TETRA TECH

UltraTEMA-4

Marine Classification Results from ESTCP Demonstration Project MR19-5073

Richard Funk, Principal Geophysicist

Jeff Gamey, PGp, PMP, CQA

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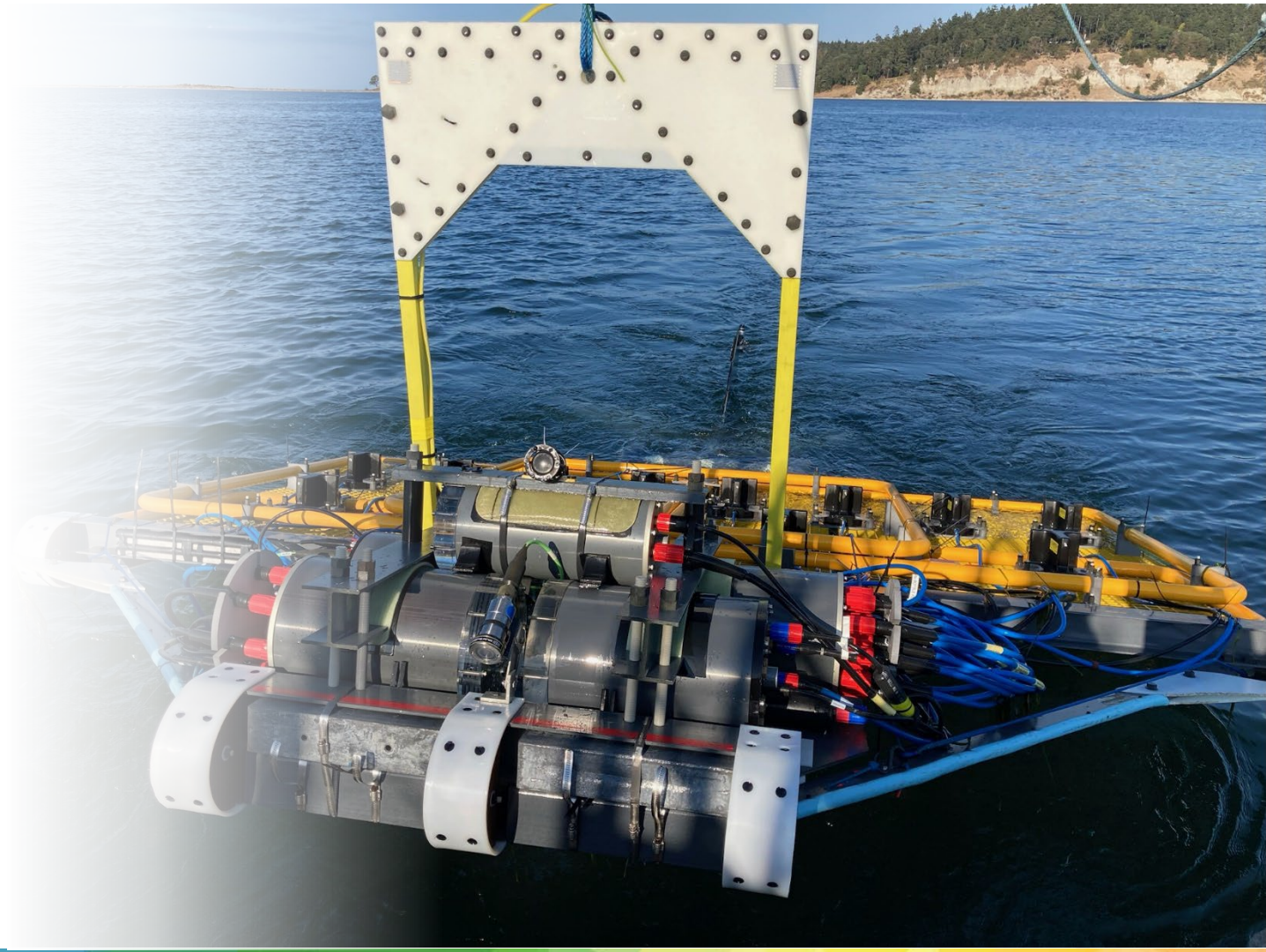
Dr. Stephen Billings

BLACK TUSK GEOPHYSICS

April 5, 2023

Agenda

- Introduction
- Overview of UltraTEMA-4
  - Design
  - Operations
- Sequim Bay 2022 Results
  - Calibration Line
  - Blind Grid 2022 – preliminary results
- Questions



Refined Over Years - UltraTEMA4

- Started underwater EM survey in 2009 with the TEMA-MK1
- 4th generation of Towed EM Array (TEMA)
- 4th generation of UltraTEM
- Integration of Gap Explosive Ordnance Detection's and Black Tusk Geophysics' existing UltraTEM® package and associated software into Tetra Tech's towed electromagnetic array platform

UltraTEMA-4 System Components

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1. TEMA tow-platform (Tetra-Tech)

- "Next generation" towfish
- Tested and proven remotely operated marine towed-array system
- **Advanced subsea positioning**
- 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

Black Tusk GEOPHYSICS | GapEOD Explosive Ordnance Detection | ESTCP

UltraTEMA-4 Marine System

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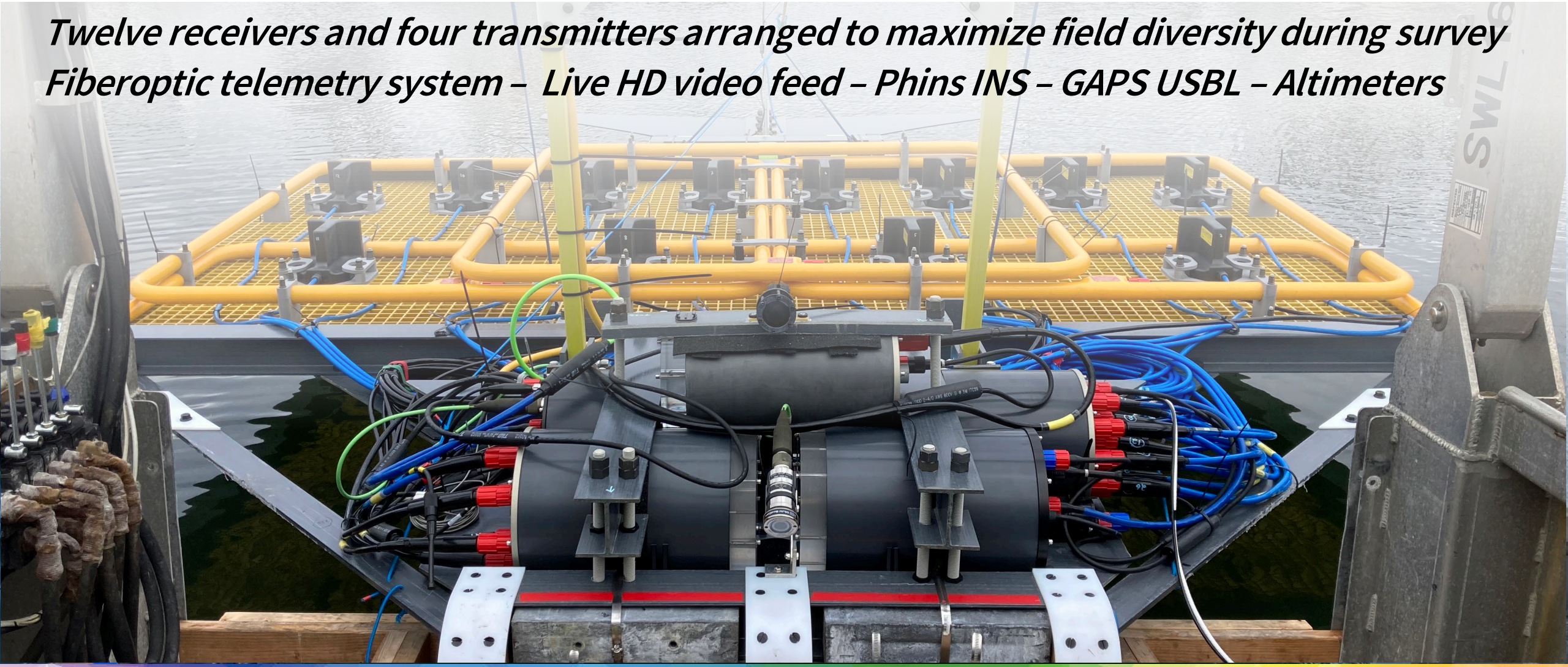
Twelve receivers and four transmitters arranged to maximize field diversity during survey

Fiberoptic telemetry system – Live HD video feed – Phins INS – GAPS USBL – Altimeters



