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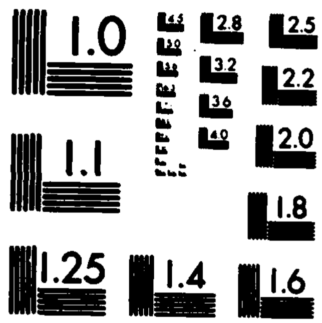
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NUSC Technical Report 7079
11 January 1984

AD A137385

Connecticut ELF Field Strength Measurements, March to May 1978

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Submarine Electromagnetic
Systems Department

Naval Underwater Systems Center
Newport, Rhode Island / New London, Connecticut

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Preface

This report was prepared under NUSC Project No. A59007, "ELF Propagation RDT&E" (U), Principal Investigator, P. R. Bannister (Code 3411), Navy Program Element No. 11401N and Project No. X0792-SB, Naval Electronic Systems Command, Communications Systems Project Office, D. Dyson (Code PME-110), Program Manager ELF Communication Dr. B. Kruger (Code PME-110-X1).

The Technical Reviewer for this report was Raymond F. Ingram.

Reviewed and Approved: 11 January 1984

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REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER: TR 7079

2. GOVT ACCESSION NO.: AD-A137 385

3. RECIPIENT'S CATALOG NUMBER:

4. TITLE (and Subtitle): CONNECTICUT ELF FIELD STRENGTH MEASUREMENTS, MARCH TO MAY 1978

5. TYPE OF REPORT & PERIOD COVERED:

6. PERFORMING ORG. REPORT NUMBER:

7. AUTHOR(s): Peter R. Bannister

8. CONTRACT OR GRANT NUMBER(s):

9. PERFORMING ORGANIZATION NAME AND ADDRESS: Naval Underwater Systems Center, New London Laboratory, New London, Connecticut 06320

10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: A59007

11. CONTROLLING OFFICE NAME AND ADDRESS:

12. REPORT DATE: 11 January 1984

13. NUMBER OF PAGES:

14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office):

15. SECURITY CLASS. (of this report): UNCLASSIFIED

15a. DECLASSIFICATION/DOWNGRADING SCHEDULE:

16. DISTRIBUTION STATEMENT (of this Report):

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report):

18. SUPPLEMENTARY NOTES:

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

ELF Propagation Measurements
Connecticut
Nighttime Fades
Atypical Polarization Behavior
PCA Event

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

From August 1976 to December 1978, extremely low frequency (ELF) field-strength measurements were taken continuously in Connecticut. The results of measurements taken from March through May 1978 are discussed in this report. During March, 5 dB, or greater, nighttime signal fades occurred during 46 percent of the measurement days. A comparison of the normal and abnormal Connecticut horizontal magnetic-field strengths during disturbed propagation conditions revealed atypical behavior. Field-strength measurements were also taken before, during, and after the 29 April PCA event (9.8 dB riometer absorption).

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GLOSSARY OF ABBREVIATIONS

ELF	Extremely low frequency
EW	East-west
GMT	Greenwich Mean Time
LF	Low frequency
MEV	Million electron volts
NS	North-south
NUSC	Naval Underwater Systems Center
PCA	Polar cap absorption
SNR	Signal-to-noise ratio
SRTP	Sunrise transition period
SSTP	Sunset transition period
STIU	Signal timing and interface unit
VLF	Very low frequency
WTF	Wisconsin Test Facility

CONNECTICUT ELF FIELD-STRENGTH MEASUREMENTS, MARCH TO MAY, 1978

INTRODUCTION

Since June 1970, sporadically we have made farfield extremely low frequency (ELF) horizontal magnetic field-strength measurements in Connecticut.[1-13] The local measurement site from June 1970 to October 1971 was in the Nehantic State Forest, East Lyme, CT. From October 1971 through November 1975, it was located in Hammonassett State Park, Madison, CT. Since July 1976, the AN/BRS-1 ELF receiver has been located at the Naval Underwater Systems Center (NUSC), at New London, CT. The loop receiving antenna is now located at Fishers Island, NY, (about 10 km from New London). The receiver and receiving antenna are connected by means of a microwave link from Fishers Island to New London.

The AN/BSR-1 receiver is composed of an AN/UYK-20 minicomputer, a signal timing and interface unit (STIU), a rubidium frequency time standard, two magnetic tape recorders, and a preamplifier.

The transmission source for these 1.6-Mm range measurements is the U. S. Navy's ELF Wisconsin Test Facility (WTF), located in the Chequamegon National Forest in north-central Wisconsin, about 8 km south of the village of Clam Lake. The WTF consists of two 22.5-km antennas; one antenna is located approximately in the north-south (NS) direction and one is located approximately in the east-west (EW) direction. Each antenna is grounded at both ends. At 76 Hz, the electrical axis of the NS antenna is 14 deg east of north, while the electrical axis of the EW antenna is 114 deg east of north. The WTF array can be steered electrically toward any particular location and its radiated power is approximately 1 W.

In this report, we will discuss the results of the March through May, 1978, Connecticut measurements, which were taken to investigate further the diurnal and seasonal ELF propagation variations.

CONNECTICUT MARCH 1978 MEASUREMENTS

During this time period, data were obtained on 25 days at the Connecticut site. The daily plots of signal strength (both amplitude and relative phase), effective noise,* and signal-to-noise ratio (SNR) versus Greenwich Mean Time (GMT) (in 30-min increments) are presented in appendix A. The data are broken up into four time periods, which should be representative of nighttime, sunrise transition period (SRTP), daytime, and sunset transition period (SSTP) propagation conditions. From 8 to 18 March, the WTF antenna phasing angle, ψ,

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*The effective-noise spectrum level (in dBH = dBA/m$\cdot\sqrt{1}$ Hz) is defined as the spectrum level of ELF noise at the signal frequency divided by the improvement (in SNR) using nonlinear processing.[14]

was 201 deg. During the rest of the month, ψ was 291 deg. The transmitting frequency was 76 ±4 Hz. As was mentioned in previous reports,[4,7] the Connecticut effective-noise measurements are sometimes contaminated by industrial noise at the Fishers Island receiving site. Thus, the effective-noise values presented here are on the high side.

Presented in table 1 are the March 1978 Connecticut daily field-strength averages. For a WTF antenna phasing angle of 291 deg, the average Connecticut field strength should equal -143.3 dBA/m during the day, -144.4 dBA/m during the SRTP and SSTP, and -145.5 dBA/m at night.[7] For ψ = 201 deg, the values should be 1 dB lower. Referring to table 1 and to the figures in appendix A, we see that, with the exception of the minimum nighttime field-strength period, the average field-strength levels are about as expected.

Amplitude peak-to-trough variations of 5 dB, or greater, occurred during 11 of the 24 measurement days (6, 11 through 18, 24, and 26 March). The largest variation (6.5 dB) occurred on 13 March. These variations are illustrated in figures 1 through 4* and in appendix A.

As was mentioned in a previous report,[13] for the 1-yr period of August 1976 to July 1977, 5 dB, or greater, signal-strength fades occurred during 26 percent of the measurement days that included a nighttime measurement period. The most frequent nighttime fading occurred during March (48 percent) and September (45 percent). Referring to table 1 and appendix A, we see that 5 dB, or greater, signal-strength fades occurred during 46 percent of the measurement days, which is almost identical to the 48 percent that occurred during March 1977. In particular, these March 1978 nighttime field-strength fades occurred during 8 straight days (11 through 18 March).

Referring to figure 1, we see that on 9 to 10 March the field strength was essentially constant during the SSTP and the 0130-0600 nighttime measurement period. The field strength decreased ~2 dB by 0900 and, then, increased ~3 dB by the end of the SRTP. Meanwhile, the relative phase steadily increased ~15 deg from 0130 to 0830 and, then, steadily decreased ~40 deg by 1200.

During 11 March, the signal strength steadily decreased ~4.5 dB during the nighttime period of 0200 to 0930 and, then, steadily increased ~4 dB during the SRTP. Meanwhile, the nighttime relative phase increased ~20 deg from 0200 to 0830. The relative phase then decreased (by ~35 deg) to its normal daytime level by 1130.

The 11 to 12 and 12 to 13 March field strengths are plotted versus GMT in figure 2. Here, we see that, on 12 March, the nighttime field strength was essentially constant until 0430, then rapidly decreased ~4 dB by 0630. The field strength then steadily increased ~5 dB from 0500 to 1230. During 13 March, the nighttime field strength steadily decreased ~5 dB from 0330 to 0730, then steadily increased ~6 dB by the middle of the SRTP (1100). During both of these nights, the nighttime relative phase increased 10 to 20 deg from 0130 to 0600, then rapidly decreased 10 to 20 deg by 0730.

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*All figures have been placed together at the end of this report or in the applicable appendix.

Table 1. March 1978 Connecticut Daily Field-Strength Averages

Date	ψ (deg)	SSTP H_ϕ (dBA/m)	Night H_ϕ (dBA/m)	SRTP H_ϕ (dBA/m)	Day H_ϕ (dBA/m)	Relative Phase (deg)	Peak/ Trough $\geq$5 dB
3/3	291	-144.0	-145.8	-144.2	-143.2	15.6	No
3/4	291	-143.8	-145.3	-144.9	-143.6	16.5	No
3/5	291	-144.6	-145.6	-144.8	-143.6	23.1	No
3/6	291	-144.9	-146.2	-145.2	-143.1	20.0	Yes
3/7	291	-144.4	-145.7	-144.7	-143.3	21.2	No
3/8	201	-145.9	-146.4	-145.5	-144.3	29.2	No
3/9	201	-145.4	-146.4	-146.1	-144.7	23.0	No
3/10	201	-145.9	-146.4	-145.5	-144.5	28.5	No
3/11	201	-145.8	-147.0	-146.8	-144.7	25.7	Yes
3/12	201	-145.9	-147.0	-145.5	-144.6	24.0	Yes
3/13	201	-145.6	-147.6	-145.3	-144.3	29.3	Yes
3/14	201	-145.6	-147.3	-145.2	-144.3	27.0	Yes
3/15	201	-145.5	-147.2	-145.2	-144.3	29.0	Yes
3/16	201	-145.8	-147.0	-145.0	-144.7	25.1	Yes
3/17	201	-145.2	-146.9	-144.8	-144.4	20.6	Yes
3/18	201	-144.9	-146.2	-144.4	-	28.6	Yes
3/21	291	-143.9	-145.6	-144.4	-143.3	24.9	No
3/22	291	-143.9	-145.7	-143.9	-143.3	26.9	No
3/23	291	-144.2	-145.5	-144.4	-143.1	27.6	No
3/24	291	-143.9	-145.9	-143.9	-143.5	27.2	Yes
3/25	291	-144.1	-145.4	-144.2	-143.3	26.6	No
3/26	291	-144.3	-145.8	-143.9	-143.1	24.0	Yes
3/28-3/29	291	-143.7	-145.1	-143.5	-143.3	20.4	No
3/30	291	-144.1	-145.6	-143.5	-143.2	21.0	No
3/3-3/7 Avg.	291	-144.3	-145.7	-144.7	-143.3	19.3	1/5
3/8-3/18 Avg.	201	-145.6	-146.8	-145.4	-144.5	26.4	8/11
3/21-3/30 Avg.	291	-144.0	-145.5	-144.0	-143.3	24.8	2/8
Monthly Avg.	Norm. to 291	-144.3	-145.7	-144.4	-143.4	24.4	11/24 (45.8%)

Referring to figure 3, we see that the 14 and 15 March nighttime field strengths decreased 3 to 4 dB, leveled off, then increased 3 to 4 dB by the end of the nighttime measurement period. Meanwhile, during both nights, the relative phase increased 15 to 20 deg by 0600, then decreased 15 to 20 deg by the end of the nighttime measurement period.

Presented in figure 4 are the 15 to 16, 16 to 17, and 17 to 18 March field strengths versus GMT During 16 March, the field strength steadily decreased ~4 dB from 0200 to 0700, then steadily increased ~4 dB by the middle of the SRTP (1100). Meanwhile, the relative phase was essentially constant during the nighttime measurement period.

During 17 March, the field strength rapidly decreased ~5 dB from 0300 to 0530, then steadily increased ~5 dB from 0530 to 1130. The nighttime relative phase increased ~15 deg from 0200 to 0500, decreased ~15 deg by 0700, then increased ~10 deg by 0930.

Referring to figure 4, we see that the 18 March nighttime field strength was essentially constant until 0400. The nighttime field strength then rapidly decreased ~4 dB by 0600, and steadily increased ~4 dB by the end of the nighttime measurement period (1000). Meanwhile, the nighttime relative phase steadily increased ~15 deg from 0200 to 0500, rapidly decreased ~20 deg by 0700, then steadily increased ~10 deg by 1000. The relative phase then decreased to its normal daytime level by 1230.

On several occasions, we have also measured the vertical electric-field strength (E_V) produced by the WTF. The Connecticut vertical electric-field strength behavior is usually very similar to the horizontal magnetic-field strength (H_ϕ) behavior (in amplitude and relative phase) during both normal and disturbed propagation conditions. For further details, see figure 3 of reference 13.

On a few occasions, we have also measured the abnormal horizontal magnetic-field strength (H_ρ) produced by the WTF. Usually, accurate measurements of the H_ρ component can be made in Connecticut only during the late fall, winter, and early spring months, when the effective atmospheric noise is <-140 dBH. This is because the H_ρ component is 6 to 10 dB less in magnitude than the H_ϕ component, and the effective noise in the H_ρ direction is 1 to 3 dB greater than the effective noise in the H_ϕ direction.

During normal propagation conditions, the Connecticut abnormal horizontal magnetic-field strength (H_ρ) behavior is usually similar to the normal horizontal magnetic-field strength (H_ϕ) behavior. Presented in figure 5 is a comparison of the normal and abnormal Connecticut horizontal magnetic-field strengths during disturbed propagation conditions (17 to 18 March). Here, we see that, during the daytime and SRTP periods, the H_ρ and H_ϕ behavior was nearly the same. However, during the SSTP and nighttime propagation periods, their behavior was quite different.

During 18 March, the SSTP and nighttime H_ϕ field strength was essentially constant until 0400. The nighttime field strength then rapidly decreased ~4 dB by 0600, then steadily increased ~4 dB by the end of the nighttime measurement period (1000). Meanwhile, the H_ϕ nighttime relative phase steadily increased ~15 deg from 0200 to 0500, rapidly decreased ~20 deg by 0700, then steadily increased ~10 deg by 1000. The relative phase then decreased to its normal daytime level by 1230.

On the other hand (figure 5), the H_ρ field strength steadily decreased ~4 dB from the start of the SSTP to 0130, then increased ~3 dB by 0530. It then decreased ~3 dB by 0800 and rapidly increased ~2 dB by the end of the nighttime measurement period (1000). Meanwhile, the H_ρ relative phase increased ~30 deg during the SSTP, decreased ~30 deg from 0100 to 0300, increased ~20 deg by 0600, and remained essentially constant during the rest of the nighttime measurement period.

CONNECTICUT APRIL 1978 MEASUREMENTS

During this time period, data were obtained on 27 days at the Connecticut site. The daily plots of signal strength (both amplitude and relative phase) versus GMT (in 30-min increments) are presented in appendix B. During April, the WTF antenna phasing angle was 291 deg and the transmitting frequency was 76 ±4 Hz.

Presented in table 2 are the April 1978 daily field-strength averages. For a WTF antenna phasing angle of 291 deg, the <u>average</u> Connecticut field strength should equal -143.3 dBA/m during the day, -144.4 dBA/m during the SRTP and SSTP, and -145.5 dBA/m at night.[7] Referring to table 2 and to the figures in appendix B, we see that, with the exception of the nighttime minimum field-strength period, the average field-strength levels are about as expected.

Amplitude peak-to-trough variations of 5 dB, or greater, occurred during 6 of the 27 days that included a nighttime measurement period (2, 4, 9, 19, 29, and 30 April). The largest variations (6 to 7 dB) occurred on 4, 19, and 30 April. These variations are illustrated in figures 6 and 7 and in appendix B.

Referring to figure 6, we see that both the 19 and 30 April nighttime field strengths rapidly decreased ~5 dB from 0400 to 0630. The field strengths then rapidly increased 6 to 7 dB from 0630 to 1100 and leveled off at the beginning of the daytime measurement period (1130). Meanwhile, during both nights, the relative phase increased ~20 deg from 0200 to 0500, decreased ~20 deg by 0700, increased ~10 deg by 0830, and returned to the normal daytime value at the end of the SRTP (1130).

Figure 7 is a comparison of the normal and abnormal Connecticut horizontal magnetic-field strengths measured during the disturbed propagation period of 3 to 4 April. Here, we see that, during the SSTP and SRTP, the H_ρ and H_ϕ behavior was nearly the same. However, during the nighttime propagation period, their behavior was quite different.

