# ON SOME REMARKABLE CHARACTERISTICS ON WHISTLER ATMOSPHERICS

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*Abstract*—This paper describes some remarkable characteristics of whistlers observed in IGY and IGC at Toyokawa and at Wakkanai in Japan.

The author found that the frequency of occurrences of whistlers has a definite seasonal variation due to thunderstorm activities and distributions of electron density and geomagnetic intensity in the exosphere.

Correlation of the number of whistlers with geomagnetic activities, superimposed on this variation, is found very close in the period of heavy geomagnetic disturbances or of abundant occurrence of whistlers : Correlation coefficient of the effective K-index and number of whistlers on the 2nd day after geomagnetic disturbances is +0.60.

The average dispersion of whistlers per month lags 2 months behind from solar activities expressed by sunspot numbers. Characteristics of dispersion of whistlers observed simultaneously at both stations are discussed in some detail. Diurnal and seasonal variations for 2 years are also described.

## 1. Introduction.

Since the beginning of IGY, 1st July 1957, we have continued a regular observation of whistler atmospherics at every 5-7 minutes and 35-37 minutes of U.T. at Toyokawa and Wakkanai in Japan, and will continue the same observation for the future. Results of 1st year, i.e. from 1st July 1957 to 30 June 1958 were reported last year. (1)

In the present paper the author describes some remarkable characteristics of whistlers found in our records obtained at Toyokawa and Wakkanai in the 1st and 2nd years, i.e. from 1st July 1957 to 30 June 1959. Specifically the correlation of occurrence of whistlers with geomagnetic activities as well as thunderstorm activities, of their dispersion with solor activities, characteristics of whistlers observed simultaneously at Toyokawa and at Wakkanai, and diurnal and seasonal variations of occurrences of whistlers are discussed in detail. Documents sent to me by Dr. Webster in Australia were very useful to my study, and often referred to.

## 2. Seasonal Variation.

Table 1A shows the number of whistlers observed at Toyokawa and Wakkanai in the 2nd year of IGY, i.e. from 1 July 1958 to 30 June 1959; "a" in Table 1A indicates the total number of whistlers in each month, "b" number of long whistlers and "c" the ratio of "b" to "a" in percentage. As it is difficult to obtain actual data concerning thunderstrm activities in each month, we referred to informations on average activities published by WMO as shown in Table 1B and studied the correlation between thunderstorm activities and the number of whistlers.

TABLE 1 A Number of Whistlers Observed Every Month

| Year→ Month↘ Observatories↓ | | 1958 | | | | | | 1959 | | | | | | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 7 | 8 | 9 | 10 | 11 | 12 | 1 | 2 | 3 | 4 | 5 | 6 | |
| Wakkanai | a | 78 | 175 | 370 | 723 | 1042 | 1619 | 1796 | 3033 | 2712 | 361 | 122 | 53 | 12084 |
| | b | 9 | 3 | 11 | 5 | 1 | 1 | 1 | 2 | 0 | 0 | 14 | 1 | 48 |
| | c | 11.6 | 1.7 | 3.0 | 0.7 | | | | | | | 11.5 | 1.9 | 0.4 |
| Toyokawa | a | 0 | 2 | 10 | 12 | 18 | 176 | 215 | 169 | 440 | 29 | 0 | 11 | 1082 |
| | b | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0 | 0 | 0 |
| | c | | | | | | | | | | | | | |

"a" is a total number of whistlers observed.
"b" is a number of long whistlers among "a".
"c" is a percentage of "b" to "a".

TABLE 1 B Average Thunderstorm Days in Each Month Published by WMO

| Month → Region ↓ | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Within 1,000km from Wakkanai | 2 | 0 | 3 | 4 | 23 | 31 | 32 | 60 | 36 | 32 | 14 | 3 |
| Within 1,000km from Darwin (Conjugate point of Toyokawa) | 68 | 59 | 41 | 13 | 3 | 0 | 0 | 0 | 2 | 22 | 46 | 78 |
| Within 1,000km from Alice Springs (Conjugate point of Wakkanai) | 29 | 27 | 19 | 5 | 7 | 4 | 1 | 3 | 7 | 18 | 26 | 36 |

TABLE 1 C Number of Occurrence in Each Month in which 3-Hour-Range K-Indices Showed 5, 6 or 7 and more than 8

| K↓ Year→ | 1958 | | | | | | 1959 | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Month→ | 7 | 8 | 9 | 10 | 11 | 12 | 1 | 2 | 3 | 4 | 5 | 6 |
| 5 | 10 | 13 | 14 | 8 | 4 | 12 | 8 | 12 | 14 | 10 | 10 | 9 |
| 6 or 7 | 5 | 4 | 5 | 4 | | 4 | 2 | 6 | 6 | 3 | 2 | |
| 8 | 1 | | | | | | | | | | | |
| Effective K-Index | 90.5 | 91 | 102.5 | 66 | 20 | 86 | 53 | 99 | 109 | 69.5 | 63 | 45 |

TABLE 1 D Number of Days in Each Month in Which K-Indices Showed 5, 6 or 7 and more than 8

| K↓ Year→ | 1958 | | | | | | 1959 | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Month→ | 7 | 8 | 9 | 10 | 11 | 12 | 1 | 2 | 3 | 4 | 5 | 6 |
| 5 | 5 | 6 | 7 | 4 | 4 | 6 | 4 | 7 | 5 | 4 | 5 | 5 |
| 6 or 7 | 2 | 2 | 3 | 2 | | 4 | 2 | 4 | 3 | 2 | 2 | |
| 8 | 1 | | | | | | | | | | | |

Tables 1C and 1D show the number of occurrences and the number of days respectively in each month in which the 3-hour-range K indices of Kakioka Magnetic Observatory indicate 5, 6 or 7 and more than 8. In this paper we define as "Effective K-index" the sum of products of K-indices "5, 6.5 (for 6 or 7) and 8" and their number of occurrences; "Effective K-index" seems to reveal more clearly the effect of magnetic activities on whistlers. In K-index 5 means moderate storm, 6 or 7 moderate severe storm and more than 8 severe storm.

Fig. 1 shows informations concerning the total number of occurrences of whistlers at Wakkanai "1", at Toyokawa "2", at Brisbane "3", at Hobart "4", at Adelaide "5", long whistlers at Wakkanai "6", its percentage to total at Wakkanai

