NASA Facts

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February 1999

The Earth Observing System Terra Series

These articles focus on the overarching science priorities of the EOS Terra mission

Aerosols

What Are Aerosols?

Aerosols are tiny particles suspended in the air. Most occur naturally, originating from volcanoes, dust storms, forest and grassland fires, living vegetation, and sea spray (Figure 1). Human activities, such as the burning of fossil fuels and the alteration of natural surface cover, also generate aerosols. Averaged over the globe, aerosols made by human activities currently account for about 10 percent of the total amount of aerosols in our atmosphere. Most of that 10 percent is concentrated in the Northern Hemisphere, especially downwind of industrial sites, slash-and-burn agricultural regions, and overgrazed grasslands.

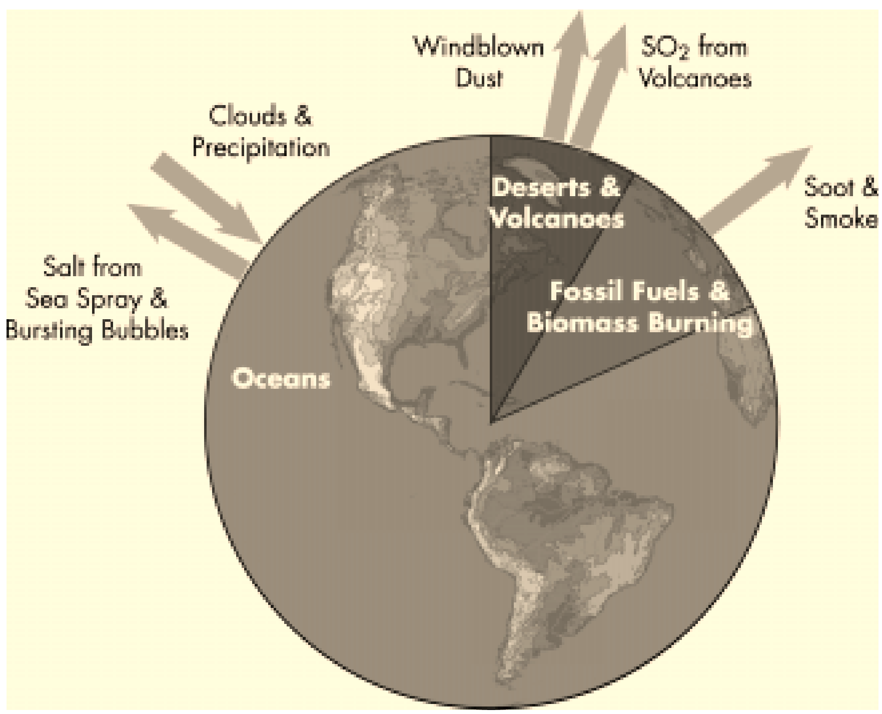

Figure 1. Aerosol particles larger than about 1 micrometer in size are produced by processes such as windblown dust and sea salt from sea spray and bursting bubbles. Aerosols smaller than 1 micrometer are mostly formed by condensation processes such as conversion of sulfur dioxide (SO_2) gas (released from volcanic eruptions) to sulfate particles and by formation of soot and smoke during burning processes. After formation, the aerosols are mixed and transported by atmospheric motions and are primarily removed by cloud and precipitation processes.

Scientists have much to learn about the way aerosols affect regional and global climate. We have yet to accurately quantify the impacts of natural aerosols on climate, relative to impacts of aerosols made by humans. Moreover, we do not know whether the total amount of atmospheric aerosol is roughly constant, is diminishing, or is increasing. Overall, we do not even know whether aerosols are warming or cooling our planet.

