Extreme Birkeland currents are more likely during geomagnetic storms on the dayside of the Earth

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We combine methods to identify substorms and geomagnetic storms into a single, novel method that identifies four categories: quiet times, storm only, substorm only, substorms in storms. We employ Birkeland current density data from the Active Magnetosphere and Planetary Electrodynamics Response Experiment (AMPERE) between 2010–2017 and use our new combined identification method to sort data in this range into one of the four categories. We then subsample such that each category comprises the same number of data, in order that each category behaves statistically similarly.

We then examine the large global behaviour of each category for the first time. We find that the mean current density is larger during substorms and its standard deviation is larger during geomagnetic storms. We assess the kurtosis and variance of the underlying distributions, and determine that the kurtosis is far higher during geomagnetic storms than during substorms. We use the survival function to quantify the probability of current densities above set thresholds and find that current densities which are above a low threshold are more likely during substorms, but that extreme currents are far more likely during geomagnetic storms.

We shift the data into an adaptive coordinate system defined by the boundary between Regions 1 and 2 Birkeland current and demonstrate that extreme currents are most likely to flow within Region 2 current during geomagnetic storms. This is consistent with the literature on geomagnetic storms driving extreme behaviour, but unexpected in a paradigm of the current systems in which Region 1 current is generally larger.