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The First Real-World Live-Site Survey with the UltraTEMA-4

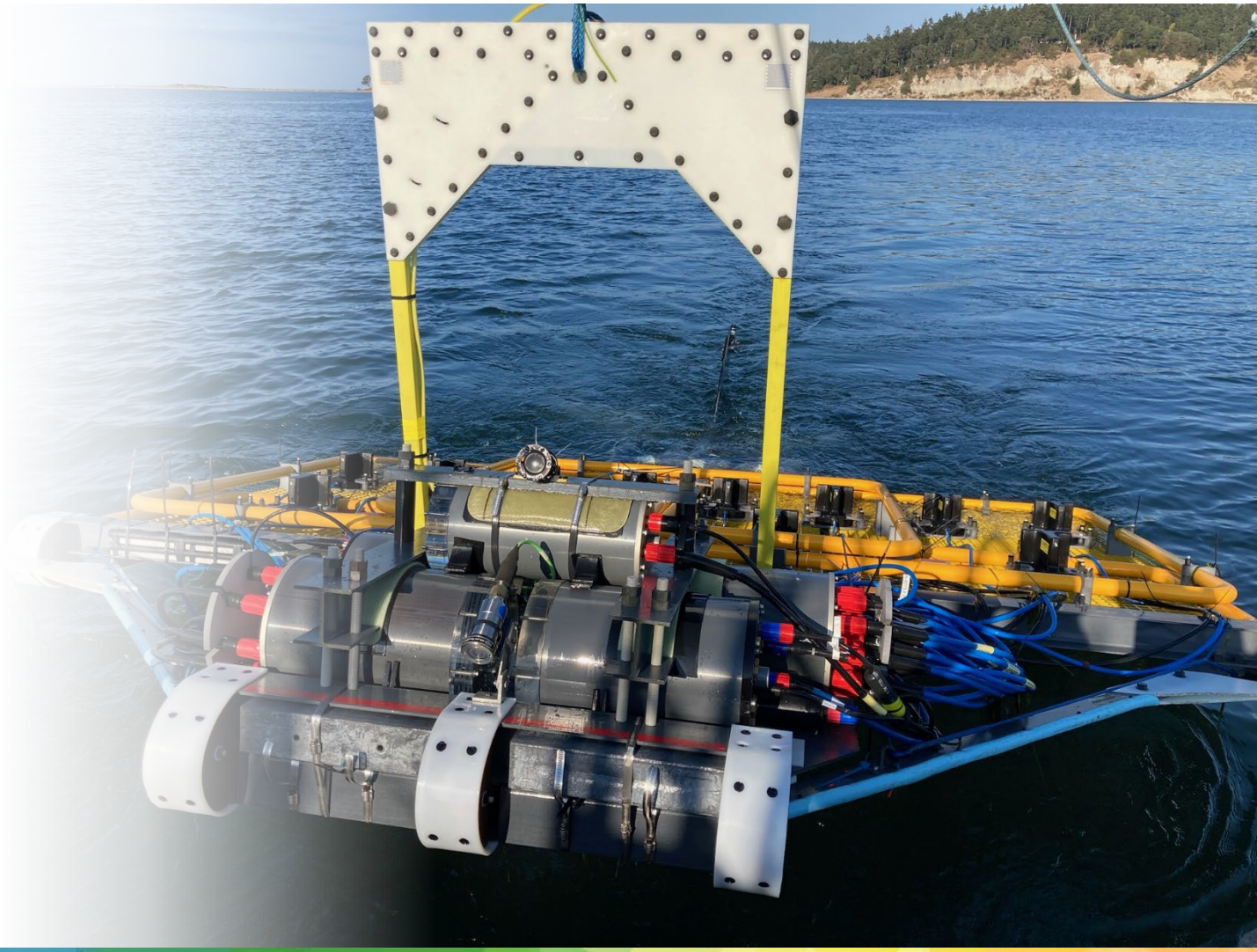
Marine Classification Results from USCG Base Kodiak Fuel Pier Survey

Richard Funk, Principal Geophysicist
Jeff Gamey, PGp, PMP, CQA
TETRA TECH
Kevin Kingdom
Nicholas Lhomme
BLACKTUSK GEOPHYSICS

April 15, 2025

Agenda

- Introduction
- Overview of UltraTEMA-4
  - Design
  - Operations
- Kodiak, AK 2024
  - New **Mini-DP** system on boat
  - Survey Data
    - MBE – with debris analysis
  - BT Field Results
    - EM Data–results
- Questions



Refined Over Years – UltraTEMA-4

- Started underwater MEC survey in 2007 in Ostrich Bay
- 4th generation of Towed EM Array (TEMA)
- 4th generation of UltraTEM

- Integration of UltraTEM® EM Hardware package and associated software into Tetra Tech's Remotely Operated Towed Vehicle (ROTV)

- **MiniDP system** (new for 2024)

UltraTEMA-4 System Components

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1. TEMA tow-platform (Tetra-Tech)

- "Next generation" towfish
- Tested and proven remotely operated towed-array system (ROTV)
- Advanced subsea positioning
- Capable of controlled low-level flight above the sea-bottom
- **Improved vessel line following**

2. UltraTEM hardware

- "Next generation" Time-domain EM based sensor
- Hardware DAGCAP validated
- Existing marine systems deployed on European projects

3. BTField software

- Flexible data acquisition and processing software
- Well tested in terrestrial and underwater applications

Black Tusk GEOPHYSICS | GapEOD Explosive Ordnance Detection | ESTCP

UltraTEMA-4 System Components

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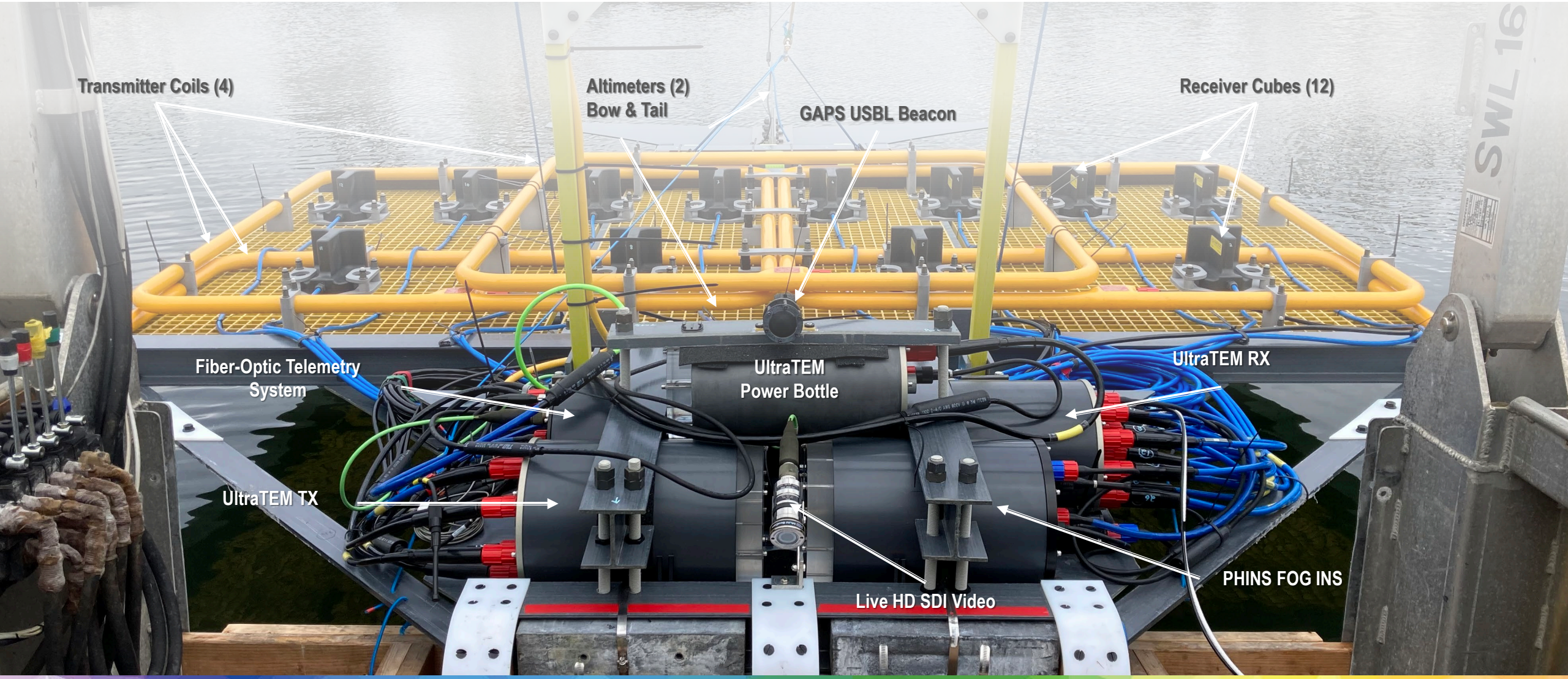

Overview of the UltraTEMA-4 Data Collection System

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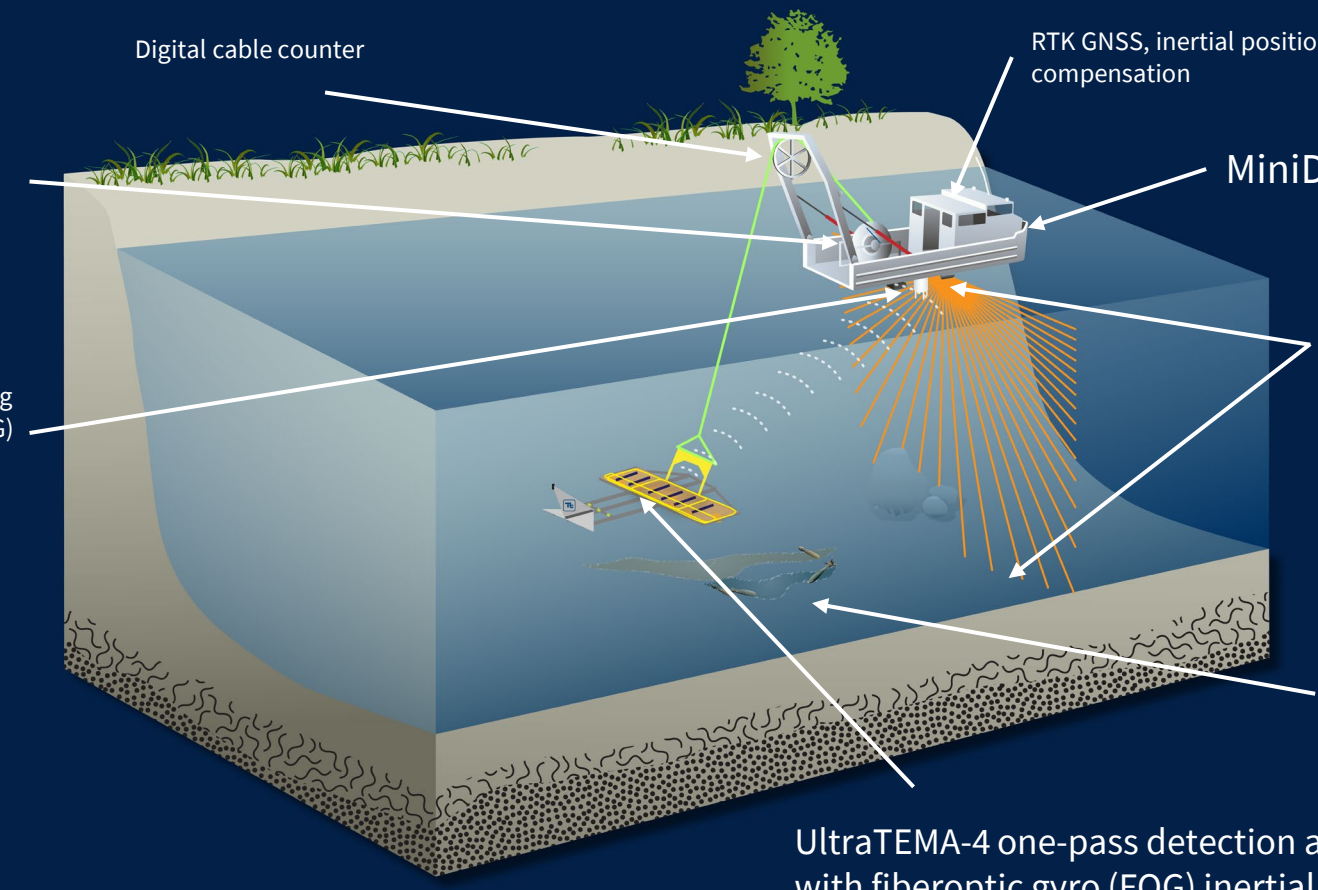

