

2. Physical background (historical outline)

2.1 Polar geomagnetic disturbances influenced by solar wind

The first examinations of the relations between solar wind variations and geomagnetic activity, represented by the Kp index, displayed the dependence of the Kp value on the solar wind speed v and the interplanetary magnetic field (IMF) intensity B (Coleman *et al.*, 1961; Snyder *et al.*, 1963). Later, it was found that magnetic activity is much better determined by the IMF southward (B_{zs}) component (Fairfield and Cahill, 1966; Wilcox *et al.*, 1967; Rostoker and Fälthammar, 1967), or by the IMF transverse fluctuations $(\delta B_p)^2 = (\delta B_z)^2 + (\delta B_y)^2$ (Baliff *et al.*, 1967). The dependence of the auroral AE index on southward IMF was shown by Pudovkin *et al.* (1970), Arnoldy (1971), Foster *et al.* (1971), Kokubun (1972) and Meng *et al.* (1973). It was found that magnetic activity in the auroral zone starts to increase about 15–30 minutes after the IMF turns south, and the correlation between B_z and AE variations is maximal for the delay time ~ 40 minutes. As analyzes (Kokubun, 1972; Kane, 1974) showed, geomagnetic storms are also affected by the IMF southward component, but they develop only if the magnetosphere is exposed to the southward IMF for some hours. According to Hirshberg and Colburn (1969) and Russel *et al.* (1974), Dst variation develops when the value of southward IMF exceeds the threshold level of $-(3-5)$ nT. The correlation of the AE index with the solar wind fluctuations distinctly increases if the product of the solar wind speed and southward IMF is taken into account (Rostoker and Fälthammar, 1967; Garrett *et al.*, 1974; Murayama and Hakamada, 1975). The conclusion made by Rostoker and Fälthammar (1967) is that the interplanetary electric field $E = [vB_{zs}]$ plays a crucial part in geomagnetic disturbances.

The actual distribution of magnetic disturbances at ground level is commonly described by systems of equivalent currents being hypothetic currents, providing the observed magnetic effect on the ground surface. Nagata and Kokubun (1962) were the first to examine under the name of S_p^q a current system of high-latitude magnetic variations observed within the polar cap in periods free of magnetic disturbances. Next, Obayashi (1967) separated a special class of magnetic disturbances (DP2) from magnetic substorms (DP1): the DP2 current system consists of two vortices without any peculiarities in the auroral zone and with currents flowing sunward in the near-pole region. 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), a DP2 currents system is a global system expanding from pole to equator, with focuses located at the latitudes of $\Phi=72-74^\circ$. Further studies (Troshichev, 1975) showed that a two-vortices DP2 current system is terminated by the latitudes of $\Phi=50-60^\circ$, the disturbances at the lower latitudes of $\Phi < 50^\circ$ being produced by equivalent zonal currents of the extra-ionospheric origin. Current vortices focuses in system (Troshichev, 1975) turned out to be located at the morning and evening poleward boundaries of the auroral oval ($\Phi=76-78^\circ$). This peculiarity made it possible to further identify the current vortices focuses with disposition of the magnetospheric field-aligned currents flowing in and out of the polar ionosphere. Kuznetsov and Troshichev (1977) also noted that variations similar to DP2 are observed in the absence of southward IMF. This fact has been attributed to the permanent availability of the geomagnetic variation of (S_p^q) type (Nagata and Kokubun, 1962). Similar permanent disturbances were also separated by Mishin *et al.* (1978) and Levitin *et al.* (1982). To explain generation of these weak disturbances, a mechanism of quasi-viscous interaction between the solar wind and the magnetosphere (Axford, 1964) was accepted.

Besides the DP2 currents affected by southward IMF, some other types of disturbances are also typical of the polar caps. An abnormal 'near-pole DP variation' with direction of currents opposite to that in DP2 was separated by Iwasaki (1971) in the dayside summer polar cap. It was shown by Maezawa (1976) and Kuznetsov and Troshichev (1977) that these disturbances (named as DP3 by Kuznetsov and Troshichev (1977)) are observed when northward IMF impacts on the magnetosphere, and their current system consists of two less-scale current cells centered at latitudes of $\phi \sim 82^\circ$ with the current flow opposite to that in DP2.

