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# New ocean sensors could transform how scientists track the marine carbon cycle

EU-funded researchers are developing a new generation of ocean sensors able to monitor previously hard-to-reach areas, promising clearer insight into how marine ecosystems are responding to climate change.

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The world's oceans do far more than support vital marine ecosystems and provide food and recreation. They help regulate the Earth's climate, absorbing vast amounts of heat and CO2, acting as one of the planet's most important buffers against climate change.

Yet despite this vital role, scientists still struggle to track exactly how and where the ocean absorbs and stores CO2 – and how that process is changing.

The ocean soaks up around a third of human-made CO2 emissions every year, according to EU data. But observations are sparse, leaving large blind spots in our understanding.

## Extending ocean observation

Scientists have long relied on commercial ship-based measurements and fixed moorings to study ocean chemistry, but these approaches do not provide comprehensive coverage.

"We don't really have that many observations," explained Janne-Markus Rintala, a Finnish marine scientist based at the Integrated Carbon Observation System (ICOS), a European research network that measures greenhouse gases in the air, on land and in the oceans.

Its data helps scientists understand where carbon comes from, where it ends up and how fast the system is changing.

"Sometimes it looks like we know much more than we do, because models give the impression we have monitored everywhere." In reality, he explained, direct observations cover only about 3% of the ocean.

Rintala is leading an international team that aims to extend ocean observing capacity by developing sensors for platforms that can operate beyond normal shipping routes and deep below the surface – far from ships and human intervention

Their goal is to monitor ocean carbon continuously for months or even years, including in places that have, until now, been largely out of reach.

This work is part of an EU-funded initiative called GEORGE, which ends in 2027.

Coordinated by ICOS, it brings together leading experts from across Europe, including three major research infrastructures: ICOS, the European Multidisciplinary Seafloor and water-column Observatory (EMSO), and Euro-Argo, the European section of the Argo global ocean observation network.

## Measuring carbon in the deep

At the heart of the effort is the development of the world's first autonomous sensor capable of accurately measuring total alkalinity in the ocean – from the sea floor to the surface.

Total alkalinity is a key chemical indicator that scientists use to understand the ocean carbon system and estimate how much $CO_2$ seawater can absorb and store.

It is also critical for tracking ocean acidification – a process driven by rising $CO_2$ levels that lowers seawater pH and threatens marine ecosystems, particularly shell-building plankton and molluscs.

"Ocean acidification is very harmful for many marine organisms," said Rintala. "It can cause cascading effects that ripple up the food web."

Until now, total alkalinity has usually been measured by collecting fixed seawater samples from ships and analysing them later in onshore laboratories. That approach provides valuable data, but only at isolated points in time and space.

"If we are interested in the carbon content of the ocean as a whole, we need to measure deeper," said ocean scientist Socratis Loucaides, based at the UK's National Oceanography Centre (NOC).

Loucaides and his colleagues at NOC are leading the development of a radically different approach: a compact lab-on-a-chip sensor that performs a miniature chemistry experiment inside the instrument itself.

Inside the device, a small seawater sample is mixed with an acid of known strength and a dye that changes colour depending on acidity. A light-based sensor then reads those colour changes to calculate the alkalinity of the surrounding seawater.

By doing this directly in the deep ocean, the sensor can build up a far more detailed picture of how carbon is stored and transported over time – and potentially reveal early warning signs of change.

## Built to survive the deep sea

Before it could be deployed, the sensor had to prove it could withstand some of the most extreme conditions on Earth: the crushing pressure of the deep sea.

This was done at a high-pressure facility in the UK, where it was tested at pressures equivalent to depths of up to six kilometres.

The team then trialled it in real-world environments, from shallow estuaries to underwater landers and autonomous vehicles.

In its most demanding test so far, the sensor was lowered to nearly 5 000 metres below the surface in the North Atlantic.

There, it was mounted on a seabed lander, which was then lowered into position at the Porcupine Abyssal Plain Sustained Observatory – a remote open-ocean monitoring station almost five kilometres beneath the waves.

At that depth, real-time communication is impossible. The sensor runs on batteries, storing data internally until the lander is recovered.

“We won’t know exactly how this deployment has gone until we retrieve everything in May 2026,” Loucaides said.

## Reaching the ocean’s blind spots

Looking ahead, researchers hope to extend the lifespan of seabed sensors and reduce the cost and risk of deployment by using autonomous underwater vehicles to collect data from them.

The wider effort also aims to reach parts of the ocean that are rarely visited by research vessels, including remote regions and storm-prone areas such as the Southern Ocean. This is a task for another research initiative named TRICUSO, which builds on the work done in GEORGE.

To do this, scientists are developing sensors that can be carried by autonomous vehicles, from torpedo-shaped underwater gliders to wind- and solar-powered surface vessels and drifting instruments that travel on ocean currents.

Some sensors will measure multiple carbon-related parameters at once, while others will collect and preserve seawater samples during long voyages for later laboratory analysis.

Miniaturisation and accuracy are key, said Rintala. Smaller, lighter instruments require less power and fewer chemical reagents, which makes them easier to deploy widely and for long periods.

As climate change accelerates, a growing network of autonomous sensors could transform scattered measurements from a tiny fraction of the ocean into a far denser, more detailed map of its carbon cycle.

Over time, that information could reveal where the ocean is changing fastest, which regions are approaching critical thresholds, and how its capacity to absorb carbon is evolving.

“We’re facing enormous changes – and huge unknowns,” said Rintala. “To understand what’s happening, and how fast, we need many more measurements than we have today.”

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## More info

- GEORGE (CORDIS)
- GEORGE project website
- EU Mission: Restore our Ocean and Waters