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Historic geomagnetic storm drivers determined exclusively from ground-based magnetometer measurements

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Geomagnetic disturbances at the Earth are mainly driven by two large-scale solar wind structures. Of most relevance to space weather are interplanetary manifestations of coronal mass ejections (ICMEs), their associated shocks, sheaths, magnetic clouds and ejecta. The second driver are co-rotating interaction regions (CIRs), together with recurring high speed streams. These structures have characteristic solar wind speed (v), magnetic field (B_{sw}), plasma and compositional signatures, which can be identified in-situ by near-Earth satellite measurements (e.g. Wind, ACE). As geomagnetic activity responds closely to $v \cdot B_{sw,z}$ ("driving electrical field"), ICMEs and CIRs trigger different signatures in activity indices derived from ground-based magnetometer measurements (e.g. Dst). Spanning more than 10 solar cycles, geomagnetic observatory time series offer a quantitative (statistical) approach to the identification of geomagnetic storm drivers in addition to the qualitative one based on satellite data.
We present a feasibility study investigating the capability of geomagnetic observatory data to predict geomagnetic storm drivers in the past, prior to the satellite era. Our analysis is based on the Hourly Magnetospheric Currents (HMC) index (Pick et al., JGR, under revision) and the underlying observatory time series. HMC's correct absolute level and the high power at low frequencies, especially at the 11-year period, justify its preference over other indices. First, geomagnetic storm events are identified based on a HMC threshold, scaled according to the solar cycle phase (target set, since 1930). Secondly, events with known drivers are gathered from the literature (training set, since 1995) and superposed at HMC peak times in order to identify distinguishing model features. These are derived from five basic properties: (1) HMC, (2) dHMC/dt, (3) B(MLT) - the main magnetic field disturbance in dependence on magnetic local time, (4) dB/dt and (5) ASY$_{dd}$ - the difference in B at dawn (6 MLT) and dusk (18 MLT). Lastly, the binary classification problem, 0: CIR-driven or 1: CME-driven, is solved by training and cross-validating a logistic regression model on the training set. The prediction step is subsequently applied to the target set, yielding the driver class and its probability for each event. We assess the capability of the classifier and discuss, whether our findings can contribute beyond an application in the past to the study of geomagnetic storm drivers today.