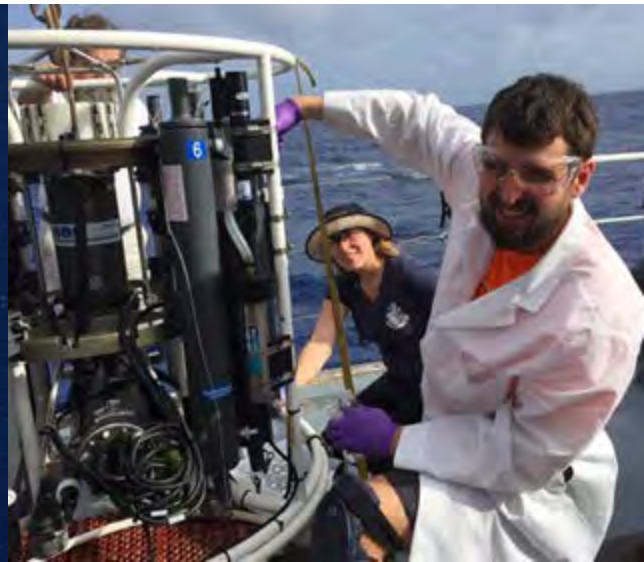
Technology and Methodology Development

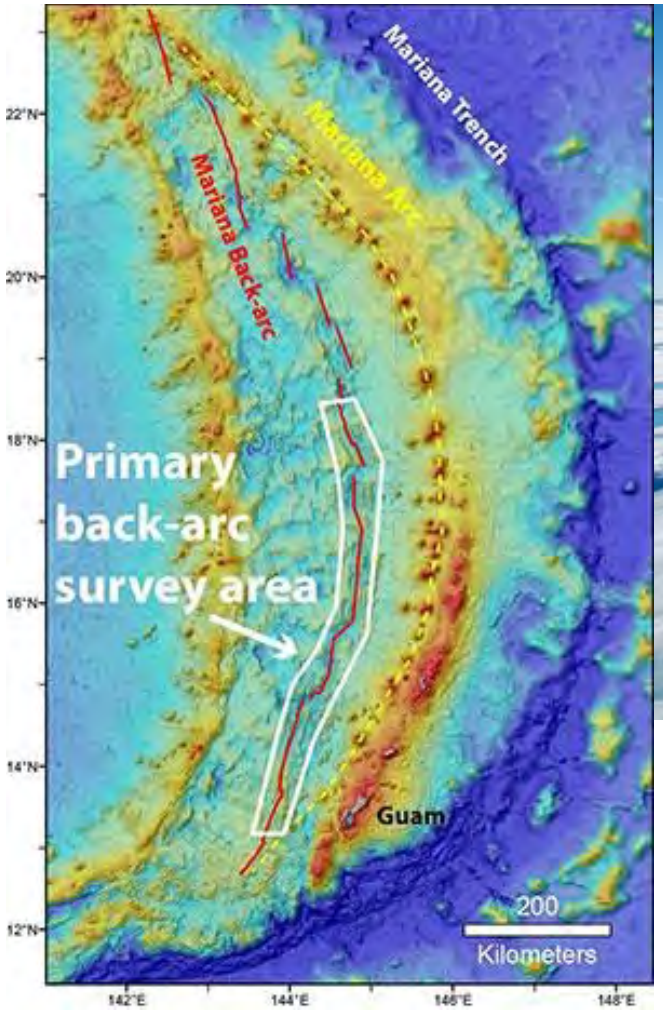
Steve Hammond, PhD
Senior Science Advisor

Technology Innovation, Application, and Program Use

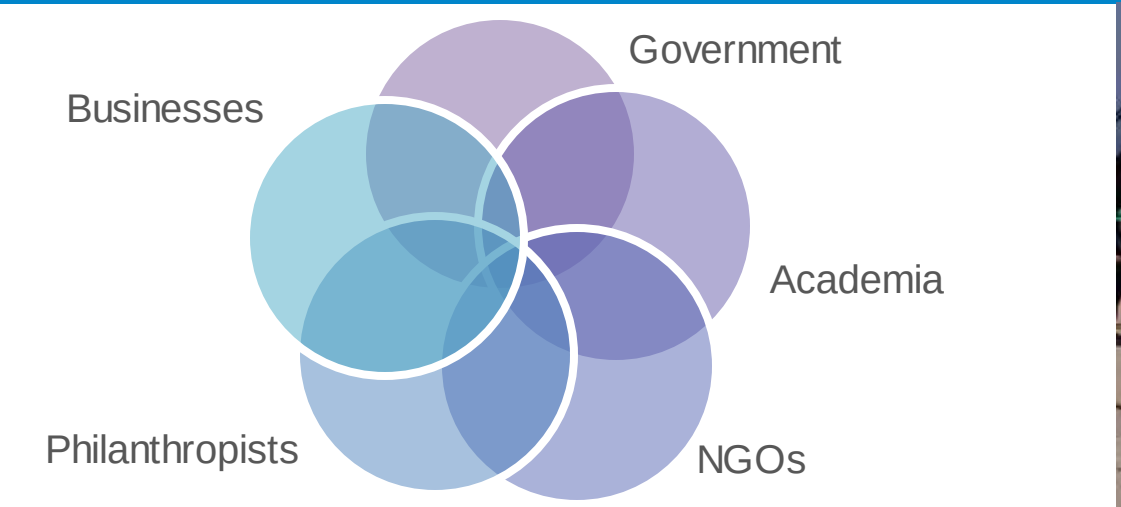
- Evolving technology innovation and development
- Evolving the scope of ocean exploration
- Enabling means for observations and sampling

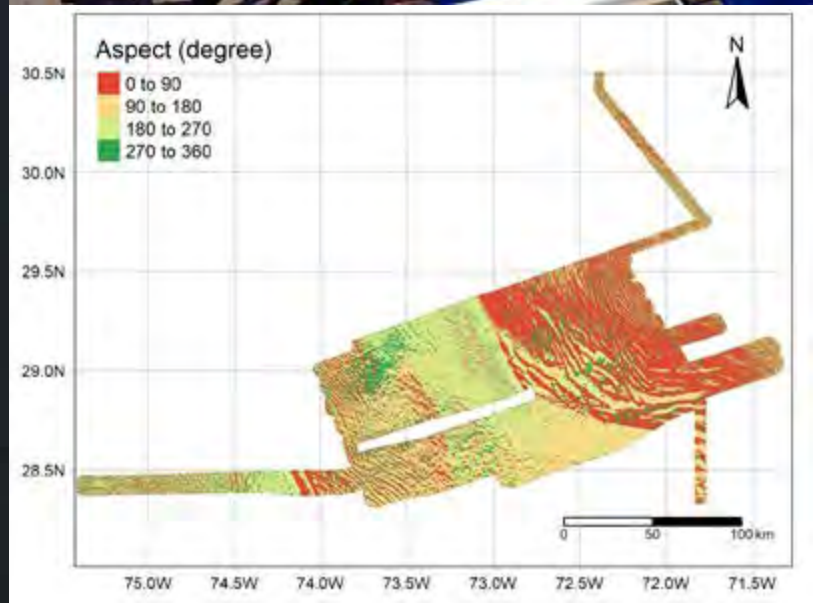


OER Competitive Grants Program Impacts



Evolving OER's Abilities to Explore and Characterize the Ocean





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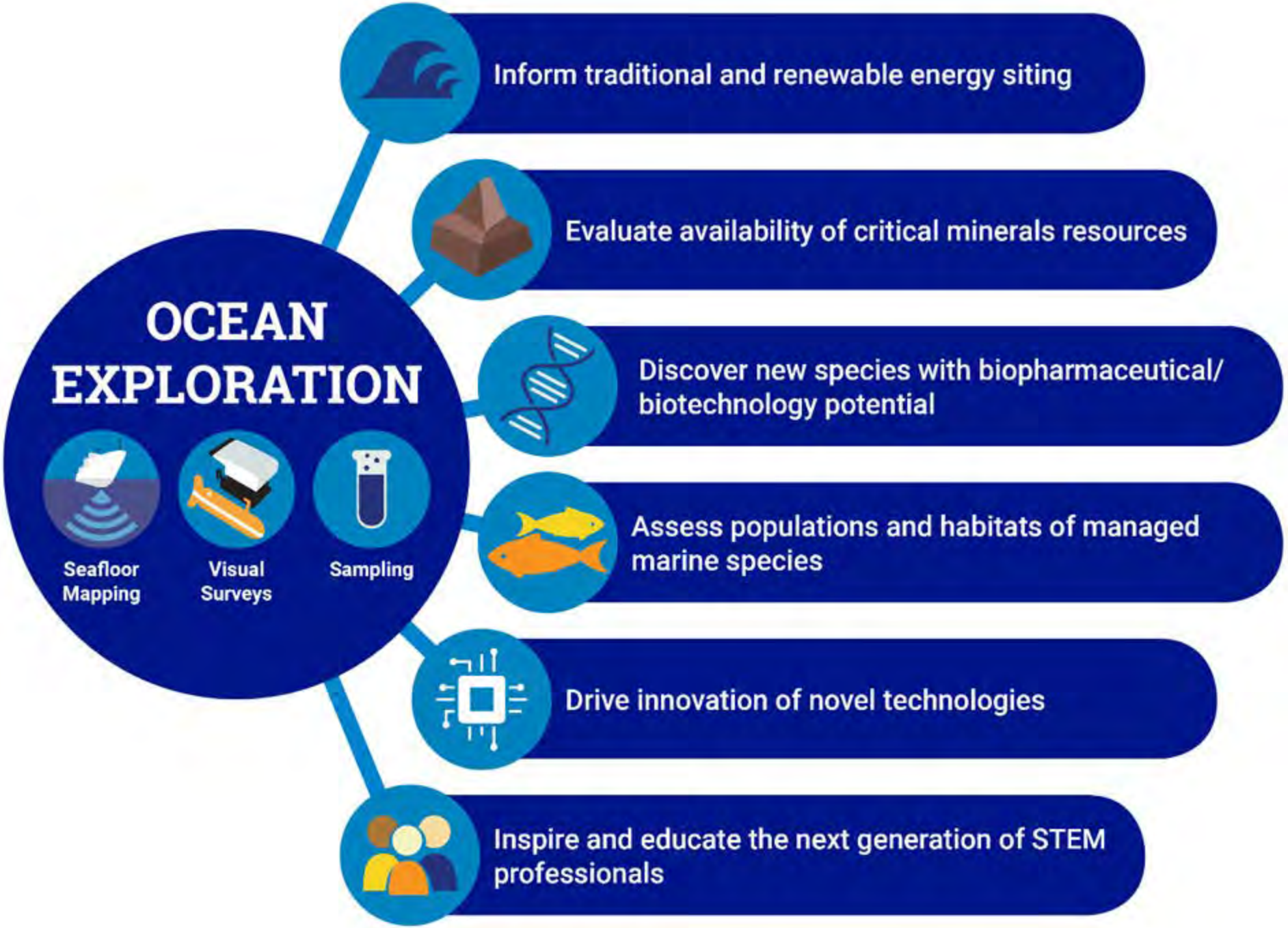
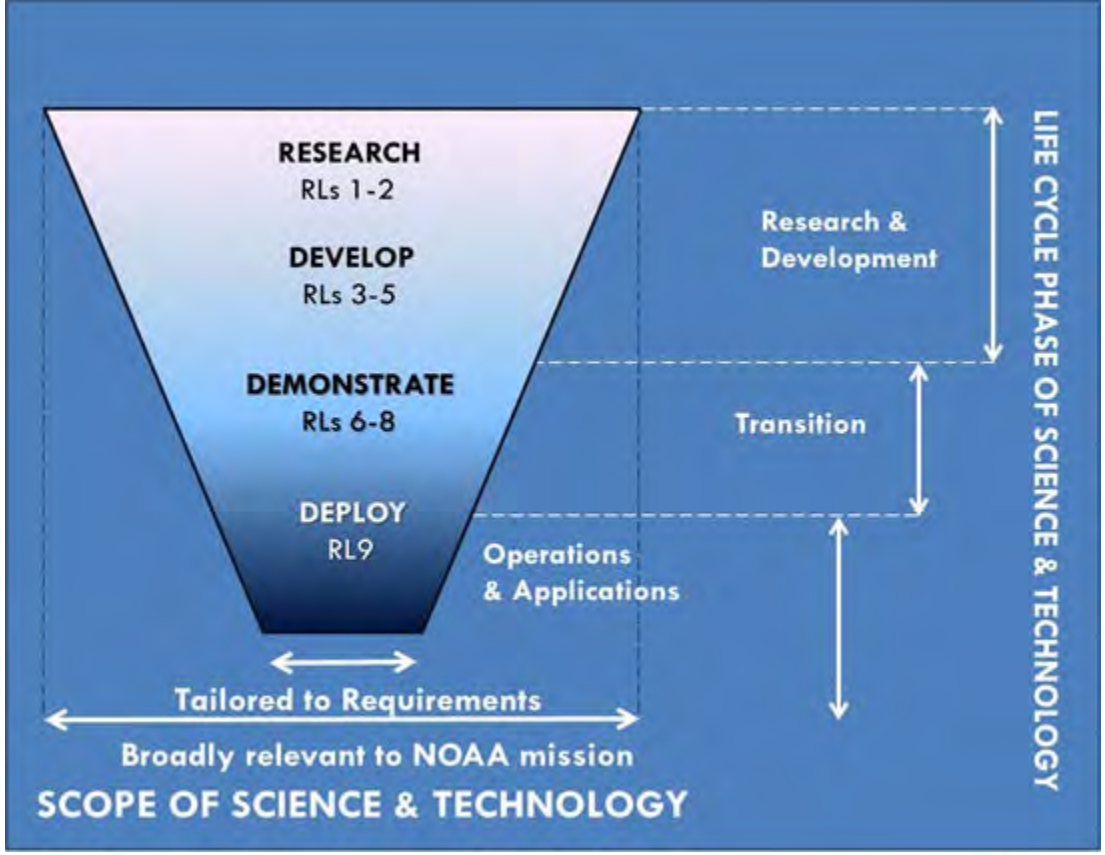
Ocean Exploration and Research

