Available online at www.sciencedirect.com

ScienceDirect

Advances in Space Research 53 (2014) 233–236

ADVANCES IN SPACE RESEARCH
(a COSPAR publication)

www.elsevier.com/locate/asr

Space radiation environment in low earth orbit during influences from solar and geomagnetic events in December 2006

H. Koshiishi *

Japan Aerospace Exploration Agency, Tsukuba, Japan

Received 30 May 2013; received in revised form 31 October 2013; accepted 2 November 2013
Available online 13 November 2013

Abstract

In low earth orbit, the SAA region is the dominant contributor to both proton environment and electron environment from the standpoint of radiation dose for spacecraft lifetime. However, the polar region and the horn region are sometimes strongly disturbed due to large solar and geomagnetic events. During large disturbances, enhancements in proton flux are measured in the polar region, which gives temporary more severe space radiation environment than that given in the SAA region. On the other hand, enhancements in electron flux are measured mainly in the horn region corresponding to the outer radiation belt, which are likely sources of high-energy electrons in the inner radiation belt. These short-term disturbances have another radiation hazard to spacecraft such as single event and electrostatic discharge.

Keywords: Space environment; Space weather; Radiation belt; Low earth orbit

1. Introduction

Space radiation environment in low earth orbit is less severe as compared with that at Geo-Stationary orbit because of shielding effects of the geomagnetic field and the atmosphere. However, space radiation environment both in the polar region and the horn region is sometimes strongly disturbed due to large solar and geomagnetic events, in addition that the SAA (South Atlantic Anomaly) region always has radiation influence. (In this study, area having geomagnetic cut-off rigidity lower than 1 GV, and having L-value between 3 and 8, are defined as the polar region and the horn region, respectively.) In this paper, space radiation environment in low earth orbit during influences from solar and geomagnetic events in December 2006 is reported.

2. Measurements

The ALOS satellite (Advanced Land Observing Satellite: so-called Daichi in Japanese) was developed by the JAXA (Japan Aerospace Exploration Agency), launched on 24th January 2006, and had been operated until 12th May 2011 for about 5 years. The orbital parameters of this satellite were 700-km altitude, 98° inclination, and 46-day recurrent period. The TEDA (Technical Data Acquisition Equipment) was on board this satellite for measurements of protons in the energy range from 1 MeV to 250 MeV and electrons in the energy range from 0.1 MeV to 10 MeV with 1-s temporal resolution. The field of view pointed 45° inclined from the zenith in the opposite direction of satellite movement (Koshiishi and Matsumoto, 2013). In this study, energy range at around 10 MeV for protons and 1 MeV for electrons are chosen to evaluate space radiation environment, because particles in these energy range have highest population among particles that can penetrate spacecraft walls.

The sensor of the TEDA consists of SSD (Solid State Detector), and adopts ΔE-E method for particle discrimination. The response of SSD to incident particles is very simple as compared with that of scintillator. Then, severe contamination from high-energy particles is not observed in those energy range. Flux counts obtained in plural consecutive channels around those energy range are also

---

* Tel.: +81 50 3362 4508.
E-mail address: koshiishi.hideki@jaxa.jp

0273-1177/$36.00 © 2013 COSPAR. Published by Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.asr.2013.11.014

integrated to avoid contaminations from adjacent channels. Thus, influences of contamination on particle discrimination in this study are very faint and negligible.

Additionally, data at Geo-Stationary orbit is used, which is obtained by the SDOM (Standard Dose Monitor) on board the DRTS satellite (Data Relay Test Satellite: so-called Kodama in Japanese) (see JAXA; SEES).

3. Results

Fig. 1 and Fig. 2, respectively, illustrate the geographic distributions of proton flux and electron flux averaged from 2006 through 2011 except strongly disturbed period by large solar and geomagnetic events. The distributions are, in principle, determined by the geomagnetic cut-off rigidity distribution except in the SAA region that corresponds to the inner radiation belt. Both proton flux and electron flux become higher as the rigidity goes lower. The distribution of electron flux also shows the horn region that corresponds to the outer radiation belt. In low earth orbit, the SAA region is the dominant contributor to both proton environment and electron environment from the standpoint of radiation dose for spacecraft lifetime.

