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VLF/LF Reflectivity of the Polar Ionosphere 4 January - 3 July 1976

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This report provides a summary of high latitude ionospheric reflectivity as observed by the USAF high resolution VLF/LF ionosounder operating in northern Greenland. Ionospheric reflectivity parameters, including reflection heights and coefficients, are presented as a function of time of day. VLF long path propagation measurements, along with magnetometer and riometer data, are presented as supplementary information.

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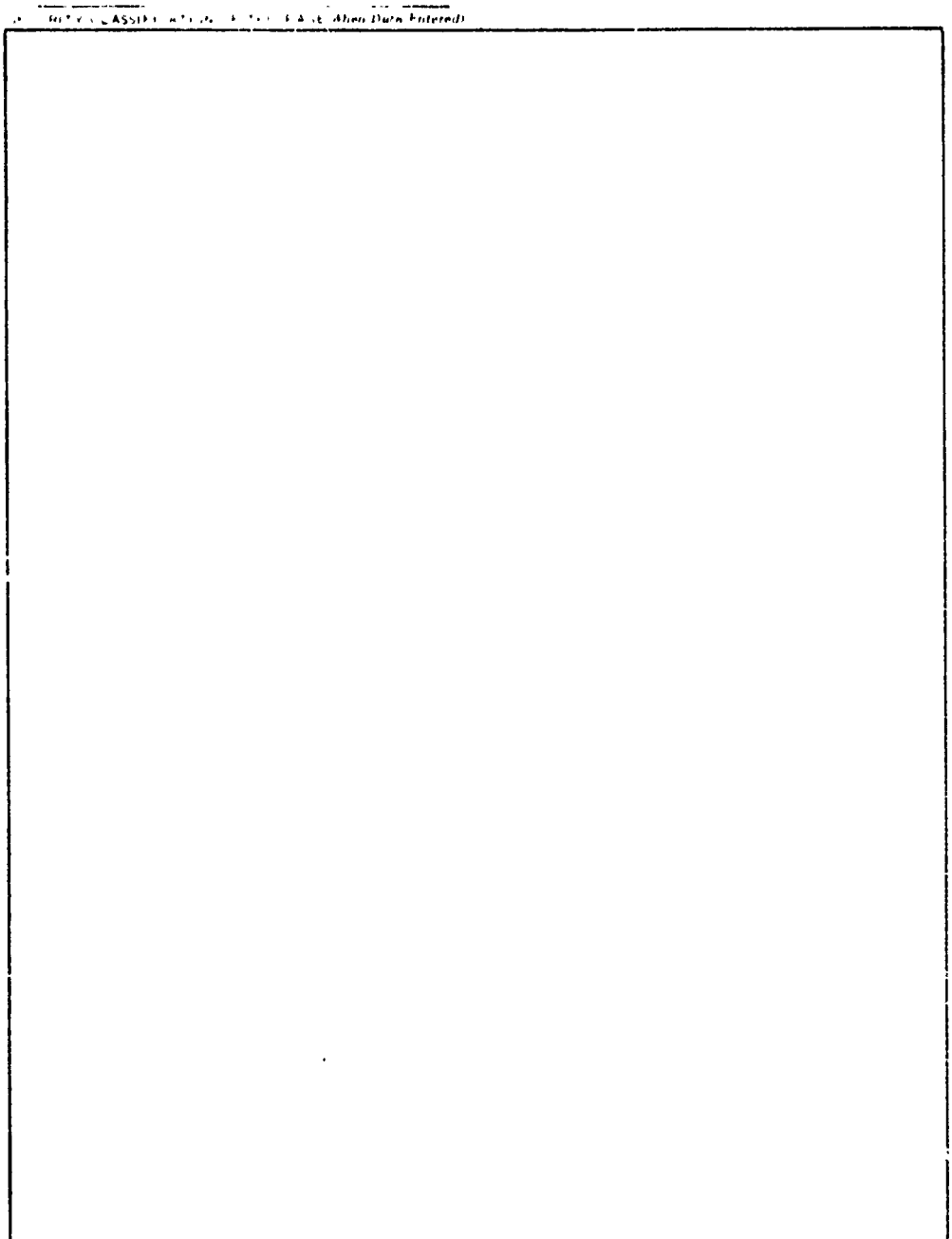
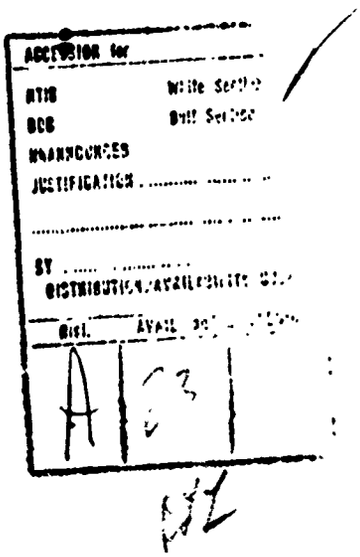


Preface

The authors thank in particular Dr. Edward A. Lewis for valuable discussions on preparing this report. Mr. Royce C. Kahler of Barkley & Dexter Labs for help with the equipment that made the measurements possible, and Mr. Jens Ostergaard of the Danish Meteorological Institute for the outstanding operation at Qanaq, Greenland.

This research effort was funded in part by the Defense Communication Agency under the Tri-Service Propagation Program.



Contents

Illustrations

VLF/LF Reflectivity of the Polar Ionosphere 4 January—3 July 1976

1. INTRODUCTION

This report provides a summary of high latitude ionospheric reflectivity, as observed by the USAF's high resolution VLF/LF ionosounder operating in northern Greenland.[1,2] As shown in Figure 1, the transmitter is located at Thule Air Base Greenland (76° 33'N. Lat., 68° 40'W. Long.), and the receiving site is 106 km north at the Danish Meteorological Institute's Ionospheric Observatory in Qanaq, Greenland (77° 24'N. Lat., 69° 20'W., Long., Geomagnetic Lat. 89° 06' N.). The ionosounding transmissions consist of a series of extremely short (approximately 100 μ sec) VLF pulses, precisely controlled in time, and radiated from a 130 meter vertical antenna. At the receiving site, orthogonal loop antennas are used to separate the two polarization components of the ionospherically reflected skywave signal. One antenna, oriented in the plane of propagation, is used to sense the groundwave and the "parallel" component of the downcoming skywave. The second loop, nulled on the groundwave, senses the "perpendicular" skywave component. The signal from each of the antennas is digitally averaged to improve the signal-to-noise ratio

(Received for publication 15 February 1977)

1. Lewis, E.A., Rasmussen, J.E., and Kossey, P.A. (1973) Measurements of ionospheric reflectivity from 6 to 35 kHz, J. Geophys. Res., 78:19.

2. Kossey, P.A., Rasmussen, J.E., and Lewis, E.A. (1974) VLF pulse ionosounder measurements of the reflection properties of the lower ionosphere, Akademie Verlag, COSPAR, July.

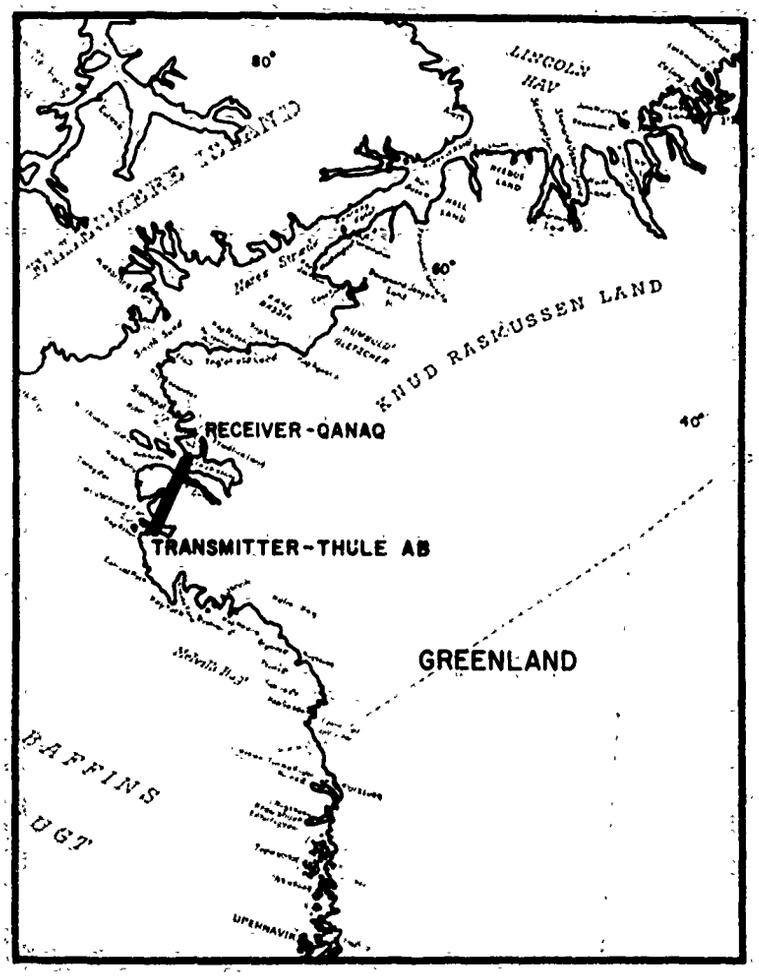


Figure 1. Geometry of the Propagation Path

of the individual received waveforms before they are recorded on magnetic tape. An example of the observed waveforms is given in Figure 2, where the parallel waveform (Figure 2a) consists of (1) a groundwave propagated pulse, (2) a quiet interval containing low level, off path groundwave reflections, followed by (3) the first-hop skywave signal. The perpendicular waveform is shown in Figure 2b.

Ionospheric reflection parameters are derived by computer (AFGL's CDC 6600) processing of the ground and ionospherically reflected waveforms with allowance made for factors such as ground conductivity (see Section 4) and antenna patterns.

Although the data are recorded about once per minute, for this report the waveforms are averaged into 2-hr time blocks and the resulting information is presented in a weekly format (Figures 3 through 26) as described below.

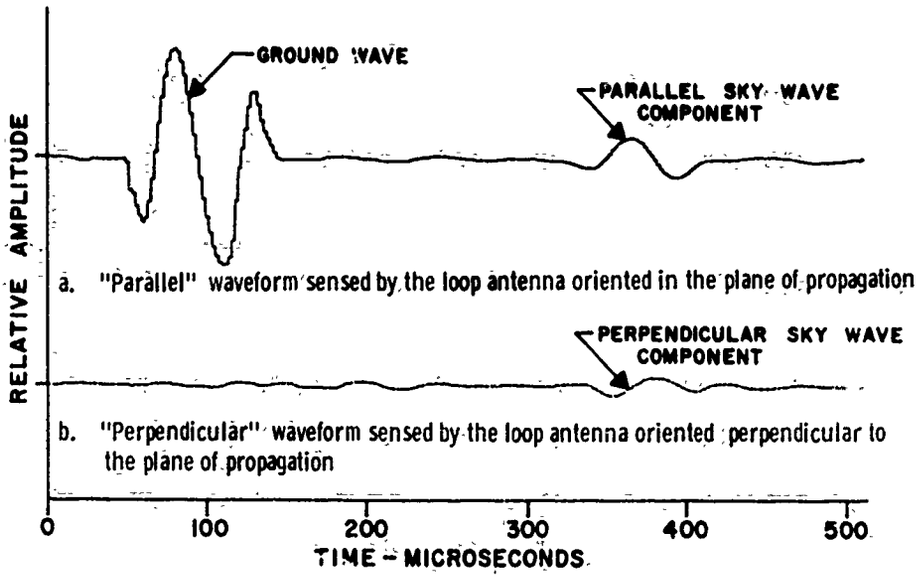


Figure 2. Example of the Observed Waveforms

2. OBSERVED WAVEFORMS

2.1 Weekly Example of Individual Waveforms

In Part A of Figures 3 through 28 a set of averaged parallel and perpendicular waveforms is presented for the time block centered near local noon of the indicated day. Each of these waveforms is comprised of 256 digitally averaged points space 2 μsec apart. In Part B of the figures, the groundwave Fourier amplitudes are shown as a function of frequency. Although the data presented in Parts C through L of the figures are generally limited to frequencies in the first, or principal, lobe of the spectrum, information at higher frequencies can be used when sufficient signal-to-noise conditions exist. There is, however, a frequency range around each spectral null where insufficient signal exists for measurements.

2.2 Three-Dimensional Waveform Presentation

A three-dimensional display of the recorded $\parallel$ waveforms covering each weekly period is shown in Part R of each figure and the corresponding $\perp$ waveforms are shown in Part S. For these plots the data has been averaged into 15-min time blocks.

The Polar Cap Absorption event of DAY 121 caused the skywave reflection to advance approximately 110 μsec, moving it into the time period occupied by the apparent off-path groundwave reflections. Because of the stability of these ground-

wave reflections, they can be removed by computer processing so as not to interfere with the skywave signals. This has been done in Parts R and S of Figures 19 and 20 in the portion of the waveforms between 140 and 280 μ sec.

3. REFLECTION HEIGHTS

The group mirror height (GMH) of reflection was obtained by determining the group delay of the skywave relative to the groundwave and attributing this time difference, by simple geometry (assuming a sharply bounded mirror-like ionosphere), to a difference in propagation distance. As discussed in Lewis et al,[1] the group delay can be defined as the rate of change of phase with frequency. For the GMH data presented in this report, a finite frequency difference of 1.0 kHz was used, and the corresponding phase difference as a function of frequency for the groundwave and both skywave signals was obtained by Fourier analysis of the respective pulses. The GMH calculations took into account ground conductivity (10^{-3} mho/meter is assumed), and the corrections of Wait and Howe[3] were applied.

Group mirror heights are plotted as a function of frequency in Parts C and D of Figures 3 through 28, as obtained from the parallel and perpendicular waveforms, respectively. The GMH's are also presented as a function of time-of-day for the average frequency of 16.5 kHz in figure Parts E and I. The parallel GMH's in Part E are shown along with an average reflection height for reference purposes. Each point of the reference height is a weekly average, by time block, for the 7-day period indicated. The corresponding perpendicular GMH's, Part I of the figures, are also shown with the weekly average for comparison. Part G gives the average, by time block, for the daily parallel GMH data of Part E, and Part K gives the corresponding perpendicular GMH averages from the daily data of Part I.

4. REFLECTION COEFFICIENTS

Assuming that the ionosphere acts as a "mirror" at the GMH, plane wave reflection coefficients[4] were obtained by comparing the ratio of the skywave Fourier amplitude at a specific frequency to that of the groundwave, taking into account the antenna patterns, wave spreading, earth curvature, ground conductivity, path lengths, and antenna patterns including ground image effects.

3. Wait, J.R. and Howe, H.H. (1956) Amplitude and Phase Curves for Ground-Wave Propagation in the Band 200 Cycles per Second to 500 Kilocycles, Nat. Bur. Stand. U.S. Circ., p. 574.

4. Budden, K.G. (1961) Radio Waves in the Ionosphere, p. 85, Cambridge University Press, London.

The reflection coefficient $_{\|}R_{\|}$ was obtained from analysis of the parallel skywave component and is plotted as a function of frequency in Part C of Figures 3 through 28. The $_{\|}R_{\|}$ coefficient for 16 kHz is plotted as a function of time-of-day in Part F along with the average of the indicated week for reference purposes. From the perpendicular skywave pulse, the coefficient $_{\|}R_{\perp}$ was obtained and appears as a function of frequency in Part D. The 16 kHz $_{\|}R_{\perp}$ is shown along with its reference in Part J. Parts H and L present the average, by time block, of the daily $_{\|}R_{\|}$ and $_{\|}R_{\perp}$ data presented in Parts F and J, respectively.

For certain coefficient data points, plotted as asterisks (*), the reflection coefficient appears without a corresponding GMH. For these particular data, only the skywave-groundwave ratios could be obtained as the skywaves were too weak to provide reliable group delay information. The reflection coefficients were therefore estimated using a nominal GMH of 80 km in the calculations. These estimated coefficient values are included in the averages presented in Parts H and L, but the assumed heights are not used in the GMH averages shown in Parts G and K.

5. SUPPLEMENTARY INFORMATION

For purposes of comparison and interpretation, certain supplementary data are presented. Figure Parts M and N give the received VLF phase and amplitude from the 18.6 kHz station NLK (transmitter location: Jim Creek, Washington), as observed at Thule AB over a 3900-km propagation path. Part O of the figures shows the magnitude of the horizontal component of the polar magnetic field observed with a three-axis fluxgate magnetometer, and Part P presents 30-MHz riometer data, an indicator of D-region particle precipitation. These supplementary data were recorded at 30-sec intervals by AFGL's Geopole Observatory at Thule AB, the curves represent the average of 10-min periods. The Geopole Observatory was closed by AFGL in June 1976; however, the operation of the VLF/LF receivers, riometers, and magnetometers has been assumed by RADC/ETEE. The solar zenith angle is given in Part Q of Figures 3 through 28 for the indicated mid-week date.

6. ADDITIONAL COMMENTS

It is noted that during the period covered by this report the effects of three polar ionospheric disturbances can be seen in the data. The first occurred at about 0230 UT on DAY 23 (23 January). At this time the 30 MHz-riometer shows a spike of absorption which generally indicates the passage of an intense polar auroral substorm. At approximately the same time the VLF/LF reflectivity data shows a rapid lowering of the reflection height which recovers within about two hours.

The effects of a second disturbance can be seen in the ionosounder data for the period DAY 86 – 91 (26 March – 1 April). The magnetometer records indicate that there was strong magnetic activity during this period. The third disturbance was a moderate energetic particle event which resulted in a peak of about 3 dB absorption on the 30 MHz riometer during DAY 121 (30 April). The VLF/LF ionospheric reflectivity data again shows a rapid lowering of the reflection height; however, in this case it does not return to the normal diurnal pattern for about six days.

This report is one of a series.[5,6,7,8,9] Comments and suggestions for improving its usefulness should be addressed to the VLF/ULF Techniques Branch (ETEE), Electromagnetic Sciences Division, Deputy for Electronic Technology (RADC/ETEE) Hanscom AFB, Massachusetts 01731.

5. Rasmussen, J.E., McLain, R.J., Capt, USAF, and Turtle, J.P. (1976) VLF/LF Reflectivity of the Polar Ionosphere, 19 January – 2 March 1975, AFCRL-TR-76-0045.

6. Rasmussen, J.E., McLain, R.J., Capt, USAF, and Turtle, J.P. (1976) VLF/LF Reflectivity of the Polar Ionosphere, 2 March – 3 May 1975, RADC-TR-76-146.

7. Rasmussen, J.E., McLain, R.J., Capt, USAF, Turtle, J.P. and Klemetti, W.I. (1976) VLF/LF Reflectivity of the Polar Ionosphere, 4 May – 5 July 1975, RADC-TR-76-270.

8. Rasmussen, J.E., McLain, R.J., Capt, USAF, Turtle, J.P. and Klemetti, W.I. (1976) VLF/LF Reflectivity of the Polar Ionosphere, 20 July – 20 September 1975, RADC-TR-76-327.

9. Rasmussen, J.E., McLain, R.J., Capt, USAF, Turtle, J.P. and Klemetti, W.I. (1976) VLF/LF Reflectivity of the Polar Ionosphere, 21 September 1975 – 3 January 1976, RADC-TR-76-378.

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1. Lewis, E.A., Rasmussen, J.E., and Kossey, P.A. (1973) Measurements of ionospheric reflectivity from 6 to 35 kHz, J. Geophys. Res., 78:19.

2. Kossey, P.A., Rasmussen, J.E., and Lewis, E.A. (1974) VLF pulse ionosounder measurements of the reflection properties of the lower ionosphere, Akademie Verlag, COSPAR, July.

3. Wait, J.R. and Howe, H.H. (1956) Amplitude and Phase Curves for Groundwave Propagation in the Band 200 Cycles per Second to 500 Kilocycles, Nat. Bur. Stand. U.S. Circ., p. 574.

4. Budden, K.G. (1961) Radio Waves in the Ionosphere, p. 85, Cambridge University Press, London.

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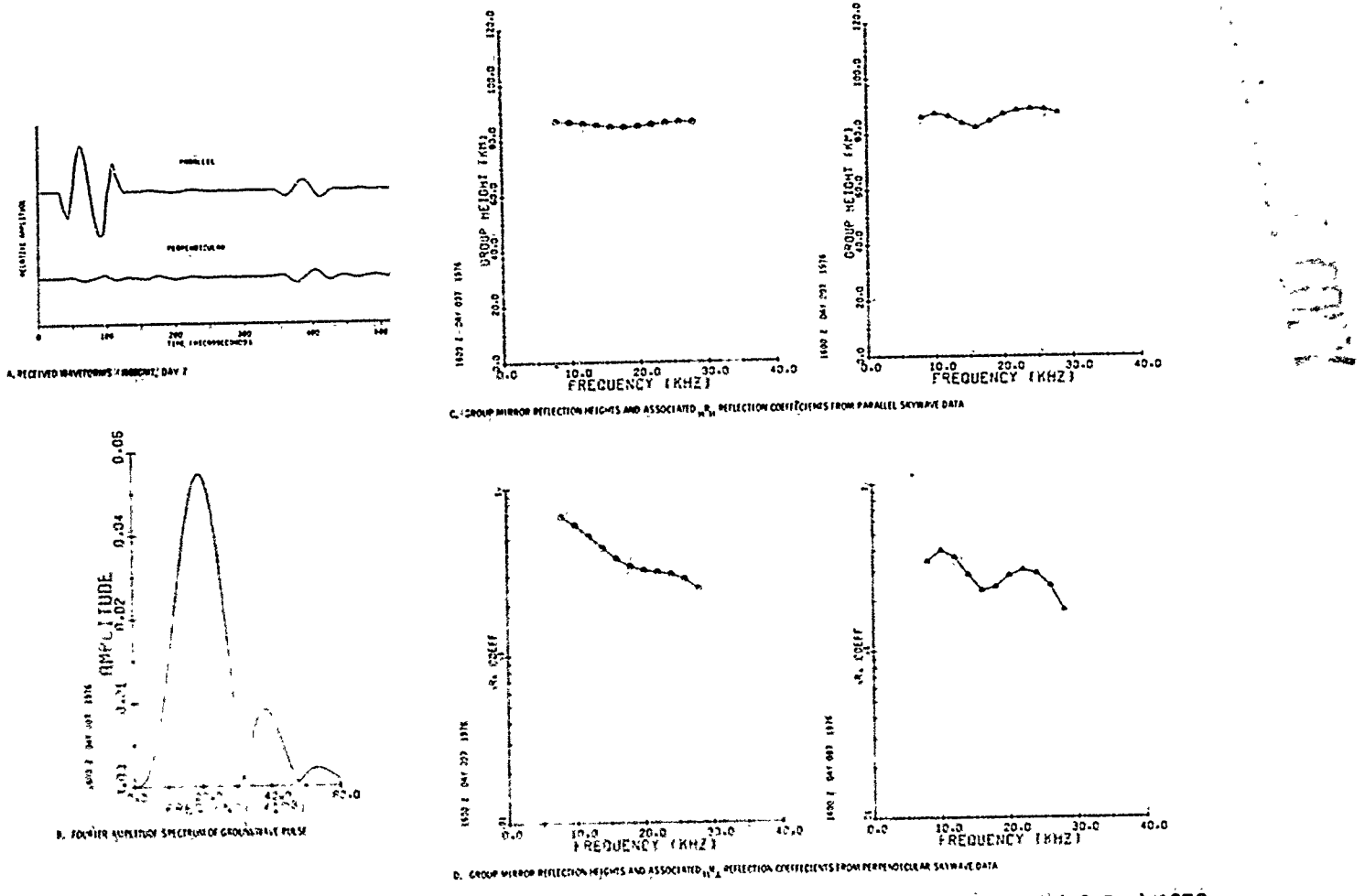
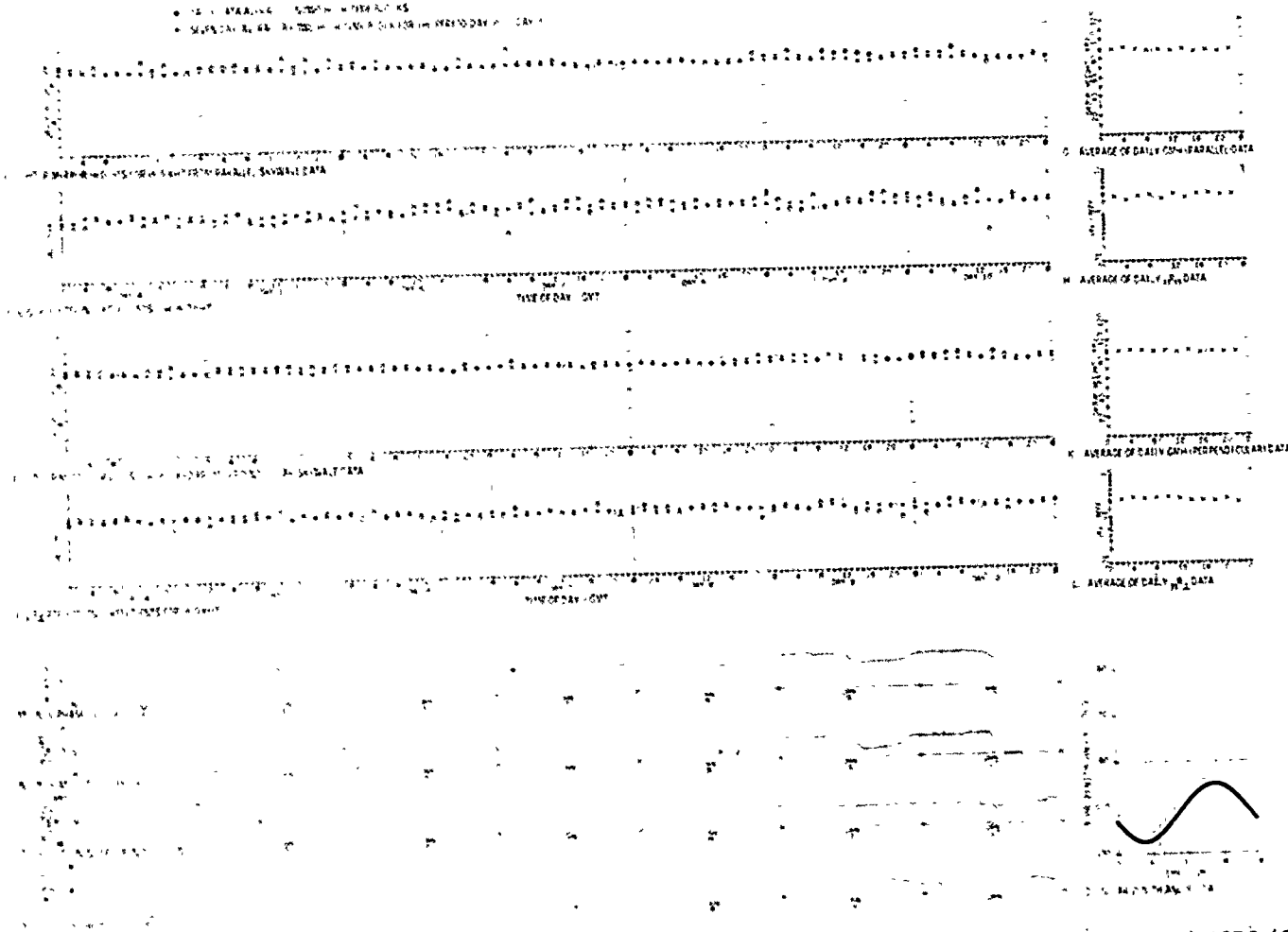


Figure 3. VLF/LF Reflectivity Data for the Polar Ionosphere, DAY 4 (4 Jan) — DAY 10 (10 Jan) 1976



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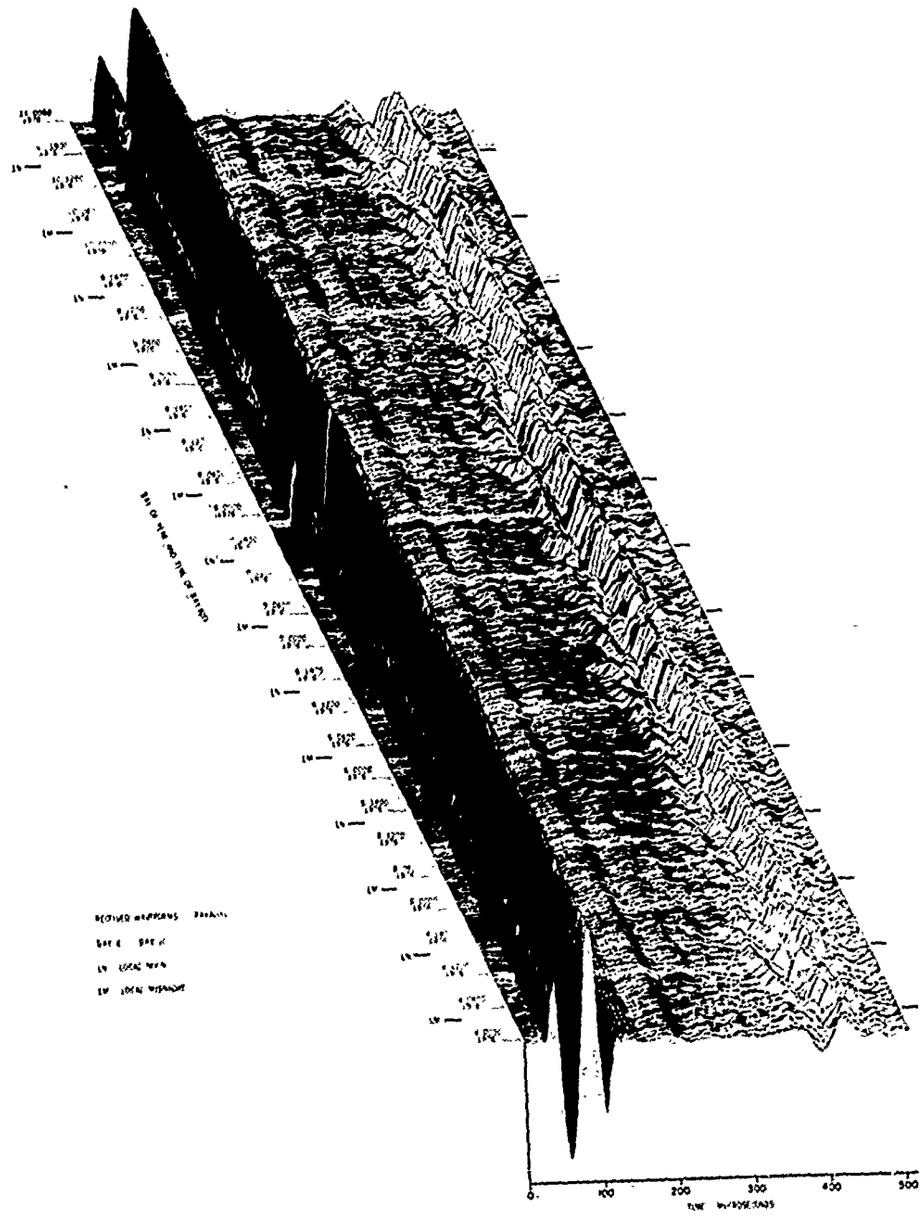

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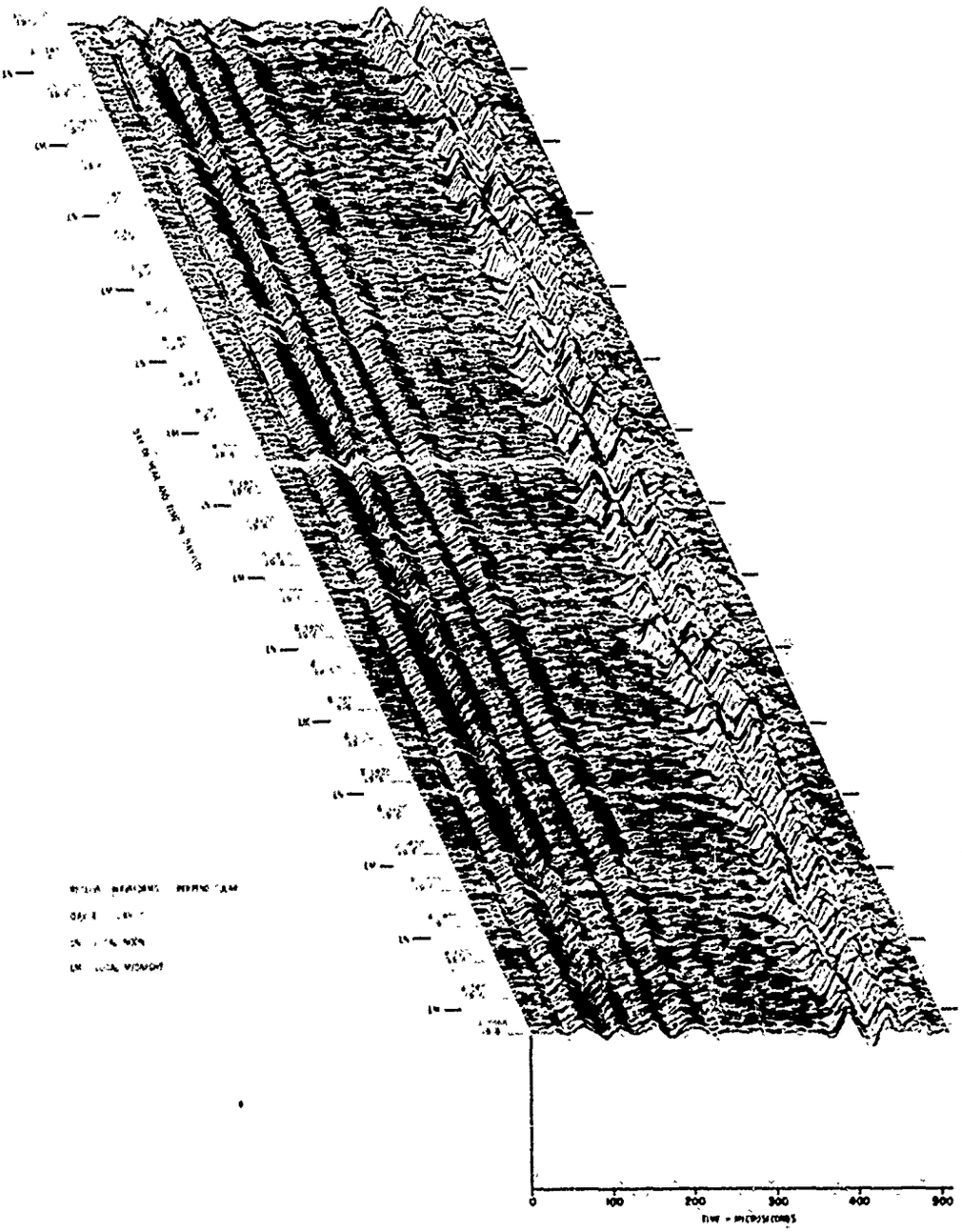

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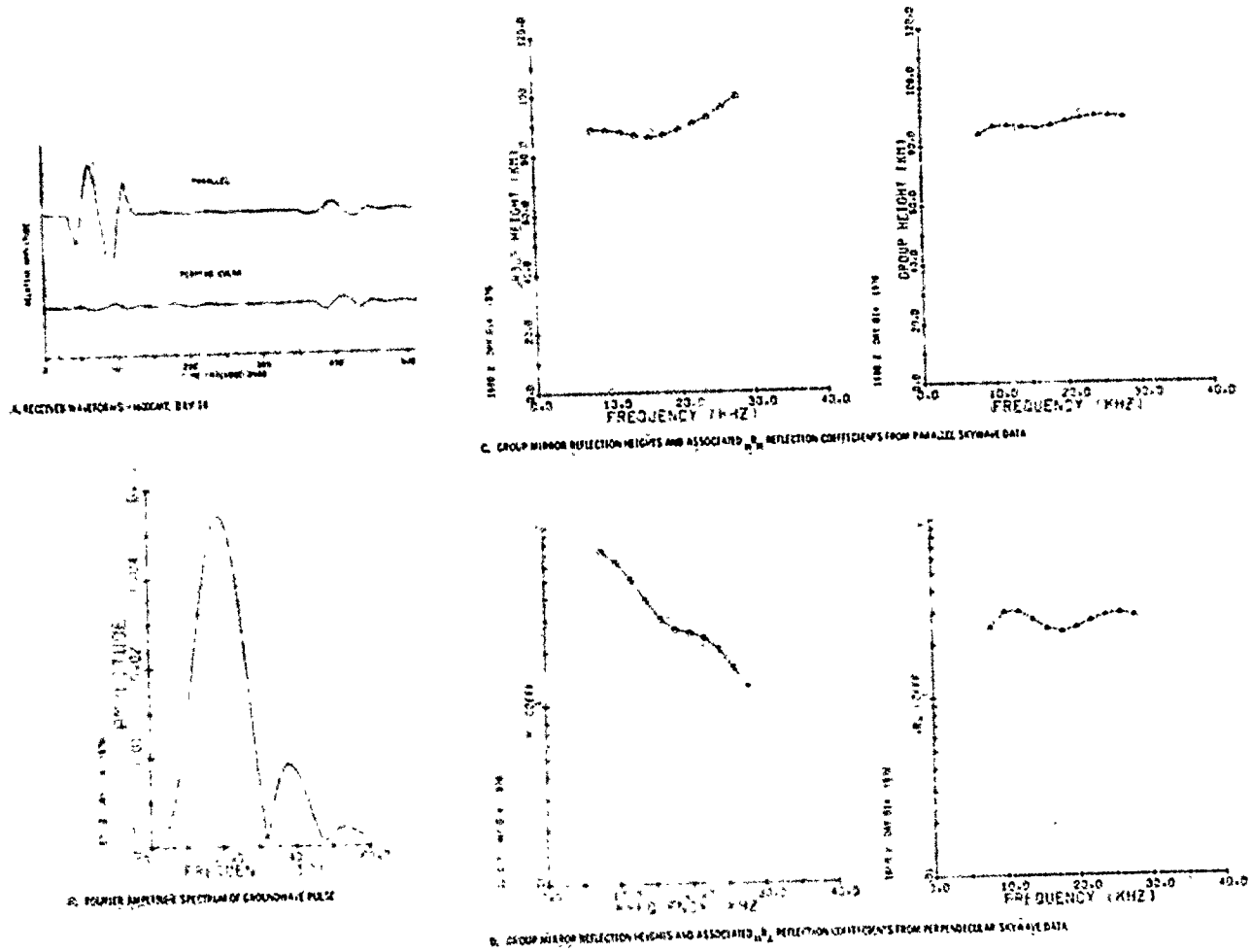

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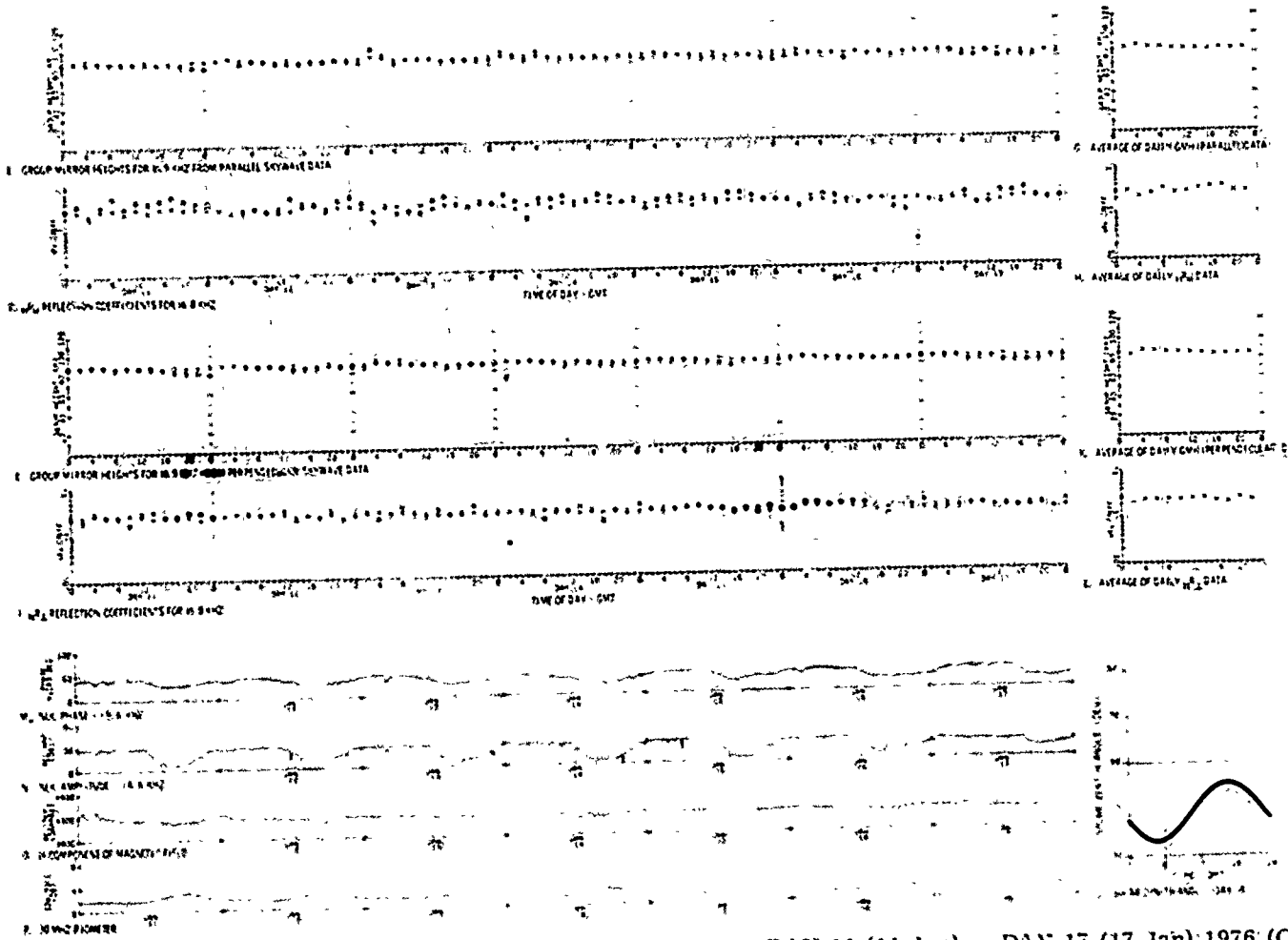

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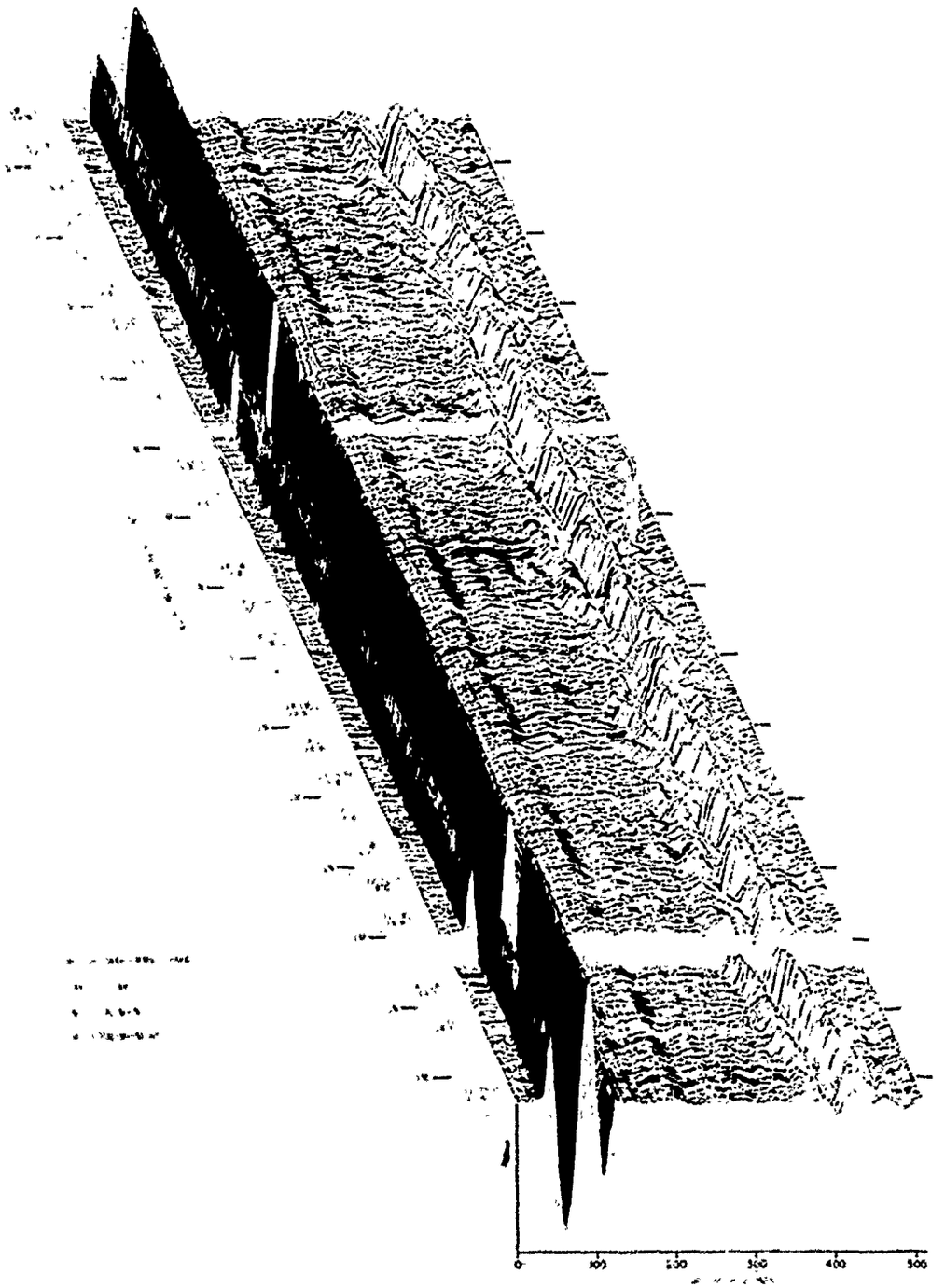

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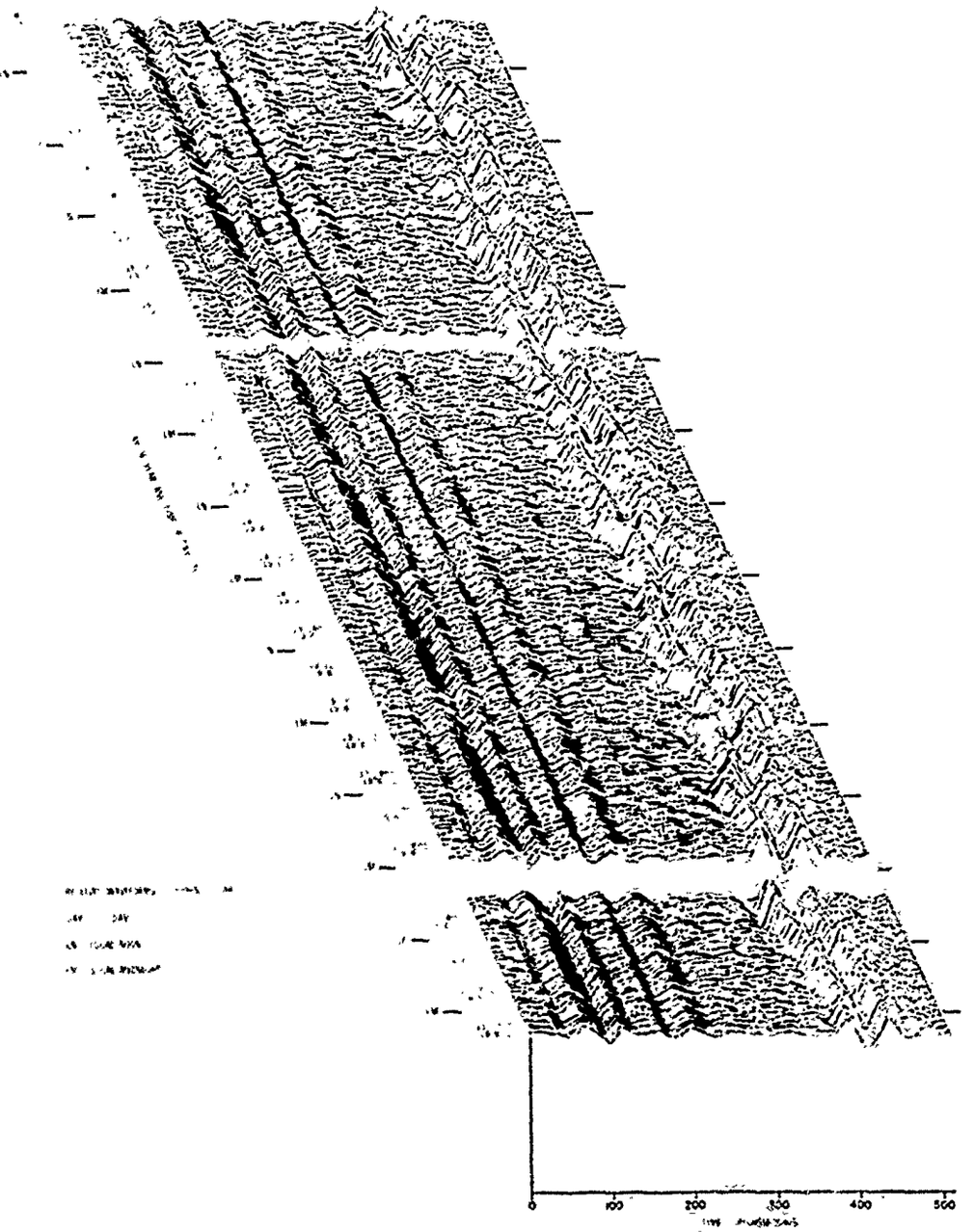

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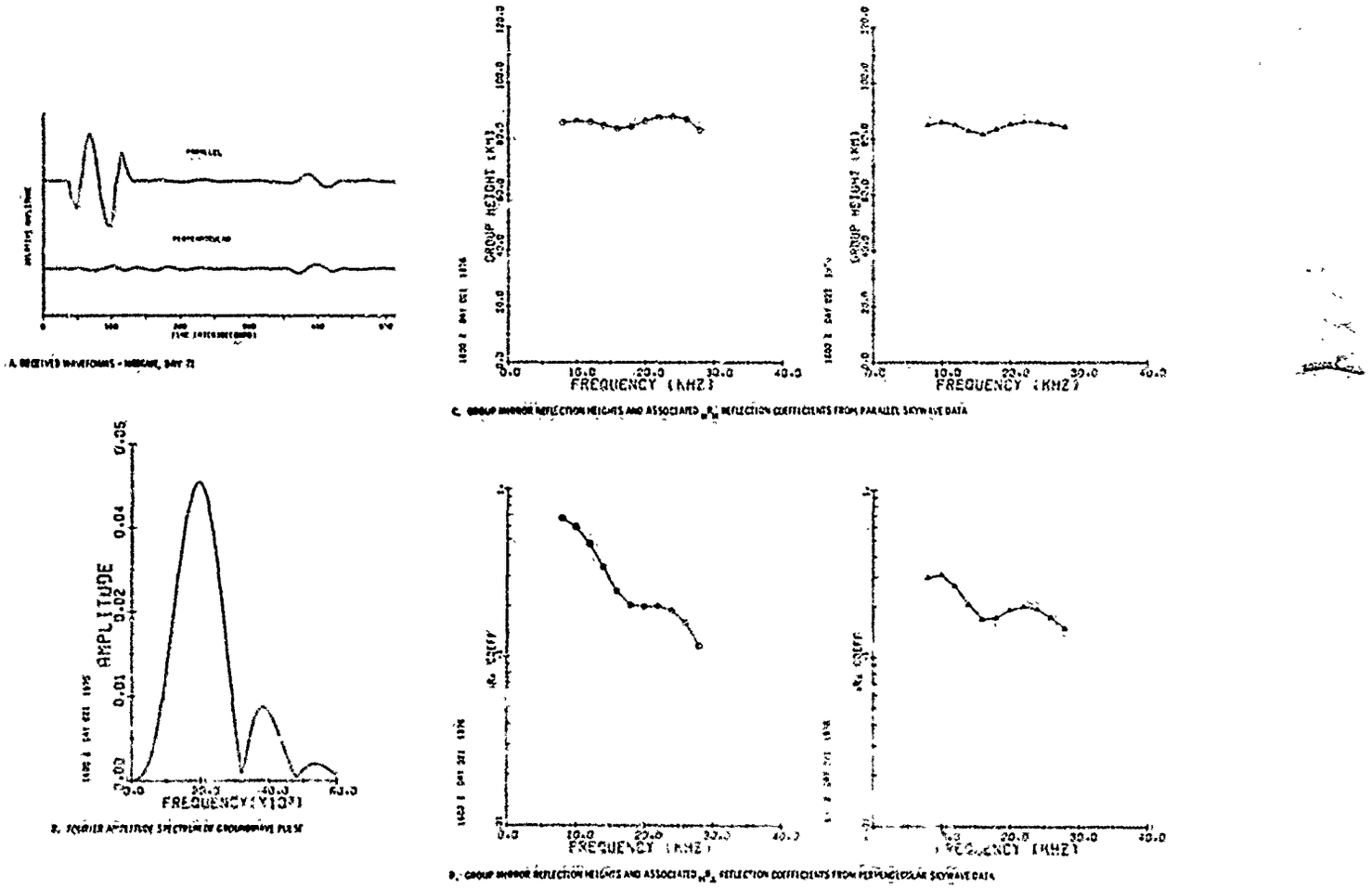

