Copernicus Marine Service

04

Issue 4, 2020

OCEAN STATE REPORT SUMMARY

Implemented by MERCATOR OCEAN INTERNATIONAL

ABOUT THE OCEAN STATE REPORT

The Ocean State Report is an annual publication of the Copernicus Marine Service that provides a comprehensive and state-of-the-art report on the current state, natural variations, and ongoing changes in the global ocean and European regional seas. It is meant to act as a reference European Union report for the scientific community, international and national bodies, and the general public.

Using satellite data, models and reanalyses, and *in situ* measurements, the Copernicus Marine Ocean State Report provides a 4-dimensional view (latitude, longitude, depth, and time) of the blue (e.g. hydrography and currents), white (e.g. sea ice) and green (e.g. biogeochemical) ocean. It draws on expert analysis and is written by over 100 scientific experts from more than 30 European institutions. Scientific integrity is assured through a process of independent peer review in collaboration with the Journal of Operational Oceanography.

COPERNICUS MARINE REGIONAL OCEAN PRODUCT DIVISIONS

1. Global Ocean
2. Arctic Ocean
3. Baltic Sea
4. European North West Shelf Seas
5. Iberian Biscay Ireland Seas
6. Mediterranean Sea
7. Black Sea

ABOUT THIS SUMMARY

This document is a summary of the fourth issue of the Copernicus Marine Ocean State Report and highlights the current state, natural variations, and ongoing changes in the global ocean. It draws on the Copernicus Marine Ocean Monitoring Indicator (OMI) framework.

It approaches the topic from several angles, presenting the state of key ocean variables, examining ongoing changes to the ocean in line with climate change, analysing natural variability and extreme events, and discussing the services that the ocean provides to humanity. Finally, new tools and success stories from the Copernicus Marine Service illustrate how accurate, timely information is key to understanding and adapting to the evolving ocean and seas.

01 SUSTAINABLE DEVELOPMENT AND THE OCEAN

Society, a sustainable economy, and the environment —the three pillars of sustainable development— rely on the ocean. This section explores the importance of the ocean in the framework of the UN Sustainable Development Goals, supported by ocean data and information. **Page 3.**

02 CHANGING OCEAN

Key indicators are used to track the vital health signs of the global ocean. This section presents the indicators from Copernicus Marine used to monitor and understand changes already in motion and presents notable changes to the ocean over the last quarter of a century. **Page 4.**

03 MAJOR IMPACTS OF CLIMATE CHANGE

The ocean is undergoing sweeping, severe, and unavoidable changes, with major impacts on marine ecosystems and humanity. The IPCC Special Report on Ocean and Cryosphere, and the Copernicus Marine Service Ocean State Report both show that the global ocean is becoming warmer and more acidic, sea level is rising, and that sea ice is retreating. This section presents the most notable impacts of climate change on the ocean. **Page 6.**

04 THE OCEAN AS A SERVICE PROVIDER

Humans depend heavily upon the ocean through the goods, cultural importance and services provided by marine ecosystems. This section provides an overview and specific examples of ocean ecosystem services and details the key ocean variables that underlie these services. **Page 12.**

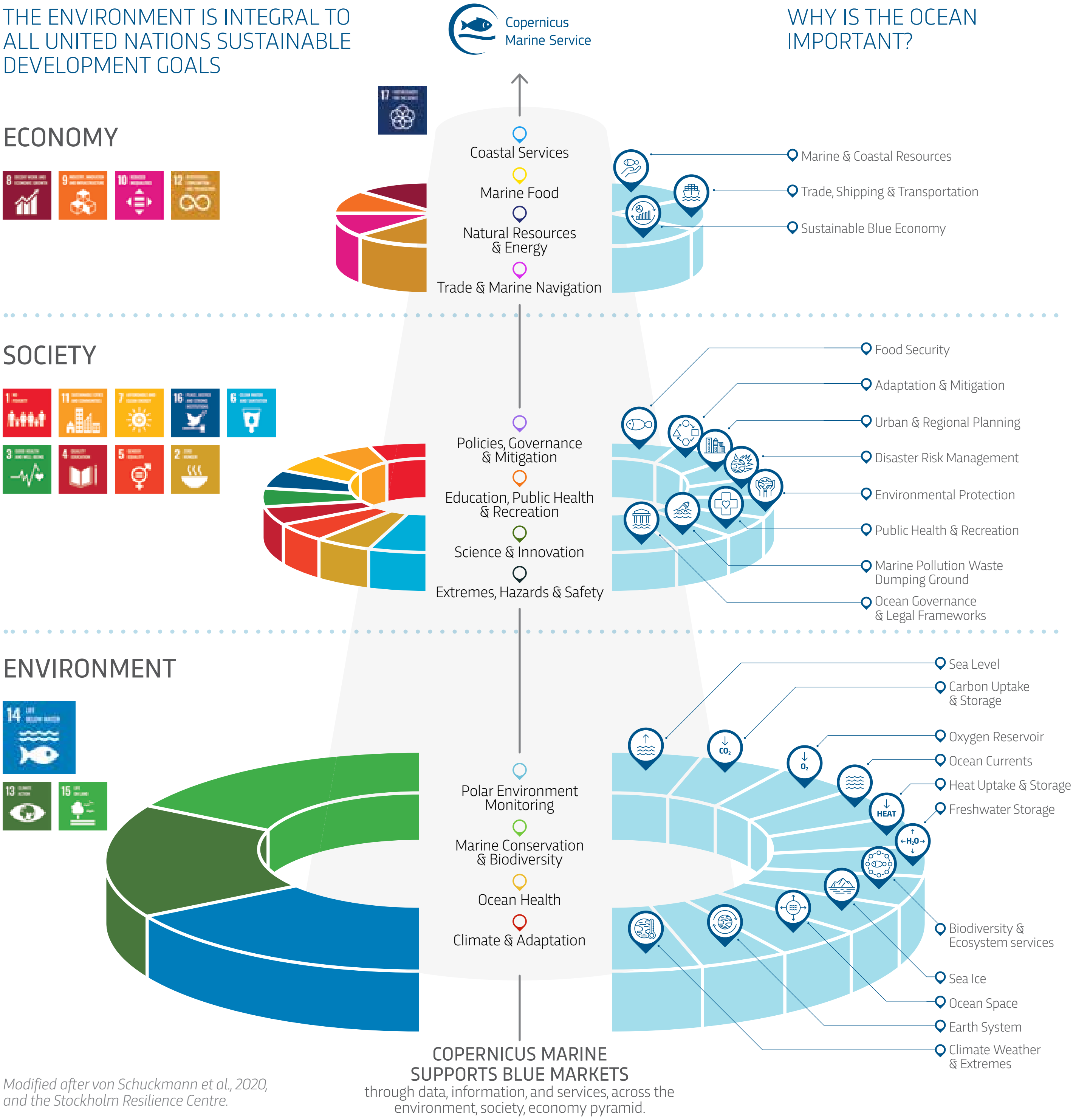
05 MONITORING THE OCEAN WITH COPERNICUS MARINE

The Copernicus Marine Service provides state-of-the-art analyses and ocean forecasts, offering a valuable capability to observe, understand, and anticipate changes and extreme events in the marine environment. This section presents advancements in the Copernicus Marine service, and successful examples of applying these tools in practice. **Page 16.**

SUSTAINABLE DEVELOPMENT AND THE OCEAN

The ocean is essential, both directly and indirectly, for nearly all life on the planet. Human well-being and civilisations rely on the ocean — billions of people depend on the ocean for their livelihoods, and the market value of marine and coastal resources and industries is estimated to be trillions of US Dollars.

The health of the environment is the basis of a sustainable future, and the infographic below provides a view of the United Nations Sustainable Development Goals showing that the ocean environment supports both economical and societal development.



Modified after von Schuckmann et al., 2020, and the Stockholm Resilience Centre.

CHANGING OCEAN

To understand long-term changes to the ocean, we must monitor ocean indicators — key variables used to track the vital health signs of the global ocean. These indicators are crucial if we are to monitor and understand changes already in motion and help us adapt to a changing climate. The Copernicus Marine Service is tuned into the needs of the international community and provides updates on these indicators split across the blue, green, and white ocean.

WHAT ARE THE WMO GLOBAL CLIMATE INDICATORS?

The World Meteorological Organization (WMO) Global Climate Indicators are a set of parameters that provide key information for the most relevant domains of climate change.

WMO GLOBAL CLIMATE INDICATORS

- Temperature and Energy
- Ocean and Water
- Cryosphere

GREEN OCEAN

CHLOROPHYLL-A

UNITS: %/YEAR

Mediterranean Sea	TREND FROM 1997-2019	↑ +0.21	±0.87 %/YEAR
Black Sea	TREND FROM 1997-2019	↓ −1.33	±1.01 %/YEAR
Baltic Sea	TREND FROM 1997-2019	↑ +0.85	±0.68 %/YEAR
Arctic Ocean	TREND FROM 1997-2019	↑ +0.71	±0.16 %/YEAR
North Atlantic Ocean	TREND FROM 1997-2019	↑ +0.17	±0.01 %/YEAR
Western Pacific Islands	TREND FROM 1997-2018	↓ −0.82	±0.01 %/YEAR
Central Pacific Islands	TREND FROM 1997-2018	↓ −0.80	±0.002 %/YEAR
Pacific Islands Total Area	TREND FROM 1997-2018	↓ −0.70	±0.001 %/YEAR

OCEAN ACIDIFICATION

UNITS: pH/YEAR
TREND FROM 1985-2018

Ocean and Water

Contributions to: Eurostat/EEA in support of SDG 14

Global Ocean

↓ −0.0016

±0.0006 pH UNITS/YEAR

As pH decreases, ocean acidification increases.

