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New Insights into the Estimation of Extreme Geomagnetic Storm Occurrences

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Space weather events such as intense geomagnetic storms are major disturbances of the near-Earth environment that may lead to serious impacts on our modern society. As such, it is of great importance to estimate their probability, and in particular that of extreme events. One approach largely used in statistical sciences for extreme events probability estimates is Extreme Value Analysis (EVA). Using this rigorous statistical framework, estimations of the occurrence of extreme geomagnetic storms are performed here based on the most relevant global parameters related to geomagnetic storms, such as ground parameters (e.g. geomagnetic *Dst* and *aa* indexes), and space parameters related to the characteristics of Coronal Mass Ejections (CME) (velocity, southward magnetic field component, electric field). Using our fitted model, we estimate the annual probability of a Carrington-type event (Dst = -850nT) to be on the order of 10^{-3}, with a lower limit of the uncertainties on the return period of $\sim$500 years. Our estimate is significantly higher than that of most past studies, which typically had a return period of a few 100 years at maximum. Thus precautions are required when extrapolating intense values. Currently, the complexity of the processes and the length of available data inevitably leads to significant uncertainties in return period estimates for the occurrence of extreme geomagnetic storms. However, our application of extreme value models for extrapolating into the tail of the distribution provides a mathematically justified framework for the estimation of extreme return periods, thereby enabling the determination of more accurate estimates and reduced associated uncertainties.