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Estimation of the International Space Station attitude effect on dose rate inside the Service module of the station when crossing the South-Atlantic Anomaly

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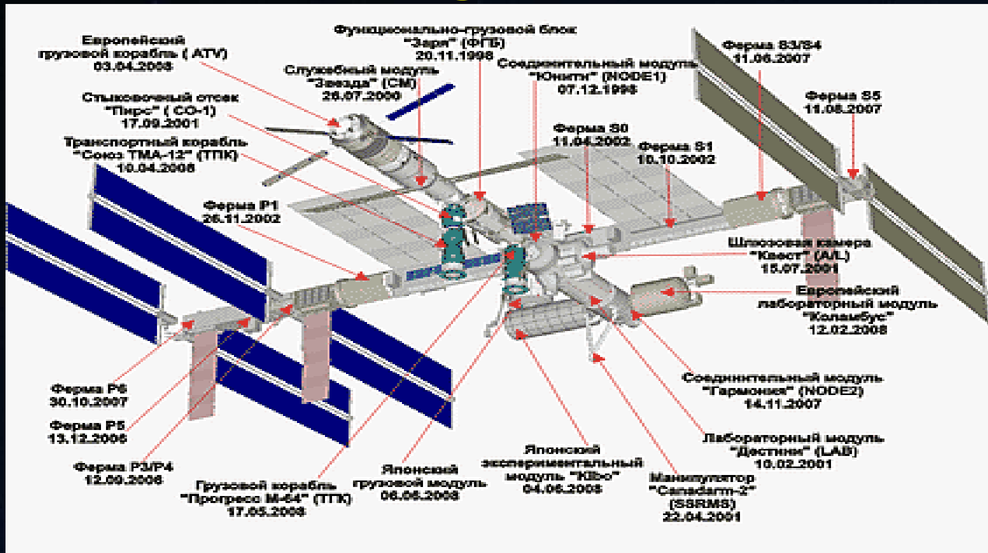
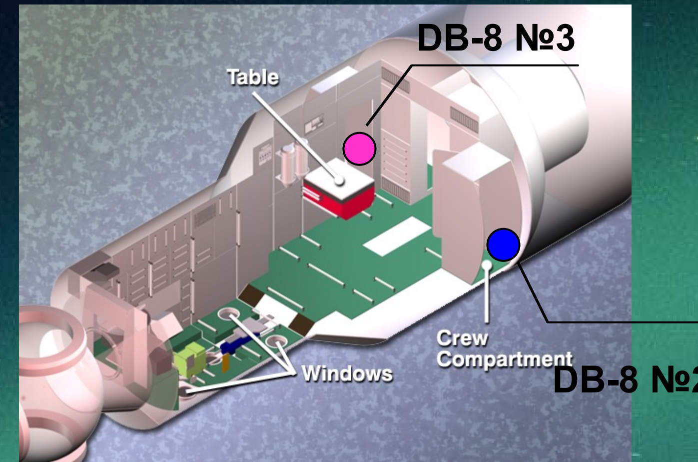
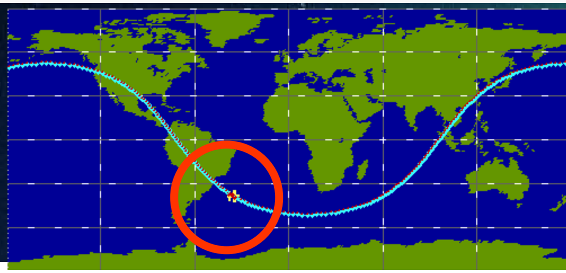
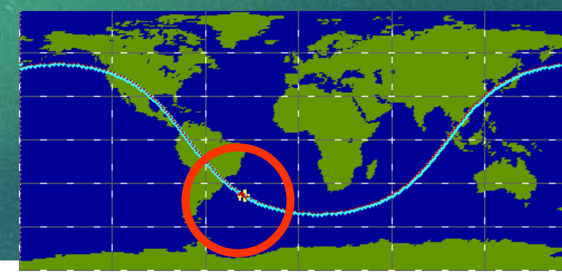
ISS configuration

