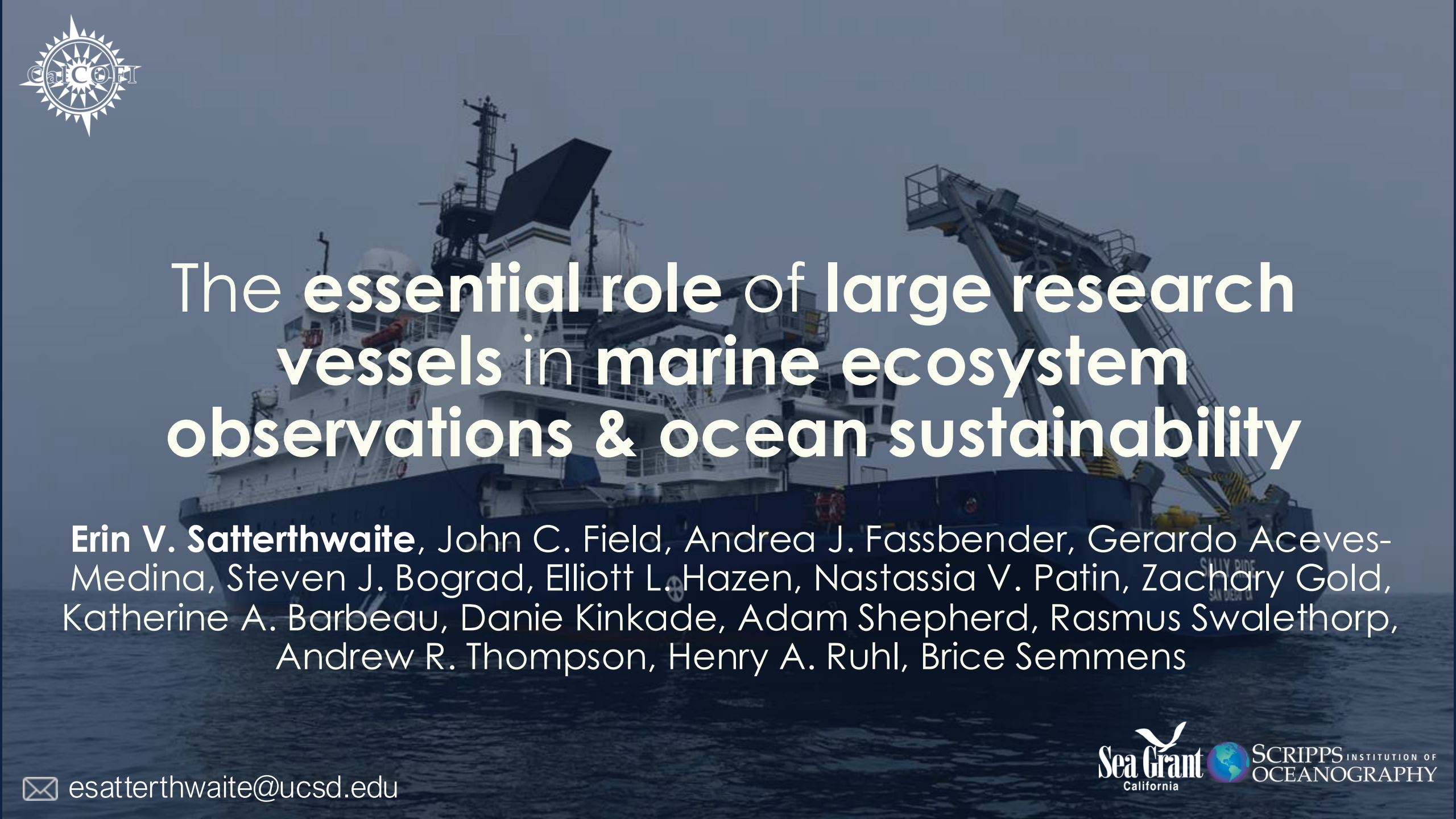

The **essential role** of **large research vessels** in **marine ecosystem observations & ocean sustainability**

Erin V. Satterthwaite, John C. Field, Andrea J. Fassbender, Gerardo Aceves-Medina, Steven J. Bograd, Elliott L. Hazen, Nastassia V. Patin, Zachary Gold, Katherine A. Barbeau, Danie Kinkade, Adam Shepherd, Rasmus Swalethorp, Andrew R. Thompson, Henry A. Ruhl, Brice Semmens

