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DATA REPORT ON WHISTLERS OBSERVED BY VANGUARD III (1959 η1)

by Ivan R. Shapiro, John D. Stolarik, and James P. Heppner

Goddard Space Flight Center
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SUMMARY

A study of 1200 whistlers observed in several longitudinal zones between ± 33.5 degrees geographic latitude and in the altitude interval from 510 to 3753 km shows an increase of the average rate of occurrence of whistlers with increasing magnetic activity, peaking at $K_p = 5$. Rising tone VLF emissions and diffuse whistlers were nearly always observed during periods of magnetic disturbance. A complete list of whistler observations and their dispersions are given in an appendix.

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INTRODUCTION

The sensing coil of the proton precession magnetometer carried on Vanguard III also served as an antenna for detecting audio-frequency electromagnetic waves. They were detected during the 2-sec readout intervals that followed each interrogation, or command, from the NASA Minitrack stations. The records thus obtained yielded 1200 whistlers, in addition to numerous magnetic field data (References 1 and 2), over the areas covered by the original network of Minitrack stations. These areas were western South America, the West Indies, a region near the southeastern United States, a region near southern California, and central Australia. Data were transmitted for 85 days, from launch on September 18, 1959 to battery exhaustion on December 11, 1959. With an orbital inclination of 33.5 degrees, the satellite had a geomagnetic latitude range of ± 45 degrees. Perigee and apogee were 510 and 3753 km. Throughout the 85 day interval, perigee remained on the night side, oscillating twice past all latitudes $\leq$ 33.5 degrees geographic. The data presented here update two preliminary analyses (References 3 and 4).

WHISTLER DISPLAY

A general description of the satellite and its electronics is given in Reference 5. For whistler purposes the bandpass characteristic of the satellite amplifier (Figure 1) is of particular interest (Reference 6). Because of the high attenuation below 300 cps, the natural low frequency cutoff of the whistlers is often indeterminable.

Since magnetic field measurements with the proton instrument are frequency-dependent only, no inflight calibrations were provided for the amplitude response of the magnetometer. Therefore, although reasonable estimates of whistler amplitudes can be made (Reference 3), no precise data exist. Also, on a given record, absolute whistler amplitude cannot be computed from relative amplitude measurements between the whistler and proton precession signals (see below), owing to unknown angles between the coil axis, magnetic field, and whistler wave normal.

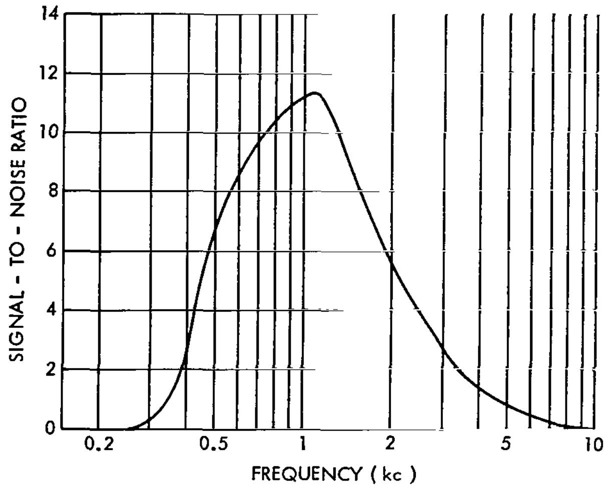

Figure 1—Bandpass characteristic of the Vanguard III amplifier.

Vanguard III transmissions were systematically monitored and photographed with the use of a new, rapid, frequency-scan type of spectrum analyzer (Reference 7). The photographs were too small to give accurate dispersion figures by direct scaling. Thus for each of the satellite transmissions that the photographs showed to contain whistlers or other VLF signals, larger sound spectrograms were made by using a slower, time-scan spectrum analyzer. These spectrograms had a time display of 2.4 sec and a frequency range from 85 cps to 12 kc in two bands of 6 kc each. The instrument used was a commercially available sound spectrograph.

Figure 2 is an example of the multiple-flash type of whistlers with small dispersions indicating single transmissions through the primary layers of the ionosphere. The name derives from the apparent origin of the individual whistlers in separate, closely spaced lightning discharges, implied by the nearly equal dispersions. If only records having 3 or more whistler elements are counted, 19 percent of the records were of this type. As many as 25 individual whistlers occurred on one spectrogram of this type. The heavy horizontal lines are the proton precession signals, $f(\text{cps}) = 4257.6\ H$ (gauss), and their harmonics. The light horizontal line at 3 kc is believed to be instrumental. The value of the whistler dispersion is obtained from the well known approximation, $D = dt/df^{-1/2}$, where D is in sec$^{1/2}$ (Reference 8).

Figure 3 illustrates a higher dispersion whistler on a record in which the proton signal is not visible, probably because of the coil orientation relative to the magnetic field. Only four samples of relatively "long" whistlers, similar to the one shown in Figure 4, were recorded. Whistlers of such a relatively high dispersion, 50 sec$^{1/2}$ and up, are more representative of those recorded by ground stations at higher latitudes. The rather diffuse whistlers in Figure 5 are typical of about 4 percent of the records. Most of the diffuse whistlers were associated with a band of noise that extended over approximately the same frequency range as the whistlers.

Only three records of a type similar to whistler echo trains were recorded. One of these is shown in Figure 6, an unusual record containing two duplicate trains in which the time separations and dispersions of the first four whistlers are closely duplicated by those of the last four. Figure 7 is an example of a rising tone VLF emission. Only ten VLF emission signals were recorded.

Examples of the large number of multiple-flash records that contain only 2 individual whistlers are not illustrated. Also not shown is an example of three records, each of which contained elements of 2 distinct multiple-flash whistlers of different dispersions. These were the only events of this type, and it is interesting to note that for all three the satellite position was nearly the

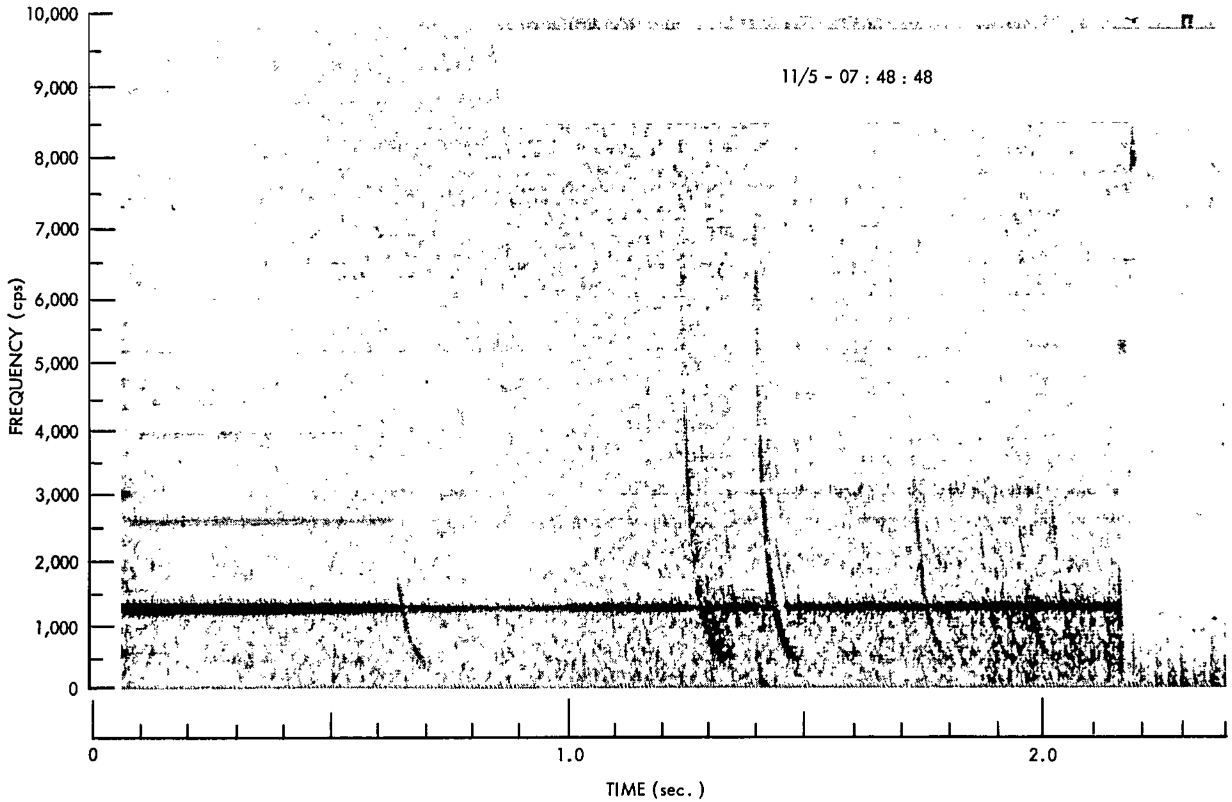

Figure 2—Multiple-flash whistlers.

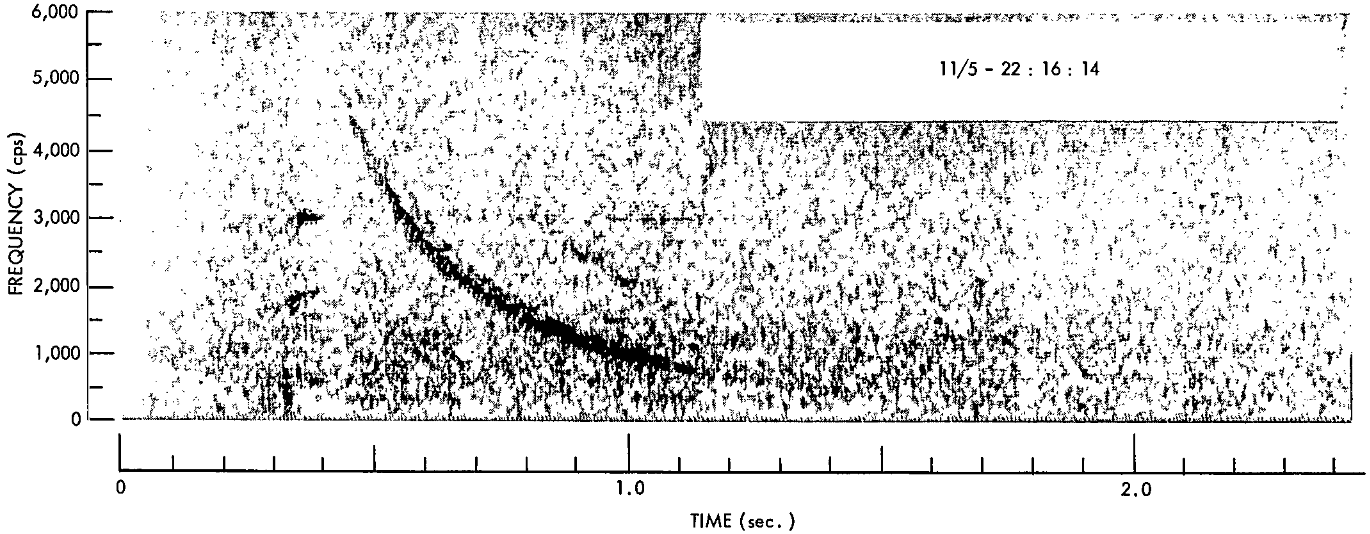

Figure 3—Higher dispersion whistler.

