New Frontiers in Seafloor Mapping and Visualization

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New Frontiers in Seafloor Mapping

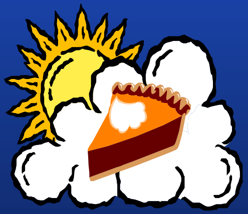
Prediction is very difficult, especially about the future. Niels Bohr

There are many methods for predicting the future. For example, you can read horoscopes, tea leaves, tarot cards, or crystal balls. Collectively, these methods are known as "nutty methods." Or you can put well-researched facts into sophisticated computer models, more commonly referred to as "a complete waste of time."

Scott Adams The Dilbert Future

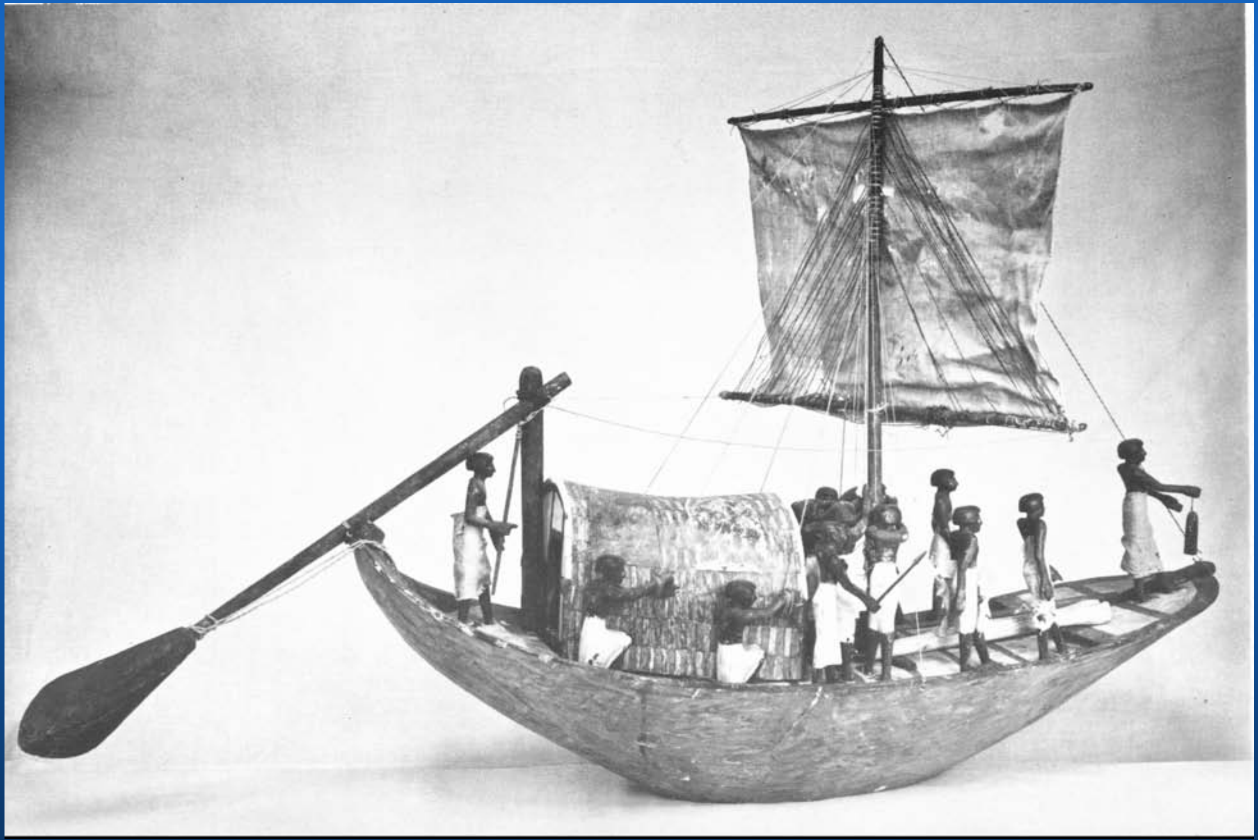
New Frontiers in Seafloor Mapping

- Focus on acoustic techniques for bathymetry
- Focus on GEBCO domain of deep sea
- Look at near-term trends with some "pie in the sky"



History of Ocean Mapping

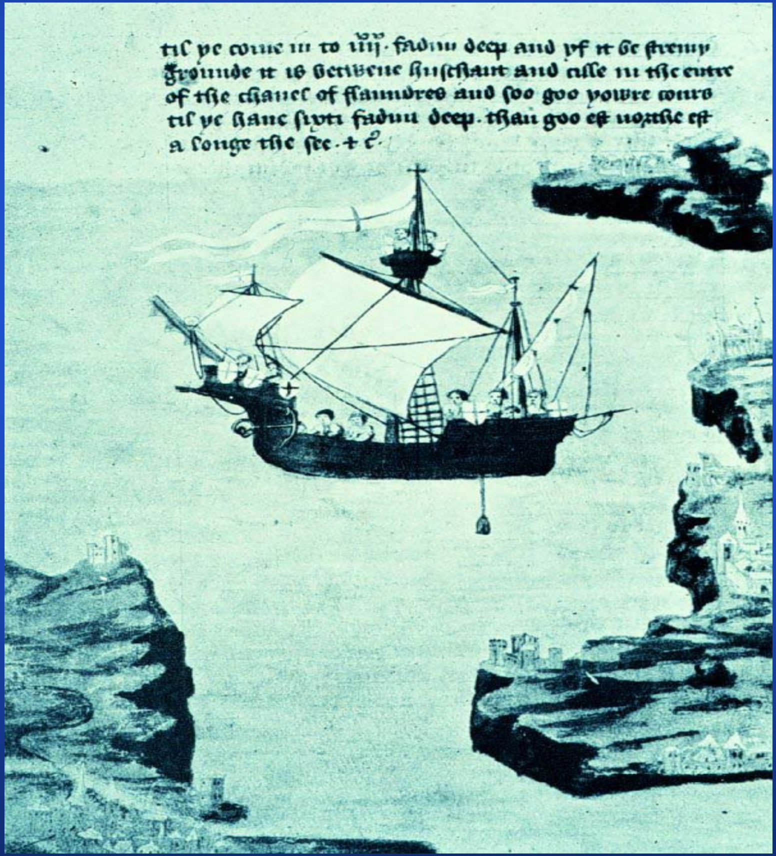
Lead Line:



2000 B.C.

The History of Ocean Mapping

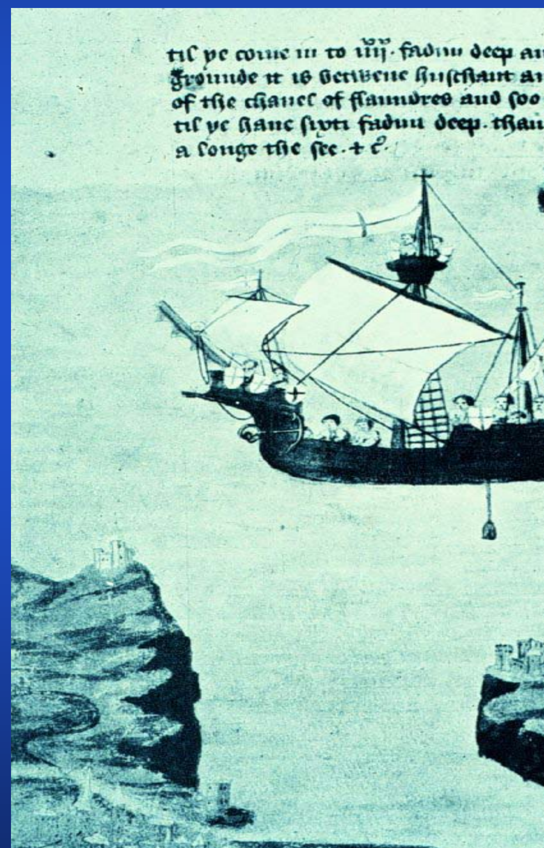
Lead Line:



1450

The History of Ocean Mapping

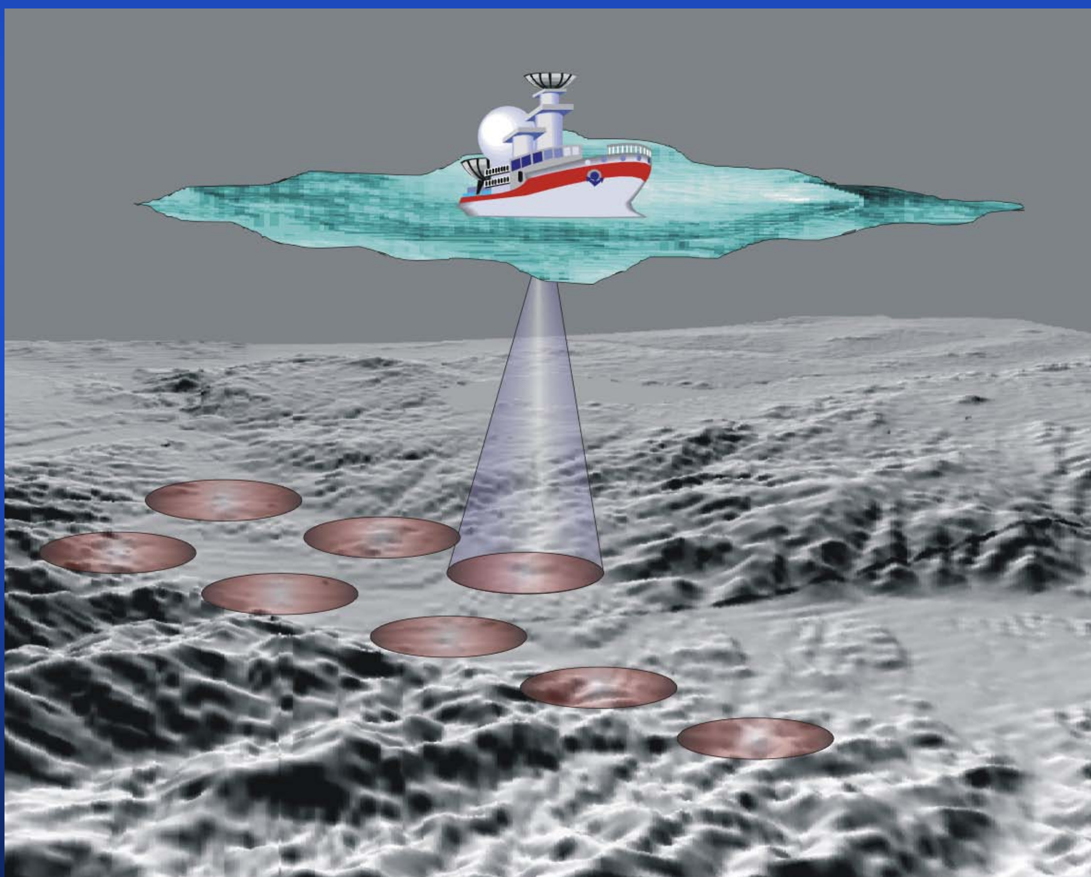
Lead Line:

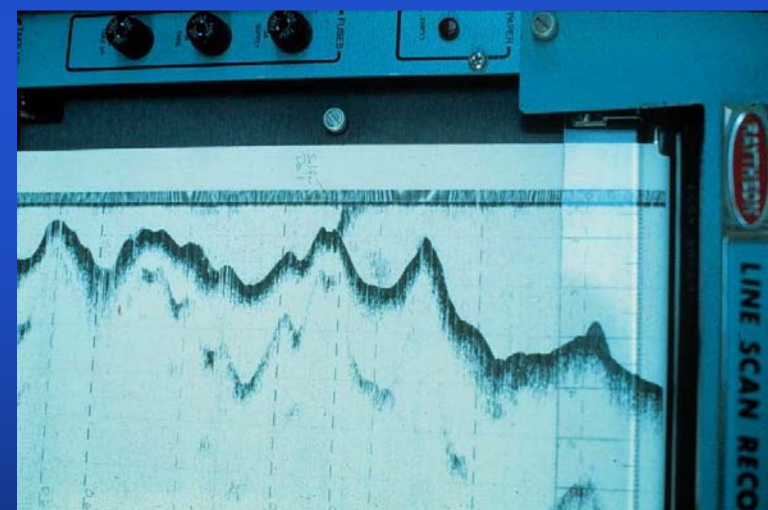


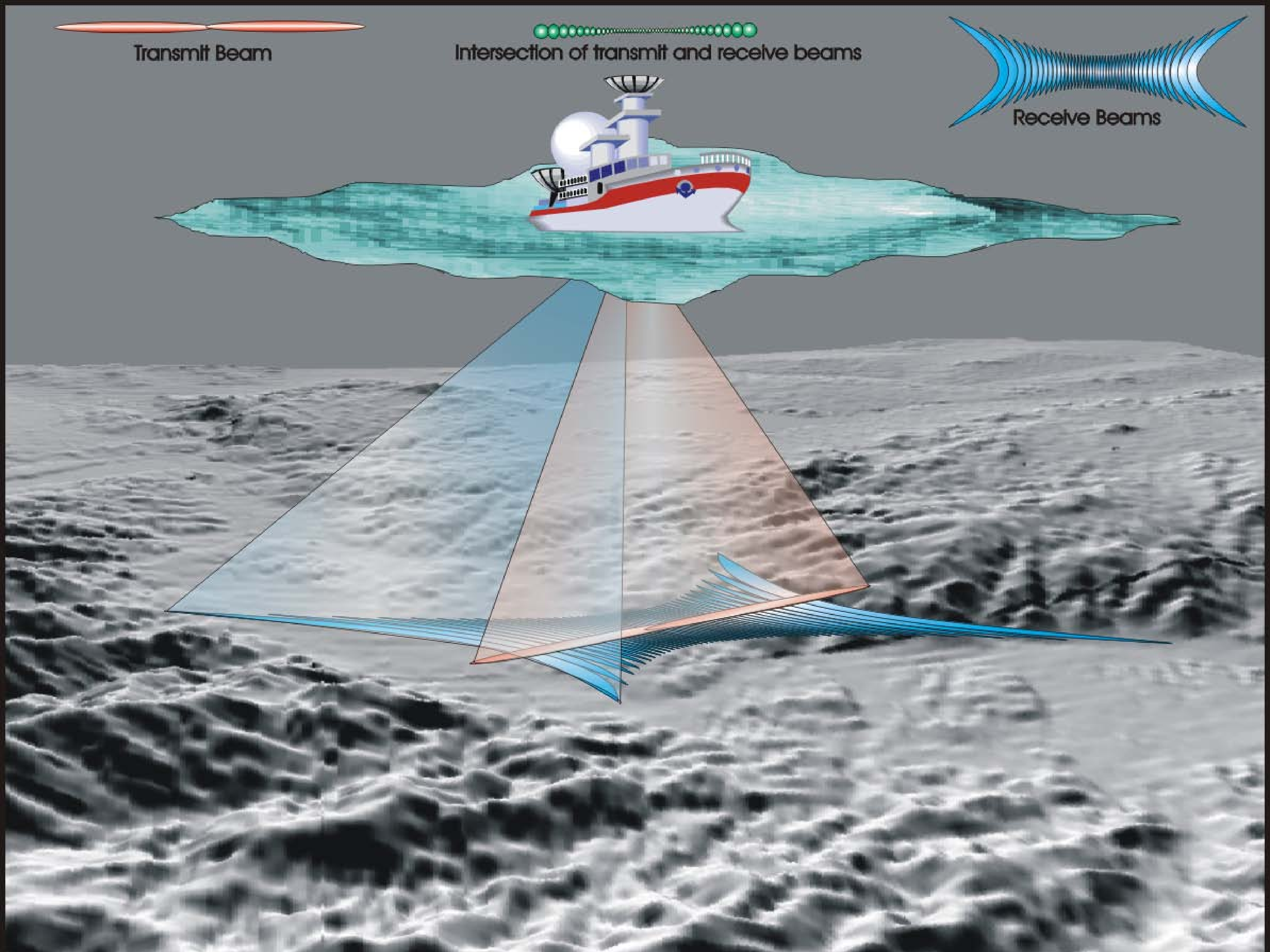
1450

1940

Single Beam Echo Sounder






Transmit Beam
Intersection of transmit and receive beams
Receive Beams

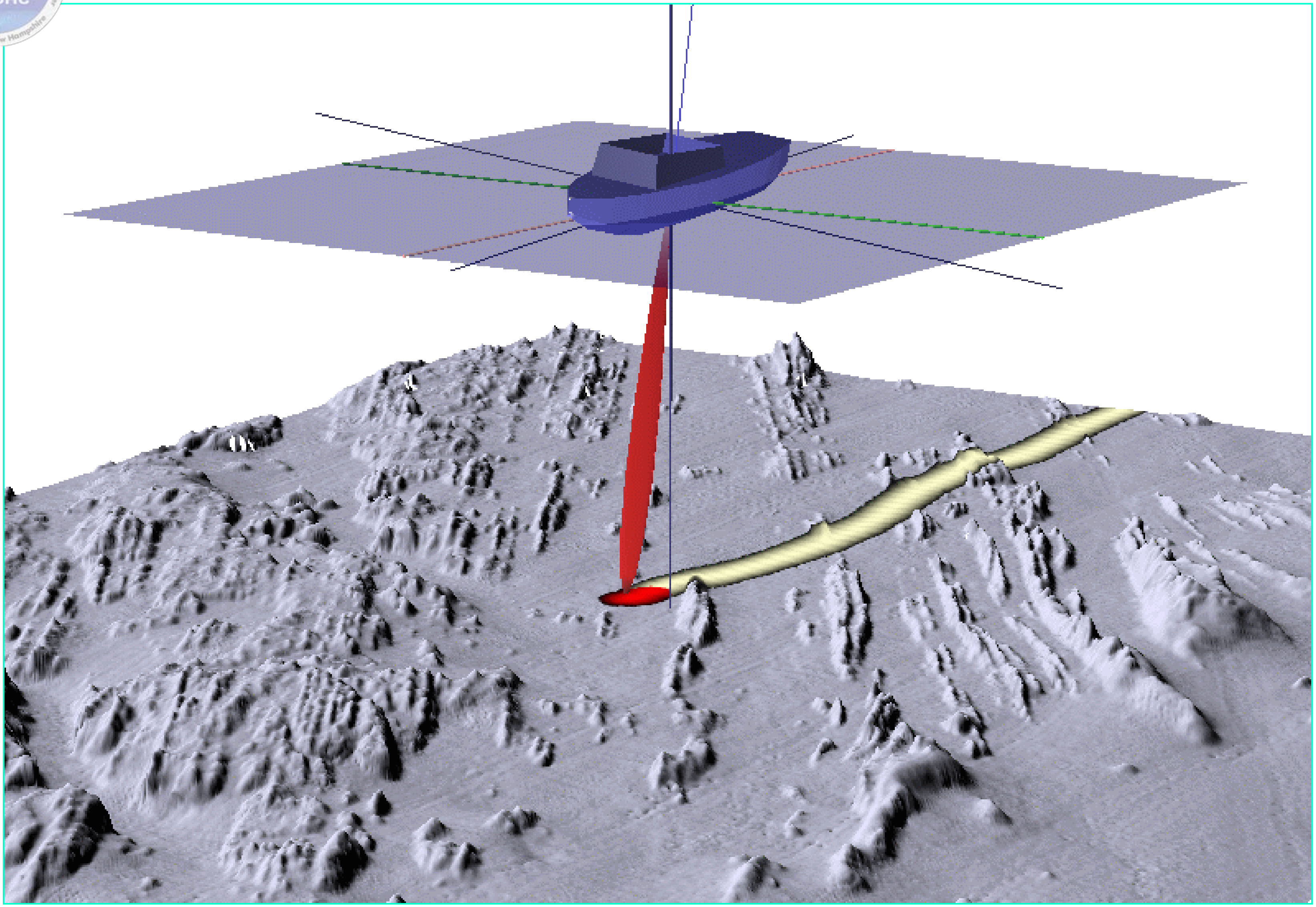
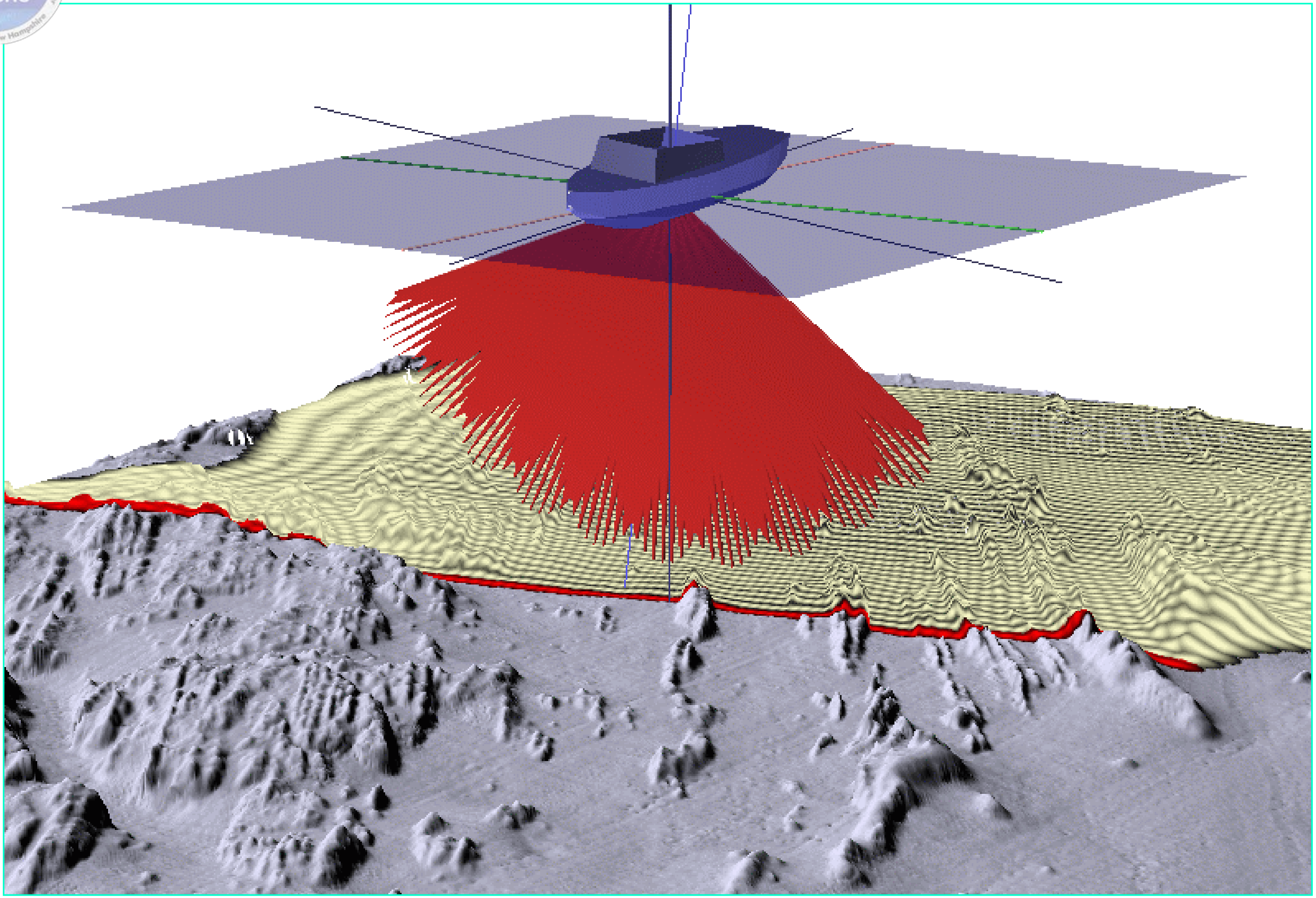


Image derived from theoretical sonar model interacting
with artificial seabed DTM using *"SynSwath"*

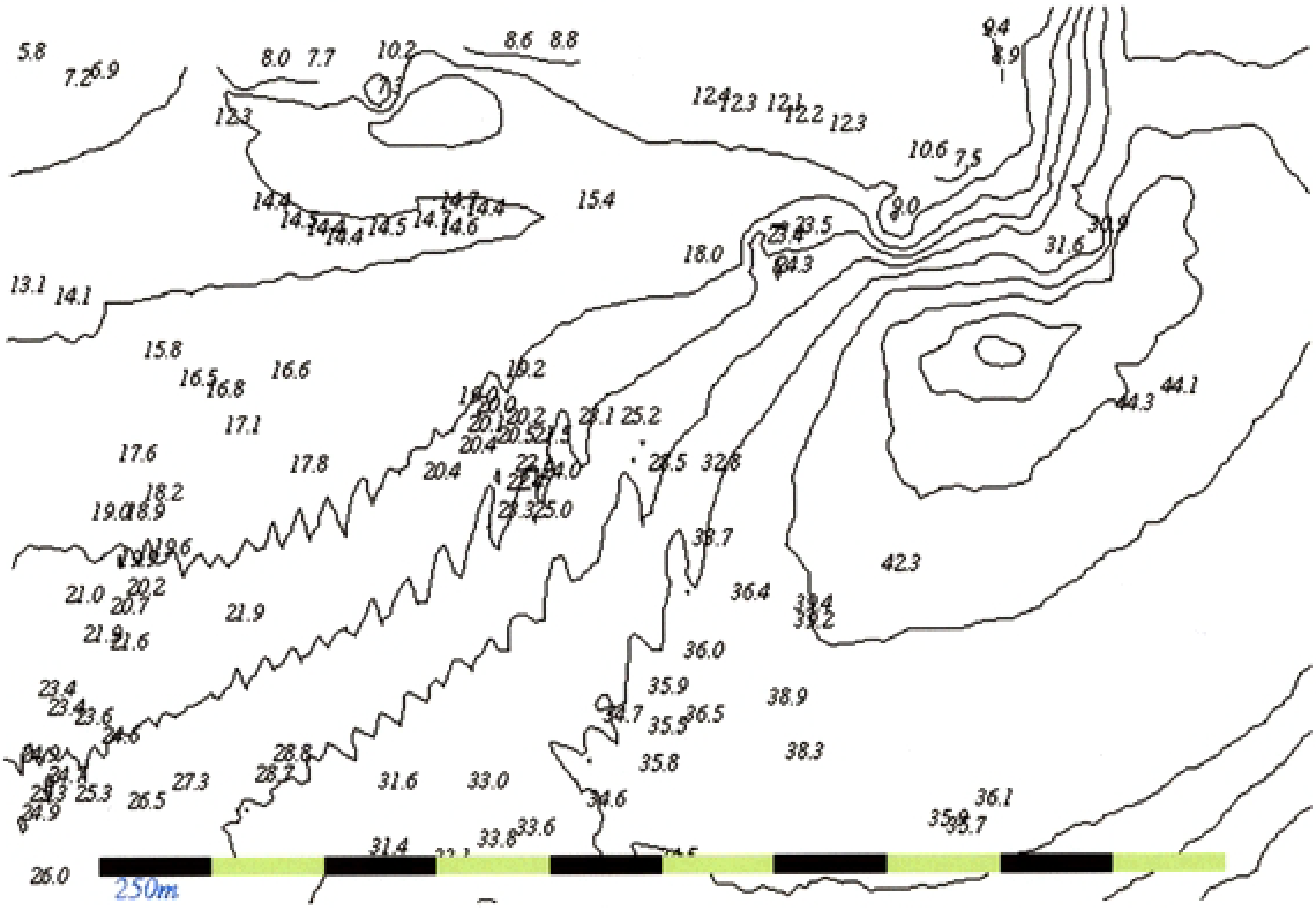
John Hughes Clarke - UNB



mage derived from theoretical sonar model interacting
with artificial seabed DTM using *"SynSwath"*

John Hughes Clarke = UNB

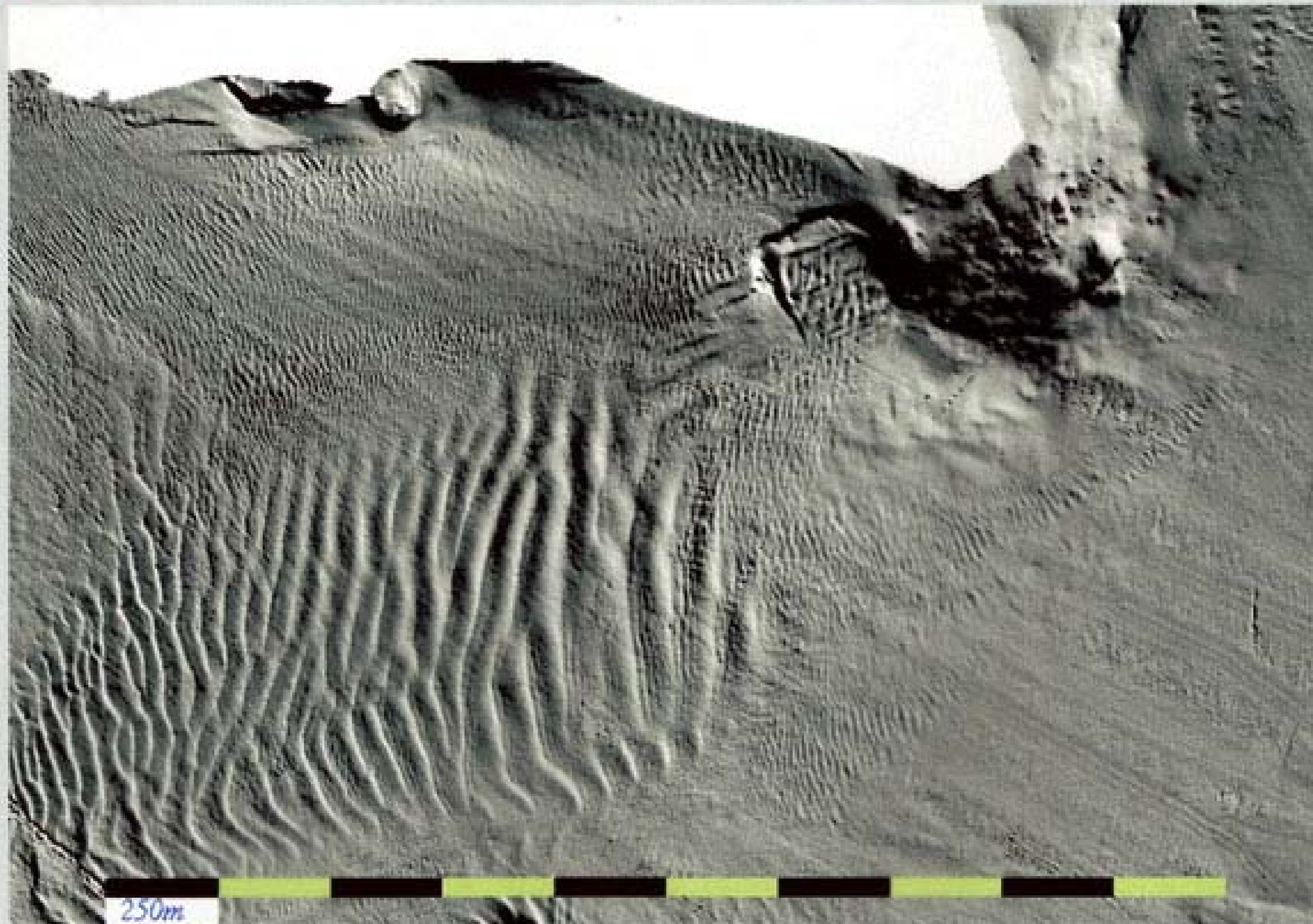
C&C Tech., San Francisco Bay: EM1000 8 knots