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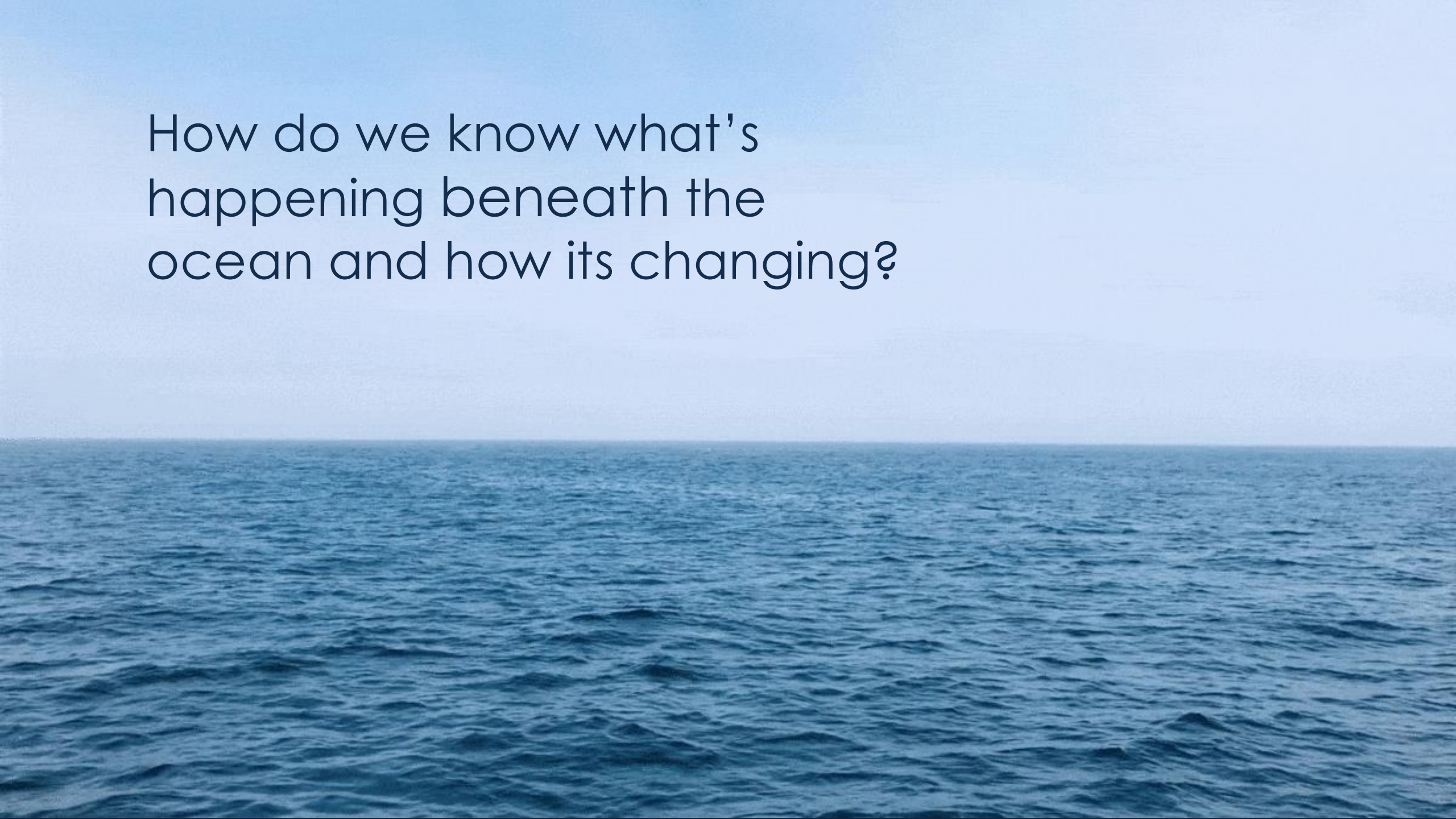
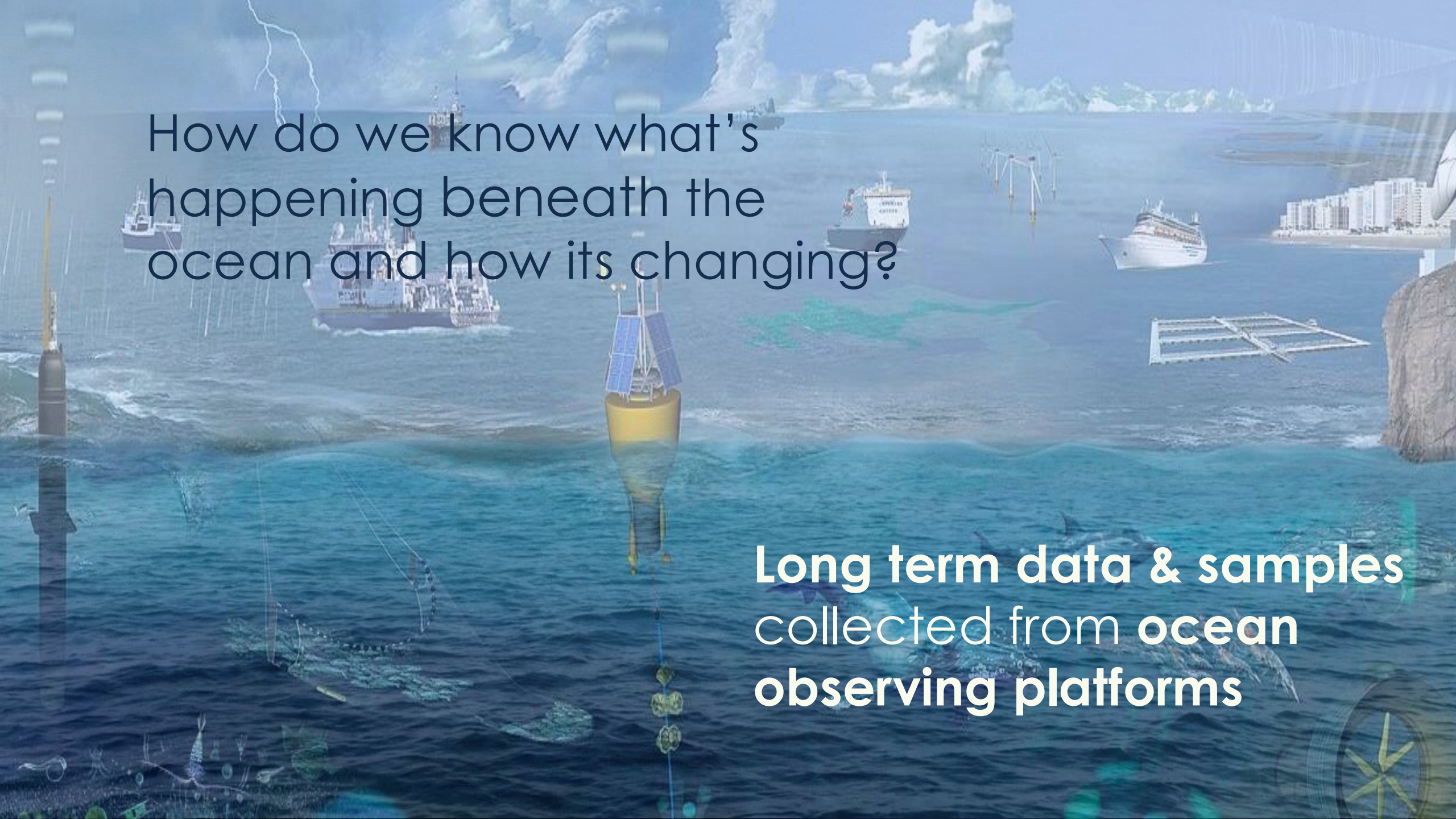
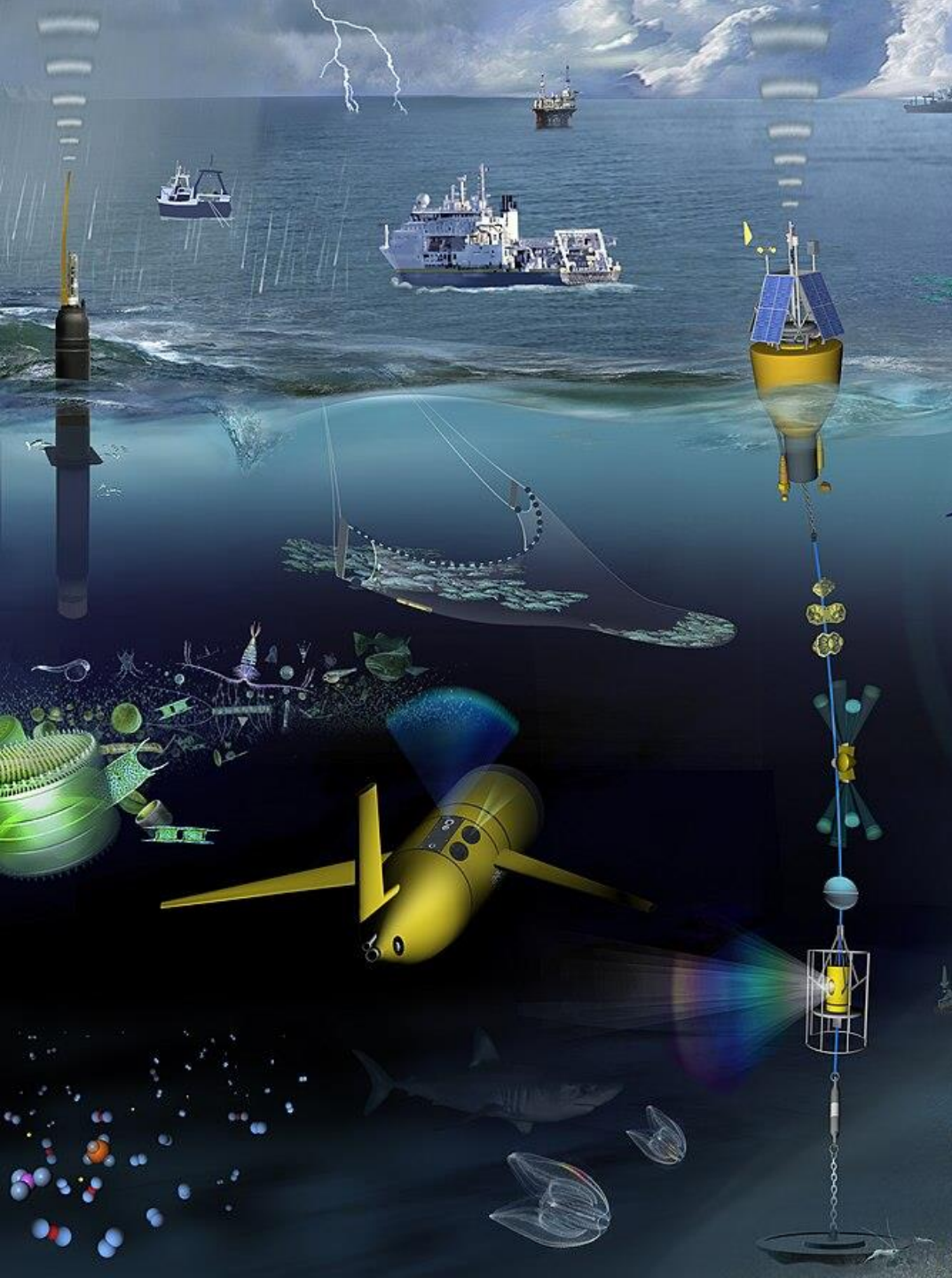

How do we know what's
happening beneath the
ocean and how its changing?


How do we know what's happening beneath the ocean and how its changing?
Long term data & samples collected from **ocean observing platforms**

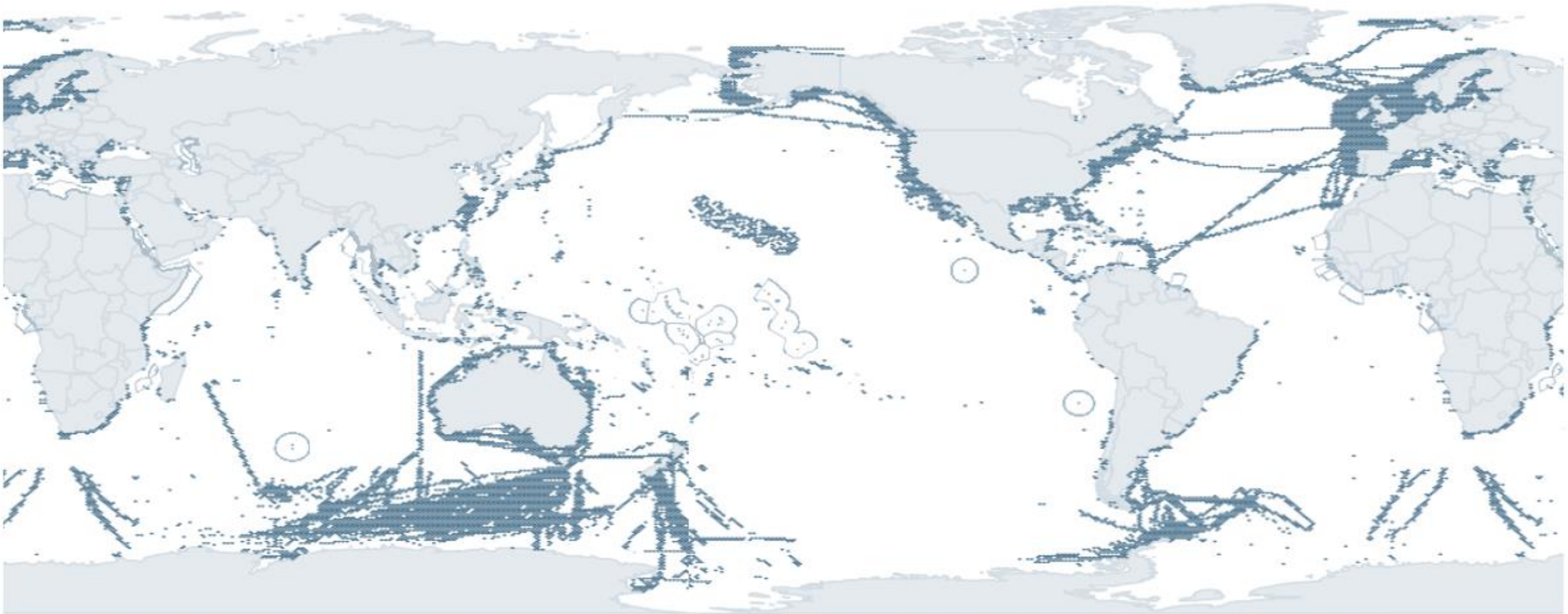
Long term ocean observations are our **sensory system for society**



Platforms are our **sensory 'organs'**

- large research vessels
- vessels of opportunity
- small boats
- animal borne sensors (e.g., marine mammals as observers)
- fixed platforms (e.g., piers, offshore structures
- moorings/buoys
- crewed vehicles (e.g., HOVs)
- remotely operated and autonomous vehicles (e.g., ROVs, AUVs/ASVs)
- mobile autonomous in-situ platforms (e.g., gliders, floats and drifters, buoyancy engine vehicles)
- Aerial platforms (e.g., UAVs, aircraft, drones, satellites)

7% of ocean surface area covered by long-term biological observations



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- Aerial platforms (e.g., UAVs, aircraft, drones, satellites)

What observing system platforms does the PICES community interact with most?

