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THE 1991 MT. PINATUBO ERUPTION PROVIDES A NATURAL TEST FOR THE INFLUENCE OF ARCTIC CIRCULATION ON CLIMATE

A recent NASA-funded study has linked the 1991 eruption of the Mount Pinatubo to a strengthening of a climate pattern called the Arctic Oscillation. For two years following the volcanic eruption, the Arctic Oscillation caused winter warming over land areas in the high and middle latitudes of the Northern Hemisphere, despite a cooling effect from volcanic particles that blocked sunlight.

Arctic Oscillation shown on two graphics of the Earth

Image 1

One mission of NASA's Earth Science Enterprise, which funded this research, is to better understand how the Earth system responds to human and naturally-induced changes, such as large volcanic eruptions.

"This study clarifies the effect of strong volcanic eruptions on climate, important by itself, and helps to better predict possible weather and short-term climate variations after strong volcanic eruptions," said Georgiy Stenchikov, a researcher at Rutgers University's Department of Environmental Sciences, New Brunswick, N.J., and lead author on a paper that appeared in a recent issue of the Journal of Geophysical Research.

A positive phase of the Arctic Oscillation has slowly strengthened over the few last decades and has been associated in prior research with observed climate warming.

"The study has important implications to climate change because it provides a test for mechanisms of the Arctic Oscillation," Stenchikov said.

A positive phase of the Arctic Oscillation is associated with strengthening of winds

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Caption for Image 1: The Arctic Oscillation (AO)

A positive phase of the Arctic Oscillation (top) is associated with strengthening of winds circulating counterclockwise around the North Pole north of 55°N, that is, roughly in line with Moscow, Belfast, and Ketchikan, Alaska. In winter these winds pull more warm air from oceans to continents causing winter warming, and like a top spinning very fast, they hold a tight pattern over the North Pole and keep frigid air from moving south. Cool winds sweep across eastern Canada while North Atlantic storms bring rain and mild temperatures to Northern Europe. Drought conditions prevail over the Mediterranean region.

During the negative phase of the Arctic Oscillation (bottom), cool continental air plunges into the Midwestern United States and Western Europe while storms bring rainfall to the Mediterranean region. Credit: David W. J. Thompson, J. M. Wallace

Caption for Image 2: Eruption of

circulating counterclockwise around the North Pole north of 55°N, that is, roughly in line with Moscow, Belfast, and Ketchikan, Alaska. In winter these winds pull more warm air from oceans to continents causing winter warming, and like a top spinning very fast, they hold a tight pattern over the North Pole and keep frigid air from moving south.

still image of Mt. Pinatubo erupting

Image 2

According to this research, temperature changes caused by a radiative effect of volcanic aerosols in two lower layers of the atmosphere, the troposphere and the stratosphere, can lead to a positive Arctic Oscillation phase. The troposphere extends from Earth's surface to an altitude of 7 miles in the polar regions and expands to 13 miles in the tropics. The stratosphere is the next layer up with the top at an altitude of about 30 miles.

The study uses a general circulation model developed at the National Oceanic and Atmospheric Administration's Geophysical Fluid Dynamics Laboratory to simulate how volcanic aerosols following the Pinatubo eruption impacted the climate.

In the troposphere, volcanic aerosols reflect solar radiation and cool the Earth's surface, decreasing temperature differences between the equator and the North Pole in the bottom atmospheric layer. These changes end up inhibiting processes that slow counterclockwise winds that blow around the North Pole mostly in the stratosphere. This in turn strengthens a positive phase of the Arctic Oscillation.

In the stratosphere, volcanic aerosols absorb solar radiation, warm the lower stratosphere (about 15 miles above the Earth's surface) and increase stratospheric temperature differences between the equator and the North Pole. These changes strengthen westerly winds in the lower stratosphere and help to create a positive phase of the Arctic Oscillation.

In previous research, an observed positive Arctic Oscillation trend has been attributed to greenhouse warming that led to an increase of stratospheric temperature differences between equator and pole. But this study finds that tropospheric temperature change in the course of climate warming may play an even greater role.

In one type of computer simulation, Stenchikov and colleagues isolated the contribution of a decreased temperature difference in the troposphere, and found that it could produce a positive phase of the Arctic Oscillation by itself. That's because greenhouse heating near the North Pole melts reflective sea ice and snow, and reveals more water and land surfaces. These surfaces absorb the Sun's rays and increasingly warm the Earth's polar regions. Polar heating at the Earth's surface

Mount Pinatubo, Philippines, July 1991

Strong explosive volcanic eruptions, like ones of the Mt. Pinatubo in Philippines in June 1991, inject millions of ton of sulfur dioxide gas at the altitudes of about 15 miles where it interacts with water vapor producing a volcanic aerosol layer that consists of tiny droplets of highly concentrated sulfuric acid. As a result of the Pinatubo eruption, globally averaged surface temperature decreased by about 0.3 Kelvin (0.3 Celsius) for two years after the eruption and the temperature in the tropical lower stratosphere increased by about 2-3 Kelvin (2-3 Celsius). The tropospheric response over most land areas in the Northern Hemisphere is characterized by summer cooling and winter warming. Credit: U.S. Geological Survey, J.N. Marso, July 1991

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lessens the temperature differences between the equator and North Pole in the troposphere, which ultimately strengthens a positive phase of the Arctic Oscillation.

The study also finds that when aerosols get into the stratosphere, very rapid reactions that destroy ozone (especially in high latitudes) take place on the surfaces of aerosol particles. When ozone gets depleted, less UV radiation is absorbed in the stratosphere. This cools the polar stratosphere, and increases the stratospheric equator-to-pole temperature difference, creating a positive phase of the Arctic Oscillation. Ozone data were obtained from NASA's Total Ozone Mapping Spectrometer (TOMS) satellite and ozonesonde observations.

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