

# High Spatiotemporal Observations of Temperature at the Main Endeavour Field using Fiber Optic Distributed Temperature Sensing

Endeavour Workshop 2024

November 11<sup>th</sup>, 2024

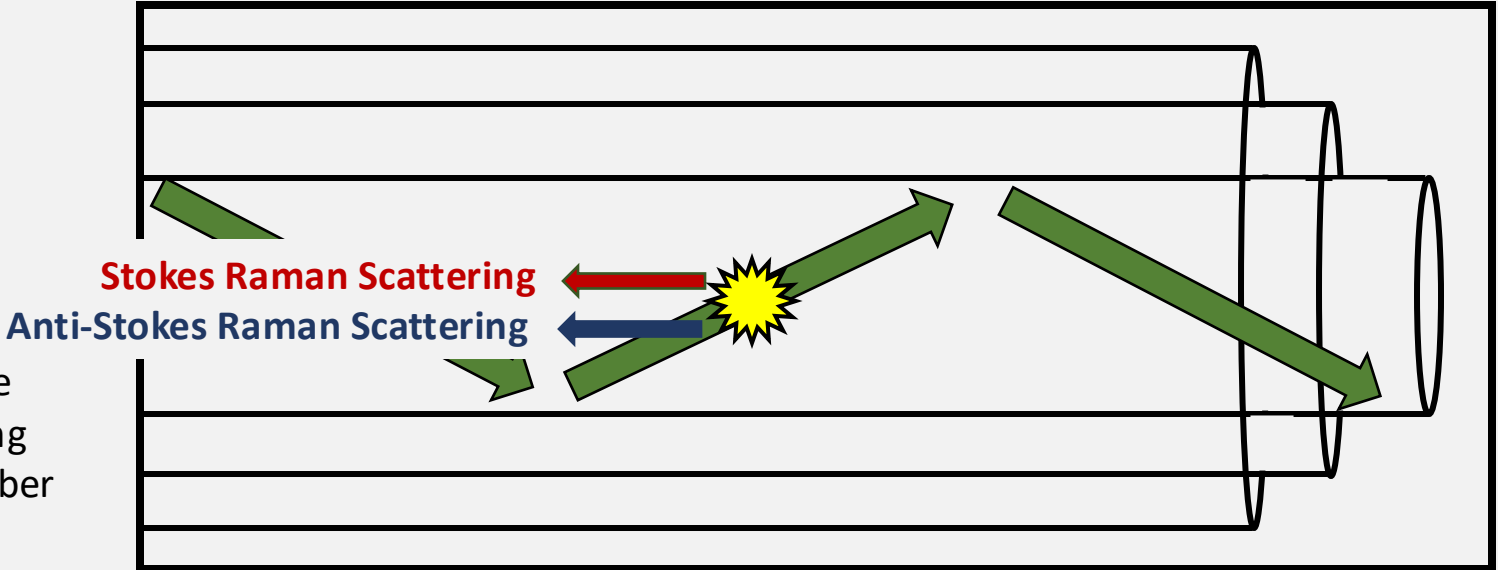
**Presented by:** Johann Becker

**Co-Authored by:** Roxanne Beinart<sup>2</sup>, Adam Soule<sup>2</sup>, Pete Girguis<sup>3</sup>, Brennan T. Phillips<sup>1,2</sup>

# Distributed Temperature Sensors (DTS) Measure Temperature Synoptically over an Optical Fiber



Laser Pulse Propagating through Fiber

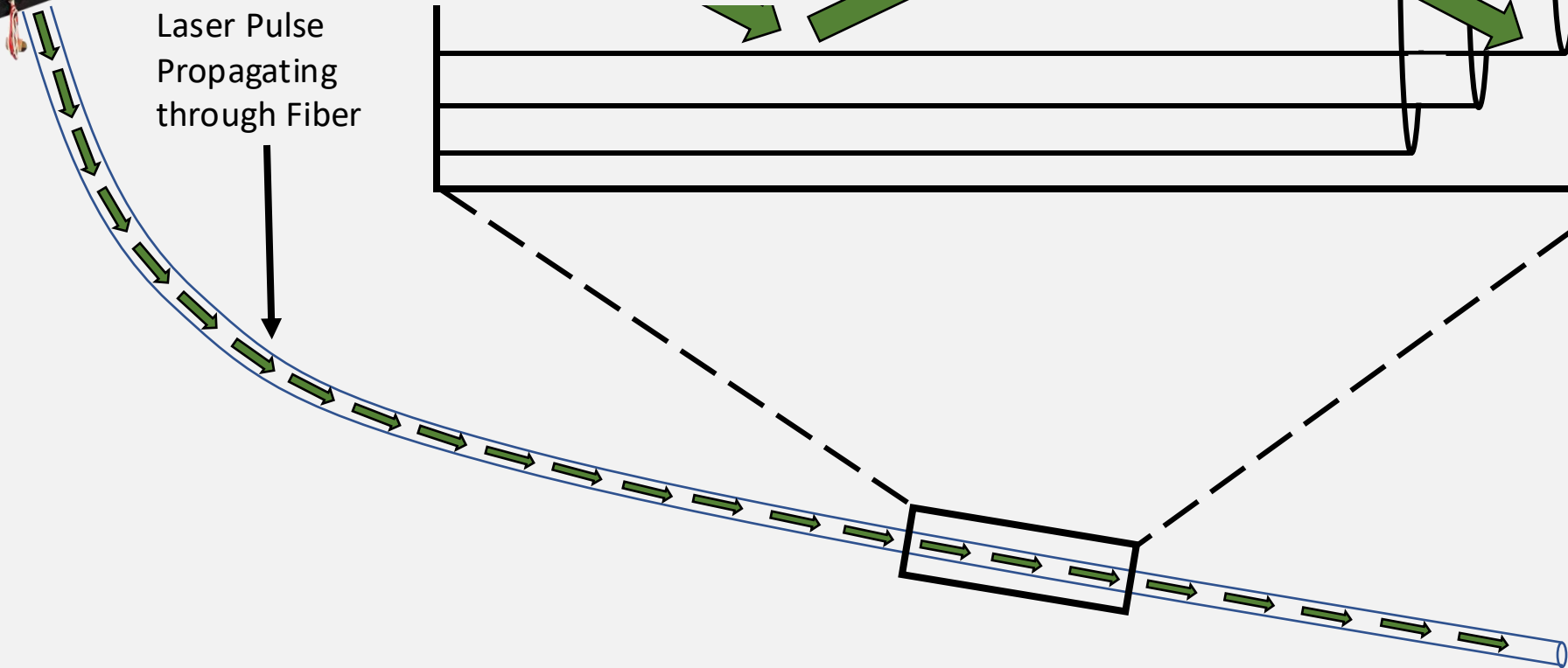


Multimode Fiber:

250  $\mu\text{m}$  Coating

125  $\mu\text{m}$  Cladding

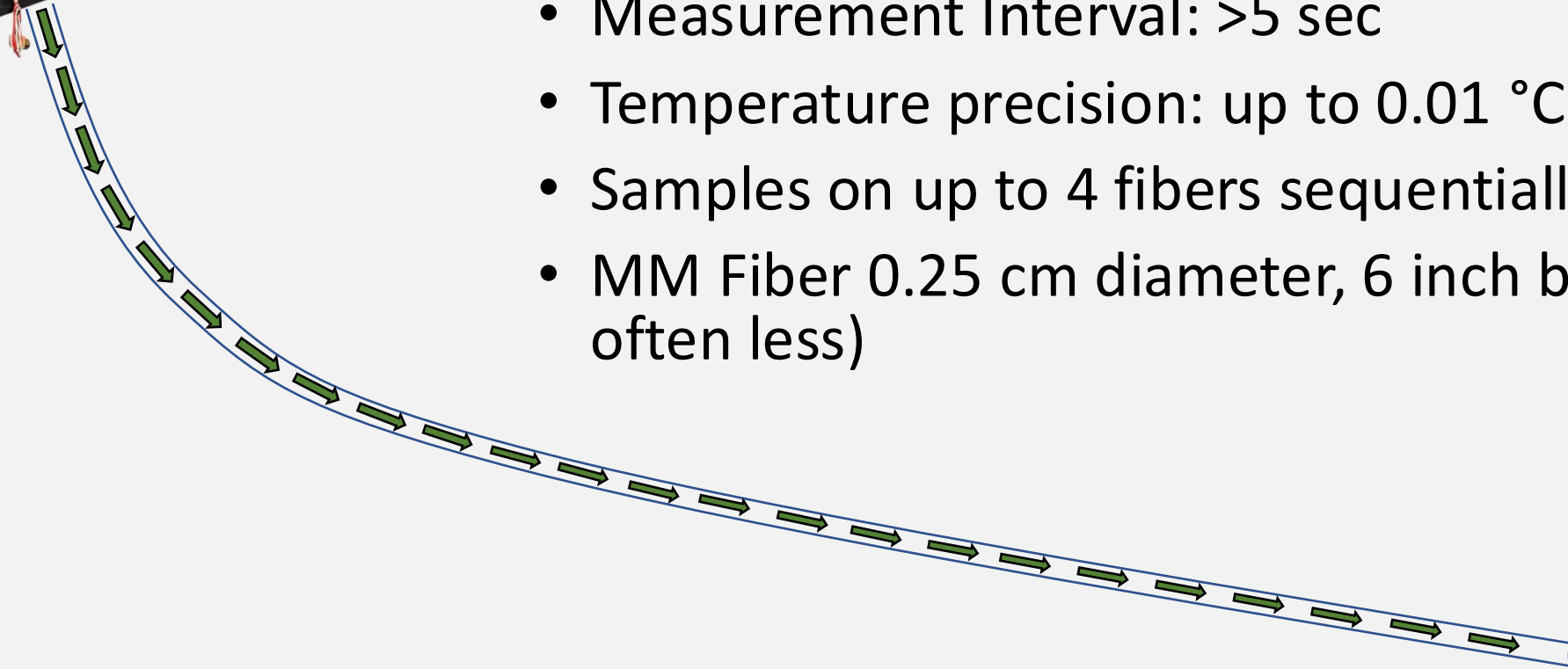
50  $\mu\text{m}$  Core



# DTS Sensing Fiber is Effectively Equivalent to an Array of Independent Temperature Sensors



- Single Interrogator
- Range: 10 km
- Spatial Resolution: 0.25 m
- Measurement Interval: >5 sec
- Temperature precision: up to 0.01 °C
- Samples on up to 4 fibers sequentially
- MM Fiber 0.25 cm diameter, 6 inch bend radius (or often less)



# Deep-Sea DTS Observatory V2

Calibrated SBE  
39+ TD Probe

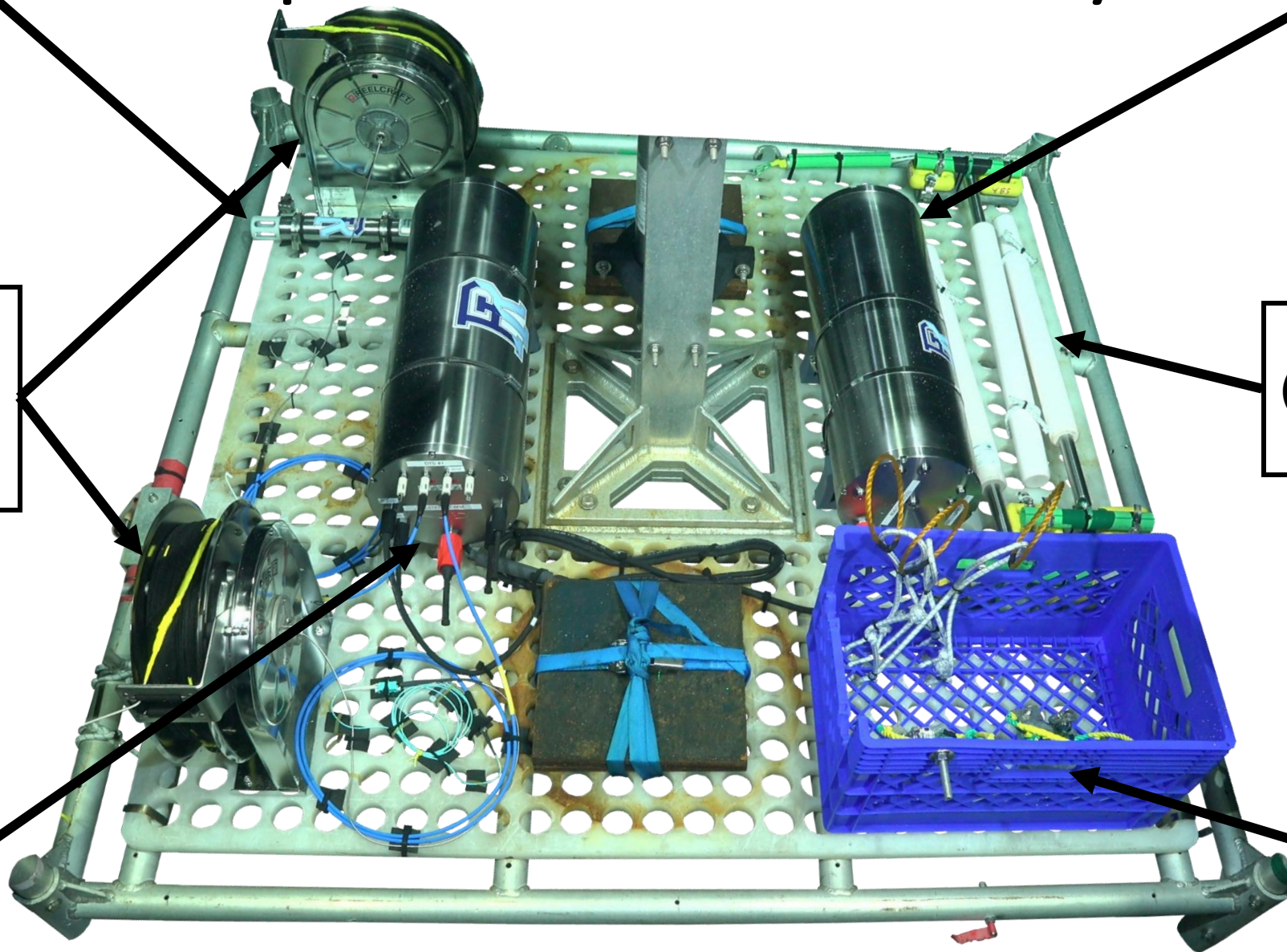
Li-ion Battery  
25.45 V, 238 Ah

Stainless Steel  
Fiber Reel with  
425m and 560m of  
Sensing Fiber

3 Tilt Current Meter  
(TCM) Payloads each with  
2 iButton Thermistors

Modified  
Silixa XT DTS

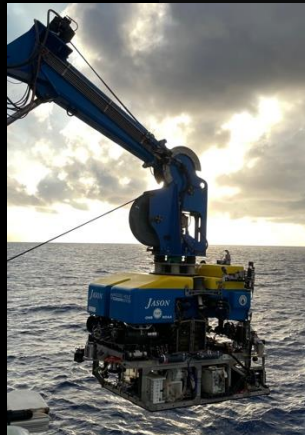
2 Deployable  
Independent  
iButton Thermistors



