Stability coefficient SC

Simple version of SC – upper estimation

We have around 7000 Tatiana continuous measurements from jan. 2005 till feb. 2007 (see Tatiana measurements archive at http://space.saske.sk/JEM/tatiana.html) [1][2][3][4]. Under continuous measurements we mean measurements not break for longer time than is time step (4 sec.) of measurements.

Stability of UV background clearly depend (see archive) 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 90°.

For (Sza>x°) we evaluate average ration $R_{Sza>108}$ between minimum and maximum UV intensity value during all continuous measurements.
Let say that we have selected measurements for Sza>108 and Mza>90.
1st measurement, long N_1 seconds, with min_1 and max_1 UV intensities, $max_1/min_1 = R_{1,\,Sza>108}$
2nd measurement, long N_2 seconds, with min_2 and max_2 UV intensities, $max_2/min_2 = R_{2,\,Sza>108}$
...
mth measurement, long N_m seconds, with min_m and max_m UV intensities, $max_m/min_m = R_{m,\,Sza>108}$

Stability coefficient for Sza>108 is $SC(Sza>108)=\frac{1}{T_{Sza}}\sum_{i=1}^{i=m} R_{i,Sza} N_{i,Sza}$ where $T_{Sza}=\sum_{i=1}^{i=m} N_{i,Sza}$

Evaluated stability coefficients for Sza thresholds from 100 to 170 degree are presented on the Figure 1.

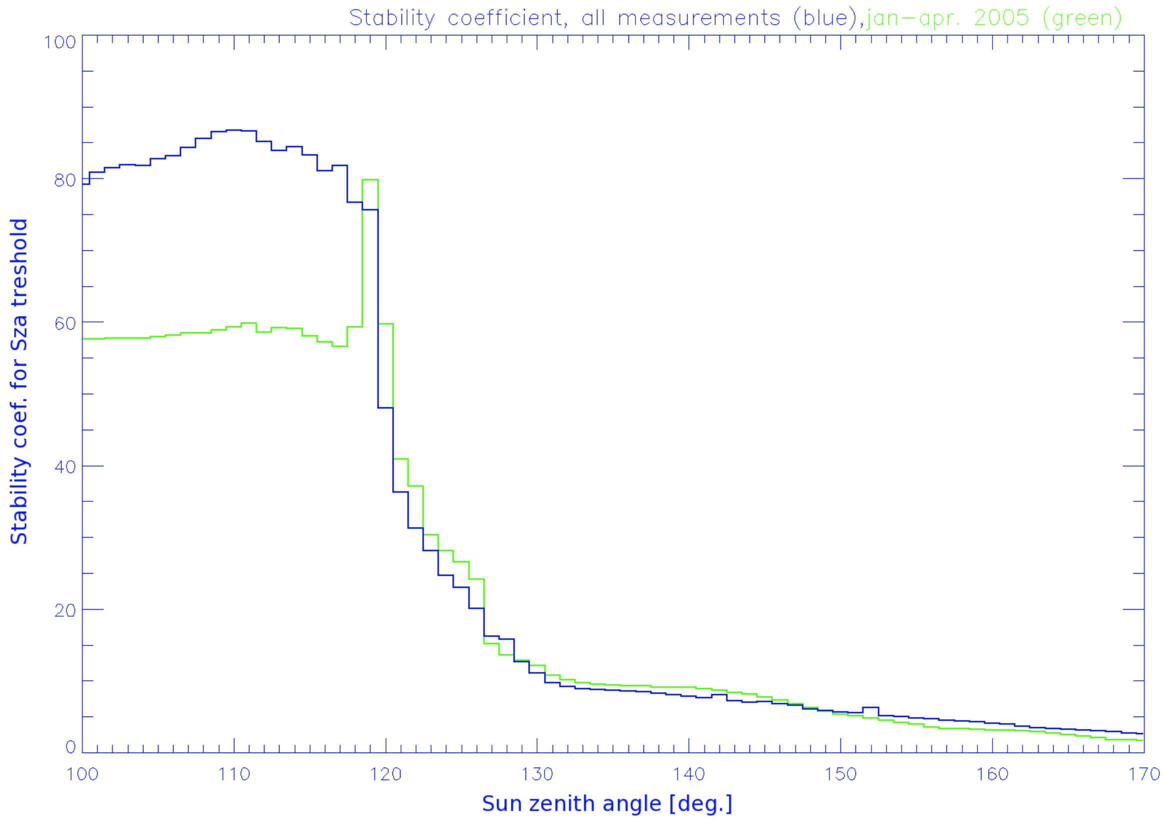

Figure 1. Stability coefficient as function of Sun zenith angle thresholds, for measurements where Mza>90°.

Figure 1. show also stability coefficient evaluated from the measurements in first four months of 2005 year (when Tatiana satellite was stable, still look to nadir). Results are very similar to reults from 2005-2007 period.

SC based on standard deviation

For selected Sza treshold bigger than x degree (Sza>x°) we evaluate average standard deviation σ of UV intensity value during all continuous measurements.

$$\sigma_i = \sqrt{\frac{1}{N_i} \sum_{j=1}^{j=N_i} \left(I_{UV,i,j} - \overline{I_{UV,i}} \right)^2}$$

Where $\overline{I_{UV,i}}$ is average UV intensity during *i-th* measurement.

