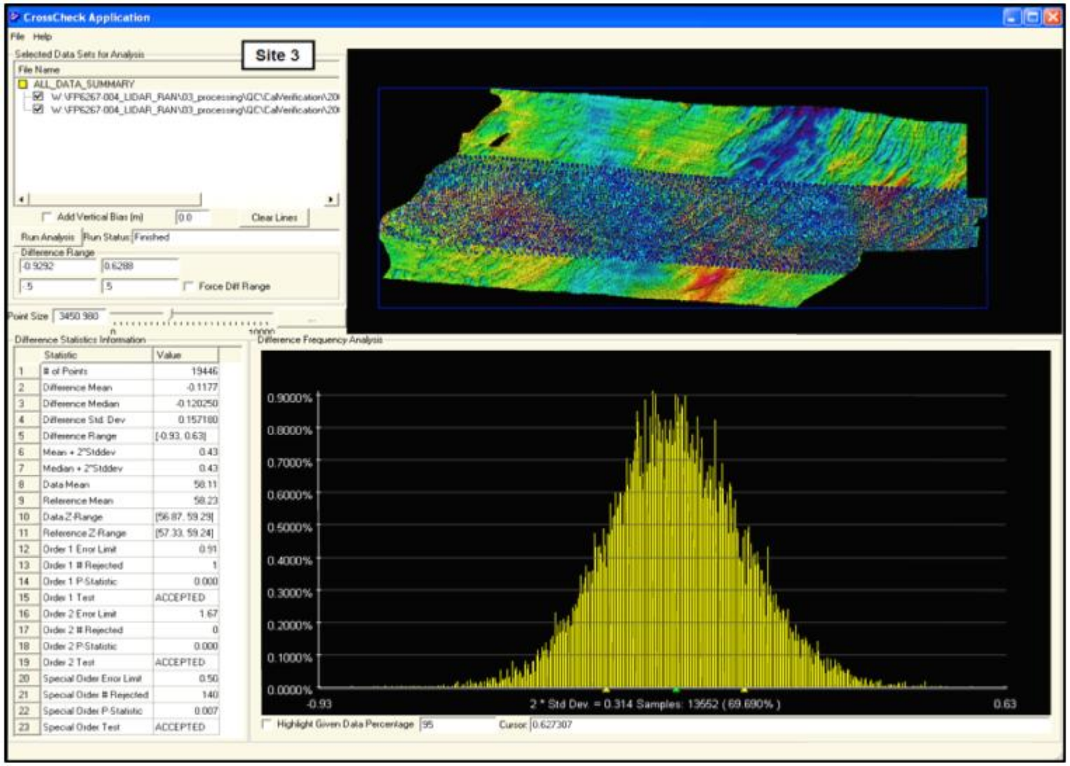
Ground Truthing

- Ground truthing provides:
  - The ability to regularly verify calibration settings
  - Identify any system changes, be they gradual or rapid
  - Trust in the data being collected over a period of time is consistent
  - An audit trail for both the survey team and the client to assess the quality of the product



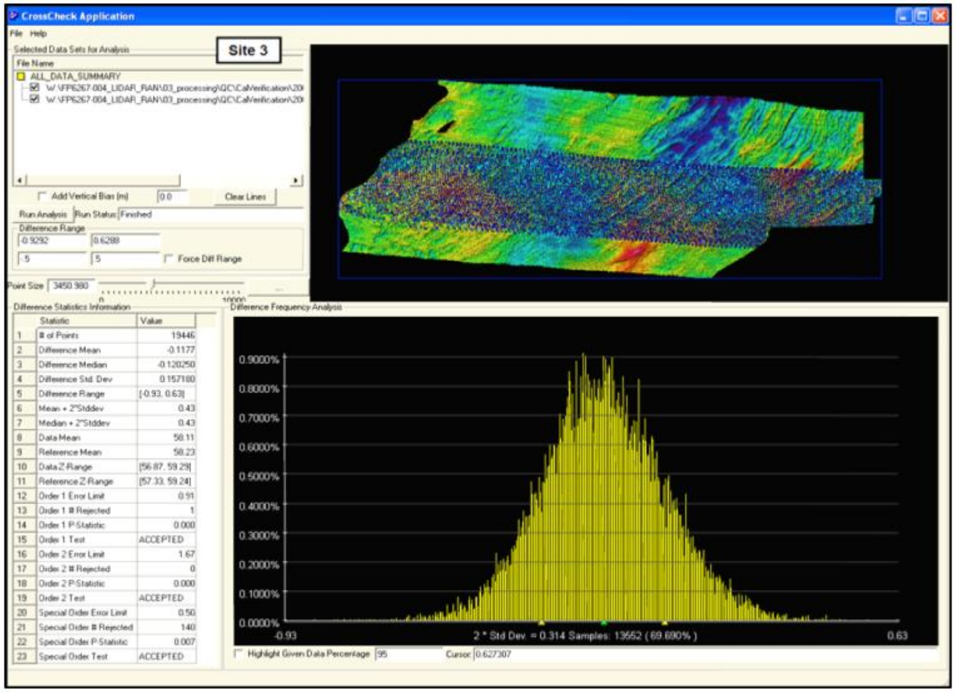
Ground Truthing

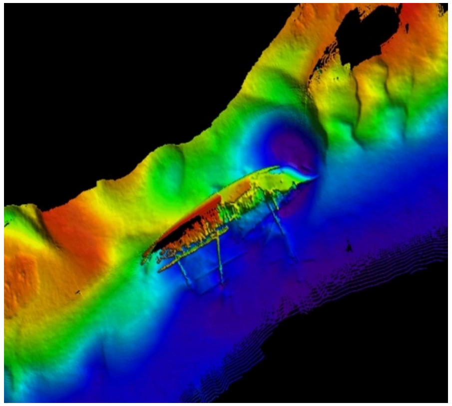
- Fugro's thorough GT includes:
  - reciprocal runs to determine the mean surface to remove angular offsets
  - Flat topo surface to remove system biases
  - Peaked –roof buildings and angular structure overflys to confirm positional accuracy
  - LPTTs before, during and at the end of every flight to confirm consistent system timing

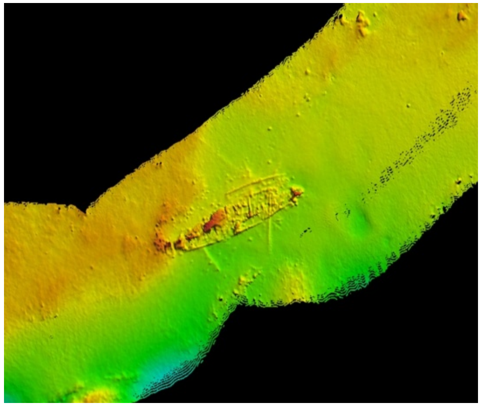


Ground Truthing over Water

- This essential check requires MBES support:
  - suitable patches are selected:
    - Flat, stable seabed
    - Areas with identifiable targets
  - Data processed to the ellipsoid
  - Lidar data also processed to the ellipsoid
  - IVS CrossCheck utility compares the resultant surfaces
  - MBES in itself has to be very carefully verified as it is relied upon for compliance

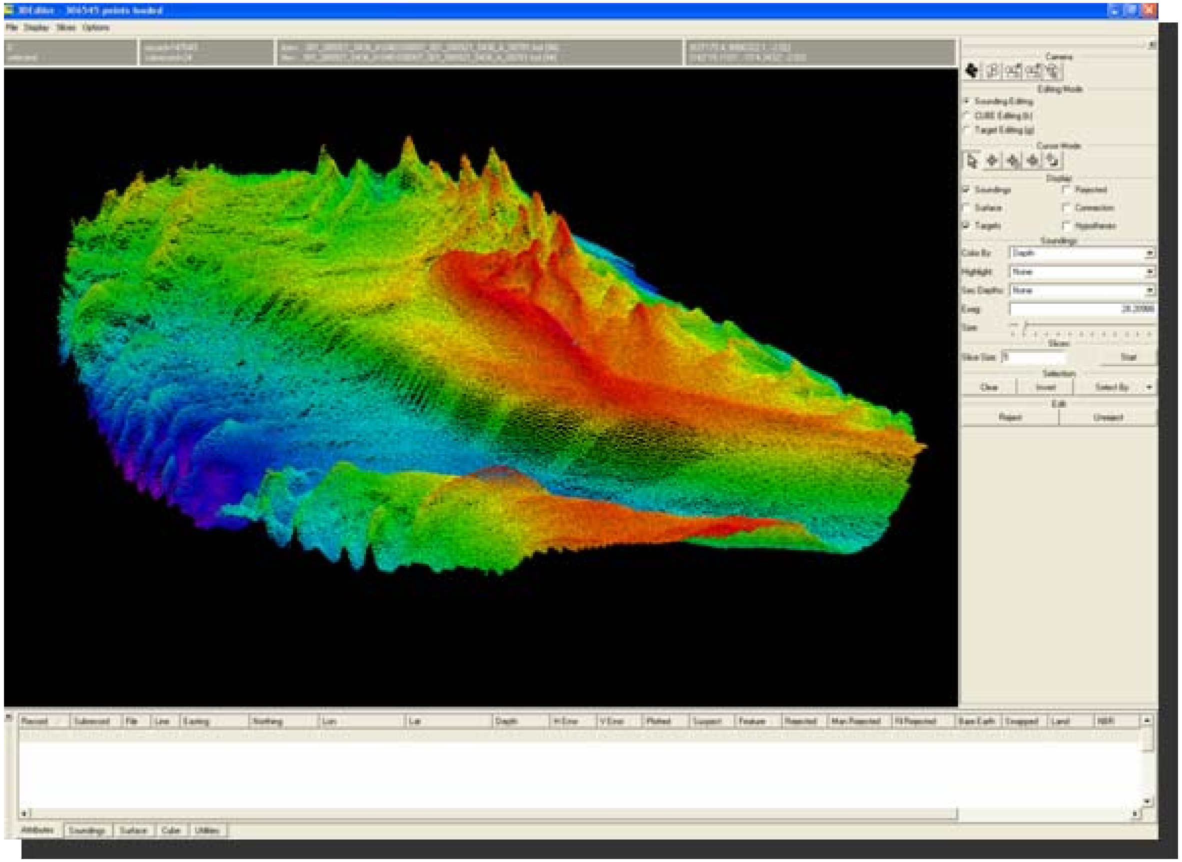






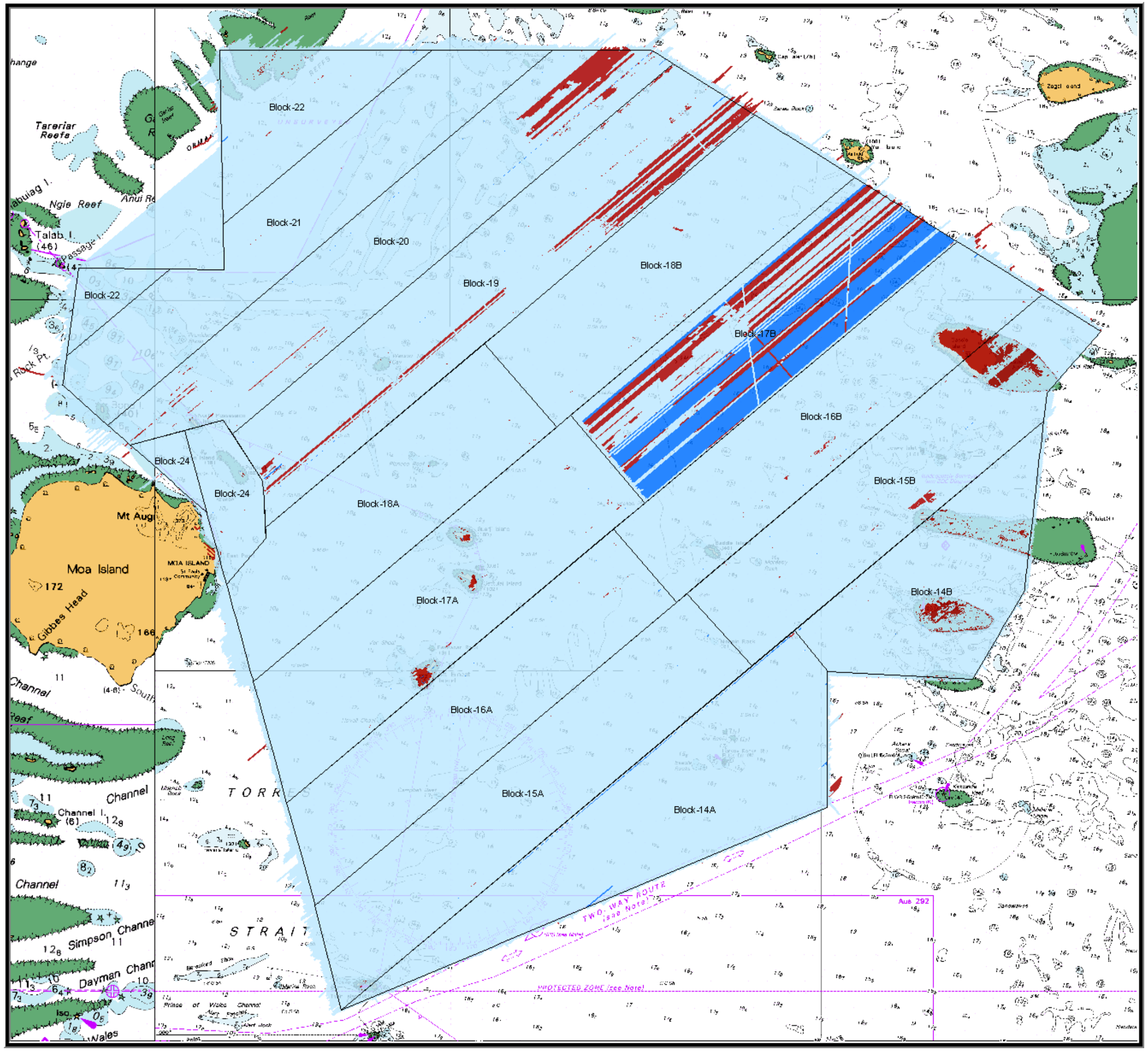
Processing and QA

– Data visualization, analyst-keyed cleaning and processing with digital camera imagery to assist
– Crossline and overlap data comparison using the IVS CrossCheck utility
– 3-D editing using Fledermaus



Coverage

- 'Lidar Workbench'
  - Calculated data coverage
  - Compared two TINS:
    - One with all data
    - One with just valid data
  - Gaps of a certain size identified
  - Informed team of required reflys



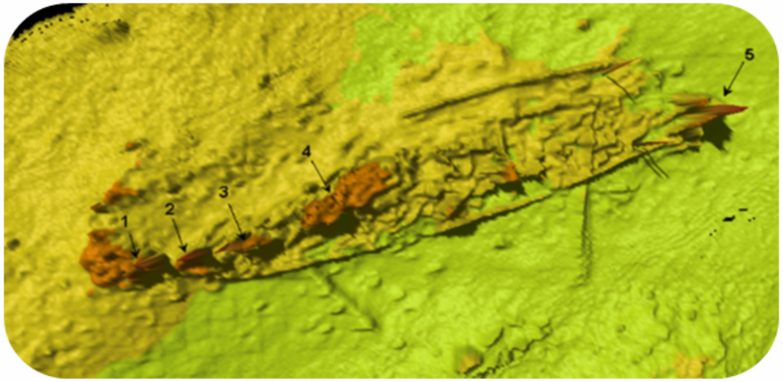
Target Detection

- MBES used to provide GT over seabed targets
  - Very careful check cal, validation and patch test procedures required – system must be at optimal performance
  - Nominal 2m^3 targets identified
  - Overflown with Lidar regularly
  - Results processed, analysed and compared
  - Lidar target detection capability and accuracy confirmed

Project No. & Name: 6267.004 - HI 436
Client Name: Royal Australian Navy
Project Location: Torres Strait, Queensland

