# Eat, prey, rain

July 25 2011

What do a herd of gazelles and a fluffy mass of clouds have in common? A mathematical formula that describes the population dynamics of such prey animals as gazelles and their predators has been used to model the relationship between cloud systems, rain and tiny floating particles called aerosols. This model may help climate scientists understand, among other things, how human-produced aerosols affect rainfall patterns. The research recently appeared in the *Proceedings of the National Academy of Sciences* (*PNAS*).

Clouds are major contributors to the climate system. In particular the shallow marine stratocumulus clouds that form huge cloud decks over the subtropical oceans cool the atmosphere by reflecting part of the incoming solar energy back to space. Drs. Ilan Koren of the Weizmann Institute's Environmental Sciences and Energy Research Department (Faculty of Chemistry) and Graham Feingold of the NOAA Earth System Research Laboratory, Colorado, found that equations for modeling prey-predator cycles in the animal world were a handy analogy for cloud-rain cycles: Just as respective predator and prey populations expand and contract at the expense of one another, so too rain depletes clouds, which grow again once the rain runs out. And just as the availability of grass affects herd size, the relative abundance of aerosols – which "feed" the clouds as droplets condense around them – affects the shapes of those clouds. A larger supply of airborne particles gives rise to more droplets, but these droplets are smaller and thus remain high up in the cloud rather than falling as rain.

In previous research, Feingold and Koren had "zoomed in" to discover oscillations in convective cells in marine stratocumulus. Now they returned to their data, but from a "top down" angle to see if a generalized formula could reveal something about these systems. Using just three simple equations, they developed a model showing that cloud-rain dynamics mimic three known predator-prey modes. Like gazelles and lions, the two can oscillate in tandem, the "predator" rain cycle following a step behind peak cloud formation. Or the two can reach a sort of steady state in which the clouds are replenished at the same rate as they are diminished (as in a light, steady drizzle). The third option is chaos – the crash that occurs when predator populations get out of hand or a strong rain destroys the cloud system.

The model shows that as the amounts of aerosols change, the system can abruptly shift from one state to another. It also reveals a bifurcation – two scenarios at different ends of the aerosol scale that lend themselves to stable patterns. In the first, relatively low aerosol levels lead to clouds in which development depends heavily on aerosol concentrations. In the second, high levels produce saturation; these clouds depend solely on the initial environmental conditions.

Using this so-called systems approach, says Koren, "can open new windows to view and understand the emergent behavior of the complex relationships between clouds, rain and aerosols, giving us a more useful view of the big picture and helping us to understand how shifting aerosol levels can lead to different climate patterns."

Provided by Weizmann Institute of Science