JEM-EUSO duty cycle estimation

P. Bobik (bobik@saske.sk), B. Khrenov, P. Klimov, K. Shinozaki,
M. Bertaina, K. Kudela, S. Pastircak, J. Urbar

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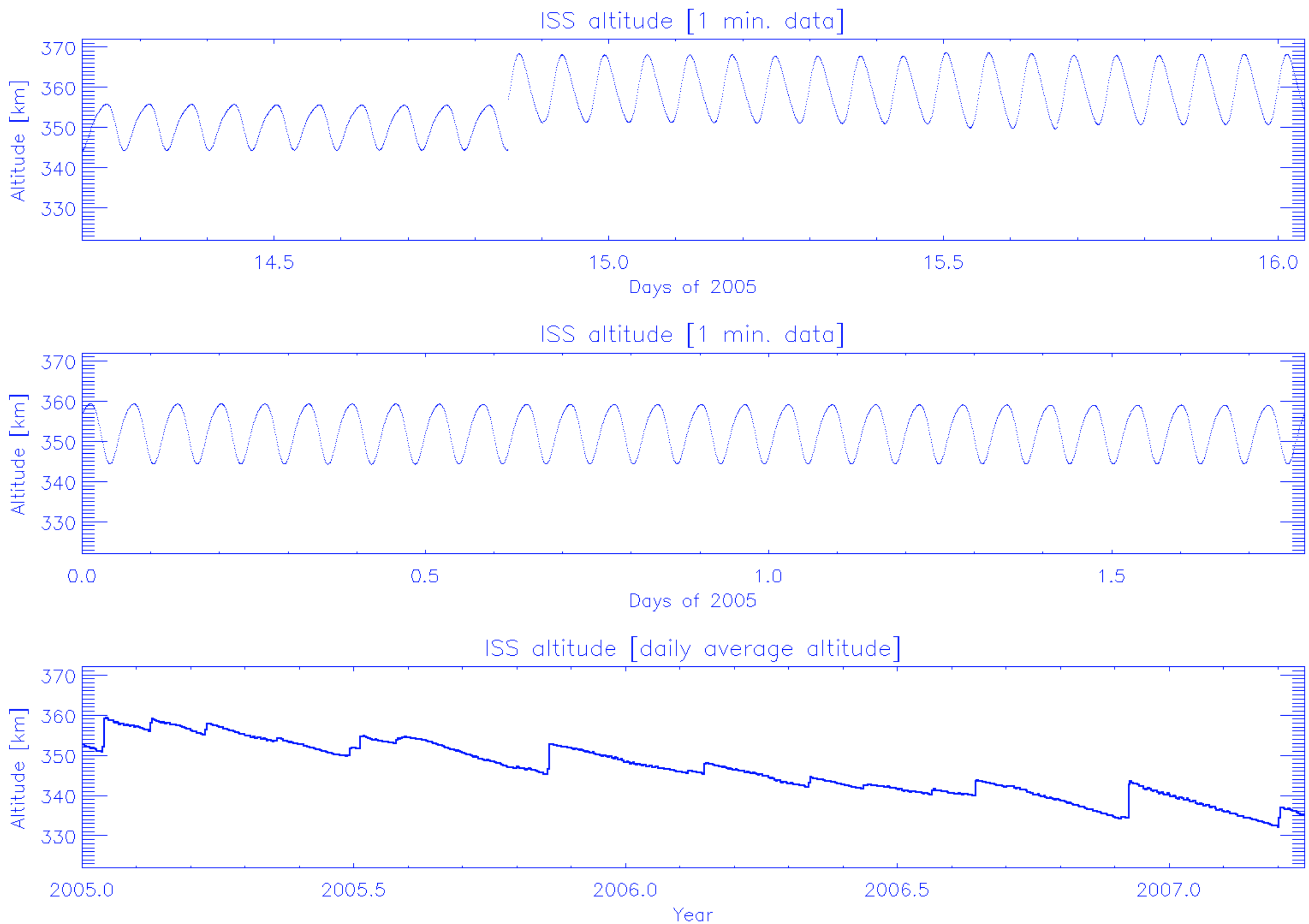
ÚEF SAV

JEM-EUSO duty cycle estimation



Data from NASA SSCweb: http://sscweb.gsfc.nasa.gov/cgi-bin/sscweb/Locator.cgi

Boosts to higher altitude of ISS.

JEM-EUSO duty cycle estimation

Previous estimations [1,2] based on ISS trajectory simulation and moonlight intensity simulations along this trajectory. ISS trajectory was simulated for one year long period with minute time-steps.

The moonlight was estimated from the Moon position and phase at evaluated positions.

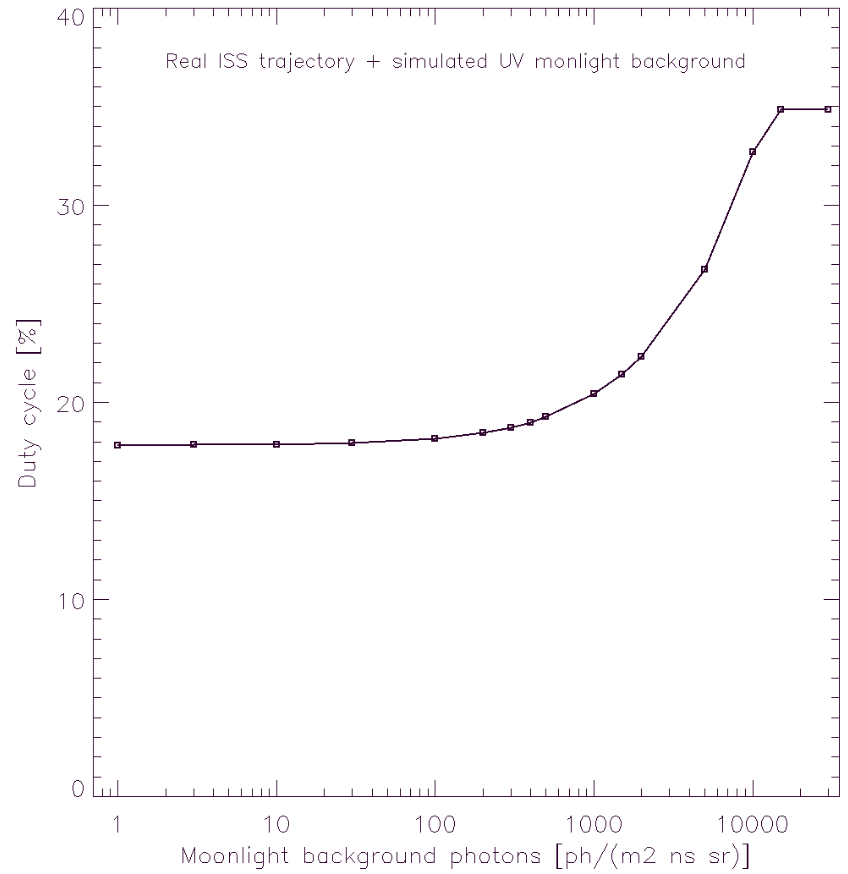
The duty cycle was evaluated as a time during the night when UV intensity from moon light was less than the selected value.

This approach do not take into account another sources of UV light on the Earth night side (i.e. zodiacal light, integrated faint star light) and partly also changes in ISS trajectory due to loosing altitude because of a slight atmospheric drag.

$$I_{Moon}(\theta,\alpha) \approx 1{,}55 \times 10^{4} \times \cos\theta \times 10^{-0{,}4\,(1.5|(\alpha)| + 4{,}3\times10^{-2}\alpha^{4})} \quad ph/(m^{2}\,ns\,sr)$$

Where θ is lunar zenith angle and α is Moon phase.

For the night defined by solar zenith angle bigger than 109.18 deg.



Duty cycle for a set of moonlight induced background values evaluated from real ISS trajectory in years 2005 till 2007 and simulated moonlight BG light.

[1] C. Berat, D. Lebrun, F. Montanet, J. Adams, Proceedings of the 28th International Cosmic Ray Conference, 2003, page 927

[2] F. Montanet, EUSO-SIM-REP-009-1.2, 2004

JEM-EUSO duty cycle estimation

The simulation with a simple Keplerian orbit with an inclination of ISS trajectory gives the results similar to those evaluated with real ISS trajectory.

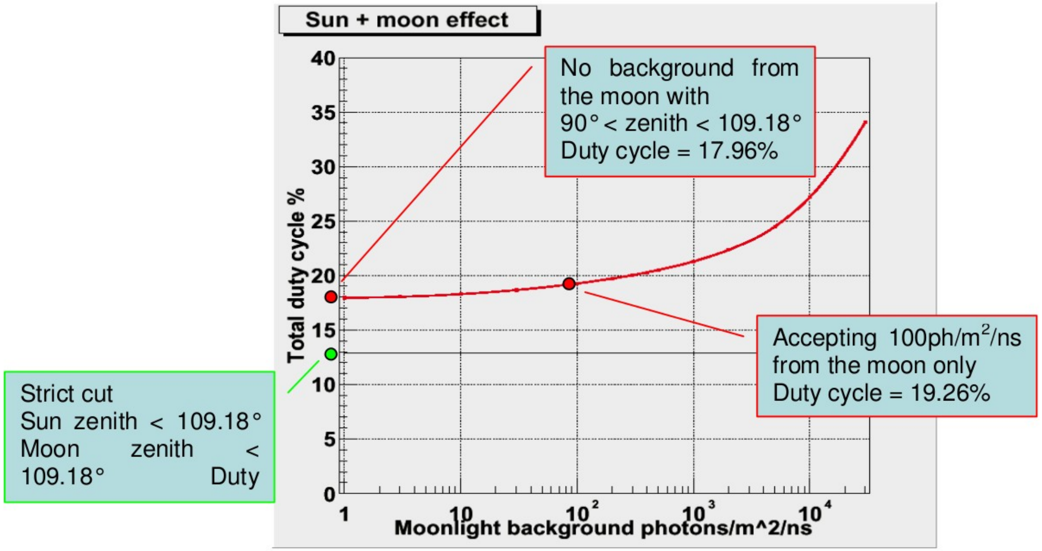
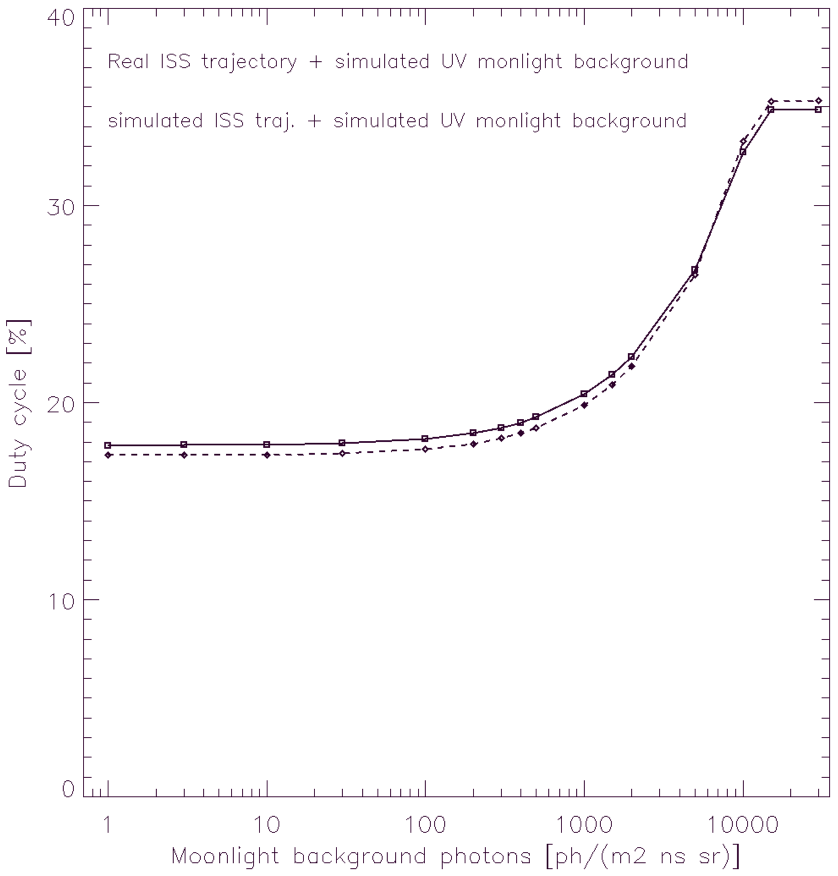


Figure 15: The year average duty cycle as a function of the moonlight induced background limit.

F. Montanet, EUSO-SIM-REP-009-1.2, 2004



Duty cycle evaluated from real ISS trajectory (solid line) in comparison with simulated ISS on Keplerian orbit (dashed line).

JEM-EUSO duty cycle estimation

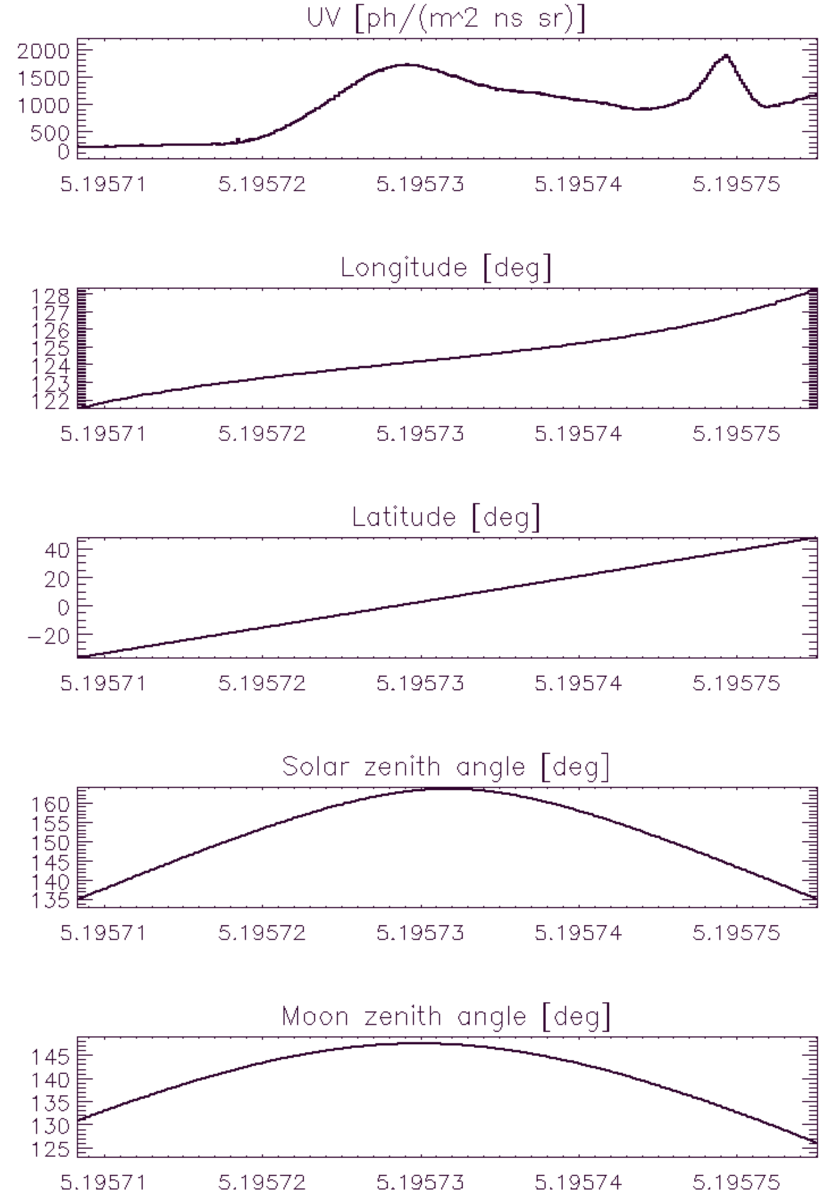
Universitetsky Tatiana satellite

The Universitetsky Tatiana was a satellite of Moscow State University launched on 20th January 2005 from the Plesetsk spaceport in RF, measuring near UV (310-400nm) light on the orbit with the inclination of 82 deg. and the altitude 950 km [3,4,5]. The detector field of view (15 deg.) corresponds to observing atmospheric surface of 250km in diameter. Satellite was operational until March 2007. For the duty cycle estimation we have used an integrated 4 second UV intensity data.