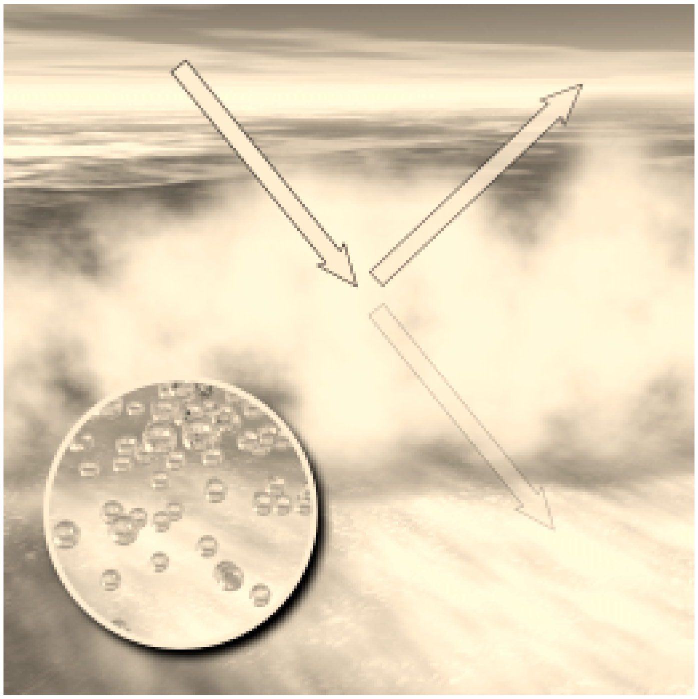

Figure 2a. The high aerosol concentrations in these clouds provide the nucleation points necessary for the formation of many small liquid water droplets. Up to 90% of visible radiation (light) is reflected from these clouds.

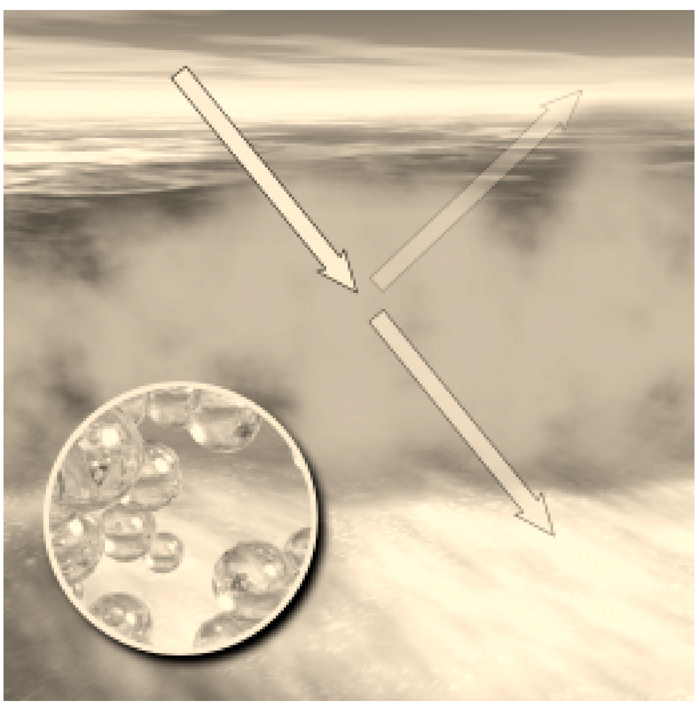

Figure 2b. Clouds with low aerosol concentrations and a few large droplets do not scatter light well, and transmit roughly half of the Sun's light.

Why do we care about aerosols?

Aerosols tend to cause cooling of the Earth's surface immediately below them. Because most aerosols reflect sunlight back into space, they have a "direct" cooling effect by reducing the amount of solar radiation that reaches the surface. The magnitude of this cooling effect depends on the size and composition of the aerosol particles, as well as the reflective properties of the underlying surface. It is thought that aerosol cooling may partially offset expected global warming that is attributed to increases in the amount of carbon dioxide from human activity.

Aerosols are also believed to have an "indirect" effect on climate by changing the properties of clouds (Figures 2a and 2b). Indeed, if there were no aerosols in the atmosphere, there would be no clouds. It is very difficult to form cloud droplets without small aerosol particles acting as "seeds" to start the formation of cloud droplets. As aerosol concentration increases within a cloud, the water in the cloud gets spread over many more particles, each of which is correspondingly smaller. Smaller particles fall more slowly in the atmosphere and decrease the amount of rainfall. In this way, changing aerosols in the atmosphere can change the frequency of cloud occurrence, cloud thickness, and rainfall amounts.

