OceanOPS

Ocean Observing System
Report Card 2021

GOOS Observations Coordination Group




The Global Ocean Observing System

United Nations Educational, Scientific and Cultural Organization

Intergovernmental Oceanographic Commission

WORLD METEOROLOGICAL ORGANIZATION

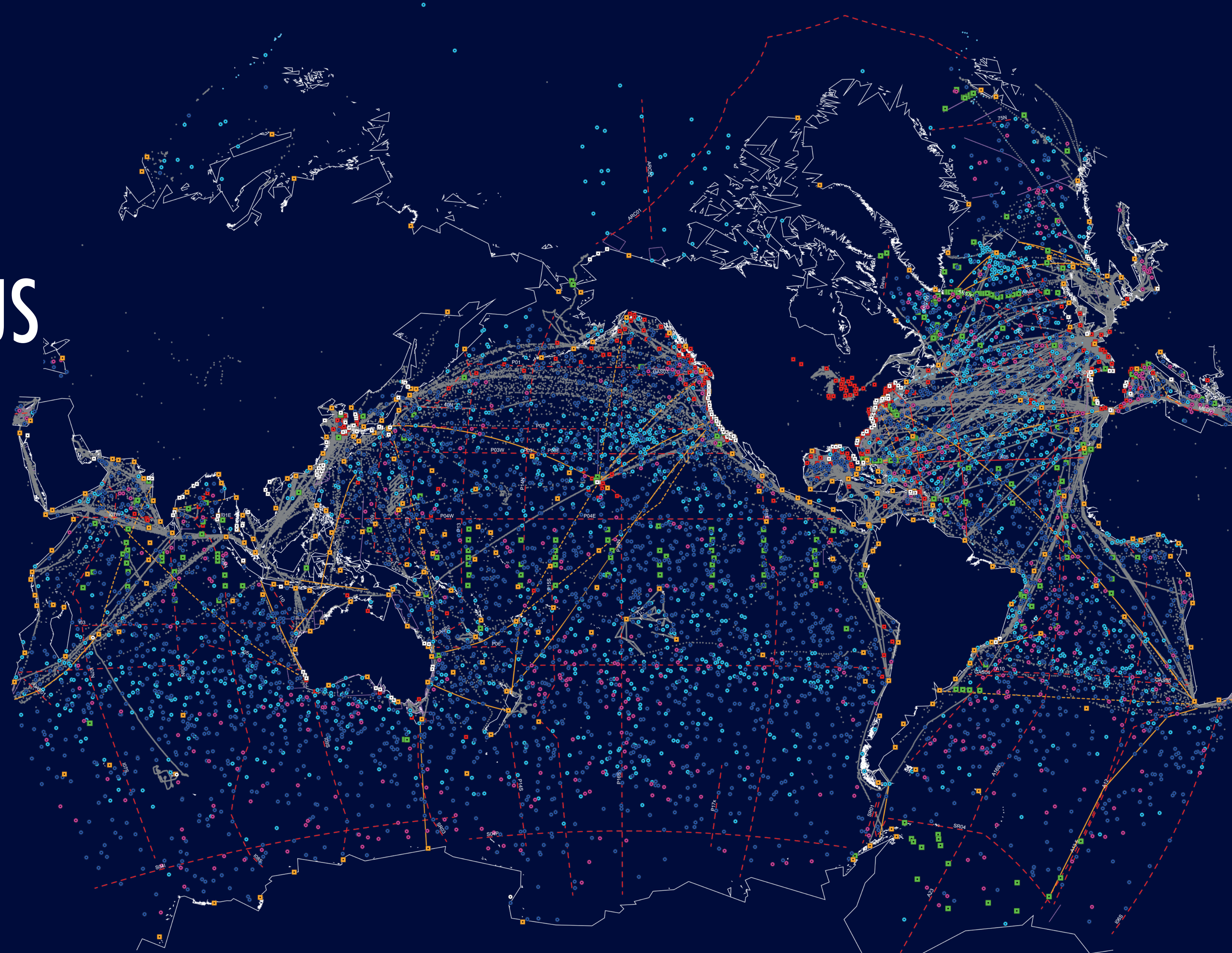
UN environment
United Nations Environment Programme