[3] G. K. Garipov, B. A. Khrenov, M. I. Panasyuk, V. I. Tulupov, A. V. Shirokov, I. V. Yashin, H. Salazar, Astroparticle Physics, 2005, **Volume 24** (4-5): page 400-4008

[4] G. K. Garipov, M. I. Panasyuk, V. I. Tulupov, B. A. Khrenov, A. V. Shirokov, I. V. Yashin, H. Salazar, Journal of Experimental and Theoretical Physics Letters, 2005, **Volume 82** (4): page 185-187

[5] V. A. Sadovnichy et. al., Cosmic Research, 2007, **Volume 45** (4): page 273-286



Example of Universitetsky Tatiana measurement. 24 minutes measurement starting at 14:34:44 11. march 2005. Time on figure in year units.

JEM-EUSO duty cycle estimation

As the night for Tatiana orbit we consider simple cut on the zenith angle [3] by solar zenith angle higher than 119.5 deg..

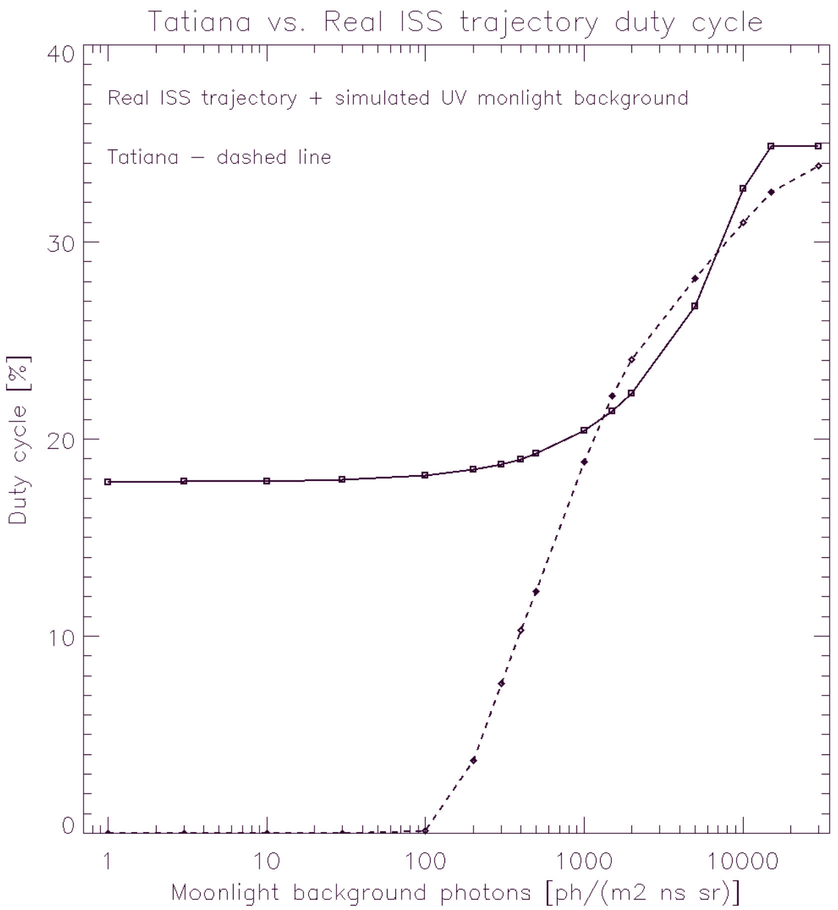
The sun eclipse times are then defined using a simple cut on the zenith angle:

Tatiana in the umbra

$$\theta_z > \pi - arcsin(R / (R + H)) = 119.5°$$

where R is the earth radius (6378 km) and H the Tatiana height above ground level (950 km).

We apply the correction for UV intensity on Tatiana orbit to ISS orbit (~16.89% - the precise value depends on the exact Tatiana altitude) and the correction taking into account the difference between night definition for Tatiana orbit and ISS orbit. Figure shows a duty cycle evaluated from Tatiana data corrected to ISS orbit together with duty cycle evaluated for real ISS trajectory and simulated moonlight.



Duty cycle evaluated from real ISS trajectory (solid line) in comparison with duty cycle from Tatiana data (dashed line).

JEM-EUSO duty cycle estimation

The night definition by simple cut on the zenith angle could not be very precise approximation for JEM- EUSO measurements. It is possible that we will need to redefine night by shifting the Sun position 19.18 deg. under horizon as used in this article to a higher value.

We have estimated a JEM-EUSO duty cycle for a set of solar zenith angles for allowed background of UV intensity less than 1500 photons/(m^2 ns sr).

The estimation from Tatiana measurements is presented in Table.

The change of solar zenith angle limit from 108 to 120 degrees decreases the JEM-EUSO duty cycle by about 3.8%.

Solar zenith angle (deg.)	Duty cycle (%)
108	22.2
109	22.1
110	21.9
111	21.7
112	21.5
113	21.3
114	21.0
115	20.6
116	20.3
117	19.9
118	19.5
119	19.0
120	18.4

Tatiana measurements archive
http://space.saske.sk/JEM/tatiana.html

To visualize Tatiana UV measurements and create reference frame for future use.

Ak http://space.saske.sk

- in internal JEM-EUSO part http://space.saske.sk/JEM.

User: jemeuso
Password: same as for RIKEN JEM-EUSO site

~7000 measurements of Universitetsky Tatiana satellite at ~25 000 figures (two types of figures)

Selection parameters
- Sun zenith angle
- Moon zenith angle
- length of one continuous measurement

Tatiana measurements archive

Visualisation of data from ultraviolet (UV) detector on board the Universitetsky-Tatiana satellite [1][2][3][4] measured in period from January 2005 to March 2007.

Archive of figures - lists (tables) of continuous measurements

Figures with maps

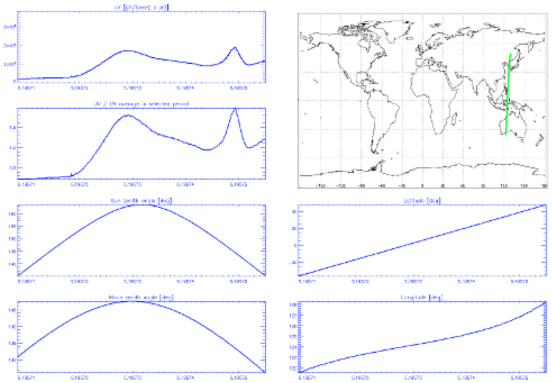
For Sun zenit angle > 108

For Sun zenit angle > 108, 20 minutes and longer measurements

For Sun zenit angle > 135 AND Moon zenith angle > 90

For Sun zenit angle > 135 And Moon zenith angle > 90, 20 minutes and longer measurements

Example:



click to enlarge

Figures without maps

For Sun zenit angle > 108

For Sun zenit angle > 108, 20 minutes and longer measurements

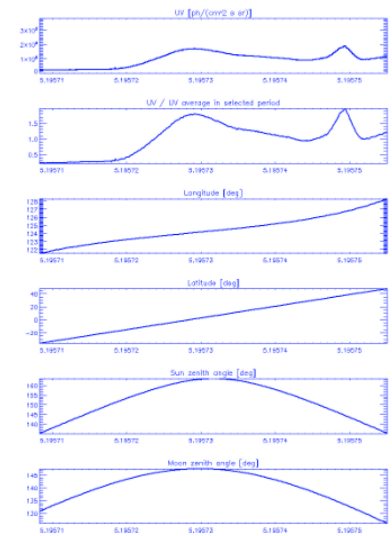
For Sun zenit angle > 135

For Sun zenit angle > 135, 20 minutes and longer measurements

For Sun zenit angle > 135 AND Moon zenith angle > 90

For Sun zenit angle > 135 And Moon zenith angle > 90, 20 minutes and longer measurements

Example:

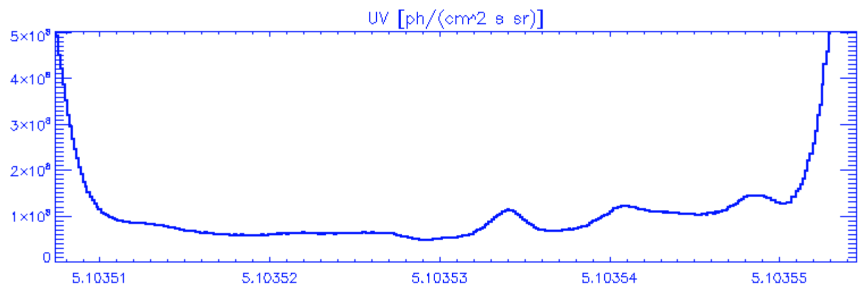


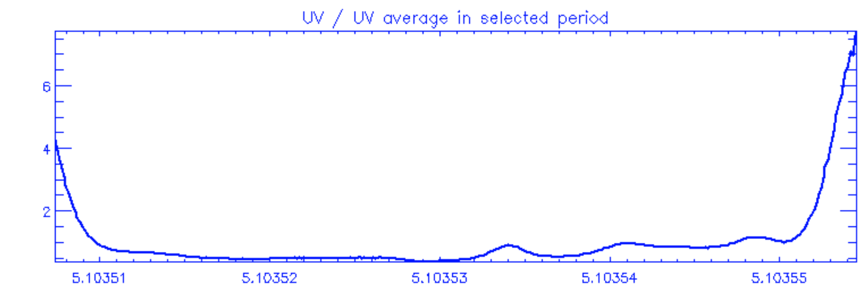
click to enlarge

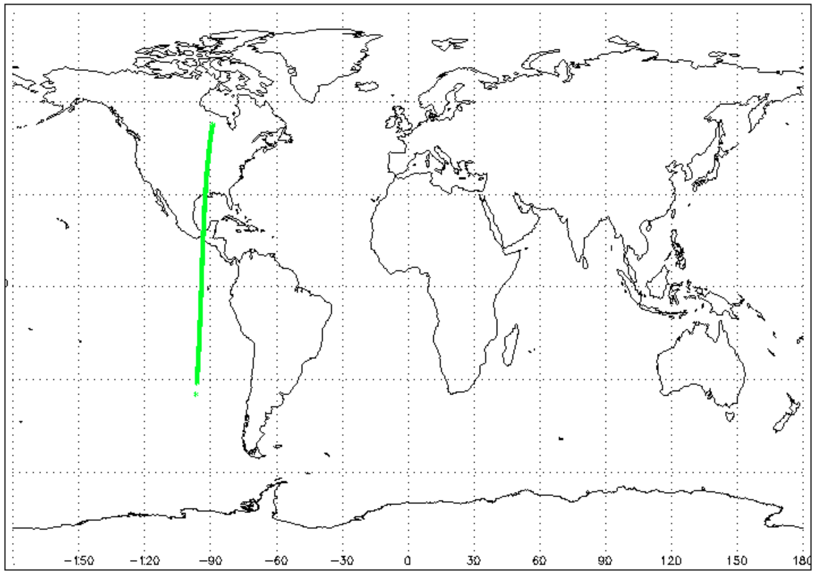
References

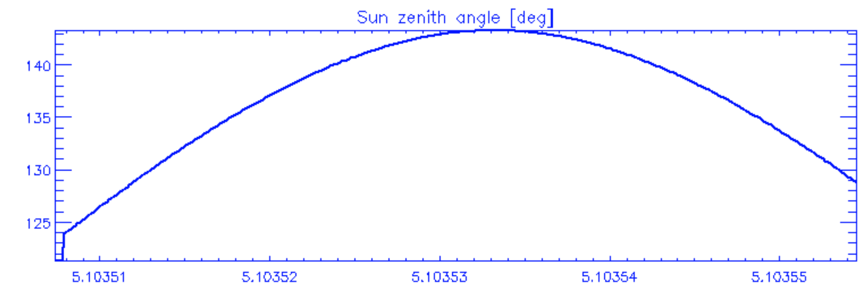
1. Garipov G. K., Khrenov B. A., Panasyuk M. I., Tulupov V. I., Shirokov A. V., Yashin I. V., Salazar H., UV radiation from the atmosphere: Results of the MSU Tatiana satellite measurements. Astroparticle Physics, Volume 24, Issue 4-5, p. 400-408, 2005
2. Garipov G. K., Panasyuk M. I., Tulupov V. I., Khrenov B. A., Shirokov A. V., Yashin I. V., Salazar H., Ultraviolet flashes in the equatorial region of the Earth, Journal of Experimental and Theoretical Physics Letters, vol. 82, issue 4, pp. 185-187, 2005
3. Sadovnichy V. A. et. al., First results of investigating the space environment onboard the Universitetskii-Tatyana satellite, Cosmic Research, Volume 45, Issue 4, pp.273-286, 2007
4. Web http://cosmos.msu.ru

