Copernicus
Marine Service

OCEAN STATE REPORT

7

SUMMARY

ISSUE 7

PROGRAMME OF
THE EUROPEAN UNION

Copernicus
Europe's eyes on Earth

Implemented by
MERCATOR OCEAN
INTERNATIONAL

ABOUT THE

OCEAN STATE REPORT

The **EU Copernicus Ocean State Report** (OSR) is an annual publication of the Copernicus Marine Service, which is implemented by Mercator Ocean International. The report provides state-of-the-art, scientific knowledge about the current conditions, natural variations, and ongoing changes in the European regional seas and the global ocean. It is meant to act as a reference for the scientific community, national and international bodies, decision-makers, blue economy actors, and the general public.

Using model data and satellite and in situ measurements, this integrated description of the ocean state feeds into a four-dimensional view (latitude, longitude, depth, and time) of the Blue, Green, and White Ocean. **The Blue Ocean** describes the physical state of the ocean, including sea surface temperature, sea level, ocean currents, waves, salinity, and ocean heat content. **The Green Ocean** describes the biological and biogeochemical state of the ocean, including nutrient concentrations, ocean acidification, and deoxygenation. **The White Ocean** refers to the lifecycle of floating ice within the polar regions, including the extent, volume, and thickness of sea ice. The Ocean State Report draws on expert analysis written by nearly 100 scientific experts from various European and international institutions. Scientific integrity is assured through a process of independent peer review in collaboration with the State of the Planet journal from Copernicus Publications.

EXPLORE THE

THIS DOCUMENT IS INTERACTIVE!

The **toolbar above** was developed to help you navigate the summary. The left and right arrows cycle through the pages and sections. Throughout the document, **blue** buttons link to supporting information found within the summary, and **yellow** buttons link to relevant supplementary information from the Mercator Ocean International website.

ABOUT THIS

SUMMARY

This document is a summary of the 7th issue of the annual Ocean State Report, highlighting the current state, variations, and ongoing changes in the ocean in Europe and around the world. Also drawing from the Copernicus Ocean Monitoring Indicators, this summary is approached from several angles over the past decades, and for recent years, particularly for 2021.

It examines the evolving signals of the changing ocean linked to climate change, the analysis of ocean natural variations and extreme events, and discusses the implications these have on ocean environments and society. Additionally, this summary presents a series of new tools and indicators developed using Copernicus Marine Service products and features an interactive layout to improve readability. The blue, green, and white icons throughout the summary denote whether the data pertains to the **Blue, Green, or White Ocean**. The **"What Is...?"** boxes provide definitions, and the **"Beyond the OSR 7"** boxes introduce news and use cases that are not included in the Ocean State Report, but offer relevant data for the topics being discussed. The **Grey 'OSR 7'** buttons provide direct links to the relevant sections of the complete OSR. Together, the information in this summary demonstrates how accurate and timely information is key for monitoring, understanding, and adapting to the evolving ocean.

- In this summary, an "**anomaly**" is defined as the difference of a measurement when compared to the long-term average, representing the mean state.
- The **UN SDGs** and **EU frameworks and directives** included throughout this summary represent non-exhaustive examples of the areas of sustainable development that could potentially be impacted.

LEGEND

Blue Ocean The physical state of the ocean

Green Ocean The biological and biogeochemical state of the ocean

White Ocean The lifecycle of floating ice within the polar regions

WHAT IS...? Provides definitions

BEYOND THE OSR 7 Introduces news and use cases that are not included in the OSR

OSR 7 Links directly to the relevant section in the complete OSR

SECTIONS

THE **REPORT** AT A GLANCE

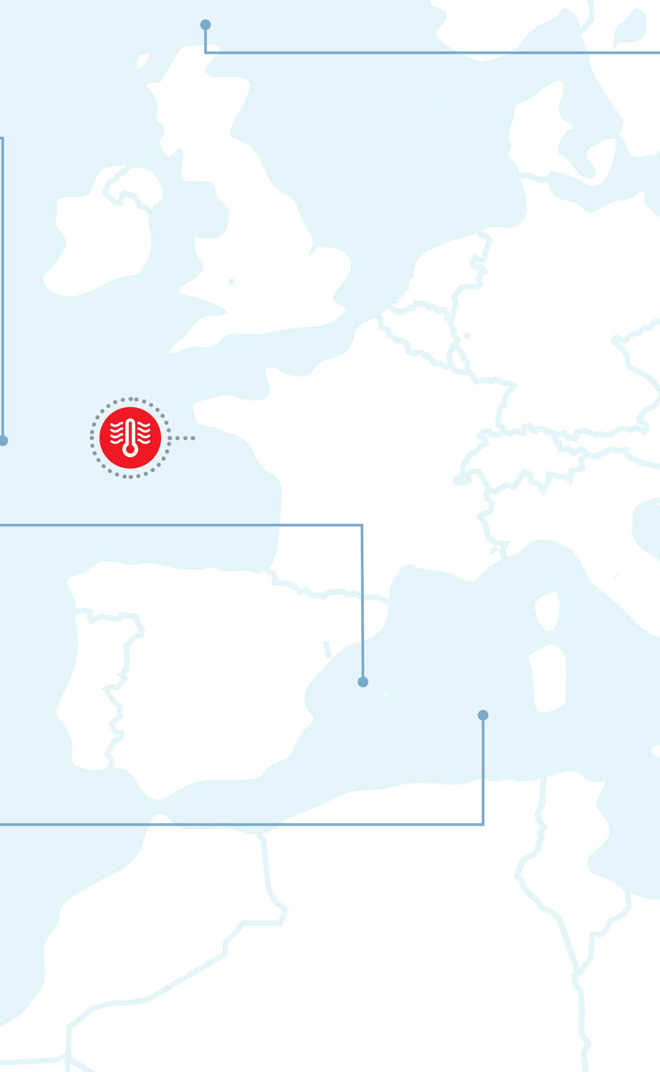
KEY TAKEAWAYS FROM THE EU COPERNICUS OCEAN STATE REPORT 7
AND THE OCEAN MONITORING INDICATORS

OCEAN STATE: EUROPE

AN OVERVIEW

The following section and accompanying map provide an overview of the events, trends, and anomalies discussed in the Ocean State Report 7. They highlight what was observed in the European seas up to and in 2021 and the effects these might represent for the state of the ocean and beyond.

- EVENT
- TREND UP TO 2021
- IN 2021
- DECREASE
- INCREASE
- OCEAN HEAT CONTENT
- DISSOLVED OXYGEN
- SALINITY



BEYOND THE OSR 7

NORTH-EAST ATLANTIC

Marine heatwaves of moderate, strong, and extreme categories were detected from July to September 2023. Concurrently, this region experienced a decrease (50–60%) compared to the climatology (1998–2018) in phytoplankton concentrations, which form the basis of the marine food web.