International Science Council

IN SITU OBSERVING SYSTEM STATUS

Over the last few years, the *in situ* observing system, made up of many thousands of ocean observing platforms, has developed significantly with emerging networks, advances in new technologies, and improved capabilities. This system supplies scientists and marine and weather forecasters with essential global, multidisciplinary, high-quality data, crucial to support safety of life and property at sea, maritime commerce, and the well-being of coastal communities. It also provides observations to monitor the impacts of long-term climate change and information on the increasing stress on the ocean from human activities.

To continue to evolve this system towards an integrated, fit-for-purpose and sustained global network, the **Ocean Observing System Report Card 2021** provides insight into the status of the global ocean observing system, assessing networks' progress, focusing on the challenges needed to keep improving this system, and encouraging collaborations and new partners to join the ocean observing community.



During the last year, Covid-19 has impacted several ocean observing networks with about a 10% decrease in data distribution, and a 15% to 20% decrease in maintenance operations. 14 tropical Pacific moored buoys are currently lost or inoperative as restrictions on research vessel operations hinder the deployment and replacement of measuring equipment. Only 1 repeat hydrographic transect was sampled in 2020 as planned, while all others were cancelled or postponed to later years. Ship-of-Opportunity based measurements of ocean temperature profiles were resumed on 50% of all reference lines thanks to the cooperation with commercial vessels who helped to maintain the array.

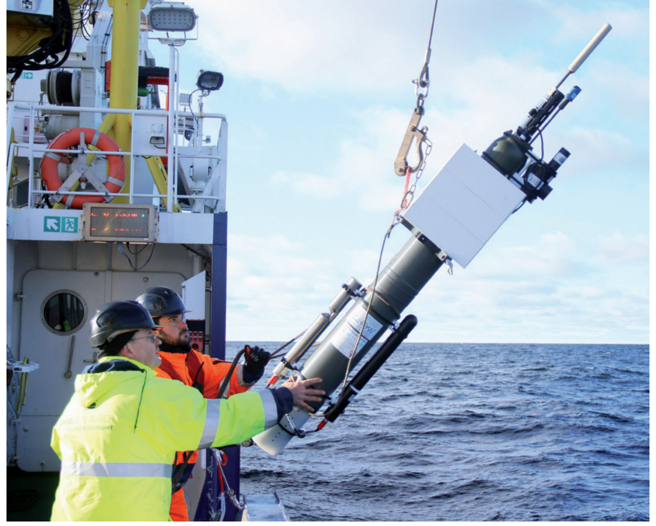
One year from the initial impacts, research vessel operations are still unstable due to Covid-19 restrictions. Although the global system showed resilience to these initial impacts due to the diversity of platforms and the increased use of autonomous instruments, as well as strengthened cooperation between operators in maintaining network function under restrictions, the overall impact on the observing system will take a few years to be absorbed. The 2021 deployment planning for most of the global networks is very ambitious and requires strong international collaboration, coordination, and increased support to implement such commitments.

See *in situ* networks table for map legend. OceanOPS data source as of June 2021: operational platforms latest location (Argo, DBCP, AniBOS, VOS, ASAP); fixed platforms location (GLOSS, HF radars, OceanSITES); reference lines (GO-SHIP, SOOP); sampled sites (OceanGliders). Dashed lines for GO-SHIP and SOOP have not been sampled after Covid-19 impact; dots for VOS and ASAP show May 2021 observations. Symbols size is not to scale, in the map they are exaggerated to an order of hundreds kilometers for readability.

