



NOAA
GLOBAL OCEAN
MONITORING & OBSERVING

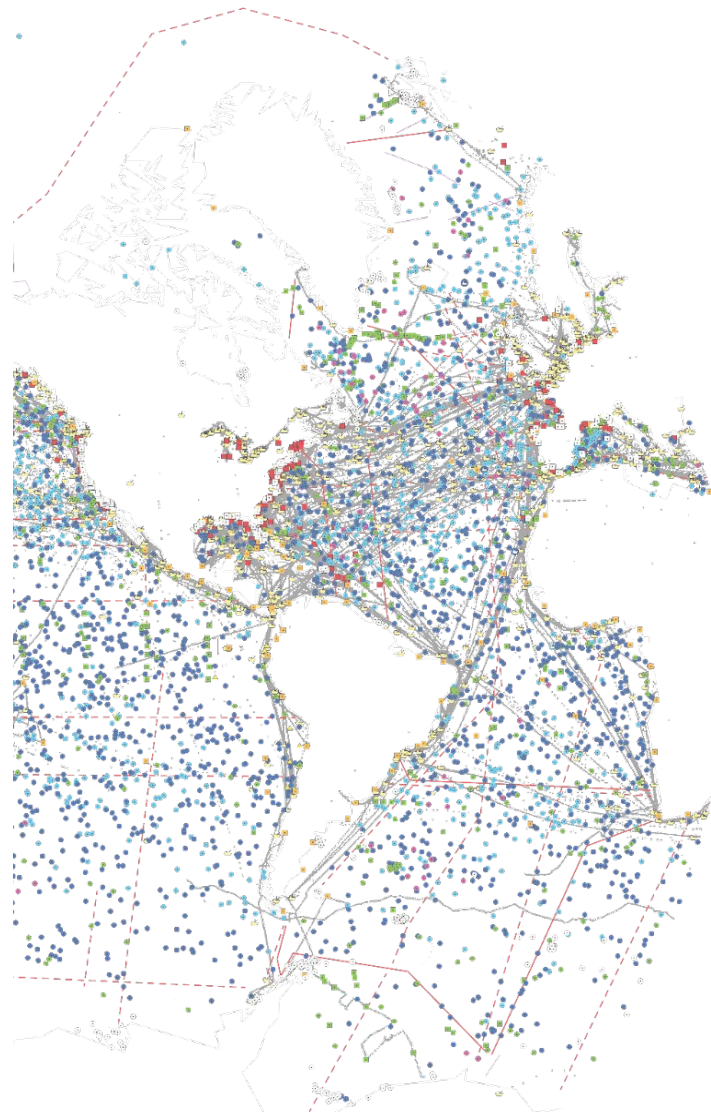
2023 Accomplishments

NOAA's Global Ocean Monitoring and Observing Program

NOAA Global Ocean Monitoring and Observing Program
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Table of Contents

- 3 Letter From the Director
- 4 Preface
- 5 Acronyms
- 6 **Goal 1: Sustain global ocean monitoring and observing for long-term continuity and improve data quality and system efficiency.**
 - 6 Long-Term Continuity
 - 7 Quality and Efficiency
- 9 **Goal 2: Innovate and evolve the ocean observing network to address emerging needs and opportunities for ocean health, ocean economy, weather and climate.**
 - 9 Innovative Technologies
 - 10 Ocean Health
 - 12 Weather and Climate
- 14 **Goal 3: Improve the value, accessibility, and usability of observational data for informed decision-making.**
 - 14 Data Accessibility and Usability
 - 15 Models and Products
 - 17 Research Capabilities
- 18 **Goal 4: Develop and capitalize on the expertise, diversity and capacity of the ocean observing enterprise.**
 - 18 Capacity Building
 - 20 Community Engagement



Letter From the Director

As I look back on 2023, I am pleased to reflect on how far NOAA's Global Ocean Monitoring and Observing (GOMO) Program has come in such a short time. Since becoming a program office in 2020, GOMO and our community have overcome numerous obstacles in continuing highly impactful ocean observations while advancing new technologies that are shaping the ocean observing system of the future.

Throughout 2023, our community worked diligently to advance many of NOAA's missions, including improving our understanding of ocean processes and enabling authoritative monitoring of global and regional changes in multiple Essential Ocean Variables (EOVs) such as ocean temperature, currents, and ocean salinity. For the first time, GOMO led a focused field experiment, CHAOS, to more systematically assess the impact of ocean and atmospheric observations on hurricane forecasting (see page 13). GOMO's global leadership of ocean carbon observing continues to provide the foundation of existing products and knowledge. We are capitalizing on new applications of AI technologies and observing new types of ocean information (eg, eDNA, phytoplankton). Finally, GOMO's leadership in capacity building has blossomed to include support of dozens of early career research professionals and indigenous community members.

This inaugural Annual Report highlights GOMO's accomplishments during calendar year 2023 and the impact of our work. It also reflects our progress towards meeting the objectives laid out in our [2021–2025 GOMO Strategic Plan](#).

Looking forward to 2024 and beyond, GOMO will be laying the groundwork for improved observational capabilities in the Arctic Oceans and for ocean surface carbon fluxes. Our emerging emphasis on data management will help improve data access and interoperability with numerous systems in the U.S. and internationally. Many challenges still remain in sustaining current observing systems in the face of rising costs and uncertain access to research vessels. We will continue to leverage and expand our partnerships to address these needs and new opportunities ahead.

Finally, I would like to express my sincere gratitude for the entire GOMO team and community, including our partners across NOAA and other federal agencies, OAR Laboratories, Cooperative Institutes, research institutions, and our other collaborators from the national and international ocean observing community over this past year.

Sincerely,



David M Legler
GOMO Director

David M Legler, Ph.D.

**Director, NOAA Global Ocean
Monitoring and Observing Program**



Preface

The ocean covers 71% of the Earth's surface and contains 97% of the Earth's water. Global ocean conditions profoundly affect weather, the environment, marine ecosystems, and coastal regions where a large fraction of the global population lives. Observing, monitoring, and understanding the role of the ocean in seasonal, interannual, and long-term variations in weather and climate is a core mission of NOAA.

NOAA's Global Ocean Monitoring and Observing (GOMO) Program is the U.S. Federal source and international leader for *in situ* global ocean observations and information in support of research, monitoring, and prediction. Our mission is to provide and support high quality global ocean observations and research to improve our scientific understanding and inform society about the ocean's role in environmental change.

Through GOMO, NOAA supports half of the world's ocean observing research – more than one million ocean observations each day.

Ocean observations are used in climate and weather prediction models to improve understanding of global ocean conditions and variables such as ocean temperature, currents, waves, sea level, salinity, and carbon and oxygen, how ocean conditions change over time, and the ocean's impact on our environment.

The activities conducted in GOMO are directly in support of NOAA's mission of Science, Service, and Stewardship. The GOMO Program supports the larger goals and objectives of NOAA's Office of Oceanic and Atmospheric Research (OAR) outlined in the [2020–2026 OAR Strategy](#), which include: (1) explore the marine environment; (2) detect changes in the ocean and atmosphere; (3) make forecasts better; and (4) drive innovative science.

GOMO collaborates with a variety of partners across NOAA labs, cooperative institutes, universities, and federal agencies to achieve NOAA's mission, and partners with over 50 countries in developing and sustaining the Global Ocean Observing System.



Acronyms

AOML	NOAA Atlantic Oceanographic and Meteorological Laboratory
ARP	GOMO Arctic Research Program
BGC	biogeochemical
CHAOS	Coordinated Hurricane Ocean-Atmosphere Sampling Project
CIMAS	Cooperative Institute for Marine and Atmospheric Studies
COM	CPO Climate Observations Monitoring Program
COP28	28th United Nations Climate Change Conference of the Parties
CPO	NOAA Climate Program Office
CVP	CPO Climate Variability Program
EPP/MSI	NOAA Educational Partnership Program with Minority Serving Institutions
GFDL	NOAA Geophysical Fluid Dynamics Laboratory
GO-SHIP	Global Ocean Ship-Based Hydrographic Investigations Program
GOMO	NOAA Global Ocean Monitoring and Observing Program
GOOS	Global Ocean Observing System
NOAA	National Oceanic and Atmospheric Administration
OAP	NOAA Ocean Acidification Program
OAR	NOAA Office of Ocean and Atmospheric Research
PI	principal investigator
PMEL	NOAA Pacific Marine Environmental Laboratory
POGO	Partnerships for Observation of the Global Ocean
Scripps/SIO	Scripps Institution of Oceanography at the University of California, San Diego
TPOS	Tropical Pacific Observing System
UW	University of Washington
WHOI	Woods Hole Oceanographic Institution
XBT	expendable bathythermograph

Goal 1 Accomplishments

Sustain global ocean monitoring and observing for long-term continuity and improve data quality and system efficiency.

