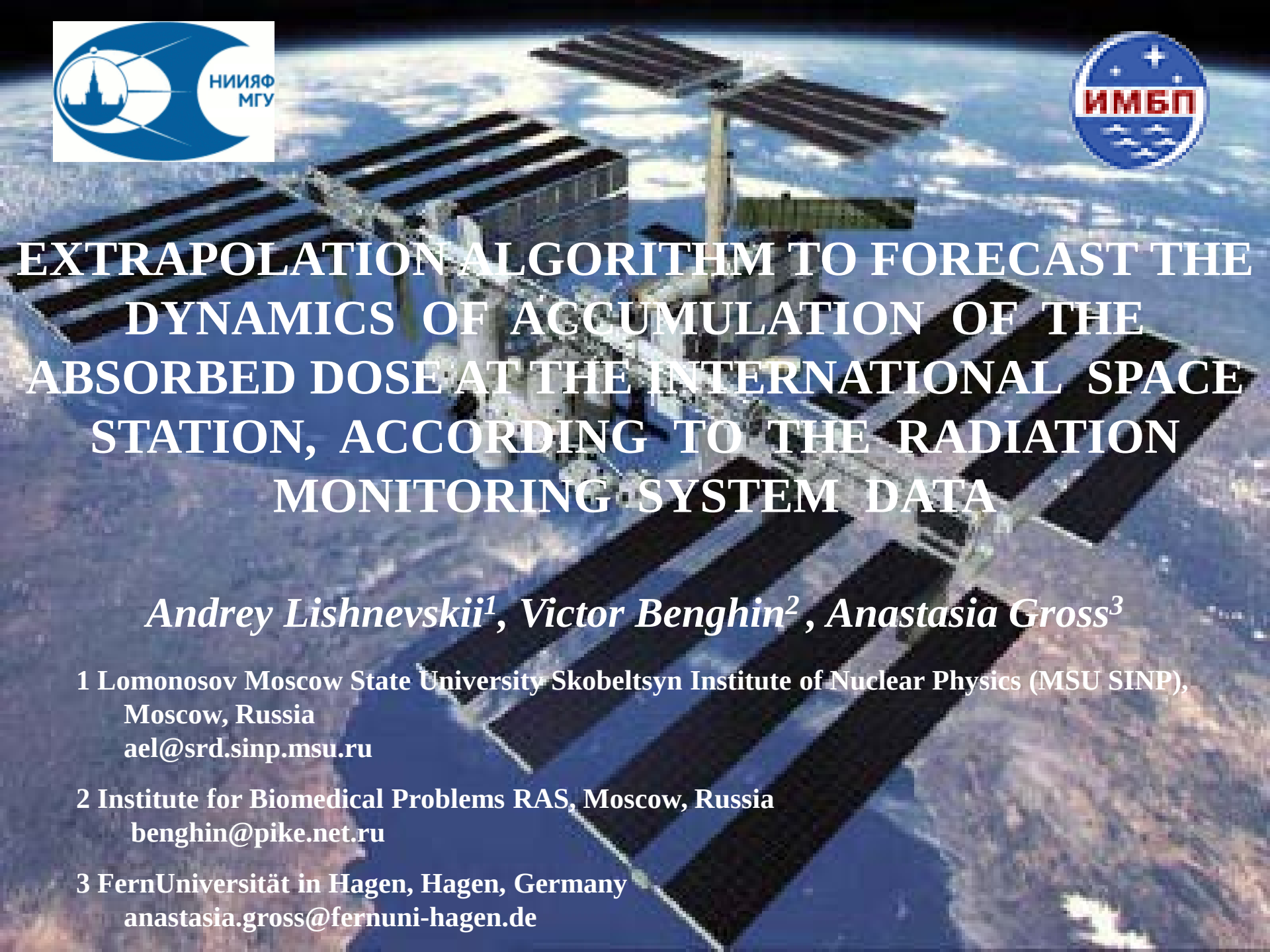

EXTRAPOLATION ALGORITHM TO FORECAST THE DYNAMICS OF ACCUMULATION OF THE ABSORBED DOSE AT THE INTERNATIONAL SPACE STATION, ACCORDING TO THE RADIATION MONITORING SYSTEM DATA

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benghin@pike.net.ru

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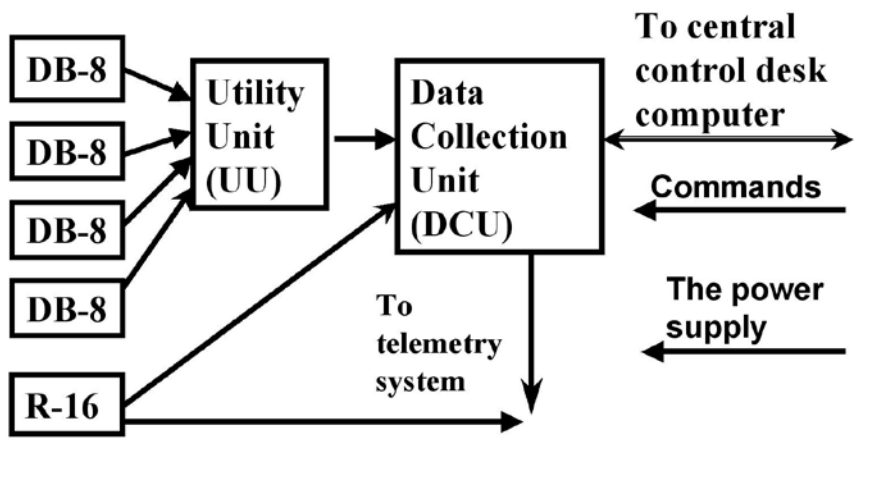
anastasia.gross@fernuni-hagen.de

Configuration of the Radiation Monitoring System (RMS)



RMS consists of 7 units:

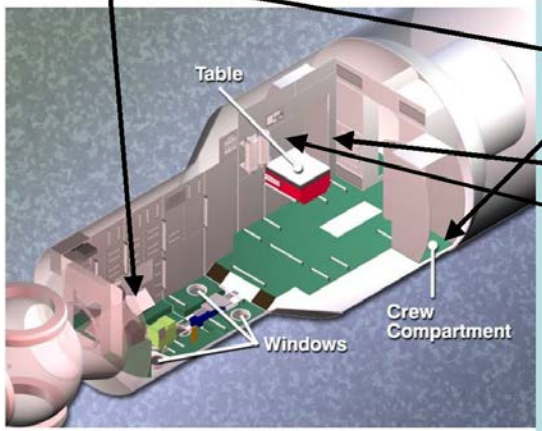
1. R-16 dosimeter (sensitive elements are two ionization chambers);

2. 4 high-sensitivity dosimetric units DB-8 with semiconductor radiation detectors;

3. 2 units (UU and DCU) for the processing and analysis of the measurement results.

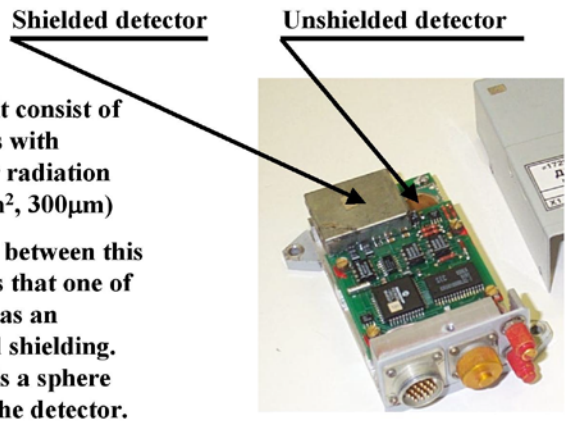
RMS integration with other systems of the ISS service module allows to transfer data to Earth on the telemetric channel, and also directly to display the parameters of a radiation environment to station crew via the personal computer.

Placements of the RMS Units



Unit	Placement
DB-8 No 1	Starboard side, behind panel No 410
DB-8 No 2	Port side, behind panel No 244 (cabin)
DB-8 No 3	Starboard side, behind panel No 447 (cabin)
DB-8 No 4	Starboard side, behind panel No 435
R-16	Ceiling of Big diameter bay, behind panel No 327
UU	Starboard side, behind panel No 447 (cabin)
DCU	starboard side, behind panel No 447 (cabin)

DB-8 unit without cover



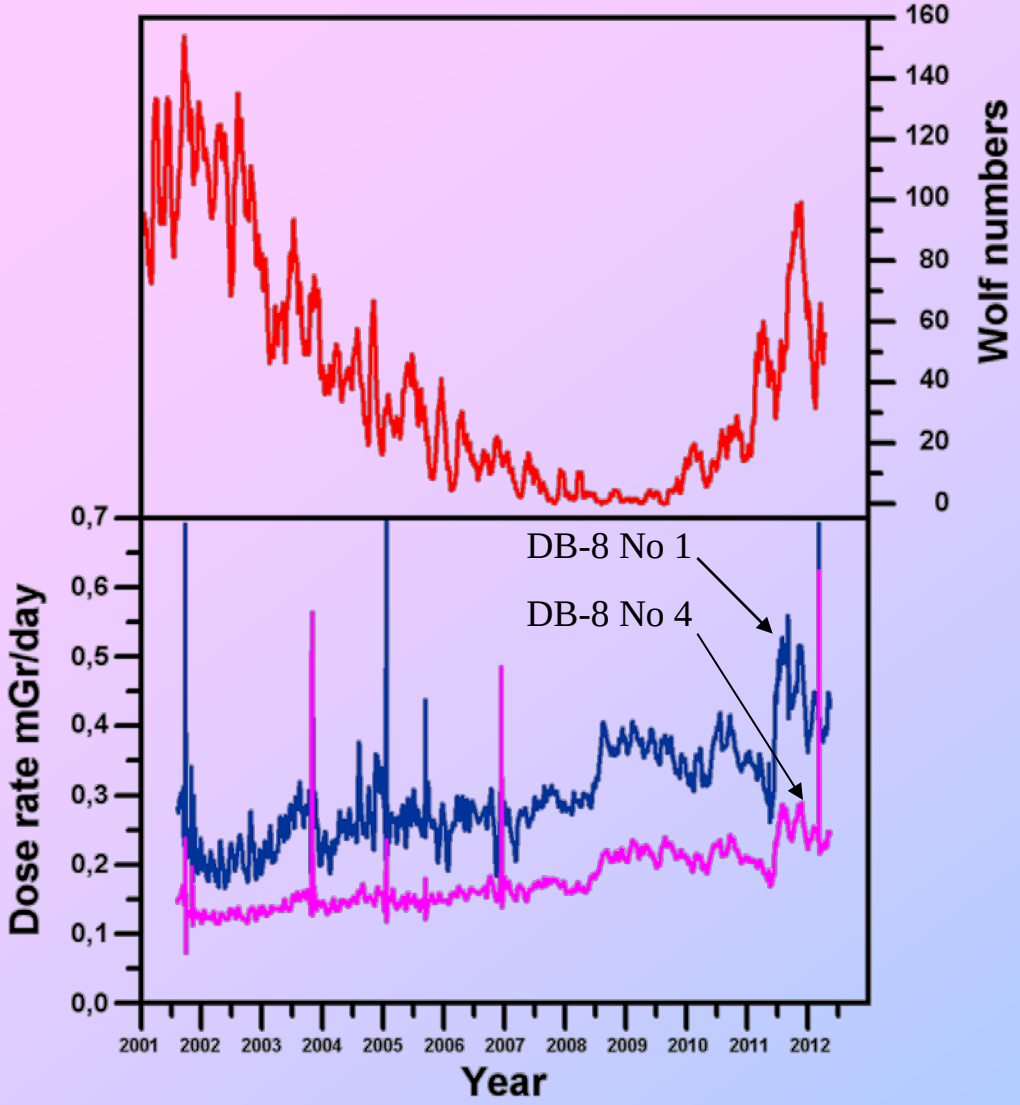
Each DB-8 unit consist of two dosimeters with semiconductor radiation detectors (1 cm^2, 300μm)

The difference between this two channels is that one of the detectors has an additional lead shielding. The shielding is a sphere surrounding the detector.

The sphere wall thickness is 3 g/cm^2 Pb

http://wrmiss.org/workshops/eighteenth/Benghin.pdf

The measurement results



Variations of Radiation Environment on the International Space Station in 2005–2009
A.E. Lishnevskii, M.I. Panasyuk, V.V. Benghin, V.M. Petrov, A.N. Volkov, and O.Yu. Nechaev Cosmic Research, 2012, Vol. 50, No. 4, pp. 319–323

Level of solar activity during the measurement period is characterized by the Wolf numbers.