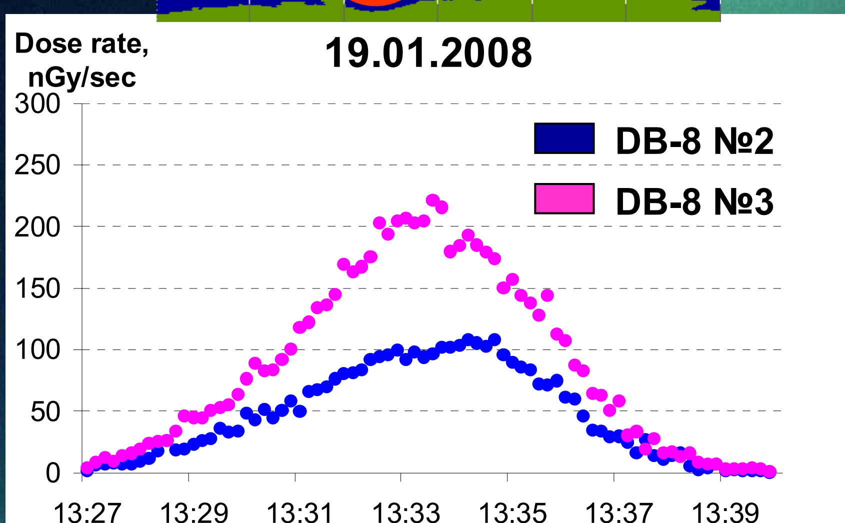


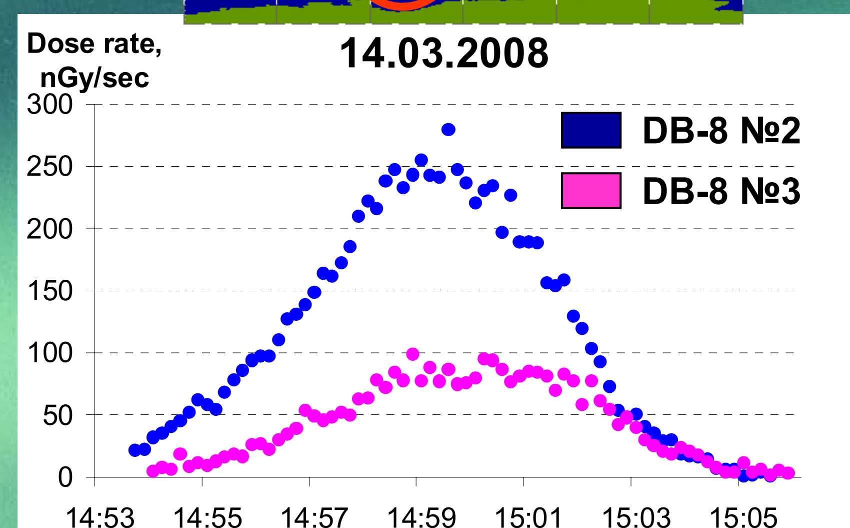
Service Module



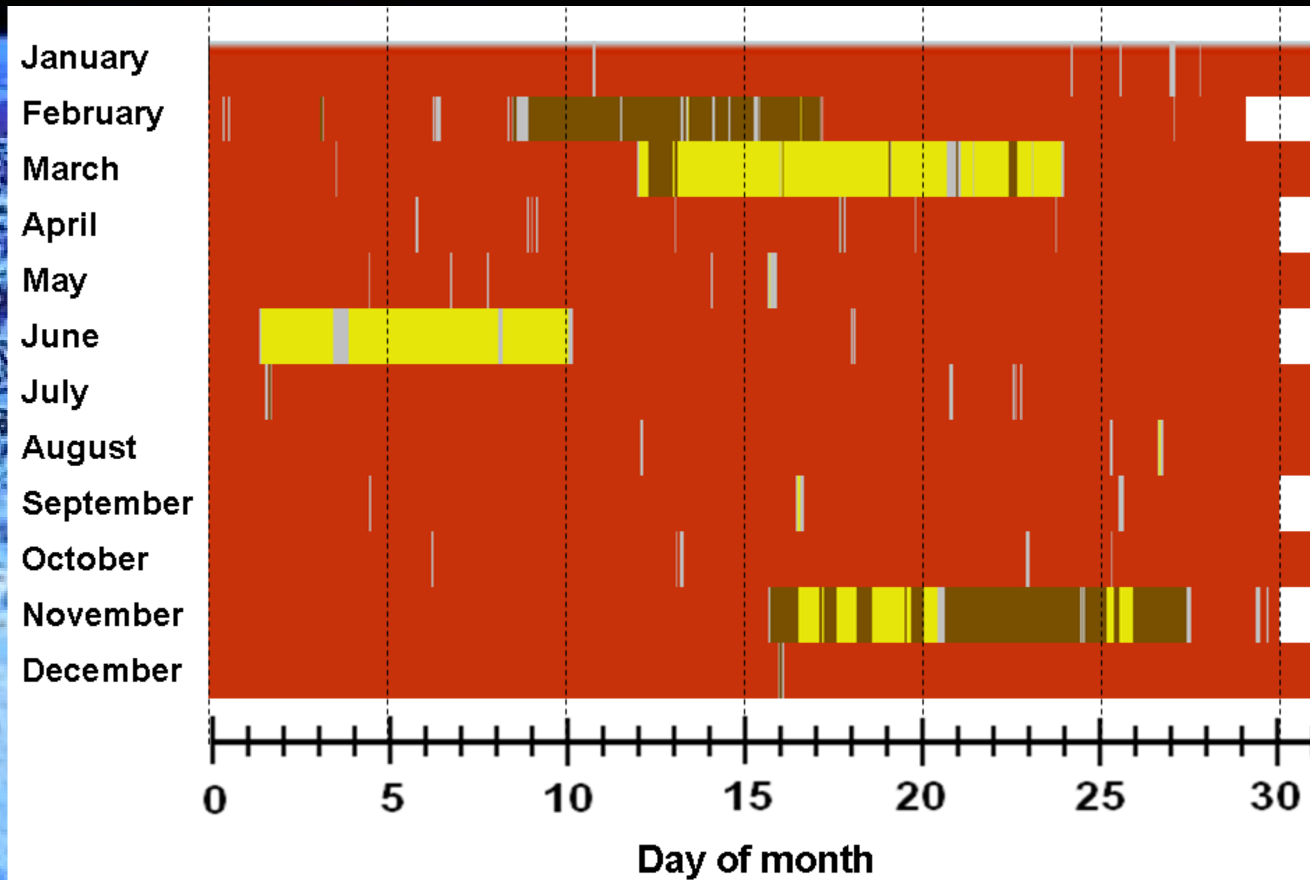








Year: 2008



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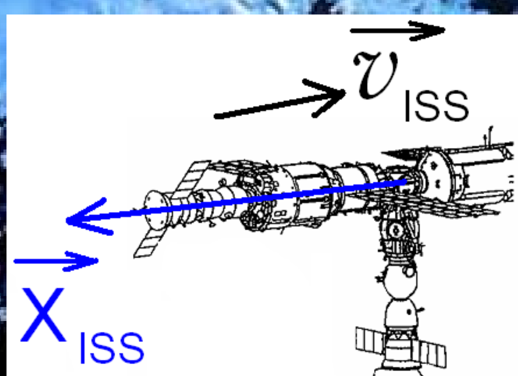
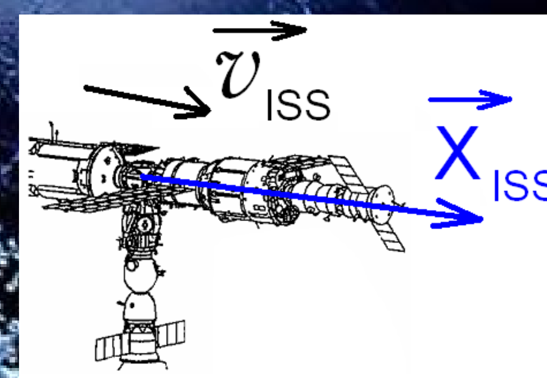


$\vec{v}_{ISS}$
$\vec{X}_{ISS}$



$\vec{v}_{ISS}$
$\vec{X}_{ISS}$

Dose calculation formula

(J. Haffner. Nuclear radiation and protection in space. 1971)

$$P(t) = \sum_{l} \int_{\Omega} \int_{E} \Phi_l(E, \vec{\Omega}, \vec{r}(t), t) \cdot C_l(E, h(\vec{\Omega})) dE d\vec{\Omega}$$

$P(t)$ – dose rate inside spacecraft at the moment t;

$\Phi_l(E,\vec{\Omega},\vec{r}(t),t)$ – flux of l-type particles falling onto the outer surface of the spacecraft from the direction $\vec{\Omega}$ with energy E;

$\vec{r}(t)$ – spacecraft coordinates;

$C_l(E,h(\vec{\Omega}))$ – translation function from l-type particle flux with energy E to dose behind a matter layer of thickness h;

$h(\vec{\Omega})$ – thickness of matter, screening the point inside spacecraft in the direction $\vec{\Omega}$.

The report structure

Dose rate calculation technique inside the ISS:

- Spectral-angular distribution of protons in the South-Atlantic anomaly (SAA)
- Way of describing an angular distribution of parameter
- Angular distribution of shield thickness for a point inside spacecraft
- Reduction of the above characteristics to the same coordinates

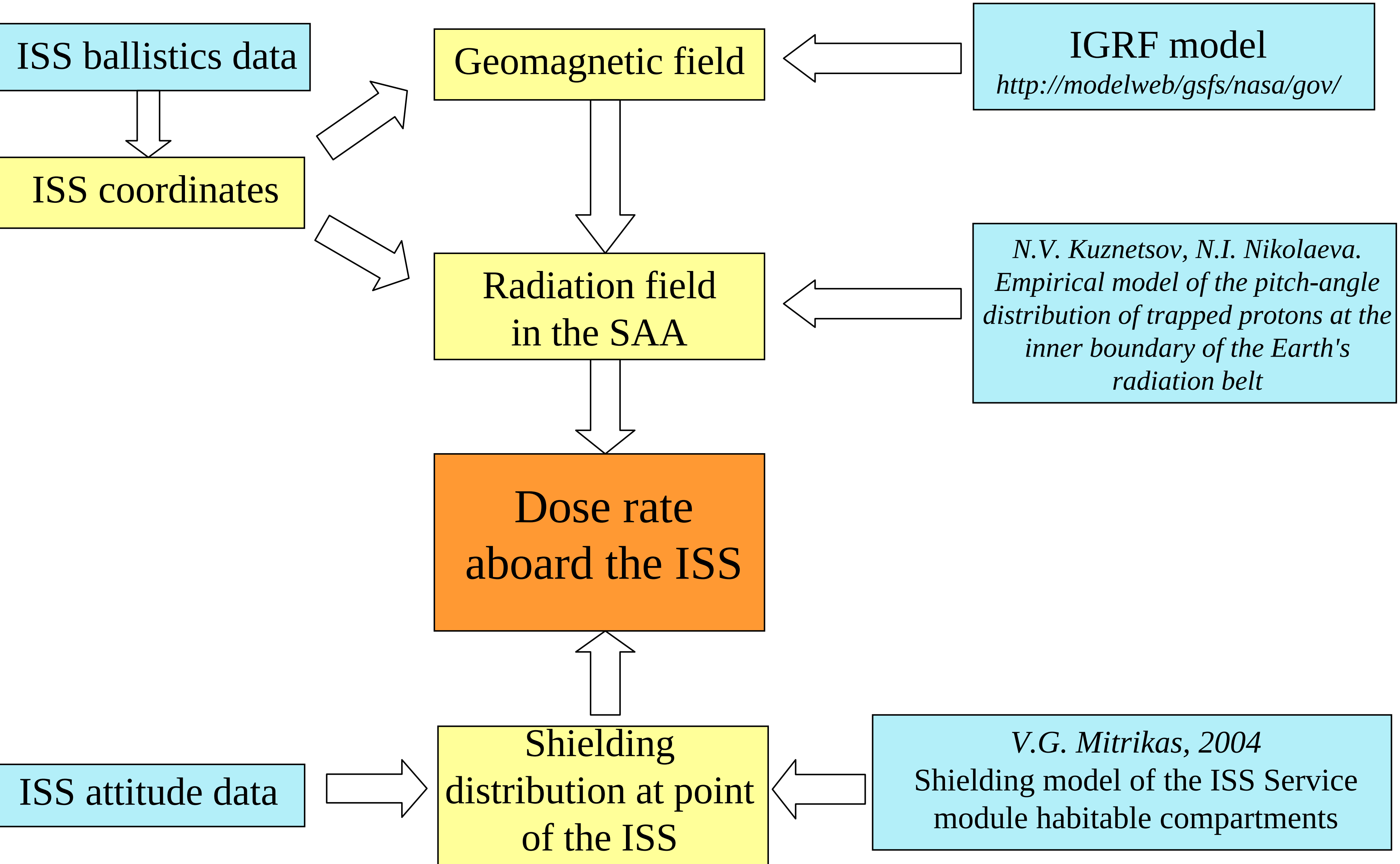
Comparison between calculation results and experimental data:

- Measurement equipment
- Analysis of ISS attitude effect on dose rate inside the habitable compartments of the Service Module

Dose rate calculation method

Dose rate at some point of spacecraft at the time point ***t***	$P(t) = \sum_{l} \int_{\vec{\Omega}} \int_{E} \Phi_l(E, \vec{\Omega}, \vec{r}(t), t) \cdot C_l(E, h(\vec{\Omega})) dE d\vec{\Omega}$ *(J. Haffner. Nuclear radiation and protection in space. 1971)*
Differential directional flux of protons in the SAA	$j(E, L, \alpha_0) = j_{\perp}(E, L) * \sin^q(\alpha_0 - k^n * \alpha_c(L))$ *N.V. Kuznetsov, N.I. Nikolaeva. Empirical model of the pitch-angle distribution of trapped protons at the inner boundary of the Earth's radiation belt*
Dose at the depth ***x*** of matter layer	$D(x) = 1{,}6 \cdot 10^{-8} \cdot \int_{E_{\min}}^{E_{\max}} \frac{dN}{dE_x}(E_x) \cdot \frac{dE_x}{dx}(E_x) dE_x$ *Russian State Standard. 1986*

Data used for calculations



Algorithm of the radiation field calculation in the South-Atlantic Anomaly

1) To find the geomagnetic field vector $\vec{B}$ at the view point;

2) To find proton pitch angle α, phase angle φ and gyroradius R for given proton movement vector $\vec{\Omega}$ and energy E;

3) To find the coordinates of proton guiding center for previously found φ and R values;