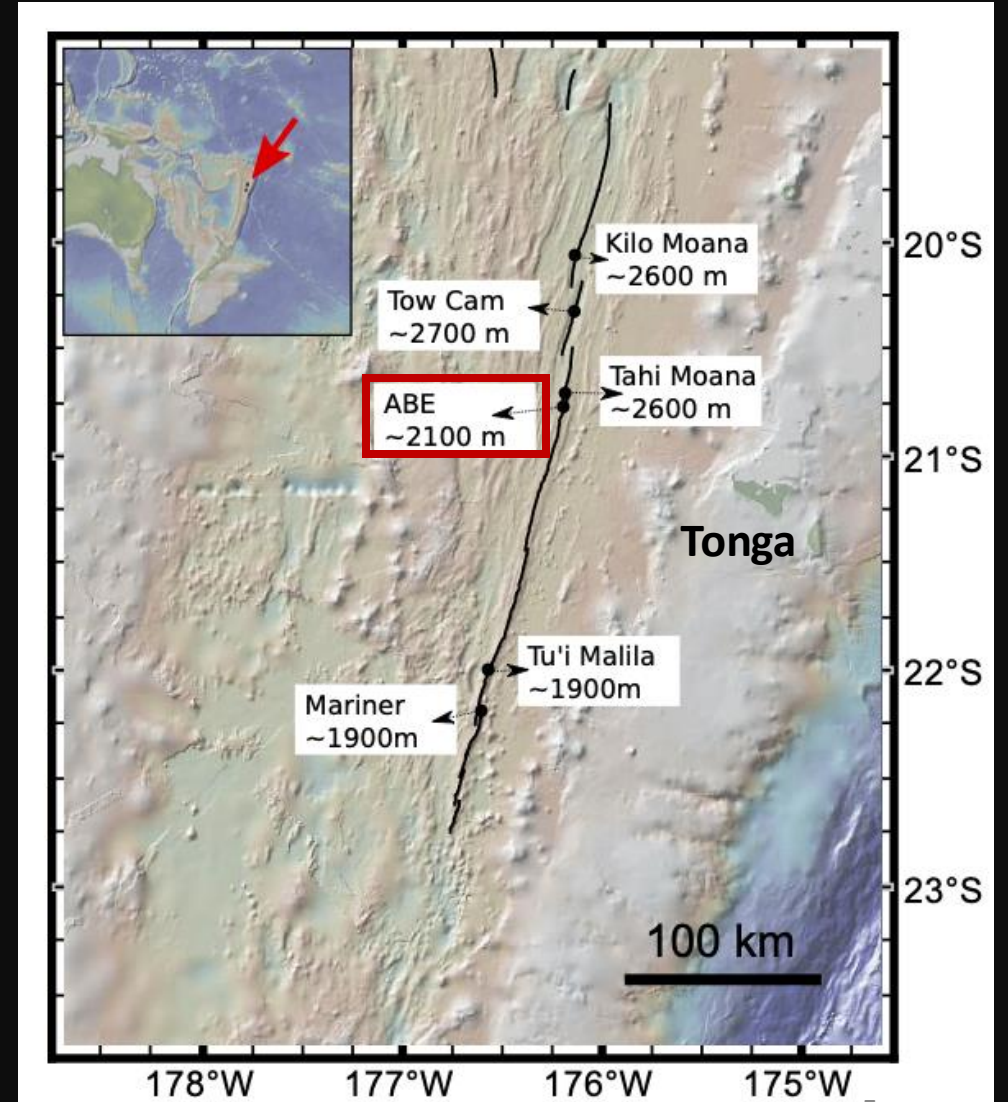
# ABE Vent Field, Lau Basin 2022






Google

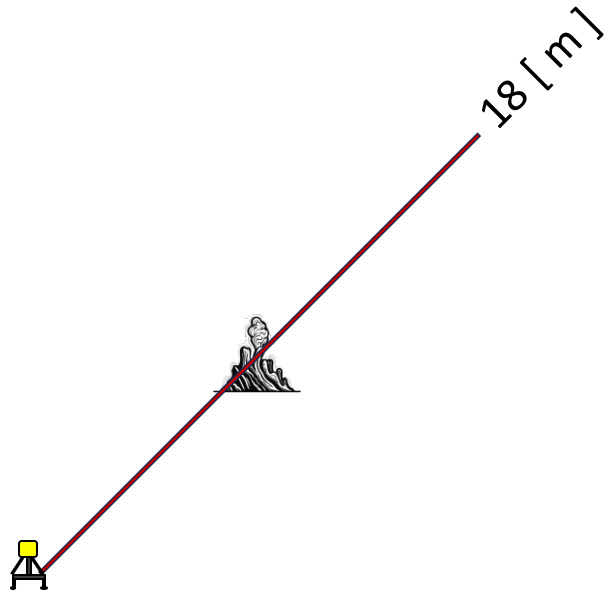


pc. Tanika Ladd



# Lau Basin, 2022

-  DTS Observatory Lander
-  DTS Sensing Fiber
-  Active Hydrothermal Venting



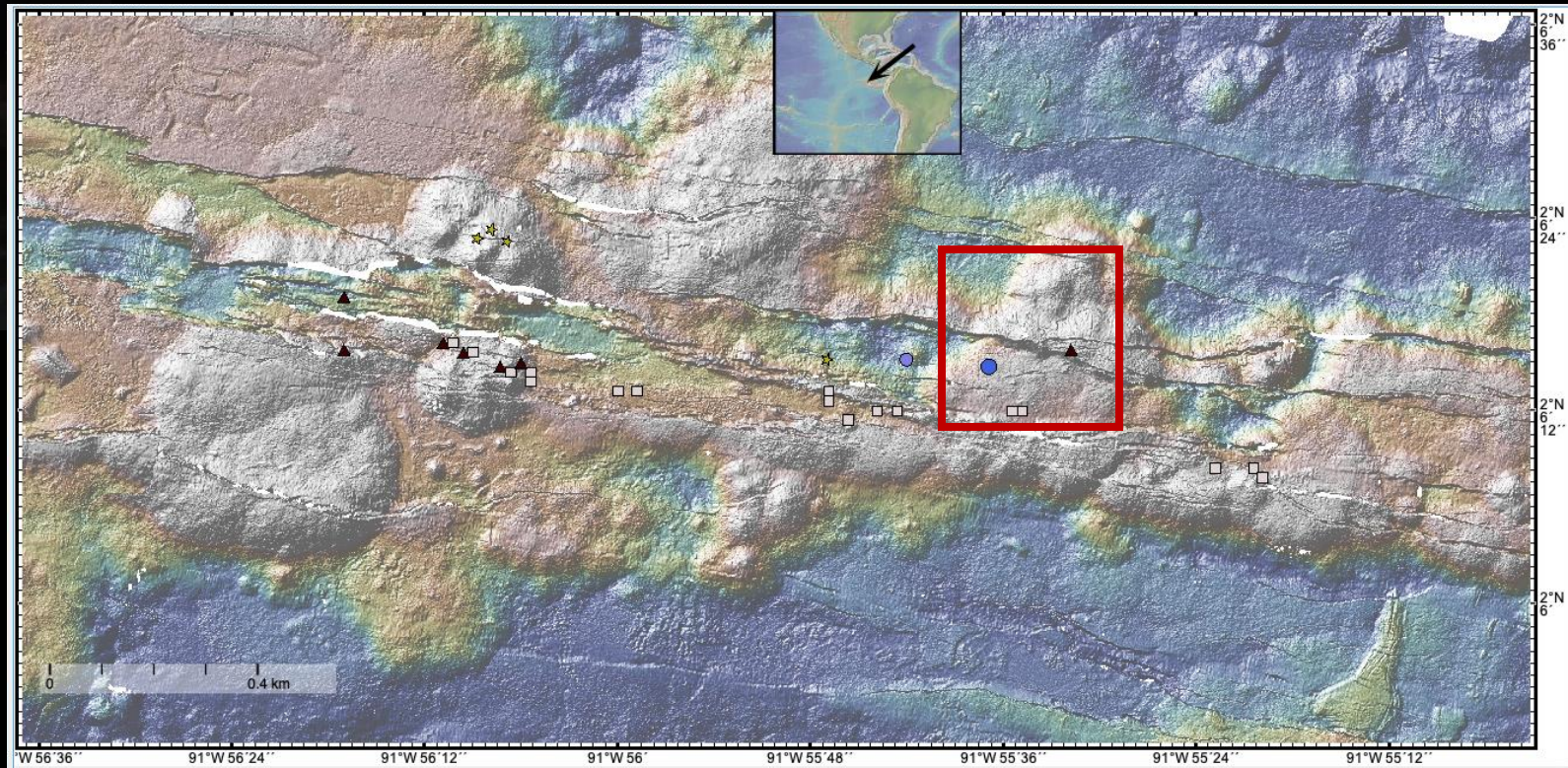
- 18m total deployed fiber length (~72 nodes on seafloor)
- DTS: 1-min sample averaging & sampling interval, 4 days continuously
- SBE 39+: 2Hz sampling frequency, 12 days continuously



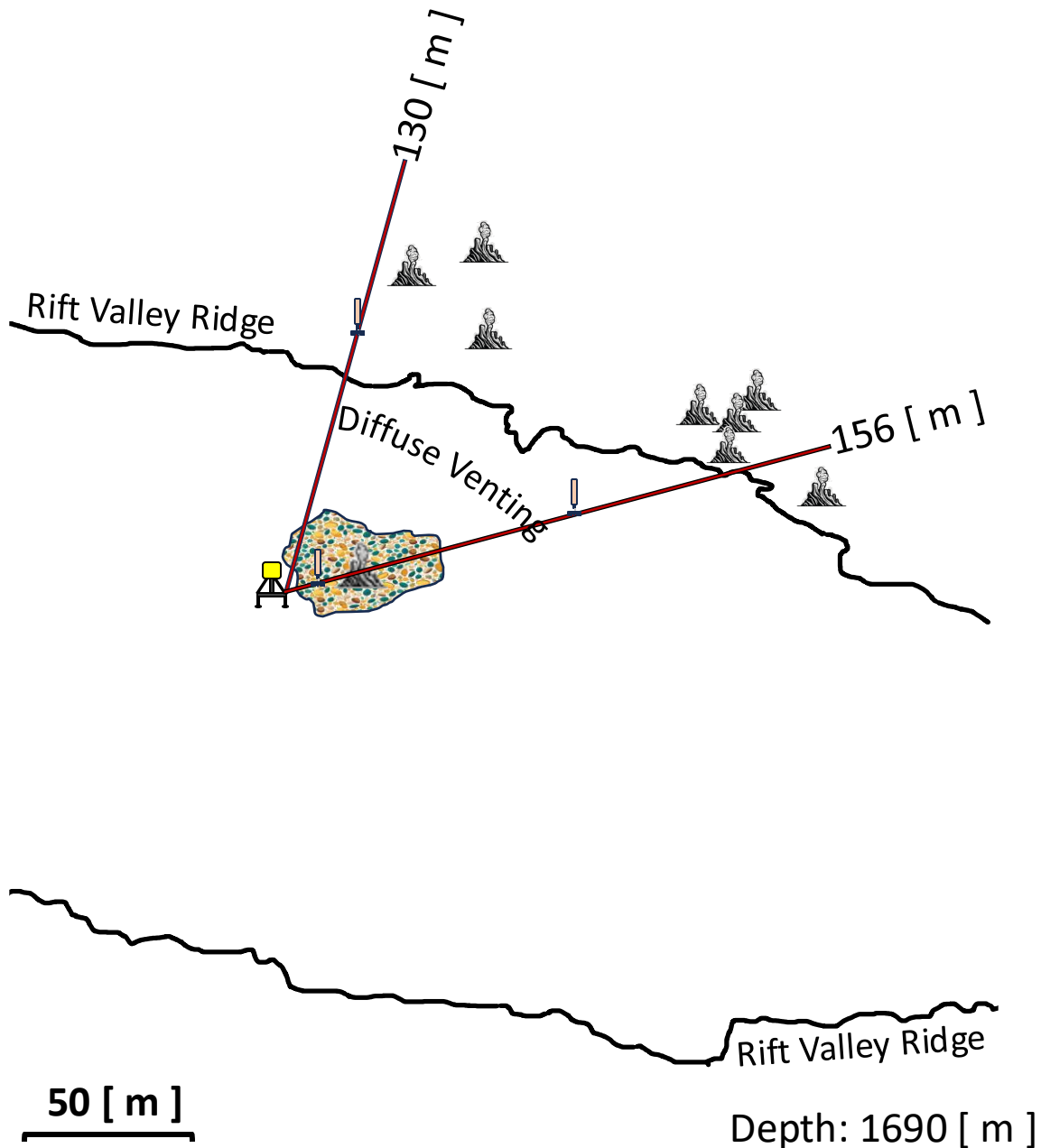
# Iguanas Vent Field, Western Galápagos Spreading Center (WGSC) 2023



pc. Alex Ingle (SOI)



# Western Galápagos Spreading Center, 2023

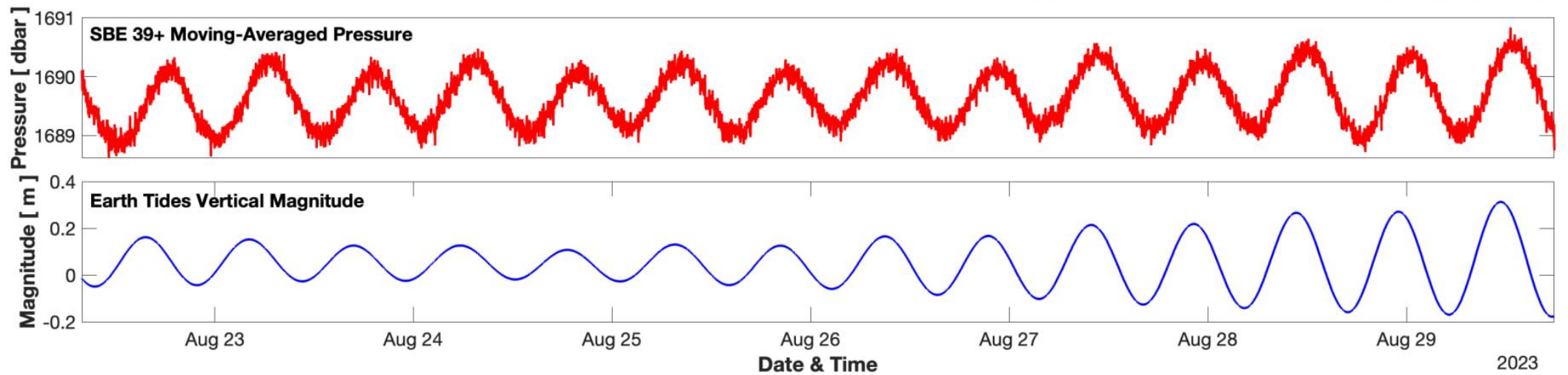
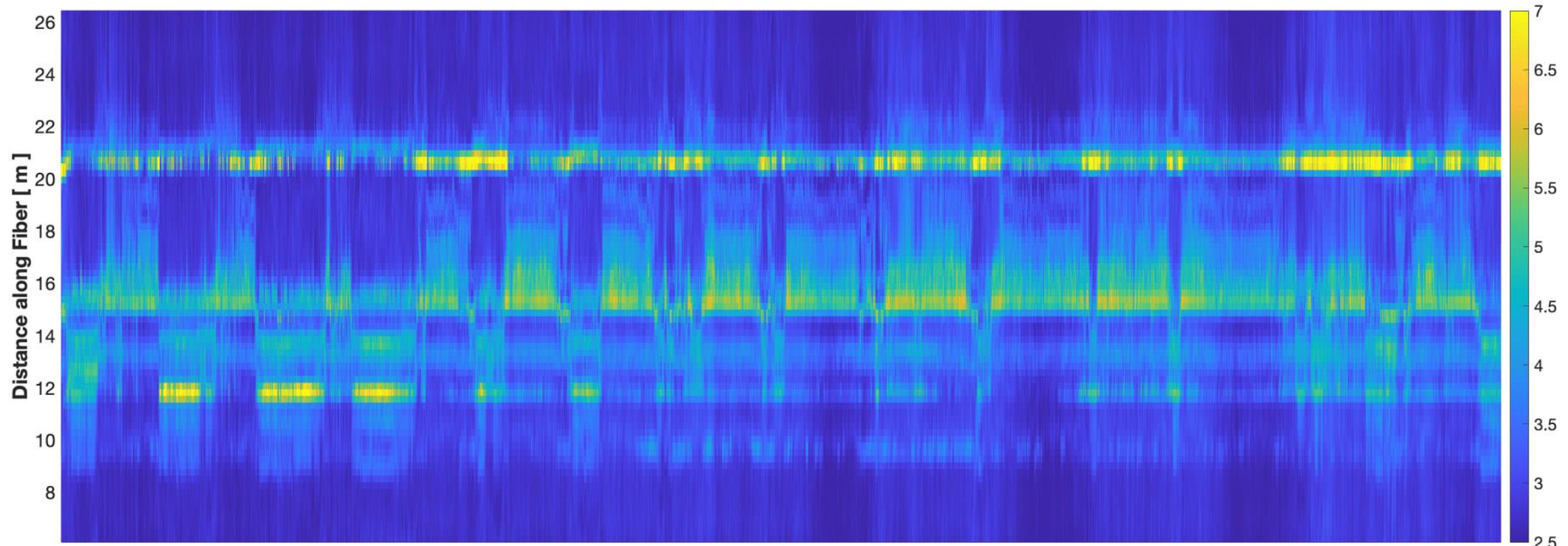
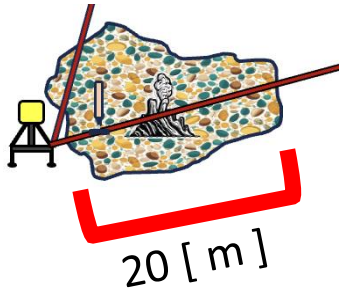


