Statistical Study of Geomagnetic Disturbances: Power Law Behavior in Frequency Distributions and the SOC Model

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We have conducted a statistical investigation of the AL index. Our detailed analysis supports the following conclusions:

1. The distributions of duration and |AL|max both fit a power law form for small values of these parameters, supporting the probabilistic model description.
2. For larger values, the distributions deviate from the power law form. This suggests that the geomagnetic disturbances described by the AL index have a characteristic time scale.
3. Defining a parameter indicating energy and examining its frequency distribution, we find that it also fits a power law form with a power law index of ~1.0. This means that larger events contribute to the yearly total energy dissipation more than smaller events.

The magnetosphere is a nonlinear system transforming the energy input from the solar wind to energy output through dissipation in the ionosphere or storage in the magnetotail. In order to study nonlinear processes in the magnetosphere, we have conducted a statistical investigation of the AL index. This index has been studied extensively in the past and it has been established that it has two components which respond to the solar wind, one in a linear fashion and one in a non-linear fashion. We have examined the maxima of | AL | for a large number of events working under the assumption that these maximum values are controlled by the nonlinear process and that our study can provide some information on the nature of that process.

Models of the magnetosphere which are dependent on nonlinear processes are electric circuit models (involving deterministic chaos), probabilistic models (involving self organized criticality (SOC) and percolation models). The latter models would predict that the frequency distribution of the sizes of geomagnetic disturbances satisfies a power law distribution, so that by examining the frequency distribution we could judge whether or not those models were appropriate and place some restrictions on them.

We define the size of a geomagnetic disturbance by its duration and the maximum value of |AL| defined for the interval of time when |AL| exceeds a certain threshold value. We derive the frequency distributions using data acquired over a 15 year period from 1978 - 1994 (omitting 1988 and 1989).

Our detailed analysis supports the following conclusions:

1. The distributions of duration and |AL|max both fit a power law form for small values of these parameters, supporting the probabilistic model description.
2. For larger values, the distributions have break points and deviate from the power law form. There is a break point for event durations of ~150 minutes suggesting that the geomagnetic disturbances described by the AL index have a characteristic time scale.
3. Investigating the long term variations, we find that the distributions show significant semi-annual and solar cycle variations.
4. Defining a parameter indicating energy and examining its frequency distribution, we find that it also fits a power law form with a power law index of ~1.0. This means that larger events contribute to the yearly total energy dissipation more than smaller events.