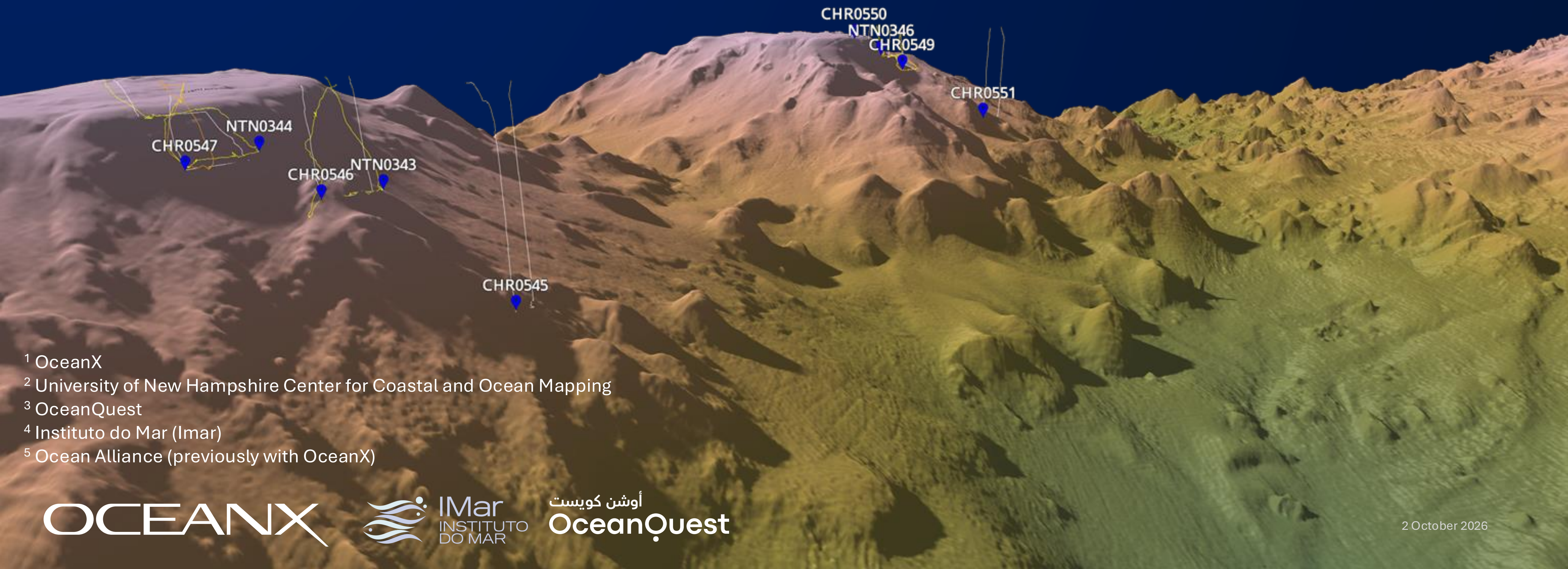


Cabo Verde Digital Deep: Acoustic Highlights and Challenges from a Multi-System, Multi-Expedition Effort to Collect a Rich Digital Dataset

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² University of New Hampshire Center for Coastal and Ocean Mapping

³ OceanQuest

⁴ Instituto do Mar (Imar)

⁵ Ocean Alliance (previously with OceanX)

OCEANX



IMar
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DO MAR

أوشن كويست
OceanQuest

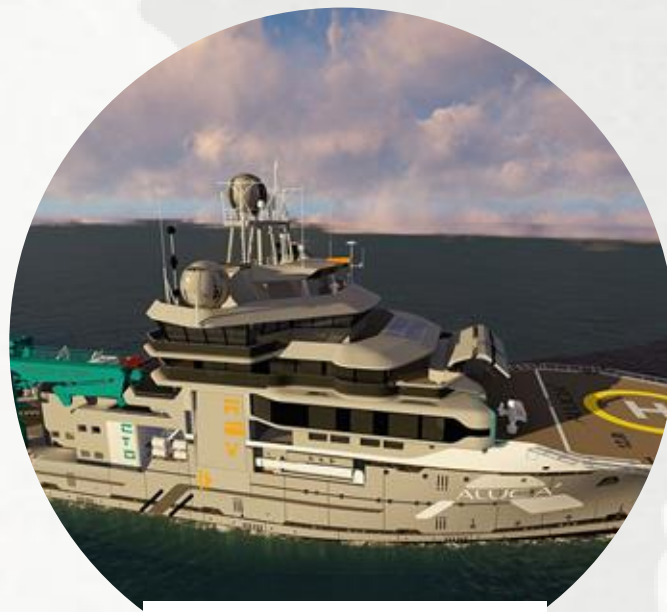
2 October 2026

Overview

- OceanX Intro
- Cabo Verde, Digital Deep, and Other Expeditions
- Challenges
- Highlights & Outcomes

OceanX is a nonprofit ocean research, media, and education organization. Our mission is to explore the ocean and bring it back to the world.

THE OCEANX PILLARS



THE SHIP

A RESEARCH & MEDIA VESSEL
LIKE THE WORLD HAS NEVER
SEEN



SCIENCE

A COMMITMENT TO
SCIENCE THAT GOES
6,000 METERS DEEP



MEDIA

CREATING TRADITIONAL, PHYSICAL, AND
DIGITAL STORYTELLING EXPERIENCES
FOR GLOBAL AUDIENCES OF ALL AGES



PARTNERSHIPS

A PURPOSE-DRIVEN COALITION OF
WORLD-CLASS PARTNERS



EDUCATION

MAKING MARINE SCIENCE
ACCESSIBLE TO EVERYONE

- Since 2012, OceanX has traveled to 47 countries, undertaking over 180 multidisciplinary science expeditions
- 70+ scientific institution partnerships globally; 150+ publications in major scientific journals
- OceanX's current exploration ship, ***OceanXplorer***, came online in 2020 (previous ship: R/V *Alucia*)
- Since 2020, *OceanXplorer* has **mapped nearly 540,000 square kilometers** and undertaken nearly **1800 combined sub, ROV, and scuba dives**
- Our data has contributed to the creation of **3 MPAs**



OCEANXPLORER

ACOUSTIC MAPPING CAPABILITIES

HULL MOUNTED:

- **KONGSBERG EM304 MKI (0.5 x 1 DEGREE)**
- **KONGSBERG EM712 (0.5 x 1 DEGREE)**
- **KONGSBERG EK80 18-38-70-120-200-333 KHZ SUITE**
- KNUDSEN CHIRP 3260 SUBBOTTOM 3.5 & 12 KHZ
- TELEDYNE OCEAN SURVEYOR 75 KHZ ADCP
- RDI WORKHORSE 300 KHZ ADCP
- **POSITIONING: SEAPATH (x 2, SP380-5+, Veripos)**

LAUNCH (METAL SHARK) / USV (OTTER):

- **KONGSBERG EM2040C DUAL HEAD**
- **KONGSBERG EM2040P**
- **KONGSBERG EK80 WBT-MINI 38-120-200 KHZ**
- POSITIONING: POSMV

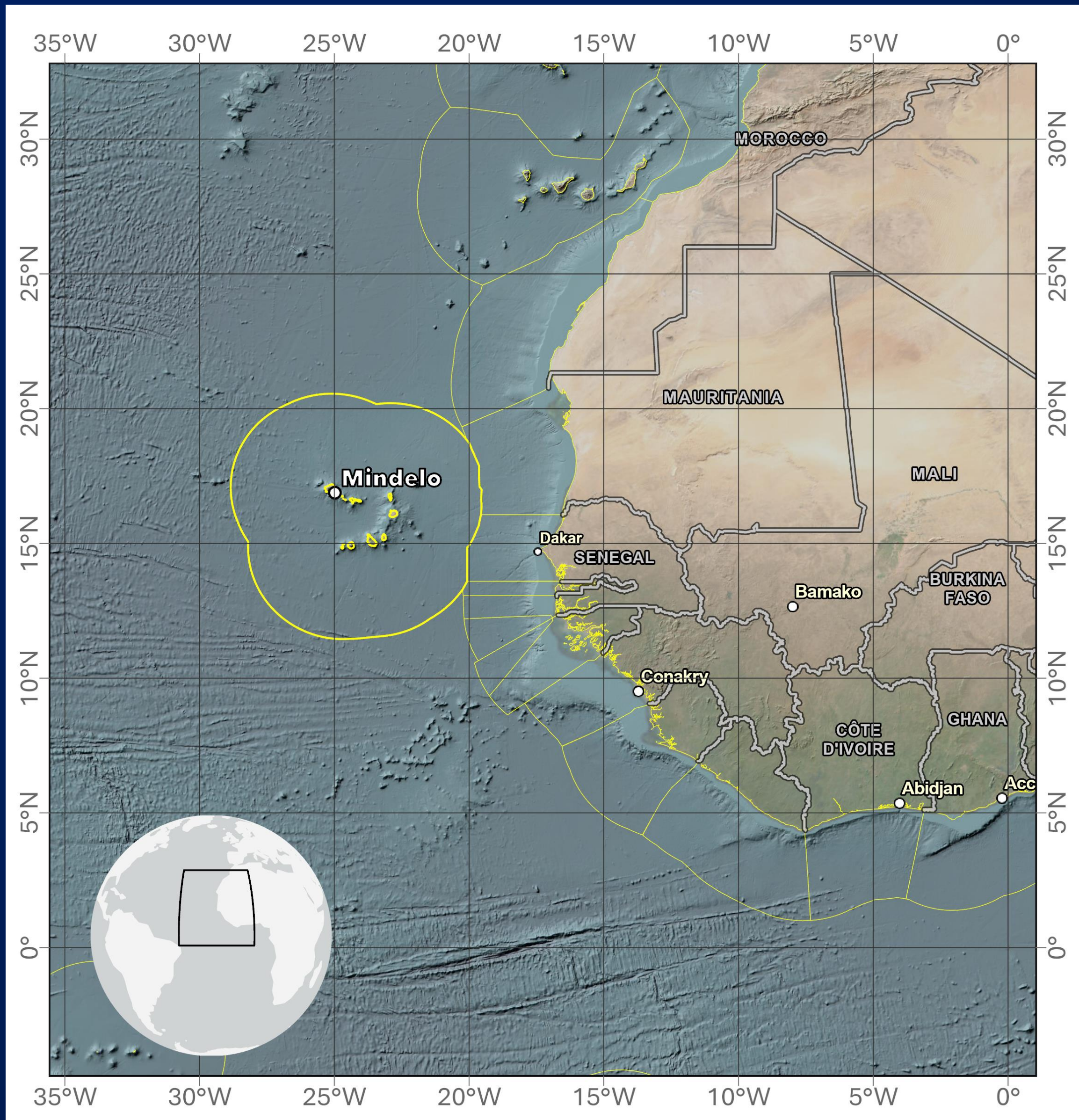
ROV:

- RESON T50

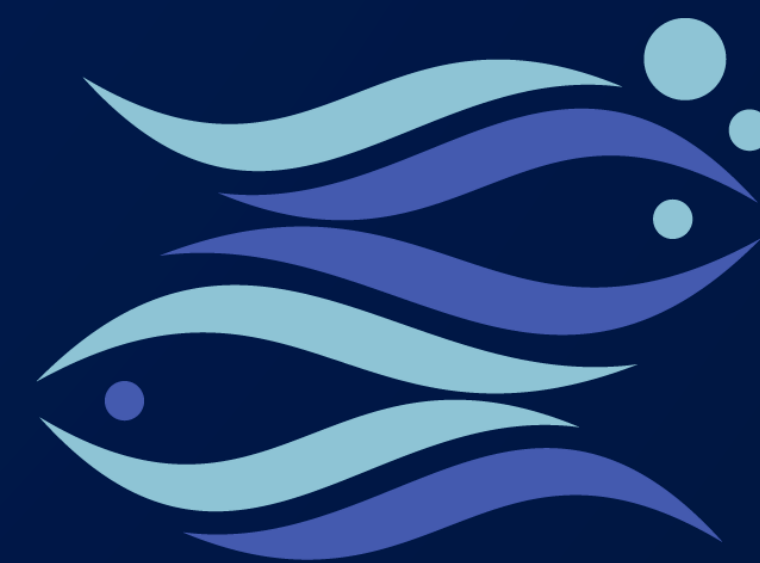
OTHER CAPABILITIES

- TWO TRITON 3300/3 MANNED SUBMERSIBLES, Nadir & Neptune (1000m)
- ARGUS MARINER XL ROV Chimaera (6000m)
- MINI-ARGUS, MINI-MOLA ROVs
- SBE CTD + ROSETTE
- HELICOPTER
- DRONES
- DIVE CENTER
- STATE-OF-THE-ART LABS
- MEDIA CENTER
- NEXT-GEN DNA SEQUENCING CAPABILITIES

Cabo Verde

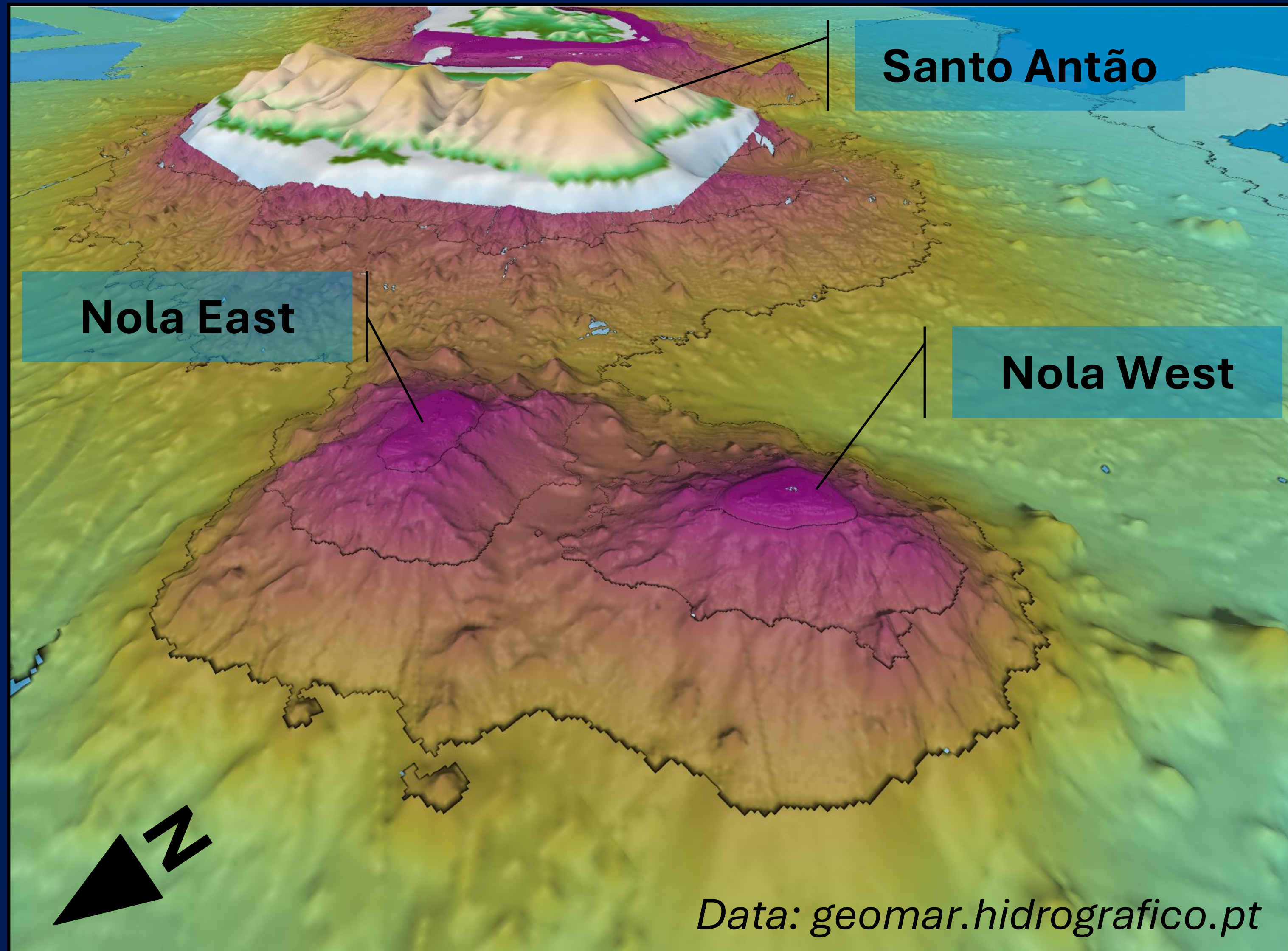


- Situated on Cabo Verde Rise, a large mid-plate bathymetric swell
- Volcanic landscape of ten islands, numerous seamounts – hotspots of marine diversity
- Regional collaborator – Cabo Verdean Institute of the Sea (Insituto do Mar – *Imar*)