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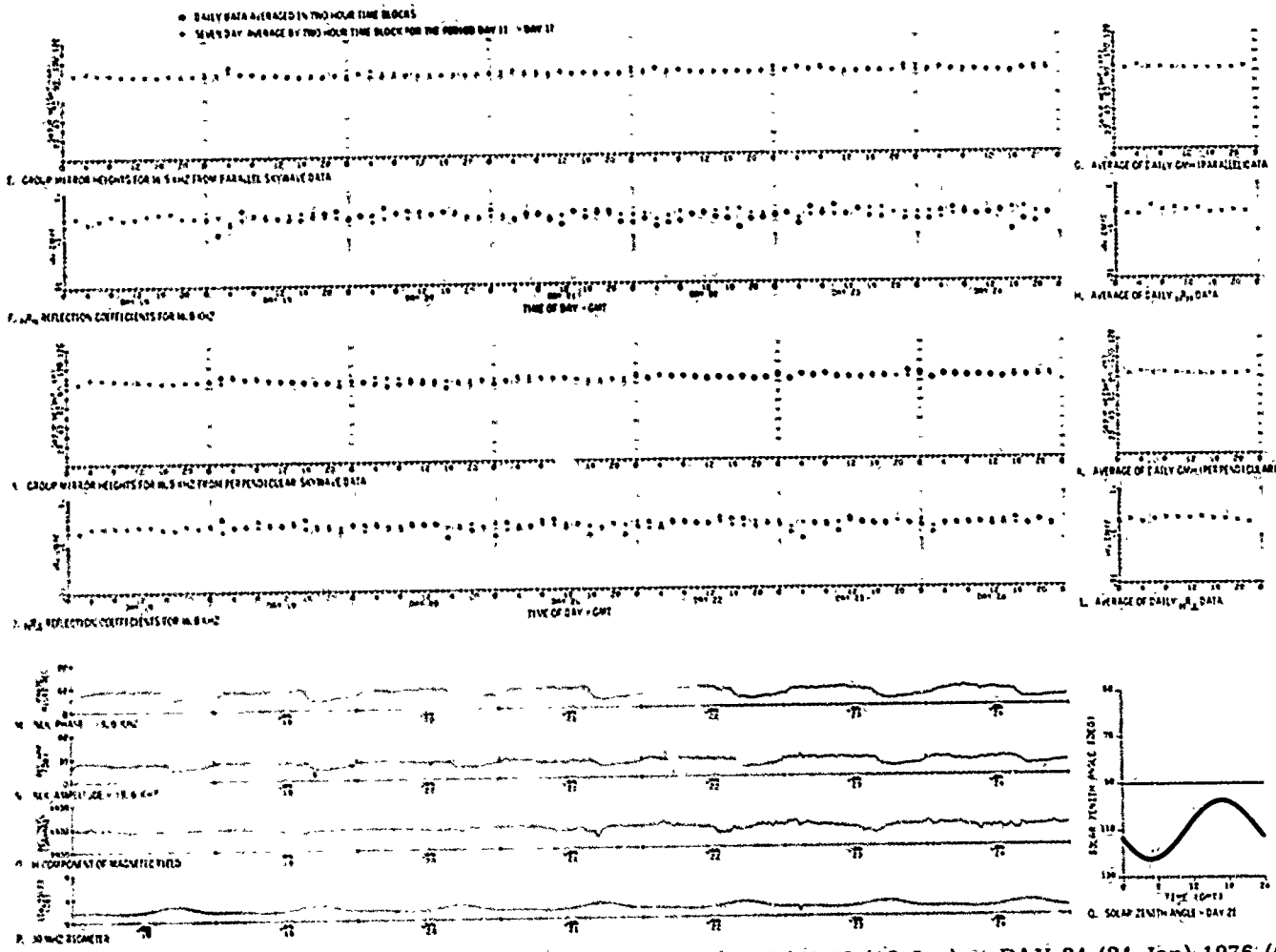

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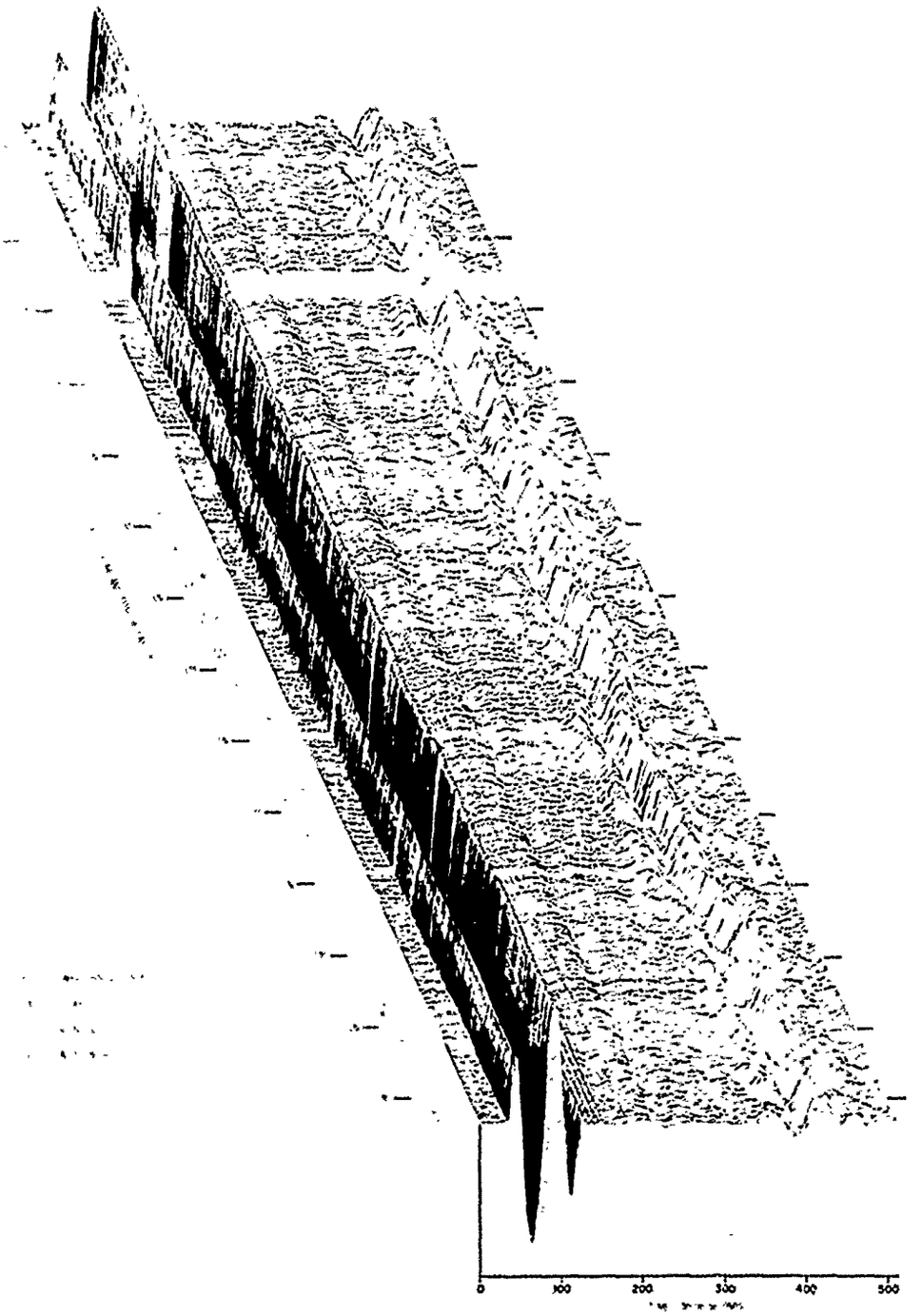

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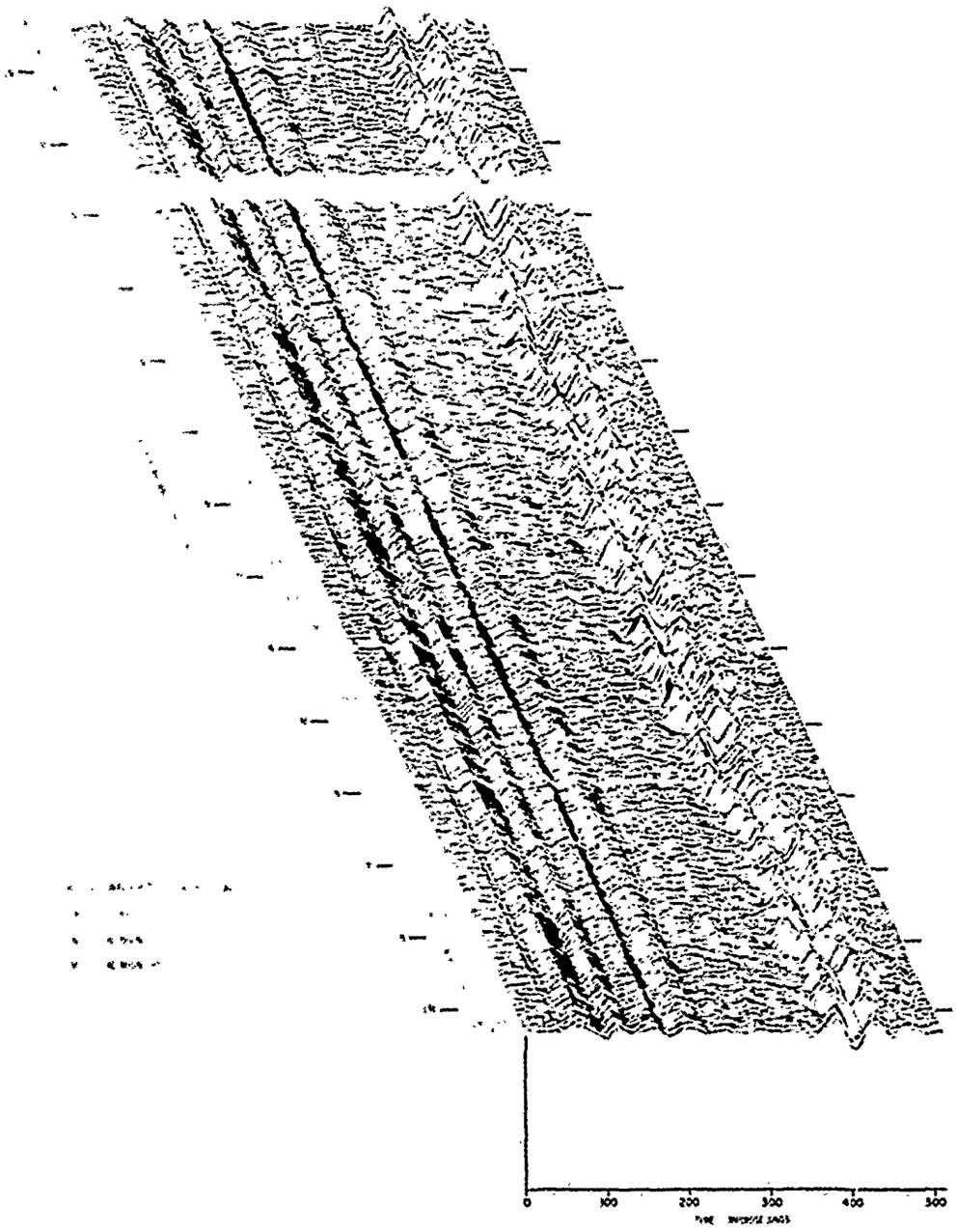

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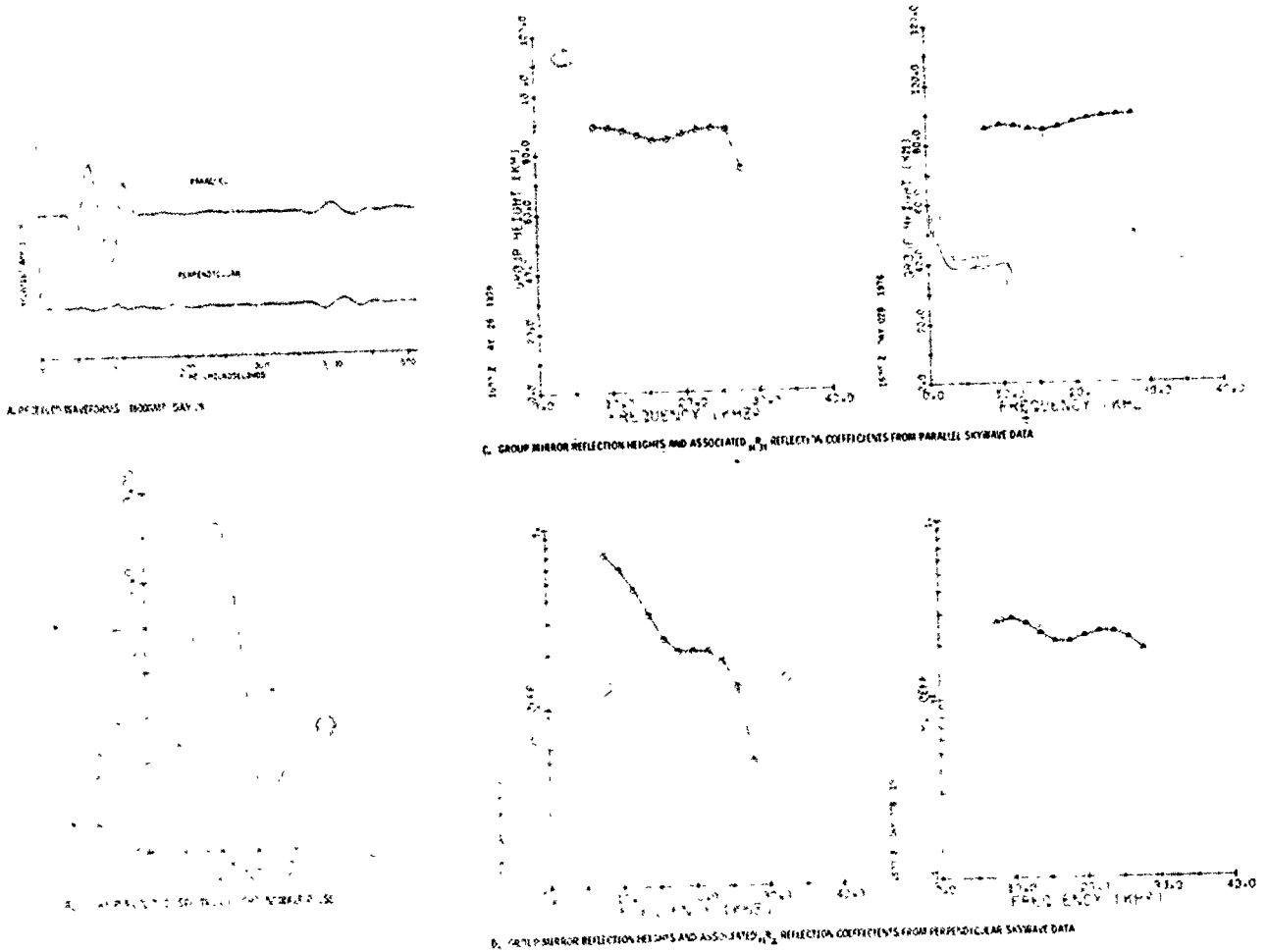

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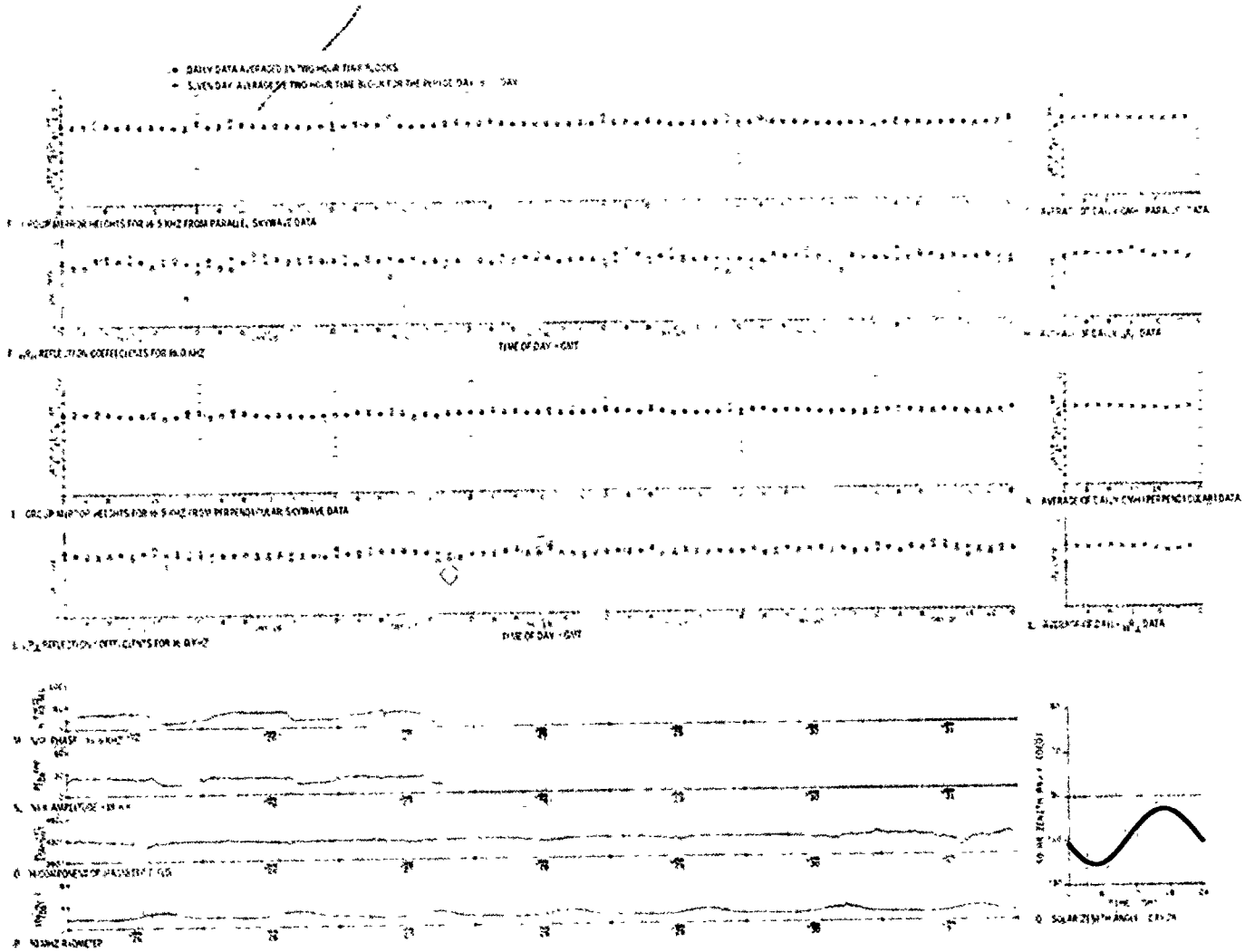

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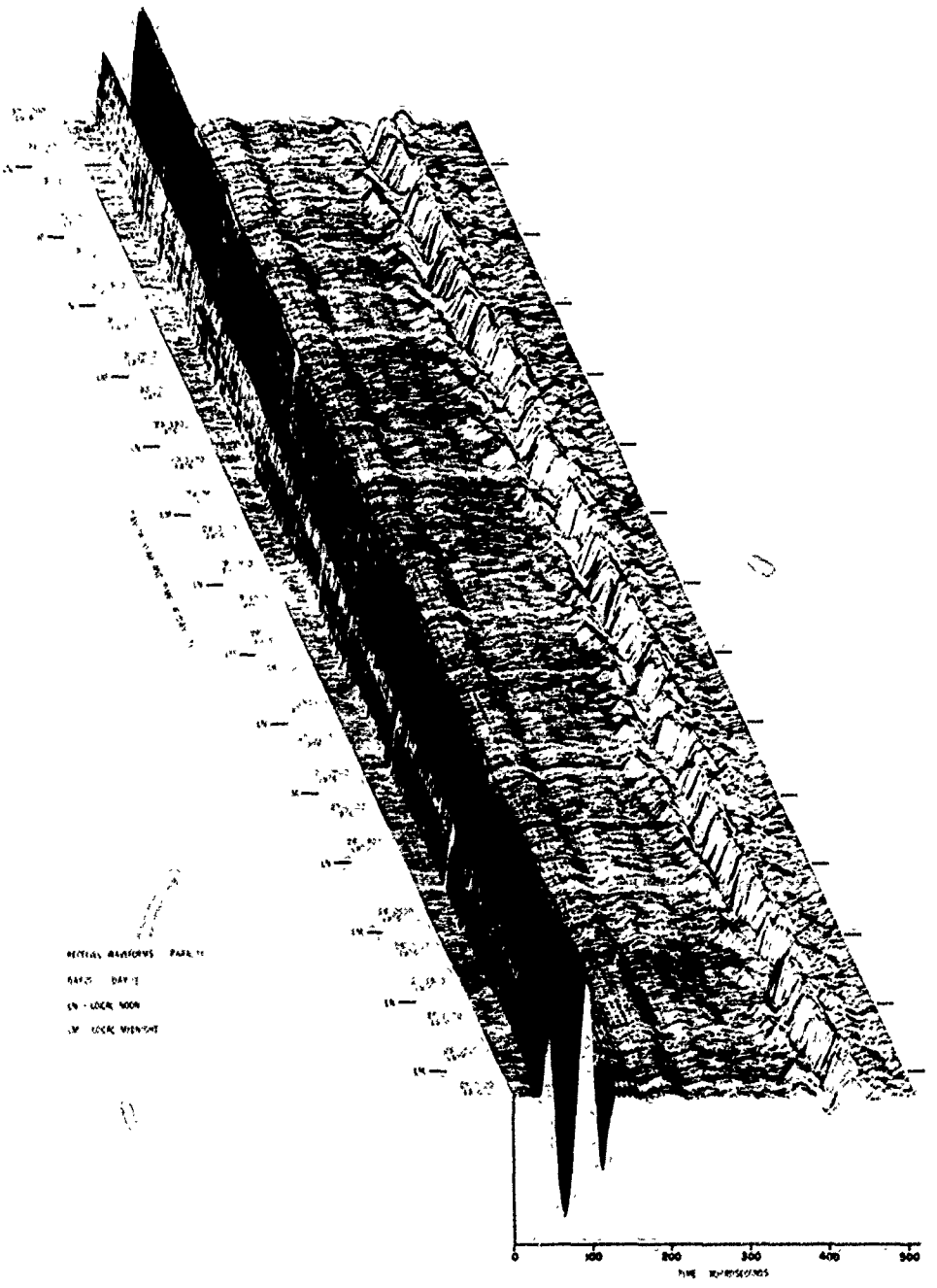

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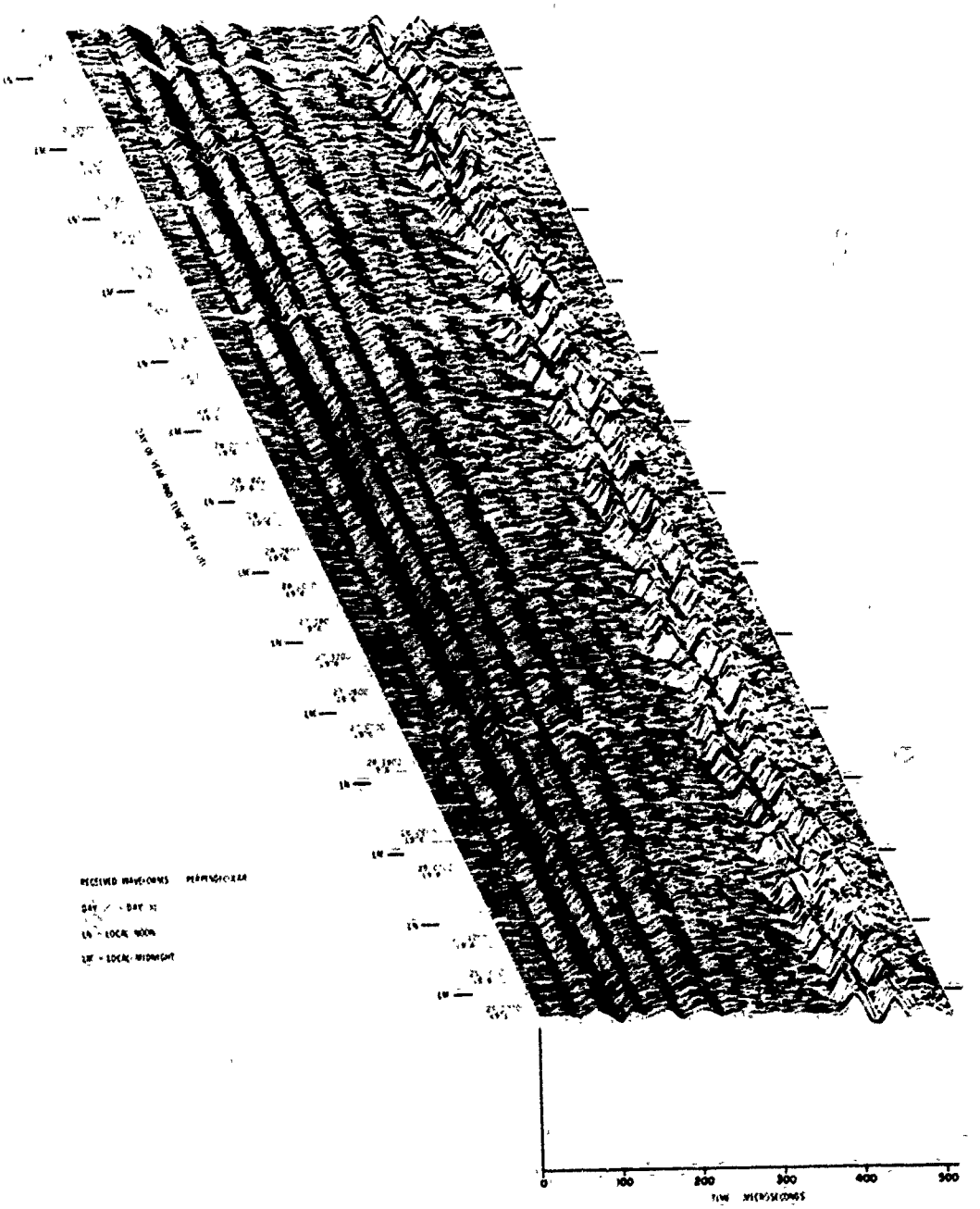

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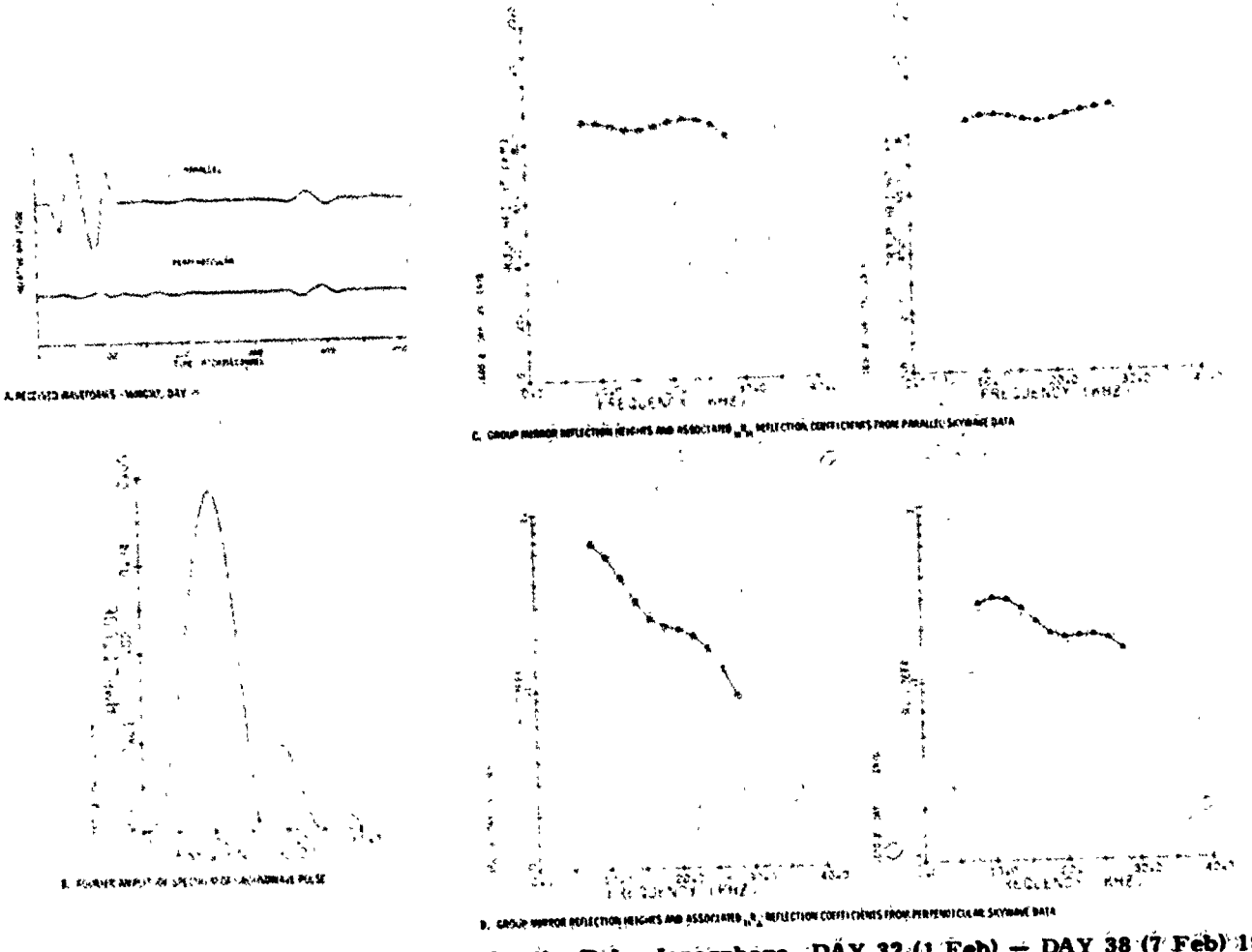


Figure 7. VLF/LF Reflectivity Data for the Polar Ionosphere, DAY 32 (1 Feb) — DAY 38 (7 Feb) 1976

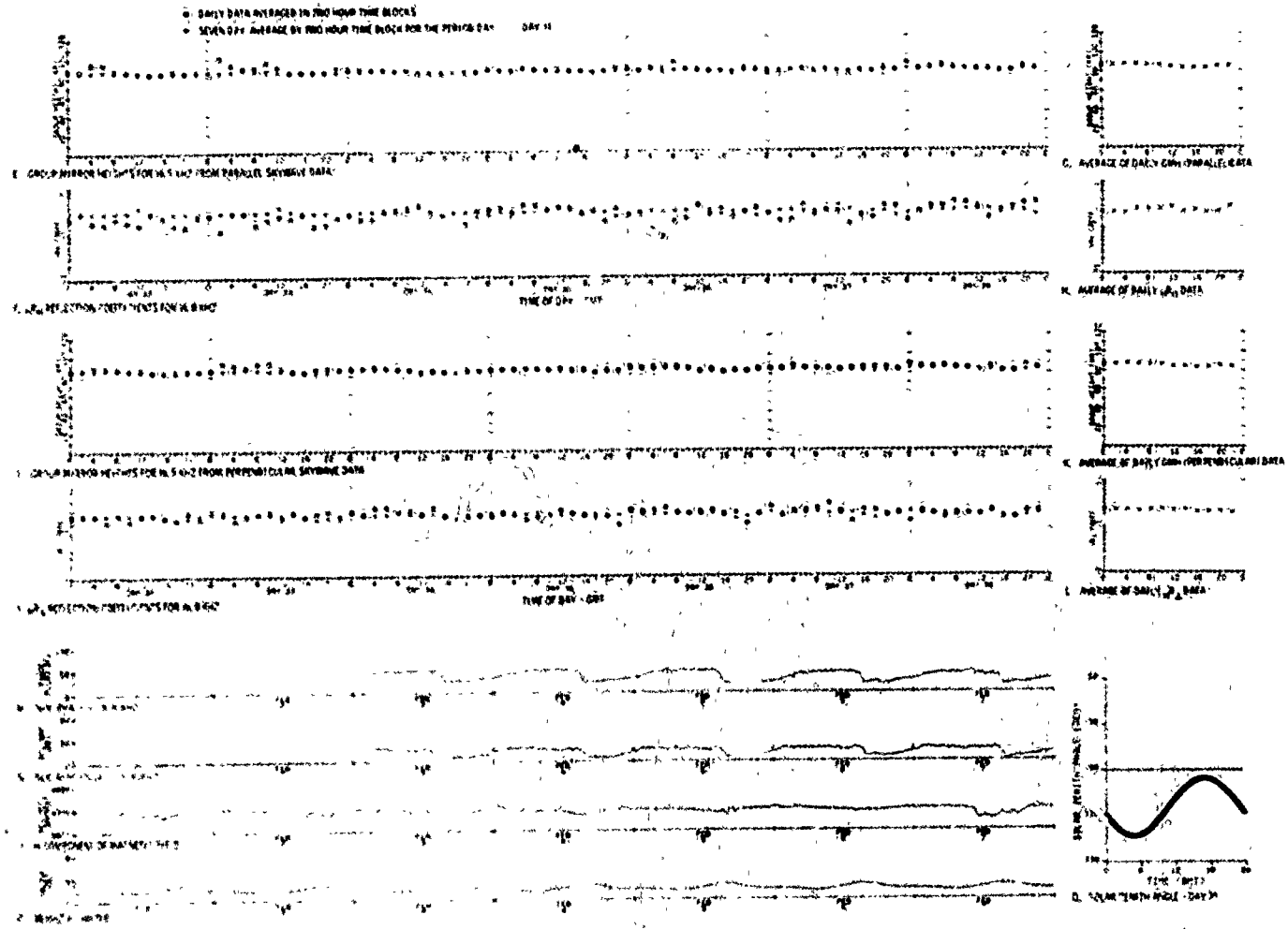
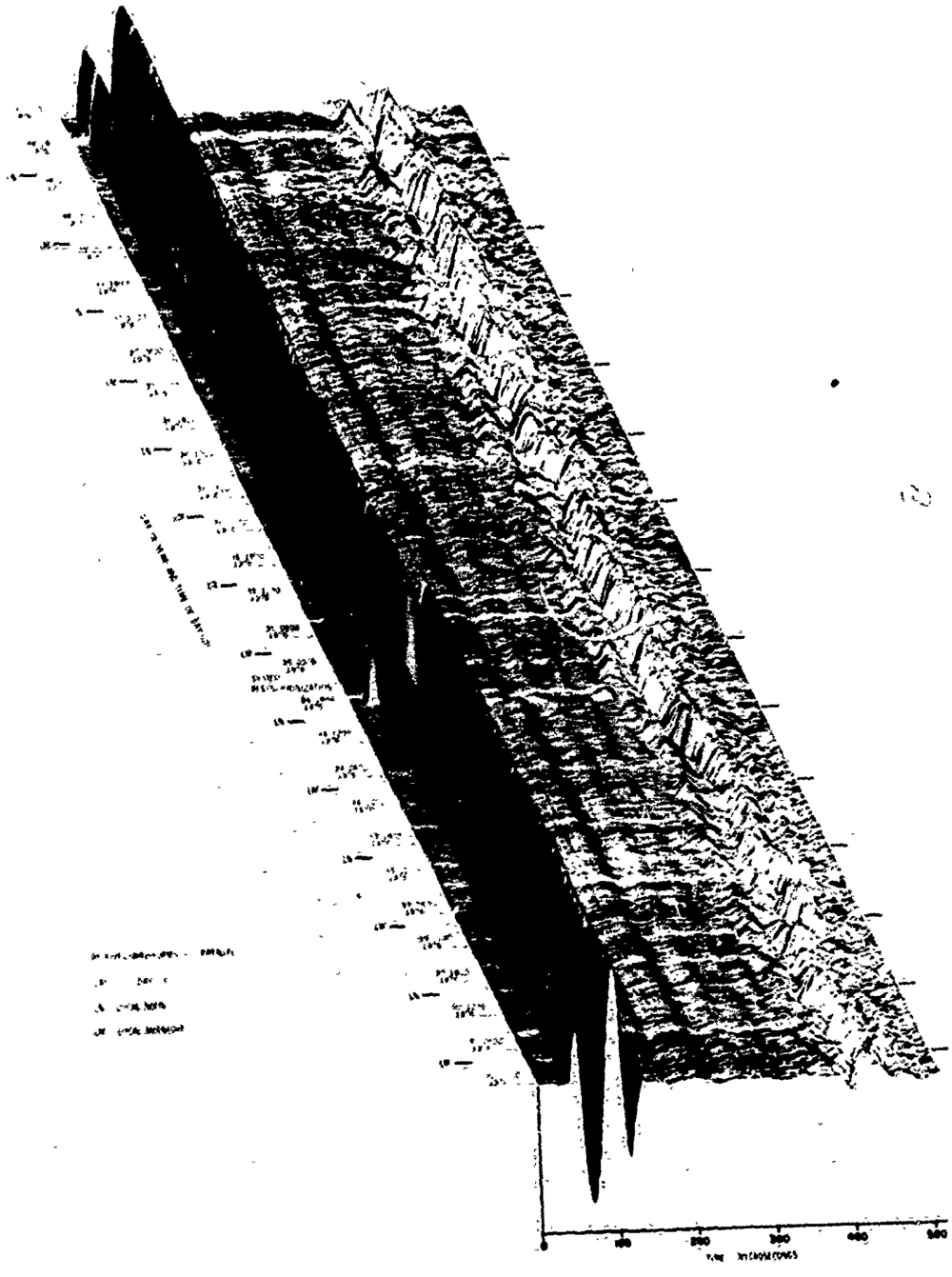


Figure 7. VLF/LF Reflectivity Data for the Polar Ionosphere, DAY 32 (1Feb) — DAY 38 (7 Feb) 1976 (Cont)



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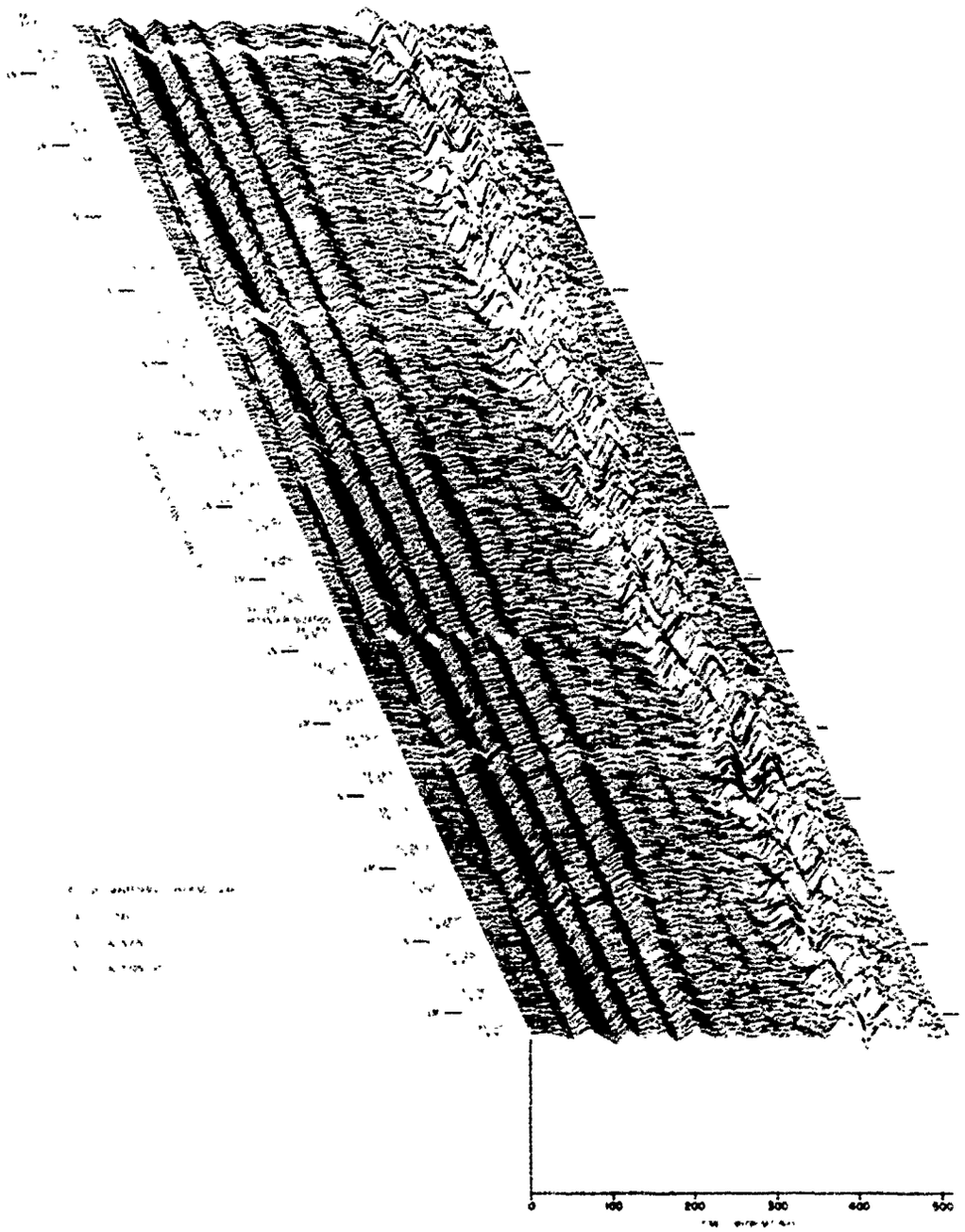

Figure 7. VLF/LF Reflectivity Data for the Polar Ionosphere, DAY 32 (1 Feb) - DAY 38 (7 Feb) 1976 (Cont) Part S. ⊥ Waveform Display

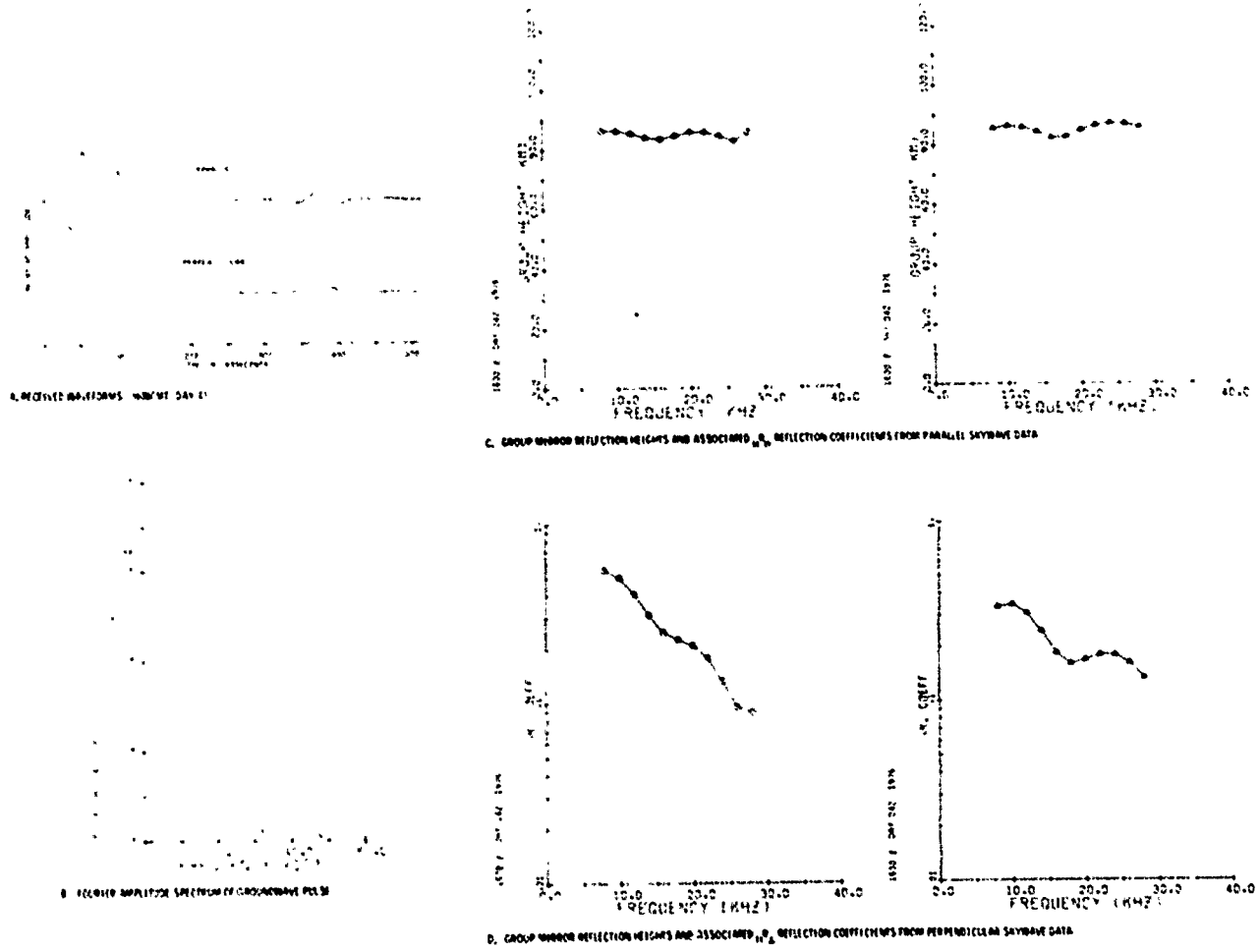

Figure 8. VLF/LF Reflectivity Data for the Polar Ionosphere, DAY 39 (8 Feb) — DAY 45 (14 Feb) 1976

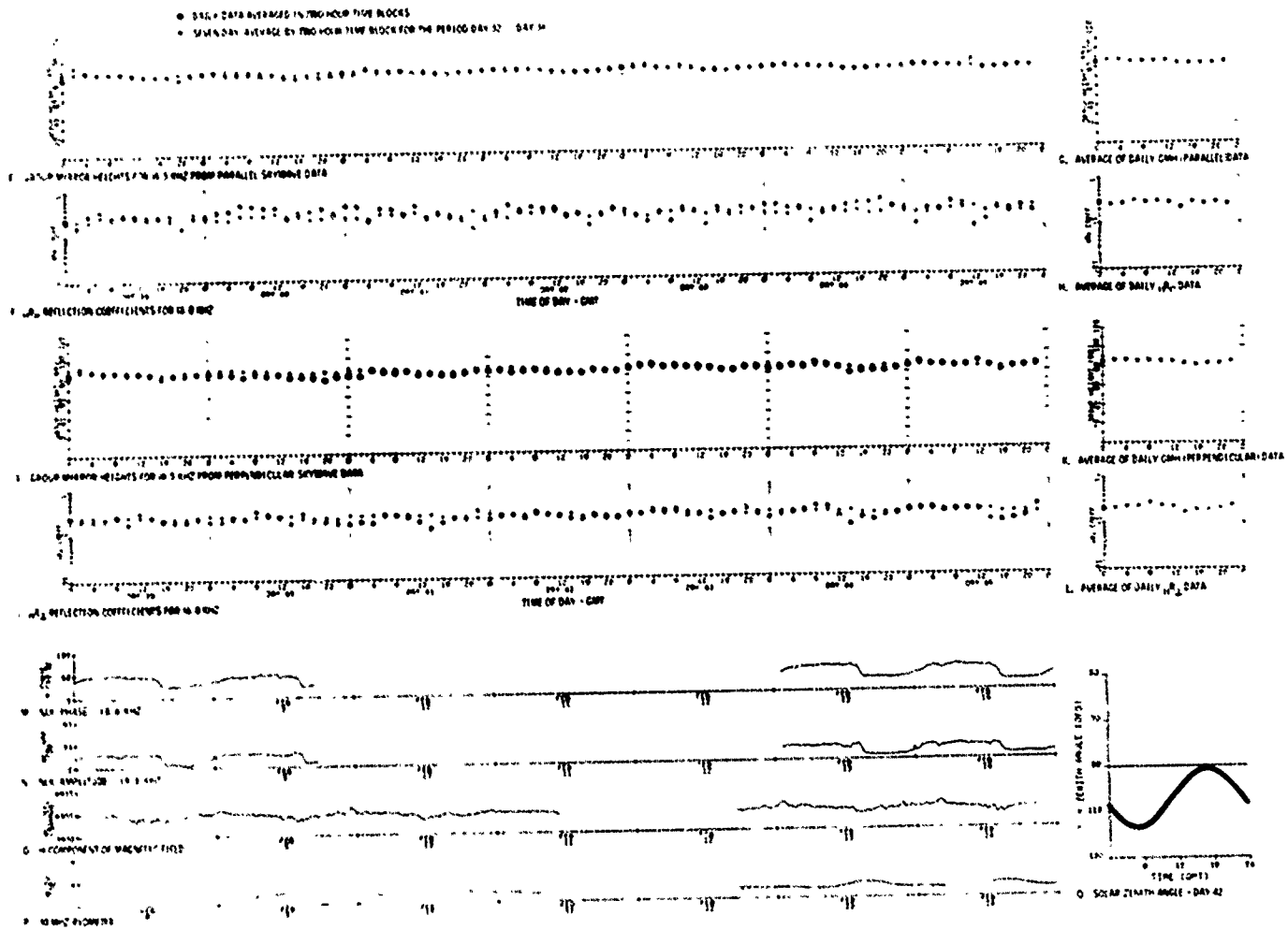

Figure 8. VLF/LF Reflectivity Data for the Polar Ionosphere, DAY 39 (8 Feb) — DAY 45 (14 Feb) 1976 (Cont)

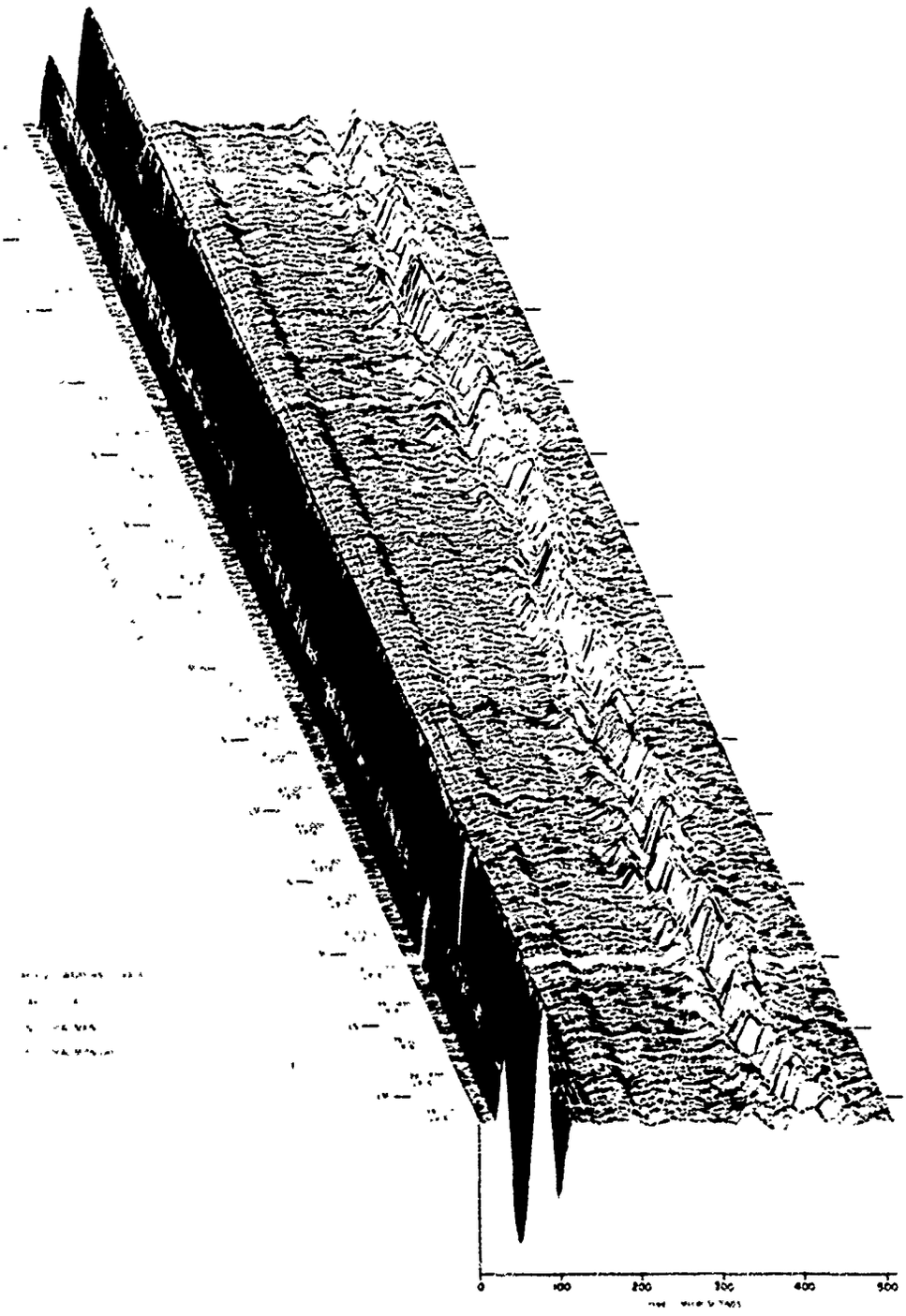

Figure 8. VLF/LF Reflectivity Data for the Polar Ionosphere, DAY 39 (8 Feb) - DAY 45 (14 Feb) 1976 (Cont) Part R. || Waveform Display