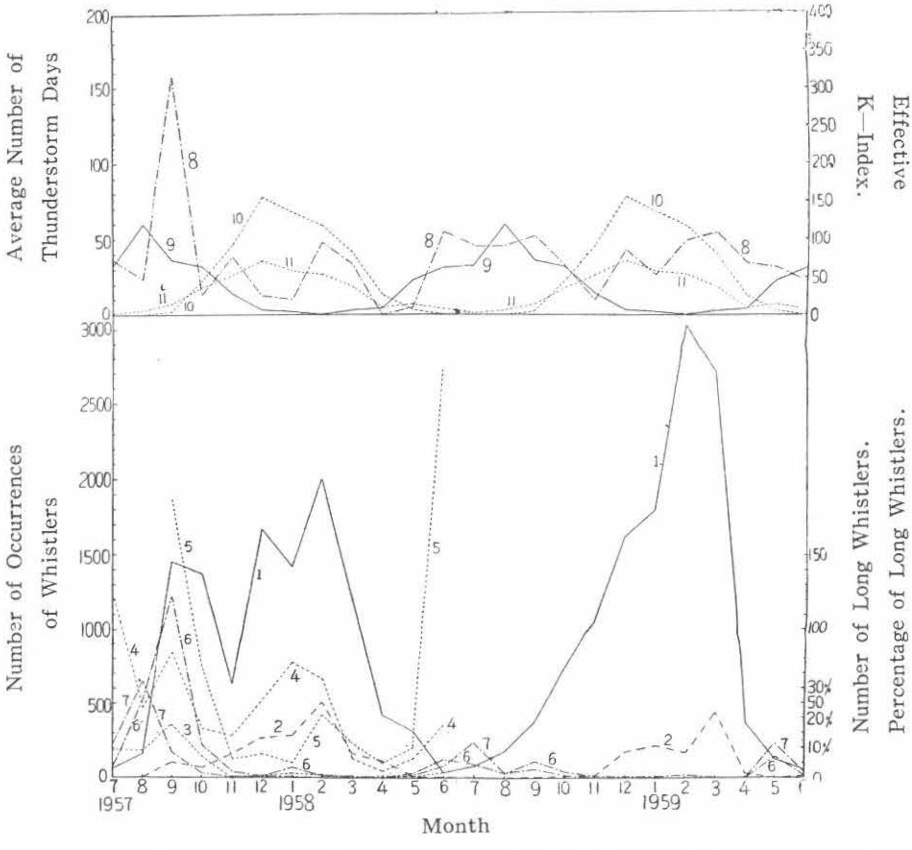


Fig. 1. Number of Whistlers Thunderstorm Activities and Geomagnetic Disturbances in Japan and in Australia in Each Month.

1. Number of whistlers at Wakkanai.
2. ditto Toyokawa.
3. ditto Brisbane.
4. ditto Hobart.
5. ditto Adelaide.
6. Number of long whistlers at Wakkanai.
7. Percentage of ratio of "6" to "1".
8. Effective K-index.
9. Average number of thunderstorm days in the neighbourhood of Wakkanai (within 1000km).
10. ditto Darwin.
11. Ditto Alice Springs.

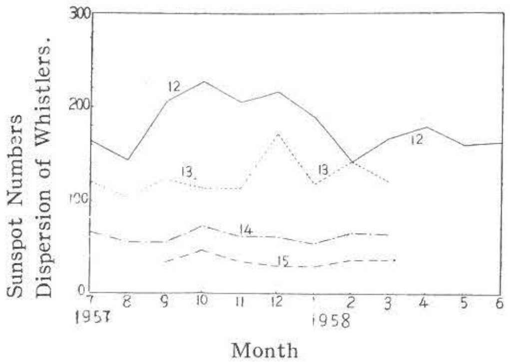


Fig. 1A. Solar Activities and Dispersion of Whistlers at Wakkanai.
12. Relative number of sunspots.
13. Dispersion of long whistlers at Wakkanai.
14. ditto short whistlers.
15. Dispersion of short whistlers at Toyokawa.

"7", effective K-index "8" and average number of thunderstorm days in the neighbourhoods (within 1000km) of Wakkanai "9", Darwin "10" and Alice Springs "11" in each month from 1st July 1957 to 30 June 1959; Fig. 1 A shows sunspot number "12", dispersions of long "13" and short "14" whistlers at Wakkanai and that of short whistlers at Toyokawa in the same period.

In this report we designate the period from 1st July 1957 to 30 June 1958 "The First Year" and that from 1st July 1958 to 30 June 1959 "The Second Year". At Toyokawa, whistlers were observed mainly from September to April, centring around winter in the 1st year, while in the 2nd, from December to March also centring around winter, and in summer a very few were observed. Maximum occurrence of whistlers was found in February in the 1st year, and in March in the 2nd. Referring to curve "8", "Effective K-index", in Fig. 1, it seems to have been due to the differences in geomagnetic activies in the 2 years.

At Wakkanai whistlers were also observed mainly in winter, but even in summer they were observed, especially long whistlers, from June to September. In the 1st year we found many whistlers in September and October and somewhat a smaller number in November, while in the 2nd, not so many in September and they increase gradually and monotonously from September to February, when they reach the maximum, and then decrease a little in March and much in April as in the 1st year.

Abnormal increase of whistlers in september in the 1st year is explained clearly by the abnormal activities of geomagnetism in september 1957 (Curve "8" in Fig. 1). Long whistlers are observed mainly in summer from June to September both in the 1st and in the 2nd years. It is due to thunderstorm activies in the neighbourhood of the station (Table 1B.). Short whistlers are also observed more often at Wakkanai than at Toyokawa due to following reasons:

(1) In the neighbourhood of Alice Springs, conjugate point of Wakkanai, more thunderstorm days are found than in that of Darwin in summer. (2) In the neighbourhood of Wakkanai there are not so many thunderstorm days as in that of Toyokawa, and consequently the noise levels at Wakkanai are lower than at Toyokawa. (3) Wakkanai is situated about 10° higher than Toyokawa in geomagnetic latitude.

Maximum number of whistlers were observed in February both in the 1st and in the 2nd years; but in the 1st, they decreased suddenly in March, while in the 2nd, they kept almost the same in March as in February, difference of behaviour being due to that in geomagnetic activities in the two months (curve "8" Fig. 1.)

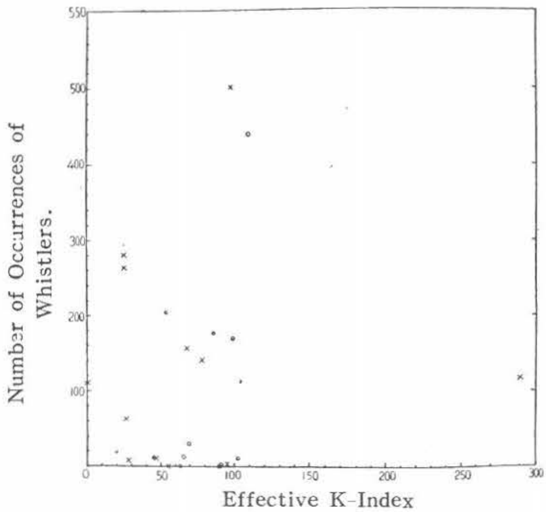


Fig. 2A Geomagnetic Activities and Number of Whistlers at Toyokawa.
× in the 1st year, ⊙ in the 2nd year.

## 3. Effective K-index and Whistlers

In order to find the correlation of geomagnetic activities with the frequency of occurrence of whistlers, we plot points (⊙) and (×) in Figs. 2A, 2B, by taking effective K-index as abscissa and the number of occurrences as ordinate from July 1957 to June 1959 both at Toyokawa and at Wakkanai. Points in Figs. 2A, 2B can be classified into 2 groups: the one belongs to the winter group from October or November to March or April, where many whistlers are found every month; the other to the summer one, from May to September, where smaller numbers are found. It is apparent that we can not find a single law applicable both to winter and to summer groups.

