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Problems of reliability of the SEP data

SEP measurements on Electro-L

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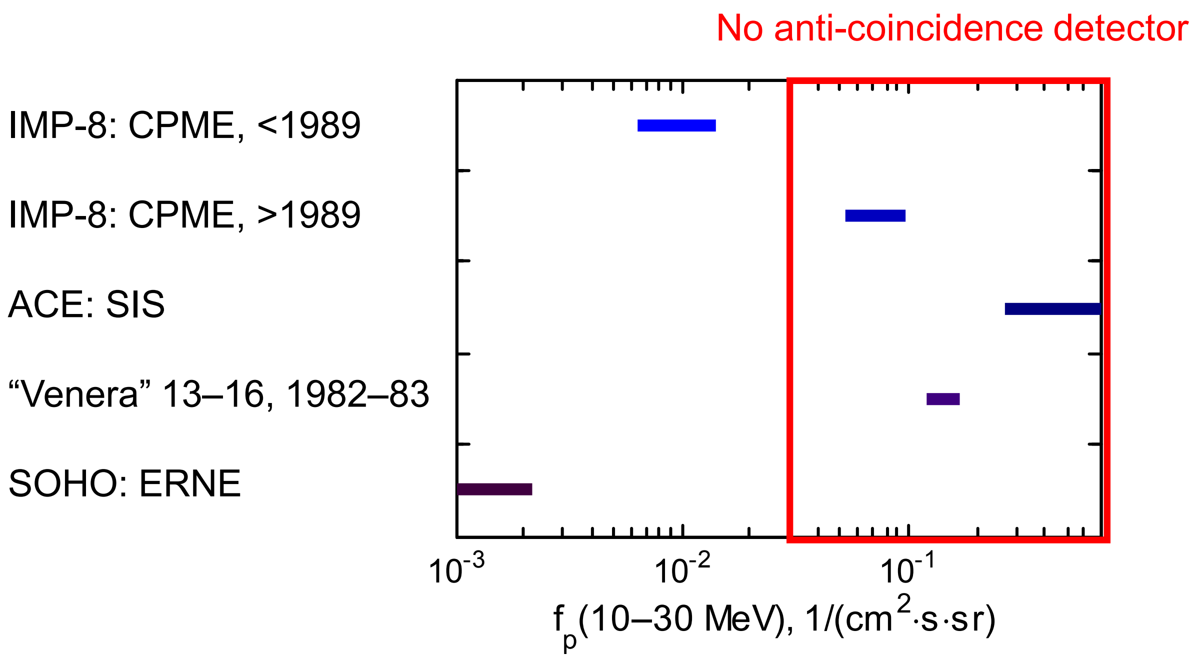
Different stages of problems of SEP measurements reliability

- Instrument calibration itself;
- Artifacts of instrument functioning, data transfer and initial processing;
- Separation of the SEP fluxes from the background fluxes of galactic protons;
- Dependence from the spacecraft location, flux anisotropy, magnetic field configuration
- Dependence from the SEP source location on the Sun and spatial expansion of particles

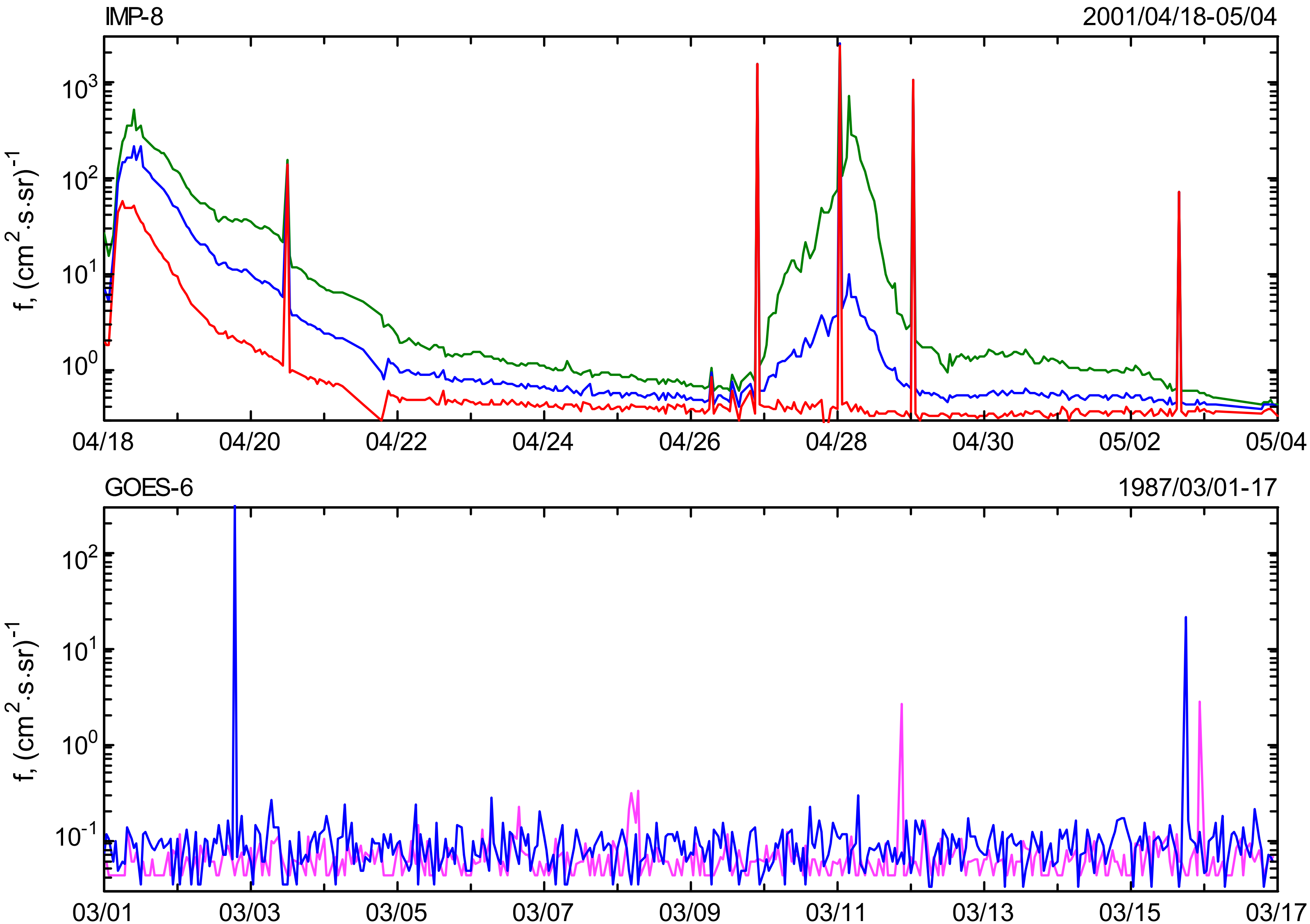
Instrument calibration and features: background galactic proton fluxes



Background integral fluxes of galactic protons with energies 10–30 MeV at different satellites outside the magnetosphere. Difference is >2 orders of magnitude.

