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Long-term variation of relativistic electrons at geostationary orbit

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It is well known that highly energetic electron at geostationary orbit altitude flux increases very much when the solar wind velocity is high. However, by closer inspection, the increase of highly energetic electrons likely to have dependence on seasons as well as on IMF (interplanetary magnetic field) polarity. We have examined relativistic electron data obtained by JAXA satellites and confirmed a significant dependence on IMF sector polarity; i.e. a large increase of highly energetic electron flux took place during a toward sector in the spring season, while the increase took place during an away sector in the autumn. This dependence is to be explained by so-called Russell-McPherron effect.

We also examined a long-term variation of highly energetic electrons based on the JAXA satellite data for twenty years. Results demonstrate that total intensity of highly energetic electrons depends on solar activity in a long time scale. We have newly identified that the minimum flux of highly energetic electrons in the last solar cycle was seen in December, 2009, which coincides with the time of the geomagnetic aa index minimum. Actually, highly energetic electron flux at geostationary orbit altitude decreased so much by two orders of magnitude around the December, 2009. The sub-storm activity in that month was minimum by looking at AE index. We are considering that completely no acceleration process took place in that month, resulting in an extremely low flux of energetic electron density.

To consider a basic physics to explain a large increase of relativistic electrons at geostationary orbit altitude, we have referred other satellite data: i.e. GPS and MDS-1, for instance. Results demonstrate that 1) radial increase of energetic electrons took place in low energy first, followed by the increase in higher energy and 2) increase of energetic electrons took place in low L region first, followed by the increase in high L region, showing outward expansion of energetic electrons in terms of L value.

We next examined Pc-5 power to investigate a relationship with a large enhancement of highly energetic electrons. Increase of Pc-5 power starts at the arrival of high speed solar wind and continues for a long time. We checked a correlation of Pc-5 power and highly energetic electron flux. Results demonstrate the increase of highly energetic electrons had a significant time delay with respect to the increase of Pc-5 power; i.e. 2 days. This means that Pc-5 fluctuation may have an important role in the radial diffusion of highly energetic electrons from the center of outer radiation belt to the geostationary orbit altitude. Such expansion was confirmed beyond the geostationary orbit altitude by the quasi-zenith satellite.

One of the major issues remained unanswered is the acceleration process of highly energetic electrons in the outer radiation belt. According to the MDS-1, which is a geostationary transfer orbit satellite, we have confirmed that a peak portion of newly formed outer belt was inversely proportional to the magnetic storm intensity; i.e. a large magnetic storm results the peak position closer to the Earth, while a small magnetic magnetic storm results the peak position far from the Earth. We investigated a spatial distribution of the intensity of very low frequency waves and confirmed that it was strongest at the peak position of highly energetic electrons. We are suggesting that low wave frequency waves have an important role in the acceleration of electrons up to the MeV energy range.

Keywords: relativistic electron, geostationary orbit, long-term variation