NASA Facts

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Space Administration

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The Earth Science Enterprise Series

These articles consider Earth's many dynamic processes and their interactions.

Volcanoes and Global Climate Change

Volcanoes and Global Cooling

Volcanic gases are thought to be responsible for the global cooling that has sometimes been observed for a few years after a major eruption. The amount and global extent of the cooling depend on the force of the eruption, the amount of particular gases emitted, and, perhaps, on the location of the volcano with respect to the world's global atmospheric circulation patterns. When large masses of gases from the eruption reach the stratosphere, they can produce a large, widespread cooling effect. As a prime example, the effects of Mount Pinatubo, which erupted in June 1991, may have lasted a few years, serving to offset temporarily the predicted greenhouse warming effect.

Figure 1 illustrates that as volcanoes erupt, they blast huge clouds into the atmosphere. These clouds are made up of particles and gases, including sulfur dioxide. Millions of tons of sulfur dioxide gas can reach the stratosphere from a major eruption. There, the sulfur

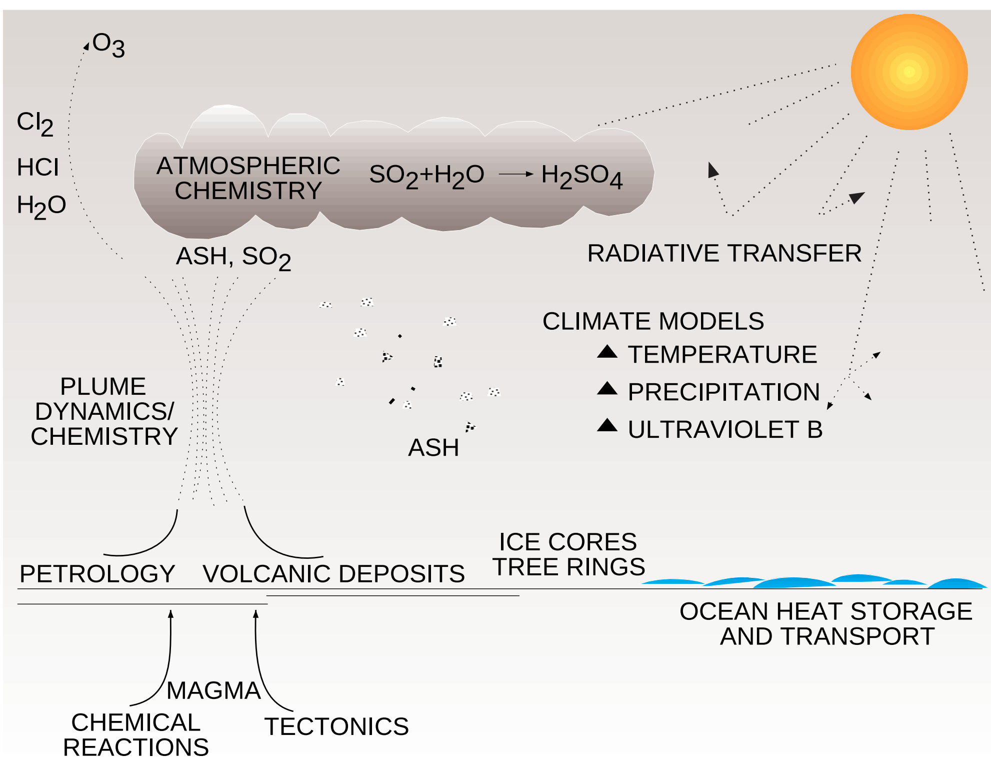


Figure 1. Volcanism studies are an important aspect of climate research (see chemistry glossary).