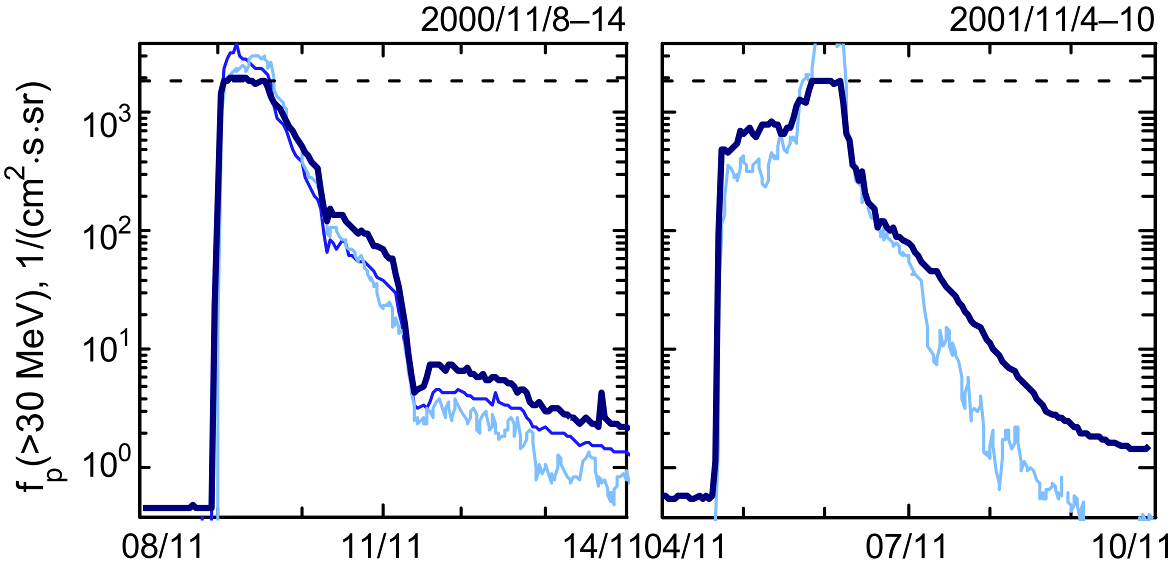
Do we know the fluxes of galactic protons with energies 10–100 MeV?

Artifacts of instrument functioning, data transfer and initial processing



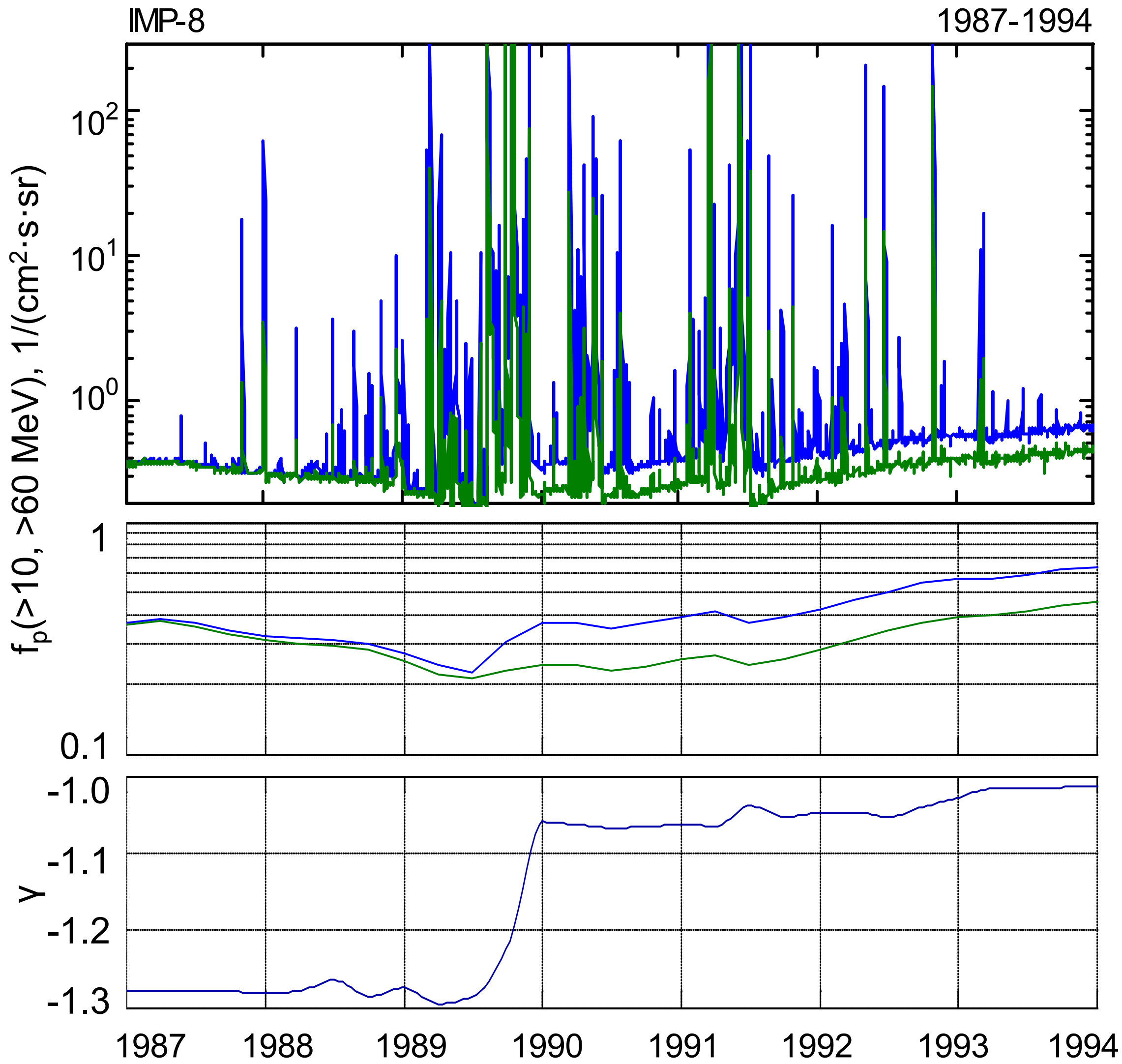
Example of anomalous short-time peak fluxes of >4, >10, >30 MeV protons by IMP-8 during 18 April – 4 May, 2001 (top), and fluxes of protons of 9–15 and 40–80 MeV by GOES-6 during 2–17 March 1987 (bottom).

