NASA Facts ONLINE

FS-1996-08-11-LaRC
August 1996

Atmospheric Aerosols: What Are They, and Why Are They So Important?

Aerosols are minute particles suspended in the atmosphere. When these particles are sufficiently large, we notice their presence as they scatter and absorb sunlight. Their scattering of sunlight can reduce visibility (haze) and redden sunrises and sunsets.

Aerosols interact both directly and indirectly with the Earth's radiation budget and climate. As a direct effect, the aerosols scatter sunlight directly back into space. As an indirect effect, aerosols in the lower atmosphere can modify the size of cloud particles, changing how the clouds reflect and absorb sunlight, thereby affecting the Earth's energy budget.

Aerosols also can act as sites for chemical reactions to take place (heterogeneous chemistry). The most significant of these reactions are those that lead to the destruction of stratospheric ozone. During winter in the polar regions, aerosols grow to form polar stratospheric clouds. The large surface areas of these cloud particles provide sites for chemical reactions to take place. These reactions lead to the formation of large amounts of reactive chlorine and, ultimately, to the destruction of ozone in the stratosphere. Evidence now exists that shows similar changes in stratospheric ozone concentrations occur after major volcanic eruptions, like Mt. Pinatubo in 1991, where tons of volcanic aerosols are blown into the atmosphere (Fig. 1).

