

# THE BLUE BOOK

COPERNICUS FOR  
A SUSTAINABLE OCEAN





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A SUSTAINABLE OCEAN



## ELŻBIETA BIENKOWSKA

EU Commissioner for Internal Market, Industry, Entrepreneurship and SMEs (2014-2019)

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Two-thirds of our planet's surface and 97% of our waters are ocean. Our future is intimately linked to its future.

The ocean is a climate regulator, absorbing 25% of our CO<sub>2</sub> emissions and releasing half of our oxygen. Ocean routes carry 90% of world trade. The ocean is the new economic frontier, with marine-related economies predicted to reach nearly 3 trillion dollars of global gross value by 2030. The ocean is a primary source of protein for more than one billion of the poorest people along the coasts of developing countries.

With a world population predicted to reach 9 to 10 billion by 2050, pressures on the ocean are steadily increasing. Considering the crucial role the ocean plays and how

much it is endangered, the Commission made commitments to protect it:

- 20 years ago, the Amsterdam treaty, calling for sustainable development, entered into force;
- 10 years ago, the Marine Strategy and the ambitious Integrated Maritime Policy for the European Seas were adopted;
- In 2012, the Commission developed the “Blue Growth” strategy based on the Ocean being a driver for a European smart, sustainable and inclusive economy.

Europe's role is pivotal. Sixty percent of the ocean surface lies beyond the borders of national jurisdictions and the issues they are facing can only be addressed globally. In 2016, along with the 17 Sustainable

Development Goals of the United Nations, the European Commission and the EU High Representative proposed 50 actions intended for International Ocean Governance to ensure safe, secure, clean and sustainable management of the ocean in Europe and around the world. The Commission also committed Europe to the G7 initiative for the “Future of seas and oceans”.

Copernicus, the European Earth Observation programme, is instrumental in supporting these actions. Since Topex-Poseidon, the first ocean satellite launched in 1992 as a joint European and USA project, the Commission worked hard to make Earth Observation an effective, reliable and sustainable means for supporting our policies, Europe’s competitiveness and growth, and for contributing to the protection of our environment.

With a dedicated fleet of satellites for the ocean, and in particular Sentinel 3 and Sentinel 6, Copernicus delivers ocean-related observations daily.

From a vision initially outlined in 2001, the Copernicus Marine Service, with more than 50 partners from 20 countries, is now a public service, the European Ocean Forecasting Centre, that freely and openly

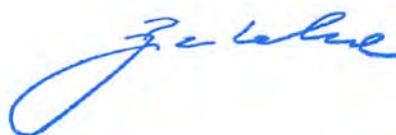
delivers relevant ocean forecasts and climate records to assess ocean health and climate, manage organic and inorganic resources, and contribute to safer routes.

The Copernicus Marine service received recognition at the First United Nations Ocean Conference for SDG14 in 2017 for its Ocean State Report which included the annual review of global warming consequences, the melting of polar ice caps, ocean acidification and the rise in sea level.

The Commission will work to reinforce Copernicus as a major, world-class reference for ocean protection and management, with continuous improvement of its services, including addressing emerging needs such as CO<sub>2</sub> monitoring or monitoring of the Arctic.

The Blue Book – Copernicus for a Sustainable Ocean tells the story of this adventure full of testimonies from citizens around the globe, business success stories, societal commitments, and visionary statements of major European and International stakeholders.

We need to continue building on this endeavour to serve the European strategy for a sustainable and healthy ocean for our future generations, and to intervene as a global actor to meet global challenges.





## **PIERRE BAHUREL**

Mercator Ocean International  
Chief Executive Officer

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The ocean is now recognised at the highest level as a key factor in our Earth system, affecting its biodiversity and human life.

In 2015, the United Nations assembly adopted the 2030 Agenda for Sustainable Development and its 17 Sustainable Development Goals, among which Goal 14 aims to conserve and sustainably use the oceans, seas and marine resources. The mention of the ocean in the Paris Agreement signed in 2016 marked another decisive milestone. The same year the Organisation for Economic Co-operation and Development (OECD) published a ground-breaking report entitled “Ocean Economy 2030”, which outlined the enormous potential for exploiting the ocean in a sustainable way, but also conveyed warnings. UNESCO announced the Decade of Ocean Science for Sustainable Development (2021-2030) in 2018: its Intergovernmental Oceanographic Commission will unite ocean stakeholders

worldwide within a common framework to foster evidence-based policy-making. The first IPCC special report on the ocean and cryosphere will be published in 2019. This unprecedented ocean agenda is timely and the European Union is naturally one of its major stakeholders. The next two pages illustrate its involvement and the many ways in which the ocean is so important.

Copernicus and its Marine Service is part of Europe’s commitment.

The European Commission has entrusted Mercator Ocean International with the conception, implementation and operation of a reliable, open, responsive and up-to-date service. These simple words hide highly complex systems and processes, drawing on many disciplines, among which, space-borne and sea-borne Earth observation technologies, ocean science and ocean modelling, quality monitoring and validation

statistics, data collection and processing, cloud technologies, while not forgetting creating and maintaining a catalogue and monitoring users, manning the service desk, market uptake activities, legal supervision and procurement.

Our goal is not only to meet all statutory and technical requirements laid down by the European Commission but also to commit to the highest standards of corporate responsibility and excellence on the part of Copernicus management worldwide. Our mandate requires us to report to the European Commission and the EU Member States at the end of each quarter, on our scientific, technological, service-related and outreach performances. In addition to this accountability, and four years after the service began, we wish today to proudly report back on our global achievements, on our progress with user uptake and on how all this benefits society. We are accountable for our mission to the European Commission, the European Parliament and the EU Member States, but we also feel accountable to our users, our supporters and ultimately to every EU citizen. This Blue Book was written in the same spirit and with the same intention as that behind the setting-up of the Copernicus Marine Service, i.e. of creating value with a service that is managed through a collaborative, open and multi-disciplinary approach. We thus consulted the various stakeholders as well as the users, prospects and prescriptors so that the book would reflect all of their perspectives. I sincerely hope that it will make an even greater contribution through being shared.

The ocean has abundant potential for eradicating poverty, ensuring food security, employment opportunities and well-being for all, and inspiring innovators around the world but it also has to face unprecedented challenges. Both sides of the coin, opportunities and issues, are explained in four chapters presenting a “Healthy Ocean”, a “Safe Ocean”, a “Living Ocean” and a “Powerful Ocean”. We have shared the many testimonies of our users and of national, European and

international decision- and policy-makers freely acting as our ambassadors. The Ocean-Climate chapter focuses on the key-role that the ocean plays in the state, the variations and more fundamental changes of our Earth system and how Copernicus Marine Service data and information are used by scientists in this respect. Many basic questions are answered in this chapter, with clear explanations based on the Ocean State Report that Mercator Ocean International has been publishing for a few years. The Blue Book is also a plea and a pledge for raising awareness of the civil society about a Sustainable Ocean. This is further echoed in the chapter entitled “Inspirational Ocean” because the Copernicus Marine Service is committed to engaging, persuading and educating citizens and young people in particular. We also play a role in stimulating ocean-related vocations in fields that will require more and more scientists and in the Ocean Economy, which the OECD predicts will account for approximately 40 million full-time equivalent jobs by 2030, in particular in offshore wind energy, marine aquaculture, fish processing and port activities.

We are grateful to our Copernicus mentors, the European Commission and the European Union Member States represented by National Copernicus Delegates, for providing us with guidance and vision, to the Members of the European Parliament for their trust and support, to Copernicus Entrusted Entities for their precious and invaluable collaboration and to our 135 partner-contractors throughout the European Union for their operational input and expertise. We would also like to acknowledge the 20,000 subscriber-users and 100,000 non-subscriber-users, throughout the world, as well as users in the future, champions of a sustainable ocean, rightly demanding excellence of all policy-makers striving to progress towards a Sustainable Ocean. I would like to warmly thank all of those who kindly contributed to the Blue Book and sincerely hope it will prove useful and relevant to all.

# WHY IS THE OCEAN IMPORTANT?



## THE OCEAN IS CENTRAL TO THE FUNCTIONING OF THE PLANET

### O<sub>2</sub> reservoir

The ocean provides nearly half of the world's oxygen

### Ocean currents

Ocean currents act as major navigation routes

### A crucial factor in weather and climate

Linked to the Earth system cycle and ocean currents

### Carbon Storage

Pivotal role in the circle of life:  
the ocean contains 50% more carbon than the atmosphere

### Protein tank

World largest source of protein

### Biodiversity tank

Production of about half the world's oxygen – phytoplankton  
90% of the planet's living biomass is found in the ocean

### Ocean waves

Vital role in transporting energy around  
the globe and shaping the coastline

### Earth water reservoir

97% of Earth water supply

### Maritime Space

71% of Earth's surface and over 90%  
of the habitable space on the living planet

### Sea Ice

Vital role in global climate, polar ecosystems and human systems

### Heat Storage

The most important climate regulator



# THE OCEAN IS CENTRAL FOR HUMAN WELLBEING



## Food Security

20% average per capita animal protein intake for 3 billion people, provided by fish food



## Urban and regional planning

Disaster Risk Management  
(40% of the world population lives within 100 km from the coast)



## Public Health

Oxygen, food and novel pharmaceutical provision



## Recreation and Tourism

Marine and coastal areas are the top tourism and recreational destinations and represent over one third of the maritime economy



## Ocean governance,

Legal Frameworks and maritime spatial planning  
(the ocean offers an enormous space resource)



## Blue Economy

Renewables | Aquaculture |  
Fisheries | Trade and Transport



# SUMMARY

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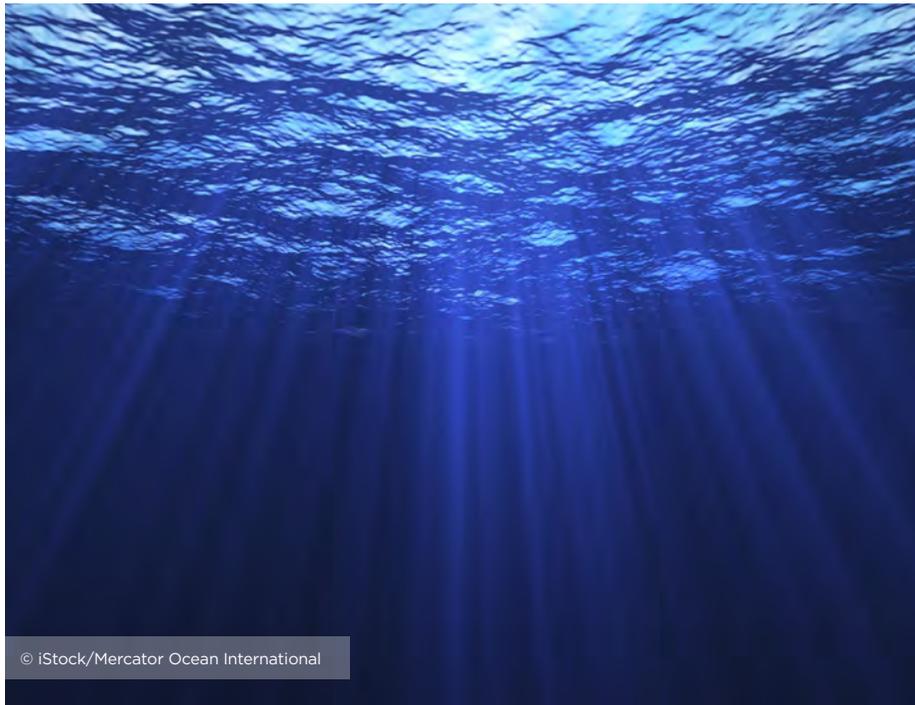


01

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# LAYING THE CORNERSTONE





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## WHAT WILL THE OCEAN BE LIKE TOMORROW?

We can all find out thanks to operational oceanography, a fairly recent scientific discipline combining progress in Earth observation by satellites with numerical modelling and assimilation of observation data. This enables scientists to analyse, simulate, predict and monitor the physical, dynamic and biogeochemical characteristics of the ocean, both at the surface and at depth, at global and regional scales. The parameters include sea temperature, salinity, currents, sea surface height, ice thickness, chlorophyll concentration, nutrients, etc.

Ocean forecasting is a core activity of Mercator Ocean International, a non-profit organisation owned by nine international and major players in operational oceanography in France, Italy, Norway, Spain and the United Kingdom. The organisation produces, disseminates and shares reliable, up-to-date ocean knowledge and services to meet the needs of its shareholders and those of national, European community and international stakeholders involved

in environmental policy, maritime safety, and defence, the stewardship of marine resources, climate studies and the promotion of sustainable blue growth.

Mercator Ocean International is fundamentally committed to a public-interest mission to ensure a sustainable ocean. It is a small and highly specialised organisation, since flexibility and responsiveness are key for ensuring adaptive and innovative capacities.

This activity is part of a huge value chain, of which each link is essential, forged by close, long-standing partnerships, as shown in this book. Upstream, Mercator Ocean International relies on two key means of observation: measurements made by sensors on satellites and measurements of the ocean in all three dimensions made at sea (in situ) by ships or by fixed or drifting autonomous systems. The observation data are assimilated in complex numerical models developed by Mercator Ocean International, thus providing any users with the best

possible digital representation of the global ocean in the past, the present and the near future. Having been in direct contact for years with thousands of users of its products that work in ocean-related domains, Mercator Ocean International is able to provide an unrivalled and reliable source of information for specifying and prescribing ad hoc marine requirements for satellite observations, in situ observations, IT infrastructures and software.

Mercator Ocean International's DNA is essentially scientific, so it is naturally involved in the UN Decade of Ocean Science. The organisation has developed strong bonds with the international research community, with which it has designed operational oceanography in Europe, led the effort to develop quality metrics and pushed for their

adoption as international standards that are now applied in the USA, Australia, China, Japan and Canada. Whereas Mercator was chiefly a scientific project 25 years ago, Mercator Ocean International is today a leading organisation in ocean modelling, ocean data management, ocean services and blue market intelligence. It is now entering the "cloud revolution".

Taking over from a long and successful demonstration phase with the European "MyOcean" research projects, Mercator Ocean International was selected by the European Commission in November 2014 and entrusted with implementing and operating the Copernicus Marine Environment Monitoring Service (CMEMS).



This book is dedicated to Michel Lefebvre, captain and master mariner, astronomer and visionary. A pioneer in satellite altimetry, his name is forever associated with the French-American mission Topex/Poseidon, which began measuring the topography of the ocean's surface with centimetre-level accuracy in 1992. He has put continents into a global perspective with international operational oceanography programmes such as GODAE.

Michel was an inspiring person with innumerable, unclassifiable facets. He never asked for anything but simply inspired his colleagues with an irresistible desire to create and get involved. It is thanks to Michel that Mercator Ocean International bears the name of the illustrious 16<sup>th</sup> century cartographer (who showed us the world with his atlas), that we always prepare our missions with an overall picture of the ocean and the world, that we speak to engineers and sailors alike, that we create opportunities for cooperation whenever we can and that we are irresistibly driven by the ambition to do better, to learn more and to offer more.

**PIERRE BAHUREL**

# COPERNICUS MARINE SERVICE IN A NUTSHELL

COPERNICUS is a flagship programme of the European Union, implemented by the European Commission as part of the **EU Space Policy**, jointly with the European Space Agency (ESA) and the European Environment Agency (EEA). Twenty-years after its launch, Copernicus is the leading provider of Earth observation data around the globe. Aligned with the **EU open data policy**, Copernicus provides free, full and open access to users of environmental data. By facilitating access to the data and lowering the entry barriers for them, new businesses and entrepreneurs can better develop new products and services, thus stimulating economic development.

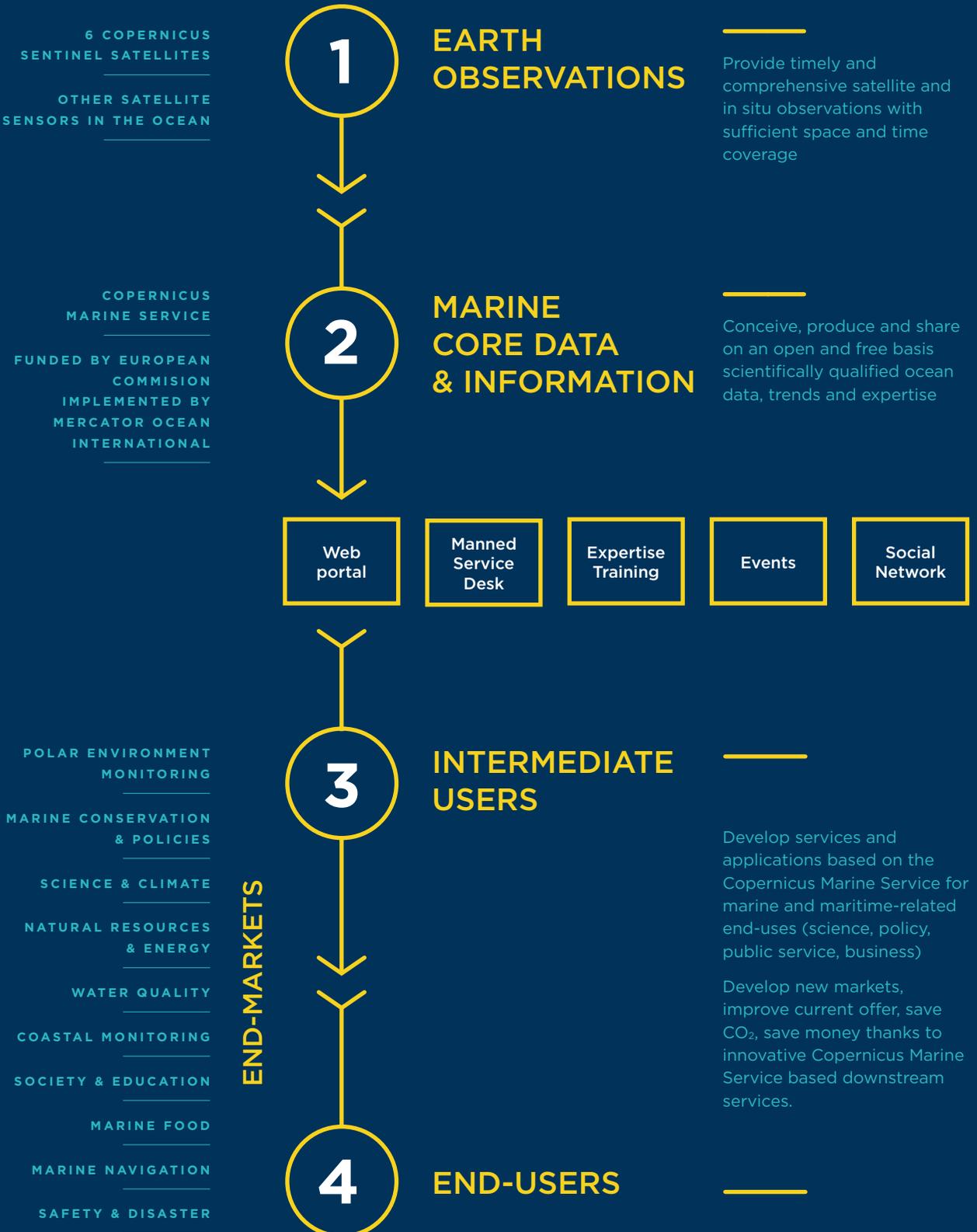
Mercator Ocean International has been creating value for the Copernicus Marine Service by managing it in a collaborative, open and multi-disciplinary way. As part of its delegation mission and commitment, Mercator Ocean International has been supervising the design, development and operations of the service with its own in-house specialists and the support of contractors duly selected through open competition. **As of October 2019, Mercator Ocean International has entrusted tasks to 140 partner-contractors in 21 countries of the European Economic Area, who help provide an efficient, reliable and timely Copernicus Marine Service every day, 40% of which comes from the private sector.**

Through permanent dialogue with a community of operational oceanography specialists, whether they be data producers or oceanographers, the Copernicus Marine Service guarantees that its products are based on the latest scientific knowledge. **About 30 of the most advanced ocean data producers are involved in the Copernicus Marine Service and 70 “Service Evolution” projects have been undertaken**

**to improve the level of service even more. The Ocean State Report, written by more than 80 scientific experts provides an annual, comprehensive and state-of-the-art assessment of the state of the global ocean and European regional seas. It is downloaded each year by more than 10,000 readers.**

The Copernicus Marine Service offers all comers information on the physical and biogeochemical state of the global ocean and the six regional seas in Europe, freely and openly, simply and instantaneously. These digital data are scientifically qualified and regularly updated. Subscribers of the Copernicus Marine Service have access to a catalogue of ocean data and monitoring indicators that they can download from a web portal ([copernicus.marine.com](http://copernicus.marine.com)) or via a Copernicus Data and Information Access Services (DIAS). The catalogue contains products derived from satellite and in situ observations, forecasts, real-time analyses and long-time series over several decades, referred to as “reanalyses”. **As of October 2019, the Copernicus Marine Service counts nigh on 20,000 subscriber users worldwide and 100,000 non-subscriber users per year, from 120 countries. Their number doubled from 2015 to 2017. A manned Service Desk supports users and registers an average of 300 to 500 new subscribers per month. The latest user satisfaction index is from the end of August 2019: 4.9/5. The data volumes have more than doubled within a year with 1.35 petabytes downloaded in 2018. The “User Uptake” programme has enabled the creation and the development of 40 downstream services in 16 EU countries, two-thirds of which are in the private sector. Since 2016, 2,000 trainees have benefitted from training sessions and 6,000 viewers have followed online tutorials.**

# FROM EARTH OBSERVATION TO END-USERS, A POWERFUL VALUE CHAIN FOR A SUSTAINABLE OCEAN





# A GLOBAL SATELLITE INFRASTRUCTURE FOR A GLOBAL OCEAN

Copernicus is the world's largest and most ambitious **Earth Observation system**. It provides accurate, timely and easily accessible information to improve management of the environment, and to enable us to understand and mitigate the effects of climate change while ensuring civil security. The initiative is headed by the European Commission in partnership with the w.

The European Commission, acting on behalf of the European Union, is responsible for the overall Copernicus programme, from defining the requirements to managing the services. ESA, which coordinates the overall Copernicus space component, ensures the delivery of data from more than thirty satellites.

ESA has developed a **new family of satellites**, the Sentinels, specifically for the operational needs of the Copernicus programme. At present, three complete constellations, each with two satellites, are in orbit plus an additional single satellite, Sentinel-5P. The Sentinels provide 150 TB of data every day to users world-wide through the ESA-managed Sentinel data hub. Further distribution is enabled thanks to the free and open data policy.

Copernicus addresses a range of thematic issues, including the central topic of the ocean and specific topics such as sea level rise, plastic pollution, coral bleaching, high fishing pressure, acidification, diminishing biodiversity, agricultural runoff, chemical pollutants and the shrinking of arctic sea ice.

The fleet of Copernicus satellites provides evidence which supports the development of tools and services to monitor the impact of European policies and decisions that are

**helping to sustain our ocean.** Sentinel-6 is dedicated to monitoring sea level change and serves as a reference for other satellite altimeters. Sentinel-3 has a multi-faceted ocean focus, providing estimates of ocean currents that, when fed into ocean models, help us understand the trajectory and fate of floating ocean plastic. It also provides a fundamental measurement of the mean ocean surface temperature and estimates of surface ocean biology describing the regional and local variability. Moreover, Sentinel-3 products can be used to study the carbon cycle in the ocean and its potential influence on our climate. Sentinel-2 allows us to monitor the evolution and dynamics of our coastal zones, both in the ocean and on land at a fine resolution of 10 metres, thus providing essential information for understanding the impact of human activities in this important region. Sentinel-1 monitors the dynamics and evolution of arctic sea ice – with an unprecedented resolution of -6 m – as well as global ocean waves and swells that affect the retreat and regrowth of sea ice. In addition, Sentinel-2 and Sentinel-1 serve to study the impact of extreme weather events such as coastal flooding, helping to optimise relief activities and to prevent outbreaks of water-borne diseases.

**Our ocean is inextricably linked to our daily lives:** what happens in the distant ocean has an impact on our weather and climate at a local scale. The Copernicus Sentinel fleet features astounding capabilities that help ensure that our ocean is effectively managed for a healthy and sustainable future.

**JOSEPH ASCHBACHER**  
Director of Earth Observation Programmes  
ESA

# DELIVERING AN INTEGRATED REAL-TIME DATA SERVICE

The blue economy contributes several hundred billion euros per year and millions of jobs to Europe, which is bound to increase with the development of marine energy.

Furthermore, living marine resources have to be protected and exploited in a responsible way, by enforcing regulations to ensure that they are complied with. The human impact on the ocean, illustrated by plastic particles trapped in ocean gyres and propagating across the food chain, must be contained and reduced. The time has come to take responsibility for the consequences, as **there is no ocean B to fall back on.**

This would be more than enough to justify the EU investment in Copernicus marine information services to citizens, businesses and policy makers, but there are other stakes involved, because our Planet is blue. The ocean not only covers 70% of Earth's surface but also plays essential roles in its functioning, which naturally are of fundamental importance to human life.

Because of its thermal inertia, the ocean influences the weather over long periods, which may result in devastating thunderstorms in the Mediterranean basin or seasonal variations of temperature worldwide. **Ocean observations and models have therefore become an integral part of weather prediction.**

The ocean also influences the climate by absorbing heat and CO<sub>2</sub> from the atmosphere and transporting them through the long cycle of ocean circulation. Thus, the ocean slows down and modulates global warming in the short term, whilst storing heat that will shape its interactions with the atmosphere in the long term, hence affecting our future climate. Awareness of its heat storage role increased in 2018, when, in response to climate sceptics claiming that global warming was a fiction because the mean global temperature had cooled down from 2017 to 2016, ocean analyses revealed that this was because the heat uptake of the upper ocean had reached a record high in 2017. Likewise, the El Niño events, which are the first order signal of climate

variability, with massive impacts worldwide, are caused by interactions between the tropical ocean and the atmosphere.

While the ocean reacts slower than the atmosphere, the “bio-ocean” is a faster and more variable CO<sub>2</sub> pump than vegetation. Consequently, ocean primary production provides important background information for estimating anthropogenic emissions, which account for only a fraction of the total CO<sub>2</sub> surface fluxes. Delivering this information supports the Paris Agreement to curtail anthropogenic emissions. Obviously, the case for marine information services is multifaceted and the stakes are extremely high.

Like weather forecasting, these services need to combine observations and modelling. However, observing the ocean is even more challenging, as phenomena on much smaller scales - eddies 10 km in size are the ocean equivalent of mid-latitude storms - need to be sampled with global coverage.

Only satellites can monitor the physical and biological ocean and the atmospheric parameters that drive its variability. The ingestion of their measurements by models, along with in-situ observations, has opened the era of operational oceanography. For this purpose, EUMETSAT operates the Copernicus Sentinel-3 and Jason-3 marine missions on behalf of the EU, in synergy with its own missions, whilst preparing for the deployment of the Sentinel-6 mission.

EUMETSAT's commitment is to deliver an integrated real-time data service to the value chain and to work hand in hand with Mercator Ocean International to offer **the broadest range of opportunities to downstream service providers and users**, in an era of planetary stewardship, requiring that we face the consequences and take responsibility.

**ALAIN RATIER**  
Director-General EUMETSAT





Monitoring coastal ecosystems needs strong cooperation between Copernicus Land and Marine Services.  
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# LAND AND SEA: A UNITED FRONT TO PROTECT THE ENVIRONMENT

Since 1994, the European Environment Agency (EEA) has helped to improve Europe's environment significantly and measurably by providing timely, targeted, relevant and reliable information to policy makers and the public. In cooperation with its European Environment Information and Observation network (Eionet), the EEA collects and collates environmental information from member countries to provide high quality and nationally validated data.

Driven by increasing European policy demands, and covering a broad range of domains which have a direct or indirect impact on the planet's environment and climate, Earth Observation is about to usher in a paradigm shift in the way we monitor the Earth, collect data, produce information and ultimately provide knowledge to support the development of EU policies. The aim of the Copernicus programme is to establish a European capability in Earth Observation, and **to monitor the planet for the benefit of all** European citizens. Vast amounts of satellite data are being used to produce information on our planet's surface, its atmosphere and its climate. The EEA is proud to be a key stakeholder in the Copernicus programme, responsible for implementing the Copernicus Land Monitoring Service (CLMS), and for ensuring cross-service coordination to facilitate the use of in situ data as an essential contribution for calibrating and validating information extracted from satellite monitoring data.

The EEA plays another role in the Copernicus programme, as a major user of the programme's information services. Since it is responsible for land monitoring, the EEA combines Copernicus satellite-based geodata with data collected from the Member States to produce **freely accessible, interactive, thematic maps of Europe** on, for instance: urban sprawl, ecosystems, air quality, water exploitation and many more. In this context, the agency is keen to use, among others, the Copernicus Marine Environment

Service (CMEMS) for its work on a series of indicators and marine assessments in support of marine-related EU policies, including the Marine Strategy Framework Directive and the Integrated Maritime Policy. CMEMS is a major information source that is increasingly used for assessing and monitoring the evolution of natural marine capital. Ultimately, it will be used to assess the capacity of marine ecosystems to supply ecosystem services, and for enabling an ecosystem-based approach for managing and exploiting the ocean. This is critical to ensure the long-term sustainability of the so-called blue economy.

The upcoming phase of the Copernicus programme will offer the opportunity for more cooperation between its information services. Mercator Ocean International and the EEA have already anticipated this by developing a common roadmap for the evolution of marine and land services with respect to the coastal zone. With half of the world population currently living within 60 km of the coast, and three-quarters of all the large cities located along coastlines, the coastal ecosystems are experiencing considerable socio-economic and environmental changes. This is why **CLMS and CMEMS have joined forces** to better monitor and understand these ecosystems, with the ultimate objective of promoting sustainable development in these vulnerable areas.

Recent findings – and their echoes in the press – about the impact of plastics and microplastics on the health of fish stocks, are just one example which highlight the necessity of safeguarding the marine environment for the benefit of generations to come, but also in relation to climate change. Much more needs to be done to raise awareness on the state of our marine ecosystems.

**HANS BRUYNINCKX**  
Executive Director EEA



# THE COPERNICUS MARINE SERVICE: A GREAT CHALLENGE AND OUTSTANDING VALUE TO HUMANITY

The global population continues to increase and consequently needs more food and energy. In this urgent context, humankind is becoming increasingly reliant on the ocean for life support services. Ninety percent of commercial goods are transported around the world by sea. Over the last fifty years, the ocean has stored more than 90% of anthropogenic excess heat as well as approximately 25% of the emitted carbon dioxide. It generates half of the oxygen in the Earth's atmosphere. The ocean helps to strengthen human health and is, furthermore, a source of inspiration. A multi-billion dollar ocean industry generates value on a par with leading national economies and is growing faster and in a more ecologically-sound direction than its land-based counterparts. However, warming, acidification, deoxygenation, pollution, invasive species and habitat destruction, individually and collectively, are rapidly deteriorating the ocean's health. Humankind is running out of time to start managing the ocean sustainably. The 2030 Agenda with 17 Sustainable Development Goals including the Ocean Goal 14, the Paris Agreement and a number of international conventions and protocols provide a framework for protecting the ocean's health. A UN inter-governmental conference is crafting a new, legally-binding regime on conservation and the sustainable use of marine biodiversity beyond areas under national jurisdiction, as an extension of the UN Convention on the Law of the Sea.

The Intergovernmental Oceanographic Commission (IOC) of UNESCO, the only organisation in the UN system that is specialised in ocean research, observations, services and the development of related capacity, is striving to transform oceanography from a purely scientific discipline to an existentially vital and efficient service to humanity and nature. In 2017, based on an IOC proposal, the United Nations General Assembly proclaimed the years 2021-2030 as a UN Decade of Ocean Science

for Sustainable Development. The "ocean-minded" community now has a life-time opportunity to join forces and achieve definitive progress in many areas of research and development including ocean mapping, understanding how ecosystems function and systems for reducing the risk of ocean-related disasters. During the Ocean Science Decade, systems

**“The United Nations General Assembly proclaimed the years 2021-2030 as a UN Decade of Ocean Science for Sustainable Development.”**

for observation and data assimilation, modelling and prediction of the ocean as a part of the Earth system will be further developed, and an unprecedented multidisciplinary data and information portal

will be created. All these resources will enable many different ecosystem-based ways of managing the ocean, including maritime spatial planning, coastal zone management, management of marine protected areas, more effective means of adapting to climate change and mitigating it, as well as systems for managing fisheries and aquaculture. Taken together they will enable much-needed, knowledge-based ocean governance.

The concerted efforts of scientific communities, oceanographic and hydrometeorological agencies, observation satellite operators, governments, the private sector and many other stakeholders are required to design and implement such a solution-oriented system and ensure that it benefits all nations of the world. In this context, the development of the Copernicus Marine Service is a convincing demonstration that key elements of an advanced predictive oceanographic service of the future are already operational. The pioneering effort required to meet this scientific and technological challenge has required talent, persistence, knowledge and resources, but the value of the created service for humanity has, without a doubt, made it worthwhile.

**VLADIMIR RYABININ**

**Executive Secretary, IOC of UNESCO, and  
Assistant-Director-General, UNESCO**



# INCREASING THE SUSTAINABILITY OF THE OCEAN ECONOMY WHILE HARNESSING ITS BENEFITS

The mission of the Organisation for Economic Co-operation and Development (OECD) is to promote policies that will improve the economic and social well-being of people around the world. We work with governments to understand the factors that drive economic, social and environmental change. The “Ocean Economy 2030” report was initiated in 2013 and conducted by the OECD’s Directorate for Science, Technology and Innovation, through extensive collaboration with a range of different OECD directorates. It defined the Ocean Economy as the sum of the economic activities of ocean-based industries, together with the assets, goods and services provided by marine ecosystems. The report, undertaken in 2016, was meant to explore the growing economic potential of the ocean, and highlight at the same time major pressures that needed to be dealt with to preserve the ocean’s health.

Ten ocean industries have been estimated as contributing a total of USD 1.5 trillion in value added in 2010, or approximately 2.5% of world gross value added for all economic sectors. Offshore oil and gas accounted for about one-third of the total value added by the ocean-based industries, followed by maritime and coastal tourism (26%), ports (13%) – measured as total value added for global port throughput – and maritime equipment (11%). Projections suggest a marked acceleration in economic activity in the ocean, estimated at USD 3 trillion in value added by 2030 (roughly equivalent to the size of the German economy in 2010). Employment in ocean industries as a whole may more than double by 2030 to more than 40 million jobs and growth is expected, particularly in marine aquaculture, fish processing, offshore wind and port activities.

The Global Ocean is still under stress from over-exploitation, pollution, declining biodiversity and climate change. By mid-century, the world’s population is likely to be at least 9 billion, with

corresponding demands for food, jobs, energy, raw materials and economic growth. A strategy based on “business-as-usual” expansion of economic activities in the ocean is not an option for the future, as it would further jeopardise the ocean’s health and resources. Developing the full economic potential of the ocean demands ever more responsible and

“Projections suggest a marked acceleration in economic activity in the ocean, estimated at USD 3 trillion in value added by 2030”

sustainable approaches. In this respect, scientific knowledge is crucial for achieving global sustainability and adequate stewardship of the ocean, since it enables us to deepen our understanding and monitor the ocean’s resources and its health, as well as to predict changes in its status. Observed data and

ocean data from the Copernicus Marine Service (satellite and seaborne products, forecasts, long time series, indicators, etc.) are for instance an essential part of worldwide efforts to further our understanding of the ocean and its functioning and also to monitor the development of ocean economic activities and to improve marine spatial planning.

Care needs to be taken to increase the sustainability of the ocean economy while harnessing its benefits. The work programme of the OECD’s Ocean Economy Group therefore aims to provide evidence-based information related to five major topics to support policies for sustainable ocean management. This will include new scientific knowledge and developing technologies, economic measurements and data products to enable ocean industries to plan ahead, knowledge and innovation networks as well as the exploration of new indicators and economic analyses based on ocean observations.

**CLAIRE JOLLY**

Head of the Innovation Policies for Space and Oceans Unit  
OECD Directorate for Science, Technology and Innovation (STI)

*Adapted from The Ocean Economy in 2030, (2016), OECD Publishing, Paris.*

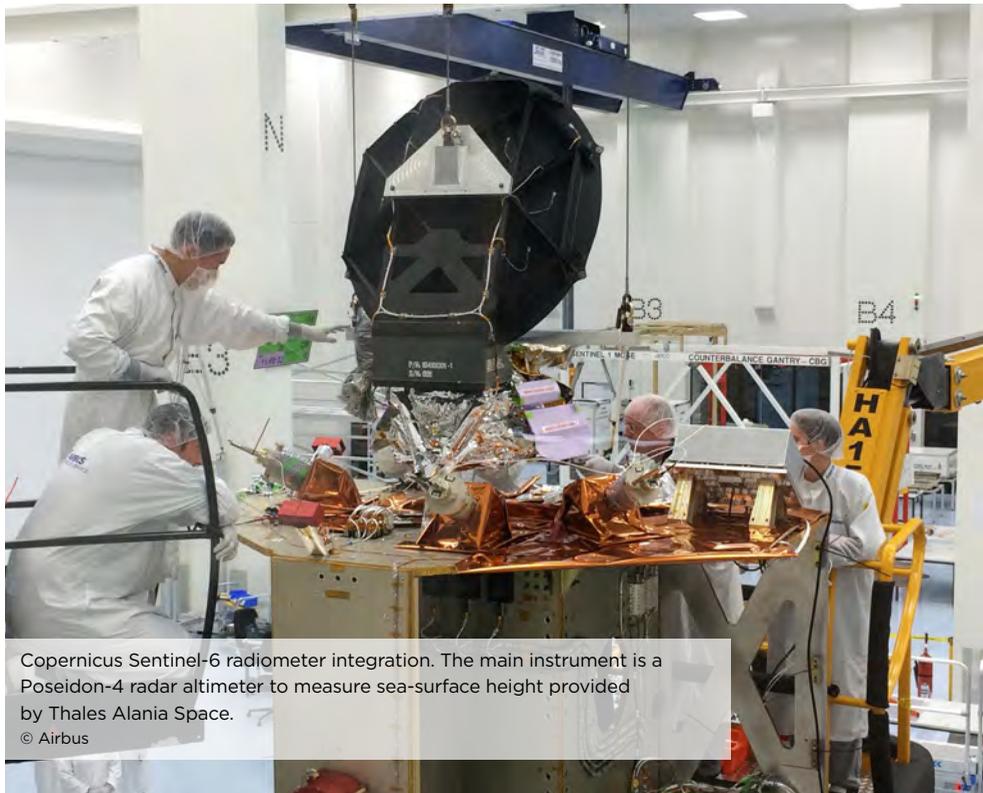
# POLICIES & LEGAL COMMITMENTS FOR A SUSTAINABLE OCEAN

The European Union (EU) is at the forefront of many policies and initiatives that are decisive for the environment, for the economy and for citizens, notably through its commitment to the Copernicus Programme, devoted to supporting policy-makers and through the Copernicus Marine Service, designed to be a real asset for EU policies and initiatives and for underpinning international legal commitments towards a sustainable ocean. The expertise and products of the Copernicus Marine Service bring value to national services and bodies implementing public policies by supplying scientifically assessed, relevant, and free ocean information. The list below is not meant to be exhaustive but rather to illustrate the great diversity and scale of the European Union's and the United Nations' legal frameworks for ensuring a sustainable ocean and for establishing mandatory policies to be applied by experts of the Copernicus Marine Service.

## EUROPEAN COMMISSION INTERNAL MARKET, INDUSTRY, ENTREPRENEURSHIP AND SMES

The EU has conducted three flagship space programmes for many years (Copernicus, Galileo and EGNOS) and is investing more than EUR 12 billion within the 2014-2021 Multiannual Financial Framework. Now that the infrastructure of EU space programmes is well advanced, the focus has shifted to ensuring a strong market uptake of space data

and services by the public and private sectors. EU Space programmes continue to deliver operational services (such as the Copernicus Marine Service) that benefit millions of people. The **EU Space Policy** aims to tackle some of the most pressing contemporary challenges, such as fighting climate change, helping to stimulate technological innovation, creating business opportunities, promoting Europe's leadership in space and maintaining Europe's strategic autonomy while providing socio-economic benefits to citizens.