Long-Term Continuity

Critical Mooring Stations Recovered and Redeployed

Observations from fixed-point locations like [OceanSITES](#) stations form a key component of our ocean observing system, providing high-quality time-series data to document changes happening in our ocean and atmosphere through time. In collaboration with partners at [NOAA's Pacific Marine Environmental Laboratory \(PMEL\)](#) and the [Woods Hole Oceanographic Institution \(WHOI\)](#), GOMO supported the successful recovery and redeployment of several moorings in 2023. These included: Station Papa in the North Pacific (April 2023), which now has observations extending back 67 years; Stratus off the eastern coast of Chile (December 2023), which [celebrated 22 years of observations](#) in February 2023; and the WHOTS mooring at Station ALOHA off the coast of Hawaii (July 2023), which now has maintained 19 years of observations.

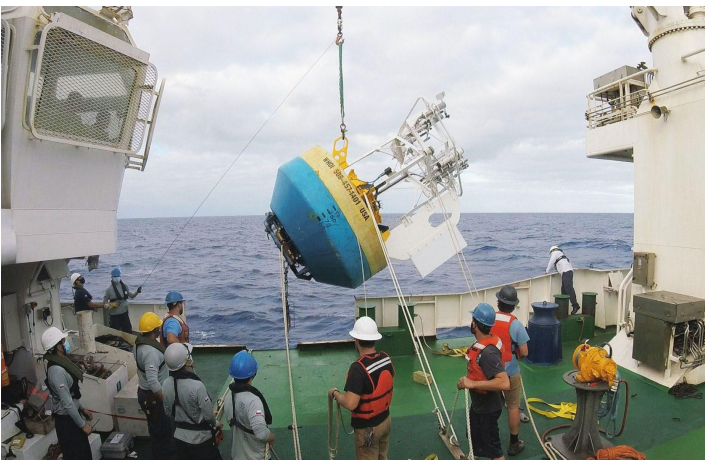
A successful deployment and recovery cruise for the Consortium on the Ocean's Role in Climate (CORC) and California Current Ecosystem (CCE) moorings was completed in July 2023 by researchers at the [Scripps Institution of Oceanography \(Scripps/SIO\)](#), as part of a collaborative effort by GOMO and [NOAA's Ocean Acidification Program \(OAP\)](#) which provides critical data on physical and biogeochemical processes in the California Current System.

First NOAA GO-SHIP Cruise in Five Years Transects the North Atlantic Ocean Basin

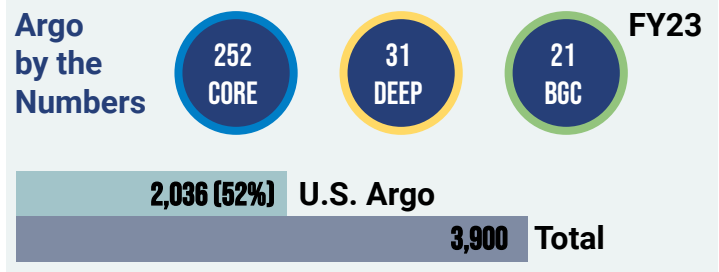
On May 9, 2023, scientists aboard the NOAA Ship *Ronald H. Brown* completed the A16N transect of the [Global Ocean Ship-Based Hydrographic Investigations Program \(GO-SHIP\)](#), sailing for 55 days from Suape, Brazil to Reykjavik, Iceland. GO-SHIP is an international effort to perform repeat observations of the ocean at decadal intervals through a global network of cruise tracks, providing critical data on changes in ocean heat content, ocean circulation, carbon cycling, and marine biogeochemistry. [Completion of A16N cruise](#) marked the fourth time this transect of the North Atlantic has been surveyed since 1993, and the [first NOAA GO-SHIP cruise to be completed in five years](#).

U.S. Argo Sustains More Half of the Global Array, Deploying Over 300 Floats in 2023

The [U.S. Argo Program](#), sponsored by GOMO, is a leader in the international Argo Program, contributing nearly half of the global Argo array, promoting the delivery of real-time and delayed-mode data, and ensuring global coverage and sampling in remote regions such as the Southern Ocean and central Pacific. In FY23, GOMO supported the successful deployment of 252 Core Argo floats, 31 Deep Argo floats, and 21 biogeochemical (BGC) floats. In total, 2,036 of the nearly [3,900 currently active Argo floats](#) were deployed by the U.S. Argo Program supported by GOMO, which includes [NOAA's Atlantic Oceanographic and Meteorological Laboratory \(AOML\)](#), PMEL, Scripps, WHOI, and the [University of Washington \(UW\)](#).



Stratus buoy S19 deployment off the coast of Chile in the eastern tropical Pacific. Credit: Raymond Graham, WHOI.



Annual Arctic Cruise Provides Insights on Climate and Ecosystem Change

In collaboration with the [Arctic Marine Biodiversity Observing Network](#), [Chukchi Ecosystem Observatory](#), [U.S. Fish and Wildlife Service](#), [North Pacific Research Board](#), and [Alaska Sikuliaq Program](#), GOMO's [Arctic Research Program \(ARP\)](#) successfully supported the U.S. Arctic and Ecosystem Climate Cruise, which took place from September 10 to October 4, 2023. As NOAA's only Arctic cruise each year, this cruise occupies five [Distributed Biological Observatory \(DBO\)](#) lines in the Northern Bering and Chukchi Seas and services the [Ecosystem Fisheries Oceanography Coordinated Investigations \(EcoFOCI\)](#) network of moorings in the same geographic region. These programs provide critical data on climate and ecosystem change in the Pacific Arctic that help to inform NOAA's management of fisheries and marine mammals.

XBT Network Enables Continued Monitoring of Atlantic and Gulf Variability

The GOMO-supported AOML [expendable bathythermograph \(XBT\) network](#) completed several missions in the Atlantic, deploying over 1,200 XBTs along three transects. Two [AX07 transects](#) were completed in May and December 2023, providing critical data to study North Atlantic subtropical gyre variability. Two missions were along the [AX10 transect](#), which provides one of the longest running time series (over 50 years) in monitoring temperature and variability in the Gulf Stream. The [AX18 transect](#), which began in 2002 to study meridional heat transport and overturning circulation in the South Atlantic, was completed in June 2023, representing the first reoccupation of this transect after the shipping hiatus during the Covid-19 pandemic.

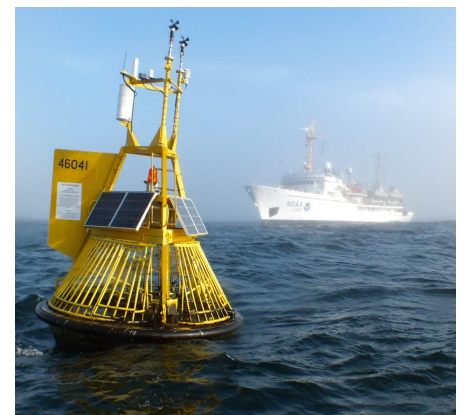
Quality and Efficiency

Ocean Observing Co-Design Workshop to Evolve GOOS

GOMO Director David Legler, with Program Managers Ann-Christine Zinkann and Cheyenne Stienbarger, led an ocean observing co-design workshop at IOC/UNESCO in Paris, France during September 18–20, 2023. The workshop was focused on reviewing progress and developing future activities of the [GOOS Ocean Observing Co-Design Programme](#), a UN Ocean Decade endorsed program which aims to evolve GOOS to be co-designed with end-users and responsive to their needs. The workshop program was centered around the Co-Design Programme's six exemplars on hurricanes, ocean carbon, marine heat waves, boundary currents, marine life, and storm surges, for which planning and implementation of information-synthesis activities is underway in pilot regions targeting these topic areas. The workshop also aimed to assess [EuroSea](#) activities and how they could best be integrated with the GOOS Co-Design Programme.

CO₂ Workshop Convenes Experts to Advance Ocean Carbon Monitoring

The [Integrated Carbon Observation System \(ICOS\)](#) held a series of [workshops on surface ocean pCO₂ observations, synthesis and data products](#) from November 6–9, 2023 at the [Flanders Marine Institute \(VLIZ\)](#) in Oostende, Belgium. Workshop sessions focused on: 1) improving uncertainty in data-based air-sea CO₂ fluxes; 2) developing the design of [SOCONET](#) and related pCO₂ products; and 3) discussing future directions of [SOCAT](#). GOMO Program Manager Kathy Tedesco served on the organizing committee for the workshop that convened over 100 ocean carbon scientists from around the world to review the status of the Surface Ocean Carbon Value Chain and discuss improvements to the structure, process and routine delivery of critical information on ocean CO₂ uptake to policy makers.