OXYGEN INVENTORY

UNITS: MOL/M²/YEAR
TREND FROM 1955-2017

Black Sea

↓ −0.15

±0.02 MOL/M²/YEAR

WHITE OCEAN

ARCTIC SEA ICE EXTENT

UNITS: KM²/DECADE

Trend 1979-2018

↓ −520,000

±30 000 KM²/DECADE

Trend 1993-2018

↓ −750,000

±60 000 KM²/DECADE

Cryosphere

ANTARCTIC SEA ICE EXTENT

UNITS: KM²/DECADE

Trend 1979-2018

↑ +120,000

±50 000 KM²/DECADE*

Trend 1993-2018

↓ −10,000

±120 000 KM²/DECADE*

* Trend not statistically significant

The **blue ocean** describes the physical state of the ocean, such as sea surface temperature, sea level, currents, waves, and winds. Measurements of ocean heat content, salinity, and density also fall under the blue ocean.

The **green ocean** is concerned with biogeochemical processes, the transfer of simple chemical substances between ocean life and the ocean environment. The green ocean encompasses, for example, variations in the biological carbon pump, chlorophyll-a concentrations, ocean nutrients, and primary production, as well as ocean acidification and ocean deoxygenation.

The **white ocean** refers to the life cycle of any kind of floating ice in the polar regions. Indicators for the white ocean include the extent, volume, and thickness of sea ice in the Baltic Sea, Arctic Ocean, and Antarctic Ocean.

BLUE OCEAN

SEA SURFACE TEMPERATURE

UNITS: DEGREES CELSIUS/YEAR
TREND FROM 1993-2018

Global Ocean

+0.014
±0.001 °C/YEAR

Mediterranean Sea
+0.037
±0.002 °C/YEAR

Black Sea
+0.07
±0.006 °C/YEAR

Baltic Sea
+0.031
±0.003 °C/YEAR

Western Pacific Islands
+0.02
±0.01 °C/YEAR

Central Pacific Islands
+0.01
±0.02 °C/YEAR

Pacific Islands Total Area
+0.02
±0.01 °C/YEAR

Temperature and Energy

OCEAN HEAT CONTENT (0-700 M)

UNITS: WATTS/M²
TREND FROM 1993-2018

Global Ocean

+0.9
±0.1 W/M²

Black Sea
+1.1
±0.1 W/M²

Western Pacific Islands
+1.55
±1.54 W/M²

Pacific Islands Total Area
+1.08
±0.74 W/M²

Central Pacific Islands
+0.85
±0.72 W/M²

Temperature and Energy

Contributions to: WMO State of the Climate 2019

THERMOSTERIC SEA LEVEL (0-700 M)

UNITS: MM/YEAR
TREND FROM 1993-2018

Global Ocean

+1.5
±0.1 MM/YEAR

SEA LEVEL

UNITS: MM/YEAR
TREND FROM 1993-2018

Global Ocean

+3.3
±0.4 MM/YEAR

Mediterranean Sea
+2.5
±2.2 MM/YEAR

Black Sea
+2.2
±2.2 MM/YEAR

North West Shelf
+2.7
±2.0 MM/YEAR

Baltic Sea
+3.9
±2.2 MM/YEAR

Iberian Biscay Ireland Seas
+3.3
±2.0 MM/YEAR

Western Pacific Islands
+4.8
±2.5 MM/YEAR

Central Pacific Islands
+3.1
±2.5 MM/YEAR

Pacific Islands Total Area
+3.5
±2.5 MM/YEAR

Ocean and Water

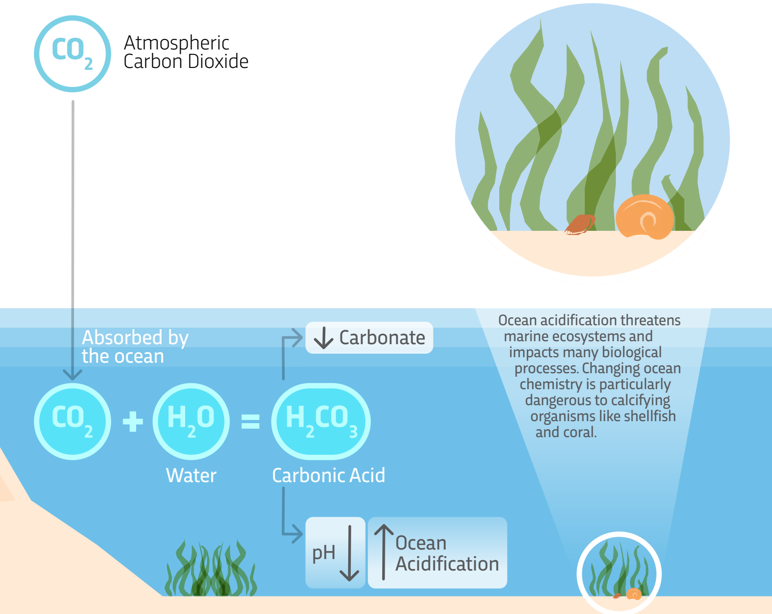
Contributions to: WMO State of the Climate 2019

MAJOR IMPACTS OF CLIMATE CHANGE

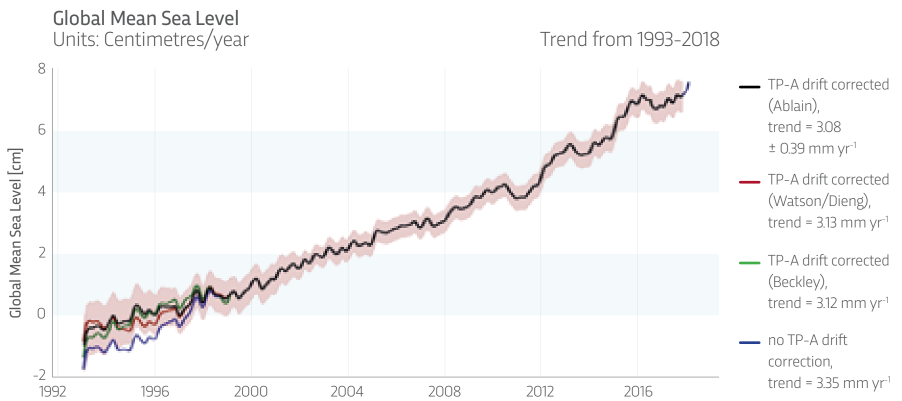
OCEAN ACIDIFICATION: THE OCEAN IS BECOMING MORE ACIDIC

The ocean is a major sink of anthropogenic excess CO_2. This absorption of carbon mitigates the effects of global warming, but it also results in a major threat to marine life — ocean acidification.

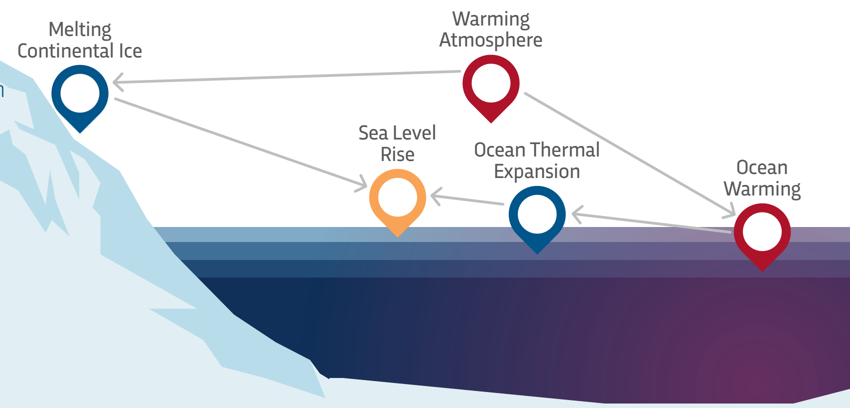
The pH of contemporary surface ocean waters is already 0.1 pH units lower than in pre-industrial times. As pH is logarithmic, this 0.1 pH unit change is equivalent to a nearly 30% increase in ocean acidity since pre-industrial times.



SEA LEVEL RISE CONTINUES, BUT AT AN ACCELERATED PACE



Sea level rise in centimetres (cm) for the period 1993-2018. The curves show different corrections for an instrument anomaly on the TOPEX-A altimeter (TP-A). The black, red and green curves show TP-A drift corrections applied based on work by Ablain, Watson/Dieng, and Beckley, respectively. The shaded red area shows a 90% confidence interval for each measurement, and the blue curve represents no TP-A correction. Source: Copernicus Marine Ocean State Report 4.



Since 1993, global mean sea level has risen at a rate of 3.3 ± 0.4 mm per year. New calculations in the fourth Ocean State Report reveal that sea level rise is accelerating, with this rate increasing by 0.12 ± 0.073 mm/year each year. An instrument drift correction to the global mean sea level time series is also discussed in the fourth Ocean State Report.

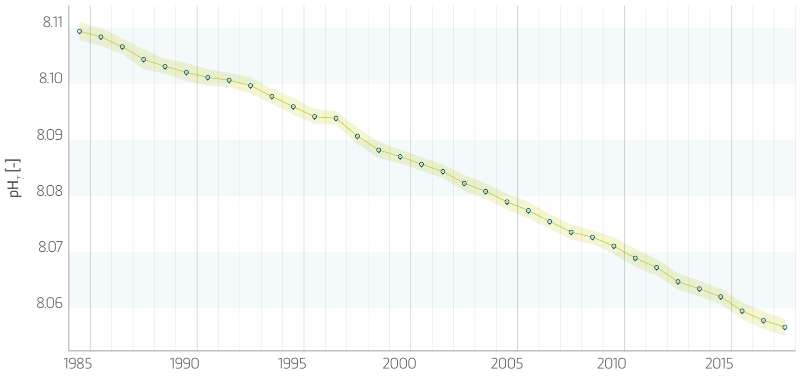
Knowledge of sea level rise is fundamental, as it allows us to better characterise the consequences of rising seas for coastal populations and low-lying areas.

The ocean is undergoing sweeping, severe, and unavoidable changes, with major impacts on marine ecosystems and humanity. Rising seas threaten coastal and low-lying areas, increased ocean acidification threatens marine organisms and ecosystems, and sea ice is retreating.