Copernicus Sentinel-6 radiometer integration. The main instrument is a Poseidon-4 radar altimeter to measure sea-surface height provided by Thales Alenia Space. © Airbus



Oyster culture in Belon, France  
© Peter Gugerell

**EUROPEAN COMMISSION  
MARITIME AFFAIRS**

The **Integrated Maritime Policy** seeks to coordinate policies on specific maritime sectors. It covers, among others, the following cross-cutting policies:

**Blue Growth** is the maritime contribution to achieving the goals of the Europe 2020 strategy for smart, sustainable and inclusive growth. The strategy focuses on 5 sectors that have a high potential for sustainable jobs and growth for Europe: aquaculture, coastal tourism, marine biotechnology, ocean energy and seabed mining. For each of them, the EU set some guidelines to foster the development of the industry with the aim of ensuring a sustainable Blue Economy.

**Marine Data and Knowledge** seeks to bring together marine data from different sources in order to improve our understanding of the ocean, to help industry, public authorities and researchers to make more effective use of data and to develop products and services. The EU data portal *EMODnet* provides access to European marine data and is linked with the Copernicus Marine Service.

**Maritime Spatial Planning** works across borders and sectors to ensure that human activities at sea take place in an efficient, safe and sustainable way. It aims at reducing conflicts between sectors and creating synergism between different activities and also at encouraging investment through early identification of impacts and opportunities for multiple use of space.

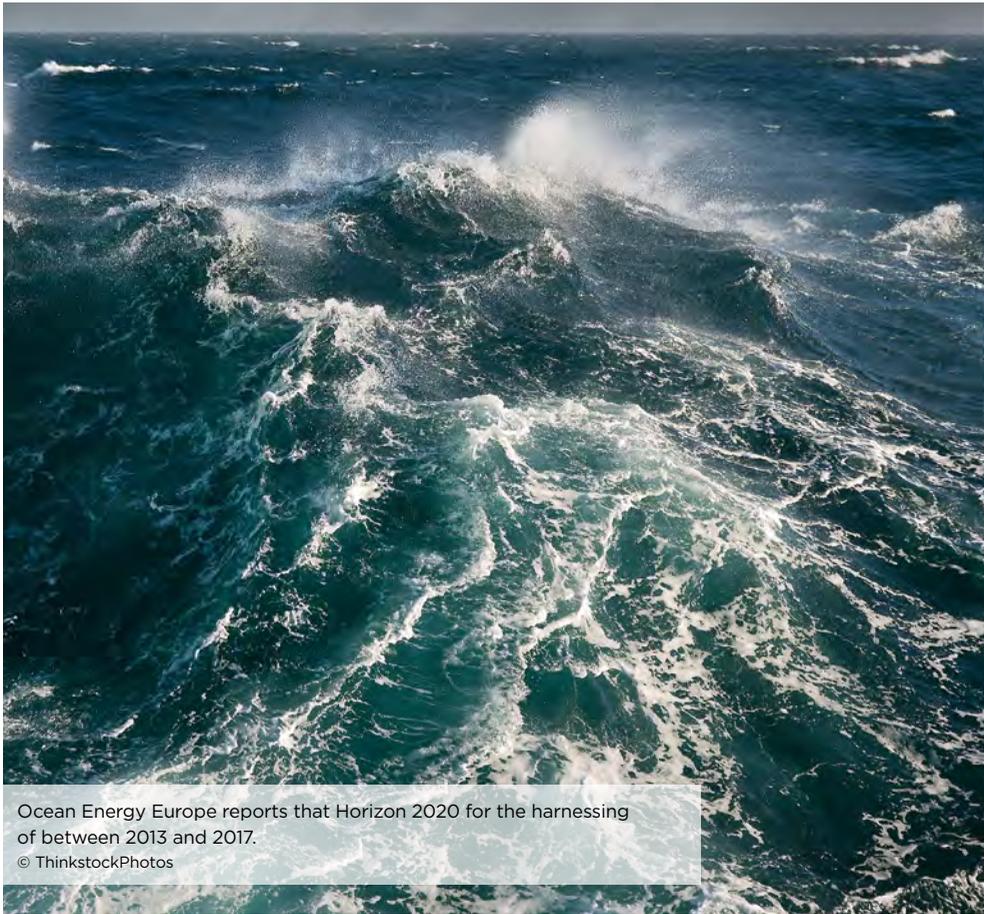
**EUROPEAN COMMISSION  
ENVIRONMENT**

The **Marine Strategy Framework Directive** aims at achieving Good Environmental Status (GES) of the EU’s marine waters by 2020 and at protecting the resource base upon which marine-related economic and social activities depend. It is the first EU legislative instrument for the protection of marine biodiversity. In order to achieve GES by 2020, each Member State is required to develop a Marine Strategy for its marine waters. The Marine Strategies must be kept up-to-date and reviewed every six years.

**The EU Water Framework Directive** aims at achieving good qualitative and quantitative status of all water bodies (including marine waters up to one nautical mile from shore).

**The Bathing Water Directive.** Since the 1970s, the European Union has implemented rules to safeguard public health and clean bathing waters. Members States are required to monitor and assess the bathing water for at least two parameters of harmful bacteria.

**The EU Biodiversity Strategy to 2020** aims at halting the loss of biodiversity and ecosystem services in the European Union. It embodies the EU commitments taken in 2010, within the international Convention on Biological Diversity.



**EUROPEAN COMMISSION  
ENERGY, CLIMATE CHANGE**

**The 2030 Framework for climate and energy** sets EU-wide targets and policy objectives in the framework of Energy Supply in Europe. These targets aim to help the EU achieve a more competitive, secure and sustainable energy system and to meet its long-term 2050 target for greenhouse gas reductions. One of the goals is to achieve at least 32% of renewable energy consumption.

**EU strategy on adaptation to climate change** aims at making Europe more climate-resilient. One of the key adaptation sectors includes coastal areas that are considered to be vulnerable to extreme weather events as well as to coastal degradation and sea level rise.

**EUROPEAN COMMISSION  
RESEARCH & INNOVATION**

**Horizon 2020 (H2020)** is the EU Framework programme in support of Research and Development, securing Europe’s global competitiveness for the purpose of driving economic growth and creating jobs.

By investing in Research and Innovation, Horizon 2020 is helping to foster excellent science and industrial leadership and to tackle societal challenges. The programme promises more breakthroughs, discoveries and world-firsts by taking great ideas from the lab to the market.

**EUROPEAN COMMISSION  
MARITIME AFFAIRS & EXTERNAL  
AFFAIRS**

The **EU Arctic Policy** refers to climate change and the Arctic environment, sustainable development in the Arctic and international cooperation. Understanding the science of climate change, helping to develop strategies to mitigate and adapt to climate change, and safeguarding the Arctic environment are part of the EU's wider efforts in relation to the Arctic.

**International Ocean Governance** sets out an agenda for the future of our ocean,

proposing 50 actions for a safe, secure, clean and sustainably managed ocean in Europe and around the world. International ocean governance involves managing and using the ocean and its resources in ways that keep our ocean healthy, productive, safe, secure and resilient. Today, 60% of the ocean is outside the borders of national jurisdiction. Under the overarching UN Convention on the Law of the Sea (UNCLOS), a plethora of jurisdictional rights, institutions, and specific frameworks have been set up to organise the way humans use these waters. This EU ocean agenda is an integral part of the EU's response to the United Nations' 2030 Agenda.

**UNITED NATIONS' AGENDA 2030  
FOR SUSTAINABLE DEVELOPMENT  
AND SUSTAINABLE GOAL 14**

The 2030 Agenda for Sustainable Development was launched during a UN Summit held in New York from 25 to 27 September 2015 and is aimed at ending poverty in all its forms. The Agenda contains 17 Sustainable Development

Goals and 169 targets balancing the three dimensions of sustainable development: economic, social and environmental. For the first time, there is a specific Goal for ocean conservation and marine life: Sustainable Goal #14 (SDG 14) aiming at conserving and sustainably using the ocean, seas and marine resources with the appointment of a Special Envoy for the Ocean to implement it.



© United Nations



02

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# HEALTHY OCEAN





### KARMENU VELLA

European Commissioner for the Environment,  
Maritime Affairs and Fisheries (2014-2019)

## STRIVING FOR A CLEAN, HEALTHY AND PRODUCTIVE OCEAN

Think of our ocean as our most important organ. You can compare it with a lung, as it ensures that we can all breathe. This is because marine phytoplankton delivers half of the oxygen on Earth. You can also compare it with a heart, pumping the flow of water around the planet, or with a hypothalamus, regulating temperature, or a kidney, taking up much of the pollution.

So, if the ocean does all that, why have we been neglecting its health for so long? The answer is probably because it was so easy to ignore for such a long time.

The ocean has always been “the great blue”: a vast, unpredictable, mysterious mass of water. What happens at sea stays at sea. The near depletion of stocks of popular fish, such as cod in the North Sea or the iconic bluefin tuna, has shown the dangers of that mindset. Images of floating garbage islands the size of France have now made us realise that what is produced on land, often ends up at sea. **The more we know, the better we can manage.**

Dramatic decline of fish stocks has taught us to base our fishery policies on science, not tit-for-tat politics

and the results are encouraging: this year, almost 99% of solely EU-managed landings in the Baltic, North Sea and the Atlantic will be from species that are at sustainable levels. Even the bluefin tuna is recovering – a huge success and proof that international cooperation can work.

With better science, we have also come to realise that despite its mighty size, the ocean is a very fragile environment. For many years, it has absorbed the impact of our bad habits on land. It sequesters CO<sub>2</sub>, slows down global warming, swallows all kinds of pollution...but its capacity to absorb is also its weakness.

The ocean temperature is slowly increasing, acidification levels are rising and even if we were to stop emitting CO<sub>2</sub> entirely, it would still take decades, if not longer, for the ocean to recover. Some of the plastic that we dumped in the ocean fifty years ago will still be there centuries from now, entering our food chain as microplastics.

“The more we know, the better we can manage.”

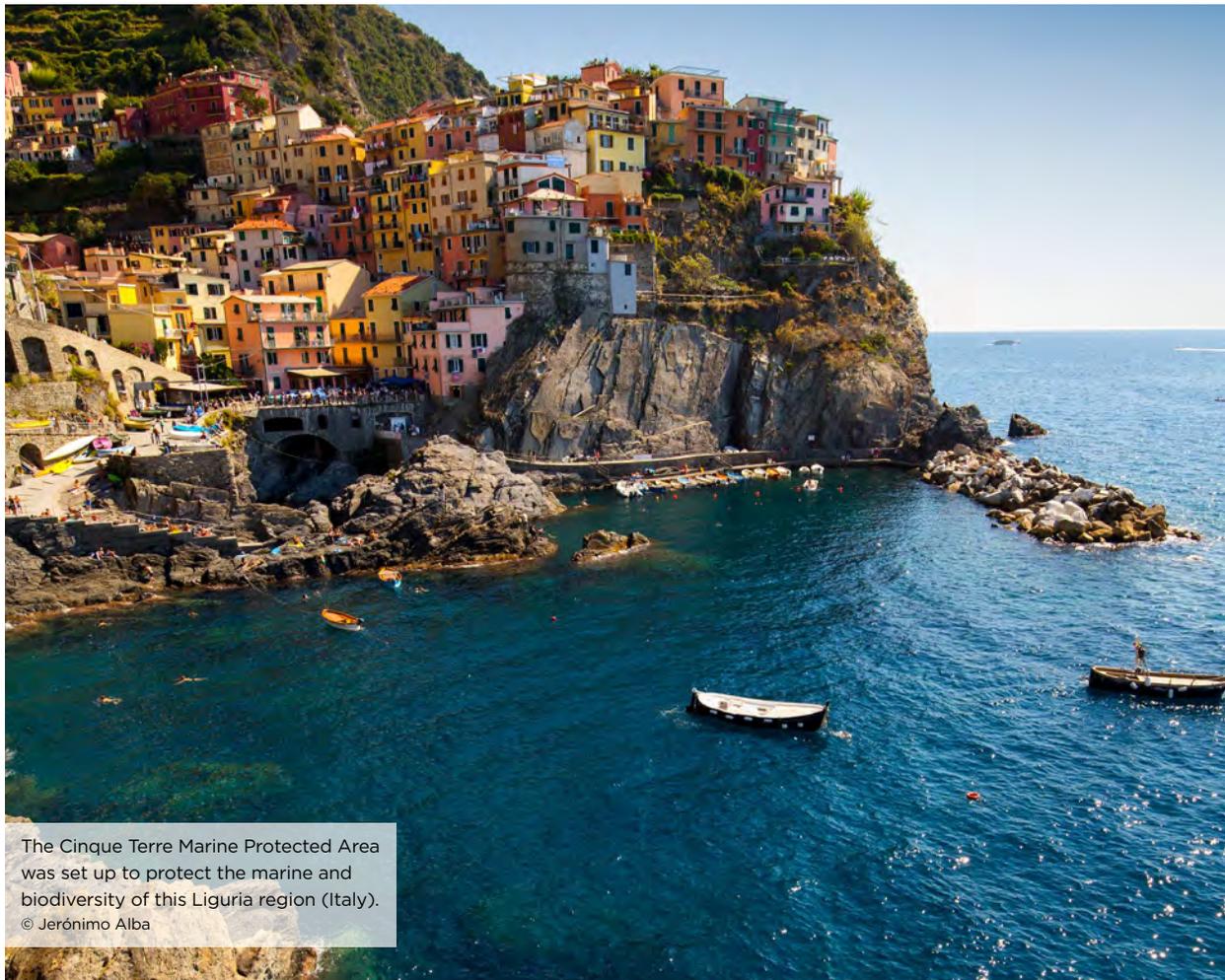
That is why, since the start of my mandate as European Commissioner, I have been striving for a clean, healthy and productive ocean. I believe we have come a long way in those five years.

For example, we have tabled ambitious proposals to restrict many single-use plastic products, especially those found most frequently on European beaches. Our legally-binding recycling targets make the EU the frontrunner of the circular economy. We have designated more than 10% of our marine and coastal areas as Marine Protected Areas, two years before the international deadline of 2020. And we have made great strides in fighting illegal fishing worldwide by using our market power as the largest global importer of fishery products.

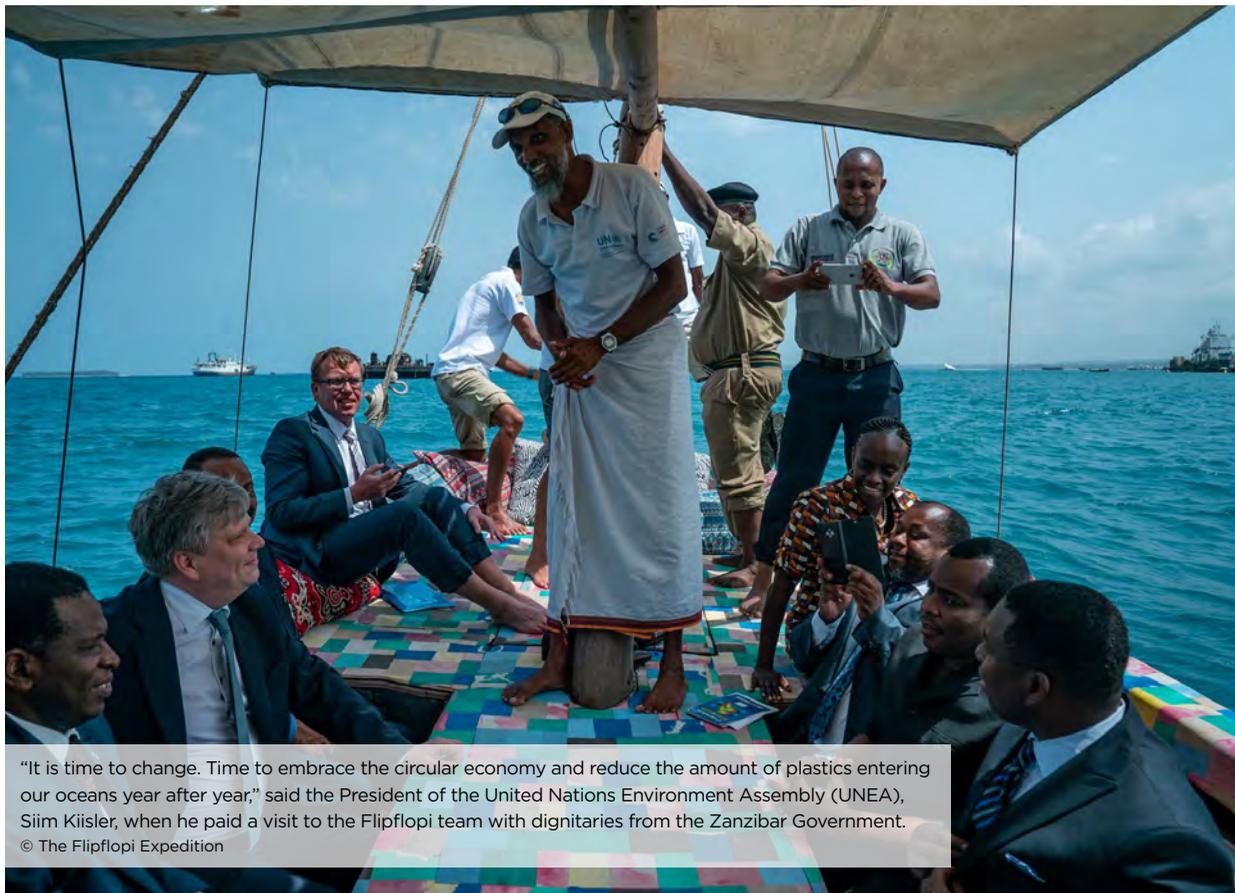
On the business side, **we have continued to support traditional activities such as fisheries and aquaculture, while putting emerging blue economy sectors firmly on the map.** Ocean energy has received substantial EU funding for research and testing, and is rapidly moving towards commercialisation. Innovative maritime businesses can benefit from our local matchmaking

events with investors, or from the blue investment platform that we plan to launch later this year. Finally, for the first time ever, we have implemented a holistic approach to international governance of our ocean. In doing so, we have strengthened the European Union's reputation as a reliable global partner, a strong supporter of marine research, and a top provider of aid and technical assistance for sustainable ocean action and economic growth.

**Sound ocean analysis and forecasting has been indispensable for all of this,** and the contribution of the Copernicus Marine Service has been extremely valuable. It allows us to manage complex issues and guides us towards sustainable, effective policy solutions for protecting and preserving our rich natural environment and the astonishing biodiversity of our seas and coastlines, while creating new economic opportunities for the future. I would like to thank Mercator Ocean International and the Copernicus Marine Service for their outstanding support and trust that they will continue to support the fight for a healthy ocean, and a healthy planet in the future.



The Cinque Terre Marine Protected Area was set up to protect the marine and biodiversity of this Liguria region (Italy).  
© Jerónimo Alba



“It is time to change. Time to embrace the circular economy and reduce the amount of plastics entering our oceans year after year,” said the President of the United Nations Environment Assembly (UNEA), Siiim Kiisler, when he paid a visit to the Flipflopi team with dignitaries from the Zanzibar Government.  
© The Flipflopi Expedition



## AFRICAN PLASTIC REVOLUTION

Two years ago, having seen the shocking quantities of “takataka” (garbage in Swahili) on Kenyan towns and beaches, a team of volunteers thought that instead of throwing it away, it would be better to upcycle the wastes into something valuable. The Flipflopi Project was born, kick-starting a plastic revolution from Africa.

“We wanted to find a positive African solution to the global problem, so we decided to build the world’s first sailing boat made from 100% waste-plastic, covered in 30,000 colourful flip-flops” tells Dipesh Pabari, who founded the project along with Ben Morison and Ali Skanda. This traditional dhow is one of the oldest forms of transport enabling people to communicate across the Indian Ocean. “Flipflopi is a message

*of hope - as we have just seen on our first expedition, she brings smiles to everyone she meets and inspires change”.*

Flipflopi has drawn the world’s attention to this vital sustainable ocean issue. “Without urgent and serious action, our children’s world will be destroyed. But we are optimistic things can change in our lifetime”. Their next goal is to build a bigger boat and sail around the world to engage more key people in the plastic revolution. “And we’ll ask them, if we can build a boat with waste plastic, what else can be done?” say the Project Founders.

**THE FLIPFLOPI  
PROJECT**

# THE OCEAN & HUMANS: ONE BUT MANY

The ocean has long been considered one of the most resilient and fascinating spaces on Earth, stimulating our thirst for adventure and nourishing our spirituality. Indeed, it plays a key role in our well-being and health, being — together with forests — the very lungs of our planet, enabling us to breathe quality air and regulating the impact of climate change. It also provides us with an essential and free source of nutrients and energy, and has helped countless humans through the centuries to fight off starvation and develop economic and social activities.

Even nowadays, we are still learning about the ocean. Indeed, 95% of it is still unexplored, and new organisms are regularly being discovered, inspiring hope for new medicines and applications in our lives.

“Humans have developed activities and practices that are harmful to the marine environment.”

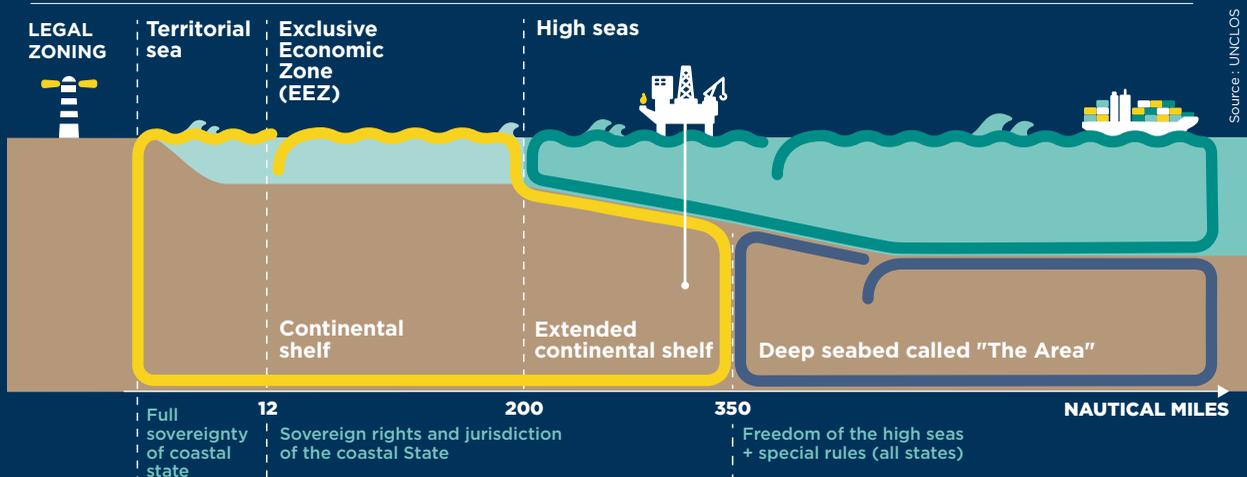
Despite this bond of survival, **humans have developed activities and practices that are harmful to the marine environment.** Amongst others, there is the past immersion of chemical ammunitions that are still leaking today, the release of waste into the planet’s seas, overfishing or air pollution, all of which are causing damage to both the ocean and humankind (e.g. depletion of fish stocks, acidification, development of diseases, conflicts and the migration of populations). These harmful practices are mainly due to our strategies of exploitation, production and consumption, which — through a ricochet effect — are damaging our well-being, health and ability to enjoy the direct and indirect services provided by the ocean (e.g. materials, resources, ecosystem functions and cultural services). The exact impact on our health is still unknown, but a number of key ocean actors, such as the European Union, are supporting research to inform future policies.

States have been working hard throughout the years to deploy frameworks to protect the marine environment. From the Helsinki Convention to the “Constitution for the Oceans” of 1982, principles of cooperation, precaution, protection and preservation have been created and are still being strengthened today (e.g. the United Nations’ ongoing negotiations on the conservation and sustainable use of marine biological biodiversity and its declaration of the 2021-2030 period as the decade of Ocean Science and Restoration of Ecosystems). These agreements and initiatives provide many efficient tools, but — despite the leadership of some — **the lack of political will to fully implement them remains the main obstacle to the effective protection of our ocean and human health.**

So what has changed? The will of each and every one of us to play our part. Since the 1970s, NGOs have become powerful actors, pushing states to strengthen their commitments. Another revolution occurred in 2015 with the recognition of the role of private individuals and actors such as enterprises or foundations to implement sustainable (ocean) development initiatives (Agenda 2030). By multiplying actors, actions and ideas are diversified, thus offering new perspectives. Today’s youth should not be forgotten. Unable to elect their political representatives, they are not able to identify with current governments. As one international society, what guarantees are we seriously offering to ensure that we take into consideration their present and future interests?

**VIRGINIE TASSIN CAMPANELLA**  
 Avocat à la Cour (Paris Bar)  
 Director & Founder of VTA Tassin

## MARITIME ZONES AND ACTORS UNDER THE UNITED NATIONS CONVENTION ON THE LAW OF THE SEA (UNCLOS)





*The Prince Albert II of Monaco Foundation is dedicated to the protection of the environment and the promotion of sustainable development on a global scale. Concerning the ocean, it follows the wish of the founder of the Oceanographic Institute, Prince Albert I of Monaco: “knowing, loving and protecting the ocean”.*



© Gaetan LUCI - Palais Princier

## CONVINCING THE WORLD

From pollution to climate change, from overfishing to unreasonable exploitation of the ocean’s floor, the ocean is a victim of our irresponsibility. **For a long time, we preferred to consider it as inexhaustible and unalterable.** But for several decades now, I have heard reports from around the world, of increasing alerts, anxiety and even despair.

Fortunately, I am also meeting more and more stakeholders that are committed to a new relationship with the environment, from the creation of marine protected areas to initiatives for promoting the circular economy. That is why I am supporting them, by all the means at my disposal.

Whether as Head of State or as head of my Foundation, my work is closely linked to that of other actors. Among them, scientists and entrepreneurs play an essential role. Scientists are needed because no coherent strategy can be implemented without first understanding the phenomena at play. And entrepreneurs are needed, because States cannot accomplish the necessary change of paradigm on their own today.

Consequently, **any coherent and effective action to protect the ocean must be coordinated** to take into account these two levels and their respective stakeholders.

Action that must offer the latter the conditions to enable them to deploy their projects, to work together and to convince the world.

Mercator Ocean International’s contribution, through the Copernicus Marine Service set up by the European Union, is crucial to enable them to coordinate and act.

But change will only take place quickly and thoroughly enough if it has widespread public support. We must therefore now inform as many people as possible of the real state of the ocean, show that there are solutions and that we can implement them together. In particular by encouraging individuals, and in particular the youngest ones to get involved and by empowering them. This is the meaning of my commitment and that of my Foundation.

I hope that the future developments of the Copernicus Marine Service will also contribute to meeting this challenge, because a blue economy that respects Nature and benefits humanity will only prosper if it is based on a strengthened ocean culture.

“For a long time, we preferred to consider the ocean as inexhaustible and unalterable”

**HIS SERENE HIGHNESS  
PRINCE ALBERT II**





# THE OCEAN IS SUBJECT TO GROWING AND WORRISOME POLLUTION PRESSURE

## OIL TANKER DISASTERS

2019 FRENCH ATLANTIC COAST  
*GRANDE AMERICA*

2,200 tonnes of HFO  
(fluorinated gases) and oil



2018 EAST CHINA SEA,  
COLLISION BETWEEN *MT SANCHI*  
AND *MV CF CRYSTAL*

116,000 tonnes  
Largest amount of oil spilt  
recorded since 24 years

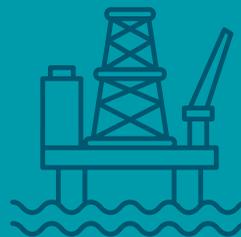
<https://www.itopf.org/knowledge-resources/data-statistics/statistics/>

## OIL RIG

2010 GULF OF MEXICO,  
BP'S OIL RIG *DEEPWATER HORIZON* EXPLOSION

550,000 tonnes

US Environmental Protection Agency



## HARMFUL ALGAE BLOOMS

EU ANNUAL COST IN TOURISM  
AND FISHING INDUSTRIES

918 million €

<https://wwz.ifremer.fr/en/Latest-news/EU-project-to-monitor-Harmful-Algal-Blooms-from-space>



580 million €

Global treatment costs due  
to algal blooms every year

## YEARLY DEATHS DUE TO PLASTIC DEBRIS

100,000,000  
sea birds

100,000  
marine mammals



## PLASTICS

80% of all litter in our  
ocean is made of plastics

8 million  
metric tonnes each year



United Nations, 2017, The Ocean Conference,  
[https://sustainabledevelopment.un.org/content/documents/Ocean\\_Factsheet\\_Pollution.pdf](https://sustainabledevelopment.un.org/content/documents/Ocean_Factsheet_Pollution.pdf)



Workers cleaning up a beach during the *Deepwater Horizon* event  
 © National Institute for Occupational Safety and Health (NIOSH)

# INTRODUCTION

The ocean’s overall health is crucial as it directly affects the marine and coastal ecosystems (providing a habitat for fish, shellfish, and birds to name a few) and the health of people consuming sea products or living near the coasts. The ocean’s health is threatened by many types of anthropic pollution and pressures. This section describes the role of the Copernicus Marine Service products in pollution mitigation operations and monitoring of environmental parameters for policy and regulatory purposes.

Pollution threatening global biodiversity comes from different sources, either natural or from anthropic activities. The pollution mitigation operations analysed in this chapter cover oil and plastic pollution, which are some of the major human activities affecting our ocean.

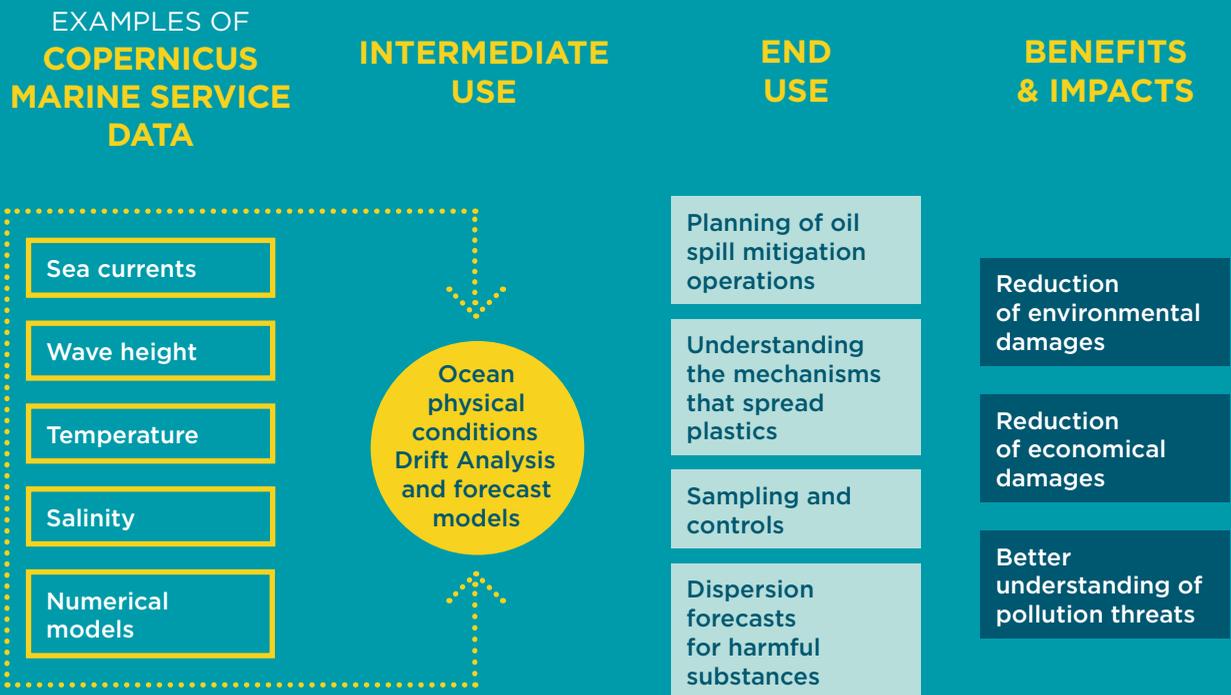
“A staggering 8 million tonnes of plastic end up in the

world’s oceans every year and if current trends continue, our oceans could contain more plastic than fish by 2050” reports the United Nations Environment Programme (UNEP).

Harmful Algal Blooms (HAB) generally caused by an excess of nutrients such as phosphorus and nitrogen, contain organisms that can severely lower oxygen levels in natural waters, thus killing marine life. Their presence seems to have increased in the past decades. Although bloom dynamics are still not completely understood, it is known that they can be fostered by human activities, environmental factors and most probably by climate change. This threat to the marine environment is addressed.

Whatever the pollution sources, they all lead to unrivalled environmental, health and economic consequences.

# COMBAT AGAINST POLLUTION



Although the statistics for spills of more than 7 tonnes from oil tankers show a clear downward trend for almost 50 years (24.5 spills per year on average from 1970 to 1979 vs 1.8 spills per year from 2010 to 2017), the total volume of oil lost to the environment was approximately 7,000 tonnes in 2017, of which one major spill accounted for more than 700 tonnes. This downward trend was unfortunately reversed in 2018 with approximately 116,000 tonnes of oil lost to the environment, mostly due to an incident in the East China Sea. This annual amount is the largest recorded in 24 years.

In addition to the destruction of ecosystems, which far outweigh any economic rationale, oil spill events have incurred corresponding economic damages. To illustrate this, the ultimate cost of the 500 to 600 KT oil spill caused by the *Deep Sea Horizon* is estimated at \$145 billion.

The annual pollution and environmental damage from plastic waste to marine ecosystems has been evaluated at €11.6 billion.

When assisting emergency teams responding to offshore marine oil spills, government agencies either use numerical-simulation software, called oil spill drift-forecast models, that are able to predict the potential oil spread or call on service providers who do. The Copernicus Marine Service provides ocean current forecasts which in turn enable forecasting the drift of the oil spread and thus better planning of the emergency response. Copernicus Marine Service ocean currents data also help locate potential polluters: by simulating backwards from the point source of the pollution and the moment the spill started, drift models can “backtrack” oil spills.



On 12<sup>th</sup> March 2019, the *Grande America* cargo ship caught fire and sank in the Bay of Biscay off the coast of France. The ship was carrying 2,200 tonnes of heavy fuel, and over 300 shipping containers. The French weather forecasting organisation, Météo France, has national and international responsibilities to respond to marine oil pollution, along with other organisations. To meet its commitments, Météo France had developed MOTHY, a pollutant drift model, to forecast the trajectory of oil spills being pushed by local winds and ocean currents. The outputs are then analysed and communicated to the relevant national and regional authorities.

**“ The MOTHY system is activated about 20 times a week for spills and for search and rescue operations. For *Grande America*, we used ocean currents from the Copernicus Marine Global Ocean Forecast Model in our drift model, which enabled us to forecast the potential trajectory of the oil spill and estimate the ensuing consequences hours and days in advance.”** ☞

Riskaware, an independent organisation developing specialised software solutions, has developed an oil spill dispersion model to help the Malaysian government tackle marine pollution.

**“ Pollution from oil spills is a major issue for the Malaysian government, which is responsible for monitoring and policing the Malacca Straits, one of the busiest shipping lanes in the world. Our model supports decision-makers by predicting the areas which will be affected when an oil spill is reported. The model also simulates mitigation strategies to assess the best course of action, and can estimate the probable point source to help identify polluter ships. Our model is connected directly to the Copernicus Marine Service and automatically uses the best available forecast data.”** ☞

Marine pollutants and debris drifting around the Global Ocean and regional seas are unfortunately incredibly diverse. Many agencies, coast guards and research organisations rely on Copernicus Marine Service’s free and up-to-date forecasts of currents to feed their drift models with accurate data. This was

the case for monitoring potential oil spills from the cruise ship *Costa Concordia*, which ran aground off the Italian coast and also for backtracking debris of Malaysia Airlines Flight MH370, which vanished over the South Indian Ocean.

Plastic pollution in the Mediterranean Sea poses considerable risks to ecosystems and human health, causing adverse economic impacts on coastal communities. The Euro-Mediterranean Centre on Climate Change (CMCC), a non-profit research institution which models our climate system, has led a four-year project to establish the very first basin-scale vision of plastics, on the sea surface, along the coastlines and on the seabed. An ensemble of more than 10 billion virtual particles has been tracked to understand the transport and fate of plastic marine debris in the Mediterranean Sea, embracing its three environmental compartments: sea surface, coastlines, and sea bottom.

**“ We used the high-resolution Copernicus Marine Service model of the Mediterranean Sea for the period 2013 to 2017. Terrestrial plastics, from human populations along the coasts and rivers, reside on the sea surface for 7 days, while plastics from shipping lanes have a mean residence time of 80 days. The coastlines with the highest plastic flows include the Cilician sub-basin (Turkey), the Catalan Sea (Spain), Israel and the Po River Delta area (Italy).”** ☞

The Marine Biology Station (MBS) in Piran, part of the Slovenian National Institute of Biology (NIB) is working to improve our understanding of Adriatic Sea circulation. Major rivers, such as the Po, end up in the Adriatic and many cities are located along its coastline, hence the strong need to better understand pollutant dispersion in this area.

**“ Our Copernicus Marine Service-based models analyse dispersion of toxic mercury in the Gulf of Trieste. As a consequence of mercury mining in Idrija (even though the mine has been closed for years), hundreds of kilos of mercury are estimated to enter the Gulf of Trieste each year through the Isonzo river. Numerical models for mercury dispersion give researchers and decision makers reliable information on which to build sensible environmental policies.”** ☞

# FOCUS ON THE EUROPEAN UNION'S MARITIME STRATEGY FRAMEWORK DIRECTIVE (MSFD)

The main goal of the Marine Directive is to achieve a Good Environmental Status of EU marine waters by 2020. The Directive defines Good Environmental Status (GES) as: "The environmental status of marine waters where these provide ecologically diverse and dynamic oceans and seas which are clean, healthy and productive" (Article 3).

The MSFD is built around the eleven descriptors below, on which the levels and trends are to be reported every 6 years by Member States.

The Copernicus Marine Service contributes at various levels. Some descriptors can already be characterised – at least partially – or built thanks to Copernicus Marine Service inputs, such as for descriptors 5, 6, 7, 8, 10 and 11. The European Commission's Joint Research Center (JRC) has created an MSFD Competence Centre intended to provide Member States with research and scientific support for the implementation of the MSFD in which the Copernicus Marine Service is referenced.



For example, Copernicus Marine Service products such as ocean colour, chlorophyll-a concentration and sea surface temperature data are used to analyse the eutrophication level for Descriptor 5, and the chlorophyll-a concentration and biogeochemical composition of water can be exploited to report on the levels of some contaminants for descriptor 8. For a few years, the implementation of MSFD by national authorities has been supported by many Copernicus Marine Service-based initiatives and portals. Here are a few examples:

**European seabed habitat maps** are produced by EMODNET, the European Marine Observation and Data Network supported by the EU integrated maritime policy. The maps help Member States fulfil their MSFD obligations, for which full coverage of benthic broad-scale habitats of all European seas is required. The maps use Copernicus Marine Service currents reanalysis over the last 20 years in the Mediterranean and Black Sea.

**WISE-Marine** is a portal and infrastructure for sharing

information with the marine community on the marine environment at the European level. The Copernicus Marine Service satellite data on global monthly ocean colour (chlorophyll-a) or other parameters such as salinity fields extracted from the Global Ocean model are displayed in the WISE-Marine map viewer. This is developed in a partnership of Commission-run departments (DG-ENV, DG-JRC), the European Environment Agency (EEA) and Eurostat.