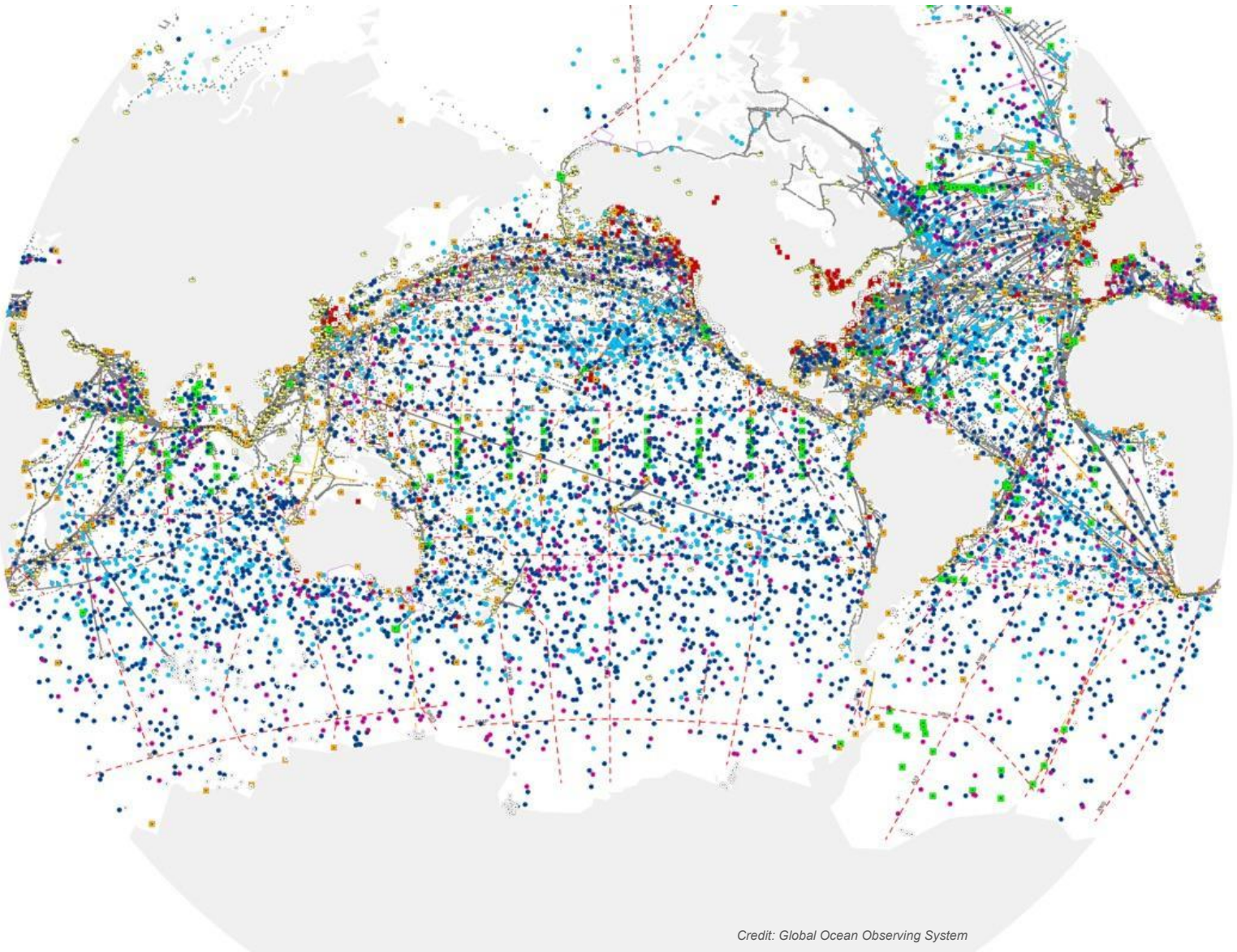
A NOAA mooring off Cape Elizabeth, Washington equipped with a sensor system to understand CO₂ trends over time in the coastal waters, with the NOAA Ship Fairweather in the background (2013). Credit: Richard Feely, NOAA.

U.S. CLIVAR Workshops Improve Coordination of Climate Variability Research Community

The [U.S. Climate Variability and Predictability \(CLIVAR\) Program](#) is a national research program that aims to enhance understanding and prediction of climate variability on intraseasonal-to-centennial timescales. Each year, CLIVAR organizes a series of community meetings and workshops. GOMO is a major supporter of U.S. CLIVAR, co-sponsoring nine workshops for the CLIVAR community in 2023, including: *"Mesoscale and Frontal-Scale Air-Sea Interactions"*, *"Meeting AMOC Observing Needs in a Changing Climate"*, *"Atlantic Tropical Variability and Tropical Basin Interactions"*, *"WCRP Open Science Conference"*, *"Polar Amplification of Climate Change across Hemispheres and Seasons"*, *"Confronting Climate Model Trends with Observations"*, *"Optimizing Ocean Observing Networks for Detecting the Coastal Climate Signal"*, *"Pathways Connecting Climate Changes to the Deep"*, and *"Summer School on Ocean Uncertainty Quantification."*

GOOS Observation Coordination Group Hosts Ocean Observing Workshops and Outreach Event

GOMO Director David Legler and Program Manager Ann-Christine Zinkann attended the [14th session of the GOOS Observation Coordination Group \(OCG\)](#) from June 6–8, 2023 in Cape Town, South Africa. The OCG works to operate, maintain, coordinate and integrate the 13 in situ global ocean observing networks, including Argo, OceanSITES, and GO-SHIP, among others. As part of the meeting, GOMO members helped co-host two workshops, a [Low Cost Technology Workshop](#) showcasing low-cost observing technologies and evaluating services to ensure public accessibility of observing data, as well as a Boundary Currents Workshop focused on setting priorities for the observation and monitoring of the Agulhas Current. Outcomes included the production of a review paper, enhancement of stakeholder mapping and consultation, and a design for an observing system.



Credit: Global Ocean Observing System

Goal 2 Accomplishments

Innovate and evolve the ocean observing network to address emerging needs and opportunities for ocean health, ocean economy, weather and climate.

Innovative Technologies

Deep Argo Regional Pilot Arrays Improve Ocean Warming Estimates

GOMO-funded scientist Gregory Johnson, in collaboration with Brian King from the UK National Oceanography Centre, used Deep Argo profile and trajectory data, as well as core Argo trajectory data and historical CTD data to describe the Zapiola Gyre in the Argentine Basin. Quantifying the large transports in the gyre illuminated revealed competing effects of mixing and advection while quantifying the bottom-intensified vertical structure, allowing insights into the gyre dynamics. These findings highlight the importance of implementing a global Deep Argo array for improving understanding on ocean circulation and transport. Read the [full article](#) published June 8, 2023 in the *Journal of Geophysical Research: Oceans*.

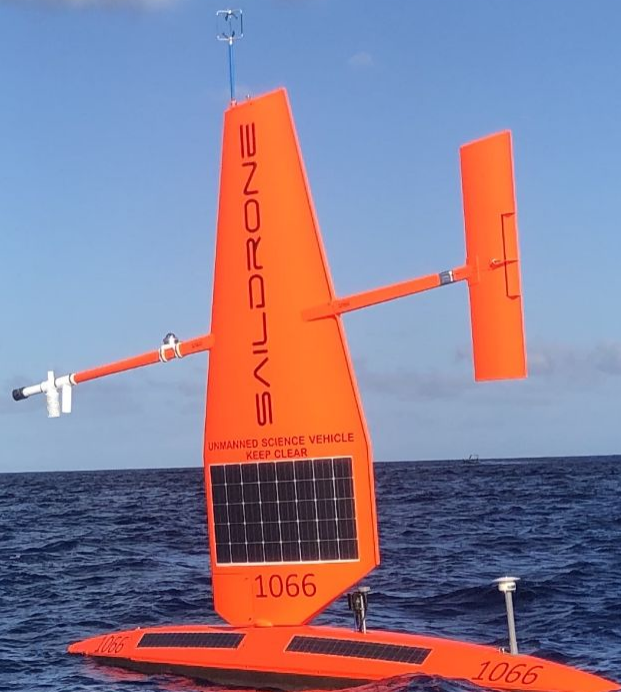
GeoCollaborate® Improves Coordination of 2023 Atlantic Hurricane Field Season

To improve coordination of hurricane observations during the 2023 hurricane season, GOMO's [Extreme Events Program](#) utilized a visualization and situational awareness tool called GeoCollaborate®. The virtual [Ocean Observations GeoCollaborate® Dashboard](#) enables users to view data from different portals in a single, interactive map and see the locations of ocean and hurricane observing platforms in relation to active or developing storms. Utilizing this data visualization tool helped hurricane researchers leverage platforms already in place and prioritize new deployments in real time. [GeoCollaborate®](#) is a software application developed by StormCenter Communications, Inc. that was developed through the [Small Business Innovation Research \(SBIR\) program](#) within NOAA's Technology and Partnerships Office.

Saildrones Depart Hawaii to Study and Improve the Tropical Pacific Observing System

Three Saildrone uncrewed surface vehicles (USVs) departed Hawaii on June 22, 2023 for a 120-day mission across the central tropical Pacific. Led by scientists at PMEL with support from GOMO, and conducted in collaboration with [NOAA's National Marine Fisheries Service](#) and the [Pacific Islands Fisheries Science Center](#), this mission represented the [sixth in a series of Saildrone missions](#) conducted since 2017 as part of an ongoing effort to improve the [Tropical Pacific Observing System \(TPOS\)](#). Data from the mission will be used to test how USVs may be used to supplement ship-based fish surveys and improve understanding of ocean-atmosphere boundary layer and equatorial upwelling processes.

Saildrone. Credit: NOAA.



