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A STATISTICAL STUDY OF ULF WAVES OBSERVED BY MAGSAT AT IONOSPHERIC ALTITUDE

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Abstract: Hydromagnetic wave characteristics at ionospheric altitude have been statistically detected in the MAGSAT magnetic field data by a cross-spectral analysis. The region where the averaged phase shift between the north-south and the east-west components has some finite value appeared systematically around the auroral oval, indicating an existence of the hydromagnetic wave component of comparable magnitude with the magnetic fluctuation generated by small-scale field-aligned currents. The low frequency waves (0.125–0.25 Hz) showed left-handed polarization (L-mode) and the amplitude was around 5–10 nT. On the other hand, the R-mode waves dominated in 1.0–2.0 Hz range and the amplitude was estimated to be about 1 nT.

1. Introduction

Short-period micropulsations (*e.g.* Pc 1 pulsation) from the magnetosphere to the ground have been studied mainly with ground magnetic observations (*e.g.* HAYASHI *et al.*, 1981 and references therein). On the other hand, micropulsations have been observed in the magnetosphere by geostationary satellites or high-altitude satellites. However, the simultaneous observations of short period micropulsations in the magnetosphere and on the ground are few (*e.g.* GENDRIN *et al.*, 1978), and most studies on the wave propagation from the magnetosphere to the ground have been limited to theoretical work.

To study the relationships between the micropulsations observed in the magnetosphere and that on the ground, the observations at ionospheric altitude seem to be extremely useful. However, it is difficult to distinguish the magnetic fluctuations in the polar region generated by hydromagnetic waves from that generated by small-scale field-aligned currents, because of a persistent existence of small-scale field-aligned currents in the polar region with their magnetic effect often exceeds that of the micropulsations. In this short paper, we show the result of statistical cross-spectral analysis of power and polarization of the hydromagnetic waves detected by the MAGSAT

Fig. 1a (opposite). Global distribution of the phase shift between the north-south and the east-west components averaged in each $2^\circ \times 2^\circ$ mesh under the quiet geomagnetic condition ($|AL| < 100$ nT). The upper and middle diagrams show the region of the right-handed (R) and the left-handed (L) polarization, respectively. In the bottom diagrams, the power distribution is shown for comparison. The left- and right-side maps are for the frequency range of 0.125–0.25 Hz and 1.0–2.0 Hz, separately.

