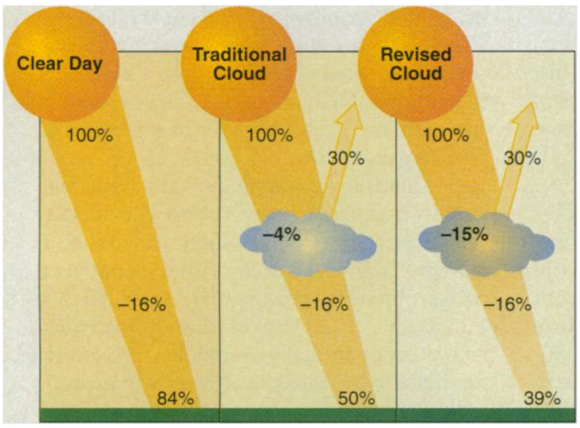
ATMOSPHERIC SCIENCE

Darker Clouds Promise Brighter Future for Climate Models

As mirrors of the real world, climate models are far from perfect. These computer simulations of how solar energy and Earth's ocean and atmosphere interact can't even get today's climate entirely right. And when they're asked to prognosticate, the results are even worse: When researchers use them to predict how the intensifying greenhouse will affect the world in the next century, the models give answers ranging from a modest warming of 1.5°C to a scorching increase of 4.5°C. These shortcomings are no great surprise, given the number of climate processes that are poorly understood or totally unknown. Now one of those processes has come into sharper focus: the fate of sunlight passing through clouds.



Sun screen. Clear air soaks up a fraction of solar radiation *(left)*; clouds not only reflect another large fraction of the light *(center)* but also absorb a surprising amount.

ILLUSTRATION: C. FABER SMITH SOURCE: JEFFREY KIEHL

For decades, the working assumption of climate modelers has been that the tiny water droplets that make up clouds reflect some solar radiation back into outer space and let almost all of the rest filter to the surface. But two new studies reported in this issue of *Science* (pp. 496 and 499) suggest that clouds actually absorb a significant portion of the sunlight passing through them. "Some of the energy that we thought was going through the atmosphere and reaching the surface isn't; it's being absorbed by the clouds," says climate modeler Jeffrey Kiehl of the National Center for Atmospheric Research (NCAR) in Boulder, a co-author on both papers.

This finding may sound straightforward, but the closely coordinated observations it required were not. And it's likely to have complex ramifications for researchers trying to understand and model Earth's climate system. "I think it's going to be a major revolution in how we look at what drives the general circulation of the atmosphere," says Kiehl. V. Ramaswamy of the Geophysical Fluid Dynamics Laboratory in Princeton, New Jersey, agrees: "This is such a basic thing; it throws a big monkey wrench into the modeling works." But unlike most monkey wrenches thrown into machinery, this one may effect some much-needed repairs. Already, researchers are finding that when they force their model clouds to act as real ones seem to, their computers yield pleasing improvements in simulated climate.

To pin down what clouds do with sunlight, all that is required is keeping track of solar energy—light in the visible and near infrared ranges—above and below the same clouds. In practice, however, this is extremely difficult. The trick has been ensuring that the high-flying instruments needed to measure incoming and reflected light above the clouds have the same calibration as the instruments measuring light below the clouds—and being certain that both sets of instruments are looking at precisely the same clouds.

In their *Science* paper Robert Cess of the State University of New York, Stony Brook, and his colleagues combined data from the ERBE and GOES satellites with ground-based observations at five sites around the world. After thorough cross-checks to make sure the satellites and ground stations were looking at the same clouds at the same time, they found that, on a global average, clouds absorb more than 25 watts of solar radiation per square meter (W/m^2), rather than the 6 W/m^2 predicted by theory. That's enough to cut the solar energy reaching the ground by about 20%.

Researchers "don't have the vaguest idea" how clouds manage to soak up so much energy, says Cess. Theories about how radiation interacts with pure cloud droplets don't predict that much absorption, and Cess is sure clouds aren't gaining their absorptive properties from pollution. If only dirty clouds were high absorbers, the phenomenon would be patchy, notes Cess, but it isn't. "It's everywhere," he says. "It's Mother Nature doing something, something we don't understand."

The mystery doesn't look likely to go away. V. Ramanathan of the Scripps Institution of Oceanography in La Jolla, California, and his colleagues report in the other paper in this issue that a different approach to accounting for energy fluxes—using the changing heat content of the surface ocean as a radiation monitor—came up with the same sizable cloud absorption over the western tropical Pacific as Cess did. Two other studies that combine satellite and ground-based data—by Thomas Ackerman of Pennsylvania State University and by Patrick Minnis of the Langley Research Center in Hampton, Virginia—are not yet ready for publication but are finding similar absorption, these researchers say. And last week, Peter Pilewskie of the Ames Research Center in Mountain View, California, and Francisco Valero of Scripps told the annual meeting of the American Meteorological Society in Dallas that they have compared data from aircraft flown in lock step above and below clouds and found similar absorption.

With all these data piling up, it seems increasingly likely that climate modelers will have to reckon with cloud absorption. And although 25 W/m^2 is a small proportion of the sunlight entering the top of the tropical atmosphere, it's a sizable part of the 60 W/m^2 that heats the tropics, powering the global air circulation that creates the world's weather. Atmospheric scientists had thought most of this energy reaches the surface of the tropical ocean, where it drives evaporation. When the resulting water vapor condenses as precipitation, they believed, it yields its latent heat energy to the atmosphere.

But if Cess and his colleagues are right and much of that energy is actually deposited directly in the atmosphere by cloud absorption, says Kiehl, the workings of the tropical "heat engine" look a lot different. Much more atmospheric heating could take place without the evaporation, ascent of moisture-laden air, and precipitation that researchers had previously assumed. And that change in the heat engine has some "fairly dramatic" effects on climate models, says Kiehl.

He and his colleagues have forced the clouds in the NCAR Community Climate Model to absorb in line with the new observations. In a simulation of present climate, they found that the modified model generates "a climate that's significantly different than what we had—it is warmer, precipitation is less, surface winds are weaker, and the circulations are slower," says Kiehl. "In general, it compares better with observations than the previous version of the model."

Modelers are eager to see what surprises come out of greenhouse simulations with more realistically absorbent clouds. "There's no way to guess what this would do if [a modified] model were run for a doubled CO_2 simulation," says Cess. But he's not going to be satisfying his curiosity until he and his colleagues have some idea of why clouds behave the way they do. "We want to understand the physics first."

–Richard A. Kerr