Digital cable counter

RTK GNSS, inertial positioning and full vessel motion compensation

Computerized marine winch

MiniDP bow thrusters and auto-pilot system

Broadband Multibeam Echosounder with 160-degree swath and multispectral seafloor characterization

Ultra-short baseline acoustic positioning system (USBL) with fiberoptic gyro (FOG) inertial positioning

Unexploded ordnance / DMM

UltraTEMA-4 one-pass detection and classification with fiberoptic gyro (FOG) inertial positioning

UltraTEMA-4 System Design

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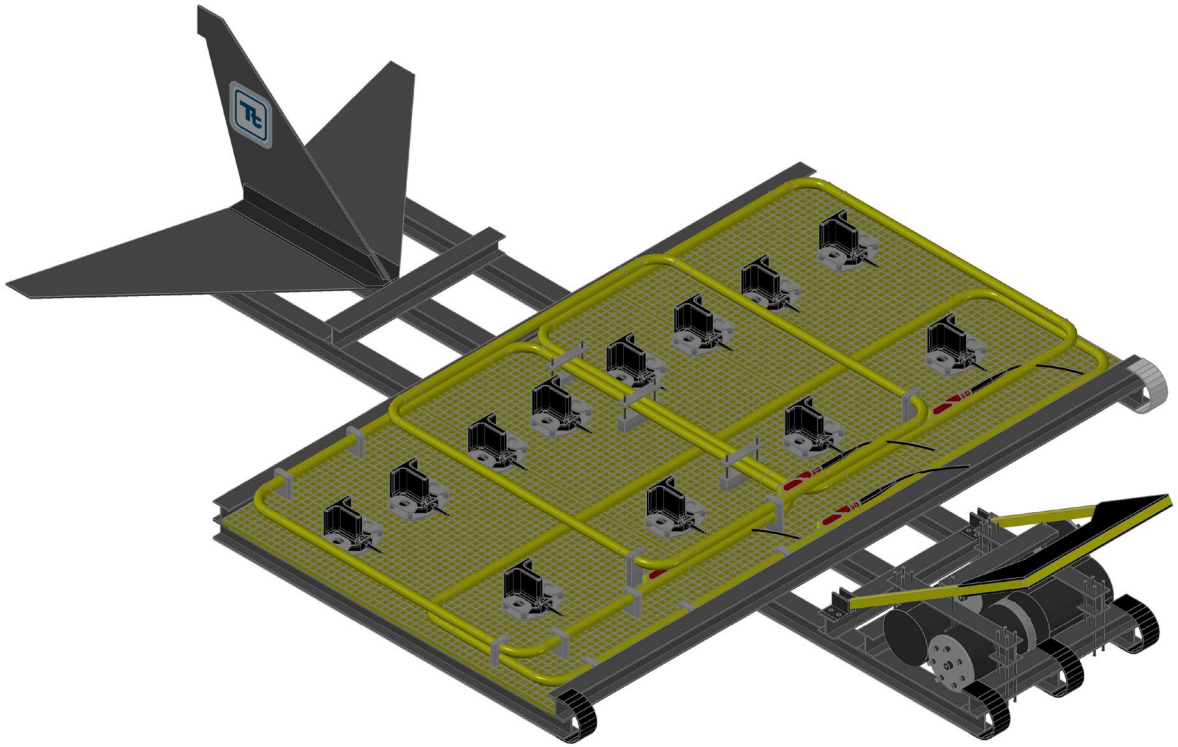

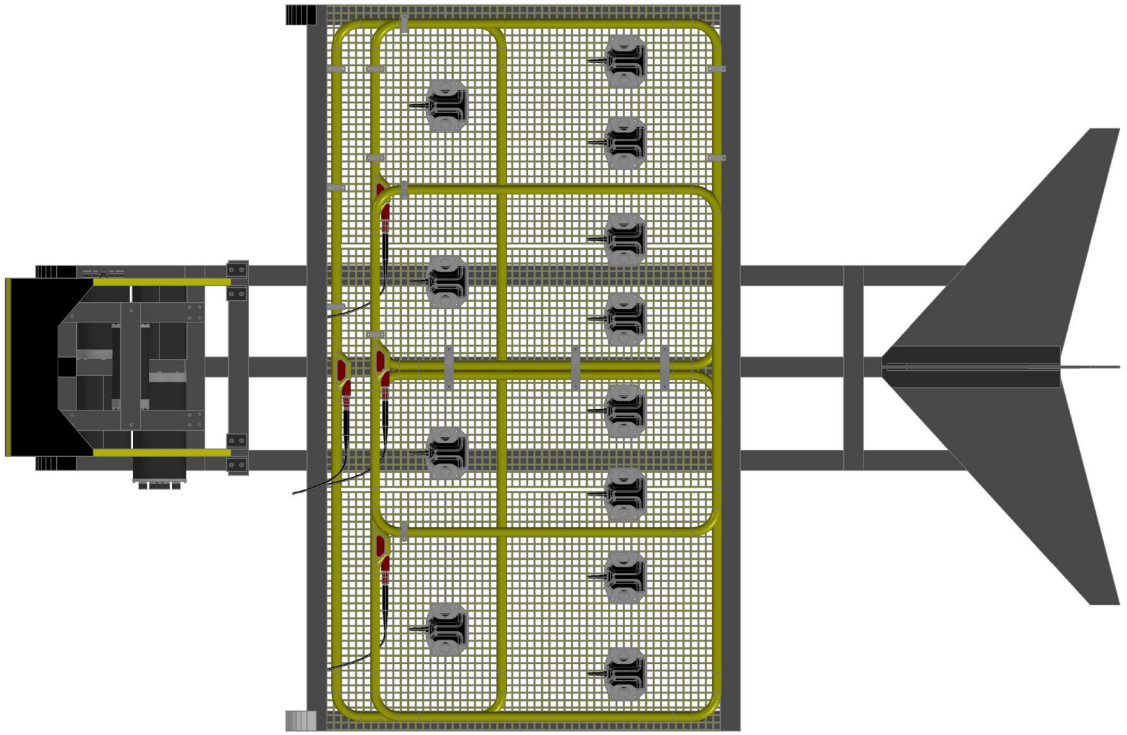

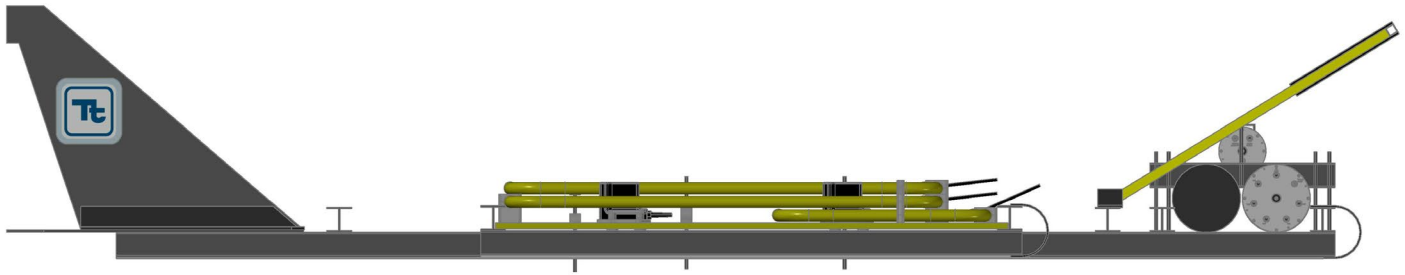

UltraTEMA-4 platform on-board the tow vessel M/V Ugle Duckling with Mini-DP bow thrusters

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- **MiniDP system**
  - Combines bow thrusters with vessel navigation and auto-pilot system
  - Auto-pilot
    - Allows for much better line following
    - Less captain fatigue
  - Bow thrusters
    - Allow vessel to hold station during diver operations (IVS Install)
    - Much faster turns possible, especially in deeper water

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2021 -2024- UltraTEMA-4 Surveys

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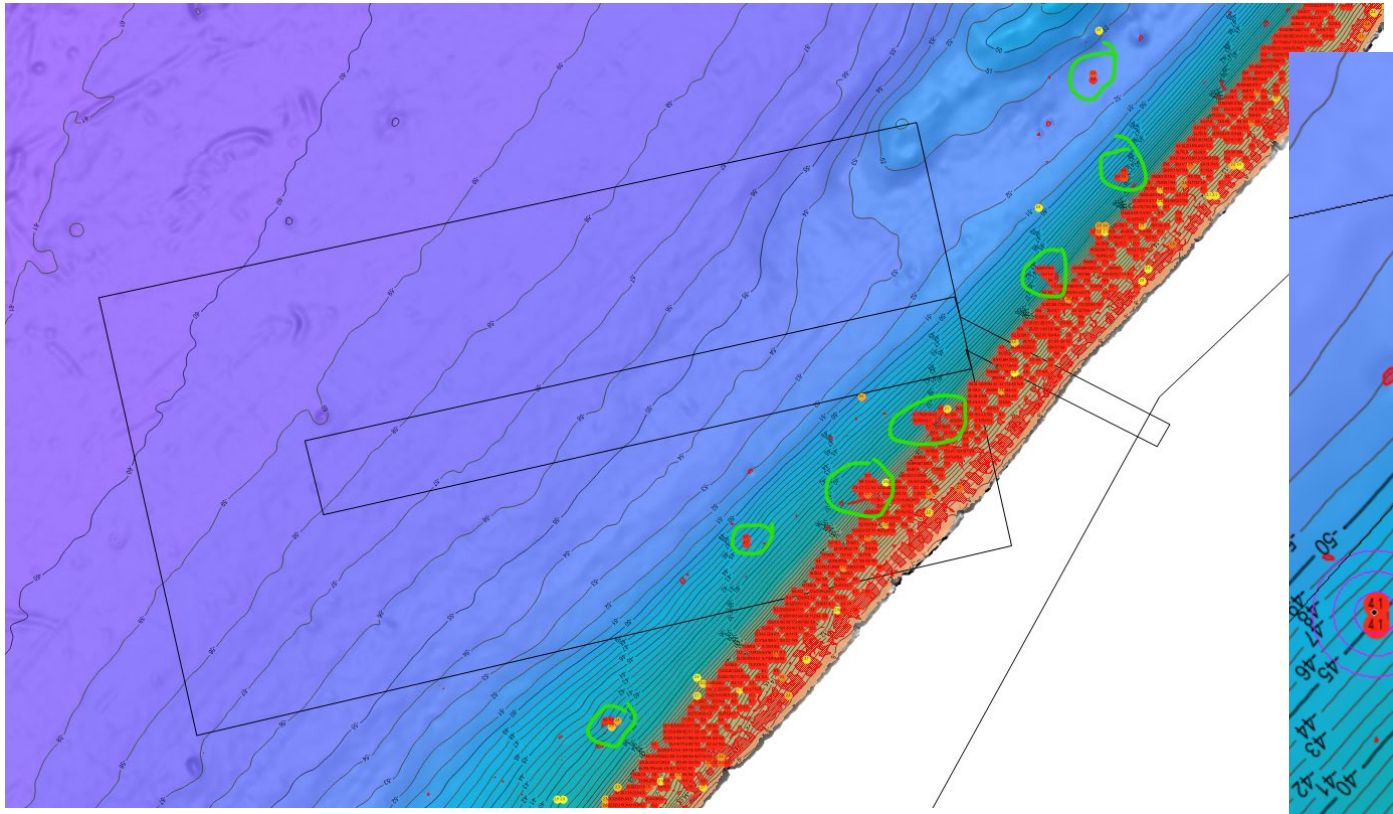
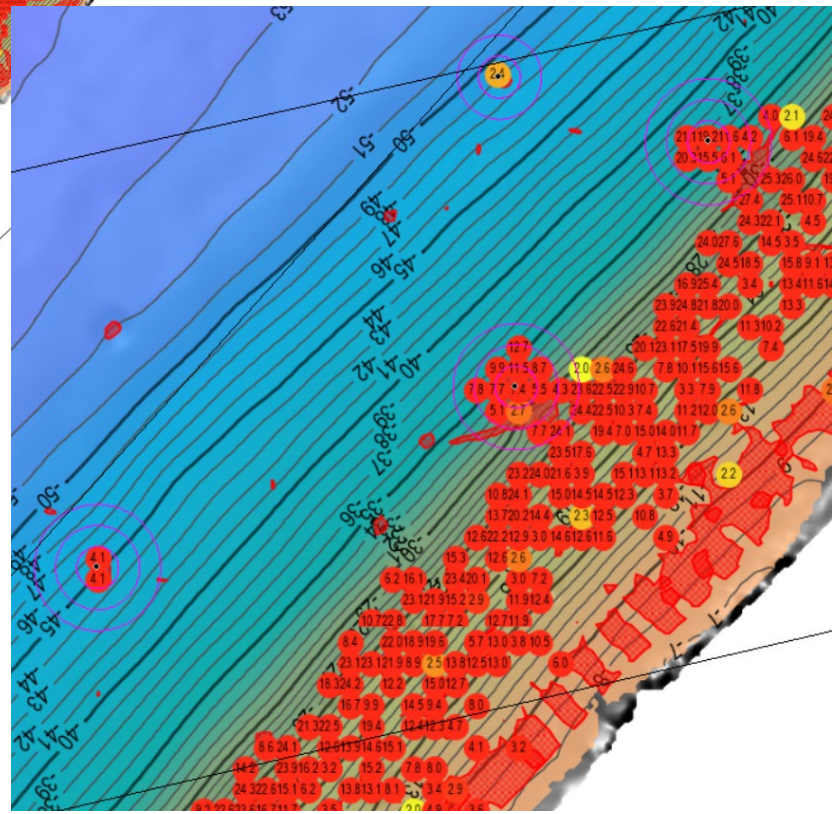
- Continuous improvement of the system – including the vessel