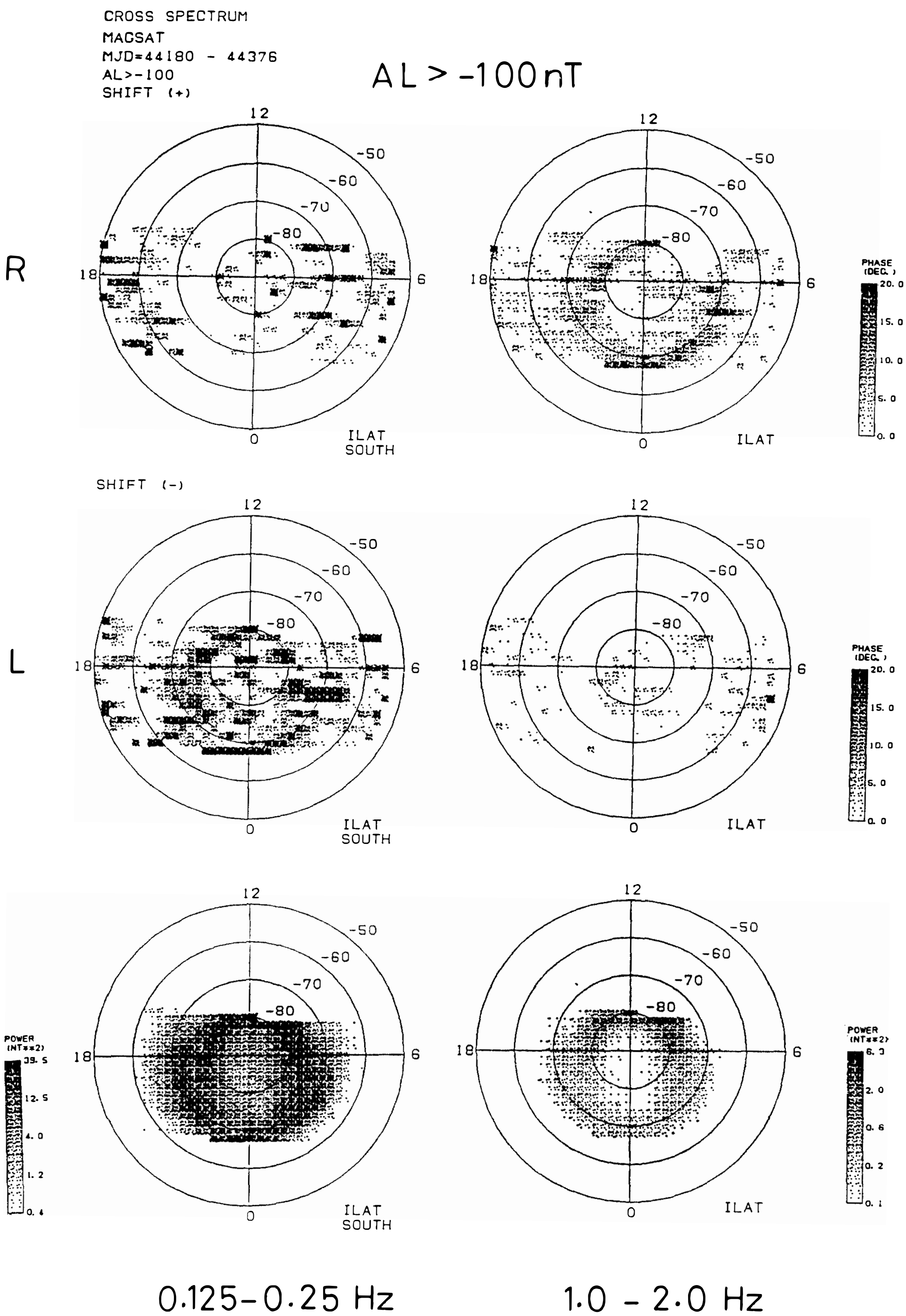
CROSS SPECTRUM
MAGSAT
MJD=44180 - 44376
AL>-100
SHIFT (+)
AL > -100nT
R
L
SHIFT (-)
12
18
6
0
-50
-60
-70
-80
ILAT
SOUTH
PHASE (DEG.)
20.0
15.0
10.0
5.0
0.0
POWER (NT**2)
39.5
12.5
4.0
1.2
0.4
6.3
2.0
0.6
0.2
0.1
0.125-0.25 Hz
1.0 - 2.0 Hz

Fig. 1a.

