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Features of 2017-2018 Solar Proton Events Determined by On-board Measurements at Russian Spacecraft in Geostationary and Polar Orbits

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The paper presents on-board measurements of space radiation characteristics during solar proton events in 2017-2018. The measurements are carried out by the spectrometers on-board Russian spacecrafts in geostationary and polar orbits. The open access GOES data are also used. The solar proton fluxes in geostationary and polar orbits during solar proton events were determined using processed measurements. The single event upset rates were calculated for different events in different orbits using obtained and simulated solar proton spectra. The single event upset rates and solar proton events magnitudes were compared for 2017-2018 and other years of the 24th cycle. The comparison analysis results are addressed in the paper.

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1. Introduction

The space radiation is one of the most important factors which can lead to failure of electronic devices and spacecrafts. According to Goddard Space Flight Center Space Mission Operations Team [1], 59% of Earth and space science missions were impacted by "space weather", including solar and galactic cosmic rays. Half of spacecraft anomalies were caused by space radiation factors [2], [3], and most of them occurred due to electrostatic and single event effects. The latter are driven basically by solar and galactic cosmic rays. So, it is important to monitor solar and galactic charge particles flux in order to estimate the level of space radiation exposure on electronic components and devices. Branch of JSC United Rocket Space Corporation - Institute of Space Device Engineering (Moscow, Russia) used flight data including spectrometers data from Russian Federation spacecraft, which operates in polar orbit 832 km altitude and another spacecraft that operates in geostationary orbit [4]. The in-flight data have been accumulating for more than 5 years (since 2010). In this paper we present processed flight data from these spacecraft and the estimation 2017-2018 solar proton events (SPE) contribution in the space radiation exposure on electronics at polar and geostationary orbits.

2. On-board measurements used

Geostationary orbit spacecraft on-board measurements include fluxes of protons with different energy ranges: from 13.7 MeV to 23 MeV; from 23 MeV to 42 MeV; from 42 MeV to 112 MeV.

Polar orbit spacecraft on-board measurements include total fluxes of protons and electrons with energies: more than 0.7 MeV for electrons and more than 15 MeV for protons, more than 1.5 MeV for electrons and more than 25 MeV for protons, and more than 6 MeV for electrons and more than 600 MeV for protons.

Also we use free access data from GOES [5]: daily integral proton flux with energy more than 10 MeV and 100 MeV.

3. Determination of SPE spectra

To determine SPE spectra at geostationary orbit we use integral daily proton fluxes which are measured by geostationary orbit spacecraft and GOES during events (an event can run on several days). The event start when proton flux with energy more than 10 MeV exceeded the level of 10 proton/cm2/s/sr, the list of SPE can be found for example here [6]. We take into account a background of protons flux (the annual level of proton flux in absence of SPE).

The power dependence is used to approximate the experimental data (it is possible for the energy range under consideration, this range is the most interest because typical electronics components sensitivity to proton exposure lies between 15-50 MeV).

Fig. 1 show an example of derived SPE spectrum from geostationary orbit spacecraft and GOES data at geostationary orbit for 02.01.2016 event. One can see that there is a good agreement of GOES and geostationary orbit spacecraft data, which is observed for all events.