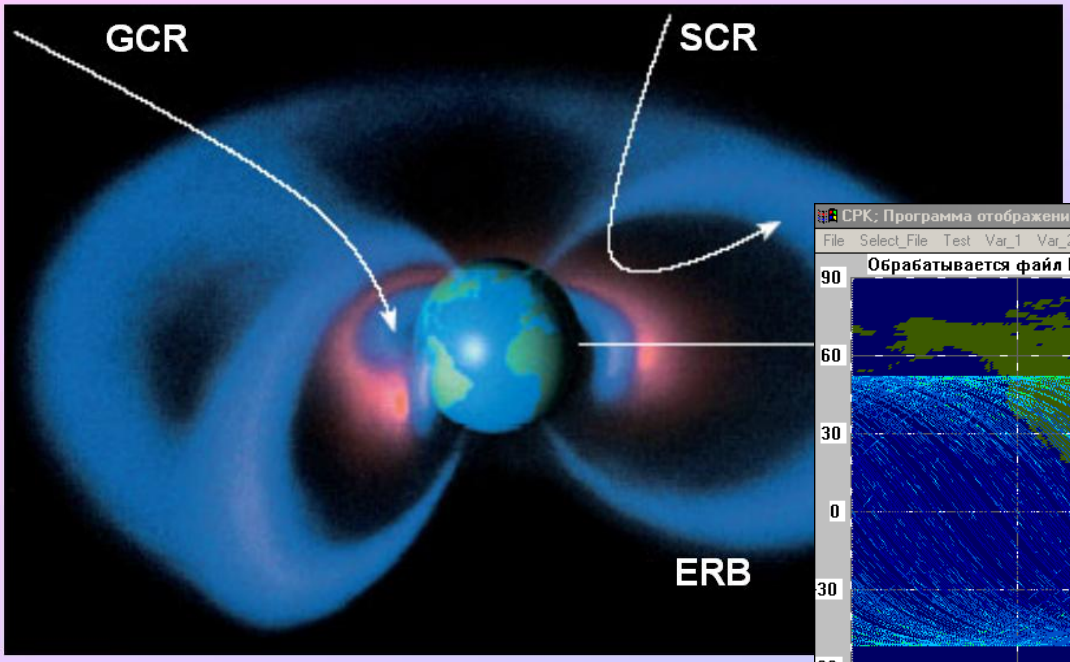
Measurement period covers the recession of the 23rd cycle of solar activity, minimum period and the beginning of the growth phase of the 24th cycle. Data on Wolf numbers taken from the site

ftp://ftp.ngdc.noaa.gov/STP// SOLAR_DATA / SUNSPOT_NUMBERS / INTERNATIONAL /

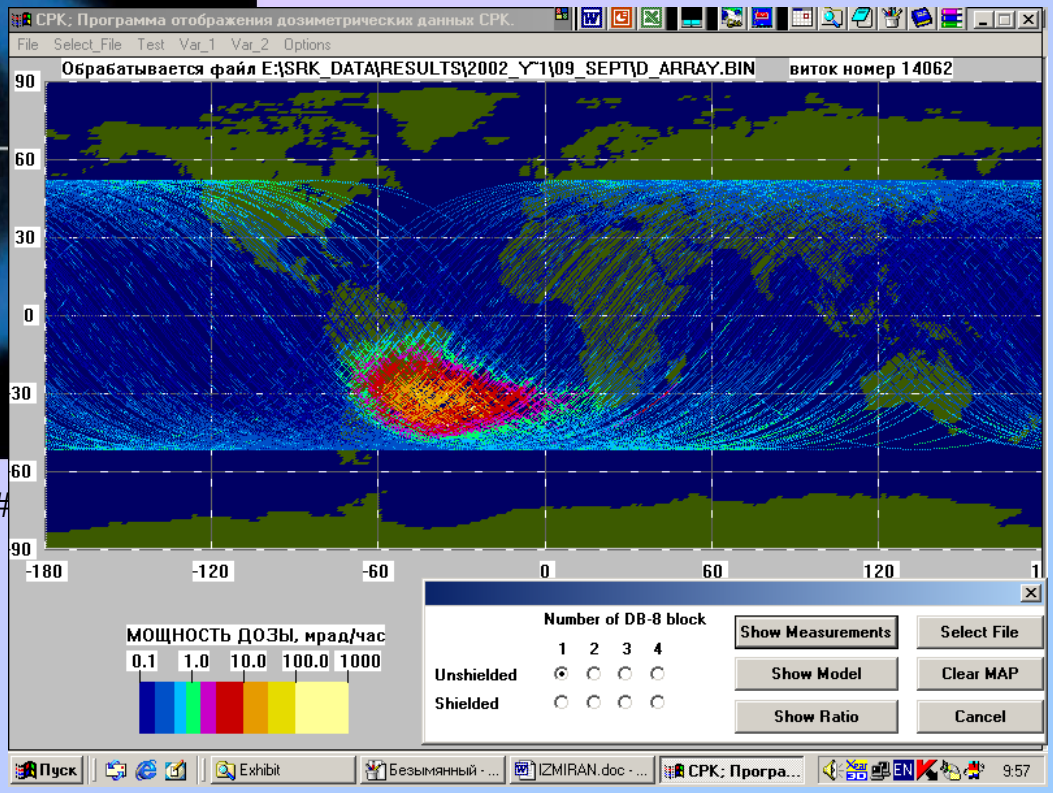
and smoothed by the "moving average" at intervals averaging 30 days.

Data on the average daily dose rate registered for the period 1 August 2001 to 15 May 2012 by unshielded detector blocks DB-8 number 1 and number 4 (the least protected detector and the most protected, respectively).

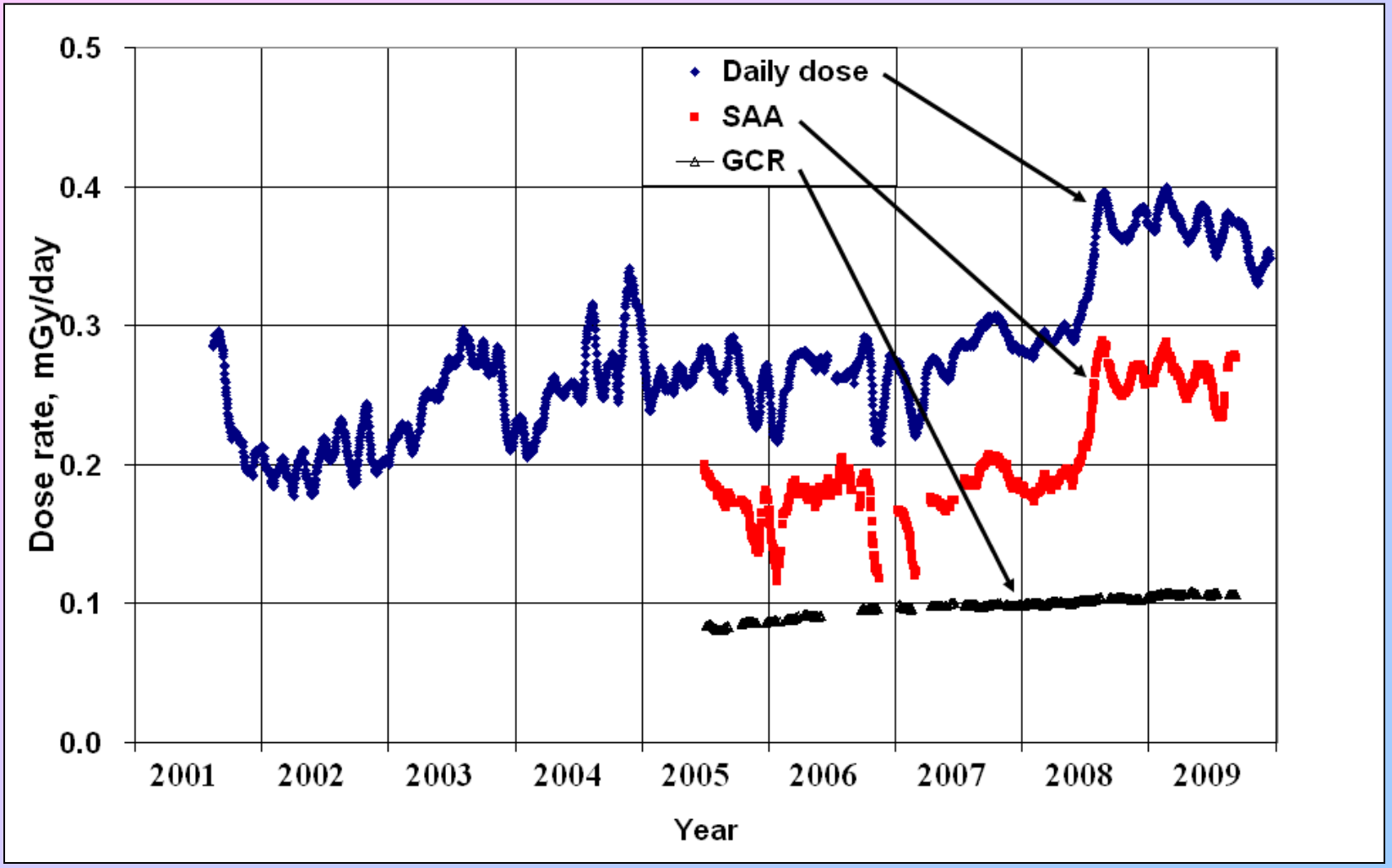
The distribution of the dose rate at the trajectory of the ISS fly



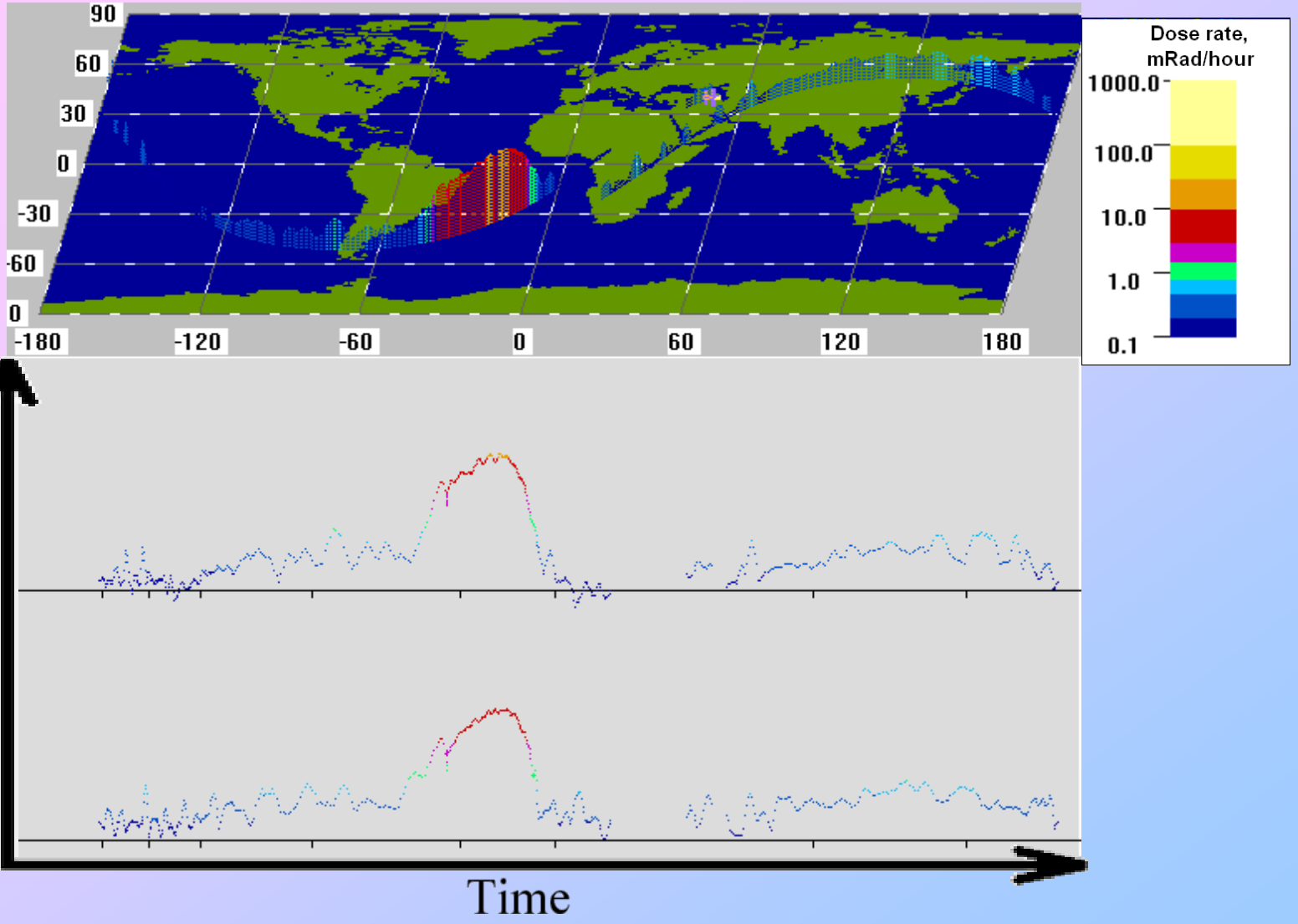
http://ligaspace.my1.ru/news/2010-01-01-197#



