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Comparison of the most intense storms and substorm periods since year 2000

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Extreme Geomagnetically Induced Currents (GIC) occur during active geomagnetic conditions and are considered as an important space weather phenomena. It is important for GIC forecasts to determine whether extreme GICs are observed during the periods of extreme storms or substorms and whether such extreme storms and substorms occur simultaneously. As a first step, the presented study aims to find the most extreme geomagnetic periods in the Cluster era since 2000 in order to examine the storm/substorm relationship and whether the extreme storms consist of a sequence of extreme substorms. Geomagnetic activity was investigated according to the different activity indices and it was shown that there is a large discrepancy in the top extreme events subsets and events ranking based on the indices derived from magnetic field measurements at stations from different latitudes. Particularly, one of the worst correlations between the ranks of the geomagnetically active periods was between extreme storm periods (based on the Dst index) and extreme substorm periods (based on the AL index), with the rank correlation coefficient for top 100 events of 0.4. This result highlights that extreme storms do not always include extreme sub-storms, and extreme substorms can occur during medium or weak storms. This finding also suggests that the extreme substorm periods might be important for the occurrence of the GICs at high latitudes which are likely caused by auroral electrojet systems.

Dependencies from the solar wind parameters and solar wind drivers in form of the Interplanetary Coronal Mass Ejections (ICME) and Corotating Interaction Regions (CIR) also have been examined and it was shown that both the most extreme storms and substorms are driven by ICMEs, however a number of extreme substorms are not associated with the ICMEs or CIRs. It was also shown that the most intense storms occur near the solar maximum, while the most intense substorms are more evenly distributed across the solar cycle, although none of the extreme events occurred near the solar minimum.