Comments to paper of P. Stauning "The Polar Cap (PC) Index, Invalid Index Series and a Different Approaches"

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Abstract

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Abstract. The paper examines the essence of discrepancies between the IAGA approved *PC* index and the approach put forward by Stauning (2020). The IAGA endorsed *PC* index was designed to serve as a proxy for energy that enters into the magnetosphere during solar wind-magnetosphere coupling. It means that the ground-based *PC* index should be indicative of the magnetosphere state in the real time. With this aim a special "running QDC derivation" procedure has been elaborated (Troshichev et al*.*, 2006) to determine a proper quiet daily curve (QDC) as a level of reference for evaluation of magnetic disturbances generated by solar wind. The most significant evidence of validity of the IAGA endorsed *PC* index is the statistically justified correspondence between the *PC* index changes and development of disturbances in the magnetosphere (with correlation as high as R=0.94). The alternative procedure (Stauning, 2011) also used QDC as level of reference, but this QDC does not consist with the *PC* index designation. The announcement (Stauning, 2020) on invalid IAGA-endorsed *PC* index series seems be devoid of any background.

Key points

The IAGA endorsed *PC* index method uses QDC as a reference level to count the magnetic activity related to solar wind influence on magnetosphere.

The QDC derivation procedure makes proper allowance for regular and irregular solar UV irradiation effects and for effect of the IMF sector structure.

The Stauning's method taking into account the only regular effects, that is why his method is unfit for PC index derivation.

1. Introduction

Index of the polar cap (*PC*) magnetic activity, elaborated in the Arctic and Antarctic Research Institute (AARI, Saint-Petersburg) (Troshichev & Andrezen, 1985), was put into the practical use in cooperation with Danish Meteorological Institute (DMI, Copenhagen) (Troshichev *et al.*, 1988). The 15-min *PC* index was calculated independently for Northern and Southern polar caps by data of magnetic observations at the near-pole stations Quanaak (Thule) in the Greenland (*PCN*) and station Vostok in the Antarctic (*PCS*) since 1998. However, the procedures of the *PCS* and *PCN* indices derivation adopted, correspondingly in the AARI and in DMI, turned out to be different in detail. As a result, when the 1-min *PCN* and *PCS* values were brought into practice (1999), inconsistency between the indices turned out to be a regular phenomenon, especially during the disturbed periods. To resolve the problem the unified method of *PC* index derivation, approved by both sides, was required. Since E. Friis-Christensen and S. Vennerstroem, our Danish collaborators, left Danish Meteorological Institute by this time, Dr. Stauning, as a representative of DMI, offered his help. Dr. Stauning got acquainted in detail with the *PC* derivation method applied in AARI. He appreciated the method, thereupon he became coauthor of principal paper on the unified *PC* index (Troshichev, Janzhura and Stauning, 2006, thereinafter *TJS*2006). Unfortunately, Dr. Stauning reversed his standpoints many times over next 4 years and eventually suggested his own method, which was published later (Stauning, 2011, thereinafter *St*2011).

In 2009 the IAGA Division V-DAT appointed a special Task Force Team for examination of the long-standing *PC* index issue. The Task Force Team extensively studied the competitive

AARI, DMI and Stauning's methods and came to conclusion that the AARI (*TJS*2006) method is the best (McCreadie & Menvielle, 2010). The problem was examined by the IAGA Division V-DAT at a special working meeting at Vienna in May 2010 and the *TJS*2006 method has been recommended for the IAGA endorsement. At the same meeting it came to light that responsibility for magnetic observations at Thule station was delivered in 2009 to the Space Research Institute of the Danish Technical University (DTU-Space). During next 2 year the AARI and DTU teams got agreement on all details of the *PC* derivation procedure. In 2013 the *PC* index was approved by IAGA as a new international index of magnetic activity characterizing the solar wind energy that enters into the magnetosphere [Resolution 3, XXII IAGA Scientific Assembly, Mexico]. At present the *PCS* and *PCN* indices are produced on-line in AARI and in DTU-Space based on the unified method with use of the restructured and harmonized code (Nielsen & Willer, 2019). The *PCN* and *PCS* indices are presented on-line at web-sites ftp://ftp.space.dtu.dk/WDC/indices/pcn/. and http://pcindex.org.

The *PC* index gains the increasingly more interest of scientific community, as the ground-based index, which can be used online to monitor geoefficiency of the solar wind impact on the magnetosphere. Nevertheless, validity of the IAGA endorsed *PC* index is repeatedly questioned by Stauning (2013a,b, 2015, 2018a.b, 2020). In the given comments we respond to the last publication "The Polar Cap (PC) Index, Invalid Index Series and a Different Approaches" (Stauning, 2020). Unprepared reader can became acquainted with the *PC* index concept (the index derivation procedure, relationship to the solar wind electric field E_{KL} and field-aligned current (FAC) systems, correlation with magnetospheric disturbances, usage for space weather monitoring) in the review article (Troshichev et al., 2021) presented in this issue of the Journal Space Weather. These comments will concern only the Dr.Stauning's critical remarks and principal distinctions between the *PC* index derivation methods put forward in *TJS*2006) and proposed in *St*2011.

2. Substitution of conceptions

The way of criticism chosen by Dr. Stauning is the following. He persistently refers to paper (Janzhura & Troshichev, 2011, thereinafter *JT*2011), where the attempt was made to elaborate the method for on-line determination of the short-term changes of the IMF By component by means of the polar cap magnetic activity data. As this takes place, the SS identification procedure suggested in *JT*2011 had no any relation to the IAGA endorsed *TJS*2006 method. Indeed, the *JT*2011 procedure was assigned for on-line determination of the short (some days) variations of the IMF B_Y component basing on the daily median values of geomagnetic H and D components. Then median values for 9 days preceding the current day were subjected to 3-days running average and the interpolation procedure was applied to these smoothing averages. By contrast the *TJS*2006 procedure (described in detail in Troshichev, et al. (2021)), includes the following operations: (1) separation of the 27-days SS effect basing on data for 3 previous months, with use of 7-days smoothing window, (2) subtraction of SS effect from data for 30 previous days, (3) separation of 5 quiet days (or quietest time segments) within the interval of these 30 days, and (4) construction of the quiet daily curve (QDC) for current day by data of 5 quietest days (or quietest segments). One can see the principal differences between the *TJS*2006 and *JT*2011 procedures.