**The iFADO project** developed by MARETEC, a multi-disciplinary research centre within the Instituto Superior Técnico (IST) in Portugal aims to create marine services for the MSFD at regional and sub-regional scales in the EU Atlantic Waters. The service uses Copernicus Marine Service forecasts for the Iberia Biscay Irish Sea (IBI).

**MSFD-Eutro** is a free and interactive web-mapping service for the chlorophyll-a indicator, developed by DELTARES, the Dutch independent institute for applied research. MSFD-Eutro facilitates the use and interpretation of ocean colour data for public authorities working on the MSFD.

## USE CASES

### OIL POLLUTION COMBAT

About 20% of the shipping in the Baltic Sea consists of tankers that are mainly medium-sized, ferrying petroleum products from Rotterdam to local ports, which means that small-scale spills occur regularly, 5 to 10 times a year on average.

The University of Latvia hosts operational services that reduce such risks. Its Laboratory for Mathematical Modelling of Environmental and Technological Processes (VTPMML) has developed an information system called “FiMar” which provides marine visualisation and decision support tools for the Baltic Sea and the North Sea. This online platform based on Copernicus Marine Service data is used, among others, by the Latvian Coast Guard and the Marine Rescue coordination centre at Riga. The Coast Guard uses FiMar for resource warnings, tracking oil spills and mitigation plans. The reliability and the sustainability of the Copernicus Marine Service help FiMar to reduce all kinds of regional risks at sea and also to develop new services in Northern Seas that they could not provide before.



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### PLASTIC POLLUTION COMBAT

The Euro-Mediterranean Center on Climate Change (CMCC) is an Italian non-profit research institution whose scientists investigate and model our climate system and its interactions with society and the environment. Their mission is to provide reliable scientific results to support sustainable growth, environmental protection and the development of science-driven policies.

In the framework of the AMAR project (Actions for Marine Protected Areas), CMCC studied the drift of plastic debris in the Mediterranean Sea with the aim of finding solutions to this key issue. The first step involves tracking plastics in the ocean to determine where they are coming from, when the pollution began and its extent. In their study, CMCC combined information about the sources of the plastic with its transport mechanisms, as waves and currents determine the trajectory of plastic in the sea. These data are provided by the Copernicus Marine Service and enable scientists to investigate this important environmental issue on a global scale. Along with this study, CMCC is also involved in raising awareness for reducing the input of plastic in the ocean.



© NIMRD

## BATHING WATER QUALITY MONITORING

The Romanian National Institute for Marine Research and Development (NIMRD) undertakes scientific research to understand, protect and preserve the Romanian Black Sea marine and coastal environment. In collaboration with ACTION Modulers, a Portuguese-based private company specialised in numerical modelling and software development, they produced a portal called “iSWIM”.

iSWIM is a free-access, dedicated system for the monitoring and forecasting of bathing water quality in Mamaia Bay, which has one of the biggest tourist resorts in Romania. Thanks to this mobile-friendly web page, the general public, foreign tourists, aquatic sport enthusiasts and also national service operators have easy access to coastal maps and charts providing 3-day forecasts of marine weather conditions, including surface currents, waves and wind. iSWIM is based on Black Sea models provided by the Copernicus Marine Service.

## WATER QUALITY MONITORING

Based in Trieste (in the North-East of Italy), the National Institute of Oceanography and Applied Geophysics (OGS) is a public research institute that produces, disseminates and applies knowledge in the fields of oceanography, geophysics and seismology.

OGS has developed a data portal called “Mediterranean Ecosystem Analysis and Forecast” (MedEAF) for policymakers, public authorities and private stakeholders who need reliable information on the Mediterranean Sea. Using Copernicus Marine Service data, the portal offers quantitative assessments of the current status and recent trends as well as short term forecasts of several ocean variables for the Mediterranean Sea (currents, temperature, salinity, phosphate, oxygen and chlorophyll-a content in seawater, with more variables to come fairly soon), with a downscaled focus on the Northern Adriatic. This free service helps users in the public and private sectors to develop applications or to comply with specific legislation and policies for environmental and civil protection, management of urban areas, fishery governance, human health, maritime transport, sustainable development and tourism.



© Jean-Dominique Dallet



## AMBASSADOR PETER THOMSON

United Nations Secretary-General's Special Envoy for the Ocean

# A PLAN TO REMEDY THE OCEAN'S AILMENTS

The ocean's health is in jeopardy. Largely as a result of anthropogenic greenhouse gas emissions, fundamental elements are undergoing unprecedented change. The ocean is becoming steadily more acidic, making life difficult for creatures such as shellfish which depend on calcium carbonate for their existence. It is also becoming increasingly warm, making it untenable for many creatures to live in their traditional habitats and causing its surface level to rise. Meanwhile the oxygen concentration in the ocean is falling, with further negative consequences for marine life.

Apart from greenhouse gas emissions, **the ocean's health is under intense pressure from two other anthropogenic forces: harmful fishery practices and pollution.** Our fishery practices have led to 33% of world fish being driven towards extinction,

with the balance being fished to maximum sustainable limits. It is deeply disturbing to consider that while the Earth's fish resources are in danger of disappearing entirely, the world continues to subsidise fishing fleets, of which there are obviously too many, to the tune of \$23 billion, while we blithely accept \$20 billion worth of illegally caught fish upon our plates every year.

Plastic pollution, most of which ends up in the ocean, is now globally recognised as a travesty due to irresponsible human behaviour, with the almost invisible permeation of plastic microfibres having as yet unknown consequences for humanity's well-being. Meanwhile other forms of pollution and toxicity, the detritus of our streets, industries and raw sewage are channelled by rivers and urban drainage systems into our coastal ecosystems, joined by excess fertilisers from

our agricultural systems, that flow down to our coasts to cause life-sapping eutrophication and algae blooms.

This long-standing disrespect for the health of the ocean is all the more perplexing when one considers that it puts our own health in jeopardy. After all, every second breath we take comes from oxygen produced by the ocean. Nor should we forget that healthy marine ecosystems are essential for all dimensions of sustainable development. The ocean is an immense source of sustenance and livelihood, enabling the eradication of poverty, food security, employment, tourism and protection from natural disasters, while through their carbon reservoir services, the ocean and its coastal ecosystems counteract the impact of climate change.

**We have a plan to remedy the ocean's ailments: the UN's Sustainable Development Goal 14 (SDG14).** Like the other SDGs, this so-called Ocean Goal was overwhelmingly adopted by all 193 Member States of the United Nations in September 2015. We are thus all committed to this universal goal to conserve and use the resources of the ocean in a sustainable way. The goal includes ten targets, four of which are to be achieved by 2020, namely: the reserving of 10% of the ocean for marine protected areas, the elimination of subsidies for harmful fisheries, the ending of illegal and destructive fishing and the sustainable management of marine and coastal ecosystems.

I firmly believe that faithful implementation of SDG14's targets will reverse the cycle of decline into which accumulated human activities have placed the ocean's health. For example, as a result of determined efforts around the world, we now have 7.59% of the ocean covered by marine protected areas, with our sights firmly set on 10% by 2020.

Similarly, if as hoped, the members of the World Trade Organisation reach agreement on eliminating harmful-fishery subsidies before the end of 2019, we expect to see a definitive end to them in 2020.

Partnerships will be central to all good efforts for achieving SDG14. Joining with UN Member States and the United Nations System, we have, with no further delay, to ensure that non-governmental organisations, the private sector, the scientific community and philanthropic organisations forge partnerships to take the necessary measures. **No one party can succeed on its own, for SDG14 is a universal responsibility and the ocean is the common heritage of mankind.**

It has been very encouraging to see the spread of ocean action initiatives around the world in the years since the 2017 UN Ocean Conference and to witness the formation of an impressive array of multi-stakeholder partnerships and more than 1,500 voluntary commitments to implement SDG14.

A particularly noteworthy example was the Global Sustainable Blue Economy Conference, convened by the Government of Kenya and co-hosted by the Governments of Canada and Japan, in Nairobi in November 2018. It resulted in voluntary commitments amounting to about \$172 billion in the various sectors of the sustainable blue economy, pulling in the private sector, the scientific community, and youth. Now preparations are underway for the 2020 UN Ocean Conference, to be held in Lisbon, from 2 to 6 June next year, with every hope that it too will be a global game-changer towards our universal aim of implementing SDG14 in its entirety by 2030.

“No one party can succeed on its own”



03

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# SAFE OCEAN





### MAJA MARKOVČIĆ KOSTELAC

Executive Director, EMSA  
Copernicus Maritime Surveillance Service

## EUROPEAN SURVEILLANCE OF SAFETY AT SEA

The EU maritime sector has an estimated value of €500 billion; it provides jobs for approximately five million people and more than 90% of EU external trade. It is of paramount importance to improve the safety of our ocean since 37% of the intra-EU trade is conveyed by ship and since in 2018 alone there were over 3,500 marine casualties and incidents, according to data from the European Marine Casualty Information Platform (EMCIP: a centralised database managed by EMSA to enable EU Member States to store and analyse information).

The European Maritime Safety Agency (EMSA) is a regulatory EU agency that was founded in 2002, in the wake of major disasters in European waters, such as the shipwrecks of the oil tankers Erika and Prestige. An important role of the agency is to facilitate technical cooperation between Member States and the

European Commission for vessel traffic monitoring and maritime surveillance based mainly on satellites.

For this purpose, EMSA has developed a set of systems and applications that enable the delivery of a wide range of tailor-made maritime data, to meet specific user-needs. These services integrate maritime information and have many applications, one of the most critical being support for safety operations at sea. Indeed, The Copernicus Maritime Surveillance Service is part of the integrated services delivered by EMSA. It

provides Earth Observation products (radar, optical satellite images and value-added products) on request and in a very short time to support a wide range of operations such as maritime safety and security, fisheries control, customs, law enforcement, marine pollution monitoring and support for international organisations, amongst others.

“It is of paramount importance to improve the safety of our ocean since 37% of the intra-EU trade is conveyed by ship ”

**The Copernicus Maritime Surveillance Service is frequently used specifically for navigation safety, as well as for search and rescue purposes. Here are a few examples:**

- **Monitoring vessel collisions:**

Following a collision between two vessels north of Corsica, the Copernicus Maritime Surveillance Service provided an optical image of the scene of the collision at the request of French authorities.

- **Locating vessels posing a threat to navigation:**

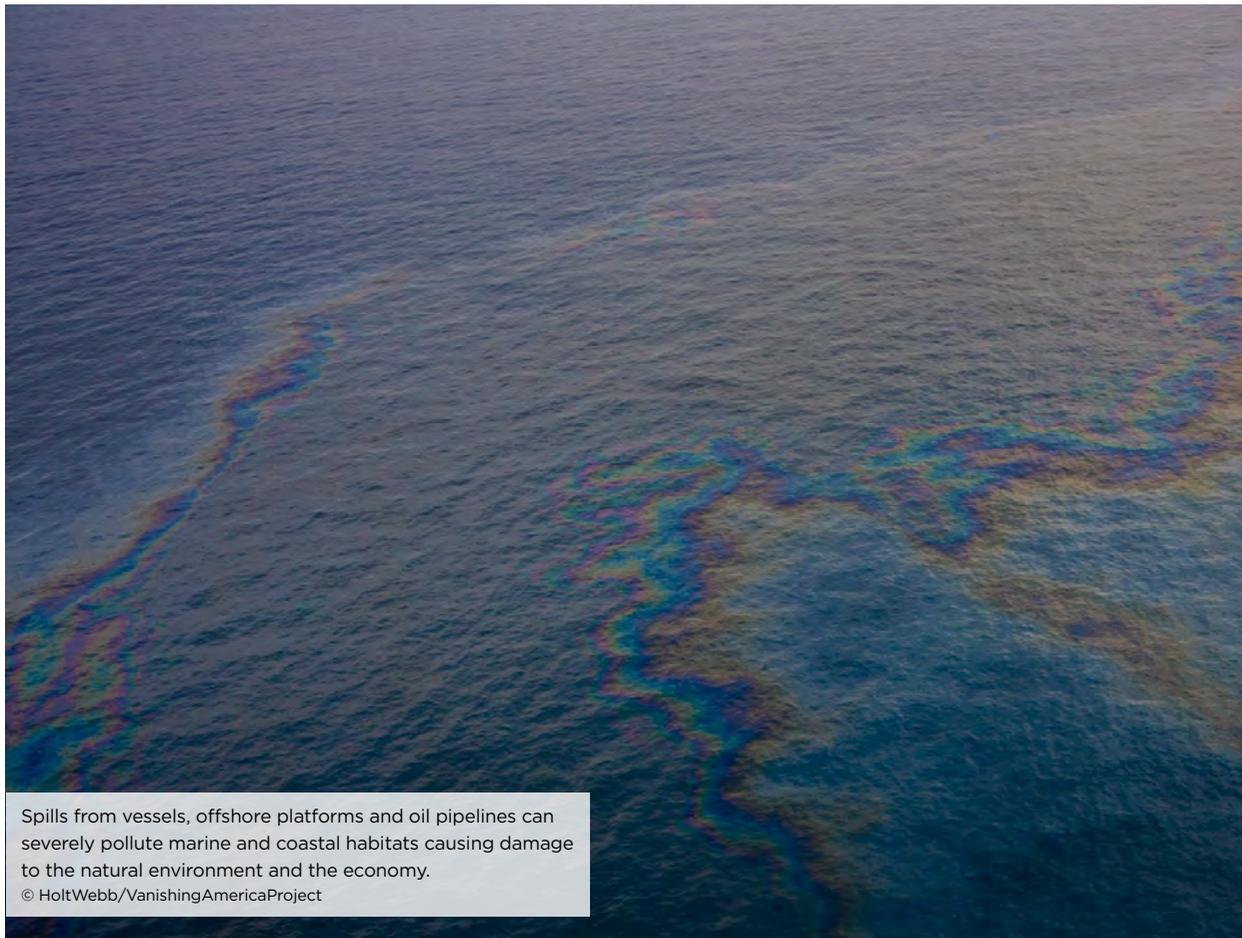
A national authority used the service to locate a drifting Taiwanese fishing vessel which had suffered fire damage near Reunion Island (Indian Ocean).

- **Search and rescue:**

Support has been provided to Croatia, Cyprus, Iceland and Portugal for search and rescue operations. These build capacity at the national level to enable prompt responses to accidents at sea, including training on how to use satellite images to detect objects such as life rafts on the sea surface.

In remote areas or in poor weather conditions, satellite-based products are a crucial support for operation and monitoring. Radar is frequently used to detect vessels and other targets at sea, while very high-resolution optical images can be used to identify specific ships and activities. Vessel location and course information combined with satellite images as well as forecasts a few days ahead, obtained thanks to oceanic models, are a very powerful tool for monitoring maritime traffic. To do so, **EMSA uses remote-sensing data and modelling products from the Copernicus Marine Service such as Temperature, Salinity, Currents and Sea Surface Height.**

The Copernicus Maritime Surveillance Service can support authorities to ensure the safe transit of vessels, people and goods in European waters, and European-registered vessels worldwide. The delivery of the Copernicus Maritime Surveillance Service is intrinsically entwined with the other activities carried out by EMSA, all with a goal of ensuring “quality shipping, safer seas and cleaner oceans”.



Spills from vessels, offshore platforms and oil pipelines can severely pollute marine and coastal habitats causing damage to the natural environment and the economy.

© HoltWebb/VanishingAmericaProject



Ndèye Ba with expert ecologist Babacar Diop in front of the destroyed houses of Santhiaba, Saint-Louis, Senegal. © Véronique Landes



## SENEGAL: THE OCEAN IS NIBBLING AWAY AT FISHERMEN’S VILLAGES

Ndèye Ba is a woman fish seller and processor of fish products in Santhiaba, a district of Saint-Louis in Senegal located on the Langu de Barbarie. This strip of land extends for several kilometres at the mouth of the Senegal River. Due to the unceasing assaults of the ocean, coastal erosion is destroying villages and some 12,000 people are now affected.

*“My house collapsed, as well as the mosque and the school has been partly destroyed,”* says Ndèye. The activity of fishermen, wholesale fishmongers and processors has been disrupted because the hall has also collapsed. *“The authorities have promised to relocate us, but in the meantime, we are sharing tents in a camp in which living conditions are very difficult”.*

In 2003, following heavy rains, a relief channel was dug to protect Saint-Louis from flood risks. From about ten metres it has been transformed into a breach of several kilometres that allows water to flow into the estuary, eroding and separating the Langu de Barbarie in two. The consequences are dramatic: disruption of ecosystems, destruction of homes and fishing villages, loss of human lives (more than 350 deaths due to the risky passing of boats through the breach). *“Our community is in danger of disappearing,”* fears Ndèye.

**Interview by Babacar Ndao and Véronique Landes**

# FIGHTING AGAINST MARITIME POLLUTION IN THE BLACK SEA

The Black Sea is a partly-closed sea connected to the ocean through the Bosphorus Strait and the Strait of Gibraltar and with a maximum depth of about 2,000m. **The Black Sea is thus very vulnerable to pressure from land-based human activity and its health is equally dependent on the coastal and non-coastal states that drain into its basin.** One hundred and sixty-two million people live in the catchment area of the Black Sea and two of the longest and largest rivers flow into it, the Danube and the Dnieper.

The Convention on the Protection of the Black Sea against Pollution, also known as the Bucharest Convention, which entered into force in 1994, provides the legal basis for combating pollution from land-based sources and maritime transport and for achieving sustainable management of marine living resources and sustainable human development in the Black Sea region. The Convention provides a regional cooperation framework involving six countries: Bulgaria, Georgia, Romania, Russia, Turkey, and Ukraine. For implementing the Bucharest Convention, the “Black Sea Commission” (BSC) supported by its Permanent Secretariat, located in Istanbul (Republic of Turkey) and six Advisory Groups, concentrates its efforts on six principal areas of concern. The six groups include the Advisory Group on Pollution Monitoring & Assessment (PMA) and the Advisory Group on Pollution Control from Land-Based Sources (LBS).

The eutrophication phenomenon and pollution of the sea by nitrogen and phosphorus compounds (also called

nutrients) is largely due to agricultural, domestic and industrial sources, but the major transboundary issue is that of chemical pollution, including oil. **Out of 50,000 vessels that pass each year through the Bosphorus Strait, 10,000 are tankers.** Chemical pollution threatens the Black Sea coastal ecosystems and the levels of pollution are unacceptable in many coastal areas and river mouths. Oil enters the marine environment as a result of deliberate or accidental discharges from vessels, as well as through insufficiently treated wastewater from land-based sources.

“Chemical pollution threatens the Black Sea coastal ecosystems and the levels of pollution are unacceptable”

To detect polluters at sea, the BSC information system counts on Copernicus Marine Service data on currents, not only to anticipate the direction in which pollution will drift, but also to “backtrack” an oil spill, simulating where the pollution came from and when the spill started. The EU Copernicus Marine Service can contribute considerably to the BSC’s Monitoring and Assessment Programme, in particular by enabling the identification and suing of polluters thanks to “Backtracking Systems” and also by helping to harmonise the strategies of the different European Regional Sea authorities to enable them to enforce relevant EU Environmental Directives (Marine Strategy Framework Directive, Water Framework Directive etc.).

**IRYNA MAKARENKO**

**Pollution Monitoring and Assessment Officer,  
Black Sea Commission**



Black Sea ports (here in Georgia) aim to develop into key hubs for goods in transit between Asia and Europe  
© Mareks Steins/Pexels



*It is essential that the Ocean Business Community make a coordinated and environmentally-responsible effort to address the cumulative impacts of anthropic activities on the global, inter-connected marine ecosystem and it was with this imperative vision in mind that I created the World Ocean Council (WOC).*



© IISD/ENB | Francis Dejon

## ALIGNED FOR CORPORATE OCEAN RESPONSIBILITY

After having worked for decades on environmental issues concerning the international ocean, with the United Nations and other organisations, it had become clear that a piece of the puzzle, the commitment of industry, was missing and critically needed in order to ensure sustainable use of the ocean and its development. In reaching out to the Ocean Business Community I discovered that there were many well-minded, smart people in flourishing, smart companies who cared about the health of the ocean, wanted to ensure their company was addressing the impact of its activities and were determined to curtail that impact.

These people and companies formed the nexus of what then became a global, multi-industry alliance for leadership, collaboration and action on

Corporate Ocean Responsibility. Ocean governance, data collection by industry vessels, plastics and other forms of pollution, biofouling and invasive species, marine underwater noise, port adaptation to extreme events: these are some examples of the main challenges that the maritime industry has to face.

This implies **bringing together all stakeholders from the full range of ocean-related industrial activities**, e.g. shipping, fishing, aquaculture, oil and gas, offshore renewables, tourism, ports and others, including investors. All these international and multi-sectoral challenges require a solid collaboration between players in all sectors: the WOC is working to achieve this via multi-industry platforms and a network including **more**

**than 35,000 ocean industry stakeholders around the world.** Our Global Blue Economy Business Organisation is recognised or accredited by numerous UN and international organisations.

To proactively address SDG target 14.a, namely “Increase scientific knowledge” of the ocean, the WOC has proposed that the ocean business community participate in a programme called “SMART Ocean-SMART Industries” which encourages the maritime industry to install or deploy instruments that can collect ocean, weather and climate data.

“A solid collaboration between players in all sectors: the WOC is working to achieve this”

**Reliable, high resolution data is essential for safe and sustainable development of the ocean.** Such data is especially critical to the shipping industry as it continues

to expand, alongside increases in other types of ocean use. Such data needs to be collated and analysed to provide applicable and operational intelligence for shipping companies, in the form of indicators and forecasts such as those provided by Copernicus.

Through our commitment to “Corporate Ocean Responsibility”, we have a vital role to play in shaping a sustainable future for our global ocean and in fostering the growth of the blue economy.

**PAUL HOLTHUS**  
Founding President and CEO  
World Ocean Council



# A SAFE OCEAN ALSO DEMANDS RESPONSIBLE AND SUSTAINABLE APPROACHES

## INTERNATIONAL

90%  
of global trade is carried  
by the shipping industry

130 million  
containers were transported  
with freighters in 2016



50,000  
merchant ships  
(international trading)



1,600  
containers, on average, were lost at sea  
each year over the last decade,  
64% of which were attributed  
to a catastrophic event

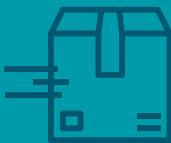
<http://www.ics-shipping.org/shipping-facts/shipping-and-world-trade>

## SHIPPING IN THE EUROPEAN UNION

90%  
of the EU's external trade

415 million  
passengers passed through the 1,200  
European seaports in 2017

<https://ec.europa.eu/eurostat/statistics-explained/pdfscache/6652.pdf>



40%  
of the EU's internal trade



~ 21,000  
casualties and incidents and...

## MARITIME TRANSPORT



2.5%  
of global greenhouse gas  
(GHG) emissions

[https://ec.europa.eu/clima/policies/transport/shipping\\_en](https://ec.europa.eu/clima/policies/transport/shipping_en)

...700  
fatalities over 7 years (2011-2017)

<http://www.emsa.europa.eu/damage-stability-study/items.html?cid=77&id=3406>



Miguel F. Chicón and Alfredo Fernández, Director and SAR Operator, respectively, of the Spanish Maritime Safety and Rescue Agency (MRCC-Palma), while using CMEMS data  
© Jerónimo Alba

# INTRODUCTION

With more than 90% of world trade using sea routes, the ocean is a vital factor for the economy and society. The safety of people at sea is a priority ensured by maritime safety management procedures and international legislation and regulations. The use of products from the Copernicus Marine Service and from the Copernicus Maritime Surveillance Service (which is entrusted to EMSA) brings unrivalled added value to maritime safety management.

Copernicus Marine Service products help reduce casualties in maritime accidents and incidents. Drift prediction models based on reliable currents and sea ice forecasts enable faster location of lost ships and passenger rescue. The products enable a more comprehensive picture of the weather and oceanic conditions under which Search and Rescue activities take place and facilitate decision making and risk management.

Maritime transport plays a major role in the European

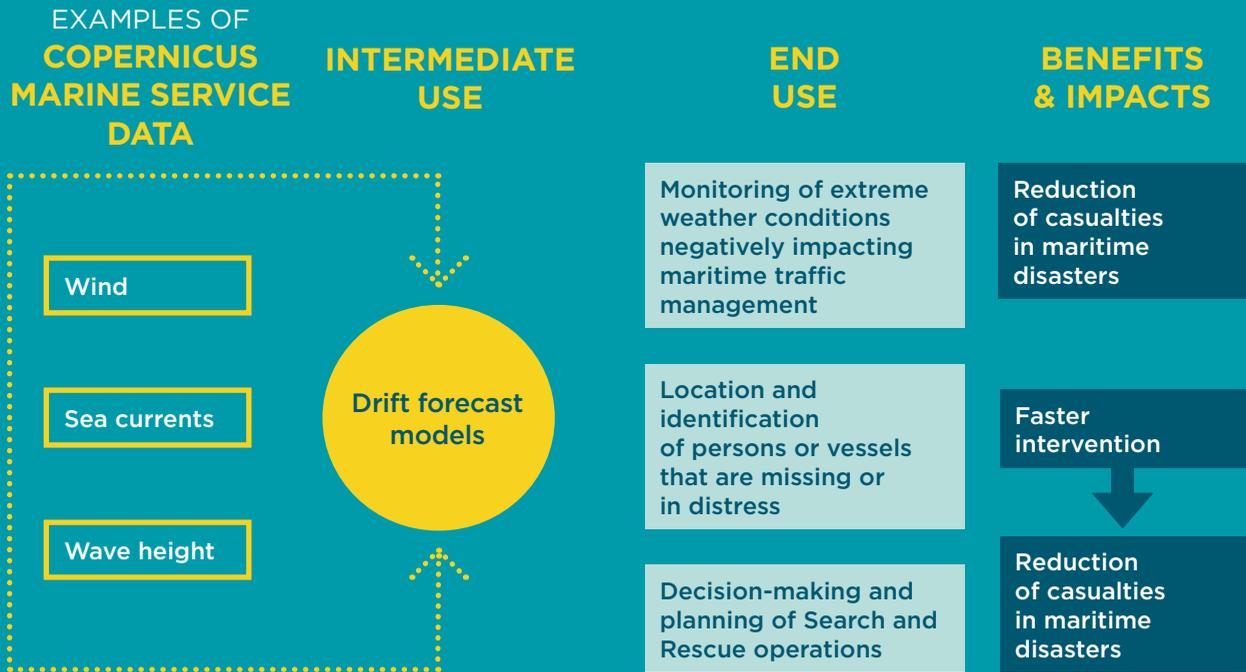
economy. The first EU Blue Economy Report estimates that the sector generates a Gross Value Added of 22 billion euros, up 20% compared with 2009. Safer and optimised ship routing has a positive economic impact by decreasing the disruption of trade and accelerating the delivery of goods.

Better ship traffic monitoring also protects the ocean environment by limiting accidents that could lead to oil spills and accidental pouring of harmful and toxic chemicals into the ocean. It also limits atmospheric pollution by reducing the fuel consumption of freighters through better use of ocean currents and waves to propel ships.

This section focuses on two safety-related domains to which the Copernicus Marine Service brings value:

- Search and Rescue
- Ship routing in maritime transport

# SEARCH AND RESCUE



The principal mission of Coast Guards and Search and Rescue (SaR) operations is to reduce risks at sea and save people. Daily forecasts of currents and wave height by the Copernicus Marine Service are key parameters for their search and rescue software and met-ocean dashboards.

The use of Copernicus Marine Service data enables faster interventions during maritime operations, incidents and disasters, and reduces the number of casualties.

Extreme weather conditions endanger lives and operations at sea. Drift models based on Copernicus Marine Service data enable the location of missing vessels and people all over the globe, by providing coastguards with information to help them better understand environmental conditions and thus save precious time for SaR.

In a general way, Copernicus Marine Service data provide a more comprehensive picture of the weather and oceanic conditions under which Search and Rescue, harbour, coastal, offshore and scientific operations at sea take place, which facilitates decision making and risk management.

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On 5<sup>th</sup> October 2017, a yacht called *Jolly Rogers* was abandoned off Spain's Cape Finisterre during the Mini Transat 6.50 race. The skipper activated his distress beacon and was lifted out by helicopter by the Spanish navy but *Jolly*

*Rogers* was left at sea and the yacht was considered lost. The consultancy company MetOcean Solutions was mandated by the insurance company to locate it and they did it a few days later by feeding a Copernicus Marine Service currents forecast into their drift models.

**“ Searching for a 6 m sailboat in the Atlantic Ocean is a bit like looking for a needle in a haystack.”**

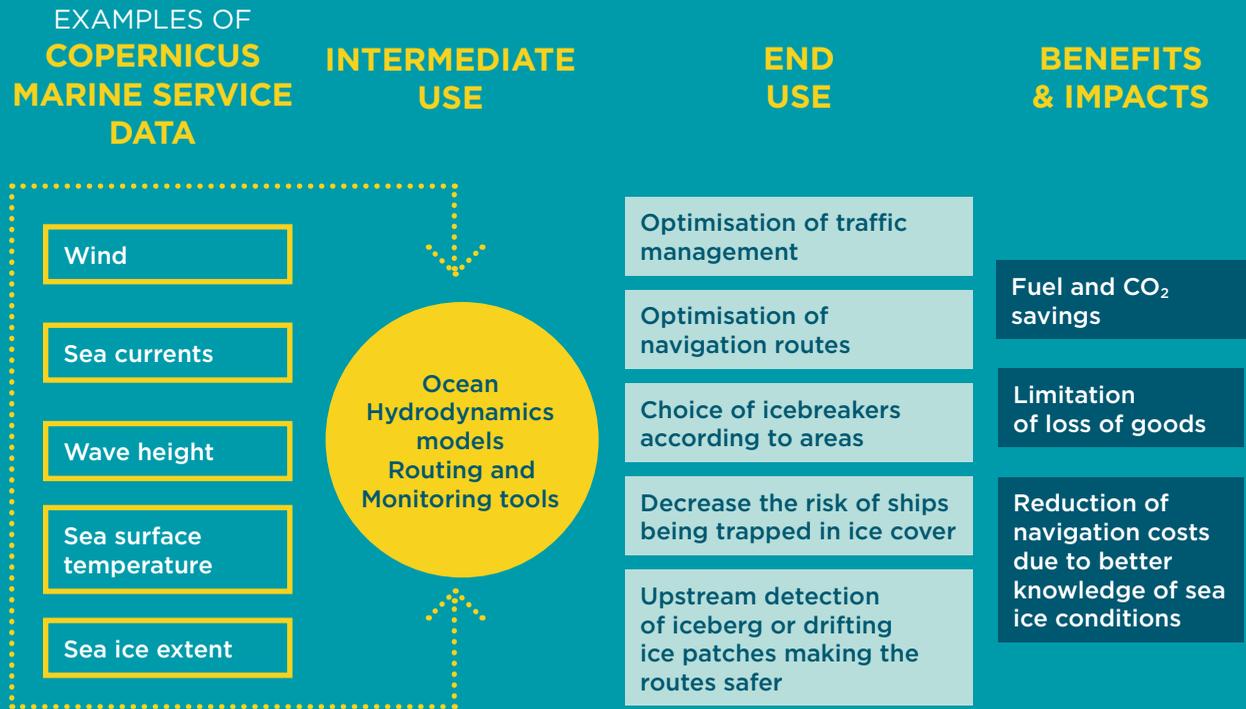
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The leading worldwide transport and logistics french group CMA CGM has developed the Fleet Navigation & Support Centre, which provides navigation support, safe routing and guidance services. They need to have a good understanding of the upper ocean and qualified ocean forecasts. “Using surface current for shiprouting in areas where the weather conditions do not prevail may allow savings of about 1% of the fuel consumption”. ACTIMAR (SUEZ group), contracted by CMA CGM, compared several ocean current products, including the Copernicus Marine Service ocean currents from the Iberia-Biscay-Irish, Mediterranean and Global hydrodynamic models and the satellite and in situ-based Global Observed Ocean current product:

**“ In addition to the constantly improved reliability of ocean forecasts provided by CMEMS, the knowledge of the forecast uncertainty represents a major step forward for safe routing.”** ∞



# SHIP ROUTING IN MARITIME TRANSPORT



Route planning has always been a crucial issue for the shipping industry. Ship routing is meant to prepare and determine the safest route possible for reaching a particular destination.

Today, ship routing is intertwined with several key maritime transport issues for the purpose of **operating safely, decreasing fuel consumption, and limiting environmental impacts.**

Services delivered to the shipping industries help operators meet their requirements for safety, protection of the environment and cost savings.

D-ICE Engineering, a French start-up, provides met-ocean and routing assistance to shipping companies.

**“ Our OCEAN Intelligent Control System, OCEANiCS, is an embedded system enabling both ship control and weather routing. The main objectives are to reduce the environmental impact and improve navigation safety. Another advantage is that it enables fuel savings ranging from 5 to 15% for ships with engines.”**

The shipping industry accounts for 2.5% of global greenhouse gas emissions. The Copernicus Marine Service ocean currents forecasts are integrated into ship routing models, not only for reducing the fuel consumption of cargo ships but also the amount of atmospheric pollution caused by ships and to protect them against potential wreckage that could lead to oil spills.

HERMESS bv is a Dutch company specialised in maritime solutions based on numerical modelling, in situ measurements and remote sensing data. It uses Copernicus Marine Service variables such as current, winds and waves to assess ship velocities.

**“ The demand for met-ocean services is growing with the expansion of offshore activities. By estimating the harbour arrival time of their ships, shipping companies can reduce the ships’ speed and therefore reduce both their fuel consumption and environmental footprint.”**

In 2014, Arctic shipping comprised 9.3% of the world’s shipping traffic, representing about 11,000 ships. The latter figure is certainly higher today given that sea ice melt has opened new waterways for shipping and the cruise industry is proposing new destinations in the Arctic Sea.

Precise sea ice mapping helps shipping companies identify risks (e.g. drifting ice patches and icebergs that might lead to accidents) and opportunities (e.g. new, faster shipping lanes) for winter navigation of commercial vessels and passenger ships. Copernicus Marine Service Sea Ice products, among other sources, are used by national Sea Ice Services to protect many user groups such as national authorities, shipping companies, public ice breakers, service and software companies, service integrators and research institutes. The data enable them to assess environmental safety, and the impacts of economic activities in both polar regions.

The Alfred Wegener Institute's spin-off company, Drift+Noise Polar Services in Germany offers a new operational ice-map service.

**“ This was also triggered by the availability of open data provided by Copernicus. Ice analysis is a big data problem. End Users want automation and integration. We compile different data sources such as radar satellite images, visual satellite images and sea ice concentration to provide a comprehensive plot of the current ice situation. Typical users are cargo ships, service ice breakers, expedition cruise ships and research or exploration vessels.”** ∞

The Finnish Meteorological Institute (FMI) provides met-ocean and sea ice monitoring services for scientific research, tourism and emergency management in the Arctic Ocean and Baltic Sea. Its expert services and operational products are available continually, night and day and throughout the year.

**“ Sea ice is a challenge that must be taken into account to ensure safe and efficient marine transport. Our main geographical focus is on the Baltic, Kara and Barents Sea regions. The key to delivering the services is to combine Copernicus Marine Service data with FMI's own and other sources of information for a comprehensive understanding of ice conditions.”** ∞

Extreme Weather Conditions have become extremely important for Insurance companies.

QuantCube Technology, a FinTech company specialised in predictive analytics based on massive unstructured data has integrated Copernicus Marine Service data into its machine learning solutions to forecast environmental crises such as droughts, floods and typhoons, and anticipate their potential social and economic impacts.

**“ Our model uses several sources of data, among which Copernicus Marine Service products, that play a prominent role in calculating insurance premiums for ships.”**



Alfred Wegener Institute's Polarstern icebreaker conducts research in polar waters. Postprocessing and delivery of data on board is done by Drift+Noise.  
© Alfred Wegener Institute/Stefan Hendricks

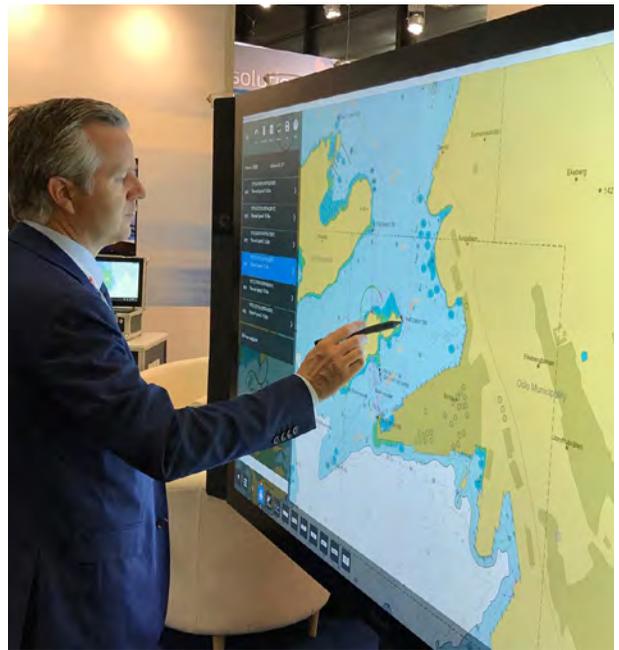
## USE CASES

### SHIP TRAFFIC INFORMATION

Based in Egersund, Norway, NAVTOR AS develops software solutions for maritime route planning and e-navigation services in the Arctic Ocean. The company uses ice forecasts provided by Copernicus Marine Service in its 7-day forecasting system, which is updated daily.

NAVTOR offers a service that features the setting of possible waypoints and the possibility of animating charts while showing the potential changes of sea ice, wind, wave and ocean-current conditions due to ice moving, freezing or melting during the voyage. The ship's crew can then take informed crucial decisions as to the safest navigation route. Choosing the optimal route allows ships to reach their final destination as fast as possible with more precisely estimated times of arrival, thus minimising ship damage and reducing fuel consumption.

With the help of the Copernicus Marine Service, NAVTOR is simplifying tasks, increasing efficiency and improving operations for navigators, ship-owners and operators.



© NAVTOR



© Jerónimo Alba

### SEARCH AND RESCUE

Based in Palma de Mallorca (Spain), SOCIB is the Balearic Islands Coastal Ocean Observing and Forecasting System, a marine research infrastructure that contributes daily to our knowledge of the ocean through state-of-the-art science, implements new technologies and develops new products to respond to social needs.

In partnership with AZTI and RPS, SOCIB coordinates the IBISAR service, a free online tool designed to meet the needs of Search and Rescue operators, such as the Spanish Maritime Safety and Rescue Agency. When it comes to saving lives, every second counts: in case of man overboard, the immediate availability of accurate ocean-current data and forecasts is vital for a prompt Search and Rescue response. Copernicus offers different models at various scales, but how can one choose the best one for a specific region and at a given time? IBISAR solves that issue by automatically analysing and ranking the performance of the various ocean forecast models available, thus speeding up Search and Rescue operations, particularly for coastal waters. As a result, users can choose in quasi real time the most accurate ocean-current prediction, which is crucial for organising the most efficient emergency response and saving lives.