Advancing Technologies for Exploration

Chris Beaverson
Science and Technology Division


OCEAN EXPLORATION
Seafloor Mapping
Visual Surveys
Sampling
Inform traditional and renewable energy siting
Evaluate availability of critical minerals resources
Discover new species with biopharmaceutical/ biotechnology potential
Assess populations and habitats of managed marine species
Drive innovation of novel technologies
Inspire and educate the next generation of STEM professionals


RESEARCH
RLs 1-2
DEVELOP
RLs 3-5
DEMONSTRATE
RLs 6-8
DEPLOY
RL9
Research &
Development
Transition
Operations
& Applications
LIFE CYCLE PHASE OF SCIENCE & TECHNOLOGY
Tailored to Requirements
Broadly relevant to NOAA mission
SCOPE OF SCIENCE & TECHNOLOGY


RESEARCH
NOAA
Private Sector
Universities
Agencies
TESTING &
EVALUATION
NOAA
Private Sector
Universities
Agencies
END USERS

Exploration Technology Priorities

Strategic approach

- Transfer of new exploration and undersea research technology into applications
- Focus on testing/transfer of TRL 6+ ocean exploration technology
- Encourage partnerships for expertise and cost-sharing

	Capability gaps
1	Advanced sampling techniques and sensors
2	Power/batteries
3	Telepresence-enabled exploration and research
4	Under-ice exploration and sampling
5	Hadal > 4000m exploration and sampling
6	Advanced video imaging and processing (3D, mosaic, recognition)
7	Undersea vehicle autonomy and swarm behavior
8	Telemetry (through-water data transmission)
9	Ocean exploration data management technology
10	Outreach and engagement pathways

OER Technology Investment Mechanisms

- Annual Federal Funding Opportunity
- Cooperative Agreements
  - Cooperative Institute for Ocean Exploration
  - Cooperative Institute for Ocean Exploration Research and Technology
  - Ocean Exploration Trust
  - Global Foundation for Ocean Exploration
- Interagency Partnerships – NOPP
- Cooperative Research and Development Agreements (CRADA)
- Small Business Incentive Research Program (SBIR)

Technology Investments

Community Assets

Nereid Under Ice, *Sentry*, NDSF

Innovative Tools

Sensors, Platform applications

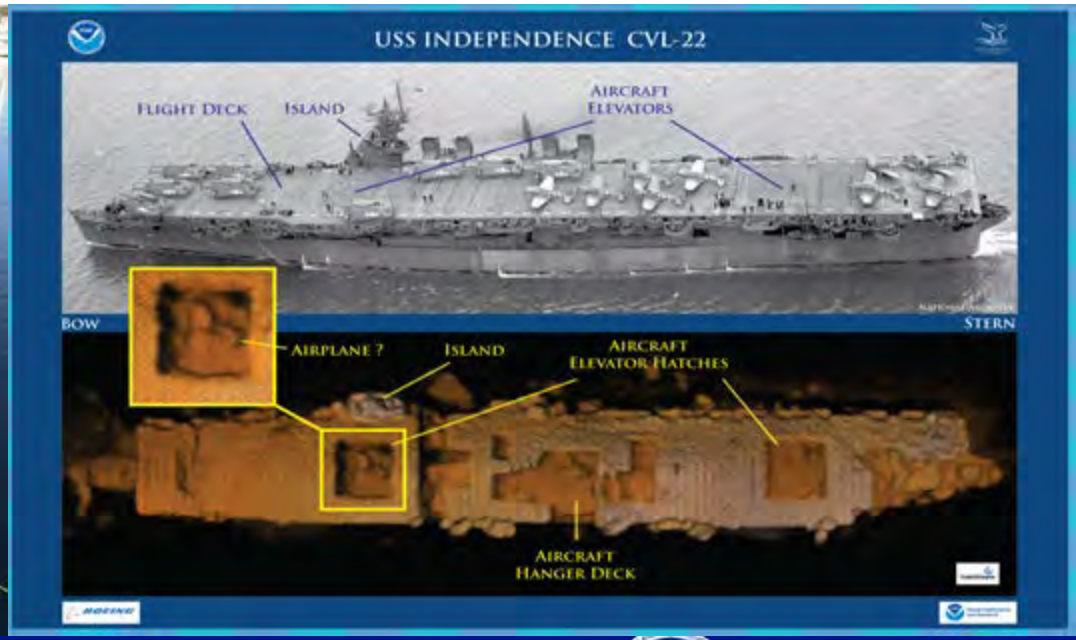
Methods

Data Analysis, Visualization

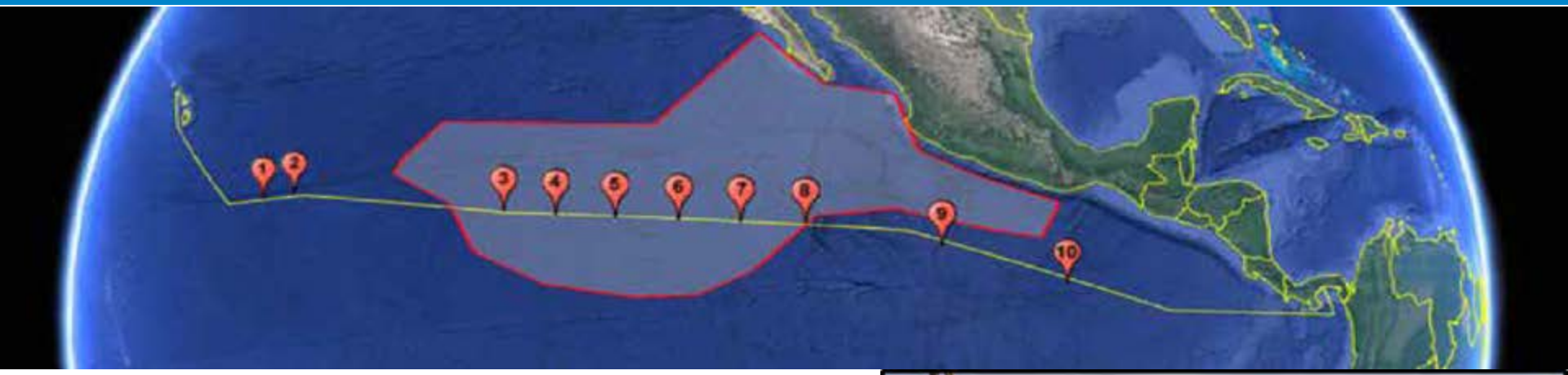
AUV Demonstration

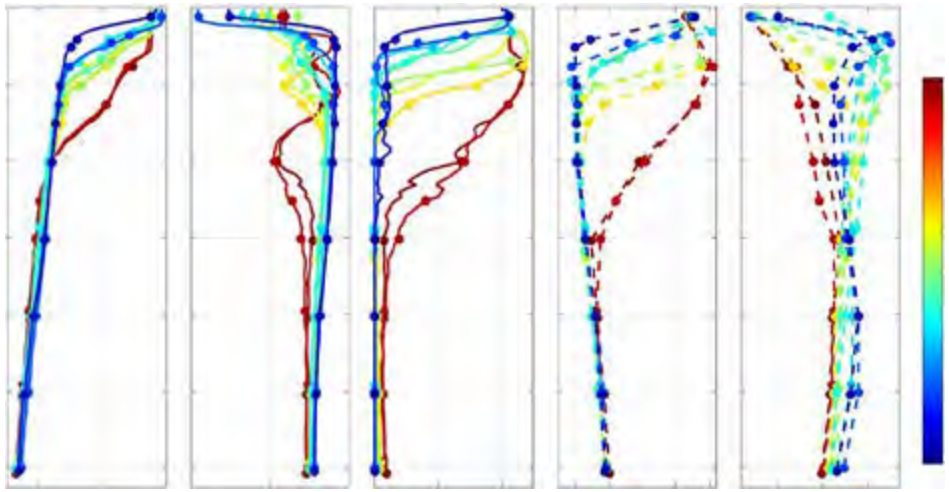
OER /Sanctuaries/ BOEING / Coda Octopus USS *Independence*

