Geophysics

A. P. NIKOLSKII

1957

SovietRxiv

Abstract

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Geophysics

A. P. NIKOLSKII

ON THE QUESTION OF THE GEOGRAPHICAL DISTRIBUTION AT HIGH LATITUDES OF ANOMALOUS ABSORPTION OF RADIO WAVES IN THE IONOSPHERE

(Presented by Academician V. V. Shuleikin on 23 January 1956)

It is known that intense ionospheric disturbances at high latitudes are characterized by a number of phenomena, in particular by the fact that, during vertical sounding, a complete absence of reflections from the ionospheric layers is observed at all frequencies of the short-wave range (anomalously high absorption —radio blackouts).

Anomalously high absorption (hereafter we shall call it simply absorption) is observed in the region of high latitudes. The greatest number of absorption cases falls approximately in the zone of maximum intensity and recurrence of magnetic disturbances and aurorae, located at geomagnetic latitudes $\Phi = 65—68^{\circ}$.

The occurrence of absorptions of the type considered is connected in a considerable number of cases with the simultaneous appearance of magnetic disturbances. This gave grounds for assuming that the cause of these absorptions is the penetration of solar corpuscles into the upper layers of the earth' s atmosphere. The regularities of the geographical distribution of absorptions and of changes in the probability of their appearance with the course of time (diurnal variation, seasonal variation, etc.) have until very recently been insufficiently studied, and many questions remain whose clarification is necessary both for solving scientific problems and for the practice of radio communication.

One of the little-studied questions is the dependence of the time of occurrence of the maximum in the diurnal variation of the probability of appearance of absorptions on geographical position. From observations it is known that absorptions of the type considered most often occur in the first half of the day. However, it has not so far been possible to characterize this in greater detail because of the absence of systematized data from a broad network of ionospheric stations.

Meek ([1]) investigated absorption using data from 17 ionospheric stations. However, his conclusions, based on an analysis of only 9 large ionospheric disturbances, require additional confirmation. Hagg ([2]) and Cox and Davies ([3]) published the results of a study of absorptions from observations at 19 ionospheric stations, most of which operated in the period from 1949 to 1953. Data on the location of these stations are given in Table 1; data for some other stations are placed in the same table.

In papers ([2,3]) there is information on the diurnal variation of the number of absorption cases and on the time of their most frequent occurrence. As the time of maximum recurrence of absorptions the authors took the moment corresponding to the phase of the maximum of the first harmonic of the Fourier series. In our opinion, taking into account the irregular character of this phenomenon, it is more correct to take the time corresponding to the immediate maximum on the curve of the diurnal distribution of the probability of absorptions, which is what we have done. Table 1 gives these moments, referred to local time, taken from the curves in paper ([2]) with an accuracy of up to ±0.5 hour, and the same moments, referred to mean

···mean Greenwich time. The difference between the moments referred to mean Greenwich time and the moments corresponding to the maximum of the first harmonic of the Fourier series reaches 4 hours for some stations.

Consideration of the data (Table 1) shows that, for those ionospheric stations for which information on magnetic activity is available, the time

Table 1

No.	Stations	ϕ	λ	Maximum time, hours: taken from the curves ([5])	Maximum time, hours: mean Greenwich	Maximum time, hours: taken from the spirals of Fig. 1, mean Greenwich	Difference
1	Kiruna	67°.8 N lat.	20°.5 E long.	6.0	5.0	2.0	+3.0
2	Tromsø	69.7	19.0	7.0	6.0	3.0	+3.0
3	Oslo	60.0	11.0	very few cases	very few cases	very few cases	very few cases
4	Reykjavík	64.1	21.8 W long.	3.0	4.5	6.0	−1.5
5	Narssarssuaq	61.2	45.4	6.0	9.0	9.0	0.0
6	St. Johns	47.6	52.7	4.0	7.5	7.0	+0.5