- Testing in:
  - Lake Washington
  - Elliot Bay
  - Ostrich Bay
- Sequim Bay 2021 Demonstration
- More Testing in Lake Washington
- Sequim Bay 2022
- **Kodiak AK, USCG 2024**
  - Shake Down Test Lake Washington
  - Survey Women's Bay

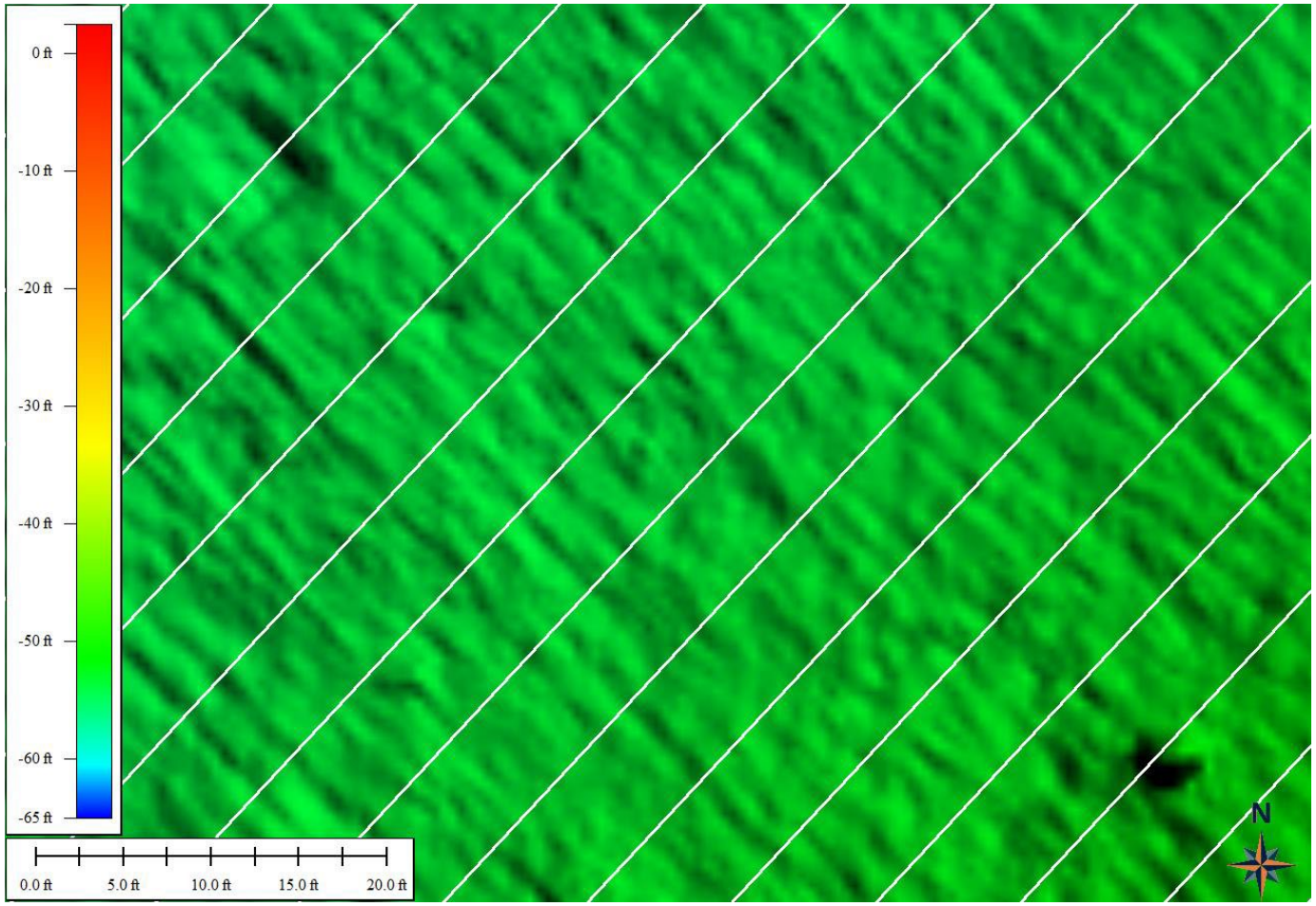
High-res Multibeam Bathymetry with Debris Analysis





- Automated detection of debris/obstacles >2-ft above seafloor
- Allows for efficient survey line planning to maximize coverage
- Precise hazard avoidance increases coverage and reduces potential equipment damage

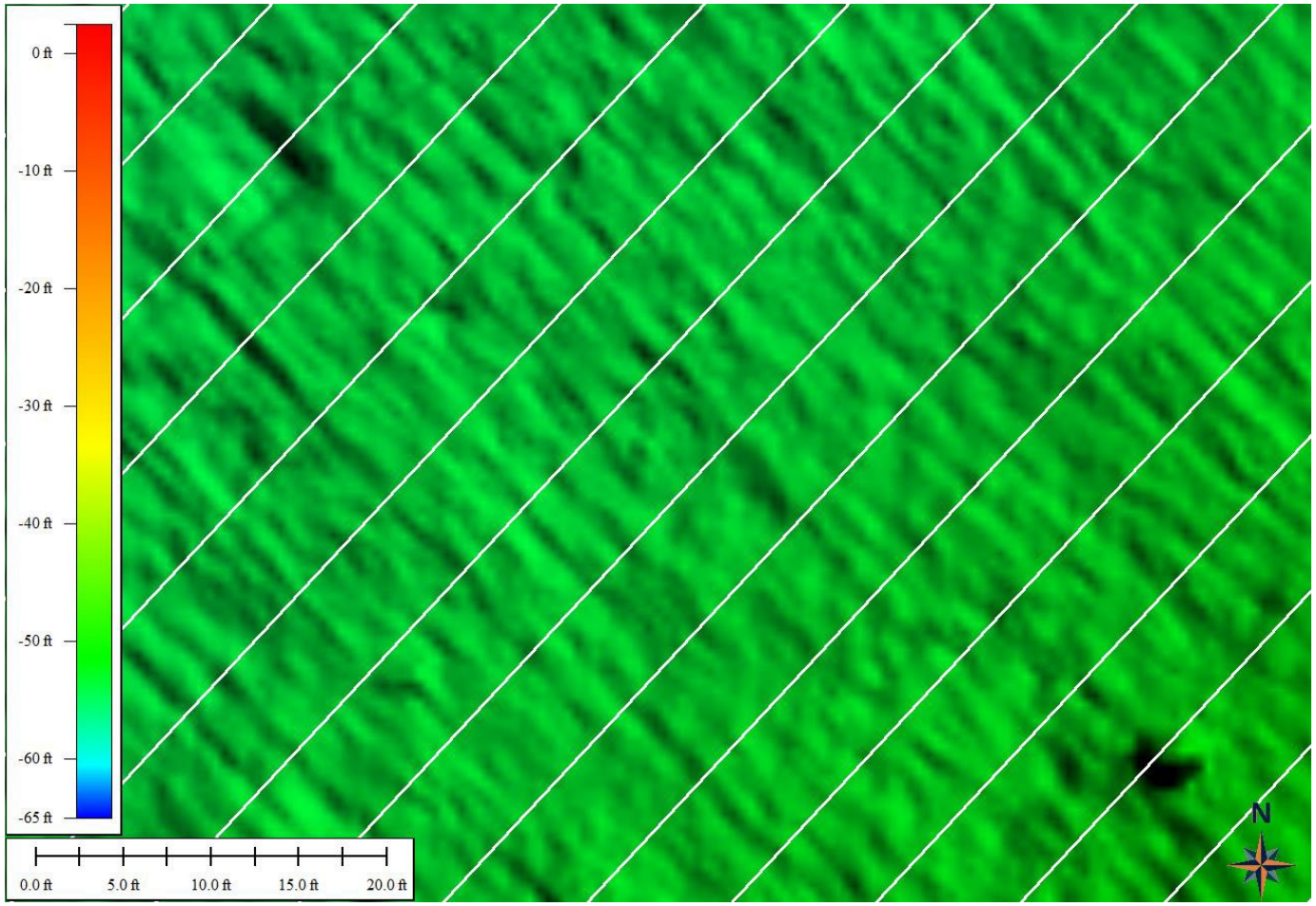
Kodiak, AK 2024: USGS Survey



- **Planned Lines**
  - **6-foot line spacing (white)**

UltraTEMA-4 Towfish Distance Off-Line (meters)			
<0.3	0.3-0.6	0.6-1	>1
59.5%	26.3%	8.6%	5.6%

Kodiak, AK 2024: USGS Survey



- **Planned Lines**
  - 6-foot line spacing (white)
- **Actual line path**

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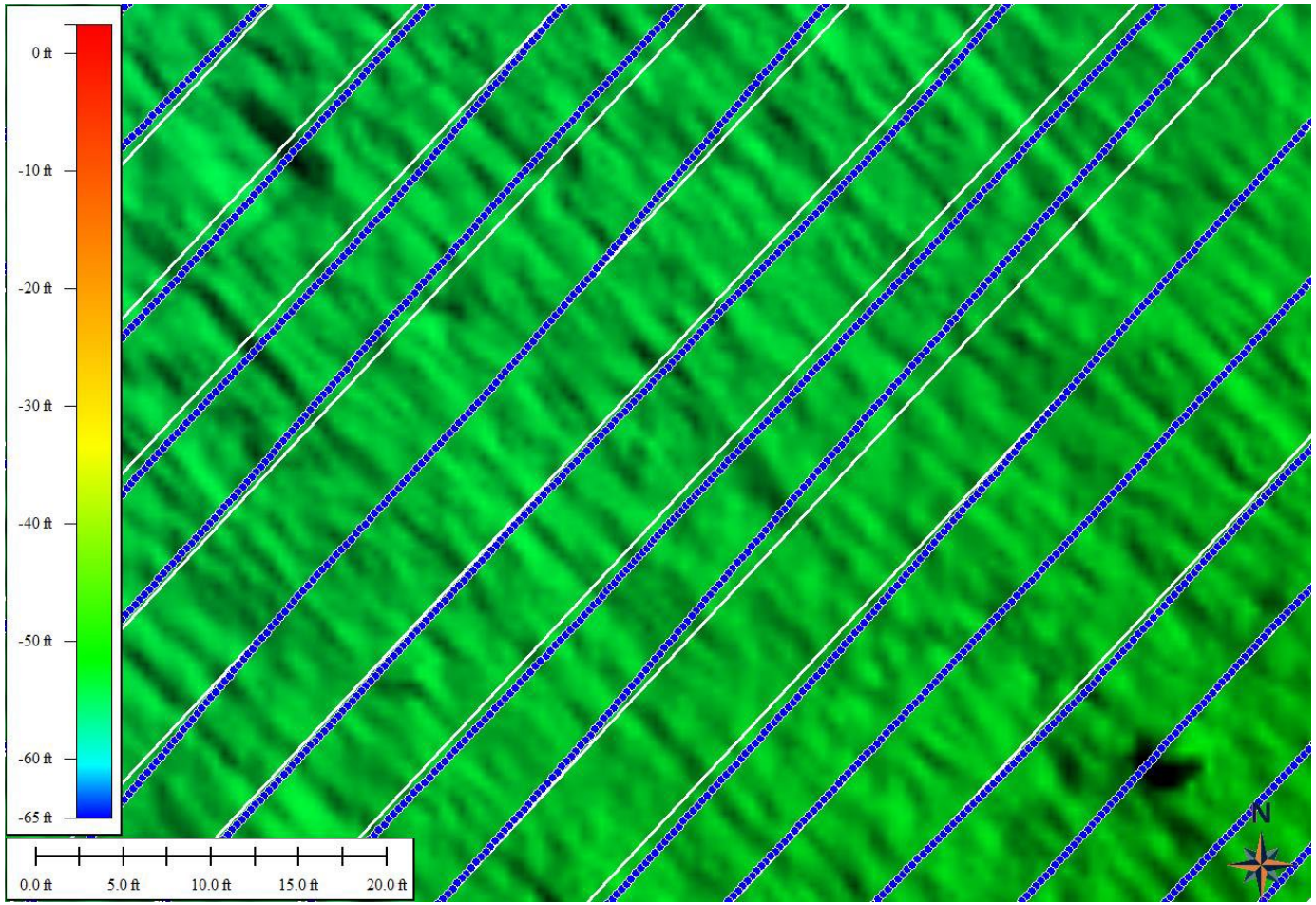