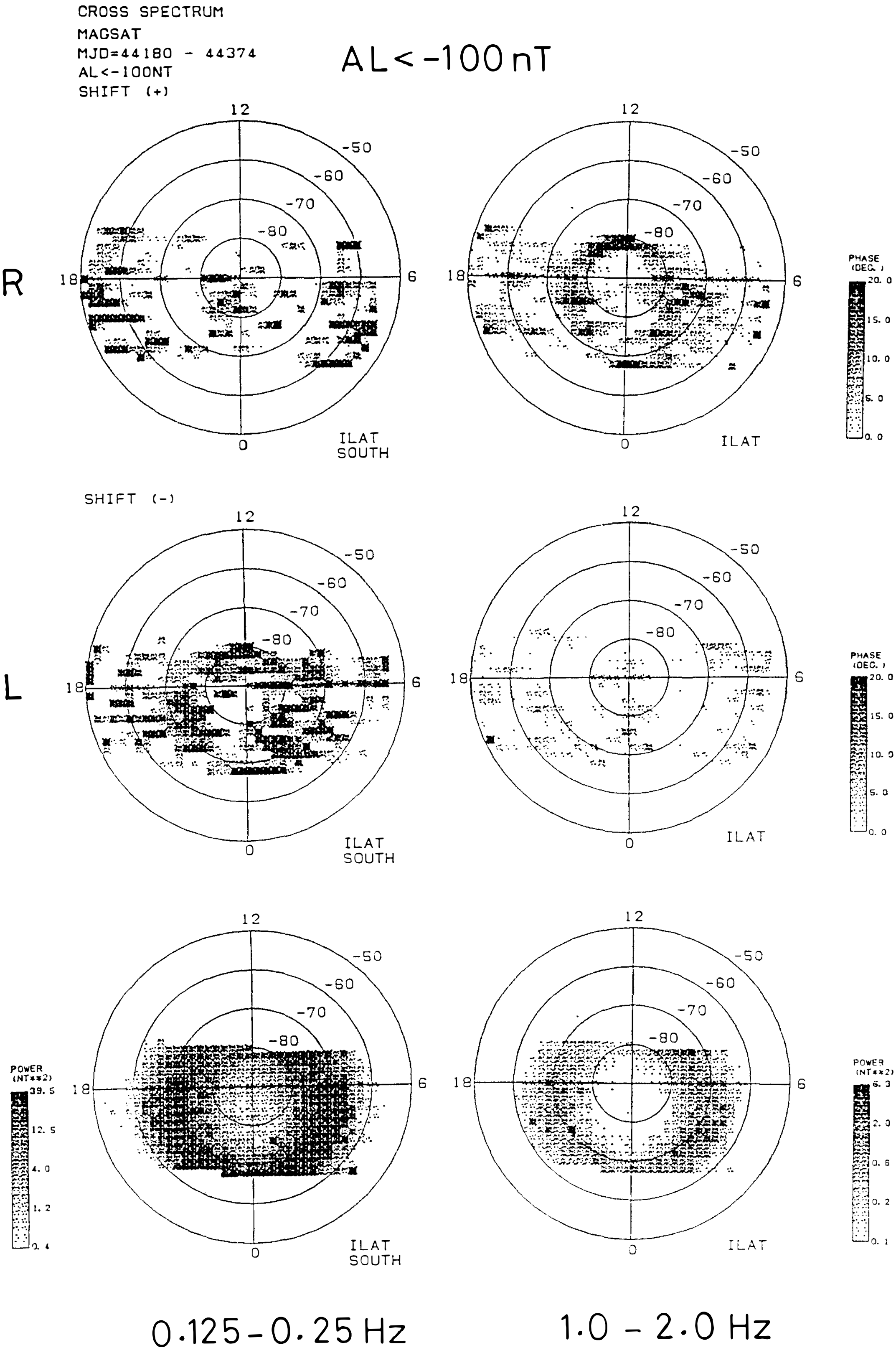

Fig. 1b. The same with Fig. 1a except that the data under disturbed geomagnetic condition ($|AL| >$ 100 nT) are used.