Processed using **OMG/UNB SwathEd**

Data courtesy of: USGS(WR) Jim Gardner

C&C Tech., San Francisco Bay: EM1000 8 knots



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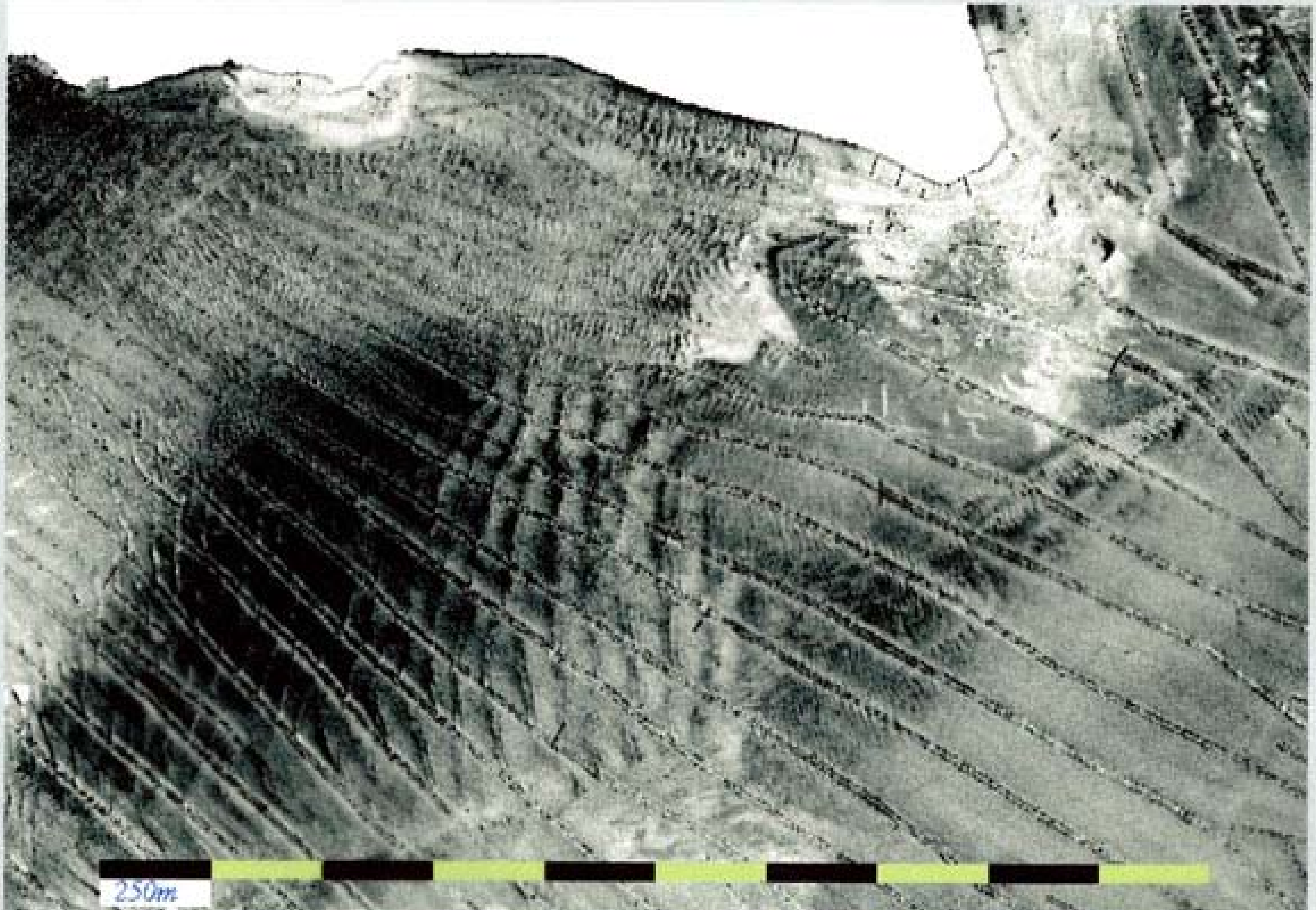
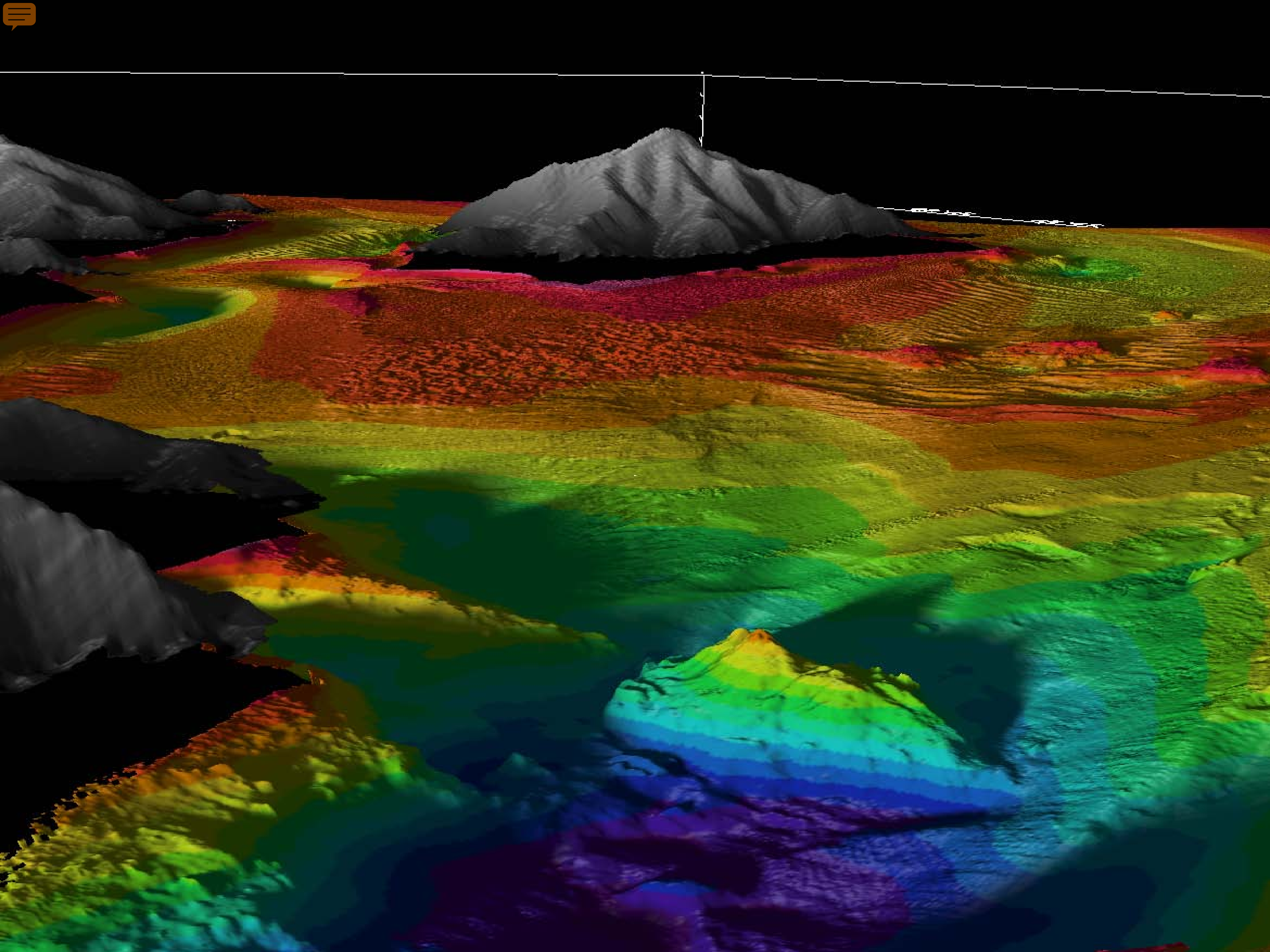
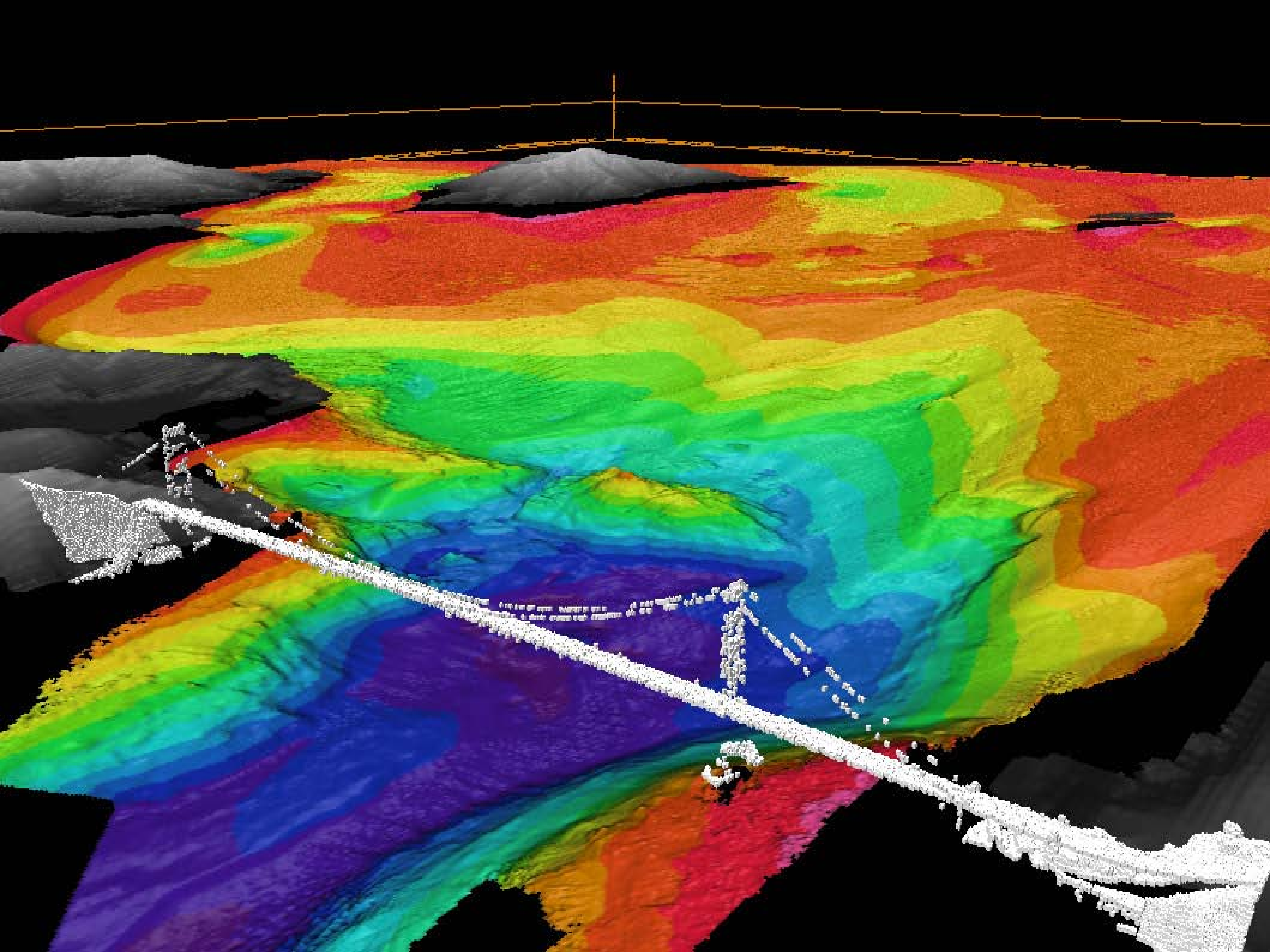
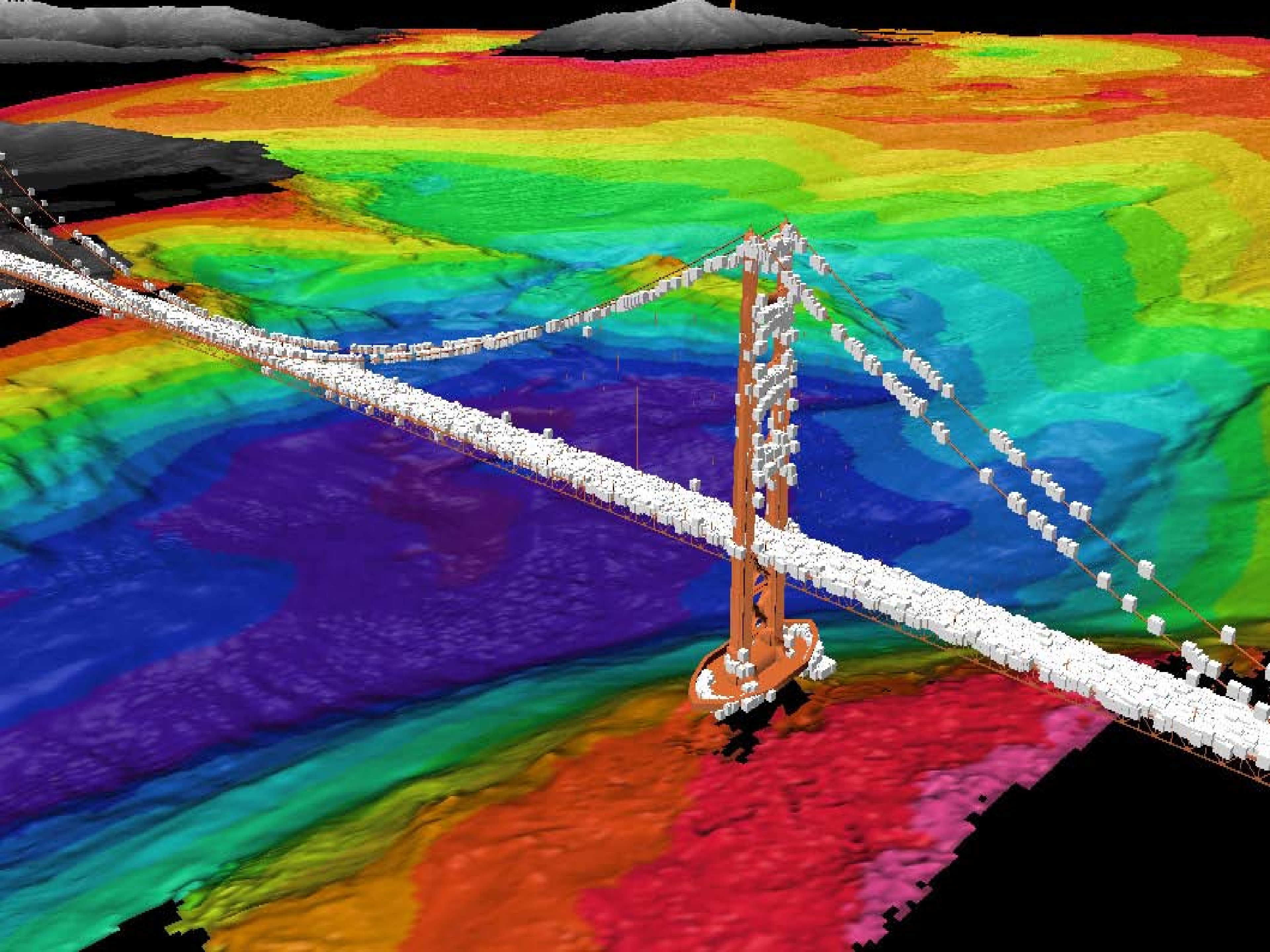


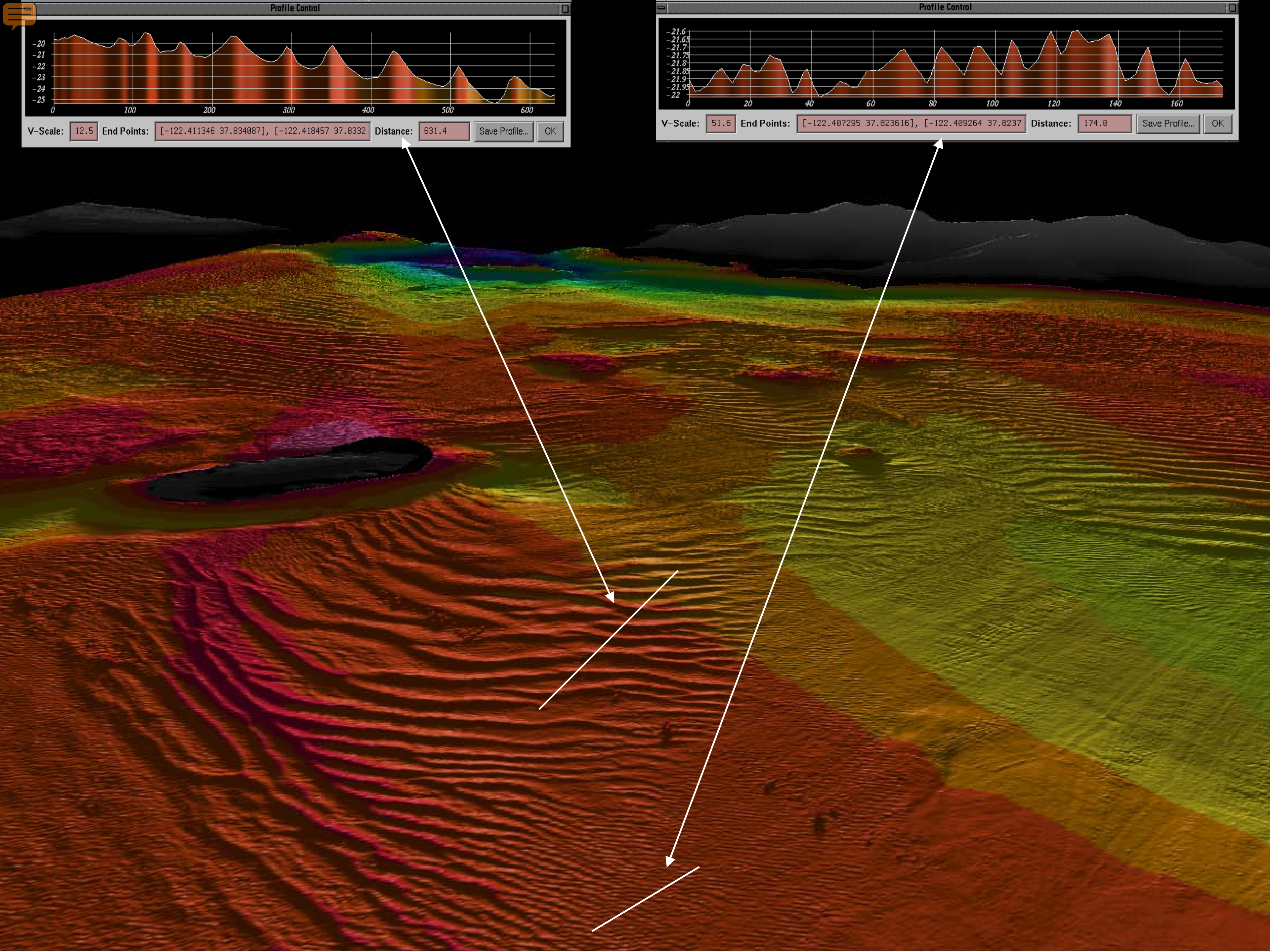
Processed using **OMG/UNB SwathEd**

Data courtesy of: USGS(WR) Jim Gardner









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-22
-23
-24
-25
0
100
200
300
400
500
600
V-Scale:
12.5
End Points:
[-122.411346 37.834087], [-122.418457 37.8332
Distance:
631.4
Save Profile...
OK
Profile Control
-21.6
-21.65
-21.7
-21.75
-21.8
-21.85
-21.9
-21.95
-22
0
20
40
60
80
100
120
140
160
V-Scale:
51.6
End Points:
[-122.407295 37.823616], [-122.409264 37.8237
Distance:
174.0
Save Profile...
OK

Advances in Offshore Positioning

System	Accuracy
1960's - Sextant	~ 1 n.m. (if good)
1970's - Transit Satellite	~ 100 m intermittently
Early 1990's - GPS	~ 100 m continuously
Late 1990's - DGPS	~ 10 m continuous
Early 00's - RTK	~ 5 cm x,y,z, continuous

Advances in Motion Sensors

1970’s - Damped pendulum

1990 - Vertical gyro

1993 - Loose inertial/GPS integration

early 00’s - Tightly integrated inertial/GPS

Attitude - .01 deg (RTK)
Heading - .02 deg (RTK or DGPS)
Velocity - .01 m/sec (RTK)
Position - .02 - .10 m (RTK)
200 Hz update rate

Increase in Data Density

in 100 m of water

Method	*Soundings/hr*	*Mb/hr*
Lead line	10	.00008
Echo sounder	21,600	.1728
EM-100	292,000	2.1
EM-1000	324,000	27.9 (ss)
EM-3000	1,500,000	79.8 (ss)
in 5 m of water	30,000,000	800 (ss)

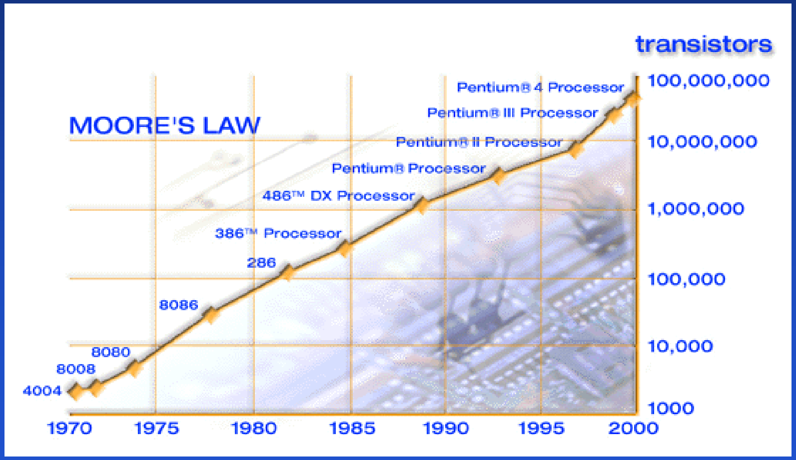
CHALLENGES

- Managing vast amounts of data
- Interacting with the data
- Presenting large amounts of data
- Verifying the data

But… the data density opens up a world of new possibilities

Advances in Computing Power

Moore's Law



- 30-year trends
  - Speed doubles every 50 months (at least)
  - Computer costs cut in half every 32 months
  - Memory costs cut in half every 18 months
- Every 10 years computers have become
  - At least 5 times faster
  - Cost 7% of original cost (memory 1%)

Advances in Computing Power

- Time to transfer 1 gigabyte of data:

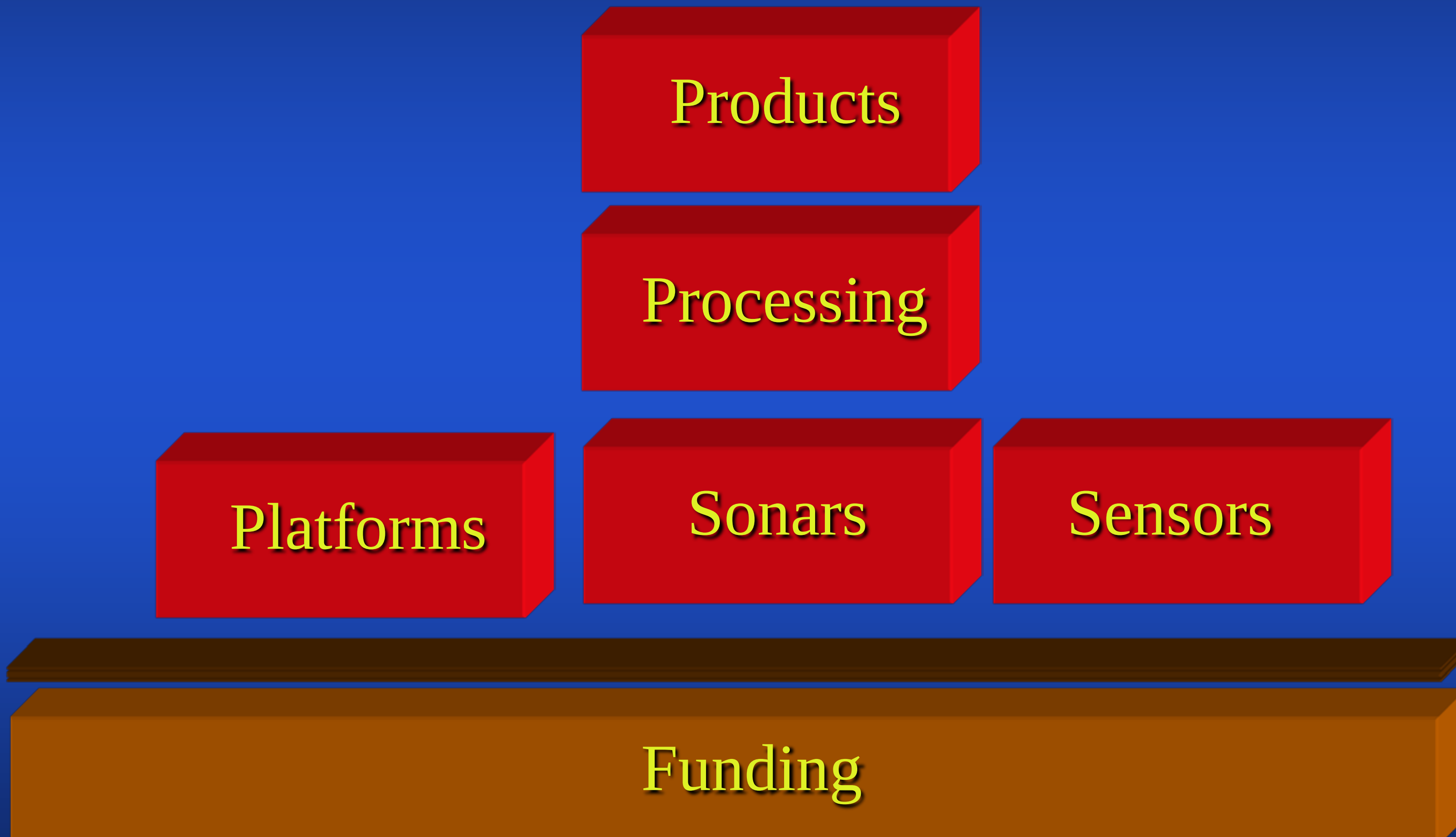
• 28.8 kbaud modem	75 hours
• ISDN	17 hours
• ADSL	30 minutes
• 10 BaseT	13 minutes
• 100 BaseT	80 seconds
•1000 BaseT	8 seconds

Benefits of Increased Data Density:

- Redundancy provides increased accuracy

- Data density allows us to visualize and quantitatively explore the data in new ways

The seafloor mapping system



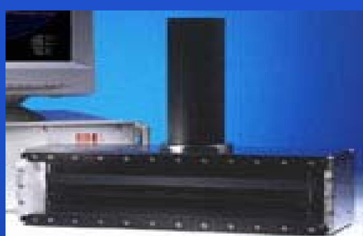
SONARS:

RESON 9001

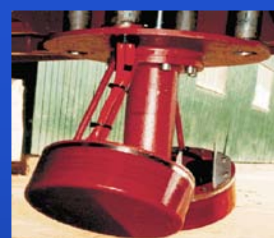
RESON 8101

RESON 8111

SIMRAD EM100

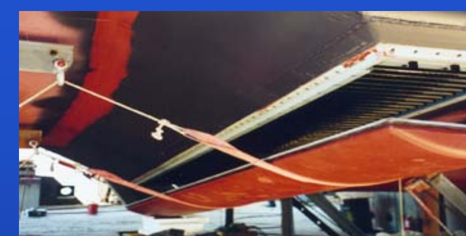


RESON 8125



EM3000

ELAC 1050



SIMRAD EM121

FANSWEEP 20

ISIS100

ODOM ECHOSCAN

Swath-mapping sonars

- **Beam forming sonars:**
  -bathymetry and co-registered backscatter with angular resolution
- **Interferometric sonars:**
  -use phase comparison to generate bathy – sidescan sonar-like imagery

SONARS:

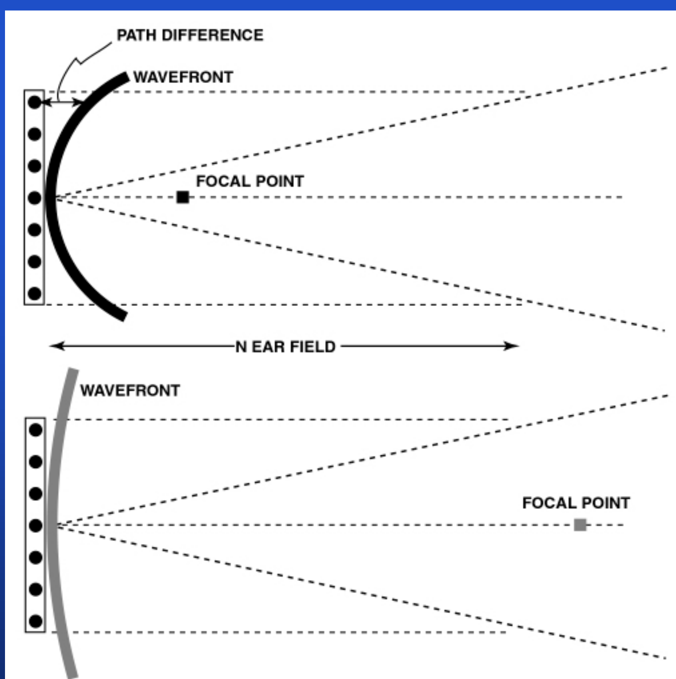
"Hybrid" sonars: use interferometry for high-quality imagery -- some beam forming for ambiguity resolution

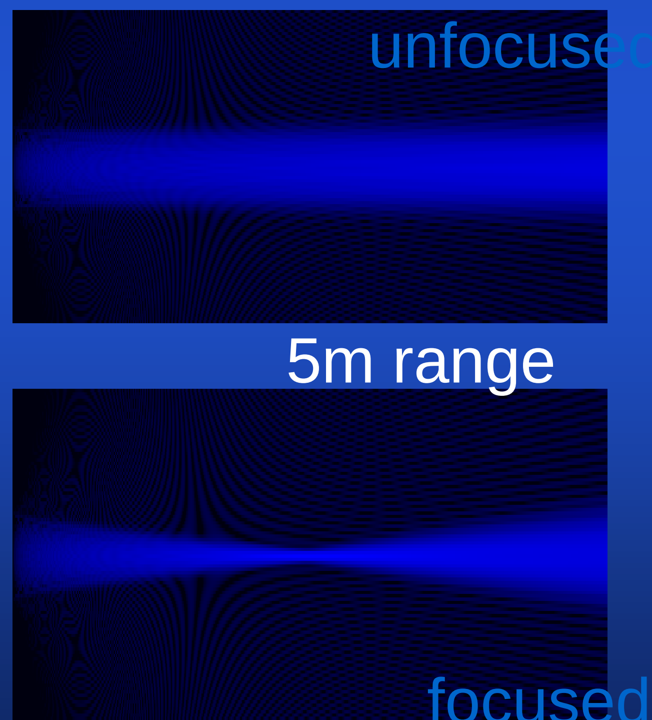
Trends: better algorithms for interferometric solutions = higher resolution bathymetry while maintaining high-quality, co-registered imagery and wide swath – also SAS

FanSweep 20

SONARS:

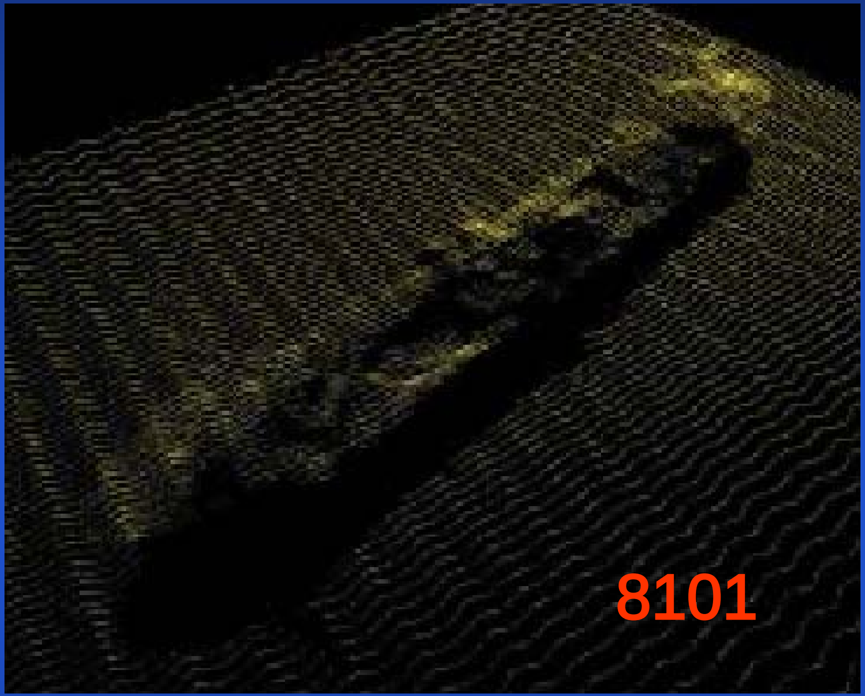
"<u>Focused</u>" sonars: compensate for wavefront curvature to allow focusing in the near-field. Much higher target resolution



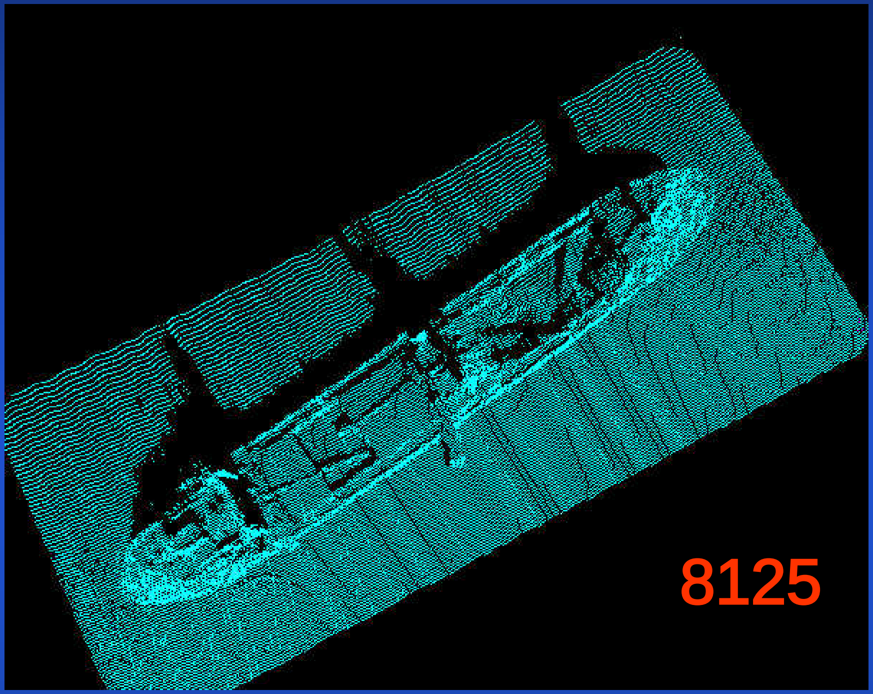


SEABAT 8125

Focused Sonar



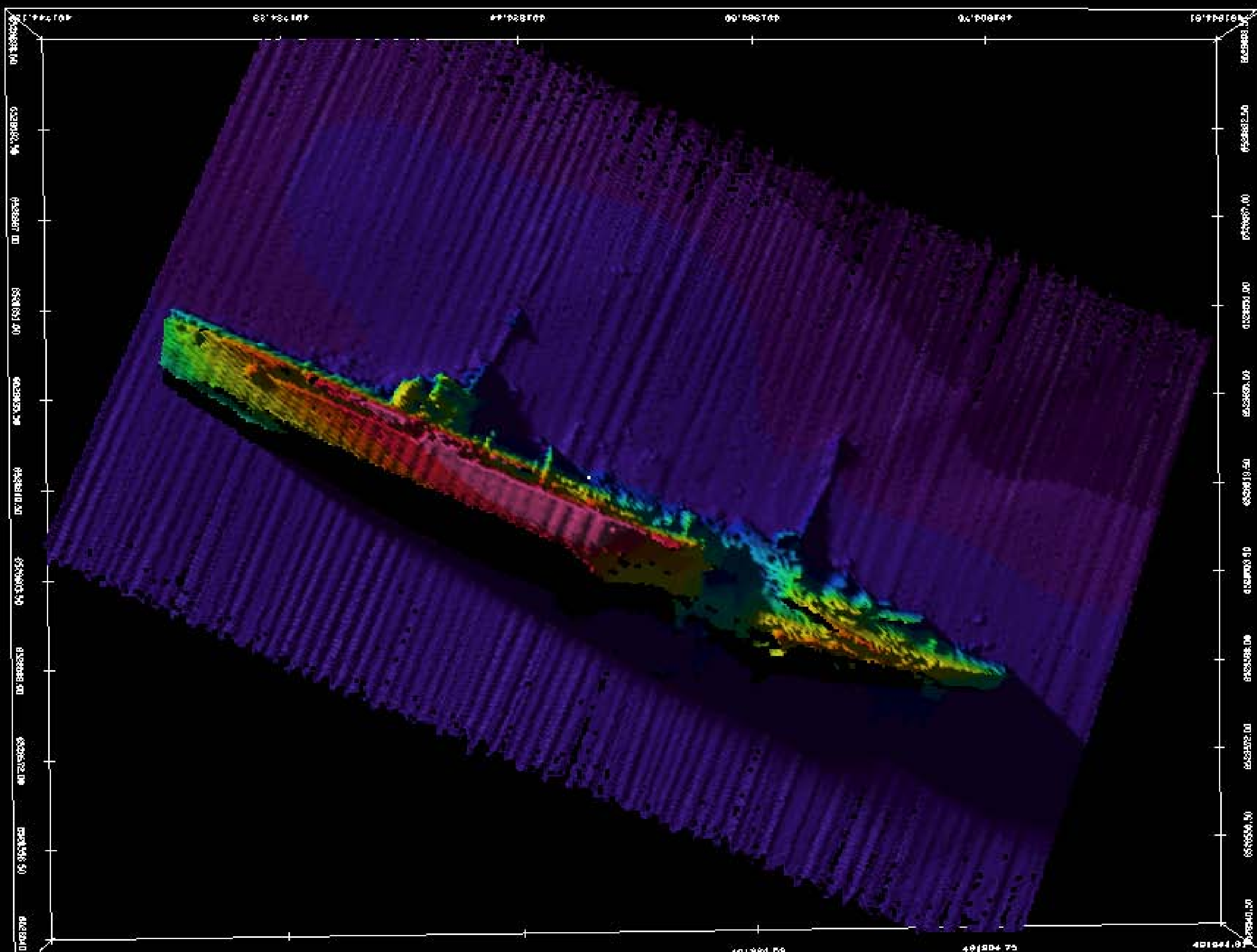
unfocused



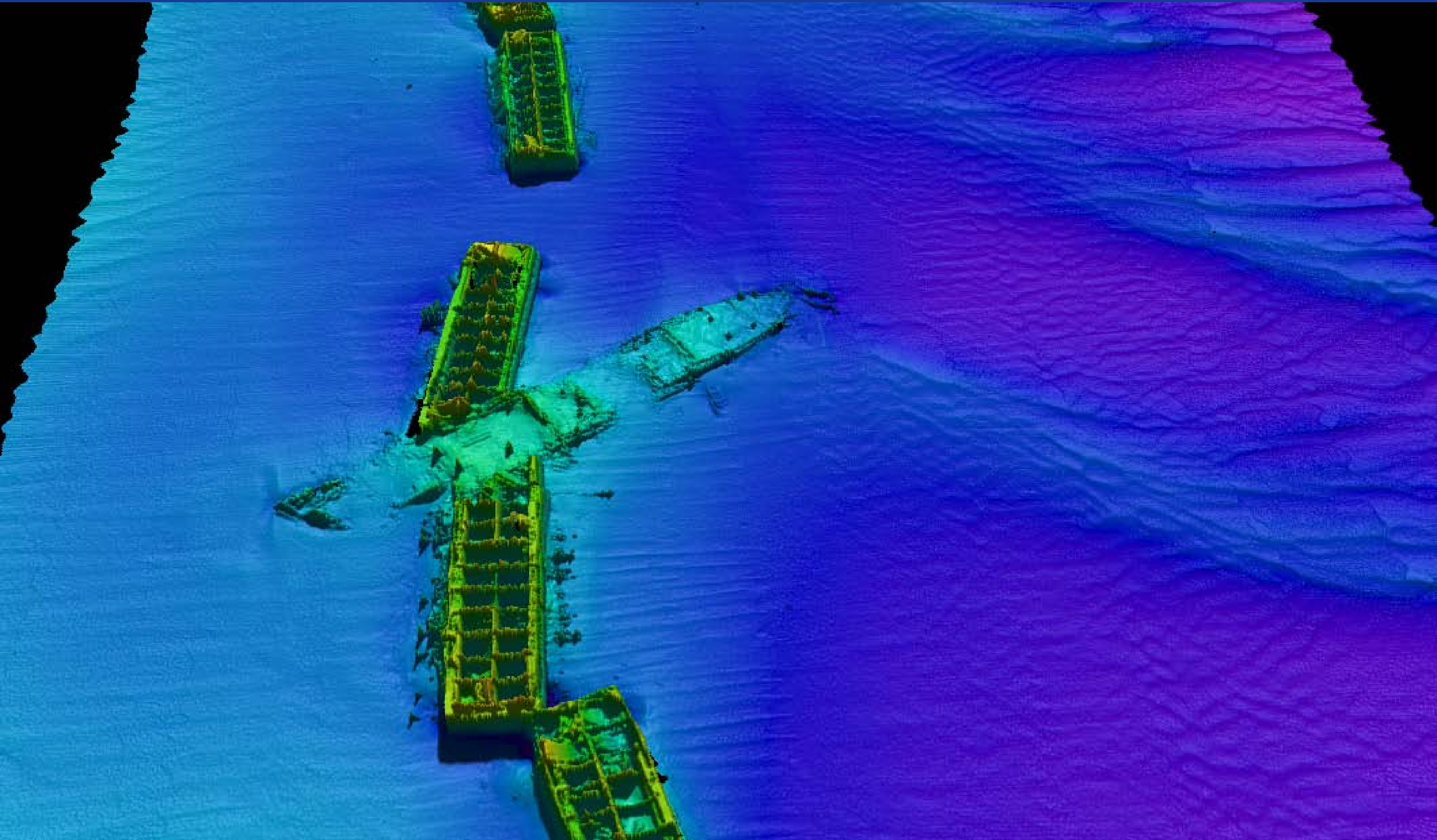
focused

SeaBat 8125 and 8101 bathymetry collected at 5 knots over the 103m long freighter, Al-Mansoura, in 50 m of water in the Persian Gulf after hitting a platform at night in 1985. (Courtesy of RESON)