Let say that we have selected measurements for Sza>108 and Mza>90.
1^{st} measurement, long N_1 seconds, with standard deviation $\sigma_{1,\ Sza>108}$
...
m^{th} measurement, long N_m seconds, with standard deviation $\sigma_{m,\ Sza>108}$

Stability coefficient for Sza>108 is $SC(Sza>108) = \frac{1}{T_{Sza}} \sum_{i=1}^{i=m} \sigma_{i,Sza} N_{i,Sza}$ where $T_{Sza} = \sum_{i=1}^{i=m} N_{i,Sza}$.

Evaluated stability coefficients for Sza thresholds 80, 81, ...170 degree are presented on the Figure 2. (upper panel).

SC based on curve length

Third way how to set a stability coefficient is evaluate length of curve describing a measurements.

For selected Sza treshold bigger than x degree (Sza>x°) we evaluate average length of measurement curve L of UV intensity value signal during all continuous measurements.

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

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

$$SC(Sza>x^o) = \frac{1}{T_{Sza}} \sum_{i=1}^{i=m} L_{i,Sza} N_{i,Sza} \quad \text{where} \quad T_{Sza} = \sum_{i=1}^{i=m} N_{i,Sza}$$

Evaluated stability coefficients for Sza thresholds from 80 to 170 degree are presented on the Figure 2. (bottom panel).

SC based on Average absolute deviation

Fourth way how to set a stability coefficient is use average absolute deviation of measurements.

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

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

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

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

We evaluate AAD stability coefficients for Sza thresholds from 80 to 170 degree. Average UV intensity for Sza thresholds from 80 degree are on figure 3. Ratio of AAD and UV average for same threholds show how much was signal stable for different nights definitions. On the figure 4. we show a AAD stability coefficient and his ratio with UV light intensity average.

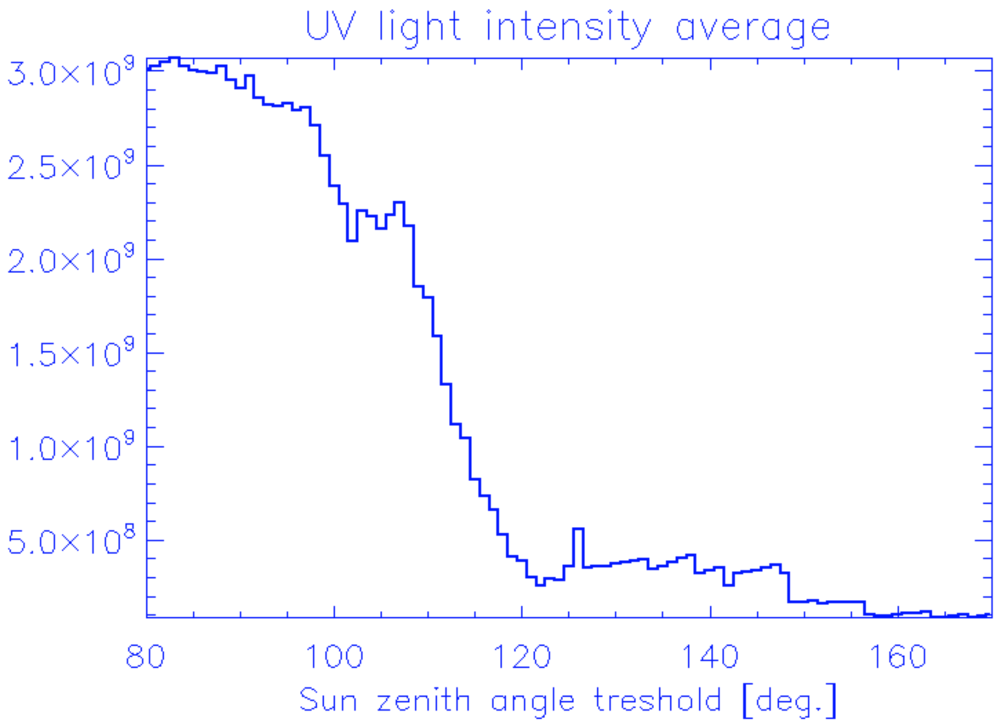

Figure 3. UV light intensity average for different sun zenith angles thresholds in ph/(cm^2 s sr) for measurements where Mza>90^o.

Conclusion

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^o. 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^o.

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 10^{ths} 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 (see Flash/TLE Appendix 1.).

