Black Tusk GEOPHYSICS | TETRA TECH | GapEOD Explosive Ordnance Detection

AGC in the Marine Environment: Blind-test results for 2022 UltraTEMA survey at Sequim Bay

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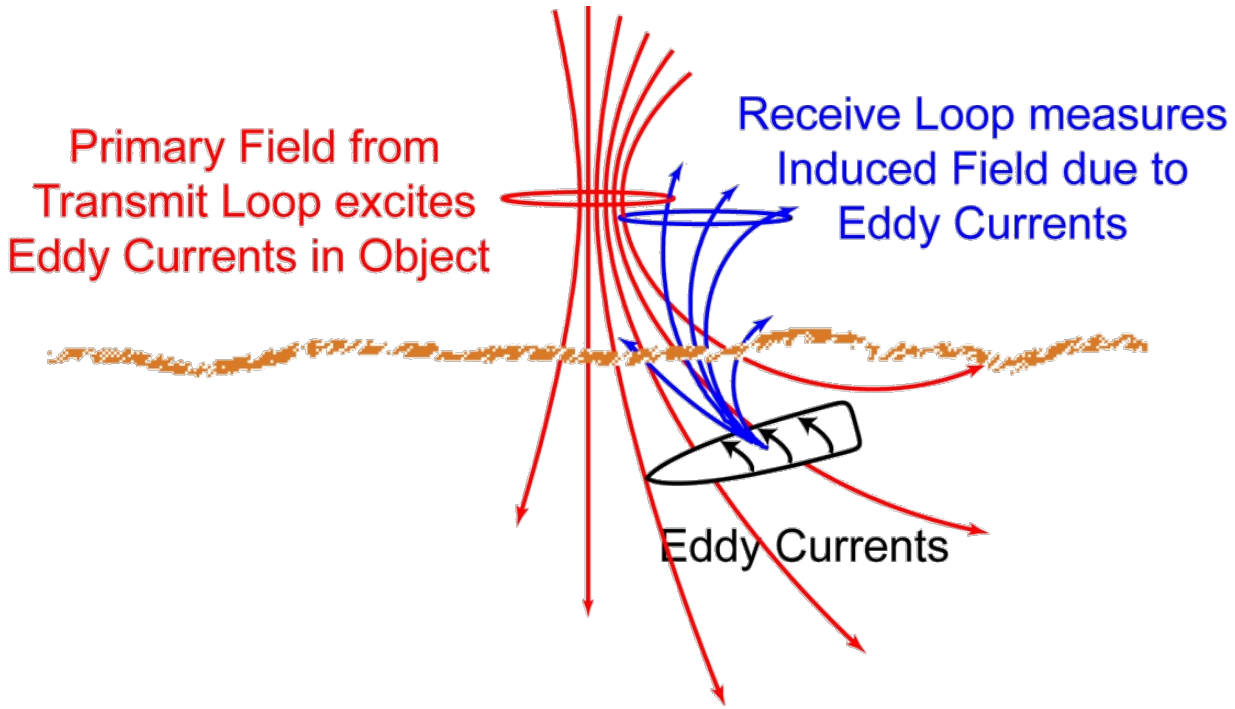
Electromagnetic Induction sensor

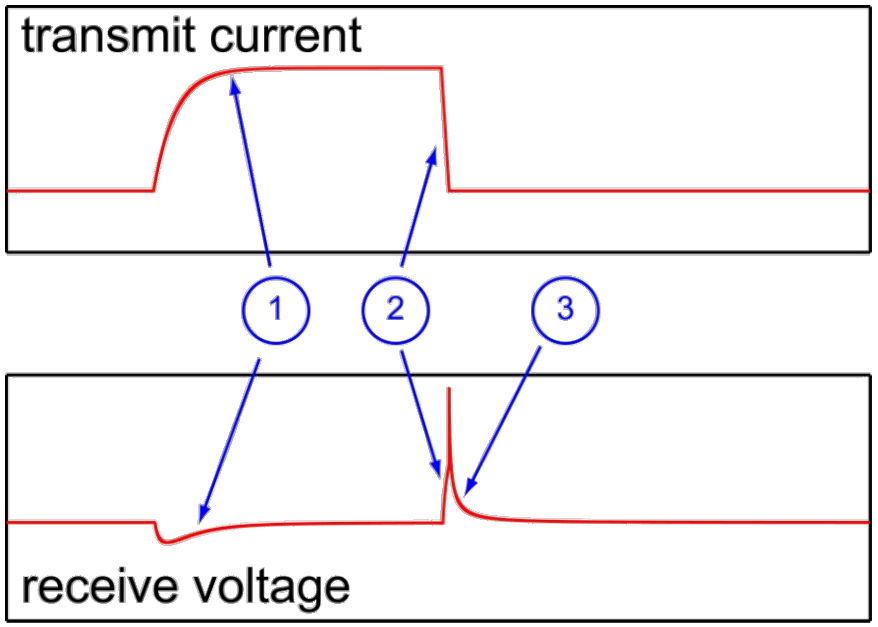
- Electromagnetic induction sensors have been the main-stay of ordnance (and mine) detection systems since before World War II

- At a minimum they comprise one transmitter coil and one receiver coil

An American soldier checks for concealed mines with a metal detector (Western Europe 1944)

Electromagnetic Induction



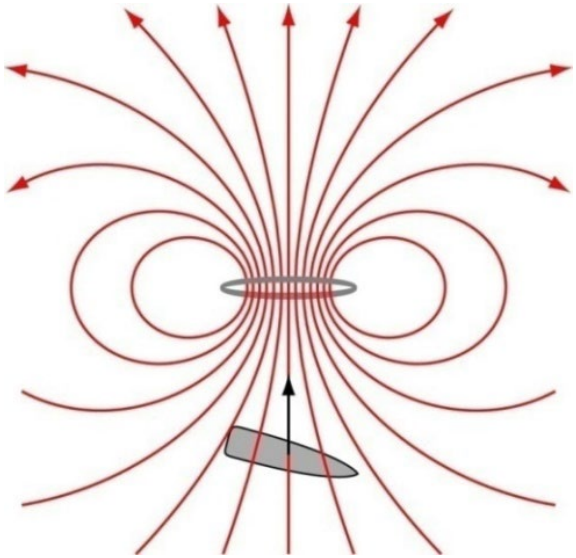


1. The primary field magnetizes the buried object (similar to magnetics)
2. Abrupt change in the primary field excites eddy currents in the object.
3. Eddy currents diffuse throughout the object and decay (basic EM response which applies to all metal objects)

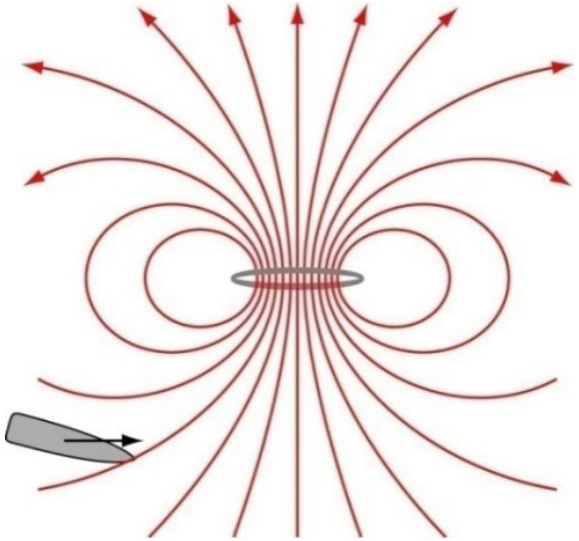
Terrestrial AGC

- Excite object from multiple different directions to extract polarizability (fingerprint)