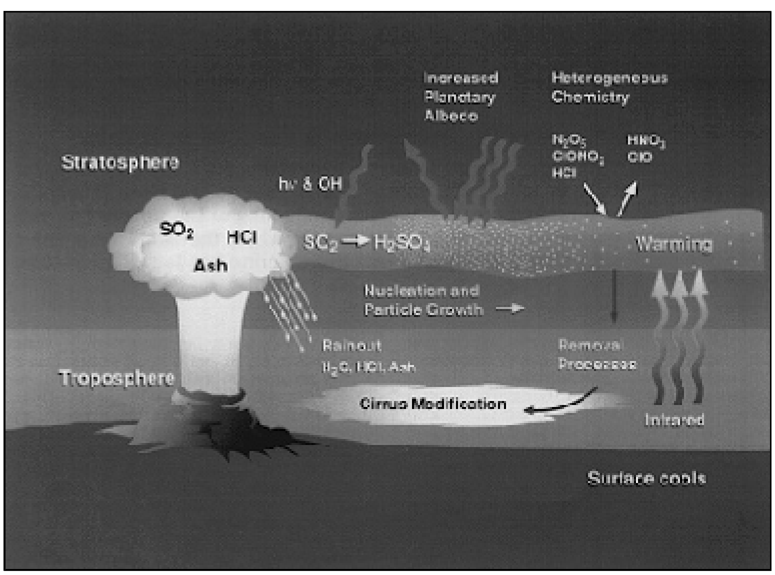


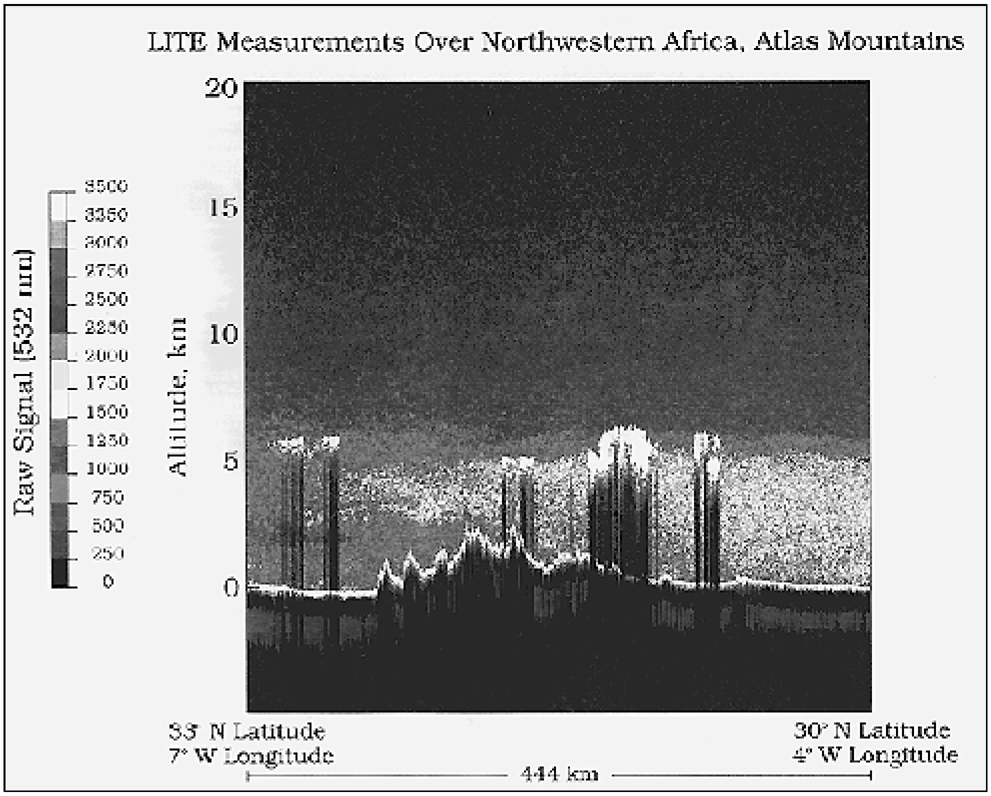
Fig. 1 The dispersal of volcanic aerosols has a drastic effect on the Earth's atmosphere. Following an eruption, large amounts of sulphur dioxide (SO2), hydrochloric acid (HCL) and ash are spewed into the Earth's stratosphere. Hydrochloric acid, in most cases, condenses with water vapor and is rained out of the volcanic cloud formation. Sulphur dioxide from the cloud is transformed into sulphuric acid (H2SO4). The sulphuric acid quickly condenses, producing aerosol particles which linger in the atmosphere for long periods of time. The interaction of chemicals on the surface of aerosols, known as heterogeneous chemistry, and the tendency of aerosols to increase levels of chlorine which can react with nitrogen in the stratosphere, is a prime contributor to stratospheric ozone destruction.

Volcanic Aerosol

Three types of aerosols significantly affect the Earth's climate. The first is the volcanic aerosol layer which forms in the stratosphere after major volcanic eruptions like Mt. Pinatubo. The dominant aerosol layer is actually formed by sulfur dioxide gas which is converted to droplets of sulfuric acid in the stratosphere over the course of a week to several months after the eruption (Fig. 1). Winds in the stratosphere spread the aerosols until they practically cover the globe. Once formed, these aerosols stay in the stratosphere for about two years. They reflect sunlight, reducing the amount of energy reaching the lower atmosphere and the Earth's surface, cooling them. The relative coolness of 1993 is thought to have been a response to the stratospheric aerosol layer that was produced by the Mt. Pinatubo eruption. In 1995, though several years had passed since the Mt. Pinatubo eruption, remnants of the layer remained in the atmosphere. Data from satellites such as the NASA Langley Stratospheric Aerosol and Gas Experiment II **(SAGE II)** have enabled scientists to better understand the effects of volcanic aerosols on our atmosphere.

Desert Dust

The second type of aerosol that may have a significant effect on climate is desert dust. Pictures from weather satellites often reveal dust veils streaming out over the Atlantic Ocean from the deserts of North Africa. Fallout from these layers has been observed at various locations on the American continent. Similar veils of dust stream off deserts on the Asian continent. The September 1994 Lidar In-space Technology Experiment **(LITE)**, aboard the space shuttle Discovery (STS-64), measured large quantities of desert dust in the lower atmosphere over Africa (Fig. 2). The particles in these dust plumes are minute grains of dirt blown from the desert surface. They are relatively large for atmospheric aerosols and would normally fall out of the atmosphere after a short flight if they were not blown to relatively high altitudes (15,000 ft. and higher) by intense dust storms.



Because the dust is composed of minerals, the particles absorb sunlight as well as scatter it. Through absorption of sunlight, the dust particles warm the layer of the atmosphere where they reside. This warmer air is believed to inhibit the formation of storm clouds. Through the suppression of storm clouds and their consequent rain, the dust veil is believed to further desert expansion.

Recent observations of some clouds indicate that they may be absorbing more sunlight than was thought possible. Because of their ability to absorb sunlight, and their transport over large distances, desert aerosols may be the culprit for this additional absorption of sunlight by some clouds.