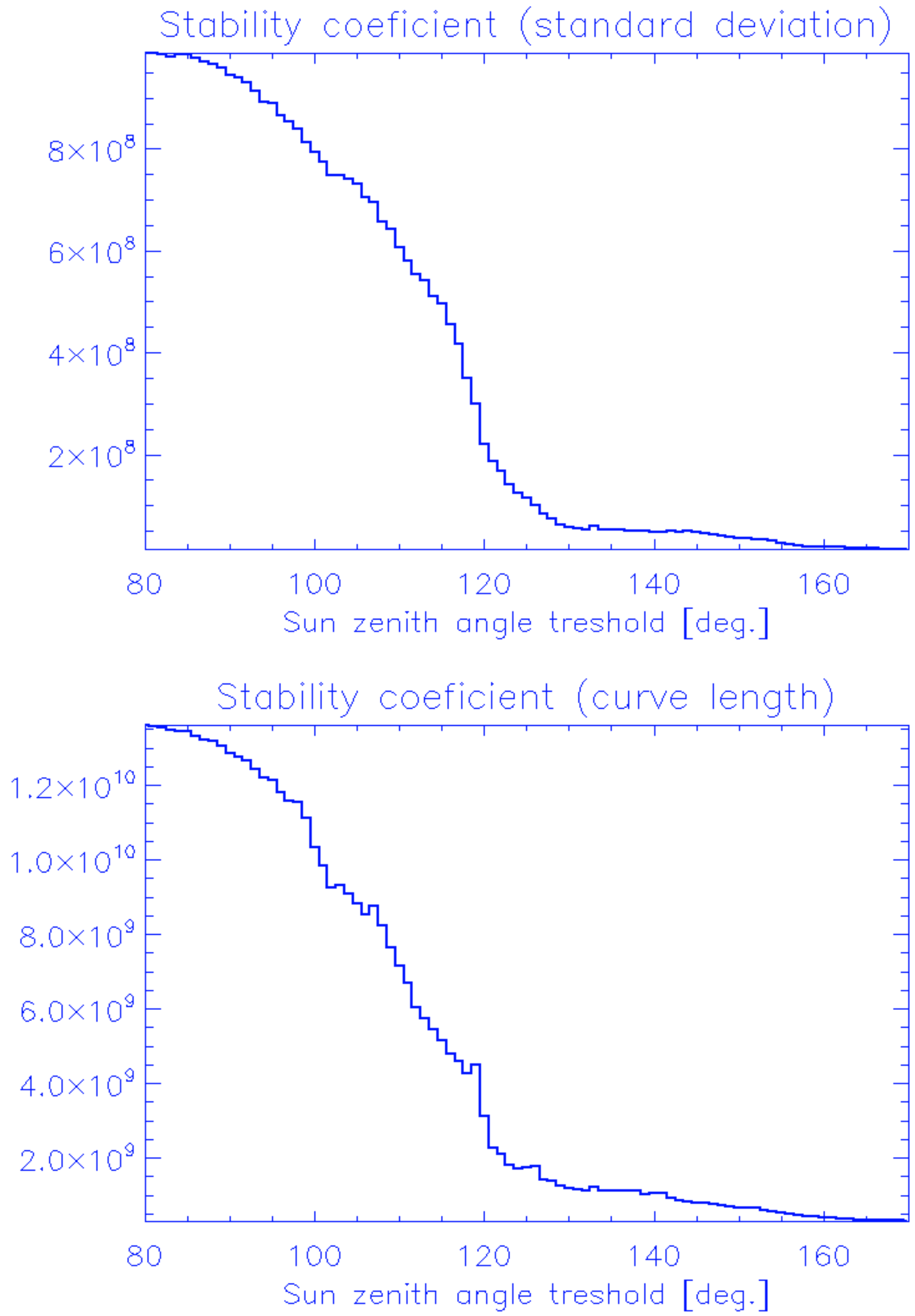

Figure 2. Stability coefficient based on standard deviation of measurements (upper panel) and on measurements curve length (bottom panel) as function of Sun zenith angle thresholds, for measurements where Mza>90°.