During 3 to 4 April, the H_ϕ field strength steadily decreased ~6 dB from 2200 to 0500, rapidly increased ~4.5 dB from 0500 to 0700, and gradually

Table 2. April 1978 Connecticut Daily Field-Strength Averages (ψ = 291 deg)

Date	SSTP H_ϕ (dBA/m)	Night H_ϕ (dBA/m)	SRTP H_ϕ (dBA/m)	Day H_ϕ (dBA/m)	Relative Phase (deg)	Peak/Trough $\geq$5 dB
4/1	-144.4	-145.8	-144.6	-143.3	22.1	No
4/2	-144.5	-146.3	-145.0	-143.4	17.5	Yes
4/3	-144.5	-145.9	-144.7	-143.6	22.3	No
4/4	-144.6	-146.3	-144.3	-143.2	22.0	Yes
4/5	-144.6	-145.3	-143.9	-143.2	21.4	No
4/6	-144.1	-145.3	-145.0	-143.1	22.3	No
4/7	-144.0	-145.2	-144.9	-143.0	18.1	No
4/8	-144.5	-145.6	-145.4	-143.3	18.0	No
4/9	-144.3	-145.8	-144.9	-143.6	21.1	Yes
4/10	-144.0	-145.5	-145.6	-144.1	18.2	No
4/11	-144.6	-145.1	-143.9	-143.7	17.3	No
4/12	-144.4	-144.4	-143.2	-143.1	17.7	No
4/13	-144.1	-144.7	-144.9	-143.6	25.1	No
4/14	-144.7	-145.9	-144.8	-143.8	18.2	No
4/15	-144.5	-145.8	-144.5	-143.3	19.3	No
4/19	-144.1	-145.9	-144.5	-143.3	19.5	Yes
4/20	-144.5	-145.8	-143.7	-143.3	23.4	No
4/21	-144.0	-145.4	-144.1	-143.3	23.6	No
4/22	-143.8	-144.9	-144.0	-143.4	23.3	No
4/23	-144.0	-145.5	-144.2	-143.2	13.6	No
4/24	-143.9	-145.9	-144.3	-143.5	17.0	No
4/25	-144.1	-145.1	-143.0	-143.3	20.8	No
4/26	-144.6	-145.2	-143.5	-143.3	20.1	No
4/27	-144.6	-145.9	-144.5	-143.8	22.3	No
4/28	-144.4	-146.1	-144.4	-143.3	-	No
4/29	-144.2	-145.9	-144.3	-143.5	16.9	Yes
4/30	-144.2	-146.3	-144.1	-143.8	16.0	Yes
Monthly Average	-144.3	-145.6	-144.4	-143.4	19.9	6/27 (22.2%)

increased by ~1 dB by the end of the SRTP. Meanwhile, the H_ϕ nighttime relative phase was relatively constant until 0500, decreased ~15 deg from 0500 to 0630, and gradually increased ~10 deg from 0630 to the end of the nighttime measurement period (0900).

On the other hand (figure 7), the H_ρ field strength rapidly decreased ~4.5 dB from 2200 to 0100, then rapidly increased ~4 dB from 0100 to 0330. The H_ρ field strength gradually decreased ~1 dB from 0330 to 0530, rapidly decreased ~4 dB from 0530 to 0630, and rapidly increased ~4 dB from 0630 to 0800. Then, it gradually increased by ~1 dB by the end of the SRTP (1130). Meanwhile, the H_ρ relative phase gradually increased ~70 deg from 2200 to 0430 and gradually decreased ~60 deg from 0530 to 1200.

Referring to figures 1 through 7, we see that, during disturbed propagation conditions, the H_ϕ versus GMT plots are usually either V-shaped (decrease/increase) or U-shaped (decrease/level-off/increase). On the other hand, the H_ρ versus GMT plots are W-shaped (decrease/increase/decrease/increase). From figures 5 and 7, we also see that, when the H_ϕ component is approaching its minimum nighttime value, the H_ρ component is near its maximum nighttime value.

Simultaneous measurements[9,15] taken in Connecticut and the North-Atlantic area during the magnetically quiet period of early March 1977 (where similar nighttime propagation anomalies occurred 2 to 4 hr apart) have indicated that a possible cause for some of these anomalies is a moving nocturnal sporadic-E layer.

Barr[16] and Pappert and Moler[17] have made calculations regarding the influence of a sporadic-E layer that encompasses the nighttime propagation path. They showed that the presence of nocturnal sporadic E produced marked maxima and minima in the propagation characteristics of ELF radio waves. One physical explanation for the enhanced absorption could be in terms of an attenuation resonance between waves reflected from normal E-region heights and from the sporadic-E region. They also showed that the polarization of ELF radio waves is very dependent on the presence of sporadic ionization.

The atypical behavior of the nighttime normal (H_ϕ) and abnormal (H_ρ) horizontal magnetic-field strengths (figures 5 and 7) could well be an indication of the presence of a nocturnal sporadic-E layer. However, it should be noted that actual measurements of sporadic-E conditions have not been made at the receiving sites when WTF was transmitting. Attempts to explain the observed ELF signal fades in terms of absorption due to sporadic-E conditions can, therefore, not be conclusive, but the theoretical efforts in this area point out the potential influences of sporadic E on ELF propagation.

CONNECTICUT MAY 1978 MEASUREMENTS

During this time period, data were obtained on 27 days at the Connecticut site. The daily plots of signal strength (both amplitude and relative phase) versus GMT (in 30-min increments) are presented in appendix C. During May, the WTF antenna phasing angle was 291 deg and the transmitting frequency was 76 ±4 Hz.

Presented in table 3 are the May 1978 daily field-strength averages. As we mentioned previously, for ψ = 291 deg, the average Connecticut field strength should equal -143.3 dBA/m during the day, -144.4 dBA/m during the SRTP and SSTP, and -145.5 dBA/m at night. Referring to table 3 and to the figures in appendix C, we see that, with the exception of (1) 2 through 8 May nighttime field strengths and (2) the minimum nighttime field-strength period, the average field-strength levels are about as expected.

Amplitude peak-to-trough variations of 5 to 5.5 dB occurred during 6 of the 27 days that included a nighttime measurement period (1, 10, 12, 17, 22, and 26 May). These variations are illustrated in figures in appendix C.

Turtle et al.[18] have recently provided a summary of disturbance effects of energetic-particle events on very-low-frequency/low-frequency (VLF/LF) propagation parameters as observed by the U. S. Air Force High Resolution VLF/LF Ionosounder in northern Greenland during 1978. Disturbance effects on ionospheric reflecting parameters, including reflection heights and coefficients, were presented along with data from a riometer, a magnetometer, and satellite particle detectors.

One of the strongest 1978 solar-particle events occurred in late April. A polar-cap absorption (PCA) (9.8 dB riometer absorption) began at 1030 GMT on 29 April and the time of maximum 13 to 25 million electron volts (MEV) proton flux was 2000 on 30 April. This event caused a 20 to 25 km drop in the VLF reflection height at Thule, followed by a gradual return to normal over the next 5 days. This PCA event was also accompanied by sustained geomagnetic activity. From 30 April to 4 May, the geomagnetic A_k index for Fredericksburg, VA, was 30, 50, 55, 33, and 50, respectively.

Imhof et al.,[19] from coordinated satellite and ELF field-strength measurements, have found that direct particle precipitation into the atmosphere can cause ELF transmission anomalies. In these anomalies, the signal strengths may be either attenuated or enhanced, depending on the spatial extent and location of the ionization. The effect appears to be due primarily to changes in the excitation factor.

Presented in figure 8 is a comparison of the Connecticut nighttime field strengths measured from 28 April through 7 May 1978. During normal propagation conditions, the average nighttime field strength should equal -145.5 dBA/m, and the average night-to-day relative-phase variation should equal -22 deg.

Referring to figure 8 and table 3, we see that the 28 April to 1 May nighttime field strengths were lower than normal with the lowest field strengths being measured on 30 April (the day after the PCA began). However, from 2 through 8 May, the nighttime field strengths were higher than normal, and the average night-to-day relative-phase variation was only -10 deg. These two factors imply a decrease in the 2 through 8 May nighttime average reflection height of 10 to 15 km. Because particle precipitation into the D region tends to increase ionization, making the ionosphere more "daylike" by lowering the effective reflecting height and improving excitation, the 2 through 8 May nighttime field-strength increases are as expected.

Table 3. May 1978 Connecticut Daily Field-Strength Averages (ψ = 291 deg)

Date	SSTP H_ϕ (dBA/m)	Night H_ϕ (dBA/m)	SRTP H_ϕ (dBA/m)	Day H_ϕ (dBA/m)	Relative Phase (deg)	Peak/Trough $\geq$5 dB
5/1	-145.1	-146.4	-145.8	-142.8	-	Yes
5/2	-144.1	-144.9	-144.4	-143.0	11.0	No
5/3	-144.0	-144.7	-144.0	-143.6	11.5	No
5/4	-145.1	-144.7	-143.7	-142.6	8.2	No
5/5	-143.6	-143.9	-144.5	-143.4	6.9	No
5/6	-143.5	-144.0	-144.5	-143.3	11.2	No
5/7	-144.5	-144.7	-145.4	-143.7	12.1	No
5/8	-143.5	-144.7	-145.3	-143.3	-	No
5/9	-145.0	-145.2	-144.2	-143.3	18.8	No
5/10	-144.9	-145.5	-146.3	-143.3	22.9	Yes
5/11	-143.0	-144.4	-143.5	-143.1	24.5	No
5/12	-143.8	-145.9	-143.9	-143.4	16.5	Yes
5/13	-143.8	-145.1	-145.4	-143.1	26.4	No
5/16	-144.5	-145.6	-145.1	-143.5	20.1	No
5/17	-143.5	-144.3	-146.1	-143.2	23.9	Yes
5/18	-143.9	-145.3	-145.0	-143.5	18.8	No
5/20	-143.9	-145.3	-145.1	-143.2	23.5	No
5/21	-144.0	-144.8	-145.2	-143.0	20.8	No
5/22	-143.9	-145.2	-144.6	-142.9	20.5	Yes
5/23	-143.1	-144.6	-144.0	-143.2	19.8	No
5/24	-144.0	-145.2	-144.9	-143.7	19.2	No
5/26	-144.4	-146.4	-144.4	-143.1	19.5	Yes
5/27	-143.9	-145.2	-145.1	-143.3	22.4	No
5/28	-143.5	-144.3	-145.0	-143.2	21.1	No
5/29	-143.8	-143.6	-143.8	-143.2	18.2	No
5/30	-144.3	-145.5	-144.5	-143.2	19.8	No
5/31	-143.9	-145.0	-144.5	-143.0	18.2	No
Monthly Average	-144.0	-145.0	-144.7	-143.2	18.2	6/27 (22.2%)

CONCLUSIONS

The horizontal magnetic-field strength measurements taken in Connecticut from March through May 1978 again have demonstrated that the short-term sample-to-sample variability of ELF nighttime propagation is much greater than the short-term sample-to-sample variability of ELF daytime propagation.

During March 1978, 5 dB, or greater, nighttime signal fades occurred during 46 percent of the measurement days, which is almost identical to the 48 percent that occurred during March 1977.[13] In particular, these March 1978 nighttime field-strength fades occurred during 8 straight days (11 through 18 March).

A comparison of the normal (H_ϕ) and abnormal (H_ρ) Connecticut nighttime horizontal magnetic-field strengths measured during disturbed propagation periods revealed that their behavior was quite different. This atypical behavior could well be an indication of a nocturnal sporadic-E layer.

Field-strength measurements were also taken before, during, and after the 29 April PCA event (9.8 dB riometer absorption). One day after the start of the PCA, the Connecticut nighttime field strength experienced a 5 dB fade. However, from 2 through 8 May, the nighttime field strengths were higher than normal, and the average night-to-day relative-phase variation was only ~10 deg (as opposed to the normal of 22 deg). These two factors imply a decrease in the 2 through 8 May nighttime average reflection height of 10 to 15 km.

