Short Range Echoes of HF Waves Observed on the Antarctic Research Expedition Ship

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宗谷船上で観測された短波海上散乱について

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要　　旨

予備観測の際の船上観測で非常に明瞭な短波海上散乱が発見された．その後2回の船上観測の際にも同様の観測がなされ且つラジオゾンデによる気象観測も特に強化された．特に1959年の船上観測の際は固定周波によるh'tの観測及び A-scope による反射波のスナップ撮影も加えて原因の究明につとめた．

これらの結果を綜合して短波海上散乱波は結局海の波による後方散乱であることが推論された．海上では大地常数が大きいために特に地上波の伝播に都合がよいので散乱波が受信されるものと思われる．但し海の波により電波が coherent に反射されると考えなければならない．更に大洋上や暴風圏内においても顕著な日変化を示すことから大気の屈折率に新らしい要素を導入する仮説をたてた．これによって日変化は電波の屈折，廻折及び低層中の反射面の日変化に帰着させることができる．

1. Introduction

During the ionospheric observations made on board the preliminary Japanese Antarctic Research Expedition Ship in 1956, it was discovered that these were many strange echoes of HF waves reflected apparently by the layers at very low levels. Since then, these echoes have always been found at every observation on the Japanese Antarctic Research Expedition Ship "Soya". As these echoes were observed at so short a range, they were considered to occur in the troposphere. Therefore, the meteorological observation by radio-sonde was also carried out with the kind cooperation of the meteorological staff in the Japanese Antarctic Research Expedition Party. In this report are described the results of these observations at three times in 1956, 1958 and 1959.

R. L. DOWDEN (1957) reported the same kind of short range echoes observed at Macquarie Island, an Australian Antarctic Expedition base. He concluded that such echoes were the back scatter on HF by the sea wave and that the observation of these echoes might make some contribution to the study of the oceanography. In former times, some reports were also written on similar echoes observed at Christmas Island and Campbell Island as the special echoes that appeared only at the island stations. It is found, however, that these echoes also appear at the stations near the seashore, for example, at Hobart, Talara, Puerto Rico, Casablanca and Christchurch

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in the Atlas of Ionograms (1957) compiled by the CRPL.

The data obtained during the preliminary expedition are most typical of the kind, and those obtained in the two subsequent cases are not always remarkable for lack of sufficient transmitting power and probably because of the directivity of the antenna. On the 1959 expedition, both the h't observation by the fixed frequency and the snap shot of the A-scope were made in addition to the ordinary h'f observation.