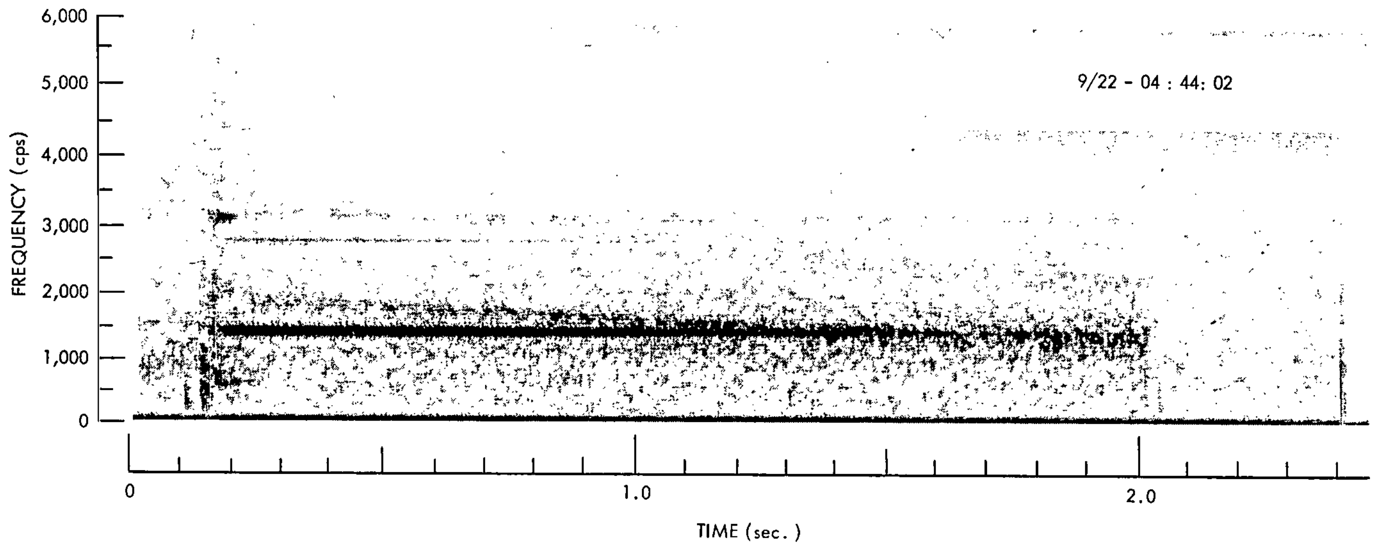

Figure 4—Spectrogram for relatively long whistler.

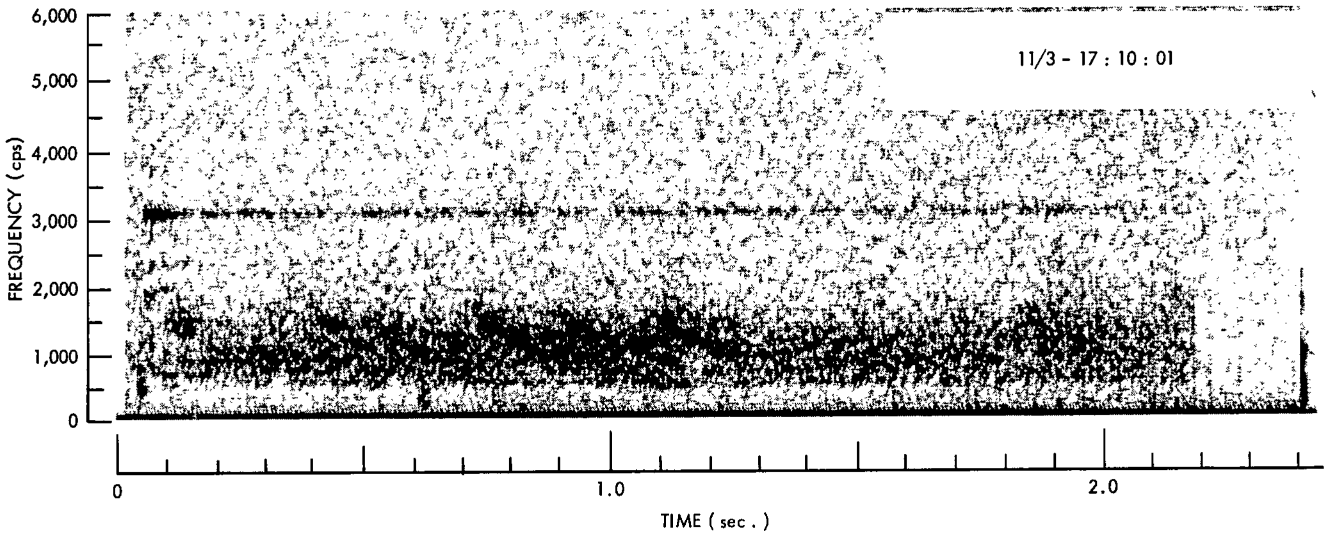

Figure 5—Diffuse whistlers.

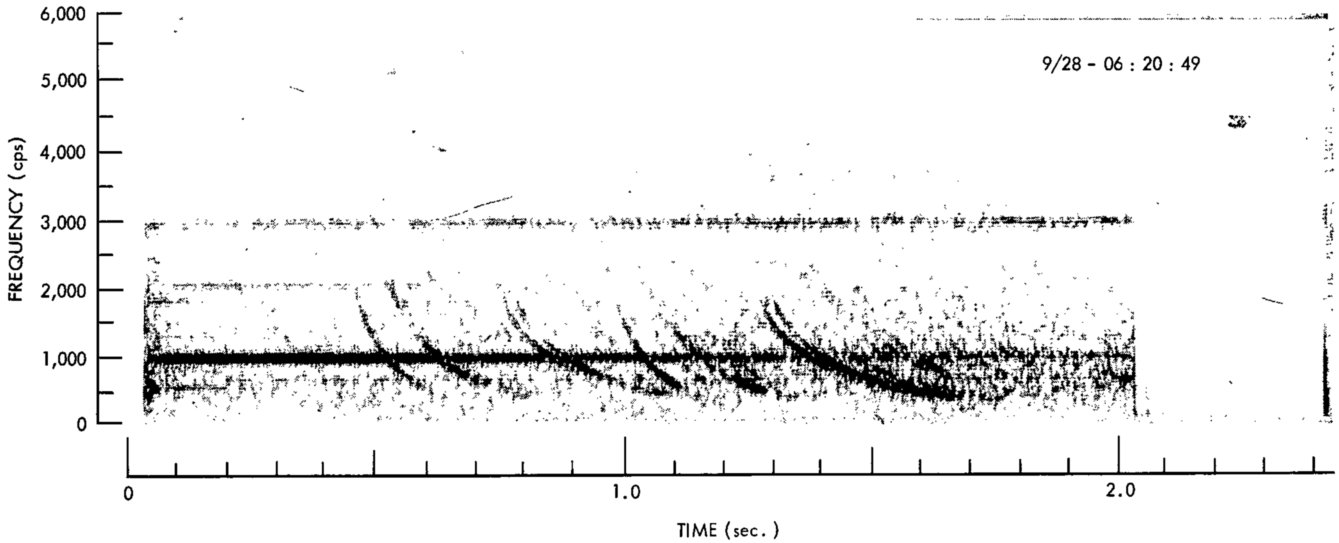

Figure 6—Duplicate whistler trains.

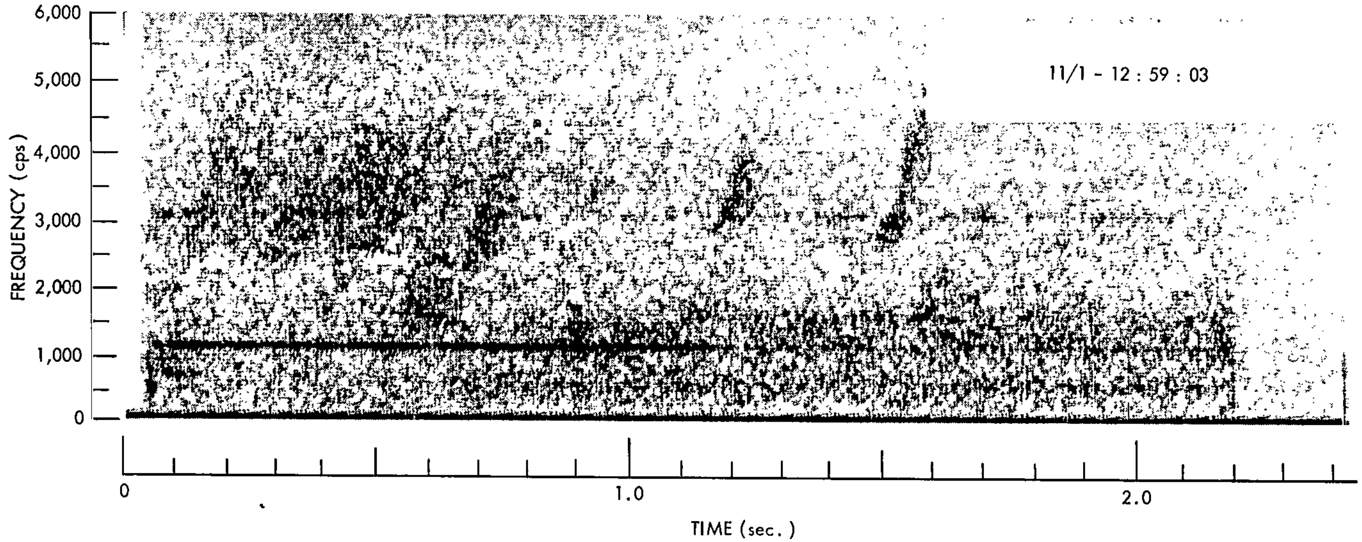

Figure 7—Rising tone VLF emissions.

same, as shown in the appendix, for the times 10/17-05:55:48, 10/19-05:37:58, and 10/19-07:55:26. Also at these times, magnetic storms of moderate and moderately severe activity were recorded in the satellite meridian at the Fredericksburg and Huancayo Observatories.

DATA

Of the approximately 4100 transmissions made by Vanguard III, about 450 or 11 percent contained whistlers; these are listed in the appendix. Times given are in GMT to the nearest second and represent the half points of the 2 sec transmissions, i.e., a readout interval is within approximately $\pm$ 1 sec of a given time. The next column lists the number of whistlers per 2 sec interval. The letter R listed in this column refers to the rising tone VLF signals discussed later.

The next four columns show satellite position, for the times listed, in geographic latitude, geomagnetic latitude, geographic longitude, and altitude. The 3-hour indices of planetary geomagnetic disturbance, K_p, are listed next. The last column gives, in time order, the dispersions in $sec^{1/2}$ of the measurable whistlers on a given record. The figure in the number column minus the number of dispersions listed equals the number of unmeasurable whistlers on a given record. Asterisks in the last column identify whistlers of the type shown in Figure 5.

The majority of the whistlers, about 1000, occurred over the first three areas referred to in the introduction. These whistlers were distributed randomly from 45°N to 22°S geomagnetic latitude, within the longitude range of the three areas, 60°W to 80°W geographic longitude. If whistlers are assumed to be due to lightning at or near the earth's surface and whistler propagation is assumed to be along magnetic field lines (Reference 8), the latitude range of these whistlers, in terms of their points of origin based on a reference field used in the Vanguard III analysis (Reference 1), extended from 15°N to 54°N and 19°S to 60°S geomagnetic.

It is estimated, from the distribution of those whistlers for which dispersions could be calculated (see the section on "Dispersions") that about two-thirds of the whistlers observed in the region under discussion had their origin in the northern hemisphere. However, because of the poor quality of many records and the lack of simultaneous ground station observations, it was not possible to determine the hemisphere of origin of many of the whistlers, especially those in the vicinity of the geomagnetic equator. Therefore, a definitive breakdown of whistler occurrence as a function of latitude was not obtained.

For the same reason and because all whistlers, except possibly those represented by Figures 4 and 5, were observed after only one passage through the ionosphere, no distinction is made in the appendix between whistlers which originate in the hemisphere through which the satellite is traveling and those which do not.

Less than 100 whistlers were observed in the region covered by the southern California Minitrack station between 30°N and 41°N geomagnetic within 104°W and 124°W geographic. About 150 whistlers were observed in the central Australia region—at 31°S to 44°S geomagnetic except for one observation at 24°S—over a longitude range from 132°E to 144°E geographic.

SUBDIVISION OF DATA

For statistical purposes the data have been divided as follows:

A = number of records (2 sec intervals)

B = number of records containing one or more whistlers

C = number of whistlers

D = B/A = fraction of records containing one or more whistlers

E = C/A = average number of whistlers per record

F = C/B = average number of whistlers per record containing one or more whistlers.

