the IGY and the Gottingen (52.3°N geom. lat.) data relative to the nucleonic component of the cosmic radiation during this period were used[6]. In Fig 4, where the bi-hourly mean intensity of this component, the K_p values and the hiss occurrence have been plotted as a function of time, one finds again the 18 hours delay between the hiss maximum activity and the SC. Moreover, it appears that the maximum amplitude of the cosmic ray storm lags about 20 hours behind the same SC, a value which is comparable to the previous one.

It is established that the cosmic ray storm occurs when the earth enters into a plasma cloud, 24 to 48 hours after an important solar event. Otherwise, some authors[7] suggested that the impact of this plasma against the lines of force of the earth's magnetic field starts the SC of the magnetic storm. As the latter is followed, 18 to 20 hours later, by the maximum of occurrence of the VLF emissions and by the cosmic ray storm maximum amplitude, one can conclude that the hypothesis of R. M. Gallet and R. A. Helliwell[8], associating the origin of VLF emissions to the presence of plasma in the exosphere, is reinforced.

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INTERNATIONAL CONFERENCE ON COSMIC RAYS AND THE EARTH STORM Part II

II-1C-2. The Disturbances of Exosphere as Seen from the VLF Emission

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If the VLF emissions propagate along the earth's magnetic lines of force, the most part of the VLF emissions will pass through the radiation belts. The investigation of VLF emissions in relation to the radiation belts is a very interesting problem. During the present analysis, we made an attempt to compare the time variation of the VLF emissions at different latitudes. This will give a clue towards solving the physical nature of the exosphere at different radial distances from the earth's surface. The VLF data used were obtained at 19 stations (see Table I) during the IGY and IGC which are reported to the World Data Center C2 at the Radio Research Laboratories, Tokyo. Only the occurrences or non-occurrences of the VLF emissions are reported in the data.

Fig. 1 shows the day-to-day variations of probability of occurrences of the VLF emissions and K_p. According to this Figure a close correlation is seen between the two quantities, and the time variations are parallel at each latitude and for each type of the VLF emission. It should be noted here that the VLF emissions occur seldom at the time of very low magnetic activity. Moreover, in order to get more detailed information concerning time development throughout the period of magnetic storms, the VLF data are arranged by the time of sudden commencement of magnetic storms, and are shown from bottom to top in the order of increasing latitudes in Fig. 2. According to this Figure the VLF emissions generally increase at the same time of the sudden commencement of magnetic storms, and time development of both dawn chorus and hiss have correlations with magnetic horizontal force H, but at higher latitudes these relationships become unclear. Figs. 3 and 4 show the diurnal variation, respectively, of dawn chorus and hiss at the time of magnetic disturbances and at magnetically quiet days at various stations. The diurnal variation of both dawn chorus and hiss seldom appear on magnetically quiet days, but at the time of magnetic disturbances only the diurnal variation of dawn chorus appears very clearly, and the times of maxima occur in the forenoon.

From the results of the analysis above,

Table I. List of Stations for VLF Emissions and Whistlers.

Station	ϕ	λ	Φ
U. S. A. and Canada			
Bermuda	32.4°N	64.7°W	44°N
Boulder	40.0°N	105.3°W	49°N
College	64°9°N	147.8°W	65°N
Frobisher Bay	63.8°N	68.6°W	75°N
Gainesville	29.7°N	82.4°W	41°N
Godhavn	69.2°N	53.5°W	80°N
Knob Lake	54.8°N	66.8°W	66°N
Kutzebue	66.9°N	162.6°W	63°N
Mont Joli	48.6°N	68.2°W	60°N
Norwich	43.8°N	72.4°W	55°N
Seattle	47.8°N	122.4°W	54°N
Stanford	37.4°N	122.2°W	44°N
Unalaska	53.9°N	166.5°W	51°N
Washington	38.7°N	77.1°W	50°N
Antarctica			
Ellsworth	77.7°S	41.1°W	67°S
Port Lockroy	64.8°S	63.5°W	53°S
Australia and New Zealand			
Dunedin	45.9°S	170.5°E	50°S
Macquarie Is.	54.5°S	159.0°E	61°S
Wellington	41.3°S	174.8°E	45°S

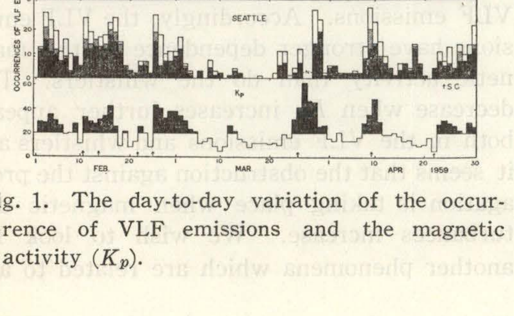

Fig. 1. The day-to-day variation of the occurrence of VLF emissions and the magnetic activity (K_p).

