NASA Facts

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SAGE II: Understanding the Earth's Stratosphere

The Stratospheric Aerosol and Gas Experiment II (SAGE II) instrument was launched in October 1984 aboard the Earth Radiation Budget Satellite (ERBS). More than ten years after being deployed from the Space Shuttle Challenger (STS-41G), SAGE II is still providing scientists world-wide with a wealth of data on the chemistry and dynamic motions of the Earth's upper troposphere and stratosphere (10-40 kilometers).

How Does the SAGE II Instrument Work?

The SAGE II instrument measures sunlight through the limb of the Earth's atmosphere (Fig. 1) in seven different wavelengths. The measured sunlight, which was scattered and absorbed by trace gases and small particles (called aerosols), is converted into vertical profiles of ozone, water vapor, nitrogen dioxide and aerosol concentrations.

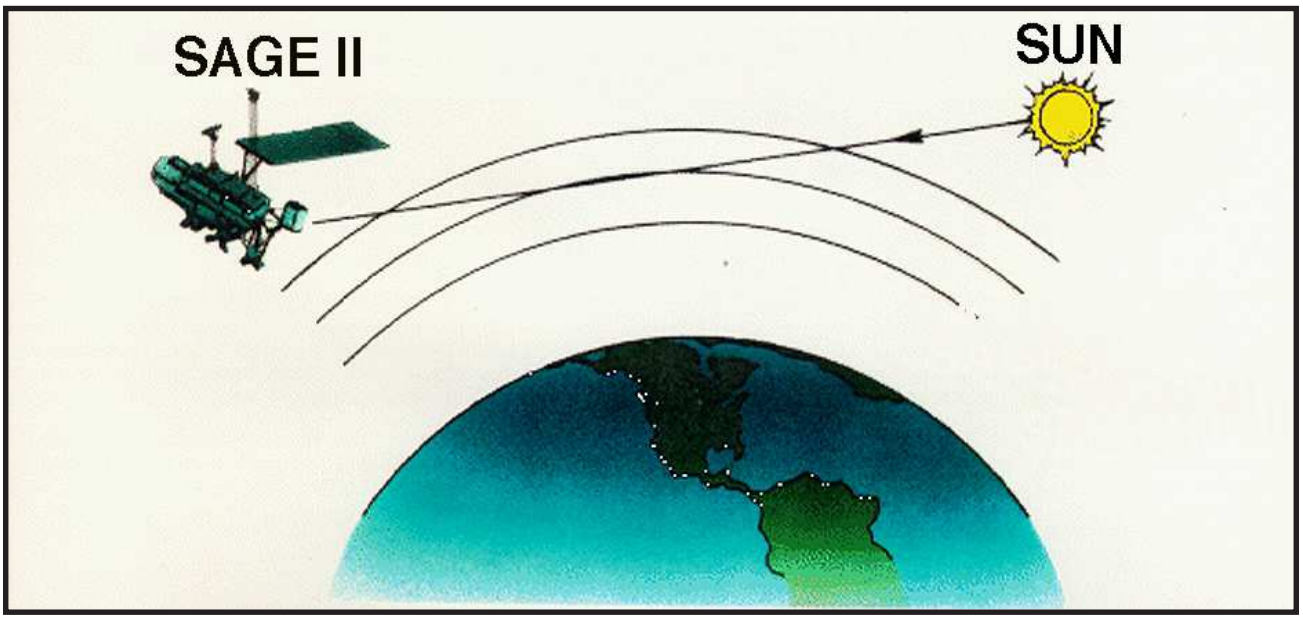


Fig. 1. The SAGE II instrument measures the amount of ozone and other trace gases that are in the atmosphere by measuring the amount of sunlight that comes through the atmosphere at different altitudes. The less sunlight that gets through the atmosphere, at a specific wavelength, the more a particular gas is absorbing it. This graphic shows a satellite measuring the amount of sunlight coming through what is known as the 'limb' of the atmosphere.

The SAGE II instrument vertically scans the limb of the atmosphere during spacecraft sunsets and sunrises (fifteen sunsets and fifteen sunrises each day). The 57° inclined orbit of the ERBS spacecraft evenly distributes the SAGE II measurements every 24° of longitude along a slowly shifting latitude circle.