The *JT*2011 procedure was never used for the QDC derivation and Dr. Stauning is perfectly informed of this circumstance (see Stauning, 2021). Nevertheless he repeatedly stated that the *JT*2011 procedure is the integral part of *TJS*2006 method (see publications by Stauning (2011, 2013a,b, 2015, 2018a,b, 2020) and proclaimed that *St*2011 method put forward for derivation of SS effect offers advantages over the *JT*2011 method. On this basis the following conclusions are made

(Stauning, 2015, 2020): (i) the *St*2011 QDC procedure "provides considerable improvements compared to the IAGA-endorsed QDC procedure" and (ii) "the IAGA recommended near- real time indices highly unreliable and thus unsuitable for space weather applications". What does this declaration mean: whether it is inability to understand difference between the QDC derivation and SS derivation procedures, or it is the conscious substitution of conceptions?

3. QDC as a level of reference to count off the *PC* value

The main discrepancy between the *TJS*2006 and *St*2011 methods concerns a proper choosing the level of reference to count off the value of the polar magnetic disturbance, related to solar wind influence. In the *TJS*2006 method the curve of the quiet daily geomagnetic variation (QDC) is taken as the counting off level. The daily geomagnetic variation is observed at all stations due to daily rotation of station around the geographic pole. In course of this rotation the station passes under areas with different ionospheric conductivity, relating to solar UV irradiation and, therefore, to the Sun zenith angle. As a result, the ionospheric electric currents, flowing above the station, and geomagnetic variations, generated by these currents at the station, appear to be dependent on local time and season.

These regular geomagnetic variations are supplemented by regular long-term (~ 27 days) deviations, related to the IMF sector structure ("SS effect") (see Svalgaard, 1968). The regular summary QDC can be easily identified in the magnetically quiet periods, with absence of additional irregular magnetic perturbations. However, during active periods the ionospheric conductivity can be strongly affected by powerful rises of the solar UV irradiance, related to solar flares, and by invasions of the high-energy solar proton (SPE). The irregular UV irradiation effect manifests itself in the sunlit polar cap, whereas SPE effects are particularly remarkable in the winter darken cap. Thus, the polar cap magnetic activity during active periods can be strongly affected by irregular sources, resulting in changes of the QDC pattern from day to day.

The IAGA endorsed *PC* index is assigned to estimate the magnetic activity caused by only factor of the solar wind impact on the magnetosphere, namely, by action of the electric field E_{KL}, the E_{KL} field being determined by formula (Kan & Lee, 1979):

$$E_{KL} = V_{SW}(B_Z^2+B_Y^2)^{1/2}\sin^2(\Theta/2),$$

where V_{SW} is the solar wind velocity, B_Z and B_Y are components of interplanetary magnetic field (IMF) and θ is the angle between the IMF transverse component $B_T = (B_Z^2+B_Y^2)^{1/2}$ and geomagnetic dipole. In order this goal was attained, the E_{KL} effect should be separated from the other factors affecting the polar magnetic activity, such as regular daily and seasonal UV effect, and SS effect, as well as irregular UV irradiation effect, related to solar flares. Furthermore, the separation should be made on-line, without any attendant (satellite) information on solar activity, solar wind parameters and IMF.

In the *TJS*2006 method this problem has been resolved taking into account the crucial distinction between the duration typical of the solar wind effects (from minutes to tens hours) and the duration of the solar UV and SS effects (some days). Consideration of the regular SS and irregular UV effects as the long-term factors in comparison with the short-term solar wind effects made it possible to incorporate the UV and SS effects in level of reference for counting off the E_{KL} effects. The SS effect, as a strongly definite modulation, is subtracted in the first stage. Then a special "running QDC calculation" procedure automatically determines QDC, as a level of reference for each particular day, the results are extrapolated for next day, and so on. Counting the magnetic disturbance value δF from the "running QDC" level makes possible to calculate online the *PC* index value and estimate the solar wind E_{KL} field influence on the magnetosphere. The "running QDC" calculation *TJS*2006 procedure is one of the main peculiarities of the modified code (Nielsen & Willer, 2019) applied at present in AARI and in DTU-Space for on-line production of the unified *PCS* and *PCN* indices.

The *St*2011 method is also used the QDC as a level of reference for counting off the E_{KL} effects. To derive the proper QDC, Stauning (2011) put forward the Solar Rotation Weighted (SRW) QDC method, which takes into account "the steady or recurrent variations in the magnetic field components during quiet conditions with time-of-day, day-of-year, and solar activity level". It was found that the solar influence on the geomagnetic activity is repeated regularly due to solar rotation with periodicity of ~ 27 days, resulting in steady or recurrent variations with period about 27 days in the IMF sector structure (most important parameter), in the solar wind velocity and in the 10.7cm radio flux (F.10.7). According to Stauning (2020), the weights factors depending on the separation in time between the QDC date and the dates of the quiet samples involved in the QDC construction are taken into account. These weight factors enhance the importance of nearby samples and also promote samples separated by one solar rotation having the same face on the Sun turned toward the Earth while avoiding samples measured with the opposite face of the Sun turned toward the Earth. In so doing the derived QDC set for any selected day can be based on data from a fixed number of quiet days extending from -40 to +40 days with respect to the day in question ("post-event" QDC pattern), as well as on data through -40 to 0 days ("real-time" QDC). It is evident from description given in Stauning (2020) that SRW method emphasizes the regular 27-days periodicity ("sector structure") and removes the irregular effects ("two-sectors structure") being about 180° out of phase with 27-periodicity. As a result, the real-time and post-event QDC patterns occurred to be very similar.