GOOS *in situ* networks [1]	Implementation	Data & metadata			Best practices [6]	GOOS delivery areas [7]		
	Status [2]	Real time [3]	Archived delayed mode [4]	Meta-data [5]		Operational services	Climate	Ocean health
Ship based meteorological measurements - SOT/VOS	★★☆	★★★	★★★	★★☆	★★☆	✓	✓	
Ship based aerological measurements - SOT/ASAP	★☆☆	★★★	☆☆☆	★★☆	★☆☆	✓	✓	
Ship based oceanographic measurements - SOT/SOOP-XBT	★★☆	★★★	★★★	★★☆	★★☆	✓	✓	
Sea level gauges - GLOSS	★★★	★★☆	★★★	★☆☆	★★☆	✓	✓	
Drifting and polar buoys - DBCP	★★★	★★★	★★☆	★★☆	★★☆	✓	✓	
Moored buoys - DBCP	★★☆	★★★	★★☆	★★☆	★★☆	✓	✓ O_2	
Long-term time series sites - OceanSITES	★★☆	Not applicable	★★☆	★★☆	★★☆		✓ O_2	✓ O_2
Profiling floats - Argo	★★★	★★★	★★★	★★★	★★☆	✓	✓	
Repeated transects - GO-SHIP	★★★	★☆☆	★★★	★★☆	★★★		✓ O_2	✓ O_2
OceanGliders	★☆☆ Emerging	★★☆	★☆☆	★★★	★☆☆	✓	✓ O_2	✓ O_2
HF radars	☆☆☆ Emerging	★★★	★★★	★☆☆	★★★	✓	✓	
Biogeochemistry & Deep floats - Argo	★☆☆ Emerging	★★★	★☆☆	★★★	★★☆		✓ O_2	✓ O_2
Animal borne ocean sensors - AniBOS	☆☆☆ Emerging	★★★	★★☆	★☆☆	★★☆	✓	✓	✓

(1) More information at goosocean.org (2) Status: status vs target, external target when exists, *e.g.* GCOS; network self-assessed status when target does not exist (3) Real time: data available on Global Telecommunication System of WMO or another global Internet based data node (GDAC) with a proper quality control mechanism; OceanSITES metocean real-time data is managed by DBCP (4) Archived high quality: self-assessed status on the availability of delayed mode data, on the web, including all historical data (5) Metadata: information required by OceanOPS (6) Best Practices: community reviewed and easily accessible documentation encompassing the observations lifecycle (7) See Network Specification Sheets: goosocean.org > Observations > Network Specification Sheets

OCEAN OXYGEN



"If you cannot breathe, nothing else matters"

Oxygen, a vital gas for all life on the planet, enters the ocean at its surface and spreads throughout. The oxygen content in any volume of ocean water is determined by multiple biological and chemical processes and controlled by ocean dynamics.

Breathing water is hard work as water holds far less oxygen than the equivalent volume of air. The physiological performance of marine organisms is highly dependent on their ability to extract oxygen from ambient sea water. Oxygen availability is thus key for marine life.

Photosynthesis in the upper, sunlit ocean is a source of oxygen and its production is closely linked to plankton growth, ultimately feeding the fish we eat. Understanding oxygen cycling and detecting oxygen variability and trends are key aspects of tracking ocean health.

The ocean is losing oxygen (around 2% since the 1950s) at an increasing rate. This decline, termed deoxygenation, affects marine life and the largest ecosystems on Earth. Both climate warming (warmer water holds less oxygen) and natural variability play roles that we need to better understand.

There is presently no model able to reproduce the latitudinal distribution of deoxygenation. Projections for future scenarios indicate a 3% to 4% decrease of the global oxygen content by 2100. With that in mind, we have to improve our numerical models and drastically increase the number of oxygen observations in the world ocean.