4) To find the magnetic L-B coordinates of proton guiding center;

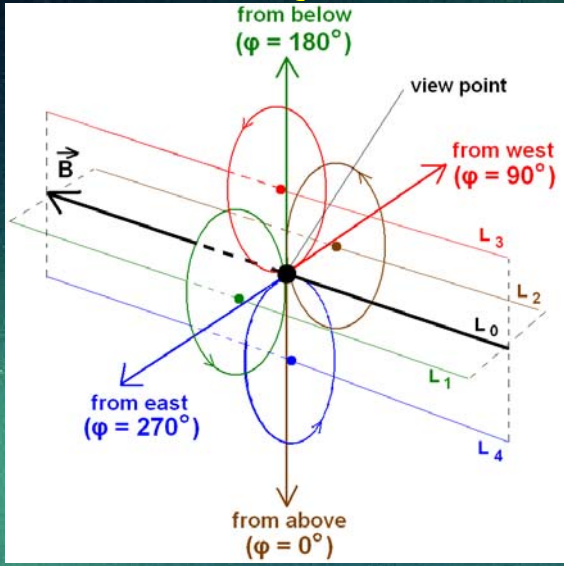
5) To find the equatorial pitch angle α_0 of protons;

6) To find the proton flux using the relation:

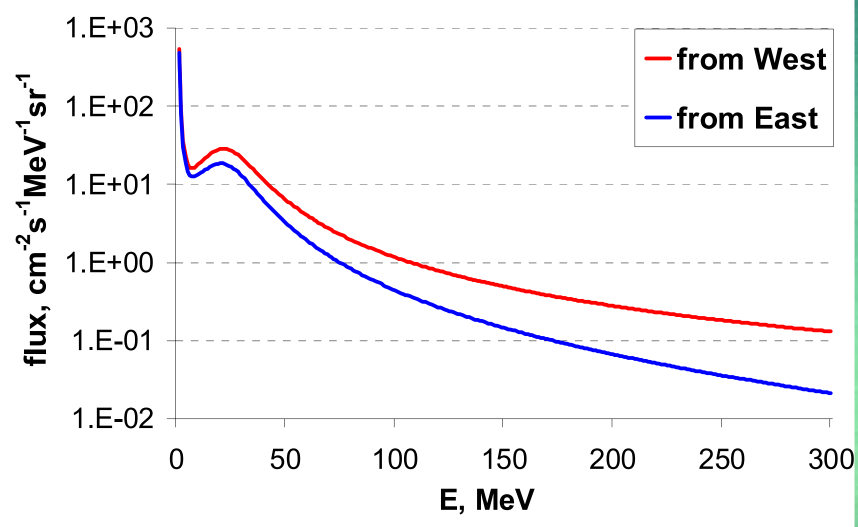
$$j(E,L,\alpha_0) = j_\perp(E,L) * \sin^q(\alpha_0 - k^n * \alpha_c(L))$$

N.V. Kuznetsov, N.I. Nikolaeva. Empirical model of the pitch-angle distribution of trapped protons at the inner boundary of the Earth's radiation belt

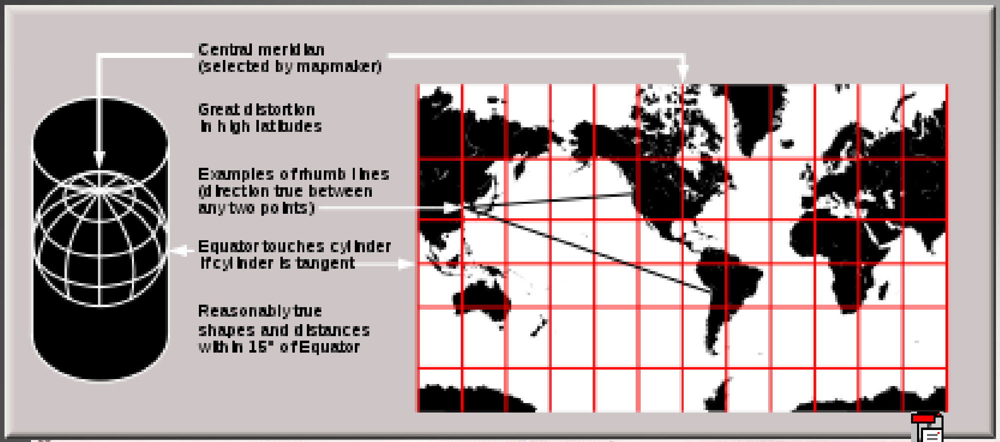
The resulting flux value is ascribed to the considered vector $\vec{\Omega}$ of proton movement.

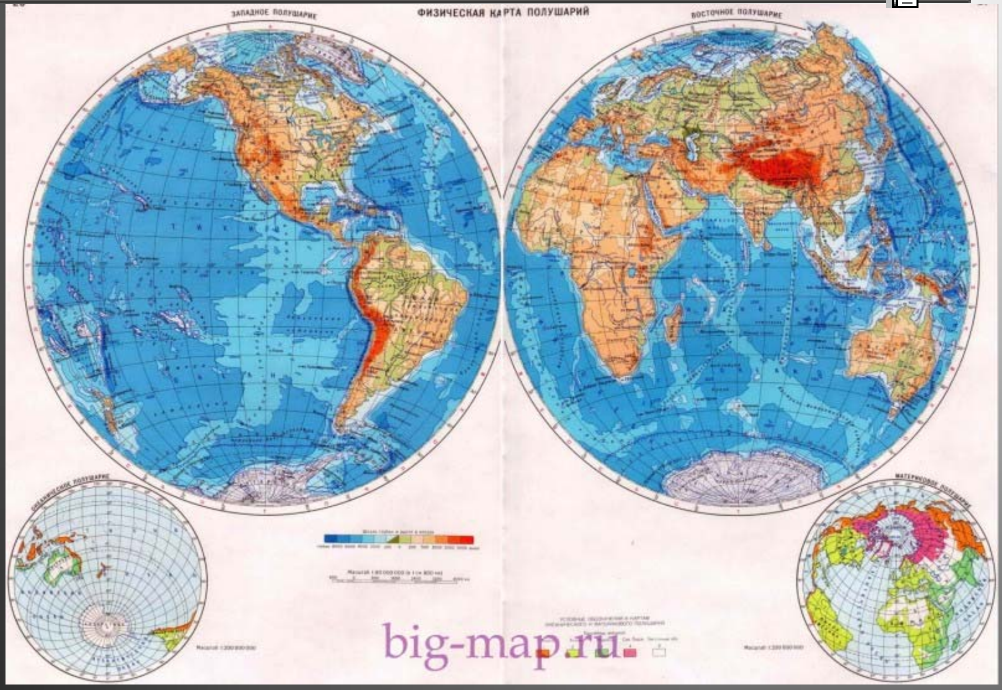


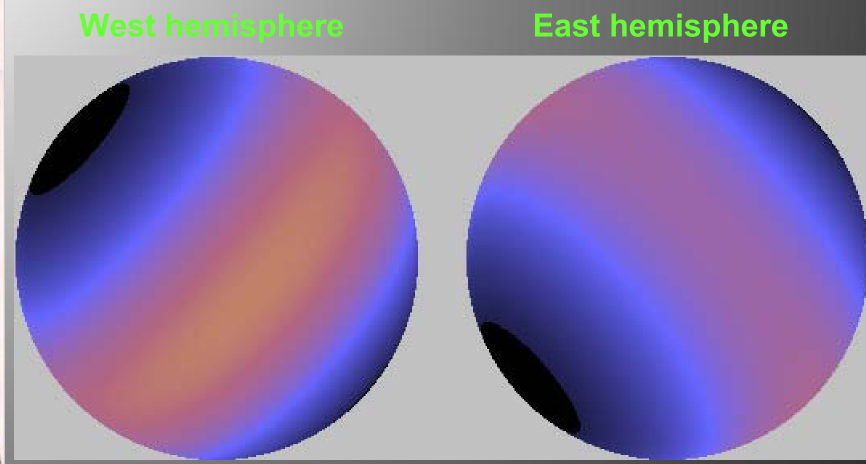
Result of calculating the proton spectrum at the point in the SAA (longitude = -50°; latitude = -30°; altitude = 350 km)



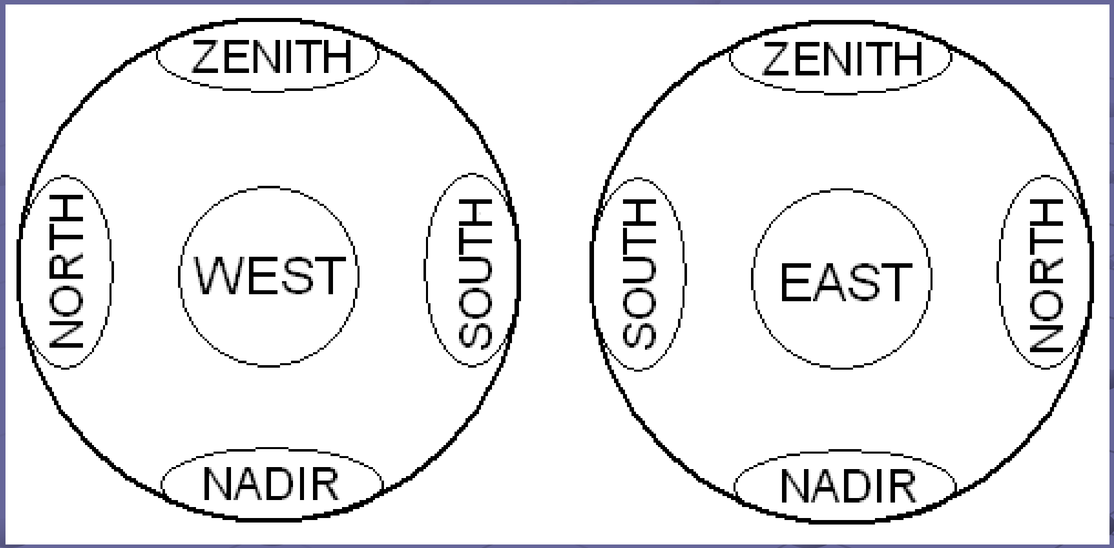
Approach used for displaying the angular distribution of parameter