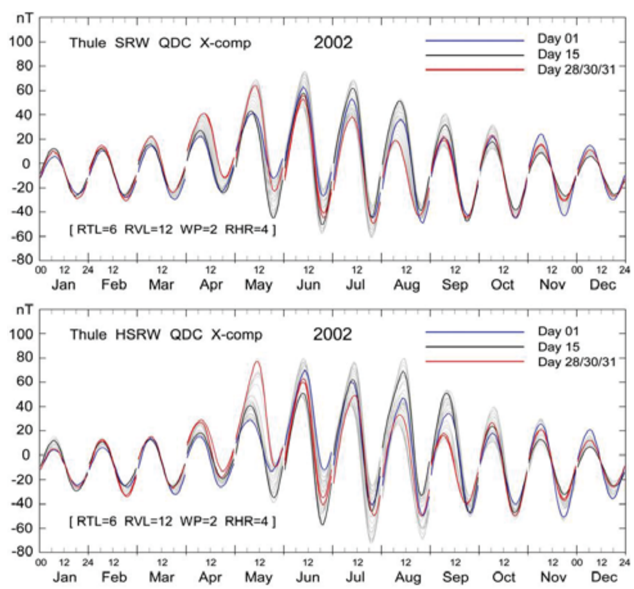

Figure 1. QDC patterns derived by SRW method for of post-event (upper panel) and real-time (lower panel) options. There is a scale for the UT hour (00–24) in each of the 12 monthly sections (Stauning, 2011).

Figure 1 shows, as an example, the SRW weighted post-event and real-time QDCs patterns based on data of X geomagnetic component at station Thule for 2002, the year of the solar maximum (Stauning, 2011). QDCs for start, middle, and end days of the each month are plotted, correspondingly, in blue, black and red colors, the QDCs for the other days are plotted in thin grey line, the average difference between the real-time and post-event QDC patterns being very insignificant (0.39 ± 4.78 nT). The analogous QDC patterns were also obtained for the geomagnetic Y component at Thule. The distinctive feature of QDC patterns presented in Figure 1 is their regular character: QDC amplitude steadily increases from 1st day to last day during first four months, reaches the maximum in middle of month in June, July, August, and steadily decreases to the end of year. Basing on these results the conclusion was made (Stauning, 2011), that the SRW procedure is well suited to deliver immediate QDC values for on-line applications. However, these QDC patterns make allowance only for regular day-of-year variations, whereas the actual QDC, responding also to irregular solar activity, can be different from the SRW QDCs in particular days.

Let us examine, as an example, the QDC patterns derived by two competitive methods, *TJS*2006 and *St*2011, for Thule station in active period of May - September 2001. Just this period, initially tested in (Janzhura and Troshichev, 2011), was repeatedly examined in critical notes of Stauning (2013a,b, 2015, 2018a, 2020). **Figure 2** shows the actual changes (thin line) of 1-min values of the geomagnetic H-component at Thule station over the period from 145th to 245th days (May 25 – September 2, 2001) and the corresponding QDC alterations for H component (black solid line) derived by *TJS*2006 method. One can see that QDC-H pattern demonstrates two well-defined waves with duration of ~27 days and maximums in 175th and 201st days (June 24 and July 20) and more slight wave with two maximums in 221st and 229th days (August 9 and 17). Analogous result was obtained while deriving QDC for D component (not shown in Figure 3a). **Figure 3**, taken from (*Stauning,* 2015), shows the same run of 1-min values of the geomagnetic H-component at Thule station (blue line) and the appropriate QDCs (red line) derived by *St*2011 procedure. The QDC-H *St*2011 pattern demonstrates three flat waves with light maximums in 167th, 194th and 221st days aligned, according to (Stauning, 2011), with days of maximal SS effect.

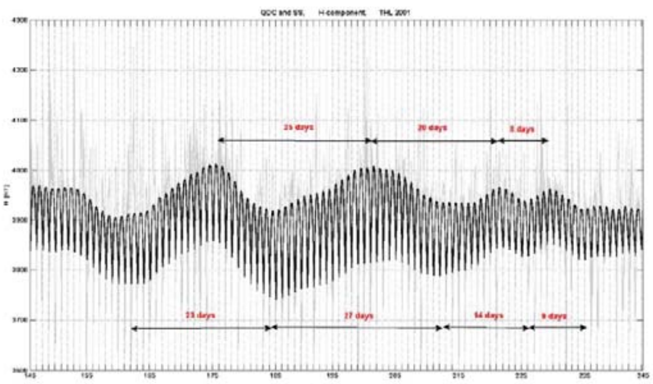

Figure 2. Actual run of 1-min *H* component at Thule station and the appropriate QDC (black line) derived by the *TJS*2006 method for the period from May 25 to September 2. 2001.

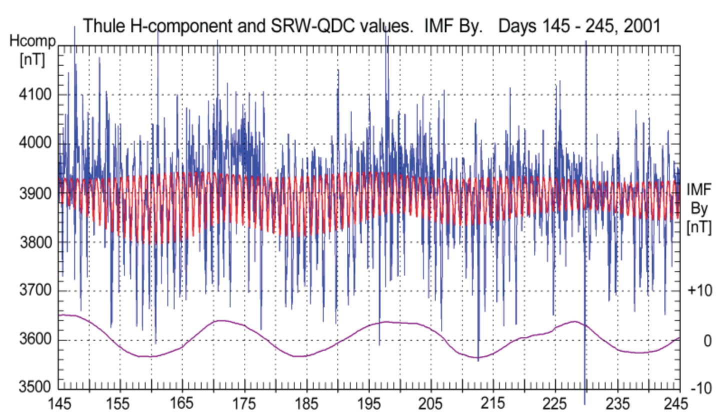

Figure 3. Actual run of 1-min *H* component at Thule station and the appropriate QDC (red line) derived by the *St*2011 method for the period from May 25 to September 2. 2001.

What conclusions can be made from comparison of QDC patterns presented in Figures 2 and 3 ? According to Dr. Stauning, the QDC pattern presented in Figure 3 is more accurate for the reason that the *St*2011 method provides the authentic presentation of the real SS effects. But the matter is that QDC in the *St*2011 method demonstrates only the regular QDC variations derived by the SRW method. By contrast, the QDC in the *TJS*2006 method takes into account both regular SS and UV irradiance effects together with the irregular UV effect. Therefore, we can suggest that difference between QDCs in Figures 2 and 3 is conditioned by irregular effect of the UV irradiation rises, produced by the corresponding solar flares.

