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HIGH LATITUDE FIELD OF POLAR DISTURBANCES

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SUMMARY

The high-latitude field of DP-disturbances is studied by construction of charts of successive disturbed field moments. Since DP-disturbances have their source in the high-latitude ionospheric currents, their dynamics were object of study as a function of D_{st}-variations by means of synoptic charts. The patterns obtained are discussed at length.

* * *

Bay-like disturbances lasting usually about two hours are observed on high-latitude stations' magnetograms even in quiet days. It is customary to call them elementary polar storms, or polar sub-storms and denote them by the symbol DP. Numerous investigations of DP show that their source is in high-latitude ionospheric currents excited by short-lived action of the corpuscular stream. For a prolonged action of the stream the polar sub-storms occur in a nearly continuous sequence.

The space-time distribution of the field of polar disturbances is usually investigated by way of construction of ionospheric current systems, equivalent to the distribution of DP field vectors on the surface of the Earth. At high latitudes the distribution of the DP field is characterized by a substantial complexity, and the net of the registering stations is limited. In order to bypass this difficulty we utilized during the construction of current systems the distribution in the course of the day of averaged polar disturbances in separate stations. However, such a construction is linked with a series of assumptions, disclosing only the average characteristics of the DP field. The first constructions of the mean current systems in the form of two vortices (morning and evening) in the region bounded by the Fritz zone ($\Phi \approx 60°$) were performed by Chapman [1]. Subsequently, as the number of stations increased, the current systems were refined by numerous authors [2-7]. Attempts were made to construct also the current systems related to a specific moment of time [2, 5, 8, 9 et al]. Because of insufficiency of stations such current systems could contain significant errors. This is why, taking advantage of the increase of the number of stations during the IGY, we undertook the investigation of dynamics of current systems as a function of the phase of D_{st}-variation in low latitude stations. The method of analysis consists in the construction of synoptic charts of successive moments of the disturbed field.

(*) [POLE POLYARNYKH VOZMUSHCHENIY VYSOKIKH SHIROT.]

During the construction of synoptic charts hourly values of vectors $\vec{\Delta X}$, $\vec{\Delta Y}$ and $\vec{\Delta Z}$ were utilized as departures from the quiet undisturbed level in the days preceding the considered storm. In the first approximation the part of the values obtained was eliminated, which was caused by induced currents in the Earth: the values of horizontal components were multiplied by 0.7, and those of vertical components were divided by 0.7. Then arrows were placed on the map (limited to $\Phi = 50°$) at places of location of stations for a chosen hour U.T., representing the perturbation vectors of the horizontal component ($\vec{\Delta T}_{hor} = \vec{\Delta X} + \vec{\Delta Y}$), and the values of the perturbation vectors of the vertical component $\vec{\Delta Z}$ were marked by numerals. Then a line was drawn through the region between positive and negative values of $\vec{\Delta Z}$ ($\vec{\Delta Z} = 0$). In the presence of a large number of successive synoptical charts (we had 480 of them), the line $\vec{\Delta Z} = 0$ is drawn sufficiently reliably. At the same time, as a rule, the vector $\vec{T}$ is perpendicular to the line $\vec{\Delta Z} = 0$; it is maximum on that line (within the region bounded by the Fritz zone) and directed from the region $\vec{\Delta Z} > 0$ to the region $\Delta Z < 0$ [10]. It should be noted that the region of the current systems' morning vortex is characterized by the values $\vec{\Delta Z} > 0$, while the region of the evening vortex is marked by the values $\vec{\Delta Z} < 0$. At the boundary, that is, along the line $\vec{\Delta Z} = 0$, the center of gravity of the basic current, responsible for the polar disturbances, is located.

