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A PRELIMINARY ANALYSIS ON THE HORIZONTAL SCALE OF THE WINTER ABSORPTION ANOMALY

By

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Abstract

The horizontal scale of the winter absorption anomaly of the radio waves in the *D*-region is estimated by using the noon values of f_{min} at 25 stations during the period from December 1965 to March 1966. The analytical method is to obtain the global distribution of the isopleth of cross correlation coefficients at 24 stations to Moscow station during the period of 90 days or 120 days. The results show a qualitatively similar west- east pattern to that of the planetary waves of wave number one.

1. Introduction

Many studies from different view points have been made on the cause of the winter absorption anomaly of the radio waves in the *D*-region (65–90 km). One important theme of these studies is dynamical effects on this phenomenon. Recent studies on this theme have generally been divided into two branches. One is that, according to the dissipation of kinetic energy of the internal gravity waves, the heating of the *D*-region occurrs and thus the photochemical reactions of producing the electron density are facilitated due to the temperature dependency of the coefficients of these reactions (Sechrist [1967]). The other is that the electron density increase is brought about by the vertical transport of electron and nitrogen oxgen which is the main source of the electron production in the *D*-region, caused by planetary waves (Geisler and Dickinson [1968], Gregory and Manson [1969], Kawahira [1971]).

However, it have not been confirmed by either direct or indirect observation whose mechanism is more valid. The horizontal scale of the internal gravity waves is, at most,in the order of hundred kilometers, on the other hand, that of planetary waves is in the order of thousands to ten thousands kilometers. Therefore, the horizontal scale of the winter absorption anomaly is the vital factor in clarifying the dynamical effects of these two waves.

In this paper, a preliminary analysis to estimate this scale is made on the assumptions that the winter absorption anomaly is the same scale of the electron density variation in the *D*-region and the stationary pattern is predominant.

2. Analytical method

For analysis, the noon values of f_{min} during the period from 1st December 1965

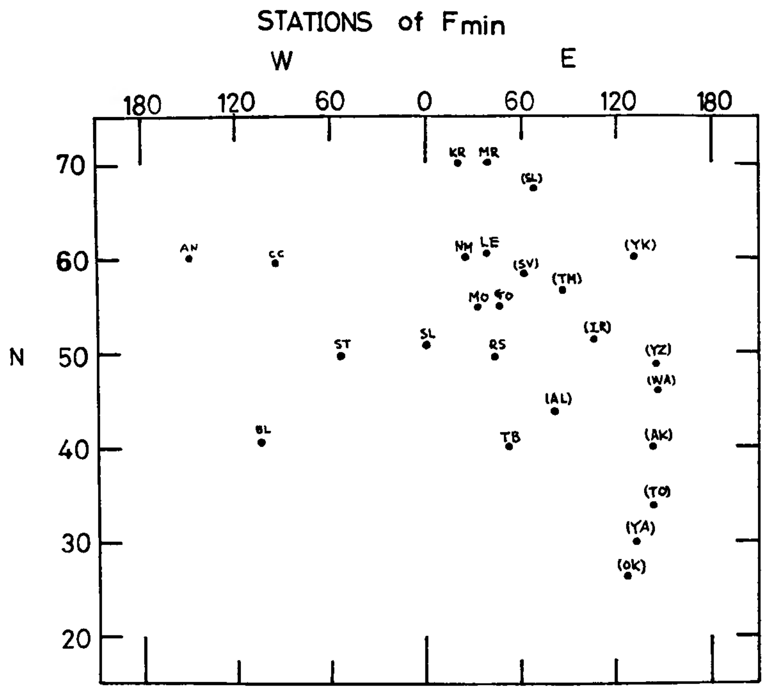

Fig. 1. Global distributions of stations.

Table 1. List of stations and their locations.