Artifacts of instrument functioning, data transfer and initial processing



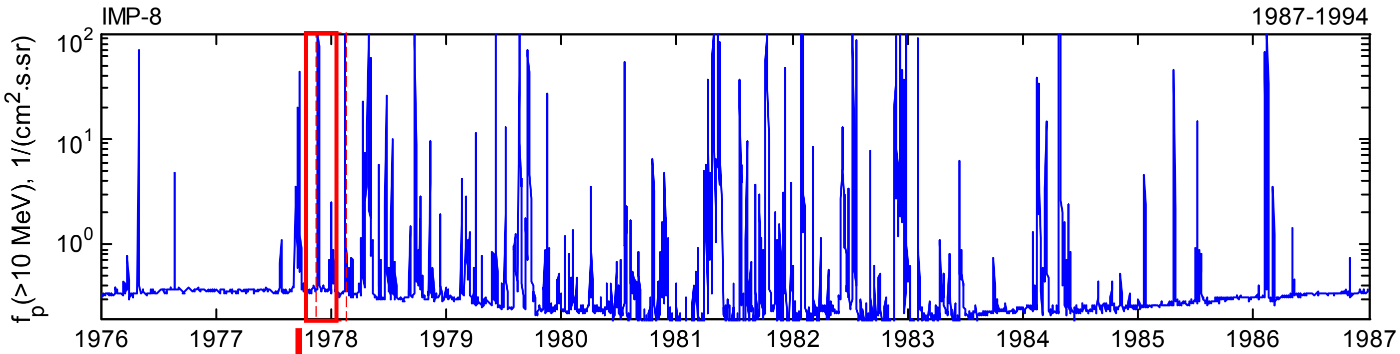
Integral proton fluxes on ACE during strong solar flares are clipped by ≈4700 cm^{-2}·s^{-1}·sr^{-1} for >10 MeV, and ≈1900 cm^{-2}·s^{-1}·sr^{-1} for >30 MeV (bold line). For comparison fluxes of >30 MeV protons on IMP-8 (thin dark line) and GOES-10 (light line) are given for 2 strong events in November 2000 and 2001.

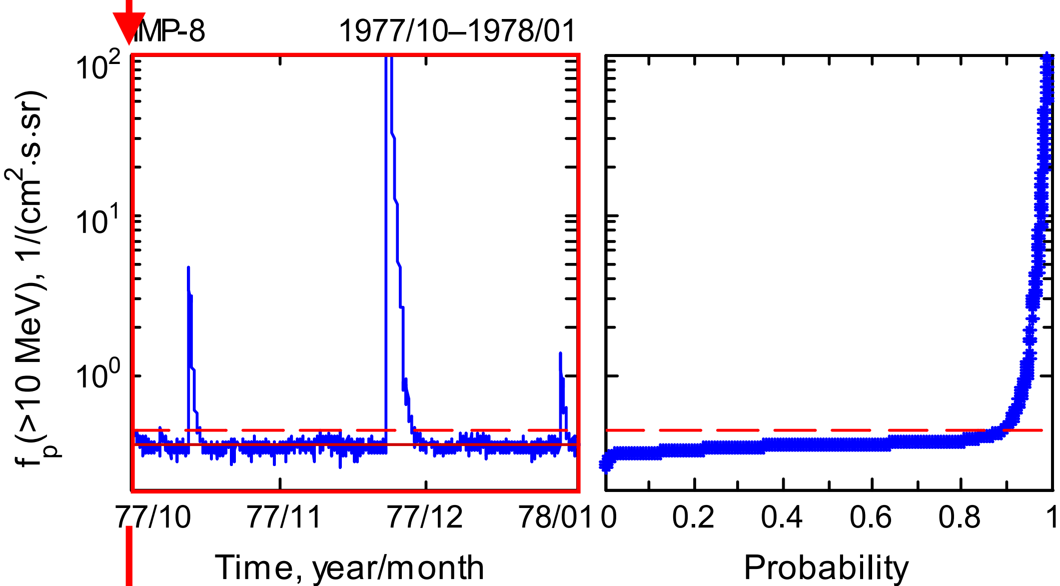
Artifacts of instrument functioning, data transfer and initial processing



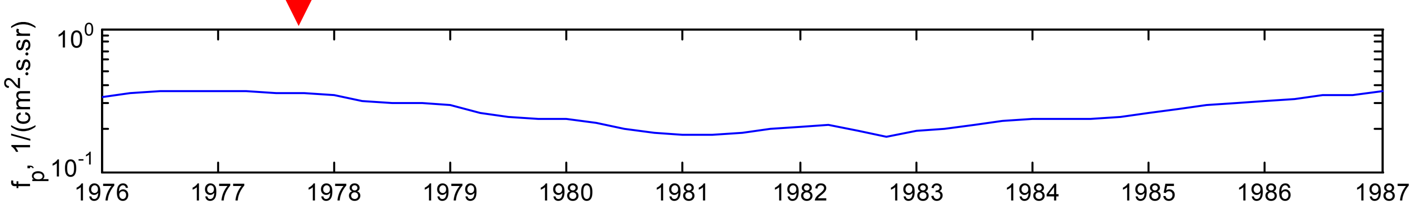
Top: integral fluxes of >10 and >60 MeV protons on IMP-8; middle: separately background galactic proton fluxes; bottom: exponent of energy spectra of 10-year interplanetary proton fluences with energies from >1 to >60 MeV (this parameter depends mainly on solar proton fluxes). All parameters experience change after the middle of 1989 due to failure of anti-coincidence contour.

