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REPLY

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We present the following analyses of facts and opinions in response to the preceding commentary by Thorne and Tsurutani on our paper [Park and Miller, 1979]. The first part is our response to their comments on the Siple results reported in our paper, followed by our own comments on the Ogo 5 ELF chorus data that they use in their commentary to contrast with the Siple VLF data.

Thorne and Tsurutani (T and T) argue that the 2- to 4-kHz waves detected at Siple and reported by Park and Miller [1979] (P and M) are plasmaspheric hiss rather than chorus. This assertion is based on the questionable premise that the statistics of the Siple data more closely resemble those of hiss rather than those of chorus as observed on satellites. First of all, the classification of VLF waves into chorus, hiss, etc., should be based on their spectral characteristics, not on their statistical properties. The statement in P and M that chorus dominates over hiss in the 2- to 4-kHz band is based on an extensive visual survey of broadband spectra using approximately 25,000 1-min samples covering a 6-month period in 1974. (The few sample spectrograms shown in P and M were selected to illustrate both chorus and hiss occurring in the same time interval.) In terms of the number of intensity enhancements due to chorus versus those due to hiss, chorus clearly dominates in the midnight-noon local time (LT) sector where the wave intensity is maximum and where the Sunday decrease is found. However, hiss is more important than chorus in the 1900-2400 LT sector, while they are about comparable in the 1200-1900 LT sector. Over all, chorus clearly dominates over hiss. Further details will be presented as part of a paper now in preparation.

Because the wave intensity data used in P and M include all spectral forms, the magnitude of the diurnal variation is less than what might be expected if chorus alone were considered. Another factor is the diurnal variation of ionospheric absorption that is maximum during daytime and thus tends to reduce the daytime peak in wave intensity. Furthermore, the wave intensity data are averages over the entire time period specified, including the times when no chorus (or hiss) could be detected. Thus, the diurnal variation shown in P and M should not be confused with the diurnal variation of occurrence rates or with the diurnal variation of the intensity of detectable chorus.

It is clearly stated in P and M that the error bars represent the standard error the the mean, not the standard deviation. The former is a more meaningful quantity when we compare two sample populations, and, of course, it decreases as $N^{-1/2}$, where N is the number of samples. The error bars are relatively small because of the large number of samples used in the study (12,726 hourly values). We fail to see any logic in their statement that small error bars mean that we 'are detecting plasmaspheric hiss rather than chorus.'

Regarding the use of ground VLF data, it is well known that magnetospheric waves received on the ground must in general propagate through the magnetosphere in ducts and that they suffer absorption in transit through the lower ionosphere. For these reasons, no claim was made that the wave intensity measured at Siple was representative of the wave intensity in the magnetosphere, and no attempt was made to interpret the measured absolute wave intensity. The important result of the Siple study is that the wave intensity is reduced on Sundays relative to the other days of the week.

Although Siple Station is located at L = 4.2, the VLF receiver there detects waves from an L range of ~2-6 [e.g., Park and Carpenter, 1978]. Whistlers and chorus propagating well inside and well outside the plasmapause as well as those propagating along the plasmapause are received at Siple [e.g., Rosenberg et al., 1971; Carpenter et al., 1975; Park et al., 1980]. The statement by T and T that the waves observed at Siple are plasmaspheric hiss propagating along the plasmapause and within the high density plasmasphere is a speculation that is not supported by fact. However, since the 'viewing area' of the Siple receiver is limited to relatively low L values, no claim is made that the Siple data are representative of chorus activity in the outer magnetosphere sampled by Ogo 5 (out to L = 15).

T and T present some ELF chorus data from the Ogo 5 search coil magnetometer for comparison with the Siple result. We need to examine the details of the Ogo 5 data coverage and analysis procedures in order to determine the relevance of their study to the issues at hand. Since no detailed description of the Ogo 5 data base is given in their commentary, we base our following comments on the assumption that they used the same data that were used in several earlier papers.

Frequency coverage. The frequency range of the Siple data used in P and M was 2-4 kHz, while the Ogo 5 instrument in question covered a range of 0.01-1 kHz [Frandsen et al., 1969] or 0.01-1.5 kHz (T and T). This difference in frequency coverage is an important factor, since magnetospheric wave activity, including power line radiation (PLR) activity, is strongly frequency dependent. To illustrate this, Figure 1 shows the frequency distribution of PLR-induced emissions observed at Siple and Eights (~185 km from Siple). The 2- to 4-kHz band used by P and M is an optimum frequency range to detect any significant PLR effects, whereas Ogo 5 clearly sampled a very different frequency regime. This frequency dependence of PLR effect was also evident in data from Ariel 3 and 4 satellites [Lefeuvre and Bullough, 1973; Bullough et al., 1976].

T and T argue that in spite of the limited

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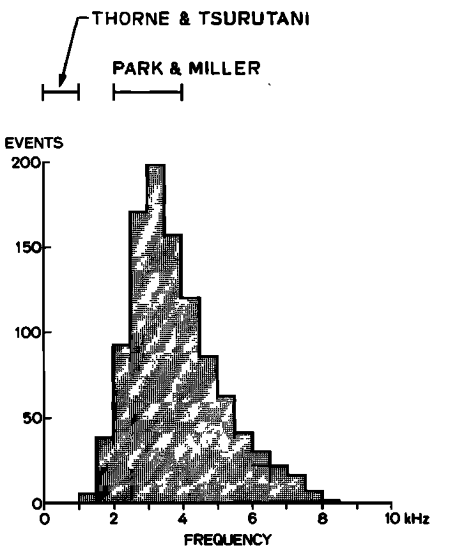