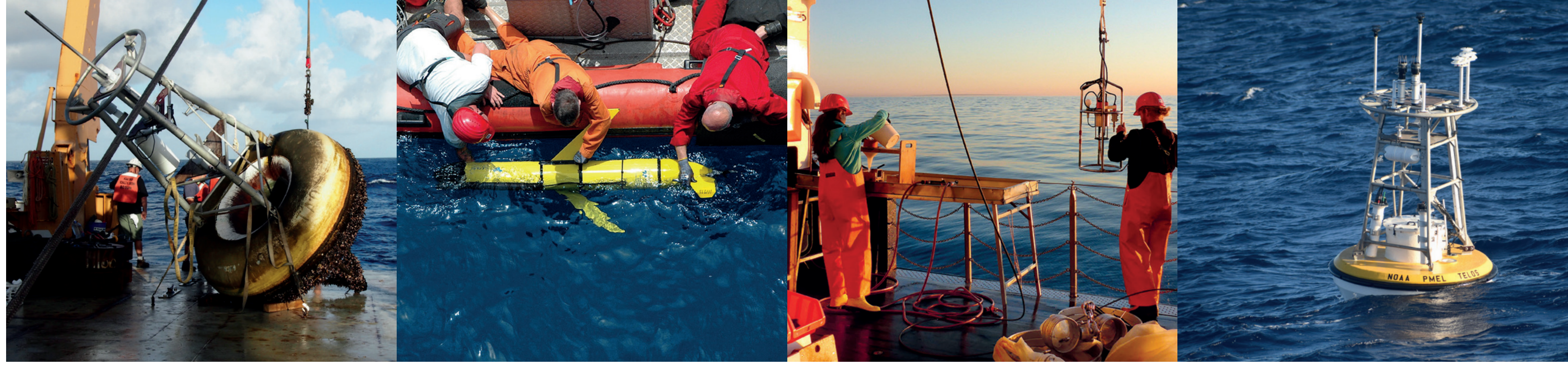
Solutions and Benefits

- Reduce emissions of greenhouse gases to reduce global warming
- For the coastal ocean: reduce nutrient inputs from land which cause eutrophication
- Globally: **1)** foster ocean observations to continuously monitor and report on the state of the ocean for co-designing solutions of mitigation and/or adaptation with stakeholders **2)** enhance ocean literacy and engagement **3)** educate people (*e.g.* the Global Ocean Oxygen Decade (GOOD) Programme for the UN Decade of Ocean Science for Sustainable Development).

Ongoing deployment of *in situ* observing instruments, such as gliders, biogeochemical floats, ships, moorings, and others are bringing new opportunities to investigate the drivers of global (de)oxygenation and the biogeochemical processes that affect oxygen cycling in both coastal and open ocean areas. In 2021, more than 70 oxygen sensors were deployed on moorings in the subpolar North Atlantic - the region where the deep ocean is taking a deep breath every winter. Every year, about 100 biogeochemical Argo floats (representing 10% of the global Argo Program) equipped with oxygen sensors are deployed, mostly in the Southern Ocean, North Atlantic, Indian Ocean, and Mediterranean Sea.

In 2021, despite the pandemic, the oceanographic community in Chile and Peru has remained mobilized for maintaining and developing the ocean observing system in the South East Pacific, a key region for the energy budget of the planet. The SEPICAF project (South Eastern Pacific Circulation from Argo Floats) launched in 2019, and supported by French oceanographic institutions, has undertaken regional coordination with universities and research labs in Chile and Peru to maintain a sufficient Argo float density in this region. This allows us to monitor the thermocline circulation and oxygen conditions, and better understand processes driving the variability in the oxygen minimum zone. As the project lead, Dr. Boris Dewitte explains: "The 16 Argo floats we are in charge of deploying are fundamental for reliable oceanic forecasts. Regional collaborations with universities and fishery companies, as well as international scientific collaborations, have been instrumental for designing the deployment strategy."