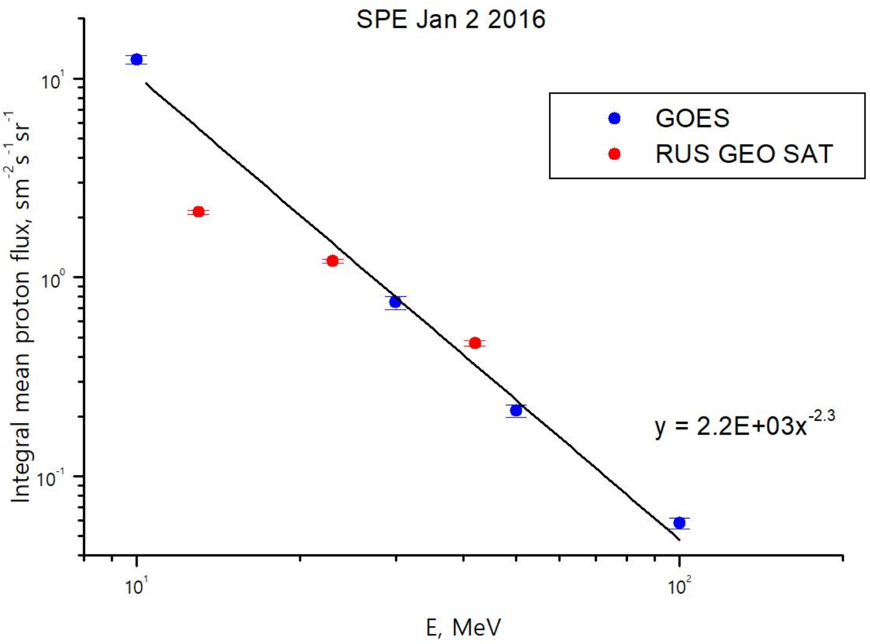

Figure 1: SPE spectrum at geostationary orbit for an 02.01.2016 event (blue points - GOES data, red point - Russian spacecraft in GEO) - good agreement of GOES and Russian spacecraft in geostationary orbit data

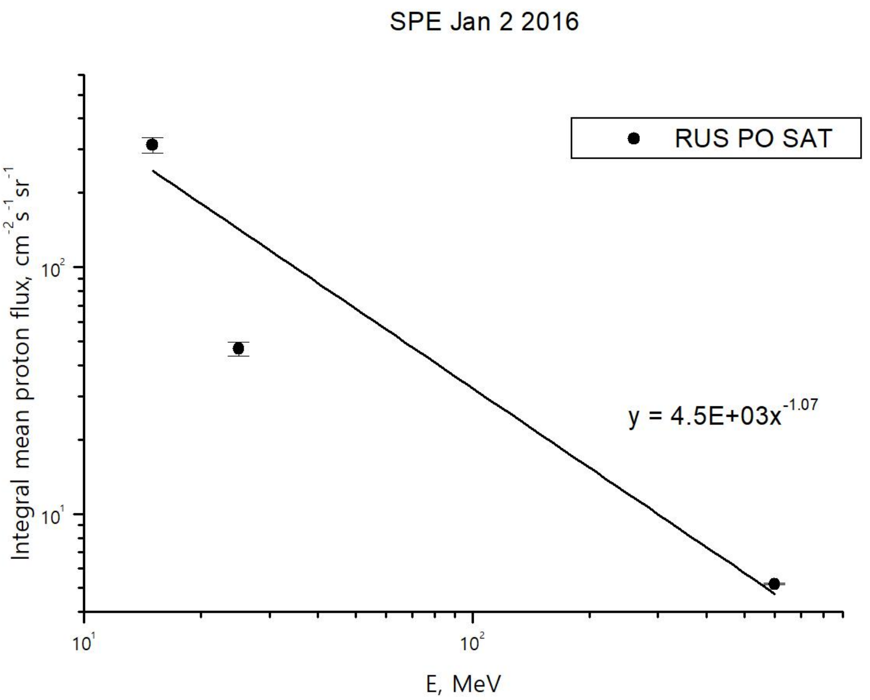

Figure 2: SPE spectrum at polar orbit for 02.01.2016 event by Russian spacecraft

To determine SPE spectra at polar orbit we use averaged integral particles fluxes during th SPE which are measured by polar orbit spacecraft during events. We determine SPE flux during an event as a particles flux in polar regions (L-shell in more than 4), details of the approach is described in [7]. To take into account contaminations of electrons in particles flux we remove background flux, which was calculated as an average particles flux in polar region during 5 days before given event.

Fig. 2 show an example of derived SPE spectrum from Meteor-M data at polar orbit for the same event.

Comparing the graphs, we can see that the value of the spectrum in the polar orbit is less than the value of the spectrum in GSO, which is explained by the rigidity of the geomagnetic cutoff.