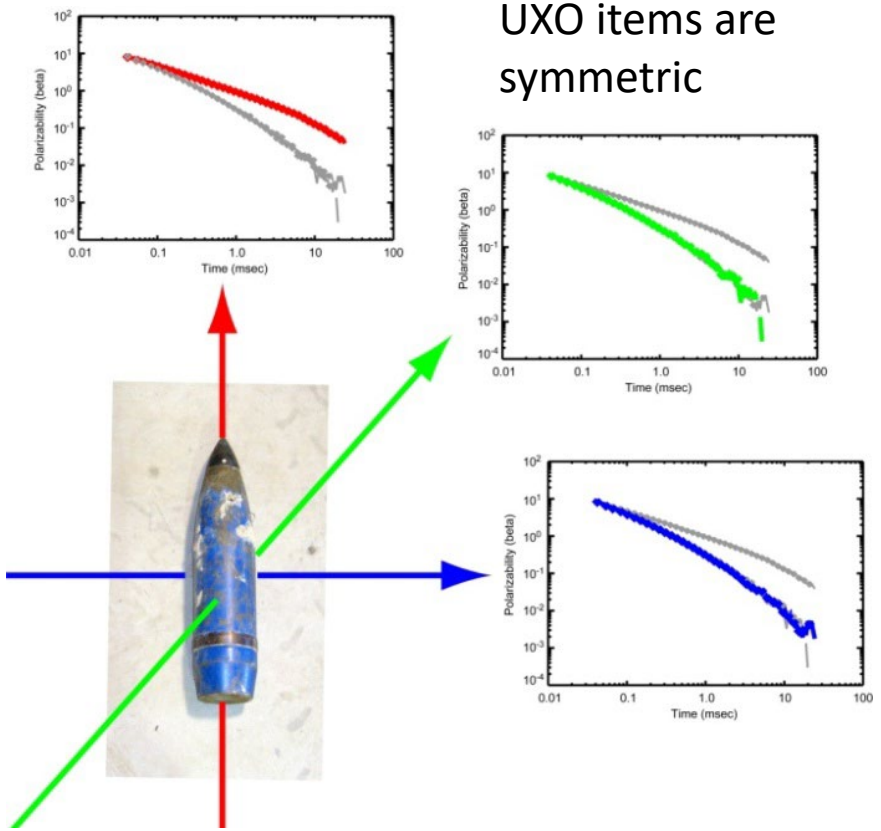
Directly on-top



Offset



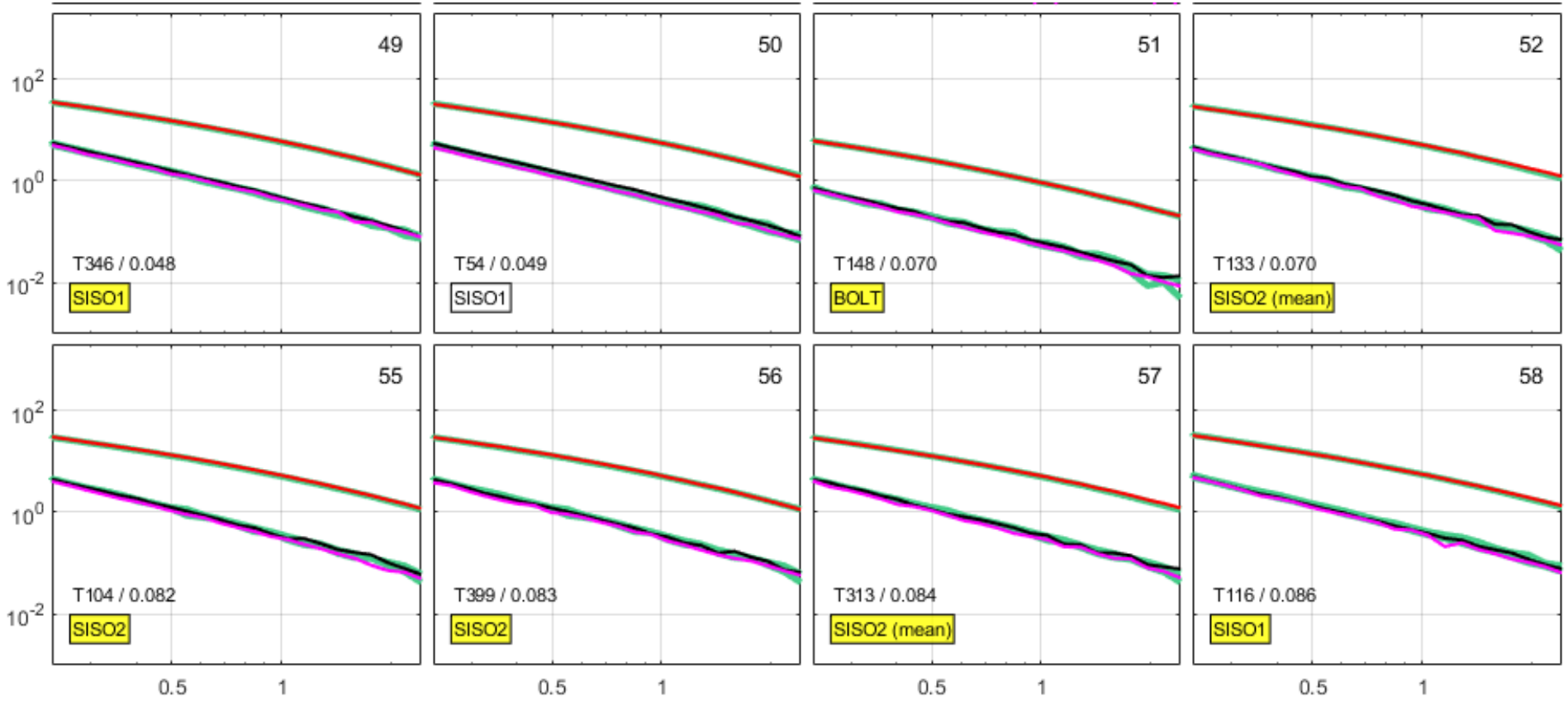
UXO items are symmetric



Terrestrial Advanced Geophysical Classification (AGC)

Example from a production project

- Polarizabilities arranged in dig-list order (reference polarizabilities in green)



Terrestrial AGC: Physical model

$$data(\mathbf{x},t) = signal(\mathbf{x},\mathbf{x_0},t) + background(\mathbf{x},t) + noise(\mathbf{x},t)$$

Terrestrial methods work because of excitation of all principal axes plus:

1. An accurate physical model

- Dipole model
- Polarization tensor
- Methods for multiple objects

2. Accurate sensor positions

- Dynamic data and high-quality RTK-GPS
- Static measurements and fixed geometry

3. Good background estimates

- Periodic background estimates
- Low background levels
- Some challenges in magnetic geology

4. High signal to noise ratio (SNR)

- Close proximity of sensor to targets of interest
- Cued collection to increase SNR

Challenges with marine AGC

$$data(\mathbf{x},t) = signal(\mathbf{x},\mathbf{x_0},t) + background(\mathbf{x},t) + noise(\mathbf{x},t)$$

The underwater environment introduces several challenges:

1. An accurate physical model

- Potential interaction effects between object and sea-water

2. Accurate sensor positions

- Underwater positioning is much less accurate
- Logistical challenges with cued measurements

3. Good background estimates

- Background varies with water depth and temperature, sensor height, sediment composition
- Background can be strong

4. High signal to noise ratio (SNR)

- Often cannot get close to the sea-bottom
- Logistical challenges with cued measurements

Requirements for marine AGC

1. Platform

- Close stand-off to sea-bottom
- Stable platform orientation
- Accurate positioning of platform
- Low electromagnetic noise from platform and auxiliary sensors

2. Sensor

- Large transmitter coils with high current
- Transmitters arranged to provide excitation in multiple directions
- Multiple 3-axis receivers

3. Software

- Avoid very early times (or include interaction effects in the model)
- Methods for removing sea-water background signal

UltraTEMA-4 System components

1. TEMA tow-platform (Tetra-Tech)

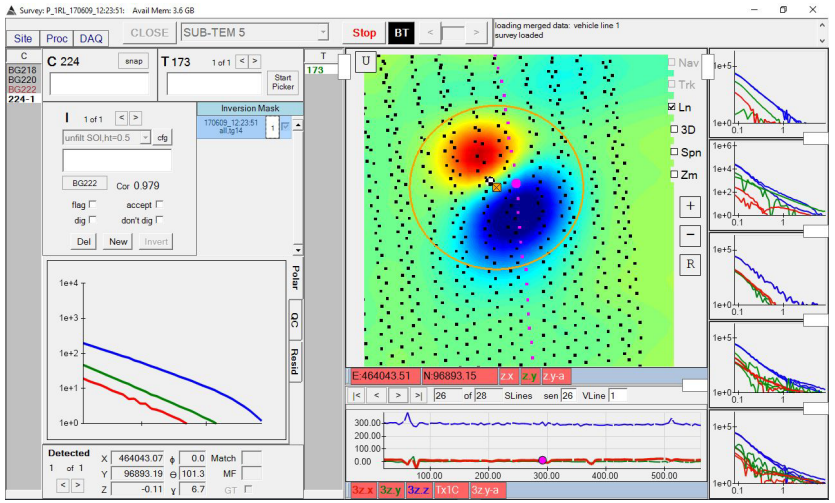
- Tested and proven marine towed-array system
- Capable of controlled low-level flight above the sea-bottom

2. UltraTEM hardware (GapEOD)

- “Next generation” TEM based sensor
- Hardware DAGCAP validated
- Existing marine systems deployed on European projects

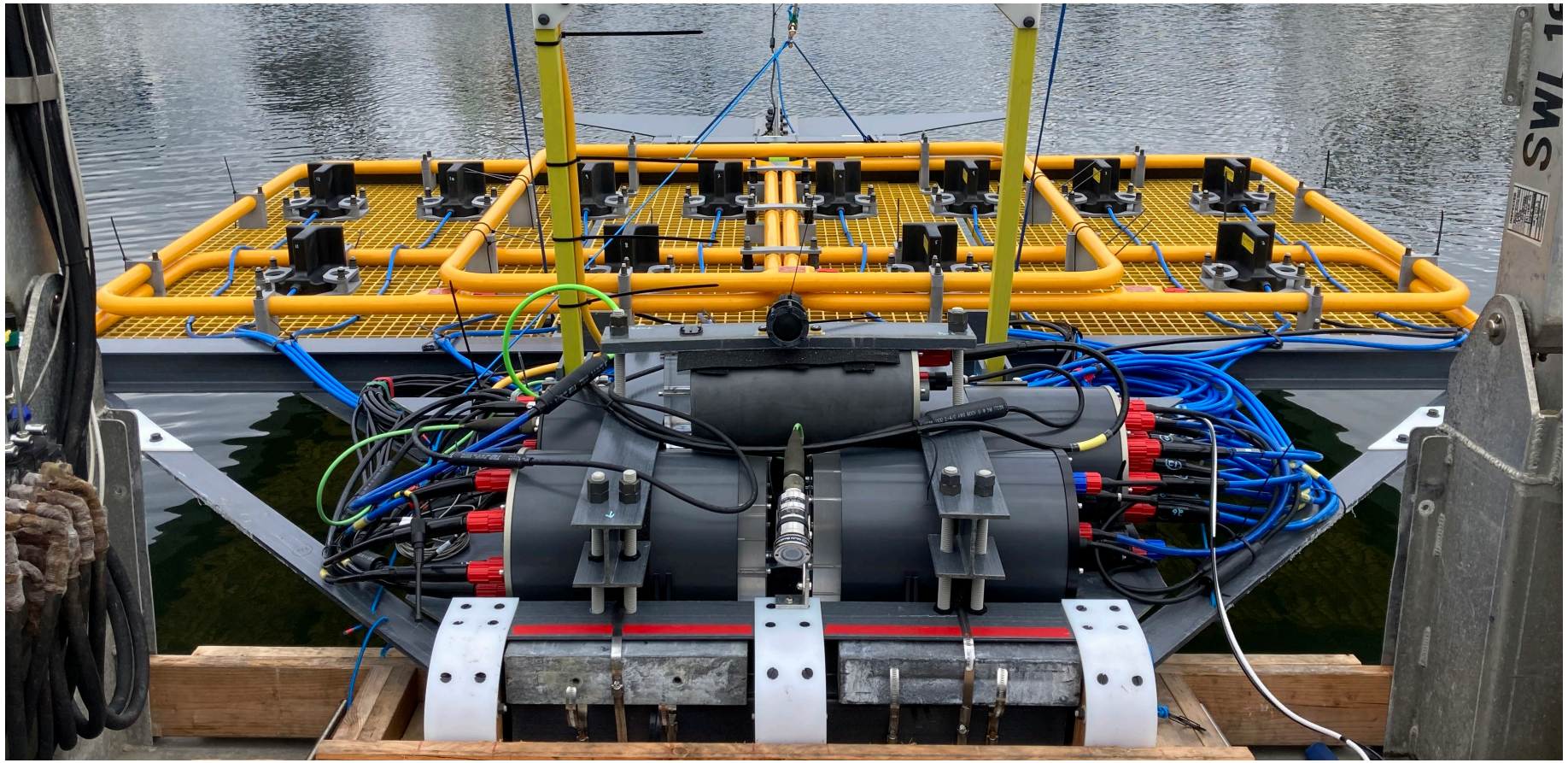
3. BTField software (Black Tusk Geophysics)