Hundreds of millions of people live alongside the ocean, and over three billion people depend on marine biodiversity for their livelihood. Consequently, these changes are forcing people across the globe to fundamentally alter how they coexist with the ocean.

Yearly mean surface sea water pH reported on total scale
Units: pH reported on total scale

Trend from 1985-2018



Annual global mean surface seawater pH derived from the Ocean Monitoring Indicator "Surface Ocean pH", showing an overall trend for decreasing pH and increasing acidification. Source: Copernicus Marine Ocean State Report 4.

KEY FIGURES

~30% — The ocean is more acidic than in pre-industrial times

20-30% — of excess CO_2 has been absorbed by the ocean since pre-industrial times

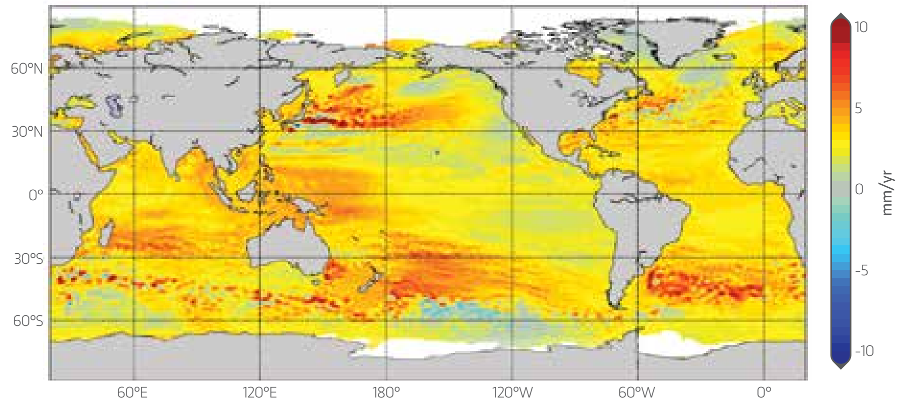
WMO GLOBAL CLIMATE INDICATORS

Ocean and Water

UN SUSTAINABLE DEVELOPMENT GOALS

Regional Mean Sea Level Trends scale
Units: Millimetres/year

Trend from 1993-2018



Regional trends in sea level change from 1993-2018 in millimetres per year (mm yr-1) showing that sea level is rising for the vast majority of the global ocean. Source: Copernicus Marine Ocean Monitoring Indicator.

KEY FIGURES

1.2 ±0.073 MM/YEAR — The rate which sea level rise is accelerating each year

3.3 ±0.4 MM/YEAR — Rate of sea level rise per year since 1993 in mm per year

WMO GLOBAL CLIMATE INDICATORS

Ocean and Water

UN SUSTAINABLE DEVELOPMENT GOALS

MAJOR IMPACTS OF CLIMATE CHANGE

OCEAN WARMING: SEA TEMPERATURE AT RECORD HIGH

2: The IPCC Special Report on Ocean and Cryosphere uses 'virtually certain' to refer to findings with a likelihood of 99-100%.

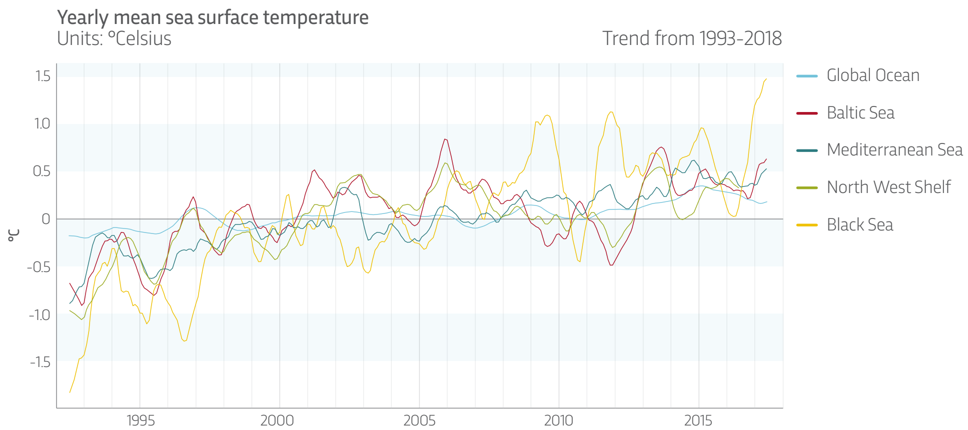
According to the IPCC Special Report on Ocean and Cryosphere, it is virtually certain[2] that the global ocean has warmed unabated since 1970, taking up about 90% of the excess anthropogenic heat in the climate system. Two important measures of ocean warming are Ocean Heat Content and Sea Surface Temperature.

Sea Surface Temperature is an Essential Climate Variable which provides insight into the flow of heat into and out of the ocean. It is a fundamental variable for

SEA SURFACE TEMPERATURE

European regional seas and the global ocean have undergone warming since the past quarter of a decade. Global Sea Surface Temperature has increased at a rate of 0.014 ± 0.001 °C per year with warming occurring over most of the globe. There continues to be unprecedented warming of the ocean surface, and the past four years are the four warmest since records began.

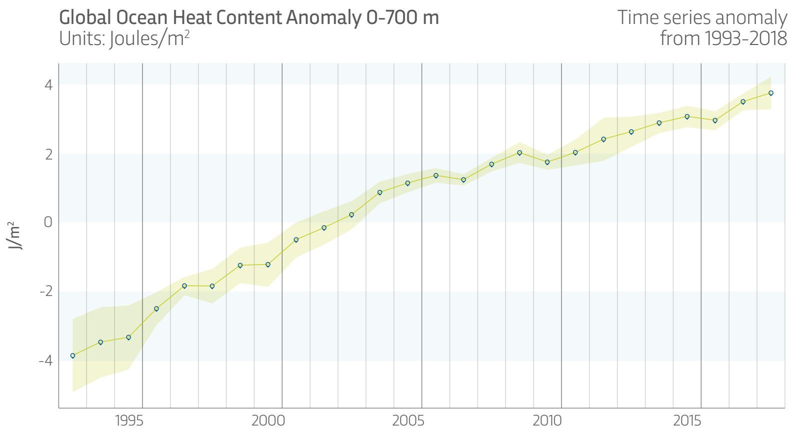
The 2018 sea surface temperature anomaly was lower than the three preceding years due to cold El Niño Southern Oscillation conditions in the Pacific Ocean which are known to have wide-reaching, global impacts.



Sea Surface Temperature trends for the global ocean and European regional seas from 1993-2018. Units are degrees Celsius per year. Source: Copernicus Marine Ocean State Report 4.

OCEAN HEAT CONTENT

Ocean Heat Content refers to the heat absorbed by the ocean. Knowing how much heat energy is stored in the ocean —and where it is stored and released— is essential for understanding the state, variability, and changes of Earth's climate system. In the last quarter of this decade, global ocean heat gain has increased in the upper 700 m of the ocean and heat has been sequestered in deeper ocean layers at depths down to more than 2,000 m. Increasing Ocean Heat Content contributes to 30-40% of observed global mean sea-level rise through the thermal expansion of seawater. Ocean warming also threatens marine ecosystems, putting economies and food security at risk.



1933-2018 time series of global Ocean Heat Content anomaly in the upper 700 m of the ocean. Units are joules per square metre. Source: Copernicus Marine Ocean Monitoring Indicator.

ocean and weather prediction, as well as for climate variability and climate change. Ocean Heat Content represents the heat energy stored in the ocean and is a key factor in the Earth's energy budget, ocean-atmosphere interactions, marine ecosystems, and sea level change.

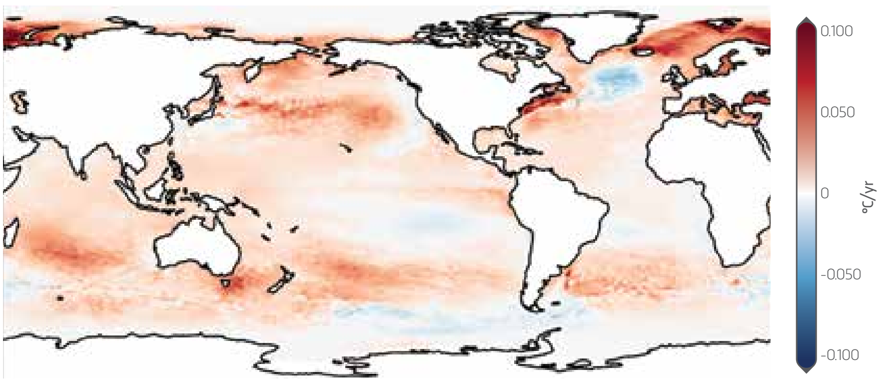
WMO GLOBAL CLIMATE INDICATORS

Temperature and Energy

UN SUSTAINABLE DEVELOPMENT GOALS

Regional Mean Sea Surface Temperature Trends
Units: °Celsius/year

Trend from 1993-2018



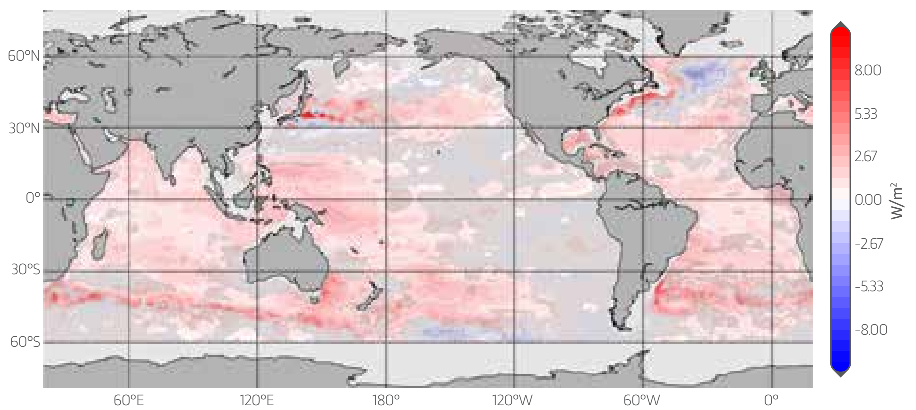
Area-averaged linear sea surface temperature trends (2-year running smoothing) over the period 1993-2018 calculated from the global Copernicus Marine Service satellite product. Units are degrees Celsius per year. Source: Copernicus Marine Ocean State Report 4.

