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Location of the Flare on the Sun and Geoeficiency of the Flare Streams

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Abstract

Magnetospheric disturbances caused by the flare streams are investigated in dependence on the location of the flare on the disk of the Sun. There is shown, that the intensity of geomagnetic disturbances is connected not only to the location of the flare on the disk of the Sun, but also to mutual orientation of magnetic fields in the compressed solar wind and in the body of the stream: a) At small angles ($|\Delta \Theta| < 60^\circ$), significant geomagnetic activity is observed in central and eastern streams; and the greatest activity is shown to correspond to the regions of the compressed solar wind in eastern streams. b) At the large angles ($|\Delta \Theta| > 60^\circ$) the geomagnetic activity also is maximal in central and in eastern streams, and in latters the most intensive disturbances are observed near the boundaries of the regions of the compressed wind and the body of the stream. With the increase of the angle $\Delta \Theta$ the increase of the intensity of geomagnetic disturbances in western streams is observed.

1 Introduction

It was shown in papers [1,2] that flares appearing not further than 20° from the central meridian, have a higher probability to cause geomagnetic activity, than flares close to the limb. At the same time, in paper [3] was obtained, that not only in central, but also in non-central (eastern) flare streams the intensity of the interplanetary magnetic field is essentially increased at the moment of arrival of the shock wave and continues to grow in the region of the compressed solar wind. Thus, it is possible to assume, that the streams from eastern flares also should be effective enough. Besides, it is known, that the geoeficiency of the flare streams depends on the angle $\Delta \Theta$ between the vectors of the magnetic field in the compressed solar wind and in the body of the stream [4]. In this connection, in this work, character of change of indices of geomagnetic activity for two types of flare streams is considered: central and not central, in dependence on mutual orientation of magnetic fields in a solar wind and in the body of the stream.

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2 Analysis of experimental data

As experimental material for the research the flares on the Sun of the importance 1B and more, and geomagnetic disturbances, caused by them listed in the paper [5] were used. All events were divided into two groups differing by the location of the corresponding flare on the disk of the Sun: the first group included the central streams \(|\lambda| < 20^\circ\) and the second - non-central flows \(|\lambda| > 20^\circ\), where \(\lambda\) in longitude of the flare. Mean variations of geomagnetic indices (obtained by the superposed epoch method) within the fluxes of the two types are presented in Figures 1a and 1b. Along the axis X there is given time measured in relative units equal to one tenth of the time of passage of the compressed solar wind region by the Earth [6], that is about one hour. It is seen in the Figure, that within the central fluxes, geomagnetic disturbances, begin with the growth of the Kp-indices at the moment of arrival of the shock front, followed by the increase of magnetic activity with the subsequent slow decrease of it in the body of the stream. On the whole, central streams cause in magnetosphere of the Earth moderate and large storms [7].

![Figure 1: Averaged variations of Kp and Dst - indices of geomagnetic activity for various locations of flares on the disk of the Sun: a - central streams; b - non-central; c - western; d - eastern. The moment \(t=0\) corresponds to the moment of the arrival of the shock wave.](image)