Station	(Abbreviation)	Latitude	Meridian
Akita	(AK)	39.7°N	140.1°E
Alma Ata	(AL)	43.2°N	76.9°E
Anchorage	AN	61.2°N	149.9°W
Boulder	BL	40.0°N	105.3°W
Churchill	CC	58.8°N	94.2°W
Gorkiy	GO	56.2°N	44.3°E
Irkutsk	(IR)	52.5°N	104.0°E
Kiruna	KR	67.8°N	20.4°E
Leningrad	LE	60.0°N	11.1°E
Moscow	MO	55.5°N	37.3°E
Murmansk	MR	69.0°N	33.1°E
Nurmijarvi	MN	60.5°N	24.7°E
Okinawa	(OK)	26.3°N	127.8°E
Rostov-on-Don	RS	47.2°N	39.7°E
Salekhard	(SL)	66.6°N	66.7°E
Slough	SL	51.1°N	0.6°W
St John's	SJ	47.5°N	52.8°W
Sverdlovsk	(SV)	56.6°N	61.1°E
Tbilisi	TB	41.8°N	44.8°E
Tokyo	(TO)	35.7°N	139.5°E
Tomsk	(TM)	56.5°N	85.0°E
Wakkanai	(WA)	45.4°N	141.7°E
Yakutsk	(YK)	62.0°N	129.7°E
Yamagawa	(YA)	31.2°N	130.6°E
Yuzho-Sakhaiinsk	(YZ)	47.0°N	143.0°E

to 31st March 1966 are adopted at 25 stations shown in Fig. 1 and their locations are shown in Table 1. The method for estimating the horizontal scale of the winter absorption anomaly is as follows.

The cross correlation coefficient C_n of the n-th station to the master station is obtained by using the daily variables. Thus the global distribution of C_n should describe the scale and C_n is defined as follows

$$C_n = \frac{\sum[R_k(I)-\overline{R_k(I)}][R_n(I)-\overline{R_n(I)}]}{[\sum R_k(I)^2-\overline{R_k(I)^2}]^{1/2}[\sum R_n(I)^2-\overline{R_n(I)^2}]^{1/2}}, \tag{1}$$

where R(I) is the daily variables at each station and suffixes k and n are master and n-th station. — means the time average of analyzed period. The variable R(I) must be independent of non-dynamical effects such as geomagnetic disturbance in order to identify dynamical effects. The evidence shown in Fig. 2 by Belrose and

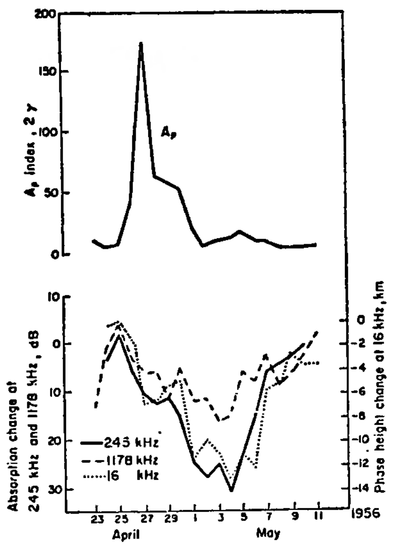

Fig. 2. Changes from normal of the mean reflection height of 16kHz waves (1800–2000hr) and of the mean absorption at 245 and 1178kHz (from time corresponding to $x=98°$ unitl 2200hr), plotted downwards, for days about the magnetic storm occurring on 27 April 1956. Also shown in the variation of the planetary magnetic disturbance idex, A_p (after Belrose and Tohmas, 1968)

Thomas [1968] suggests that the effect of geomagnetic storm causes the increase of the absorption and therefore the electron density which persists a few days after the storm is over. Considering that the standard value of f_{min} is different at each station (Sinno and Higashimura [1969]), the day to day change of f_{min} is adequate for the daily variable. Also, as the square of f_{min} is proportional to the electron density in the D-region, the daily variable, R(I), is defined as follows:

$$R(I) = \frac{f_{min}^2(I+1) - f_{min}^2(I)}{[A_p(I-3)]} \tag{2}$$

Thus, the global distribution of C_n would show the area of the similar day-to-day change of the electron density in the D-region based on the assumption that the stationary pattern is more dominant than the transient one. Also the dynamical effects on the D-region would be suggested by this result, assuming that the winter absorption anomaly is same scale to this.

3. Results

In order to avoid geomagnetic disturbance, Moscow (55.5°N, 37.3°E, geomagnetic latitude 50.8°N) is selected as the master station.