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



UltraTEM Marine sensor

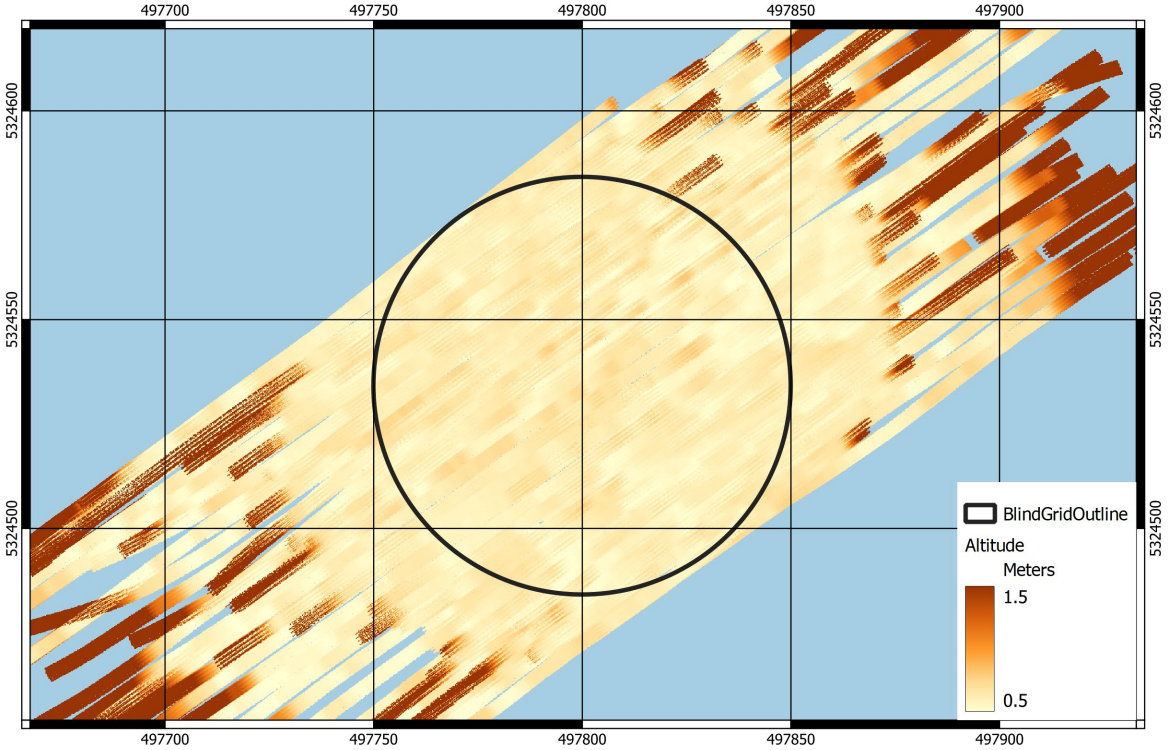
- Twelve receivers and four transmitters arranged to maximize field diversity during survey