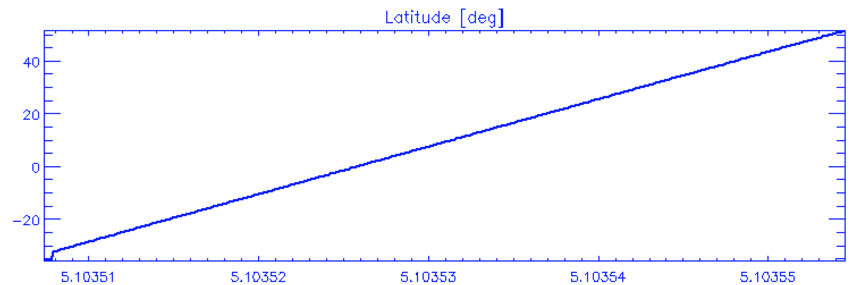
Tatiana measurements archive
ID:10, Sza > 108°, Date: 5 2 8 8 50 44 [y/m/d/h/min/sec]

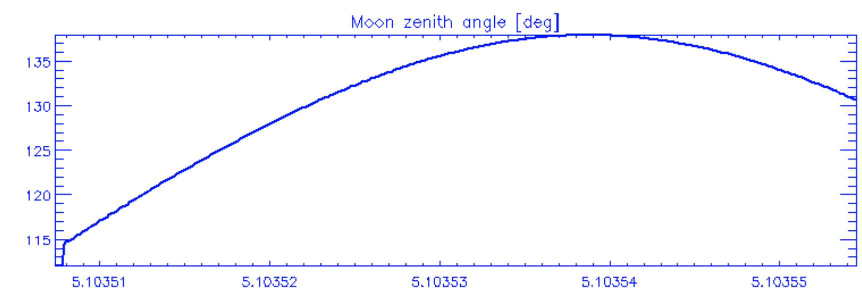


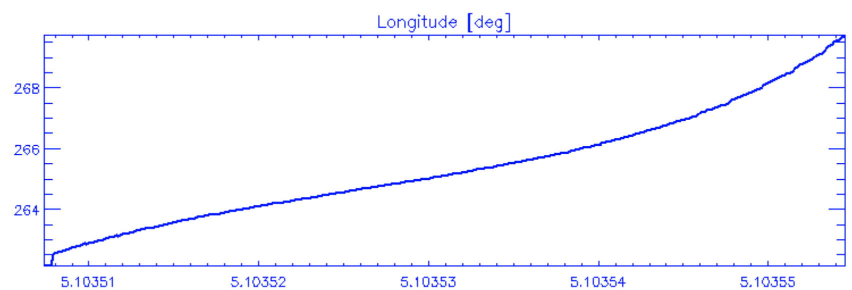




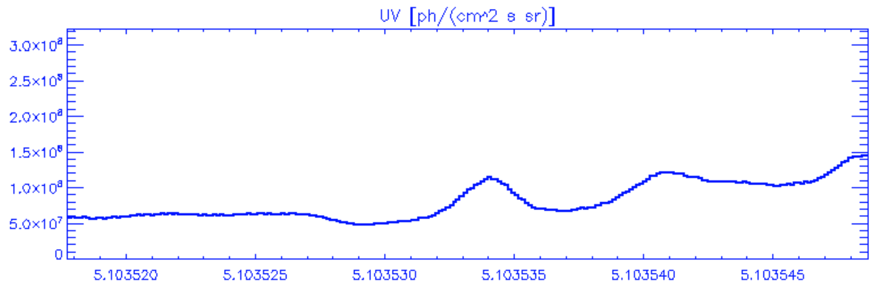


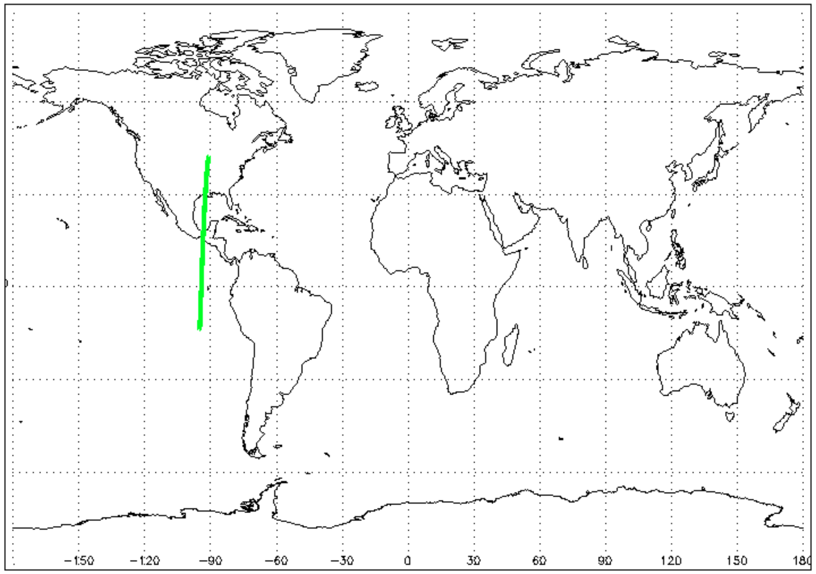


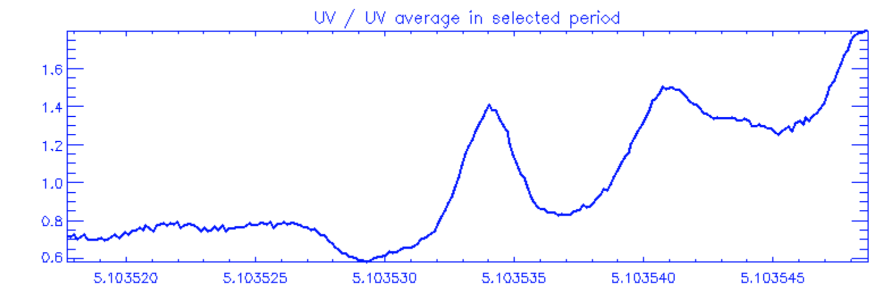


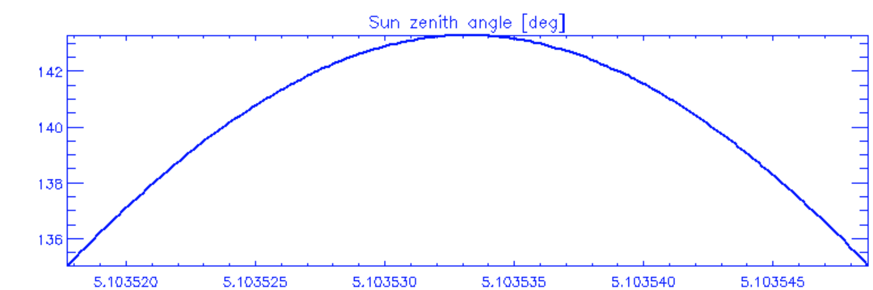


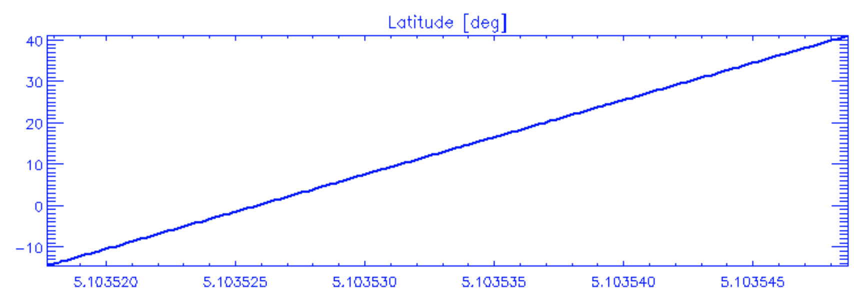
Tatiana measurements archive
ID:10, Sza > 135°, Mza > 90°, Date: 5 2 8 8 50 44

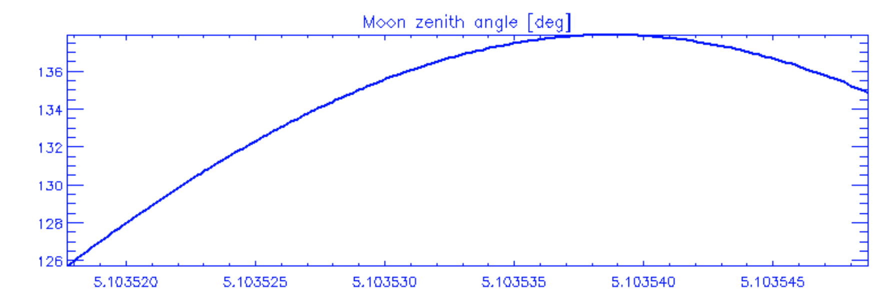


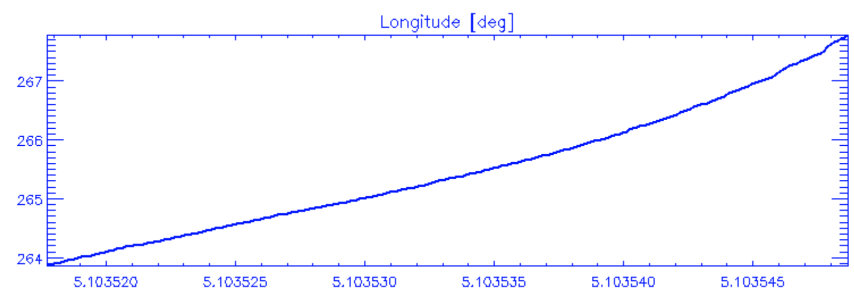




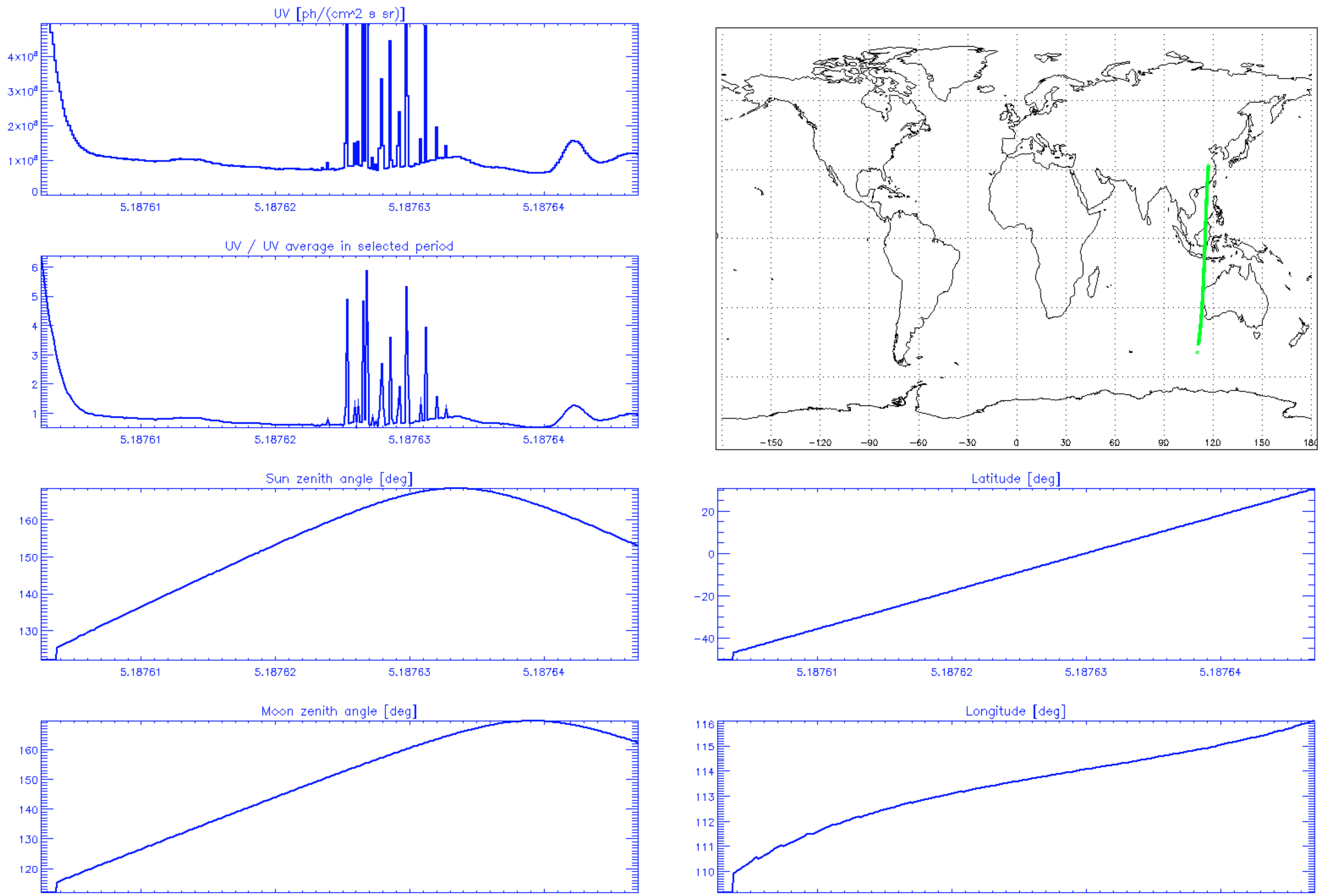






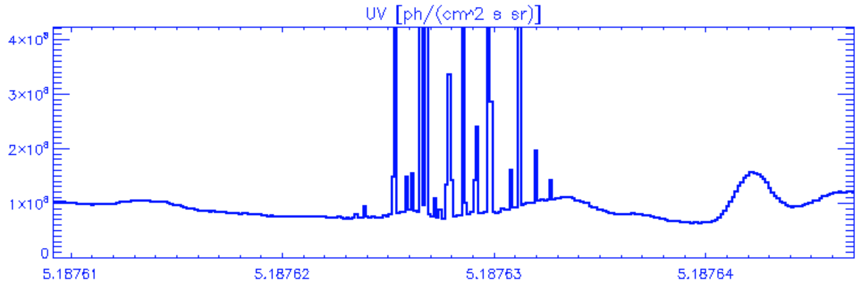


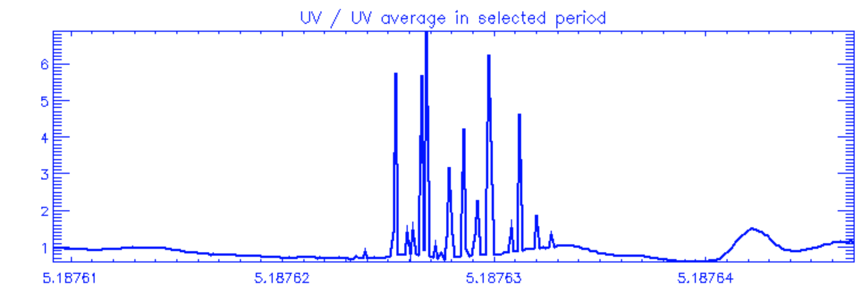
Tatiana measurements archive
ID:108, Sza > 108^o, Date: 5 3 8 15 31 26

