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# Hot and Sour in the Deep Ocean

Stable layering in the ocean limits the rate that human-derived carbon dioxide can acidify the deep ocean. Now observations show that ocean warming, however, can enhance deep ocean acidification through increased organic matter decomposition.

**Christopher L. Sabine**

The surface ocean absorbs anthropogenic (human-derived) carbon dioxide at a rate of over 18 million kilograms per minute; every minute of every day[1]. Because of stratification, density layering in the water column, most of that carbon is trapped in the upper few hundred meters of the ocean where it reacts with water molecules to increase ocean acidity[2,3]. With most of the carbon dioxide restricted to shallow regions, ocean acidification is not considered to be a significant issue in most deep and abyssal waters. Writing in *Nature Climate Change*, Chen-Tung Arthur Chen and colleagues [4] present measurements and analysis that suggest that deep-water acidification could be a bigger problem than previously thought.

The East/Japan Sea can be thought of as a proxy for the global ocean. The basin is isolated by shallow sills and with its own deep and bottom water formation, the East/Japan Sea can provide clues to changing deep water processes that still may be too small to be measured in the larger Atlantic or Pacific basins. One such process is a slowdown in the formation and movement of waters into the ocean interior[5]. Changes in deep ocean properties have been described for the East/Japan Sea in several articles over the years, but Chen *et al.* use a 50 year time series of ocean carbon and oxygen measurements to document significant secular changes in deep water pH in the context of ocean acidification.

This acidification does not come from the direct absorption of carbon dioxide from the atmosphere, but from the decomposition of organic matter raining into the deep ocean as surface dwelling organisms die and sink through the water column. Decomposition consumes oxygen and releases carbon dioxide at a rate proportional to the rate of falling particles and the length of time the water is in contact with those

decomposing particles. A change in either the source of the particles or the flow of water through the deep basin would result in a change in the chemical properties (Fig. 1).

In this case, Chen *et al.* argue that a slowdown in the deep water circulation because of warming and stabilization of the water column produced the observed secular increases in deep basin acidity, which could be a harbinger of how the global ocean might change if global warming were to stabilize and reduce deep and bottom water formation in the Atlantic and Pacific. What makes this study truly noteworthy is the rate of change, 27% over 50 years, is much larger than what previous studies would have suggested[6].

Clearly, the East/Japan Sea is not a perfect analog for the global ocean. It is only a single basin with a single deep water formation region. The global ocean has at least an order of magnitude longer residence time[7] and more complex deep-ocean mixing from multiple sources. The East/Japan Sea may also represent an extreme case since a significant reduction of deep water formation and commensurate cessation of excess carbon dioxide accumulation below 400 m has been observed since at least 1999[8]. A complete stop in the global overturning circulation is not expected in the foreseeable future. However, this study does point out the importance of understanding all sources of acidification beyond just absorption of atmospheric carbon dioxide.

The Intergovernmental Panel on Climate change defines Ocean Acidification as "a reduction in the pH of the ocean over an extended period, typically decades or longer, which is caused primarily by uptake of carbon dioxide from the atmosphere, but can also be caused by other chemical additions or subtractions from the ocean" and Anthropogenic Ocean Acidification as "the component of pH reduction that is caused by human activity"[9]. A change in pH because of ocean warming and stabilization of the water column would not be considered ocean acidification under this definition, but the work of Chen *et al.* suggests that a significant anthropogenic effect on deep ocean acidity could be in store for the future and should be considered as part of the suite of anthropogenic impacts on the ocean.

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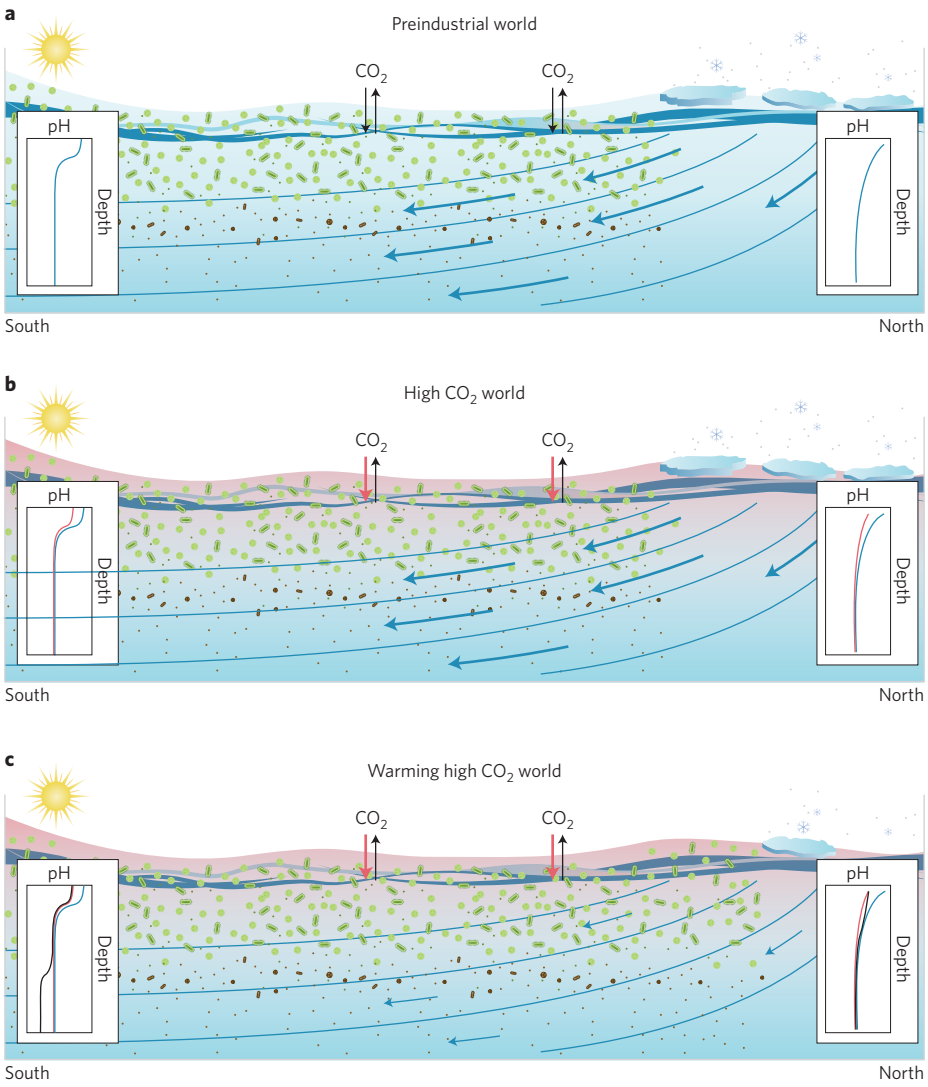
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Preindustrial world
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c
Warming high CO2 world
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