Polar Cap (PC) Index

1. Concept of the PC index

1.1 Physical background

A great number of the ground and space experiments fulfilled in about decade from 1970 to 1980 showed that the ground magnetic disturbances, such as magnetic storms and magnetospheric substorms, are related to variations of the solar wind parameters, such as the interplanetary magnetic field (IMF) southward B_{ZS} component and the solar wind velocity v. Influence of the solar wind on magnetosphere is realized mainly through the interplanetary electric field $E_Y=[v\mathbf{B}_{ZS}]$, and the solar wind dynamic pressure $P_{SW}=n(V_{SW})^2$, where n is the solar wind density. Besides the magnetic storms and magnetospheric substorms there are a family of the polar magnetic disturbances which are produced by specific systems of the field aligned currents generated in the magnetosphere under influence of the IMF southward, azimuthal and northward components.

To diagnose the solar wind influence on the magnetosphere the DP 2 magnetic variations present the main interest. DP2 variations were separated by Obayashi [1967], as a special class of magnetic disturbances, which unlike magnetic substorms (DP1) do not show any peculiarities in the auroral zone. DP2 variations were extensively studied by Nishida, who revealed their close relation to southward IMF [Nishida, 1968a,b; Nishida and Maezawa, 1971]. According to [Nishida, 1968a] DP2 currents system is a global system, expanding from pole to equator, with focuses located at latitudes Φ=72-74°. The further studies showed [Troshichev, 1975] that two-vortices DP2 current system is terminated by latitudes Φ=50-60°, the disturbances at lower latitudes Φ<50 being produced by the equivalent zonal currents of the extra-ionospheric origin. The current vortices focuses in system [Troshichev, 1975] turned out to be located at the morning and evening poleward boundaries of the auroral oval (Φ=76-78°), where the magnetospheric field-aligned currents (FAC), flowing in and flowing out of the polar ionosphere, are located [Zmuda and Armstrong, 1974; Iijima and Potemra; 1976a]. Measurements on board spacecraft Triad demonstrated the strong dependence of the field-aligned currents in Region 1 on the IMF tangential component B_T [Iijima and Potemra, 1982] and interplanetary electric field E [Bythrow and Potemra, 1983]. Relationships between the field-aligned currents and magnetic disturbances in the polar car are thoroughly examined in [Gizler et al., 1979; Troshichev et al., 1979b; Troshichev, 1982]

The actual magnetic disturbances on ground level are generated by Pedersen ionospheric currents flowing along the ionospheric electric field, by Hall ionospheric currents flowing across the electric field and by magnetospheric currents flowing along the magnetic field lines. The field-aligned DP2 currents flowing into the polar ionosphere on the morning boundary of the polar cap and flowing out of the ionosphere on the evening boundary are closed by ionospheric Pedersen currents depending on the ionospheric conductance, which is determined by the solar UV irradiation. During the summer season they close across the sunlit polar cap ionosphere with so high Hall and Pedersen conductivity as Σ_H~20 Ohm^{-1} and Σ_P>16 Ohm^{-1}. Since the magnetic effect of Pedersen currents on the ground level is roughly equal by value but opposite by sign to magnetic effect of the field-aligned currents [Fukushima, 1969], the magnetic activity, observed in the summer polar cap, constitutes mainly the magnetic effect of the ionospheric Hall currents.

In the winter dark polar cap the ionospheric conductance falls up to values of Σ_H~2 Ohm^{-1} and Σ_P~1.2 Ohm^{-1} [Vanjan and Osipova, 1975], i.e. to one-tenth of that in the summer polar cap. However, the magnetic activity in the winter season is only 2-3 times less than that in the summer season [Troshichev et al., 1979c], being in a full agreement with lowered by a factor 2-3 intensity of Region 1 currents in the winter hemisphere [Fujii et al., 1981]. It means that (1) magnetic activity in the winter polar cap is mainly related to distant effect of the field-aligned currents, and (2) these field-aligned currents close not through the low-conductive polar cap ionosphere, but through the better conductive night-time auroral oval (Σ_H~10 Ohm^{-1} and Σ_P~7 Ohm^{-1}), where the conductance is supported above the solar UV-induced level even under the quiet conditions owing to marginal precipitation of the auroral particles [Wallis and Budzinski, 1981; Kamide and Baumjohann, 1993].

Thus, the summer DP2 currents are identical with the actual Hall currents, flowing across the applied electric field. On the contrary, DP2 system in the winter polar cap describes mainly the distant effect of the FAC Region 1. As a result, the equivalent winter DP2 currents are deflected counter clockwise through angles 20-60° relative to the summer DP2 currents [Maezawa, 1976; Troshichev et al., 1979c]. **Figure 1** shows distribution of the magnetic disturbance vectors along with the corresponding equivalent current DP2 system, observed in the summer (a) and winter (b) polar caps under influence of the IMF southward component B_{ZS}=-1nT [Troshichev and Tsyganenko, 1978; Troshichev et al., 1979b].

1.2 Forming the concept

Initial attempt to examine the polar cap magnetic activity as a signature of substorm development was made by Troshichev et al. [1979a] and afterwards by Troshichev and Andrezen [1985]. Taking into account the statistically justified distribution of magnetic disturbances produced by DP2 current system in the near-pole region (see Figure 1), Troshichev and Andrezen [1985] determined the magnetic disturbance vector projection along the meridian 03.00-15.00 MLT as a measure of the polar cap activity caused by the southward (or northward) IMF component. The value of the 15-min averaged magnetic disturbance projection (δF) was calculated on the basis of magnetograms of the Vostok station (Antarctica) in reference to the quiet daily curve, obtained as average curve for 5 most quiet days of the month. This characteristic was named as a MAGPC [Troshichev and Andrezen, 1985]. The analysis of statistical relationships between the 15-min MAGPC values and various interplanetary quantities was carried for 1978-1980. The appropriate 15-min values of the solar wind parameters were calculated on the basis of 5-min data supplied by IMF-J satellite. The hourly-averaged values were obtained for every UT hour by taking all four 15-min quantities. The correlation between the MAGPC values and the solar wind parameters was examined without allowance for the delay time between them.

