# HOW A WARMING OCEAN IS CHANGING LIFE ON EARTH

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The global ocean is the engine of planet earth. By absorbing and redistributing heat the ocean regulates our climate. Through our observations we know that the ocean has absorbed more than 30% of the carbon and 91% of the excess heat generated by anthropogenic climate change. This has consequences for life in the ocean and for life on land, that we do not yet fully understand.

AtlantiS is the UK's sustained ocean observing programme, focused on documenting and predicting ocean change and understanding impacts on society and on our economy. Our research is being used to make better decisions about how we adapt and respond to climate change, and how we manage our interactions with the ocean.

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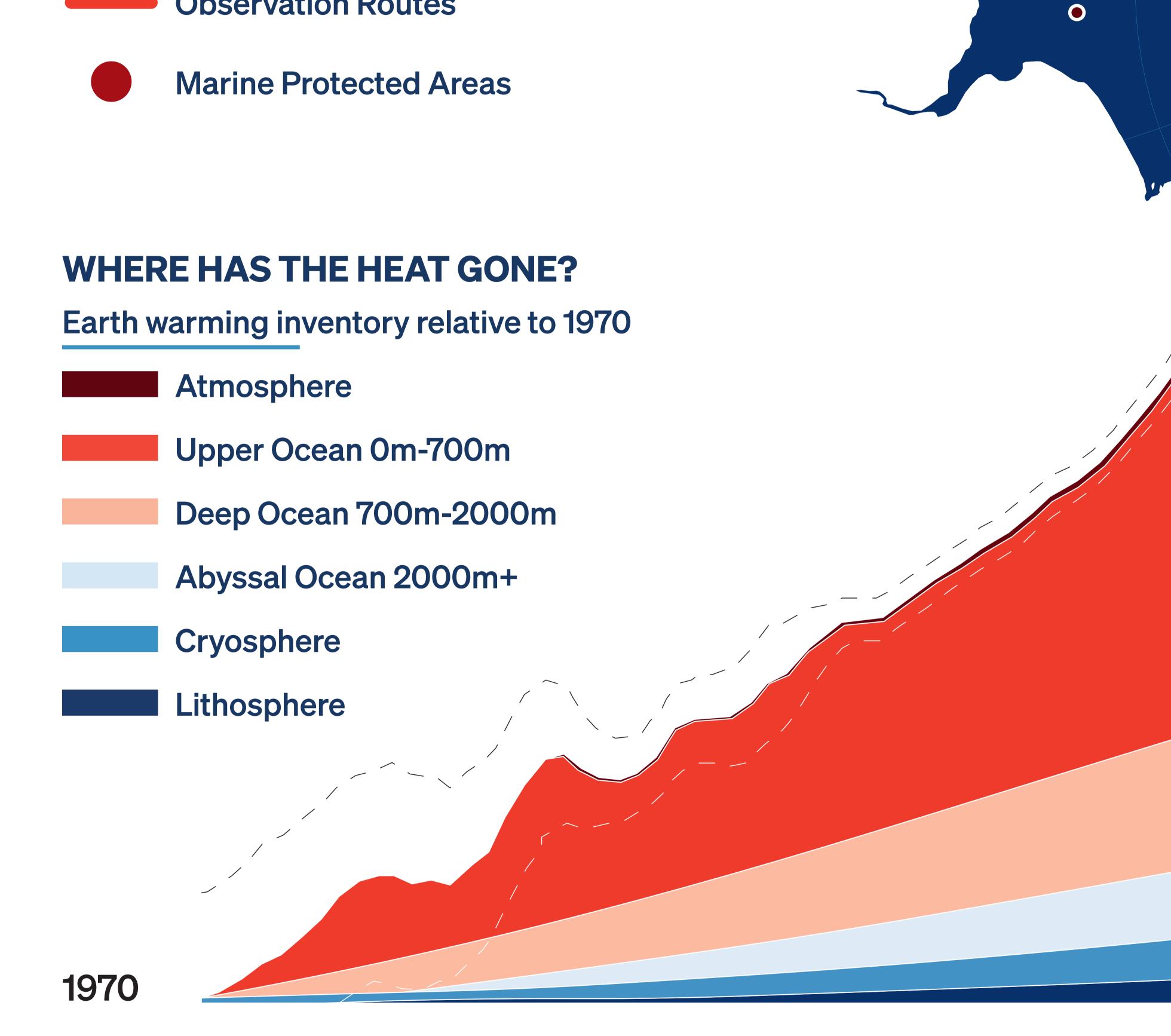
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**EXAMPLES OF MONITORING SITES & MARINE PROTECTED AREAS** 

