The Global Ocean Observing System

Ocean Observing System Report Card 2023

GOOS Observations Coordination Group

Powered by
OceanOPS

unesco
Intergovernmental Oceanographic Commission

WORLD METEOROLOGICAL ORGANIZATION

UN environment
United Nations Environment Programme

International Science Council

IN SITU OBSERVING SYSTEM STATUS

The Global Ocean Observing System (GOOS) observes our ocean through the "eyes" of thousands of ocean observing platforms that are constantly monitoring the ocean to capture the signature of various ocean phenomena. These platforms collect physical, biogeochemical and biological Essential Ocean and Climate Variables. These observations flow into data systems and are crucial for tracking, predicting and adapting to climate change, accurate weather and extreme event prediction, monitoring biodiversity for achieving key global targets, and informing sound decisions by local communities and national governments around sustainable development.

To highlight the status and development of this Global Ocean Observing System, the **2023 Ocean Observing System Report Card** provides insight into the current status of the global observing networks and shows how these networks provide vital data for society. This edition showcases achievements and challenges in tracking marine heatwaves, advancing safety of life at sea, and ensuring seagrass ecosystems continue to support coastal life.

The diversity of coastal and biological observing activities is one of the current big challenges, both to integrate new data flows and to expand capacity globally to meet real and urgent needs. This is one of the key areas that needs additional coordination capacity, new and low-technologies, however it also offers opportunities to develop a truly integrated global observing system.

Highlights

GOOS is pleased to report that the global ocean observing networks monitored by OceanOPS, have now all mostly recovered from the impact of COVID-19 on their operations.

See *in situ* networks table for map legend. Latest locations of operational platforms and ships as of July 2023; reference lines sampled since January 2022. Symbols size is not to scale, in the map they are exaggerated to an order of hundreds kilometers for readability. Data source: OceanOPS.

Over the past year, the observing system remained stable in terms of platforms and instruments at sea, however, there have been significant advances in technology, autonomous instruments, multidisciplinary approaches, and in international collaboration. Growing investment in biogeochemical sensors and deep autonomous Argo profiling floats are one of the factors driving GOOS evolution. In addition, emerging components of the system like smart cables and Unmanned Surface Vehicles continued to develop, in part due to strong collaboration with private sector partners.

The evolution of the observing system to observe biological and ecological phenomena has been underway for years, and it is now accelerating as GOOS continues to catalyze discussions to monitor change in the ocean ecosystem around 12 Essential Ocean Biological Variables, such as seagrass habitats, and to promote open access to data.

The existing *in situ* and satellite observing system is challenged to effectively track marine heatwaves, and the GOOS community is working to design and develop an ocean observation strategy to improve marine heatwave forecasts and provide actionable data and information to stakeholders. High-quality metocean (above ocean atmospheric) data from ships and autonomous instruments are vital for forecasting extreme events such as tropical cyclones, issuing timely warnings, and ensuring safety at sea. However, further observations are needed globally to improve weather and climate forecasts.

The GOOS international partnership, along with national investments from North Hemisphere countries, need to prioritize expanding basic observing coverage in Indian and Southern Ocean regions. Regular basin-based coordination meetings are improving the system's implementation bridging gaps and collaborating with national academic fleets, regional bodies, and third-parties like shipping industry and ocean racing.

> In the face of climate change, the global community must work together to improve the coverage, quality, and multidisciplinary nature of the observing system to meet vital forecasting services and societal needs. OceanOPS can help make these connections.
>
> **Mathieu Belbéoch**, OceanOPS Manager