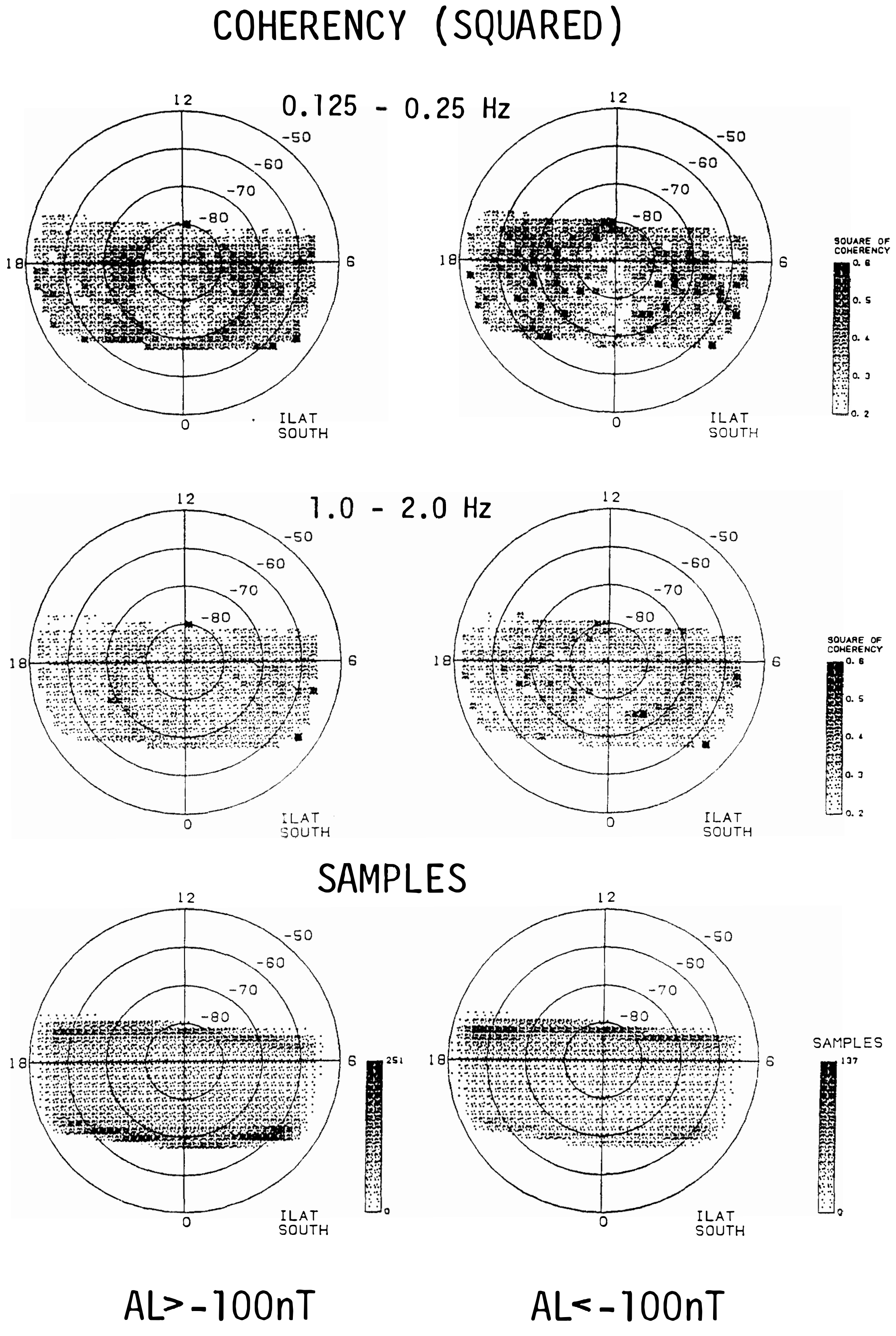

Fig. 2. Distribution of the squared coherence (upper and middle diagrams) and the number of samples used in this statistical analysis (bottom diagrams).

over the polar region.

2. Method of Analysis

The high resolution MAGSAT data (*i.e.* data in CRONFIN magnetic tapes) were used in this statistical study. The sampling rate of the magnetometer was $16\ s^{-1}$ and the resolution was 0.5 nT (LANGEL *et al.*, 1981). The cross-spectrum between the geographic north-south component (X) and the east-west component (Y) was calculated for each data record which consists of 1024 data point (*i.e.* time span of 64 s or about 4° coverage in latitude). All the data records with less than 100 missing data points were used without any other criterion. The spectra were divided into six frequency ranges (*i.e.* 0.125–0.25, 0.25–0.5, 0.5–1.0, 1.0–2.0, 2.0–4.0 and 4.0–8.0 Hz), sorted by geomagnetic activity and averaged in each mesh of $2° \times 2°$ area on invariant latitude—invariant magnetic local time parameter space. The fast Fourier transformation (FFT) method with Hanning spectral window was used for the calculation. The power density, squared coherence and phase shift between X- and Y-components were averaged after sorting by the geomagnetic activity (*i.e.* sorting by the AL index) in each mesh and in each frequency range, and the results were expressed by gray scale. The data period used in this study was from November 3, 1979 through May 17, 1980.

3. Results

Figures 1a and 1b show the phase shift between X- and Y-component. Positive and negative shift in southern hemisphere correspond to right-handed (R) and left-handed polarization (L), respectively. After taking average in each $2° \times 2°$ mesh, the positive and the negative region were expressed separately by gray scale. That is, a region of negative or zero mean value is expressed by a blank mesh when the region of positive mean value is shown and *vice versa.* Results for the two typical frequency ranges (*i.e.* 0.125–0.25 and 1.0–2.0 Hz) are shown with the power distribution for comparison. The absolute value of the averaged phase shift is not so large (*i.e.* 10–20°) but the distribution is systematic. For higher frequency range (1.0–2.0 Hz), the R-mode dominates in the auroral region. For lower frequency range (0.125–0.25 Hz), the L-mode dominates and covers most of the polar region.