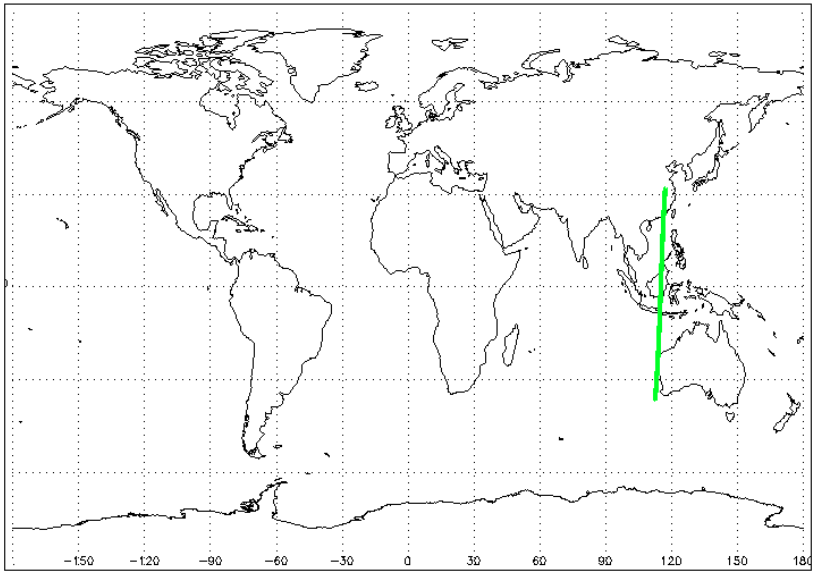


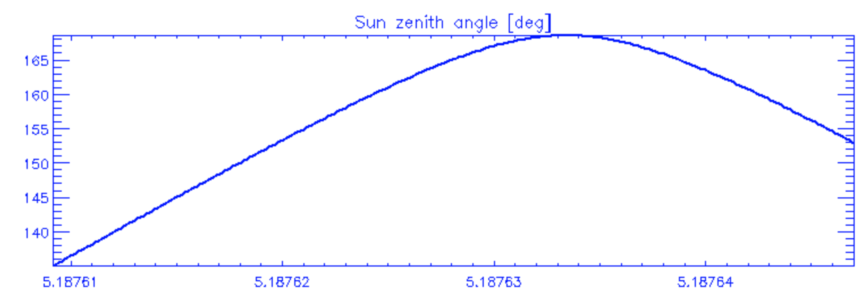
Tatiana measurements archive

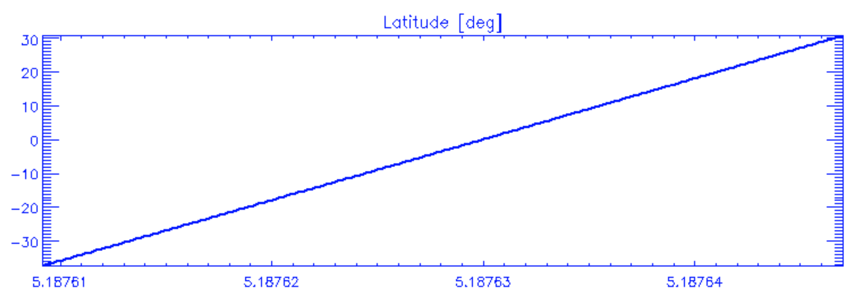
ID:108, Sza > 135°, Mza > 90°, Date: 5 3 8 15 31 26

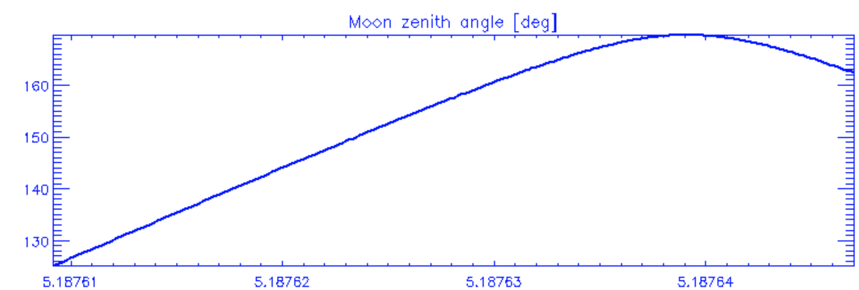


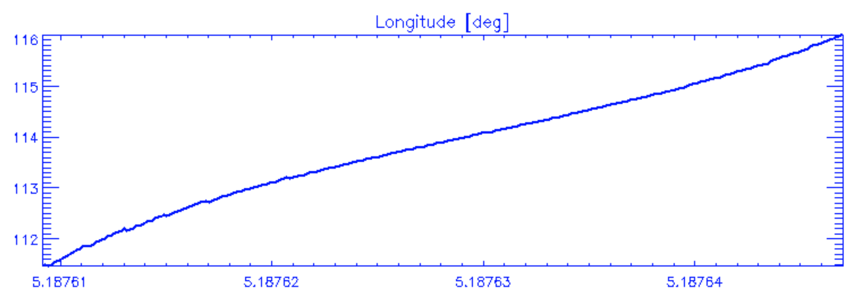






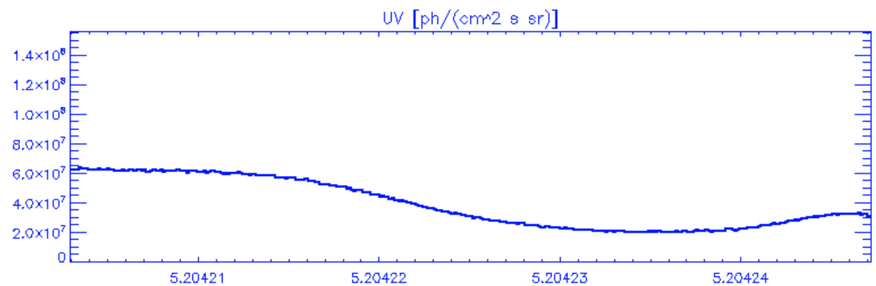


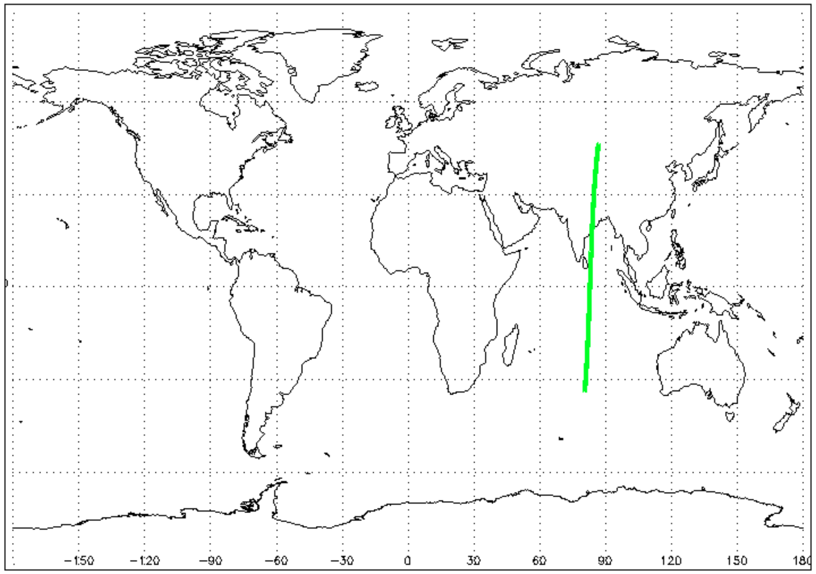


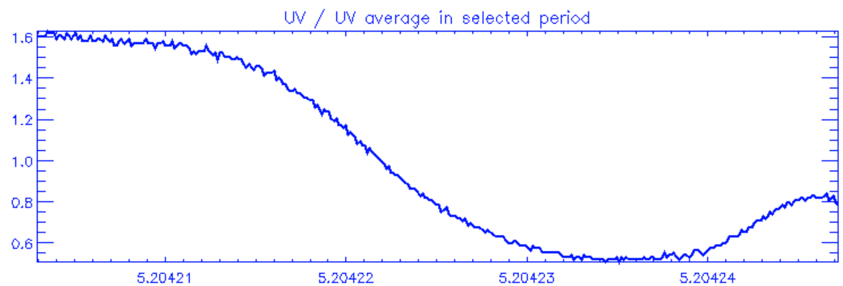


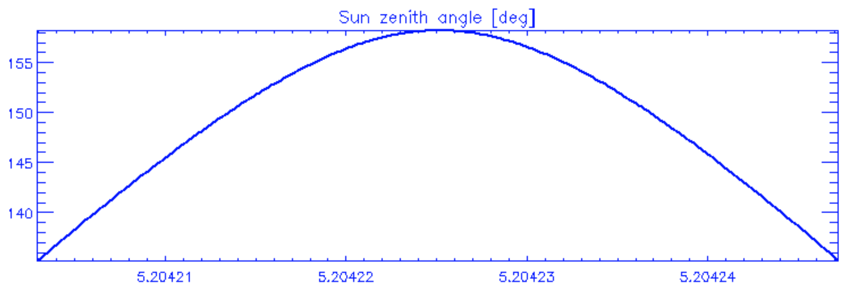
Tatiana measurements archive

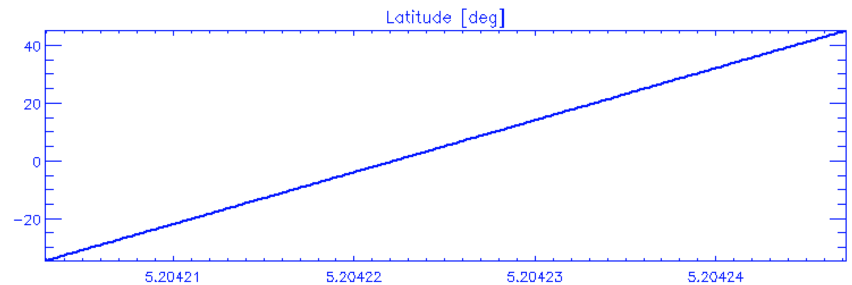
ID:142, Sza > 135^o, Mza > 90^o, Date: 5 3 14 17 2 34

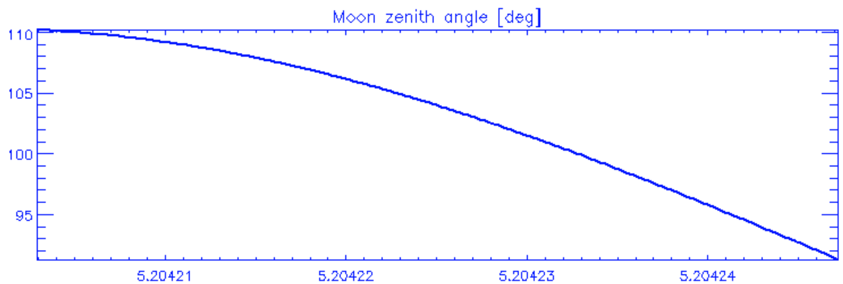


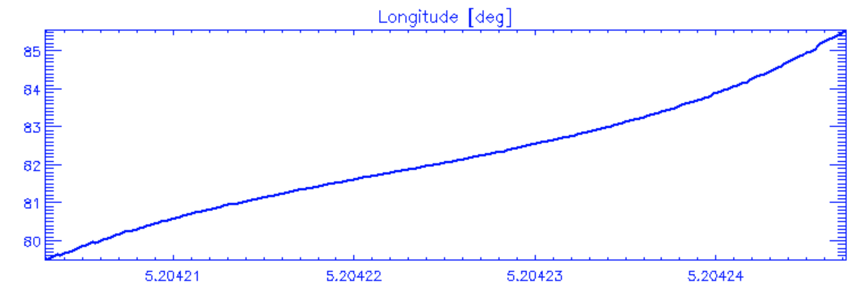












Stability coefficient

Stability of UV background clearly depend on Sun relative position to place of measurements i.e. on Sun zenith angle. It make sense then evaluate BG stability as function of Sun zenith angle threshold. To avoid moon light influence we select measurements where moon zenith angle Mza is higher than 90º.

