NASA Facts

National Aeronautics
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Using Lasers to Study Our Atmosphere

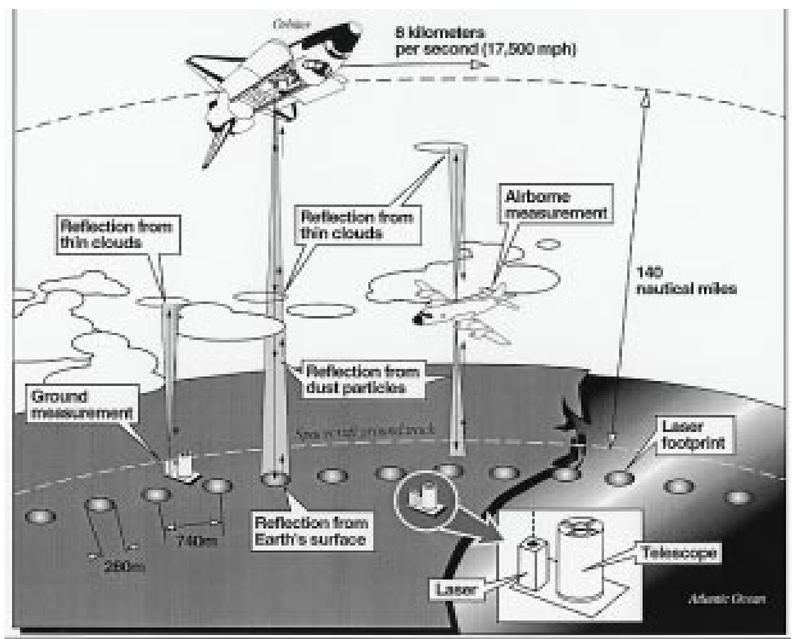
The Earth's atmosphere and climate have become big concerns — and not just to scientists. Terms like greenhouse effect, ozone hole and global climate change are now household words which conjure up either concern or controversy. What is causing them? How serious are they?

Since the 1930s, when scientists first discovered ozone, a lot of progress has been made in defining and measuring both natural and human influences on our atmosphere. Using advances in technology such as radar and lasers, scientists have gained a greater understanding of Earth's atmosphere and how it might be changing.

Our ability to gather data from ground-based, airborne and now spaceborne remote sensing devices has given us a new global perspective on our atmosphere.

Uses of Lasers

One key to understanding the atmosphere is the ability to study its components, including clouds (liquid), aerosols (suspended particles), and ozone and water vapor (gases). Researchers at NASA Langley use laser-based systems called lidars (**li**ght detection **a**nd **r**anging) to study the atmosphere with high precision. A lidar can penetrate thin or broken clouds in the lower atmosphere, where humans live, letting researchers "see" the vertical structure of the atmosphere. A space-based lidar can provide global measurements of the vertical structure of clouds and atmospheric gases. Both ozone and water vapor are involved in many important atmospheric processes that can affect life on Earth, climate change, weather, the Earth's energy budget, and regional and global pollution levels.



In September 1994, the LITE lidar instrument flew aboard the Space Shuttle Discovery (STS-64). An international team of scientists, at over 50 locations around the world, collected data to confirm the LITE laser measurements made from space.

Perhaps the greatest value of lasers as remote sensing tools is the unprecedented accuracy with which they can measure clouds. The latest advancements in laser remote sensing can fill the gaps we have in our understanding of how clouds reflect and absorb solar energy, and how heat and moisture are exchanged between the air, ocean and earth.

How Does A Lidar Work?