KEY FIGURES

0.014 °C
±0.001 °C/YEAR
rate of sea surface temperature rise per year since 1993

Global Ocean Heat Content Trends 0-700 m
Units: Watts/m²

Trend from 1993-2018



Estimates of Ocean Heat Content are obtained from integrated differences of the measured temperature and a baseline average along a vertical ocean profile of 0-700 m. The linear change over the period 1993-2018 at each grid point was then evaluated to obtain a global map of regional ocean heat content trend, expressed in watts per square metre per year. Source: Copernicus Marine Ocean Monitoring Indicator.

KEY FIGURES

~90%
Uptake of anthropogenic heat by the ocean

30-40%
Sea level rise caused by thermal expansion

MAJOR IMPACTS OF CLIMATE CHANGE

SEA ICE WELL BELOW AVERAGE

WMO GLOBAL CLIMATE INDICATORS

Cryosphere

UN SUSTAINABLE DEVELOPMENT GOALS

THE ARCTIC

Since 1993, Arctic sea ice extent has decreased significantly at an annual rate of -750,000 square kilometres (km^2) per decade. This is equivalent to losing an area of sea ice about 1.5 times the size of Spain per decade and represents a loss of -5.8% per decade of Arctic sea ice extent over the period 1993 to 2018. Summer (September) sea ice extent loss amounts to 1,180,000 square kilometres per decade, which corresponds to -14.85% per decade. Winter (March) sea ice extent loss amounts to -570,000 square kilometres per decade, a loss of -3.42% per decade. The 2018 Arctic maximum winter sea ice extent, which occurred in March, is the second lowest on record after winter 2017.

Northern Hemisphere Sea Ice Extent — September Average

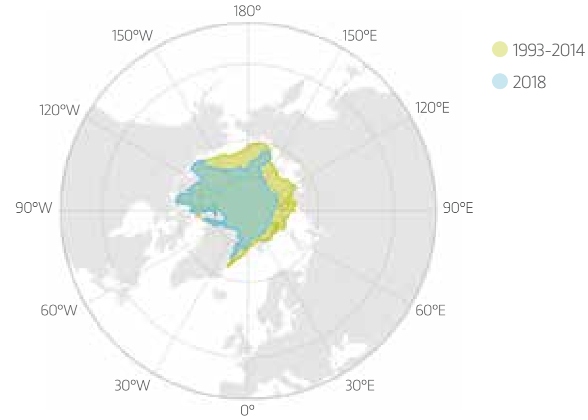


Figure shows average September sea ice extent in the Arctic Ocean. The long-term September average (from 1993-2014) is shown in green and the September 2018 average is shown in blue. Evaluated from ocean reanalysis. Source: Copernicus Marine Service.

THE ANTARCTIC

The last quarter of the years 2016, 2017, and 2018 experienced unusual losses of ice. The year 2018 has the second lowest sea ice extent since 1993, second only to 2017.

There was a sharp decrease in Antarctic sea ice extent starting in 2014, directly following a record high. From the beginning of the Copernicus Marine record in 1979 to the year 2015, Antarctic sea ice extent was slowly but steadily increasing, with a record high in 2014 that lasted several months.

However, from late 2014 to 2017 there was a loss of some 2 million square kilometres of sea ice. This is equivalent to a loss of nearly 4 times the area of Spain in 3 years. In 2018 there was a very small increase in sea ice extent.

The recent reduction after years of growth makes it difficult to establish a reliable trend for Antarctic sea ice extent, and there is not yet any scientific consensus on whether these recent changes can be attributed to climate change.

Southern Hemisphere Sea Ice Extent — September Average

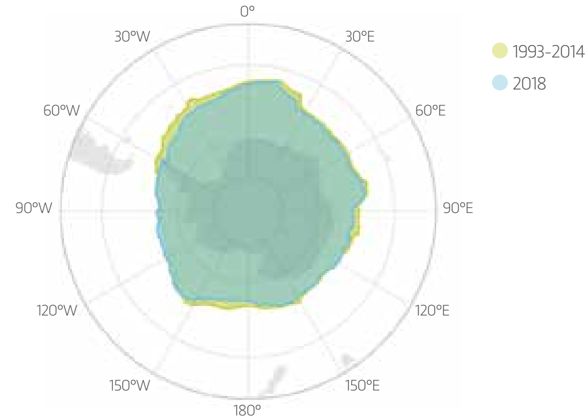


Figure shows average September sea ice extent in the Antarctic Ocean. The long-term September average (from 1993-2014) is shown in green and the September 2018 average is shown in blue. Evaluated from ocean reanalysis. Source: Copernicus Marine Service.

THE BALTIC

Sea ice coverage has a vital role in the annual course of physical and ecological conditions in the Baltic Sea. Moreover, it is an important parameter for safe winter navigation, with many merchant ships requiring icebreaker assistance.

Sea ice extent in the Baltic Sea often varies from year to year. Over the past quarter of a decade, sea ice extent has varied from 30,000 km^2 to 260,000 km^2.

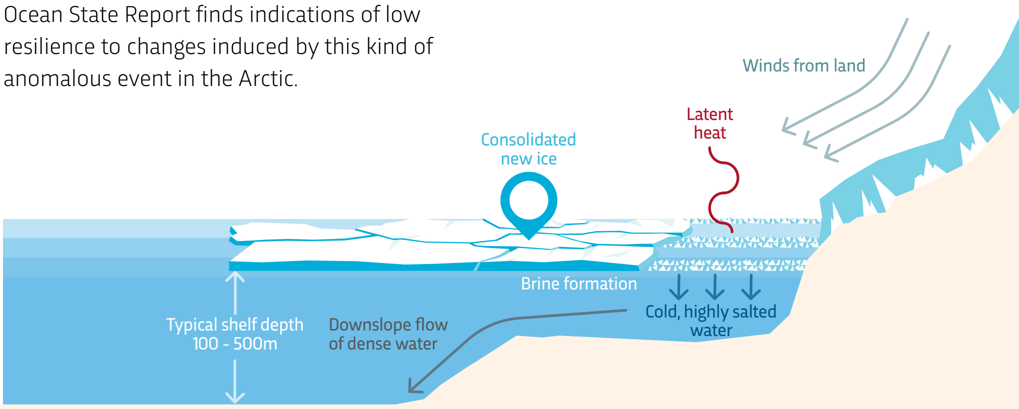
The sea ice extent when the Baltic Sea is fully covered is 422,000 km^2, which was last observed in the 1940s. The Finnish Ice Service classify the Baltic ice season as mild when the extent is below 115,000 km^2, severe when the extent is above 230,000 km^2, and extremely severe when it is above 345,000 km^2.

The 2017/18 ice season was classified as average with 38% (160,000 km^2) coverage.

FORMATION OF A SHELF WATER POLYNYA

In mid-winter of 2018, an unusual opening in the sea ice — a polynya—occurred in the Arctic. A polynya of such dimensions has never before been observed in this region, which is known for hosting some of the oldest and thickest ice.

Sea ice was pushed offshore by strong, warm south-easterly winds, and a large area of open water was exposed directly to the atmosphere. While the polynya closed within a week due to a combination of drifting old ice and the formation of new ice, the fourth Ocean State Report finds indications of low resilience to changes induced by this kind of anomalous event in the Arctic.



The mechanisms driving formation of a shelf water, "latent heat" polynya. Modified from Maqueda et al. (2004).

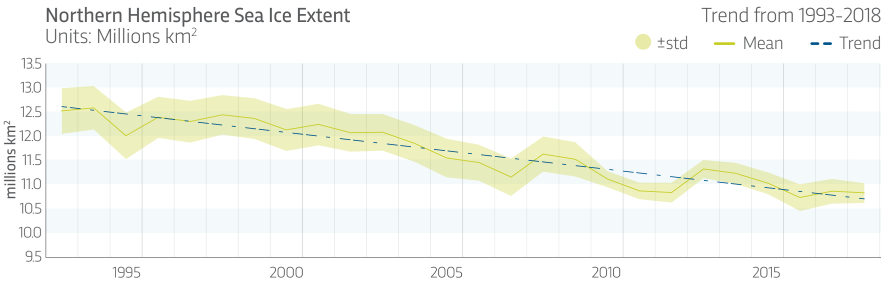


Figure shows the annual mean sea ice extent 1993-2018 averaged over the northern hemisphere, evaluated from reanalysis and expressed in millions of square kilometres (km²). The green shaded area shows one standard deviation (std). Source: Copernicus Marine Ocean Monitoring Indicator.

KEY FIGURES

−750,000 KM²

Sea ice extent lost per decade between 1993 and 2018

This is equivalent to losing an area of sea ice about 1.5 times the size of Spain per decade.