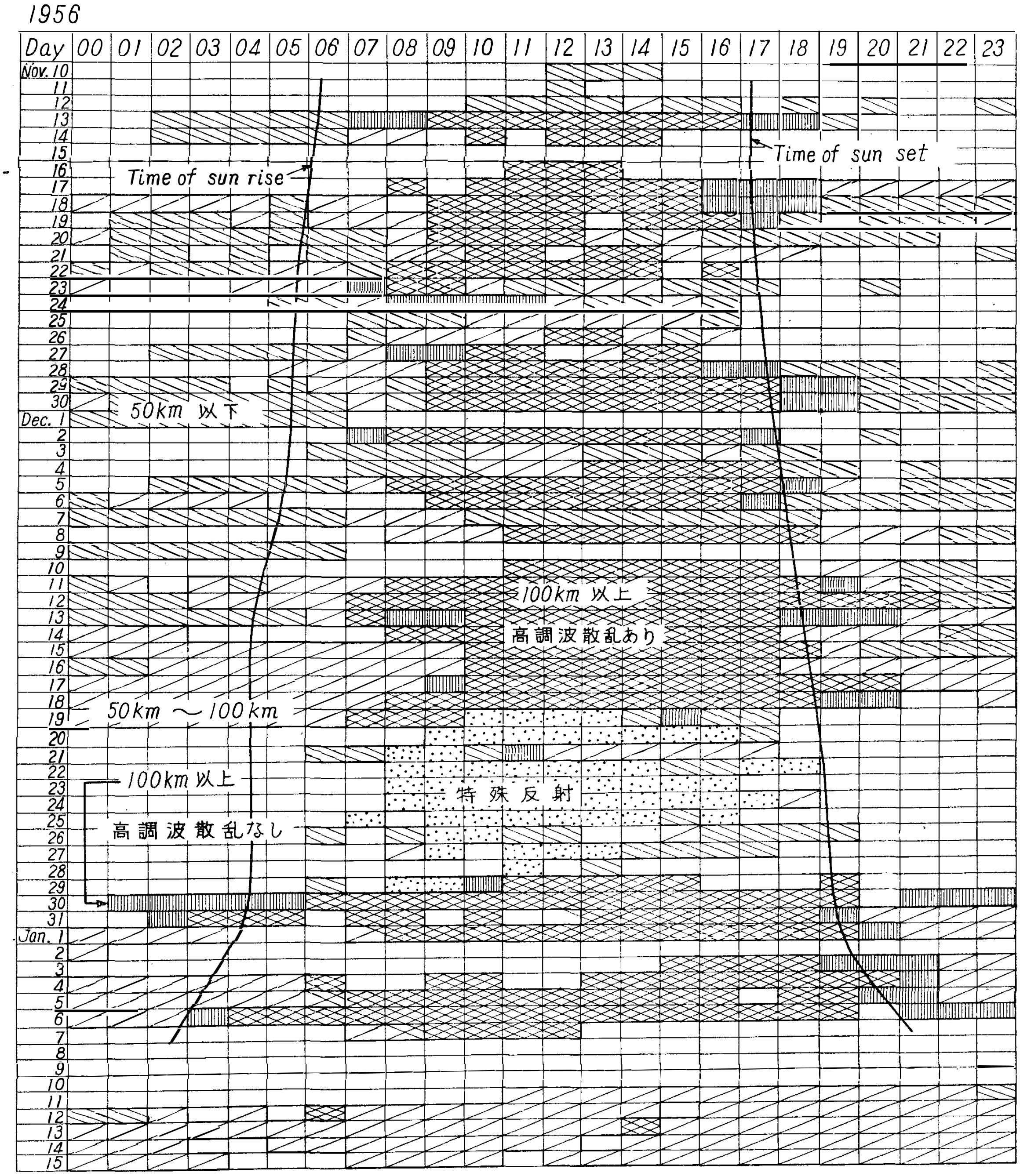

Fig. 2 (a). Variation of appearance of echoes in 1956.

: Less than 50 km. : 50～100 km. : More than 100 km.
: More than 100 km Higher harmonic component appears. : Special reflection.

2. Result of observations

Figs. 1 (a), (b) and (c) give examples of h'f observation in 1956, 1958 and 1959, respectively. These figures show that the most remarkable echoes appeared on the film obtained in 1956 and became weaker in 1958 and 1959, though this tendency cannot be attributed only to the physical condition, but to the instrumental condition. Here, another example of such echoes is shown in Fig. 1 (d), which was obtained at Talara, Peru, (04°34'S., 81°15'W.) during the period of IGY. Though the interference and noises are rather heavy, the scatter appears also in the low frequency range. From all these figures, it is found that the so-called short range echoes appear in the distance between the shortest observable range and about two hundred kilometers, and that they appear most heavily on the frequency of about 3 or 4 Mc.

In Fig. 2 are drawn the maximum distances of echoes for every hour. Each figure (a), (b) and (c), corresponds respectively to the observations made during the

