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## Rikitake Law, relating precursor time and earthquake magnitude, confirmed by Swarm satellite data

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Rikitake [1987] studied different types of ground earthquake precursors and presented an empirical law (for what he called “precursors of the 1st kind”) expressing a linear relationship between the logarithm of the anomaly precursor time and the earthquake magnitude. To look for possible in-situ ionospheric precursors of large (M5.5+) earthquakes, here we analyse a long-term time series data from the three-satellite Swarm constellation, in particular electron density and magnetic field data. We define the anomalies statistically in the whole space-time interval of interest and use a superposed epoch approach to study the possible relation with the earthquakes. We find some clear concentrations of electron density and magnetic anomalies from several months to a few days before the earthquake occurrences. Such anomaly clustering is, in general, statistically significant with respect to homogeneous random simulations, supporting a coupling of the lithosphere with the above atmosphere and ionosphere during the preparation phase of earthquakes. Finally, by investigating different earthquake magnitude ranges, we confirm the Rikitake empirical law between ionospheric anomaly precursor time and earthquake magnitude. Our work represents the first time that this empirical law has been confirmed for satellite data. We also explain this empirical law with a diffusion model of lithospheric stress.