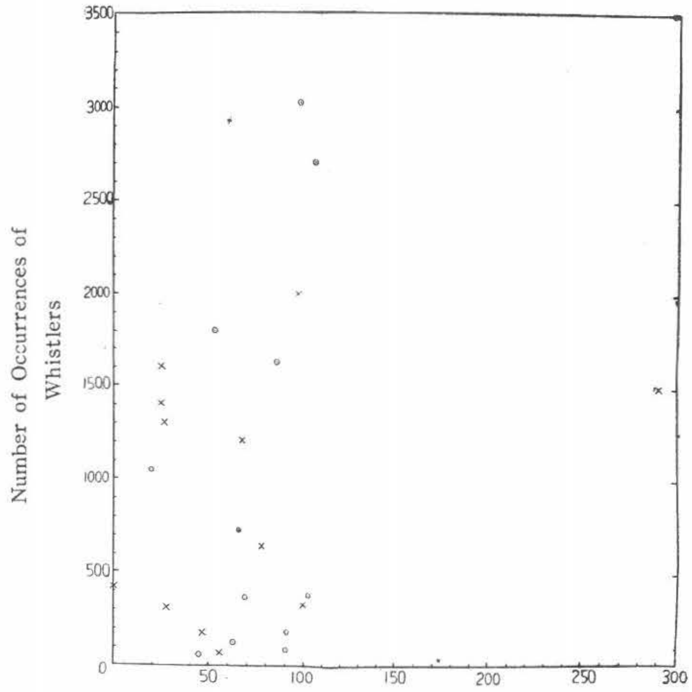


Fig. 2B. Geomagnetic Activities and Number of Whistlers. at Wakkanai.
× in the 1st year, ⊙ in the 2nd year.

It seems that the frequency of occurrences of whisiters has a definite seasonal variation depending on thunderstorm activities, distribution of electron density and geomagnetic intensity in the exosphere and in the ionosphere due to solar activities and other yet unknown cosmic phenomena; daily variations due to effective K-index are superposed upon this general seasonal variation. Thereupon we intend to investigate the correlation of effective K-index with the frequency of occurrences of whistlers observed at Wakkanai in most frequent periods, i. e. in September, December 1957, January, February, March, December 1958, January, February and March 1959.

TABLE 2 A Correlation of Effective K-Index with the Number of Occurernces of Whistlers on the Same Day (0), Next Day (+1), Second Day (+2) and Third Day (+3)

| Year→ Month→ | 1957 September | | | | | | | | | | | | | | December | | | | 1958 January | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Day | 2 | 3 | 4 | 5 | 6 | 9 | 13 | 14 | 21 | 22 | 23 | 24 | 29 | 30 | 1 | 13 | 30 | 31 | 1 | 18 | 22 |
| K | 16 | 33 | 31 | 21 | 5 | 5 | 40 | 15 | 17 | 22 | 35 | 5 | 30 | 16 | 5 | 10 | 5 | 5 | 5 | 5 | 5 |
| 0 | 9 | 3 | 47 | 40 | 84 | 14 | 33 | 5 | 19 | 26 | 14 | 2 | 25 | 135 | 19 | 108 | 22 | 12 | 163 | 86 | 37 |
| + 1 | 3 | 47 | 40 | 84 | 108 | 11 | 5 | 43 | 26 | 14 | 2 | 237 | 135 | 170 | 13 | 33 | 12 | 163 | 80 | 64 | 8 |
| + 2 | 47 | 40 | 84 | 108 | 28 | 15 | 43 | 65 | 14 | 2 | 237 | 199 | 170 | 64 | 17 | 52 | 163 | 80 | 9 | 14 | 33 |
| + 3 | 40 | 84 | 108 | 28 | 14 | 9 | 65 | 49 | 2 | 237 | 199 | 29 | 64 | 58 | 14 | 88 | 80 | 9 | 31 | 19 | 51 |

| Year→ Month→ | Jan-uary | February | | | | March | | | | | | | | December | | | | | | 1959 January | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Day | 25 | 11 | 12 | 16 | 17 | 3 | 5 | 12 | 13 | 14 | 15 | 25 | 30 | 2 | 4 | 9 | 13 | 16 | 17 | 6 | 9 |
| K | 5 | 54 | 32 | 5 | 5 | 5 | 11 | 10 | 10 | 5 | 5 | 6 | 15 | 6 | 16 | 5 | 21 | 10 | 11 | 5 | 11 |
| 0 | 51 | 122 | 84 | 89 | 50 | 50 | 69 | 47 | 111 | 21 | 3 | 28 | 3 | 0 | 38 | 25 | 6 | 236 | 42 | 120 | 69 |
| + 1 | 57 | 84 | 170 | 50 | 221 | 5 | 21 | 111 | 21 | 3 | 76 | 69 | 8 | 8 | 3 | 10 | 114 | 42 | 183 | 6 | 126 |
| + 2 | 22 | 170 | 131 | 221 | 29 | 69 | 49 | 21 | 3 | 76 | 32 | 11 | 6 | 38 | 9 | 1 | 34 | 183 | 78 | 19 | 93 |
| + 3 | 0 | 131 | 36 | 29 | 11 | 21 | 158 | 3 | 76 | 32 | 7 | 1 | 23 | 3 | 120 | 22 | 236 | 78 | 58 | 69 | 36 |

| Year→ Month→ | January | | | | February | | | | | | | | March | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Day | 10 | 16 | 25 | 26 | 11 | 14 | 15 | 16 | 25 | 26 | 27 | 28 | 1 | 2 | 18 | 26 | 27 | 28 | 29 |
| K | 15 | 5 | 11 | 5 | 12 | 11 | 5 | 20 | 28 | 6 | 10 | 5 | 11 | 5 | 5 | 24 | 27 | 25 | 10 |
| 0 | 126 | 7 | 35 | 112 | 102 | 117 | 92 | 1 | 66 | 81 | 253 | 422 | 214 | 189 | 13 | 20 | 40 | 54 | 238 |
| + 1 | 93 | 0 | 112 | 161 | 219 | 92 | 1 | 28 | 81 | 253 | 422 | 214 | 189 | 201 | 0 | 40 | 54 | 238 | 61 |
| + 2 | 36 | 2 | 161 | 88 | 142 | 1 | 28 | 26 | 253 | 422 | 214 | 189 | 201 | 209 | 8 | 54 | 238 | 61 | 24 |
| + 3 | 145 | 0 | 88 | 8 | 117 | 28 | 26 | 92 | 422 | 214 | 189 | 201 | 209 | 169 | 1 | 238 | 61 | 24 | 30 |

TABLE 2 B Correlation of Effective K-Index with the Number of Occurrences of Whistlers on the Day Before (−1), Two Days Before (−2) and Three Days Before (−3)

| Year→ Month→ | 1957 September | | | | | | | | | | | | | | December | | | | 1958 January | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Day | 2 | 3 | 4 | 5 | 6 | 9 | 13 | 14 | 21 | 22 | 23 | 24 | 29 | 30 | 1 | 13 | 30 | 31 | 1 | 18 |
| K | 16 | 33 | 31 | 21 | 5 | 5 | 40 | 15 | 17 | 22 | 35 | 5 | 30 | 16 | 5 | 10 | 5 | 5 | 5 | 5 |
| − 1 | 14 | 9 | 3 | 47 | 40 | 28 | 9 | 33 | 31 | 19 | 26 | 14 | 38 | 26 | 43 | 89 | 21 | 22 | 12 | 18 |
| − 2 | 13 | 14 | 9 | 3 | 47 | 108 | 15 | 9 | 80 | 31 | 19 | 26 | 29 | 38 | 16 | 33 | 9 | 21 | 22 | 7 |
| − 3 | 2 | 13 | 14 | 9 | 3 | 84 | 11 | 15 | 43 | 80 | 31 | 19 | 199 | 29 | 34 | 11 | 38 | 9 | 21 | 13 |

