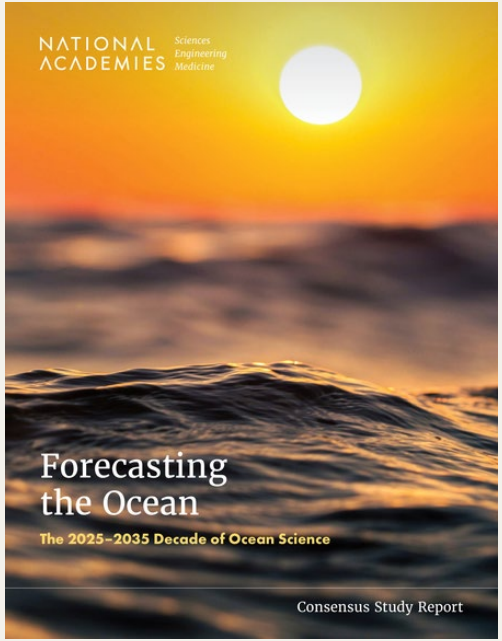
Download Now!



www.nap.edu/27586

Submit Questions!

Slido.com #5725154

NATIONAL ACADEMIES Sciences Engineering Medicine

Forecasting the Ocean: The 2025-2035 Decade of Ocean Science

Report Briefing on the 2025-2035 Decadal Survey

H. Tuba Özkan-Haller, Oregon State University

James Yoder, Woods Hole Oceanographic Institution & University of Rhode Island

FEBRUARY 2025

Motivation – Why is ocean R&D important?

- ❑National Security and International Leadership
- ❑Strong Economies and Vibrant Communities
- ❑Health and Wellbeing

Credit: John McCord, Coastal Studies Institute

Credit: Brett Pietila

Credit: Erik Jepsen, UC San Diego

Credit: Viktor Brandtneris, Reefs Unknown

Credit: UW/NSF-OOI/CSSF, V158.

Credit: ATE Impacts 2022-2023

Agenda

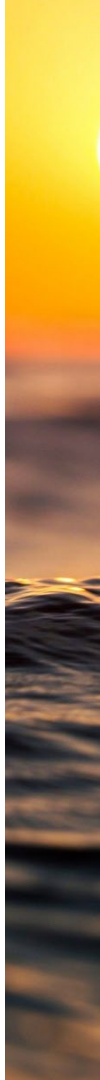
1
Study Context

2
Urgent Ocean Science Research Portfolio (Chapter 2)

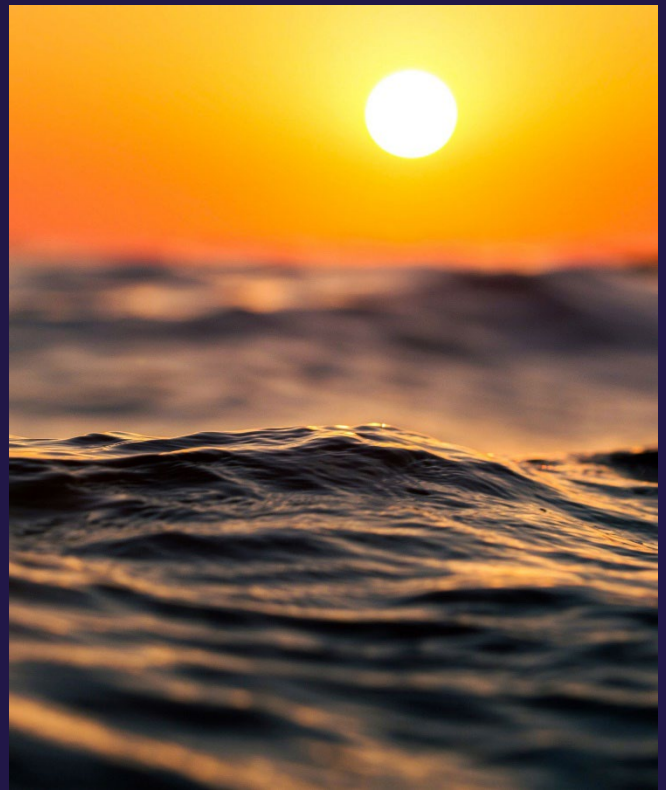
3
Opportunities to Meet the Challenge (Chapter 3)

4
Infrastructure Needed (Chapter 4)

5
The Next Decade (Chapter 5)

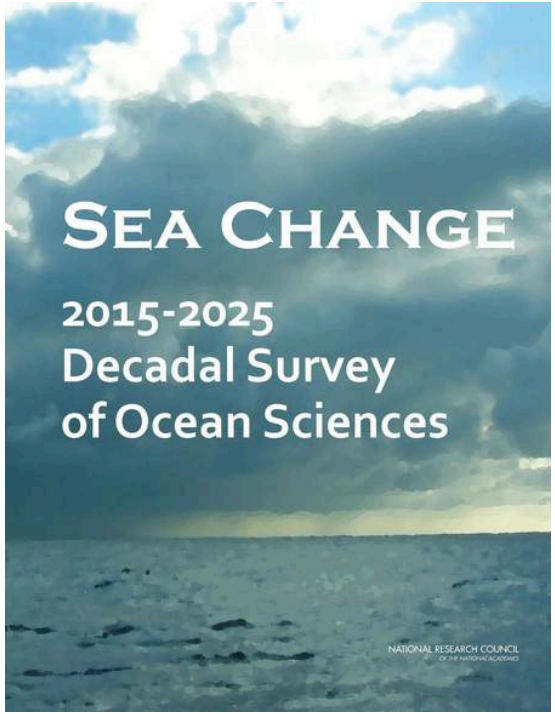


Study Context



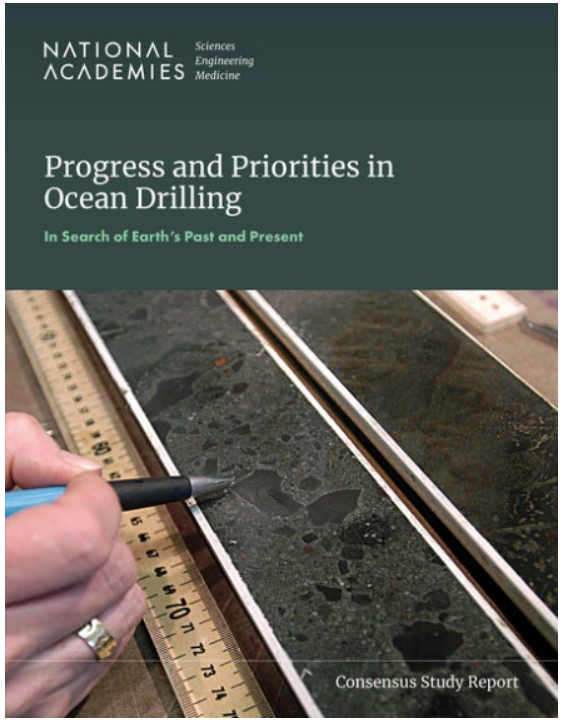
01

Study Context – First Decadal Survey of Ocean Sciences



- Infrastructure vs. “Core Science” budget
- 8 research priority questions covering:
  - Variability of sea level change
  - Influence of the global hydrologic cycle, land use, and upwelling from the deep ocean on coastal ocean and ecosystem
  - Contribution of ocean biogeochemical and physical processes to today’s climate and how will this system may change
  - Role of biodiversity in the resilience of marine ecosystems
  - Predicting change in marine food webs over the next 100 years
  - Processes that control the formation and evolution of ocean basins
  - Improving ability to forecast geohazards
  - Characterizing the subseafloor environment - how does it affect global elemental cycles and understanding of the origin and evolution of life?

Statement of Task for the Interim Report



Interim Report on Scientific Ocean Drilling

- **Assess progress** on addressing high priority science questions that require scientific ocean drilling **and identify any new questions** that would also require scientific ocean drilling.
- Of the unanswered scientific questions, which could be addressed through the use of existing assets, and **which questions would require new infrastructure or sampling investments**?
- No recommendations included; conclusions feed into the full report.

Statement of Task for the Full Report

- Identify novel opportunities regarding ocean-related, **use-inspired, solutions-oriented research and innovation**.
- Identify opportunities and strategies to promote **innovative multidisciplinary and multi-sectoral approaches** to address **complex science challenges** arising from the intersection of natural processes, societal needs, and human-driven environmental change.
- Develop a portfolio of **high-priority, scientific questions** that have the potential to transform scientific knowledge of the ocean and the critical role of the ocean in the Earth system.
- Identify the **research infrastructure needed** to advance the high-priority ocean science research questions.
- Develop a framework that OCE can apply to **leverage and complement** the capabilities, expertise, and strategic plans of **its partners.**