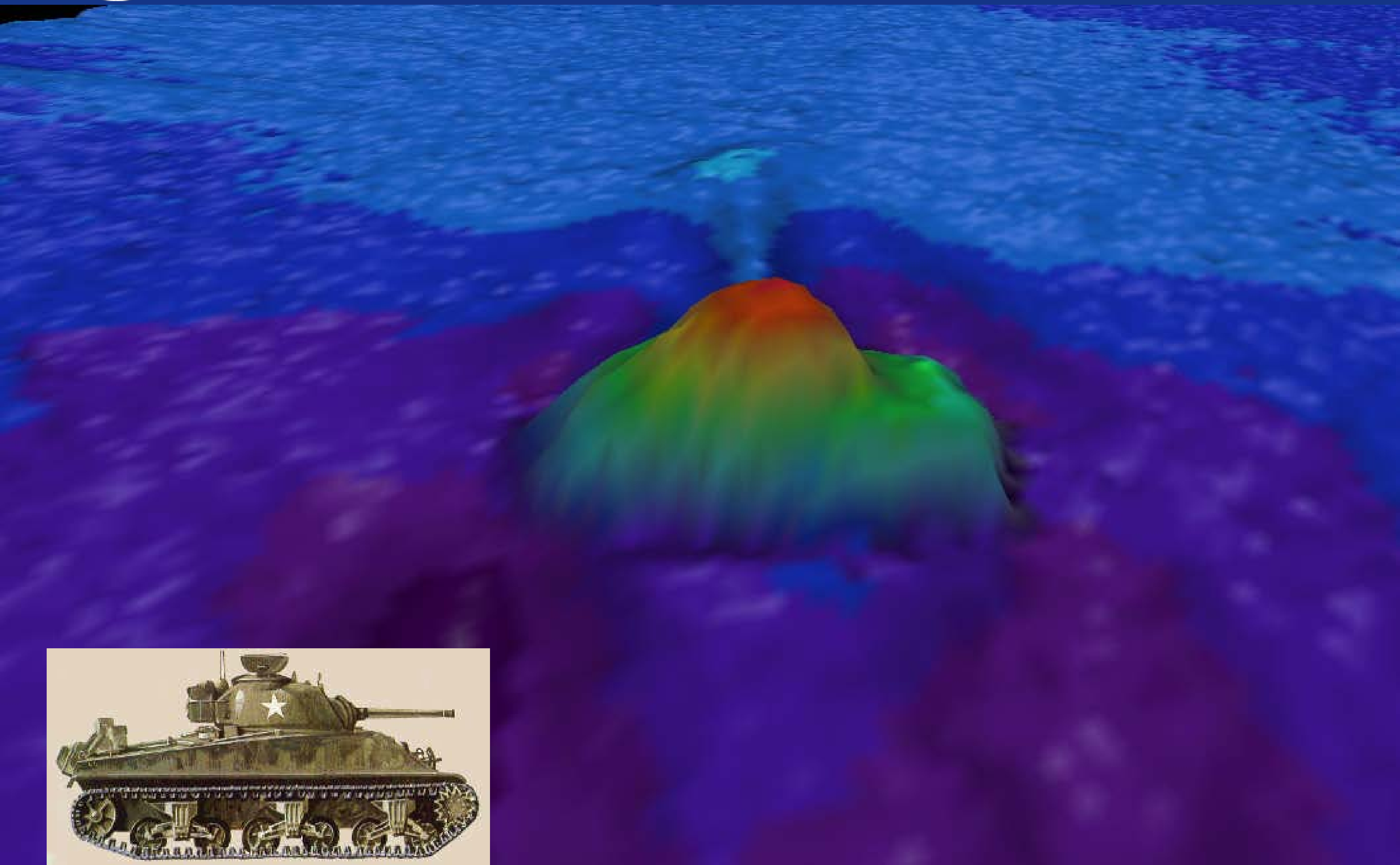
SCUTTLED GERMAN FLEET IN SCAPA FLOW



Mulberry Harbor off Omaha Beach



Sherman 'DD' Tank off Omaha Beach



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selected

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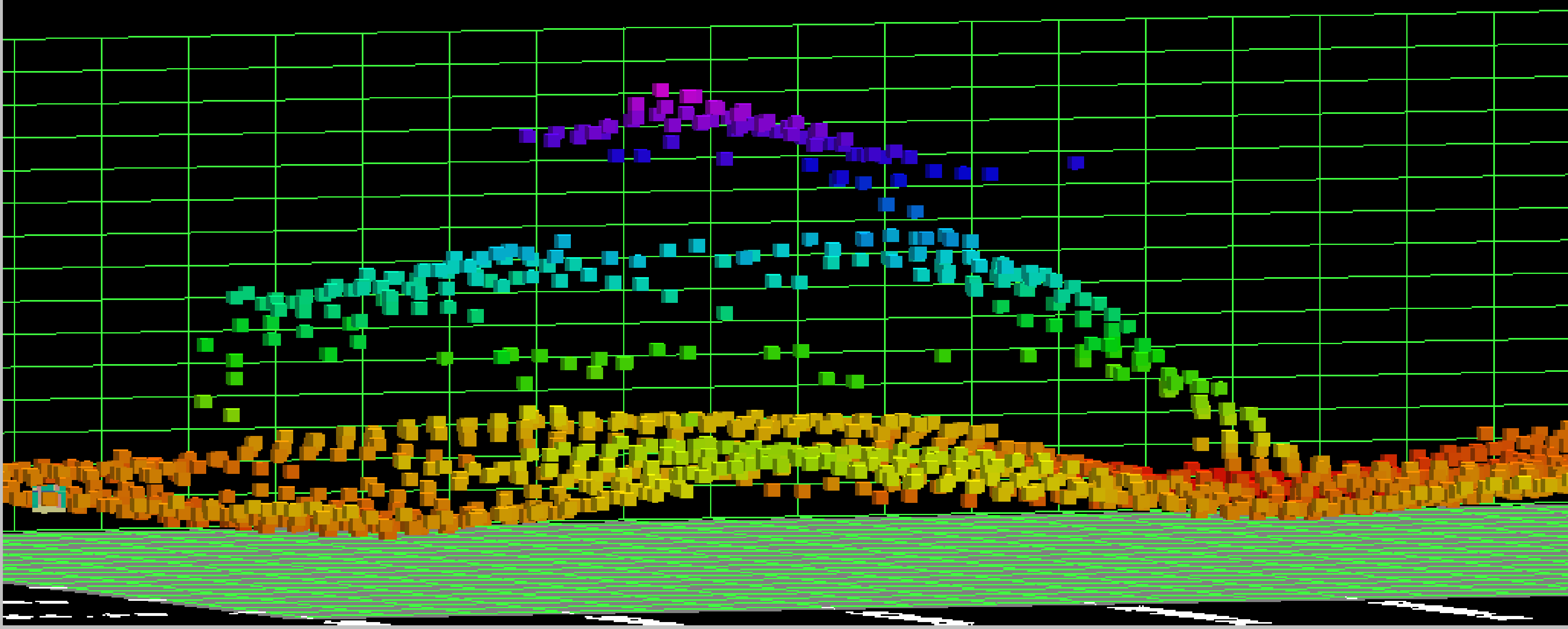
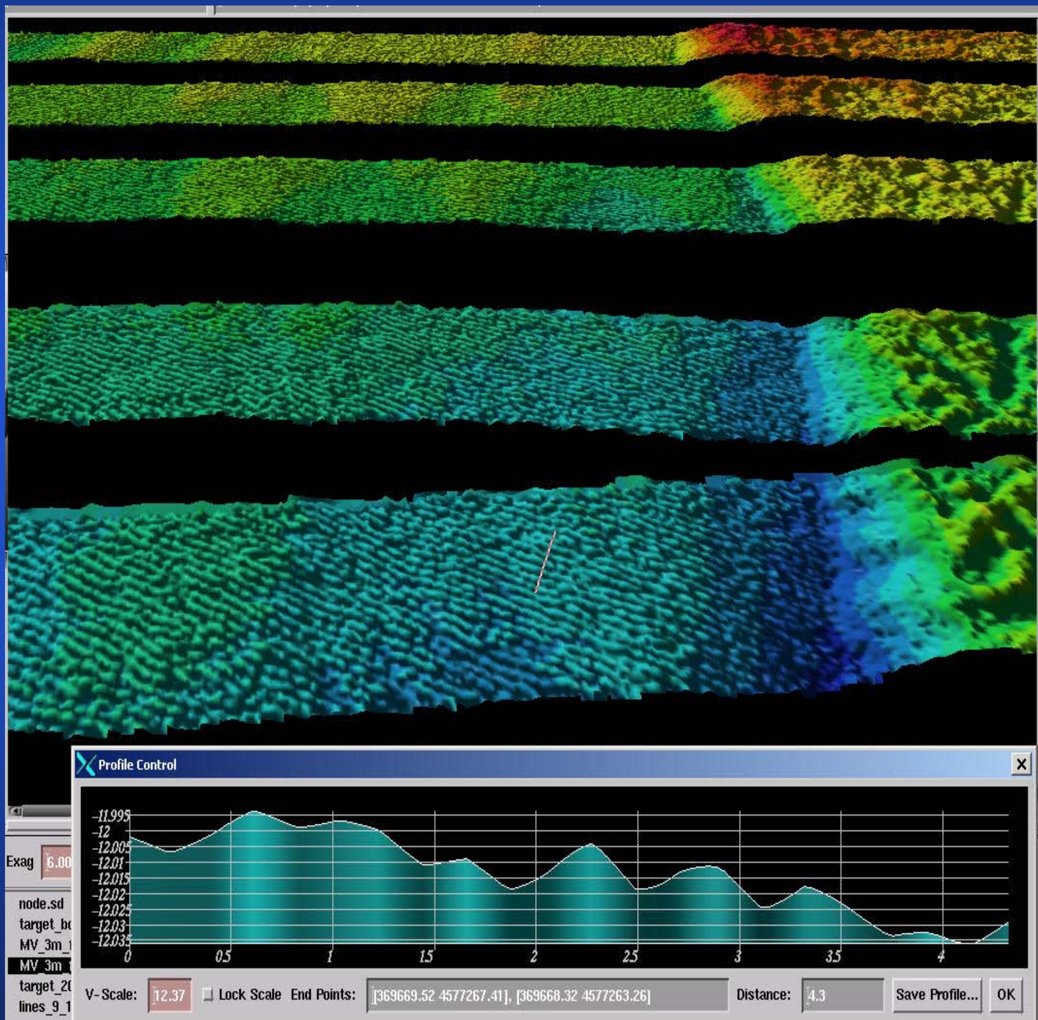
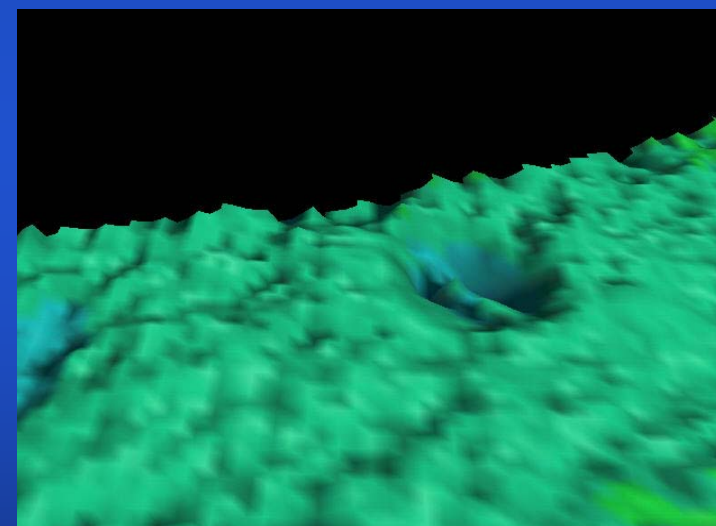
(0°49'17.3", 49°23'55.9", -18.24)

Sherman 'DD' Tank off Omaha Beach



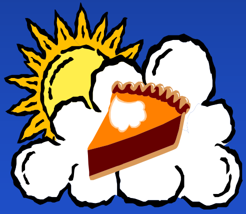
Martha's Vineyard Mine Burial Site





SONARS:

"CHIRP" multibeam sonars:



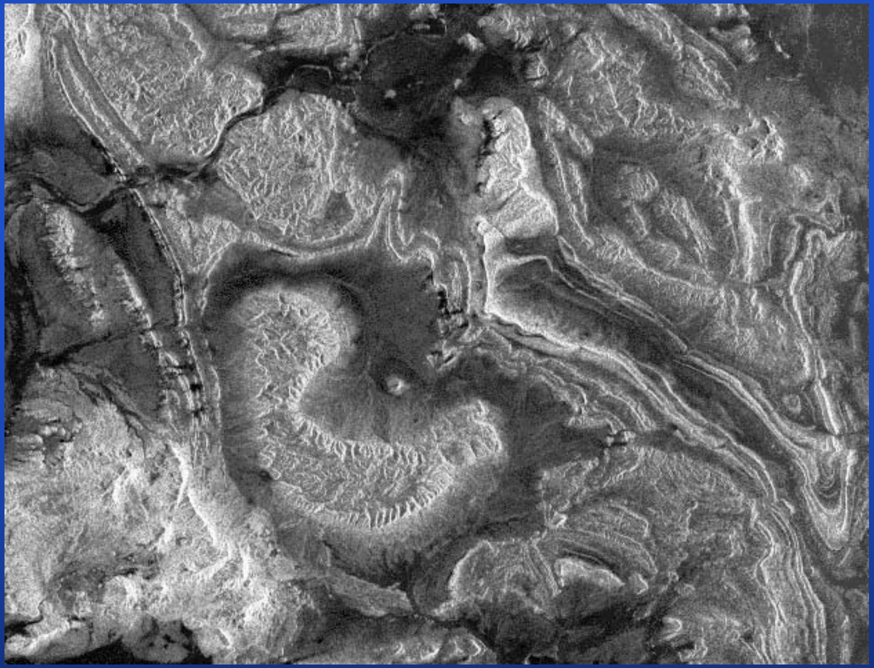
- Increased bandwidth = increased temporal resolution

- Increased bandwidth = multiple pings in water = increased sounding density

- Increased bandwidth = "multispectral" thematic mapping

The Beauty of Bandwidth

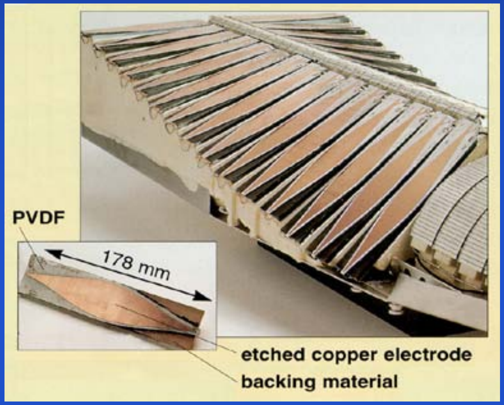
Radarsat



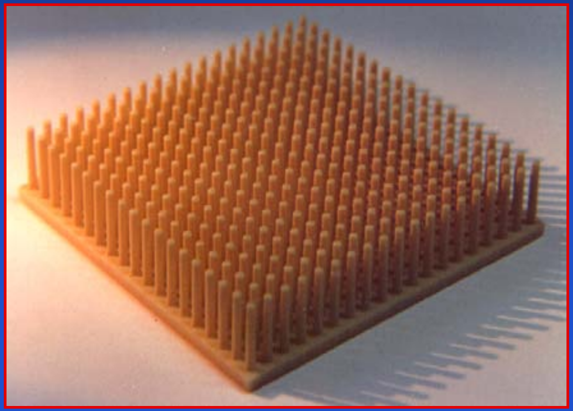
Narrow band

Full bandwidth

New Transducer Materials:

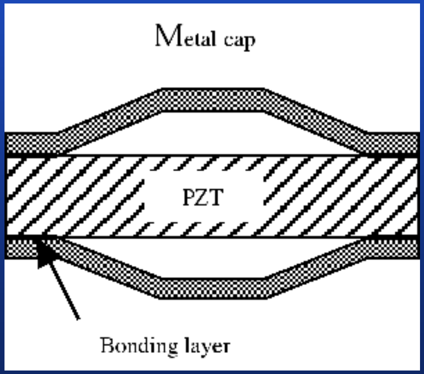


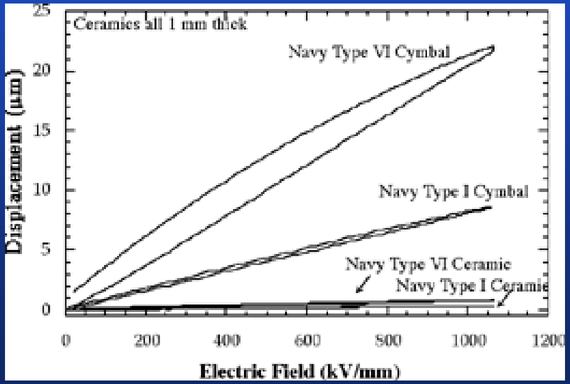
PVDF **p**oly**v**inyl**d**ene **f**luoride
(Airmar Corp)

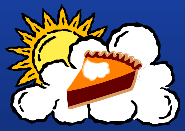


1-3 Piezocomposite
(Materials Systems Inc)

cymbals

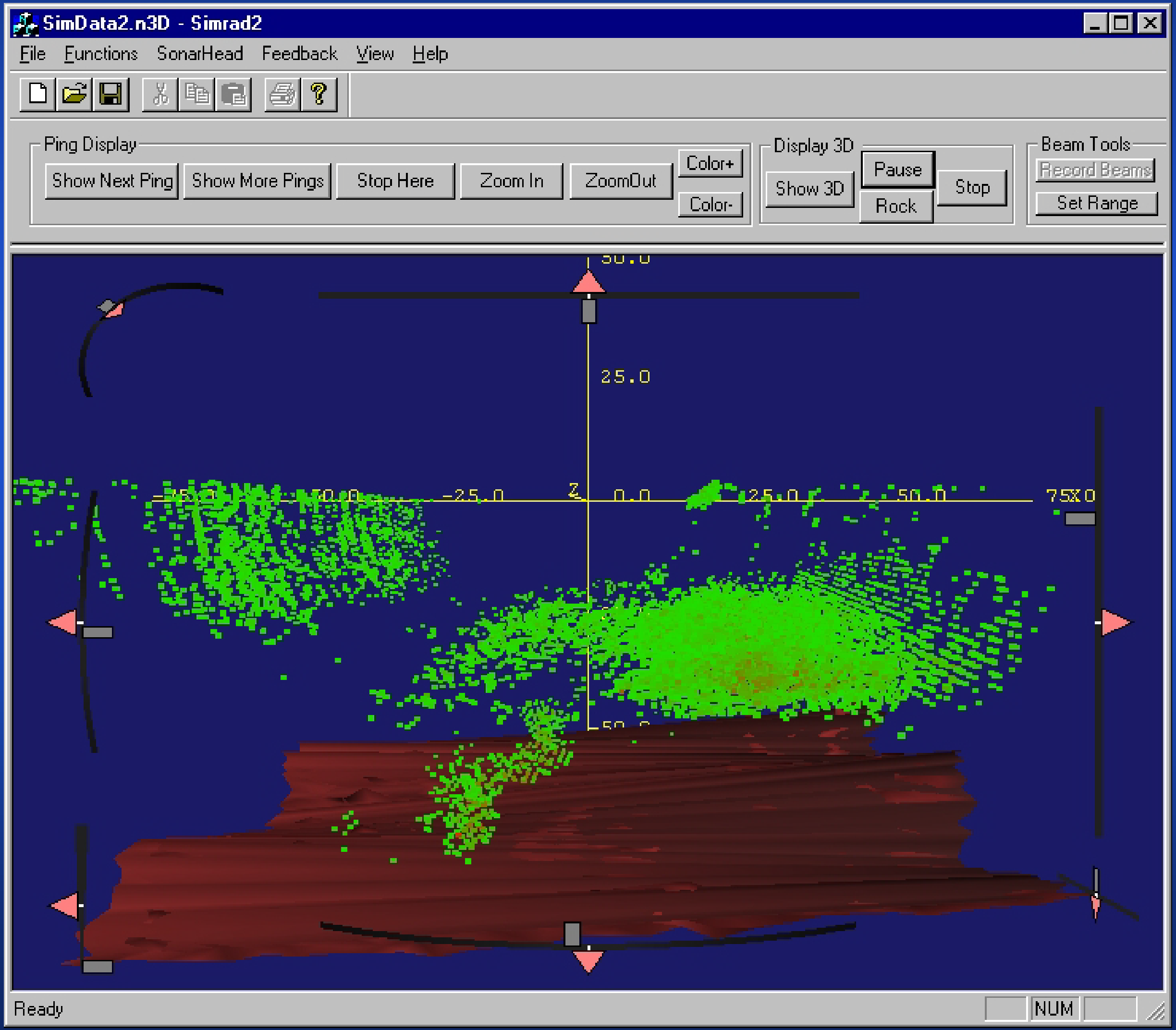




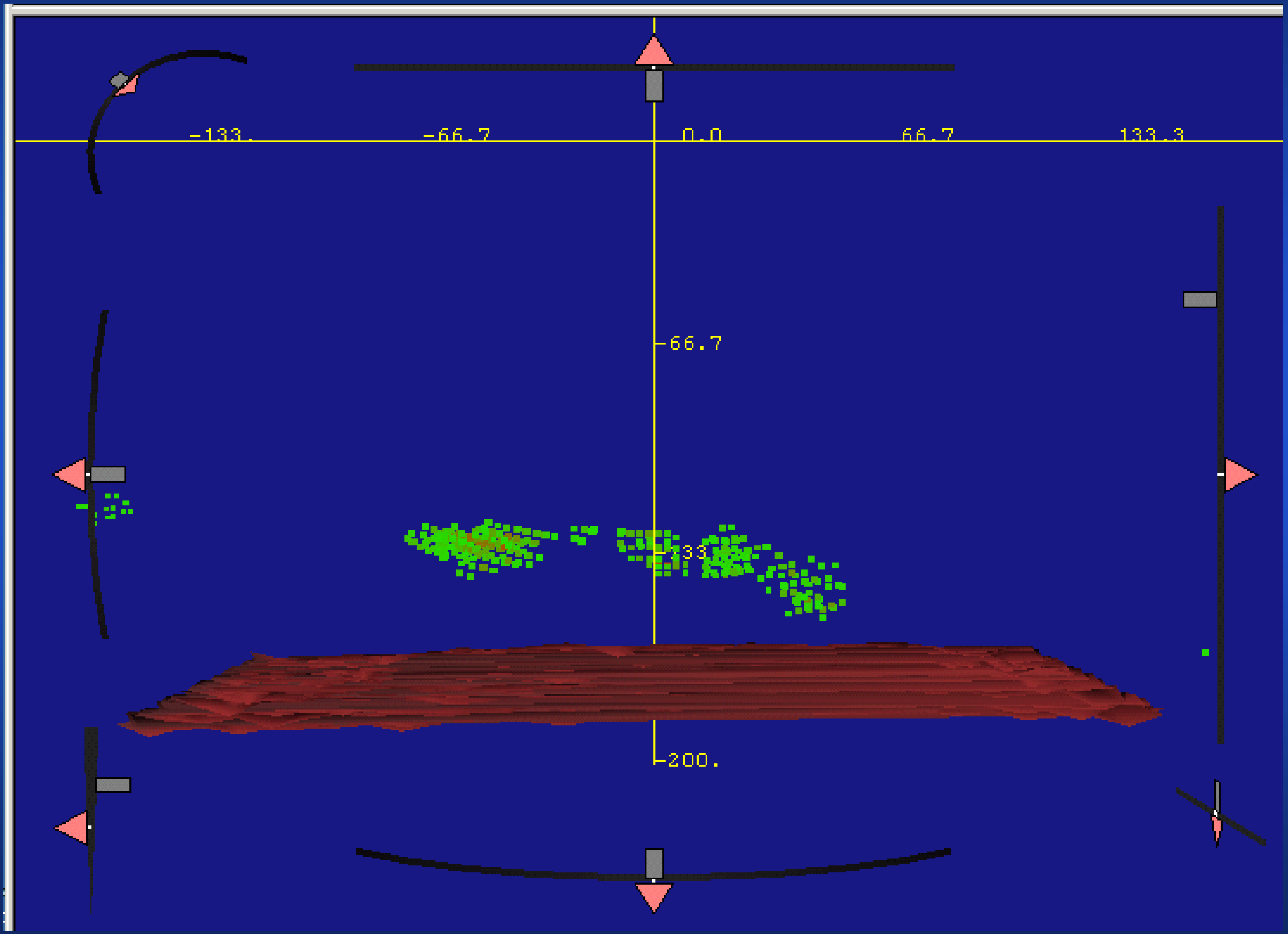


Mapping the water column:

SM2000



Midwater target mapping



SENSORS:

Motion Sensors:

Tightly integrated inertial/GPS

Attitude - .01 deg (RTK)
Heading - .02 deg (RTK or DGPS)
Velocity - .01 m/sec (RTK)
Position - .02 - .10 m (RTK)
200 Hz update rate

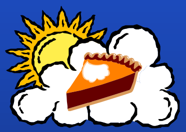
Continued improvements - not limiting factor

SENSORS:

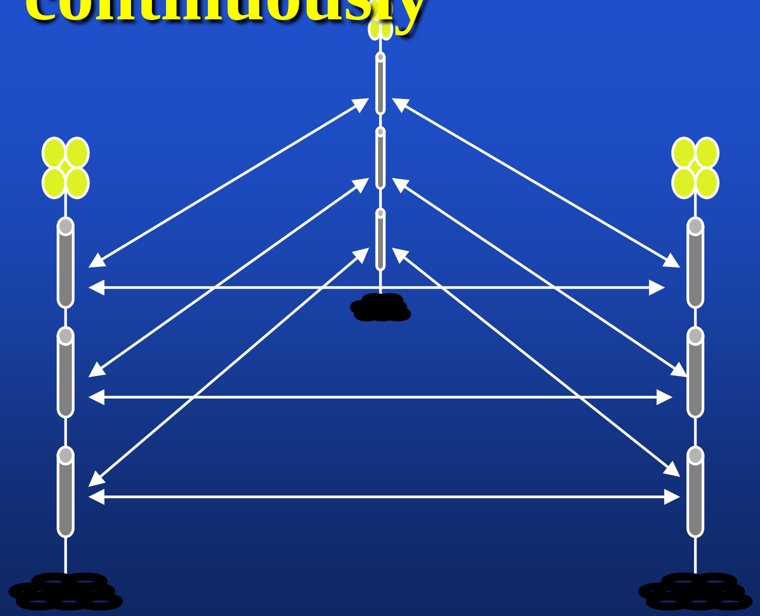
Sound Speed Profile:

Still biggest source of error

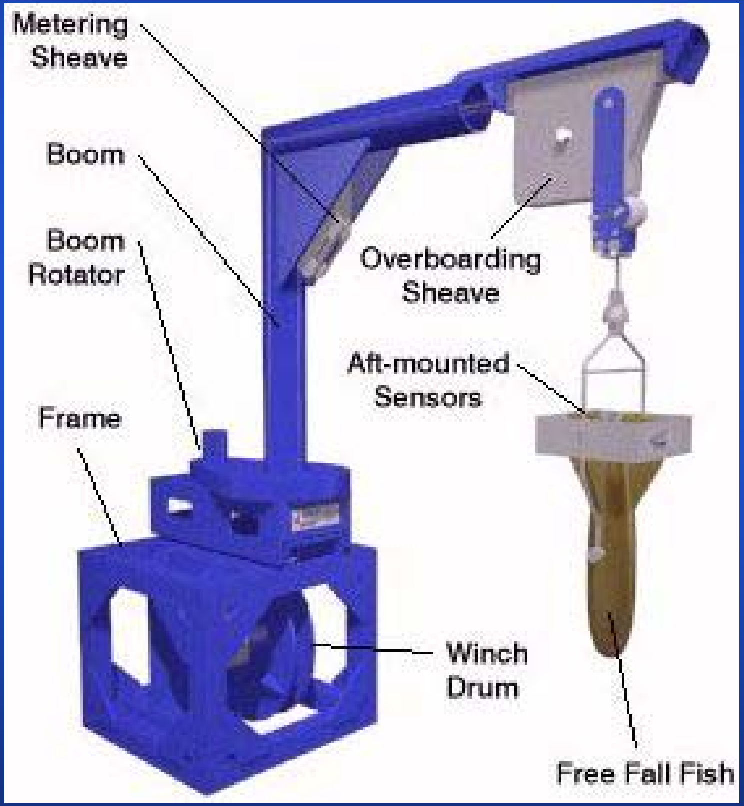
- Improved MVP and other continuously profiling sensors

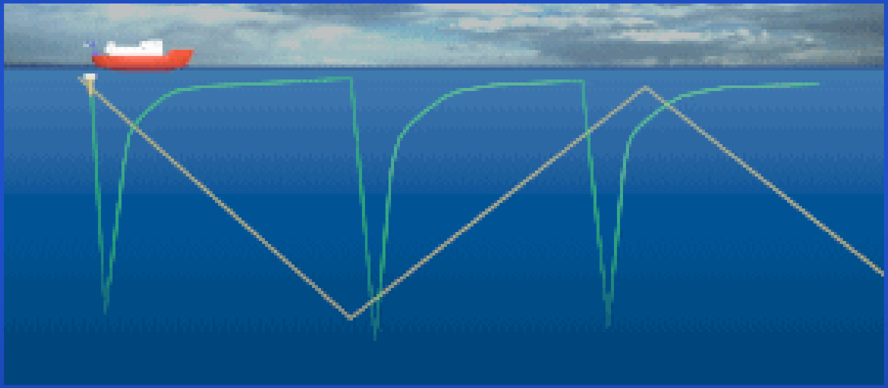


- Tomographic arrays

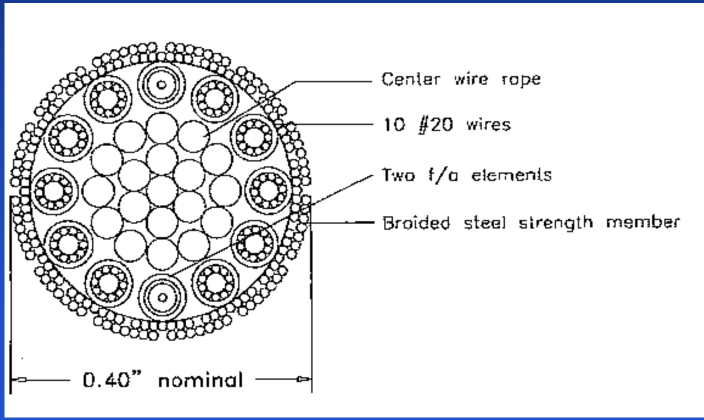


Moving Vessel Profiler

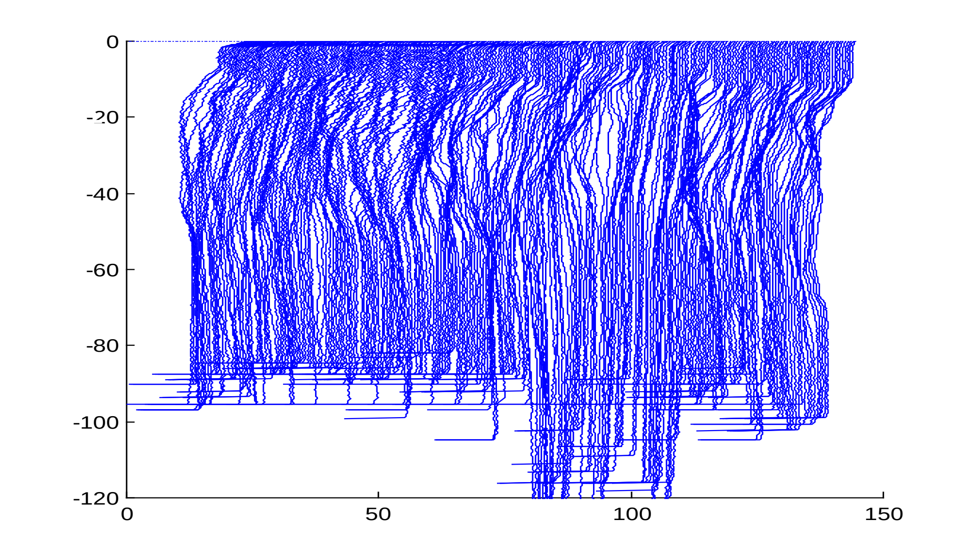




Instrumented Tow Cable



Sampled temperature data collected from South of New England using the LBVDS Instrumented Tow Cable in June 2000.