Poll Results **40 Answers**

Ships/large research vessels

24/40

Aerial platforms (eg satellites, UAVs, aircraft, drones)

12/40

Animals as observers

2/40

Remotely operated/Autonomous vehicles (eg ROVs, AUVs, ASVs)

10/40

Moorings/buoys

15/40

Crewed vehicles (eg HOVs)

3/40

Mobile autonomous in-situ platforms (eg gliders, floats, drifters)

4/40

Small boats

14/40

Fixed platform (eg pier, offshore structures)

6/40

Other

5/40

Large research vessels

- “ships” = “large research vessels”
- Global and Ocean Class vessels
- larger than 55m / 180ft
- wide range of sampling capabilities
- access nearly all parts of the global ocean

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Are **ships** going to be **replaced** by **autonomous or other observing platforms?**

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What are the **unique contributions of ships** to **marine ecosystem observations**?

Guiding question

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Essential ocean variable (EOV)	
Biology and ecosystems	Marine mammals
	Sea birds
	Fish
	Zooplankton
	Phytoplankton
	Microbes
Cross-disciplinary	Ocean sound
Biogeochemistry	Inorganic carbon
	Particulate matter
	Dissolved organic carbon
	Oxygen
	Nutrients
Physics and climate	Sea state
	Sea surface temperature
	Subsurface temp
	Surface currents
	Subsurface currents
	Sea surface salinity
	Subsurface salinity

Marine ecosystem observations means…

- comprehensive ocean observations
- across all facets of the ocean ecosystem
  - Geological
  - Physical,
  - Chemical,
  - Biological
  - Social…*someday!*
- all trophic levels across the entire food web

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Narrative review & case study

- Narrative review of existing literature
- Oldest, marine ecosystem observing program in the world – CalCOFI – as a case study

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CalCOFI
a case study

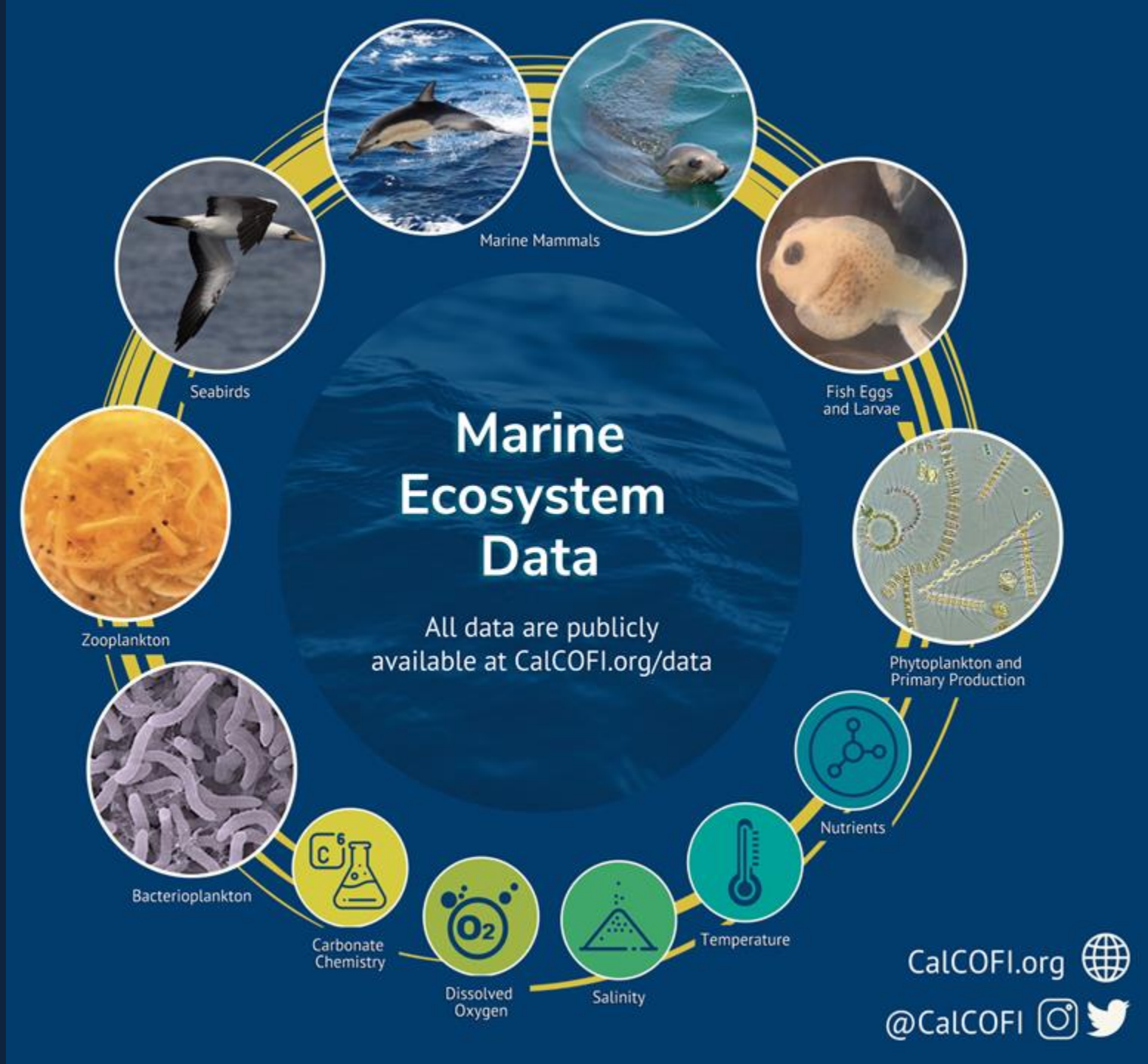
- Eastern Pacific – West Coast of the USA – California coast
- 4 times per year
- Sampling since 1949 – over 76 years!
- Currently relies on large research vessels
- Supports many other observing system component --testing, deployment, calibration