Study Committee

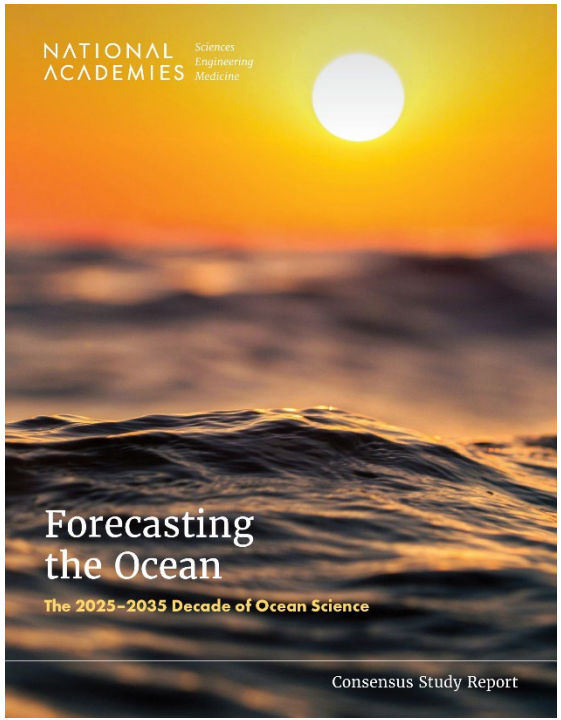
Tuba Özkan-Haller (Co-Chair), Oregon State University
James (Jim) Yoder (Co-Chair), Woods Hole Oceanographic Institution & University of Rhode Island (*emeritus*)
Lihini Aluwihare, University of California, San Diego's Scripps Institution of Oceanography
Mona Behl, University of Georgia
Mark Behn, Boston College
Brad DeYoung, Canadian Integrated Ocean Observing System & Memorial University
Carlos Garcia-Quijano, University of Rhode Island
Peter Girguis, Harvard University
Leila Hamdan, University of Southern Mississippi
Marcia Isakson, The University of Texas at Austin
Jason Link, National Oceanic and Atmospheric Administration
Allison Miller, Schmidt Ocean Institute
Bradley Moran, University of Alaska Fairbanks
Richard Murray, Woods Hole Oceanographic Institution (*emeritus*)
Stephen Palumbi, Stanford University
Ella (Josie) Quintrell, Integrated Ocean Observing System Association
Yoshimi (Shimi) Rii, Hawai'i Institute of Marine Biology
Kristen St. John, James Madison University
Kersey Sturdivant, INSPIRE Environmental & Duke University
Ajit Subramaniam, Columbia University
Maya Tolstoy, University of Washington
Shannon Valley, formerly Vistant
James (Jim) Zachos, University of California, Santa Cruz

Not pictured are Carlos Garcia-Quijano, Bradley Moran, Stephen Palumbi, Kersey Sturdivant, and James Zachos

Study Process

- Held 6 hybrid 2-day meetings + monthly virtual meetings + subgroup meetings
  - Public: information gathering; **more than 100 experts presented**
  - Closed: committee deliberation and report writing
- **Review** of relevant federally-issued reports, National Academies reports, Intergovernmental Panel of Climate Change, among others
- Virtual and in-person **town halls**
- **Interim report** released to the public in March 2024
- External peer review (additional 15 experts)
- Prepublication release of the **full report February 20th**

Context for the 2025-2035 Decadal Survey



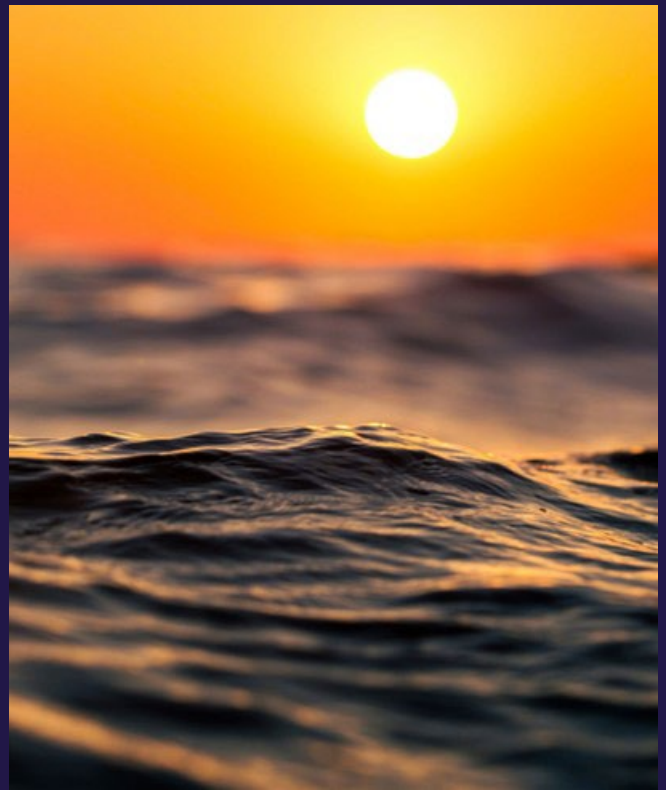
1. Funding for **basic research** across ocean science program offices must continue.

2. Articulate a challenge for the next decade

3. Additionally, what are **2-3 research priority areas** that NSF OCE should focus on over the next decade?
   - Societally-relevant
   - Use-inspired
   - Multi-sectoral, Multi-disciplinary
   - Workforce development
   - Potential for new partnerships

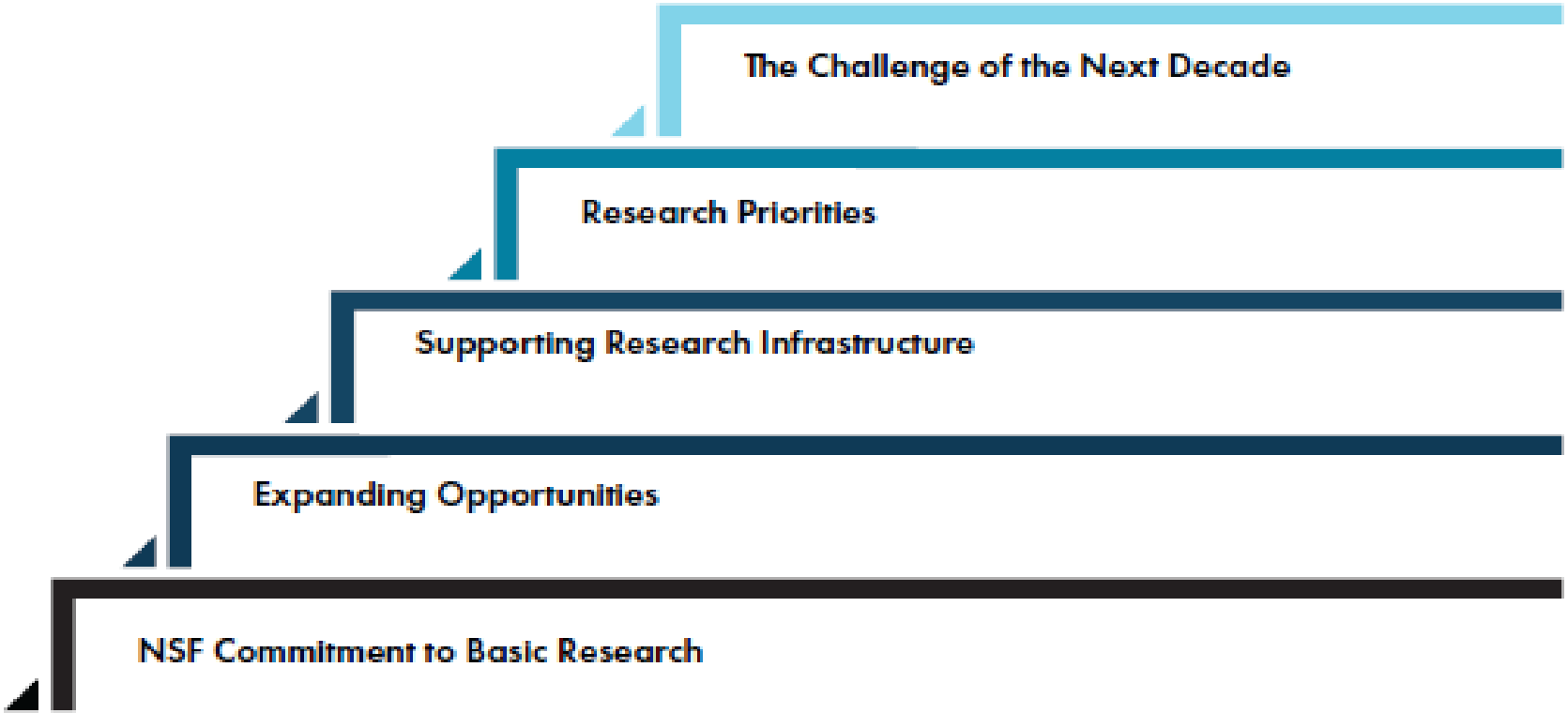
4. We were **not asked** to provide advice on balancing investments, or specifics on how to accomplish the research.