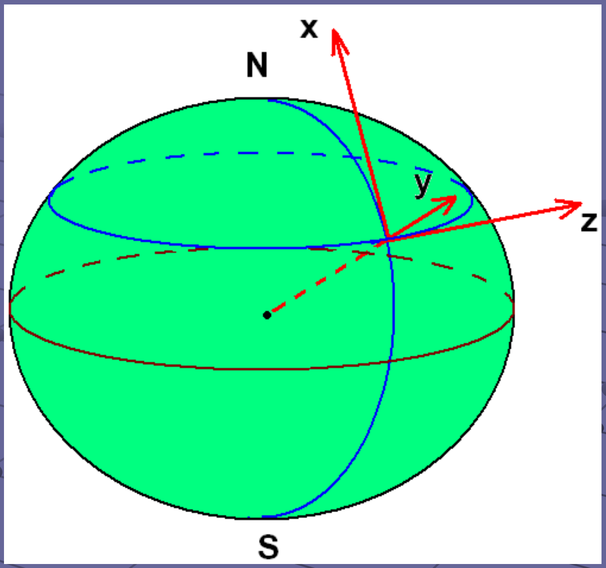


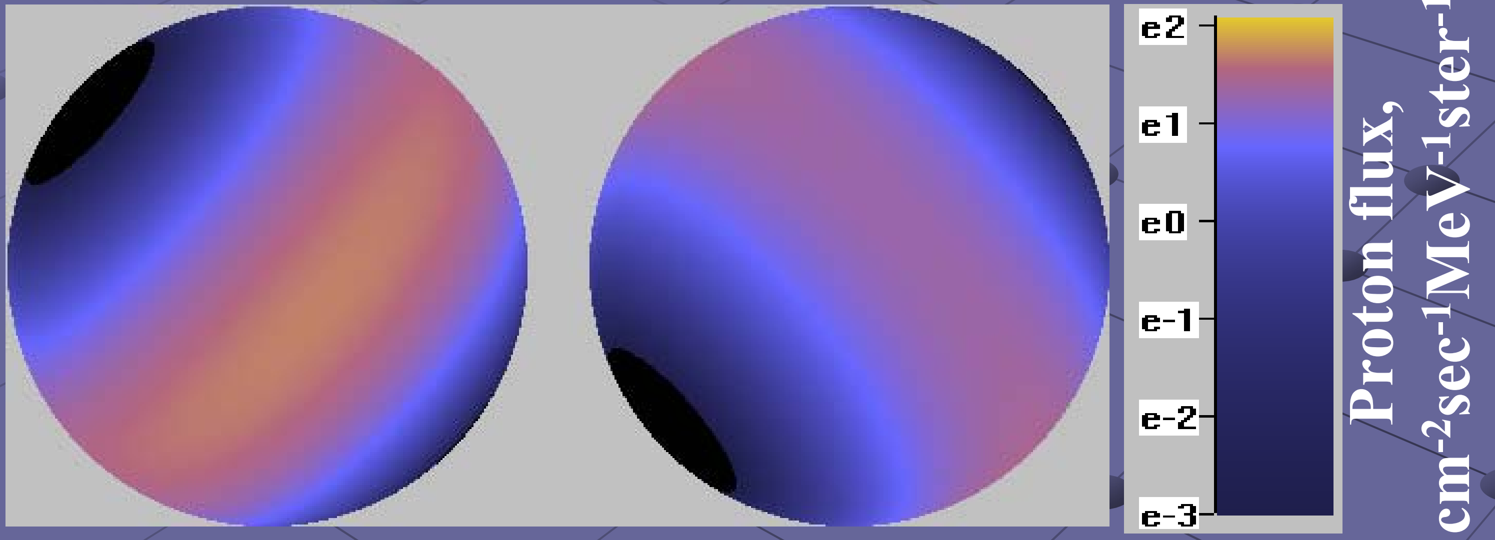




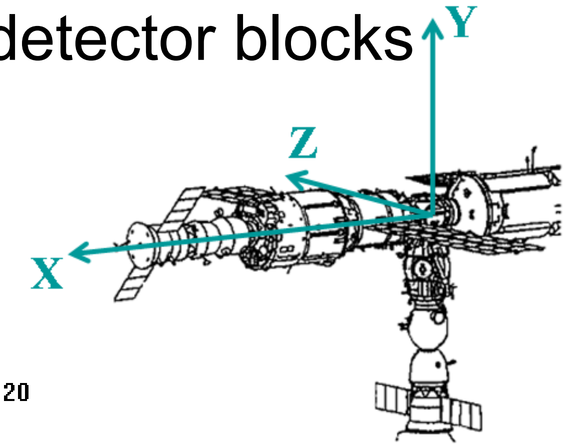
Scheme of displaying the proton flux angular distribution

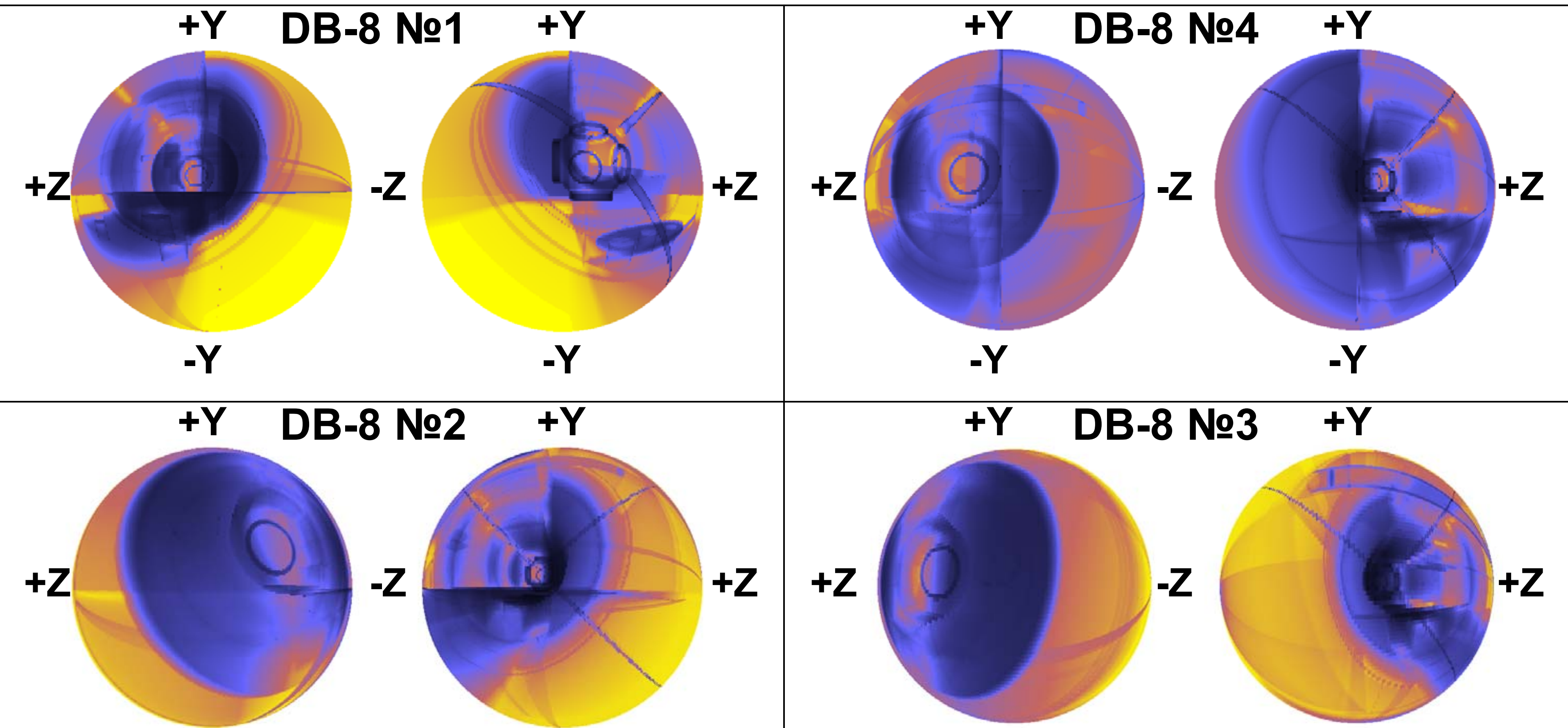






Angular distributions of shielding thickness for localization points of the Radiation Monitoring System DB-8 detector blocks





