Clouds in the Greenhouse

As vexing as they are beautiful, clouds play an important role in Earth's planetary greenhouse.

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April 22, 2002: Clouds may be a delight to children lying in a field on a summer day, letting their imaginations bend the wispy shapes into ducks or boats or dinosaurs.

But clouds can be a real pain in the neck for climate researchers.

Right: Cirrus clouds over Finland © Pekka Parviainen. [more]

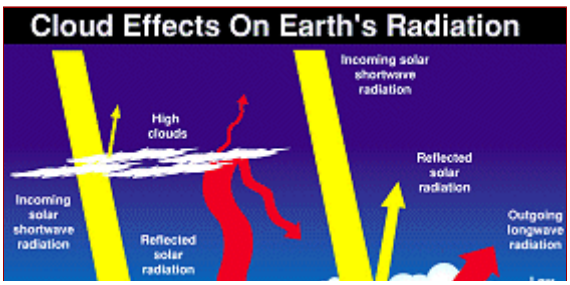
To understand why, consider again that summer day: If a big, fluffy cumulus cloud comes drifting by, it's usually good news for hot cloud-watchers. Low thick clouds cast a refreshing shadow and reflect sunlight back into space. They cool the planet and the people beneath them.

On the other hand, high wispy clouds drifting by are less refreshing. Such clouds cast meagre shadows and, because they are themselves cold, they trap heat radiated from the planet below. The air temperature near the ground might actually increase.

It is this schizophrenic behavior that makes clouds so vexing to researchers who are trying to predict the course of climate change.

Clouds are an important part of Earth's planetary greenhouse. Greenhouse gases like carbon dioxide and methane are perhaps more widely discussed, but clouds can do the same thing: they warm our planet by trapping heat beneath them. Yet unlike greenhouse gases, sunlight-reflecting clouds also have a cooling influence. Furthermore, the air temperature, which is affected by clouds, in turn affects cloud formation. It's a circular relationship that makes climate research all the more difficult.

"Clouds remain one of the largest uncertainties in the climate system's response to temperature changes," laments Bruce Wielicki, a scientist at NASA's Langley Research Center. "We need more data to understand how real clouds behave."



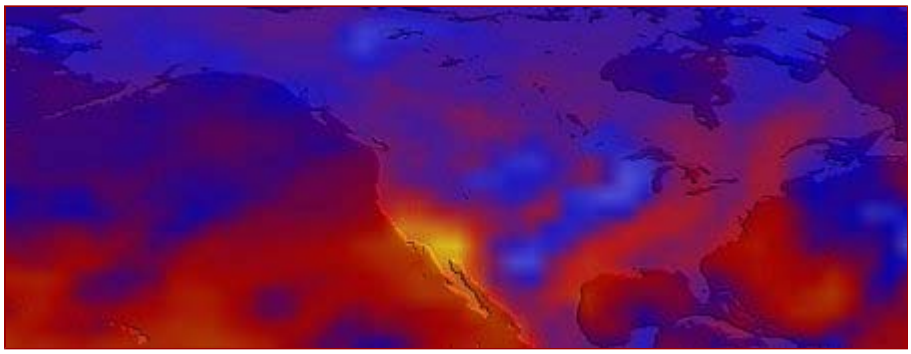
Left: The complex role of clouds in Earth's energy balance. Click on the image to view an easier-to-read version. Credit: NASA/Langley.

How much sunlight do different kinds of clouds reflect? How much heat do they absorb? And how do they respond to ambient

temperature changes? Wielicki is the principal investigator for an orbiting instrument that will answer some of these questions. "It's called CERES," he says, "short for **C**loud and the **E**arth's **R**adiant **E**nergy **S**ystem."

CERES is a package of three telescopes that watch our planet from Earth orbit. "One telescope is sensitive to ordinary sunlight," says Wielicki. "It tells us how much solar radiation is reflected from clouds or ice." The other two telescopes sense longer-wavelength infrared heat. They reveal how much heat is trapped by clouds and how much of it escapes back to space.

CERES is orbiting Earth now on board NASA's Terra satellite. The instrument was monitoring our planet last summer when a heat wave struck California and produced a remarkable surge in infrared radiation from that region. CERES revealed not only the infrared glow on the ground, but also how much of that heat was absorbed by the atmosphere -- key data for global warming studies.



Above: California is glowing in this image of infrared heat radiating from the Earth. CERES on Terra captured the data during the 2001 California heat wave.

NASA's Aqua satellite, slated to launch on May 2nd, will soon carry another package of CERES telescopes to orbit. "Having CERES on board two satellites (Aqua and Terra) will help us cover the entire planet -- to study, for example, day-night variations in Earth's energy balance," explains Wielicki.

CERES is a welcome development for scientists who are often forced to test their ideas about climate change using computer models -- models that may or may not faithfully represent our complicated planet. Using CERES, researchers can now examine some of those theories in the real world.