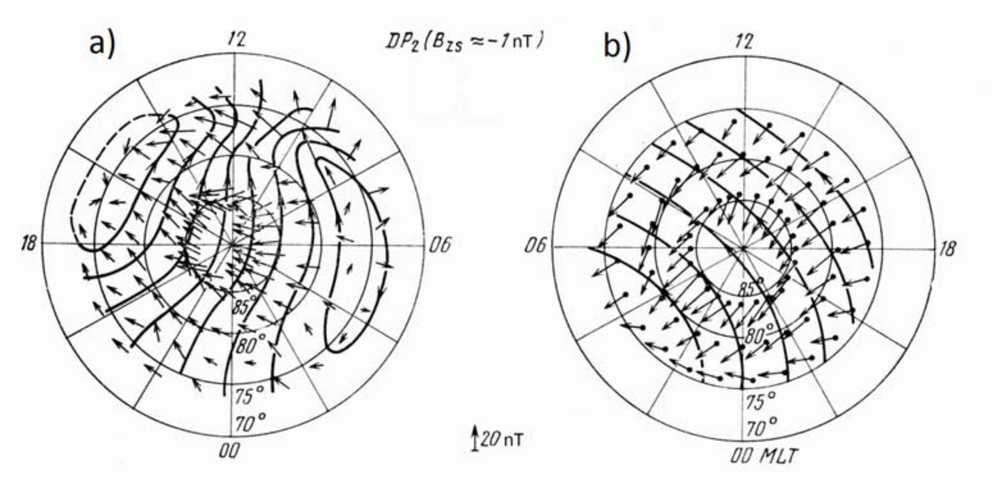

Figure 1. Distribution of the magnetic disturbance vectors δF (arrows), observed in the summer (a) and winter (b) polar caps under influence of the IMF southward component BZS= -1nT, and the corresponding systems of the equivalent DP2 currents describing the magnetic disturbance distributions [*Troshichev and Tsyganenko, 1978*; *Troshichev et al., 1979b*].

The following interplanetary quantities were examined in the analysis: IMF southward component B_{ZS}, IMF northward component B_{ZN}, azimuthal component B_Y, modulus $|B_Y|$, solar wind velocity v, interplanetary electric field $E=vB_Z$, electric field $E=v|B_Y|$, tangential component of the electric field $E_T = vB_T = v\{(B_Y)^2+(B_Z)^2\}^{1/2}$, parameter $\varepsilon = v(B_T)^2 \sin^2\theta/2$ [Akasofu, 1979], where θ is an angle between the IMF B_T component and geomagnetic Z-axis, interplanetary electric field $E_{KL}=vB_T\sin^2\theta/2$ [Kan and Lee, 1979], potential drop across the polar cap $\Delta V=Edl,$ where l is the length of stagnation line [Pudovkin et al., 1982], function $n^{1/2}vB_T(\sin\theta/2)^{1/2}$, representing the momentum flux of solar wind transported into the reconnection region [Vasyliunas, 1975]. The MAGPC has shown the best correspondence with the interplanetary electric field E_{KL}, which is examined as a coupling function:

$$E_{KL}=v\{(B_Z)^2+(B_Y)^2\}^{1/2}\sin^2\theta/2 \qquad (1)$$

MAGPC was regarded by Troshichev and Andrezen [1985] as a characteristic of convection field over the polar cap: the positive value of MAGPC indicated the antisunward convection, while the negative MAGPC pointed to the sunward convection. The analysis was fulfilled only for summer season at southern station Vostok. It was concluded [Troshichev and Andrezen, 1985] that the use of data from both, northern and southern, polar regions (Thule and Vostok) would ensure the steady monitoring of the polar cap electric field for the whole year. The idea was appreciated in Danish Meteorological Institute (DMI), and 1985 becomes a beginning of the fruitful collaboration between AARI (St.Petersburg) and DMI (Copenhagen) resulted in procedure of the *PC* index derivation.

The *PC* index has been designed to monitor the polar cap magnetic activity generated by the geoeffective solar wind parameters. The main principles of the *PC* index derivation were formulated by Troshichev et al. [1988] and they remain unchanged up to now. The principles are the following:

- PC index in any UT time should be determined by the polar cap magnetic disturbance value related to influence of the geoeffective solar wind, and therefore
- the magnetic disturbance vector δF should be counted from level of the quiet geomagnetic field to eliminate variations unrelated to the solar wind fluctuations (in the first turn, variations caused by changes in the solar UV irradiation);
- *PC* index should correspond to the value of the interplanetary electric field E_{KL} impacting the magnetosphere, irrespective of UT time, season and point of observation

Let us examine in more detail the procedure used to satisfy these principles.

2. Method of the *PC* index derivation

2.1 Determining the magnetic disturbance value δF

The value of δF can be considered as a measure of the cross-polar cap ionospheric electric field providing the ionospheric conductivity is invariant. In actuality, there are regular season and daily variations of the ionosphere conductivity, produced by the solar UV-irradiation. The seasonal variations are caused by the Earth movement around the Sun, the Earth's rotation axis being inclined to the Solar ecliptic. The daily variations are related to the Earth's daily rotation under the differently conducting ionosphere fixed relative to the Sun. As a result, each observatory elapses under the inhomogeneous ionosphere fixed relative to Sun, and the varying ionospheric conductivity related to the solar UV irradiation, affects the regular daily and seasonal variation of geomagnetic field. However, the quiet daily variation has no relation to changes of the solar wind parameters and, therefore, it should be taken away. It may be easily done by counting the δF from the level of the quiet variation. It is just procedure which makes it possible to evaluate the magnetic effect produced in the polar cap by the varying solar wind.