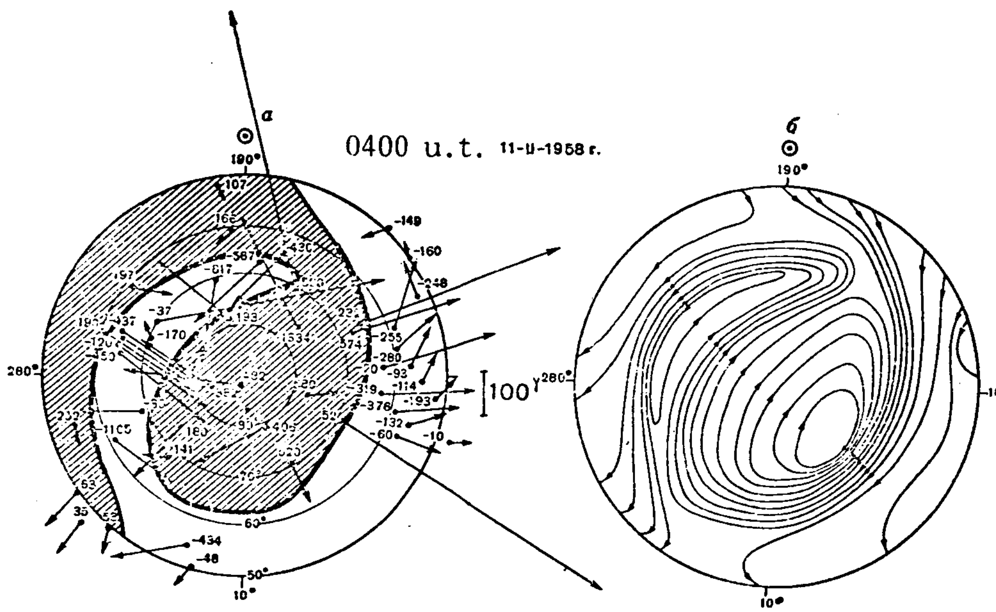

Fig.1

Let us examine several typical examples of synoptic charts of perturbed field distributions at high latitudes. Fig.1a represents a synoptic chart constructed for 0400 hours UT of the storm of 11 February 1958. Concentric circles indicate the geomagnetic latitudes; the denotations of geomagnetic longitudes and latitudes are given in degrees and the position of the Sun is marked by a circle with a dot. This moment of time refers to the period of the initial phase of a very powerful magnetic storm. The ring current had no time to develop as yet, and its field near the equator constituted $D_{st}(H) = 9\gamma$ (refer to [11]). At the same time $a_p = 236$. In Fig.1a the region $\vec{\Delta Z} > 0$ is shaded.

Such a case, when near this zone all the three branches of $\Delta\vec{Z} = 0$ are present (morning, night and evening), corresponds to the distribution of the field of polar disturbances or polar sub-storm. The well known fact that in night and early morning hours vectors $\Delta\vec{T}_{hor}$ are maximum on the line $\Delta\vec{Z} = 0$ is not very well shown in Fig.1a. This was taken subsequently into account, when constructing the current system. The moments of U.T. shown in Figures 1a as well as 2a were especially so chosen that the existing station network allow the consideration of the pecularity of the evening vortex.

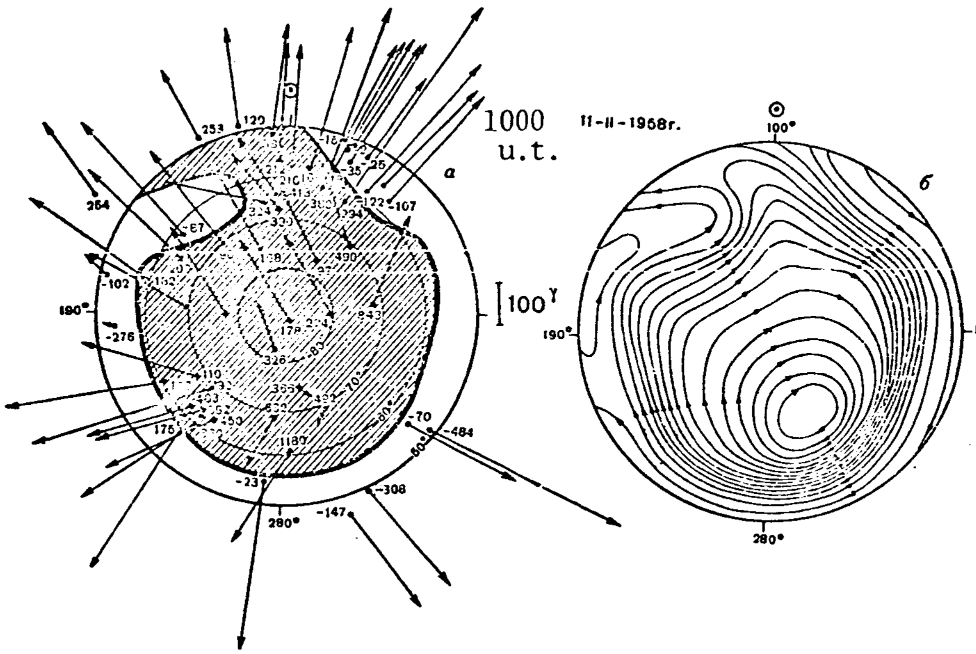

Fig.2

The idealized system of currents, equivalent to the perturbation field represented in Fig.1a for substantial a_p and $D_{st} \approx 0$ is plotted in Fig.1 . For its construction we used the approximate Chapman method and we involved additional data, namely, the latitude cross sections of $\Delta\vec{T}_{hor}$ for the meridians of local geomagnetic time 1200, 1500, 1800 and 2100 hours. When constructing the latter we took into account the distribution of $\Delta\vec{T}_{hor}$ vectors relative to the line $\Delta\vec{Z} = 0$ for analogous cases when $D_{st} \approx 0$ and a_p is significant. The system includes two vortices with foci on evening and morning meridians. The intensities of both vortices are of same order. At the same time, the full current of the evening vortex is slightly smaller than that of the morning vortex ($2.2 \cdot 10^5$ and $3.5 \cdot 10^5$ respectively). In its general traits Fig.1 agrees well with the distribution of the field of polar sub-storms, brought out in references [2, 3, 5 et al], differing by the fact that the basic current of vortices is concentrated on their boundaries.