Separating SEP fluxes from the background galactic proton fluxes



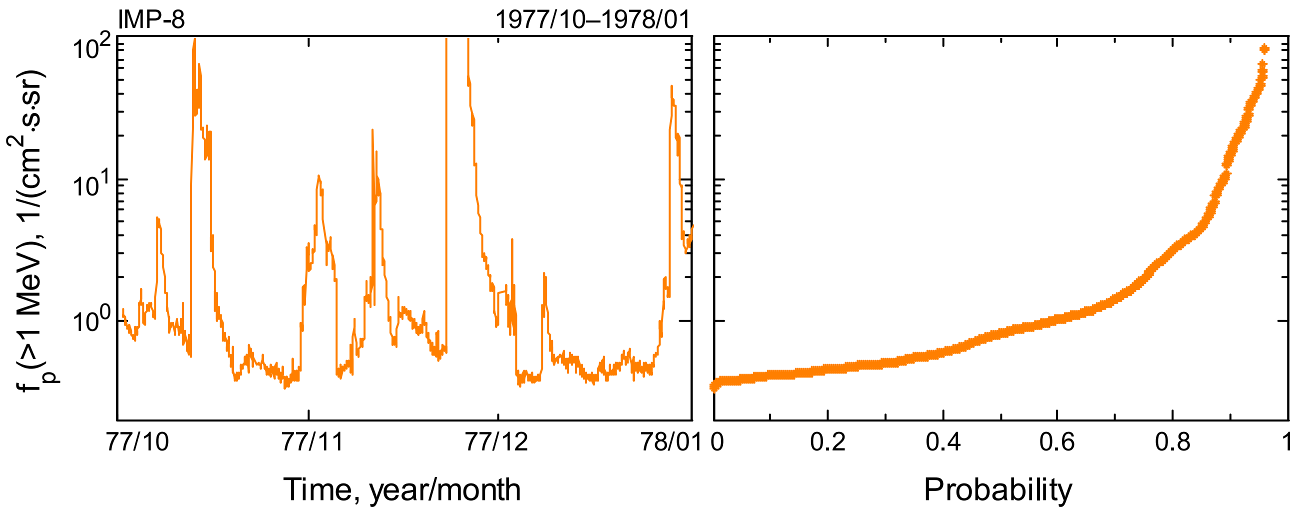


Getselev et al., Optimization of the interplanetary energetic proton flux database and its application in modeling radiation conditions, Sol. Sys. Res., 43(2), p. 136–142, 2009.



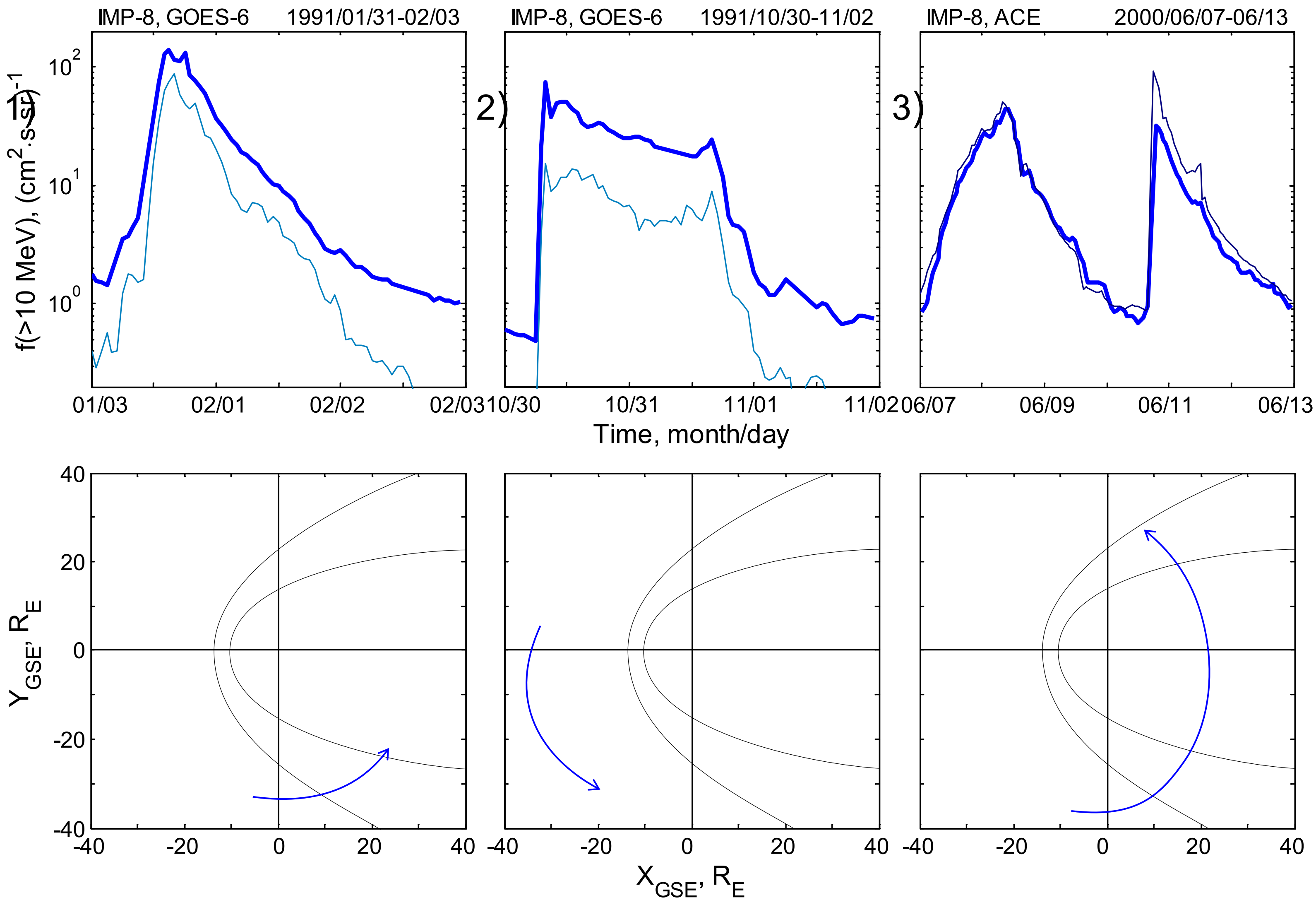
Statistical method of separating SEP fluxes from the background galactic proton fluxes. Smoothed monthly maximum value of background flux is determined as a “knee” in the flux distribution.

Separating SEP fluxes from the background galactic proton fluxes



The method does not work for the proton energies <4–5 MeV. For example, below the fluxes of >1 MeV protons on IMP-8 during the same 3-months period are shown. The value distribution does not have an evident “knee”. We can conclude that the type of contribution of various sources to the fluxes of <4 MeV protons differs from that for >4 MeV.

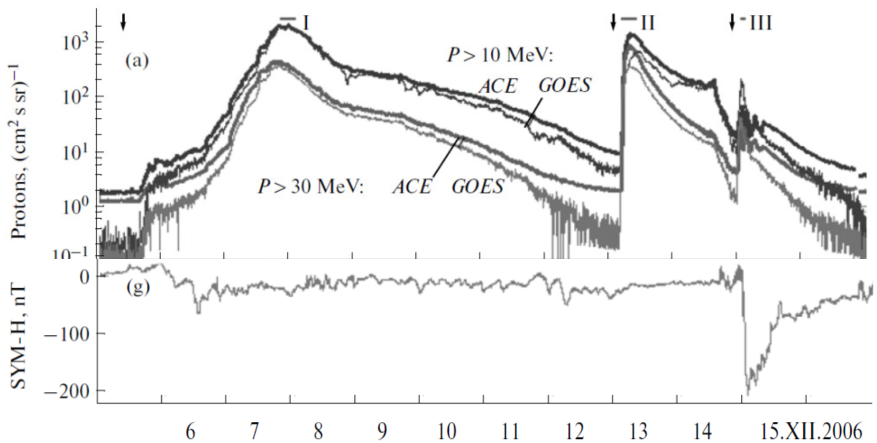
Dependence from the spacecraft location and flux anisotropy