Right: Clouds in the tropical Pacific. [more]

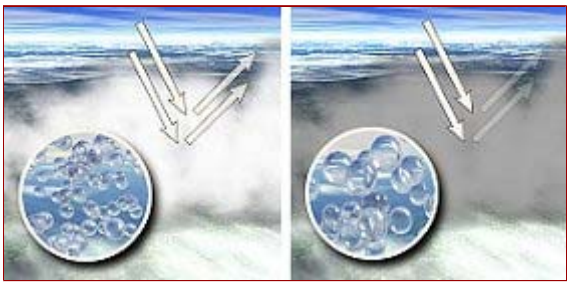
For example, a group of scientists recently proposed an idea called the "iris hypothesis." They suggested that the canopy of clouds over the tropical Pacific Ocean recedes when the water's surface temperature increases. Fewer clouds would open a window through which heat could escape to space and thus cool the planet. Earth, they argued, has a natural response that counteracts rising temperatures -- a bit like an iris in a human eye dilating to

adapt to low light.

But does Earth really respond that way?

Wielicki and other NASA scientists used CERES to test the idea. It turned out that such clouds did trap infrared heat. But even more so they reflected visible sunlight back into space. Fewer of the clouds would mean more global warming, not less.

The iris hypothesis was wrong.



Another problem CERES will tackle concerns aerosols. Aerosols are tiny particles like volcanic dust, pollution and even sea spray suspended in the air. Aerosols reflect sunlight. They also help clouds form by serving as "nucleation sites" around which water droplets grow. No one knows if increasing numbers of aerosols will cool or warm our planet.

Above: Clouds containing many aerosols (left) also contain many water droplets. Such clouds reflect light well. Clouds containing fewer aerosols (right) tend to harbor larger water droplets; they transmit more solar energy to the planet below. [more]

"The aerosols are a mess," says Thomas Charlock, a senior scientist at NASA's Langley Research Center and co-investigator for CERES. "We don't know how much is out there, and every gosh-darned aerosol particle looks different from every other one. So we just can't estimate their influence with calculations alone."

"What we can do is look at the energy balance in a dusty area and a non-dusty area," Charlock continues. "That's where CERES and MODIS (a Terra instrument that can sense aerosol properties) used together will be very powerful."

Right: Tracks in Earth's atmosphere left by ... ocean vessels! The clouds pictured here were created when aerosols from the ships' exhaust caused moisture in the air to condense into clouds. [more]

When Aqua joins Terra in orbit, it will bring its own special set of tools to bear on climate research. Says Charlock: "Part of our mission we can do much better with [instruments on board] Aqua -- things relating to humidity and water clouds."

Scientists hope the unprecedented "cloud watching" power of these two satellites will reveal much about the inner workings of climate change. Don't expect any pictures of ducks or dinosaurs, though. Neither satellite has that kind of imagination. Yet in their own way, they will reveal the complex beauty of clouds as never before.

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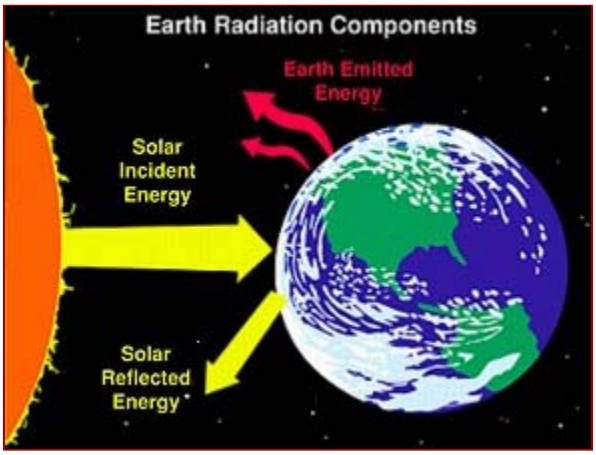
Web Links

Changing Global Cloudiness -- in-depth article on clouds and climate change, from NASA's Earth Observatory

Aerosols and Climate Change -- a good article about the questions scientists have on the role aerosols play in climate change, from NASA's Earth Observatory

Earthshine: Our planet reflects about 30% of incoming sunlight, and clouds are responsible for the most of that reflected light. See a 2 MB mpeg animation of the Earth's outgoing long-wave heat and its reflected sunlight.

Left: The energy that Earth gains from incoming sunlight is approximately balanced by the energy reflected or radiated into space. Click on the image for a detailed view of Earth's energy budget. Image courtesy NASA.



Recent aerosol events -- a global map of recent dust and smoke events imaged by NASA satellites

Clouds and Climate Change -- brief summary of scientists' effort to understand the role of clouds in climate change, from NASA's Goddard Institute for Space Studies

Climate Change 2001: the scientific basis -- index of the comprehensive report from the Intergovernmental Panel on Climate Change

CERES -- home page for the Clouds and the Earth's Radiant Energy System sensor

CERES on Terra -- information about the energy-balance sensor aboard the Terra satellite

Home pages for Terra and Aqua

Cloud type chart -- from the S'COOL Aqua verification project Web site

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