TARGET DETECTION LOG

TARGET DETECTION POINTS



TARGET POSITIONS

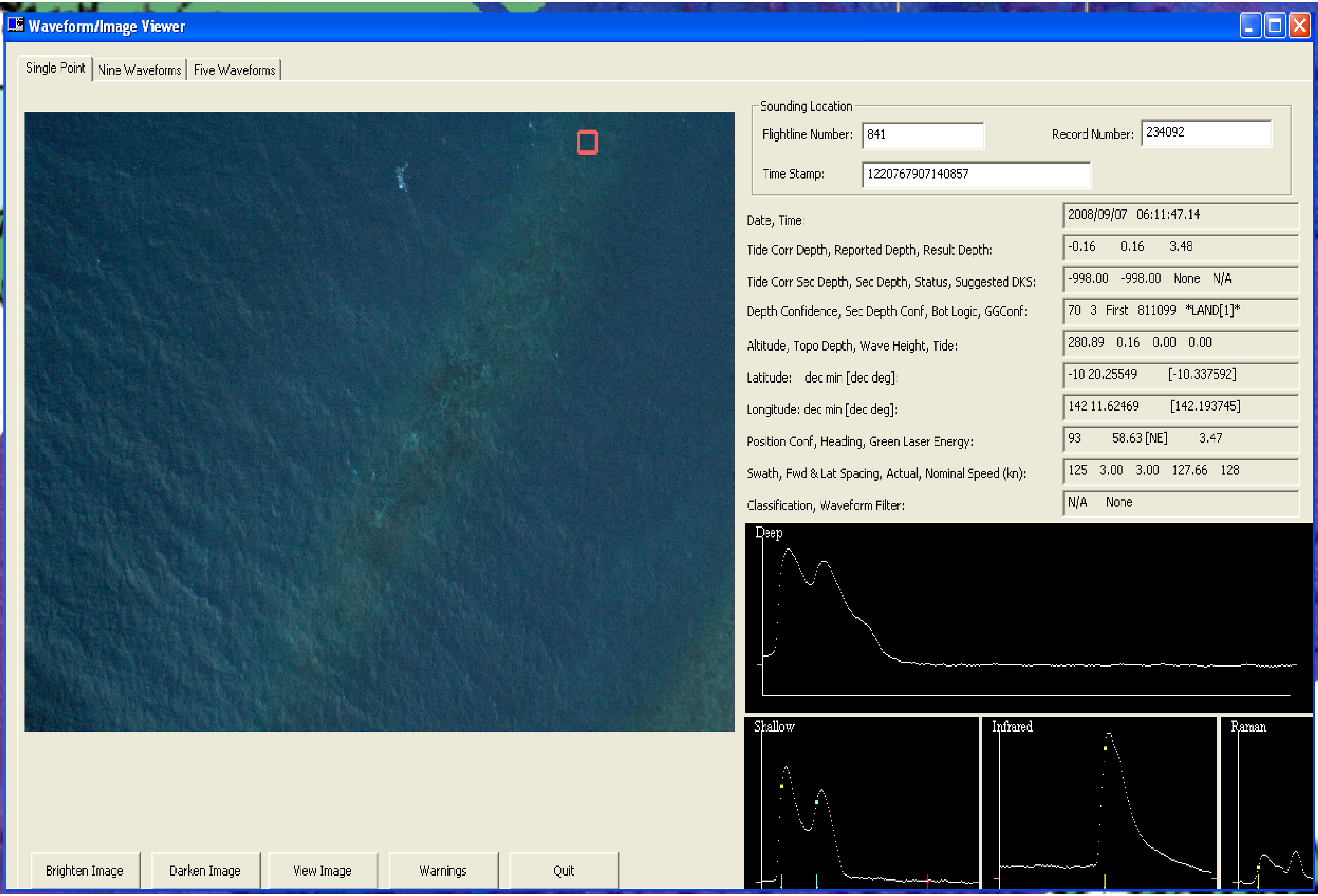
Date: 2-Oct-2008 Flightline: 4-1 (127 knots) ☑ Compute Difference

Page 1

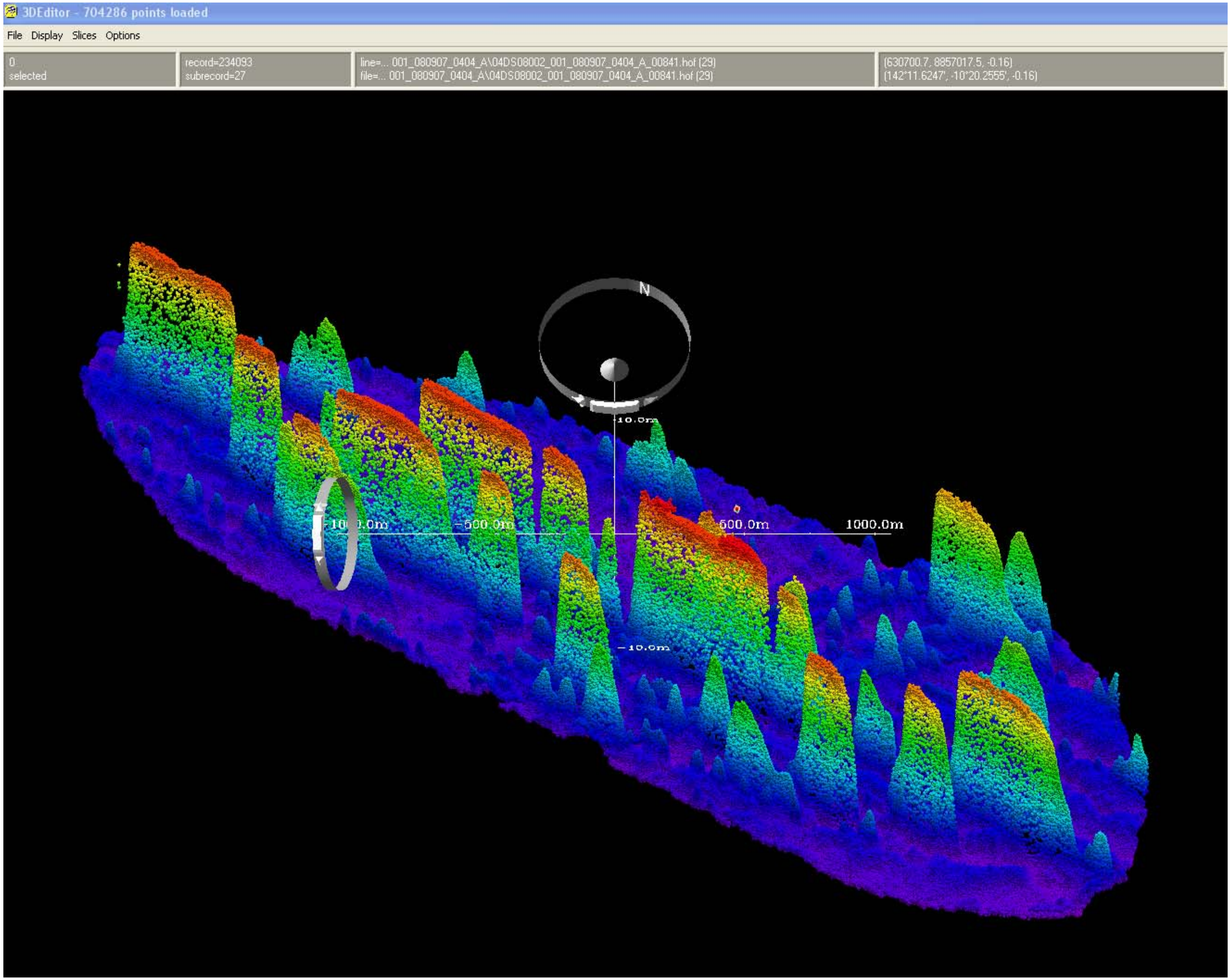
TARGET #	POSITION		LiDAR POSITION		DIFFERENCE			
1	Lat:	-10 31 04.761	Lat:	-10 31.07930	Dist:	2.584 m	ΔN:	0.11 m
	Long:	142 08 14.581	Long:	142 08.24160	Azm:	272.34 °	ΔE:	-2.58 m
2 x 2 x 2	Elev:	67.40	Elev:	66.34			ΔZ:	1.06 m
2	Lat:	-10 31 04.732	Lat:	-10 31.07890	Dist:	4.957 m	ΔN:	-0.05 m
	Long:	142 08 14.755	Long:	142 08.24320	Azm:	269.39 °	ΔE:	-4.96 m
1 x 1 x 2	Elev:	67.70	Elev:	67.09			ΔZ:	0.61 m
3	Lat:	-10 31 04.675	Lat:	-10 31.07830	Dist:	1.791 m	ΔN:	-0.71 m
	Long:	142 08 14.964	Long:	142 08.25030	Azm:	113.22 °	ΔE:	1.65 m
2 x 1 x 2	Elev:	67.03	Elev:	66.57			ΔZ:	0.46 m
4	Lat:	-10 31 04.466	Lat:	-10 31.07470	Dist:	0.823 m	ΔN:	-0.48 m
	Long:	142 08 15.334	Long:	142 08.25520	Azm:	234.04 °	ΔE:	-0.67 m
4 x 3 x 2	Elev:	67.09	Elev:	66.75			ΔZ:	0.34 m
5	Lat:	-10 31 04.124	Lat:	-10 31.06880	Dist:	0.800 m	ΔN:	-0.12 m
	Long:	142 08 16.666	Long:	142 08.27820	Azm:	98.84 °	ΔE:	0.79 m
2 x 1 x 3	Elev:	67.92	Elev:	67.70			ΔZ:	0.22 m
6	Lat:		Lat:		Dist:		ΔN:	
	Long:		Long:		Azm:		ΔE:	
	Elev:		Elev:				ΔZ:	

Checked By: DCV

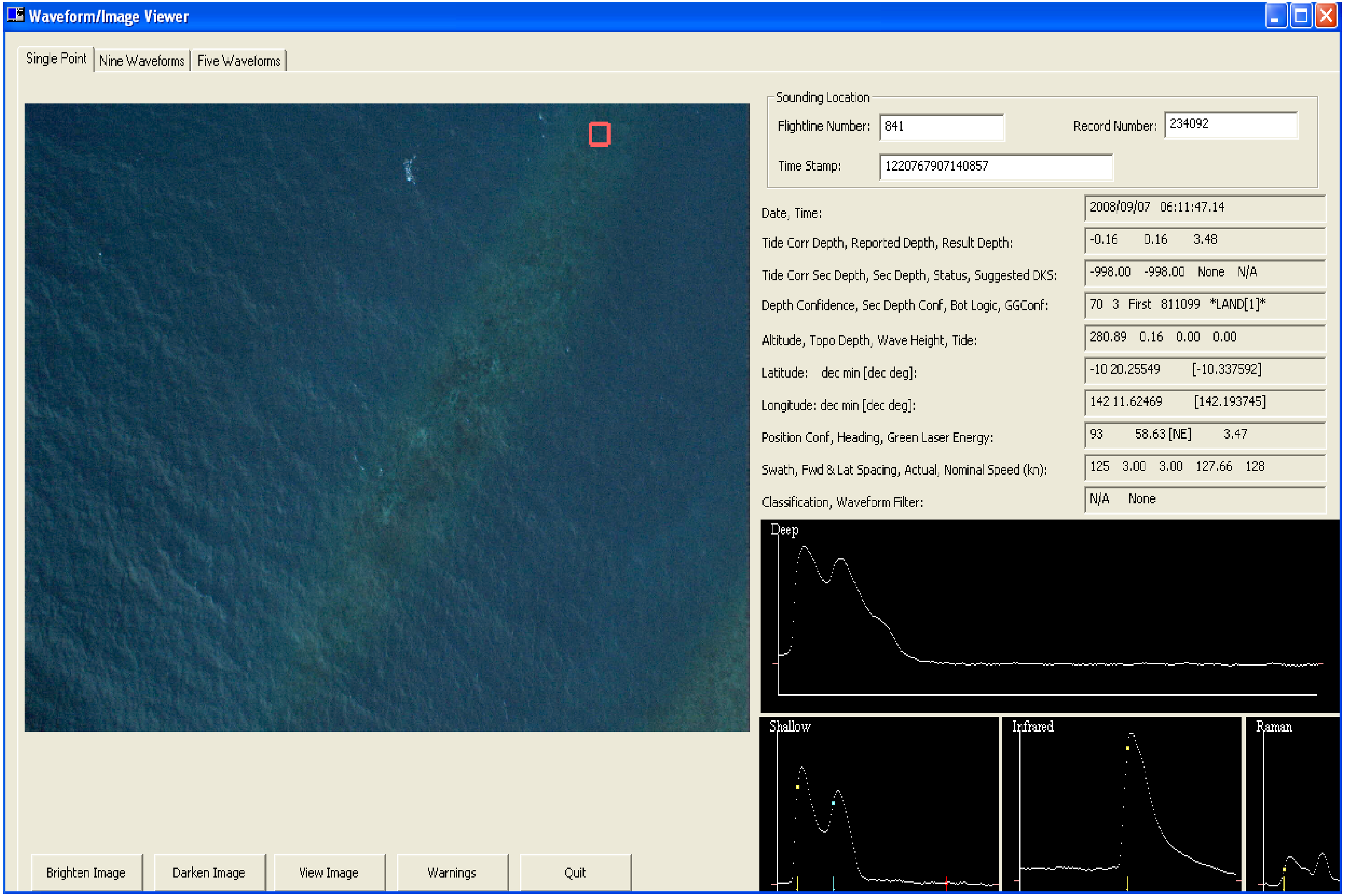
Data Analysis



Data Analysis – 3-D Viewer

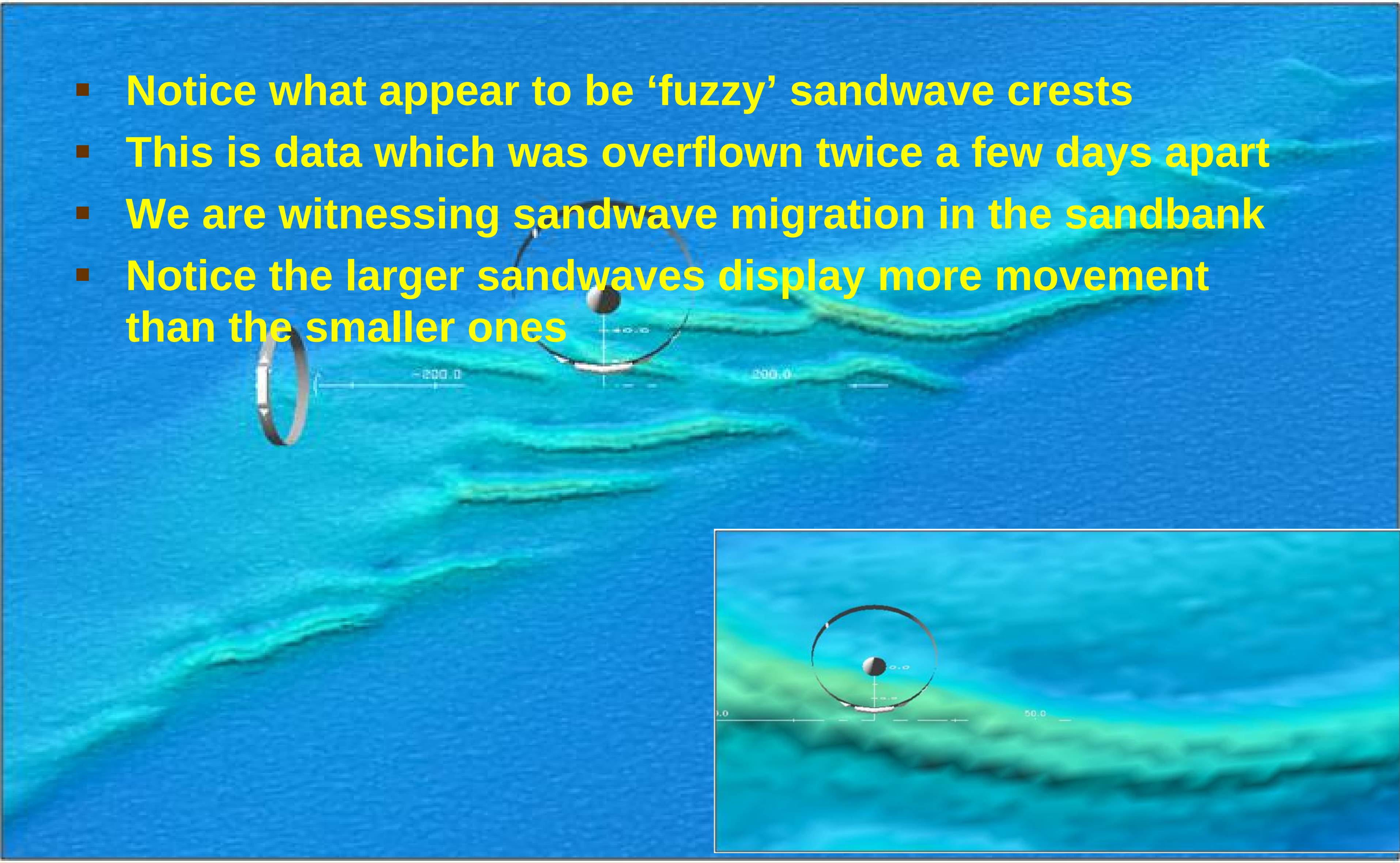


Data Analysis – Aerial Images in Waveform Viewer



Data Analysis - Sediment Transport

- Notice what appear to be ‘fuzzy’ sandwave crests
- This is data which was overflown twice a few days apart
- We are witnessing sandwave migration in the sandbank
- Notice the larger sandwaves display more movement than the smaller ones