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## PORT MANAGEMENT

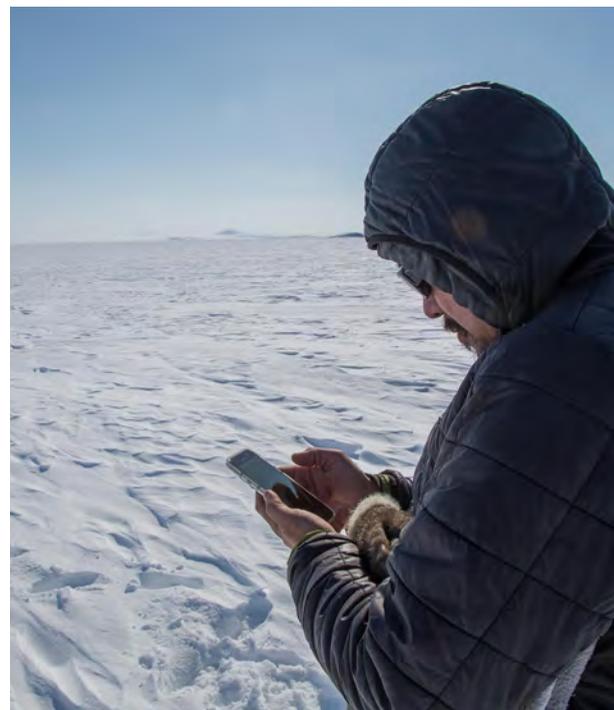
Hidromod is a Portuguese consultancy company based in Lisbon specialised in the field of computational modelling of aquatic environments. With solid expertise in advanced data mining techniques, it provides support to operational services in water related projects.

Hidromod has developed an open web service (with paying premium options) called AQUASAFE, fed by Copernicus Marine Service data among others, as a support to maritime operational services (shipping and harbour activities). AQUASAFE is particularly useful for pilot crews close to a seaport: the online tool, which provides reliable and updated data on wind, waves, currents and sea depth (among others) is an efficient decision-making aid to help pilots determine the most suitable manoeuvres for safe arrival at the port of destination. The tool enables time and cost savings for shipping companies and also for harbours undertaking dredging activities.

## ICE MONITORING

Polar View is an international organisation specialised in operational monitoring of the Polar Regions and the cryosphere. It provides users with information related to safety of operations, environmental protection and sustainable economies, in geographic areas affected by ice and snow.

In line with its mission, Polar View developed the *Community Ice Information Service*, accessible through both a web portal and an Android application fed by various data from the Copernicus Marine Service. Traditional ways of life, transportation and the economies of Arctic Region communities depend greatly on the state of the ice. The boundary between the land-fast ice along the coastline and the mobile ice in the open ocean is a very biologically productive area chosen for hunting and fishing. As importing southern food is a very expensive option for northern communities, relying on traditional and local sources of food is crucial. The Community Ice Information Service is intended particularly to support the Inuit's needs, as climate change is having a significant impact on their lives.



© David Arthurs



**SALVADOR ANTONIO DE LA ENCINA ORTEGA**  
President of Puertos del Estado

## MONITORING SPANISH PORTS WITH OCEAN DATA

Geographically and culturally, Spain has strong bonds with the sea due to its approximately 8,000 km of coastline. Its geographical location strengthens its strategic importance for international shipping and logistics platforms in southern Europe.

Spanish ports are a fundamental part of Spain's economy and handle nearly 60% of its exports and 85% of its imports, accounting for 53% of Spanish foreign trade with the European Union and 96% with third countries. In addition, the activity of the State port system contributes almost 20% of the transport sector's GDP and directly generates more than 35,000 jobs and indirectly, around 110,000. Over the last 25 years, the number of cruise liner passengers has been multiplied by 18, currently representing more than 10 million visitors per year, while regular transport lines count more than 26 million passengers per year.

Safety is a leading priority of Puertos del Estado, the Spanish governmental agency (under the Ministry of Public Works) in charge of implementing the national port policy. The state-owned port system includes 46 ports of general interest, managed by 28 port authorities, which are coordinated and supervised by Puertos del Estado. As in many other countries, safety is their daily concern as ports can experience extreme ocean weather conditions due to strong winds, currents, waves and sea level that could affect operations in the port. Nowadays, **ports have to be managed in a more holistic and integrated way** that takes into account the full range of activities with an eye to safety, security, cost efficiency, sustainability, etc. **Decisions based on multiple factors have to be taken with the help of specific decision-making support tools.** *Metocean* data are among these tools and are truly relevant in this emerging context.

Puertos del Estado uses a supercomputer to forecast ocean conditions such as waves, sea level, currents and water temperature and climate time series. To respond to the complex needs of port facilities, we have developed a new monitoring system called SAMOA (Sistema de Apoyo Meteorológico y Oceanográfico a las Autoridades portuarias - System of Meteorological and Oceanographic Support for Port Authorities.) co-financed with the Port Authorities. **SAMOA has revolutionised port management with its sophisticated resources.** This is an integrated “all in one” system, based on Copernicus Marine Service data, high-resolution atmospheric models, wave models and ocean circulation models. Twenty-five Ports falling under 18 Port Authorities benefit from these new modelling and monitoring capabilities. The system, which will soon also be providing wave overtopping forecasts and extremely

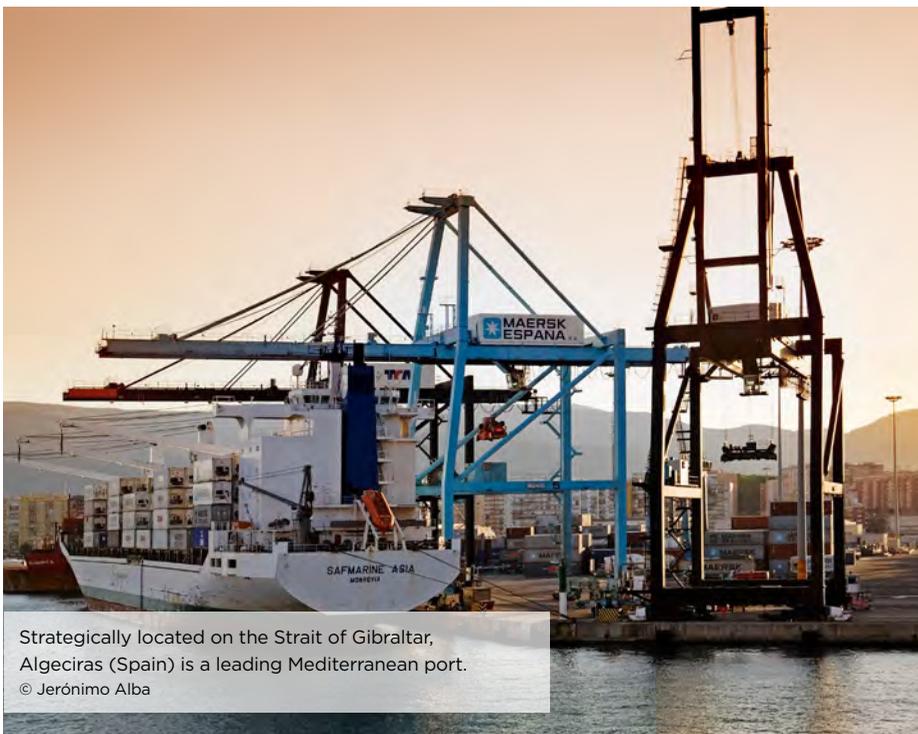
high-resolution wind prediction, is a precious decision-making aid for ensuring safe operational activities on a daily basis, such as for ports closing due to extreme events, for crane operations affected by winds, for planning Roll-On, Roll-Off operations<sup>1</sup>, for fighting against oil spills and even for controlling water and air quality.

**Copernicus Marine Service data help Puertos del Estado to continuously improve the safety of Port operations.**

Ocean data will soon be used for auto-pilot systems on ships and will help reduce greenhouse gas emissions by supporting traffic systems. In the future, ports will include more and more advanced technology, such as SAMOA's, integrating *metocean* data as a fundamental component of the logistics chain.

“SAMOA has revolutionised port management with its sophisticated resources.”

1 - Vessels designed to carry wheeled cargo, such as cars, trucks, semi-trailer trucks, trailers, and railroad cars, that are driven on and off the ship on their own wheels or using a platform vehicle.



Strategically located on the Strait of Gibraltar, Algeciras (Spain) is a leading Mediterranean port.  
© Jerónimo Alba



04

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# LIVING OCEAN





### RICARDO SERRÃO SANTOS

Member of the European Parliament (2014-2019)

## THE FUTURE OF FOOD RELIES ON OUR OCEAN

*“With every drop of water you drink, every breath you take, you’re connected to the sea. No matter where on Earth you live”,* this quote of Sylvia Earle (an American marine biologist, explorer, author, and lecturer) synthesises perfectly the interconnected nature of our planet and the influence of the ocean from global to regional levels. Observation of the ocean is fundamental for understanding its impact on daily life.

A few years ago, I had the opportunity to observe such a reality. During a working visit to Malawi (East Africa), I was confronted with the regional effects of the conjugation of climate change and distant massive oceanographic processes on the daily life of millions of people. Oceanographic currents that alternate near Chile define the effect on nutrition, health and happiness or the lack of it in a remote and landlocked country of Africa. The Malawians suffer dry seasons or devastating floods as a result of oceanographic phenomena that take place far away in the eastern Pacific.

The ocean provides crucial environmental services, enabling food production both on land and at sea.

The seas and the ocean, that are stabilising forces of bio-geophysical processes, in particular by regulating the carbon cycle, are themselves weakened. Acidification and the increase in mean temperature cause the sea level to rise and have an impact on biodiversity, living resources, and also deplete oxygen levels in the ocean. The problems go far beyond overfishing, transport of invasive species or pollution.

While many of these processes may seem regional, and there are certainly specifically regional issues and approaches, the fact is that they have to be tackled as general concerns.

The 2030 Agenda for Sustainable Development incorporated for the first time the SDG14, a stand-alone goal related to the conservation and sustainable use of the ocean and marine resources. This goal, however, cannot be dissociated from

**“Space-based observation as well as in situ technology have become inescapable tools with multi-level objectives”**

other SDGs such as SDG3 on “Good Health and Well Being”, SDG12 “Responsible Consumption and Production”, and SDG2 “On Zero Hunger”.

**The ocean is being targeted to better feed mankind.** The world population may reach 10 billion people by 2050 and 800 million are already suffering from hunger and undernourishment while the actual loss and waste of food amounts to 35% according to the FAO. More and more people are dying of non-communicated diseases such as obesity, diabetes and cardio-vascular problems. So, a lot has to be done. Due to over-proliferation of unhealthy food, ocean resources are being looked at as a way of changing our paradigm to use our planet better.

The logical result is that the growing need for nutritious and healthy food will increase the demand for marine products, whose productivity is already highly compromised by fishing pressure, intensive aquaculture relying on protein, nutrient and other contamination while also contributing to coastal degradation and climate change. Looking towards 2050, the question is how the governance of fisheries and aquaculture and the national and international policy and legal frameworks within which they function, will ensure sustainable stocks, protect biodiversity, ecosystems, and store “blue carbon” in the form of biomass and sediments, and thus adapt to climate change.

Data on economic and food loss at sea is very disturbing, namely in underdeveloped or developing regions that suffer from food insecurity. In Africa alone, around €9 billion are lost each year due to

overfishing. In West Africa around €1 billion is lost due to illegal, unreported and unregulated (IUU) fishing, while in the Western and Central Pacific Ocean, IUU amounts to at least €381 million annually. Furthermore, the actual lost revenue to Pacific Island countries is estimated at €114 million annually.

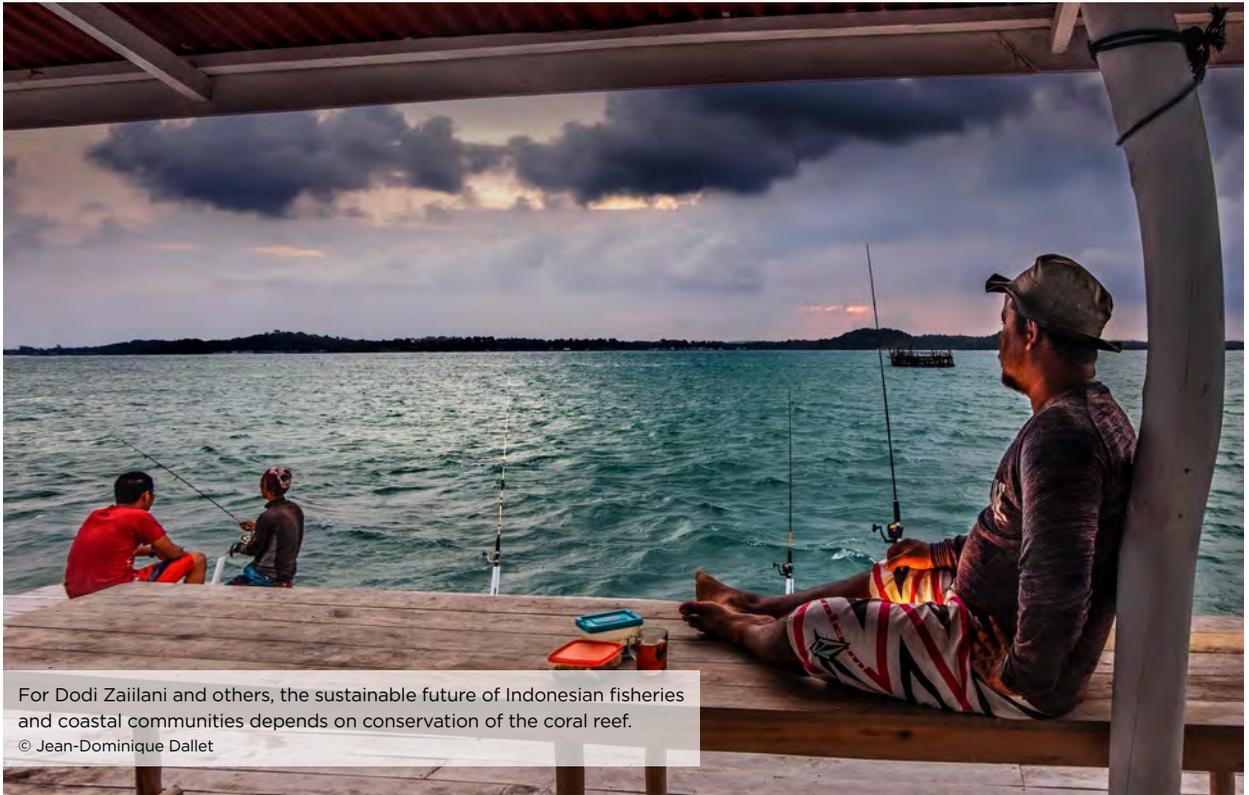
**Ocean observation is in fact a crucial tool in the modern world.** This has been recognised in the SDGs of the United Nations, in the IPCC 2018 Special Report “Global Warming of 1.5 °C” and, in the Outline of the IPCC Special Report on “climate change and oceans and the cryosphere” to appear in late 2019, just to mention a few.

Our ability to observe the ocean environment, including its biodiversity and fishery resources has to catch up with our imagination, and **space-based observation as well as in situ technology have become inescapable tools with multi-level objectives.**

The exploration of any ecosystem requires detailed studies and observations. The ocean is the most complex, harsh and difficult environment to assess on the planet. To be able to see the big picture, encompassing the global ocean and its different dimensions, we must cooperate by sharing data, information and knowledge. To do that, it is necessary to ensure that scientific and technological partners speak the “same” language and share their tools and methodologies. For me, this is one of the major goals of the implementation of the Copernicus Marine Environment Monitoring Service entrusted by the European Commission to Mercator Ocean International in 2014.



Traditional fishing boat on the Costa del Sol, Andalusia (Spain)  
© Jerónimo Alba



For Dodi Zailani and others, the sustainable future of Indonesian fisheries and coastal communities depends on conservation of the coral reef.  
© Jean-Dominique Dallet



## INDONESIA: A SUSTAINABLE OCEAN FOR FISHING AND TOURISM

Dodi Zailani enjoys fishing on his *kelong* (house on the sea) outside the village of Taluk Bakao, on Bintan Island (Indonesia). This island has a large coastal area and many marine biological resources with high economic value. Tourism benefits from these as well, hence the development of luxury resorts along its beautiful coast.

Dodi, 47, is a fisherman and diver, who believes his future lies not only in fishing but in the development of sustainable tourism, taking into account this rich marine environment. “We have been sea-people

for many generations, with our traditional *kelong* fishing houseboats, anchored near the shore. But fishing no longer brings in enough money to support my family, my wife, two daughters and son. So I’m renting my two *kelongs* as guest houses and taking the clients diving”. A sustainable ocean is necessary for the welfare of the Bintan community. “This is why we must protect our coral reef and our mangrove. And if sea-level rise is not an immediate problem for me, it may well be one for my children!”

Interview by Jean-Dominique Dallet

# TUNA AND FOOD SECURITY IN THE PACIFIC

With fourteen independent States and eight Territories (belonging to France, United States, New Zealand and the United Kingdom), the Pacific Islands are strongly dependent on tuna for their economic development, and, along with reef and lagoon fish, for food security.

The Western and Central Pacific Fisheries Commission (WCPFC) monitors the catches of tuna fisheries, then estimates the available stocks. **Total tuna catches in the region amount to 2.5 to 3.0 million tonnes annually, nearly 60% of the world's production.** The Pacific Community's Oceanic Fisheries Programme (OFP) provides scientific services under a contract with the WCPFC, compiling data from the fisheries, carrying out biological and ecological research and conducting stock assessments that must take ocean variability into account.

The El Niño Southern Oscillation (ENSO) provokes ocean variability over time scales of several years. El

Niño events cause an easterly expansion of the Western Pacific Warm Pool, shifting the location of tuna abundance to the east. La Niña events lead to a contraction of the Warm Pool and thus shift tuna abundance to the west. ENSO consequently affects the distribution of fishing across the tropical Pacific, in particular in the EEZs of the eight members of the PNA (Parties to the Nauru Agreement, Federated States of Micronesia, Kiribati, Marshall Islands, Nauru, Palau, Papua New Guinea, Solomon Islands and Tuvalu). The PNA has adapted its management arrangements to cope with this variability, but there is an important need to monitor oceanographic conditions, and, to the extent that it is possible, provide forecasts to keep managers informed.

**Climate change will have profound effects on tuna fisheries.** Sea surface temperature in the warm pool is expected to rise by 1.2 to 1.6 °C by 2050 relative to the mean temperature for the

period from 1980 to 1999. Weaker trade winds and equatorial currents are predicted, which would reduce the transport of primary and secondary productivity from the central equatorial Pacific into the Warm Pool, which would in turn reduce the abundance of tuna prey.

Since the ocean is absorbing a large proportion of the atmospheric CO<sub>2</sub> generated by human activity, the seawater pH level is slowly dropping (which means higher acidity), resulting in lower calcium carbonate saturation states. While the direct impact of ocean acidification on tuna is considered to be minor in relation to other aspects of climate change, **fundamental ecosystem changes could affect the pelagic food web causing potentially strong indirect effects at a number of tuna life stages.**

Research indicates that these changes will cause an easterly displacement of tropical tuna stocks from the western Pacific towards the central and eastern Pacific,

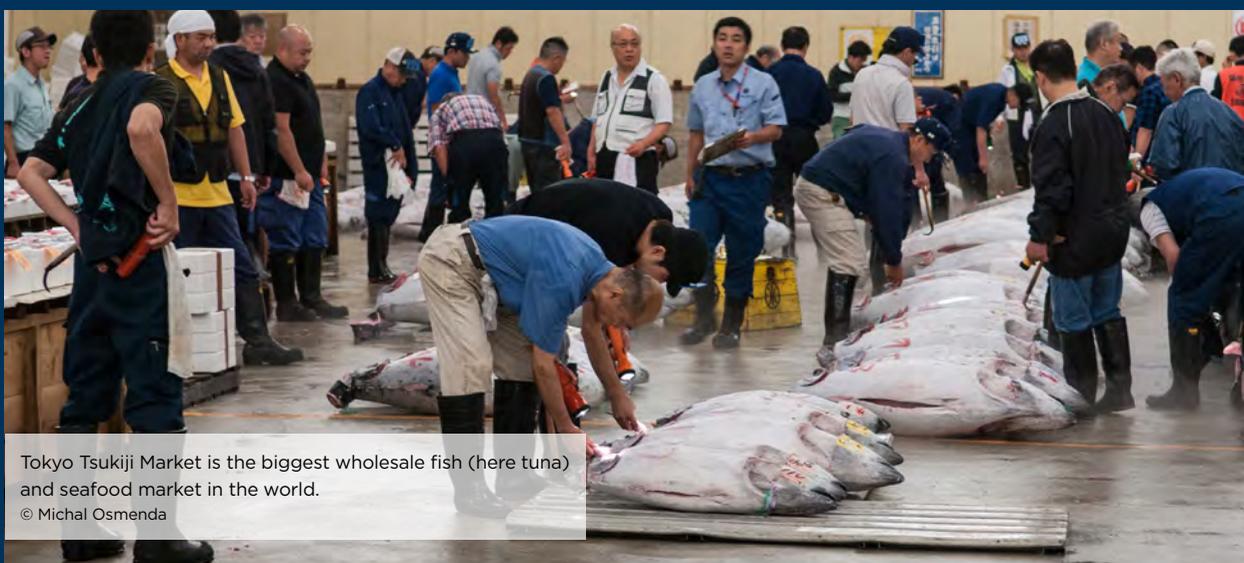
particularly in the second half of the 21<sup>st</sup> century. Models predict median reductions in biomass of 38% for skipjack, 18% for yellowfin and 15% for bigeye tuna in the WCPFC area overall.

The monitoring of oceanic variables, particularly SST, nutrients, primary and secondary productivity, dissolved oxygen and pH will thus be crucial. All these are made available by the EU Copernicus Marine Service, and enable updating of predictive models of tuna abundance. Such information will allow the vulnerable countries of the Pacific to plan ahead in order to minimize the negative consequences of the changes that will occur through the 21<sup>st</sup> century.

**“The Pacific Islands are strongly dependent on tuna for their economic development and for food security”**

**JOHN HAMPTON**

Pacific Community's Oceanic Fisheries Programme (OFP)  
Chief Scientist, SPC



Tokyo Tsukiji Market is the biggest wholesale fish (here tuna) and seafood market in the world.

© Michal Osmenda



*The African Union Commission is determined to manage fishery and aquaculture resources in a sustainable way to mitigate serious challenges, threats and vulnerabilities, such as sea level rise, pollution, habitat destruction, ocean acidification and illegal, unreported and unregulated (IUU) fishing, responsible for losses of USD 10 billion per year on the continent including Western Africa*



## FEEDING AFRICA

Africa has vast natural resources along its coastline of 47,000 km bordering and surrounding thirty-eight coastal and island states respectively. More than 12 million people are employed in the fishery sector, which provides food security and nutrition to over 400 million people. Fisheries generate value-added products estimated at more than USD 24 billion, or 1.26% of the GDP of all African countries taken together (FAO, 2014). Aquaculture, which is still developing in Africa, is mostly concentrated in a few countries that produce an estimated value of almost USD 3 billion per year.

The African Union Commission (AUC) understands that **expanding fisheries and aquaculture can help reduce African poverty by enhancing food security, stimulating economic growth and creating jobs** and has developed appropriate policy and strategic frameworks to update Agenda 2063.

The GMES & Africa Support Programme, based on the Copernicus programme, implemented by the AUC and co-financed by the European Commission, designs tailor-made Earth Observation services to meet African needs at the continental, regional and local levels. It supports Africa for the monitoring, assessment and forecasting of maritime wealth and assets including fisheries & aquaculture for the benefit of policymakers, scientists, businesses and the public. For marine and coastal issues, **GMES & Africa Programme works closely with the Copernicus Marine Service to take advantage of its experience with users in many marine sectors**, but also sharing in situ data if needed

and available. Four GMES & Africa Marine projects have been carefully selected to cover rim countries bordering the Indian Ocean, Atlantic Ocean and Mediterranean Sea. The countries involved in the projects are Benin, Cape Verde, Ivory Coast, Egypt, Ghana, Kenya, Madagascar, Mauritania, Mauritius, Morocco, Namibia, Nigeria, Senegal, Seychelles, South Africa, Tanzania and Tunisia. To support fishery resource management, maps of potential fishing zones will be developed using Copernicus data and overlaid with vessel traffic information. This derived information will help to optimise fishing efforts, increase the safety of fishers at sea, improve decision-making for fishery management, and enhance compliance and enforcement actions. In addition, maps identifying suitable aquaculture sites, water quality monitoring reports, assessments of harmful algal bloom risk and other key environmental parameters will be made available to responsible end users.

Last but not least, **maps of sensitive ecosystem habitats** (coral reefs, seagrass beds and mangroves) will be disseminated to decision makers and enforcement agencies responsible for monitoring and protecting healthy coastal ecosystems that are essential for sustainable artisanal and small-scale fisheries.

**TIDIANE OUATTARA,**  
Space Science Expert and GMES  
& Africa Programme Coordinator,  
African Union Commission





# PROVIDING FOOD AND LIVELIHOODS TO MORE THAN 9 BILLION PEOPLE BY 2050

THE OCEAN SUPPORTS THE LIVELIHOODS OF

10% to 12% of the world's population

<http://www.fao.org/3/i9705EN/i9705en.pdf>

AND PROVIDES ABOUT

3.2 billion people with almost 20% of their average per capita intake of animal protein

<http://www.fao.org/3/i9540en/i9540en.pdf>

## GLOBAL CAPTURE FISHERIES

91 million tonnes of fish production in 2016 (out of which EU = 6 million tonnes ) Estimated growth 2016-2030 = 18%

<http://www.fao.org/state-of-fisheries-aquaculture/en/>



23% of worldwide catches of fish are thrown overboard every year.

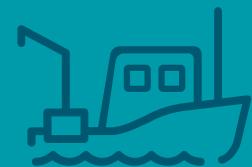
[https://ec.europa.eu/maritimeaffairs/press/new-%E2%80%9Ccoastal%E2%80%9D-magazine-euronews-explores-sustainable-eu-fisheries\\_en](https://ec.europa.eu/maritimeaffairs/press/new-%E2%80%9Ccoastal%E2%80%9D-magazine-euronews-explores-sustainable-eu-fisheries_en)

33% of the world's marine fish stocks are overfished in 2015

[http://www.fao.org/fileadmin/templates/SOFIA/2018-l/src/images/charts/EN\\_Graph\\_14.pdf](http://www.fao.org/fileadmin/templates/SOFIA/2018-l/src/images/charts/EN_Graph_14.pdf)

0.5% of the world's CO<sub>2</sub> emission come from fishing vessels (marine and inland)

<http://www.fao.org/3/i9705EN/i9705en.pdf>



## GLOBAL AQUACULTURE (FOOD FISH)

Aquaculture grows faster than other major food production sectors with

5.8% annual growth rate (2001-2016)

<http://www.fao.org/state-of-fisheries-aquaculture/en/>



80 million tonnes of aquaculture production in 2016

(out of which <2 million tonnes in the EU) Estimated Growth 2016-2030: 37%

<http://www.fao.org/state-of-fisheries-aquaculture/en/>



Fish farming at Sellonda in the Saronic Gulf, Greece. The main species farmed are sea bass and sea bream. © George E. Koronaiois

## INTRODUCTION AND CONTEXT

The ocean is one of Earth's most valuable natural resources, especially in terms of food supply and biodiversity. In the context of climate change, the Food and Agriculture Organisation of the United Nations (FAO) has recognised the essential role of fisheries and aquaculture for food security and nutrition, particularly in the developing world. Fish provide more than 20% of the average per capita animal protein intake for 3.2 billion people (more than 50% in some less developed countries). According to the FAO, fish are especially critical for rural populations, which often have less diverse diets and higher rates of food insecurity.

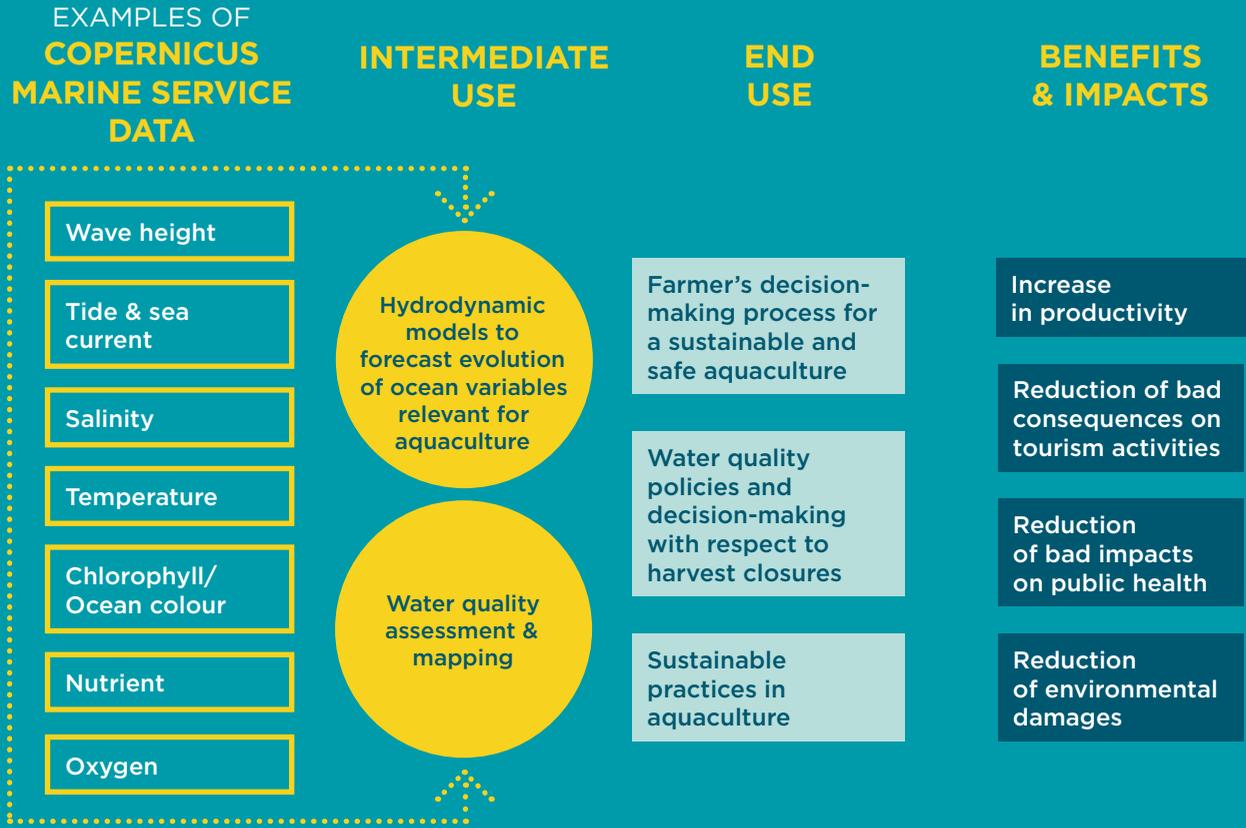
As stated in the FAO report on “The State of World fisheries and Aquaculture 2018”, aquatic ecosystems are structurally and functionally highly biodiverse. They form a food chain of interconnected species, which support fisheries and aquaculture, and contribute to the nutritional, economic, social, cultural and recreational betterment of human populations.

Products from the Copernicus Marine Service provide fundamental support for sustainable practices in fisheries and aquaculture, as well as for the monitoring of marine biodiversity to protect its health. As explained in the following section, Copernicus Marine information is used by fisheries management authorities, public and scientific organisations, and developers of downstream services for monitoring relevant water parameters, habitat status and species movements. Such value-added information ultimately provides fish farmers and fishermen with crucial support for their daily decision-making processes.

With regards to the Living Ocean, the Copernicus Marine Service information serves three important domains, which will be fully described in the following pages:

- Aquaculture Farm Management
- Fishery management
- Biodiversity monitoring

# AQUACULTURE FARM MANAGEMENT



One of the eleven descriptors in the EU Marine Strategy Framework Directive, related to a human-induced pressure is eutrophication. It is caused by pollution and nutrient runoff (mainly nitrogen and phosphorus) into coastal waters and leads to Harmful Algal Blooms (HAB), oxygen depletion, and possibly dead-zones. **The annual cost of HABs affecting tourism and fishing activities in the European Union is reported to be almost a billion Euros.** HABs are one of the main challenges to aquaculture farm management. They are microorganisms that produce harmful toxins and can kill fish, shellfish and even humans when they eat contaminated fish. They affect human health and more generally marine biodiversity and can cause financial losses for farmers and more generally for coastal economies (public authorities sometimes have to close beaches to protect people against toxic gasses emanating from HABs and which they might inhale).

**While HABs cannot be prevented, they can be anticipated, thanks to models that use Copernicus Marine information to predict their occurrence and movements.** One such product is the near real time variable, "ocean colour", provided by satellite observations. It enables aquaculture farmers to take relevant actions before HABs reach the shore, such as harvesting, moving cages, or installing aeration systems. Ocean colour information is a proxy for

chlorophyll-a and phytoplankton biomass and as such is a crucial parameter for monitoring water quality.

The Irish Marine Institute (IMI) is a state agency responsible for marine research, technology development and innovation in Ireland. Aquaculture farms around Ireland are subject to water pollution by diarrhetic shellfish poisoning (DSP) toxins. In the framework of the ASIMUTH project, IMI publishes weekly bulletins of off-shore waters around Ireland, based on satellite data, in situ observations and a hydro-dynamical model downscaled from Copernicus Marine Service Regional forecasts.

**“During toxic algae bloom episodes, the high-resolution local model forecast is a useful tool for predicting a week before instead of merely 3 days before, the risk of a HAB episode that would oblige aquaculture farms to stop harvesting,”** says Tomasz Dabrowski. **“Fish farmers can increase their productivity from 5% to 12.5% by using our accurate Copernicus Marine based HAB bulletins.”**

Rheticus® is an automatic, cloud-based geo-information service platform, designed by the private company Planetek, based in Italy and Greece, that delivers recent and accurate

## BENEFITS & IMPACTS

data and information, *inter alia* in coastal areas and seawater. The Rheticus® Aquaculture service uses Copernicus Marine products to help farmers identify the best harvesting time in the Mediterranean Sea.

“In 2017, the early breeding season led to a 20% economic loss in value terms versus 2016, due to mass reduction of mussels. Rheticus® would have alerted the farmers and reduced the economic loss by more than 50%.”

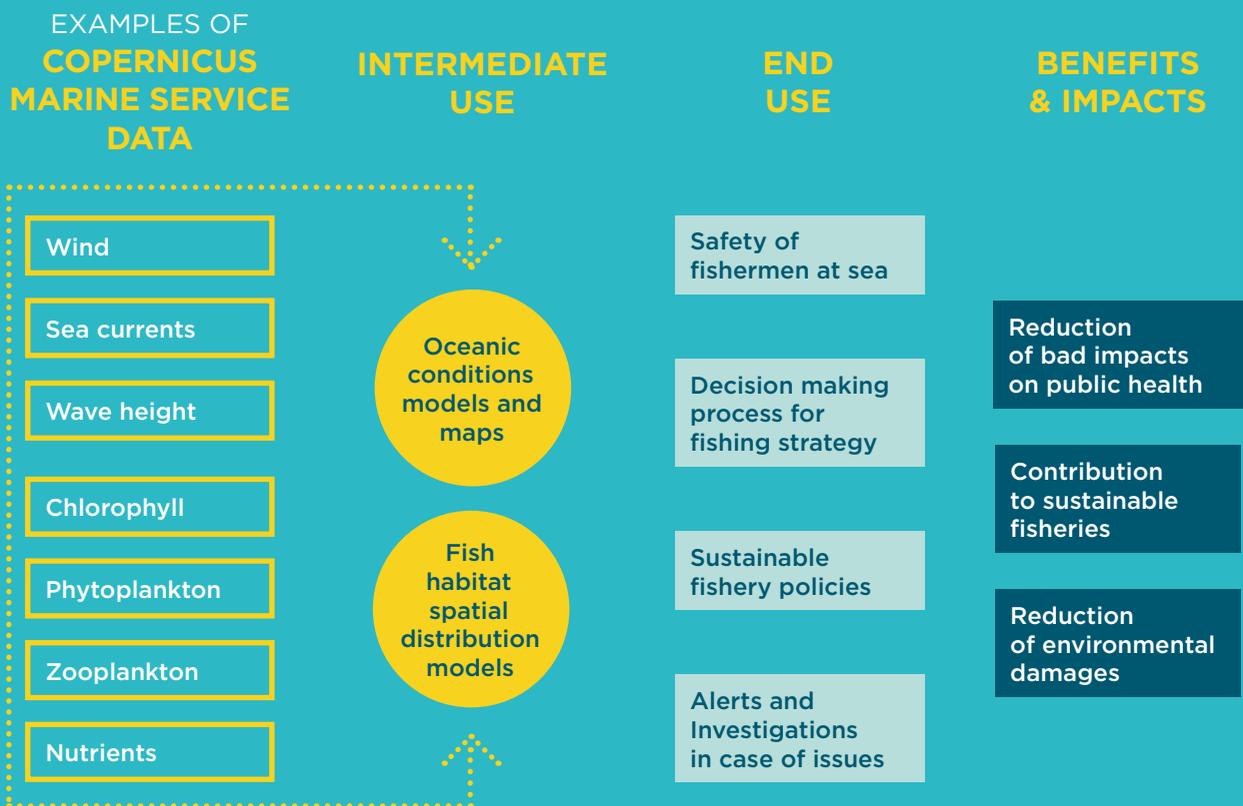
Similar to HAB, jellyfish swarms can also negatively affect aquaculture. Applications based on Copernicus Marine data

such as currents, temperature and ocean colour, have been developed to predict and monitor this phenomenon.

Colombo Sky, located in Verona, Italy, is currently improving its portfolio of aquaculture products, with the JellyX service, a monitoring tool for identifying jellyfish swarms, and predicting their movements, based on knowledge of oceanographic patterns.

“Our system alerts farmers so they have enough time to activate their mitigation plan.”

## FISHERIES MANAGEMENT



Ecosystem-based fishery management is a holistic way of managing fisheries and marine resources by taking into account the entire ecosystem of the species being managed. The goal is to keep ecosystems healthy and resilient. Beyond the Copernicus Marine Service’s contribution to healthy waters, its variables such as temperature, salinity or mixed layer thickness that can affect fish habitats, are used to monitor fish resources. Copernicus Marine’s ocean currents and biogeochemical data such as plankton are used for modelling fish stock or for predicting fish school movements and spawning site distribution.

The MESA Programme in Africa (“Monitoring for Environment and Security”) is part of the GMES & Africa initiative, implemented by the African Union Commission. It aims to increase African capacity in information management, decision making and planning. Forty-eight ACP countries from five African Regions benefit from the MESA programme. Two new services in the West African States (ECOWAS region) led by the University of Ghana support both fishery resource management and forecasting of ocean conditions.



Fresh fish from the sea (Sierra Leone)  
© Lianqin Wang/World Bank

**“ Copernicus Marine Service’s contribution to the services consists of the provision of ocean model and satellite products (sea surface temperature and currents, ocean colour data, in situ data for validation) which allow MESA to publish monthly bulletins and maps of potential fishing zones and oceanic conditions. It benefits fishermen and also policy makers by enabling them to better manage fishery resources along the western African coast.”** ∞

Fishing can both negatively affect the environment and be harmed by changes in the ecosystem.

DEIMOS Engenharia is a private Portuguese Engineering company. It coordinates the SIMOcean project, which is intended to join a Portuguese Government system providing access to national marine data. SIMOcean provides the Portuguese government with a decision-making tool for characterising fishing areas.