BALEARIC ISLANDS

Record-low sea surface temperatures were classified as an ocean extreme due to the long-lasting and intense Storm Blas in November 2021.

BEYOND THE OSR 7

MEDITERRANEAN SEA

Marine heatwaves in the Mediterranean Sea during summer 2022 were record-breaking in terms of their **intensity and duration.**

HOW DOES THIS IMPACT THE OCEAN AND BEYOND?

SEA LEVEL

Global sea levels are rising due to human-induced global warming. The warming of Earth's climate system causes land ice to melt, such as glaciers and ice sheets in Greenland and Antarctica. Additionally, ocean waters are absorbing increasing heat, expanding, and further contributing to the rise in sea levels. Human communities in close connection with the ocean, especially low-lying and coastal areas, are particularly vulnerable to changes in sea level, posing risks to coastal infrastructure (e.g., ports, roads, and tourism facilities).

EU Strategy on Adaptation to Climate Change
UN Sustainable Development Goals

SEA SURFACE TEMPERATURE

Long-term rising sea surface and subsurface temperatures and marine heatwaves can dangerously impact the survivability of species, such as corals, seagrasses, kelp, and fish, and cause mass mortality events and mass marine species migration, leading to lower catch amounts and placing economic pressure on fishing industries.

EU Marine Strategy Framework Directive
UN Sustainable Development Goals

SCOTTISH WATERS

Unusual **coccolithophore** blooms observed during summer 2021: one in the Clyde Sea and one near the Shetland Islands.

ADRIATIC SEA

A lower content of dissolved oxygen was observed in 2021 due to a negative anomaly of subsurface biological production that year and a sharp increase in salinity since 2019.

O_2

SALINITY & FRESHWATER CONTENT

Differences in salinity and freshwater levels in the ocean can alter oceanic circulation, currents, and water cycles. A decrease in freshwater content or an increase in salinity could be an indicator for species that favour higher salinity conditions. Additionally, salinity and freshwater can affect the freezing point of seawater, leading to less sea ice and warmer ocean water temperatures.

EU Strategy on Adaptation to Climate Change
UN Sustainable Development Goals

TRENDS IN THE COPERNICUS OCEAN MONITORING INDICATORS

WMO GLOBAL CLIMATE INDICATORS

Temperature and Energy | Ocean and Water | Cryosphere

BLUE OCEAN

SEA SURFACE TEMPERATURE

UNITS °C/decade
TREND FROM 1993–2022
Temperature and Energy

Mediterranean Sea	+0.34 ± 0.02 °C/decade
North West Shelf	+0.16 ± 0.01 °C/decade
Baltic Sea	+0.48 ± 0.06 °C/decade
Black Sea	+0.70 ± 0.04 °C/decade
Iberian-Biscay-Ireland Seas	+0.13 ± 0.01 °C/decade

SEA LEVEL

UNITS mm/year
TREND FROM JANUARY 1993–AUGUST 2022
Ocean and Water

Mediterranean Sea	+2.5 ± 0.83 mm/year
North West Shelf	+3.1 ± 0.83 mm/year
Baltic Sea	+4.8 ± 0.84 mm/year
Black Sea	+1.4 ± 0.83 mm/year
Iberian-Biscay-Ireland Seas	+3.9 ± 0.82 mm/year

OCEAN HEAT CONTENT

UNITS watts/m²
Temperature and Energy

Mediterranean Sea	TREND FROM 1993–2019	0–700m	+1.4 ± 0.3 watts/m²
Black Sea	TREND FROM 2005–2020	0–300m	+1.0 ± 0.1 watts/m²
Iberian-Biscay-Ireland Seas	TREND FROM 1993–2021	0–2000m	+0.41 ± 0.4 watts/m²

GREEN OCEAN

OXYGEN INVENTORY

UNITS mol/m²/year
TREND FROM 1955–2021

Black Sea
−0.18 ± 0.016 mol/m²/year

WHITE OCEAN

15% of the Baltic Sea was covered by ice in 2021–2022. Sea ice extent in the Baltic Sea has shown a decreasing trend over the period 1993–2022, although the observed trend is not statistically significant.

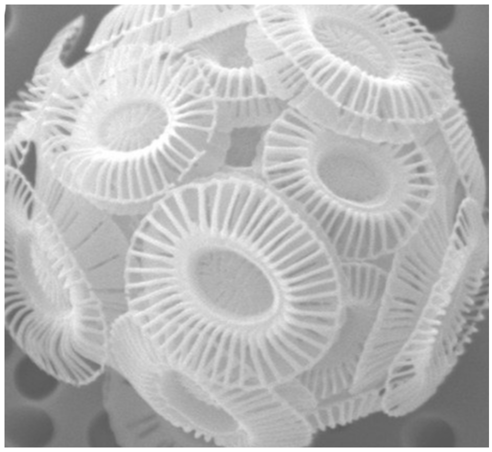
OCEAN STATE: EUROPE

SUMMER 2021

UNUSUAL COCCOLITHOPHORE BLOOMS IN SCOTTISH WATERS

WHAT IS A COCCOLITHOPHORE?

A **coccolithophore** is a single-celled marine phytoplankton that produces an exoskeleton consisting of calcium carbonate (one part carbon, one part calcium, and three parts oxygen) plates known as coccoliths. During the later stages of the bloom life cycle, these coccolith exoskeletons shed, turning the sea a milky turquoise colour. Most coccolithophores are not harmful or toxic, but instead are important for the marine carbon cycle and the Earth's climate through the production of coccoliths and the capturing and storage of carbon.

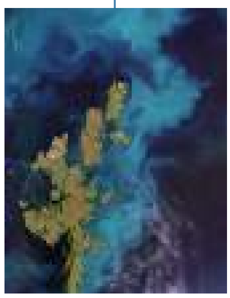


Scanning electron micrograph of a coccolithophore sample from the Clyde Sea, June 2021, identified as *Emiliania huxleyi* Morphotype B. Credit: Eileen Bresnan (Marine Laboratory, Aberdeen)

WHAT HAPPENED?

CLYDE SEA

- The coldest April in the last 30 years in the Clyde Sea occurred in April 2021.
- The cold weather was hypothesised to restrict the usual spring bloom of diatoms, a type of phytoplankton.
- Fewer diatoms would leave nutrients for the summer bloom and reduce the grazing pressure on the coccolithophores.
- A wet and stormy May also added nutrients to the sea.
- As temperature and sunlight increased, ideal conditions emerged for coccolithophores to flourish in the summer in the Clyde Sea.