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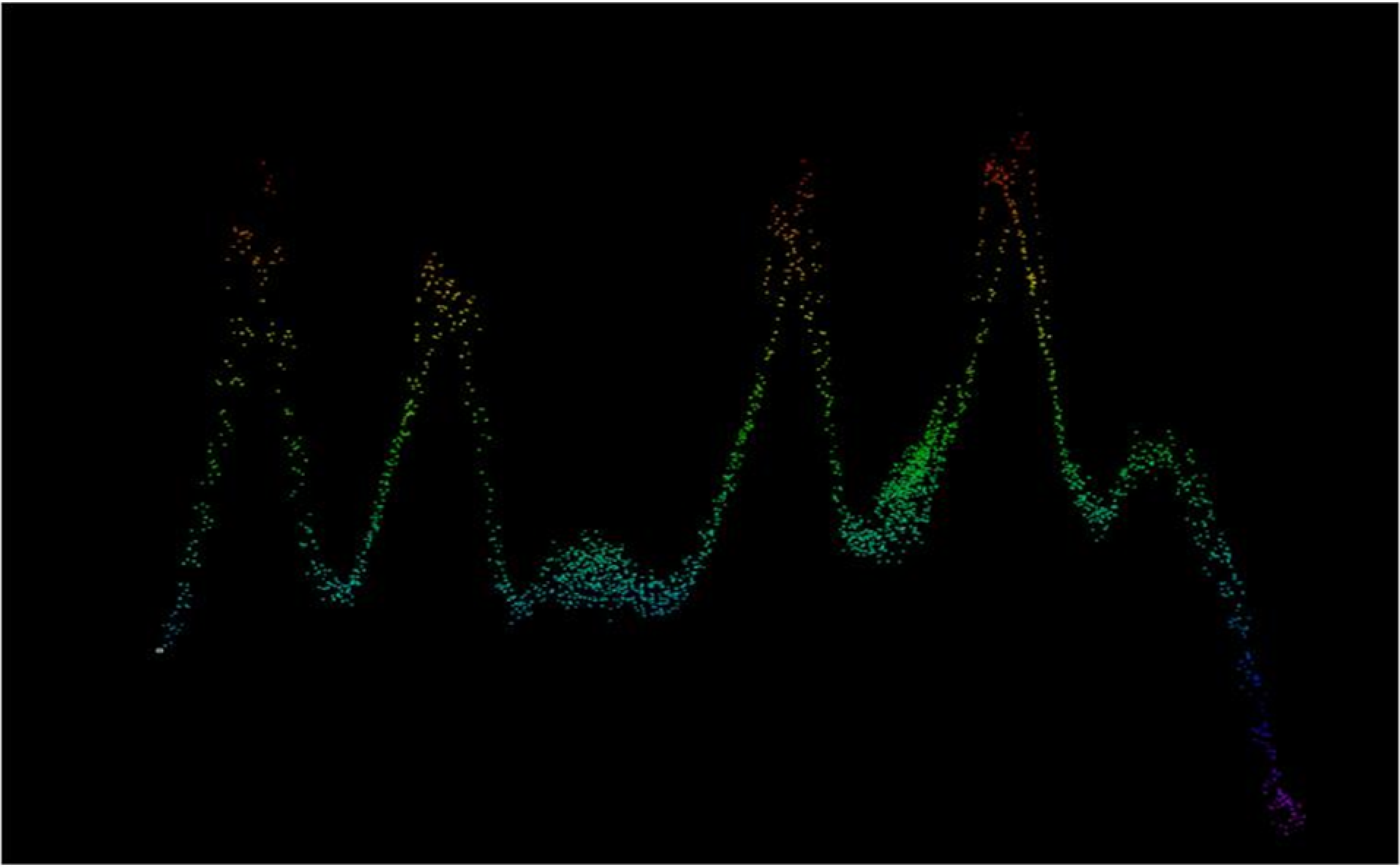
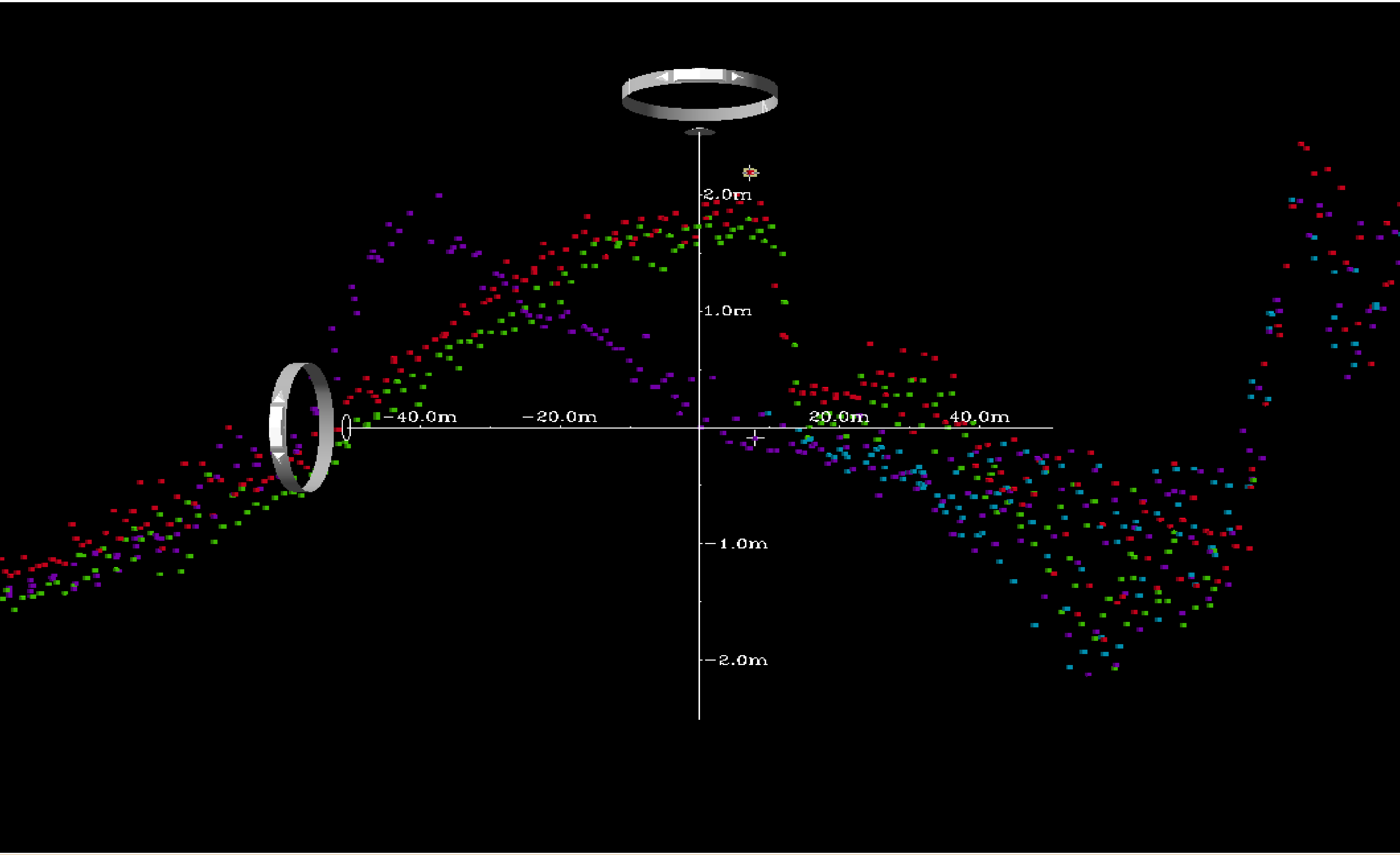
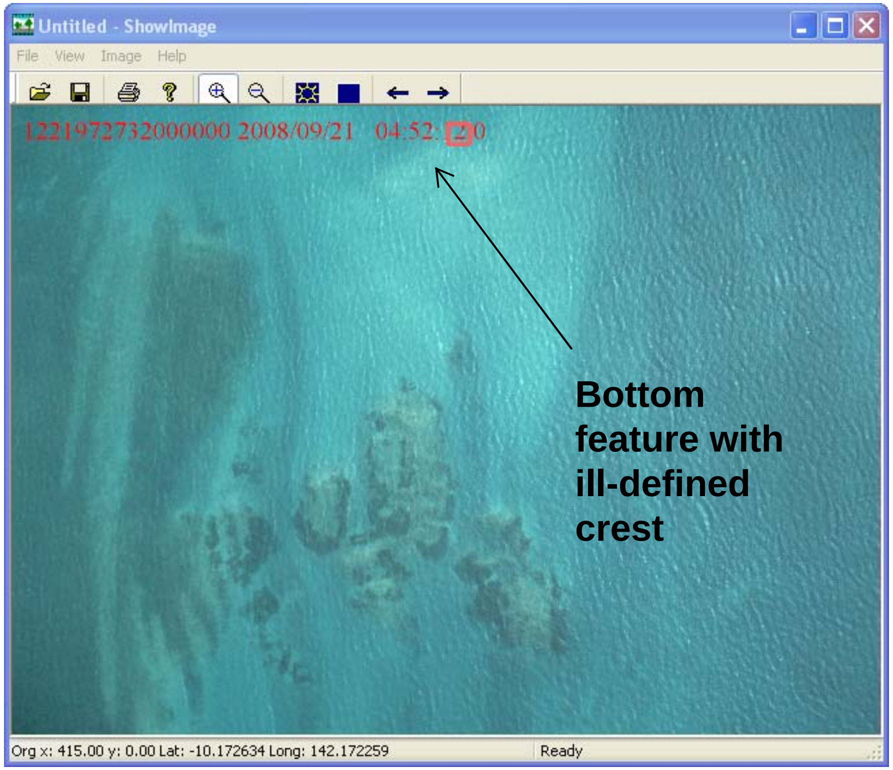


