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Performance Tests for Techniques that measure long-range Persistence in Gaussian, log-normal, and Levy distributed Time Series

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Many time series in the Earth Sciences exhibit persistence (memory) where large values (small values) 'cluster' together. Here we examine long-range persistence, where one value is correlated with all others in the time series. A time series is long-range persistent (a self-affine fractal) if the power spectral density scales with a power law. The corresponding scaling exponent beta characterizes the 'strength' of persistence. We compare five common techniques for quantifying long-range persistence in time series: (a) Power-spectral analysis, (b) Wavelet variance analysis, (c) Detrended Fluctuation analysis, (d) Semivariogram analysis, and (e) Rescaled-Range (R/S) analysis. To evaluate these methods, we construct 31,200 synthetic fractional noises with lengths between 512 and 4096, different persistence strengths, and different distributions (Gaussian, log-normal, Levy). We empirically find: (i) Power-spectral and wavelet analyses are very robust for measuring long-range persistence across all beta, although 'antipersistence' is over-estimated for asymmetric distributed time series (log-normal); (ii) Detrended Fluctuation Analysis is appropriate for signals with long-range persistence strength beta between -0.2 and 2.8 and has large 95% confidence intervals for non-Gaussian signals. In addition, we find for Gaussian and log-normal distributions that using different polynomial orders in detrending (DFA2, DFA3, ...) has little influence on the size of the error bars, and recommend using quadratic polynomials (DFA2) for detrending.; (iii) Semivariograms are appropriate for signals with long-range persistence strength between 1.0 and 2.8; it has large confidence intervals and systematically underestimates beta for asymmetric distributed time series (log-normal) in this range; (iv) Rescaled-Range Analysis is only accurate for beta of about 0.7, and systematically under- or over-estimates for other values. We conclude that

some techniques are much better suited than others for quantifying long-range persistence, and the resultant beta (and associated error bars on them) are sensitive to the one point probability distribution, the length of the time series, and the techniques applied.