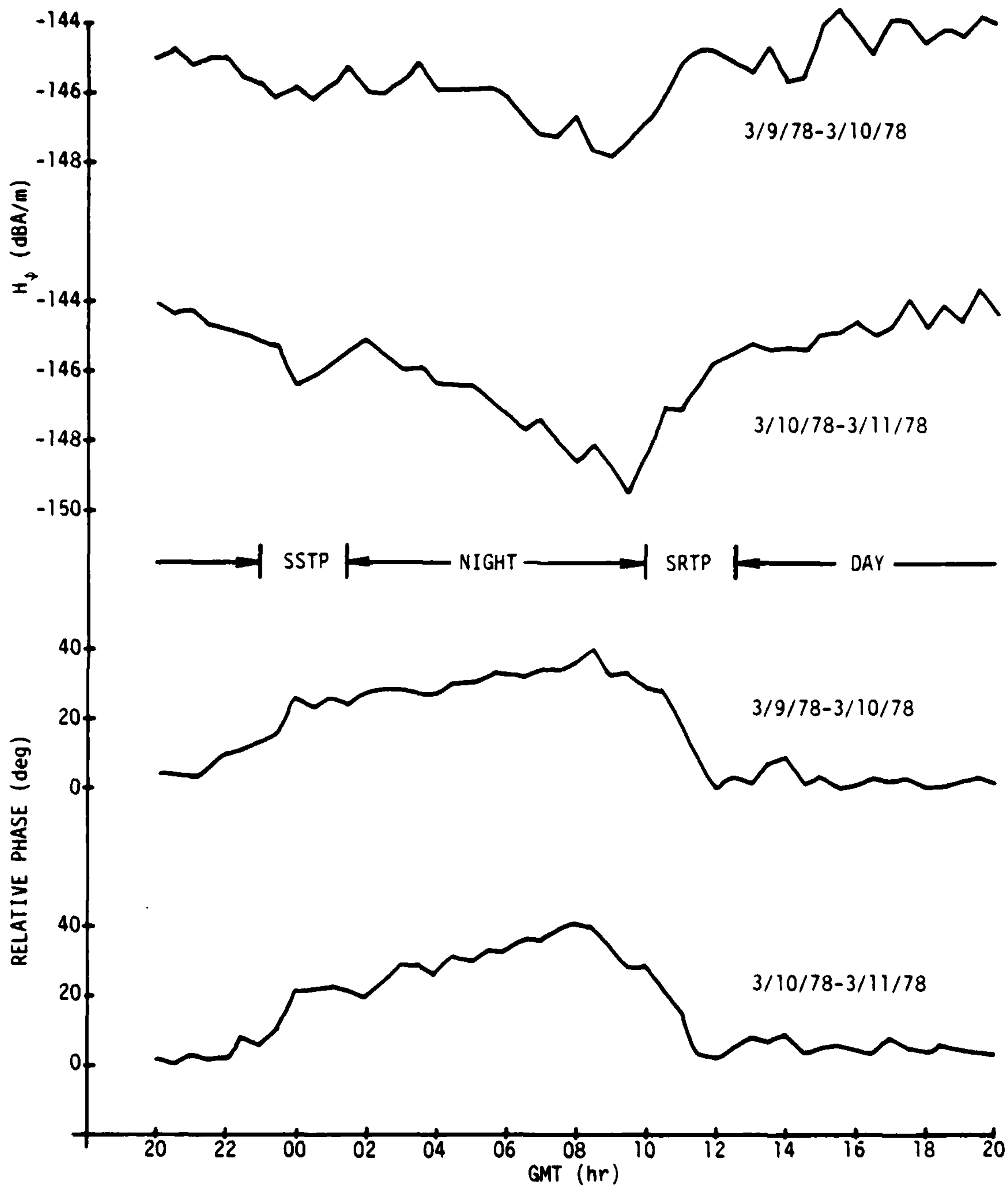

Figure 1. Connecticut Field Strength Versus GMT, 9 to 10 and 10 to 11 March 1978

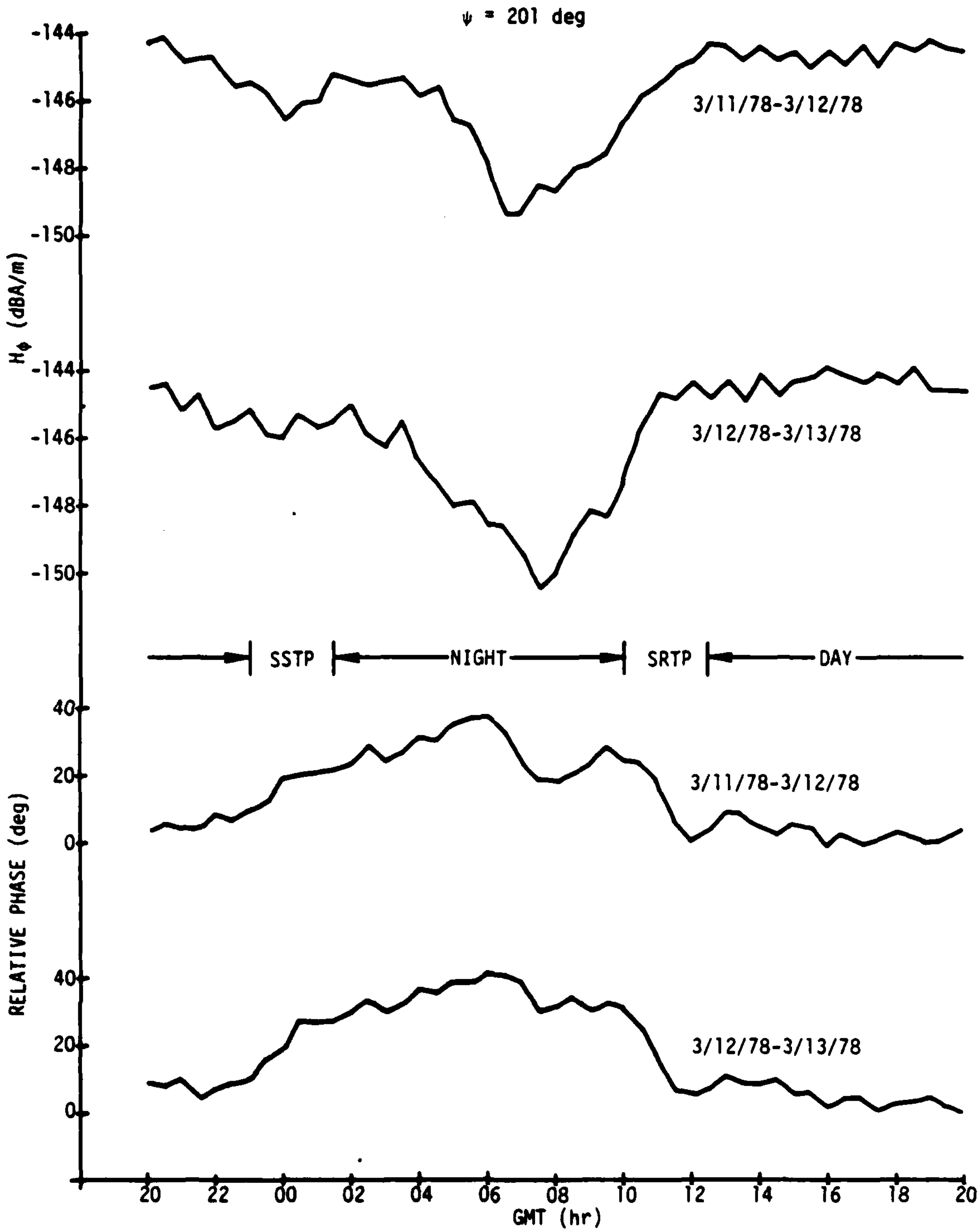

Figure 2. Connecticut Field Strength Versus GMT, 11 to 12 and 12 to 13 March 1978

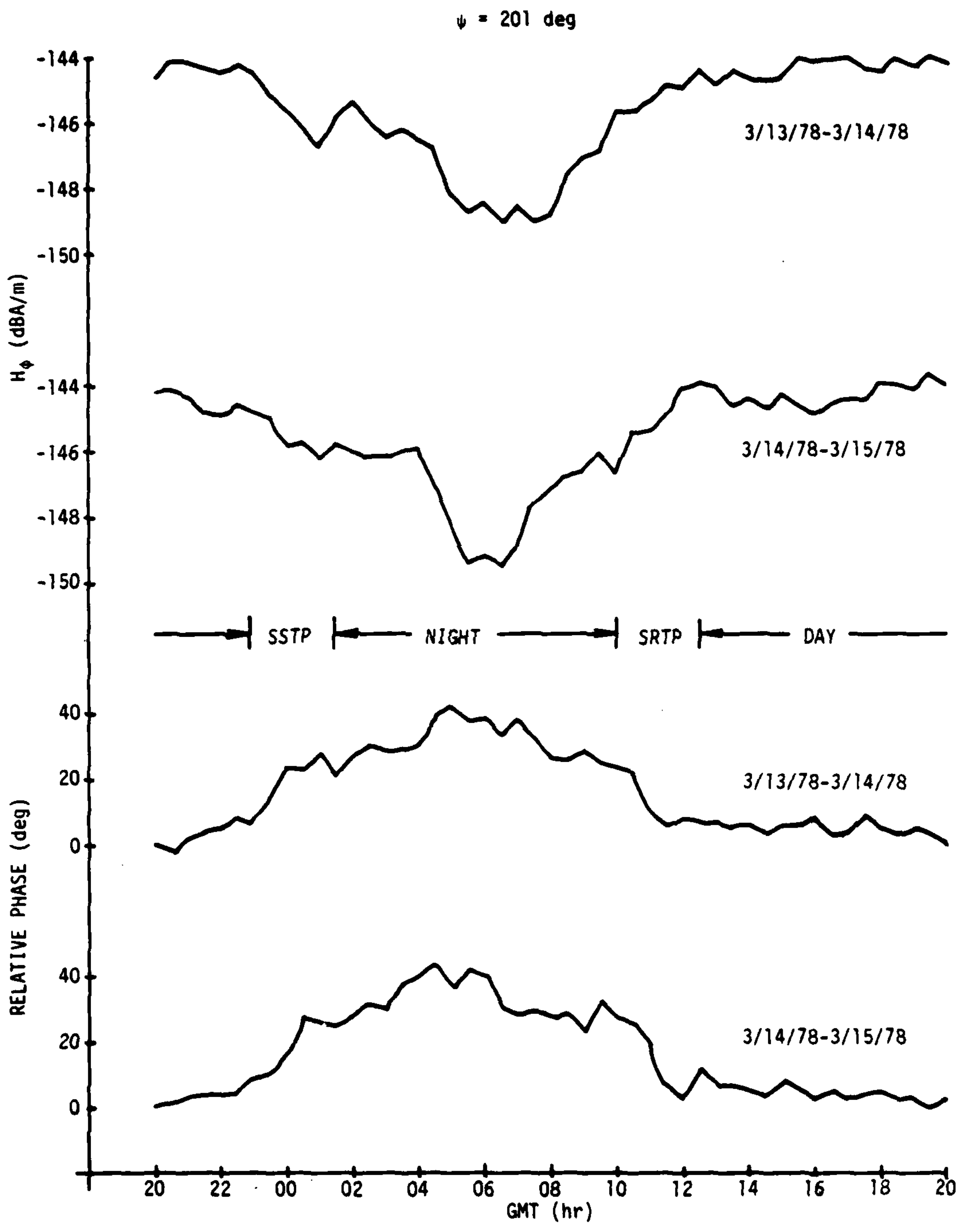

Figure 3. Connecticut Field Strength Versus GMT,
13 to 14 and 14 to 15 March 1978

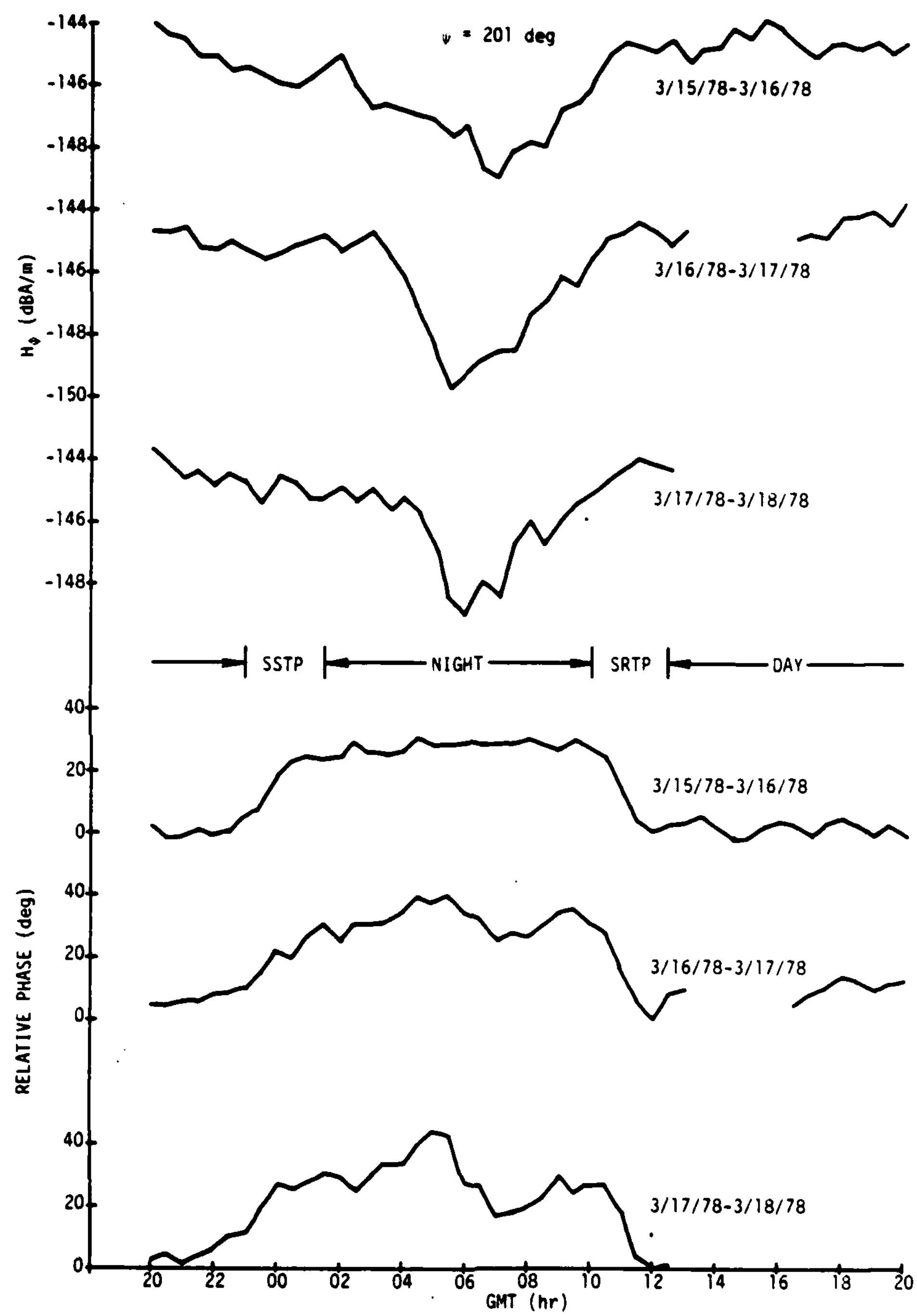

Figure 4. Connecticut Field Strength Versus GMT, 15 to 16, 16 to 17, and 17 to 18 March 1978

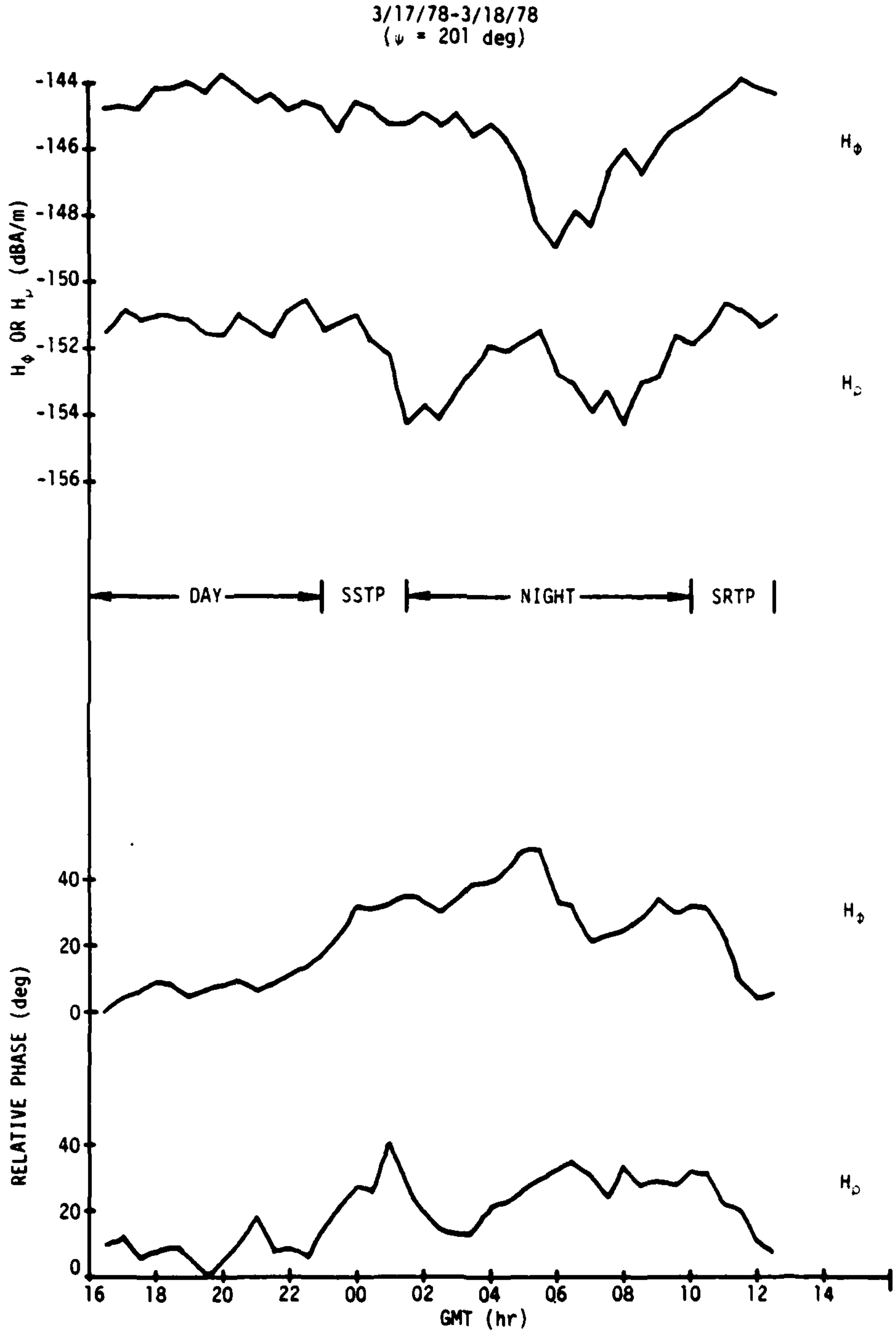

Figure 5. Comparison of Normal and Abnormal Horizontal Magnetic-Field Strengths, 17 to 18 March 1978

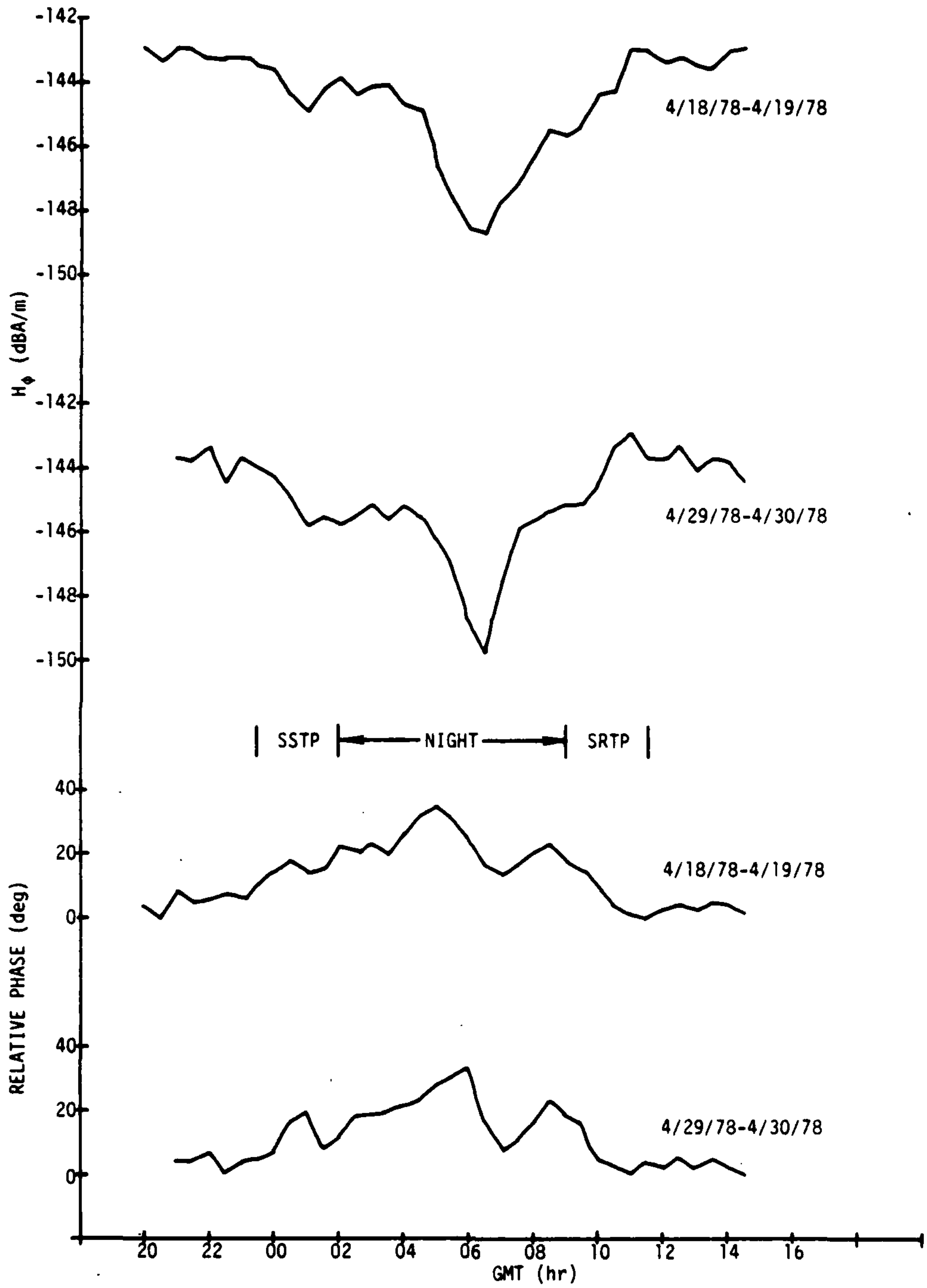

Figure 6. Connecticut Field Strength Versus GMT, 18 to 19 and 29 to 30 April 1978