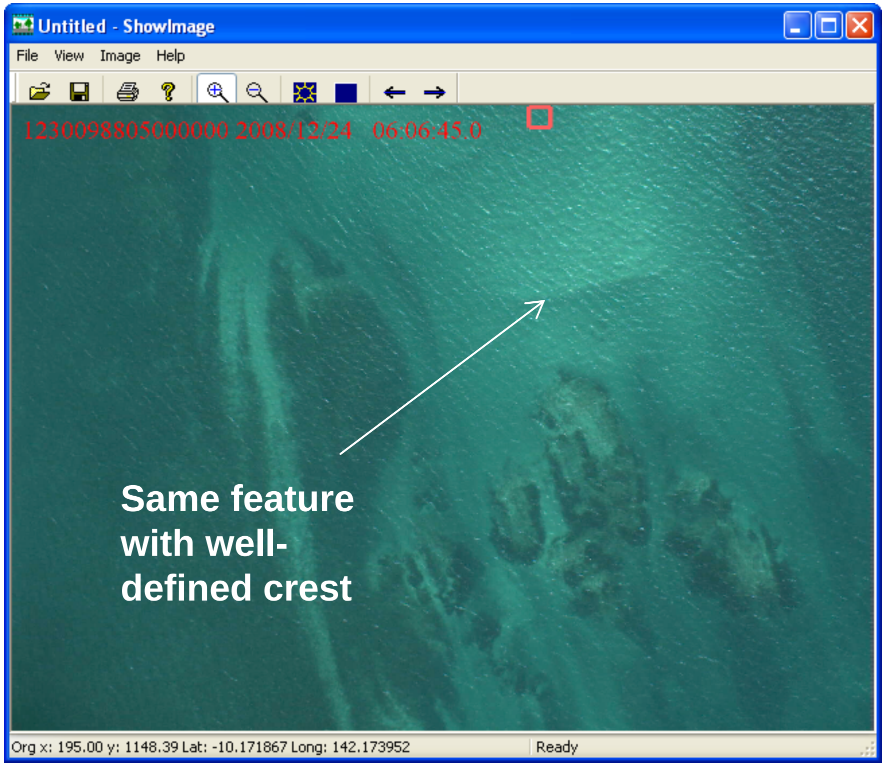
Data Analysis - Sediment Transport



Data Analysis – Unusual Seabed Features

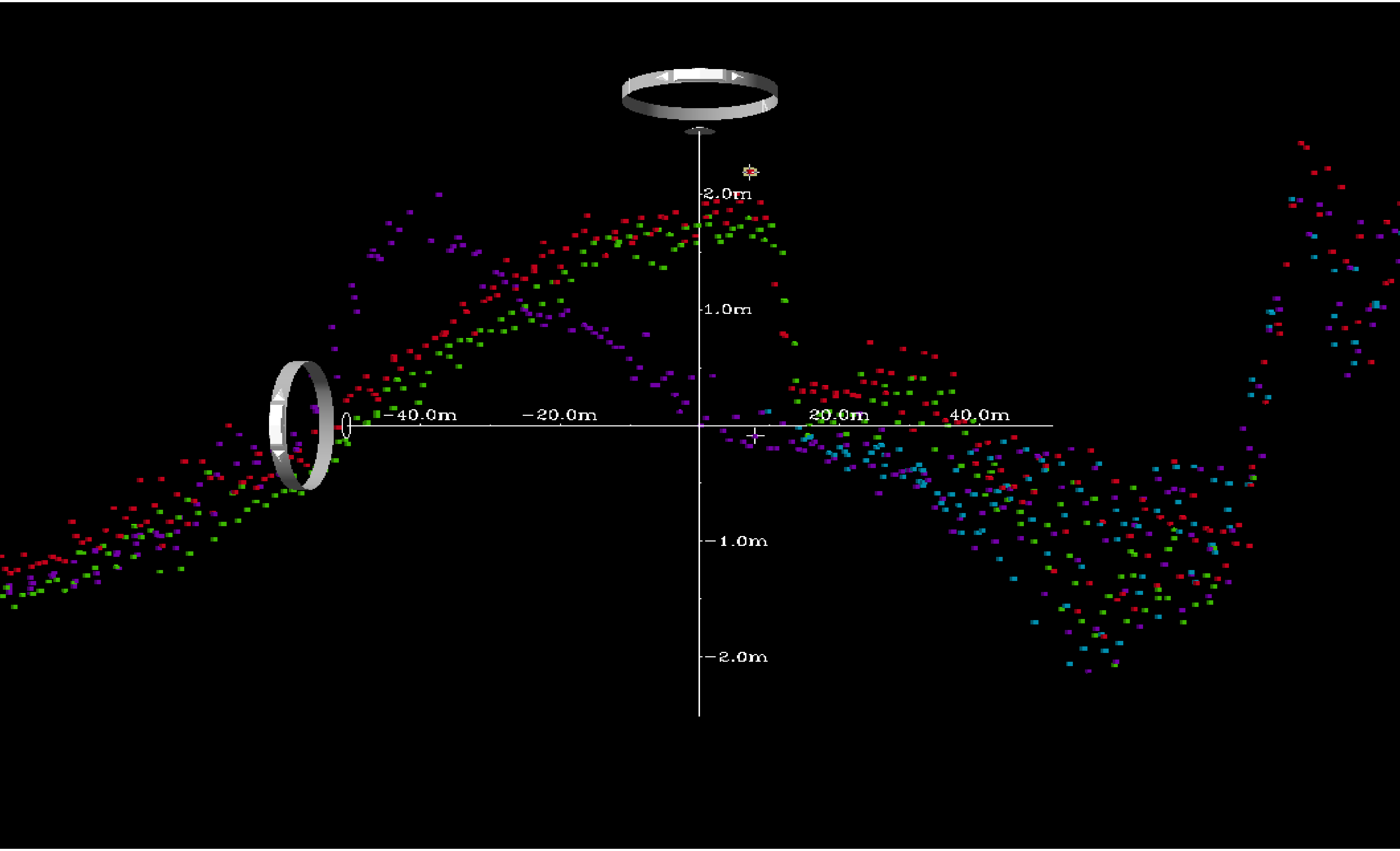


21 Sep 2008

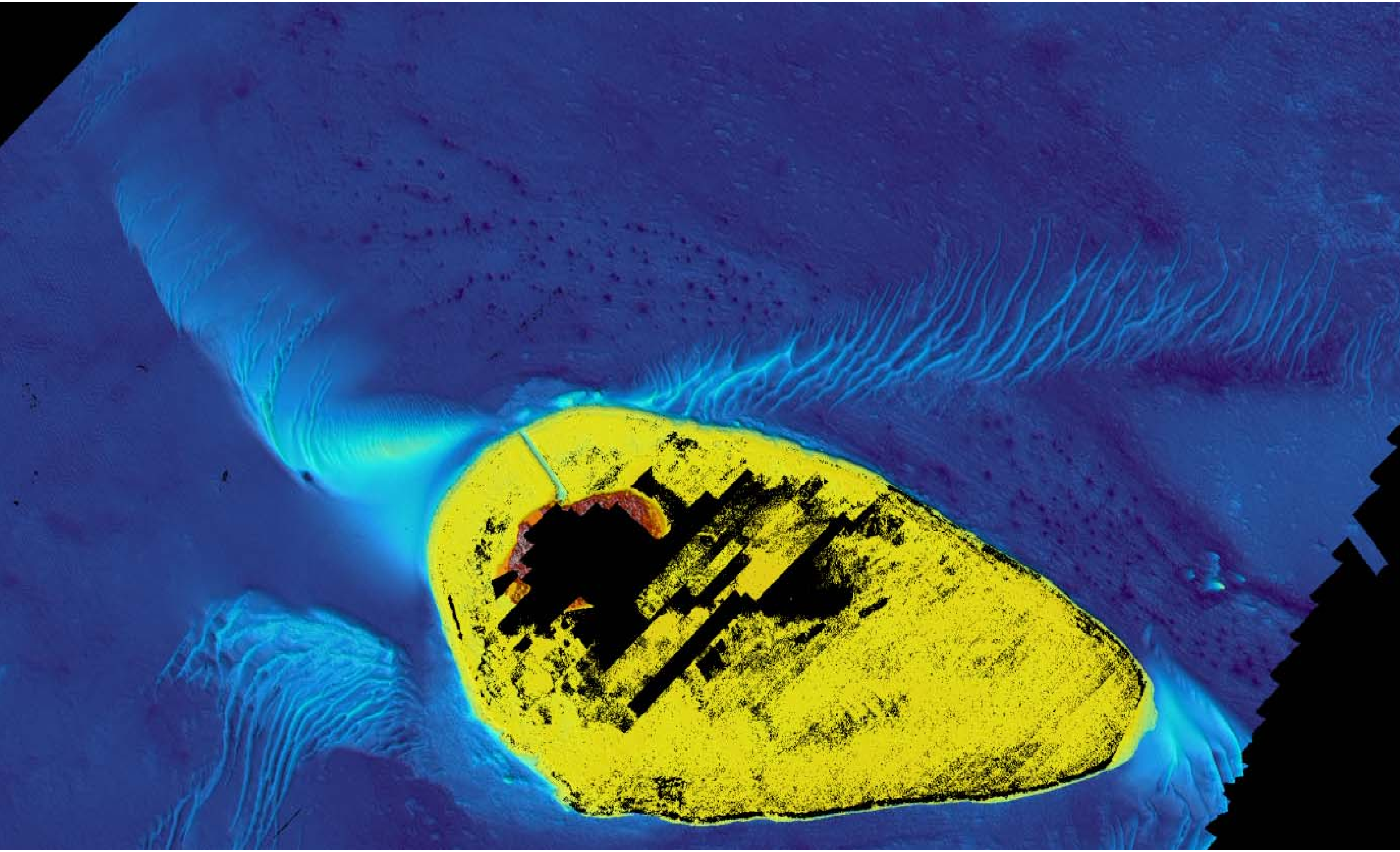


24 Dec 2008

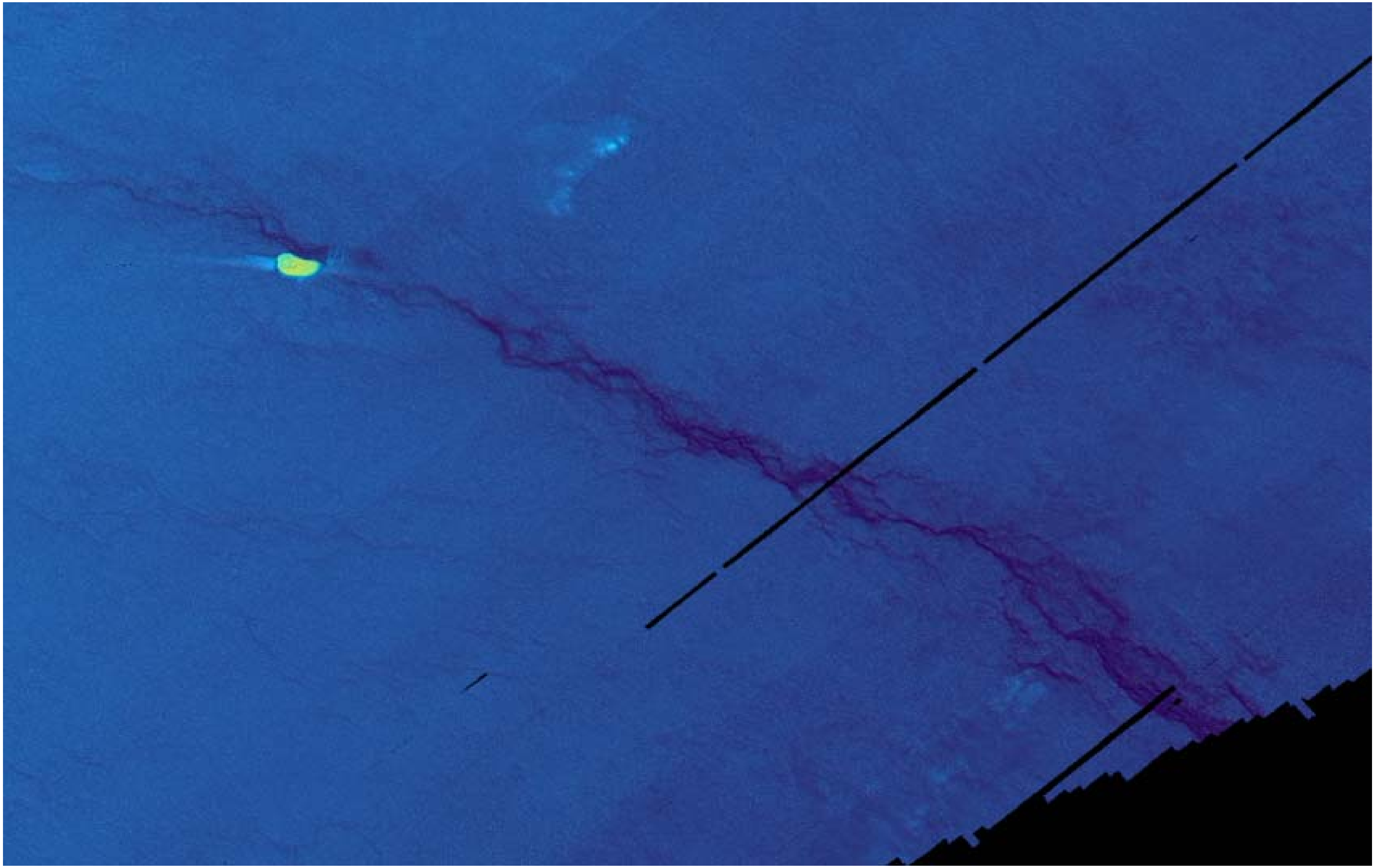
Data Analysis - Sediment Transport



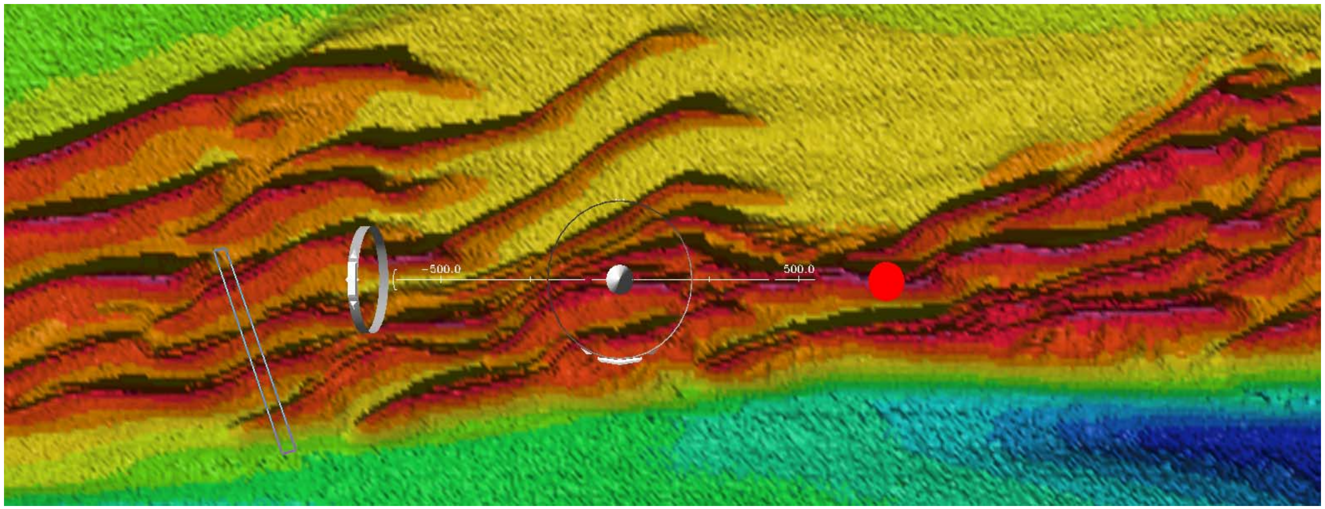
Data Analysis – Linear Pockmarking

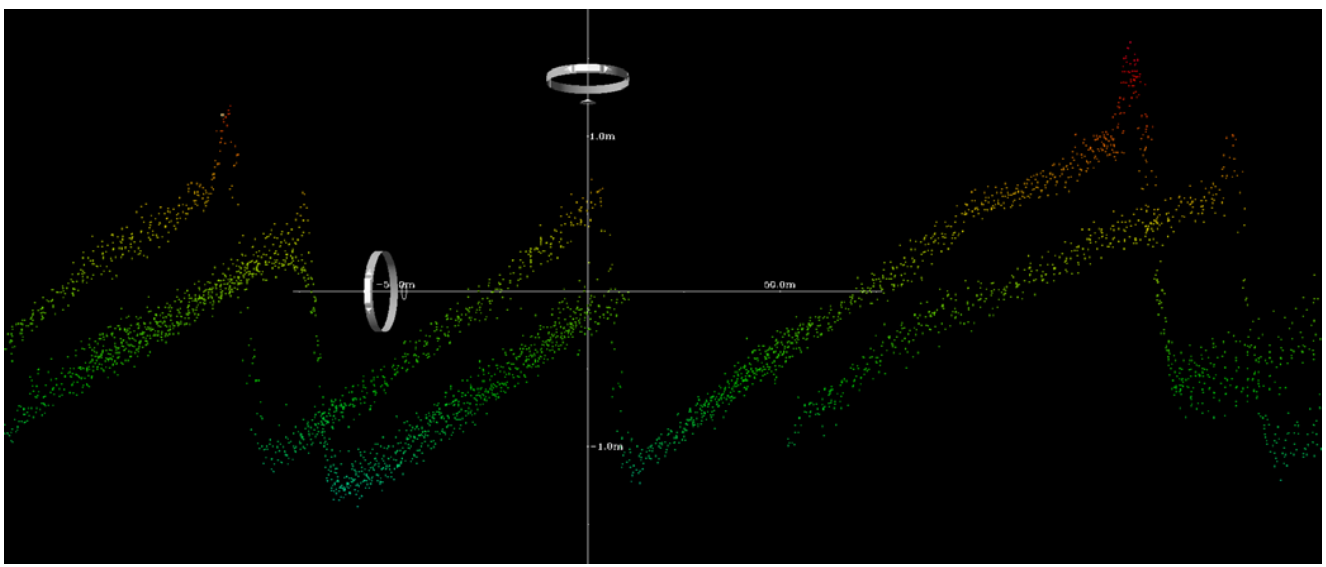


Data Analysis – Riverine Features



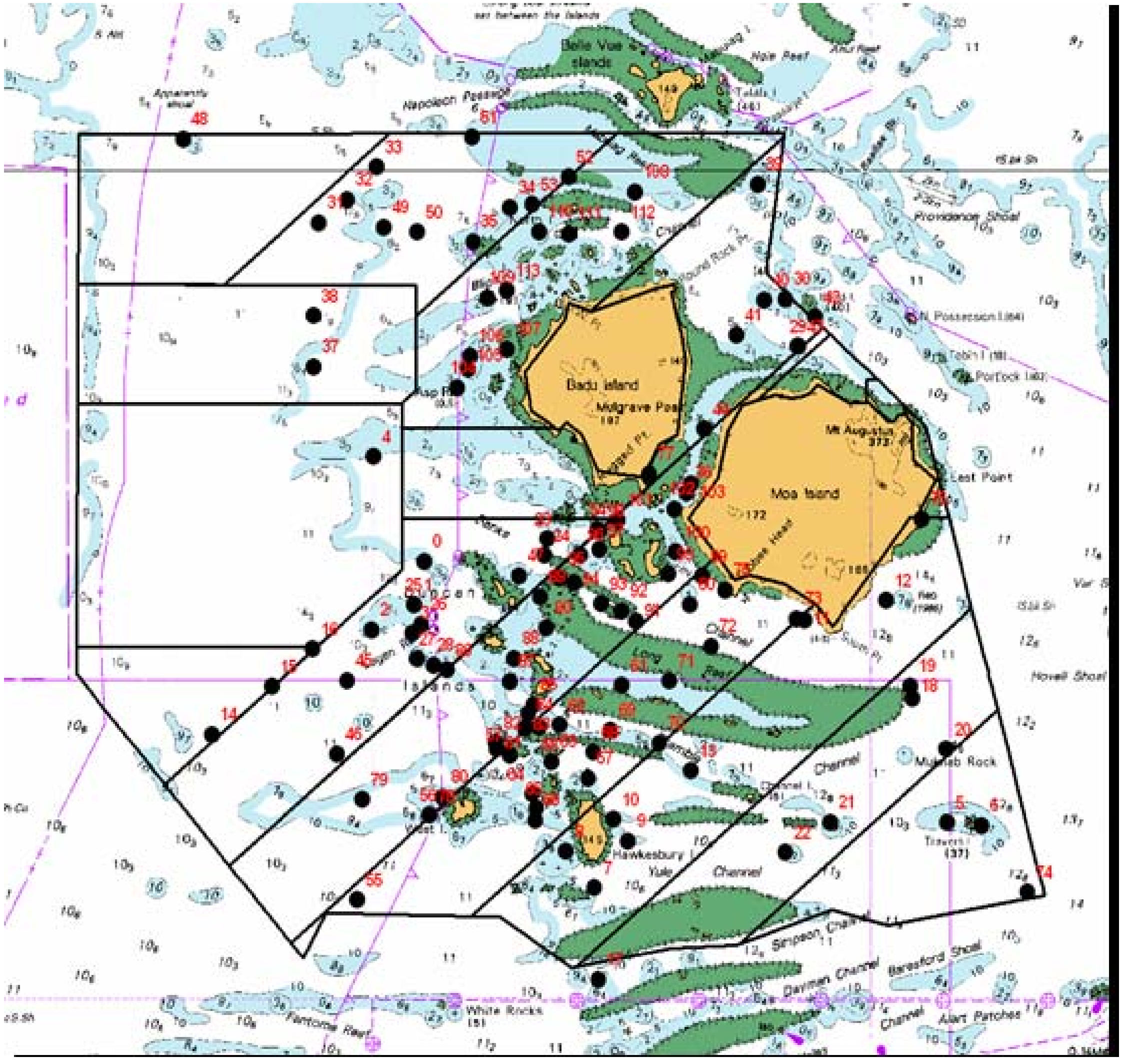
Data Analysis – Sandwave Areas



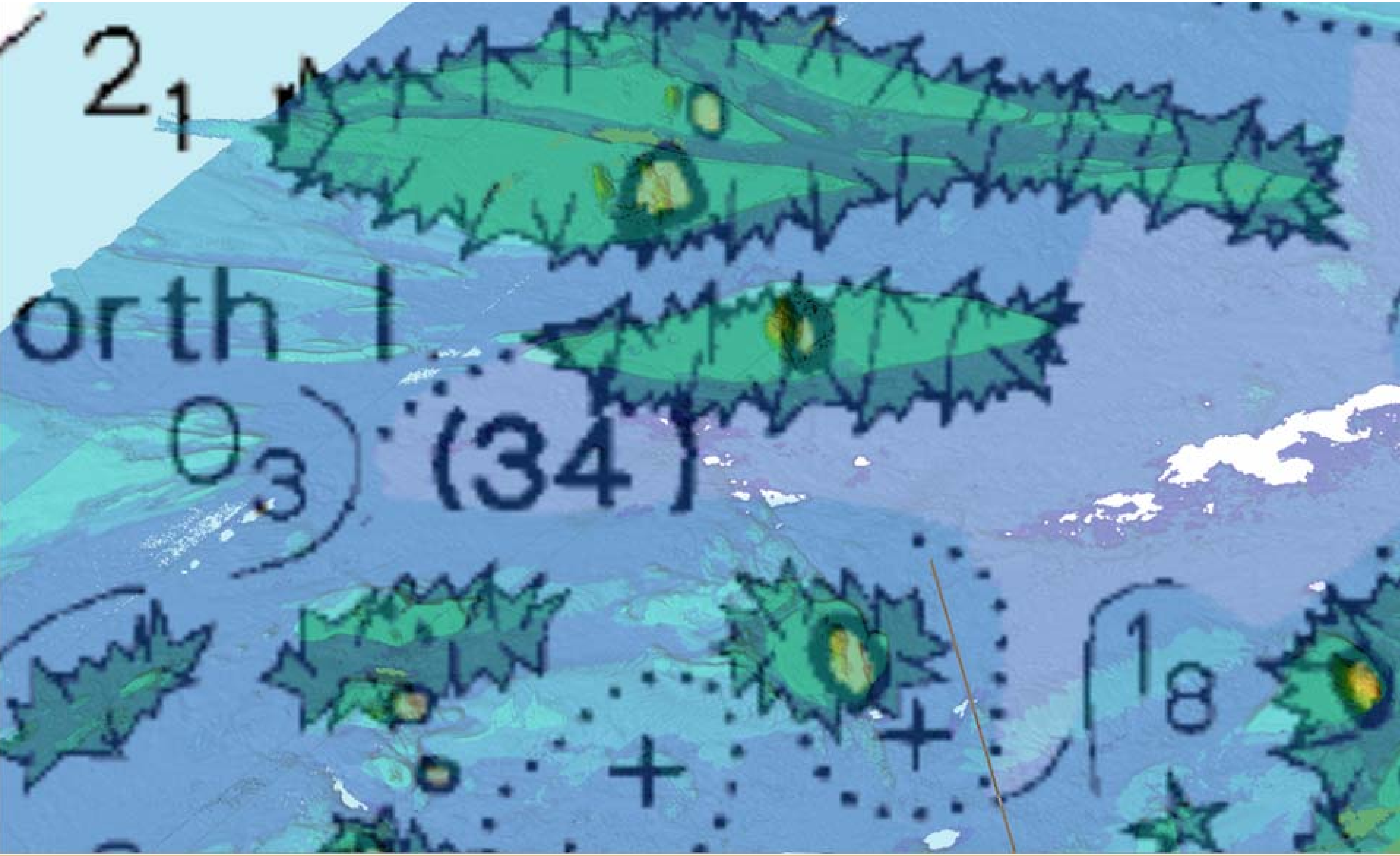


