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Timescale-dependent stability of surface air temperature and the forced temperature response

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Earth's climate can be understood as a dynamical system that changes due to external forcing and internal couplings. It can be characterized from the evolution of essential climate variables, such as surface air temperature. Yet, the mechanisms, amplitudes, and spatiotemporal patterns of global and local temperature fluctuations around its mean, called temperature variability, are insufficiently understood. Discrepancies exist between temperature variability from model and paleoclimate data at the temporal scale of years to centuries and at the local scale, both of which are important socio-economic scales for long-term planning.
Here, we clarify whether global and local temperature signals from the last millennia show a stationary variance on these timescales and thus behave in a stable manner or not. Therefore, we contrast power spectral densities and their scaling behaviors using simulated, observed, and reconstructed temperatures on periods between 10 and 200 years. Despite careful consideration of possible spectral biases, we find that local temperatures from paleoclimate data tend to show unstable behavior, while simulated temperatures almost exclusively show stable behavior. Conversely, the global mean temperature tends to be stable. We explain this by introducing the gain as a powerful tool to analyze the forced temperature response, based on a novel estimate of the joint power spectrum of radiative forcing.
Our analysis identifies main deficiencies in the properties of temperature variability and offers new insights into the linkage between raditative forcing and temperature response, relevant to the understanding of Earth’s dynamics and the assessment of climate risks.