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RED AURORAL ARCS AND GEOMAGNETIC STORMS

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Abstract. The red auroral arc or the high latitude red arc is a rare form of the red aurora of the A type. In the years of high solar activity during the 19, 20 and 22 cycles there were distinguished 13 cases of such arc occurrence. Average behavior of the *Dst* variation during the observations of these arcs was constructed by the superimposed epoch analysis. It is shown that in general red auroral arcs are observed during the storm main phase when the *Dst* variation subsides from -65 nT to -102 nT within 2 hours. Using the well-known empirical relationships we estimated the solar wind parameter - the average value of the southward oriented IMF B_z component - as well as the voltage drop across the polar cap. The average potential drop appeared to reach 140 kV during such events, which is significantly higher than 50 kV, the value typical for usual auroras.

1. Introduction

Red auroral arcs or the high latitude red arcs (HLRA) are one of the forms of the red auroras of the A type: their luminosity is determined by enhancement of intensity of the forbidden red oxygen lines [OI] λ 6300-6364 Å within their spectrum. Unlike the stable middle latitude red arcs (SAR arc) (see, for example, [*Rees and Roble*, 1975]), the red auroral arcs are investigated less thoroughly.

The first instrumental observations of such an arc were performed during the International Geophysical Year on Alaska [*Rees and Deehr*, 1961]. Later, at the symposium in Boulder the first preliminary results of the investigations of such arcs were discussed and some conclusions on the relationship of the red auroral arcs and SAR were made (see, for example, [*Elvey*, 1965]). Later a red auroral arc was registered by ISIS-II satellite. *Shepherd et al.* [1980] named this arc an unusual SAR-arc because of its high latitude location and high intensity of 6300 Å red emission.

The first attempt to generalize and systematize the features of the red auroral arcs has been taken recently [*Yevlashin et al.*, 1998]. It has been shown that such arcs always appear during the periods of high helio-geophysical activity. Besides the intensity enhancement of the 6300-6364 Å emissions within the spectra of the red auroral arcs, there have been registered the 1NGN_2^+ bands, and, in particular, the (0-1) 4278 Å band, the green oxygen line [0I] 5577 Å, and some other emissions.

This work is aimed to estimate the magnetospheric parameters during great helio-geophysical disturbances on the basis of the information about geomagnetic activity during the observations of the red auroral arcs.

2. Results of observations

The data of 50 nights with good atmospheric transparency have been analyzed to distinguish the regularities of the red auroral arcs (HLRA). These nights were characterized by high geomagnetic disturbance and belonged to the periods of great solar activity of 19, 20 and 22 Solar cycles when the red aurora of the A type were observed. Experimental material of the spectral camera C-180-S, all-sky camera C-180 combined with the recordings of visual observations at the stations of Murmansk (=64 °) and Loparskaya located 40 km southward has been used. 11 cases of red auroral arcs have been registered altogether. The results of measuring the HLRA parameters for these cases are presented in Table 1 including the data on the red auroral arcs given in former works [*Rees and Deehr*, 1961; *Shepherd et al.*, 1980].

Analyzing the data from Table 1 as well as from the paper by *Yevlashin et al.* [1998] it can be seen that the red auroral arcs are mainly observed during large geomagnetic storms which are characterized by minimum values of the *Dst* within the limits from -57 nT to -354 nT with the mean value of Dst_{min} = -192 nT. The time of the red auroral arc existence as observed at one station is about 2 hours. The mean meridian extent of the arcs in the zenith of the observation station is about 200 km as measured at the level of half maximum intensity of the arc. The scale of intensities of the red oxygen line 6300 Å referred to the zenith deviates within the limits from 7 to 70 kR with the average values of the main emissions being I_{6300} = 22.2 kR; I_{5577} = 6.7 kR; I_{4278} = 9.3 kR. The height of the maximum luminosity of the emission 6300 Å according to the measurements presented in the works [*Rees and Deehr*, 1961; *Shepherd et al.*, 1980] reaches the value of about 350 km; indirect data of measuring the height of the maximum luminosity according to the emission ratio I_{6300}/I_{5577} (following the presentation developed in [*Rees and Luckey*, 1974]) yield less definite values (>250 km).

Table 1. Geomagnetic activity during the observation of the the high latitude red arcs (HLRA)

	Date	Place of observation	Time of observation, *UT*	*Dst* in the moment of observation, nT	Dst_{min}, nT
1	10.11.58	Murmansk	17.00-19.30	-10	-57
2	13.12.58	Murmansk	12.50-15-50	-25	-111
3	30.10.59	Murmansk	16.00-18.20	6	-83
4	05.12.59	Murmansk	13.00-15.00	-44	-170
5	09.04.59	Murmansk	20.45-22.30	-8	-127
6	01.11.68	Loparskaya	14.40-16.00	-123	-231
7	23-24.03.69	Loparskaya	23.00-01.00	-166	-240
8	24.03.91	Loparskaya	20.00-21.40	-128	-298
9	24-25.03.91	Loparskaya	23.40-01.40	-298	-298
10	28.10.91	Loparskaya	15.00-17.00	-193	-251
11	08.11.91	Loparskaya	13.40-16.00	-42	-354
12	04.08.72	New Zealand, ISIS-2	6.00	-70	-125
13	27.11.59	Alaska	02.35-05.20	-22	-160
	Average	$L = 4$-6	$\Delta T \approx 2$ hr	-86	-192

