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Do GCM's predict the climate.... Or the low frequency weather?

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Over twenty-five years ago, a three-regime scaling model was proposed describing the statistical variability of the atmosphere over time scales ranging from weather scales out to ≈ 100 kyrs. Using modern in situ data reanalyses, monthly surface series (at 5ox5o), 8 “multiproxy” (yearly) series of the Northern hemisphere from 1500 - 1980, and GRIP and Vostok paleotemperatures at 5.2 and ≈ 100 year resolutions (over the past 91-420 kyrs), we refine the model and show how it can be understood with the help of new developments in nonlinear dynamics, especially multifractals and cascades.

In a scaling range, mean fluctuations in state variables such as temperature ΔT vary in power law manners ≈ Δt**H the where Δt is the duration. At small (weather) scales the fluctuation exponents are generally H>0; they grow with scale (Δt). At longer scales $\Delta t > \tau w$ (≈ 10 days) H changes sign, the fluctuations decrease with scale; this is the low variability, “low frequency weather” regime. In this regime, the spectrum is a relatively flat “plateau”, it's variability is low, stable, corresponding to our usual idea of “long term weather statistics”. Finally for longer times, $\Delta t > \tau c$ ≈ 10 - 100 years, once again H>0, so that the variability increases with scale: the true climate regime. These scaling regimes allow us to objectively define the weather as fluctuations over periods $< \tau w$, to define “climate states” as fluctuations at scale τc and then “climate change” as the fluctuations at longer periods ($\Delta t > \tau c$).

We show that the intermediate low frequency weather regime is the result of the weather regime undergoing a “dimensional transition”: at temporal scales longer than the typical lifetime of planetary structures (τw), the spatial degrees of freedom are rapidly quenched so that only the temporal degrees of freedom are important. This low frequency weather regime has statistical properties well reproduced not only by stochastic cascade models of weather, but also by control runs (i.e. without climate forcing) of GCM based climate forecasting systems including those of the Institut Pierre Simon Laplace (Paris) and the Earth Forecasting System (Hamburg).

In order for these systems to go beyond simply predicting low frequency weather i.e. in order for them to predict the climate, they need appropriate climate forcings and/ or new internal mechanisms of variability. Using statistical scaling techniques we examine the scale dependence of fluctuations from forced and unforced GCM outputs, including from the ECHO-G and EFS simulations in the Millenium climate reconstruction project and compare this with data, multiproxies and paleo data. Our general conclusion is that the models systematically underestimate the multidecadal, multicentennial scale variability.