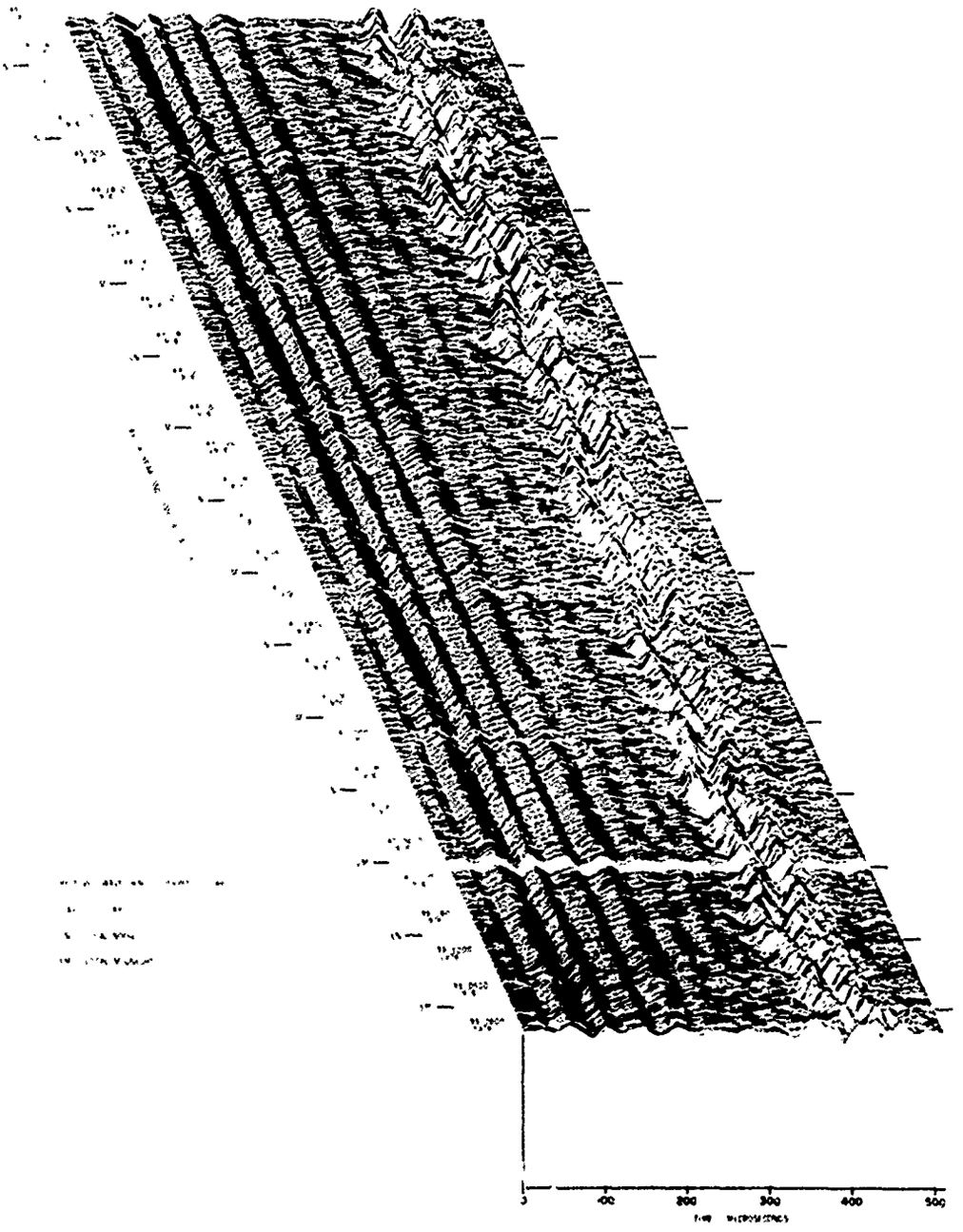

Figure 8. VLF/LF Reflectivity Data for the Polar Ionosphere, DAY 39 (8 Feb) - DAY 45 (14 Feb) 1976 (Cont) Part S. ⊥ Waveform Display

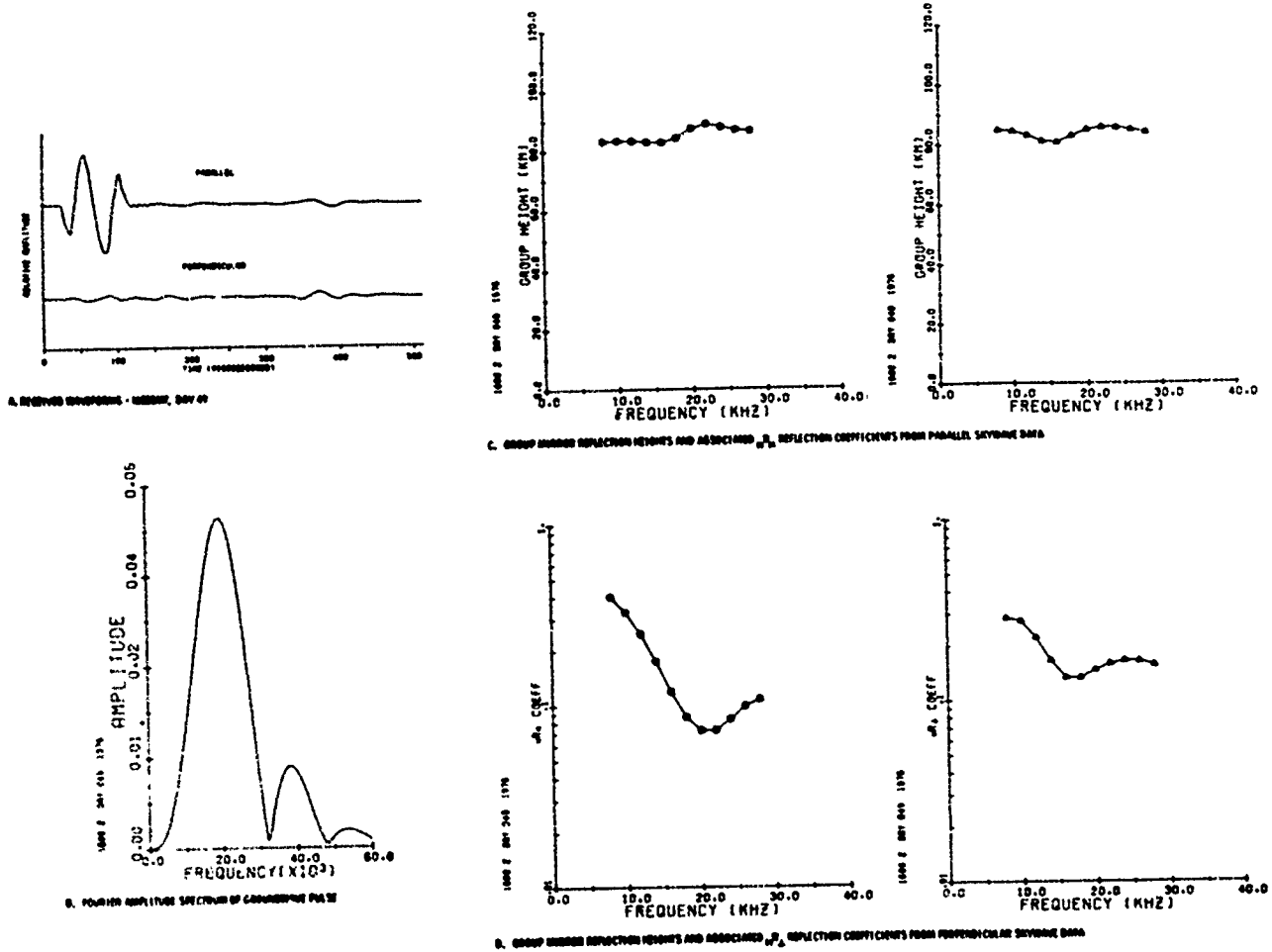

Figure 9. VLF/LF Reflectivity Data for the Polar Ionosphere, DAY 46 (14 Feb) —DAY 52 (21 Feb) 1976

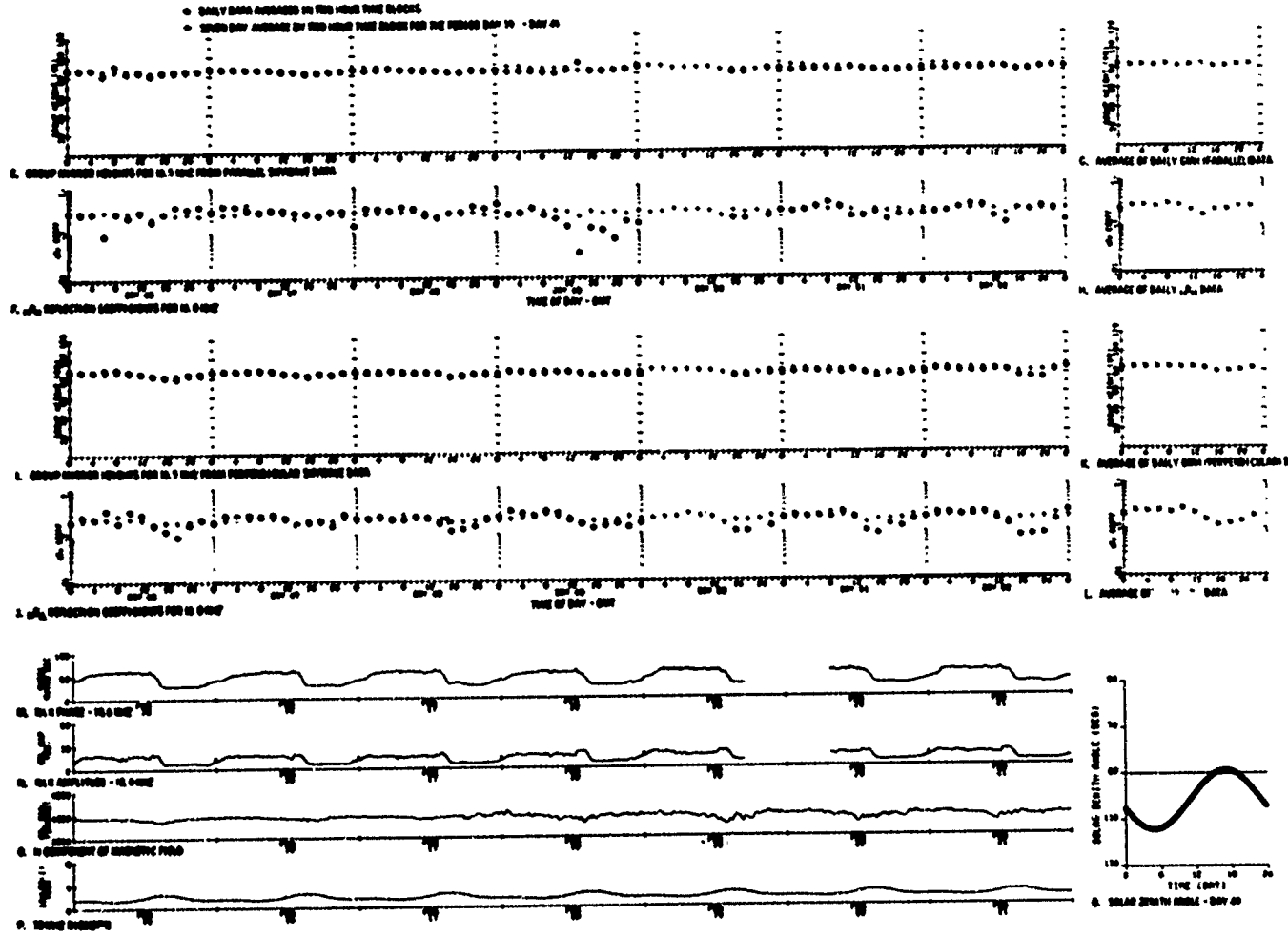

Figure 9. VLF/LF Reflectivity Data for the Polar Ionosphere, DAY 46 (14 Feb) — DAY 52 (21 Feb) 1976 (Cont)

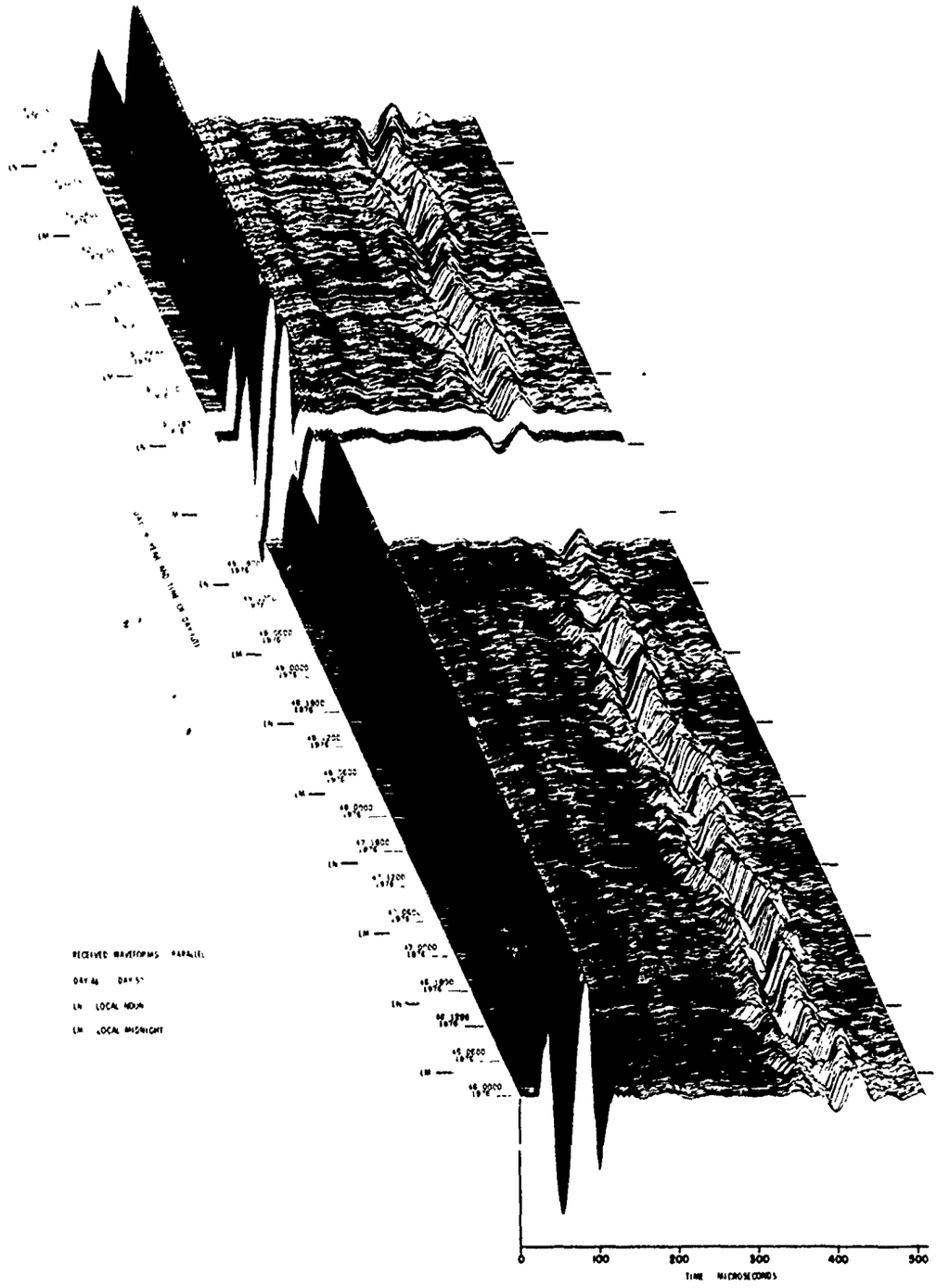

Figure 9. VLF/LF Reflectivity Data for the Polar Ionosphere, DAY 46 (14 Feb) - DAY 52 (21 Feb) 1976 (Cont) Part R. /M Waveform Display

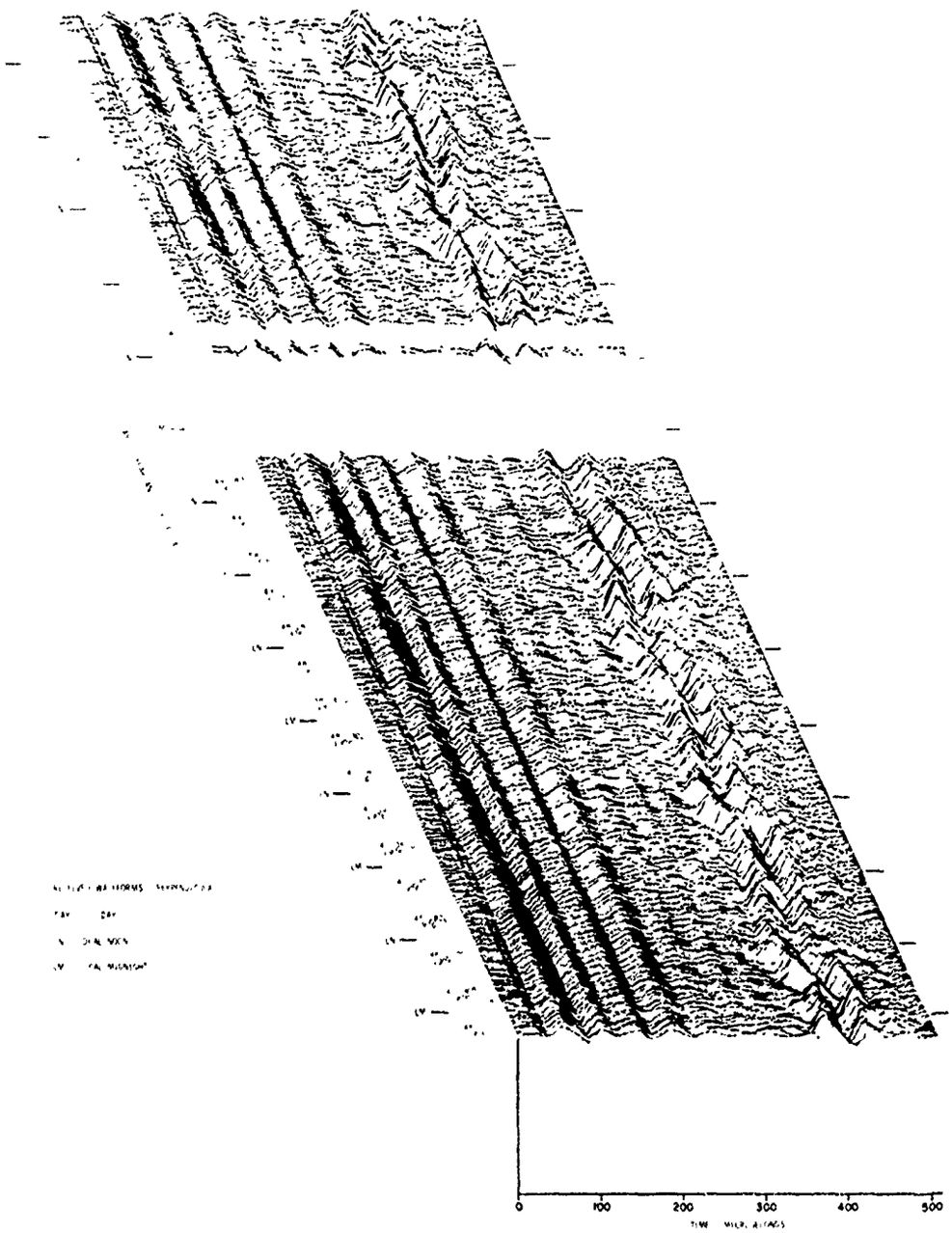

Figure 9. VLF/LF Reflectivity Data for the Polar Ionosphere, DAY 46 (14 Feb) – DAY 52 (21 Feb) 1976 (Cont) Part S. ⊥ Waveform Display

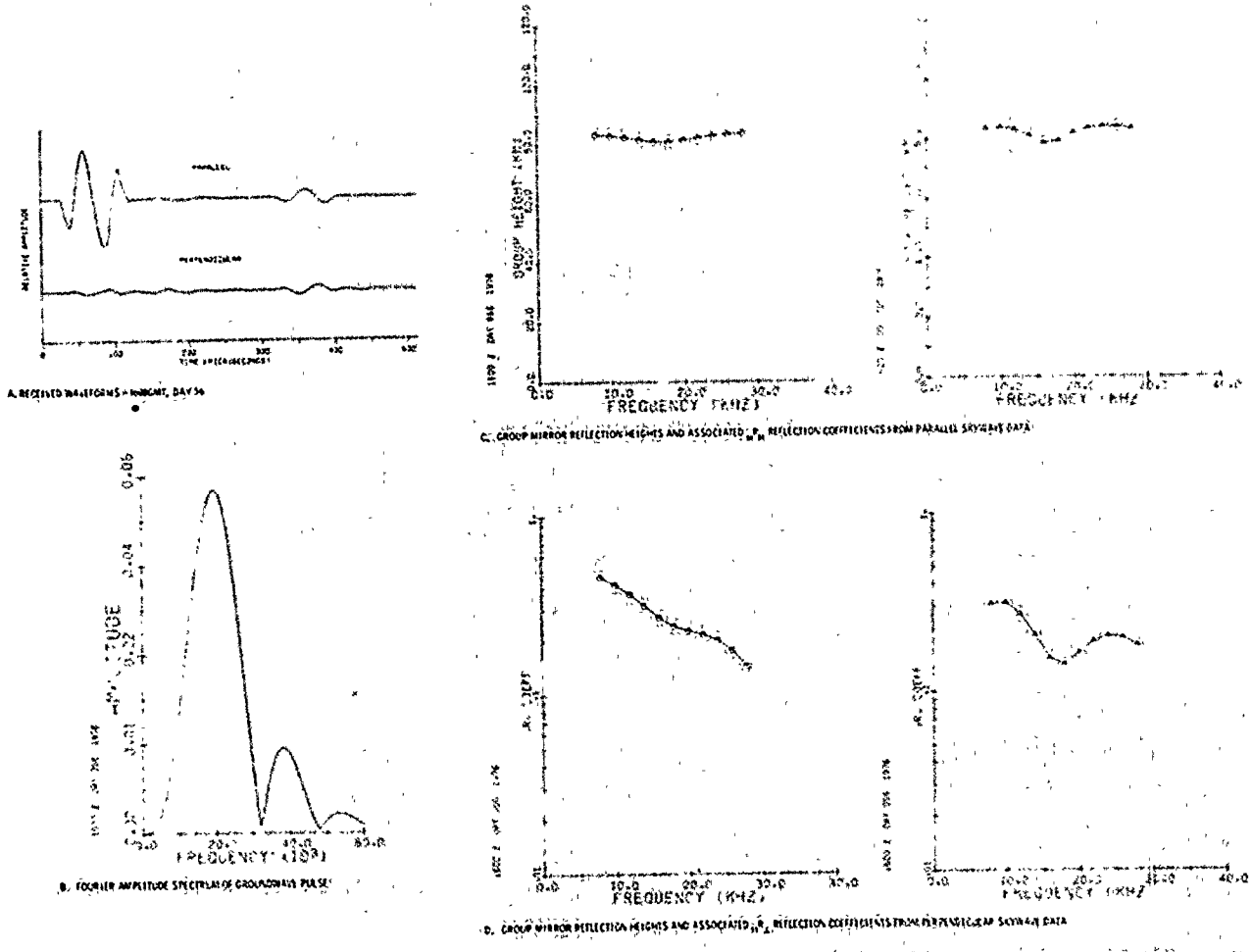

Figure 10. VLF/LF Reflectivity Data for the Polar Ionosphere, DAY 53 (22 Feb) — DAY 59 (28 Feb) 1976

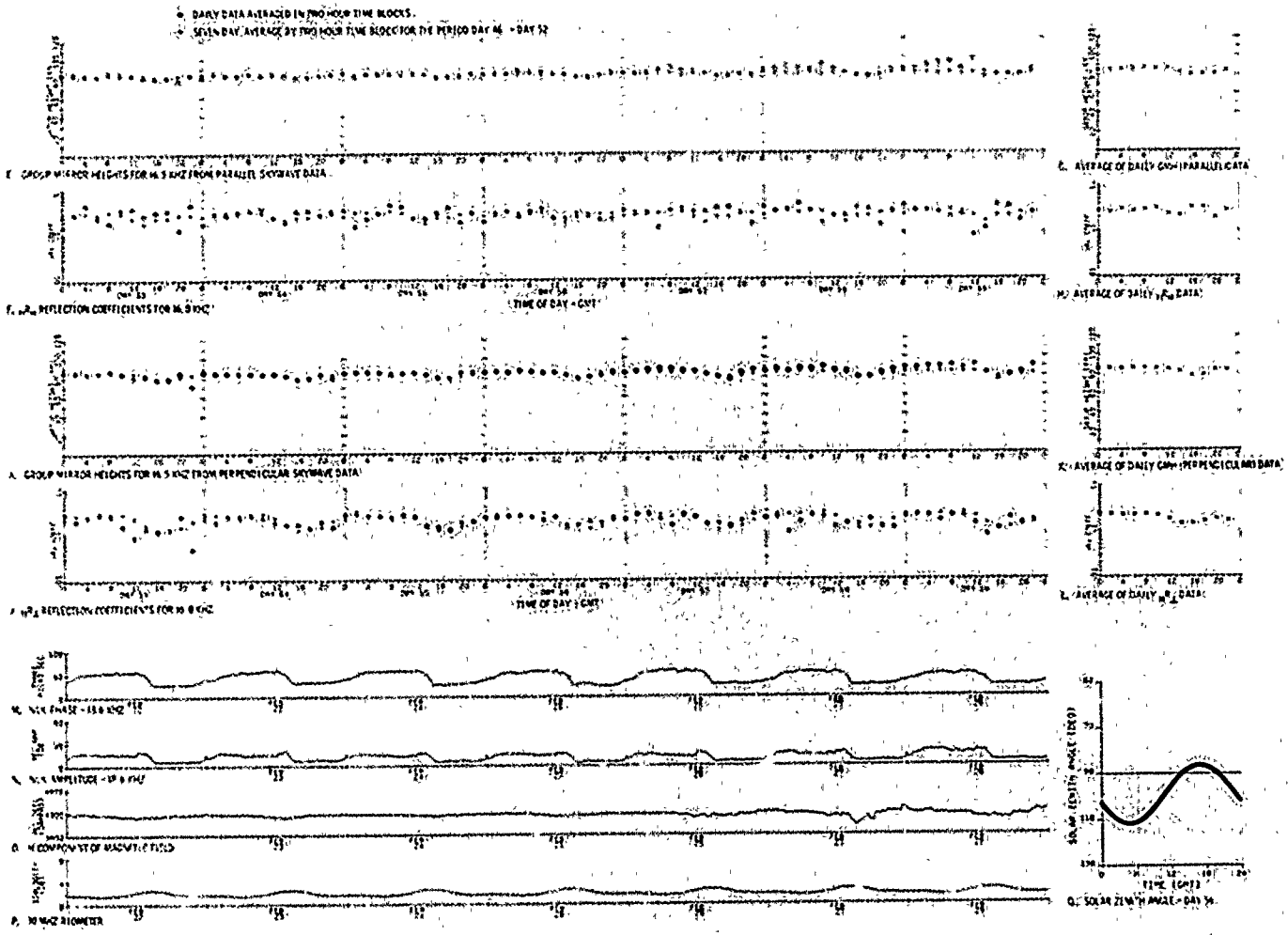

Figure 10. VLF/LF Reflectivity Data for the Polar Ionosphere, DAY 53 (22 Feb) — DAY 59 (28 Feb) 1976 (Cont)

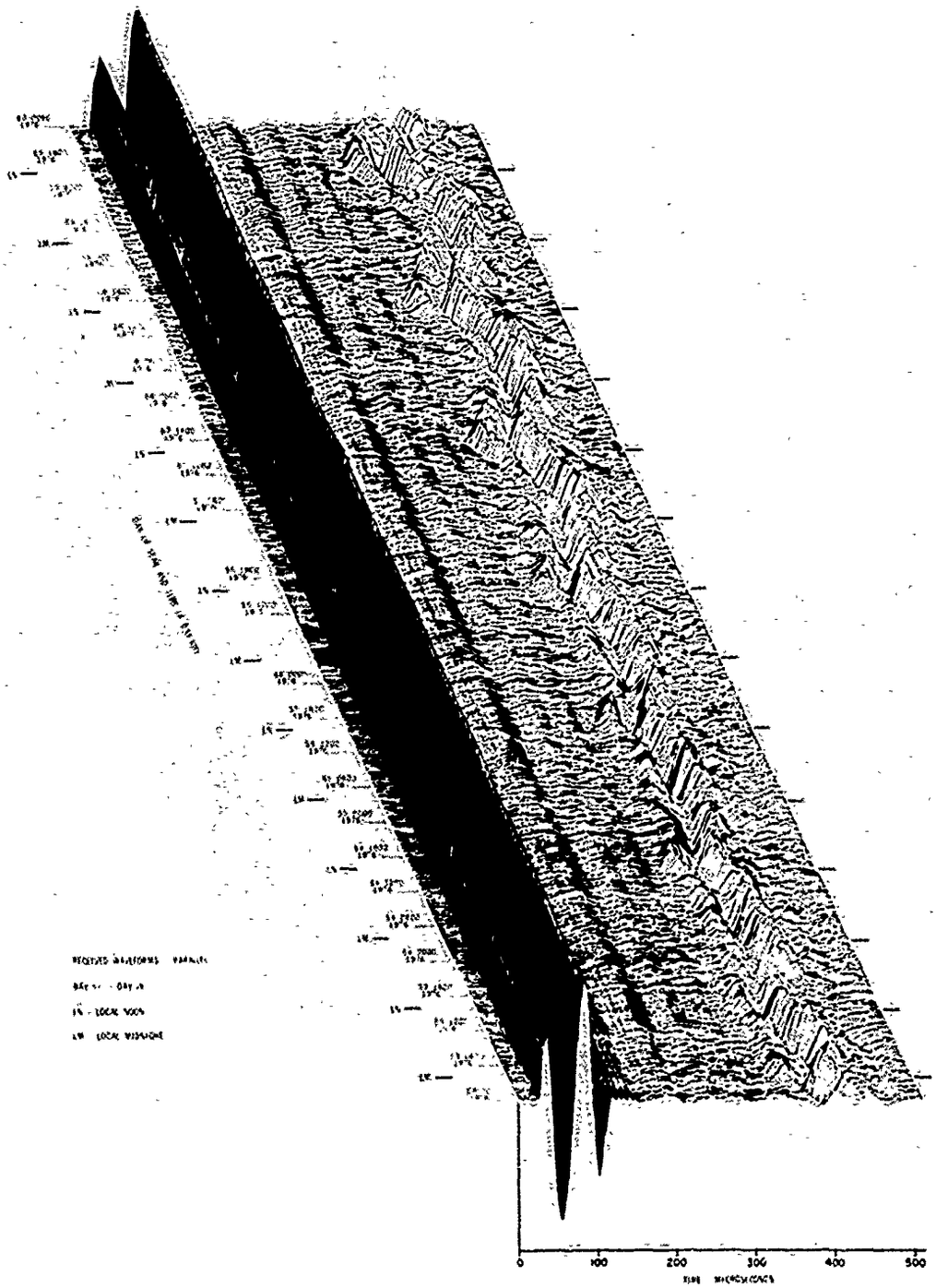

Figure 10. VLF/LF Reflectivity Data for the Polar Ionosphere, DAY 53 (22 Feb) - DAY 59 (28 Feb) 1976 (Cont) Part R. || Waveform Display

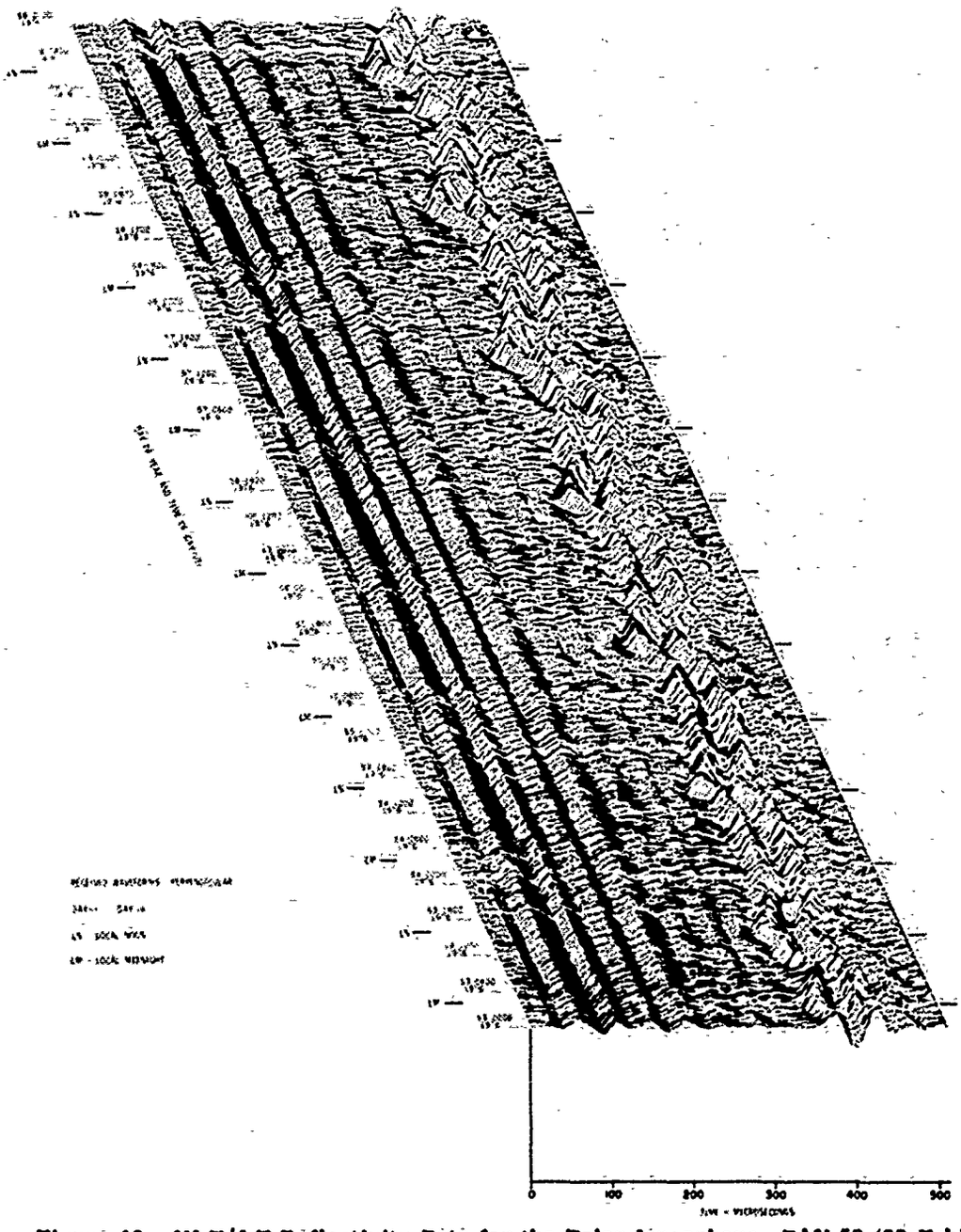

Figure 10. VLF/LF Reflectivity Data for the Polar Ionosphere, DAY 53 (22 Feb) – DAY 59 (28 Feb) 1976 (Cont) Part S. ⊥ Waveform Display

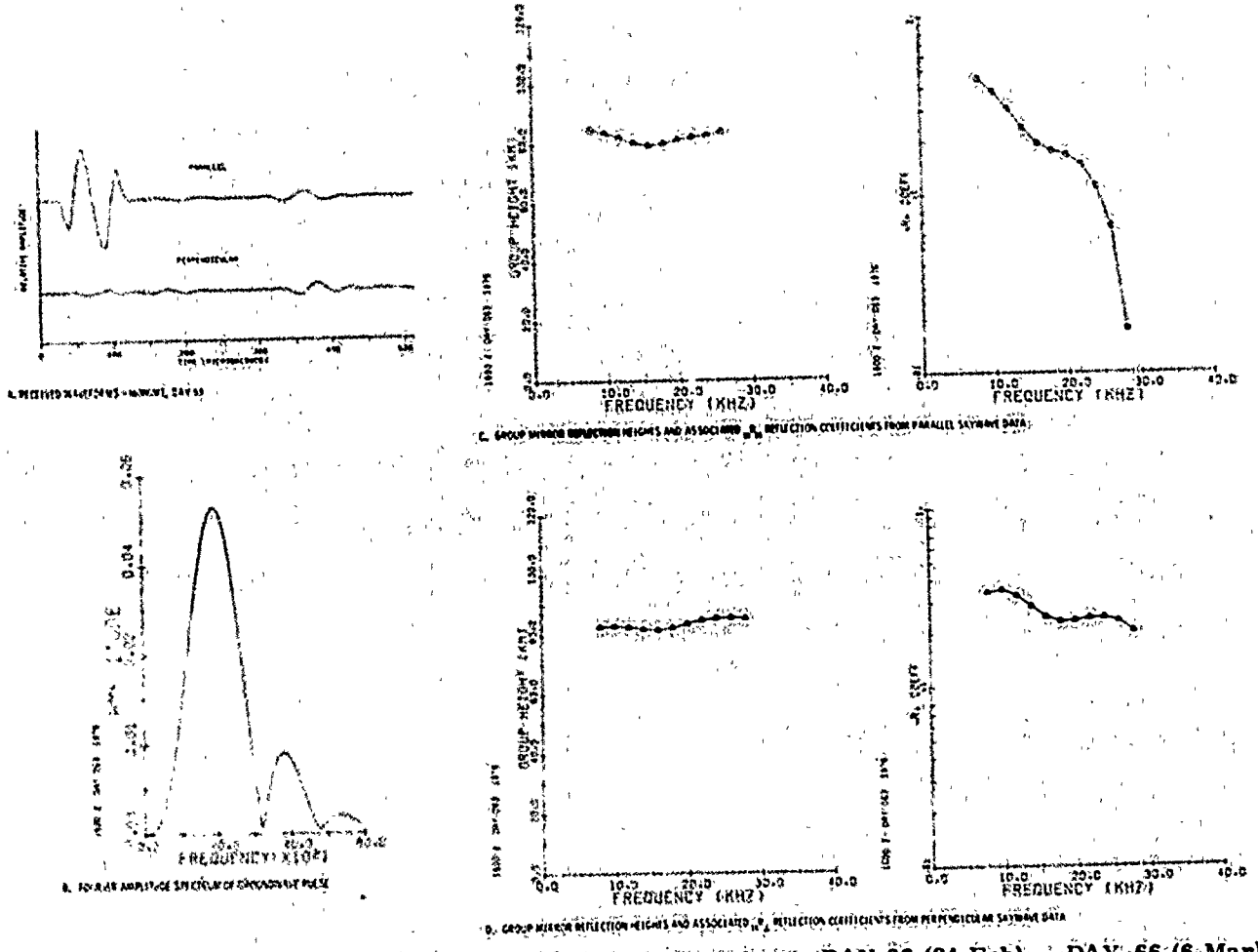

Figure 11. VLF/LF Reflectivity Data for the Polar Ionosphere, DAY 60 (24 Feb) — DAY 66 (6 Mar) 1976

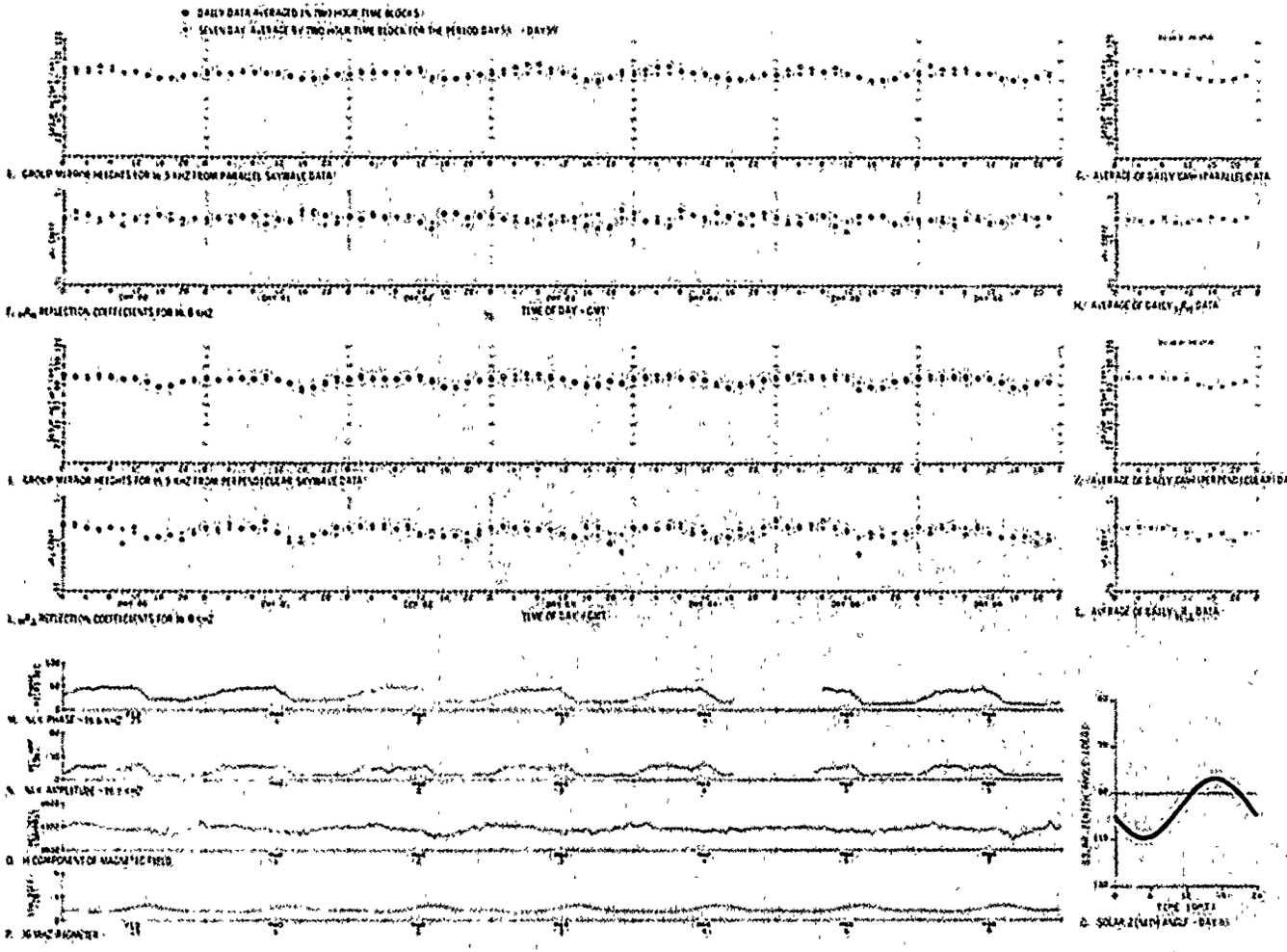

Figure 11. VLF/LF Reflectivity Data for the Polar Ionosphere, DAY 60 (24 Feb) — DAY 66 (6 Mar) 1976 (Cont)

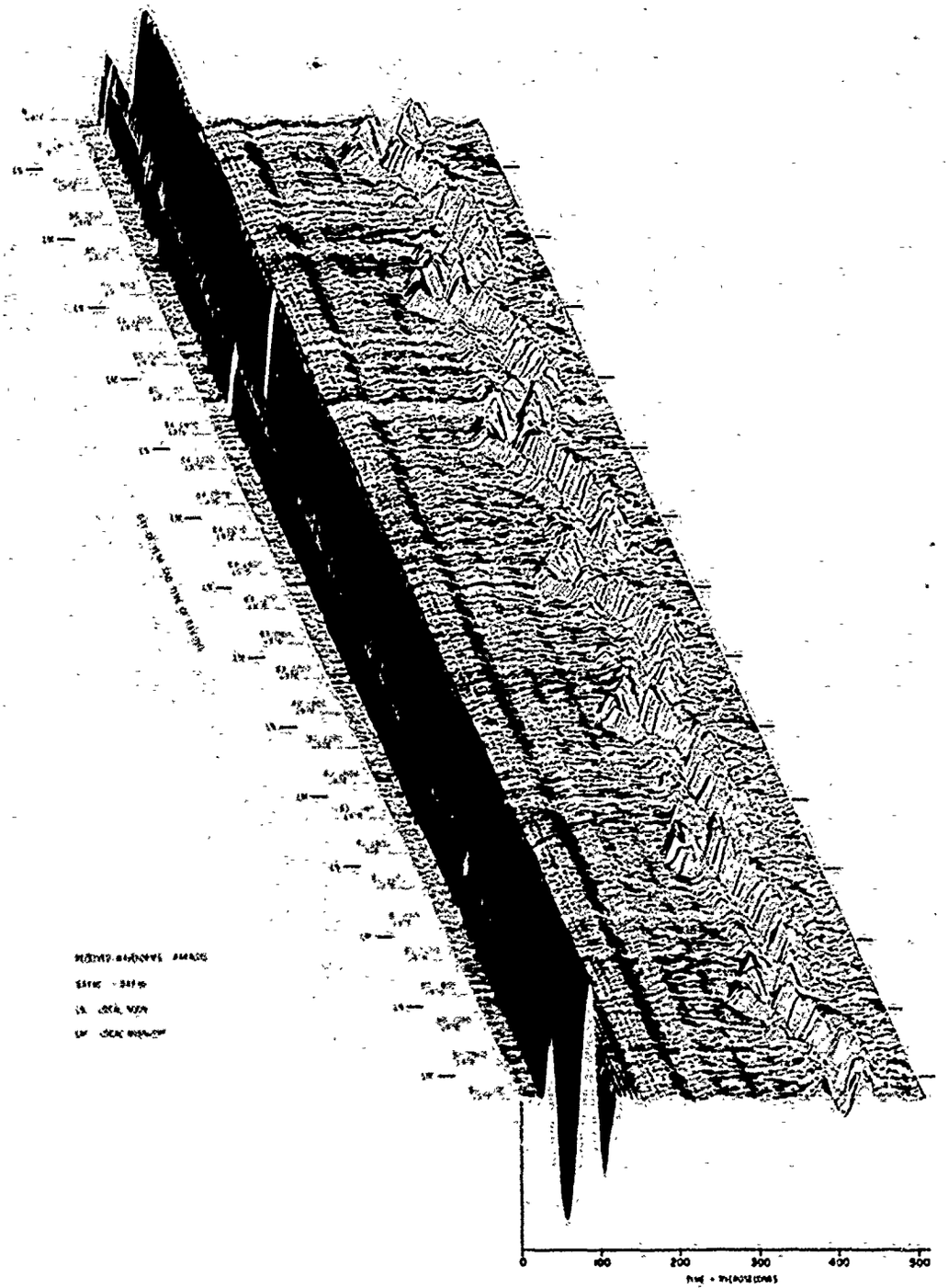

Figure 11. VLF/LF Reflectivity Data for the Polar Ionosphere, DAY 60 (24 Feb) - DAY 66 (6 Mar) 1976 (Cont) Part R. II Waveform Display

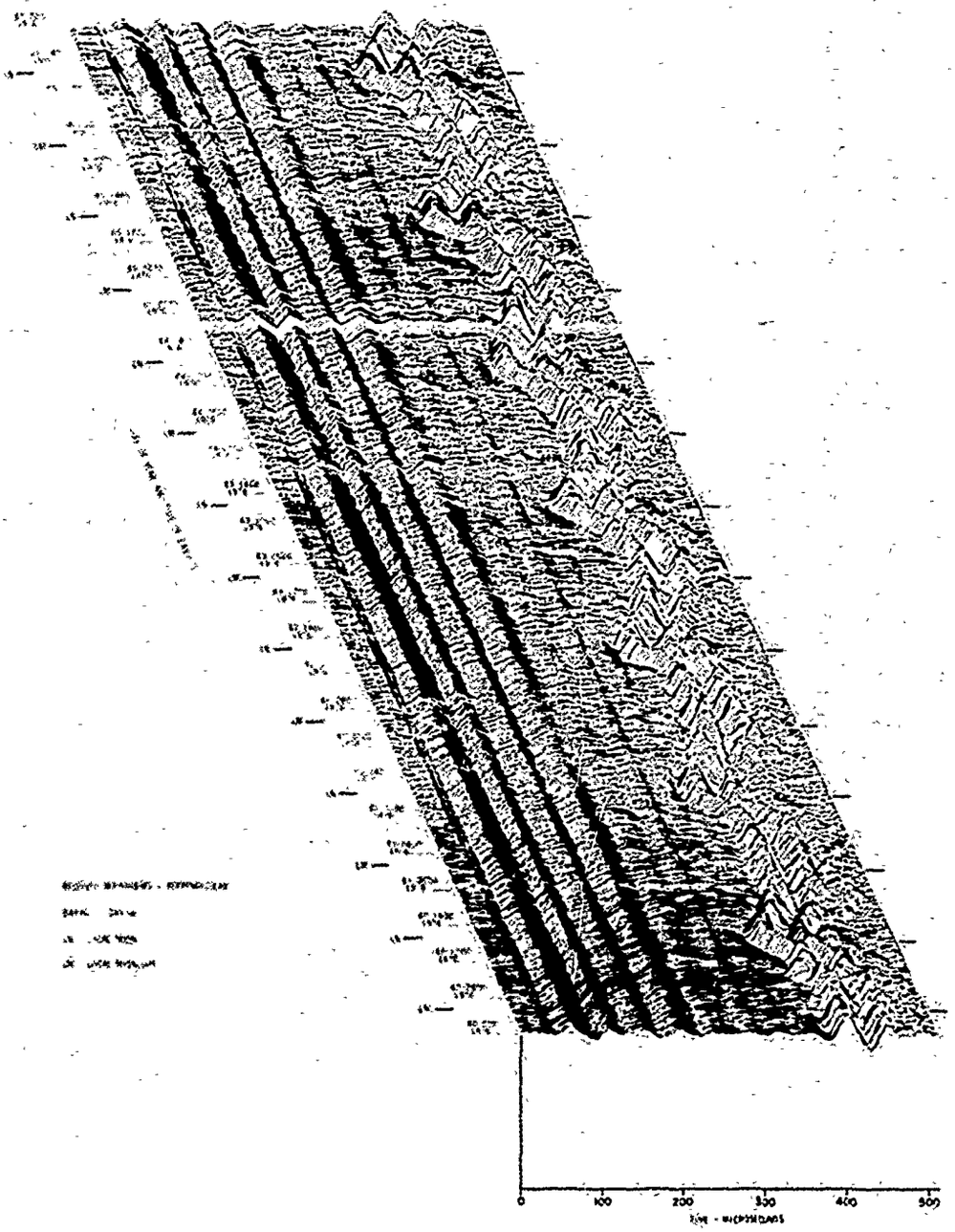

Figure 11. VLF/LF Reflectivity Data for the Polar Ionosphere, DAY 60 (24 Feb) – DAY 66 (6 Mar) 1976 (Cont) Part S. ⊥ Waveform Display