- CRADA
- Multi-partnership

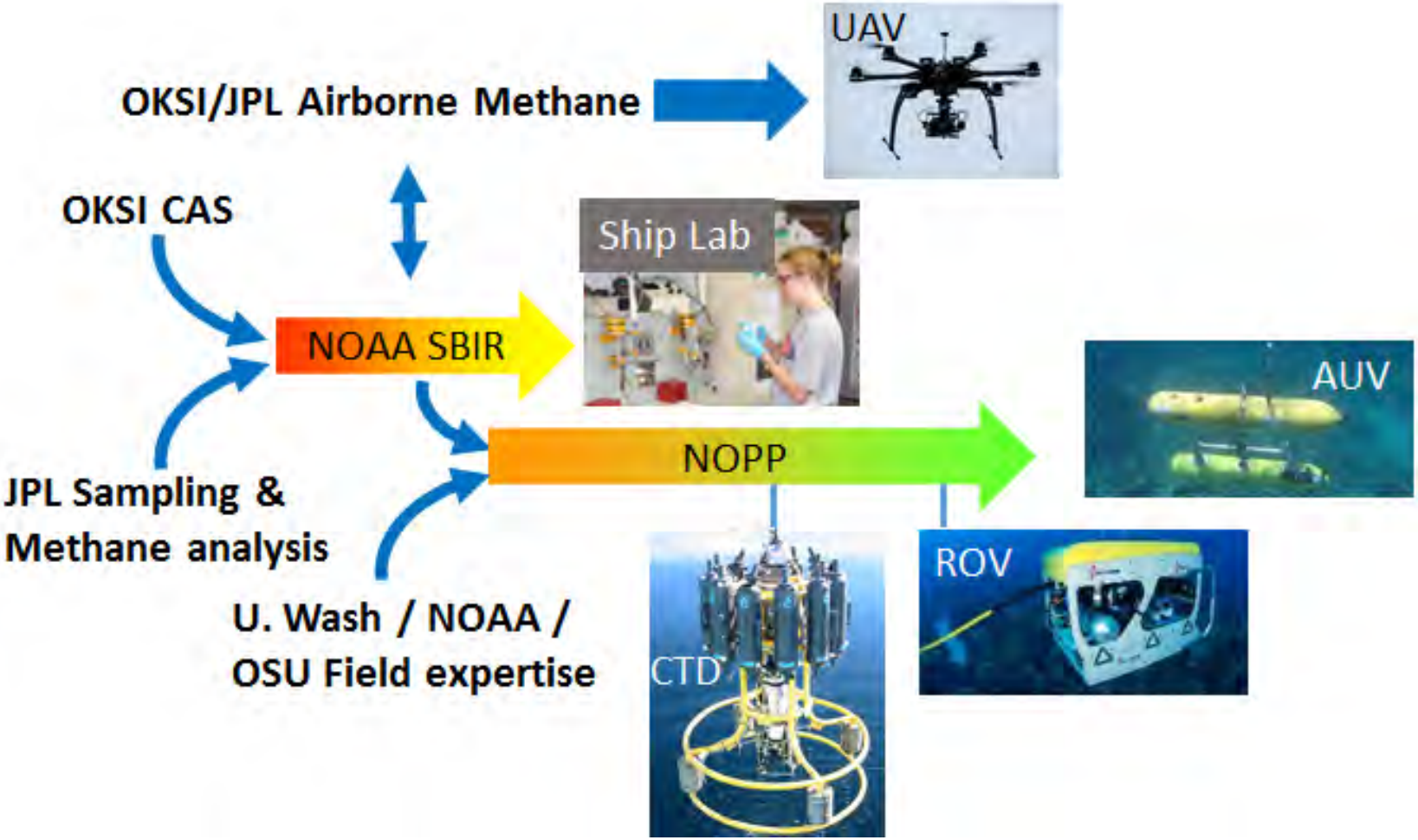


Nitrogen Sensor





Isotopic Methane Sensor



Prize Incentive

Ocean Mapping XPRIZE - NOAA $1M Bonus Prize

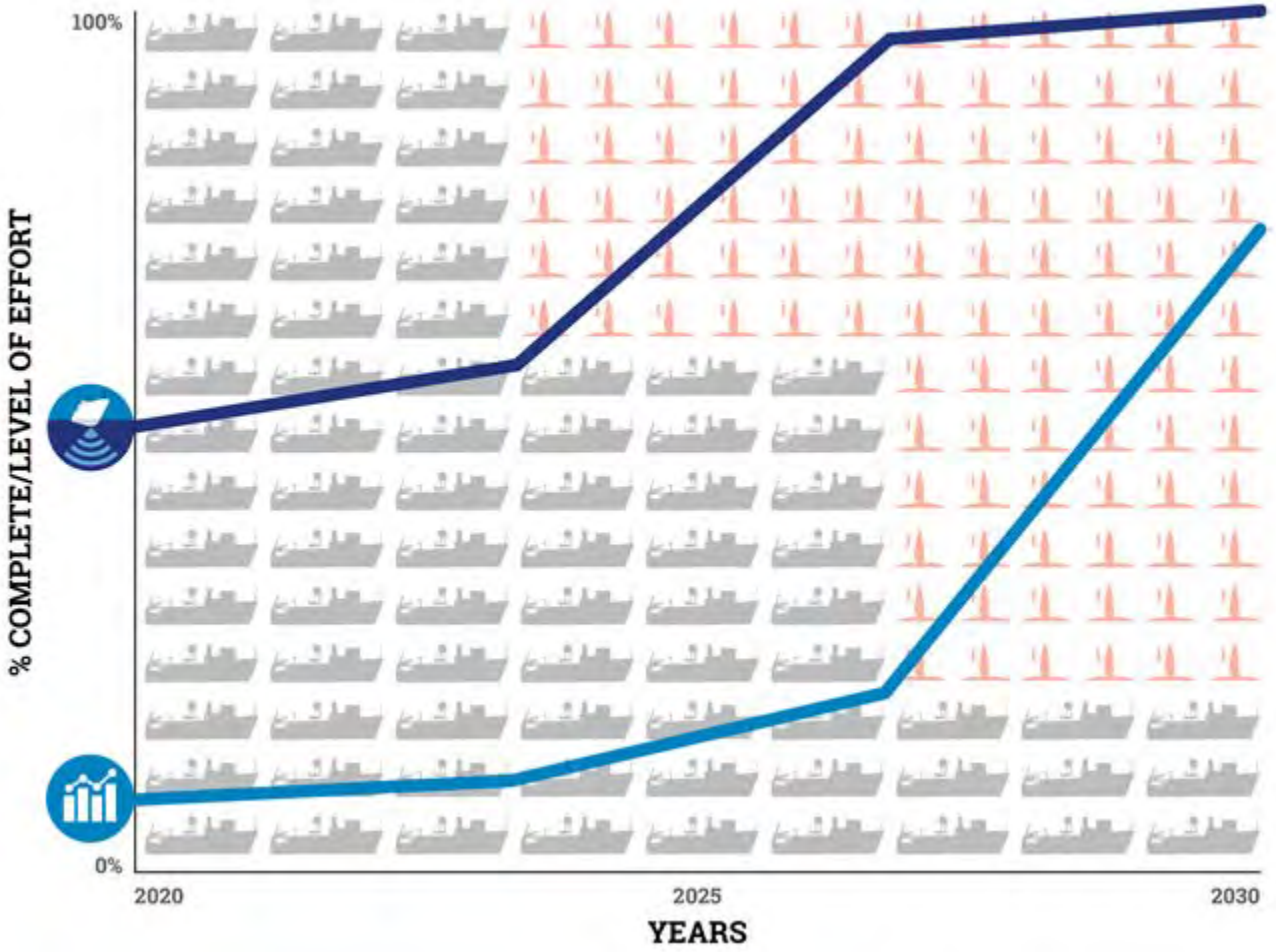
National Ocean Partnership Program

- NOPP Broad Agency Announcement (BAA)
  - ONR leads BAA process; Contributes $6-8M
  - NOPP Agencies define solicitation topics
  - Partners bring money or other resources
- NOPP Agencies Partner Outside BAA Process
  - Partners agree on projects and level/type of support
  - Partners are generally federal and non-federal

Autonomous systems to get us there

Mapping

Characterization

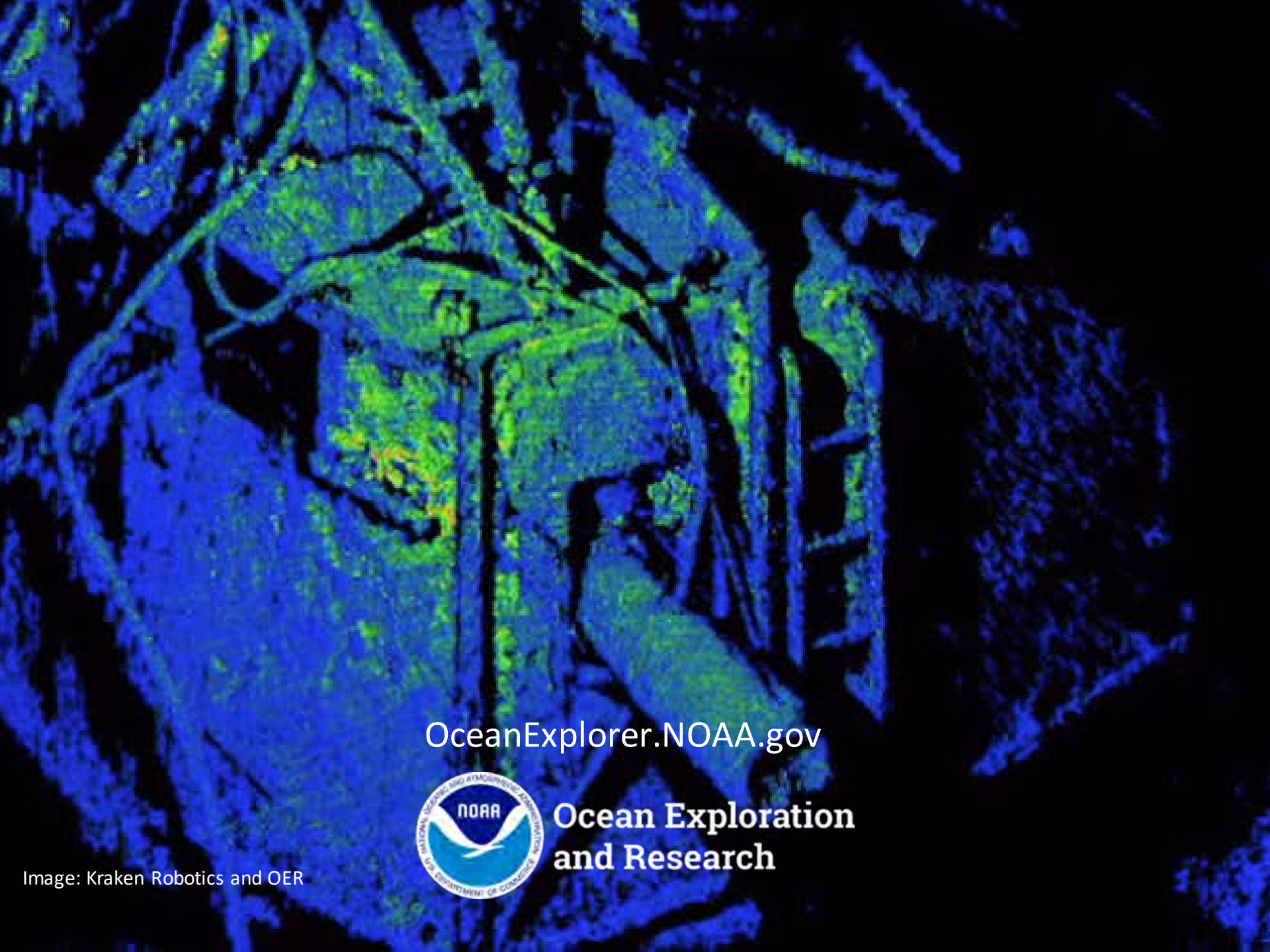


FY19 Autonomous Mapping Awards

NOPP National Oceanographic Partnership Program

$3M advancing autonomous mapping in the deep ocean

- OER leveraged $1.5M of OAR NOPP funds
- 3 awards, three different platform types