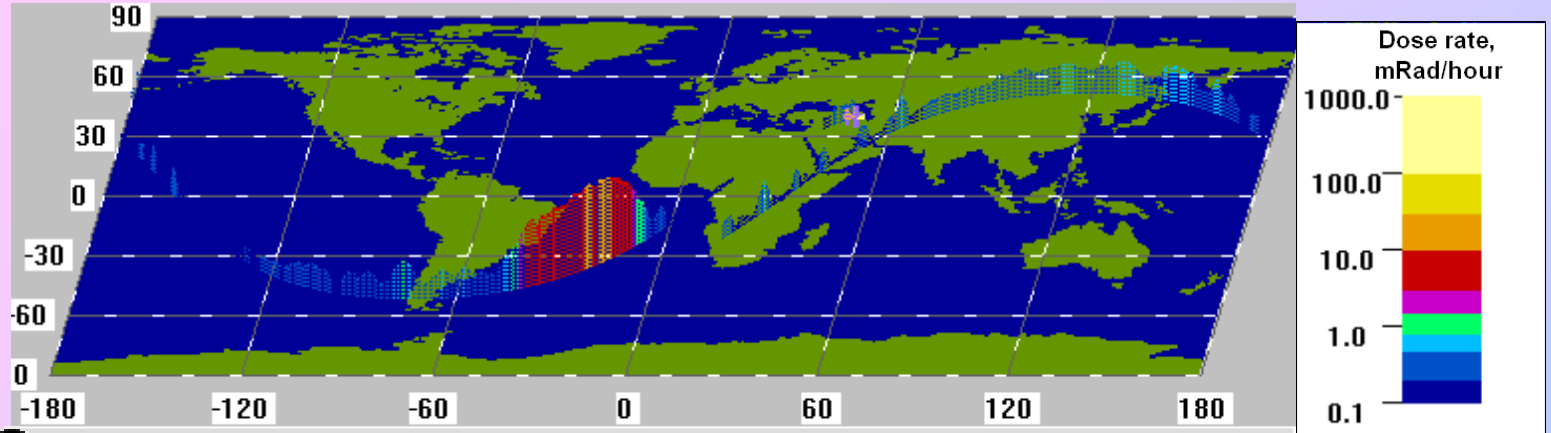
Contribution to a daily dose from galactic cosmic rays and from the inner radiation belt of the Earth

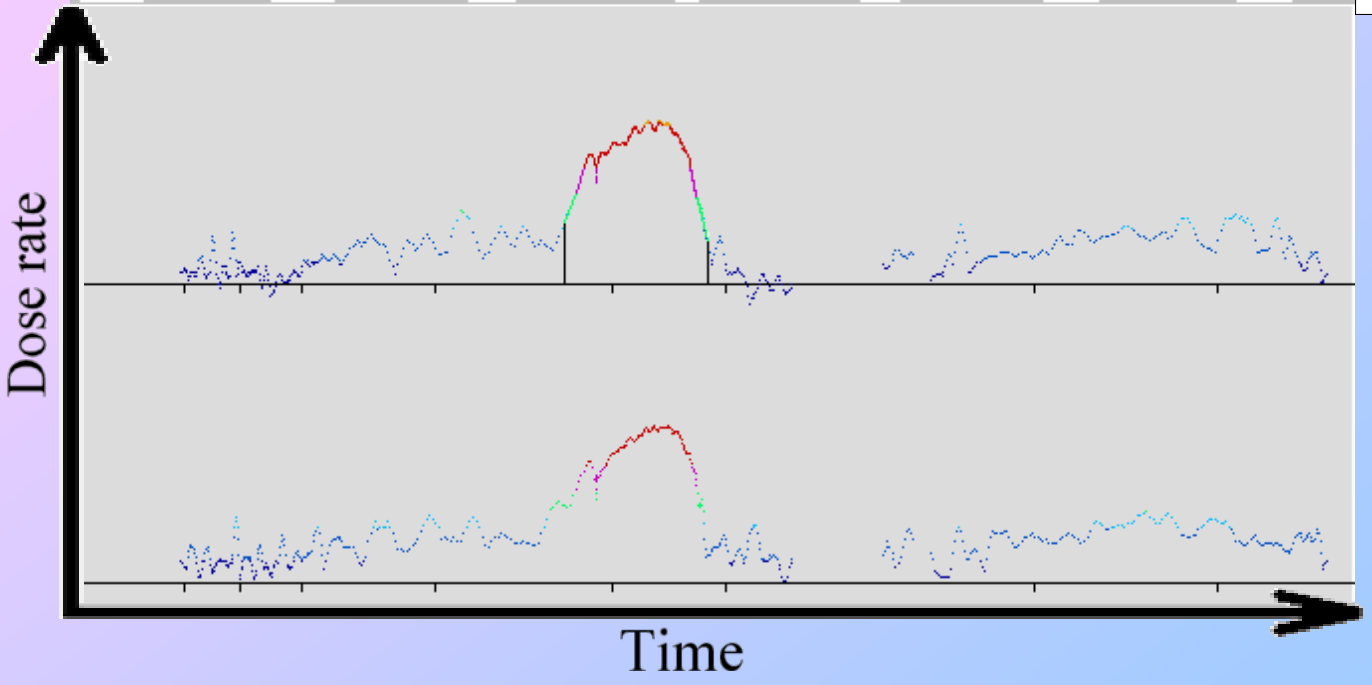


The dose rate recorded by the detector unit DB-8 No 1

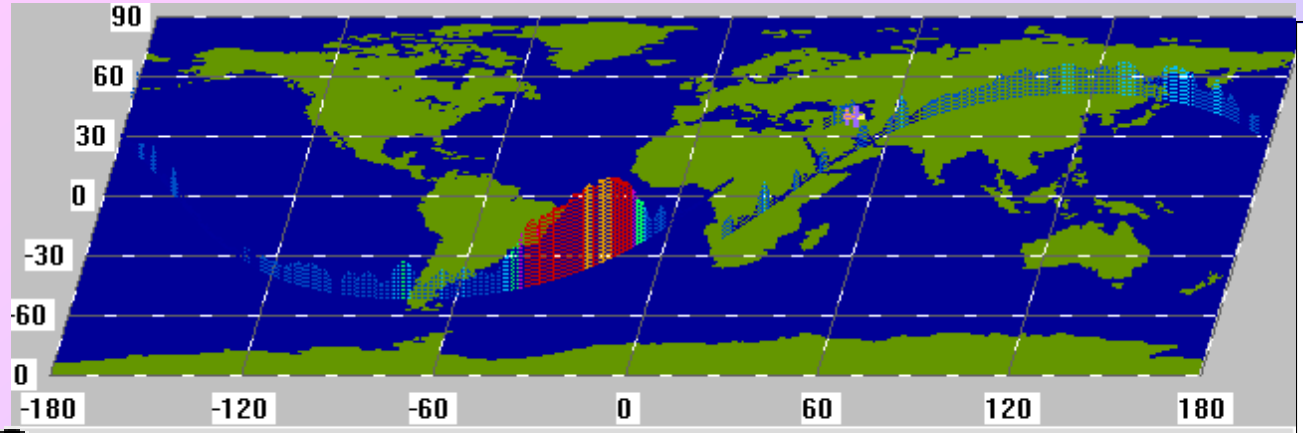


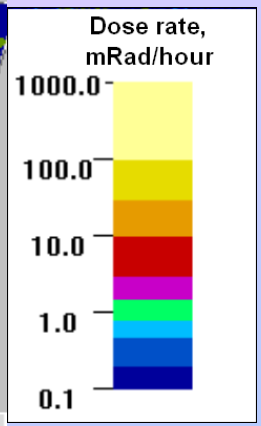
The dose rate recorded by the detector unit DB-8 No 1