Satellite perspective from 1 July 2021 of the coccolithophore bloom in the Shetland Islands, highlighting the vivid, turquoise-coloured bloom along the east coast of the island. Source: ESA/Copernicus, CC BY-SA 3.0 IGO.

Sentinel-2 MSI image of the Clyde Sea on 21 June 2021 11:35 UTC, True Colour with enhanced contrast. Processed by NEODAAS, using ACOLITE atmospheric correction.

SHETLAND ISLANDS

- Coccolithophore blooms around the Shetland Islands formed in water coming from the shelf edge.
- The 2021 bloom originated in Atlantic water that was brought north of the Shetland Islands by the Slope Current.
- A period of anomalous easterly winds in May delayed the water's passage eastward.
- A shorter period of easterly winds steered the water towards the Shetland coast.
- Coincidences in the timing and weather with coccolithophore-laden water near the coast created the unusual phenomenon of a visible bloom on the eastern coast.

HOW DOES THIS IMPACT THE OCEAN AND BEYOND?

- Changing weather and ocean patterns can influence the occurrence of unusual coccolithophores blooms.
- In recent decades, the distribution of coccolithophore blooms has expanded polewards due to changes in ocean temperature, dissolved inorganic carbon, and ocean pH.
- Coccolithophores influence the marine carbon cycle and the Earth's climate by producing coccoliths and capturing and storing carbon.

EU Marine Strategy Framework Directive
UN Sustainable Development Goals

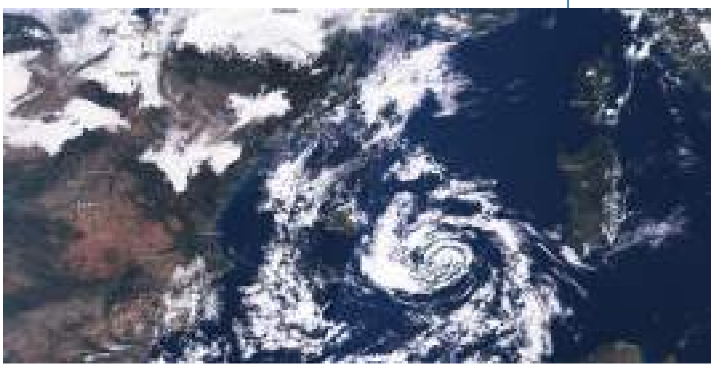
AUTUMN 2021

STORM BLAS CAUSED UPWELLING IN THE BALEARIC ISLANDS

WHAT HAPPENED?

BALEARIC ISLANDS, SPAIN

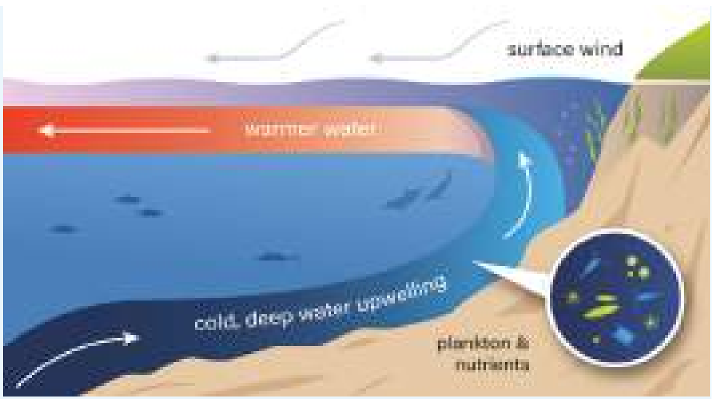
- An intense cyclone, Storm Blas, impacted the western Mediterranean Sea from 6–18 November, causing intense winds, high waves, and heavy rainfall in the Balearic archipelago, resulting in landslides and flooding.
- The storm caused a total of nine deaths, six in Algeria and three in Sicily, and significant economic and property damages.
- The severe northeasterly winds created favourable conditions for intense upwelling along the northwestern coasts of Mallorca and the Ibiza Islands.
- The upwelling event was characterised by intense cold coastal sea surface anomalies of approx. -6°C and lasted for 3 days with a spatial off-shore extension of approximately 20 km.



Satellite perspective from 13 November 2021 of Storm Blas near the Balearic Islands off the coast of Spain in the Western Mediterranean Sea. Source: Copernicus Sentinel data (2021).

WHAT IS UPWELLING?

Upwelling occurs when cold sea water rises to the surface and decreases the sea surface temperature. It is usually caused by strong winds that blow across the ocean surface and push warm surface water away, causing cold water from deeper layers in the ocean to "well up" to the surface. This cold water is usually rich in nutrients, which fertilise surface waters and enhance biological productivity.



HOW DOES THIS IMPACT THE OCEAN AND BEYOND?

- Coastal upwelling plays a critical role in the connectivity between offshore waters and coastal ecosystems, impacting water quality, fisheries, and aquaculture production.
- Favourable conditions for upwelling can occur during specific storms, with winds blowing in the appropriate orientation, in areas where upwelling is not common.
- Key nutrients brought to the surface with rising cold water can "fertilise" surface waters, providing good fishing grounds.

UN Sustainable Development Goals

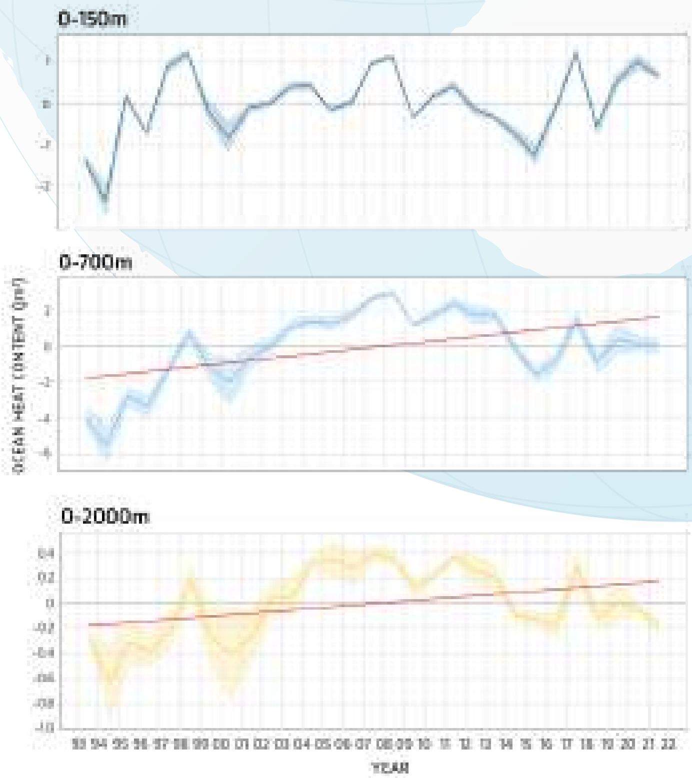
OCEAN STATE: EUROPE

OCEAN WARMING

OCEAN HEAT CONTENT KEEPS RISING

WHAT IS OCEAN HEAT CONTENT?