4. Derived SPE spectra

Fig. 3 shows maximal SPE spectra at geostationary orbit for different years.

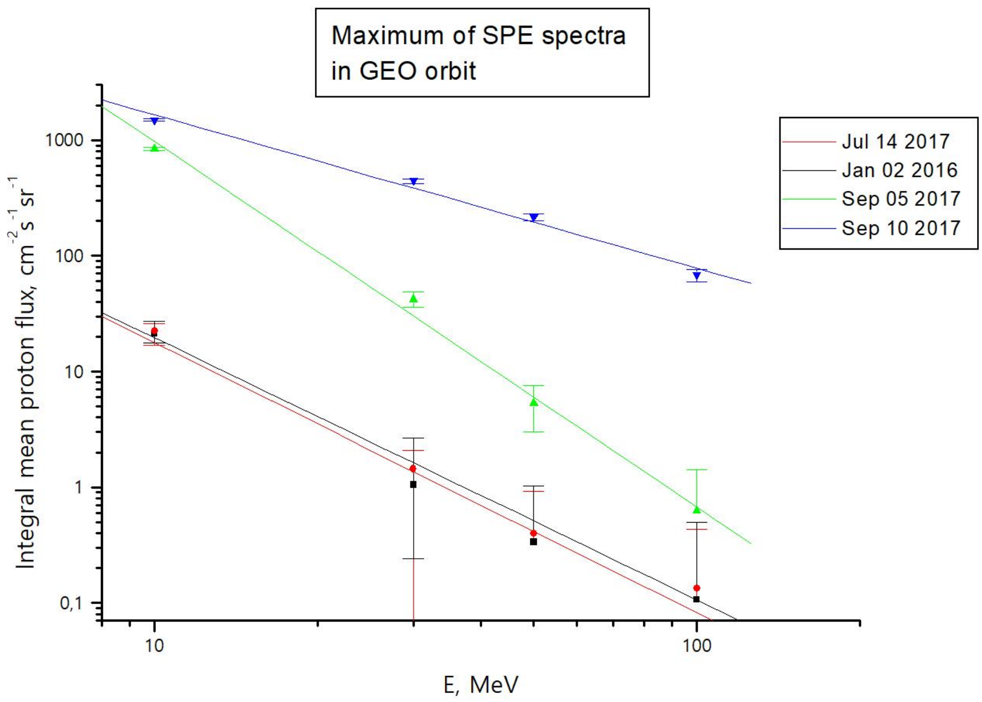

Figure 3: Maximal SPE spectra at geostationary orbit

Analogous selection of SPE spectra at polar orbit are presented in Fig. 4.

During the analysis of the GOES spacecraft data, we founded that there was no SPE events at 2018, so in this work we will limit ourselves to a sample for 2016 and 2017, as well as for 2015 to identify the frequency of single events.

Table 1 shows summary data about maximal characteristics of SPE spectra at geostationary orbit: the most rigid spectrum slope (multiplied by 10), the most spectrum magnitude (logarithm of the magnitude), total number of event, and also yearly mean total sunspot number (divided