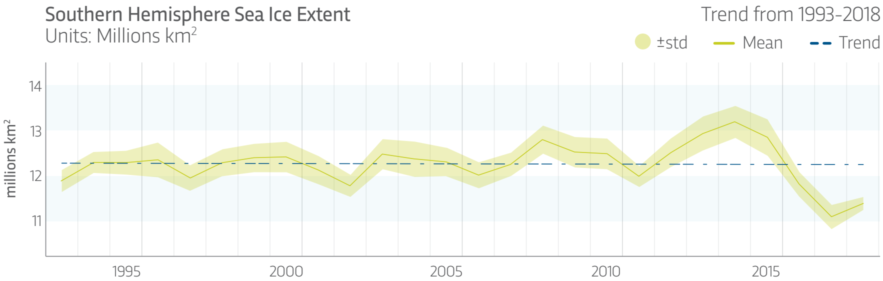
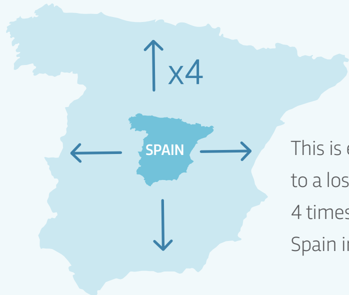


Figure shows the annual mean sea ice extent from 1993-2018 averaged over the southern hemisphere and expressed in millions of square kilometres (km²). The green shaded area shows one standard deviations (std). The trend is not statistically significant. Evaluated from reanalysis of Copernicus Marine Ocean Monitoring Indicator.

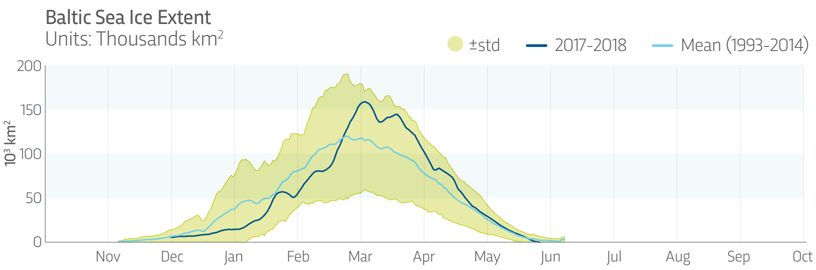
KEY FIGURES

−2.0 MILLION KM²

loss of sea ice extent between 2014 and 2017



This is equivalent to a loss of nearly 4 times the area of Spain in 3 years.



Baltic sea ice extent expressed in thousands of square kilometres (km²), showing the 1993-2014 mean and the value for 2017-2018. The green shaded area shows one standard deviation (std). Source: Copernicus Marine Ocean Monitoring Indicator.

KEY FIGURES

38% Sea ice extent coverage in 2017/18*

160,000 KM²

Sea ice extent coverage in 2017/18*

*classified as an average sea ice season

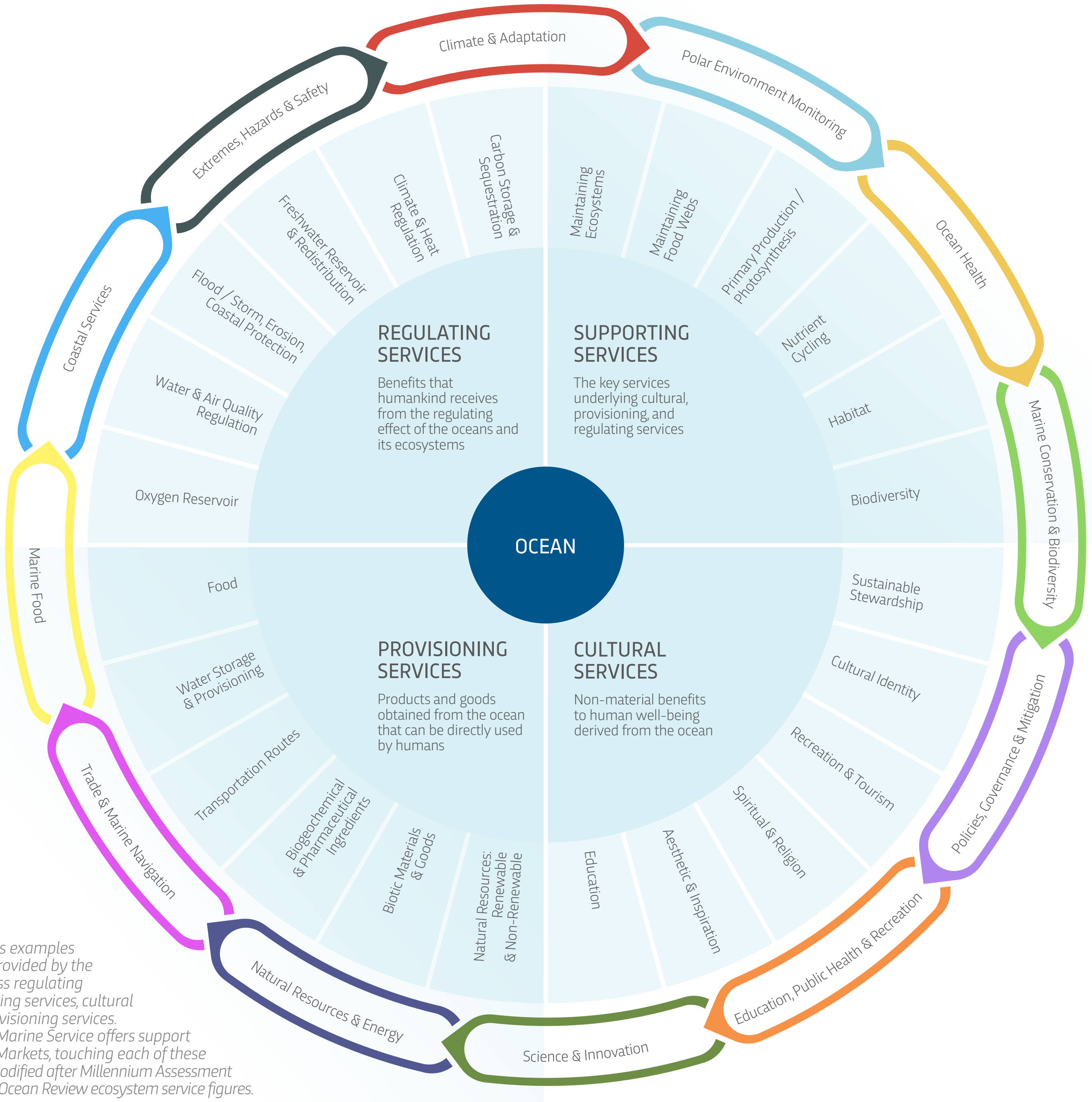
THE OCEAN AS A SERVICE PROVIDER

Human communities depend heavily upon the goods and services provided by marine ecosystems. However, changes to the ocean, including ocean warming, acidification, loss of oxygen, and sea-level rise have impacted these marine ecosystems and they are being stretched to unsustainable limits. Though all marine ecosystem services are interconnected, these services can be divided into four categories: regulating services, supporting services, cultural services and provisioning services.

Copernicus Marine Service

COPERNICUS MARINE SERVICE MARKETS

- Polar Environment Monitoring
- Marine Conservation & Biodiversity
- Ocean Health
- Climate & Adaptation
- Policies, Governance & Mitigation
- Education, Public Health & Recreation
- Science & Innovation
- Natural Resources & Energy
- Extremes, Hazards & Safety
- Coastal Services
- Marine Food
- Trade & Marine Navigation

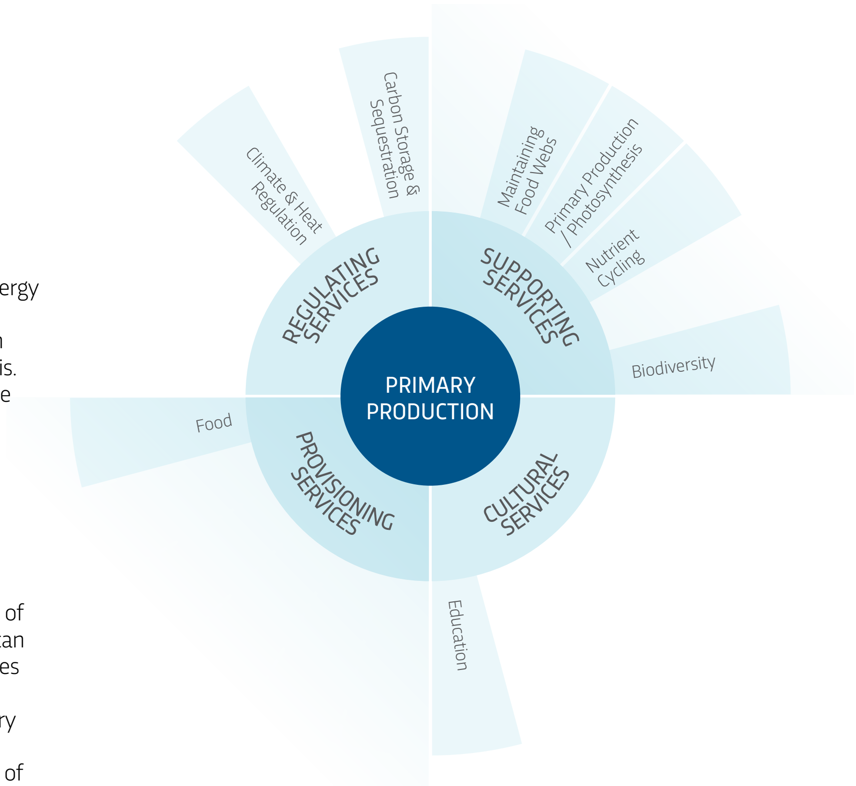


This figure shows examples of the services provided by the ocean, split across regulating services, supporting services, cultural services and provisioning services. The Copernicus Marine Service offers support across the Blue Markets, touching each of these ocean services. Modified after Millennium Assessment 2005 and World Ocean Review ecosystem service figures.

PRIMARY PRODUCTION

WHAT IS IT?

Ocean primary production is the synthesis of organic carbon by organisms in the ocean. Oceanic primary production provides the energy required to support entire marine food webs, and it is the base of all marine ecosystems. The main source of this energy is sunlight, which drives the uptake of dissolved carbon dioxide through photosynthesis. Primary production supports all marine life and plays a key role in the Earth's carbon cycle.



This figure shows marine ecosystem services and how they can be linked to monitoring primary production.

HOW IS IT ESTIMATED?

