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Substorm and Magnetosphere Characteristic Scales Inferred from the SuperMAG Auroral Electrojet Indices

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A generalization of the traditional 12-station auroral electrojet index, AE, to include more than 100 magnetometer stations, SME, is an excellent predictor of global auroral power, even at high cadence (1-min). We use this index, and a data base of more than 53,000 substorms derived from it, covering 1980-2009, to investigate time and energy scales in the magnetosphere, during substorms and otherwise. We find, contrary to common opinion, that substorms do not have a preferred recurrence rate, but instead have two distinct dynamic regimes, each following a power law. The number of substorms recurring after a time Δt, N(Δt), varies as Δt -1.19 for short times (<80 min) and as Δt -1.76 for longer times (>3 hr). Other evidence also shows these distinct regimes for the magnetosphere, including a break in the power law spectra for SME at about 3 h. The time between two consecutive substorms is only weakly correlated (r=0.18 for isolated and r=0.06 for recurrent) with the time until the next, suggesting quasi-periodicity is not common. However substorms do have a preferred size, with the typical peak SME magnitude reaching 400-600 nT, but with a mean of 656 nT, corresponding to a bit less than 40 GW auroral power. More surprisingly, another characteristic scale exists in the magnetosphere, namely a peak in the SME distribution around 61 nT, corresponding to about 5 GW precipitating auroral power. The dominant form of auroral precipitation is diffuse aurora, thus these values are properties of the magnetotail thermal electron distribution. The characteristic 5 GW value specifically represents a preferred minimum below which the magnetotail rarely drops. The magnetotail experiences continuous loss by precipitation, so the existence of a preferred minimum implies driving which rarely disappears altogether. Finally, the distribution of SME values across all times, in accordance with earlier work on AE, is best fit by the sum of two distributions, each normal in log(SME). The lower distribution (with a 40% weighting) corresponds to the characteristic quiet peak, while the higher value distribution (60% weighting) is an average over the characteristic substorm peak and the subsequent prolonged recovery.