Comparison of the simultaneous measurement results of SCR fluxes received by geostationary satellites «Electro-L» and «GOES»

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Abstract. In the present paper the comparison of the results of the simultaneous measurements of solar proton fluxes on board geostationary satellites “GOES” and “Electro” was made for the purpose of calibration of “Electro-L” detectors and determination of the possibility to utilize “Electro-L” data for space weather monitoring. It was shown that the solar proton observation data on board “Electro-L” recalculated to energy thresholds of “GOES” 10 and 30 MeV are in a good consistent with “GOES” data and may be used for control of radiation conditions in near-earth space.

Introduction
Solar Cosmic Rays set of the heliophysical complex of the “Electro-L” spacecraft, designed to measure the flux of the energetic particles, has not passed an appropriate on ground calibration procedure. The lack of reliable information about the energy threshold levels of recorded fluxes and effective areas for various flux energies challenges the opportunity to properly evaluate the degree of radiation hazard for space weather monitoring.

The palliative of the ground calibration is “on-board” one due to measurement data of another detector, taken as the model. In this case, the measurements are taken as the model measurement on a geostationary satellite “GOES”.

For the purpose of calibration of the “Electro-L” detectors the comparison of the data on solar proton events observed with “Electro-L” and “GOES” was made. Here the following circumstances should be taking onto account: the possibility of the different values of the proton flux due to the different spacecraft localizations in space [1]; different values of the background proton fluxes due to the different detector sensitivities; the influence of flux anisotropy on detector display; different times of data averaging used on different satellites.

The data analysis with different times of the data averaging indicates that the minimal time of data averaging, which exceeds 100 seconds, exists for the spacecraft “Electro-L” sensors. We used the averaging corresponding to the averaging of the “GOES” satellite data.

Recalculating formula
For comparision the proton flux data during solar proton events it is necessary to recalculate the data, received by the spacecraft “Electro-L” detectors for three energy channel : 13.5-23 MeV, 23-42 MeV, 42-112 MeV(all these threshold values must be defined more exactly ) to the data which correspond to the spacecraft “GOES” values: 10 MeV, 30 MeV, 50 MeV. We will suppose that if to summ up the values of the three detectors, we will receive the proton flux value in the integral channel with the threshold of 13.5 MeV, if to summ up the values of the second and the third detectors we will receive
the proton flux value in the integral channel with the threshold of 23 MeV, the value of the third detector we will take for the proton flux value in the integral channel with the threshold of 42 MeV. We will suppose that flux value for protons with the energy more than 100 MeV is negligible in the comparison of flux values, registered by the sensors of the spacecraft “Electro-L”.

Supposing power law spectrum for small intervals of the spectrum, we may get the formulae for the calculation the value of the proton flux with the threshold energy \( E_3 \) on the given values of proton fluxes with the threshold energies \( E_2 \) and \( E_3 \) (supposing, that all three energies values relate to the energetic interval with power low spectrum).

These formulae for recalculating the values of fluxes with the threshold energies 13.5, 23 and 42 MeV to the values of fluxes with the threshold energies 10, 30, 50 MeV for “GOES” are:

\[
\begin{align*}
LgI(>10) &= LgI(>13.5) + 0.563 \times (LgI(>13.5) - LgI(>23)); \text{ where } E_2 = 23 \text{ MeV}, E_1 = 13.5 \text{ MeV} \\
LgI(>30) &= LgI(>23) - 0.439 \times (LgI(>23) - LgI(>42)); \text{ where } E_2 = 42 \text{ MeV}, E_1 = 23 \text{ MeV} \\
LgI(>50) &= LgI(>42) - 0.290 \times (LgI(>23) - LgI(>42)); \text{ where } E_2 = 42 \text{ MeV}, E_1 = 23 \text{ MeV} 
\end{align*}
\]

(1)

Comparison of the results of observation.

The values of the recalculating fluxes to energies >10 and >30 MeV, measured on the spacecraft “Electro-L” we compared with the spacecraft “GOES” fluxes. The data of 4 events in 2012 were used.

On figures 1 and 2 the dependences \( Lg(I_{Electro}(>10\text{MeV)}) \) on \( Lg(I_{Goes13}(>10\text{MeV})) \) and \( Lg(I_{Electro}(>30\text{MeV})) \) on \( Lg(I_{Goes13}(>30\text{MeV})) \) are shown (the flux for “GOES” satellite in particle/cm\(^2\)sec sr and the flux for “ELECTRO-L” satellite in counts/sec sr).