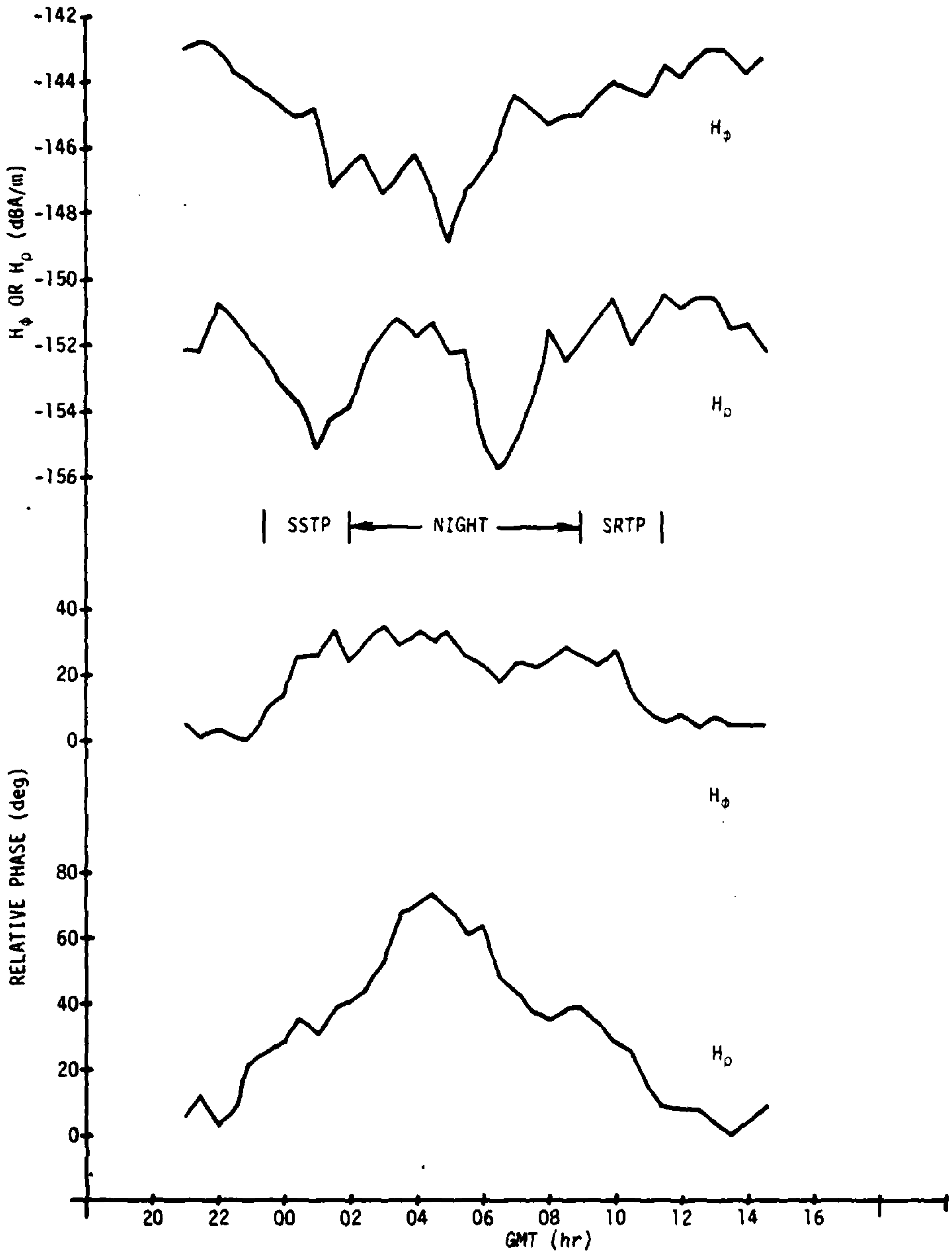

Figure 7. Comparison of Normal and Abnormal Horizontal Magnetic-Field Strengths, 3 to 4 April 1978

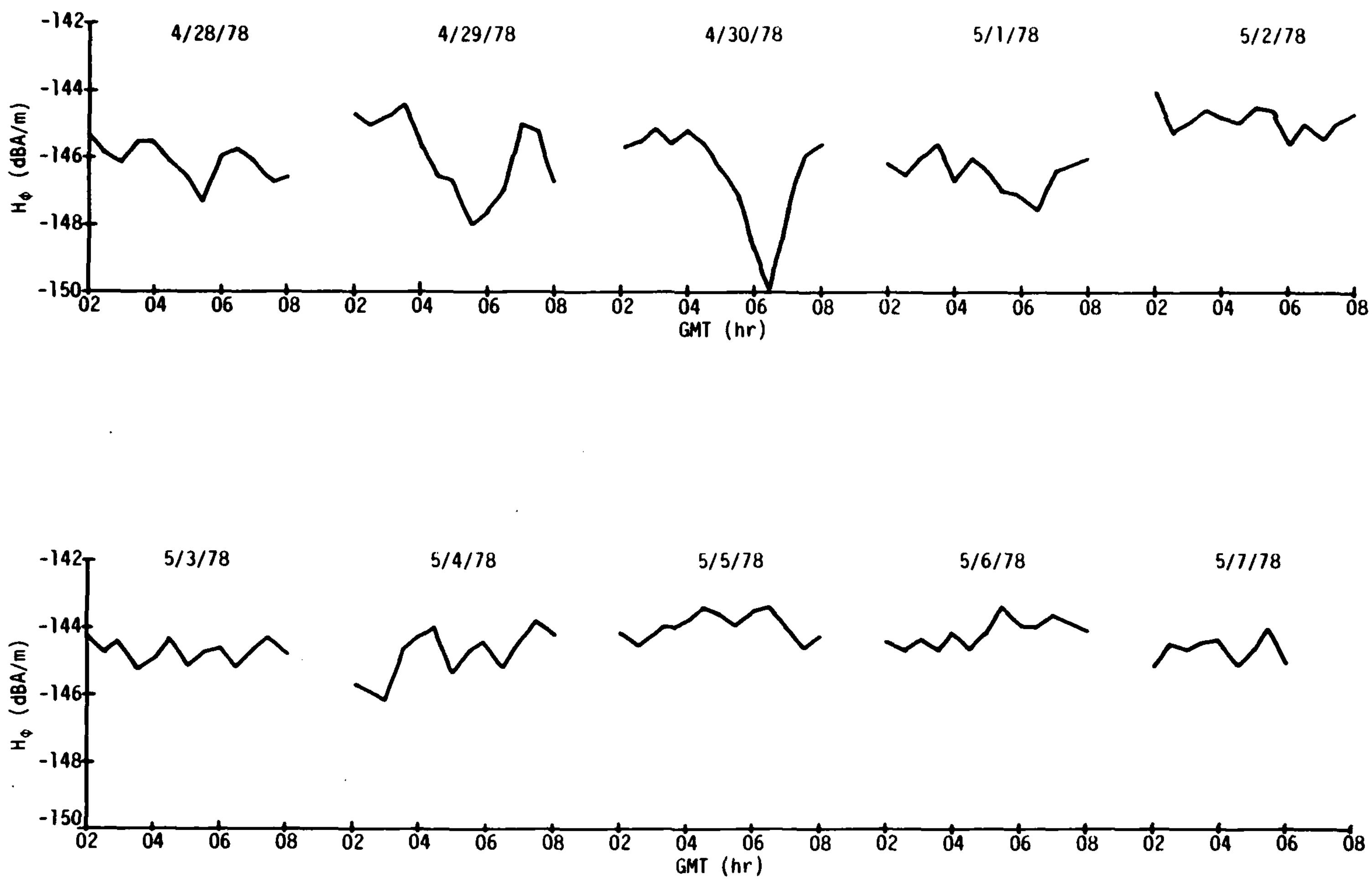

Figure 8. Connecticut Nighttime Field Strengths Versus GMT, 28 April Through 7 May 1978

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Appendix A

CONNECTICUT DAILY DATA, MARCH 1978

Daily plots of Connecticut signal-strength, effective-noise, and SNR values versus GMT for March 1978 are given in this appendix as figures A-1 through A-14.