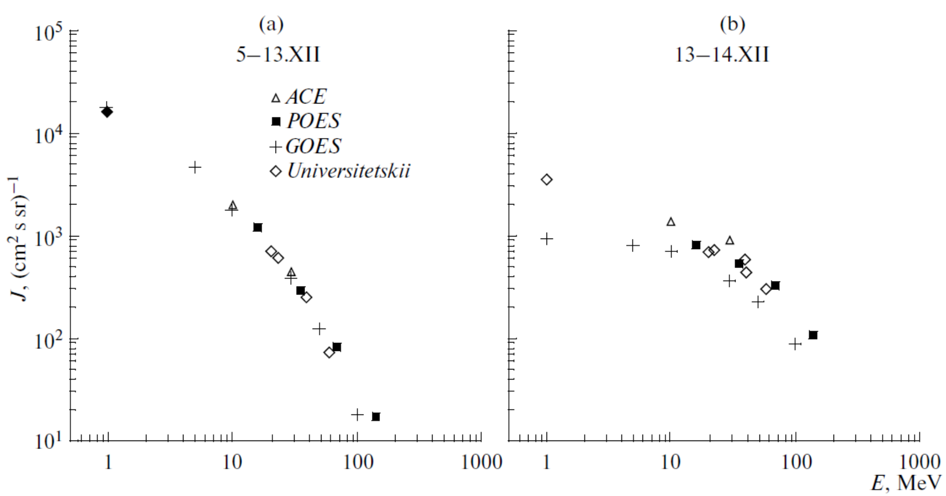
Top: >10 MeV proton fluxes in 1) January 31 and 2) October 30, 1991 SPEs from IMP-8 (bold curves) and GOES-6 (thin); 3) Jun 7 and 10, 2000 SPEs from IMP-8 (bold curve) and ACE (thin). Bottom plots: the location of IMP-8 in X and Y GSE-coordinates for the corresponding time intervals. It appears that the fluxes measured by IMP-8 becomes lower, when it is located inside the magnetosheath region.

Some Features of Solar Cosmic Ray Penetration into the Earth's Magnetosphere[1]

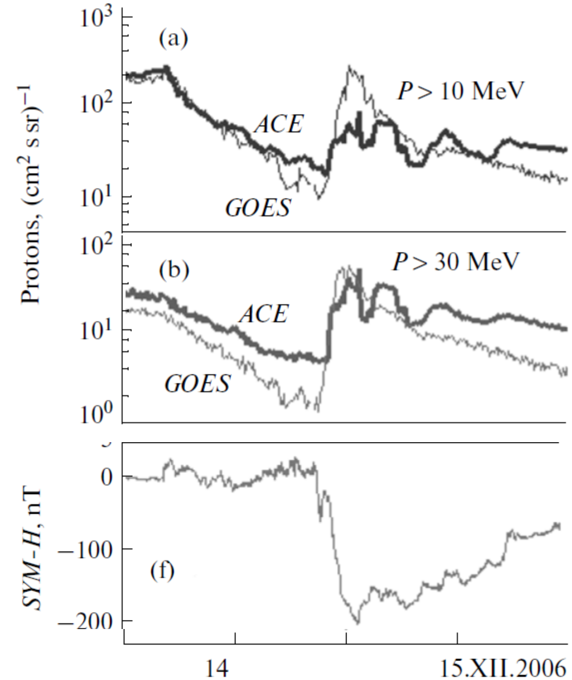
N. A. Vlasova et al., *Cosmic Research, 2011, Vol. 49, No. 6, pp. 485–499.*



SEP events of December 2006.



Integral energy spectra of the SEP peak-intensity fluxes observed in IM and MS in events I (a) and II (b).

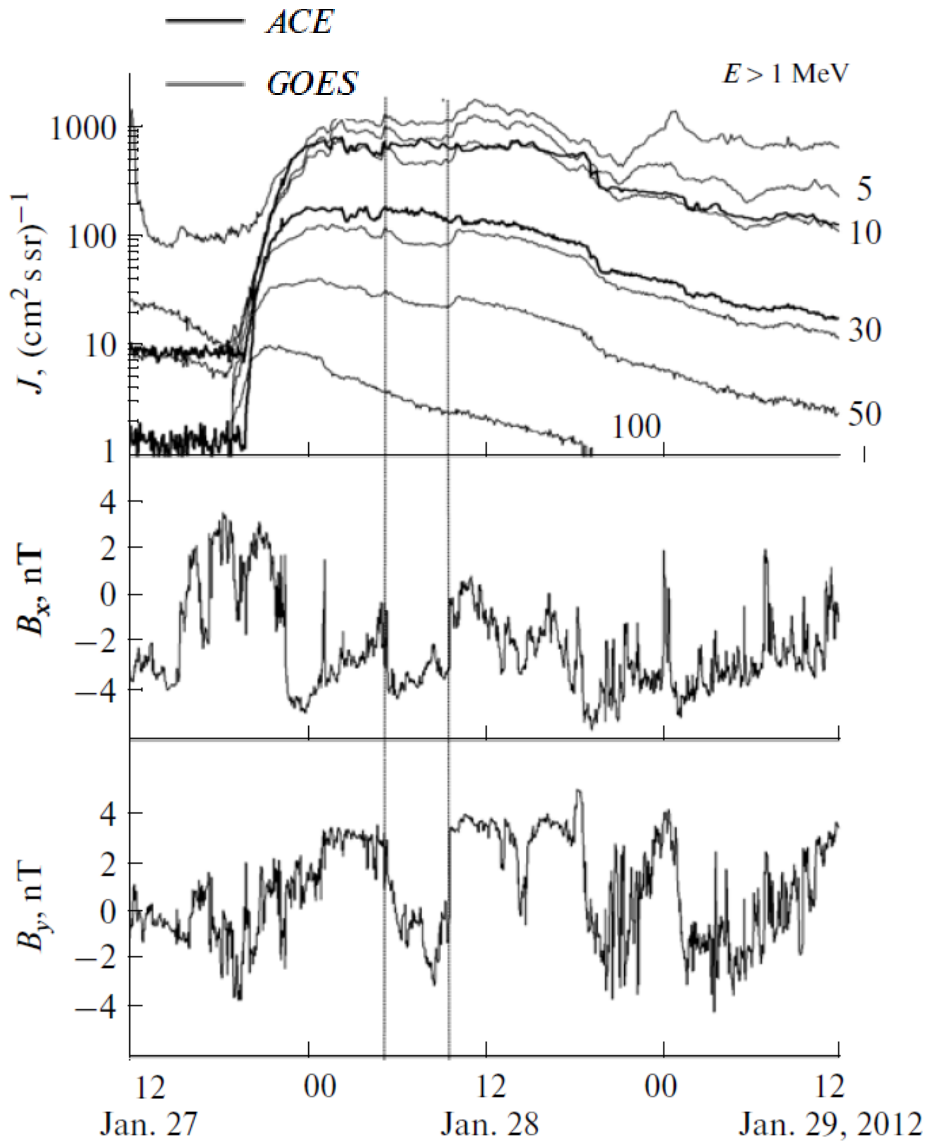


Event III—14–15.XII.2006.