To verify this suggestion we examined the behavior of solar UV irradiation with wavelengths in range 121.5 - 201.5 nm during the same period. It should be reminded that ionospheric conductivity and, correspondingly, the magnitude of geomagnetic variations, are responsive to the solar UV irradiation with wavelengths 100-200 nm. **Figure 4** shows, based on data (https://lasp.colorado.edu/lisird/data), the run of relative values of the UV irradiation in range 121.5 - 201.5 nm (think color lines) and their average (black solid line) in period from May 25 to September 2, 2001. One can see that the UV irradiation 121.5 - 201.5 nm demonstrates maximums just in the days 170^{th}-176^{th}, 196^{th}-202^{nd} and 222^{nd}-232^{nd} (the latter was double-peaked). It implies that both effects, the IMF sector structure (SS) and the solar flares UV irradiation, were the main drivers of the ~ 27 days QDC alterations at Thule station in the summer period of 2001, but the double-peaked maximum in 222^{nd}-232^{nd} days was conditioned exclusively by irregular UV irradiation related to solar flares. In support of this conclusion we can point to results (Troshichev et al., 2020) which have demonstrated that the yearly values of QDC magnitude (derived by *TJS*2006 method) were altered in course of 23/24 solar activity cycles (1998-2019) in high correspondence with the changes of solar UV 100-200 nm irradiation, the correlation between the QDC magnitude and the UV 160 nm irradiation being so high as R=0.943. This perfect conformity between the QDC magnitude and solar UV irradiation is evidence for validity of the "'running QDC derivation" procedure applied in the *TJS*2006 method.

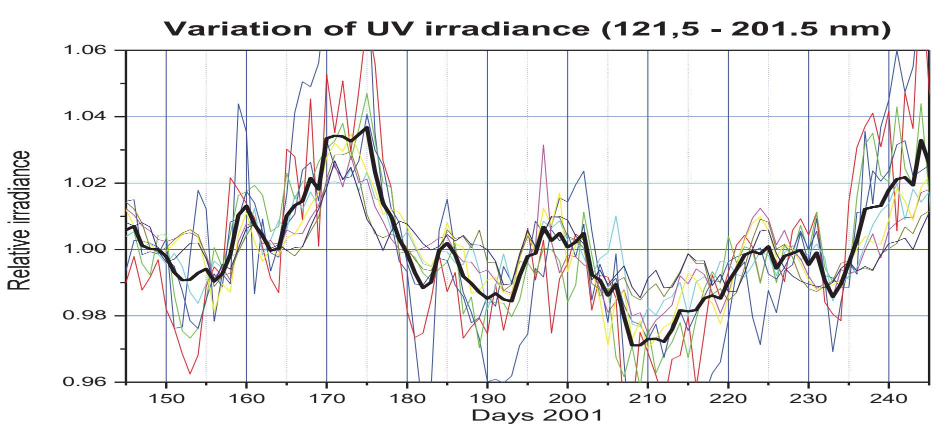

Figure 4. Variation of the solar UV irradiation 121.5-201.5 nm for the period from May 25 (145^{th} day) to September 2. 2001 (245^{th} day).

What does it mean as applied to the *St*2011 method? Since quiet level in Figure 3 does not make allowance for the irregular changes of the UV irradiation related to solar flares, these irregular UV effects are included automatically in the *PC* index value, which is counted off from the SRW QDC level. Basing on these results and following Dr. Stauning it is possible to announce that the (PC) indices, determined by the SRW method, are the invalid index series. The problem is that the

PC index series produced by Dr. Stauning is absent, there is only declaration. In addition, it is conceivable that the SRW method gives incorrect results only in epoch of solar maximum, whereas in years of solar minimum both methods, *TJS*2006 and *St*2011 will provide the similar QDCs.

4. "Prompt" and "post-event" *PC* indices.

In paper (Stauning, 2020) it was suggested to justify advantage of *PC* indices derived by different methods by comparison of the "prompt" and "post-event" *PC* indices. According to Stauning, "the name "prompt" is given to the series of near real-time indices ending at the most recent PC index value derived from occasional downloads from http://pcindex.org, whereas the designation "post-event" is given to values from the same stretch of time but downloaded from http://pcindex.org at a later time. The large differences between elements referring to the same UT time and date of the two sets of PC index value from http://pcindex.org indicate that at least one of two sets holds invalid indices". This viewpoint can be regarded as a correct, but with some proviso. The data presented at website http://pcindex.org are separated at two sets: "quick-look" data and "preliminary" data. The "quick-look" *PC* indices are calculated on-line from current magnetic data incoming from the Vostok station with use of QDC derived from data for preceding 30 days by method described in Troshichev et al., (2021). The "preliminary" *PC* indices are calculated for this (last) day with use of the same geomagnetic data, the QDC being recalculated with inclusion of information for the last day. The "preliminary" *PC* index can be designated as post-event index, but in a quite another sense than in (Stauning, 2001): "preliminary index" means the index calculated next day after the day of interest (last day), not after 40 days, as in case of "post-event index". We can only ascertain again that the *TJS*2006 method is assigned to separate QDC which makes allowance for irregular UV irradiation effects in each particular day, whereas *St*2011 method is assigned to determine the regular SWR QDC structure, varying with the solar rotation.

5. Validity of the unified PC index.

Formal criteria for the IAGA endorsement of geomagnetic indices were formulated as long as 40 years ago (Mayaud, 1980). According to these criteria, any geomagnetic index should correspond, as much as possible, to a single and well defined phenomenon and should be derived in such a manner that the data used will be consistent with this phenomenon. With this aim the following questions should be solved:

- phenomenon is worth to be monitored,
- phenomenon should be identified through characterization of all their constituents as a whole,
- phenomenon under consideration should be discriminated from others in the records.

The IAGA endorsed *PC* index, based on *TJS*2006 method satisfies these criteria, as follows:

- the polar cap magnetic activity *PC* index is worth to be monitored, as a proxy of the solar wind energy input into the magnetosphere and subsequent development of magnetospheric disturbances.
- the *PC* index is identified, through statistically justified characterization, as the magnetic activity generated in polar caps by the solar wind electric field $E_{KL} = V_{SW} B_T^2 \sin^2(\Theta/2)$, where V_{SW} is the solar wind velocity, B_Z and B_Y are components of interplanetary magnetic field (IMF) and θ is the angle between the IMF transverse component $B_T = (B_Z^2+B_Y^2)^{1/2}$ and geomagnetic dipole..
- the polar cap magnetic activity, generated by the E_{KL} field impact on the magnetosphere, can be discriminated from the magnetic activity manifestations related to other solar sources, such as regular and irregular solar UV irradiation and the IMF sector structure.