Urgent Ocean Science Research Portfolio



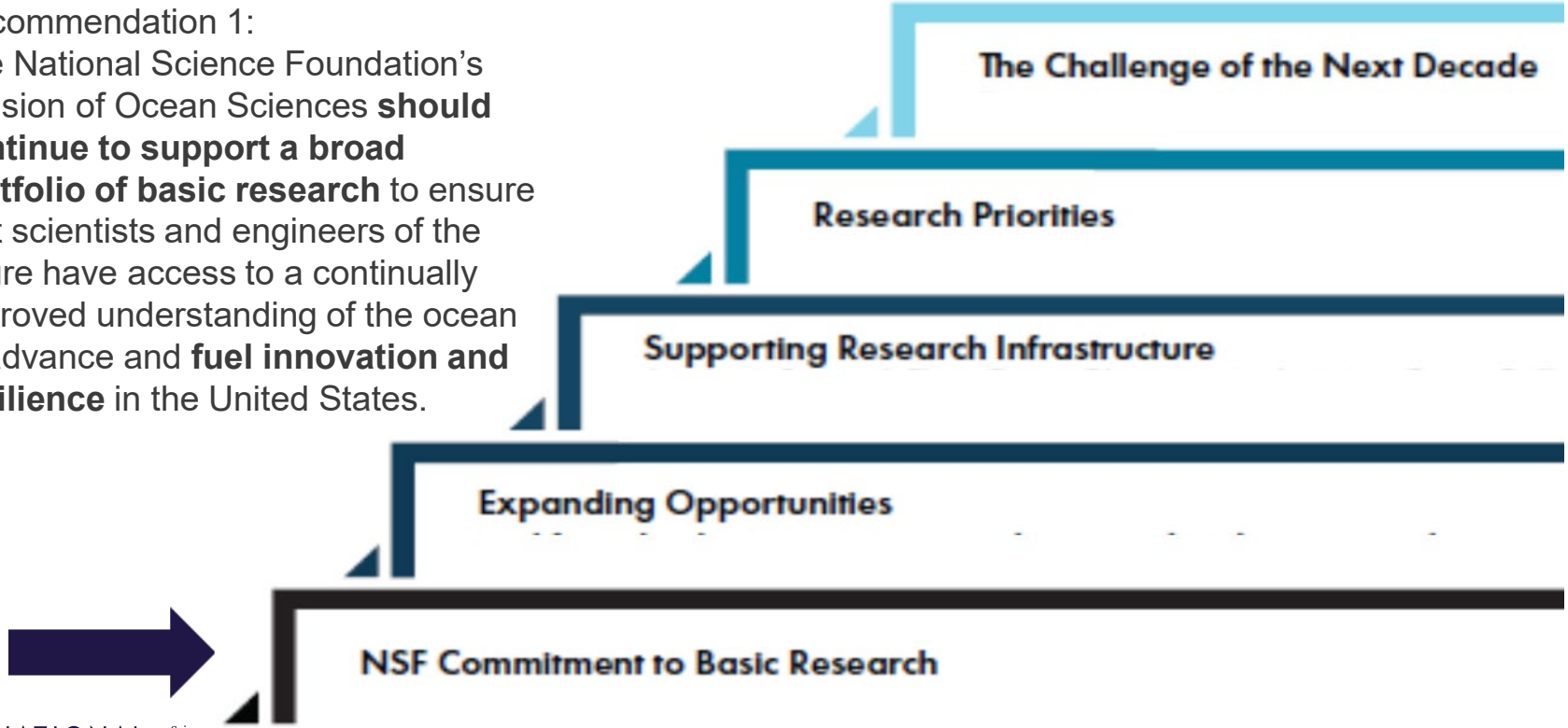
02

The Next Decade of Ocean Science Research



The Next Decade of Ocean Science Research

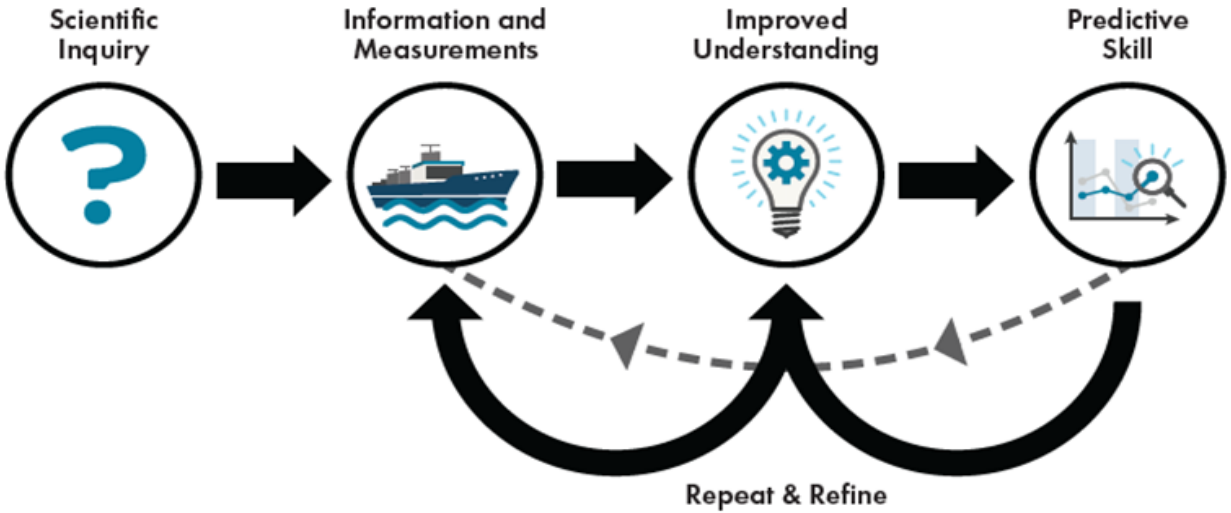
Recommendation 1:
The National Science Foundation's Division of Ocean Sciences **should continue to support a broad portfolio of basic research** to ensure that scientists and engineers of the future have access to a continually improved understanding of the ocean to advance and **fuel innovation and resilience** in the United States.



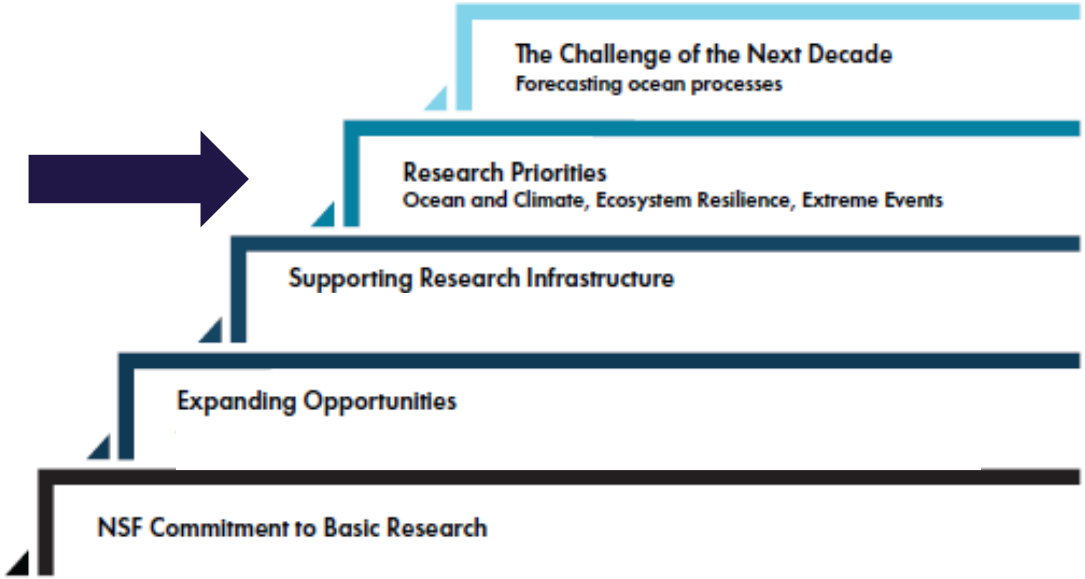
NATIONAL ACADEMIES Sciences Engineering Medicine

The Challenge for the Next Decade

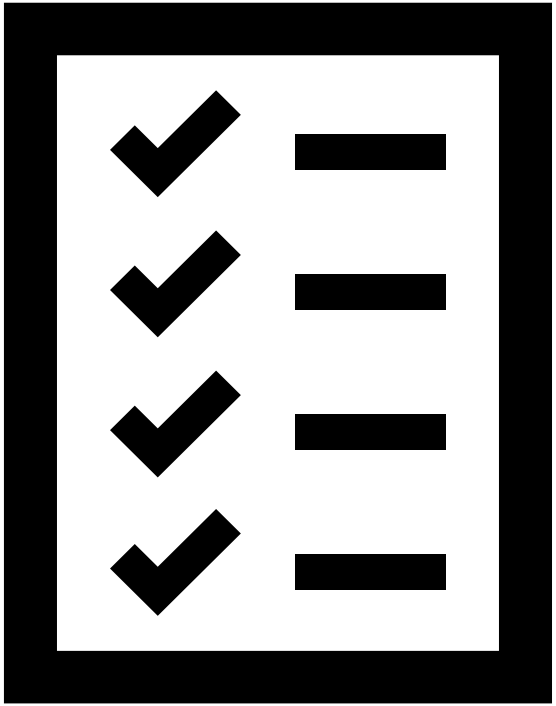
A **new paradigm to forecast** ocean processes **at scales relevant to human wellbeing**



Research Priorities in Support of the Challenge



Evaluation Criteria

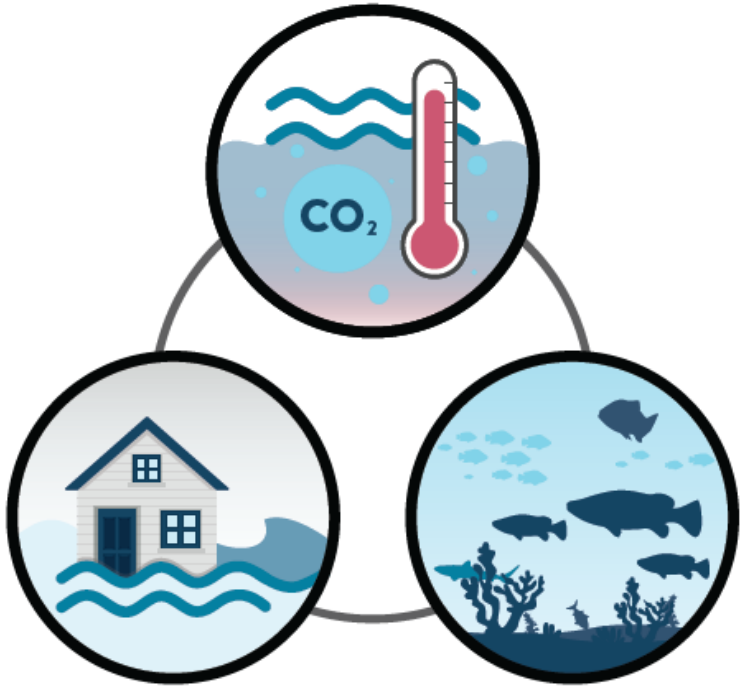


- ❑ Appropriateness for NSF's and OCE's unique responsibility
- ❑ Importance
- ❑ Impact
- ❑ Transdisciplinarity

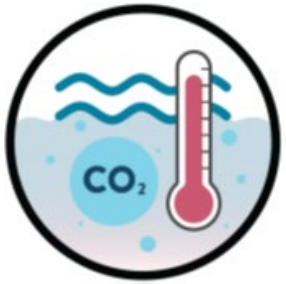
Research Priorities – Recommendation 2

The National Science Foundation's Division of Ocean Sciences should **support basic research** that addresses the **goal of forecasting** ocean processes at scales relevant to human well-being, with emphasis on the following themes and questions:

- **Ocean and Climate**: How will the ocean's ability to absorb heat and carbon change?
- **Ecosystem Resilience**: How will marine ecosystems respond to changes in the Earth system?
- **Extreme Events**: How can the ability to forecast extreme events driven by ocean and seafloor processes be improved?