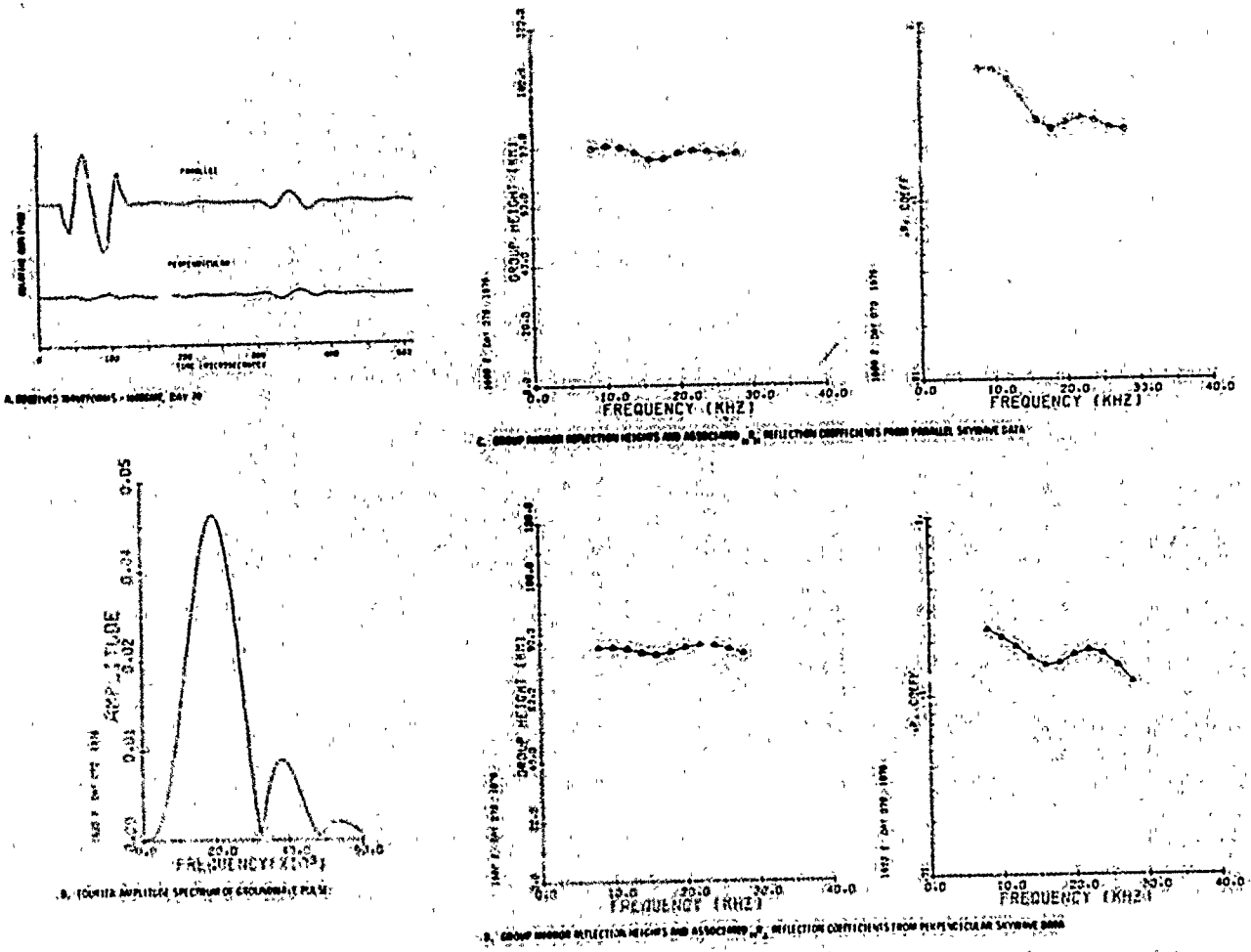

Figure 12. VLF/LF Reflectivity Data for the Polar Ionosphere, DAY 67 (7 Mar) — DAY 73 (13 Mar) 1976

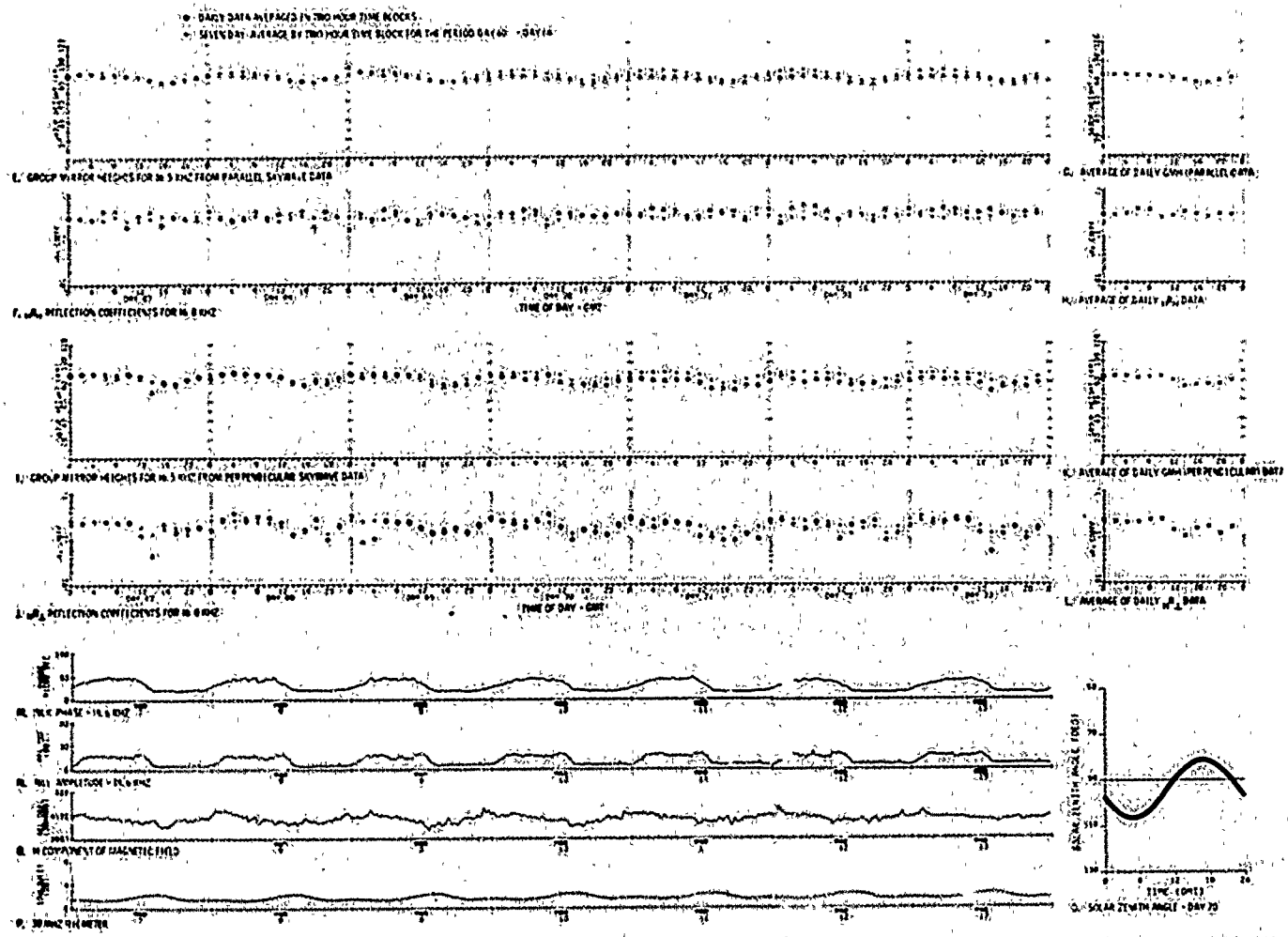

Figure 12. VLF/LF Reflectivity Data for the Polar Ionosphere, DAY 67 (7 Mar) — DAY 73 (13 Mar) 1976 (Cont)

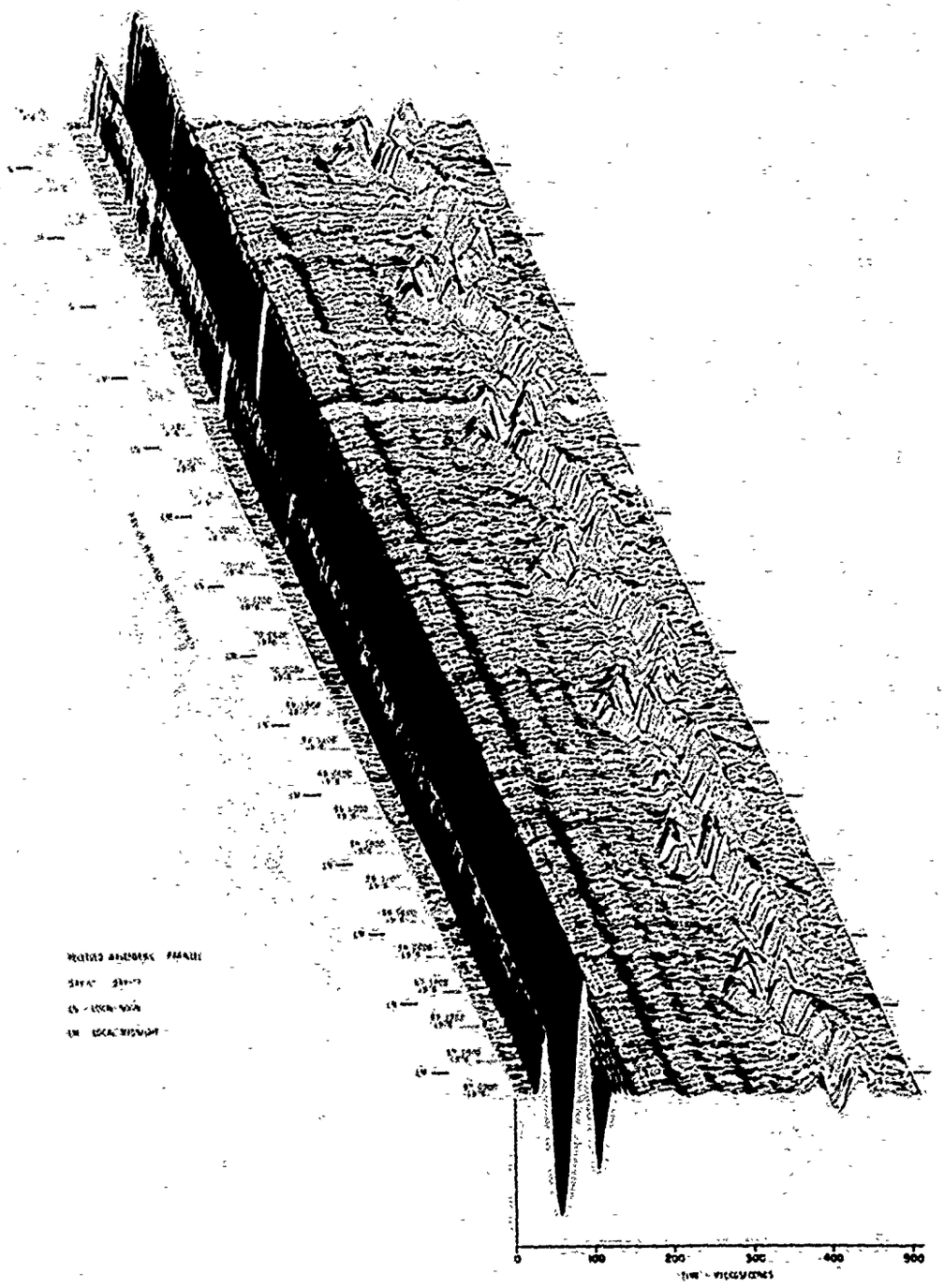

Figure 12. VLF/LF Reflectivity Data for the Polar Ionosphere, DAY 67 (7 Mar) – DAY 73 (13 Mar) 1976 (Cont) Part R. ||Waveform Display

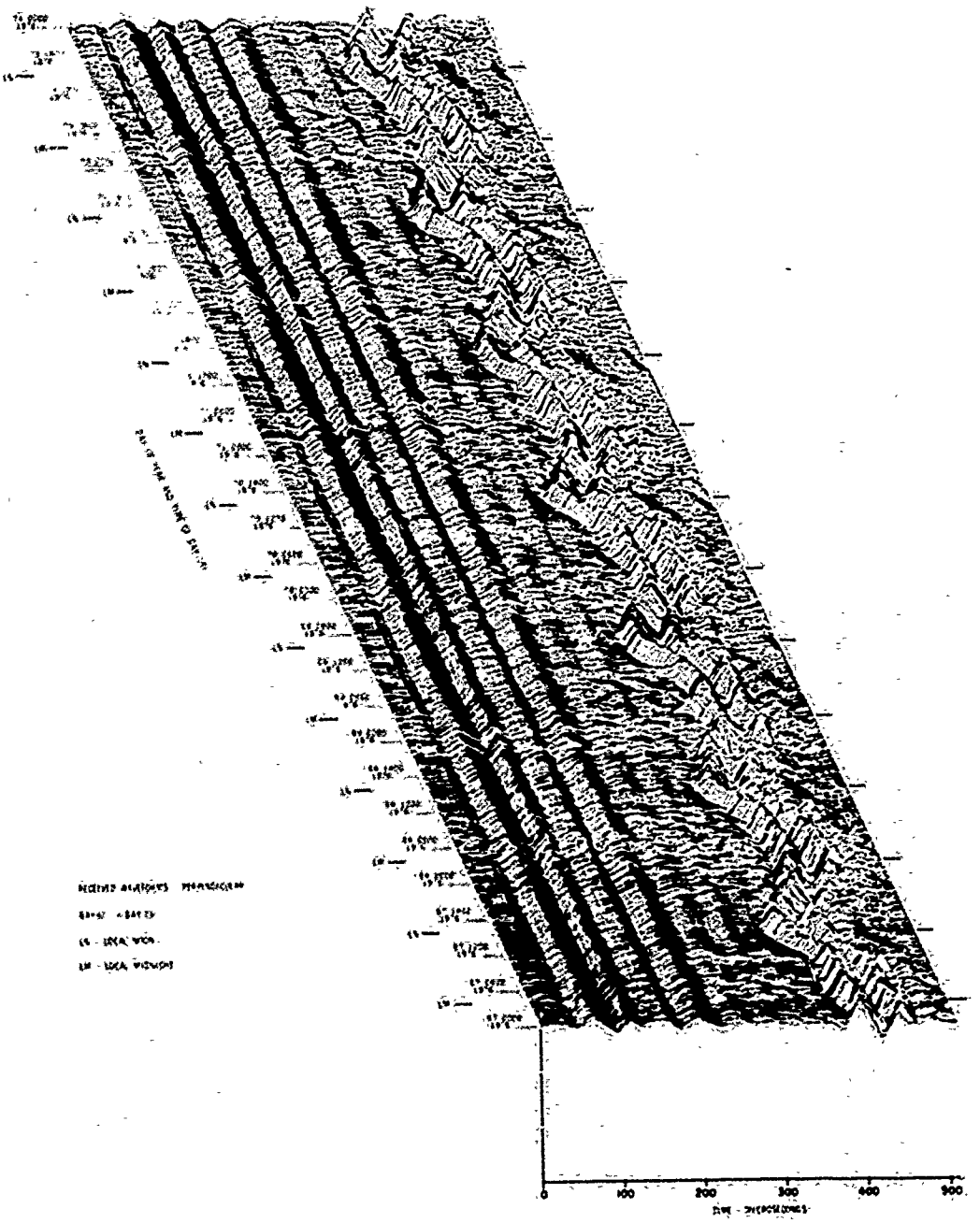

Figure 12. VLF/LF Reflectivity Data for the Polar Ionosphere, DAY 67 (7 Mar) - DAY 73 (13 Mar) 1976 (Cont) Part S. ⊥ Waveform Display

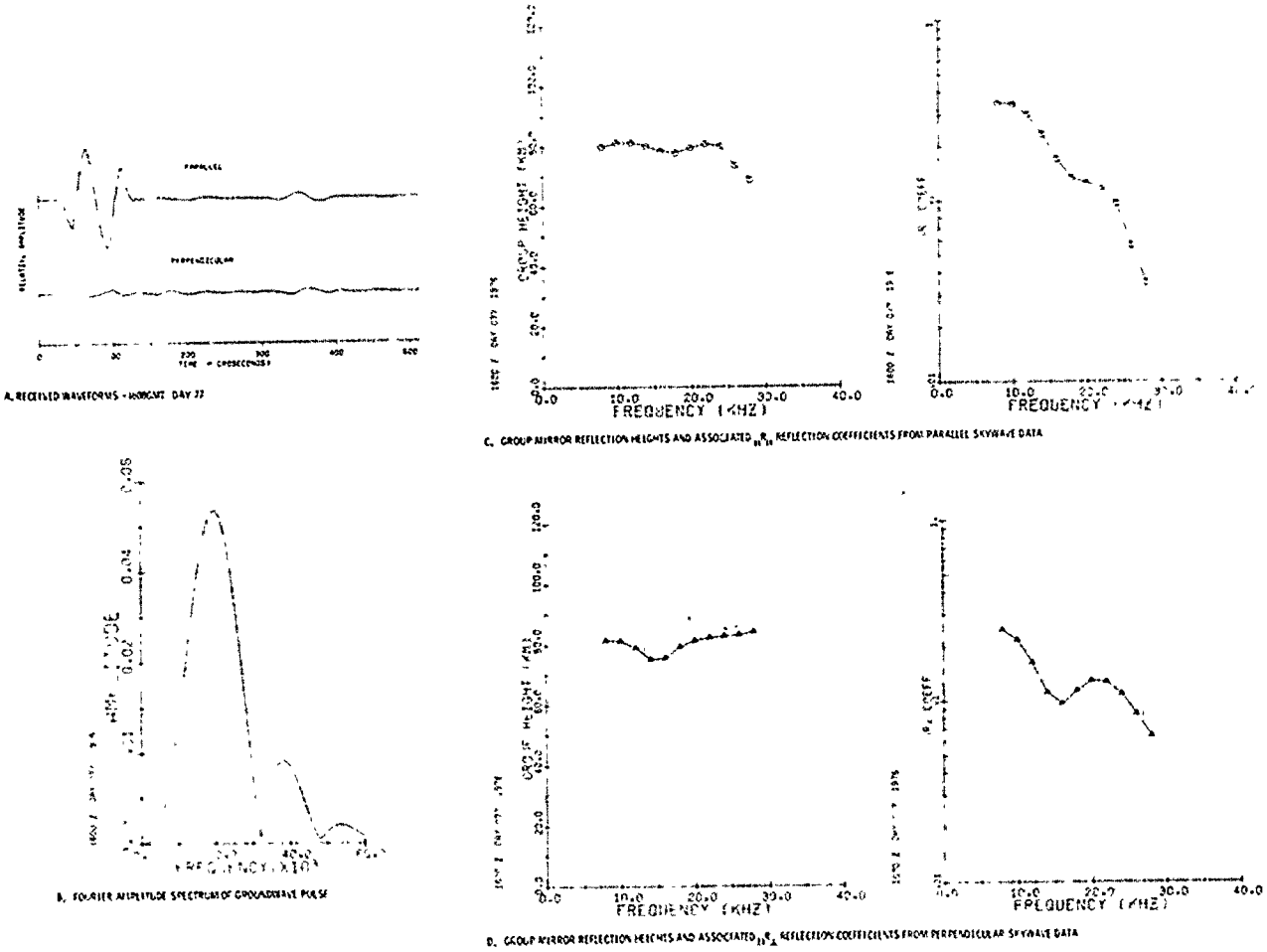

Figure 13. VLF/LF Reflectivity Data for the Polar Ionosphere, DAY 74 (14 Mar) — DAY 80 (20 Mar) 1976

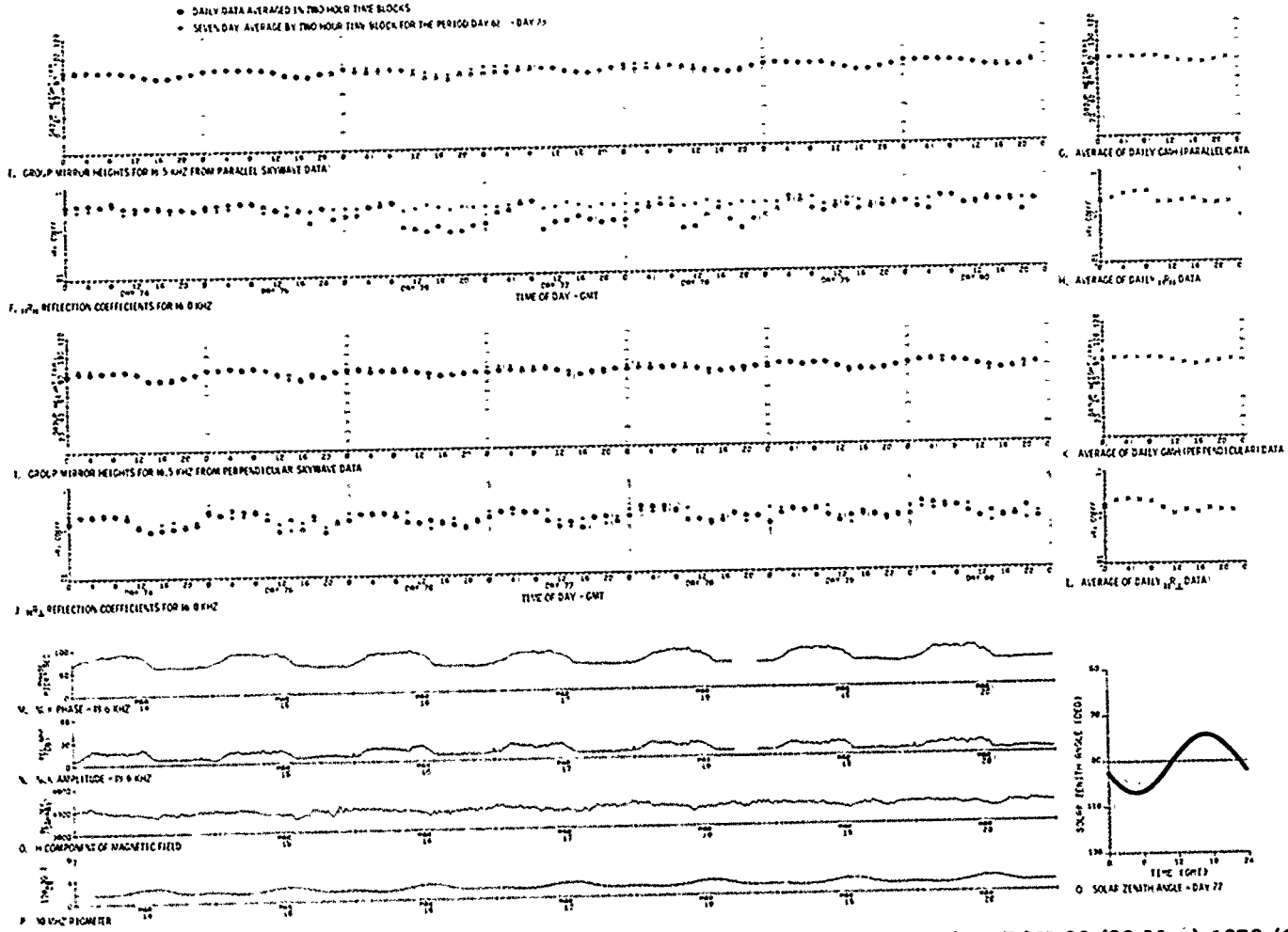

Figure 13. VLF/LF Reflectivity Data for the Polar Ionosphere, DAY 74 (14 Mar) — DAY 80 (20 Mar) 1976 (Cont)

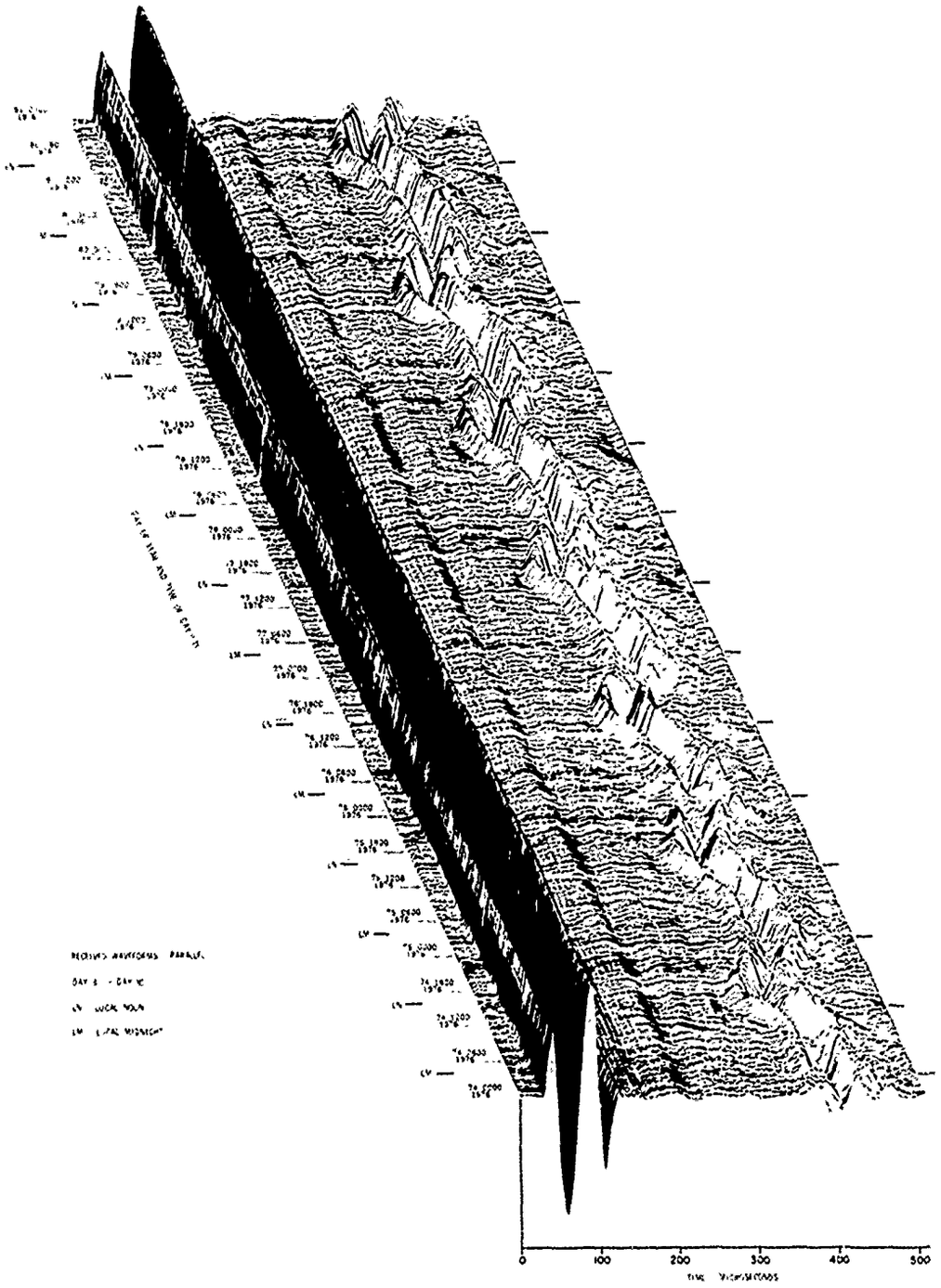

Figure 13. VLF/LF Reflectivity Data for the Polar Ionosphere, DAY 74 (14 Mar) - DAY 80 (20 Mar) 1976 (Cont) Part R. || Waveform Display

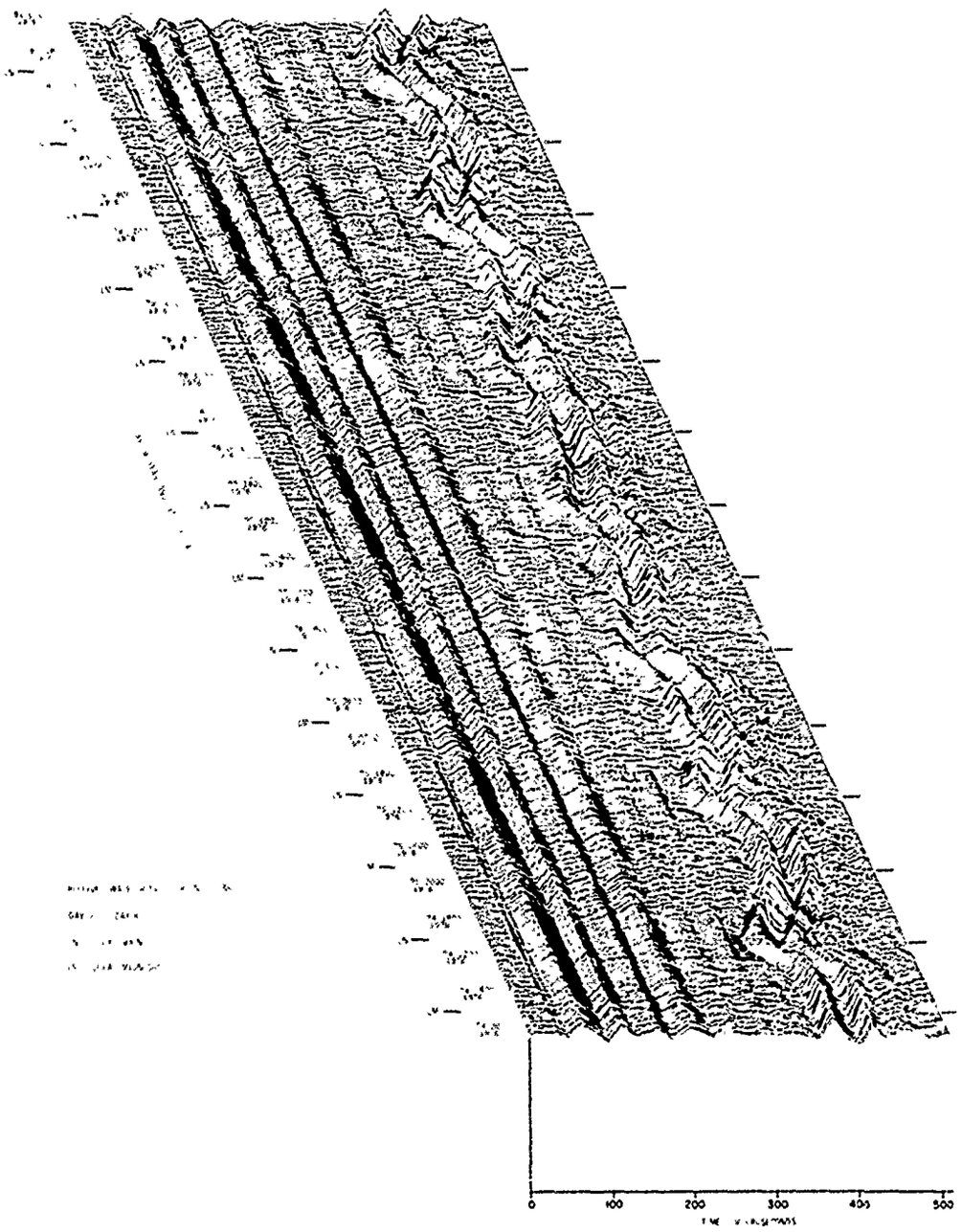

Figure 13. VLF/LF Reflectivity Data for the Polar Ionosphere, DAY 74 (14 Mar) – DAY 80 (20 Mar) 1976 (Cont) Part S. ⊥ Waveform Display

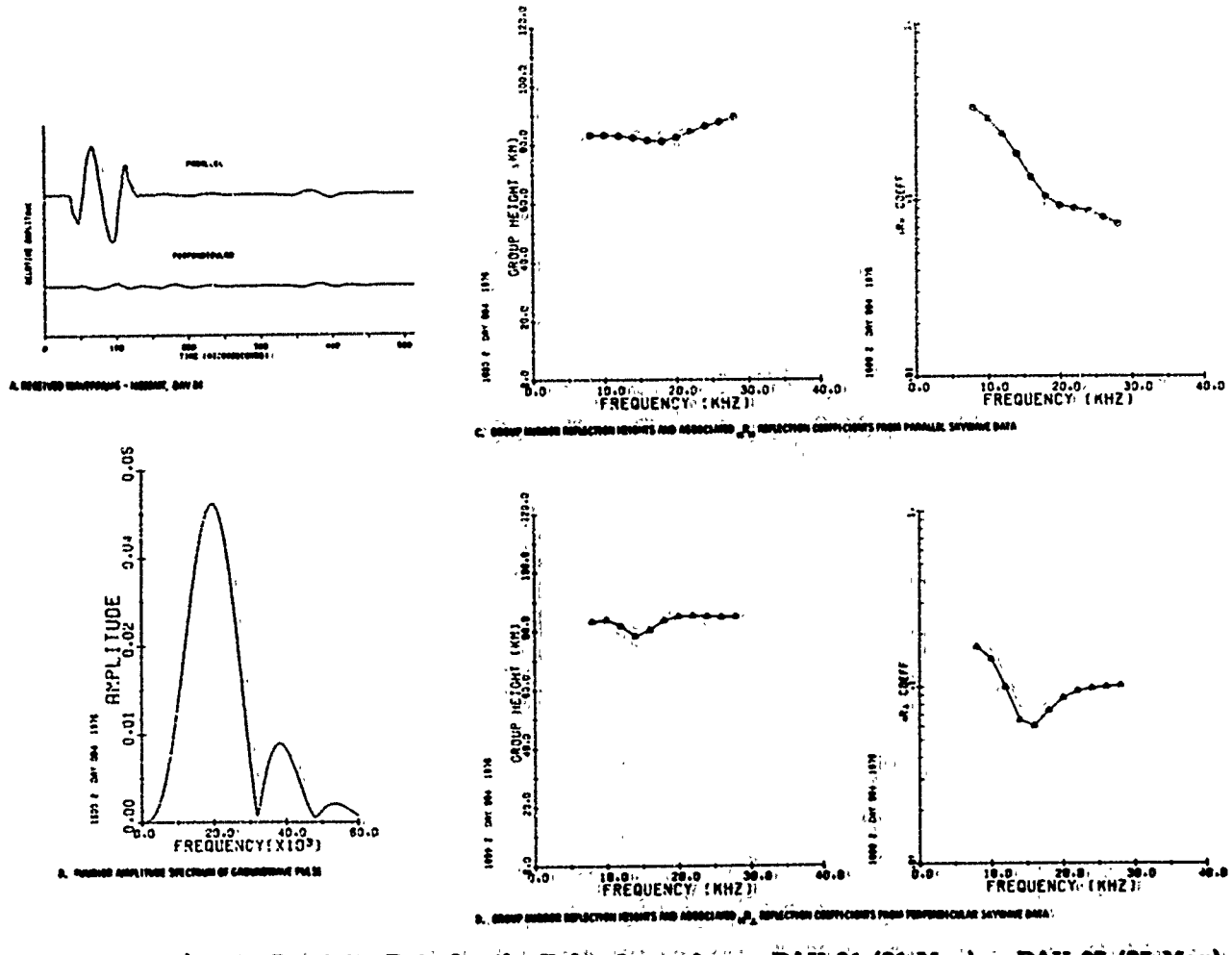

Figure 14. VLF/LF Reflectivity Data for the Polar Ionosphere, DAY 81 (21 Mar) — DAY 87 (27 Mar) 1976

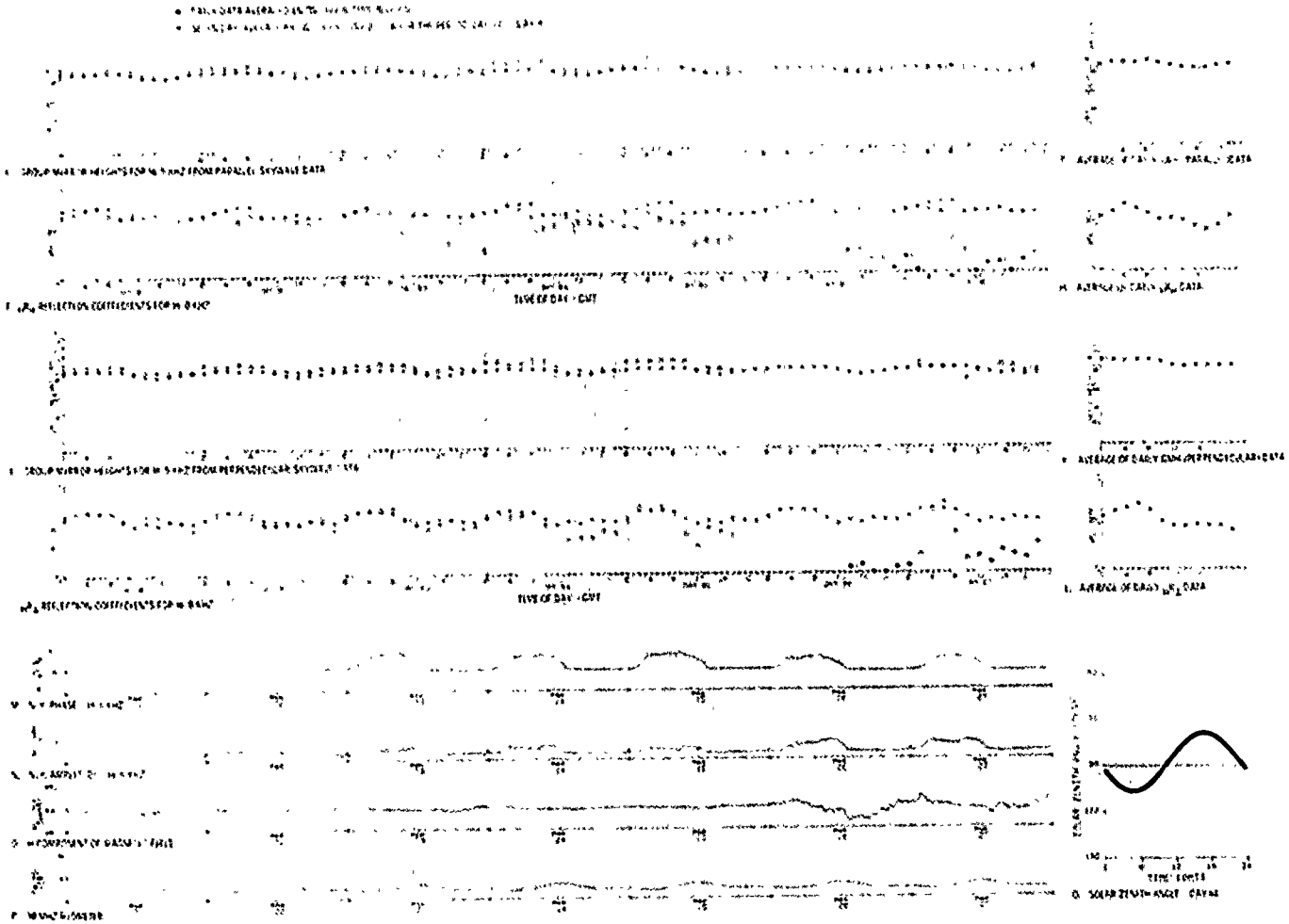

Figure 14. VLF/LF Reflectivity Data for the Polar Ionosphere, DAY 81 (21 Mar) — DAY 87 (27 Mar) 1976 (Cont)

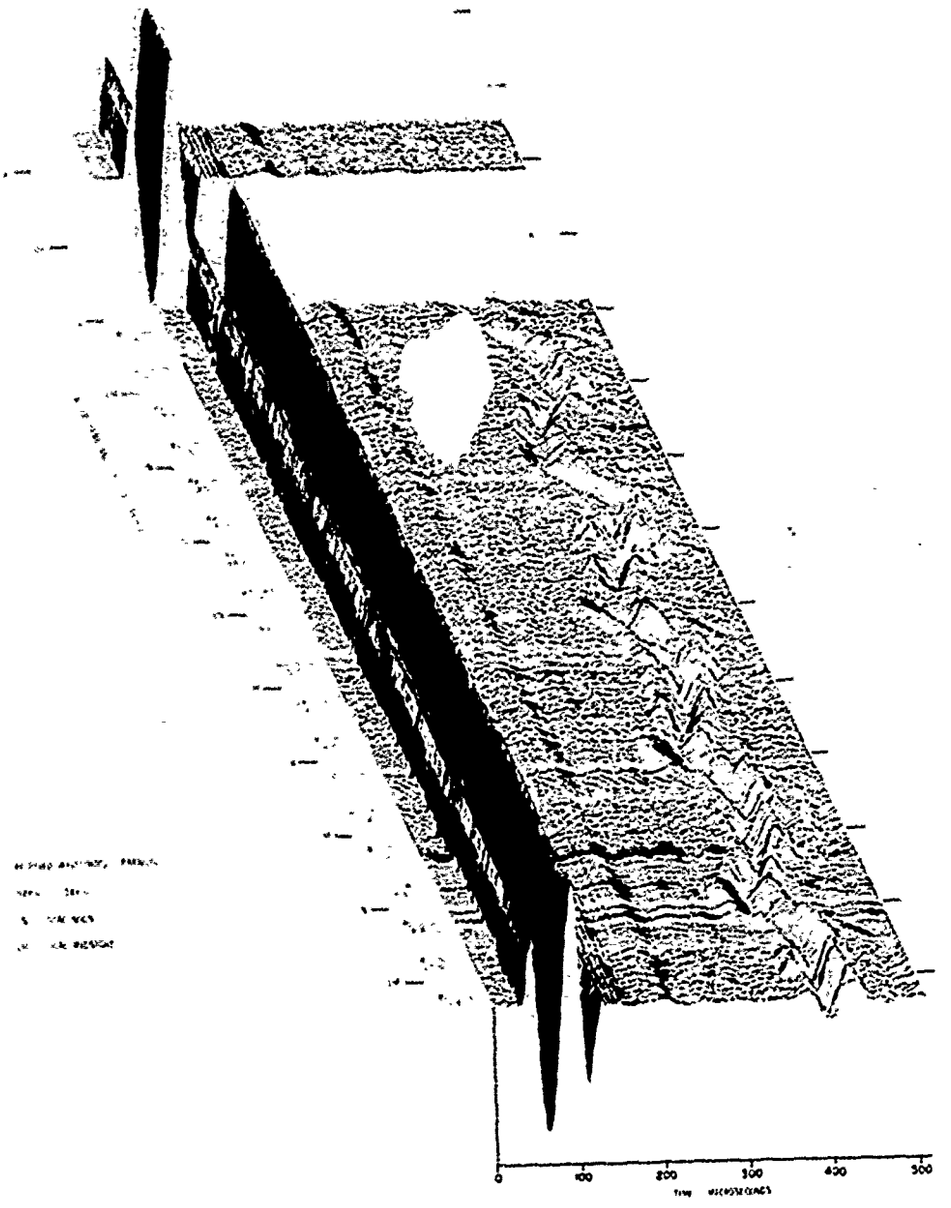

Figure 14. VLF/LF Reflectivity Data for the Polar Ionosphere, DAY 81 (21 Mar) - DAY 87 (27 Mar) 1976 (Cont) Part R. ‖ Waveform Display

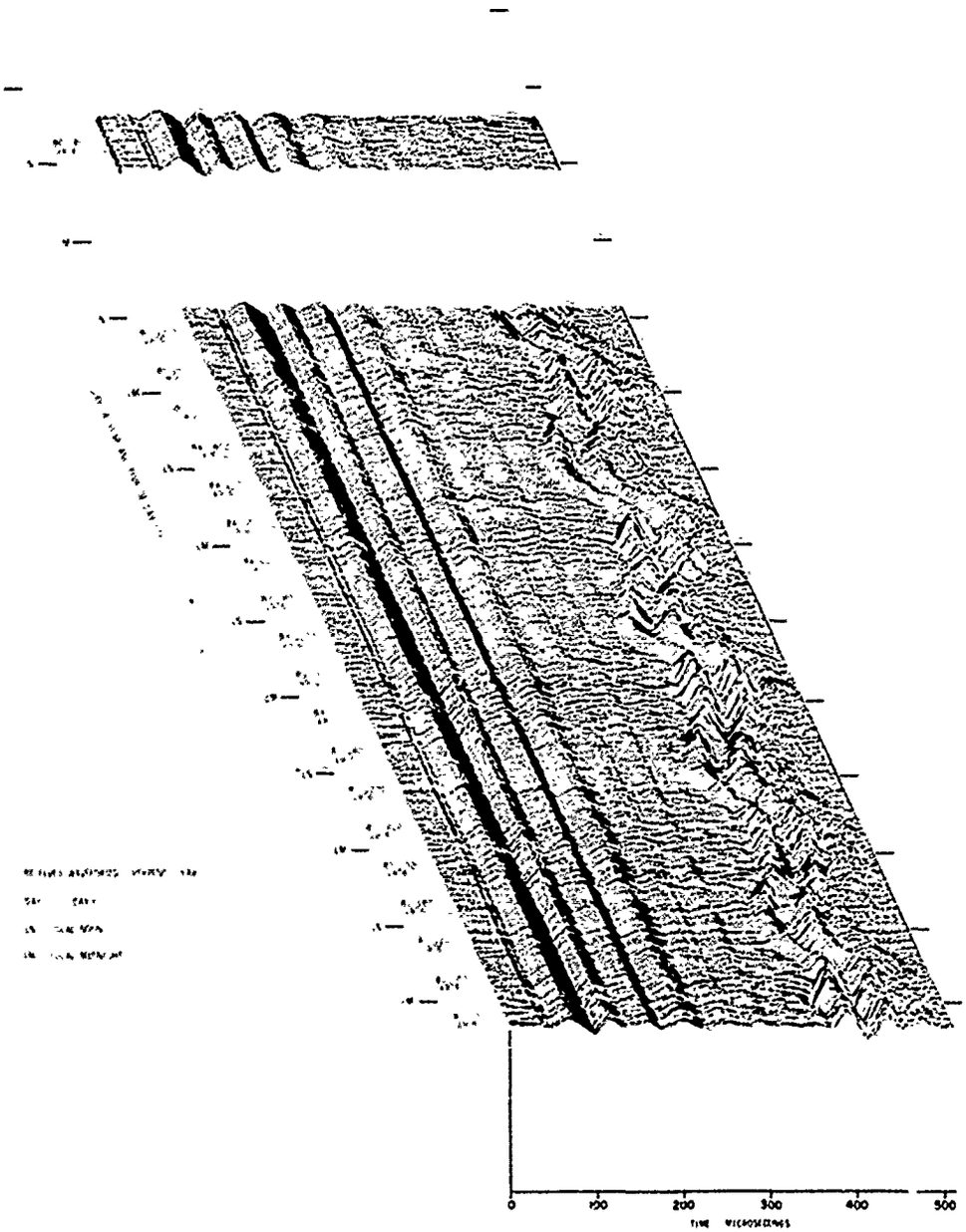

Figure 14. VLF/LF Reflectivity Data for the Polar Ionosphere, DAY 81 (21 Mar) - DAY 87 (27 Mar) 1976 (Cont) Part S. ⊥ Waveform Display

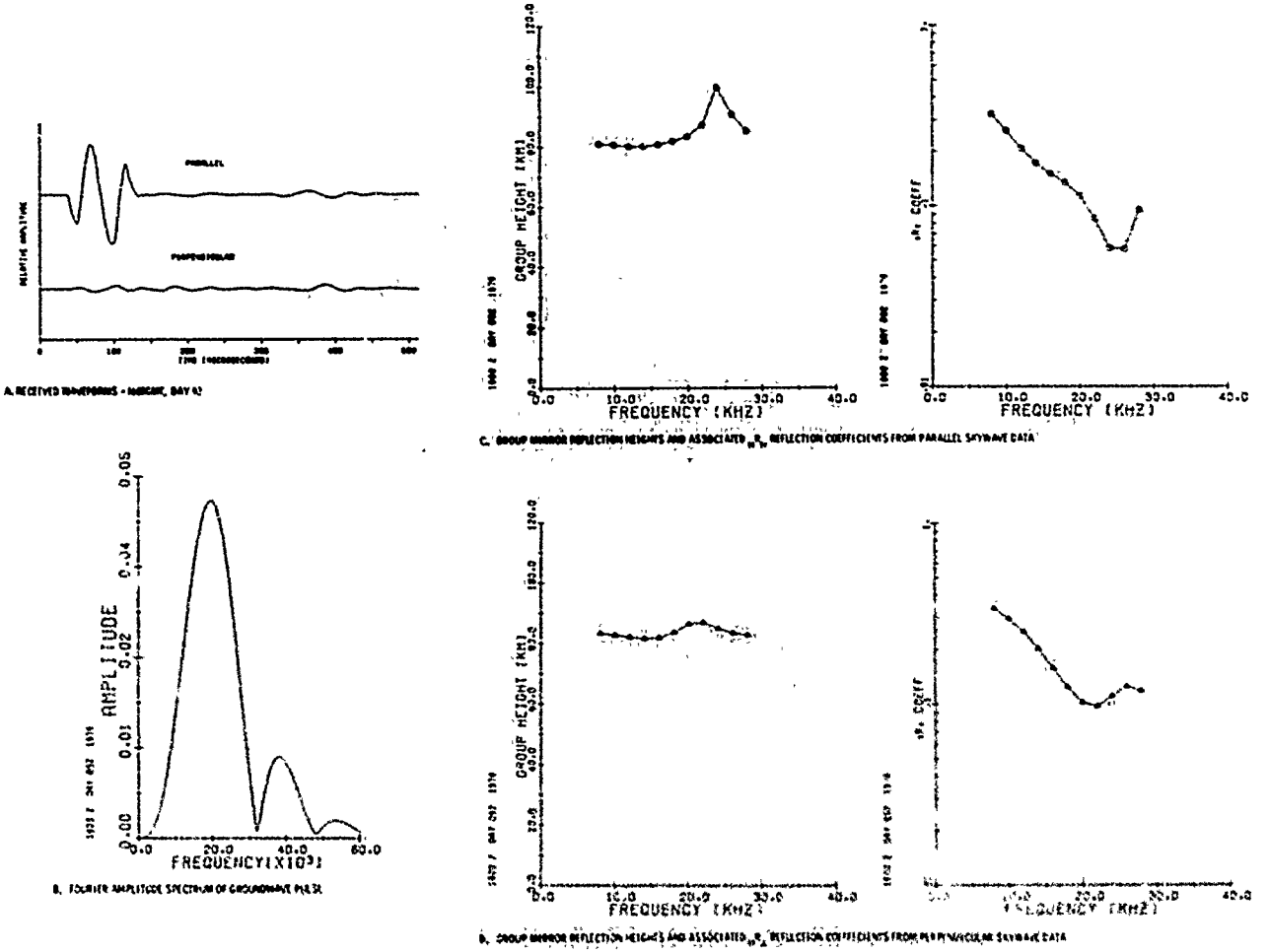

Figure 15. VLF/LF Reflectivity Data for the Polar Ionosphere, DAY 88 (28 Mar) — DAY 94 (3 Apr) 1976

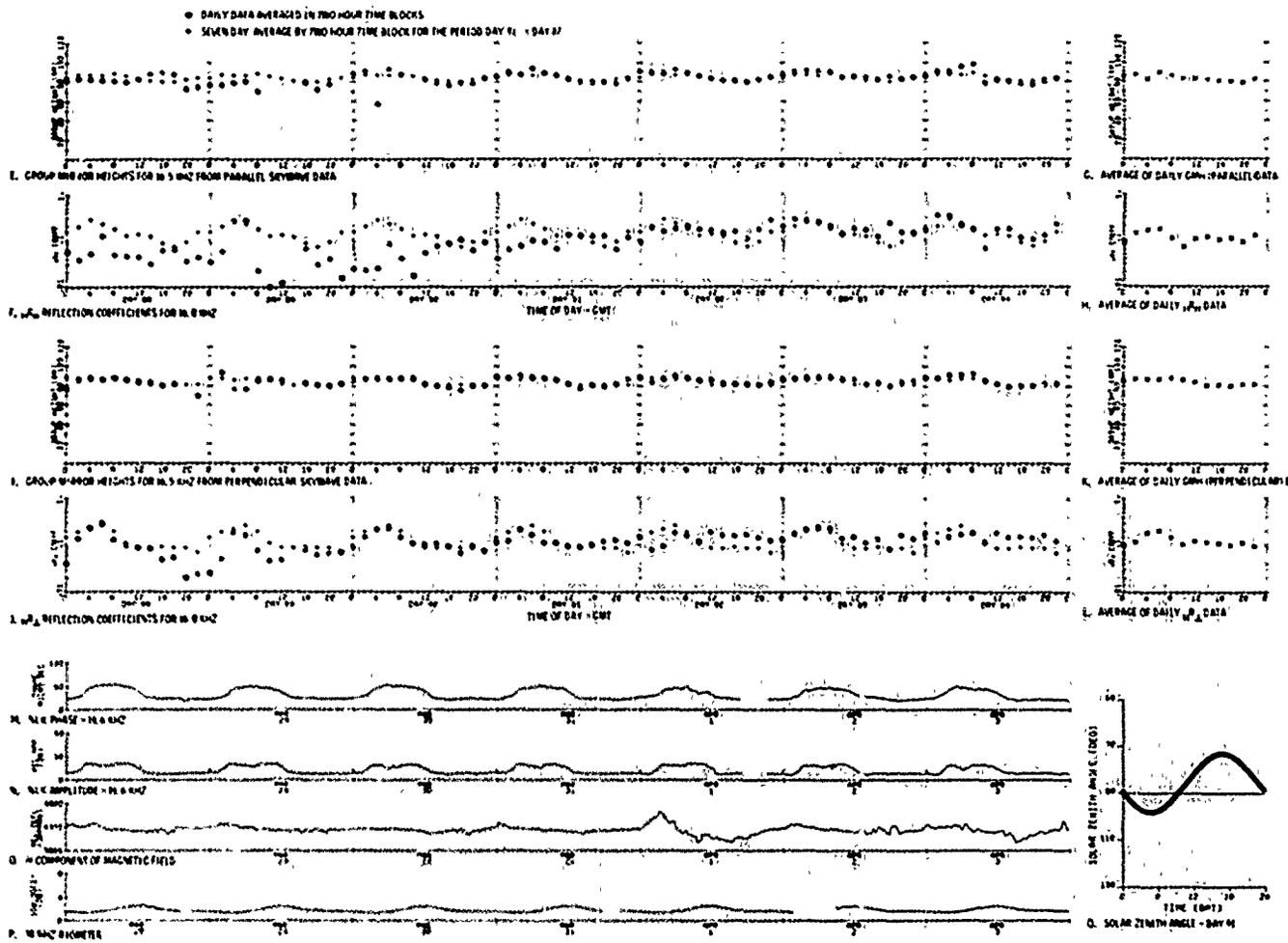

Figure 15. VLF/LF Reflectivity Data for the Polar Ionosphere, DAY 88 (28 Mar) – DAY 94 (3 Apr) 1976 (Cont)