GOOS *in situ* networks [1]	Implementation	Data & metadata			Best practices [6]	GOOS delivery areas [7]		
	Status [2]	Real time [3]	Archived delayed mode [4]	Metadata [5]		Operational services	Climate	Ocean health
Ship based meteorological - SOT	★★☆	★★☆	★★☆	★★½	★★☆	✓	✓	
Ship based oceanographic - SOT	★★½	★★½	★★★	★★☆	★★★	✓	✓	
Repeated transects - GO-SHIP	★★★	Not applicable	★★★	★½☆	★★★		✓	✓
Sea level gauges - GLOSS	★★½	★★☆	★★★	½☆☆	★★☆	✓	✓	
Time series sites - OceanSITES	★★☆	Not applicable	★★½	★☆☆	★★☆		✓	✓
Coastal moored buoys - DBCP	★★★	★★★	★★★	★☆☆	★★½	✓	✓	✓
Tsunami buoys - DBCP	★★½	★★★	★★★	★★☆	★★★	✓		
Tropical moored buoys - DBCP	★★½	★★★	★★★	★★★	★★☆	✓	✓	✓
HF radars	★½☆	★½☆	½☆☆	½☆☆	★★★	✓	✓	

GOOS *in situ* networks [1]	Implementation	Data & metadata			Best practices [6]	GOOS delivery areas [7]		
	Status [2]	Real time [3]	Archived delayed mode [4]	Metadata [5]		Operational services	Climate	Ocean health
Drifting buoys - DBCP	★★★	★★½	★★½	★★½	★★★	✓	✓	
Profiling floats - Argo	★★★	★★★	★★★	★★★	★★½	✓	✓	
Deep & biogeochemistry floats - Argo	★½☆	★★½	★★½	★★★	★★☆	✓	✓	✓
OceanGliders	★½☆	★★☆	★☆☆	★★☆	★★☆	✓	✓	✓
Animal borne sensors - AniBOS	½☆☆	★☆☆	★★☆	½☆☆	★★☆	✓	✓	✓

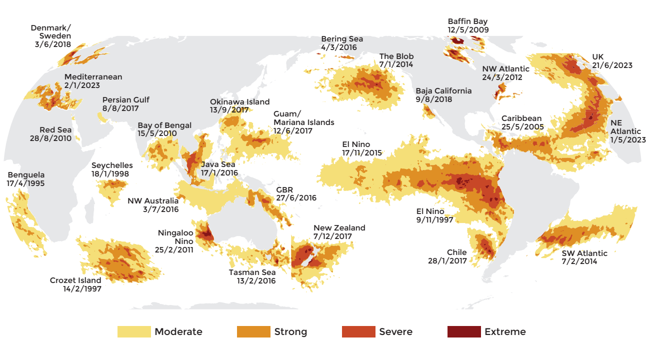
(1) More information at goosocean.org (2) Status: status of the implementation compared to the community widely adopted targets when it exists; network self-assessed status when target doesn't exist. (3) Real time: data freely available, without any restriction, on Global Telecommunication System of WMO and internet. (4) Archived delayed mode: data of the highest quality available for scientific analysis (*e.g.* climate studies). (5) Metadata completeness by OceanOPS: ocean-ops.org/metadata (6) Best practices: community reviewed and easily accessible documentation encompassing the observations lifecycle (7) See Network Specification Sheets:goosocean.org > Observations > Network Specification Sheets. More information on networks status & indicators definition at: ocean-ops.org/reportcard

CLIMATE

MARINE HEATWAVES

Marine heatwaves are periods of intense, anomalously warm ocean temperature that have garnered growing interest over the last two decades due to their increasing impact on the overall state of the ocean and marine life, and because they are becoming more frequent as the ocean warms. Often extending deep below the sea surface, marine heatwaves have disastrous effects on marine ecosystems across the global ocean, including shifts in locations of economically valuable ecosystem species, and high mortality rates of vulnerable marine species. They also influence other extreme events on land, such as droughts and heatwaves, and the intensification of tropical cyclones.

