



30 AUG 2010: ANALYSIS

The Effect of Clouds on Climate: A Key Mystery for Researchers

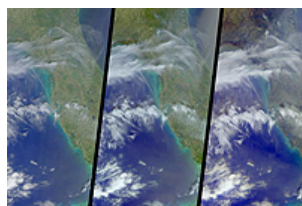
As climate scientists wrestle with the complexities of how the planet will react to rising greenhouse-gas levels, no variable is more difficult to decipher than the impact of clouds. But thanks to new satellite data and other technologies, clues are emerging that may help solve the puzzle.

BY MICHAEL D. LEMONICK

Back in the 1920's, the cartoonist Rube Goldberg became a household name by drawing a seemingly endless series of fanciful and absurd contraptions in which a simple action, such as pushing a lever, would lead to an unfolding mechanical drama. The lever might drop a ball into a chute, where it would roll to the bottom and knock a wheel into motion, which in turn would activate a scissors that would cut a rope... You get the idea.

It's no surprise, therefore, that when scientists began to wrestle with the potential impact of human-generated greenhouse gases, they often used Goldberg's machines as an analogy. Earth's climate is a complex, interrelated system involving the land, atmosphere, biosphere, and oceans. If you push on a lever by pumping extra CO₂ into the air, it sets off a cascade of events — warming air; warming oceans; melting ice; changes in evaporation, vegetation, ocean currents, wind patterns and more — which themselves push on the system in various ways, leading to more changes, which further alter the system, and so on.

Over decades, improvements in observations of the present climate, reconstructions of ancient climate, and computer models that simulate past, current, and future climate have reduced some of the uncertainty in forecasting how rising temperatures will ripple through the climate system. Except, that is, when it comes to clouds. No variable has more confounded climate scientists than how clouds will react to — and influence — a warming world.



NASA

Satellite technology allows scientists to localize clouds in 3-D and associate different cloud types with their amount of solar reflection.

And although researchers are still far from certain whether an anticipated increase in cloudiness will further heat up the planet or offset the warming a bit, a growing consensus among climate modelers is that clouds will increase, rather than hold back, the warming triggered by greenhouse gases. That's largely because water vapor itself is a powerful greenhouse gas, which means that clouds should trap more heat than

they are likely to reflect back into space.

Still, at this point, few climate scientists would be willing to stake their reputations on a definitive forecast of how clouds will impact the climate system in coming decades and centuries. Stanford University climate

scientist Stephen Schneider, in an e-mail written just a week or so before his untimely death on July 19, said, “Cloud feedback has been uncertain by a factor of 3 since I did the first paper with that title nearly 40 years ago — we are still no closer to an answer.”

Many of Schneider’s colleagues would argue that they are farther along in understanding cloud “feedbacks” than that. But the uncertainty is understandable, given the many variables at play in studying the effect of clouds on a warmer planet: What types of clouds will form and at what altitude, what particles will the clouds form around, and how can modelers go from predicting the ways any given bank of clouds might behave as opposed to forecasting how the effects on systems of clouds on a regional or global scale? Then there is the problem that, unlike temperature readings — which have been taken in many parts of the globe for more than a century — cloud observations have been far less complete.

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Given the uncertainties, it’s no surprise that climate skeptics, including prominent ones like [Freeman Dyson](#) of the Institute for Advanced Study in Princeton, N.J., have argued that vagaries in the response of clouds undercut the reliability of climate projections.

Despite the many unknowns, however, Dave Randall, a cloud modeler at Colorado State University, insists that “we do know a lot about clouds. We just don’t know enough. We’re not in the infant stages of understanding any more; we’re in first or second grade, and on the way to adolescence.”

A Challenge for Climate Modelers

Generally, in a warming world, scientists expect more evaporation of the oceans, leading to more water vapor in the atmosphere and more cloudiness. That would probably increase surface temperatures, but clouds block the sun, keeping some of its energy from heating the Earth’s surface, which should hold the warming back. That’s the case, at least, if they’re low-level clouds; high-altitude cirrus clouds are much less reflective, so they tend to enhance warming. And more water in the atmosphere might not lead to more cloudiness anyway: A warmer atmosphere needs more H₂O to become saturated — the fundamental requirement for cloud formation.