In both institutes the value of the magnetic disturbance vector δF was calculated from level of geomagnetic field for quiet days, however choosing this level in AARI and DMI was not identical. In AARI the value δF was counted from level of the daily quiet curve, obtained from 5 quiet days for examined month of the examined year. In DMI the appropriate "quiet level" was traditionally deduced from interpolation between the magnetic field's absolute values determined at nighttime hours of quiet winter days in the two consecutive years, the seasonal and daily variations being taken into account by series of coefficients. Comparison of sets of the corresponding 15-min *PC* indices was carried out basing on data from Thule and Vostok for 1978-1979. Since the results demonstrated the consistency of the 15-min *PCN* and *PCS* indices, it was decided that the procedures for quiet level deduction applied in DMI and AARI can be kept.

2.2 Determining the correlation between δF and coupling function E_{KL}

The magnetic disturbances vector δF is determined basing on data of the magnetic observations at the certain near-pole station (Thule or Vostok)

$$\delta F = \delta H \cdot \sin\gamma \pm \delta D \cdot \cos\gamma \qquad (2)$$

where δD and δH are deviations of the magnetic horizontal components from the quiet level. Angle γ is assigned to estimate the E_{KL} influence effect in deviations δH and δD from the quiet level. Angle γ is determined by expression

$$\gamma = \lambda \pm D_E + \varphi + UT; \qquad (3)$$

where D_E is the mean declination angle for the given station; λ is geographycal longitude; φ is angle between the transpolar current and the noon-midnight meridian; signs (+) and (-) are valid, correspondingly, for southern and northern hemispheres. Sense of expression (2) and (3) is very simple: they are assigned to arrange vector of magnetic disturbance into alignment with the current system, caused by E_{KL}, while daily rotating the station under this current system. The optimal direction is defined for any moment UT by angle φ, which is determined as an angle ensuring the best correlation between the values δF and E_{KL}

$$\delta F = \alpha E_{KL} + \beta \qquad (4)$$

Thus, the regression coefficient α (slope) and β (intersection) describing the linear link between the values δF and E_{KL} are calculated in combination with optimal angle φ providing the highest correlation between the δF and E_{KL}. Parameters α, β and φ were derived basing on sets of data for some years (1978-1980 in case [Troshichev et al., 1988]). The statistically justified parameters α, β and φ have been derived for each 15-min interval k of each day of year. Just these once derived parameters were used for calculation of the 15-min *PC* index.

2.3 Determining the *PC* index

PC index for certain UT moment k is calculated according to expression:

$$PC_k = \xi\,(\delta F_k - \beta_k)/\alpha_k \qquad (5)$$

where δF_k is value of magnetic disturbance obtained, according to formulas (2) and (3), for the moment k, and coefficients α and β are the statistically justified normalization coefficients describing, according to formulas (4), the link between δF and E_{KL} just for this time. The normalization coefficients α and β are intended to eliminate the diurnal and seasonal changes in response of the magnetic disturbance vector δF to the E_{KL} value in different hemispheres. In other words, two stations, locating in various points of the northern and southern polar caps and gaining, correspondingly, the different normalization coefficients, should demonstrate the analogous *PC* indices, consistent with the E_{KL} value irrespective of UT time, season, and hemisphere. It was suggested that the once derived set of coefficients α and β ensure calculation of the *PC* index for any time basing on the observed magnetic disturbance vector δF. Coefficient ξ is the scale coefficient. If dimensionality of ξ is taken as m/mV/nT, the *PC* index is expressed as dimensionless value, if ξ=1/nT, the *PC* will be expressed in mV/m, as the field E_{KL}.

The *PC* index for the northern polar cap (*PCN*) was calculated in DMI by magnetic data from station Thule (Greenland), the *PC* index for the southern polar cap (*PCS*) was calculated in AARI by magnetic data from station Vostok (Antarctica).

3. Unified procedure for derivation of 1-min PCN and PCS indices

3.1 Necessity in the unified procedure

When concept of the *PC* index was in elaboration, the mechanism of the electric field generation in the polar cap ionosphere was suggested to be associated with convection the merged IMF and geomagnetic field lines across the polar cap. In such a case, the actual time of the merged lines passage from the dayside polar cap to the nightside should cover more than 20 minutes, if the merged field lines move with the solar wind speed. This circumstance has motivated a choice of *PC* index resolution (15-minutes). However, it has become evident soon that the electric fields in the polar ionosphere, being determined by the field-aligned current variations, demonstrate much shorter time changes. The *PC* index with 1-min resolution, like to AE index, turned to be required.

The principles of the *PC* derivation remained unchanged while transiting from the 15-min *PC* index to the 1-min *PC* index, but more complicated methods were required to remove outliers and separate the leading trends in behavior of the solar wind parameters and the polar cap magnetic activity. Transition to 1-min was carried out independently in AARI and DMI and was completed by 1999. The results occurred to be far from perfection: inconsistency between the *PCN* and *PCS* values occurred as a regular phenomenon, especially during the disturbed periods. The reason for the inconsistency were various: first of all, a difference in choice of level of reference for magnetic disturbances taken in AARI and DMI, secondly, an inaccuracy in derivation of coefficients determining the relationship between the interplanetary electric field and the polar cap magnetic activity (AARI), and thirdly, some diversities in procedure for derivation of the 1- min *PC* index. Inconsistency in the *PCN* and *PCS* indices gave rise to discrepancies in results of various analyses, such as: different frequency of the negative *PC* index occurrence in the northern and southern hemispheres; different relation of the *PCN* and *PCS* indices demonstrated the to the electric field; different response of the *PCS* and *PCN* indices responded in manner to the solar wind dynamic pressure pulses. In addition a programming error in the *PCN* index derivation has been fixed [Papitashvili et al., 2001].

It became evident that a unified method for *PCN* and *PCS* derivation is required to eliminate any influence of the calculation technique on results of the analysis and physical conclusions. The agreement concerning elaboration of the unified procedure was attained between AARI and DMI in 2005. Description of the agreed principles of the unified procedure is given in paper [Troshichev et al., 2006].