The whistler occurrence rate E, equivalent to the number of whistlers per unit time (2 sec), is the usual figure quoted in whistler statistics. The fraction D is the probability that at least one whistler will be recorded within one record of 2.0 sec length. The F ratio is, by definition, a direct measure of multiple-element whistler activity per unit time. Because the data presented here include just a small number of the echo train and diffuse types of multiple-element whistlers, the F ratio is essentially the occurrence rate for multiple-flash whistlers only.

CORRELATION WITH MAGNETIC ACTIVITY

Table 1 shows a comparison of whistler activity with K_p indices for data of all the regions mentioned in the introduction. It was necessary to combine $K_p = 0$ and 1 and $K_p = 6$ and 7 because of a statistically poor number of records for $K_p = 0$ and 7. $K_p = 2$ and 3 are combined since whistler activity was almost identical for each. The comparison shows that D, E, and F increase with magnetic activity through $K_p = 5$ and then decrease slightly for $K_p \geq 6$.

Table 2 shows a breakdown by mean local time of the results in Table 1. Time groupings are, in the order listed: sunrise, day, sunset, and night. For a given period, K_p indices are subdivided as far as is statistically meaningful. For example, only two K_p groups are used in the sunrise period because of the lack of data to warrant further subdivision. In all but the sunset period there is a general increase of the three ratios with increased magnetic activity. In the daytime period, D peaks at $K_p = 5$, E peaks at $K_p = 4$, 5, and F, though generally rising, shows a decrease at $K_p = 5$. For the nighttime period, E and F peak at $K_p = 5$ and D increases with all indices. For the sunset period the correlation is reversed. E and F are maximum at $K_p \leq 1$, and F decreases as the indices increase.

Table 1

All Data vs. K_p.

K_p	A	B	C	D	E	F
≤ 1	730	57	128	0.078	0.175	2.25
2, 3	1739	167	380	0.096	0.219	2.28
4	766	109	298	0.142	0.389	2.73
5	499	79	266	0.158	0.533	3.37
≥ 6	334	39	127	0.117	0.380	3.26

Table 3 shows a comparison of whistler and magnetic activity for the South America, West Indies, and southeastern United States data only. The mean geographic meridian for this region, the 70th, will be used as a shorthand notation to refer to data for the entire region, hence the table heading. The purpose of Tables 3 and 4 is to separate a region that might involve different whistler activity by excluding Australia and California data. A comparison with Table 1 shows that whistler activity is greater in all categories for all K_p indices, except for D at $K_p \geq 6$.

Table 2

All Data vs. K_p for Local Time.

Time	K_p	A	B	C	D	E	F
4^h-6^h	< 4	152	26	56	0.171	0.368	2.15
	≥ 4	127	39	92	0.307	0.724	2.36
6^h-18^h	≤ 1	392	9	11	0.023	0.028	1.22
	2, 3	893	42	62	0.047	0.069	1.48
	4	413	27	58	0.065	0.140	2.15
	5	223	20	31	0.090	0.139	1.55
	≥ 6	196	7	19	0.036	0.097	2.71
18^h-20^h	≤ 1	90	5	11	0.056	0.122	2.20
	2, 3	181	8	11	0.044	0.061	1.38
	≥ 4	140	11	12	0.079	0.086	1.09
20^h-4^h	≤ 1	212	36	95	0.170	0.448	2.64
	2, 3	558	98	262	0.176	0.470	2.67
	4	240	56	184	0.233	0.767	3.29
	5	169	43	202	0.254	1.195	4.70
	≥ 6	82	24	93	0.293	1.134	3.88

Table 4 is the local time division of Table 2, with the same time blocks as used in Table 2, its counterpart. In all four periods, variations of the ratios with K_p are nearly the same as in Table 2, the chief difference being the day period F ratio at $K_p \geq 6$ which is a minimum in Table 4 and a maximum in Table 2. Two other differences are the sunset D and E figures at $K_p \geq 4$ which have maximum and intermediate values in Table 2 and minimum values in Table 4. Possible nighttime E and F peaks in Table 4 at $K_p = 5$ are lost because of the combined form of $K_p = 5$ and $K_p \geq 6$.

Seventieth meridian data show considerably more nighttime whistler activity throughout than do the corresponding "all" data blocks. Similar increases occur for sunrise D and E for both K_p groups, and for sunset D and E for $K_p \leq 1$. Seventieth meridian and "all" data activity are almost identical in the daytime period for $K_p \leq 3$ and are essentially the same for sunrise and sunset F for all K_p. For daytime $K_p \geq 4$, with the exception of D, and for sunset D and E for $K_p \geq 4$, the "all" data activity is the greater. It is interesting to find that the 70th meridian daytime occurrence rate at $K_p = 5$ is 3.7 times the rate at $K_p \leq 1$ and that the nighttime occurrence rate for $K_p \geq 5$ is 3.5 times that for $K_p \leq 1$. The E ratios of Table 3 and of the 20^h-4^h period of Table 4, in whistlers per minute, are shown in Figure 8.

Table 3

70th Meridian Data vs. K_p.

K_p	A	B	C	D	E	F
≤ 1	477	40	92	0.084	0.193	2.30
2, 3	1214	129	318	0.106	0.262	2.47
4	531	85	240	0.160	0.452	2.82
5	303	57	223	0.188	0.736	3.91
≥ 6	222	23	95	0.104	0.428	4.13

Table 4

70^{th} Meridian Data vs. K_p for Local Time.

Time	K_p	A	B	C	D	E	F
4^h-6^h	< 4	86	23	53	0.267	0.616	2.30
	≥ 4	94	37	85	0.394	0.904	2.30
6^h-18^h	≤ 1	261	6	7	0.023	0.027	1.17
	2, 3	630	31	45	0.049	0.071	1.45
	4	308	20	36	0.065	0.117	1.80
	5	140	10	14	0.071	0.100	1.40
	≥ 6	131	1	1	0.008	0.008	1.00
18^h-20^h	≤ 1	68	5	11	0.074	0.162	2.20
	2, 3	134	4	6	0.030	0.045	1.50
	≥ 4	86	2	2	0.023	0.023	1.00
20^h-4^h	≤ 1	127	23	64	0.181	0.504	2.78
	2, 3	387	77	224	0.199	0.579	2.91
	4	146	43	155	0.295	1.062	3.60
	≥ 5	148	52	265	0.351	1.791	5.10

Figure 9 shows a comparison of average daily rates of occurrence for all data, in whistlers per minute, versus average K_p indices. The three breaks in the rate curve, at September 30 and October 10 and 21, are due to three 24-hour periods when magnetometer transmissions were discontinued in order that the extent of interference with other experiments on the satellite might be determined.

The comparison shows a correlation of approximately 50 percent, considering only those portions of the two traces that simultaneously increase or decrease for at least 2 consecutive days and not counting the three silent periods. This implies that at least some of the correlation between magnetic and whistler activity, shown in Tables 1-4, occurs within a much shorter interval, perhaps on the order of several hours or less.

The fall-off in whistler activity beginning about mid-November is apparently a seasonal effect, a reflection of decreasing thunderstorm activity in the northern hemisphere, the hemisphere of origin of most of the whistlers. If there had been a corresponding seasonal decrease of K_p, then the correlation between whistler and magnetic activity in Figure 9 and probably that of Tables 1-4 would not be valid. Since K_p is independent of thunderstorm activity the seasonal decrease in the latter should be a reason for the fact that the correlations of Tables 1-4 are not more pronounced.

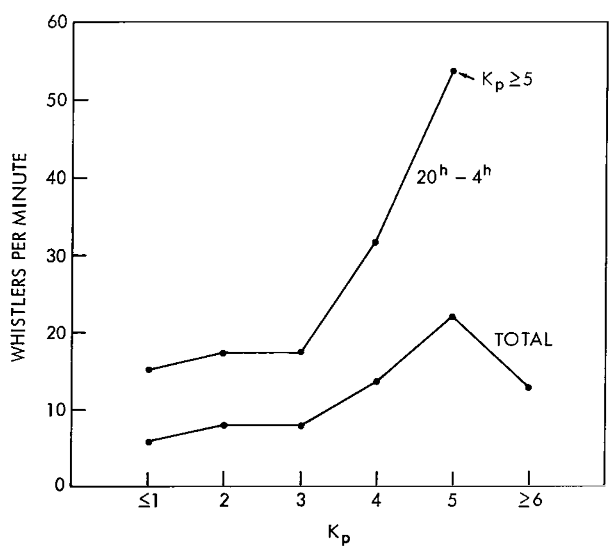

Figure 8—E vs. K_p for 70^{th} meridian data.

DIURNAL VARIATION

Figure 10 is a diurnal histogram, in quarter-hour divisions, of E for the 70^{th} meridian data. The diurnal variation of the rate of occurrence of multiple whistlers is shown in the F histogram, Figure 11, in whistlers per record with whistlers. Because the F ratio always equals at least 1.0, the presentation is for F > 1.0 only. The similarity between the two histograms might suggest that the nighttime increase in E is only a reflection of the nighttime increase in F. That this is not generally so is illustrated in the D histogram, Figure 12. Since D weights all whistler records equally and is therefore not a measure of the multiple occurrence rate, the overall agreement of the D and E histograms shows that the nighttime increase in E is not a general consequence of the diurnal variation in multiple whistlers. However, comparing histograms shows that some of the high E rates do

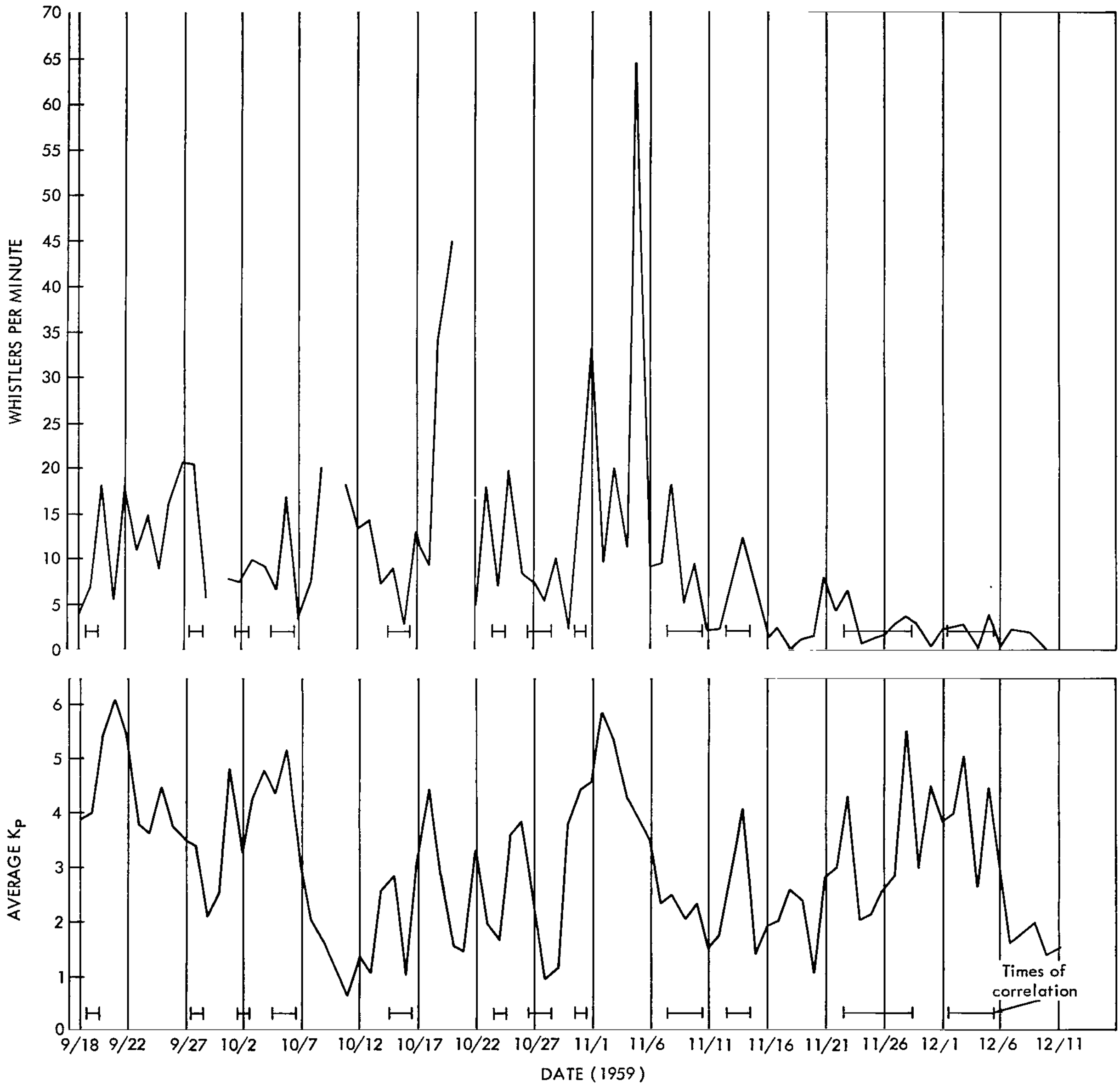

Figure 9—Comparison of average daily E with average daily K_p for all data.

