National Aeronautics and Space Administration
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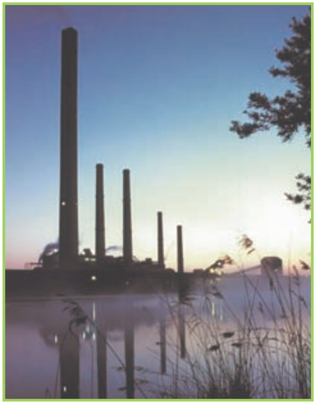
CloudSat & CALIPSO

The Air We Breathe



Clean air is important to everyone's health and well-being.

Clean air is vital to life on Earth. An average adult breathes more than 3000 gallons of air every day.

In some places, the air we breathe is polluted. Human activities such as driving cars and trucks, burning coal and oil, and manufacturing chemicals release gases and small particles known as aerosols into the atmosphere. Natural processes such as forest fires and wind-blown desert dust also produce large amounts of aerosols, but roughly half of the total aerosols worldwide results from human activities.

Aerosol particles are so small they can remain suspended in the air for days or weeks. Smaller aerosols can be breathed into the lungs. In high enough concentrations, pollution aerosols can threaten human health.

Aerosols can also impact our environment. Aerosols reflect sunlight back to space, cooling the Earth's surface and some types of aerosols also absorb sunlight—heating the atmosphere. Because clouds form on aerosol particles, changes in aerosols can change clouds and even precipitation. These effects can change atmospheric circulation patterns, and, over time, even the Earth's climate.

We need better information, on a global scale from satellites, on where aerosols are produced and where they go. Aerosols can be carried through the atmosphere-traveling hundreds or thousands of miles from their sources. We need this satellite information to improve daily forecasts of air quality and long-term forecasts of climate change.

The Water We Drink

There is a lot of water on Earth, but relatively little is usable to humans.

Freshwater is a precious resource. Of the small amount of freshwater on our planet, two-thirds of it is locked away in ice caps at the poles. The remaining freshwater resides in lakes, rivers and in underground reservoirs.

Water cycles continuously throughout the Earth system, rising from oceans, lakes, and the land surface to the atmosphere, forming into clouds, and eventually falling from clouds back to Earth's surface as rain and snow.

Clouds play an important role in the cycling of water over the planet. They effectively wring out some of the invisible water vapor contained in the atmosphere and convert it to liquid and solid water that falls back to Earth, replenishing our reservoirs of freshwater.

Clouds are thus essential for replenishing the water we drink. Clouds are made of water and are thus essential for replenishing the water we drink. If our world had no clouds, there would be no way to replenish these reservoirs of freshwater.

There's still a great deal we don't know about clouds and the water cycle. We don't know how much of the water in clouds falls as rain or snow, and we can't predict how clouds—and thus our reservoirs of freshwater—might change as our climate changes. Scientists need better global information on clouds so they can begin to answer some of these difficult questions.

What CALIPSO Does and Why

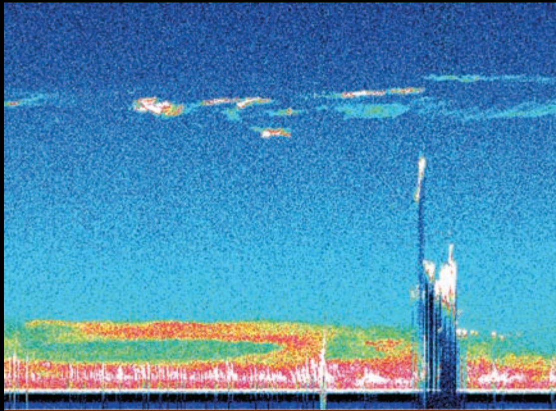
CALIPSO (Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations) uses an innovative lidar and imaging system to see natural and human-produced aerosols and thin clouds that are invisible to radar, and sometimes even to the human eye.