Ocean colour, measured by satellites, is a proxy for the measurement of chlorophyll-a in the ocean. This pigment, produced by green plants, can be used in turn to estimate concentrations of phytoplankton and rates of primary production. Phytoplankton are the microscopic algae that form the base of the marine food chain and are key players in primary production. Innovations in satellite observation have allowed ocean colour measurements to reveal the concentrations of different types of phytoplankton based on their reflective properties.

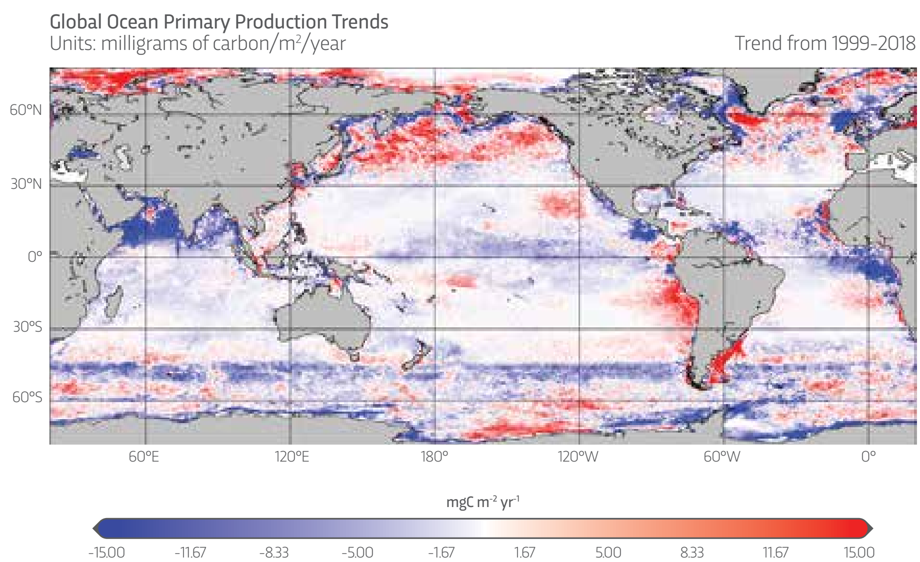
WHY IS IT IMPORTANT?

As well as being the base of oceanic food-webs, primary production drives the biological carbon pump, and contributes to carbon uptake through CO_2 fixation. It also serves as a proxy for the food potentially available to organisms higher in marine food webs, making it a potential indicator for fishery management strategies, such as the Common Fisheries Policy in the European Union.

In addition, primary producers such as phytoplankton produce more than half of the oxygen content in the Earth's climate system. Fluctuations in primary production have strong impacts on carbon and oxygen cycling, as well as on the marine ecosystems that provide humans with food.

WHAT DID WE OBSERVE?

Copernicus Marine Service satellite observations show that, on a global scale, the most productive areas for primary production are located in the Arctic and coastal regions. Primary production shows seasonal variation, and peaks during summer on both a global and European scale. Globally, a small but significant decrease of primary production has been observed over the past 20 years. Year-to-year changes are potentially linked to physically driven changes in the ocean such as the strength of vertical mixing.



Primary production trend from 1999 to 2018 from the satellite archive of the global ocean. This figure presents a global map of the trend of primary production, computed at each pixel from the satellite archive, except for the Mediterranean Sea. Blue indicates a decrease of primary production and red indicates an increase, though some low trend values are not statistically significant. Units are milligrammes of carbon per square metre per year. Source: Copernicus Marine Ocean State Report 4.

THE OCEAN AS A SERVICE PROVIDER

DID YOU KNOW?

Seafood provides protein, fatty acids, vitamins and other micronutrients essential for human health such as iodine and selenium. Over 4.5 billion people in the world obtain more than 15% of their protein intake from seafood.

MARINE DIATOMS

WHAT ARE THEY?

Diatoms are a major group of microscopic algae found in the ocean and in fresh water. Diatoms are the most abundant class of phytoplankton, and have an exoskeleton composed of silica. Marine diatoms generate 40% of the organic matter that serves as food for life in the ocean and are responsible for around 40% of carbon sequestration into the deep ocean layers.

A photo of a diatom

HOW ARE THEY ESTIMATED?

Similar to primary production, marine diatom concentration is derived from satellite observations of ocean colour. Ocean colour is a proxy for the measurement of chlorophyll-a in the ocean, and the amount of chlorophyll-a from different types of phytoplankton —including diatoms— can be estimated due to the differing reflective properties of various phytoplankton.

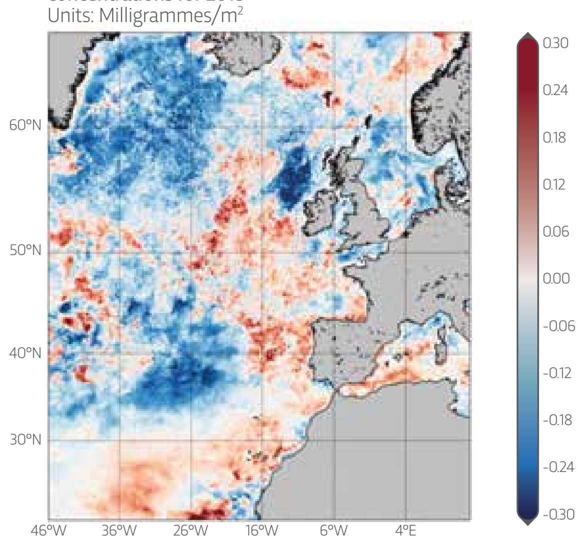
WHY ARE THEY IMPORTANT?

Diatoms underpin ocean biological productivity and transfer carbon from the surface to the deep layers of the ocean when they die. Globally, they are responsible for 40% of marine primary production and 40% of the particulate organic carbon exported to the deep ocean. Consequently, changes in diatom concentration can greatly influence global climate, atmospheric carbon dioxide concentration, and the function of marine ecosystems. In addition, diatoms produce around 20% of the oxygen generated on Earth each year — more than all the world's rainforests combined.

WHAT DID WE OBSERVE?

The fourth Copernicus Marine Service Ocean State Report has presented a new data product on diatom chlorophyll concentration. The study is focused on the North Atlantic Ocean, where changes in diatom chlorophyll concentration exhibit a clear seasonal pattern and are mostly determined by light and nutrient availability. Some regions presented distinct anomalies, with concentrations ranging from twice to half the long-term baseline values. In 2018, the peak value of diatom chlorophyll concentration, averaged over the entire study area, was the lowest measured in the entire 1997-2018 period. In 2018, diatoms continued to be the dominant variety of phytoplankton in the coastal regions of the English Channel and the North Sea, but the period of diatom dominance was one week shorter, on average, than the 1997-2017 mean value.

Anomaly of diatom chlorophyll-a concentrations for 2018
Units: Milligrammes/m^2



Anomaly in annual mean diatom concentration for 2018 with respect to the long term baseline value. Positive anomalies are shown in red and negative anomalies are shown in blue. Units are milligrammes per square metre. Source: Copernicus Marine Ocean State Report 4.

THE ECONOMIC VALUE OF MARINE ECOSYSTEMS

Ocean-based economic activities are worth trillions of dollars and the ocean generates hundreds of millions of jobs. However, marine ecosystem services worldwide are often ignored or underestimated due to their limited or indirect visibility. It is critically important to assess these services to improve marine management and policy.

KEY FIGURES

1,733
Million €/Year
Value of the carbon sink ecosystem service in the Mediterranean Sea, 1993-2014

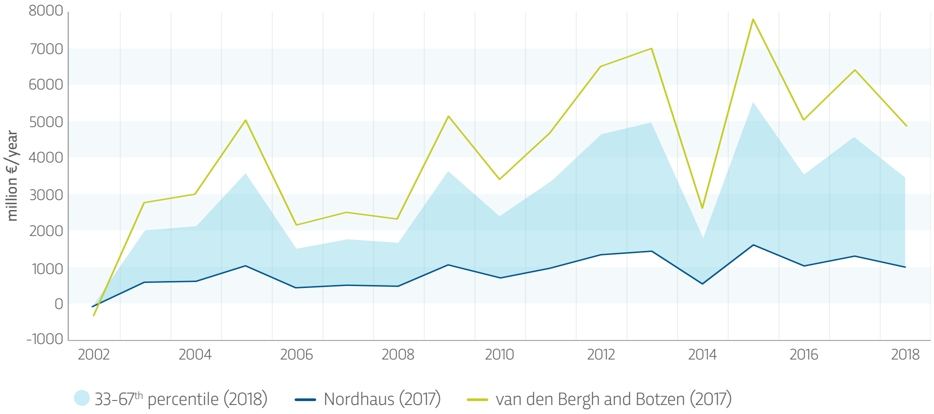
2,095
Million €
Value of the carbon sink ecosystem service in the Mediterranean Sea in 2018

MEASURING THE ECONOMIC VALUE OF THE CARBON SINK ECOSYSTEM SERVICE WITH THE COPERNICUS MARINE SERVICE

The ocean is key to controlling atmospheric CO_2, and the majority of carbon which is not trapped in sediments or fossil fuels can be found dissolved in the ocean. The ocean's absorption of 20 to 30% of total anthropogenic emissions in the last two decades has mitigated the effects of climate change but has also led to increased ocean acidification.

The sequestration of carbon varies over time and space – and therefore needs to be monitored. In the fourth Ocean State Report, researchers present measurements and models of CO_2 flux combined with the Social Cost of Carbon (SCC) to estimate the value of the Mediterranean Sea as a carbon sink in 2018. In total, the carbon sink ecosystem service provided by the Mediterranean had a value of almost €2.1 billion in 2018, but this natural capital is absent from measures of national accounting such as the Gross Domestic Product (GDP).

Value of Carbon Sink Ecosystem Service for the Mediterranean Sea
Units: Millions €/year



Values of the Mediterranean Sea's carbon sink ecosystem service for the years 2002-2018 using different carbon price estimates. Units are millions of Euros per year. Source: Copernicus Marine Ocean State Report 4.