Disturbances related to azimuthal IMF component were first separated as an effect of the IMF sector structure (Svalgaard, 1968; Mansurov, 1969). Later, their dependence on azimuthal IMF component was demonstrated (Friis-Christensen *et al.*, 1972; Sumaruk and Feldstein, 1973; Mishin *et al.*, 1973). The current system of these disturbances, named as BY or as DP4 (Kuznetsov and Troshichev, 1977), includes currents flowing along geomagnetic latitudes with maximal intensity in the daytime cusp region ($\Phi \sim 80^\circ$), the current direction being dependent on the sign of the IMF azimuthal component. The actual interplanetary magnetic field usually contains both vertical and azimuthal components, and the ground magnetic disturbances display the combined effect of DP2+DP4 or DP3+DP4 current systems. In these conditions, the influence of the azimuthal IMF component reveals itself in the deformation of the DP2 (or DP3) current systems: in the northern polar cap, the evening DP2 current vortex expands into the dawn sector under conditions of $B_y > 0$, and the morning vortex expands into the dusk sector under conditions of $B_y < 0$ (Matsushita *et al.*, 1973).

The multi-functional analysis of relationships between the IMF and geomagnetic components has been fulfilled by Troshichev and Tsyganenko (1979) to separate effects of the IMF B_x , B_y , B_z components in the case of their combined influence. Results of this analysis (presented in Figure 2.1) demonstrate, as in previous studies, availability of the DP2, DP3 and DP4 current systems associated with the action of southward, northward and azimuthal IMF components respectively. DP2 currents are shown in Figure 2.1 for two different IMF B_{zs} values: $B_z = -1\text{nT}$ (left) and $B_z = -0.25\text{nT}$ (right). DP4 currents are shown for $B_y > 0$ in

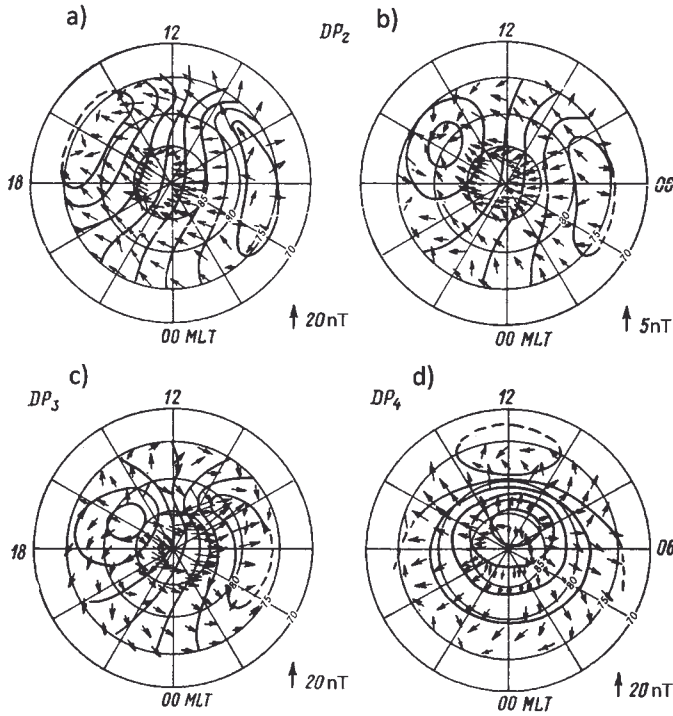


Figure 2.1 Current systems of DP2, DP3 and DP4 disturbances generated by variations of IMF components: (a) southward $B_{zs} = -1\text{nT}$, (b) southward $B_{zs} = -0.25\text{nT}$, (c) northward B_{zn} , (d) azimuthal B_y (Kuznetsov and Troshichev, 1977). Short arrows present distribution of the magnetic disturbance vectors on the ground surface.

the northern hemisphere. The current flow in DP4 system is quite opposite in the southern polar cap.

In addition, the residual magnetic disturbance DP0 unrelated to the IMF has been separated in line with the conclusion made by Kuznetsov and Troshichev (1977). The DP0 current system shown in Figure 2.2 for conditions of (a) northward and (b) southward IMF component is similar to the DP2 system, but exists permanently irrespective of the IMF polarity. Therefore, under the influence of southward IMF, the DP2 currents can be considered as an enhancement of currents in the constantly existing DP0 system. Later, Sergeev and Kuznetsov (1981) showed that intensity of the DP0 currents well correlates with the solar wind velocity v in the second power and, therefore, can be associated with the solar wind dynamic pressure.

It should be noted that DP3 and DP4 disturbances are only typical of the summer polar cap; in the winter season their intensity is negligible, as a rule. On the contrary, the DP2 (and DP0) systems are available irrespective of season; however, the current intensity in the summer season is 2–3 times larger than in the winter one (Pudovkin and Troshichev, 1972).