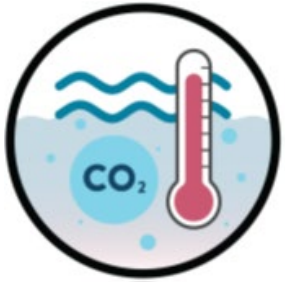
Ocean and Climate:
How will the ocean's ability to absorb heat and carbon change?



Example Research Directions:

- Developing new approaches to observe Atlantic Meridional Overturning Circulation (AMOC) strength, specifically heat transport in the North and South Atlantic
- Improving predictions of marine ice sheet instability driven by warming ocean waters.
- Obtaining better observations of surface pCO_2 in the Southern Ocean in the winter to constrain ocean CO_2 uptake
- Developing ways to help to help quantify variability in the carbon cycle
- Testing and validation of models with observations of past changes in the carbon cycle and climate, and rapid glacial to interglacial transitions.

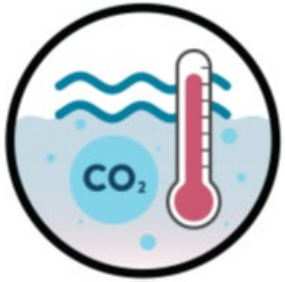
Ocean and Climate:
How will the ocean's ability to absorb heat and carbon change?



Use-Inspired Cases:

- **Marine Carbon Dioxide Removal**: (mCDR) Understand potential for the ocean's natural CO_2 removal and sequestration processes to be accelerated safely and at a scale that would draw additional CO_2 from the atmosphere and mitigate changes in ocean pH.
- **Earth System Science**: Identification of potential Tipping Points in the Earth System

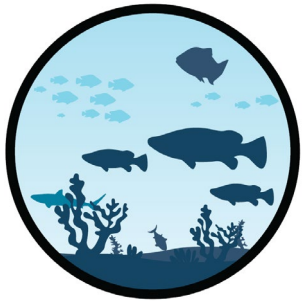
Ocean and Climate:
How will the ocean's ability to absorb heat and carbon change?



Potential Outcomes:

- Improved forecasts of potential tipping points
- Ability to monitor and predict ocean uptake of CO_2
- Gained understanding of changes to the processes moving carbon from the atmosphere to deep ocean waters

Ecosystem Resilience:
How will marine ecosystems respond to changes in the Earth system?



Example Research Directions:

- Determining the effects of warming, acidification, and de-oxygenation on the dynamics of ocean populations, from human to biome scales, in order to anticipate the early signals and downstream consequences on marine ecosystems.
- Predicting the weakening of the biological pump/export production and how this will affect trophic structure and function, and subsequently food security, and exploring innovating solutions integrating multiple knowledge systems and resource management approaches
- Co-developing tools for rapid measurements and assessments of ocean biological and functional diversity – specifically using advancements in environmental and organismal DNA and –omics.
- Understanding and forecasting energy and biomass transfer in and across marine ecosystems and how that contributes to resilience

Ecosystem Resilience:
How will marine ecosystems respond to changes in the Earth system?

Use-inspired Cases:

- **Sustainable Fisheries**: Forecast impacts of ocean acidification, warming temperatures, and sea level rise, as well as other demands from multiple ocean-use sectors (including overfishing) on food web dynamics essential to food security.
- **Storms, or sea level rise**: Understanding the baseline seasonal variability in plankton dynamics in coastal or coral reef ecosystems, then examining shifts in biodiversity and timescale for resilience during storms, sea level rise, or related extreme events.
- **Deep-sea Mining**: Understand the effects of seafloor mining or deep sea ecosystems and what their response and recover may be, and respective timescales

Ecosystem Resilience:
How will marine ecosystems respond to changes in the Earth system?

Potential Outcomes:

- Better understanding of organisms at the base of the food web, the trophic links and biomass transfers, and models to ultimately predict changes in food security
- Development of interventions to support recovery of damaged coral reef and other coastal ecosystems.
- Improve models that link short term changes to ocean processes to fisheries Spatial forecasts of ocean changes to support creation and adaptive management of effective area-based conservation measures.

Extreme Events:

How can the ability to forecast extreme events driven by ocean and seafloor processes be improved?

Example Research Directions:

- Integrating existing and new data and knowledge to elucidate precursory signals, if they exist, that can improve forecasting of earthquakes, underwater volcanic eruptions, submarine landslides, and associated extreme events such as tsunamis, and improve early warning systems.
- Increasing ability to model the future impact of ocean processes on global weather extremes. Forecasting the extent of deoxygenation and dead zones and thus anticipating the impact on ecosystem health and fisheries.
- Producing extreme event forecasts to inform new societal adaptation and ecosystem restoration approaches that use nature-based design features.
- Enhancing forecasts by integrating existing and new data and knowledge from across disciplines and communities to improve our ability to respond to extreme events.

Extreme Events:

How can the ability to forecast extreme events driven by ocean and seafloor processes be improved?

Use-Inspired Cases:

- **Coastal Resilience**: Increasing ability for the co-development of mitigation strategies with coastal communities potentially impacted by extreme events such as coastal flooding.
- **Sustainable agriculture:** Increasing efficiency in natural resource production through accurate forecasts that inform sustainable agricultural and forestry practices.
- **Infrastructure Investment**: Improving forecasts of ocean extreme events from sea level rise to earthquakes to provide guidance on sustainable urban planning, safety, and insurance.
- **Instrumentation of existing infrastructure such as telecommunication cables for monitoring:** Partnering with industry to provide real-time offshore seismic monitoring or carry out temperature-sensing to track ecosystem health for blue economic development.

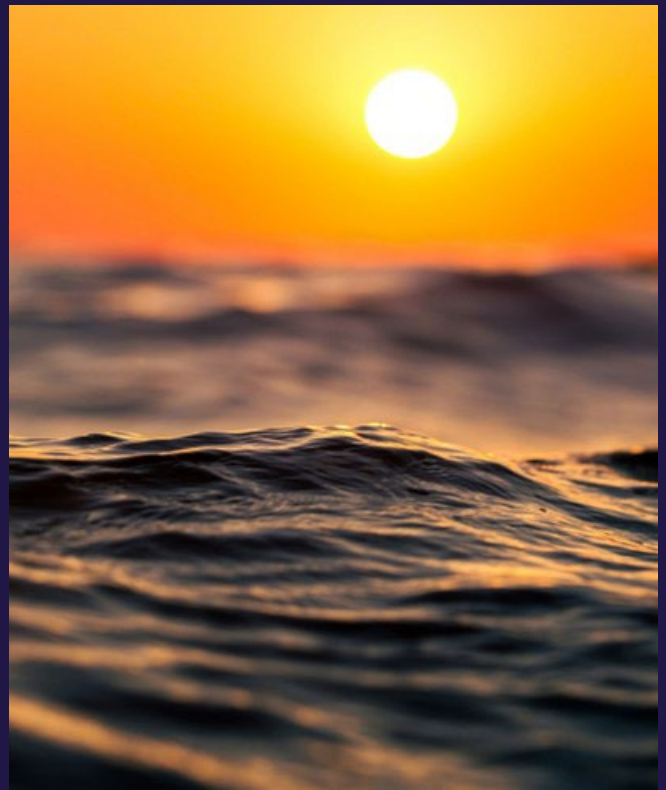
Extreme Events:

How can the ability to forecast extreme events driven by ocean and seafloor processes be improved?

Potential Outcomes:

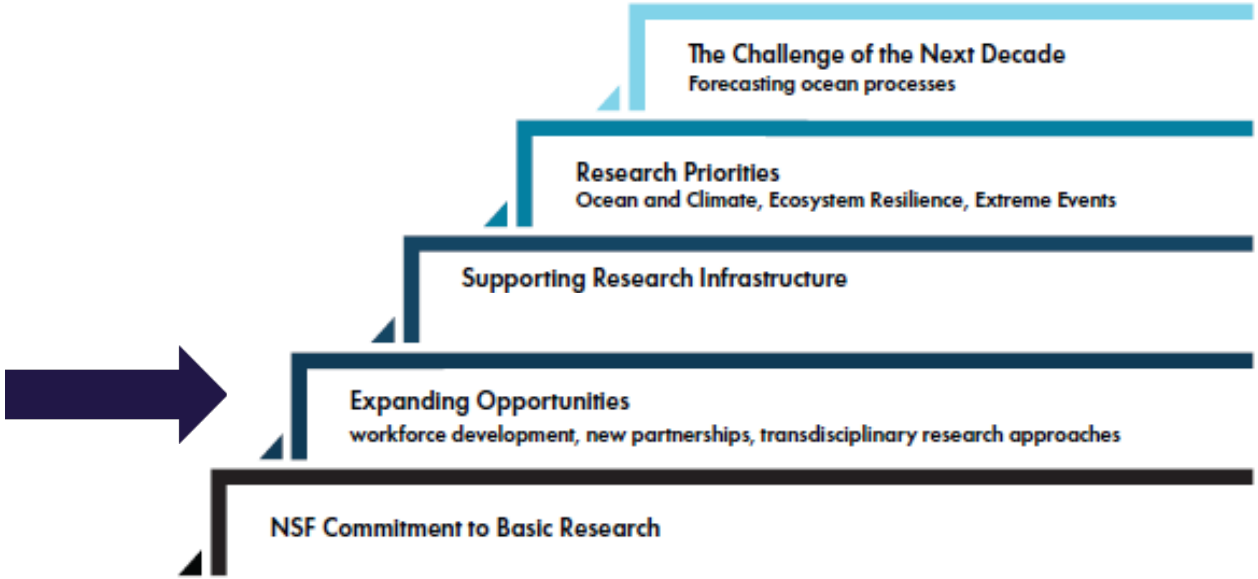
- Improved crop yield due to ability to plant with long-term forecasts in mind.
- Transdisciplinary research to improve the safety of communities vulnerable to extreme weather events and geophysical hazards.
- Sustainable fisheries and healthy ecosystems in waters prone to oxygen depletion.