Fig. 1. Frequency distribution of PLR-induced events observed at Siple and Eights, Antarctica (after Park and Helliwell [1978]). The horizontal bars indicate the frequency ranges covered by the two studies.

frequency coverage of the Ogo 5 instrument, they could detect essentially all chorus. This is not true. Both satellite [e.g., Burtis and Helliwell, 1976] and ground-based [e.g., Helliwell, 1965; Park, 1977; Park et al., 1980] observations show banded chorus with the low cutoff frequency well above the upper limit of the Ogo 5 receiver. T and T state that the frequency of maximum chorus intensity is 0.25-0.3 of the equatorial gyrofrequency f_{Ho}. On the other hand, Burtis and Helliwell [1976], using VLF (0.3-12.5 kHz) data from Ogo 3, found that the normalized chorus frequency f/f_{Ho} extends beyond 0.6 and has two well-defined peaks at 0.35 and 0.55. They suggested that the low values of f/f_{Ho} found in the Ogo 5 data were due to the limited frequency coverage of the instrument. Burton and Holzer [1974] examined chorus from the same Ogo 5 instrument in question, and they also concluded that the difference in f/f_{Ho} between Ogo 3 and Ogo 5 data was most likely due to the difference in frequency ranges of the instruments.

Chorus detection and identification. It is also claimed by T and T that the Ogo 5 instrument had sufficient sensitivity to detect essentially all chorus. They quote the detector sensitivity at different frequencies, but it is misleading to imply that any chorus with signal strength exceeding that level can be detected as chorus. The sensitivity figures they give represent the equivalent wave intensity of instrument noise [Frandson et al., 1969]. In practice, the threshold of chorus detection depends on a number of factors including (1) noise from the spacecraft and other instruments, (2) the receiver gain setting, (3) spectrum analysis on the ground, and (4) criteria used in identifying chorus. A few more comments on items (2) and (4) follow.

The Ogo 5 ELF experiment employed linear receivers, and since their dynamic range was less than the dynamic range of magnetospheric signals of interest, the receiver gain was adjusted by ground command in an attempt to avoid saturation by strong signals [Frandsen et al., 1969; C. Russell, private communication, 1980]. This would tend to discriminate against relatively weak chorus in regions where strong waves are anticipated.

Regarding the criteria used in accepting a chorus event, Tsurutani et al. [1979] state that 'if the 10-min average intensity was a factor of 2 above background, the interval was considered to have significant chorus power.' 'Background' is not precisely defined, but however it is defined, it is clear that the threshold of chorus detection was much higher than the instrument sensitivity.

Another very important question concerns the classification of chorus. It is stated in Tsurutani and Smith [1974] that the 'two most common types of chorus were narrowband chorus without structure and falling tones.' We point out that the defining characteristics of chorus is fine structure in the frequency-time domain [Eckersley, 1928; Storey, 1953; Helliwell, 1965]. 'Chorus without structure' or 'banded structureless chorus' should be classified as hiss according to generally accepted practice. The predominance of falling tones is also puzzling, since it is well established that most of chorus consists of discrete rising tone emissions. For example, Burtis and Helliwell [1976] found that rising tone emissions comprised 77% of all chorus.

It is probably due to a combination of the factors mentioned above that the Ogo 5 description of 'chorus' is significantly different from that of many other studies. For example, Tsurutani and Smith [1974, 1977] reported that postmidnight chorus was confined to within 15° of the equator and that there was a 'distinct absence of chorus from 1600 to 2400 LT.' These statements were challenged by Burtis and Helliwell [1976], who found chorus at all local times and all latitudes to 50°. Chorus has also been detected at high magnetic latitudes by numerous polar-orbiting low-altitude satellites [e.g., Gurnett and O'Brien, 1964; Taylor and Gurnett, 1968]. Anderson [1976] and Anderson and Maeda [1977] observed and made detailed studies of chorus in the premidnight sector. The overall occurrence probability of 'chorus' in Ogo 5 data is less than 10% [Tsurutani et al., 1979], compared to 27% probability in Ogo 3 data [Luette et al., 1977].

Spatial coverage. Ogo 5 chorus coverage extends to L = 15, and because of the low frequency range of the instrument, the outer portions of the satellite orbit tend to be emphasized. In particular, a significant fraction (perhaps about 0.5, judging from Figure 13 of Tsurutani and Smith [1977]) of Ogo 5 chorus occurs in the dayside high-latitude minimum-B region and therefore well beyond the range of the Siple receiver. It is clear that Ogo 5 data cannot be directly compared with Siple data, which are limited to L less than ~6.

Size of data base. T and T do not show the number of data samples in their Figure 1. They only state that one year's data were used. However, broadband waveform data that are needed to identify 'chorus' require a special-purpose real-time telemetry, and therefore the coverage cannot be continuous [Frandson et al., 1969]. A knowledge of the size of the data base is needed to properly assess the significance to any statistical analysis, particularly in the case of a null result.

Two other minor points need to be brought up. The questions raised by Russell [1980] have been satisfactorily answered by Luette et al. [1980]. The title of Luette et al.'s [1979] paper has been corrected to read 'The Control of the Magnetosphere by Power Line Radiation' [Luette et al., 1979a, b].

We have attempted to clarify several misconceptions and misinterpretations in the preceding commentary. We have also pointed out several reasons why the Ogo 5 ELF results should not be construed as contradictory to our Siple results. We conclude by restating the main points in P and M: Wave intensity in the 2- to 4-kHz range measured at Siple shows statistically significant decreases on Sundays in comparison with the other days of the week. We put forth a hypothesis that these decreases are due to reduced excitation from PLR sources in the conjugate region.

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