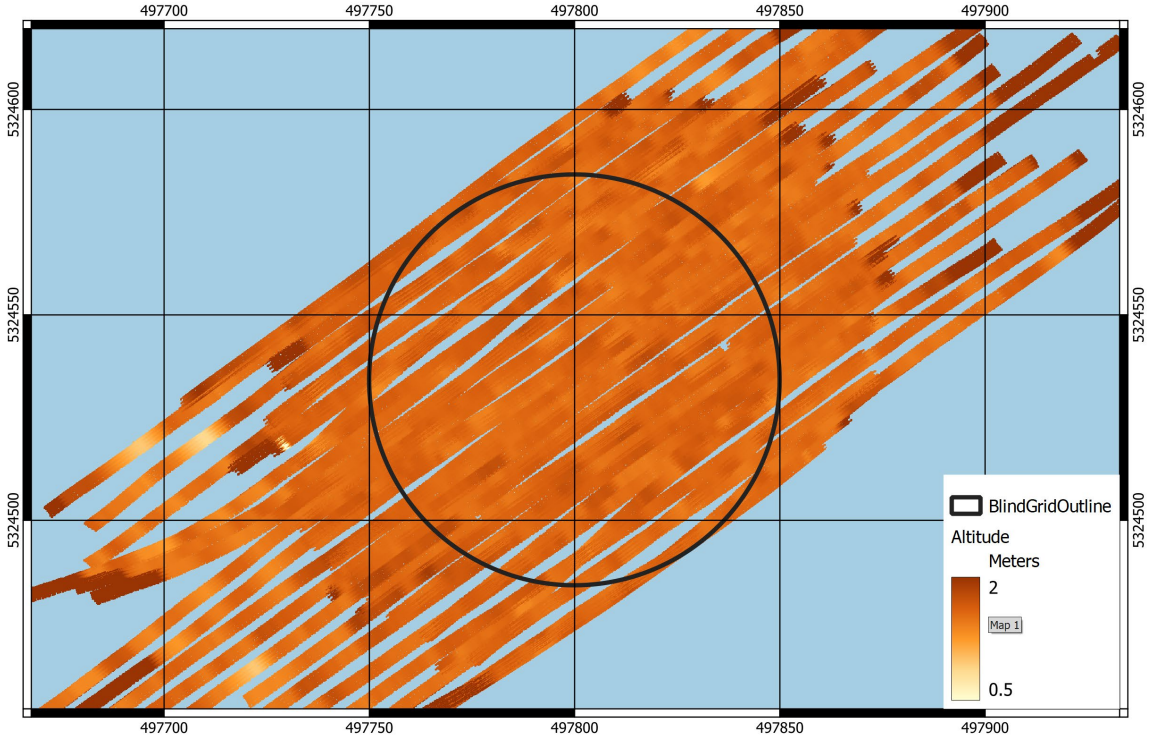
Sequim Bay 2022

Sequim Bay 2022: High and low altitude surveys

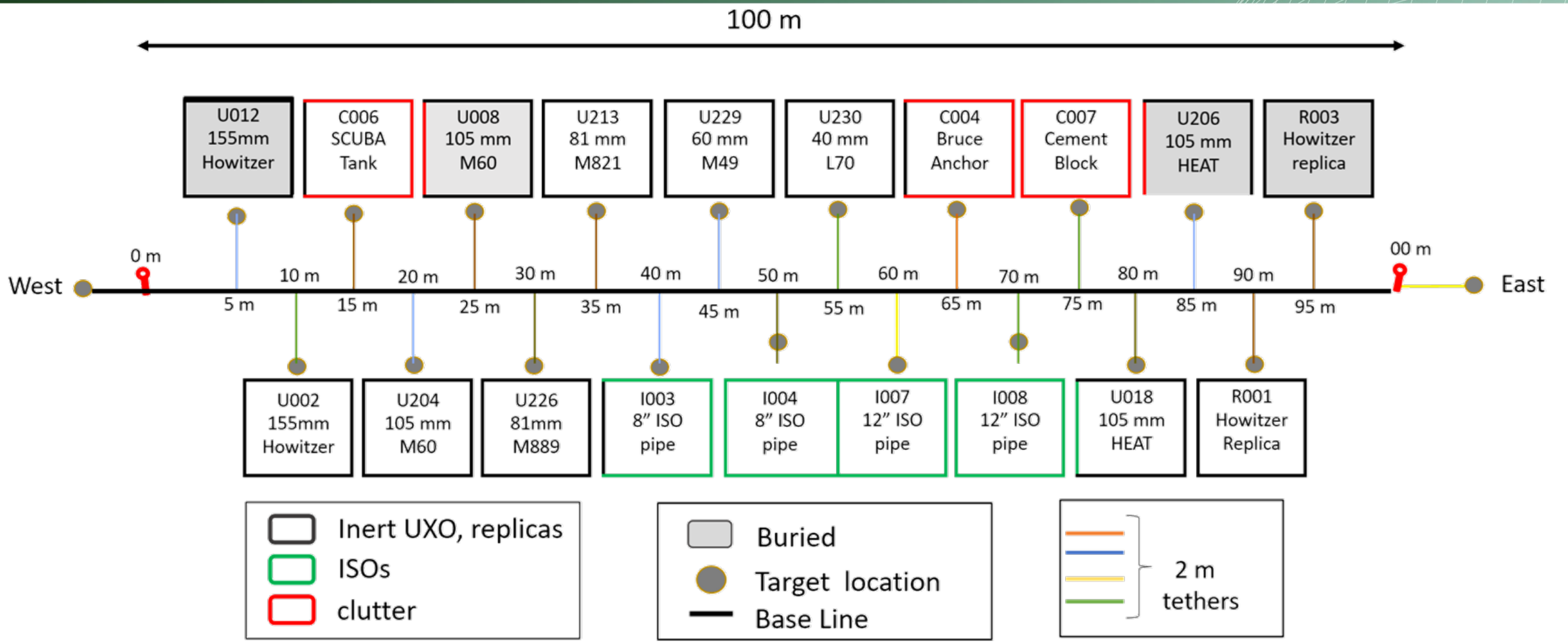
Low altitude



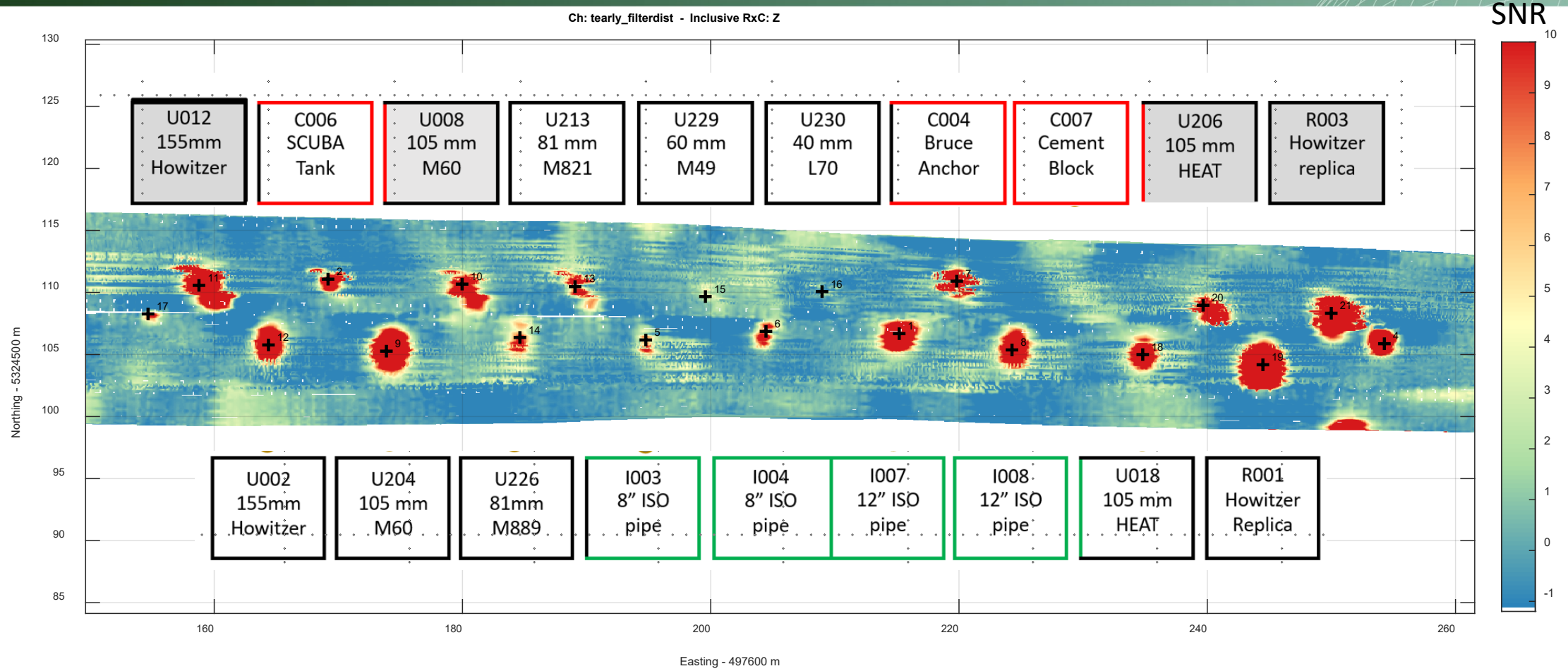
High altitude



Sequim Bay 2022

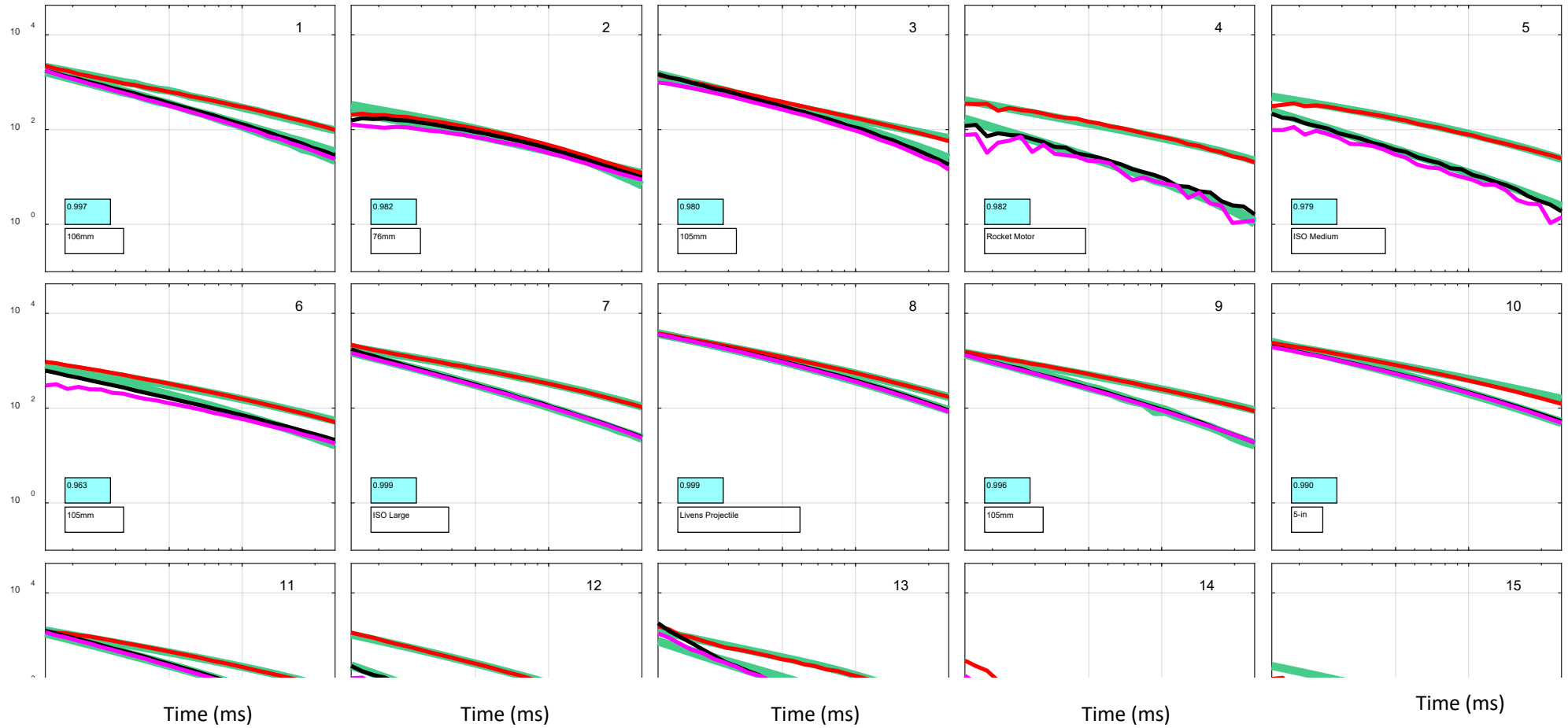


Calibration Lane: 1 to 1.25 m altitude



Calibration Lane: 1 to 1.25 m altitude

1	Large ISO
2	Scuba Tank
3	East Anchor point
4	Medium ISO
5	Medium ISO
6	Bruce Anchor
7	Large ISO
8	155mm Howitzer
9	105mm M60
10	155mm Howitzer
11	105mm M60
12	81mm M821
13	81mm M821
14	60mm M49
15	40mm L70
16	West Anchor
17	105mm HEAT
18	Howitzer Replica
19	105mm HEAT
20	Howitzer Replica



Black Tusk GEOPHYSICS TETRA TECH GapEOD Explosive Ordnance Detection

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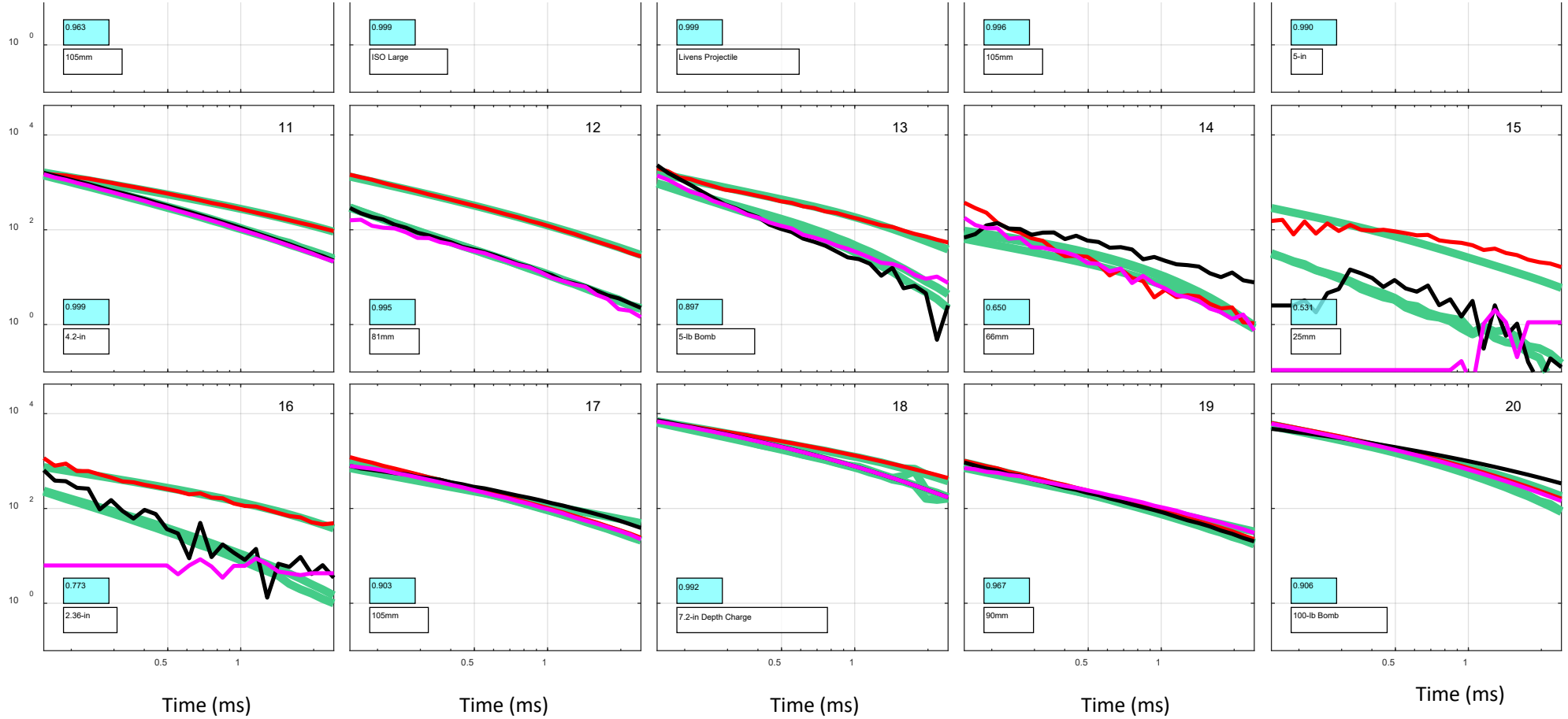

