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by Cassie Martin

ANTARCTIC SEA ICE AND THE OZONE HOLE: A MATTER OF TIME

A recent multi-institution study, co-authored by John Marshall, Alan Plumb, and Susan Solomon, reveals complicated connections between ozone, oceans, and warming polar regions.

ANTARCTICA AND ITS SURROUNDING OCEAN present a fascinating mystery which could hold answers to some of today's most pressing climate change questions. MIT researchers have spent decades studying this complex environment—from the physical dynamics of the Southern Ocean below to ozone depletion in the atmosphere above. Now they are combining their expertise to understand how the atmosphere and ocean work together in the climate system.

MIT faculty John Marshall, Alan Plumb, and Susan Solomon, world authorities on the Southern Ocean and Antarctic ozone hole, formed the Ozone and Climate Project, which is part of the NSF Frontiers in Earth System Dynamics project. The ambitious five-year study, in collaboration with colleagues from Columbia University, Johns Hopkins University, and the National Center for Atmospheric Research, aims to understand how the Antarctic ozone hole affects climate by watching what happens as it heals.

"We have a unique opportunity to examine the basic robustness of the climate system as it reacts to and recovers from the ozone hole, while also responding to ever increasing greenhouse gas concentrations," said Marshall, lead investigator and the Cecil and Ida Green Professor of Oceanography. "And so we've assembled a uniquely cross-disciplinary, multi-institutional project team to match."

As Arctic sea ice melts at an alarming pace, Antarctic sea ice continues to expand, perplexing scientists. Some climate models of the region indicate sea ice should be melting. Ideas as to why sea ice is shrinking in the northern hemisphere and growing in the southern hemisphere abound, but a prominent theory points to the influence of ozone—or lack thereof. In results from the study published earlier this year in the Journal of Climate, the researchers provide a better understanding of ozone's role and why sea ice continues growing in a rapidly warming world.

"[This research] highlights the strong interaction between the ocean and the atmosphere in the climate system," said Solomon, the Ellen Swallow Richards Professor of Atmospheric Chemistry and Climate Science. "It shows how important the ocean actually is and it's helping to define what questions we should be asking of our models for climate change and the Antarctic in particular."

Ozone depletion peaked at the turn of the milennium and is slowly stabilizing thanks to policy changes which were spurred by Solomon's research. But the hole, still hovering over Antarctica, has combined with increasing greenhouse gas concentrations to cause strong westerly winds that cool the Southern Ocean's surface, enhancing sea ice growth.

Although observational data support this interpretation, some model simulations beg to differ. Various studies investigating the impact of ozone depletion on Earth's oceans found that when ozone is reduced or removed, wind strength increases as expected. However, instead of cooling sea surface temperatures (SSTs), the increased winds induce upwelling of warm water to drive a warming trend.

"That's where ideas clash," said study lead author David Ferreira, a lecturer at the University of Reading and former MIT researcher. "There was a lot of confusion because models of ozone depletion were not explaining sea ice expansion." University of Washington Atmospheric Chemist Cecilia Bitz also contributed and co-authored the study.

Using MIT's Global Circulation Model (MITgcm), the researchers looked at ocean-atmosphere-sea ice simulations over various time periods ranging from years to decades. They found that while SSTs cool and sea ice expands under ozone forcing in the short-term, ultimately the oceans warm and sea ice declines. In other words, both real-world observations and model simulations are correct, they just happen on different timescales. Eventually, we may start to see model outcomes—ocean warming and Antarctic sea ice decline—become reality.

The study may have resolved a key discrepancy between models and observations, but there are still questions left unanswered, such as when Antarctica's sea ice decline will begin, if at all. The models agree that the ocean's response to ozone depletion is a complex process of cooling then warming, but they don't agree on when the temperature transition will happen.

"Ocean temperature transitions typically take anywhere from 5 to 20 years," said Ferreira. "We can't predict exactly when Antarctic SSTs will begin warming, because we don't yet fully understand all the processes that will conspire to control the timing."

The researchers are currently working on constraining their models with more real-world data to better understand the mechanism of this two-timescale process and make predictions of when we can expect Antarctica to begin warming.

"As time passes, it is going to be a race to see whether the ozone hole will heal before the deep ocean has a chance to reassert itself," Solomon said. "I'm interested to see what happens in the next decade. It's going to be about time to see the other timescale pretty soon; it could be any year now."

Read more about the research: http://bit.ly/ozone-ice