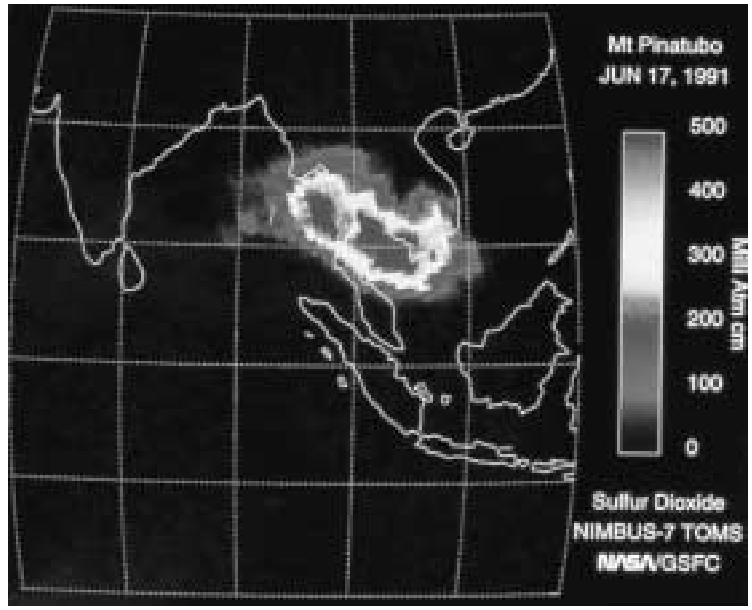
dioxide converts to tiny persistent sulfuric acid (sulfate) particles, referred to as aerosols. These sulfate particles reflect energy coming from sun, thereby decreasing the amount of sunlight reaching and heating the Earth's surface.

Short term global cooling often has been linked with some major volcanic eruptions. The year 1816 has been referred to as “the year without a summer.” It was a time of significant weather-related disruption in New England and in Western Europe with killing summer frosts in the United States and Canada. These strange phenomena were attributed to a major eruption of the Tambora volcano in 1815 in Indonesia. The volcano threw sulfur dioxide gas into the stratosphere, and the aerosol layer that formed led to brilliant sunsets seen around the world for several years.

But, not all volcanic eruptions, not even all *large* volcanic eruptions, produce global-scale cooling. Mount Agung in 1963 apparently caused a considerable decrease in temperatures around much of the world, whereas El Chichón in 1982 seemed to have little effect, perhaps because of its different location or because of the El Niño that occurred the same year. (See NASA Facts NF-211.) El Niño is a Pacific Ocean phenomenon, but it causes worldwide weather variations that may have acted to cancel out the effect of the El Chichón eruption.

Volcanoes and Ozone Depletion

Another possible effect of a volcanic eruption is the destruction of stratospheric ozone. Researchers now are suggesting that aerosol particles containing sulfuric acid from volcanic emissions may contribute to ozone loss. When chlorine compounds resulting from the breakup of chlorofluorocarbons (CFCs) in the stratosphere are present, the sulfate particles may serve to convert them into more-active