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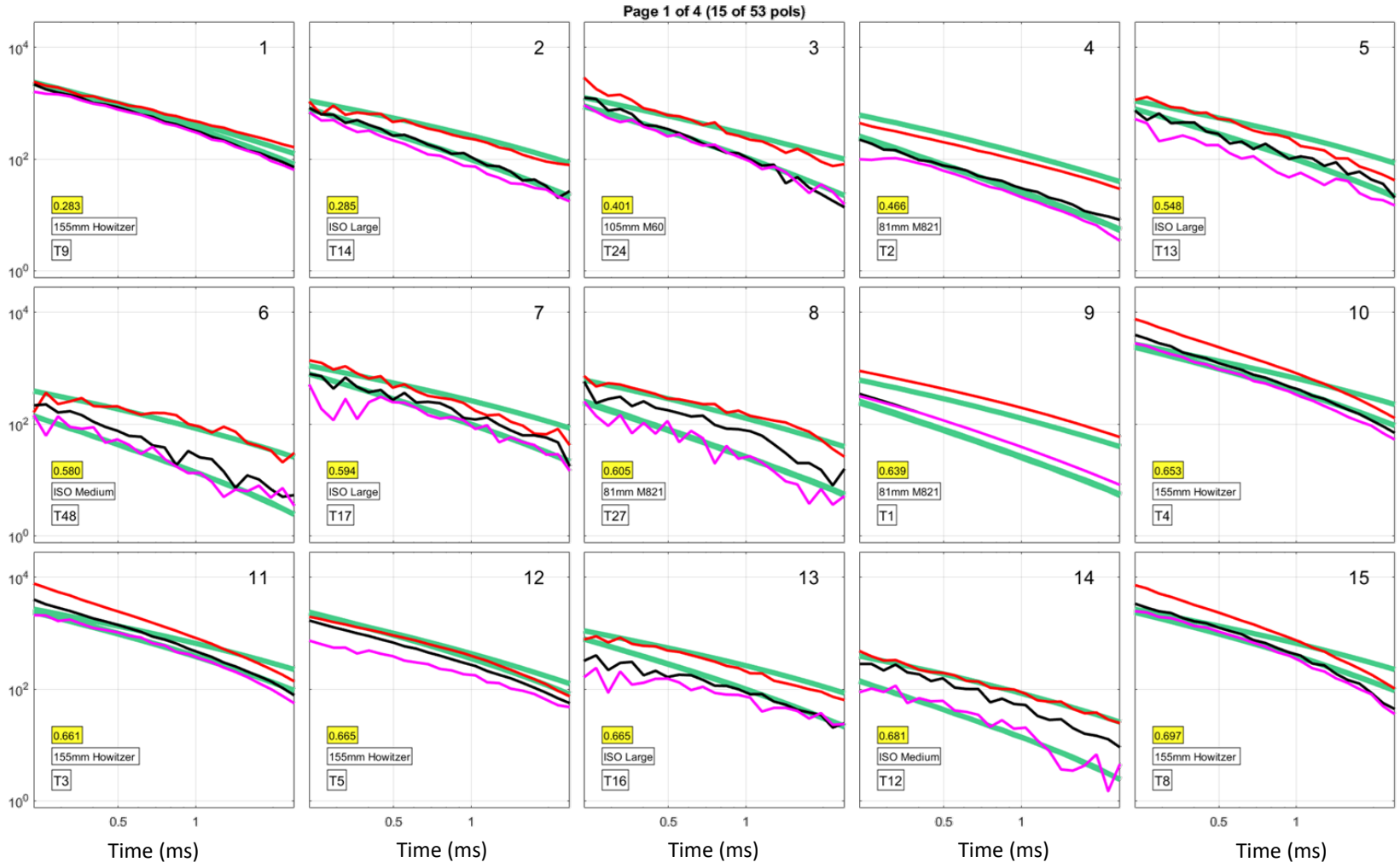
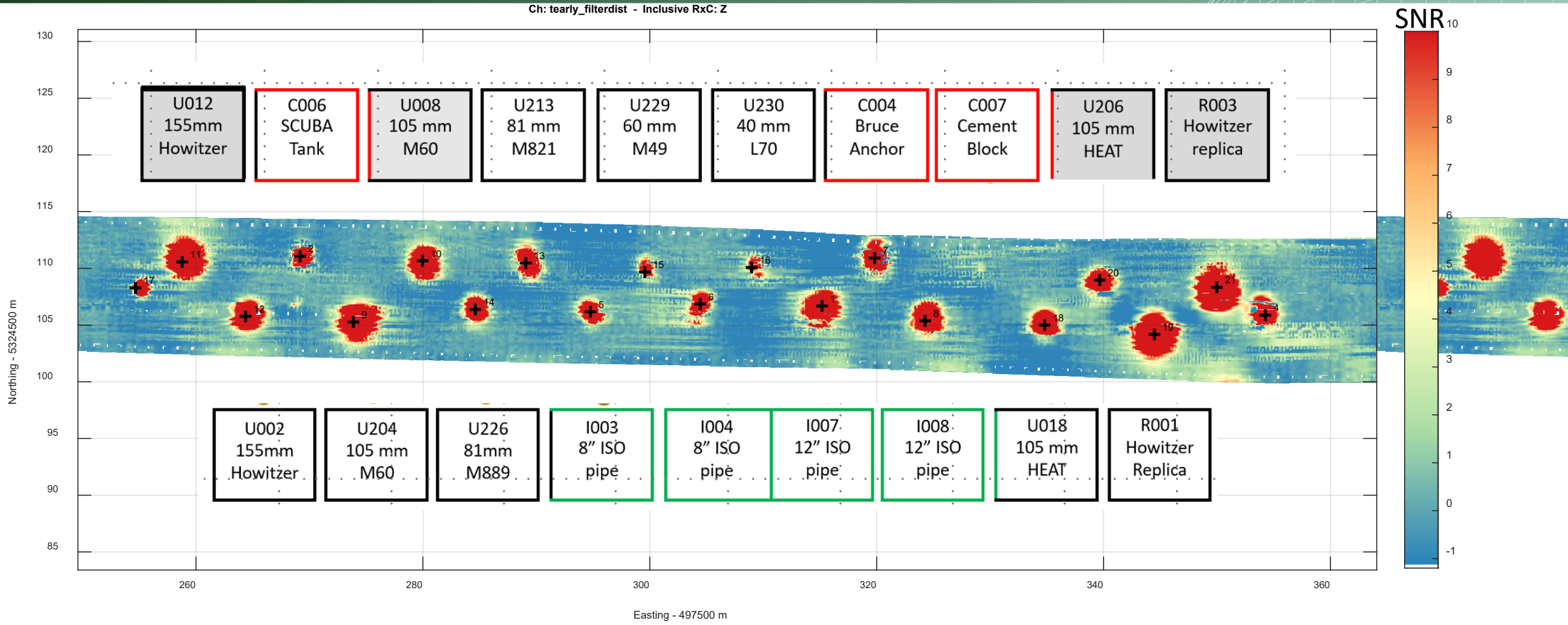
2022 Sequim Bay Blind-Grid
High altitude data (1.5 m plus)



Difficult to constrain polarizabilities

Calibration Lane: 0.5 to 0.75 m altitude



Calibration Lane: 0.5 to 0.75 m altitude

1	Large ISO
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6	Bruce Anchor
7	Large ISO
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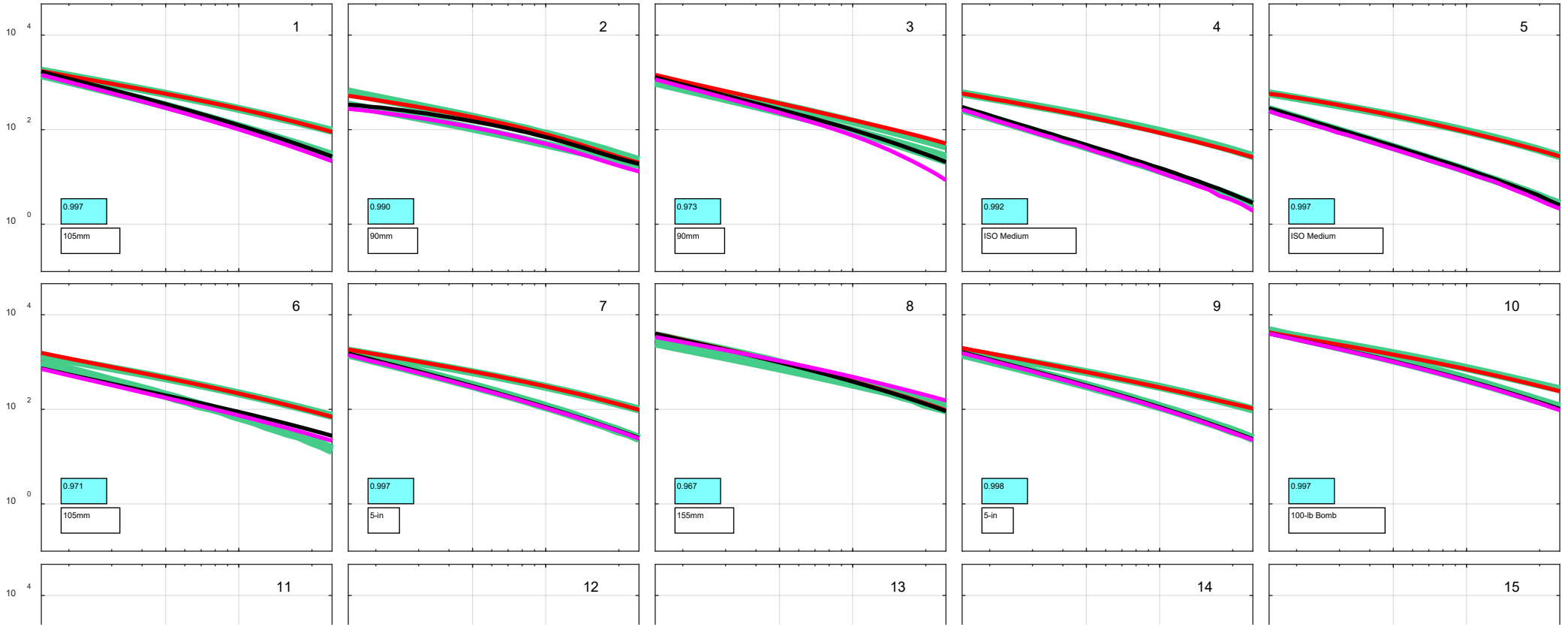

