R006-32
B 会場 ： 11/27　PM1（13:45-15:45）
15:15〜15:30:00

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Ionospheric Joule heating and neutral density variations at low Earth orbits during geomagnetic storms

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During geomagnetic storms intense Joule heating causes thermal expansion of the upper atmosphere, thus increasing satellite drag at low Earth orbits (LEO). This chain of events often begin when high-speed stream/stream interaction regions (HSS/SIR) or interplanetary coronal mass ejections (ICME) impact Earth's space environment. In the "Joule heating effects on ionosphere-thermosphere coupling and neutral density (JOIN)" project we determine the statistical distribution of the auroral Joule heating in the northern hemisphere during geomagnetic storms using SuperMAG, SuperDARN and AMPERE data. This is compared with the large-scale atmospheric density variations at LEO observed by the Swarm, GRACE and GRACE-FO satellites.

Based on superposed epoch analysis of 231 geomagnetic storms between 2014 and 2024, it is found that the Joule heating in the ionospheric E-region and neutral density enhancements at LEO show different characteristics depending on the geomagnetic storm driver. The Joule heating has a faster increase at the beginning of the storm main phase when the storm is initiated by a HSS/SIR or sheath region of ICMEs, while a more gradual and longer lasting increase is found in storms driven by magnetic clouds within ICMEs. The thermospheric density enhances gradually during the storm main phase and the enhancements are typically largest (median peak increase of 120%) and longest-lasting for storms driven by MC due to the prolonged interval of intense Joule heating.