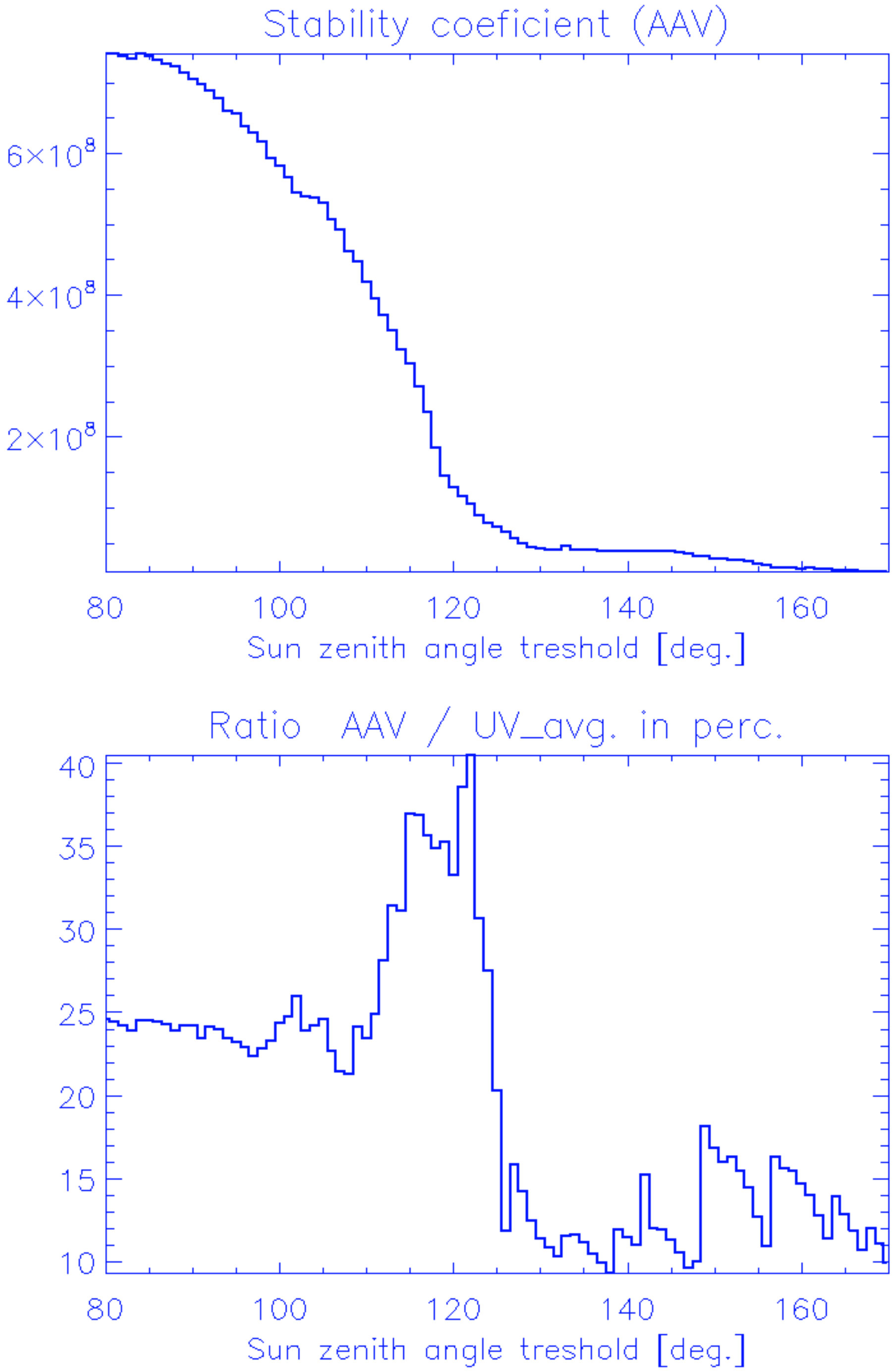

Figure 4. AAV stability coefficient in ph/(cm^2 s sr) at upper panel. Ratio of AAV and UV light average intensities in percents. Both for measurements where Mza>90º.

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/

Time stability of UV signal

We start with evaluation of average length $T_{AVG,Sza}$ of one continuous measurements during Tatiana operation period for different Sun zenith angles tresholds. We use a values with $I_{UV} < 2e9$ ph/(cm^2 s sr) for ISS orbit range.

$$T_{AVG,Sza} = \frac{1}{m} \sum_{i=1}^{i=m} N_{i,Sza}$$

Results are presented at figure 11.

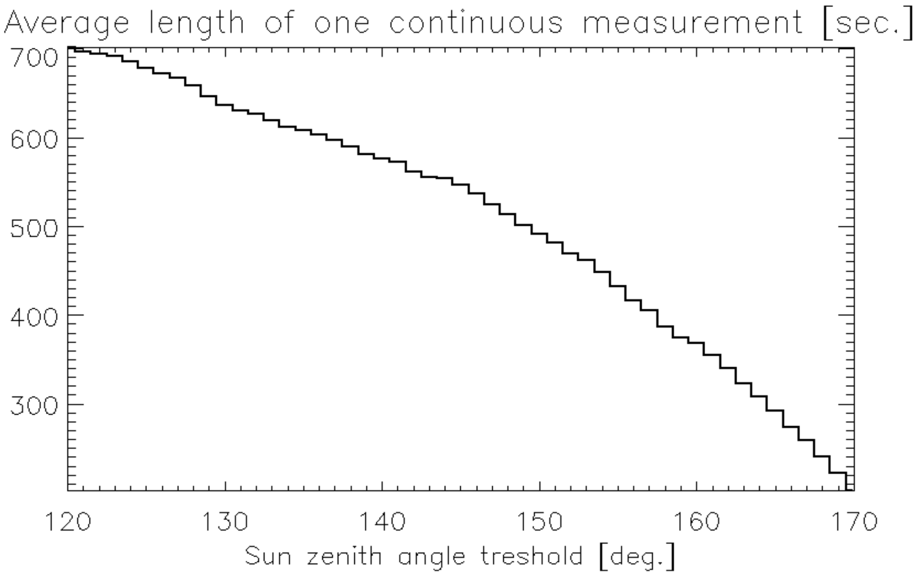

Figure 11. Average length of one continous measurement as function sun zenith angle treshold.

Average length $T_{AVG,Sza}$ on the nicht side is roughly 10 minutes and decrease with increasing sun zenith angle treshold.
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 treshold. Results are presented on figure 12.

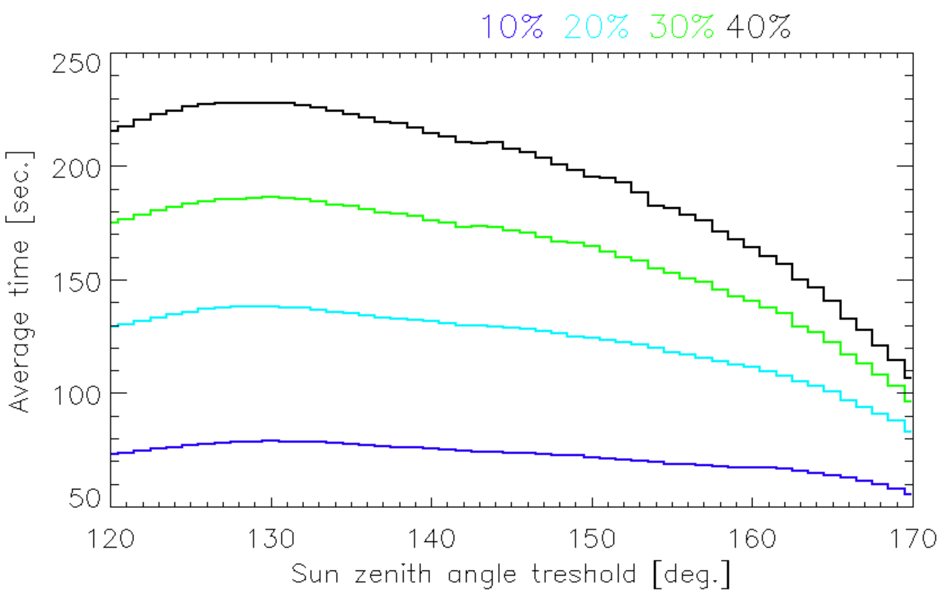

Figure 12. Average length of measurement when UV signal not change more than ±10% (dark blue), not more than ±20% (light blue), ±30% (green) and ±40% (black).

