Hot oceans weaken Earth's carbon sink

By **Andrei Ionescu** Earth.com staff writer **09-03-2025**

The world's oceans are our biggest climate ally, soaking up roughly a quarter of the carbon dioxide humanity releases and about 90% of the excess heat we've trapped in the atmosphere. In 2023, that ally got pushed to the limit.

Sea-surface temperatures jumped to unprecedented levels – from a supercharged El Niño in the tropics to blistering warmth across the North Atlantic – raising a pressing question: what happens to the ocean's carbon sink when the water itself is record hot?

Stress test for the ocean carbon sink

An international team led by ETH Zurich dug into ship, buoy, and satellite observations. The researchers used machine learning to stitch those measurements into daily maps of surface CO_2 across most of the global ocean.

The results showed that in 2023, the ocean absorbed nearly one billion tons less CO_2 than recent trends would suggest, a drop of about 10 percent. That shortfall is roughly half the European Union's annual emissions, or more than 20 times Switzerland's.

"This sudden warming of the ocean to new record temperatures is challenging for climate research," said ETH professor Nicolas Gruber. The results, he added, are "not good news," but the decline was smaller than many feared when temperatures first spiked.

Why heat weakens the sink

The basic physics are familiar to anyone who has watched a cold fizzy drink go flat in the sun. Warm water holds less dissolved gas.

In 2023, exceptional heat in the extratropical Northern Hemisphere, especially the North Atlantic, reduced CO_2 solubility and flipped parts of the ocean from absorbing CO_2 to letting it escape.

Study lead author Jens Daniel Müller explained that high temperatures reduced the solubility of CO_2, resulting in abnormal CO_2 outgassing and reducing the strength of the ocean carbon sink.

On paper, that solubility effect alone should have been devastating – large enough to nearly collapse the global carbon sink. It didn't, and the reason is the ocean's built-in capacity to counterpunch.

The forces that blunted the blow

Three processes helped keep surface waters less saturated with carbon than they otherwise would have been, softening the hit to the sink.

First, as some CO_2 outgassed, it left the surface temporarily depleted, which slightly improved the gradient for uptake elsewhere and later. Second, extreme surface warmth strengthened stratification, limiting the upward supply of CO_2-rich deep water.

Third, the biological pump kept working: plankton captured CO_2 in sunlit layers and exported carbon to depth as organic matter sank.

Taken together, these mechanisms created a tug-of-war. Temperature pushed CO_2 out of the ocean; stratification, biology, and the drawdown created by outgassing itself pulled the system back toward balance.

As Gruber noted, the 2023 outcome reflects a permanent tug-of-war between temperature-induced outgassing and the concurrent depletion of dissolved CO_2.

El Niño helped – just not enough

El Niño usually weakens upwelling of cold, carbon-rich water in the tropical Pacific, which slashes the region's natural CO_2 emissions and, paradoxically, tends to strengthen the global sink even in a warm year.

That pattern held in 2023: the tropical eastern Pacific, a typical source of outgassing, emitted relatively little.

But the extratropics overwhelmed that gift. The sheer intensity of warming outside the tropics – again, with the North Atlantic as a standout – negated the El Niño boost. In net terms, the global sink still declined.

How the team measured the dip

Unlike many assessments that lean primarily on models, this study is grounded in observations.

The researchers combined decades of CO_2 measurements from research vessels and cargo ships with readings from autonomous buoys and satellite data to build daily global maps of surface CO_2.

Machine-learning tools filled gaps and kept the reconstruction consistent, allowing the team to calculate air-sea CO_2 fluxes and compare 2023 with recent years on an apples-to-apples basis.

Future of the ocean carbon sink

The ocean has cooled little since the 2023 records, and the planet continues to warm. Marine heat waves are becoming more frequent and intense, which makes the big unknown painfully clear. Will the compensating mechanisms that steadied the sink last year keep doing so as background temperatures climb?

“We cannot yet say with certainty how this important carbon sink will develop in the future,” Müller cautioned.

Gruber said that it’s unclear whether those counteracting processes will remain effective over the long term and limit temperature-driven outgassing.

The bottom line: the ocean is still helping – don’t make it do all the work. For now at least, the ocean remains a formidable buffer.

“For the time being, however, the global ocean is still absorbing a great deal of CO_2 – fortunately,” Gruber said. But 2023 was a stress test that revealed both vulnerability and resilience. Extreme warmth can dent the sink significantly, even when physics and biology rally to soften the blow.

The practical takeaway is straightforward. Cutting emissions reduces the heat and acidity the ocean must absorb, preserving the sink’s strength. Every tenth of a degree avoided keeps more of the carbon sponge intact and buys time for the planet’s biggest ally to keep doing what it does best.

The study is published in the journal *Nature Climate Change*.