The *PC* index gains the increasingly more interest of scientific community, as the ground-based index, which can be used online to monitor geoefficiency of the solar wind impact on the magnetosphere. The close association between the *PC* index behaviour and development of magnetospheric substorms (AL index) and magnetic storms (Dst/SymH indices) has been displayed in numerous studies (Janzhura et al., 2007; Troshichev & Janzhura, 2009; Troshichev et al., 2011a,b, 2012, 2014; Troshichev & Sormakov, 2015, 2018). **Figure 5** demonstrates, as an example, the relationship between the *PC* and *AL* indices in course of substorms. In this connection it should be especially notified that the *PC, AL* and *Dst*/*SymH* indices are derived from absolutely independent series of magnetic data and characterize magnetic activity in quite different regions of the magnetosphere. The high correlation between the *PC* index growth and development of the magnetospheric disturbances (R>0.94) and the typical delay time in response of the substorm sudden onset to the *PC* leap (ΔT=0-10 minutes), and delay of the storm maximal intensity time relative to the *PC* index maximum time (ΔT=30-120 minutes) testify that the PC index serves as a proxy of the solar wind energy input into the magnetosphere, whereas AL and Dst/SymH indices are indicators of the solar wind energy, which was realized in the magnetosphere in form of magnetospheric substorms and magnetic storms.

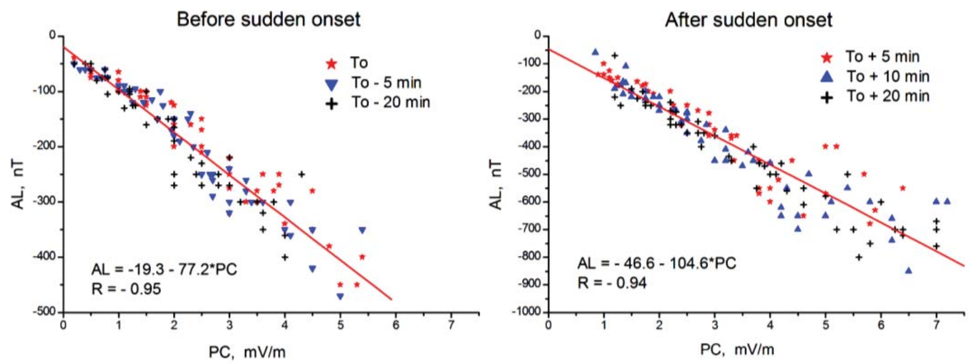

Figure 5. Relationship between the *PC* and *AL* indices in course of substorms in moments of the substorm sudden onset and before (T_0, T_0-5 min, T_0-20 min) and after the sudden onset (T_0+5, T_0+10 min, T_0+20 min) (Troshichev et al., 2014). .

6. Summary

1. The IAGA endorsed *PC* index is designated to monitor the solar wind energy input into the magnetosphere and, correspondingly, the solar wind influence on magnetosphere. It means that the quality of the derived on-line *PC* index can be asserted only through correlation of the *PC* index with magnetic substorms (*AL* index) and magnetic storms (*Dst/SymH* indices), which are considered as indicators of the magnetoshere state. Validity of the *PC* index derived by TJS2006 method has been evidenced by results of numerous analyses demonstrating the evident link of the *PC* index rises with development of the magnetospheric disturbances.
2. The quality *PC* index derived by TJS2006 method is ensured by proper determination of the quiet daily curve with use of the “running QDC derivation” procedure, which takes into account the effect of the regular and irregular solar UV irradiation as well as the regular effect of the IMF sector structure (SS). Such choice of QDC provides the correct evaluation of the polar cap magnetic activity generated by geoeffective solar wind impact on the magnetosphere in each particular day.
3. The value of *PC* index proposed by Stauning (2011, 2020) is also counted off from the QDC, which is derived by the Solar Rotation Weighted (SRW) method. The SRW procedure takes into account the steady or recurrent UV and SS effects repeated regularly due to solar rotation with periodicity of ~ 27 days and neglects the effects “being about 180° out of phase with 27-periodicity”. In this case the UV effect of irregular solar flares, typical of epochs of solar maximum,

is automatically eliminated from QDC level and, therefore, is attributed to the *PC* index value, i.e. it is assigned to influence of the solar wind impact on the magnetosphere.

4. Since QDC derivation procedures, applied in *TJS*2006 and *St*2011 methods, are designed on different principles, the *PC* indices, produced by these method, are condemned to be different in active periods, but seems to be similar in the quiet period.

5. Validity of the ground-based *PC* index is easily ascertained by inspection of correlation between the PC index and the magnetic activity in the auroral zone. However, Dr. Stauning never tried to get the statistically justified correlation between the *PC* (*St*2011) index and the appropriate magnetic disturbances.

6. The Dr. Stauning's declarations on invalid *PC* (*TJS*2006) index series should be regarded as devoid of any background till is not proved that the *PC* (*St*2011) index correlates with the magnetospheric disturbances better than the *PC* (*TJS*2006) index.

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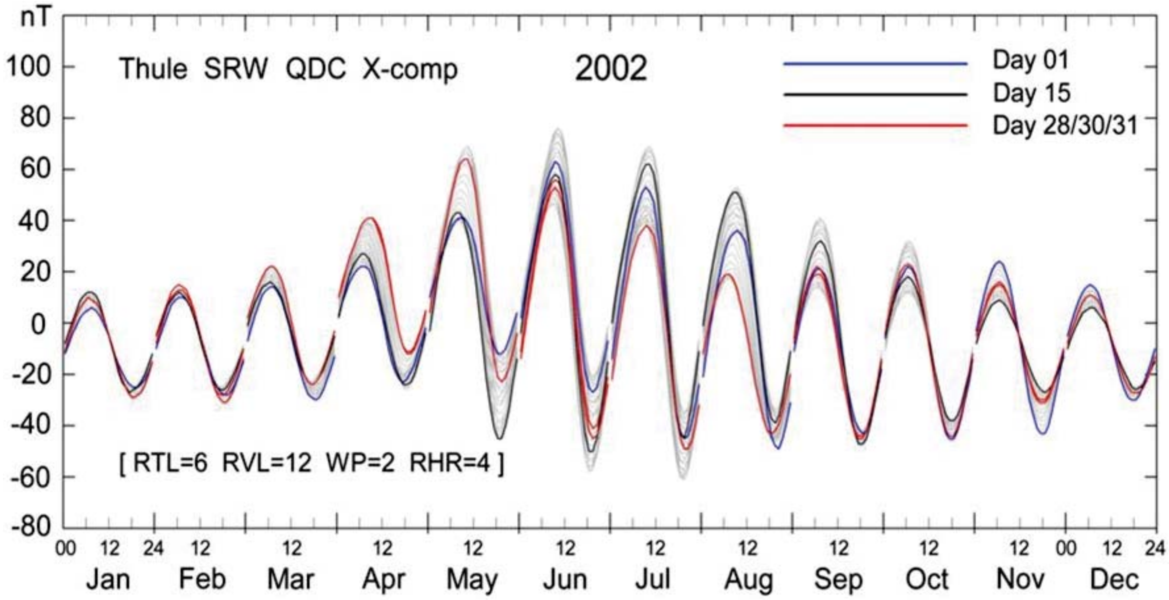
Figure 1.


