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European Commission

CORDIS Results Pack on

ocean observing

A thematic collection of innovative EU-funded research results

January 2024

Diving deeper: Propelling ocean knowledge and its sustainable management

Research and Innovation

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Editorial

The ocean covers more than 70 % of the Earth's surface and contains nearly 80 % of all life. As a source of oxygen, food, and employment, it supports billions of people, and also forms the planet's largest carbon sink. This new Results Pack highlights 13 EU-funded research projects, amongst multiple other research efforts in ocean observing and shows how they are essential for the sustainable management of the ocean.

Sustainable management of the global ocean is key to successful biodiversity conservation, climate action, food security, renewable energy, and human health. Monitoring and protecting marine habitats are therefore essential to both human well-being and the world we live in, yet the majority of the global ocean is currently poorly observed or unexplored.

To fill these gaps in scientific knowledge, understand the present state of the ocean, and predict the conditions affecting it in the future requires accurate, reliable data on the relationship between climate change, biodiversity, and ecosystem services.

Building a digital replica of the ocean

The goal of the EU Mission Restore our Ocean and Waters is to protect and bring back the health of our ocean and waters by 2030 through research and innovation, and stakeholder engagement (including with citizens), and to invest in the blue economy. Under the Mission, the EU is developing the European Digital Twin of the Ocean (European DTO), a digital replica to help scientists understand and predict the impact of human activities and climate change.

This powerful tool collates data from European assets like the Marine Observation and Data Network (EMODnet) and the Copernicus Marine Environment Monitoring Service (CMEMS) and feeds it into state-of-the-art computer models to simulate the ocean under different scenarios. By building a digital replica, researchers can study the ocean's past, present, and future, which can help inform EU policy and foster new connections between science, business and society.

In addition, the European DTO is bringing together researchers from different fields into a single cutting-edge virtual environment. Connecting the physical, biological, and socioeconomic dimensions of the ocean will revolutionise work practices and help make informed, science-based decisions.

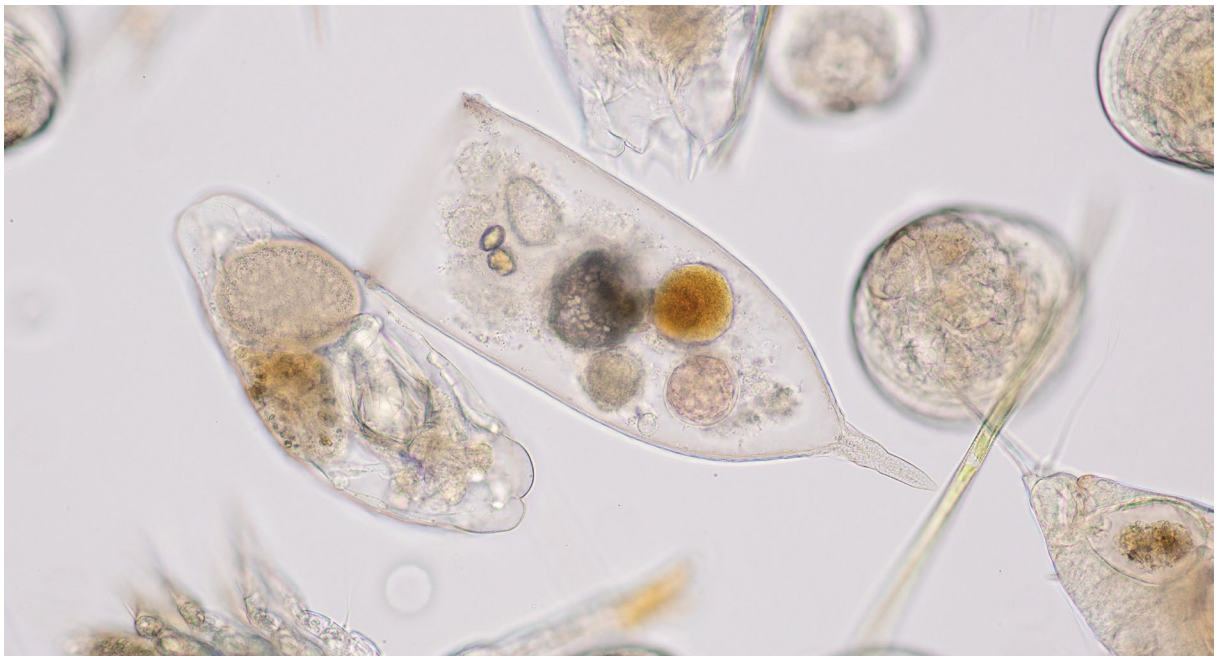
Road to sustainable management

This Pack shows how ocean observing is essential for the sustainable management of the ocean. It also indicates how the European DTO will make observation data more widely available, to facilitate its transformation into actionable knowledge for ocean communities.

The projects featured address the entire knowledge value chain, including sensing technologies and platforms, ocean observing systems, data sharing and services, and the European DTO. Their results cover ocean observing from the physical, geochemical, and biological perspectives, and address both coastal and ocean zones, in addition to highlighting the role of the marine research infrastructures.

Putting the Atlantic Ocean under the microscope

Exploration of the hidden world beneath the ocean's surface unveils the complexities of marine life, helping to understand the balance of oceanic ecosystems.



Beneath the Earth's oceans lies a complex web of life, characterised by extensive biodiversity ranging from microorganisms – classically knows as plankton – to marine mammals. Oceanic ecosystems play a vital role in the Earth's balance – regulating climate and sequestering heat and carbon dioxide. They also produce oxygen, nurture life and provide invaluable resources.

However, environmental and climate stressors, including changes in water temperature, ocean circulation, overfishing and the amount of chemicals in the water, threaten the resilience of oceanic ecosystems. Understanding the precise implications of these challenges demands a deeper comprehension of the intricate mechanisms governing ecosystem responses.

Insight into the oceanic microbiome

With a focus on the Atlantic Ocean, the EU-funded AtlantECO project sought to unravel the mysteries and dynamics of oceanic ecosystems, using cutting-edge techniques.

We combined molecular biology with ecology and oceanography to investigate the interactions of marine organisms and their interplay with their environments.

"We combined molecular biology with ecology and oceanography to investigate the interactions of marine organisms and their interplay with their environments," explains project coordinator Daniele Iudicone.

Through metagenomic data analysis, the project unveiled the geographic spread of the microbiome, shedding light on diverse responses to climate change that impact carbon production and export. Another study exposed increased species interactions toward the poles, unveiling biome-specific vulnerabilities.

Ocean currents emerge as a pivotal player in microbiome distribution. In principle, the microbiome can reach any surface location but it is constrained by the water temperature and resources availability. Therefore, rising oceanic temperatures may modulate microbiome movement, directly impacting the ecosystem. Using mathematical modelling, researchers charted the routes and timing of microbiome movement across the ocean in correlation with temperature.

Evolving ocean behaviour

"The oceans contribute and respond to climate change through intricate mechanisms. Analysing singular factors, such as temperature, is insufficient to untangle the underlying processes," states Iudicone.

By studying 25 years of oceanic and atmospheric data, AtlantECO yielded invaluable insights into long-term trends. Researchers discovered significant alterations in ocean circulation, water temperature and salinity levels. AtlantECO's findings indicate that these changes have deeply altered the distribution of the abundance of the microbiome across the Atlantic.

Changes in atmospheric air patterns over the ocean are disrupting the normal interaction between the ocean and the atmosphere, which typically aids in stabilising Earth's temperature. These disruptions have an immediate impact on the ocean response to global warming. Analysis of these new ocean dynamic patterns and their contributing environmental factors led to a more comprehensive framework for assessing the accuracy of climate models and predicting these changes.

