What can a magnet tell you about rain patterns?

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If someone said you can understand rain patterns and the dynamics of the atmosphere by studying magnets and magnetism -- and therefore make better predictions of the effects of global warming -- would you think he's crazy? Brilliant? The atmosphere spans the entire globe, while a magnet fits easily in your hand; can they really be so similar?

Ole Peters, a 27-year-old physicist with expertise in "critical phenomena" and "self organized criticality" -- which he acknowledges is "a bit of a rogue field" -- doesn't sound the least bit crazy.

In the June issue of the respected journal *Nature Physics*, he and J. David Neelin, UCLA professor of atmospheric and oceanic sciences, report that the onset of intense tropical rain and magnetism share the same underlying physics.

Peters and Neelin analyzed statistical properties of the relationship between water vapor in the atmosphere in the tropics and rainfall, using remote sensing from a satellite over the tropical oceans.

"We studied properties of that relationship that are also observed in equivalent quantities for systems with 'continuous-phase transitions' like magnets," said Peters, a research scientist with UCLA's Institute of Geophysics and Planetary Physics and a visiting scientist at the Santa Fe Institute.

"The atmosphere has a tendency to move to a critical point in water vapor where the likelihood of rain dramatically increases. The system reaches a point where it's just about to rain; it's highly susceptible. Any additional water vapor can produce a large response."

Finding the simple predictions of this statement confirmed in a complex meteorological system is unexpected, and may lead to more accurate climate models, Peters and Neelin said.

Neelin is working to incorporate these findings into models for atmospheric dynamics. Predicting the effects of global warming on precipitation is currently difficult to assess, he said.

"Global climate computer simulations make assumptions about how rainfall depends on moisture and temperature that are imperfect approximations," said Neelin, a member of UCLA's Institute of Geophysics and Planetary Physics. "This research may lead to improved ways of treating rainfall in these models, which could help scientists improve rain prediction in daily weather or how it might change under global warming."

"Our study showed that absolutely everything we dreamed of finding was actually there," Peters said. "The predictions from critical phenomena showed up in the data. This is a huge step forward in self-organized criticality and critical phenomena. There really is a critical point. We observed the system in a whole range of different water vapors. This is the strongest evidence for any physical self-organized critical system to really have a critical point."

How does a critical threshold point work?

Consider a pile of rice, Peters said. You can add a single grain of rice and measure its effect on the pile. After slowly adding rice grains, at some point you eventually trigger an avalanche; the release is very fast.

A similar principle is behind the coin machines you can find in casinos, where it looks as if dropping in one or two quarters will create an avalanche of coins that will come crashing down for you. In fact, it is much more likely that it only looks like the system is at a critical point; you are more likely to lose your quarter.

Imagine that you add one raindrop into a cloud. Like the pile of rice, where adding a single grain can produce an avalanche or nothing at all, or like the coin machine, the one additional raindrop could trigger a huge downpour, but most of the time produces nothing. You can heat a magnet to a point where it loses its magnetization; it no longer has a north and south direction.

"When a magnet is near the critical temperature, a slight perturbation can cause it to switch north and south," Peters said. "When the system reaches the critical point and is so susceptible, a slight change -- one more grain of rice, one more coin -- can produce a massive response of the system. This phenomenon can be studied using statistical mechanics and critical phenomena."

The sun slowly evaporates water from the oceans, pumping water into the atmosphere. Much of that water vapor is stored and transported in the atmosphere before there is any rain, Neelin noted.

What finally triggers the rain?

Peters and Neelin were able to tie their findings back to seminal work in the 1970s at UCLA by Akio Arakawa, who sought to connect what is known about individual clouds to larger-scale atmospheric motions. As these motions increase water vapor in some regions, clouds begin to rise, heated by the condensing rainwater. Arakawa postulated a balance between the clouds and the large scale. But if the clouds were reacting smoothly to the large-scale flow, rain would be much more predictable than it is.

"Arakawa's work was amazingly far-sighted," Neelin said, "but there's a new twist."

Complex interactions among the cloud motions organize the rainfall into clusters in space and a cascade of smaller and larger rain events. And these share the same mathematical structure as systems that physicists have studied.

"It's very hard to predict rainfall because of this type of interaction," Peters said. "In the last 20 years, scientists have become much better at predicting temperature and wind, but predicting precipitation has not improved much.

"Whenever you find different systems that are governed by the same mathematical laws, you are hitting on something fundamental. You have found a thread in the mathematical fabric of reality. This study raises the concept of 'self-organized criticality' to a higher status. It's not just a far-fetched possibility."

The research is federally funded by the National Science Foundation and the National Oceanic and Atmospheric Administration.

Peters began studying "avalanche distributions" in 2002, measuring how much rain falls in one storm. This led him to make predictions about the functional relationship between water vapor and rainfall.

"It's a self-organized critical system, from which we can make predictions," said Peters, who described physics as "beautiful."

Source: University of California - Los Angeles