IMar
INSTITUTO
DO MAR

Cabo Verde – Nola Seamount Complex

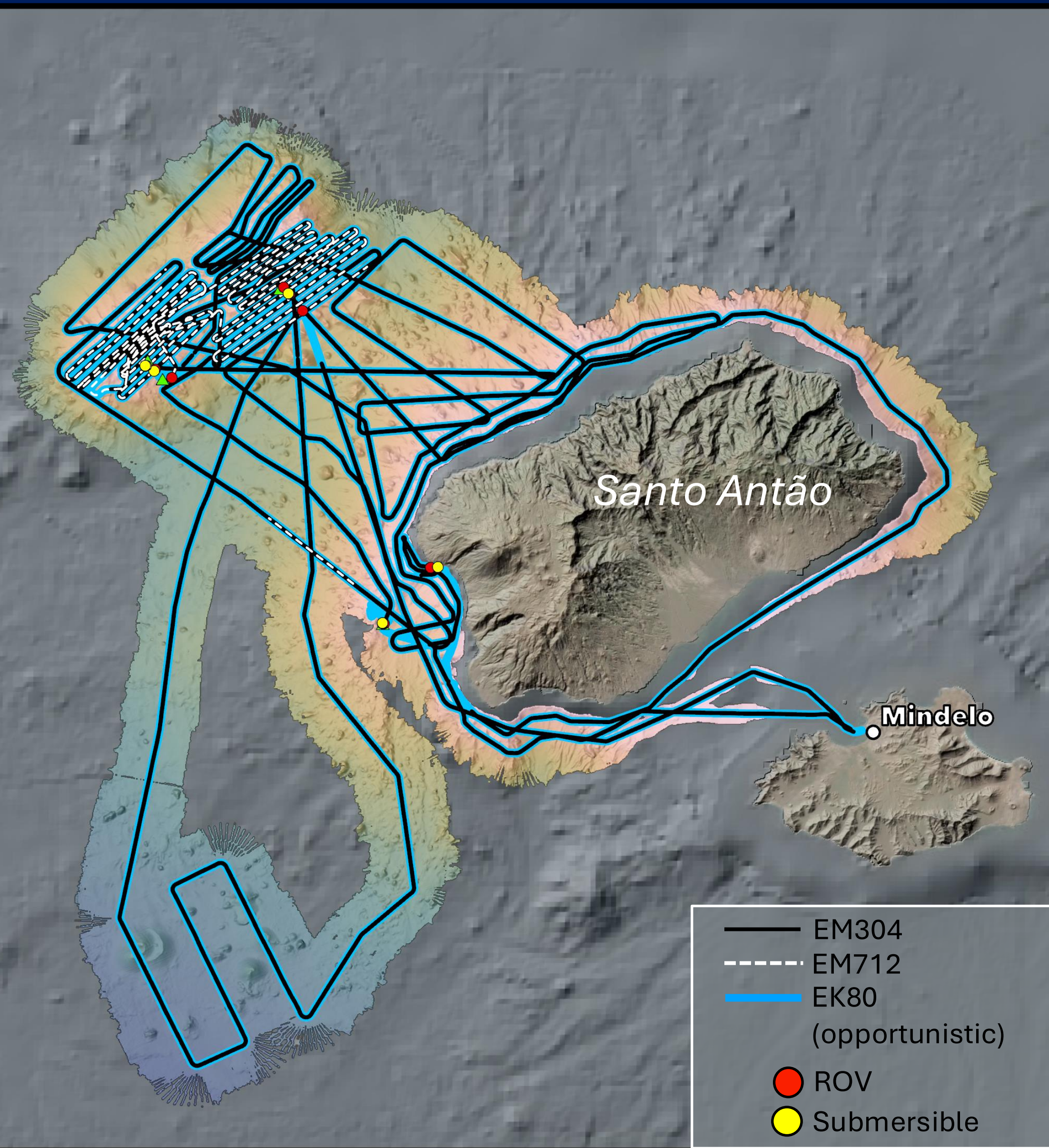


- Selected based on Imar internal RFP, most interesting conservation potential
- Possibility to use each peak independently for ground truthing models

Cabo Verde Digital Deep

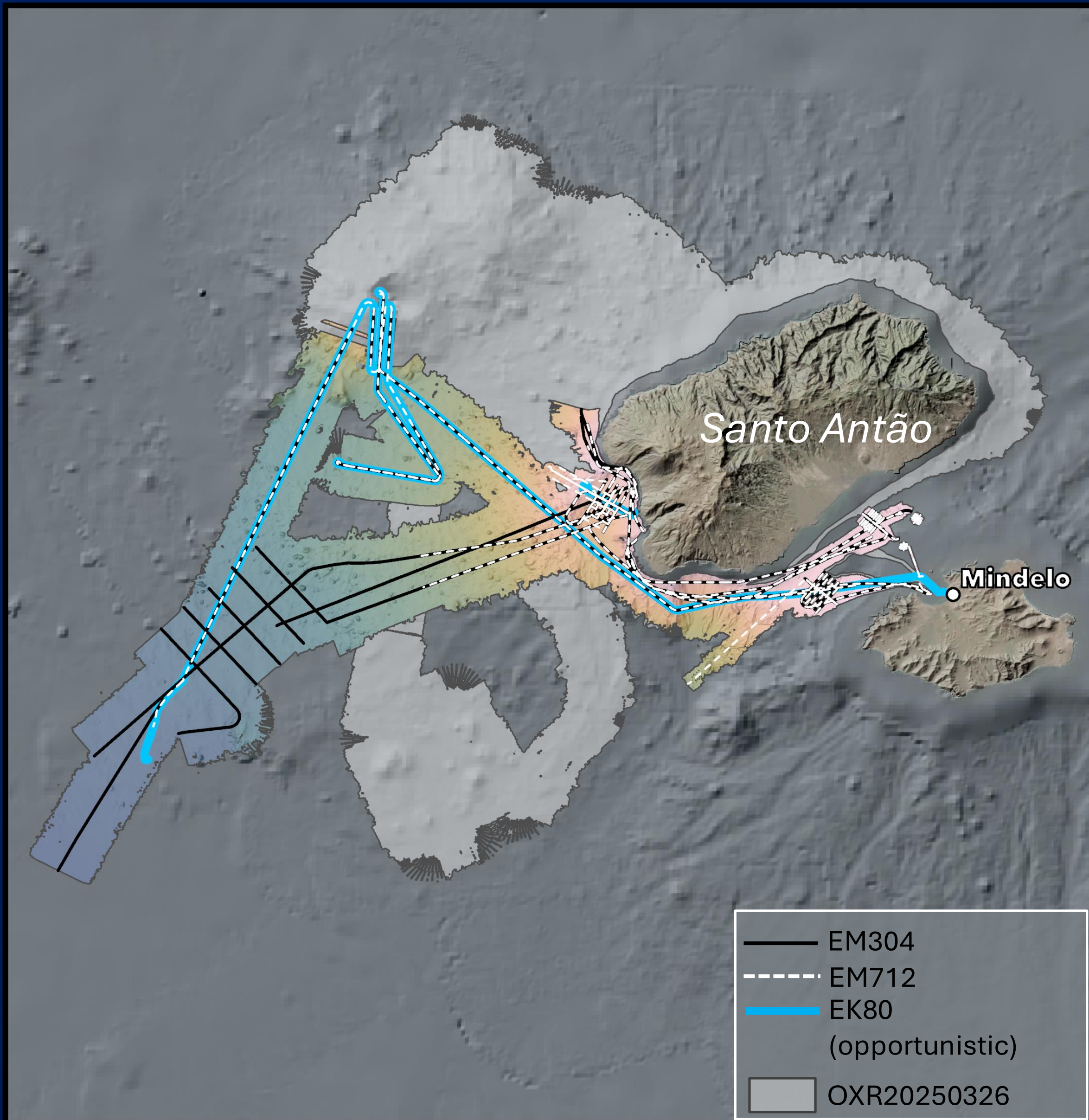
- Digital Deep Idea: Plan an expedition to collect the data necessary to create a digital model of Cabo Verde's Nola Seamount complex, with a strong focus on collecting underwater visual census data of Vulnerable marine Ecosystem (VME) taxa and eDNA to determine baseline biodiversity → **Digital Deep Expedition – OXR20250706**
 - Goal of building a robust dataset for in-house machine learning, visualization projects, and analysis
 - In all we did **SEVEN** expeditions collecting data in Cabo Verdean waters, all of which contributed to our bathymetric synthesis and observations for the region and to the development of the digital model

OXR20250326 – Characterization of the Nola Seamount Complex



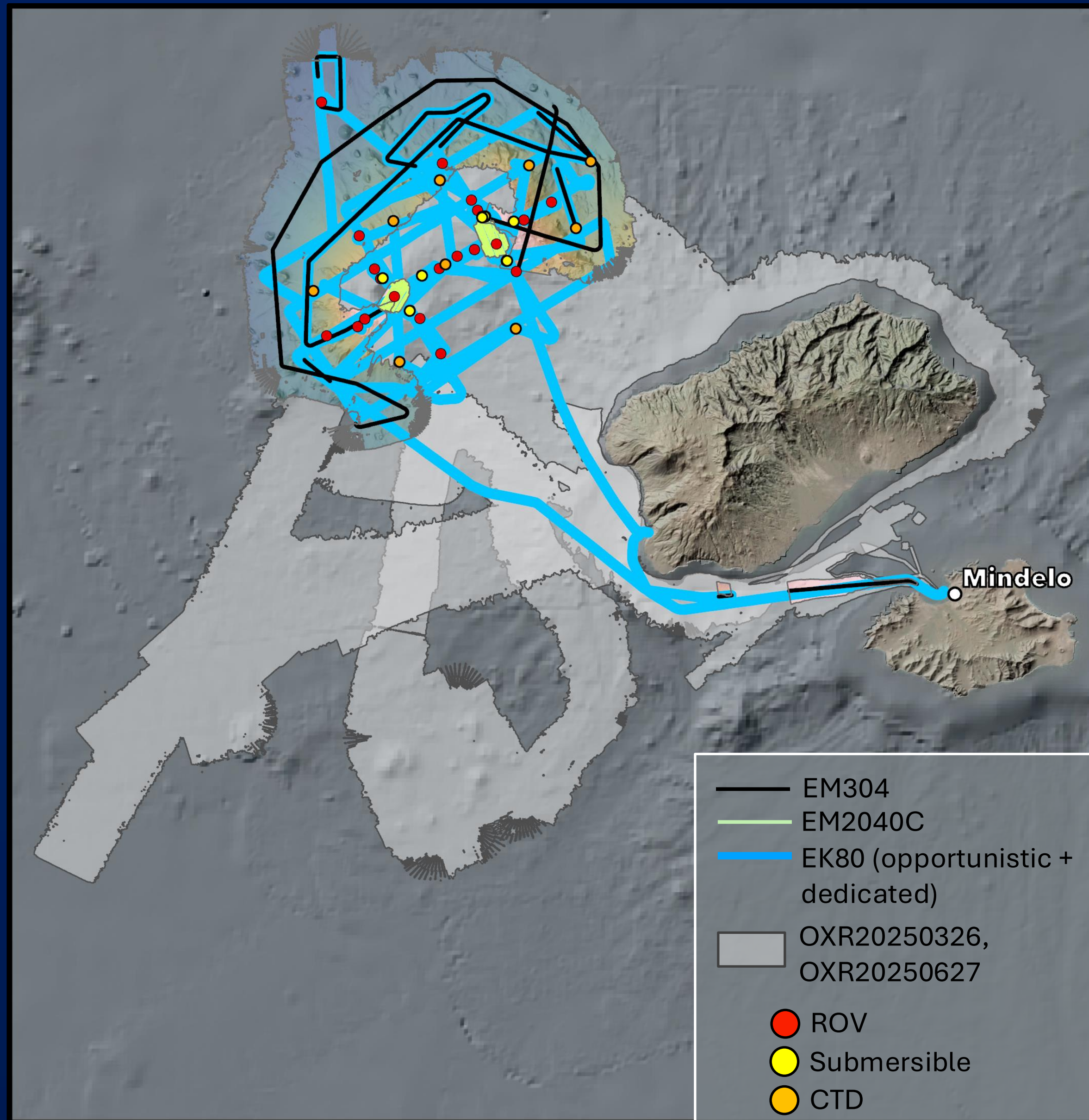
- Part of Around Africa Expedition 2025, partnership with OceanQuest
- Seafloor mapping & geology (multibeam mapping) – **2591 km²**
- Standardized visual census (Challenger 150 protocol, ROV) + additional ROV and submersible transects – **8 ROV, 9 sub dives**
- eDNA, net sampling
- Helicopter megafauna surveys
- Collaboration with GEOMAR (RV *Meteor*) – dual ship ops – CTDs, currents, towed camera observations