Contrary to this, in non-central streams (Figure 1b) geomagnetic disturbances begin with an insignificant jump of the Kp- indices at the moment of arrival of the shock wave, followed by a smooth increase of its intensity in the region of the compressed solar wind and smooth reduction of it in the body of the stream. Thus, non-central streams result in moderate and weak magnetic storms [7]. The behaviour of the Dst-indices in the central and non-central streams is as follows. In the fluxes of the first type, the disturbance begins with an abrupt increase of the geomagnetic field followed by a rather intensive main phase. Fluxes of the second type are characterized by a smooth increase of the geomagnetic field during the initial phase of the substorm, and by rather weak DR-currents during the main phase. As was shown by Bogdanova and Pudovkin [3], there is observed a certain asymmetry in the parameters of fluxes from western and eastern flares. In this connection the non-central flares were separated onto two groups. To the first group the flares located to the west from the central meridian, were referred, and to flares of the second group -
the flares observed to the east of the central meridian. In Figures 1c and 1d the variations of indices of geomagnetic activity for western and eastern streams are shown. It is seen in the Figure, that variations of the Kp-indices in western streams begin with smooth increase of its values at the moment of arrival of the shock wave accompanied by its growth in the region of the compressed wind, up to the arrival of the body of the stream, where they are maximum. At the same time, in eastern streams the intensive growth of the Kp-index begins at the moment of arrival of the shock wave, and the maximum intensity is achieved in the region of the compressed solar wind, then the intensity of geomagnetic disturbances, gradually decreases. The behaviour of the Dst-variation during the main phase of the storm in western and eastern streams is noticeably different. In eastern streams the main phase is more intensive and deep; in western streams the Dst-currents slowly increase in the region of the compressed solar wind and achieve the maximal intensity in the body of the stream. Thus, Figure 1 shows, that the level of geomagnetic disturbances depends on the location of the stream source on the disk of the Sun by an asymmetrical manner so that, not only central, but also eastern flare streams produce at the surface of the Earth relativity intensive magnetic storms. At the same time it is seen that on the whole geomagnetic disturbances in both the western and eastern streams are expressed more poorly, than in central ones (Figure.1a). In the paper by Bogdanova and Pudovkin [4] there was shown, that the level of geomagnetic activity is influenced also by mutual orientation of magnetic fields in the solar wind and in the body of the stream. In this connection we have separated all the streams: central, western and eastern ones into two groups: according to the value of the angle $|\Delta \Theta| < 60^\circ$ and $|\Delta \Theta| > 60^\circ$. In Figure 2, the average variations of indices of geomagnetic activity Kp and Dst within the flare streams of the two groups, are shown.

As it is seen in Figures 2a and 2c, within central and eastern streams the values of Kp-indices achieve their maximum in the region of the compressed wind, increasing there by 2 times, then their recession in the body of the stream up to a level corresponding to that within the background wind are observed. In western streams (Figure 2b) the moment of arrival of a shock wave is marked by insignificant jump of the Kp-indices with its subsequent growth in the region of the compressed solar wind. The behaviour of the Dst-indices in central and eastern streams of considered group (Figure 2a and 2c) corresponds to the development of typical geomagnetic storms. So, in some hours after a well expressed initial, the abrupt and deep main phase (especially obviously expressed at eastern streams) follows. Another picture is observed at western flare streams. Here duration and, in particular, intensity of Dst-disturbances are insignificant; an initial and main phase storm are developed un insignificantly. Let us consider character of disturbances of the geomagnetic field (Kp, Dst-indices), caused by passage by the Earth of the streams caused by flares of the second group ($|\Delta \Theta| > 60^\circ$). In Figures 2 it is seen, that the most intensive geomagnetic disturbances are connected to passage of the shock wave of the central streams (Figure 2d), here intensity of the Kp-indices increases by 2.5 times at the shock wave and in the region of the compressed wind, and with the arrival of the body of the stream begins to decrease. In contrast to eastern streams in western streams the maximum Kp-indices are observed during passage of the body of the streams, instead of the region of the compressed solar wind. In the central streams the initial and main phase is well expressed. At eastern streams, as it is seen in Figure 2f, after passage of the
Figure 2: Averaged variations of Kp and Dst - indices of geomagnetic activity for various locations of flares on the disk of the Sun for various mutual orientations of magnetic fields $|\Delta \Theta|$ streams with: $|\Delta \Theta| < 60^\circ$: a - central streams; b - western; c - eastern; $|\Delta \Theta| > 60^\circ$: d - central streams; e - western; f - eastern. The moment $t=0$ corresponds to the moment of the arrival of a shock wave.

The obtained results allow one to arrive at the following conclusions:

1. The intensity of geomagnetic disturbances is connected not only to the location of the flare on the disk of the Sun, but also to the mutual orientation of magnetic fields in the compressed solar wind and in the body of the stream.
a) At small angles ($|\Delta \Theta| < 60^\circ$), significant geomagnetic activity is observed in central and east streams; and the greatest activity is shown to correspond to the regions of the compressed solar wind in eastern streams.

b) At large angles ($|\Delta \Theta| > 60^\circ$), geomagnetic activity also is maximal in central and in eastern streams, and in latters the most intensive disturbances are observed near the boundaries of the region of the compressed wind and the body of the stream.

2. With the increase of the angle $\Delta \Theta$ the increase of the intensity of geomagnetic disturbances in western streams is observed.

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