**“ Copernicus Marine Service data such as Ocean Colour and Observed Sea Surface Temperature are important data sources for the Fishing Areas Characterisation Service, since they are used as environmental variables to model the possible distribution of sardine and mackerel.**

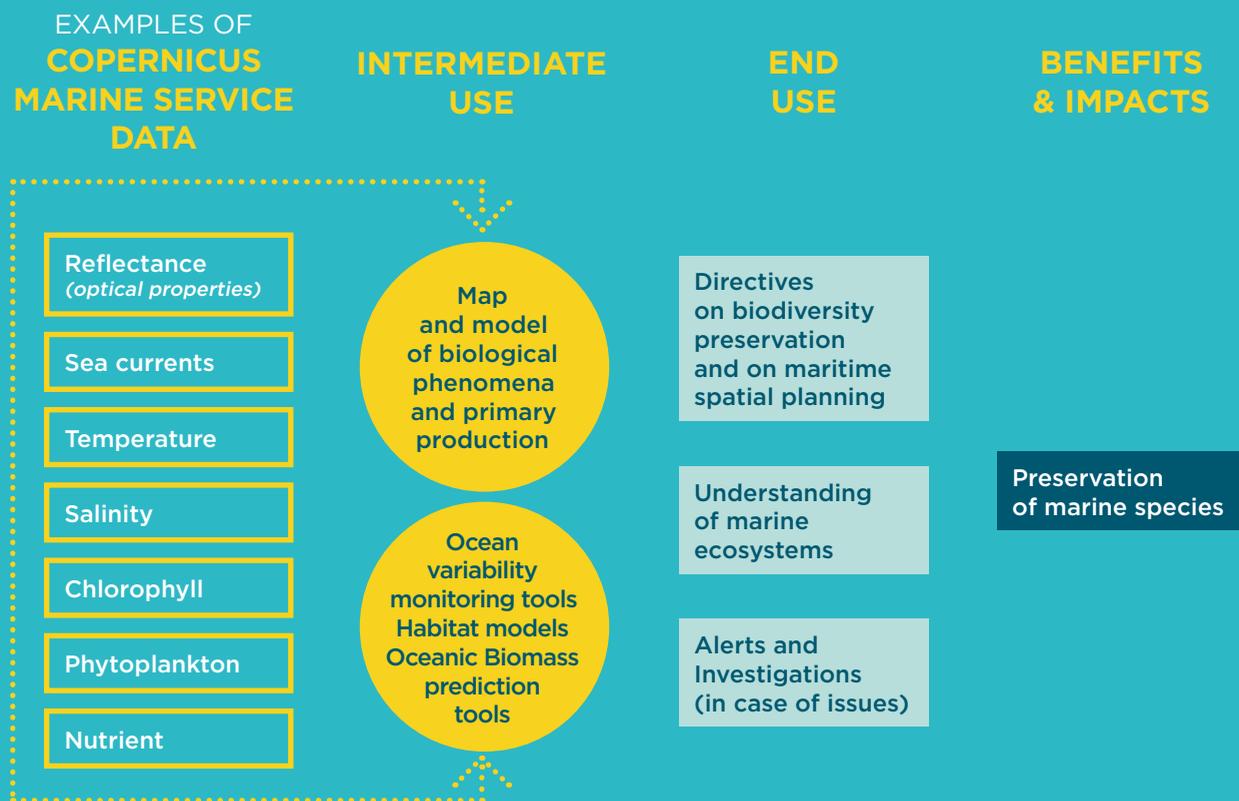
**The Fishing Area Characterisation Service enables the Portuguese authorities to reinforce the surveillance of fishing in areas where sardines are located.”** ∞

Copernicus Marine products are also an important input for modelling the impact of climate change on fishing and aquaculture grounds, so that authorities, fishermen and farmers can identify the best areas for fishing or for installing aquaculture cages.

The Oceanic Fisheries Programme (OFP) of the Pacific Community (SPC) explains:

**“ El Niño events cause an expansion of the western Pacific warm pool to the east, which generally results in an easterly shift in the location of tuna abundance and catches. Oceanographic variables, particularly sea surface temperature, nutrients, primary and secondary production, dissolved oxygen and pH, provided by the Copernicus Marine Service, enable us to update predictive models of tuna abundance.”**

# BIODIVERSITY MONITORING



The ocean contains nearly 200,000 identified species, but actual numbers may be closer to millions. Marine species are seriously affected in many regions and Marine Protected Areas (MPAs) are crucial for maintaining biodiversity and protecting endangered species. Via its Sustainable Goal 14, the UN has fixed a target to conserve at least 10 % of coastal and marine areas by 2020. The Convention on Biological Diversity, drawn up during the first UN Ocean Conference in June 2017, estimates that 5.7% of the global ocean is protected and that the 10% target should be achieved. Still, there are close to 500 marine dead zones covering more than 245,000 km<sup>2</sup> globally, equivalent to the surface of the United Kingdom according to UNESCO.

**The Copernicus Marine Service helps preserve endemic marine species and supports the decision to designate and create protected areas** dedicated to biodiversity such as Natura 2000 sites or MPAs. As the Copernicus Marine Service provides most of the relevant variables needed to monitor the marine environment (salinity, temperature, turbidity, current, etc.), scientists can rely on it to study anthropogenic pressures on specific areas and investigate in case of an abnormal decline of species.

The Store Middelgrund reef in the Baltic Kattegat has been

designated as a Natura 2000 protected area for harbour porpoises. These aquatic marine mammals are found all year round on the reef, with a higher density from May to August and a peak in June. Aarhus University (AU) in Denmark has studied the extent to which the presence of harbour porpoises is linked to variations of their environmental conditions such as ocean salinity, temperature, water currents and chlorophyll-a, obtained from the Baltic Sea physical and biogeochemical models of the Copernicus Marine Service.

Developing human activity at sea also increases environmental pressures. The correlation between sonar exercises and whale beaching has been proven. The Copernicus Marine Service contributes to the monitoring of underwater noise, which can harm sea life, by providing a key input to sound models: the ocean water density.

The Netherlands Organisation for applied scientific research (TNO) participates in the International Quiet Ocean Experiment, aimed at understanding the impact and combatting underwater anthropogenic noise to protect aquatic life. The speed and the propagation of sound in seawater depend on water density (i.e. temperature, pressure and salinity).

**“ The Copernicus Marine Service global model is an accurate tool for providing seawater density, which affects our underwater sound propagation model.”** ∞

The Copernicus Marine Service is also useful for modeling species’ habitats and migrations, that are strongly linked to ocean temperature and currents.

CLS, a worldwide company and pioneer in monitoring and surveillance solutions, along with the Italian Research Council CNR, has developed a model to predict oceanic biomass of micronektons. By monitoring habitats of micronektons, they can monitor habitats of their predators such as marine mammals, turtles, tuna etc.

**“ Copernicus Marine Service ocean temperature and currents products are key inputs for our model, as the development and migration of micronekton are strongly linked to temperature and ocean currents respectively. We also use Copernicus Marine Service global high-resolution models to validate our micronekton model.”** ∞

.....  
Invasive species are impacting marine biodiversity. Be they invasive fish species such as silver-cheeked toad-fish colonising the Eastern Mediterranean basin via the Suez Canal or Sargassum Algae landing in the French Antilles, they threaten native biological diversity and regional economies as well. Copernicus Marine Service contributes to the monitoring systems (bulletins or maps) of national mitigation plans.

.....  
In 2018, the International Year of the Reef, the Copernicus Marine Service supported Coral Guardian, an association dedicated to protect, restore and preserve coral reefs. The association produced awareness-raising materials based on Copernicus Marine Service products. Charting changes in temperature and currents helps to identify reef areas that are at risk and to explain how this can stress the coral. Copernicus Marine Service’s temperature, temperature anomaly and surface current forecasts enabled members of the association to identify in advance the areas that could be affected by the environmental changes. ∞



Coral Guardian’s reef restoration programmes stand out by involving local communities as shown here on the island of Flores (Indonesia).  
© Coral Guardian/Michel Colognoli

## USE CASES

### AQUACULTURE MANAGEMENT

ISPRA, based in Rome, is the Italian Institute for Environmental Protection and Research acting under the guidance of the Italian Ministry for the Environment and the Protection of Land and Sea.

In the framework of the Copernicus Marine Service, ISPRA – in collaboration with OGS Trieste (chapter 2) – delivered “CADEAU”, a downstream service designed for the Northern Adriatic coasts, that are popular for seaside tourism and shellfish aquaculture.

This service transforms biogeochemical and hydrodynamic data into practical information for several end-users. Local authorities use it to regulate bathing safety, while aquaculture farmers are provided with data on water quality and the suitability of areas for shellfish production, e.g. levels of nutrients and chlorophyll-a. They are also informed about the potential impact on shellfish farms of microbial contamination from urban wastewater treatment plants and related risks for consumers. CADEAU has responded perfectly to local demands, which has led ISPRA to offer the same service for other coastal areas in Italy.



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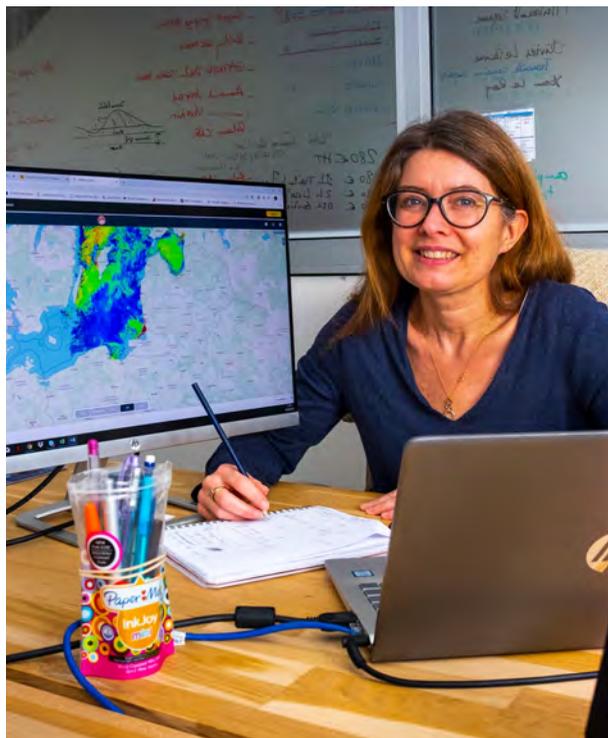


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### AQUACULTURE MANAGEMENT

ACRI-ST provides a range of services, from satellite remote sensing to environmental monitoring and forecasting. ARGANS, a branch of ACRI-ST specialised in Earth science, is developing satellite imagery services.

In collaboration with 7 partners, ARGANS developed the “Service to Aquaculture and Fishery Industry” (SAFI) to provide support for fishery and aquaculture industries in marine coastal regions, targeting users such as industrialists, public authorities in charge of fishery/aquaculture planning, Earth Observation service providers and the general public. Using relevant satellite-based data such as ocean colour and sea surface temperature measurements from the Copernicus Marine Service, SAFI researchers developed useful indicators for fishery management, for instance, concentrations, locations and reproduction of various fish and mollusc species. For the benefit of the aquaculture industry, they developed indicators to enable finding the optimal location of aquaculture cages and suitable water quality. These data are broadcast on a website to the various users concerned.



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## BIODIVERSITY MONITORING

Located in the Nouvelle-Aquitaine region in the south-west of France, i-Sea is a remarkable start-up launched in 2014 by ocean scientists to develop and market services for Water, Biodiversity and Coastal surveillance, supported by data from the Copernicus Marine Service.

The i-Sea team proposes geo-information products and services based on the most recent observation technologies, combining field data with satellite observations. They have contributed to monitoring of the Sargassum Algae landing in the French Antilles and their know-how is now recognised in Europe. i-Sea provides services to local and regional authorities, national agencies such as the French Biodiversity Agency (AFB), port authorities and consultancy companies. i-Sea expects to more than double its turnover in 2019 and its team now counts 9 people with 7 working in space applications.

## FISHERIES MANAGEMENT

The fishing industry needs information about fish migrations to determine where to go out to sea and the best time to do so. By targeting fish, fishermen can save fuel and reduce bycatches (marine species caught unintentionally).

With this in mind, DTU Aqua (the National Institute of Aquatic Resources at the Technical University of Denmark) developed OCEBIS, a free operational web service which maps the best ocean conditions for marine life. OCEBIS provides value-added data layers, for example, maps of marine fronts, based on physical variables supplied by the Copernicus Marine Service. These maps show narrow zones where temperature, salinity, nutrients, etc. vary significantly in space: this makes them potential biological hot-spots with high marine productivity.

OCEBIS is used along the coastline in the North Sea and the Baltic Sea and could also be harnessed in the Mediterranean and the Gulf of Biscay. Copernicus Marine data is of great value for the monitoring and management of fisheries. Services like OCEBIS can facilitate a higher degree of user-uptake in this economic sector.



© DTU Aqua



## MANUEL BARANGE

Director of the FAO Fisheries and Aquaculture Division

# KEY ISSUES FOR NUTRITION AND SOCIAL BENEFITS

For hundreds of millions of people, fisheries and aquaculture are essential sources of nutritious animal protein. World fish consumption per capita has doubled from 9 kg in 1961 to 20.5 kg at the current time. All the fish came from fishery capture in the 60's, and now half of them are produced by aquaculture.

**Fishing and aquaculture also provide jobs and income.** It has been estimated that 10% of the world population relies on them for their living, mainly in Asia and Africa. Moreover, around 90% of fishers work on a small scale, often in the poorest regions of the world where there is no other employment option.

In order to help fisheries contribute to achievement of the UN Sustainable Development Goals, marine resources have to be assessed. The United Nations Food and Agriculture Organisation (FAO) is the

only agency which has been monitoring the state of global marine resources since the 1970's. Its regular scientific assessments indicate that 33% of the global fish stock is now exploited beyond a sustainable level whereas it amounted to 10% in the 1970's. Even though this number has now stabilised, we do not see any sign of it decreasing.

The FAO aims at ensuring that fisheries change their practices to ensure a long-term sustained contribution to food security and a significant contribution to income. To do so, there is a need both to stop overfishing and to protect stocks that have not yet been depleted. The FAO also has to resolve the issue of unmanaged expansion of aquaculture - which can cause pollution and habitat degradation - and thereby promote sustainable aquaculture practices more effectively.

As Director of the FAO Fisheries and Aquaculture Division, my first port of call is to implement and enforce existing and effective policies rather than to define new ones. Mainly due to social conflicts, wars or lack of management and infrastructures, some countries do not have the capacity to monitor, control and enforce these regulations. Moreover, **with climate change, fish stock distribution fluctuates erratically, sometimes from one country to another.** Institutions and industrial market-oriented fisheries have to adapt to these changes. The FAO is here to help them meet those challenges.

**New tools such as applications using satellite and in situ ocean data, models and big data, are extremely useful for advancing scientific knowledge of the ocean and for locating marine resources, particularly tuna.** High-resolution, quality data allow us to estimate the increase in the number of aquaculture farms and ponds

and their aggregated surface area.

To go further and actually transform the way we look at what happens in the ocean, local management realities in the field must be taken into consideration. For example, fishing is managed in a year-to-year annual or bi-annual way by local fisheries. The information provided by the FAO needs to be adapted to this type of management.

**The world population is growing rapidly and aquaculture is one of the ways of transforming energy from feed to plate.**

The natural production of the ocean cannot be enhanced artificially. Aquaculture, the fastest growing food industry in the world, can partly take over and by 2030 it could be producing most of the fish we eat. We need to accompany this transition so that it is as sustainable as possible.

“10% of the world population relies on aquaculture and fishing for their living”



Aquaculture in Mayotte (Comoro Islands, France). Measures to ensure the sustainability of the fishing and aquaculture sectors have been implemented through the 2014 -2020 European Maritime and Fisheries Fund (EMFF).

© Agnès Poiret/Agence française pour la biodiversité



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# POWERFUL OCEAN





### DOMINIQUE RISTORI

EU Director-General, Directorate-General for Energy (2014-2019)

## THE EU'S ENERGY UNION AND THE POTENTIAL OF MARINE RENEWABLE ENERGY

Building a resilient Energy Union with a forward-looking climate policy is one of the main political priorities of the Juncker Commission. Its aim is to deliver accessible, affordable, secure, competitive and sustainable energy for all Europeans.

After 5 years, the policies implemented have put the EU on the right track to fully embrace the clean energy transition, seizing the opportunities that it offers, creating growth and jobs and a healthier environment for our citizens. Europe is already a world leader in fighting climate change, and the complementary measures in the Energy Union bring us in line with our commitments under the Paris Agreement, while ensuring a socially fair transition.

A key component of our policy has been to equip Europe with the world's most advanced energy and climate framework with ambitious targets for 2030. For renewable energy, this means a new and binding target for the EU of at least 32%, including a review clause for an upward revision by 2023. To reach this goal, we shall need all renewable energy sources including the yet largely untapped potential of marine renewable energies.

**Europe is a leader in this field and a natural home for this new industry. Two thirds of ocean energy companies, test centres and installed capacities are located in Europe.** The sector already accounts for 2,000 highly-skilled jobs – 70% of them in advanced research and development. Over the past decade, private developers and public authorities have invested some 3 billion euros in ocean energy in Europe.

Clean energy from the sea is ideal for meeting Europe's ambition to become world leader in renewables, and it is good for our environment. It is a natural energy source that can reduce our fossil fuel dependence while cutting our greenhouse gas emissions. By the middle of this century, some predict that Europe will have an installed capacity of 100 GW, meeting around 10% of the European Union's power demand.

It should be noted that the ocean energy sector is still at the beginning of its development. Compared

**“Two thirds of ocean energy companies, test centres and installed capacities are located in Europe.”**

to offshore wind, which has clearly come of age in Europe, ocean energy is still a relatively small sector. However, several ocean energy technologies, in particular tidal and wave energy, are now at an advanced stage where they can move on from the research phase towards full deployment.

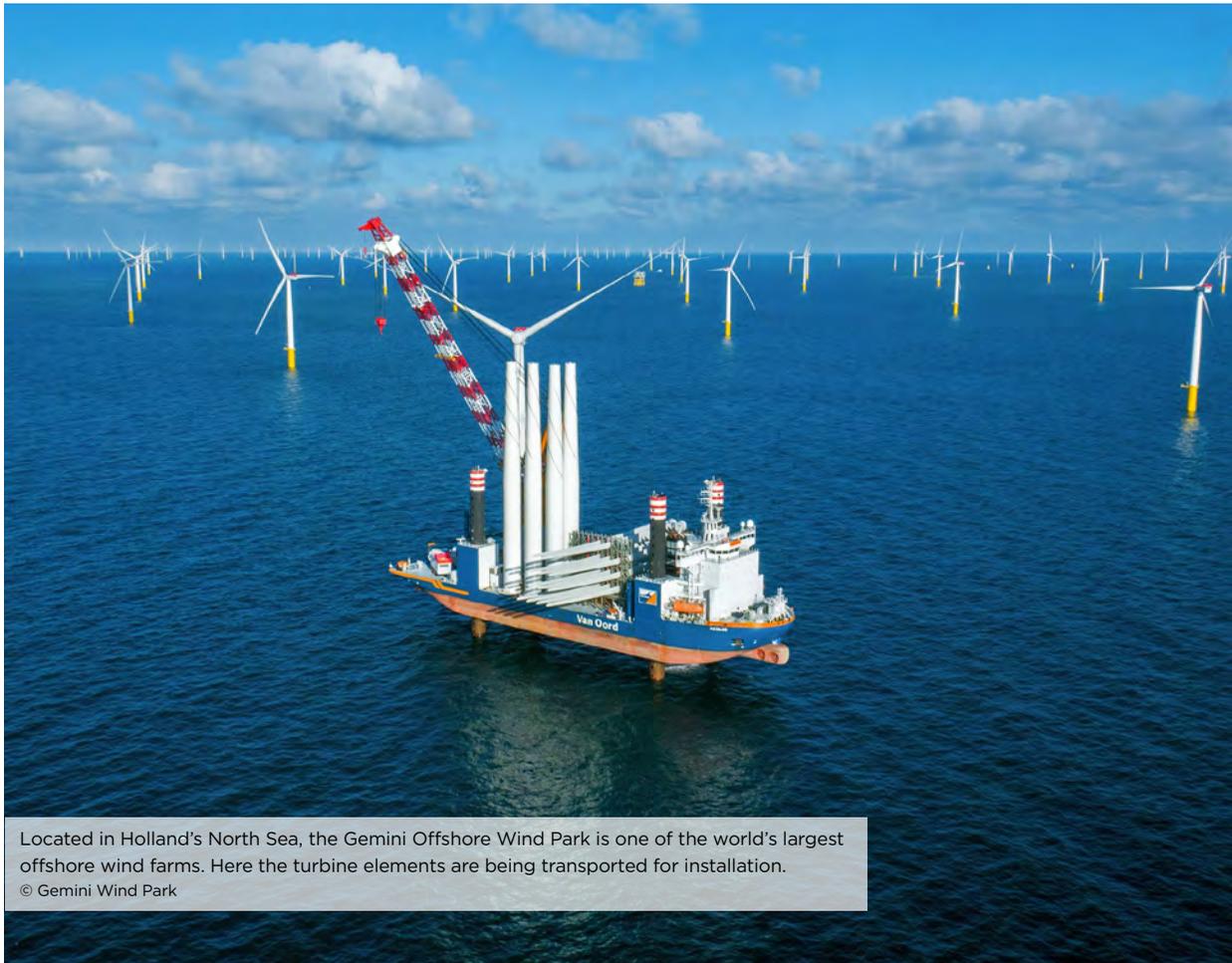
**It is the European Commission's role to support these new technologies and build confidence for investors.** We are directly funding technological developments and test centres to improve reliability and performance. In the new pan-European investment fund for 2021-2027 InvestEU (the successor to the very successful European Fund for Strategic Investments, or "Juncker Plan"), the ocean is explicitly mentioned in its "sustainable infrastructure" category. With match-making events such as the BlueInvest Forum, the Commission tries to bring blue economy companies and investors together.

The EU also helps marine renewable energy to reach its true potential through its Copernicus Earth Observation programme, which provides accurate,

timely and easily accessible information to improve stewardship of the environment, and to understand and mitigate the effects of climate change and ensure civil security. Specifically, **the Copernicus Marine Service provides precise products for the ocean energy sector, helping build Europe's technology leadership in this area.**

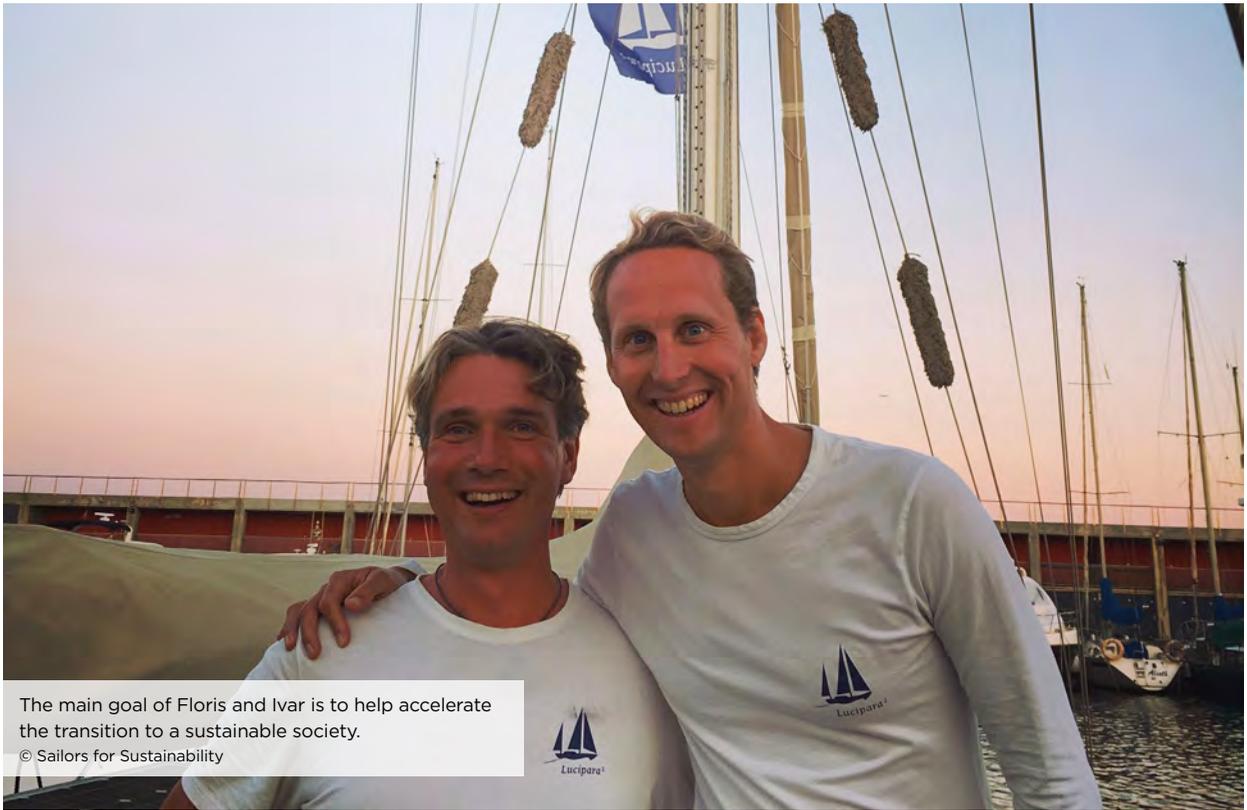
Finally, as part of the Energy Union, the Commission has kick-started a clean islands initiative called "Clean Energy for All EU Islands" to accelerate the clean energy transition of Europe's islands. By tapping into islands' locally available renewable energy sources, such as marine energy, we can make EU islands self-sufficient in energy, reduce environmental pollution and create local growth and jobs.

We believe clean energy from the seas has an important role to play in the future of renewables, and it is now on the EU's political agenda. As part of a clean and secure energy transition and a sustainable future, we have to look after our seas and ocean and use them wisely.



Located in Holland's North Sea, the Gemini Offshore Wind Park is one of the world's largest offshore wind farms. Here the turbine elements are being transported for installation.

© Gemini Wind Park



The main goal of Floris and Ivar is to help accelerate the transition to a sustainable society.

© Sailors for Sustainability



## SAILORS FOR SUSTAINABILITY, CONNECTING COMMUNITIES

Sailors for Sustainability, Ivar and Floris left Amsterdam in June 2016 to sail around the world in search of sustainable solutions. *“We are concerned about the precarious state of our natural world and the increasing social inequality. To stimulate cooperation and motivate people and communities to change their habits we search for and share sustainable and practical solutions”,* says Ivar.

They chronicle their trip through their website, social media networks, press articles and videos. Some partners are supporting the sailors’ mission by publicising the solutions, yet their sailboat *Lucipara 2* and the trip are mostly financed with their own savings.

*discovered that marine renewable energies are an important part of the energy transition”,* Floris points out.

*“When combined with other forms of renewables, they can provide a constant, reliable and safe part of the energy mix for specific locations.”*

After crossing the Atlantic, sailing around South America, then across the Pacific to Oceania and Asia, the Sailors for Sustainability will return to Amsterdam. *“We hope that we will inspire many people, companies and governments to follow the numerous sustainable examples we find”* say Ivar and Floris.

*“In the Scottish Orkney archipelago we*

**Interview by Richard Clavud**

# AN OCEAN OF POWERFUL RESOURCES

European seas and the global ocean have enormous potential as a source of renewable energy, particularly along the Atlantic coast. Technologies are being developed to convert the ocean energy in tidal streams and waves, as well as to exploit the differences in temperature and salinity of the ocean and seas. Given the resources available, by 2050 up to 10% of the projected European electricity demand could be delivered by ocean energy, avoiding the equivalent of 276 million tonnes of CO<sub>2</sub> emissions per year, and thus contributing to the decarbonisation of the EU energy system. From a societal perspective, **the development of the ocean energy sector is expected to stimulate investment and job creation in coastal areas, in one of the developing domains of the blue economy.**

The ocean energy market is still at an early stage compared to other renewable energy technologies. Currently, ocean energy capacity has reached 0.1% of its potential with about 40 MW installed globally (excluding tidal barrages). About 78% of these installations are in European Waters, where this nascent industry provides an estimated 2,250 jobs across 430 companies.

The European Commission (EC) supports the development of ocean energy technologies through the Energy Union, the Strategic Energy Technology Plan (SET-Plan), and the Blue Growth Strategy policy initiatives. To stimulate the development of ocean energy, the EC provides support through different programmes, such as Horizon 2020, which promotes technology development, the Innovation Fund (one of the world's largest funding programmes

for climate action) and the European Investment Bank's programme, InnovFIN (for market uptake), and regional-scale programmes such as Interreg.

The European Commission's Joint Research Centre (JRC) helps to implement EU ocean energy policies. It assesses the current status of the sector, identifies gaps that are hindering the development of ocean renewable energy, and suggests activities and actions to overcome them, by providing input to EC initiatives.

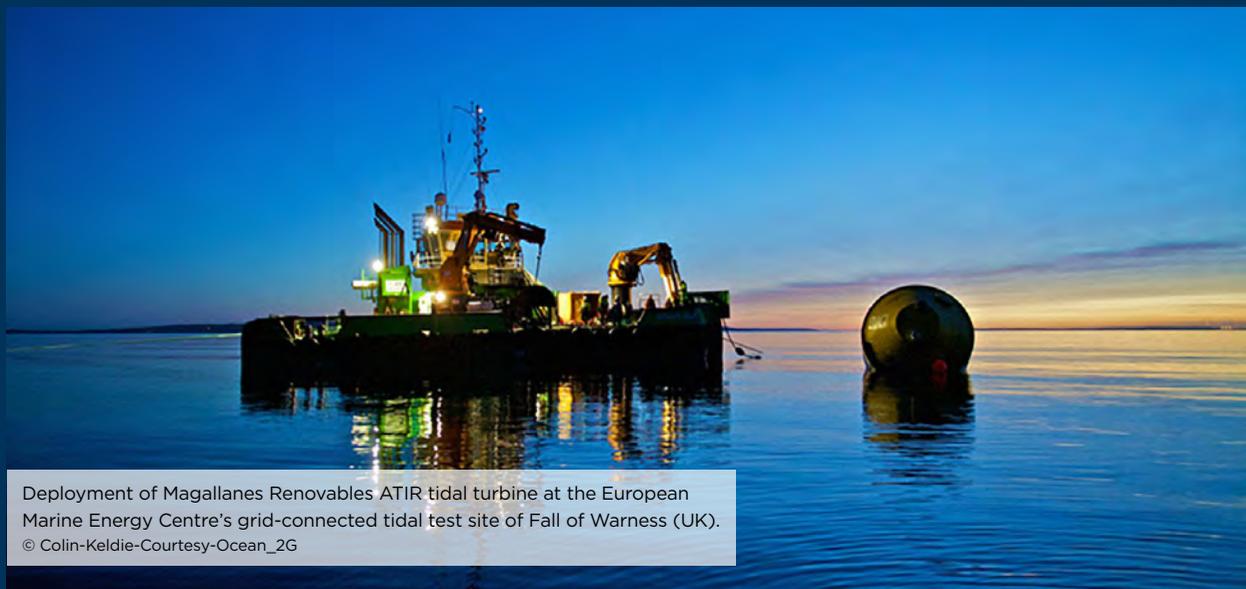
“By 2050 up to 10% of the projected European electricity demand could be delivered by ocean energy”

Since 2014, the Horizon 2020 programme has supported 44 projects with more than €165 million, focusing mainly on the development and demonstration of tidal and wave energy technologies. The emphasis is on the performance, reliability and survivability of ocean energy converters, whilst ensuring that cost-reduction pathways are found. In this context, **informed design of ocean energy converters relies on the availability of vast amounts of data.** The Copernicus Marine Service provides ocean energy developers and researchers with current and historical data sets that are extremely valuable in this respect, such as sea conditions (wave height, storms) and current velocities.

The combination of EU support and the data provided by the Copernicus Marine Service could help Europe take full advantage of its ocean energy potential.

**DAVIDE MAGAGNA**

Scientific Officer - European Commission  
Joint Research Centre



Deployment of Magallanes Renovables ATIR tidal turbine at the European Marine Energy Centre's grid-connected tidal test site of Fall of Warness (UK).  
© Colin-Keldie-Courtesy-Ocean\_2G



*The energy sector is undergoing an unprecedented revolution with the transition from fossil fuels to renewables. This will reduce global warming, our impact on the planet and generate massive advantages: a less centralised energy network with both economic benefits and jobs spread across a broader geographic and population base.*



## OCEAN ENERGY, EUROPE'S NEXT INDUSTRIAL SUCCESS

Wind and solar photovoltaic energy have become mature and cost-competitive sources of power. They do not need heavy (or potentially any) subsidies, to compete with fossil fuels. Forecast models and the flow of investment capital show this trend is here to stay. The only questions remaining are what the mix of this New Renewable World will look like and how long it will take.

In 2008, DP Energy (a renewable energy and sustainable development specialist operating in sites around the world) added Ocean Energy to its Wind and Solar Energy portfolio, convinced that systems including tidal and wave energy and also Ocean Thermal Energy Conversion (OTEC), once they are commercially mature, can be a valuable part of the overall energy system.

Mixed generation-technology hybrid projects will become the new “conventional” generation, which will be supported by the expansion of battery storage capacity and the reinvigoration of other storage mechanisms including pumped hydro plants. Whether this is storage with wind/solar, wind/tidal, wind/wave, solar/tidal or other will depend on the resource and geography and the economics of the overall kWh output. **How long the transition takes will depend on the economics of the technologies and on societies' willingness to accept the transition and its benefits.**

DP Energy has been actively involved in the Ocean Energy sector for some ten years, supporting ocean technologies and developing its projects in Scotland, Northern Ireland and Canada. We believe the sector has the potential, along with wind and solar, to become one of Europe's next industrial success stories: **ocean energy alone could create 400,000 jobs in Europe by 2050 and is potentially worth billions in export opportunities for European companies.**

The EU has been incredibly helpful politically and financially in bringing ocean energy to its current level of maturity, and the Copernicus Marine Service is another valuable EU asset for developing the market. What is needed now is market visibility and revenue support at the national level to reap the benefits of years of R&D. It is becoming more and more urgent to kick start our European home market and ensure the development of our industrial champions.

**“How long the transition takes will depend on the economics of the technologies and on societies' willingness to accept the transition and its benefits.”**

**SIMON DE PIETRO,**  
CEO OF DP ENERGY





# THE OCEAN, A MOST UNDERVALUED RESOURCE FOR MEETING ENERGY DEMAND



**30%**  
Share of global renewable energy capacity vs global power capacity in 2019 (~2,350 GW in 2018)  
[www.irena.org](http://www.irena.org)



**60%**  
Part of the Energy Sector in the global CO<sub>2</sub> emissions in 2017 (33 Gt)  
[www.iea.org](http://www.iea.org), [www.ipcc.ch](http://www.ipcc.ch)



**x 7**  
Global investment in Renewable Energy from 2004 to 2015 (USD 50/348 billion)  
[www.irena.org](http://www.irena.org)

## MARINE RENEWABLE ENERGY 2018

**0.1%**  
Share of global investment in Marine Renewable Energy

**x 2**  
Installed Marine Renewable capacity between 2010 and 2018 (532 MW)  
[www.irena.org](http://www.irena.org)

**3%**  
Estimated increase of electricity generated from marine technologies in 2018  
[www.iea.org](http://www.iea.org)



**24%**  
Annual growth rate required from electricity generated by marine technologies to meet 2030 Sustainable Development Scenario (SDS)  
[www.iea.org](http://www.iea.org)

## MARINE RENEWABLE ENERGY BY 2050

**300**  
GW Global installed capacity  
[www.oceanenergysystems.org](http://www.oceanenergysystems.org)



**0.7 million**  
direct jobs to be deployed globally  
[www.oceanenergysystems.org](http://www.oceanenergysystems.org)



The Gwynt-Y-Mô' (Sea Wind) 576-megawatt offshore wind farm is located off the coast of North Wales.  
© Tim Laws, WaterPIX/EEA

## INTRODUCTION AND CONTEXT

Since the early 2010s, a large emphasis has been put at both the international and European levels on the reduction of greenhouse gas (GHG) emissions, a large part of which is due to the energy sector. Transitioning from the use of polluting fossil energies to renewable energy is essential for reducing toxic emissions, as set by the Paris Agreement (COP21). The EU 2030 climate & energy strategy includes EU-wide targets and policy objectives for the period from 2021 to 2030, namely at least a 40% cut in greenhouse gas emissions (from 1990 levels), at least a 32% share for renewable energy and at least a 32.5% improvement in energy efficiency.

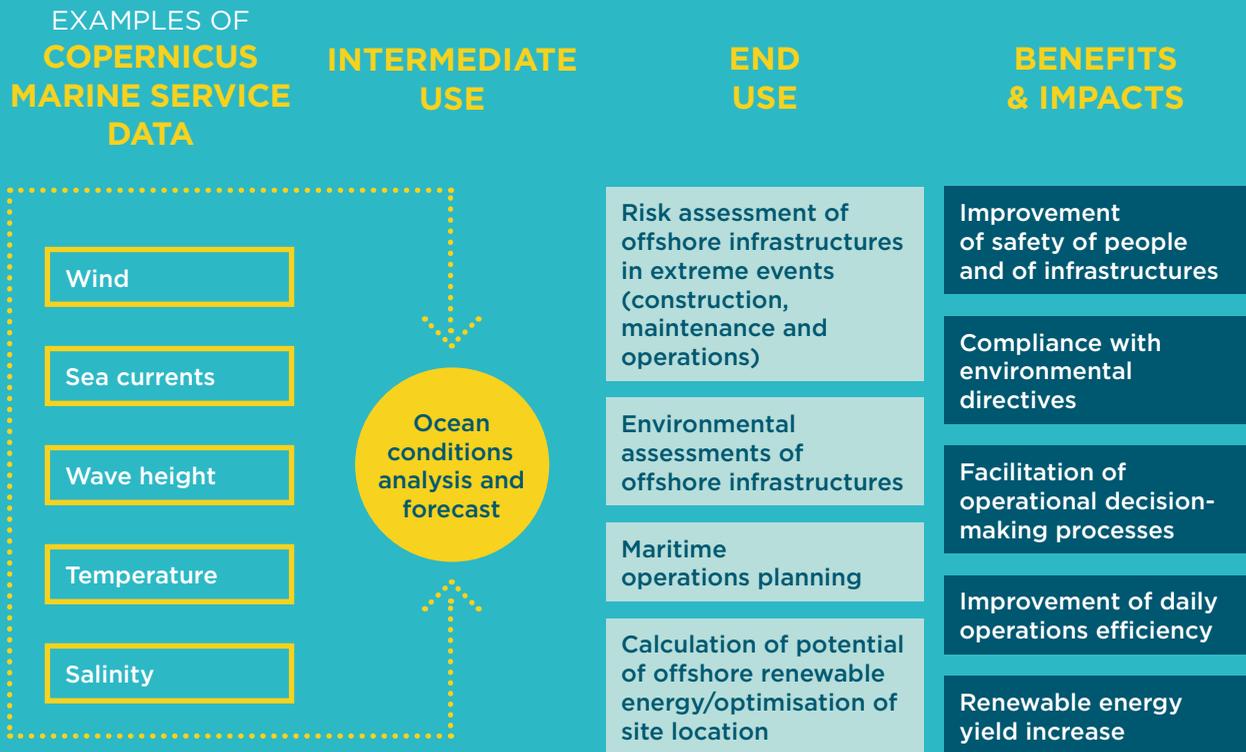
The ocean still has potential for offshore fossil energy exploitation and Copernicus Marine Service products are used by many downstream services in this sector. Nevertheless, demand today outstrips supply. Huge efforts must be therefore undertaken to develop the Marine Renewable Energy sector.

A third marine energy sector is currently emerging but will not be covered in this section: biomass management. There is great potential for marine biomass resources to be used for energy production. Seaweed and algae for example are transformed into biofuels, enabling more renewable energy generation (and thus fewer toxic emissions) or the freeing-up of land-used biomass that could then be used for cultivation. Copernicus Marine Service products are apparently little used in this sector, but that might change shortly, in particular for helping companies assess and locate potential biomass production areas.

This section focuses on two energy-related fields to which the Copernicus Marine Service brings value:

- Offshore renewable energy production
- Fossil energies infrastructure management

# OFFSHORE RENEWABLE ENERGY PRODUCTION



The ocean offers substantial sustainable resources for renewable energy production, among which: offshore wind, tidal currents, waves, temperature and salinity gradients, deep cold sea water. Whatever the technologies used to harness energy in the ocean, Copernicus Marine Service models and observations (using long time series or their forecasts) are needed to estimate ocean energy yields, to minimize the risks for operations at sea (i.e. construction or maintenance operations) and to contribute to the mandatory environmental assessment and monitoring of offshore sites.