EASTERN NORTH EASTAMERICA

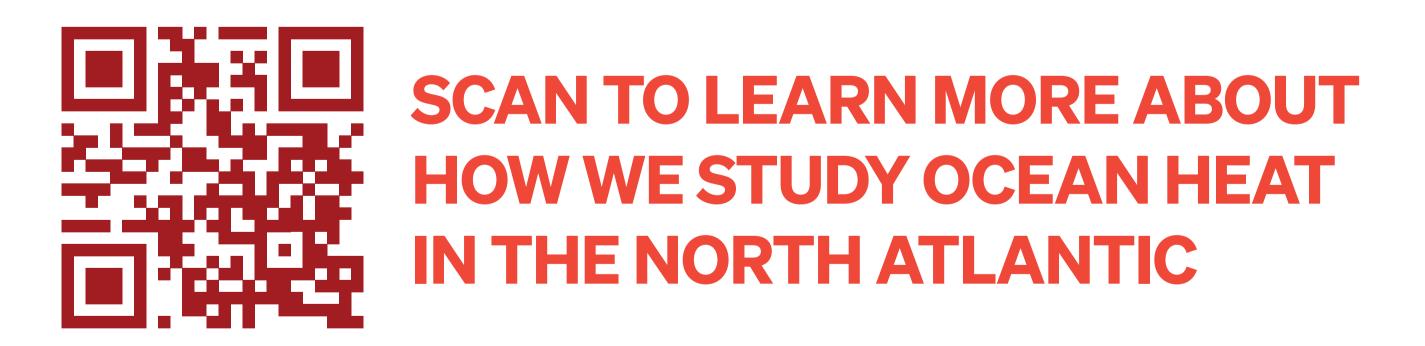
**Drifting Floats (Argo)** 

**Observation Routes** 

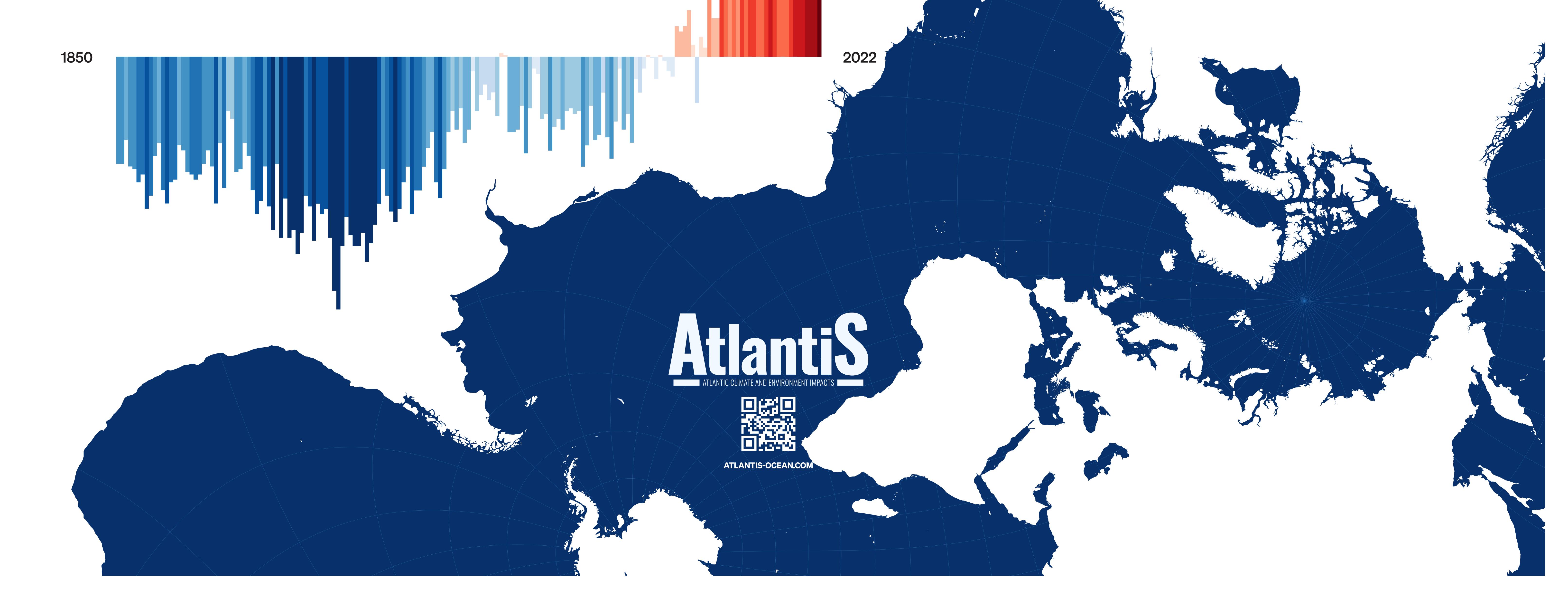


### **TEMPERATURE CHANGE IN THE ATLANTIC OCEAN**

Relative to average of 1971 – 2000



WESTERN NORTH AMERICA



# WHY DO CHANGES IN THE OCEAN MATTER FOR PEOPLE ON LAND?

Ocean research shows us that there are global, regional and local implications for society and the environment resulting from increasing levels of heat and carbon in the ocean.

For example, the ocean acts as an enormous heat reservoir. It is constantly but slowly moving, exchanging heat, water and carbon with the atmosphere. Ocean current systems, such as the Atlantic Meridional Overturning Circulation (AMOC), move such vast amounts of heat and water, that they are a primary influence on our weather. As the ocean warms there is evidence that these ocean circulation patterns are changing.

Changes in the strength of ocean circulation influence not only the distribution of heat but also the concentrations, locations and availability of carbon and nutrients. Together these changes have impacts ranging from ecosystem function, biological productivity and fisheries, through to sea surface temperature, sea level and ice (on land and sea), atmospheric circulation, seasonal cycles and extremes of weather on land.