Adding aerosols to a cloudy area may create smaller cloud droplets. This could produce brighter clouds (reflecting more sunlight), and ones that last longer, since smaller cloud droplets are less likely to fall out of the atmosphere as rain. Very little is known about the scale of these indirect effects and the circumstances under which they operate. We need frequent global observations of cloud and aerosol properties to help us gain a better understanding of how they interact with one another.

Aerosol particles may be solid or liquid; they range in size from 0.01 microns (or micrometers) to several tens of microns. For example, cigarette smoke particles are in the middle of this size range and typical cloud drops are 10 or more microns in diameter. Under normal circumstances, the majority of aerosols form a thin haze in the lower atmosphere (troposphere), where they are washed out of the air by rain within about a week. Aerosols are also found in the atmosphere just above the troposphere (called the “stratosphere”). A severe volcanic eruption, such as Mount Pinatubo in the Philippines in 1991, can put large amounts of aerosol into the stratosphere. Since it does not rain in the stratosphere, these aerosols can remain there for many months, producing beautiful sunsets around the globe, and possibly causing summer temperatures to be cooler than normal. Scientists estimate that Mount Pinatubo injected about 20 million tons of sulfur dioxide into the atmosphere, cooling average global temperatures over the following year by about half a degree (Figure 3).

During the last 30 years, scientist have identified several major aerosol types and they have developed general ideas about the amount of aerosol to be found in different seasons and locations. Still, key details about the amount and properties of aerosols are needed to calculate even their current effect on surface temperatures and so far it has not been possible to make these measurements on a global scale.

New Measurement Capabilities

Currently, satellite instruments provide our best hope of making, at a reasonable cost, continuous, global observations of aerosols to help scientists measure how these particles influence climate. Two instruments onboard NASA’s Terra spacecraft will work together to measure atmospheric aerosols.

The Multi-angle Imaging SpectroRadiometer (MISR) instrument has nine separate cameras that will collect global imagery on the daylit side of the Earth. These cameras will look at the Earth in nine different directions and at four separate wavelengths. MISR will produce a multi-angle, multi-spectral data set unlike any ever before obtained by satellite instruments. The new information will make it possible to accurately estimate average particle size and composition, as well as aerosol amount, measured over ocean.

MISR data will also measure aerosol properties in the atmosphere over land and over dense, dark vegetation.

With MISR data, scientists will be able to distinguish air masses containing different aerosol types on a routine basis around the globe. Experimenters with instruments on the ground and in aircraft will work with the MISR team to characterize the particles in these air masses. MISR’s global aerosol monitoring program will contribute to studies of the Earth’s energy balance, (see Earth's Energy Balance, NASA Facts FS-1999-**-***) and will provide inputs to computer models of regional and global trends in Earth’s climate.

The Moderate Resolution Imaging Spectroradiometer (MODIS) will study the atmosphere, land, and ocean in a wide range of “colors”—spectral bands in the visible and infrared regions of the spectrum. The daily multispectral measurements from MODIS will be used to measure global aerosol amounts, and to distinguish between relatively large desert dust particles and small