Observed inside-outside difference depends mainly on direction of interplanetary magnetic field, on degree of the SEP anisotropy (pitch-angle distribution) in IMF, and on distance of the magnetopause from the Earth.

Penetration of Solar Cosmic Rays into the Earth's Magnetosphere on January 28, 2012

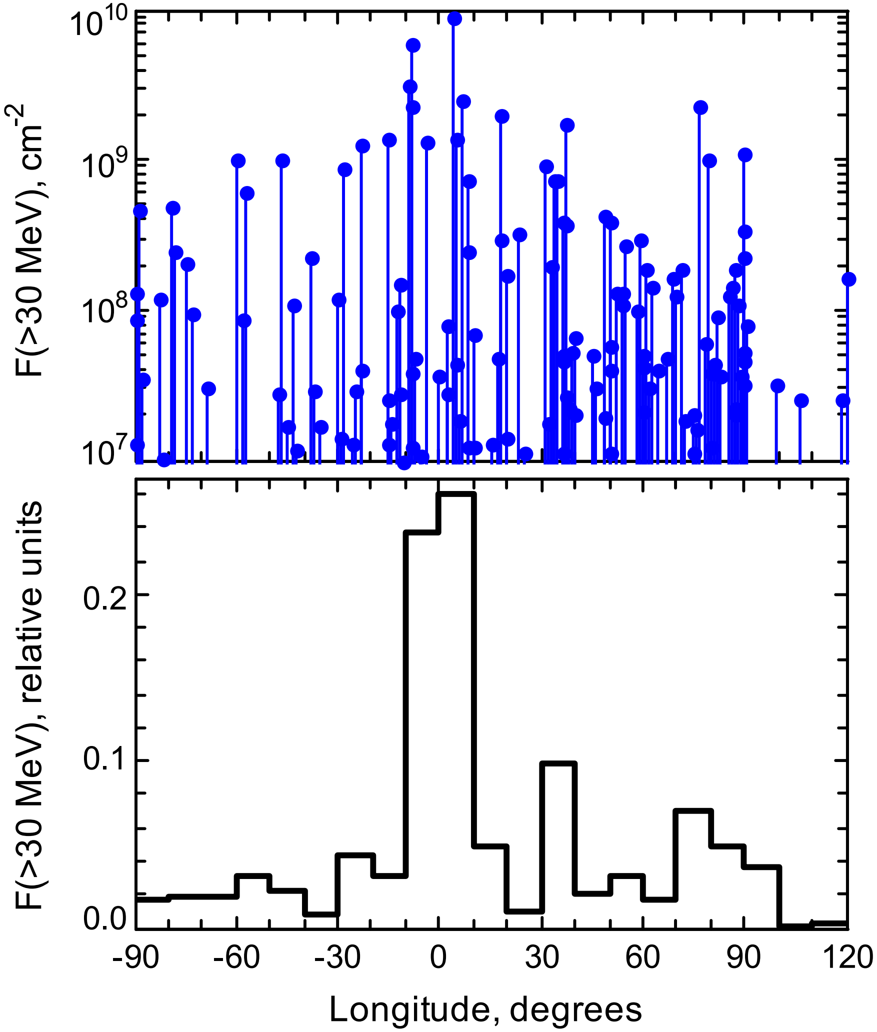
N. A. Vlasova et al., *Cosmic Research, 2013, Vol. 51, No. 5, pp. 319–325.*



The decrease of the efficiency of SCR penetration into the Earth's magnetosphere in the region of the orbits under study on January 28, 2012, is related to the passage of the Earth's magnetosphere through the interplanetary environment structure with a quasi-radial interplanetary magnetic field and a small pressure of the solar wind.

Figure. Time profiles of SCR fluxes and Bx,y-components of IMF

Dependence from location of SEP source on the Sun and particle propagation



Tasenko et al., Peculiarities of time-spatial distribution of cosmic ray injection areas on the Sun, Proc. of ICRC2013, p. ICRS2013-0616.

Distribution of >30 MeV SEP fluences in ≈420 solar proton events 19–24 solar cycles over their source longitude relative to central visible meridian of the Sun. The maximum of the distribution is located in vicinity of the central meridian. Overall asymmetry of ≈10° towards west is present.

Requirements for an “ideal experiment”

- Detectors with known parameters, known placement on the spacecraft, 3D-modeling, intercalibrating;
- Long-term measurements;
- Wide energy range (for example, there is a difference in contributions of different sources for the energies <1 and >5 MeV);
- Uninterrupted energy range;
- Presence of the information about algorithms of initial data proceeding and correction
- Presence of the information about spatial orientation of the detectors;
- Data on flux anisotropy: several detectors with different orientation;
- Several spacecraft: observing the Sun from different positions (STEREO);
- Spacecraft in GEO, in the orbits crossing both the Earth’s magnetosphere and the interplanetary space, and outer-magnetospheric spacecraft (Sun-Earth L1 point etc.);
- MANY satellites: analyzing the particle propagation dynamics

