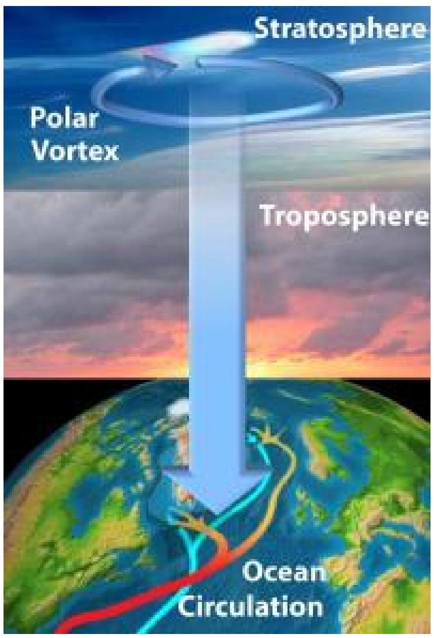
North Atlantic 'Achilles heel' lets upper atmosphere affect the abyss

September 23 2012



The simplified artist's conception shows how changes in polar vortex winds high in the stratosphere can influence the North Atlantic to cause changes in the global conveyor belt of ocean circulation. Credit: Thomas Reichler, University of Utah.

A University of Utah study suggests something amazing: Periodic changes in winds 15 to 30 miles high in the stratosphere influence the seas by striking a vulnerable "Achilles heel" in the North Atlantic and changing mile-deep ocean circulation patterns, which in turn affect Earth's climate.

"We found evidence that what happens in the stratosphere matters for the ocean circulation and therefore for climate," says Thomas Reichler, senior author of the study published online Sunday, Sept. 23 in the journal *Nature Geoscience*.

Scientists already knew that events in the stratosphere, 6 miles to 30 miles above Earth, affect what happens below in the troposphere, the part of the atmosphere from Earth's surface up to 6 miles or about 32,800 feet. Weather occurs in the troposphere.

Researchers also knew that global circulation patterns in the oceans – patterns caused mostly by variations in water temperature and saltiness – affect global climate.

"It is not new that the stratosphere impacts the troposphere," says Reichler, an associate professor of atmospheric sciences at the University of Utah. "It also is not new that the troposphere impacts the ocean. But now we actually demonstrated an entire link between the stratosphere, the troposphere and the ocean."

Funded by the University of Utah, Reichler conducted the study with University of Utah atmospheric sciences doctoral student Junsu Kim, and with atmospheric scientist Elisa Manzini and oceanographer Jürgen Kröger, both with the Max Planck Institute for Meteorology in Hamburg, Germany.

Stratospheric Winds and Sea Circulation Show Similar Rhythms

Reichler and colleagues used weather observations and 4,000 years worth of supercomputer simulations of weather to show a surprising association between decade-scale, periodic changes in stratospheric wind patterns known as the polar vortex, and similar rhythmic changes in deep-sea circulation patterns. The changes are:

— "Stratospheric sudden warming" events occur when temperatures rise and 80-mph "polar vortex" winds encircling the Artic suddenly weaken or even change direction. These winds extend from 15 miles elevation in the stratosphere up beyond the top of the stratosphere at 30 miles. The changes last for up to 60 days, allowing time for their effects to propagate down through the atmosphere to the ocean.

— Changes in the speed of the Atlantic circulation pattern – known as Atlantic Meridional Overturning Circulation – that influences the world's oceans because it acts like a conveyor belt moving water around the planet.

Sometimes, both events happen several years in a row in one decade, and then none occur in the next decade. So incorporating this decade-scale effect of the stratosphere on the sea into supercomputer climate simulations or "models" is important in forecasting decade-to-decade climate changes that are distinct from global warming, Reichler says.

"If we as humans modify the stratosphere, it may – through the chain of events we demonstrate in this study – also impact the ocean circulation," he says. "Good examples of how we modify the stratosphere are the ozone hole and also fossil-fuel burning that adds carbon dioxide to the stratosphere. These changes to the stratosphere can alter the ocean, and any change to the ocean is extremely important to global climate."

A Vulnerable Soft Spot in the North Atlantic

"The North Atlantic is particularly important for global ocean circulation, and therefore for climate worldwide," Reichler says. "In a region south of Greenland, which is called the downwelling region, water can get cold and salty enough – and thus dense enough – so the water starts sinking."

It is Earth's most important region of seawater downwelling, he adds. That sinking of cold, salty water "drives the three-dimensional oceanic conveyor belt circulation. What happens in the Atlantic also affects the other oceans."

Reichler continues: "This area where downwelling occurs is quite susceptible to cooling or warming from the troposphere. If the water is close to becoming heavy enough to sink, then even small additional amounts of heating or cooling from the atmosphere may be imported to the ocean and either trigger downwelling events or delay them."

Because of that sensitivity, Reichler calls the sea south of Greenland "the Achilles heel of the North Atlantic."

From Stratosphere to the Sea

In winter, the stratospheric Arctic polar vortex whirls counterclockwise around the North Pole, with the strongest, 80-mph winds at about 60 degrees north latitude. They are stronger than jet stream winds, which are less than 70 mph in the troposphere below. But every two years on average, the stratospheric air suddenly is disrupted and the vortex gets warmer and weaker, and sometimes even shifts direction to clockwise.

"These are catastrophic rearrangements of circulation in the stratosphere," and the weaker or reversed polar vortex persists up to two months, Reichler says. "Breakdown of the polar vortex can affect circulation in the troposphere all the way down to the surface."

Reichler's study ventured into new territory by asking if changes in stratospheric polar vortex winds impart heat or cold to the sea, and how that affects the sea.

It already was known that that these stratospheric wind changes affect the North Atlantic Oscillation – a pattern of low atmospheric pressure centered over Greenland and high pressure over the Azores to the south. The pattern can reverse or oscillate.

Because the oscillating pressure patterns are located above the ocean downwelling area near Greenland, the question is whether that pattern affects the downwelling and, in turn, the global oceanic circulation conveyor belt.

The study's computer simulations show a decadal on-off pattern of correlated changes in the polar vortex, atmospheric pressure oscillations over the North Atlantic and changes in sea circulation more than one mile beneath the waves. Observations are consistent with the pattern revealed in computer simulations.

Observations and Simulations of the Stratosphere-to-Sea Link

In the 1980s and 2000s, a series of stratospheric sudden warming events weakened polar vortex winds. During the 1990s, the polar vortex remained strong.

Reichler and colleagues used published worldwide ocean observations from a dozen research groups to reconstruct behavior of the conveyor belt ocean circulation during the same 30-year period.

"The weakening and strengthening of the stratospheric circulation seems to correspond with changes in ocean circulation in the North Atlantic," Reichler says.

To reduce uncertainties about the observations, the researchers used computers to simulate 4,000 years worth of atmosphere and ocean circulation.

"The computer model showed that when we have a series of these polar vortex changes, the ocean circulation is susceptible to those stratospheric events," Reichler says.

To further verify the findings, the researchers combined 18 atmosphere and ocean models into one big simulation, and "we see very similar outcomes."

The study suggests there is "a significant stratospheric impact on the ocean," the researchers write. "Recurring stratospheric vortex events create long-lived perturbations at the ocean surface, which penetrate into the deeper ocean and trigger multidecadal variability in its circulation. This leads to the remarkable fact that signals that emanate from the stratosphere cross the entire atmosphere-ocean system."

More information: DOI: 10.1038/ngeo1586

Provided by University of Utah