nT
Thule SRW QDC X-comp
2002
Day 01
Day 15
Day 28/30/31
[RTL=6 RVL=12 WP=2 RHR=4]
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

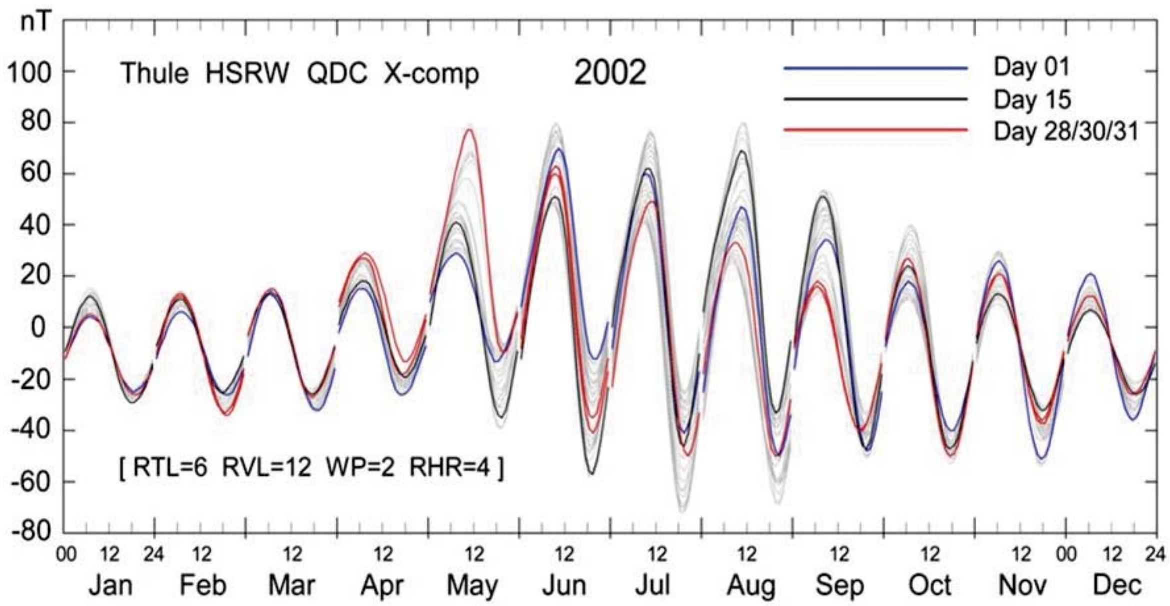

nT
Thule HSRW QDC X-comp
2002
Day 01
Day 15
Day 28/30/31
[RTL=6 RVL=12 WP=2 RHR=4]
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

Figure 2.