Ocean heat content is a measure of the amount of heat that is stored in the ocean from the surface to the ocean layers, such as 2000 metres in depth. The ocean has the largest capacity for heat storage than any other component of the Earth's climate system, and nearly 90% of the extra heat trapped in the Earth system from anthropogenic activities is absorbed by the ocean. With continuing greenhouse gas emissions, the amount of heat stored in the ocean has increased over the last decades.



Integrated ocean heat content from the ocean's surface down to 150 m (top), 700 m (middle), and 2000 m (bottom) for the period from 1993–2021. The red line (middle and bottom) represents a significant trend of increasing ocean heat content. No trend was obtained for the 150m depth (top) where natural variability dominated the temporal variations.

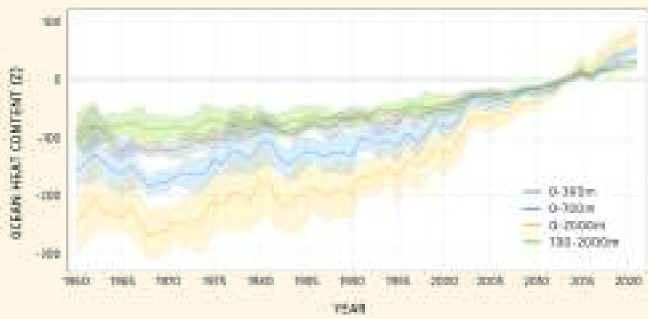
WHAT DID WE OBSERVE?

In the **Iberian-Biscay-Ireland regional seas,** the ocean heat content of the subsurface waters showed significant warming. Regional ocean warming is superposed by natural variations, which are triggered in this region remotely by water mass dynamics from the North Atlantic and the Mediterranean Sea. In the surface water layer (150 m) of this specific region, no trends were detected. The analysis presented in the Ocean State Report 7 has provided a closer look into what is happening in the interior of the ocean and the interplay between long-term changes and natural variability. While ocean warming has been established for the global average, warming variations and trends at a regional scale are less understood and require further analysis.

BEYOND THE OSR 7

GLOBAL OCEANS CONTINUE TO WARM

Mercator Ocean International contributed key Copernicus Marine data to the WMO annual state of the global climate report published in 2023. The contributed data observed that ocean heat content was the **highest on record in 2022,** with a sustained increase in temperature in the top 2000 m of the ocean. Over the past 15 years, the rate of change of the accumulated heat in the ocean **has risen by nearly 50%** compared to the accumulation rate over the last 50 years. Beyond its ocean products and expertise, MOi maintains an active participation in providing key ocean data and resources to better understand the big picture of ocean changes.



The 1960–2021 mean time series of global ocean heat content anomalies relative to the 2005–2021 average for the 0–300 m (grey), 0–700 m (blue), 0–2000 m (yellow), and 700–2000 m (green) depth layers. The mean ocean heat content anomalies for 2022 were added as separate points. Source: WMO State of the Global Climate 2022, contributed by Mercator Ocean International.

HOW DOES THIS IMPACT THE OCEAN AND BEYOND?

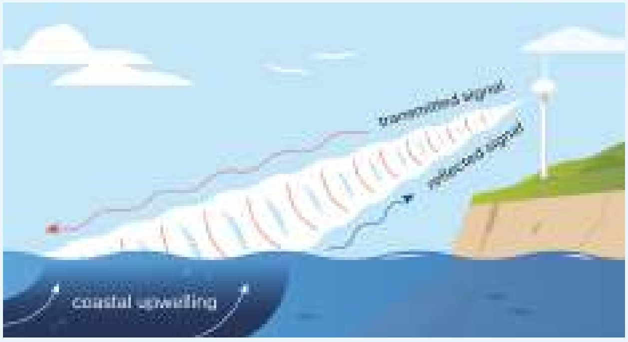
- Warming ocean water is causing global sea level to rise since water expands when it warms.
- Warming ocean waters contribute to the loss of ice shelves and sea ice, degrading polar ecosystems and affecting local communities.
- Rising sea levels from melting land ice and thermal water expansion threaten ecosystems, human structures, and populations living near coastlines worldwide.
- Rising ocean temperatures pose a significant threat to marine ecosystems and human livelihoods, such as endangering corals and marine species, while also potentially harming the socio-economic stability of human communities reliant on marine fisheries for sustenance and employment.

EU Strategy on Adaptation to Climate Change

UN Sustainable Development Goals

MEASURING COASTAL UPWELLING WITH HIGH FREQUENCY RADAR

WHAT IS HIGH FREQUENCY RADAR?



Land-based devices along the coast can measure ocean surface currents and ocean waves, along with other variables. **HFR systems** transmit radio waves that hit the ocean surface and are reflected back, providing information on the direction and speed of currents. Scientists are using this technology to measure, for example, upwelling and downwelling at the coast.

HOW DOES THE NEW TOOL WORK?

A novel ocean-based coastal upwelling index (CUI) was constructed using hourly surface current maps provided by two high frequency radar (HFR) systems. Tested in the northwestern Iberian Sea and the Bay of Biscay and compared against hourly wind observations, the CUI–HFR tool categorises upwelling and downwelling episodes and is intended to be used for direct global upwelling monitoring.

HOW DOES IT HELP AND WHAT HAVE WE LEARNED?

Coastal upwelling – a process in which deep, cold water rises toward the surface – plays a critical role in the connectivity between offshore waters and coastal ecosystems. The CUI–HFR tool was proved to effectively categorise upwelling and downwelling events. It provides a more complete portrait of this phenomenon by producing high-resolution 2D maps that explain the spatial distribution and magnitude of coastal upwelling with greater consistency. This tool can be used to help with efficient marine resources management, the preservation of vulnerable marine ecosystems, and sustainable “blue economy” development.

HOW DOES THIS IMPACT THE OCEAN & BEYOND?

- HFR devices can indirectly inform about sea surface temperature shifts, which can be helpful for establishing fishing grounds and monitoring the health of marine ecosystems.
- HFR-derived surface circulation is a reliable source of information for search-and-rescue operations and oil spill tracking, among other practical applications.

UN Sustainable Development Goals

DISSOLVED OXYGEN MONITORING, ESSENTIAL FOR MARINE LIFE

WHAT IS DISSOLVED OXYGEN?