OXR20250627 – Multibeam QAT



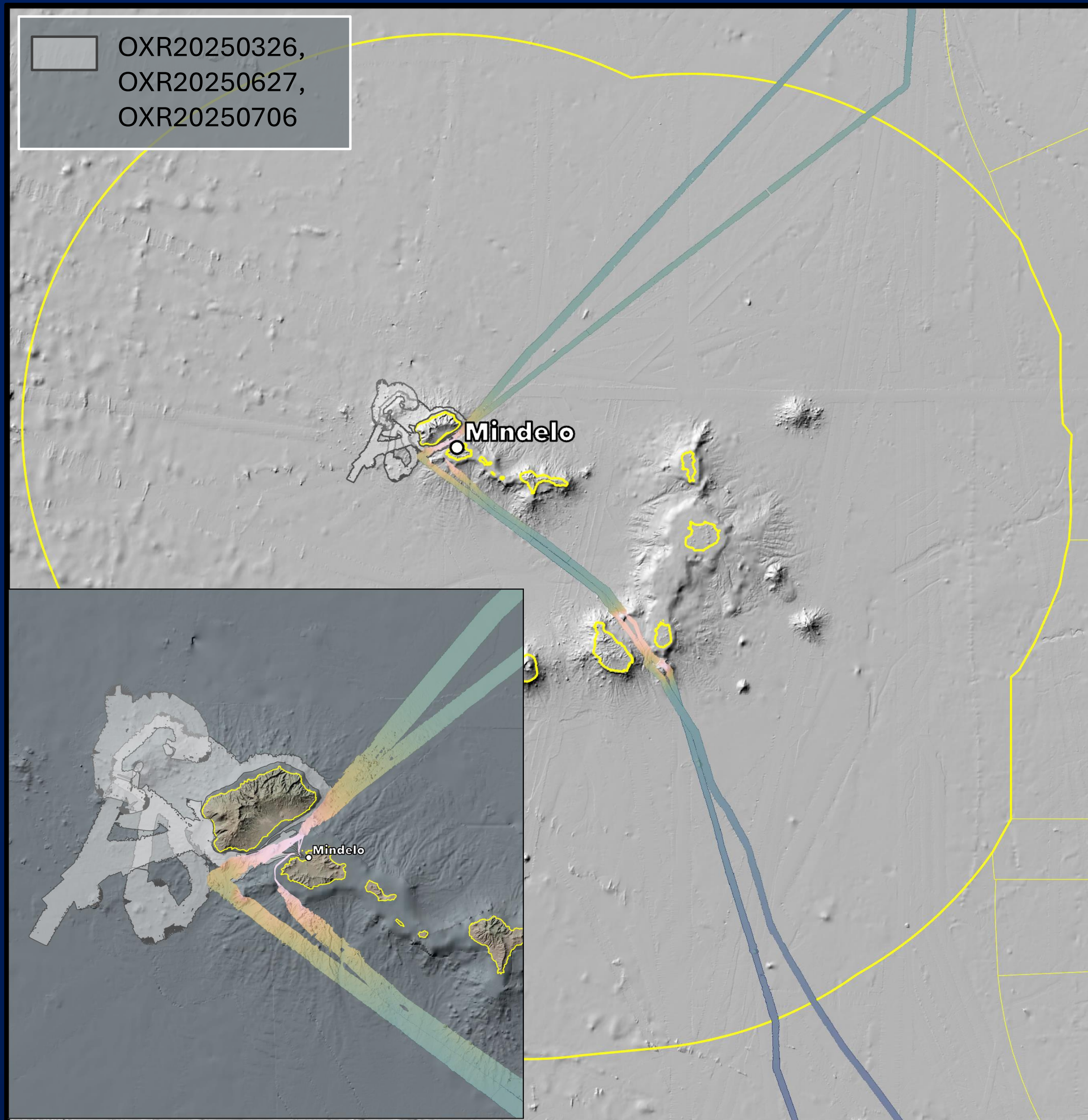
- Regular evaluation of our mapping systems, post-dry dock
- **1708 km²** collected as part of standard QAT series

OXR20250706 – Digital Deep Expedition



- Survey focus was on supplementing/completing MBES survey started on OXR20250326, collecting data at different resolutions, and **dedicated EK80 and ADCP surveys**
- Building a robust dataset for in-house machine learning and visualization projects
- **1114 km²** of EM304 and EM2040 data collected at base and summit of seamount (respectively)
- **9 CTDs**
- **25 ROV, 11 sub dives**

Transits – OXR20250306, OXR20250403, OXR20250620, OXR20250730



- **97,310 km²** of EM304 data total,
15,445 km² within the Cabo Verdean EEZ

CHALLENGES

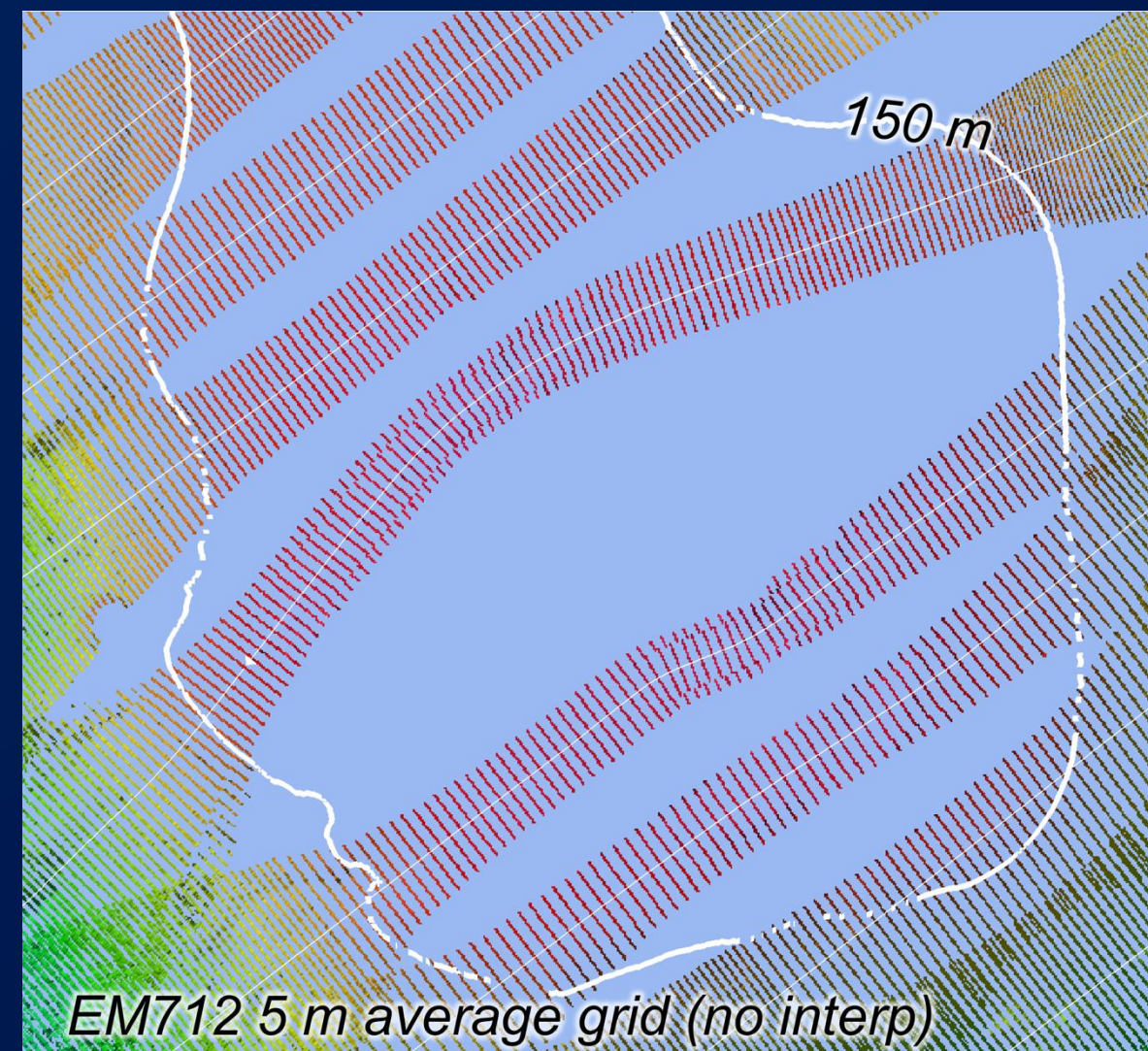
A yellow and black striped underwater vehicle, possibly a submersible or a specialized boat, is shown in a deep blue ocean. Two people are visible inside the vehicle, looking out. The vehicle is surrounded by a large school of fish, likely sardines or similar small fish, swimming in the water. The scene is illuminated by the vehicle's lights, creating a bright glow around the interior and the fish.

Challenge: Overlapping Coverage, Multiple Systems

- Intention to acquire full EM304, EM712 and EM2040 datasets over summits to have at least one area to compare systems, effects of resolution on modeling.

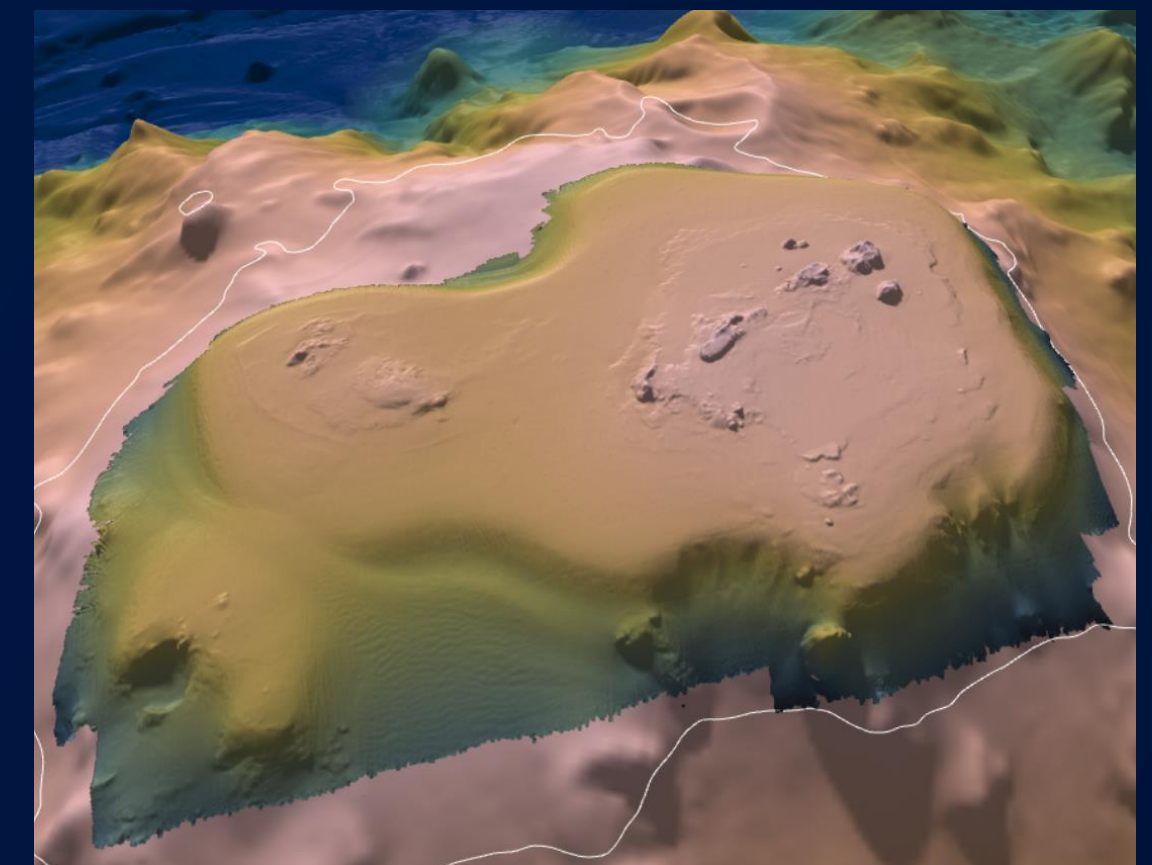
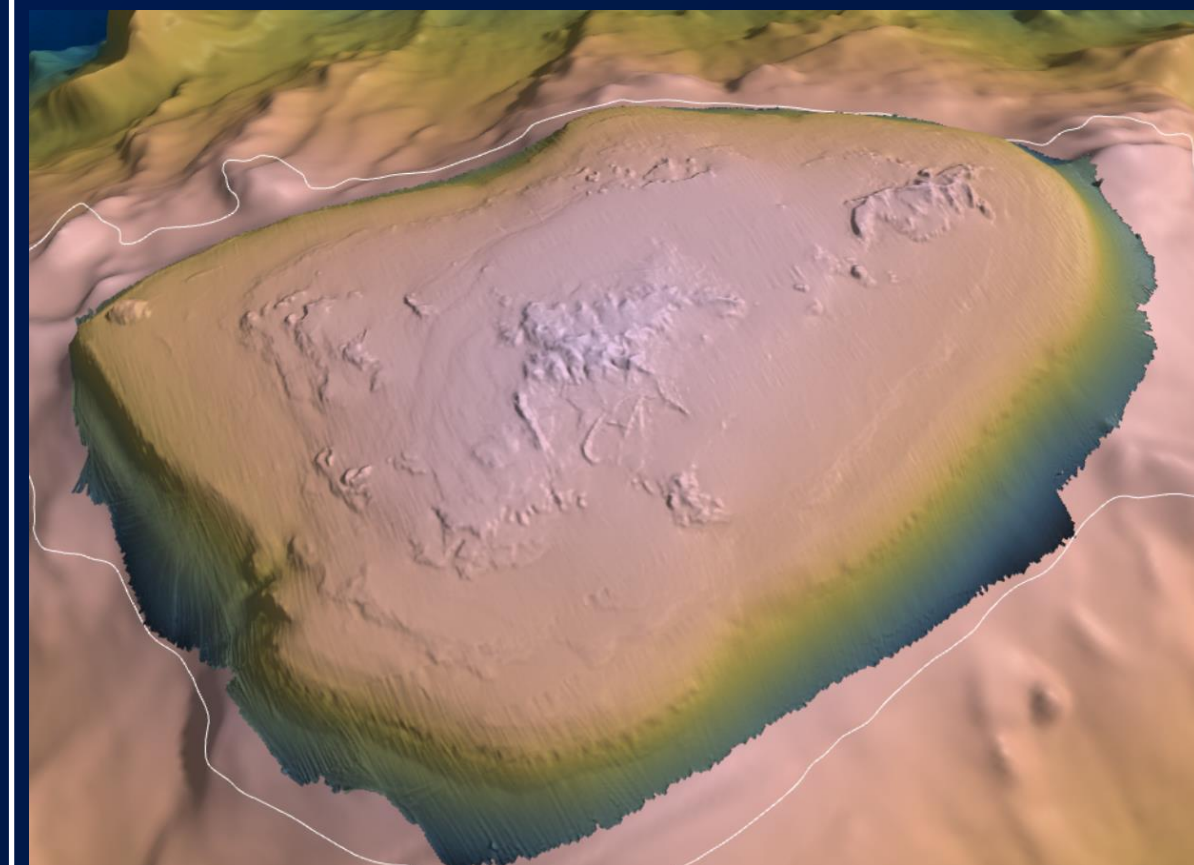
OXR20250326

- EM304, EM712 (synchronized)
- Challenges
 - Fishing boats at summit
 - Reduced ping density



OXR20250706

- EM712, EM2040 intended
 - EM2040 success! ✓
- Challenge
 - EM712 out of commission