> Rising deoxygenation is one of the most significant threats to the ocean. Access to continuous, quality data is critical to understanding and finding ways to address this challenge. It's time to expand international collaboration to achieve global coverage of *in situ* oxygen observing networks.
>
> **Dr Vladimir Ryabinin**
> IOC Executive Secretary



TROPICAL PACIFIC OBSERVING SYSTEM 2020

A Regional Pilot

Sustained observations of the Tropical Pacific Ocean have been a priority for nations around the basin for more than 25 years, driven principally by the global climate effects of the El Niño/Southern Oscillation (ENSO), and by the demonstrated prediction skill based on ocean and air-sea interface observations. The Tropical Pacific Observing System (TPOS) 2020 goals were to redesign and enhance the TPOS, to meet today and future needs of both research and operational centers. It aimed at building a more integrated, modern and robust observing system, taking advantage of new science and technology.

The TPOS 2020 project identified gaps in the current system, the variables and scales to be sampled, and areas of needed research. It proposed a redesign, taking full advantage of the diverse remote and *in situ* techniques available today, considering their complementarity, and fitting them together in an integrated system. It also specified the model and assimilation improvements needed to fully utilize the observations. TPOS 2020 accelerated advancements in technology, and motivated sponsors to make significant investments to many observational and modelling initiatives.

The new TPOS will provide enhanced capabilities for observing upper ocean and air-sea interactions across a diversity of climate regimes, based on enhanced moorings configuration, and a doubling of Argo floats. It will enable a major gain in biogeochemical sampling, and recommends specific observations for the low-latitude western boundary currents and the eastern Pacific where extreme El Niño events develop.

The new TPOS will also deliver many gains to accelerate advances in the understanding and prediction of tropical Pacific variability and its profound impacts at regional scales. Improving our forecasting capabilities will positively impact agriculture, water management, marine ecosystems management, human health, and disaster preparedness.

> Major gaps in data over the ocean hinder our ability to observe our changing climate and accurately forecast weather at sub-seasonal to seasonal timescales. We need to close those gaps and ensure the delivery of timely and accessible information available to all users.
>
> **Professor Petteri Taalas**
> WMO Secretary-General

WMO supports TPOS 2020 to meet growing demand for forecasts and services

We need accurate and reliable observations and prediction models from land and sea to meet the ever-increasing demand for more sophisticated weather, water, climate and ocean services, and forecast products, and multi-hazard early warning systems.

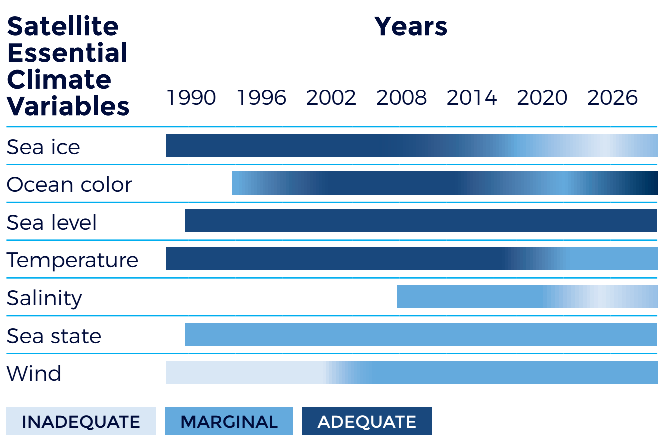
Implementation of the sustained backbone TPOS is essential if we are to improve our prediction of ENSO cycles and associated extreme events that have profound societal impacts around the globe. It will also underpin efforts to understand and project changes in the ocean and atmosphere, particularly on decadal and longer timescales.

More than 90% of the excess heat trapped by greenhouse gases is stored in the ocean. It is therefore critical to have high-quality, long-term records of sea surface temperature and the deep ocean – especially in areas like the eastern equatorial Pacific where the instrumental record is sparse. We welcome the TPOS 2020 aims to double Argo observations in the tropical Pacific.