Most aquatic plants and animals require oxygen to survive. **Dissolved oxygen** is a measurement of how much oxygen is dissolved in seawater. Hence, it is key for monitoring the status of the marine environment. Monitoring the trends of biogeochemical indicators, such as dissolved oxygen, is crucial for evaluating the impact of climate change on the ocean and its effects on marine ecosystems.

HOW DOES THE NEW TOOL WORK?

The joint analysis of Copernicus biogeochemical reanalysis in the Mediterranean Sea and in situ data from the southern Adriatic Sea allowed scientists to explore the interannual dissolved oxygen variations over the period 1999–2021; an essential undertaking to further understand how marine ecosystems function and to assess the environmental status of the ocean.

HOW DOES IT HELP AND WHAT HAVE WE LEARNED?

The results of the analysis highlighted the critical role of deep ocean ventilation controlled by an interplay of various ocean processes (e.g., ocean circulation, heat flux), which are known to drive variations in biological production. In the OSR 7, record low dissolved oxygen was detected in the southern Adriatic Sea, and could be linked to a decrease in biological production in 2021. These changes were observed deep below the subsurface ocean, such as up to nearly 600m in depth in the focus area of this study.

HOW DOES THIS IMPACT THE OCEAN & BEYOND?

- Persistent low levels of dissolved oxygen can have an adverse impact on local marine organisms.
- Regime shifts in the regional circulation can have substantial implications on the ventilation of the subsurface ocean, such as in the southern Adriatic Sea region.
- Low dissolved oxygen can impact the blue economy (i.e., fisheries) through changes in catch distribution.

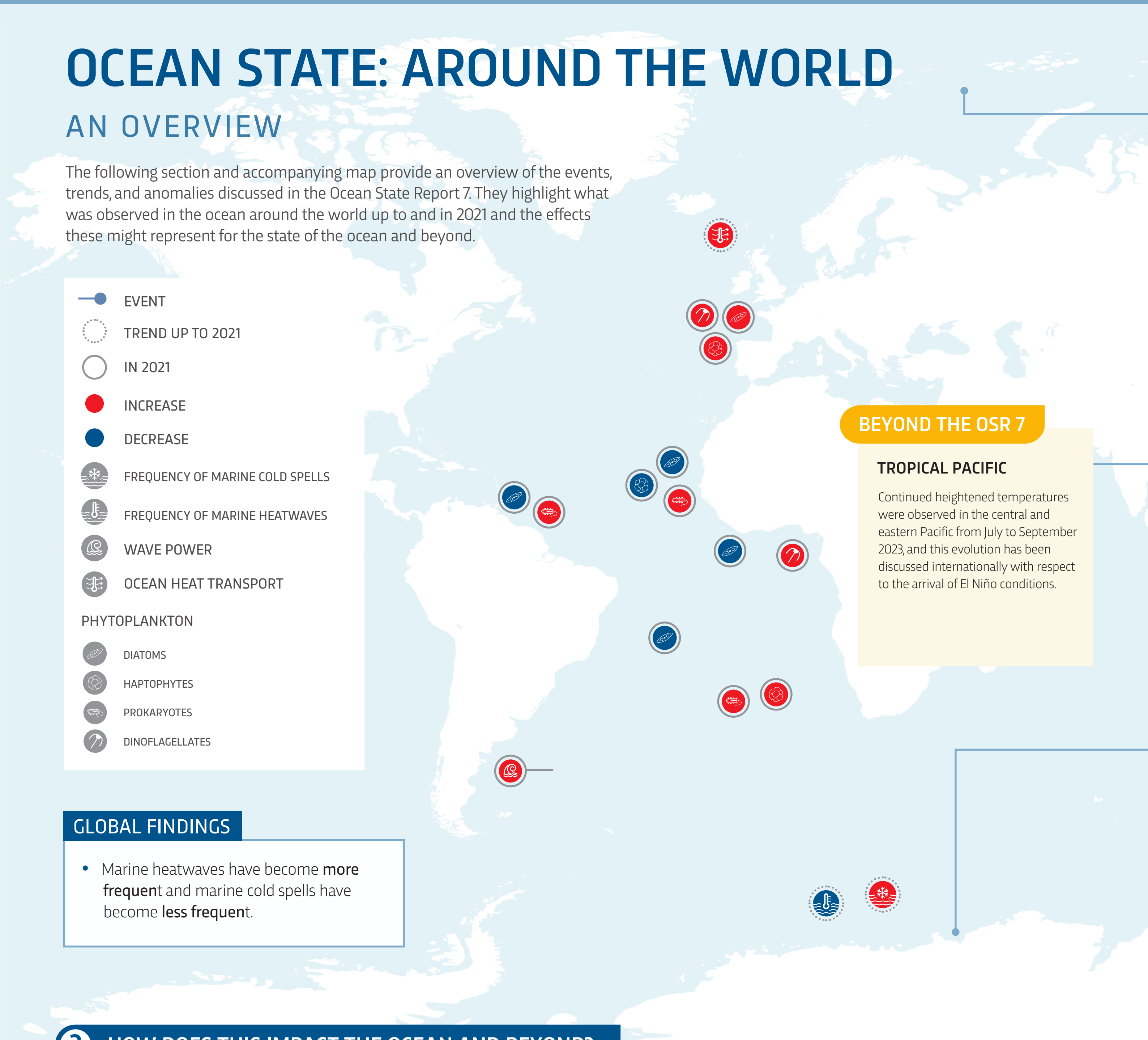
EU Marine Strategy Framework Directive

UN Sustainable Development Goals

OCEAN STATE: AROUND THE WORLD

AN OVERVIEW

The following section and accompanying map provide an overview of the events, trends, and anomalies discussed in the Ocean State Report 7. They highlight what was observed in the ocean around the world up to and in 2021 and the effects these might represent for the state of the ocean and beyond.



BEYOND THE OSR 7

TROPICAL PACIFIC

Continued heightened temperatures were observed in the central and eastern Pacific from July to September 2023, and this evolution has been discussed internationally with respect to the arrival of El Niño conditions.

GLOBAL FINDINGS

- Marine heatwaves have become **more frequent** and marine cold spells have become **less frequent**.

HOW DOES THIS IMPACT THE OCEAN AND BEYOND?

OCEAN HEAT TRANSPORT

- Variations in ocean heat transport are vital for regulating the global climate.
- Changes in ocean heat transport can decrease sea ice extent, leading to increased sea ice loss with implications for polar ecosystems and communities.
- Ocean heat transport can influence marine heatwaves, which in turn adversely affect marine species and disrupt ecosystems, with implications for catches and the fisheries sector.