3.2 Peculiarities of the unified procedure

As it was shown above, the idea behind the PC index derivation is to use the polar cap ground based magnetic data with the once derived normalization coefficients. The normalization coefficients are calculated as the statistically justified regression coefficients connecting the corresponding values δF and E_{KL} in different UT times during a year. In the unified procedure [Troshichev et al., 2006] the vectors E_{KL} are determined by the horizontal magnetic disturbances ($\delta H_k, \delta D_k$) or ($\delta X_k, \delta Y_k$), counted from the corresponding quiet daily curve (QDC). Procedure for near-real time determination of QDC is described in details in [Janzhura and Troshichev, 2008].

The vectors δF_k, rotated by angle φ to arrange them with the DP2 equivalent current system, denoted as $\delta F_{k,\varphi}$. The values E_{KLk} are calculated from measurements of the solar wind parameters in space, shifted to 12 R_E (Earth Radii GSM, subsolar point) using the actual solar wind velocity. Then a time delay ΔT ~ 20 min is required for the E_{KL} signal to be transferred from the bow shock position to the polar cap. The normalization coefficients α and β are derived by the linear relation $\delta F_{k,\varphi} = \alpha E_{KLk} + \beta$, where the $\delta F_{k,\varphi}$ and E_{KLk} values are determined for each *k-th* 5-minute interval of data forming the "learning" data-set (1998-2001 in case of Troshichev et al. (2006)). The linear regression coefficients α and *β* are calculated for all angles *φ* in range ±90° from the suggested dawn-dusk orientation of the DP2 disturbance vectors in the near-pole region. When the correlation coefficient reaches the maximum that angle *φ* is chosen and those coefficients *α* and *β* are used for that UT-time and month. To eliminate the random oscillations, these 5-min values are subjected to the 6-point running "loss smoothing" that is resistant to outliers. Then the 6-point smoothed values are averaged for 1998-2001. As a result, the average yearly courses of the parameters are derived that makes it possible to obtain the averaged 1-min parameters *α, β* and *φ* for each UT time during a year. The values *α, β* and *φ* are calculated once only, afterwards the table of these parameters is used for definition of the *PCN* and *PCS* indices in any time according expression (5). The dimensionality of scale coefficient ξ in the unified procedure is taken as 1/nT, in such a case the *PC* index is expressed in mV/m that makes convenient it's comparison with E_{KL}.

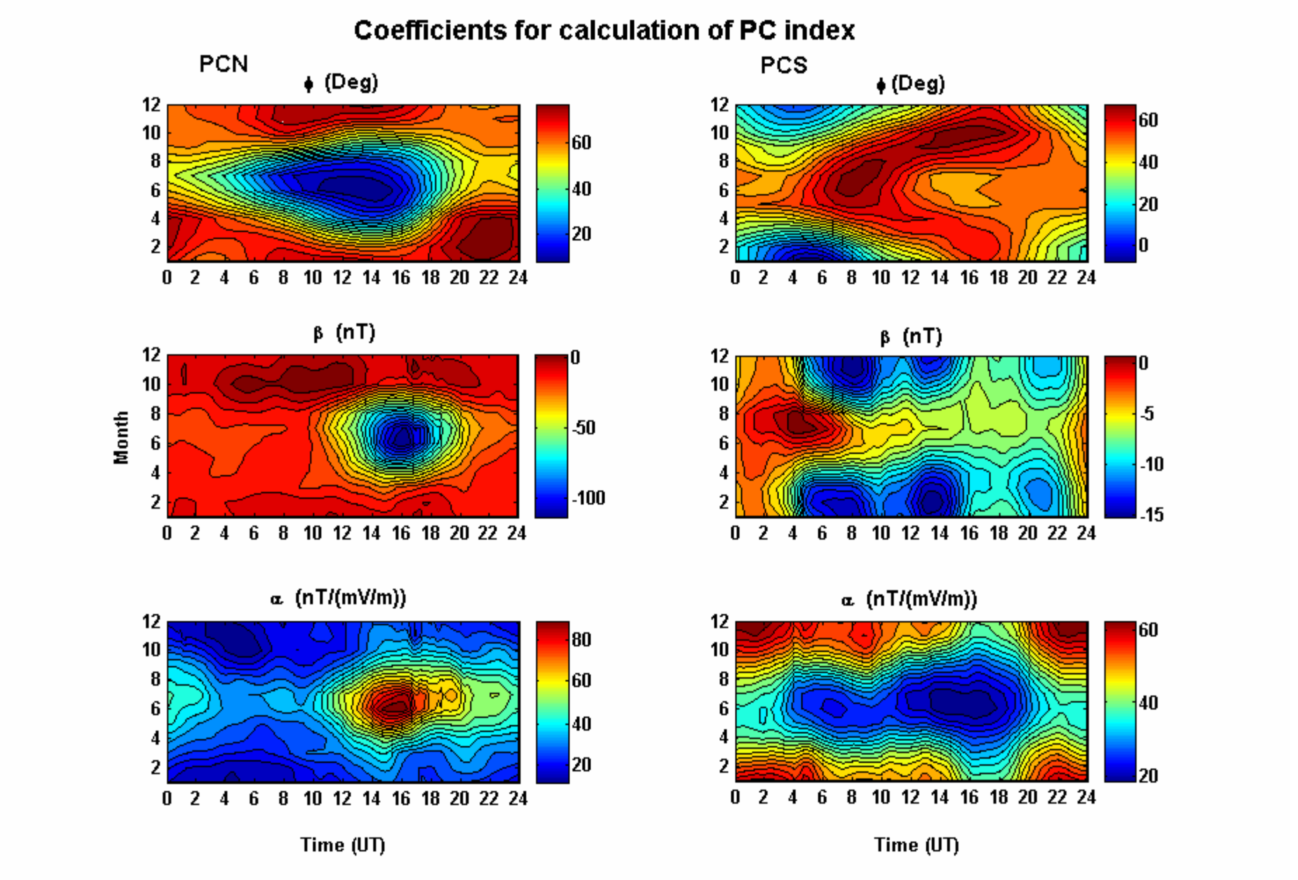

Figure 2. Angle *φ* and coefficients *α* and *β* used for calculation of the unified *PCN* and *PCS* indices at stations Thule and Vostok [Troshichev et al., 2006].