SEP measurements on a GEO satellite Electro-L: SKL-E instrument

Launch: 20 Nov. 2011

Lifetime: 10 years

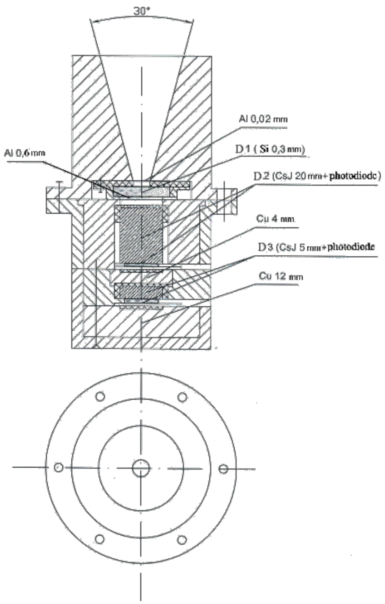
GEO Position: 76° east

Mass: 1766 kg

Application: meteorology

http://smdc.sinp.msu.ru/

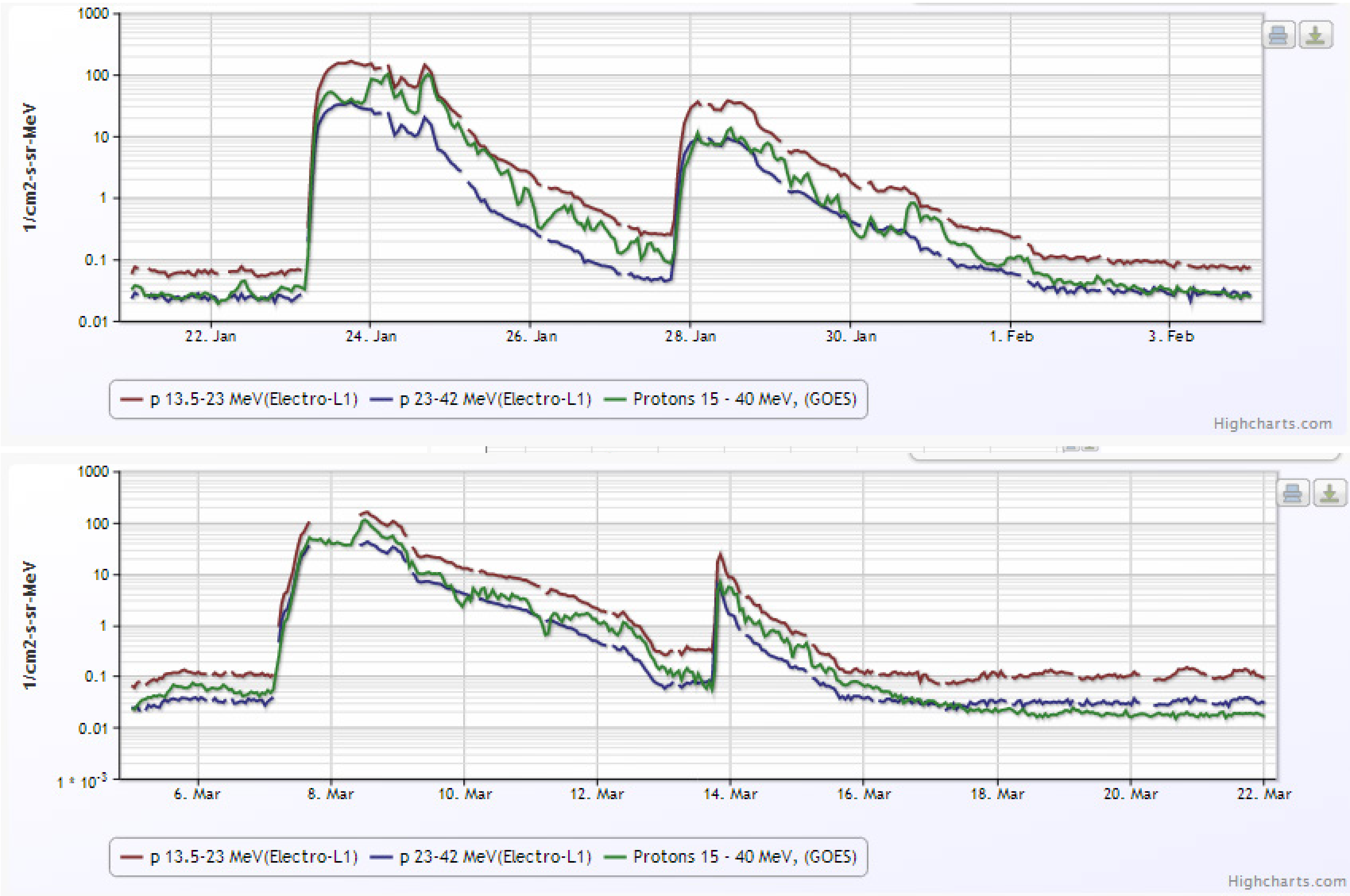
128 Mpx
full Earth images



SKL-E spectrometer parameters

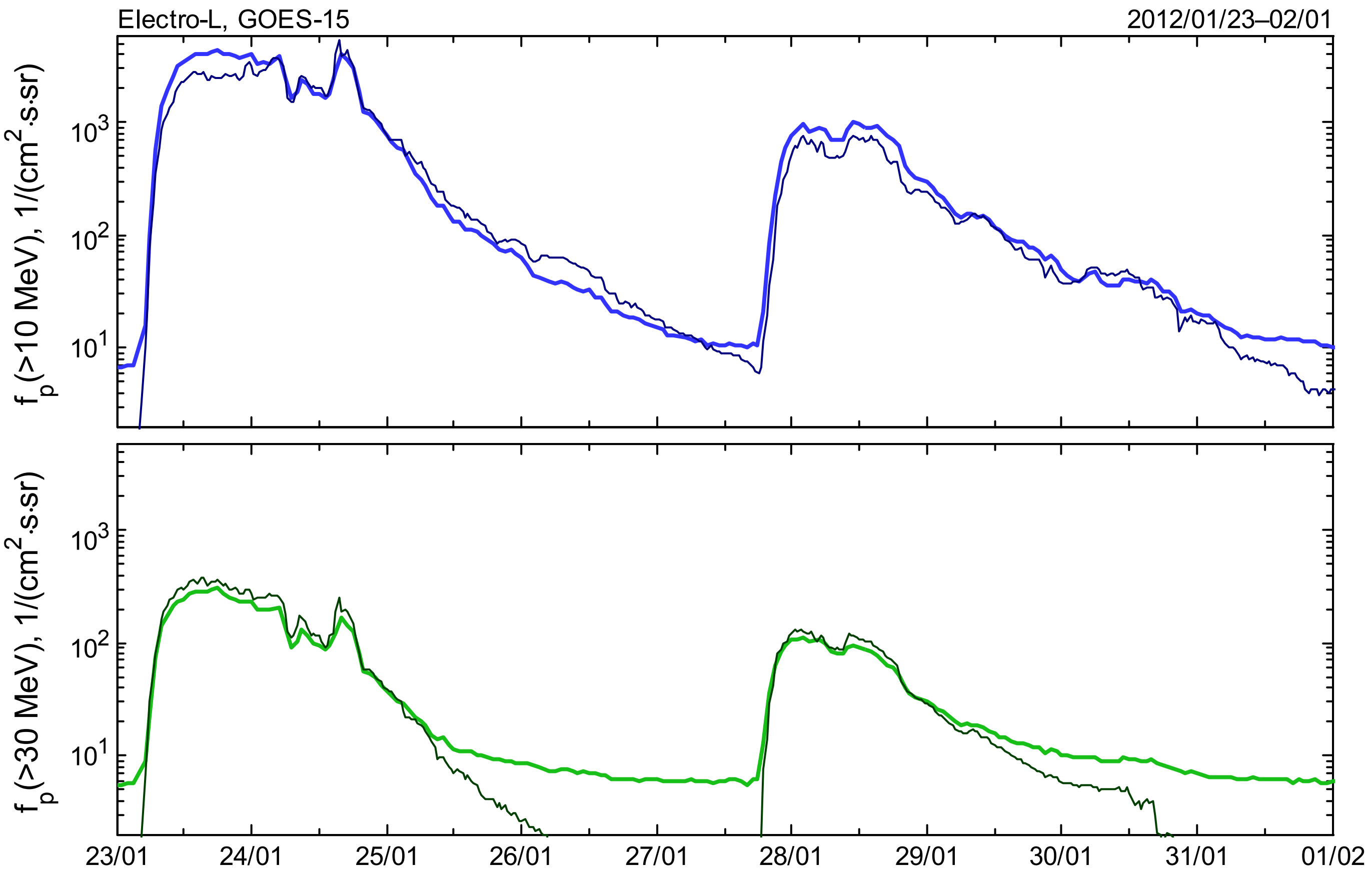
Param.	Energy of registered particles	
	electrons	protons
1	170–300 keV	>1.2 MeV
P2	>2.3 MeV	>13.5 MeV
P3	2.3–4.2 MeV	-
P4	4.2–6.0 MeV	-
P5	6–20 MeV	-
P6	-	13.5–23 MeV
P7	-	23–42 MeV
P8	-	42 –112 MeV
P9	-	112–320 MeV
P10	>1.3 MeV	1.2–95 MeV
P11	-	>100 MeV