In the case of the period of 90 days from 4th December 1965, the analytical result is shown in Fig. 3(a). The broken line signifies the zero line of the isopleth and the thick line, that of positive coefficients, 0.5. Positive region includes the values larger than 0.5, but, negative region includes, at most, the value of −0.4. However, the pattern of isoplth shows the similar pattern of the planetary waves of wave number one whose scale is the order of ten thousands kilometers. Lateral width along 120°E is about 30 degrees latitude but, in the other region, this width is not clear. In Fig. 3(b), the results in the case of a 90 days period from 3rd January 1966 is shown. Similarly in Fig. 3(a) negative values are, at most, −0.4 and the west-east distribution is similar to that of planetary waves of wave number

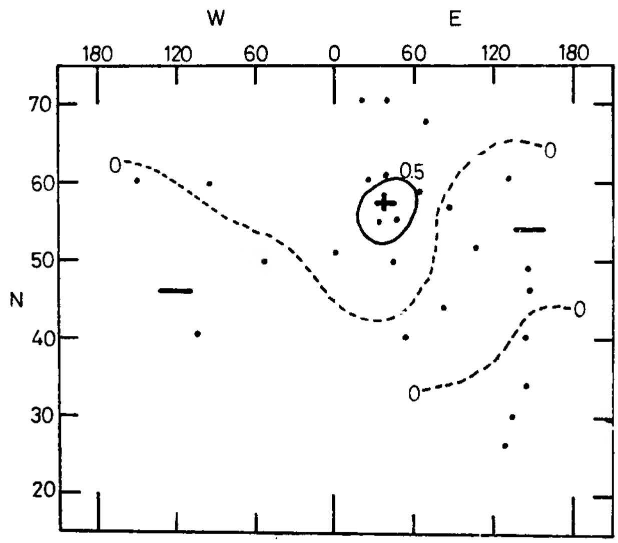

Fig. 3(a). Isopleth of the global distribution of the cross correlation coefficients to Moscow station during the period of 90 days from 4th December 1965.

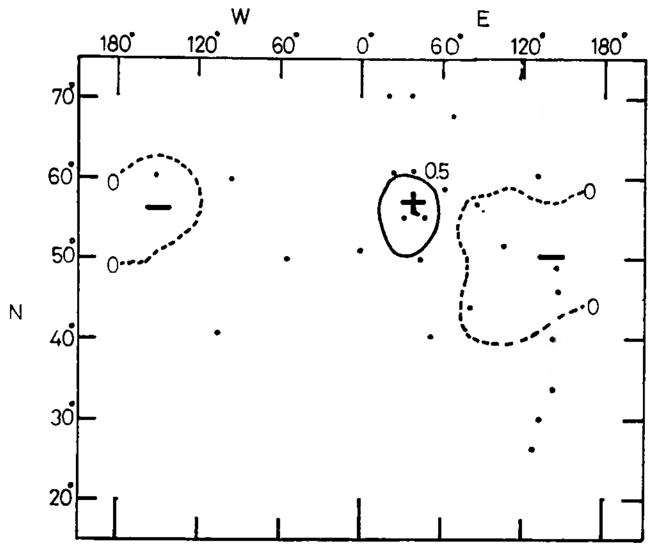

Fig. 3(b). Same as in Fig. 3(a), except the period of 90 days from 3rd January 1966.

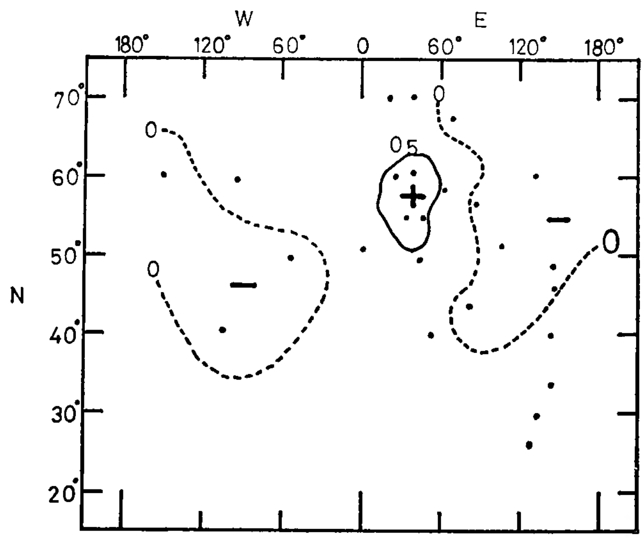

Fig. 4. Same as in Fig. 3(a), except the period of 120 days from 4th December 1965.

one. The lateral width, however, is more vague than in Fig. 3(a). The period for analysis changes from 90 days to 120 days for the statistical results to become more valid. The result of this period is shown in Fig. 4. The west-east pattern is more clearly similar to that of the planetary waves of wave number one than former results. The lateral width seems to be more than 30 degrees latitudes and also the negative values are not less than —0.4.