For any offshore renewable energy infrastructures, the Copernicus Marine Service provides support for preliminary phases before construction of the farms (exploration, marine resources evaluation, environmental impact assessments, etc.) and then for operating phases such as maintenance operations, by providing reliable knowledge of ocean conditions (currents, sea level, sea surface height and temperature). **For tidal energy**, which is currently taking off in Northern Europe and **wave energy**, Copernicus Marine Service currents and wave forecasts are also cost drivers for operational feasibility studies.

.....  
 A Master’s thesis at the Piraeus University of Applied Sciences in Greece has been undertaken to estimate wave energy resources in the North Aegean Archipelago.

**“All islands in the North Aegean Archipelago face water and energy related issues due to limited resources and obsolete infrastructures. Problems are more intensive during the mass tourism in summer that increases the population by up to 700%. The Copernicus Marine Service wave model for the Mediterranean Sea has been used to estimate the wave energy potential. It determined that Skyros Island is the most suitable place to develop a wave energy farm.”**

.....  
 Tropical Islands are looking for energy autonomy for cost and environmental reasons. Since it covers 70% of our globe, the ocean is the world largest solar collector. This solar energy is captured as heat in the upper layers of the ocean. Ocean Thermal Energy Conversion (OTEC) exploits

## BENEFITS & IMPACTS

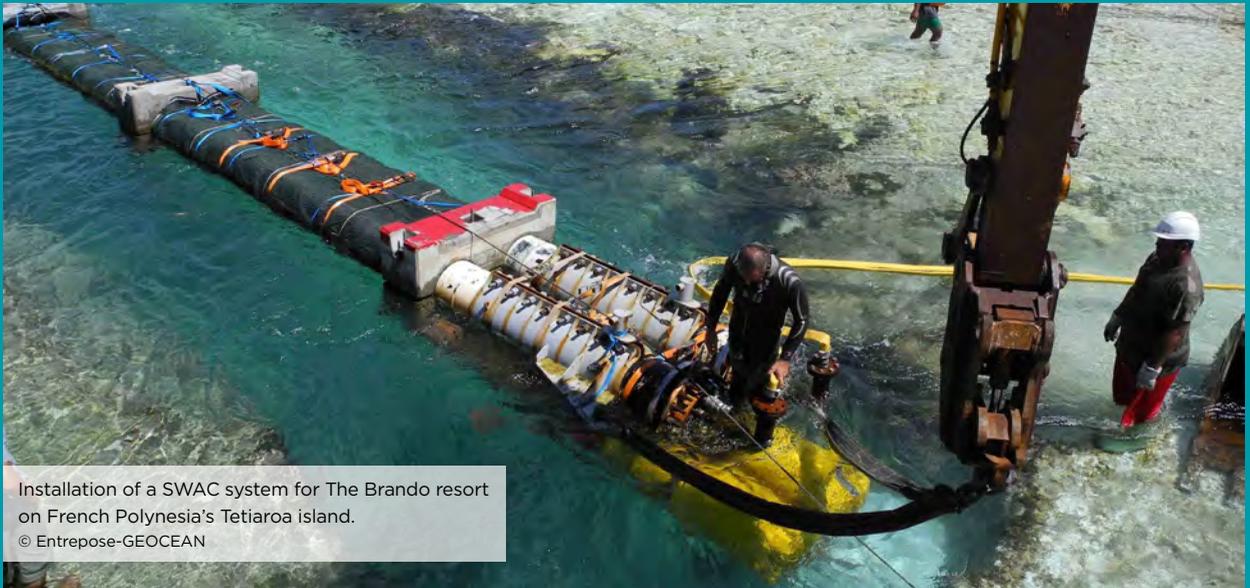
the difference in temperature between deep and surface ocean waters to produce electricity (e.g. for heating public buildings such as hospitals).

Sea Water Air Conditioning (SWAC) takes advantage of deep cold water for air conditioning purposes, for hotels in particular. Both technologies offer highly relevant opportunities in tropical islands where a vast reservoir of cold oceanic water is available close by.

Deprofundis is a private company specialised in ecological air conditioning technology using cold water. Deep cold sea water is pumped to the surface and passes through a heat

exchange system to cool down the air conditioning network. The pumped water is finally released back into the ocean.

**“The SWAC system provides low operating costs for residential, commercial and public buildings and facilities located along the coast and saves energy consumption by 80 to 90% compared to regular air conditioning systems. Copernicus Marine Service temperature fields from ocean models and in situ observations are crucial for qualifying SWAC potential and yields around the world. Currents are also very relevant to our business for securing the underwater cables and pipes used to pump deep sea water.”** 



Installation of a SWAC system for The Brando resort on French Polynesia's Tetiaroa island.  
© Entrepose-GEOCEAN

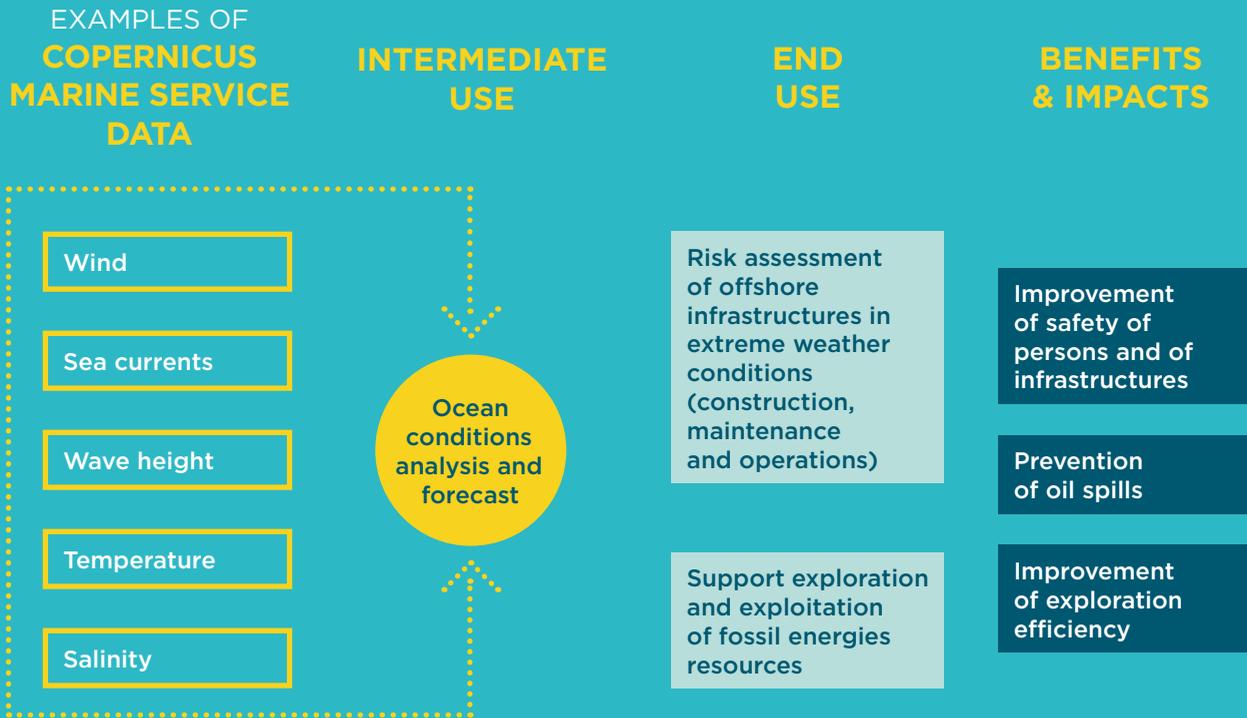


© Maura Tronci

My name is Angélique Melet. I'm an oceanographer at Mercator Ocean International and I'm in charge of the Copernicus Marine Service "Service Evolution" programme.

This programme supports scientific and technical developments of the service that are required for its future, to provide that its operating systems and products continue to be state-of-the-art to ensure the best possible response to existing and emerging user needs. Projects funded as part of the Service Evolution cover broad scientific issues, including ocean circulation, ocean-sea ice-wave-atmosphere interactions, biogeochemistry and ecosystems, seamless interactions between the Copernicus Marine Service and coastal modelling systems, and ocean climate change. Marine energy is one of our major benefit areas. Several Service Evolution projects have led to more accurate Copernicus Marine Service information on ocean currents, waves, or salinity and heat content, which are key for the marine energy sector. In particular, the on-going LATEMAR project, led by the Italian National Research Council, aims at producing information on maximum wave heights, for instance during storms, which could be useful for management of offshore infrastructures and the wave-based marine energy sector.

# FOSSIL ENERGY INFRASTRUCTURE MANAGEMENT



Offshore oil & gas infrastructures need to be kept under careful surveillance.

Extreme events (such as extreme waves) can lead to injuries of workers on site and can furthermore affect the functioning of the platform/rig. Damage on platforms can also result in oil spills that are detrimental to the environment (see the Healthy Ocean chapter).

Copernicus Marine Service data, mostly wave, wind and current analyses and forecasts are used as *metocean* information in Geographic Information Systems (GIS) for safety prevention or safety monitoring activities.

**OPEN OCEAN**, a French company specialised in decision-making tools for offshore oil & gas and renewable energy applications, has developed a Copernicus Marine Service-

based dashboard called *Metocean Analytics*, providing information on oceanic conditions and collecting data from various sources in order to contribute to the monitoring of operations. [↗](#)

**CGG**, a large geoscience group specialised in marine seismic operations, serves oil & gas companies around the world, from frontier exploration to the renewal of existing fields.

**“Today, Copernicus Marine Service information is used as a complement to dedicated weather forecasting services, before the seismic survey, to assess operational risks, identify performance issues and trigger external support in case of anomalies arising and then during the seismic survey to support operation performance and trigger safety decisions.”** [↗](#)

## USE CASES

### TIDAL ENERGY

Noveltis is a private company based in Toulouse (France). It is specialised in scientific engineering studies and the implementation of customised end-user solutions in the fields of space, the environment and sustainable development, with noteworthy expertise in tidal modelling to enable the use of marine renewable energy.

Using Copernicus Marine Service satellite data and in situ data to validate their high-resolution tidal models, Noveltis developed TidEa, a free service intended for stakeholders of the maritime shipping and marine renewable energy sectors. TidEa provides a global atlas with several indicators that are updated regularly, such as maximum current speed and average power density, which enable its users to identify the most promising areas for harnessing tidal energy on a global scale. Such valuable and detailed information facilitates the decision-making process leading to the installation of turbines. By using the force of marine currents (mainly tides), turbines generate mechanical energy that in turn produces renewable and inexhaustible electricity.



© Javier Bernal Revert



© Bluerise

### SUSTAINABLE ENERGY FROM THE DEEP OCEAN

Ocean Thermal Energy is one of the world's largest ocean power resources available, particularly in the Tropical areas. Ocean Thermal Energy Conversion (OTEC) and Sea Water Air Conditioning (SWAC), two marine renewable energy technologies, are both core activities of Bluerise, a company based in Delft (the Netherlands).

OTEC uses the difference in seawater temperature between the surface and deep layers to generate electricity, whereas SWAC consists in pumping up cold, deep sea-water from around 1000 meters in depth to cool buildings such as hotels, hospitals, airports, data centres and greenhouses.

Bluerise is currently working on a deep sea-water cooling technology project in Jamaica to provide hotels in Montego Bay with an entirely self-sufficient energy system. The Copernicus Marine Service temperature data is fed into their expert software to identify and monitor the best intake locations, ocean temperature profiles and yearly fluctuations that may affect the performance of the cooling plants.



© Jean-Dominique Dallet

## UNDERWATER NOISE FORECASTING AND MONITORING

Quiet Oceans is a private company based in Brest (France) and specialised in the forecasting and monitoring of underwater noise, which is regulated in Europe through the EU Marine Strategy Framework Directive.

Human activities along the coasts or offshore generate sounds that propagate very well in the ocean, better and at much longer distances than in the air, thus affecting marine ecosystems. This propagation is affected by variables like temperature and salinity. Using such data provided by the Copernicus Marine Service, as well as the surface roughness needed to calculate the noise produced by waves, Quiet Oceans is able to produce high quality, underwater noise maps.

Besides providing governments with sound maps needed to meet regulatory requirements, Quiet Oceans also supports maritime industries by undertaking noise impact assessments and providing risk mitigation solutions. Project managers are thus guided during the decision-making process, to enable them to manage the impact on marine fauna produced by the development of their projects, such as the installation of marine renewable energy infrastructures, in a sustainable way.

## MARINE RENEWABLE ENERGY FOR AQUACULTURE

The European Parliament and the European Council have adopted legislation to create a common framework for maritime spatial planning in Europe. Maritime Spatial Planning (MSP) works across borders and sectors to ensure that human activities at sea take place in an efficient, safe and sustainable way.

IHCantabria, the Environmental Hydraulics Institute based in Santander (Spain) and specialised in both fresh and saltwater research, has implemented an MSP tool fed by Copernicus Marine Service data (waves and currents) designed to identify opportunities for the co-location of marine RENEwable energy and AQUAculture facilities (hence the service named "RENAQUA"). How can such different activities be related? The answer is quite simple: areas that are suitable for both infrastructures might have similar environmental requirements. RENAQUA is a practical tool that defines the areas where such requirements are met and thus helps optimise the use of maritime space. As a result, in co-located aquaculture farms and offshore energy plants, operation and maintenance costs are reduced for both parties, in a win-win approach.



© IHCantabria/Jerónimo Alba



## RÉMI GRUET

Chief Executive Officer, Ocean Energy Europe

# BLUE IS THE NEW GREEN

The European Union (EU) imports over half the energy it consumes, spending €266 billion a year on imports of fossil and nuclear fuels. Not only does the EU's dependence on expensive, polluting fuel weaken its determination to decarbonise, it also weakens its political power, as imports often come from autocratic regimes and unstable regions.

**Ocean energy, along with other renewable sources, can provide a real alternative of clean, indigenous and secure power.** Blessed with some of the greatest ocean energy resources in the world, the EU could slash its fuel bill and make the most of the potential of its own seas.

In 2050, the EU's energy landscape will look very different from today. Moving towards an electrified, carbon-neutral system means significantly increasing the uptake of renewable energy, with 80-100% of the future electricity supply set to come from clean energy sources.

With wind and solar power as the mainstays of the future energy market, other renewables will be needed when the wind drops, or the sun doesn't shine. Ocean energy is a perfect choice to complement the others, with each technology contributing to the system.

Tidal energy is fully predictable — even hundreds of years into the future. Wave energy devices capture the energy from the wind-whipped sea, with swells continuing to provide power even after the wind has dropped. For fully flexible, on-demand electricity, ocean thermal energy conversion (OTEC) and salinity gradient technologies can deliver non-stop power and can be ramped up or down as needed.

The EU has a rich resource of clean, predictable ocean energy — and it will be needed, as its energy transition accelerates. The industry estimates that 100 GW of wave and tidal energy capacity can be deployed in Europe by 2050, which would meet around 10% of its electricity consumption.

**According to Ocean Energy Europe forecasts, this would create 400,000 jobs.**

The vast majority of this employment will directly benefit the European economy, be it through local jobs in coastal areas or further afield in the extensive supply chain.

As with wind turbines, ocean energy devices need to be assembled close to where they are installed, and deployed using specialised infrastructures, crews and vessels. This means a new lease of life for Europe's coastal communities, strengthening their highly-skilled workforce and using the compatible infrastructures of traditional shipbuilding, fishing and oil & gas industries. The supply chain is truly European, with components, materials and specialist services coming from countries across the continent, whether or not they have a coastline.

With 66% of the world's tidal energy patents, and 44% of its wave energy patents registered in the European Union, it is already a global leader since most projects around the world use its technology.

The EU can convert this first-mover advantage into export success and become a dominant force in a market projected to be

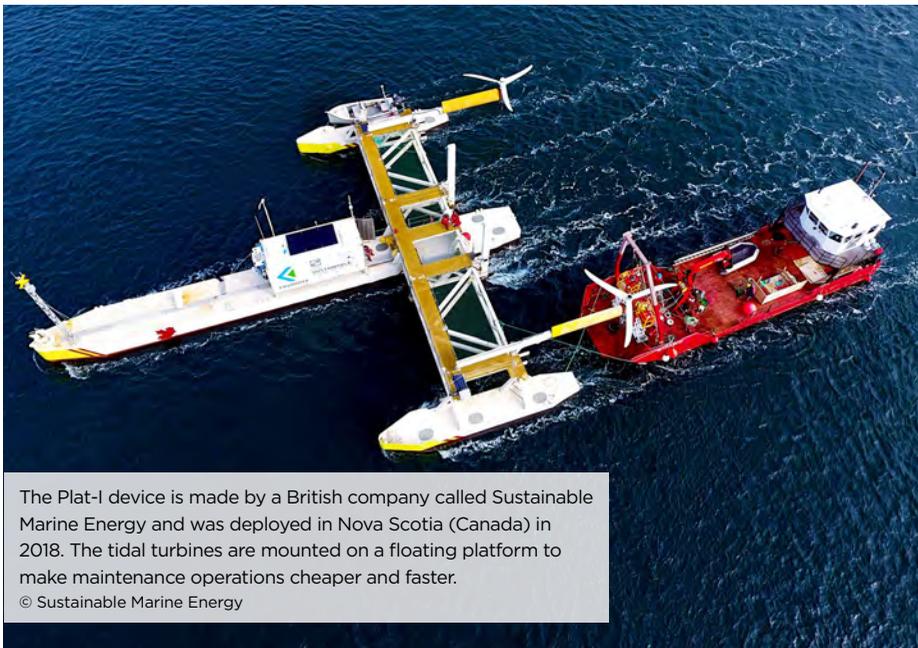
worth €53 billion per year by 2050. This is a real opportunity to export its successful offshore wind energy technology. Thanks to their foresight and early investment in the then emerging offshore wind energy sector, European wind turbine manufacturers Siemens and Vestas were able to secure 95% of the current global market. The EU also consistently exports €7-€8 billion of wind energy goods and services each year. The stage is now set for the EU to play the leading role in developing ocean energy across the globe.

This growing industry needs reliable and precise marine data at each phase of an ocean energy project. Resource assessment, installation, operations and maintenance, environmental impact assessment and decommissioning all require accurate marine and *metocean* data.

**Copernicus is the only service providing worldwide data on ocean energy resources.**

Both wave and tidal developers are already using its products to find suitable sites for projects in Europe and beyond.

“100 GW of wave and tidal energy capacity can be deployed in Europe by 2050, which would meet around 10% of its electricity consumption.”



The Plat-I device is made by a British company called Sustainable Marine Energy and was deployed in Nova Scotia (Canada) in 2018. The tidal turbines are mounted on a floating platform to make maintenance operations cheaper and faster.  
© Sustainable Marine Energy



06

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# OCEAN CLIMATE





### PIERRE-YVES LE TRAON

Scientific Director, Mercator Ocean International

## THE OCEAN, A KEY PLAYER IN THE EARTH CLIMATE SYSTEM

Over the past 50 years, more than 90% of the heat added to our climate system, predominantly by the burning of fossil fuels, has been stored by the ocean, which is also reducing the rate of climate change in the atmosphere by absorbing about 30% of human emissions of carbon dioxide. These fundamental buffering effects are not without consequences on the health of the ocean. It is warming, sea level is rising and sea ice is shrinking. The ocean is also becoming more acidic due to CO<sub>2</sub> absorption and less ventilated due to surface warming. These changes will have an even greater impact on marine ecosystems and marine resources, which are already subject to strong pressures from other human activities, including pollution and overfishing.

The development of systematic observations of the global ocean over the past decades has increased our understanding of its fundamental role in regulating the Earth's climate, thus enabling an unambiguous diagnosis of climate change and its impact on the ocean. However, it remains vastly undersampled. **There is an imperative need to improve its observation and monitoring** to enable us to detect and determine the impact of climate change on the ocean and to predict

the long term evolution of our climate. This is also essential for sustainable management of the ocean and its resources and to enable informed political decisions on how to attenuate and mitigate climate change and adapt to it.

To address these ocean and climate monitoring challenges, the Copernicus Marine Service provides a comprehensive and high-quality retrospective description (covering 30 years) of the ocean state for the global ocean and European regional seas. These long time series of ocean data are based on satellite and in situ (at sea) observations (reprocessing of past observations) and on models (reanalyses that merge observations with models through data assimilation techniques). They cover physical parameters (e.g. sea level, temperature, salinity, and currents), sea ice (e.g. sea ice concentration, drift, thickness) and biogeochemistry parameters (e.g. oxygen, pH levels and carbon concentration, nutrients and phytoplankton). The Copernicus Marine Service products are used to monitor and report on past and present marine environmental conditions, in particular, the response of the ocean to climate change and other stressors. They also provide detailed and high-

quality descriptions of the ocean state to initialise coupled ocean/atmosphere models to predict changes in the atmosphere/climate. **Each year the Copernicus Marine Service publishes an Ocean State Report that provides reliable information on changes and variations of the global ocean and European regional seas over the past decades.** The reports rely on the unique capability and expertise of the Copernicus Marine Service in Europe to monitor and assess past and present marine environmental conditions. They are based on Ocean Monitoring Indicators that are used to monitor oceanic trends in relation to climate change, including ocean warming, ocean acidification, sea level rise and melting of sea ice. These activities are organised in close cooperation with the Copernicus Climate Change Service.

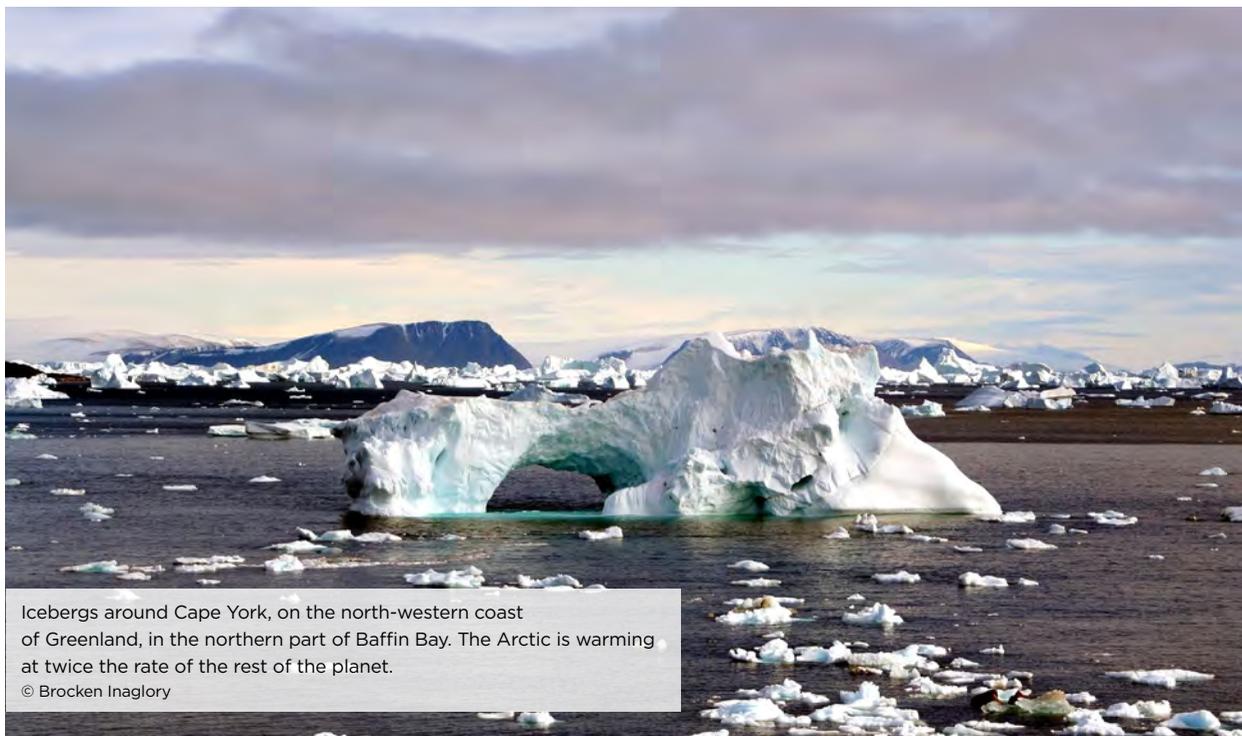
**The Copernicus Marine Service ocean and climate products and assessments are used to inform European policy-makers, and environment and climate reporting agencies** (e.g. the European Environment Agency/EEA, the Intergovernmental Panel on Climate Change/IPCC and the Global Ocean Observing System/GOOS). They are used by public and private sectors for the development of downstream services (e.g. coastal zone management, fishery management, and development of renewable marine energy) and

by the scientific community to better understand and characterise climate change impacts on the ocean, and biodiversity in particular, on marine ecosystems and marine biodiversity. Last but not least, they are a reliable source of information for the general public, including citizens, education professionals and the media.

Observations provide fundamental data to the Copernicus Marine Service value chain that includes all the steps from observation to information. The quality of our products and assessments are highly dependent on the availability of comprehensive satellite and in situ observations. The continuity and improvement of satellite (in particular the Copernicus Sentinel missions) and in situ observing systems are essential. New Copernicus

Sentinel missions are required, particularly for more detailed observation of the rapidly changing polar areas. Key in situ observations of the deep ocean, ocean biogeochemistry and the coastal ocean are also lacking. The development of the new phase of the Argo international programme (global array of profiling floats) with an extension to the deep ocean (Deep Argo) and biogeochemistry (BGC Argo) is thus a strong priority for the Copernicus Marine Service.

“There is an imperative need to improve ocean observation and monitoring.”



Icebergs around Cape York, on the north-western coast of Greenland, in the northern part of Baffin Bay. The Arctic is warming at twice the rate of the rest of the planet.  
© Brocken Inaglory



Jakob Tobiassen,  
an Inuit fisherman in the Arctic.  
© Pierre Taverniers



## LIVING WITH CLIMATE CHANGE IN THE ARCTIC

Jakob Tobiassen, 55, a fisherman, lives in Qeqertaq, a small community north of Disko Bay on the west coast of Greenland. The village is located at the mouth of a fjord where a glacier calves many icebergs that are dangerous for navigation. Halibut fishing is the main economic activity. Until the early 1990s, fast ice surrounded the island for 6 to 8 months. “In the autumn we were eagerly waiting for the sea to freeze. As soon as the ice was strong enough, we would go on the pack-ice. Elders, women and children could fish for cod near the shore. The men went further away, by dog sled. Since the pack-ice immobilised the icebergs in the fjord, it was possible to fish there. A hole was dug in the ice in the middle of the fjord to install a bottom line. Throughout the winter our line stayed in

the same place and we brought back a lot of halibut. I liked to travel by sled. It didn't cost us anything to feed the dogs. When the weather was good, I took my sons with me as soon as they could walk, so that they could learn about the pack-ice.

Now there is less and less pack-ice. It has become dangerous, often covered with melting ponds. We had to buy motorboats. They're expensive and icebergs often take our lines with them... I don't know if my grandchildren will still be able to sled on the ice pack, like our ancestors did, like the “true” Inuit.”

**Interview by  
Pierre Taverniers**

# INUIT HUNTERS FACING CLIMATE CHANGE

The Inuit, an age-old people of the Far North, were nomadic hunters, mainly of marine mammals. From Alaska they reached the islands of the Canadian High Arctic and then Greenland by travelling on the frozen sea. Nomadism, which was necessary for them to follow migrating game, has also allowed them to adapt to climatic variations. Through contact with the peoples of the South, their way of life changed and they have become sedentary, sometimes by force. In 1983, the European embargo on the sale of seal skins deprived hunters of their main income, and many of them turned to fishing, out of necessity.

**Until the early 1990s, the Inuit of the north west coast of Greenland were still living apace with the rhythm of the ice pack.** In October, as the sea began

to freeze, they could use their sleds to reach the middle of the fjords and set up long lines to fish for halibut for export. With their nets stretched under the ice, they caught seals, eating their meat and fat, and using the skins to make winter clothing. The ice pack immobilised icebergs, that were common along the Greenland coast and a shipping hazard in the summer, but that provided the Inuit with a valuable supply of freshwater blocks.

This ice pack has long been a space for learning and transmitting knowledge. In the spring, entire communities would travel by sleigh on the ice to visit other communities, to exchange, share and start new families.

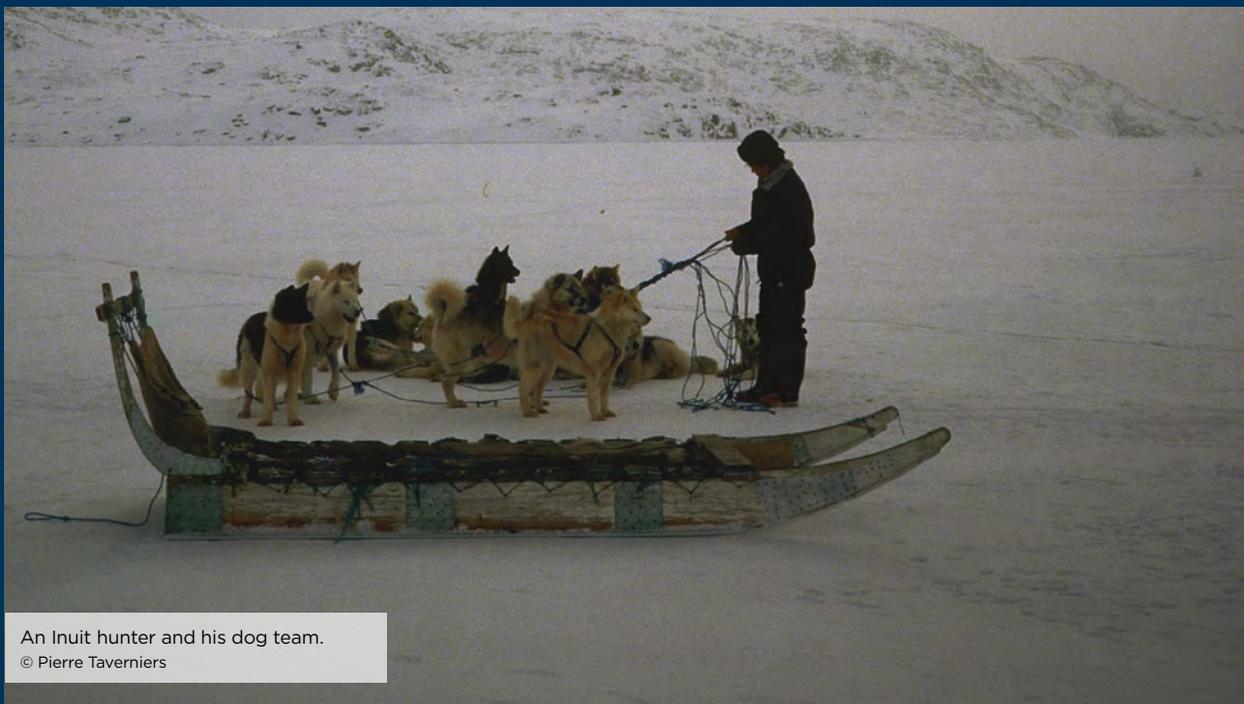
**Today, climate change is weakening both Inuit culture and their economy.** While the ice pack was thick enough to travel on until mid-June, it now forms later, is thinner and breaks up earlier. Some winters, it no longer even forms south of 70° north in latitude. Many Inuit can no longer feed a dog team which is used less with each passing year and end up abandoning dog breeding and sledding, which are nevertheless an intrinsic part of their identity. Knowledge related to the ice pack is less likely to be transmitted and may be lost, as may the skills needed for making sealskin clothes, which are mainly used on sea ice. As the water is open most of the year, fishing is now done with motorboats, but the equipment is often damaged by drifting icebergs.

“Today, climate change is weakening both Inuit culture and their economy.”

Climate change is resulting in more fog and, here and there, more icebergs, making fishing more difficult. “*The weather has become unpredictable,*” say many Inuit. Traditional knowledge in this area is now less relevant and Inuit fishermen expect more local ice and wind forecasts from meteorological and oceanographic services such as those provided by the Copernicus Marine Service.

**PIERRE TAVERNIERS**

Météo France Meteorologist  
Siku Project Manager



An Inuit hunter and his dog team.  
© Pierre Taverniers

# MONITORING EL NIÑO EVENTS IN THE PACIFIC

The El Niño-Southern Oscillation (ENSO) is a main source for interannual large-scale climate predictability with sometimes dramatic consequences on agriculture and fishing, affecting food security in the Pacific, Latin America, Southern Africa, the Horn of Africa and Asia. It can favor to cyclones, hurricanes, flooding, and warm or drought episodes resulting in lower harvests or huge fires. The El Niño of 2015/16 was one of the strongest El Niño events observed since 1950, **affecting over 60 million people according to United Nations reports.**

Every few years the tropical Pacific warms abnormally in association with a decrease in intensity of the easterly winds over the equatorial Pacific (so called trade winds). These factors produce the oceanic Kelvin wave, which, in turn, causes surface warming in the central-eastern equatorial Pacific and further weakens the trade winds.

“The El Niño can lead to cyclones, hurricanes, flooding, and warm or drought episodes”

The concept of El Niño initially concerned the anomalous increase of the coastal sea surface temperature off northern Peru, normally kept cool by the process of coastal upwelling. It is only since the '70s that El Niño has been considered to be a large-scale climate oscillation with a negative phase (La Niña), involving both the ocean and the atmosphere and impacting many regions around the globe through “teleconnections”. **Today, the concept of ENSO diversity has emerged.** It refers to whether the El Niño events have peak sea surface temperature anomalies in the eastern Pacific or in the central Pacific and to whether they are strong or moderate.

Strong to extreme events usually occur in the Eastern Pacific and have the largest impact in the surrounding regions of the tropical Pacific. The coastal warming along western South America produces local climate anomalies that can cause serious economic and social damage.

Oceanic Kelvin waves are generated in the central-western equatorial Pacific a few seasons (8 to 10 months) ahead of the mature phase of El Niño, it takes a few months for them to reach the coast of South America. For Peru, Ecuador and Chile, **the ability to predict the evolution of oceanic circulation during El Niño events sufficiently in advance is thus key** for designing resource and risk management strategies. This is now possible thanks to ocean modelling and observations. The Geophysical Institute of Peru (IGP) is using products from the Copernicus Marine Service to monitor oceanic Kelvin wave activity along the equator and Peruvian coast providing vital information to the Peruvian Multisectoral Commission for the Study of El Niño (ENFEN) in charge of making regional predictions of climate and ocean anomalies and informing stakeholders.

Copernicus Marine products are also used by scientists to improve our understanding of the way in which air-sea interactions along the coast of Peru and Chile can influence El Niño development and to investigate “coastal El Niño” warming events, that are not necessarily associated with anomalous large scale conditions. These can produce heavy rainfall as dramatic as that during extreme El Niño events for Peru, as was the case in February 2017, but they are supposedly less predictable than large scale El Niño events.

**BORIS DEWITTE**  
 Laboratoire d'Etudes en Géophysique et  
 Océanographie Spatiales (LEGOS), France  
**KOBI MOSQUERA**  
 Centro de Estudios Avanzados  
 en Zonas Áridas (CEAZA), Chili  
 Instituto Geofísico del Perú (IGP), Peru



El Niño causes cyclones, hurricanes, flooding and warm or drought episodes. In 2015/16 it affected over 60 million people according to United Nations reports. Here, flooding in the Lima region.  
 © Rodrigo Rodrich/Practical Action



*The need for coordinated observations relating to the state of the Earth emerged during the first World Summit on Sustainable Development in Johannesburg in 2002. One year later, during the first Earth Observation Summit in Washington DC, representatives of 34 governments created an intergovernmental Group on Earth Observations (GEO), co-chaired by the European Commission, Japan, South Africa and the US.*



## EARTH OBSERVATIONS: SHARING DATA AND KNOWLEDGE TO PROTECT THE OCEAN

The GEO community counts 105 Member countries, and 129 Participating Organisations. We are working to develop initiatives and implement projects that solve global problems, thus supporting the UN 2030 Agenda for Sustainable Development, the Paris Climate Agreement, and the Sendai Framework for Disaster Risk Reduction. GEO was set up to improve the availability, access and use of Earth observations for the benefit of society. The community actively works to improve and coordinate global Earth Observation systems, to promote broad, open data sharing and to convert Earth observations into support for decision-making and action.

GEO has been striving for years to show that **open data and knowledge sharing play an important role in monitoring the health of the planet, including our ocean.** Evidence-based decisions in the marine realm need to be underpinned by the collection of physical, chemical and biological data on coastal and open-ocean areas through in situ measurements and remote sensing technologies. These observations are transformed into information products, ocean forecasts and services, such as those produced and disseminated free of charge by the Copernicus Marine Service and that can be used to create knowledge for effective management and policy decisions. For example, the implementation of the Sendai Framework for Disaster Risk Reduction requires

ocean observations for early warning systems, to allow people to prepare for and mitigate ocean-related hazards, such as tsunamis, storm surges and extreme waves. The current GEO work programme includes activities that are addressing these phenomena.

GEO Blue Planet is a GEO initiative bringing together a wide network of ocean and coastal-observers, social scientists and end user representatives from a variety of stakeholder groups, including international and regional organisations, NGOs, private sector organisations, national institutes, universities and government agencies. A prime example of this collaboration is the Early Warning System (EWS) for marine flooding of coral reef-lined islands. Developed in close consultation with users, its aims to provide all nations and people living on a reef-lined coast anywhere in the world with forecasts of wave-driven flood events.

Only by working together, by sharing our data, software, expertise and lessons learned, can we protect one of the world's most valuable shared resources, our ocean.

**GILBERTO CÂMARA,**  
Secretariat Director,  
Group on Earth Observations (GEO)



# A FUNDAMENTAL BASELINE OF REGULAR SCIENCE-BASED OCEAN REPORTING

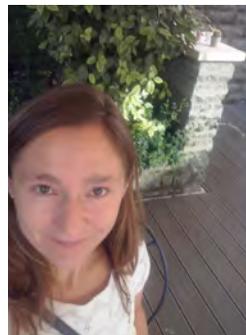


The ocean covers 71% of the Earth's surface, and plays a fundamental role in each of the three categories that are crucial for sustainable development: the Environment (the ocean regulates and triggers Earth's climate), the Economy (it meets basic needs for transportation, energy and natural resources) and Society (it supplies food

and livelihoods). Multiple anthropogenic stressors such as climate change, over-exploitation and pollution have become a major threat to the marine environment and hence jeopardise its services for the human species and biodiversity in general.

Scientifically-sound ocean reporting is crucial for monitoring the ocean's responses to pressures, for supporting national and international environmental reporting, for shaping evidence-based policies, and for taking appropriate measures to promote sustainable development, including the mitigation of and adaptation to climate change.

The Ocean State Report (OSR) of the Copernicus Marine Service is an internationally recognised annual report, written by nearly 100 scientific experts from more than 30 institutions throughout Europe. It serves as a fundamental baseline of regular science-based ocean reporting for the blue ocean (physical processes driven by changes in temperature, salinity and currents), the green ocean (biogeochemical processes such as fluctuations of ocean chlorophyll, eutrophication, the uptake of carbon and ocean deoxygenation), and the white ocean (sea ice melt). An annual OSR Summary highlights key outcomes for non-scientists. Major essential variables and ocean climate indicators that are accessible to all are disseminated via the Copernicus Marine Service web portal. This section is based on OSR findings and indicators.