Value of Carbon Sink Ecosystem Service for the Mediterranean Sea for 2018
Units: Millions €/year

	Country	SCC Minimum	SCC Maximum	SCC Average	EU ETS
1	GREECE	240.62	1,802.45	716.60	92.97
2	ITALY	134.72	1 009.21	401.23	52.06
3	SPAIN	38.38	287.47	114.29	14.83
4	FRANCE	33.19	248.63	98.85	12.82
5	ALGERIA	30.67	229.77	91.35	11.85
6	CROATIA	22.34	167.32	66.52	8.63
7	MOROCCO	9.00	67.42	26.80	3.48
8	TURKEY	7.13	53.42	21.24	2.76
9	MALTA	3.49	26.17	10.40	1.35
10	ALBANIA	2.07	15.51	6.17	0.80
11	MONTENEGRO	0.87	6.54	2.60	0.34
12	GIBRALTAR	0.19	1.43	0.57	0.07
13	SLOVENIA	0.08	0.58	0.23	0.03
14	PALESTINE	-3.97	-0.53	-1.58	-0.20
15	ISRAEL	-7.10	-0.95	-2.82	-0.37
16	LEBANON	-7.19	-0.96	-2.86	-0.37
17	CYPRUS	-11.94	-1.59	-4.75	-0.62
18	SYRIA	-12.06	-1.61	-4.79	-0.62
19	EGYPT	-40.39	-5.39	-16.06	-2.08
20	LYBIA	-59.08	-7.89	-23.49	-3.05
21	TUNISIA	-309.22	-41.28	-122.94	-15.95

Values of the Mediterranean Sea's carbon sink ecosystem service in the year 2018 for the Mediterranean countries. Values were calculated using the Social Cost of Carbon (SCC) and the European Union's Emissions Trading System (EU ETS), which allows companies to receive or buy greenhouse gas emission allowances. Source: Copernicus Marine Ocean State Report 4.

MONITORING THE OCEAN WITH COPERNICUS MARINE

New information and methods presented in the fourth issue of the Ocean State Report.

MONITORING TROPICAL STORMS

WHY IS IT IMPORTANT?

Tropical Cyclones rank among the most devastating natural hazards. Tropical storms can wreak havoc for coastal communities and island states and with staggering social, economic and environmental impacts. As our climate changes, extreme weather is occurring more frequently, lasting longer, and becoming more severe. Consequently, better monitoring and forecasting of these storms are key tools for policymakers taking preventive, life-saving, and reconstructive measures. Despite their destructive potential, predicting the intensity, paths and evolution of tropical storms is still challenging, due to various unknown and unmonitored environmental factors, including interactions with the ocean interior.

HOW CAN THE NEW TOOL HELP?

The Copernicus Marine Ocean State Report 4 demonstrates how the combined use of models, *in situ* measurements, and satellite data can provide unique information to analyse and monitor tropical cyclones. Measurements of the subsurface layer from a range of profiling floats, models, and satellite data allow the upper ocean's response to tropical storms to be efficiently captured and monitored.

PREDICTING HIGH WAVES

WHY IS IT IMPORTANT?

Reliable prediction of the largest waves during a storm event has always been foremost for offshore platform design, coastal activities, and navigation. Many severe accidents and casualties at sea have been most probably ascribed to abnormal and unexpected waves. Activities such as offshore wind power, port management, and coastal recreation require information about the sea state with high resolution in both space and time. High-quality predictions of extreme events caused by storms could substantially contribute to avoiding or minimising damage to humans and equipment. This makes reliable wave forecasts and long-term observations of utmost importance.

HOW CAN THE NEW TOOL HELP?

The Black Sea is a European sea which lacks long-term wave measurements from traditional *in situ* wave-riding buoys. The only available long-term observational data comes from Copernicus satellite observations. By combining these observations with wave forecasting models, researchers can assess the predictability of high waves and demonstrate the variability of significant wave height in the Western Black Sea.

MONITORING EUTROPHICATION

WHY IS IT IMPORTANT?

European coastal areas are commercially important for fishing and tourism yet are subject to the increasingly adverse effects of eutrophication. Eutrophication occurs when agricultural run-off and other nutrient-containing pollutants are flushed into the ocean, leading to a runaway growth of algae and phytoplankton on the surface. These overwhelming blooms consume excessive amounts of oxygen through the decomposition of dead organic matter, block sunlight, and reduce water quality. Eutrophication is devastating for ocean ecosystems and can leave some zones almost lifeless. This was first recognised as a problem in Europe in the 1960s and reached damaging proportions by the 1980s.

HOW CAN THE NEW TOOL HELP?

Reducing the outflow of nutrients from rivers to the ocean is an important method to counteract the harmful effects of eutrophication. For countries bordering the North Sea, reducing nutrient outflow from rivers relies on a central set of procedures to assess eutrophication. Combining existing *in situ* measurements with satellite observations has the potential to enhance these assessment procedures.

The Copernicus Marine Service was designed to respond to issues emerging in the environmental, business and scientific sectors. Using information from both satellite and *in situ* observations, it provides state-of-the-art analyses and forecasts daily, which offer a valuable capability to observe and understand the marine environment. In addition to ongoing monitoring of the ocean, the Copernicus Marine Service provides new tools to help keep track of the changing ocean.

HOW DOES IT WORK AND WHAT HAVE WE LEARNT?

This study shows that the combination of low- and high-resolution satellite sensors are of paramount importance to better depict and monitor the wind patterns of tropical cyclones, as well as to interpret the coupling between the air and sea in a cyclone's wake. Upcoming measurements from the Surface Water Ocean Topography Satellite mission will provide a unique opportunity for further research with 2D mapping of sea level anomalies caused by tropical cyclones.

Tracks of Tropical Cyclones
Units: Sea Surface Temperature: Degrees Celsius (°C), Wind Speed: metres per second (ms^{-1})

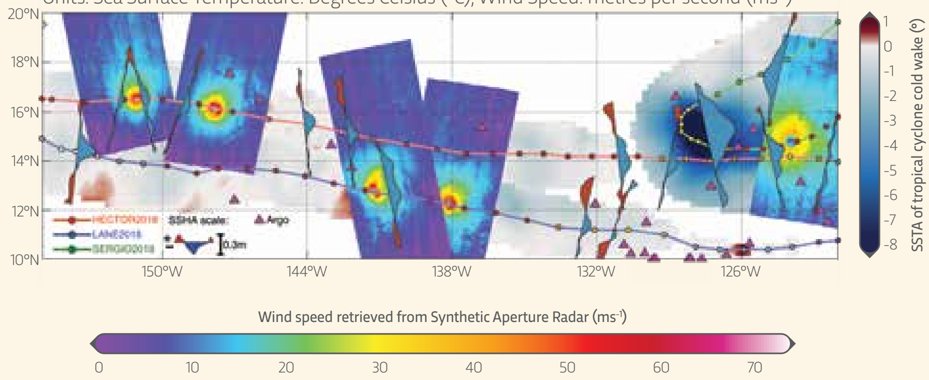
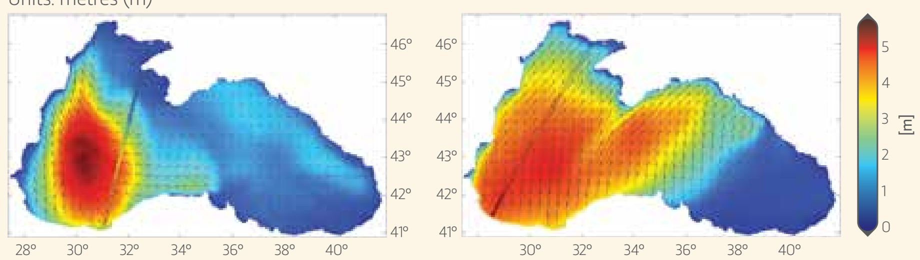


Figure shows three tropical cyclones, Hector, Lane and Sergio. The wakes of the three cyclones are shown, along with Sea Surface Temperature Anomaly (SSTA) data and Wind Speed measured by Synthetic Aperture Radar. Units are degrees Celsius (°C) for Sea Surface Temperature and metres per second (ms^{-1}) for Wind Speed. Source: Copernicus Marine Ocean State Report 4.

HOW DOES IT WORK AND WHAT HAVE WE LEARNT?

Reliable wave forecasts can be achieved by demonstrating and predicting the characteristics of the largest waves. In this study, severe storms in the Black Sea during autumn and winter of 2018 were identified and analysed. The large amount of data allowed the most extreme events to be examined statistically, providing insight into the characteristics of the largest waves and paving the way to reliable wave forecasts.

Wave Directions and Heights in the Black Sea
Units: metres (m)

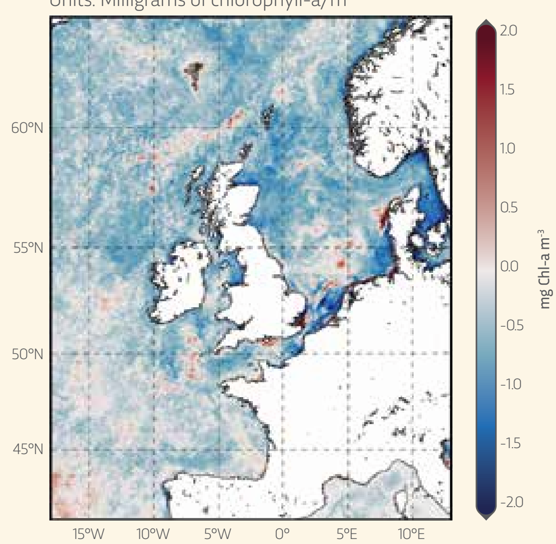


The left-hand figure shows the distribution of wave field in the Black Sea on 18 January 2018. The right-hand figure shows significant wave height in metres and mean wave direction on 28 November 2018. The prominent straight lines in the figure are satellite tracks. Source: Copernicus Marine Ocean State Report 4.