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UN Sustainable Development Goals

WAVE POWER

- Understanding extreme wave changes is crucial for supporting the design and safety of ships and maritime vessels, offshore coastal structures (e.g., energy platforms, wind farms), and coastal infrastructure (e.g., ports, roads, tourism facilities).
- Wave power trends are valuable for identifying areas that are vulnerable to climate change hazards (e.g., flooding, erosion) and have a direct application for coastal risk assessment.
- Knowledge of the changes in wave power is useful for helping stakeholders and engineers implement sustainable maritime activities.

European Green Deal
UN Sustainable Development Goals

SEA ICE

- Changes in water salinity and temperature the polar regions could impact the streng paths of ocean currents, potentially affect global climate state.
- Low sea ice extent offers increased transp and access to the Arctic and Baltic seas, bu also poses risks, such as increased polluti Arctic data allows policymakers to develo infrastructure and emergency strategies f human activity in these regions.
- Monitoring sea ice extent and its fast, shor variability can improve maritime navigati safety, and mitigation and adaptations str

EU Strategy on Adaptation to Climate Chan
UN Sustainable Development Goals

BEYOND THE OSR 7

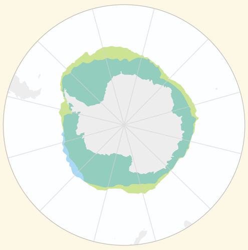
MINIMUM ARCTIC SEA ICE EXTENT 2022

Arctic sea ice is consistently declining at alarming rates. During the period from 1979 to 2022, **September Arctic sea ice extent** saw a **loss of approximately 3,5 million km², the** equivalent to approximately **seven times the area of Spain.**

BEYOND THE OSR 7

MINIMUM ANTARCTIC SEA ICE EXTENT 2023

Antarctic sea ice extent in May and June 2023 reached the lowest recorded levels since the beginning of satellite records. A loss of nearly **2.20 million km² of sea ice** was observed in June compared to the long-term average (1981 to 2010), which is equivalent to an area of more than **seven times the size of Poland.**



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PHYTOPLANKTON DISTRIBUTION

- Due to changes in ocean temperatures and dissolved inorganic carbon, the distribution of phytoplankton has expanded toward the poles.
- Blooms of phytoplankton can occur in many areas and can be potentially harmful to other marine life, block sunlight from penetrating ocean waters, and produce toxins that can be dangerous for humans
- The continuous monitoring of phytoplankton concentrations is important to understand the biogeochemical processes (nutrient uptake; carbon and energy transfer) of the ocean as well as to maintain fisheries, water quality, marine environments, and human health.

UN Sustainable Development Goals

TRENDS IN THE COPERNICUS OCEAN MONITORING INDICATORS

WMO GLOBAL CLIMATE INDICATORS

Temperature and Energy | Ocean and Water | Cryosphere

BLUE OCEAN

SEA SURFACE TEMPERATURE

UNITS: °C/decade
TREND FROM: 1993–2021

Global Ocean
↑ +0.15
± 0.01 °C/decade

Temperature and Energy

SEA LEVEL

UNITS: mm/year
TREND FROM: JANUARY 1993–AUGUST 2022

Global Ocean
↑ +3.3
± 0.3 mm/year

Ocean and Water

OCEAN HEAT CONTENT

UNITS: watts/m²
TREND FROM: 2005–2022

Temperature and Energy

Global Ocean

0–300m	0–700m	0–2000m
↑ +0.4	↑ +0.6	↑ +1.0
± 0.1 watts/m²	± 0.1 watts/m²	± 0.1 watts/m²

GREEN OCEAN

OCEAN ACIDIFICATION

UNITS: pH units/year
TREND FROM: 1985–2021

Ocean and Water

Global Ocean
↓ -0.0017
± 0.0004e-1 pH units/year

*A decrease in pH denotes an increase in ocean acidification.

WHITE OCEAN

ANNUAL SEA ICE EXTENT

UNITS: million km²/decade

Cryosphere

Arctic Observations
TREND FROM 1979–2022
↓ -0.51
± 0.03 10⁶ km²/decade

Antarctic Observations
TREND FROM 1979–2022
↑ +0.02
± 0.05 10⁶ km²/decade

The observed trend is not statistically significant.

MARINE HEATWAVES

WHAT ARE MARINE HEATWAVES?

Marine heatwaves (MHW) are temporary, prolonged, and anomalously warm water events that occur at a particular location and which are defined by unusually high ocean temperatures for a minimum of five consecutive days. Marine heatwave events are assigned a category from I (moderate) to IV (extreme) based on their intensity.

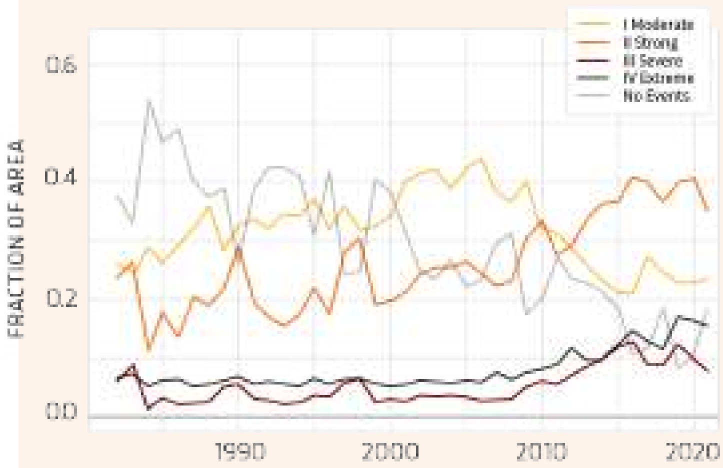
MARINE COLD SPELLS

WHAT ARE MARINE COLD SPELLS?

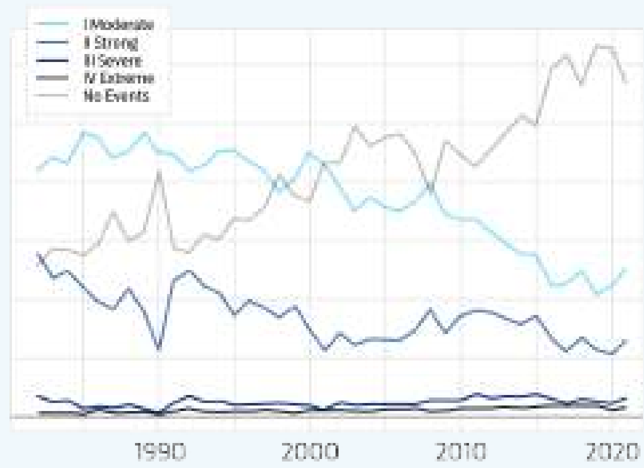
Marine cold spells (MCS) are temporary, prolonged, and anomalously cold water events. These events are driven by fluxes in the atmosphere, bringing cold water currents (upwelling) into a particular location. However, marine cold spells are less discussed than marine heatwaves. Marine cold spell events are assigned a category from I (moderate) to IV (extreme) based on their intensity.