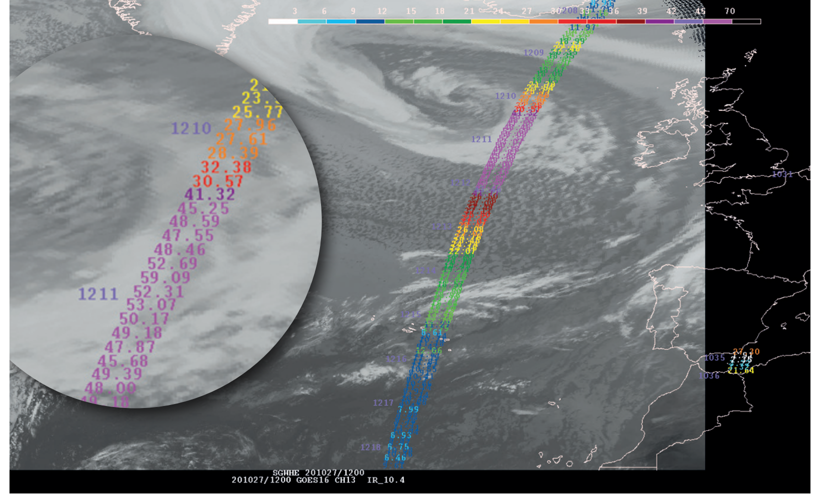
The TPOS 2020 project will provide substantial input to the World Meteorological Organization Integrated Global Observing System and help close gaps in ocean observations.

SATELLITE-BASED OBSERVATIONS

The satellite network enables us to accurately measure fundamental variables such as ice coverage, ocean color, sea level, ocean surface temperature and salinity. Together with *in situ* observations, satellites provide foundational knowledge about the ocean environment and enable a wide range of forecasts and services.



More information on satellite status at ocean-ops.org/reportcard2021



Seas from the Sentinel 3-A, 1211 UTC, 27 October 2020, with infrared image from GOES-16 underlaid (wide view). Zoomed view with maximum seas circled. Courtesy, the European Space Agency and NOAA. GOES: "Geostationary Operational Environmental Satellite"

Satellite Altimetry

Satellite-based sensors are also capable of retrieving ocean surface wind speed and direction, wave height, and sea-surface height anomalies. Typically taken by polar-orbiting satellites, information is gathered in "strips" as the satellites pass over the earth. The data are very important for forecasts and warnings, as well as to understand more about climate change, providing information from some of the gaps in the ocean where no ship or buoy data is available.

On October 27, 2020, a low pressure system with hurricane-force winds was located over the north Atlantic west of the United Kingdom. The European Space Agency's Sentinel-3A observed seas of 18 meters (59 ft in the satellite image above), which can pose a risk to vessels at sea. Satellite altimetry complements data from vessels and other observing networks, helping forecasters better understand the scope of such hazards, and validate forecasts and warnings.

EMERGING NETWORKS GROWTH

During the last few years, emerging networks have developed considerably to meet new observing requirements. For some, the pandemic impacted deployment operations between 2019-2020. Since the launch of the OceanGliders program in 2017, the number of yearly glider deployments has nearly doubled. This great improvement goes along with an increasing number of countries involved in the program and harmonization of the data exchange format that strongly contributes to achieving the FAIR (findability, accessibility, interoperability, and reusability) data principles promoted by the Global Ocean Observing System.

While the deployment of Biogeochemical and Deep Argo floats was stable during the last few years, the level of commitments from supporting countries for the next year will enable the expansion of a multidisciplinary Argo program. This expansion, and in particular the Deep mission, requires coordination and long-term funding to optimize efforts and resources towards developing a sustained, globally distributed and integrated observing network.

Animal bourne ocean sensors (AniBOS) have been contributing essential ocean observations since 2004 and the number of deployments and observations has almost tripled in this time. While much of the AniBOS effort has been focused in the polar regions, the program is now expanding and includes observations from the tropical ocean. These observations, freely available to the community, enhance an integrated observing system by providing complementary data from regions poorly sampled by other means.