However, short-term disturbances of space radiation environment in the polar region and the horn region have another radiation hazard to spacecraft such as single event and electrostatic discharge (e.g. Hastings and Garrett, 1996). Though the operation period of the ALOS satellite corresponded to solar-activity minimum period, several GOES X-class solar flares occurred, some of which were followed by large proton events and geomagnetic storms that strongly disturbed space radiation environment. Most influence events among them were the X9 solar flare associated with large proton event on 5th December 2006, and the X3 solar flare followed by large geomagnetic storm on 13th December 2006 (e.g. Myagkova et al., 2009; Malandraki et al., 2009). Fig. 3 and 4, respectively, demonstrate the geographic distributions of the enhancements in proton flux and electron flux due to the solar and the geomagnetic events. Both proton environment and electron environment in the polar region were disturbed directly by the solar event. For electron environment, the horn region was also disturbed by the geomagnetic event. (Both solar flares were followed by proton events. In case of the X9, temporal variation of electron flux was very similar to that of proton flux in the polar region. On the other hand, in case of the

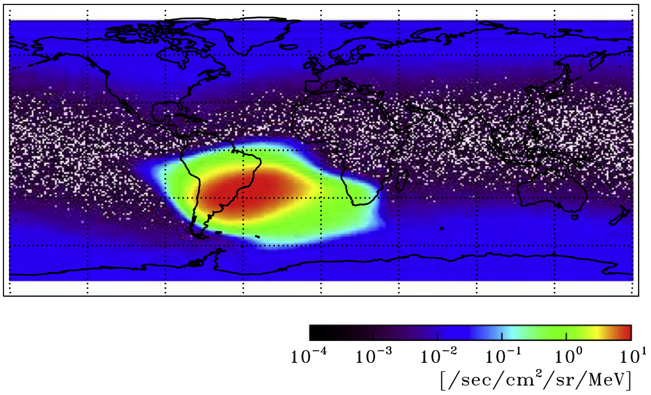

Fig. 1. Geographic distribution of proton flux in energy range from 7 MeV to 18 MeV averaged from September 2006 through February 2011.

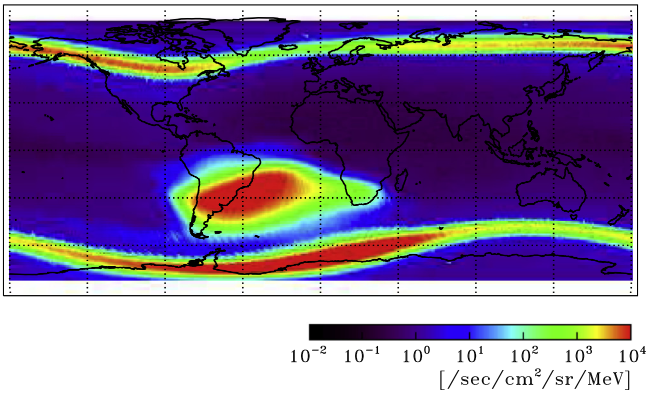

Fig. 2. Geographic distribution of electron flux in energy range from 0.6 MeV to 1.2 MeV averaged from September 2006 through February 2011.

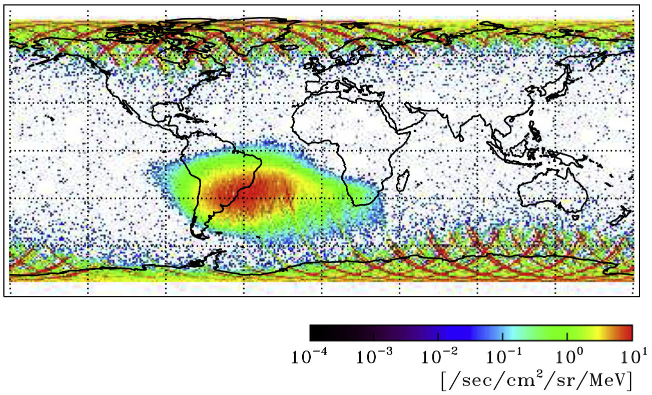

Fig. 3. Geographic distribution of enhancements in proton flux in energy range from 7 MeV to 18 MeV due to solar and geomagnetic events averaged over December 2006.

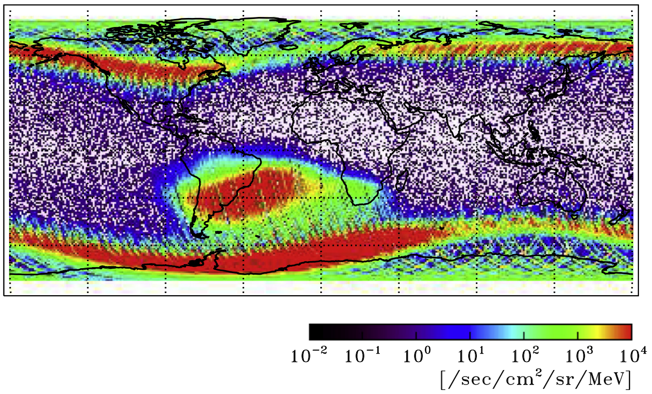

Fig. 4. Geographic distribution of enhancements in electron flux in energy range from 0.6 MeV to 1.2 MeV due to solar and geomagnetic events averaged over December 2006.