2.2 Structure of electric fields in polar ionosphere

Electric fields in the polar caps were first measured at satellites Injun-5 ($h=1200\text{--}2000\text{km}$) (Frank and Gurnett, 1971) and OGO-6 ($h=750\text{km}$) (Heppner *et al.*, 1971). It was found that the electric field in the polar cap was oriented from the morning side to the evening side on average, and the field direction was reversed at the poleward boundaries of the auroral oval. Since the electric field action on collisionless plasma is adequate to the plasma convection movement with an electric drift speed, the electric field's distribution in the ionosphere is usually represented as a system of convection, where convection lines are identified with electric equipotentials. According to Heppner (1972), electric fields within the polar cap are directed from dawn to dusk, and their distribution is represented by a convection system with two vortices positioned symmetrically relative to the Sun–Earth line, the morning

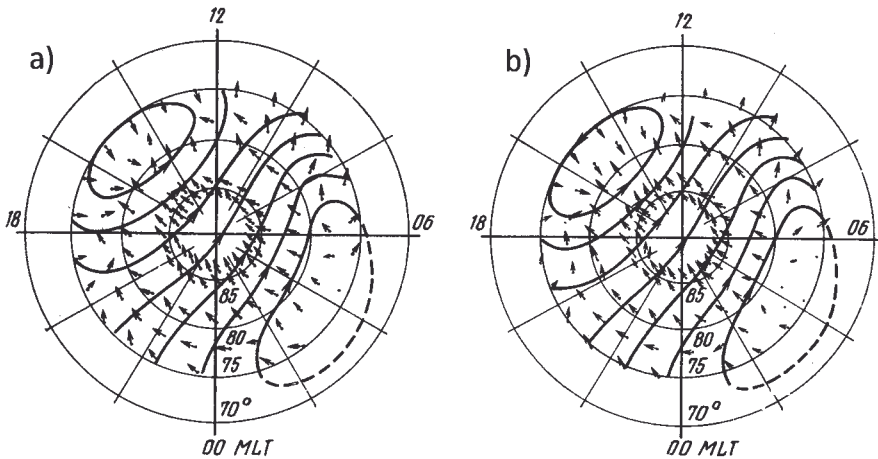


Figure 2.2 Current system of residual, unconnected with IMF, magnetic disturbance DP0 obtained for conditions of northward (a) and southward (b) IMF components.

or evening vortex being expanded at the larger part of the polar cap under the influence of the appropriate IMF B_y component. The measurements of the polar cap electric field in balloon experiments (Mozer *et al.*, 1974) showed an evident dependence of the electric field on both vertical and azimuthal IMF components. It was noticed that dawn–dusk electric fields in the polar cap increase under the influence of the southward IMF, but keep a noticeable intensity for $B_z=0$. The electric field in the near-pole region changes its polarity under conditions of the considerable northward IMF.

Electric fields ensuring the generation of magnetic disturbances in the summer polar cap were calculated by Kuznetsov *et al.* (1977) with the supposition of the ionosphere homogeneity. The electric field structure and intensity derived from magnetic DP2 and DP3 disturbances turned out to be in total agreement with the results of direct measurements (Heppner *et al.*, 1971; Heppner, 1972; Mozer *et al.*, 1974). The strongest effect of the IMF azimuthal component is manifested in deformation of the usual two-vortex convection pattern: the convective flow in the northern polar region increases in the dawn sector when B_y is positive, and in the dusk sector when B_y is negative. In the southern polar region the asymmetry is reversed. A reversal of B_z affects the direction of the convection (rotation from antisunward to sunward) and asymmetry patterns related to B_y influence respectively displaces to the opposite side of the polar cap.

A scheme of polar cap convection in the dayside northern hemisphere generalized for various IMF orientations is shown in Figure 2.3 (Troshichev, 1984). Since ionospheric

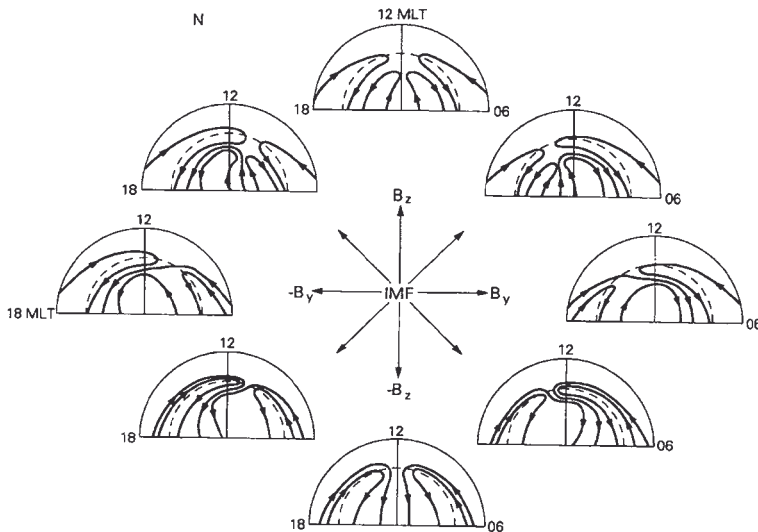


Figure 2.3 A generalized scheme of the polar cap convection in the dayside northern hemisphere for various IMF orientations (Troshichev, 1984).

convection is realized at the expense of electrons, a convection system can be regarded as an ionospheric current system, provided the flow direction is changed for the opposite one. As Figure 2.3 demonstrates, an uncontaminated current system DP2 is observed when the IMF is mainly southward, and ionospheric DP3 currents are observed under conditions of the strongly northward IMF. The effect of B_y currents is insignificant under conditions of southward IMF and becomes noticeable under conditions of northward IMF. Similar convection patterns for different IMF orientations were obtained later by Shue and Weimer (1994), while analyzing electric field distribution in the polar cap ionosphere.

