LONG-TERM VARIATION OF WHISTLER DISPERSION

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Variation of the whistler dispersion in a period of July 1, 1957 to December 31, 1965 has been investigated using short whistlers observed at Wakkanai (July 1, 1957-Nov. 15, 1962) and Moshiri (Nov. 16, 1962-Dec. 31, 1965) according to the IGY, IGC and IQSY program. The geomagnetic latitudes of Wakkanai and Moshiri is about 35° and 34° respectively and the difference between them is only one degree or so. Therefore the data from the both stations have been equally treated here.

We have examined whistlers in two time belts of a day, the one is 0000-0050 JST (midnight-dawn) and the other is 1500-2000 JST (late noon-evening), in order to study a possible difference in the dispersion variation between night and evening. The data used are selected as follow:

1. Whistlers of extreme dispersions are excluded, i. e., those values larger than 100-120$\sqrt{s}$ and smaller than 15-20$\sqrt{s}$.

Table 1. Number of data

	1957	1958	1959	1960	1961	1962	1963	1964	1965	Sum
Jan.		76 36	51 36	87 89	43 31	45 65	110 144	85 126	50 47	547 574
Feb.		52 49	68 44	87 48	81 60	50 82	107 98	127 156	65 54	637 591
Mar.		115 22	94 38	77 22	50 33	58 51	83 67	86 71	64 55	627 359
Apr.		52 13	28 13	64 13	102 92	5 0	131 68	117 47	52 38	551 284
May		23 7	12 6	32 16	8 1	19 4	35 26	72 51	35 48	236 159
Jun.		9 0	10 2	2 0	21 9	5 6	27 36	58 63	36 23	168 139
Jul.	12 2	10 1	4 1	24 1	2 0	1 8	18 7	37 17	15 5	123 42
Aug.	29 7	26 7	23 5	9 4	5 1	45 13	20 3	8 2	32 18	197 60
Sep.	111 48	40 6	8 2	27 8	36 15	30 18	36 35	11 5	41 40	340 177
Oct.	125 46	57 23	4 3	79 37	48 41	91 69	80 85	83 53	56 38	623 395
Nov.	35 17	37 40	16 9	62 39	21 19	13 12	90 97	76 39	108 59	458 331
Dec.	66 39	69 49	61 34	68 95	22 16	108 125	62 126	82 31	54 96	529 611
Sum	378 159	566 253	379 193	618 372	439 318	470 453	799 792	842 661	608 521	5,099 3,722

2. For multipath whistlers, one component whistler is used which shows a trace down to the lowest frequency.

Numbers of data for each month and year thus selected are shown in Table 1, where the upper number in each column is for 0000-0050 JST and the lower number for 1500-2000 JST.

1. Solar-cycle variation

Fig. 1 shows the variation of average yearly values of dispersion. The curves clearly indicate dispersion variations corresponing to the shifted sunspot cycle. The sunspot activity reached the maximum during the year of 1958 and the minimum during 1964. Corresponding to this change of solar activity, the dispersion generally decreased continuously after the sunspot maximum if we neglect slight exceptions. The amount of decrease during the period from 1958 to 1964 is about 79% and 77% for the midnight-dawn and evening whistlers respectively. The difference of disper-

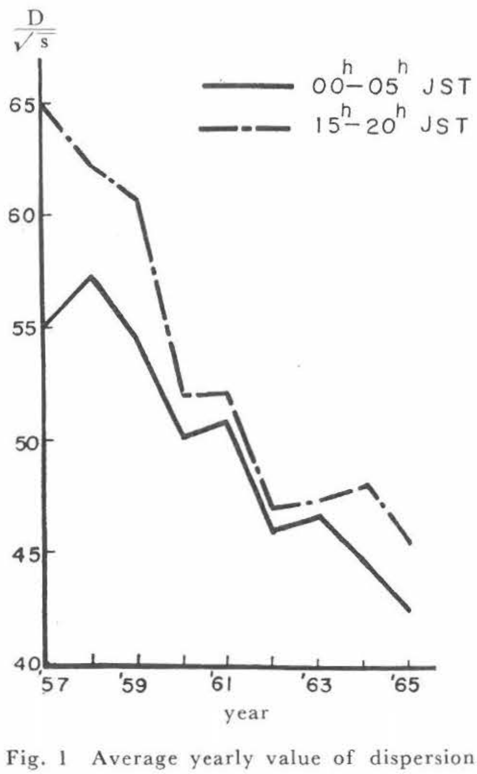

Fig. 1 Average yearly value of dispersion. July 1, 1957-Nov. 15, 1962: Wakkanai Nov. 16, 1962-Dec. 31, 1965: Moshiri