CalCOFI collects **Essential Ocean Variables (EOVs)** simultaneously

~ 36 physical/ chemical parameters

~ 2500 biological parameters

~ 50,000 eDNA sequences



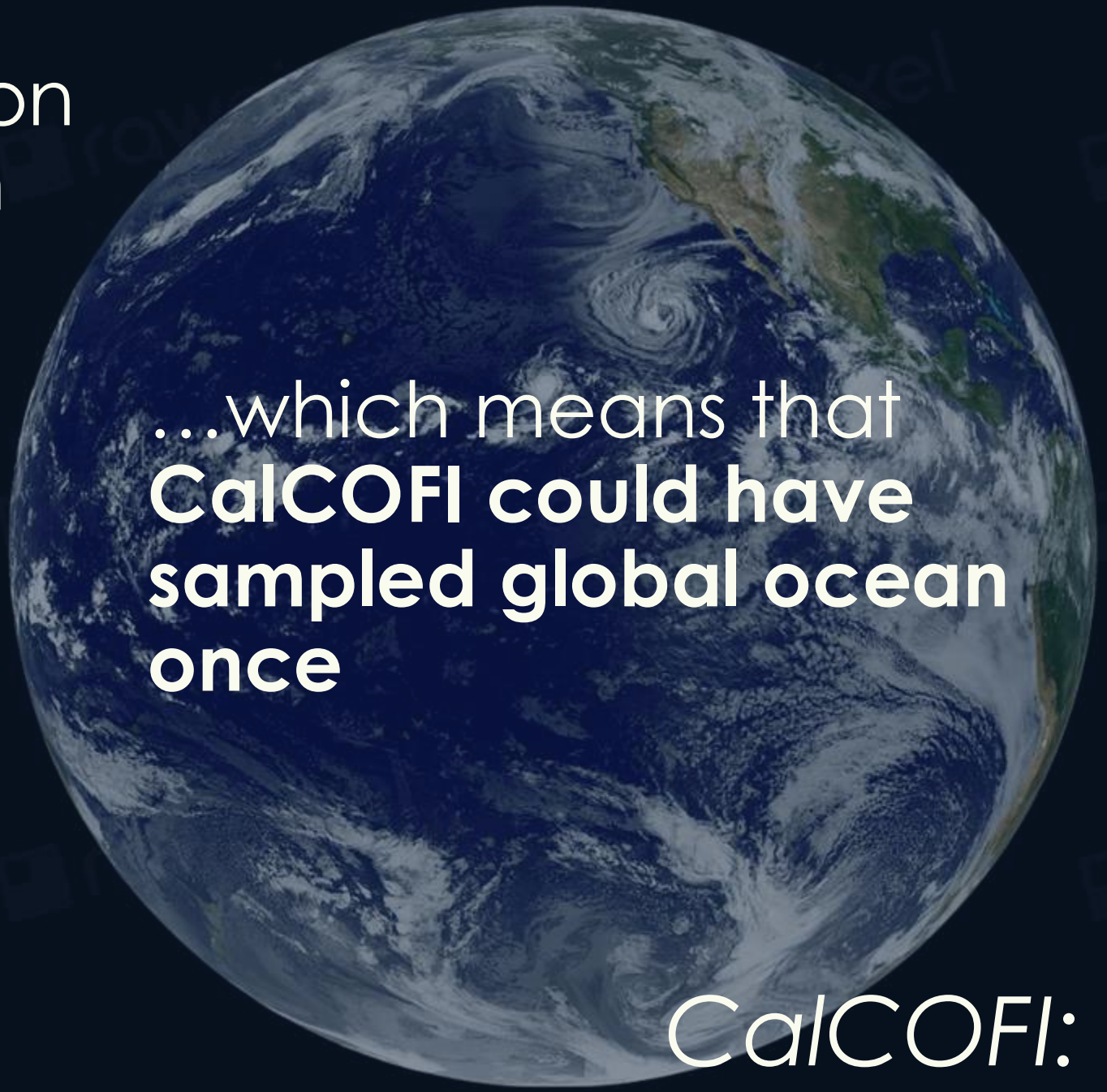

~ 388 cruises
…which equates to **35 years on the ocean**
CalCOFI: Fun facts

~ 2.3 million miles of ocean transited

…which means that CalCOFI **could have gone to the moon and back 5 times**

CalCOFI: Fun facts

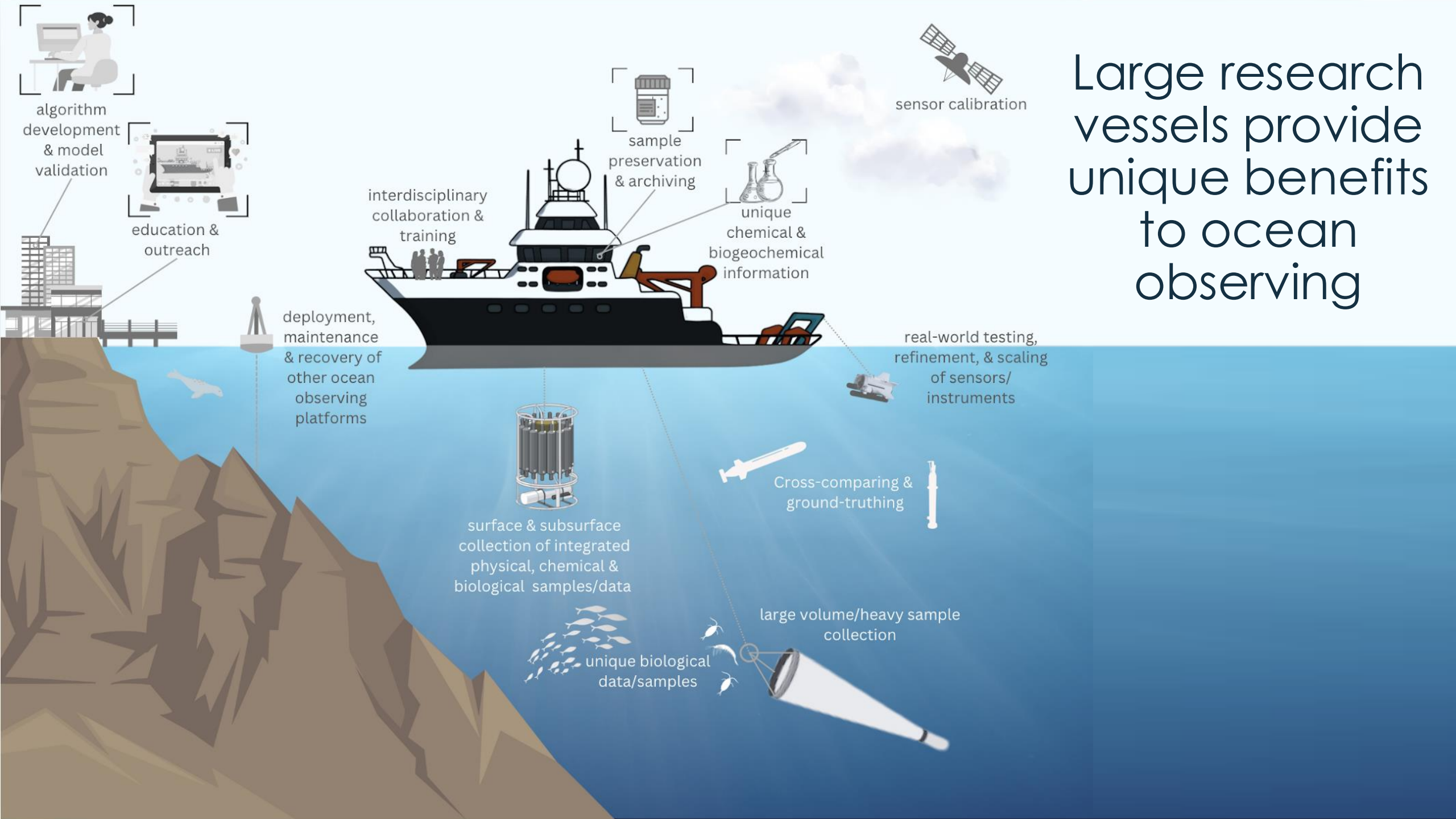
~ 142 million mi^2 ocean covered



….which means that **CalCOFI could have sampled global ocean once**

CalCOFI: Fun facts

Large research vessels provide unique benefits to ocean observing



Stable platforms to collect uniquely valuable in situ data and large volume samples

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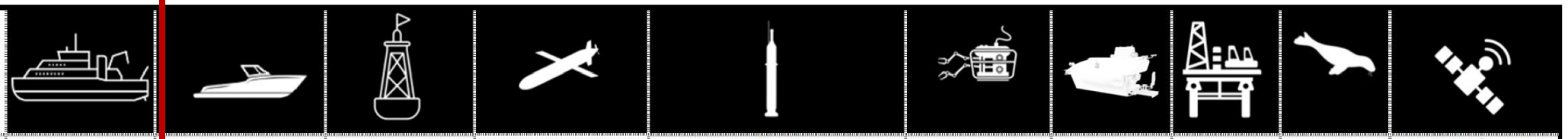
Unique benefits of large research vessels



	Large Ships/Research Vessels	Small Boats	Moorings & Buoys	Autonomous Vehicles (AUVs, ASVs) & Gliders	Floats Profiling Floats Drifters Buoyancy Engine Vehicles	Remotely Operated Vehicles (ROVs)	Human-Occupied Vehicles (HOVs)	Fixed Platforms	Marine Mammals as Observers	Remote Sensing Devices (e.g., Satellites, Aircraft, or Drones)
Specimen collection methods	*commonly*	*commonly, but with limitations*	*rarely*	*sometimes*	*rarely*	*sometimes*	*sometimes*	*commonly*	*rarely*	*rarely*
Water sample collection methods	*commonly*	*commonly, but with limitations*	*sometimes*	*sometimes*	*rarely*	*sometimes*	*sometimes*	*commonly*	*rarely*	*rarely*
Camera or visual imaging systems	*commonly*	*commonly, but with limitations*	*sometimes*	*commonly, but with limitations*	*rarely*	*commonly*	*commonly*	*commonly*	*sometimes*	*commonly, but with limitations*
Physicochemical and optical sensors	*commonly*	*commonly*	*commonly*	*commonly*	*commonly*	*commonly*	*commonly*	*commonly*	*commonly*	*commonly*
Current and flow measurement instruments	*commonly*	*commonly, but with limitations*	*commonly*	*commonly*	*sometimes*	*sometimes*	*sometimes*	*commonly*	*rarely*	*rarely*
Visual observations by humans	*commonly*	*commonly*	*rarely*	*rarely*	*rarely*	*rarely*	*commonly*	*commonly*	*rarely*	*sometimes*
Acoustic imaging instruments	*commonly*	*commonly, but with limitations*	*rarely*	*commonly, but with limitations*	*rarely*	*commonly*	*rarely*	*sometimes*	*rarely*	*rarely*
Active/passive acoustic instruments	*commonly*	*commonly, but with limitations*	*commonly*	*commonly*	*sometimes*	*commonly*	*commonly*	*commonly*	*sometimes*	*rarely*
Sediment trap	*commonly*	*commonly, but with limitations*	*commonly*	*sometimes*	*sometimes*	*sometimes*	*sometimes*	*commonly*	*rarely*	*rarely*
Benthic coring/sediment devices	*commonly*	*commonly, but with limitations*	*rarely*	*rarely*	*rarely*	*sometimes*	*commonly*	*commonly*	*rarely*	*rarely*

Mobile laboratories that enable the collection, immediate processing, and preservation of unique samples and data

Unique benefits of large research vessels

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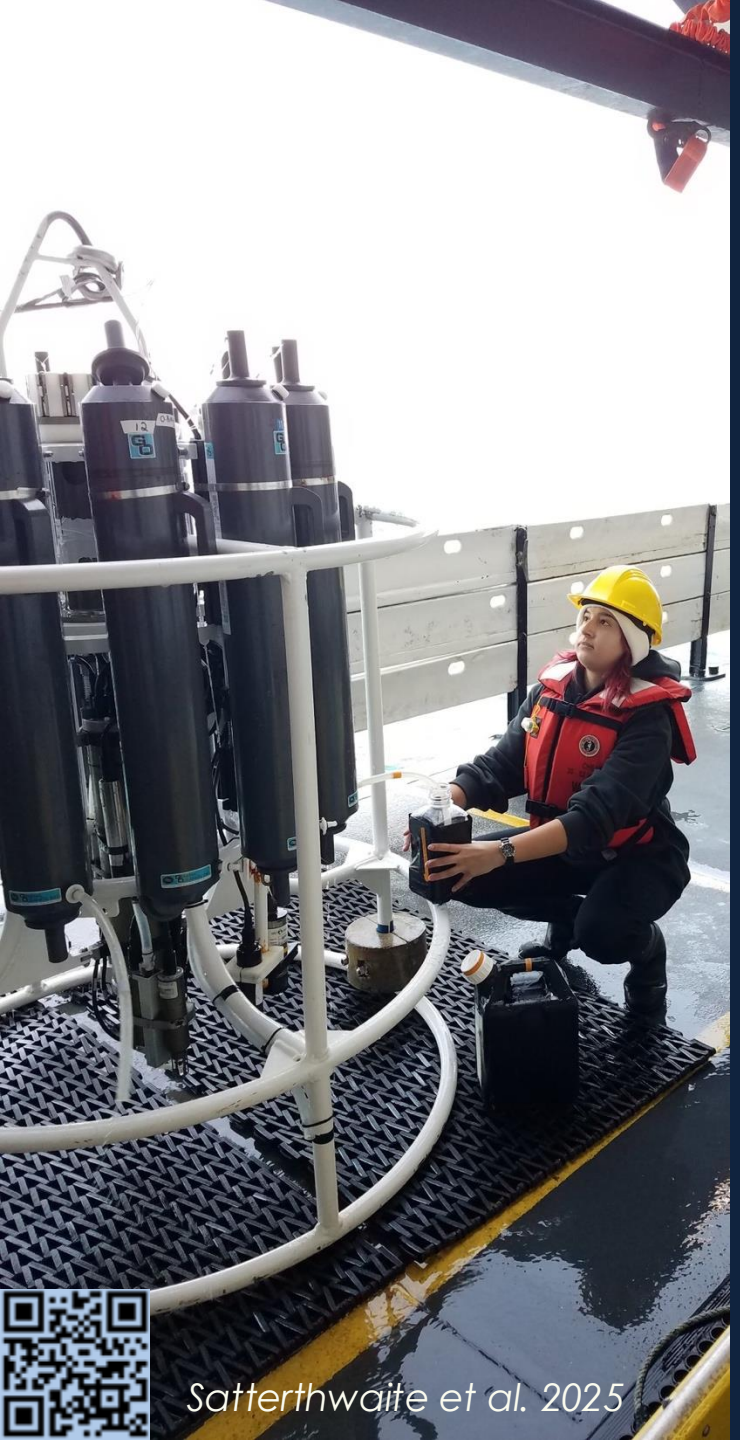