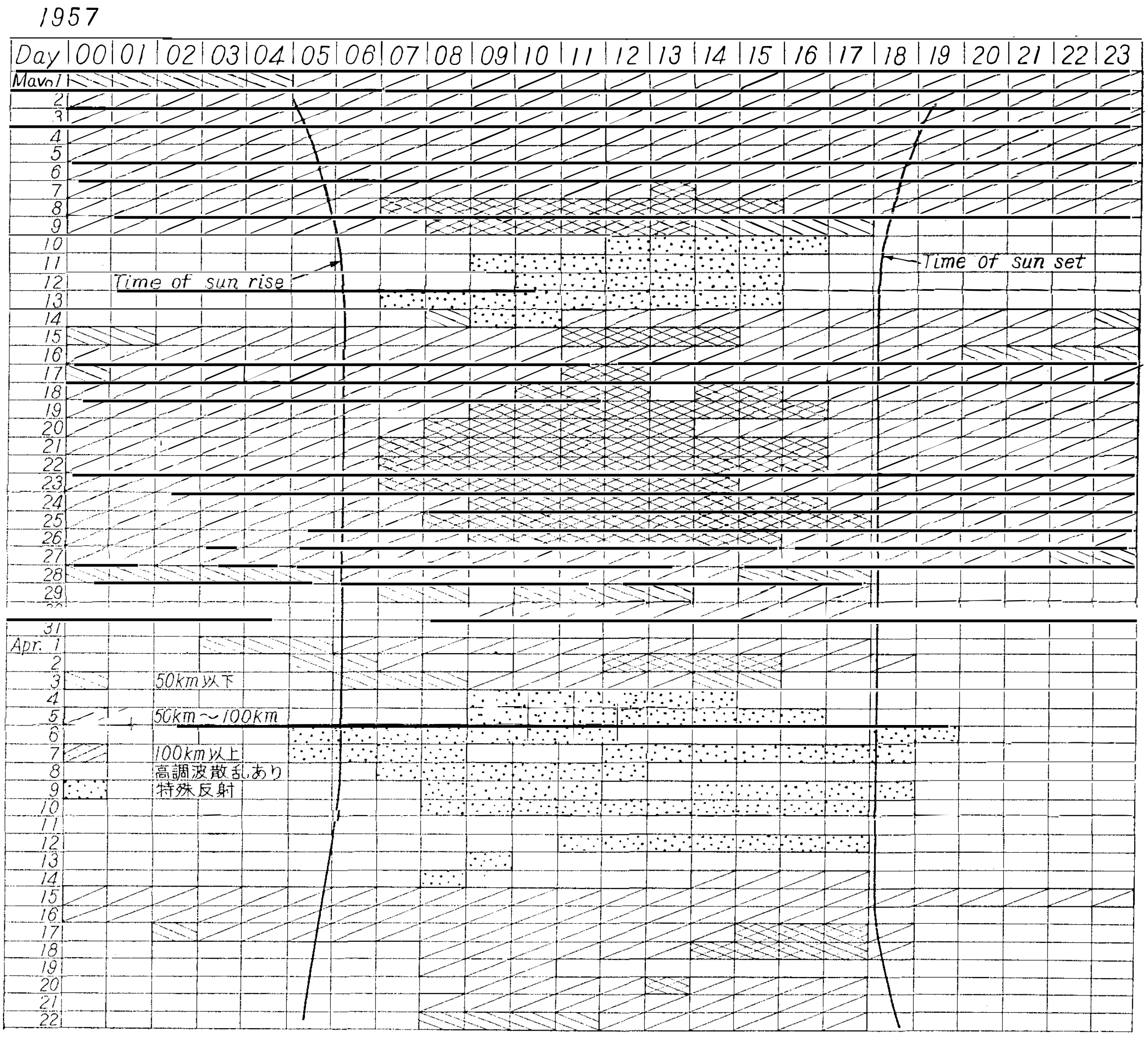

Fig. 2 (b). Variation of appearance of echoes in 1957.

: Less than 50 km. : 50～100 km. : More than 100 km
Higher harmonic component appears. : Special reflection.