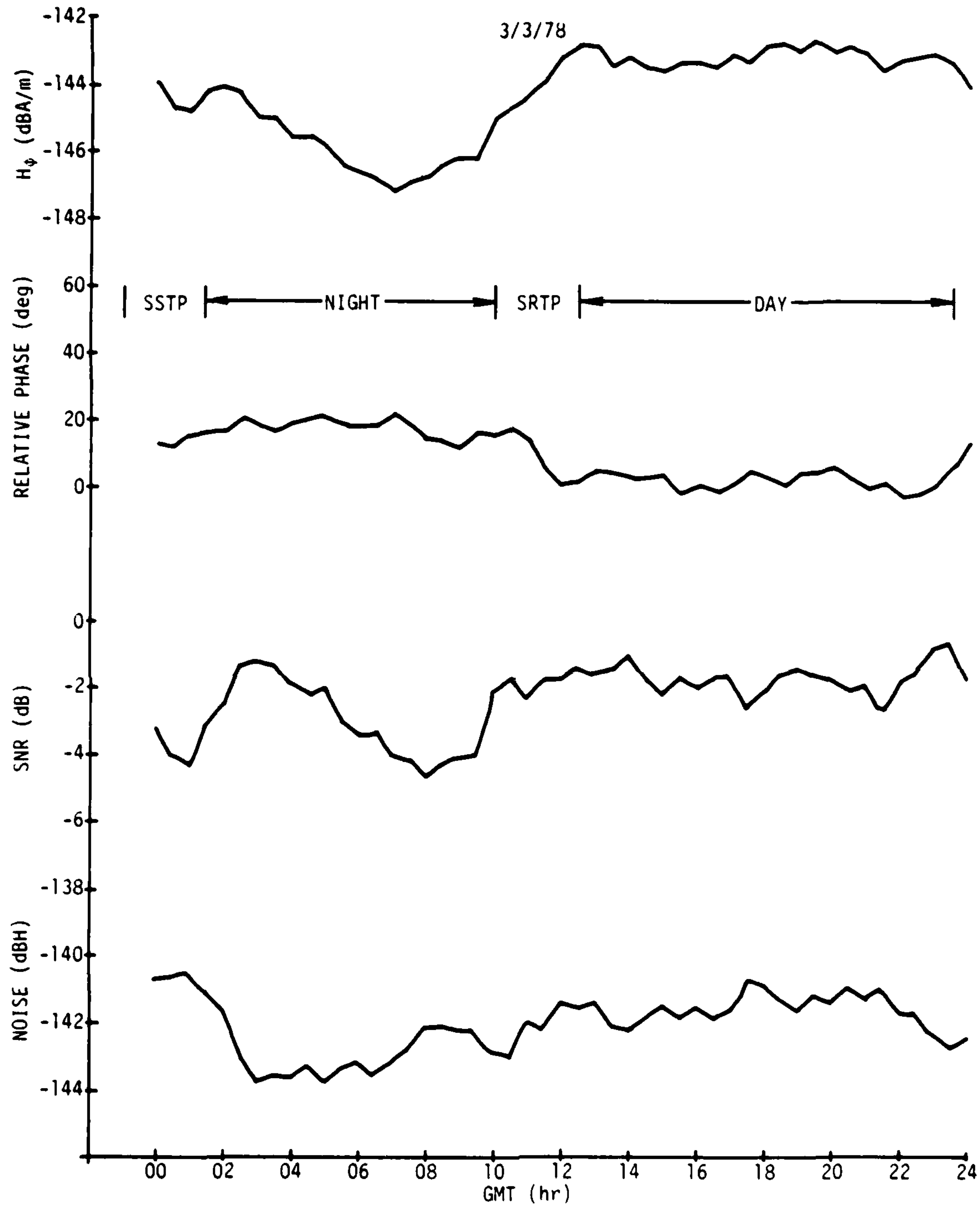

Figure A-1. Connecticut Data Versus GMT (ψ = 291 deg), 3 March 1978

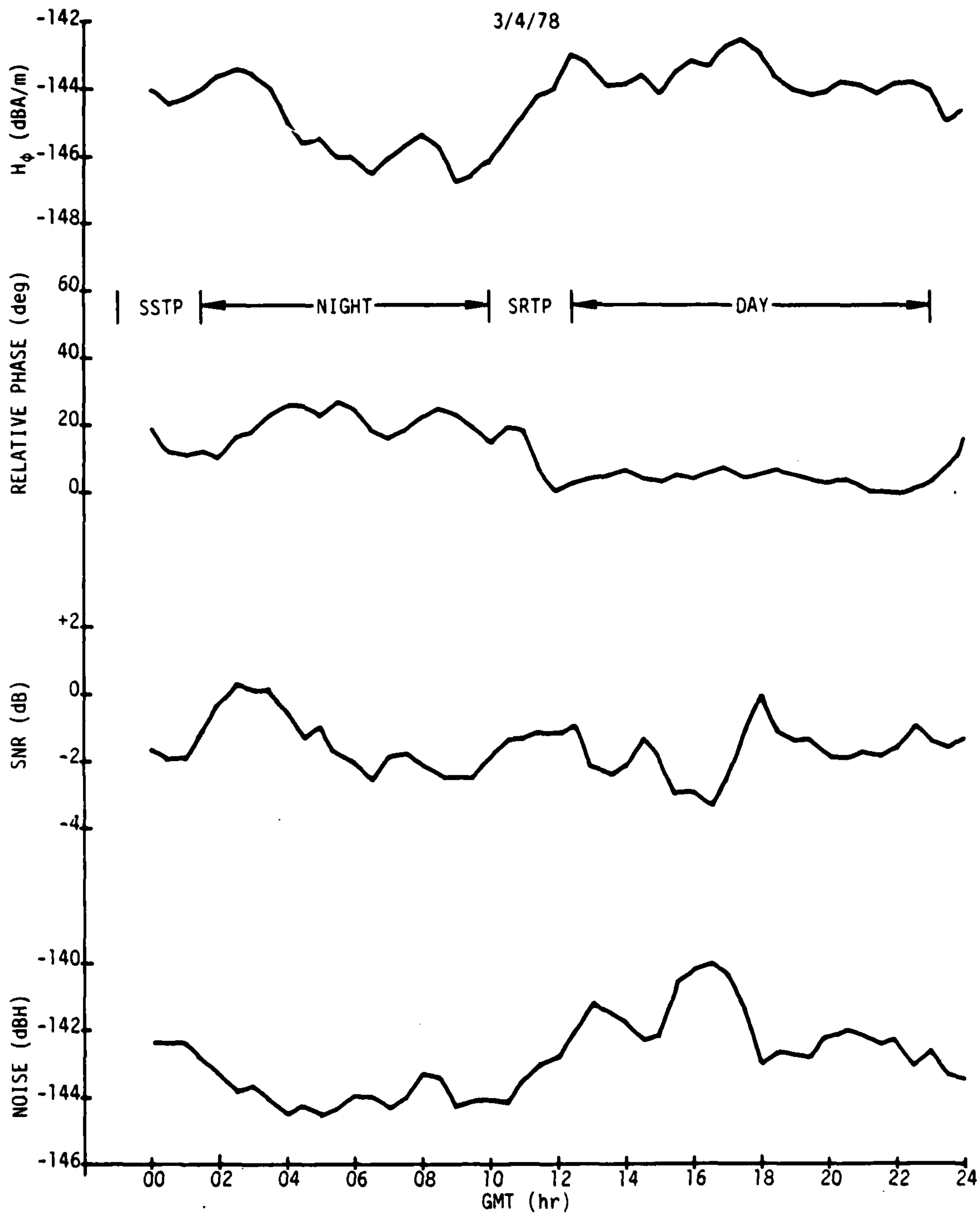

Figure A-2. Connecticut Data Versus GMT (ψ = 291 deg), 4 March 1978

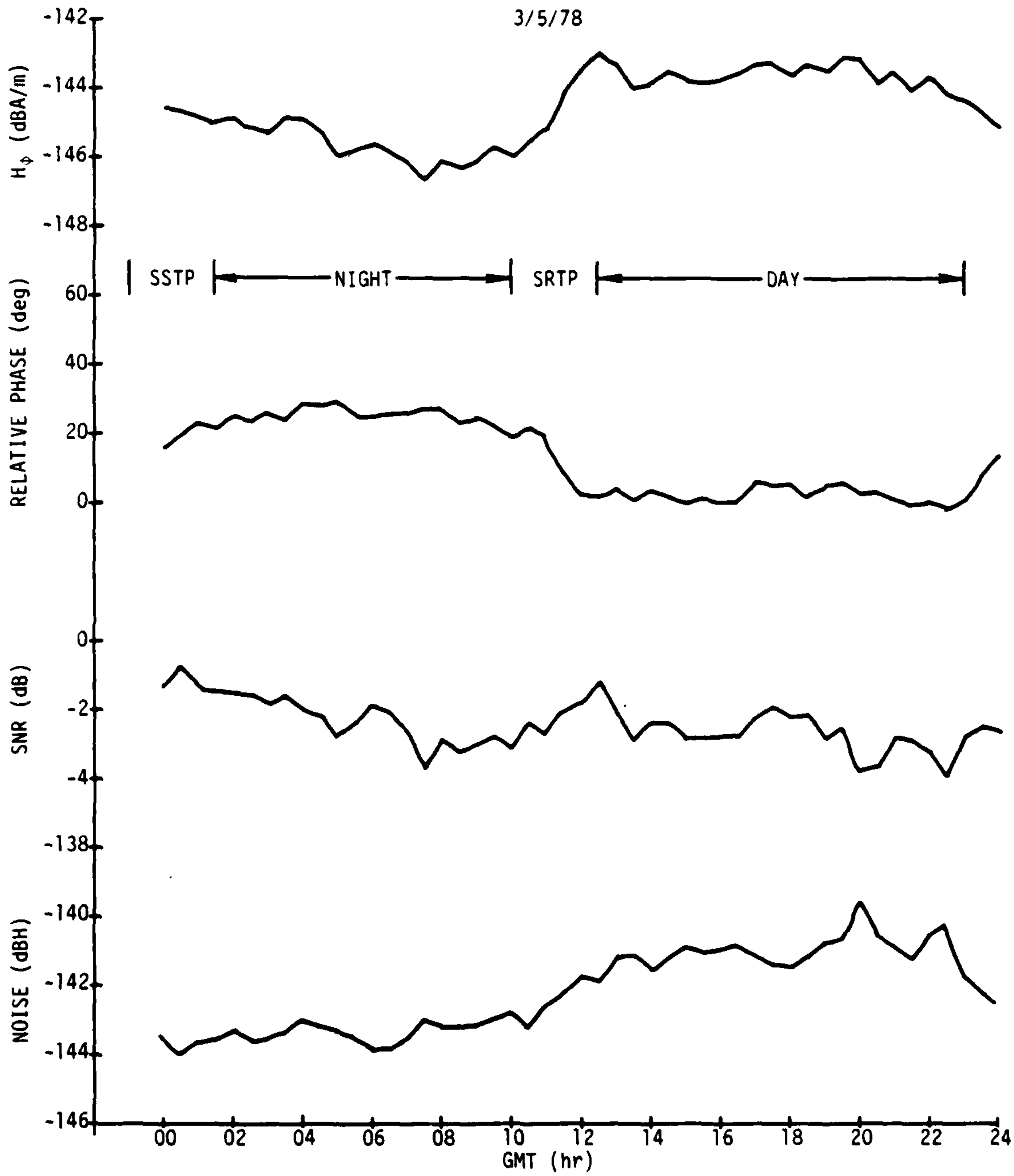

Figure A-3. Connecticut Data Versus GMT (ψ = 291 deg), 5 March 1978

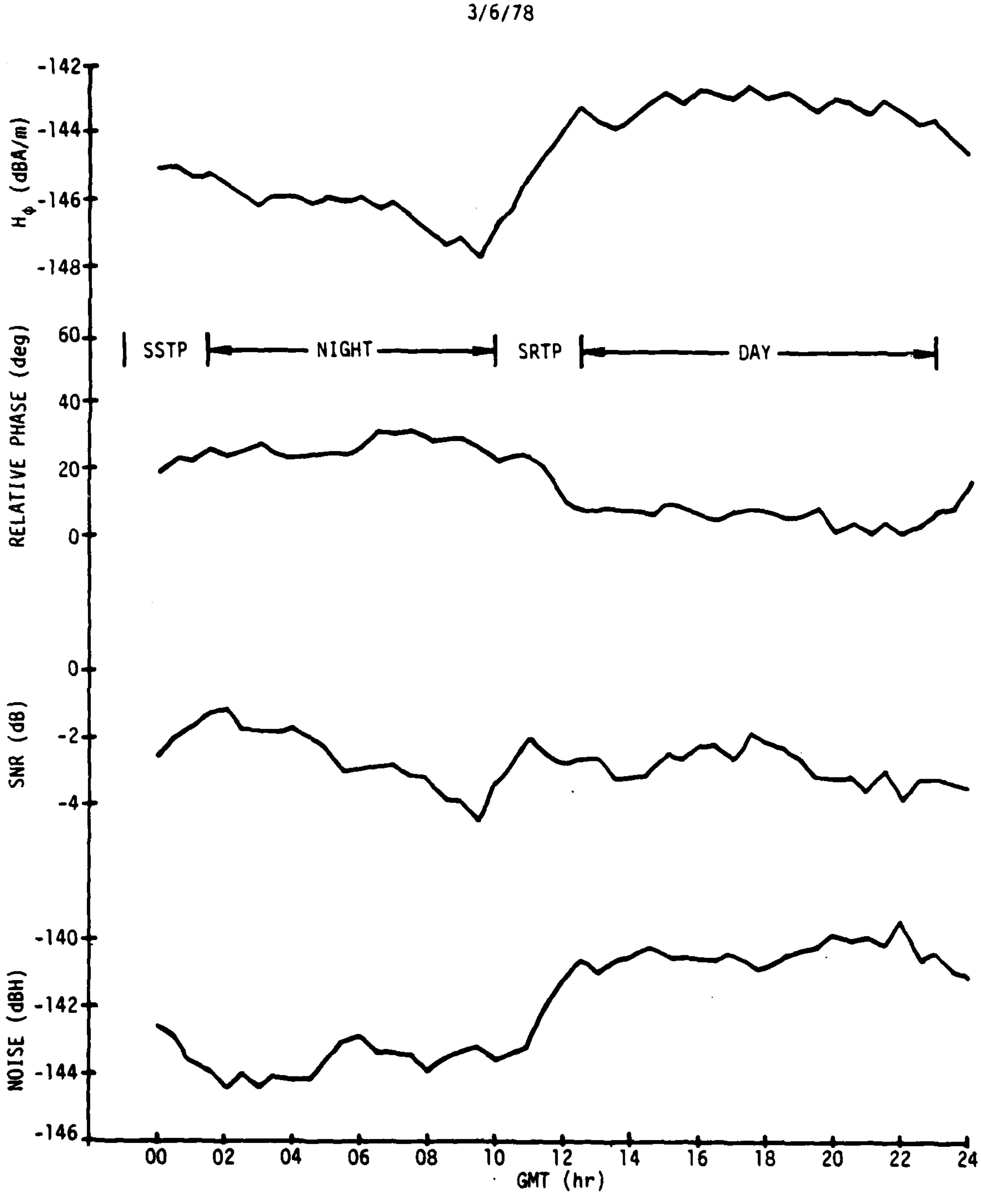

Figure A-4. Connecticut Data Versus GMT (ψ = 291 deg), 6 March 1978

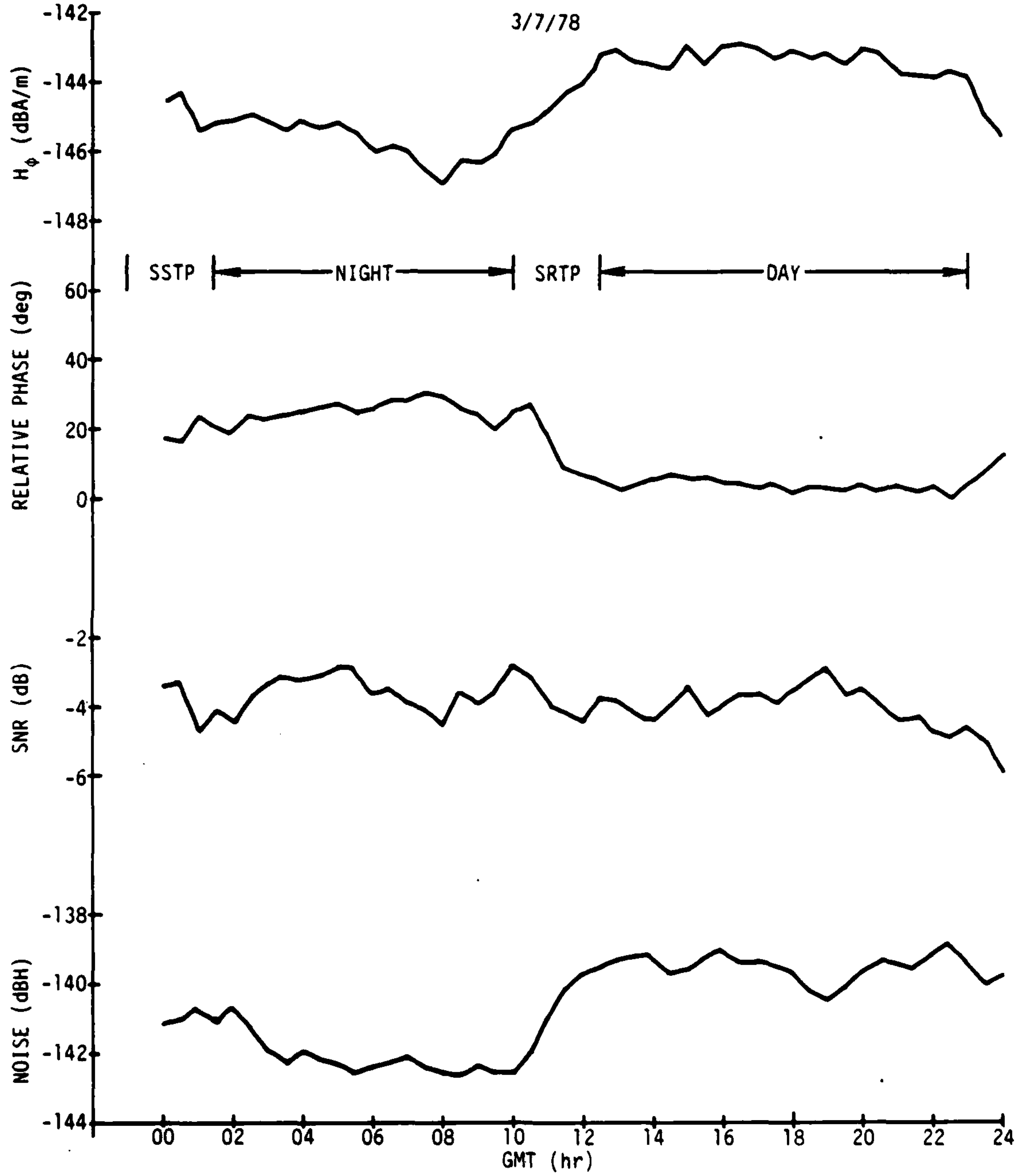

Figure A-5. Connecticut Data Versus GMT (ψ = 291 deg), 7 March 1978

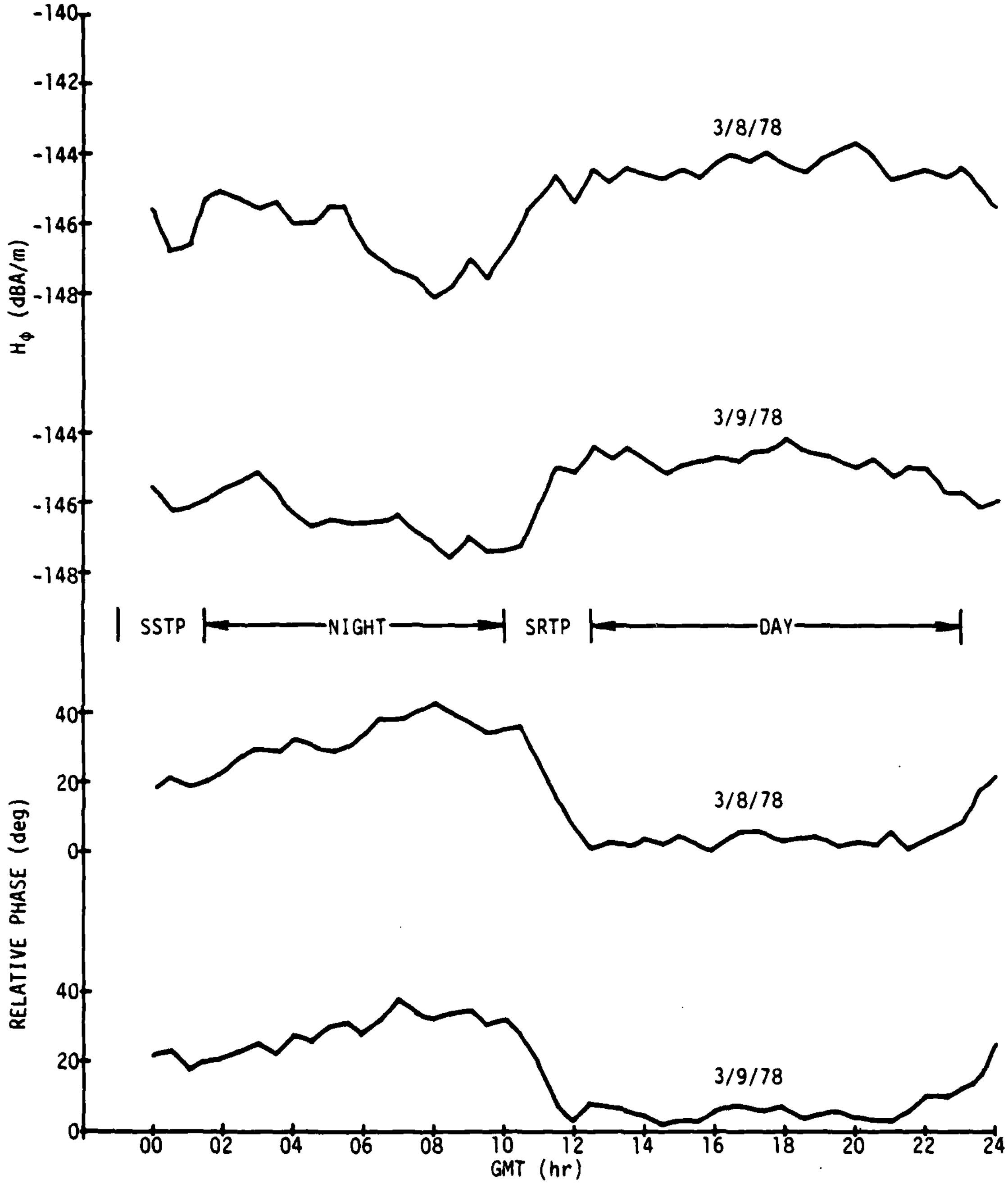

Figure A-6. Connecticut Data Versus GMT (ψ ≈ 201 deg), 8 and 9 March 1978