| Year→ Month→ | January | | February | | | | March | | | | | | | | December | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Day | 22 | 25 | 11 | 12 | 16 | 17 | 3 | 5 | 12 | 13 | 14 | 15 | 25 | 30 | 2 | 4 | 9 | 13 | 16 | 17 |
| K | 5 | 5 | 54 | 32 | 5 | 5 | 5 | 11 | 10 | 10 | 5 | 5 | 6 | 15 | 6 | 16 | 5 | 21 | 10 | 11 |
| − 1 | 19 | 38 | 114 | 122 | 36 | 89 | 69 | 5 | 19 | 47 | 111 | 21 | 2 | 8 | 4 | 8 | 189 | 22 | 34 | 236 |
| − 2 | 14 | 8 | 56 | 114 | 131 | 36 | 39 | 50 | 11 | 19 | 47 | 111 | 59 | 1 | 21 | 0 | 120 | 1 | 114 | 34 |
| − 3 | 64 | 37 | 29 | 56 | 170 | 131 | 71 | 69 | 122 | 11 | 19 | 47 | 34 | 11 | 2 | 4 | 9 | 10 | 6 | 114 |

| Year→ Month→ | 1959 January | | | | | | February | | | | | | | | March | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Day | 6 | 9 | 10 | 16 | 25 | 26 | 11 | 14 | 15 | 16 | 25 | 26 | 27 | 28 | 1 | 2 | 18 | 26 | 27 | 28 | 29 |
| K | 5 | 11 | 15 | 5 | 11 | 5 | 12 | 11 | 5 | 20 | 28 | 6 | 10 | 5 | 11 | 5 | 5 | 24 | 27 | 25 | 10 |
| − 1 | 8 | 19 | 69 | 154 | 102 | 35 | 20 | 142 | 117 | 92 | 22 | 66 | 81 | 253 | 422 | 214 | 70 | 0 | 20 | 40 | 54 |
| − 2 | 0 | 6 | 19 | 98 | 109 | 102 | 211 | 219 | 142 | 117 | 19 | 22 | 66 | 81 | 253 | 422 | 77 | 1 | 0 | 20 | 40 |
| − 3 | 24 | 120 | 6 | 145 | 15 | 102 | 381 | 102 | 219 | 142 | 26 | 19 | 22 | 66 | 81 | 253 | 18 | 2 | 1 | 0 | 20 |

Taking days where effective K-indices are more than 6 as reference, the frequency of occurrences of whistlers on the same day (•), that on the next day (×), that on the 2nd day (◉) and that on the 3rd day (△), is compared with the effective K-index as shown in Fig. 3A. Fig. 3B is that of September 1957, the most active period of geomagnetic disturbances in 2 years. At a glance it seems that there are very little correlation on the same day (in Fig. 3), but some correlation on the 2nd day. According to our computation of correlation coefficient, it is −0.25 on the day, −0.19 on the next day, +0.60 on the 2nd, +0.20 on the 3rd, −0.12 on the previous day, −0.21 on 2 days before, −0.11 on 3 days before (Fig. 3C), and therefore we can conclude that whistlers occur most frequently on the day which lags two days after geomagnetic disturbances. In the summer group we can not find the same correlation as that in the winter group.

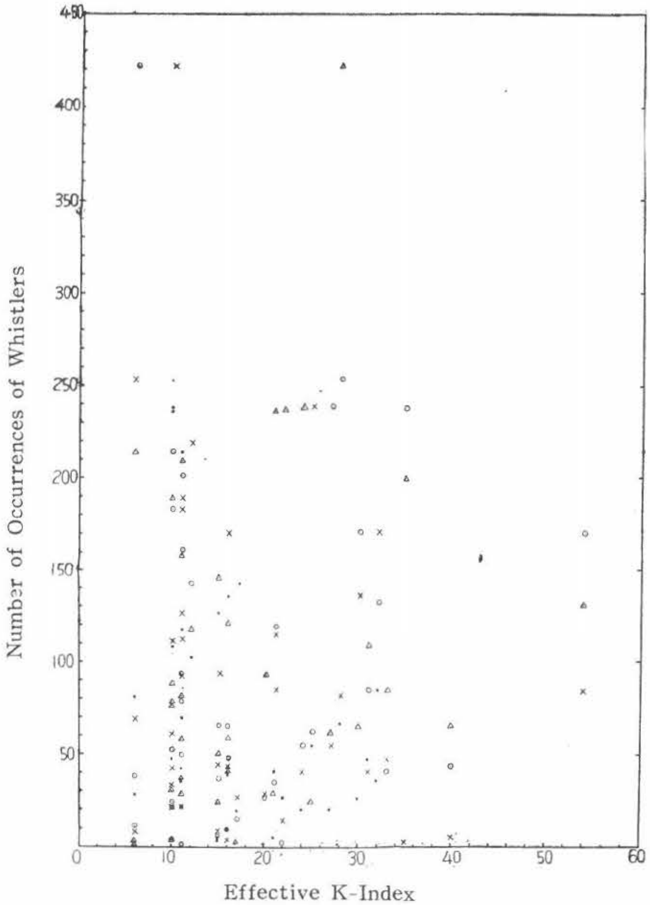


Fig. 3A.
Number of whistlers at Wakkanai on the Same Day, Next, 2nd and 3rd after Geomagnatic Disturbed Days durnig 9 Months in Winter.

● on the same day
× on the next day
⊙ on the 2nd day
△ on the 3rd day

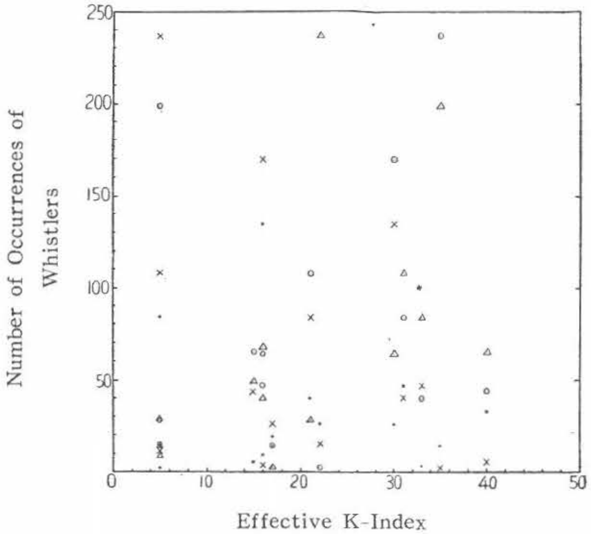


Fig. 3B.
Number of Whistlers at Wakkanai on the Same Day, Next, 2nd and 3rd after Geomagnetic Disturbed Days in September 1957.

