Secrets to Southern Ocean's critical role in slowing climate change revealed

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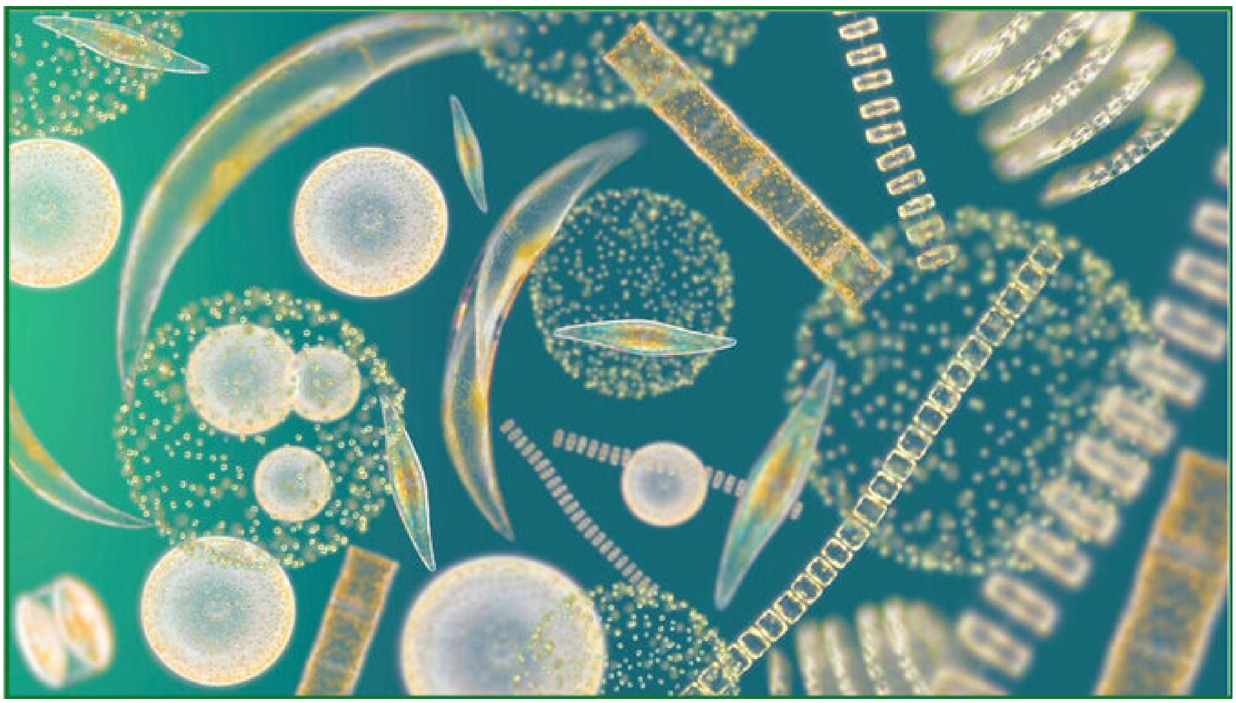

Phytoplankton. Credit: Richard Kirby

A new paper provides insights on one of the most important factors in the Southern Oceanic carbon cycle, the "biological pump," where carbon is utilized by organisms at the surface and transferred to ocean depths, away from contact with the atmosphere. The study, authored by scientists from NOAA's Pacific Marine Environmental Laboratory and the University of Hawaiʻi at Mānoa, was published in *PNAS*.

The Southern Ocean, also known as the Antarctic Ocean, plays a central role in moderating the rate of climate change, absorbing an estimated 40% of the total amount of human-generated carbon dioxide (CO_2) emissions and 60%–90% of the excess heat trapped by greenhouse gasses in the atmosphere. Understanding how the Southern Ocean absorbs CO_2 is one of oceanography's top priorities, but remote, harsh conditions of the Southern Ocean challenge scientists' ability to accurately characterize how carbon cycling occurs.