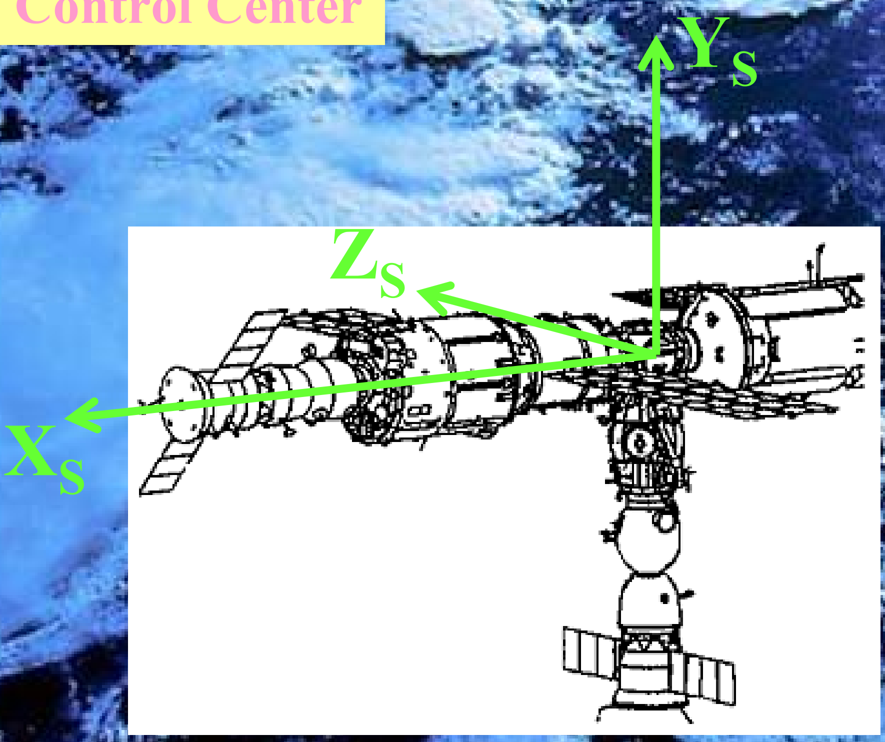
ISS attitude calculation method

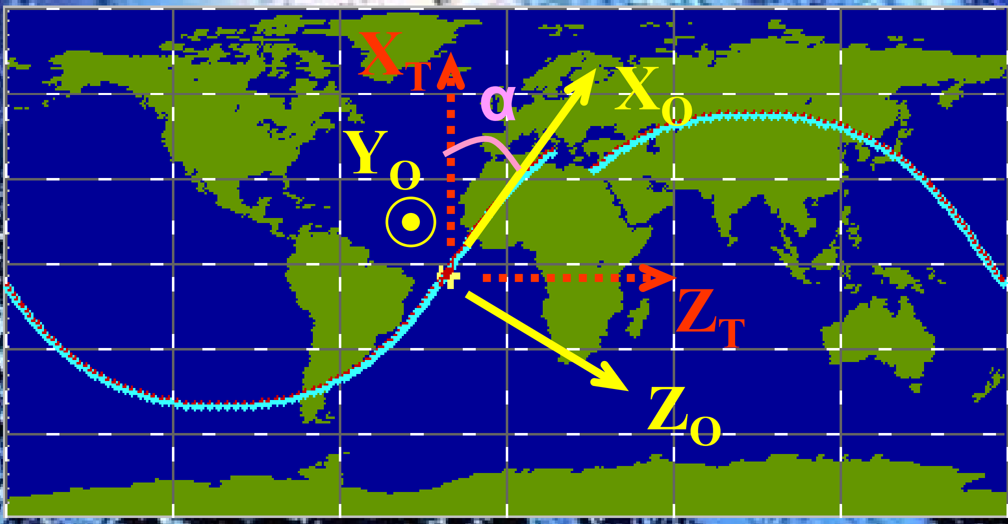
$$M_{S\to O} = \begin{pmatrix} X_S X_O & X_S Y_O & X_S Z_O \\ Y_S X_O & Y_S Y_O & Y_S Z_O \\ Z_S X_O & Z_S Y_O & Z_S Z_O \end{pmatrix}$$

$$M_{O\to T} = \begin{pmatrix} \cos(\alpha) & 0 & -\sin(\alpha) \\ 0 & 1 & 0 \\ \sin(\alpha) & 0 & \cos(\alpha) \end{pmatrix}$$

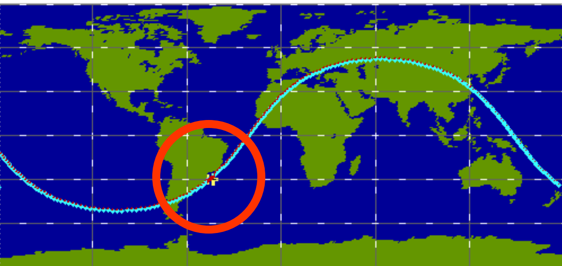
Data of the Space Flight Control Center

$$M_{S\to T} = M_{S\to O} \times M_{O\to T}$$





Dose rate calculation result for the DB-8 №1 location point

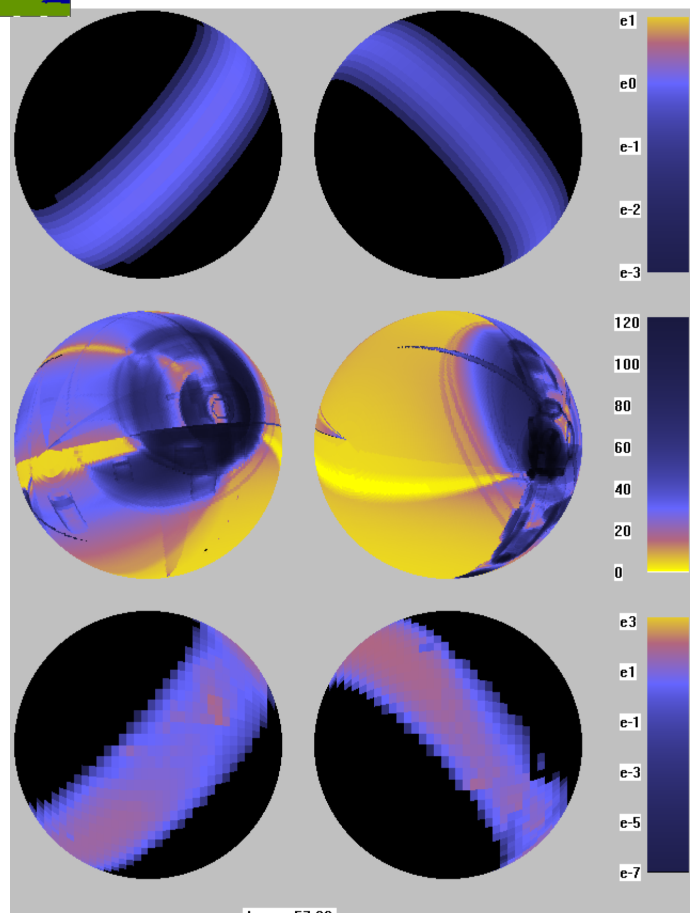


Angular distribution of 100 MeV proton flux [1/(cm2*sec*MeV*ster]

Angular distribution of shielding thickness [g/cm^2]

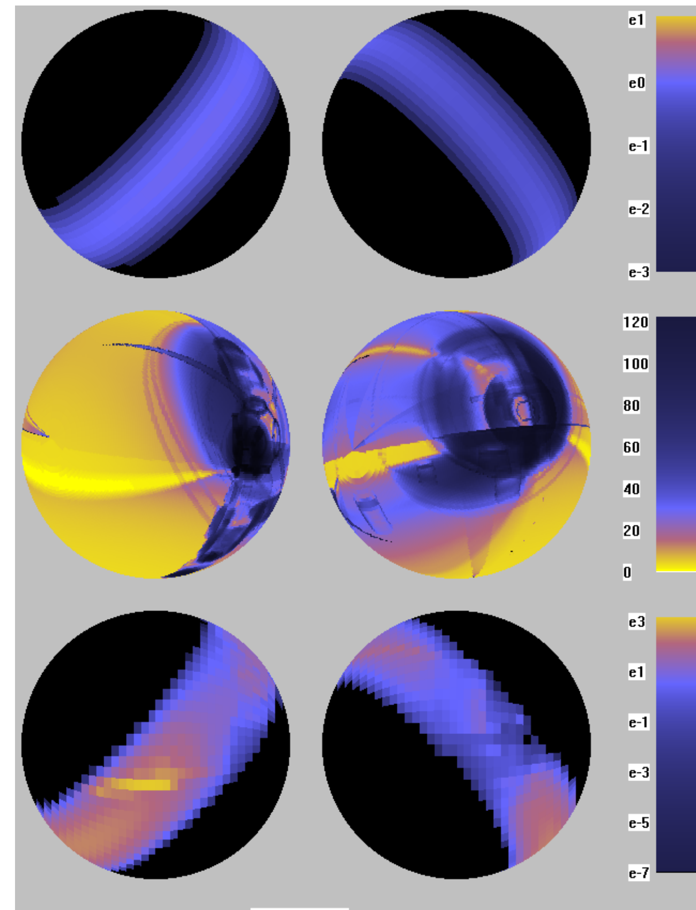
Angular distribution of dose rate contribution [nGy/(sec*ster)]