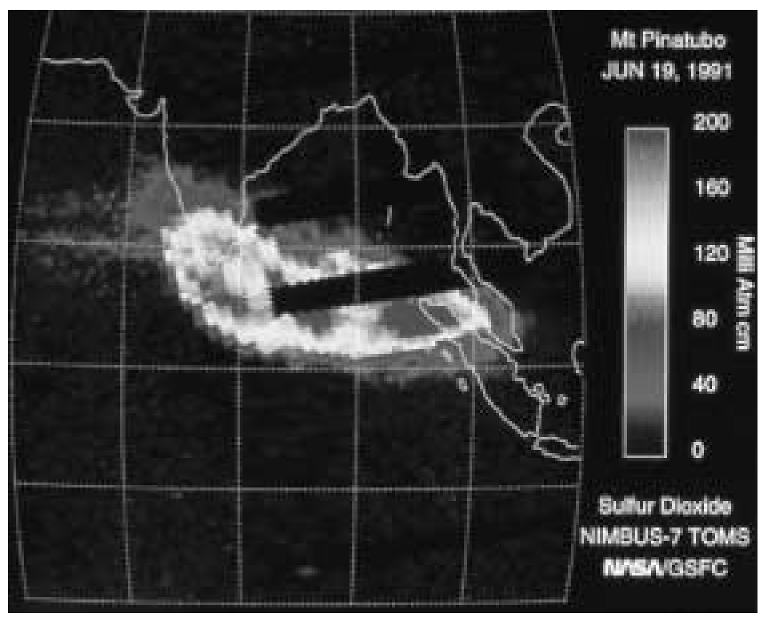


Figure 2. Images from NIMBUS-7: TOMS—June 17 (Top) and 19 (Bottom), 1991, showing the spread of sulfur dioxide from the Mt. Pinatubo eruption. The “gray scale” indicates the thickness the sulfur dioxide cloud layer would have had if it were obseved at standard surface conditions of temperature and pressure.

forms that may cause more-rapid ozone depletion. (See NASA Facts NF-198.)

Monitoring the Effects of Volcanoes

Space-based instruments are the only practical way to observe large and transitory volcanic eruption clouds. NASA's Total Ozone Mapping Spectrometer (TOMS) instruments have contributed significantly to our knowledge of the total amount of sulfur dioxide emitted into the atmosphere in the course of major volcanic eruptions. Figure 2 shows TOMS images of sulfur dioxide spreading across the Indian Ocean region following the eruption of Mount Pinatubo. Several weeks later the sulfur dioxide had spread around the world as observed by the Microwave Limb Sounder (MLS) instrument on NASA's Upper Atmosphere Research Satellite (UARS) (see Figure 3).

In addition to detecting the sulfur dioxide from Mount Pinatubo, TOMS has made similar observations of more than 100 volcanic events, including a major eruption from the Cerro Hudson volcano in Chile in 1991. TOMS instruments were launched on a Nimbus-7 spacecraft in 1978; a Russian Meteor-3 spacecraft in 1991; and on the Earth Probe and the Japanese Advanced Earth Observing System (ADEOS) platforms in 1996. A TOMS instrument is also scheduled to fly on a Russian-3M satellite in 2000.

Data from the Stratospheric Aerosol and Gas Experiment (SAGE II) instrument on NASA's Earth Radiation Budget Satellite (ERBS) have shown that during the first five months after the Mount Pinatubo eruption, the optical depth of the stratospheric aerosol increased up to 100 times in certain locations. Optical depth is a general measure of the capacity of a region of the atmosphere to prevent the passage of visible light through it. Greater optical depths mean greater blockage of the light. In this case, the increased optical depth means that considerably less of the sun's energy can get through the cloud to warm the Earth's surface. An advanced SAGE III instrument, which will make similar observations, is scheduled to be launched on a Russian Meteor-3M spacecraft in the second half of 1998.

A few years after an eruption most of the aerosol clouds will have decayed so that their effects on radiation will become negligible.

Observations of the effects of Mt. Pinatubo aerosols on global climate have been used to validate scientists' understanding of climate change and our ability to predict future climate. Researchers at NASA's Goddard