The dominant mode is switched gradually between these two frequency ranges. Figure 2 shows the distribution of the squared coherence and that of the number of samples used to obtain the averaged spectrum. The number of samples in one mesh is around 50–100. The squared coherence is typically around 0.3–0.4 and rather uniform over the polar region. The coherence is small in the highest frequency range (4.0–8.0 Hz) because of the decrease of the signal amplitude (not shown here). In the cusp region (*i.e.* dayside ILAT$\sim$80° for $AL > -100$ nT case), the coherence is also low though the power density is high (see Fig. 1a). This tendency could be explained as an effect of randomly distributed line-type field-aligned currents.

4. Discussion

If the source of the magnetic fluctuation were the small-scale field-aligned currents, the statistical average phase shift between the *X*- and *Y*-component should be zero, regardless of line or sheet-type field-aligned currents. Therefore, the systematic appearance of the R- or L-mode dominant region around the auroral oval indicates an existence of the hydromagnetic wave component in the MAGSAT data and its amplitude is not at all negligible compared with that of the fluctuation generated by small-scale field-aligned currents.

The R-mode dominates when the frequency is higher (1.0–2.0 Hz) and the L-mode dominates in a lower frequency range (0.125–0.25 Hz). As the Alfvén mode wave shows the left-handed polarization, the wave which appeared in L-mode region in Fig. 1 may be of the Alfvén mode. The R-mode wave can propagate along the magnetic field-line down to the ionosphere, but the L-mode wave cannot propagate if the frequency is higher than the He^+ gyrofrequency (YOUNG *et al.*, 1981). This may be the reason why the R-mode dominates in the higher frequency region.

The amplitude of the wave component is not explicitly obtained by our statistical study, because the contribution from small-scale field-aligned currents to the power distribution in Fig. 1 (bottom diagrams) may be the same order of magnitude or greater than that of the hydromagnetic wave. However, if we assume that these two contributions are the same order of magnitude, the amplitude of the wave is estimated from Fig. 1 to be about 5–10 nT for 0.125–0.25 Hz range and about 1 nT for 1.0–2.0 Hz range. These estimated amplitudes are much greater, especially for the wave in 1.0–2.0 Hz range, than those observed on the ground. The amplitude of the typical Pc 1 micropulsation observed on the ground is less than 0.1 nT. If we are observing by MAGSAT the incident wave to the ionosphere from the magnetosphere, however, these large amplitudes are not surprising because the waves decay through the ionospheric screening effect (HUGHES and SOUTHWOOD, 1976) or the ionospheric dissipation during their horizontal propagation before being detected on the ground.

We identified the hydromagnetic wave only by the fact that the averaged polarization is not linear. Therefore, the region of linearly polarized waves, if they exist, cannot be identified in Fig. 1. That is, the region of small phase shift (*i.e.* white region in Fig. 1) for both R- and L-mode is the region of linear polarization, but the magnetic fluctuation by small-scale field-aligned currents also shows a linear polarization. The distribution of the linearly polarized waves should be examined by different methods, for example, by a combination of electric field data and magnetic field data (*e.g.* GURNETT *et al.*, 1984).

In this research note, we have only shown the results of the statistical analysis. In order to study the latitudinal extent of the incident wave, the spectrum of each event, or relationship to the simultaneous ground observations, it is necessary to identify the wave in each time series of data record. It is, however, difficult because the effect from small-scale field-aligned currents is supposed to be greater than the wave amplitude. However, in the subauroral region, the effect of field-aligned currents is small and it is expected that some types of Pc 1 micropulsations are generated near the plasmapause and propagate to the ionosphere. Therefore, in the subauroral region, it may be possible to distinguish the hydromagnetic waves from small-scale field-aligned currents in each time series. This is indeed true, and the results of such an analysis will appear elsewhere.

Acknowledgments

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