Temperature Profiles every 2 minutes over 12 hours
Units: Degrees C (offset by time in minutes since comex)

Sampled temperature data collected from South of New England using the Instrumented Tow Cable in June 2000

- Cable Characteristics
  - Unfaired 0.40” Diameter Steel Cable
  - Weight in Air = 0.22 lb/ft
  - Total Length = 6000 ft
  - Winch: 54” width; 48” height; 38” depth; 1000 kg
  - Achievable Depth = 400 ft at 16 knots
  - Survival Speed = 30 Knots
  - Depth and Temperature Sensor at bottom

PLATFORMS:

The future of deepwater mapping is SHALLOW WATER MAPPING

Hugin AUV

PLATFORMS:

ROV's and particularly AUV's:

•HIGH RESOLUTION BATHYMETRY

Example - 2000m Depth:

Surface Ship - 7.0m Depth Resolution

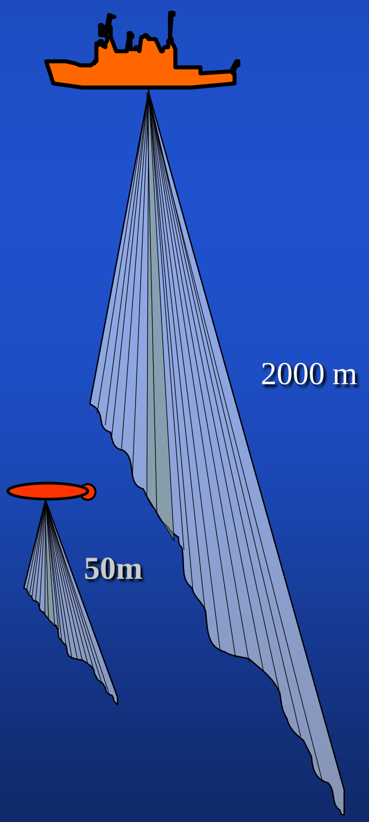
AUV - 0.2m Depth Resolution

•HIGH RESOLUTION CO-LOCATED IMAGERY

Example - 2000m Depth:

Surface Ship - 40.0m pixel

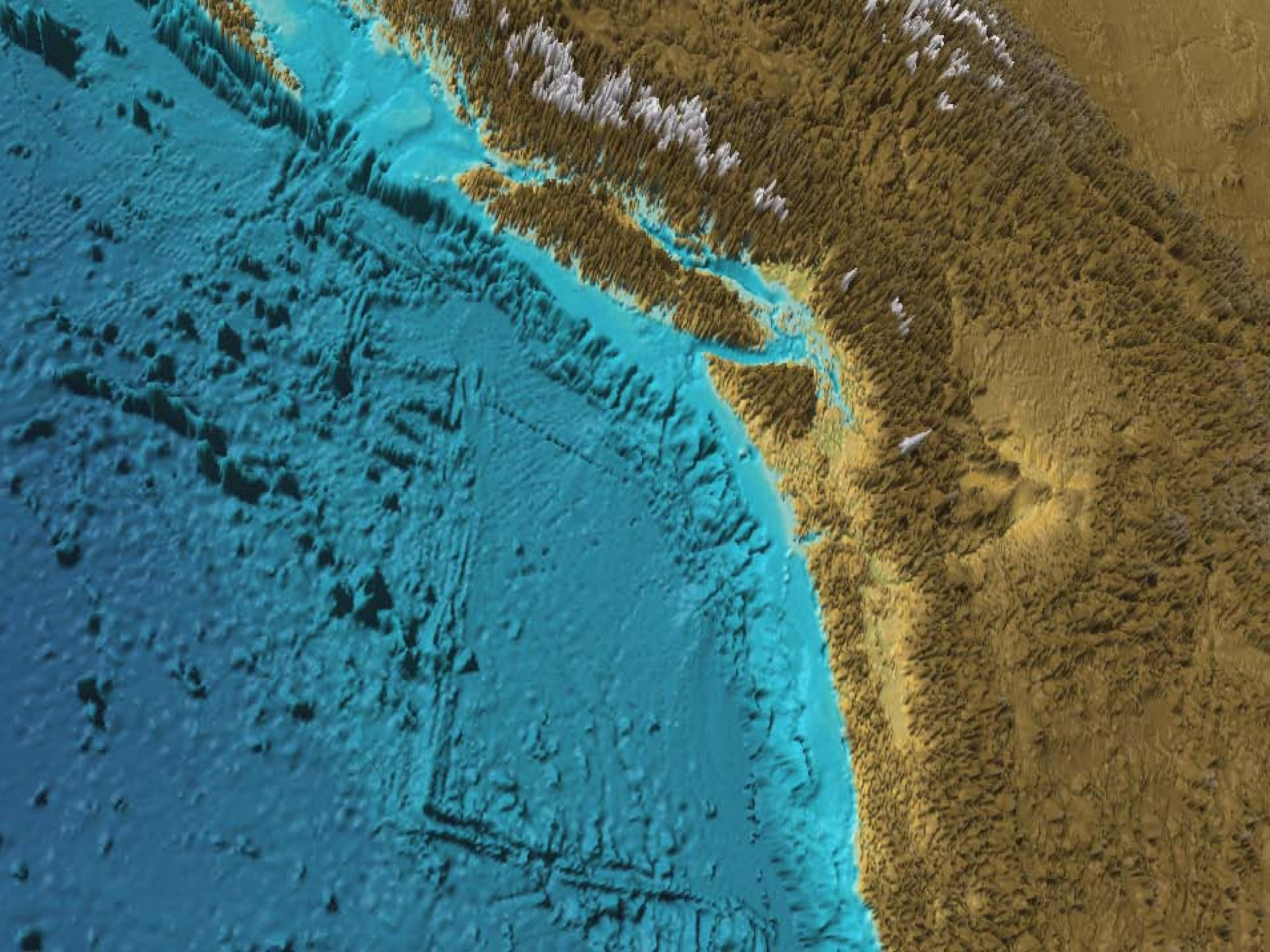
AUV - 0.5m pixel

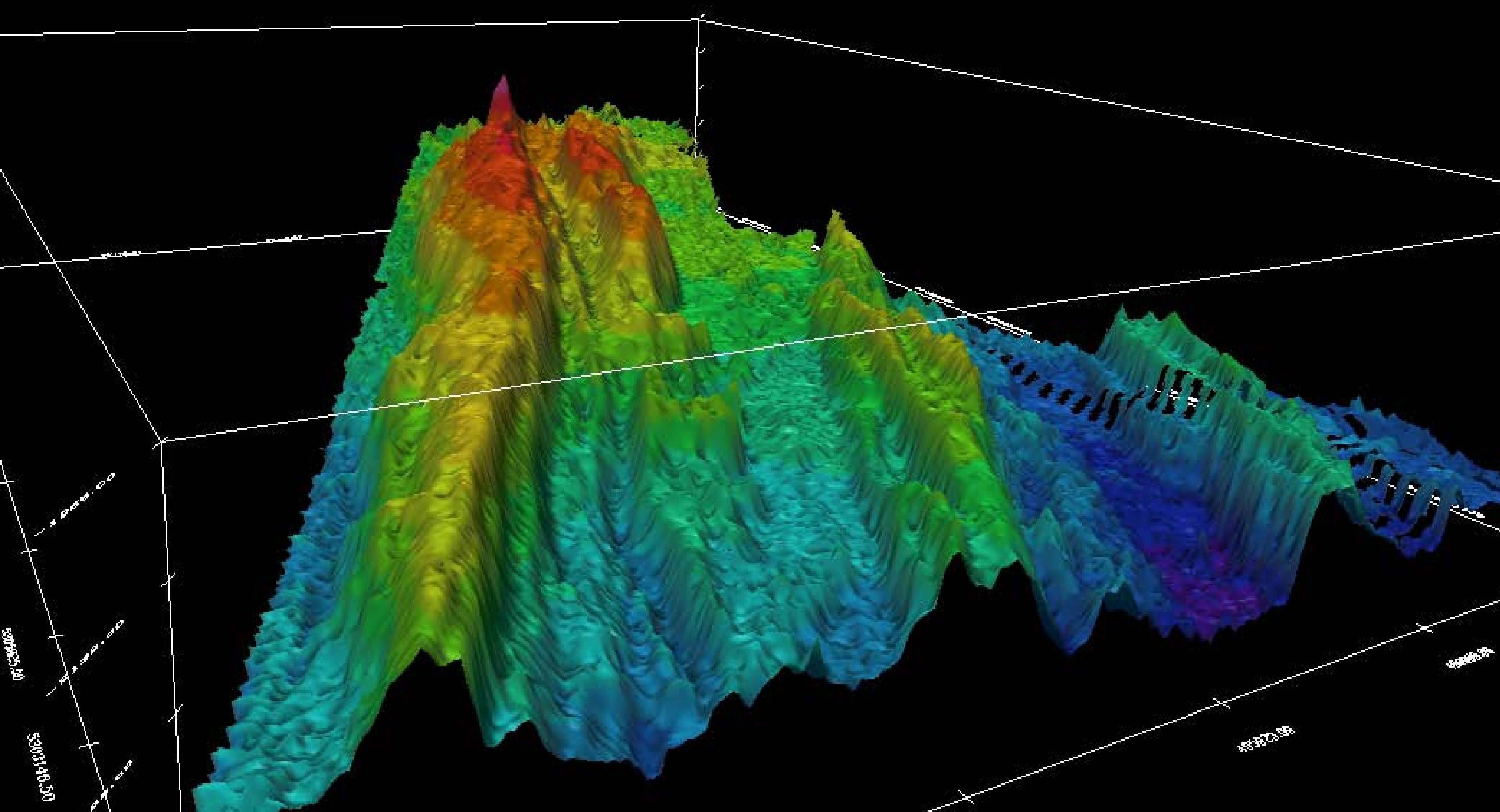


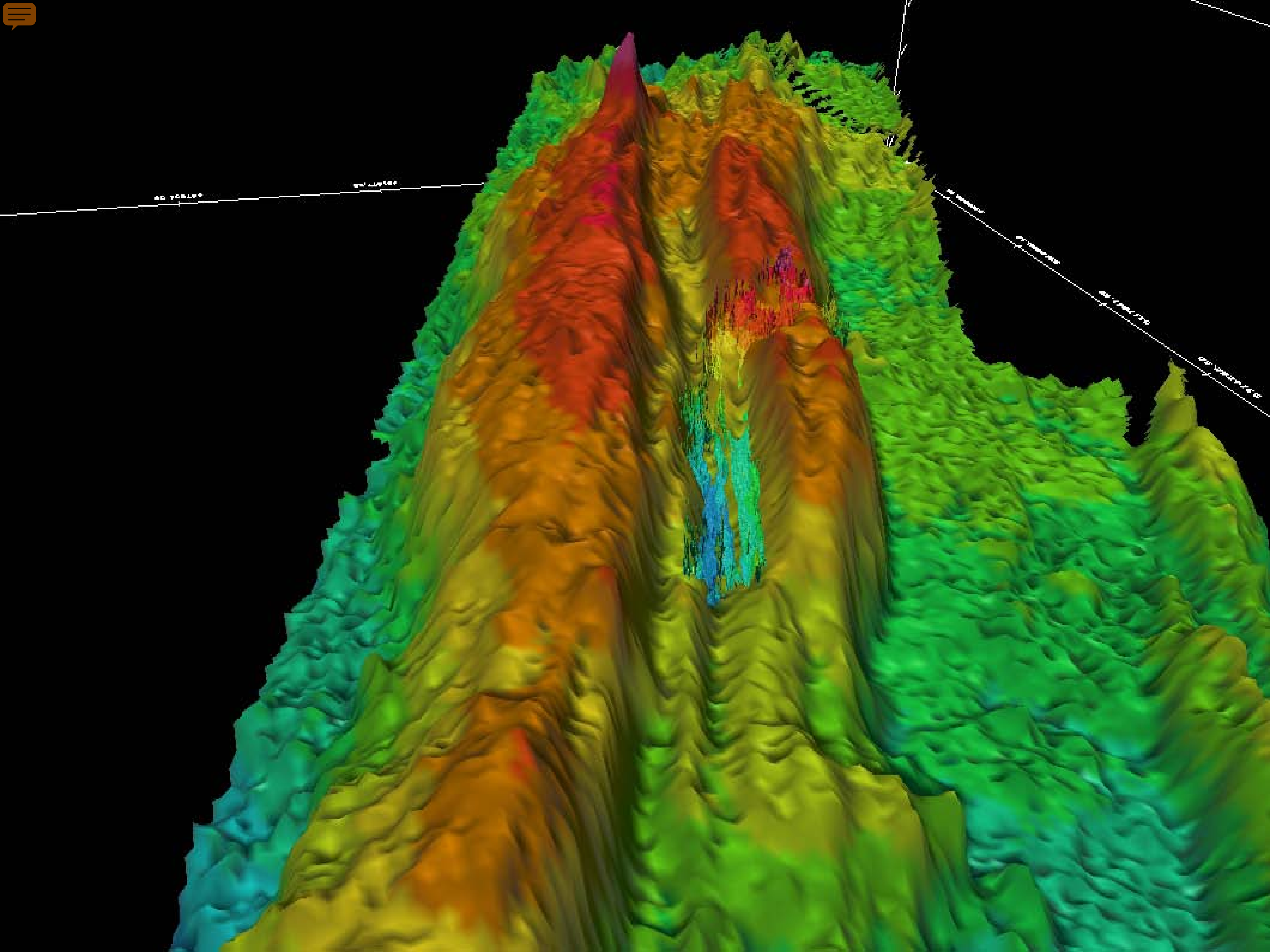
NESTED SURVEYS:

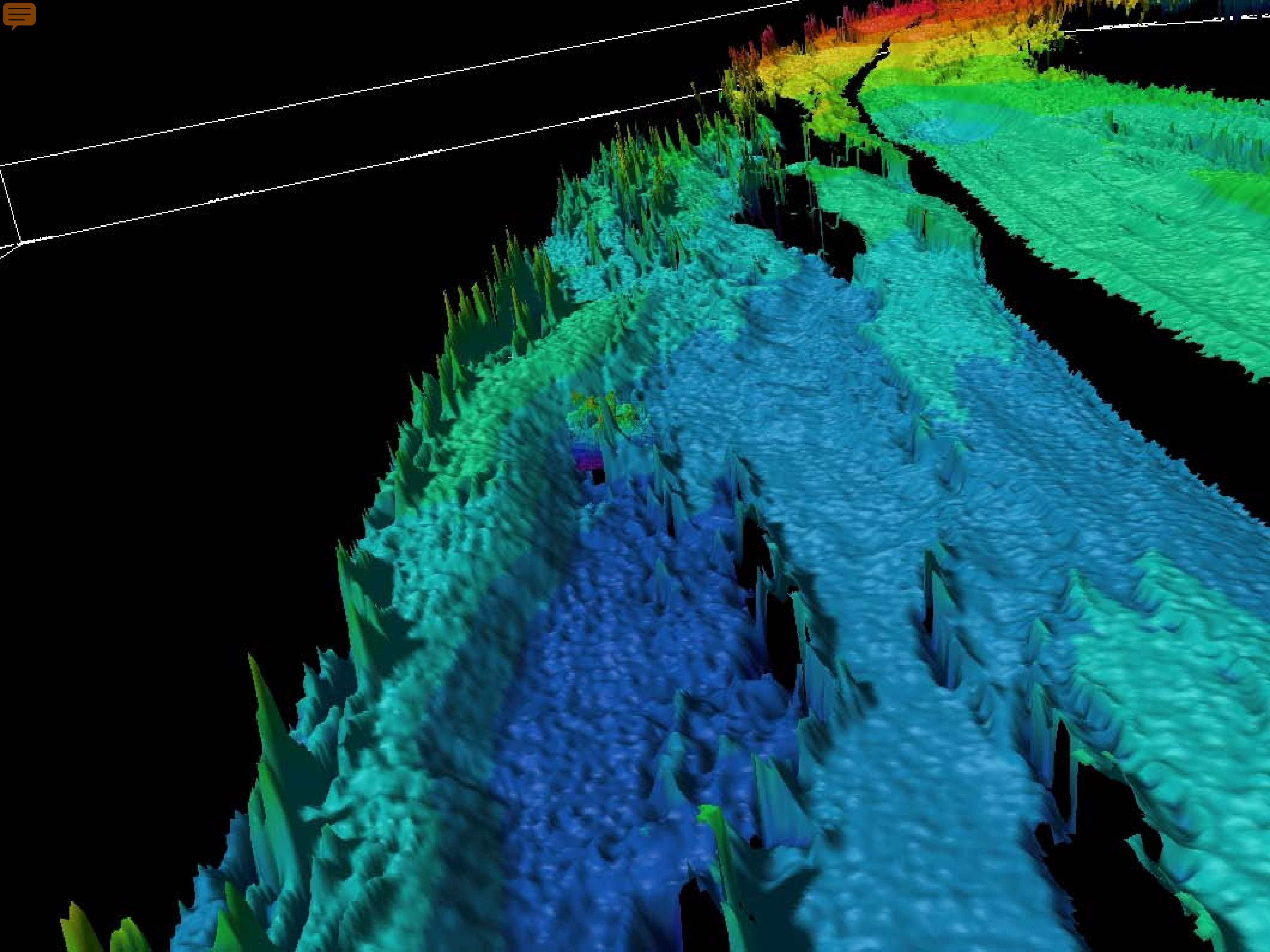
Satellite, Multibeam, Deep Tow, ROV, Submersible

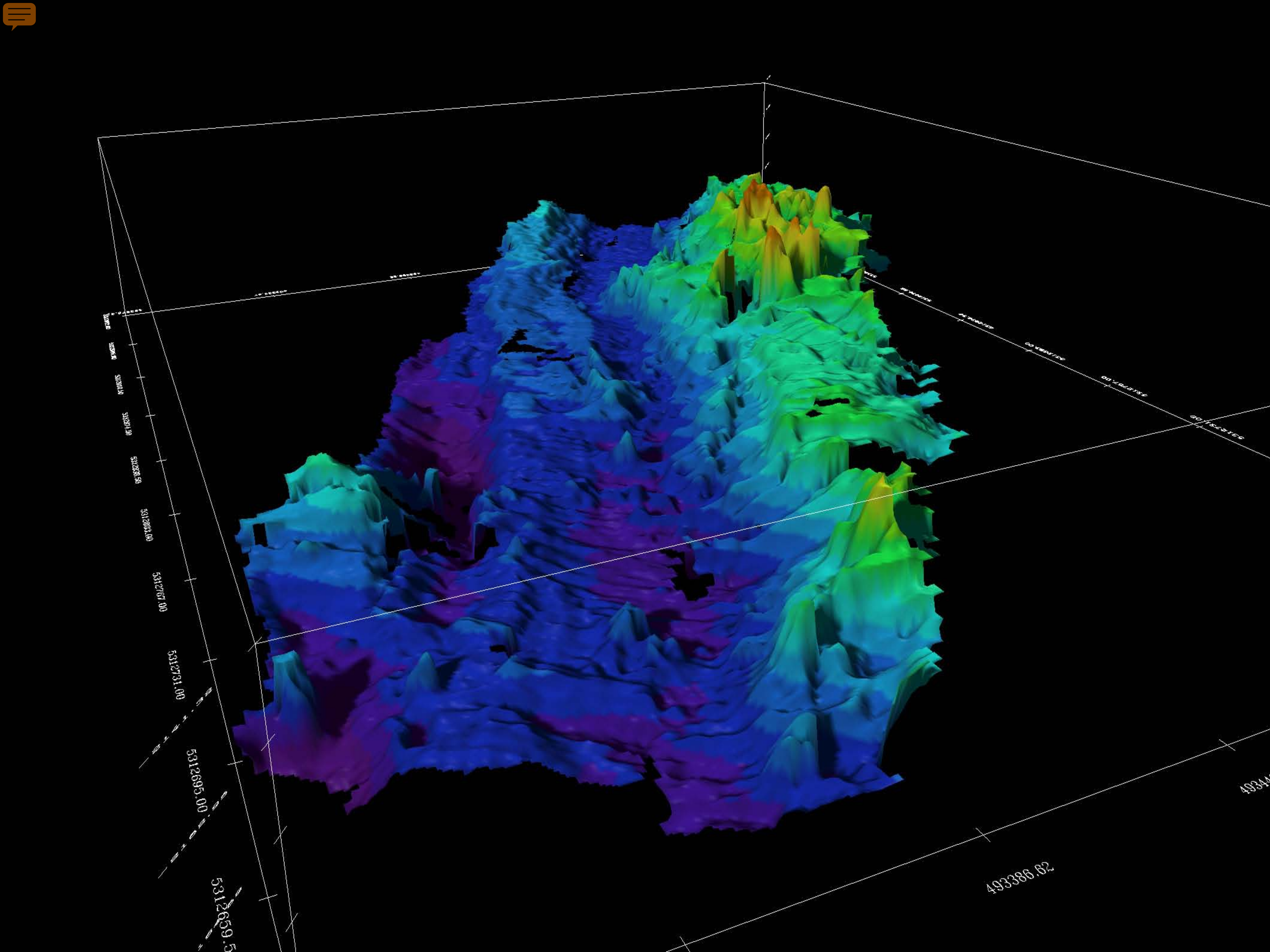
- an example from ROPOS -- poor man’s multibeam -- IMAGENIX sector scanner











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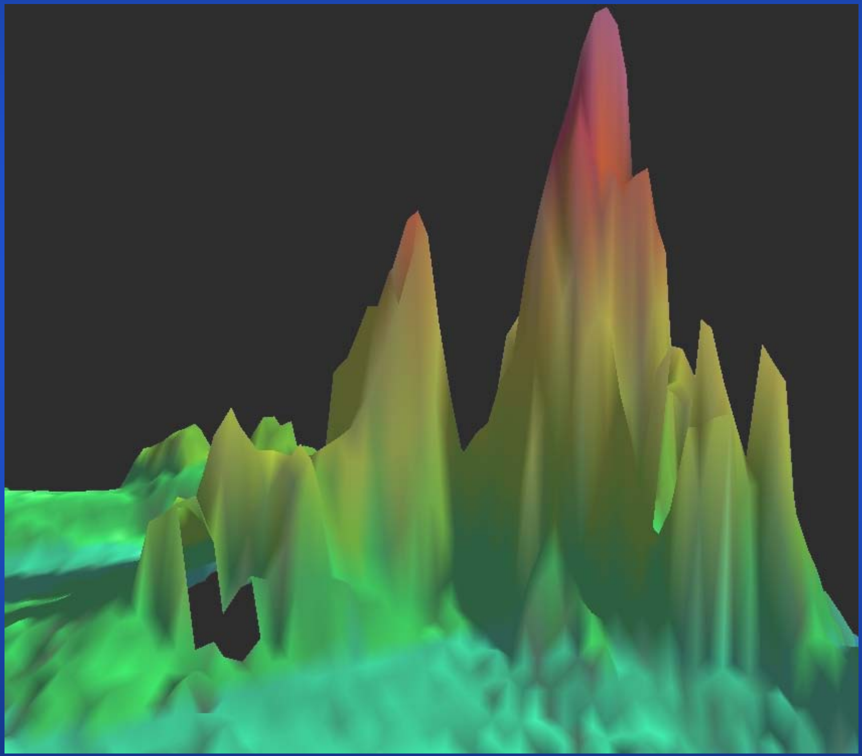
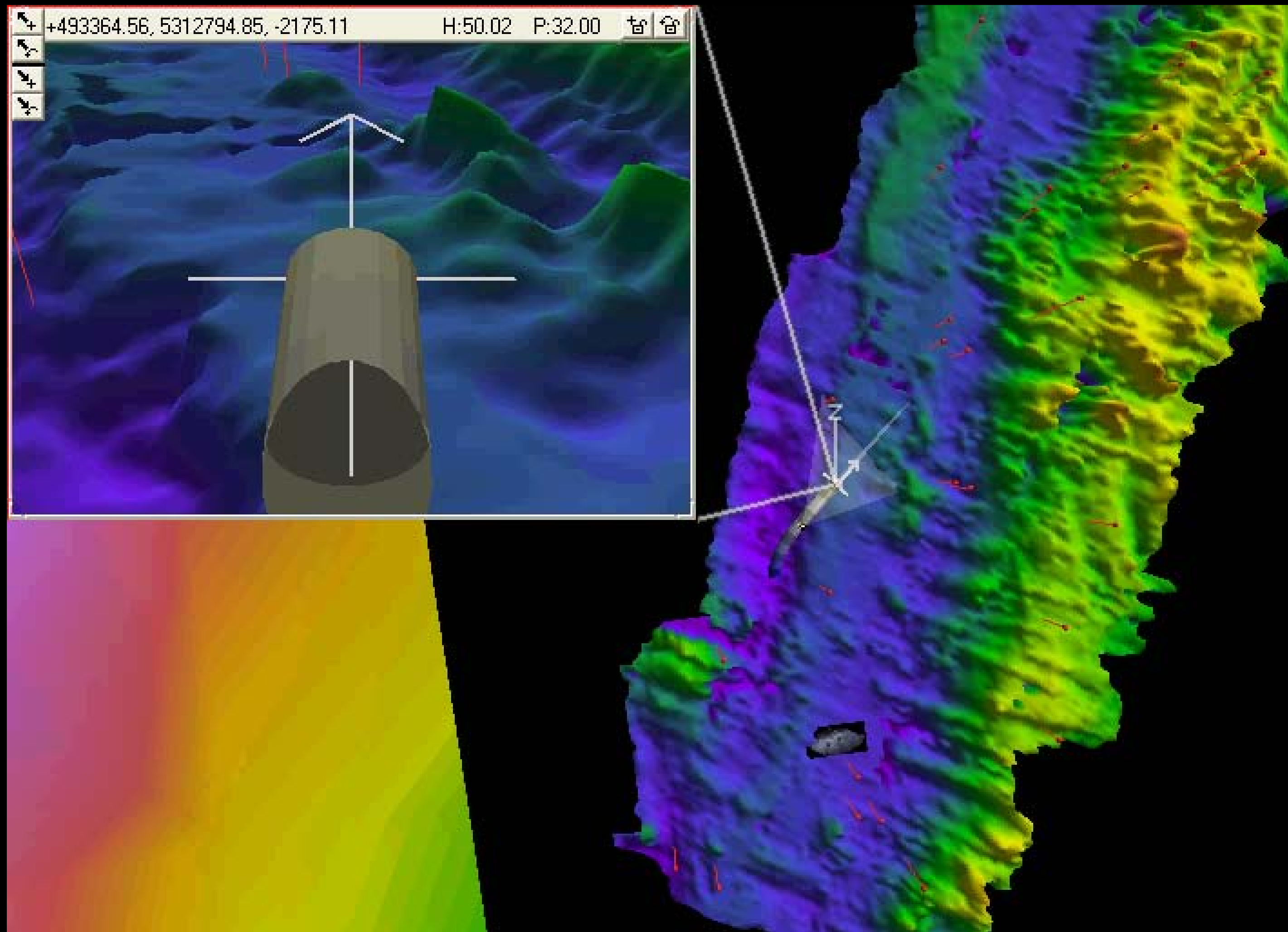
Juan de Fuca Ridge

Mothra Hydrothermal Field



3-D acoustic image of Mothra field from Imagenix sonar data

Photomosaic of Mothra field generated by Univ. of Washington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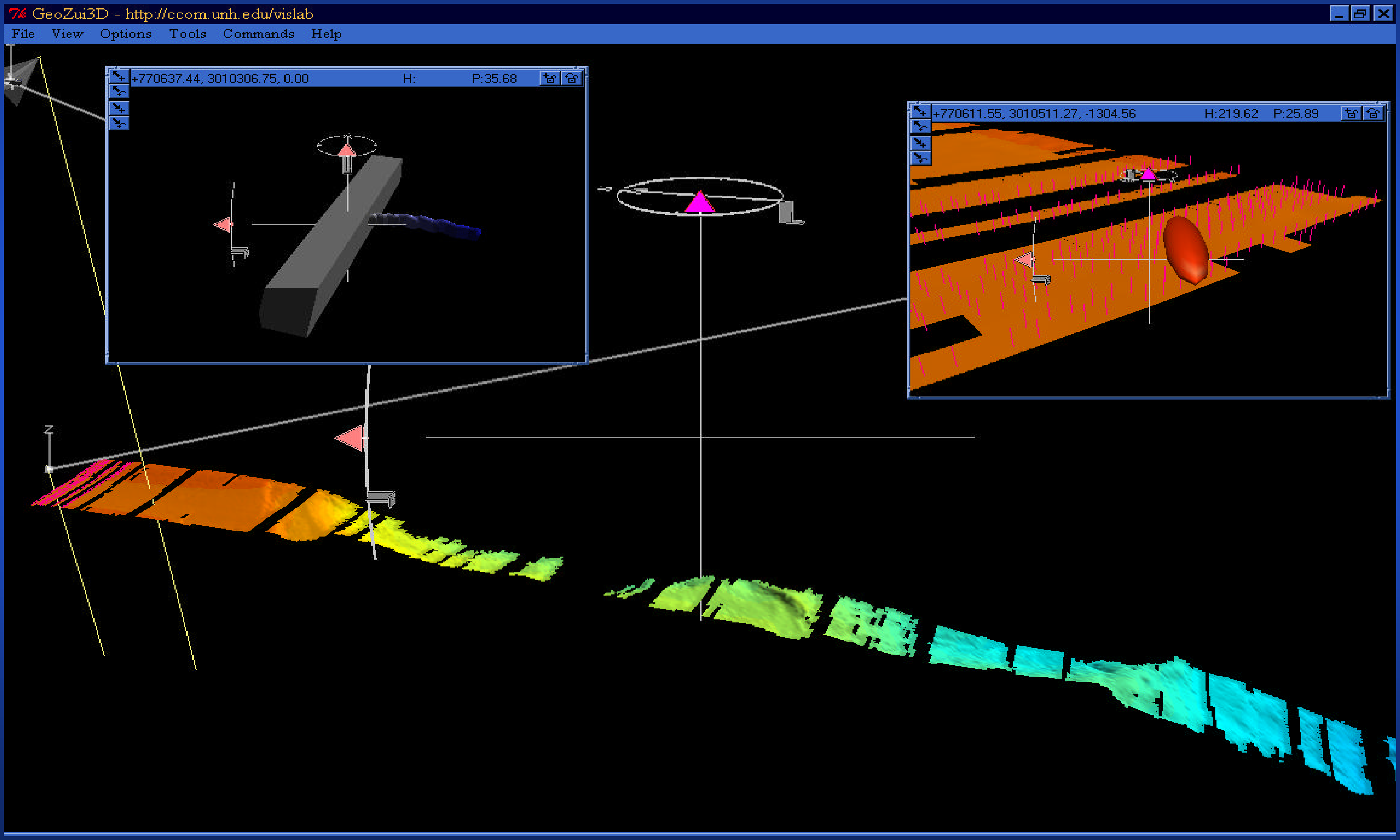
P:32.00
Z

Real-time 3-D visualization of AUV data



PROCESSING:

- Faster
- Cheaper
- Better

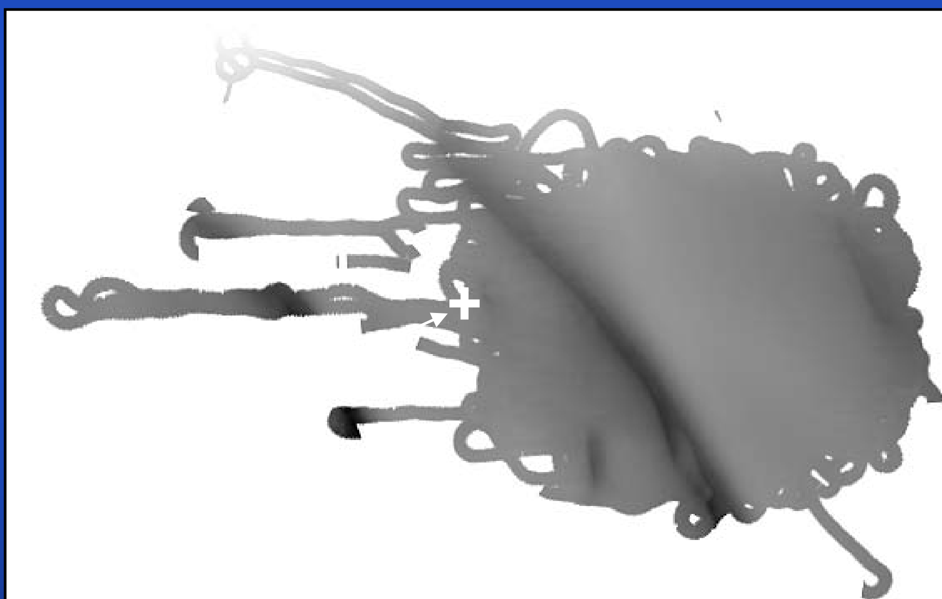
CUBE

Combined Uncertainty and Bathymetry Estimator --

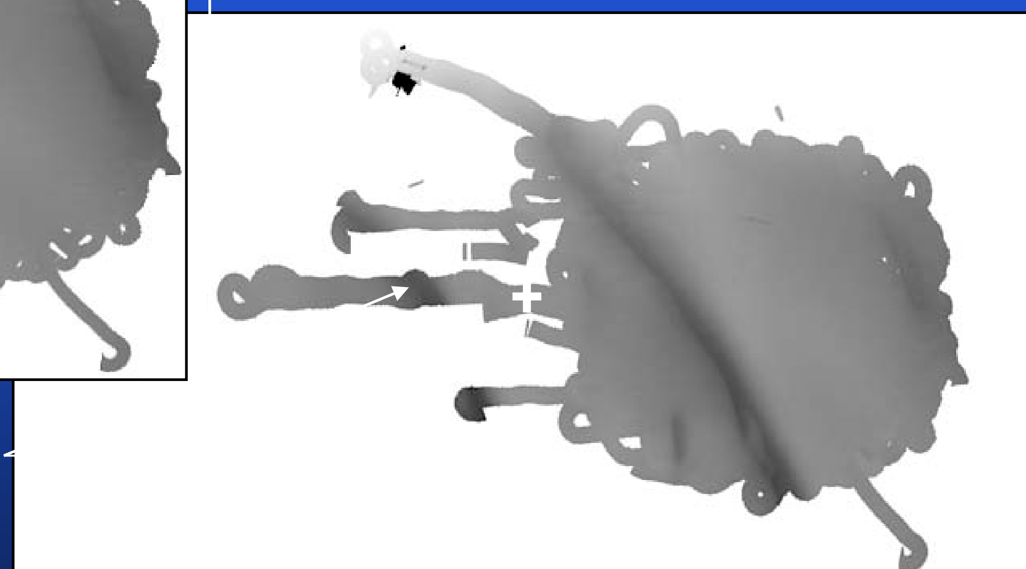
Brian Calder

Hand Edited – 48 hours

4820m



CUBE Edited – 10 minutes



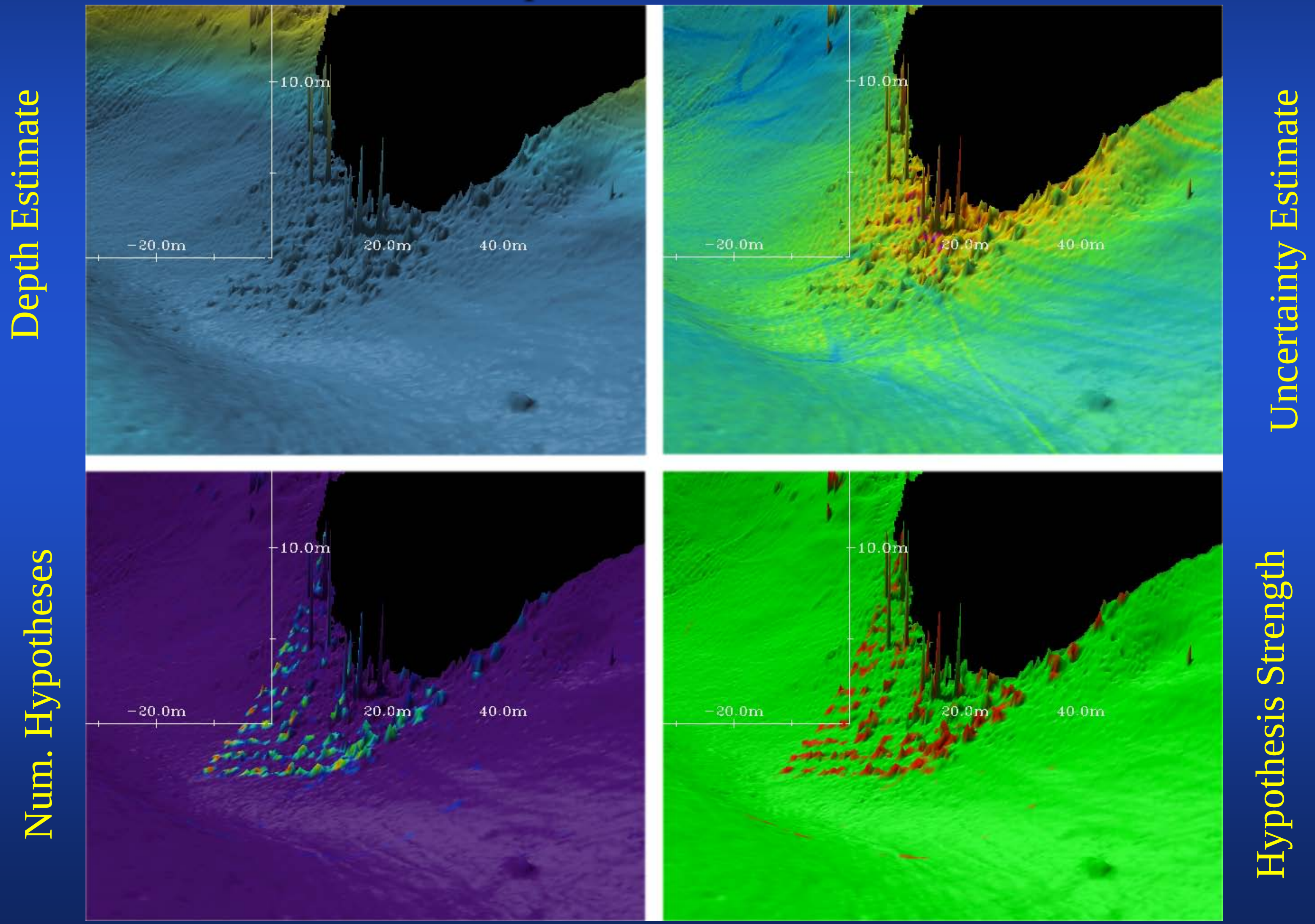
Projection: Mercator
Ellipsoid: WGS84

Projection: UTM
Ellipsoid: WGS84

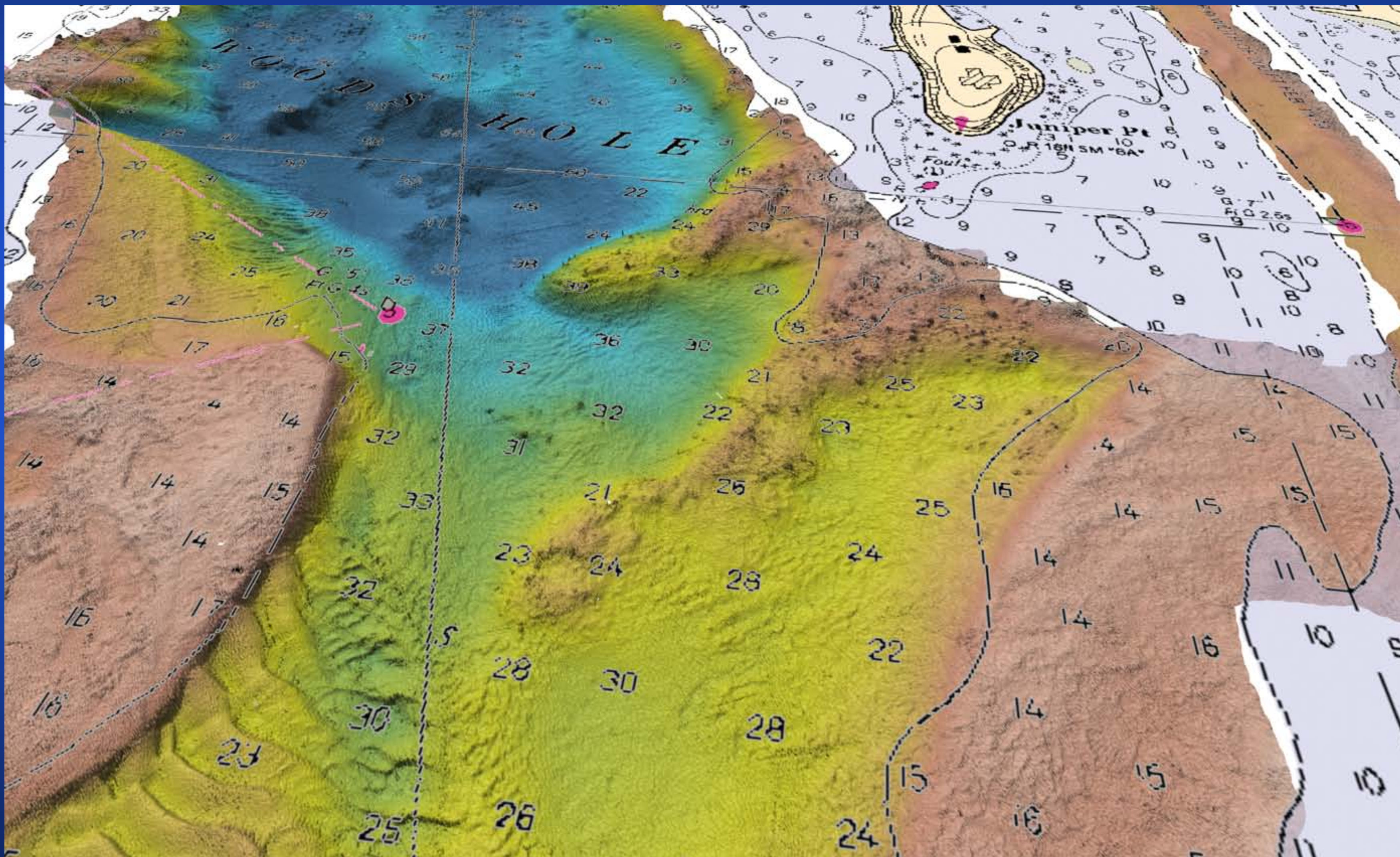
CUBE

Combined Uncertainty and Bathymetric Estimator

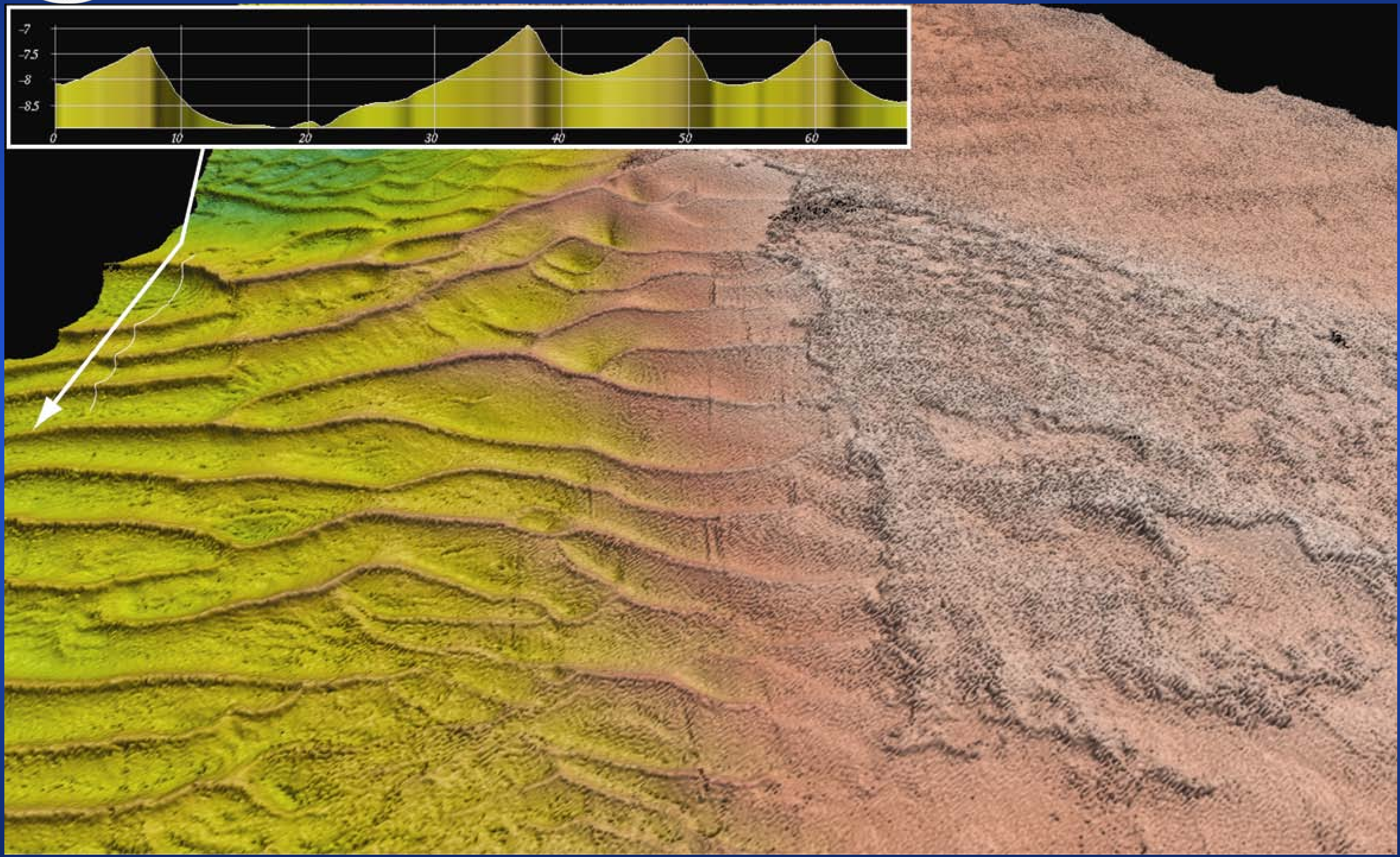
Output Surface Data



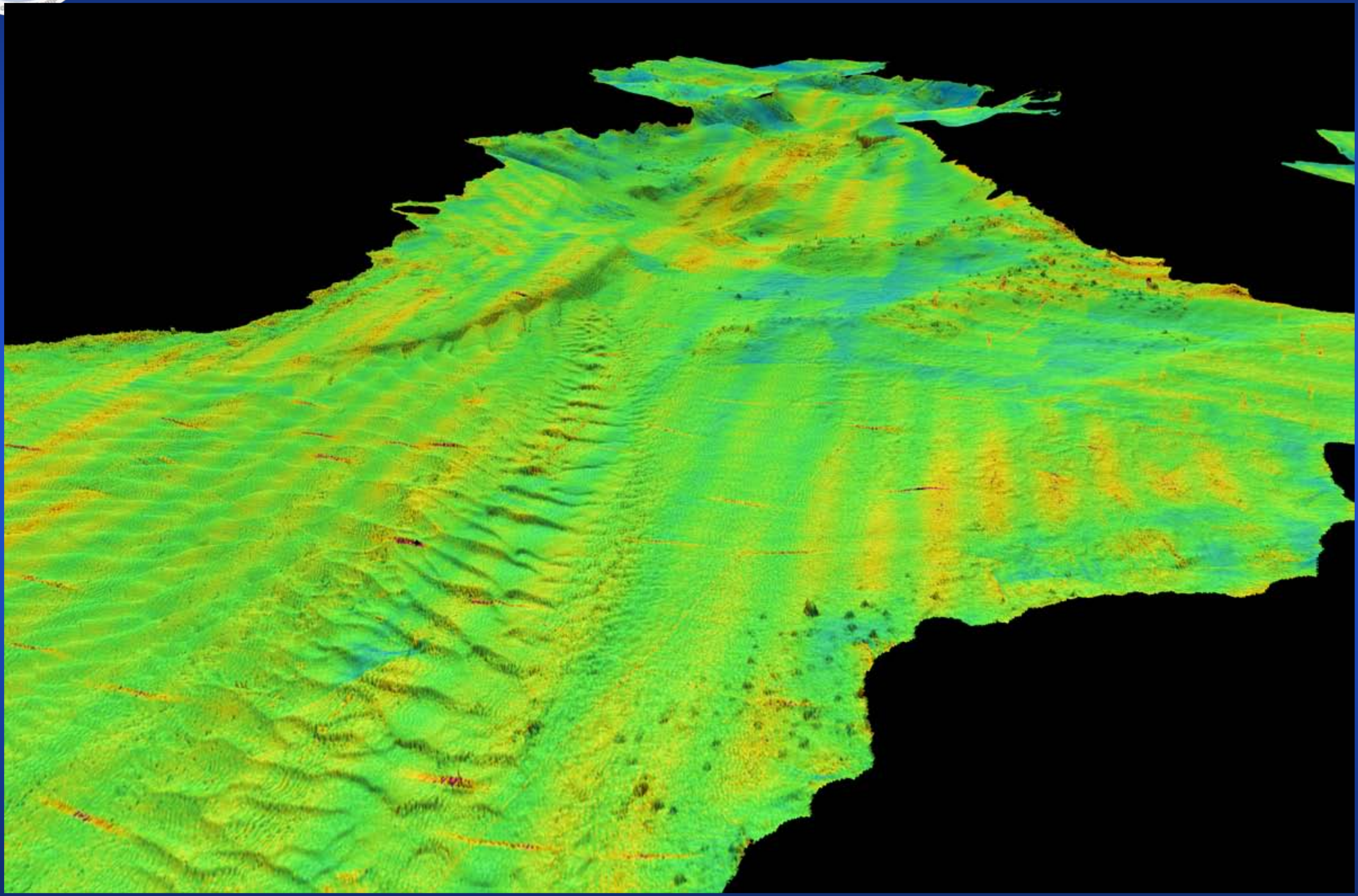
Example: Wood’s Hole, MA



Example: Wood's Hole, MA

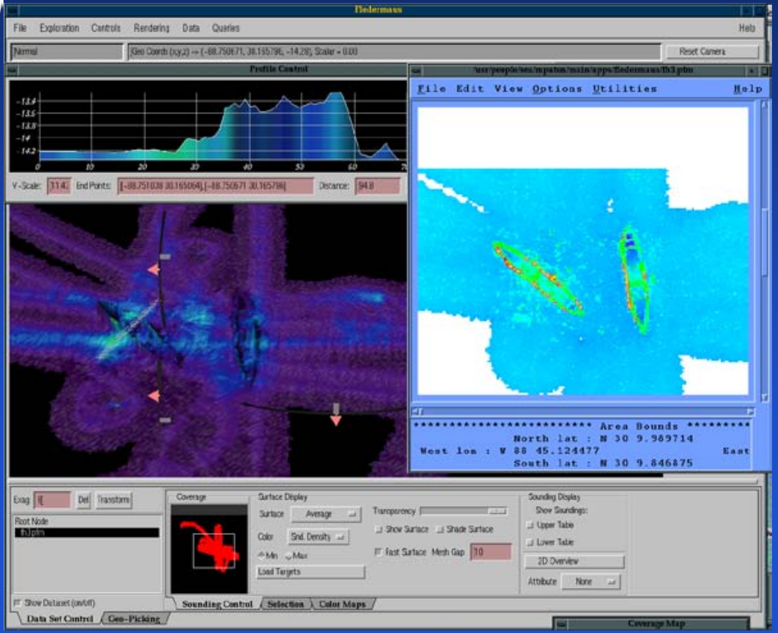


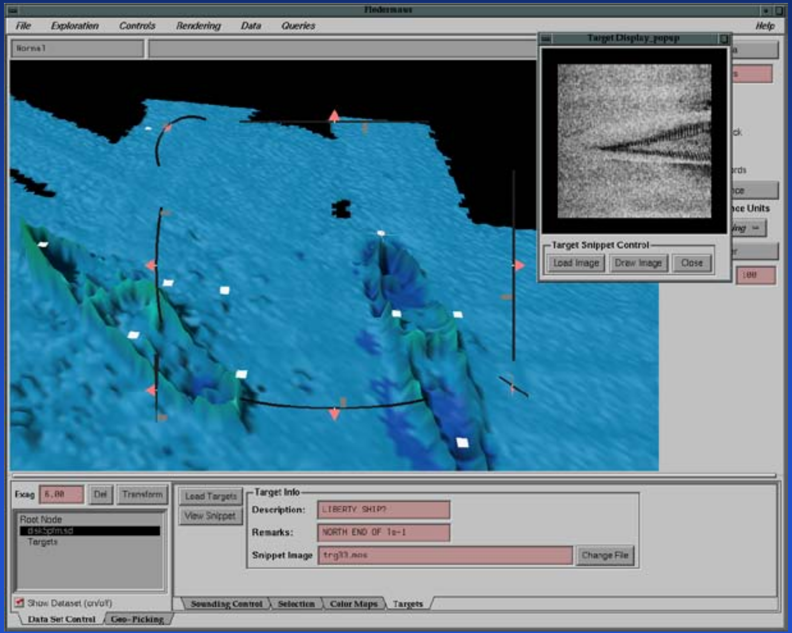
Example: Wood's Hole, MA

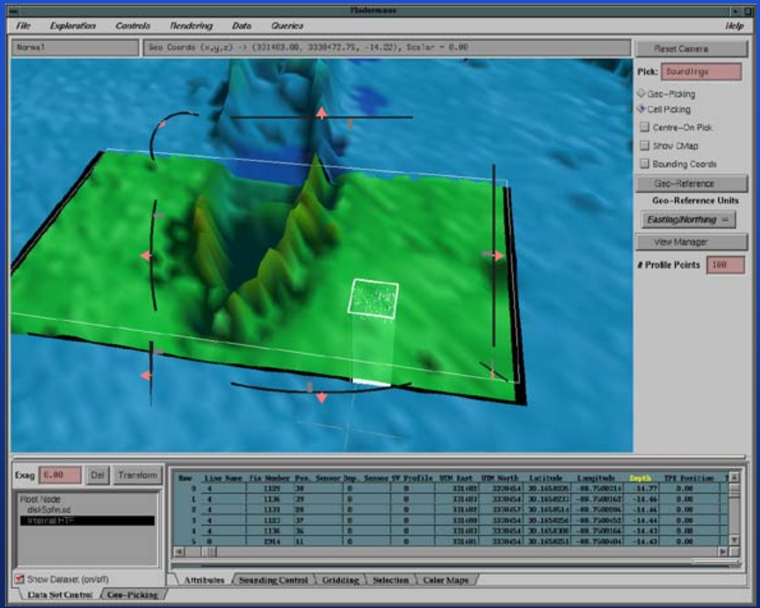


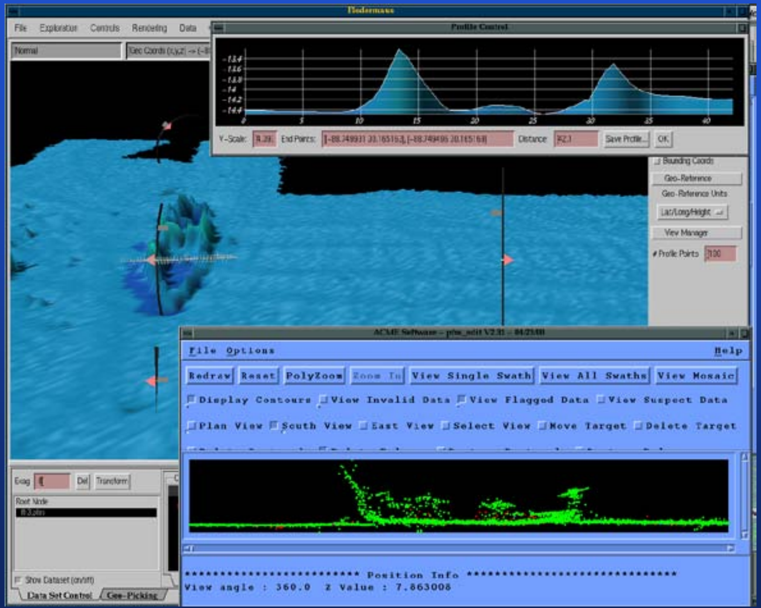
Uncertainty

NAVO AREA-BASED EDITOR in Fledermaus:









THE “NAVIGATION SURFACE”

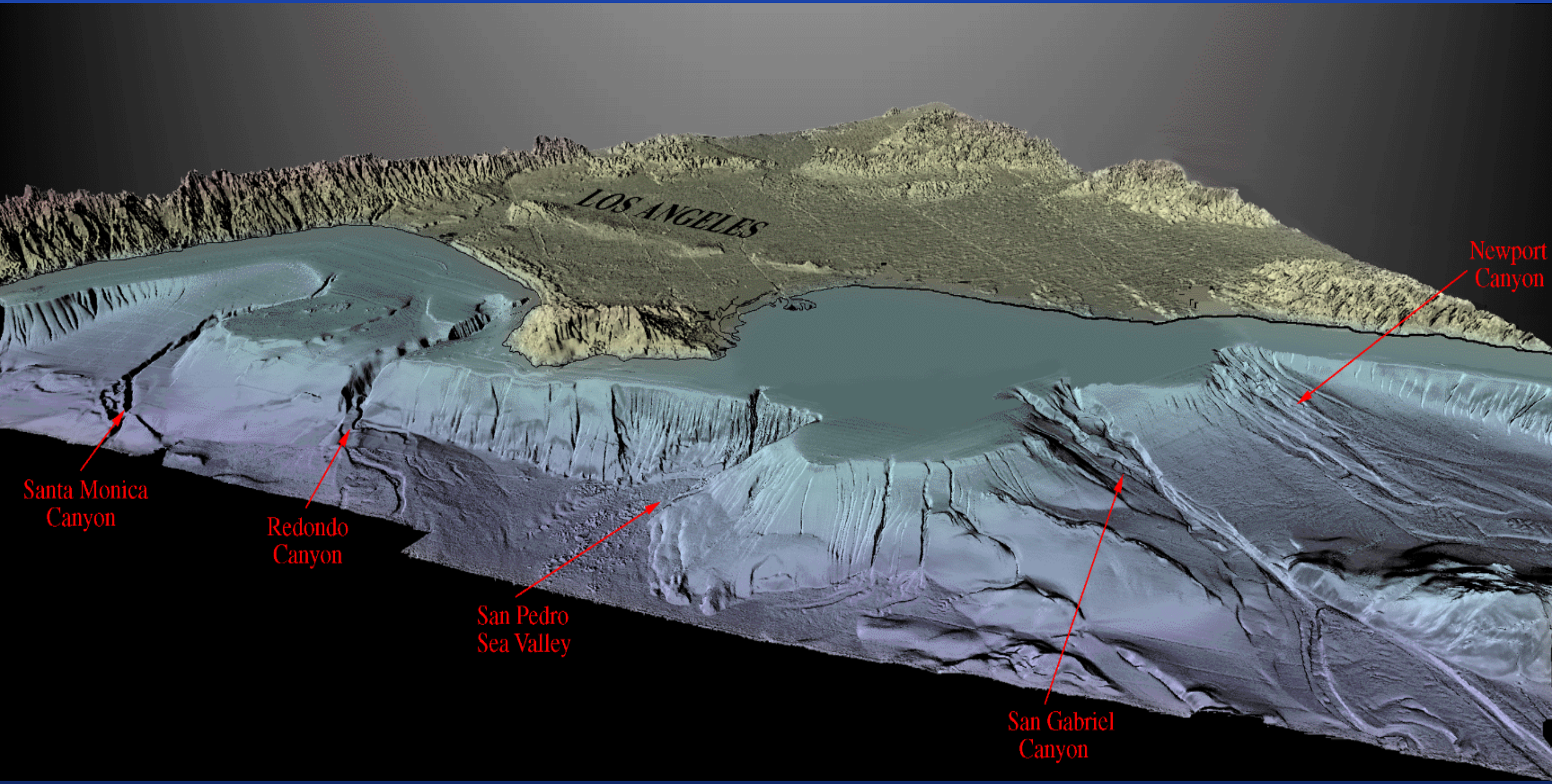
(Shep Smith)

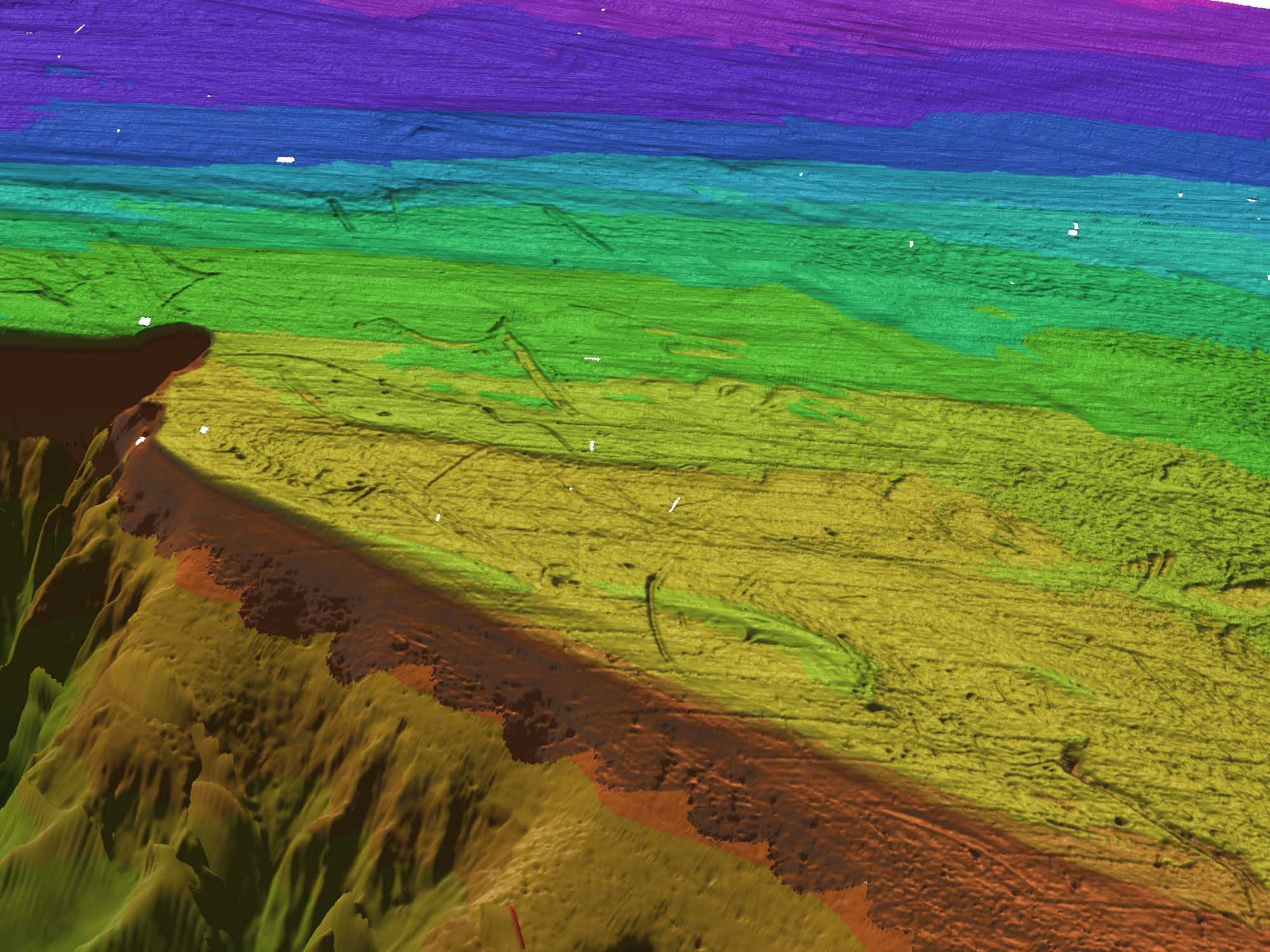
- Gridded product but preserves shoal soundings
- Removes system noise
- Multiple uses and display forms
- Horizontal resolution appropriate to navigation purpose and survey horizontal uncertainty.
- Vertical resolution appropriate to data source
- Local minima shoal biased/respected
- All other areas follow a “conservative best estimate” rule

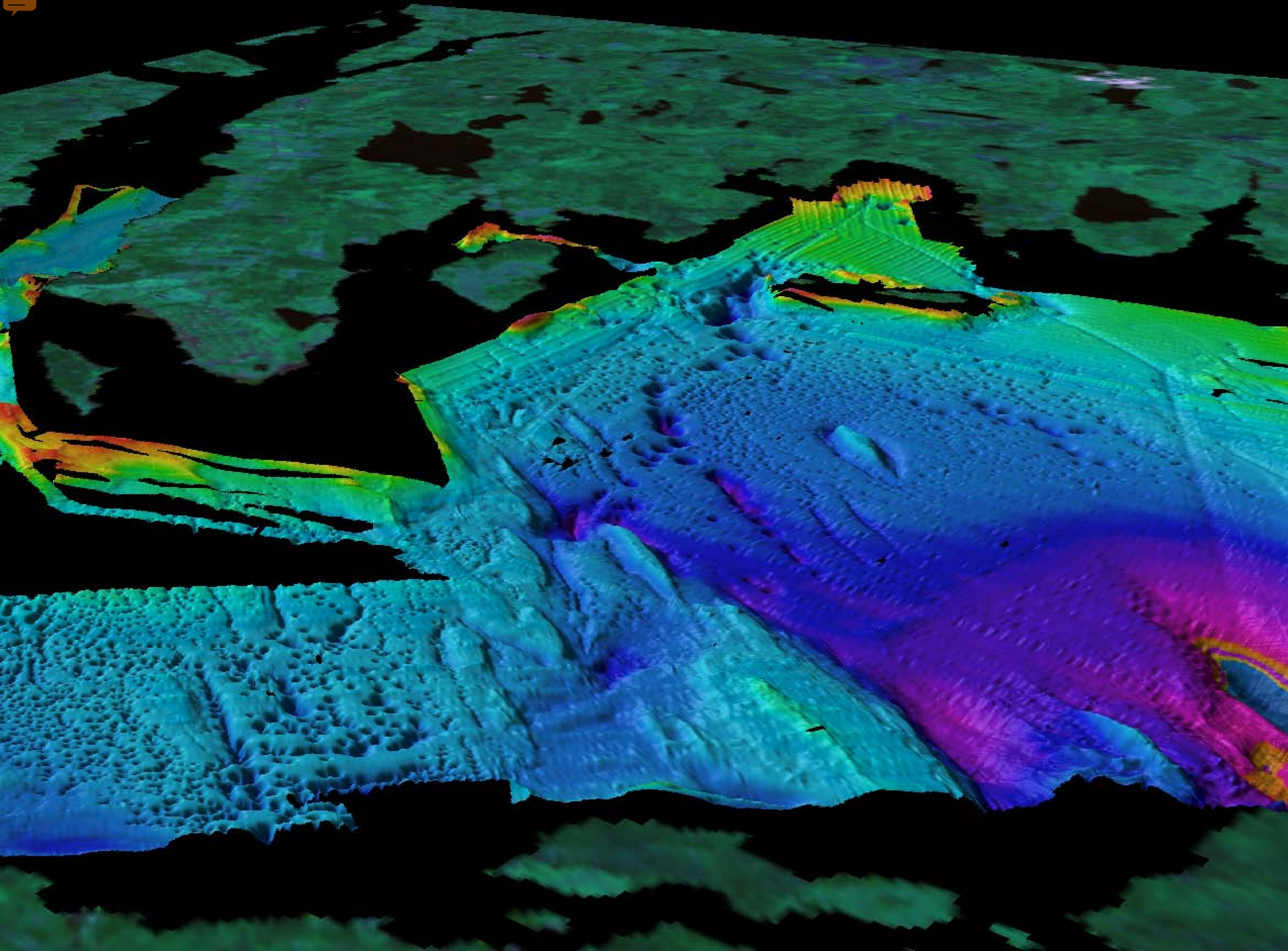
PRODUCTS:

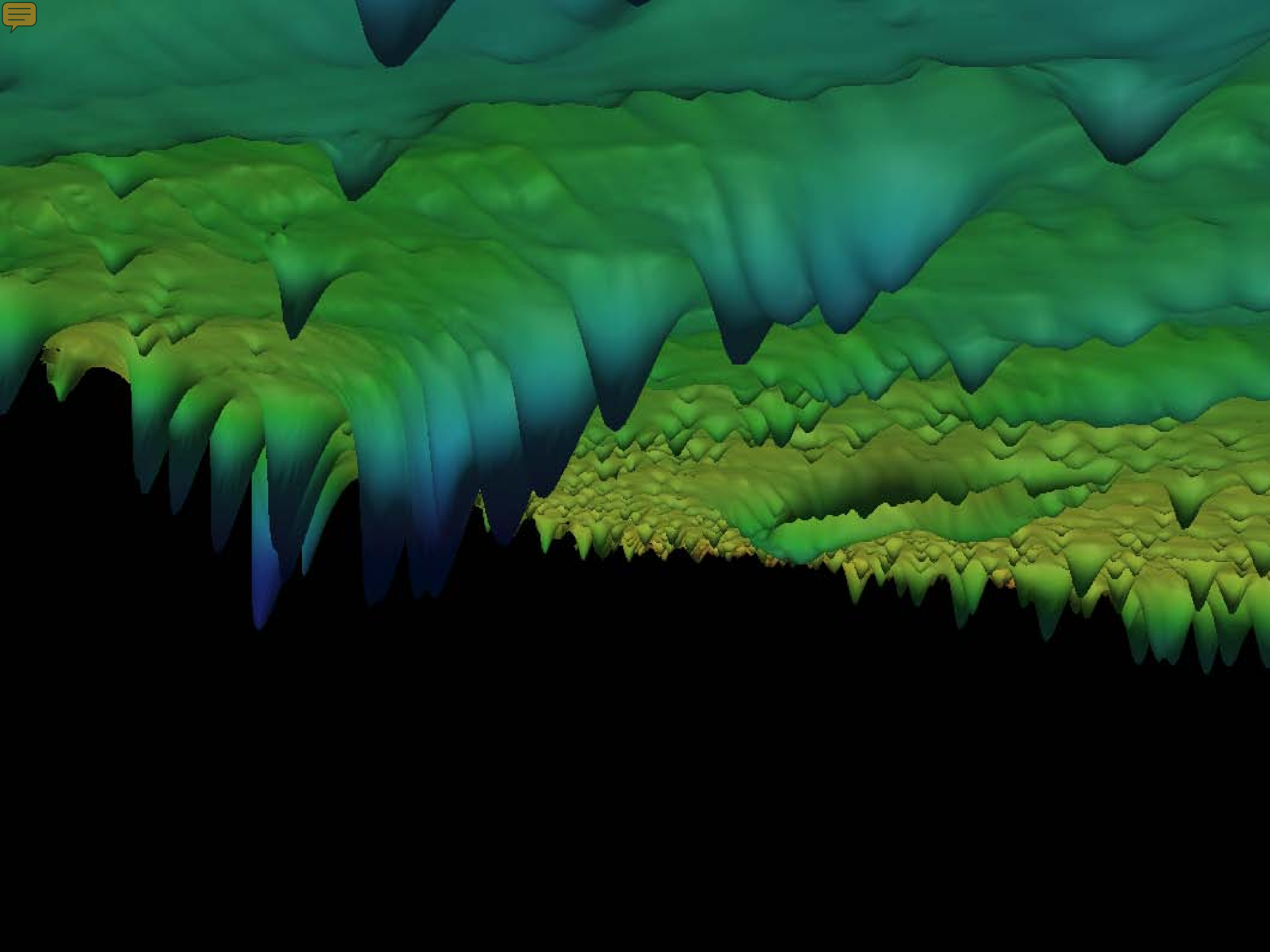
- Real-time 3-D updates and DATA FUSION for QC and interpretation
- Near-real-time derivative maps