#### **SEA LEVEL RISE**

The relentless rise of sea levels is a direct consequence of climate change, primarily driven by the melting of glaciers and ice sheets, and the thermal expansion of seawater as it warms. This gradual inundation threatens coastal ecosystems, erodes shorelines, and displaces human communities.

As sea levels continue to climb, the risk of catastrophic flooding events increases, necessitating urgent and adaptive responses to safeguard vulnerable areas.



#### **WEATHER PATTERNS**

The ocean is a key player in shaping global weather patterns. As ocean temperatures rise, the delicate balance of atmospheric conditions is disrupted, leading to more extreme and unpredictable weather events.

Warmer oceans can supercharge storms, intensify tropical cyclones, and shift precipitation patterns, resulting in prolonged droughts in some regions and devastating floods in others.

Understanding these changes is vital for preparing for future climatic shifts.





#### **MARINE HEATWAVES**

Marine heatwaves are periods of abnormally high ocean temperatures that can last for days to months, wreaking havoc on marine ecosystems.

These extreme events can cause widespread coral bleaching, alter fish migration patterns, and disrupt the food chain.

The frequency and intensity of marine heatwaves have increased, highlighting the need for comprehensive monitoring and strategies to mitigate their impact on ocean biodiversity.



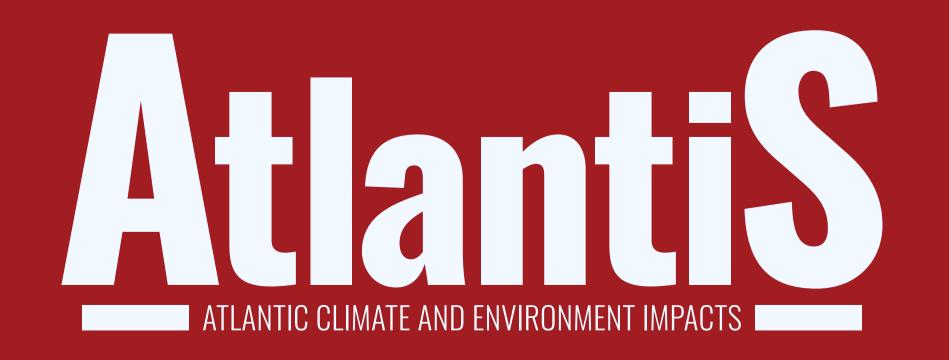
#### **ACIDIFICATION - THE OTHER CARBON PROBLEM**

Currently around 30% of annual anthropogenic CO<sub>2</sub> emissions dissolve in the Earth's oceans each year, helping to mitigate human-driven warming and climate change. As CO<sub>2</sub> dissolves it decreases the pH of seawater through a chemical reaction. This is known as ocean acidification.

Acidification can change an organisms energy budget, as well as reducing the amount of carbonate available in seawater which can cause marine organisms with shells and skeletons to dissolve. The impacts of this on many species are not yet understood. The North Atlantic Ocean contains more anthropogenic CO<sub>2</sub> than any other ocean basin, with the high latitudes acidifying fastest.