Figure 2 shows how the parameters φ, β and α, derived for Thule and Vostok stations change with UT (axis of abscises) and month (axis of ordinates). The behavior of coefficients α and β is characterized by the well-defined seasonal and daily variations with peak values during the local summer and near the local noon. Designation of the coefficients α and β is quite apparent from Figure 2: they are of the greatest value at both stations when the geomagnetic effect of E_{KL} field is maximal, and they are of the least value when the effect of E_{KL} is minimal. Just in such a manner the *PC* index at Thule and Vostok stations is calibrated for the electric field E_{KL} intensity with allowance for season and UT. As a result, the *PCN* and *PCS* indices appear to be consistent one with other and with E_{KL} value, irrespective of season and UT time. One can see that the coefficients at Thule alternate in the larger range than at Vostok station. This peculiarity is explained by the absence of the ground-induced currents in the ice dome at Vostok and by the higher latitude location of Thule station, as a consequence, the IMF effect being more distinguished at Thule than at Vostok.

3.3 Verification of the unified procedure

If procedure for the *PC* derivation works properly, the calculated *PCN* and *PCS* indices should fit the following requirements:

- *PCN* and *PCS* indices should be consistent with the interplanetary electric field E_{KL};
- *PCN* and *PCS* indices should be in close agreement one with the other, irrespective of season and UT time;
- indices should not demonstrate the seasonal variation;
- indices should not demonstrate the daily variation (i.e. dependence on UT-time).

Figure 3 shows the run of the calculated *PCN* and *PCS* indices for 1998-2001. One can see the remarkable agreement in behavior of the positive PCS (red) and *PCN* (blue) indices irrespective of local season, the largest value ~ +20 mV/m being reached simultaneously at both, Thule and Vostok stations. The seasonal changes are absent in run of the positive *PC* indices, and can be seen in run of the negative *PC* indices related to the specific BZN current system. As it was noted above, BZN system is formed in the summer polar cap under the influence of northward IMF. Occurrence of DP3 disturbances generated by the BZN system was not taken into account by the *PC* derivation procedure, which is aimed at estimation of only effects, produced by the geoeffective electric field E_{KL}. To check the consistency of *PCN* and *PCS* with the interplanetary electric field E_{KL} the differences between values E_{KL} and *PCN* and between values E_{KL} and *PCS* have been calculated and compared.

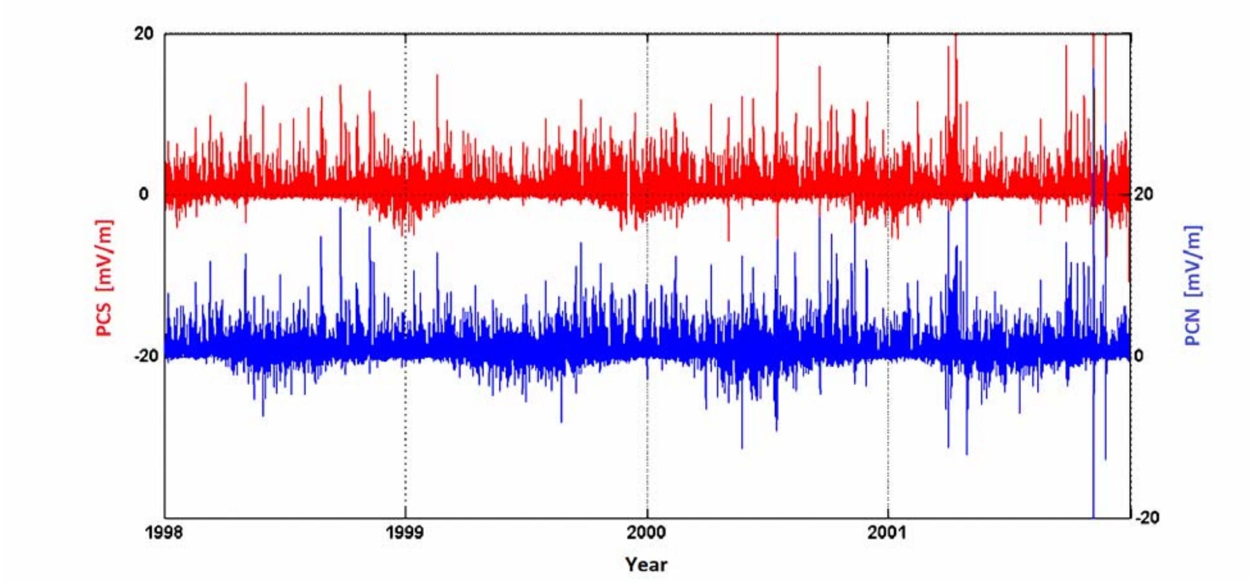

Figure 3. Run of the unified PCN and PCS indices in 1998-2001 [Troshichev et al., 2006].

Figure 4 shows, as an example, run of these differences for 2000. One can see that difference between PC and E_{KL} values lies in range ±1mV/m, with except for few extremely disturbed events. The results of the statistical analysis demonstrate almost one-to-one correspondence between values (E_{KL} - PCS) and (E_{KL} - PCN). It means that requirements of the PCN and PCS identity and their consistency with E_{KL} values are well satisfied.