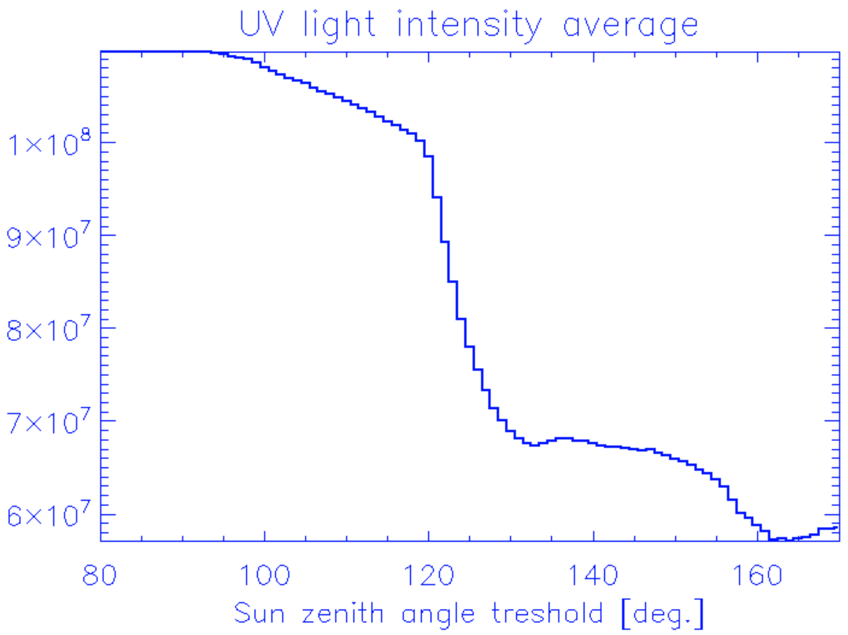
- four different stability coefficients was tested

- as upper estimation coefficient based on ratio between maximum and minimum UV intensity values of measured periods

- stability coefficient based on standard deviation of UV signal during measured periods

- stability coefficient based on on curve length of UV signal graph during measured periods

- stability coefficient based on average absolute deviation of measurements



For selected Sza treshold (Sza>x°) we evaluate average absolute deviation AAD of UV intensity signal during all continuous measurements.

$$AAD_{i,Sza>x^o} = \frac{1}{T_i} \sum_{j=1}^{j=(N_i-1)} \left| I_{UV,i,j} - \overline{I_{UV,i}} \right|$$

where T_i is lenght (time) of *i-th* measurements. Then stability coefficient for Sza>x° is

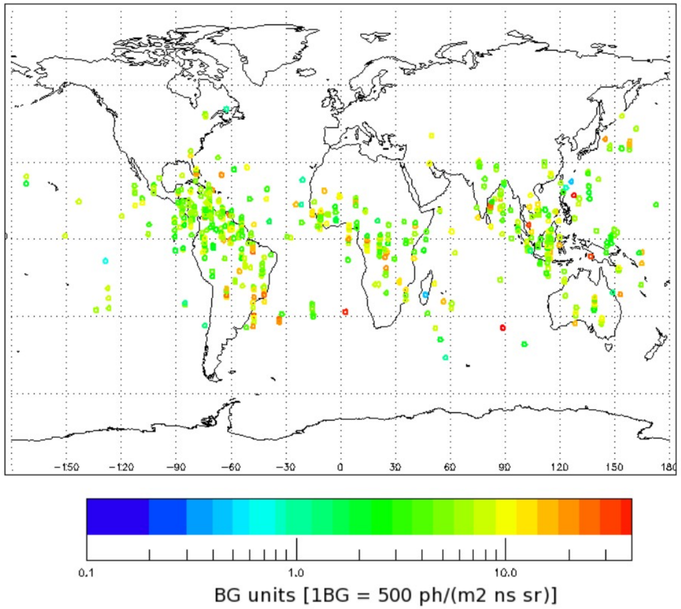
$$SC(Sza>x^o) = \frac{1}{T} \sum_{i=1}^{i=m} AAD_{i,Sza>x^o} N_i \quad \text{where} \quad T = \sum_{i=1}^{i=m} N_i$$

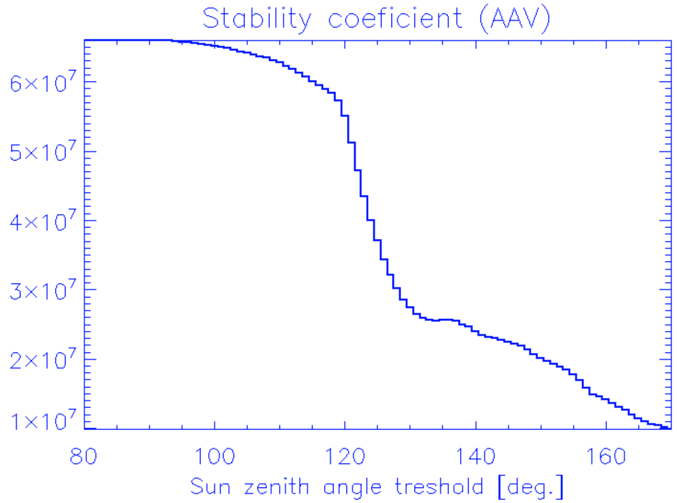
Stability coefficient

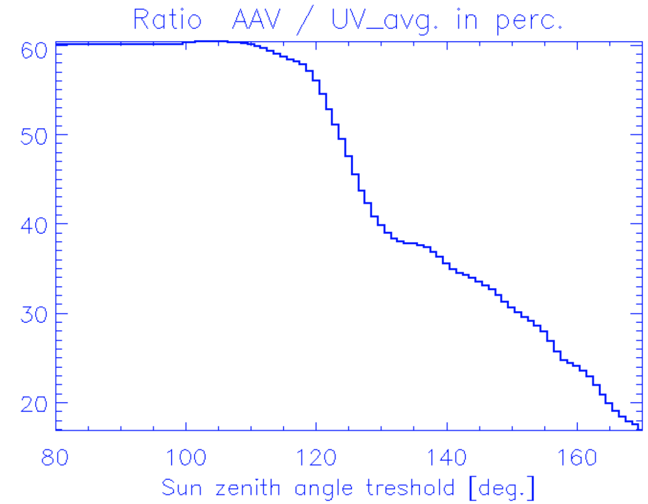
Different stability coefficient evaluate how UV light change during measurements on Earth orbit. From all coefficients we can see that stability of signal depend on Sun zenith angle, and change relatively fast till Sza reach 132°. This lead us to change (redefinition) of night definition for Tatiana orbit. Now we redefine night for orbit ~940 km as time when satellite local Sza>132°.

- Stability coefficient based on average absolute deviation show that stability of signal on the night side, when moon is under horizon is in order of 10ths percents from average value of UV intensity during measurement in previous/surrounding moments/orbit (flashes and TLE events are exception from this conclusion).

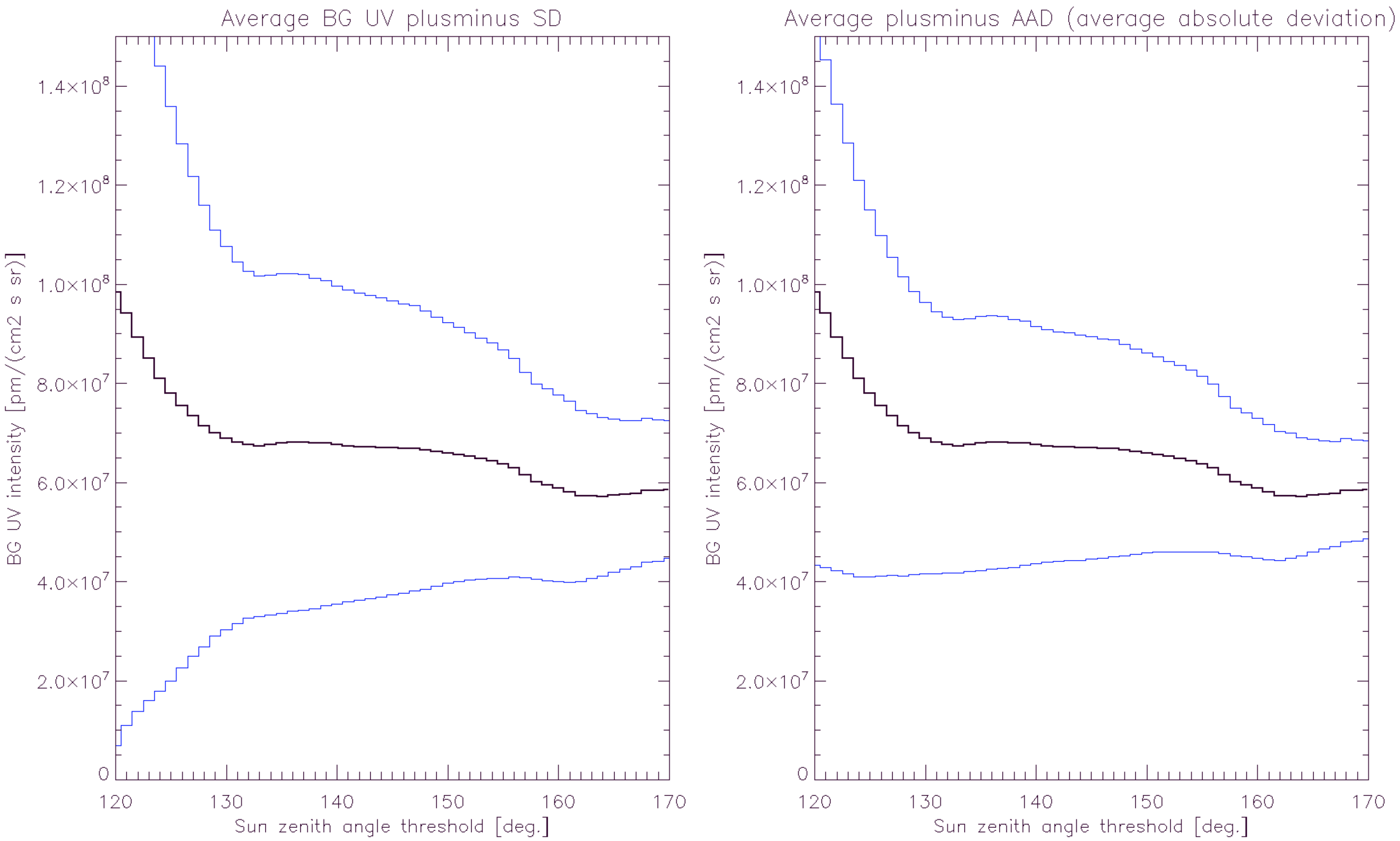
- Let us note that this results are evaluated from signal with flashes (TLE) events. Flashes was not cleaned from signal. If measurements with flashes will be cleaned out, stability increase.





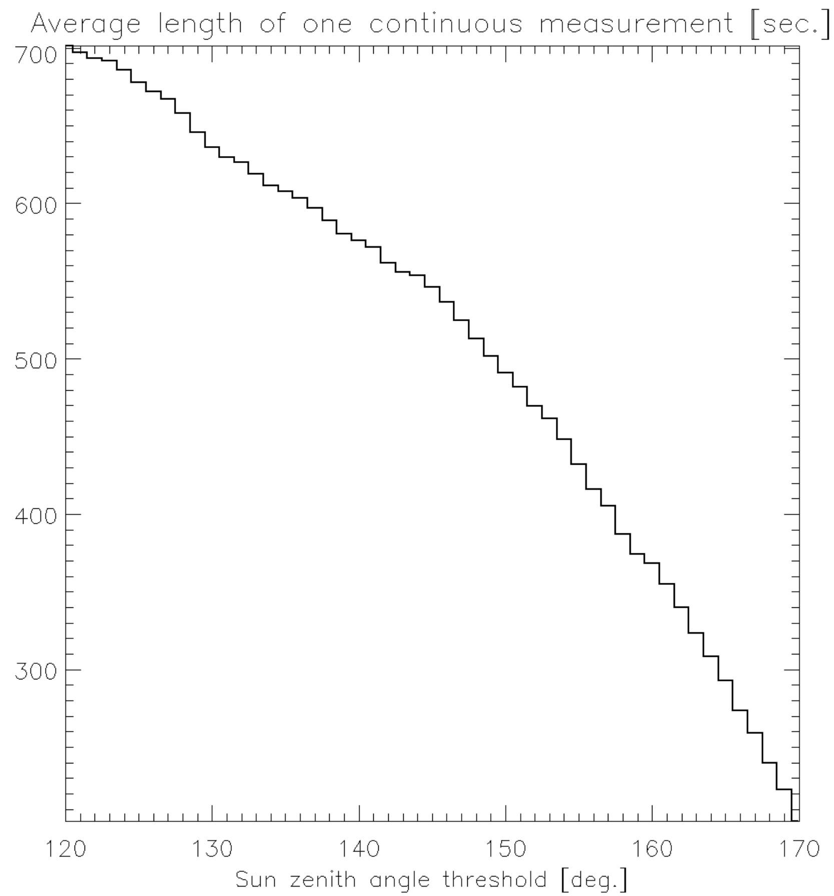


Stability coefficient

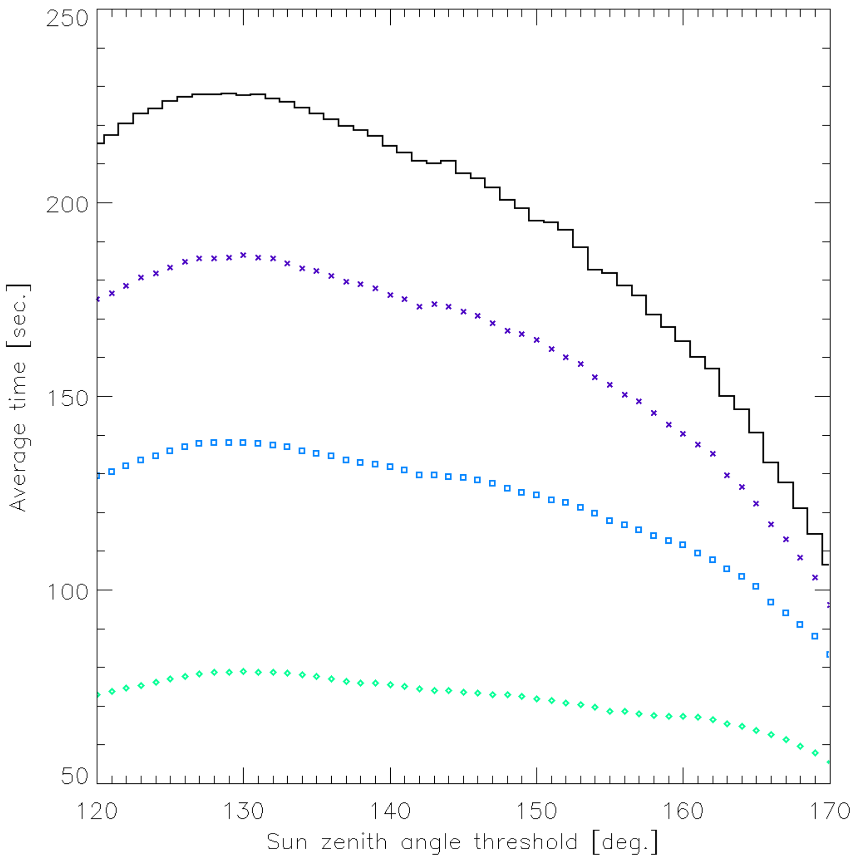


Stability coefficient

We evaluate average length $T_{AVG,Sza}$ of one continuous measurement during Tatiana operation period for different Sun zenith angles thresholds. Average length $T_{AVG,Sza}$ the night Earth side is roughly 10 minutes and decrease with increasing solar zenith angle threshold.