- **Planned Lines**
  - 6-foot line spacing (white)
- **Actual line path**
  - Blue path

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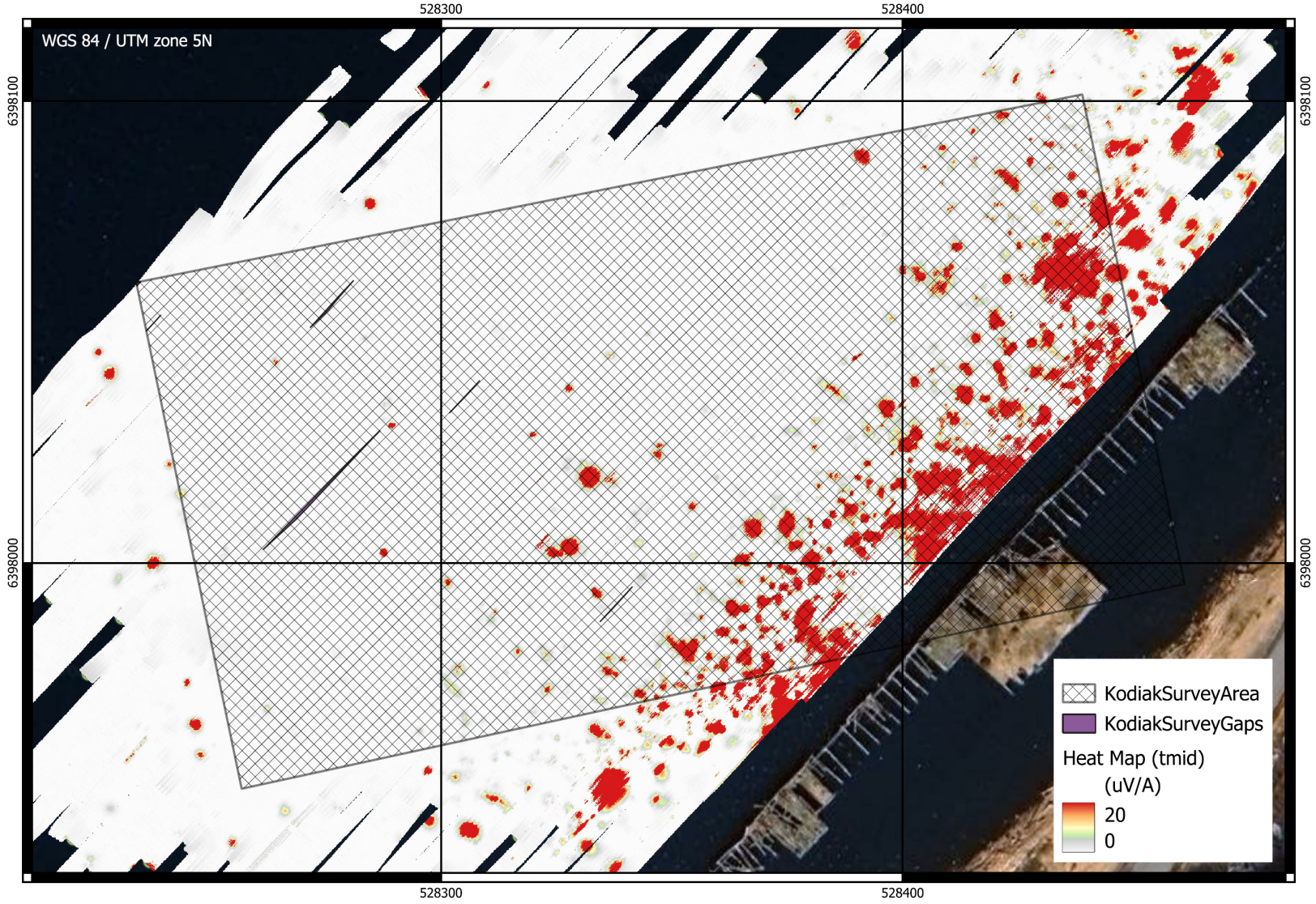
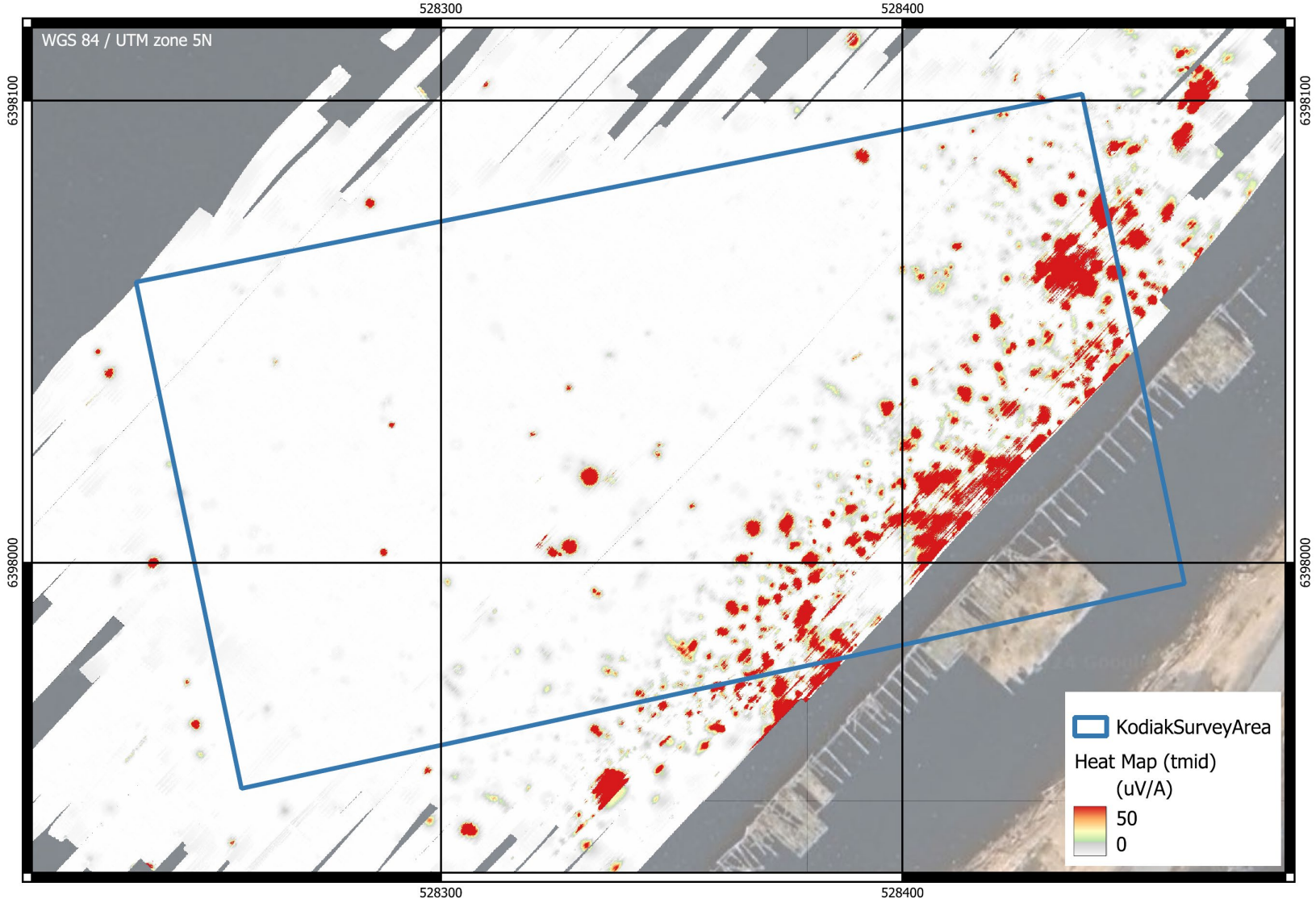
Kodiak, AK 2024: USGS Survey



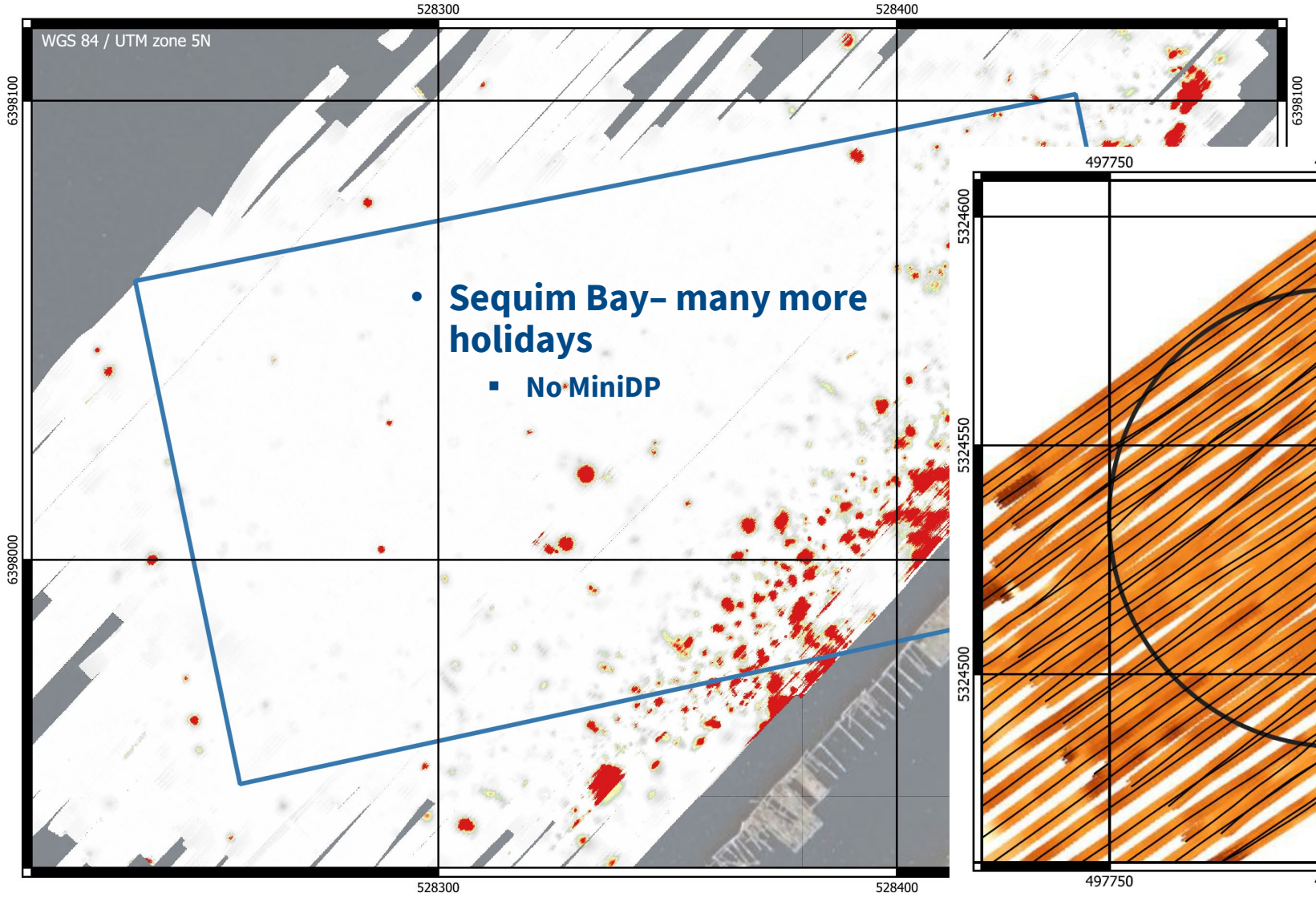
- **First Pass – very few holidays**
  - **MiniDP / auto pilot**