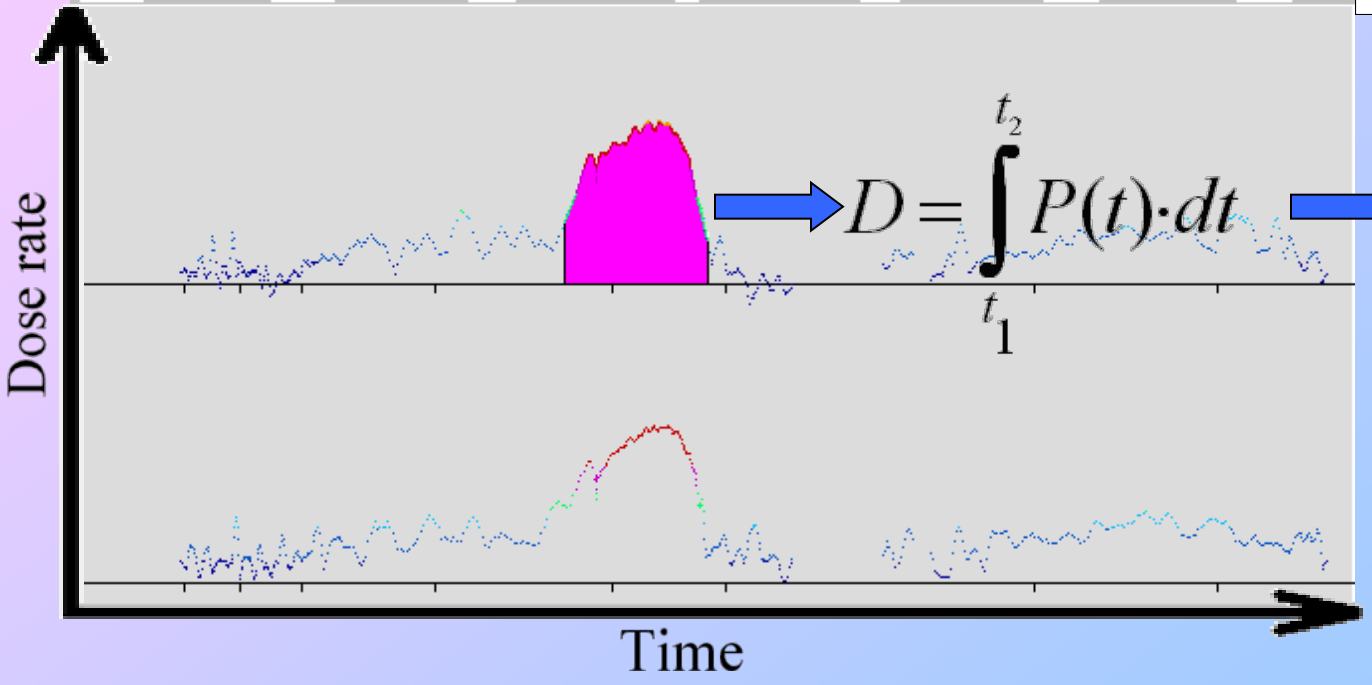




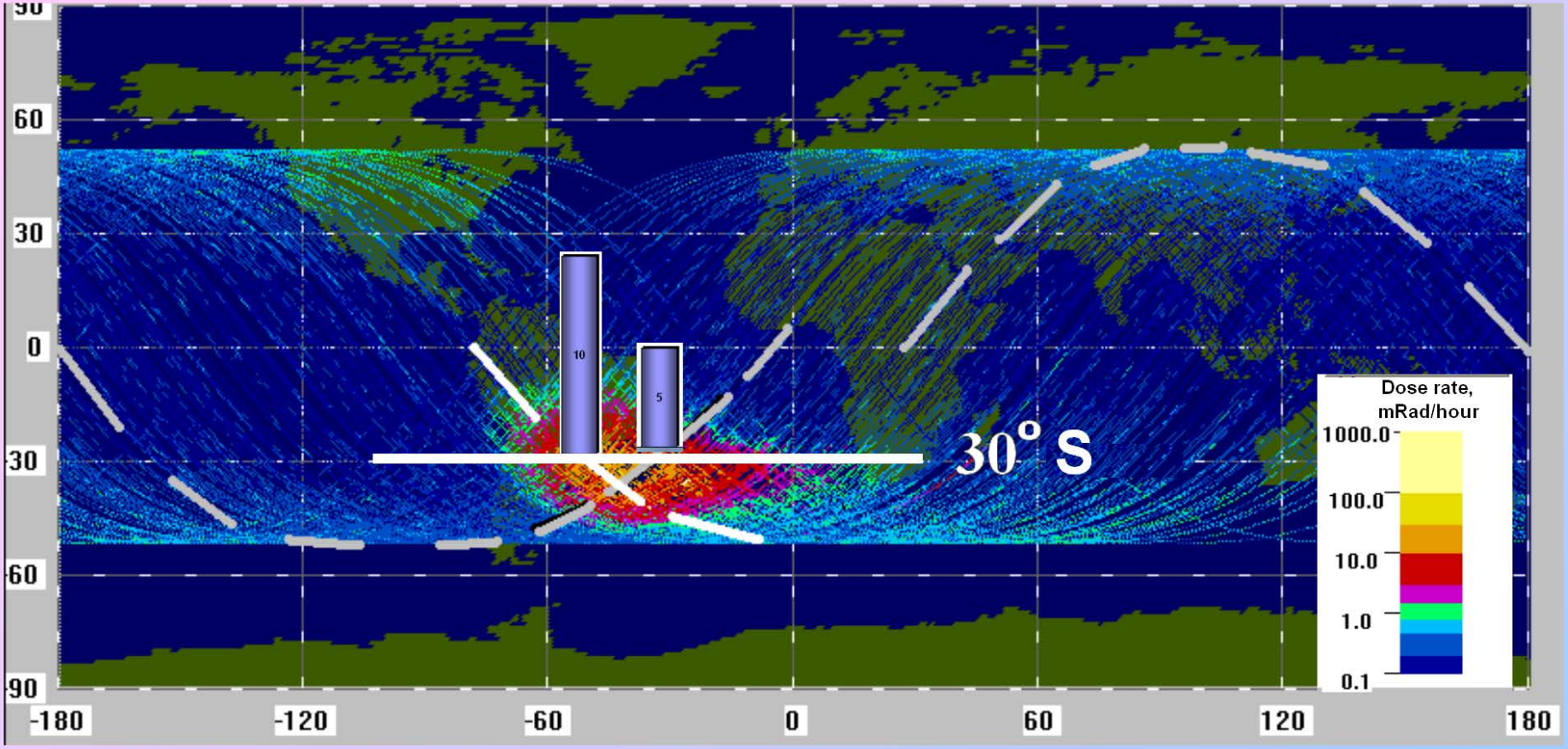
The dose rate recorded by the detector unit DB-8 No 1

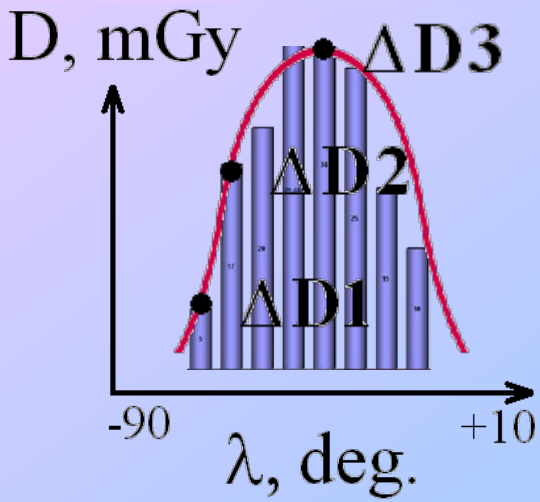






$$D = \int_{t_1}^{t_2} P(t) \cdot dt$$

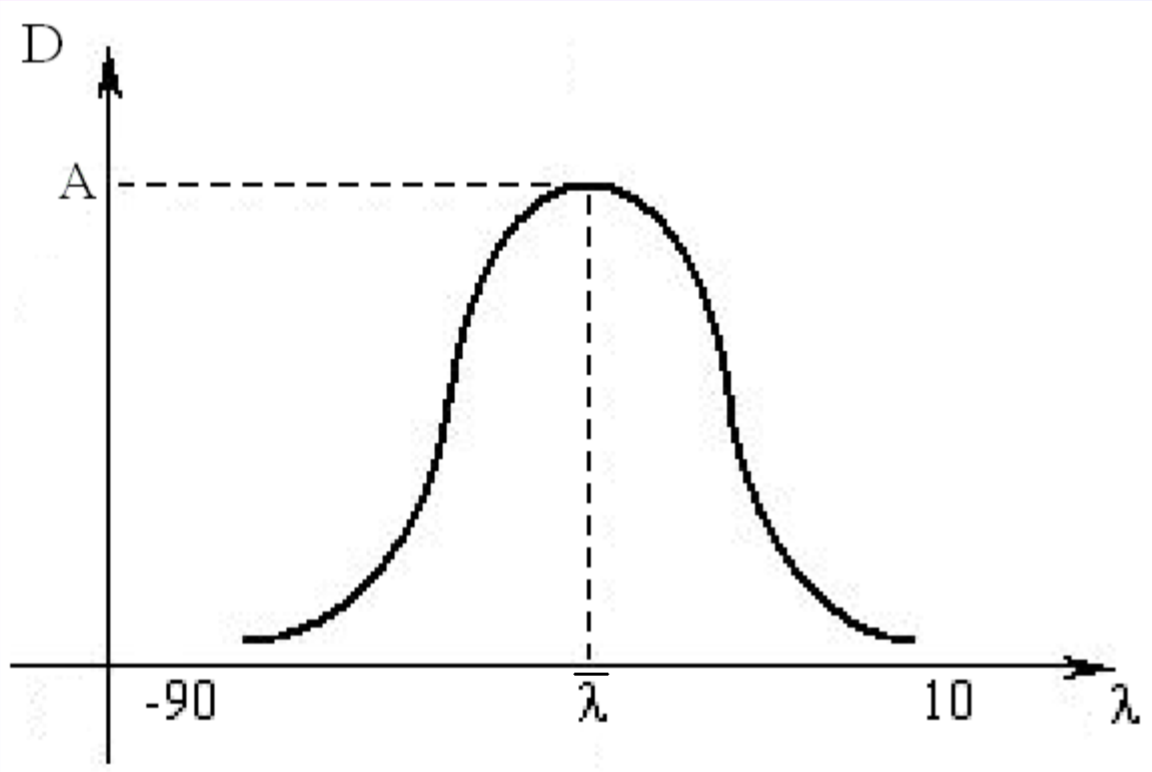

90
60
30
0
30
60
90
-180
-120
-60
0
60
120
180
10
5
30° S
Dose rate,
mRad/hour
1000.0
100.0
10.0
1.0
0.1


D, mGy
ΔD3
ΔD2
ΔD1
-90
+10
λ, deg.

$$D = A * e^{-\frac{(\lambda - \bar{\lambda})^2}{2\sigma^2}}$$

$$A(h) = k*(h - h_0) + b$$

$$D_{calc} = f(h, \lambda)$$

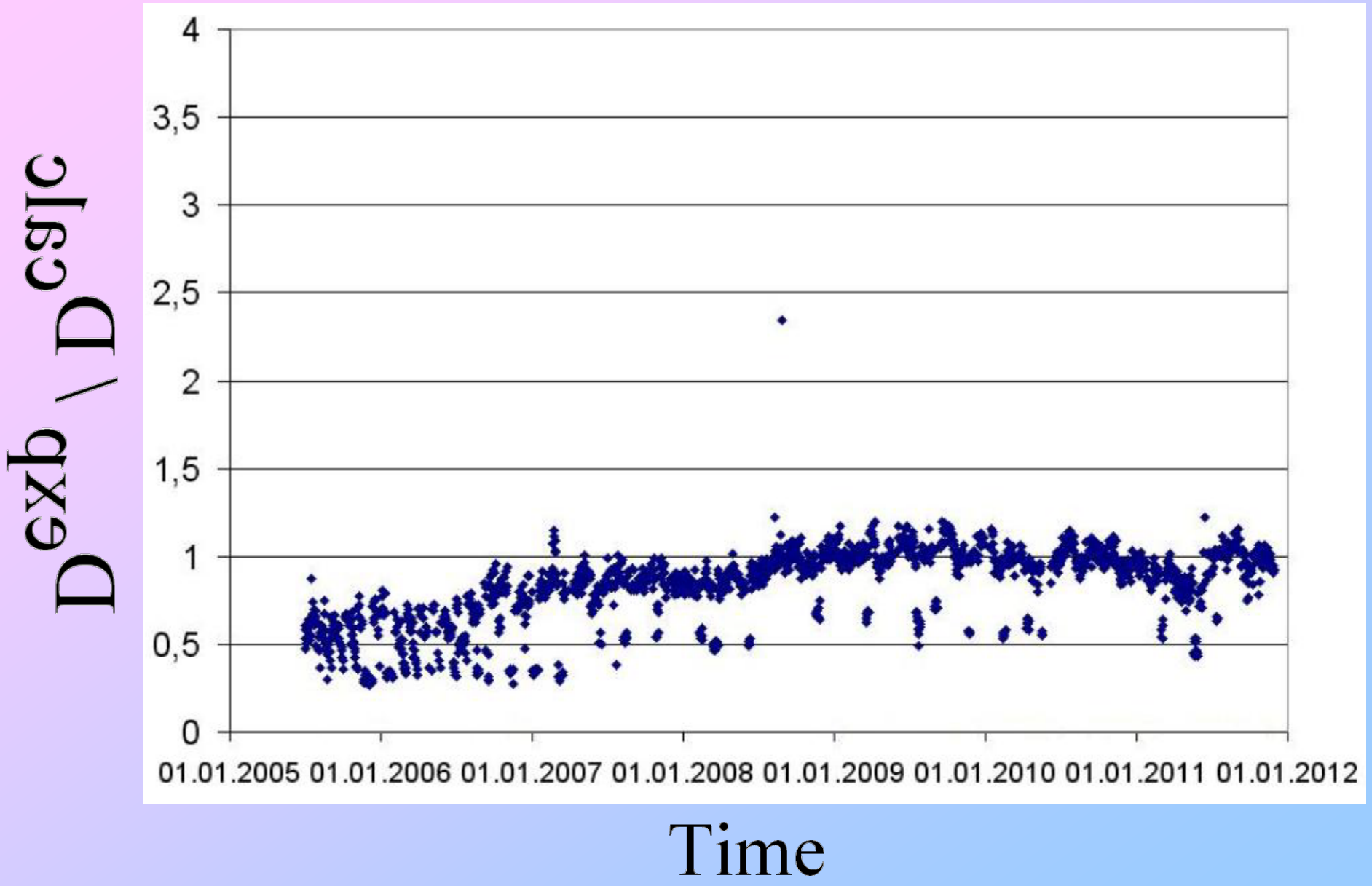


Results of Monitoring Variations of Absorbed Dose Rate onboard the International Space Station during the Period 2005–2011

A. E. Lishnevskii, M. I. Panasyuk, O. Yu. Nechaev, V. V. Benghin, V. M. Petrov, A. N. Volkov, V. I. Lyagushin, and I. V. Nikolaev

Cosmic Research, 2012, Vol. 50, No. 5, pp. 391–396

The ratio of the experimental value of a dose for passing SAA to the calculated



Algorithm of short-term forecast of the dynamics of accumulation of the absorbed dose at the ISS

•Empirical forecast algorithm based on the results of on-board dosimetry measurements and ballistics

•Forecast of dose accumulation dynamics on "subsequent" period (1-2 days) is based on the analysis of the dosimetry data "preceding" period (1 day - 2 weeks)

•Forecast for the "subsequent" period is based on the determination of the contribution to the daily dose from the GCR and the characteristics of the doses received by the ISS passes SAA on dosimetric data of "preceding" period

•It is assumed that the altitude of the ISS fly during the "preceding" and "subsequent" periods of time does not change significantly