"This advancement will refine climate predictions and deepen our understanding of environmental shifts," highlights Iudicone.

Safeguarding oceanic ecosystems

Various pollutants including heavy metals and pesticides, excess nutrients from agriculture and sewage as well as pharmaceuticals and plastics affect oceanic microbiomes. Climate-induced temperature shifts reduce nutrient supply, escalate toxicity and create oxygen-depleted zones. These stressors combine nonlinearly, affecting aquatic life, particularly through amplified pollution via riverine inputs and altered precipitation patterns.

The AtlantECO-BASE database encapsulates ocean-related information, bridging comprehension gaps and serving as a unified resource for studying ocean dynamics and ecosystems within the Atlantic region. The predictive AtlantECO-MAPS provides a detailed view of ocean dynamics and connectivity, microbiomes and microplastics. Together, these resources aim to inform more effective ocean policies and initiatives, ensuring better management of Atlantic Ocean ecosystems.

PROJECT
AtlantECO – Atlantic ECOsystems assessment, forecasting & sustainability

COORDINATED BY
Anton Dohrn Zoological Station in Italy

FUNDED UNDER
H2020-EU.3.2., H2020-EU.3.2.5.2., H2020-EU.3.2.5.1.

CORDIS FACTSHEET
cordis.europa.eu/project/id/862923

PROJECT WEBSITE
atlanteco.eu/

Open science ecosystem for the blue economy further expands in Europe

The Blue-Cloud 2026 project will create a federated European ecosystem and a collaborative web-based research environment to share and exploit research data that is fundamental for preserving oceans and seas.

Recently, Europe has become a leader in marine ecosystems research, with infrastructures, programmes and major R&D projects that have increased its capacity for aquatic environmental observation, modelling, forecasting, data-handling and sharing. Open science programmes are an integral part of this capability, contributing significantly to the advancement of marine preservation.

In 2019, the EU-funded Blue-Cloud project started, with the aim of developing a virtual pilot platform that provides open and seamless access to multidisciplinary data and research tools for ocean sustainability. After a successful 4-year process, Blue-Cloud 2026 kicked off in 2023 with a more ambitious goal: to evolve the pilot platform into a federated European ecosystem to deliver FAIR (findable, accessible, interoperable, reusable) and open data and analytical services to deepen the research of oceans, seas and coastal and inland waters.

With a team of 40 partners from 13 countries, this project is essential in developing a marine extension to the European Open Science Cloud, supporting fundamental strategies of the European Union, such as the Green Deal, the Destination Earth initiative and the 'Restore our Ocean and Waters' mission.

The current Blue-Cloud platform

With oceans covering 70 % of the Earth's surface and representing over 95 % of the planet's biosphere, it is easy to see how complex the data for marine preservation can be, requiring an approach that involves various disciplines.

The Blue-Cloud ecosystem currently enables users to search and access more than 10 million data sets. It also federates leading European data marine infrastructures, which collect *in situ* and remote data related to marine biodiversity, surface ocean CO_2 observations, ocean physics, biogenomics and bathymetry among many other fields.

The project's virtual research environment is already one of the most mature communities in open science in the cloud. Users can not only discover and access data, but store and publish their work, execute analysis and processes and interact with fellow researchers through social networking functionalities.

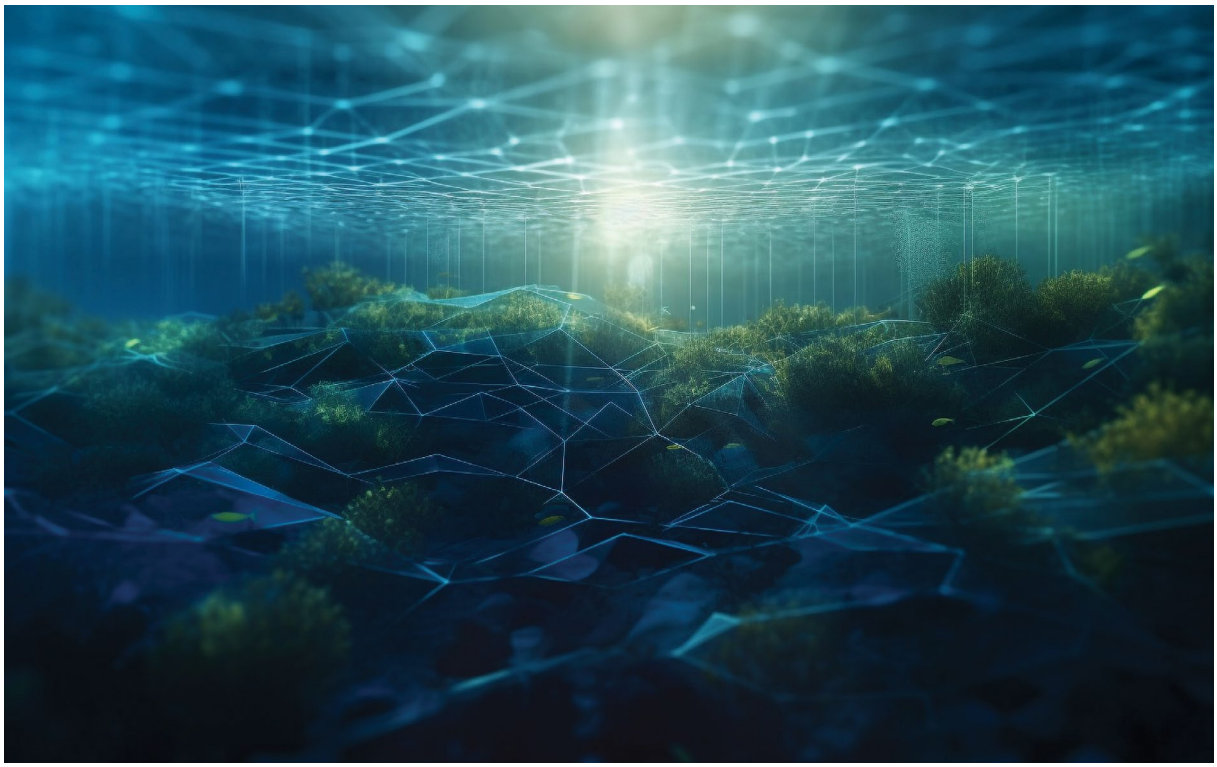
Next developments

Over the course of 42 months, Blue-Cloud 2026 will improve and integrate more services in the platform. The data discovery and access services will be expanded, more blue data infrastructures will be federated and data lakes for storing and maintaining raw data from the infrastructures will be deployed.

Next steps will focus on developing, testing and documenting new workbenches that will result in highly qualified data sets of Essential Ocean Variables (EOVs). EOVs are divided into physics, linked to temperature and salinity; chemistry, related to nutrients, chlorophyll and oxygen; and ecosystem, concerning plankton biomass and diversity.

The challenge ahead is to deal with large *in situ* data sets. The consortium will face this by leveraging its high-level performance environment based on cloud computing, associated with big data, data lakes and data management.

The resulting workbenches will be fundamental to position Blue-Cloud 2026 as an important collaborator of the European



Digital Twin of the Ocean. Together with other research projects, like the EDITO-infra, Blue-Cloud will support this interactive replica of the ocean to provide knowledge for better decision-making. The project's EOV collections will be used for analysing the state of the environment, as well as forecasting its evolution and testing possible impacts of sustainability measures.

PROJECT
Blue-Cloud 2026 - A federated European FAIR and Open Research Ecosystem for oceans, seas, coastal and inland waters

COORDINATED BY
The National Research Council in Italy

FUNDED UNDER
H2020-EU.1.3., H2020-EU.1.3.1.