1-st ISS attitude type



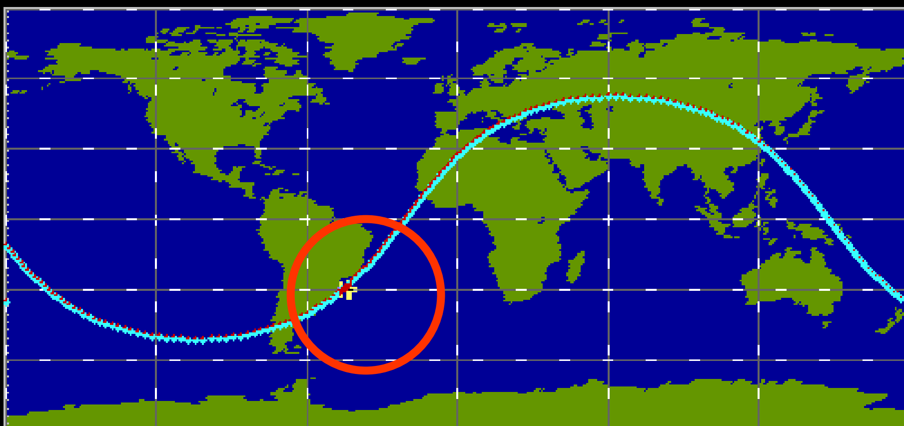
Dose rate = 58 nGy/sec

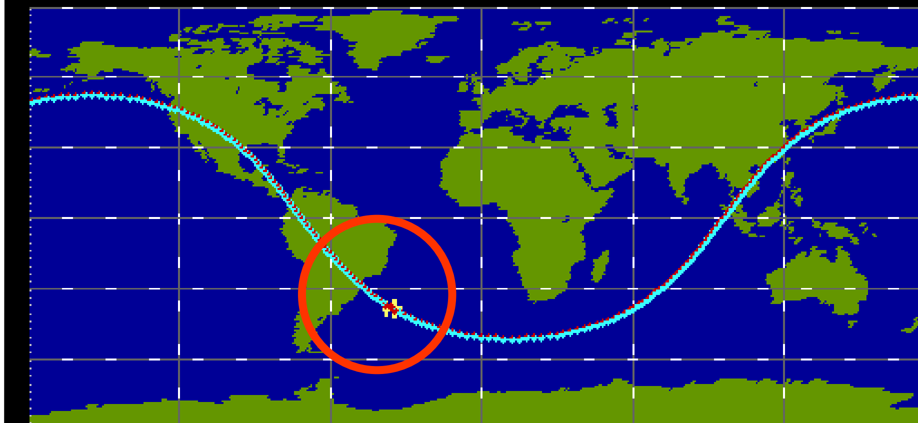
2-nd ISS attitude type



Dose rate = 172 nGy/sec

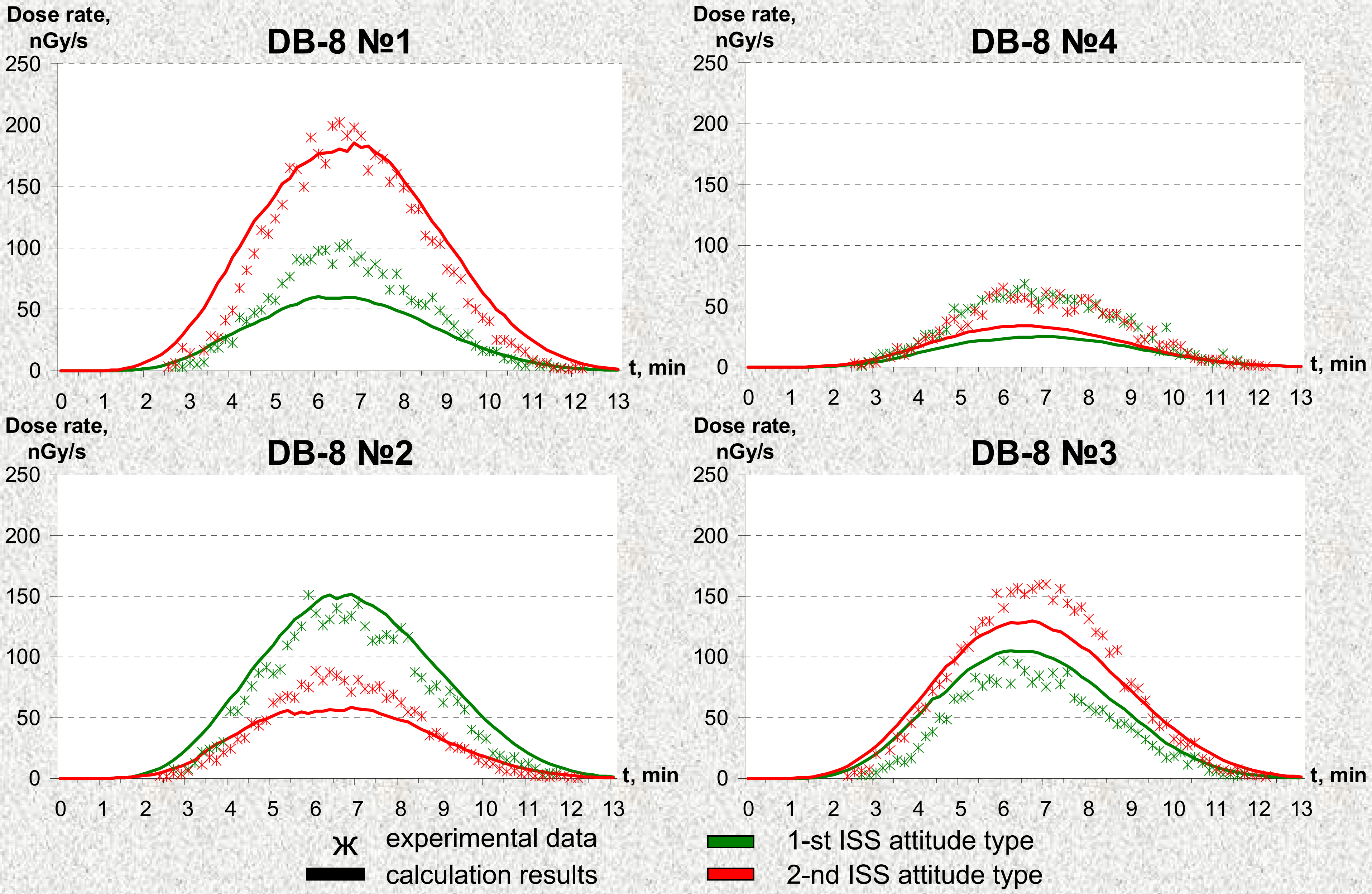
Experimental data selection



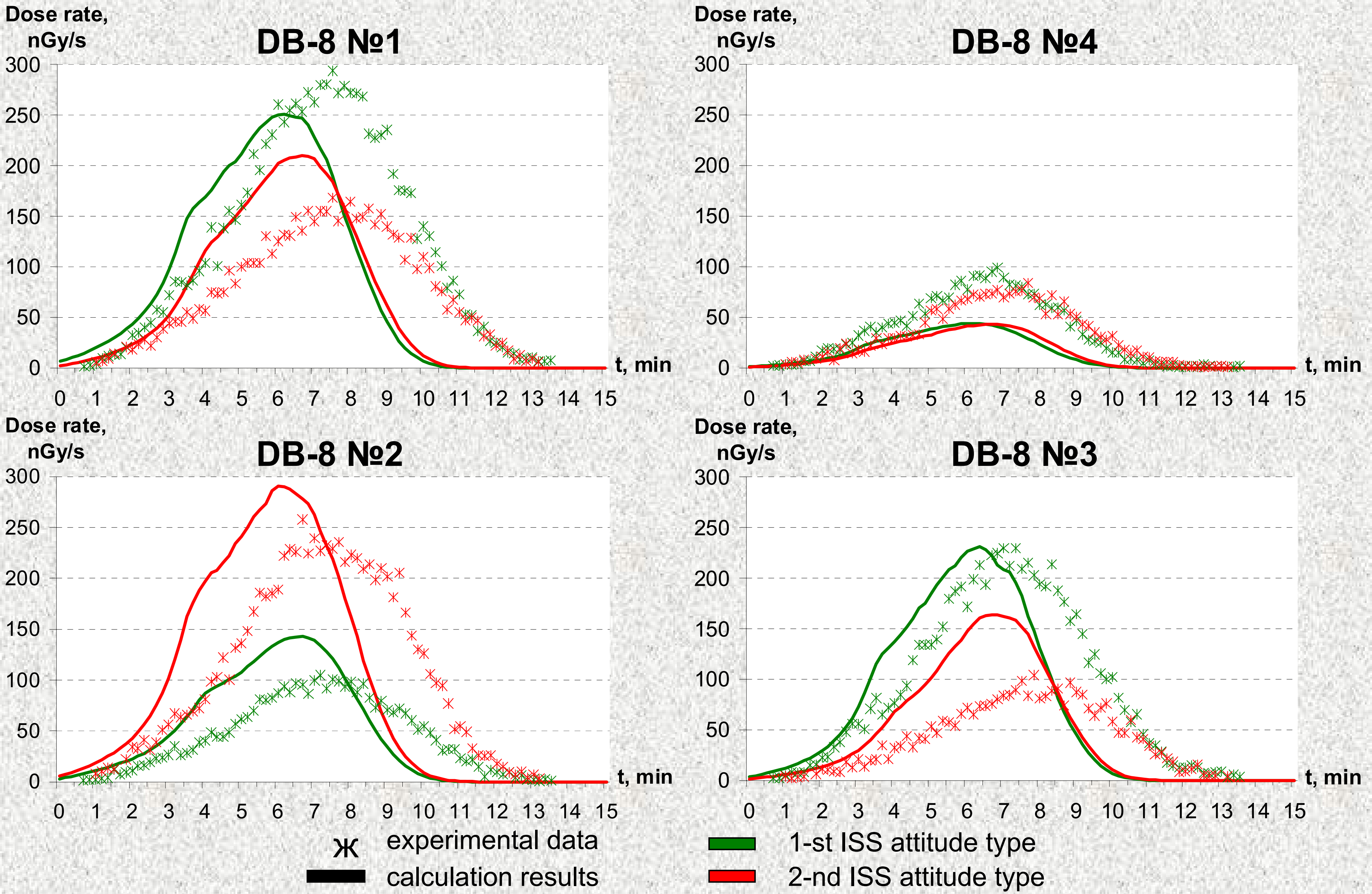


1-st ISS attitude type	2-nd ISS attitude type	1-st ISS attitude type	2-nd ISS attitude type
22.10.2006	16.01.2007	16.10.2007	13.08.2007
30.04.2007		18.10.2007	14.03.2008
07.08.2007		19.01.2008	
22.09.2007		18.04.2008	
09.03.2008		27.09.2008	
29.07.2009			