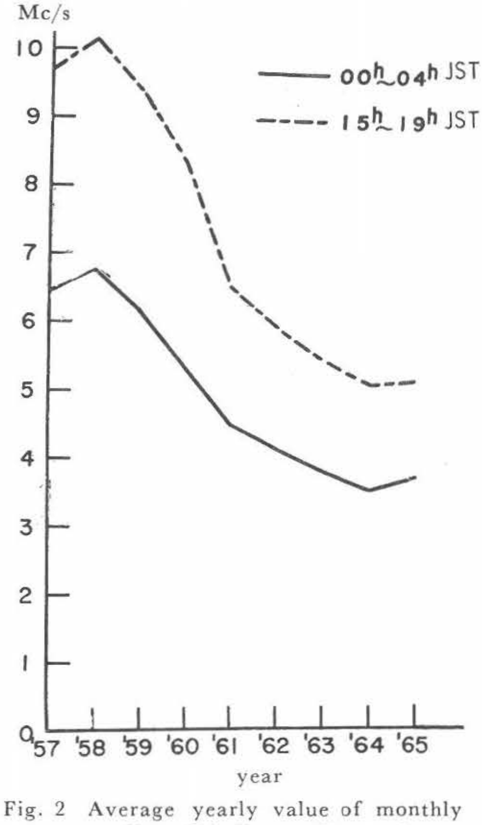

Fig. 2 Average yearly value of monthly median of f_0F_2. Data of Wakkanai and Akita are used.

sion between whistlers in both time belts seems to be larger for the period when the solar activity was high. Fig. 2 shows the variation of average yearly values of monthly medians of $f_0 F_2$ observed at Wakkanai and Akita Ionospheric Observatories. The values of $f_0 F_2$ indicate a similar decreasing tendency. During the same period, the values of $f_0 F_2$ decreased by about 50% and 53% for the midnight-dawn and evening whistlers, respectively. Both dispersion and $f_0 F_2$ are proportional to the square root of electron density, so the above changes in dispersion and $f_0 F_2$ correspond to the reductions in the electron density of about 60 per cent and 25 per cent for the magnetosphere and F_2-layer, respectively. These values are nearly consistent with the values by Carpenter[1] inferred for a period of sunspot minimum. These results have made clear, as was suggested by him that the magnetosphere is less sensitive than the F_2 region to the long-term variation of solar activity. The variation of the $f_0 F_2$ seems to have changed in phase with the sunspot activity, while the dispersion of whistlers seems to have decreased till the end of 1965. The phase of the change in electron density in the magnetosphere is likely to be behind the phase of the sunspot activity.

2. Seasonal variation

Fig. 3 indicates the annual variation of monthly means of dispersions averaged for a period from July 1957 to December 1965. And for comparison, the corresponding variations of $f_0 F_2$ are shown in Fgi. 4. The variations of dispersions show clear semi-annual changes. A larger dispersion occurs in March, April, September and October for the midnight-dawn whistlers and in April, May, August, September and October for the evening whistlers. A smaller dispersion occurs in June, July, December and January for the midnight-dawn whistlers and in June, July, November, December, January and February for the evening whistlers. Hence, in a rough sense, it can be said that a larger dispersion occurs in spring and autumn and a smaller one in summer and winter. These results differ from what have been obtained by Helliwell[2] using data from stations in higher latitudes, such as Stanford, Seattle, Unalaska, and Wellington. Their results showed annual changes of the same phase in both hemispheres and the minimum dispersion occurred in either June or July, and the maximum in November, December or January, depending on the station and year. The minimum dispersion in June or July agrees well with our present results, but the maximum in November, December or January differs seriously from ours. In the latter months, the dispersion falls to the lowest level according to our present analysis. As the whistlers propagate between both hemispheres, the semi-annual variation seems to be more plausible than the annual variation. So the annual variation obtained from higher latitude whistlers is rather difficult to explain. In

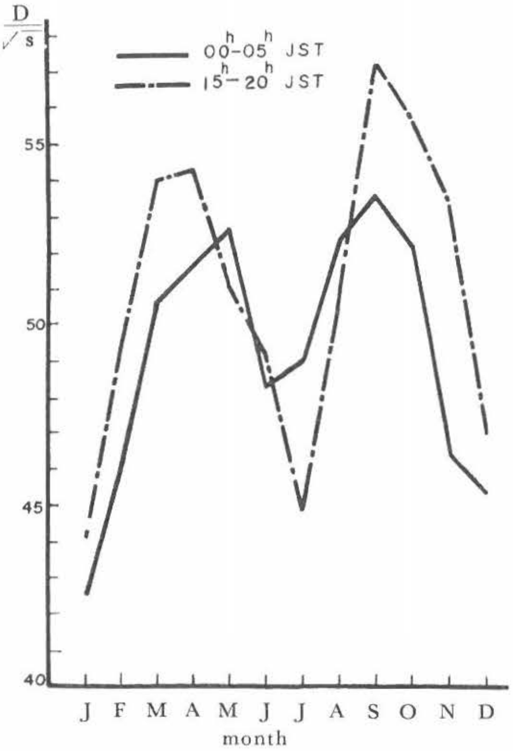

Fig. 3 Annual variation of monthly means of dispersion averaged for July 1957-Dec. 1965.
July 1, 1957-Nov. 15, 1962 : Wakkanai
Nov. 16, 1962-Dec. 31, 1965 : Moshiri