Black Tusk GEOPHYSICS | GapEOD Explosive Ordnance Detection | ESTCP

2021 & 2022 - Sequim Bay, Washington

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- ESTCP Test Bed - Pacific Northwest National Laboratory (PNNL)
  - PNNL installed & administered
- Sequim Bay 2021
  - Three days of collection
  - Calibration lanes at multiple flying heights & different transmitter modes (fast & medium transmitter frequency)
  - “Blind” grid partial survey
- Sequim Bay 2022 –
  - Three Blind Grid Surveys
  - 90 Hz low altitude
  - 90 Hz high altitude
  - 25 Hz low altitude

2022 What a Difference from 2021

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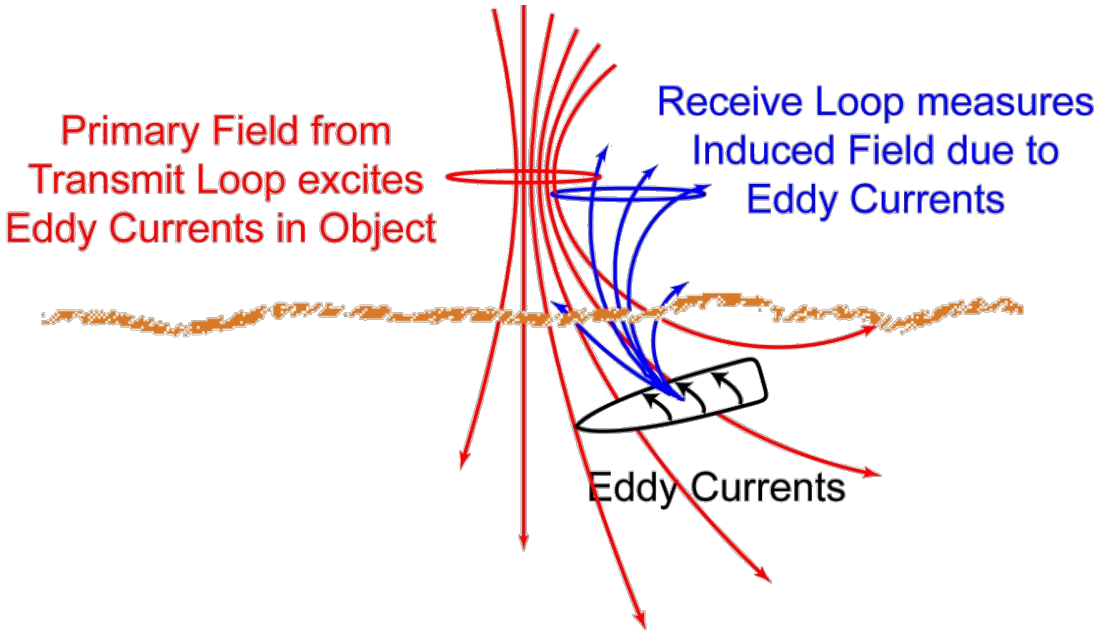
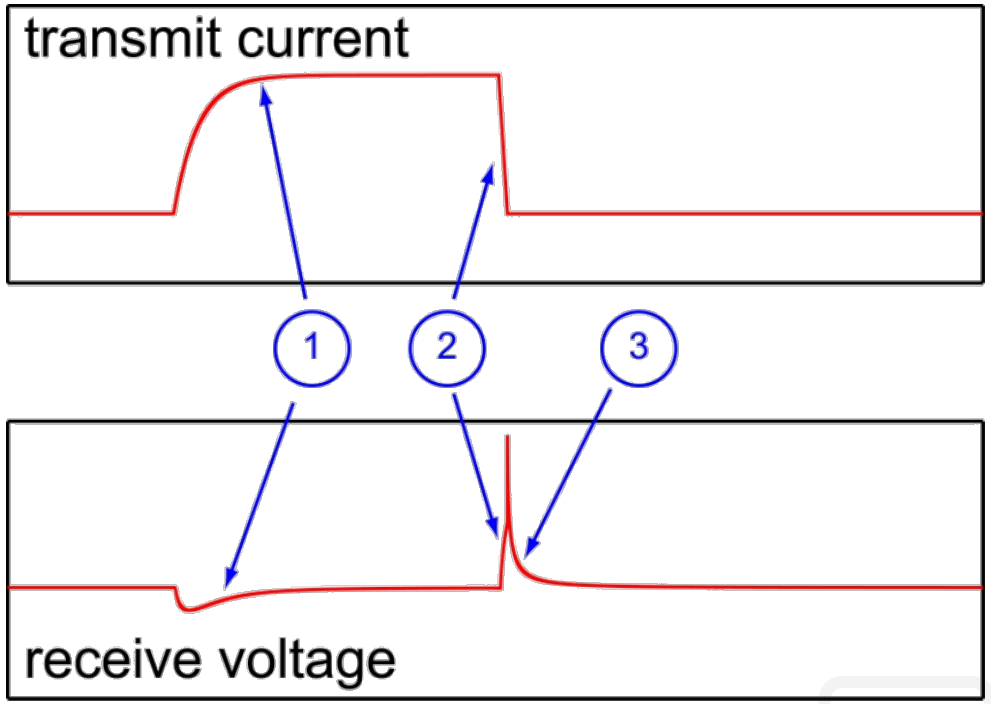
- New tow cable – finally a solution
  - They also make torpedo umbilicals
- New power bottle no leaks
  - And a spare just in case
- Transport of UltraTEMA-4
  - No more wide load
- Crab season not open
  - No snagged crab pots
- One loose wire in the Tx bottle
  - It did travel from Australia

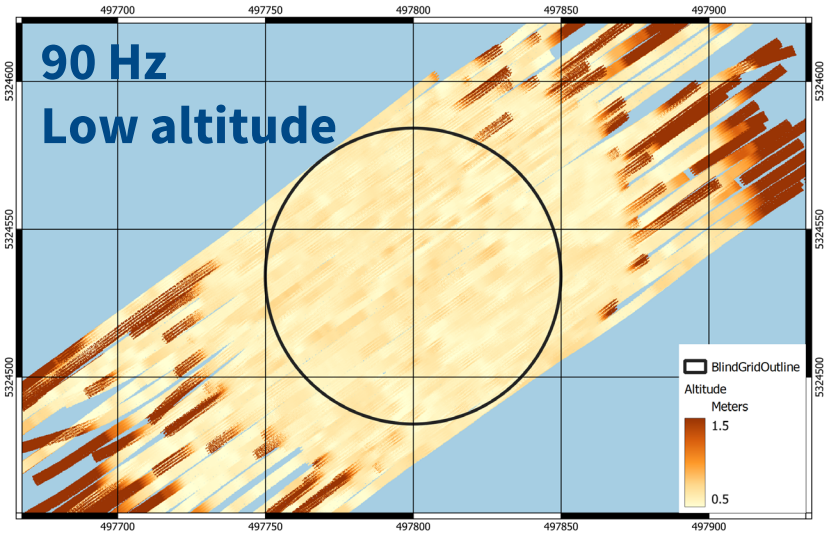
TEM Measurement

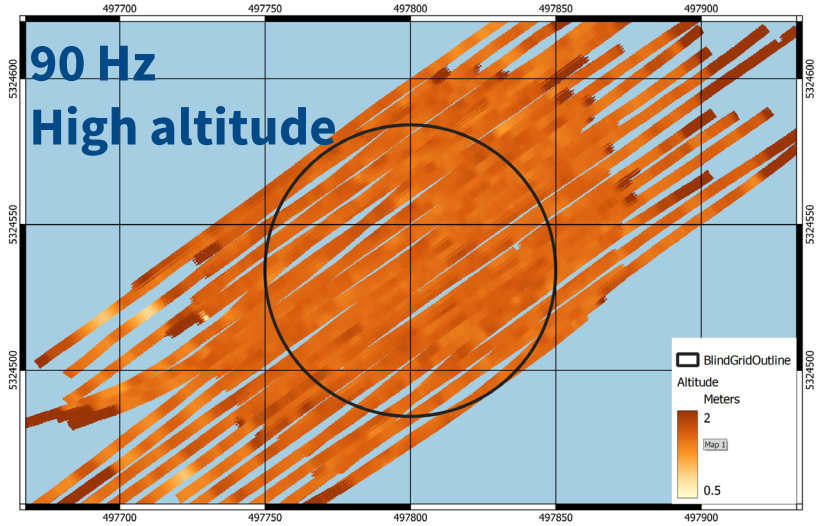


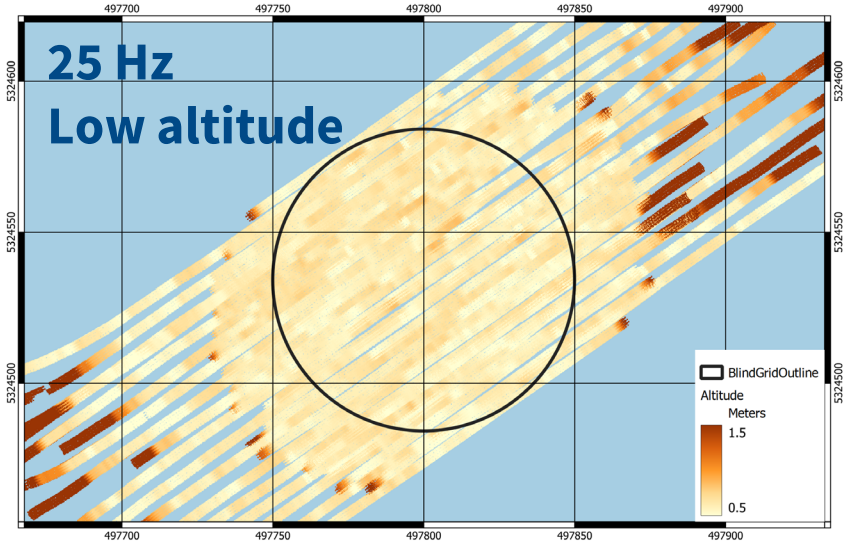


1. The primary field magnetizes the buried object
2. Abrupt change in the primary field excites eddy currents in the object.
3. Eddy currents diffuse throughout the object and decay (basic EM response which applies to all metal objects)