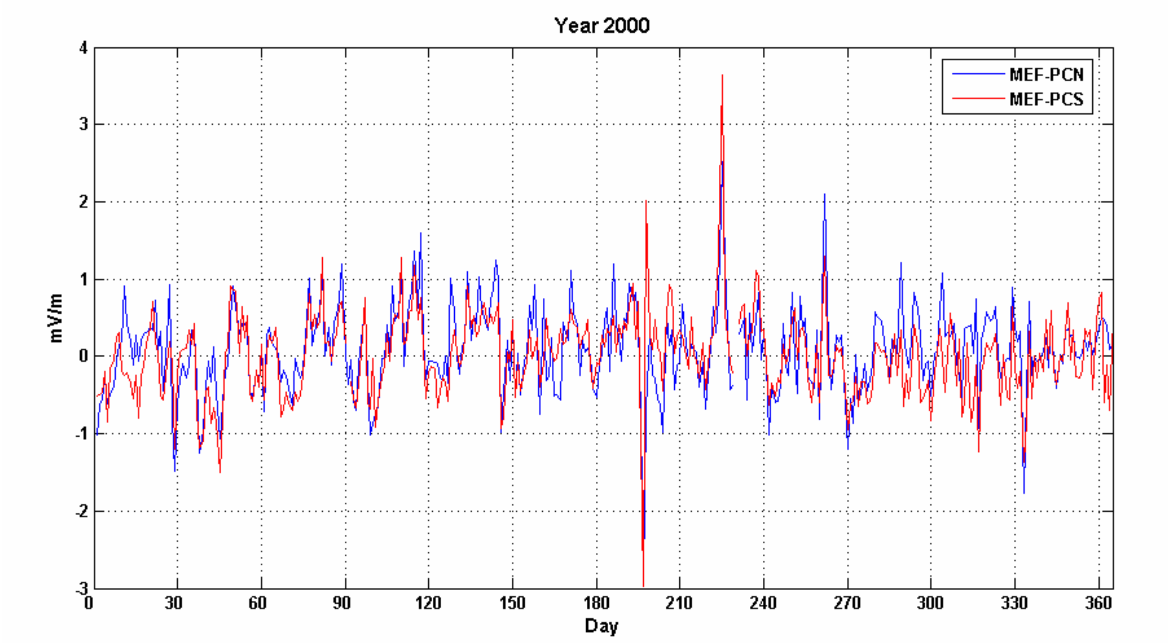

Figure 4. Differences between E_{KL} (in mV/m) and PCN (blue) or PCS (red) through year 2000 [Troshichev et al., 2006].

Since the PC index is designated to monitor the E_{KL} field changes, the properly derived *PC* index can not show evidence of any regular UT dependence. In another case we have to allow that the solar wind is influenced by the Earth's rotation. Availability or absence of the UT dependence in the *PC* run is, possibly, the most sensitive pointer to quality of the *PC* derivation procedure. As an example, **Figure 5** shows superposition of the *PCS* index daily traces for days in April of 1997 (left) and in April of 1998 (right), the *PCS* index being derived by the unified method [Troshichev et al., 2006] in the upper panel and by method adopted in [Lukianova, 2003] in the lower panel. One can see the lack of any obvious UT dependence in the daily run of the positive *PC* indices in the upper panel. Only in the run of negative *PC* index the certain UT effect is displayed as effect of NBZ system in the insignificant rise near the local noon (at 03 – 06 UT for Vostok). To the contrary, the lower panel demonstrates the regular throbs in the *PCS* value around 03, 05, 10 and 14 UT for both Aprils in 1997 and 1998. Comparison of the *PCS* index traces at both panels indicates, without questions, on artificial character of UT oscillations in the *PCS* daily run at lower panel owing to the incorrect determination of parameters φ and α for derivation of the *PCS* index in data-base [Lukianova, 2003].

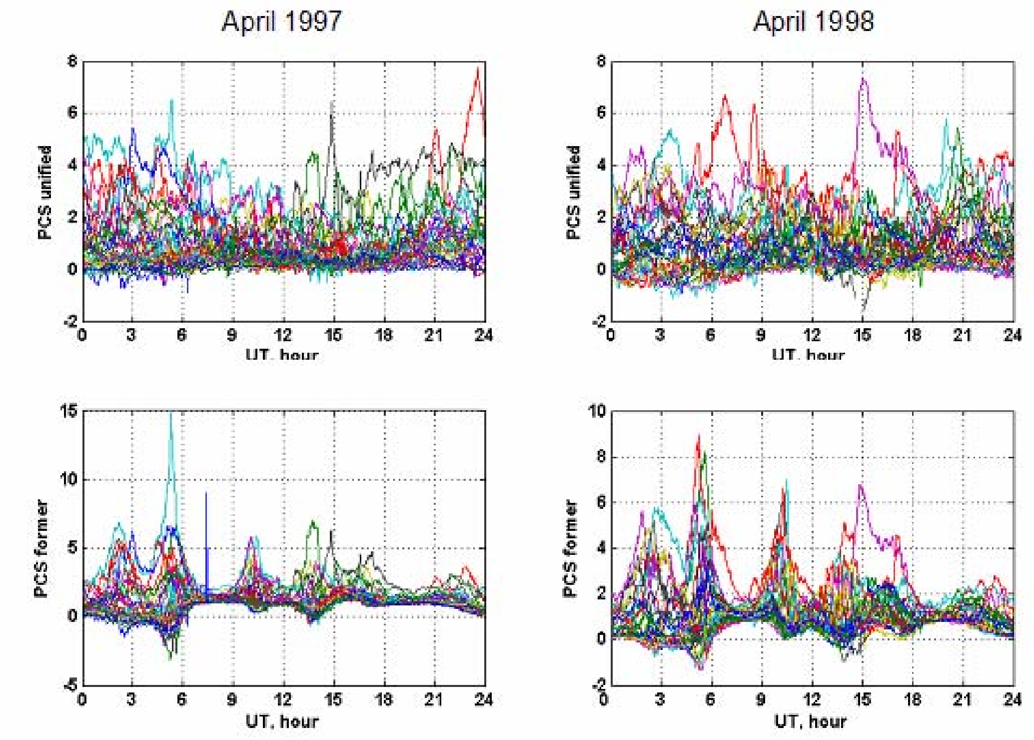

Figure 5. Superposition of the PCS index daily traces for 30 days in April of 1997 (left) and in April of 1998 (right), the PCS index being derived by the unified method [Troshichev et al., 2006] in the upper panel and by method adopted in [Lukianova, 2003] in the lower panel.