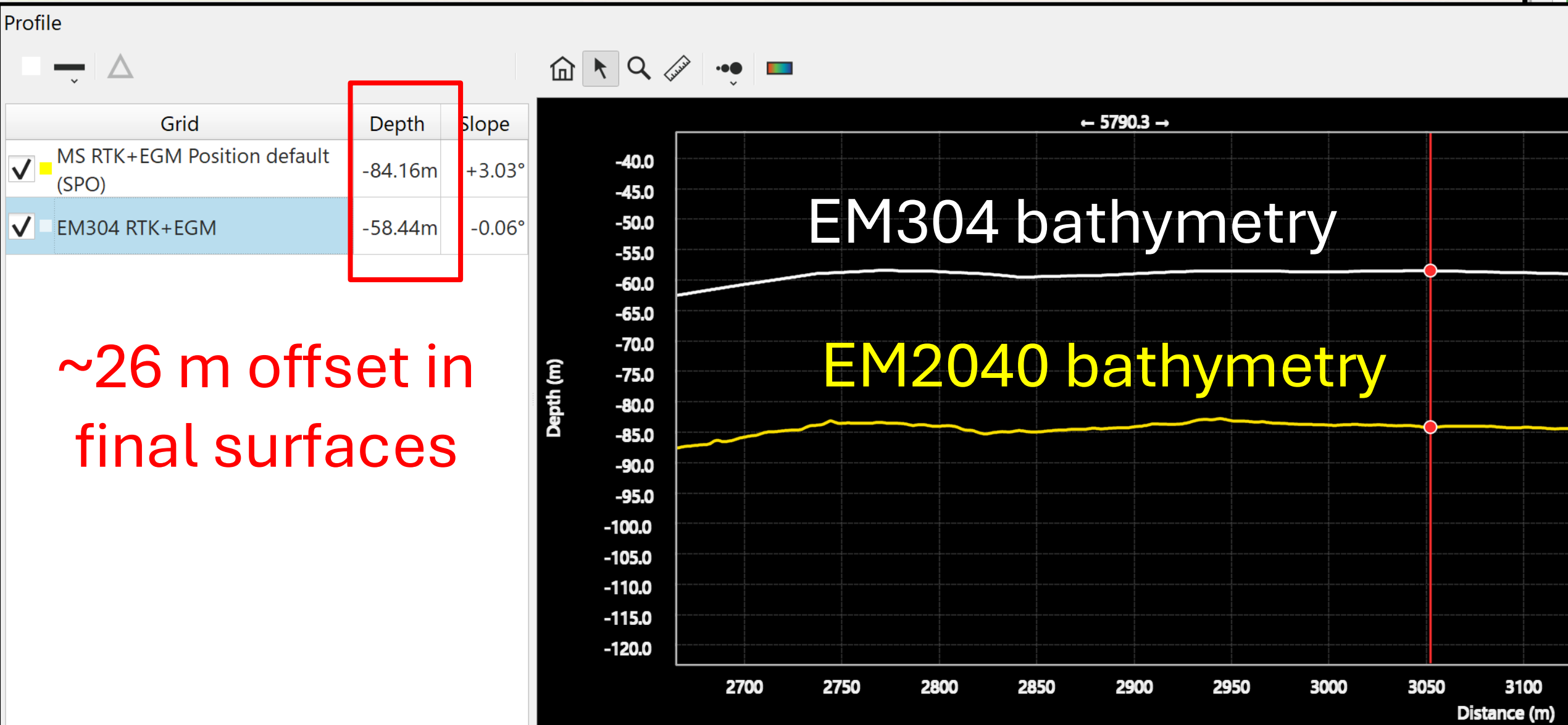
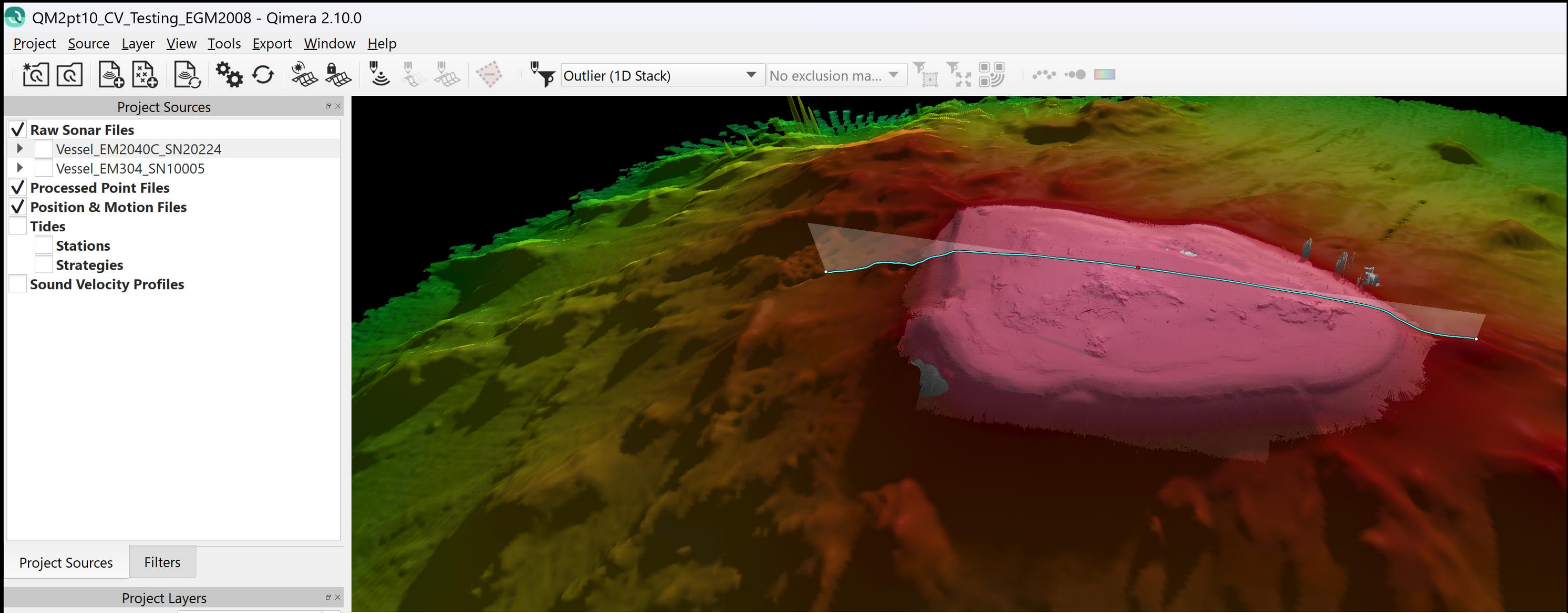


Nola West (left) and Nola East (right), 5m weighted moving average grid

Challenge: Vertical Referencing Issues

- Typical OceanX workflow -
 - Acquisition:
 - All acquisition through SIS, logging KMAIL files
 - QINSY used for situational awareness (mapping, ROV & sub ops), line planning, etc. but not as primary acquisition software
 - Processing software: Qimera
 - EM2040C: POSMV. Log POS files, post-process, apply SBETs in post-processing.
 - EM304, EM712: Seapath + Veripos corrections. Use online solution.
 - Set all to use ellipsoid heights and reduce to MSL using EGM2008.
- Challenge:
 - OXR20250706 – POSMV files failed to log during EM2040C survey
 - *...No problem, use online solution in KMAIL files....*

Vertical Referencing Issues



~26 m offset in final surfaces

Processing Settings Editor

Vertical Referencing Options, Qimera 2.7.6

Sound Velocity Position, Motion, Heading Vertical Referencing Depth Blocking Sonar Shifts

Vertical Geodetic Offset

Note: Separation values will be subtracted from input heights to obtain output heights, following the geodetic convention $H=h-N$. Static offsets are subtracted from heights, for example, an offset of -1 will adjust heights to be 1 m shallower.

☐ Static offset: 0.000 m SD offset: 0.050 m

☐ Separation model: ... SD model: 0.100 m

☒ Qinsy model: Common Files/QPS/GeodeticResources/Geoid/EGM2008.BIN SD model: 0.058 m

Vertical Referencing Method

☐ None (Instantaneous Water Height)

☐ Qinsy Online Computation (Object Track)

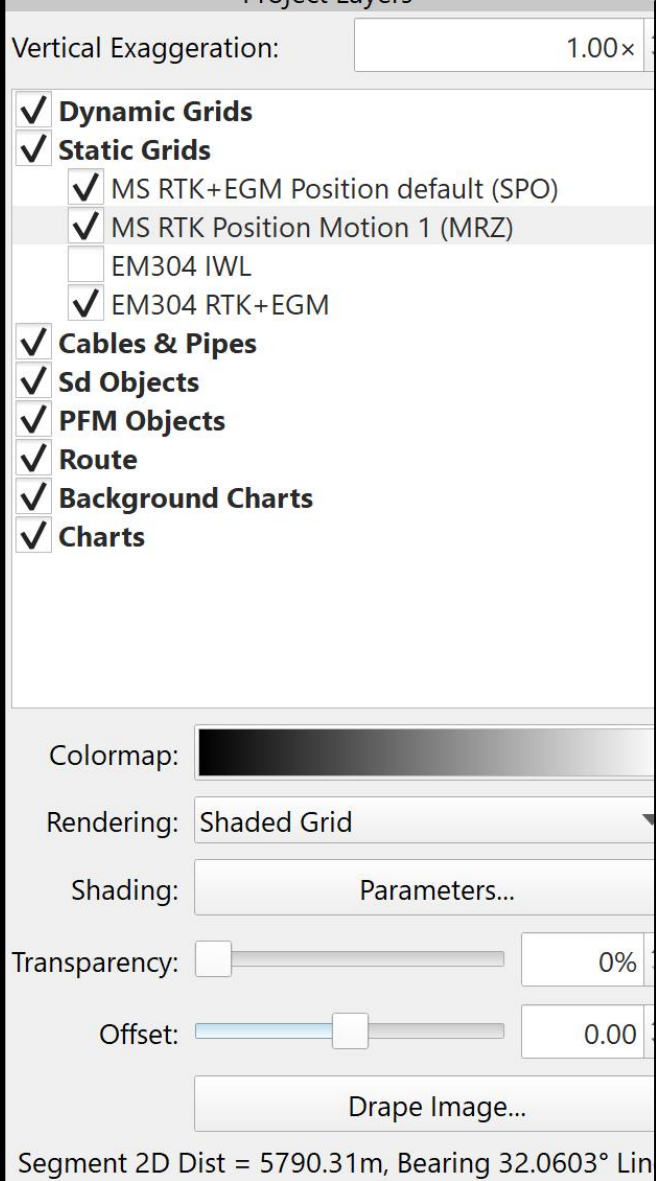
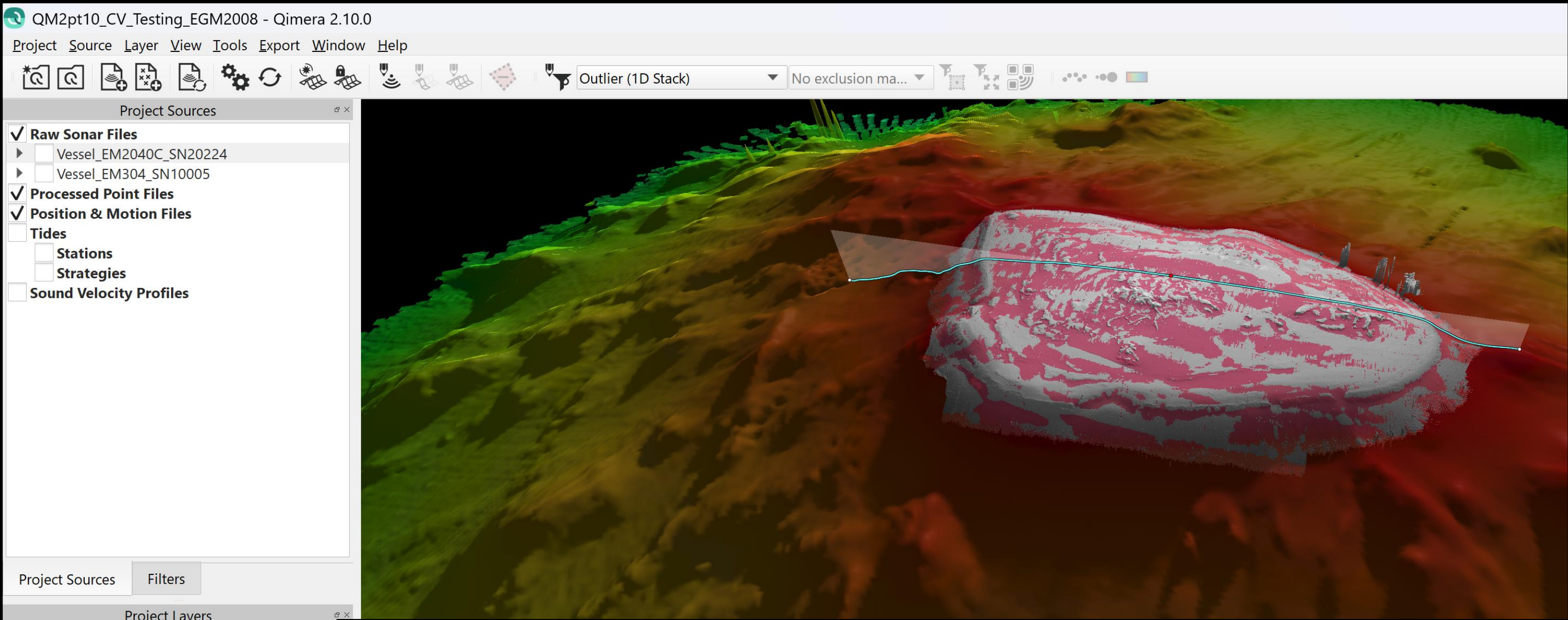
☒ RTK (Accurate Height)

☒ Position 1

Only option → Read from KMAIL SPO datagram. 'Ellipsoid' values coming from POS (via GGA) are not ellipsoid, but orthometric heights based on EGM96. Qimera *also* applying geoid correction (EGM2008) = offset