Calibration Lane: 0.5 to 0.75 m altitude

1	Large ISO
2	Scuba Tank
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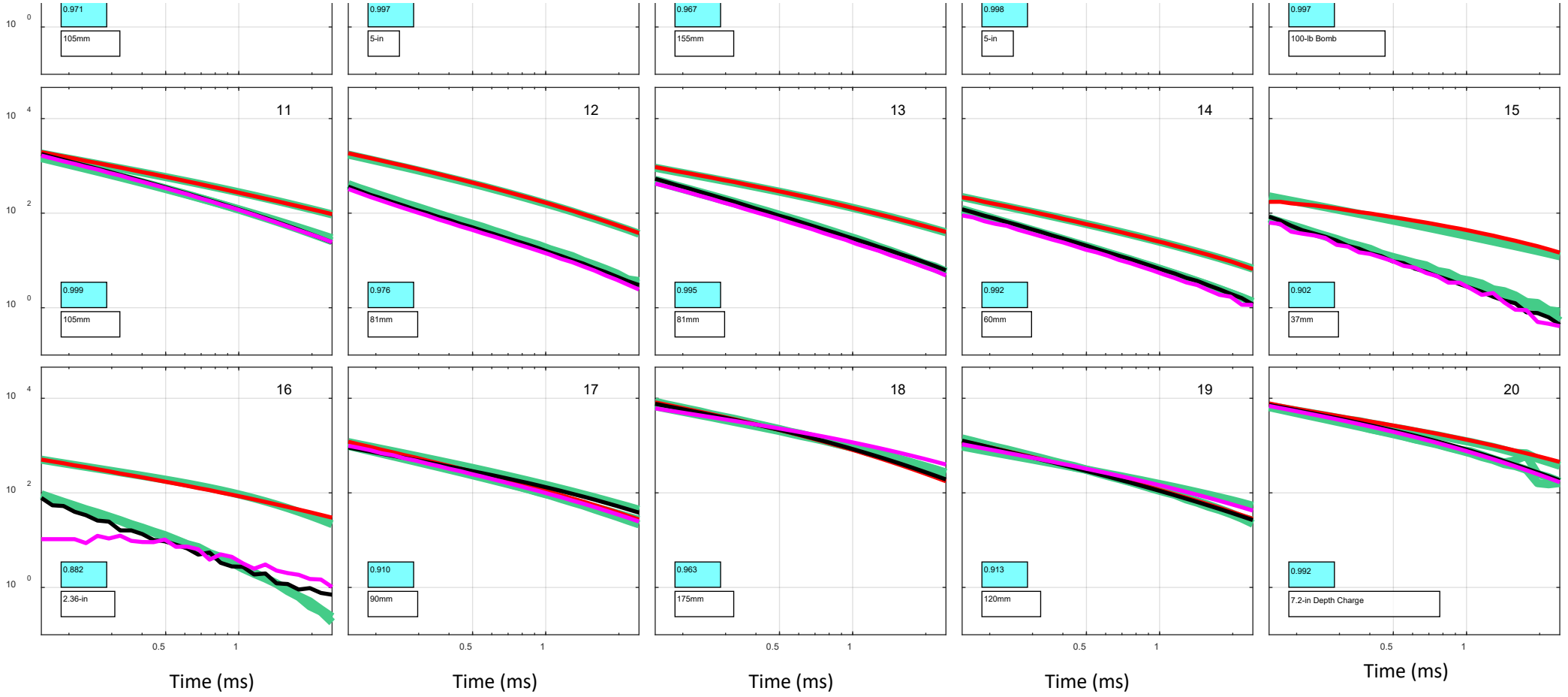
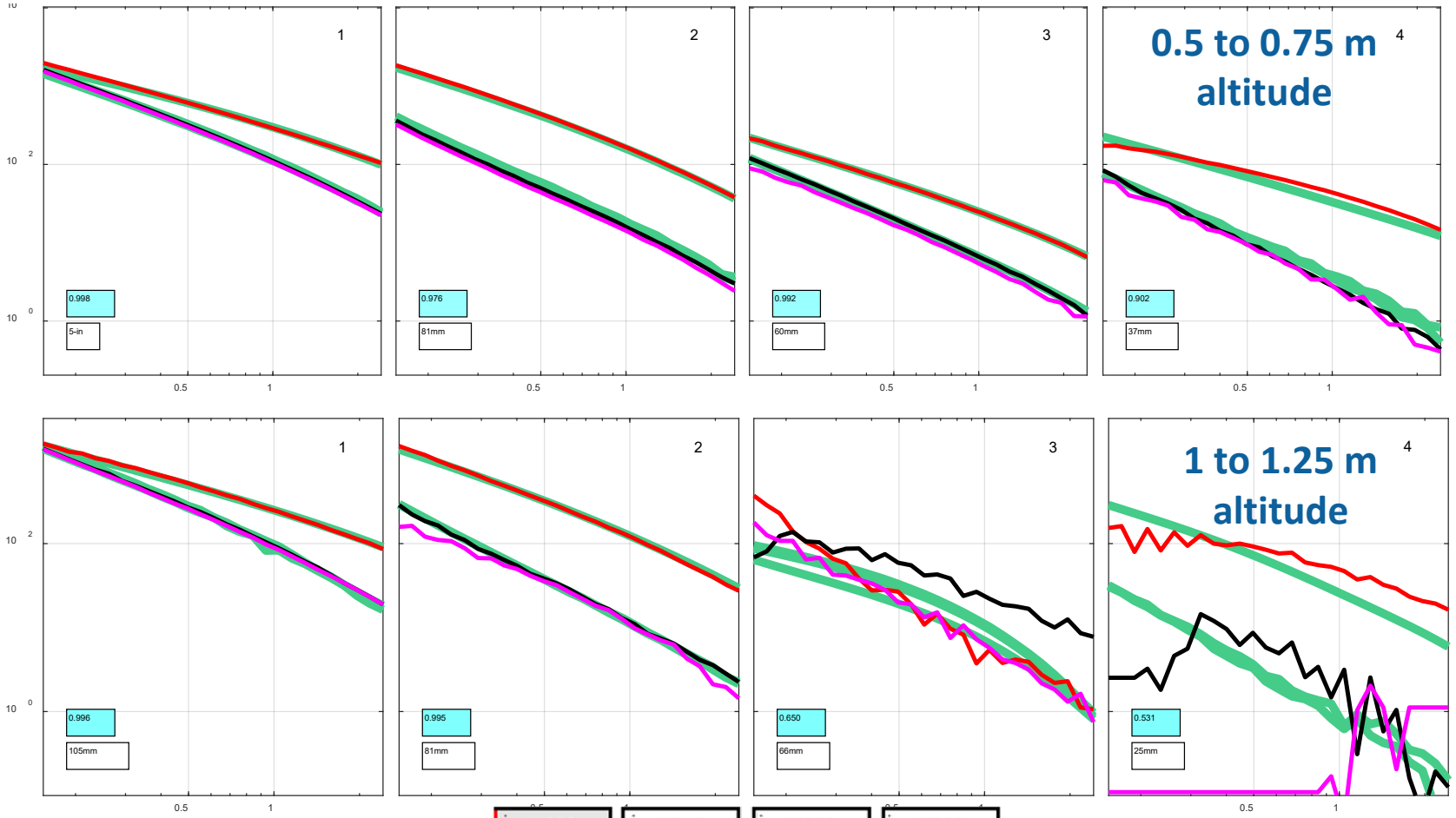


Large to small item comparison



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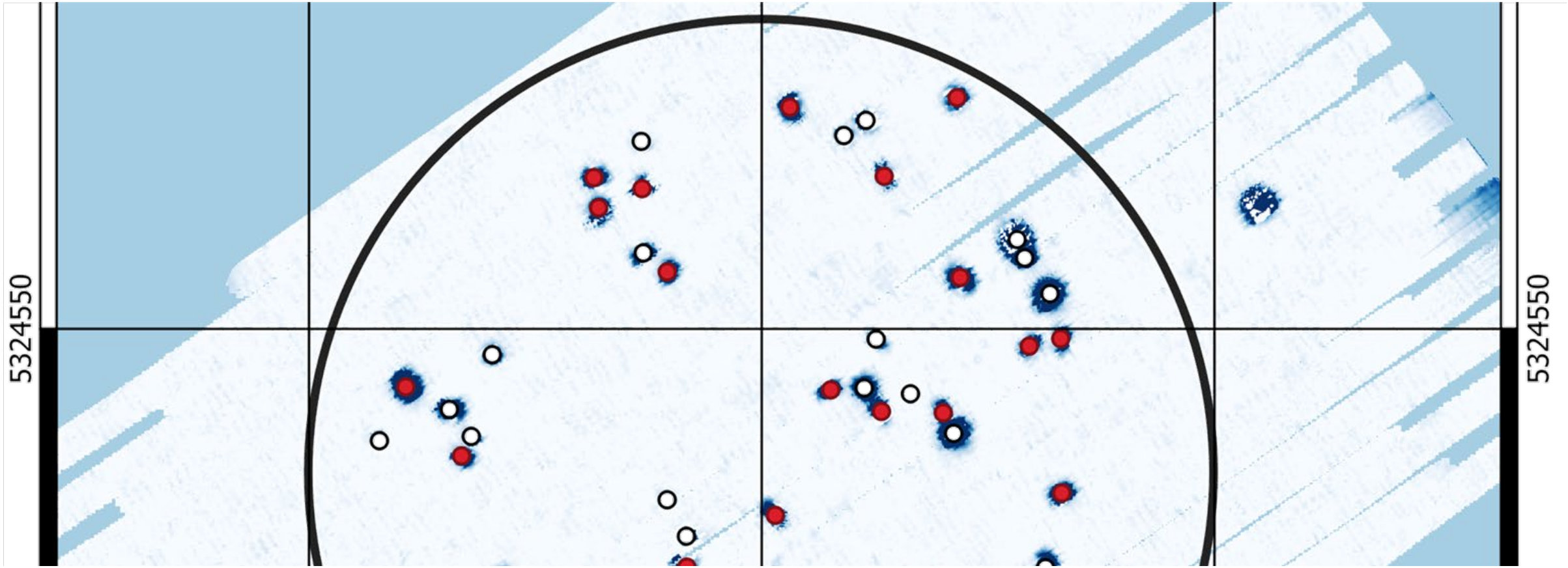