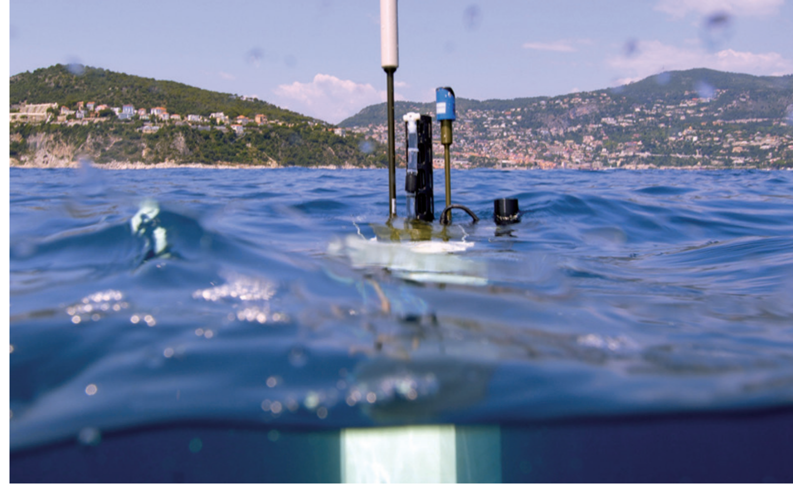
Due to climate change, marine heatwaves are becoming more frequent, more intense and lasting longer. They now occur in all ocean basins, putting an array of ocean ecosystems and communities at risk. For example, a 2014 Northeast Pacific event was associated with a large mortality rate of many species and toxic algal blooms. In 2022, despite the occurrence of La Niña - a climatic phenomenon characterized by cooler-than-normal global mean sea surface temperatures, 58% of the ocean surface suffered at least one marine heatwave event[1]. June 2023 has marked the onset of El Niño, characterized by warmer-than-normal sea surface temperatures in the Pacific - La Niña's opposite. It is therefore likely that 2023-2024 will witness even more intense marine heatwaves, like the northeastern Atlantic event in June 2023.



Global map of major marine heatwaves events occurred since 1995. The intensity scale of each extreme (moderate to extreme) represents conditions corresponding to the peak date of the event. Adapted from Smith et al. 2021.

There is an urgent need to develop a sustained and integrated observing capacity to monitor and predict these extreme events. This can be developed efficiently by considering the information needs of highly impacted end-users and policymakers, and through integrating satellite and *in situ* observations.

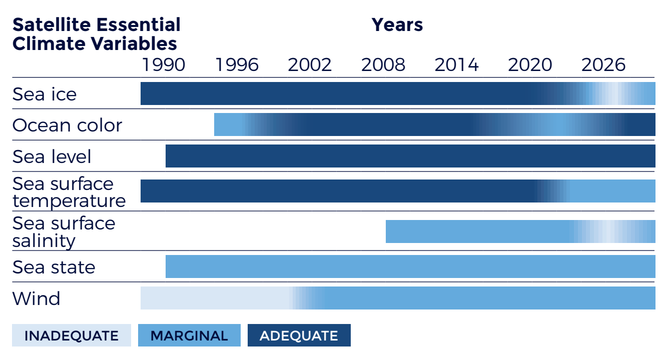
(1) As per the WMO State of the Global Climate 2022 report, released April 21, 2023.



How do we track marine heatwaves?

Marine heatwaves are generally identified by measuring the sea surface temperature at large to regional scales, while their impacts are more evident at sub-regional to local scales and at depth. This requires an observing capacity that extends from the open ocean to the coast, and from the surface to some depth.

Complementary to *in situ* surface measurements, satellite observations of sea surface temperature enable us to track marine heatwaves on a global scale, with high accuracy. Many buoys and profiling floats provide some sea surface and subsurface observations; however, they do not meet regional needs and thus we must rely on assimilation of this data into ocean models to quantify and predict the extent of subsurface ocean marine heatwaves and their impacts.



Sea surface temperature is one of the sets of Essential Climate Variables measured by satellites. More information on satellite status at ocean-ops.org/reportcard.

Different international programs such as GOOS, the World Climate Research Programme, and the Global Climate Observing System are now working in synergy to address the complexity of these phenomena and their impacts in order to help society face this challenge.