3.4 Procedure adopted in AARI for on-line calculation of the PC index

The *PC* index was assigned to monitor effects of the solar wind fluctuations on the polar cap magnetic activity. In so doing, the parameters α, β and φ determining correlation between the coupling function E_{KL} and magnetic activity δF are justified for common (averaged) relationship between the polar cap magnetic activity and solar wind fluctuations. They are not intended for description of extraordinary relationships between E_{KL} and δF observed, for example, in course of irregular enhancements of the ionospheric conductance during the solar flares or while changing the IMF sector structure (SS). To put into use the common procedure of the *P*C calculation we need in these cases to include the mentioned effects into the quiet daily variation, which serves as a level of reference for counting the δF value. Since duration of magnetic effects related to the solar flares or IMF sector structure influence is much longer (some days) than duration of the interested for us solar wind fluctuations (hours), the effects can be easily taken into account after their completion, i.e. post-factum.

However, identification of these effects in the quasi-real time becomes a large problem. Indeed, the procedure of the QDC derivation [Janzhura and Troshichev, 2008] implies consideration of the quiet magnetic field for different quiet days or quiet lapses during the different days under the fixed condition that the quiet lapses are related to the same level on reference. Sudden enhancement of the ionospheric conductivity leads to unpredicted changes in the DP2 current intensity under conditions of the undisturbed solar wind, i.e. to discrepancy in levels of reference for different quiet days. The IMF sector structure, determining by the *By* IMF influence on the magnetosphere, leads to regular distortion of the DP2 current system: the morning or evening current circle is expanded and enhanced. As a result of the DP2 current system modification, the daily run of the polar cap magnetic activity changes, so that the daily mean value of activity at the certain station either increases or decreases being dependent on the sign of sector structure. Since SS sign changes with period from few to 14 days (depending on the solar activity, maximum or minimum, epoch) the mean value of magnetic field periodically increases or decreases with the same period.

To clearly demonstrate the SS significance we show in **Figure 6** the actual run of magnetic disturbances (thin lines) at Thule station in summer season of 2001 and QDC (thick solid lines) including the SS effect. One can see that QDC presents the well-defined daily variations, the level of which changes in wave-like manner with periodicity from 8 days to 27 days. These long-term changes are determined just by SS polarity: the average level of QDC at Thule is higher under conditions of the positive sector polarity and lower under conditions of the negative sector polarity. The amplitude of deviation is maximal in the summer season (from May to August at the Thule station). As soon as the ground SS effect reduces while moving from the summer solstice, the QDC level becomes invariable. The regularity is accompanied by changes in the QDC amplitude, which is the largest during the summer months and minimal during the winter months. It is obvious that with no allowance for the SS effect, the level and amplitude of QDC would remain unchangeable, and SS effect will be accounted as a value of the polar cap magnetic disturbance δF.

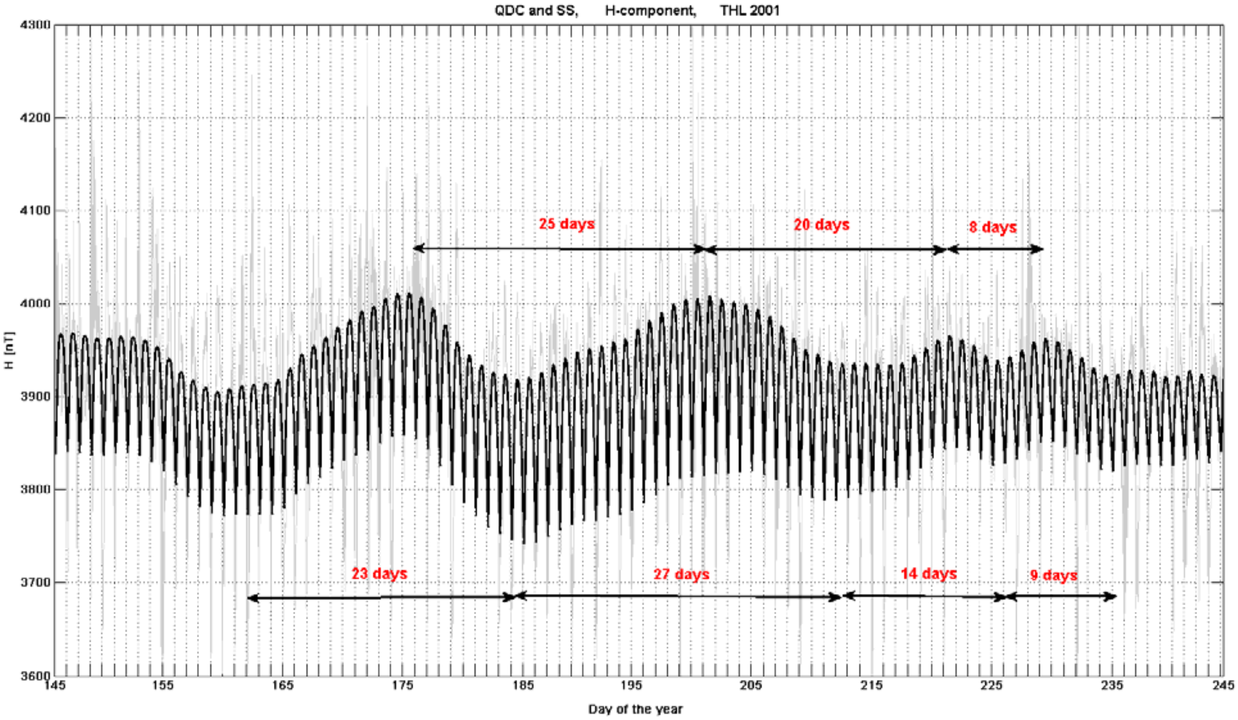

Figure 6. Superposition of the actual variation of 1-min values of the geomagnetic *H* component observed at Thule station in the summer season of 2001 (thin lines) and the quiet daily curve (QDC) characterizing the daily variation of the quiet geomagnetic field (thick solid lines).