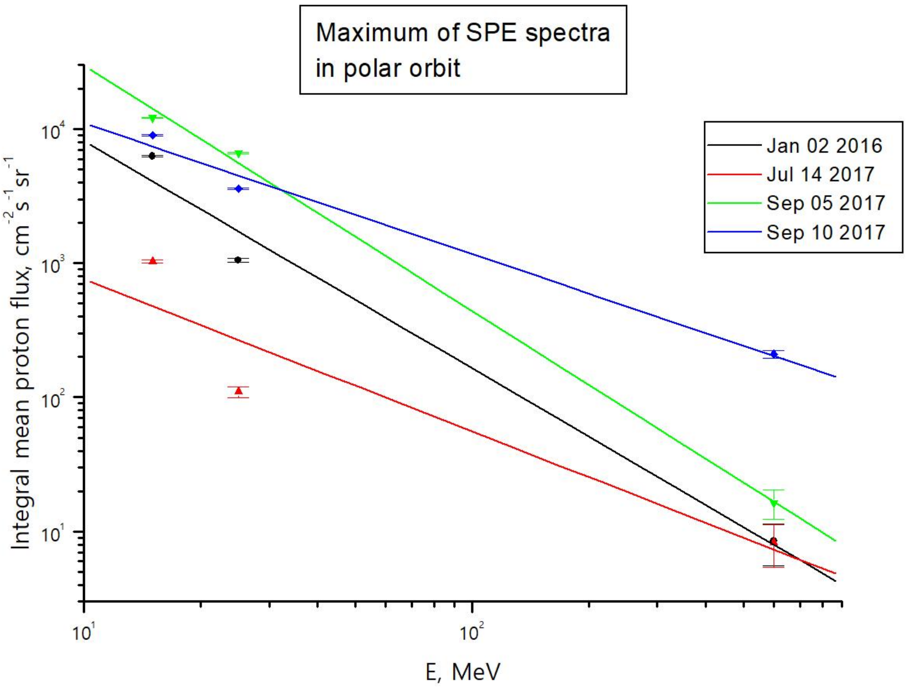

Figure 4: SPE spectra at polar orbit for 02.01.2016 event by Russian spacecraft

on 10) [8]. It is interesting that years with maximal characteristics do not match with year with maximal sunspot number (2016): 2017 has maximal number of events and spectrum magnitude, 2017 - maximal spectrum rigidity. So, SPE spectra characteristics depend on not only solar activity (sunspot number).

Table 1: The most rigid spectrum slope (multiplied by 10), the most spectrum magnitude (logarithm of the magnitude), total number of event, and also yearly mean total sunspot number (divided on 10) for different years

Year	Slope*10	Log (magnitude)	Number of events	SSN/10
2016	14.2	1.1	1.0	5.4
2017	17.5	3.1	3.0	4.3

5. Single event effects rate calculation

To calculate single event rate (SER) we use sensitivity parameters of electronic component, which were determined during radiation test [9], [10]. Calculation results for geostationary and polar orbits are presented in Table 2 and 3

There is a strong variation of SER during one year and four years too. However, SER in 2017-2016 more than 2015. This correlates with the behavior of solar activity during this period.

Table 2: Single events rates during SPE at geostationary orbit for different years

Dates of 2017	SER	Dates of 2016	SER	Dates of 2015	SER
14.07.2017	7,8E-01	02.01.2016	3,4E-01	18.06.2015	2,6E-01
08.09.2017	6,9E-01	total	3,4E-01	22.06.2015	3,5E-01
11.09.2017	6,1E-01			27.06.2015	5,4E-01
total	2.08E+00			29.10.2015	5,0E-01
				total	1,65E+00

Table 3: Single events rates during SPE at polar orbit for different years

Dates of 2017	SER	Dates of 2016	SER	Dates of 2015	SER
14.07.2017	4,5E-01	02.01.2016	2,2E-01	18.06.2015	1,6E-01
08.09.2017	5,4E-01	total	2,2E-01	22.06.2015	2,5E-01
11.09.2017	5,0E-01			27.06.2015	3,5E-01
total	1,49E+00			29.10.2015	4,8E-01
				total	1,24E+00

As can be seen from the tables 2 and 3, the total value of the SER in the polar orbit in 2017 is 1.4 times less than in GEO and 1.5 times less than in 2016, due to the rigidity of geomagnetic cutoff.

6. Conclusions

Solar proton fluxes were determined for different events for several years in 24th solar cycle at geostationary orbit according to measurements of geostationary orbit spacecraft and GOES spacecrafts as well as at polar orbit according to measurements of polar orbit spacecraft. We observed a good agreement between GOES and geostationary orbit spacecraft.

Single events upset rate values were calculated for different events in different orbits using derived solar proton spectra. Analysis results of comparing of solar proton events frequency and magnitude for 2017-2018 years of 24th solar cycle were discussed. We show that solar proton events contribution vary considerably depending on the event and the orbit type.

References

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