- ! Tilt Current Meter (TCM)
- A DTS Observatory Lander
- DTS Sensing Fiber
- Active Hydrothermal Venting
- Mussel Bed

- 130m & 156m deployed fiber length (1144 nodes on seafloor)
- DTS: 1-min sampling averaging & **2-min sampling interval, 7.5 days continuously**
- SBE 39+: 2Hz sampling frequency, 15 days continuously
- **3x TCM:** 1-min sampling interval, 15 days continuously
- **9x iButton Thermistors:** 6-min sampling interval, 15 days continuously
- Detailed fiber overs before and after sampling
- M3 ~10cm resolution bathymetry



# Iguanas Vent Field, Galápagos 2022





# ENDEAVOUR

## NEPTUNE Observatory

### Ocean Networks Canada

**NW Mooring (-2141 m to -1891 m)**

- > CTD (4)
- > Current Meter (4)
- > Current Profiler

**Ridge Flank (-2360 m)**

- > Accelerometer
- > Broadband Seismometer (2)
- > Bottom Pressure Recorder
- > Current Meter

**Regional Circulation North (-2158 m)**

- Short Period Seismometer
- Bottom Pressure Recorder

NE Mooring (-2153 m to -1953 m)

- > CTD (4)
- > Current Meter (4)
- > Current Profiler

Metres

0 30 60 90

**High Rise (-2152 m)**

- Benthic and Resistivity Sensor (BARS)

**Main Endeavour Field (-2192 m)**

- > Broadband Seismometer
- > Datalogger
- Hydrophone (4)
- Water Sampler
- Plankton Sampler
- Camera
- Benthic and Resistivity Sensor (BARS)
- Current Profiler
- Autonomous Sediment Trap
- Bottom Pressure Recorder
- Short Period Seismometer
- Bottom Pressure Recorder
- Benthic and Resistivity Sensor (BARS)

Metres

0 50 100 150

**West Ridge Crest North Mooring (-2092 m)**

- Autonomous Sediment Trap

**Endeavour Node (-2323 m)**

- Broadband Seismometer
- Data Logger
- Oxygen Sensor
- CTD
- Bottom Pressure Recorder

Metres

0 10 20 30

**Regional Circulation South (-2230 m)**

- SE Mooring (-2220 to -1970)
- > Current Profiler (2)
- > Current Meter (4)
- > CTD (4)

**Mothra Field (-2276 m)**

- > Broadband Seismometer
- > Accelerometer

**West Ridge Crest South Mooring (-2115 m)**

**SW Mooring (-2163 m to -1966 m)**

- > Autonomous CTD (4)
- > Autonomous Current Meter (4)

- Node
- Instrument Platform
- Mooring
- Fibre-optic Cable

Hydrothermal Vent Density (vents/km<sup>2</sup>)

790

0

Bathymetry (m)

-2450

-2700

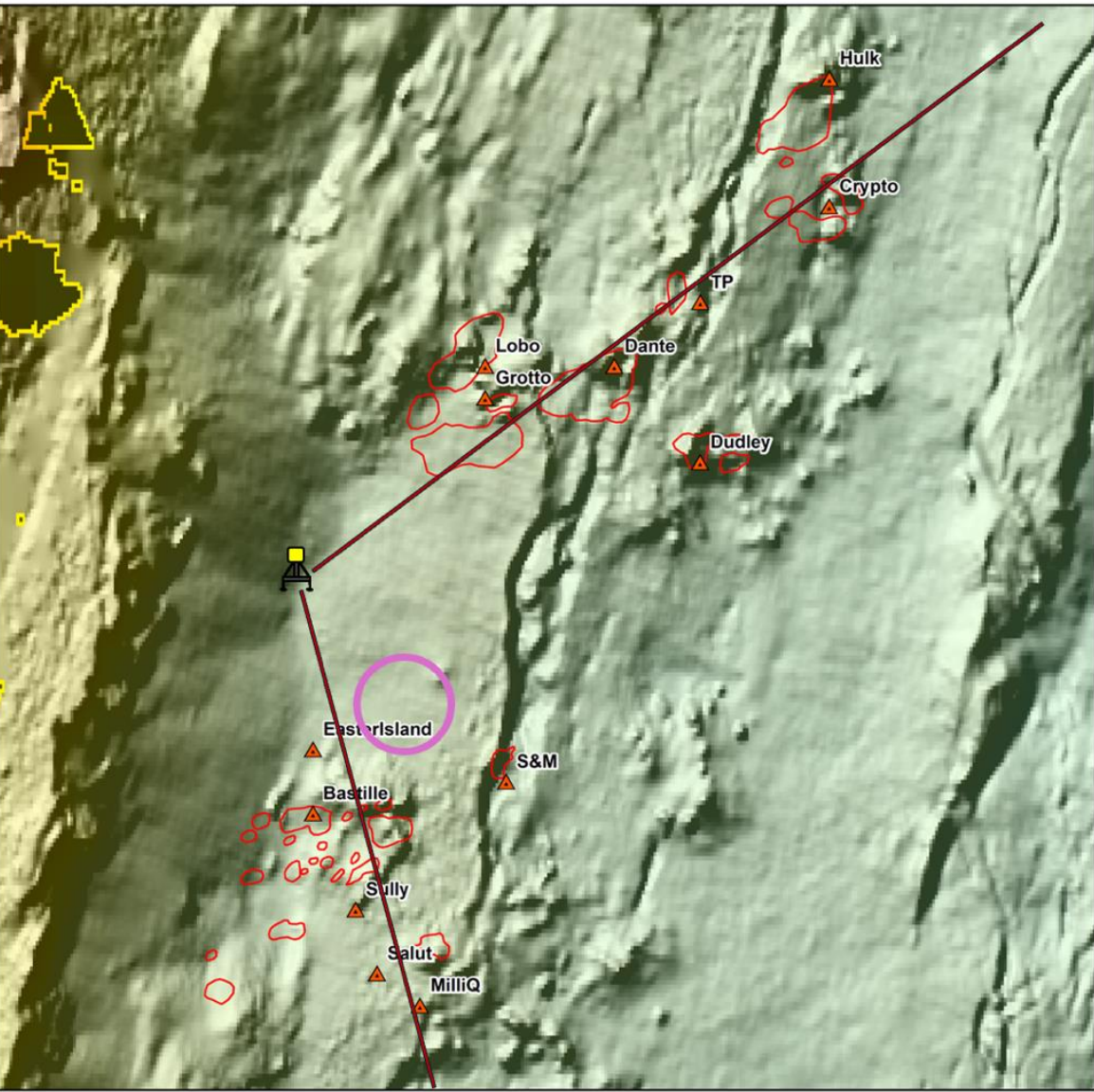
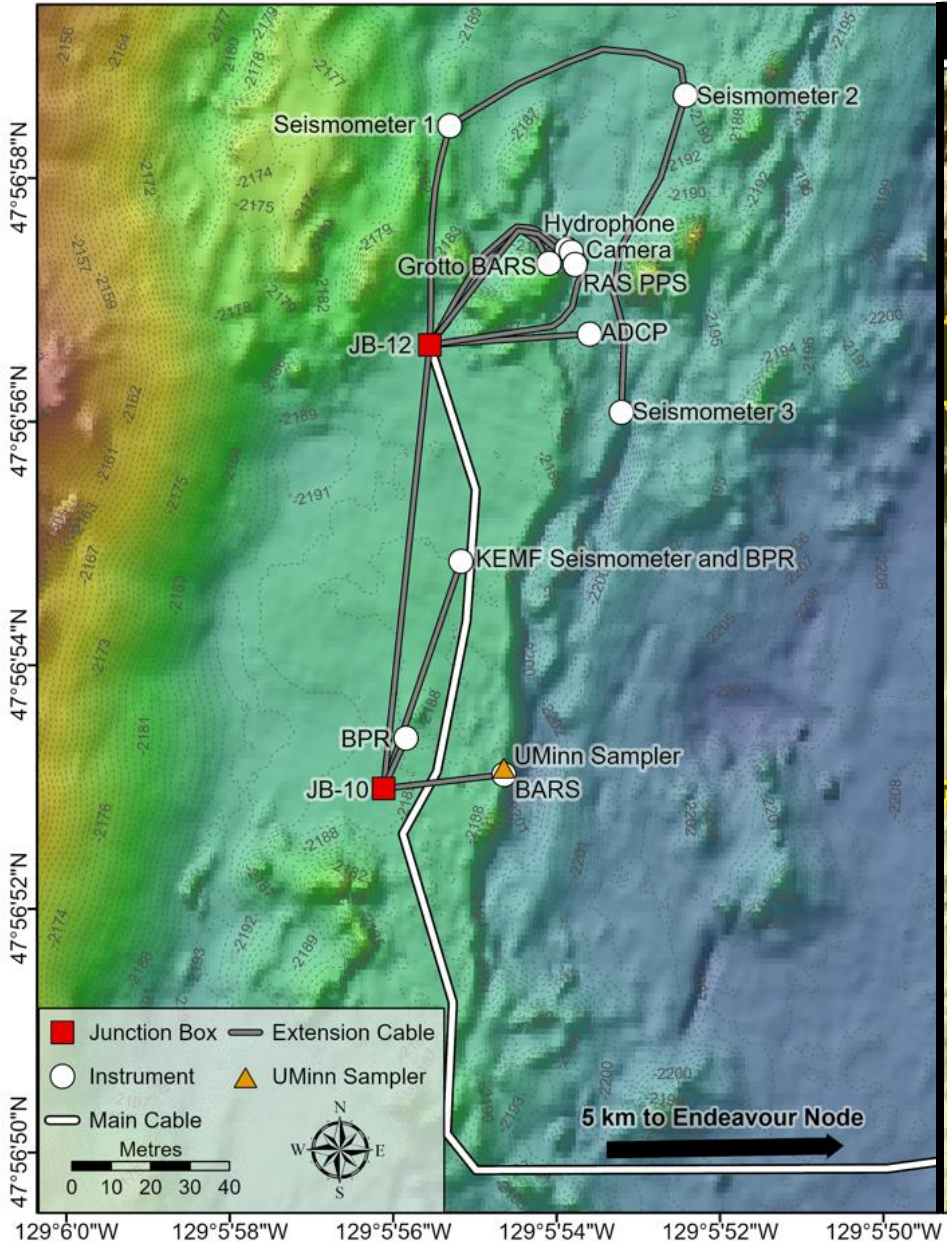
1000 m

AN INITIATIVE OF University of Victoria

Data Sources: Ocean Networks Canada TNO56 (2013)  
Last Updated: 14 December 2023

Proposed DTS deployment at MEF, Summer 2025

# NEPTUNE OBSERVATORY: ENDEAVOUR



**Main Endeavour Field**

Description: This map outlines active sulfide structures as shown by Lilley in a 2003 nature article.

Coord System: WGS 1984 UTM Zone 9N  
 Projection: Transverse Mercator  
 BaseMaps: MBARI AUV 2 m bathymetry (Clague et al., 2014), TN298 30 m Bathymetry (Ocean Networks Canada)  
 Scale: 1:1,000  
 Date: February 01, 2021

0 25 50 75 100 Metres

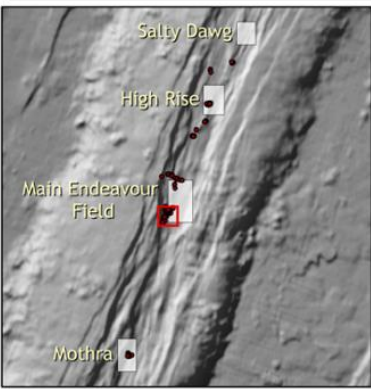
— DTS Sensing Fiber

○ Junction Box 10

■ DTS Observatory Lander

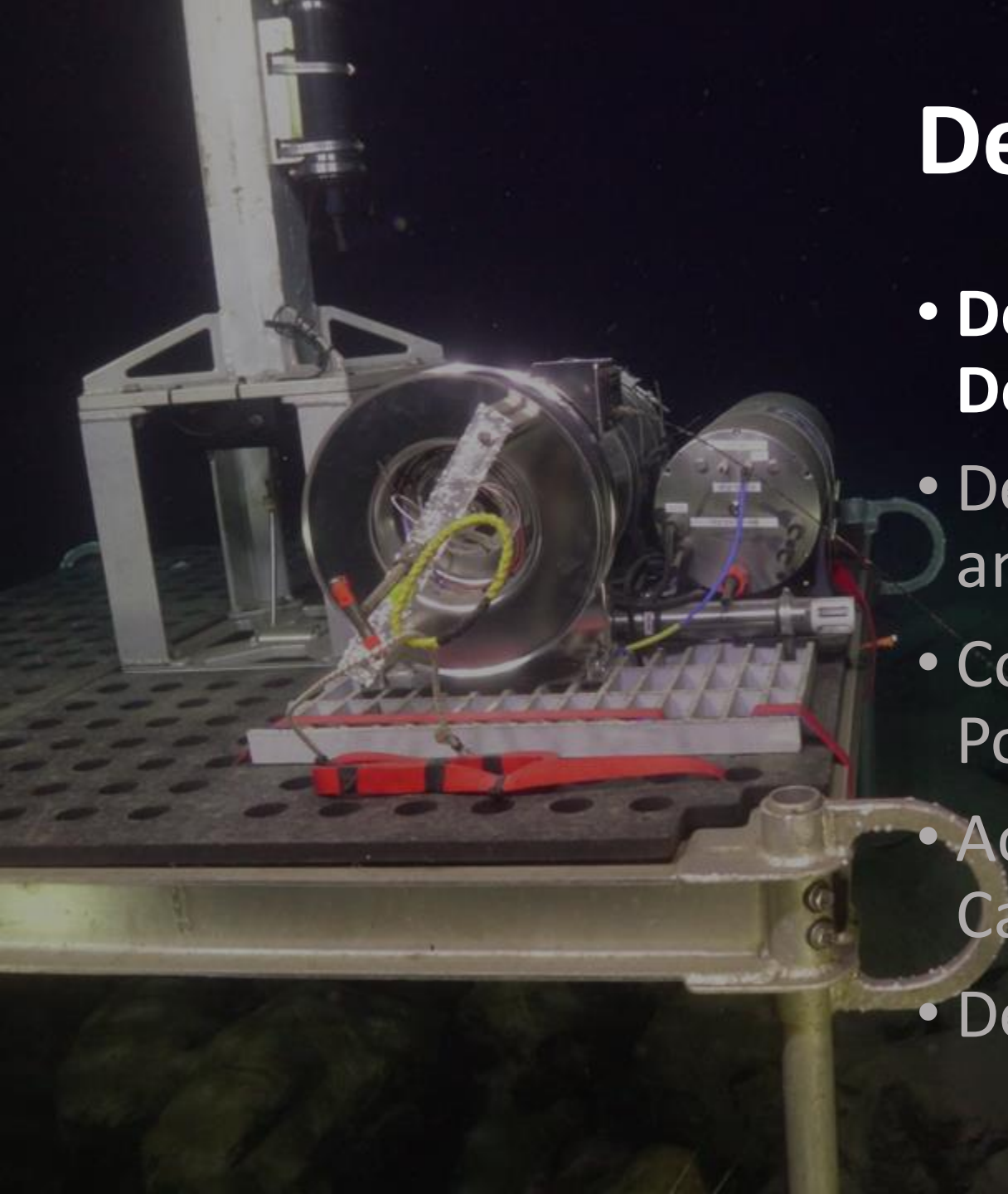
▲ Vent Structures (Source: Kelley et al., UW) [Labeled]