**SCAN TO LISTEN TO OUR PODCAST ABOUT** THE AMOC



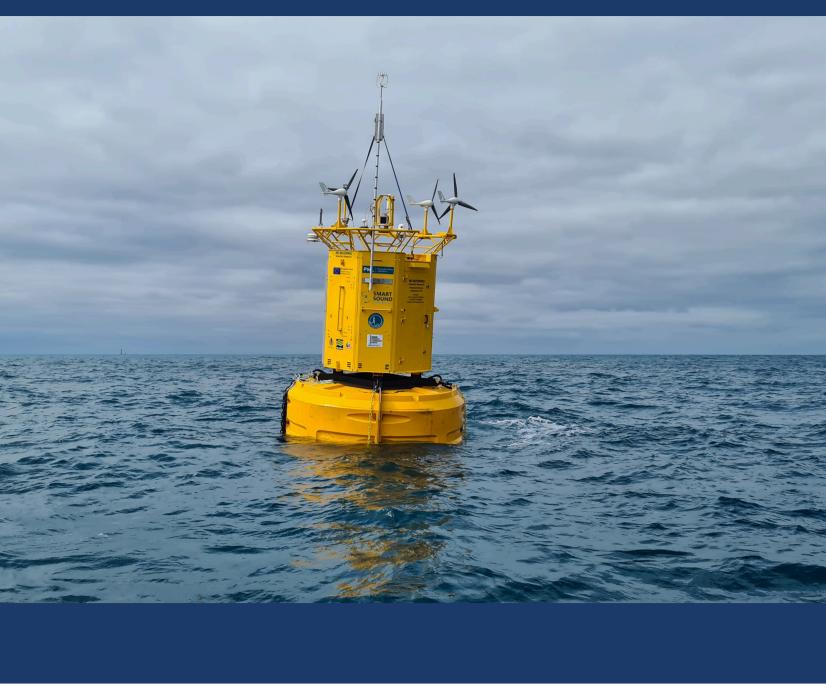


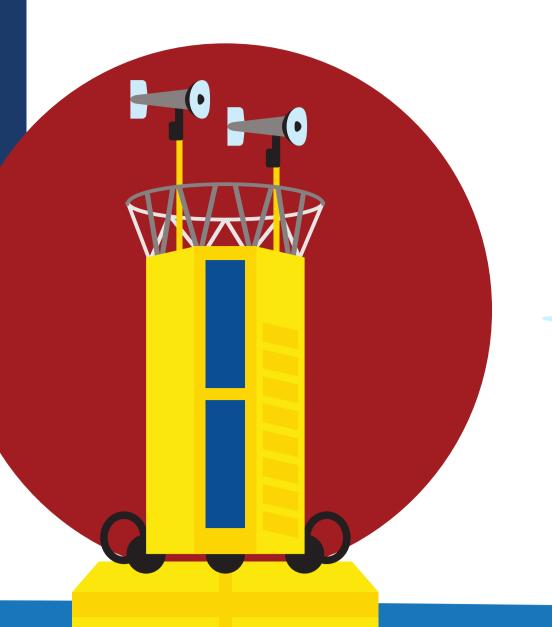
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A globally unique oceanographic time-series and marine biodiversity reference site, the WCO comprises pelagic (the open sea), benthic (the bottom of the sea) and atmospheric observations. Here we are observing key elements in the functioning of the marine ecosystem, such as zooplankton and toplankton as we nt, temperature,

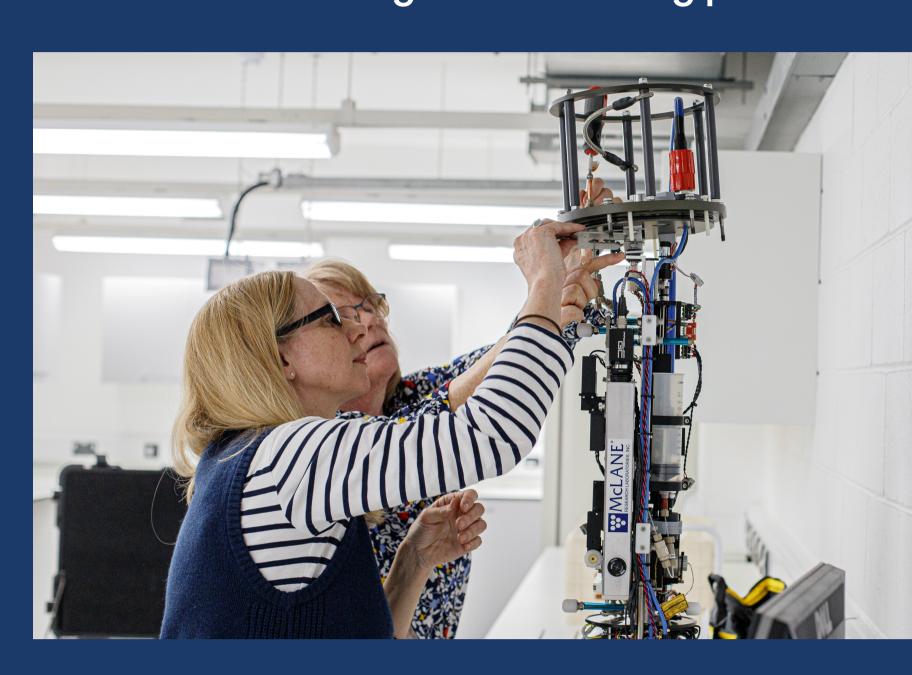
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### APICS

The Automated, in situ Plankton Imaging and Classification System (APICS) uses Artificial Intelligence (AI) technology to automatically image and classify plankton. The APICS is revolutionising the speed and volume of data that can be analysed, helping us to understand how environmental changes are affecting plankton.



**AUTOSUB LONG RANGE** 

by batteries and a propeller. They are

Autonomous vehicles, such as Autosub Long

designed to undertake long-range missions

spending weeks or months at sea. They are

of seabed habitats, but can measure a wide

Range (ALR), are robot submarines powered

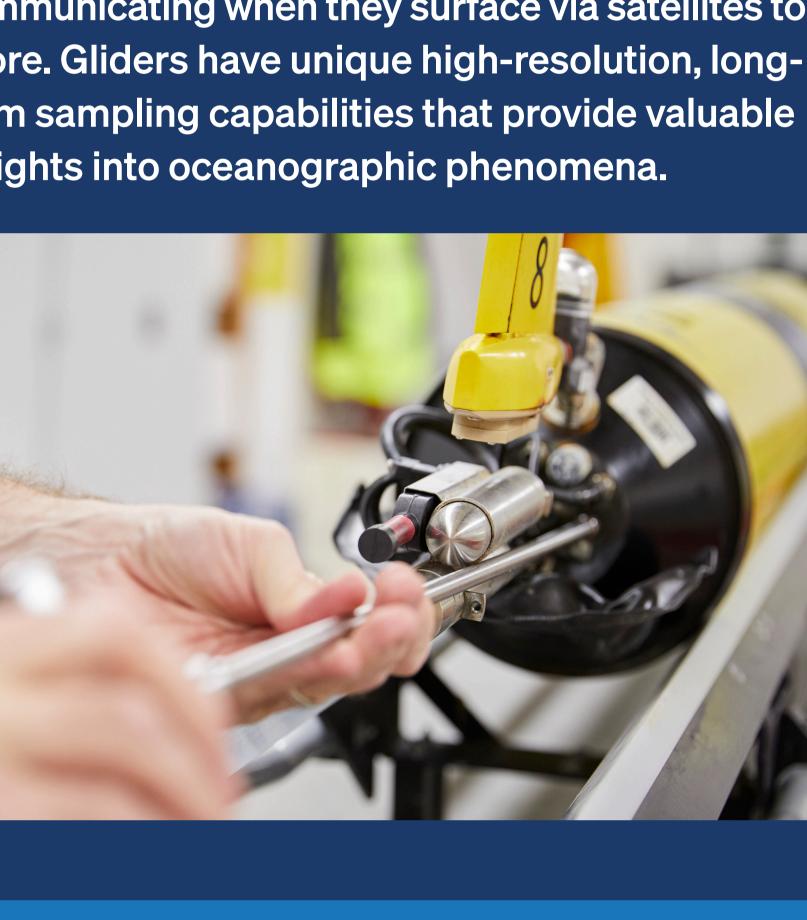
often used to conduct high-resolution surveys