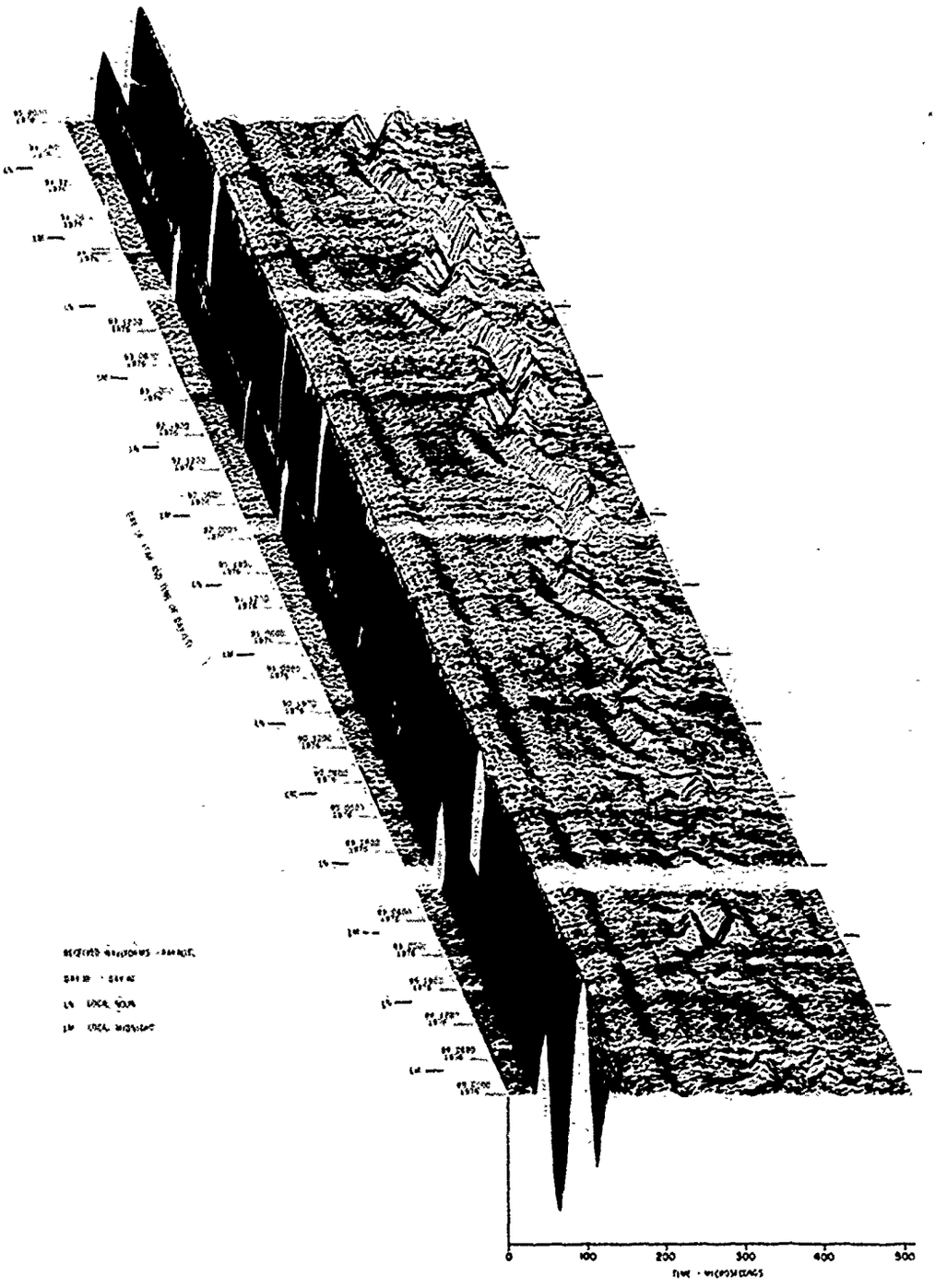

Figure 15. VLF/LF Reflectivity Data for the Polar Ionosphere, DAY 88 (28 Mar) – DAY 94 (3 Apr) 1976 (Cont) Part R. || Waveform Display

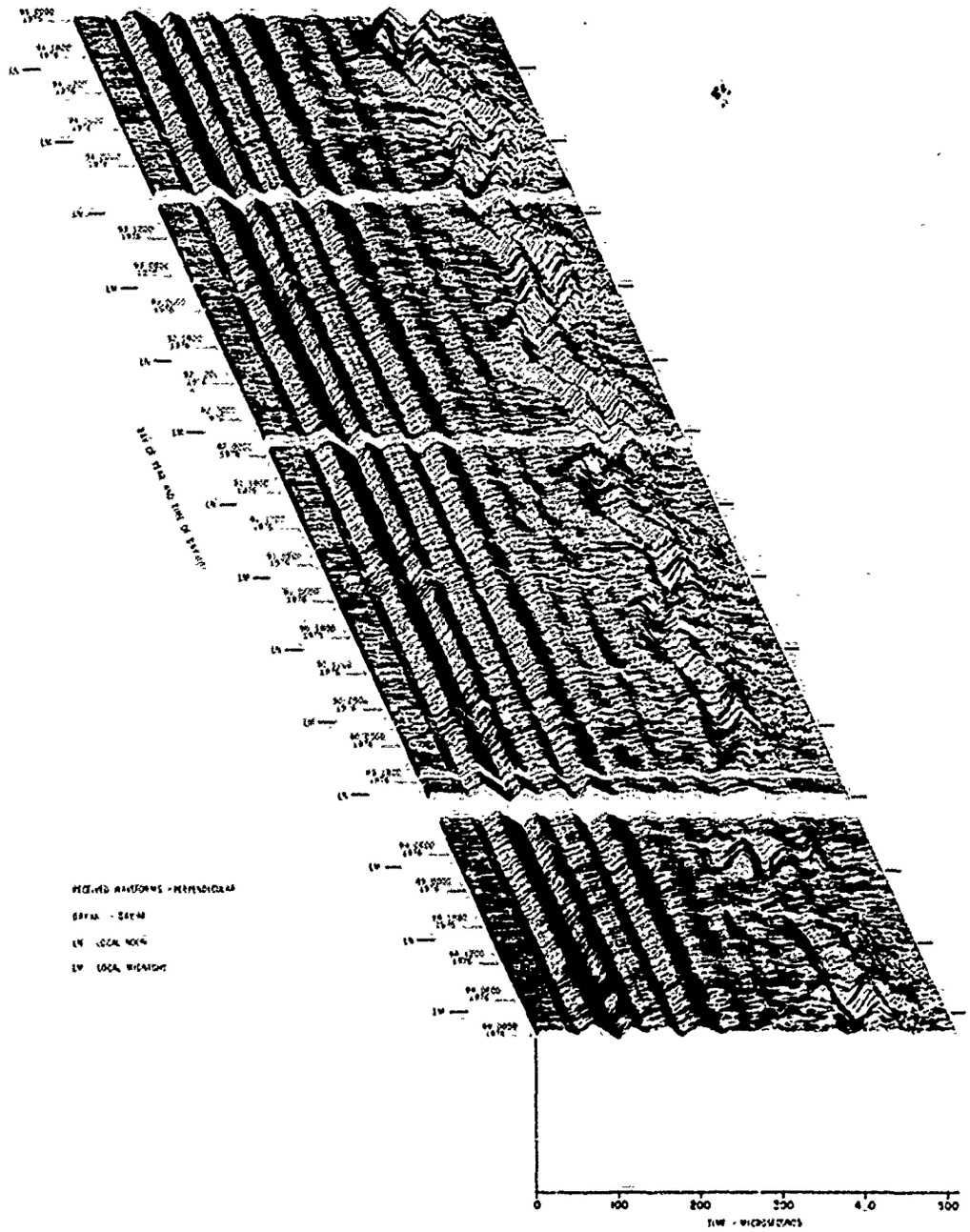

Figure 15. VLF/LF Reflectivity Data for the Polar Ionosphere, DAY 88 (28 Mar) - DAY 94 (3 Apr) 1976 (Cont) Part S. ⊥Waveform Display

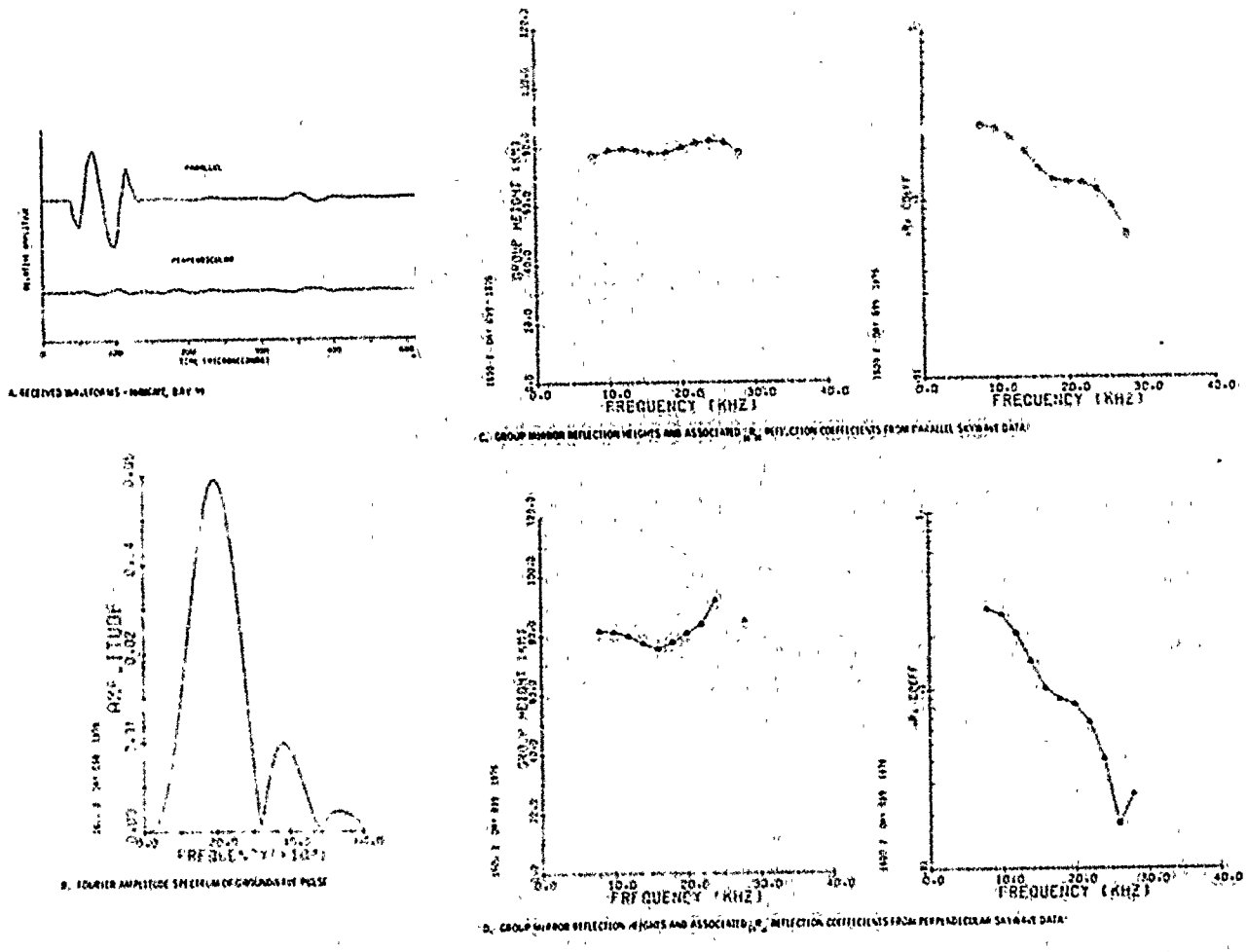

Figure 16. VLF/LF Reflectivity Data for the Polar Ionosphere, DAY 95 (4 Apr) — DAY 101 (10 Apr) 1976

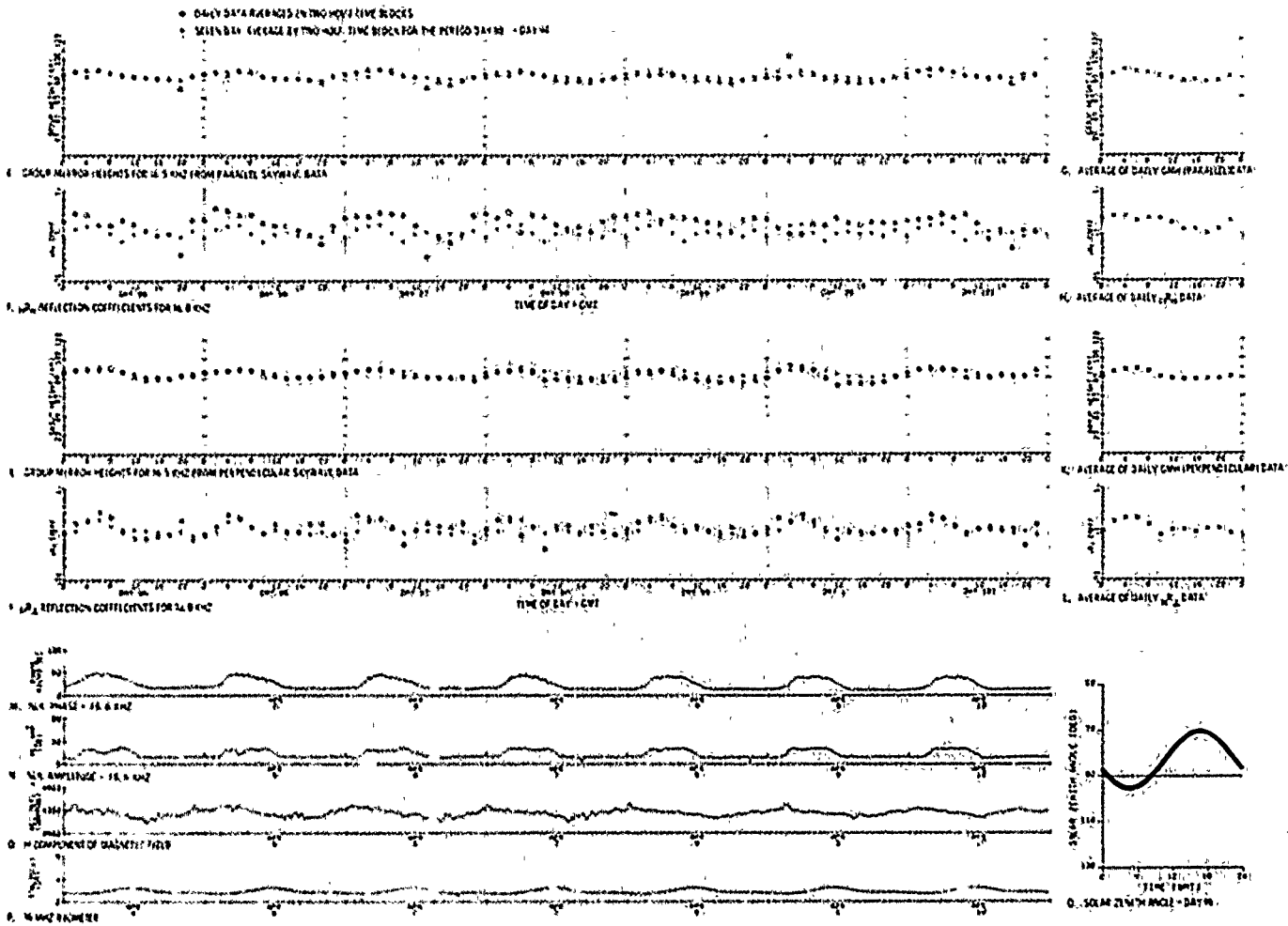

Figure 16. VLF/LF Reflectivity Data for the Polar Ionosphere, DAY 95 (4 Apr) — DAY 101 (10 Apr) 1976 (Cont)

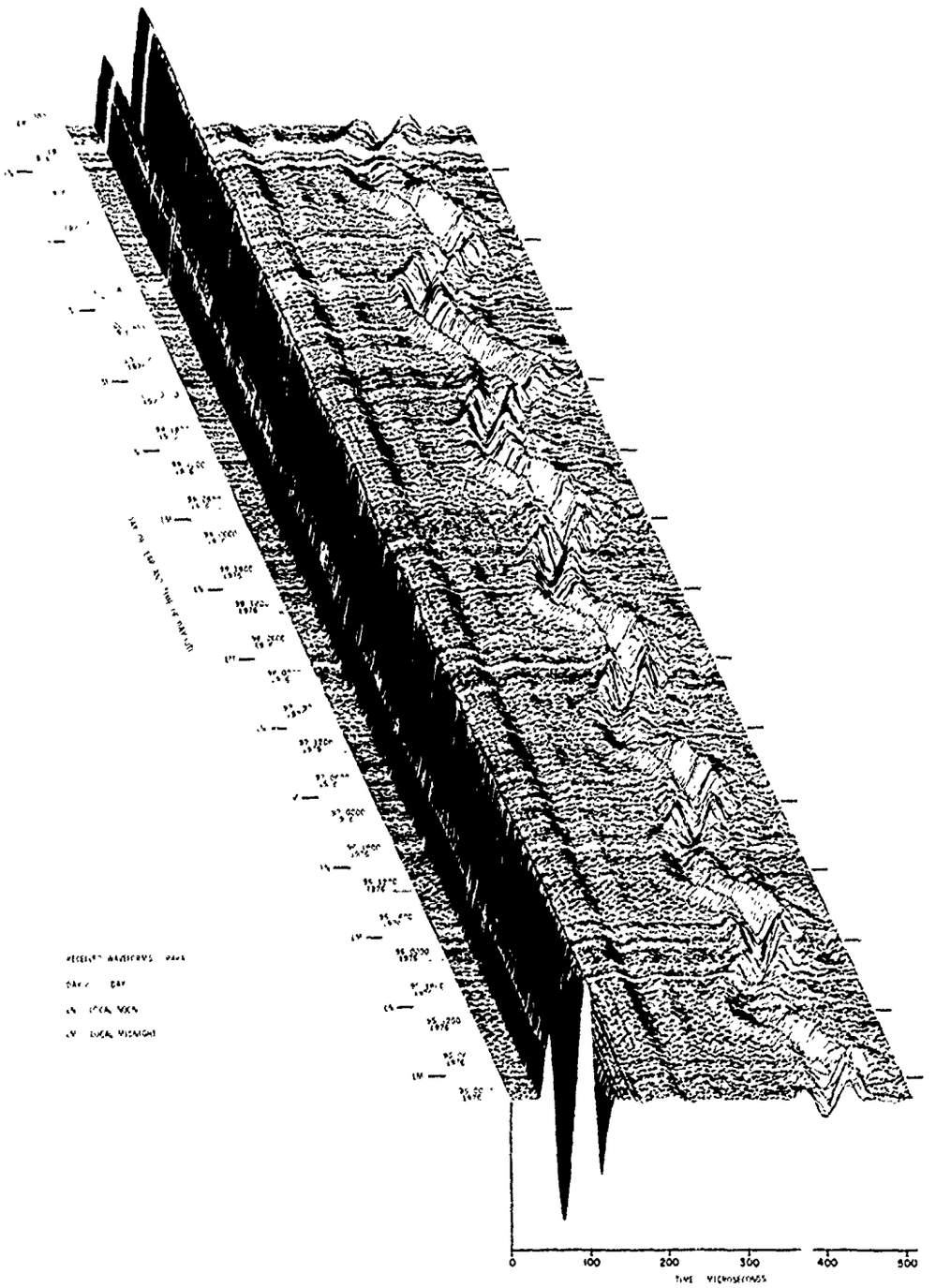

Figure 16. VLF/LF Reflectivity Data for the Polar Ionosphere, DAY 95 (4 Apr) – DAY 101 (10 Apr) 1976 (Cont) Part R. || Waveform Display

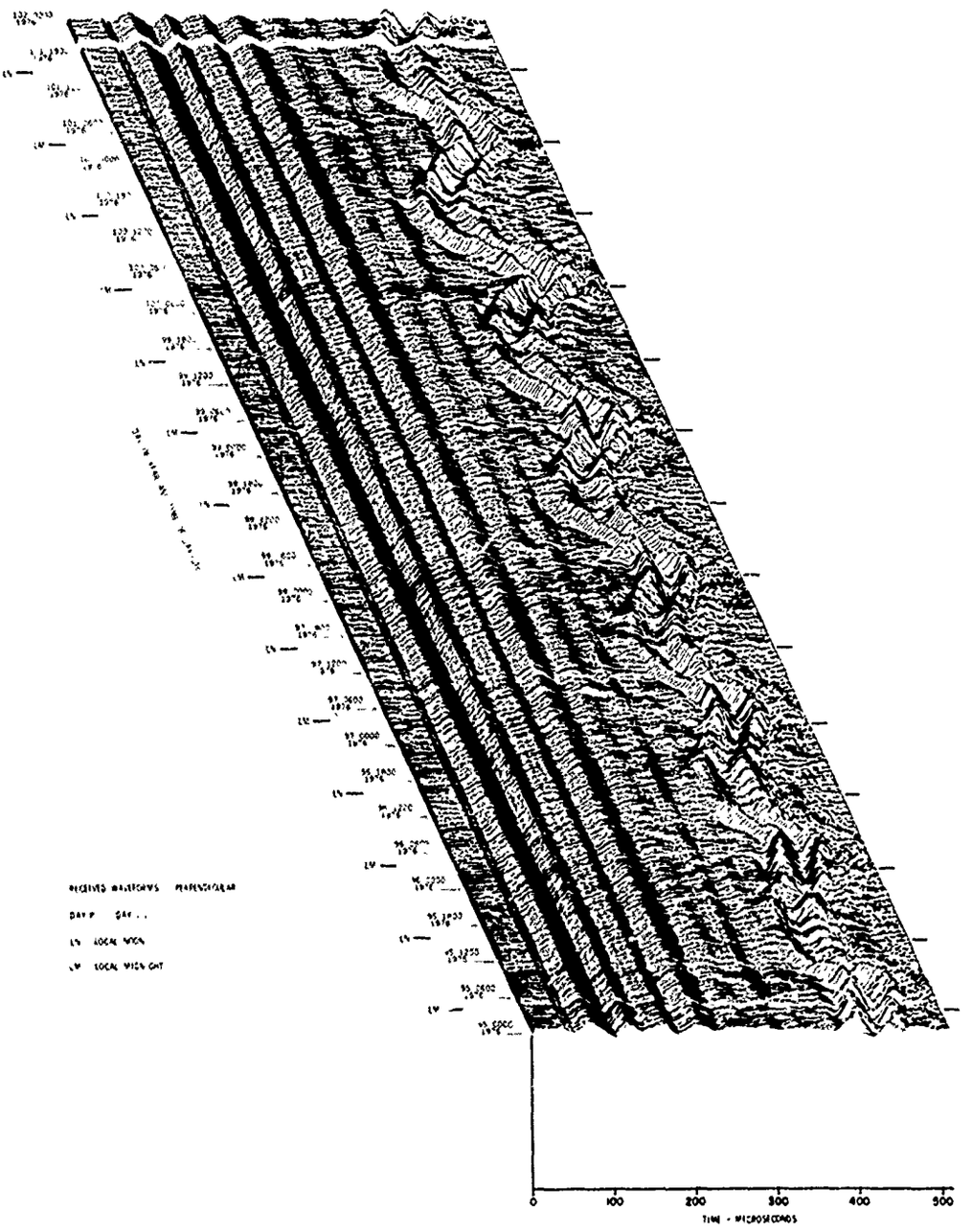

Figure 16. VLF/LF Reflectivity Data for the Polar Ionosphere, DAY 95 (4 Apr) - DAY 101 (19 Apr) 1976 (Cont) Part S. ⊥Waveform Display

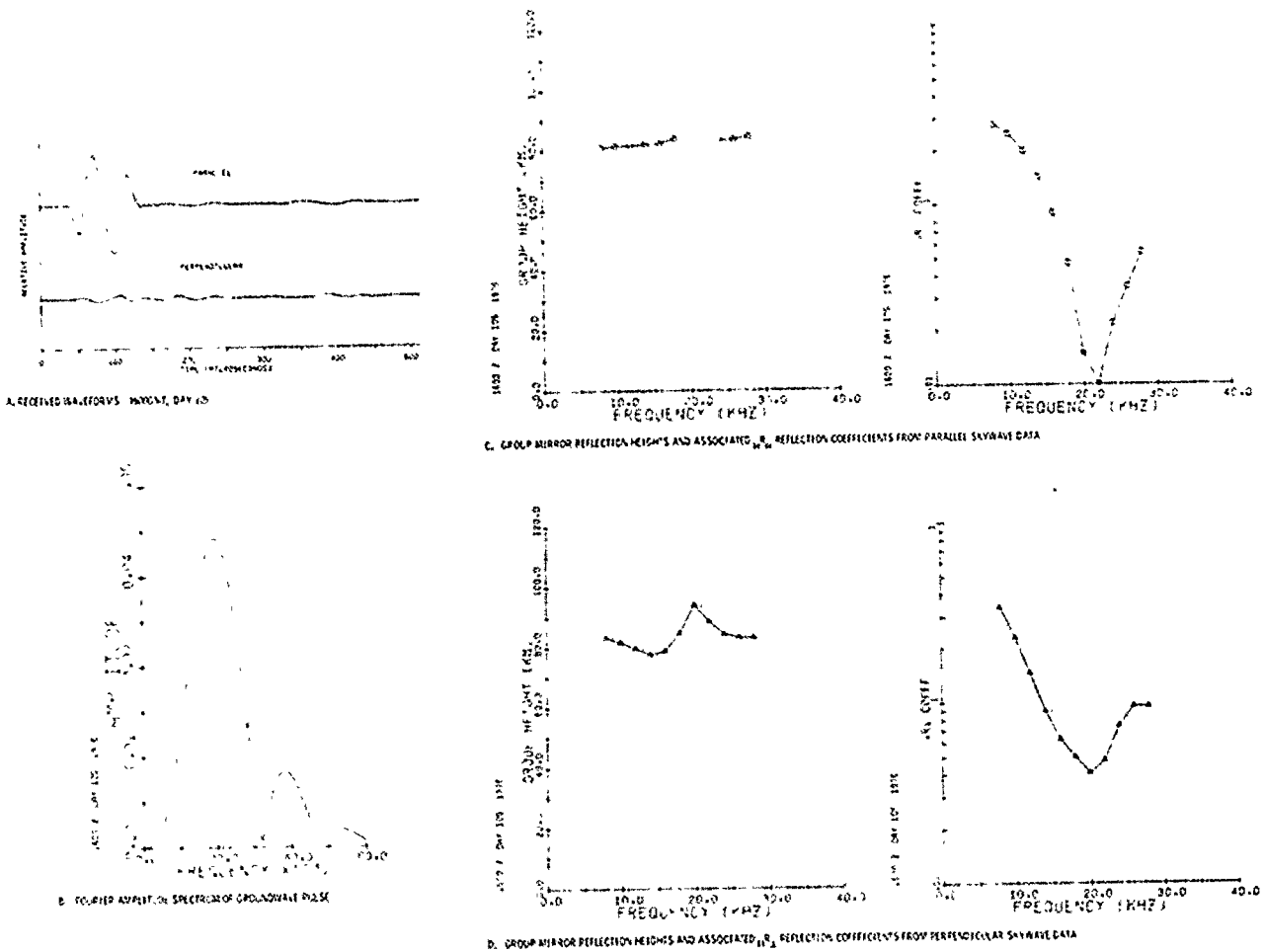

Figure 17. VLF/LF Reflectivity Data for the Polar Ionosphere, DAY 102 (11 Apr) — DAY 108 (17 Apr) 1976

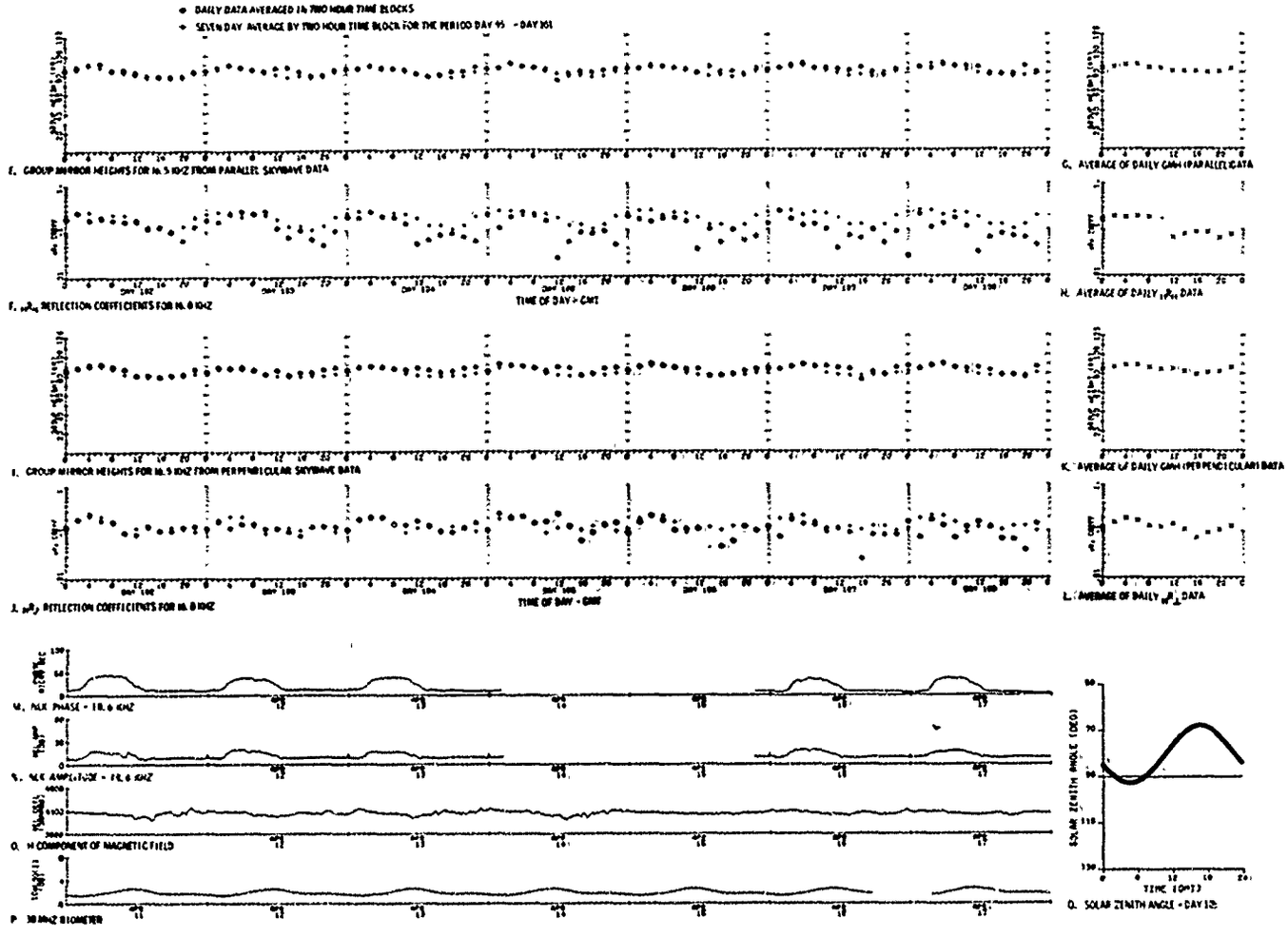

Figure 17. VLF/LF Reflectivity Data for the Polar Ionosphere, DAY 102 (11 Apr) — DAY 108 (17 Apr) 1976 (Cont)

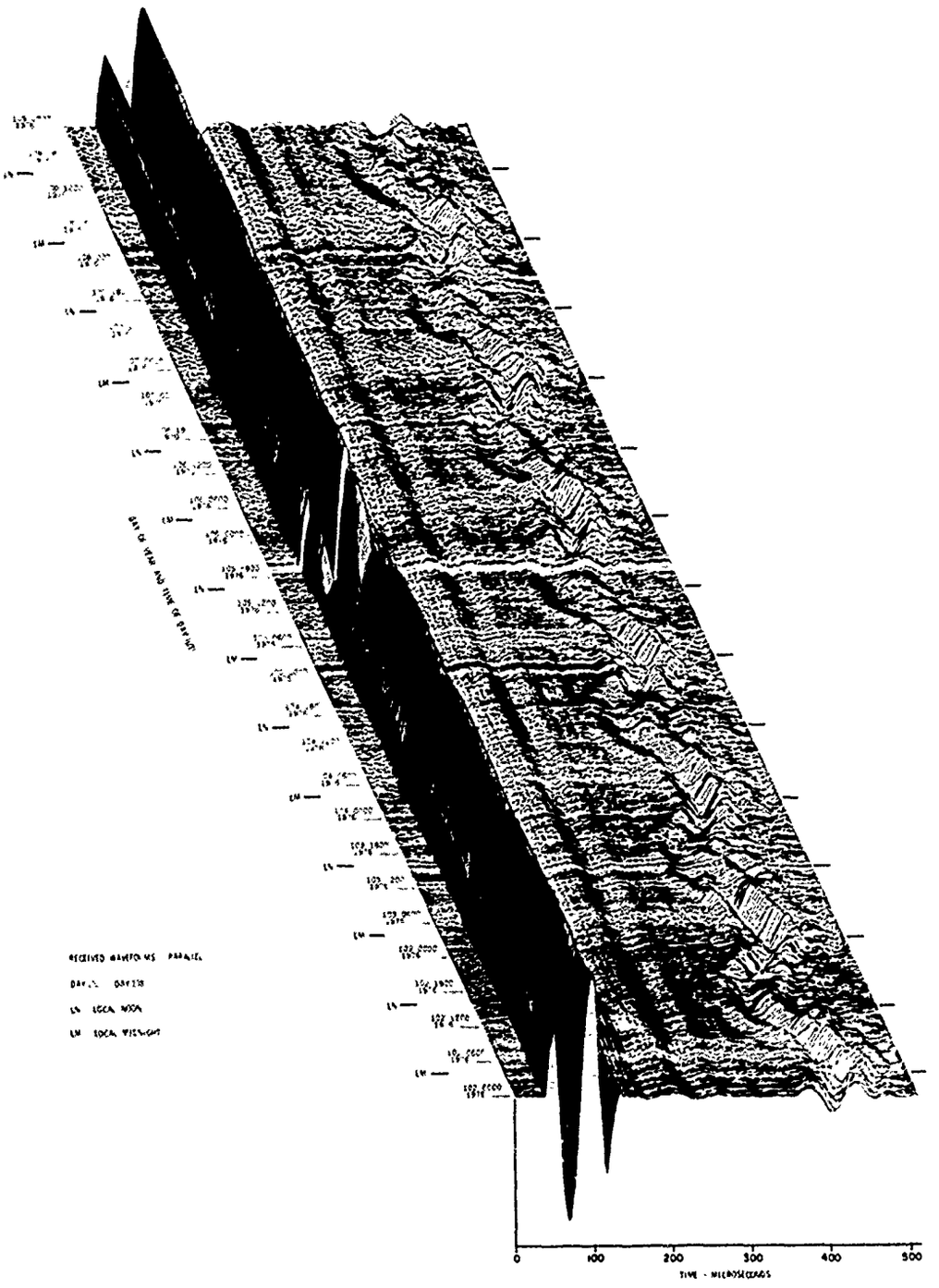

Figure 17. VLF/LF Reflectivity Data for the Polar Ionosphere, DAY 102 (11 Apr) - DAY 108 (17 Apr) 1978 (Cont) Part R. || Waveform Display

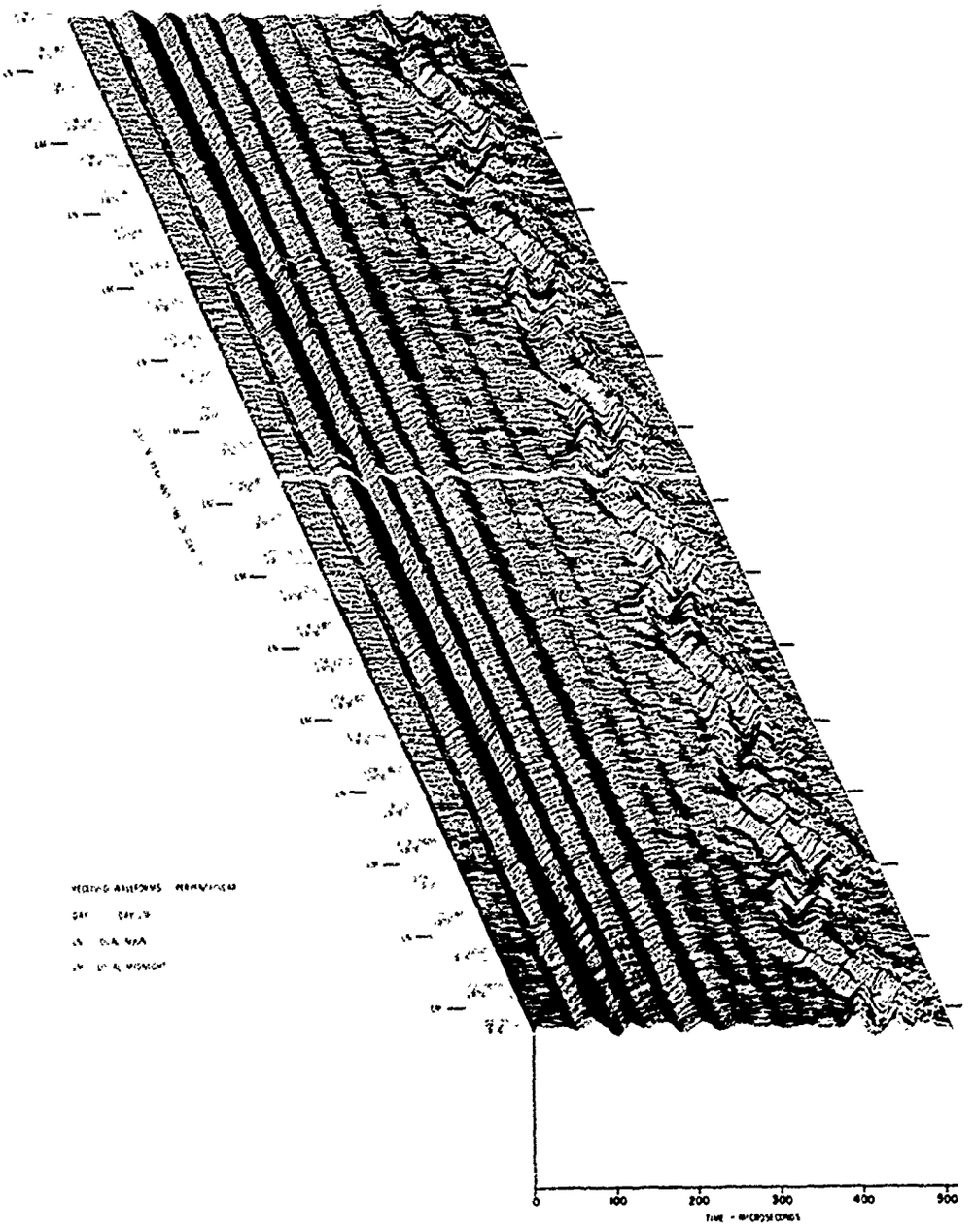

Figure 17. VLF/LF Reflectivity Data for the Polar Ionosphere, DAY 102 (11 Apr) - DAY 108 (17 Apr) 1976 (Cont) Part S. ⊥Waveform Display

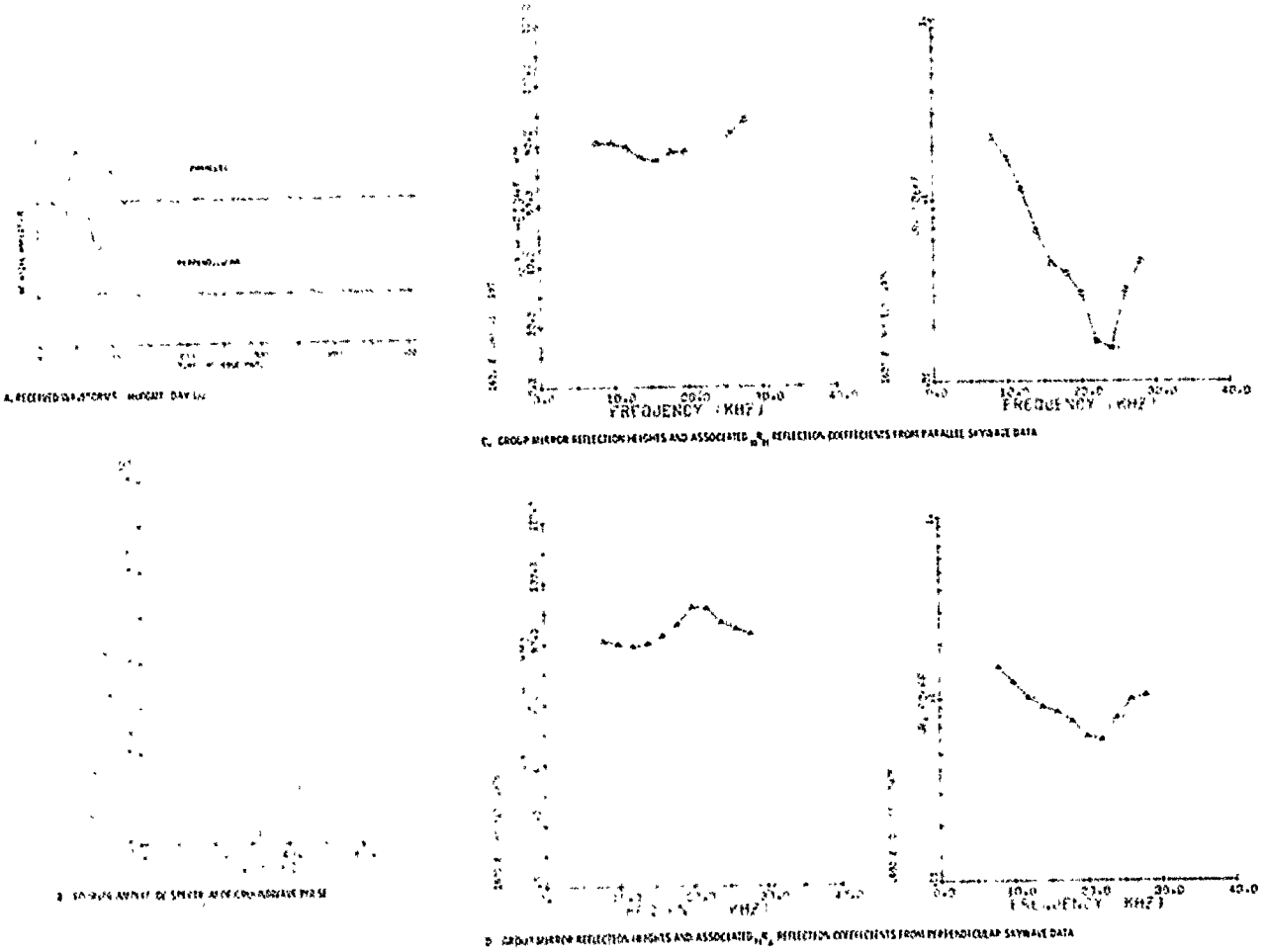

Figure 18. VLF/LF Reflectivity Data for the Polar Ionosphere, DAY 109 (18 Apr) — DAY 115 (24 Apr) 1976

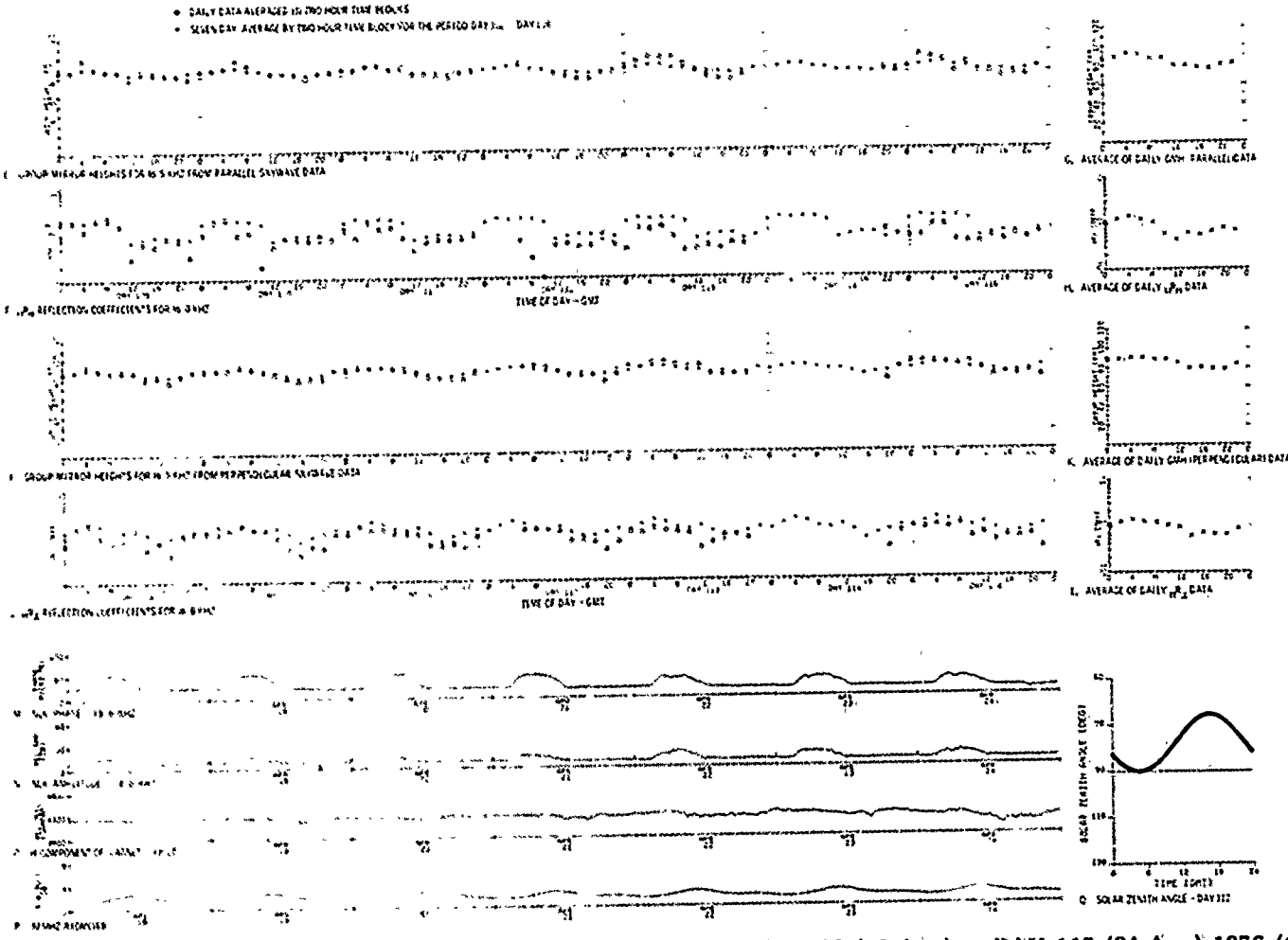

Figure 18. VLF/LF Reflectivity Data for the Polar Ionosphere, DAY 109 (18 Apr) — DAY 115 (24 Apr) 1976 (Cont)

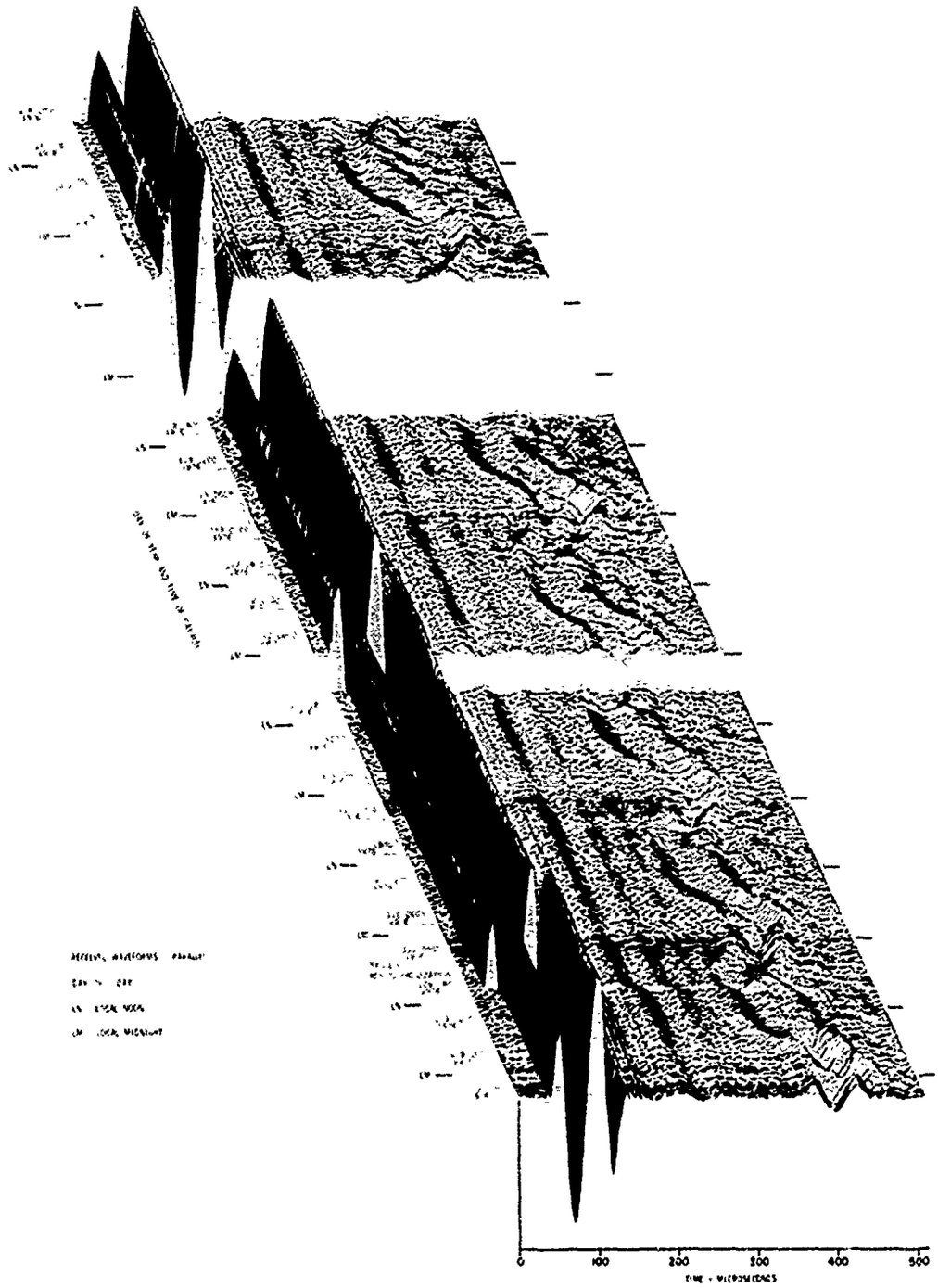

Figure 18. VLF/LF Reflectivity Data for the Polar Ionosphere, DAY 109 (18 Apr) – DAY 115 (24 Apr) 1976 (Cont) Part R. || Waveform Display