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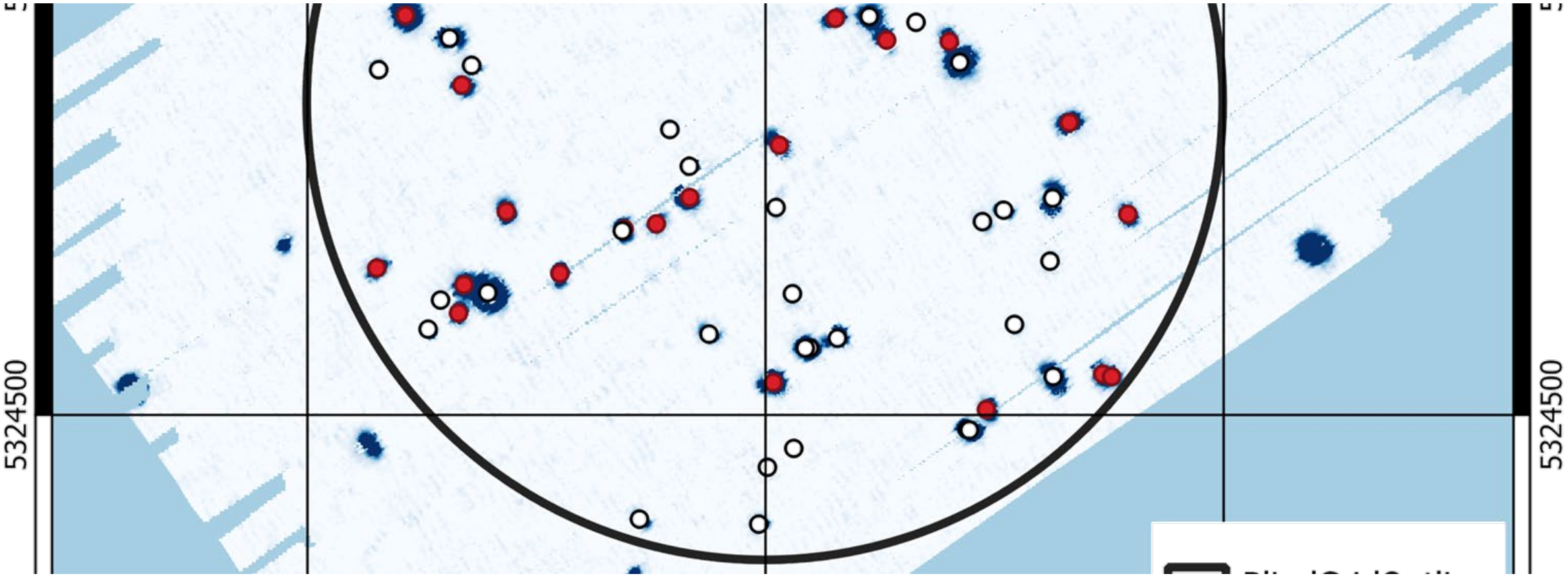
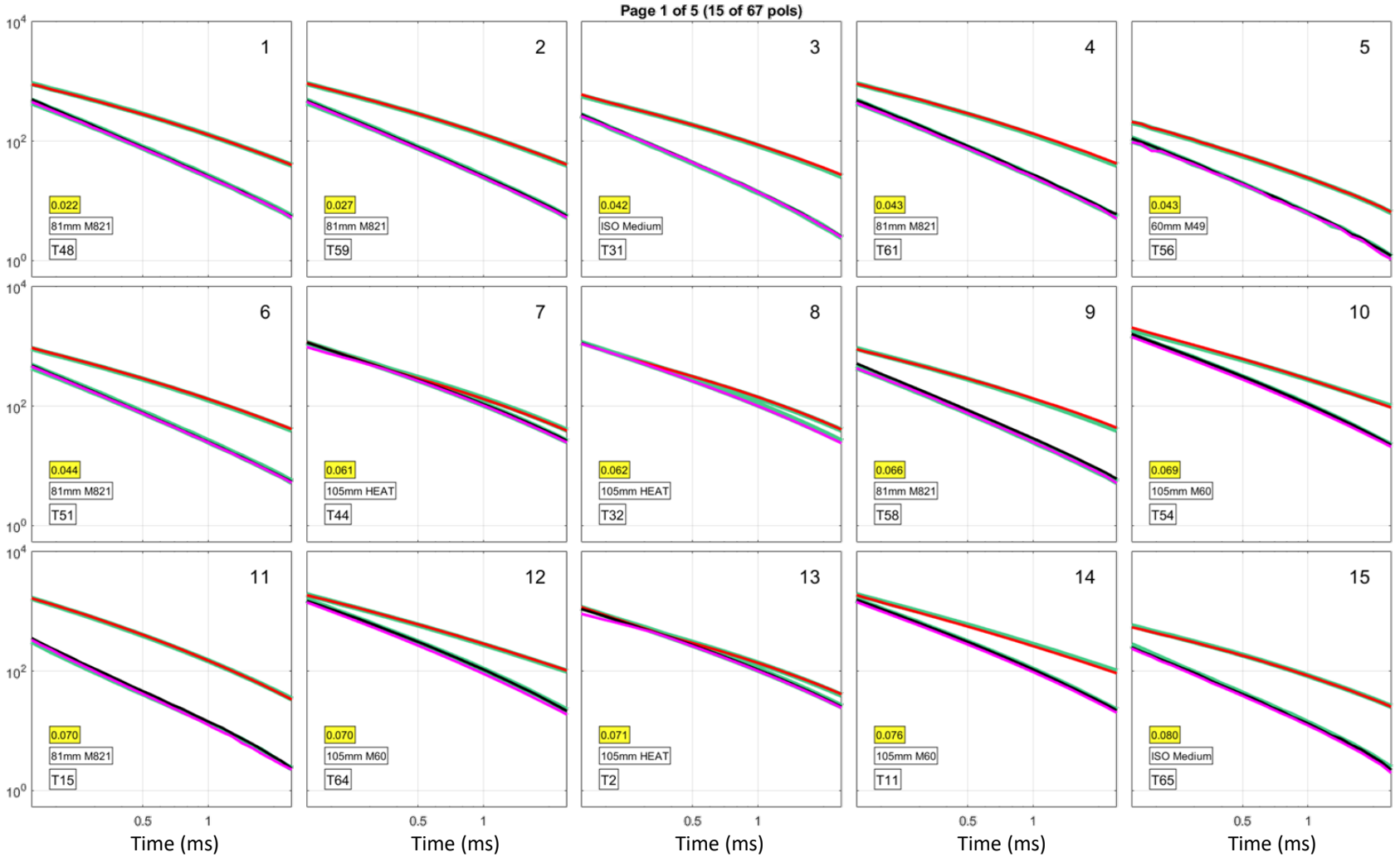


2022 Sequim Bay Blind-Grid
Low altitude data



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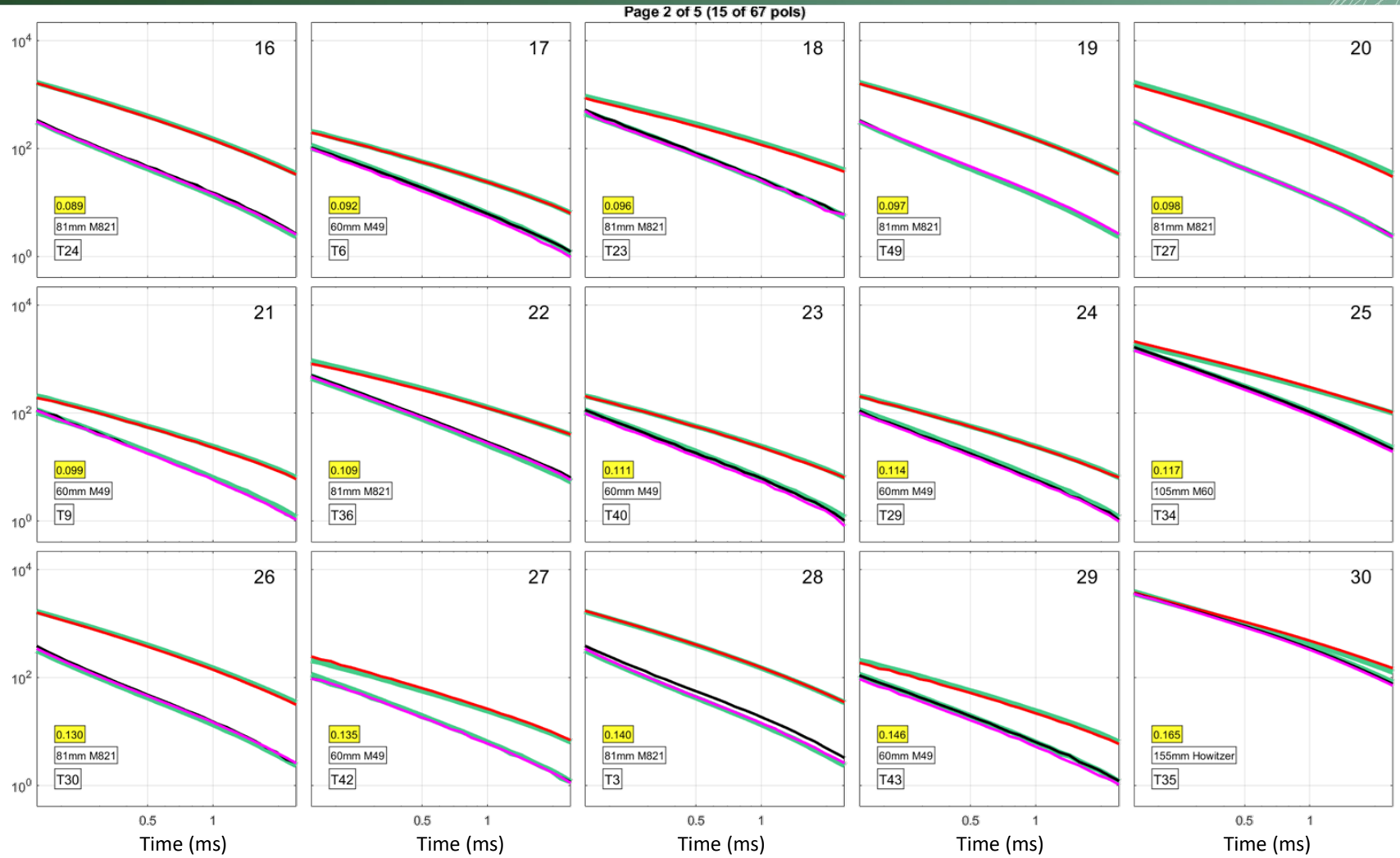
Low altitude data