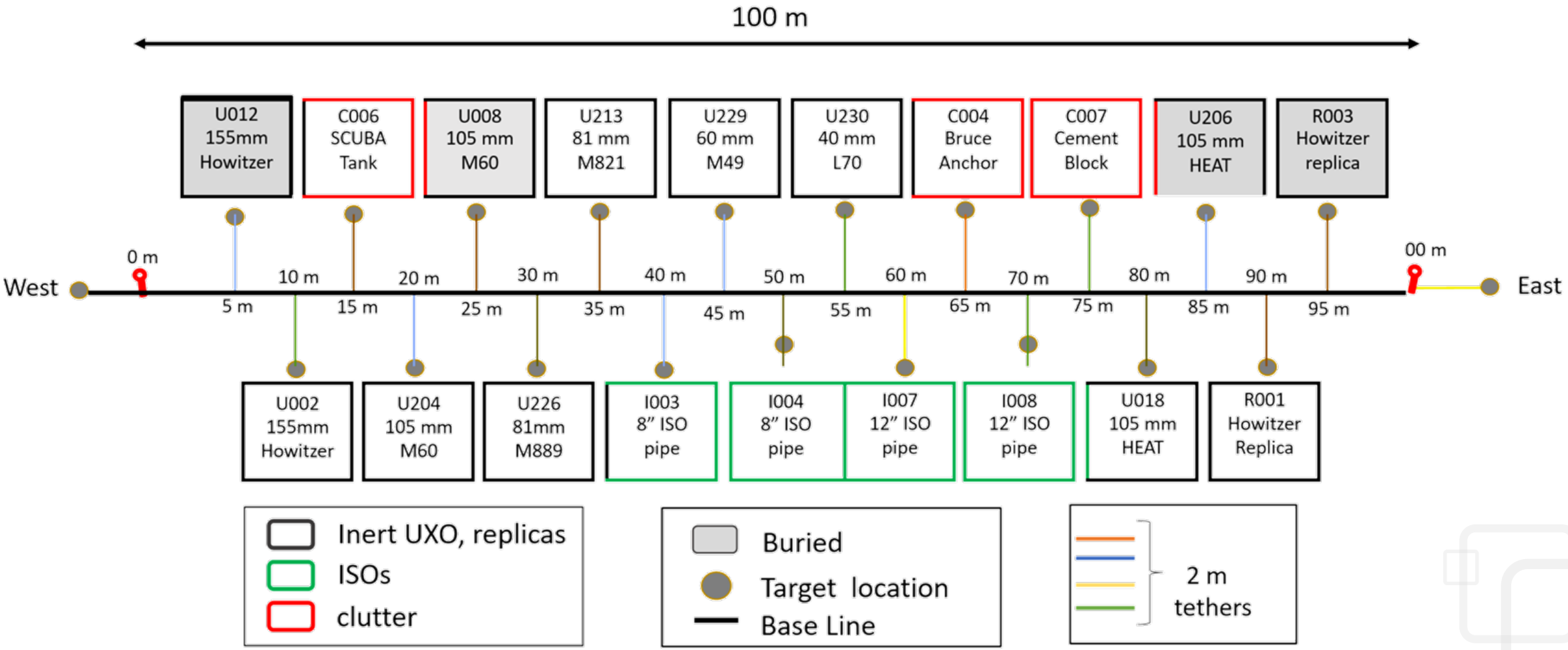
Sequim Bay 2022: Three Blind Grid Surveys