CORDIS FACTSHEET
cordis.europa.eu/project/id/101094227

PROJECT WEBSITE
blue-cloud.org/

Building the backbone of a more interconnected and accessible oceanic landscape

Integrating marine big data from real-world observations and advanced simulations, the European digital twin of the ocean will revolutionise marine knowledge creating a high-resolution virtual representation of the ocean.

The European Commission unveiled plans for developing a European digital twin of the ocean European DTO at the One Ocean Summit held in France in February 2022. This initiative should help transform our understanding of the ocean, turning raw data into usable knowledge that can be utilised by citizens, entrepreneurs, scientists, policymakers and decision makers alike.

At the heart of this endeavour are two EU-funded projects: EDITO-Infra and EDITO-Model Lab. Both projects are crucial in further developing the European DTO as they will provide the fundamental infrastructure to host multiple DTO applications from ongoing and future twinning projects.

EDITO-Infra is co-led by Mercator Ocean International, the trusted entity of the Copernicus Marine Service, and the Flanders Marine Institute, the operator of the Central Portal of the European Marine Observation and Data Network (EMODnet). Marina Tonani, EDITO project manager at Mercator Ocean International, explains: "EDITO-Infra is building the core infrastructure of the European DTO by upgrading, combining and integrating key service components of existing EU ocean observing, monitoring, forecasting and data programmes." These programmes include the Copernicus Marine Service and EMODnet, aiming to create a single digital framework that complements existing services.

Single infrastructure for a safe, healthy and productive ocean

Among the key components of EDITO-Infra will be a data lake, a processing engine and a virtual simulation environment. The data lake will integrate openly accessible marine data sets and make them available for European DTO usage. Once ready, it will offer public access to an extensive range of *in situ* and remote marine observation data sets as well as model-derived products, and host new data sources.

EDITO-Infra is building the core infrastructure of the European DTO by upgrading, combining and integrating key service components of existing EU ocean observing, monitoring, forecasting and data programmes.

EDITO-Infra promises an unprecedented combination of marine data, computing power and cloud-native tools, forming the backbone of the European DTO as a public, open and inclusive infrastructure. It will enable unprecedented collaboration among data scientists, ocean modellers and software developers, accelerating the creation of new knowledge and innovation in marine data analyses and ocean modelling.

Currently, there is no single European infrastructure offering these capabilities. EDITO-Infra is a game changer in the field, poised to become the central hub connecting multiple DTO applications from local, national and European efforts that will shape and evolve the European DTO.

Overcoming challenges in marine data management

Conor Delaney, technical coordinator of the EMODnet Secretariat at Seascape Belgium, states: "EDITO-Infra will empower those people with ideas, knowledge and ambition to develop solutions to ocean challenges, free from the restrictions of poor data or high computing costs. This could trigger innovation in ways we cannot yet foresee."

The immediate goal of the European DTO is to develop decision-making tools that bring us closer to achieving the policy objectives of EU mission 'Restore our Ocean and Waters by 2030'.

But the vision for the European DTO also extends beyond these goals. It aims to evolve into an open and inclusive ecosystem that caters to the needs and expectations of all types of stakeholders. These include not only policymakers but also multidisciplinary researchers, blue-economy industries and SMEs, non-governmental organisations and even citizens from Europe and beyond.

PROJECT
EDITO-Infra - EU Public Infrastructure for the European DIgital Twin Ocean

COORDINATED BY
Mercator Ocean, France

FUNDED UNDER
H2020-EU.2.5.

CORDIS FACTSHEET
cordis.europa.eu/project/id/101101473

PROJECT WEBSITE
edito-infra.eu/

Boosting Europe's ocean-monitoring capabilities

By upgrading a network of marine sensors, the EU-funded Euro-Argo RISE project is helping scientists to build more accurate weather models and better understand long-term climate trends.

Accurate ocean data is critical to understanding the Earth's climate, and to making estimates of how it will change in the future. To this end, the international Argo programme, launched in 1999, established a network of floats, deployed across the world's oceans.

The network consists of thousands of autonomous instruments that spend almost all their life below the surface, at depths of up to 2 000 metres. Data on temperature, salinity and the chemical make-up of the sea is relayed to satellites, and then sent on to receiving stations onshore.

"This data, which is freely and openly accessible, is delivered in real time for operational users, such as meteorological offices, and for climate change research and monitoring," explains Euro-Argo RISE project manager Estérine Evrard, from Euro-Argo ERIC in France.

Better coverage and more precision

Euro-Argo ERIC coordinates Europe's contribution to the programme and is responsible for operating around a quarter of the global Argo floats array. Around 2019, it was recognised that ocean coverage needed to be extended further into partially ice-covered polar regions and shallower waters, along with more biogeochemical sensors deployed and data management systems updated.

To monitor climate change, we need long-term data. This is why ensuring the sustainability of the Argo network is essential.

These were some of the key objectives of the Euro-Argo RISE project, which also sought to bring Europe's contribution into line with the programme's long-term vision, called OneArgo. "To monitor climate change, we need long-term data," says project coordinator Sylvie Pouliquen, also part of Euro-Argo ERIC. "This is why ensuring the sustainability of the Argo network is essential."

To achieve this goal, Euro-Argo RISE tested new sensors to assess their accuracy and performance, as well as floats' capacity to survive in ice-covered areas. Ice-sensing software was used to ensure that instruments did not attempt to surface until they drifted into open sea.

Similarly, float configurations were tuned for shallower waters and tested in selected sites of the Baltic, Mediterranean and Black Seas. The result is that the Euro-Argo RISE project has expanded the programme's ocean coverage, in terms of both deployed devices and monitored range of parameters.

Data for informing climate policy

The project has also made it easier to access Argo data. A new data selection tool has been designed to help users select, visualise and download data in different formats through a user-friendly interface.

"This data is used by the Copernicus Marine Service for analysing and forecasting the state of the ocean," says Evrard. "It can also be used by intergovernmental organisations such as the European Centre for Medium-Range Weather Forecasts."

The advances will also benefit researchers and oceanographers interested in better understanding the long-term processes under way within our oceans, such as how interactions between the ocean and atmosphere work, and how ocean acidification evolves.

"This information is critical for informing climate policy," notes Pouliquen. "It is currently being used by bodies such as the IPCC."

Sustainability of ocean monitoring network

The project has been an important step forward in ensuring the success of this research infrastructure over the long term and helped to expand its reach.

For example, a series of regional workshops led to Denmark's application as a candidate Member of Euro-Argo ERIC, which includes 28 institutes (19 of which were partners in Euro-Argo RISE) across 12 countries.

"The huge amounts of data and knowledge being created can only be achieved through the sustainability of the network," adds Pouliquen. "We are currently working with national ministries to identify any gaps in coverage and the different scenarios to sustain the European contribution to OneArgo over the long term."

PROJECT
Euro-ARGO RISE - Euro-Argo Research Infrastructure Sustainability and Enhancement

COORDINATED BY
EURO-ARGO ERIC in France

FUNDED UNDER
H2020-EU.1.4., H2020-EU.1.4.1.1

CORDIS FACTSHEET
cordis.europa.eu/project/id/824131

PROJECT WEBSITE
euro-argo.eu/EU-Projects/Euro-Argo-RISE-2019-2022

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Specialised fleet is cornerstone for ocean observation

An interoperable fleet provides equipment crucial to understanding marine environments, prioritising the study of clean and healthy oceans.