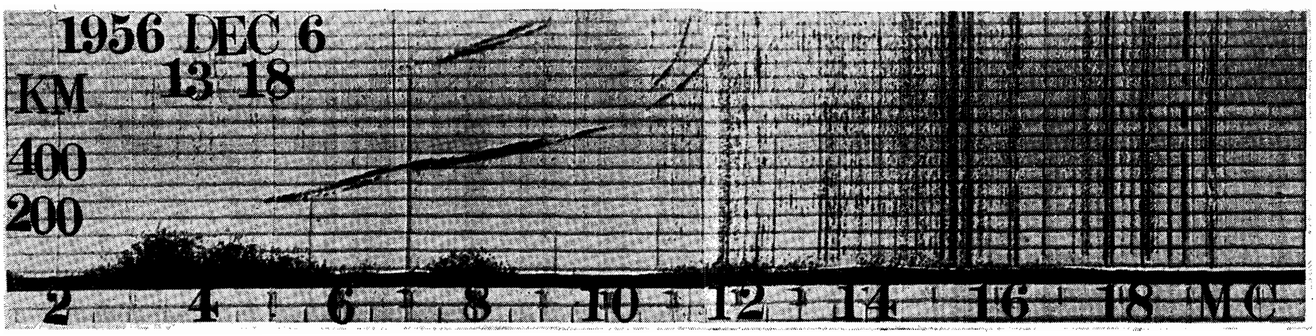

Fig. 1 (a). An example of h'f curve observed in 1956.

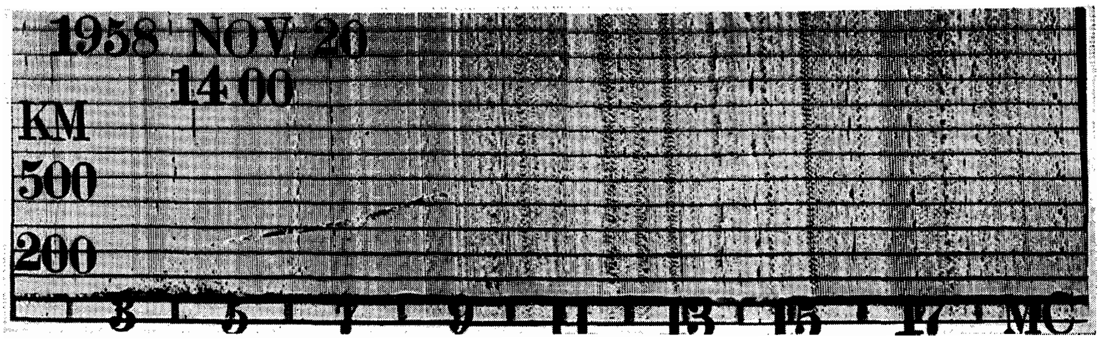

Fig. 1 (b). An example of h'f curve observed at 1958.

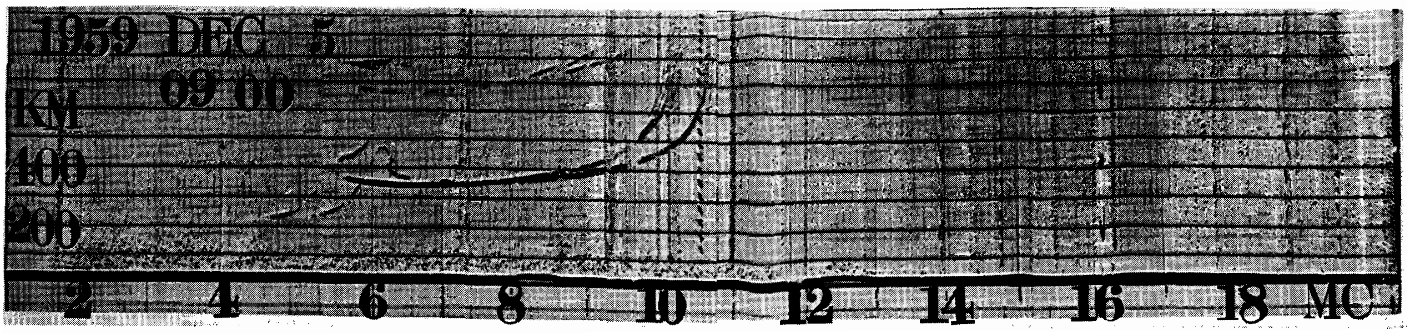

Fig. 1 (c). An example of h'f curve observed at 1959.