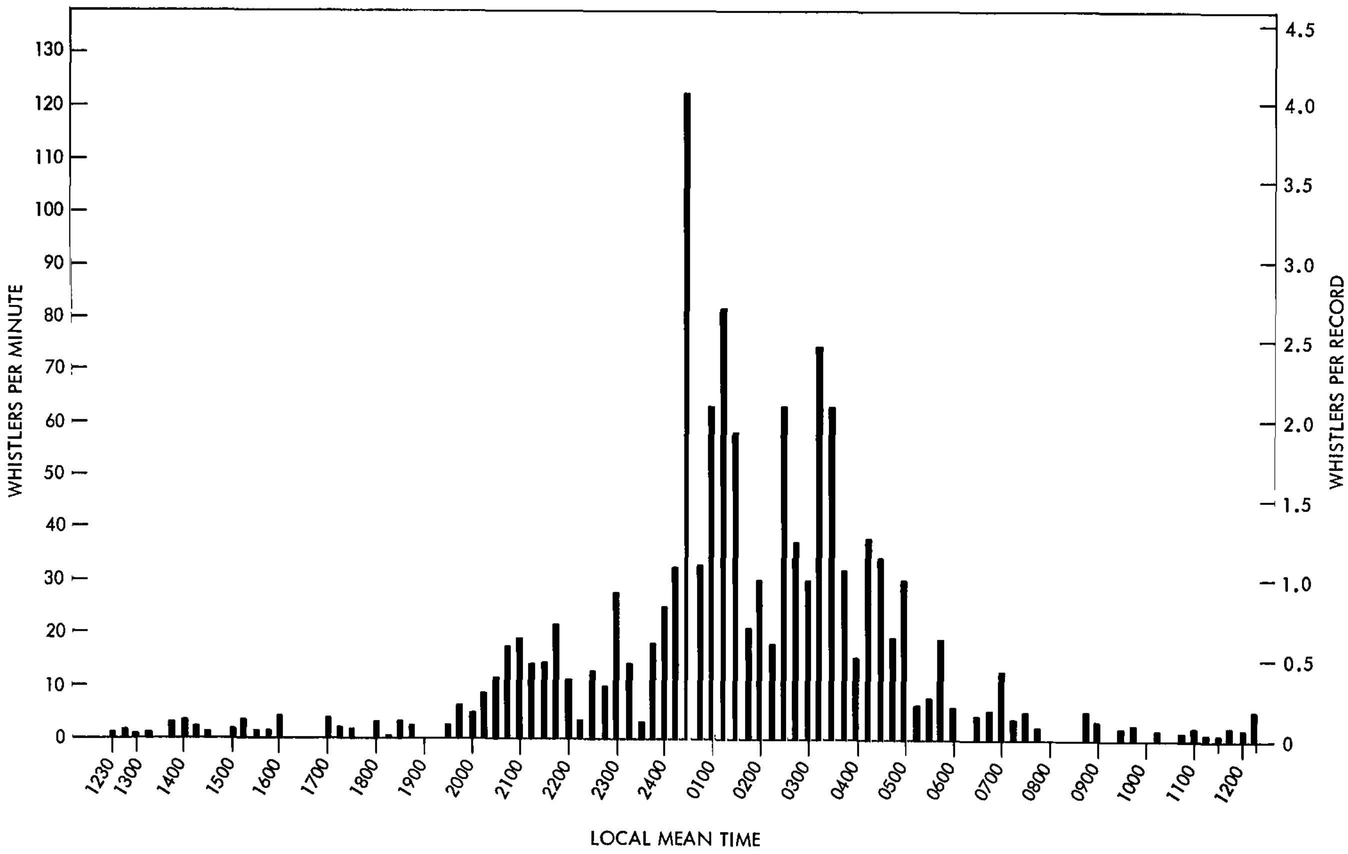

Figure 10—Diurnal variation of E for 70th meridian data.

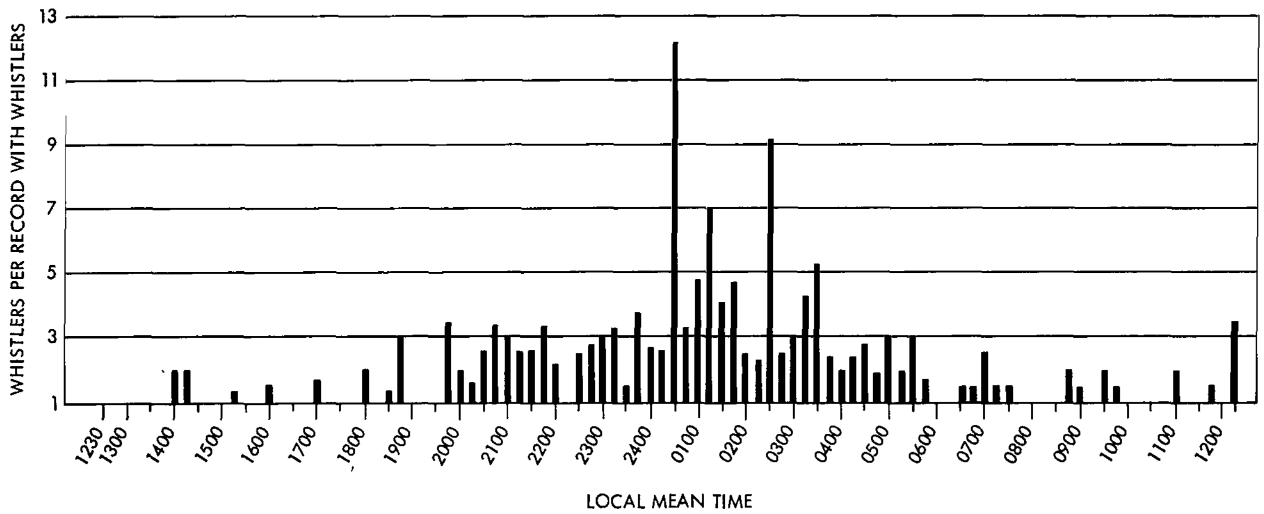

Figure 11—Diurnal variation of F for 70th meridian data.

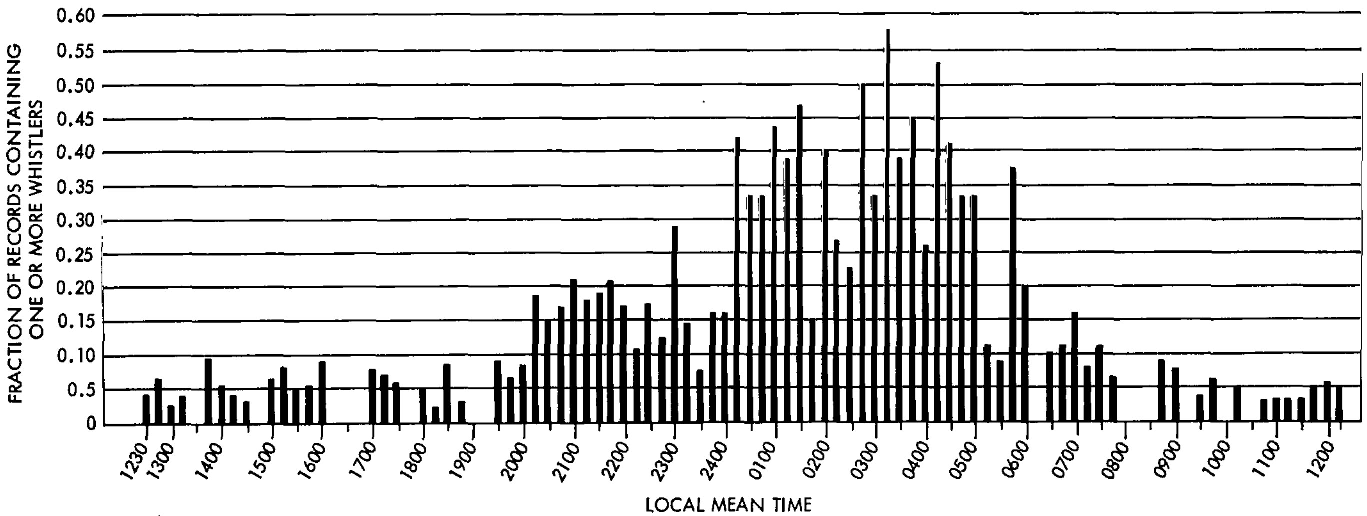

Figure 12—Diurnal variation of D for 70th meridian data.

strongly reflect short periods of unusually high multiple activity, e.g., the high E and F ratios at 0030 hours (see the appendix data for 05 hours on November 5). On the other hand, the high E rate at 0315 hours, when the D ratio is also high, is a more valid measure of nonmultiple peak activity.

Table 5 shows the lack of dependence of diurnal variation on magnetic activity. For each time period the percentage of data for different K_p indices is about the same, especially for the day and night periods. The percentages of data for the sunrise and sunset periods are not as uniform, showing maximums at $K_p \geq 4$ and $K_p \leq 1$, respectively, which may be weighting factors in the tabulations for these periods in Tables 1-4.

Satellite altitudes were always higher during the day than at night. Therefore, from consideration of the shorter nighttime transmission paths and subsequent greater signal-to-noise ratio, it was not improbable that diurnal variation would be weighted in favor of the nighttime period. That it is not so weighted is apparent in Table 5 which shows that less than half of the data were recorded during the nighttime period.

Diurnal histograms for "all" data, not illustrated, show the same relative activity per quarter hour as those for 70th meridian data, but with marked average decreases in magnitude; 27, 42, and 7 percent for D, E, and F, respectively. Comparing an average E of 10.8 whistlers per minute for 70th meridian data with that of 5.7 whistlers per minute for both the Australia and California data, shows that the lower "all" data ratios are due to less average whistler activity in both of the latter areas. For the California data this is consistent with the relatively low thunderstorm activity in the southwestern United States.

The average rate of occurrence of 10.8 whistlers per minute is comparable with that of 6.7 whistlers per minute based on 5 years of September and October short whistler observations at the Port Lockroy ground station, located at 53.4°S geomagnetic and 63.5°W geographic (Reference 9). This is consistent with the estimate that most of the satellite-observed whistlers originated in the northern hemisphere. The somewhat greater rate for satellite data is due perhaps to

Table 5

Data Sampling vs. Magnetic Activity for 70th Meridian Data.

Time	$K_p \leq 1$		$K_p = 2, 3$		$K_p \geq 4$	
	A	Percentage of Total	A	Percentage of Total	A	Percentage of Total
4^h-6^h	24	5	62	5	94	9
6^h-18^h	261	54	630	52	579	55
18^h-20^h	68	14	134	11	86	8
20^h-4^h	127	27	387	32	294	28
	480		1213		1053	

greater thunderstorm activity at the satellite latitudes, which are lower than the Port Lockroy conjugate latitude. The fact that Port Lockroy rates of occurrence are often higher than 50 whistlers per minute agrees with the very high nighttime rates of occurrence for the satellite data.

DISPERSIONS

Twenty-five percent of the total number of whistlers had sufficient signal-to-noise ratio, time duration, and definition to allow dispersion measurements to be made. All measurements are accurate to at least ± 10 percent.