Emerging networks & extended capabilities	2016	2017	2018	2019	2020	2021 Planned deployments
OceanGliders	129	139	166	233	194	225
Argo-BGC mission	119	149	133	94	118	264
Argo-Deep mission	31	30	54	53	58	86
AniBOS	41	26	51	95	99	75

Number of deployments per year (as registered at OceanOPS)

COMMUNITY COLLABORATION

Covid-19 impacts on observing activities

The impacts of Covid-19 on ocean observing networks range from increased time spent on ship expeditions due to quarantine and port restrictions, to cancellations of ship expeditions, resulting in fewer deployments, and limited servicing of equipment. In many cases, particularly in remote areas, regular data collections and ocean observations ceased or were drastically reduced in 2020.

A number of observing communities have risen to the challenge, however. Overturning in the Subpolar North Atlantic Programme (OSNAP) is one example of coordinated efforts to ensure the continuity of ocean observing. OSNAP provides estimation of the overturning volume transport across nominal 60°N and successfully redeployed equipment on 7 cruises between June and November 2020. Another example is the SURVOSTRAL XBT observations program carried out by Australia, France, and the US, which has been collecting critical upper ocean temperature data in the Southern Ocean for nearly 30 years. Covid-19 restrictions required a 14-day quarantine prior to departure, and upon return, significantly increasing time spent on this ship expedition.

"At times, the quarantine was hard, but the moment we saw the ice, I instantly forgot about the 14-days cold meals and the old towels and felt very fortunate to have the opportunity to see the white continent. I personally feel extremely proud to contribute to a much larger cause", said Pat McMahon, CSIRO.

Under these conditions, maintaining an uninterrupted data collection is an extraordinary achievement.

Strengthening maintenance capacity in the Pacific Islands

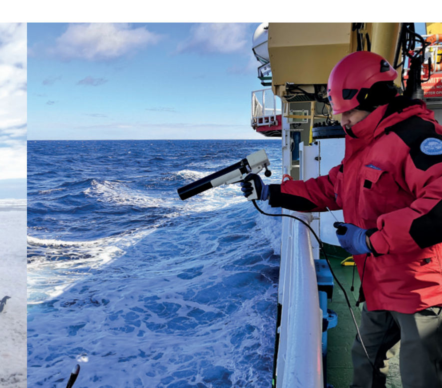
"The border closure has actually helped us improve our sea-level station maintenance capability," notes Ofa Fa'anunu, the Director of Tonga Meteorological Service, referring to one of the 13 permanent sea-level observation stations across the Pacific Islands. Established in partnership with Australia in 1991, these stations provide an indispensable record of *in situ* sea level and near-real time ocean and climate observations in a region where sea level rise and climate change impacts are of primary concern.

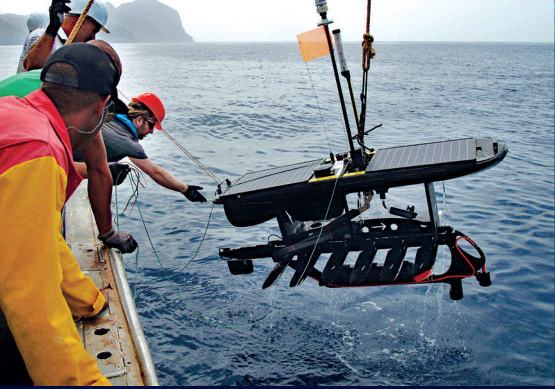
"It's important to have your own data at the national level and this is our only tide gauge in Tuvalu," says Pepetua Latasi, Director of Climate Change and Disaster Coordination in the low-lying atoll nation of Tuvalu. "People are noticing changes, especially during high tide. They ask, 'Is the sea level really rising?' and to give an answer we rely on the data from this station."