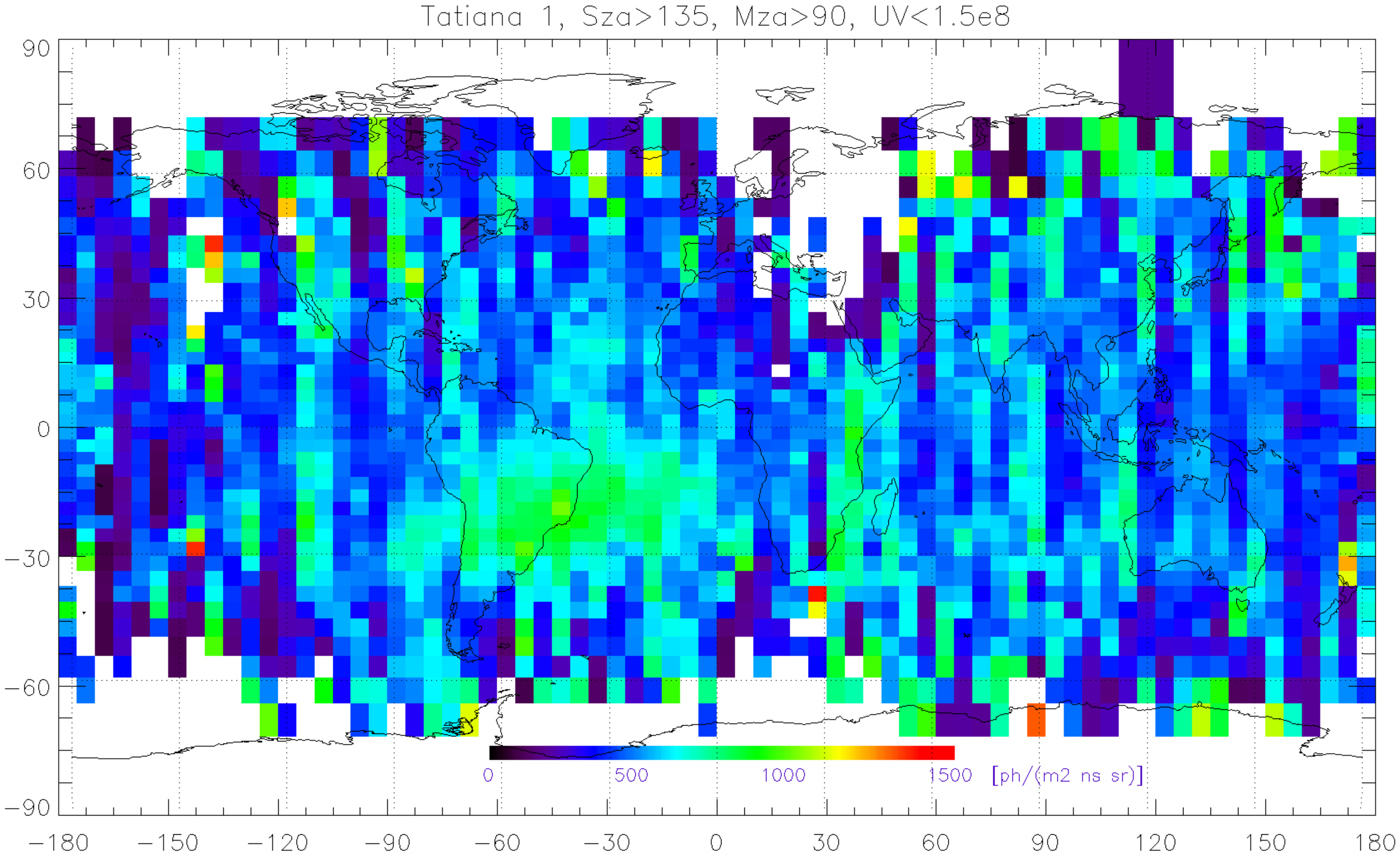


The average length of measurements when UV intensity not change more than preselected percentage level we evaluate for plusminus 10, 20, 30 and 40% as function of Sza threshold.



Average length of measurement when UV signal not change more than ±10% (diamonds), not more than ±20% (squares), ±30% (crosses) and ±40% (solid line).

JEM-EUSO duty cycle estimation



Conclusion

We have estimated a duty cycle for JEM-EUSO detector at ISS orbit from Universitetsky Tatiana measurements for the set of allowed UV background thresholds. For the allowed background less than 1500 photons/(m^2 ns sr) we have got the duty cycle as 22% for the operational time of experiment. The influence of different night definitions to the duty cycle was presented. Alternative estimations based on simulation of ISS trajectory together with evaluation of amount of moonlight reaching ISS orbit leads for 1500 photons/(m2 ns sr) to similar values of duty cycle. Difference between the real ISS trajectory and previously used trajectory simulations do not change the estimated values of duty cycle significantly. A more conservative estimation of the duty cycle which includes further cut on the Sun location lowers the duty cycle to 18.4%. This result is in agreement with the value assumed so far by the collaboration (19%).

This work was supported by Slovak Academy of Sciences MVTS JEM-EUSO.

- Back-up slides

UV background: Tatiana measurements

Tatiana data: web of the MSU-250 project: *http://cosmos.msu.ru*

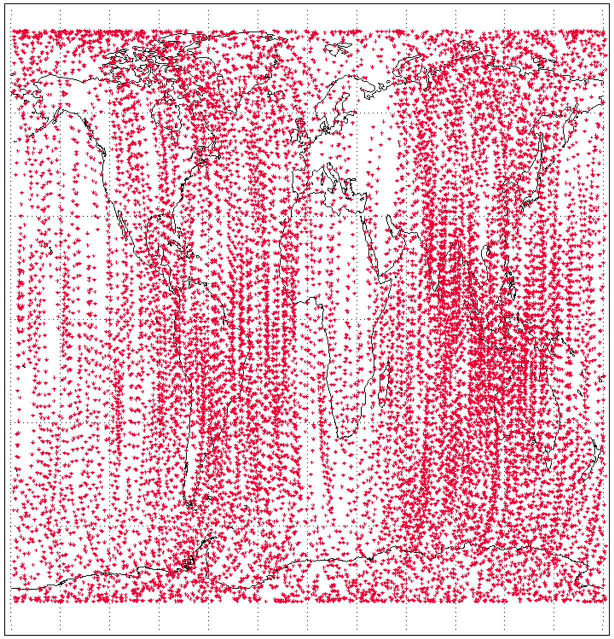
Measurements from January 2005 to March 2007

UV range: 300-400 nm

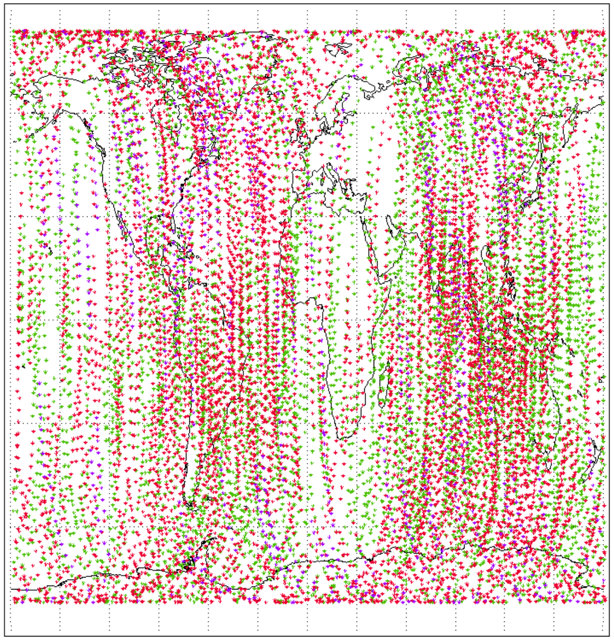
Acceptance cone of UV detector 14^{o} - diameter of the observed area in the atmosphere 250 km, area ~44000 km^{2}

D3 data - see article: UV radiation from the atmosphere: Results of the MSU "Tatiana" satellite measurements, G.K. Garipov et al., Astroparticle Physics, Volume 24, Issues 4-5, 2005, Pages 400-408

We thank to MSU team to let us analyse data, and for consultation of analysis results.

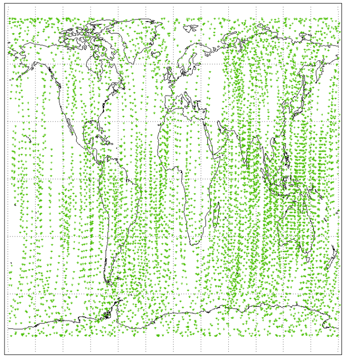


All Tatiana data - positions of measurements (upper panel)

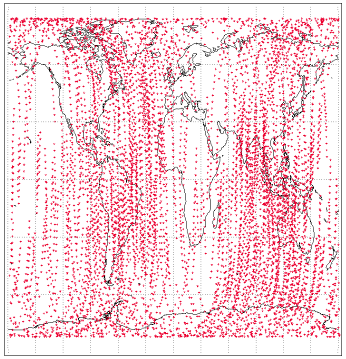


All Tatiana data, green for 2005, red for 2006 and magenta for 2007 (bottom panel)

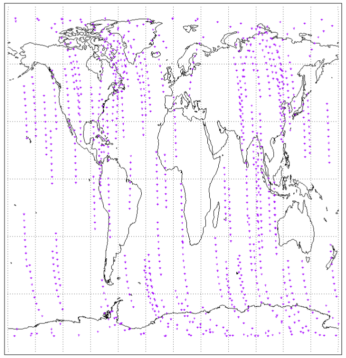
2005



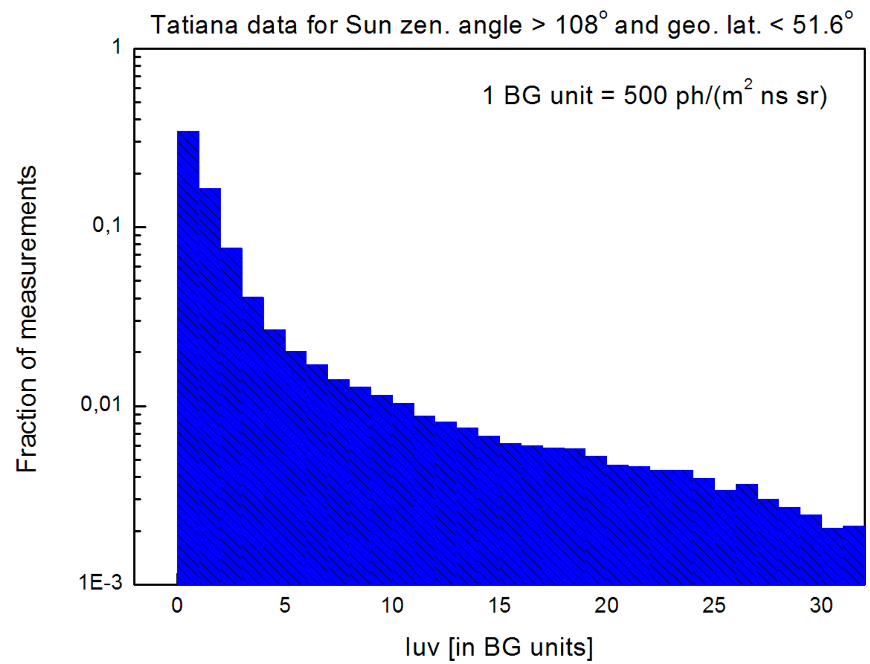
2006



2007



UV background: Tatiana measurements



Because JEM-ESUO will measure on the night side, we select from Tatiana data just those where Sun is 18º under local horizon i.e. Sun zenith angle (S_{ZA}) is more than 108º.

Alternatively we use for selection S_{ZA}>112.5º and S_{ZA}>90º combined with Moon zenith angle M_{ZA}>90º.

$\text{Average}_{<3xBG}$ = 521.2650 ph/(m^2 s sr)

Table:

1. column - UV intensity in BG units, 1 BG = 500 ph/(m^2 s sr)

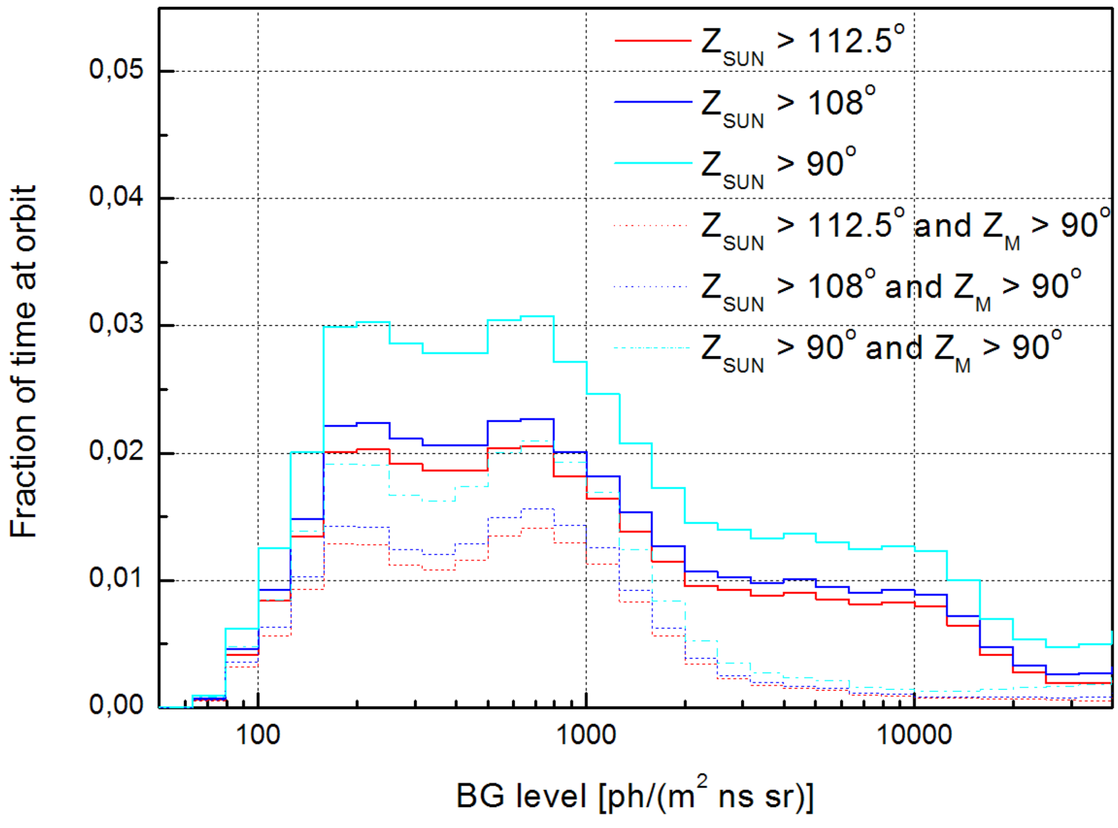
2. column - fraction of measurements with selected BG level in %

3. column - sum of fractions for BG with UV intensity less than selected BG (= value from 1. column)