Data Analysis – Shoal Investigations

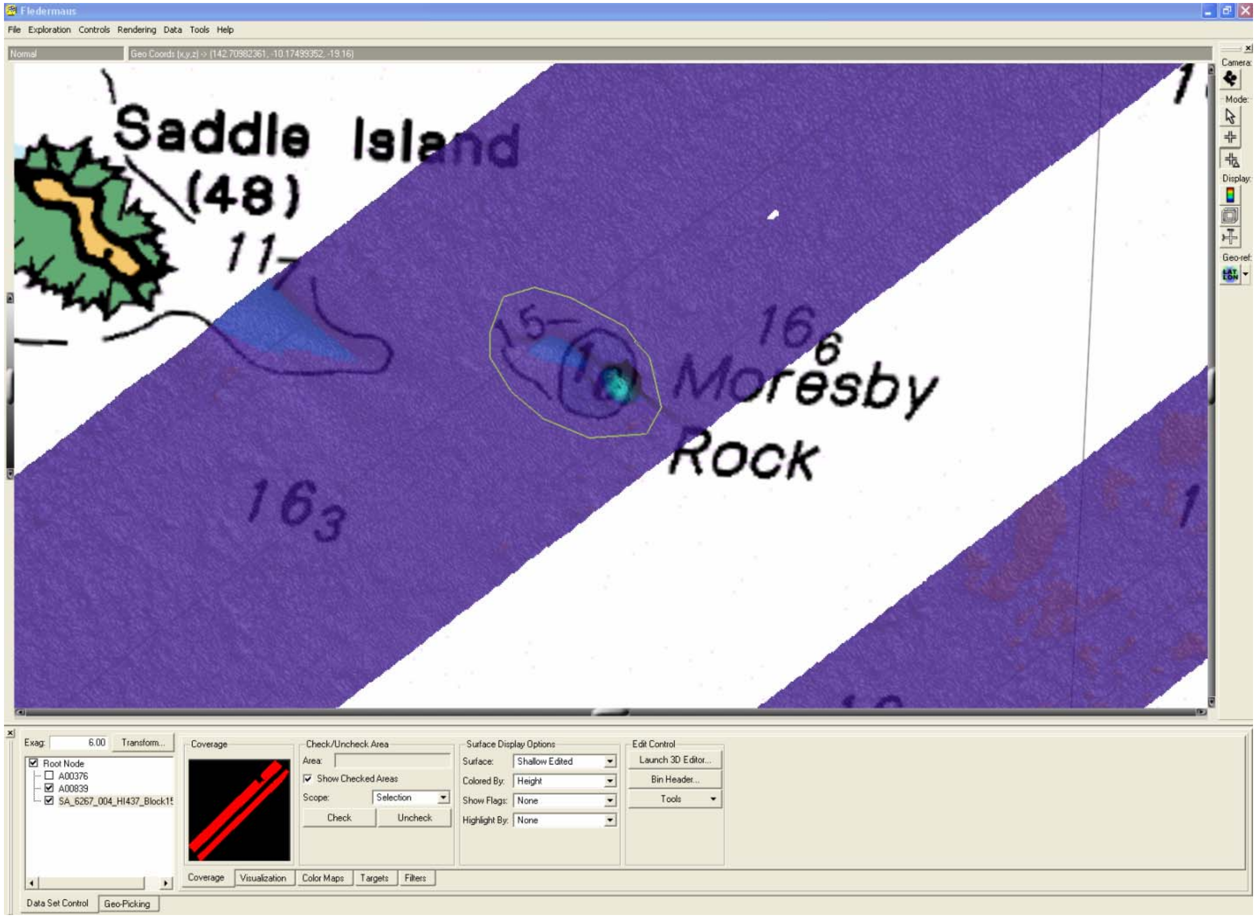
- AH102s – Australian Hydrographic Notes
  - Raised when an uncharted feature was considered a hazard to navigation
  - There were plenty!



Data Analysis – Chart Comparison Routine



Data Analysis – Wreck Identification



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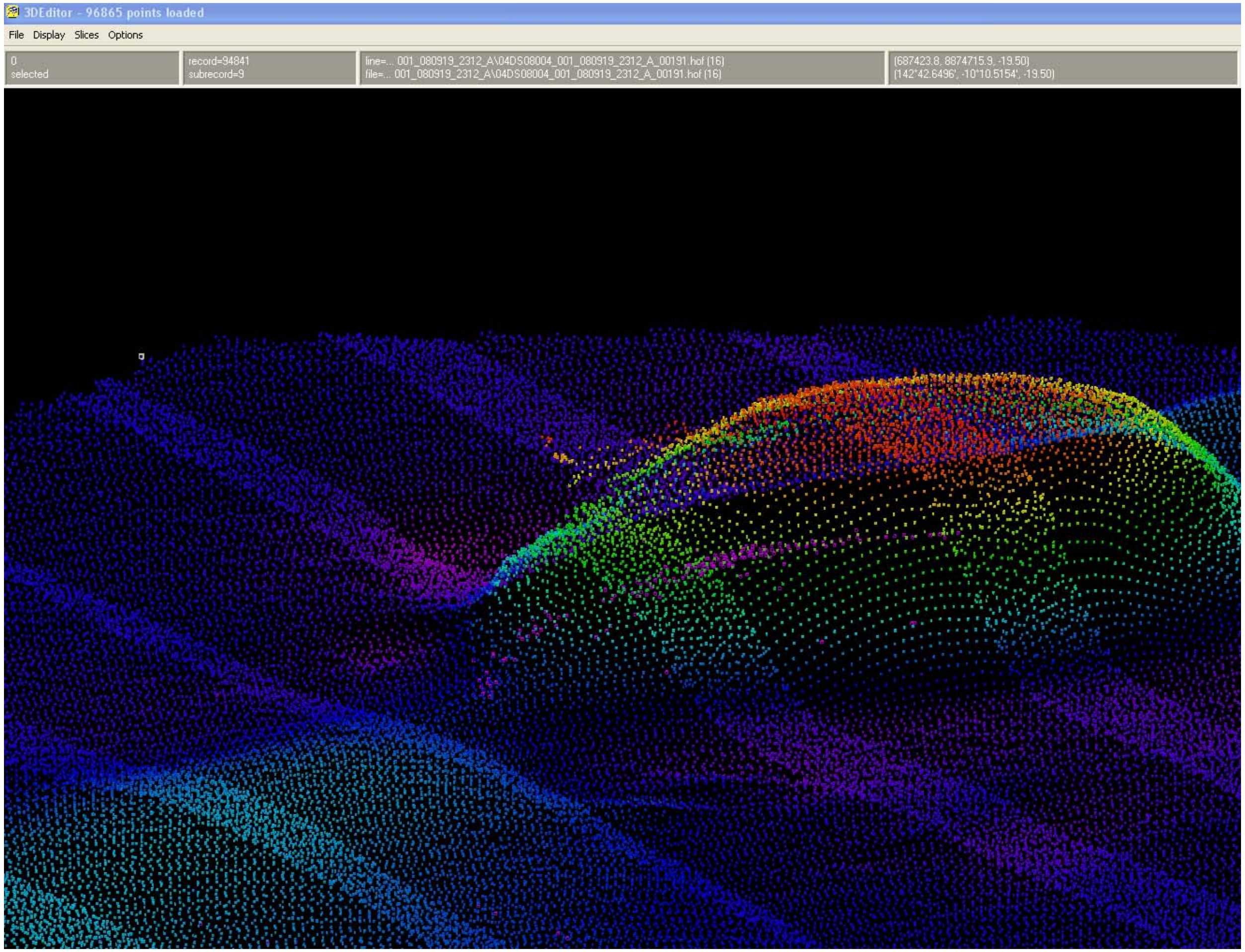

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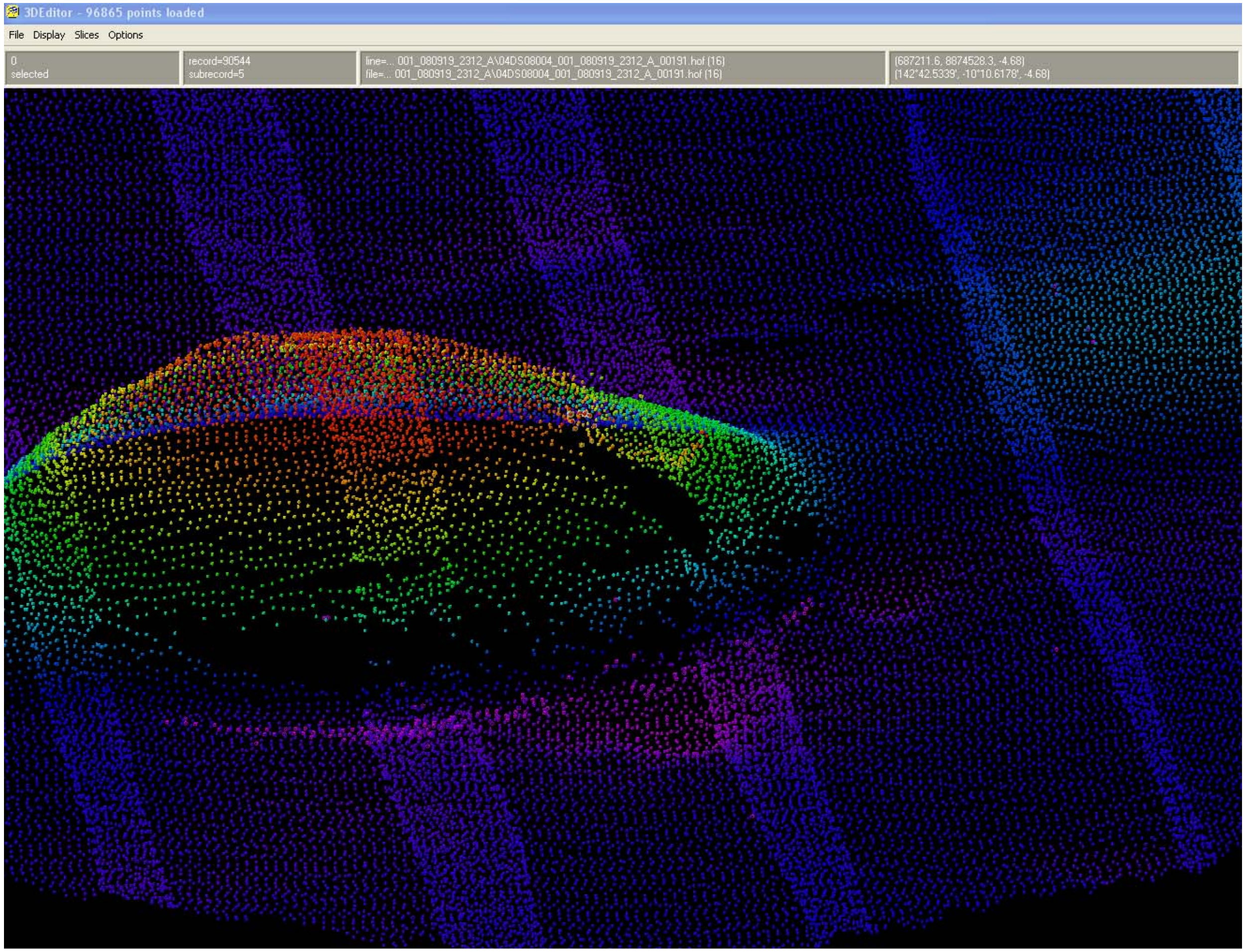

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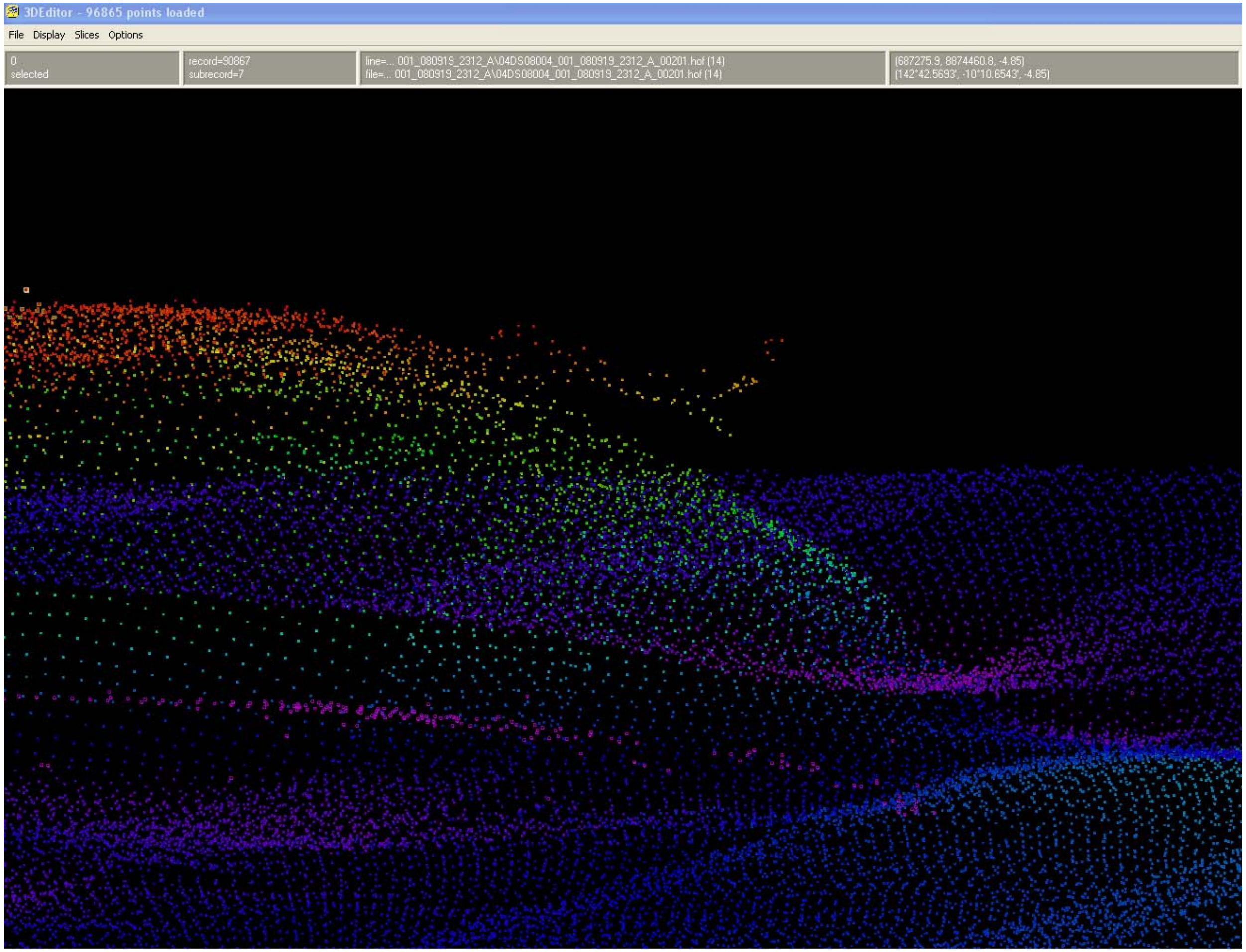