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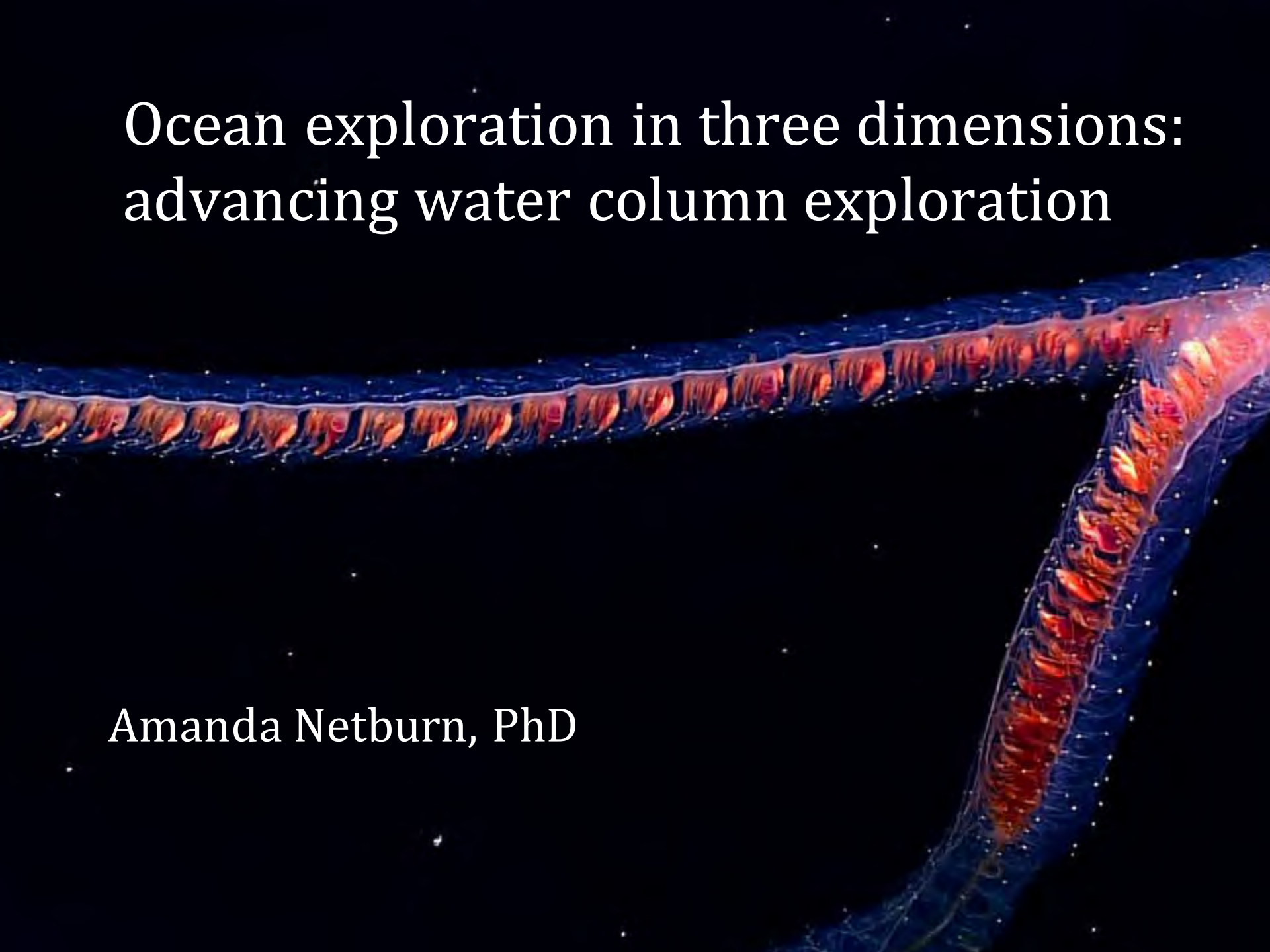
Ocean Exploration and Research

Image: Kraken Robotics and OER

Ocean exploration in three dimensions: advancing water column exploration



Amanda Netburn, PhD

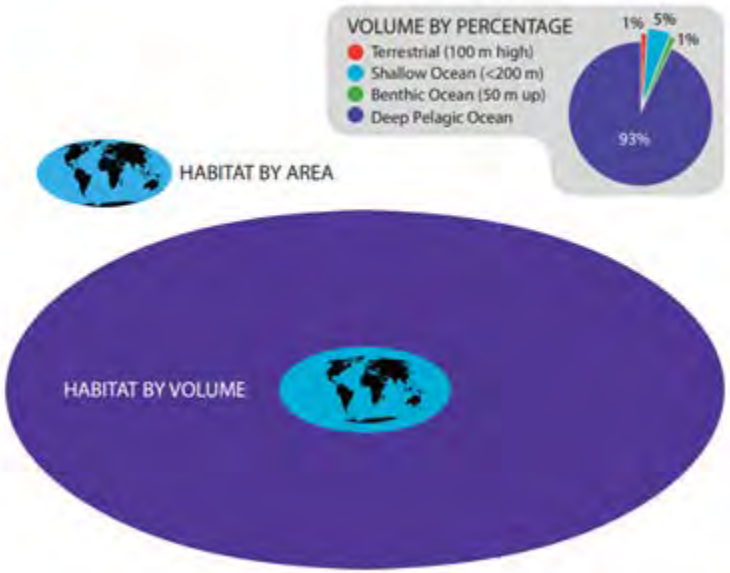
Water column identified as gap

OE early focus on seafloor geology and biology

2013 and 2015 OE forums: water column identified as gap in program

Why explore the water column?

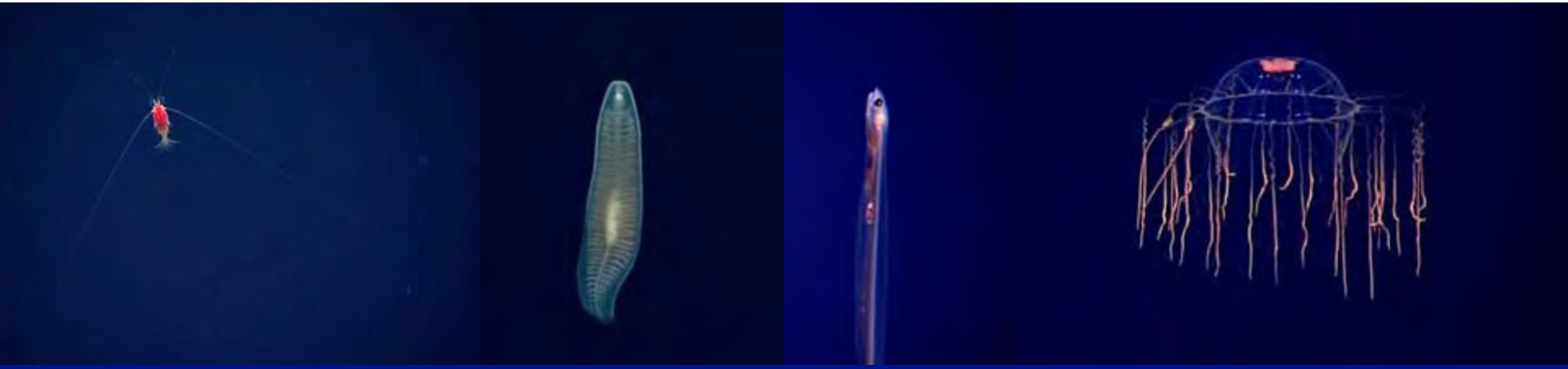
- Largest inhabitable volume on the planet for multicellular life
- Important to: marine food webs, carbon sequestration, nutrient cycles, heat transfer



Haddock et al. 2017

Why explore the water column?

- Gelatinous animals and behaviors are poorly observed by traditional means (e.g., trawls)
- Observations are rare throughout most of the ocean

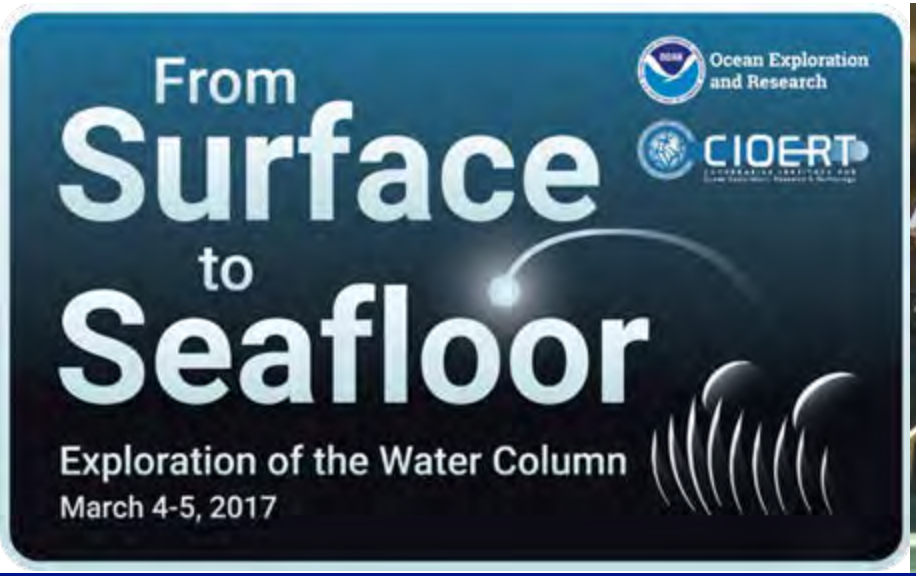


2017 Water Column Workshop

47 participants

25 institutions and programs

Multidisciplinary and international



Workshop Outcomes

1. Review of past efforts
2. Identified unanswered questions
3. Recommendations
    a. Geographic priorities
    b. Community building
    c. Opportunistic data collection
    d. Technology development- Animals as sensor platforms and as sensors, Moorings for long-term monitoring (temporal recon), Autonomous systems to cover ground