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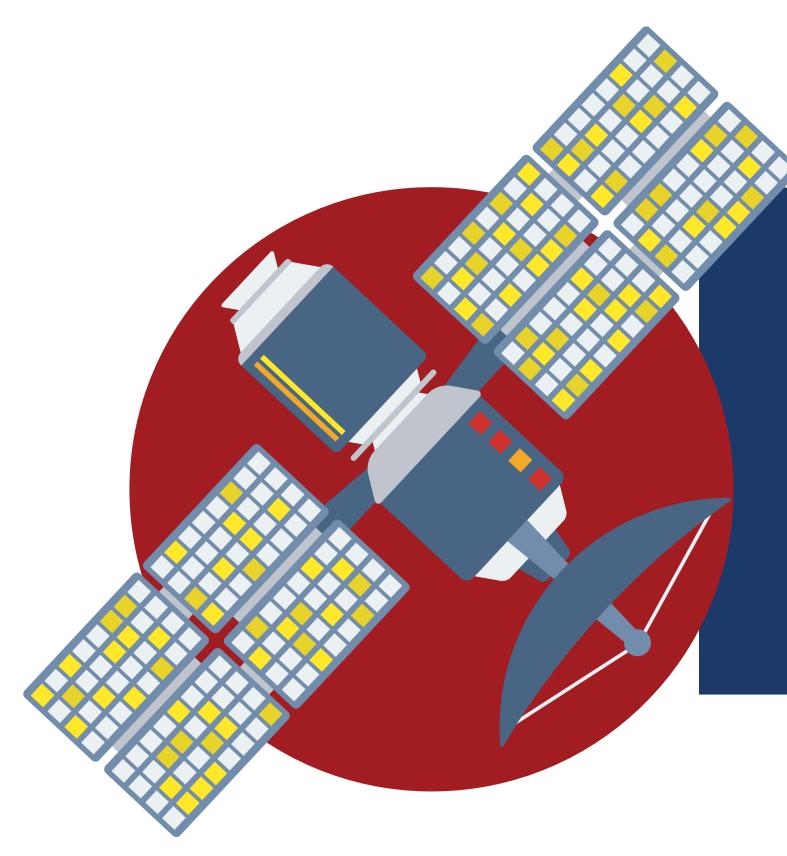
range of parameters.

#### GLIDERS

An internal pump enables gliders to easily change buoyancy, gliding up and down in the water taking measurements. They can stay at sea for several months communicating when they surface via satellites to shore. Gliders have unique high-resolution, longterm sampling capabilities that provide valuable insights into oceanographic phenomena.



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## SATELLITES

Providing large scale repeat mapping of the ocean surface, satellites enable the generation of data on sea surface height, roughness, temperature and colour. This data is fundamental to understanding change on a global scale.

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**RRS DISCOVERY** 

# **RESEARCH VESSELS**

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RRS DISCOVERV

Vital for ocean observations, research vessels are equipped with onboard labs, they take a wide range of high-quality measurements over the full water column and deploy and recover equipment from our ocean monitoring sites. They are also used in the deployment of tethered equipment, such as the Remotely Operated Vehicle (ROV) Isis which can dive down to 6,000m.



### AMT

A multi-disciplinary programme, the Atlantic Meridional Transect (AMT) undertakes biological, chemical and physical research during voyages between the UK and destinations in the South Atlantic. The result is a unique, over 25 year long, time series. These findings can then be used to address important questions, such as how the global carbon cycle is changing due to climate change.

PAP-SO **SCAN HERE TO** The Porcupine Abyssal Plain Sustained 思想

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Observatory (PAP-SO) is a fixed-point, openocean, observatory. Operating since 1985, this is one of a small number of sites that have achieved time series datasets to full ocean FIND OUT MORE depth over several decades, providing key information for the assessment of long-term change in the ocean and its ecosystems.



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ROV 

Unoccupied robotic

submersibles, Remotely **Operated Vehicles (ROV),** are linked to a ship via an umbilical cable. Power and control systems are transmitted down the cable allowing highdefinition video and data to be streamed back up to the operators and scientists on board the ship.