Expanding Opportunities



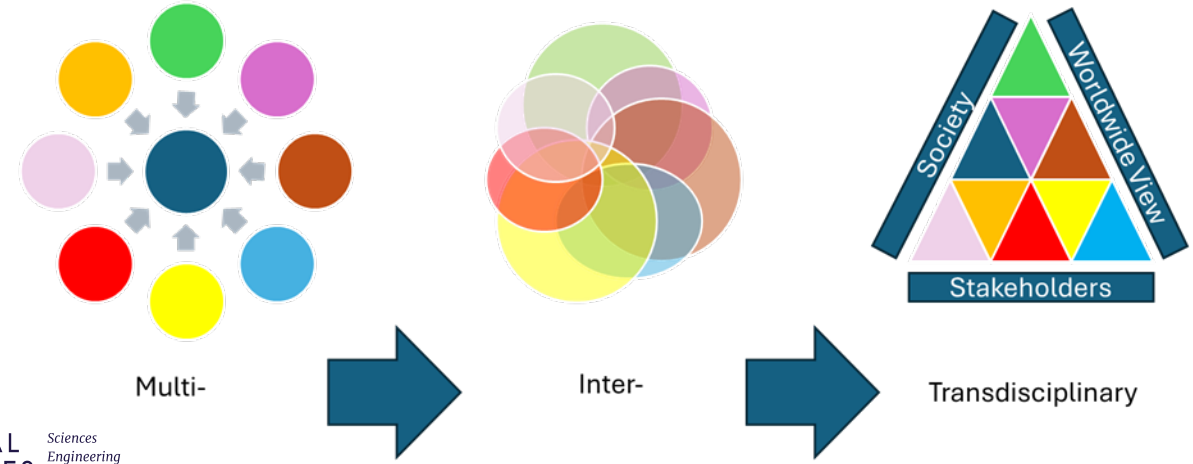
03

Expanding Opportunities



Transdisciplinary Research - Recommendation 3

To foster transdisciplinary research that promotes emerging solutions to challenges related to changes in ocean systems and processes, the National Science Foundation's Division of Ocean Sciences should **invest in** projects that utilize a participatory process toward relationship-building and **collaborative efforts**, establishing **long-term trust** and knowledge-sharing and impacting broad interests. NSF should explicitly enable research that **crosses directorates and programs** and intentionally facilitate efforts to dismantle barriers to transdisciplinary approaches and implementation.



Workforce Development - Recommendation 4

OCE is uniquely positioned to shape the future of ocean sciences research and policy by cultivating a workforce that includes multiple skillsets and knowledge systems. OCE should:

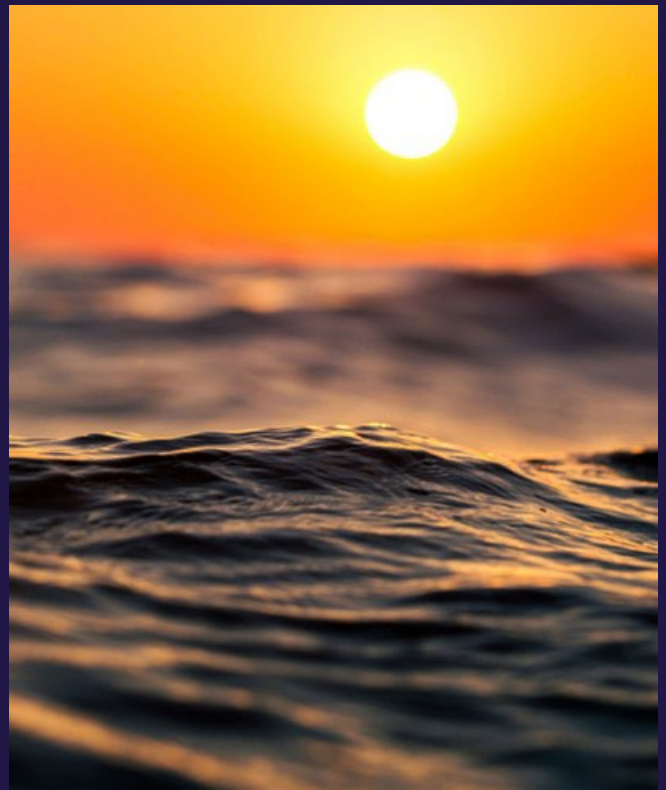
- Explicitly support **reskilling and upskilling**, as well as **mentorship**, of the academic ocean science workforce to better **engage with industry, entrepreneurs, interest holders**, and other partners
- Support workforce development by **investing in vocational and academic pathways**,
- **Promote safe working environments** by enforcing and incentivizing policies that protect people from discrimination, harassment, and bullying.

Strategic Partnerships – Recommendation 5

National Science Foundation's Division of Ocean Sciences (OCE) should explore various ways of bringing new resources to this work, including **expanding partnerships** with other NSF directorates, related mission agencies, industry, and other organizations. OCE should seek greater **interagency cooperation** through federal policies and mechanisms for leveraging NSF-funded basic ocean science research with those mission agencies.

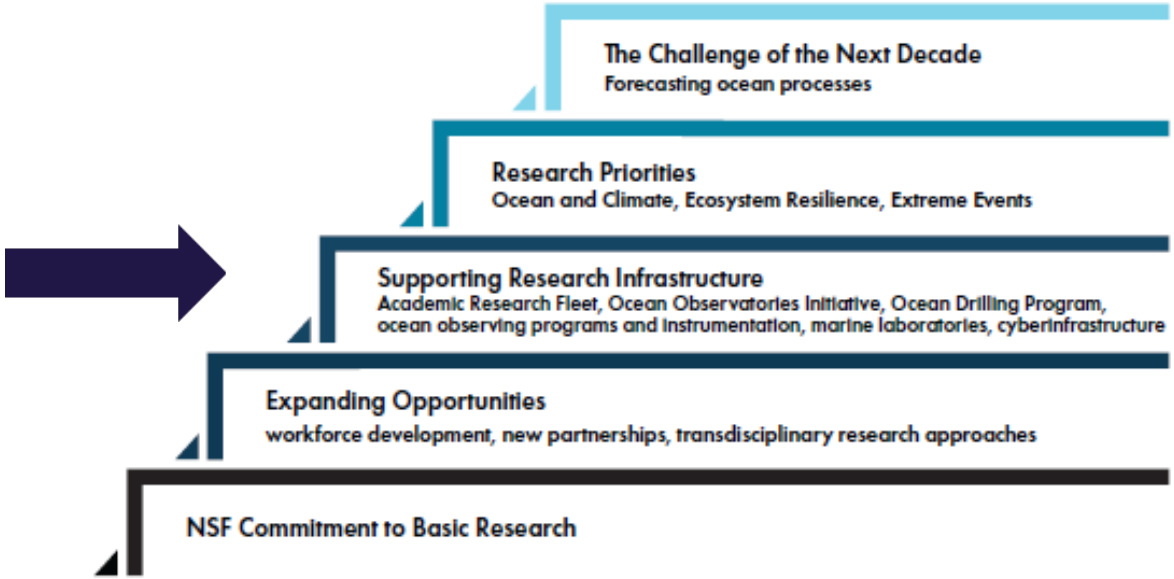
Source: Michael Freilich

Infrastructure Needs



04

Infrastructure Needs



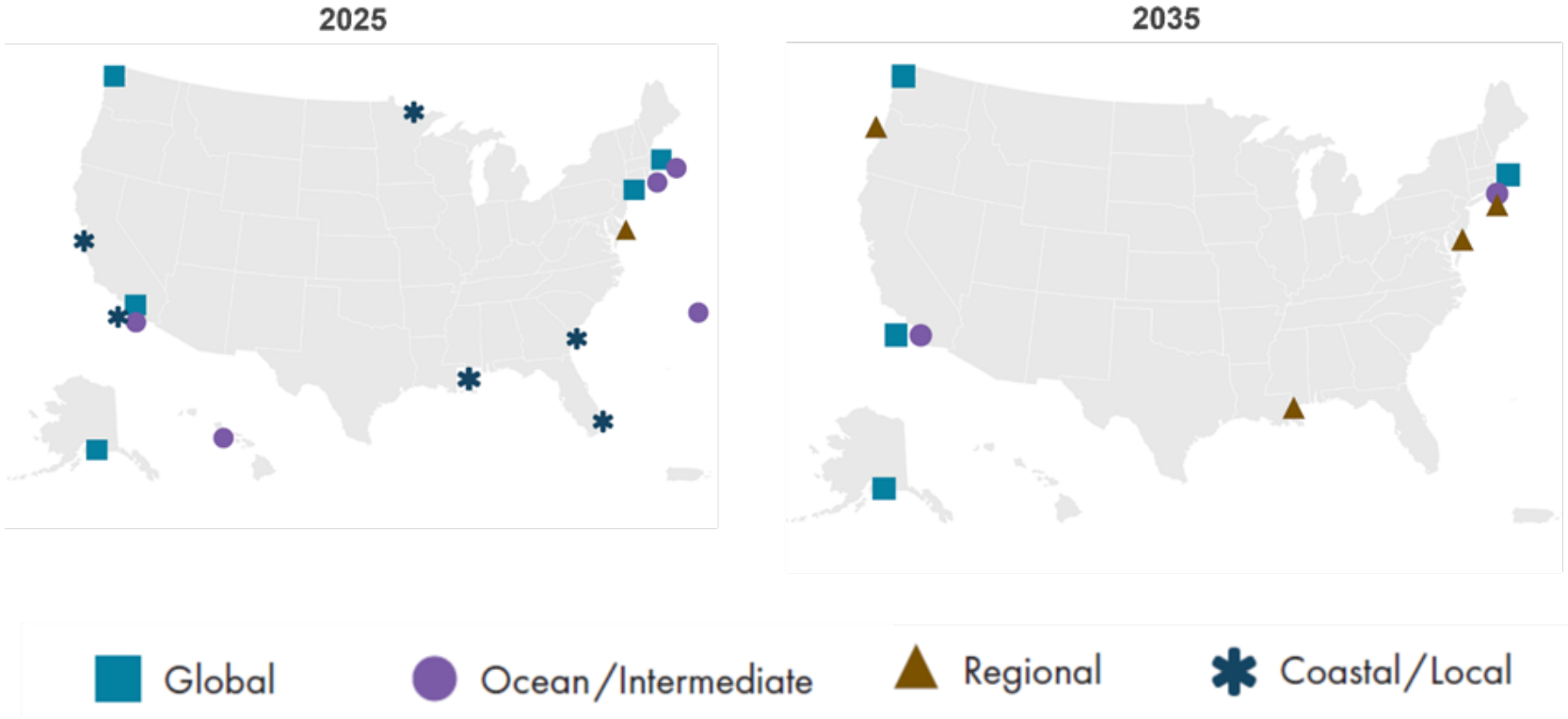
Academic Research Fleet -

- The Academic Research Fleet (ARF) is required infrastructure to address the portfolio of urgent ocean research over the next decade.
- The ARF is a critical component to building ocean literacy and development of the ocean science workforce.
- In the coming decade, research vessel capacity will be greatly reduced.
- Prioritization of developing new modes of autonomous or remote sensing could reduce future reliance.
- OCE has an important role to play in regaining U.S. leadership in ocean sciences by providing access to the sea with research vessels.