2.3 Magnetospheric field-aligned currents

The first evidence for magnetospheric field-aligned currents was obtained when transverse magnetic disturbances ΔB were detected at $h=1100\text{km}$ on board the OGO 4 spacecraft (Zmuda *et al.*, 1966). The idea of field-aligned currents, as a reason of the transverse disturbances, was realized only four years later (Armstrong and Zmuda, 1970) and the first pattern of field-aligned currents distribution in the polar cap was presented by Zmuda and Armstrong in 1974. The pattern of Zmuda and Armstrong (1974) included a layer of field-aligned currents on the poleward boundary of the auroral oval, with currents flowing into the ionosphere in the morning sector and flowing out of the ionosphere in the evening sector, and a layer of field-aligned currents on the equatorward boundary of the oval, with oppositely directed field-aligned currents. A similar pattern of field-aligned currents was later derived by Iijima and Potemra (1976a,b) from experiments on board the Triad spacecraft (Figure 2.4). Field-aligned currents positioned at the poleward oval boundary were determined as Region 1 FAC and currents at the equatorward oval boundary were determined as Region 2 FAC.

Large-scale characteristics of field-aligned currents associated with substorms were examined by Iijima and Potemra (1978). It was noted that the basic spatial distribution and flow direction pattern of field-aligned currents observed during geomagnetically quiet or less active periods comprise the backbone of the field-aligned currents' distributions through disturbed substorm periods. During active periods ($|AL| > 100\text{ nT}$) the average latitude width of Regions 1 and 2 increases by 20–30% and complicated small-scale structures are superimposed upon the large-scale field-aligned current features, especially on the nightside during a substorm event. The currents in Region 1 are observed permanently, even during quiet conditions, whereas Region 2 currents are detected in periods of magnetic disturbances in the auroral zone. The current density in Region 1 is statistically larger than the current density in Region 2 at all local times except during active periods in the after-midnight local time sector, where the westward electrojet is most active. The average total amount of field-aligned currents flowing into the ionosphere always equals the current flow away from the ionosphere during a wide range of quiet and disturbed conditions.

Langel (1975) was the first to point out the relation of field-aligned currents to IMF variations. He showed that the value of geomagnetic disturbance ΔB fixed by spacecraft OGO above the polar cap rises with an increase of the southward IMF. High correlation

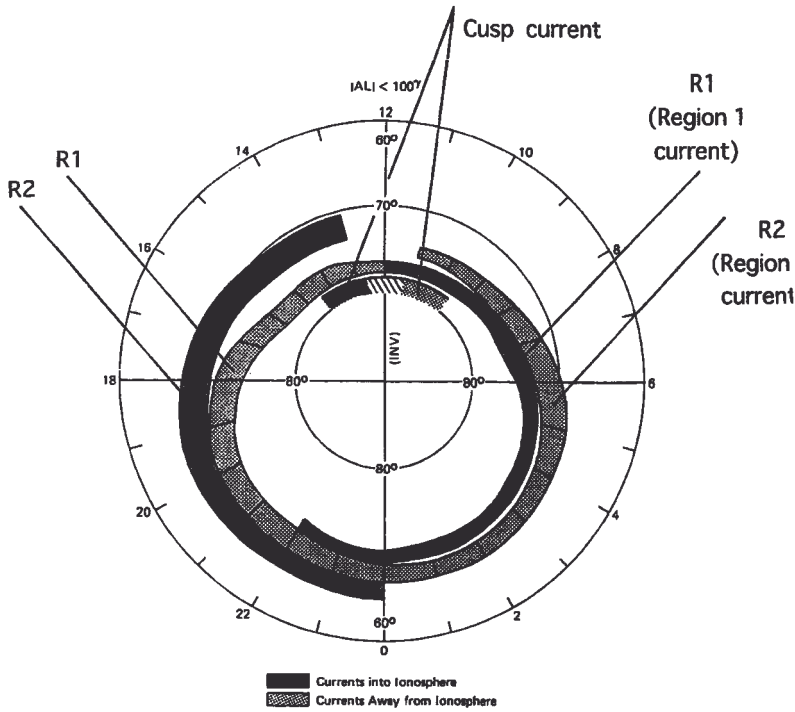


Figure 2.4 Pattern of field-aligned currents derived by Triad data (Iijima and Potemra, 1976a).

of value of ΔB with southward IMF was also demonstrated by McDiarmid *et al.* (1977) who relied on the data from the ISIS-2 satellite. Measurements of ΔB on board the Triad spacecraft were used later to study the relationship between the Region 1 FAC density and the IMF tangential component B_T (Iijima and Potemra, 1982) and between the Region 1 FAC total intensity and interplanetary electric field E (Bythrow and Potemra, 1983). Both analyzes confirmed the strong dependence of Region 1 currents on the solar wind parameters B_T and E .