Kodiak, AK 2024: USGS Survey



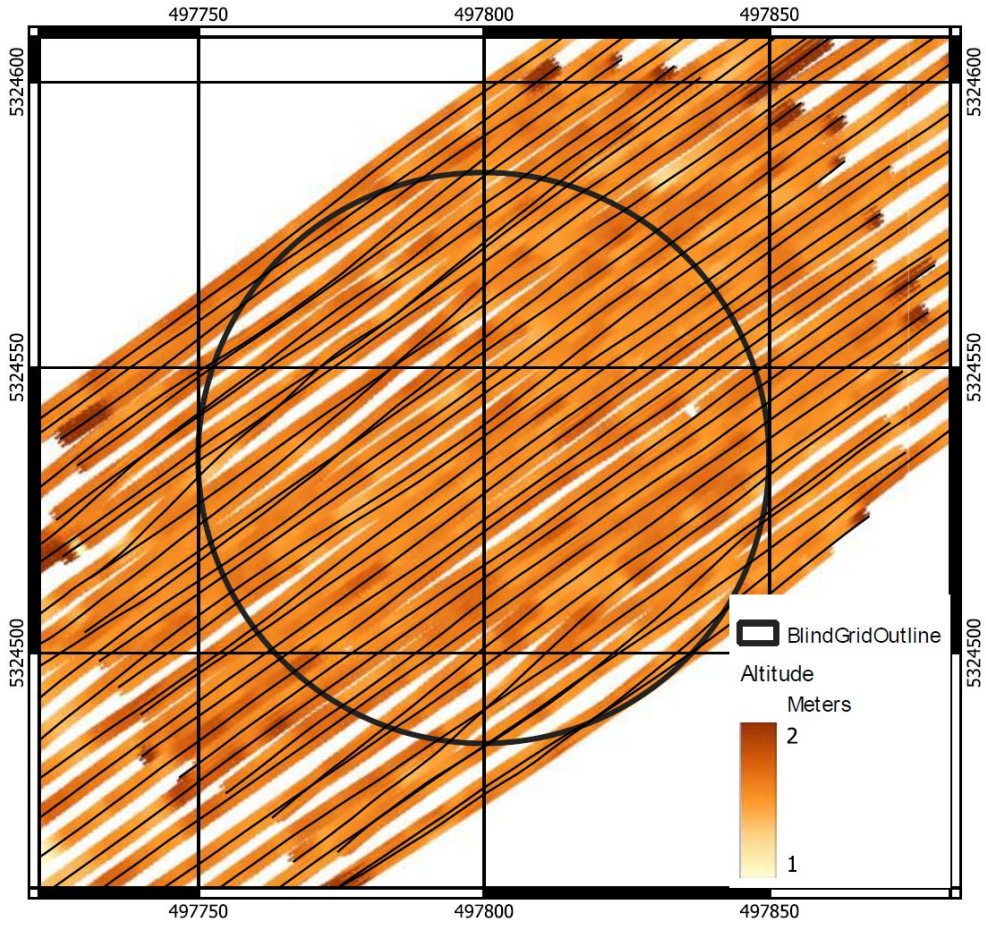
- **First Pass – very few holidays**
  - **MiniDP / auto pilot**
- **Holiday Fill –**
  - **completed first pass**

Kodiak, AK 2024: USGS Survey

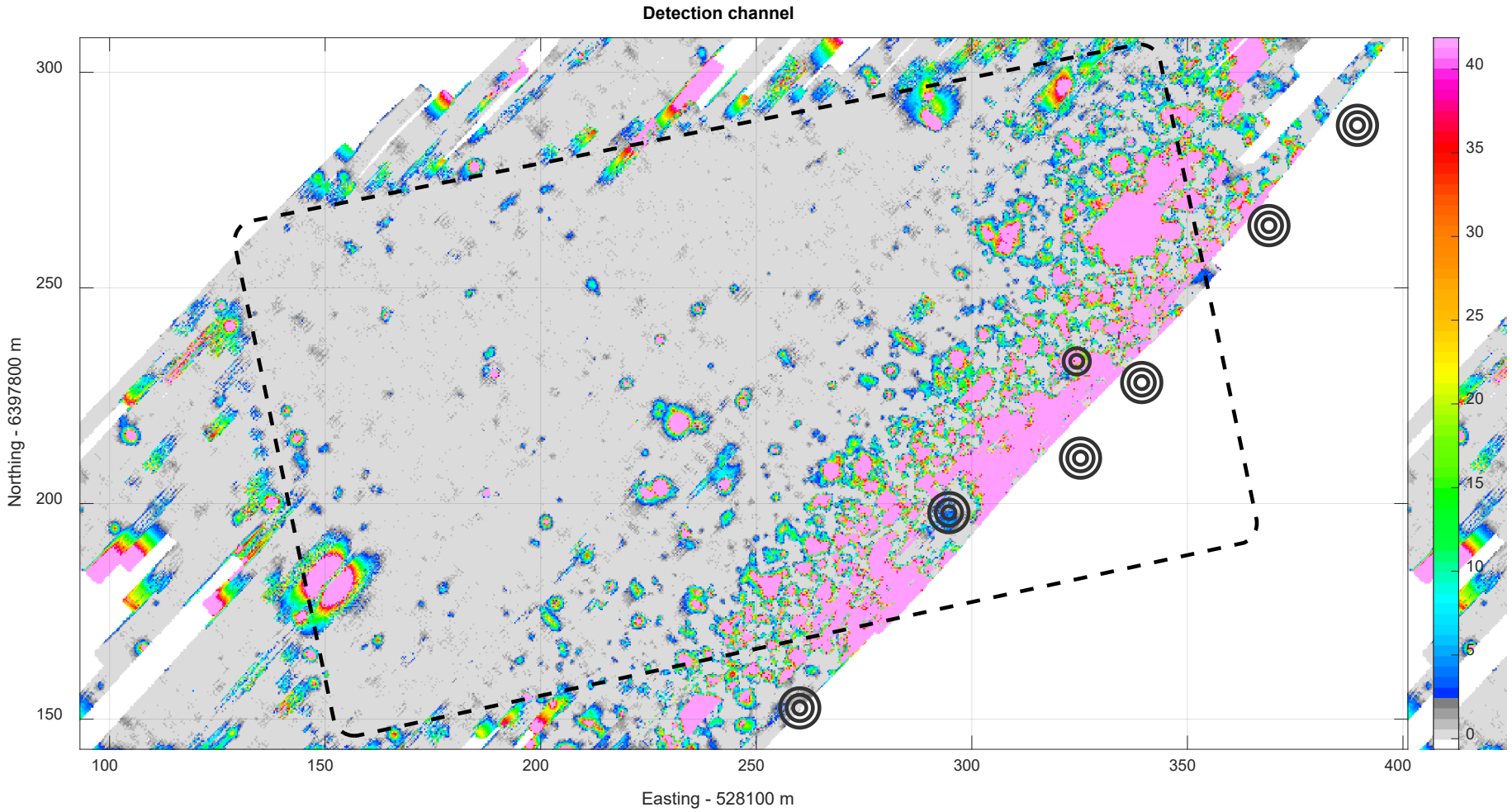


- **Sequim Bay– many more holidays**
  - **No MiniDP**

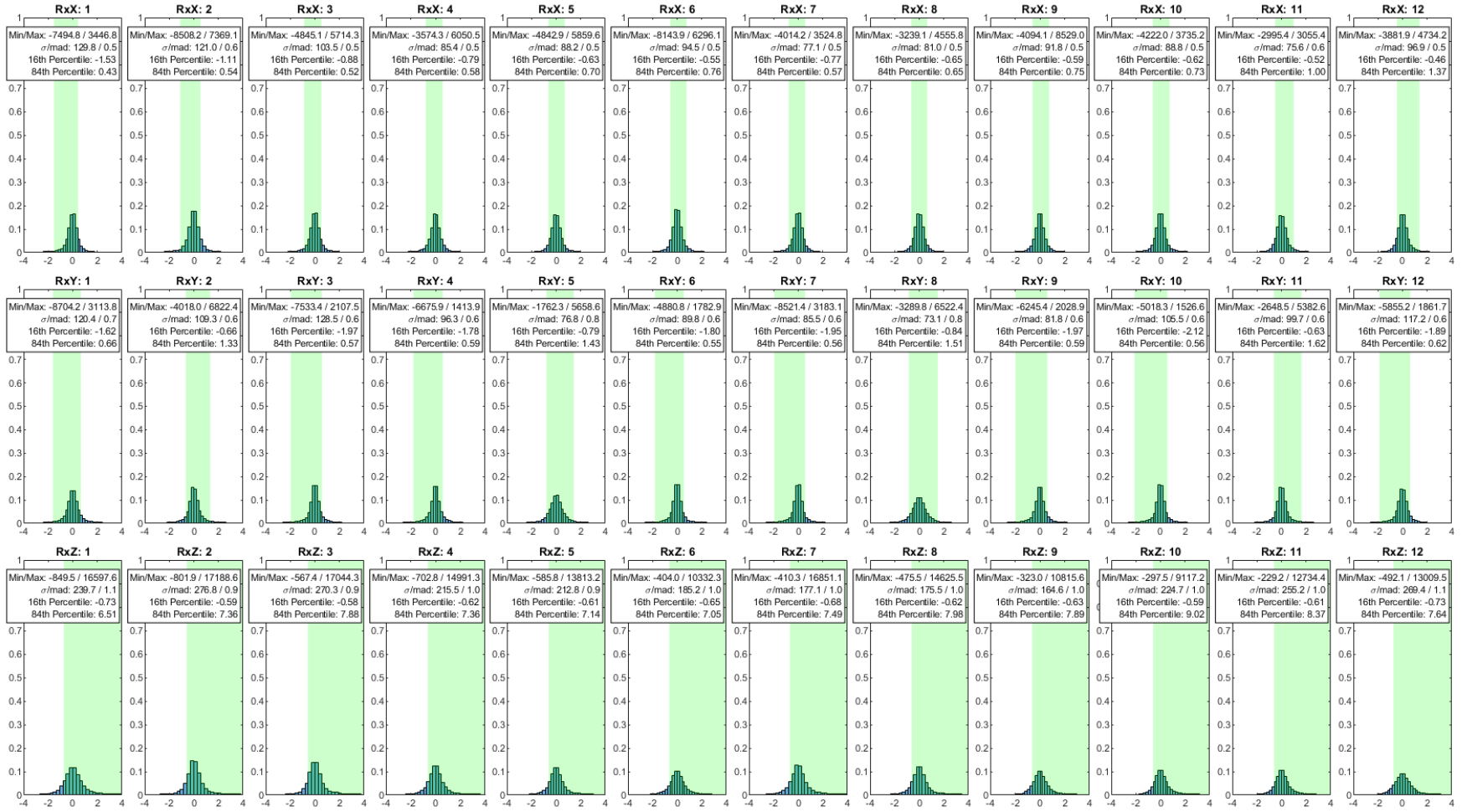
- **First Pass – very few holidays**
  - **MiniDP / auto pilot**



AGC processing



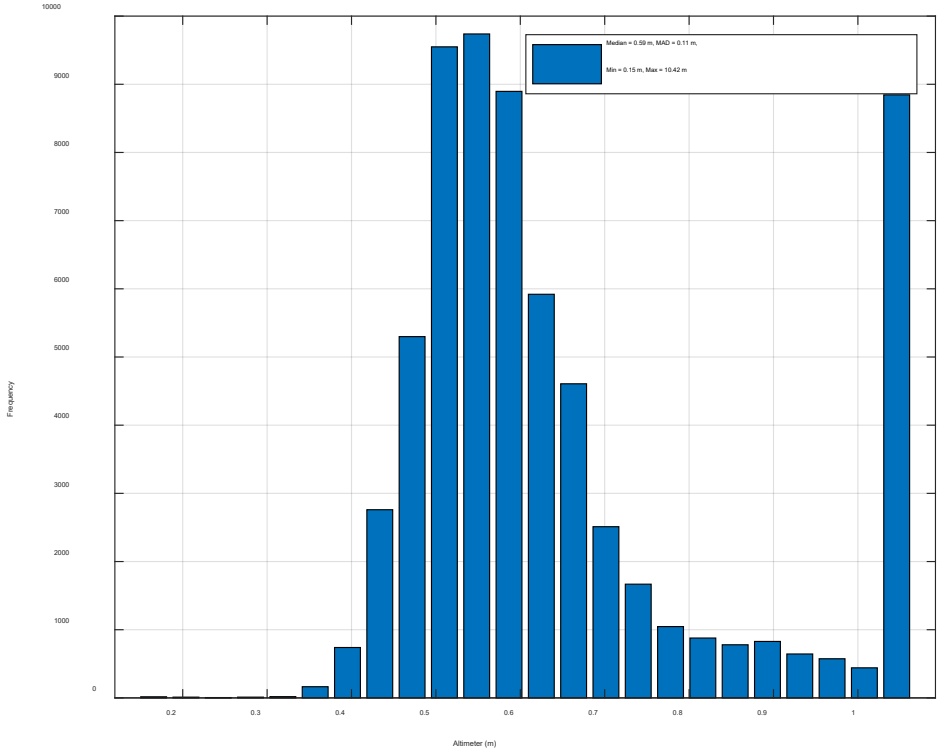
Detection capabilities: Low noise system