How long is signal stable at level ±10%, ±20%, ±30% and ±40% in comparisson to total length of measurements is expressed as ratio on figure 13. For example, we can expect ~half measurements on the night side be in 30% stability level and ~3/4 of measurements in the 40% stability level.

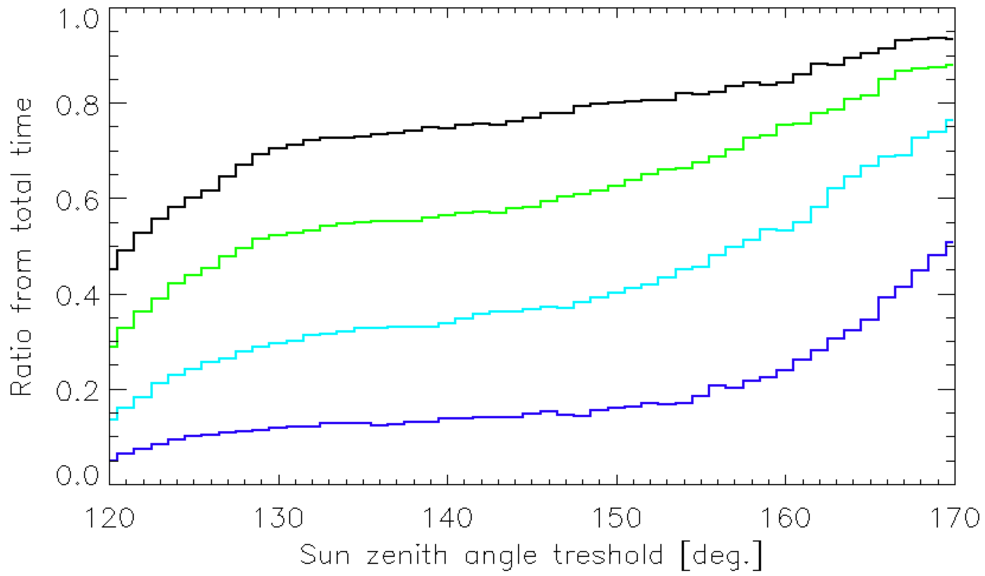

Figure 13. Ratio for total time of measurements for different stability levels. Ratio for meaurements where UV signal not change more than ±10% is denoted by dark blueline, not more than ±20% by light blue, ±30% (green) and ±40% (black line).

Appendix 1. Flashes and TLE events in Tatiana measurements

Examples of flashes in archive:
http://space.saske.sk/JEM/Sza135_Mza90/maps/22_Sza135_Mza90_map.png
http://space.saske.sk/JEM/Sza135_Mza90/maps/108_Sza135_Mza90_map.png

Distribution of registered UV flashes is presented at figure 5. Open circles denote position of flash, color intensity of UV light signal.