□ Active Sulfide Structures (Lilley, 2003)



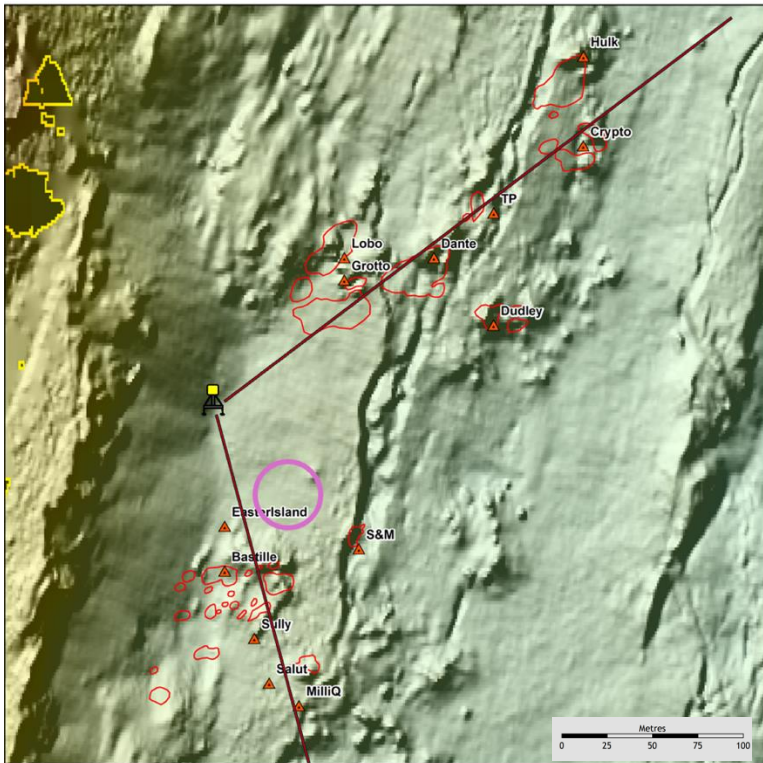
# Development Steps

- **Determine Scientific Objective/Fiber Deployment configuration**
- Decouple DTS interrogator and Reel and/or Order new lengths of fiber
- Construct a DTS Platform and JB->DTS Power cable
- Access to a TD for DTS Temperature Calibrations (at depth)
- Develop Software Driver

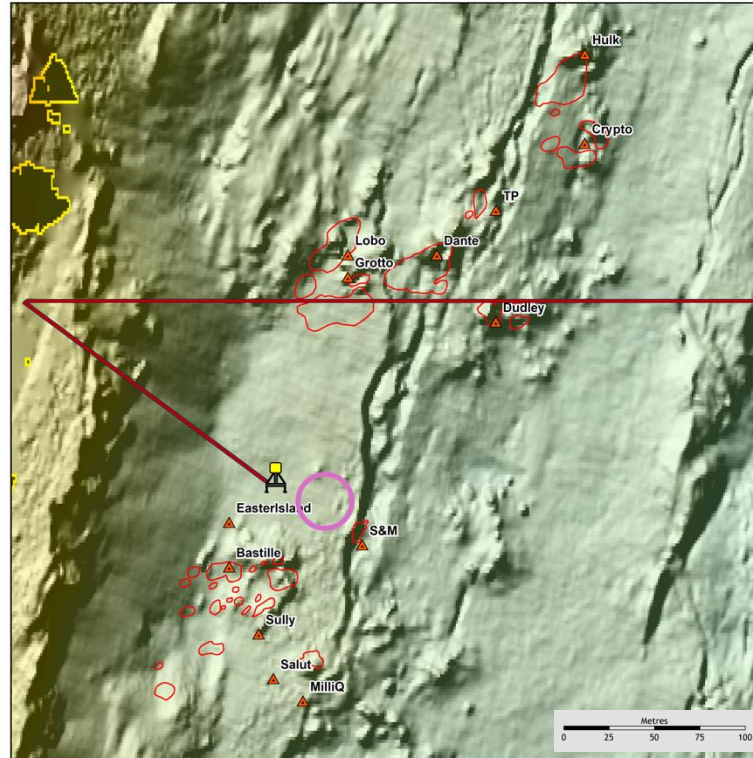


# Fiber Deployment Configurations

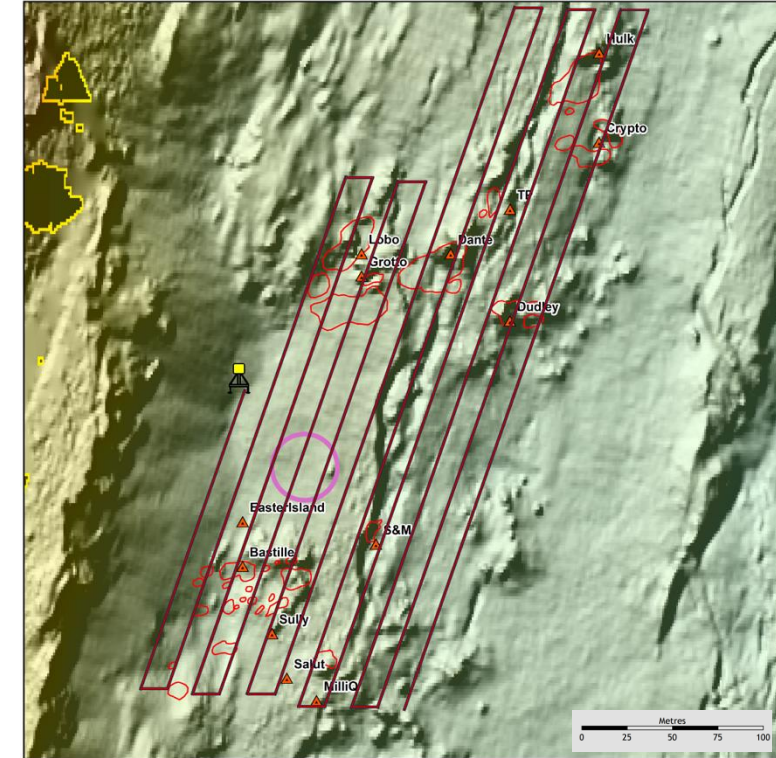
## Venting Focused



## Across Axial Valley



## Maximum Coverage

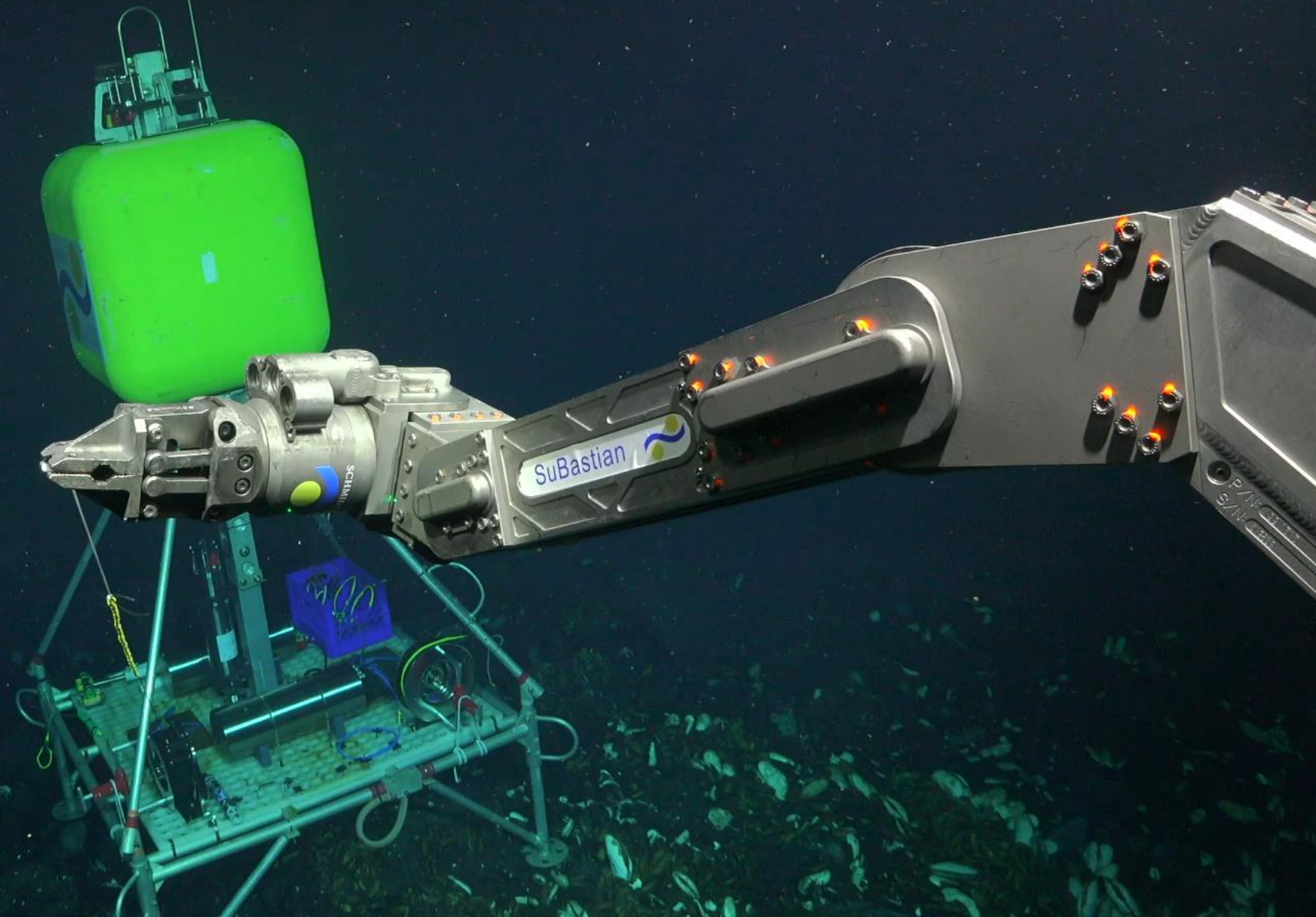


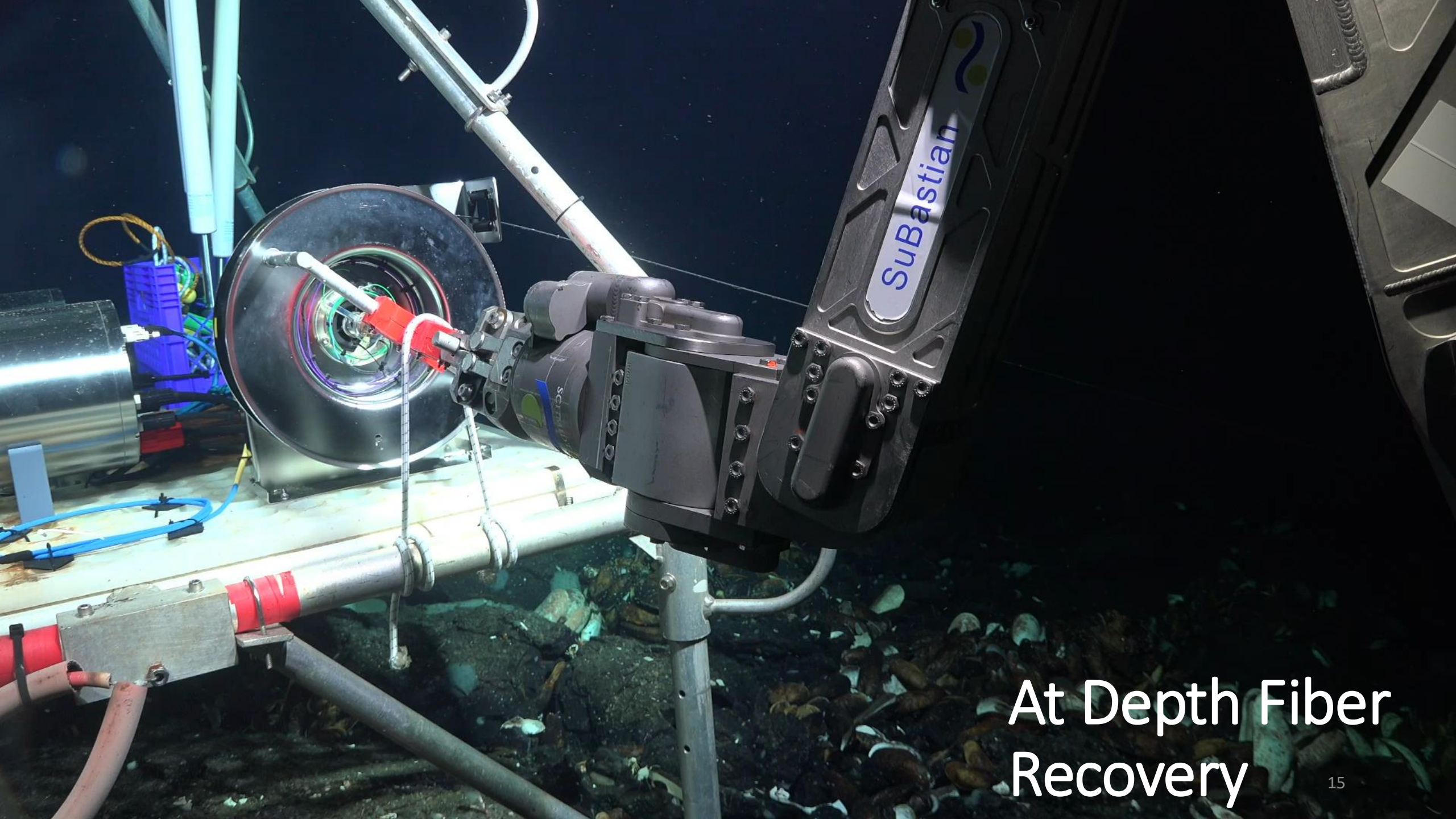
## Dive Time Considerations:

- Length of deployed fiber
- Terrain/Configuration complexity
- Fiber deployment method

**\*Consider conflict with other cables/maintenance**

# At Depth Fiber Deployment

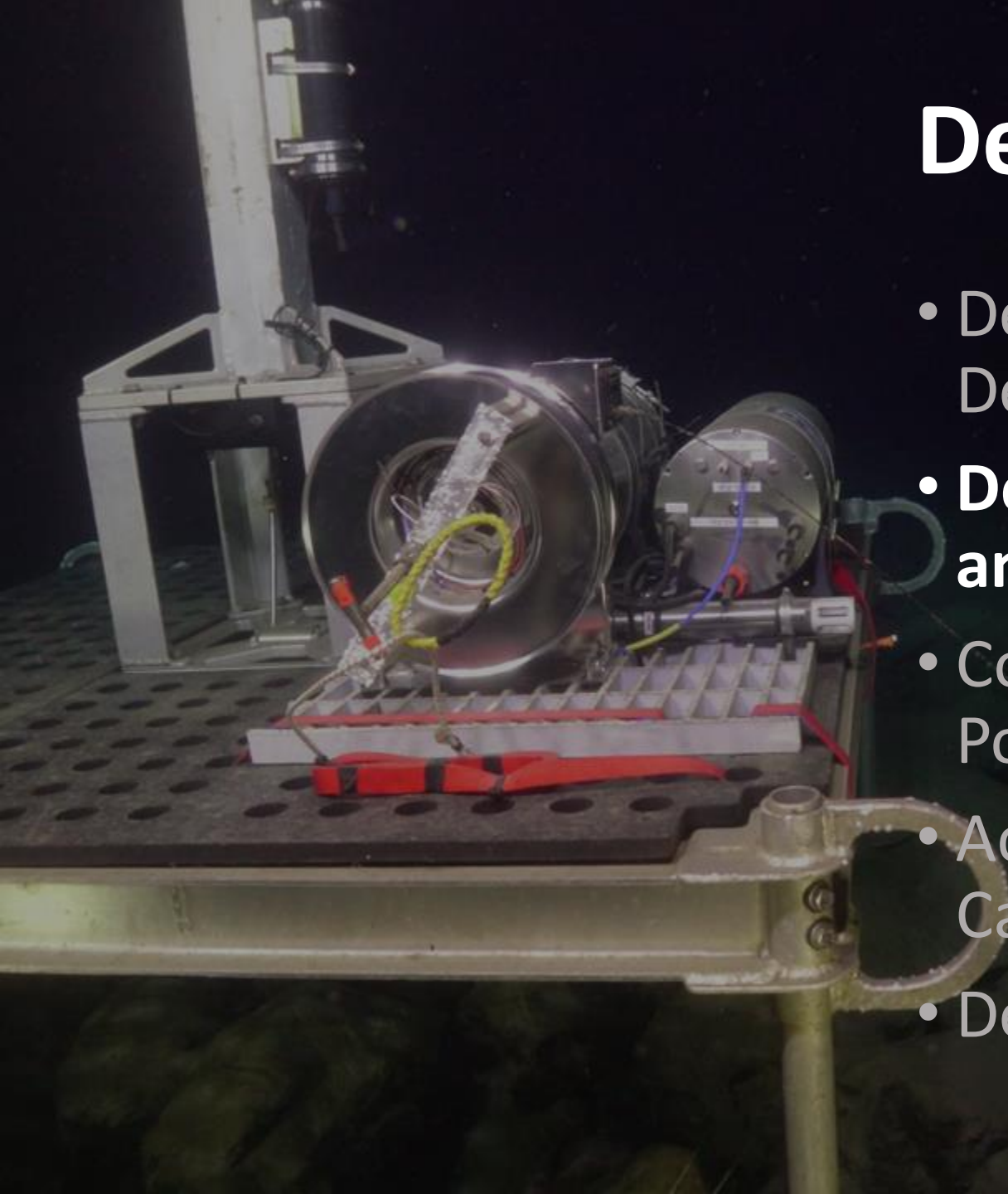




# At Depth Fiber Recovery

# Development Steps

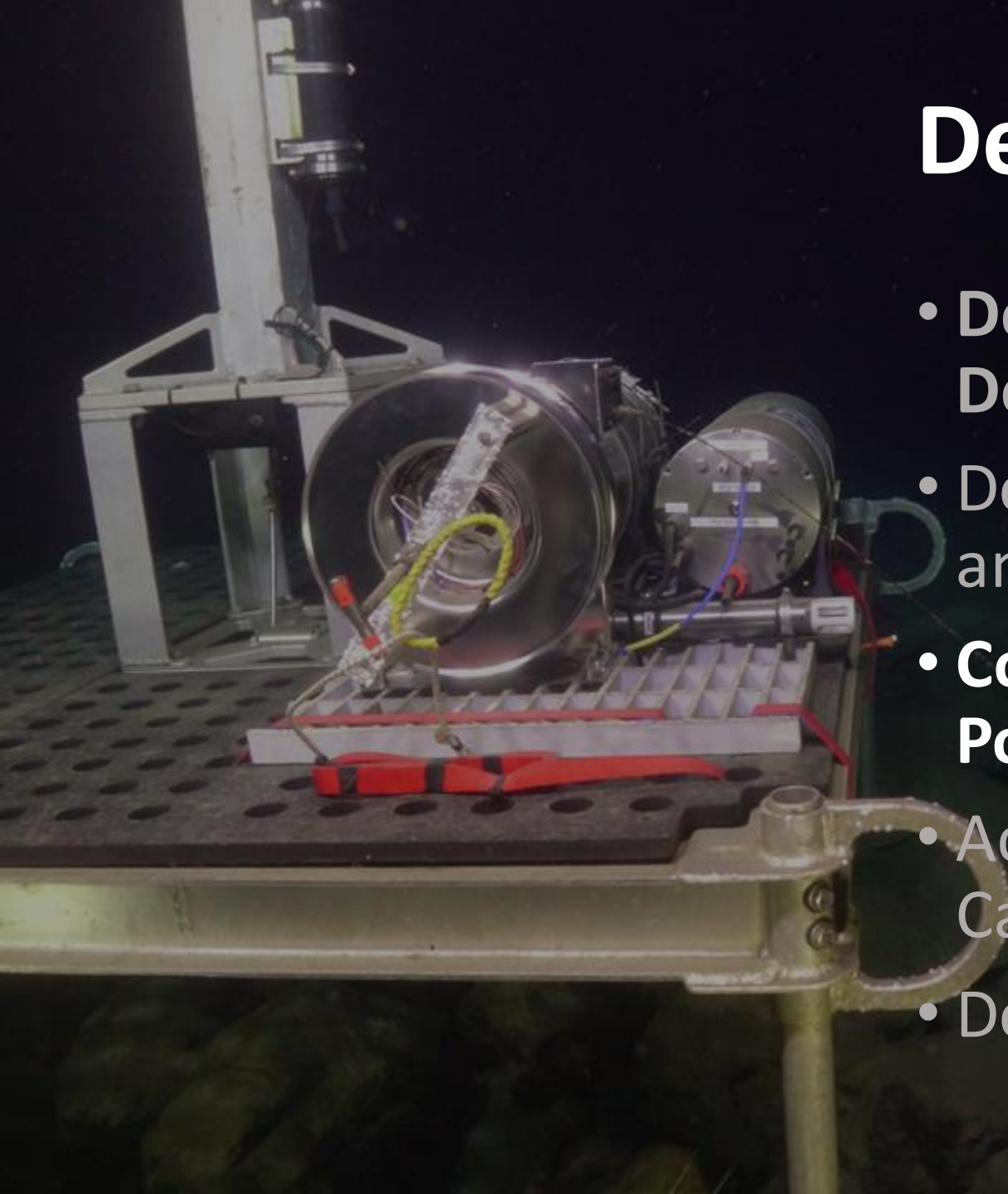
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39+ TD Probe

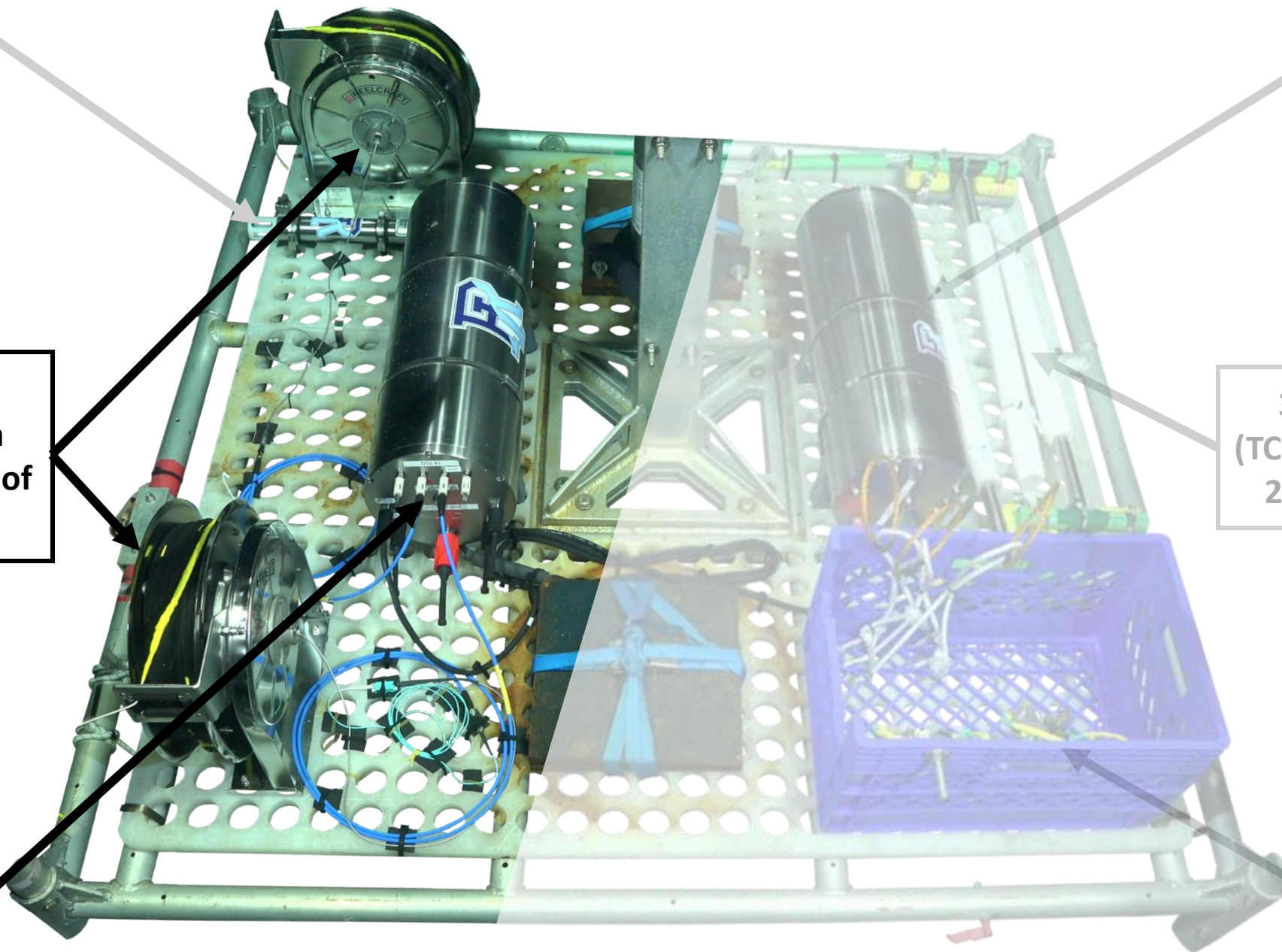
Li-ion Battery  
25.45 V, 238 Ah

Stainless Steel  
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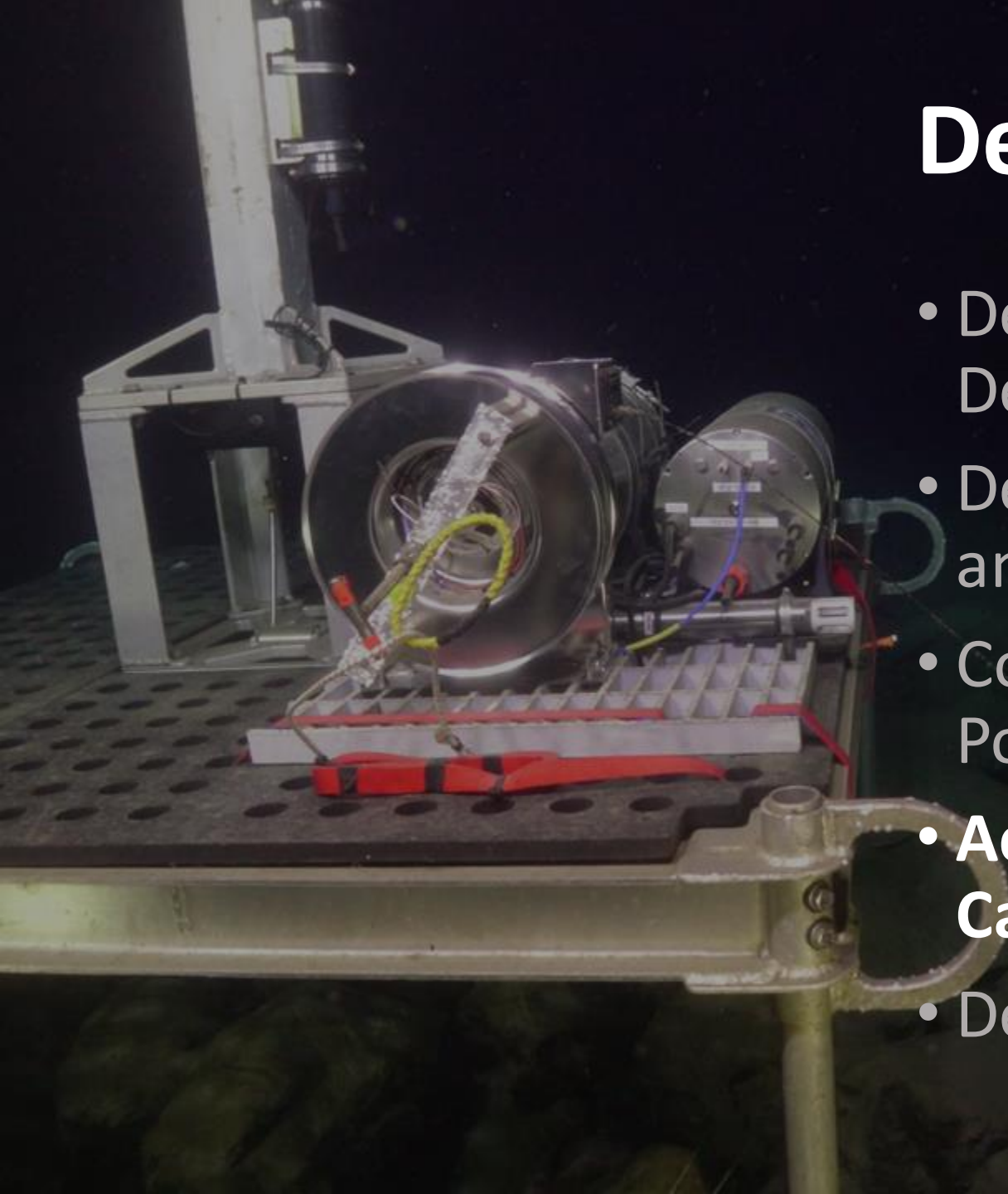
Modified  
Silixa XT DTS