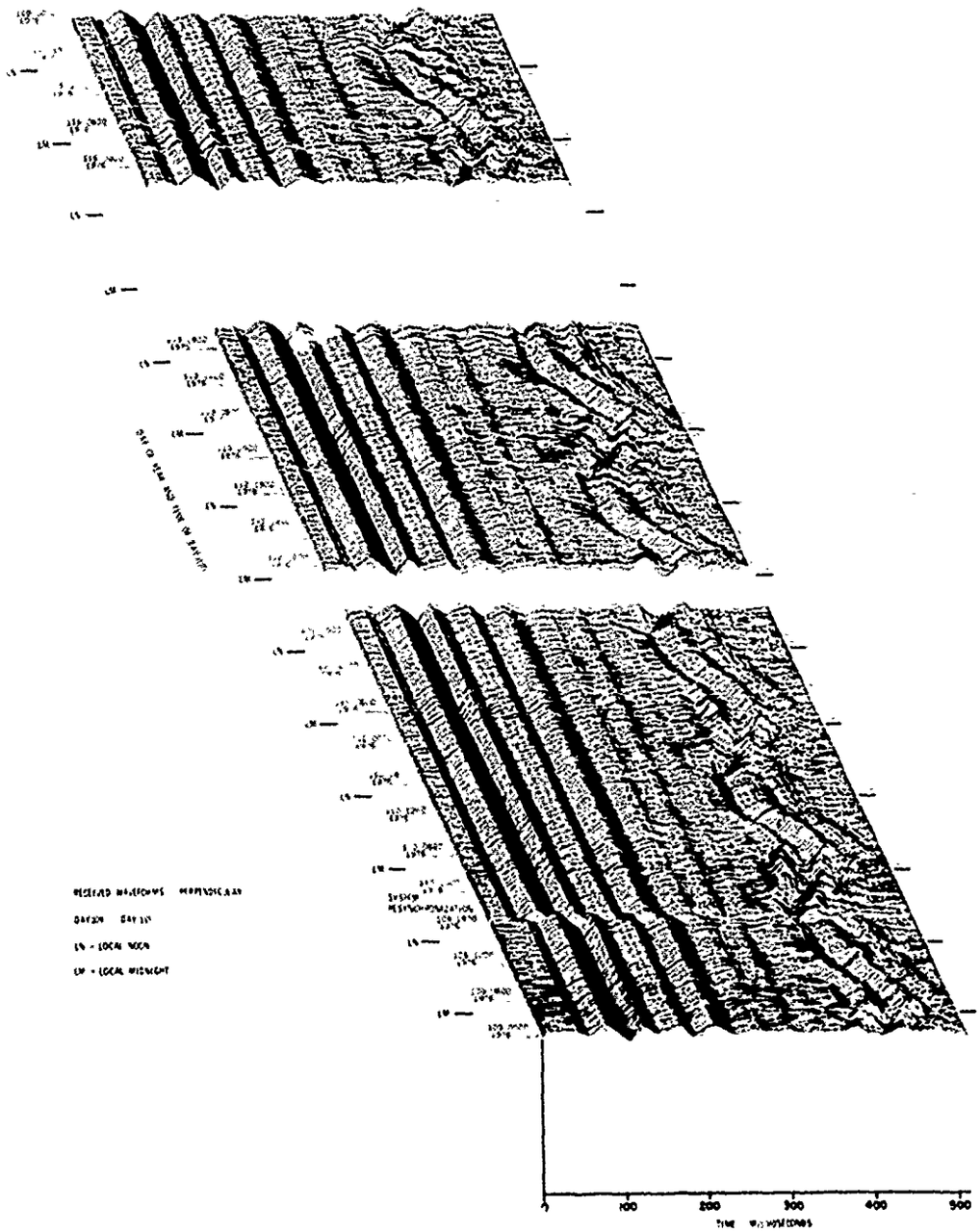

Figure 18. VLF/LF Reflectivity Data for the Polar Ionosphere, DAY 109 (18 Apr) - DAY 115 (24 Apr) 1976 (Cont) Part S, ⊥ Waveform Display

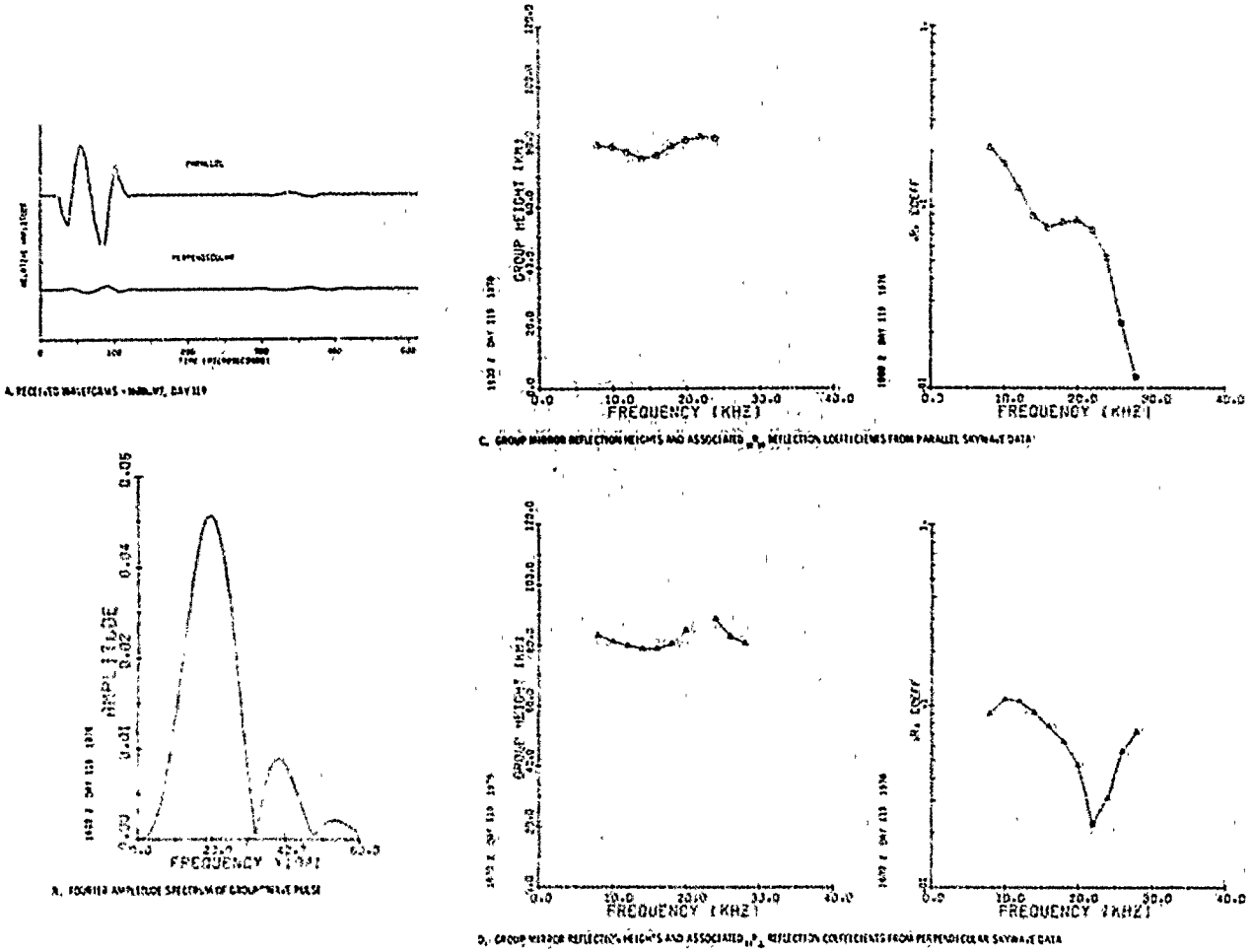

Figure 19. VLF/LF Reflectivity Data for the Polar Ionosphere, DAY 116 (25 Apr) — DAY 122 (1 May) 1976

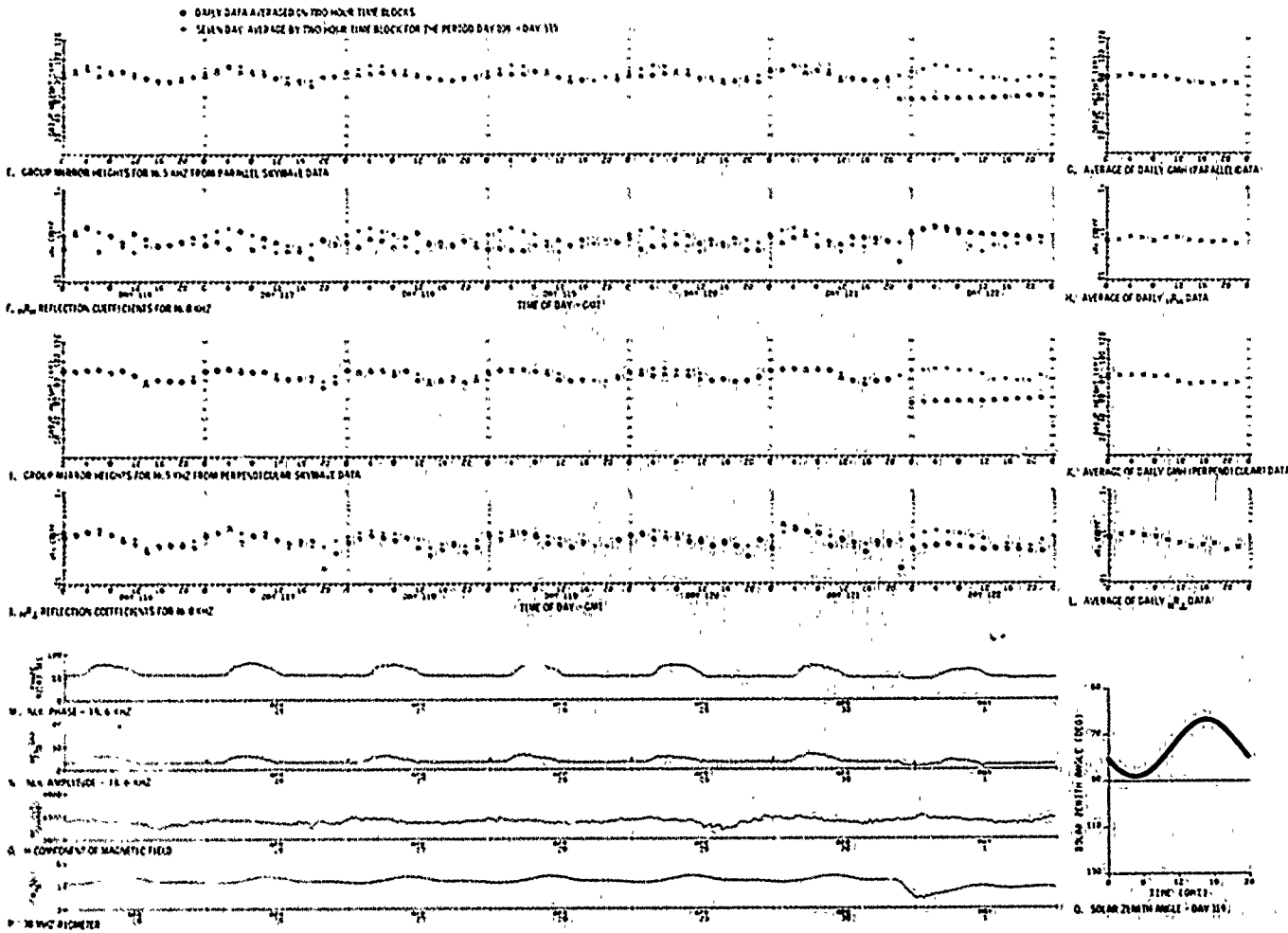

Figure 19. VLF/LF Reflectivity Data for the Polar Ionosphere, DAY 116 (25 Apr) — DAY 122 (1 May) 1976 (Cont)

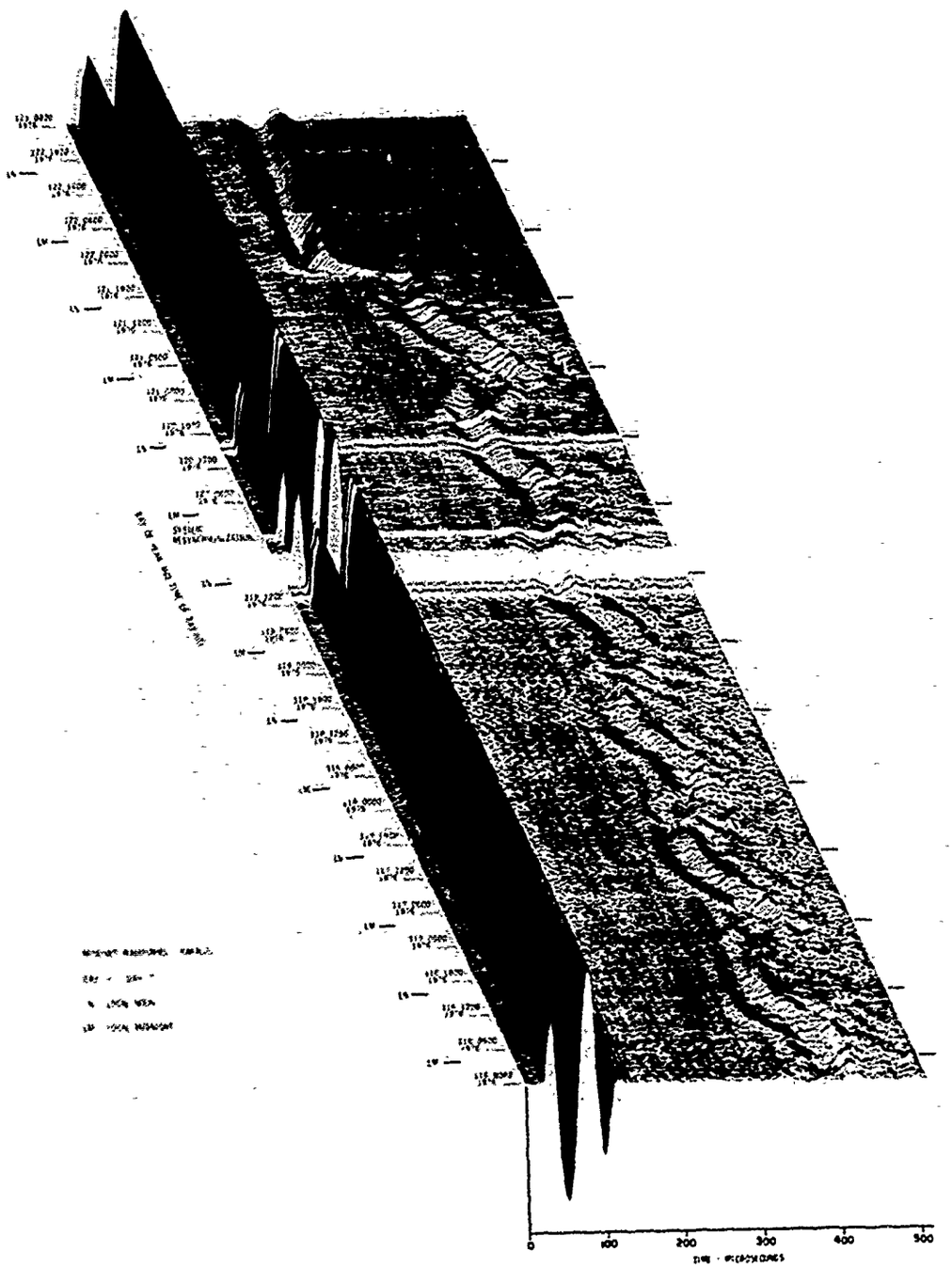

Figure 19. VLF/LF Reflectivity Data for the Polar Ionosphere, DAY 116 (25 Apr) – DAY 122 (1 May) 1976 (Cont) Part R. || Waveform Display

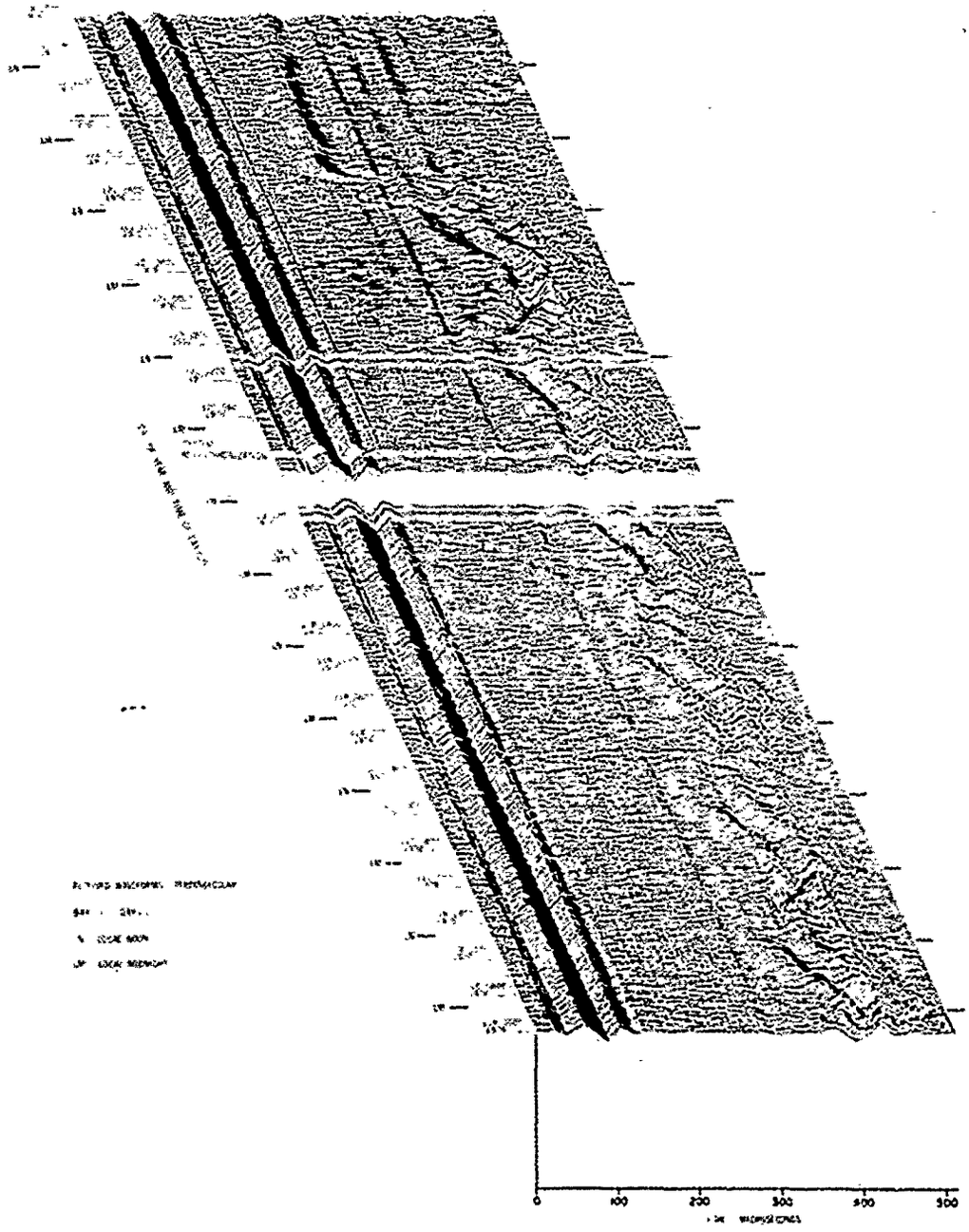

Figure 19. VLF/LF Reflectivity Data for the Polar Ionosphere, DAY 116 (25 Apr) – DAY 122 (1 May) 1976 (Cont) Part S. ⊥ Waveform Display

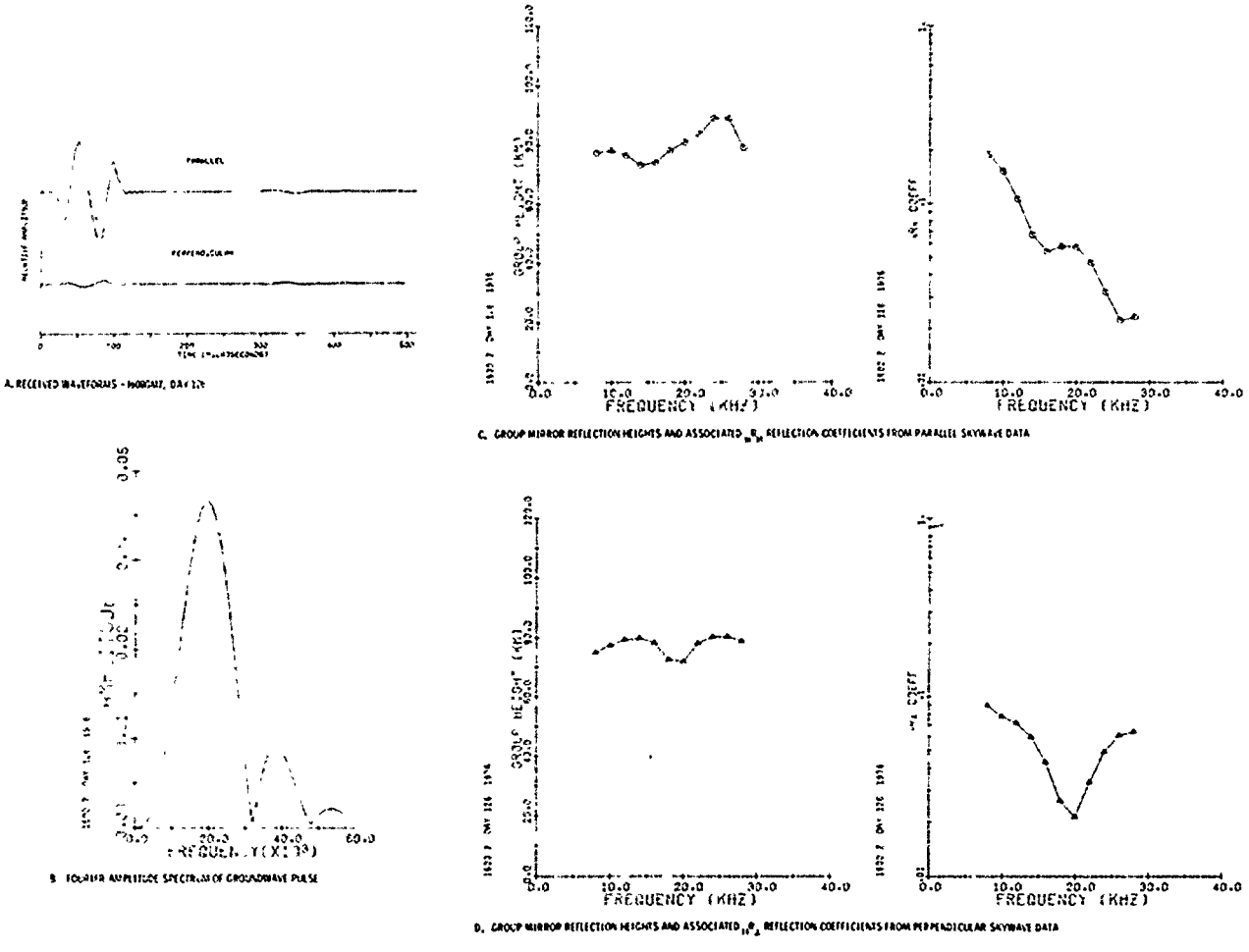

Figure 20. VLF/LF Reflectivity Data for the Polar Ionosphere, DAY 123 (2 May) — DAY 129 (8 May) 1976

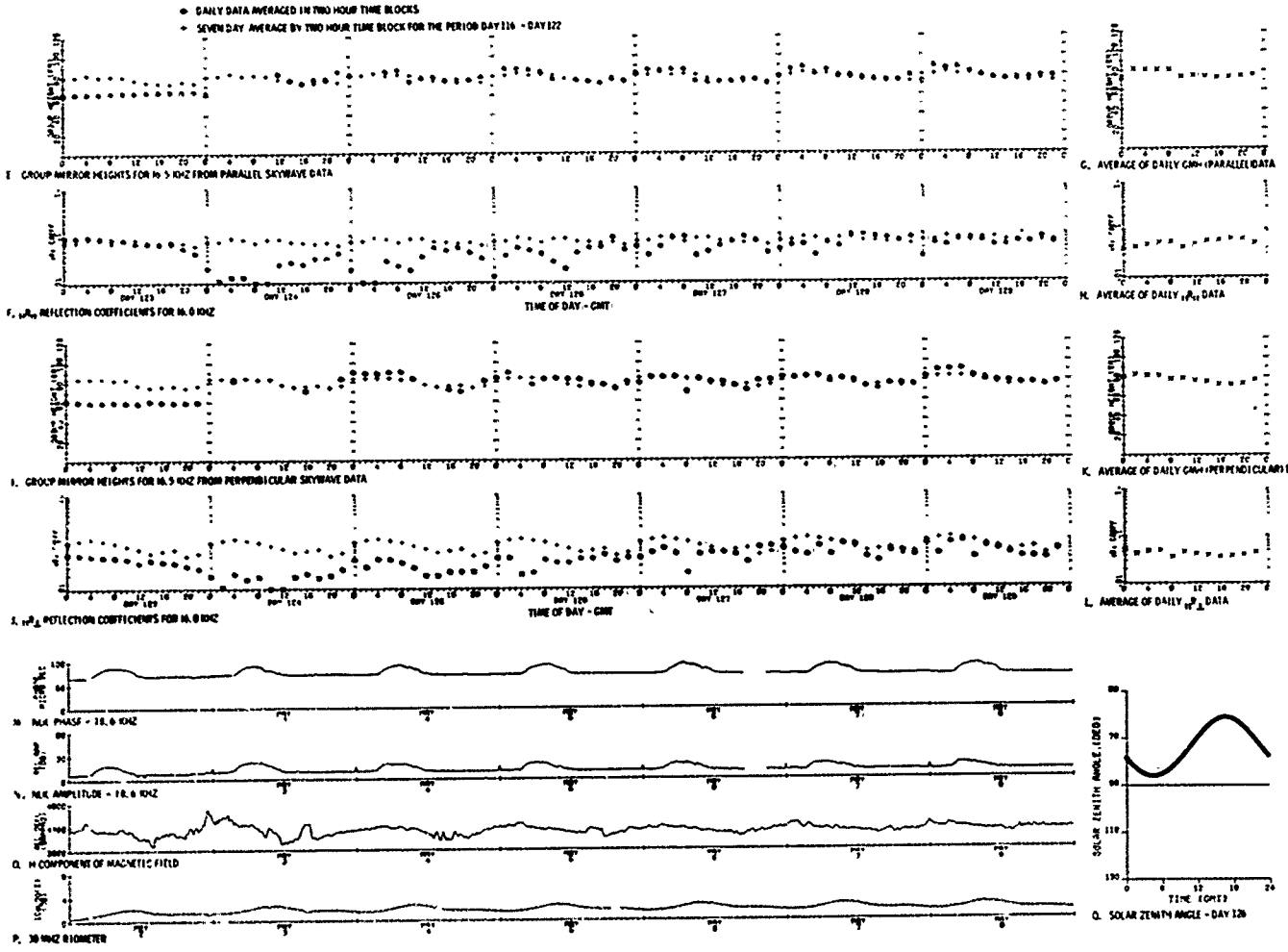

Figure 20. VLF/LF Reflectivity Data for the Polar Ionosphere, DAY 123 (2 May) — DAY 129 (8 May) 1976 (Cont)

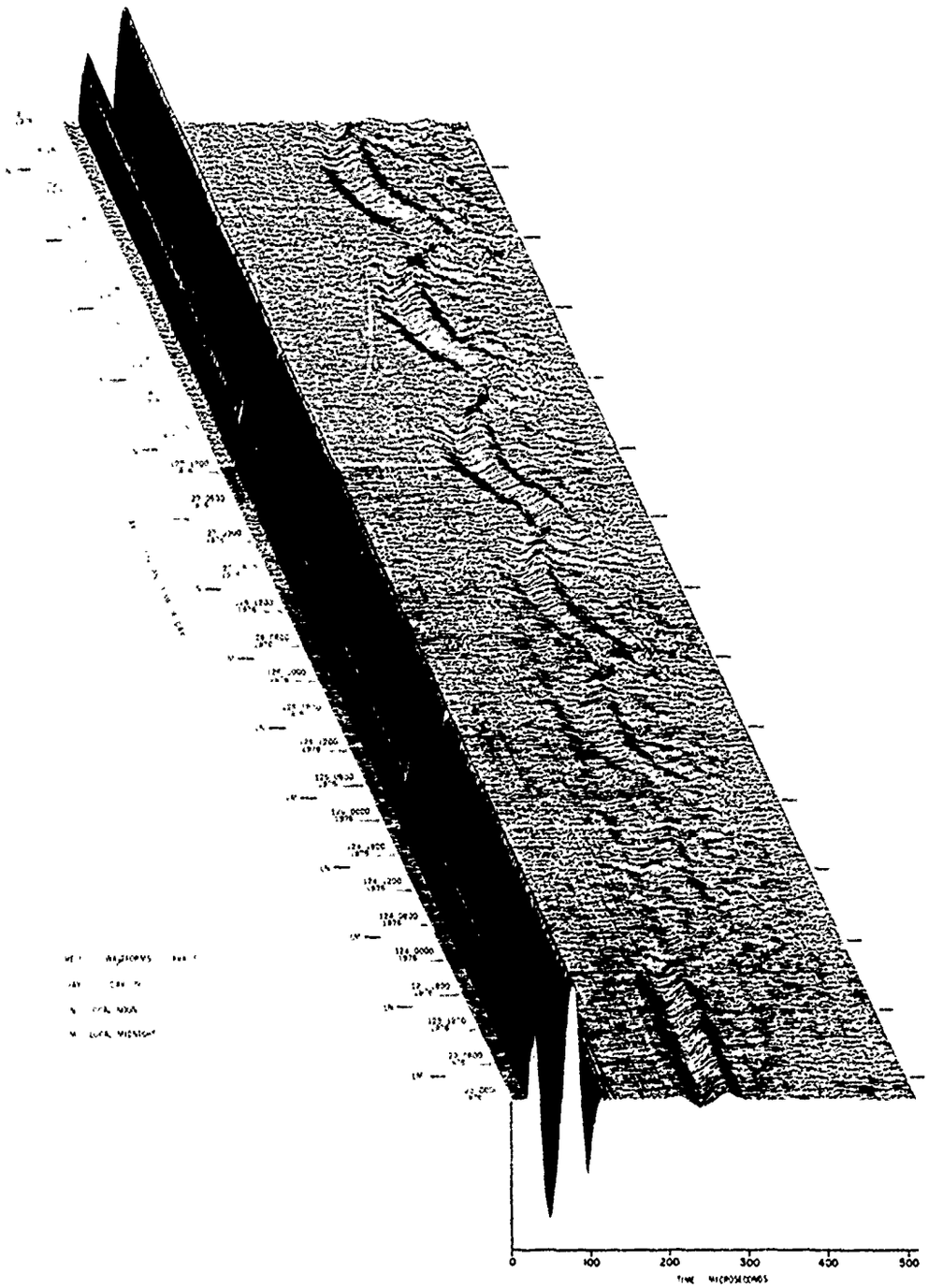

Figure 20. VLF/LF Reflectivity Data for the Po'ar Ionosphere, DAY 123 (2 May) - DAY 129 (8 May) 1976 (Cont) Part R. II Waveform Display

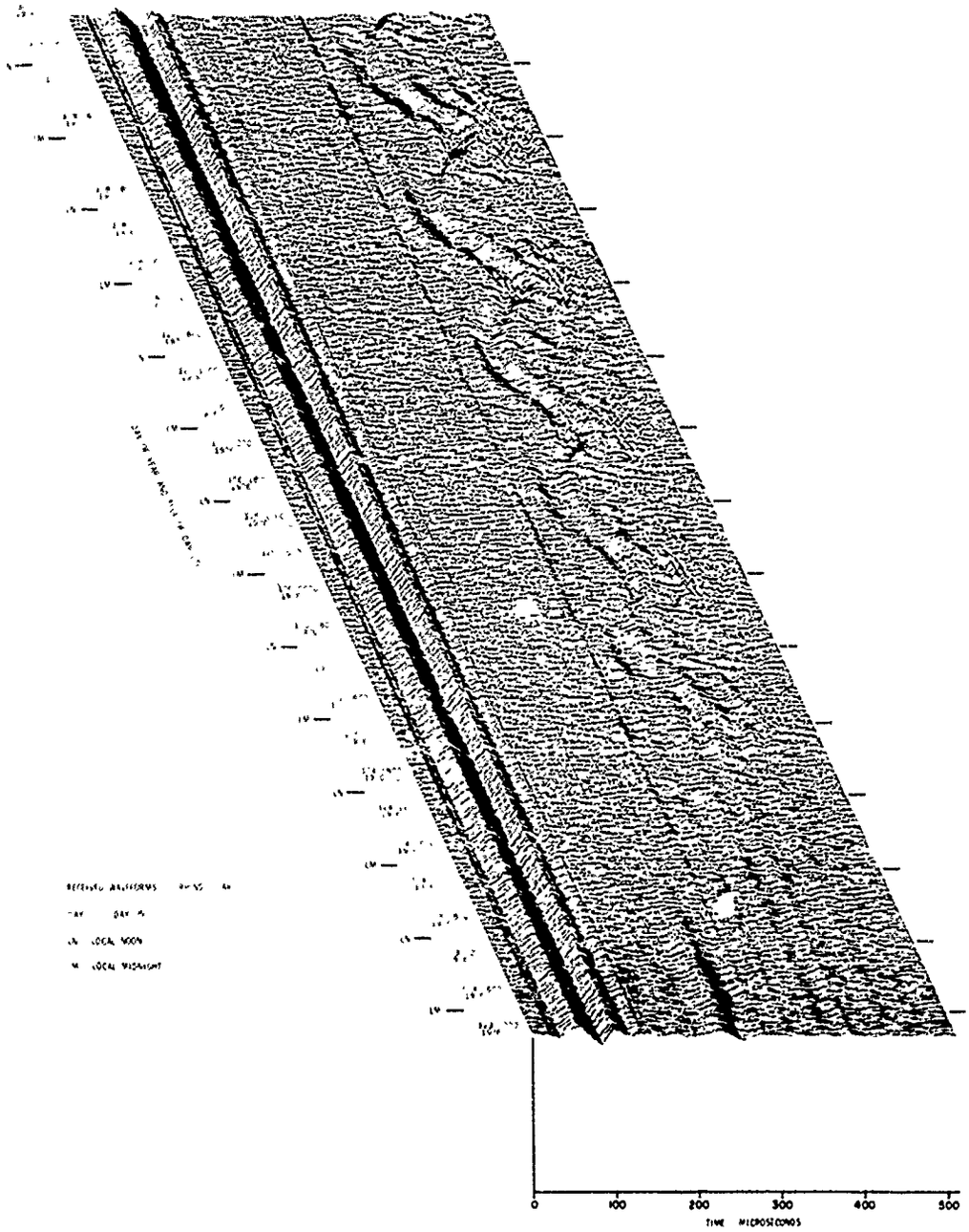

Figure 20. VLF/LF Reflectivity Data for the Polar Ionosphere, DAY 123 (2 May) – DAY 129 (8 May) 1976 (Cont) Part S. ⊥ Waveform Display

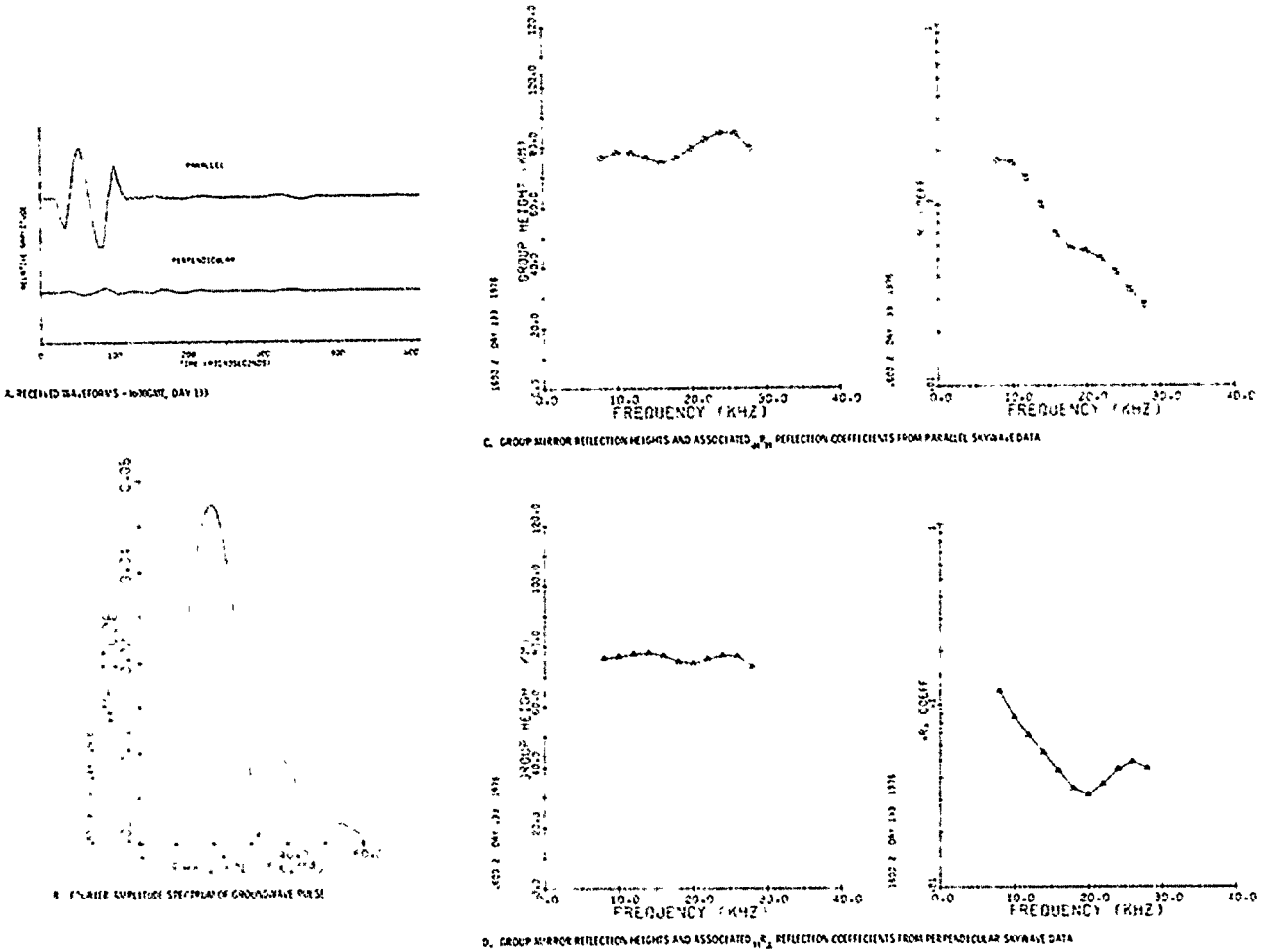

Figure 21. VLF/LF Reflectivity Data for the Polar Ionosphere, DAY 130 (9 May) — DAY 136 (15 May) 1976

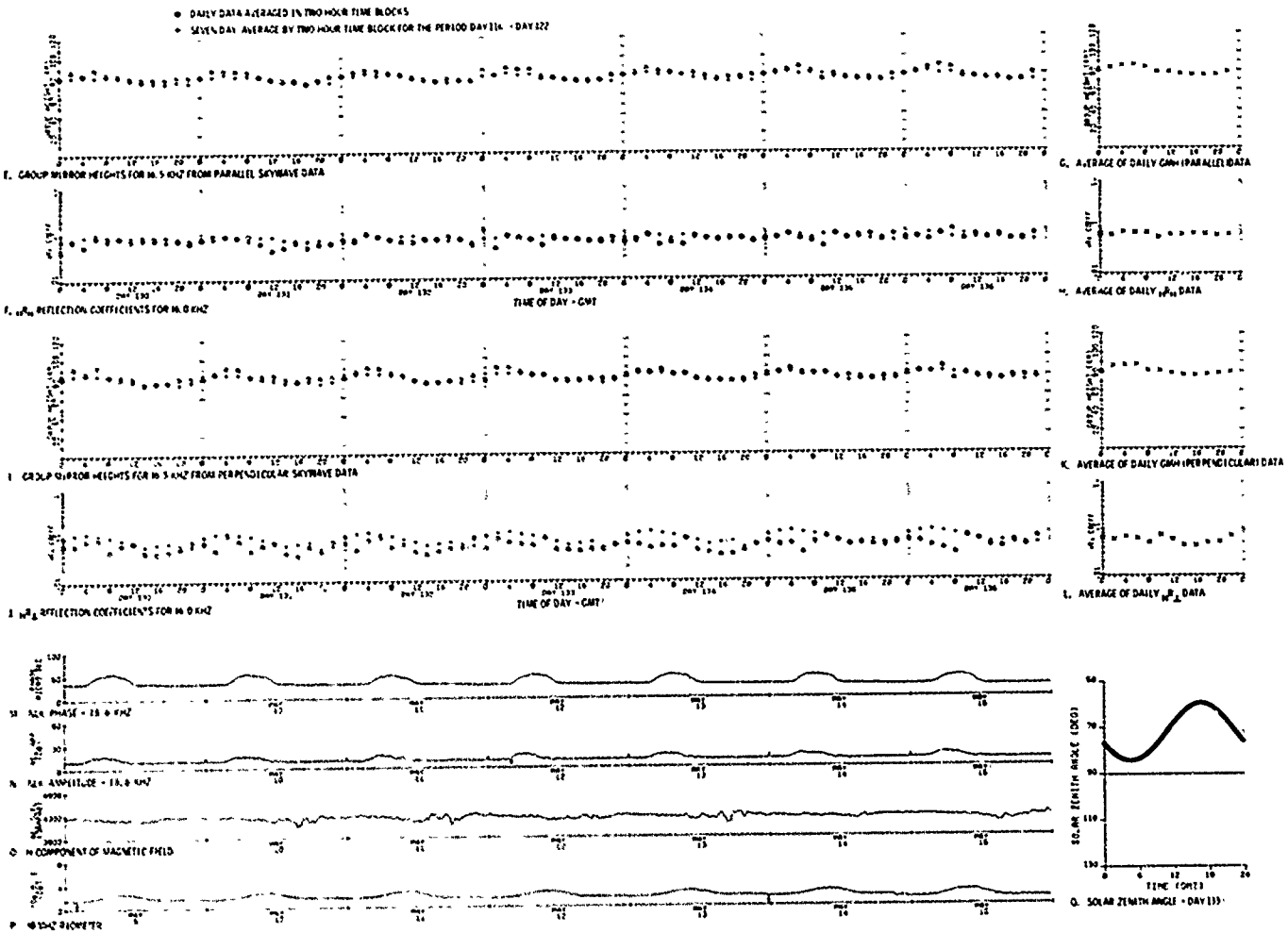

Figure 21. VLF/LF Reflectivity Data for the Polar Ionosphere, DAY 130 (9 May) — DAY 136 (15 May) 1976 (Cont)

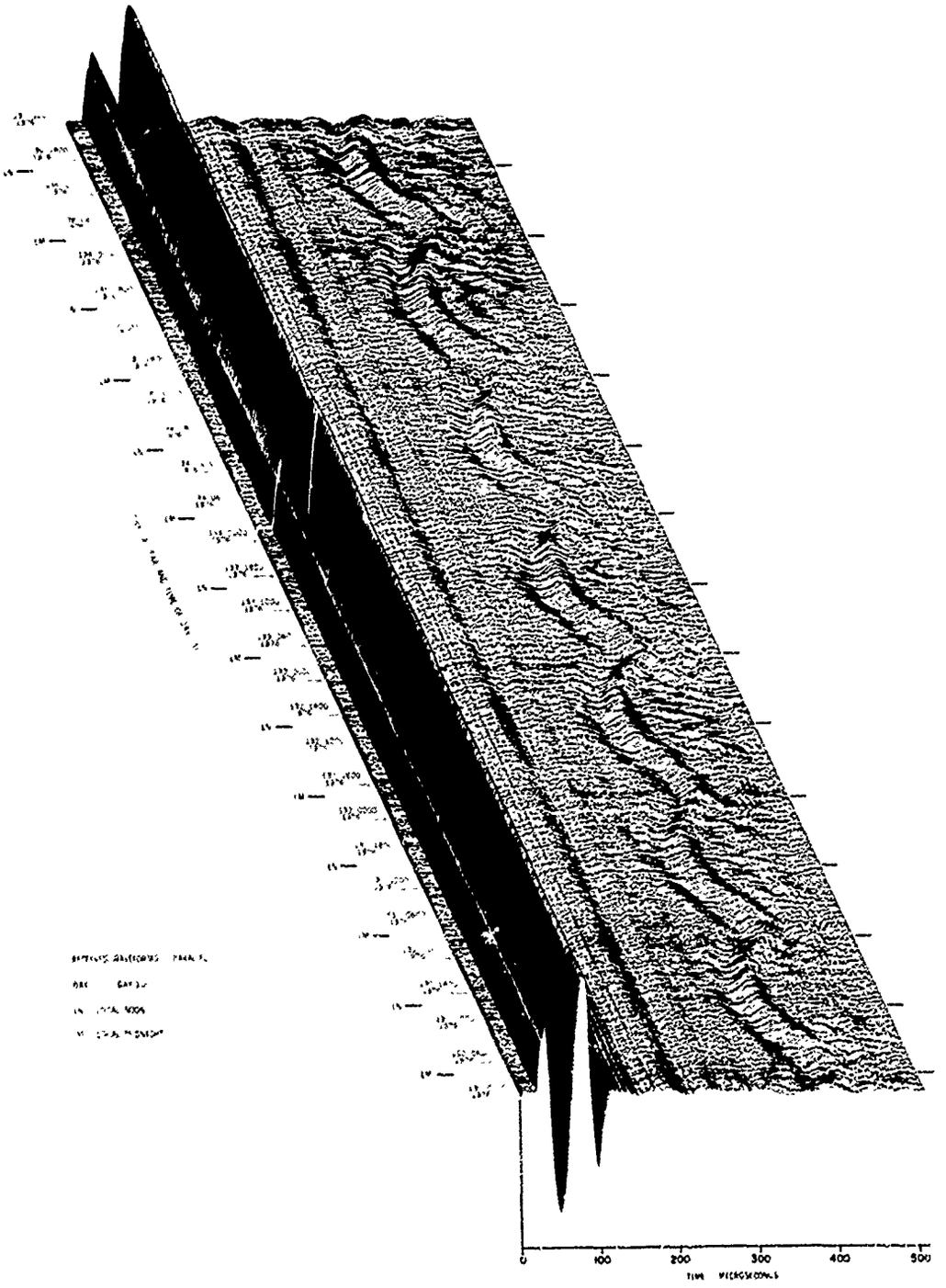

Figure 21. VLF/LF Reflectivity Data for the Polar Ionosphere, DAY 130 (9 May) -- DAY 136 (15 May) 1976 (Cont) Part R. ||Waveform Display

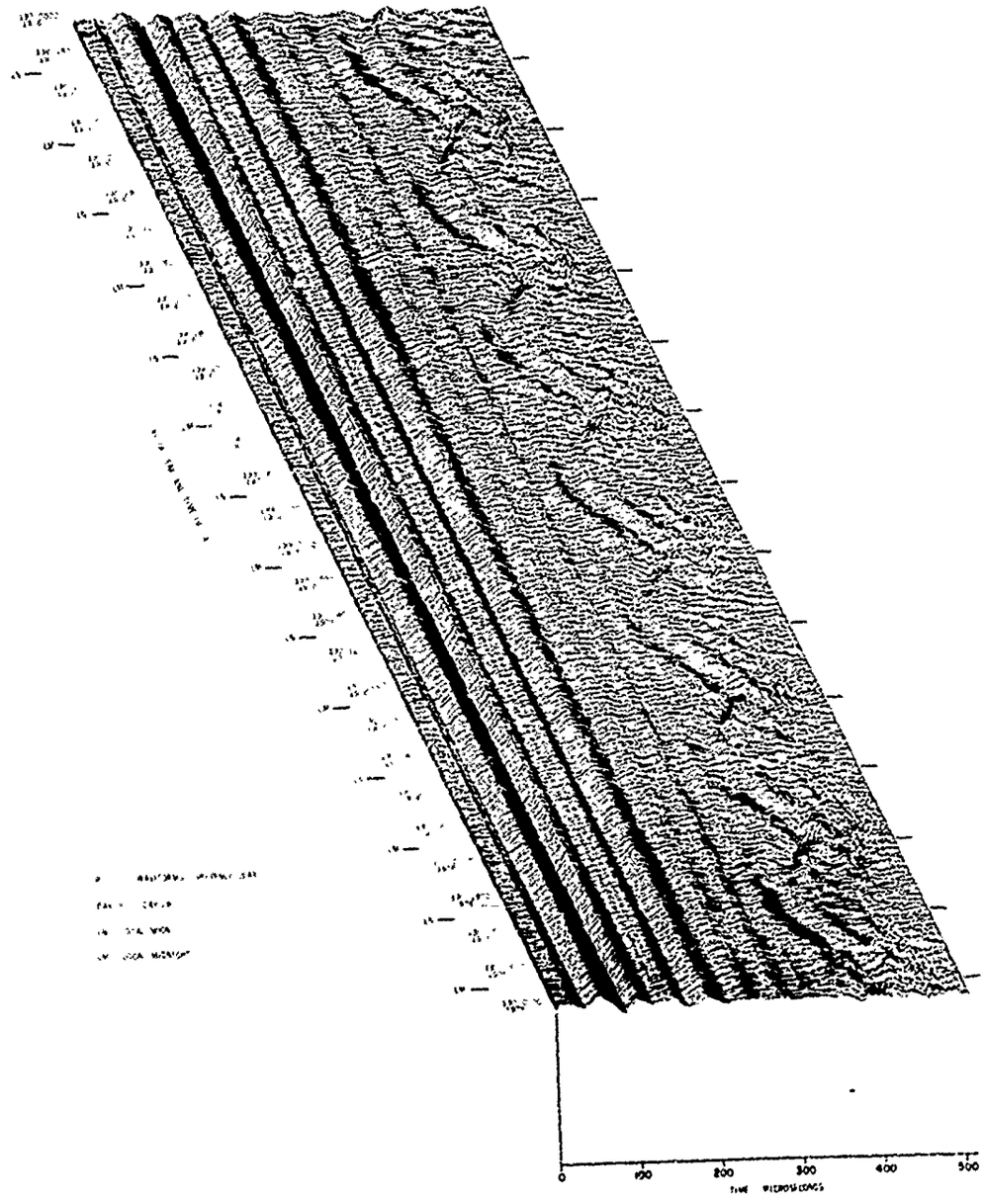

Figure 21. VLF/LF Reflectivity Data for the Polar Ionosphere, DAY 130 (9 May) - DAY 136 (15 May) 1976 (Cont) Part S. ⊥ Waveform Display

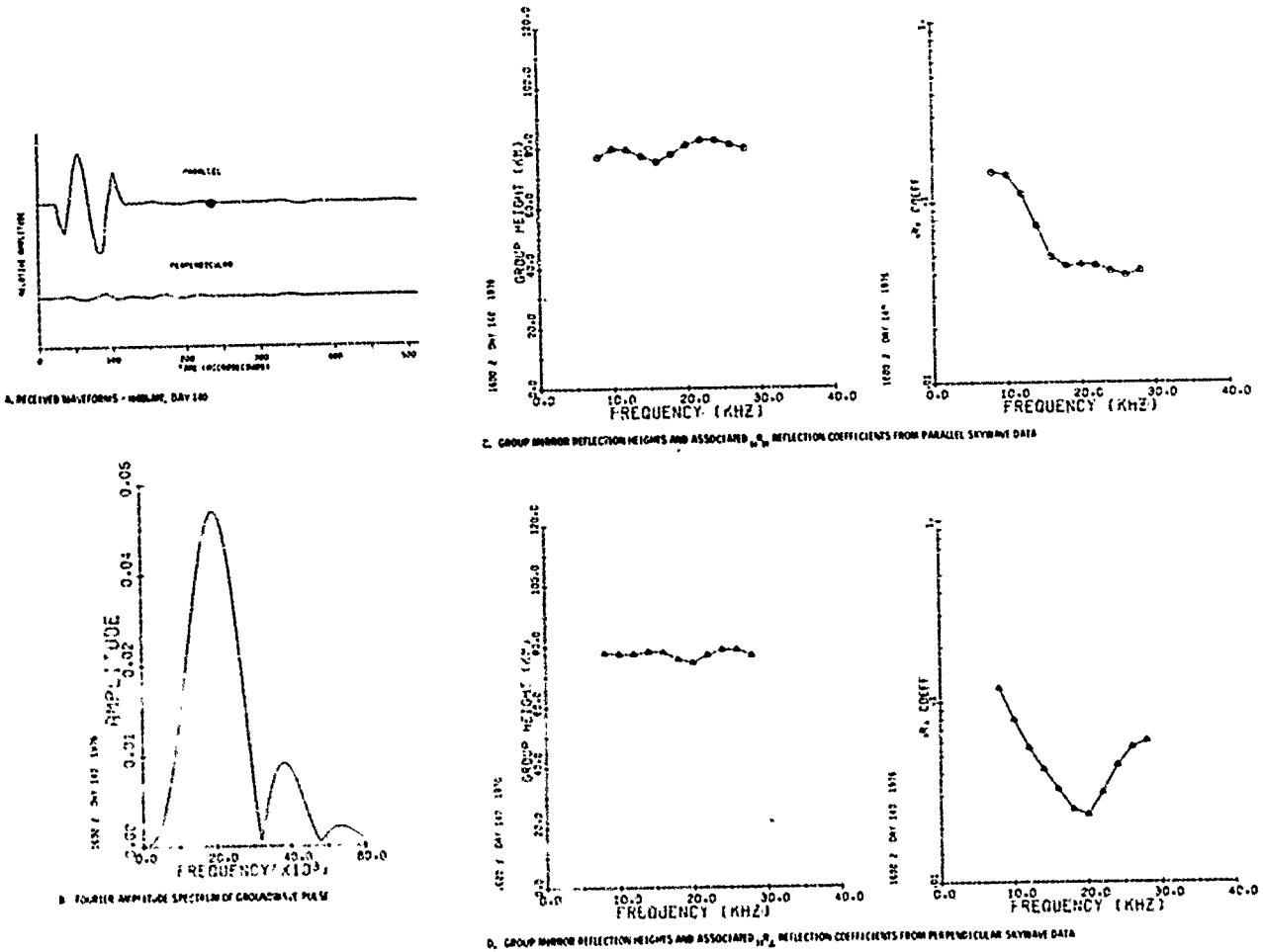

Figure 22. VLF/LF Reflectivity Data for the Polar Ionosphere, DAY 137 (16 May) — DAY 143 (22 May) 1976