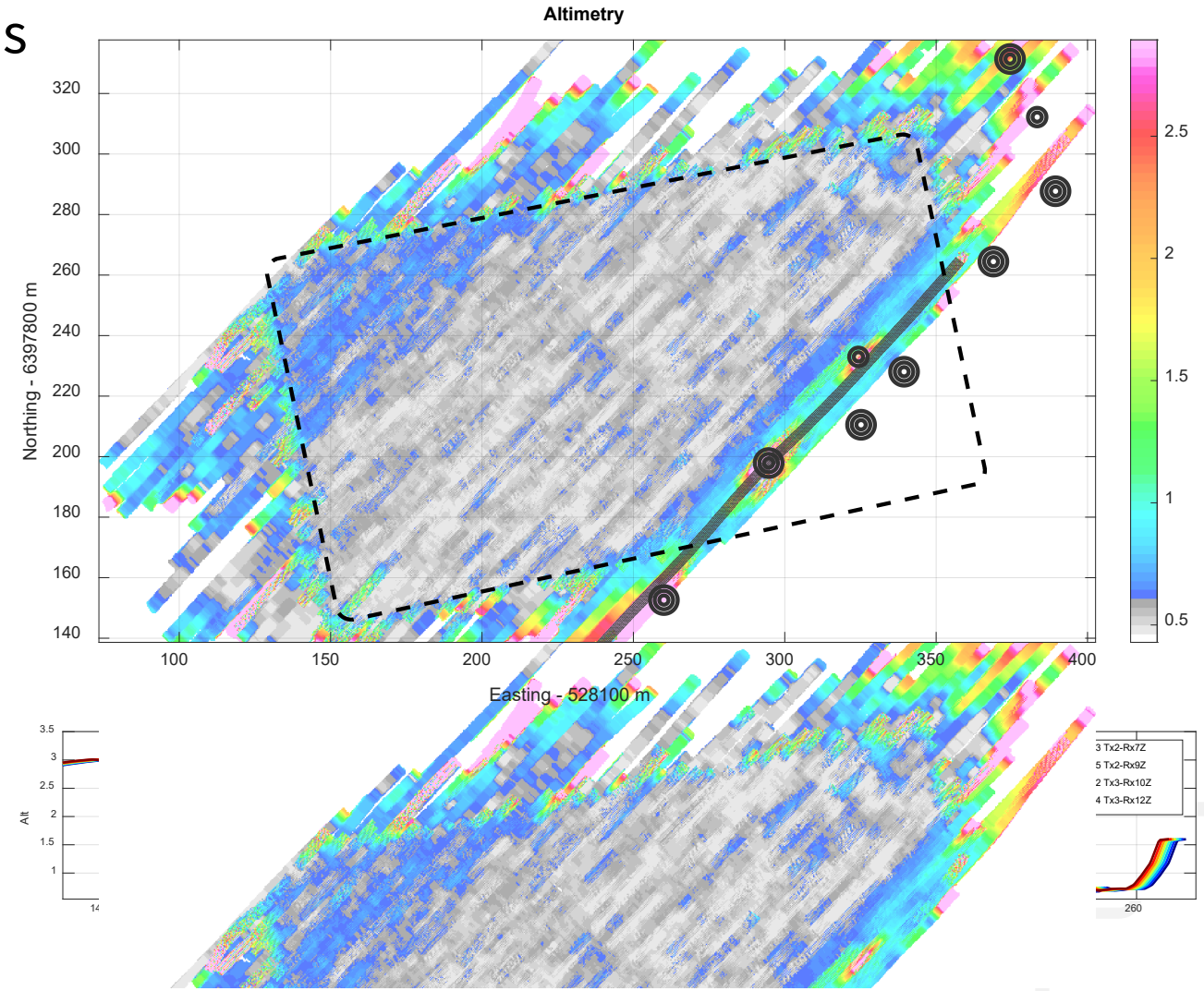


MAD Threshold: 2.50

Detection capabilities: Low standoff above seafloor

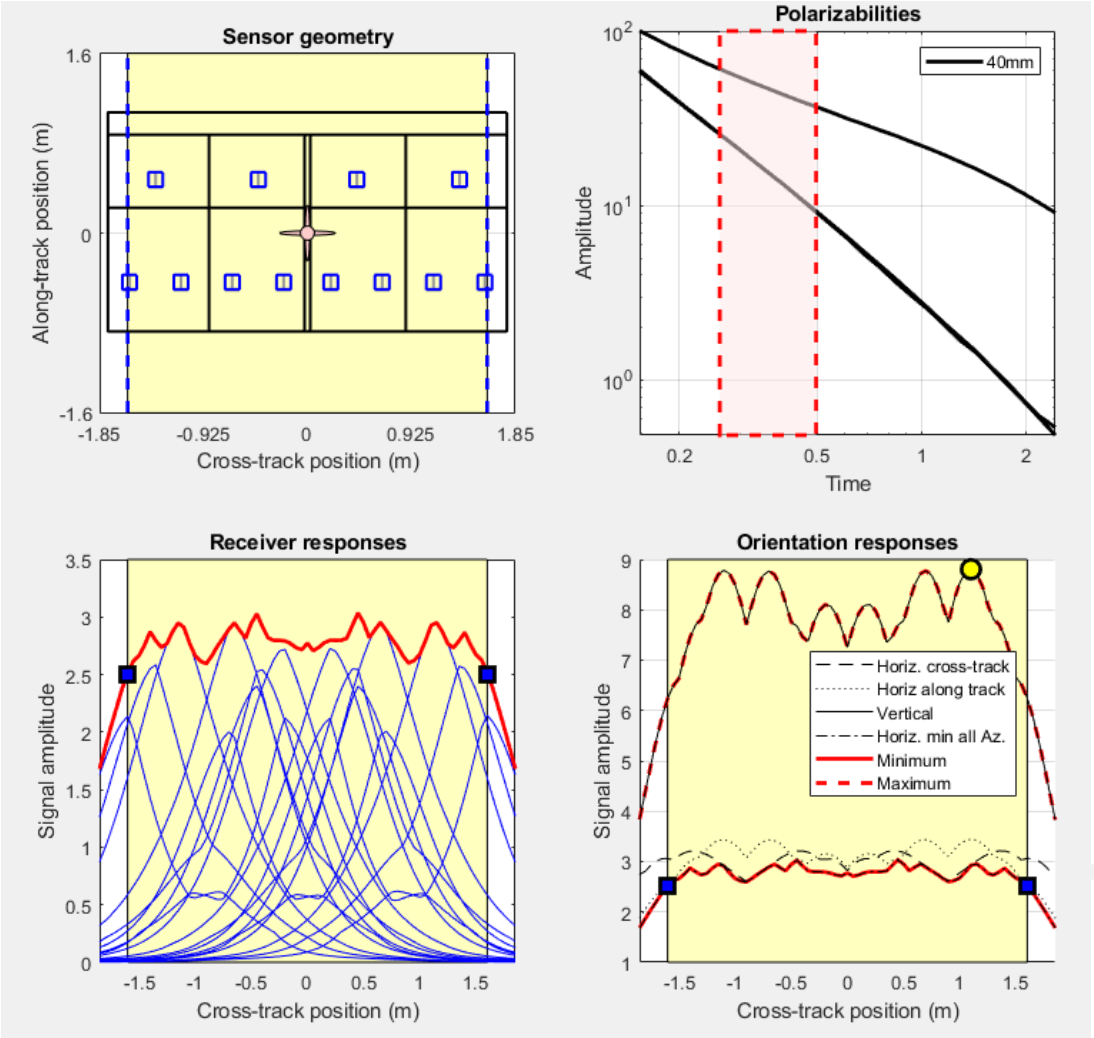
- Most of the survey data was acquired as close as possible to the seafloor
- The platform standoff is 0.5-0.6 m





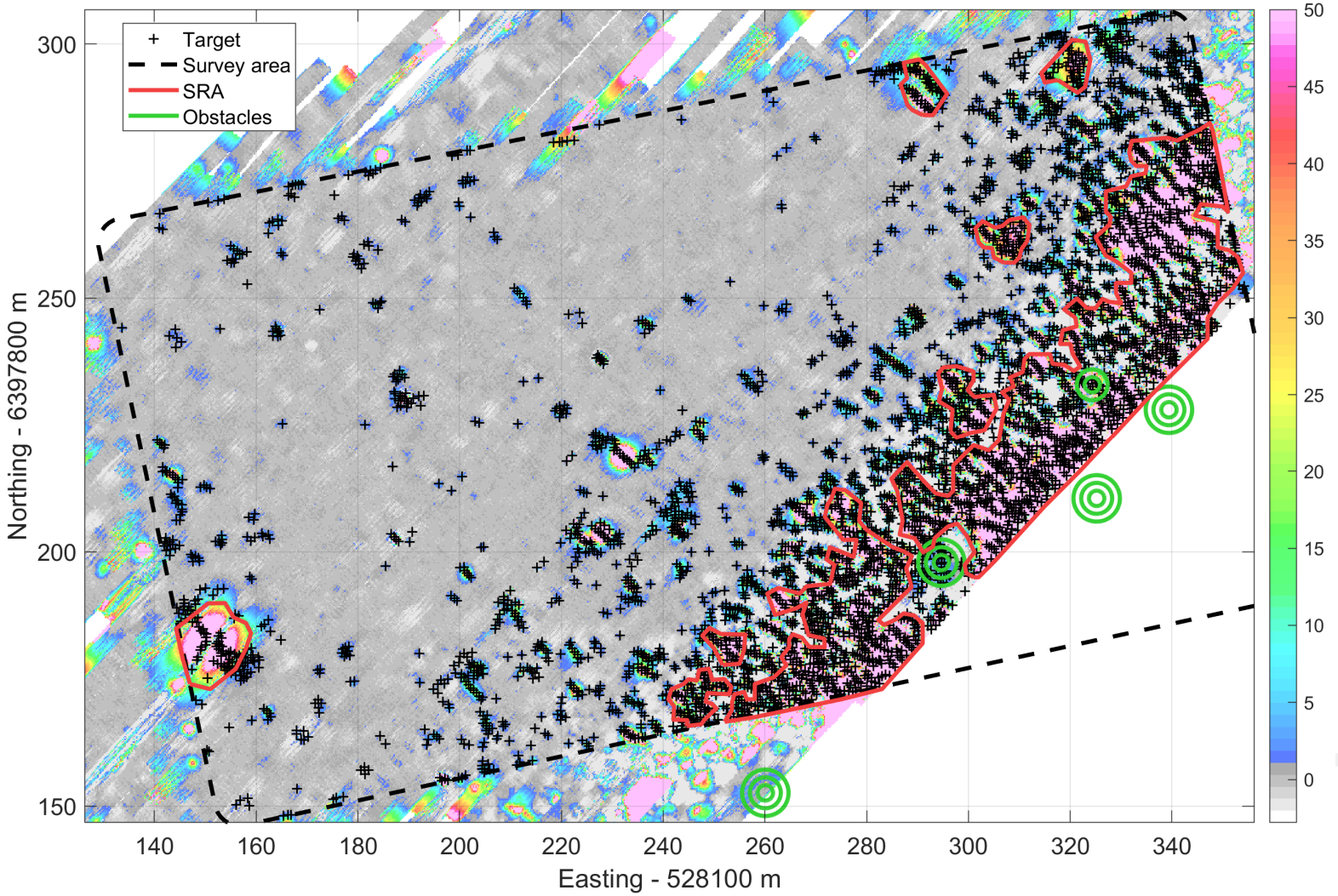
Detection depth and sensor coverage

- Use Detection Modeller software to predict detectability of the smallest TOI (40mm projectile)
  - Prior survey: Identify maximum line spacing to meet the objective (using noise from previous surveys)
  - Post survey: Characterize the detection and classification that can be expected (based on site noise)
    - At 5x the site noise
    - 40 mm projectile should be detectable at 0.2-0.3 m below seafloor.
    - 81 mm mortar detectable at 0.7-0.9 m below seafloor.