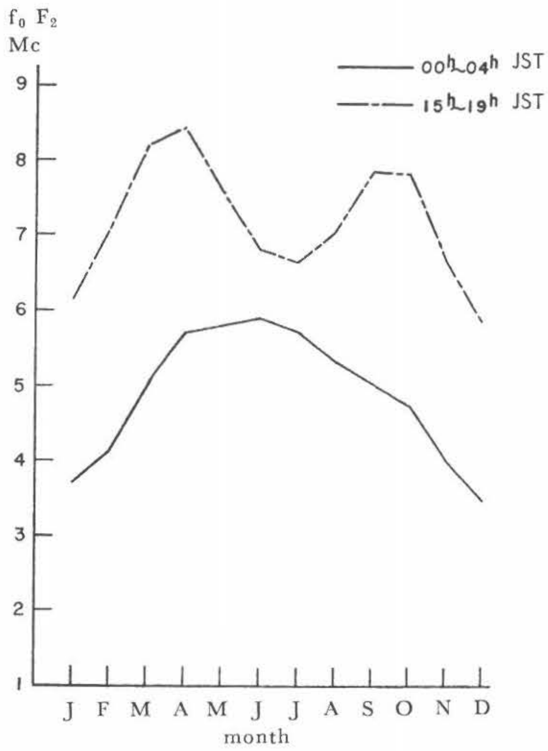

Fig. 4 Variation of monthly median value of f_0 F_2 averaged for July 1957-Dec. 1965. Data of Wakkanai and Akita are used.

this sense, the difference in the seasonal variation of whistler dispersions between higher and lower latitudes is a problem to be solved by a future study.

The variation of the f_0 F_2 is similar to that of dispersion in the evening. That is, the variation is a semi-annual type and the larger values appear in spring and autumn and the smaller values in summer and winter and the valley in the variation curve is deeper in winter than in summer. However, the peak is higher in spring than in autumn and this differes from the variation of the dispersion, though this difference seems to be not significant.

On the other hand, the variation of f_0 F_2 at the time of 0000-0040 JST is quite different from that of the dispersion. For, the variation of f_0 F_2 is an annual type in contrast with the dispersion variation of semi-annual type and that the f_0 F_2 has the maximum value in July while the variation curve of the dispersion shows a valley in the same month. The discrepancy between the seasonal variation of f_0 F_2 and the dispersion seems not to have caused by the scantiness of whistler data in summer. At present the reason of this discrepancy can not be known, but one possible explanation may be that the electron density changes semi-annualy in the magnetosphere even when it changes annually in the F_2-layer.

3. Conclusions

The whistler dispersions vary according to the sunspot activity, the phase being rather lag behind the sunspot cycle. The electron density in the magnetosphere deduced from the whistler dispersion decreased by about 60 per cent during the period from the sunspot maximum to minimum, while the corresponding reduction at the F_2-maximum level is about 25 per cent. This result clearly shows that the magnetosphere is less sensitive than the F_2 region to the long-term variation of solar activity. The seasonal variation in whistler dispersions indicates semi-annual changes in contrast with the former results obtained from whistlers in higher latitudes, which showed annual changes having the maximum in winter. Further study is necessary to solve the difference in seasonal variation of the dispersion of whistlers between higher and lower latitudes.

The corresponding seasonal variation in f_0 F_2 indicates a similar change for the time of 1500-1900 JST, but shows a quite different change for the time of 0000-0040. The variation in f_0 F_2 for the time of 0000-0040 is an annual type, having maximum in June and minimum in December, while that in the dispersion is a semi-annual type. So that it appears at present that the electron density in the magetosphere changes semi-annually even when it changes annually in the F_2-layer.

References

(1) Carpenter, D. L. : Electron-density variations in the magnetosphere deduced from whistler data, Tech. Rep. No. 11 prepared under AF Contract AF-18 (603) -126 and NSF Grant NSF-G-17037, Radioscience Lab., Stanford Electronics Lab., Stanford Univ. (1962)

(2) Helliwell, R. A. : Exospheric electron density variations deduced from whistlers, Ann. Geophys., **17**, 76 (1961)