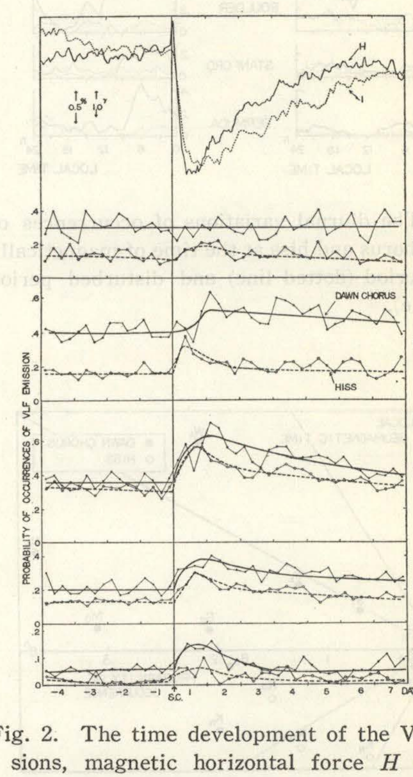

Fig. 2. The time development of the VLF emissions, magnetic horizontal force H (Kakioka) and the cosmic-ray neutron intensity I (Mt. Norikura) correlated with magnetic storms (at earlier and later times).

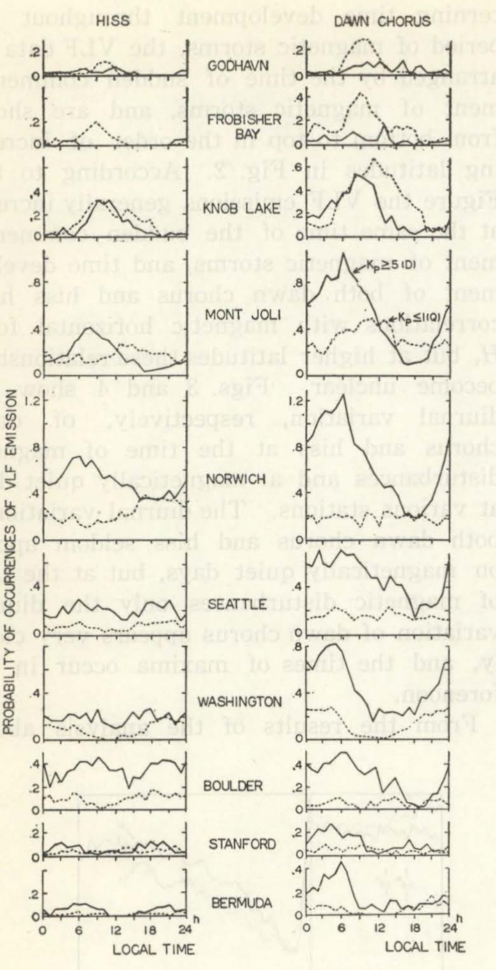

Fig. 3. The diurnal variations of occurrences of dawn chorus and hiss at the time of magnetically quiet period (dotted line) and disturbed period (full line).

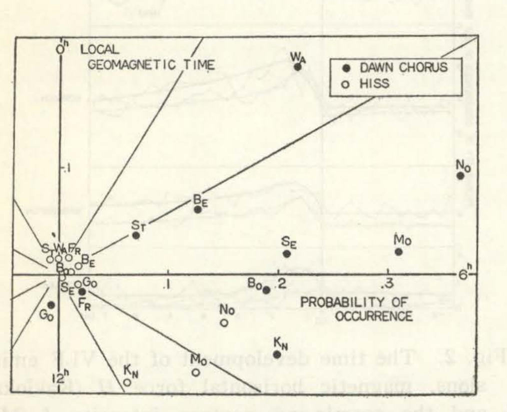

Fig. 4. The diurnal vectors of occurrences of dawn chorus and hiss at disturbed period are shown by a harmonic dial.