NOAA Completes Field Testing of New Technology to Observe Arctic Phytoplankton

A team of scientists from NOAA and UW, with support from GOMO, have been testing a [cutting-edge imaging system to observe distributions of phytoplankton from aircraft](#). The hyperspectral camera uses a sensor to take images, which are translated to an absorption spectrum based on the colors reflected by different phytoplankton in the water. This imaging technology, with combined data from ship-based samples and satellite images, is aimed at increasing the ability to monitor and manage phytoplankton blooms. The research team successfully completed two fields tests in the U.S. Arctic during 2023: one in June 2023 where 60 nautical miles of flights were coordinated with a research trip in the Chukchi Sea to test the multispectral camera, and another in September 2023 coordinated with the U.S. Arctic and Ecosystem Climate Cruise to enable comparisons between the aircraft and ocean measurements.



Top: Phytoplankton bloom in the Bering Sea. Credit: NASA; Bottom: June 2023 Arctic Airborne Investigations and Research Crew. Credit: Bren Schoumaker, OMAO.

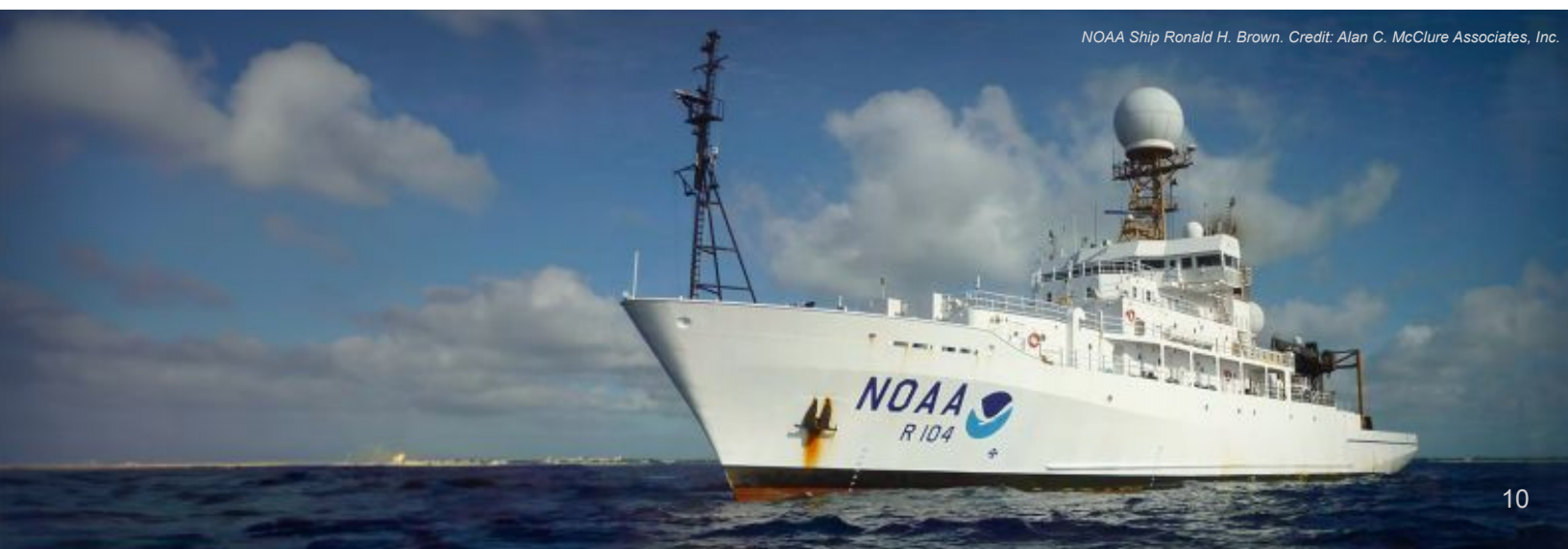
Ocean Health

Bio-GO-SHIP Collects eDNA to Track Biological Changes in the Atlantic Ocean

GOMO supported the completion of the [A16N transect](#) of the [international Bio-GO-SHIP Program](#), which sailed for 55 days between Suape, Brazil and Reykjavik, Iceland from March 6 to May 9, 2023. AOML scientists on board the *NOAA Ship Ronald H. Brown* collected a variety of [biological measurements including environmental DNA \(eDNA\)](#). The Atlantic Ocean is the only ocean basin showing widespread, dramatic shifts in fundamental nutrients necessary to support marine life. The eDNA data collected on this cruise will be used to explore the diversity, distribution, and functioning of marine life in the Atlantic Ocean, and was the first time this data was collected along the A16N transect.

Biogeochemical Argo Float Provides Critical Data on Hurricane Idalia

A GOMO-supported biogeochemical (BGC) Argo float came within the path of Hurricane Idalia during its development in August to September 2023. Using this opportunity to study the impact of hurricanes on biogeochemical processes, the AOML Argo team worked with the Hurricane Field Program to rapidly cycle the float, increasing the frequency of its normal profile cycle from ~10 days to hourly. Approximately twelve hour-long cycle profiles were collected during the passage of the storm and in the days following. Oxygen and nitrate data collected from the BGC Argo float is being analyzed to characterize biogeochemical dynamics associated with the storm, in combination with the temperature and salinity data collected by this float and others nearby.



NOAA Ship Ronald H. Brown. Credit: Alan C. McClure Associates, Inc.

Moorings Improve Understanding on Ocean Circulation and Ecosystem Processes in the California Current

On July 29, 2023, a team from Scripps completed a week-long cruise aboard the on the *R/V Sally Ride*, successfully servicing a number of moorings off the coast of Southern California from the continental shelf to deep offshore waters. This critical field work served two project missions: 1) the [Consortium on the Ocean's Role in Climate \(CORC\)](#) project, which studies the circulation of the California Current system; and 2) the [California Current Ecosystem \(CCE\)](#) project, which combines physical observations, such as temperature and currents, with biogeochemical measurements to learn more about the ecosystem. Both projects receive funding from GOMO, with CCE being co-funded by the OAP with additional in-kind contributions from the [NOAA Southwest Fisheries Science Center](#).

Biogeochemical Profiling Floats Reveal Phytoplankton Bloom Dynamics Beneath Antarctic Sea Ice

A new study by Ph.D. Student Shannon McClish and Researcher Seth Bushinsky from the University of Hawaii at Manoa sheds light on biology beneath the sea ice in the Southern Ocean. Through the [Southern Ocean Carbon and Climate Observations and Modeling \(SOCCOM\)](#) project, McClish and Bushinsky used biogeochemical profiling floats to show that nutrients from melting sea ice fuel phytoplankton productivity, with peak blooms occurring before the sea ice has broken up, which was not previously observable. This work, funded by a partnership between GOMO and NOAA's [Climate Program Office \(CPO\) Climate Observations and Monitoring \(COM\)](#) and [Climate Variability and Predictability \(CVP\) Programs](#), highlights the potential impacts of sea ice and biological processes on the broader ecology of the Southern Ocean, and the need to advance observation technology to better understand these complex systems. Read the full article published October 20, 2023 in [Geophysical Research Letters](#).



New Global Plankton Data Product Links Climate and Fisheries Models

Jessica Luo, a scientist at NOAA's [Geophysical Fluid Dynamics Laboratory \(GFDL\)](#), and Rainer Kiko of Sorbonne Université in France were funded through a collaboration between GOMO and CPO's COM and CVP Programs to develop a global plankton database, called the [Pelagic Size Structure database](#). Based on imagery from emerging technologies using autonomous underwater instruments taken over the past several decades, this database will be used to explore how shifts in plankton communities are linked to changing environmental conditions and their impacts on marine fisheries. Postdoctoral scholars Mathilde Dugenne and Marco Corrales-Ugalde gave presentations on this work at the [2023 Aquatic Sciences Meeting](#) (Palma de Mallorca, Spain) and [U.S. Ocean Carbon and Biogeochemistry Summer Workshop](#) (Woods Hole, Massachusetts).

Ocean waves. Credit: NOAA.



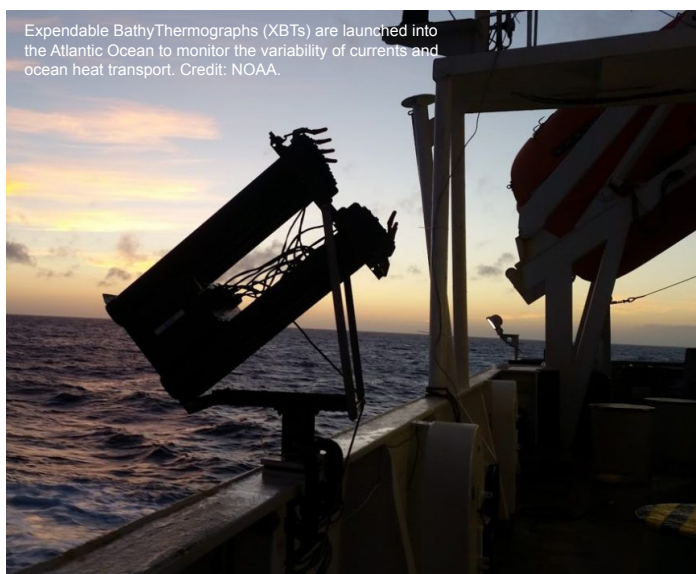
Weather and Climate

GOMO Supports Finalization of Plans for TPOS Ocean-Atmosphere Process Studies

The [Tropical Pacific Observing System \(TPOS\)](#) is an international effort to advance understanding and prediction of tropical Pacific variability (e.g., the El Niño-Southern Oscillation, ENSO) and its impacts. GOMO serves in a leadership role to TPOS, helping to advance and coordinate TPOS implementation activities. In 2023, GOMO facilitated discussions with intra/interagency and international partners to develop plans for interdisciplinary studies focused on ocean-atmosphere processes to advance weather and climate model representations of the tropical Pacific, which will take place during 2026–2027.