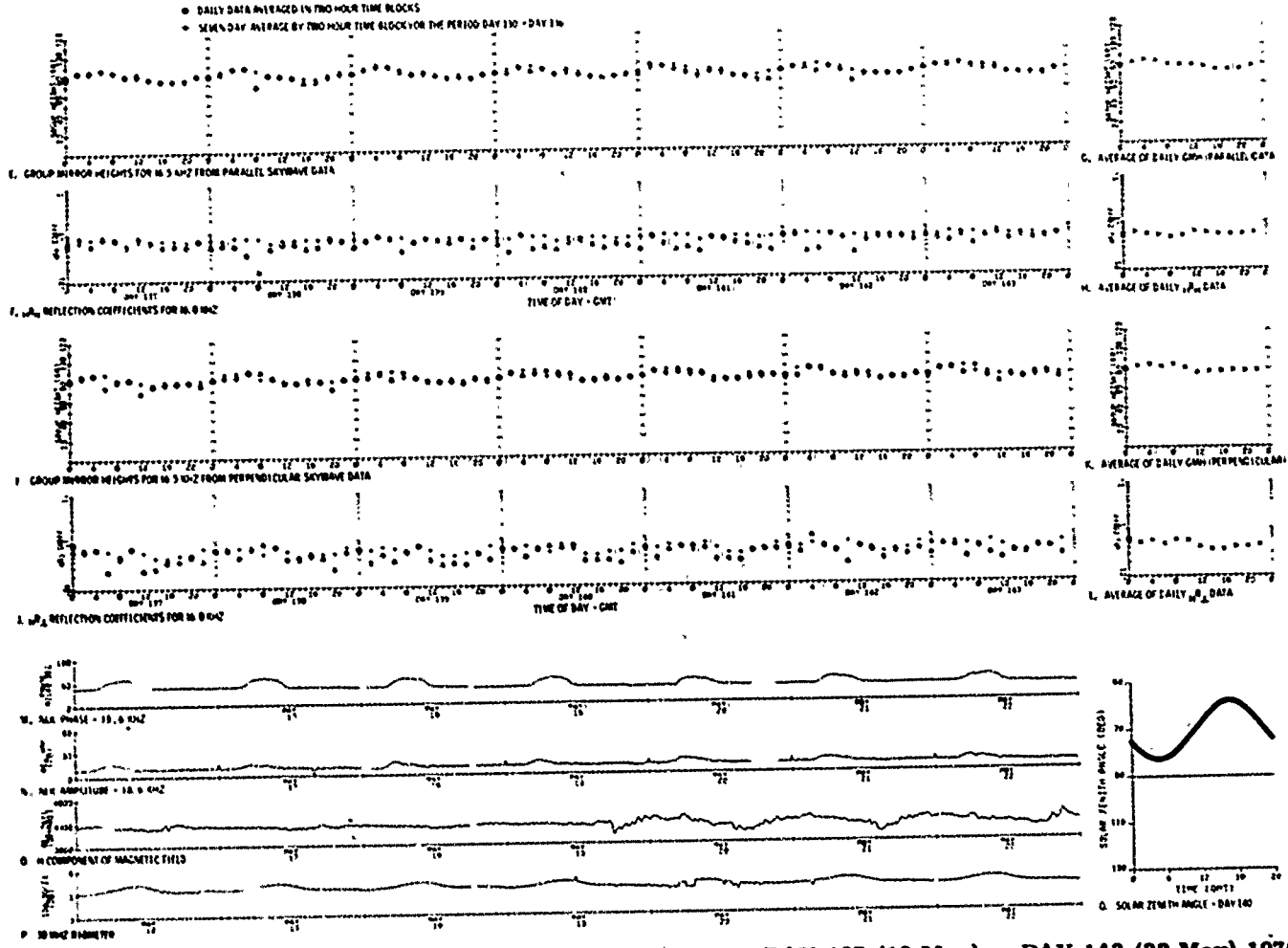

Figure 22. VLF/LF Reflectivity Data for the Polar Ionosphere, DAY 137 (16 May) — DAY 143 (22 May) 1976 (Cont)

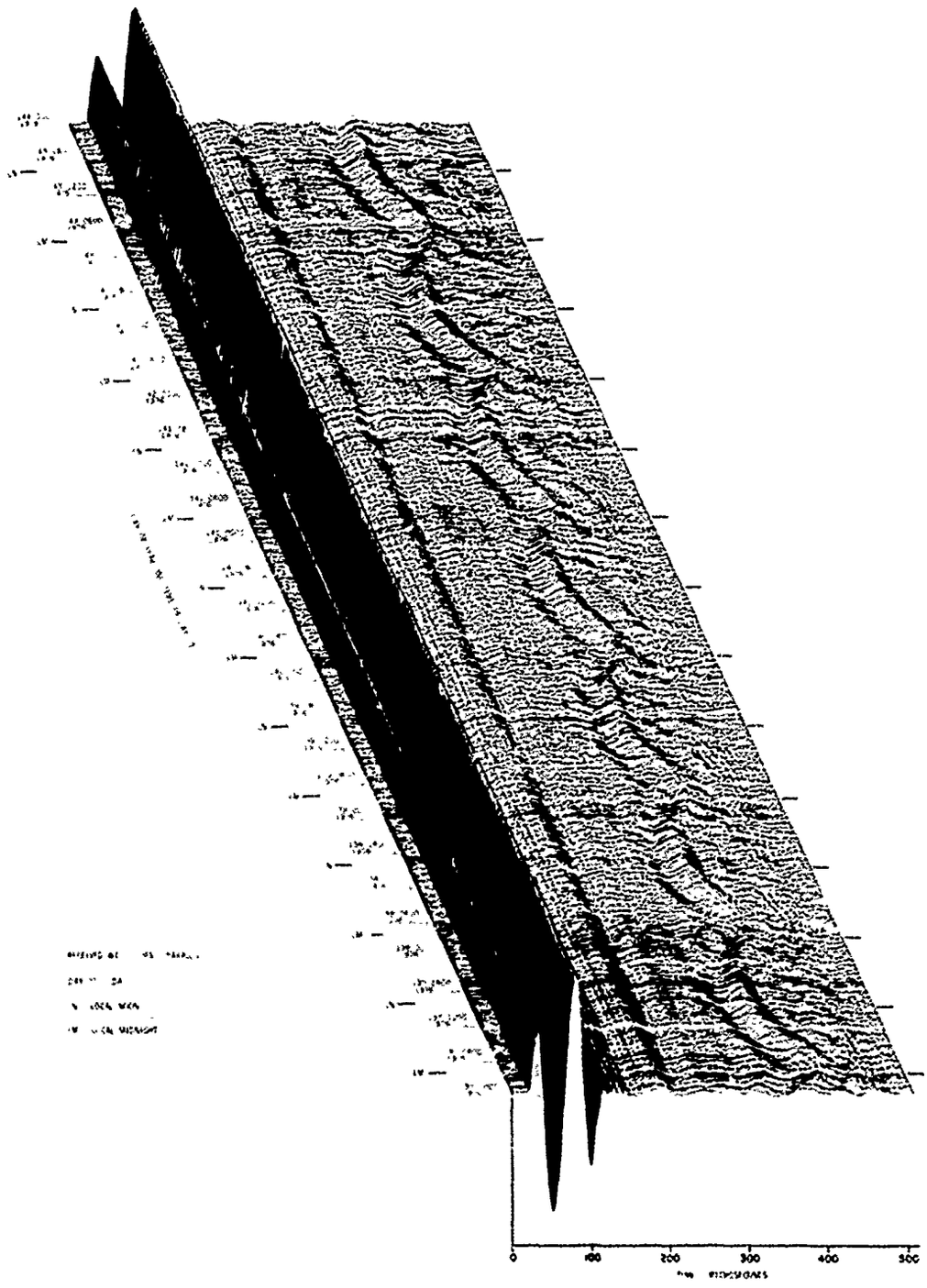

Figure 22. VLF/LF Reflectivity Data for the Polar Ionosphere, DAY 137 (16 May) - DAY 143 (22 May) 1976 (Cont) Part R. ||Waveform Display

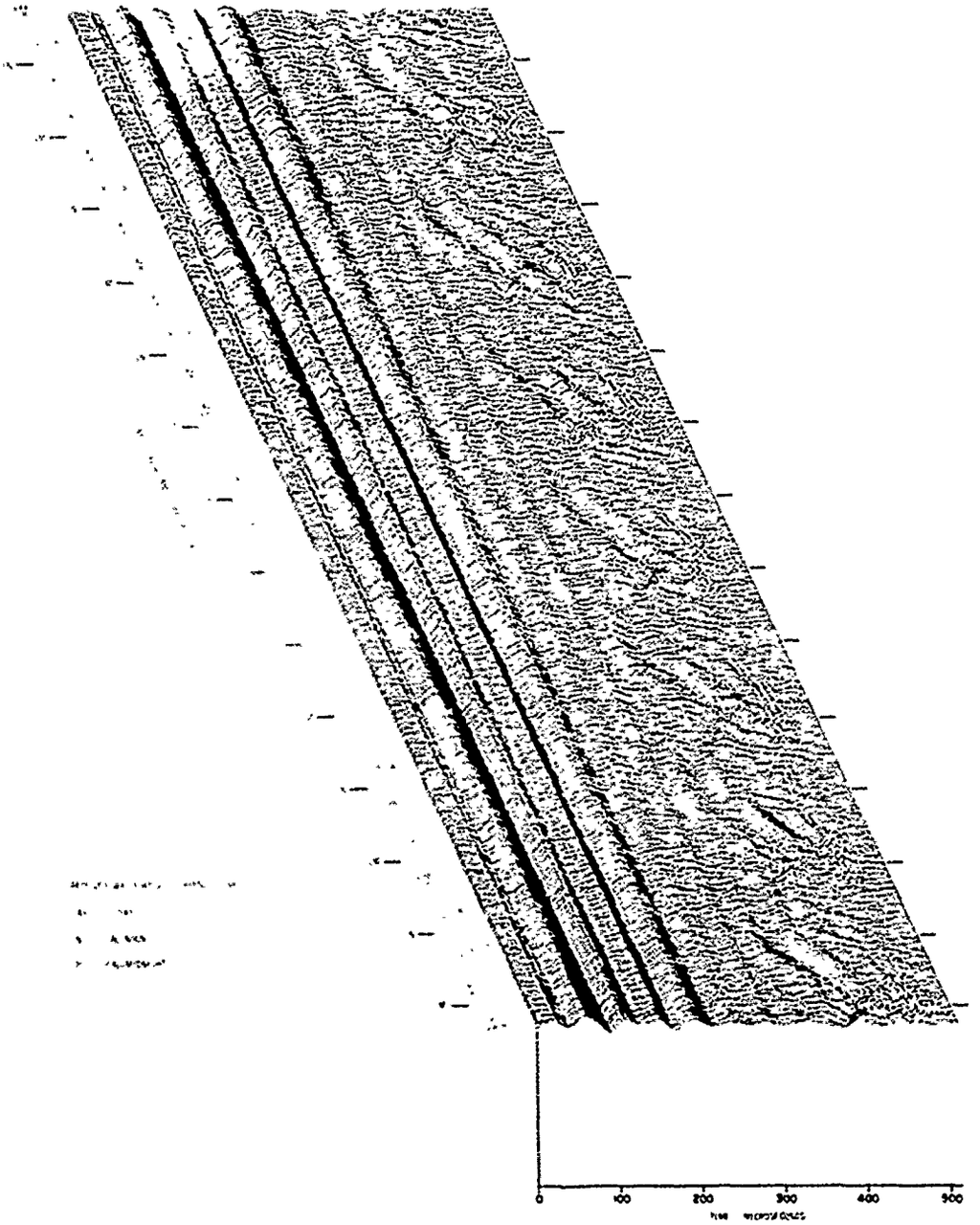

Figure 22. VLF/LF Reflectivity Data for the Polar Ionosphere, DAY 137 (16 May) - DAY 143 (22 May) 1976 (Cont) Part S. ⊥ Waveform Display

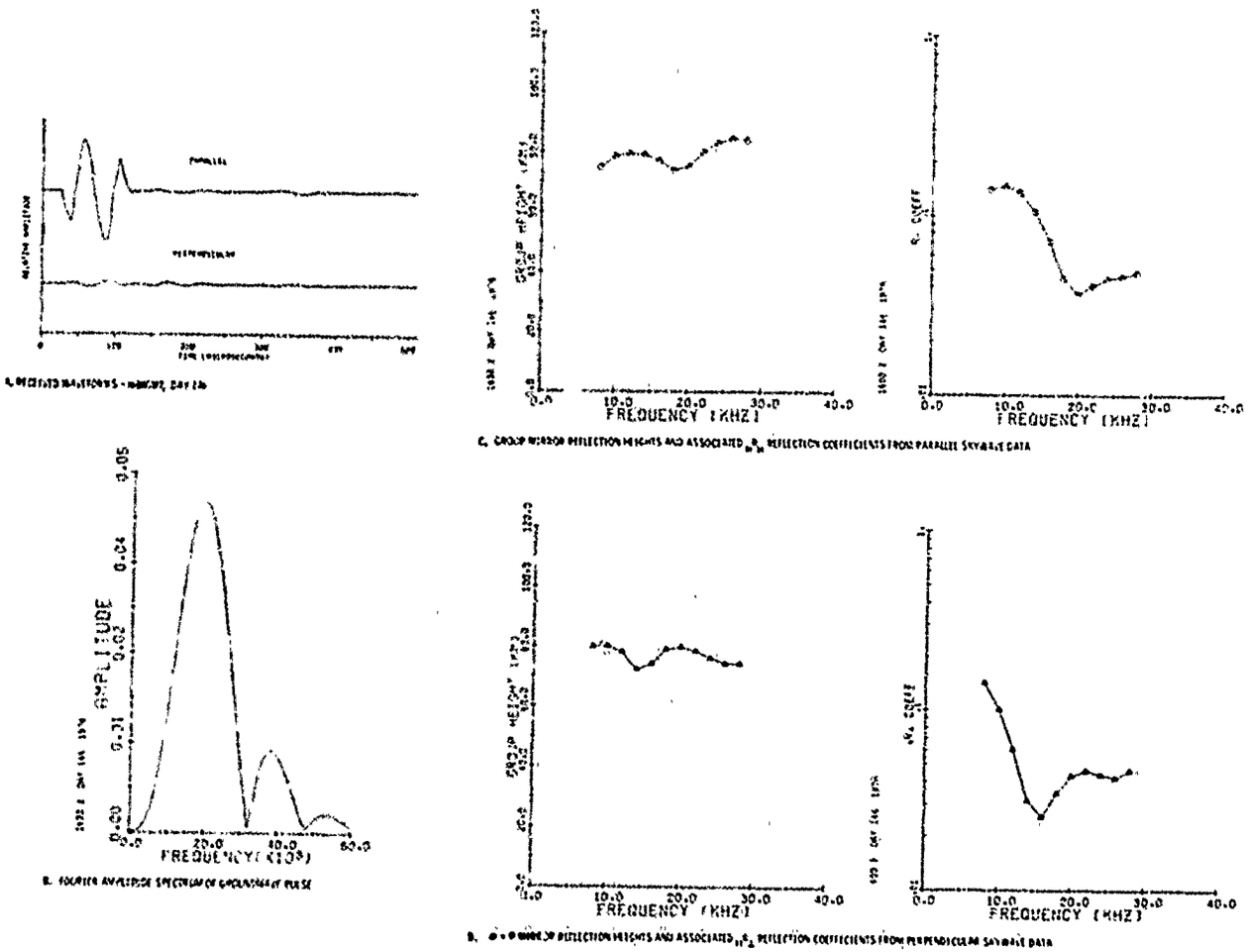

Figure 23. VLF/LF Reflectivity Data for the Polar Ionosphere, DAY 144 (23 May) — DAY 150 (29 May) 1976

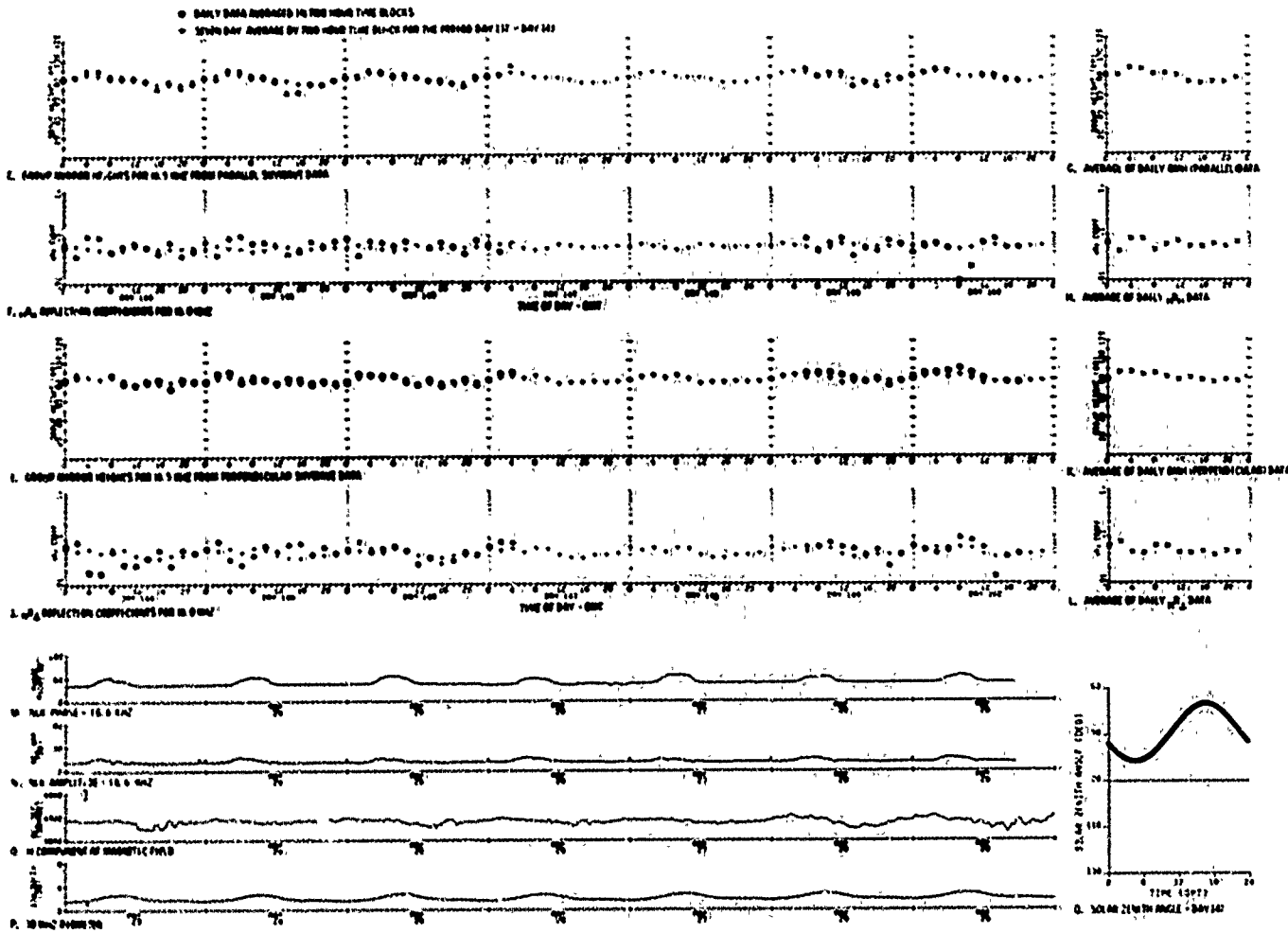

Figure 23. VLF/LF Reflectivity Data for the Polar Ionosphere, DAY 144 (23 May) — DAY 150 (29 May) 1976 (Cont)

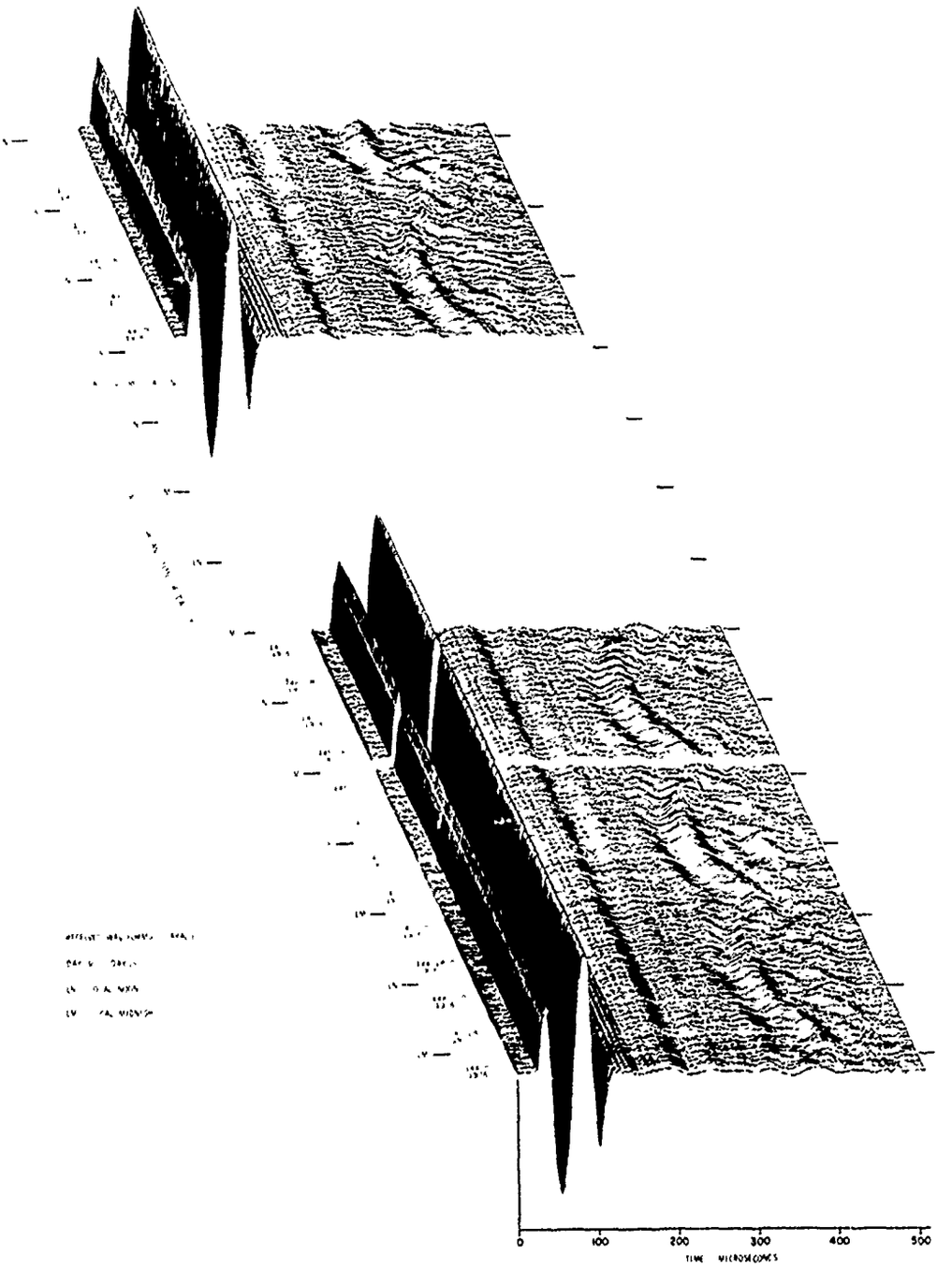

Figure 23. VLF/LF Reflectivity Data for the Polar Ionosphere, DAY 144 (23 May) – DAY 150 (29 May) 1976 (Cont) Part R. || Waveform Display

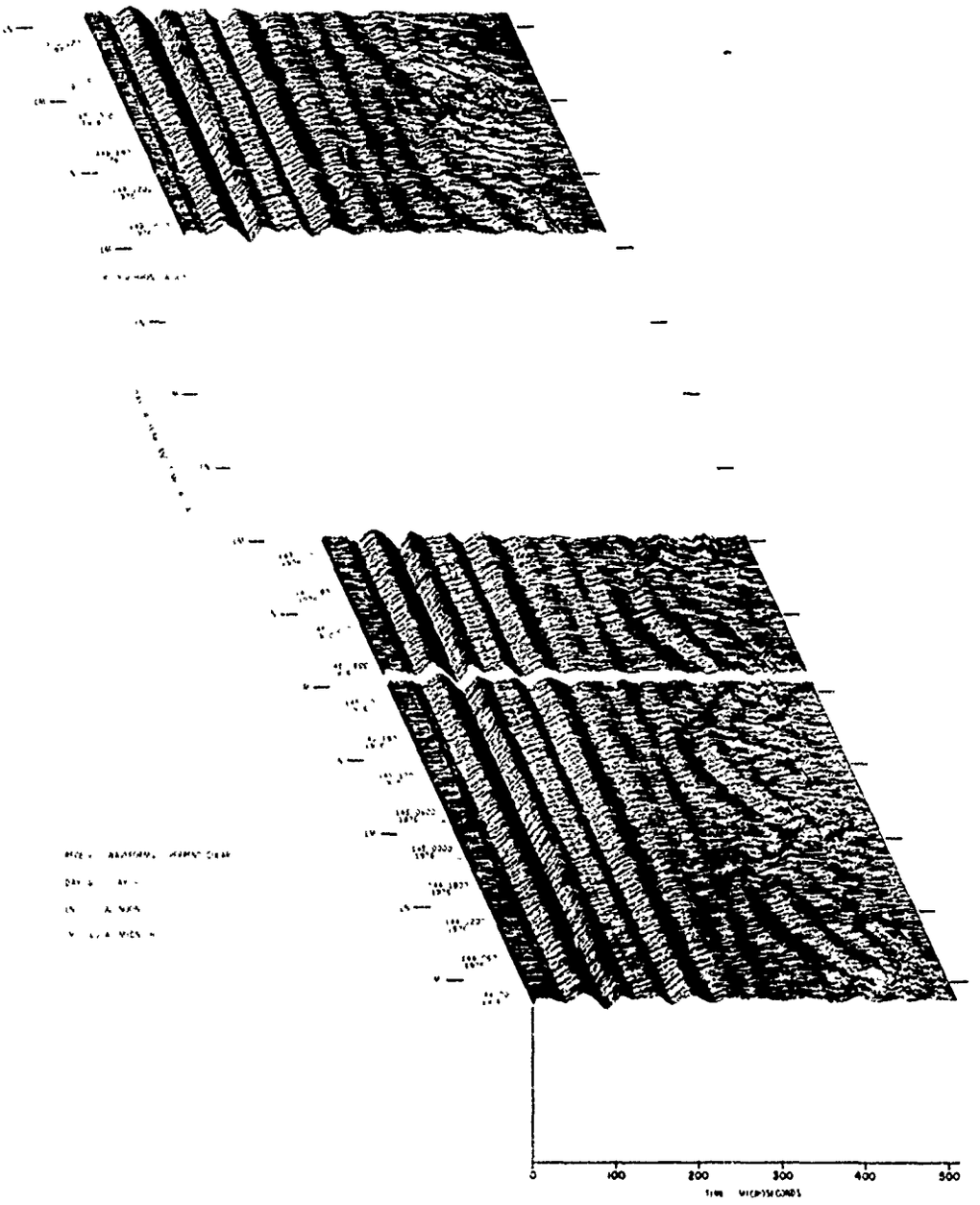

Figure 23. VLF/LF Reflectivity Data for the Polar Ionosphere, DAY 144 (23 May) - DAY 150 (29 May) 1976 (Cont) Part S. ⊥ Waveform Display

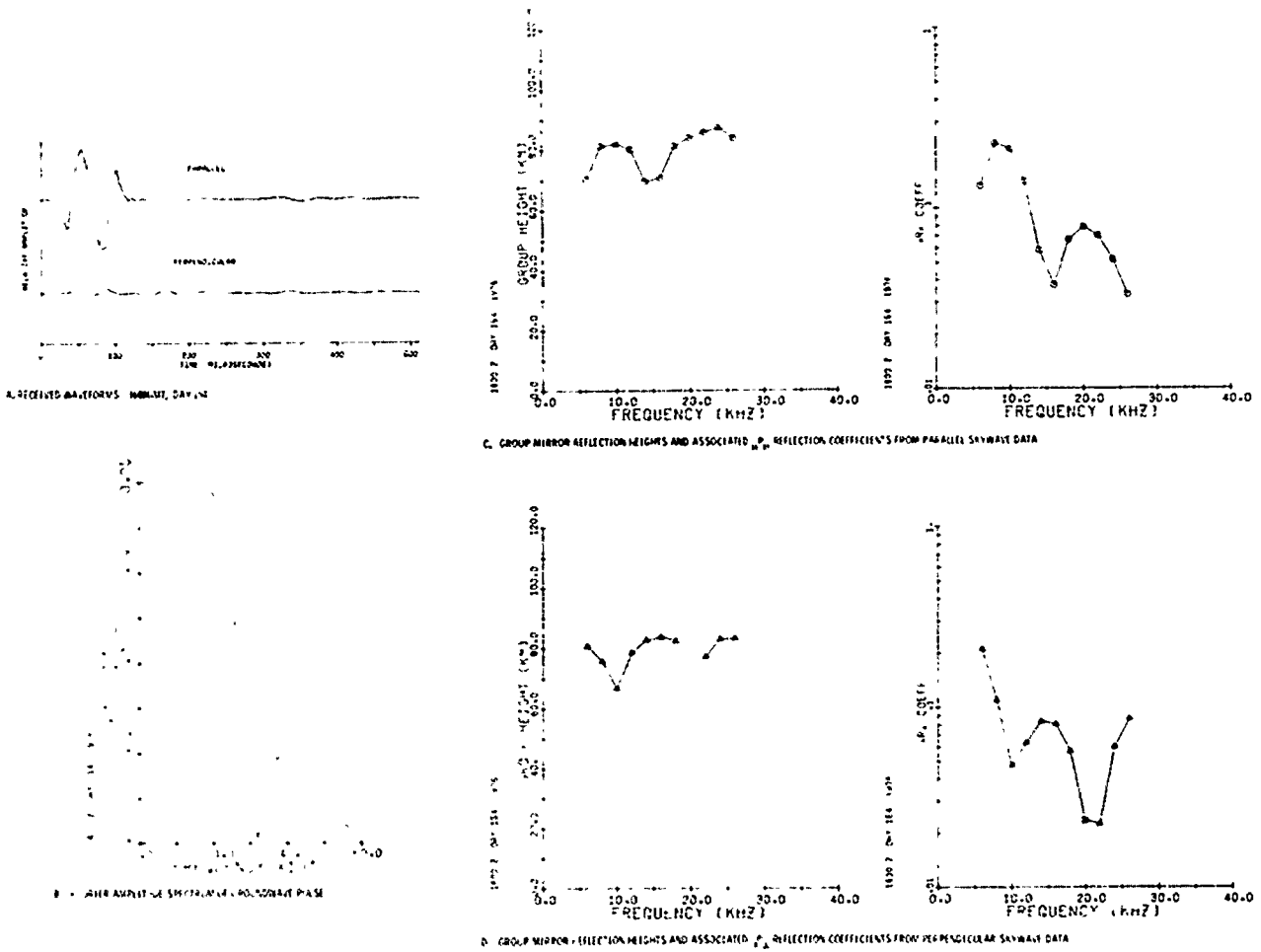

Figure 24. VLF/LF Reflectivity Data for the Polar Ionosphere, DAY 151 (30 May) — DAY 157 (5 Jun) 1976

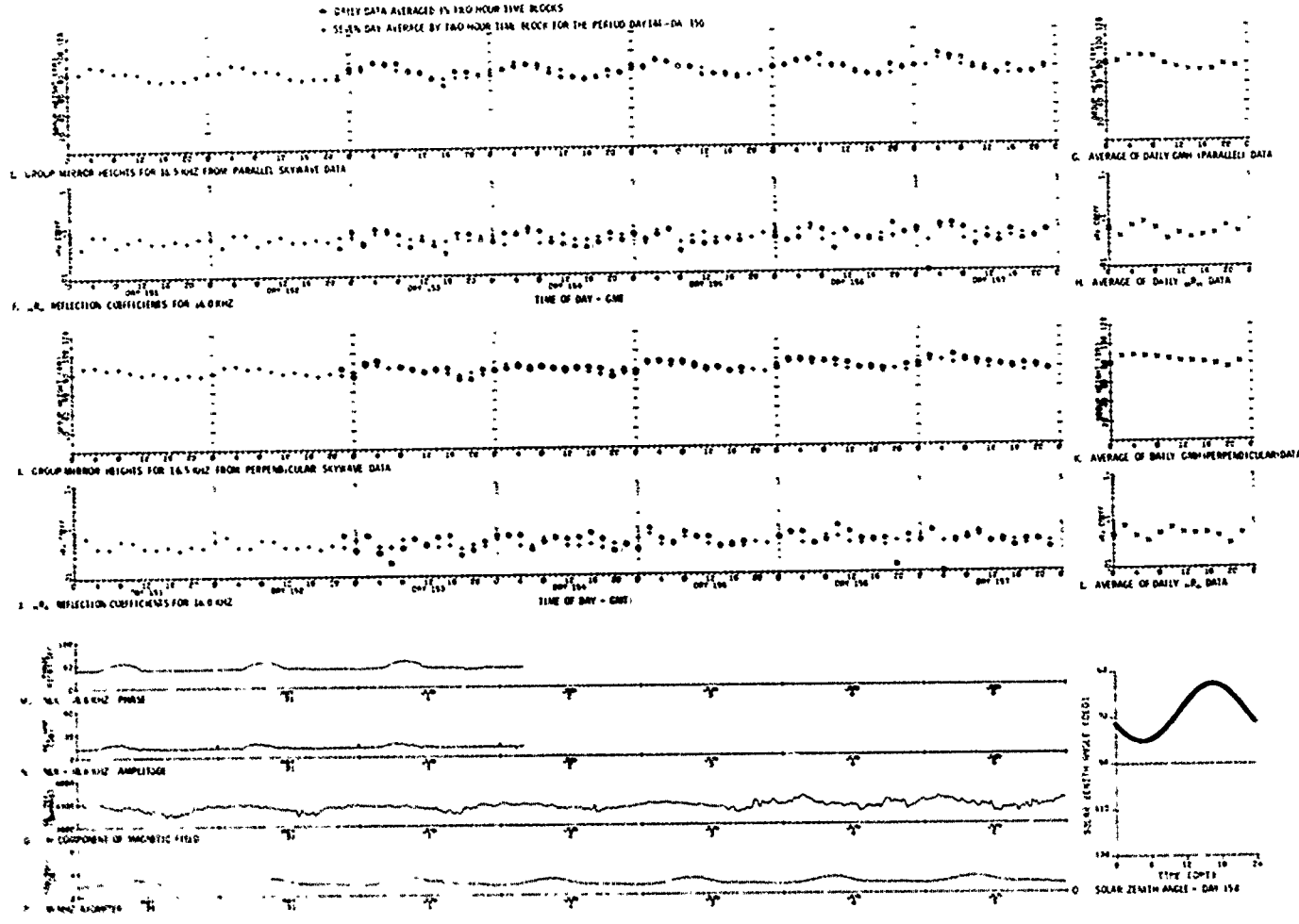

Figure 24. VLF/LF Reflectivity Data for the Polar Ionosphere, DAY 151 (30 May) — DAY 157 (5 Jun) 1976 (Cont)

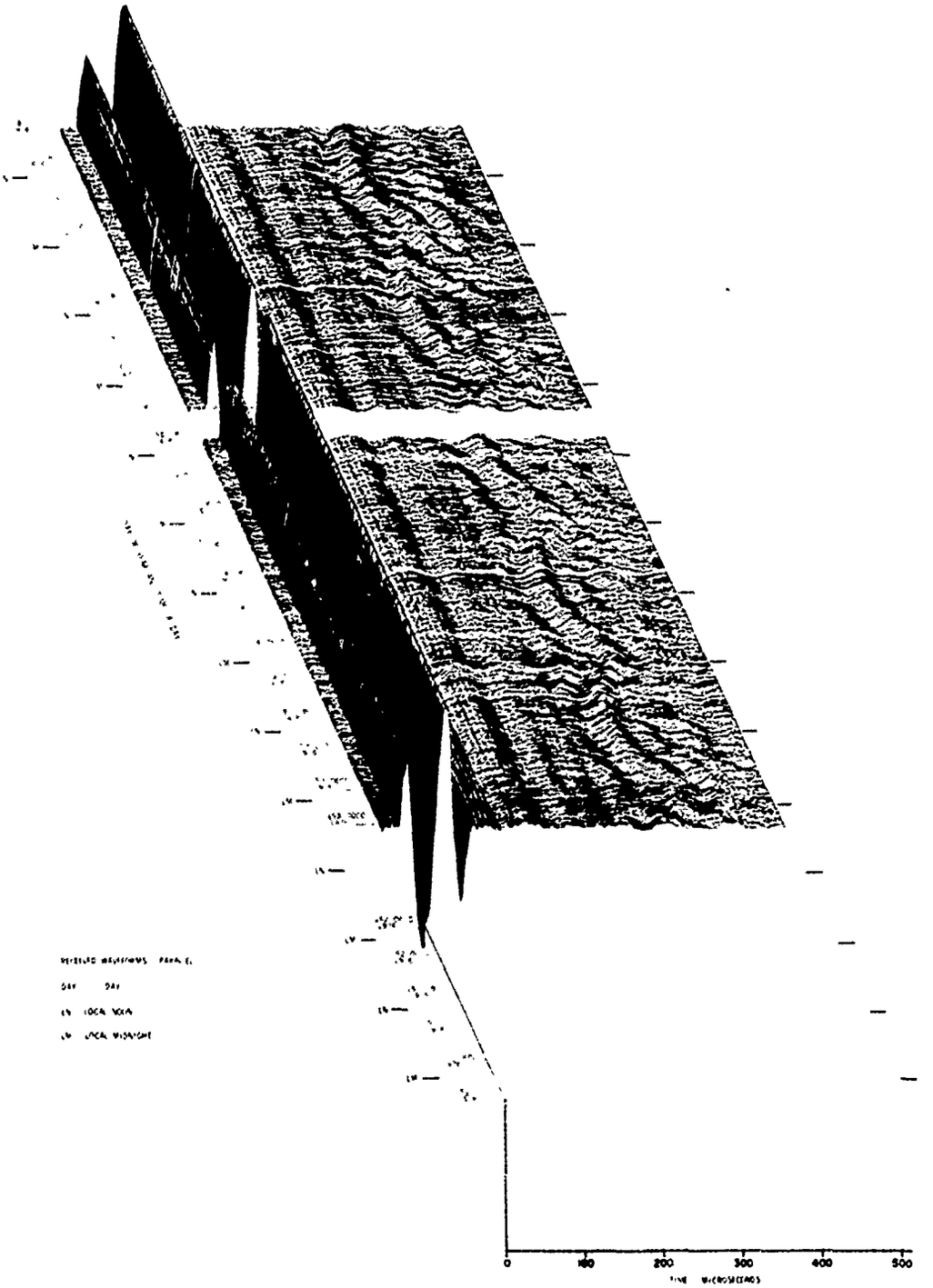

Figure 24. VLF/LF Reflectivity Data for the Polar Ionosphere, DAY 151 (30 May) - DAY 157 (5 Jun) 1976 (Cont) Part R. || Waveform Display

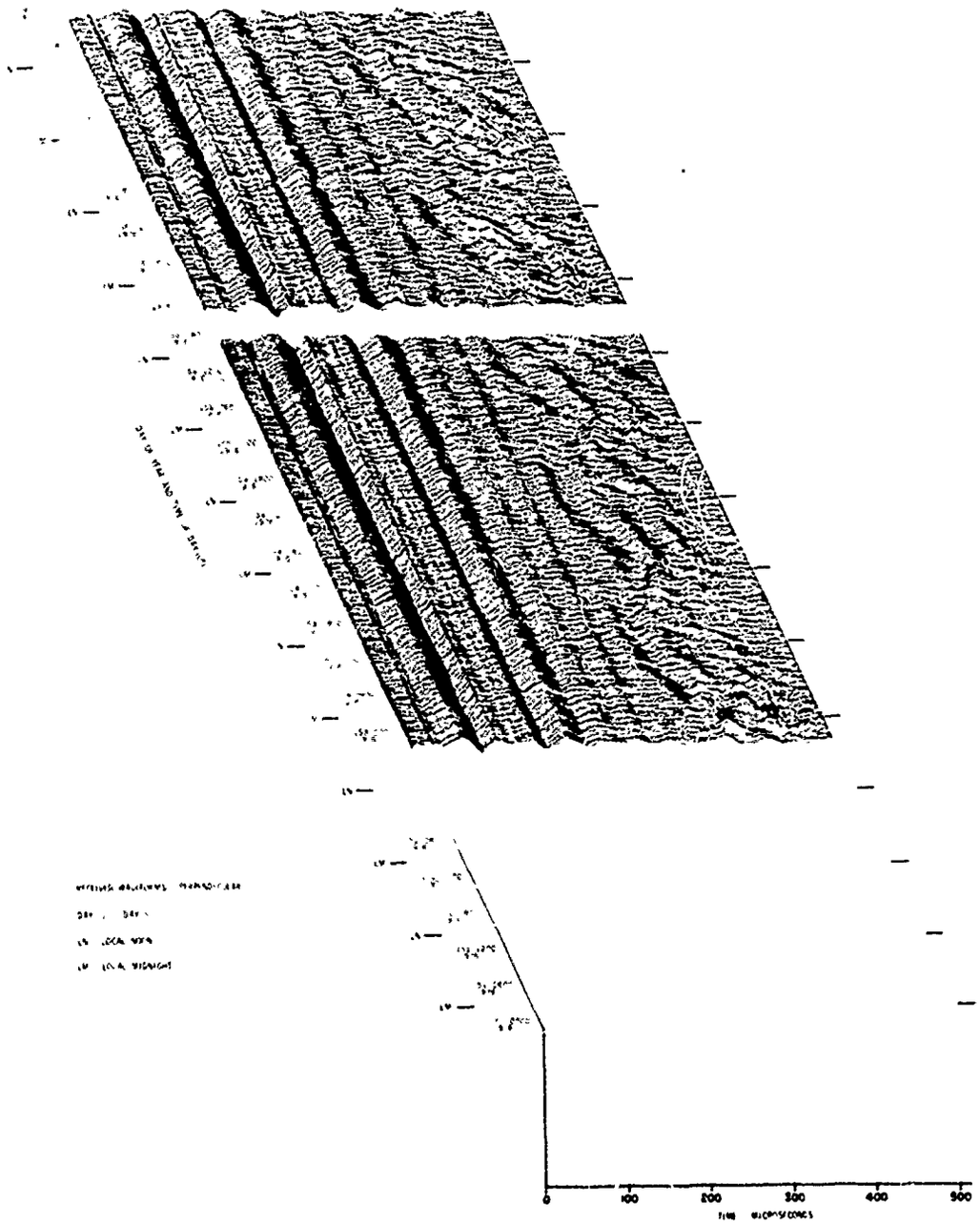

Figure 24. VLF/LF Reflectivity Data for the Polar Ionosphere, DAY 151 (30 May) - DAY 157 (4 Jun) 1976 (Cont Part S. ⊥ Waveform Display

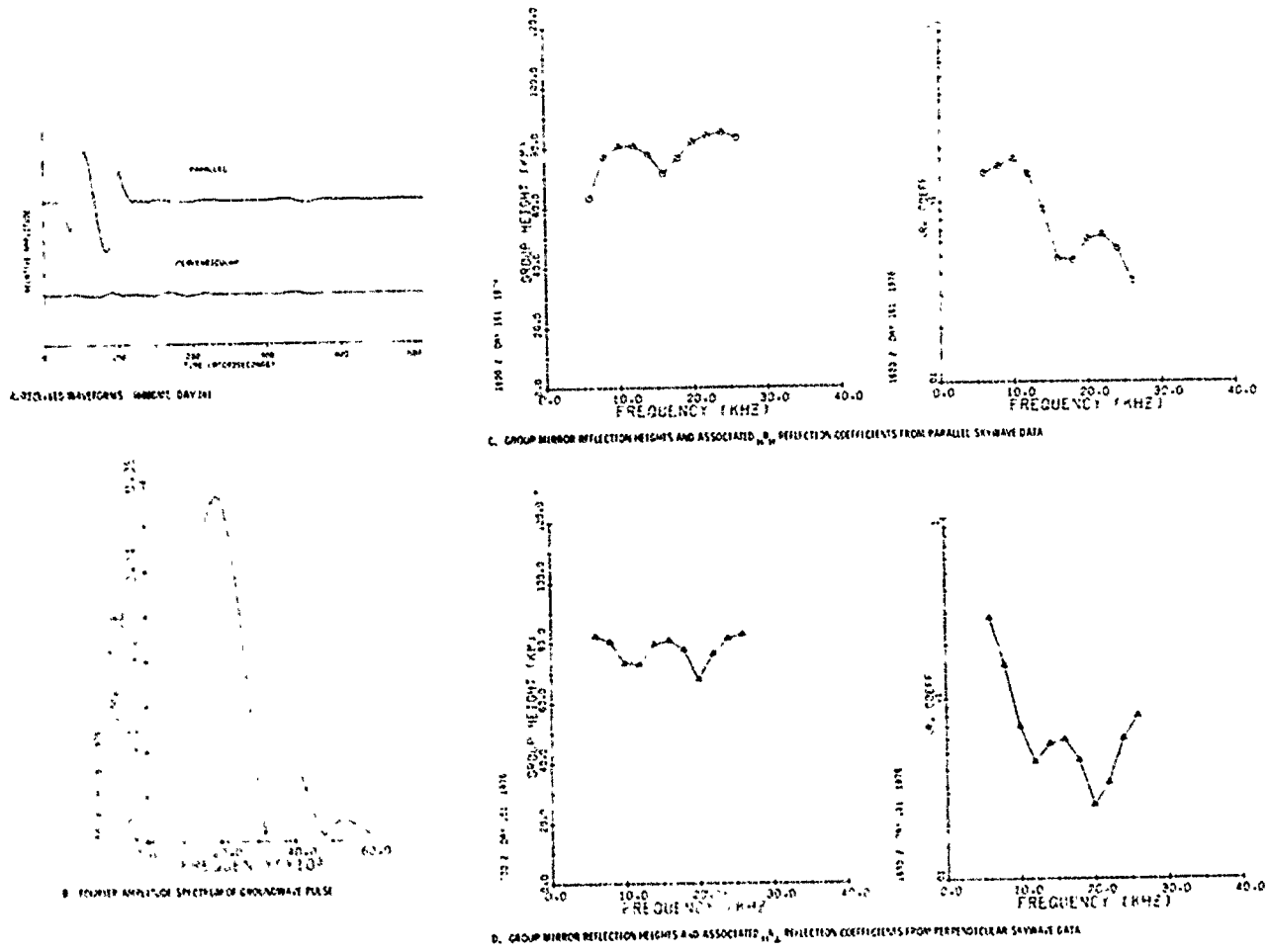

Figure 25. VLF/LF Reflectivity I[illegible] for the Polar Ionosphere, DAY 158 (6 Jun) — DAY 164 (12 Jun) 1976

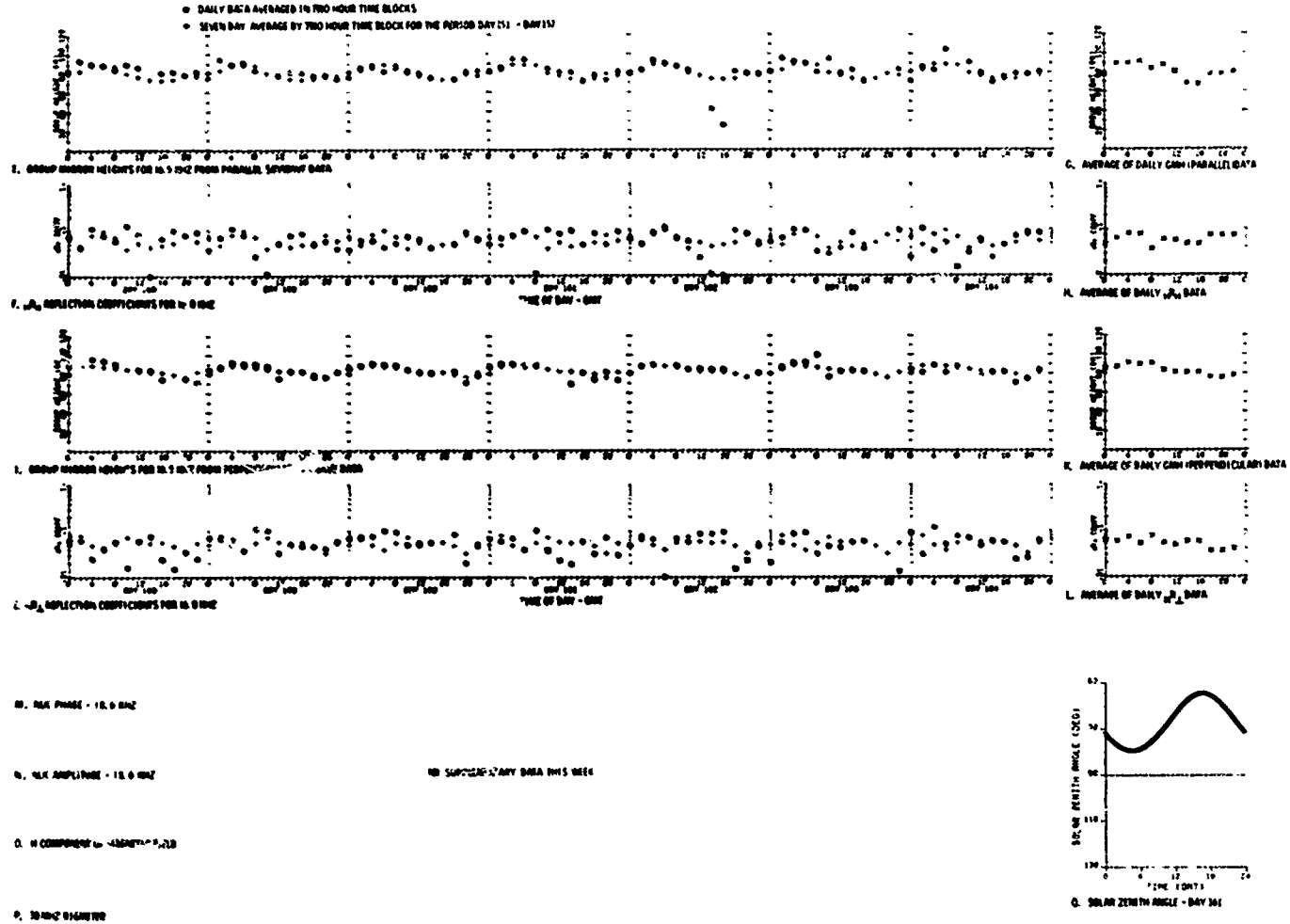

Figure 25. VLF/LF Reflectivity Data for the Polar Ionosphere, DAY 158 (6 Jun) — DAY 164 (12 Jun) 1976 (Cont)