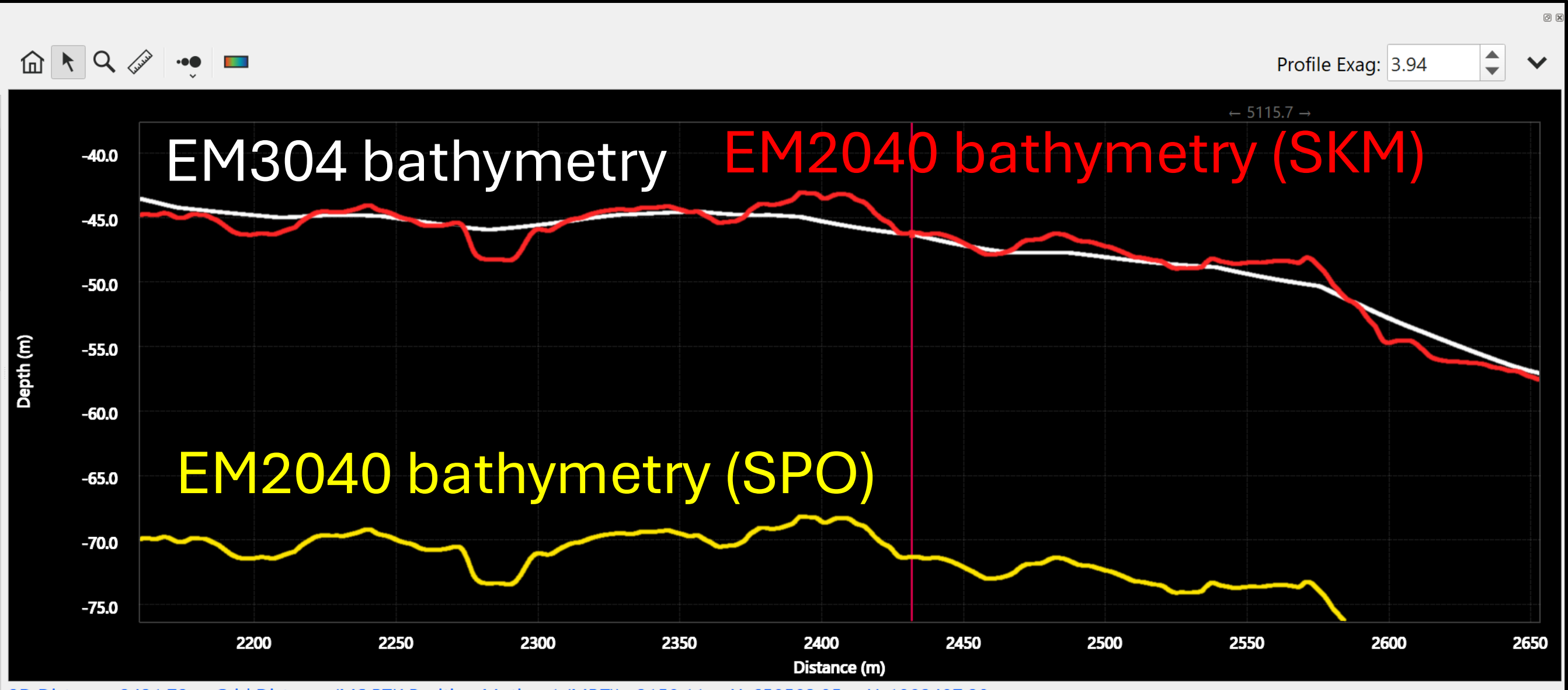
OK Cancel Apply

Vertical Referencing Issues



Grid	Depth	Slope
✓ MS RTK+EGM Position default (SPO)	-71.28m	+0.69°
✓ MS RTK Position Motion 1 (SKM)	-46.15m	+0.69°
✓ EM304 RTK+EGM	-46.31m	-1.37°

Small offsets as expected for differences in system, grid resolution



Vertical Referencing Options, Qimera 2.8.1+

Sound Velocity Position, Motion, Heading Vertical Referencing Depth Blocking Sonar Shifts

Vertical Geodetic Offset

Note: Separation values will be subtracted from input heights to obtain output heights, following the geodetic convention $H=h-N$. Static offsets are subtracted from heights, for example, an offset of -1 will adjust heights to be 1 m shallower.

☐ Static offset: 0.000 m SD offset: 0.050 m

☐ Separation model: ... SD model: 0.100 m

☒ Qinsy model: Common Files/QPS/GeodeticResources/Geoid/EGM2008.BIN SD model: 0.058 m

Vertical Referencing Method

☐ None (Instantaneous Water Height)

☐ Qinsy Online Computation (Object Track)

☒ RTK (Accurate Height)

☒ Position from Motion 1

☒ Position 1

☐ Tide (Unreliable Height)

OK Cancel Apply

New 'Position from Motion 1' option to read position from SKM packet → actual ellipsoid heights, handled properly

Kongsberg Record Viewer 1.1.0

File directory:

Zoom: + - Export to: CSV TXT ?

GroupedSequencedDatagram Statistics < >

Files

0007_20250709_160637_OXR20250706_EM2040... X

Record typeTotal

Installation (#IIP)1

Runtime (#IOP)1

Sound Velocity Profile (#SVP)1

Sensor sound Velocity (#SVT)28351

Position Sensor (#SPO)11340

Compatibility position (#CPO)11340

Range and Depth (#MRZ)4518

Clock (#SCL)1134

Attitude and attitude velocity (#SKM)1116

IndexTimePing/Seq.

12025/07/09T18:06:37.871Z

22025/07/09T18:06:37.971Z

32025/07/09T18:06:38.714Z

42025/07/09T18:06:38.171Z

52025/07/09T18:06:38.271Z

62025/07/09T18:06:38.371Z

72025/07/09T18:06:38.471Z

82025/07/09T18:06:38.571Z

92025/07/09T18:06:38.671Z

Datagram infoSystem infoTime info

Datagram length in bytes146

Multibeam datagram type#SPO

Datagram version0

System ID40

Echo sounder identity2045

File revisionJ

DateWedn 2025/

UTC time18:06:

Common

Number of bytes common part8

Sensor system number0

Sensor status1089

Sensor data

Time sec16:06:37.000Zseconds

Time nanosec866000000

Position quality0.30m

Corrected latitude17.21888017decimal degree

Corrected longitude-25.57736683decimal degree

Speed3.38m/s

Course208.75degree

Ellipsoid height1.48m

Position data\$INGGA,160637.866,1713.13281,N,02534.64201,W,5,29,0.6,1.48,M,,4,0803*07

SPO vs SKM Packets, EM2040 data

(positioning source = POSMV)

Kongsberg Record Viewer 1.1.0

File directory:

Zoom: + - Export to: CSV TXT ?

GroupedSequencedDatagram Statistics < >

Files

0007_20250709_160637_OXR20250706_EM2040... X

Record typeTotal

Installation (#IIP)1

Runtime (#IOP)1

Sound Velocity Profile (#SVP)1

Sensor sound Velocity (#SVT)28351

Position Sensor (#SPO)11340

Compatibility position (#CPO)11340

Range and Depth (#MRZ)4518

Clock (#SCL)1134

Attitude and attitude velocity (#SKM)1116

IndexTimePing/Seq.

12025/07/09T18:06:37.261Z

22025/07/09T18:06:38.271Z

32025/07/09T18:06:39.291Z

42025/07/09T18:06:40.301Z

52025/07/09T18:06:41.321Z

62025/07/09T18:06:42.331Z

72025/07/09T18:06:43.351Z

82025/07/09T18:06:44.361Z

92025/07/09T18:06:45.381Z

Datagram infoSystem infoTime info

Datagram length in bytes13368

Multibeam datagram type#SKM

Datagram version1

System ID40

Echo sounder identity2045

File revisionJ

DateWedr 2025/

UTC time18:06:

Display data:

All

Accelerations

Attitude

Errors

Info

Position

Rates

Velocities

#KMB

Datagram length132bytes

Datagram version1

UTC time

Nano seconds remainder255545336

Bit pattern0

Position

Latitude17.21889488decimal degrees

Longitude-25.57735536decimal degrees

Ellipsoid height26.40m

Rates

Roll rate0.20degree/s

Pitch rate0.87degree/s

Yaw (heading) rate0.13degree/s

Velocities

Velocity North (X)-2.58m/s

Velocity East (Y)-1.93m/s

Velocity downwards-0.41m/s

Delayed heave

Time in sec1752077062.000seconds

Challenge: Ship ↔ Shore Processing

- Typical OceanX workflow -
 - Processing software: Qimera
 - Build project on ship, load data near acquisition to check
 - Process when possible, focusing on areas needed for subsea (ROV & sub) ops
 - Generate ‘preliminary final’ products for end-of-expedition data package
 - Complete processing shoreside post-expedition to generate ‘submission final’ products for submission to syntheses and archive and to provide to collaborators, internal data users, and 3rd party data requests (*...timeline 1 month – 5+ years...*).
- Required data transfer:
 - KMALLs transferred to shore as part of standard CruiseData package – happens pretty regularly
 - Transfer of partially completed processing projects ship → shore – large projects, not transferred regularly = delay before processing can continue
 - + software version concerns when returning to old projects etc.

Ship ↔ Shore Processing

- Improvement:
 - Qimera 2.7.0 update: Ability to export out *QPD edits* from processing project – lightweight files containing edit flags, saved in CruiseData, easy automatic transfer to shore
 - Shoreside, allowed for loading KMALLs from various expeditions, applying QPD edits from various processing projects started on ship, and continuing processing on combined datasets

The image displays three screenshots of the Qimera software interface, illustrating the process of applying QPD edits to a project.

Left Screenshot (Qimera 2.7.6): Shows the 'Project Sources' panel with a list of raw sonar files. The 'Export QPD Edits' option is highlighted in the 'Project Sources' menu.

Middle Screenshot (Qimera 2.10.0): Shows the 'Project Sources' panel with a list of files. The 'Apply Edits from...' option is highlighted in the 'Project Sources' menu.

Right Screenshot (Qimera 2.10.0): Shows the 'Project Sources' panel with a list of files. The 'Apply Edits from QPD' option is highlighted in the 'Project Sources' menu.

Challenge:

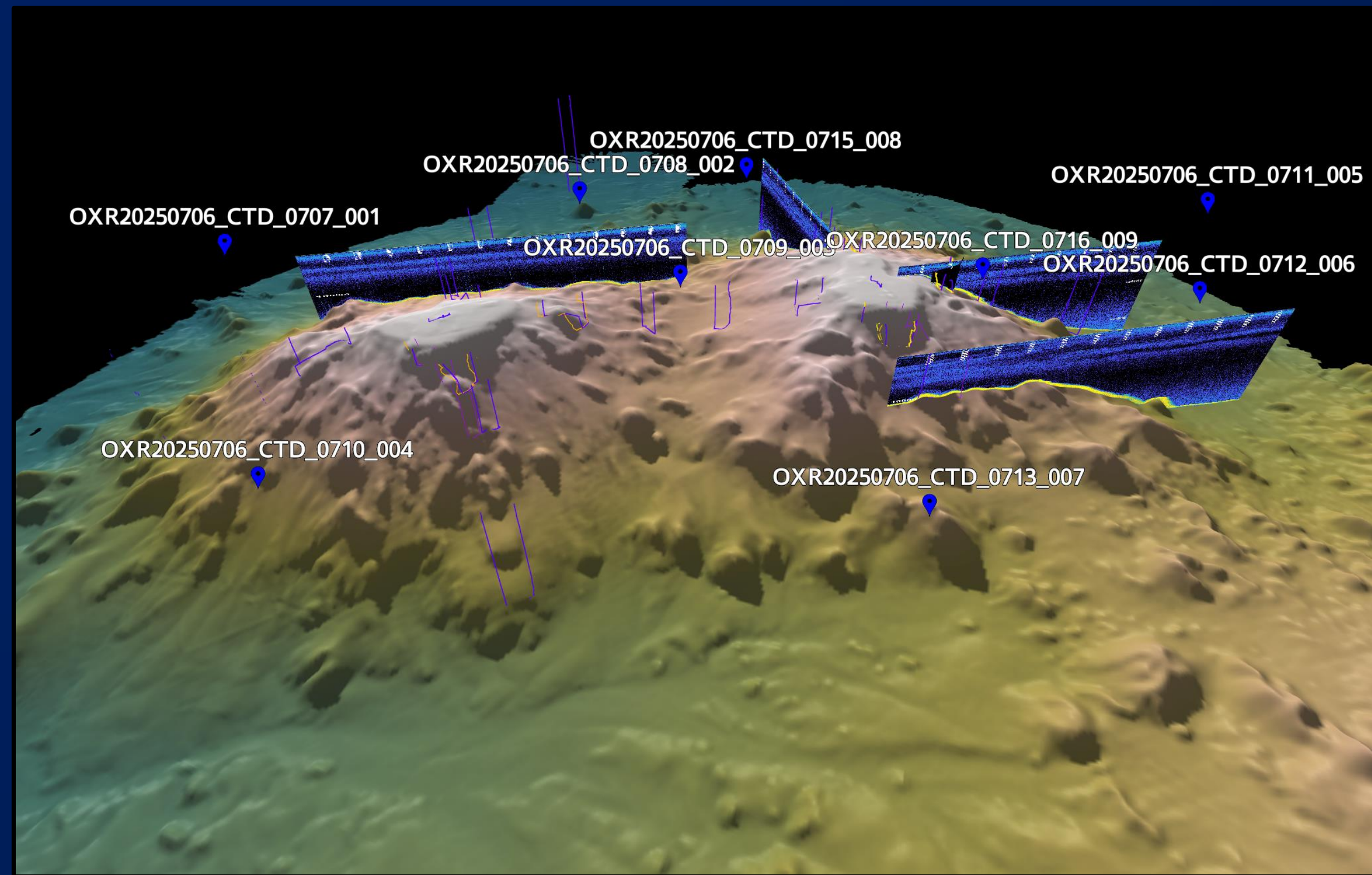
- Errors when trying to apply QPD edits
- QPS tracked back to an ID mismatch in metadata, provided workaround for older projects and updated in new versions – resolved Qimera 2.9.0

The bottom of the screenshots shows the 'Job Activity' panel, which displays the progress of the processing tasks. The 'Apply Edits from QPD' task is shown as successful, with a duration of 00:00:39.073.

HIGHLIGHTS & OUTCOMES

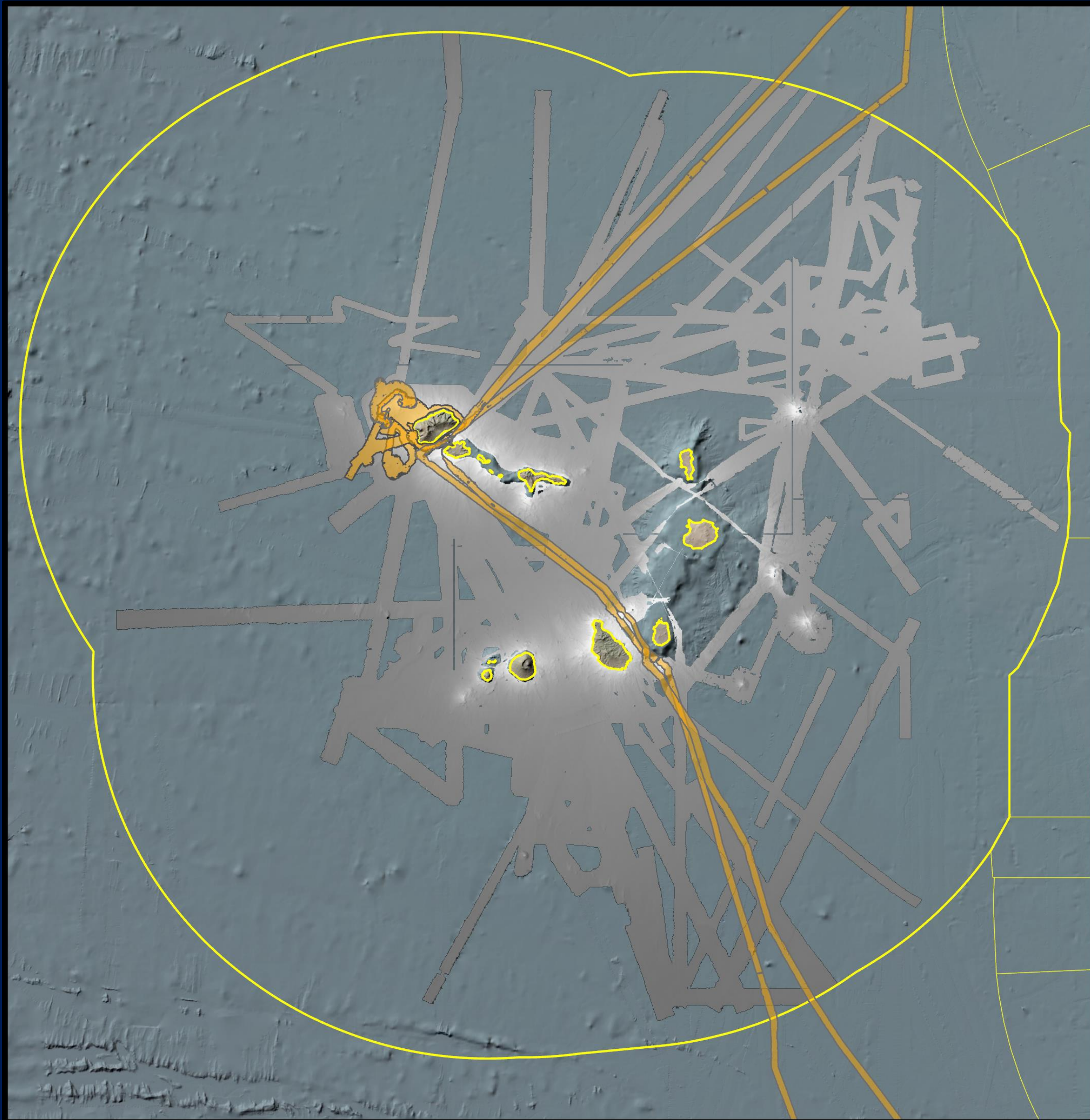


Rich Dataset for Analysis & Modeling



- Bathymetry, seabed backscatter, and water column backscatter ranging from 35 – 3500+ m from three Kongsberg MBES systems
- 4000+ km of EK80 data including 550 km of dedicated EK80 survey
- Dedicated and opportunistic ADCP data
- Subbottom data
- 9 CTD casts
- 33 ROV dives
- 21 submersible dives
- ? hours of ROV and sub video and imagery
- Net tows
- Water sampling, eDNA
- Helicopter megafauna survey