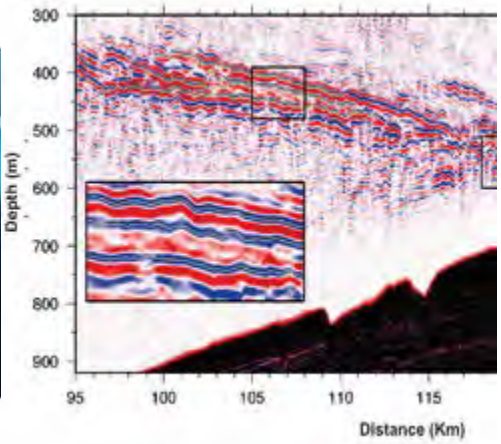
Recommendations: Use a "Toolbox"

	Measurement	Platform/Sensor/Sample Type Required
Physical/Chemical		
First tier	Basic Hydrography- temperature, density, salinity, oxygen	CTD with oxygen sensor
	Chla Fluorescence	Fluorometer
	Bathymetry	Multibeam sonar (1st), Side Scan sonar (2nd)
	Irradiance/Light scattering	Light scattering sensor
	Light Transmission	Transmissometer
	Ocean color, SSH, temp, etc.	Imaging satellites
Second tier	Macro- and micronutrients/metals	Water
	DIC, POC/POM, pH/alkalinity	Water
	Dissolved gases	Water
	Currents	Acoustic Doppler Current Profiler (ADCP)
	Methane	Water
	Hydrogen	Water
	Resuspended sediment	Video, Water, Transmissometer
	Small-scale turbulence	Aquadopp® Profiler
Biological - single cell		
First tier	Genomics	Water, Tissue samples
	Single-cell imaging/sorting	Flow Cytometer
Second tier	ChlA/accessory pigments	Water
	Biological rates	Water
Biological - multicellular		
First tier	Specimens for physiology, morphological ids, genomics	Net trawls (mult. sizes), including optical tools
		ROV for fragile organisms
	In situ imaging	ROV, AUV (e.g., i2MAP), Low-light imaging, Microscopy
		Video Plankton Recorder, In Situ Ichthyoplankton Imaging System
	High resolution biological "mapping"	Active acoustics
	Bulk biodiversity	eDNA/Metabarcoding- from split net tow and water samples
Second tier	Food web analysis	Animal specimens (ROVs, nets)
	Biological rates	Animal specimens (ROVs, nets)
	Tracking of large animals	Hydrophone, Surface observations (megafauna)
	Bioluminescence	Splat screen, Low light camera, Photometers
	In situ responses	In situ experiments- light, metabolism, predation, flux

Competitive grants – Water column theme (FY17)

Journey into Midnight: Light & Life Below the Twilight Zone

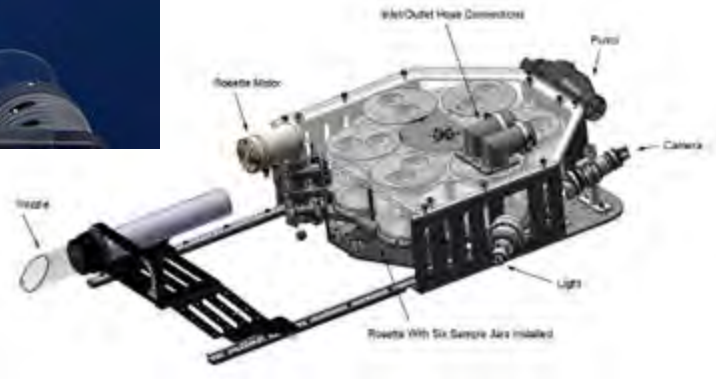
3D "Seismic Oceanography": The New Frontier in Ocean Water-Column Exploration



Integrating Echosounding into the Wire Flyer Profiling Vehicle

Exploratory water column ROV transects

- 2013 - first midwater ROV survey on *Okeanos*
- Now typically 3-5 sites per expedition
- New capability to collect midwater animals



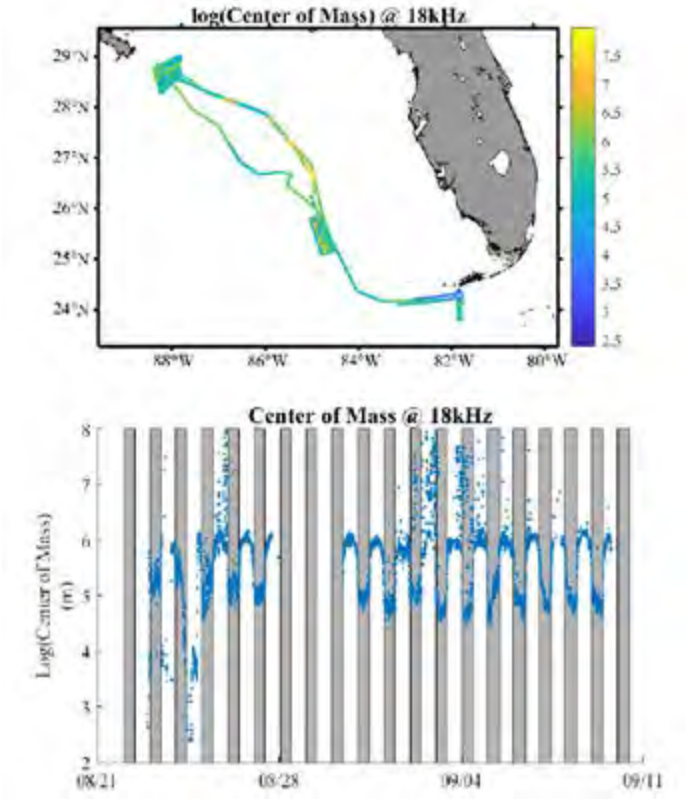
Ocean Exploration and Research

NOAA Ship *Okeanos Explorer* EK60 Optimization Workshop (Sept. '17)

Recommendations & Outcomes:

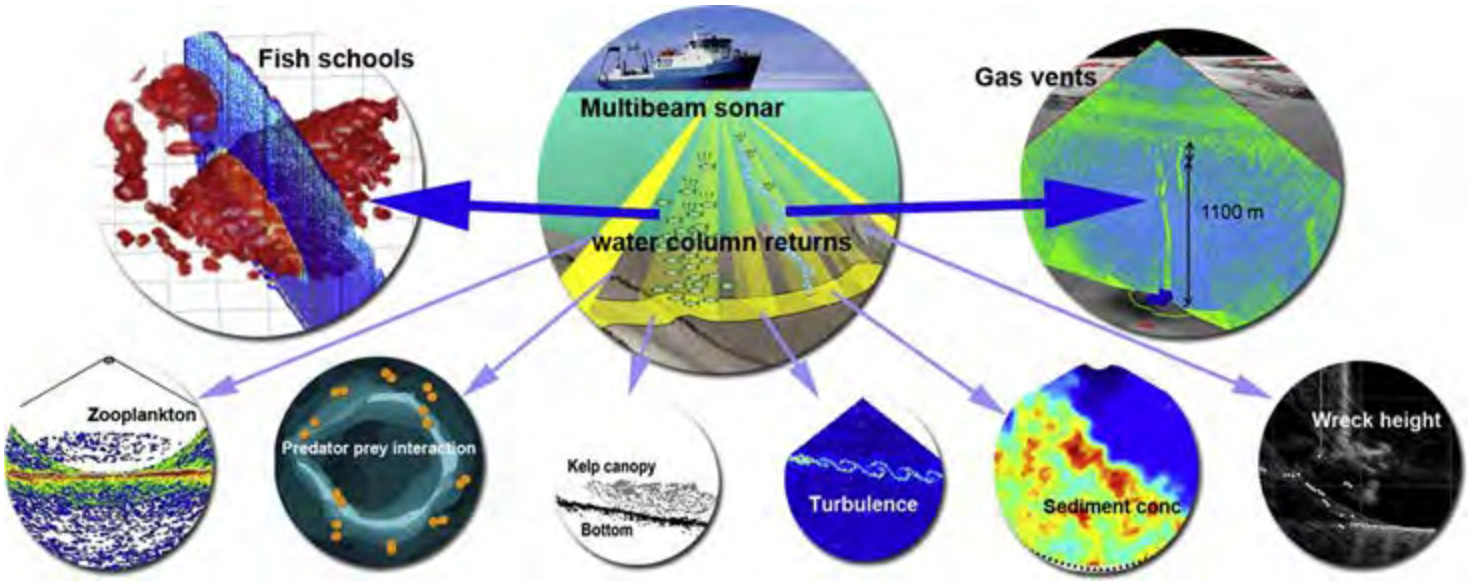
- Calibrate based on fisheries standards
- Solicit input for water column surveys in expedition planning
- NCEI partnership for data visualization

NATIONAL CENTERS FOR ENVIRONMENTAL INFORMATION



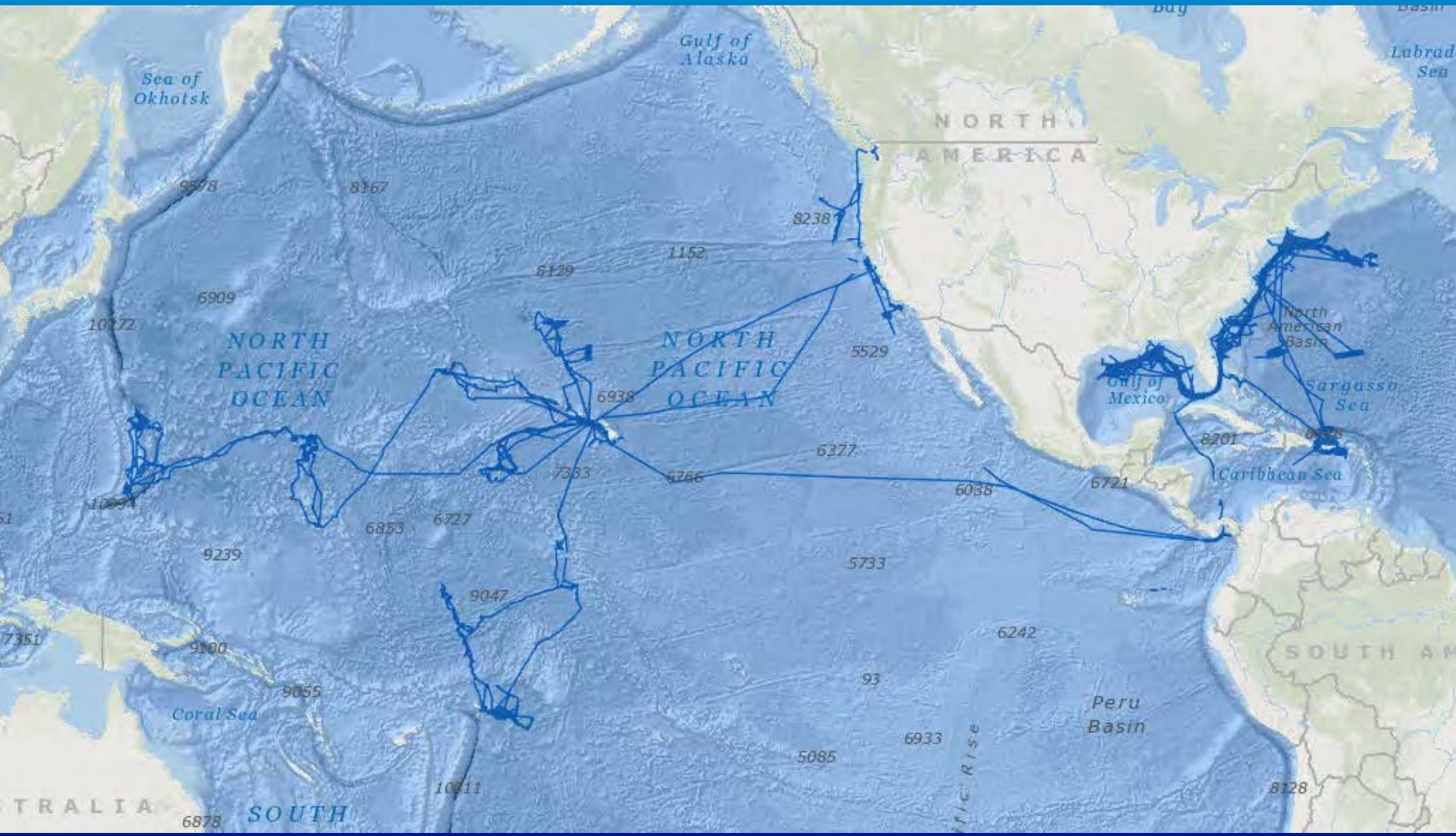
NOAA Ship *Okeanos Explorer* water column sonar