Oceans play a key role in climate change, and monitoring these environments is critical. The EU-funded project EurofleetsPlus widens scientific understanding by providing essential infrastructure. Building on earlier work, the project has advanced the interoperability of vessels and added remotely operated vehicles (ROVs) and autonomous underwater vehicles (AUVs) to the fleet.

Knowledge gained from research cruises

A principle aim of the project, accounting for almost 50 % of funding, are cruises supported through transnational access calls. Project coordinator Aodhán Fitzgerald states "Of the 68 applications received, the project provided 268 funded ship days, over 28 scientific campaigns involving 315 embarked participants, and included 144 early career scientists."

Of the 68 applications received, the project provided 268 funded ship days, over 28 scientific campaigns involving 315 embarked participants, and included 144 early career scientists.

Notable for its breadth and depth, the project maintains a focus on healthy ocean environments. Many of the studies deal directly with mapping poorly understood areas. These include the Mid-Atlantic Ridge, the eastern Alboran Sea, the Western Mediterranean Transition, and the Ceuta Canyon.

The project has also been instrumental in supporting education and early career scientists. A series of six training initiatives introduces students to scientific instrumentation, data analysis, and the collection and processing of specimens. Seven lab courses train the next generation of marine scientists in using the equipment on the research vessels. Overall, the project has hosted 14 individual courses, 19 different nationalities and 102 participants.

Data management coordination through EVIOR

To fulfil its role as Europe's key infrastructure for marine studies, EurofleetsPlus provides for open access to data. Project partners, led by the Dutch company MARIS, ensure the full capture and publication of crucial data related to the cruises.

The European Virtual Infrastructure in Ocean Research EVIOR portal is the publication platform for all data related to the vessels and the cruises. The level of disclosure, transparency and accessibility of the content on EVIOR reflect the concepts of FAIR data.

Information from the cruises is quite detailed. Vessels are equipped with Eurofleets Automatic Reporting System (EARS). This allows for the automatic collection and transfer of data during the cruise via fixed onboard sensors. EARS also allows for the capture of data from ROVs, AUVs and floats.

Collaboration is key to developing interoperability

According to Fitzgerald: "EurofleetsPlus has successfully demonstrated that interoperability is not only possible but can be implemented in a cost-effective and efficient manner, delivering added value not only to users but across the European research vessel fleet." Key implementation strategies include upskilling,

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training and education opportunities delivered through technical exchange and hands-on learning.

Vessel operators, in conjunction with large exchangeable instrumentation (LEXI), enable interoperability of vessels and equipment in transnational access calls. Industry participation and innovation are central to realising the EurofleetsPlus focus on technological evolution, pooling knowledge and skills from a range of experts.

Industry-led innovation impacts hardware as well. While LEXI provides standardisation of mechanisms, collaboration has also yielded improved tools. EurofleetsPlus has overseen a new deep-sea winch design, a dual mode system for launching and retrieving overboard equipment and a multipurpose crane used for deep-sea expeditions.

The work of EurofleetsPlus will surely achieve that most coveted goal of research proposals – to have an influence that outlives the duration of the project. From novel technological solutions to open access data to the advancement of the next generation of ocean scientists, EurofleetsPlus has accomplished what it intended to do: it has created key infrastructure for European ocean observation.

Learn more about EurofleetsPlus transnational access activity by searching for 'Eurofleets+ TNA activities' on YouTube.

PROJECT
EurofleetsPlus - An alliance of European marine research infrastructure to meet the evolving needs of the research and industrial communities

COORDINATED BY
Marine Institute in Ireland

FUNDED UNDER
H2020-EU.1.4., H2020-EU.1.4.1.2.

CORDIS FACTSHEET
cordis.europa.eu/project/id/824077

PROJECT WEBSITE
eurofleets.eu/

Science-based governance of oceans benefits blue economy

Improving observation and forecasting systems in Europe delivers ocean data that is useful for tourism, aquaculture, fisheries and maritime transportation.

The world's oceans control climate, provide food and are the source of livelihoods for 3 billion people. Marine ecosystems are arguably the most important on the planet. In recognition of this, the UN has deemed 2021-2030 the Ocean Decade. The EU-funded EuroSea project dovetails nicely with this global initiative, as one of the project's overarching goals is to integrate European national ocean observation systems into an international system.

Observation systems foster sustainability

We were able to support the combination of observations and information from the oceanographic and fisheries communities in both the Atlantic and the Baltic Sea. This way there is a better exchange of information to the benefit of all.

Collecting information about the condition of ocean environments creates a vast amount of data. EuroSea worked to increase the quality of data gathered as well as to improve access and connectivity between stakeholders. One example of how EuroSea facilitated data collection pertains to farmed fishing. According to project coordinator Toste Tanhua: "We were able to create information around aquaculture sites by installing special moorings with instruments and combine this with other data to provide forecast services for the operators."

In addition to helping to improve the data available about specific marine environments, EuroSea did much to facilitate the sharing of information with diverse partners. Tanhua elaborates with an example: "For instance, we were able to support the combination of observations and information from the oceanographic and fisheries communities in both the Atlantic and the Baltic Sea. This way there is a better exchange of information to the benefit of all."

The oceans contain a multitude of natural resources. Improving observation systems with respect to quality of data and how data is shared is essential to maintaining healthy marine environments. By coordinating communication, EuroSea fosters a global environment in which economic interests can be balanced against the need for environmental protection.

Ocean forecasting strengthens the blue economy

Data gleaned from observations becomes a powerful tool when it is used for predictive modelling. One of the services the project provided was an integrated set of tools to forecast waves, sea levels and temperatures. Researchers combined tide gauge data with satellite altimetry to validate ocean models. They have helped industries to better foresee extreme marine events, such as ocean heat waves or low oxygen levels in the water.

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One important climate indicator is carbon measurements. Using autonomous surface vehicles, EuroSea collected data on carbon fluxes and uptake in the Atlantic and the Western Mediterranean. Awareness of trends in climate patterns allows industries to prepare, recognising when ecosystems may be particularly vulnerable and when they are in a more robust state.

EuroSea initiatives range from optimising technologies and information sharing systems to aligning European ocean governance with global best practices and strengthening the European Ocean Observing System. Communication was an important part of bringing together diverse constituencies and ensuring all stakeholders were working towards the common goal of sustainable, science-based ocean management.

The project brought together partners from 16 nations and two UN agencies. Pilot sites in Bueno Ventura, Barcelona and Taranto (Italy) focused on services and improvement for fisheries and aquaculture, ports and coastal communities. EuroSea has received a lot of positive feedback from these stakeholders, and given its focus on observation and forecasting infrastructures, project work is slated to have a sustained positive impact.

PROJECT
EuroSea – Improving and Integrating European Ocean Observing and Forecasting Systems for Sustainable use of the Oceans

COORDINATED BY
HELMHOLTZ-ZENTRUM FUR OZEANFORSCHUNG KIEL (GEOMAR) in Germany

FUNDED UNDER
H2020-EU.3.2., H2020-EU.3.2.5.1.

CORDIS FACTSHEET
cordis.europa.eu/project/id/862626

PROJECT WEBSITE
eurosea.eu/

European research infrastructure opens new possibilities to observe the marine world

Through the design of a structured marine research network, this EU-funded project is strengthening the use of marine autonomous systems in Europe.

Underwater and surface marine autonomous systems (MASs), especially underwater gliders, have been pivotal in supporting environmental observations and blue economy activities for some years. These agile and cost-efficient vehicles can carry scientific payloads even under 6 000 metres. But to exploit all the advantages of these assets, it is necessary to have an infrastructure capable of meeting different demands – from marine research and monitoring to public services and industry needs.