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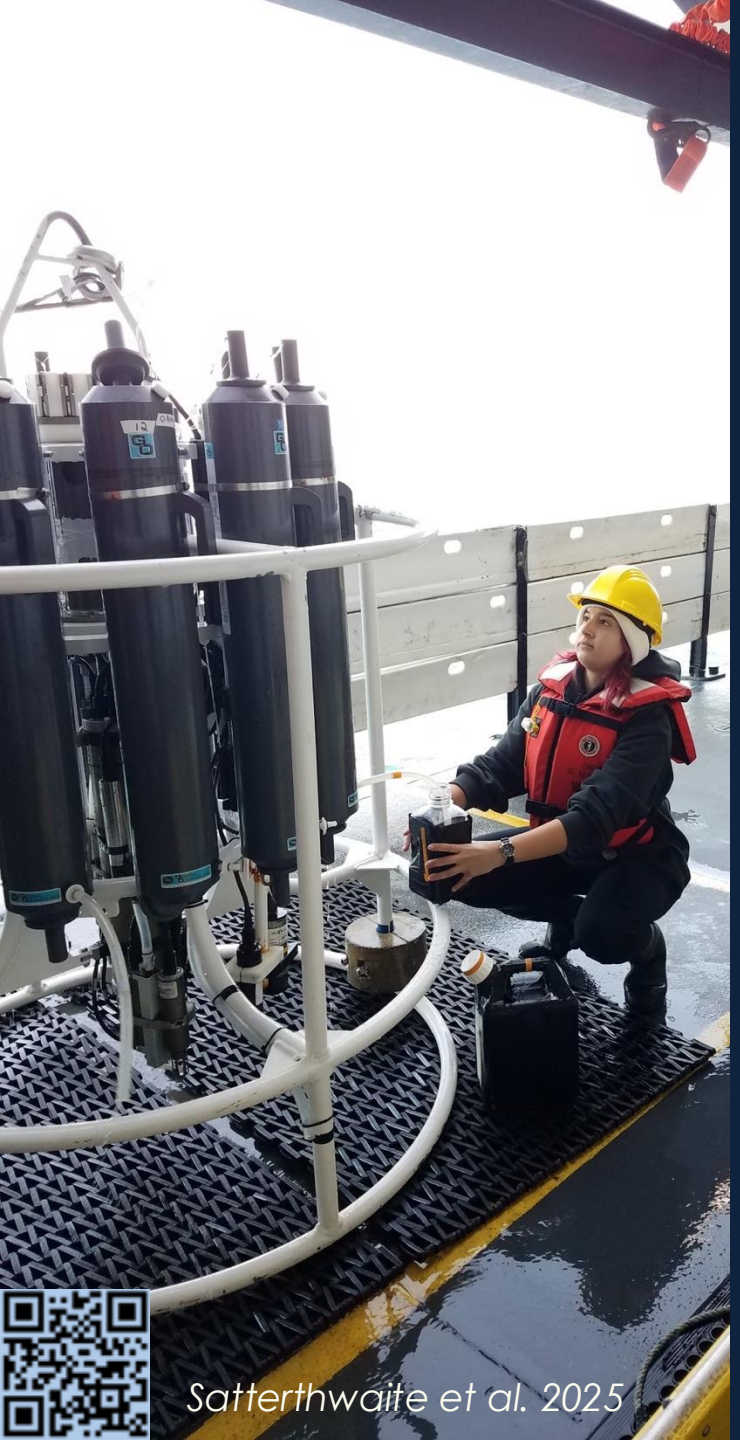
Sources of essential high-resolution, long-term, and comprehensive ecosystem information