Developing a comprehensive set of observations to address marine heatwaves impacts

To focus on the needed observations to better monitor and help prediction of the impacts of marine heatwaves, GOOS and the Global Climate Observing System are collaboratively designing an improved ocean observing system. This co-design effort involves working with national and international stakeholders, such as managers of marine ecosystems and fisheries, to provide better actionable data, products, and information. This will enable more accurate forecasts and preparation for marine heatwaves.

OPERATIONAL SERVICES

SAFETY AT SEA

Bridging the gap from observations to safety warnings at sea

The ocean and atmosphere are inextricably linked, and nowhere is this more evident than aboard a ship in a storm. With approximately 90% of global trade transported by sea, how do ships keep out of harm's way from hazards such as high winds, large waves, dense fog, sea ice, and icebergs?

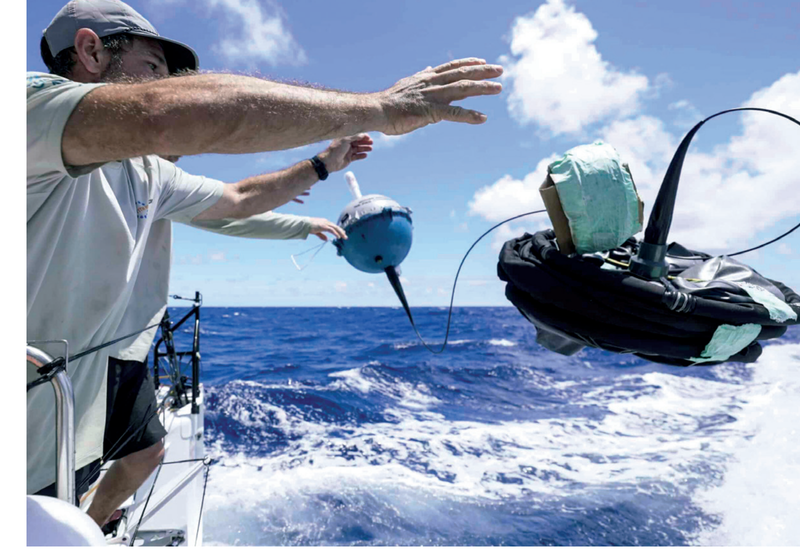
After the 1912 Titanic disaster, international bodies established safety protocols for shipping - the International Convention on the Safety of Life at Sea (SOLAS). Later, the International Maritime Organization (IMO) established the Global Maritime Distress and Safety System as a key element of SOLAS, to transmit maritime safety information such as metocean (weather) warnings and navigational hazards to ships.

To ensure timely and accurate metocean warnings and forecasts requires a robust linkage from marine observations to data processing, forecast models, and services. The World Meteorological Organization (WMO) and the Intergovernmental Oceanographic Commission of UNESCO work together through GOOS to connect the links in this chain.

The value of metocean observations cannot be overstated[1], particularly in undersampled areas like higher latitudes. More quality observations, taken more often, will improve forecasts for all vessels at sea.

Global integrated ocean observations are key. Satellites monitor conditions globally, providing huge volumes of data for weather, ocean, and climate models. Data collected by moored and drifting buoys, and profiling floats, provide *in situ* measurements of surface weather and below surface ocean parameters. Variables, such as atmospheric pressure, wind speed and direction, and ocean temperature help verify remotely sensed satellite data, like ocean surface winds and wave heights. Ship and buoy observations also provide critical data for validating and updating marine weather warnings and forecasts as they are prepared. In addition, shipboard observations provide crucial information about conditions at sea, including winds and ocean currents. Today, over

(1) ECMWF Newsletter No. 152, 27-31. doi:10.21957/51j3sa



1,600 ships provide nearly 10,000 observations per day, sharing them in real-time through the WMO Global Telecommunications System.

