The Science of Clouds—Why They Matter, and Why There May be Fewer of Them

Feature Stories Julie Chao (510) 486-6491 • **MARCH 13, 2013**

The climate models that scientists use to understand and project climate change are improving constantly, with better representations of the oceans, ice, land surfaces and other factors in the atmosphere. While there is still some degree of uncertainty in all these components, the largest source of uncertainty in today's climate models are clouds.

Clouds can both cool the planet, by acting as a shield against the sun, and warm the planet, by trapping heat. But why do clouds behave the way they do? And how will a warming planet affect the cloud cover?

Lawrence Berkeley National Laboratory scientist David Romps has made it his mission to answer these questions. "We don't understand many basic things about clouds," he says. "We don't know why clouds rise at the speeds they do. We don't know why they are the sizes they are. We lack a fundamental theory for what is a very peculiar case of fluid flow. There's a lot of theory that remains to be done."

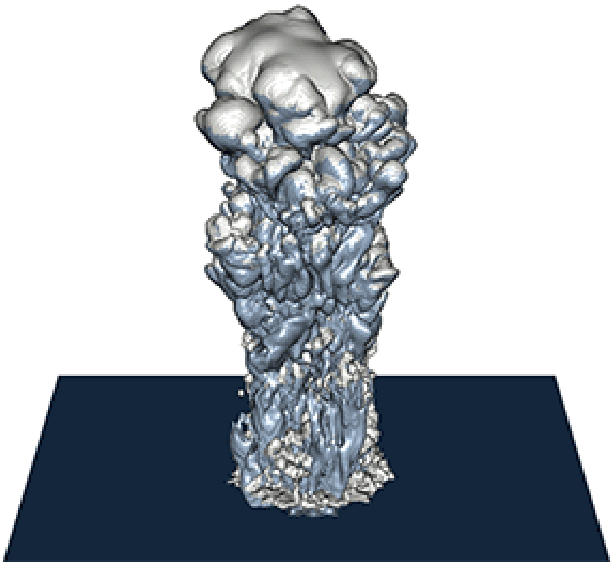
Berkeley Lab scientist David Romps

The Earth's response to changes in atmospheric CO_2 is studied using what are known as global climate models (GCMs), which run on supercomputers. Due to computational limitations, however, these GCMs are unable to explicitly model atmospheric phenomena less than 100 kilometers in size. Since convective clouds have sizes closer to 1 km, they cannot be resolved by a GCM. "So the GCM has to ask a submodel: what clouds do I have and what are they doing?" Romps says.

The submodel takes the temperature and humidity profile of a column of air and has to answer the question, "what's happening right now?" Unfortunately, despite decades of research and development on these submodels, they remain far from perfect.

"If you ask meteorologists to do this, it would be a very challenging task," Romps says. "There are some things you can infer, but it's hard to know, for example, what the rain rate is. That's one of the key things this model has to tell the GCM."

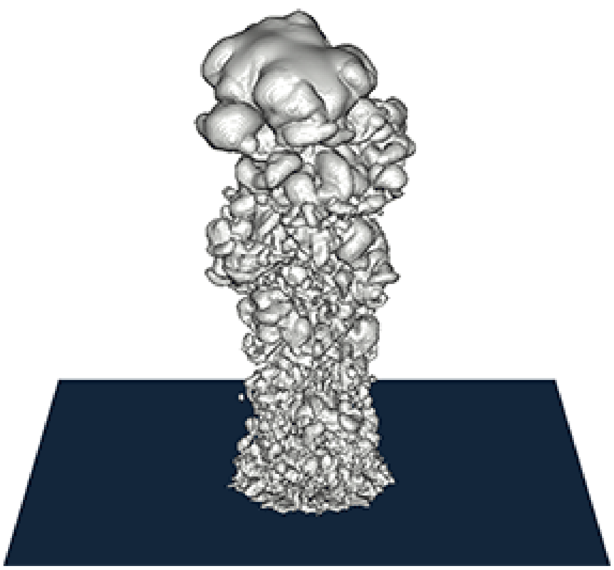
A cloud may look like just a billowing mass of air, but cloud dynamics in fact involve complicated physics. One of the most important factors in cloud dynamics, for example, is entrainment, which is when convecting clouds take environmental air and fold it into themselves as they are rising—a turbulent exchange of air between clouds and their environment. The more they do this, the less buoyant the cloud becomes and the less likely it is to rain. This process is difficult to study and build a model for because of the phase changes and complicating influence of latent heat being released.



This is a large-eddy simulation of a deep cumulonimbus (a tall rain cloud). The grey color shows the cloud, and the bluish color shows the precipitation.

What's worse, the entrainment rate may be the single most influential factor on climate models. "The entrainment rate is this parameter representing this really esoteric process, and it's the parameter to which the climate is most sensitive — that's an awful state of affairs!" Romps says. "We don't understand entrainment."

How would an improved understanding and model of clouds affect the global climate model? "It would rain in the right places," Romps says. "The large-scale winds would look better because the release of latent heat drives a lot of those winds, and climate sensitivity would be better constrained because not only is the base state highly dependent on convective parameterization but the model predictions for future climate change are also very sensitive to that as well."



The same cloud, without precipitation. David Romps uses these simulations to learn more about the turbulent entrainment process.

Romps has also tested theories on how future climate change will affect clouds. One of the biggest predictions is that higher temperatures will result in, roughly, fewer clouds, or more precisely, a smaller convective mass flux. Why? If the earth is warmed by 1 degree Celsius, then the amount of water vapor in the atmosphere increases by 7 percent. Meanwhile climate models say that the amount of rain in the future will increase by 1 to 3 percent.

"If you think of a cloud as rising up and wringing out the water from a column of air, then you know something from those two numbers," Romps explains. "The column of air holds 7 percent more water. But clouds need to release only 1 to 3 percent more water in a warmer world. That means there's going to be between 4 to 6 percent fewer convecting clouds."

Tests that he ran using a high-resolution model confirmed this theory.

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