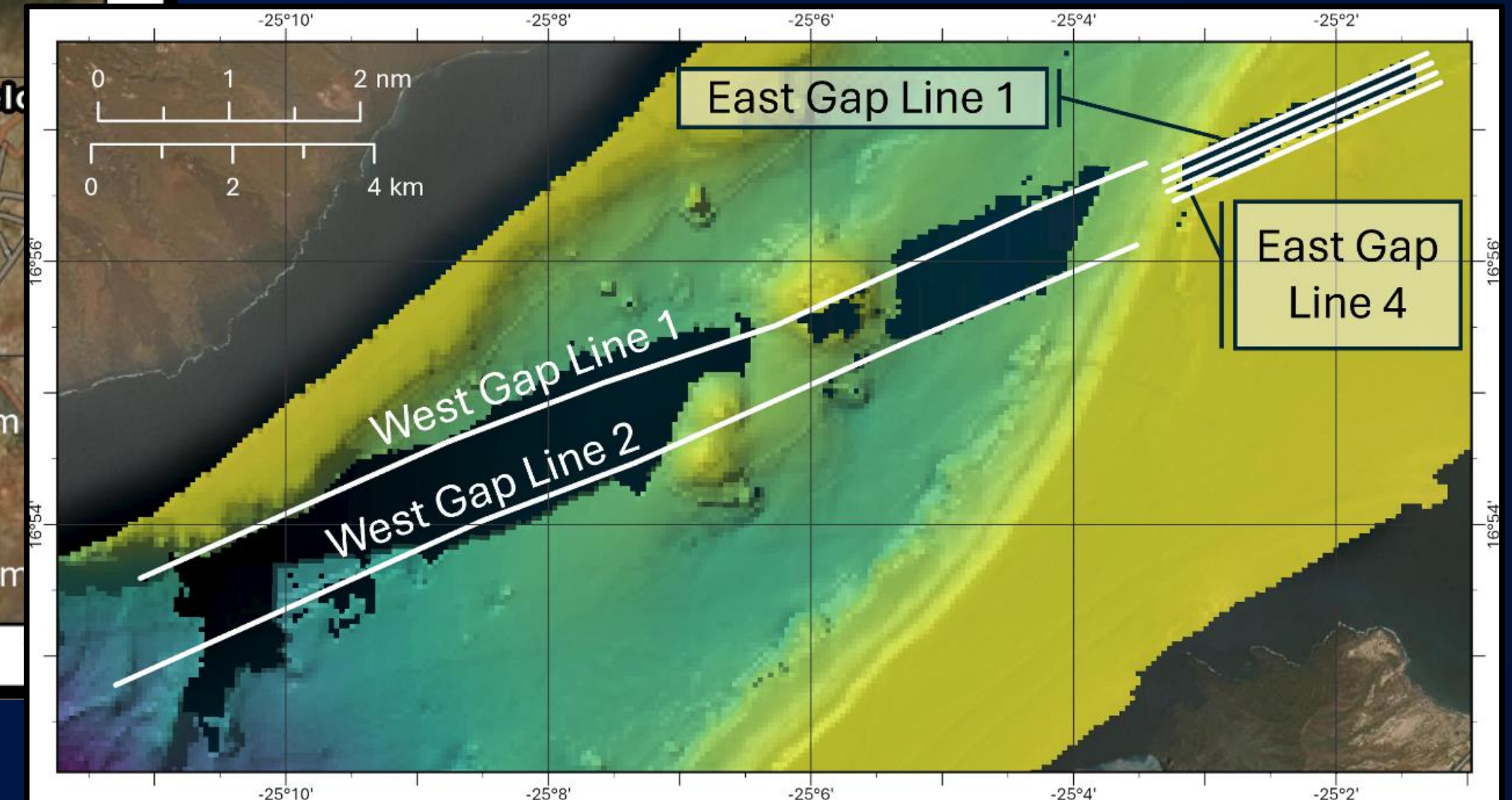
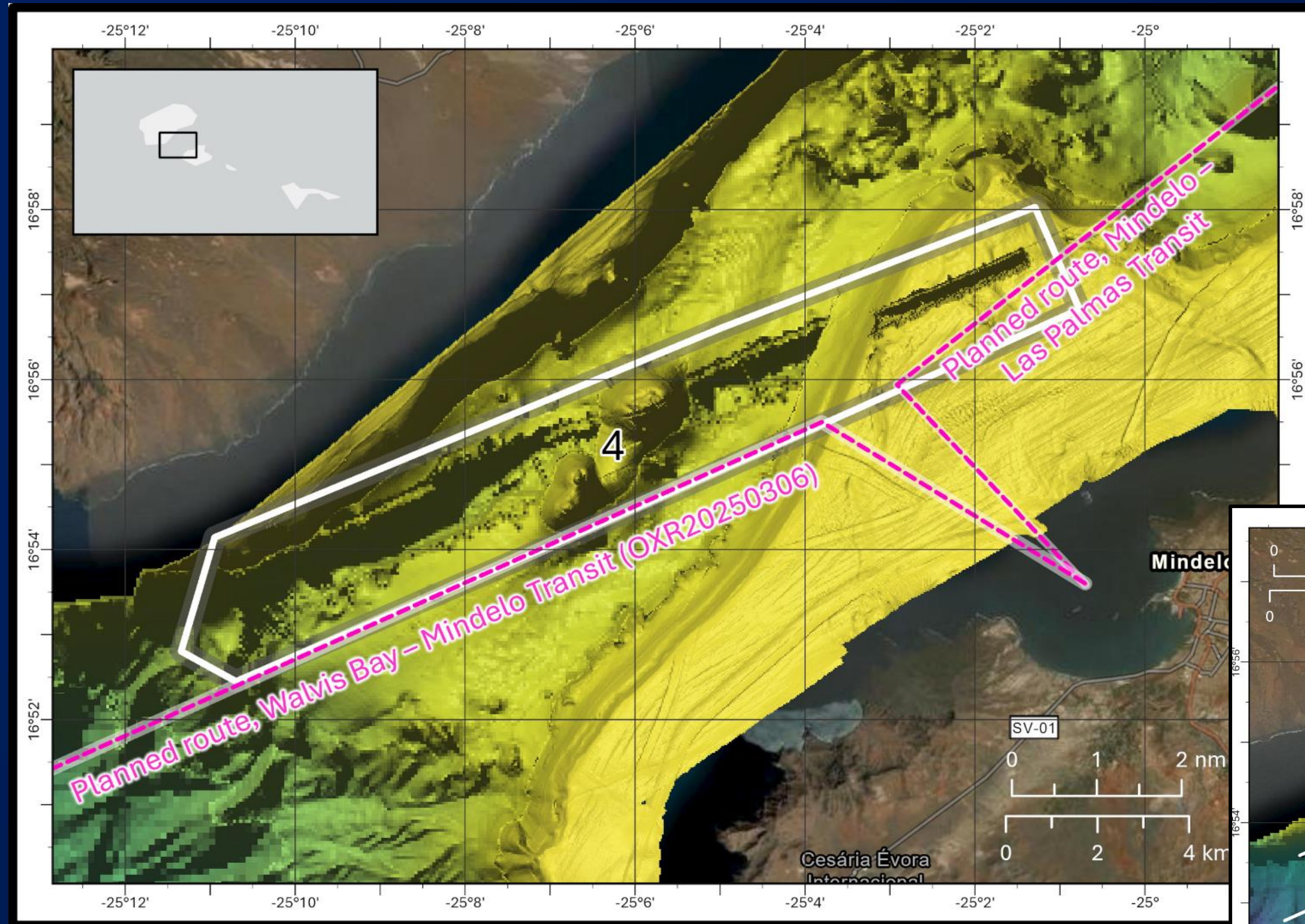
Gap Mapping When Possible



- **19,000+ sq km** mapped in CV waters
- Adjusted transits when possible to increase coverage

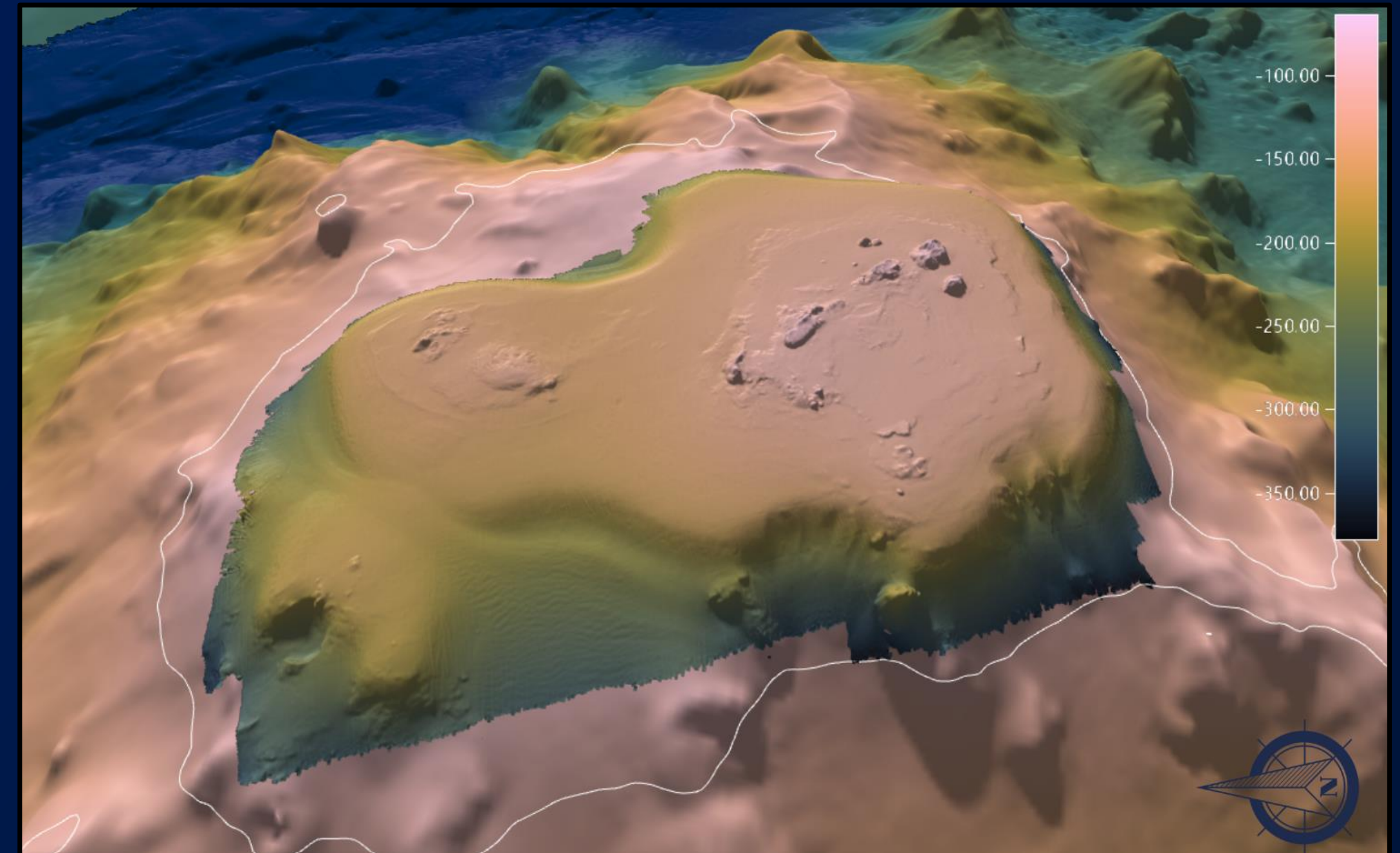
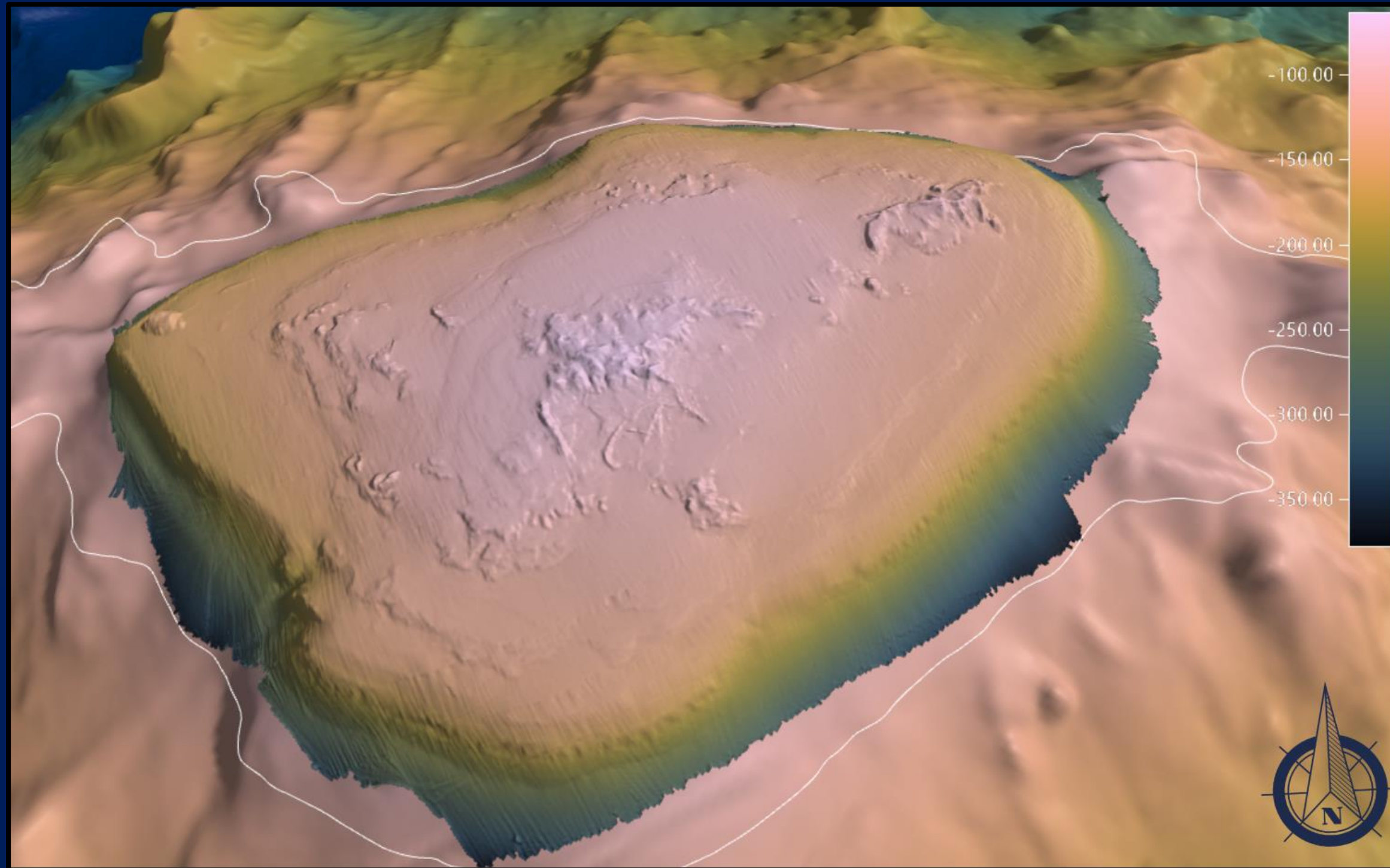
Opportunistic Re-mapping of Problem Areas