Addressing the issues of weather-related damage at sea

Despite recent gains in forecast skill, ships still sustain weather-related damage, with cargo, vessels and lives continuing to be lost at sea. To address this, the first WMO-IMO International Symposium on Extreme Maritime Weather in 2019 initiated a dialogue among key maritime and metocean stakeholders, including GOOS. The outcomes recognized the growing importance of strengthening the linkages from the collection of marine weather and ocean observations to better impact decision support services. A second WMO-IMO International Symposium will be held in September 2024. GOOS will again be prominent, focusing on key themes such as leveraging evolving technology to increase participation in global ocean observing and exploring the potential of adaptive sampling using autonomous vehicles.

GOOS is currently engaging with the shipping community to expand metocean observations from all vessels at sea, for the benefit of services to the mariner.

Weather related losses at sea must be reduced. To do so requires "all hands on deck" from ships' crews to forecasters, to collect better data, improve forecasts, and enhance maritime safety.

2023 marks the 150th anniversary of the WMO which has its roots in maritime safety and ship-based observations.

WORLD METEOROLOGICAL ORGANIZATION

150 1873 2023 IMO-WMO

LIVING COASTS

Seagrass ecosystems: a haven for marine life

Seagrasses are the foundation of important but threatened coastal ecosystems along all continents except Antarctica. They offer refuge, breeding grounds, and nursery areas for numerous fish and invertebrate species, creating rich habitats that are home to various animals of conservation concern: from tiny seahorses to charismatic creatures such as sea turtles or manatees.

The societal importance of seagrass beds goes beyond their role in maintaining biodiversity. Seagrasses are also known for their contribution in storing blue carbon, as well as protecting shorelines from wave damage, while seagrass-associated fishery species are key contributors to food security and the livelihoods of many coastal communities, particularly in the developing world.

An essential variable for monitoring ocean health

GOOS has designated seagrass cover and composition as an Essential Ocean Variable (EOV) - a critical ocean measurement for monitoring the state and health of the ocean. But collecting seagrass observations is currently a patchwork of local and regional efforts.

Building on the foundation established by the GOOS Biology and Ecosystems Expert Panel, the International Science Council's Scientific Committee on Oceanic Research is supporting a working group, "Coordinated Global Research Assessment of Seagrass Systems[1]" (C-GRASS), to engage a global community of seagrass researchers and managers to operationalize the seagrass EOV. This involves developing peer-reviewed standards for monitoring the seagrass EOV, which will support local to global seagrass assessments, facilitate detection of change in coastal ecosystems, and add value to the work of local data collectors by improving the rigor of observations, supporting data flow, and connecting them in a global context. Such interoperable protocols are increasingly implemented through Seagrass-Watch[2] and Smithsonian's SeagrassNet[3] programs.

In liaison with GOOS, the World Seagrass Association will promote and facilitate the development of seagrass EOV standards and the C-GRASS community of practice. These efforts will contribute significantly to achieving and sustaining a globally interoperable system for monitoring seagrass habitats' status and trends.

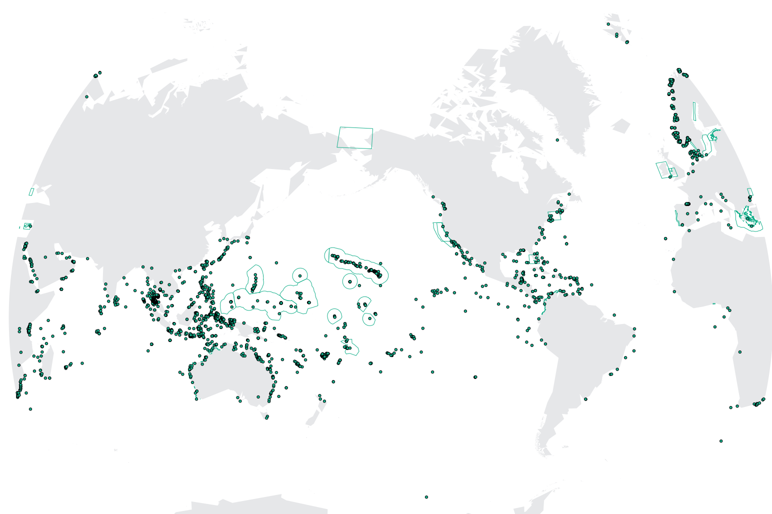
Seagrasses are important contributors to biodiversity, living coasts and human wellbeing worldwide – we need global coordination to safeguard those benefits.