Credit: Oregon State University and Glosten Associates.

Credit: Mark Teckenbrock, UAF.

Academic Research Fleet



Academic Research Fleet – Recommendation 6

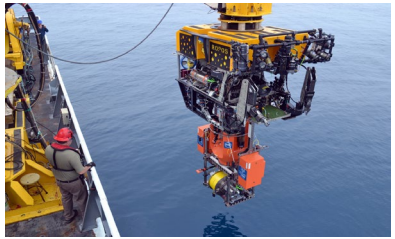
The National Science Foundation's (NSF's) Division of Ocean Sciences and appropriate partners should **conduct an evaluation** that details the funding allocation for the Academic Research Fleet in order **to make informed distributions of the limited resources** available over the next decade and beyond. The evaluation should consider metrics such as days of use funded by NSF; use of local vessels for NSF-funded research; geographic distribution of assets; and alternative mechanisms for providing researchers with access to the coasts (including salt marshes) and sea, such as through marine laboratories or new partnerships.

The long-term status of global-class research vessels is concerning; the committee urges interested parties to **initiate and/or continue significant and intentional planning for replacements**. Without such planning and subsequent implementation, accomplishing high-priority basic and solutions-oriented science will be compromised and U.S. leadership in providing access to the ocean will be curtailed.

Ocean Observatories Initiative

- Several aspects of OOI are aligned with the three urgent research priorities within this report, e.g.,
  - Cascadia Region Earthquake Science Center – forecasting extreme events
  - Irminger Sea – critical for forecasting changes in circulation, carbon and heat exchanges between the ocean and atmosphere, data vital to understanding fisheries and ecosystem changes

- Although the Ocean Observatories Initiative (OOI) program has enabled new discoveries, such as important seafloor and seismic processes around the Axial Seamount, and episodic events related to the Gulf Stream or the California Current system, there is a disconnect between the established program, the science achieved, and the current and future needs of the ocean science community broadly.



Credit: Ocean Observatories Initiative

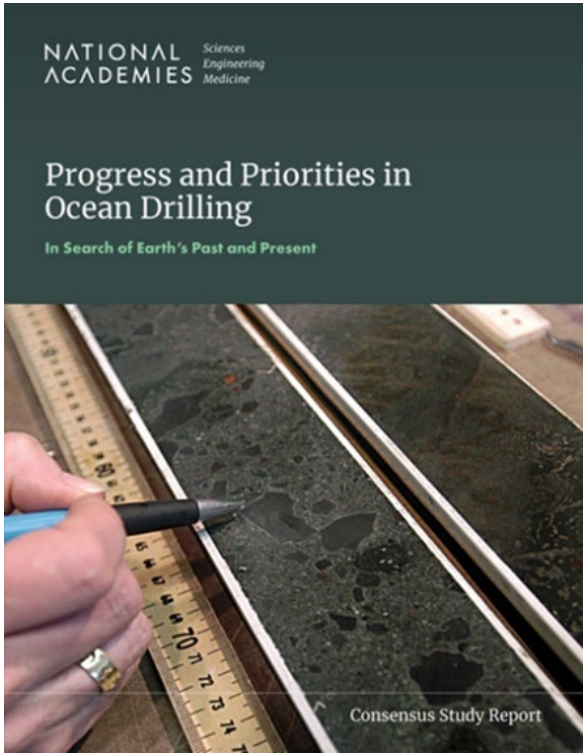
Ocean Observatories Initiative– Recommendation 7

The National Science Foundation's Division of Ocean Sciences (OCE) should conduct **a revisioning and restructuring exercise for the future of the Ocean Observatories Initiative (OOI).** The review, which should occur as a fully separate activity from the usual renewal/recompete discussions, could include:

- an **analysis of the scientific contributions** of each of the OOI arrays;
- **reconsideration of the goals and objectives** of the program to better address the needs of the ocean science community and align with the evolving and urgent ocean science questions for the next decade; and
- consideration of how to **incorporate** technology that may not have existed when OOI was originally envisioned, including **innovative ways to observe and measure** biological abundances and processes, such as low-cost distributed observational networks.

This recommended review **differs from**, and should be independent of, **the renewal process**…

Scientific Ocean Drilling



Following the release of the report, NSF OCE took many important steps toward planning for a future ocean drilling program:

- Planning for a dedicated research vessel
- Securing mission-specific platforms for near team
- Continued support for preservation and curation of legacy assets

Retaining the ability to support U.S. scientists pursuing scientific research remains critical to basic research and to the urgent ocean science research portfolio identified this report.

Due to the decommissioning of the *JOIDES Resolution* there will be substantive and significant unmet drilling objectives that are integral to address the research of the next decade.

Scientific Ocean Drilling – Recommendation 8

The National Science Foundation (NSF) should take action to regain U.S. leadership in scientific ocean drilling on a global stage. To support basic ocean science and the urgent ocean science research portfolio identified in this report for the next decade and beyond, the committee makes the following recommendations:

Legacy assets: NSF's Division of Ocean Sciences (OCE) should **create a dedicated funding line for the Legacy Asset Projects** program to support expedition-scale collaborations, which maximize the return on legacy assets by providing funding to scientists to conduct large-scale research with existing cores and data.

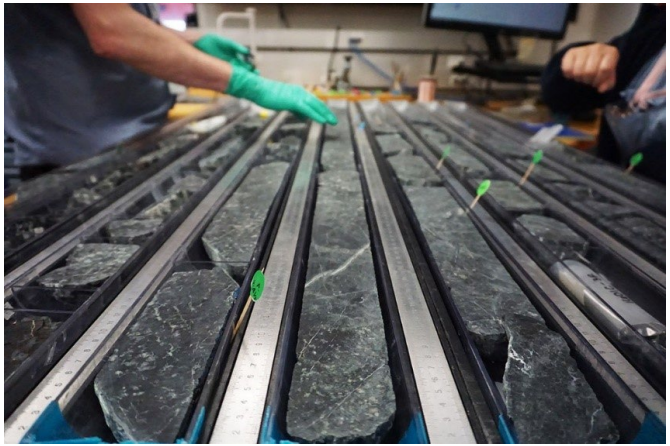
New drilling infrastructure:

- OCE should **develop a sustainable ocean drilling program**, taking into account the need for a U.S.-based drillship. The committee urges NSF to creatively implement management and operational models that ensure viable long-term operations of such a vessel, including developing and nurturing more options for industry work. Such new management and operational models may differ significantly from the recently concluded drilling program.
- Until a dedicated drillship is available, OCE should **continue to support the use of mission-specific platforms** for addressing high-priority, urgent science questions, and to the extent possible, support efforts to retain the technical and engineering expertise in deep-sea coring previously employed by the United States with the *JOIDES Resolution*.

Scientific Ocean Drilling – Recommendation 8 (continued)

International Collaboration and Coordination:

- NSF and international funding agencies and governments should **coordinate and collaborate globally** toward an integrated, long-term strategy for scientific ocean drilling. Such collaboration will require meaningful and transparent reciprocity in scientific participation levels, financial support, scientific planning, and more among contributing partners.
- OCE should renew dialog with both new and long-standing international partners to **identify cost-sharing models** for dedicated drillship operations; such models may include scientist shipboard participation proportional to international contribution levels.

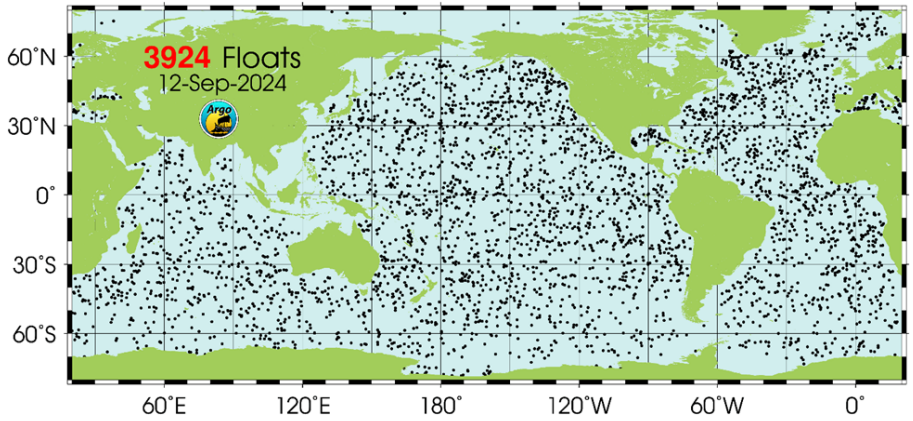


Credit: Johan Lissenberg, Cardiff University, IODP

Supporting Infrastructure

Autonomous Platforms will play an important role in answering the urgent questions of the next decade. New assets are needed and opportunities exist for partnership with commercial entities.