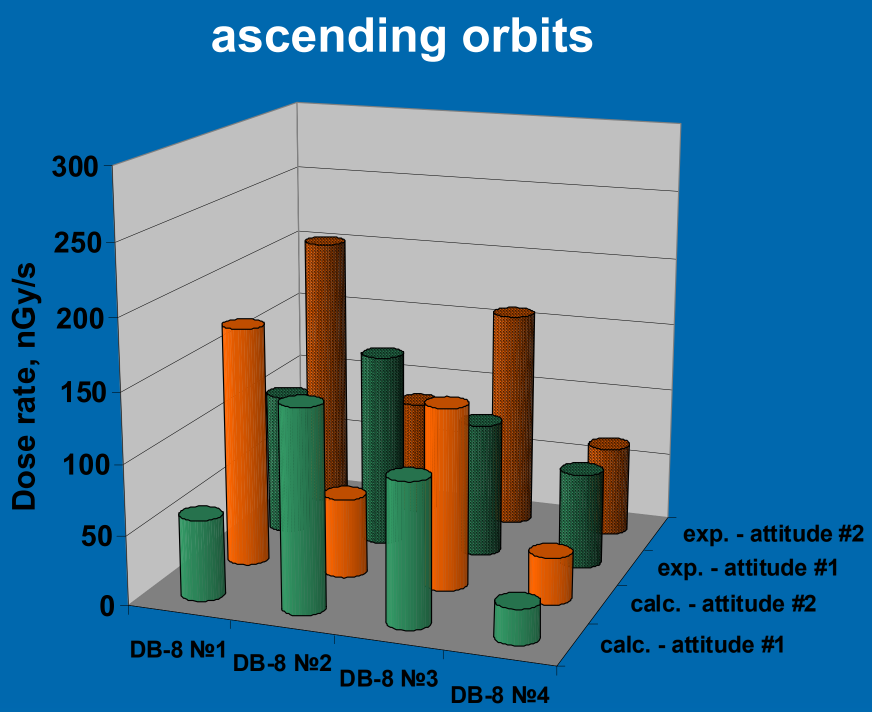
Dose rate dynamics inside the ISS Service module when crossing the SAA region at the ascending orbits

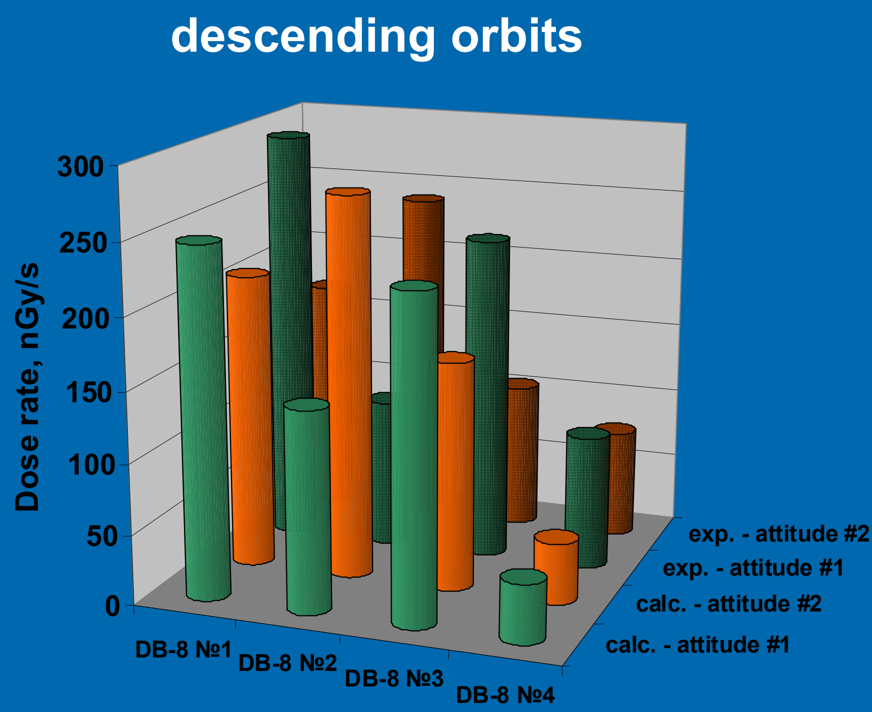


Dose rate dynamics inside the ISS Service module when crossing the SAA region at the descending orbits



Dose rate data near the center of the SAA region





1-st ISS attitude type

2-nd ISS attitude type

$$\delta = \frac{|D_{calc} - D_{\exp}|}{D_{\exp}}$$

		DB-8 #1			DB-8 #2			DB-8 #3			DB-8 #4		
		calc.	exp.	δ	calc.	exp.	δ	calc.	exp.	δ	calc.	exp.	δ
ascending orbits	1-st ISS attitude type	58	103	44%	144	140	3%	102	97	6%	25	69	63%
	2-nd ISS attitude type	172	202	15%	57	85	32%	131	159	18%	33	65	49%
descending orbits	1-st ISS attitude type	247	294	16%	142	106	34%	228	230	1%	42	95	56%
	2-nd ISS attitude type	209	168	24%	271	240	13%	162	104	56%	43	77	44%