Unique benefits of large research vessels



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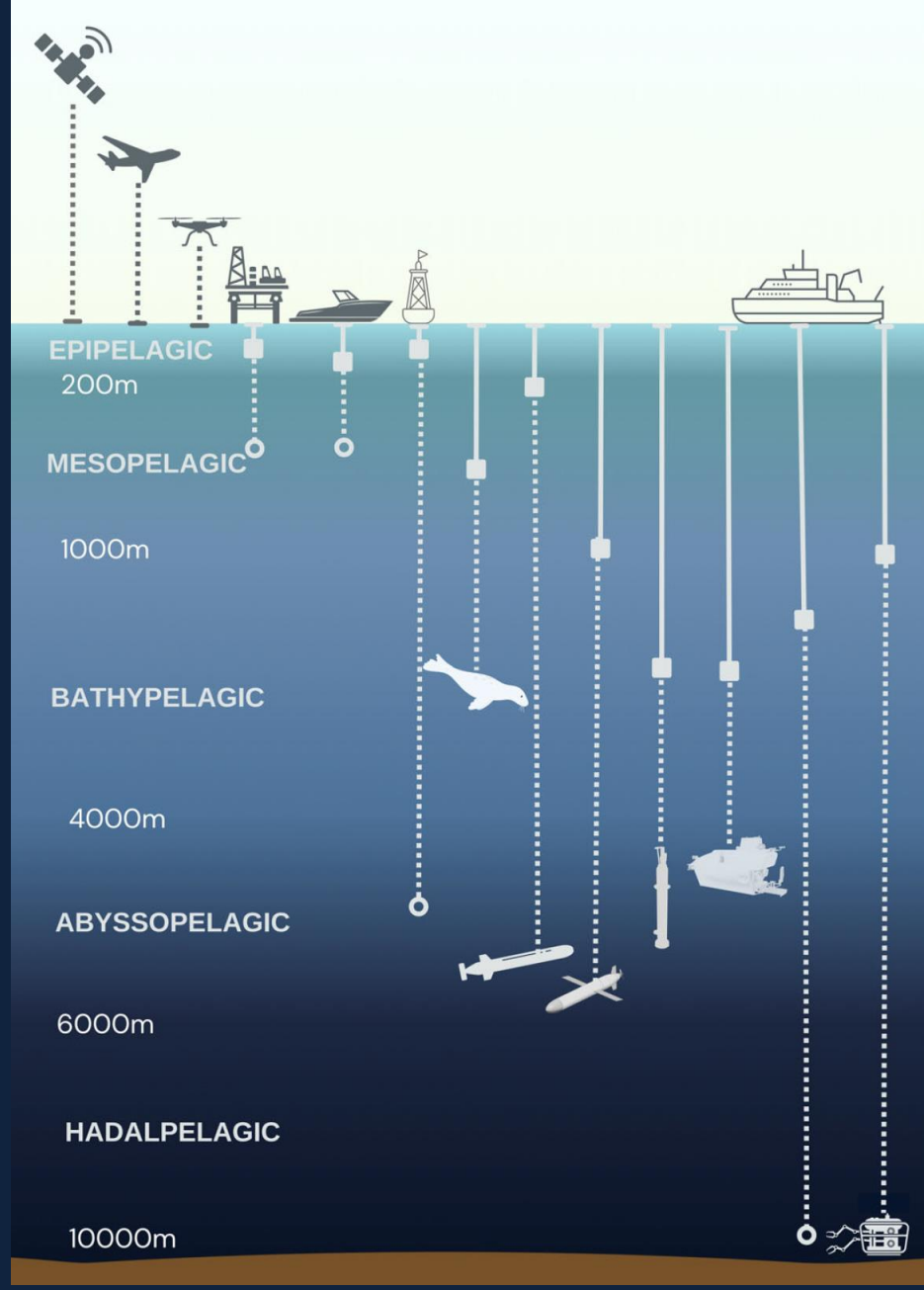
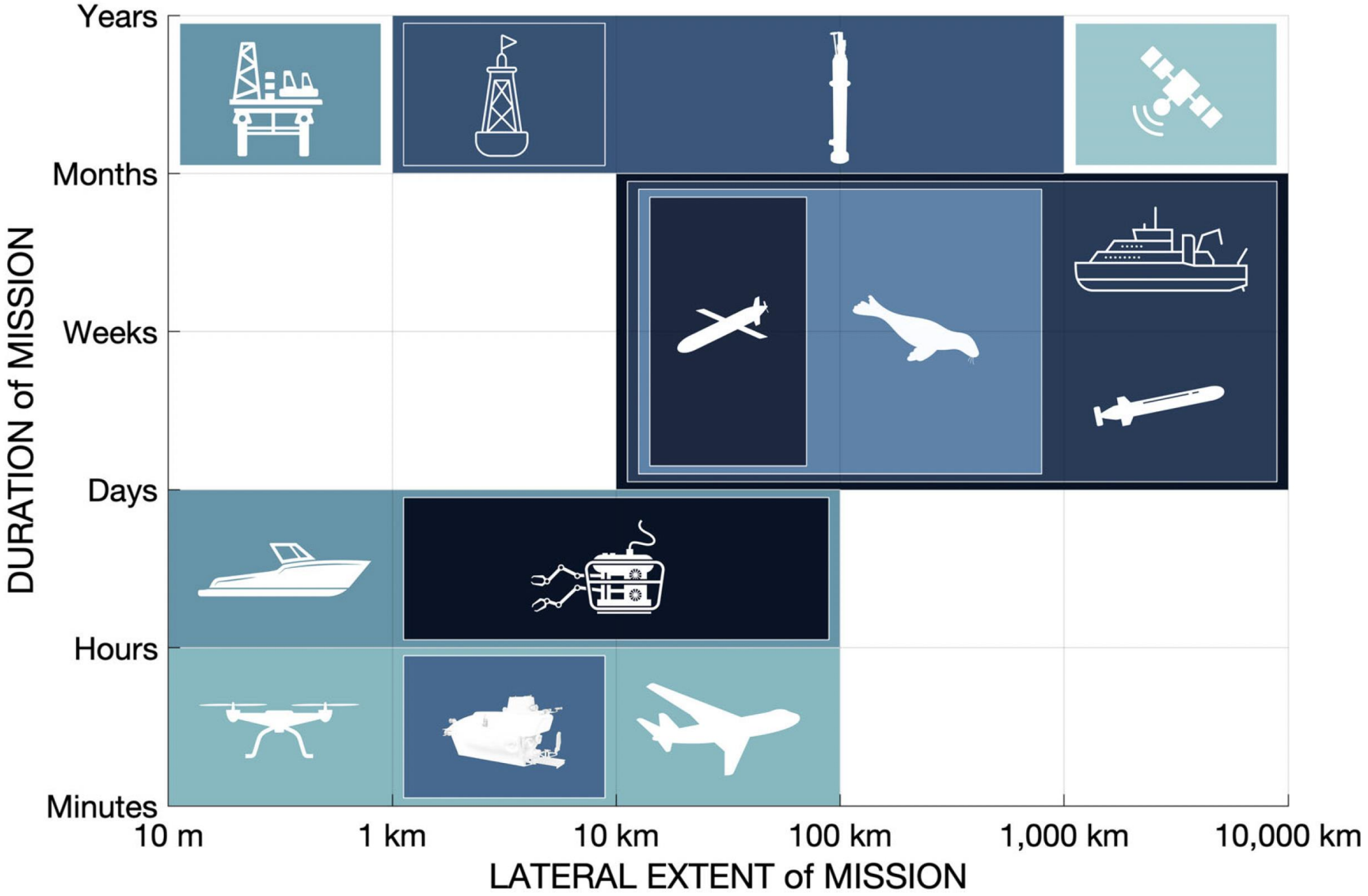
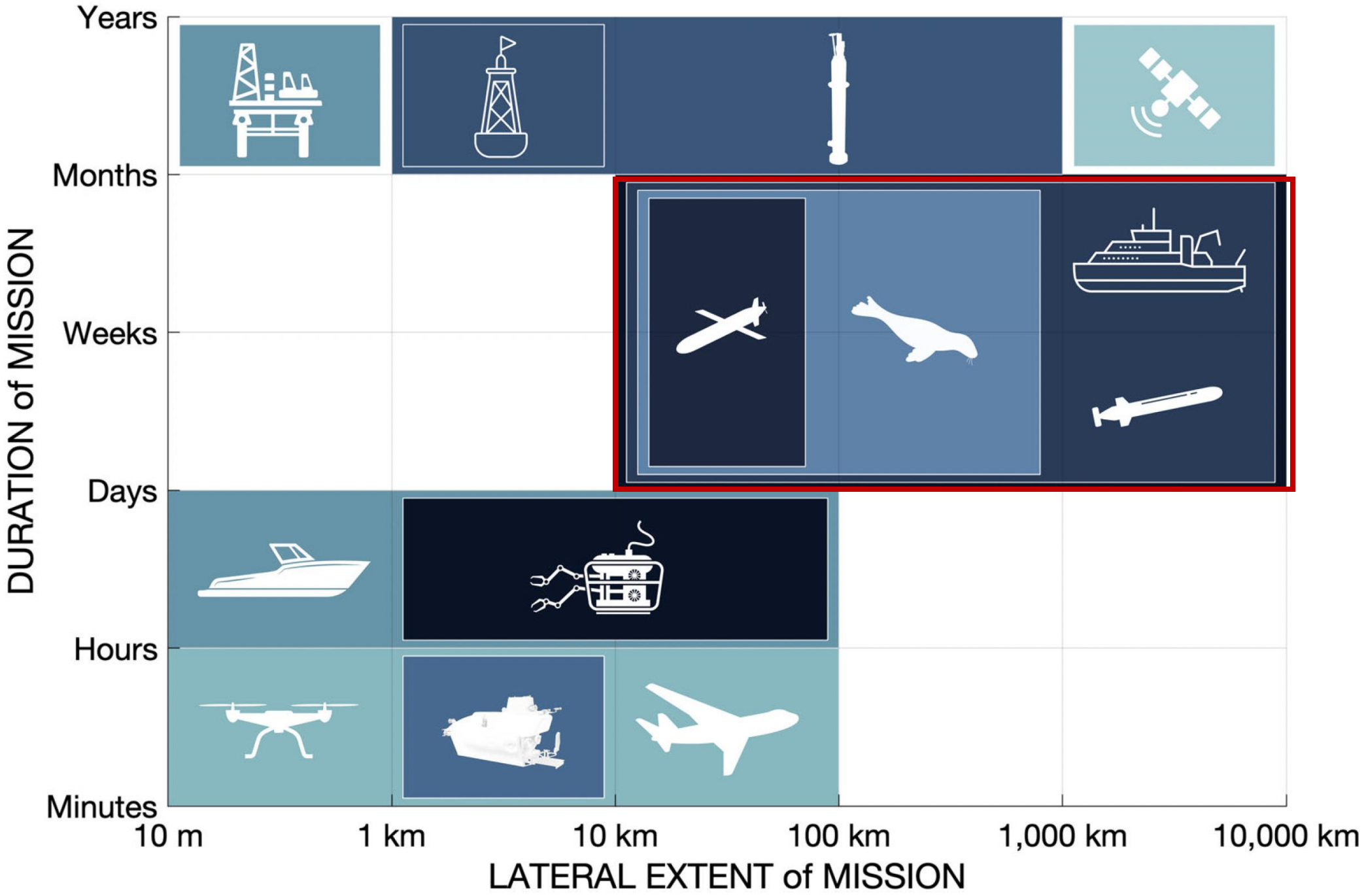


Unique benefits of large research vessels


Years
Months
Weeks
Days
Hours
Minutes
DURATION of MISSION
10 m
1 km
10 km
100 km
1,000 km
10,000 km
LATERAL EXTENT of MISSION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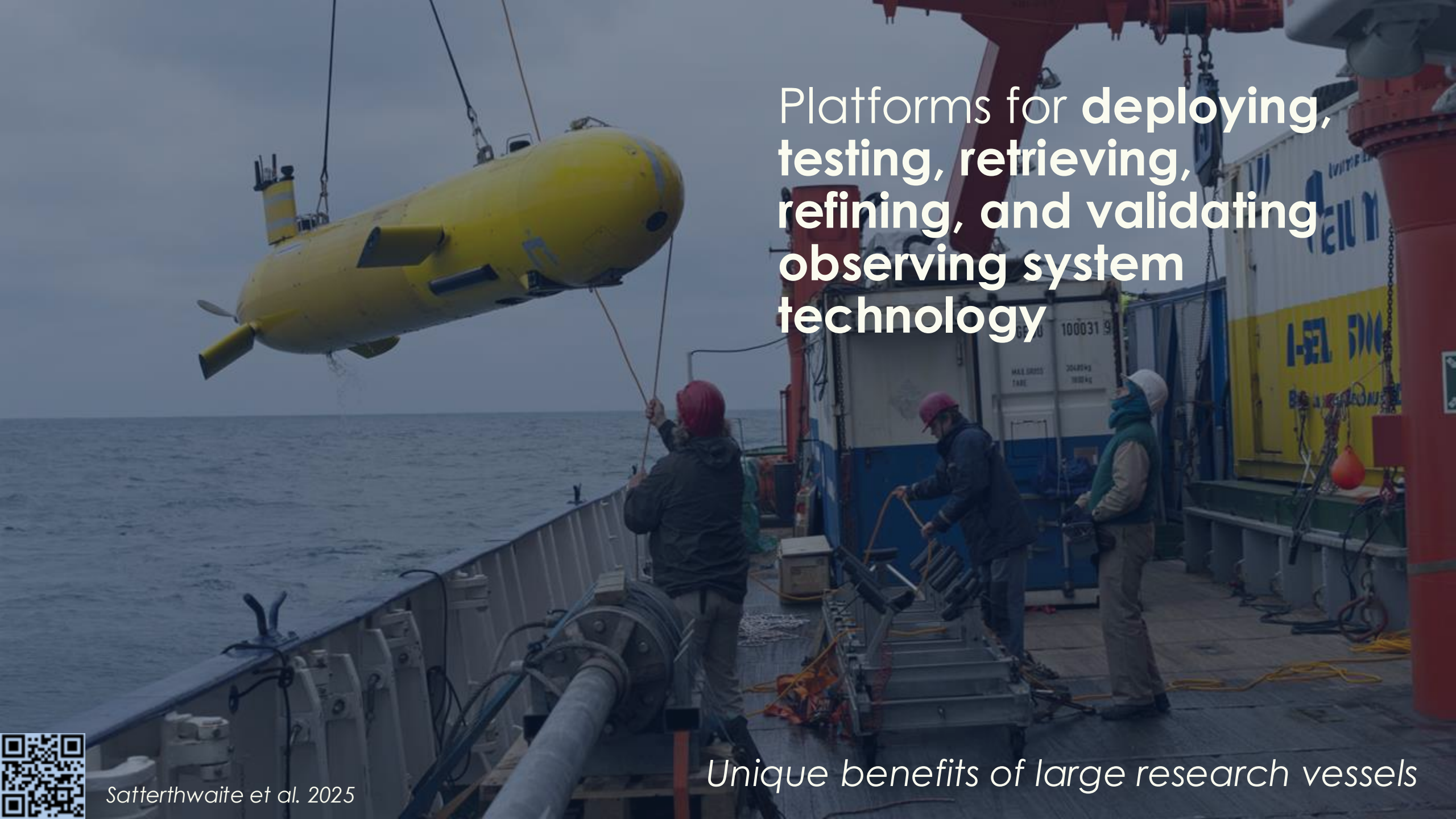