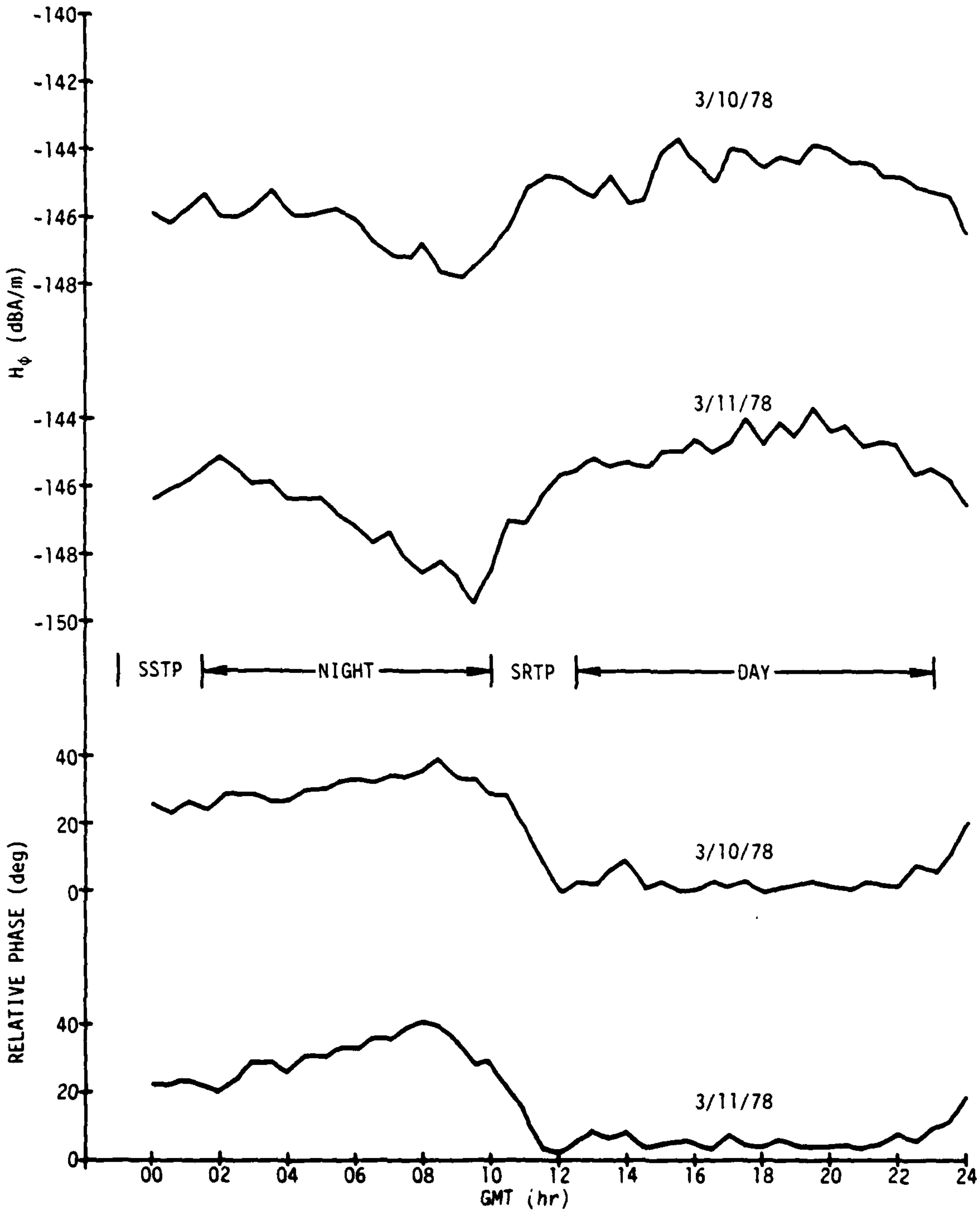

Figure A-7. Connecticut Data Versus GMT (ψ = 201 deg), 10 and 11 March 1978

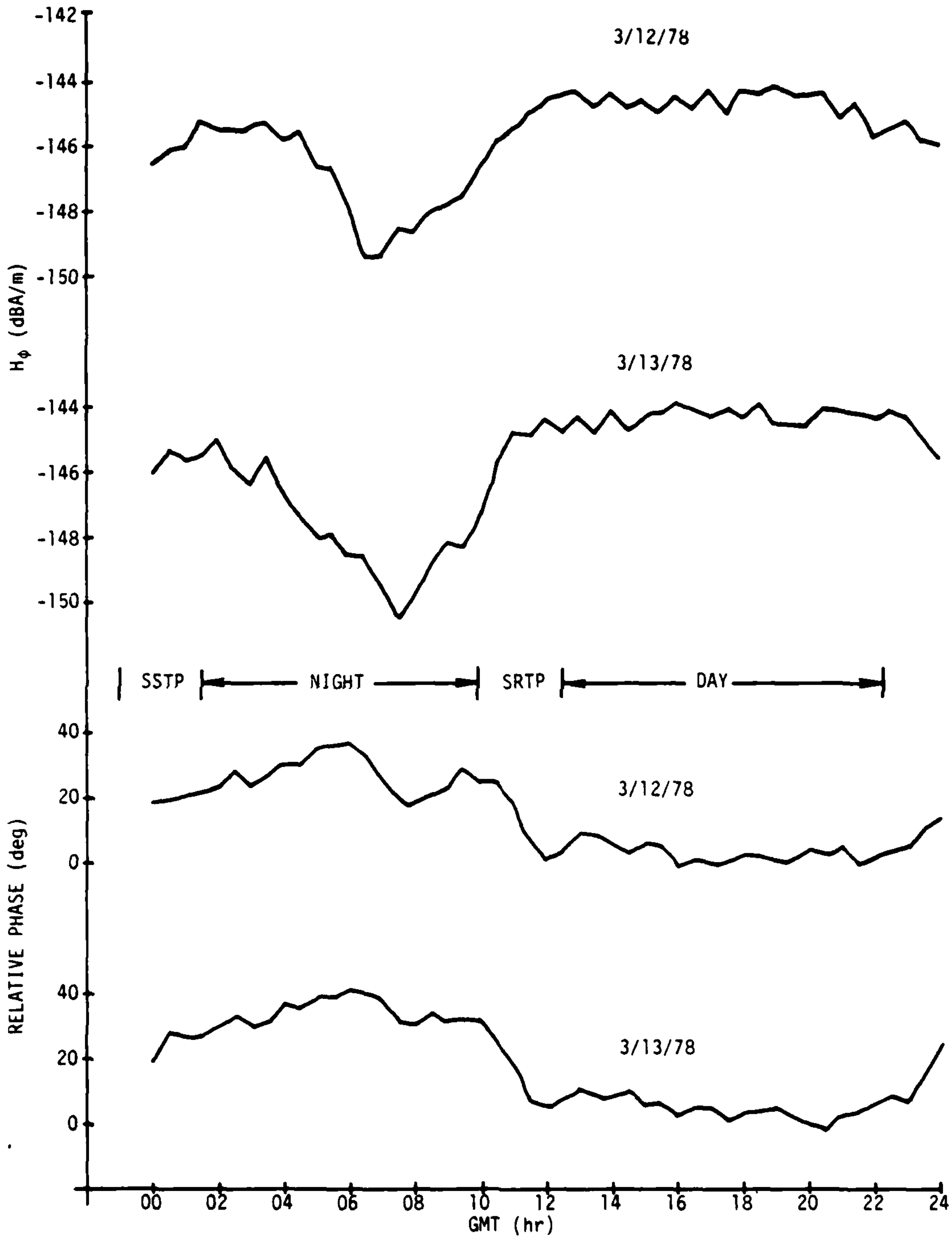

Figure A-8. Connecticut Data Versus GMT (ψ = 201 deg), 12 and 13 March 1978

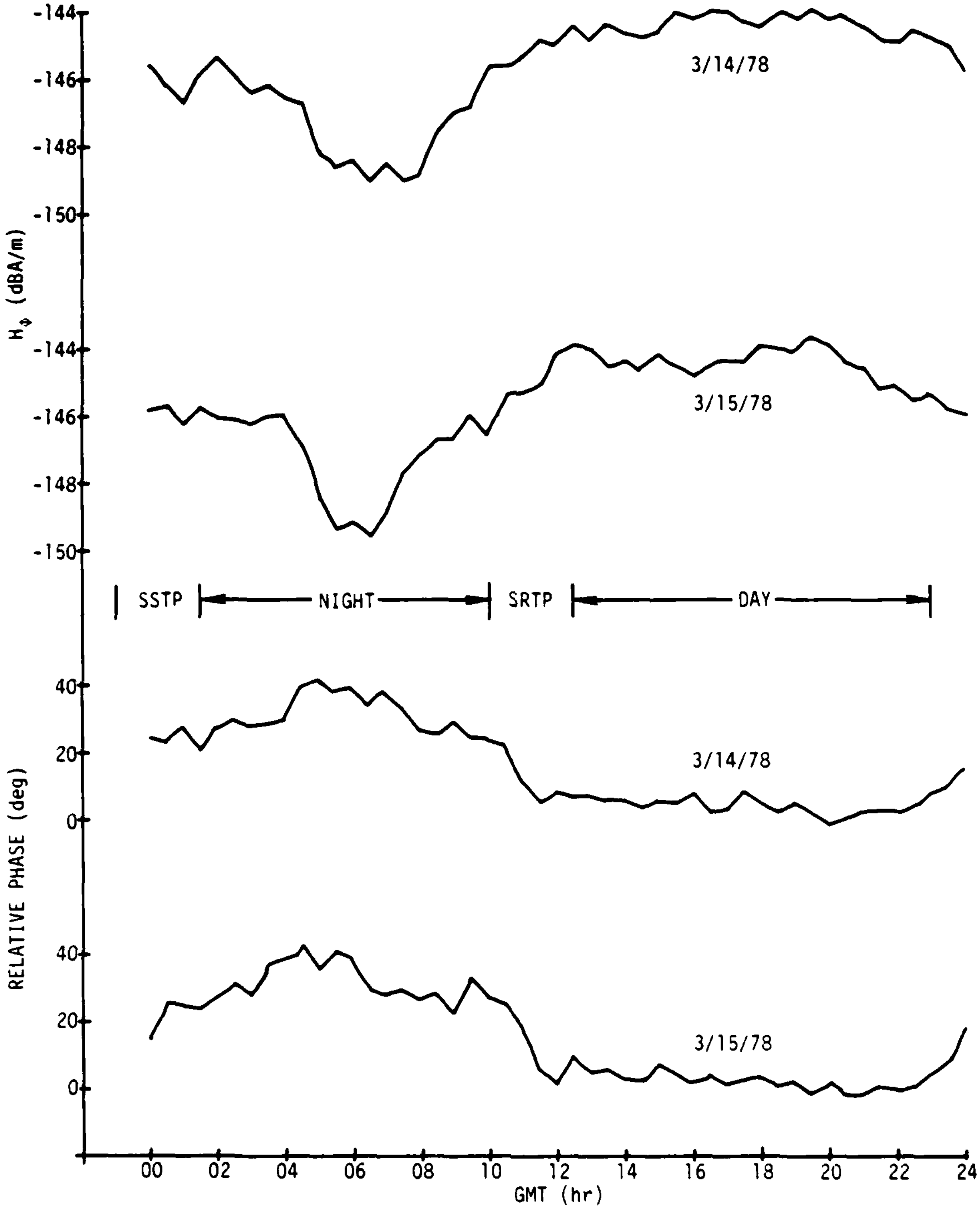

Figure A-9. Connecticut Data Versus GMT (ψ = 201 deg), 14 and 15 March 1978

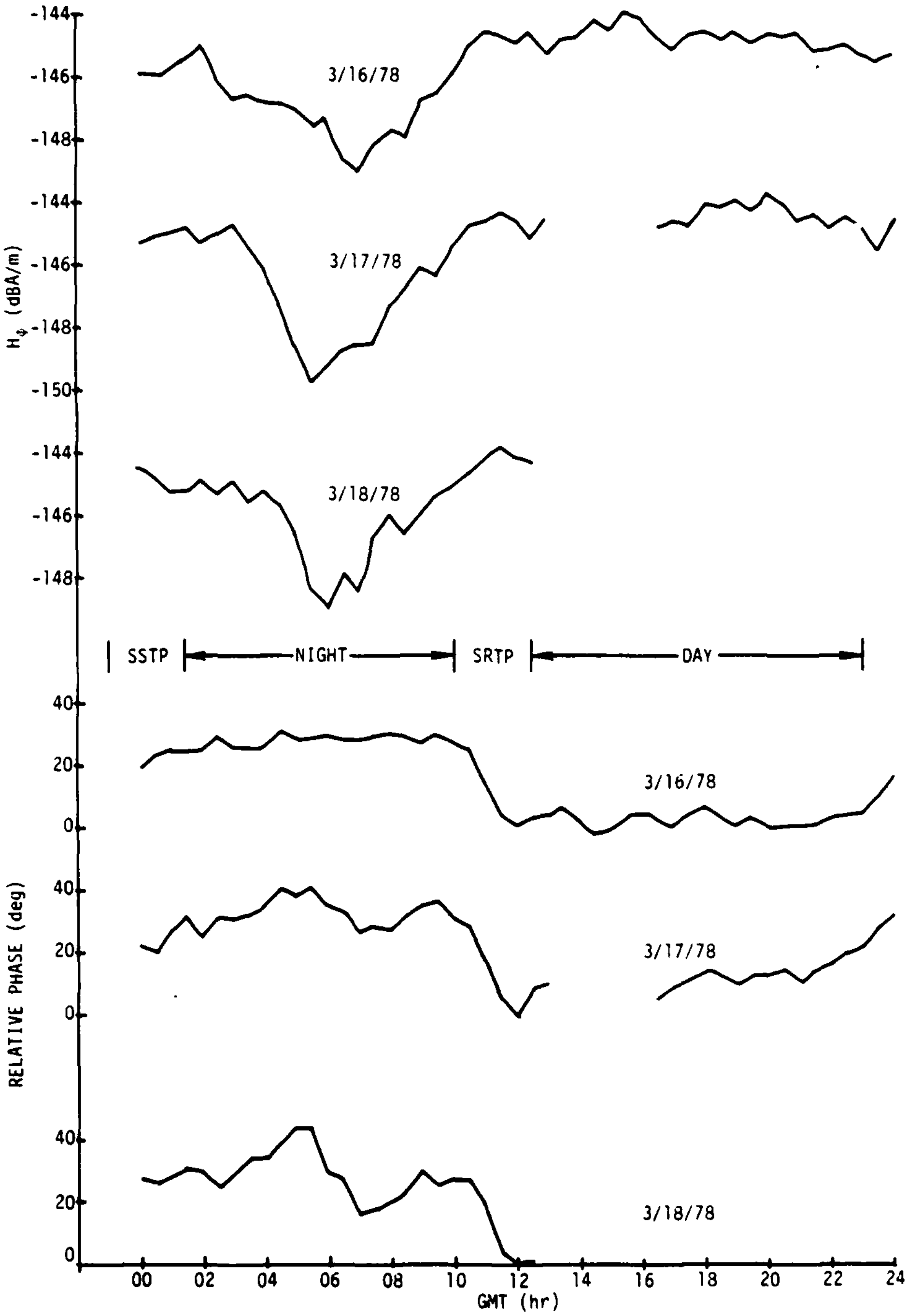

Figure A-10. Connecticut Data Versus GMT (ψ = 201 deg), 16 Through 18 March 1978

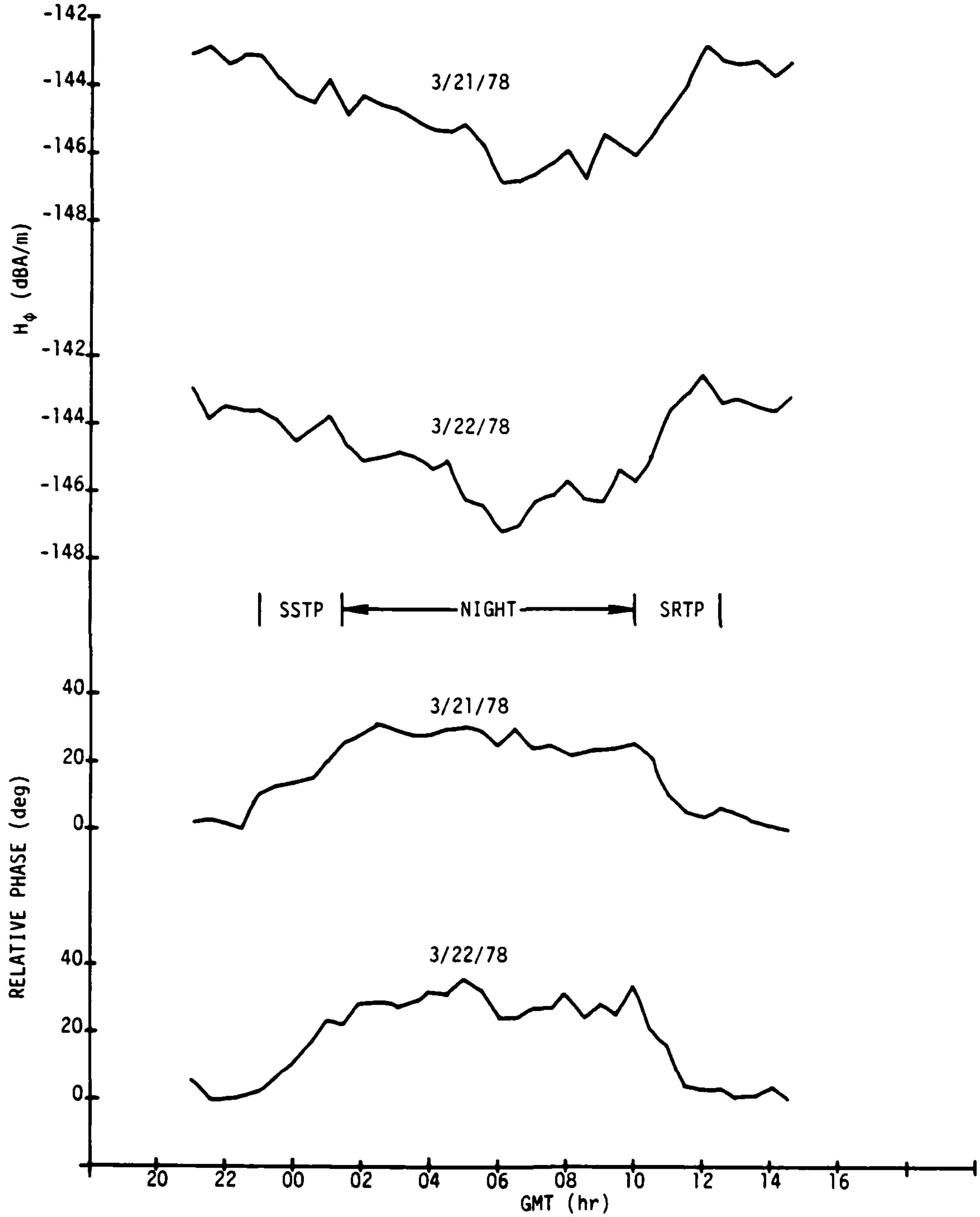

Figure A-11. Connecticut Data Versus GMT (ψ = 291 deg), 21 and 22 March 1978

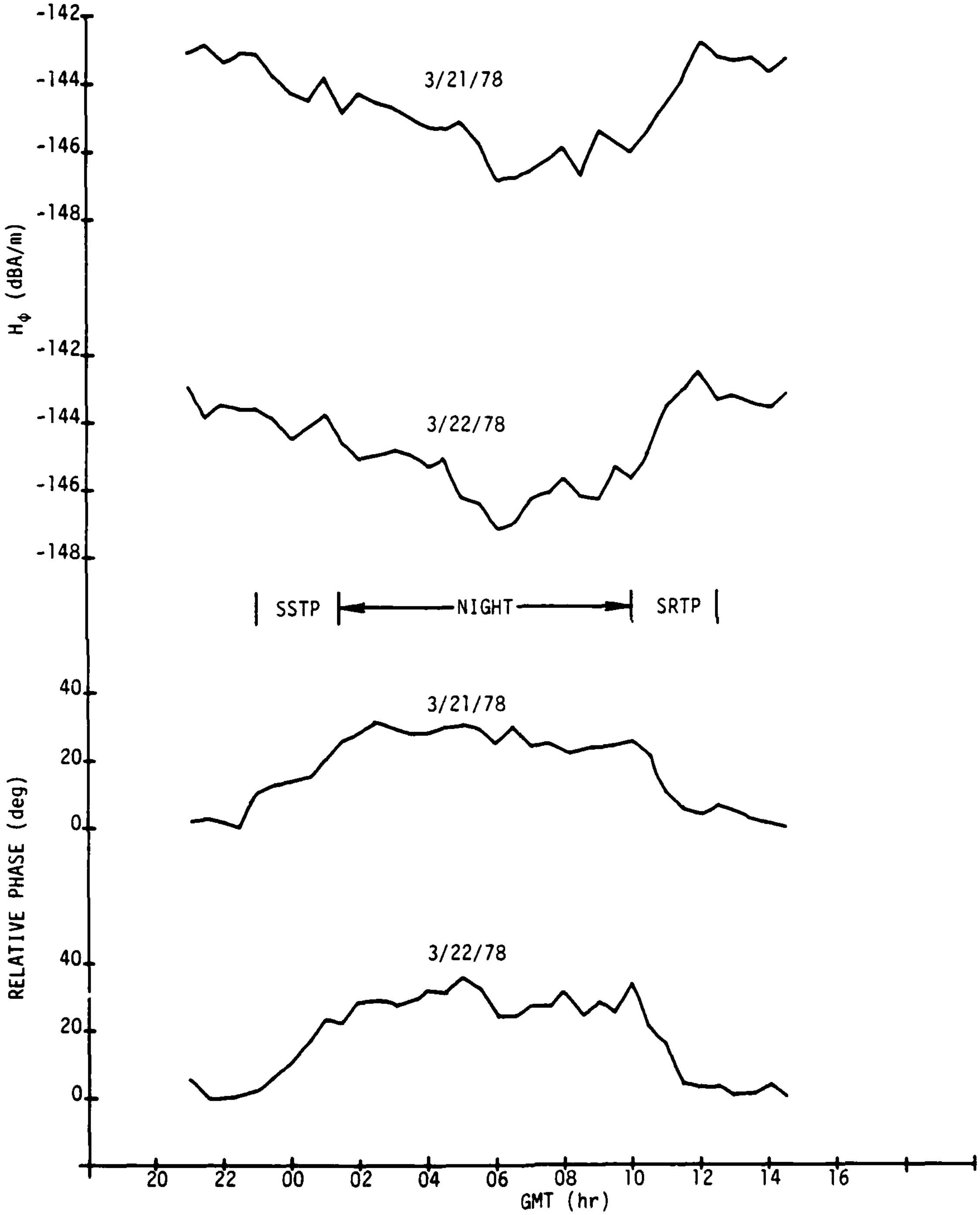