however, it was expected that the relationship between the VLF emissions and magnetic activities would not be so simple at higher latitudes. Fig. 5 shows, therefore, a relationship between dawn chorus, hiss and K_p, at various stations. According to this Figure, a nearly linear relationship seems to exist between these two quantities at lower latitudes, though the occurrences of VLF emissions decrease for very large value of K_p. At higher latitudes, we find that this tendency becomes more pronounced. As to hiss, it shows almost the same tendency as that of dawn chorus, but the relationship is not so clear as in dawn chorus. From this fact it may be considered that the magnetic activity not only generates the VLF emissions actively, but also it has a role to obstruct against the propagation of VLF emissions. We therefore tried to separate them by using whistler data. The origin of whistlers and VLF emissions are different, and whistlers seem to originate in the atmospheric discharge which is independent of the magnetic activity. But, the frequency bands of these waves are the same and the processes they undergo in the course of propagation seem to be the same also. If this is true, the observed VLF emissions can be separated into its generation and propogation by using the whistler data. The correlation between the whistler and K_p is shown in Fig. 5. Let us compare the results of whistlers with VLF emissions. The increase in the early stage due to the increase of K_p is greater for the VLF emissions than for whistlers. In the case of VLF emissions, both the increase of the generation and amplification in the course of the propagation will depend on K_p. On the other hand, the generation of whistlers is independent of the magnetic activity, but we suggest that the amplification of whistlers in the propagation is dependent on magnetic activity as is the case of the VLF emissions. Accordingly, the VLF emissions have stronger dependence on the magnetic activity than do the whistlers. The decrease when K_p increases further appears both in the VLF emissions and whistlers and it seems that the obstruction against the propagation is taking place when magnetic disturbances increase. We wish to look for another phenomena which are related to and

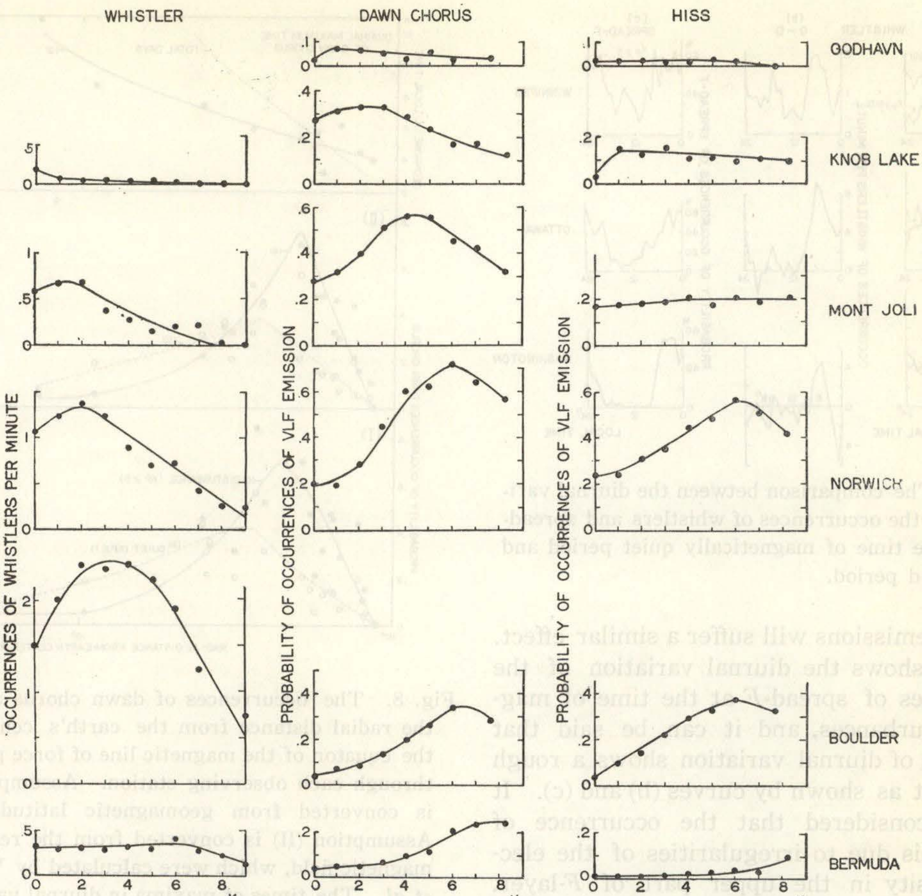

Fig. 5. The relationship between the occurrences of dawn chorus, hiss, and whistlers against magnetic activity (K_p).

might account for this fact.