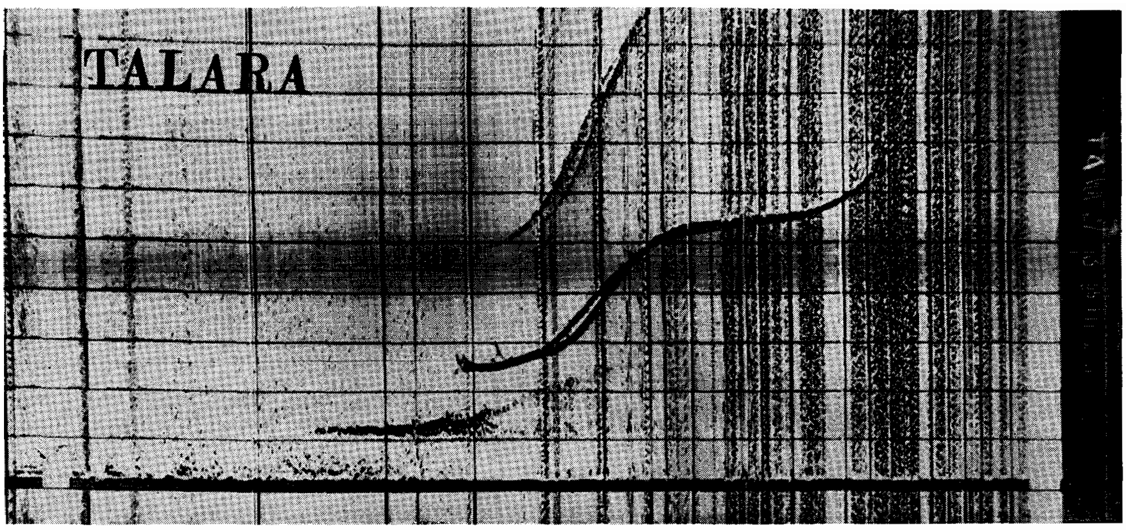

Fig. 1 (d). An example of h'f curve at Talara observed during the IGY.

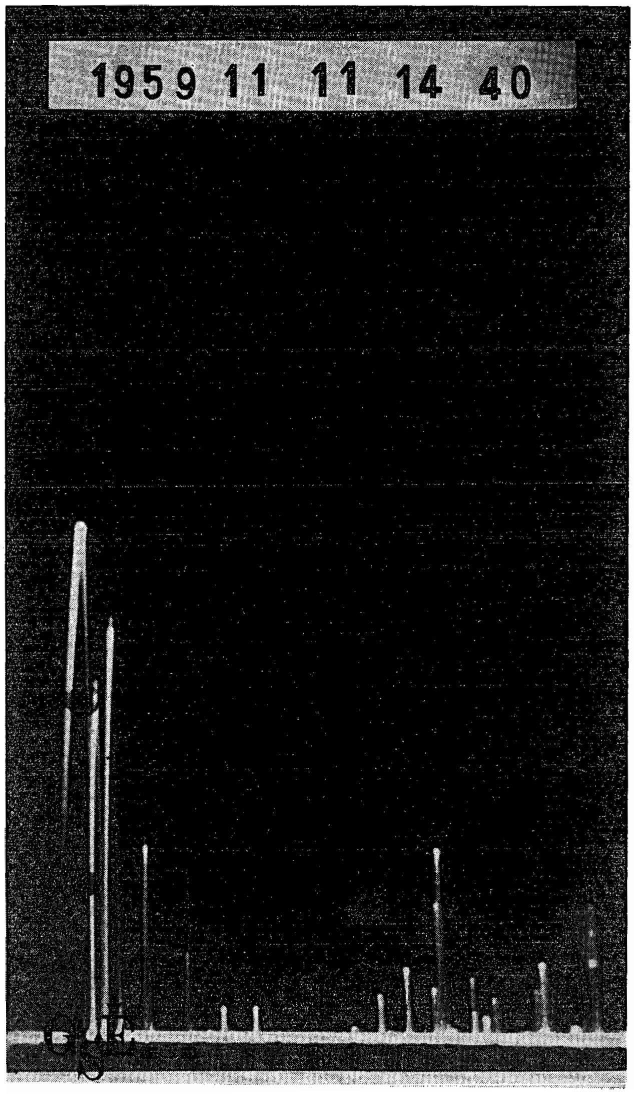

Fig. 3. A snap shot of A-scope.