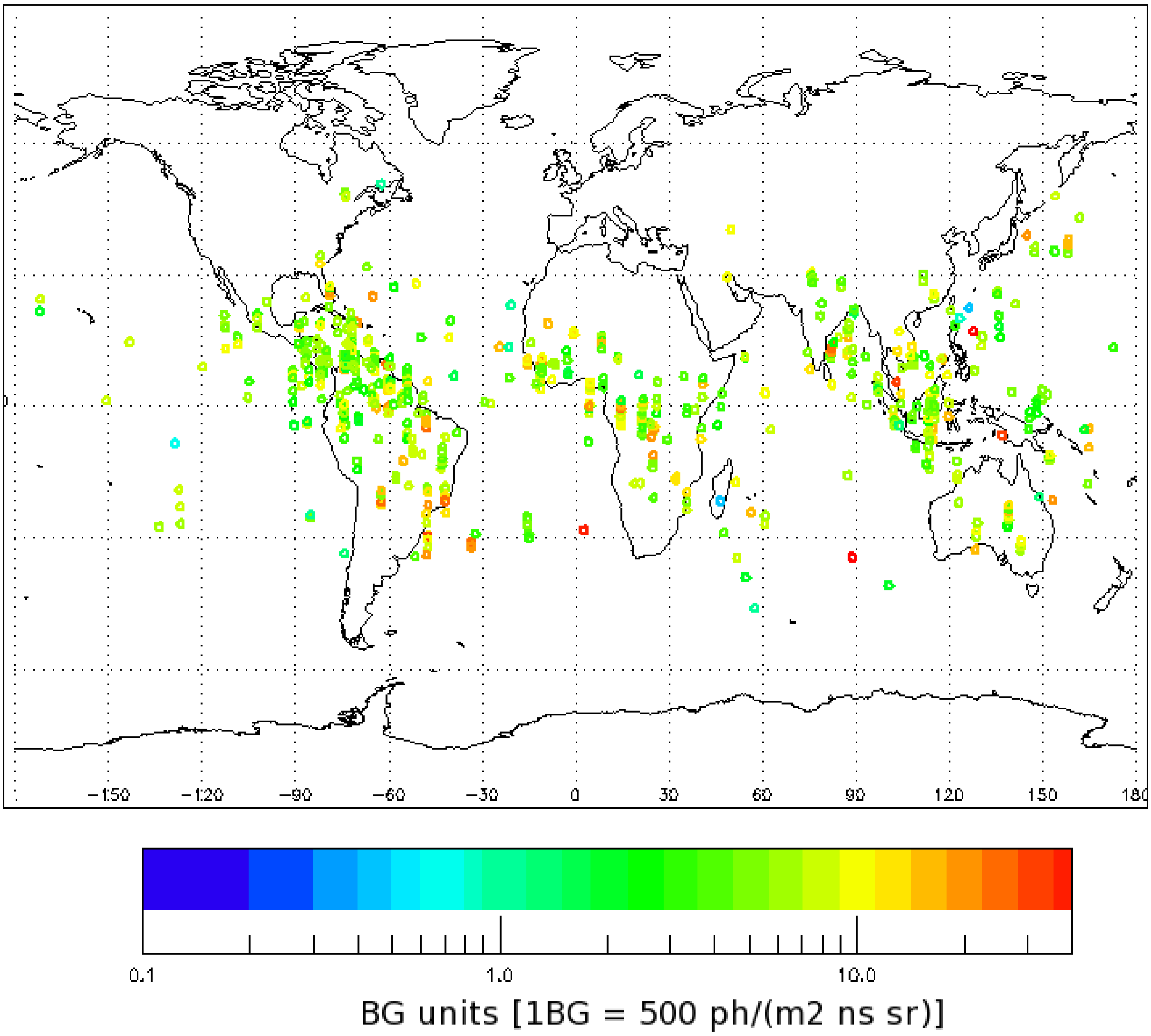

Figure 5. UV light flashes positions. Color denote UV light intensity in BG units.

Flashes increase level of UV light for short time very fast (abruptly) few times (~10).

Appendix 2. Errors in measurements, influence to SC

Data contains few measurements with unrealistically high values of UV light intensity.

See for example http://space.saske.sk/JEM/Sza108/maps/1317_Sza108_map.png

However we have very few of them (less than 0.1% of measurements) due to their high values they can reasonably affect values of stability coefficients. If we apply simple filter to data, for example not take in account measurements with values more than 10^{11} ph/(cm^2 s sr) = 10^6 ph/(m^2 ns sr) we get following figures (6. and 7.) for stability coefficients. If compare figures 3. with 6. and 4. with 7. we see difference, but conclusions (new night definition and stability of signal in order od 10^{ths} percents) remains same.

If we try use simple filters where we take in account just meaurements for Mza<90° with intensities less than 10^{10} and $2x10^9$ and ph/(cm^2 s sr) (figures 8. and 9.) and we compare average intensity and time when intensities was under filtered values we see that time is almost not change. But average intensity change significantly (figure 10.), what means that average intensity is changed by few errors in measurements.

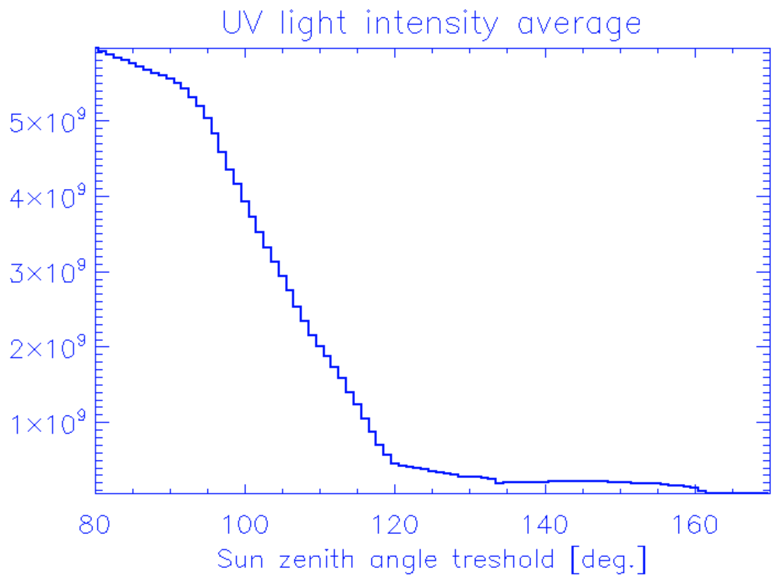

Figure 6. UV light intensity average for different sun zenith angles thresholds in ph/(cm^2 s sr) with applied filter $I_{UV} < 10^{11}$ ph/(cm^2 s sr) for measurements where Mza>90°..