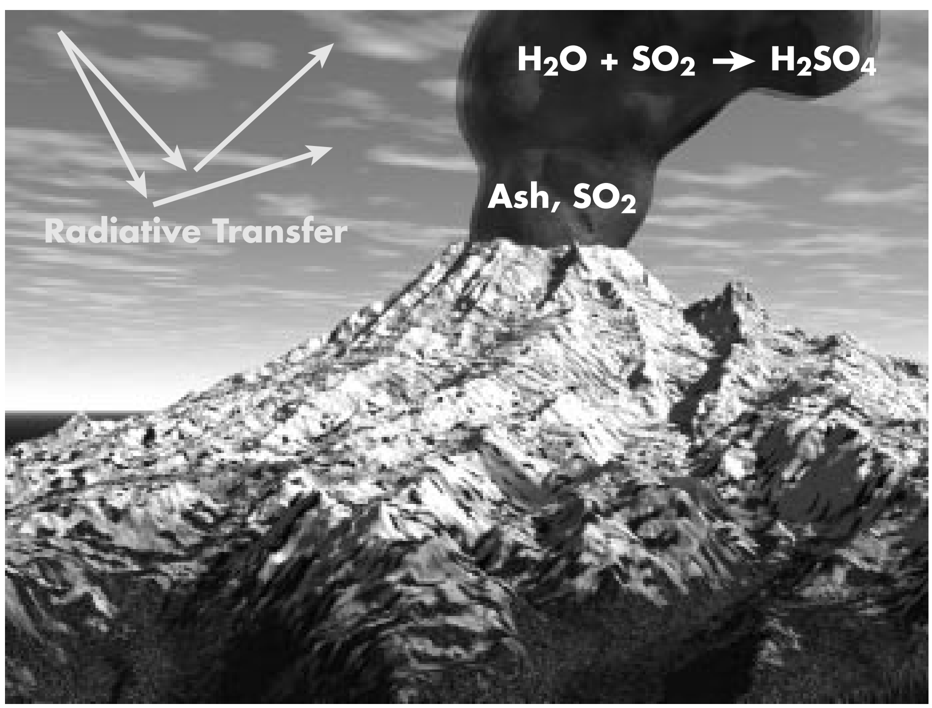

Figure 3. As volcanoes erupt, they blast huge clouds into the atmosphere. These clouds are made up of particles and gases, including sulfur dioxide (SO_2). Millions of tons of sulfur dioxide gas from a major volcanic eruption can reach the stratosphere. There, with the help of water vapor (H_2O), the sulfur dioxide converts to tiny persistent sulfuric acid (H_2SO_4) aerosols. These aerosols reflect energy coming from the sun, thereby preventing the sun's rays from heating the Earth. Volcanic eruptions are thought to be responsible for the global cooling that has 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 and, possibly, on its latitude.

particles in smoke and industrial/urban pollution. The instrument contains an alarm that will alert scientists when a volcano erupts, enabling them to observe and measure the volcanic plume. MODIS will also provide information about the distribution and characteristics of forest fires and help scientists estimate their emissions (e.g., gases and smoke particles) released from burning biomass. Moreover, MODIS will measure the properties of clouds—such as droplet size—and will determine how aerosols may impact clouds' abilities to reflect sunlight back into space.

Detailed measurements of aerosol properties from 100 ground-based automated instruments distributed around the world will complement the aerosol data obtained by MISR and MODIS. This network of robotic aerosol observing stations, called AERONET, looks upward from the ground, providing information about aerosol amount, particle properties, and their effect on solar radiation. Each AERONET station contains a computer that operates the instrument automatically, collects and organizes the data, and sends the results via satellite to NASA.

Using MISR, MODIS, and AERONET data, along with field and aircraft measurements by teams of scientists from many countries, researchers will determine with greater accuracy than ever before the role aerosols play in reflecting and absorbing sunlight, and the indirect effect aerosols have on the properties of clouds.

The Terra Spacecraft

Terra is the flagship of the Earth Observing System (EOS), a series of spacecraft to observe the Earth from the unique vantage point of space. Focused on key measurements identified by a consensus of U.S. and international scientists, EOS will enable research on the complex interactions of Earth's land, ocean, air, ice and life systems.

Terra will circle the Earth in an orbit that descends perpendicularly across the equator each day at 10:30 a.m. local time, when cloud cover is at a minimum and the space-based view of the surface is least obstructed. Each individual swath of measurements can be compiled into global images as frequently as every two days. Over a month or more, in combination with measurements from other polar orbiting satellites, Terra measurements will provide accurate monthly-mean climate assessments that can be compared with computer model simulations and predictions.

The Earth Observing System has three major components: the EOS spacecraft, an advanced ground-based computer network for processing, storing, and distributing the resulting data (the EOS Data and Information System); and teams of scientists and applications specialists who will study the data and help users in industry, universities and the public apply it to issues ranging from agriculture to urban planning.

Additional information on NASA's Terra mission can be found on the World Wide Web at http://terra.nasa.gov.