Field-aligned currents of reverse polarity were found in the near-pole area (at latitudes of $\Phi > 75^\circ$) under conditions of the IMF northward component (McDiarmid *et al.*, 1977, 1978a,b). A concept of a specific large-scale current system in the dayside polar region generated by a strong northward IMF was formulated only on the basis of MAGSAT data (Araki *et al.*, 1984; Iijima *et al.*, 1984). It was found out that these specific field-aligned

currents (designated as NBZ) occur at latitudes poleward of Region 1 at daytime (06 MLT through noon to 18 MLT) and show remarkable stability during periods of prolonged northward IMF. NBZ currents flow out of the ionosphere in the pre-noon sector, and flow into the ionosphere in the post-noon sector of the polar cap. NBZ currents are absent when the IMF is southward, but a combination of NBZ and DP0 currents under conditions of the moderate northward IMF can result in a four-vortices equivalent current system in the summer polar cap.

The azimuthal IMF component strongly controls field-aligned currents in the daytime cusp region. The corresponding FAC system consists of two current sheets (Wilhelm *et al.*, 1978), one of which is located on the equatorward side of the cusp, i.e. in Region 1, whereas the other sheet is located on the poleward boundary of the cusp (Region 3). The direction of field-aligned currents is determined by sign of the IMF B_y component, as well as the direction of ionospheric currents flowing between current sheets (Friis-Christensen and Wilhelm, 1975). The measurement of transverse magnetic disturbances ΔB over the polar cap (McDiarmid *et al.*, 1978b, 1979; Doyle *et al.*, 1981) revealed that the sign of the IMF azimuthal component influences the flow direction and the intensity of currents in Regions 1 and 3. For the conditions of $B_y > 0$, field-aligned currents in the northern dayside region flow into the ionosphere in the equatorward layer (Region 1), and flow out of the ionosphere in the poleward layer (Region 3). For the conditions of $B_y < 0$, field-aligned currents in the southern polar cap flow out of the ionosphere in the equatorward layer and flow into the ionosphere in the poleward layer. The currents reverse their direction in both hemispheres for $B_y < 0$. As a result, downward (upward) field-aligned currents in the northern polar region increase in the prenoon (postnoon) part of Region 1 and intrude into the post-noon (pre-noon) part of Region 1. According to the measurements taken by the Viking spacecraft (Erlandson *et al.*, 1988), the meridian that separates dawnside and duskside currents in Region 1 in the northern hemisphere is shifted to magnetic local times before noon when $B_y < 0$, and toward the afternoon side when $B_y > 0$. In the southern polar region, the dependence of field-aligned currents on the IMF azimuthal component is quite opposite to that in the northern hemisphere. Similarly, the IMF B_y component affects the distribution of NBZ currents in such a way that the region of morning (upward-flowing) or evening (downward-flowing) currents becomes dominant responding to the sign of the IMF B_y component (Iijima and Shibaji, 1987).

2.4 Relation of field-aligned currents to aurora and particle precipitation

It was noted (Zmuda and Armstrong, 1974) that regions where field-aligned currents are observed are statistically coincident with the visual auroral oval defined by Feldstein (1966) and, correspondingly, with the region of the auroral electrons $E_e > 5$ keV precipitation derived from measurements on board the Injun-IV satellite (Craven, 1970). The first experimental evidence for a strong relationship between field-aligned currents and aurora were obtained when sounding rockets with magnetometers and particle detectors on board