The EU-funded project GROOM II has designed a sustainable marine research network at European level. Building on its predecessor study, it aims to be the basis for an advanced marine research infrastructure for MASs, called GROOM RI, that promotes scientific excellence, fosters innovation, supports the blue economy and establishes public and industrial partnerships.

Shifting to marine autonomous systems

With 14 partners from 12 countries, the project is taking a step further in integrating the European infrastructure landscape for MASs, supporting connections for the global and European Ocean Observing Systems.

"GROOM II maintains a unique centralised provision of cyberinfrastructure, data and knowledge for the optimised use of MASs to study climate and marine environments, and to support operational services and the blue economy," states Laurent Mortier, GROOM II project coordinator.

The European landscape is shifting towards more autonomy, and marine autonomous systems will and already do in some cases, play a central role in the future of ocean observing.

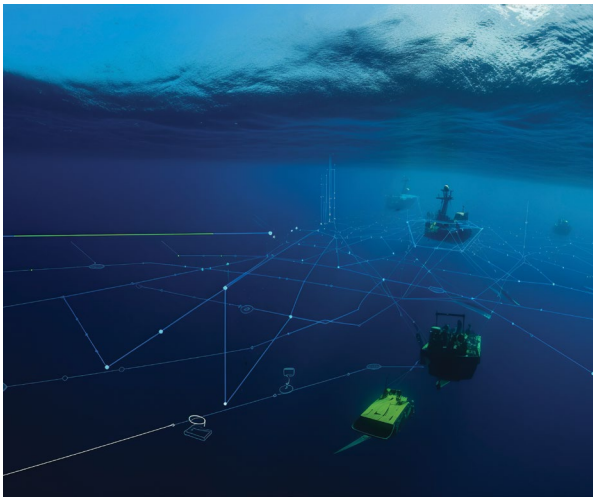
According to Laurent Mortier, "the European landscape is shifting towards more autonomy, and marine autonomous systems will and already do in some cases, play a central role in the future of ocean observing."

He mentions the Future Marine Research Infrastructure programme in the UK, which aims to move towards net-zero activities using floats and more MASs – a vision also shared by the GROOM II partners. To make this outlook a reality, a strong operational research infrastructure is paramount.

Impacts of the project

The consortium has considered a set of use cases to better understand how to link the services of a future distributed marine research infrastructure.

For instance, a main impact of GROOM II is to improve ocean forecasts by increasing observing capabilities and adequacy of observations with a minimum increase of carbon footprint. To ensure that MAS operations at sea are useful for this purpose, a digital infrastructure could allow for complex piloting activities, minimising human supervision of the system with automation and AI. In this scenario, the project also develops a framework that enables interoperability at all levels, creating standards for data formats and quality so it can be best assimilated in forecast models and optimally exploited.



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Other potential contributions of the project's research network include monitoring of biodiversity and biogeochemistry, response to emergency situations and discovery science as well as providing support to different international initiatives related to ocean observing.

"By developing solutions to increase the MAS deployment capacities, the GROOM II partners will be able to provide data that will break down present barriers in marine environment observing," asserts Laurent Mortier.

Overall, this involves better monitoring for EU climate goals and marine policies, emergency response to disasters such as oil spills or harmful algal blooms, and other needs from the blue economy sectors.

GROOM RI's vision and work has also led to the creation of a new project, named Advance Marine Research Infrastructures Together (AMRIT), which aims to be the cornerstone of the European Ocean Observing System, integrating key services from all European Marine Research Infrastructures for ocean observation within a single framework open to all users.

PROJECT
GROOM II – Gliders for Research, Ocean Observations and Management: Infrastructure and Innovation

COORDINATED BY
ARMINES in France

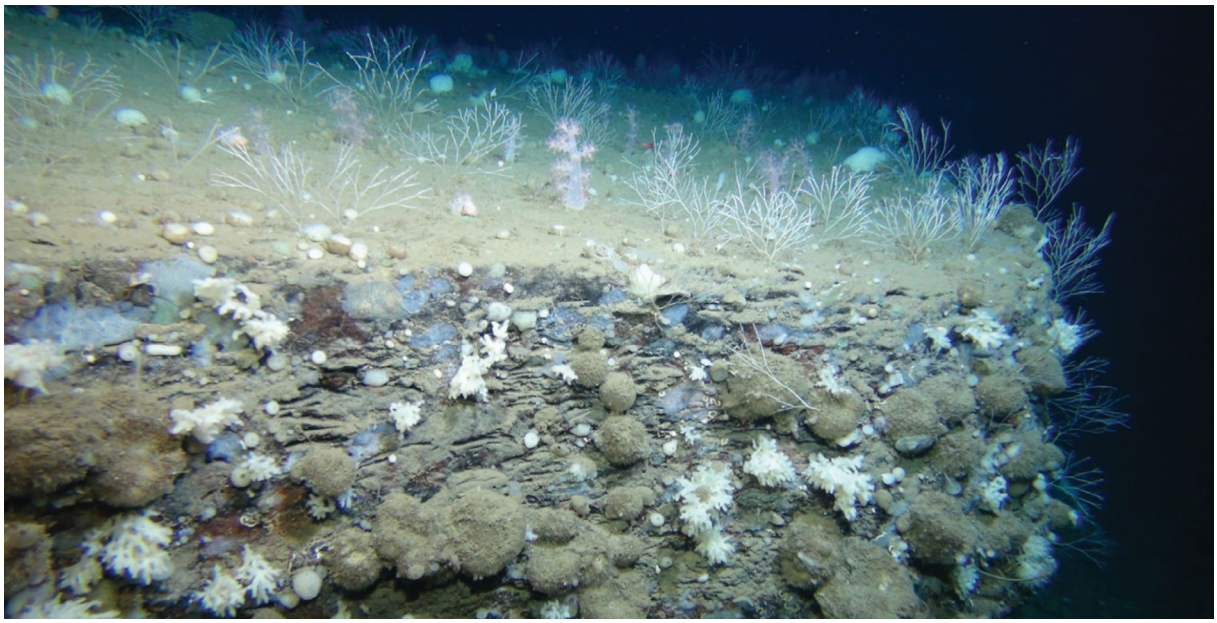
FUNDED UNDER
H2020-EU.1.4., H2020-EU.1.4.1.1.

CORDIS FACTSHEET
cordis.europa.eu/project/id/951842

PROJECT WEBSITE
groom-ri.eu/

Mapping the Atlantic basin improves ocean management

Marine scientists improve data collection and information sharing about ecosystem resilience and climate change drivers in deep and open ocean environments.



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As climate change continues and human activities expand into the deep ocean, scientists strive to provide knowledge that will inform sustainable management of marine resources. The EU-funded project iAtlantic is using new ocean technologies, employing innovative approaches and investing in early-career researchers to give Atlantic ecosystems a health check.

According to project coordinator J. Murray Roberts: "The ocean is at the very heart of Earth's life support system. It has already absorbed over 90 % of global warming and 25 % of humanity's carbon dioxide emissions, and thanks to this, is changing faster than ever before. iAtlantic has come up with a unique coordinated approach that doesn't just focus on the science but puts huge emphasis on sharing human and technical capacities."

New knowledge about the Atlantic basin

The project has focused on 12 key zones in the Atlantic Ocean. These areas are of international conservation significance and important to the blue economy. iAtlantic sent over 70 missions to these sites and nearby areas to record data, collect samples and run remote experiments on the deep seafloor. As well as scientists, iAtlantic works closely with stakeholders from industry and policymaking agencies to ensure results can be used to support responsible decision-making.