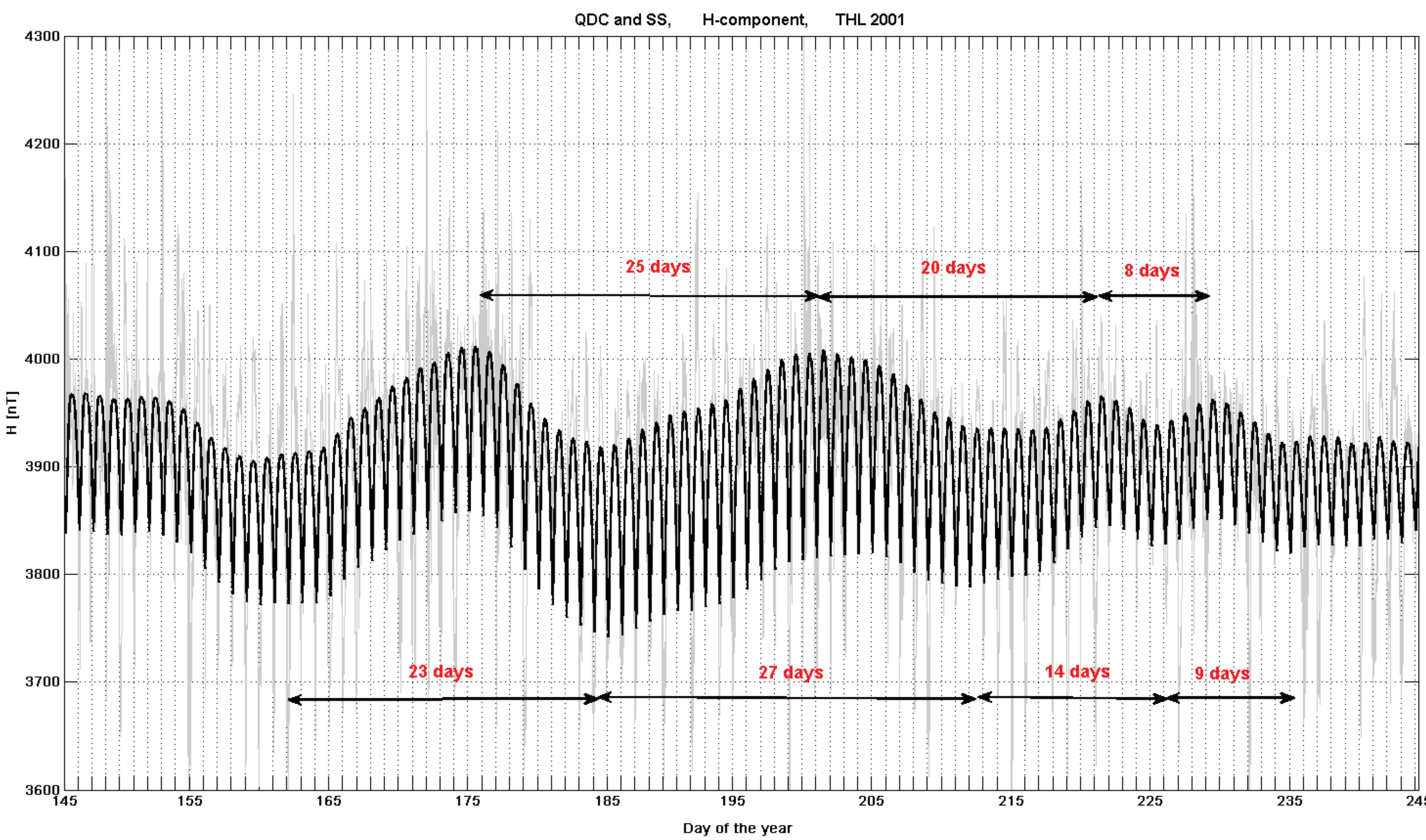
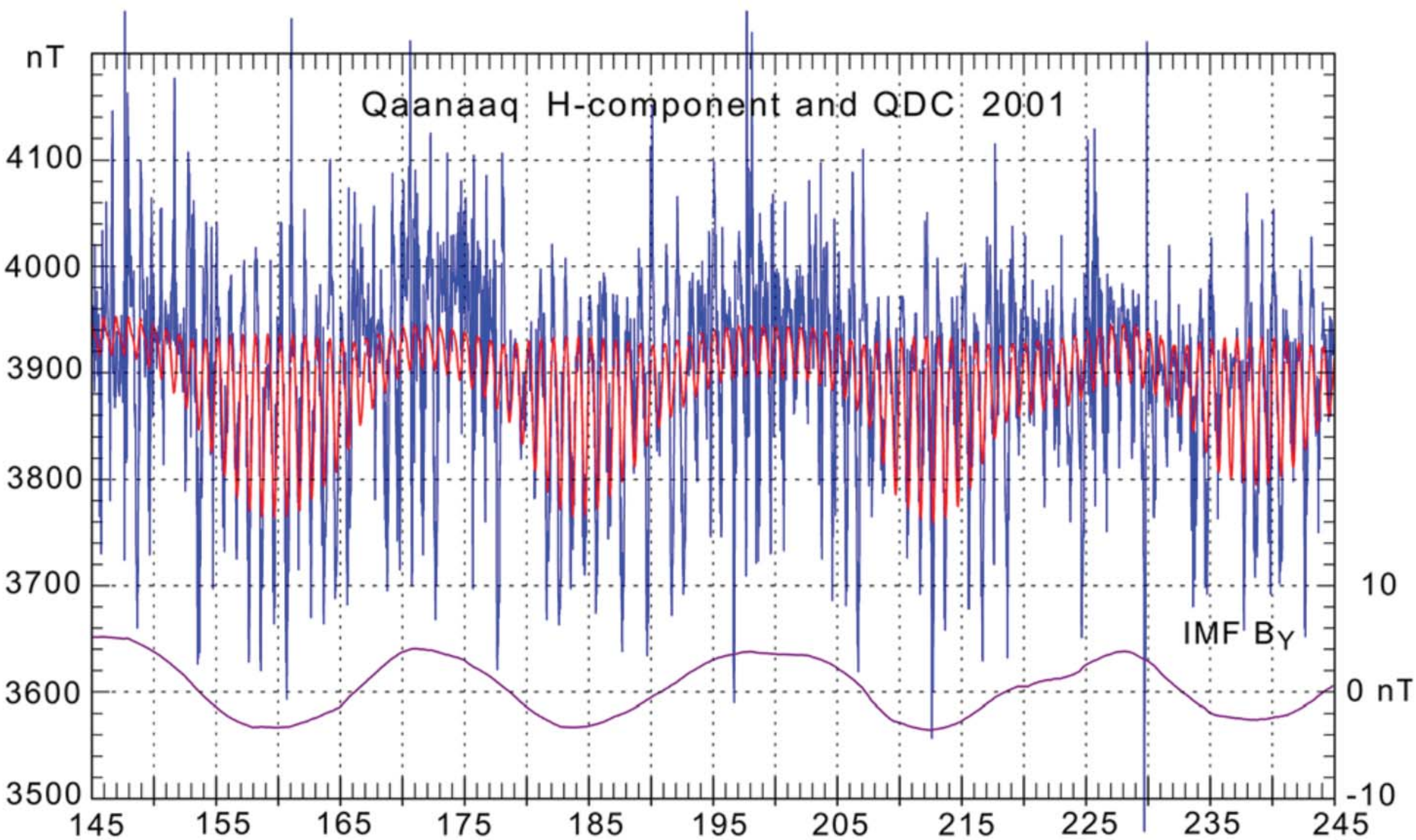

QDC and SS,   H-component,   THL 2001
H [nT]
Day of the year
4300
4200
4100
4000
3900
3800
3700
3600
145
155
165
175
185
195
205
215
225
235
245
25 days
20 days
8 days
23 days
27 days
14 days
9 days

Figure 3.



nT
Qaanaaq H-component and QDC 2001
4100
4000
3900
3800
3700
3600
3500
10
IMF B_Y
0 nT
-10
145
155
165
175
185
195
205
215
225
235
245

Figure 4.