- The Argo program serves as a main source for collecting critical observations of the ocean's interior. NSF OCE's continued role in the national and international partnerships that support and enhance the Argo floats, particularly Biogeochemical Argo, will be essential to accomplishing the urgent ocean science research questions of the next decade.



Source: https://argo.ucsd.edu/about/status/

Supporting Infrastructure

Local Research Vessels contribute to NSF-funded research, but no data exists to evaluate the extent. Evaluation metrics, such as days of use funded by NSF on non-ARF local vessels reported by the ARF community, would be helpful to OCE in order to make informed allocations of the resources available.

Geophysical Instrumentation: Seafloor geodetic instruments and ocean bottom seismometers (OBSs) provide data essential to understanding extreme events originating on the seafloor. The end-of-life of the Marcus Langseth will leave the community without capacity to collect active seismic measurements.

Marine Laboratories, Marine Stations, and Oceanographic Institutions make significant contributions to the infrastructure and workforce supporting OCE-funded research; financial and administrative attention is needed for their continued support.

Source: NSF, http://nsf-ate.pbrc.hawaii.edu/.

Underutilized and/or Emerging Technologies

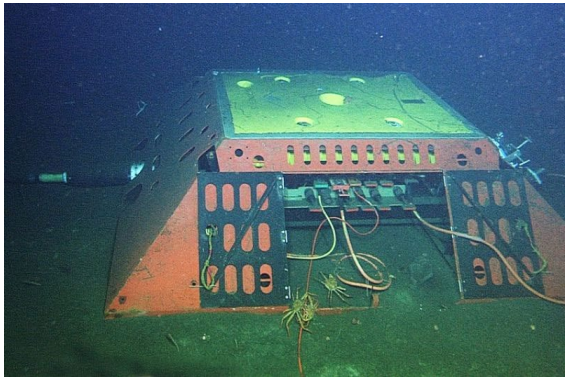
Acoustics

SMART Cables

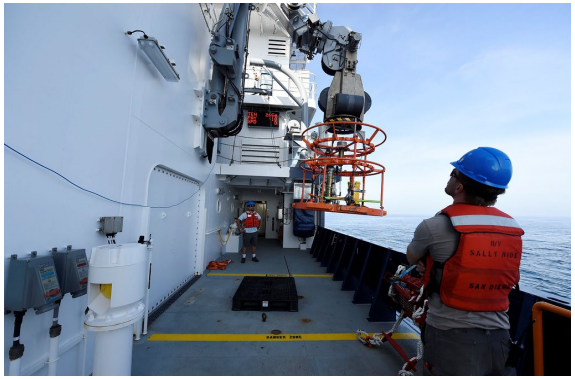
Ocean Biotechnology

Novel Sensors

- Ocean Chemistry
- Biological Data

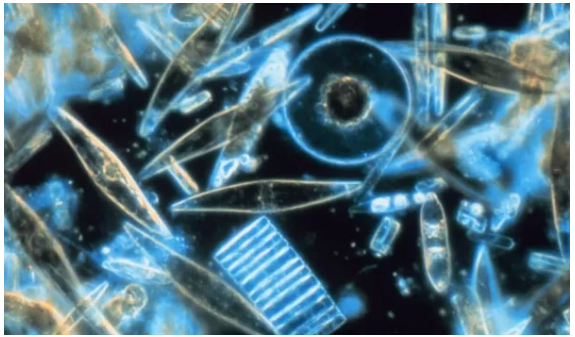


Credit: Monterey Bay Aquarium Research Institute



Credit: U.S. Navy

Credit: U.S. Naval Research Laboratory



Credit: Gordon T. Taylor, Stony Brook University

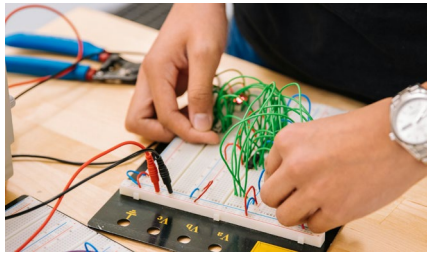
Ocean Science Infrastructure – Recommandation 9

In addition to continuing funding for existing facilities as they support ocean science research priorities for the next decade, the National Science Foundation's Division of Ocean Sciences, in cooperation with agency and other partners (including private philanthropies), should explicitly support:

- the **increased use of autonomous assets** for making **sustained observations** and increasing the efficiency of oceanographic expeditions (expanding the footprint of the vessel while at sea);
- new mechanisms for providing researchers with **access to instrumentation**—for example, shared instrument pools;
- the collaborative development of revolutionary and **innovative sensor technologies** for such efforts as collecting ocean chemistry data (e.g., partial pressure of carbon dioxide), biological data (e.g., environmental and organismal DNA, bio-sensors for species abundance), and measuring seafloor geodesy;
- new avenues for **bringing novel sensors to market** at scale and broadening access to the larger research and management community;
- **expansion of data curation efforts** to support bioinformatics, artificial intelligence, other analyses, and modeling; and
- **the evaluation of new applications of acoustics** (e.g., distributed acoustic sensing), Science Monitoring and Reliable Telecommunications cables, and other emerging technologies to identify their potential to contribute to future research.

Cyberinfrastructure

: the necessary hardware, software and procedures to support data acquisition, transmission, curation, storage, protection and distribution and computer modeling and analysis





Sourced from: istockphoto, Pixabay, and unsplash

Cyberinfrastructure – Recommendation 10

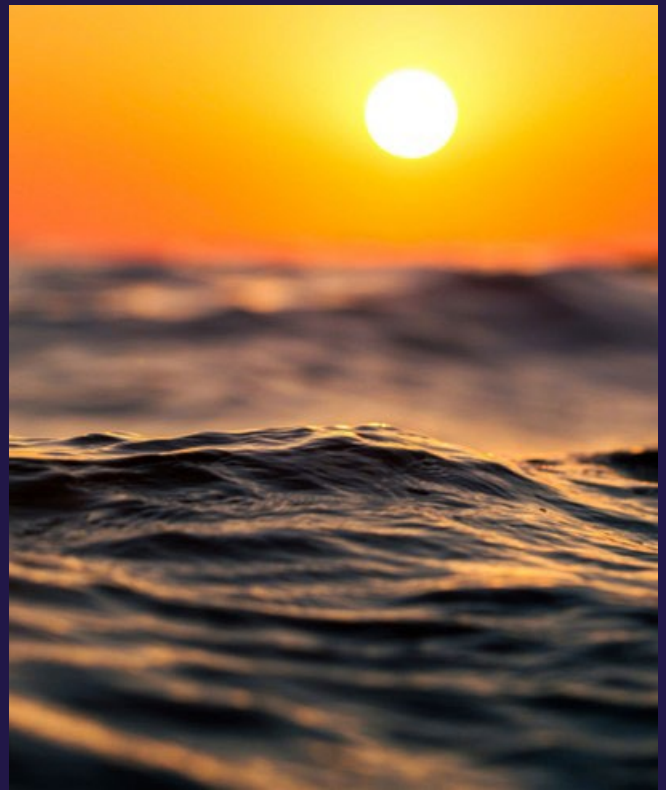
The National Science Foundation's Division of Ocean Sciences should fund a **convening activity**, such as a series of workshops, that seeks to gather expert advice and input, **review established strategies**, and **develop peer-reviewed guidelines and practices for ocean science data curation, computing, and security**, both on research vessels and on shore, integrating Findable, Accessible, Interoperable, and Reusable (FAIR) and Collective benefit, Authority to control, Responsibility, Ethics (CARE) principles and the required supporting cyberinfrastructure. Data and computational experts from adjacent fields (e.g., applied mathematics) should be encouraged to participate.

Credit: Pixabay

Ocean Science Infrastructure Needs

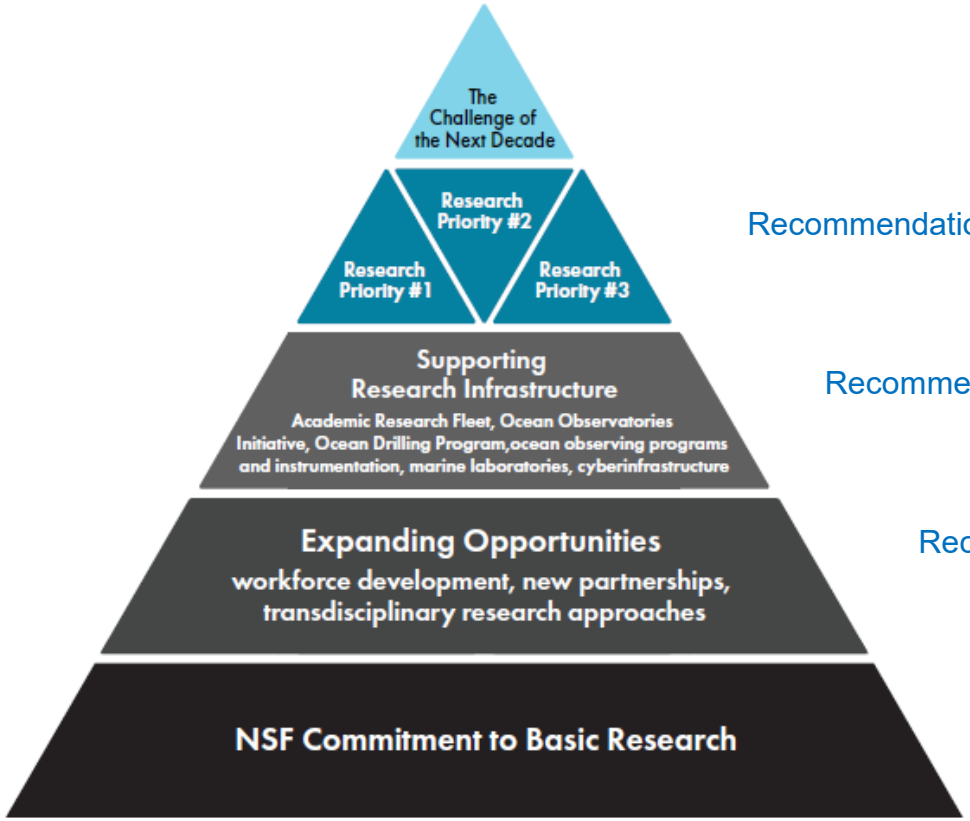
Major Facilities	Ocean and Climate	Ecosystem Resilience	Extreme Events
Academic Research Fleet[4]	R	R	R
Scientific Ocean Drilling Capabilities	R	G	R[1]
OOI Arrays			
Pioneer	R	I	G[3]
Cabled	I	NDE	R[1, 2, 3]
Endurance	R[2]	I	G[3]
Open Ocean	R[2]	I	G[3]
INFRASTRUCTURE ASSETS			
Non-UNOLS, non- ARF institution- owned Research Vessels	R	R	R
Marine Laboratories and Stations	R	R	R
Autonomous Platforms	R	R but NDE	R[3]NDE
Geophysical Instrumentation	NR	NR	R
Instrumented Cables	R	G	G[1]
Ocean Biotechnology	NDE	NDE	NDE
Novel Sensors	R and NDE	R and NDE	R and NDE