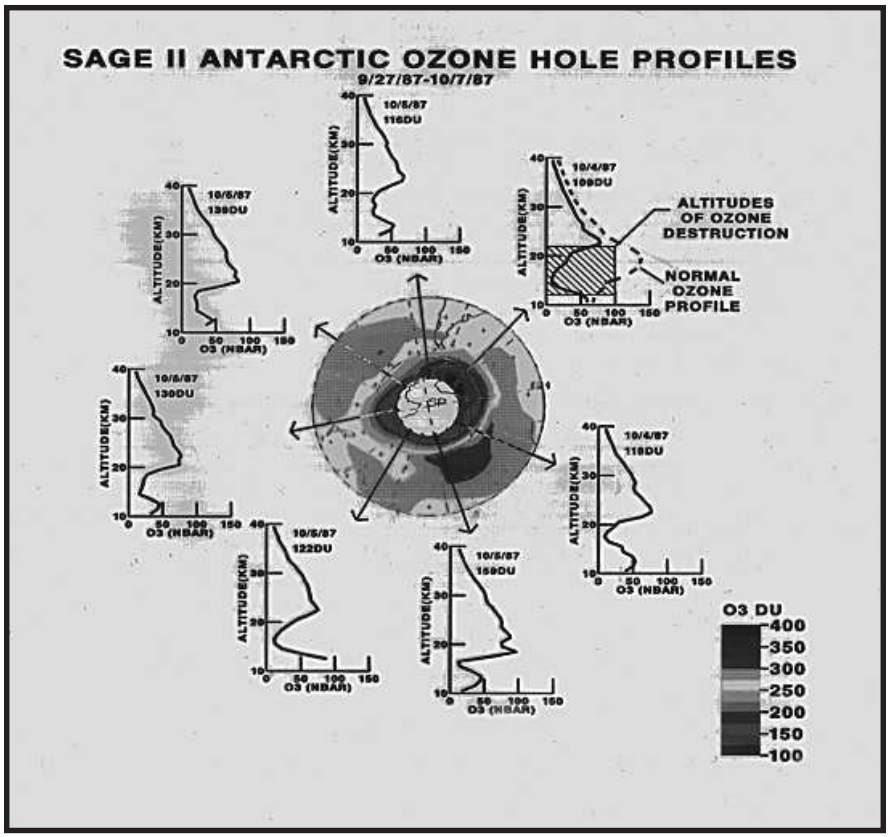


Fig. 2. The small plots around the center figure represent the vertical distribution of ozone, from SAGE II data, at various locations in the Antarctic region. The vertical profiles show at which levels the greatest depletion of ozone is occurring. The central figure is from another satellite (TOMS) which measures how much ozone is in the whole atmosphere directly below the satellite. By using SAGE II data, scientists were able to pinpoint where the greatest ozone depletion was occurring and better determine the causes of the Antarctic ozone hole.

The Antarctic Ozone Hole and Polar Stratospheric Clouds

Measurements by SAGE II have played a crucial role in understanding the causes and effects of the Antarctic ozone "hole." SAGE II has been used to measure the decline in the amount of stratospheric ozone over the Antarctic since the ozone hole was first noted in 1985. The high resolution SAGE II measurements allow scientists to study the vertical structure of ozone in the Antarctic (Fig. 2) and, more importantly, allow scientists to study the correlations between various trace gases. SAGE II measurements showed that the loss of water vapor in the region of depleted ozone was due to the formation of Polar Stratospheric Clouds (PSCs). PSCs were first noted by a team of NASA Langley scientists using another Langley satellite data set (Stratospheric Aerosol Measurement II). PSCs play a major role in the destruction of stratospheric ozone by providing a surface on which chemical reactions that activate chlorine can occur. SAGE II measurements showed that PSCs also were present unusually far south of the Arctic region during certain meteorological conditions, meaning ozone destruction similar to that over the Antarctic was possible at lower latitudes.

A study of the SAGE I (precursor to SAGE II) and SAGE II data sets showed that ozone decreased in the upper stratosphere over the high latitudes of both hemispheres and in the lower stratosphere over most of the globe. This information is very important for scientists studying global stratospheric ozone depletion mechanisms. SAGE II was the only instrument to show ozone loss below 20 kilometers globally.