TRENDS IN COMPARISON

MARINE HEATWAVES		MARINE COLD SPELLS
In large areas of the ocean, marine heatwaves have become **more frequent** (99% confidence). *Exception: MHW are becoming slightly less frequent in parts of the Southern Ocean.*	FREQUENCY	In large areas of the ocean, marine cold spells have become **less frequent** (99% confidence). *Exception: MCSs becoming more frequent in parts of the Southern Ocean.*
The occurrence of marine heatwaves has increased by **one extra event** every 5 to 10 years.	FREQUENCY	The occurrence of marine cold spells has been reduced by **one event every 5 years.**
Category III and IV (extreme) marine heatwave events are less common, but are occurring at a **slightly increased rate.**	INTENSITY	Category III and IV (extreme) marine cold spells are infrequent and their rate of occurrence has **remained constant.**
The spatial extent of the ocean affected by marine heatwaves is **increasing at a faster rate.**	AREA	The spatial extent of the ocean affected by marine cold spells has **remained constant.**



The temporal evolution of the ocean from 1982–2021 showing the areas affected by MHW, highlighting Category I (yellow), Category II (orange), Category III (red), and Category IV (black) events and the instances when no events were detected (grey). The year of an event is defined as the year of the peak intensity.



The temporal evolution of the ocean from 1982–2021 showing the areas affected by MCS, highlighting Category I (yellow), Category II (orange), Category III (red), and Category IV (black) events and the instances when no events were detected (grey). The year of an event is defined as the year of the peak intensity.

HOW DOES THIS IMPACT THE OCEAN AND BEYOND?

MARINE HEATWAVES (MHW)

- MHW events cause mortality in a wide variety of marine species, from corals to seagrasses, fish, and birds, and cause shifts in local biodiversity.
- Unusual warm temperatures trigger coral bleaching events, cause changes in fish communities, and deteriorate physical reef structures, leading to habitat loss. Coral reef decay increases the vulnerability of coastal areas to large wave events..

EU Strategy on Adaptation to Climate Change
UN Sustainable Development Goals

MARINE COLD SPELLS (MCS)

- Extreme cold temperature events are ecologically important phenomena that can shift the distribution of species, alter the composition of communities, and even bring about evolutionary change.
- MCS can cause the decay of warm water corals, potentially leading to mass mortality events of non-migratory marine species.

EU Strategy on Adaptation to Climate Change
UN Sustainable Development Goals

BEYOND THE OSR 7

OCCURRENCE OF MODERATE TO EXTREME MARINE HEATWAVES, SUMMER 2023

In April 2023, the global sea surface temperature reached a record high of 21.1°C, surpassing the previous record in 2016. During the months of June to August, various areas of the global ocean experienced moderate to severe and even extreme marine heatwave events.

HEATWAVE HOTSPOTS

1 NORTH-EAST ATLANTIC

Marine heatwaves of moderate to strong and extreme categories were detected. Concurrently, compared to the climatology (1998–2018), this region experienced a **decrease (50–60%) in phytoplankton concentrations**, which form the basis of the marine food web.

2 TROPICAL NORTH ATLANTIC

From July onwards, a marine heatwave stretched across the entire width of the basin, ranging from moderate to severe categories.

3 MEDITERRANEAN SEA

Moderate to extreme marine heatwaves swept across the basin in June, July, and August.

4 NORTH-EAST PACIFIC

Marine heatwaves of moderate to strong categories were observed during July, August, and September 2023.

5 TROPICAL PACIFIC

Sea surface temperature in this area steadily increased from July to September 2023, and this evolution has been discussed internationally with respect to the arrival of El Niño conditions.

USE CASE

CAN WE TRACK THE EFFECTS OF CLIMATE CHANGE IN THE MEDITERRANEAN?

This section is an example of a use case on how Copernicus Marine heatwave data can be applied for tracking ocean climate change.

The **T-MEDNet initiative** is aimed at establishing a fully operative and cost-effective “marine protected area” climate change observation network in Mediterranean coastal ecosystems. It provides insight into coastal thermal stratification, analyses warming trends and MHWs in nearshore waters, and offers more realistic 21st century coastal warming scenarios. The T-MEDNet initiative uses Copernicus data to provide insight into mass mortality events affecting the ability of marine ecosystems to support biodiversity and to identify changes in the abundance of native warm and cold water fish species, as well as invasive tropical fish, affecting fish stocks and fisheries. This initiative aids the development of adaptive management strategies to tackle the impacts on marine biodiversity caused by climate change.

TRACKING OCEAN CIRCULATION WITH THE COPERNICUS MARINE SERVICE

HOW DOES THE NEW TOOL WORK?

Copernicus Marine Service ocean reanalysis (combination of ocean models and observations) estimates of Meridional Ocean Circulation and heat transport have been compared with observation-based estimates in the South Atlantic ocean and the Greenland–Scotland Ridge. A record-low biennial reduction in oceanic heat exchange was uncovered across the Greenland–Scotland Ridge around 2018. Ocean reanalyses help improve our understanding of Meridional Overturning Circulation and heat transport throughout the global ocean.

WHAT IS THE MOC?

The **Meridional Overturning Circulation (MOC)** is responsible for transporting heat, salt, carbon, and nutrients around the global ocean. It connects the atmosphere, the ocean surface, and the deep ocean. The MOC helps drive and regulate the Earth's climate. It is driven by differences in water density as well as wind. Changes in water salinity and temperature, especially at ocean convection sites in the polar and subpolar areas, could impact the MOC's strength and physics, affecting the global climate.

HOW DOES IT HELP?

Tracking the volume and heat transport changes in the ocean is key for monitoring the variability of the Atlantic MOC. Ocean reanalyses can be used alongside observational estimates to refine sampling methodologies, ultimately improving our understanding and estimations of ocean heat transport.

HOW DOES THIS IMPACT THE OCEAN & BEYOND?

- The Southern Ocean region is a major driver of global ocean circulation. The Atlantic MOC is an important element of the Earth's climate system, which is vulnerable to climate change.
- Oceanic exchanges across the Greenland–Scotland Ridge play a crucial role in shaping the Arctic climate and linking with the Atlantic MOC.
- The recent IPCC 6th assessment report states that the Atlantic MOC is very likely to weaken over the 21st century for all emission scenarios. Moreover, the IPCC assessment revealed that an abrupt collapse before 2100 cannot be ruled out, and in this case it would very likely cause abrupt shifts in regional weather patterns and water cycles, such as a southward shift in the tropical rain belt, weakening of the African and Asian monsoons and strengthening of Southern Hemisphere monsoons, and drying in Europe.