XBT Data Used to Explore Antarctic Ocean Circulation

A 15-year time series of high-resolution XBT data and underway Acoustic Doppler Current Profilers velocity data collected by GOMO-supported Scripps scientists was used to explore [changes in the Antarctic Circumpolar Current \(ACC\) transport in the Drake Passage](#). The results show that, while the net transport in the Drake Passage showed insignificant acceleration, the net transport comprised compensating trends across the frontal regions caused by increasing eddy activity. The high-resolution measurements from XBTs were key to resolving these fronts and the impact of the eddies on ACC transport. Increased eddy-driven upwelling is expected to intensify around Antarctica, which has significant implications for ice-melting, sea level rise, and global climate.



USS Tennessee during WWII. Credit: Bettmann/Getty Images.



Citizen-Science Project Fills Vital Gaps in Historical Meteorological Observations

A recent publication in the [Geosciences Data Journal](#), which was covered in an article by the [Washington Post](#), highlighted work to recover WWII-era historical weather data through citizen science. Over 4,000 volunteer transcribers digitized observations from 28,000 logbook images from the U.S. Navy Pacific Fleet stationed in Hawaii during 1941–1945, providing access to invaluable observations from an information-limited region and time. The late Kevin Wood, a scientist at the Joint Institute for the Study of the Atmosphere and Ocean at PMEL and UW, co-authored the study, with funding provided in part by GOMO's Arctic Research Program.

New Research on “Triple Dip” La Niña Upends Current Understanding of ENSO

Research from GOMO-funded scientist Michael McPhaden shows that development of the [2020–2023 “triple-dip” La Niña](#) did not follow previous theories on how these rare phenomena occur. The 2020–2023 triple-dip La Niña caused many extreme weather impacts around the world, and may have played a role in masking rising global temperatures until the reemergence of El Niño in June 2023, which coincided with record-breaking heatwaves and temperature throughout the summer. McPhaden wrote about the 2020–2023 La Niña in the [2022 State of the Climate Report](#), describing potential drivers behind the event, including influences from ocean basins outside of the Pacific influencing ENSO dynamics as well as shifting background conditions, possibly linked to climate change.

Expansion of the Global Sea Level Observing System Helps Address Geologic Threats and Validate Satellite Measurements

In 2023, the [University of Hawai'i Sea Level Center \(UHSLC\)](#) installed five new climate quality tide gauges to address critical global concerns. Four tide gauges were installed in American Samoa, which is experiencing rapid subsiding as well as increased tectonic activity that has raised tsunami risks. These tide gauges will provide local communities with decision-relevant observations of climate impacts and improve the local tsunami warning system. The fifth tide gauge was installed at Vandenberg Air Force Base near Lompoc and Santa Maria, California. This tide gauge replaces the now defunct Harvest Oil Platform tide gauge, which was one of only four global tide gauges used to validate satellite altimeter data. The new Vandenberg tide gauge will enable the continuation of a stable and accurate climate data record of global sea level change from satellite altimetry.



Tide Gauge.
Credit: NOAA.

Integrated Field Campaign Improves Understanding on the Ocean's Role in Hurricanes

In 2023, GOMO allocated \$2M in funding made available through the FY22 Disaster Relief Supplemental Appropriations Act to support a focused ocean-atmosphere observing experiment, the Coordinated Hurricane Atmosphere-Ocean Sampling (CHAOS) campaign. CHAOS is an integrated field campaign within GOMO's new [Extreme Events Program](#) and conducted as part of the [AOML Hurricane Field Program](#) to improve our understanding of the role of the ocean, waves, and air-sea interactions in the development and intensification of hurricanes in order to produce more accurate and reliable models and forecasts. Accomplishments for the 2023 Atlantic hurricane season include:

Projects and Partners

 **4** Hurricanes Observed
Idalia, Lee, Nigel, Tommy

Projects Funded **8** 

 **20+** Partners in Collaboration


Early Career Co-PIs **7** 

Expendables & Remote Sensing

 **5** A-sized directional wave spectra drifters

Dropsondes **40** 

 **4** Small uncrewed aircraft systems

Numerous aircraft remote sensing overflies of other assets 

In Situ Observing Platforms

Gliders fitted with Acoustic Doppler Current Profilers **2** 

 **5** Rapid cycling Argo floats

Unique Sairdrone hurricane or tropical cyclone encounters **19** 

Hurricane Idalia, August 2023.
Credit: NOAA.



Goal 3 Accomplishments

Improve the value, accessibility, and usability of observational data for informed decision-making.

Data Accessibility and Usability

GOMO Advances Development of Data Strategy with Community Input

GOMO has been working to develop a Data Strategy to describe the vision, goals, and objectives to effectively manage, share, and maximize the value of data assets that are aligned with GOMO and NOAA's strategic vision and priorities. The Data Strategy was introduced at the 2023 GOMO Community Workshop, and key areas were discussed over a half-day data workshop to guide the development of an implementation plan. To support this effort, GOMO is hiring a permanent Data Management Specialist and a temporary Global Ocean Data Manager through [NOAA's LANTERN Program](#).

IARPC Vessel Tracking Tool Improves Coordination of Arctic Research Activities

GOMO supported the [Interagency Arctic Research Policy Committee \(IARPC\)](#) Field Operations Community of Practice's launch of the [2023 Research Vessel Tracking and Coordination](#) tool. This tool provides information on international research expeditions through Alaskan and Arctic waters in order to improve collaboration among Arctic researchers throughout the year as well as communication and coordination with local and Indigenous communities. The vessel tracking tool provided details on more than forty expeditions during the [2023 research season](#). Pre- and post-field season meetings were held to share information on planned vessel movements.



USCGC Healy in Arctic sea ice. Credit: Jessica Cross, NOAA PMEL.



Argo APEX float deployment.
Credit: UCSD.

U.S. Argo Data Assembly Center Reaches 1.5 Million Total Argo Profiles

In 2023, the U.S. Argo Data Assembly Center, which is hosted at AOML and supported by GOMO, marked 1.5 million total Argo profiles processed. An Argo profile includes the data collected during each 10-day profiling cycle. A total of 84,279 profiles were made publicly available at the Argo Global Data Assembly Center during FY23, with 99% of the non-under-ice float profiles made available in 24 hours (97% were available within 12 hours). As of October 2023, a total of [484 publications](#) used data from the global Argo observing system, with 39 publications using Argo data authored or co-authored by GOMO-funded Argo project principal or co-principal investigators (PIs) during FY23.

ARP Releases New Research Web Pages to Improve Data Access

GOMO's Arctic Research Program (ARP) released [twelve new web pages](#) that summarize goals and objectives and provide access to datasets for ARP-funded projects, highlighting the program's commitment to the findability, accessibility, and reusability of vital Arctic data. The web pages were developed by Kelli Ong, who joined ARP as an undergraduate scholar with [NOAA's Educational Partnership Program with Minority Serving Institutions \(EPP/MSI\)](#) during the summer and was mentored by GOMO Program Manager Cynthia Garcia.