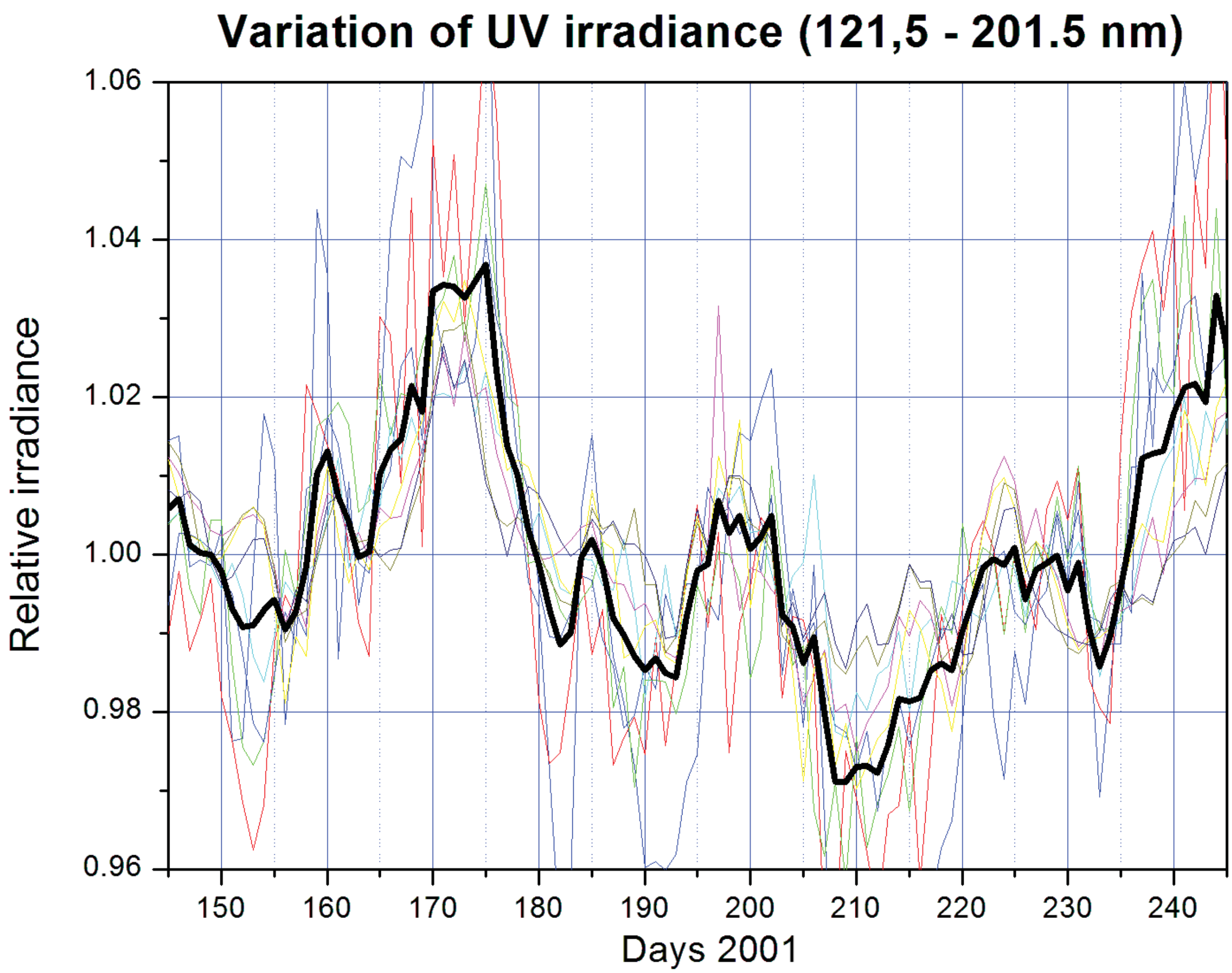
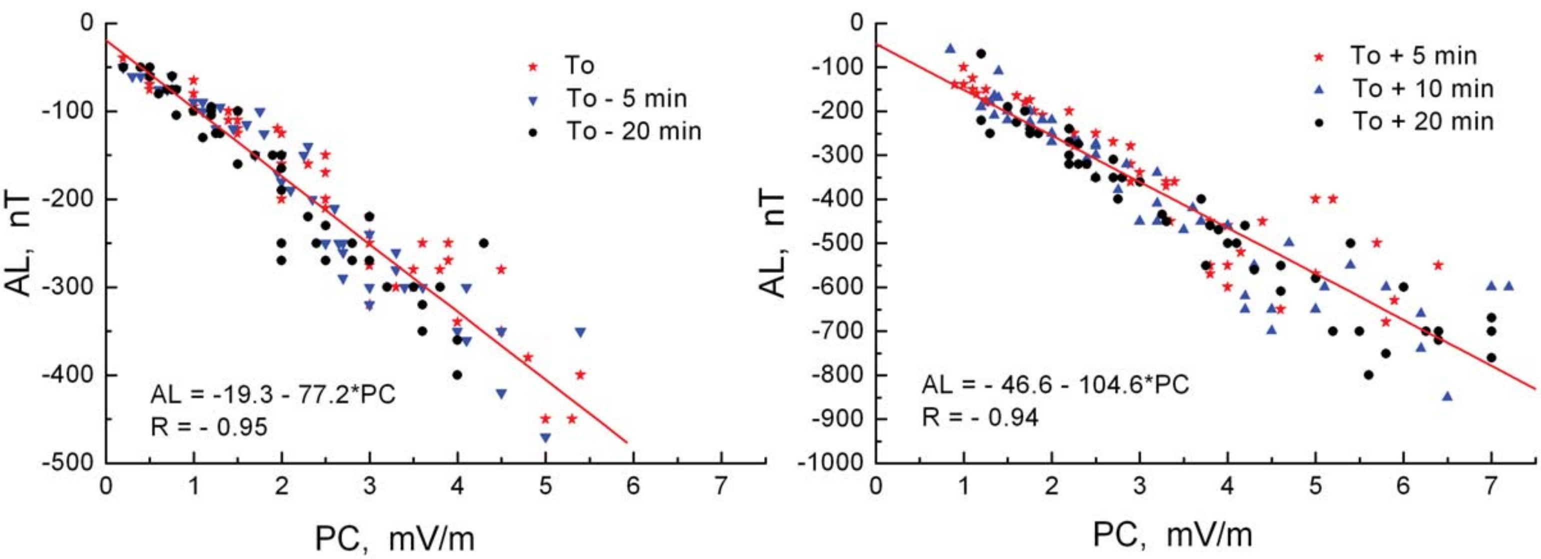

Variation of UV irradiance (121,5 - 201.5 nm)
Relative irradiance
1.06
1.04
1.02
1.00
0.98
0.96
150
160
170
180
190
200
210
220
230
240
Days 2001

Figure 5.



AL, nT
PC, mV/m
To
To - 5 min
To - 20 min
AL = -19.3 - 77.2*PC
R = - 0.95
To + 5 min
To + 10 min
To + 20 min
AL = - 46.6 - 104.6*PC
R = - 0.94