For the entire region referred to as 70^{th} meridian data, there are about 270 measurable whistlers which is 90 percent of the approximate total of 300 measurable whistlers. Dispersion measurements are therefore very thinly distributed. This makes it difficult to arrive at any conclusions regarding dispersion as a function of magnetic activity or time of day. However, several regions near perigee altitude, extending 5 degrees or less in both latitude and longitude, contain a number of time-distributed measurements adequate to allow a few comments on the variation of dispersion.

A group of observations between 26°N and 31°N geomagnetic and 60°W and 63°W geographic show average dispersions of 4.4 and 2.5 $sec^{1/2}$ for whistlers occurring between September 18-24 and November 5-9, respectively. Another group of observations, between 11°N and 16°N geomagnetic and 77°W and 80°W geographic, show average dispersions of 6.1 and 3.1 $sec^{1/2}$ for occurrences between September 24-27 and November 4-5, respectively. For both sets of observations, all whistlers occurred during local night. Observations in each set contain magnetically disturbed and quiet time observations.

The comparisons show decreases in dispersion by factors of 1.8 and 2.0 in the higher and lower latitude zones, respectively, during the six-to-seven week period. If we assume similar propagation paths for September and November whistlers of similar latitude, the "short term" seasonal decreases in dispersion are probably due to the average integrated ionospheric electron densities, of the two latitude zones, decreasing as the square of the ratio for each zone from dispersion approximation

$$D = \frac{1}{2c} \int_{path} \frac{f_p}{\sqrt{f_h}} \, ds ,$$

where f_p = plasma frequency = $9N^{1/2}$, N being the electron density (Reference 10), and f_h = electron gyro-frequency. For the higher latitude zone a comparison was made between the September to November dispersion ratio and the National Bureau of Standards electron density profiles (Reference 11) for the same region. It showed that the average electron density, based on mean data of the quiet ionosphere, decreased from September to November approximately as the square of the ratio. A similar comparison was not made for the other zone since its latitude was lower than those of the NBS profiles.

Examination of dispersions as a function of magnetic activity did not reveal significant differences in dispersions for quiet and disturbed periods for whistlers observed at about the same time of day and location over a period of a week or more. Because satellite altitudes were higher during the day than at night, nothing can be said regarding dependence of dispersion on the time of day.

ELECTRON DENSITIES

The detection of whistlers of sufficient quality for dispersion measurements suggests the possibility of deriving electron densities above the ionosphere. To this end, two types of analysis were attempted.

In the first approach the attempt was made to construct a chart of "iso-dispersion" contours which could then be interpreted in terms of an average electron distribution. To construct such a contour plot satellite positions were displayed on a polar "altitude-latitude" grid accompanied by the measured dispersion. Dipole field lines were superimposed as an interpretive aid. In the case of "multiple events" in which the various whistlers may have followed different propagation paths, the minimum dispersion was plotted. Practical limitations were encountered in sketching the contours of equal dispersion. Above 1000 km, data were generally too sparse. Below this altitude diurnal, seasonal, and storm variations, as well as probable anomalous propagation paths, made it very difficult to establish a set of contours which could be treated with confidence. Breakdowns of the data to eliminate or minimize the above effects either were unsuccessful or left too few points to analyze accurately.

In the second approach average electron densities above $h_{f_{max}}$ were derived for 10 points (5 points at altitudes greater than 1000 km, 5 points at altitudes less than 1000 km). To make this calculation, electron density profiles are required up to $h_{f_{max}}$ to enable substraction of the contribution due to this region from the total measured dispersion. This immediately restricts attention to a region in the vicinity of the 75^{th} W meridian (e.g., ± 10 degrees), and bounded by geographic longitudes 15°N and 50°N, for which electron density information was regularly available from vertical sounding stations operated by the Central Radio Propagation Laboratory. Consequently, the lack of sufficient ancillary data as well as redundant measurements and elimination of multiple events reduced the field of data available for analysis from approximately 270 points to about 25 points. These in turn are distributed in space, time, and magnetic activity over the 85 days of useful life of the satellite. Clearly, any attempt to infer electron distributions would represent a very crude estimate, compared with the potential of currently active experiments such as those aboard the dramatically successful Alouette (1962 $\beta\alpha 1$) satellite. This objective, therefore, was not pursued in further detail.

DIFFUSE WHISTLERS AND RISING TONES

Since all of the rising tones and most of the diffuse whistlers occurred at relatively high latitudes and altitudes (primarily during the magnetic storm period of October 30 to November 5) they are treated together here. Of the twenty samples of diffuse whistlers (Figure 5) fifteen occurred during this storm period, and thirteen of these occurred at times of $K_p \geq 4$, at geomagnetic latitudes higher than 38°N, and at altitudes above 1200 km., i.e., on dipole field lines terminating at, or higher than, 43 degrees geomagnetic. Also, four occurred from October 29-31 (two in the storm period) between 6°S and 10°S geomagnetic at altitudes near perigee.

The ten records of rising tones (Figure 7) occurred at times of $K_p \geq 4$, at geomagnetic latitudes greater than 40 degrees, and at altitudes higher than 1600 km, i.e., on field lines terminating at, or higher than, 47 degrees geomagnetic. Six of the occurrences were in the above disturbed period. The fact that all of these signals were recorded during local day may be attributed to the high daytime satellite altitudes, referred to earlier.

Whistlers of dispersion greater than 50 $sec^{1/2}$ (Figure 4) were also observed at relatively high latitudes and altitudes. As it was difficult to accurately measure the dispersion of these whistlers, only minimum figures are given for them in the appendix.

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REFERENCES

1. Cain, J. C., Shapiro, I. R., Stolarik, J. D., and Heppner, J. P., "Vanguard III Magnetic-Field Observations," *J. Geophys. Res.* 67(13):5055-5070, December 1962.
2. Cain, J. C., Shapiro, I. R., Stolarik, J. D., and Heppner, J. P., "Measurements of the Geomagnetic Field by the Vanguard III Satellite," NASA Technical Note D-1418, October 1962.
3. Cain, J. C., Shapiro, I. R., Stolarik, J. D., and Heppner, J. P., "A Note on Whistlers Observed above the Ionosphere," *J. Geophys. Res.* 66(9):2677-2680, September 1961.
4. Cain, J. C., Shapiro, I. R., Stolarik, J. D., and Heppner, J. P., "Whistler Signals Observed with the Vanguard III Satellite," *J. Phys. Soc. Japan* 17(Supp. A-II):84-88, January 1962.
5. Heppner, J. P., Stolarik, J. D., Shapiro, I. R., and Cain, J. C., "Project Vanguard Magnetic Field Instrumentation and Measurements," in: *Space Research, Proc. First Internat. Space Science Symp., Nice, 1960,* Amsterdam: North Holland Publ. Co., 1960, pp. 982-999.
6. Mansir, D., "Magnetometer at Work in Outer Space," *Radio-Electronics* 31(4):38-41, April 1960.
7. Colburn, V. R., and Cope, J. E., "A Spectrum Analyzer for Atmospheric 'Whistler' Studies," Ballistics Res. Lab. Rept. BRL-MR-1316, August 1961.

8. Storey, L. R. O., "An Investigation of Whistling Atmospherics," *Roy. Soc. Phil. Trans.* A246(908):113-141, 1953.

9. Laaspere, T., Morgan, M. G., and Johnson, W. C., "Some Results of Five Years of Whistler Observations form Labrador to Antarctica," *Proc. IEEE* 51(4):554-568, April 1963.

10. Helliwell, R. A., and Morgan, M. G., "Atmospheric Whistlers," *Proc. IRE* 47(2):200-208, February 1959.

11. Wright, J. W., Wescott, L. R., and Brown, D. J., "Mean Electron Density Variations of the Quiet Ionosphere," Nat. Bur. Standards Technical Notes 40-7 and 40-9, September and November 1959.

Appendix A

Whistler Data

DATE	TIME(UT) HR	MN	SEC	NUMBER	LAT	GM LAT	LONG	ALT(KM)	KP	DISPERSIONS(SEC)$^{1/2}$
9/18	10	6	52	1	-10.2	1.1	-80.0	1196	5	7.8
9/18	10	8	17	1	-12.7	-1.3	-76.2	1299	5	
9/18	10	8	38	1	-13.3	-1.9	-75.3	1325	5	
9/18	19	54	57	1	-3.5	8.0	-69.9	3286	4	
9/18	22	19	50	1	15.0	26.4	-77.2	2359	5	15.4
9/18	22	26	52	1	23.9	35.3	-60.7	1811	5	>110
9/19	0	41	46	1	29.2	40.6	-79.2	1442	6	
9/19	2	49	21	1	26.7	33.7	-119.7	1643	6	9.6
9/19	3	1	7	7	33.3	44.7	-76.4	823	6	5.0 5.4 5.2 5.0
9/19	5	22	49	3	19.9	31.3	-61.4	514	6	4.6 4.8 4.4
9/19	5	23	2	2	19.5	30.9	-60.6	515	6	4.6
9/19	12	21	3	1	-28.7	-17.3	-78.1	2128	4	
9/20	2	43	56	1	30.6	39.2	-108.7	1447	4	6.5
9/20	2	52	9	5	33.3	44.7	-77.2	880	4	4.7 4.9
9/20	2	52	23	11	33.2	44.6	-76.2	867	4	4.8 5.0 5.0 5.1 4.7 4.9 4.8
9/20	5	14	3	2	19.3	30.7	-62.1	512	5	4.1
9/20	9	49	48	8	-13.1	-1.8	-79.3	1114	5	15.8 15.8
9/20	9	50	34	1	-14.5	-3.1	-77.1	1168	5	
9/20	9	52	52	2	-18.4	-6.9	-70.6	1336	5	16.9
9/21	2	43	10	1	33.2	44.6	-78.0	942	6	
9/21	5	5	26	2	18.3	29.7	-62.3	514	7	
9/21	5	5	44	1	17.7	29.0	-61.2	513	7	
9/21	22	59	15	2	-33.0	-43.2	135.1	2373	5	
9/21	23	0	14	R	-33.2	-43.2	137.8	2445	5	
9/22	2	23	16	1	29.3	36.6	-117.5	1821	6	
9/22	2	34	6	2	33.1	44.5	-78.9	1011	6	5.7 5.7
9/22	2	34	18	1	33.1	44.4	-78.1	999	6	
9/22	4	42	34	4	33.4	40.5	-118.2	1127	7	
9/22	4	44	2	1	33.2	41.2	-112.4	1028	7	> 65
9/22	4	56	40	7	17.6	29.0	-62.9	518	7	4.1 4.3 3.7
9/22	4	56	49	5	17.3	28.7	-62.4	517	7	4.1
9/22	9	33	16	1	-16.9	-5.5	-76.9	1073	6	
9/22	19	14	18	2	-2.7	8.7	-75.4	3615	5	
9/23	2	16	34	2	31.4	39.8	-110.4	1721	3	
9/23	4	48	29	1	15.6	27.0	-61.5	520	3	
9/23	9	24	4	1	-17.1	-5.8	-78.5	992	4	7.8
9/23	11	46	40	4	-31.8	-20.3	-72.7	1927	4	
9/23	11	47	29	5	-32.2	-20.7	-70.2	1991	4	28.4 28.4 28.2 28.6
9/23	19	5	21	1	-1.1	10.3	-75.0	3639	4	27.6
9/23	19	5	34	3	-0.9	10.5	-74.7	3634	4	23.0
9/23	22	41	17	2	-33.3	-43.5	136.3	2217	5	
9/24	2	16	44	2	32.6	44.0	-77.7	1107	4	5.9
9/24	4	26	28	4	32.8	40.9	-111.8	1138	4	5.3
9/24	4	39	58	2	14.3	25.7	-61.3	526	4	5.2
9/24	6	54	52	7	3.7	15.0	-78.3	529	4	5.4
9/24	9	17	49	2	-22.2	-10.7	-70.8	1106	3	
9/24	9	18	36	2	-23.4	-11.9	-68.3	1161	3	15.4
9/24	11	38	17	2	-32.4	-20.9	-70.6	1894	3	
9/24	18	50	49	1	-5.5	5.8	-82.1	3739	3	
9/24	18	52	35	1	-3.6	7.7	-79.7	3723	3	
9/24	19	5	18	1	10.2	21.6	-61.7	3371	3	
9/24	21	32	28	1	27.9	39.3	-61.4	2331	3	
9/25	2	7	57	1	32.3	43.7	-77.3	1164	5	
9/25	6	46	7	7	2.8	14.1	-79.0	520	4	7.9 8.3
9/25	18	46	20	1	0.9	12.3	-75.6	3699	3	
9/25	21	16	4	2	21.9	33.3	-77.4	2916	5	
9/25	21	16	18	1	22.1	33.5	-76.9	2901	5	