- Simrad EK60/EK80: GPTs (18, 120, 200 kHz) and WBTs (38 and 70 kHz)
- Kongsberg EM302 Multibeam



Calbo et al. 2014

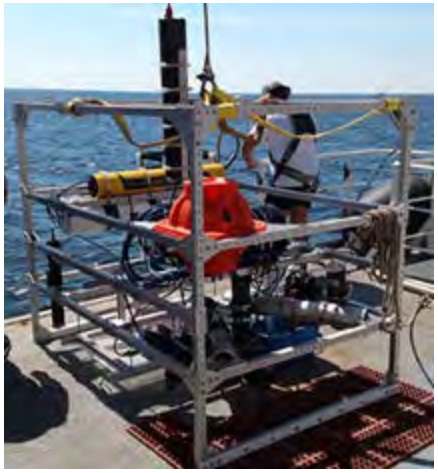
>8 TB water column sonar data in data archive

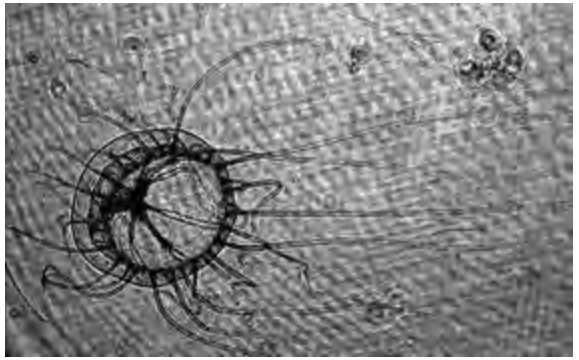


Okeanos Explorer Technology Demonstration

- Spring 2018 in the Gulf of Mexico
- CIOERT/FAU Midwater Profiler
- Multi-scale imaging/acoustics

CIOERT
COOPERATIVE INSTITUTE FOR Ocean Exploration, Research & Technology

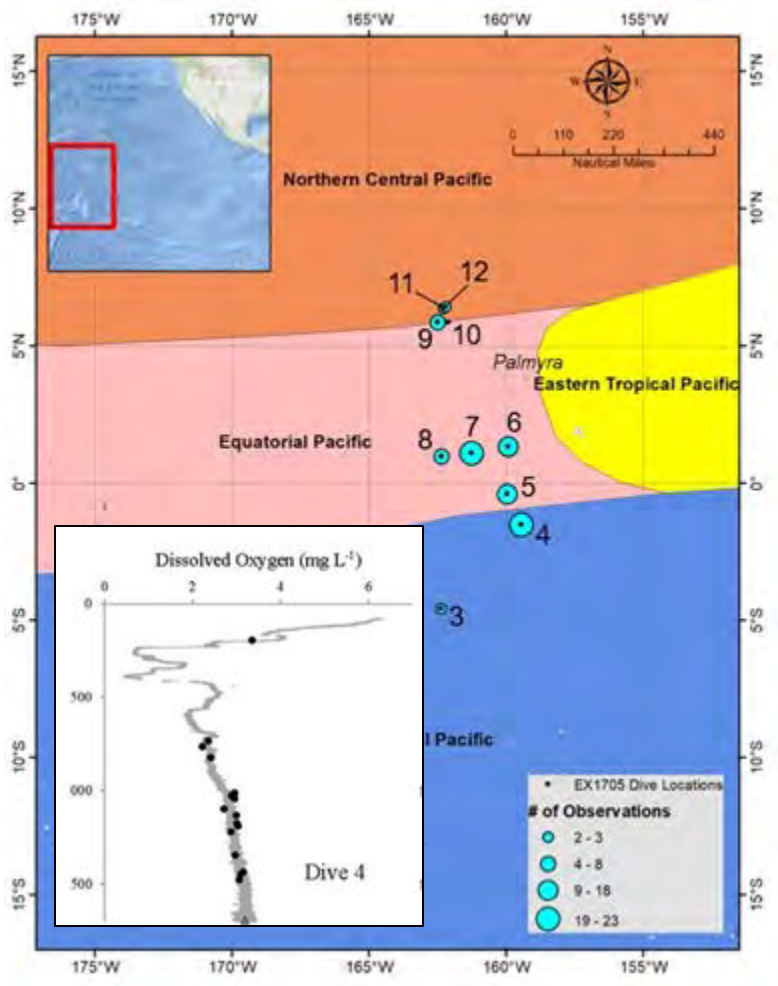




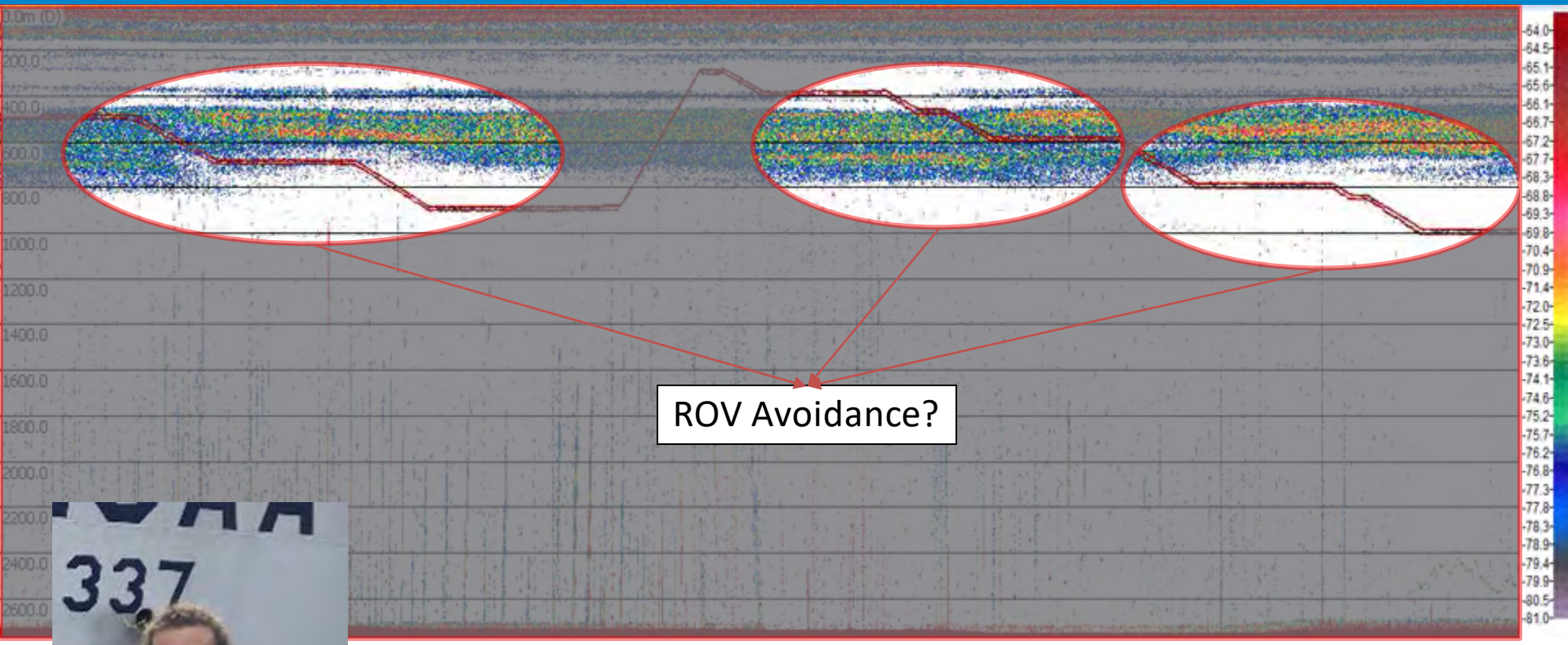
Data Synthesis

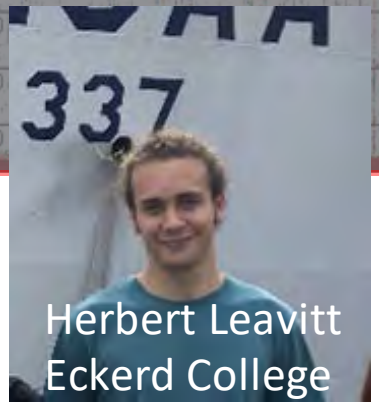
- EPP/MSI Scholar -2018
- Distributions of *Pelagothuria* in the central Pacific ocean