Elaborated in AARI technique of allowance for the sector structure in quasi-real time is described in details in [Janzhura et al., 2011]. Accounting the SS and irregular UV effect is one of the main peculiarities and advantages of the unified procedure, adopted in AARI. Along with the seasonal and the solar cycle variations, the QDC amplitude is modified on time scales less than a month following the solar activity fluctuations and sector structure alterations. A new method of a running QDC calculation ensures the on-line determination of QDC even during the maximum solar activity epochs. Just this peculiarity ensures the invariability of parameters φ, α and β in the solar activity cycle (i.e. their independence on occurrence and intensity of the solar flares).

Comparison of techniques used in AARI and DMI for derivation of the PC index is зкуыутеув in the comprehensive analysis of McCreadie and Menvielle (2010). There are now the two separate PCN index versions constructed from the different procedures used at the Danish Meteorological Institute (DMI http://web.dmi.dk/projects/wdcc1/pcnu/pcnu.html), and at the Danish National Space Institute (DTU Space http://omniweb.gsfc.nasa.gov/html/ow_data.html).

4. Physical meaning of the PC index

The *PC* index is a value of polar cap magnetic activity, calibrated by the coupling function E_{KL} and parametrized by a season, UT and a hemisphere. By its derivation, the *PC* index might be regarded as a measure of E_{KL} function controlling the polar cap magnetic activity, applying the same PC index dimensionality as that for the E_{KL} quantity (mV/m). Nevertheless, the PC is not a true index of the E_{KL} impacting on the magnetosphere since the actual E_{KL} value is calculated basing on the solar wind parameters measured in the solar wind outside of the bow shock.

In addition, the correspondence between the *PC* index and E_{KL} is often missing details in spite of the overall conformity in value and behavior of these two quantities. This circumstance is quite reasonable owing to the following reasons: (1) the E_{KL} value calculation is based on the solar wind parameters measured far from the magnetosphere, near the point of libration, and the actual E_{KL} value at the magnetopause can differ from that measured by a distant solar wind monitor even if it is time-shifted to the magnetosphere; (2) a very high level of magnetic field turbulence is typical of the region between the bow shock and the magnetopause with incorporation of very probable nonlinear processes within the boundary magnetosphere (Rossolenko *et al.*, 2008), and hence it is unlikely that changes in the solar wind parameters in their true shape are converted into polar cap voltage variations, while transmitting a signal through the highly turbulent region; and (3) in addition to its response to E_{KL} influence, the PC index also responds to a solar wind dynamic pressure impact on the magnetosphere making allowance for the solar wind dynamic pressure effects.

By its derivation, the *PC* index might be regarded as an indicator of electric currents responsible for polar cap ground magnetic disturbances. Nevertheless, the *PC* index is not also a true measure of field-aligned or ionospheric currents responsible for polar cap magnetic activity, because the actual ionospheric currents in the polar region as well as field-aligned currents are strongly dependent on UT, a season and a site. A special correction is applied to magnetic data by means of appropriate coefficients matching in order to eliminate these dependencies in the *PC* index, so that the *PC* index correctly reproduces E_{KL} variations.

The more so, the PC index can not be a measure of ionospheric electric field which value is determined by altitude where they are measured. As an results [Troshichev et al., 1996] show, at heights of DMSP spacecraft (h≈840 km) the ionospheric electric field is nearly twice as large as a value of corresponding *PC* index. To derive the ionospheric electric field for altitude about 110 km, we have to take into account the magnetic field convergence factor (~1.17). It worthy to note the tendency to ionospheric field saturation for PC values larger 5 mV/m.

Comprehensive studies fulfilled in recent years demonstrated [Troshichev *et al.*, 2007*;* Janzhura *et al*., 2007*,* Troshichev and Janzhura, 2009*;* Troshichev *et al.*, 2011] that physical meaning of the PC index goes out of limits of simple polar cap activity characteristic: the magnetospheric storms and substorms start only if the PC index reaches the definite threshold value (~ 2 mV/m for storms, and >1.5mV/m for substorms); the substorm growth phase duration and substorm intensity are determined by the PC growth rate; the substorms are stopped as soon as PC index falls below 1-1.5 mV/m; the storm length is terminated by duration of period, if PC>2mV/m, the storm intensity being linearly related to the PC index averaged for the storm time interval; periodicity of saw-tooth substorms occurring under conditions of steadily high level of geoeffective interplanetary electric field is determined by duration of “PC growth phase” and “PC decline phase”; development of storms and substorms is better consistent with the PC behavior than with the coupling function variations; requirement PC>1.5mV/m is executed in case of “extraordinary” storms and substorms occurring under conditions of ineffective northward IMF owing to the large IMF B_Y component influence on the polar cap magnetic activity; the *PC* index adequately responds to sharp changes in the solar wind dynamic pressure; and so on. All these experimentally established relationships make it possible to conclude that the polar cap magnetic activity expressed by the PC index can be regarded as an adequate and convenient proxy of the solar wind energy that entered into the magnetosphere while solar wind – magnetosphere coupling.

If the PC index characterizes the energy that entered into the magnetosphere, the index can be used to monitor the state of magnetosphere and readiness of magnetosphere to producing substorm or storm. Since disturbances in magnetosphere are always preceded by energy input, the PC index usage makes it possible to realize the space weather nowcasting (including the auroral ionosphere state and even the anomalous processes in polar atmosphere). A large advantage of the PC index before other methods based on satellite data is a permanent availability of information about magnetic activity in both, northern and southern, polar caps.

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