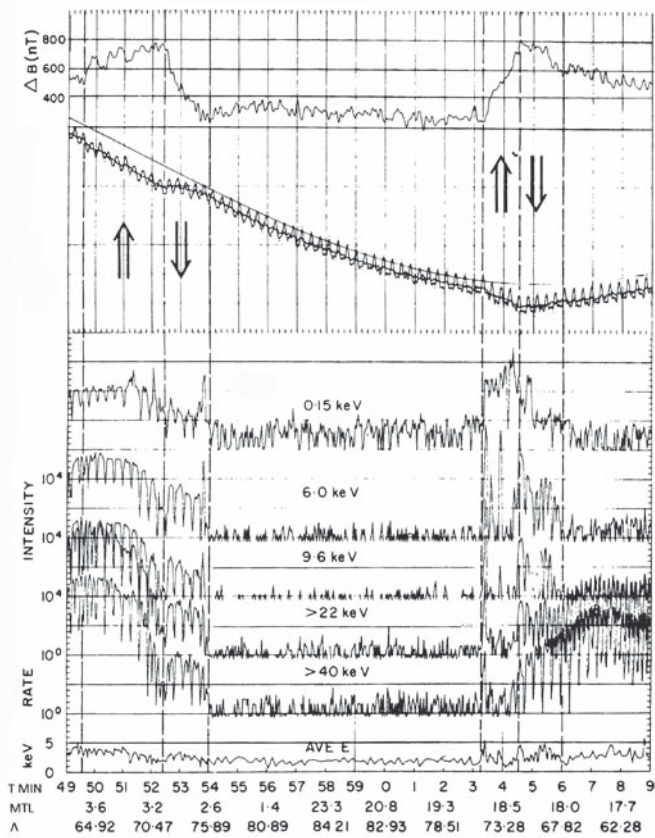


Figure 2.5 Example of transverse magnetic distribution (upper panel), corresponding field-aligned currents (arrows) and electron precipitation fluxes at five different energies (lower panels) along the dawn-dusk pass of the ISIS-2 satellite (McDiarmid *et al.*, 1977).

were launched in the auroral forms. Magnetometers provide information on the geomagnetic field deviations caused by field-aligned currents and particle detectors provide data on flux of particles and their pitch-angle distribution. These experiments demonstrated (Cloutier and Anderson, 1975) that the field-aligned flux of auroral particles $0.5 < E_e < 30$ keV is typical of bright auroral forms. The field-aligned flux of the precipitating electron can provide as high density of field-aligned currents as 10^{-5} – 10^{-4} A/m².

The simultaneous particle and magnetic measurements on board satellites provide the most comprehensive information about the relation of field-aligned currents to auroral precipitation (Klumpar *et al.*, 1976; McDiarmid *et al.*, 1977). [Figure 2.5](#) shows a typical

example of distribution of field-aligned currents (arrows) and electron fluxes at five different energies along the dawn–dusk pass of the ISIS-2 satellite. One can see a distinct boundary between the auroral oval, where the field-aligned currents are coincident with auroral electron precipitation, and the polar cap, where neither current nor auroral particle fluxes are observed. The spatial relationship between field-aligned currents and auroras in the evening and morning sectors was studied by Armstrong (1974), Kamide and Akasofu (1976) and Kamide and Rostoker (1977) basing results on the Triad spacecraft measurements in the northern hemisphere. The conclusion was made that the poleward discrete arc in the evening sector marks the northernmost boundary of the Region 1 field-aligned currents, whereas Region 2 FAC corresponds to the region of the diffuse aurora. The same results were obtained while examining data from the DMSP satellite (Meng, 1976): the northernmost arcs were consistent with the sharp rise of the electron flux at all energy channels from the polar cap background level to the about 10-fold increase level of the auroral oval.

The downward current flow in the morning sector occurs in a region of auroral luminosity generated by the precipitating electrons, although the strength of the downward field-aligned current and the auroral intensity are anticorrelated. The upwelling cold electrons are considered as charge carriers of the downward currents in the morning sector (Maier *et al.*, 1980; Kamide and Baumjohann, 1993). The region of the upward field-aligned current coincides well with the region of the visible aurora in the equatorward half of the morning auroral belt. Thus, the existing experimental data (see also reviews by Burch, 1988; Kamide, 1988) distinctly indicate that both Region 1 and 2 field-aligned currents flow within the auroral oval.

2.5 Model computations of field-aligned currents and ionospheric electric field and currents

As soon as some knowledge on field-aligned currents was acquired, model computations of ionospheric fields and currents were developed. The problem was attacked in two ways. In studies (Nisbet *et al.*, 1978; Troshichev and Gizler, 1978; Gizler *et al.*, 1979; Troshichev *et al.*, 1979b, 1982) the systems of electric fields and currents in the polar ionosphere were calculated for the field-aligned currents patterns. In studies (Kamide and Matsushita, 1979; Mishin *et al.*, 1981; Levitin *et al.*, 1982) the simulation schemes were elaborated to calculate the field-aligned current distribution by data of ground-based magnetic observations. A number of realistic assumptions was made in both approaches to simplify the entire calculation procedure. The results of model computations turned out to be compatible as a whole.