Challenges to monitoring seagrass habitats

One of the main challenges to tracking change in seagrass habitats is the currently insufficient mapping of seagrass distribution, as well as poor access to existing data. The best recent estimates based on available and accessible data put the global extent of seagrass between 160,000 - 266,000 km^2.

Coordinating and better resourcing efforts to constrain these numbers and provide accurate country-scale estimates are essential to delivering reliable national contributions to biodiversity monitoring and to greenhouse gas emission reductions, as seagrasses represent a potentially substantial but poorly constrained store of blue carbon. Standardized observations of seagrass will also be important to quantifying the ecosystem services they provide, including fishery support and protection against coastal erosion and storm hazards, and how this is changing with climate change or other pressures, such as pollution.

An integrated observing system providing physical, biogeochemical and biological observations enables the connection between processes, cause, and effect, to be evaluated. GOOS, EOV standards, and the observing networks, play a leading role in advancing capacity to reach this goal.



Locations of the 75 seagrass monitoring programs currently available in the GOOS BioEco Metadata portal (bioeco.goosocean.org). Adapted by OceanOPS.

(1) scor-int.org/group/158 (2) seagrasswatch.org (3) seagrassnet.org

COMMUNITY COLLABORATION

Dialogues with Industry: maturing the ocean enterprise

Until now, vital ocean observing activities that underpin human safety, marine health, blue economies and sustainable development have largely been undertaken by government agencies and the scientific sector, supported by public funding. Now, private companies are stepping into the field with promising opportunities for a blue economy data revolution and a strengthened ocean observing system.

The recently completed Dialogues with Industry[1], hosted by GOOS, the Marine Technology Society and the National Oceanic and Atmospheric Administration (NOAA), brought together representatives from new and established companies, academia, and government to discuss possibilities for increased collaboration in the future.

> The Dialogues with Industry clearly identified the enormous interests of the public and private sector ocean observing communities in collaborating to address the rapidly growing demand for ocean information. We look forward to working with the community to now turn dialogue into action.
>
> **Rick Spinrad**
> NOAA Administrator

An official activity of the United Nations Ocean Decade, the dialogue series aimed to dismantle existing barriers and highlight opportunities towards achieving a mature next generation global ocean observing system to meet the needs of society. With observers from over 40 countries and an especially high industry participation, it provided a one-of-a-kind space for defining pathways for greater public-private partnership and integration – towards a thriving ocean observing enterprise.

Training the new generation of ocean observers in West Africa

The archipelago of Cabo Verde, a Small Island Developing State located about 350 nautical miles off the west coast of Africa in the North Atlantic, heavily relies on the well-being of the marine ecosystem surrounding it. Its remote but representative location in the trade wind region makes Cabo Verde a very attractive location for atmospheric and ocean monitoring and research.

GOOS long-term observational efforts started in 2006 through a Cabo Verde-Germany partnership that, from the beginning, paid particular attention to training and capacity development of the Cabo Verdean experts. Through frequent observational efforts from various countries, the Cabo Verde Ocean and Atmospheric Observatories evolved, and in 2017 the Ocean Science Centre Mindelo[2] was established as a regional research and knowledge exchange hub.

Besides long-term observations and intensive field campaigns contributing to the development of the GOOS, science, and technology in the region, the initiative also supports and facilitates the academic education of early career researchers. As part of the WASCAL (West African Science Service Centre on Climate Change and Adapted Land Use) program, endorsed as a United Nations Ocean Decade project, students from 12 West African countries are currently eligible for support to study Climate Change & Marine Sciences for two years in Cabo Verde.

Each student cohort is taught by international experts in various disciplines and a dedicated Ocean Observation module is held under authentic work conditions. During a two-week expedition onboard German research vessels, students learn how to take oceanographic observations by deploying profiling floats, zooplankton nets, and collecting and analyzing seawater samples.