# TING WAVES OF DATA **TECHNOLOGY TO TRACK OUR OCEAN**

AtlantiS is a Natural Environment Research Council (UKRI) funded programme that provides evidence, tools and knowledge to support the UK ambition for healthy, biologically diverse & resilient marine environments, a sustainable blue economy and communities safe from natural hazards.

Monitoring such a vast and diverse environment requires many different approaches. By making consistent observations over time we are able to distinguish between natural variability and environmental shifts in response to human-driven climate change.

AtlantiS is using cutting-edge innovation to meet our ocean observing needs which includes some of the longest marine and climate time-series in the world.

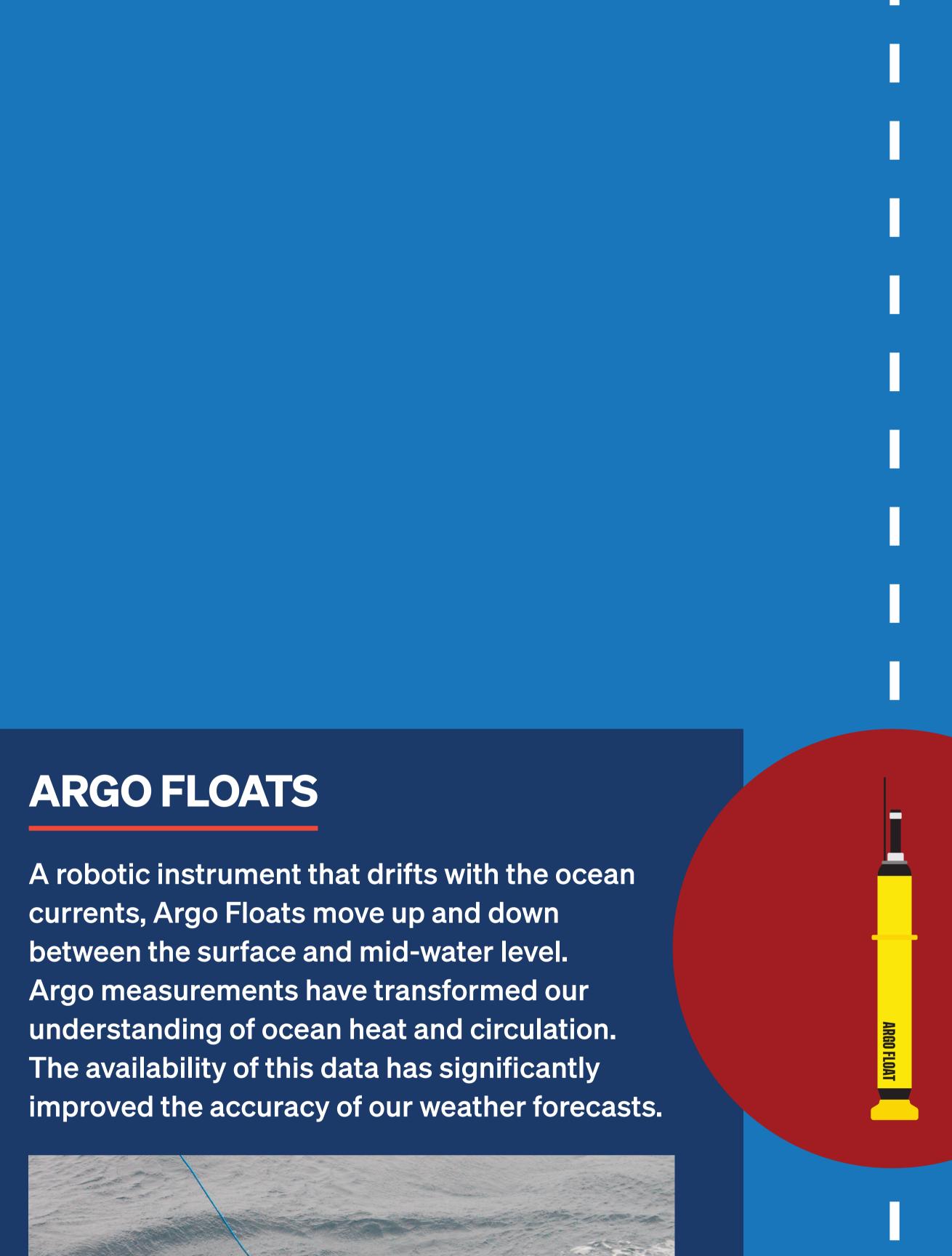
The data and knowledge generated by AtlantiS informs UK government and influences policy decisions, as well as supporting the UK's contribution to several important international scientific collaborations some of which are shown below.



# **OBSERVING THE AMOC**

Using a combination of instrumented moorings, gliders, floats and observations from satellites and Argo floats we continuously monitor the AMOC to understand how it varies over timescales from days to decades and uncover the processes through which the AMOC influences our weather. The AMOC has been identified as a climate tipping point with the potential for abrupt change.

the AMOC.