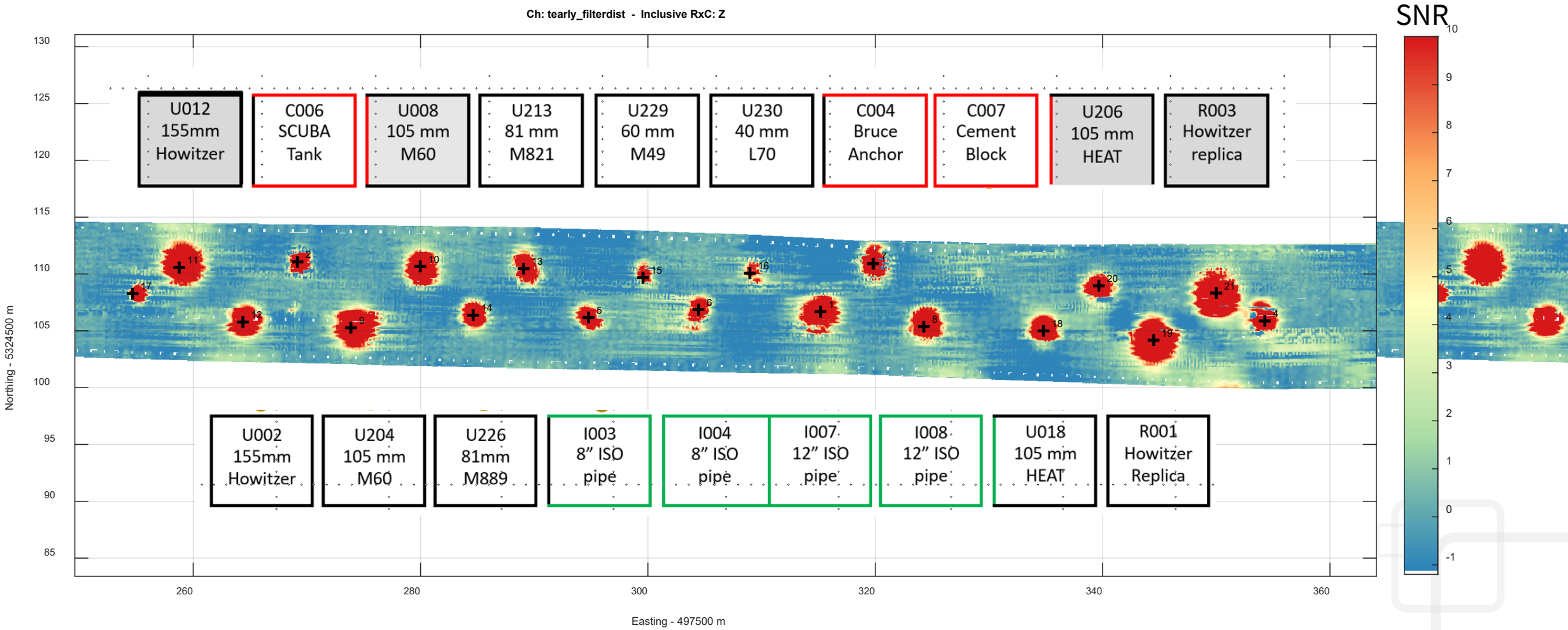




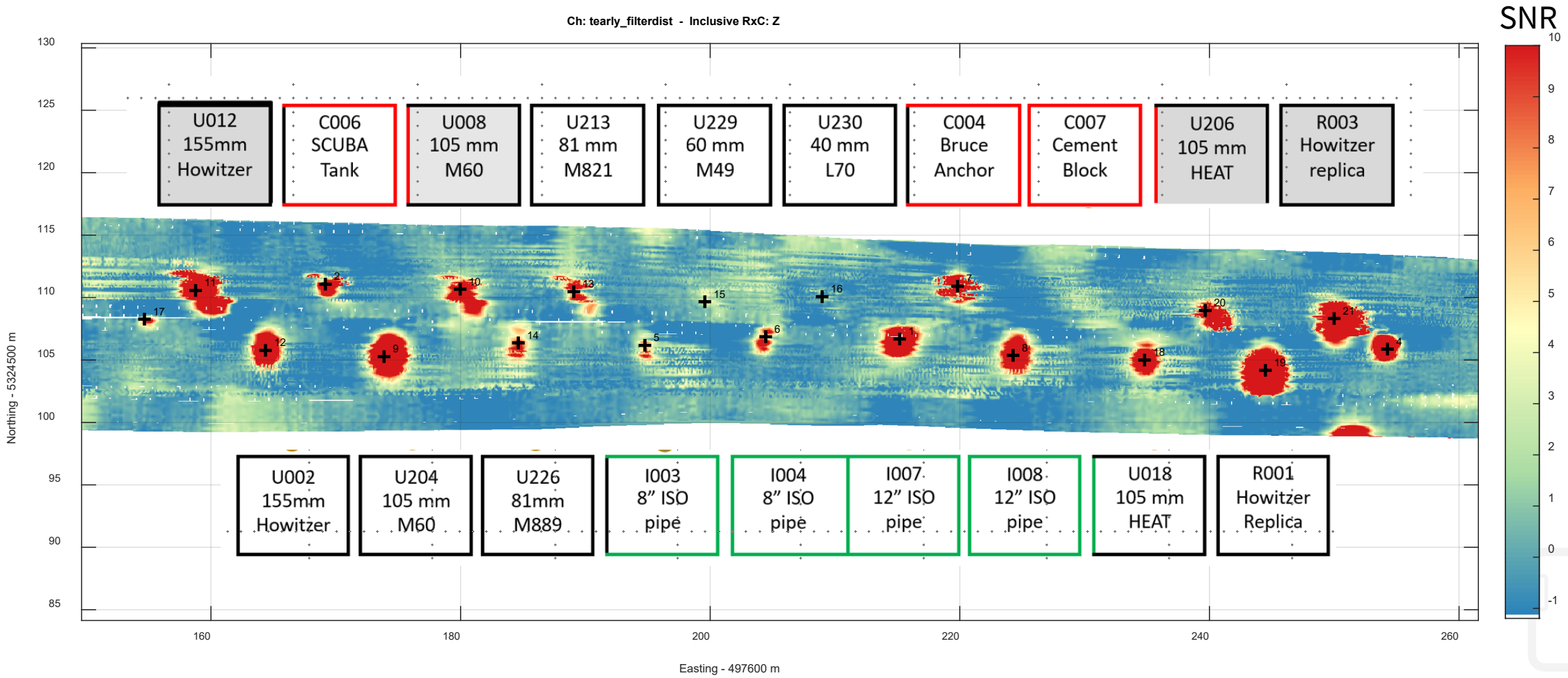
Sequim Bay 2022 Calibration Lane



Sequim Bay 2022 Calibration Lane: 0.5 to 0.75m Altitude

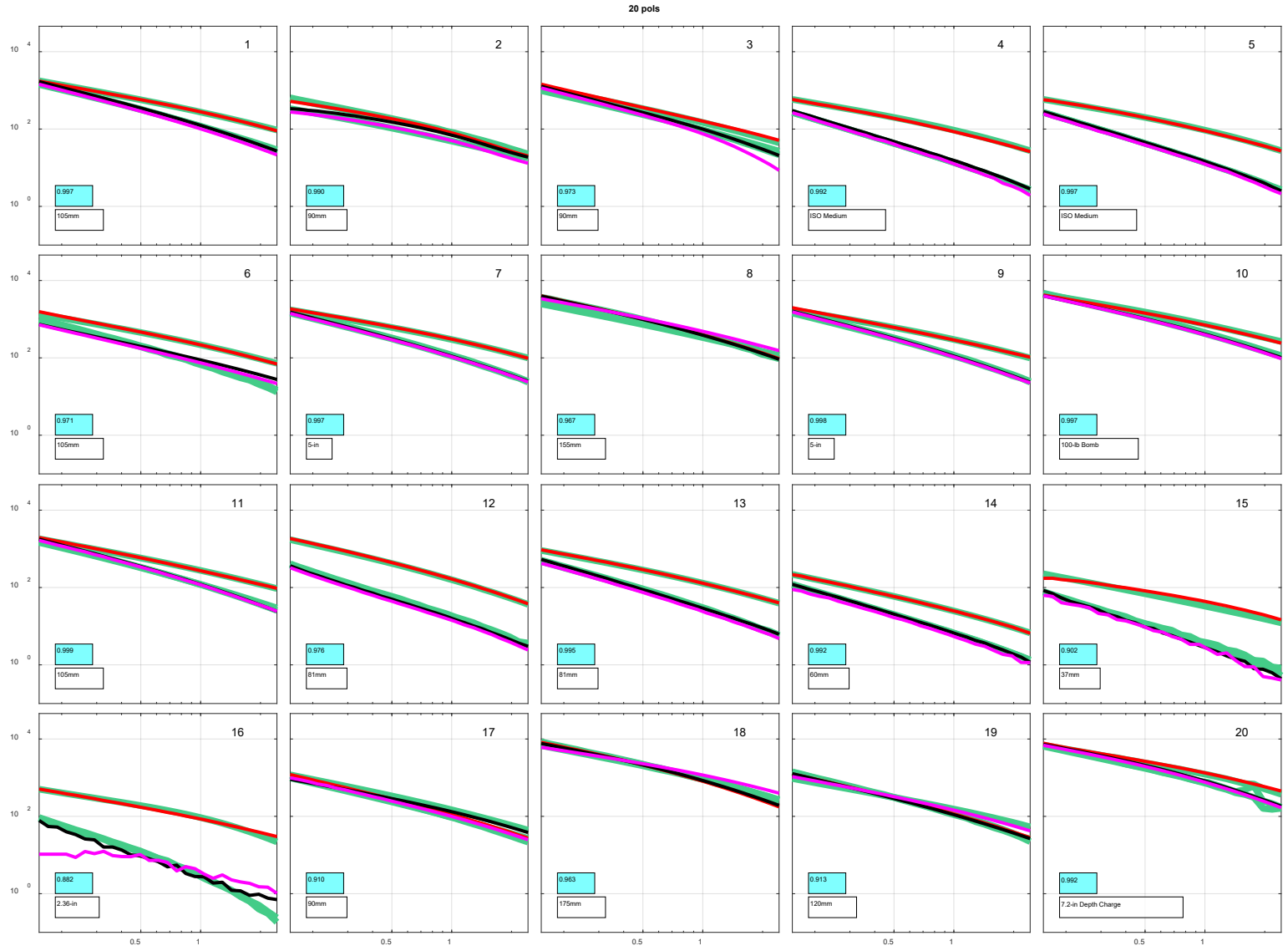


Sequim Bay 2022 Calibration Lane: 1 to 1.25m Altitude



Calibration Lane: 0.5 to 0.75 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