No.	Stations	ϕ	λ	Maximum time, hours: taken from the curves ([5])	Maximum time, hours: mean Greenwich	Maximum time, hours: taken from the spirals of Fig. 1, mean Greenwich	Difference
7	Fort Chimo	58.1	68.3	6.0	10.5	11.0	−0.5
8	Clyde River	70.5	68.6	10.0	14.5	14.5	0.0
9	Ottawa	45.4	75.7	4.0	9.0	9.0	0.0
10	Churchill	58.8	94.2	9.0	15.0	14.5	+0.5
11	Resolute Bay	74.7	94.9	13.5	19.5	19.0	+0.5
12	Baker Lake	64.3	96.0	10.5	17.0	15.5	+1.5
13	Winnipeg	49.9	97.4	6.5	13.0	14.0	−1.0
14	Portage	49.9	98.3	no data	no data	no data	no data
15	Prince Rupert	54.3	130.3	6.5	15.0	15.5	+0.5
16	College	64.9	147.8	8.0	18.0	17.0	+1.0
17	Anchorage	61.2	149.9	6.0	16.0	16.5	−0.5
18	Point Barrow	71.3	156.8	10.5	21.0	18.0	+3.0
19	Adak	51.9	176.6	very few cases	very few cases	very few cases	very few cases
20	Washington	39.0	77.5	4.0	9.0	9.0	0.0
21	Spitsbergen	78.0	15.0 E long.	7.0	6.0	6.0	0.0
22	Tikhaya Bay	80.3	52.8	7.5	4.5	4.0	+0.5

of maximum probability of absorptions falling in the first half of the day agrees well with the time of occurrence of the maximum of morning magnetic disturbances.

On the basis of an analysis of observations from 28 high-latitude magnetic sta-

Fig. 1. Dependence of the occurrence of anomalous absorption on geographic latitude according to ([3]). The numbers at the points correspond to the stations in Table 1.

Figure 1: Fig. 1. Dependence of the occurrence of anomalous absorption on geographic latitude according to ([3]). The numbers at the points correspond to the stations in Table 1.

tions, including observational data for the Central Arctic, we showed ([4], [6]) that the isolines of simultaneous (in universal time) occurrence of the maximum of morning magnetic disturbances constitute a system of spirals emerging from the pole of homogeneous magnetization of the Earth.

Since it had been noted that the maximum probability of the occurrence of absorptions in their daily distribution at some stations coincides with the maximum of morning magnetic disturbances, for all stations listed in Table 1 the moments of the maximum in universal time were taken from the spirals (Fig. 1 ([6])) with an accuracy of $±0.5hour(seeTable1).ItshouldbenotedthatthespiralsofFig.1(^{6}$), on the basis of the magnetic data available to us, were drawn in the western hemisphere only down to $\phi = 60°$. Therefore, in order to obtain the moment of the maximum for such stations as Winnipeg, Ottawa, and others, the spirals were extrapolated to latitude $\phi = 40°$. The time

Fig. 1. Dependence of the occurrence of anomalous absorption on geographic latitude according to ([3]). The numbers at the points correspond to the stations in Table 1.

of the maximum probability of absorption, obtained from the experimental curves, practically coincides with the time taken from the spirals.

Consideration of the discrepancies shows that for 16 stations this discrepancy is approximately ± 0.5 hour, i.e., equal to the accuracy with which the moments are taken from the curves. Only for stations located in the zone of the maximum of magnetic disturbances (Kiruna, Tromsø, and Barrow) does this discrepancy reach larger values, up to 2–3 hours. In this connection it should be borne in mind that the accuracy with which the spirals were drawn in Fig. 1 of work ([6]) is least precisely in this region, since the intensity of the morning maximum of magnetic disturbances at these latitudes is very small and the time of its occurrence is difficult to determine.

With regard to the results of this consideration, however, it is necessary to note the following. The absolute maximum in the frequency of occurrence of absorptions falls approximately in the zone of the maximum of magnetic disturbances and auroras, in which nocturnal magnetic disturbances attain their greatest development, whereas the time of the most frequent occurrence of absorptions for stations located in this zone (Churchill) agrees better with morning magnetic disturbances. For stations located in the auroral zone, the maximum in the

Figure 2

Figure 2: Figure 2

number of absorptions does not coincide with the nocturnal maximum of magnetic disturbances, but appears 3-6 hours later. All these questions are subject to further investigation and discussion.