Stratospheric Aerosols

Stratospheric aerosols scatter and absorb

SAGE II Monitored the Effects of the Mt. Pinatubo Volcanic Eruption

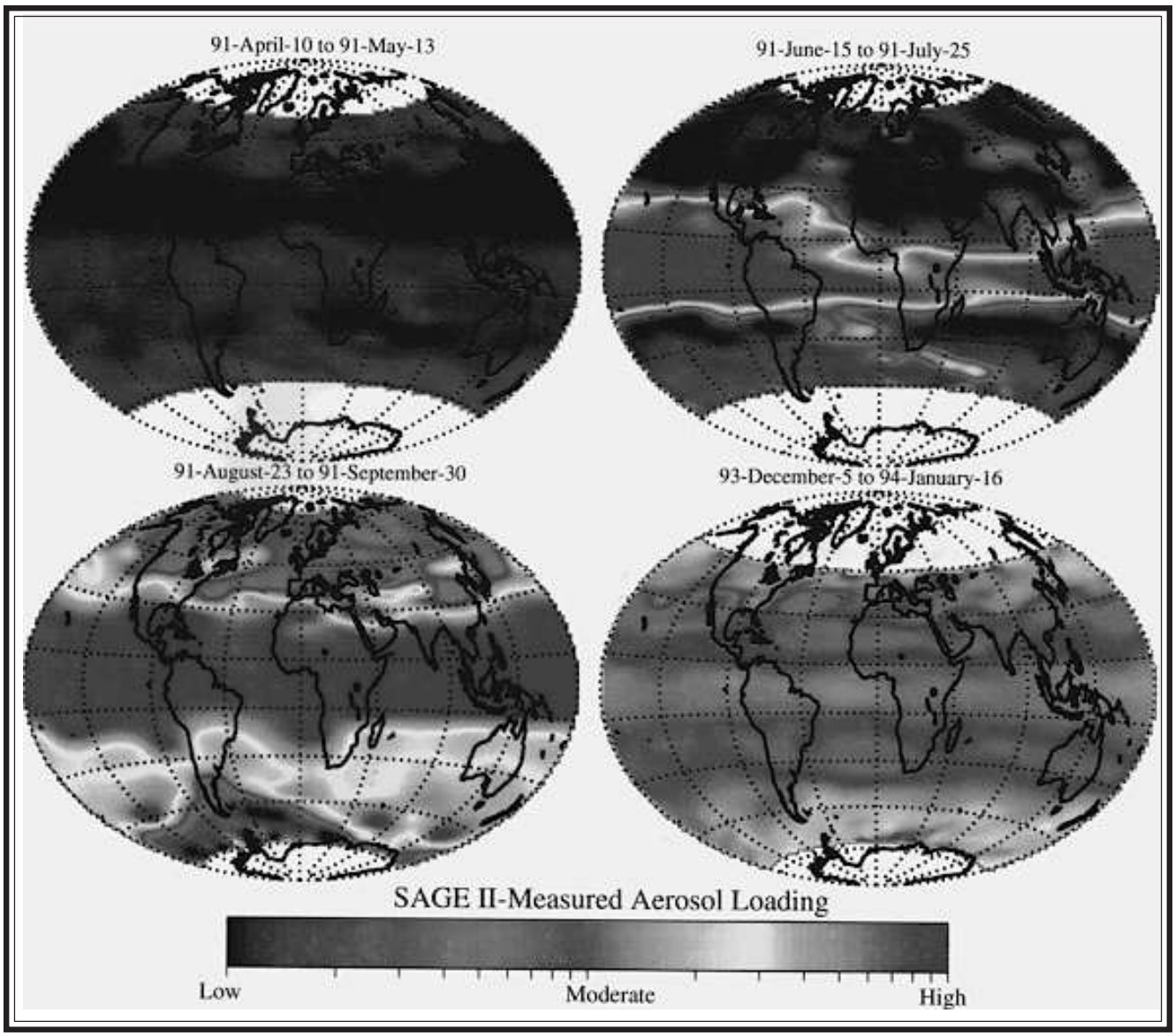


Fig. 3. Since mid-June 1991, NASA Langley's SAGE II instrument has been monitoring the long-term global effects of the Mt. Pinatubo eruption. When the volcano erupted, it dispersed large quantities of particles or aerosols into the Earth's upper atmosphere which reacted with atmospheric chemicals to form massive aerosol concentrations across the globe. The first graphic shows a relatively aerosol-free atmosphere before the eruption (black). The second graphic reveals the tremendous aerosol dispersal in the tropics immediately following the eruption (gray). The third graphic (bottom left) shows the movement of aerosols approximately three months following the eruption. The fourth graphic illustrates how volcanic aerosols tend to linger in the atmosphere for many months following an eruption (lighter gray). The global distribution of aerosols is one of the many important stratospheric characteristics regularly monitored by SAGE II.