![Figure 1](https://via.placeholder.com/150)

Figure 1. The flux values for protons with energy > 10 MeV according to «Electro» data (axis Y) and «GOES» data (axis X). Red dots – flux values for 6.03.2012 event, green dots – flux value for 13.03.2012 event, blue dots – flux value for 23.01.2012 event, black dots – flux value for 27.01.2012 event.

![Figure 2](https://via.placeholder.com/150)

Figure 2. The flux values for protons with energy > 30 MeV according to «Electro» data (axis Y) and «GOES» data (axis X). Red dots – flux values for 6.03.2012 event, green dots – flux value for 13.03.2012 event, blue dots – flux value for 23.01.2012 event, black dots – flux value for 27.01.2012 event.

According the figures the dependencies are linear one’s with a 45 inclination to axis.

For recalculation from the rate in counts/sec to the flux in particle/cm\(^2\)sec sr we have plotted the linear dependencies with the minimum dispersion on the Y-axis (for all dots besides dots on the
rise phase of proton event, dots when the flux values were small <2 part/cm²/sec, dots when the fluxes were disturbed during magnetic storms).

In this case the coefficient of recalculation is determined by formula:

\[ \text{LgK} = \text{Lg} I_{\text{Electro}(>E)} - \text{Lg} I_{\text{Goes13}(>E)} \]

Here the brackets mean the averaging on data of observation.

The calculated coefficients values for the proton fluxes with energy thresholds 10 and 30 MeV are approximately the same and are equal to 9 and 10, respectively. This justifies the conversion from differential channels of “Electro-L” satellite to integral one’s which was made in our calculation first. Also in this case of the energetic spectra for proton fluxes observed with both satellites detectors have to coincide. This really takes place besides the rise phase of the proton event.

To define more exactly the energy threshold values of “Electro-L” satellite detectors the time profiles of the proton fluxes during the events should be compared for both space crafts. If the time profiles obtained with “Electro-L” detectors are expanded or compressed along the time axis in comparison with time profiles obtained with “GOES” detectors, so the values of energy thresholds should be changed (for solar proton events with energy dispersion).

We have compared the time profile for four proton events in 2012 year. The time profiles for 2 events obtained with “GOES” satellite detectors and with “Electro-L” satellite detectors with recalculation to energies >10 and >30 MeV and shown on figures 3 and 4.

![Figure 3](image-url)  
**Figure 3.** The time profile of the proton fluxes with energy >10 MeV (upper curves) and >30 MeV (lower curves) obtained with “GOES-15” detectors (red curves) and “Electro-L” detectors (black curves) for the event 23.01.2012.

As we can see from these figures, the time profiles are not expanded or compressed along the time axis and then the energy threshold values of “Electro-L” should not be changed. Using the recalculating coefficient, received from analysis of the solar proton event data, to the recalculating of the background fluxes obtained with “Electro-L” detectors shows that background fluxes equal to 1-2 particle/sm²/sec, that exceeds by order of magnitude the real background values 0.1-0.01 particle/cm²/sec (according data from “GOES” satellite). Hence it follows that observing with “Electro-L” satellite the background values are due to the detected devices noises.
Conclusion.
The comparative analysis of the observation solar proton event data obtained with the “Electro-L” and “GOES” satellites shows that:
1) The background values for proton fluxes observing with “Electro-L” satellite are equal 1-2 particle/cm$^2$secsr and are due to the detector devices noises.
2) A linear dependence exists for the “Electro-L” satellite data in counts/sec and in particle/cm$^2$secsr in the interval of intensity from 2 particle/cm$^2$secsr to 10$^3$ particle/cm$^2$secsr.
3) As it follows from similarity of the solar proton event time profiles obtained with “GOES” and “Electro-L” satellites the threshold values of the “Electro-L” satellite detector in 13, 5, and 23 MeV are corrected and should not be changed.
4) The geometric factors for detectors registered protons in energy channels 13, 5-23 MeV and 23-42 MeV are approximately the same. The recalculating coefficients from data in counts/sec to data in particle/cm$^2$secsr are equal 9 and 10, respectively.
5) The dispersion of the proton flux values for the “Electro-L” and “GOES” satellites doesn’t exceed 100 % of value for the proton energy more than 10 MeV and 50 % for the proton energy more than 30 MeV.
6) The discrepancy can be much more during the rise stage of the proton event what may be due to the anisotropy of the proton fluxes and the hard energy spectrum of event on this stage. But this question should be studied further.

References:
[1] Gecelev I V, Podzolko M V and Veselovsky I S 2009 Solar System Research 43 145-151.
[2] Burov V A and Ochelkov Yu P 2007 Advances in Space Research 39 1109-1114.