● on the same day
× on the next day
⊙ on the 2nd day
△ on the 3rd day

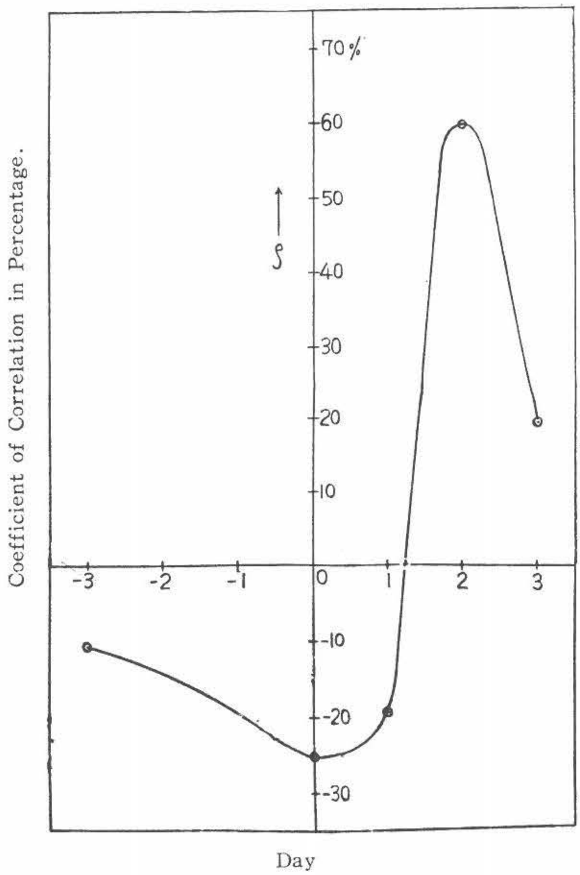


Fig. 3C Lag of days of occurrences of whistlers behind geomagnetic disturbances.

## 4. Whistlers and Thunderstorm activevies.

As we could not obtain any actual exact information of thunderstorm activities, we referred to the average data published by WMO(2) in Table 1B, and got a fairly good correlation between the frequency of occurrences of whistlers at Wakkanai and the unmber of thunderstorm days in the neighbourhood of conjugate point. But as the informations of thunderstorm activities are an average in several years and not the actual ones, we could not explain the difference of the frequency of occurrences of whistlers in the same month on different years, e. g. Fedruary and March in 1958 and in 1959, though the solar and geomagnetic activities are same in these months in both years. The cause of these differences should be attributed to the thunderstorm activities in the neighbourhood of Alice Springs, but at present we can not determine.

## 5. Solar Activities and Whistlers.

Comparing the dispersion of long whistlers observed at Wakkanai shown in curve "13" with sunspot numbers in curve "12" in Fig. 1 A, we may find some correlation between them if we displace the dispersion curve "13" 2 months forward; in fact we could find correlation coefficient +0.65. Allen[3] made an extensive study of the correlation of sunspot numbers with corona activities, and found that the latter lags 0.87 month behind; therefore we may probably be able to conclude that the dispersion, which depends on the distributions of electron density and geomagnetic intensity in the exosphere, lags 2 months behind after activities shown by sunspot numbers.

As to other elements than thunderstorm activities, solar activitities and geomagnetic activities, which determine the general tendency of seasonal variations of characteristics of whistlers, we should expect on future studies.

## 6. Characteristics of Whistlers Observed Simultaneously at Both Stations.

To briefly investigate the whistlers observed simultaneously at Toyokawa and Wakkanai, we pick out the records of September 1957 as an example of geomagnetically the most disturbed month and those of February 1958 as that of the most frequent occurrence of whistlers. Although the records in February 1959 are the most frequent, the analysis is not yet finished for them.

The total number of whistlers observed in September 1957 is 107 at Toyokawa, 1502 at Wakkanai and 80 simultaneously at both stations, while that in February 1958 is 502 at Toyokawa, 1999 at Wakkanai and 156 simultaneously at both stations.

Taking the observed time at Toyokawa as standard, that at Wakkanai is designated +1, +2, +3, sec., when the observed time there is 1, 2, 3 sec. later than at Toyokawa, and −1, −2, −3, sec., when it is 1, 2, 3 sec. earlier than at Toyokawa. Times were measured to an accuracy of 0.1 sec. Records of simultaneous observations in September and February are tabulated in Table 3 and drawn in Fig. 4 in accordance with the frequency of occurrence at each

LABLE 3 Number of Whistlers Arrived at Wakkanai −3, −2, −1, 0, +1, +2, +3 Seconds after at Toyokawa.

| Second→ | −3 | −2 | −1 | 0 | +1 | +2 | +3 |
|---|---|---|---|---|---|---|---|
| September 1957 | 1 | 2 | 8 | 14 | 12 | 8 | 2 |
| February 1958 | 5 | 10 | 35 | 57 | 46 | 13 | 5 |
| Total | 6 | 12 | 43 | 71 | 58 | 21 | 7 |

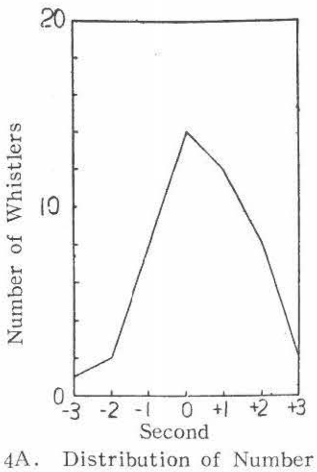


Fig. 4A. Distribution of Number of the Same Whistlers Arrived at Wakkanai Later than at Toyokawa in September 1957.

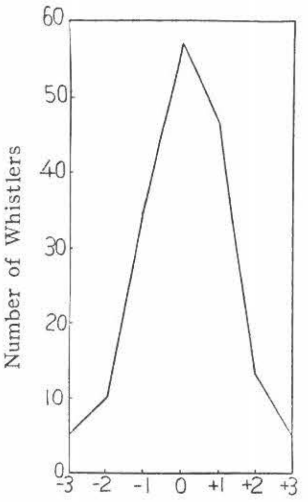


Fig. 4B. Distribution of Nunber of the Same Whistlers Arrived at Wakkanai Later than at Toyokawa in February 1958.

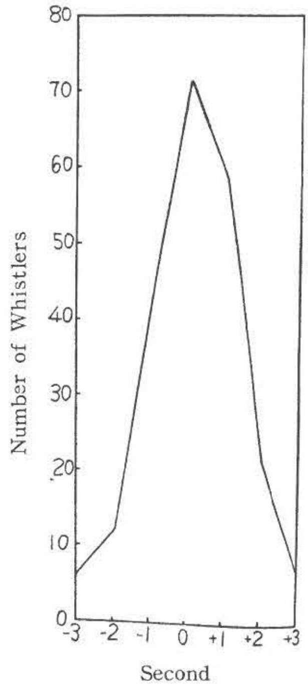


Fig. 4C. Sum of the Results in Fig. 4A and Fig. 4B.