Human-Made Aerosol

The third type of aerosol comes from human activities. While a large fraction of human-made aerosols come in the form of smoke from burning tropical forests, the major component comes in the form of sulfate aerosols created by the burning of coal and oil. The concentration of human-made sulfate aerosols in the atmosphere has grown rapidly since the start of the industrial revolution. At current production levels, human-made sulfate aerosols are thought to outweigh the naturally produced sulfate aerosols. The concentration of aerosols is highest in the northern hemisphere where industrial activity is centered. The sulfate aerosols absorb no sunlight but they reflect it, thereby reducing the amount of sunlight reaching the Earth's surface. Sulfate aerosols are believed to survive in the atmosphere for about 3-5 days.

The sulfate aerosols also enter clouds where they cause the number of cloud droplets to increase but make the droplet sizes smaller. The net effect is to make the clouds reflect more sunlight than they would without the presence of the sulfate aerosols. Pollution from the stacks of ships at sea has been seen to modify the low-lying clouds above them. These changes in the cloud droplets, due to the sulfate aerosols from the ships, have been seen in pictures from weather satellites as a track through a layer of clouds. In addition to making the clouds more reflective, it is also believed that the additional aerosols cause polluted clouds to last longer and reflect more sunlight than non-polluted clouds.

Climatic Effects of Aerosols

The additional reflection caused by pollution aerosols is expected to have an effect on the climate comparable in magnitude to that of increasing concentrations of atmospheric gases. The effect of the aerosols, however, will be opposite to the effect of the increasing atmospheric trace gases - cooling instead of warming the atmosphere.

The warming effect of the greenhouse gases is expected to take place everywhere, but the cooling effect of the pollution aerosols will be somewhat regionally dependent, near and downwind of industrial areas. No one knows what the outcome will be of atmospheric warming in some regions and cooling in others. Climate models are still too primitive to provide reliable insight into the possible outcome. Current observations of the buildup are available only for a few locations around the globe and these observations are fragmentary.

Understanding how much sulfur-based pollution is present in the atmosphere is important for understanding the effectiveness of current sulfur dioxide pollution control strategies.

The Removal of Aerosols

It is believed that much of the removal of atmospheric aerosols occurs in the vicinity of large weather systems and high altitude jet streams, where the stratosphere and the lower atmosphere become intertwined and exchange air with each other. In such regions, many pollutant gases in the troposphere can be injected in the stratosphere, affecting the chemistry of the stratosphere. Likewise, in such regions, the ozone in the stratosphere is brought down to the lower atmosphere where it reacts with the pollutant rich air, possibly forming new types of pollution aerosols.

Aerosols As Atmospheric Tracers

Aerosol measurements can also be used as tracers to study how the Earth's atmosphere moves. Because aerosols change their characteristics very slowly, they make much better tracers for atmospheric motions than a chemical species that may vary its concentration through chemical reactions. Aerosols have been used to study the dynamics of the polar regions, stratospheric transport from low to high latitudes, and the exchange of air between the troposphere and stratosphere.

Future NASA Aerosol Studies

NASA's ongoing Atmospheric Effects of Aviation Project **(AEAP)** has measured emissions from the engines of several commercial and research aircraft. Jet engine emissions have been shown to affect the concentrations of atmospheric water vapor and aerosols, and they may affect how clouds form and the concentrations of atmospheric ozone. Few actual measurements of their effects have been made, however.

In the spring of 1996, the Subsonic Aircraft Contrail and Cloud Effects Special Study (SUCCESS) focused on subsonic aircraft contrails and the impact of the aerosols in those contrails on cirrus clouds and atmospheric chemistry. Researchers have determined that aircraft contrails can prolong the presence of high altitude cirrus clouds while also decreasing the size of the ice crystals that make up the clouds.Studies like SUCCESS and AEAP will be ongoing as scientists continue to try to understand how aerosols affect our atmosphere and climate.

For more information, please contact:
NASA Langley Research Center
Office of Public Affairs
Mail Stop 115
Hampton, VA 23681-0001
(757) 864-6124

OR

Visit NASA Langley's Atmospheric Sciences Division (ASD) Homepage

[an error occurred while processing this directive]