Experiments in the field and in the laboratory identified ecosystem tipping points in response to physical changes in the environment. The project developed new knowledge with respect to specific stressors, including temperature rise, deoxygenation, sedimentation, and pollution from deep-sea mining.

iAtlantic developed new knowledge through a host of innovative techniques and technologies. Scientists sampled environmental DNA in the water column, advanced seafloor imaging through machine learning, and showed that shifts in upper ocean systems caused by climate change negatively impact ecosystems underneath. iAtlantic also unlocked important data sets from industry stakeholders that improved mapping coverage of the seafloor.

The intergenerational and interregional experience of iAtlantic is essential to help shape a more inclusive and multidimensional next generation of deep-sea scientists.

Planning for the future through iAtlantic fellows

Work on the iAtlantic project has spanned four continents and is dedicated to collaboration and information sharing. By working together, the partners created a blueprint for collaborative Atlantic research. After 4 years, the project boasts more than 50 iAtlantic Fellows from countries all around the Atlantic basin. These early-career researchers formed the backbone of the project, and their collaboration points to a bright future for ocean science.

Project Fellows achieved many successful outcomes in their research. These include evidence of the tropicalisation of the South Atlantic, where scientists observed the poleward movement of warm-water species. Fellows worked on identifying the toxic effects of deep-sea mining on important cold-water corals. They also created ecological time series that shed new light on the impacts of climate change on Atlantic ecosystems.

Despite limited travel and in-person meetings due to the pandemic, Fellows were able to make the most of digital platforms. They engaged with one another through online events such as webinars and working group meetings, and built a very supportive community. According to iAtlantic Fellow Beatriz Vinha: "The intergenerational and interregional experience of iAtlantic is essential to help shape a more inclusive and multidimensional next generation of deep-sea scientists."

A fundamental goal of iAtlantic was to provide scientific evidence that informs sustainable governance of the Atlantic Ocean. The project has met that goal by focusing on international science, cooperation and communication.

PROJECT
iAtlantic - Integrated Assessment of Atlantic Marine Ecosystems in Space and Time

COORDINATED BY
The University of Edinburgh in the United Kingdom

FUNDED UNDER
H2020-EU.3.2., H2020-EU.3.2.5.2, H2020-EU.3.2.5.1.

CORDIS FACTSHEET
cordis.europa.eu/project/id/818123

PROJECT WEBSITE
iatlantic.eu/

Expanding infrastructure for coastal observatories

Observatories along European coastlines foster collaboration, provide access to data and equipment, and connect research infrastructures.

The scientific community all over Europe has committed itself to a series of projects to harmonise data, share facilities, extend scientific knowledge and develop tools for decision support.

Coastal environments are complex. Humans utilise these waters for food, construction materials, transport and recreation. But climate change and human activities put great pressure on these areas. The EU-funded JERICO-S3 project is the latest in a series dedicated to advancing observation of European coastal waters.

Understanding coastal environments is the work of decades, and the JERICO Research Infrastructure (JERICO-RI) will inform scientists and decision makers well into the future. According to project coordinator Laurent Delauney: "The scientific community all over Europe has committed itself to a series of projects to harmonise data, share facilities, extend scientific knowledge and develop tools for decision support." Built on the work of JERICO-NEXT, the current project focuses on the harmonisation of the coastal observation system and the development of infrastructure and services to support scientists.

Physical infrastructure and supersite observatories

There is an extensive array of equipment that researchers can access through the project. Delauney points out that these include "600 multidisciplinary platforms such as fixed platforms, high frequency radars, coastal sea bottom observatories, ferryboxes, coastal and open sea profilers, gliders, manual sampling, research vessels, surface drifters and observations from citizen scientists." Platforms are operated by governments, institutes and SMEs in more than 19 countries.

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To optimise access to infrastructure, the project created supersites. Four pilot supersites provide multi-platform access in the Gulf of Finland, the North-Western Mediterranean, the North Sea and English Channel, and the Cretan Sea. Delauney states: "We feel confident that integrated and jointly steered transnational multi-platform observations are the future of European coastal observing systems."

Transnational access

All of the infrastructure available – both physical and virtual – is of little consequence if it is under-utilised. Transnational access (TA) calls, which ensure free of charge access to JERICO-RI, optimise utilisation. The project has coordinated four calls, through which 36 projects have been funded, enabling users to access 42 facilities.

TAs, an essential and growing feature of JERICO-RI, are important to encouraging knowledge transfer and collaborative relationships. Project partners have been able to determine the most popular tools in the JERICO collective. Delauney says: "The most successful infrastructures have been the coastal cabled observatories, which have provided the greatest number of access days, and gliders, which have supported 22 % of all the projects."

JERICO-CORE

Not all of what JERICO-RI has to offer is in the form of physical infrastructure. A major initiative of the project is the JERICO-CORE pilot, which consolidates virtual resources. Available through this central hub are datasets, software and manuals as well as publications and e-libraries. Driving the pilot is the understanding that the complexity of ocean problems requires experts from multiple disciplines to co-design solutions.

Collaboration and co-designing drive much of what the project set out to do, especially when it comes to harmonising virtual resources. With an eye on sustainability, JERICO-S3 focuses on aligning efforts with other ocean RIs, including EURO ARGO, EMSO ERIC, ICOS, DANUBIUS, EMBRC and JERICO-RI.

JERICO-S3 has overseen the evolution of ocean research infrastructure from a project-based approach to a collective poised to influence societal change. Composed of 36 partners in 19 countries, project participants have had to walk the talk when it comes to the value of collaboration. Describing funding for ocean research, Delauney states: "There may be as many different approaches as there are beaches or cliffs in Europe, but we're committed to sharing best practices." Despite diversity in approach, all involved in JERICO-RI are unified in their support for ongoing ocean observation.

PROJECT
JERICO-S3 – Joint European Research Infrastructure of Coastal Observatories: Science, Service, Sustainability

COORDINATED BY
French Research Institute for Exploitation of the Sea (IFREMER) in France

FUNDED UNDER
H2020-EU.1.4., H2020-EU.1.4.1.2.

CORDIS FACTSHEET
cordis.europa.eu/project/id/871153

PROJECT WEBSITE
jerico-ri.eu/

Coastal biodiversity: the guardian of our planet's ecosystems

Climate change endangers marine and coastal ecosystems – but preserving biodiversity with nature-based solutions offers crucial support.

Nearly half of the global population lives within 100 km of marine coastal regions, reaping the invaluable benefits provided by these ecosystems. In addition to human well-being, marine and coastal ecosystems play a pivotal role in supporting diverse economic activities, notably fisheries.

These ecosystems exhibit remarkable resilience and an ability to adapt to environmental changes through various mechanisms. Among these, biodiversity stands out as a crucial indicator of an ecosystem's vitality, encompassing a spectrum of life from animals to microorganisms and plants.

However, these ecosystems face mounting pressures stemming from climate change and human intervention – particularly through overexploitation. This is pushing marine and coastal ecosystems to their limits, leading to shifts in ecological balance and loss of biodiversity. The ecological processes behind the provision of ecosystem services that could help us mitigate the effects of climate change are at risk.

Nature-based solutions against marine and coastal ecosystem degradation

These escalating threats were the driving force for the EU-funded MaCoBioS project to take action. It explored nature-based solutions for the conservation and sustainable management of marine and coastal ecosystems against the impact of climate change. The first step was to understand the relation between climate change, biodiversity and ecosystem services.

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"Nature-based solutions aren't uniform; they're context-dependent, demanding tailored approaches," emphasises Cindy Cornet, member of the project's coordination team.

Researchers developed a framework to guide practitioners in selecting the most suitable intervention depending on the societal challenge they want to address, the ecosystems and their ecological condition as well as the services they provide. From marine protected areas to coral restoration efforts, these solutions were designed to safeguard ecosystems while meeting societal needs.