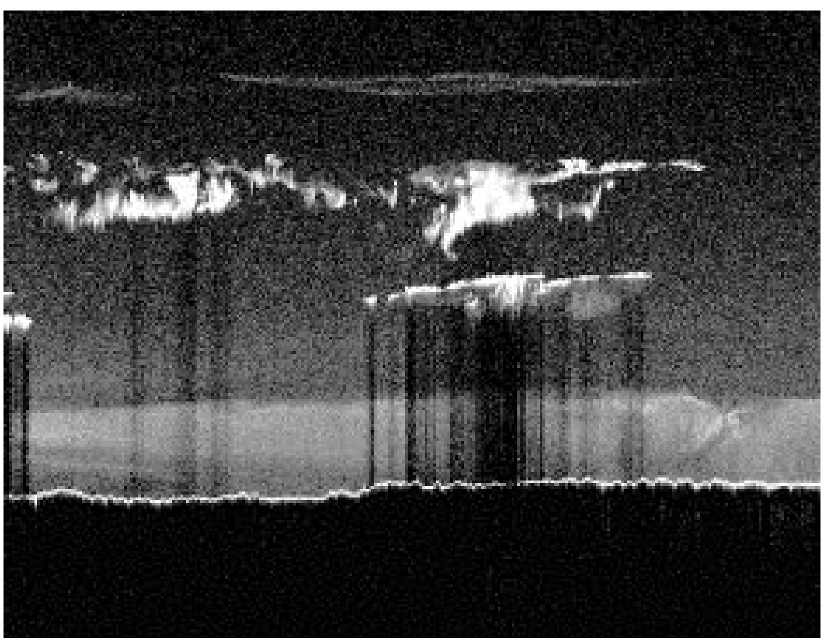
A lidar is similar to radar, which is commonly used to track everything from airplanes in flight to thunderstorms. Instead of bouncing radio waves off its target, however, a lidar uses short pulses of laser light to detect particles or gases in the atmosphere. Traveling as a tight, unbroken beam, the laser light disperses very little as it moves away from its origin – such as from space down to the Earth's surface. Some of the laser's light reflects off of tiny particles — even molecules — in the atmosphere. The reflected light comes back to a telescope and is collected and measured. By precisely timing the collected light, and by measuring how much reflected light is received by the telescope, scientists can accurately determine the location, distribution and nature of the particles.

A lidar carries its own source of laser light, which means it can make measurements both in the daytime and at night. The result is a revolutionary new tool for studying what's in our atmosphere - from cloud droplets to industrial pollutants - many of which are difficult to detect by other means.

Remote Sensing Lasers in Space

In September 1994, NASA launched the **L**idar **I**n-Space **T**echnology **E**xperiment (**LITE**). LITE was the first use of a lidar system for atmospheric studies from space. LITE orbited the Earth while positioned inside the payload bay of the Space Shuttle Discovery (STS-64). During the ten-day mission, LITE measured the Earth's clouds and various kinds of aerosols in the atmosphere for 53 hours.

Because this type of lidar had never flown in space before, the LITE mission was primarily a technology test. Scientists and engineers wanted to verify that the entire system worked as planned



LITE measurements of desert dust (light gray over black surface), and multilayered clouds (white) over Africa in September 1994. High cirrus clouds can be seen at the top of the figure (gray whiffs).

A hundred and thirty nautical miles above the Earth, the LITE instrument measured clouds and particles in the atmosphere below. The LITE experiment was part of a multipurpose space shuttle mission in September 1994.

while on orbit.

An important secondary goal of the LITE mission was to explore the applications of space-based lidars and gain operational experience for a future satellite-based lidar system. Such a satellite could provide continuous global atmospheric data.