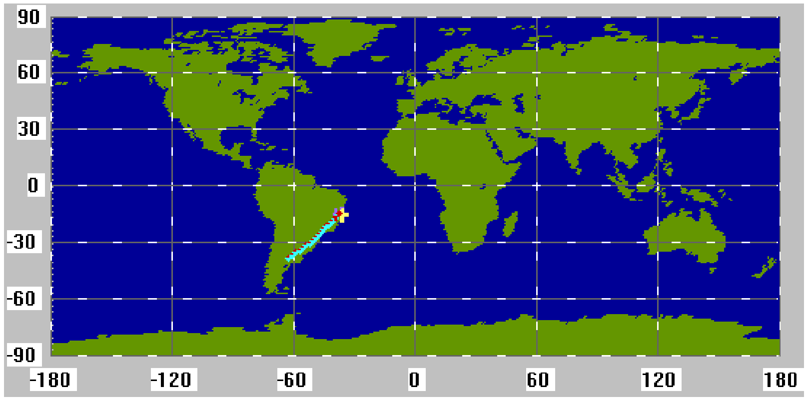
Conclusion

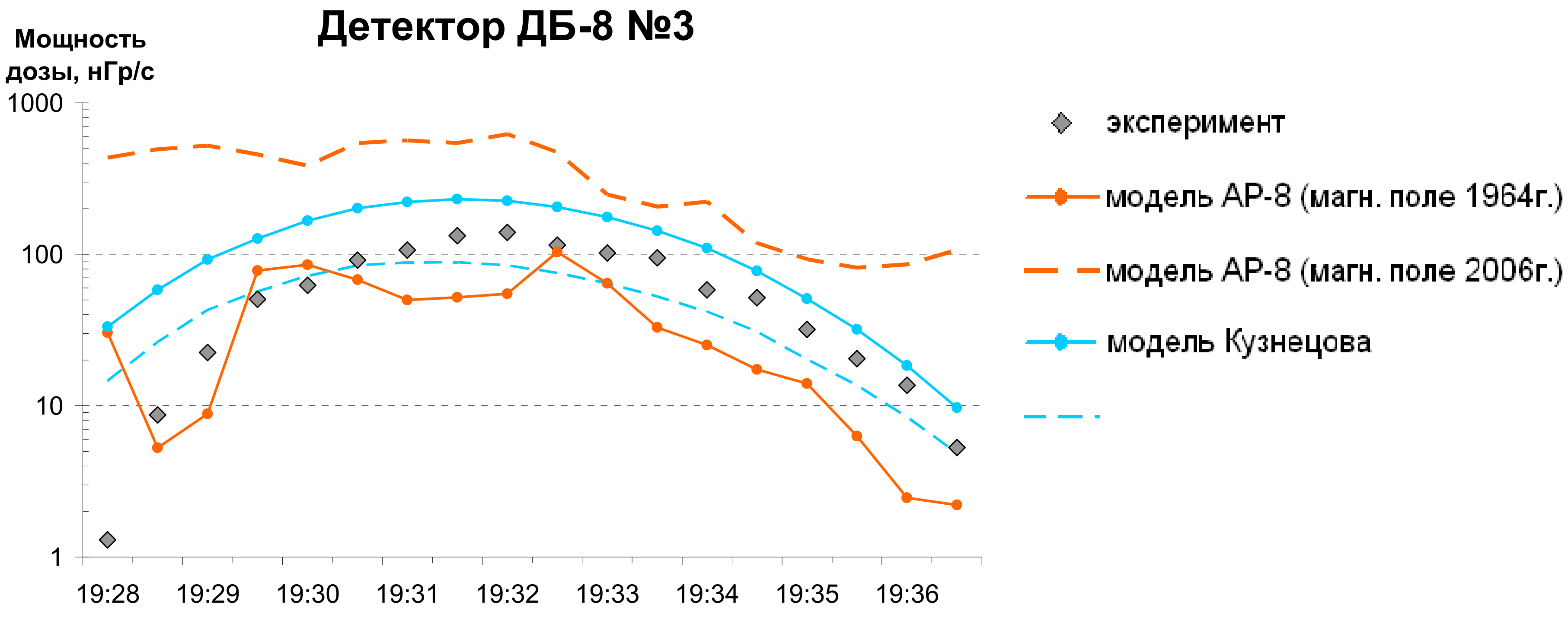
- It has been shown that ISS attitude changing can have a considerable effect on dose rate aboard the Service module of the station in the anisotropic radiation field of the South-Atlantic Anomaly. Registered dose rate can vary by a factor of 2 at some points of the station.
- The calculation technique for dose rate evaluation aboard the ISS has been developed taking into account the anisotropy of both falling radiation field and distribution of shielding thickness of the point inside the station.
- Using of the recently created models of proton pitch-angle distribution and of the ISS Service module shielding has allowed to take into account the ISS attitude effect for interpretation of the Radiation Monitoring System registrations.

Thank you for attention!

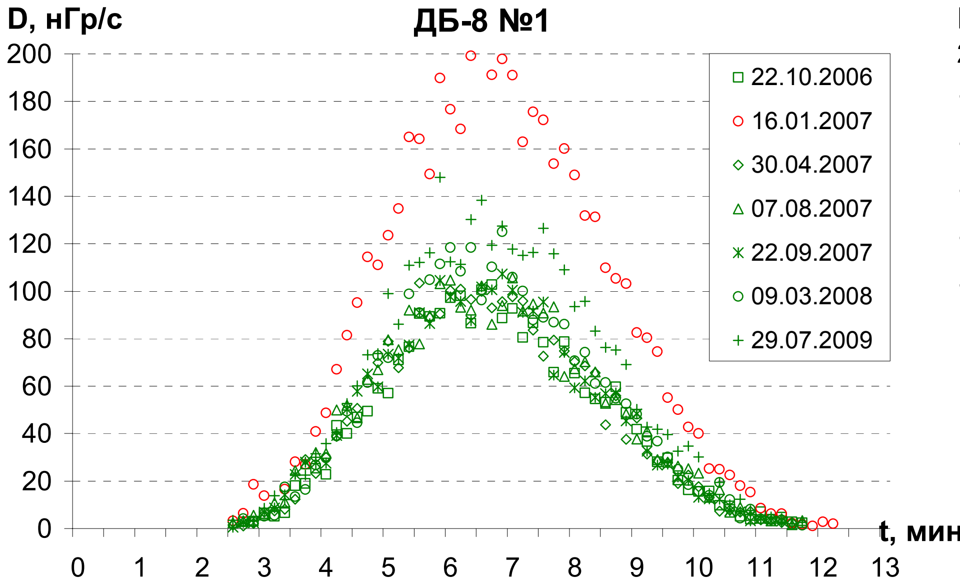
Влияние выбора модели потоков протонов на динамику мощности дозы

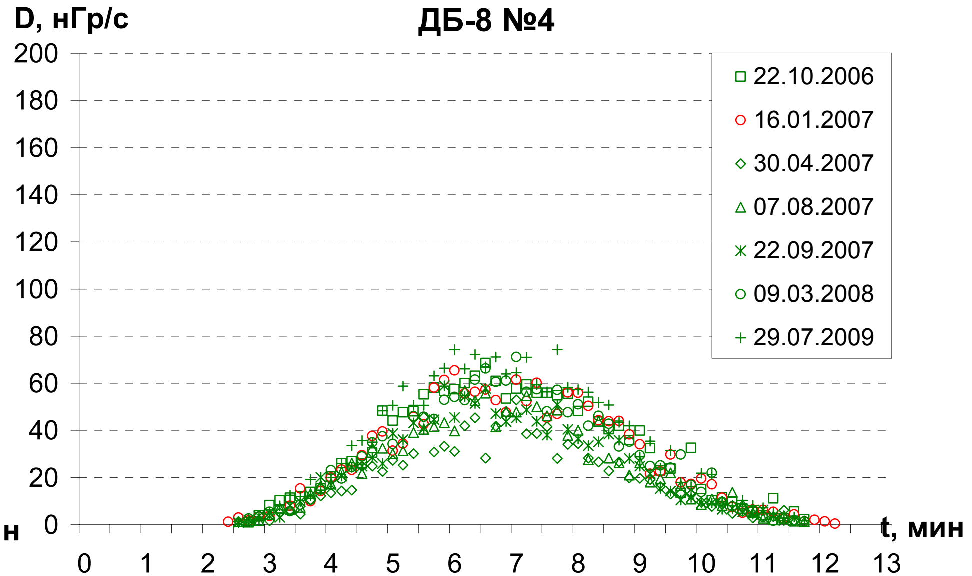
21.02.2006
(восходящий участок)

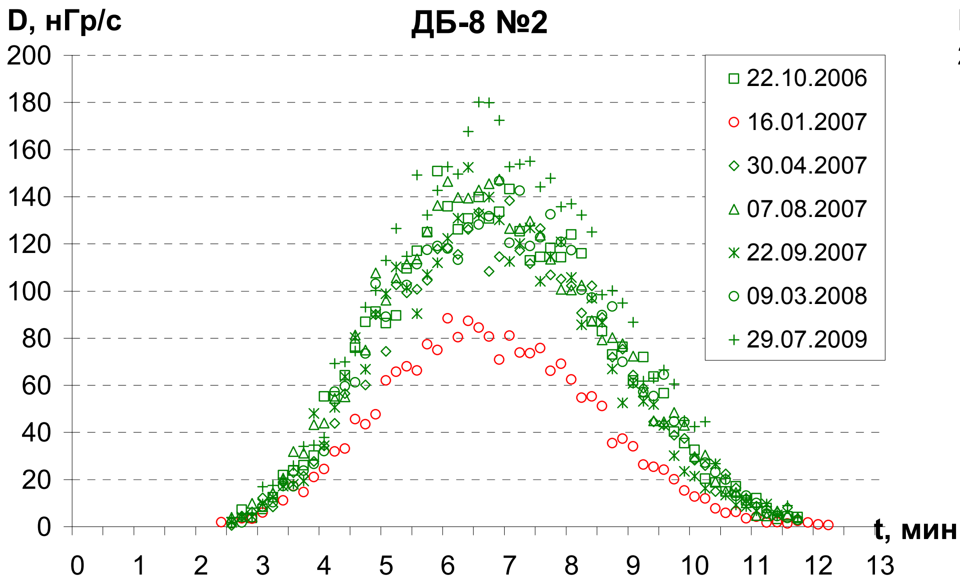


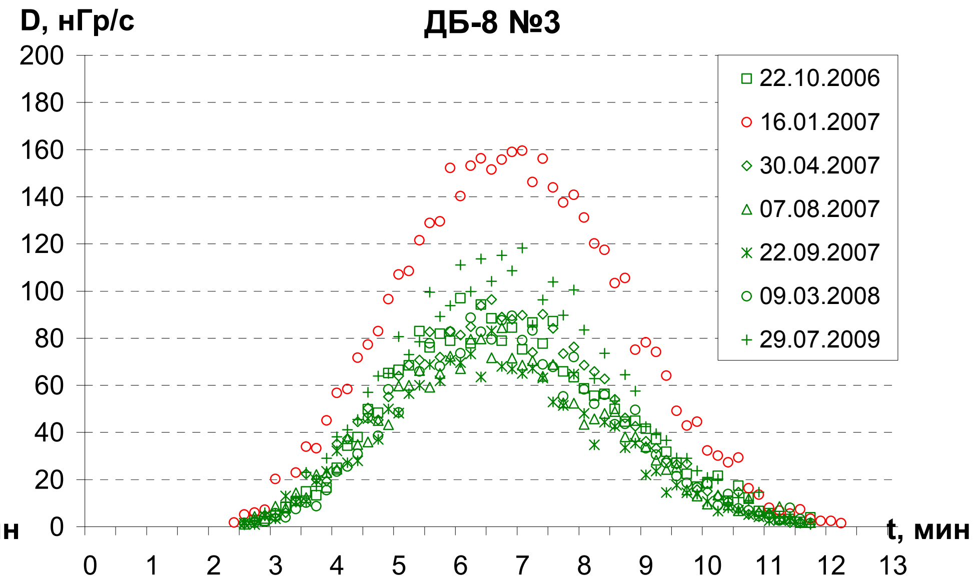


Данные измерений мощности дозы в зоне ЮАА на восходящих траекториях МКС









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