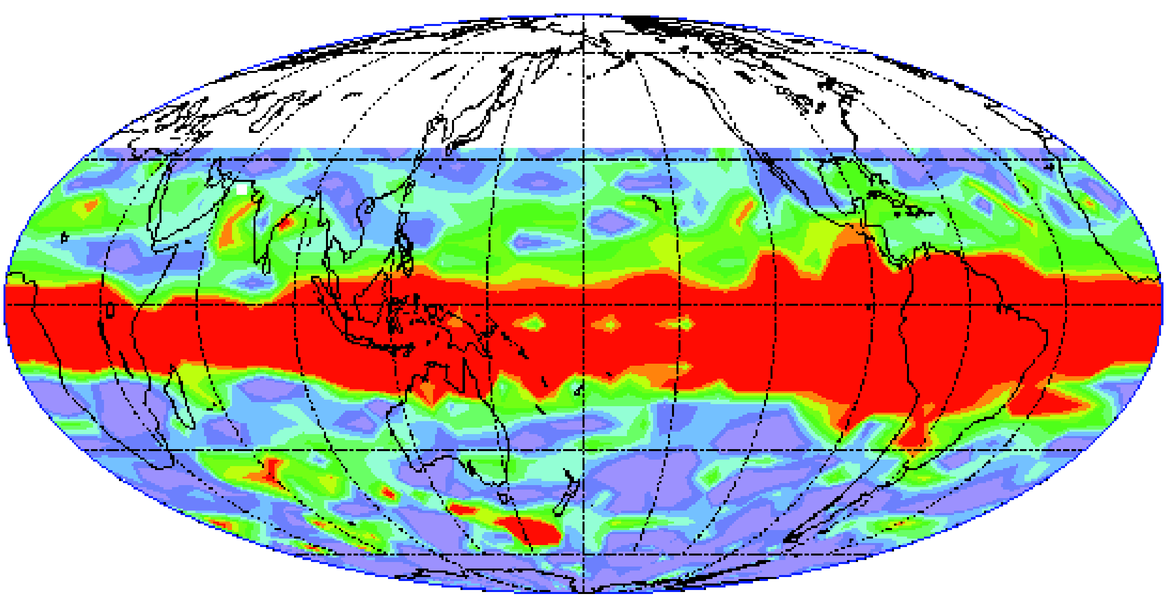


Figure 3. Images from the UARS satellite—sulfur dioxide cloud from Mt. Pinatubo on September 23, 1991, after dispersal around the world.

Institute for Space Studies in New York city have applied their general circulation model of Earth's climate to the problem. They have reported success in correctly predicting many of the effects of the sulfate aerosols from Mount Pinatubo's eruption on lowering global temperatures.

NASA Missions to Study Volcanoes

Some of NASA's past and present missions that contribute to the study of volcanoes are listed in the accompanying table. Included in the table is the Earth Observing System (EOS), the key element of NASA's Earth Science Enterprise. The first launch in the series of EOS satellites is scheduled to take place in 1998.

The High Resolution Infrared Radiometer (HRIR), first flown on NASA's Nimbus-1 satellite in 1964, has been used to observe both active and dormant volcanoes. On Nimbus-2, HRIR recorded energy changes from the volcanic activity on Surtsey, Iceland in 1966. The Multispectral Scanner (MSS) and Thematic Mapper (TM) instruments on the Landsat satellites have provided a long series of images of volcanic activity, such as venting, volcanic ash falls, and lava flows.

The EOS program will incorporate a series of satellites that will carry advanced instruments to provide a highly-accurate, self-consistent, and long-term data base of many aspects of Earth's atmosphere, land, and ocean characteristics. The information gained from this major effort to study Earth phenomena will expand our knowledge of the interactions of volcanoes with Earth's climate.

Glossary of Chemistry

Cl_2	*chlorine molecule*
HCl	*hydrogen chloride*
H_2O	*water*
O_3	*ozone*
H_2SO_4	*sulfuric acid*
SO_2	*sulfur dioxide*

Earth Science Enterprise

Selected Missions Related to the Study of Volcanoes

Mission	Launch	Scientific Objective
Nimbus Series	1964-1978	Observe thermal emissions from active and dormant volcanoes (beginning with Nimbus-1 HRIR) Observe stratospheric sulfur dioxide (beginning with TOMS in 1978)
Landsat Series	1972-1998	High-spatial-resolution imagery of volcanic activity
TOMS/Meteor-3 TOMS/Earth Probe TOMS/ADEOS TOMS/Meteor-3M	1991 1996 1996 2000	Observe stratospheric sulfur dioxide and volcanic ash
SAGE III/ERBS SAGE III/Meteor-3M	1984 1998	Measure changes in stratospheric aerosol optical depth and the resulting changes in Earth's radiation budget due to volcanic emissions
Earth Observing System (EOS)	1998-	Observe Ozone Observe stratospheric sulfur dioxide Measure changes in stratospheric aerosol optical depth and changes in the radiation budget due to volcanic emissions Measure thermal anomalies due to volcanoes