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A better understanding of gas exchange between the atmosphere and ocean can improve global climate models

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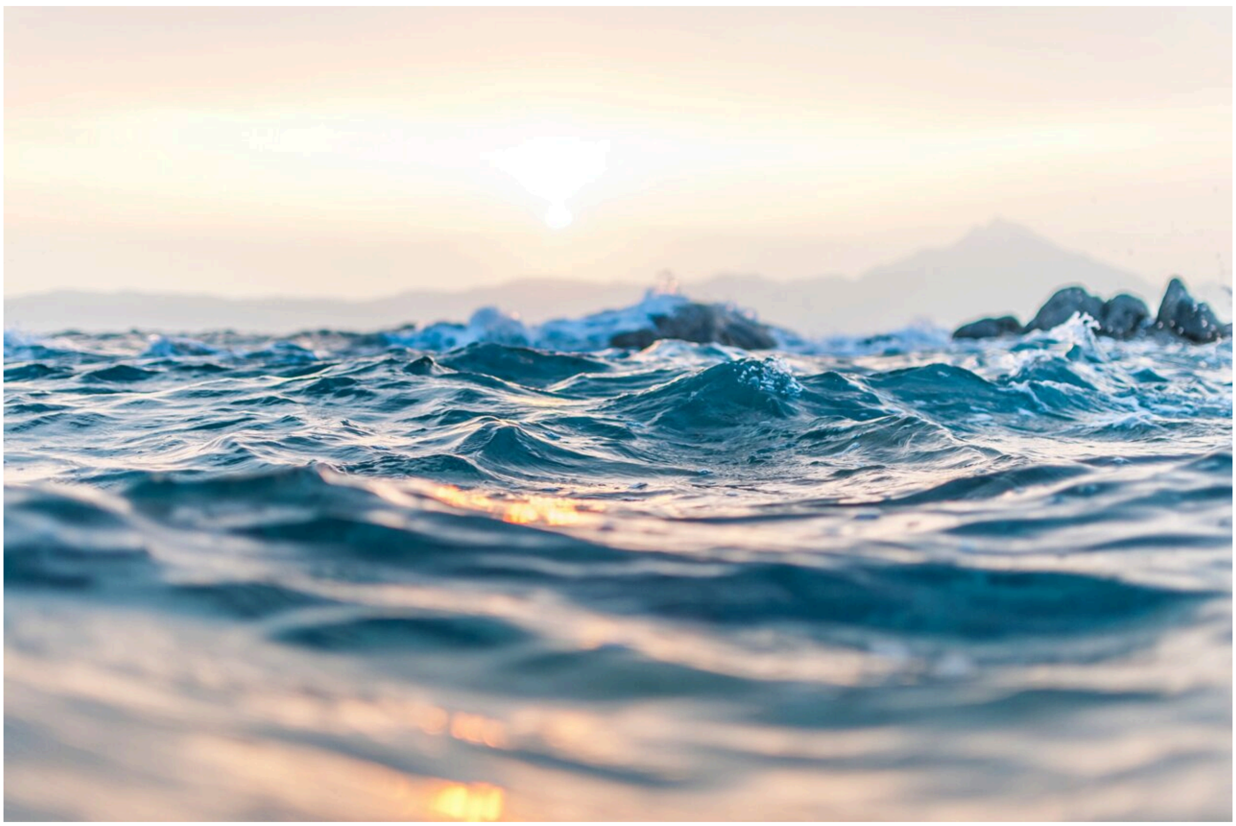

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The injection of bubbles from waves breaking in turbulent and cold high-latitude regions of the high seas is an underappreciated way in which atmospheric gases are transported into the interior ocean. An improved mechanistic understanding of gas exchange in high latitudes is important for several reasons, including to better constrain climate models that are used to predict changes in the ocean inventory of key gases like oxygen and carbon dioxide.