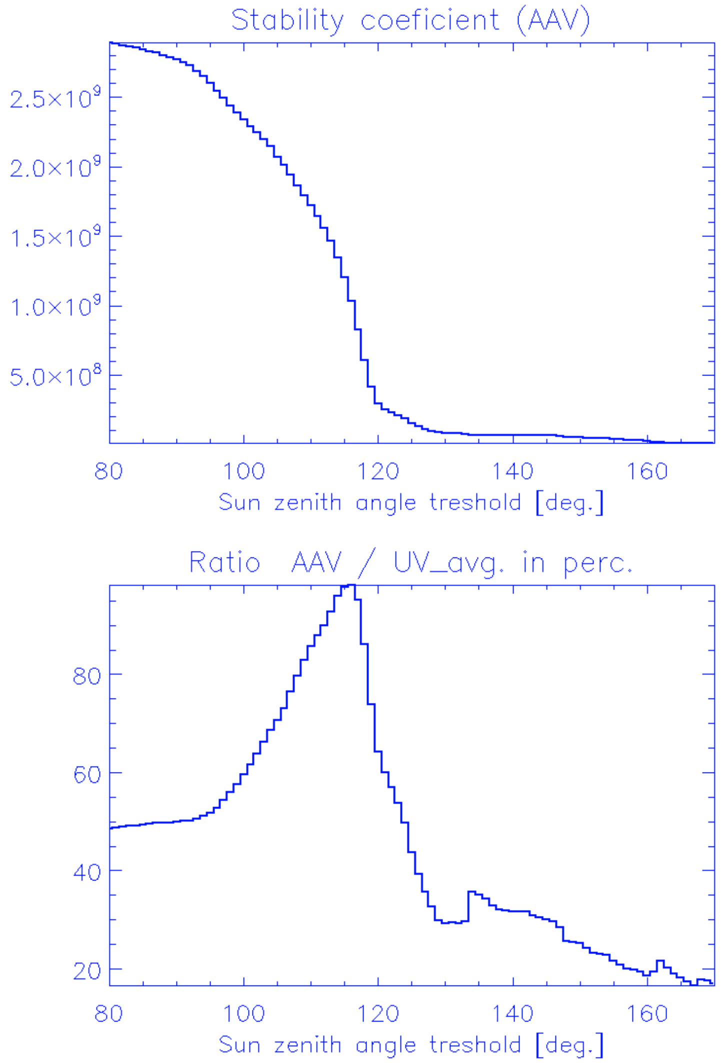

Figure 7. AAV stability coefficient in ph/(cm^2 s sr) at upper panel. Ratio of AAV and UV light average intensities in percents with applied filter $I_{UV} < 10^{11}$ ph/(cm^2 s sr) for measurements where Mza>90^o..

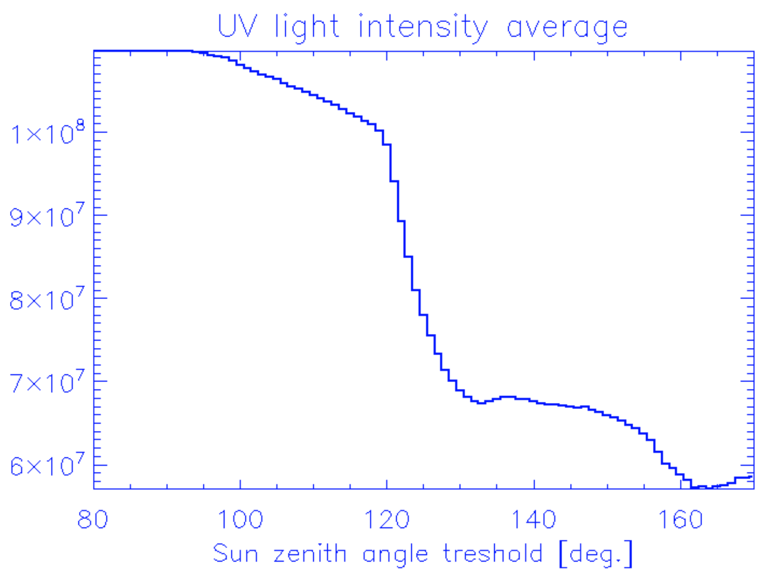

Figure 8. UV light intensity average for different sun zenith angles thresholds in ph/(cm^2 s sr) with applied filter $I_{UV} < 2.10^9$ ph/(cm^2 s sr) for measurements where Mza>90^o.