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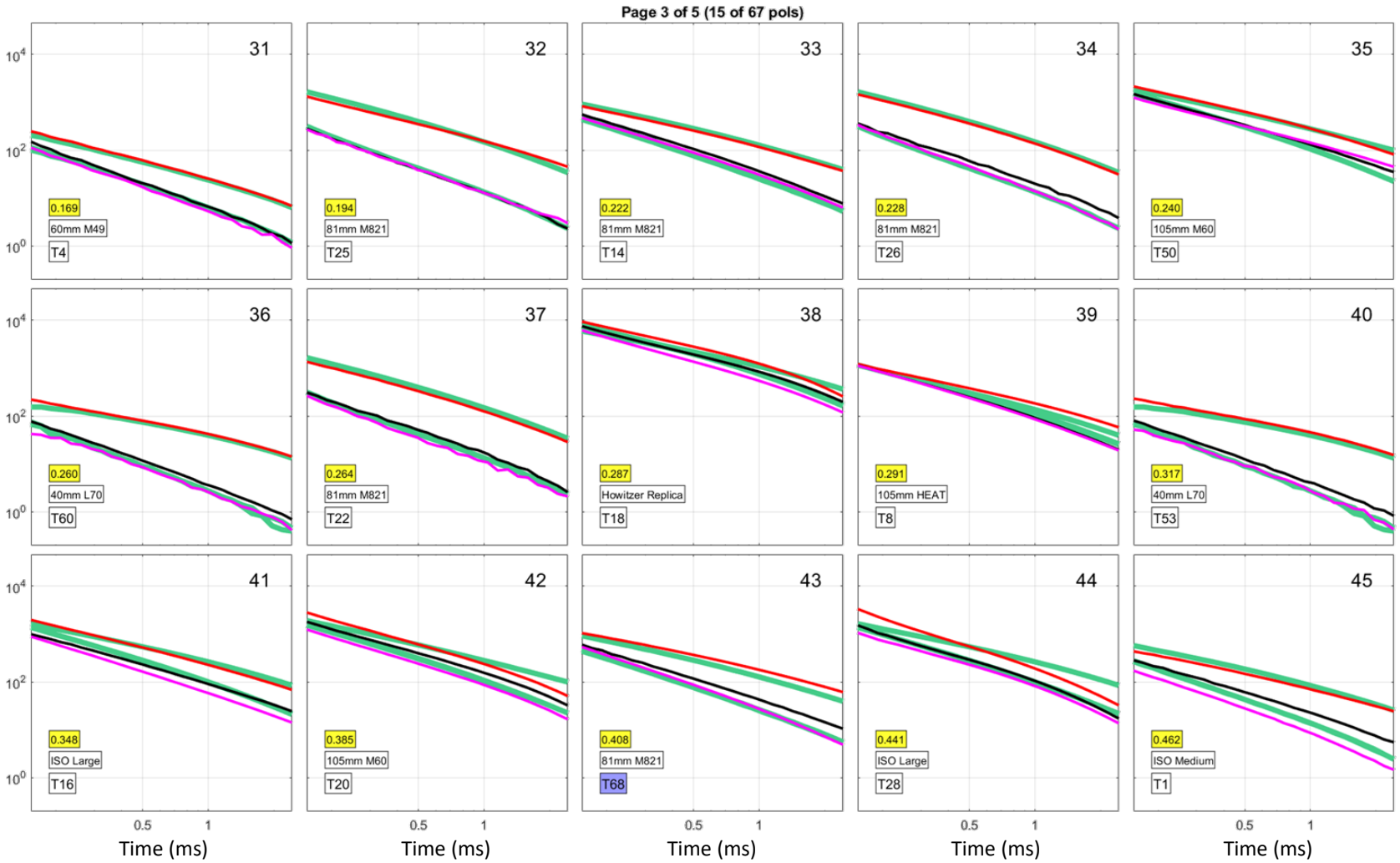
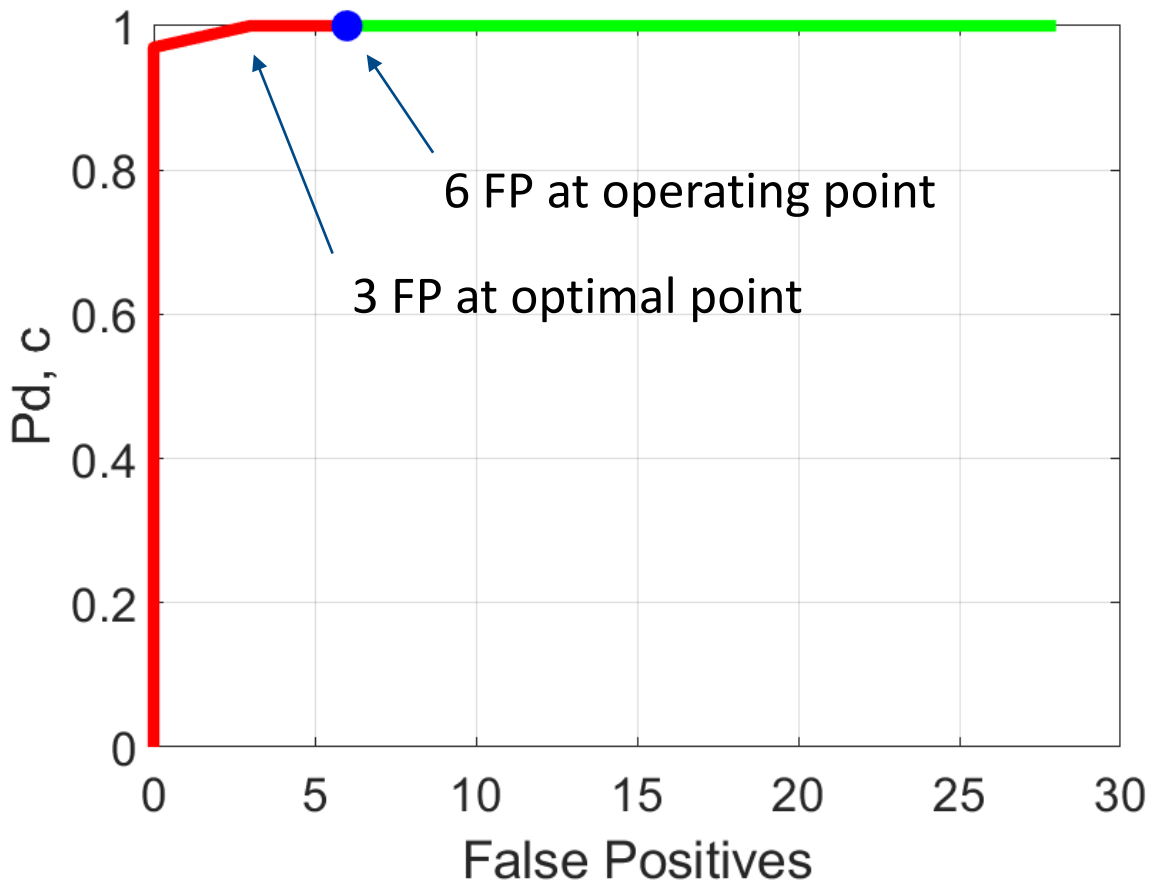
Low altitude data



Receiver Operating Characteristic Curve
Low altitude data



UltraTEMA-4: Marine AGC capable

1. An accurate physical model

- Interaction effects are only important at very early times
- Terrestrial dipole model is accurate

2. Accurate sensor positions

- USBL positioning is accurate (better than 50 cm positional uncertainty)
- IMLI method can account for positional differences between lines

3. Good background estimates

- Integral equation technique can be used to accurately model the background
- Background is slowly varying and can be effectively removed

4. High signal to noise ratio (SNR)

- UltraTEMA-4 can maintain close standoff to the sea-bottom
- Large loops and high transmitter current maximize SNR

UltraTEMA-4: Marine AGC capable

1. Platform: TEMA-4

- ✓ Close stand-off to sea-bottom
- ✓ Stable platform orientation
- ✓ Accurate positioning of platform
- ✓ Low electromagnetic noise from platform and auxiliary sensors

2. Sensor: UltraTEM-IV

- ✓ Large transmitter coils with high current
- ✓ Transmitters arranged to provide excitation in multiple directions
- ✓ Multiple 3-axis receivers

3. Software: BTField

- ✓ Avoid very early times (or include interaction effects in the model)
- ✓ Methods for removing sea-water background signal