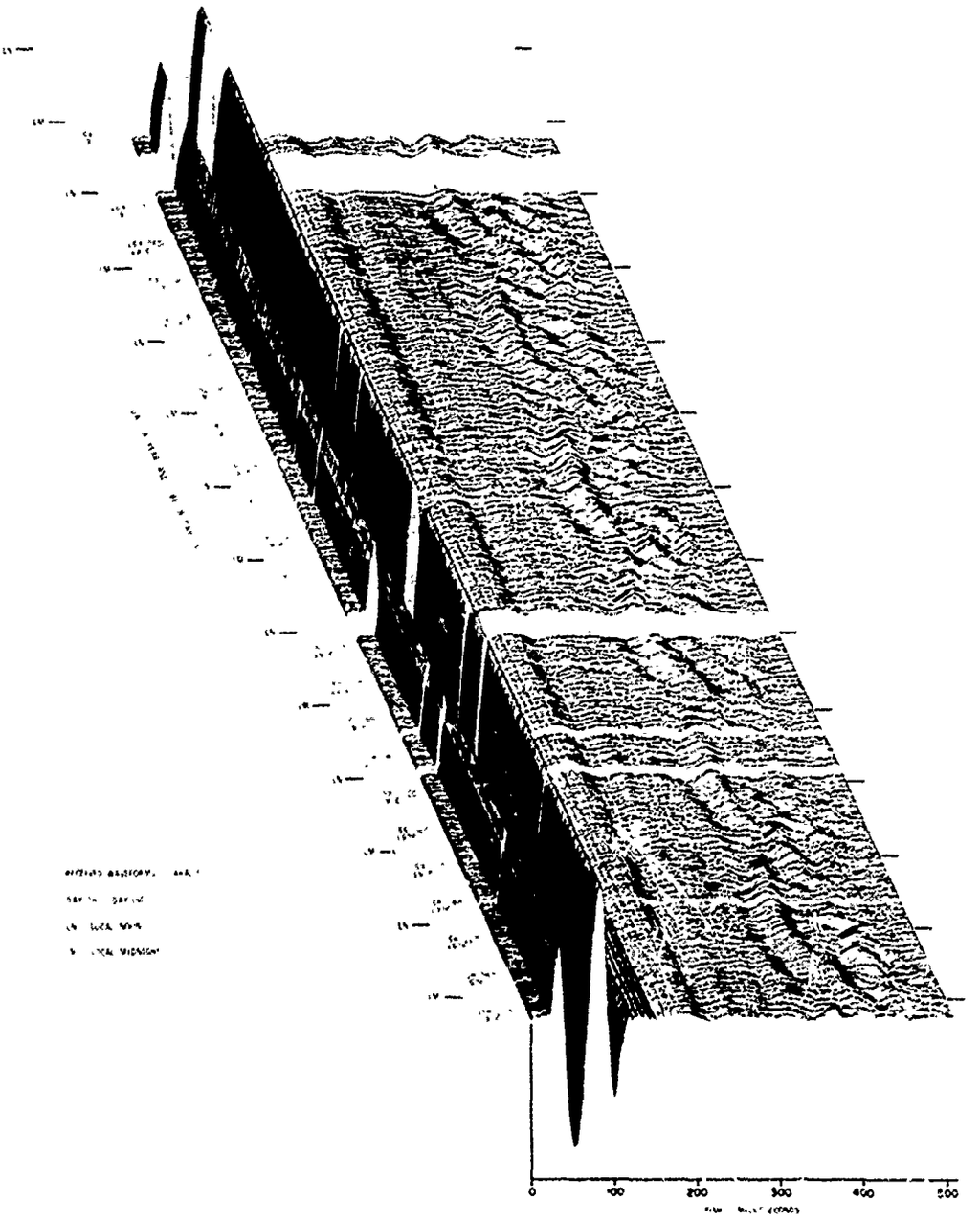

Figure 25. VLF/LF Reflectivity Data for the Polar Ionosphere, DAY 158 (6 Jun) – DAY 164 (12 Jun) 1976 (Cont) Part R. || Waveform Display

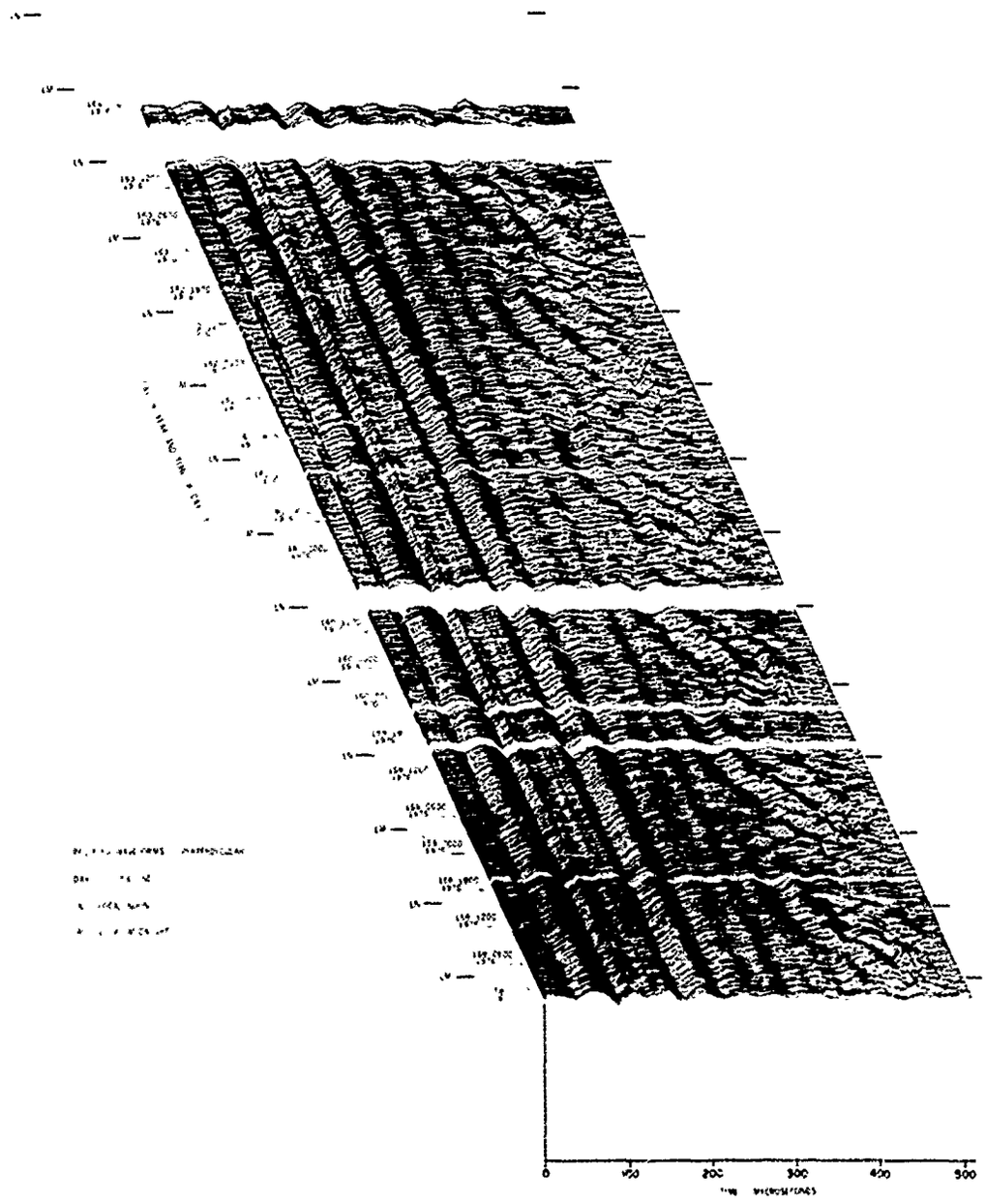

Figure 25. VLF/LF Reflectivity Data for the Polar Ionosphere, DAY 158 (6 Jun) - DAY .64 (12 Jun) 1976 (Cont) Part S. ⊥ Waveform Display

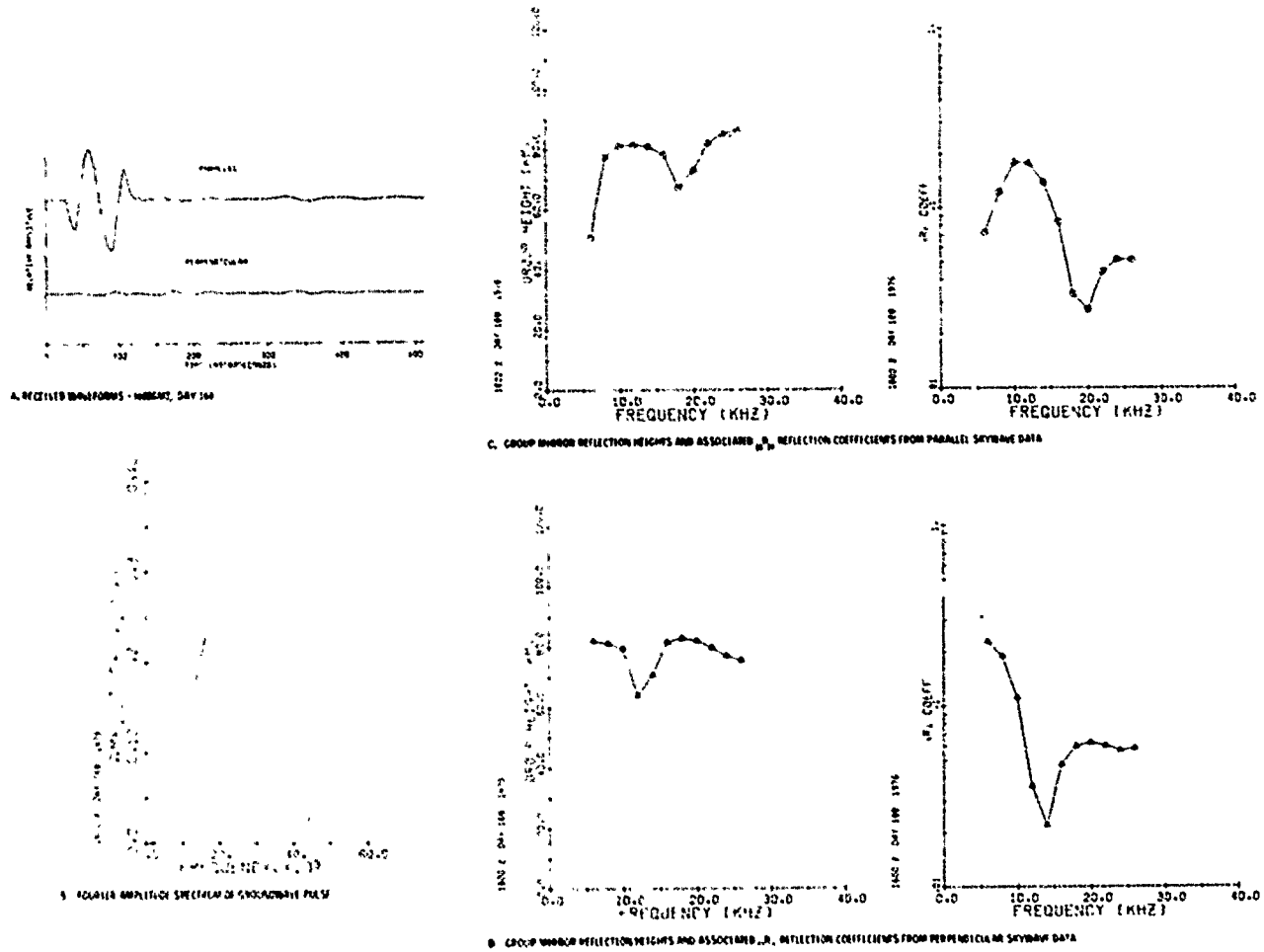

Figure 26. VLF/LF Reflectivity Data for the Polar Ionosphere, DAY 165 (13 Jun) — DAY 171 (19 Jun) 1976

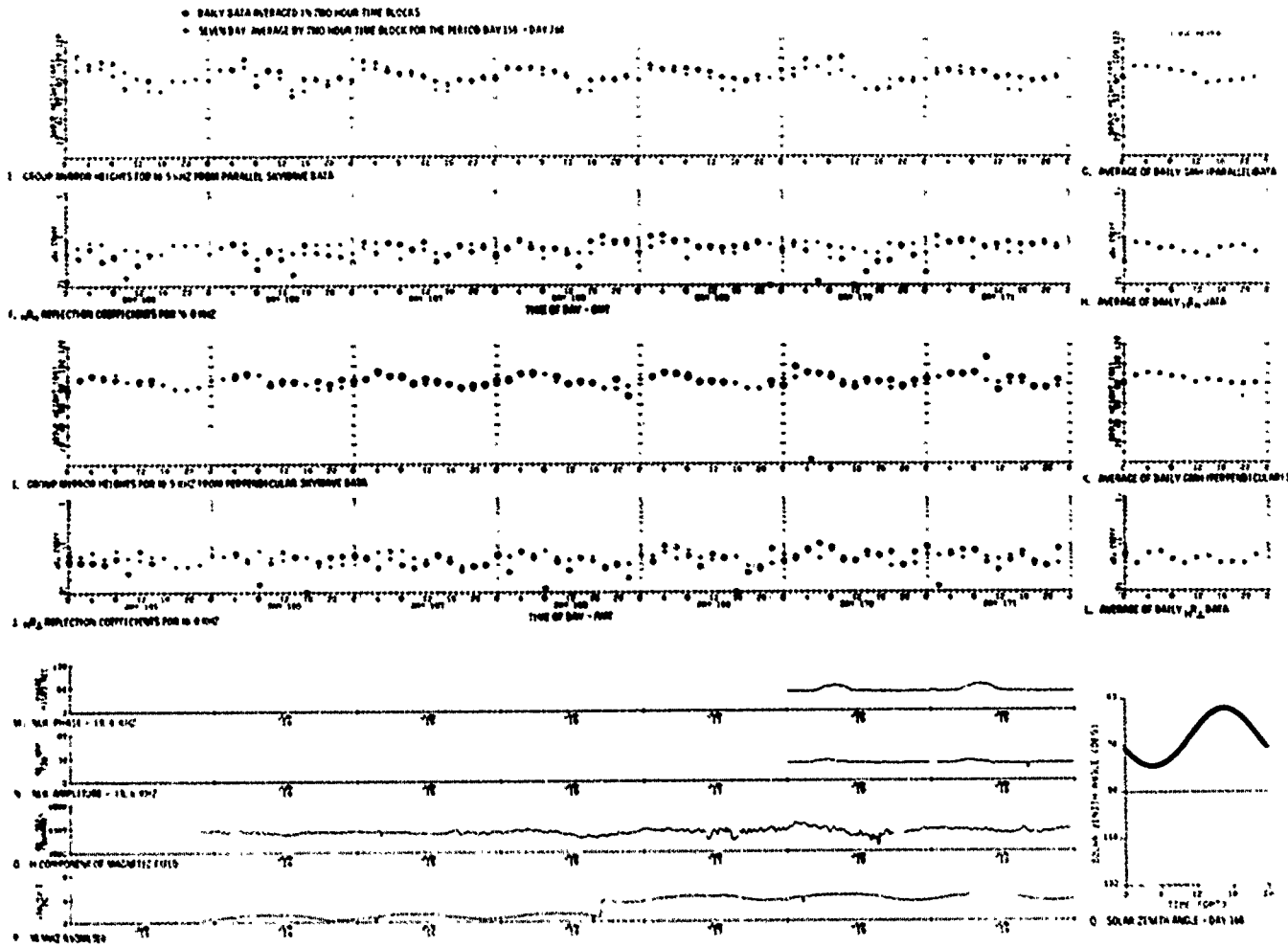

Figure 26. VLF/LF Reflectivity Data for the Polar Ionosphere, DAY 165 (13 Jun) — DAY 171 (19 Jun) 1976 (Cont)

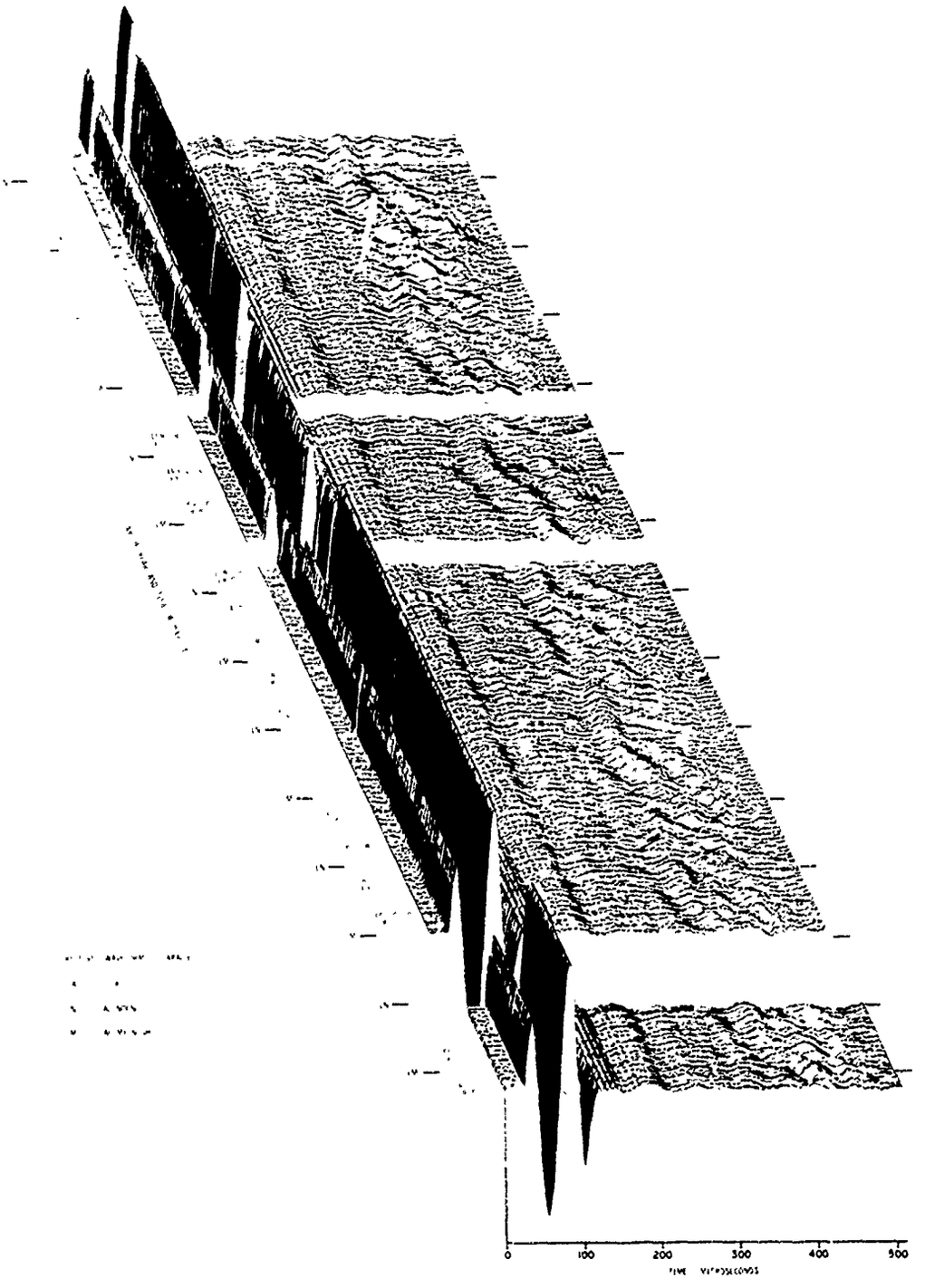

Figure 26. VLF/LF Reflectivity Data for the Polar Ionosphere, DAY 165 (13 Jun) - DAY 171 (19 Jun) 1976 (Cont) Part R. || Waveform Display

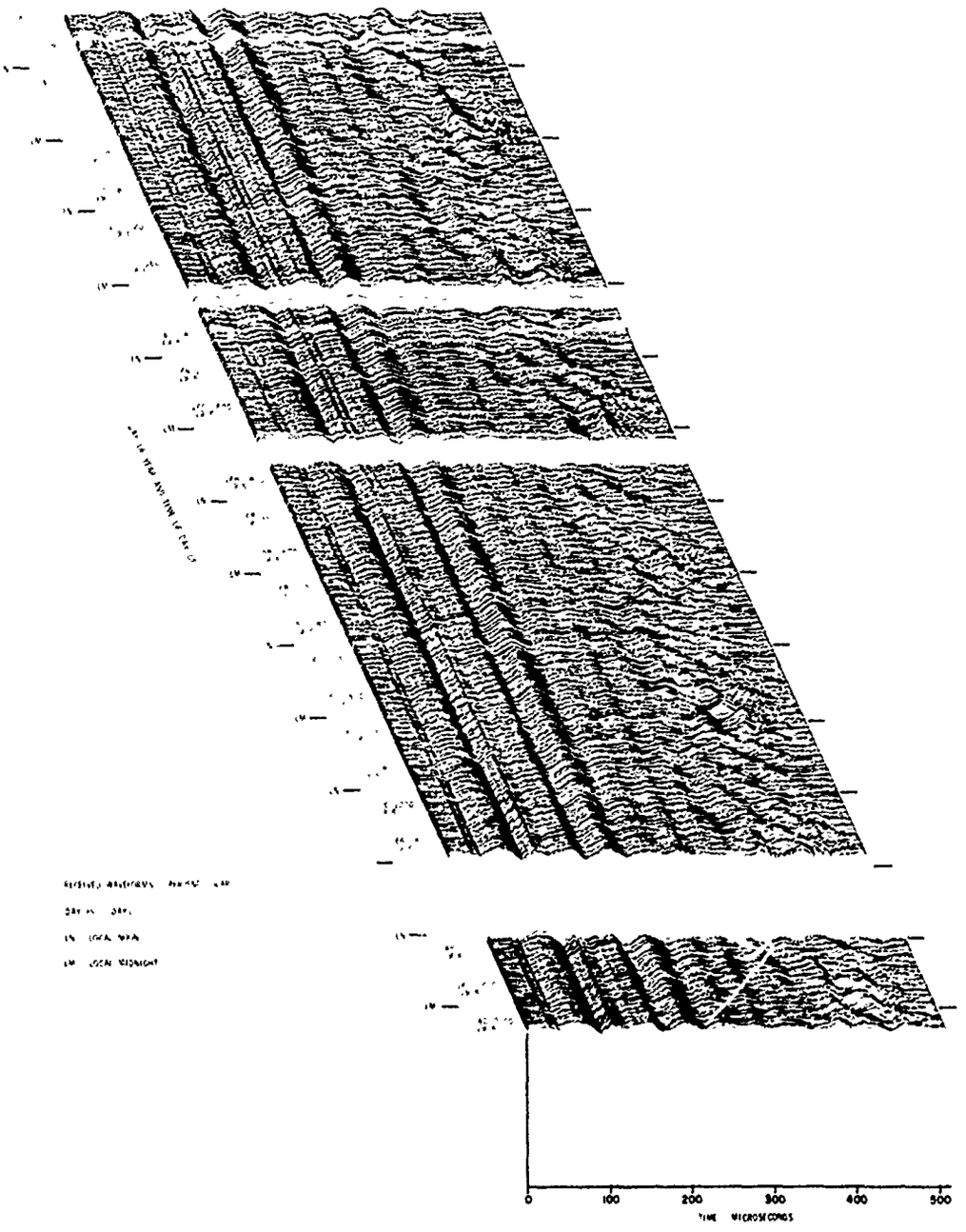

Figure 26. VLF/LF Reflectivity Data for the Polar Ionosphere, DAY 165 (13 Jun) - DAY 171 (19 Jun) 1976 (Cont) Part S. ⊥ Waveform Display

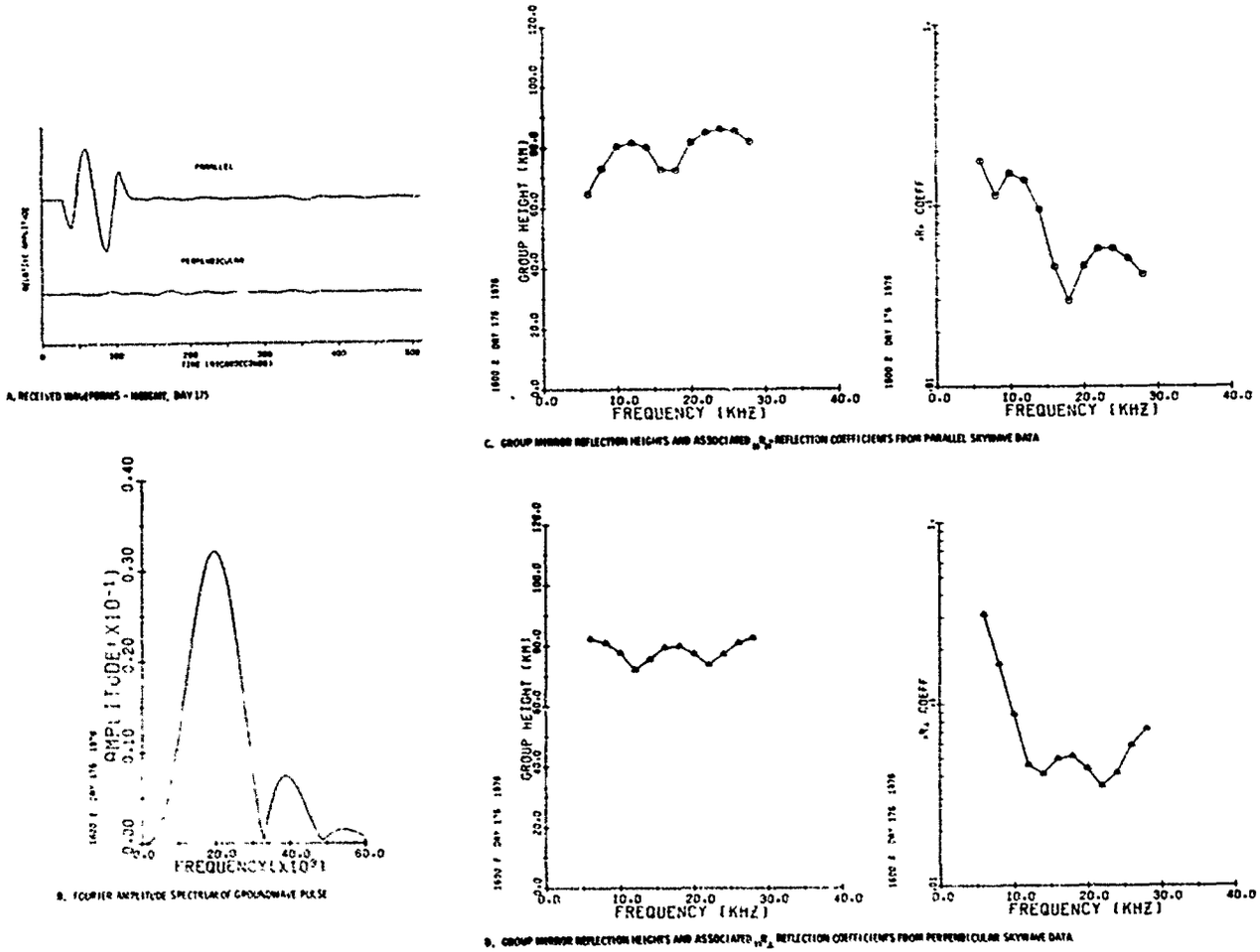

Figure 27. VLF/LF Reflectivity Data for the Polar Ionosphere, DAY 172 (20 Jun) — DAY 178 (26 Jun) 1976

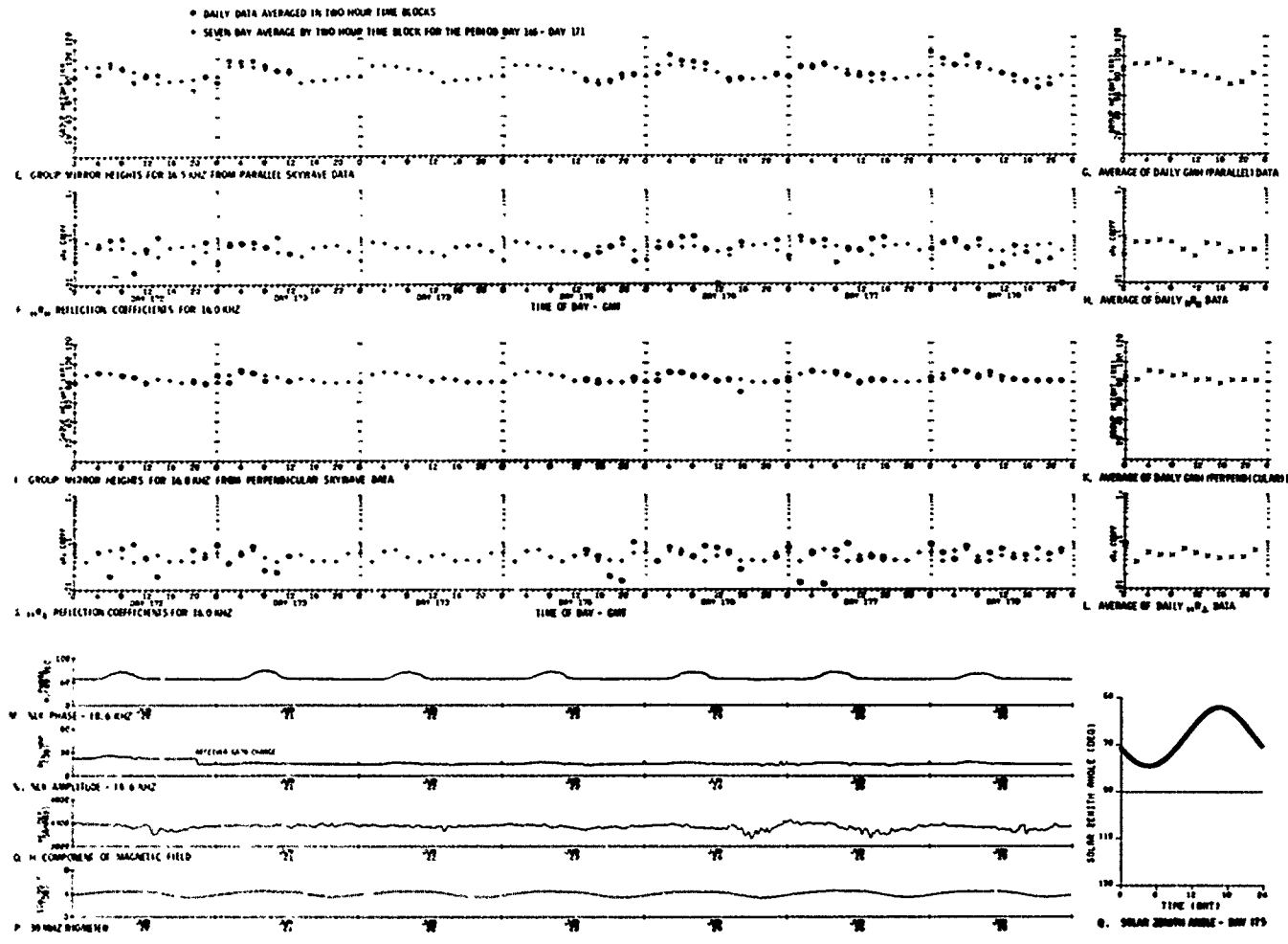

Figure 27. VLF/LF Reflectivity Data for the Polar Ionosphere, DAY 172 (20 Jun) — DAY 178 (26 Jun) 1976 (Cont)

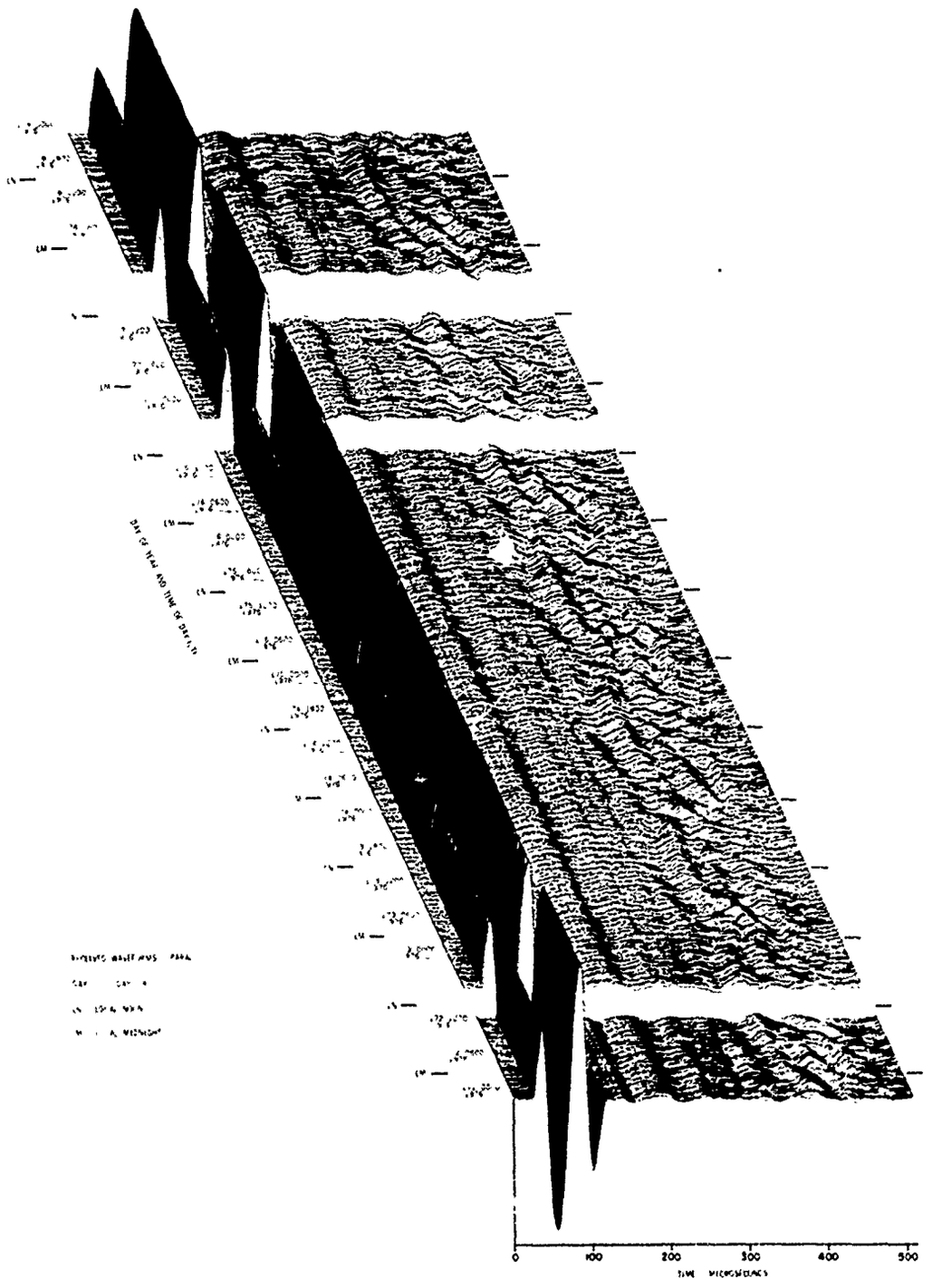

Figure 27. VLF/LF Reflectivity Data for the Polar Ionosphere, DAY 172 (20 Jun) - DAY 178 (26 Jun) 1976 (Cont) Part R. || Waveform Display

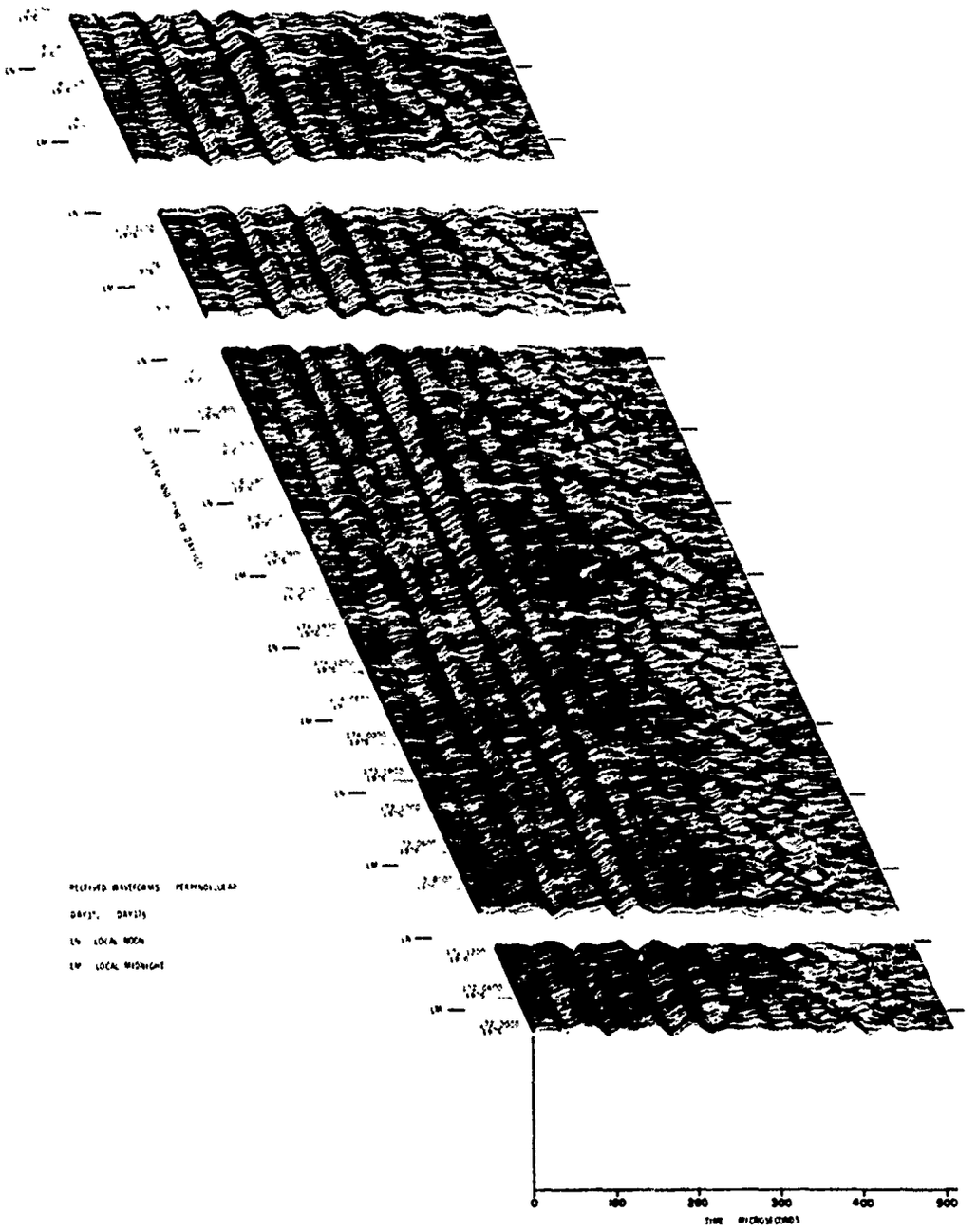

Figure 27. VLF/LF Reflectivity Data for the Polar Ionosphere, DAY 172 (20 Jun) - DAY 178 (26 Jun) 1976 (Cont) Part S. ⊥ Waveform Display

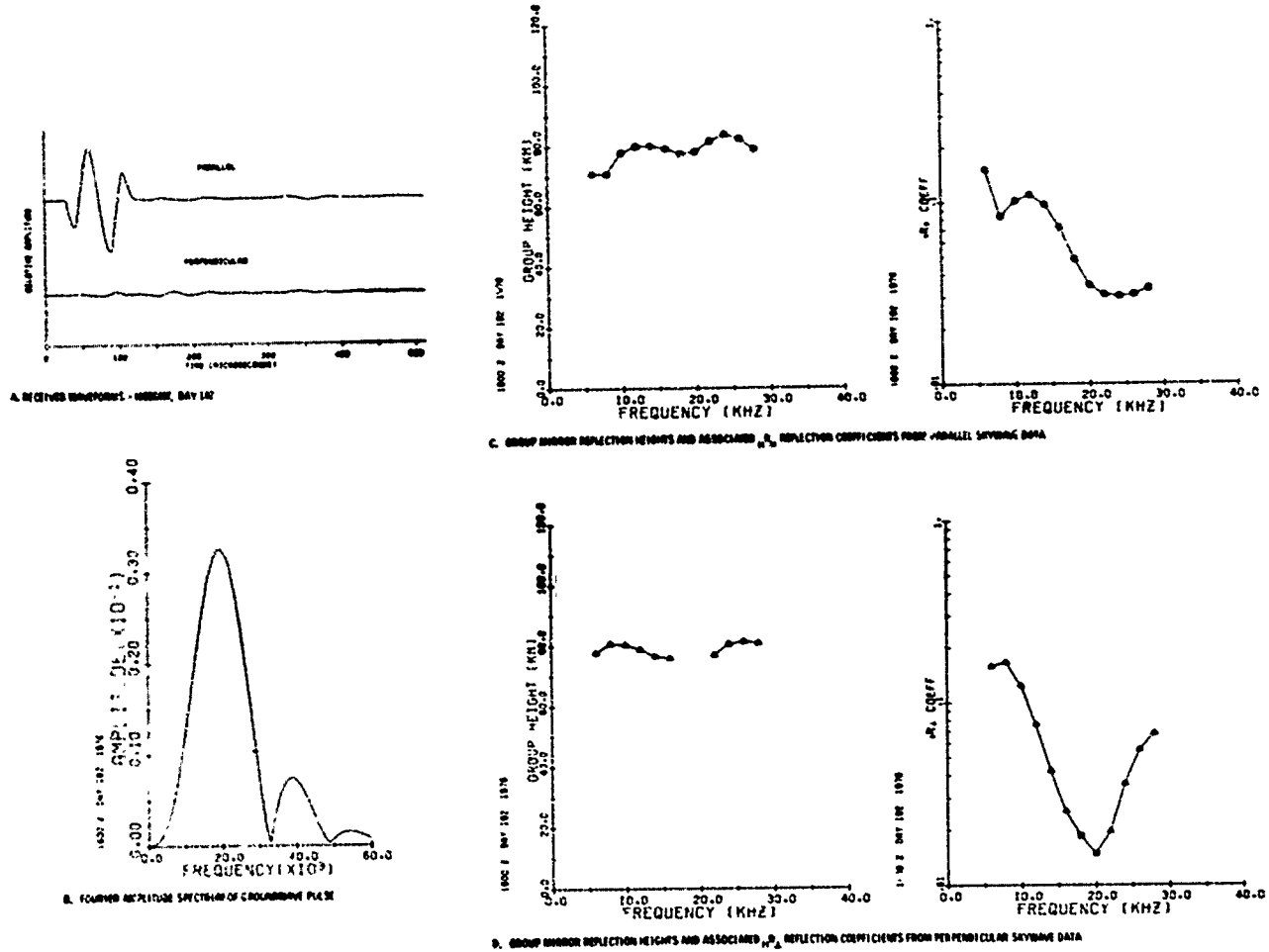

Figure 28. VLF/LF Reflectivity Data for the Polar Ionosphere, DAY 179 (27 Jun) — DAY 185 (3 Jul) 1976

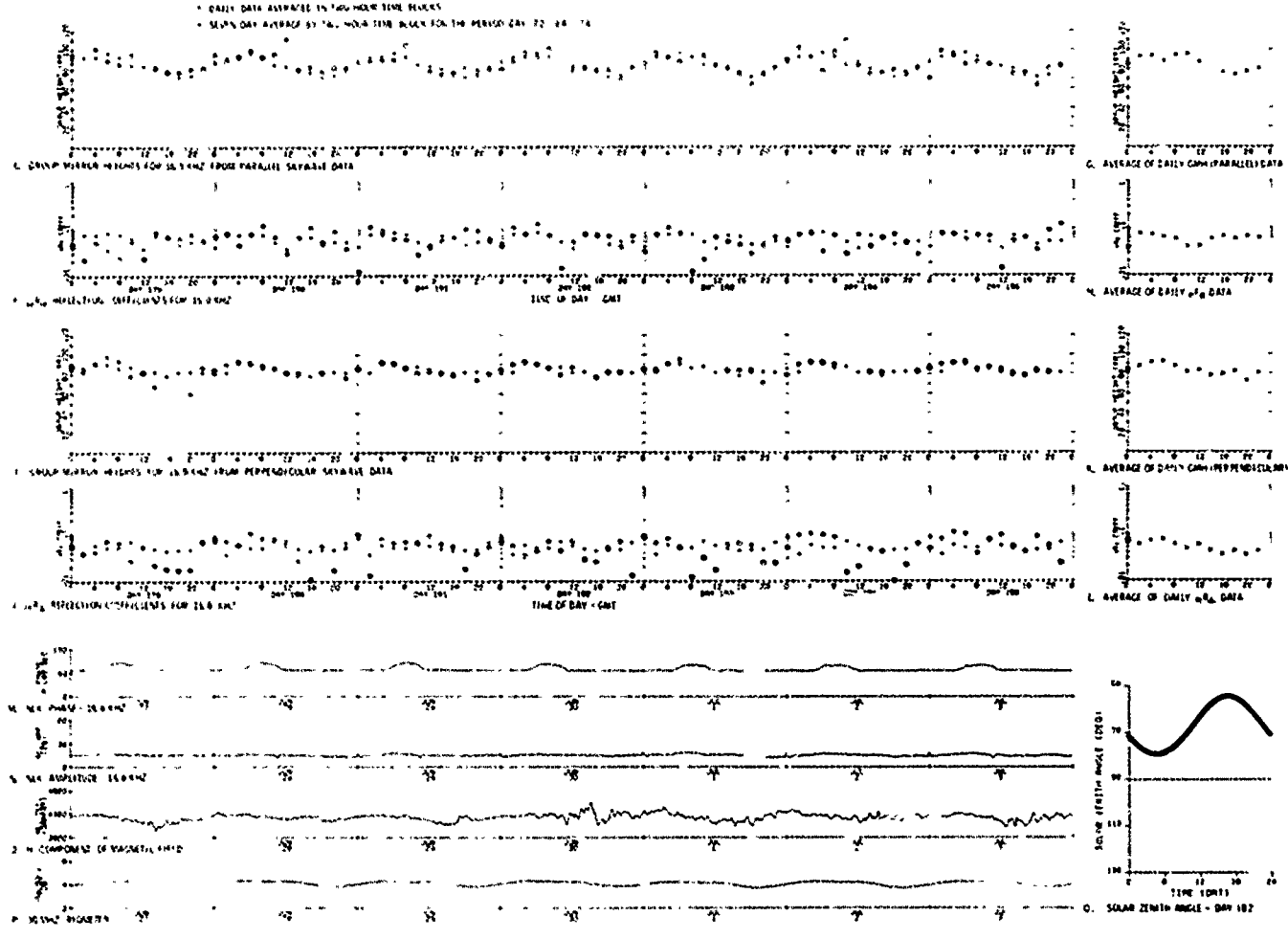

Figure 28. VLF/LF Reflectivity Data for the Polar Ionosphere, DAY 179 (27 Jun) — DAY 185 (3 Jul) 1976 (Cont)

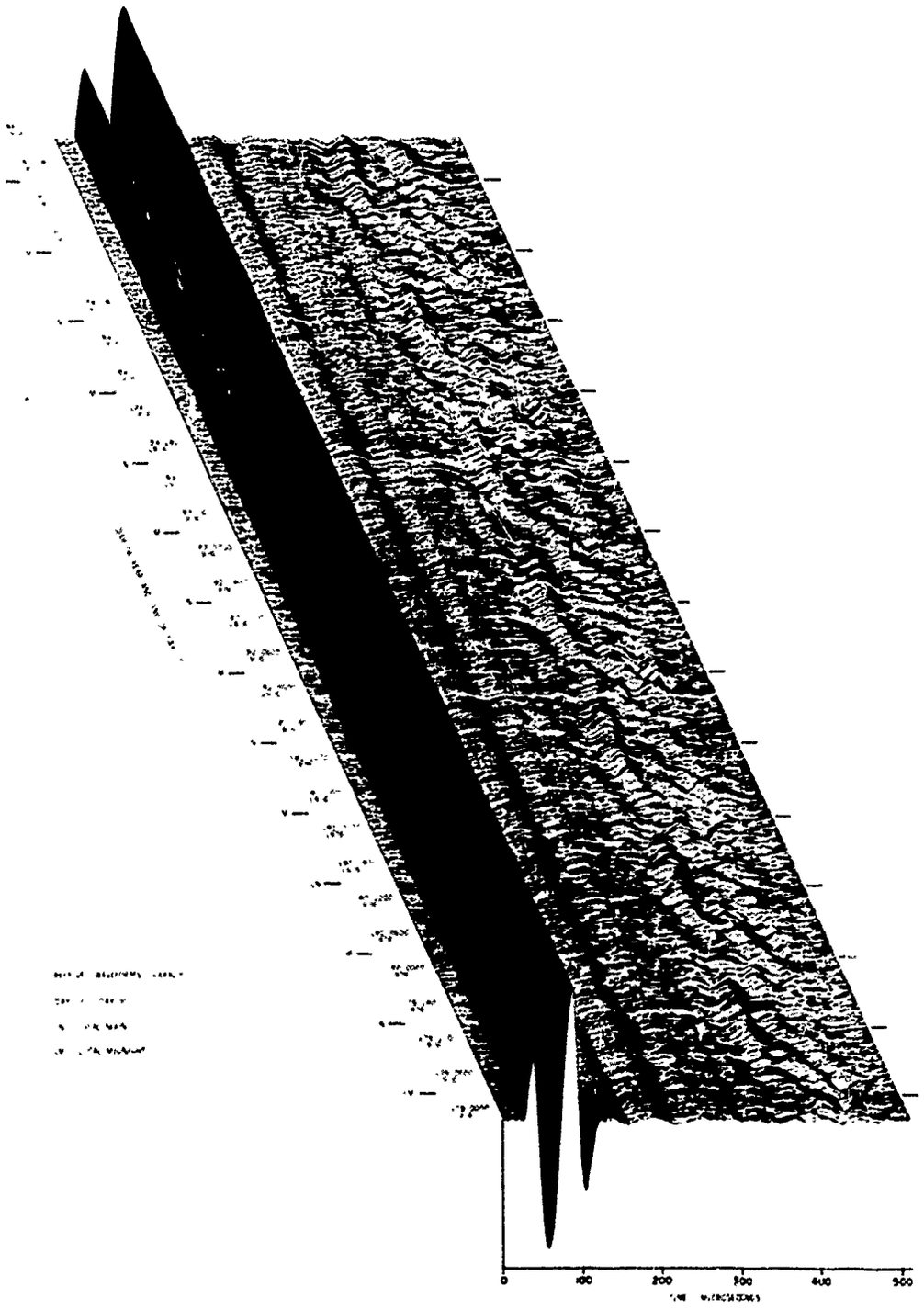

Figure 26. VLF/LF Reflectivity Data for the Polar Ionosphere, DAY 179 (27 Jun) - DAY 185 (3 Jul) 1976 (Cont) Part R. || Waveform Display

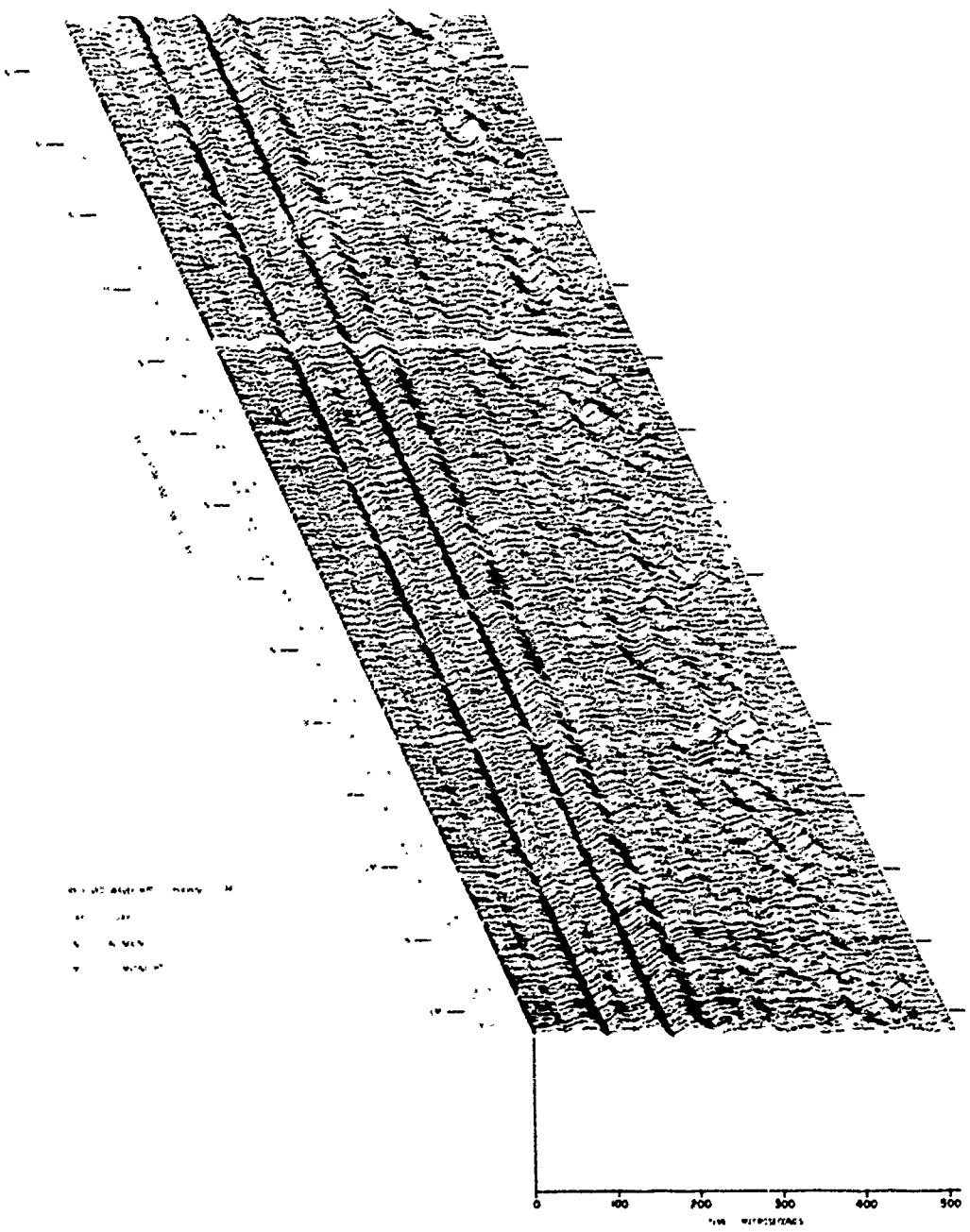

Figure 28. VLF/LF Reflectivity Data for the Polar Ionosphere, DAY 179 (27 Jun) - DAY 185 (3 Jul) 1976 (Cont) Part S. ⊥Waveform Display

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