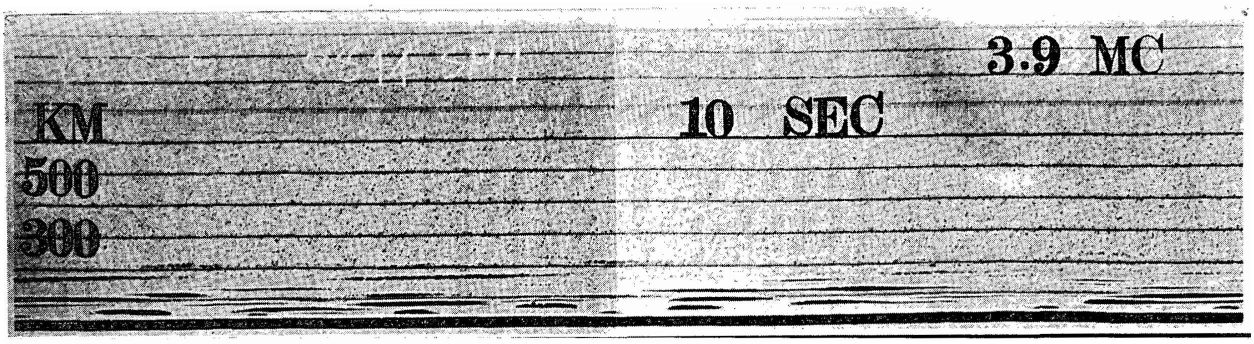

Fig. 4. h'f curve using 3.9 Mc wave.