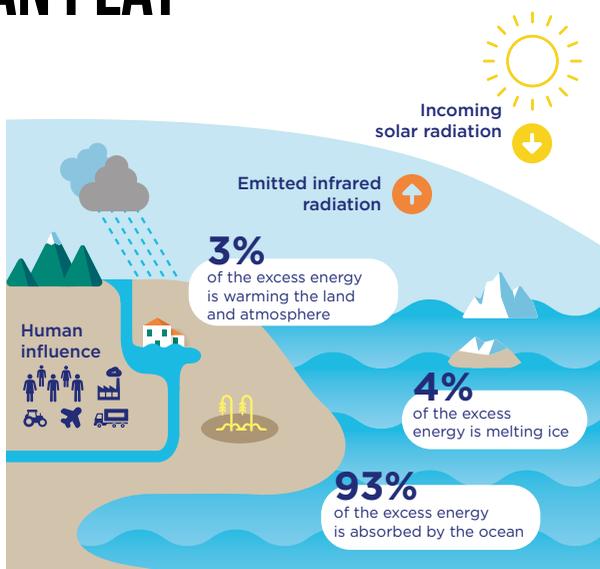


**KARINA VON SCHUCKMANN**  
Oceanographer specialised in ocean climate monitoring  
Mercator Ocean International

## WHAT ROLE DOES THE OCEAN PLAY IN CLIMATE CHANGE?

There are two major ocean characteristics that buffer global warming: **OCEAN HEAT** and **CARBON UPTAKE**.

- Nearly 0.5 to 1.0 Watts per square metre of excess heat from human activities is trapped in the Earth system and is driving global warming. About 93% of that excess heat is absorbed by the ocean. As a result, the global ocean and regional European seas are warming.
- The ocean is absorbing CO<sub>2</sub>: about a quarter of human-induced CO<sub>2</sub> in the atmosphere is stored in the ocean through carbon uptake. As such, the ocean buffers the warming effects that this CO<sub>2</sub> would have if left in the atmosphere.

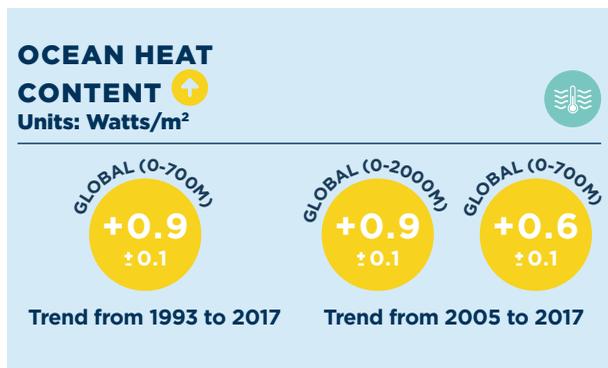


# HOW DOES CLIMATE CHANGE AFFECT THE OCEAN?

The negative effects of the ocean’s buffering of global warming are for example: **ocean warming, ocean acidification, sea level rise, and sea ice melt**. The information below is based on Copernicus Marine Service’s Ocean State Report and indicators.

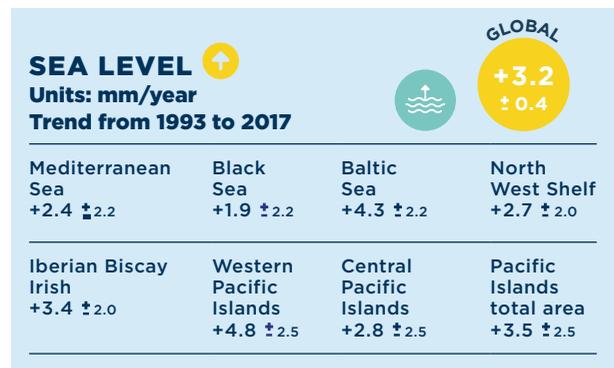
## OCEAN WARMING OCEAN HEAT CONTENT

Ocean Heat Content is the total amount of heat stored in the ocean (from top to bottom). Ocean warming contributes to sea level rise, coral bleaching and infectious diseases, changes in ocean currents, and sea ice melt, and modifies air-sea interactions, affecting weather and climate patterns from local to global scales.



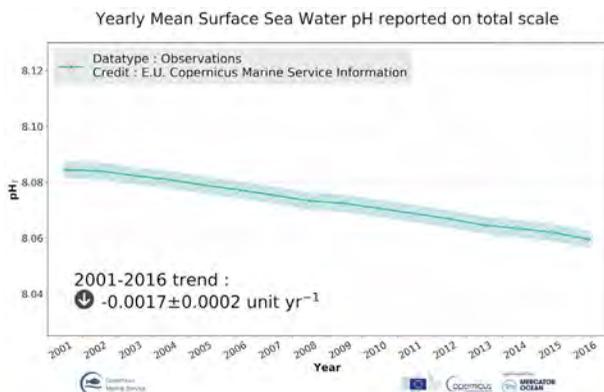
## SEA LEVEL RISE

Sea level rise can seriously affect human populations in coastal and island regions and natural environments such as marine ecosystems. Global and regional mean sea levels are affected by natural climate variability and by human-induced changes. Because of ocean warming and melting land-ice, the sea level rises. Water expands when heated and about 30% of contemporary sea level rise can be attributed to this thermal expansion (called “thermosteric sea level”).



## OCEAN ACIDIFICATION SEAWATER PH

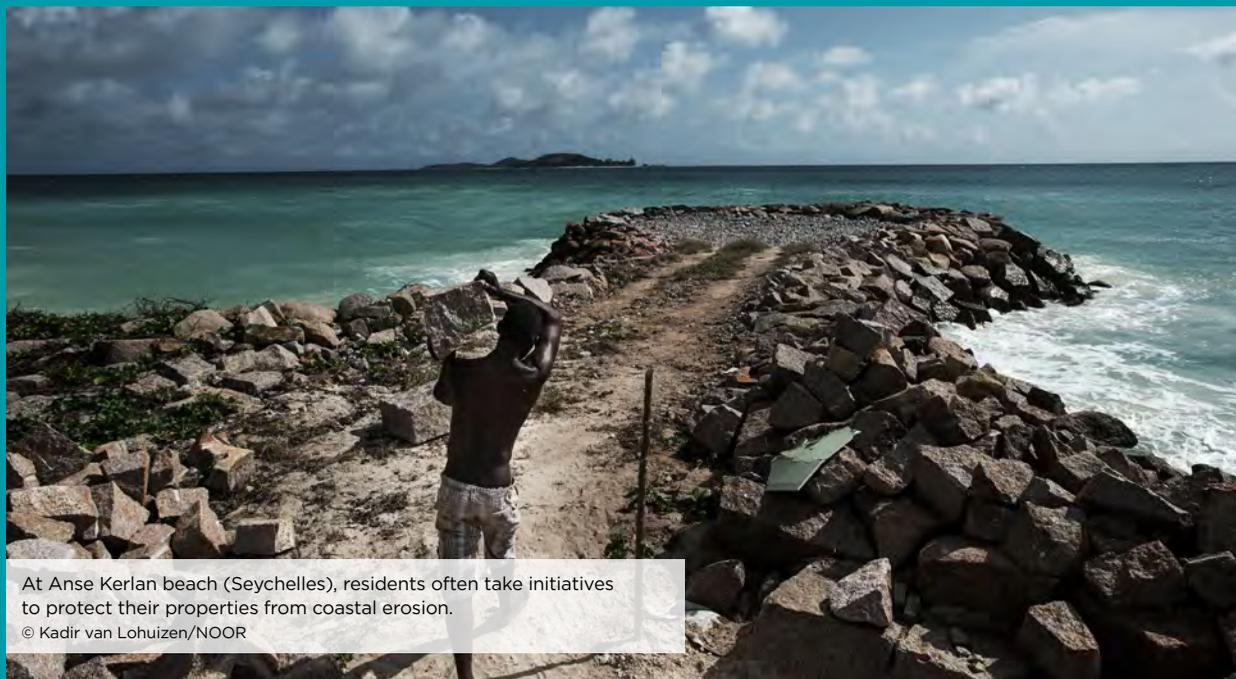
The ocean is increasingly acidic. As a result of increasing concentrations of CO<sub>2</sub> in the atmosphere that are being absorbed by the ocean, the ocean pH is decreasing, which causes ocean acidification. Ocean acidification is considered to be a stressor for a host of organisms as it may affect photosynthesis, respiration, calcification, and reproduction among other things.



## SEA ICE MELT

The extent of Arctic sea ice has been reduced drastically during summers over the last years. Within 40 years, from the late 1970s until 2017, about 2 million square kilometres of sea ice have melted, which is like losing nearly 4 times the area of Spain. Within 25 years, from 1993 to 2017, there has been a loss in sea ice cover of nearly 770,000 km<sup>2</sup> per decade in the Arctic, which is the equivalent of losing well over twice the area of Germany every ten years.





At Anse Kerlan beach (Seychelles), residents often take initiatives to protect their properties from coastal erosion.

© Kadir van Lohuizen/NOOR

# FOOD PRODUCTION AND SUSTAINABILITY IN RELATION TO CLIMATE VARIABILITY

The ocean is a key component of the climate system and provides a wide range of vital eco-system services to humanity. These range from climate stability, global transportation, resource extraction, uptake and dispersion of pollutants to cultural and recreational opportunities. Unfortunately, a growing and more affluent global population continues to cause a measurable impact on the environment with symptoms ranging from climate change to overexploitation of the marine environment, pollution and habitat destruction.

Nevertheless the picture is not entirely bleak as the last two decades have seen significant advances in systematic ocean observation and the knowledge gained has enabled more insightful ocean assessments, improved ocean state forecasting and a sustained and increasing effort to develop ocean modelling.

There are many examples of ocean information yielding significant societal benefits. They include improved seasonal and, in some cases, up to decadal climate prediction and monitoring of related phenomena such as regional global warming, the rise in mean sea level, ocean acidification and the loss of dissolved oxygen as well as insights into the interactions between human induced ocean changes and the loss of marine biodiversity. However, one very specific opportunity should be emphasised: the relation between climate change, fishing pressure and ocean food.

In the Atlantic sector there are several commercially significant, offshore ocean capture fisheries. The cold and nutrient-rich North Atlantic and the gateways to the Arctic support significant large-scale commercial fishing. The other regimes are the upwelling zone along the Equator – and more significantly the upwelling offshore of Northwest and Southwest Africa – the Canary current upwelling regime connecting Morocco, Mauritania and Senegal and the Benguela current upwelling regime connecting Angola, Namibia and South Africa.

The European Union has negotiated fishing rights in both zones but is also concerned about the sustainability of this potentially renewable resource. However, how will climate variability and change affect the productivity of these fishing grounds? The Copernicus Marine Service has a unique opportunity to provide critical information to those actors who supervise the harvesting and sustainability of ocean food and have the authority to enforce fishing quotas. It can connect ocean temperature, the rate of upwelling of nutrient rich water and its chemical composition with models of fishing pressure to provide seasonal forecasts of stock reproduction and long term scenarios for the future potential for fishing.

**MARTIN VISBECK**

**GEOMAR Helmholtz Centre for Ocean Research  
Kiel & Kiel University**

# THE OCEAN AND CLIMATE NEED SCIENCE DIPLOMACY

The climate of our planet depends largely upon the ocean, but how many are aware of it nowadays?

Climate change is having a major impact on the ocean, its ecosystems, maritime activities and coastal populations. Simultaneously, the ocean has great potential that may help us to adapt and thus mitigate the impact. In light of this ambivalent observation, the Ocean and Climate Platform – a vibrant and coordinated international effort by States, the scientific community and civil society – arose to place the ocean in the forefront of climate negotiations prior to the United Nations Framework Convention on Climate Change (UNFCCC) COP21 in Paris in 2015. This concerted mobilisation led to integration of the ocean into the preamble of the Paris Agreement, followed a year later by the ocean being put on the Global Climate Action Agenda at COP22 in Marrakech. Since then, the Ocean and Climate Platform has played an important role in raising the ocean’s profile on the global climate agenda.

Launched during the World Oceans Day on 8 June 2014, with the support of IOC-UNESCO and France, the Ocean and Climate Platform brings together 70 members including research institutes, non-governmental organisations, higher education institutions, aquariums, representatives of the private sector and international institutions. Working at the interface between science and policy, the Platform

aims to provide civil society and decision-makers with new knowledge and insights on the interlinkages between the ocean, climate and biodiversity. To do so, the actions of the Platform are carefully structured with three strategic pillars in mind, Mobilisation, Scientific Knowledge, and International Advocacy, with which the Copernicus Marine Service is involved. The Platform issues regular recommendations for policy- and decision-makers who are integrating the ocean into the future climate regime.

The ocean-climate-biodiversity nexus is becoming increasingly important on the political agenda and countries will have to meet their international commitments. The 2019-2021 agenda will offer incredible opportunities to further protect the ocean and better understand its role in the global climate system, especially ahead of the UNFCCC COP25, announced as the “Blue COP”, the IUCN World Congress and the COP15 of the Convention on Biological Diversity.

Confronted with climate change, the ocean still acts as a vital shield for protecting the future of our planet.

**FRANÇOISE GAILL**

Vice-President of the ocean and climate platform for science, Research Director & Scientific advisor at the French Centre for Scientific Research (CNRS)

## INTERNATIONAL MILESTONES OF THE OCEAN-CLIMATE-BIODIVERSITY AGENDA - (2019 - 2021)





Some coastal communities of the Canary archipelago (Spain) are at risk of flooding from the rise in sea-level. Here the village of Arrieta, Lanzarote island.  
© Jerónimo Alba

# WEATHER AND OCEAN SCIENCE, COMPLEMENTARY DISCIPLINES

The European Centre for Medium-Range Weather Forecasts (ECMWF) is an intergovernmental organisation set up to develop state-of-the-art science for medium-range weather forecasting and to operate a 24/7 operational service. By improving its global, medium-range weather forecasting products, with a particular emphasis on early warnings of severe weather, the Centre provides national meteorological services with access to higher resolution and improved data to help them provide weather forecast services. ECMWF has been strongly involved in the development of Copernicus information services and is operating two services on behalf of the European Union: the **Copernicus Atmosphere Monitoring Service (CAMS)** and the **Copernicus Climate Change Service (C3S)**. Climate change issues are cutting across current thematic disciplines within the Marine, Land and Atmosphere Monitoring Services of Copernicus.

The winds, solar radiation, and heat and freshwater exchanges with the atmosphere drive the evolution of the Ocean. Meanwhile, the ocean state affects the atmosphere on timescales ranging from days to months, for example the evolution of tropical cyclones, weather systems over the Gulf Stream and El Niño, and on longer timescales, with heat storage and transport in the deep oceans.

The evolution of the atmosphere and the ocean are closely linked. It is therefore important to consider the evolution of these two components of the Earth system together to determine its future evolution.

The collaboration between Copernicus Atmosphere/Climate Change services and Copernicus Marine Service works both ways. Atmospheric models are essential for developing and forcing ocean models, as they always require the input of atmospheric parameters to serve as boundary conditions. With products from the Copernicus Climate Change Service, ECMWF makes a major contribution to the set of “ocean reanalyses” produced by the Copernicus Marine Service, which provide a coherent description of the state of the ocean over the past decades. ECMWF also improves the ocean state estimation and gauges uncertainty levels.

Long historical data records of, for instance, sea-ice, sea surface temperature, sea level, ocean heat content or ocean acidity are critical for monitoring the Earth’s climate and its evolution. For example, the mean sea level provided by the Copernicus Marine Service is an essential climate indicator reported in the C3S publication “**European State of the Climate**” (ESOTC): “Over the last 25 years, global sea level has seen an increase of about  $3.3 \pm 0.4$  mm/year. About 30% of this global sea level rise can be attributed to ocean thermal expansion and 70% to the loss of glacier mass due to melting”.

**JEAN-NOËL THEPAULT**

Director of Copernicus Services  
ECMWF



Pierre-Boileau  
 Head of GEO-6 UNIT, UNEP  
 © Mercator Ocean International

## CHANGING THE PATH WE ARE ON

The Global Environment Outlook (GEO) is a flagship document of the UN Environment Programme, an integrated environmental assessment published every 4-5 years. The aim is to report on the state of the global environment, the extent and effectiveness of existing policy responses in addressing major environmental challenges and the prospects or outlook for the environment for the foreseeable future. In March 2019 the sixth edition of this major assessment, entitled **Healthy People, Healthy Planet**, was published by UN Environment with contributions from more than 140 experts and the guidance of key governments and stakeholders. The report is meant to help policy-makers define the environmental problems we are facing in a comprehensive way, in order to make progress in finding solutions to help us achieve UN Agenda 2030 and its 17 Sustainable Development Goals as well as a truly sustainable world by 2050.

The report's findings paint a stark picture of the environmental and health impacts of our daily actions and the fact that we will not achieve any of our ambitious environmental goals if we remain on the

path we are now on. Some key-findings are:

- **Five drivers of environmental change**, namely, population growth, economic development, urbanisation, technological change and climate change, are pushing us towards a future with 9-10 billion people on the planet in 2050, possibly a 3 to 4 degree Celsius increase in mean global temperatures, more pollution, up to 7 million premature deaths from air pollution, and other dramatic impacts on a scale never seen before.
- The main activities that are contributing to these trends include the way we produce and consume energy, how we produce and consume food, and how our activities generate waste.
- Current projections are that energy demand will increase by 50-60% between now and 2050, yet the amount of fossil fuels in that energy mix must decrease by about 45 percent by 2030 and be net zero by 2050 if we are to keep global warming below 2.0 °C (IPCC report: "Global Warming of 1.5°C"). There are significant environmental and health synergies in this



“About 50% more food will be needed to feed a population of up to 10 billion by 2050”

shift away from fossil fuels, with decreases in Greenhouse gas emissions reducing ocean acidification as well as the likelihood of oceanic warm pools and flooding from extreme storm surges.

- Current projections show **that about 50% more food will be needed to feed a population of up to 10 billion by 2050**, yet the

environmental impact of food production will need to decrease significantly to mitigate the effects of climate change, biodiversity loss, land degradation and chemical pollution associated with this sector. Meeting this demand for food will require a combination of dietary and technological changes, and a significant reduction in food waste. Increased protein from marine sources (sustainable capture fisheries and expanded mariculture) can reduce demand for meat while improving overall nutrition and lowering the land transformation and greenhouse gas footprints from the food production sector.

• Currently about 8 million tonnes of plastic waste find their way to the ocean each year. Waste generation is expected to continue to increase to 2050, given population

growth, economic development scenarios and current consumer practices. Policies such as circular economies, mandatory recyclable packaging, and responsible consumer practices are necessary to reach a near-zero-waste society by 2050; such actions would provide significant social and economic benefits and a healthier planet with healthy people.

Despite its stark review of the state of the environment, the sixth Global Environment Outlook establishes that **there are pathways that can achieve the Sustainable Development Goals and a Sustainable World by 2050**. These pathways will have to address how the three main large systems, energy, food and waste, currently work and propose transformational changes that will allow them to contribute to a sustainable world rather than continuing to harm it.

Climate change is warming the ocean, altering major currents, increasing ocean acidification and expanding areas of low oxygen. As a result, coral reefs and other marine organisms with calcium carbonate shells are at increasing risk, mobile species are changing their ranges to more pole-ward distributions, and “dead zones” and zones of low productivity are increasing in size and frequency of occurrence. UN SDG14 calls

for a Healthy Ocean with Targets for 14.3.1 (acidification), 14.4.1 (sustainable fisheries), 14.a.1 (improved marine technologies) and 14.c.1 (improved conservation instruments) focused directly on efforts to help reduce the consequences of climate change in the ocean and help us to adapt to them. In addition, other Targets, including all Targets for SDG7 (Energy), Target 9.4.1 (Reduced industry emissions), several Targets for Disaster Risk Reduction in SDG11 (Cities and communities), most Targets of SDGs 12 (Responsible Lifestyles) and 13 (Climate Action) all call for actions that can reduce the pressure of climate change on the ocean or increase the resilience of the ocean to climate change.

How can the UN Decade of Ocean Science help turn these trends around? **Ocean Indicators such as those provided by the Copernicus Marine Service (pH, Sea Level Rise, Sea Ice Extent, Storage of Heat, etc.)** alone cannot reduce pressure on the ocean (or lands), but they can be very useful

**in assessing impacts and** in tracking the consequences of policy actions from the global scale down to that of communities. This feedback provides incentives to improve and expand effective practices and revise ineffective ones. The UN Decade of Ocean Science can contribute by substantially increasing the coverage of existing indicators, clarifying their sensitivity and robustness, and strengthening the ability to attribute causation (drivers) and consequences (environmental and societal changes) to trends in the indicators.

**ELAINE BAKER,**  
University of Sydney

**PIERRE BOILEAU,**  
UN Environment

**PEDRO FIDELMAN,**  
University of Queensland

**JAKE RICE,**  
Chief Scientist Emeritus,  
Fisheries and Oceans Canada



To face rising seas in Jamaica, young coral is being re-planted on the reefs, shown here at the Oracabessa bay coral nursery.  
© Kadir van Lohuizen/NOOR



07

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# INSPIRATIONAL OCEAN





### CATHERINE JEANDEL

Research Director, French National Centre for Scientific Research

## THE SUSTAINABLE OCEAN, A CIVIC ISSUE

Whether it be through grass roots activism, activities proposed by associations, or frequenting scientific events or conferences, it is clear that young people are very aware of the issue of climate change and in particular of the current and future situation of the ocean.

This interest can become a vocation when students move on after their bachelor's degree to read for masters' degrees in oceanography, an attractive sector. While some specialised programmes have difficulty recruiting students, our Master's degree in "Continental Surfaces - Ocean Atmosphere", which awards 20 degrees annually, attracts more candidates than we can accommodate. Scientific stakeholders from all over the world, such as the CNRS in France, but also companies, public services and NGOs are recruiting oceanographers. This is why **one of the priorities of European research framework programmes is the**

**training of the scientific community in operational oceanography.**

About 60% of the world's population live along the coastline and rising water levels have become a major societal issue. The future of these populations depends on enlightened political choices for which social science, serious economic studies and the relaying of our scientific information are fundamental. The scientific community as a whole must therefore build sound interdisciplinary relationships. This involves, in particular, promoting a multi-disciplinary approach by means of complementary programmes between several European universities.

Furthermore, teachers, researchers and "Ocean Literacy" actors will certainly continue to make their voices heard in the public arena, alerting us to the situation in the ocean, because humanity, which

**"Part of our professional work involves explaining scientific advances on the future of the planet."**

draws a large part of its resources from it, is in danger. Many of these people are already playing an active role in raising public awareness. Many researchers and teachers do not limit their transmission of knowledge to the academic world alone. They also inform a very wide audience, including those who are excluded from access to scientific culture. In this context, for example, **animations based on Copernicus Marine Service data, and representing ocean temperature, currents and the presence of sea ice are of great help when we intervene in schools.** Part of our professional work involves explaining scientific advances on the future of the planet.

Throughout Europe, the scientific community is involved in civic actions such as *le Train du Climat* [the Climate Train], an initiative from the scientific community to raise public awareness of the challenges established by the worldwide COP21 agreement of 2015. The Climate Train has travelled between and through 19 cities in France to explain the role of the ocean, its interactions with the atmosphere, currents, the evolution of polar ice caps and the production of plankton and carbon sequestration at the bottom of the sea. This citizen-inspired action was made possible through fruitful collaboration between the research collective, *Messagers du Climat* [Climate Messengers] (led by

the association *Météo et Climat* under Jean Jouzel, former Vice-President of the IPCC), the French Ministry of Research and Higher Education, the French Ministry of the Environment and SNCF (the French national railways company).

Another train also travelled through Morocco in 2016 for COP22. Together we now want to mobilise scientists all over Europe to create a Climate Train, which would travel through each member state of the European Union.

**Training, awareness raising and sharing of knowledge is indispensable for dealing with the climate crisis, but should as well lead to the creation of new jobs.**

All over Europe, a galaxy of companies is taking advantage of the protection and enhancement of ocean resources to develop new business and in turn stimulate economic relays. Thanks to the quality of its data and its free access, the Copernicus Marine Service is a valuable tool which enables them to create new services. The oceanographers we have trained have a solid foundation for specialising in marine energy, fish farming, navigation, satellite and in situ data processing and big data. With sufficient determination and the support of the European Union, the European Commission and European Members of the Parliament, the blue economy can become a reality.



The CNES (the French space agency) Argonautica project helps young people to understand the relationships between ocean, climate and the environment.  
© CNES/Jacob Chetrit



# OCEAN LITERACY FOR ALL

The two words “ocean literacy” have become symbolic of a global initiative to improve our individual and collective knowledge about the ocean and our relationship with it. It was originally an American concept devised to describe a project to use ocean science to teach general science in schools for students of all ages. The project began in earnest in 2002 and led to a definition of “ocean literacy” along with seven essential principles and 45 fundamental concepts for learners of all ages. The need for ocean literacy was incorporated in an intergovernmental agreement between the USA, Canada and the European Union in the Galway statement in 2013. The development of ocean literacy plans, programmes and applications in Europe, Asia, Canada, South Africa, Australia and New Zealand, China, Taiwan and many other African countries, continues.

In this context, “Ocean Literacy” is defined as being “an understanding of the influence of the ocean on you and your influence on the ocean”. **An ocean literate person understands the Essential Principles and Fundamental Concepts concerning the ocean**, can communicate about the ocean in a meaningful way, and is able to make informed and responsible decisions regarding the ocean and its resources.

The essential principles of ocean science are:

1. The Earth has one big ocean with many features
2. The ocean and life in the ocean shape the features of Earth
3. The ocean is a major influence on weather and climate

4. The ocean made Earth habitable
5. The ocean supports a wide diversity of life and ecosystems
6. The ocean and humans are inextricably interconnected
7. The ocean is largely unexplored.

These seven principles form the basis for a suggested range of topics and a pedagogical sequence for students from kindergarten through high school.

“Ocean Literacy for All” is an international initiative supported by the International Oceanographic Commission of UNESCO and is included in the programme for the Decade of the Ocean from 2021 to 2030.

We learn about nature by observing it. The same is true for the ocean and we are even able to digitize and simulate its physical and bio-geochemical states from the bottom to the surface, which is an indispensable stage for understanding it better. “Ocean Literacy” is about observing and understanding our relationship with the sea and ocean around the world. The Copernicus Marine Service with its online ocean data and indicators, easily accessible to all and translated into images, supports ocean literacy through its many outreach activities aiming at increasing the number of ocean-literate people among European citizens.

**PETER TUDDENHAM**  
Executive Director  
College of Exploration

# TOWARDS AN OCEAN-LITERATE SOCIETY

The ocean is one of our planet's life support systems, and many aspects of our everyday life depend on it. However, most people are not aware of all of the reasons why we should be grateful to the ocean.

The Intergovernmental Oceanographic Commission (IOC) of UNESCO is leading the "Ocean Literacy for All" initiative, a global partnership formed in 2017 to **raise awareness of how the ocean affects us and how we affect the ocean**. Ocean literacy is a way of informing citizens and stakeholders of the importance of the ocean for humankind, and to encourage them to make informed and responsible decisions that promote ocean sustainability. To reach this goal, the IOC has developed resources, lesson plans and activities adapted to different levels of classes and ages. These are freely available on UNESCO's Ocean Literacy Portal. For many years, Mercator Ocean International has contributed by designing pedagogical tools based on ocean data from the Copernicus Marine Service to explain ocean facts by depicting them visually.

Europe's history, culture, and economy are inextricably linked to its seas and ocean, and this is one of the reasons why European institutions, such as the European Commission and the European Parliament, together with European scientists and marine educators, are promoting ocean literacy. Activities to foster a European ocean-literate society are

seen as a way of making ocean knowledge more accessible to everyone, of highlighting the role of science for decision and policy-making, and of preparing Europe for a more sustainable future.

It has been observed that there is increasing interest in the European marine space due to the development of the blue economy, the commitments to implementation of the 2030 Agenda, with particular reference to SDG14 and its targets, the negotiation of new legal instruments to protect biodiversity beyond national jurisdictions, and the need for providing scientifically sound solutions to emerging threats to the ocean. For this reason, the various actors and stakeholders concerned, not only need to have a better understanding of ocean characteristics and processes but also of the importance of ocean science, observation and data. We are optimistic that we are beginning to achieve this goal. In particular, we have observed an increased need for marine services, from ocean forecasting to ocean health indicators. **In this evolving "marine landscape" the Copernicus Marine Service provides essential knowledge for making "science open and relevant to society"**.

**FRANCESCA SANTORO**  
Programme Specialist, IOC  
UNESCO Regional Bureau  
for Science and Culture in Europe

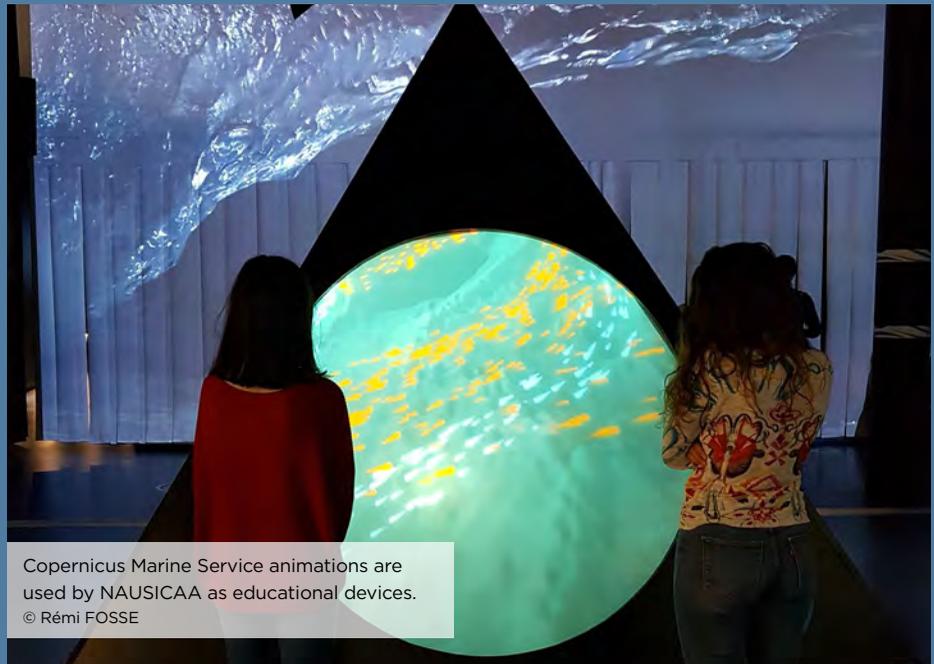


© Dragos Dumitrescu

## WHAT IS WORLD OCEANS DAY?

Following the UN Environment and Development Conference held in Rio de Janeiro in June 1992, many countries have celebrated this special "Oceans Day". To keep the momentum going, the UN General Assembly decided in 2008 that as of 2009, the 8<sup>th</sup> June each year would be the United Nations' "World Oceans Day".

The 8<sup>th</sup> of June represents the opportunity to raise global awareness of the benefits humankind derives from the ocean and our individual and collective duty to use its resources sustainably. In this context, aquariums, science centres and research institutions, NGOs, communities and governments worldwide, mobilise millions of people with all sorts of events. The UN has developed a portal to help find events that are happening around the world.



Copernicus Marine Service animations are used by NAUSICAA as educational devices.  
© Rémi FOSSE

## NAUSICAA: A PLACE TO LEARN AND DREAM

Located at Boulogne-Sur-Mer, in the Pas-de-Calais department (France), NAUSICAA, *Centre National de la Mer*, aims to raise public awareness for better stewardship of the ocean and its resources. What we offer goes far beyond visiting the largest aquarium in Europe. It is also about building a commitment to work for a sustainable ocean.

We want all visitors to become aware of the influence the ocean has on them and, in return, the care they must take of the ocean. For this, a scenography combining aquariums, images, visual and sound environments, immerses them in the ocean ecosystem.

To arouse their wonder when faced with beautiful marine life, we propose an immersive experience, both playful and scientific, focused mainly on the relationship between human beings and the sea. Nausicaa's team has developed a set of educational items and devices, some of which draw on the tools of the Copernicus Marine Service. For example, an animated view of ocean circulation at the global level as well as maps for the interactive bridge of an oceanographic research station, have been integrated into the centre's new extension on the High Seas.

Other devices explain the evolution of the ocean environment related to human activities, an increase in mean sea temperature, seasonal evolution, the role of phytoplankton, surface oxygenation, etc. Nausicaa is a tool that is accessible to all audiences and, in particular, to schools. Hence its success: in 28 years, we have welcomed more than 17 million visitors. Nausicaa has been recognised as a "Centre of Excellence" by the UNESCO Intergovernmental Oceanographic Commission (IOC).

It is urgent to realise that the ocean is an essential opportunity for our future! Its tremendous potential widens the range of possibilities: provided that we know how to preserve it by exploiting its resources in a sustainable way, for today and tomorrow, it can enable us to live better on our planet. It is a question of inventing a new society: the Blue Society. Alone we can do nothing, together we can do everything!

**PHILIPPE VALETTE**  
General Director  
NAUSICAA

# ECSITE: BRINGING CITIZENS AND THE SEAS CLOSER TOGETHER

Ecsite is a European network connecting organisations whose mission is to engage citizens with science and technology. Our 320+ members include science centres, museums, research institutes, festivals, universities, planetariums, foundations and learned societies, companies and local authorities, etc. Our common goal is to foster creativity and critical thinking in European society, by emboldening citizens to engage with science. Ecsite members together attract more than 40 million citizens each year to science-related debates, exhibitions, workshops, events or platforms.

Ocean literacy has been an important strategic objective of our network for many years. We are convinced that **healthy societies need a healthy ocean and we are striving** to achieve the United Nations' Sustainable Development Goal 14:

“Conserve and sustainably use the oceans, seas and marine resources for sustainable development”. Together with our members, we have worked on several pan-European projects that bring citizens and the seas closer together, such as “Sea for Society” or “Sea Change”. Our actions have ranged from multi-stakeholder dialogues on sustainable fishery to citizen data collection on crabs.

To Ecsite and its members, the Copernicus Marine Service offers a key source of data and learning tools for public engagement. It is an example of open data enabling evidence-based decision making, an EU-funded service that deserves to be better known by EU citizens.

**CATHERINE FRANCHE**  
Executive Director  
ECSITE



Youth mobilisation action organised in A Coruña (Spain) by Ecsite member *Casa Ciencias - Museos Científicos Coruñeses*, as part of the EU-funded project “Sea for Society”.

© Jonathan Vos Photography



# TARA OCEAN: EXPLORE TO UNDERSTAND THEN SHARE TO CHANGE

The Fondation Tara Océan, created in 2003 by Agnès Troublé (founder of the fashion brand agnès b.) and her son Etienne Bourgeois, has two goals: increasing knowledge by supporting scientific exploration and promoting education by sharing the knowledge with the general public. This is the whole purpose of the schooner Tara's voyage around the planet.

Tara has already logged almost 400,000 nautical miles while exploring the global ocean, with 11 expeditions dedicated successively to the investigation of plankton or coral reef biodiversity, plastic pollution at sea, and climate change. The main objective of the expeditions is scientific research: over twelve years, around a hundred research laboratories from 35 countries have collaborated with Fondation Tara Océan. In all, two hundred and fifty researchers have embarked on Tara, along with a hundred sailors, artists and journalists. The missions have enabled several laboratories to publish

more than a hundred scientific articles, including a dozen in highly-reputed journals such as Science, Cell and Nature. Mercator Ocean International, along with the Copernicus Marine Service has been one of the "co-pilots" of this epic adventure for many years, since its maps and daily services have been used to chart Tara's route in real time.

The voyages have enabled the foundation to share its stories and impart knowledge, and the two hundred or so stop-overs in about fifty countries have provided the opportunity to welcome schoolchildren, the general public, political partners and local journalists, aboard the ship. The quest for knowledge must be funded, shared, and explained, to convince everyone how important it is to protect the ocean, and to promote sustainable development of our societies.

**ROMAIN TROUBLÉ**

Managing Director, Fondation Tara Océan



eXXpedition North Pacific leg 1 Hawaii to Vancouver Mission  
© Eleanor Church Lark Rise Pictures



## EXXPEDITION: ALL-WOMEN VOYAGES TO MAKE THE UNSEEN SEEN

As an ocean advocate and skipper, I have dedicated my career to tackling ocean plastic. After first realising the extent of the problem in 2008, when I was hitch-hiking to Australia from the UK on a biofuelled boat, I've become an international speaker and advisor to individuals, businesses and governments on how we can tackle plastic pollution in our respective parts of the global ocean. In 2014, I founded an organisation to take women from a wide range of disciplines to see the problem first-hand. eXXpedition is a community interest company that organises all-women sailing trips to explore the impact of plastics and toxic substances on our ocean.

In the summer of 2018, the eXXpedition ship sailed through the North Pacific gyre with 10 women who were fully committed to getting to grips with the issue. The crew members included teachers, filmmakers, scientists, engineering students, circular economy specialists and product designers.

Supported by our fantastic sponsors, including the Copernicus Marine Service, the crew carried out citizen science which fed into global studies on the impact, movement and type of plastics found in the North Pacific Ocean.

The Copernicus Marine Service provided us with a drift model of the movement of currents and plastics in the gyre. This model has been instrumental in sharing the story of plastic in the ocean with our network online - through our website and social media channels - and when the crew and I speak to global audiences about our North Pacific voyage. The model, a clear visual aid based on real data, has been an essential tool for engaging with people and increasing their understanding of the movement of ocean plastic.

**EMILY PENN**  
Co-Founder, eXXpedition

## ADVOCATING



Thomas Lesage during an awareness-raising session at the British School of Amsterdam.  
© Children for the Oceans



## CHILDREN FOR THE OCEANS

Our ocean is vital for humankind: not only does it provide us with oxygen, food and many key resources, it also plays a crucial role in maintaining a temperature range that allows life on Earth. Once I had understood that the ocean is threatened by global warming, plastic pollution and overfishing, I could not help wondering why governments worldwide are not actively working to save our ocean? Then I realised that everyone could make a contribution to change and that I had to act at my own level. As a teenager, I believe that a community of motivated young people can convince adults to change their set ways of thinking and living: our future is at stake and we deserve a future.

It was this realisation that led me to found Children for the Oceans, an association aiming at creating a big community of young people acting as ocean ambassadors and making their voice heard to strengthen protection of the environment and the ocean at international gatherings.

The European Commission and the Copernicus Marine Service strongly supported my project by helping me to create Children for the Oceans and providing me with key ocean data, materials and ocean models that we use to organise awareness-raising sessions around the world. Thanks to their support, I was able to complete a worldwide sailing tour for the ocean (16,000 km), which lasted four and a half months. It has been a great experience discussing the major threats to the ocean and its decisive role in our lives with more than two-hundred young people in six different countries.

Children for the Oceans is growing with more and more ocean ambassadors. It has set challenging new goals with the implementation of pedagogical tools, attendance at key international conferences and events and has also organised new awareness-raising sessions in Europe and Asia. Yes, young people can help change the future of our ocean.

**THOMAS LESAGE**  
Founder Children for the Oceans

# ERASMUS MUNDUS: STUDYING SUSTAINABLE USE OF THE OCEAN

Erasmus+ is the European Union's programme for supporting education, training, youth, and sport. From 2014 to 2020, more than 4 million people will be involved in exchange programmes in Europe and with the rest of the world, including 2 million university students, 650,000 from vocational education and training courses, and more than 500,000 young people involved in youth exchanges.

Erasmus Mundus Joint Master Degrees are programmes of excellence developed through university partnerships within Erasmus+. Erasmus Mundus students study at universities in a minimum of two European countries and benefit from learning in a global setting. Those who meet the selection criteria for enrolling in a programme receive valuable scholarships to enable them to study. These graduate programmes are highly integrated, interdisciplinary, and prepare students to address complex problems across the world. Ocean resource management and protection as well as renewable forms of ocean-powered energy are some of the critical issues covered in the curriculum. The professors and university bodies who craft these degree Programmes are often aiming to address multi-layered problems that also happen to be of interest to other global institutions.

Four specific Erasmus Mundus programmes cover marine science studies:

- **The European Master of Science in Marine Environment (MER+)** is a collaborative effort of four European universities. The course is supported by a global network of associated partners including research institutions, companies, and universities.
- **The Erasmus Mundus Joint Master's Degree in Renewable Energy in the Marine Environment (REM)** supported by four

universities across Europe, has a truly international focus and has been crafted to meet companies' needs in Offshore Renewable Energy.