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FIND OUT MORE

**BGC ARGO FLOATS** 

The next generation of Argo floats can carry biogeochemical sensors down even further to operate in the deep ocean. These advancements are expanding our ability to observe and predict the effects of climate change on ocean metabolism, carbon uptake

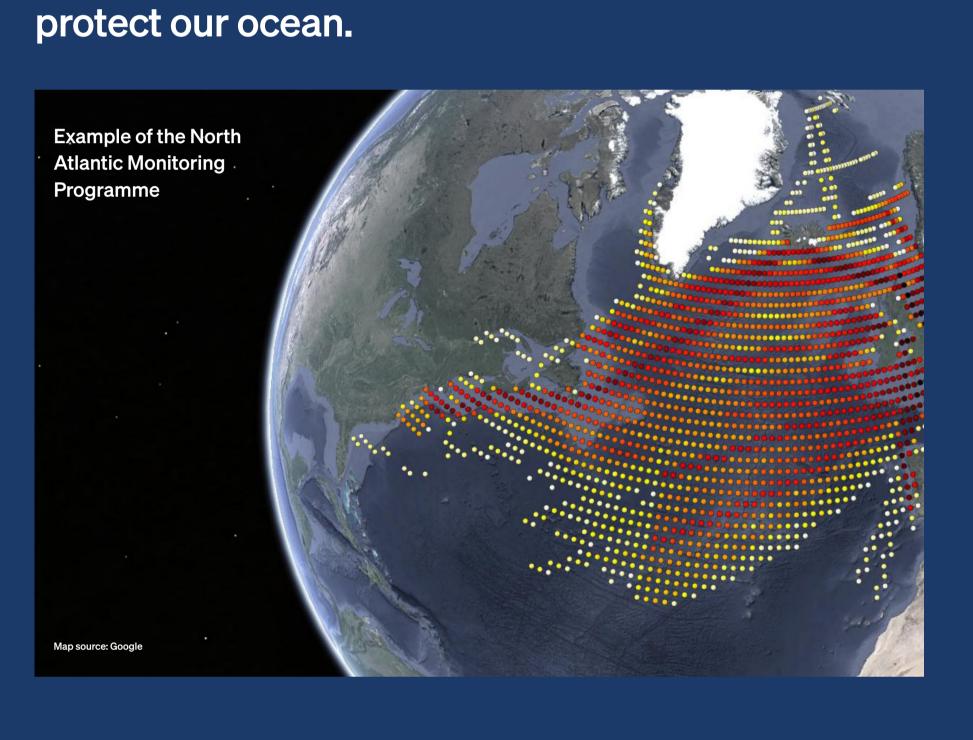




### CPR

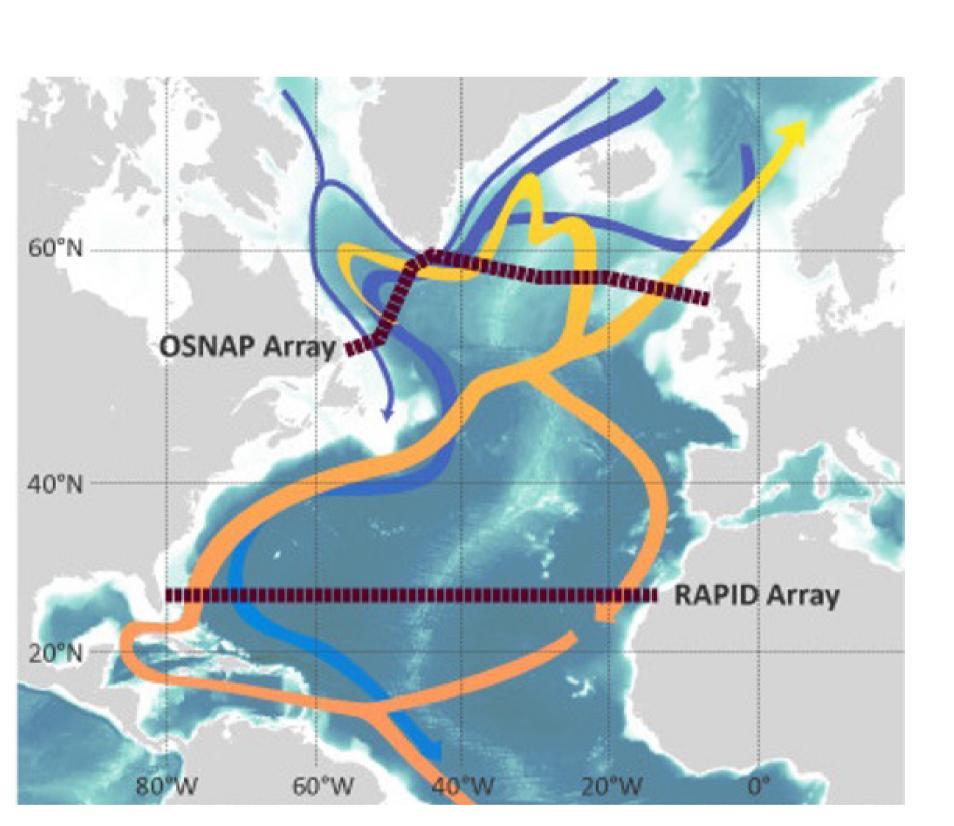
**Continuous Plankton Recorders (CPR) are** towed behind merchant ships, collecting plankton. The programme is the world's largest monitoring programme and has covered more than 7 million nautical miles of ocean in over 90 years, and provides a unique insight into ocean health which helps SCAN HERE TO

FIND OUT MORE



The Atlantic Meridional Overturning Circulation (AMOC) is a highly complex system of ocean currents which move heat over thousands of kilometres from one end of the Atlantic Ocean to another.

