



Dynamical Complexity in Swarm-Derived Storm and Substorm Activity Indices Using Information Theory: Further Evidence for Interhemispheric Asymmetry

Constantinos Papadimitriou^{1,2}, Georgios Balasis¹, Adamantia Zoe Boutsis^{1,2}, Stelios Potirakis³, Ioannis A. Daglis^{4,2,1}, and Omiros Giannakis¹

¹National Observatory of Athens, IAASARS, Athens, Greece (constantinos@noa.gr)

²National and Kapodistrian University of Athens, Athens, Greece

³University of West Attica, Athens, Greece

⁴Hellenic Space Center, Athens, Greece

In November 2023, the ESA Swarm constellation mission celebrated 10 years in orbit, offering one of the best-ever surveys of the topside ionosphere. Among other important achievements, it has been recently demonstrated that Swarm data can be used to derive space-based geomagnetic activity indices. These can be used like the standard ground-based geomagnetic indices for monitoring magnetic storm and magnetospheric substorm activity. Given the fact that the official ground-based index for the substorm activity (i.e., the Auroral Electrojet – AE index) is constructed by data from 12 ground stations, solely in the northern hemisphere, it can be said that this index is predominantly northern, while the Swarm-derived AE index may be more representative of a global state, since it is based on measurements from both hemispheres. Recently, many novel concepts originated in time series analysis based on information theory have been developed, partly motivated by specific research questions linked to various domains of geosciences, including space physics. Here, we apply information theory approaches (i.e., Hurst exponent and a variety of entropy measures) to analyze the Swarm-derived magnetic indices around intense magnetic storms. We show the applicability of information theory to study the dynamical complexity of the upper atmosphere, through highlighting the temporal transition from the quiet-time to the storm-time magnetosphere, which may prove significant for space weather studies. Our results suggest that the spaceborne indices have the capacity to capture the same dynamics and behaviors, with regard to their informational content, as the traditionally used ground-based ones. A few studies have addressed the question of whether the auroras are symmetric between the northern and southern hemispheres. Therefore, the possibility to have different Swarm-derived AE indices for the northern and southern hemispheres respectively, may provide, under appropriate time series analysis techniques based on information theoretic approaches, an opportunity to further confirm the recent findings on interhemispheric asymmetry. Here, we also provide evidence for interhemispheric energy asymmetry based on the analyses of Swarm-derived auroral indices AE North and AE South.