Numerical simulations of ionospheric electric field and currents fulfilled by Gizler *et al.* (1979) and Troshichev *et al.* (1979b) were based on data on actual ionospheric conductivity distribution in the summer polar cap (Vanjan and Osipova, 1975) and satellite data on a field-aligned current structure and intensity (Iijima and Potemra, 1976a,b) with allowance for their dependence on the IMF and level of activity. [Figure 2.6](#) shows, as an example, the

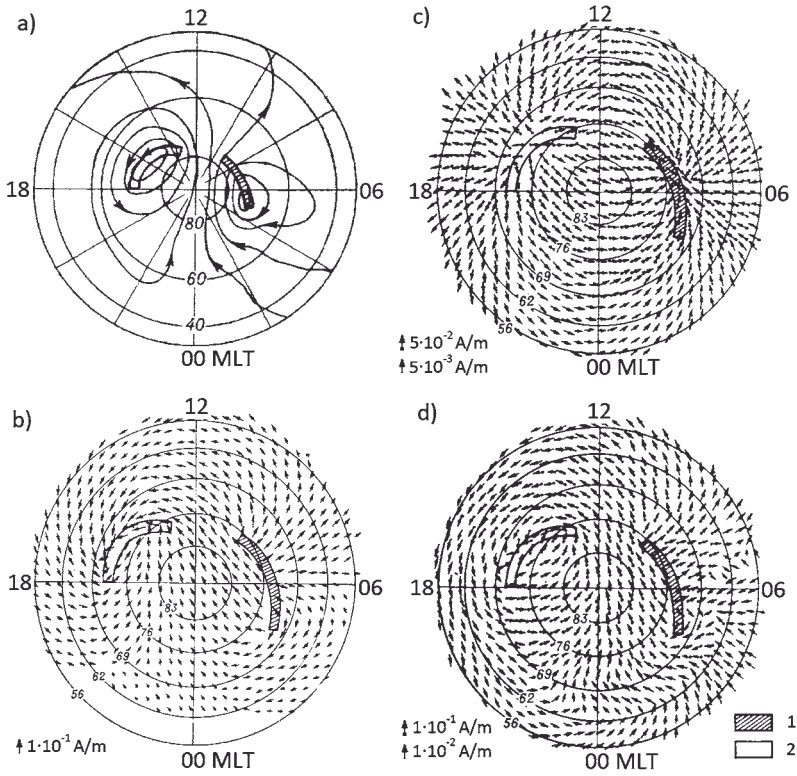


Figure 2.6 Current systems of the polar cap magnetic disturbances derived from numerical simulations (Gizler and Troshichev, 1979; Troshichev *et al.*, 1979b) for the quiet-time Region 1 FAC pattern: (a) system of ionospheric Hall currents; (b) full system of ionospheric Hall and Pedersen currents; (c) equivalent current system describing a distant magnetic effect of field-aligned currents; (d) equivalent current system describing a summary effect of ionospheric and field-aligned currents. Field-aligned currents flowing into the ionosphere (1) and flowing out of the ionosphere (2) are shown.

current systems produced by Region 1 field-aligned currents under conditions of low magnetic activity (Gizler *et al.*, 1979; Troshichev *et al.*, 1979b). One can see that the magnetic effect of the ionospheric Pedersen currents is roughly annihilated by the distant magnetic effect of the field-aligned currents, and actual polar cap magnetic disturbances distribution is described mainly by ionospheric Hall currents, in full agreement with the theorem of Fukushima (1969).

Eventually, ionospheric electric fields and currents, responding to southward, northward, or azimuthal IMF component, separately and in combination, were calculated (Gizler *et al.*, 1979; Troshichev *et al.*, 1979b) with setting the FAC patterns considering the effect of different IMF components (as for Region 1, NBZ and BY FAC systems). Results of model simulations perfectly reproduced DP2, DP3 and DP4 current systems derived from ground magnetic disturbances (see Section 2.1). A conclusion was made by Troshichev (1982) that the diversity of polar magnetic disturbances is determined by field-aligned currents, responding to IMF variations in the solar wind. It was also suggested that development of magnetic disturbances in the auroral zone can be predictable by monitoring the polar cap magnetic activity.

2.6 Approaches to the idea of PC index

2.6.1 PC_L index

When examining magnetic disturbances at the northern high-latitude stations Resolute Bay, Mould Bay, Alert and Thule, it was found (Kuznetsov and Troshichev, 1977) that enhancement of fluctuations in horizontal geomagnetic components at these stations often preceded magnetic disturbances in the auroral zone. It was proposed to characterize polar cap activity by magnetic fluctuation activity and to introduce a corresponding index (PC_L) as a measure of a geomagnetic horizontal components length per hour. A special mechanical device was constructed to count X and Y (or H and D) traces length at magnetograms. The analysis carried out with the use of the magnetic data from Thule and Alert stations showed (Kuznetsov and Troshichev, 1977) that the PC_L index served as a precursor only for about 70% of the isolated substorms examined. The reason was evident since the PC_L index, by method of its derivation, allowed for any polar cap magnetic activity irrespective of its reason: changes in southward, or azimuthal, or even northward IMF components. It should be noted that in this relation the PC_L index looks like the index introduced previously by Fairfield (1967) as a measure of maximum of horizontal disturbance at three stations Thule, Alert, and Resolute Bay.

