Investigation of Dynamical Complexity in Swarm-Derived Geomagnetic Activity Indices Using Information Theory

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ESA's ongoing Swarm satellite mission provides a unique opportunity for gaining better knowledge of the near-Earth electromagnetic environment by identifying and measuring magnetic signals from the Earth's core, mantle, lithosphere, oceans, ionosphere, and magnetosphere. Additionally, Swarm data are used to study the solar influence on the Earth system by analyzing electric currents in the magnetosphere and ionosphere and understanding the impact of solar wind on the dynamics of the upper atmosphere. Swarm currently offers one of the best-ever surveys of the Earth's core and crustal magnetic field as well as the near-Earth electromagnetic environment. Ground-based geomagnetic activity indices have been used for decades to monitor the dynamics of the Earth's magnetosphere, and provide information on two major types of space weather phenomena, that is, magnetic storm and magnetospheric substorm occurrence and intensity. We have been recently demonstrated how magnetic field data from the Swarm constellation can be used to derive corresponding space-based geomagnetic activity indices. Recently, many novel concepts originated in dynamical systems or information theory have been developed, partly motivated by specific research questions linked to geosciences, and found a variety of different applications. Here, we apply information theory approaches (i.e., Hurst exponent and a variety of entropy measures, including Tsallis entropy) to analyze the Swarm-derived magnetic indices from 2015, a year that includes 3 out of 4 most intense magnetic storm events of the previous solar cycle, including the strongest storm of solar cycle 24. We show the applicability of information theory to study the dynamical complexity of the upper atmosphere around storms, through highlighting the temporal transition from the quiet-time to the storm-time magnetosphere, which may prove significant for space weather studies.