Forecast constructing algorithm

SAA area passage dosimetric data (preceding period)

$$A = \frac{D}{e^{-\frac{(\lambda - \bar{\lambda})^2}{2\sigma^2}}}$$

$$\bar{A} = \frac{\sum_{i=1}^{N} A_i}{N}$$

$$D = \bar{A} * e^{-\frac{(\lambda - \bar{\lambda})^2}{2\sigma^2}}$$

$$D_{sum} = D_{end} - D_{start}$$

$$D_{\Sigma} = \sum_{i=1}^{N} D_i$$

$$D_{GCR}^{daily} = \frac{D_{sum} - D_{\Sigma}}{t_{pp}(days)}$$

$$D_{GCR}^{daily}$$

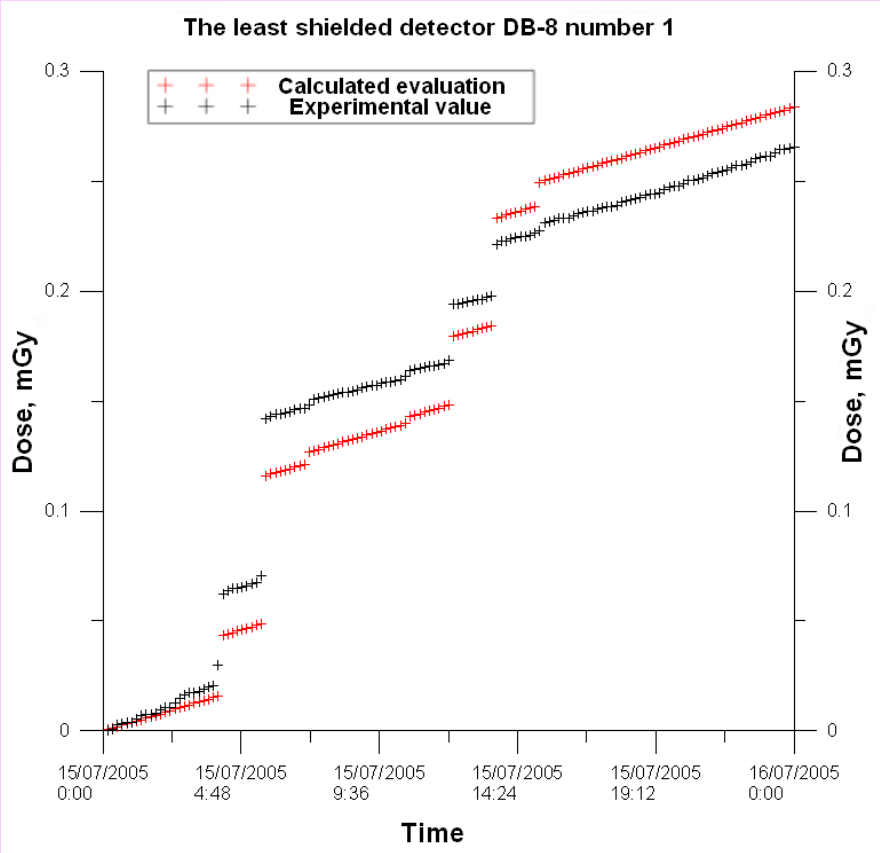
$$D_{ERB} = \bar{A} * e^{-\frac{(\lambda - \bar{\lambda})^2}{2\sigma^2}}$$

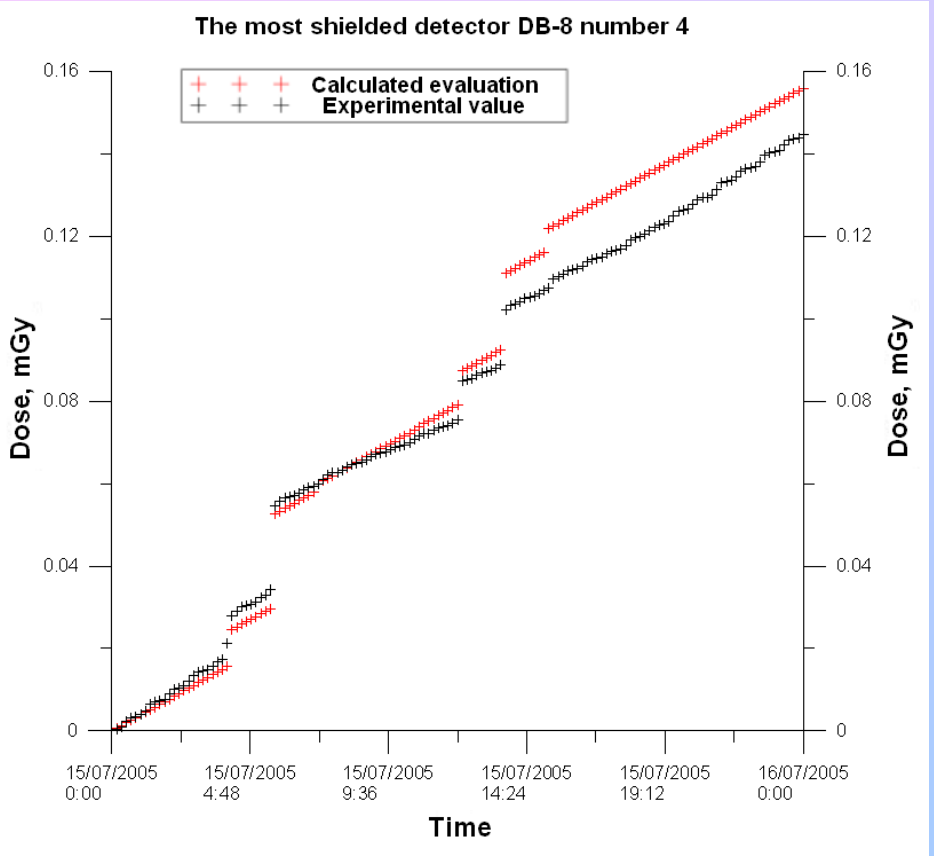
(subsequent period)

Calculation of the dynamics of absorbed dose accumulation (subsequent period)

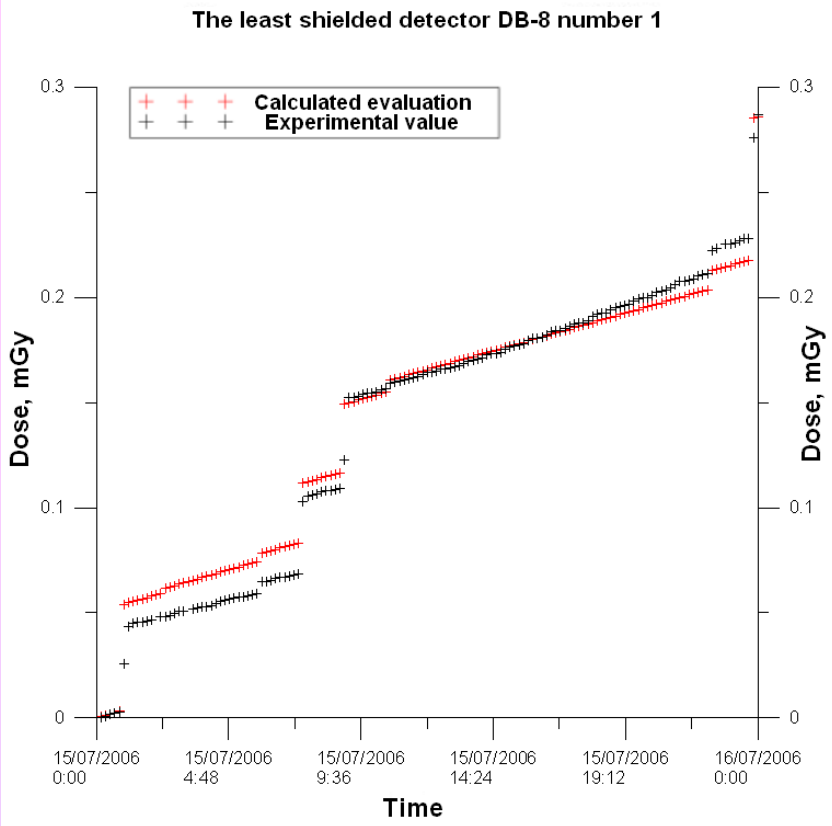
Used data from RMS ISS during the time interval
01.07.2005 - 30.11.2011

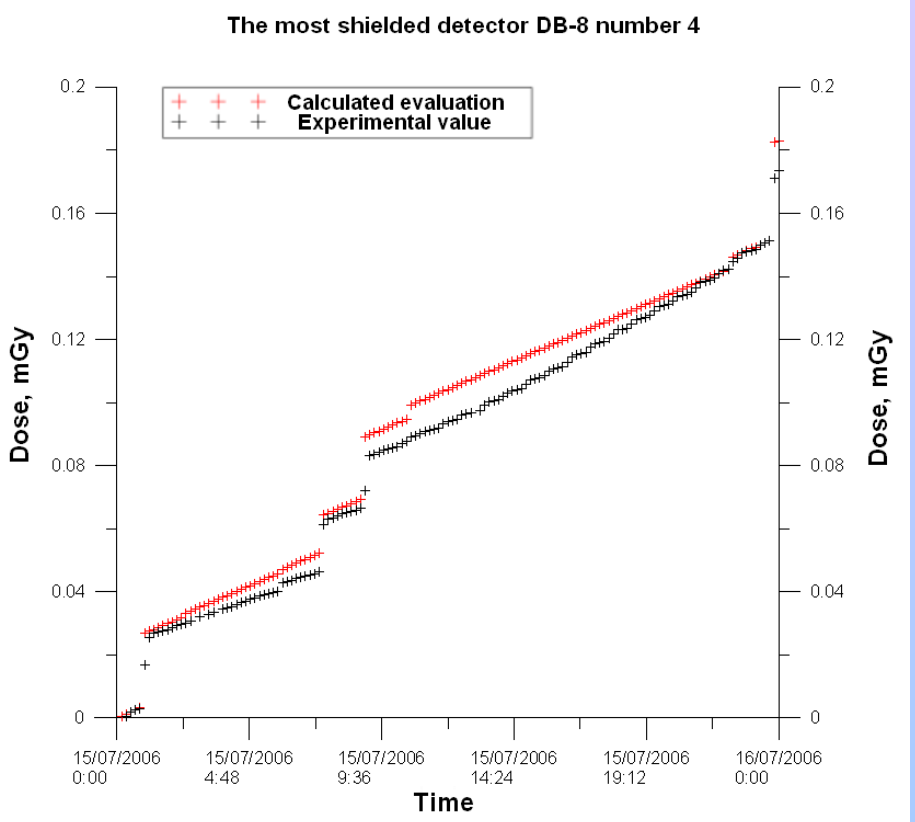
RESULTS:



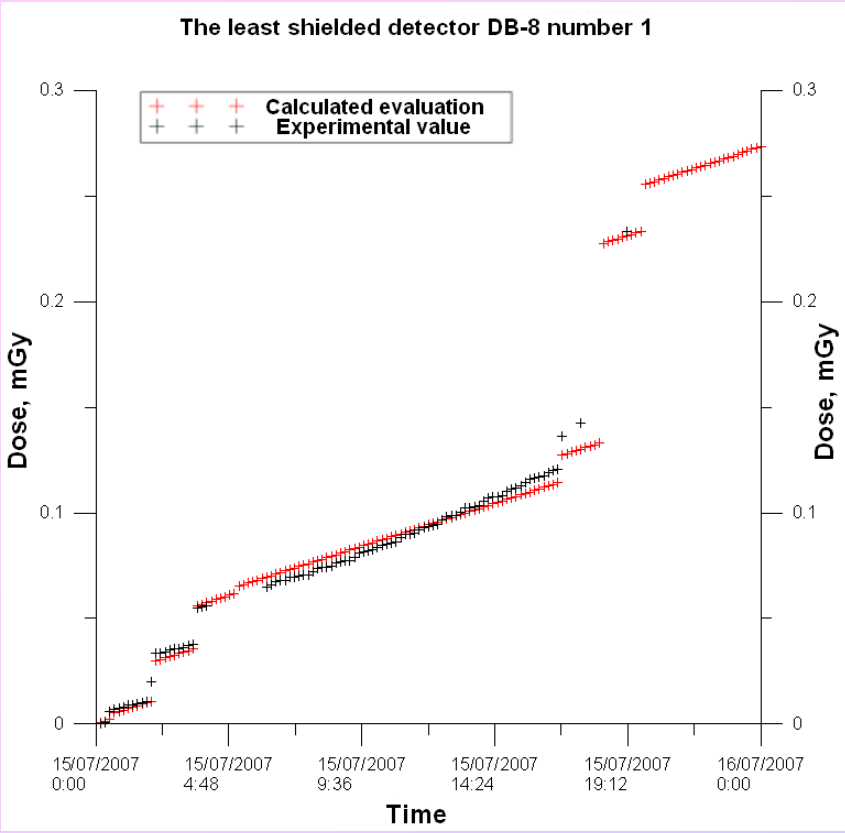


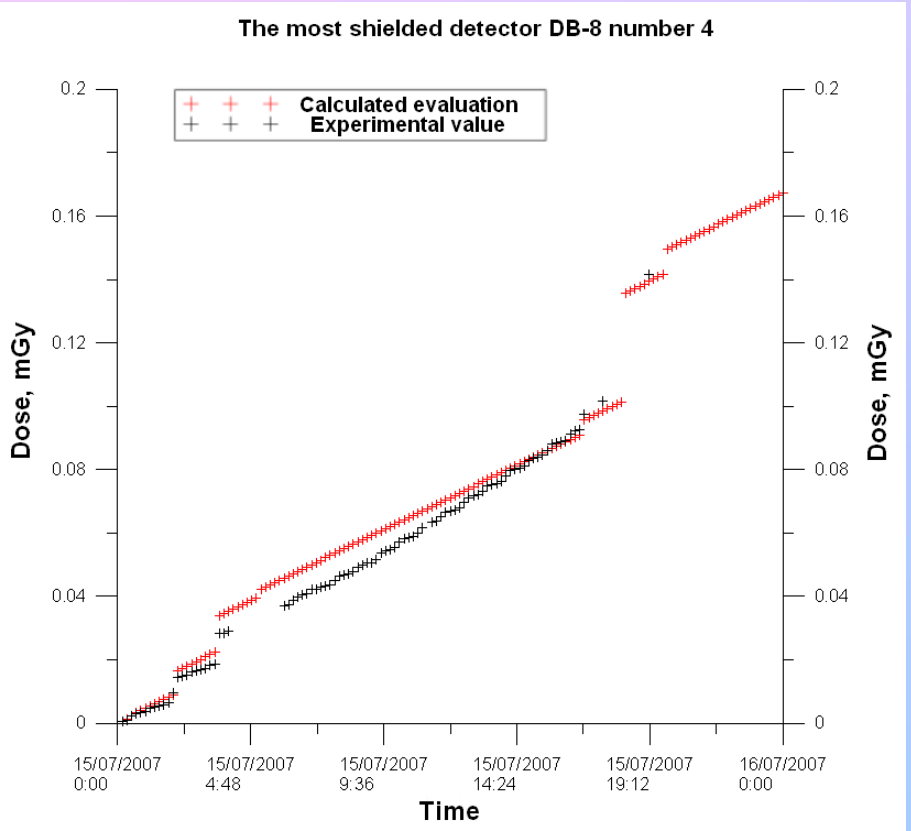
An example of forecast results. The comparison of the dynamics of accumulated doses calculated estimate with the experimental data (for 15/07/2005 the "subsequent period" is 24 hours, the “preceding period” is 2 weeks (from 01/07/2005 till 14/07/2005))