European Green Deal
UN Sustainable Development Goals

USING OCEAN TRENDS TO MEASURE EXTREME WAVE EVENTS IN THE SOUTH ATLANTIC

HOW DOES THE NEW TOOL WORK?

Extreme wave event trends in the southwestern Atlantic region from the last 29 years were analysed using wave products and a coastal hazard database to identify regional changes associated with the mean sea wave height, wave period, and wave power affecting the São Paulo State in Brazil.

HOW DOES IT HELP?

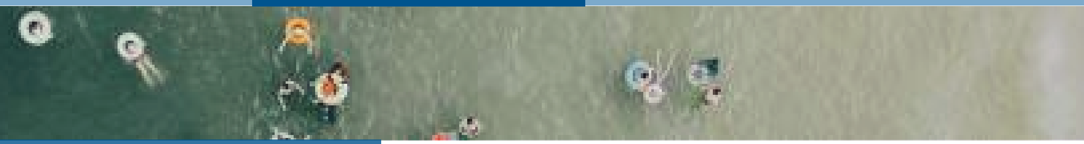
In recent years, an increase in extreme wave and storm surges have been reported in the southwestern South Atlantic, which hosts the most economically important harbours in South America. Combining extreme wave event trends with wave products and a historical database of coastal hazards identified significant changes in the region associated with an increase in the mean wave height, wave period, and wave power. These changes led to an increase in coastal hazards in the São Paulo State as well as an increase in the number of extreme wave events in certain areas.

HOW DOES THIS IMPACT THE OCEAN & BEYOND?

- Changes in wave height, wave period, and wave power directly impact offshore and coastal zones, aggravating hazards along the coast.
- Understanding extreme wave changes is crucial for supporting the design and safety of ships, offshore structures (e.g., energy platforms, wind/wave farms), and coastal infrastructure (e.g., ports, roads, tourism facilities).
- Identifying the trends associated with wave power and ocean extremes help identify areas that are potentially vulnerable to climate change hazards, helping to establish improved risk assessment and adaptation strategies for coastal protection (e.g., constructing dikes).
- Wave power, mean wave direction, and period changes are useful for engineers and stakeholders working towards the sustainable development of maritime activities.

UN Sustainable Development Goals

ABOUT US



Implemented by
MERCATOR OCEAN INTERNATIONAL

ABOUT MERCATOR OCEAN INTERNATIONAL

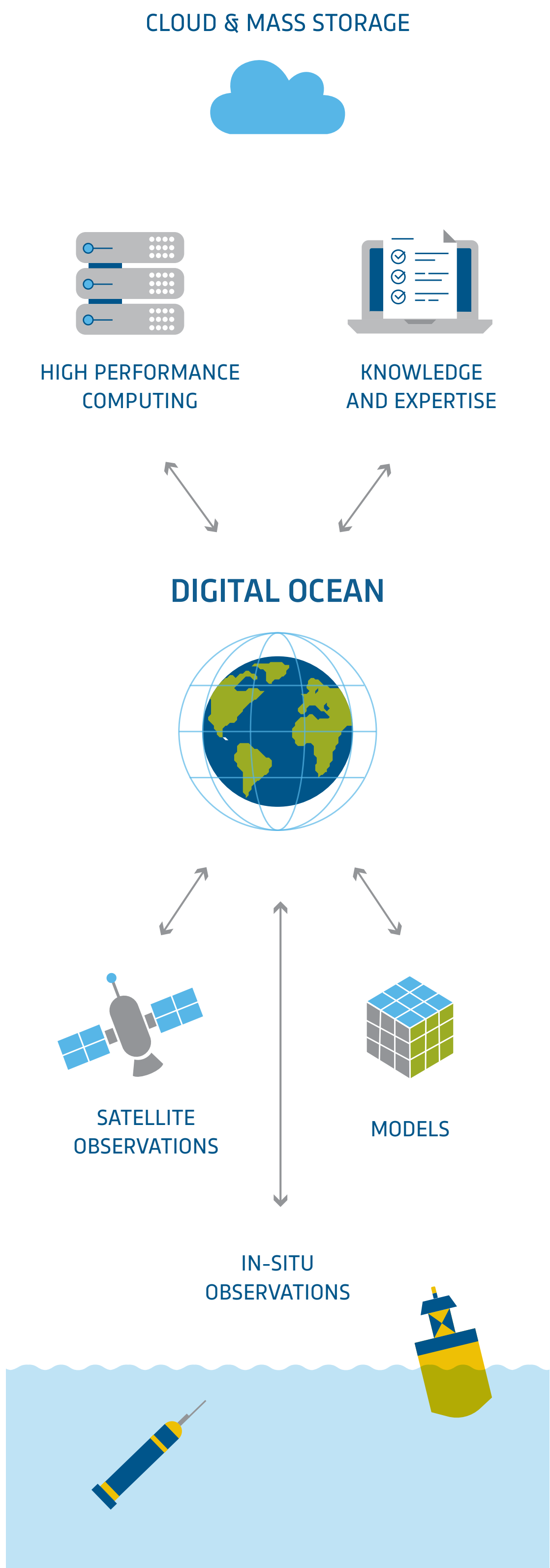
Mercator Ocean International was selected by the European Commission to implement the Copernicus Marine Service in 2014. Based in France, Mercator Ocean International (MOi) is a non-profit organisation in the process of becoming an intergovernmental organisation dedicated to ocean prediction. MOi provides ocean intelligence, data, and expertise that covers the global ocean and is a part of developing the European Digital Twin of the 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).

Copernicus
Europe's eyes on Earth

ABOUT THE COPERNICUS MARINE SERVICE

The **Copernicus Marine Service** (also known as CMEMS) is dedicated to ocean monitoring and forecasting. It is implemented by Mercator Ocean International, a global ocean analysis and forecasting centre, and funded by the European Commission (EC). It is one of the six services that comprise Copernicus, the European Union's Earth Observation Programme. The agreement was established in 2014 for Copernicus 1 and renewed in 2021 for Copernicus 2.

The Copernicus Marine Service provides regular and systematic reference information on the state of the physical and biogeochemical ocean at the global and European regional scales. 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 among the general public by providing European and global citizens with information about ocean-related issues.



The Copernicus Marine Service uses satellite observations, in situ platforms, and models to create a digital representation of the ocean. Scientific knowledge and expertise feed into these models to help describe and forecast the state and variability of the global ocean and the European regional seas and to provide a foundation for the development of marine protection and sustainable ocean stewardship.

PROGRAMME OF THE EUROPEAN UNION

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Copernicus Marine Service

Mercator Ocean International

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