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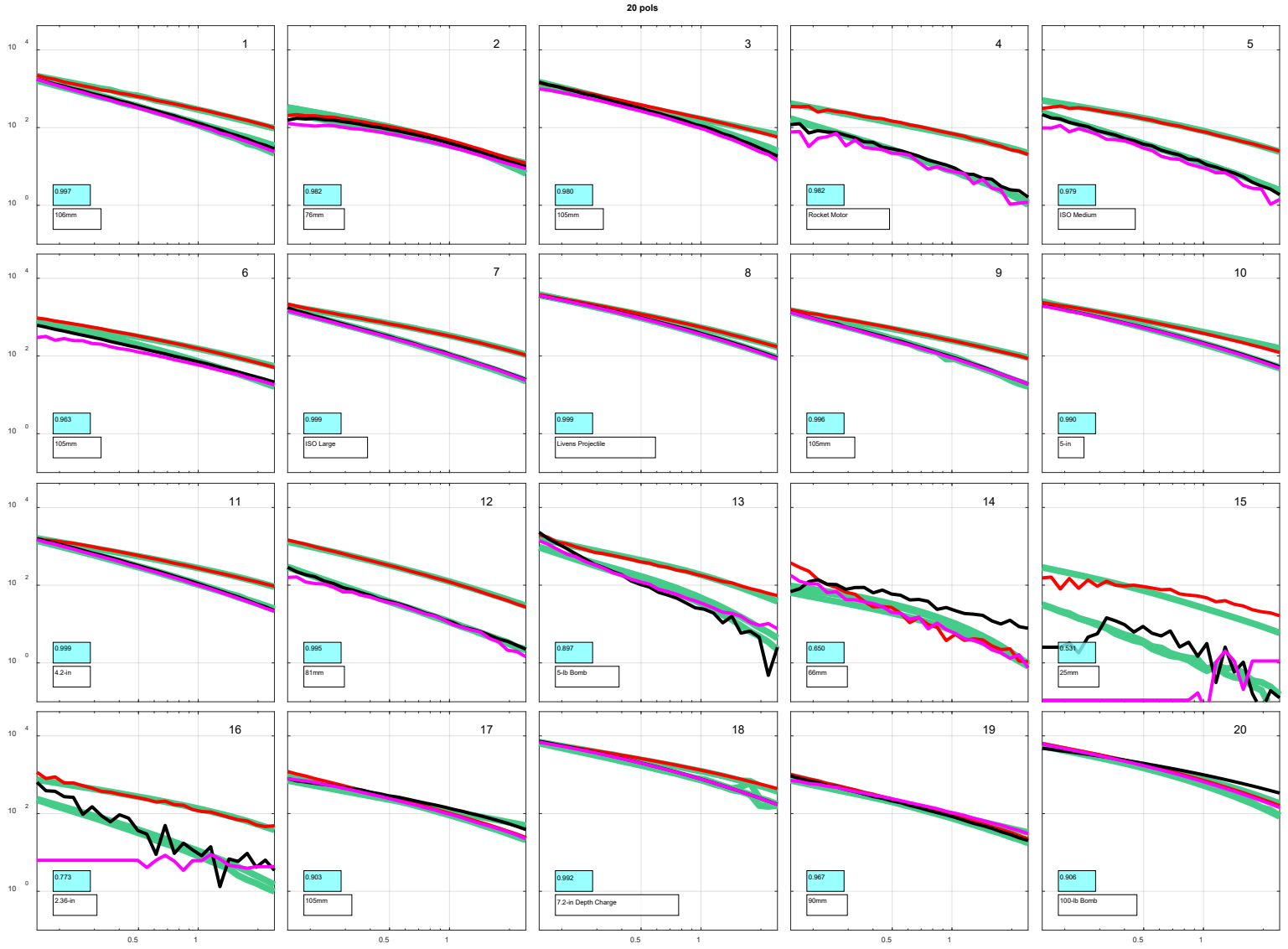
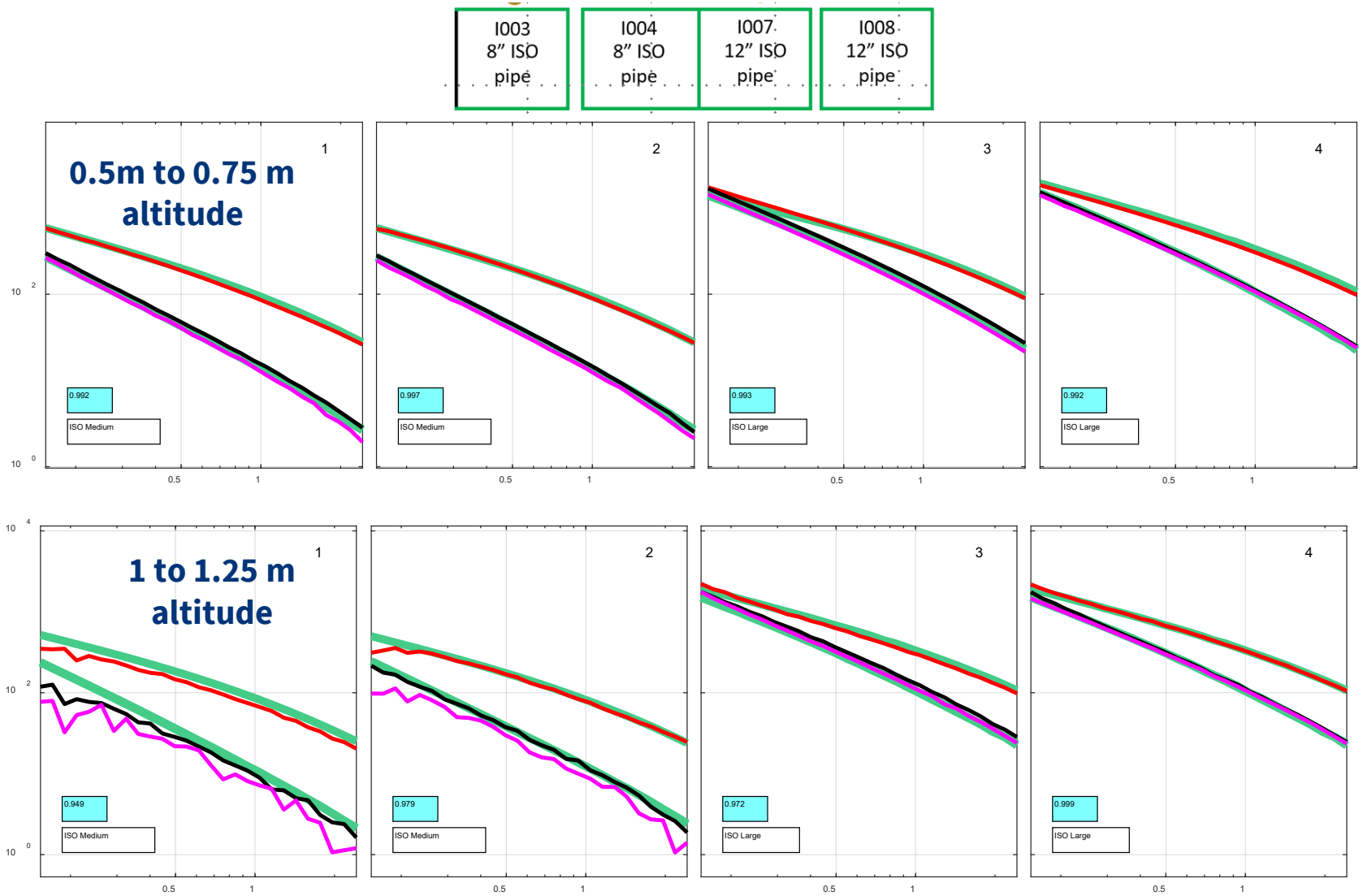