Detection: Target picking and SRAs

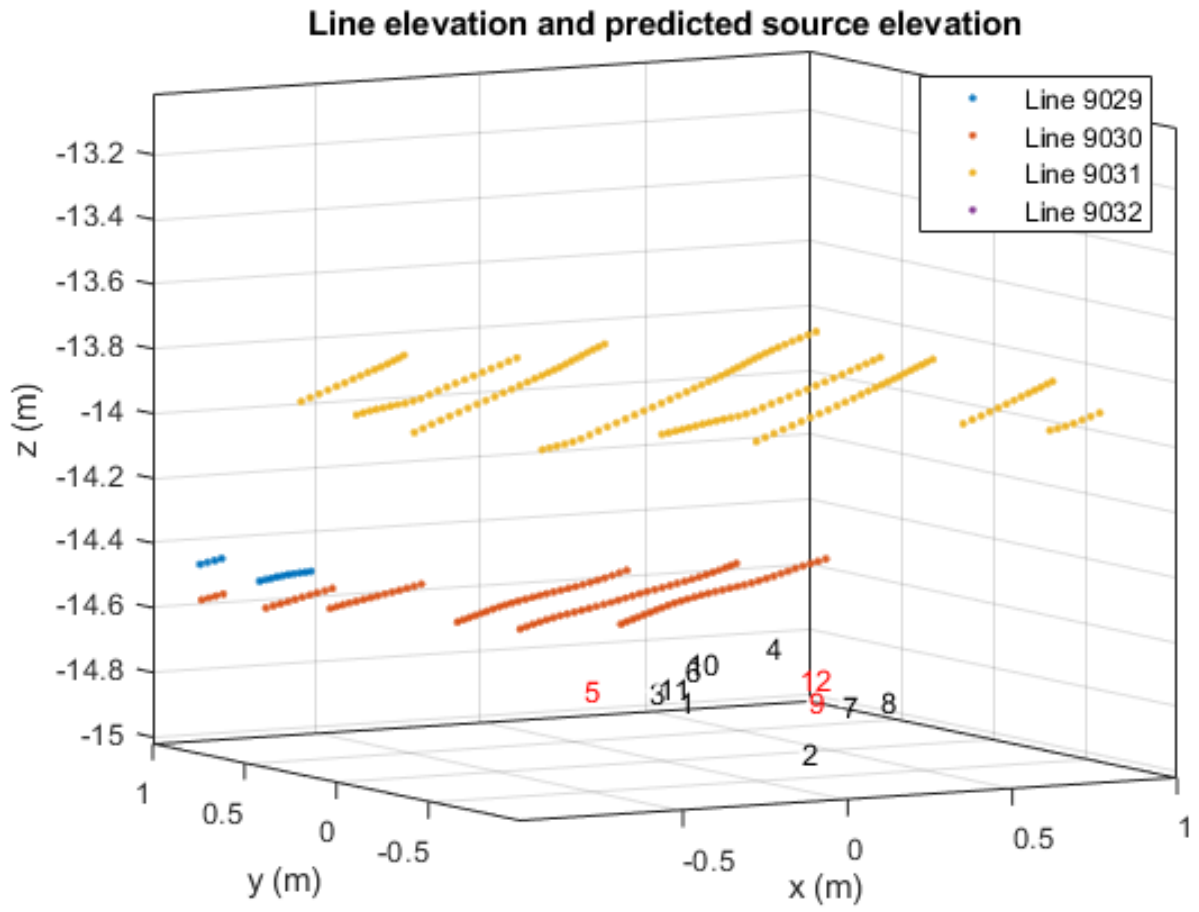
- Detection at 5x noise:
  - Threshold = 2.5 uV/A.
  - 4765 anomalies.
- SRA selection:
  - Select data tiles where the amplitude exceeds 10x the detection threshold.
  - Keep anomalies within SRAs and attempt AGC in SRAs.



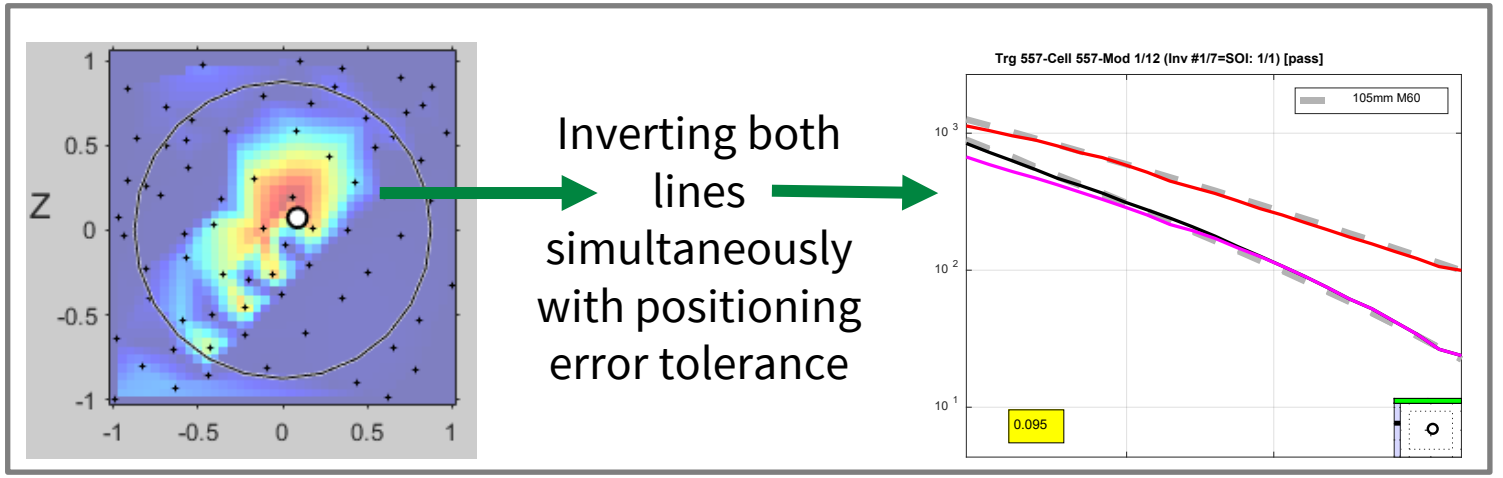
Inversion of EM marine data

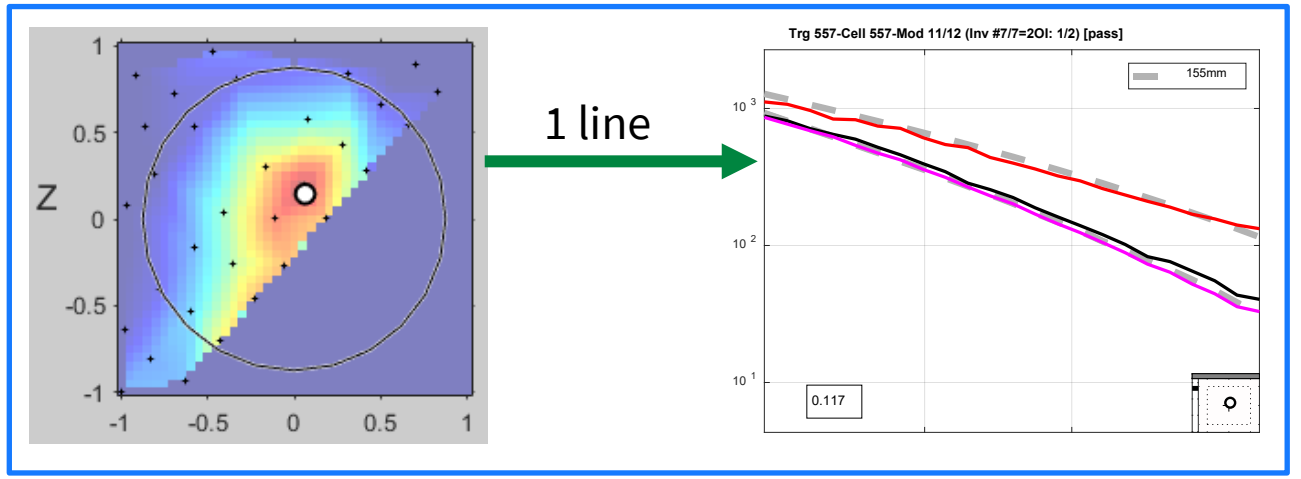
- For AGC, tiles of EM data around each anomalies are inverted to extract target features.
  - Dipole model extract position, orientation, and 3 polarizability decay curves.
- Challenges:
  - Inversion generally requires accurate positioning.
  - Positioning is difficult and not always accurate under water.
    - Along-line positioning is relatively consistent.
    - Lines may be shifted: problem when interpreting anomalies covered by multiple lines.
    - Elevation: Inaccurate because derived from altimeter data and interpolation of the bathymetry data (plus tide).
- Inversion approach:
  - Data were inverted by considering lines separately, and by using them jointly with a method that allows positional errors between different data subsets.
  - Inversions assumed 1, 2 or 3 objects for each anomaly.

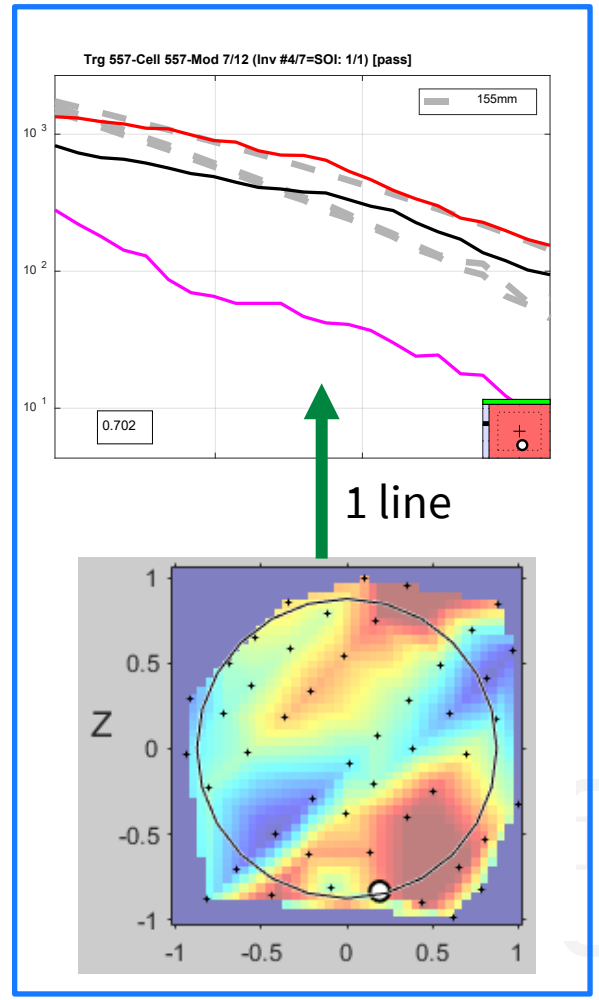
Inversion: Example of an anomaly covered by two lines collected with a difference in elevation of 0.7 m



Inversion of anomalies covered by multiple lines







Classification approach

- Potential targets of interest:
  - The site-specific polarizability library was based on a CSM. Additional items were added for cases with good match to plausible items from the full DoD library.
  - Proposed TOI: 100lb bomb, 105mm, 155mm, 2.25in, 2.36in bazooka rockets, 20lb and 250lb bombs, 40mm, 5in warhead and practice bombs, 60mm mortars, 7.2in depth charge, 81mm mortar, rifle grenade, rocket motor and underwater Mk6 mine.

- Classification was based on library matching in two stages:
  - The first stage was ranked based on matching all three polarizabilities (L1L2L3).
  - The second stage was ranked based on the best of L1L2 and L1L3 to allow for situations where one of the polarizabilities could not be constrained.