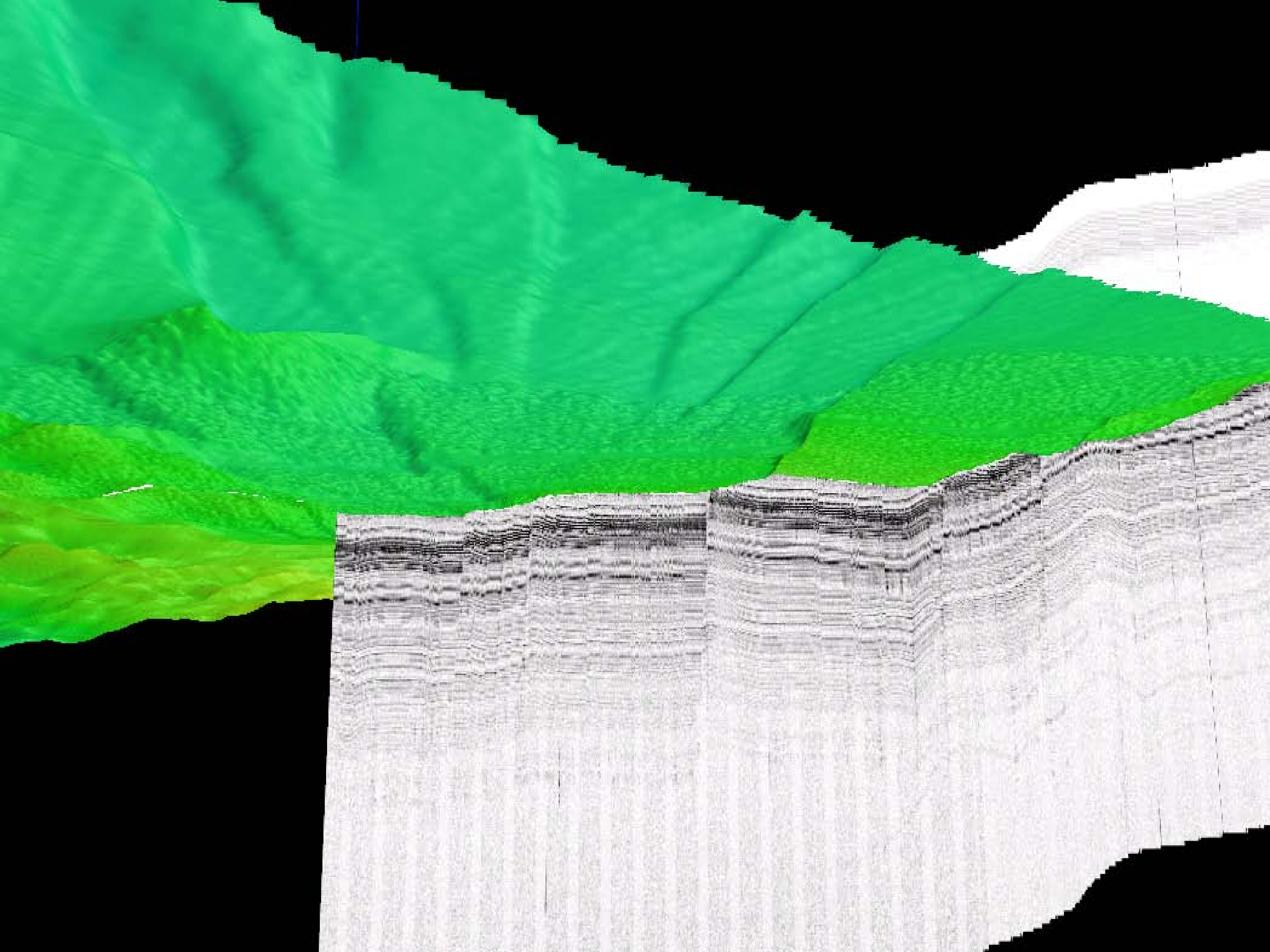
A new perspective → new insights



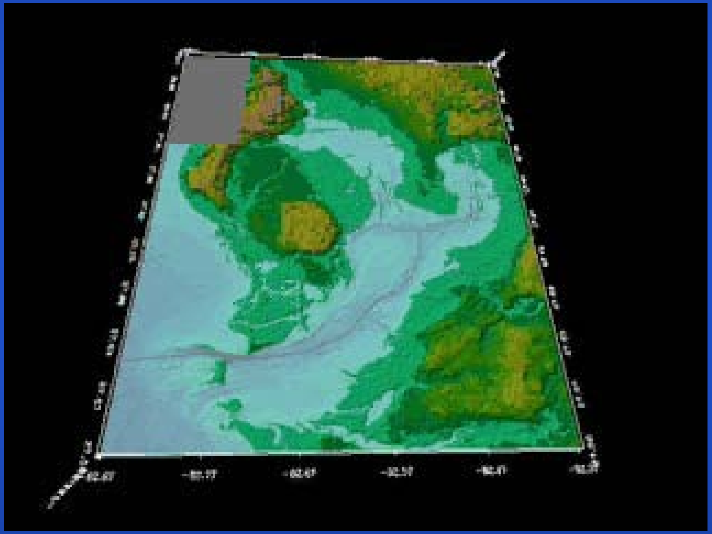




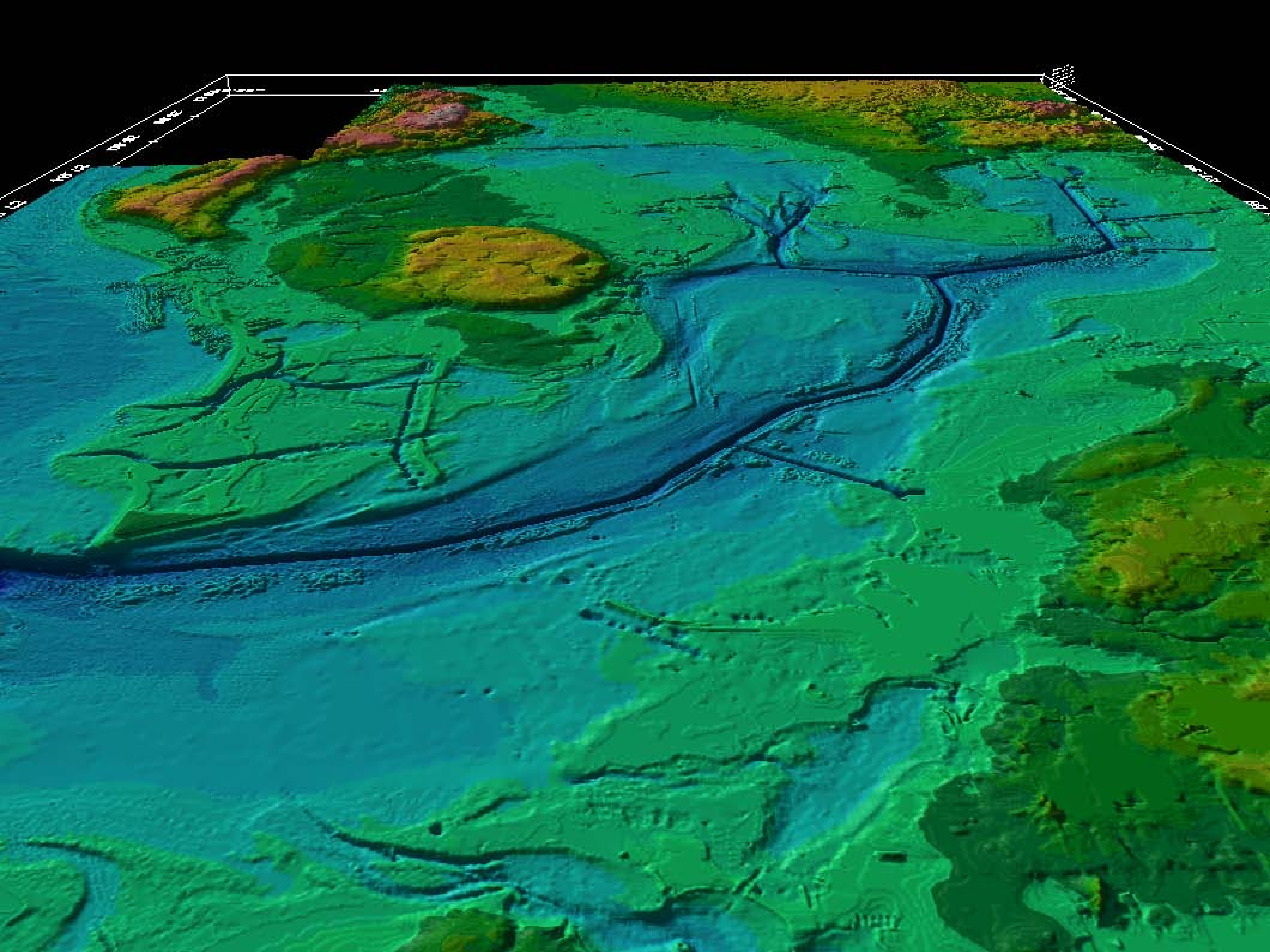


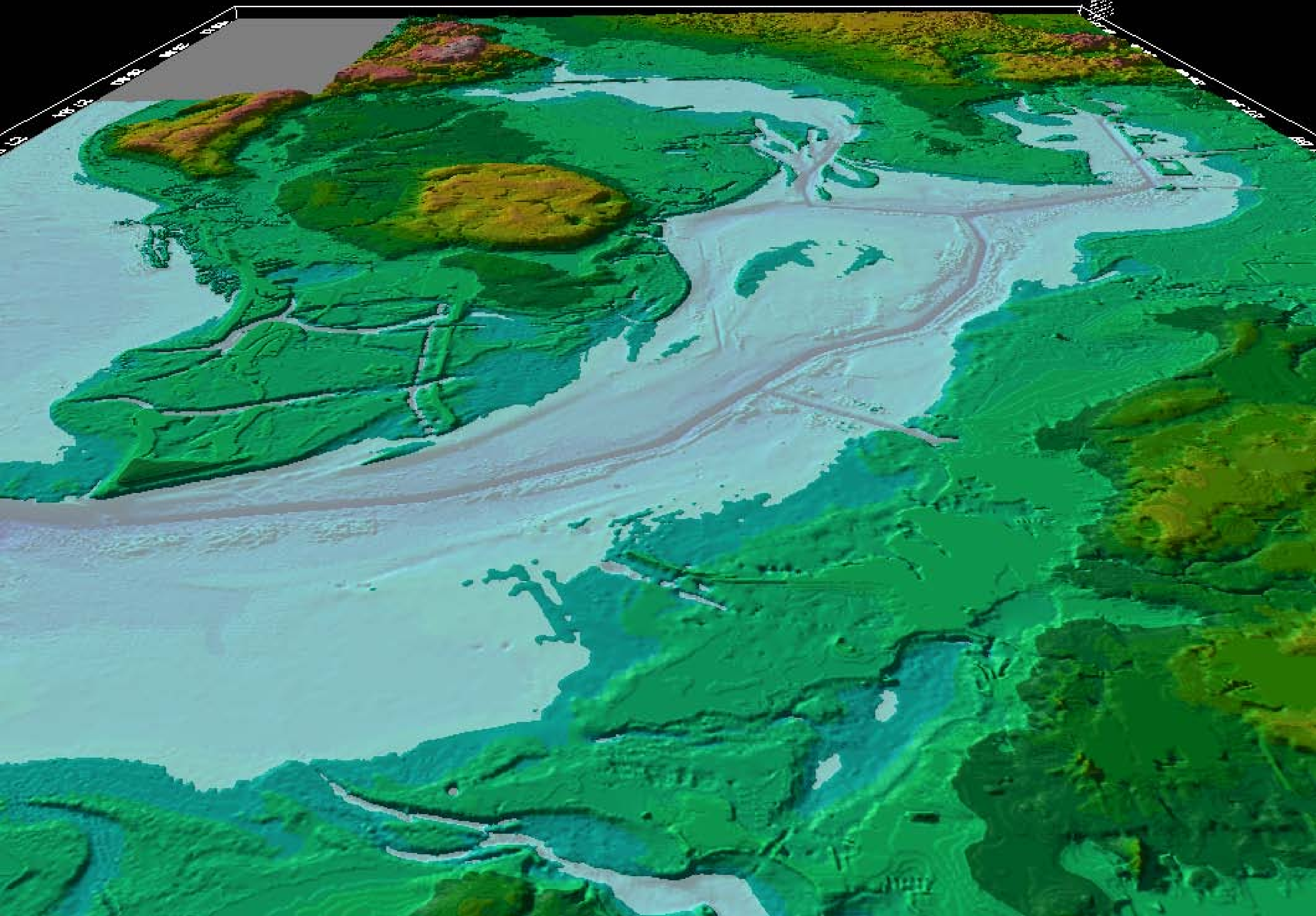


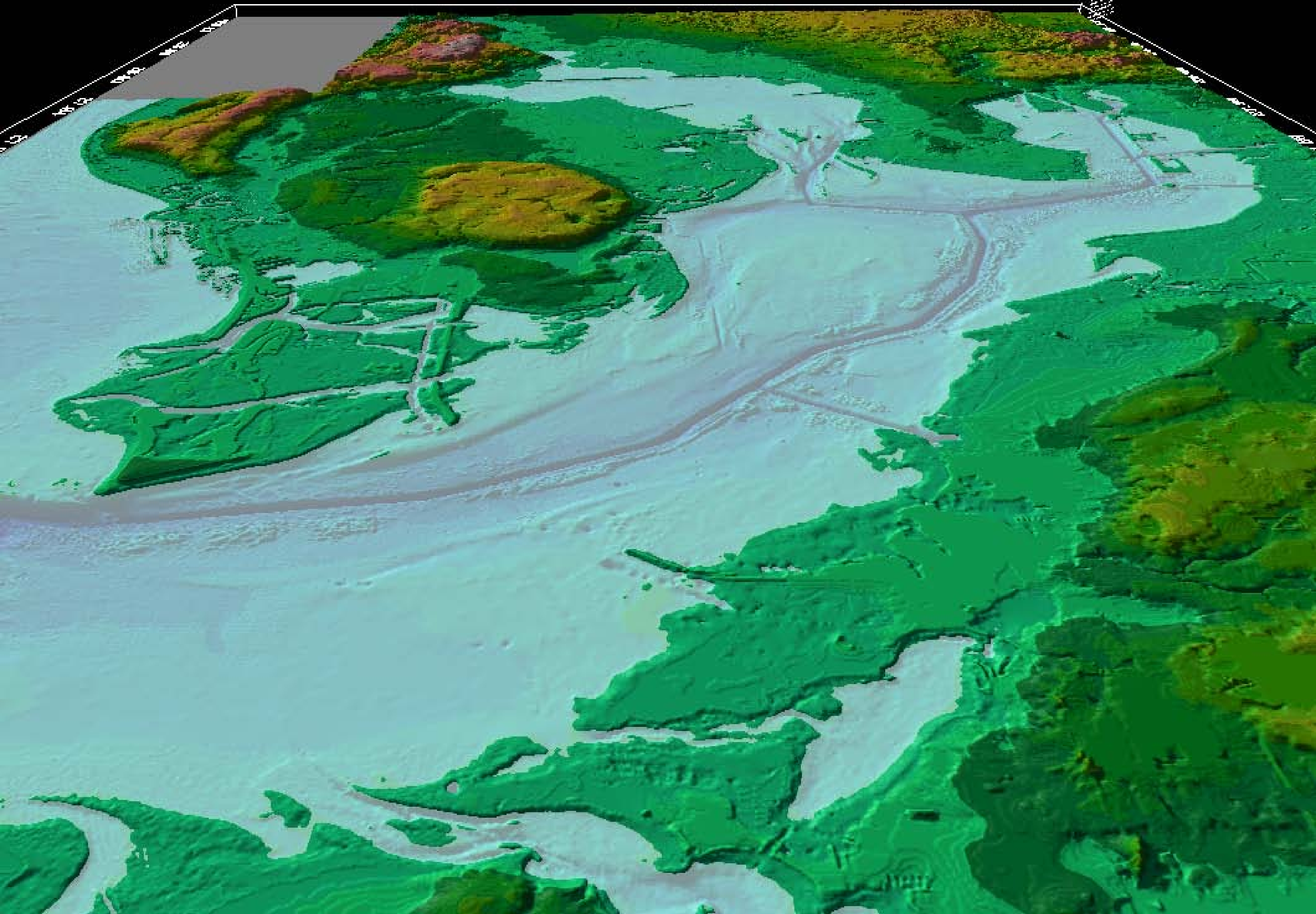
NOAA BATHY-TOPO PROJECT

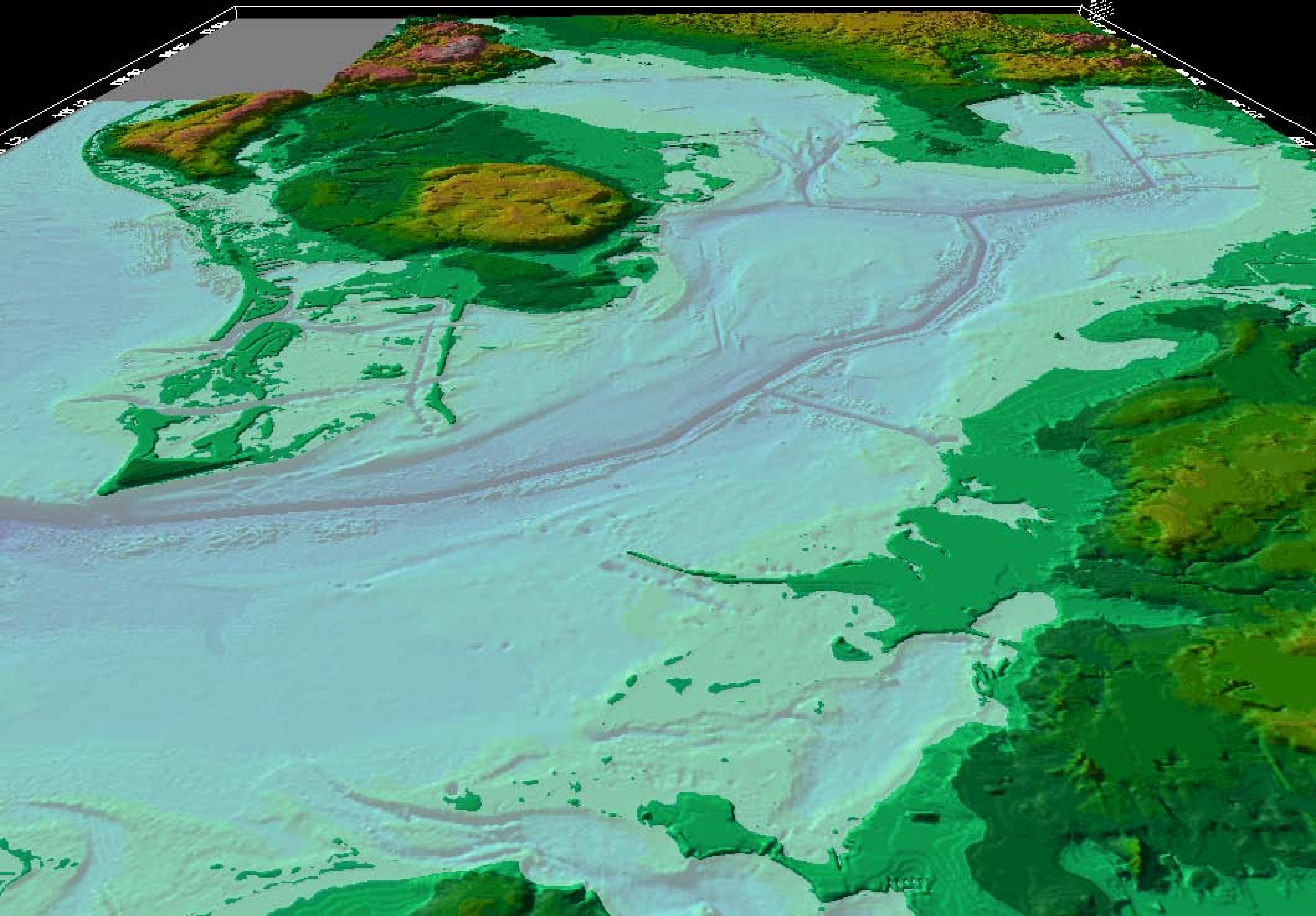


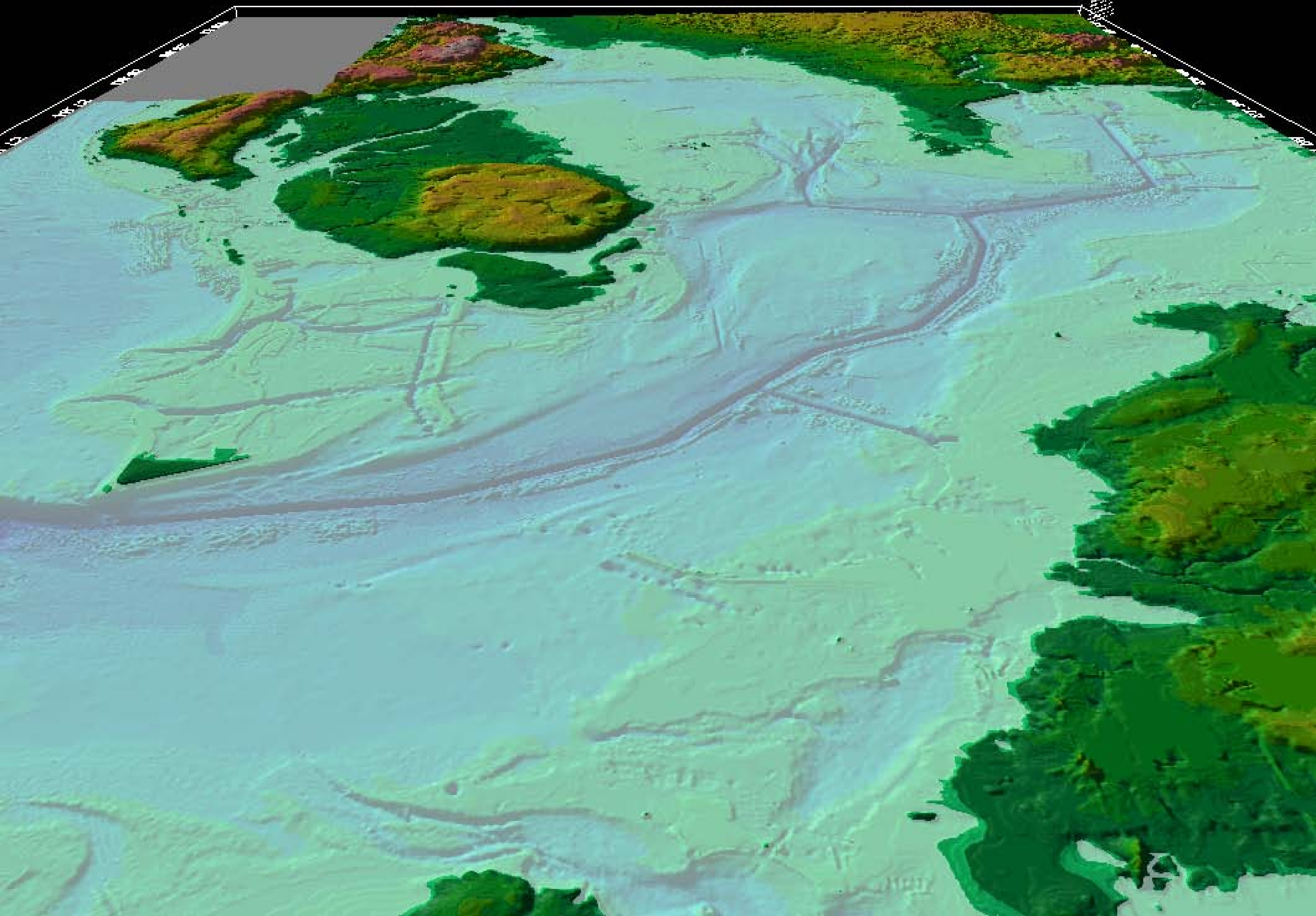
Flight into Tampa Bay, Florida

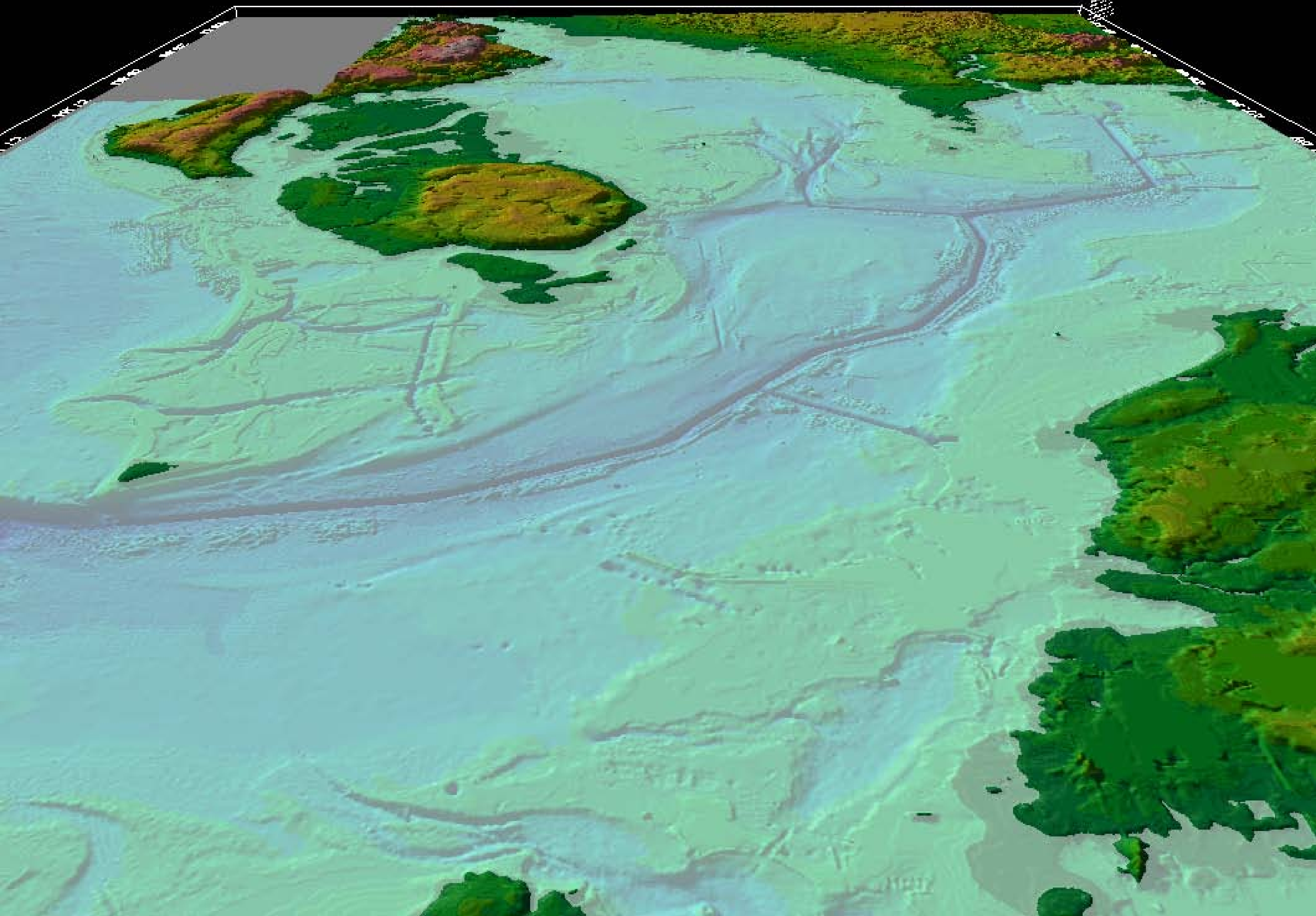


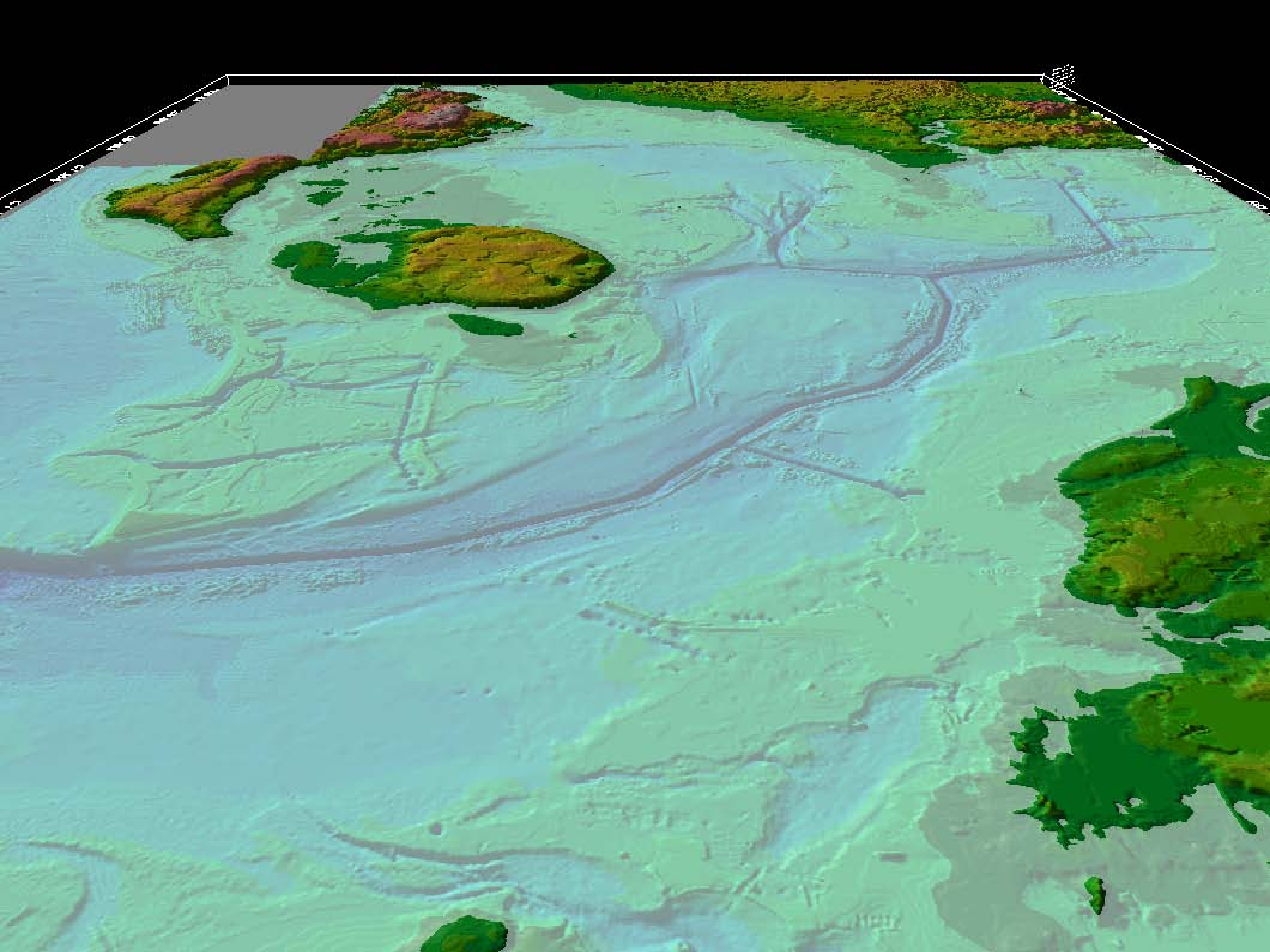


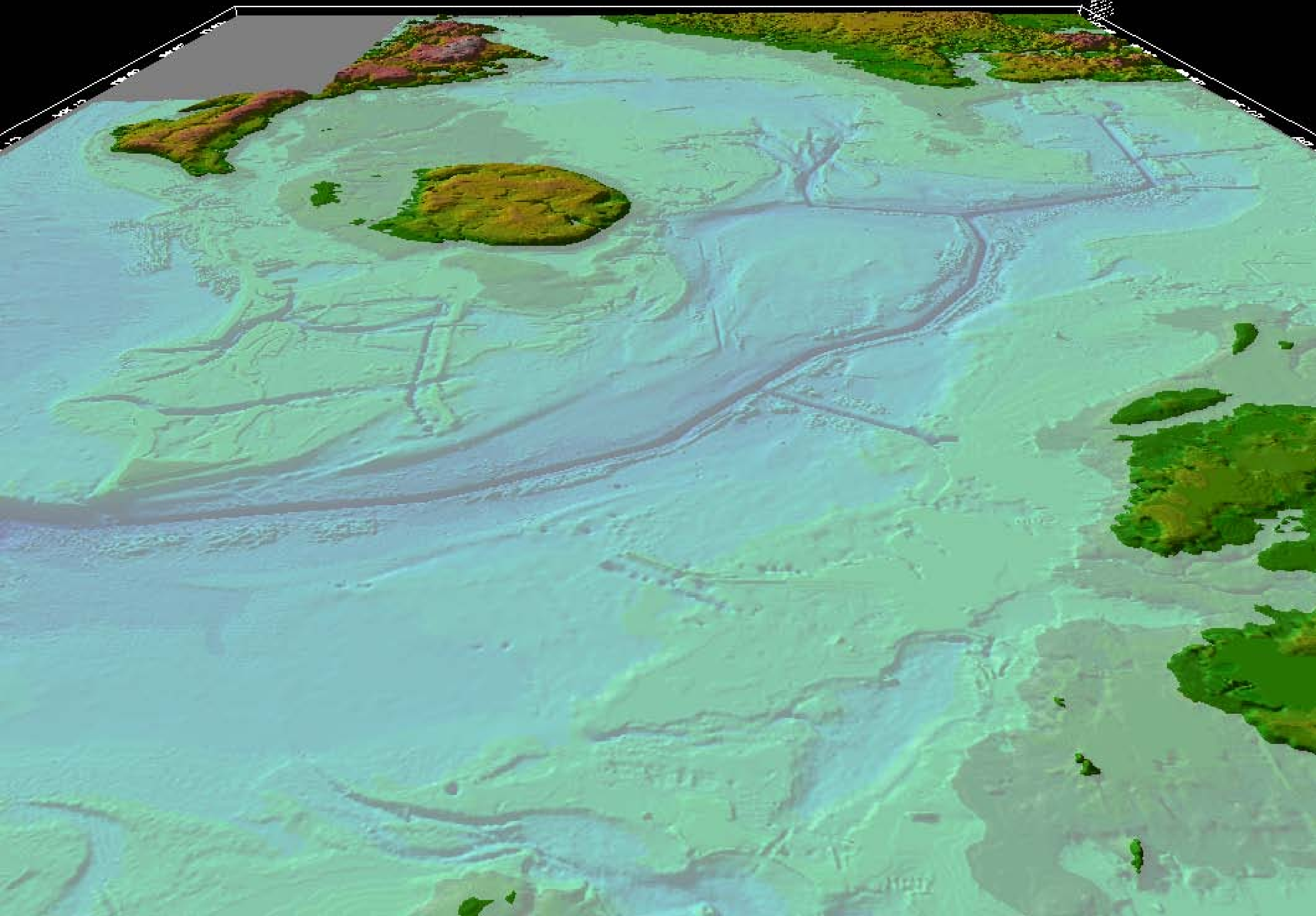


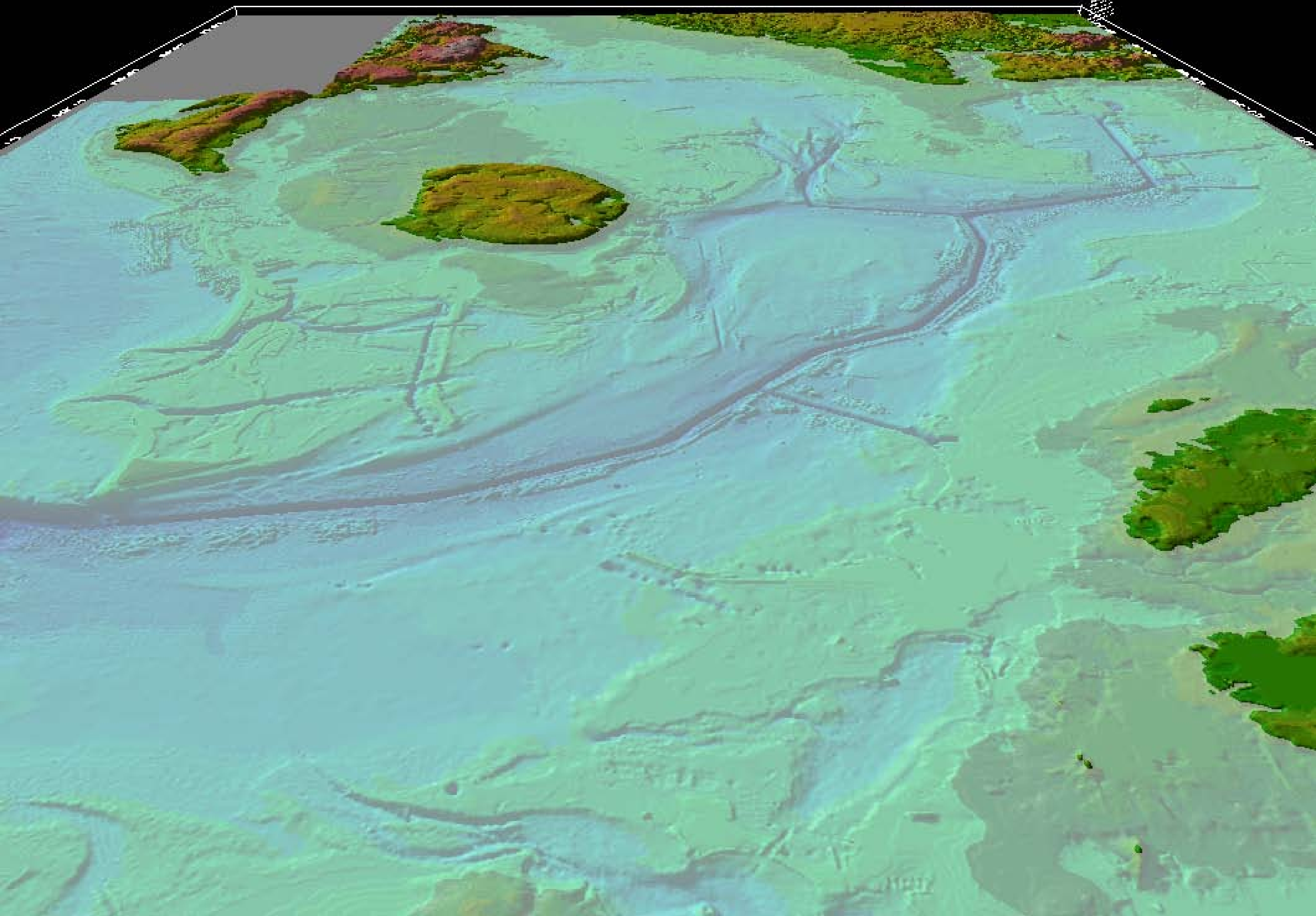




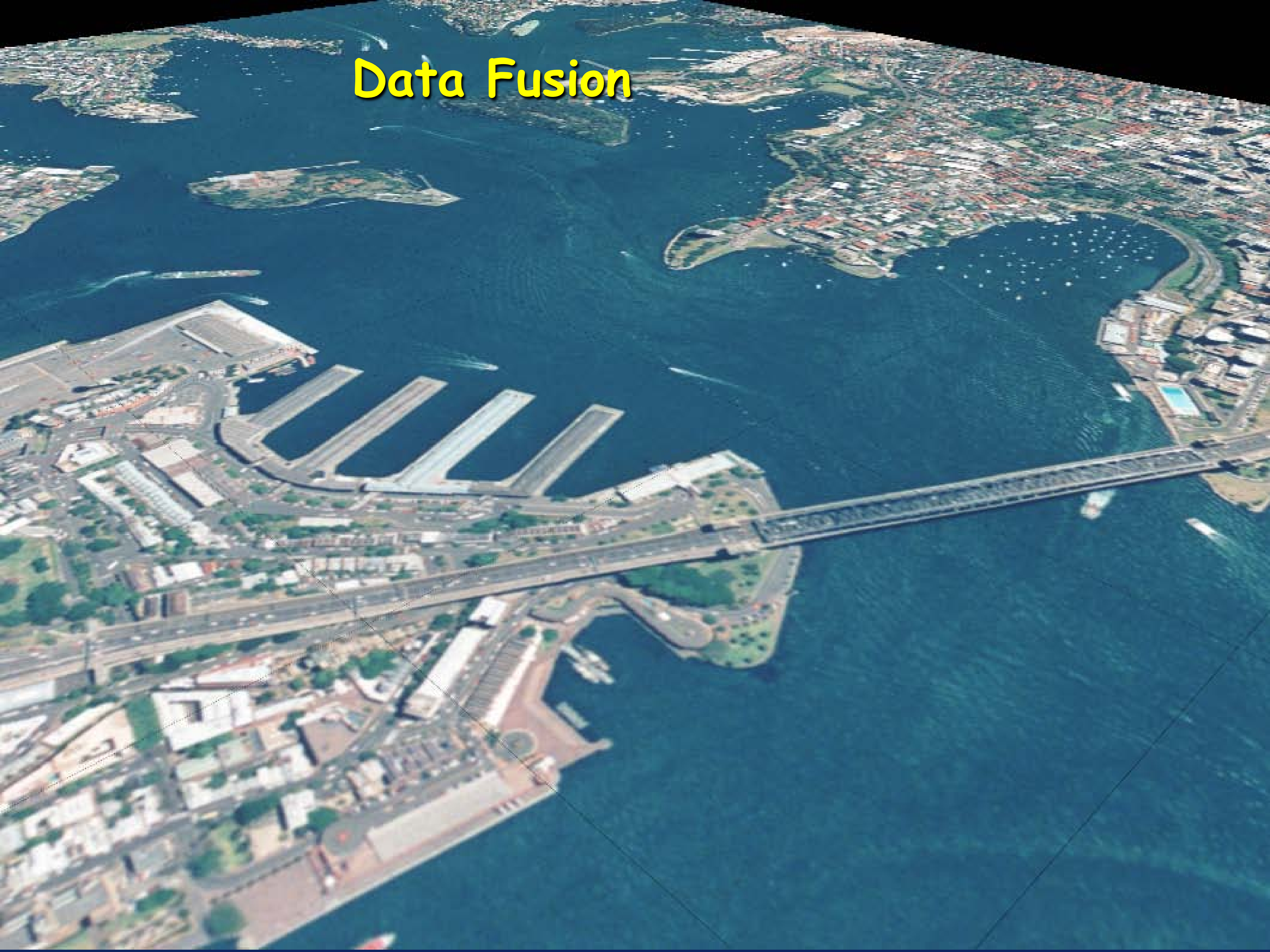


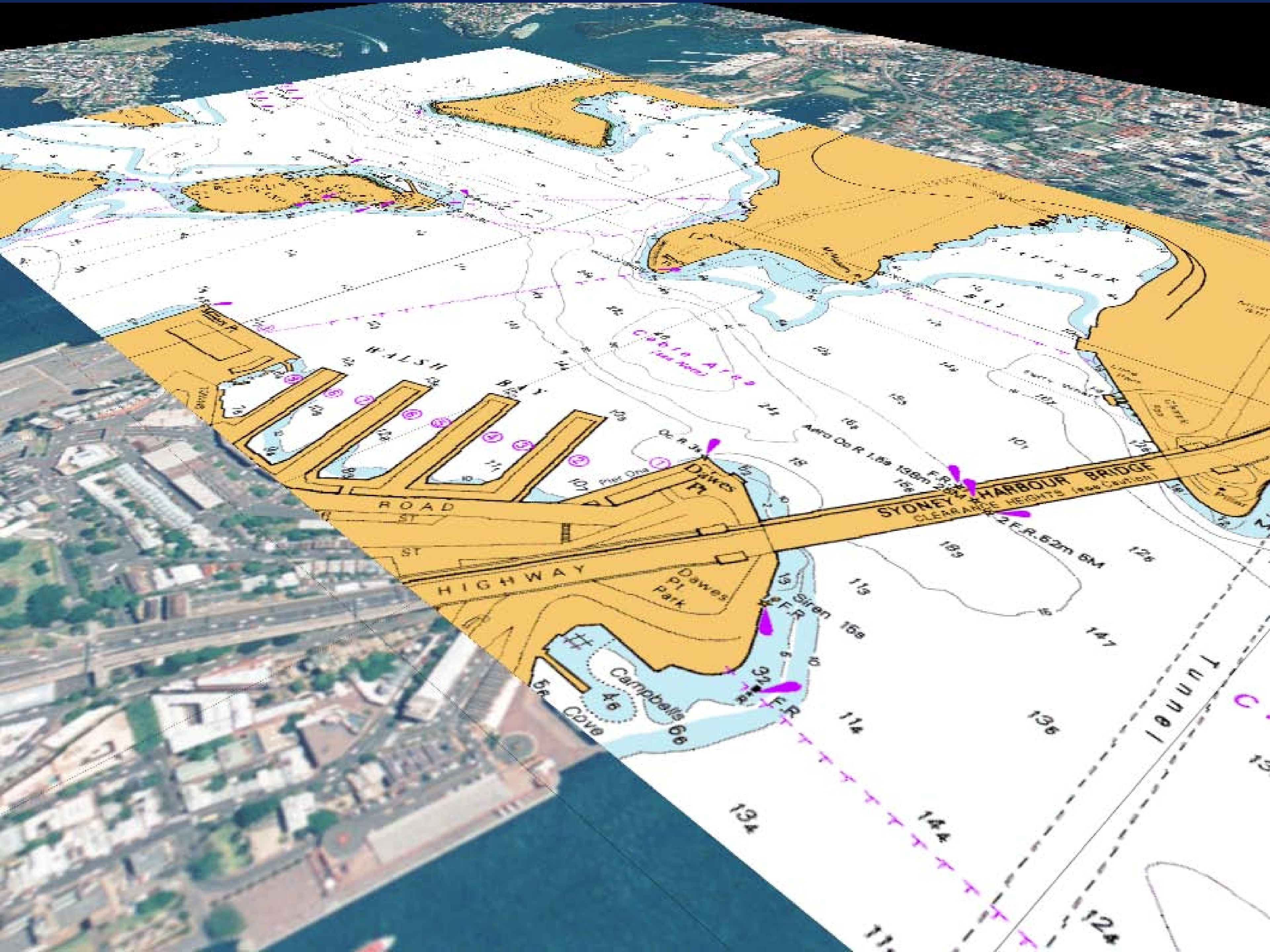




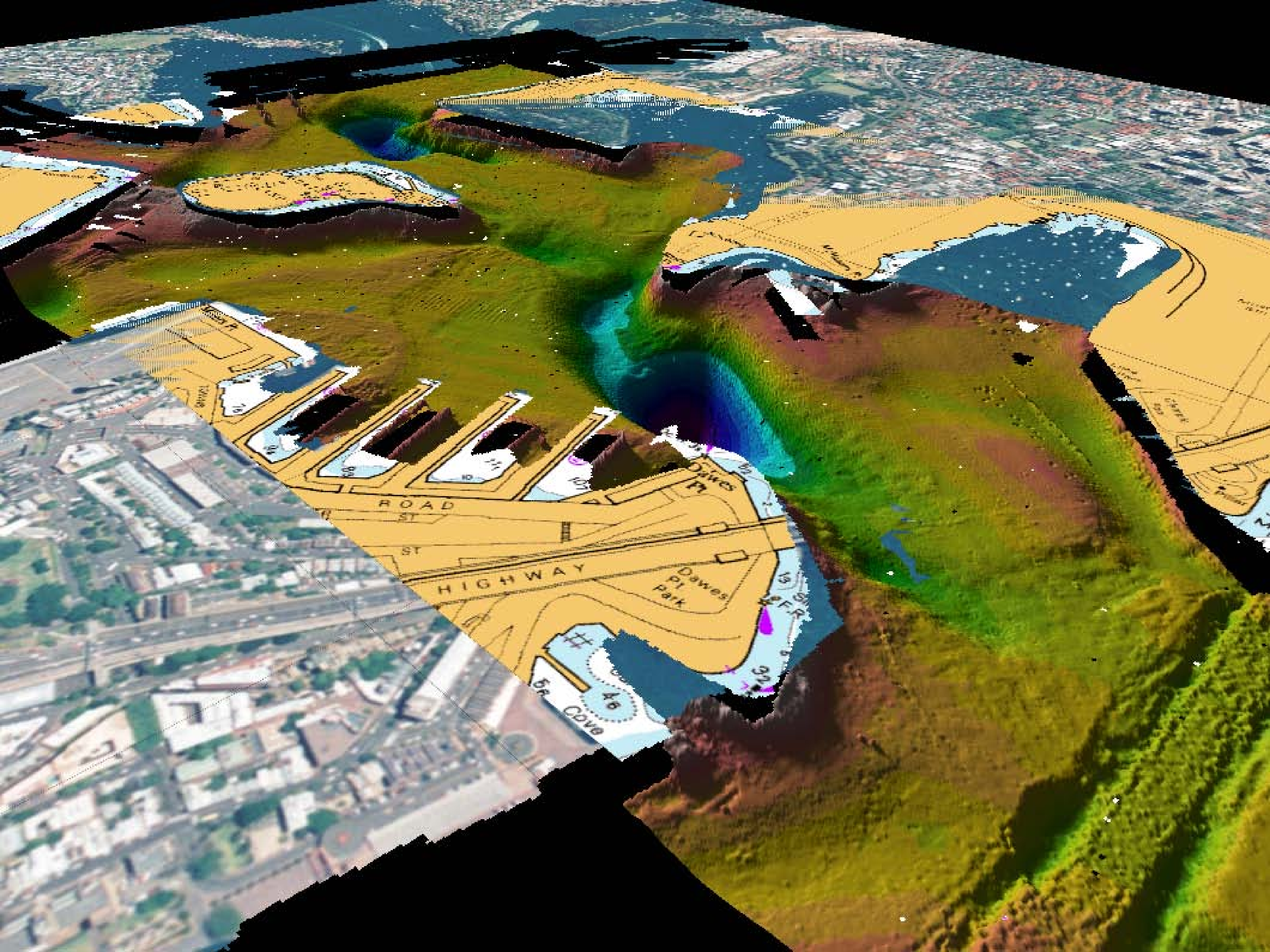


Data Fusion

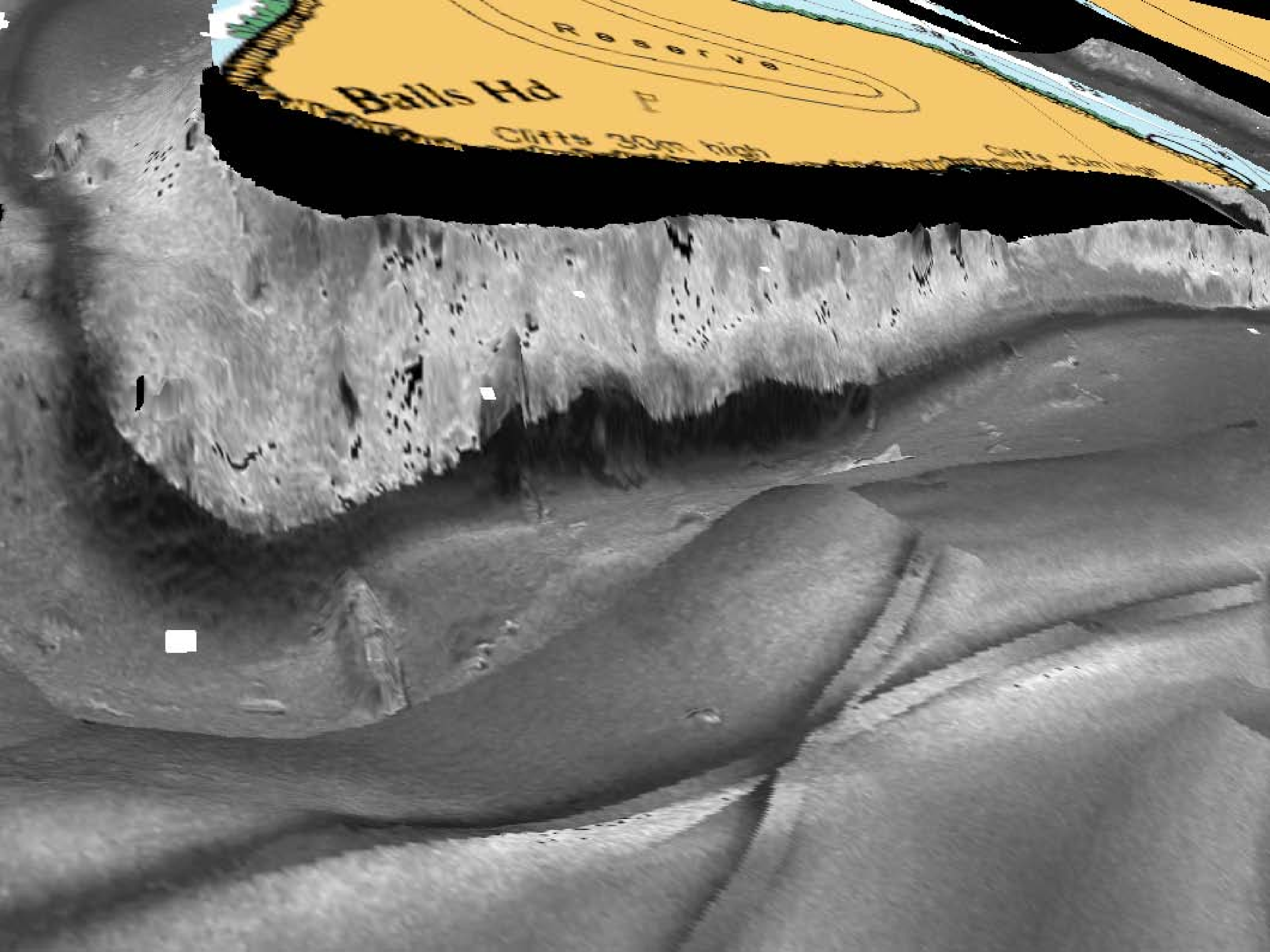


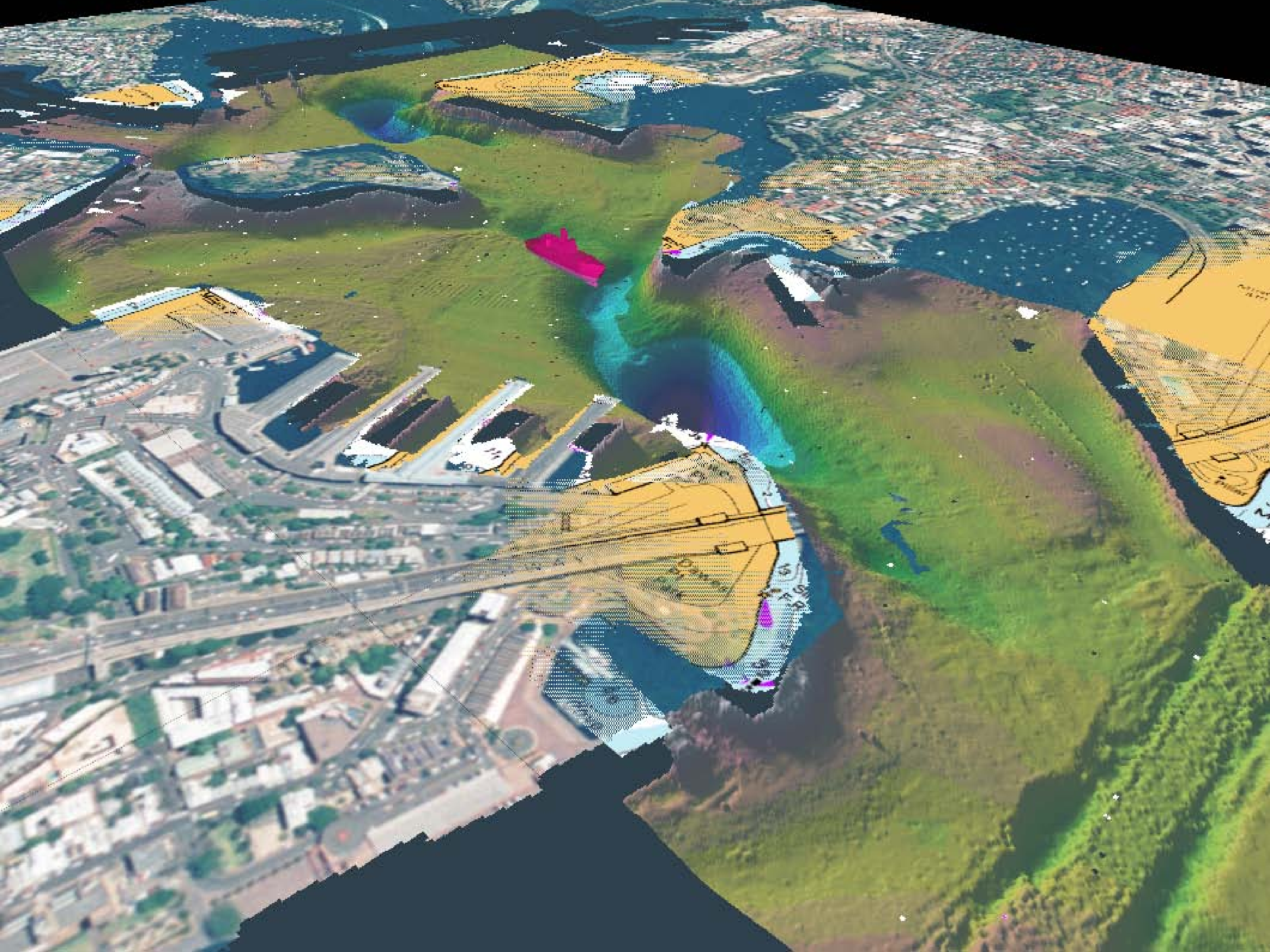


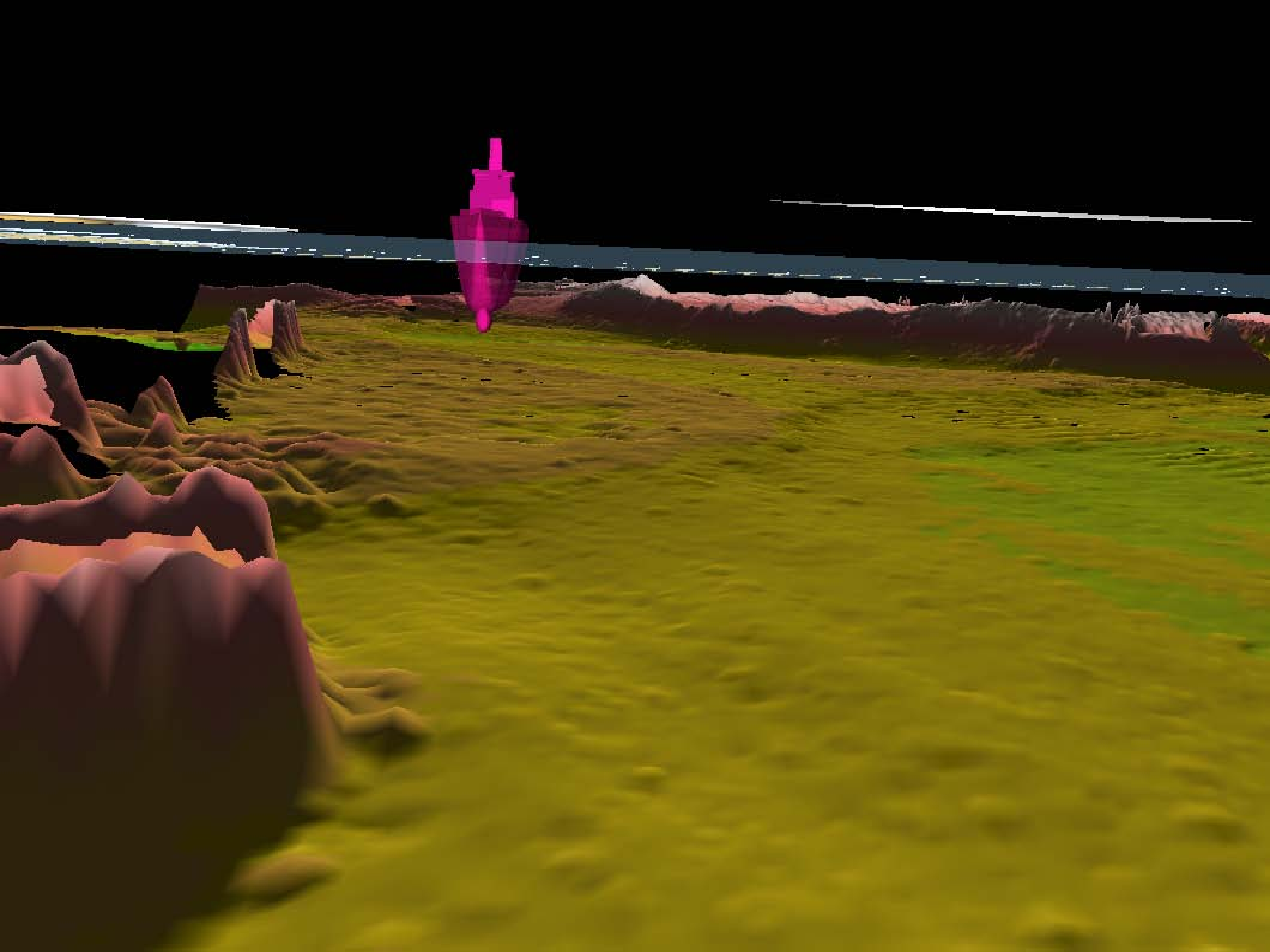
SYDNEY HARBOUR BRIDGE
CLEARANCE HEIGHTS (see Caution)
WALSH
BAY
ROAD
HIGHWAY
ST
Dawes Pt
Dawes Pt Park
Pier One
Campbells Cove
Siren
F.R
2 F.R.52m 8M
Tunnel

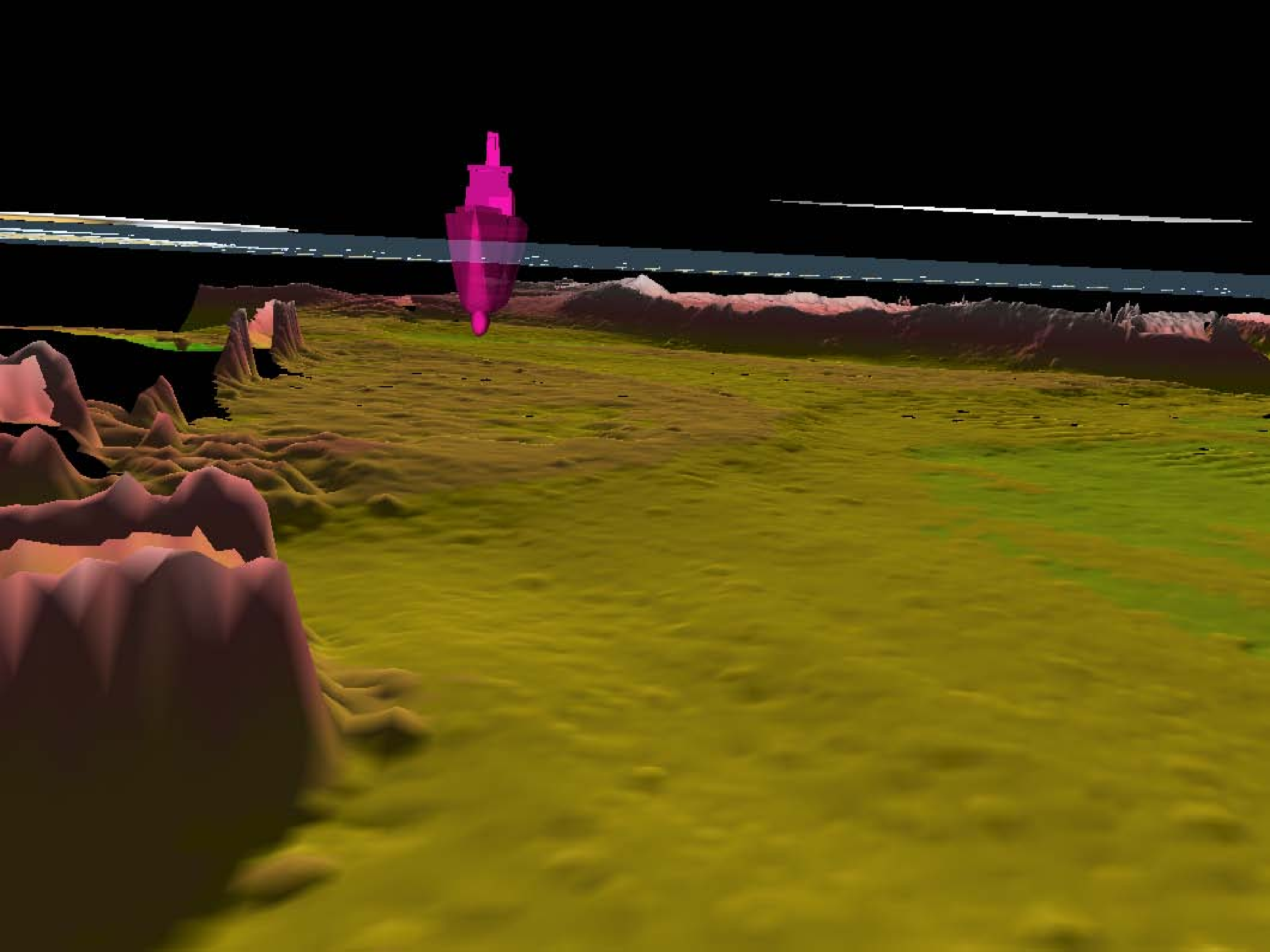


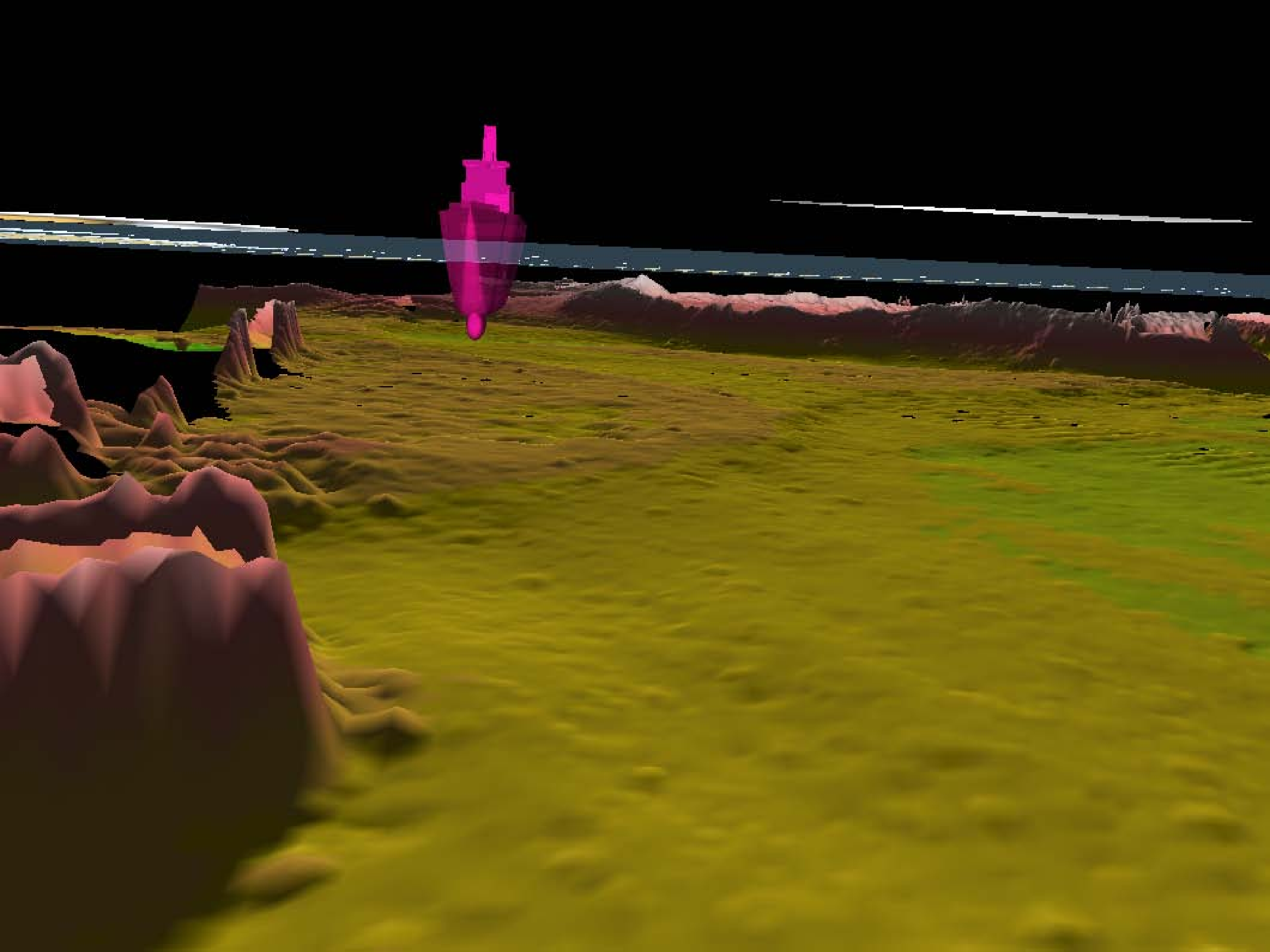
ROAD
ST
ST
HIGHWAY
Dawes Pt
Dawes Pt Park
Cove