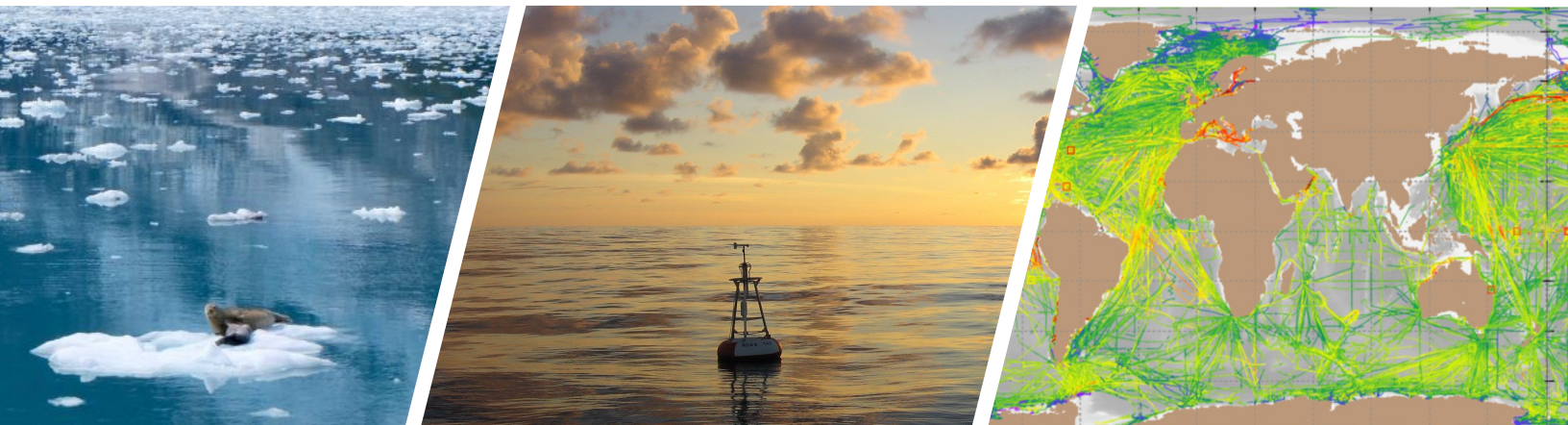
Models and Products

2023 Arctic Report Card Documents Warmest Arctic Summer on Record

NOAA's 18th [Arctic Report Card](#) was released during a press conference at the [American Geophysical Union \(AGU\) Annual Meeting](#) in December 2023. The Arctic Report Card is an annually-produced compilation of essays describing the state and changing conditions in the Arctic each year. The 2023 Report Card documented new records showing that human-caused warming of the air, ocean and land is affecting people, ecosystems and communities across the Arctic region, which is heating up faster than any other part of the world. This year's Report Card offered 12 essays describing peer-reviewed research, with contributions from 82 scientists from 13 countries. Coordination of the Arctic Report Card is led by GOMO's [Arctic Research Program](#) in collaboration with partners at PMEL, CPO, NOAA Communications and NOAA's [Global Systems Laboratory \(GSL\)](#).

2023 Release of the Surface Ocean CO₂ Atlas (SOCAT) Shows Alarming Decline in Ocean CO₂ Observing Capacity

The latest [Surface Ocean CO₂ Atlas \(SOCAT\)](#) update shows a dramatic decline in open ocean data collection efforts since 2017. Gaps in the ocean CO₂ observing system threaten our ability to quantify global ocean CO₂ uptake which provides vital information for climate policy during a time when mitigating and constraining the impacts of greenhouse gasses is critical. This latest SOCAT update delivered 35.6 million in situ surface ocean CO₂ measurements collected between 1957 and 2022, and included contributions from over 100 members of the international marine carbon research community including several GOMO-funded PIs.



Left: Seals on sea ice near Whittier, Alaska, June 2023. Credit: Sarah Tucker, NOAA GOMO; Center: Ocean buoy. Credit: NOAA; Surface CO₂ from ships, drifters, autonomous surface platforms and moorings. Credit: SOCAT 2023.

State of the Climate in 2022 Chapter on Global Oceans Features GOMO-Funded Research

The [State of the Climate in 2022 Report](#), published in the *Bulletin of the American Meteorological Society* in September 2023, documents the annual status and trajectory of the climate system. GOMO-funded researcher Gregory Johnson served as co-editor of the [Global Oceans](#) chapter, which details global ocean conditions relevant to climate such as sea-surface temperature, ocean salinity, air-sea flux, sea-level, surface currents, meridional overturning circulation, and phytoplankton fluorescence. Johnson also led the ocean heat content and the ocean salinity sections, both of which drew heavily on Argo data. Johnson co-leads PMEL's [Global Observations of Biogeochemistry and Ocean Physics](#) group, and leads PMEL's Core and Deep Argo profiling float projects supported by GOMO.

Annual Global Carbon Budget Projects Record Greenhouse Gas Emissions

The Global Carbon Project's [2023 Global Carbon Budget](#) was released on December 5, 2023 at the [UN Climate Change Conference of the Parties \(COP28\)](#) held in Dubai, United Arab Emirates. Several GOMO-supported PIs contributed to the report, which showed that greenhouse gas emissions from fossil fuels are projected to reach a record 36.8 billion metric tons in 2023, an increase of 1.1% over 2022, and that global action to reduce fossil fuel consumption is not happening fast enough to prevent dangerous impacts from climate change. GOMO provides roughly half of all the surface ocean CO₂ observations, collected from hundreds of sensors on ships, buoys, moorings and autonomous surface vehicles, which are essential for understanding the global carbon cycle and ocean carbon sink. Read the full [NOAA Research story](#).

Global Ocean Data Analysis Project Provides Updated Ocean Measurements

The 2023 release of the [Global Ocean Data Analysis Project \(GLODAP\)](#) data product provides access to quality controlled surface to bottom ocean biogeochemical data, with an emphasis on seawater inorganic carbon. Several GOMO-funded PIs contribute to GLODAP, with version 2.2023 providing an update of the previous version and including measurements from more than 1.4 million water samples from the global oceans collected on 1108 cruises. The data for the 13 core variables have undergone extensive quality control, especially systematic evaluation of bias. The original data, their documentation and DOI codes are available at the [Ocean Carbon Data System \(OCADS\)](#) of NOAA NCEI.

Deep Argo Grounding Measurements Expand Data on Global Bathymetry

GOMO-funded PIs at Scripps produced the first bathymetry product using Deep Argo float grounding measurements. The preliminary results of the [Deep Argo-derived bathymetry show good agreement with multibeam bathymetry data](#), providing a promising tool to enhance global bathymetry measurements, particularly in remote regions that are more costly, time-intensive, or challenging to survey using traditional ship-based platforms. The [General Bathymetric Chart of the Oceans \(GEBCO\)](#) community is in the process of adding Deep Argo to their bathymetry data sources.

New AI-Based Data Product Provides Tool for Studying Ocean Biogeochemistry

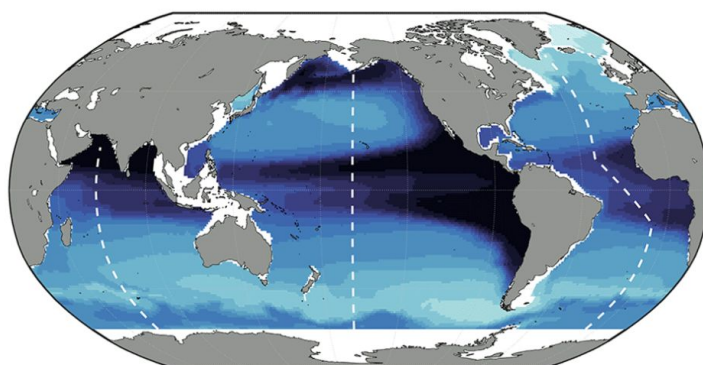
Researchers at PMEL, GFDL, and UW collaborated to create an observation-based gridded data product of ocean oxygen concentration and variability. [Gridded Ocean Biogeochemistry from Artificial Intelligence - Oxygen \(GOBAI-O₂\)](#) uses machine learning to provide three-dimensional monthly fields of dissolved O₂ from 2004–2021 along temperature and salinity gradients, and was trained and evaluated using ship and Argo-based observations. GOBAI-O₂ will serve as a valuable resource for researchers studying marine biogeochemical cycling, long-term ocean deoxygenation trends, and oxygen fluxes between the ocean and atmosphere. This work was led by PMEL's [Global Observations of Biogeochemistry and Ocean Physics](#) group and was funded by GOMO and CPO's COM Program. Read the [full article](#) published in August 2023 in *Earth System Science Data*.

GOMO Supports the 2023 Supplement to *Frontiers in Ocean Observing*

In March 2023, The Oceanography Society released the second supplement to *Frontiers in Ocean Observing: Emerging Technologies for Understanding and Managing a Changing Ocean*, which describes new technologies and research that advance understanding of the ocean. The publication features 30+ articles with topics focused on marine carbon dioxide removal (mCDR), trends in ocean biodiversity, ocean pollutants, multi-hazard warning systems, and eDNA technologies. The publication represents an international effort supported by GOMO in collaboration with [Ocean Networks Canada \(ONC\)](#) and [Partnerships for Observation of the Global Ocean \(POGO\)](#), with contributions by ocean experts from around the world. GOMO Program Manager Emily Smith served on the *Frontiers in Ocean Observing* Executive Committee and helped to procure funding and coordinate activities leading to publication of the 2023 Supplement. Read the full [GOMO web story](#).

New Machine Learning Tool Produces Maps of Ocean Heat Content

PMEL Researchers John Lyman and Gregory Johnson used machine learning to develop [Random Forest Regression Ocean Maps \(RFROM\)](#) of ocean heat content anomalies at much higher spatial and temporal resolution than previously possible. The RFROM training data included in situ ocean temperature data and the predictors include maps of satellite sea-surface height and sea-surface temperature, as well as location and time. These new maps will help to better quantify the contribution of ocean warming to Earth's Energy Imbalance, a key climate metric. The PIs estimate that Deep Argo floats in the Argentine Basin provide a 10-fold increase in the certainty of Antarctic Bottom Water warming rates. Read the [full article](#) published in May 2023 in the *Journal of Atmospheric and Oceanic Technology*.



Long-term mean surface O₂ concentrations from GOBAI-O₂ at 300 dbar. Source: Sharp et al., 2023, *Earth System Science Data*.