The Next Decade



05

Forecast ocean processes at scales relevant to human wellbeing



Recommendation 2

Recommendations 6, 7, 8, 9, 10

Recommendations 3, 4, 5

Recommendation 1

NATIONAL ACADEMIES Sciences Engineering Medicine

Regaining U.S. Leadership in Ocean Science

The next decade of ocean science research is critical and without significant new investment, U.S. leadership will continue to erode. Demonstrating strong US leadership in ocean science research will improve management and decision-making of our coastal and ocean resources, enhance national security and economic prosperity, and propel the blue economy.

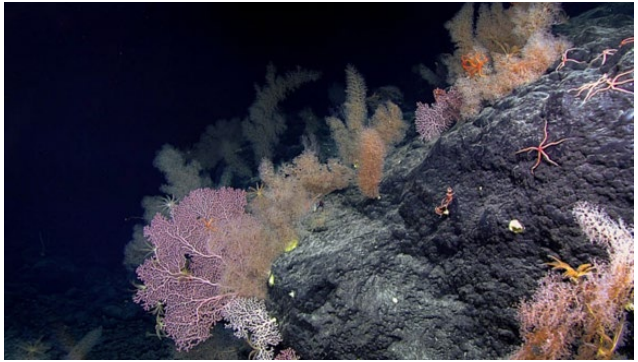
Credit: Pixabay

Credit: Tim Fulton, International

Credit: Mark Teckenbrock

Credit: Luis Lamar © WHOI

Credit: University of Washington. V20



Source: National Oceanic and Atmospheric Administration Office of Exploration, Deep-Sea Symphony: Exploring the Musicians Seamounts

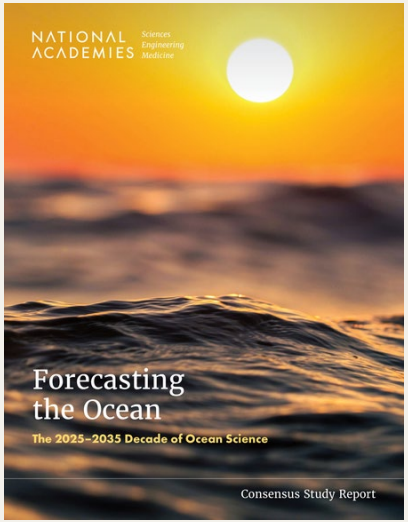
Mark Abbott (Woods Hole Oceanographic Institution), Merryl Alber (University of Georgia), Rosie Alegado (University of Hawai‘i), James Allen (National Science Foundation [NSF]), Katie Arkema (Pacific Northwest National Laboratory), Katherine Barbeau (University of California, San Diego), Paul Barber (University of California, Los Angeles), Jack Barth (Oregon State University/Northwest Association of Networked Ocean Observing Systems [NANOOS]), Joey Bernhardt (University of Guelph), Jennifer Biddle (University of Delaware), Donna Blackman (University of California, San Diego), Tim Boyer (National Oceanic and Atmospheric Administration [NOAA] National Centers for Environmental Information [NCEI]), Stefanie Brachfeld (Montclair State University), Carl Brenner (U.S. Science Support Program), Emily Brodsky (University of California, Santa Cruz), Deborah Bronk (Bigelow Laboratory for Ocean Sciences/University-National Oceanographic Laboratory System [UNOLS] Chair), Almesha Campbell (Jackson State University), Gabrielle Canonico (NOAA), Jackie Caplan-Auerbach (Western Washington University), Eric Chassignet (Florida State University), Shuyi Chen (University of Washington), Patrick Christie (University of Washington), Eric Cordes (Temple University), Sarah Davies (Boston University), John Delaney (University of Washington), Ed Dever (Oregon State University), Steven D'Hondt (University of Rhode Island), Scott Doney, University of Virginia, Emmett Duffy (Smithsonian Institute), Rose Dufour (NSF), Sonya Dyhrman (Lamont-Doherty Earth Observatory), Jim Edson (Woods Hole Oceanographic Institution), Duane Elgin (author of *Choosing Earth*), Melanie Fewings (Oregon State University), Patrick Fulton (Cornell University), Amy Gartman (U.S. Geological Survey), Corey Garza (University of Washington), Peter Gerstoft (Scripps Institution of Oceanography), Sarah Giddings (Scripps Institution of Oceanography), Sarah Gille (Scripps Institution of Oceanography), Holly Greening (Tampa Bay Estuary Program), Karen Grissom (NOAA NCEI), Zachary Gold (NOAA), Sean Gulick (The University of Texas at Austin), Patricia Hernandez (The University of Texas at Austin), David Hodell (University of Cambridge), Russ Hopcroft (University of Alaska Fairbanks), Bruce Howe (University of Hawai‘i at Mānoa), Kelly Hu (Yale University), David Hutchins (University of Southern California), Minoru Ikehara (Kochi University), Fumio Inagaki (Japanese Agency for Marine-Earth Science and Technology), Alex Isern (NSF), Kim Johnson (Monterey Bay Aquarium Research Institute), Kevin Johnson (NSF), Brandon Jones (NSF), Henry Jones (University of Southern Mississippi), Bo Barker Jorgensen (Arhaus University), David Karl (University of Hawai‘i at Mānoa), Maria Kavanaugh (Oregon State University), Deborah Kelley (University of Washington), Brandi Kiel Reese (University of South Alabama), Frieder Klein (Woods Hole Oceanographic Institution), Anthony Koppers (Oregon State University), David Koweek (OceanVisions), Larry Krissek (The Ohio State University), Kristy Kroeker (University of California, Santa Cruz), Jessica Labonté (Texas A&M University at Galveston), Adriane Lam (Binghamton University), Craig Lee (University of Washington), Lisa Levin (Scripps Institution of Oceanography), Chris Lowery (The University of Texas at Austin), Kelly Lucas (University of Southern Mississippi), Mitch Malone (Texas A&M University), Kathie Marsaglia (California State University, Northridge), Robert McKay (Victoria University of Wellington), Galen McKinley (Columbia University), Craig McLean (NOAA, retired), Jim McManus (NSF), Margaret McManus (University of Hawai‘i), Lisa McNeil (Southampton University), Diego Melgar (University of Oregon), Charna Meth (International Ocean Discovery Program Science Support Office), Steve Murawski (University of South Florida), Mark Ohman (University of California, San Diego), Kirsten Oleson (Pacific Research on Island Solutions for Adaptation), Beth Orcutt (Bigelow Laboratory for Ocean Sciences), John Orcut (Scripps Institution of Oceanography), Heiko Pälike (University of Bremen), Ross Parnell-Turner (Scripps Intuition of Oceanography), Malin Pinsky (University of California, Santa Cruz), Charlie Plybon (Surfrider Foundation), Julie Pullen (Propeller Ventures), Kanna Rajan (RAND), Becky Robinson (University of Rhode Island), Yair Rosenthal (Rutgers University), Doug Russell (UNOLS), Demian Saffer (The University of Texas at Austin), Prasanna Sattigeri (International Business Machines [IBM]), Robert Shearman (Office of Naval Research), Joe Schumacker (NANOOS), Amelia Shevenell (University of South Florida), Daniel Sigman (Princeton University), David Smith (University of Rhode Island), Heidi Sosik (Woods Hole Oceanographic Institution), Andrew Solow (Woods Hole Oceanographic Institution), Robert Sparrock (Office of Naval Research), Robert Sterner (University of Minnesota Duluth), Mike Stukel (Florida State University), Chijun Sun (National Center for Atmospheric Research), Jason Sylvan (Texas A&M University), Lynne Talley (Scripps Institution of Oceanography), Allyson Tessin (Kent State University), Jeremy Testa (University of Maryland Center for Environmental Science Chesapeake Biological Laboratory), LuAnne Thompson (University of Washington), Masako Tominaga (Woods Hole Oceanographic Institution), Amy Trice (Ocean Conservancy), Aradhna Tripati (University of California, Los Angeles), Robert Twilley (Louisiana State University), Alexis Valauri-Orton (The Ocean Foundation), Martin Visbeck (GEOMAR), Maureen Walczak (Oregon State University), Allen Walker (NSF's Technology, Innovation, and Partnership Directorate), Shelby Walker (NSF), Jessica Warren (University of Delaware), Doug Wiens (Washington University), Susan Wijffels (Woods Hole Oceanographic Institution), William Wilcock (University of Washington), Trevor Williams (Texas A&M University), Earle Wilson (Stanford University), Warren Wood (U.S. Naval Research Laboratory), Christine Yifeng Chen (Lawrence Livermore National Laboratory), and Zhongwen Zhan (California Institute of Technology).

Thank you!

Questions?

Slido.com #5725

Download Now!



www.nap.edu/27586

Study Director, Kelly Oskvig
koskvig@nas.edu