Figure A-11. Connecticut Data Versus GMT (ψ = 291 deg), 21 and 22 March 1978

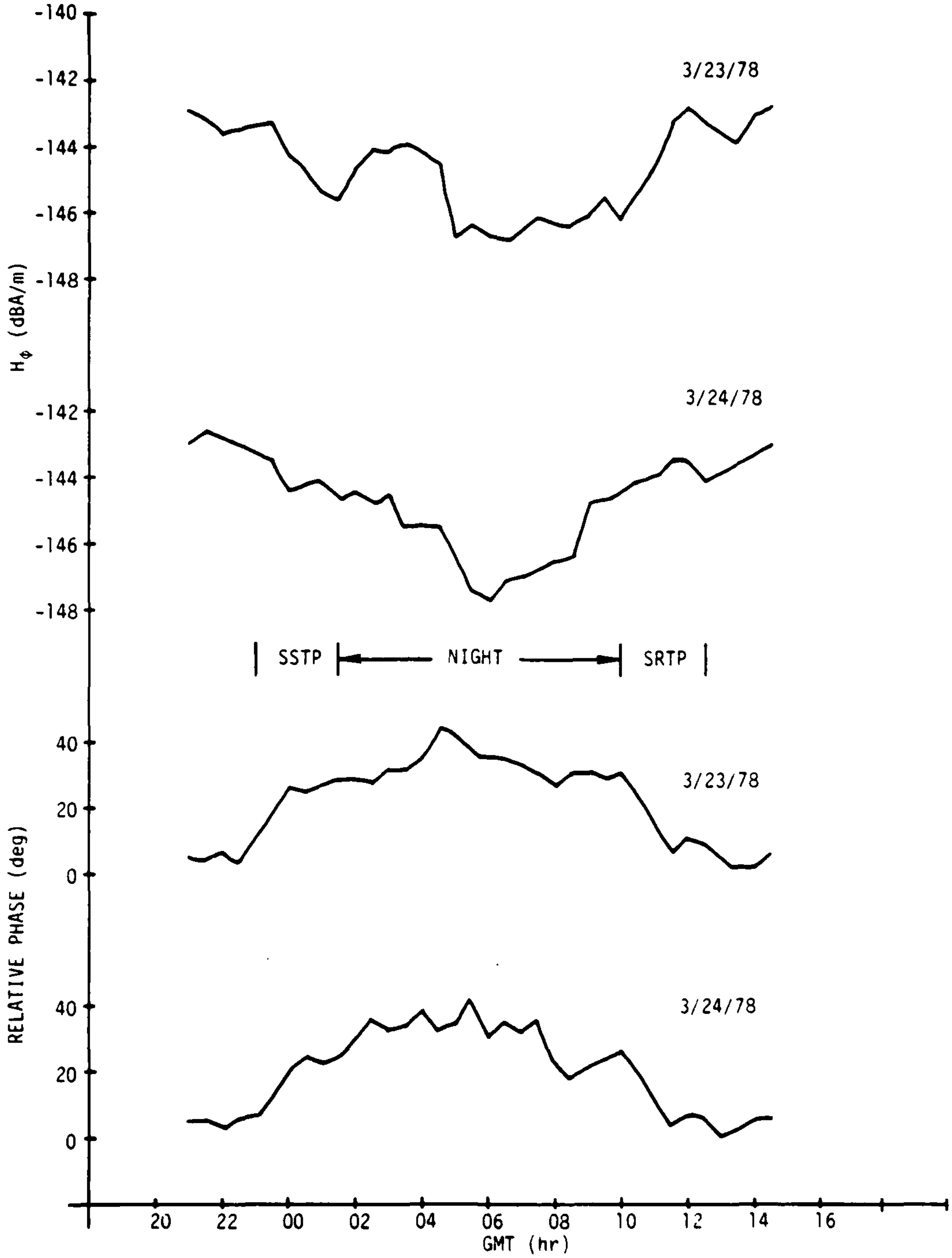

Figure A-12. Connecticut Data Versus GMT (ψ = 291 deg), 23 and 24 March 1978

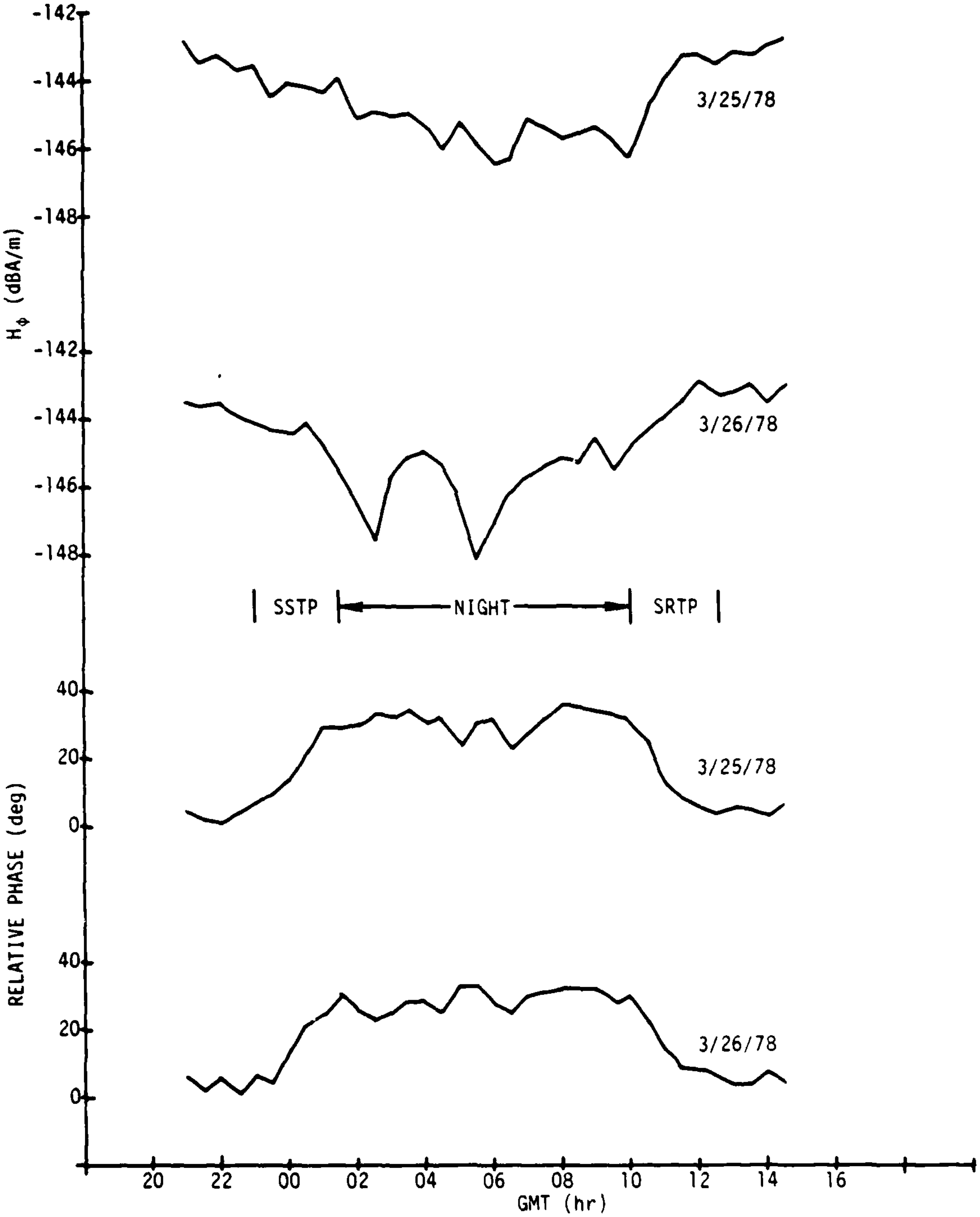

Figure A-13. Connecticut Data Versus GMT (ψ = 291 deg), 25 and 26 March 1978

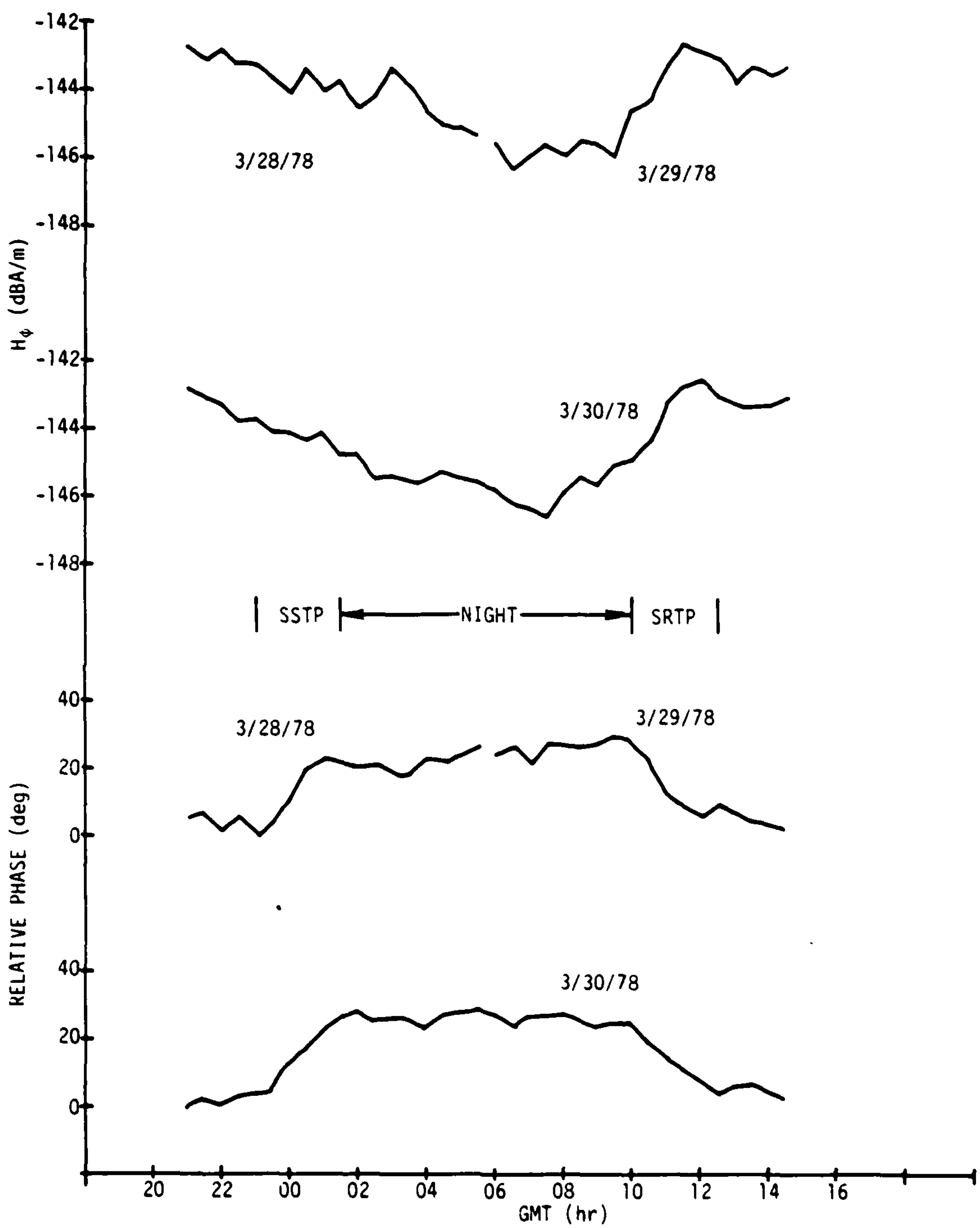

Figure A-14. Connecticut Data Versus GMT (ψ = 291 deg), 28 Through 30 March 1978

Appendix B

CONNECTICUT DAILY DATA, APRIL 1978

Daily plots of Connecticut signal strength (both amplitude and relative phase) versus GMT for April 1978 are given in this appendix as figures B-1 through B-13.