HOW DOES IT WORK AND WHAT HAVE WE LEARNT?

This study combined *in situ* data with satellite measurements of chlorophyll-a concentration in the North Sea. Under eutrophic conditions, the concentration of chlorophyll-a increases due to the rapid bloom of chlorophyll-hosting phytoplankton. The researchers found a decrease in chlorophyll-a concentrations in known hotspots, including coastal areas within the Southern North Sea. Furthermore, the researchers were able to conclude that data products from satellite observations — used in combination with indicators derived from *in situ* data— have the potential to enhance existing eutrophication assessment procedures.

Chlorophyll-a concentration anomalies over the European Northwest Shelf
Units: Milligrams of chlorophyll-a/m^3



Chlorophyll-a concentration anomalies over the European Northwest Shelf based on satellite measurements. The figure shows surface chlorophyll-a concentrations in 2018 relative to the reference period 2009–2014. Units are milligrammes of chlorophyll-a per cubic metre (mg Chl-a m^{-3}). Source: Copernicus Marine Ocean State Report 4.

USING COPERNICUS MARINE SERVICE TOOLS: **A SUCCESS STORY**

In March 2018, the Gulf of Cadiz region in Spain suffered the most severe wave storm in the past 20 years. This extreme sea state, with waves higher than 7 metres, was produced by storm Emma and was aggravated by the combined effect of waves, high tide and sea level surge.

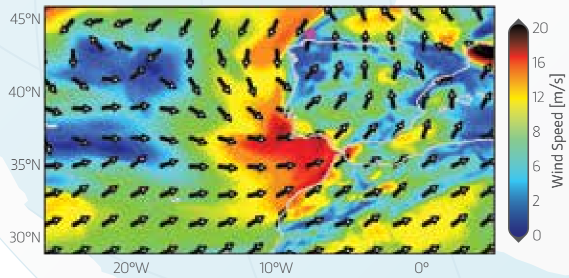
Chart of the Gulf of Cadiz

The figure shows the location of measurement instruments (buoy and tide gauges) and harbours in the Gulf of Cadiz, Spain. Source: Copernicus Marine Ocean State Report 4.

WHAT ROLE DID THE COPERNICUS MARINE SERVICE PLAY?

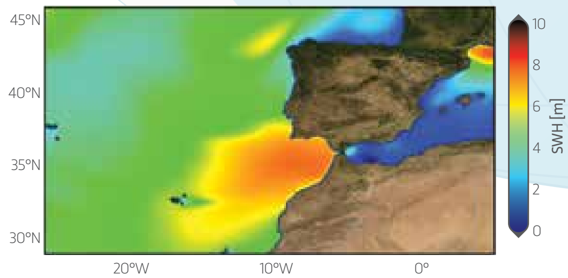
Several ocean monitoring services were operational in the area during this event, including Copernicus Marine Service products and local wave and sea level forecast systems. These services were accurate, allowing the storm to be forecast properly. Downstream alerts warned users in advance, with harbours stopping operations to prevent accidents and assure safety. The extreme seas had devastating effects on the coastal area but, probably due to the preventive actions, nobody was harmed.

Wind Forecast
1 March 2018, 12:00 UTC



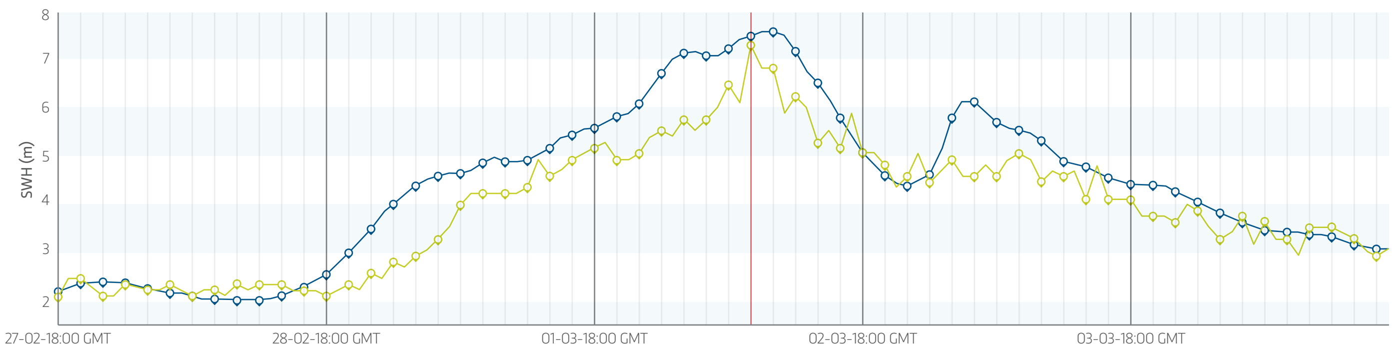
Speed (colour scale) and direction (arrows) of 2 m wind forecasted for 1 March 2018 at 12:00 UTC. Wind speed is shown in metres per second (ms^{-1}). The magenta circle marks the low pressure minimum. Source: Copernicus Marine Ocean State Report 4.

Wave Forecast
1 March 2018, 12:00 UTC



Significant Wave Height (SWH) forecast for 1 March 2018 at 12:00 UTC. Units are in metres. SWHs over 7 m were forecasted in the Gulf of Cadiz. Source: Copernicus Marine Ocean State Report 4.

Significant Wave Height
at Cadiz Buoy (62085)



The figure compares measurements and forecasts for Significant Wave Height (SWH) at the Cadiz Buoy (62085) in the Gulf of Cadiz over five days at the end of March 2018. The units are in metres (m), and wave heights peaked at 7.2 m, marked by the red line. The forecast (shown in blue) and the measurement (shown in green) show remarkable agreement. Source: Copernicus Marine Ocean State Report 4.

ABOUT THE COPERNICUS PROGRAMME

Copernicus is the European Union's Earth Observation Programme, looking at our planet and its environment for the ultimate benefit of all European citizens. It includes a satellite component (the Sentinel missions) and offers information services based on satellite Earth observation, *in situ* (non-space) data, and numerical models. Vast amounts of global data from satellites, numerical models, ground-based, airborne and seaborne measurement systems are being used to provide information to help service providers, public authorities and other international organisations to improve the quality of life for the citizens of Europe. The information services provided are freely and openly accessible to users. The Programme is coordinated and managed by the European Commission and includes six services implemented by different entities.

6 COPERNICUS SERVICES

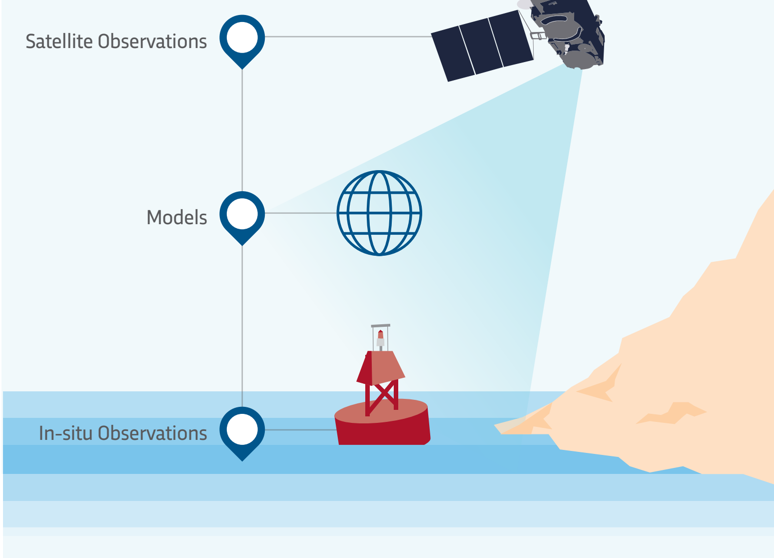
- Marine Monitoring
- Land Monitoring
- Atmosphere Monitoring
- Emergency Management
- Security
- Climate Change

ABOUT THE COPERNICUS MARINE SERVICE

Copernicus Marine Service

The Copernicus Marine Service (also referred to as CMEMS) is dedicated to ocean observation, monitoring and forecasting. It is funded by the European Commission (EC) and implemented by Mercator Ocean international, a centre for global ocean analysis and forecasting. Copernicus Marine provides regular and systematic reference information on the state of the physical and biogeochemical ocean at the global and European regional scale. It provides key inputs that support major EU and international policies and initiatives and can contribute to: combating pollution, marine protection, maritime safety and routing, sustainable use of ocean resources, developing marine energy resources, blue growth, climate monitoring, weather forecasting, and more. It also aims to increase awareness amongst the general public by providing European and global citizens with information about ocean-related issues.

HOW DOES THE COPERNICUS MARINE SERVICE MONITOR THE OCEAN?



ABOUT MERCATOR OCEAN INTERNATIONAL

MERCATOR OCEAN INTERNATIONAL

Mercator Ocean international was selected by the European Commission (EC) to implement the Copernicus Marine Service in 2014. Based in France, Mercator Ocean international is a non-profit organisation providing oceanographic products covering the global ocean. Its scientific experts design, develop, operate and maintain state-of-the-art numerical modelling systems that describe and analyse the past, present, and near-future state of the ocean in 4D (reanalyses, hindcasts, near-real time analyses and forecasts). It has also been selected by the EC as one of three implementers of the Copernicus WEkEO DIAS cloud computing platform.

Mercator Ocean international has taken all the measures necessary to provide continued state-of-the-art operation of the Copernicus Marine Service during the COVID-19 crisis.

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Full Ocean State Report will be available at:
https://www.tandfonline.com/toc/tjoo20/accepted

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Disclaimer: This summary is written in collaboration with both scientists and communication professionals and it is intended to provide some context and basic scientific explanation surrounding the key findings of the Ocean State Report.

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