DATE	TIME(UT) HR MN SEC	NUMBER	LAT	GM LAT	LONG	ALT(KM)	KP	DISPERSIONS(SEC)$^{1/2}$
9/26	1 49 26	1	32.4	40.8	-110.3	1975	4	9.9
9/26	4 22 49	3	11.9	23.2	-61.3	545	3	
9/26	6 37 23	3	1.8	13.1	-79.5	515	3	
9/26	6 37 49	13	0.8	12.2	-78.1	518	3	5.7 5.2 5.4 5.6
9/27	0 36 24	1	-27.9	-38.0	137.1	2851	3	
9/27	1 50 9	1	31.7	43.1	-77.3	1295	3	
9/27	1 54 27	1	27.6	39.0	-61.8	996	3	
9/27	6 17 34	1	23.4	30.9	-117.0	831	4	
9/27	6 29 4	2	-0.1	11.2	-78.8	513	4	5.9
9/27	6 29 20	1	-0.7	10.6	-77.9	515	4	
9/27	8 51 33	1	-24.8	-13.3	-70.8	956	4	
9/27	8 51 50	2	-25.2	-13.7	-69.8	974	4	
9/27	8 52 1	5	-25.4	-14.0	-69.2	985	4	10.5 14.9
9/27	8 52 9	3	-25.6	-14.1	-68.7	994	4	
9/27	8 52 16	1	-25.8	-14.3	-68.3	1001	4	
9/27	8 52 22	3	-25.9	-14.4	-68.0	1008	4	10.2 10.2
9/27	8 52 55	1	-26.6	-15.2	-66.0	1044	4	
9/27	8 53 4	2	-26.8	-15.4	-65.5	1054	4	
9/27	8 53 10	1	-27.0	-15.5	-65.2	1061	4	10.0
9/27	8 53 14	1	-27.0	-15.6	-64.9	1065	4	10.3
9/27	8 53 36	3	-27.5	-16.1	-63.7	1090	4	
9/27	11 10 56	2	-33.0	-21.5	-71.2	1626	4	23.8
9/27	15 58 5	1	-17.1	-5.6	-70.7	3405	4	
9/28	1 45 42	2	26.9	38.2	-61.6	1045	4	
9/28	1 46 1	1	26.5	37.8	-60.5	1024	4	
9/28	1 46 18	2	26.1	37.4	-59.5	1006	4	6.8
9/28	1 46 25	1	26.0	37.2	-59.1	998	4	6.6
9/28	3 49 59	1	32.1	39.8	-114.7	1475	3	
9/28	6 20 3	7	-0.5	10.8	-80.2	513	4	
9/28	6 20 49	8	-2.2	9.1	-77.8	513	4	8.9 11.3 12.0 15.1 7.8 11.5 13.6 15.6
9/28	8 43 12	1	-26.2	-14.7	-69.2	936	4	
9/28	11 2 32	1	-33.3	-21.8	-69.1	1594	3	
9/28	20 47 37	1	23.9	35.2	-78.4	3174	3	
9/29	1 32 13	2	31.0	42.3	-77.5	1442	3	
9/29	1 32 23	1	30.8	42.2	-76.9	1429	3	
9/29	6 12 8	1	-3.3	8.0	-78.2	513	2	
9/29	13 15 34	1	-28.5	-17.0	-65.6	2439	2	
9/29	18 6 33	1	3.3	14.7	-78.9	3740	1	
10/ 1	1 14 39	1	29.7	41.2	-76.2	1562	4	
10/ 1	8 16 30	3	-27.7	-16.2	-70.6	785	6	8.1
10/ 1	17 48 41	1	6.7	18.1	-77.7	3726	4	
10/ 1	19 9 58	4	-31.1	-41.2	137.2	930	4	
10/ 1	23 50 16	1	-24.4	-34.5	137.3	2424	5	
10/ 2	8 7 19	3	-27.8	-16.3	-72.2	729	5	18.2
10/ 2	8 7 56	2	-28.6	-17.1	-69.8	758	5	
10/ 2	10 25 43	1	-33.5	-22.0	-72.2	1232	4	
10/ 2	10 26 18	2	-33.5	-22.0	-70.0	1273	4	>50 >65
10/ 2	15 7 6	1	-16.9	-5.6	-78.7	2813	2	
10/ 2	15 8 50	1	-15.0	-3.5	-75.6	2922	2	
10/ 3	7 58 59	8	-29.0	-17.5	-70.4	715	4	9.3 9.4 18.8 9.4
10/ 3	10 17 28	3	-33.5	-22.0	-69.5	1215	3	21.5
10/ 3	18 52 11	1	-31.8	-41.9	136.8	831	7	
10/ 4	0 52 43	1	22.0	33.3	-61.3	1396	5	
10/ 4	2 55 29	2	29.9	37.6	-115.2	1979	5	
10/ 4	7 49 51	5	-29.1	-17.6	-71.9	669	5	21.1
10/ 4	7 50 10	1	-29.5	-18.0	-70.5	682	5	
10/ 4	10 8 38	2	-33.4	-21.9	-69.1	1158	5	

DATE	TIME(UT) HR	MN	SEC	NUMBER	LAT	GM LAT	LONG	ALT(KM)	KP	DISPERSIONS(SEC)$^{1/2}$
10/ 4	12	28	15	1	-27.0	-15.5	-69.9	1879	6	
10/ 4	22	2	24	1	29.0	37.7	-107.8	3499	3	
10/ 5	7	41	46	1	-30.4	-18.9	-68.9	668	3	
10/ 5	7	42	1	4	-30.7	-19.2	-67.9	677	3	10.0 9.5
10/ 5	17	11	46	4	12.1	23.5	-76.8	3648	4	
10/ 6	2	51	3	5	9.9	21.3	-77.5	1089	6	7.5 7.0 7.3
10/ 6	7	32	32	3	-30.4	-18.9	-70.8	624	5	8.5 8.3
10/ 6	7	32	44	9	-30.6	-19.1	-69.9	631	5	8.1
10/ 6	17	0	7	1	10.9	22.2	-80.0	3550	5	17.3
10/ 6	17	1	7	2	11.9	23.3	-78.6	3581	5	
10/ 6	17	2	22	1	13.2	24.6	-76.7	3615	5	18.9
10/ 6	19	39	45	R	32.7	44.0	-61.4	3355	5	
10/ 6	20	44	3	3	-31.6	-41.6	138.1	1200	5	
10/ 7	0	26	8	1	18.9	30.3	-61.0	1587	3	9.4
10/ 7	7	23	46	1	-30.9	-19.4	-70.6	601	3	
10/ 7	7	23	54	3	-31.0	-19.5	-70.0	605	3	
10/ 7	9	41	26	1	-33.1	-21.6	-70.7	954	3	6.7
10/ 8	2	33	30	5	7.5	18.8	-77.6	1191	3	8.5 8.5 8.5
10/ 8	4	55	3	2	-15.9	-4.5	-76.5	590	3	20.3 21.3
10/ 8	9	32	41	1	-32.9	-21.4	-70.1	912	3	
10/ 8	11	52	14	1	-24.0	-12.5	-69.8	1574	3	21.6
10/ 9	2	24	25	5	6.7	18.1	-78.4	1265	3	8.8 9.0
10/ 9	2	25	5	4	5.5	16.9	-76.7	1217	3	
10/ 9	7	6	16	1	-31.8	-20.3	-70.2	565	2	
10/11	2	6	44	5	4.3	15.6	-78.7	1383	1	10.5 10.5
10/11	2	7	2	6	3.7	15.1	-77.9	1360	1	10.1 10.0 10.1 9.7
10/11	4	30	39	1	-22.3	-10.8	-70.3	598	0	22.0
10/11	6	48	22	3	-32.2	-20.7	-71.5	533	1	7.4
10/11	11	25	17	1	-21.6	-10.1	-70.3	1358	0	
10/11	15	24	6	3	-27.3	-37.4	137.2	541	0	27.8 34.7
10/11	17	41	37	4	-33.4	-43.5	137.3	578	0	
10/12	1	58	45	10	1.5	12.9	-76.7	1378	1	10.2 10.7
10/12	1	59	52	1	-0.6	10.9	-73.9	1293	1	
10/12	6	39	43	2	-32.6	-21.1	-70.7	527	0	6.8
10/12	8	57	10	1	-31.9	-20.4	-70.1	735	0	
10/12	13	37	33	1	-3.4	8.0	-76.4	2150	2	
10/13	1	48	19	4	3.0	14.3	-80.6	1561	1	10.0 9.8
10/13	1	49	12	2	1.5	12.8	-78.5	1491	1	10.4
10/13	4	13	13	1	-24.1	-12.6	-70.1	643	1	13.4
10/13	6	31	17	5	-33.0	-21.5	-68.9	525	1	6.6
10/13	15	54	54	1	18.7	30.1	-79.3	3174	1	
10/13	17	23	40	2	-33.5	-43.7	136.0	541	1	
10/13	17	23	57	1	-33.5	-43.5	137.4	546	1	>55
10/14	1	40	35	5	-0.2	11.1	-78.0	1535	2	12.1 12.6 12.0 11.9
10/14	19	32	14	1	-28.5	-38.8	135.3	748	3	
10/14	19	32	33	1	-28.1	-38.3	136.5	763	3	3.8
10/15	1	30	42	3	0.2	11.5	-80.4	1677	3	14.0
10/15	1	32	7	1	-2.2	9.2	-77.1	1567	3	
10/15	6	13	8	1	-33.1	-21.6	-71.3	522	2	5.6
10/15	6	13	28	2	-33.2	-21.7	-69.8	521	2	
10/15	17	5	58	1	-33.5	-43.7	135.8	524	3	
10/15	23	4	42	3	9.7	21.1	-62.4	2288	3	11.8
10/16	10	40	48	1	-17.0	-5.5	-71.0	1057	0	
10/16	10	41	2	1	-16.5	-5.0	-70.3	1073	0	
10/17	5	55	49	6	-33.4	-21.9	-69.8	532	2	23.8 6.4 22.2
10/17	14	30	58	1	-30.3	-40.5	135.8	679	4	5.0
10/17	14	31	11	5	-30.5	-40.6	136.7	670	4	