CALIPSO provides a new and unique perspective on the amount, height, and type of aerosols and thin clouds. The lidar can even tell if a cloud is made of water or ice.

CALIPSO helps us answer difficult questions about aerosols and make improved forecasts of air quality and predictions of climate change.

From CALIPSO observations we will be able to:

- observe the vertical layering of clouds and aerosols with a high level of detail,
- learn about the sources of aerosols, how they are transported, and how long they remain in the atmosphere; and
- study where thin clouds occur and why, how they form and how they affect the climate.



Aerosols are often lifted up into the atmosphere both by winds or surface heating and can be found in layers far above the surface.

CALIPSO's lidar sends a series of short pulses of light down through the atmosphere, and a fraction of these return to the satellite. The strength of the returned signal reveals the characteristics of the cloud and aerosol layers that lie below. The time required for the signal to travel down through the atmosphere and return to the satellite is used to construct a vertical map showing locations of thin clouds and aerosol layers.

This image of the western Atlantic Ocean comes from a lidar similar to CALIPSO's flown on the space shuttle. The thick red layer near the surface is aerosol, primarily from sea spray. The light blue and white layers near the top of the image are thin cirrus clouds, some of them not visible to the naked eye or the CloudSat radar. A layer of desert dust (orange and yellow) is underneath these clouds. A thick mid-level cloud (white) located in the right half of the image prevents the lidar pulse from penetrating any deeper, creating a black shadow beneath the cloud.

Jeff Schmaltz, MODIS Rapid Response Team

The satellite image shows an example of how clouds and aerosols interact. As ships cross the Pacific Ocean, their exhaust releases tiny aerosol particles around which water droplets aggregate, resulting in smaller, more numerous cloud droplets packed closely together. Thus, there are bright white streaks in the cloud where the ships' exhaust has intermingled with the surrounding stratiform cloud.

Without aerosols, cloud formation would be next to impossible. The amount and type of aerosols present help determine the physical characteristics of the clouds that form. The properties of the clouds affect how much sunlight is reflected from clouds and how much precipitation falls. CloudSat and CALIPSO should help us figure out how much influence aerosols are having on cloud formation and precipitation worldwide.

Formation Flying: The Afternoon 'A-Train'

The Afternoon Train or 'A-Train' is the nickname given to a group of satellites that fly close together and pass over the equator in the early afternoon. The A-Train provides coordinated science observations of the Earth and its atmosphere. Besides CloudSat and CALIPSO, other members of the A-Train include the NASA missions Aqua and Aura, a Centre National d'Etudes Spatiales (CNES) mission called PARASOL (Polarization and Anisotropy of Reflectances for Atmospheric Sciences coupled with Observations with a Lidar), and may eventually include NASA's OCO (Orbiting Carbon Observatory). Each satellite has a unique set of Earth observing capabilities, but this is a case where the whole is greater than the sum of the parts. Together, these diverse tools give us the most comprehensive set of observations of the Earth's atmosphere ever obtained.

Jacques Descloitres, MODIS Rapid Response Team

Aerosols and clouds play important roles in regulating our weather and climate:

Aerosols change the amount of solar radiation that reaches the Earth's surface and how much is reflected back to space. We are not certain the extent to which aerosols impact solar energy, how human activities may influence their impact, and how aerosols might offset the effects of greenhouse gases.

Clouds regulate how much solar radiation reaches the Earth, the amount of heat the Earth returns to space, and the water cycle of the planet. Not only that, changes in the amount of aerosols and greenhouse gases in Earth's atmosphere affect the amount of clouds globally.

CloudSat and CALIPSO give us valuable new information to help answer these questions and should lead to improved predictions of how weather and climate (*e.g.*, characteristics of hurricanes) might be changing.

CloudSat & CALIPSO

Clouds and aerosols affect our climate in ways we do not completely understand.