"Central to the implementation of these strategies is the engagement of stakeholders and especially local communities", she continues.

Monitoring ecosystem capacity to cope with climate change

Monitoring ecosystem resilience against climate change requires diverse indicators. By reviewing the literature, the team determined critical thresholds for various ecosystems, such as coral reefs' bleaching temperatures or how much sea level rise mangrove forests can tolerate.

"Employing diverse indicators, including molecular and ecosystem-level variables, provides a comprehensive understanding of climate change impacts," states research fellow Ewan Trégarot.

Moreover, researchers used paleoclimatology to retrace the growth of coral species over multiple decades and centuries in relation to specific stressors. The advantage of this method is that it provides observations at a time scale that is more relevant to climate change. Predictive modelling and machine learning also helped forecast future ecosystem conditions, offering insights into long-term resilience.

Shaping global policies on climate change

MaCoBioS consolidated a suite of tools and frameworks to guide decision makers. According to Cornet, an integrated theoretical model, designed to answer crucial questions and facilitate implementation of nature-based solutions signifies the most significant accomplishment of the project.

Key project outputs and perspectives on biodiversity and climate change have been presented at the conference while collaboration with the African Union highlighted the potential of restoring coastal and marine natural habitats for the future of African fisheries. The project's nature-based solutions also align with the EU's mission to restore ocean and waters by 2030.

"Collectively, MaCoBioS is committed to raising global awareness on the transformative potential of nature-based solutions in safeguarding coastal habitats," concludes Pierre Failler, Director of the Centre for Blue Governance at the University of Portsmouth.

Collectively, MaCoBioS is committed to raising global awareness on the transformative potential of nature-based solutions in safeguarding coastal habitats.

PROJECT
MaCoBioS - Marine Coastal Ecosystems Biodiversity and Services in a Changing World

COORDINATED BY
University of Portsmouth in the United Kingdom

FUNDED UNDER
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CORDIS FACTSHEET
cordis.europa.eu/project/id/869710

PROJECT WEBSITE
macobios.eu/

Expanding ocean observation and data sharing

New technologies, open-source software and citizen science tools will boost ocean monitoring's spatial and temporal resolution to better preserve and protect our oceans.

Oceans are the largest liveable space on our planet. They are also an incredible repository of biodiversity, a source of food and employment as well as oxygen and the planet's largest carbon sink.

Monitoring and protecting marine habitats are essential to our well-being and the world we live in, yet the majority of the global ocean is poorly observed or unexplored. The EU-funded NAUTILOS project is complementing and expanding current EU tools and services to fill important gaps in marine observation and modelling.

New cost-effective sensing and sampling technologies

"NAUTILOS developed 14 new technologies that monitor a multitude of parameters including dissolved oxygen, sound (for both noise and porpoise and dolphin clicks for abundance estimation), phytoplankton, ocean acidification, silicate, nanoplastics and microplastics. Our low-cost, autonomous microplastics sensor for real-time on-site analysis will be the first-ever *in situ* sensor, revolutionising microplastics monitoring," notes project coordinator Gabriele Pieri of the Institute of Information Science and Technologies at the National Research Council of Italy.

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The project's large-scale demonstration will monitor 70 % of the more than 30 essential ocean variables defined by the Global Ocean Observing System. It will also address nine qualitative descriptors for determining good environmental status as defined in the Marine Strategy Framework Directive.

Enhancing temporal regularity and spatial resolution

One of the key issues with current technologies is a lack of widespread use and temporal regularity of sampling or data collection. "NAUTILOS targeted enhanced adoption and deployment via several approaches to address this: modular design and easy integration into existing platforms and observation stations; cost-effectiveness; and use in citizen science initiatives," explains Pieri.

Many heterogeneous platforms are candidate hosts, including those supporting calibration, validation and demonstration. Among them are moored buoys, drifters (drifting on the surface moved by currents), ARGO robotic profiling floats, autonomous underwater vehicles and autonomous surface vehicles. Others include deep-ocean observation platforms, landers (sea floor platforms), unmanned aerial vehicles (drones) and finned animals (via tagging).

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"NAUTILOS software and data products are open-source and, most importantly, the data products are also seamlessly integrated into external EU thematic centres such as the European Marine Observation and Data Network and SeaDataNet, a pan-European infrastructure supporting access to marine data," adds Peri.

From citizen science to the European Commission

While companies, NGOs and researchers are key target users of NAUTILOS technologies, the team is raising awareness among citizens and policymakers too. "Our citizen science campaigns are one of the major outcomes of the project. Valuable feedback from diverse users is helping us to improve our solutions – including a new citizen science app, a tool for performing algal bloom analysis, and a near-infrared scanner for microplastics, all easy-to-use smartphone tools," notes Pieri.

NAUTILOS also organised a policy round table in Genoa this year in the context of the Ocean Race Grand Finale. Representatives of the European Commission's Directorate-General (DG) for Maritime Affairs and Fisheries and its DG for Research and Innovation (Healthy Oceans and Seas) highlighted the significance of ocean protection and ocean observation.

NAUTILOS has delivered a wealth of tools and services to enhance the spatial and temporal resolution of the EU's marine observation programmes. Open access and citizen science will support engagement and use by stakeholders across the board, making a fundamental impact on marine preservation and environmental, individual and planetary health and well-being.

PROJECT
NAUTILOS - New Approach to Underwater Technologies for Innovative, Low-cost Ocean obServation

COORDINATED BY
National Research Council of Italy in Italy

FUNDED UNDER
H2020-EU.3.2., H2020-EU.3.2.5.1.

CORDIS FACTSHEET
cordis.europa.eu/project/id/101000825

PROJECT WEBSITE
nautilos-h2020.eu/

Research reveals how heat and carbon uptake in the Southern Ocean affect our climate

The Southern Ocean significantly affects our global climate by regulating critical heat and carbon exchanges between the atmosphere and ocean. EU-funded researchers provide new insight into how these intricate processes work over decades.

Over the past six decades, the simultaneous uptake of heat and CO_2 by the Southern Ocean has been instrumental in moderating the rate of global warming. The gap in knowledge regarding the underlying oceanic processes arises from a lack of observations in this extreme environment and inherent difficulties in capturing the intermittent processes across various scales in current Earth system models.

The EU-funded SO-CHIC project was established to further understand and quantify the variability of heat and carbon budgets in the Southern Ocean. "We investigated key physical processes that control exchanges between the atmosphere, ocean and sea ice by combining various observational and modelling approaches," notes project coordinator Jean-Baptiste Sallee.

Exploring the impact of tiny and short-lived processes

Fine-scale (1-10 km) and transient (days to weeks) processes challenge understanding of how the Southern Ocean moves heat, carbon and other important elements from its surface down to its depths. These processes occur in the mixed layer – a part of the ocean where different water properties combine together. The layer characteristics, such as depth and buoyancy, are key to understanding how these elements move up and down in the ocean.

"We showed that local and transient processes such as storm-induced turbulence, or mesoscale and sub-mesoscale processes developing in the open ocean or at the sea-ice edge might be instrumental in tracer transfer across the base of the mixed layer," explains Sallee. Efforts are ongoing to better comprehend the net effect of these small-scale processes on large-scale Southern Ocean circulation and their impact on climate.

Assessing what causes polynyas to open

Around Maud Rise – an submarine mountain located in the eastern Weddell Sea – anomalous water masses and cross-frontal fluxes can create favourable conditions for the formation of an open-ocean polynya. The latter provides a direct link between the surface and deep ocean. Such a cross-frontal flux is beneficial for Maud Rise because large-scale, horizontal water movement helps divide different water bodies around the edges of this plateau. The strength of this circulation evolves seasonally and is strongly controlled by winds and slightly by sea-ice coverage.