DATE	TIME(UT) HR MN SEC	NUMBER	LAT	GM LAT	LONG	ALT(KM)	KP	DISPERSIONS(SEC)$^{1/2}$
10/18	5 46 46	3	-33.5	-22.0	-70.7	546	4	7.5
10/18	5 46 56	9	-33.5	-22.0	-69.9	543	4	7.8
10/19	3 19 47	1	-27.7	-16.2	-72.2	885	4	
10/19	3 20 14	6	-28.3	-16.8	-70.5	859	4	24.7 23.0
10/19	5 37 58	14	-33.5	-22.0	-70.5	560	4	6.4 27.1 7.2
10/19	7 55 13	5	-28.9	-17.4	-70.9	552	2	19.9
10/19	7 55 25	10	-28.6	-17.1	-70.1	555	2	9.1 20.0 18.8 20.5
10/19	10 12 15	1	-17.7	-6.3	-77.9	799	3	11.1
10/19	12 35 23	2	6.3	17.7	-75.7	1699	2	11.7 12.1
10/19	14 13 28	1	-31.3	-41.4	136.7	738	2	
10/20	5 29 0	5	-33.5	-22.0	-70.9	580	2	21.7
10/20	10 3 48	9	-15.9	-4.5	-76.8	780	2	8.4
10/20	16 21 56	2	-32.8	-42.9	136.5	539	0	3.4
10/20	16 22 10	2	-32.7	-42.7	137.6	535	0	
10/22	13 45 54	1	-31.7	-42.2	133.2	913	3	5.7
10/22	13 46 49	2	-32.4	-42.4	137.0	860	3	5.6
10/22	16 3 53	2	-32.5	-42.8	135.0	575	4	
10/22	16 56 18	R	33.5	44.8	-76.5	3367	4	
10/23	7 20 21	1	-25.8	-14.3	-69.5	521	3	19.4
10/23	7 20 33	1	-25.5	-14.0	-68.7	522	3	
10/23	7 20 45	1	-25.2	-13.7	-67.9	523	3	11.4
10/23	9 37 4	3	-13.5	-2.1	-78.4	668	3	9.2
10/23	9 37 36	2	-12.3	-0.9	-76.7	690	3	
10/23	9 38 3	2	-11.4	0.0	-75.3	709	3	8.5
10/23	9 38 34	5	-10.4	1.1	-73.6	733	3	7.9
10/23	13 37 46	2	-32.5	-42.7	136.5	916	2	
10/23	13 38 13	1	-32.8	-42.7	138.3	890	2	
10/23	13 38 36	5	-32.9	-42.7	139.9	868	2	
10/23	15 55 12	5	-32.1	-42.3	135.8	590	0	
10/23	15 55 23	1	-32.0	-42.1	136.6	585	0	
10/24	4 53 27	4	-33.2	-21.7	-71.1	688	1	
10/24	4 53 40	3	-33.1	-21.6	-70.1	679	1	10.5 10.4
10/24	9 28 13	2	-12.5	-1.1	-78.8	639	2	7.8
10/25	4 44 31	6	-33.1	-21.6	-71.2	723	5	9.1 8.9 8.8
10/25	4 44 43	1	-33.0	-21.5	-70.3	714	5	9.4
10/25	4 45 3	1	-32.8	-21.3	-68.9	700	5	
10/25	9 20 53	8	-8.3	3.2	-74.4	667	4	9.3 9.0 8.8
10/25	11 47 11	1	21.5	32.9	-62.0	1730	4	
10/25	15 37 17	3	-31.6	-41.8	135.0	645	3	
10/25	15 37 39	1	-31.3	-41.4	136.6	632	3	
10/25	15 37 57	3	-31.0	-41.0	137.9	621	3	
10/25	16 33 39	3	32.0	43.4	-62.2	3436	3	13.6 13.7 14.0
10/26	2 19 3	1	-32.5	-21.0	-65.1	1146	4	14.4
10/26	4 36 13	1	-32.6	-21.1	-68.5	732	4	10.7
10/26	4 36 24	3	-32.4	-21.0	-67.8	723	4	10.4
10/26	9 11 0	2	-9.5	1.9	-78.0	603	4	
10/26	9 11 32	3	-8.3	3.1	-76.3	620	4	7.4
10/26	9 12 0	2	-7.3	4.1	-74.8	637	4	7.8
10/26	15 28 21	3	-31.2	-41.5	134.8	676	4	3.7 3.8
10/27	2 8 22	2	-31.8	-20.3	-71.2	1334	2	26.3 26.3
10/27	6 45 8	2	-22.7	-11.2	-69.8	529	4	14.6
10/27	9 2 39	2	-7.4	4.0	-76.9	597	3	
10/27	10 41 8	1	-25.1	-35.4	134.6	1950	3	8.1
10/27	13 2 8	3	-33.3	-43.3	137.7	1124	2	
10/27	15 19 47	2	-30.5	-40.7	136.1	696	2	3.6
10/27	15 20 19	1	-30.0	-39.9	138.3	674	2	3.9
10/27	18 14 38	2	33.4	40.6	-118.0	2727	1	

DATE	TIME(UT) HR MN SEC	NUMBER	LAT	GM LAT	LONG	ALT(KM)	KP	DISPERSIONS(SEC)$^{1/2}$
10/28	8 54 8	1	-5.7	5.8	-76.3	585	2	
10/28	8 54 29	2	-4.9	6.5	-75.2	595	2	4.8
10/28	10 33 32	1	-27.4	-37.3	138.8	1910	2	
10/28	15 10 45	2	-30.2	-40.4	135.6	737	0	4.5
10/28	15 11 17	2	-29.6	-39.7	137.7	713	0	
10/28	20 30 8	1	27.8	35.3	-116.6	3452	0	
10/28	23 25 33	1	-18.6	-7.2	-77.5	2592	0	18.8
10/28	23 26 2	2	-19.2	-7.7	-76.5	2558	0	
10/29	6 27 49	1	-20.3	-8.8	-68.9	544	1	*
10/29	6 28 4	5	-19.9	-8.4	-68.0	539	1	17.4 *
10/29	6 28 16	1	-19.5	-8.0	-67.3	536	1	
10/29	8 45 23	2	-4.4	7.0	-76.4	569	1	
10/29	8 45 54	2	-3.3	8.2	-74.8	582	1	
10/29	12 43 8	1	-33.3	-43.7	134.2	1324	2	
10/29	15 2 17	1	-29.2	-39.3	137.3	754	1	4.8
10/29	15 2 44	5	-28.7	-38.6	139.1	732	1	4.8 5.0
10/30	6 18 14	1	-20.9	-9.4	-71.9	574	3	*
10/30	8 36 6	1	-4.4	6.9	-78.3	543	3	
10/30	10 13 16	1	-26.9	-37.3	133.9	2226	2	10.4
10/30	14 53 27	1	-28.6	-38.6	137.5	789	3	
10/31	6 10 29	5	-17.9	-6.4	-68.2	563	3	*
10/31	6 10 39	2	-17.6	-6.1	-67.6	559	3	
10/31	8 27 15	1	-3.3	8.0	-78.7	530	3	
10/31	8 27 28	11	-2.9	8.5	-78.1	533	3	4.3 4.3 4.2
10/31	10 5 21	1	-28.7	-38.7	137.4	2210	5	
10/31	10 5 32	1	-28.8	-38.8	137.9	2196	5	*
10/31	14 44 3	1	-28.6	-38.8	135.7	855	4	4.9
10/31	14 44 32	3	-28.0	-38.1	137.5	829	4	5.0
11/ 1	1 23 12	2	-33.1	-21.7	-69.7	1688	4	25.0
11/ 1	6 0 32	17	-19.1	-7.6	-72.3	615	6	16.7 14.3 15.4
11/ 1	6 0 48	14	-18.6	-7.1	-71.4	607	6	16.9 16.4 17.1 16.7 15.8
11/ 1	6 1 2	6	-18.2	-6.7	-70.6	599	6	15.5
11/ 1	8 23 47	1	9.6	21.0	-62.1	654	6	
11/ 1	8 23 57	5	10.0	21.4	-61.6	661	6	3.3 3.2
11/ 1	12 58 49	1	31.4	42.7	-79.3	1595	5	
11/ 1	12 59 3	R	31.6	42.9	-78.5	1614	5	
11/ 1	12 59 47	R	32.0	43.4	-76.1	1672	5	
11/ 1	13 4 15	2	33.4	44.8	-61.9	2026	5	
11/ 1	14 35 12	1	-27.9	-38.1	135.9	898	5	
11/ 1	14 35 46	1	-27.2	-37.2	138.0	865	5	6.0
11/ 1	15 8 7	2	30.9	38.6	-114.5	1527	4	
11/ 1	15 8 34	4	31.2	39.2	-113.1	1562	4	*
11/ 1	15 8 56	4	31.5	39.6	-111.8	1591	4	*
11/ 1	15 9 19	4	31.7	40.0	-110.6	1621	4	*
11/ 1	15 20 6	R	32.6	44.0	-77.8	2460	4	
11/ 1	15 20 20	R	32.5	43.9	-77.2	2477	4	
11/ 1	15 26 34	1	29.2	40.6	-61.8	2903	4	
11/ 1	17 46 7	1	21.5	32.9	-75.8	3396	4	
11/ 2	1 13 33	4	-33.2	-21.7	-71.1	1809	5	28.8 31.3
11/ 2	1 13 43	1	-33.2	-21.7	-70.6	1795	5	
11/ 2	1 14 23	1	-33.3	-21.9	-68.4	1742	5	16.3
11/ 2	8 15 29	4	11.8	23.1	-60.7	647	6	
11/ 2	9 46 24	1	-29.4	-39.6	136.5	2417	5	
11/ 2	12 7 38	1	-33.4	-43.4	137.7	1554	6	
11/ 2	14 26 5	1	-27.5	-37.8	135.2	958	6	
11/ 2	14 26 23	2	-27.1	-37.3	136.3	939	6	
11/ 2	14 26 32	1	-26.9	-37.1	136.8	930	6	

DATE	TIME(UT)			NUMBER	LAT	GM LAT	LONG	ALT(KM)	KP	DISPERSIONS(SEC)$^{1/2}$
	HR	MN	SEC							
11/ 2	14	58	50	1	31.2	38.8	-115.1	1438	6	
11/ 2	14	59	37	3	31.7	39.7	-112.4	1499	6	*
11/ 2	17	18	35	R	33.1	40.4	-116.7	2192	6	
11/ 2	17	19	5	R	32.9	40.5	-115.2	2230	6	
11/ 3	3	23	23	1	-30.6	-19.1	-72.9	1208	5	14.3
11/ 3	3	23	35	1	-30.4	-18.9	-72.2	1194	5	
11/ 3	8	6	28	4	12.5	23.9	-61.6	615	5	
11/ 3	11	58	56	1	-33.1	-43.0	139.3	1598	5	
11/ 3	14	17	32	4	-26.3	-36.5	136.6	983	5	
11/ 3	14	50	43	2	32.1	40.3	-111.7	1439	5	
11/ 3	14	50	55	2	32.2	40.5	-111.0	1455	5	
11/ 3	14	51	15	2	32.4	40.8	-109.8	1480	5	
11/ 3	17	9	5	3	33.0	40.3	-117.1	2086	6	*
11/ 3	17	9	24	3	32.9	40.3	-116.2	2110	6	*
11/ 3	17	9	46	3	32.7	40.4	-115.1	2139	6	*
11/ 3	17	10	1	5	32.6	40.4	-114.4	2158	6	*
11/ 3	19	33	35	2	23.0	30.8	-114.9	3078	5	
11/ 4	3	15	8	1	-29.4	-17.9	-70.1	1217	3	
11/ 4	5	31	52	1	-20.2	-8.8	-80.0	798	3	
11/ 4	7	52	34	1	2.4	13.8	-78.3	512	5	2.6
11/ 4	9	28	52	1	-31.1	-40.9	139.7	2511	4	9.8
11/ 4	11	48	25	2	-33.3	-43.6	134.9	1787	4	
11/ 4	11	48	52	2	-33.2	-43.4	136.4	1751	4	
11/ 4	11	49	15	1	-33.1	-43.1	137.7	1720	4	
11/ 4	14	8	15	6	-26.1	-36.3	135.4	1058	5	6.3
11/ 4	14	9	7	4	-24.9	-34.9	138.4	1001	5	6.9
11/ 4	14	9	24	1	-24.5	-34.4	139.3	983	5	6.2
11/ 4	14	41	38	1	32.4	40.6	-111.6	1366	5	
11/ 4	17	0	20	1	32.6	40.1	-115.5	2037	5	
11/ 4	17	15	48	1	20.6	31.9	-79.0	3107	5	
11/ 5	3	6	1	1	-29.0	-17.5	-70.4	1288	5	
11/ 5	3	6	29	2	-28.5	-17.0	-68.8	1253	5	16.7
11/ 5	5	23	48	4	-17.8	-6.4	-77.4	794	5	18.0
11/ 5	5	24	21	22	-16.7	-5.3	-75.7	766	5	23.5 20.0 19.0
11/ 5	5	24	34	25	-16.3	-4.9	-74.9	755	5	19.4 19.0
11/ 5	5	24	50	10	-15.8	-4.3	-74.1	742	5	16.3
11/ 5	7	43	38	24	3.2	14.5	-79.0	512	5	3.9 3.6 3.4 3.3 3.4 3.3
11/ 5	7	44	9	18	4.4	15.8	-77.3	511	5	3.4
11/ 5	7	44	46	4	5.8	17.2	-75.3	512	5	
11/ 5	7	48	48	9	14.6	26.0	-62.0	573	5	2.7 2.8
11/ 5	7	48	58	2	14.9	26.3	-61.5	578	5	2.7
11/ 5	7	49	7	5	15.3	26.6	-60.9	582	5	
11/ 5	12	22	58	2	32.9	44.2	-77.0	1339	4	
11/ 5	12	23	7	1	32.9	44.3	-76.4	1350	4	
11/ 5	14	0	12	1	-24.1	-34.1	138.4	1051	4	
11/ 5	14	31	40	2	32.2	39.9	-114.8	1231	4	*
11/ 5	14	32	12	4	32.5	40.5	-112.8	1270	4	*
11/ 5	14	32	37	2	32.7	40.9	-111.3	1301	4	
11/ 5	14	42	51	2	31.4	42.8	-77.3	2100	4	*
11/ 5	14	43	0	2	31.3	42.7	-76.8	2113	4	*
11/ 5	19	38	5	1	-3.6	7.7	-79.1	3740	3	25.8
11/ 5	22	9	34	1	-24.7	-13.3	-78.9	3263	2	
11/ 5	22	16	14	1	-29.7	-18.2	-65.0	2886	2	32.9
11/ 6	0	38	10	1	-33.4	-21.9	-65.8	2035	4	
11/ 6	2	57	2	1	-28.3	-16.8	-70.2	1351	4	*
11/ 6	7	40	1	6	15.7	27.1	-62.1	558	4	
11/ 6	7	40	11	4	16.1	27.4	-61.5	561	4	2.4