2 Deployable  
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iButton Thermistors



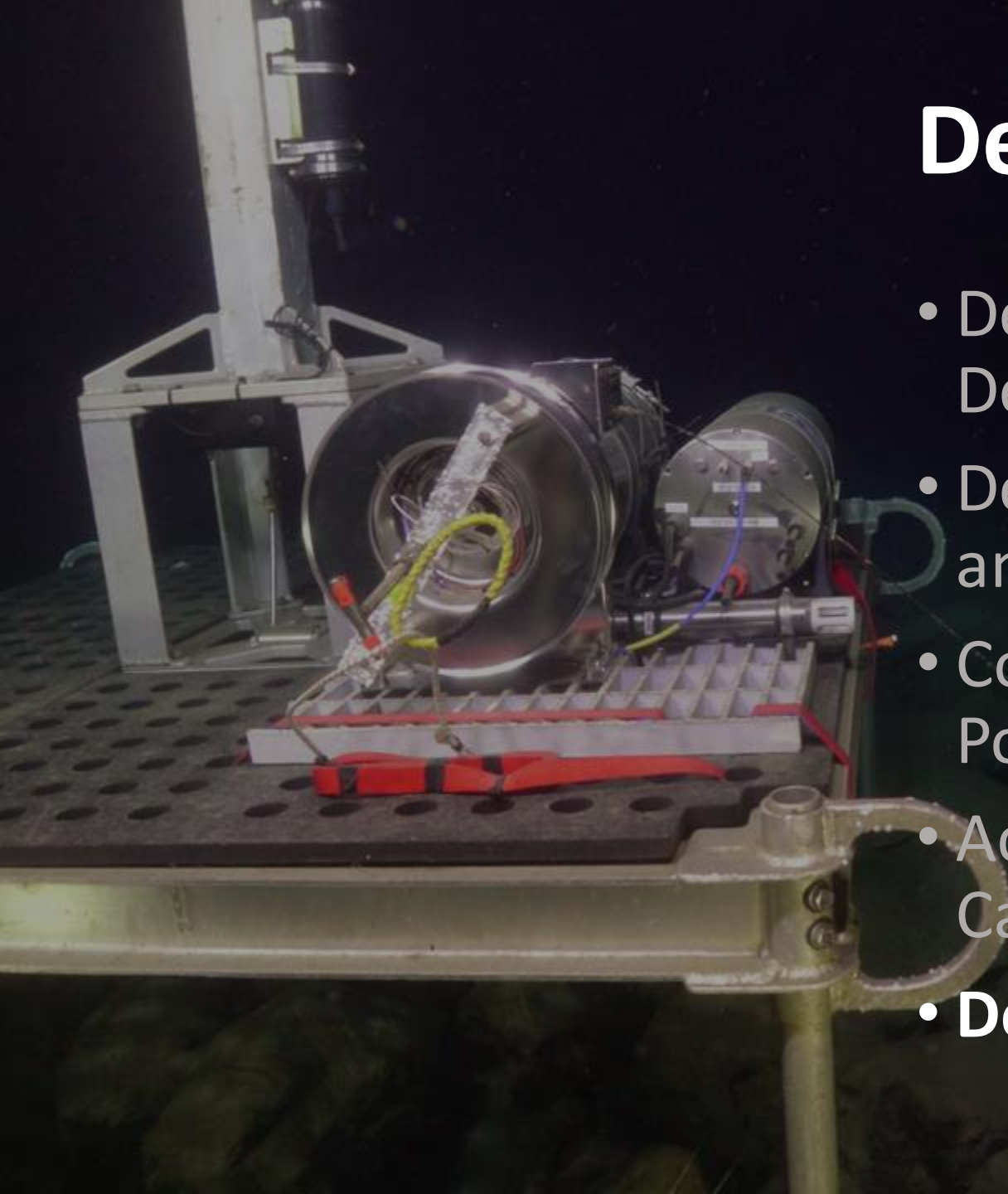
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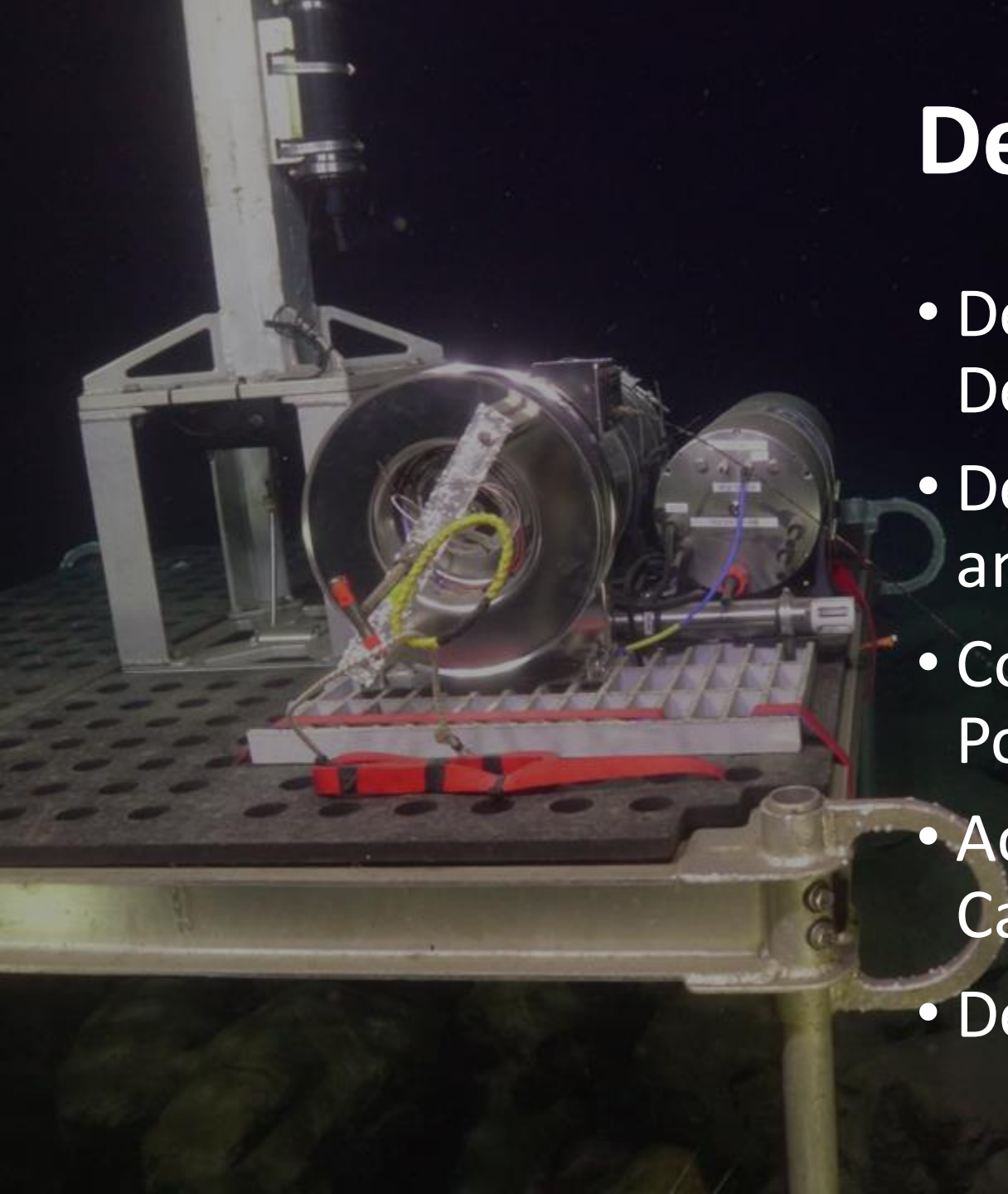
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# Acknowledgements

- Kingdom of Tonga
- Fundación Charles Darwin
- Parque Nacional Galapagos, Ecuador
- INOCAR
- Dave Casagrande, University of Rhode Island
- Todd Gregory, Gregory Designs LLC
- Captain & Crew of *R/V Falkor (too)*
- Pilots & Engineers of *ROV SuBastian*
- Captain & Crew of *R/V Thomas G. Thompson*
- Pilots & Engineers of *ROV JASON*
- National Science Foundation (Lau cruise support)
- Office of Naval Research (DTS support)

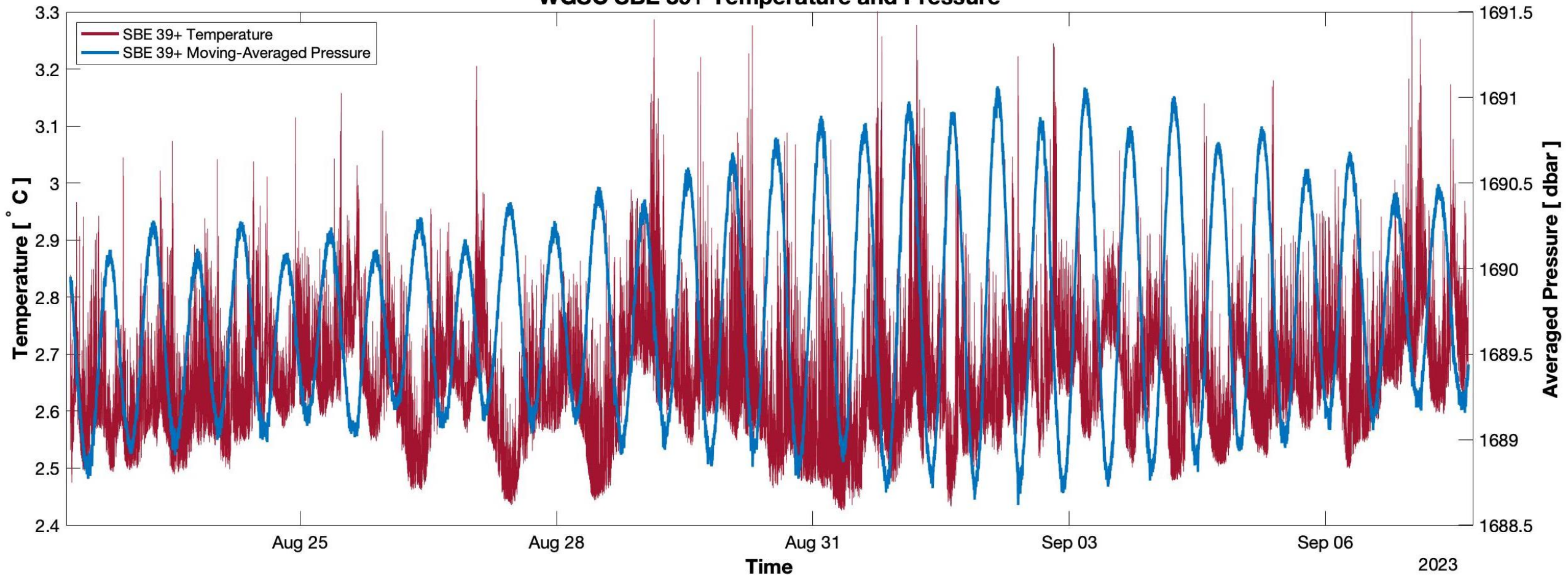
## Questions?

Contact:

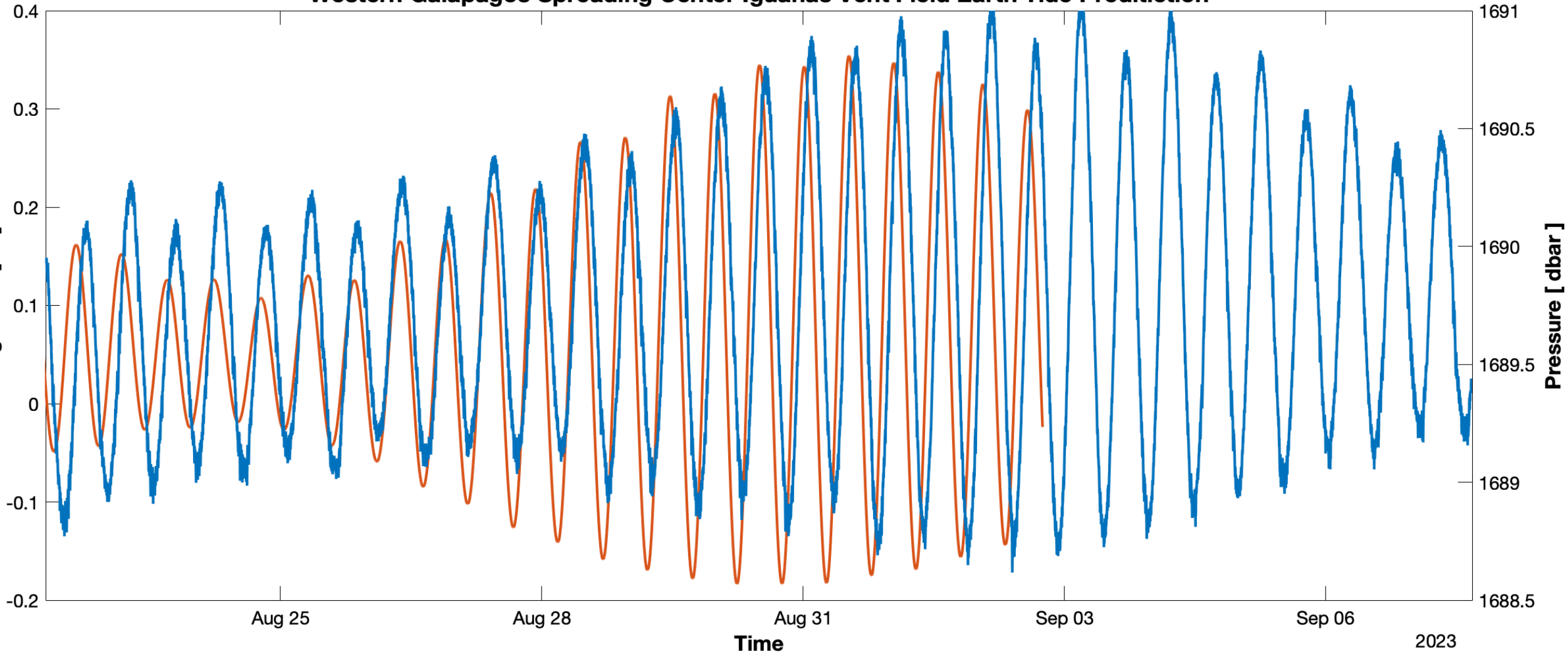
Johann Becker

Beckerj@uri.edu

### WGSC SBE 39+ Temperature and Pressure

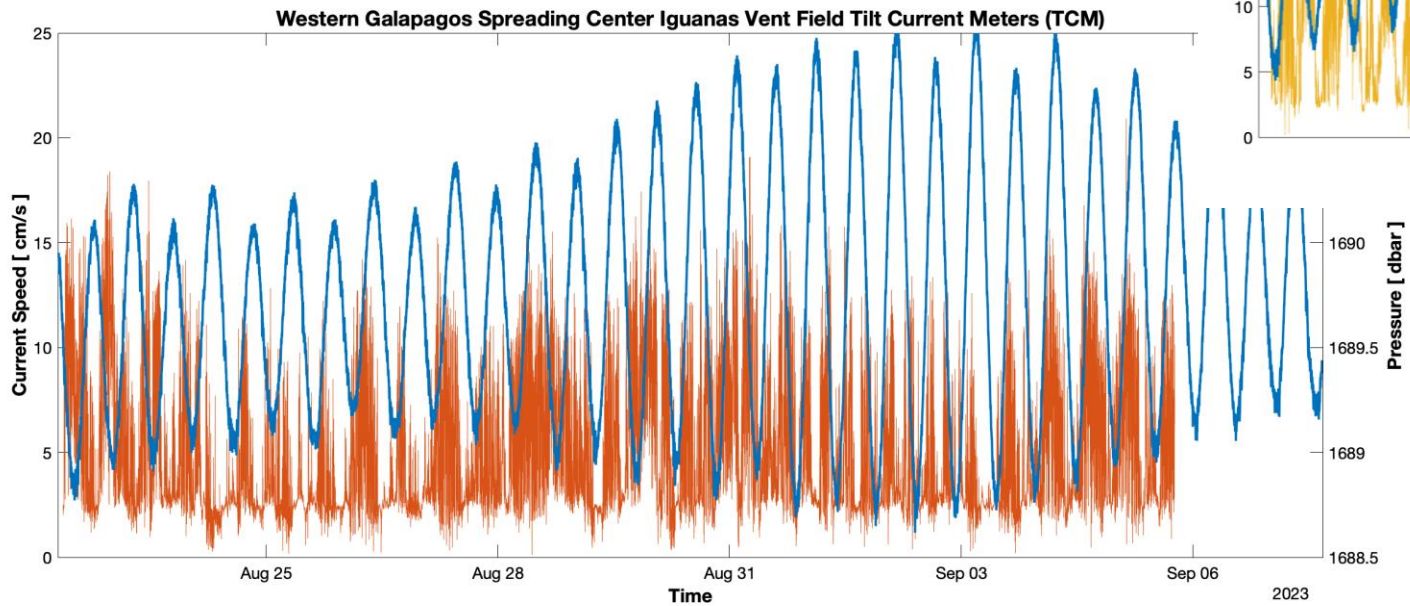
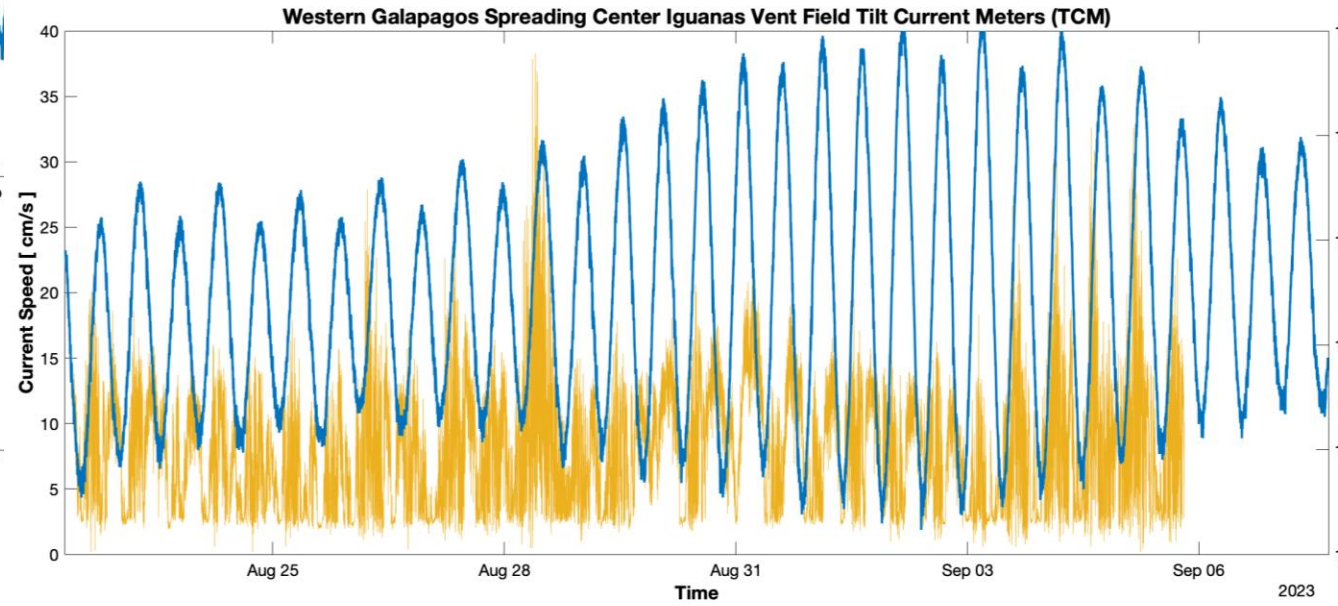
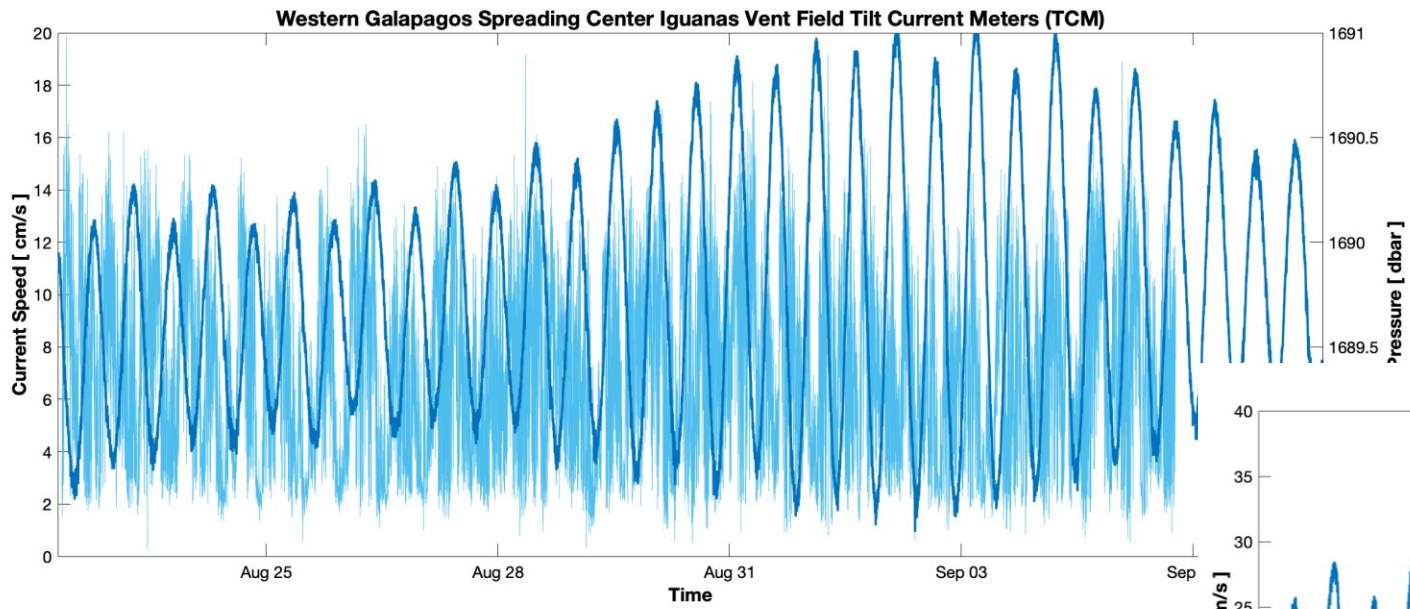


# Western Galapagos Spreading Center Iguanas Vent Field Earth Tide Prediction

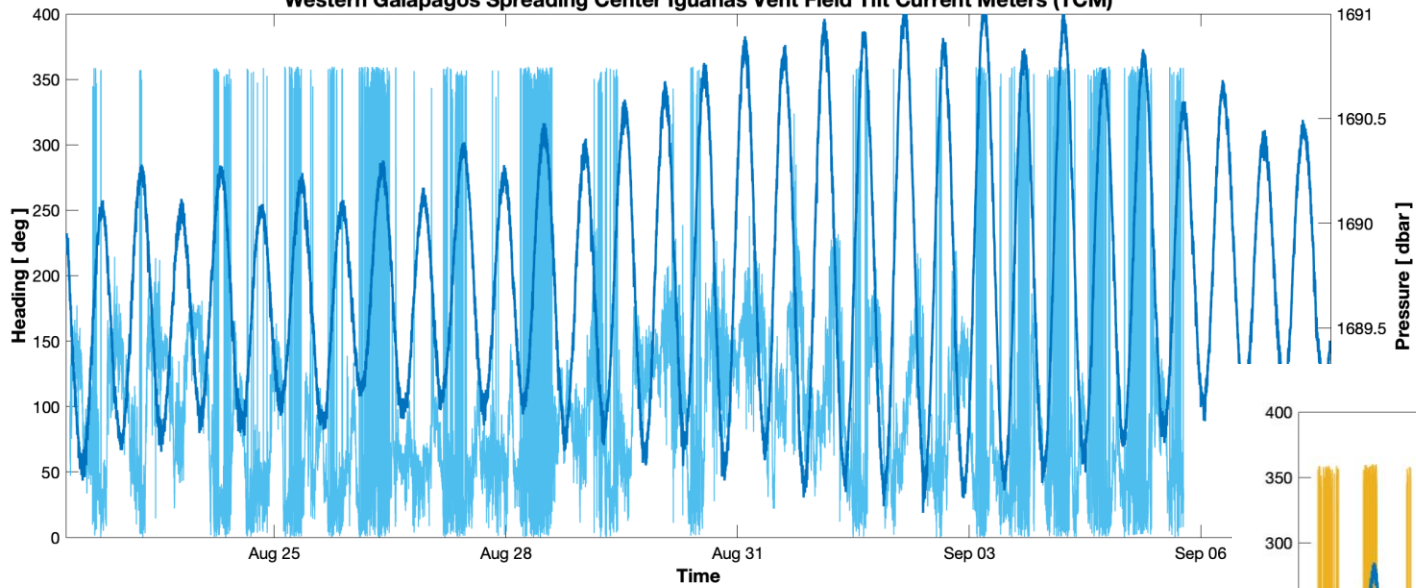


Earth tide signal in orange  
SBE pressure data in blue

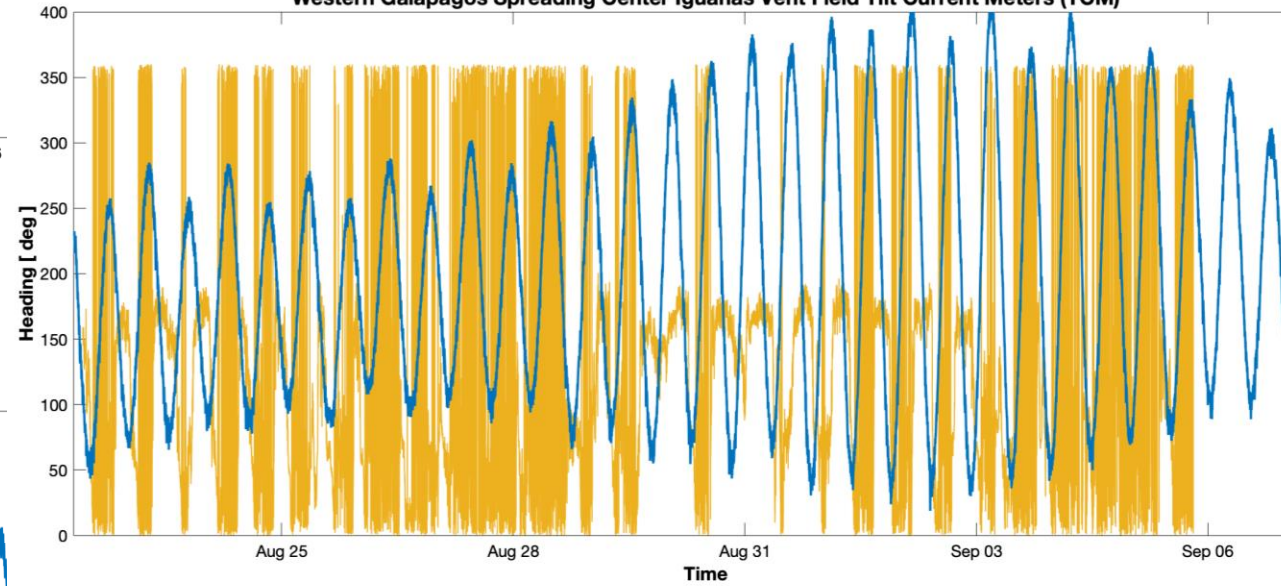




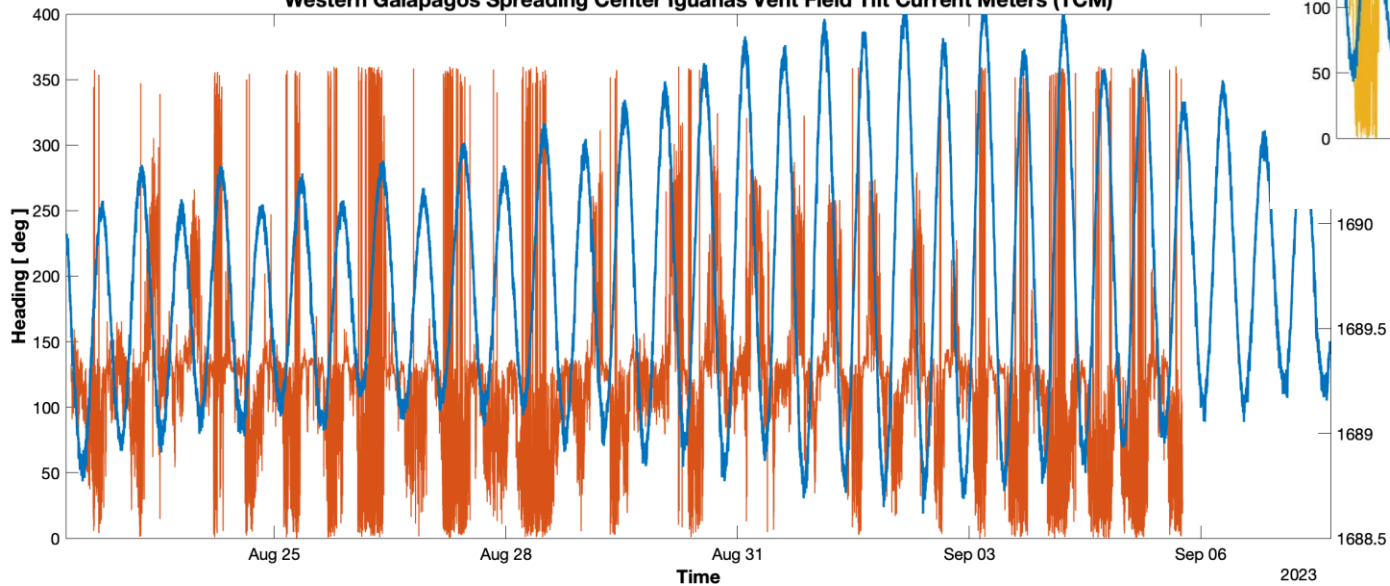
Western Galapagos Spreading Center Iguanas Vent Field Tilt Current Meters (TCM)