SEP measurements on a GEO satellite Electro-L: SKL-E instrument



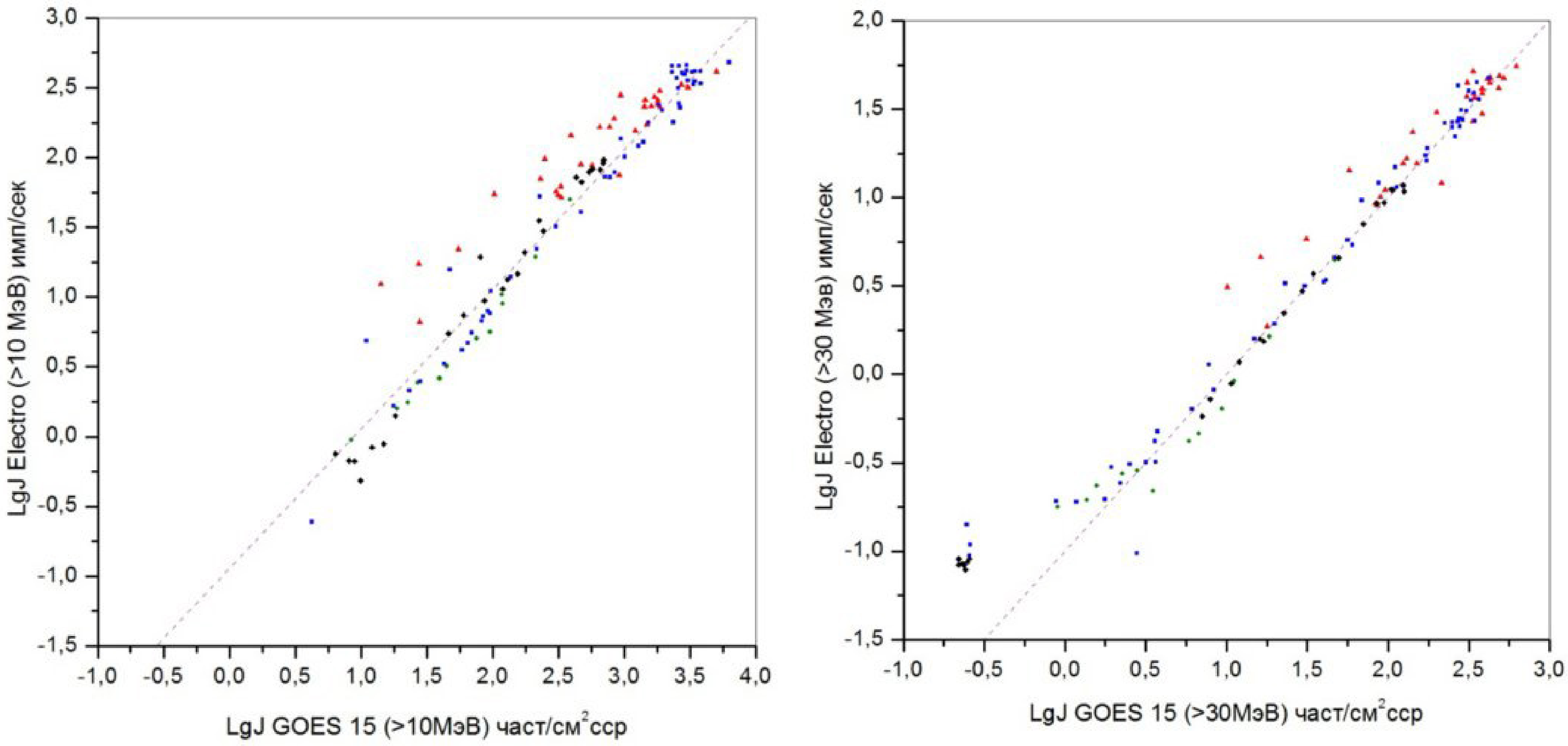
Differential fluxes of protons with energies 13.5–23 и 23–45 MeV measured on Electro-L, and 15–40 MeV on GOES-15 during two series of strong solar flares in January and March 2012.

SEP measurements on a GEO satellite Electro-L: SKL-E instrument



Integral fluxes of >10 (top plot) and >30 MeV (bottom) protons measured by Electro-L (bold lines) and GOES-15 (thin lines) during 2 strong solar proton events in the end of January, 2012. A good coincidence is observed.

SEP measurements on a GEO satellite Electro-L: SKL-E instrument



Arakelov et al., Heliogeophysical Research, 6, 2014. (In Russian).

Correlation of >10 (left) and >30 MeV (right) proton fluxes on Electro-L and GOES-15 during several strong solar proton events in 2012.

Conclusions

- The calibration of the detector itself is only one part of the problem of SEP measurement reliability; various other factors have been considered during this talk
- A suggested statistical method of separating the SEP fluxes from the background fluxes can be taken as a supplemental method for constructing the long-term intercalibrated data set of SEP fluxes.
- Considered dependencies of solar proton fluxes from the flux anisotropy and particles propagation in the interplanetary and near-Earth's environment demand further study.
- Current SEP measurements on the geostationary satellite Electro-L have been presented.