TABLE 4 Characteristics of Whistlers Arrived at Toyokawa and Wakkanai Simultaneously.

| | September, 1957 | February, 1958 |
|---|---|---|
| (1) Number of perfect coincidence of arrival and equal D | 5 | 7 |
| Ditto, range of D in $sec^{\frac{1}{2}}$ | 30～35, 35, 40, 50, 60 | $30^{III}$, $40^{II}$, 50, 65 |
| (2) Number of perfect coincidence of arrival and different D | 1 | 9 |
| Ditto, range of D in $sec^{\frac{1}{2}}$ at Toyokawa | 75 | 40, 25, 30, 20, 25, 45, 40, $35^{II}$ |
| Ditto, range of D in $sec^{\frac{1}{2}}$ at Wakkanai | 90 | 35, 30, 45, 40, 45, 50, 70, $30^{II}$ |
| (3) Number of different arrival and equal D, (Range of D in $sec^{\frac{1}{2}}$ in parenthesis) +2 sec. | 1 (45) | 1 (70) |
| +1 | 5 (40, $95^{IV}$) | 3 (35, $30^{II}$) |
| −1 | | 2 ($40^{II}$) |
| −2 | | 1 (40) |
| (4) Number of different arrival and different D, +1 sec. | 1 | 10 |
| Ditto, range of D in $sec^{\frac{1}{2}}$ at Toyokawa | 50 | 65, $25^{IV}$, 35, 32.5, $25^{II}$, 22.5 |
| Ditto, range of D in $sec^{\frac{1}{2}}$ at Wakkanai | 35 | 70, $30^{IV}$, 30, 75, $45^{II}$, 40 |
| Number of different arrival and different D, −1 sec. | 4 | 2 |
| Ditto, range of D in $sec^{\frac{1}{2}}$ at Toyokawa | 90, 50, $90^{II}$ | 25, 40 |
| Ditto, range of D in $sec^{\frac{1}{2}}$ at Wakkanai | 60, 45, $95^{II}$ | 30, 70 |
| Number of different arrival and different D, +2 sec. | | 1 |
| Ditto, range of D in $sec^{\frac{1}{2}}$ at Toyokawa | | 27.5 |
| Ditto, range of D in $sec^{\frac{1}{2}}$ at Wakkanai | | 47.5 |

Roman letters on decimals mean number of times.

delayed or advanced time. There we find that the number of exact coincident arrival of whistlers at Toyokawa and Wakkanai, i. e. zero difference of arriving time, is maximum and the area on the negative side is much smaller than that on the positive side in Fig. 4. This fact shows that the average propagation path to Wakkanai is larger than that to Toyokawa, though the individual path has a wide range around geomagnetic lines of force, somewhat independent of a small difference of geomagnetic latitude between Toyokawa and Wakkanai.

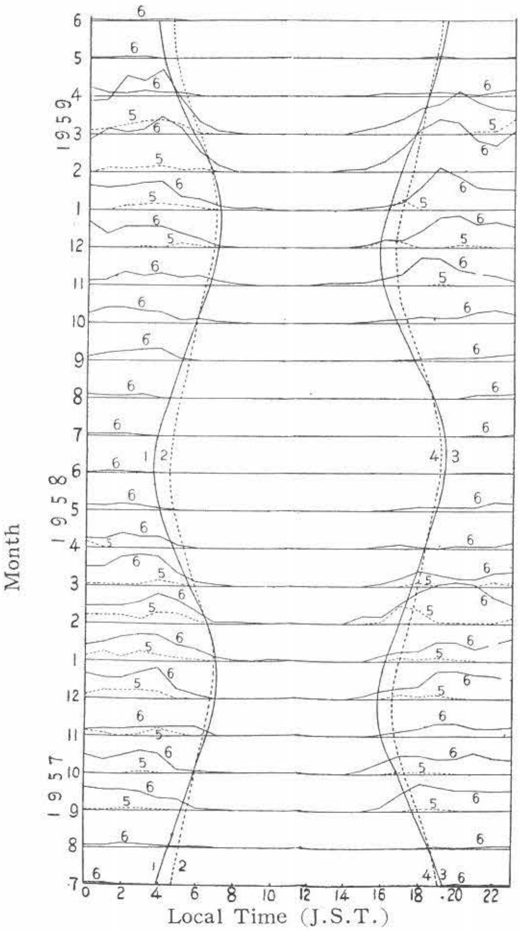


Fig. 5. Diurnal Variation of the Number of Occurrences of Whistlers at Toyokawa and Wakkanai in Each Month from 1st July 1957 to 30 June 1959.

1. Sunrise at Wakkanai.
2. Sunrise at Toyokawa.
3. Sunset at Wakkani.
4. Sunset at Toyokawa.
5. Number of whistlers at Toyokawa.
6. Number of whistlers at Wakkanai.

As to dispersion (D)—although there was a very small number of cases in which D was obtained simultaneously at Toyokawa and at Wakkanai, we tabulated some features of D in Table 4, where we find the following tendencies:

"1" in Table 4 shows that these whistlers arrive at both stations by way of almost the same path from their sources, though two stations are situated 10° apart in geomagnetic latitutde. It indicates that they can take rather a wide range of propagation path around geomagnetic lines of force, as Storey (4) and Maeda (4) described. "2" and "4" in Table 4 show that D at Wakkanai is generally larger than that of Toyokawa. This means that the mean propagation path to Wakkanai is longer than that to Toyokawa. In records of −1 sec. in "4" in Table 4, D at Wakkanai is generally smaller than that at Toyokawa; this means that when whistlers arrive at Wakkanai earlier than at Toyokawa, the propagation path to Wakkanai takes a shorter one. Characteristics of D shown in Table 3 and Table 4 show that the propagation path has rather a wide range around geomagnetic lines of force and therefore sometimes the path to a station in a higher latitude is shorter than that to a station in a lower latitude.

## 7. Daily Variation of Whistlers.

The frequency of occurrences of

TABLE 5 A Hourly Value of Number of Whistlers Observed in Each Month

(Wakkanai)

| Month→ Time in JST ↓ | 7 | 8 | 9 | 10 | 11 | 12 | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 12 (3) | 21 | 21 (1) | 54 | 28 (1) | 140 | 132 | 179 | 178 | 44 | 11 (6) | 9 |
| 1 | 11 (1) | 17 | 42 (1) | 85 (2) | 32 | 77 | 122 | 235 | 187 | 25 | 10 | 3 |
| 2 | 15 (3) | 15 (1) | 50 (1) | 85 (1) | 76 | 115 | 131 | 214 | 309 | 21 | 16 (3) | 4 (1) |
| 3 | 7 | 25 | 60 | 65 (1) | 51 | 118 | 147 | 226 | 288 | 35 | 16 (2) | 6 |
| 4 | 1 | 3 | 67 | 62 | 59 | 115 | 151 | 294 | 346 | 22 | 5 | 8 |
| 5 | 3 | 2 (1) | 13 | 19 | 43 | 74 | 71 | 235 | 189 | 26 | 4 | 5 |
| 6 | 3 | 4 | 0 | 24 | 55 | 51 | 60 | 105 | 64 | 9 | 1 | 0 |
| 7 | 1 | 9 | 1 | 9 | 27 | 11 | 21 | 37 | 19 | 0 | 0 | 0 |
| 8 | 0 | 2 | 1 | 4 | 9 | 0 | 9 | 2 | 6 | 0 | 2 | 0 |
| 9 | 0 | 0 | 0 | 1 | 2 | 0 | 16 | 0 | 0 | 0 | 3 | 0 |
| 10 | 0 | 0 | 0 | 0 | 0 | 4 | 0 | 0 | 0 | 0 | 0 | 0 |
| 11 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 3 | 0 | 0 | 0 |
| 12 | 0 | 0 | 0 | 0 | 1 | 3 (1) | 0 | 1 | 0 | 0 | 0 | 0 |
| 13 | 0 | 0 | 2 | 0 | 13 | 8 | 2 | 5 | 0 | 0 | 0 | 0 |
| 14 | 0 | 0 | 0 | 0 | 13 | 4 | 1 | 15 | 4 | 7 | 3 | 0 |
| 15 | 0 | 1 | 1 | 5 | 19 | 16 | 12 | 17 | 29 | 6 | 0 | 0 |
| 16 | 0 | 1 | 2 | 19 | 37 | 43 | 22 | 53 | 46 | 20 | 0 | 0 |
| 17 | 0 | 6 | 4 (1) | 20 | 61 | 41 | 43 | 130 (1) | 83 | 13 | 2 | 0 |
| 18 | 0 | 1 | 7 | 33 | 149 | 92 | 125 | 231 | 141 | 19 | 10 | 1 |
| 19 | 3 (1) | 6 | 14 (3) | 30 | 146 | 164 | 226 | 278 | 161 | 23 | 17 | 2 |
| 20 | 1 | 1 | 11 | 29 | 81 | 172 | 175 (1) | 260 | 228 | 18 | 3 | 5 |
| 21 | 8 | 20 | 14 (1) | 54 | 67 | 126 | 117 | 166 | 168 | 9 | 5 | 0 |
| 22 | 3 | 18 (1) | 24 (2) | 67 | 51 | 135 | 107 | 140 (1) | 135 | 24 | 5 | 1 |
| 23 | 10 (1) | 23 | 36 (1) | 59 (1) | 21 | 110 | 106 | 213 | 128 | 40 | 9 (3) | 9 |
| Total | 78 (9) | 175 (3) | 370 (11) | 723 (5) | 1042 (1) | 1619 (1) | 1796 (1) | 3033 (2) | 2712 (0) | 361 (0) | 122 (14) | 53 (1) |