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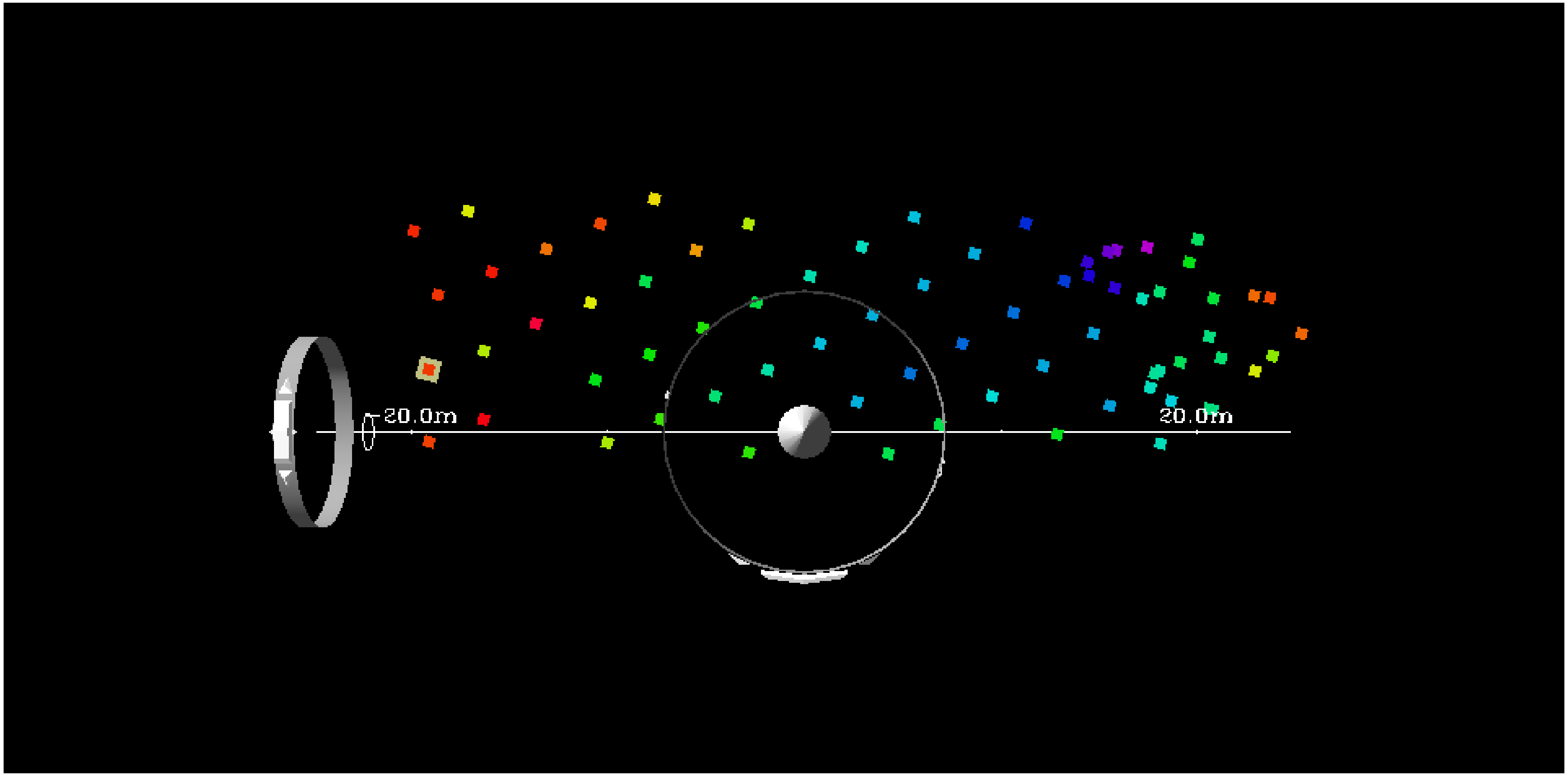
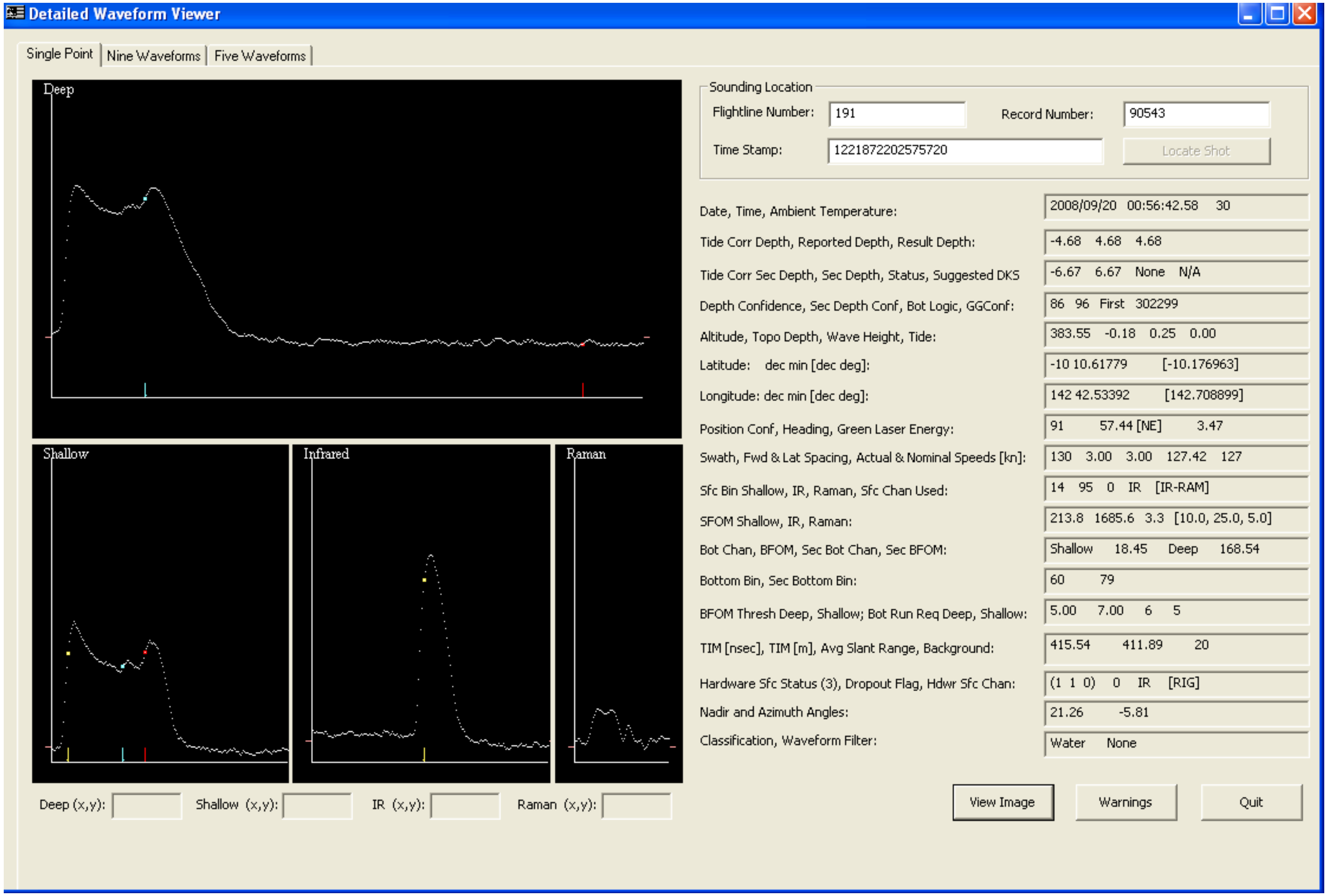
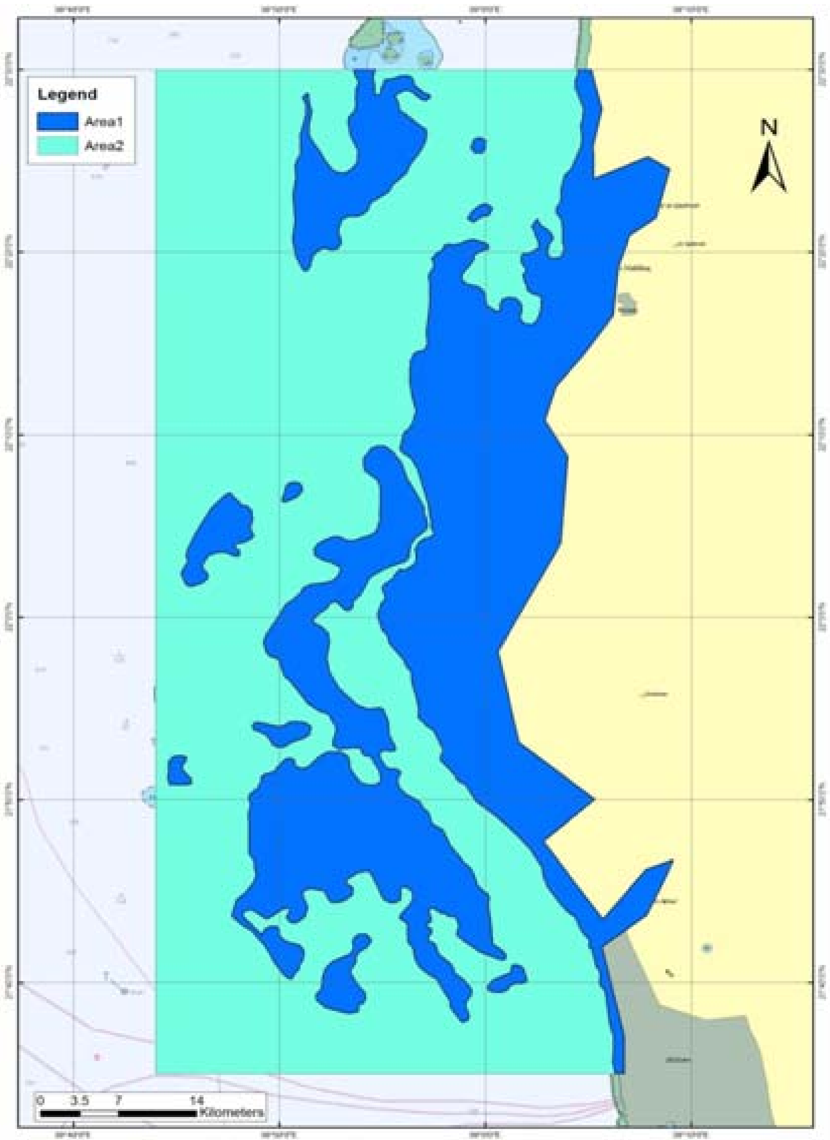


Data Analysis – Wreck Identification - Waveforms



NIOHC Case 2: Red Sea – Jeddah, KSA

- Total Project surveyed area: 3852 km^2
- MBES: 2635 km^2
- LIDAR: 1517 km^2
- Mar-June data acquisition period



Executive Summary

- MBES:
  - 3 vessels
  - 5 MBES systems
    - Full ocean depth range
  - Sidescan sonar; Magnetometer
  - 112% utilization (i.e. 12% above planned efficiency target)
  - Fully compliant acquisition program
  - **97% Acquisition in 5 weeks of operation!**

Executive Summary

- LIDAR:
  - 4 flights per day
  - 5 days per week
  - total 445 hrs flying
  - 1KHz Lidar
  - 4mpix digital camera
  - Hydro and topo capability
  - 2049 flight lines
  - 395 hrs data collection
  - **89% utility (data collection vs. flying)**

Executive Summary

- Highlights
  - Evolution of a strong Client-Contractor partnership
  - IHO Order 1a & 2; high resolution coverage
  - HSE: zero Loss Time Incidents

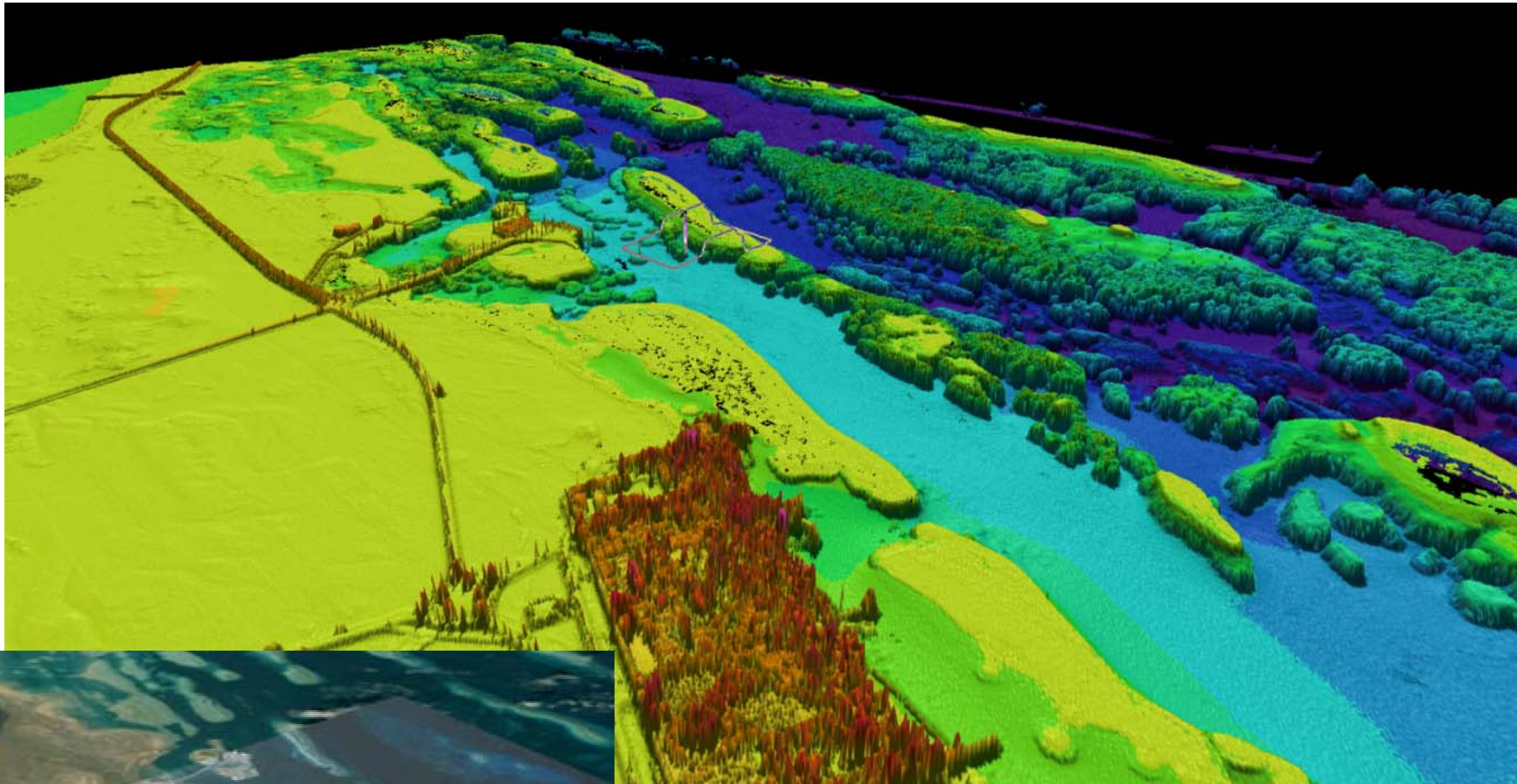
Aircraft

Dynamic Aviation Beechcraft A90 – N80Y

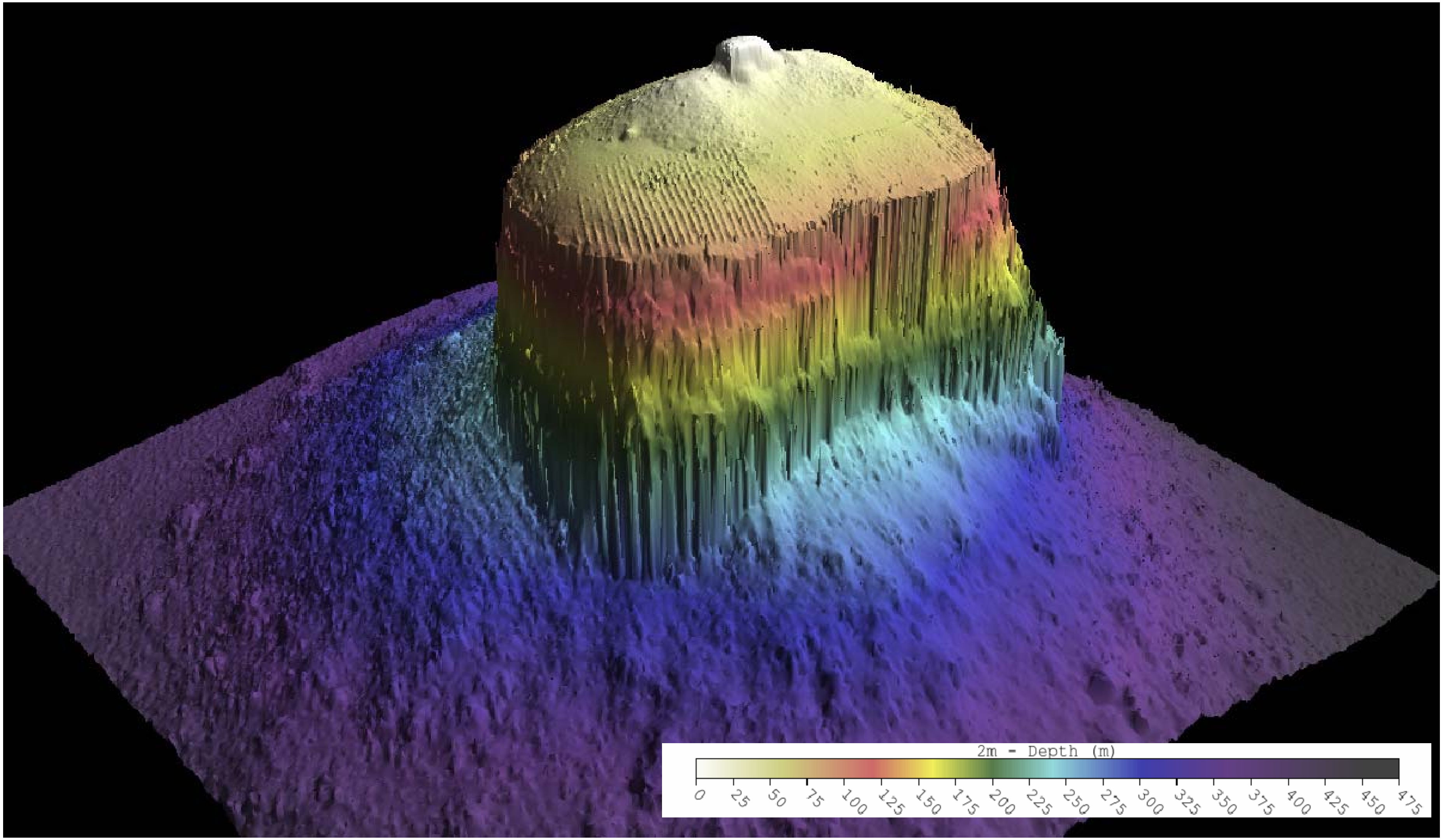
Wing Span: 14.6m
Length: 11.0m
Survey Mode Endurance: 4 – 5 hrs
Engines/Fuel: PT6A-20/Jet A