A major problem facing climate modelers is extrapolating the behavior and impacts of clouds from an individual level to a regional scale. The resolution of climate models — the grid boxes researchers divide the atmosphere into for the purposes of simulations, analogous to the pixels that make up a digital image — is much bigger than any individual cloud. And, says Randall, what goes on inside those grid boxes in the real world varies widely depending on local conditions, including the type of particles around which water vapor condenses to form clouds.

If you pour lots of sunshine into, say, the Amazon basin, you’ll evaporate a lot of water from the surface, which favors cloud formation. But once the clouds form, they cast shadows, which cuts off evaporation. If you get a big plume of dust blowing off the Sahara, that dust absorbs solar radiation, creating a warm layer of air a kilometer or two above the ocean, which inhibits cloud formation. If ice particles in the upper atmosphere are a certain size, they’ll seed the formation of cirrus clouds — but if they’re a little too big, they can’t stay aloft, so clouds don’t form.

Randall cited one example of a huge regional cloud phenomenon in the tropics whose behavior in a warming world is uncertain. Known as the Madden-Julian Oscillation, the

New data can show how

phenomenon involves the formation of enormous systems of thunderstorms over the oceans, driving weather patterns affecting millions of people. “Most models do not even produce this phenomenon, even though it’s the largest feature in tropical atmosphere,” said Randall. “If you’re missing that, you’re missing an important thing. We’d like to be able to predict whether it will get stronger and more common, or less.”

the presence or absence of clouds correlates with temperature changes.

Climate scientists would obviously be far more confident in the models if the simulations of cloud behavior matched the real world. But just as with the computer models, observations of clouds have been too spotty to get an accurate picture of what’s going on. Meteorologists have been taking reasonably consistent readings of temperatures around the world for more than a century, which is why the Intergovernmental Panel on Climate Change can talk so confidently about the fact of global warming. But there’s no comparable data set on clouds, which means that “there’s really nothing we can say about how clouds have changed globally over the 20th century,” says Amy Clement, a climatologist at the University of Miami.

But that began to change about a decade ago with a set of satellite-borne NASA experiments known as “Clouds and the Earth’s Radiant Energy System,” or CERES. “What we measure,” says CERES principal investigator Norman Loeb, of NASA’s Goddard Space Flight Center, “is how much radiation is being reflected from the Earth and how much is being emitted, all the way from the top of the atmosphere down to the surface.”

When you combine that with data from other instruments that look at the physical properties of what’s going on down below — whether those emissions and reflections are coming from clouds, aerosols, or the surface itself — you can see where the clouds are and where they aren’t, how they ebb and flow, and, crucially, how their presence or absence correlates with changes in temperature. You can, in Loeb’s words, “unscramble the egg.” The bad news is that it will take several decades to unscramble it fully.

Over the past decade when scientists have finally begun to get high-quality, uninterrupted data on clouds, there have also been strong El Nino and La Nina events — the sort of short-term natural variations that can temporarily mask the underlying signal of climate change. “As you collect more data,” says Loeb, “the signal will emerge from that natural variability. In 15 or 20 years, it will start getting interesting.” Nevertheless, he says, the measurements so far suggest that there’s no strong negative climate feedback from clouds, and some indication of a positive feedback — just as the models have been forecasting.

Given the preliminary nature of these results, it’s too soon to rule out a negative cloud feedback. MIT’s Richard Lindzen, for example, has proposed a mechanism called the Iris Hypothesis that could in principle produce a cooling effect. The idea is that as the Earth warms, the increase in humidity leads to a change in the balance between heat-reflecting cumulus clouds and heat-trapping cirrus in the tropics, with the former increasing and the latter diminishing. The result would be a strong counterweight to greenhouse warming — not enough, perhaps, to overcome it, but enough to make the warming minimal.

All the evidence so far suggests that clouds will accelerate warming.

The problem, says Clement, is that “there’s no empirical evidence for it.” Atmospheric scientist Bing Lin has used CERES data to test Lindzen’s hypothesis, finding that instead of a strong negative feedback, there’s actually a weak positive one.