ISO Item Comparison



Large to Small Item Comparison

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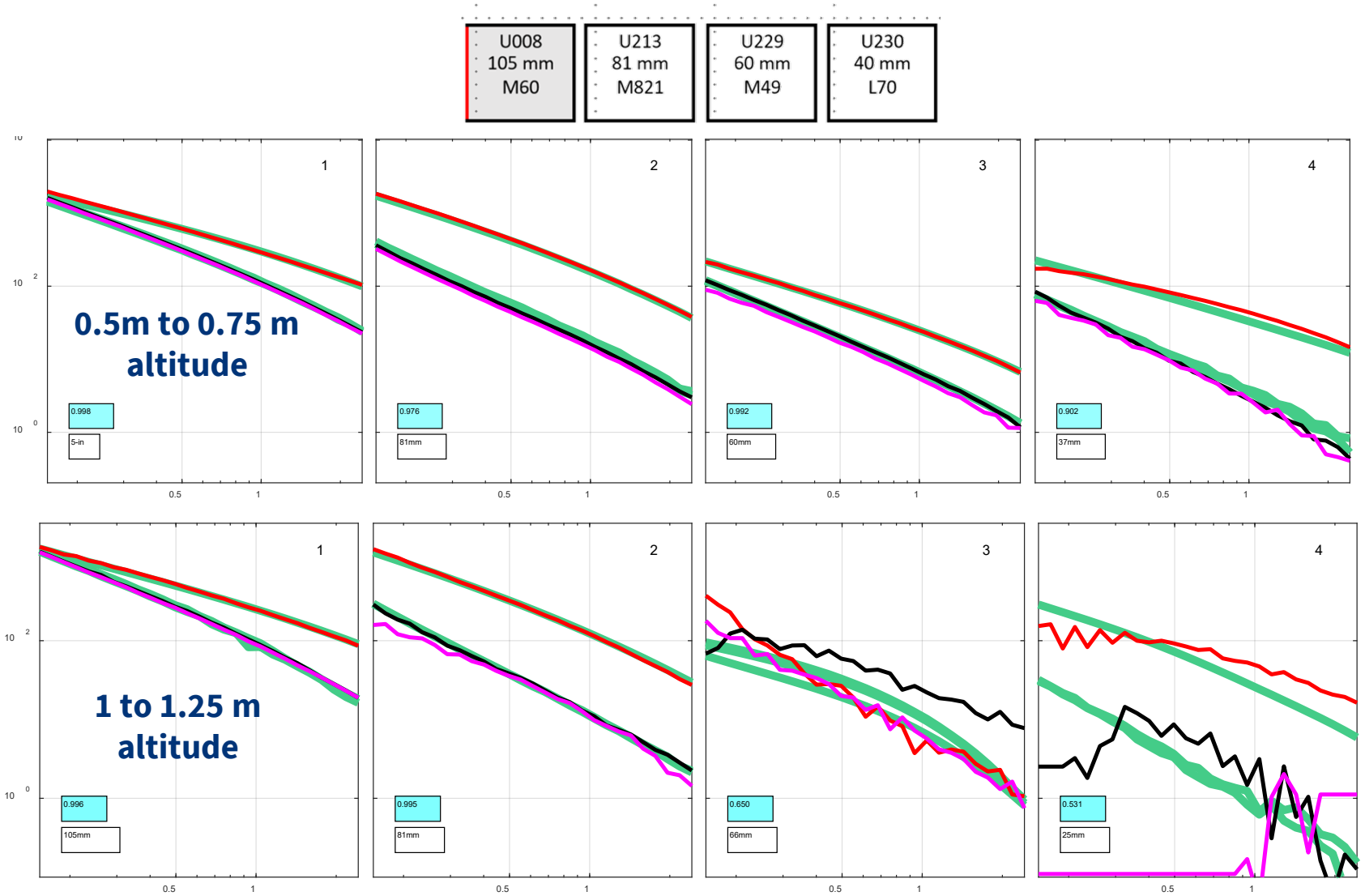
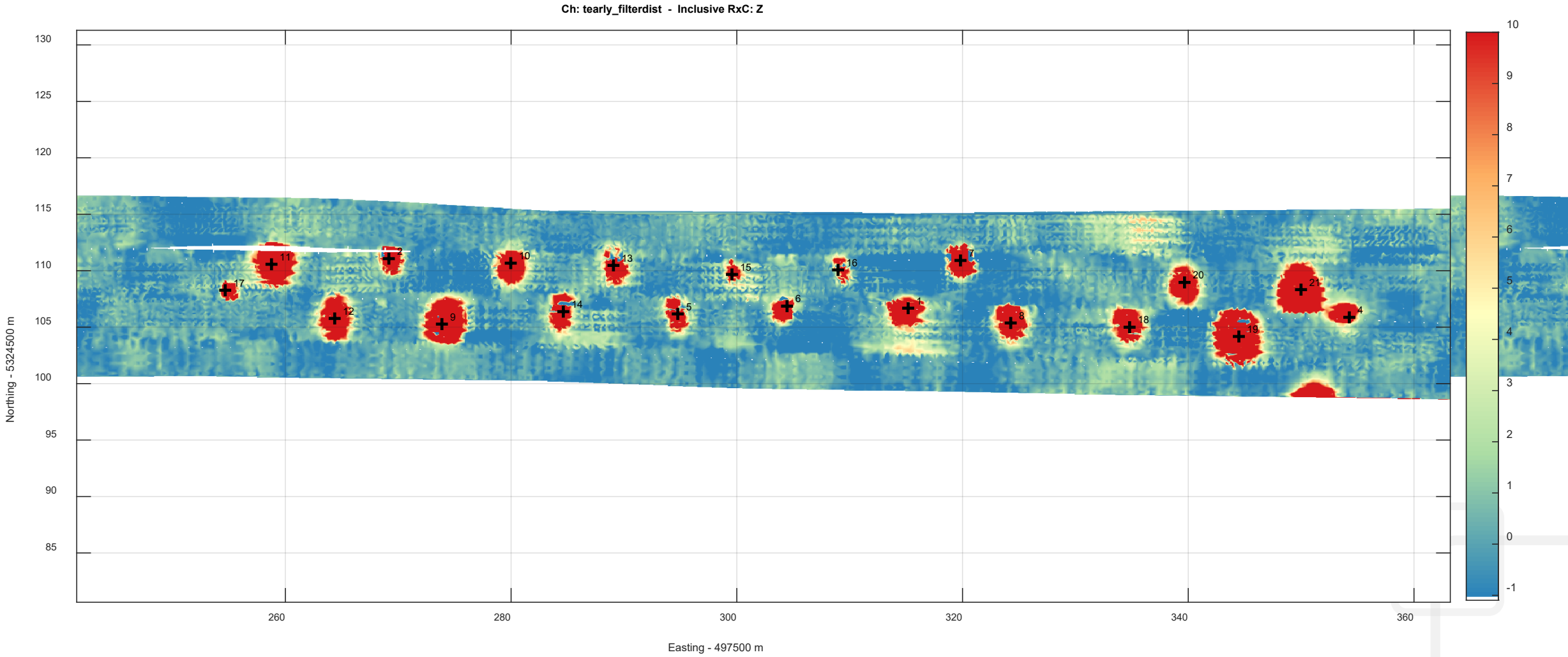
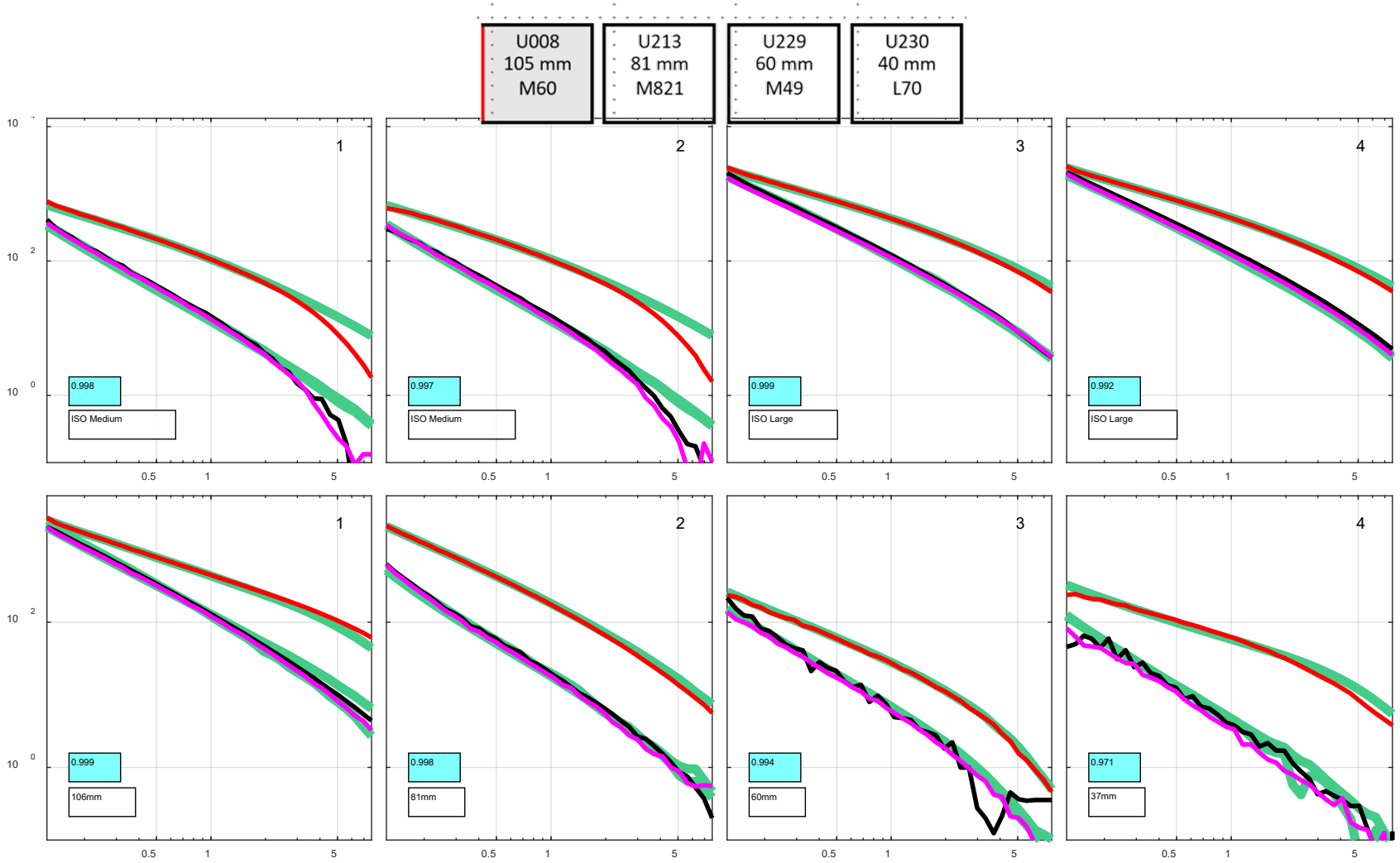


Slower Frequency: 1 to 1.25 m Altitude



Longer Time-Window



Independent Model Location Inversion (IMLI)

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- Break the full dataset into subregions & allow the position & orientation of the item in each subregion to differ
- The principal axis polarizabilities $\boldsymbol{\beta}(t)$ are shared across the regions

Solve standard problem first

Minimize the function

$$\left\| \boldsymbol{d}_{RT}(\boldsymbol{x}, t) - \boldsymbol{s}_{RT}\left(\boldsymbol{x}, \boldsymbol{\beta}(t), \boldsymbol{\theta}, \boldsymbol{x}_{\boldsymbol{\beta}}\right) \right\|$$

by solving for

$$\boldsymbol{\beta}(t), \boldsymbol{\theta}, \boldsymbol{x}_{\boldsymbol{\beta}}$$