An entirely different pattern is obtained when considering the perturbed field during the main phase of D_{st}-variation. Such a case is illustrated in Fig.2 a. Here the synoptic chart refers to 1000 hours U.T. of the same storm of 11 February 1958. This moment of time corresponds to the period of a well developed and intense ring current in the region of radiation belts. Near the equator the value of the outer part of $D_{st}(H) = -270$ [11]; $a_p = 236$, thus the same as in Fig.1. Inside the Fritz zone the "evening" branch of the line $\Delta\vec{Z} = 0$ to which in Fig.1 a corresponded the horizontal vectors directed toward the pole (positive bays in the H-component), is no longer visible. This branch moves away to lower latitudes, where the current intensity decreases abruptly, nearly by one order by comparison with the values in the Fritz zone. Besides, the horizontal vectors of the "evening" branch in Fig.2 a are decreased by comparison with the case of Fig.1 a because Dst(H) and DP(H) are here directed oppositely. By comparison with Fig.1, the night and morning branches of the line $\Delta\vec{Z} = 0$ in Fig.2 shifted substantially toward lower latitudes and formed near the midday meridian an open oval. The latter is displaced relative to the geomagnetic pole toward lower latitudes on the night side. A certain current amplification in these branches of the line $\Delta\vec{Z} = 0$ may be explained by the geometrical addition of horizontal vectors of the polar perturbation with a field of $D_{st}(\vec{H})$ of identical sign. A particularly large amplification of polar storm's $\Delta\vec{T}_{hor}$ will take place on the night side of these branches, since they are disposed in lower latitudes.

However, the influence of the field of D_{st} on the distribution of the perturbed field at high latitudes can not be reduced to a simple geometrical addition of fields DP and D_{st}. It is well known that the sources of both fields are spatially dispersed: the source of DP is in ionospheric currents induced by the penetration of corpuscular particles; the source of D_{st} is in currents at a range of several Earth's radii. Besides the geometrical addition there apparently takes place a particle intrusion. This will lead to a substantial redistribution of current lines' position in high latitudes. It is obvious that the displacement of the evening branch of the line $\Delta\vec{Z} = 0$ toward lower latitudes in Fig.2 a is precisely due to this redistribution. Had there been only a simple geometrical addition of fields DP and D_{st}, the evening branch should have shifted in the opposite direction, that is, toward higher latitudes. Indeed, during the main phase of the storm $D_{st}(\vec{Z}) > 0$ at high latitudes of the northern hemisphere, and the addition with the field DP should be leading to the shift of the evening branch to higher latitudes. However, it may be seen in Fig.2 that the evening branch moved away to lower latitudes. This is corroborated by the presence of negative values of ΔZ on the day-evening side near the night branch of the line $\Delta\vec{Z} = 0$. Moreover, data of the station Irkutsk were especially plotted in Fig.2 a, though this station is located beyond the circle of latitude $\Phi = 50°$. Here the positive value $\Delta\vec{Z} = 254\gamma$ points to the fact that the line $\Delta\vec{Z} = 0$ passes somewhere between Irkutsk and Yakutsk, where $\Delta\vec{Z} = -102\gamma$.

The case considered in Fig.2 a corresponds to a very powerful magnetic storm (on the equator the outer part $D_{st}(H) = -270\gamma$), having caused a substantial shift toward lower latitudes of the branches forming the oval. During average magnetic storms, when $D_{st}(H) \approx 100\gamma$ on the equator, the branches of the line $\Delta\vec{Z} = 0$ are less displaced toward lower latitudes, and the oval on the night side coincides with the Fritz zone. If we convert the distribution of perturbed field illustrated in Fig.2 a into an equivalent current system, we shall obtain in high latitudes a single vortex of oval shape (Fig.2). It may be seen that nearly the entire near-polar region is occupied by the morning vortex, whereupon the main current is concentrated at its boundary. In the morning vortex the total current rose to $7 \cdot 10^5$ a. The evening vortex has been shifted to lower latitudes and attenuated ($0.4 \cdot 10^5$ a). The polar disturbance acquires such a form under the action in the region of radiation belts of the extra-ionospheric current system D_{st}.

In ref.[6, 7] the winter distribution of the perturbed field in high latitudes was constructed by the international perturbed days of the period November-December 1957 and January-February 1958. A simple calculation of the mean value of the D_{st}(H)-variation according to [11] gives for that period near the equator $D_{st}(H) = -57\gamma$. At the same time the mean value of intensity of corpuscular stream's action is estimated by the value $a = 44$. From the above it is clear that for such a relation between D_{st} and $\underline{a}$ one should not neglect the value of D_{st} and in this case it is essential to distort the real field of DP.

It should be noted that the intensity of polar sub-storms is essentially dependent on ionosphere conduction. In winter period (polar night) the intensity of DP is significantly less than that of summer DP, induced by a corpuscular stream of identical intensity. This stems from the fact that in the summer season such a substantial shift toward lower latitudes and the compensation of the evening branch of the line $\Delta Z = 0$ do not usually take place. This may also be well seen from summer synoptical charts of ref. [10].

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*** THE END ***

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