Research Capabilities

GOMO Co-Sponsors Competitive Research on Marine Carbon Dioxide Removal

NOAA funded several new large-scale, multi-sectoral projects to advance research in marine carbon dioxide research and removal. The funding was awarded through NOAA OAP on behalf of the [National Oceanographic Partnership Program \(NOPP\)](#), which aims to facilitate partnerships between federal agencies, academia, and industry. GOMO, with OAP and the [National Science Foundation](#), contributed funding to support a three-year project led by Dennis McGillicuddy and scientists at WHOI, GFDL, and the [National Center For Atmospheric Research \(NCAR\)](#) on “Multiscale observing system simulation experiments for iron fertilization in the Southern Ocean, Equatorial Pacific, and Northeast Pacific.”

ARP Announces Funding Opportunities to Enhance Arctic Data Management, Develop Products, and Improve Sea Ice Models

In December 2023, GOMO’s Arctic Research Program (ARP) announced an [FY24 Notice of Funding Opportunity](#) with competitions focused on: 1) Enhancing Arctic Data Management for FAIR Compliance, and 2) Building Climate Resilience through Data-Driven Products and Tools funded through the Inflation Reduction Act (IRA). ARP also released a [Request for Short Proposals](#) available to PIs at NOAA Cooperative Institutes for projects that support the coordination, collaboration, and development of improved sea ice models and products in partnership with Alaskan communities, especially those dependent on sea ice for hunting and transportation. This opportunity is also funded through the IRA. Visit [GOMO’s Funding Opportunities webpage](#) for more information.



Left: Credit: NOAA; Center: Arctic melt. Credit: NOAA; Right: Ocean glider, Puerto Rico, July 2018. Credit: NOAA

GOMO and OAP Announce Funding Opportunity for Ocean and Coastal Carbon Observing Optimization Studies

In November 2023, GOMO partnered with OAP to announce a new funding opportunity for [Ocean and Coastal Carbon Observing Optimization Studies](#) to optimize sampling strategies that improve carbonate chemistry observing systems co-developed with an observing data product end user. Full applications are due in March 2024, with anticipated funding available in FY24 for two to five projects. Read more on GOMO’s [Funding Opportunities](#) page.

GOMO Secures Funding for 2024 AtlantOS Workshop

GOMO, on behalf of the [Atlantic Observing System \(AtlantOS\)](#), successfully secured support from POGO and the [National Oceanography Centre](#), UK to organize an AtlantOS requirements workshop. The workshop will aim to produce and publish requirements and recommendations for an essential ocean variables-based Atlantic integrated ocean observing system around key tipping points in the Atlantic Ocean. This activity will be developed in collaboration with the [Ocean Observing Co-Design Program](#) and other GOOS partners. The workshop is tentatively being planned as part of the [All-Atlantic Forum](#) to be held in Canada in late 2024.

Goal 4 Accomplishments

Develop and capitalize on the expertise, diversity and capacity of the ocean observing enterprise.

Capacity Building

GOMO Sponsors Nine Early Career Hurricane Researchers

With funding from the Disaster Relief Supplemental Act, GOMO's [Extreme Events Program](#) led the Coordinated Hurricane Atmosphere-Ocean Sampling (CHAOS) integrated field campaign, which was conducted as part of AOML's [2023 Hurricane Field Program](#). To support the development of early career scientists and researchers, GOMO prioritized funding projects co-led by early career scientists, investigators and collaborators who are current graduate students, postdoctoral researchers, or within 10 years since the completion of their highest graduate degree. [Read more about the nine researchers](#) selected for the CHAOS campaign and their work improving hurricane forecasts.



GOMO Sponsors Training Course on Biogeochemical Sensors

GOMO partnered with the [International Ocean Carbon Coordination Project \(IOCCP\)](#) and the [Integrated Carbon Observing System \(ICOS\)](#) Ocean Thematic Centre to sponsor, "Instrumenting Our Ocean for Better Observation: A Training Course on a Suite of Biogeochemical Sensors" hosted by the [Kristineberg Center for Marine Research and Innovation](#) in Sweden. The 13-day workshop brought together ocean observing experts from around the world to train the next generation of Ph.D. and early career scientists in measuring biogeochemical essential ocean variables, with a focus on oxygen, particulate organic carbon, pH, pCO₂, and nitrate.

GOMO Sponsors ECOP Participation in the Ocean Decade OASIS Program

GOMO provided financial support for Early Career Ocean Professionals (ECOPs) to participate in the [Observing Air-Sea Interactions Strategy \(OASIS\)](#) United Nations (UN) Ocean Decade activities led by Dr. Meghan Cronin of PMEL. OASIS is a community working to harmonize observational strategies and develop a practical, integrated approach to observing air-sea interactions through capacity development, leveraging of multi-disciplinary activities, and advancement of understanding. GOMO's sponsorship provided honoraria to support ECOP leadership across OASIS initiatives, as well as travel and registration for key workshops and meetings.

GOMO Sponsors Participation of Early Career Scientists at the Ocean Carbon and Biogeochemistry Summer Science Workshop

The [Ocean Carbon and Biogeochemistry \(OCB\) Program](#) hosted its [Summer Science Workshop](#) at WHOI in Woods Hole, Massachusetts in June 2023. OCB's goal is to explore the ocean's role in the global carbon cycle and the response of marine ecosystems to environmental changes. The annual OCB summer workshop features plenary sessions on state-of-the-art science and provides a forum for community discussion on new research directions and opportunities. GOMO sponsored the travel of 25 workshop participants including several early career scientists, and assisted in planning the plenary session titled Sustained Observations of Ocean Biology.



"Instrumenting Our Ocean for Better Observation" training course attendees. Credit: IOCCP.

Pacific Partnerships Project to Build Capacity in the Pacific Islands

Throughout 2023, GOMO, in partnership with PMEL and The Ocean Foundation (TOF), advanced its new Pacific Partnerships project, which aims to strengthen ocean observing, science, and service capacity in the Federated States of Micronesia (FSM) and the broader Pacific Islands region. GOMO Program Manager Cheyenne Stienbarger and Knauss Fellow Jesse Gwinn attended regional scientific and stakeholder meetings hosted by The Pacific Community (“SPC”) to identify gaps and develop partnerships. To support this effort, TOF hired a Local Ocean Observing Coordinator (Jasmine Mendiola) based in FSM in November 2023. Jasmine will play a key role in facilitating connections with the local ocean science community and ensuring that our effort best meets the technical and data needs of FSM.



GOMO Supports World Ocean Day Outreach Event in Cape Town, South Africa

From June 8–11th, roughly 1,000 high school students and 4,000 members of the public gathered to celebrate World Ocean Day at a [multi-day outreach event](#) in Cape Town, South Africa. Visitors were exposed to life as a sea-going marine scientist through a tour of the [440 foot South African Agulhas II research vessel](#) and were given hands-on demonstrations of the use of ocean observing platforms, including Argo floats, drifting buoys, and gliders. The event was [commemorated by South African Minister of Forestry, Fisheries and the Environment](#), Ms. Barbara Creecy. This celebration of World Ocean Day was co-hosted by members of the Observation Coordination Group of the [GOOS](#), including GOMO Program Manager Ann-Christine Zinkann.

GOMO Allocates \$75K to Support Participation of Arctic and Pacific Island Indigenous Community Members

Through an internal call for proposals addressing Strategic Initiatives, GOMO allocated \$75K to support travel and participation for tribal, Indigenous, and underrepresented community members from the Arctic and tropical Pacific to attend key meetings and engagements. The funds will be used to support participation by members of the Saint Paul Tribal Government and Saint George Traditional Council during an Indigenous community meeting in Hawaii; and to support the establishment of an Indigenous expert panel for salmon, in collaboration with the [Research Networking Activities for Coordinated Observations](#) and the [Sustained Arctic Observing Network](#). GOMO is also working on identifying engagements/recipients to support participation of tropical Pacific Island community members.

GOMO Hosts Successful 2023 Women in Sciences Leadership Workshop and Transfers Coordination to ODIAC

GOMO hosted the fifth installment of the [Women in Sciences Leadership Workshop](#) on April 12–13, 2023 at the University of Arizona. The two-day workshop hosted 50 women representing different fields, sectors, and career levels. With this cohort, the workshop series has now reached over 350 women from across the U.S. and internationally. The program was started in 2018 by GOMO Program Manager Emily Smith to provide leadership training opportunities for women, who remain a minority in scientific leadership and management roles. After five years of successfully establishing, organizing and growing the program, GOMO transferred future coordination of the program to the NOAA OAR Diversity and Inclusion Advisory Committee (ODIAC).



2023 Women in Sciences Leadership Workshop attendees. Credit: NOAA.

The GOMO Workforce Grows and Supports Interns and Fellows

During 2023, GOMO hosted [two undergraduate interns](#) through NOAA's EPP/MSI and Hollings Scholarship programs, Kelli Ong and Diego Rivera, as well as two [Knauss Marine Policy Fellows](#), Sarah Tucker and Jesse Gwinn. GOMO Program Managers Cheyenne Stienbarger and Cynthia Garcia, who joined GOMO as Knauss Fellows in 2020 and 2022, respectively, and have since worked in GOMO as UCAR contractors, were hired as NOAA Federal employees. GOMO has also hired two new employees who will start in early 2024: a Web Developer who will support both GOMO and OAP, and an Administrative Officer. In addition, in late 2022 GOMO hired an Arctic Research Program Director, Sandy Lucas, and a new Program Manager Alyse Larkin.

