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Memory in stochastic component and multi-decadal trends of solar activity

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We consider various proxies for solar activity, such as the sunspot number (SSN), the total solar irradiance (TSI) and the solar flare index (SFI) over the last 2-3 solar cycles, and analyze time series of daily data $x(t)$. We demonstrate that these time series can be modelled as a stochastic process of the form $x(t) = y(t) + \sigma\sqrt{y(t)}\, w_H(t)$, where $y(t)$ is the almost periodic 11 year smooth component, and $w_H(t)$ is stationary fractional noise with memory (Hurst) exponent H. Standard Hurst analysis applied directly to a process $z(t)$ discerns the correct H only if the integrated process is *stationary*, and such analysis on these data typically yield $H > 0.9$, which suggests strong long-range memory (LRM) in the data. However, the solar activity time series $x(t)$ is nonstationary due to the smooth component $y(t)$ and does not discern the correct Hurst exponent for the stochastic component.

The problem is resolved by applying the analysis to the detrended signal $z(t) = (x(t) - y(t))/\sqrt{y(t)}$ which is stationary except in those periods close to solar minima where there are days with zero sunspot number. This analysis reveals that the SSN is a fractional Gaussian noise and ensemble simulations of the stochastic model shows that the Hurst exponent with 90% confidence is in the range $0.5 < H < 0.7$, with the most probable value $H = 0.64$. Similar analysis of detrended TSI and SFI shows that they can be modelled as fractional stable noises with somewhat smaller Hurst exponents. The hypothesis $H = 0.5$ (no LRM) is well inside the 90% confidence interval. Since the analysis is limited to the years 1978-2010, and data around solar minima has been excluded, the results are valid only for time scales up to 10^3 days. Effects of solar rotation distort the analysis on time scales shorter than 30 days, so we cannot conclude that the scaling is valid on these short scales. Thus, the memory in the stochastic component of solar activity on time scales $30 < \tau < 10^3$ days is much smaller than reported in most previous studies, and the hypothesis that no LRM exists is not rejected by this analysis.

Trends in solar activity over the last 30 years has been a debated issue in the context of global warming. Fractional noises give rise to spurious trends when these are estimated from a limited data set, i.e. ensemble simulations of finite time series of such noises yield a distribution of trend estimates, and a trend estimated from an observed time series is significant only if it falls outside the confidence limits of this distribution. The linear trends estimated for SNN and SFI over the last three decades are clearly not significant, even for uncorrelated stochastic component ($H = 0.5$). For the TSI there exist a multitude of different composites of satellite data that are subject to revisions all the time, with trend estimates varying in the range $\pm 0.01\%$ per decade. The extremes of these trend estimates are significant if the stochastic component is an uncorrelated stable noise process.