4. column - 100% minus value in 3. column

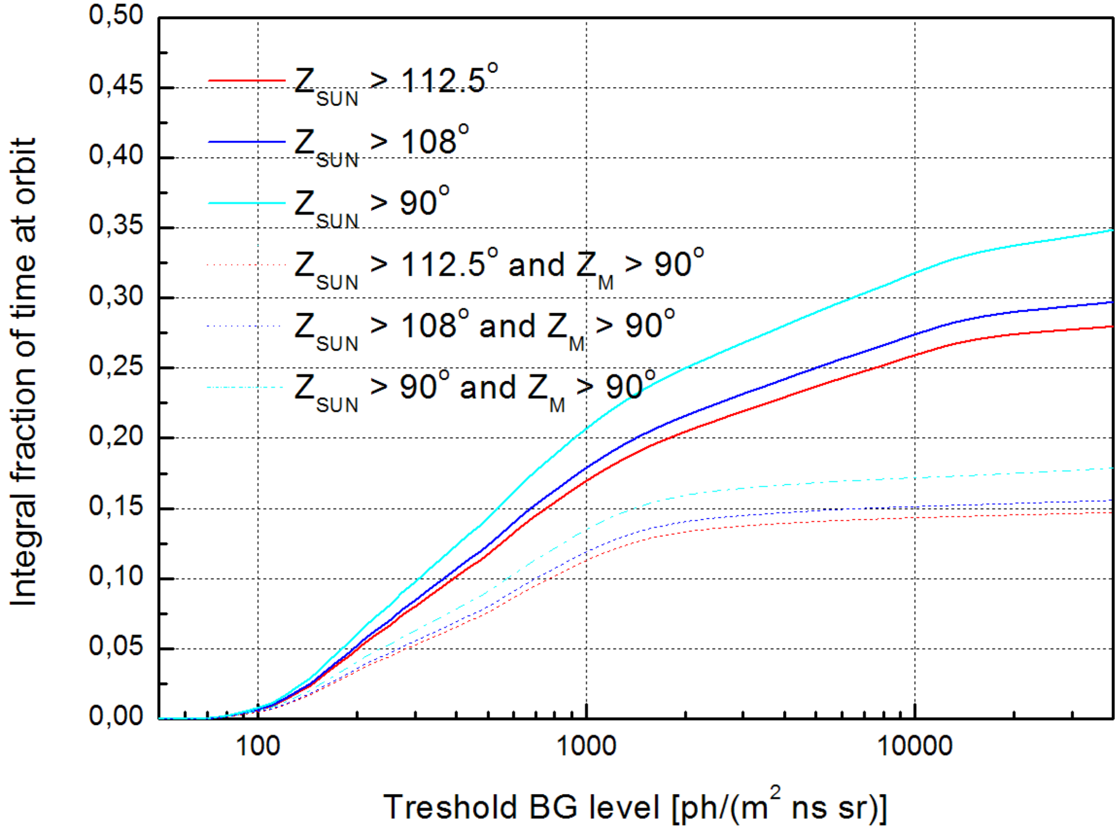
BG in 500 ph/(m² s sr)	Coverage [%]	Sum [%]	Rest of hist. [%]
BG x 1	34.4205	34.4205	65.5795
BG x 2	16.5006	50.9211	49.0789
BG x 3	7.6335	58.5546	41.4454
BG x 4	4.0558	62.6104	37.3896
BG x 5	2.6692	65.2797	34.7203
BG x 6	2.0302	67.3099	32.6901
BG x 7	1.7067	69.0166	30.9834
BG x 8	1.3996	70.4161	29.5839
BG x 9	1.2782	71.6943	28.3057
BG x10	1.1520	72.8463	27.1537
BG x11	1.0358	73.8821	26.1179
BG x12	0.8807	74.7629	25.2371
BG x13	0.8142	75.5771	24.4229
BG x14	0.7536	76.3307	23.6693
BG x15	0.6790	77.0097	22.9903
BG x16	0.6153	77.6250	22.3750
BG x17	0.5997	78.2247	21.7753
BG x18	0.5822	78.8069	21.1931
BG x19	0.5760	79.3829	20.6171
BG x20	0.5252	79.9081	20.0919

UV background: Tatiana measurements



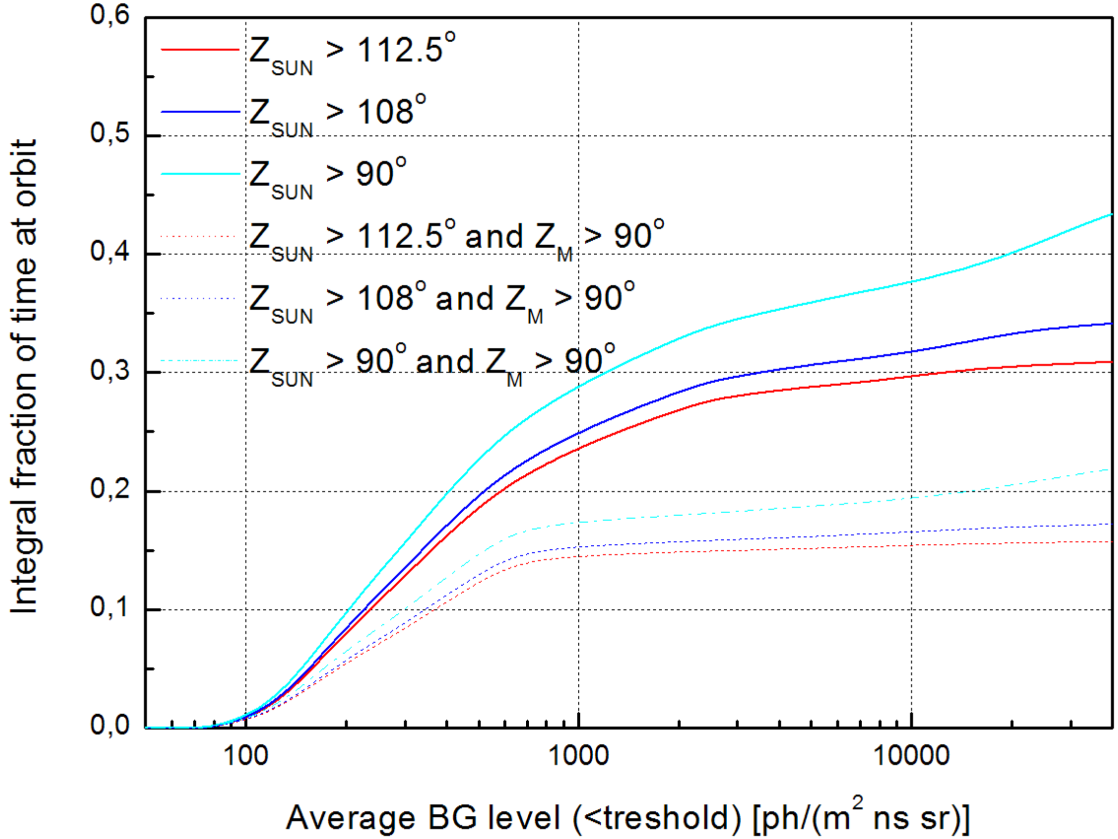
Fraction of time at orbit (D3 data) for set of Sun zenith angle (Z_{SUN} on figure) and Moon zenith angle 90^{o}.

UV background: Tatiana measurements



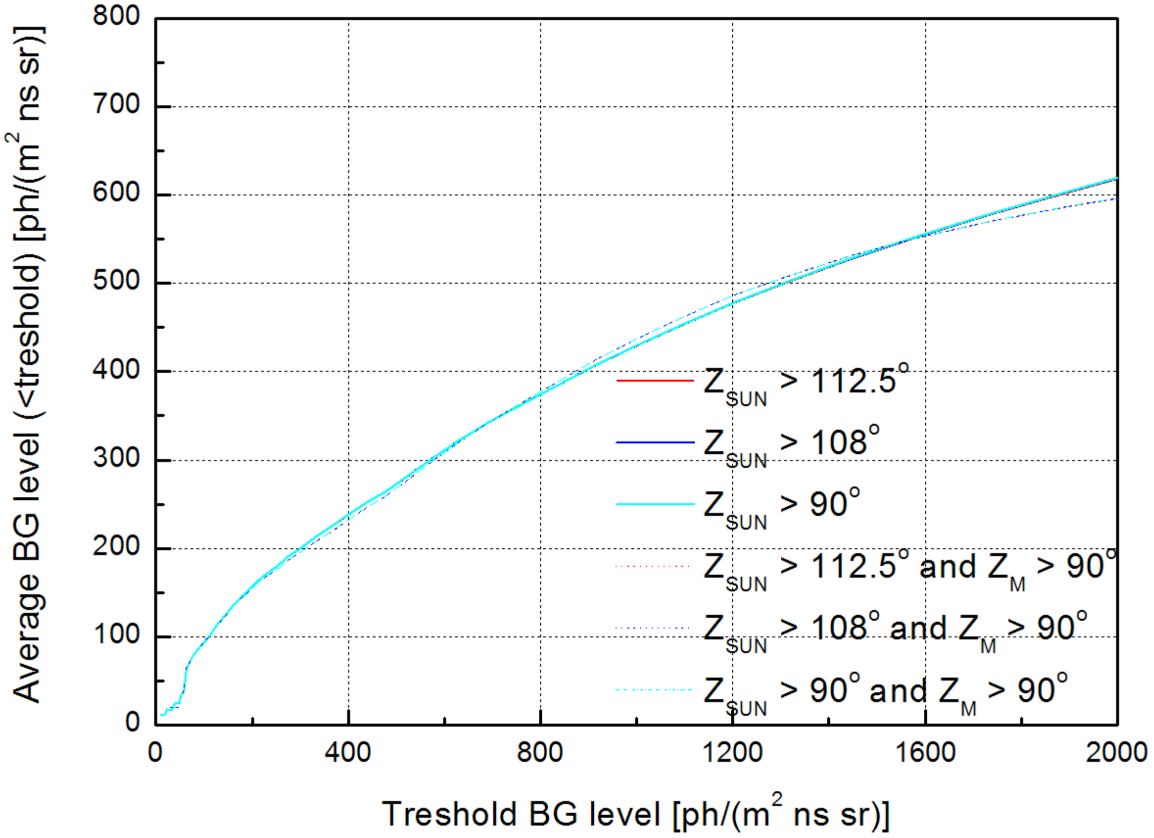
Integral fraction of time at orbit (D3 data) for set of Sun zenith angles (Z_{SUN} on figure) and Moon zenith angle 90° as function of BG treshold.

UV background: Tatiana measurements



Integral fraction of time at orbit (D3 data) for set of sun zenith angles (Z_{SUN} on figure) and Moon zenith angle 90° as function average BG level.

UV background: Tatiana measurements



Average BG level (D3 data) for set of Sun zenith angles (Z_{SUN} on figure) and Moon zenith angle 90º as function of treshold BG level.

UV background: Tatiana measurements

Trend in data

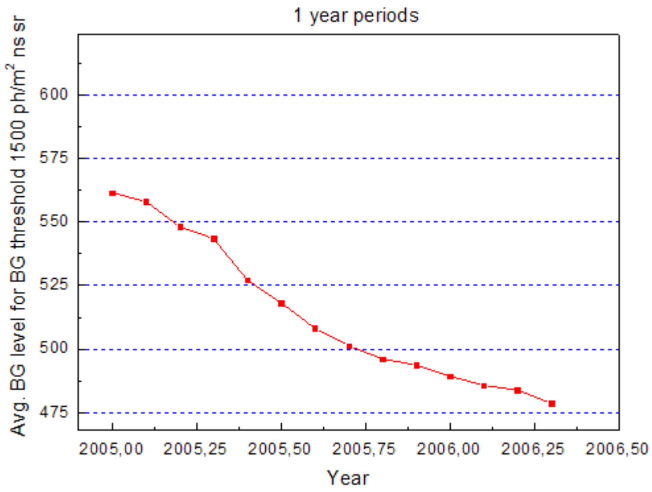
We take 6 month and 1 year periods and evaluate duty cycle and average background UV intensity for threshold 1500 ph/(m^2 ns sr) :

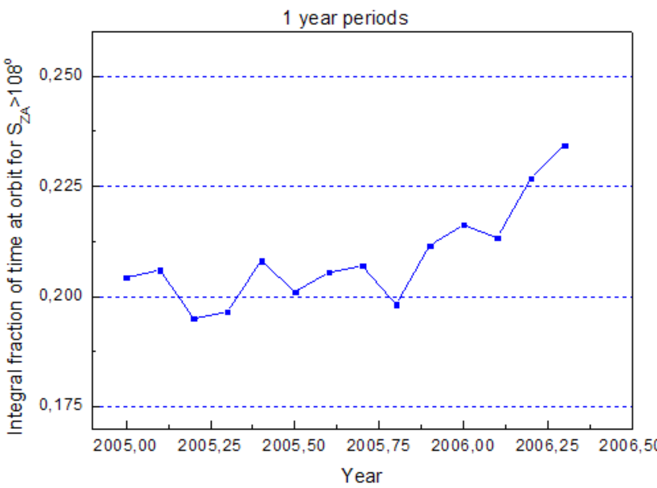
6 months periods i.e. (2005.0-2005.5), (2005.1-2005.6), (2005.2-2005.7) etc.

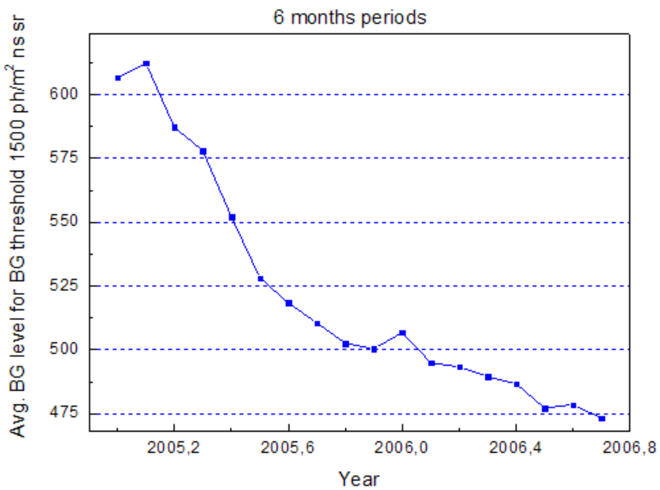
1 year periods i.e. (2005.0-2006.0), (2005.1-2006.1), (2005.2-2006.2) etc.

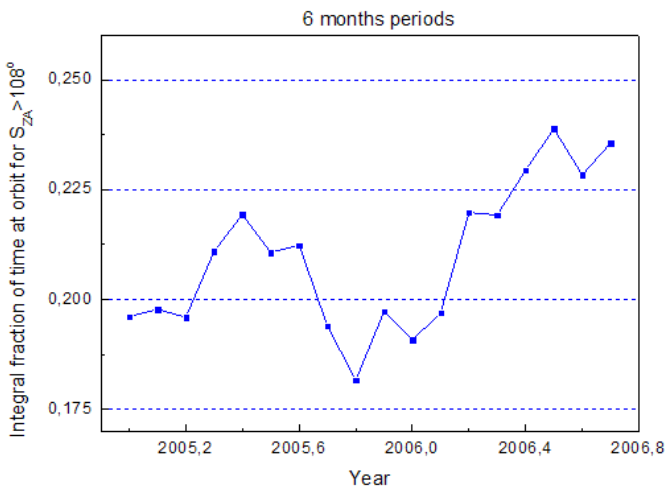
I another words we evaluating average BG intensity of UV light for all measurements with intensity below treshold 1500 ph/(m^2 ns sr) in selected periods.