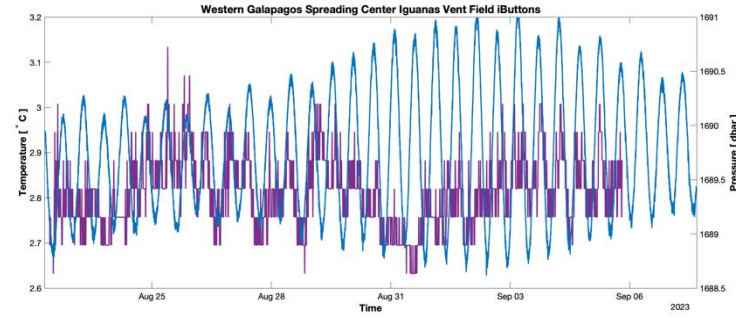
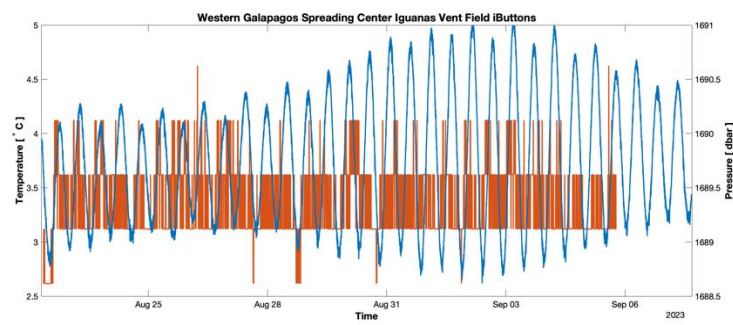
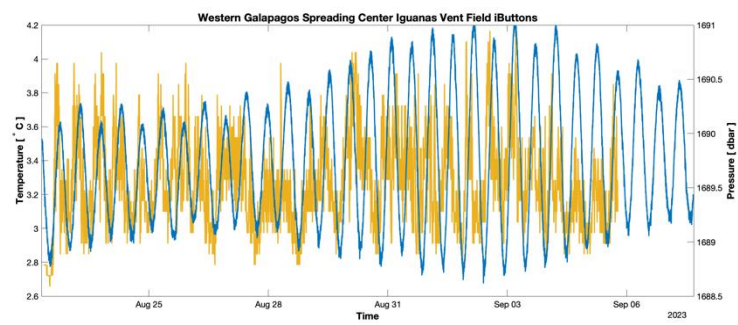
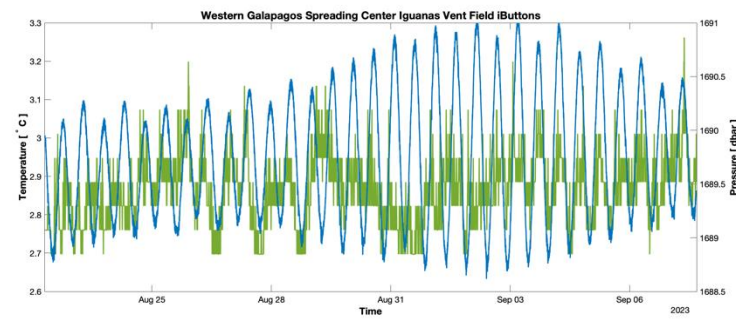
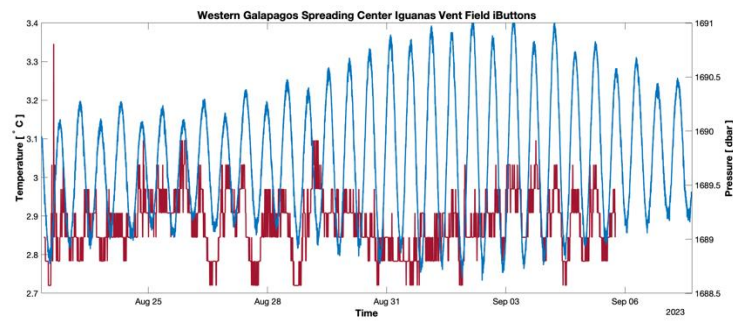
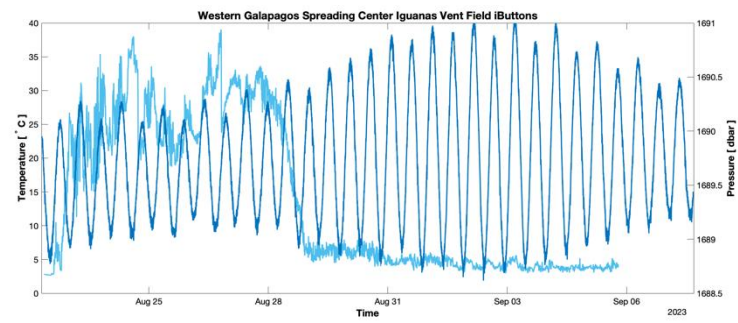
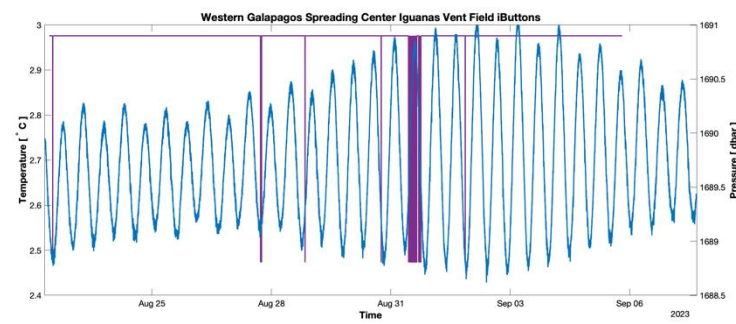
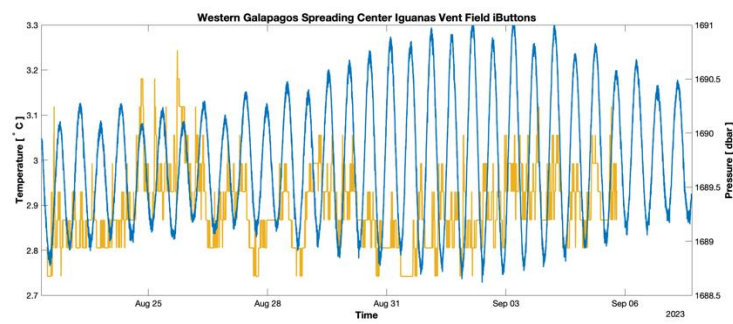
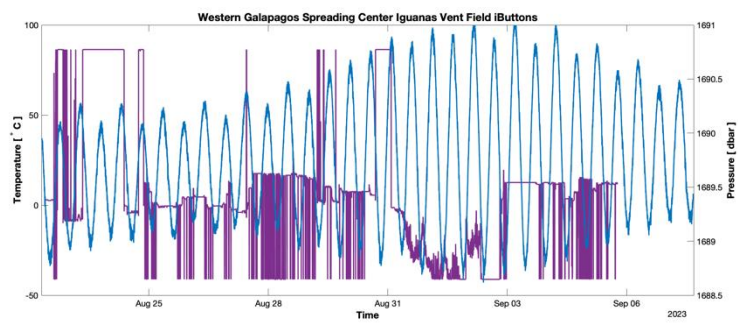


Western Galapagos Spreading Center Iguanas Vent Field Tilt Current Meters (TCM)

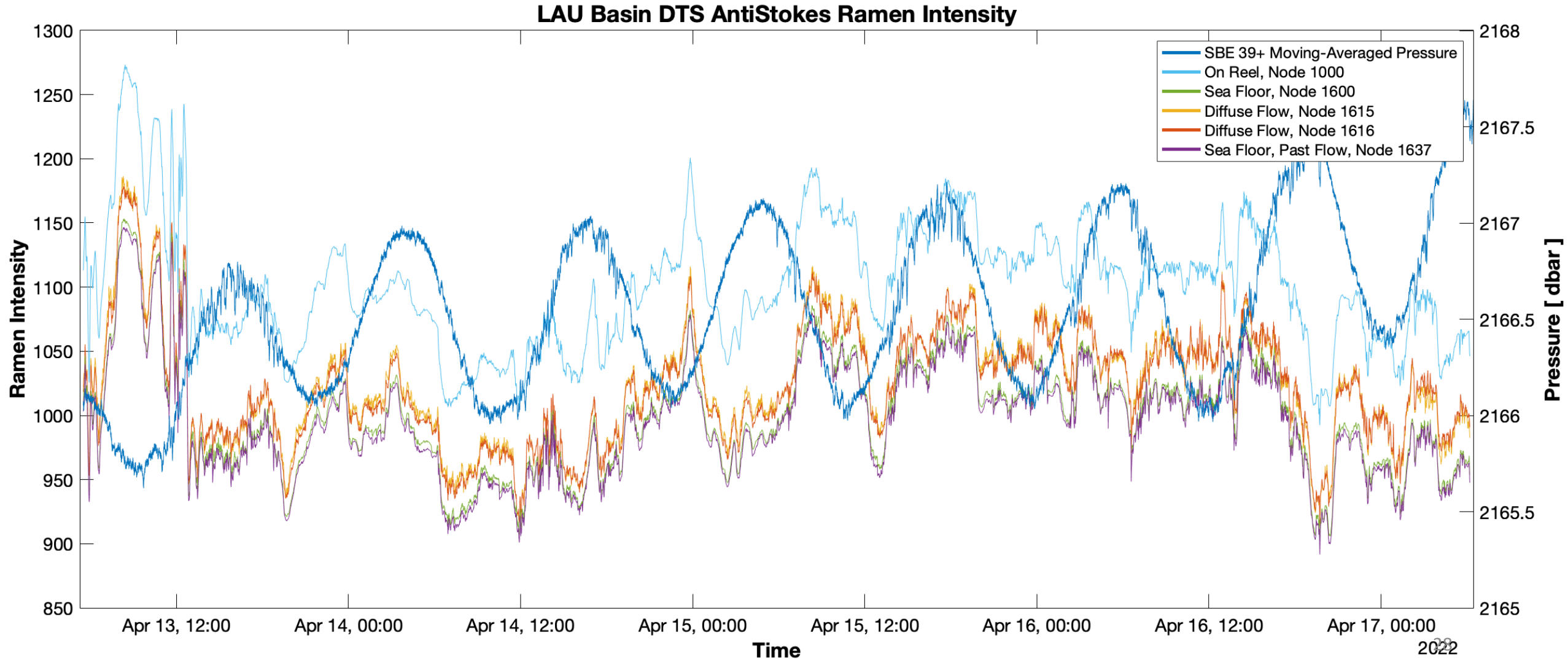


Western Galapagos Spreading Center Iguanas Vent Field Tilt Current Meters (TCM)





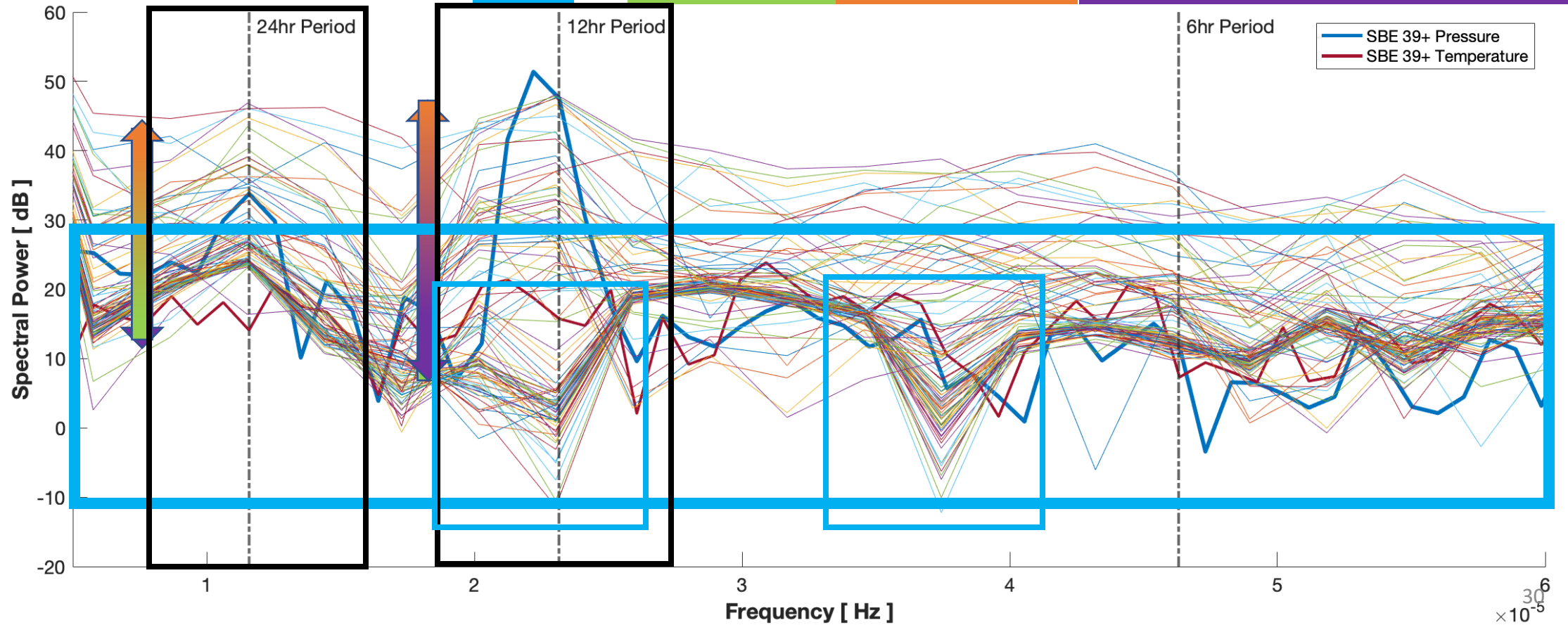
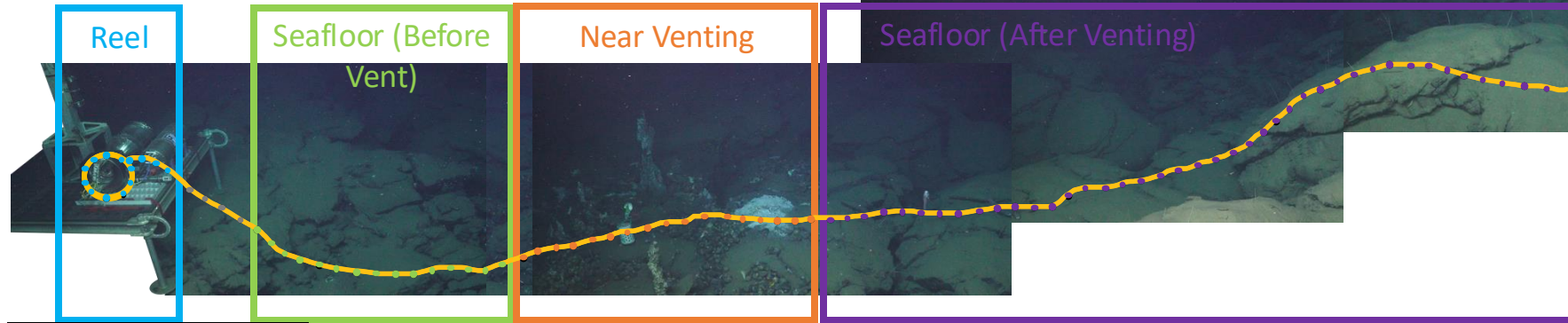
# Appendix 1: Anti-Stokes



## Appendix 2: Temperature Calculation from Raman Scattering

$$T(z) = \frac{\gamma}{K - \Delta\alpha \cdot z - \ln\left(\frac{I_s(z)}{I_{aS}(z)}\right)}$$

# Tidal correlation was found to increase near venting area



# Appendix 3: Measured Tidal Variation v. Predicted Tidal Variation