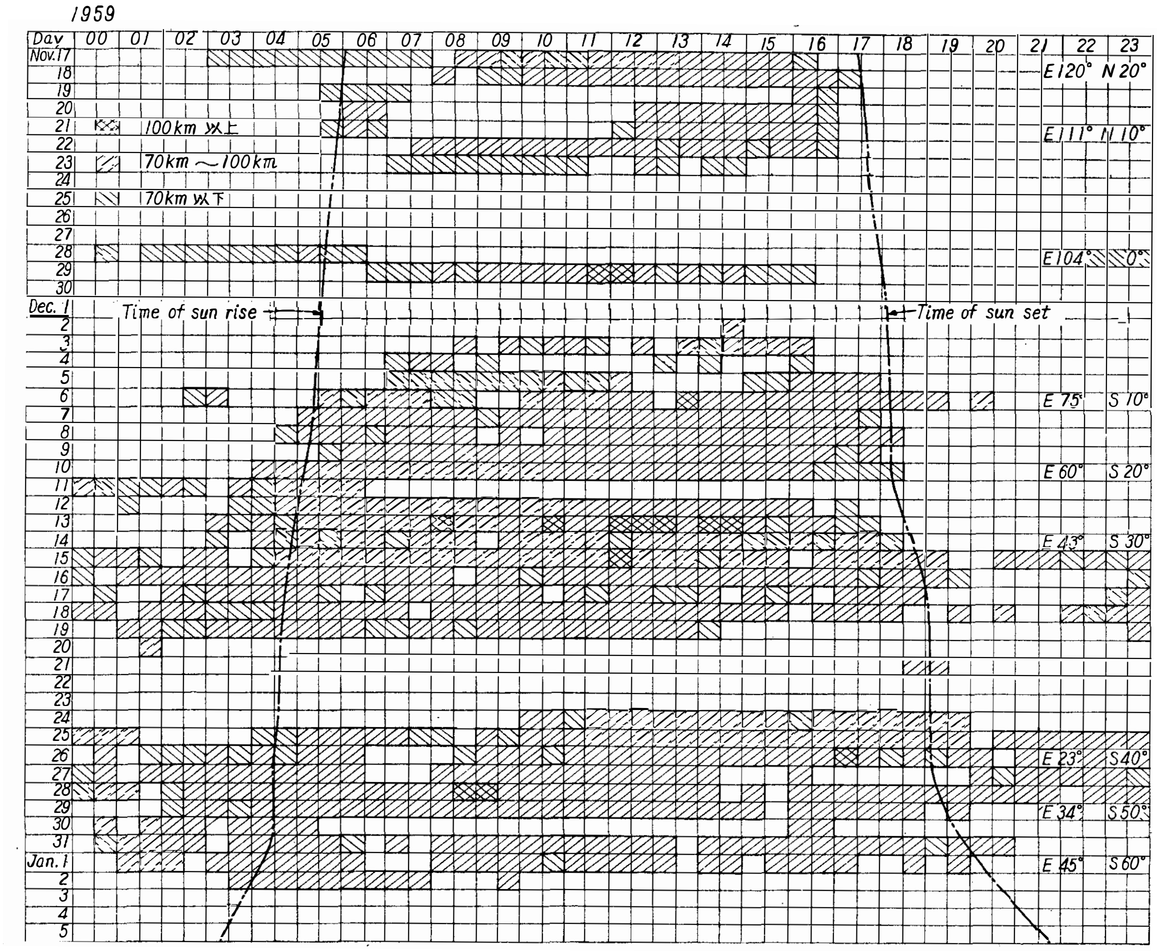

Fig. 2 (c). Variation of appearance of echoes in 1959.

▧: Less than 70 km. ▨: 70∼100 km. ▩: More than 100 km.

outward voyage in 1956, the homeward voyage in 1957, and the outbound passage in 1958. From these figures, one can find that the echoes are strong between 20°S. and 30°S. and rather weak between 0°S. and 10°S.

It can be seen most remarkably that the echoes appear with noticeable diurnal variation during the period between sunrise and sunset. It is very difficult to understand why such noticeable diurnal variation appears on the ocean. In later sections, some discussion may be attempted.

In Fig. 3 is shown, an example of a snap shot of the A-scope obtained at the last observation, where G is the ground wave, E the reflected wave from the E-layer, and S the echo in question. It is seen that the short range echo has about the same field strength as the E-echo. This will also be discussed in later sections.

Fig. 4 shows an example of h't observation using the most desirable wave frequency, which was also carried out on the last expedition. As shown in this figure, the echo has so short a duration, as previously expected, that the echo is considered to be due to the scattering of the radio wave probably by the sea wave.

In Fig. 5 are shown, some examples of the vertical distribution of radio refractivity in the lower atmosphere, calculated on the results of the meteorological observations made on the Soya during its outward voyage in 1959. However, there is not always one-to-one correspondence between the radio and meteorological data.

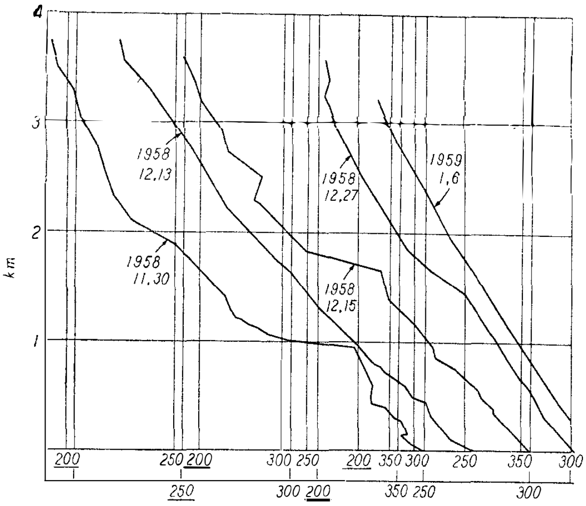

Fig. 5. Some examples of vertical distribution of radio refractivity.