The science team was led by Yibin Huang and Andrea Fassbender from NOAA's Pacific Marine Environmental Laboratory, in collaboration with Seth Bushinsky, an assistant professor of oceanography in the UH Mānoa School of Ocean and Earth Science and Technology (SOEST). They examined data collected from more than 60 autonomous profiling floats over 10 years to quantify for the first time the role that tiny organisms called phytoplankton play in Southern Ocean CO_2 absorption from the atmosphere through their creation of different types of biogenic (brought about by living organisms) carbon. Each type of biogenic carbon has a different impact on carbon export and on the exchange of CO_2 between the atmosphere and ocean.

Understanding how much carbon gets captured in the ocean interior by the biological pump and how this influences the amount of CO_2 taken up by the ocean is critically important because a change in the rate at which biogenic carbon is stored in ocean waters could result in more CO_2 remaining in the atmosphere and potentially affect the rate of climate change.

Lead author Huang, a Cooperative Institute for Marine and Atmospheric Research scientist working at the Pacific Marine Environmental Laboratory, said that simultaneously monitoring the three different types of carbon produced by biological activity has posed a longstanding challenge for oceanographers. Due to the complexity of traditional methods, he said, scientists usually treat the total carbon production as a black box.

"Our study applies a recently developed method for estimating the production and export of distinct biogenic carbon pools in a cost-effective way and at ocean basin scales to monitor how marine ecosystems function and their response to future climate change," said Huang.

How phytoplankton pull carbon from the atmosphere

Through the unique Southern Ocean circulation south of 35°south latitude, the interaction of physical and biological processes shapes regional biogeochemistry that influences the global ocean interior. Prevailing upwelling south of the Antarctic Circumpolar Current brings deep waters rich in dissolved inorganic carbon into contact with the atmosphere. The deep waters are also rich in nutrients, which fuel biological activity peaking during spring and summer. Phytoplankton consume dissolved inorganic carbon, with some species using it to make their exoskeletons, and subsequently transport it to depth when they die.

While plankton flourish in this rich, cold water, they can't fully utilize available nutrients and the dissolved inorganic carbon brought to the surface during upwelling. Some of the dissolved inorganic carbon is outgassed to the atmosphere locally. The unused nutrients are subsequently transported toward the equator via large-scale circulation, fueling a large fraction of the biological production in the subtropics and tropics. The seasonal pattern of carbon cycling in the Southern Ocean is shaped by the slowdown in phytoplankton growth during the winter, when deep-water mixing is most vigorous.

The paper focuses on quantifying the amount of dissolved inorganic carbon used by these tiny organisms, and how the natural process of carbon export influences the modern air-sea exchange of CO_2.

Tiny creatures, huge carbon sink

The researchers found that organic carbon production captures roughly 3 billion tons of carbon per year, which is equivalent to about one quarter of total human emissions, while particulate inorganic carbon production diminishes CO_2 uptake by about 270 million tons per year. Differences in the amount of each type of carbon produced from north to south across the Southern Ocean influence how the biological pump impacts local air-sea CO_2 exchange.

Without the action of plankton consuming carbon during the southern hemisphere's growing season, the Southern Ocean would be a CO_2 source to the atmosphere, the scientists said.

The significant role played by phytoplankton in the modern Southern Ocean carbon sink suggests that understanding year-to-year variability in biogenic carbon production may be of central importance to understanding variability in the overall Southern Ocean carbon sink, said Fassbender, who is also an adjunct professor at the University of California, Santa Cruz.

"Expanding persistent year-round observations from biogeochemical profiling floats would serve as a cost-effective way to monitor the biological pump throughout the Southern Ocean and globally," she said.

More information: Yibin Huang et al, Biogenic carbon pool production maintains the Southern Ocean carbon sink, *Proceedings of the National Academy of Sciences* (2023). DOI: 10.1073/pnas.2217909120

Provided by University of Hawaii at Manoa

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