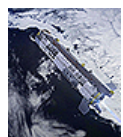
Another set of real-world experiments is known collectively as the GEWEX Cloud System Study. (GEWEX stands for Global Energy and Water Cycle Experiment). Scientists from different government agencies go out for several weeks at a time, using some combination of aircraft, ships, and remote sensing instruments to observe clouds in great detail on small scale. Then they compare the observations, not against global climate models, but against models that simulate clouds on those same scales. It's a sort of bottom-up approach that's helping inform the top-down models climate modelers use, says Anthony Del Genio, of NASA's Goddard Institute for Space Studies.

All of the evidence so far is only suggestive, not definitive, that clouds will accelerate warming. Yet most climate scientists say that the case is getting stronger. And researchers who remain uncertain about the impact of clouds on the climate say that even if clouds have a slight cooling effect, it will not be sufficient to put the brakes on human-caused warming.

"I'm as skeptical as any other scientist," says Clement. "I still ask myself, 'Do I really believe this global warming thing?' I can't just give students the party line. But the conclusion I come to is that it's really hard to see anything in the data or models that suggest clouds can overwhelm the effects of CO₂ on temperature."

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Del Genio comes to pretty much the same conclusion. "The only possible way to explain the warming we've experienced from 1970 onward," he says, "is if the climate has a significant sensitivity to greenhouse gases. We've monitored volcanoes, the sun, pollution aerosols, and despite all of these things [which would tend to slow temperature increases], we've seen systematic warming. That's telling us that even if clouds end up being a negative feedback, it couldn't be large enough to offset the warming

significantly."

And cloud feedbacks could equally well end up being a more strongly positive feedback than the models are suggesting.

"In most things where uncertainty goes both ways, we tend to plan against the worst-case scenario," says Del Genio. If you have high cholesterol, for example, you try to reduce it — even though high cholesterol doesn't necessarily guarantee a heart attack. With climate change, he says, "We freely admit that we don't understand everything. But if we're anywhere close to being right, there's significant warming in our future."

Correction, Aug. 30, 2010: Due to an editing error, an earlier version of this story incorrectly stated that the Institute for Advanced Study is affiliated with Princeton University. The Institute, located in Princeton, is a private, independent academic institution and is not affiliated with Princeton University.

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COMMENTS

Glad to see a balanced, scientifically-sound look at this subject -- very intriguing article. This is the kind of approach I'd like to see more of when it comes to the climate -- something that's informed and not hysterical.

Posted by Anthony Ruffalo on 03 Sep 2010

It is puzzling to read the article and find no mention of Roy Spencer's work. Could Lemonick be persuaded to add a supplement? Spencer's work has been available in various forms for more than a year.

Posted by Richard Hill on 03 Sep 2010

Have you asked Roy Spencer to comment on this?

Posted by Peter Foster on 06 Sep 2010

I'm surprised there was no mention of the definitive paleoclimatic evidence against a negative cloud feedback sufficient to put a damper on the current warming trend. To argue otherwise one would have to e.g. explain why such a negative feedback would operate significantly in the near future and yet have had no apparent effect on the rapid warmings associated with the Pleistocene deglaciations (~6C warmings over the course of a few thousand years). Similarly, it's been firmly established that the last time CO2 levels were ~350 ppm (we're at 390 now) in the mid-Pliocene (~3.3 million years ago), global temperatures were 2-3C higher than present and sea levels were ~25 meters higher. Going farther back in time, we see that CO2 levels of ~500 ppm (a level we're likely to pass by 2050) are incompatible with the presence of any permanent ice on the planet (=> ~70 meters of sea level rise). Whatever the cloud feedback is, that's the sort of climate impact we're guaranteed if we leave CO2 high enough for long enough.

All of that said, determining the sign and exact magnitude of the cloud feedback is critical to establishing how quickly the climate system will respond to the increasing CO2 levels. Paleoclimatic evidence alone isn't fine-grained enough to prove that there's no short-term cloud feedback that will stretch what would otherwise be decades of warming into centuries. But as scientists focus on this critical work, let's not lose track of the larger picture.

Posted by Steve Bloom on 06 Sep 2010

I do not believe any discussion on the influence of cloud cover on global climate change can be considered "informed" if it fails to mention the experiments, results and hypotheses of Heinrich Svensmark et al.

Posted by Keir Douglas on 07 Sep 2010

Comments have been closed on this feature.