4. Discussion

Thomas [1961] estimated the horizontal scale of the winter absorption anomaly by using the daily noon values of f_{min} and absorption during the period from December 1958 to January 1959. His results shown in Fig. 5 indicate that the same day to day changes of these variables have the scale of near 20 degrees latitude and 100 degrees meridian. These results are summarized in Fig. 6 in vector form. The length of arrow singifies the magnitude of day-to-day changes of absorption and northward direction of that signifies the increasing tendency of absorption and the southward direction, the decreasing tendency. The thick line is the geomagnetic latitude. The global pattern of the winter absorption anomaly is similar to the pattern of the planetary waves of wave number one. According to these results, Thomas suggested that the area of the winter absorption anomaly would be at least 10^6 km^2.

Comparing the results described in this paper with Thomas's, the feature of west-east distribution is the same and the lateral width is partly the same if the electron density variation is the same scale as that of the winter absorption anomaly.

Following the computation by Matsuno [1971], the stationary planetary waves of wave number one could propagate vertically and reach, at most, mesopause level ($\sim$85 km) in winter. This result suggests that the planetary waves should affect the electron density profile in the *D*-region. This consideration would suggest that the

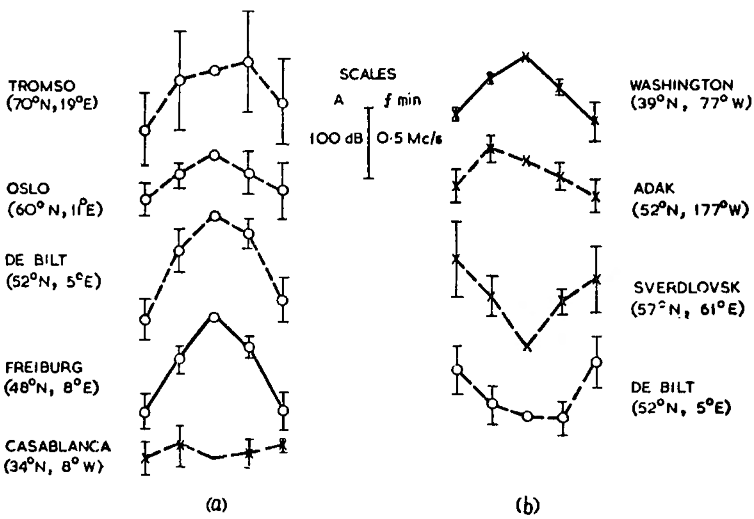

Fig. 5. Mean diviations of absorption about values on epoch days which are the days of peak absorption of each master station during the period from December 1957 to January 1958: (a) Freiburg as Master; (b) Washington as Master (0-*Absorption used*; ×-f_{min} *used*) (after Thomas, 1961)

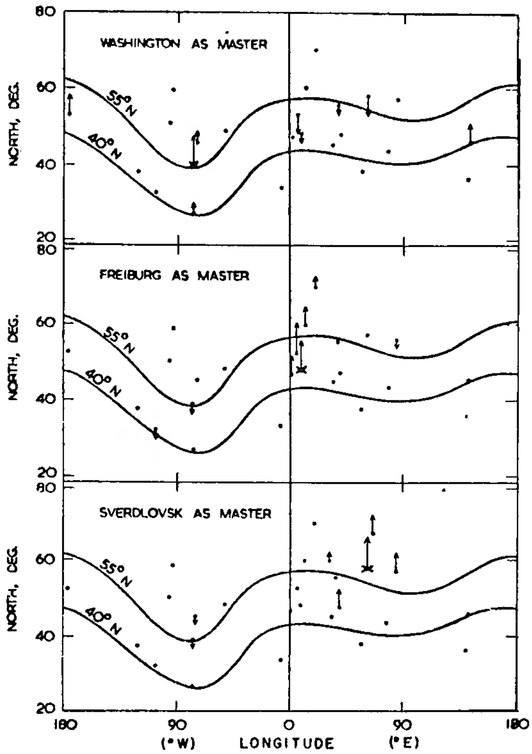

Fig. 6. Superposed epoch relations using different master stations (—40°N and 55°N magnetic latitude; ×Master Station) (after Thomas, 1961)

scale of the winter absorption anomaly would be in order of ten thousand kilometers. The results obtained in this paper may support the dynamical effects of planetary waves on this phenomenon.

However, as the value of coefficients is not large, it is likely not easy to decide finally the scale of the winter absorption anomaly by the results described in this paper. For estimating this, the vital problem is how the effect of geomagnetic disturbances eliminate from the analysis. Thus, for future analysis, a day with as little geomagnetic disturbances as possible would be chosen.

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