incoming solar and outgoing Earth-emitted energy, affecting the energy balance of the Earth. Three months after the 1991 Mt. Pinatubo eruption in the Philippines, scientists found that the stratosphere at latitudes near Mt. Pinatubo had warmed 2.5-3 degrees Centigrade due to the increased concentrations of volcanic aerosols. Large concentrations of aerosols in the stratosphere also can cause global surface cooling by reflecting sunlight back into space before it has a chance to warm the Earth's surface. Aerosols also enhance ozone destruction in the stratosphere by acting as a surface for chemical reactions, as do PSCs.

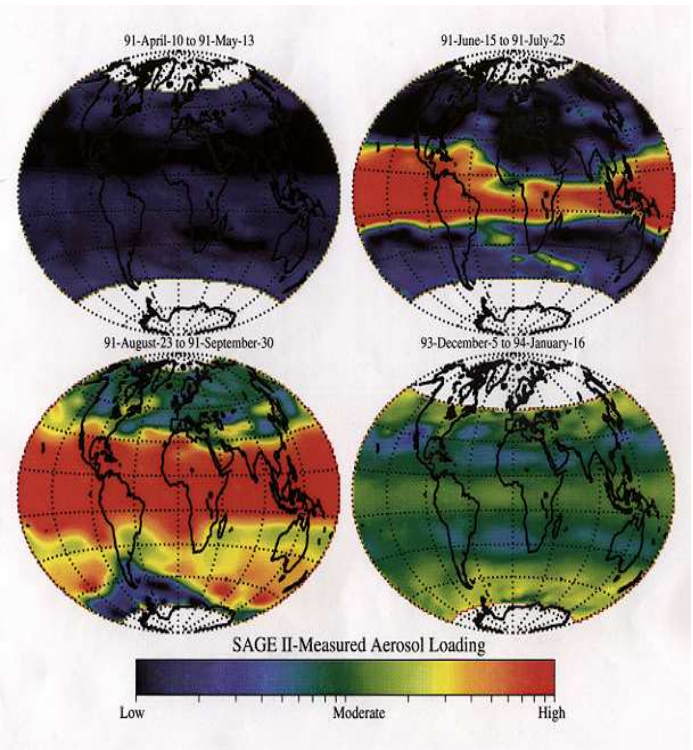
SAGE II aerosol data have also been used to study the large-scale motions of the stratosphere. After Mt. Pinatubo, SAGE II measurements showed the transport of volcanic aerosols across the entire tropical stratosphere and into the middle and high latitudes in the months following the eruption (Fig. 3). Scientists believed volcanic aerosols cause the destruction of nitrogen dioxide, an important player in many stratospheric chemical cycles. This theory was verified by SAGE II measurements.

SAGE II aerosol measurements also have been used to study cirrus clouds in the tropics which are important to the understanding of cloud effects on global climate.

Atmospheric Water Vapor

Atmospheric water vapor plays an important part in the Earth's energy balance, in many chemical cycles, and can also be used to trace the exchange of material between the upper and lower atmosphere. SAGE II has provided chemical and climate modelers with more than 10 years of high-resolution water vapor measurements, helping these scientists to better understand both the chemistry and motion of the atmosphere. Scientists are also studying how varying water vapor concentrations can affect the Earth's long-term weather (or climate). By studying SAGE II water vapor profiles, scientists can determine the long- and short-term effects of variable water vapor concentrations on the temperature of the atmosphere.

The next generation of SAGE instruments, SAGE III, will include additional wavelengths that will improve aerosol measurements and the retrieval of ozone, water vapor and nitrogen dioxide concentrations. In addition, SAGE III adds the capability to make measurements during moonrises and moonsets, permitting observations of nighttime chemical species like chlorine dioxide and nitrogen trioxide. SAGE III is scheduled for launch in 1998 aboard the Russian METEOR-3M spacecraft and then on the International Space Station in about 2000.

For more information, please contact:

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