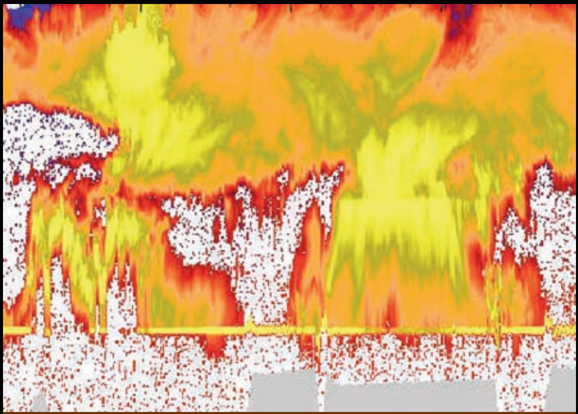
Clouds and aerosols affect the amount of solar energy that reaches the Earth, and the amount of energy that leaves the Earth. Shifts in this energy balance influence our climate.

Aerosols also affect where and how clouds form, and how much rain falls.

We do not know enough about clouds and aerosols to make accurate predictions of climate change.

Combining data from the CloudSat and CALIPSO missions with observations from the other A-Train satellites will help us:

- improve the computer models used to simulate Earth's climate,
- answer significant questions about climate processes, and
- create a better understanding of global climate change.



Clouds are composed of tiny particles of liquid water and ice. The number and size of the particles vary depending on how much water vapor exists in the surrounding air and how many small aerosol particles are available to act as seeds for cloud formation. The number and size of the particles and the amount of water and ice present determine how much sunlight the cloud reflects back to space and whether it will produce precipitation.

CloudSat's radar sends a series of short pulses of microwave energy down through the atmosphere, and a fraction of these return to the satellite. The strength of the returned signal reveals the characteristics of the cloud layers that lie below. The time it takes for the signal to travel down through the atmosphere and return to the satellite (called an echo because it is similar to the echo we hear when we yell across a canyon) is used to construct a vertical map of the atmosphere showing locations of cloud layers.

The figure above is an example of thunderstorms observed by a radar, similar to CloudSat's, flown on an aircraft above the storm. Strong echoes of precipitation are shown in yellow; weaker echoes of liquid and ice particles appear in blue, red and orange.

What CloudSat Does and Why

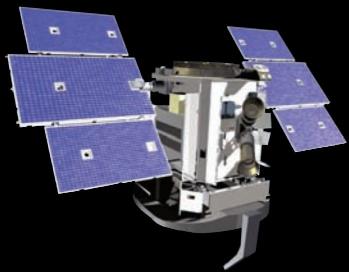
CloudSat flies a first-of-a-kind radar system that is much more sensitive than any weather radar.

CloudSat provides a never-before-seen perspective on clouds; its radar allows us to see inside the large cloud masses that make our weather. We will be able to study the processes that convert the tiny cloud particles to precipitation.

CloudSat observations will also allow us to predict the effects of clouds on our climate and improve predictions of climate change.

From CloudSat observations we will be able to:

- improve on our ability to predict where and why clouds and precipitation form,
- learn how much water condenses in clouds, and
- gain a better understanding of how the water cycle works, where and how much it will rain, and if our freshwater supplies might change in the future.



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Participants

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Ball Aerospace and Technologies, Inc. (BATC)
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Canadian Space Agency (CSA)
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Colorado State University (CSU)
Department of Energy, Atmospheric Radiation Measurement Program (DOE-ARM)
European Centre for Medium-Range Weather Forecasting (ECMWF)
Hampton University
Institut Pierre Simon Laplace
The GLOBE Program for Hands-On Education and Science
U.S. Air Force Research, Development, Test and Evaluation Support Complex (USAF-RSC)
U.S. Air Force Space Test Program (USAF-STP)

For further information on CALIPSO, CloudSat, or the A-Train:

www.nasa.gov/calipso
www.nasa.gov/cloudsat

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