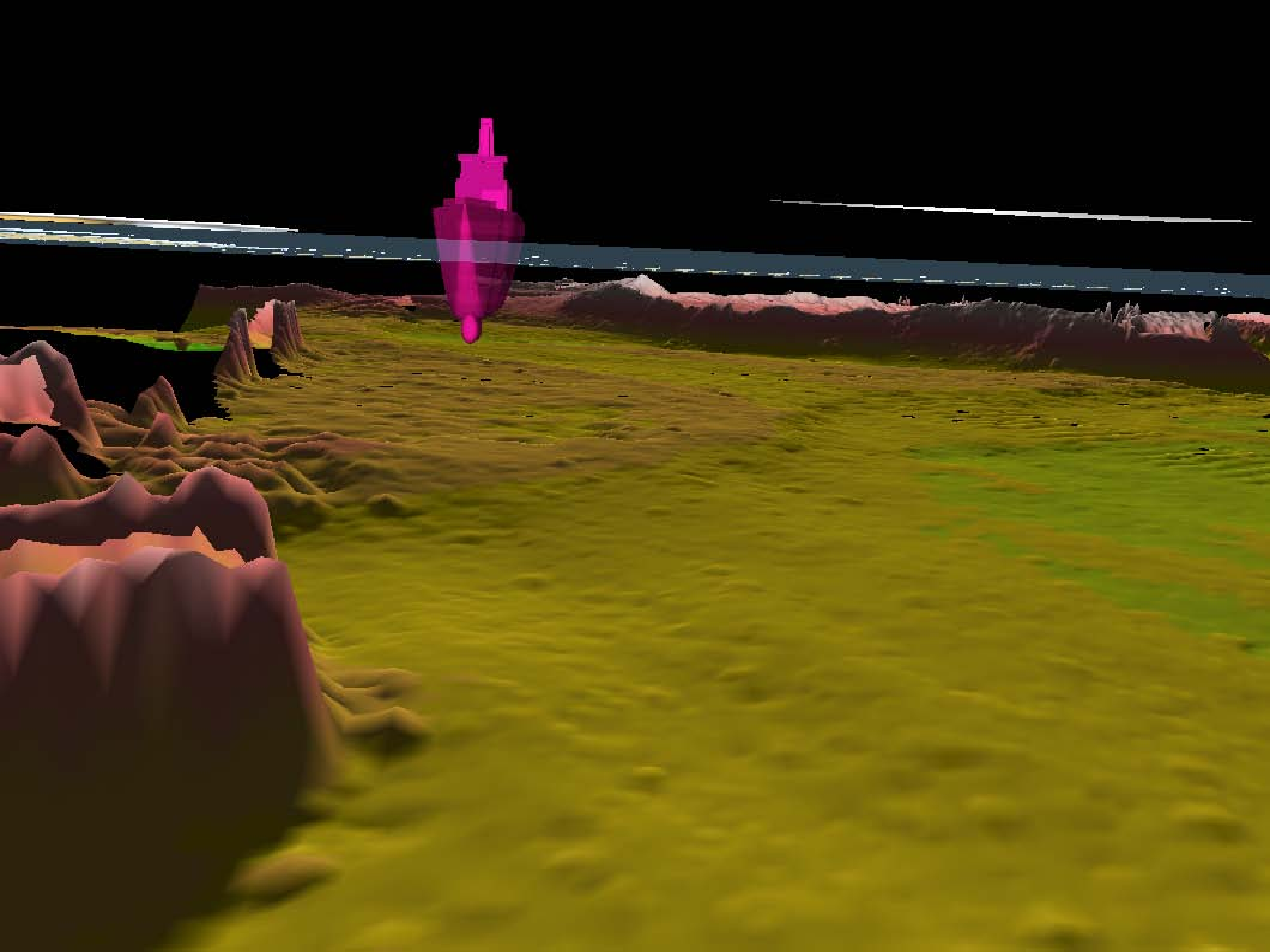

Reserve
Balls Hd
Cliffs 30m high

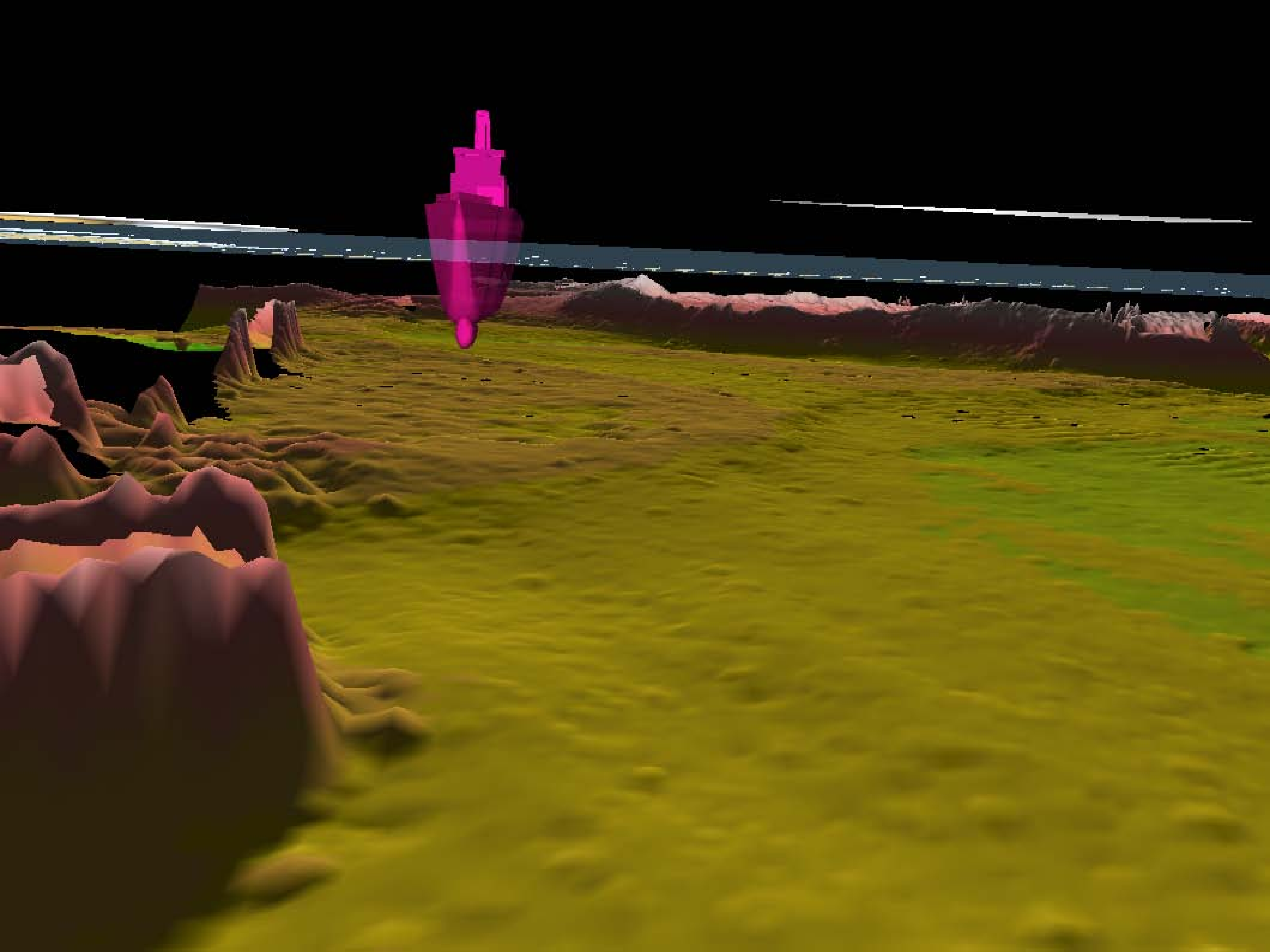


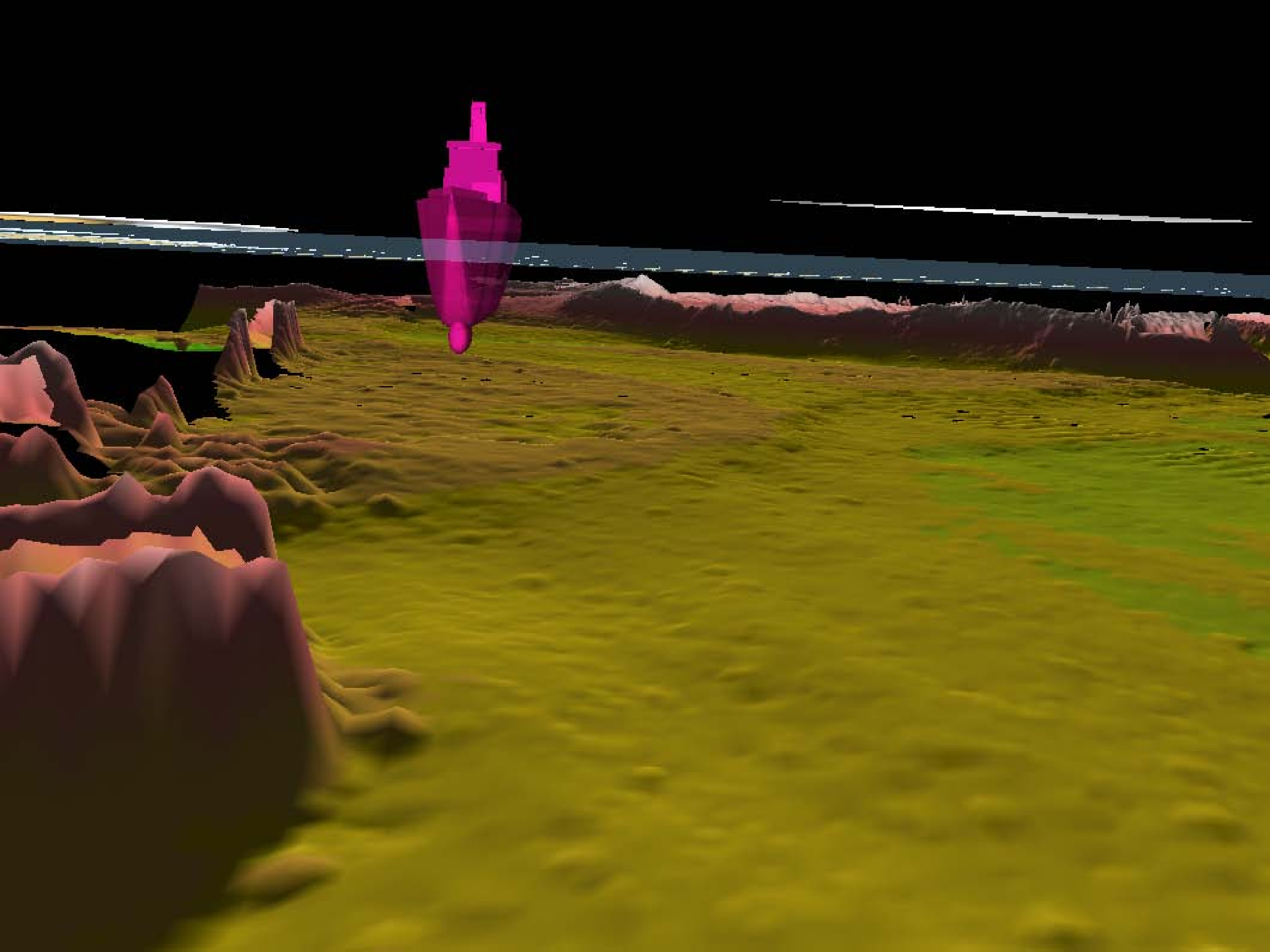


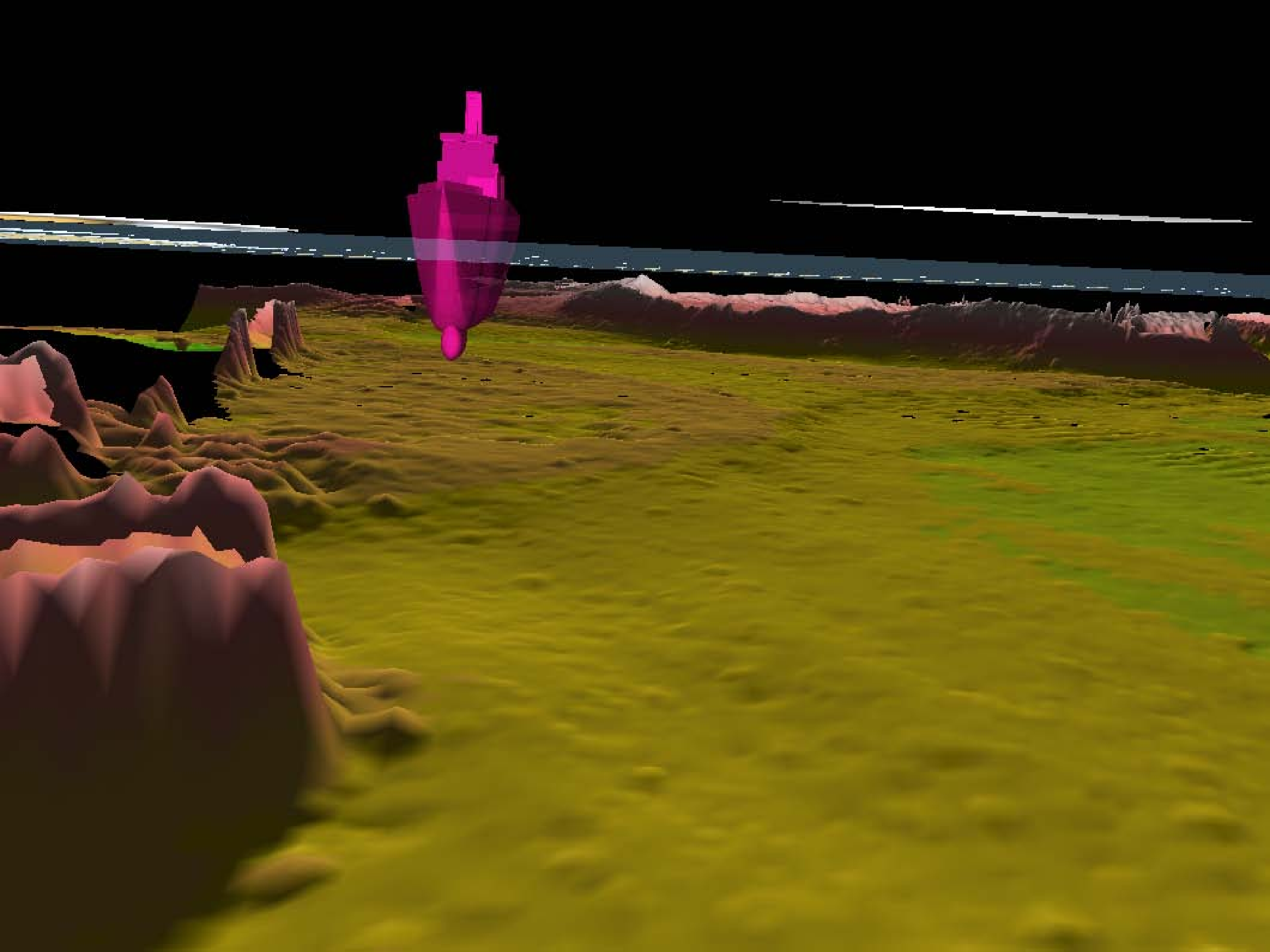


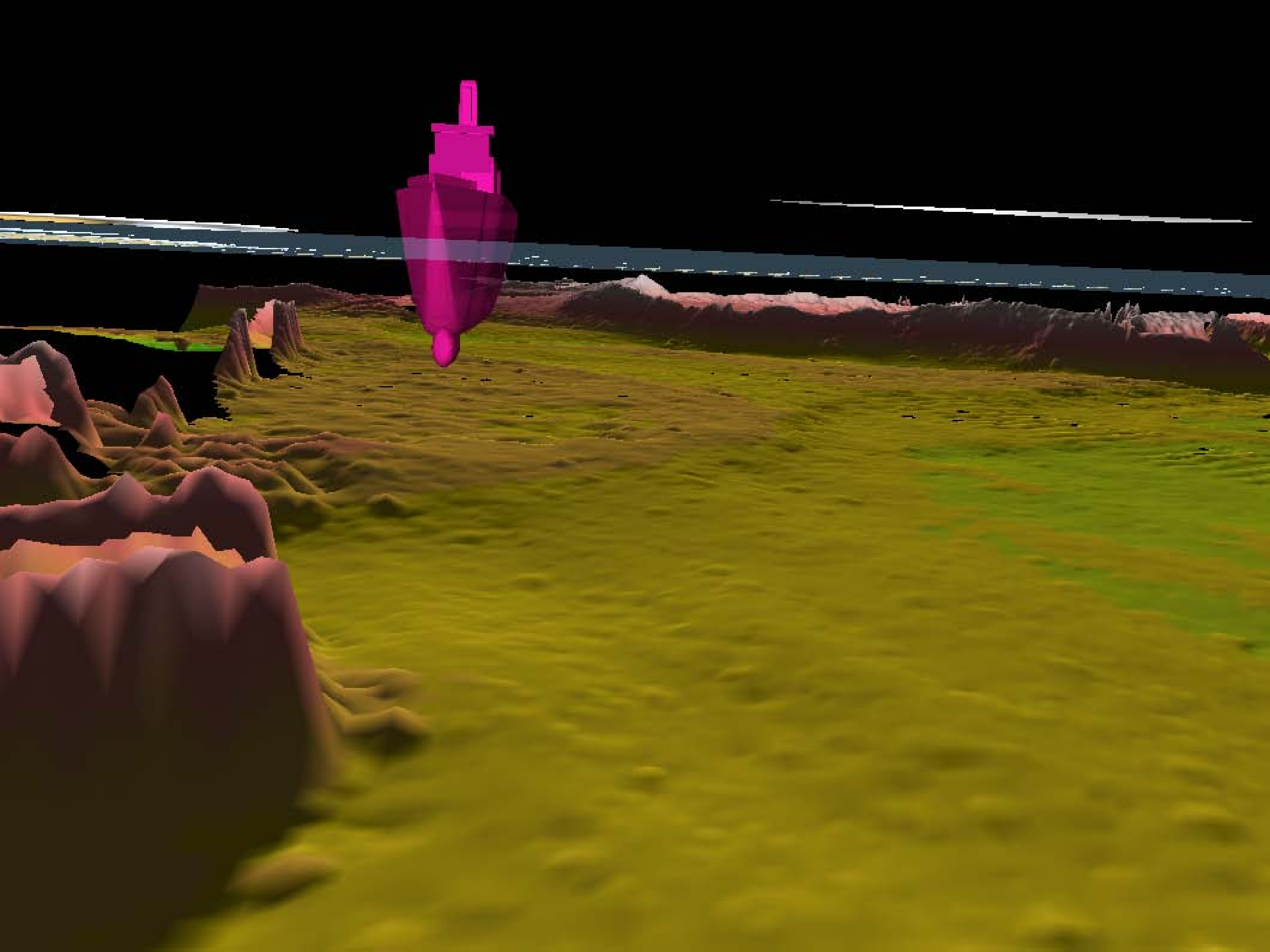


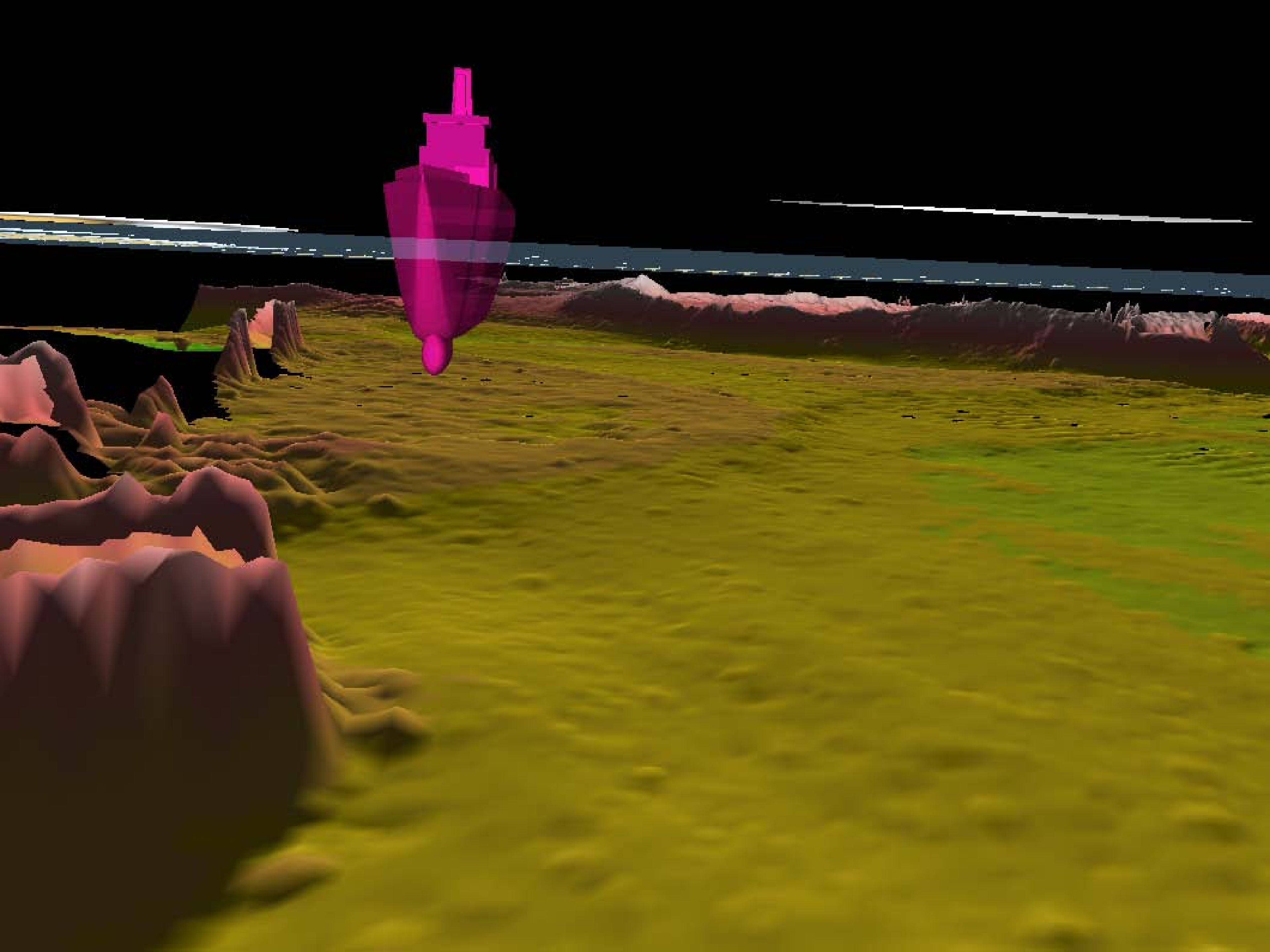


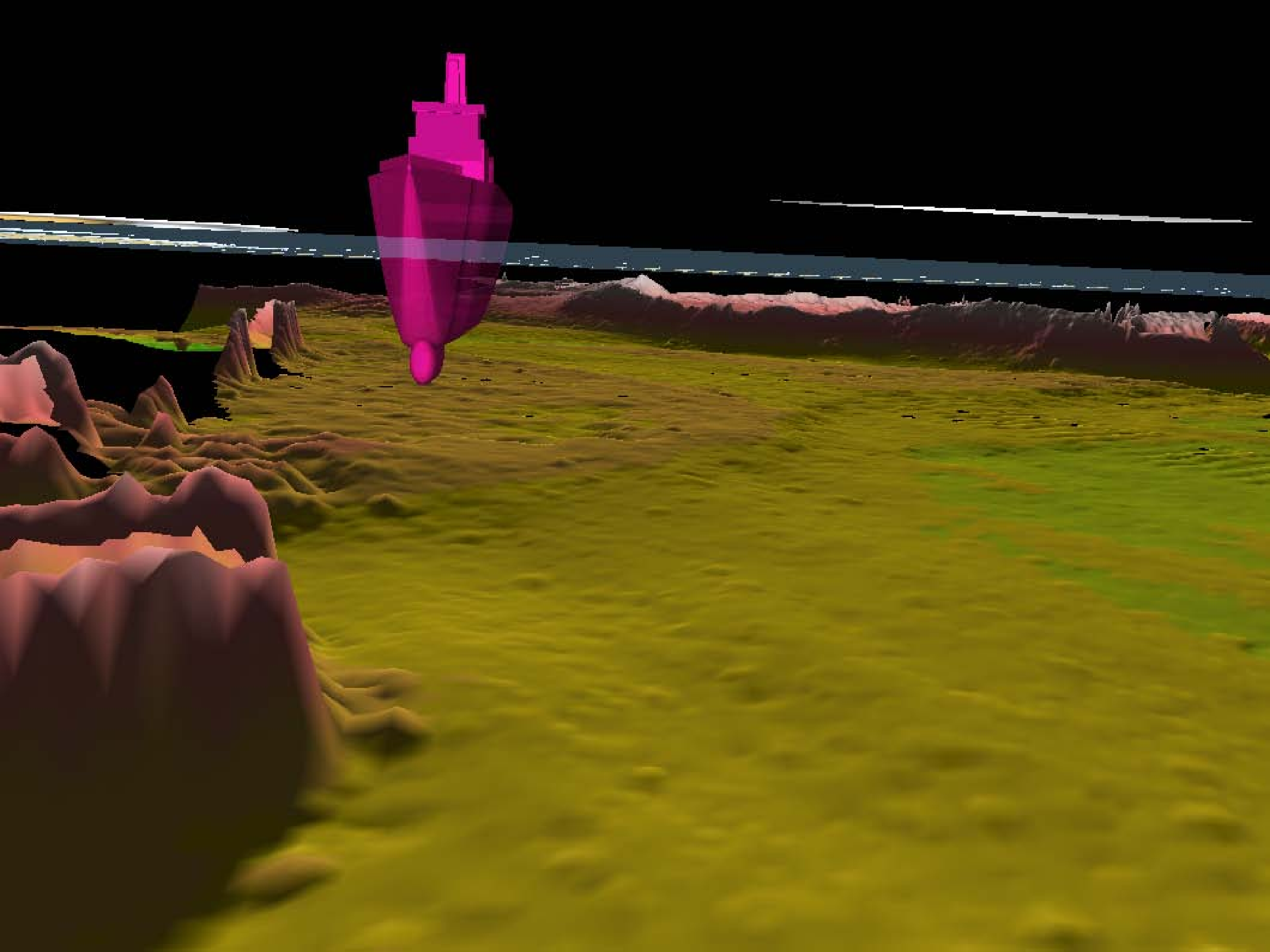


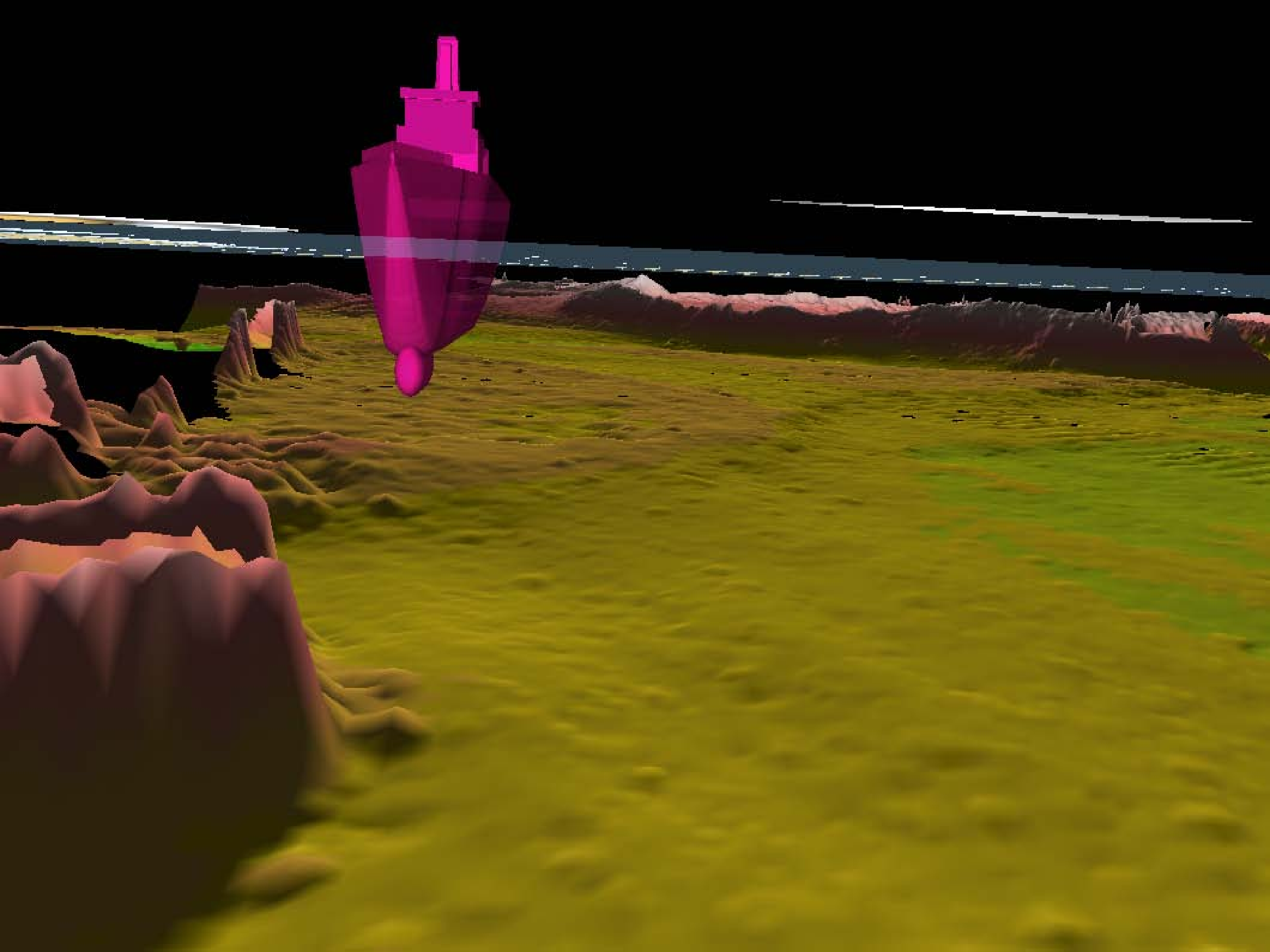


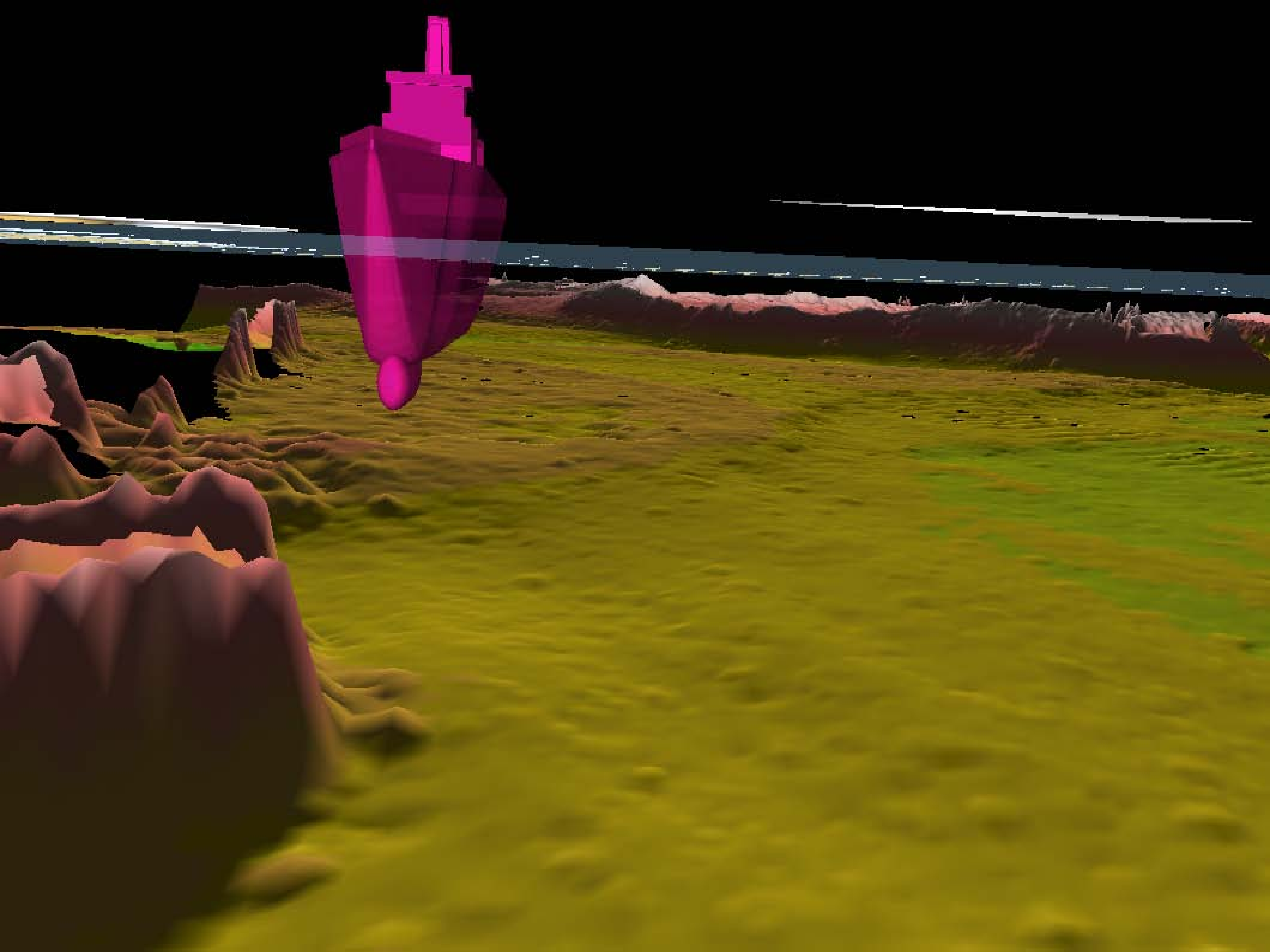












The Chart of the Future