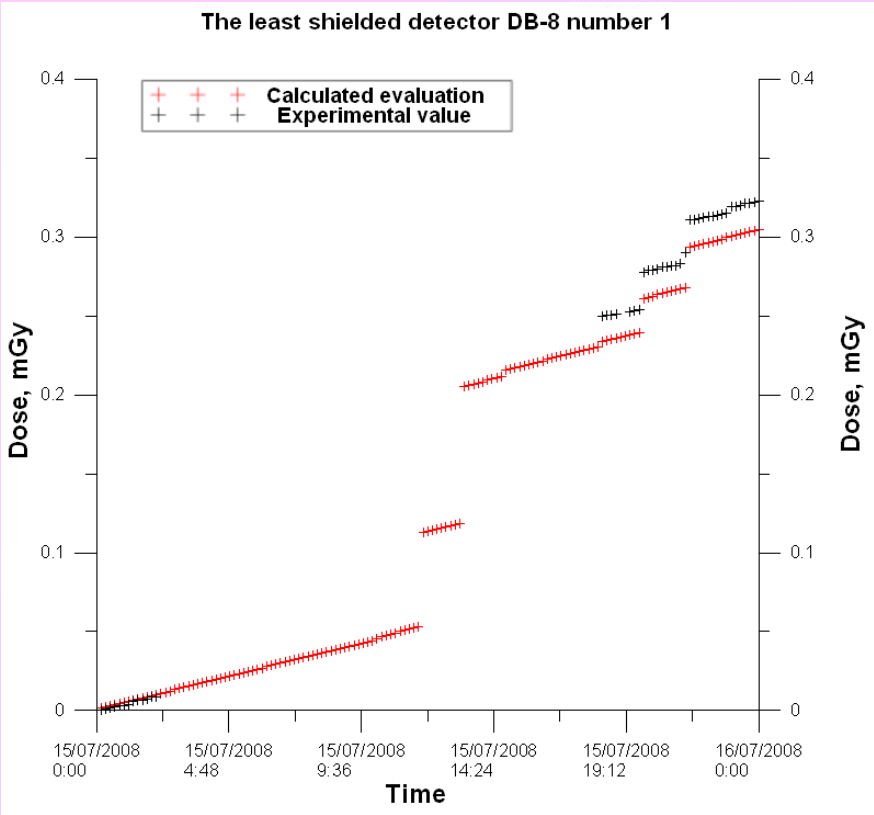


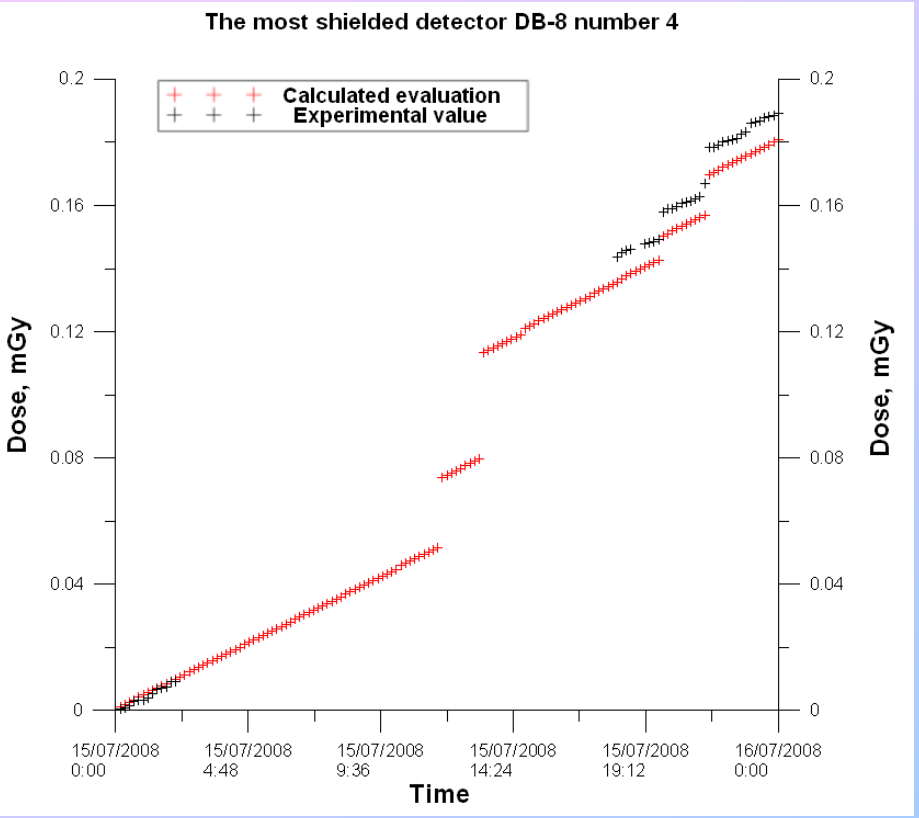
An example of forecast results. The comparison of the dynamics of accumulated doses calculated estimate with the experimental data (for 15/07/2006 the "subsequent period" is 24 hours, the “preceding period” is 2 weeks (from 01/07/2006 till 14/07/2006))



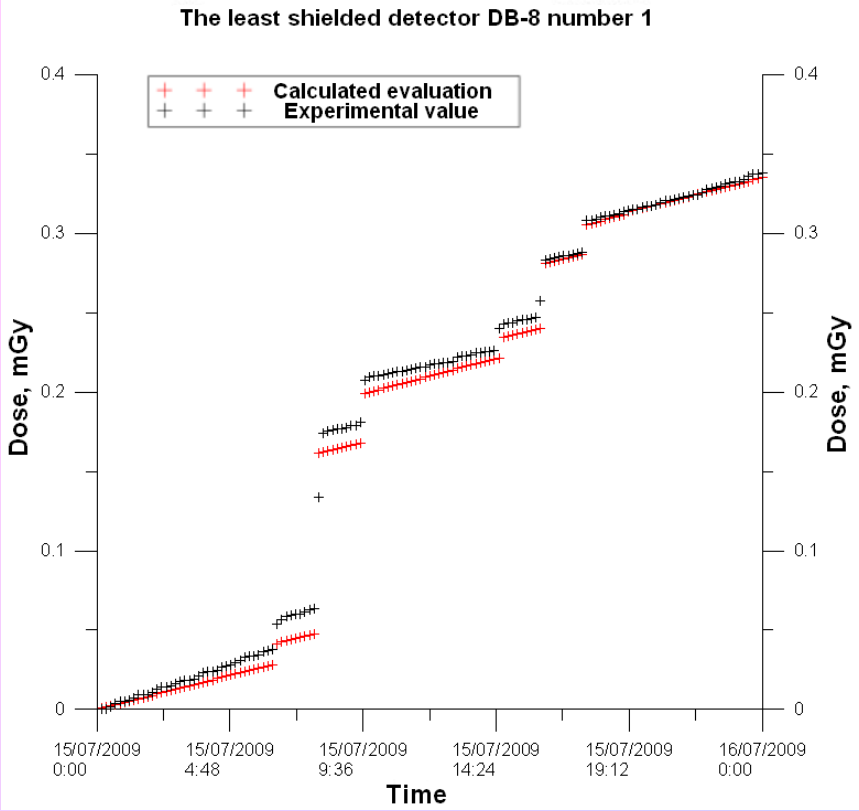


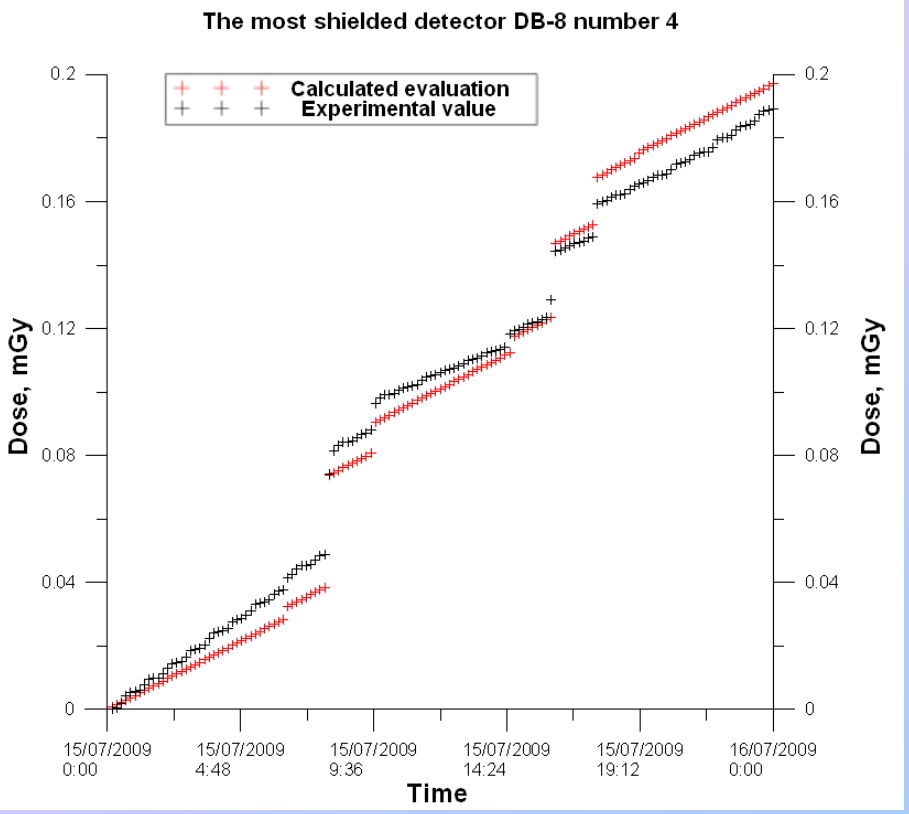
An example of forecast results. The comparison of the dynamics of accumulated doses calculated estimate with the experimental data (for 15/07/2007 the "subsequent period" is 24 hours, the “preceding period” is 2 weeks (from 01/07/2007 till 14/07/2007))