3. Result of analysis

A) **Diurnal variation** As previously described, the appearance of echoes has a remarkable diurnal variation. The echoes appear mainly during the daytime in the present case. It was also true in the case of the auxiliary observations made at Ōarai and Wajima, and also in the data at the observatories which were selected from the Atlas of Ionograms. R. L. DOWDEN also indicated such a diurnal variation and thought the cause of this variation to be instrumental. But, in the present paper, it is considered that the diurnal variation actually exists. However, we must take note of the fact that the diurnal variation does exist in the observational data obtained on the ocean and even in the roaring forties, the storm zone. If the present echo is assumed to come back to the receiver after being reflected by the sea wave, the diurnal variation of the echo may be due to that of refractivity distribution in the lower atmosphere, because the shortest range of the echo is far lower than the height of the ionosphere. Generally, the radio refractivity in the troposphere has been considered to be derived from the pressure, temperature and humidity. But, in the present case where the back scattered echo shows such diurnal variation on the ocean, the variations of these meteorological elements are too small to explain the result. For example, the temperature gradient must show diurnal change at least in the amount of 5° C/km to explain the radio observation. Such a wide diurnal variation cannot be expected over the ocean, especially in the roaring forties.

C. M. CRAIN, J. E. BOGGS, and D. C. THORN (1957) reported that the atmospheric refractivity was affected by aerosol in the atmosphere. Here, an assumption is made in explanation of the diurnal variation of the scattered echo as follows: Some kinds of aerosol in the atmosphere over the ocean are photochemically affected by the solar radiation, and they have some effects on the atmospheric radio refractivity. Then, the diurnal variation in appearance of echoes may be rigorously explained. This assumption will be tested experimentally in the near future.

B) Echoes As is seen Fig. 3, the intensity of scattered echo is almost equal to that of the E-echo, though the absolute value cannot be determined exactly.

Taking the distance into account, the apparent reflection coefficient, i. e. the difference between the total loss and free space loss, is considered to be about 10^{-2} in its order. This value fairly agrees with what was obtained by R. L. DOWDEN.

The frequency distributions of the duration and height of appearance of the echo are shown as some examples in Fig. 6. The duration of appearance is mostly one to two seconds and the distance is 80 to 100 km. These distributions were obtained every day, but no day-to-day change or regional variation was taken into account in the result. The length of duration is similar to those observed at Ōarai and Wajima. Further, the echo appears rather periodically. It is, therefore, rather rigorous that the echo is considered to come back from the sea waves. At an inland station also, the reflection from a fixed targed may be considered to appear on the film. But such an echo cannot be expected to appear because of the bad condition, i. e. the bad ground constant, of propagation of ground waves.

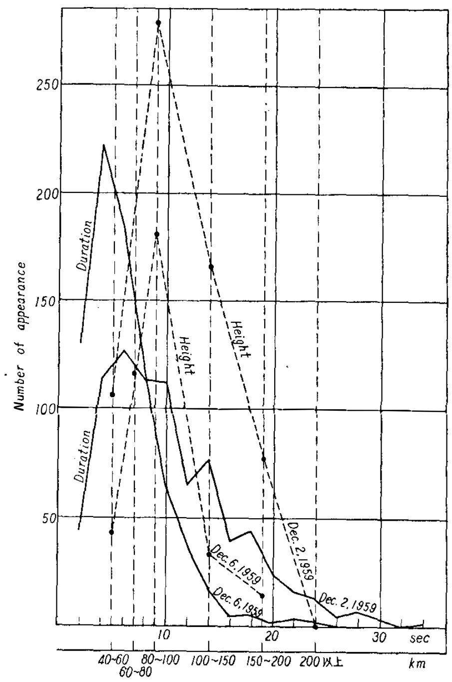

Fig. 6. Frequency distribution of dration and height of echoes.

4. Conclusion

The conclusion may be summarised as follows:

First, the good propagation condition over the ocean causes the back scatter of HF wave from a far distance.

Secondly, the back scatter of HF wave may be due to the sea wave, because the received signals appear with a short duration and rather periodically, as shown in Fig. 4.

Thirdly, since the echo shows a noticeable diurnal variation as shown in Fig. 2, it is presumed that the propagation condition may change daily; i. e. the daily changes may occur in the refraction and diffraction of radio waves or in the reflection thereof in the lower troposphere. But, in this case, as the refractivity defined by the pressure, temperature and humidity cannot explain this diurnal variation, there is assumed the existence of a new element that partly controls the refractivity. It is also assumed that some aerosol in the air over the sea may affect the radio refractivity by aid of the solar radiation. This assumption, however, will be checked experimentally in the near future.

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