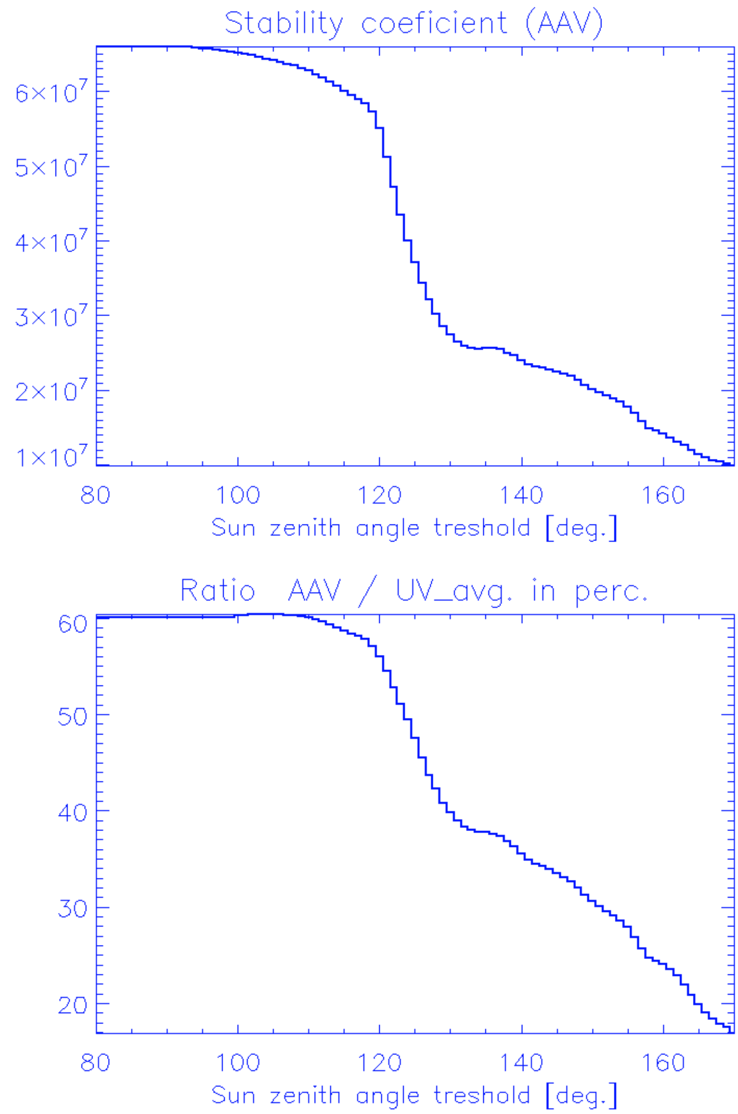

Figure 9. AAV stability coefficient in ph/(cm^2 s sr) at upper panel. Ratio of AAV and UV light average intensities in percents with applied filter $I_{UV} < 2.10^9$ ph/(cm^2 s sr) for measurements where Mza>90°.

Because errors in Tatiana data has significant effect to stability coefficient, errors from data was filtered by set of filters based on stability coefficients (results with this set of filters is presented for example at Figure 4).

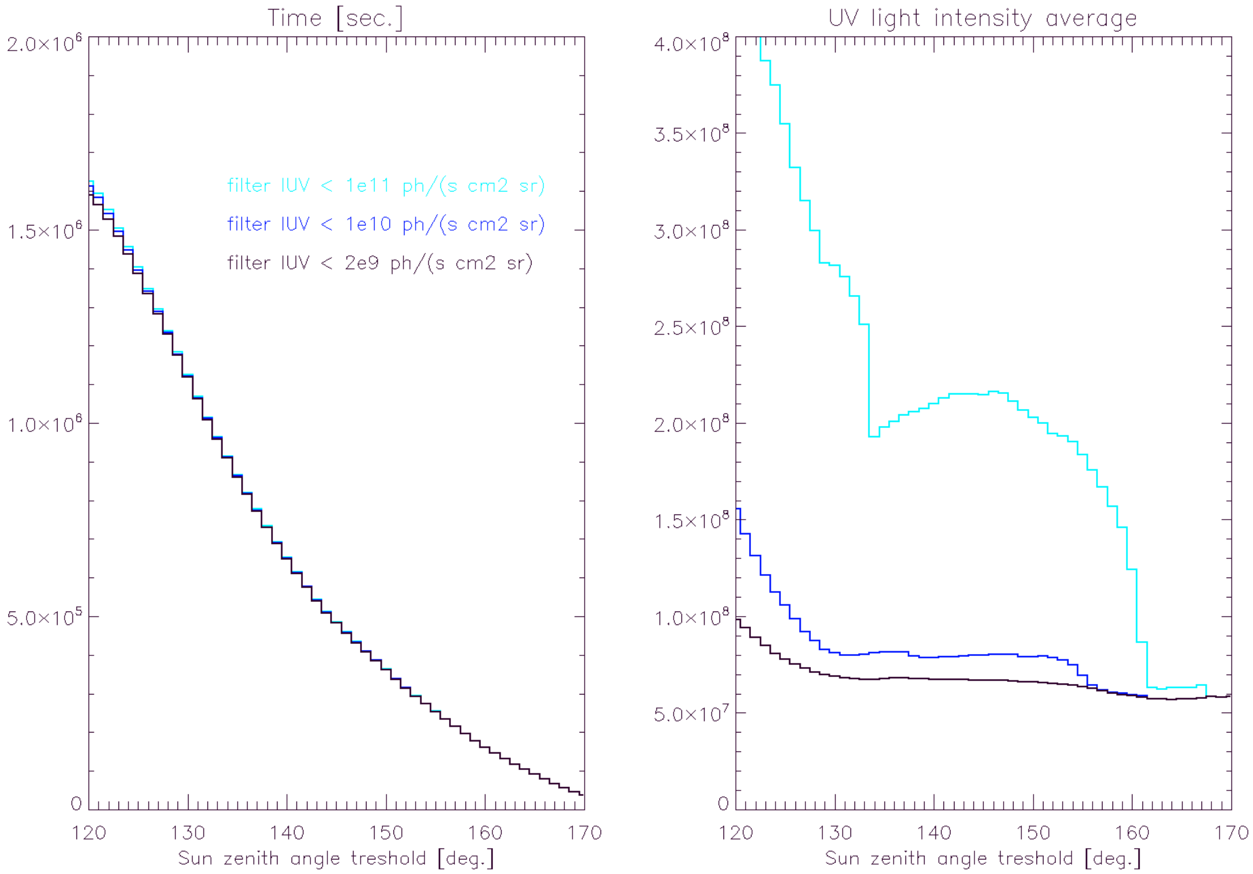

Figure 10. Cumulative time when measurements was under filtered values on the left panel. UV light intensity averages for different sun zenith angles thresholds in ph/(cm^2 s sr) with applied filter I_{UV} < 2.10^9, 10^{10}, 10^{11} ph/(cm^2 s sr) on right panel for measurements where Mza>90°.