DATE	TIME(UT) HR MN SEC	NUMBER	LAT	GM LAT	LONG	ALT(KM)	KP	DISPERSIONS(SEC)$^{1/2}$
11/ 6	13 51 42	2	-22.6	-32.4	139.9	1075	3	
11/ 6	16 41 7	2	32.4	39.6	-117.6	1803	2	*
11/ 6	16 41 27	1	32.2	39.6	-116.6	1830	2	
11/ 6	16 41 49	1	32.0	39.6	-115.4	1859	2	
11/ 7	0 26 56	5	-33.5	-22.0	-71.5	2276	1	*
11/ 7	0 27 14	2	-33.5	-22.0	-70.6	2252	1	28.6
11/ 7	2 47 30	1	-28.2	-16.7	-71.7	1456	1	
11/ 7	5 6 33	4	-14.8	-3.4	-76.2	846	4	
11/ 7	5 6 44	2	-14.4	-3.0	-75.6	835	4	
11/ 7	13 41 32	1	-23.5	-33.7	136.0	1217	1	7.4
11/ 7	14 30 3	1	25.7	37.1	-61.9	2367	1	10.3
11/ 7	21 54 58	1	-29.3	-17.8	-69.7	3178	2	
11/ 7	21 55 9	1	-29.4	-17.9	-69.3	3168	2	
11/ 8	7 22 35	5	18.2	29.6	-61.6	535	3	
11/ 8	7 22 45	12	18.5	29.8	-61.0	538	3	2.8 2.6 2.5 2.6
11/ 8	7 22 53	8	18.8	30.1	-60.5	540	3	2.6
11/ 8	7 23 4	2	19.1	30.4	-59.9	544	3	2.5
11/ 8	13 32 21	2	-22.9	-33.2	135.4	1292	3	
11/ 8	13 33 22	3	-21.4	-31.5	138.5	1217	3	8.6 8.5
11/ 8	14 4 41	2	33.0	40.8	-114.1	1052	3	
11/ 9	2 30 20	1	-25.8	-14.3	-68.6	1523	1	
11/ 9	4 48 44	1	-12.7	-1.3	-76.6	934	2	11.2
11/ 9	4 49 10	1	-11.9	-0.5	-75.4	908	2	
11/ 9	7 13 44	1	19.1	30.5	-61.8	524	0	2.3
11/ 9	7 14 3	2	19.7	31.0	-60.7	529	0	
11/ 9	13 24 11	1	-20.8	-30.9	137.8	1292	2	
11/ 9	14 5 35	4	29.9	41.3	-78.1	1729	2	8.1
11/10	2 19 33	1	-27.0	-15.5	-73.5	1731	3	
11/10	4 40 5	9	-11.2	0.3	-76.1	964	2	
11/10	4 40 19	7	-10.7	0.7	-75.4	950	2	
11/10	7 4 53	2	20.0	31.4	-62.0	517	2	2.5
11/11	4 30 49	1	-10.7	0.6	-77.3	1036	2	10.4
11/11	15 54 19	1	31.4	38.1	-120.9	1331	1	
11/11	16 11 2	2	12.7	24.0	-77.7	2615	1	13.6 13.7
11/12	13 28 54	1	33.5	41.4	-112.9	856	1	
11/12	13 38 39	1	27.8	39.2	-76.5	1534	1	8.9
11/12	23 27 52	1	-33.3	-21.9	-76.8	2981	2	
11/13	1 51 2	3	-26.0	-14.5	-76.1	2052	2	21.9
11/13	1 53 8	1	-23.6	-12.1	-70.7	1885	2	21.0
11/13	4 14 1	7	-6.4	5.0	-74.7	1067	2	9.9 9.6 9.7
11/13	6 38 44	1	23.3	34.7	-60.8	511	2	
11/14	1 44 36	4	-22.0	-10.5	-69.0	1913	4	20.7 21.4
11/14	4 4 33	8	-6.3	5.1	-76.4	1157	4	11.9 12.5 11.8 12.0 12.0 11.6
11/14	4 4 52	3	-5.7	5.7	-75.6	1135	4	12.3
11/14	4 5 12	2	-5.1	6.4	-74.6	1111	4	
11/14	4 5 33	1	-4.4	7.1	-73.7	1088	4	
11/14	18 13 49	1	-15.5	-4.1	-76.9	3531	4	
11/14	23 8 18	3	-33.1	-21.7	-77.4	3167	3	
11/15	3 55 2	3	-6.2	5.2	-78.0	1254	2	10.3 10.3
11/15	3 55 18	6	-5.7	5.7	-77.3	1234	2	10.5 10.7 9.4
11/15	3 55 34	2	-5.2	6.2	-76.7	1215	2	9.3
11/15	3 56 4	2	-4.3	7.2	-75.4	1180	2	
11/16	12 20 52	1	-13.9	-24.0	137.2	1771	2	
11/16	22 52 56	1	-31.4	-19.9	-68.2	3112	3	
11/17	1 13 31	3	-23.4	-12.0	-77.1	2424	2	22.1
11/17	3 43 14	2	7.9	19.3	-62.0	944	4	
11/19	0 58 8	2	-17.9	-6.4	-70.2	2350	2	20.2 19.7

DATE	TIME(UT) HR	MN	SEC	NUMBER	LAT	GM LAT	LONG	ALT(KM)	KP	DISPERSIONS(SEC)$^{1/2}$		
11/20	0	47	50	1	-18.2	-6.7	-72.3	2507	3			
11/20	0	48	20	2	-17.6	-6.1	-71.3	2471	3			
11/21	0	36	23	1	-19.6	-8.2	-76.6	2737	1			
11/21	3	7	33	4	12.6	24.0	-62.5	1141	2	5.3	5.8	
11/21	3	7	54	2	13.2	24.6	-61.5	1117	2			
11/21	7	41	4	1	32.2	43.5	-79.3	533	2	2.2		
11/21	7	41	34	2	32.5	43.9	-77.0	526	2	2.0		
11/21	7	41	49	1	32.7	44.1	-75.9	523	2	2.1		
11/21	9	58	48	5	31.9	43.3	-76.6	581	3	2.0	2.1	1.9
11/21	9	59	3	1	31.7	43.2	-75.5	588	3	2.0		
11/21	22	3	6	1	-30.1	-18.6	-70.7	3519	3			
11/22	2	50	40	2	0.1	11.3	-82.0	1806	3			
11/22	2	52	1	1	2.3	13.6	-79.0	1699	3			
11/22	2	52	12	1	2.6	13.9	-78.6	1685	3	9.4		
11/22	2	52	48	2	3.6	15.0	-77.2	1636	3			
11/22	9	50	5	2	31.4	42.8	-75.6	567	4			
11/23	2	43	33	3	4.5	15.9	-77.8	1721	5	8.8	9.2	
11/23	2	43	48	1	4.9	16.3	-77.2	1702	5			
11/23	7	23	3	2	32.6	43.9	-79.9	565	5	2.5	2.8	
11/23	7	23	18	5	32.8	44.1	-78.7	559	5	2.4	2.5	
11/23	12	4	34	1	9.9	21.3	-61.9	1217	4			
11/23	21	43	59	3	-28.9	-17.4	-69.7	3605	2			
11/24	7	14	48	1	33.2	44.6	-76.6	566	2	1.7		
11/25	7	5	56	1	33.3	44.7	-76.1	584	2			
11/25	8	27	58	1	-25.5	-36.0	133.4	3564	2			
11/26	8	19	49	3	-23.6	-33.8	136.2	3562	3	13.8	13.8	
11/27	8	9	59	1	-22.9	-33.2	136.0	3609	3			
11/27	8	10	34	2	-22.4	-32.6	137.0	3593	3	13.5		
11/27	8	10	45	2	-22.3	-32.4	137.3	3588	3			
11/28	2	4	44	5	20.3	31.7	-62.0	1551	6	7.7		
11/28	6	28	28	1	25.4	32.8	-117.0	1291	7			
11/28	9	0	5	1	23.0	34.4	-61.2	547	7	2.9		
11/28	18	26	34	1	-33.4	-22.0	-72.9	3431	4			
11/29	8	51	2	2	22.4	33.8	-61.7	532	2			
11/29	8	51	12	1	22.1	33.5	-61.1	535	2	2.5		
11/29	10	55	50	3	30.2	37.7	-116.1	532	4			
11/30	8	41	57	1	21.9	33.3	-62.5	521	5			
12/ 1	5	2	2	R	-32.1	-42.4	134.5	3472	4			
12/ 1	8	33	14	2	20.7	32.0	-61.9	516	4			
12/ 1	20	21	25	2	-26.9	-15.5	-76.5	3698	3			
12/ 1	20	21	46	1	-26.7	-15.2	-75.9	3703	3			
12/ 1	20	24	28	1	-24.7	-13.2	-71.2	3736	3			
12/ 2	6	2	20	1	33.4	44.7	-78.2	849	4	3.0		
12/ 2	8	24	11	1	20.0	31.4	-62.6	512	4			
12/ 2	8	24	31	3	19.4	30.8	-61.3	513	4	2.7		
12/ 3	4	44	13	2	-30.7	-40.6	138.4	3417	5			
12/ 3	5	53	39	1	33.2	44.6	-76.5	874	5			
12/ 3	5	53	50	2	33.1	44.5	-75.8	864	5			
12/ 4	3	25	34	1	30.9	42.2	-77.5	1556	4			
12/ 5	5	35	46	1	32.7	44.1	-75.3	961	0			
12/ 5	7	57	42	2	16.7	28.1	-62.1	515	4			
12/ 5	7	57	53	2	16.3	27.7	-61.5	514	4	2.3		
12/ 5	10	12	39	3	6.1	17.4	-78.6	545	5	2.1		
12/ 6	19	37	11	1	-19.4	-7.9	-68.6	3630	3			
12/ 7	9	55	40	3	1.9	13.3	-76.5	536	0			
12/ 7	12	17	47	2	-22.2	-10.7	-71.4	1084	2	23.4	23.4	
12/ 8	7	31	12	1	13.1	24.5	-61.8	538	2			

DATE	TIME(UT) HR MN SEC	NUMBER	LAT	GM LAT	LONG	ALT(KM)	KP	DISPERSIONS(SEC)$^{1/2}$
12/ 8	9 45 49	2	2.9	14.3	-79.8	516	1	2.9
12/ 8	9 46 18	2	1.8	13.2	-78.2	520	1	3.2
12/ 9	9 37 9	1	1.2	12.6	-79.2	512	3	4.2
12/ 9	11 58 3	2	-21.3	-9.9	-77.0	878	3	
12/ 9	11 60 2	1	-24.4	-12.9	-70.3	1001	3	23.5

2171 PS

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