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#井上　一成 [1], 藤本　晶子 [2]
[1] 九工大,[2] 九工大

Effects of CME-driven and CIR-driven storms to satellites and debris orbital decay

#Issei Inoue[1],Akiko Fujimoto[2]
[1]Kyutech Institute of Technology,[2]Kyushu Institute of Technology

Space weather refers to the environmental conditions near the Earth as influenced by solar activity, and is closely related to our daily lives. For example, solar flare is a typical space weather phenomenon and can cause malfunctions of spacecraft flying near the Earth. Various Space weather phenomena especially affect the plasma environment in the upper atmosphere, known as the ionosphere. As, a recent sever space weather impact related to the ionosphere, February in 2022, a geomagnetic storm caused by CME knocked out about 40 satellites of SpaceX Starlink network shortly after launch. The February CME-driven geomagnetic storm created a disturbance in the upper atmosphere that enhanced satellite drag conditions and reduced satellite stability, leading to the loss of 38 satellites. In other words, most of the satellites were forced into lower levels of the atmosphere where they burned up.

Recent increase in the number of near-Earth flying objects means an increase in the risk of collisions between flying objects, such as satellites and debris, and their re-entry into the atmosphere, causing them to fall to the ground. Engineering approaches include satellite operation planning and satellite design to prevent further increase of space debris.

On the other hand, as a space weather research approach, it is important to estimate the scale of influence of space weather phenomena (especially, magnetic storms), which are external factors of orbital change and decay of satellite and debris, and to monitor there orbits by using appropriate space weather-induced orbital decay effect prediction models. This study addresses the latter perspective.

We investigated the relationship between space weather and debris parameters (Dst, IMF Bz, debris size, inclination and initial altitude) and orbital decays of satellite and debris during 55 magnetic storms occurring from 2006 to 2018. The 55 magnetic storms include both CME-driven and CIR-driven storms. We divided them to two groups corresponding to the source of storms and analyzed the effect of the size, inclination and initial altitude of satellites or debris to the orbital decays. During the analysis period, we found the long-duration large-amplitude IMF Bz, as a proxy of the Rule heating effect to the thermospheric dynamics and composition, significantly associated with large decay events. We will discuss the influence of CME-driven and CIR-driven magnetic storms on satellite and debris decays in the short, medium, and long term in terms of space weather.