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Observational constraints on the climate of space weather and implications for the upcoming solar maximum

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Space weather is driven by the sun and how the sun's expanding atmosphere (the solar wind) interacts with earth's own plasma environment. The sun has a roughly 11 year cycle with space weather at its most active at solar maximum. However, each solar cycle has a different maximum level and duration, which is reflected in space weather activity levels at earth. Observations of both in-situ solar wind parameters and geomagnetic indices are available over the last five solar cycles. We looked [1] across these to quantify how the full distribution of observed values varies between and across solar cycle phases and found that whilst the overall amplitude of activity does vary with each distinct solar maximum, the larger excursions of parameters that characterize space weather follow an underlying distribution that does not change from one solar maximum to the next. Our results may inform what the level of space weather activity may be in the next upcoming solar maximum.

To look across more solar cycles we analyse the aa index, which tracks the geomagnetic response at the earth's surface, over the last 14 solar cycles. We find that the largest 1% and 0.1 % of aa values (the 99th and 99.9 th percentiles) all occurred within a well defined region of aa and sunspot number, there is both a lower and an upper limit to the high percentiles of aa. The largest geomagnetic storms generally correspond to the 99.9 aa percentile being well above 200nT, a value that was not reached during the last anomalously weak solar cycle. Possible implications for the upcoming solar maximum will be discussed.

We need to know how frequent, long-lasting, and intense large-scale disruptive events are likely to be and how this changes as space weather changes with the solar cycle. Since these are by definition rare events, it is challenging to obtain this information directly from observations. We have sufficiently high time (minute) resolution observations if solar wind parameters in-situ to directly characterize bursts in the timeseries over the last two solar cycles. We analysed this data and found that whilst burst event intensity and duration both vary with solar cycle changes in activity, there is a relationship between them that does not change [2]. Event intensity predicts event duration and vice versa. This provides a constraint on the potential impact of space weather events and is a check on models. It may even be useful in real-time characterization of space weather events.

[1] S. C. Chapman, N. W. Watkins, E. Tindale, Reproducible aspects of the climate of space weather over the last five solar cycles, Space Weather, (2018)DOI:10.1029/2018SW001884

[2] E. Tindale, S. C. Chapman, N. R. Moloney, and N.W. Watkins, The dependence of solar wind burst size on burst duration and its invariance across solar cycles 23 and 24, JGR, (2018) DOI: 10.1029/2018JA025740