The Tonga station was damaged when Category 4 Tropical Cyclone Harold struck in April 2020, but with remote assistance from the Australian Bureau of Meteorology and the Pacific Community (SPC), an in-country team of technicians were able to identify the issue and bring the station back online.

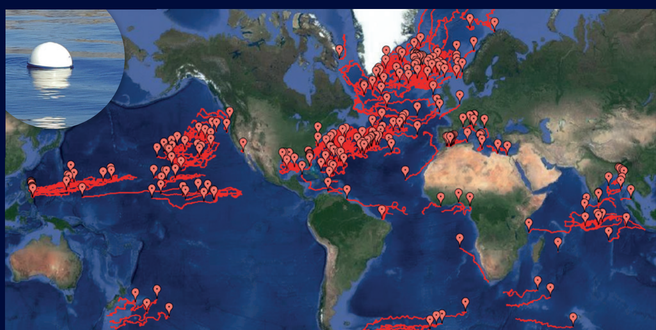
Engaging Alaskan students and local communities

The integration of local communities is a vital piece in sustaining ocean observing, considering local knowledge, and raising awareness of the state of the ocean. The US Interagency/International Arctic Buoy Program (USIABP) is a fundamental component of the Arctic Observing Network, with a diverse outreach program engaging local students and communities in Arctic ocean observations. Many buoys deployed by USIABP were designed and built by high school students as part of the Sea Cadets Arctic Buoy Program and USIABP works directly with school districts to decorate "Ice Tracker" buoys for deployment. In March 2021, USIABP returned to Utqiaġvik to deploy 10 "Ice Cadets" and other decorated buoys to maintain fundamental Arctic observations. Since its inauguration in 2020, 31 buoys were created and 44 students involved. This year 21 Ice Cadets are joining field projects including tagging of icebergs in Baffin Bay. Lauren Bird says that she and her younger sister both thought "that it would be a fun experience to have our art showcased on something that would be used for interesting research projects in the future. This is a cool project, and one that even relates to our living in Alaska since our buoy will be out on the ice! Having a small piece of ourselves in the wider world than our town is exciting."





TECHNOLOGY DEVELOPMENT



DWSD™ and Pilot array ©LDL/SIO

The Data Buoy Cooperation Panel (DBCP) has been tracking progress of a new generation of wave measuring surface drifters. These Directional Wave Spectra Drifters (DWSD™) measure 3-D spectra wave and are increasingly supporting the DBCP-Global Drifter Array via the NOAA-funded Global Drifter Program. Dr. Luca Centurioni, Director of the Lagrangian Drifter Laboratory (LDL) at the Scripps Institution of Oceanography, and developer of the DWSD drifters, says: "Directional wave observations are crucial to understand the role of wave dynamics in ocean-atmosphere coupling. As part of extreme weather events studies, we have air-deployed several DWSDs under hurricanes and atmospheric rivers, and with ships in areas of intense ocean cooling. We encourage the analysis of these data which are accessible without restriction through the Global Telecommunication System and LDL servers. The buoy is made either with recycled or biodegradable plastics and it represents a very cost-effective solution for global wave measurements."

CALL FOR ACTION

This year we note the continued progress of developing our global ocean observing system despite the significant challenges of responding to a global pandemic.

Thanks to all the implementers and funders for this remarkable development!

Looking ahead, we must continue to increase cooperation and coordination across the international community, and engage more fully with the private sector.

Testing and entraining new lower-cost technologies and multidisciplinary observations globally will enable new discoveries, monitor changes in remote parts of the ocean, and increase system resiliency.

Increasing capacity within indigenous and underserved populations and local communities to contribute towards, and benefit from, increased ocean knowledge is vital to future sustainable communities.

Finally, we must fully embrace the range of ocean-observing opportunities under the UN Decade of Ocean Science to strengthen the system in support of sustainable ocean development.

Dr David Legler
Chair GOOS Observations Coordination Group

More information at:

ocean-ops.org/reportcard2021

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