Geophysical Research Abstracts
Vol. 13, EGU2011-9956, 2011
EGU General Assembly 2011

Universal Hurst exponent of local and global Earth temperature records?

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Local and global temperature records on time scales from a month up to decades seem to exhibit Gaussian persistent fluctuations which suggest that they can be completely characterized as fractional Gaussian noises with Hurst exponents H >0.5. However, standard tests for long-range memory applied directly to the temperature signals yield relatively low persistence (H ∼0.6) for local records and strong persistence (H ∼0.9) for global surface records. Northern hemisphere sea-surface temperature appears even more persistent on these time scales. This is true for both standard variogram or R/S-analysis as well as detrended fluctuation analysis (DFA).

This wide range of Hurst exponents is puzzling if H is interpreted as a quantity representing a universal characterization of the long-range memory in climatic processes on monthly to decadal time scales. We argue, however, that the spread is due to spuriously high Hurst exponents resulting from standard analysis applied to date that exhibits complex trend patterns like oscillations on different time scales. Even the DFA fails in such cases because first and second order DFA cannot deal with the complex multi-decadal trend pattern, and DFA of fourth order and higher suppresses the fluctuations on annual scales and shorter.

The paradox is resolved by modeling the signals as a fractional Gaussian noise superposed on a multi-decadal trend found by fitting a fourth-order polynomial to the 150 year instrumental temperature records (1860-2010). Subtraction of this trend from the temperature records leaves residuals that are fractional Gaussian noises with roughly the same Hurst exponent (H ∼0.6-0.7) for local as well as global records. The relative amplitude of the stochastic fluctuations compared to the trend signal is much smaller for global than for local records, and is the reason for the spuriously high Hurst exponents for the global records. The fourth order polynomial trend is shown to be clearly statistically significant for global temperature, and involves a sixty-year oscillation superposed on a monotonically rising signal. We argue that the oscillation is part of internal dynamics in the climate system, while the monotonic rise is due to external forcing which most likely is anthropogenic. The residual fluctuations are completely specified by the exponent H which is characteristic for the present state of global climate.

At present, however, it is not known whether this value of the Hurst exponent is the same for other climatic regimes, and it is conceivable that rapid regime shifts associated with glaciations/deglaciations will involve a change in H. Such changes may be studied in high time-resolved paleoclimatic records. Some preliminary results from analysis of such data are presented.