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How well does a minimal monofractal model capture the scaling of extreme bursty fluctuations in space plasmas ?

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Direct inspiration for the investigation of scaling behaviour in space plasmas has come from inherently multiscale physical theories such as self-organised criticality and turbulence. Work in complexity science is now contributing to a better physical understanding of the ways by which the interactions between components of such systems cause driven or random perturbations to be nonlinearly amplified and spread out over a wide range of spatiotemporal scales. These mechanisms thus lead both to non-Gaussian fluctuations and to long-ranged temporal memory (referred to by the late Benoit Mandelbrot as the “Noah” and “Joseph” effects, respectively). An additional benefit of scaling analysis, with “space weather" implications, is an ability to assess the likelihood of an extreme fluctuation of a given size. If present, however, scaling behaviour may not be captured by a single self-similarity exponent H, but might instead require a multifractal spectrum of scaling exponents.

We have elsewhere argued that it is nonetheless useful to try capture the “stylised facts" of the scaling behaviour of auroral indices and solar wind quantities by simple, purely phenomenological, monofractal models. To make this idea more concrete we here illustrate it by studying the use of linear fractional stable motion (LFSM) as a model for solar wind and ionospheric time series. Our example could be taken as a prototype for other possible models. LFSM has only three parameters: the Levy stability exponent α; the self-similarity exponent H; and a persistence exponent d which depends additively on the other two. By postulating an LFSM description we can semi-numerically explore how the previously experimentally measured scaling exponents for quantities like superposed epoch averaged activity, or the probability distribution of the differenced time series, depend on the model parameters. We can then also derive predicted scaling exponents for the exponents of more complicated measurements which have also been made, such as size and duration of bursts above a threshold, or the survival probability of a burst. Comparison of these predictions with data can then used to assess the usefulness of LFSM as a toy model of extreme bursts in space physics time series. The relation to recent work by Moloney and Davidsen, and Rypdal and Rypdal [both JGR, 2010] will be touched on.