With every student cohort, the alumni network in West Africa continues to grow, advocating for access to sustained ocean observations in West Africa, and preparing students for their future careers in academia, ocean governance or in the blue economy sector.

> Going through the whole process of getting and analyzing a single sample, now I really understand where the data comes from, and appreciate what goes into each measurement in global data sets. It's quite amazing and something that you don't learn in the lab at home.
>
> **Amadou Biteye**
> WASCAL student from Senegal

(1) Dialogue with Industry Final Synthesis Report: goosocean.org > Our work > Dialogue with Industry (2) ocsm.cv

CO-DESIGNING TROPICAL CYCLONE OBSERVING

Many regions face economic damage and numerous deaths from tropical cyclones, with an average of $78 million in damages and 43 deaths every day. Such events are becoming more frequent and intense as the climate changes.

Countries need increased capacity to forecast tropical cyclones more accurately and issue timely warnings about cyclone intensity.

Ocean Observing Co-Design - one of the three GOOS United Nations Ocean Decade programmes - has launched a first set of "exemplar" projects to refine the ocean observing system to better serve society. One of these focuses on tropical cyclones. The aim of the Tropical Cyclone exemplar is to work with the observing and the cyclone forecasting community to expand cyclone forecasting capacity and enable more accurate predictions.

By co-designing the observing system with relevant stakeholders, the Co-Design project will bring a step change in our forecasting capabilities and ability to better serve society, enabling lives and property to be saved.

CALL FOR ACTION

As the **2023 Ocean Observing System Report Card** notes, we have continued to make progress in systematically observing the global ocean. However, extreme events such as cyclones, marine heatwaves, and extreme marine weather are motivating urgent action within the GOOS community to develop and improve a wide range of ocean services. We have also noted the need for developing completely new capabilities (*e.g.* marine life, and ocean carbon – see in our 2022 Report Card) to address urgent needs for healthy oceans, carbon policy decisions, and nascent carbon economies.

GOOS has never been better positioned to usher in a new era of ocean information: new observing technologies, and private sector engagement are presenting new opportunities for GOOS to address these and other urgent ocean observing needs.

> Together with the satellite and modeling communities, GOOS is actively developing new paradigms of stakeholder interactions through new actions under the United Nations Ocean Decade to hasten delivery of actionable information. More support is required to meet the growing needs of global sustainable communities.
>
> **David Legler**
> GOOS Observations Coordination Group Chair

We acknowledge all the funders for their continued support, as well as the dedicated observing system implementers for their outstanding efforts in advancing the development of our global ocean observing system!

More information at:
ocean-ops.org/reportcard

OceanSITES
Taking the pulse of the global ocean
OceanGliders
Global HF Radar Network

General information: **goosocean.org** · Networks status: **ocean-ops.org** · Report Card information: **reportcard@ocean-ops.org** · If you wish to contribute to the global ocean observing system, please contact: **support@ocean-ops.org** · Authors: OceanOPS, GOOS Observations Coordination Group, GOOS-BGC and BioEco Panels, OOPC Panel, WMO and IOC/UNESCO Secretariats · GOOS Report No. 292

Special thanks to all editors and authors: Corrine Almeida, Mathieu Belbéoch, Lance Braasch, Forest Collins, Thomas J. Cuff, Brad de Young, J. Emmett Duffy, Björn Fiedler, Darin Figurskey, Severine Fournier, Sarah Grimes, Alex Sen Gupta, Emma Heslop, Long Jiang, Johannes Karstensen, Elizabeth Kent, Roxy Mathew Koll, Arne Körtzinger, David Legler, Belén Martin Miguez, Ivanice Monteiro, Lina Mtwana Nordlund, Clare Nullis, Joanna Post, Regina Rodrigues, Emanuela Rusciano, Alex Sen Gupta, Raquel Somavilla, Sabrina Speich, Laura Stukonyte, David Wyatt, Weidong Yu, Ann-Christine Zinkann.