IMLI method

Break region into N subregions: $\boldsymbol{x}_n, \boldsymbol{d}_n$

Minimize the function

$$\sum_n \left\| \boldsymbol{d}_n(\boldsymbol{x}_n, t) - \boldsymbol{s}_{RT}\left(\boldsymbol{x}_n, \boldsymbol{\beta}(t), \boldsymbol{\theta}_{\boldsymbol{n}}, \boldsymbol{x}_{\boldsymbol{\beta n}}\right) \right\|$$

by solving for

$$\boldsymbol{\beta}(t), \boldsymbol{\theta}_{\boldsymbol{n}}, \boldsymbol{x}_{\boldsymbol{\beta n}}$$

Positional accuracy RMS Error ~ 20 cm (8”)

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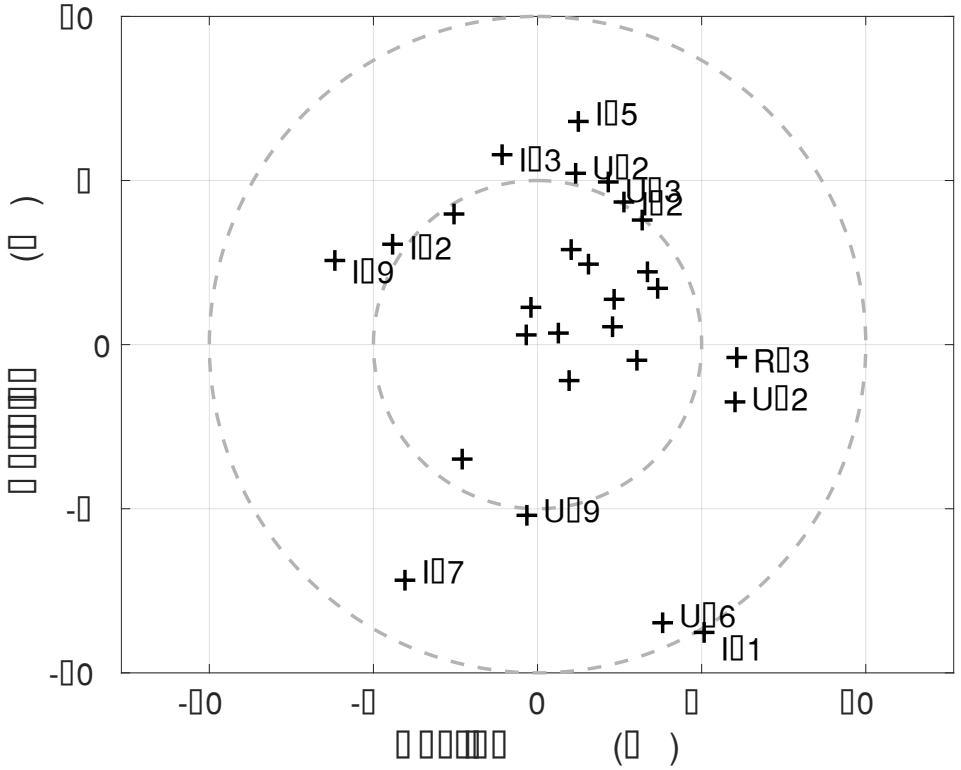
Compared to ground-truth

All items



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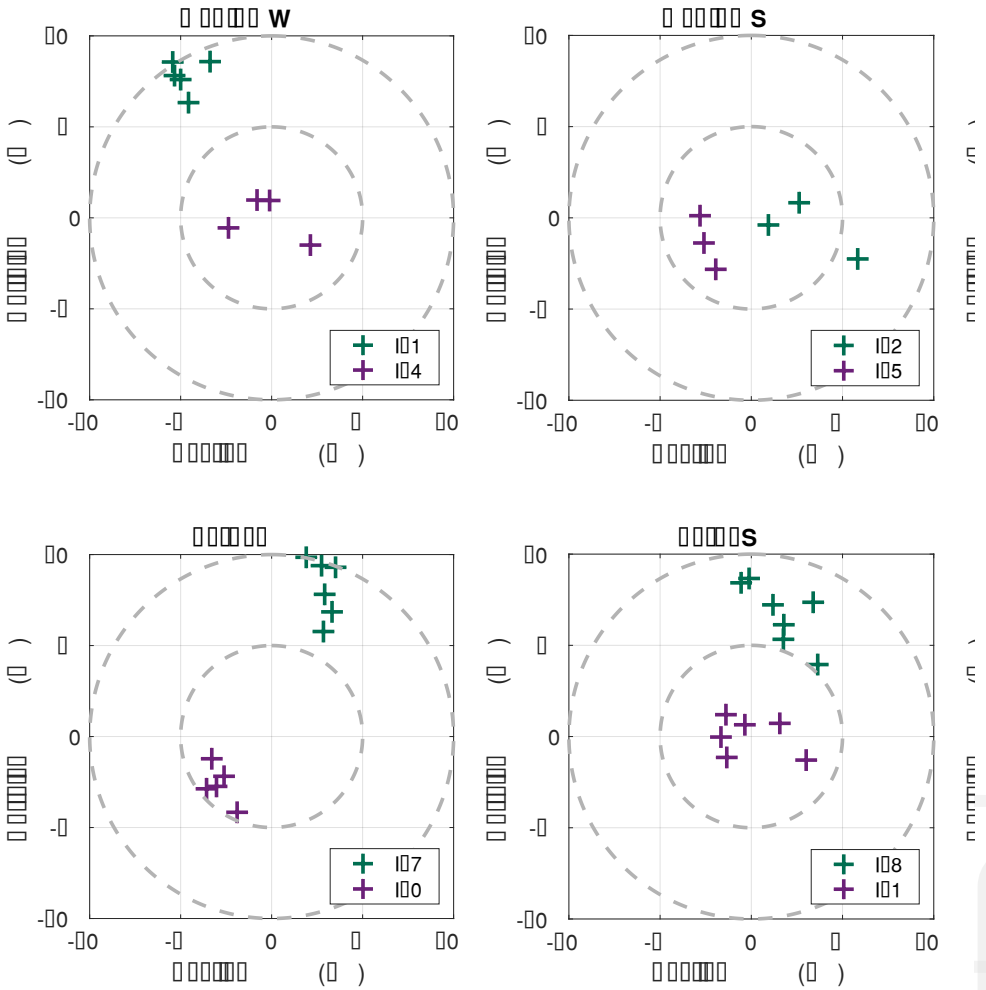
Relative error on 8 items



Independent Model Location Inversion (IMLI)