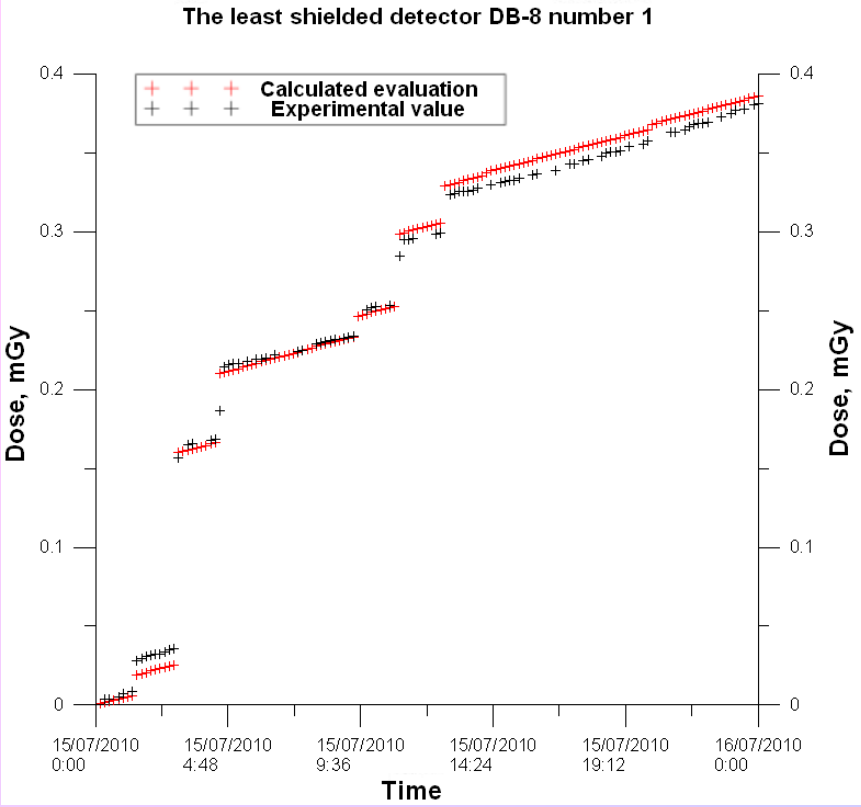


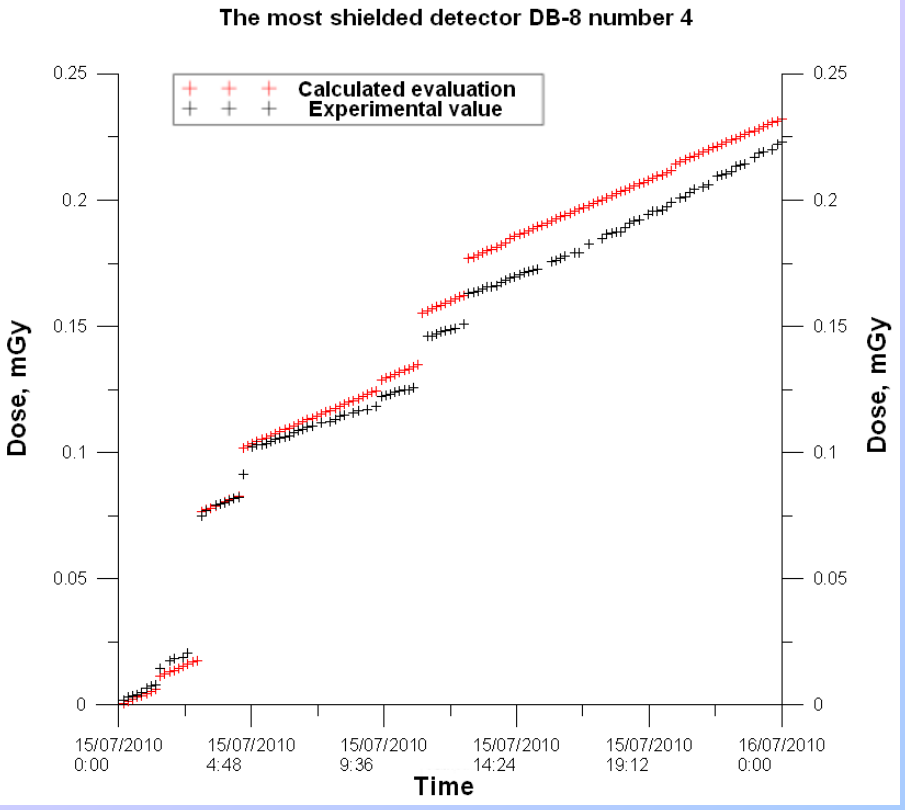
An example of forecast results. The comparison of the dynamics of accumulated doses calculated estimate with the experimental data (for 15/07/2008 the "subsequent period" is 24 hours, the “preceding period” is 2 weeks (from 01/07/2008 till 14/07/2008))



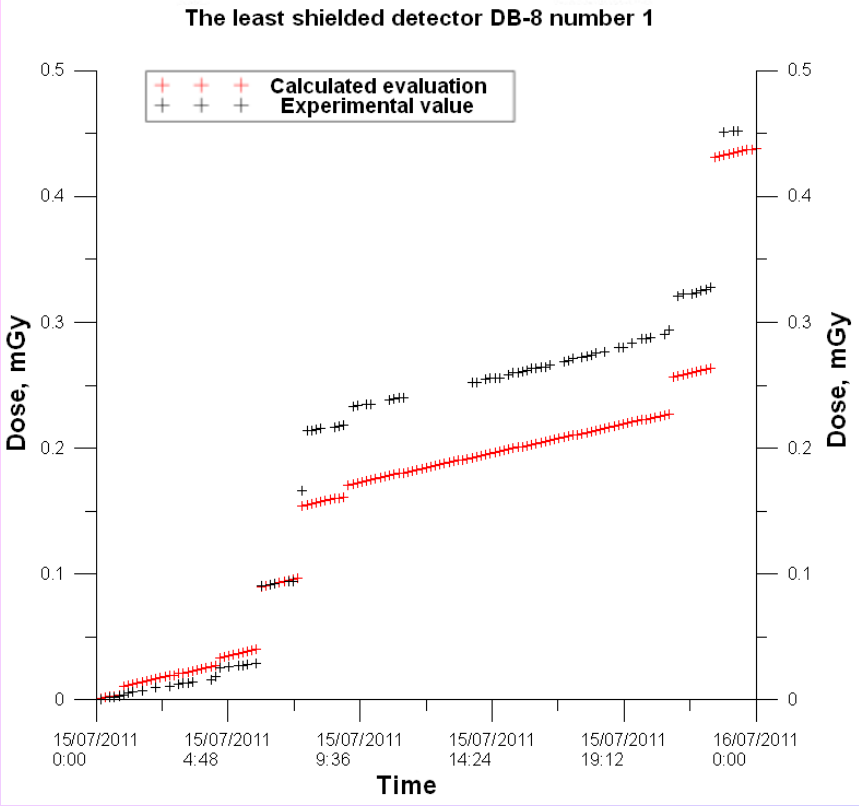


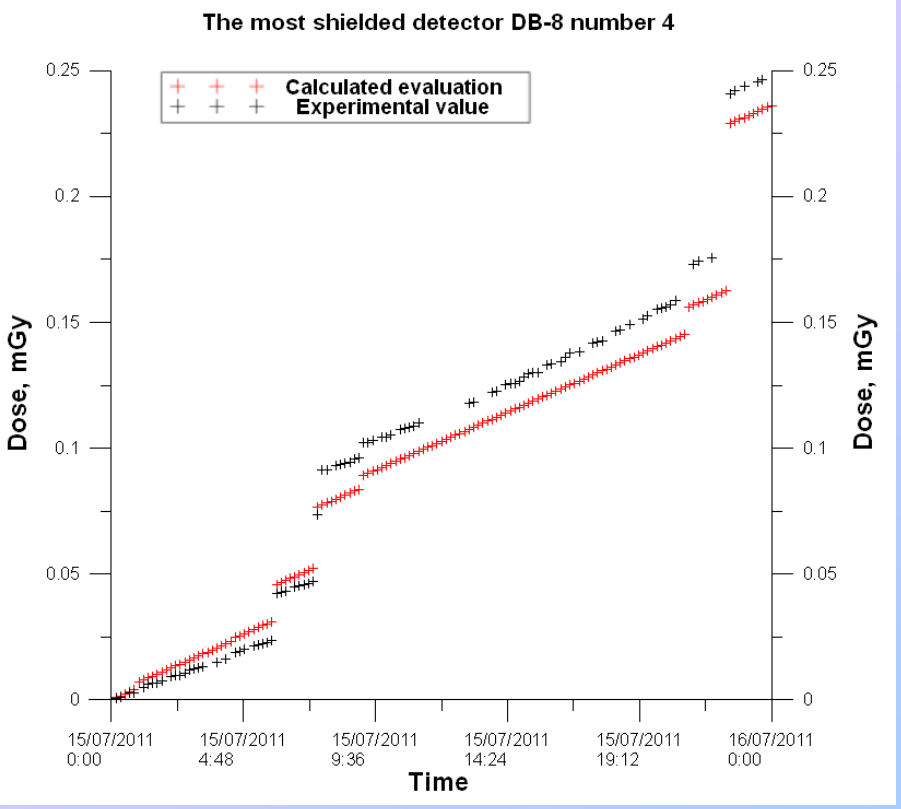
An example of forecast results. The comparison of the dynamics of accumulated doses calculated estimate with the experimental data (for 15/07/2009 the "subsequent period" is 24 hours, the “preceding period” is 2 weeks (from 01/07/2009 till 14/07/2009))





An example of forecast results. The comparison of the dynamics of accumulated doses calculated estimate with the experimental data (for 15/07/2010 the "subsequent period" is 24 hours, the “preceding period” is 2 weeks (from 01/07/2010 till 14/07/2010))