- Worked with regional researchers to identify problem areas in existing mapping data and collect new data during transits



Increased Resolution on Summits – EM2040C Survey

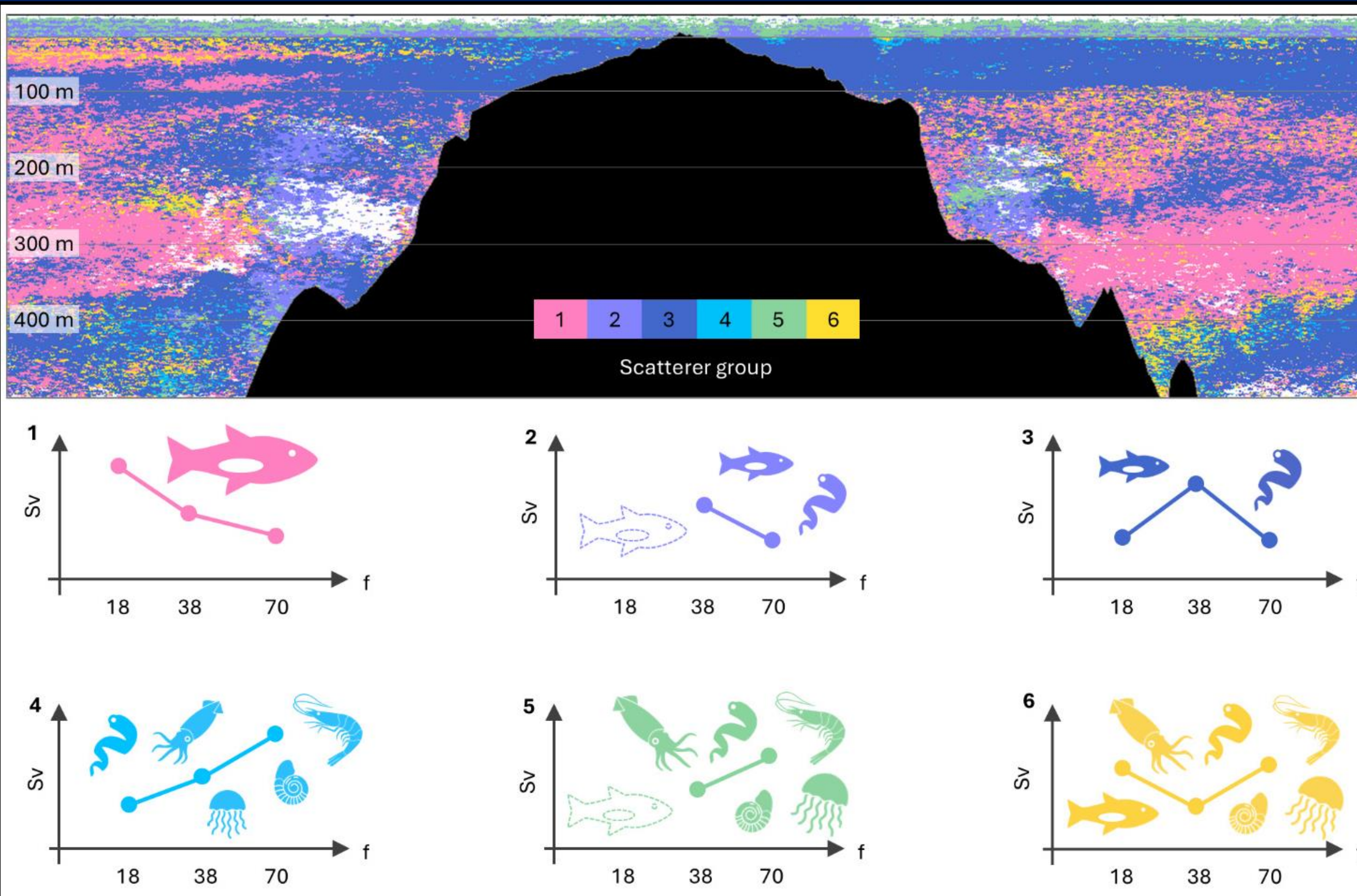
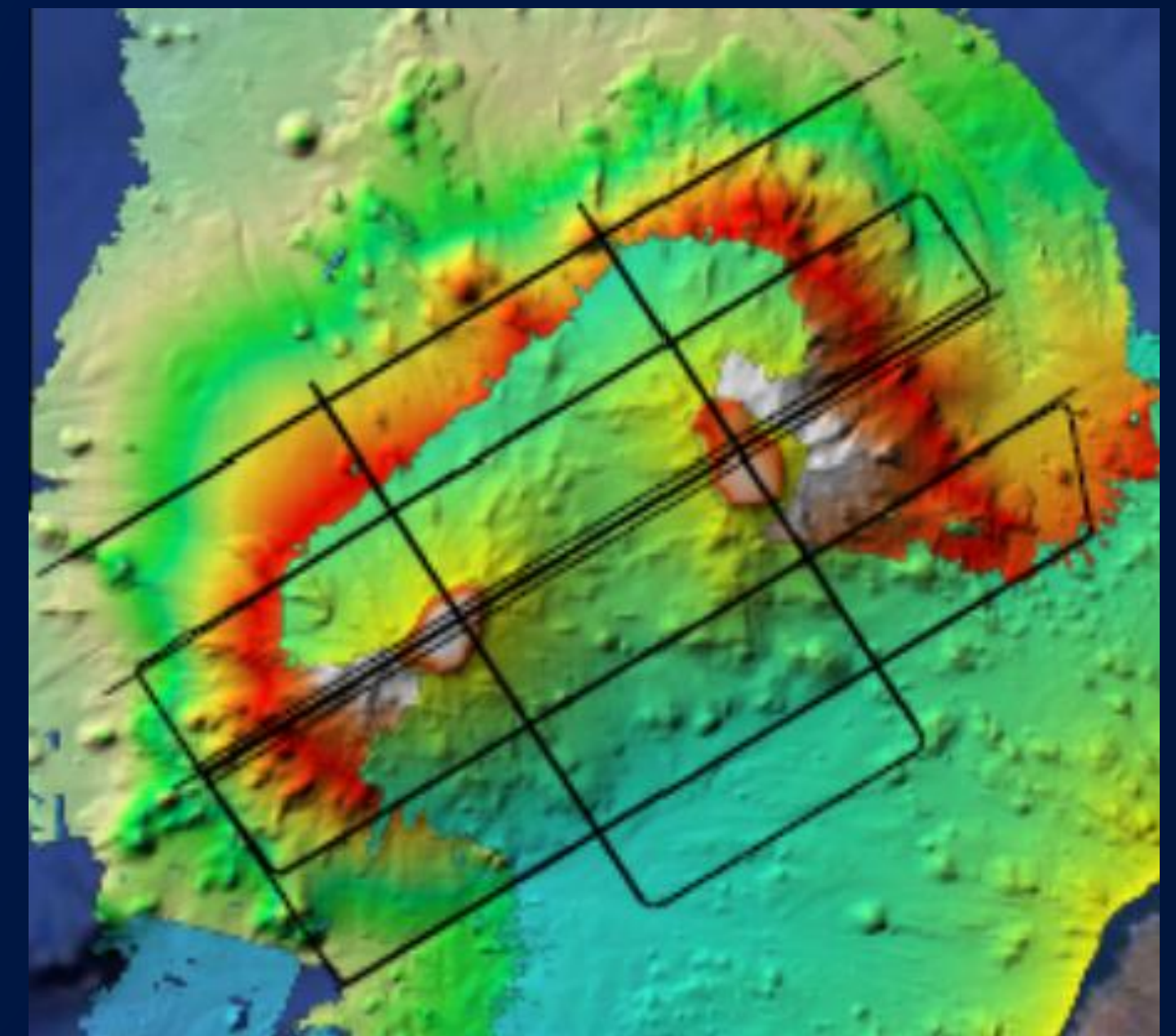
- 5 m on the summits
- Improved resolution elsewhere too (at least over what is publicly available)



Images of EM2040C data on the Nola West (left) and Nola East (right) summits by Hayley Drennon

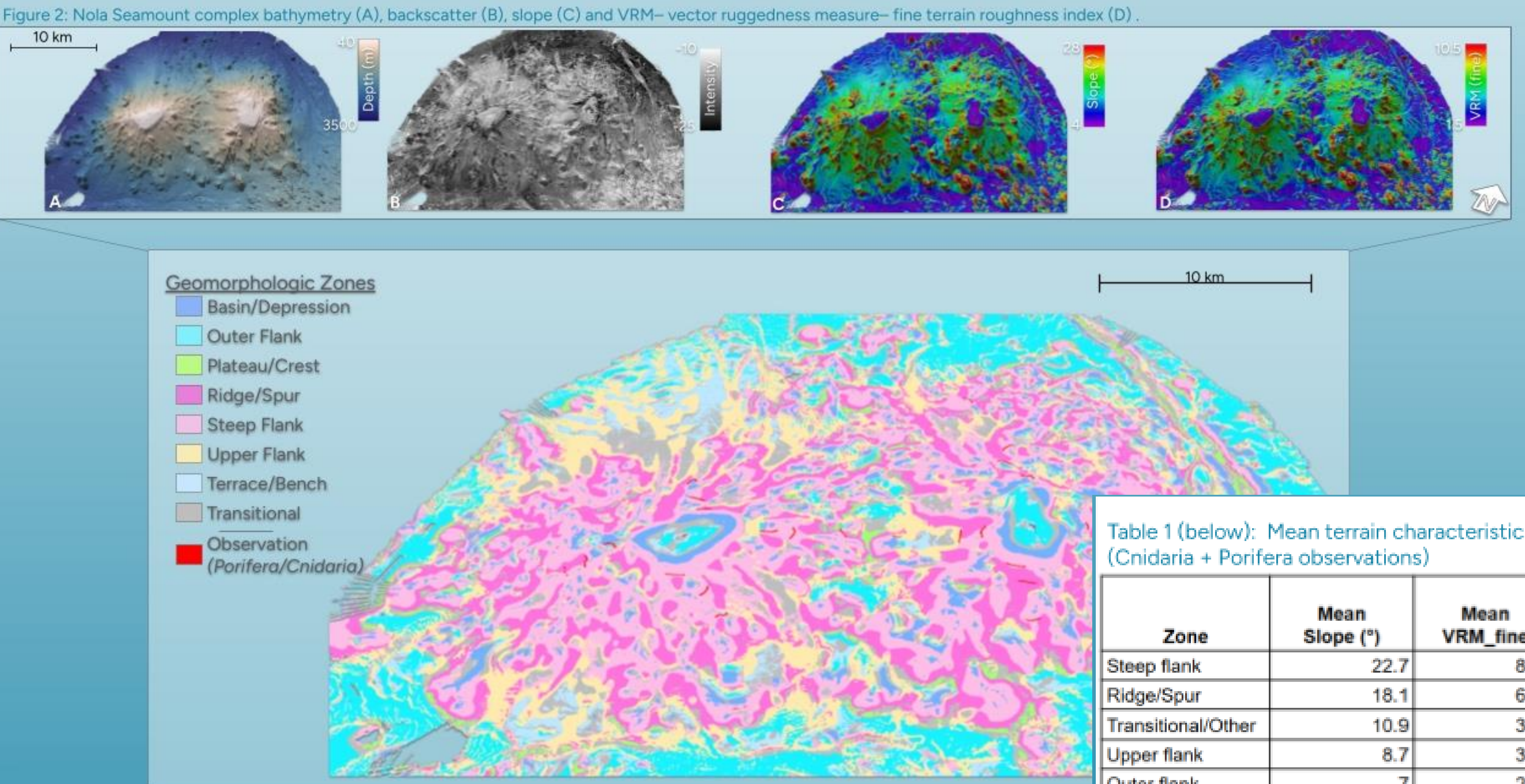
Dedicated EK80 Survey & Analysis of Acoustic Scattering

- Dedicated **EK80-only** survey, including 24-hour continuous repeated transect of summits
- Echowiew analysis
- Strong interest from collaborators for this type of analysis



Scattering group analysis and image by Haley Viehman, Echowiew

Preliminary Geophysical Analysis



Drennon et al.
analysis presented at
AGU 2025 Fall
Meeting

Table 1 (below): Mean terrain characteristics by zone (Cnidaria + Porifera observations)

Zone	Mean Slope (°)	Mean VRM_fine	Mean Backscatter (Z-score)
Steep flank	22.7	8.15	0.67
Ridge/Spur	18.1	6.33	0.44
Transitional/Other	10.9	3.74	0.99
Upper flank	8.7	3.34	0.43
Outer flank	7	2.49	0.55
Basin/Depression	8.6	2.54	0.77
Terrace/Bench	2.2	0.77	-0.09

Zone	Count
Steep flank	3,603
Ridge/Spur	586
Transitional/Other	301
Upper flank	135
Basin/Depression	131
Outer flank	36
Terrace/Bench	9

Table 2 (above): Distribution of Cnidarians and Porifera by Zone

Quantitative analyses demonstrate strong coupling between terrain and community structure:

- Cnidarian observations cluster in areas of high slope (18–23°), high rugosity (VRM_fine 6–8), and elevated backscatter, most commonly in Steep flank and Ridge/Spur zones.
- Porifera occur across a wider environmental envelope but show increased presence in moderately rugged upper flanks.