Small changes in the strength of the AMOC can bring about large changes in the air temperature and rainfall in the UK. It can even change rainfall in the Amazon Basin, over central Africa, the strength



of hurricanes in the Caribbean, and the severity of monsoons in southeast Asia.

The observations we make are vital to help improve our predictive models which do not yet effectively represent



# THE INVISIBLE OCEAN DISCOVER THE IMPORTANT ROLE OF PHYTOPLANKTON

Phytoplankton, the microscopic plants of the sea, are the foundation of the aquatic food web. These tiny organisms perform a colossal task, having produced more than half of the Earth's oxygen through photosynthesis, much like the plants and trees on land. They flourish in vast blooms that can be seen from space, painting the ocean's surface in swaths of vibrant colour.

Beyond their beauty, both phytoplankton and zooplankton (microscopic animals of the sea), play a critical role in carbon sequestration, helping to regulate our climate. This is a testament to the profound interconnectedness of life, where even the smallest beings have the power to shape our world.









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# <u>10 CHALLENGES</u> THE UNITED NATIONS OCEAN DECADE, WHICH CHALLENGE WILL YOU TAKE ON?

The UN Ocean Decade presents a bold vision and mission for addressing the pressing issues facing our Ocean. The vision, succinctly encapsulated in the phrase, "the science we need for the ocean we want", underscores the importance of scientific innovation and collaboration in shaping a sustainable future for our ocean.



#### **CHALLENGE 01**

UNDERSTAND AND BEAT MARINE POLLUTION

Understand and map land and sea-based sources of pollutants and contaminants and their potential impacts on human health and ocean ecosystems and develop solutions to remove or mitigate them.



#### CHALLENGE 02

#### PROTECT AND RESTORE ECOSYSTEMS AND BIODIVERSITY

Understand the effects of multiple stressors on ocean ecosystems, and develop solutions to monitor, protect, manage and restore ecosystems and their biodiversity under changing environmental, social and climate conditions.



#### CHALLENGE 03

SUSTAINABLY FEED THE GLOBAL POPULATION

Generate knowledge, support innovation, and

develop solutions to optimise the role of the

population under changing environmental,

ocean in sustainably feeding the world's

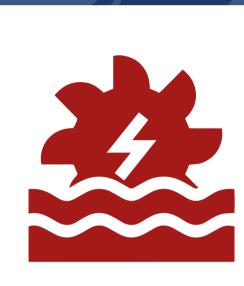
social and climate conditions.



### CHALLENGE 04

#### DEVELOP A SUSTAINABLE AND EQUITABLE OCEAN ECONOMY

Generate knowledge, support innovation, and develop solutions for equitable and sustainable development of the ocean economy under changing environmental, social and climate conditions.



#### **CHALLENGE 05**

#### UNLOCK OCEAN-BASED SOLUTIONS TO CLIMATE CHANGE

Enhance understanding of the ocean-climate nexus and generate knowledge and solutions to mitigate, adapt and build resilience to the effects of climate change across all geographies and at all scales, and to improve services including predictions for the ocean, climate and weather.



#### **CHALLENGE 06**

INCREASE COMMUNITY RESILIENCE TO OCEAN HAZARDS

Enhance multi-hazard early warning services for all geophysical, ecological, biological, weather, climate and anthropogenic related ocean and coastal hazards, and mainstream community preparedness and resilience.





#### EXPAND THE GLOBAL OCEAN OBSERVING SYSTEM

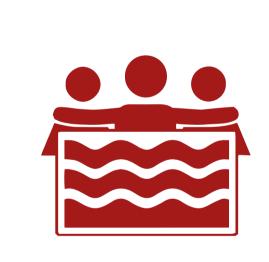
Ensure a sustainable ocean observing system across all ocean basins that delivers accessible, timely, and actionable data and information to all users.



#### CREATE A DIGITAL REPRESENTATION OF THE OCEAN

CHALLENGE 08

Through multi-stakeholder collaboration, develop a comprehensive digital representation of the ocean, including a dynamic ocean map, which provides free and open access for exploring, discovering, and visualizing past, current, and future ocean conditions in a manner relevant to diverse stakeholders.



#### CHALLENGE 09

SKILLS, KNOWLEDGE AND TECHNOLOGY FOR ALL

Ensure comprehensive capacity development and equitable access to data, information, knowledge and technology across all aspects of ocean science and for all stakeholders.



#### **CHALLENGE 10**

#### CHANGE HUMANITY'S RELATIONSHIP WITH THE OCEAN

Ensure that the multiple values and services of the ocean for human wellbeing, culture, and sustainable development are widely understood, and identify and overcome barriers to behaviour change required for a step change in humanity's relationship with the ocean.



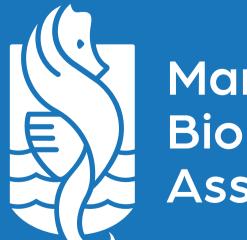
# DEEP HEAT: HOW A WARMING OCEAN IS CHANGING LIFE ON EARTH

#### WAS PRODUCED IN PARTNERSHIP BY



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Plymouth Marine Laboratory



Marine Biological Association



**FOR THE** 



#### **PROJECT, WITH FUNDING FROM**



Natural Environment Research Council