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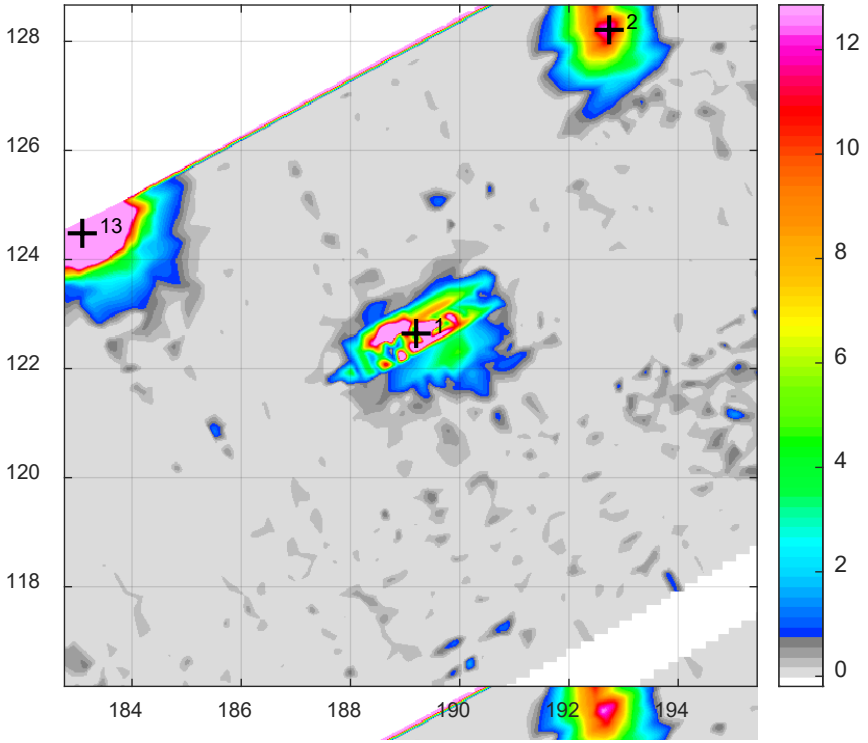
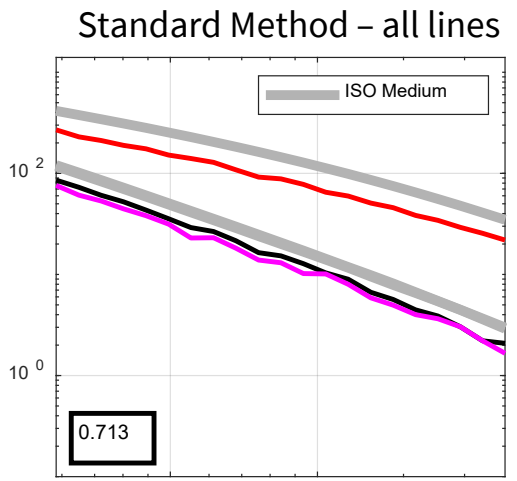
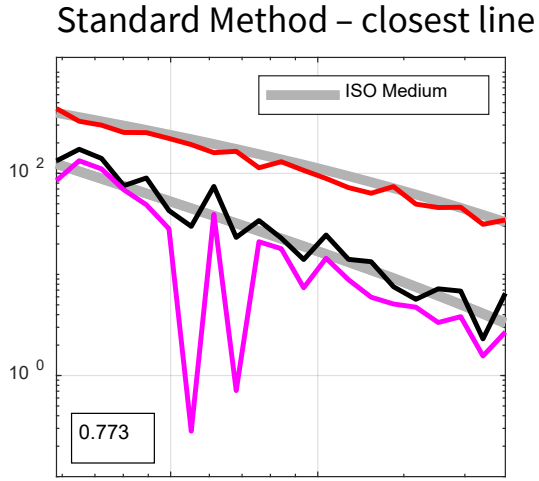
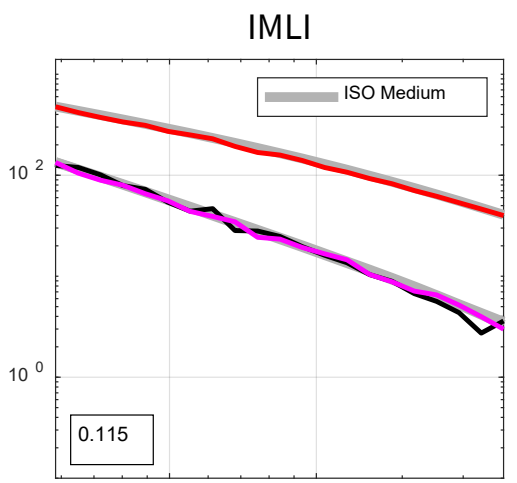
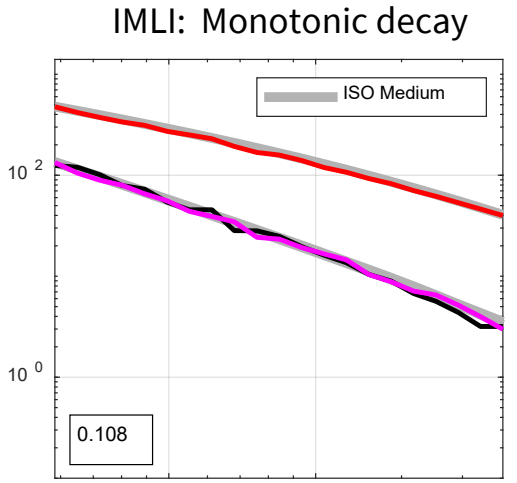
- Data fit for standard is 0.86
- Data fit for IMIL is 0.95











2022 Sequim Bay Blind-Grid Preliminary Results

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- TOI ranged in size from 40 mm to 155 mm.
- Results have only been scored for the low altitude; 90Hz dig list.
- At the demonstrator stop dig point, **UltraTEMA successfully detected and classified all TOI** with 5 false alarms.
- Use of the optimum stop dig point would have resulted in only 2 false alarms at the Pd,c = 100% point on the ROC curve.

- Not all 2022 Blind-Grid data have been submitted to ESTCP therefore only these preliminary results are available for the 2022 UltraTEMA survey

UltraTEMA-4: Marine AGC Capable

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Sequim Bay surveys demonstrated the AGC capabilities of the UltraTEMA-4

1. An accurate physical model

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

2. Accurate sensor positions

- INS with 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

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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

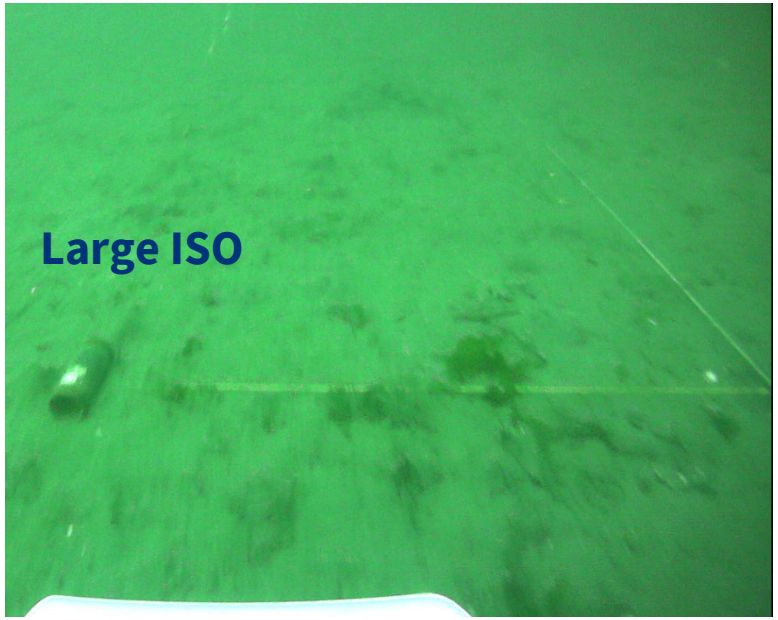
- ✓ Large transmitter coils with high current
- ✓ Transmitters arranged to provide excitation in multiple directions
- ✓ Multiple 3-axis receivers

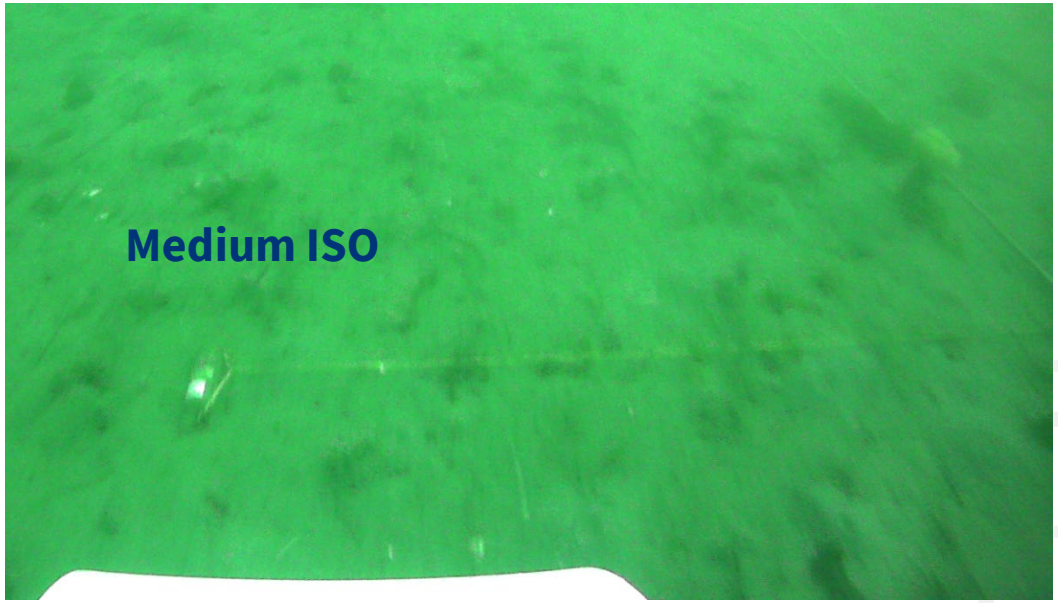
3. Software: BTField

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

Realtime Operations

- Navigation screen above
- Video frames from real-time HD feed from system (~20-25 meters deep)





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Questions?

Contact: richard.funk@tetratech.com

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TETRA TECH SNAPSHOT

WORKS IN
100+
COUNTRIES

7
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Publicly traded on NASDAQ as

TTEK

$4.5 billion
ANNUAL REVENUE

WORKS ON
100,000
PROJECTS
ANNUALLY

550 OFFICES WORLDWIDE

ENR RANKINGS

#1	Water
#1	Environmental Management
#1	Water Treatment/Desalination
#1	Hydro Plants

22,000 CLIENTS

27,000 EMPLOYEES

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With 550 offices worldwide, we can quickly respond to our clients' needs.