Platforms for **deploying, testing, retrieving, refining, and validating observing system technology**

Unique benefits of large research vessels

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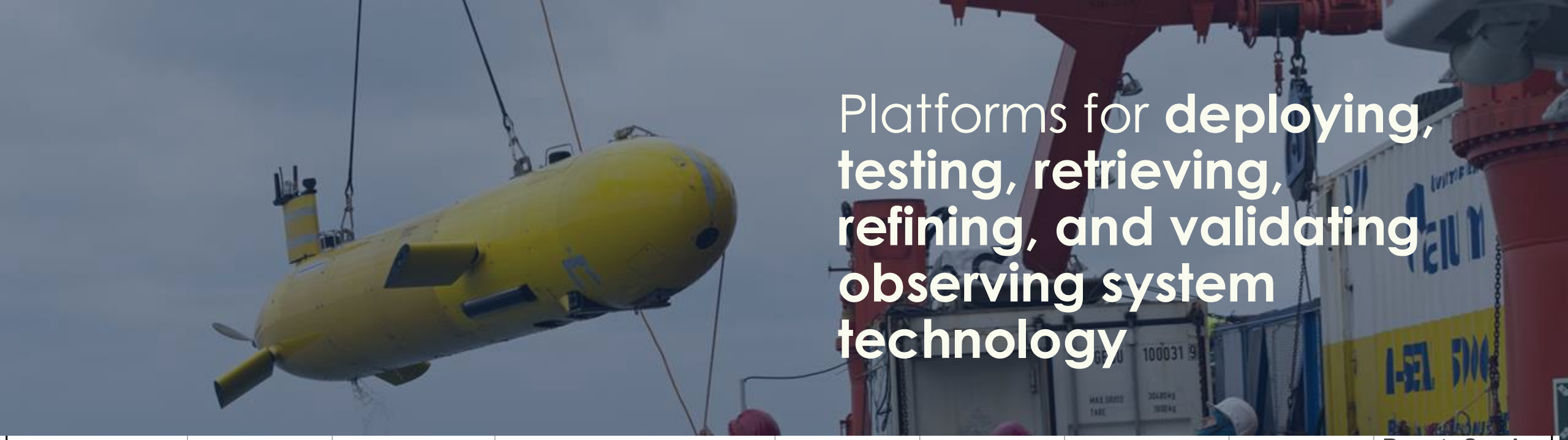

Platforms for **deploying, testing, retrieving, refining, and validating observing system technology**

	Moorings & Buoys	Autonomous Vehicles (AUVs, ASVs) & Gliders	Floats Profiling Floats Drifters Buoyancy Engine Vehicles	Remotely Operated Vehicles (ROVs)	Human-Occupied Vehicles (HOVs)	Fixed Platforms	Marine Mammals as Observers	Remote Sensing Devices (e.g., Satellites, Aircraft, or Drones)
Deployed, retrieved, or serviced from large research vessels	*common*	*common*	*common*	*common*	*sometimes*	*sometimes*	*rarely*	*rarely*

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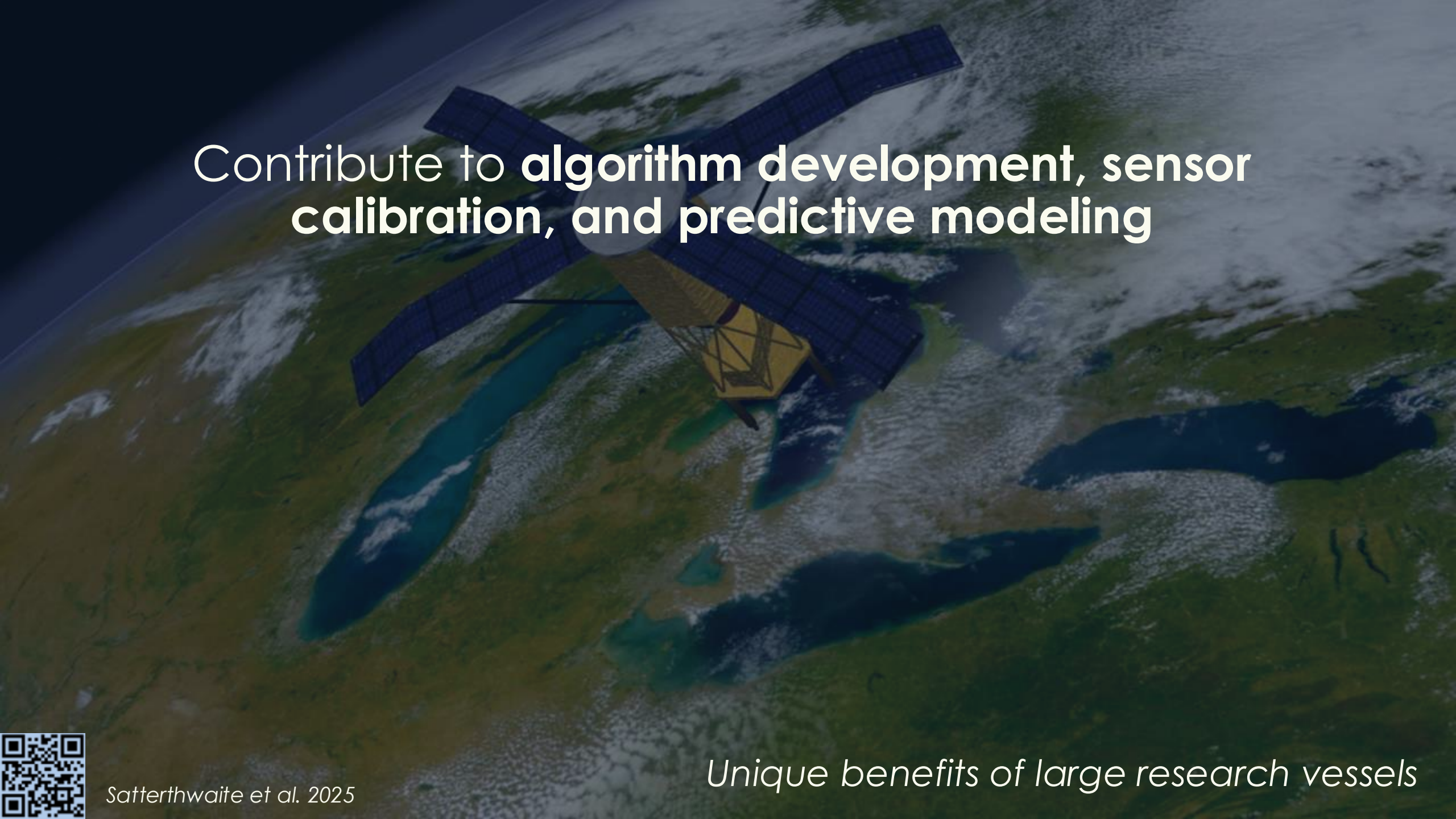
Unique benefits of large research vessels



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Unique benefits of large research vessels

Contribute to **algorithm development, sensor calibration, and predictive modeling**

	Moorings & Buoys	Autonomous Vehicles (AUVs, ASVs) & Gliders	Floats Profiling Floats Drifters Buoyancy Engine Vehicles	Remotely Operated Vehicles (ROVs)	Human-Occupied Vehicles (HOVs)	Fixed Platforms	Marine Mammals as Observers	Remote Sensing Devices (e.g., Satellites, Aircraft, or Drones)
Data from large research vessels used in calibration or cross validation	*common*	*common*	*common*	*common*	*common*	*sometimes*	*sometimes*	*sometimes*

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Unique benefits of large research vessels

Mobile platforms for **experiential training, discovery, education, and collaboration**

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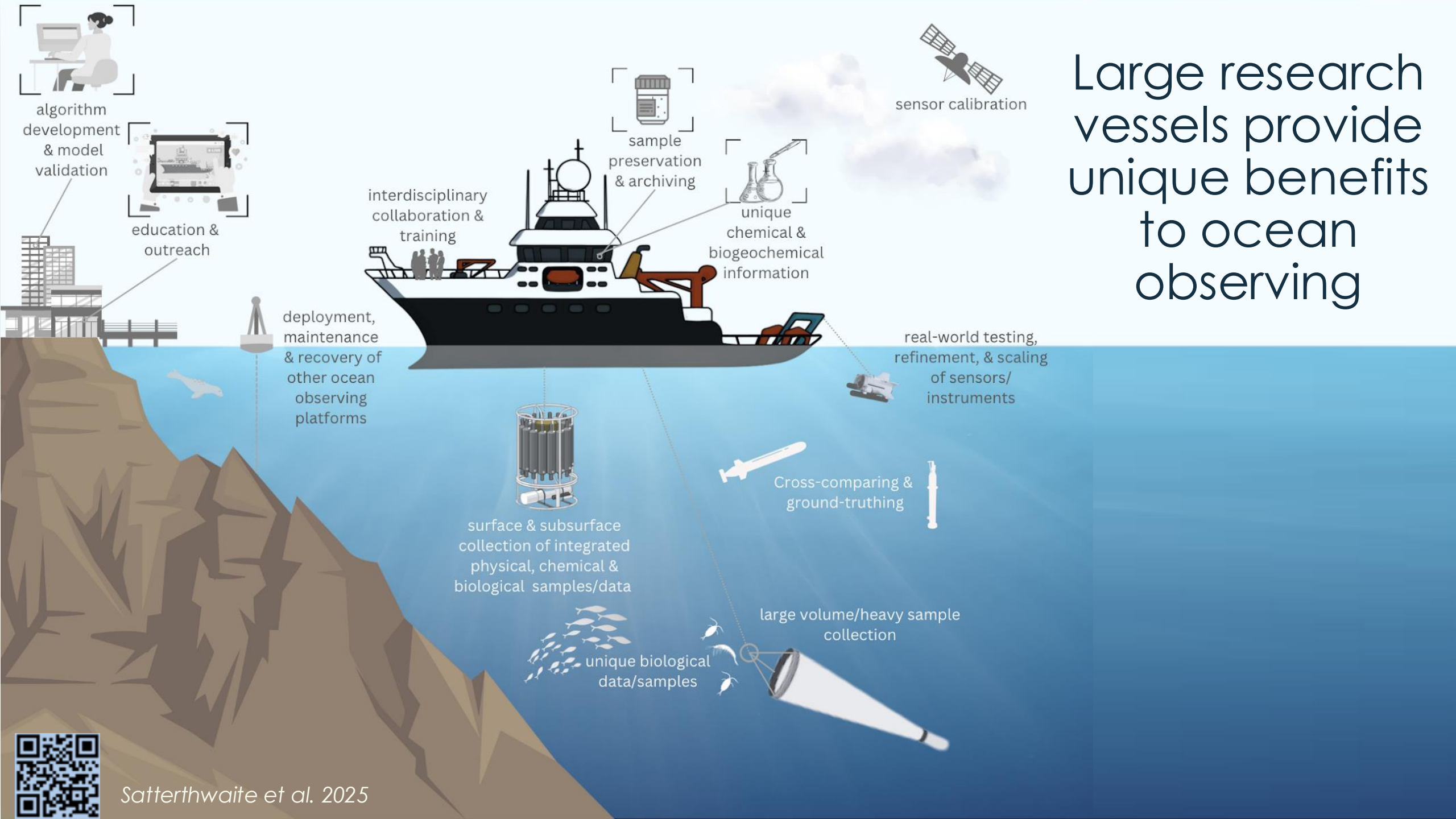
Unique benefits of large research vessels