- **The International Master in Marine Biological Resources (IMBRSea)** is a programme organised by eight European universities and supported by fourteen Marine Research Institutes affiliated to the European Marine Biological Resource Centre.

- **The Copernicus Master in Digital Earth (CDE)** is a partnership between three European universities focusing on the interaction between humans and virtual representations of our world. Through this Erasmus Mundus joint Master, geospatial technologies have been leveraged for better management of our marine environment.

Through these four Erasmus Mundus Programmes alone, nine European countries are facilitating the study of a sustainable ocean: Austria, the Czech Republic, France, Ireland, Italy, Norway, Portugal, Spain, and the United Kingdom. By fostering collaboration at the international and university levels, Erasmus Mundus Joint Master Degrees produce critical thinkers and problem solvers who are making waves in marine science and countless other disciplines across the world. Universities begin taking applications for degree programmes under Erasmus+ Erasmus Mundus in February of each year. In general, students can apply for scholarship opportunities between October and February of each year for courses starting the following academic year.

**CLAIRE MOREL**

Head of International Unit,  
Directorate General for Education,  
Youth, Sport and Culture, European Commission



Erasmus students at the Paulina Polder (Netherlands)  
© The International Master in Marine Biological Resources (IMBRSea)



OTGA training course in Malaysia  
© IOC/OTGA

## OCEAN TEACHER GLOBAL ACADEMY: THE OCEAN WE NEED FOR THE FUTURE WE WANT

The OceanTeacher Global Academy (OTGA) Project set up a global network of Regional Training Centres (RTCs) to deliver customised training for ocean experts and professionals to increase national and regional capacity in coastal and marine sciences, services and management.

The OceanTeacher e-Learning Platform enables sharing of standardised, quality training content in a coordinated framework, whilst allowing the use of different languages as well as a range of local/regional case studies. The e-Learning Platform is a web-based training platform that supports classroom training (face-to-face), blended and online/distance learning. Courses cover a range of topics related mainly to the Intergovernmental Oceanographic Commission (IOC) Programmes, thus contributing to the IOC Mandate and the implementation of the IOC Capacity Development Strategy, enabling equitable participation of all IOC Member States and IOC Programmes.

Since its implementation, OceanTeacher has organised and/or supported the organisation of well over 250

courses, involving over 3,000 participants from 134 Coastal States. The e-Learning Platform currently has more than 5,500 registered users. The current network of RTCs includes Belgium, Colombia, China, India, Iran, Kenya, Malaysia, Mozambique and Senegal. All OceanTeacher content is freely and openly available.

OTGA and the Copernicus Marine Service recently started collaborating via training courses for beginners on the Discovery of Operational Ocean Data Products and their use. However, there is vast potential for collaboration in capacity development and this is currently being explored.

The OceanTeacher Global Academy is a Project of the IOC/ IODE (International Oceanographic Data and Information Exchange) supported by the Flanders-UNESCO Trust Fund (FUST) of the Government of Flanders, Belgium.

**CLAUDIA DELGADO**  
IODE Training Coordinator &  
OTGA Project Manager

# FROM NAUTICAL CHARTS TO THE COPERNICUS MARINE SERVICE

Since I was a child, the ocean has always been an inspiring universe to me. That is why I devoted my life to the ocean, first as a Portuguese Navy captain, and later, as a researcher on the history of nautical charts. When it was time to retire, I could have become an admiral, but I preferred to start a PhD in the History of Cartography. In 2016 I received a European Research Council Starting Grant to launch the MEDEA-CHART project, dedicated to the study of medieval and early, modern nautical charts, for which I applied a multidisciplinary approach including cartometric methods of analysis and numerical modelling.

For a navy captain and an historian of cartography, the Copernicus Marine Service and historical nautical charts have one thing in common: they are both tools we can use to better understand and use the ocean in a sustainable way. Copernicus tools are based on complex scientific research and a set of applications related to the sustainability of the ocean. Old nautical charts were instruments to help

pilots solve the practical problem of navigating across the ocean as safely and as effectively as possible. For example, the celebrated cartographical projection used by Gerard Mercator in his 1569 map is considered a major achievement in the history of cartography and marine navigation.

Nautical charts played a key role in the construction and conveying of the first coherent image of the world. The Copernicus Marine Service is another historical breakthrough. The maps it provides are effective tools for educating people and helping to raise awareness of the state of our ocean, its resources, limitations and all the problems that unsustainable human activities are creating.

**JOAQUIM ALVES GASPAR**

Project Medea-Chart

Centro Interuniversitário de História das Ciências e da Tecnologia Faculty of Science, University of Lisbon



Mercator and Historic and Copernicus Marine Service mapsexamined by Joaquim Alves Gaspar (right) and his MEDEA-CHART project team.  
© Jerónimo Alba

# INSPIRING THE YOUTH

## ENGAGING AND ADVOCATING

General public acceptance and support are crucial for achieving a sustainable ocean. This is why ocean literacy experts and ocean ambassadors are learning about and defending the many ocean-related causes all around the world, namely the challenges to be met in protecting the Global ocean. The way it affects our lives and the way we interact with it have to be understood by as many people as possible and by young people in particular, so that they will care for it their whole life long and transmit the same commitment to the next generations.

Mercator Ocean International considers that it is vital to inform the general public about the European Union vision of a Sustainable Ocean and how the Copernicus Marine Service helps to achieve it. This Blue Book is part of its commitment to citizens, along with the many pedagogical “MyOcean” branded tools and the partnerships with Museums and Expeditions undertaken since 2015.



In this chapter a few partners explain how their activities benefit from the Copernicus Marine Service. It is also worth mentioning its contribution to the Oceanographic Institute of Monaco in helping to fulfil the vision of its founder, Prince Albert I of Monaco: “knowing, loving and protecting the oceans” with 670,000 visitors per year, and also the outstanding permanent exhibition “Spacecraft Earth” at the *Cité de l’Espace*, which attracts more than 400,000 people each year in Toulouse (France). At the exhibition there is a dedicated booth to explain the El Niño phenomena or ice-melting in the Arctic Sea through a visual display of

Copernicus Marine Service infographics. The Service also contributed to the Surfrider Europe Foundation campaign “Voice For The Ocean”, by reaching out to more than 50,000 people in the EU and abroad with a survey to find out what they consider to be their top priorities for conserving the ocean (fighting against plastic pollution was priority #1).



© VFTO Surfrider campaign

Copernicus Marine Service also contributes to international events such as COP21’s “*Train du Climat*”, which took place in France in 2015, with stop-overs in 16 stations and a total of 25,000 visitors including 3,500 from schools, or the annual “World Oceans Day” held on the 8<sup>th</sup> June. The Copernicus Marine Service commitment to fight plastic pollution of the ocean actually started in 2014 through a partnership with the 7<sup>th</sup> Continent Expedition, an association which has been actively involved in ocean conservation efforts for many years, reaching out to thousands of youngsters and policy-makers all over the world by popularising scientific research, promoting education and drawing on media skills.

**Altogether, it has been estimated that the Copernicus Marine Service has succeeded in informing 1,5 to 2 million people in the EU by contributing to publicised events, expeditions and museum activities.**

The more Copernicus Marine Service convinces youngsters of the need to tackle the many threats to the global ocean and informs them of the new opportunities for developing the blue economy, the more it reinforces their enthusiasm for ocean science while also encouraging them to follow careers in marine and maritime activities.



Sep. 2000

NÔTRE  
Océan,  
MIEUX  
PROTÉGÉ

Un Océan surveillé  
dit l'état des océans  
pour l'Europe

Copernicus  
European Space Agency

## EDUCATING

### SKILL-BUILDING

Education and Raising awareness are two sides of the same coin and are part of the same ambition: furthering our **knowledge**. In undertaking “educating and skill-building” as a particular marine service provision, Mercator Ocean International has followed sound advice and recommendations from major global and European stakeholders that are worth highlighting:

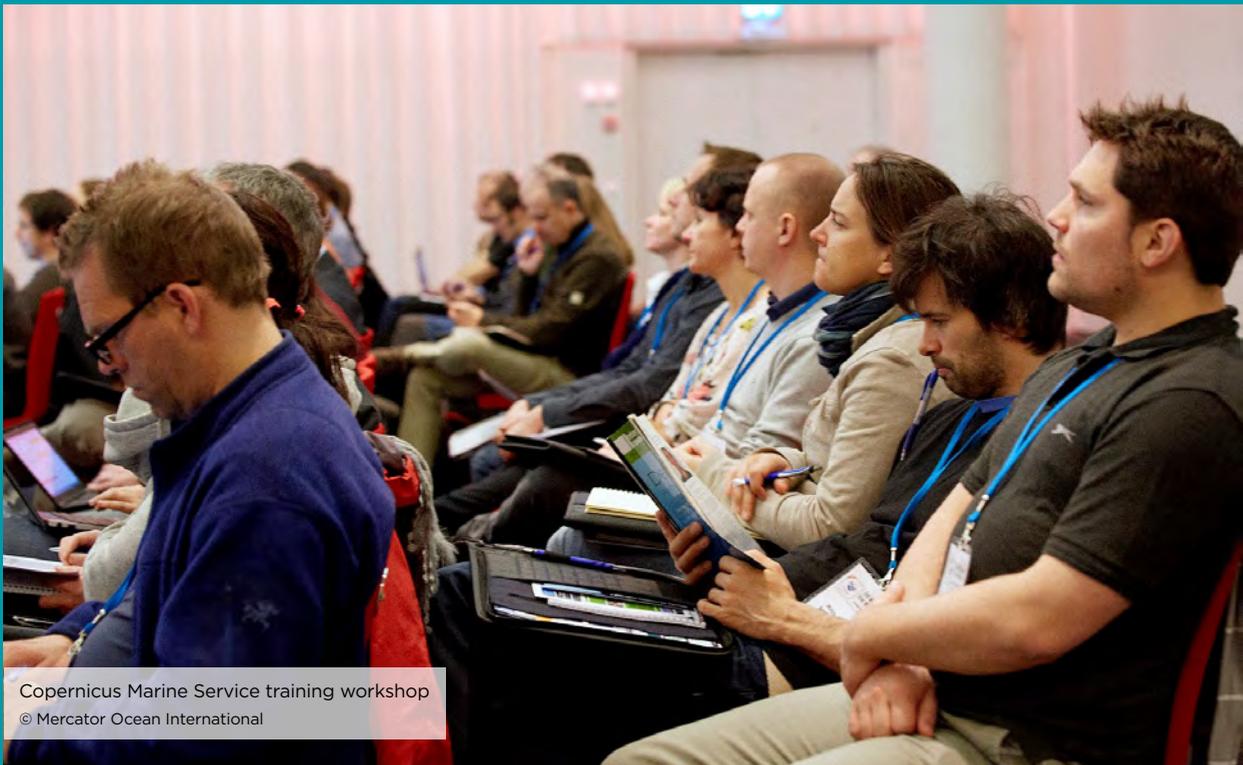
- The need for enhanced ocean science is timely and has been relevantly expressed by the proclamation of the Decade of Ocean Science by the United Nations for Sustainable Development (2021-2030). IOC/UNESCO has been mandated by the UN to coordinate preparation of the Decade and to federate the global ocean community (with which Mercator Ocean International associates the Copernicus Marine Service). For IOC/UNESCO, **“Accelerating Ocean Science for a better World”** also means more and more specialised and fit-to-purpose educational programmes for building tomorrow’s skills. While ocean science is essential, inter alia, for fighting on a global level against the rapid degradation and over-use

of the ocean, the number of skilled individuals in ocean science varies greatly depending on the country: from more than 300 people skilled in ocean science to less than one per million inhabitants (IOC Global Ocean Science Report). Surprisingly, according to the report, specialisation in ocean science also varies according to regions, for example, “marine ecosystem functions and processes” in North and South America, “human health and well-being” in Africa, “ocean technology and engineering” in Asia, “ocean and climate” in Europe, and “blue growth” in Oceania.

- For the OECD “the greatest uncertainty in Marine R&D and Education is the **prospect of disruptive technological innovations**” and it is the responsibility of policy makers, businesses and educational establishments “to prepare together for such deep-seated changes by ensuring that the workforce is equipped with the necessary skills and qualifications to handle upcoming disruptive and transformative changes” (Ocean Economy 2030 report). The report also emphasises “the need for academia and business to help drive a new culture of education and skills.”



Geo 6 Youth Event in Nairobi (Kenya).  
The 4<sup>th</sup> United Nations Environment Assembly UNEA 4.  
© Natalia Mroz/UNEP



Copernicus Marine Service training workshop  
© Mercator Ocean International

- Linking Academia and Industry is the main subject of the European Commission Communication entitled *Innovation in the blue economy* (2014), highlighting potential job and growth opportunities for marine and maritime sectors in the EU. Science and Business have to share a core responsibility “as we are at the dawn of a century that will be largely affected by how we are able to manage our oceans and their resources”.

The European Union’s Directorate-General for Maritime Affairs and Fisheries has also created an “Expert Group on Skills and Career Development in the blue economy”. It pointed out the **“importance of the attractiveness of maritime careers and ocean literacy in general. Clear communication of the career paths in the sector is essential, to understand opportunities in the blue sectors but also possible bridges with other sectors”**.

The Marie Skłodowska-Curie Actions (MSCA), the main support mechanism in EU Horizon 2020 for human resources in all areas of research and innovation, focuses on **combining research excellence with mobility, training and attractive career opportunities**.

The Erasmus Programme also supports the development of skills in the blue economy and closer cooperation

between higher education and the private sector via **Knowledge Alliances**, structuring partnerships between higher education and business.

- The European Marine Board set out clear recommendations to achieve a modern vision of marine graduate training in Europe in its report entitled **Future Science Brief on Marine Graduate Training**. One of them consists in **“fostering active partnerships between academia, policy and industry”** and in updating Masters and PhD programmes in the marine sciences in Europe, “to avoid designing PhD programmes which only prepare graduates for an academic career, given that most PhD graduates will leave academia and pursue a career in another sector, or create their own business opportunities”.

Both threats and opportunities pertaining to the global ocean may potentially lead to an unprecedented need for skilled people. According to the EU’s first annual report on the blue economy (including all economic activities related to the ocean, seas and coastal areas) the sector currently generates a turnover of €566 billion, accounting for €174 billion of value added and creating jobs for nearly 3.5 million people and this might double in the EU by 2030.

## EDUCATING

In delivering ocean data and ocean expertise, the Copernicus Marine Service is at the crossroads of many skills related to ocean monitoring and the ever growing ocean-related applications they are allowing. Specialisations that did not exist even thirty years ago and will still evolve considerably in the years to come, include observation from satellites, observation at sea, ocean data assimilation, ocean modelling, coastal modelling, ocean forecasting, cloud-based solutions, Geographic Information Systems (GIS), data science, climate change impacts, Marine Renewable Energy and biodiversity conservation, among others.

Whatever the purpose of the users, they all need quality ocean data that is accessible and timely. Concretely, the Copernicus Marine Service has been contributing to the sharing of knowledge by developing its own training activities in EU Member States and by joining educational programmes such as the H2020 JERICO-NEXT summer schools or the International Ocean Institute (IOI) training programmes in Malta. More recently, the Copernicus Marine Service started contributing to the GMES & Africa Training Strategy for the development and implementation of marine & coastal area services. Training sessions enable users to integrate Copernicus Marine Service data more easily in their operational systems or in their projects. For users in business and public services, session materials and hands-on exercises are designed to help them be more creative, more innovative and ultimately more competitive while respecting the rules for a sustainable ocean.



H2020 and training session

© Institute of Entrepreneurship Development (IED)

By participating in Copernicus Marine Service face-to-face training sessions, trainees also join its Blue Community and benefit from opportunities for discussing issues with a mixed audience including business people, policy makers and scientists. For the Marine Service, these sessions are precious opportunities for collecting the participants' needs and requirements. Since 2016, 2,000 trainees from eleven EU Member States have benefitted from training in the European Union. During the same period, Copernicus Marine Service on-line tutorials have been followed by 6,000 visitors.

Copernicus Marine Service also benefits from highly skilled people on its teams, its partners and contractors.



My name is Babette Tchonang, I started reading for my PhD thesis in oceanography at **Toulouse University** in November **2017**. My research project aims to evaluate the potential contribution of the future SWOT (Surface Water Ocean Topography) satellite for Copernicus Marine Service ocean monitoring and forecasting activities. The advent of satellite observation marked a technological breakthrough for Oceanography. SWOT, in its turn, will be a new revolution thanks to its enhanced capability for fine-scale observation of sea level and ocean currents. As part of my research, I am interacting with many scientists around the world. My PhD thesis will be completed by the end of 2020 and will hopefully pave the way for a successful integration of SWOT observations in the Copernicus Marine Service.



Mercator Ocean International is supported by the European Commission in order to help it promote a new culture of education and skills and Copernicus Marine Service efforts in favour of Education and Skill Building will be continued with dedicated or specialised resources depending on the markets (e.g.: aquaculture, Marine Renewable Energy, etc.) and on the policies concerned (Arctic, MSFD, etc.). Summer schools, tutorial catalogues, E-learning, partnerships with business, academia and IOC's Ocean Teacher Global Academy will all be reinforced. Echoing the recommendations of the European Commission, IOC/ UNESCO, OECD and the European Marine Board, the more Copernicus Marine Service succeeds in engaging marine communities across academia, European and national policy-makers, public services & agencies and business through its training programmes, the better it will serve the sustained development of skilled people and "blue careers".

**CÉCILE THOMAS-COURCOUX**

International development and cooperation director  
Mercator Ocean International



Digital ocean leverages blue growth, innovation and job creation.  
© Freepik



08

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# CONCLUSION



# HOW WOULD A COPERNICUS MARINE SERVICE BENEFIT THE PLANET AND SOCIETY?

Mercator Ocean International began with the aim of answering the questions “A Copernicus Marine Service? How would it benefit the planet and society?» with an explanation and examples of its achievements and usefulness. During completion of the Blue Book, new Members of the European Parliament have been elected and President-elect Ursula von der Leyen has been preparing a new Commission. The Blue Book therefore contains testimonies from policy makers who are no longer in office but who have been working for a sustainable ocean for many years. This book is not only a narrative and testimony for accountability purposes, but also a legacy to the commitment of men and women from all walks of life and many member countries of the European Union. Furthermore, it pays homage to the work done over many years to successfully implement the Copernicus Marine Service. The ambitious objectives of the Blue Book, Copernicus for a Sustainable Ocean are threefold:

## STRIVING FOR OCEAN ADVOCACY

The challenges related to the ocean are considerable and affect the entire ecosystem of our planet: climate change, preservation of biodiversity, pollution, overexploitation of its resources, but also economic and societal potential. **By dipping into the testimonies, facts and figures provided in each chapter, uninformed or curious citizens will be able to learn more, in particular by contacting Mercator Ocean International and all the actors of the Copernicus Marine Service, associations and NGOs or the other contributors to the book. They may also decide to get more involved in protecting the ocean or simply in keeping a close eye on what is happening to over 70% of the surface of their planet and 97% of the water of their planet.**

## SHARING COPERNICUS VALUE

By highlighting a service of the European Union’s Copernicus programme and its societal impact, the book sheds light on the incredible ambition of the programme for society, its environment, its health, its safety, its jobs, its well-being, by guaranteeing regular monitoring of the atmosphere, the ocean and continental surfaces. **The European Union’s Copernicus programme today represents undisputed know-how, expertise and global leadership, driven by a far-reaching vision and political determination, a proven systemic framework, networks of experts and an ever-increasing number of users. As Copernicus will soon be the world’s leading producer of environmental data, it is important that entrepreneurs, industrialists, public services and authorities, teachers and policy makers - among others - know and understand its importance and potential in their work and in their daily lives.**

## ENHANCING ENGAGEMENT

The European Commission has entrusted Mercator Ocean International with the task of implementing the Copernicus Marine Service for the benefit of environmental policies and also of companies, scientists and citizens. **By reporting transparently and to as many people as possible on some of the achievements of the Copernicus Marine Service for a Sustainable Ocean, Mercator Ocean International intends to inspire all citizens, especially young readers, to realise the progress that has been made in these fields and how much knowledge, skills and know-how will be required for further research: the range covers ocean science, ocean forecasting, satellite and offshore observation infrastructures, cloud and data science, not to mention all sectors of the blue economy (renewable energies, fisheries and sustainable aquaculture, coastal applications, maritime transport, education, etc.) There are considerable career opportunities in Europe and around the world. The younger generations can also change the world through their choice of career path.**

# HOW CAN WE BETTER MEET TOMORROW'S NEEDS?

Continuous improvement of the service is an intrinsic aspect of the operational objectives set by Mercator Ocean International, particularly in terms of data and information, functionalities and user support. The relevance and usefulness of customer service are rated by users for each request (the last index is from the end of August 2019: 4.9/5), by quarterly surveys, by feedback from users at Copernicus Marine Service events or through partnerships. This feedback is included in numerous reports on the service for the European Commission and the EU Member States.

**As part of the book, we invited the Copernicus delegates of the EU Member States to answer a short questionnaire on the quality of the Copernicus Marine Service and to suggest areas of improvement that should be considered as a priority.**

Six EU Member States replied in April 2019, based on feedback from users in their own countries (France, Germany, Italy, the Republic of Malta, Norway and Sweden). This valuable feedback does not have any statistical value, but provides very good indicators and general guidance for improving the service in the years to come.

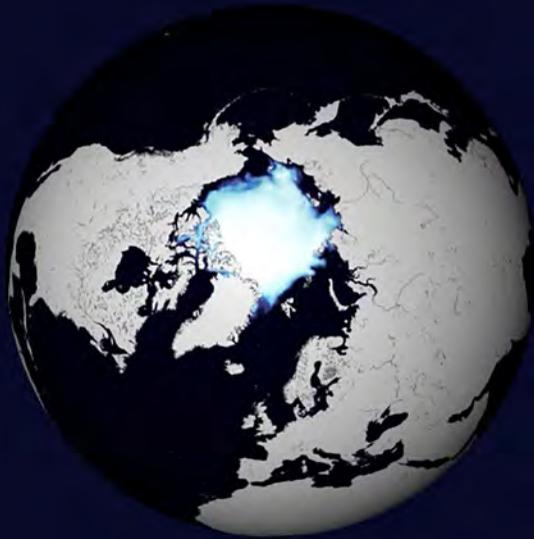
Their answers to the closed questions on

service quality reveal that the service is considered to be very reliable, timely and relevant, that it is very effective in informing and engaging citizens and that access to the service and the contribution to business competitiveness are activities that should be consolidated.

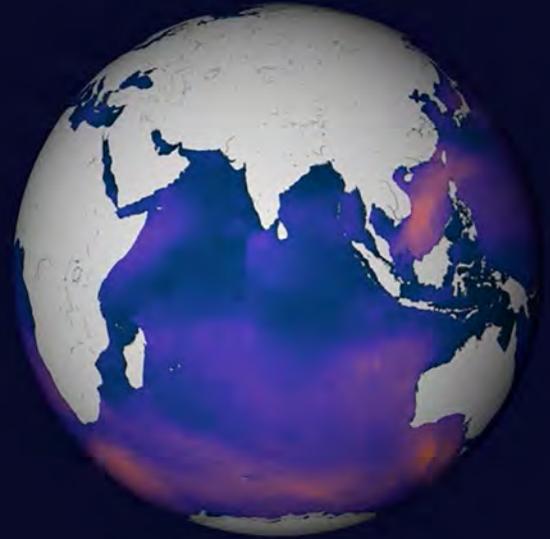
Their answers to the open questions on the areas of improvement of the Copernicus Marine Service focus above all on the need to provide ever greater support for European and international policies related to governance, a good ecological status and sustainable exploitation of the ocean (e.g.: UN Sustainable Goals, Integrated Maritime Strategy, Arctic Policy, etc.), and then to meet the needs of coastal regions, by improving the spatial and temporal resolution of ocean analyses and forecasts. A third need is to develop the range of data observed at sea (in situ). A fourth is to extend the product ranges related to marine biology for the benefit of sustainable fisheries and aquaculture management and the preservation of marine biodiversity. Fifth, there is a need to facilitate and accelerate access to Copernicus data and their processing, particularly through cloud technologies and sixth, to continue to be proactive on the United Nations initiative with regard to the Decade for Ocean Science and educational activities for young citizens.



The manned Service Desk of the Copernicus Marine Service  
© Laura Clem



SEA ICE FRACTION



SURFACE WAVES

© EU Copernicus Marine Environment Monitoring Service 2018

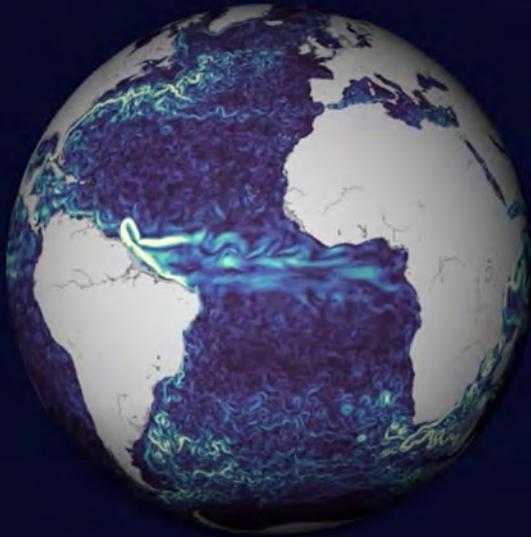
## LEADS FROM THE FEEDBACK AND THE MAIN DRIVING FACTORS

These requests from EU Member States coincide with the main guidelines driving the evolution of the Copernicus Marine Service as developed by Mercator Ocean International.

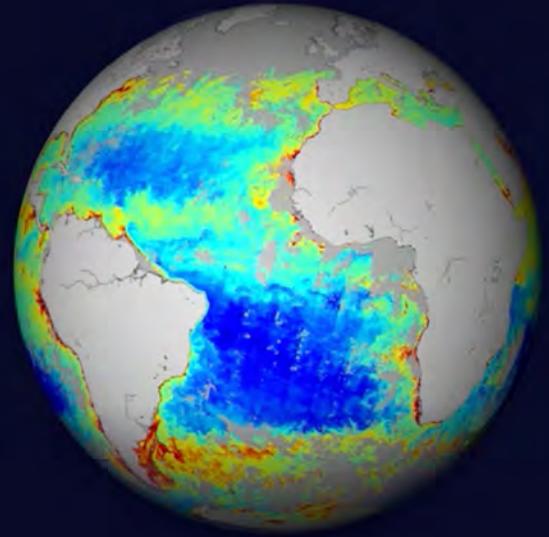
**With regard to observations at sea and from space** Mercator Ocean International is working with the European Commission, ESA and EUMETSAT to deploy the Copernicus Marine Service's "observation" portfolio through an evolution of the SENTINEL satellite missions, particularly for future space observation of the poles and with the Ocean Observation Networks (the Global Ocean Observation GOOS Network and its European component EOOS) to improve observation at sea, and along the coastline and of both physical and marine biology parameters.

**Advanced collaboration with national bodies and the European Environment Agency** will provide essential support for coastal environmental services.

**The assessment of blue carbon and CO<sub>2</sub>** in the oceans and the production of scenarios for the marine domain are indispensable, while IPCC experts are working on the impact of climate change on the oceans and on glaciers



**SURFACE CURRENTS**



**SEA SURFACE CHLOROPHYLL**

**Future generations of ocean modelling and coupling** with atmospheric models will enable Mercator Ocean International to improve the representation, accuracy, and spatial and temporal resolution of the Blue Ocean (physical characteristics such as currents, temperature, salinity, sea level, waves, etc.), the White Ocean (sea ice characteristics, etc.) and the Green Ocean (biogeochemical characteristics such as oxygen, pH, phytoplankton and micronekton) of the Copernicus Marine Service as well as the coherence between their models.

**Easy and open access to data** remains one of Mercator Ocean International's priorities for the Copernicus Marine Service and will remain so, in particular by integrating advanced digital solutions based on cloud technologies that are strongly recommended and supported by the European Commission. In the future, all the data of the Copernicus programme will be accessible via unique portals, which will combine other data and offer computing spaces, thus opening up prospects for innovation, open science and unprecedented transformations.

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Whether you are a biologist, developer of applications for renewable energies, aquaculture farm manager, climatologist, professor, digital entrepreneur, environmental assessment specialist, political decision-maker at the regional, national, European or international level, ocean defender in a foundation, NGO or association, data-scientist, creator of a start-up, maritime transport expert, marine safety actor, environmental defender, fisherman, offshore infrastructure insurer, re-insurer for extreme events, scientific mediator or citizen concerned by the health of your planet, etc. **the Copernicus Marine Service will continue to support, structure, enrich and promote your projects in favour of a sustainable ocean.** It must maintain its international leadership in the service of the EU and remain the global reference for delivering expert, reliable and timely ocean insight for decisions concerning the global ocean.

**Capitalising on its achievements, its strong Copernicus value chain and its wide and global uptake, the European Union's Copernicus Marine Service has the necessary means to play a much more comprehensive role in ensuring a safe, healthy and productive ocean, thus continuing to help preserve biodiversity, the Arctic and to contribute to climate change studies.**

# MERCATOR OCEAN INTERNATIONAL RELIES ON THE FOLLOWING 135 PARTNER-CONTRACTORS WHO HELP US PROVIDE OUR EFFICIENT COPERNICUS MARINE SERVICE EVERY DAY

40% of whom are businesses from the private sector in 21 countries of the European Economic Area

- ▶ ACRI-ST
- ▶ ACTIMAR SAS
- ▶ AEROSPACE VALLEY
- ▶ AGENCIA ESTATAL METEOROLOGICA
- ▶ AKKA
- ▶ ALTRAN
- ▶ ARGANS
- ▶ ARTELIA
- ▶ ATOS
- ▶ AZTI
- ▶ BALEARIC ISLANDS OBSERVING AND FORECASTING SYSTEM
- ▶ BARCELONA SUPERCOMPUTING CENTRE
- ▶ BARCELONA EXPERT CENTRE
- ▶ BENTLEY/ACTION MODULERS
- ▶ BLUE RISE
- ▶ CAP GEMINI
- ▶ CEFAS
- ▶ CELAD
- ▶ CESGA
- ▶ CHILDREN FOR THE OCEANS
- ▶ CIÊNCIA VIVA
- ▶ CITÉ DE L'ESPACE
- ▶ CITICAN
- ▶ CLS
- ▶ CMA-CGM
- ▶ CMCC
- ▶ CNR
- ▶ CNRS
- ▶ COLOMBOSKY
- ▶ CONFERENCE OF PERIPHERAL MARITIME REGIONS
- ▶ CSIC
- ▶ CSIRO
- ▶ DELTARES
- ▶ DHI
- ▶ DHI GRAS
- ▶ D-ICE Engineering
- ▶ DLTM
- ▶ DMI
- ▶ DriftNoise
- ▶ DTU
- ▶ EARSC
- ▶ ECMWF
- ▶ ENVEX
- ▶ ENVITIA Ltd
- ▶ ETT
- ▶ EUROGICIEL-SCALIAN
- ▶ EuroGOOS
- ▶ EVENFLOW
- ▶ eXXpedition
- ▶ BSH
- ▶ FIHAC
- ▶ SYKE
- ▶ FMI
- ▶ FORTH

- ▶ FUGRO
- ▶ FUNPAR
- ▶ GEO
- ▶ HZG
- ▶ HCMR
- ▶ HIDROMOD
- ▶ HYDROCOTE
- ▶ IFREMER
- ▶ IH CANTABRIA
- ▶ IMT
- ▶ INRIA
- ▶ IMR
- ▶ INTERNATIONAL OCEAN INSTITUTE
- ▶ IOBAS
- ▶ I-SEA
- ▶ ISARDSAT
- ▶ ISPRA
- ▶ IST
- ▶ INGV
- ▶ OGS
- ▶ MARETEC
- ▶ MARINE INSTITUTE
- ▶ MARINE SCOTLAND SCIENCE
- ▶ MEEO
- ▶ MET NORWAY
- ▶ MET OFFICE UK
- ▶ METEO FRANCE
- ▶ METEO75
- ▶ N7MOBILE
- ▶ NERSC
- ▶ NIHWM
- ▶ NIMRD GRIGORE ANTIPA
- ▶ NIVA
- ▶ NOC
- ▶ NOLOGIN
- ▶ NOVELTIS
- ▶ OCEAN DATA LAB
- ▶ OCEAN ENERGY EUROPE
- ▶ OCEAN NEXT
- ▶ OCEANSCOPE
- ▶ OPEN OCEAN
- ▶ ORION
- ▶ PAIC
- ▶ PLANETEK
- ▶ PML
- ▶ POLAR VIEW
- ▶ PUERTOS DEL ESTADO
- ▶ PWC
- ▶ QUIET OCEANS
- ▶ RBINS
- ▶ READING UNIVERSITY
- ▶ RIXEN
- ▶ ROCKETT BROTHERS
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- ▶ VTT

# GLOSSARY

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## **ANALYSIS AND RE-ANALYSIS**

An analysis is a snapshot of the state of the ocean at any given time. It is done using a model (that is typically under development, with changes occurring regularly), data and observations to provide a best fit produced on the fly. An analysis is generally used as a starting point for forecasts to make them as close to reality as possible (i.e. with all the data available).

An oceanographic reanalysis consists in modelling the state of the ocean over a long period of time (several years) while correcting it with the best available past observations.

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## **ASSIMILATION (OF DATA)**

Data assimilation is a branch of numerical modelling that uses techniques to reduce the errors (differences) between observations and models. The model forecast is called the “first guess” before the observations are incorporated. The result of data assimilation (first guess corrected with observations) is called an analysis.

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## **BOUNDARY CONDITIONS**

In a physical system, the boundary conditions are the values of the parameters on the edges of the defined domain. In other words, the boundary conditions are the way the model “interacts” with the “outside” world, to allow some continuity and exchange. In global ocean modelling, boundary conditions can be at the surface (representing exchanges with the atmosphere), at the bottom and along coastlines.

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## **CHLOROPHYLL-A**

A green pigment (basically composed of molecules) found in autotrophic organisms (plants, algae...) - first level of the food chain - and essential for the photosynthesis process as it allows plants to absorb energy from light and form organic compounds.

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## **CO<sub>2</sub>**

It is the main greenhouse gas in Earth’s atmosphere. It is consumed and stored by photosynthetic organisms (algae, plants, cyanobacteria...) and is responsible for ocean acidification.

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## **CURRENT VELOCITY**

Speed of movement of water particles (m/s) in a given direction.

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## **DOWNSCALING**

Generally, this is the process used to exchange information from a lower resolution parent model to a higher resolution child model at its boundaries over a specific area. Downscaling provides a more detailed description of processes in a smaller area, and it is widely used in downstream services.

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**EUTROPHICATION**

This is a common, human-induced phenomenon occurring in coastal waters often induced by the river discharge of nitrate or phosphate-containing detergents, fertilizers or sewage. An oversupply of nutrients in rivers (mainly nitrogen and phosphorus) leads to an overgrowth of algae. When these algae die, their bacterial degradation consumes oxygen, resulting in oxygen depletion in underlying waters.

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**GLOBAL OCEAN**

All seas and oceans of the globe.

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**HAB**

Harmful Algal Blooms - Type of algal efflorescence (accumulation of algae, stimulated by ambient conditions such as high concentrations of nutrients), which leads to detrimental effects on the nearby fauna, through water de-oxygenation or emission of toxins. HAB can affect humans through consumption of intoxicated sea food or through breathing or swallowing toxins in the air/water.

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**HINDCAST**

A “forecast” carried out *a posteriori*, after the event has passed, with all the information and data available. The aim is to see if your model is capable of predicting reality, and how close your prediction is to reality (it is a comparison between a prediction in the past and what actually happened in the past).

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**IN SITU OCEAN OBSERVATIONS**

Environmental measurements collected from sea-borne monitoring systems (profiling floats, gliders, surface moorings, etc.) referred to as in situ data.

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**METOCEAN**

Abbreviation of “meteorology and oceanography”, which refers to the environmental conditions, including winds, waves and other meteorological parameters that can be evaluated in a region.

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**MIXED LAYER THICKNESS**

Thickness of the ocean layer, from the surface (measured in meters) for which the physical parameters of the ocean vary little on the vertical axis. This vertical mixing is caused by surface processes, such as wind stress or wave breaking, that create turbulence and homogenize the mixed layer.

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**NUTRIENT**

Substance used by an organism to survive, grow and reproduce. For instance, in the ocean, phytoplankton consume inorganic nutrients (nitrate, phosphate...) to build their organic matter.

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**OCEAN ACIDIFICATION**

Ongoing decrease of the pH of the Earth's ocean due to the dissolution in seawater of anthropogenic carbon dioxide (released in the atmosphere by the burning of fossil fuels and deforestation).

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**OCEAN HEAT CONTENT**

The ocean heat content is a parameter that represents the thermal energy stored in the ocean. In the context of climate change, OHC is an important factor because it contributes to sea level rise by thermal expansion.

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**OCEAN MODEL**

Numerical model (run on a computer) to do calculations to predict ocean behaviour. These models solve physical equations that describe the dynamics of the ocean (processes) in response to driving forces and can predict its evolution over time. The models are improved by assimilating actual satellite or in-situ measurements.

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**OCEAN MONITORING INDICATORS (OMI)**

Ocean Monitoring Indicators (OMIs) by the Copernicus Marine Service are free and can be downloaded. They indicate trends based on data sets covering the past quarter of a century. They are key variables used to track the vital health signs of the ocean and their evolution due to climate change.

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**NEKTON/  
MICRONEKTON**

**Nekton:** Actively swimming aquatic organisms: crustacean, fish, jellyfish, and molluscs.

**Micronekton:** a subdivision of nekton based on size (> than 4-5 mm, between zooplankton and nekton). Small fish, small crustaceans, molluscs, etc (prey of larger fish). They tend to migrate in the water column, towards the surface, at night (to avoid being eaten) and they are thought to play an important role in the ocean food web.

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**PLANKTON/  
PHYTOPLANKTON/  
ZOOPLANKTON**

Small organisms drifting in ocean currents. They are at the bottom of the food chain. Phytoplankton form the first bottom level of the food chain: unicellular autotrophic organisms (algae, the equivalent of plants and grass on land) that synthesize organic matter through photosynthesis. Zooplankton form the second bottom level of the food chain, they are small animals that feed on phytoplankton.

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**PRIMARY PRODUCTION**

The production of organic carbon products (carbohydrates, such as glucose) from inorganic carbon and light, occurring principally through photosynthesis, done by primary producers (phytoplankton).

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**REFLECTANCE** Part of solar energy that is reflected by seawater. It is measured by satellite remote sensors at different wavelengths to differentiate ocean colours in the upper layer of the ocean.

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**SDG** Sustainable Development Goal

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**SEA ICE** Frozen sea water, evolving on the sea, such as icebergs and ice floes.

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**SEA LEVEL/  
ALTIMETRY** Altimetry is a technique used to measure the sea surface level by satellite. The latter carries an altimeter, an instrument capable of determining variations in the ocean surface elevation by transmitting/receiving a radar signal and by making a simple distance calculation.

.....

**SEA SURFACE  
HEIGHT** The sea surface height represents the local elevation of the ocean relative to its resting level called the geoid. Local variations in sea surface height generally reflect dynamic phenomena/structures in the ocean, such as eddies or large currents.

.....

**SEA SURFACE WAVE** What we commonly call just “waves”. Deformation of the surface caused by the friction of the wind, which then propagates in wave trains forming the wind sea and swells. There are other types of ocean waves such as internal waves, tides and tsunamis.

.....

**SENTINEL  
SATELLITES** The Sentinel satellites are specifically designed to meet the needs of the EU Copernicus services and their users. Since the launch of Sentinel-1A in 2014, the European Union undertook a project to place a constellation of almost 20 more satellites in orbit before 2030.

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**TRANSPARENCY** Parameter that measures how clear a fluid is. It is the opposite of turbidity.

.....

**TURBIDITY** It is a measure of the degree of haziness of a fluid. It is the opposite of transparency.

.....

# BLUE BOOK - Copernicus for a sustainable ocean

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