Fig. 6 shows the ratios of the occurrences of spread-F, sporadic-E and whistlers in magnetically disturbed period to those in quiet period as functions of latitude. The ratio for spread-F of the ionosphere does not come

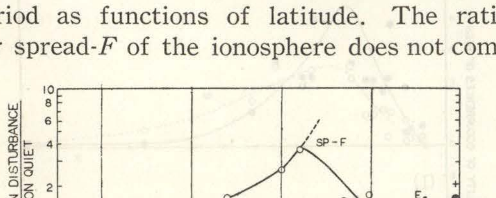

Fig. 6. The latitude dependence of some magnetic disturbance effect around the auroral zone. The sporadic-E reported by Smith[1].

down to unity until comparatively low latitudes are reached, and its phase is just opposite to that for whistlers except at higher latitudes. At higher latitudes the ratio for spread-F decreases rapidly. This is probably due to the occurrences of auroral zone blackout, because the blackout occurs just around this latitude. Moreover, we investigated these from the view point of the diurnal variation. Fig. 7(a) shows the diurnal variation of whistlers at the time of magnetic disturbance and quiet days. According to these curves, the diurnal variations of whistlers show a sharp maximum, and the time of maximum is about at $6h$ local time during magnetically quiet period, and maximum becomes less pronounced at the time of disturbances. Fig. 7 (b) shows the obstructed part in the propagation of whistlers due to magnetic disturbances. It is supposed that

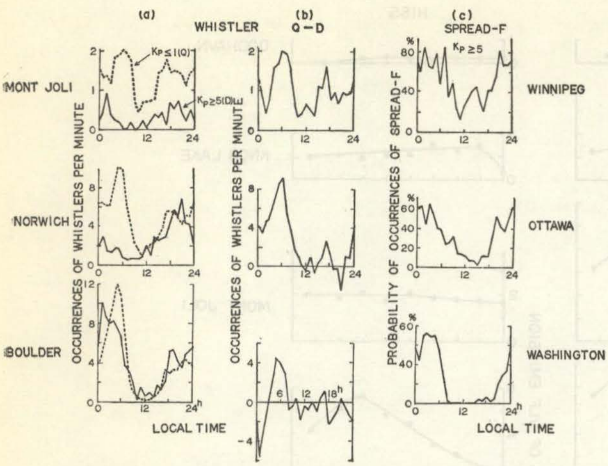

Fig. 7. The comparison between the diurnal variation of the occurrences of whistlers and spread-*F* at the time of magnetically quiet period and disturbed period.

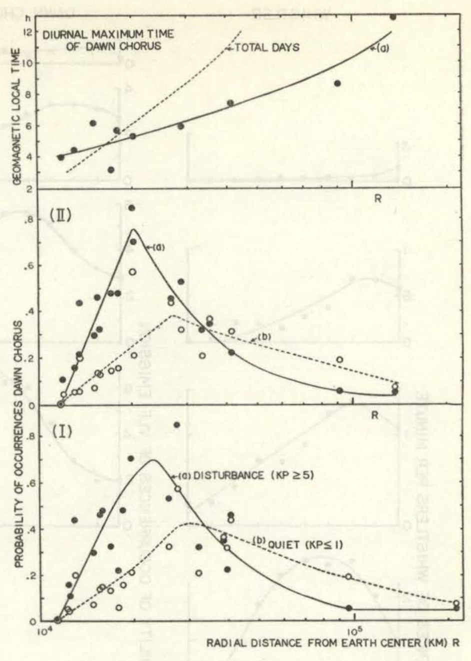

Fig. 8. The occurrences of dawn chorus against the radial distance from the earth's center on the equator of the magnetic line of force passing through each observing station. Assumption (I) is converted from geomagnetic latitude, and Assumption (II) is converted from the real geomagnetic field, which were calculated by Vestine *et al.* The times of maxima in diurnal variation are shown in upper two curves. The top one corresponds to the total days reported by Pope[3].

the VLF emissions will suffer a similar effect. Fig. 7(c) shows the diurnal variation of the occurrences of spread-*F* at the time of magnetic disturbances, and it can be said that the shape of diurnal variation shows a rough agreement as shown by curves (b) and (c). It can be considered that the occurrence of spread-*F* is due to irregularities of the electron density in the upper part of *F*-layer. However, it is not necessarily true that VLF emissions and whistlers are obstructed by spread-*F* itself. We suggest that these are caused by the change of physical condition in the exosphere which is the main propagation course for VLF emissions and whistlers. In other words, irregularities of the electron density are occurring during the spread-*F* in the ionosphere, and further more, irregularities of the electron density and also irregularities of the earth's magnetic field in the exosphere will appear at the same time.

