Ocean sink for man-made CO2 measured

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An international research project led by scientists from ETH Zurich has determined the amount of man-made CO_2 emissions taken up by the ocean between 1994 and 2007. Not all of the CO_2 generated during the combustion of fossil fuels remains in the atmosphere and contributes to global warming. The ocean and the ecosystems on land take up considerable quantities of these man-made CO_2 emissions from the atmosphere.

The ocean takes up CO_2 in two steps: first, the CO_2 dissolves in the surface water. Afterward, the ocean's overturning circulation distributes it: ocean currents and mixing processes transport the dissolved CO_2 from the surface deep into the ocean's interior, where it accumulates over time.

Carbon sink in the ocean

This overturning circulation is the driving force behind the oceanic sink for CO_2. The size of this sink is very important for the atmospheric CO_2 levels: without this sink, the concentration of CO_2 in our atmosphere and the extent of anthropogenic climate change would be considerably higher.

Determining what share of the man-made CO_2 the oceans absorb has long been a priority for climate researchers. An international team of scientists led by Nicolas Gruber, Professor for Environmental Physics at ETH Zurich, has now determined this oceanic sink over a period of 13 years. As reported in the latest issue of *Science*, the researchers have found that the ocean has taken up from the atmosphere as much as 34 gigatonnes (billions of metric tonnes) of man-made carbon between 1994 and 2007. This figure corresponds to 31 per cent of all anthropogenic CO_2 emitted during that time.

The marine sink is intact

This percentage of CO_2 taken up by the oceans has remained relatively stable compared to the preceding 200 years, but the absolute quantity has increased substantially. This is because as long as the atmospheric concentration of CO_2 rises, the oceanic sink strengthens more or less proportionally: the more CO_2 is in the atmosphere, the more is absorbed by the oceans—until it eventually becomes saturated.

So far, that point has not been reached. "Over the examined period, the global ocean continued to take up anthropogenic CO_2 at a rate that is congruent with the increase of atmospheric CO_2," Gruber explains.

These data-based research findings also confirm various earlier, model-based estimates of the ocean sink for man-made CO_2. "This is an important insight, giving us confidence that our approaches have been correct," Gruber adds. The results further allow the researchers to draw conclusions about the CO_2 sink of the ecosystems on land, which are more difficult to determine.

Regional differences in the absorption rate

While the overall results suggest an intact ocean sink for man-made CO_2, the researchers also discovered in the different ocean basins considerable deviations from the uptake expected from the rise in atmospheric CO_2. The North Atlantic Ocean, for instance, absorbed 20 per cent less CO_2 than expected between 1994 and 2007. "This is probably due to the slowdown of the North Atlantic Meridional Overturning Circulation in the late 1990s, which itself is most likely a consequence of climate variability," Gruber explains. But this lower sink in the North Atlantic was offset by a considerably greater uptake in the South Atlantic, such that the uptake by the entire Atlantic developed as expected.

The researchers documented similar fluctuations in the Southern Ocean, in the Pacific and in the Indian Ocean. Gruber emphasises: "We learned that the marine sink does not just respond to the increase in atmospheric CO_2. Its substantial sensitivity to climate variations suggests a significant potential for feedbacks with the ongoing change in climate."

Results of two surveys

The results are based on a global survey of CO_2 and other chemical and physical properties in the various oceans, measured from the surface down to depths of up to 6 kilometres. Scientists from 7 countries participated in the internationally coordinated programme that started in 2003. Globally they carried out more than 50 research cruises up to 2013, which were then synthesized into a global data product.

For their analyses, the researchers used a new statistical method developed by Gruber and his former Ph.D. student, Dominic Clement. This method allowed them to distinguish between the changes in the man-made and the natural CO_2 components that make up the changes in the total concentration of dissolved CO_2 in the water. Natural CO_2 refers to the amount of CO_2 that existed in the oceans prior to industrialisation.

Gruber had already participated in a similar study around the turn of the millennium. Using observations obtained from the very first global CO_2 survey conducted between the late 1980s and the mid-1990s, that study estimated that the ocean had taken up around 118 gigatonnes of carbon from the beginning of industrialisation around 1800 until 1994. His current team of researchers extended this analysis up to 2007, permitting them not only to establish the budget for man-made CO_2 for the 1994 through 2007 period, but also to assess the intactness of the ocean carbon sink.

Increasing CO_2 content acidifies marine habitats

By moderating the rate of global warming, the oceanic sink for man-made CO_2 provides an important service for humanity, but it has its price: the CO_2 dissolved in the ocean acidifies the water. "Our data has shown that this acidification reaches deep into the ocean's interior, extending in part to depths of more than 3000 m," Gruber says.

This can have serious consequences for many marine organisms. Calcium carbonate spontaneously dissolves in acidified environments, which poses a hazard to mussels and corals whose shells and skeletons are made of calcium carbonate. The changing chemical composition of the ocean can also impact physiological processes such as the breathing of fish. Gruber is convinced: "Documenting the chemical changes imparted on the ocean as a result of human activity is crucial, not least to understand the impact of these changes on marine life."

More information: N. Gruber el al., "The oceanic sink for anthropogenic CO2 from 1994 to 2007," *Science* (2019). science.sciencemag.org/cgi/doi … 1126/science.aau5153

Provided by ETH Zurich

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