SHOALS 1000T
Ng-Yag pulsed laser
1000Hz
520; 1024 nm

North Jeddah – Chart Comparison

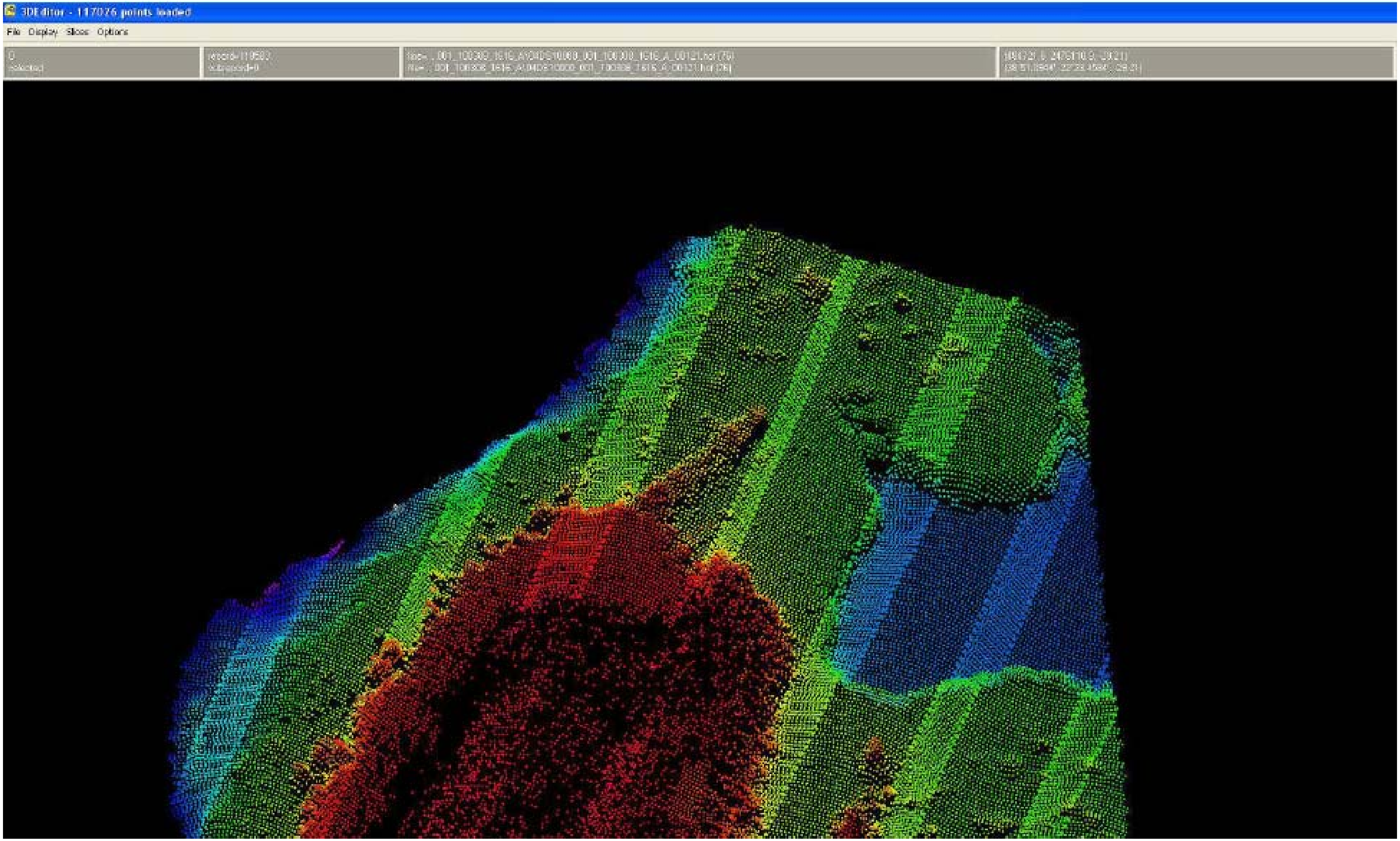


High Resolution MBES: Deep to Shallow

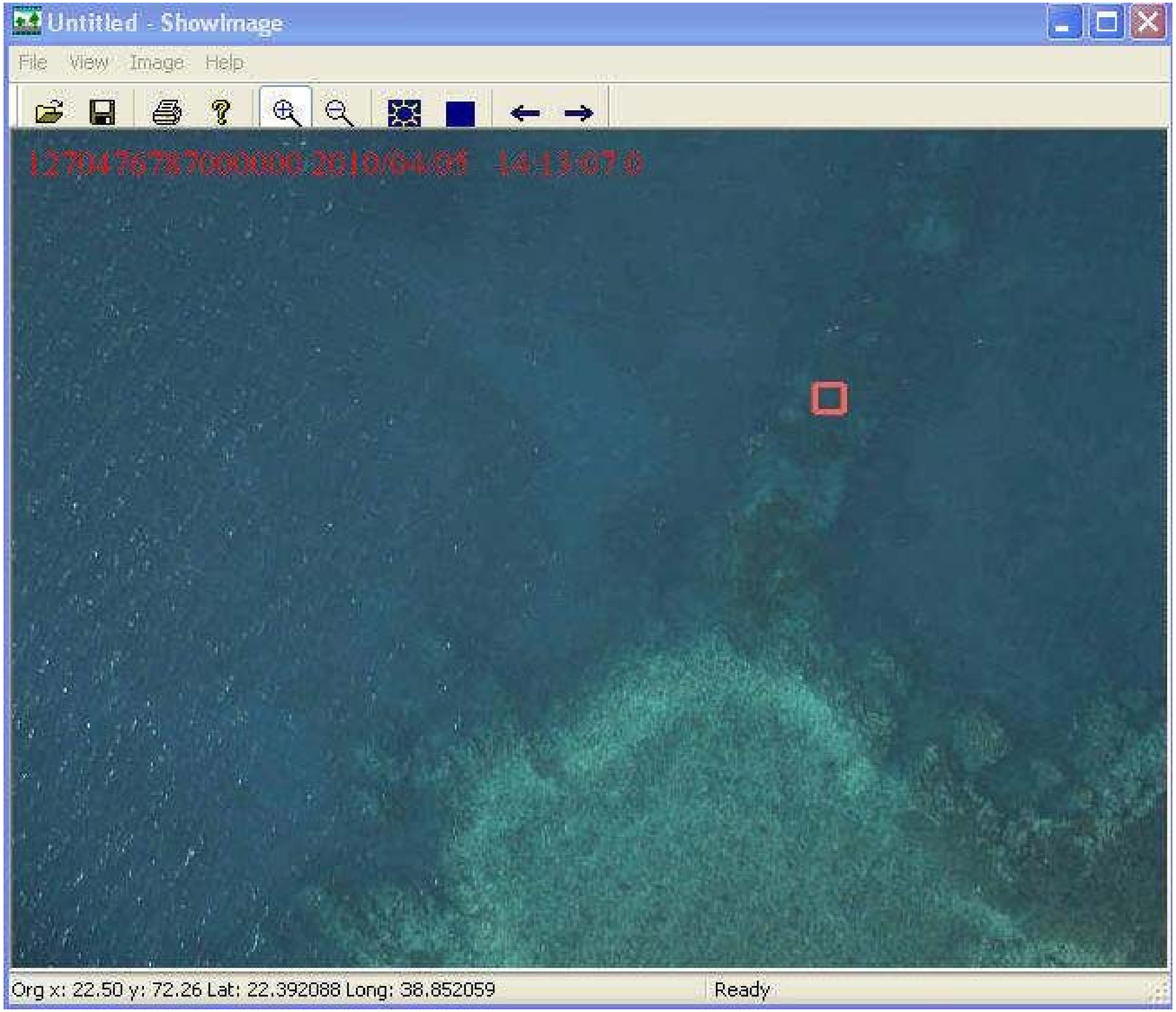


Seamount Feature shoaling from 355m to 2m

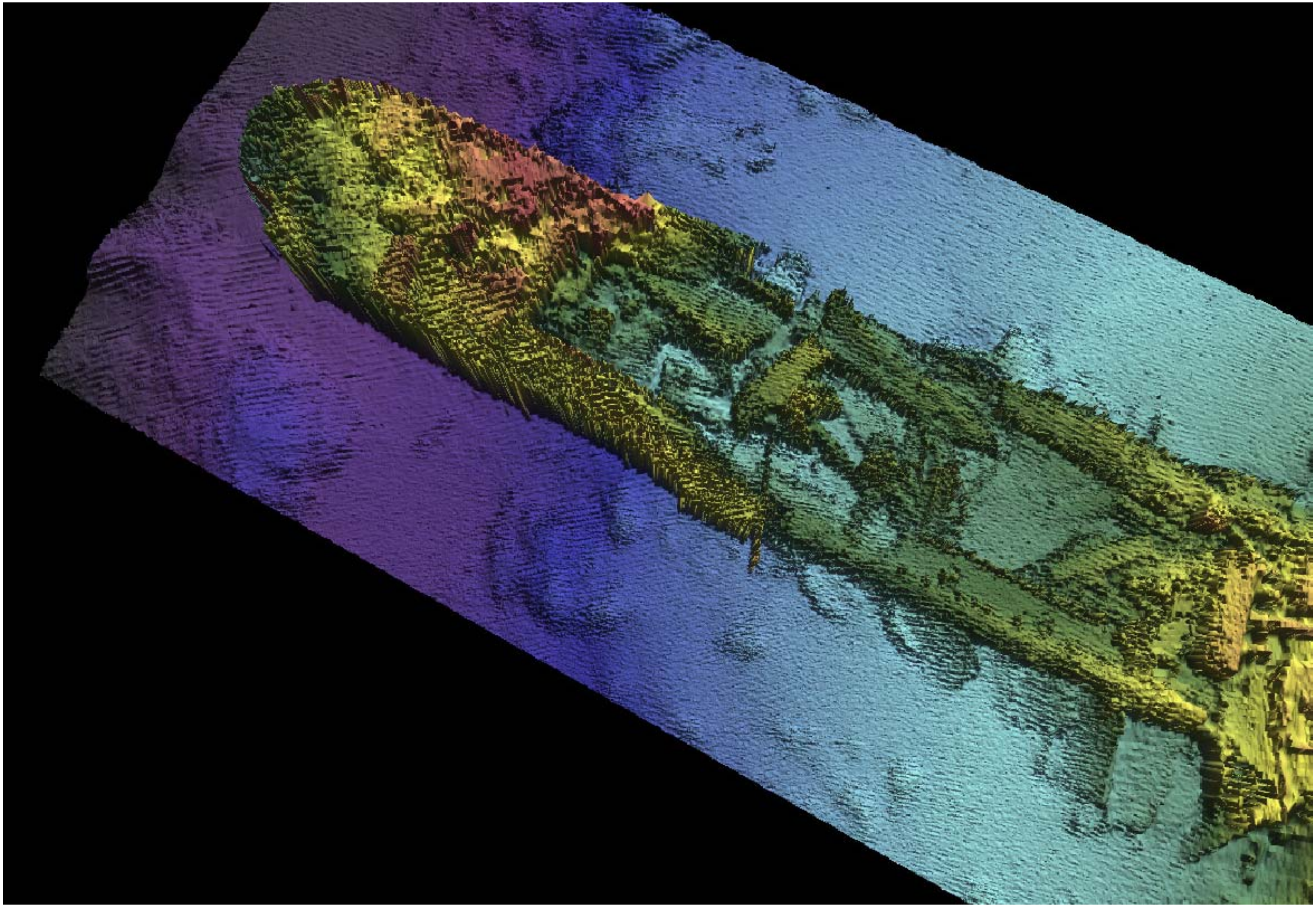
Wreck inspection - LIDAR



Wreck investigation – Aerial Imagery

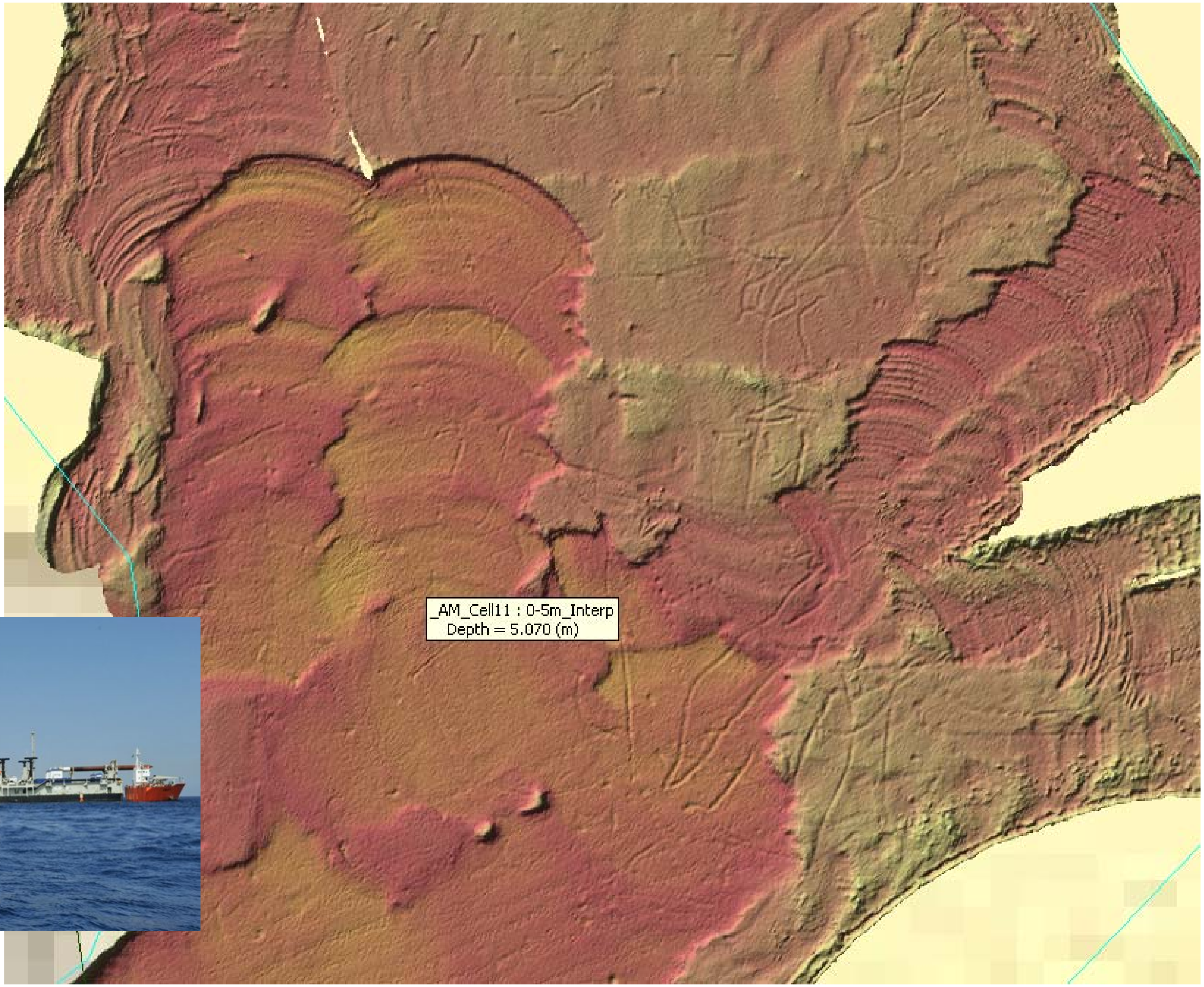


Wreck investigation - MBES

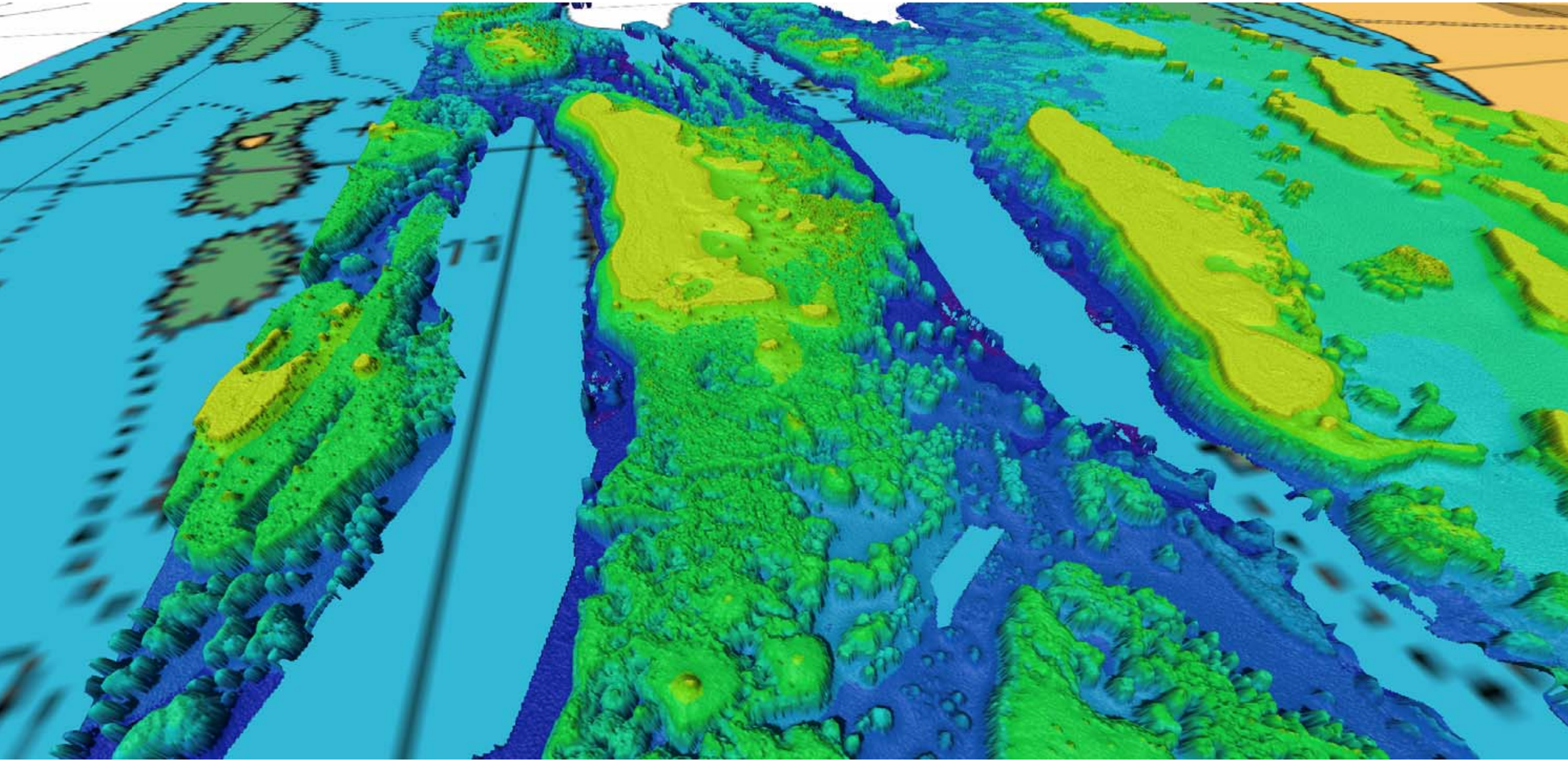


Site Activity - Dredging

Spud dredger activity captured by survey launch 'Alumaster'

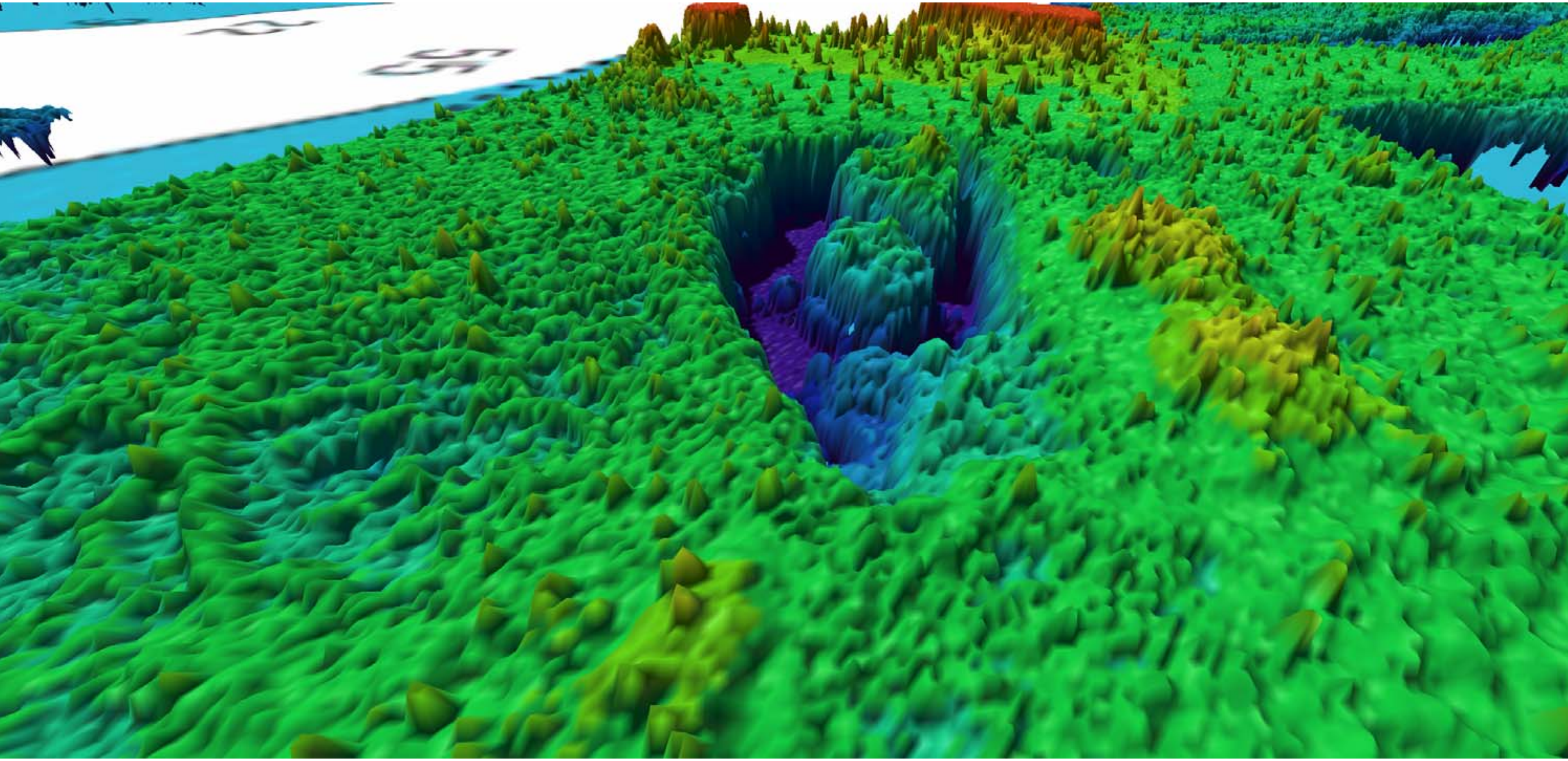


QA Lidar Data Imagery



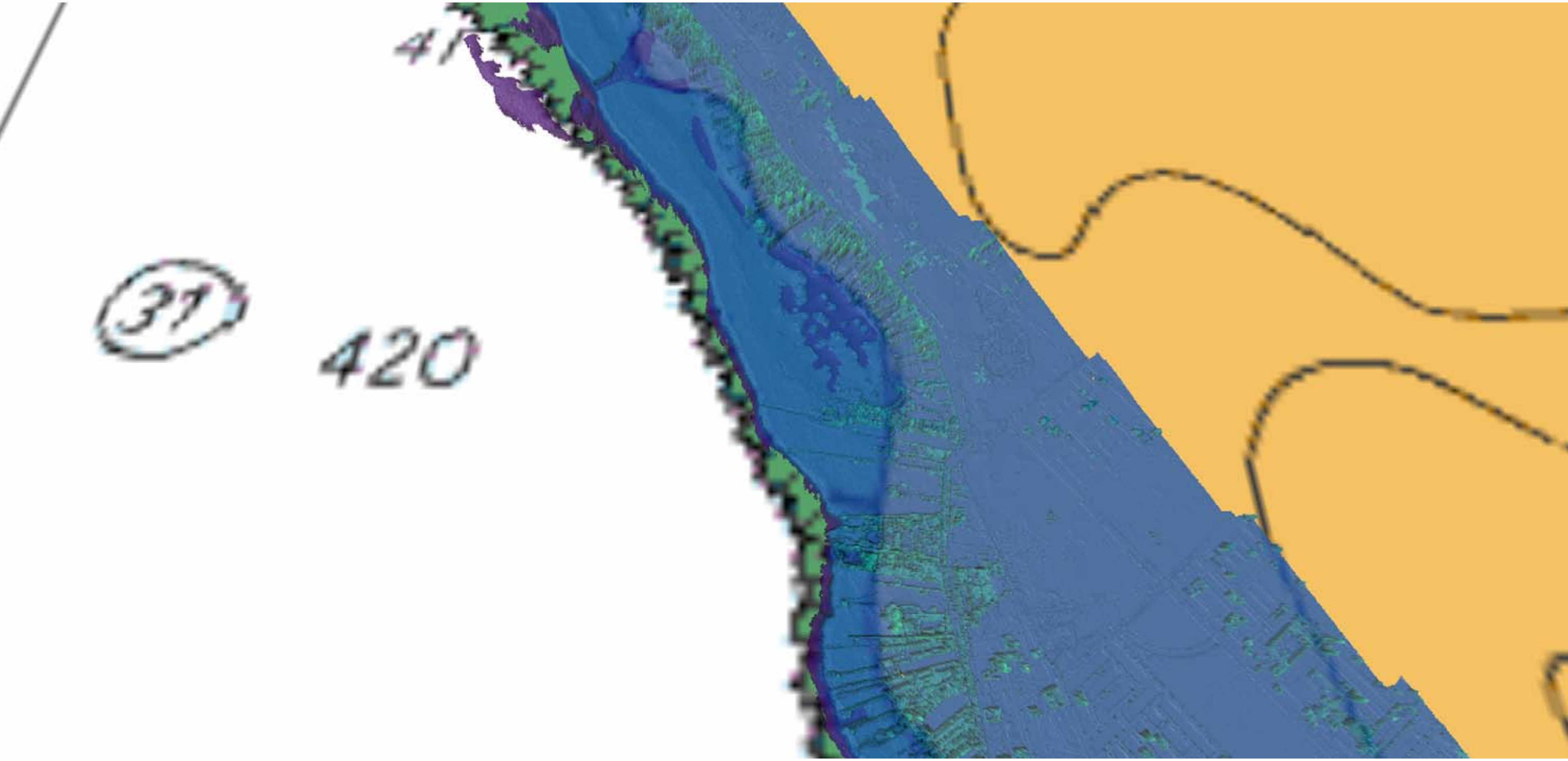
The complexity of ultra shoal and/or hazardous areas can be captured to good effect, complementing the deeper, hi-res data of vessel-based MBES

QA Lidar Data Imagery



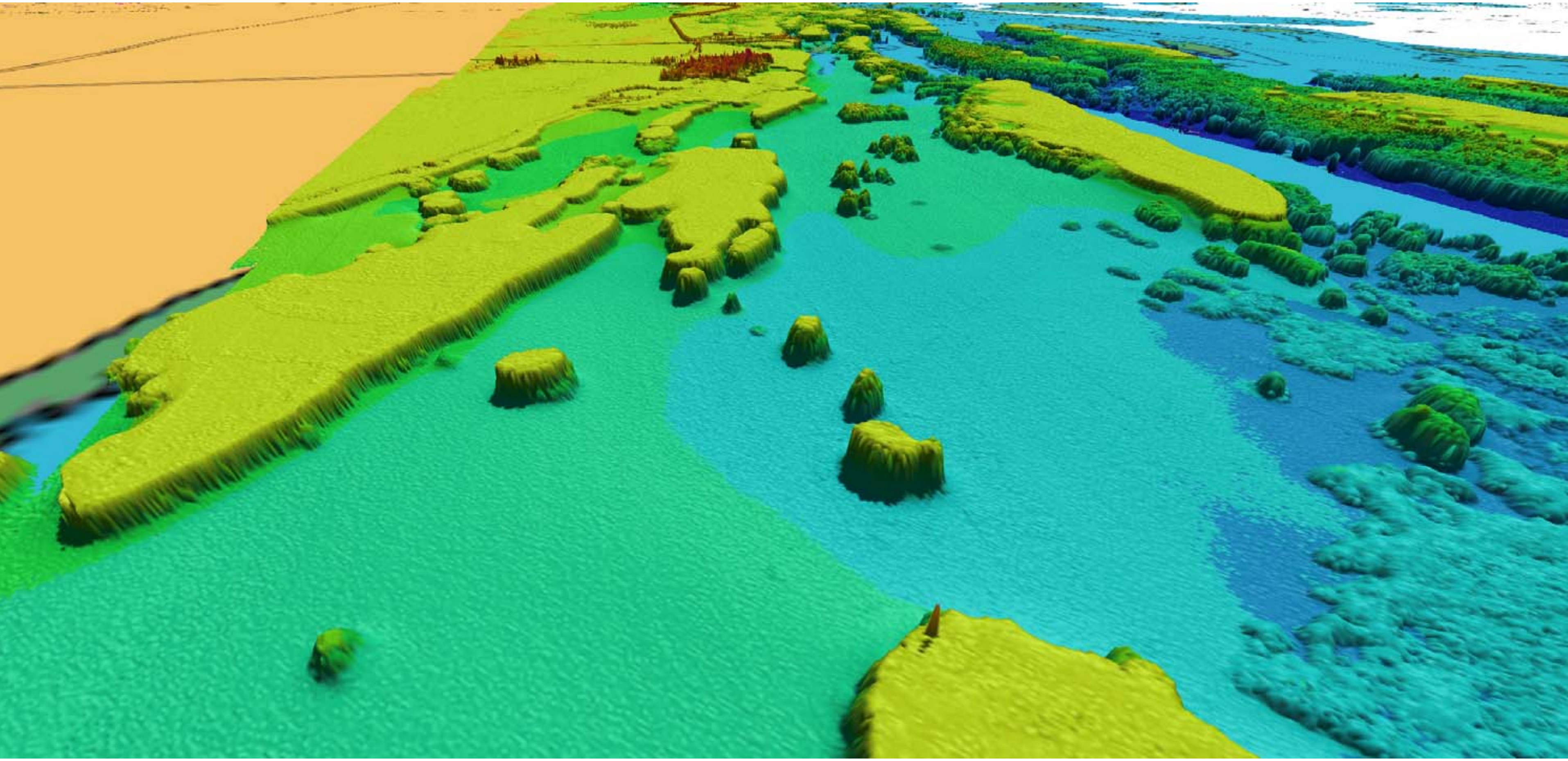
Areas very awkward to depict with a vessel can be captured to sufficient detail by Lidar, such as this deeper ‘pond’ in the reef

QA Lidar Data Imagery



The ability to collect both topo and bathy data allows major land usage changes to be identified and presented to the charting authority

QA Lidar Data Imagery



Artifacts are typically sub-decimetre when the data is processed using PPK methods and referenced to the ellipsoid – what you see here are impacts of environmental changeability.

Conclusions and Summary

- ALB is an augmentation technology available to the hydrographic and cartographic industries for use in areas inaccessible to acoustic technologies; it does NOT replace or compete with MBES
- It provides rapid data collection over land, sea and inter-tidal areas
- Accuracies meet or exceed IHO Order 1 standards
- Coverage (spot density) determines Order 1 A or B attainment
- Data collection rates can exceed 200km^2 per day, depending on conditions, mission time and data density requirements (70km^2 is a better working average but this is depth-independent)
- Turbidity is the biggest environmental limiter
- Aircraft support is the biggest operational limiter
- Planning considerations for ALB are markedly different to that for traditional shipborne/acoustic techniques
- Processing tends to be analyst-heavy, although auto processing techniques are continually improving
- New technologies are emerging providing topo-survey type data densities in shallow (1 secchi depth/k = >0.2) nearshore regions
- Consideration should be given to the utility of ALB to provide better cost-effective survey solutions.

Thank You