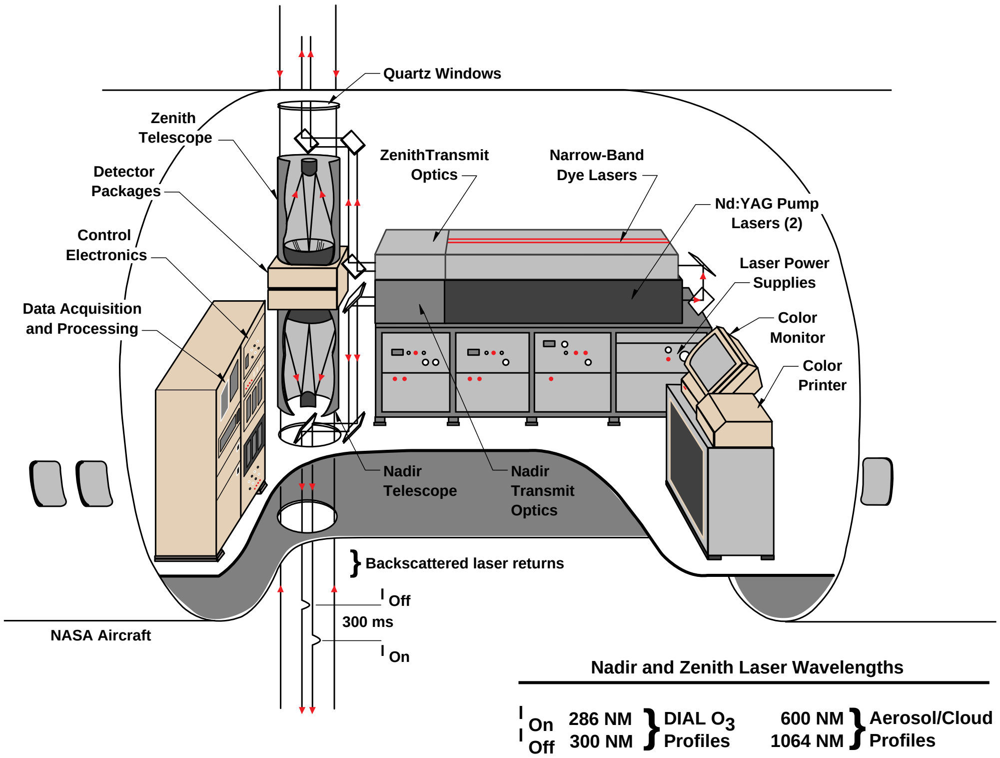
NASA Langley researchers are now exploring the feasibility and potential advantages of using lidar instruments on Earth-observing satellites.

Measuring Atmospheric Gases

While lidars like LITE measure the vertical distribution of clouds and small particles in the atmosphere, they cannot measure important atmospheric gases, such as water vapor and ozone. This type of measurement can be made with a **Di**fferential **A**bsorption **L**idar (**DIAL**). The DIAL technique was first demonstrated in the mid-1960s, and DIAL systems have been flying on research aircraft for over a decade.

DIAL uses two pulsed beams of light at two slightly different wavelengths. One beam determines the location of the particles or gases - its beam strength remains relatively unchanged regardless of how many particles or how much gas is present. The second beam, which is tuned to a slightly different wavelength, is partially absorbed by the particles or gas. The amount of the second beam that is absorbed is used to determine the amount of gas or particles present.

In September 1994, during the LITE project, an advanced DIAL system flew aboard a high-altitude ER-2 aircraft, which is a U-2 spy plane modified for atmospheric research. Capable of flying at altitudes up to 75,000 ft., the ER-2 carried the **L**idar **A**tmospheric **S**ensing **E**xperiment (**LASE**). LASE was the first fully computer-controlled lidar system and the first water vapor lidar to operate in space-like conditions. LASE also measured ozone and atmospheric particles. LASE tested its technical ability as an autonomous instrument at the same time as the LITE project paved the way for using laser technology on satellites.



Schematic of a NASA Langley Research Center airborne DIAL system

Why Put Lasers in Space?

Ground-based lidar instruments can profile the atmosphere over a single viewing site, while lidars aboard aircraft can gather data over a larger area. Each of these methods, however, is limited to sampling a comparatively small region of the Earth. Spaceborne lidars, including instruments on satellites, have the potential for collecting data on a global scale, including remote areas like the open ocean, in a very short period of time.

The Future of Laser Remote Sensing

LITE and LASE collected data on a wide range of phenomena, from aerosols in the upper atmosphere, to cloud droplets, pollutants and ozone in the lower atmosphere. Future lidar instruments will be tailored to more specific purposes. While one instrument studies the vertical structure of clouds, another will track urban smog or desert dust storms; all of which affect Earth's atmosphere, and, in turn, its weather and climate.

Only by gathering more accurate information can scientists improve their understanding of the atmosphere to the point where they can confidently predict its behavior, and determine how it is being affected by human activities. This improved understanding would enable us to prepare for natural phenomena and take stronger measures to protect Earth's irreplaceable atmosphere. LITE, LASE and their successors will continue to make unique and valuable additions to our understanding of the Earth's atmosphere.

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