The red auroral arcs observed at the latitudes corresponding to $L = 4$-6 are mainly (i.e. in 8 cases out of 13) located poleward the region of proton precipitation. For 4 cases it was impossible to localize HLRA and proton precipitation for certain reasons. For one case on 5-6.12.59 the quantitative measuring of the location of the proton precipitation regions and red auroral arc was performed. The difference of the hydrogen emission intensity maximum under supposition of proton precipitation at the height of 110 km and the red auroral arc located at the height of 350 km was taken as mapped to the earth surface. It turned out that the maximum distance between these two phenomena at 13.45 UT reached the latitude of 3 degree. The drift of the HLRA in the north-south direction varied within the limits from 3 to 18 km/min with the average value of 8.5 km/min. Electron density in the F ionospheric region reached 10^6 cm^{-3} when HLRA was in the zenith of st. Murmansk on 13-14.12.58 as evaluated by the ionospheric station data according to the formula $N = 1.24\times10^4 f_c$, where f_c is the critical frequency of $F2_s$ layer in MHz.

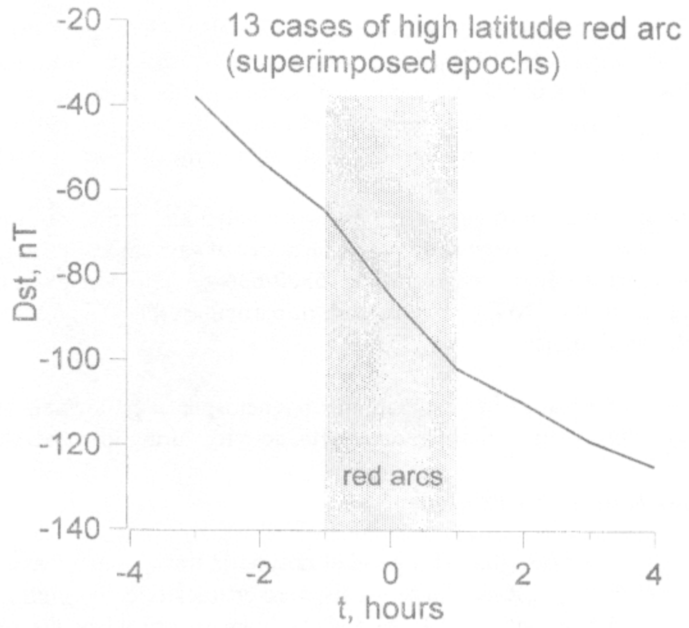

Figure 1. Average behavior of the Dst variation during the HLRA observations.

3. Average geophysical parameters during observations of the red auroral arcs

3.1. Behavior of the *Dst* variation

Averaged behavior of the *Dst* variation during the 13 cases of the appearance of the red auroral arcs has been found by the superimposed epoch method. The moment of the red auroral arc observation half time rounded to the whole hour has been accepted as a zero moment. The result of this superposition is presented in Figure 1. The mean duration of the arc observations at the ground-based stations was 2 hours.

Figure 1 shows that the red auroral arcs are mainly observed during the main phase of a geomagnetic storm when *Dst* drops from -65 nT to -102 nT for two hours. Such a rapid drop of *Dst* is usually associated with a significant southward component of the IMF and intensification of the magnetosphere-ionosphere convection.

3.2. Estimate of the IMF southward component

Behavior of the *Dst* variation is usually described by the equation (see, for example, [*Feldstein*, 1992])

$$\frac{dDst}{dt} = Q - \frac{Dst}{\tau} \qquad (1)$$

where Q is a certain function of the solar wind parameters, τ is the characteristic time of decay of the currents responsible for the storm depression. *Burton et al.* [1975] obtained the following empirical relation for storm conditions:

$$Q = -5.4\,(E_y - 0.5)\,, \qquad (2)$$

$$\tau = 7.7 \text{ hr} \qquad (3)$$

where $E_y = -VB_z$ is the dawn-to-dusk electric field component in the solar wind expressed in mV/m, V is the solar wind velocity, B_z is the IMF vertical component. Figure 1 yields (within the interval from -1 to 1 hour) $dDst/dt$ = -18.5 nT/h, $\langle Dst \rangle$= -86 nT. Substituting these values and (3) into (1) we get Q = -30 nT/hr. Substituting the latter value into (2) we get E_y = 6 mV/m. Assuming V = 500 km/s we obtain the southward IMF B_z = -12 nT.

3.3. Estimate of the potential drop between the morning and evening boundaries of the polar cap

Doyle and Burke [1983] obtained the following empirical formula, which relates U, the potential drop between the morning and evening boundaries of the polar cap, with E_y, the dawn-to-dusk electric field component in the solar wind:

$$U = 14\,E_y + 55.3 \qquad (4)$$

where U is expressed in kV, E_y in mV/m. Substituting the value E_y = 6 mV/m obtained in the previous subsection into (4) we get U = 140 kV that is significantly higher than during appearance of ordinary auroras (50 kV [*Akasofu*, 1979; *Stern*, 1984]).

4. Conclusion

Some data on the parameters of the interplanetary medium and earth's ionosphere have been obtained as a result of investigations of the *Dst* variation behavior during the red auroral arc observations. Further, it is supposed to evaluate other features of the near-earth space by using the characteristics of the red auroral arcs.

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