Fig. 2. Geographic distribution of equal recurrence of anomalous absorption for the summer season according to ([2])

From the analysis of the diurnal variation of magnetic activity at high latitudes, we ([4]) put forward the supposition that in the near-polar region, north of $\Phi = \sim 75^{\circ}$, there should be situated a second zone of increased intensity and recurrence of magnetic disturbances; the form and position of the proposed second zone are shown in Fig. 1. The results of absorption observations given in ([2], [3]) confirm this supposition well. Thus, for example, it is seen from Fig. 1 that the largest number of absorptions is observed at the station Churchill, which is located in the well-known first, more southerly zone of maximum intensity and recurrence of magnetic disturbances and auroras. Then, farther to the north, there is a strong decrease in the number of absorptions up to Baker Lake station, after which a large rise is again observed toward Resolute Bay station. Comparison of these data with Fig. 1 ([6]) shows that Resolute Bay station is indeed located precisely in the second zone proposed by us, whereas Baker Lake station lies between the first and second zones.

Thus, the distribution of the occurrence of absorptions at four high-latitude stations located on one meridian does not contradict the supposition of the existence in the near-polar region of the Arctic of a second zone of increased intensity and recurrence of magnetic disturbances, but rather confirms it.

The supposition concerning the possible existence of a second zone is also confirmed by the data presented in work ([2]). These data (see Figs. 2 and 3) are presented in the form of isolines of equal recurrence of absorptions and of equal diurnal amplitudes of its variability. The points in these figures correspond to the stations listed in Table 1 (Nos. 1-19).

Examination of these figures clearly shows that in the sector of longitudes 90-100° W, both the total number of absorption cases and the diurnal amplitude of the recurrence of their occurrence north of the first, more southerly, zone decrease. However, this decrease continues

only up to the latitude $\varphi = 65^{\circ}$, after which both characteristics of the absorption phenomenon again increase appreciably. What occurs farther to the north, still closer to the pole, cannot be stated. It should be noted that such a latitudinal dependence in the changes in the total number of cases of absorption and in the amplitude of their diurnal variation is observed most distinctly in summer. If one takes into account that magnetic disturbances in the near-polar

Fig. 3. Geographical distribution of equal diurnal amplitudes of variation in the recurrence of anomalous absorption according to ([2])

Figure 3: Fig. 3. Geographical distribution of equal diurnal amplitudes of variation in the recurrence of anomalous absorption according to ([2])

region of the Arctic also attain their greatest intensity in summer, then the connection between the phenomena of morning magnetic disturbances and morning absorptions in the ionosphere becomes still more probable.

Consideration of Figs. 2 and 3 shows that the data on the geographical distribution of absorptions and on the diurnal variations in the probability of their occurrence well confirm the supposition of the existence in the near-polar region of the Arctic of a second zone of increased intensity and recurrence of magnetic disturbances, and that the position and form of this zone have been shown correctly as a first approximation. There is now reason to suppose that it is also a second zone for ionospheric disturbances, more precisely, for anomalously high absorption.

Fig. 3. Geographical distribution of equal diurnal amplitudes of variation in the recurrence of anomalous absorption according to ([2])

It should also be pointed out here that Alfvén, in his latest work ([5]), shows the possibility of the existence of a second, inner zone, proceeding from theoretical considerations.

The results obtained make it possible to conclude that the regularities of morning magnetic disturbances and anomalously high absorption of radio waves in the ionosphere, characteristic of high latitudes, are in a number of respects the same as regards their geographical distribution. This gives grounds for assuming that the corpuscles responsible for the occurrence of morning magnetic disturbances are probably at the same time the cause of a significant part of the cases of anomalously high absorption of radio waves in the ionosphere. On the basis of an analysis of the results of the study of morning magnetic disturbances, we ([6]) presented evidence indicating the correctness of certain propositions of Birkeland–Størmer' s theory of magnetic disturbances and auroras. The results of the present work also confirm this.

Arctic Scientific Research Institute
of the Main Northern Sea Route Administration

Received
1 VIII 1955

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