Gina Selig
U. HI Hilo



ROV Avoidance





- 2018 Hollings Scholar

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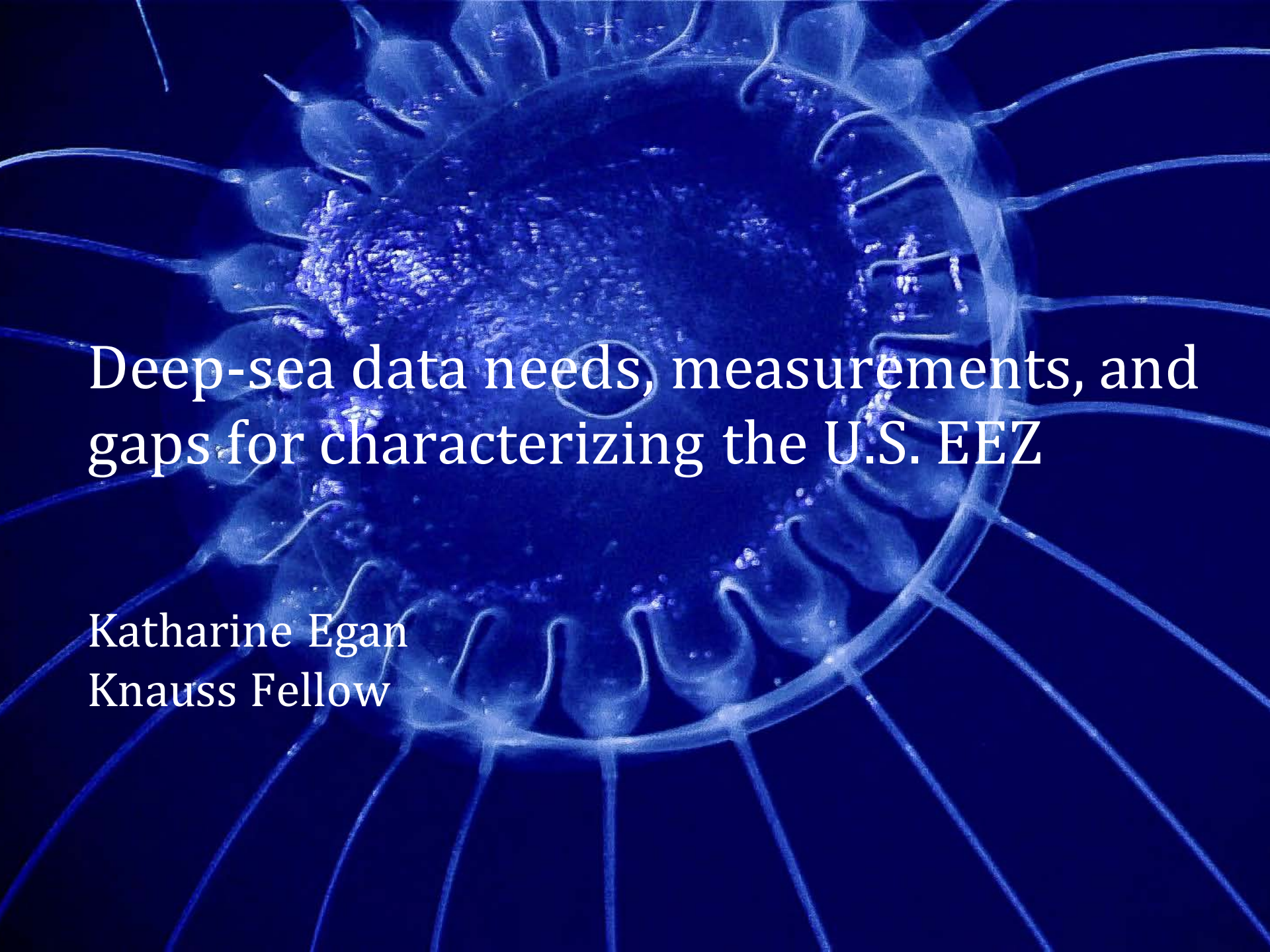
and Research



Deep-sea data needs, measurements, and gaps for characterizing the U.S. EEZ

Katharine Egan
Knauss Fellow

ROV OPERATIONS

		HD VIDEO WITH LASERS FOR SCALE	ANNOTATIONS	DIVE SUMMARY FORM	DIVE PLANNING FORM	PRIMARY BIOLOGICAL SAMPLES	PRIMARY ROCK SAMPLES	ASSOCIATED BIOLOGICAL SAMPLES	ROV NAVIGATION	CTD	TURBIDITY & OXIDATION REDUCTION POTENTIAL
FREQUENCY OF OPERATION		ROV cruises only	ROV cruises only	ROV cruises only	ROV cruises only	ROV cruises only	ROV cruises only	ROV cruises only	ROV cruises only	ROV cruises only	ROV cruises only
COLLECTION RATE DURING OPERATION		continuous (turned off for close-up imaging)	variable	1/dive	1/dive	≤8/dive	≤3/dive	variable	1/sec	continuous	continuous
WATER COLUMN	BIOLOGICAL	X	X	X	X	X		X	X	X	X
	CHEMICAL/ PHYSICAL							X	X	X	X
SEAFLOOR/ SUB-SEAFLOOR	BIOLOGICAL	X	X	X	X	X	X		X	X	X
	CHEMICAL/ PHYSICAL	X		X			X		X	X	X
	GEOLOGICAL	X	X	X	X		X	X	X	X	X
	ARCHAEOLOGICAL	X	X	X	X	X			X	X	X

MAPPING OPERATIONS

		XBT	MULTIBEAM BATHYMETRY/ BACKSCATTER	SUBBOTTOM PROFILER	EK60/EK80
FREQUENCY OF OPERATION		every cruise	every cruise	every cruise	every cruise
COLLECTION RATE DURING OPERATION		2 - 6 hours	continuous	continuous	continuous (based on sonar frequency)
WATER COLUMN	BIOLOGICAL		X		X
	CHEMICAL/ PHYSICAL	X	X		X
SEAFLOOR/SUB-SEAFLOOR	BIOLOGICAL				
	CHEMICAL/ PHYSICAL		X	X	X
	GEOLOGICAL		X	X	X
	ARCHAEOLOGICAL		X	X	

CTD ROSETTE OPERATIONS

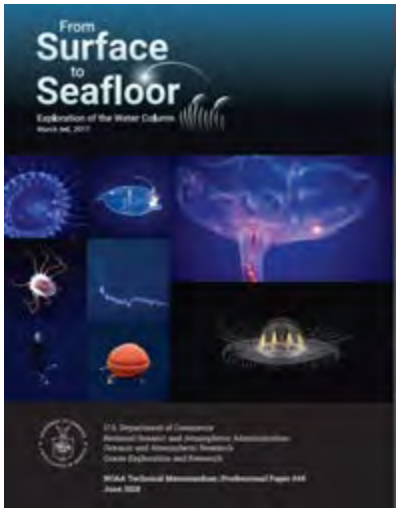
		CTD ROSETTE SUMMARY FORM	CTD-O	TURBIDITY & OXIDATION REDUCTION POTENTIAL AND FLUOROMETER	WATER SAMPLES
FREQUENCY OF OPERATION		if requested	if requested	if requested	if requested
COLLECTION RATE DURING OPERATION		1/cast	continuous	continuous	≤12/cast
WATER COLUMN	BIOLOGICAL		X	X	X
	CHEMICAL/ PHYSICAL	X	X	X	X

SHIP-BASED MEASUREMENTS

		METOC SENSORS	THERMOSALINOGRAPH	ADCP
FREQUENCY OF OPERATION		every cruise	every cruise	every ROV cruise; if requested on other cruises
COLLECTION RATE DURING OPERATION				every ROV dive; As request
ATMOSPHERE	BIOLOGICAL			
	CHEMICAL/ PHYSICAL	X	X	
WATER COLUMN	BIOLOGICAL			
	CHEMICAL/ PHYSICAL			X

Data Gaps - Identified through community recommendations

Literature review conducted of published community reports synthesizing deep-ocean data needs

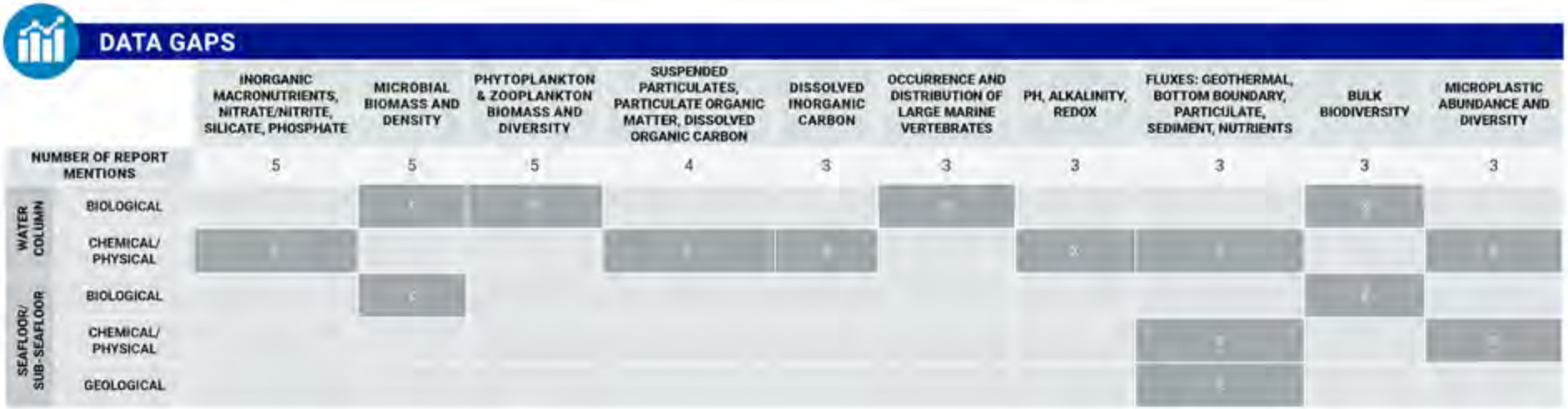


Data Gaps

- A list of observation types was compiled meeting the following criteria:
  - A deep-sea observation was identified as critical to measure
  - That measurement is not currently collected by OER
- Reports were also assessed for overlapping measurements (i.e. a measurement appeared in more than one report).