together with Number of Long Whistlers in Parenthesis in 1958~1959

(Toyokawa)

| Month→ Time in JST↓ | 7 | 8 | 9 | 10 | 11 | 12 | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 | 0 | 6 | 6 | 1 | 24 | 13 | 0 | 2 |
| 1 | 0 | 0 | 0 | 7 | 1 | 2 | 3 | 27 | 33 | 2 | 0 | 0 |
| 2 | 0 | 0 | 1 | 5 | 1 | 3 | 24 | 20 | 53 | 1 | 0 | 0 |
| 3 | 0 | 0 | 7 | 0 | 0 | 10 | 32 | 28 | 69 | 5 | 0 | 0 |
| 4 | 0 | 0 | 0 | 0 | 0 | 2 | 34 | 34 | 79 | 3 | 0 | 0 |
| 5 | 0 | 0 | 0 | 0 | 2 | 28 | 29 | 12 | 54 | 0 | 0 | 0 |
| 6 | 0 | 0 | 0 | 0 | 0 | 13 | 14 | 20 | 8 | 0 | 0 | 9 |
| 7 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 0 |
| 8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 9 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 11 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 12 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 13 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 14 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 15 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 16 | 0 | 0 | 0 | 0 | 0 | 48 | 0 | 0 | 0 | 0 | 0 | 0 |
| 17 | 0 | 0 | 0 | 0 | 0 | 31 | 59 | 7 | 2 | 0 | 0 | 0 |
| 18 | 0 | 0 | 0 | 0 | 0 | 1 | 2 | 3 | 3 | 0 | 0 | 0 |
| 19 | 0 | 0 | 0 | 0 | 10 | 1 | 1 | 1 | 3 | 0 | 0 | 0 |
| 20 | 0 | 0 | 0 | 0 | 2 | 19 | 0 | 0 | 0 | 0 | 0 | 0 |
| 21 | 0 | 0 | 0 | 0 | 0 | 12 | 6 | 4 | 16 | 3 | 0 | 0 |
| 22 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 7 | 17 | 1 | 0 | 0 |
| 23 | 0 | 0 | 2 | 0 | 1 | 0 | 2 | 5 | 79 | 1 | 0 | 0 |
| Total | 0 | 2 (0) | 10 0 | 12 (0) | 18 (0) | 176 (0) | 216 (0) | 169 (0) | 440 (0) | 29 (0) | 0 | 11 (0) |

TABLE 5 B Hourly Value of Number of Whistlers Observed in Each Month

| Month→ Local time ↓ | (Adelaide 1958) 1 | 2 | 3 | 4 | 5 | 6 | (Brisbane) 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 8 | 35 (5) | 11 | 4 | 8 | 110 (3) | 7 (1) | 2 | 0 | 0 | 1 | 3 |
| 1 | 4 | 36 (7) | 10 | 1 | 11 | 84 | 1 | 0 | 0 | 0 | 1 | 11 |
| 2 | 6 | 25 (2) | 7 | 3 | 13 | 80 (1) | 2 | 0 | 0 | 1 | 0 | 12 |
| 3 | 9 | 22 (5) | 14 | 5 | 13 | 55 | 6 | 4 | 0 | 0 | 0 | 4 |
| 4 | 5 | 23 (4) | 20 | 3 | 16 | 40 | 4 | 3 | 0 | 4 | 2 | 0 |
| 5 | 7 | 15 | 36 | 7 | 18 | 56 | 1 | 1 | 0 | 1 | 0 | 1 |
| 6 | 0 | 3 | 7 | 8 | 7 | 68 (4) | 0 | 0 | 0 | 0 | 0 | 0 |
| 7 | 1 | 8 | 2 | 1 | 5 | 37 | 0 | 0 | 0 | 0 | 0 | 0 |
| 8 | 0 | 4 | 2 | 0 | 0 | 16 (5) | 0 | 0 | 0 | 0 | 0 | 0 |
| 9 | 3 | 1 | 0 | 0 | 2 | 21 | 0 | 0 | 0 | 0 | 0 | 0 |
| 10 | 0 | 2 | 0 | 0 | 0 | 18 | 0 | 0 | 0 | 0 | 0 | 0 |
| 11 | 2 | 1 | 0 | 0 | 0 | 21 (4) | 0 | 0 | 0 | 0 | 0 | 0 |
| 12 | 0 | 0 | 0 | 0 | 2 | 46 (10) | 0 | 0 | 0 | 0 | 0 | 0 |
| 13 | 1 | 6 | 1 | 0 | 2 | 36 (2) | 0 | 0 | 0 | 0 | 0 | 0 |
| 14 | 1 | 4 | 0 | 0 | 8 | 61 (3) | 1 | 0 | 0 | 0 | 0 | 0 |
| 15 | 1 | 0 | 0 | 0 | 4 | 75 | 0 | 0 | 0 | 0 | 0 | 0 |
| 16 | 1 | 3 | 3 | 0 | 9 (3) | 83 | 0 | 0 | 0 | 3 | 0 | 0 |
| 17 | 0 | 21 | 13 | 1 | 12 | 290 (11) | 0 | 0 | 0 | 0 | 0 | 0 |
| 18 | 0 | 26 (2) | 21 | 13 | 15 | 210 | 1 | 0 | 0 | 0 | 0 | 0 |
| 19 | 10 | 52 (6) | 38 | 14 | 13 | 203 | 2 | 3 | 0 | 0 | 0 | 0 |
| 20 | 6 | 74 (5) | 10 | 9 | 16 | 353 (4) | 2 | 3 | 0 | 0 | 1 | 0 |
| 21 | 15 | 64 (8) | 7 | 10 | 11 | 320 (10) | 1 | 4 | 0 | 0 | 0 | 2 |
| 22 | 9 | 50 (3) | 19 | 4 | 9 | 311 | 0 | 0 | 0 | 1 | 0 | 1 |
| 23 | 11 | 45 | 7 | 11 | 3 | 136 | 5 | 2 | 0 | 0 | 0 | 1 |
| Total | 100 (0) | 520 (47) | 228 (0) | 94 (0) | 197 (3) | 2730 (57) | 33 (1) | 22 (0) | 0 | 10 (0) | 5 (0) | 35 (0) |