Classification Results – Planned Diver Dig Locations

- The classification process yields three orthogonal polarizabilities from the field data that are then matched to a library of known UXO model signatures for the targets of interest (TOI)
- The following slide show graphs for some selected polarizability curves for a variety of small to large UXO from the Women's Bay data.
  - The green dashed lines are the model predictions for the UXO item
  - The red, black and pink (magenta) are the field data
  - The closer the red, black and pink lines match the dashed green lines the more likely the item is a TOI

Selected Polarizabilities

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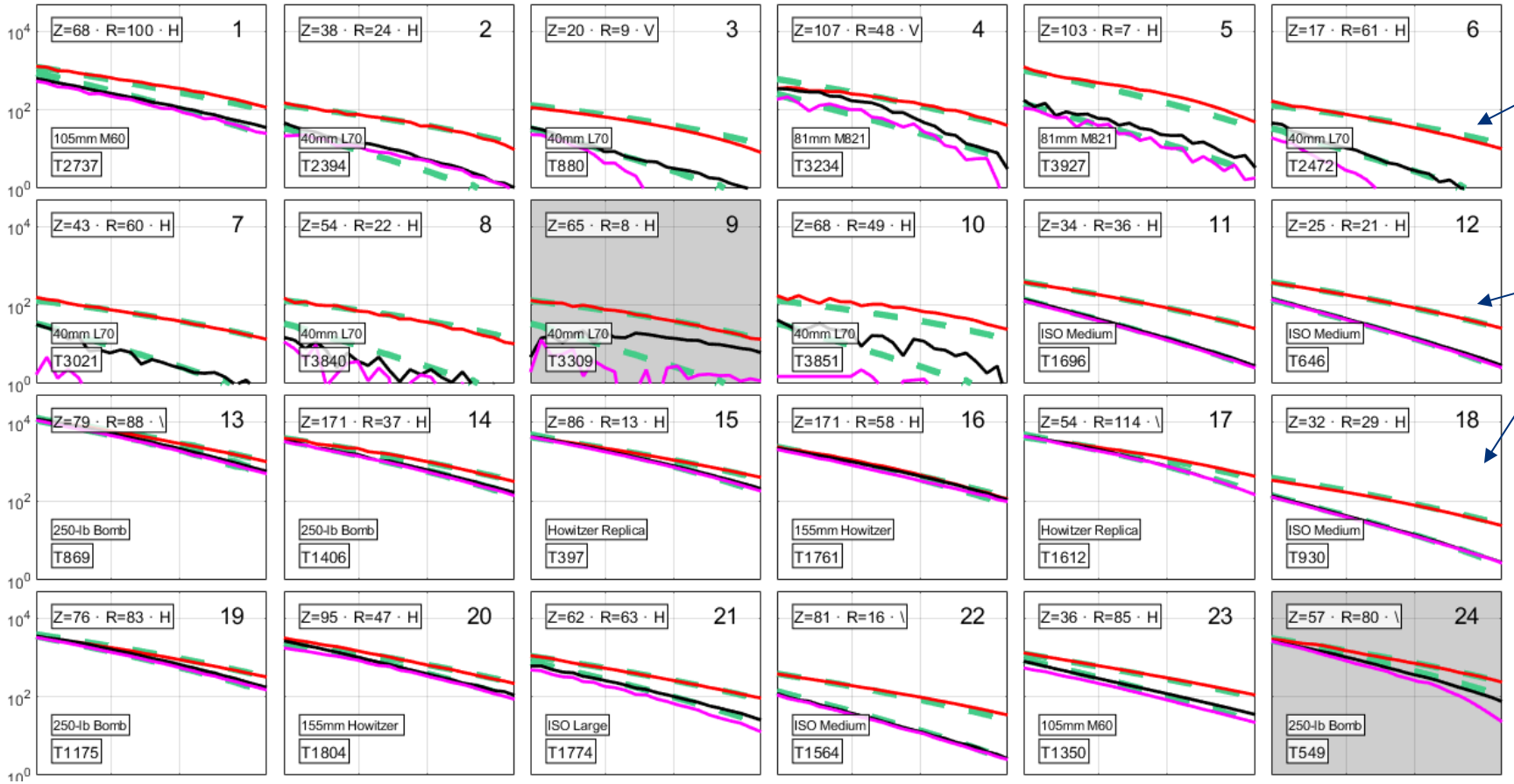
Possible TOI
40 mm
81mm
105mm
250lb bomb
155mm

Large size range

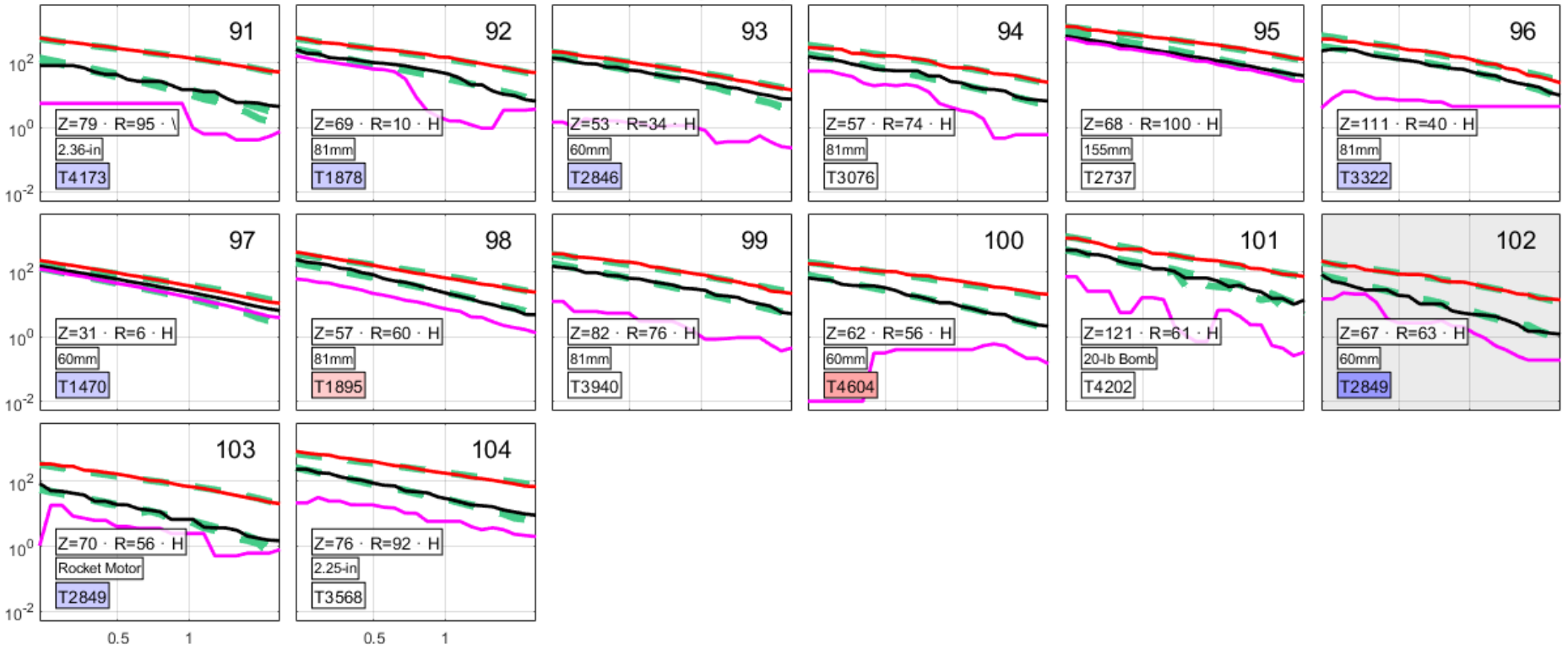


Possible 40 mm

Emplaced seeds

30

Selected polarizabilities in the second classifier stage: only two polarizabilities are matched against the library



Classification Results – Planned Diver Dig Locations

- The classification process yields levels of fit of the data collected in the field to the library of known UXO signatures for the targets of interest (TOI). The map on the next slide has the targets defined as follows:
  - **Likely TOI**, these are **very good fits** (all three polarizabilities match), and are expected to be UXO
  - **Inconclusive TOI**, these are good fits, but not as good a fit as the Likely TOI, or fits for only 2 of the 3 polarizabilities. These items are possible UXO
  - **Saturated Response Areas (SRA)** The pink (magenta) areas that are outlined in black, represent areas of high EM readings. These areas may pose a challenge for the divers if there is excessive/large/heavy metallic items (chain, wire rope, other debris from the Marginal Wharf)
    - There are **Likely TOI**, and **Inconclusive TOI** within the SRAs that are on the planned diver dig list.

Classification Results – Planned Diver Dig Locations

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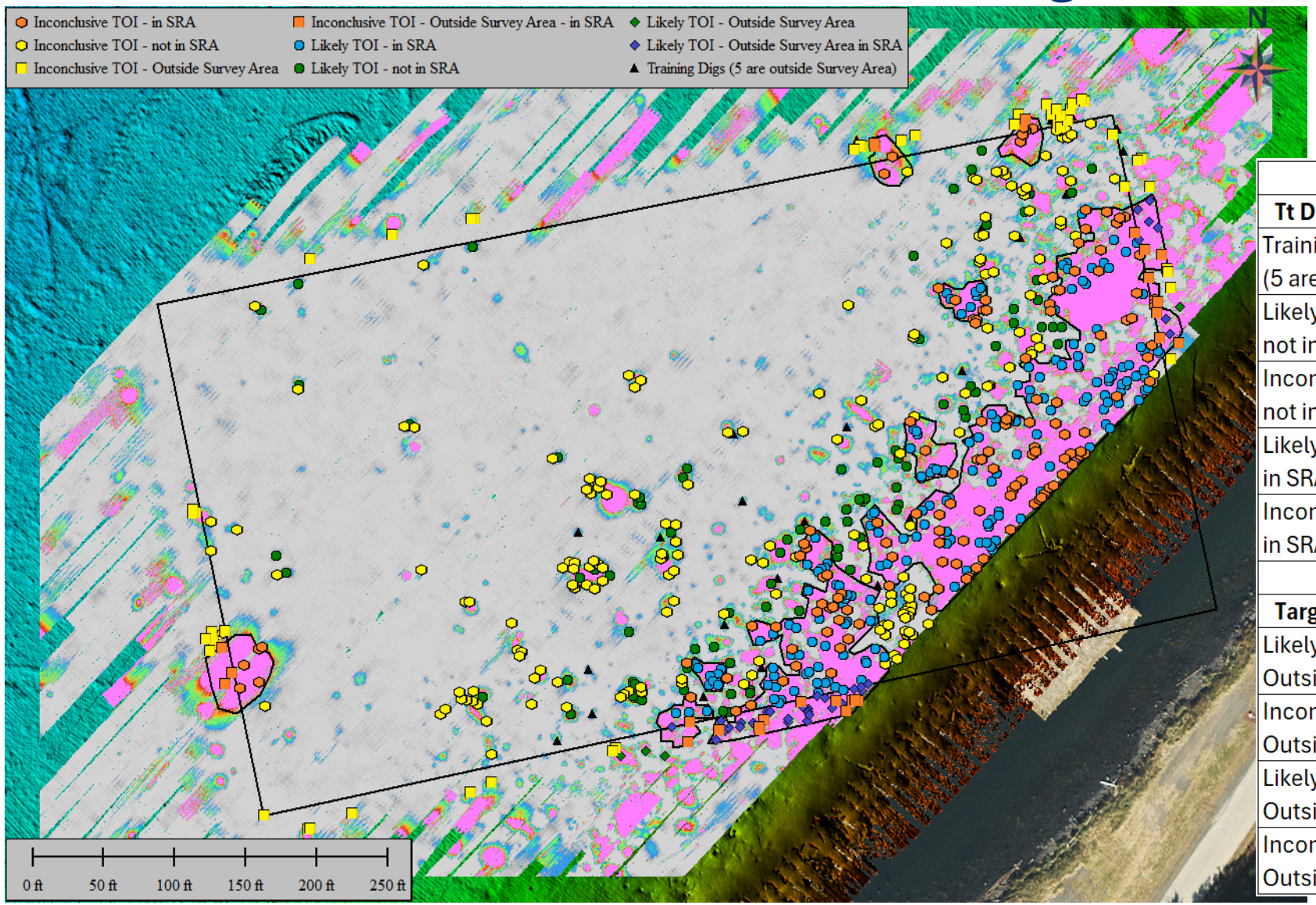

Saturated Response Area (SRA)

Tetra Tech Dig List Details			
Tt Dig List Details	**Color**	**Shape**	**Quantity**
Training Digs (5 are outside Survey Area)	Black	Triangle	24
Likely TOI - not in SRA	Green	circle	86
Inconclusive TOI - not in SRA	Yellow	octagon	183
Likely TOI - in SRA	Blue	circle	185
Inconclusive TOI - in SRA	Orange	octagon	135
Total Targets for Diver Investigation			**613**
Targets Outside of the Survey area			
Likely TOI - Outside Survey Area	Green	diamond	4
Inconclusive TOI - Outside Survey Area	Yellow	square	52
Likely TOI - Outside Survey Area in SRA	Blue	diamond	33
Inconclusive TOI - Outside Survey Area - in SRA	Orange	square	26

Advanced Geophysical Classification (AGC) Results

- **Kodiak Results**
  - **There are 728 recommended dig locations out of 2,657 derived sources which was reduced from >4,700 targets.**
    - **Derived sources are the inversion derived items (TOI) to generate the EM response measured in the field**
    - **Targets are unique pickable EM anomalies**
  - **Of the 728 locations, 120 are outside the survey area**
    - **5 of which are training digs**
  - **Leaving 613 targets to be investigated by UXO Divers**
    - **Including 24 targets to be used for informing/refining the AGC data processing "training digs"**

The MiniDP system can support many other projects
The MiniDP system is also being added to a second Tt boat

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- ROV / HAUV Operations
- Diver operations / support
- Live boating sampling
  - Vibracores, grabs
- Buoy deployment and recovery
- Other Geophysical Surveys

Questions?

Contact: richard.funk@tetratech.com