Data Gaps

- Total: **53 data gaps** identified
- Ten data gaps were identified in three or more community reports



Feasibility Assessment

- Used to evaluate the feasibility of incorporating new measurements, instruments, or processes into OER standard operations to fill data gaps

- Assessments are completed in consultation with experts in that field

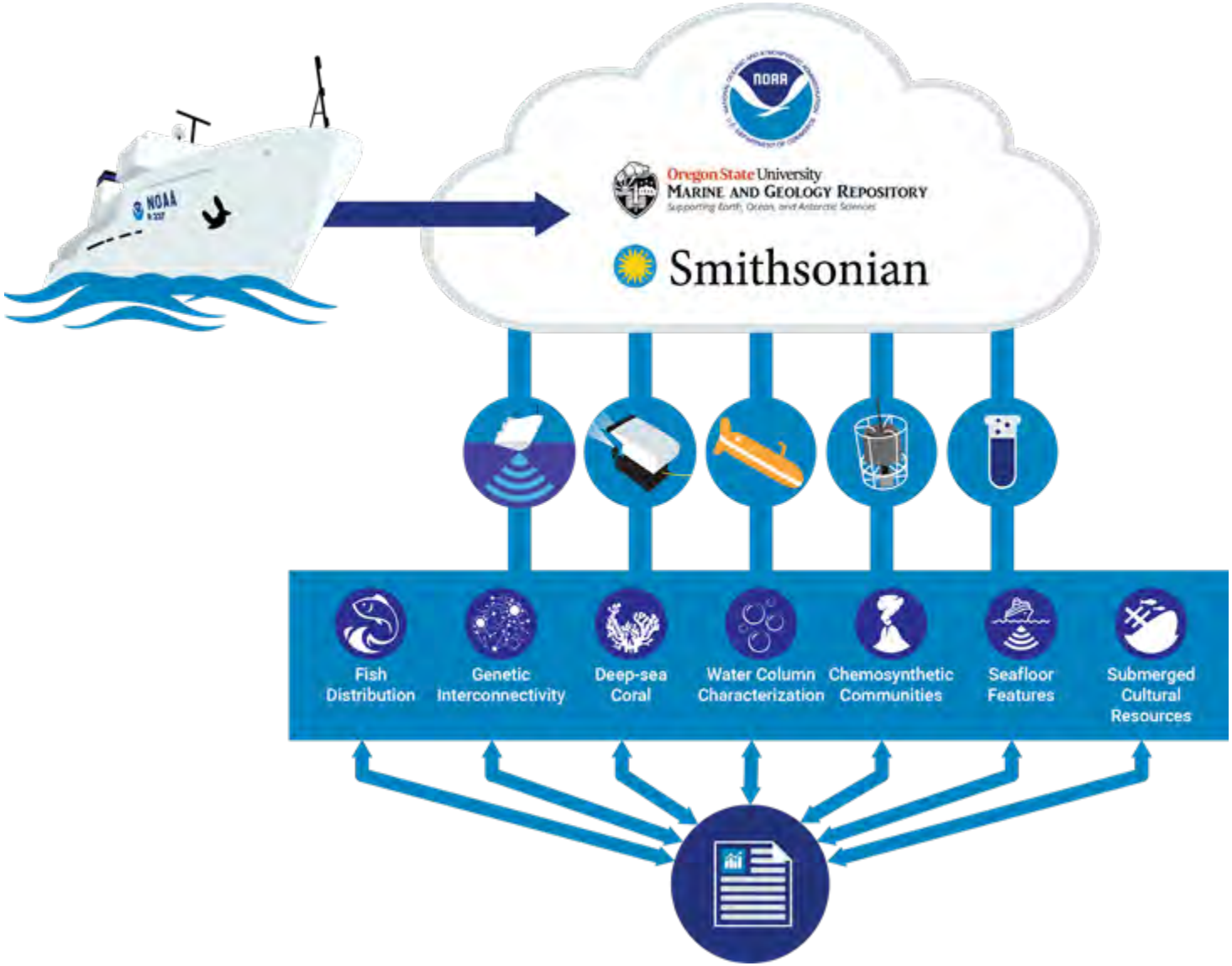
Feasibility Assessment

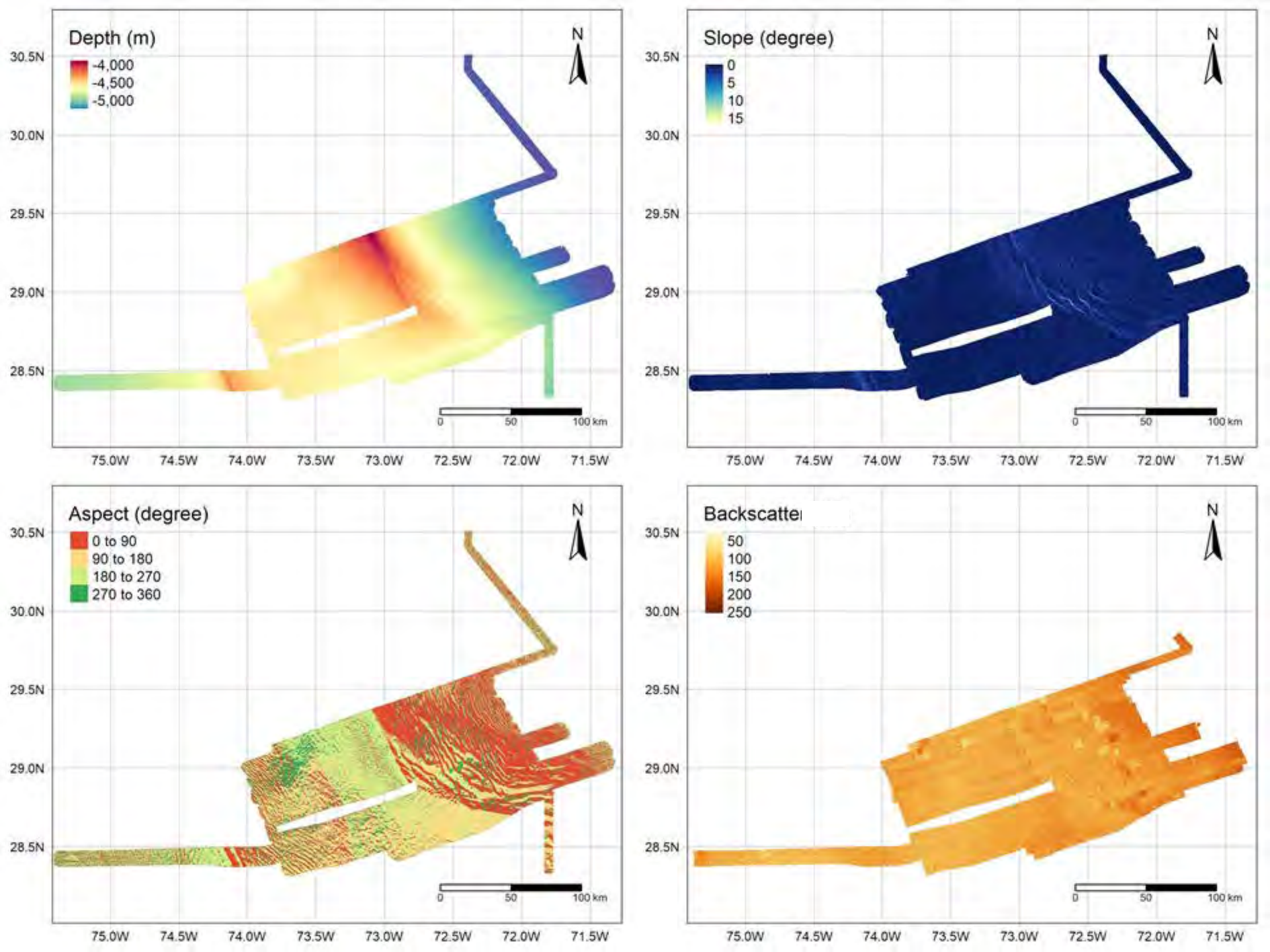
- Background and justification
- Relevance to NOAA and OER missions/strategic goals
- Materials
- Methods
- Cost
- Personnel
- Time
- Data management, processing, accessibility, summaries
- Permitting
- Environmental risk

Feasibility Assessment: eDNA

- Equipment to collect water samples and lab space on the EX is adequate for filtering samples.
- Personnel time and identifying a repository to store the samples or conduct the analysis remain challenges.
- Team is making recommendations based on the assessment.

Data Synthesis




Depth (m)
-4,000
-4,500
-5,000
N
30.5N
30.0N
29.5N
29.0N
28.5N
0
50
100 km
75.0W
74.5W
74.0W
73.5W
73.0W
72.5W
72.0W
71.5W
Slope (degree)
0
5
10
15
Aspect (degree)
0 to 90
90 to 180
180 to 270
270 to 360
Backscatte
50
100
150
200
250

Questions?

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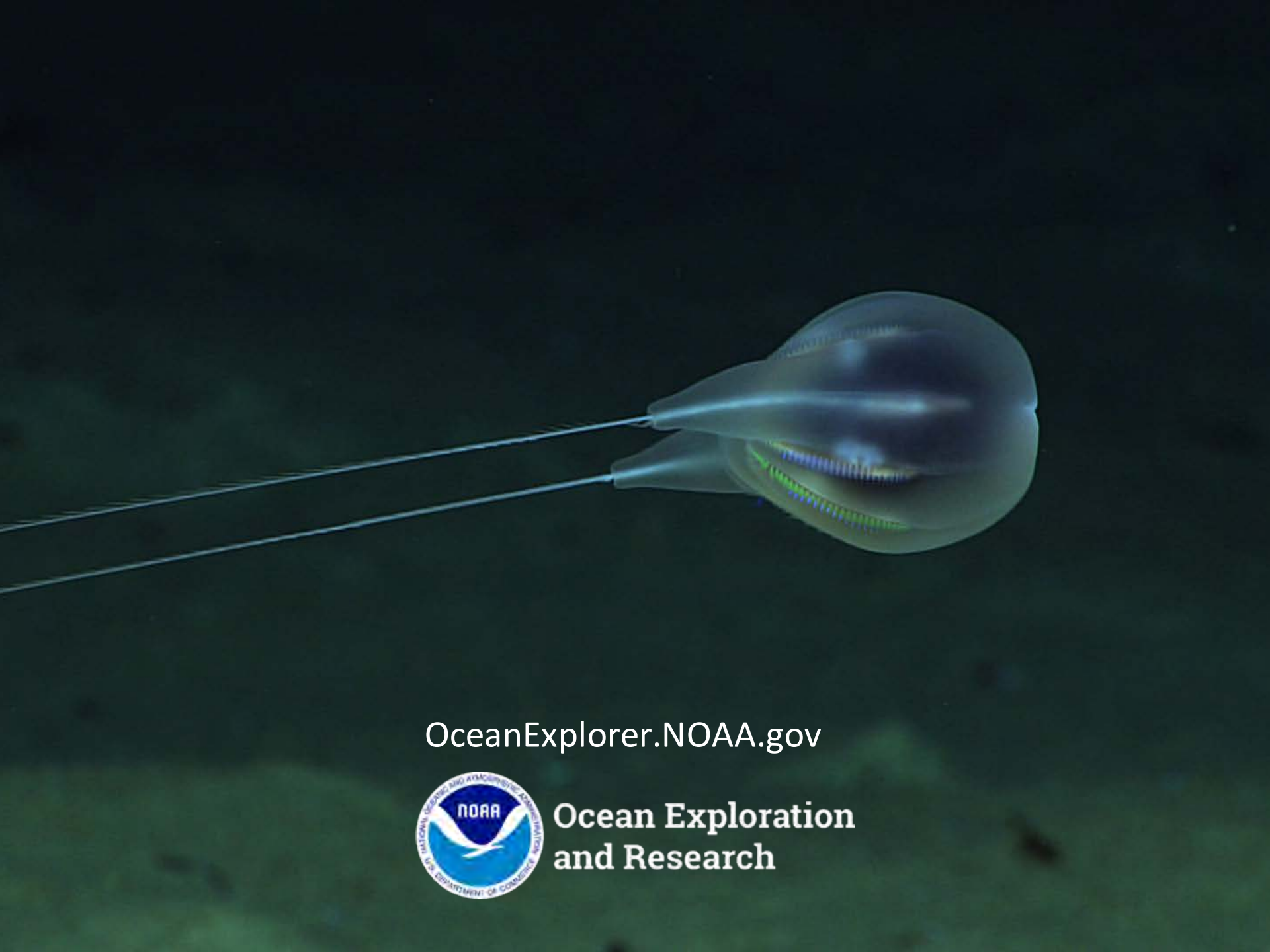

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and Research