together with Number of Long Whistlers in Parenthesis in 1958

| (Hobart) | | | | | | (Macquarie 1958) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 1 | 2 | 3 | 4 | 5 | 6 |
| 104 (32) | 67 (2) | 14 | 2 | 5 | 25 (3) | 0 | 3 (3) | 6 (3) | 2 (1) | 2 (2) | 3 (3) |
| 100 (18) | 98 | 11 | 1 | 4 | 26 | 2 | 1 | 1 (1) | 0 | 10 (7) | 6 (4) |
| 100 (23) | 53 (5) | 20 | 7 | 12 | 13 | 0 | 0 | 11 (11) | 2 (2) | 7 (6) | 5 (1) |
| 85 (6) | 120 (11) | 21 (6) | 1 | 6 | 14 | 0 | 1 | 3 (3) | 5 (4) | 7 (6) | 5 (3) |
| 62 (7) | 61 (8) | 8 | 0 | 4 | 23 | 0 | 0 | 0 | 0 | 4 (4) | 1 (1) |
| 13 | 7 | 0 | 0 | 3 | 16 | 0 | 0 | 0 | 0 | 1 (1) | 4 (3) |
| 16 | 0 | 0 | 1 | 3 | 20 | 0 | 0 | 0 | 0 | 1 (1) | 7 (6) |
| 4 | 0 | 0 | 0 | 3 | 11 | 0 | 1 | 0 | 0 | 0 | 7 (3) |
| 4 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 2 (2) | 2 (2) |
| 4 | 0 | 0 | 0 | 3 | 5 | 0 | 0 | 0 | 0 | 3 (2) | 9 (8) |
| 10 | 1 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 5 (4) |
| 1 | 0 | 0 | 0 | 2 (2) | 4 | 0 | 1 | 0 | 0 | 2 (2) | 5 (5) |
| 0 | 1 | 0 | 0 | 1 | 6 | 0 | 1 | 0 | 0 | 13 (12) | 3 (1) |
| 0 | 1 | 0 | 0 | 2 | 3 | 0 | 0 | 0 | 0 | 6 (6) | 8 (8) |
| 0 | 3 | 0 | 0 | 7 | 11 | 0 | 0 | 0 | 0 | 1 (1) | 8 (2) |
| 2 | 3 | 1 | 3 | 11 | 16 | 0 | 1 (1) | 0 | 1 (1) | 2 (2) | 8 (4) |
| 6 | 7 | 9 | 1 | 5 | 10 | 2 | 0 | 0 | 2 (1) | 5 (5) | 7 (5) |
| 2 | 4 | 12 (1) | 4 | 3 | 11 | 0 | 1 (1) | 2 (2) | 3 (3) | 10 (10) | 6 (4) |
| 41 (5) | 23 | 12 | 6 | 9 | 21 | 1 (1) | 5 (4) | 5 (5) | 6 (6) | 10 (10) | 9 (7) |
| 27 (1) | 34 | 2 | 3 | 9 | 23 | 0 | 2 (2) | 3 (2) | 7 (4) | 5 (4) | 5 (4) |
| 13 | 14 | 1 | 2 | 9 | 8 | 0 | 2 (2) | 3 (3) | 4 (3) | 5 (4) | 4 (2) |
| 23 | 9 | 0 | 0 | 4 | 11 | 0 | 4 (3) | 6 (6) | 2 (2) | 4 (4) | 3 (1) |
| 69 (15) | 60 | 3 | 4 | 3 | 26 | 0 | 0 | 1 | 3 (2) | 4 (4) | 1 |
| 84 (13) | 91 | 13 | 6 | 22 | 41 | 1 (1) | 4 (3) | 1 (1) | 2 (2) | 9 (7) | 3 |
| 770 (120) | 657 (26) | 127 (7) | 41 (0) | 130 (2) | 347 (3) | 6 (2) | 27 (19) | 42 (37) | 39 (31) | 113 (102) | 124 (81) |

whistlers observed in each month at Toyokawa and at Wakkanai in the 2nd year of IGY is tabulated in Table 5 and drawn in Fig. 5 together with that of the 1st year. Generally speaking, the number of whistlers at night is larger than that in the daytime due to absorption in D layer; at sunrise the frequency of occurrence decreases to daytime value; it begins to increase at sunset, reaches the nighttime maximum after 3-4 hrs. and then decreases or increases to reach the second maximum at 3-4 hrs. before sunrise. However, in February and March in the lst and 2nd years, and in September and October in 1957, when remarkable occurrences were observed, the number of whistlers began to increase at 2 hrs. before sunset.

## 8. Conclusion.

The definite conclusion should be made by consulting IGY, IGC, etc. Data of all over the world in the future. Examing our results obtained in 2 years, from 1st July 1957 to 30 June 1959, at Toyokawa and Wakkanai, the author concludes preliminarily as follows.

The frequency of occurrence of whistlers has a definite seasonal variation depending upon thunderstorm activities as well as distributions of electron density and geomagnetic intensity in the exosphere and in the ionosphere, influenced by solar activities and other yet unknown cosmic phenomena. In general this frequency of occurrence increases in winter and decreases in summer; long whistlers are observed mainly in summer, but both long and short whistlers are observed very often in this season so long as the observatory is situated in a high geomagnetic latitude, in a low noise region, and favoured by remarkable thunderstorm activities in its conjugate point.

Geomagnetic activities, expressed by effective K-index, have intimate correlation with the occurrence of whistlers in a favourable period, e. g. in winter, and really the correlation coefficient of +0.60 is obtained between the geomagnetically disturbed day and the number of whistlers on the 2nd day; dut in an unfavourable period such as in summer at Toyokawa, we can not find any correlation between them.

The average disperion of whistlers in each month has a close correlation with the sunspot numbers of two previous months, and the correlation coefficient between them is +0.65, i. e. the solar activities influence, two month later, the distributions of electron density and geomagnetic intensity in the exosphere.

Although the information of actual thunderstorm activivies can not be easily obtained, we could find a fairly intimate correlation of the number of whistlers with the average thunderstorm activities in the conjugate point.

Among whistlers observed simultaneously at Toyokawa and at Wakkanai within ±5 sec., perfect coincidence was most frequent and we could detect whistlers to ±3 sec. difference of arrival. The greater part of whistlers arrived at Wakkanai later than at Toyokawa and the dispersion of the former is generally larger than the latter, probably due to the difference in latitude. As whistlers have fairly large freedom of selecting propagation path around geomagnetic lines of force, some one takes a nearer path to Wakkanai than to Toyokawa and therefore the dispersion of the former is often smaller than that of the latter.

In diurnal variation the number of whistlers at night is much larger than that in the daytime. They begin to increase at sunset, reach their night times value after 3-4 hrs., then begin to decrease at 3-4 hrs. before sunrise and reach their day time values at sunrise. In active months such as February and March they begin to increase about 2 hrs. before sunset.

## 9. Acknowledgements.

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