We investigated key physical processes that control exchanges between the atmosphere, ocean and sea ice by combining various observational and modelling approaches.

Sea-ice, in turn, plays a crucial role in forming dense water on the Antarctic shelf, which is then transformed by interacting with ice shelves and warmer waters. The dense shelf waters are exported off the Weddell shelf mainly through canyons and are linked with the import of warmer deep water.

Investigating the processes controlling bottom waters

"Carbon and heat can enter the Southern Ocean through the formation, export and consumption of bottom waters. The bottom waters from the Weddell Sea are consumed by abyssal mixing processes, which control the overall water circulation in the deep ocean. New findings show that large ocean regions are not connected with this global water movement," explains Sallee.

Upper ocean processes, polynya events and bottom water formation and consumption combine to ventilate the Southern Ocean. This ventilation allows to propagate climate change signals at depth, which modify the Southern Ocean thermohaline structure. These changes are unequivocal when looking at multi-decadal repeated observations of the Southern Ocean.

SO-CHIC has not only generated and spread new knowledge but also helped ensure its practical application beyond the project itself. The project impact has featured in the Intergovernmental Panel on Climate Change sixth assessment cycle, through its reports and involvement in high-level policy events.

PROJECT
SO-CHIC - Southern Ocean Carbon and Heat Impact on Climate

COORDINATED BY
Sorbonne University in France

FUNDED UNDER
H2020-EU.3.5., H2020-EU.3.5.1.

CORDIS FACTSHEET
cordis.europa.eu/project/id/821001

PROJECT WEBSITE
sochic-h2020.eu/

Shining new light on the ocean's contents and processes

Remote ocean sensing technologies will fill important gaps with previously inaccessible data on the ocean's biogeochemistry, habitats and litter.

Our ability to sustainably manage the global ocean is essential to biodiversity conservation, climate action, food security and even renewable energy and human health. Ocean science can support this with data that helps us understand the present and predict future conditions that affect ocean health.

The EU-funded TechOceanS project has identified critical gaps in ocean monitoring and developed new or improved technologies to fill them. They cover at least 12 of the 19 biogeochemical and biology and ecosystems essential ocean variables and at least 39 of 73 subvariables, as well as litter, plastics, biotoxins, parasites, pathogens and organic pollutants.

The new [in situ sensor using time-resolved fluorometry] is 72 % more compact, requires 80 % less power (less than two Watts) and can operate in much deeper waters (2 000 m versus 600 m) compared to previous versions. It will enable comprehensive measurements of ocean primary productivity for the first time.

The carbonate system and ocean nutrients

CO_2 measurement is a priority for ocean chemistry. TechOceanS developed an *in situ* sensor using time-resolved fluorometry to remotely measure the rate at which the oceans fix CO_2 using sunlight (photosynthesis or primary productivity). "The new sensor is 72 % more compact, requires 80 % less power (less than two Watts) and can operate in much deeper waters (2 000 m versus 600 m) compared to previous versions. It will enable comprehensive measurements of ocean primary productivity for the first time," explains project coordinator Matt Mowlem of the National Oceanography Centre.

Improved microfluidic chemical sensors can measure two parameters simultaneously. They will enable remotely measuring dissolved CO_2 (complementing pH or acidity) via paired total alkalinity and dissolved inorganic carbon measurements. They will also measure important ocean nutrients such as nitrate/phosphate and phosphate/silicate.

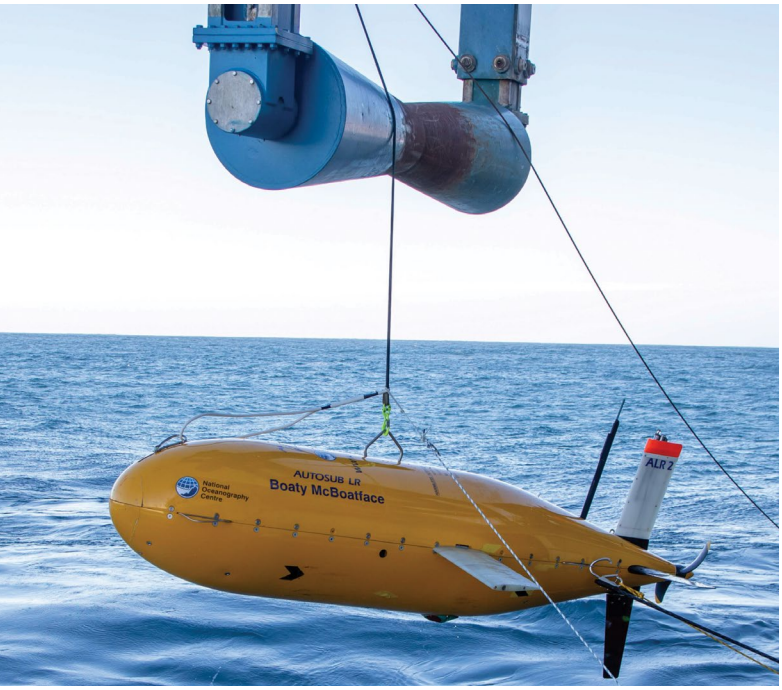
Biological populations, organic materials and habitats

"To ascertain which species are present and their abundance in specific areas, TechOceanS adapted and optimised a cartridge-based nucleic acids sampler to be simpler and more robust whilst taking more samples. Now commercially available from McLane Research Laboratories (USA), it can capture both DNA shed from large and smaller whole organisms," Mowlem states. This should help scientists answer questions about the abundance, diversity and distribution of marine organisms including phytoplankton and zooplankton, microbes, microalgae, invertebrates, fish, turtles, birds, mammals, coral, seagrass and mangrove.

An *in situ* sensing concept for high-capacity measurement of organic materials (hundreds to potentially thousands of measurements) including pollutants, toxins and nucleic acids was also developed. It uses reagents in solid, powder or gel form, extending lifetimes from hours to months compared to reagents in solution.

Phytoplankton and microplastics

The Underwater Vision Profiler 6 (UPV6) is an existing quantitative imaging sensor used to monitor large particulate matter and



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plankton. TechOceanS developed UVP6m, which reduced the minimum size for particle detection to 10 µm and for classification to 100 µm. "The sensor has been integrated with two types of ocean glider using SIRMA™, a smart device that transforms a conventional cable assembly into an intelligent processing unit. Automated image processing and edge computing are under development," notes Mowlem. Together, these outcomes will address key gaps in identifying marine organisms and monitoring habitats and litter.

All protocols and data collection techniques contribute to the established open-access platforms Ocean Best Practices System and Better Biomolecular Ocean Practices, and all project data will be made public at project end. TechOceanS has delivered a treasure trove of technologies and data that will support the ocean science community, industry, regulatory groups and policymakers work toward sustainable ocean management.

"TechOceanS has assembled a highly skilled team of technology developers and application experts who are eager to hear from prospective collaborators, contributors, users and partners," concludes Mowlem.

PROJECT
TechOceanS – Technologies for Ocean Sensing

COORDINATED BY
National Oceanography Centre in the United Kingdom

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RESULTS PACK ON OCEAN PLASTIC POLLUTION

The EU aims to bring back a healthy ocean by 2030, in line with its commitment to protecting and restoring the marine environment. This CORDIS Results Pack highlights 12 EU-funded Horizon projects that are helping to clean up aquatic ecosystems, paving the way to a thriving ocean.

Check out the Pack here:
cordis.europa.eu/article/id/449175

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