Large research vessels provide unique benefits to ocean observing



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Costs

Ships are a long-term investment

	Ships	Satellites	Smaller platforms (AUVs, buoys, floats)
Upfront cost	High	High	Low
Lifespan	decades	years	years
Parameters	many	some	few

Costs
per variable

30% of the parameters in BCO-DMO are *only* collected by large research vessels.

cost per variable per day on large research vessels can be up to **75% less expensive** than other platforms

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Toward a vision for a modern, sustained marine ecosystem observing system

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Toward a vision for a modern, sustained marine ecosystem observing system

- Embrace **emerging technologies & methods** for marine ecosystem data collection and analysis (e.g., miniaturized sensors, eDNA)

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Individually, we are
one drop.
Together, we are
an ocean.

~Ryunosuke Satoro

Thank you!

LTJG Bonnie Vierra
Alice Doyle
Linsey Sala
Noelle Bowlin
George Watters
CalCOFI Committee & Council
CalCOFI Collaborative programs
CalCOFI Community

Please mark your calendars for…

May 27-28, 2026
San Diego, CA, USA

A Decade of Remarkable Change: Heatwaves, HABs, hypoxia, and Other Ocean Changes off the California coast

esatterthwaite@ucsd.edu

CalCOFI Sea Grant California SCRIPPS INSTITUTION OF OCEANOGRAPHY

Individually, we are
one drop.
Together, we are
an ocean.

~Ryunosuke Satoro

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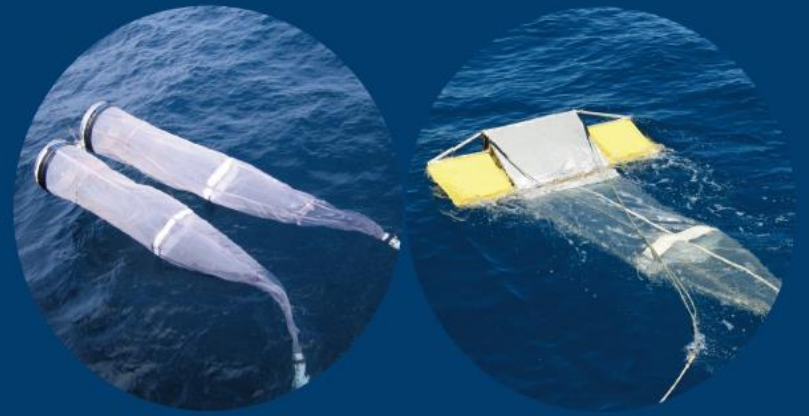
CalCOFI uses **visual, acoustic, molecular methods**

Visual Observations

CTD and Bottle Samples



Net Tows

Ship Underway Data

Environmental DNA

Costs

Ships are a long-term investment

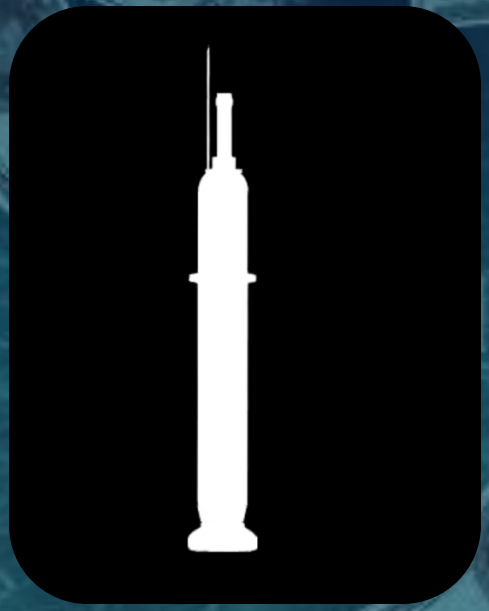
Satellites

€47 million per year

Ships

$1.78 million per year

Floats



$4,000 per year

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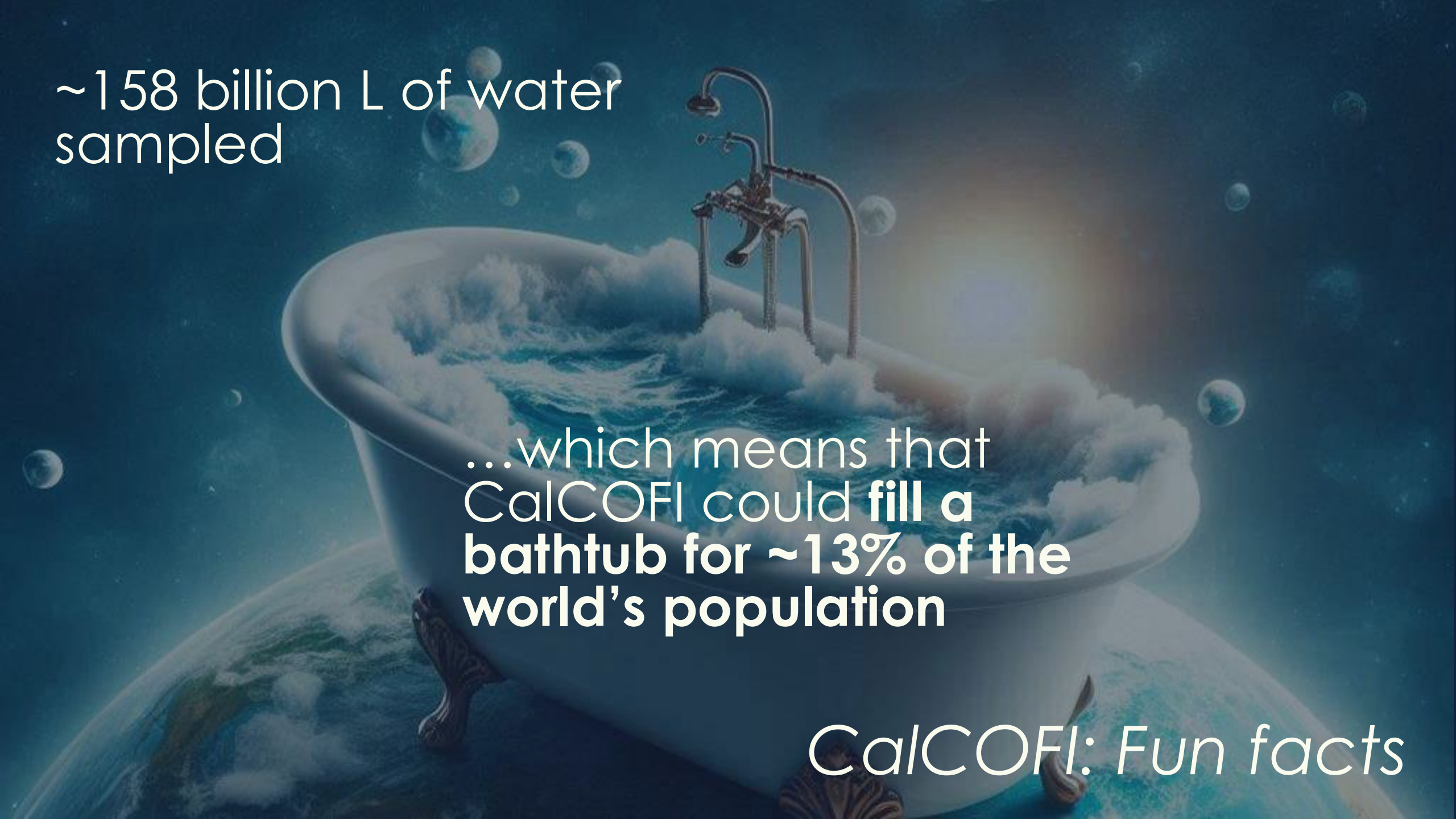
~ 35,000 CTD casts diving to a total of 201 million meters depth over time

…which means that CalCOFI could have sampled to the **deepest part of the ocean and back 9,200 times**

CalCOFI: Fun facts



~158 billion L of water sampled

…which means that CalCOFI could **fill a bathtub for ~13% of the world's population**

CalCOFI: Fun facts

Unique benefits of large research vessels

- **Stable platforms** to collect uniquely valuable in situ data and large volume samples
- **Mobile laboratories** that enable the collection, immediate processing, and preservation of unique geological, chemical, and biological samples and data
- **Sources of essential high-resolution, long-term, and comprehensive ecosystem information**
- Platforms for **deploying, testing, retrieving, refining, and validating observing system technology**
- Contribute to **algorithm development, sensor calibration, and predictive modeling**
- Mobile platforms for **experiential training, discovery, education, and collaboration**