A new WHOI-led study, "Dissolved gases in the deep North Atlantic track ocean ventilation processes", published this week in *Proceedings of the National Academy of Sciences*, combines new geochemical tracers and ocean circulation models to investigate the physics by which atmospheric gases get into the deep ocean.

The study uses a new technique to precisely measure noble gas isotopes dissolved in samples of seawater collected from as deep as 4.5 kilometers in the North Atlantic. Noble gases—the elements on the far right-hand side of the periodic table—are unreactive and unused by biology, making them useful tracers of physics.

Noble gases are neither added nor removed from water after the exchange with the atmosphere at the sea-surface. As a result, measuring dissolved noble gases in the deep North Atlantic off the coast of Bermuda tells scientists about the physics of gas exchange that happened in special regions like the Irminger Sea, where the surface ocean becomes dense enough under stormy wintertime conditions to sink and form deep water that slowly flows south.

Alan Seltzer, lead author of the paper, said these new findings suggest that the dissolution of bubbles in the high-latitude ocean "may be the dominant pathway by which all of the noble gases, oxygen, and nitrogen get into the deep ocean." This study is a step forward toward understanding the basic physics by which gases get into the ocean, said Seltzer, an assistant scientist in the Marine Chemistry and Geochemistry Department at the Woods Hole Oceanographic Institution (WHOI).

"Anything we can do to improve the accuracy of the way models represent our world is helpful, especially when it has to do with gases," he said. "We care about oxygen for global ecosystems, and we care about CO_2 because the ocean is a huge player in taking up our emissions. So if we can improve the way models represent physical processes such as gas exchange, we can have more confidence in future simulations with models as a way of predicting how things will change in a warmer world with more CO_2."

"Understanding how the ocean takes up and releases gases to the atmosphere is a challenging but critically important step toward predicting their response to climate change. Being chemically and biologically inert, noble gases are powerful tools for probing the physical processes involved," said journal article co-author William Jenkins, an emeritus research scholar in WHOI's Marine Chemistry and Geochemistry Department.

"The Seltzer et al. paper is an important step forward in this journey in that it combines new high-precision noble gas concentration and isotope ratio measurements that are key to unlocking an understanding of these vital processes. Their results also shed light on the oceanic nitrogen cycle, which is both important for climate change issues, but also our fundamental understanding of how ocean food web is supported."

Measurements for the study come from the Bermuda Atlantic Time Series (BATS) site (31°40 N, 64°10 W), where repeat cruises have surveyed the ocean from top to bottom nearly monthly since 1988. The BATS site is an ideal place to collect samples, because it is located downstream of deep-water formation regions.

Deep-ocean noble gas concentrations at the BATS site allow scientists to study gas exchange during wintertime events where the deep ocean is formed as surface waters cool and become more dense. Under these harsh conditions, direct observations are challenging and scarce, which is why measurements from the deep ocean in warmer, more southern locations are so valuable.

Seltzer said a way to understand why bubbles play such a huge role in transporting noble gases, oxygen, and nitrogen into the deep ocean is to realize that "every time a wave breaks, that massively increases the available surface area for the exchange of gases between the atmosphere and the ocean."

"The exchange of carbon dioxide and other greenhouse gases between the deep ocean—approximately 75% of the total ocean volume—and the atmosphere occurs at high latitudes during winter, particularly during storm events. Measurements of inert noble gas concentrations in the deep North Atlantic Ocean documented the importance of large bubbles that form during windy storm events, significantly increasing our understanding of the gas exchange rate for the deep water," said co-author William Smethie, special research scientist and retired research professor at the Lamont-Doherty Earth Observatory of Columbia University.

"This improves our ability to quantify the exchange of carbon dioxide and greenhouse gases between the ocean and atmosphere and predict how their atmospheric concentrations will impact the earth's climate, which is critical for developing policies to mitigate global warming."

More information: Alan M. Seltzer et al, Dissolved gases in the deep North Atlantic track ocean ventilation processes, *Proceedings of the National Academy of Sciences* (2023). DOI: 10.1073/pnas.2217946120

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