Fig. 8 shows the occurrences of dawn chorus at each station plotted as a function of the radial distance from the earth's center on the equator of the magnetic line of force passing through each observing station. We compared two assumptions. (I) is converted from magnetic latitude on the assumption that the earth's field is a dipole placed at the center. On the other hand, (II) is converted from the real magnetic field, using the sixth order spherical harmonic representation which was calculated by Vestine *et*

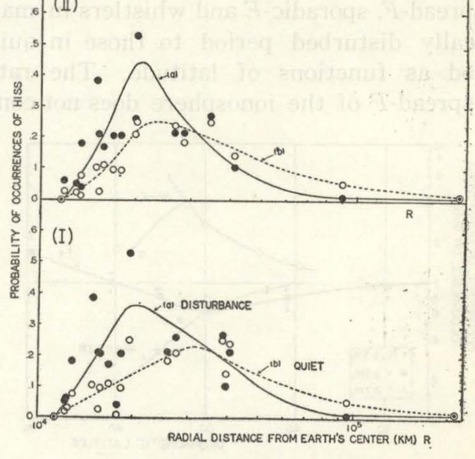

Fig. 9. The occurrences of hiss against the radial distance from the earth's center. Assumptions (I) and (II) are the same as in Fig. 8.

al[2]. It is seen from this Figure that almost all the data of dawn chorus can be very well characterized by the Assumption (II). Fig. 9 is the similar one for hiss. The plots are more scattered than that for dawn chorus, but, Assumption (II) is a better representation for hiss as well as for dawn chorus. This means that the VLF emissions certainly propagate along the real magnetic lines of force. The maximum position of dawn chorus and hiss shifts inwards to the earth at the time of magnetic disturbances. However, at that time, the occurrences of VLF emissions decrease due to the obstruction against the propagation at higher latitudes. Fig. 10 is replotted from the upper diagrams in Fig. 8.

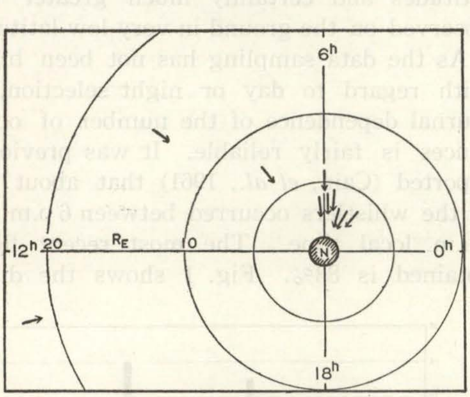

Fig. 10. The arrows are replotted from top (a) of Fig. 8, and suggest the positively charged particles coming from the sun.

The arrows mean the directions of arrival of the solar particles. This result is consistent with Allcock's suggestion[4] that the dawn chorus is generated by the positively charged particles coming from the sun, travelling in the equatorial plane and being deflected by the earth's magnetic field.

As mentioned in the statistical results, it is presumed that there are different mechanisms of generation for hiss and for dawn chorus. Concerning hiss, it seems that hiss are emitted by the particles which have already been trapped in the outer radiation belt and are amplified by the particles which are in the coming solar stream at the time of magnetic storms. The following facts give support to this explanation. (a) Fig. 11 shows a comparison between the distribution of hiss and the intensity-structure of the radiation belts[5]. The position of the maximum occurrence for hiss coincides with the position of the maximum intensity of the outer belt. (b) The receiving-tones of hiss have continuous noise spectrum. (c) The diurnal variation of hiss is not so clear. On the other hand, it seems that the origin of dawn chorus is due to

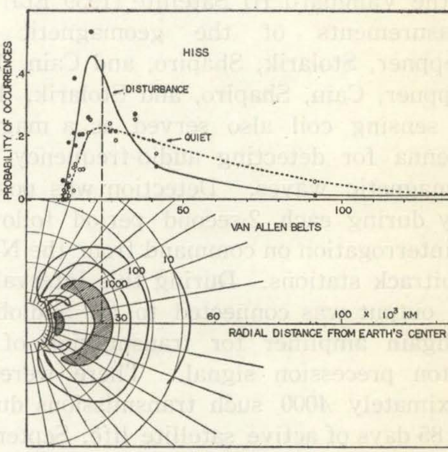

Fig. 11. The comparison between the distribution of occurrences of hiss and the intensity-structure of the radiation belts around the earth.

positively charged particles coming from the direction of the sun and penetrating directly into the earth's field. The following facts give support to this explanation. (a) According to the receiving-tones of dawn chorus, it seems that the waves do not occur at the same time as do in the cases of hiss and whistler, but the waves occur as the particles are being penetrated. (b) The diurnal variation of dawn chorus appears clearly, and the significance of this has already been discussed above.

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