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Why does global surface temperature exhibit more persistent temporal scaling than local temperatures?

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Analysis of instrumental surface temperature records show that most records, both local and spatially averaged, can be modeled as stochastic processes exhibiting varying degree of temporal persistence, at least in time scales from months to several decades. With the exception of the tropical Pacific, which is dominated by ENSO, the local records can be well characterized by only two parameters; the variance and a spectral exponent.

We have found that this exponent is higher over ocean than over land and increases with increasing degree of spatial averaging. It is close to zero at locations in continental interiors and approaches unity for global temperature.

The goal of the present work is to provide a qualitative explanation of this feature and establish the connection to existing knowledge about the modes of natural variability in the climate system. It is obvious that spatial correlations are a prerequisite for the described phenomenon, since aggregation of uncorrelated time series cannot provide stronger persistence than those found in the individual series.

The temporal correlation structure of climate modes like ENSO is similar to an AR(1) process with a characteristic correlation time. By postulating that the surface temperature can be modeled as a superposition of modes of different degree of bipolarity, different spatial extent, and some positive scaling relation between characteristic time and length scales, we can demonstrate that the temporal scaling exponent increases with increased degree of spatial averaging. The mechanism is that spatial averaging reduces the weight of the structures of small spatiotemporal scales and hence the signal will be increasingly dominated by the temporal scaling of the large-scale modes.

Empirical orthogonal function (EOF) analysis applied to the NOAA-CIRES 20th Century Reanalysis data set is one way to demonstrate this mechanism in a given spatiotemporal field. The first EOFs with the accompanying principal components could be interpreted as the “global temperature field,” and their principal components exhibit persistent scaling similar to the globally averaged temperature. The first EOFs are stronger over oceans than over land and hence offer an explanation to why ocean temperatures are more persistent than land temperatures.