Terrace/Bench and basin zones show very low rugosity (VRM_fine < 1) and correspondingly low biological density.

Machine Learning Efforts - SeaSwipe

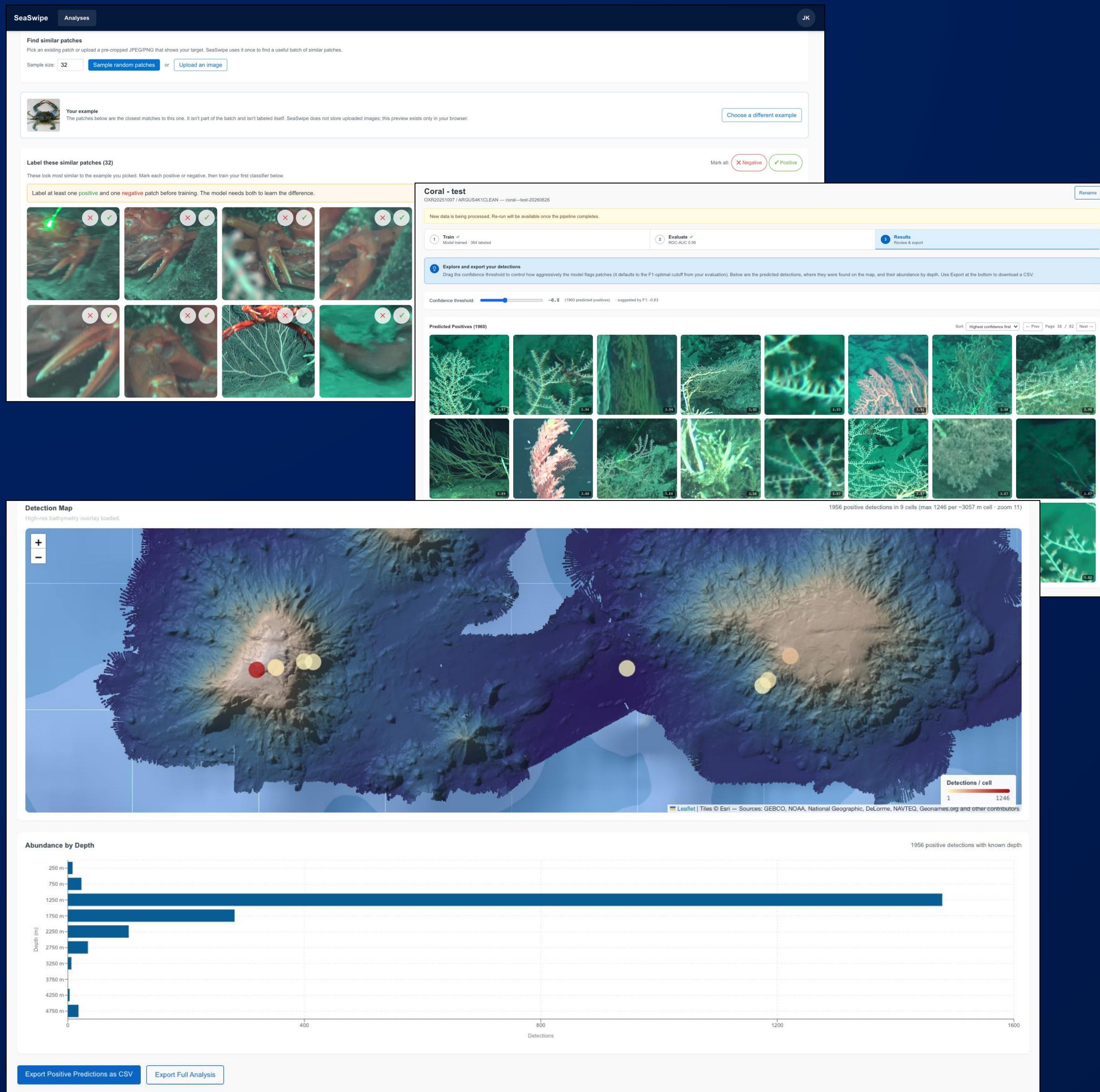
In-house AI-accelerated annotation + predictive modeling

- Scans video for target organisms (based on researcher training set), extracts frames and georeferences

- Presents frames to reviewer for verification

- Results presented as collection of positive detections, distributions plotted on map, depth distribution chart

- Working on predictions aspect, integrating environmental variables (bathymetric derivatives + other observation – salinity etc.)



Data Visualization Efforts - DATAXPLOER

OCEANX

DATAXPLOER

17.456°N · 25.450°W
CABO VERDE

HEIGHT

CTD

SONAR

ROV

OCEANX EXPEDITION

Elevation Colormap

Step 2 — Map the seafloor

False-colour mapping from pink peaks to blue depths. Each hue represents a specific depth range, making the vertical structure legible at a glance.

Sonar resolves features down to a few centimetres across thousands of square metres per hour.



EK80

PREV

1 / 3

NEXT

HEIGHT

-30m

1000m

FILENAME OXR20250706_EK80_D20250708_T222826_raw_WBT_976729_15_ES38_7
_ES_325_parula_0to2400m_CROPPED.png

START 17.3180°, -25.3939°

END 17.2704°, -25.4723°

DEPTH 2,400 m

TRACK 9.9 km

EFFECTS

SCAN REVEAL

FRESNEL GLOW

PARTICLES

SONAR IMAGE

ALT+DRAG ORBIT ALT+RMB PAN SCROLL ZOOM 1 2 3 LAYER ↔ PREV/NEXT Q E VIEW MODE SPACE PLAY/DRAWER ESC BACK F 1 CAPTURES

MANUAL

NARRATION

EVENT

MISSION Cabo Verde

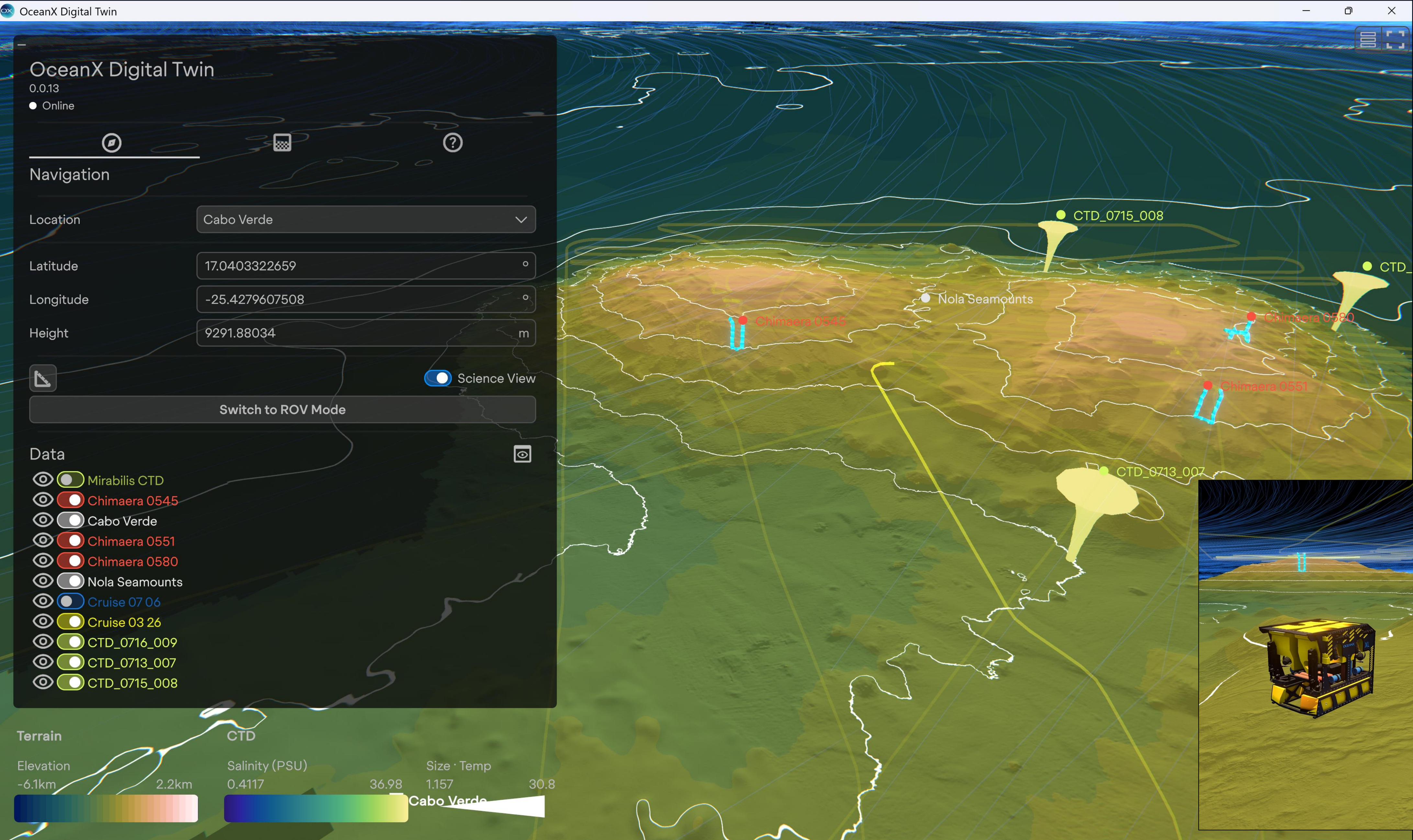
SERVER ONLINE

XBOX

CAM OFF

- 100% + FS

Data Visualization Efforts – OceanX Digital Twin



Data Sharing

Sharing data back to Portuguese Hydrographic Institute for integration in charts and their Cape Verde Bathymetric Model (*in progress*)

hidrográfico

Hydrographic+

To look for

Map

To enter

Portuguesa

Back to Search

< Previous

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To go down

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Cape Verde Bathymetric Model

Bathymetric grids constructed from multibeam hydrographic surveys carried out in the area(s) of interest under the Mar Aberto initiative, and data acquired during scientific cruises crossing the waters of Cape Verde.

The resolution of the bathymetric grids is as follows:

- Depth between 50m and 250m – Resolution of 32m;
- Depth between 250m and 1000m – Resolution of 64m;
- Depth between 1000m and 2000m – Resolution of 128m;
- Depth between 2000m and 4000m – Resolution of 256m;
- Depth with values greater than 4000m – Resolution of 512m.

Instructions for accessing the data are available at: <https://www.facebook.com/share/r/1FKz78kvpp/?mibextid=wwXlfr>

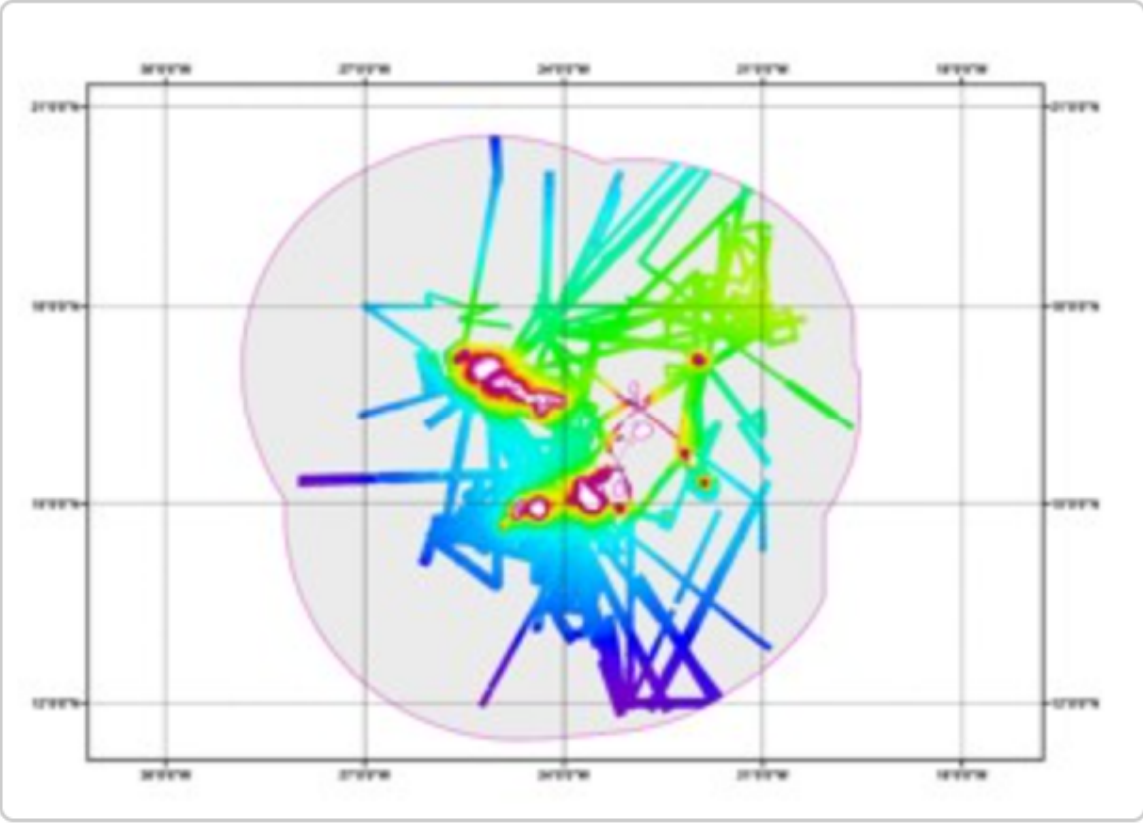
Download data and links

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<https://geomar.hidrografico.pt/>

Open link

Overview



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Data Accessibility

Data Type	Data Repository	Status	
Acoustic Seafloor Mapping (Bathymetry, Backscatter, and/or Coverage Area)	NOAA NCEI, IHO DCDB	Likely available after March 2027	
	GMRT, MGDS	Within next few weeks: - OXR20250326 EM304 - OXR20250627 EM304 - OXR20250706 EM304	ASAP (a few more months): - All transits - EM2040 - EM712 if it adds coverage
	Seabed2030, GEBCO	via MGDS	
Subbottom Acoustics	NOAA National Center for Environmental Information (NCEI)	Likely available after March 2027	
Underway and Deployment Sensor Data (CTD, ADCP, SV, vessel & vehicle Tracks, multibeam and single/split-beam water column, meteorological)	NOAA National Center for Environmental Information (NCEI)	Likely available after March 2027	
Visual Data: Imaging and video (ROV, Sub)	TBD	Likely available after March 2027, and likely on request for foreseeable future	

OceanX’s goal is for all scientific research and data arising out of the Vessel’s operations and activities to be properly collected, catalogued and stored, and made available publicly and usable for general educational purposes, including in scientific publications and in public repositories.

Summary

- The Cabo Verde Digital Deep Expedition, along with six other expeditions in or through Cabo Verde waters, utilized multiple Kongsberg systems to build a comprehensive dataset for the Nola Seamount complex and surrounding area
- This data has been (and is being) used for development of visualizations and AI-assisted modeling of the environment
- Challenges with data processing led to improvements in software tools, to the benefit of the wider mapping community
- In addition to ongoing in-house and collaborator analysis, the data is making its way to the regional hydrographic organization and public repositories, extending its accessibility, *and we hope*, its use

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