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Continuum climate variability: Long-term memory, extremes, and predictability (Lewis Fry Richardson Medal Lecture)

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Continuum temperature variability represents the response of the Earth's climate to deterministic external forcing. Scaling regimes are observed which range from hours to millennia with low frequency fluctuations characterizing long-term memory. The presence of 1/f power spectra in weather and climate is noteworthy: (i) In the tropical atmosphere 1/f scaling ranging from hours to weeks is found for several variables; it emerges as superposition of uncorrelated pulses with individual 1/f spectra. (ii) The daily discharge of the Yangtze shows 1/f within one week to one year, although the precipitation spectrum is white. (iii) Beyond one year mid-latitude sea surface temperatures reveal 1/f scaling in large parts of the global ocean. The spectra can be simulated by complex atmosphere-ocean general circulation models and understood as a two layer heat diffusion process forced by an uncorrelated stochastic atmospheric forcing. Long-term memory on time scales up to millennia are the global sea surface temperatures and the Greenland ice core records (GISP2, GRIP) with δ18O temperature proxy data during the Holocene. Complex atmosphere ocean general circulation models reproduce this behaviour quantitatively up to millennia without solar variability, interacting land-ice and vegetation components.