GOMO Expands and Invests in Education and Outreach

GOMO allocated \$75K through an internal Strategic Initiatives proposal to advance outreach, education, and capacity building initiatives across program activities during FY24. As part of this initiative, GOMO's Communications Specialist Jessica Mkitarian and Knauss Fellow Jesse Gwinn worked with NOAA Education to increase the visibility of GOMO activities and news stories, such as the article co-authored by GOMO Program Manager Emily Smith titled "[Keeping An Eye on Earth's Oceans With Argo Robots](#)," published in the journal *Frontiers for Young Minds* that delivers accessible STEM research to children aged 8 to 15 years. The GOMO Communications team also developed a set of [ocean observing-inspired pumpkin stencils](#), which were featured on the [NOAA Education](#) website.



"Keeping An Eye on Earth's Oceans With Argo Robots" cover art. Credit: Frontiers for Young Minds.

Community Engagement

2023 GOMO Community Workshop Addresses Ways Forward on GOMO's Strategic Goals

GOMO sponsored and led its biennial [GOMO Community Workshop](#), held on July 25–27, 2023 in Silver Spring, Maryland. During the two and a half day workshop, we welcomed over 170 virtual and in-person attendees from the GOMO ocean observing community and delivered several sessions focused on cross-cutting strategic topics including: new and innovative science, developing GOMO's Data Strategy Plan, identifying GOMO stakeholders, broadening engagement and DEIJA, and communicating the importance of ocean observing.



2023 GOMO Community Workshop attendees. Credit: NOAA GOMO.

GOOS-MTS Dialogues with Industry Explore Opportunities for Public-Private Collaboration

In partnership with GOOS and the Marine Technology Society (MTS), GOMO co-sponsored a series of four [Dialogues with Industry](#), held between September 2022 and January 2023. Dialogue discussions centered around exploring opportunities and barriers for developing public-private collaboration to address the need for actionable ocean data and delivery of economic, societal, and environmental benefits. A summary of the dialogues and recommended next steps are detailed in the [Dialogues with Industry Synthesis Report](#), published in June 2023.



Dialogues with Industry Synthesis Report cover. Credit: GOOS, MTS.

Greenhouse Gas (GHG) Monitoring Workshop Unifies Efforts Across NOAA

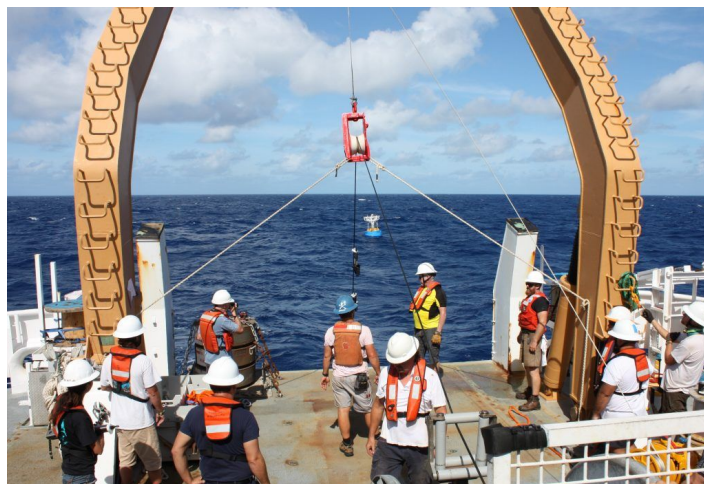
GOMO helped to organize the [NOAA Greenhouse Gas \(GHG\) Workshop: Towards MMRV \(Measurements, Monitoring, Reporting, and Verification\)](#), hosted by CPO in June 2023. Bringing together members of the GHG community across NOAA, the workshop aimed to advance NOAA's role in the provision of GHG measurements, models, and products through increased coordination of relevant activities and more streamlined product delivery. GOMO Program Manager Kathy Tedesco served on the workshop organizing committee, and Deputy Director Jessica Snowden and Program Managers Alyse Larkin and Kathy Tedesco attended the workshop and presented on GOMO's leadership role in quantifying global ocean carbon uptake and storage through the SOCONET, GO-SHIP, and BGC Argo Programs.

GOMO Expands Communication and Outreach on the Importance of Ocean Observing

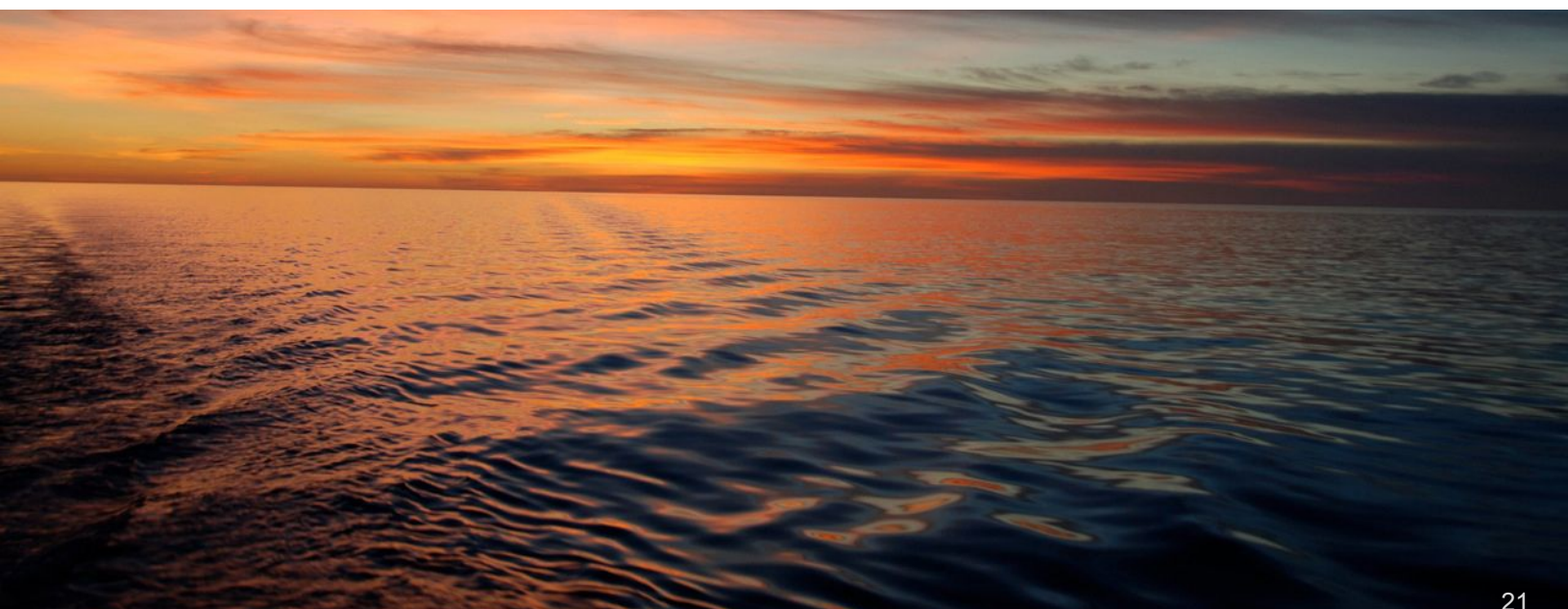
GOMO expanded the development of communications and outreach materials showcasing the societal benefits and impacts of GOMO's products and services to inform policymakers and the public. This included the release of [22 GOMO news stories](#), the release of the [Evolution of the Global Ocean Observing video](#), development of Congressional outreach materials on the [U.S. Argo Program](#) and [Arctic Report Card](#), a revamping of the [Arctic Research Program \(ARP\) webpage](#), and creation of three new webpages for GOMO's [Funded Projects](#), [Funding Opportunities](#), and [Extreme Events Program](#), and 12 new web pages with project descriptions and data access for the [ARP's funded projects](#).

COP28 Ocean Pavilion Panel Highlights Argo and GO-SHIP

Argo and GO-SHIP took center stage during The Ocean Pavilion's "[Observing the Changing Global Ocean: Heating, Salinity Changes, Carbonization, Acidification, Deoxygenation, and Greening](#)" session of COP28, which was held from November 30 to December 12, 2023 in Dubai, United Arab Emirates. The session, organized by Scripps, highlighted how global ocean observations are used to track changes in our ocean through time and featured speakers from Scripps, Monterey Bay Aquarium Research Institute, MIT/WHOI, NOAA, and Mercator Ocean International. The Ocean Pavilion, organized by WHOI and Scripps and held throughout COP28, served as a hub for events, meetings, and discussions on various conference themes including ocean carbon and climate, stressors, resources, sea level rise, climate justice, and more. [View the recording of the session live-stream on YouTube.](#)



Recovery of the WHOTS mooring off the coast of Hawaii (2018). Credit: James Todd, NOAA.



Ocean sunset. Credit: NOAA.