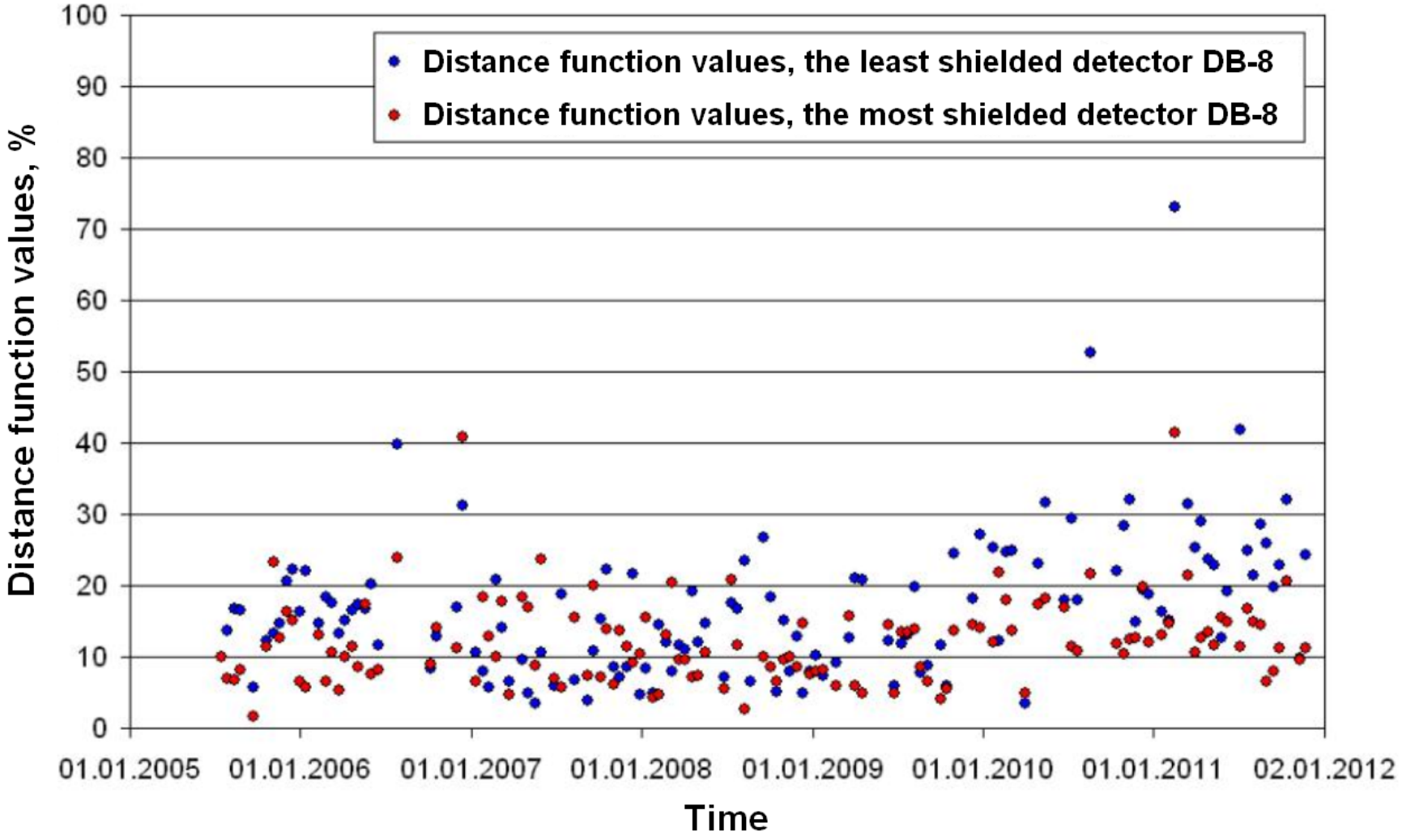




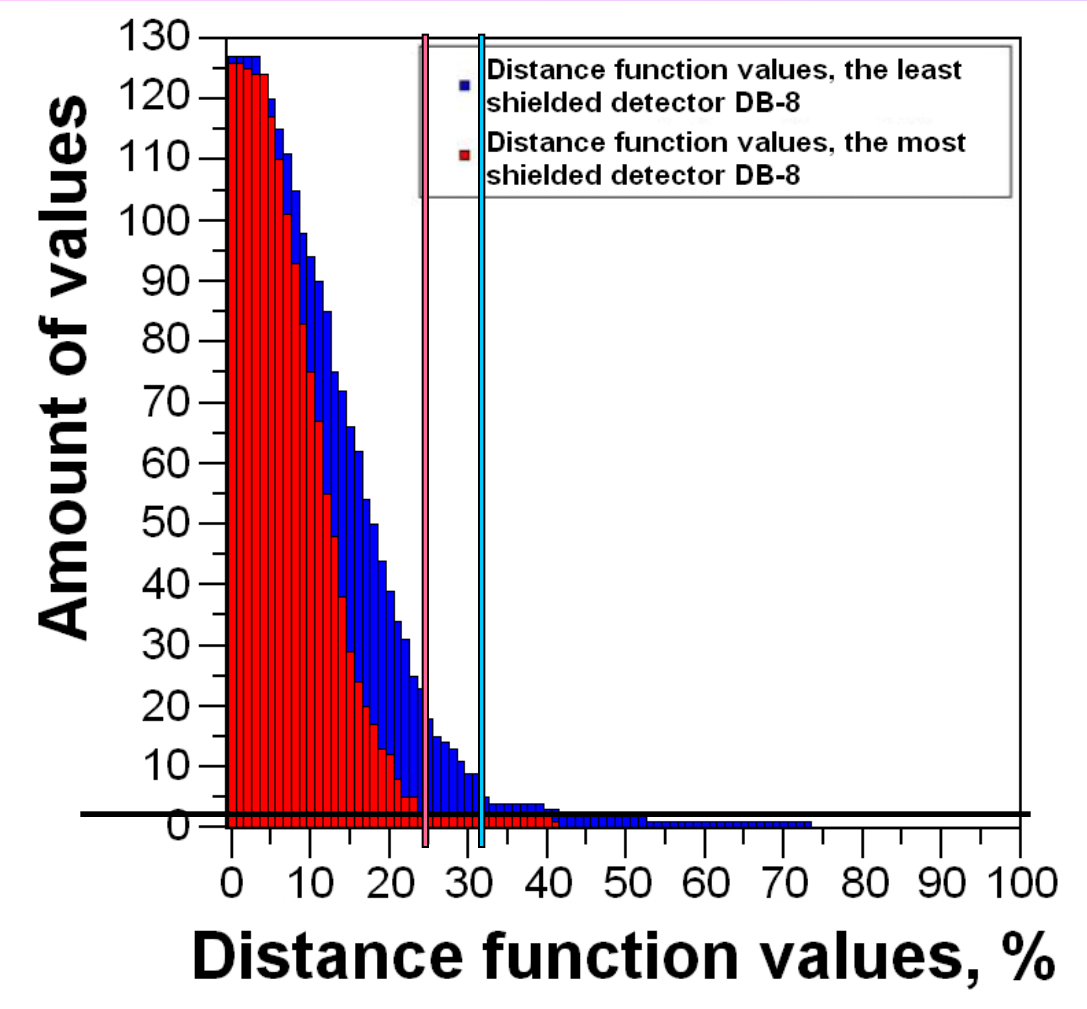
An example of forecast results. The comparison of the dynamics of accumulated doses calculated estimate with the experimental data (for 15/07/2011 the "subsequent period" is 24 hours, the “preceding period” is 2 weeks (from 01/07/2011 till 14/07/2011))

$$M = \frac{|D_{exp} - D_{calc}|_{max}}{D_{daily}} * 100\ \%$$

M is the distance function of the experimental data and the calculated evaluation, D_{exp} is the experimental dose value, D_{calc} is the calculated dose value, D_{daily} is the dose value for the “subsequent period” interval (24 hours in this case), $|D_{exp} – D_{calc}|_{max}$ is the supremum norm, the absolute value of the difference between the experimental and calculated values of the dose, the maximum of all values calculated for the "subsequent period".



The temporal distribution of quantity evaluation of closeness between accumulated doses dynamics estimates forecast to real experimental data for the most and least shielded channels of DB-8 detectors



Distribution function of quantity evaluation of closeness between accumulated doses dynamics estimates forecast to real experimental data for the most and least shielded channels of DB-8 detectors

Conclusion

An engineering method of the short-term forecasting of dose accumulation dynamics on the ISS has been developed based on the data from RMS. Based on the analysis of the RMS of the ISS data for the period from 2005 till 2011 using the developed techniques it was shown that with the confidence level equal to 96% the developed technique has the error rate no more than:

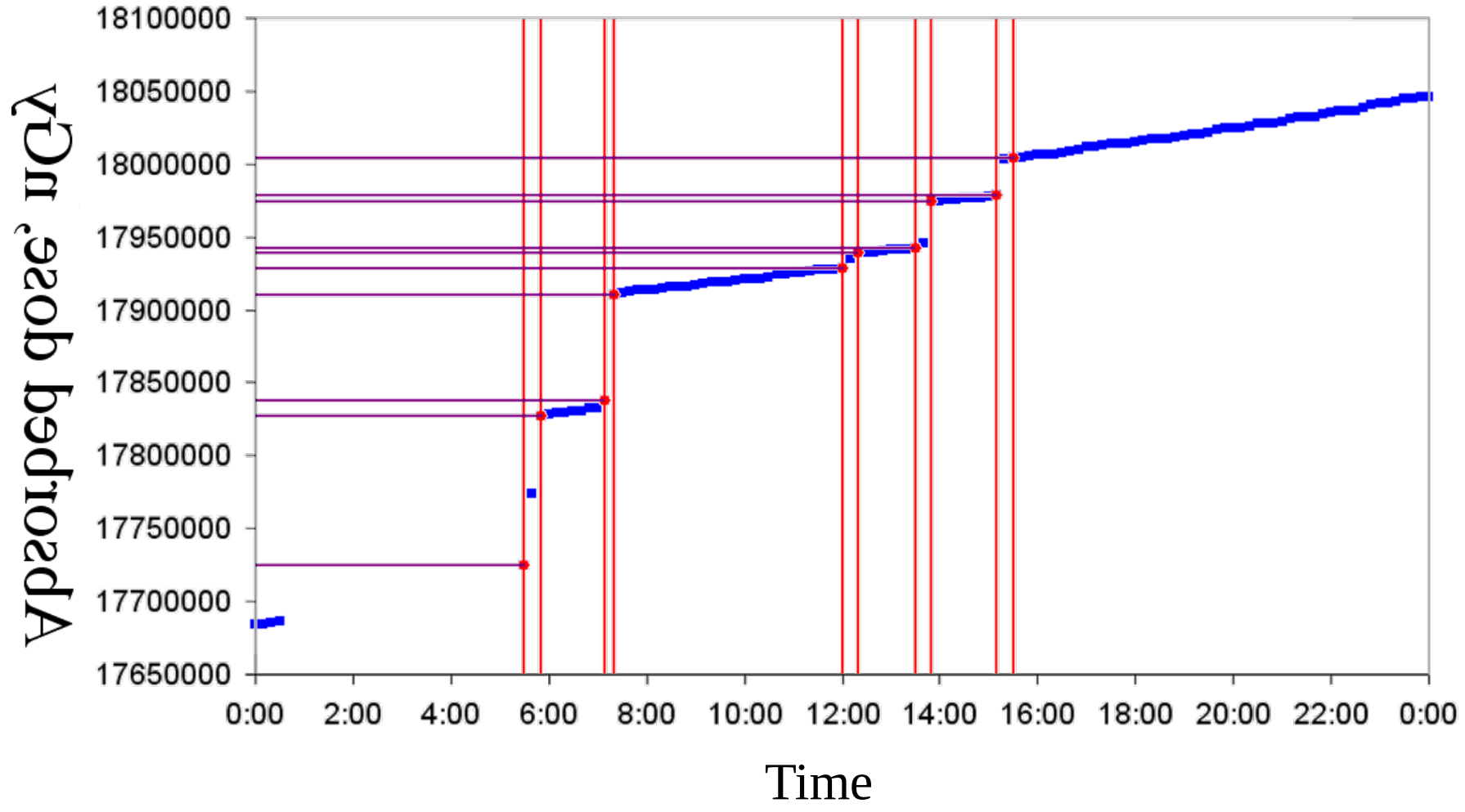
32% - for the least shielded detector DB-8 number 1
25% - for the most shielded detector DB-8 number 4

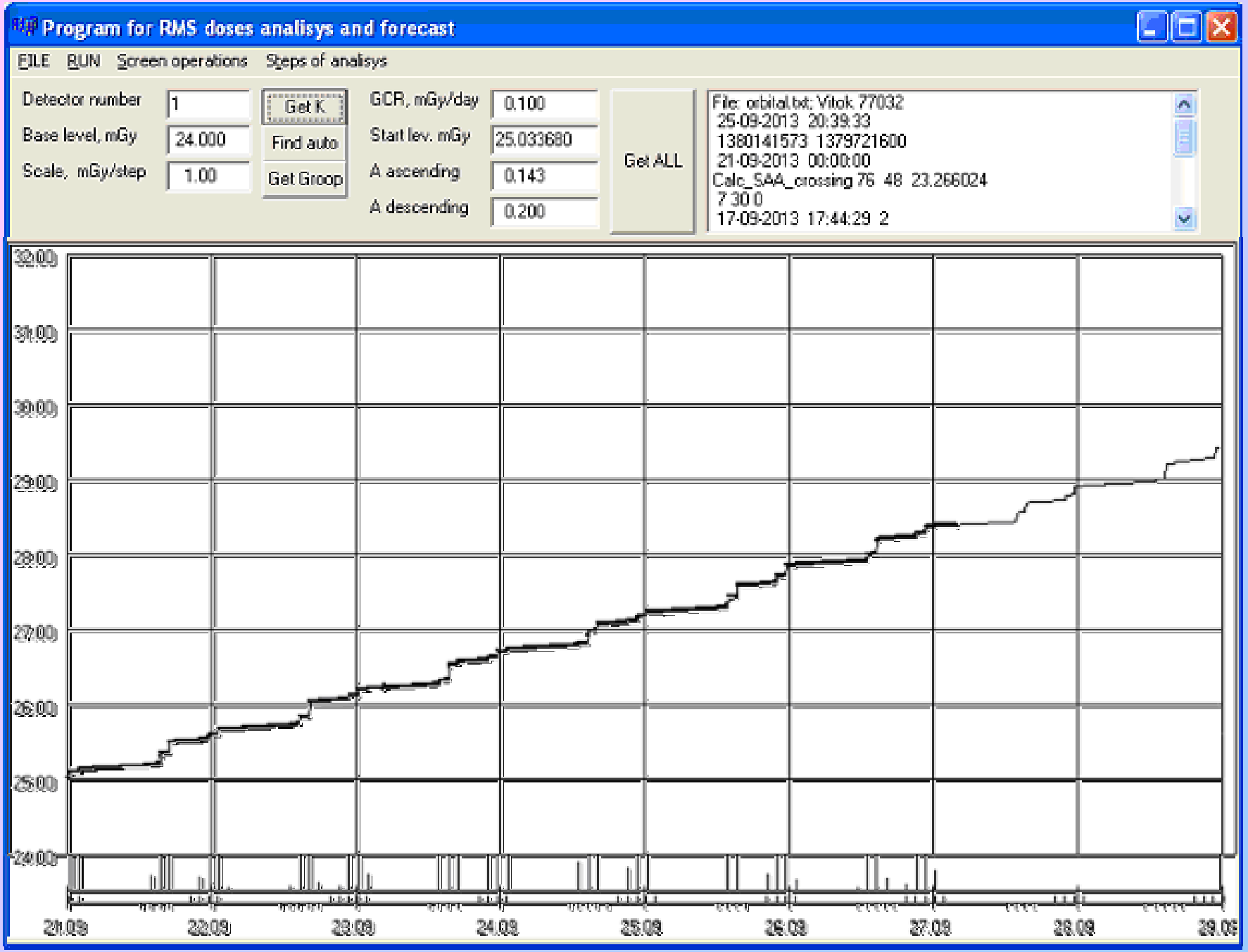
Information contained in the RMS data is enough for short-term (for 24 – 48 hours) dose accumulation dynamics forecast aboard the ISS with acceptable (about 30%) error rate.
The developed technique for the radiation environment forecast can be used for processing and analysis of current RMS data in providing operational radiation safety of the ISS crews.

Thank you for your attention!

Separation of the contribution to the absorbed dose registered on board the ISS due to the GCR and ERB

For example, information for 31.07.2008




Program for RMS doses analisys and forecast
FILE RUN Screen operations Steps of analisys
Detector number
1
Get K
Base level, mGy
24.000
Find auto
Scale, mGy/step
1.00
Get Groop
GCR, mGy/day
0.100
Start lev. mGy
25.033680
A ascending
0.143
A descending
0.200
Get ALL
File: orbital.txt; Vitok 77032
25-09-2013 20:39:33
1380141573 1379721600
21-09-2013 00:00:00
Calc_SAA_crossing 76 48 23.266024
7 30 0
17-09-2013 17:44:29 2
32.00
31.00
30.00
29.00
28.00
27.00
26.00
25.00
24.00
21.09
22.09
23.09
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