2.6.2 $MAGPC$ index

In order to allow only for magnetic disturbances generated by the southward IMF, polar cap activity was determined in the second approach (Troshichev *et al.*, 1979a) as a measure of magnetic disturbance vector projection along the meridian of 03.00–15.00 MLT (see Figure 2.1). A magnetic disturbance magnitude in this direction was taken as a characteristic of polar cap magnetic activity caused by southward (or northward) IMF. The value of a 15-min averaged magnetic disturbance vector was counted off from a quiet daily curve, obtained as an average curve for the five quietest days of the month. This characteristic was termed a $MAGPC$ index. To verify the method, a new $MAGPC$ index was calculated in a quasi-real time at the near-pole station Vostok in Antarctica during 1982–1983.

The *MAGPC* index was treated as a characteristic of sunward or antisunward convection flows in the polar cap. In this case, there must be a close connection between *MAGPC* and solar wind parameters, including the IMF B_z component. The analysis of statistical relationships between *MAGPC* indices and various interplanetary quantities was carried out by Troshichev and Andrezen (1985). By interplanetary quantities are meant solar wind parameters or their different combinations designated at present as solar wind–magnetosphere coupling functions. The *MAGPC* index was calculated every 15 minutes on the basis of magnetogrammes of the Vostok station. The data of summer months of November, December, January, and February of 1978–1980 were used. The appropriate 15-min values of the solar wind parameters were calculated on the basis of 5-min data supplied by the IMF-J satellite. The hourly-averaged values were obtained for every UT hour by taking all four 15-min quantities.

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 $\varepsilon = l_0^2 v B^2 \sin^4((\theta_c)/2)$ (Akasofu, 1979), where θ is an angle between the IMF B_T component and the geomagnetic Z-axis, 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 stagnation line length (Pudovkin *et al.*, 1982), function $n^{1/2} v B_T (\sin \theta / 2)^{1/2}$, representing a momentum flux of the solar wind transported into the reconnection region (Vasyliunas, 1975).

The *MAGPC* index showed the best relationship to such coupling functions as the interplanetary electric field E_{KL} , determined by Kan and Lee (1979). The index was regarded as a characteristic of the convection field over the polar cap: the positive value of the *MAGPC* indicated antisunward convection, while the negative *MAGPC* pointed to sunward convection. Availability of 5-min IMF data makes it possible to determine correlation between the 15-min *MAGPC* index and interplanetary quantities for different delay time values with time solution of 5 minutes. The study of Troshichev and Andrezen (1985) revealed that correlation between the coupling function E_{KL} and the polar cap disturbances ΔF was optimal when a delay of about 20–25 minutes between the E_{KL} and ΔF values was taken into account. It meant that magnetosphere responds to changes in the solar wind parameters with a definite time delay. Subsequent analyzes based on 1-min E_{KL} and ΔF quantities showed that the *PC* starts to grow in approximately 10 minutes after the E_{KL} rise beginning and the maximums of *PC* being reached 15–30 minutes later than the maximum in E_{KL} (see Chapter 6).

The analysis was fulfilled only for the summer season at the 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 steady monitoring of the polar cap electric field for the whole year. The idea was appreciated by Danish colleagues, and 1985 was the beginning of fruitful collaboration between Arctic and Antarctic Research Institute (AARI, St. Petersburg) and Danish Meteorological Institute (DMI, Copenhagen) resulted in a method of *PC* index calculation.

2.7 Summary

Within about one decade (1970–1980) an amount of evidence was accumulated indicating that polar cap electric fields and currents and corresponding magnetic disturbances are produced by the magnetospheric field-aligned currents. The structure and intensity of the field-aligned currents and proper magnetic disturbances are controlled by the solar wind parameters, the most geoeffective of which is the IMF southward component producing the polar cap DP2 magnetic disturbances. Region 1 field-aligned currents responsible for DP2 disturbances are positioned within the auroral oval, along its poleward boundary, and associated with the auroral particle precipitation.

Since the polar cap magnetic activity is controlled by the IMF variations it can be considered as a signature of the solar wind impact on the magnetosphere, and the corresponding polar cap activity index *MAGPC*, characterizing the intensity of the DP2 disturbances affected by geoeffective southward IMF variations, has been examined. Statistical analysis of the relationships between the *MAGPC* index and various interplanetary quantities showed that the *MAGPC* index correlates the best with the coupling function E_{KL} , which was introduced by Kan and Lee (1979) as a geoeffective interplanetary electric field $E_{KL} = vB_r \sin^2 \theta / 2$.

2.8 References

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