6th Asia-Pacific Conference on Plasma Physics, 9-14 Oct, 2022, Remote e-conference

Inner Radiation Belt Modeling for Space Weather Applications

Kirolosse Girgis[1], Tohru Hada[2,1], Akimasa Yoshikawa[3,1] and Shuichi Matsukiyo[2,1]

[1]International Research Center for Space and Planetary Environmental Science (I-SPES), Kyushu University, Japan, [2]Department of Advanced Environmental Science and Engineering, Faculty of Engineering Sciences, Kyushu University, Japan, [3]Department of Earth and Planetary Sciences, Graduate School of Sciences, Kyushu University, Fukuoka, Japan

e-mail (speaker): girgiskirolosse@esst.kyushu-u.ac.jp (Kirolosse M. Girgis)

Abstract

The Low-Earth Orbit (LEO) space missions are regularly subject to radiation risks when passing through the inner radiation belt. As a matter of fact, the South Atlantic Anomaly (SAA) and the high-latitude regions represent the most relevant radiation issues for space mission design. In addition, both regions are significantly affected by space weather. In our research project, we have developed several test particle simulation codes to simulate the inner radiation belt response with respect to various space weather conditions to study the proton flux variations and the corresponding radiation effects at the Low-Earth orbits. The background magnetic field was generated by Tsyganenko model combined with IGRF-12 model. We found that during a geomagnetic storm, the computed proton flux was significantly enhanced by about 50% in the southern cell of the SAA in its recovery phase [1]. Moreover, we have found that during equinox, the proton flux inside the SAA was increased by about 70% in comparison to other seasons along the year [2]. The previous numerical results did agree with satellite measurements.

In this work, we have modelled the proton flux distribution at the high-latitude regions in addition to the SAA for different geomagnetic storm conditions using numerical simulations.

It is known that during geomagnetic storms the proton flux in the high-latitude regions is intensified and is moving to lower latitude range due to the closer approach of the inner radiation belt. This phenomenon had been widely reported by observations such as [3] [4], but not adequately modelled by the semi-empirical models AP8.

Using the same test particle simulation code, we extended the proton flux study in the LEO environment. Then, we assessed the corresponding radiation effects on LEO and Polar Orbiting missions.

Simulation results successfully reproduced the enhancement of the high-latitude proton flux bands during geomagnetic storms. In addition, during intense geomagnetic storms (|Dst|=210 nT), the probability of the occurrences of the Single Event Upset (SEU) rates for a LEO mission were increased by 20%.

References

[1] Girgis et al. (2021). Inner radiation belt simulations of the proton flux response in the South Atlantic Anomaly during the Geomagnetic Storm of 15 May 2005. Journal of Space Weather and Space Climate,11(48), 1-10.https://doi.org/10.1051/swsc/2021031

[2] Girgis et al. (2022). Seasonal variation and geomagnetic storm index effects on the proton flux response in the South Atlantic Anomaly by test particle simulations. Journal of Atmospheric and Solar-Terrestrial Physics,228(105808),1-9.https://doi.org/10.1016/j.jastp.2021.105808

[3] Falguere et al. (2000). In-fight observations of the radiation environment and its effects on devices in the SAC-C polar orbit. IEEE Transactions on Nuclear Science,49(6),2782-2787.https://doi.org/10.1109/TNS.2002.805380

[4] Pierrard et al. (2014). The energetic particle telescope: First results. Space Sci. Rev.,184, 87-106. https://doi.org/10.1007/s11214-014-0097-8

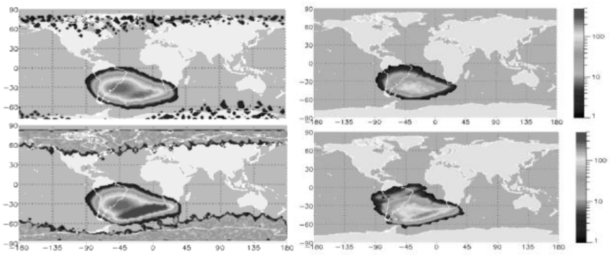

Figure 1: The two left panels show mappings of 10 MeV proton flux measured by ICARE instrument before the geomagnetic storm event of March 2001 (top) and after (bottom). The two right panels show mappings of 9.4 MeV proton flux predicted by AP8-min (bottom) and AP8-max (top) [1].

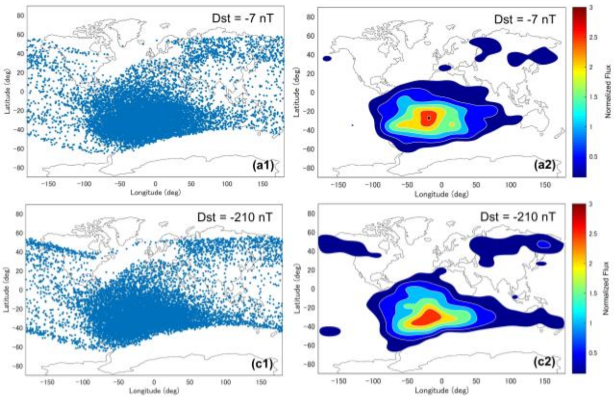

Figure 2: The left panels display proton distribution during quiet and active geomagnetic conditions; right panels visualize the corresponding proton flux maps.