As authors of data explain trend in data appear in connection with increasing difficulties in keeping detector in nadir direction.



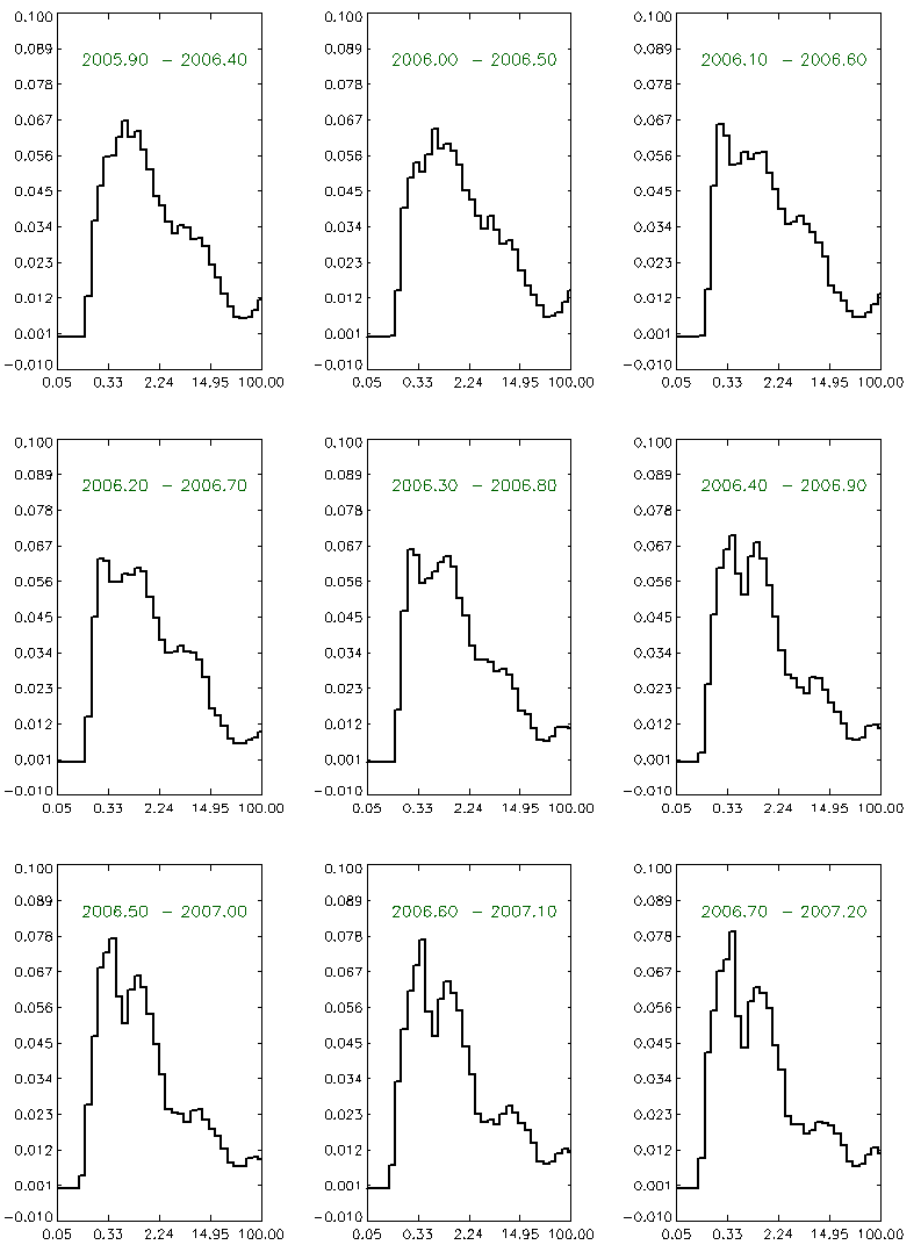




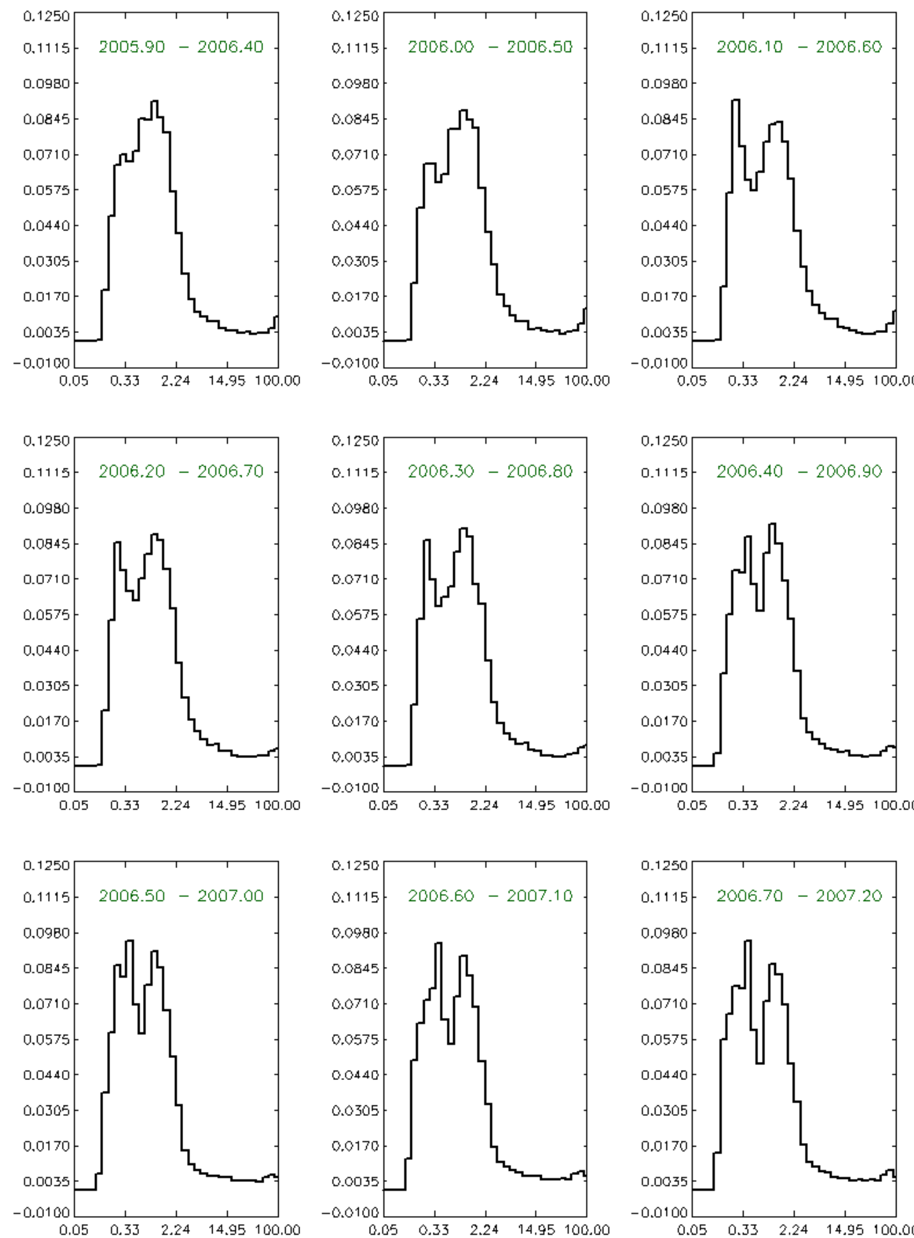


UV background: Tatiana measurements

Fraction of time at orbit for $S_{ZA} > 108^{o}$ D3 data, $S_{ZA} > 108^{o}$, lat.< 51.6^{o}, in BG units [1 BG = 500 ph/(m^2 ns sr)]



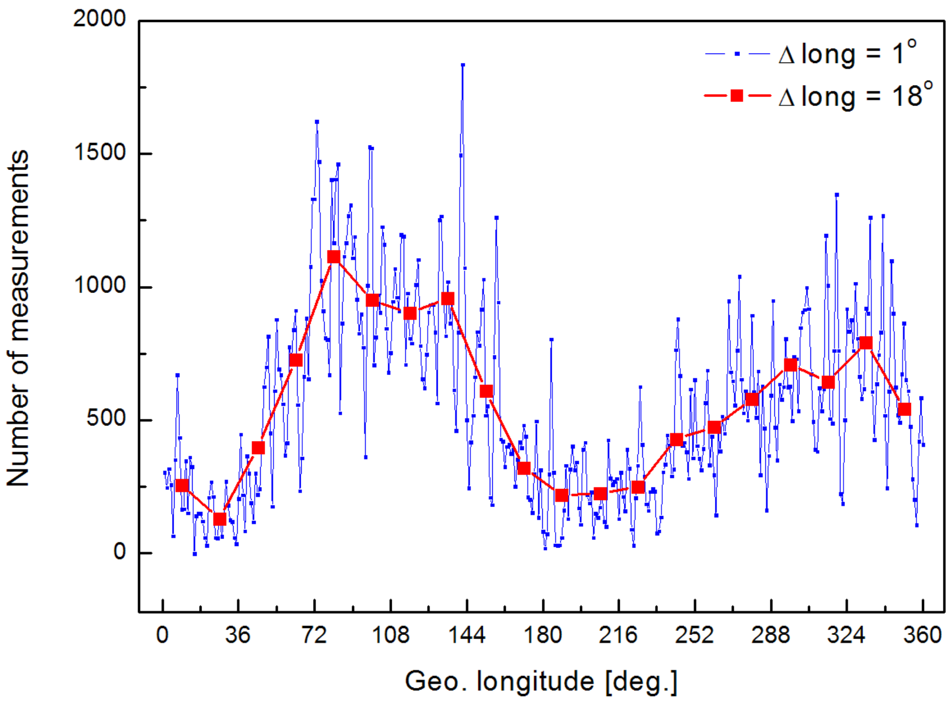
Fraction of time at orbit for $S_{ZA} > 108^{o}$, $M_{ZA}>90^{o}$ D3 data, lat.<51.6^{o}, in BG units [1 BG = 500 ph/(m^2 ns sr)]

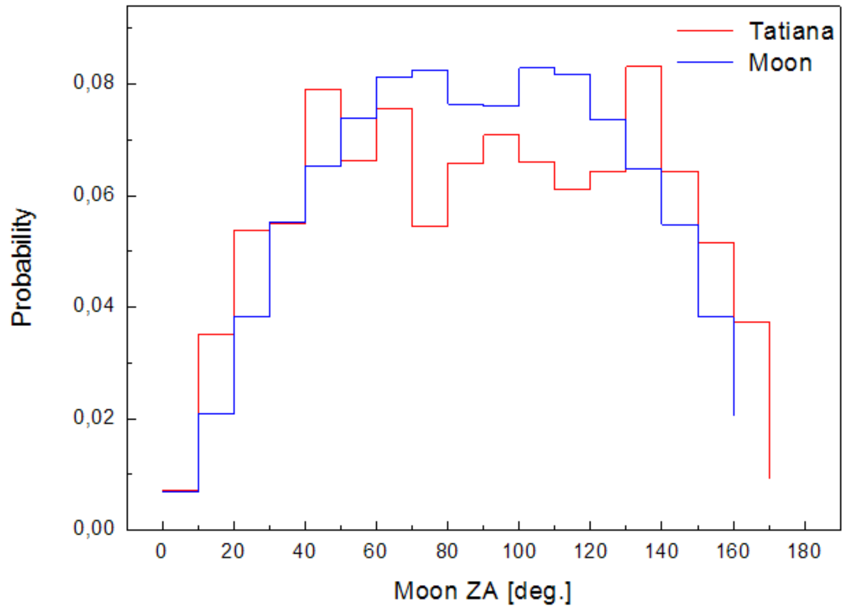


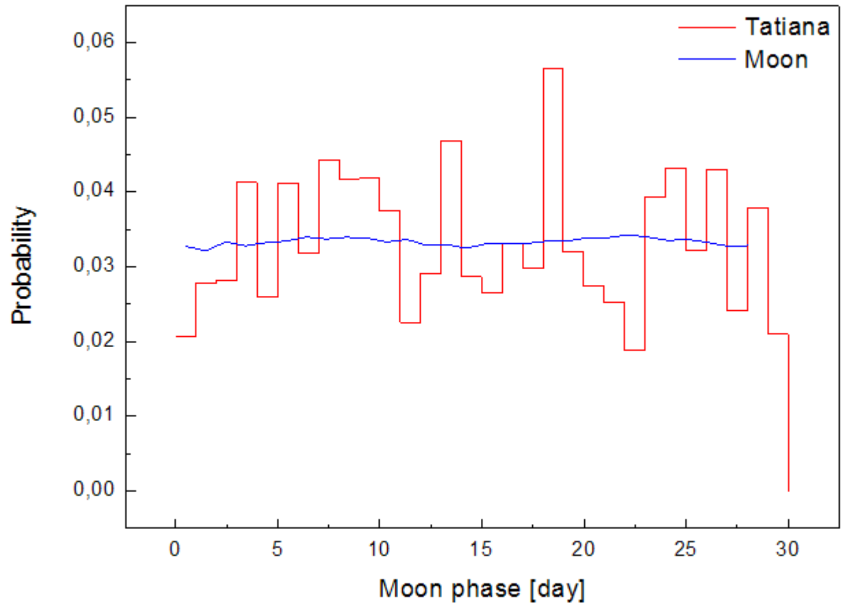
Effects of second order

- Latitude and longitude normalization
- Moon data distribution in the Tatiana measurements

Distribution of Tatiana measurements in different geo. longitudes







Conclusions – Tokio 2010

We estimate a JEM-EUSO duty cycle as measurements whose will be realized in time when UV background will be less than 3xBG (i.e. less than 1500 ph/(m^2 ns sr)) and correspond to 55.6% of Tatiana measurements in time when Sun zenith angle was greater than 108º and geo. latitude was less than 51.6º. This leads to estimation of duty cycle as 20.98% of time at ISS orbit. Average UV light intensity during period with the UV intensity less than 3xBG was 521.27 ph/(m^2 ns sr).

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