Improving Assessments of Climate Tipping Points

Statistical properties of fluctuations of certain parameters describing a complex system can reveal when that system is approaching a tipping point.

By **Marric Stephens**

From the last ice age until 6000 years ago, what we now know as the Sahara Desert was green and wet. This "African humid period" ended abruptly, but researchers don't know whether the change was a result of random fluctuations whose average changed gradually over time or of a growing external influence that eventually pushed the climate beyond a critical point. Andreas Morr and Niklas Boers at the Technical University of Munich have developed a new statistical method for assessing whether a complex system is nearing a tipping point [**1**]. Applying their method to simulations of the Sahara climate, they suggest that it was destabilized by increasing solar radiation caused by changes in Earth's orbit.

Key to spotting an imminent tipping point is the so-called linear restoring rate λ, which quantifies negative-feedback mechanisms that pull a perturbed system back into equilibrium. Near a tipping point, λ weakens, and the system spends more and more time in its perturbed state. The parameter λ can be estimated from the variance in time of certain system parameters (such as vegetation coverage in the case of the Sahara) and by observing temporal correlations in such parameters' values. This approach, however, relies on an unrealistic assumption: the system's noise must be frequency independent, or "white," and its features should be relatively stable in time.

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Morr and Boers estimate λ from more complex measures. Instead of variance, they use power spectral density—the distribution of variance across different frequencies. They also account for correlations between steps that are not adjacent but further separated in time. Morr says that this approach should deliver more reliable tipping-point assessments even when considering "red" noise—a correlated form of noise thought to better capture the behavior of natural systems like the climate.

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REFERENCES

1. A. Morr and N. Boers, "Detection of approaching critical transitions in natural systems driven by red noise," **Phys. Rev. X 14, 021037 (2024).**