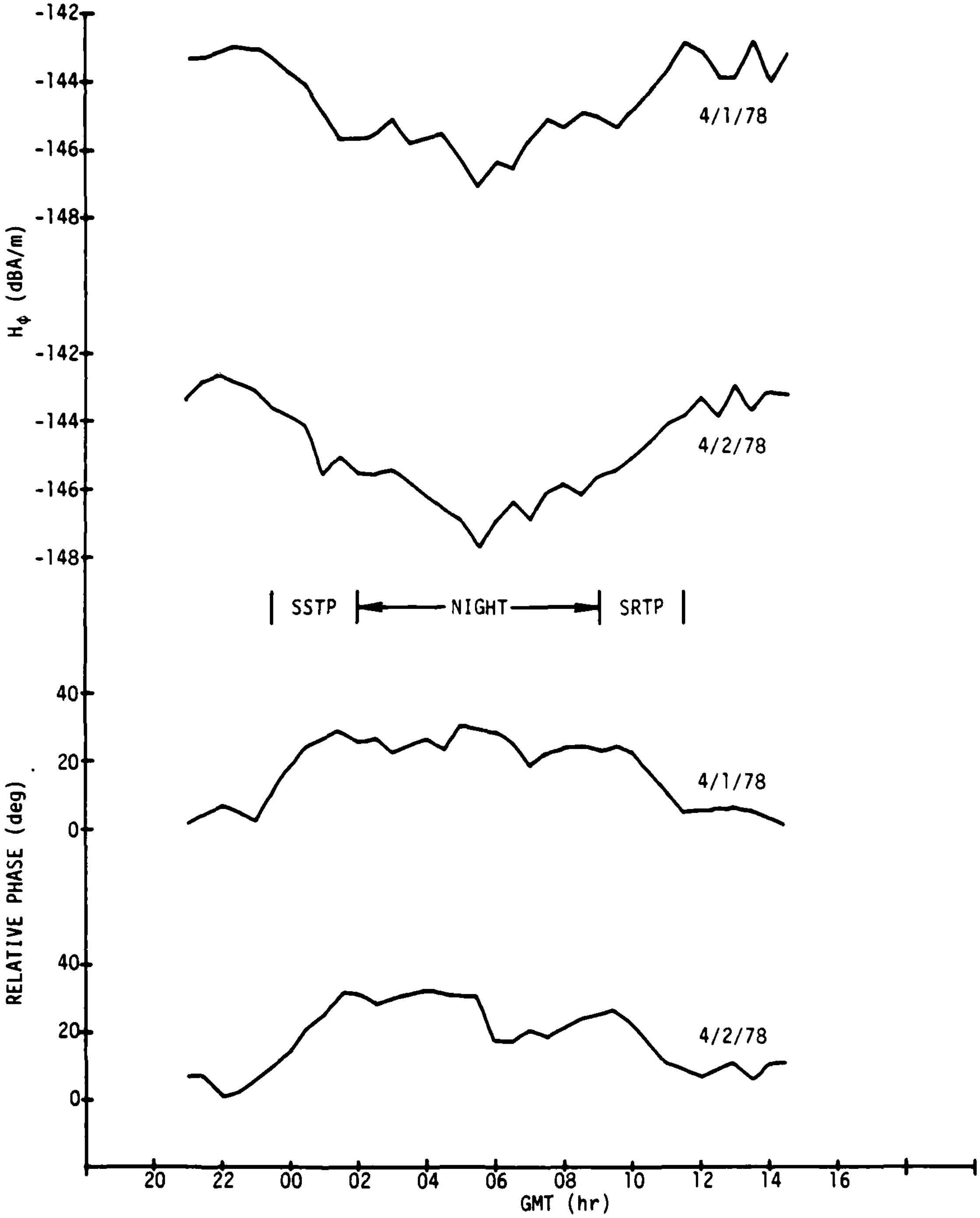

Figure B-1. Connecticut Data Versus GMT (ψ = 291 deg), 1 and 2 April 1978

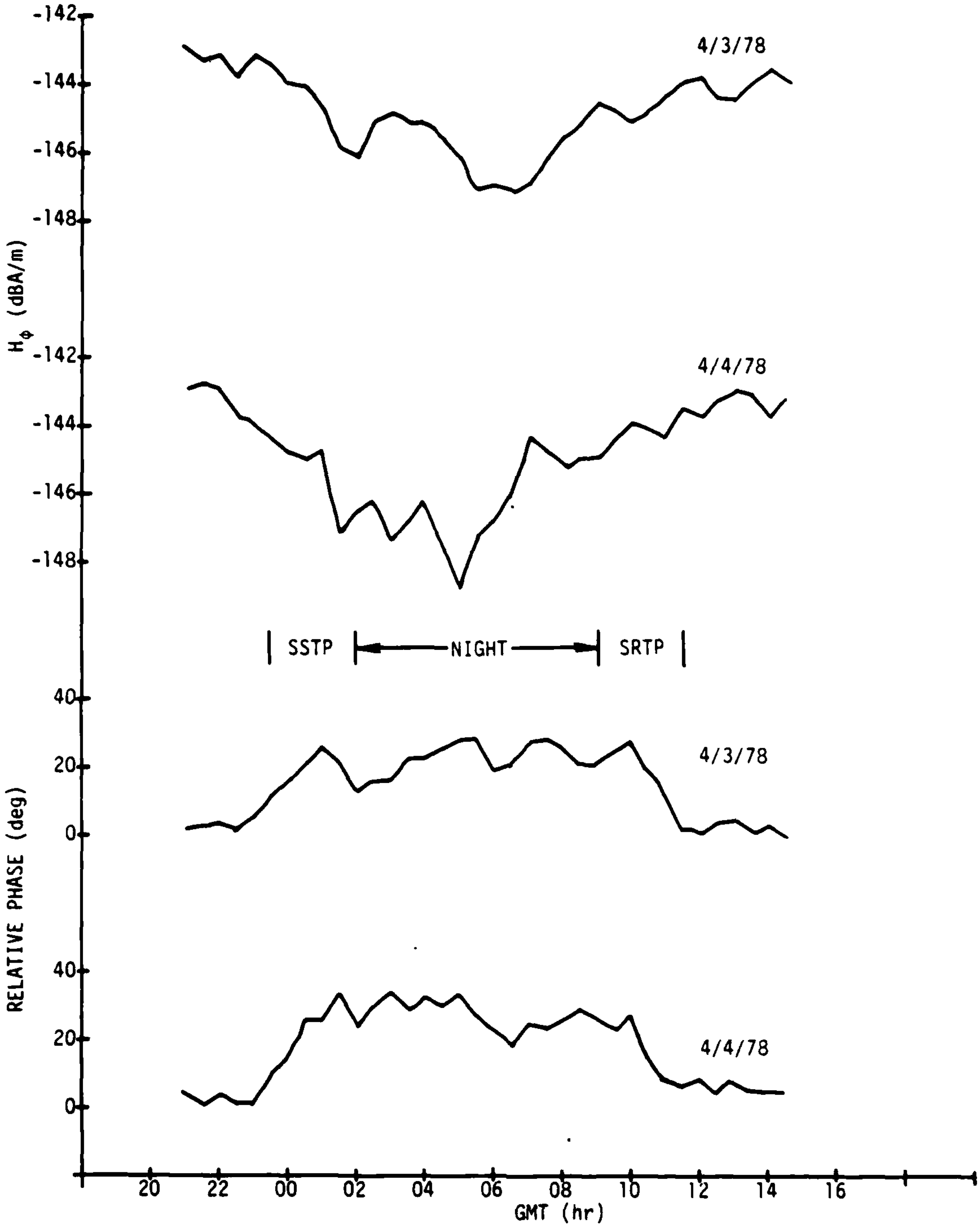

Figure B-2. Connecticut Data Versus GMT (ψ = 291 deg), 3 and 4 April 1978

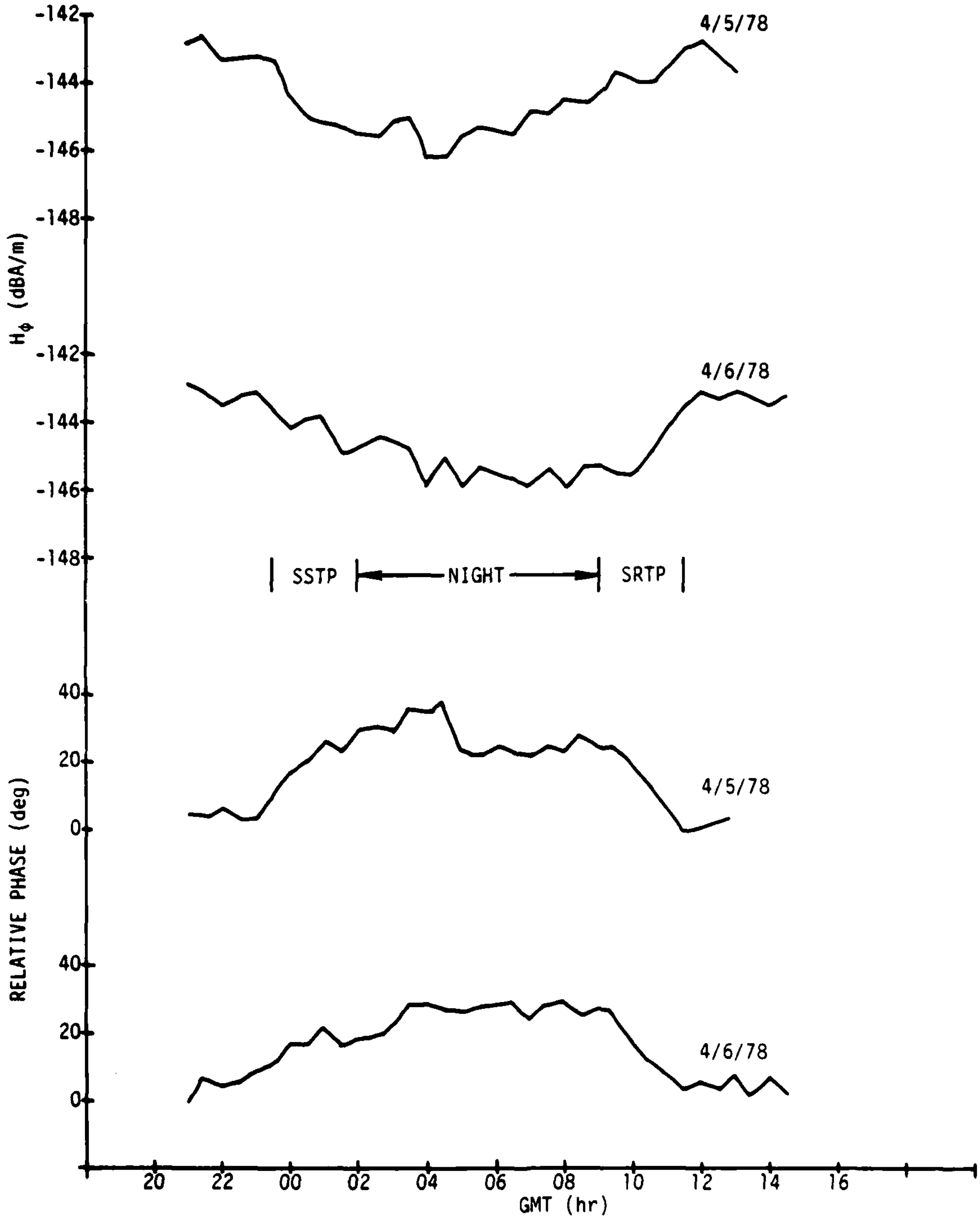

Figure B-3. Connecticut Data Versus GMT (ψ = 291 deg), 5 and 6 April 1978

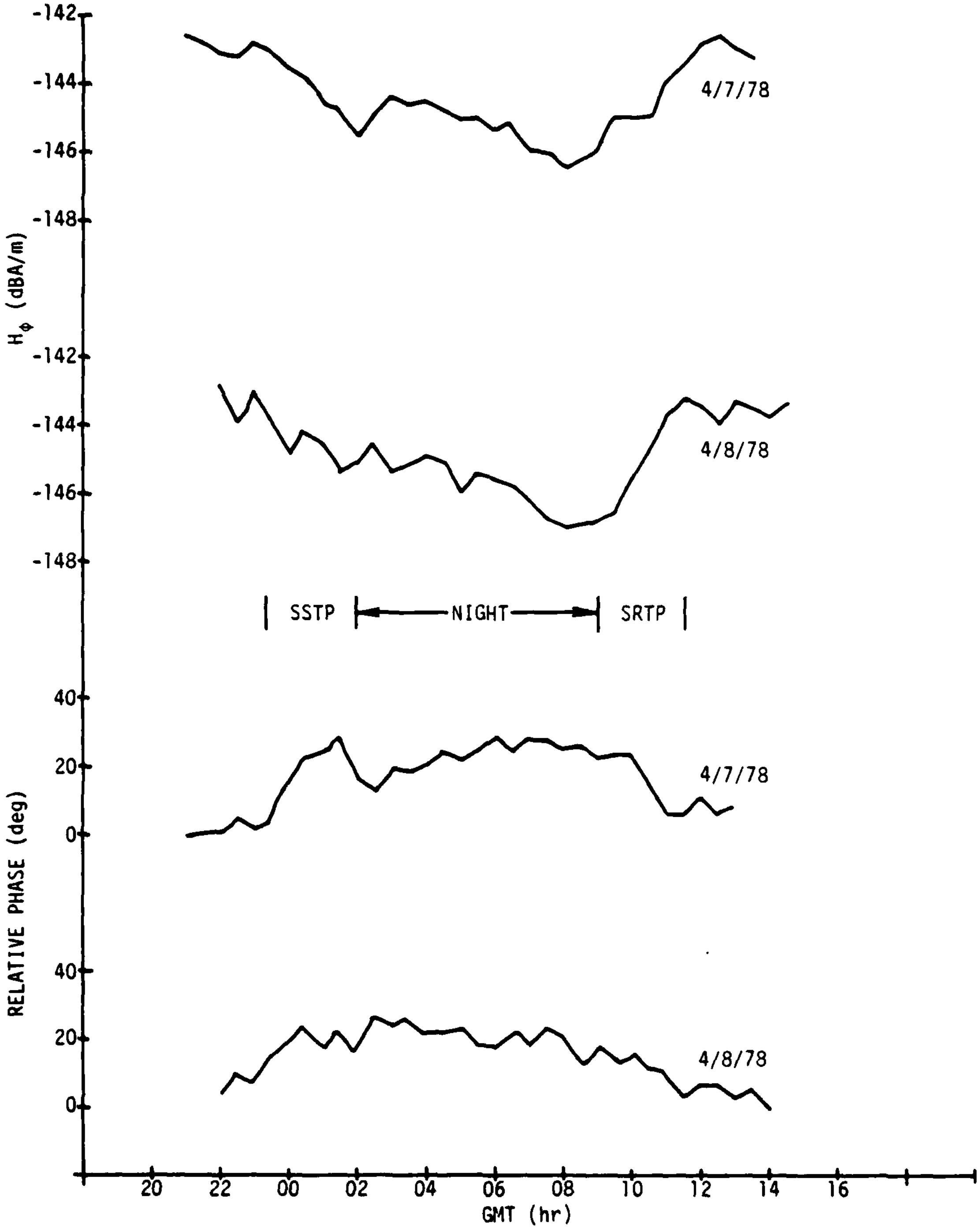

Figure B-4. Connecticut Data Versus GMT (ψ = 291 deg), 7 and 8 April 1978

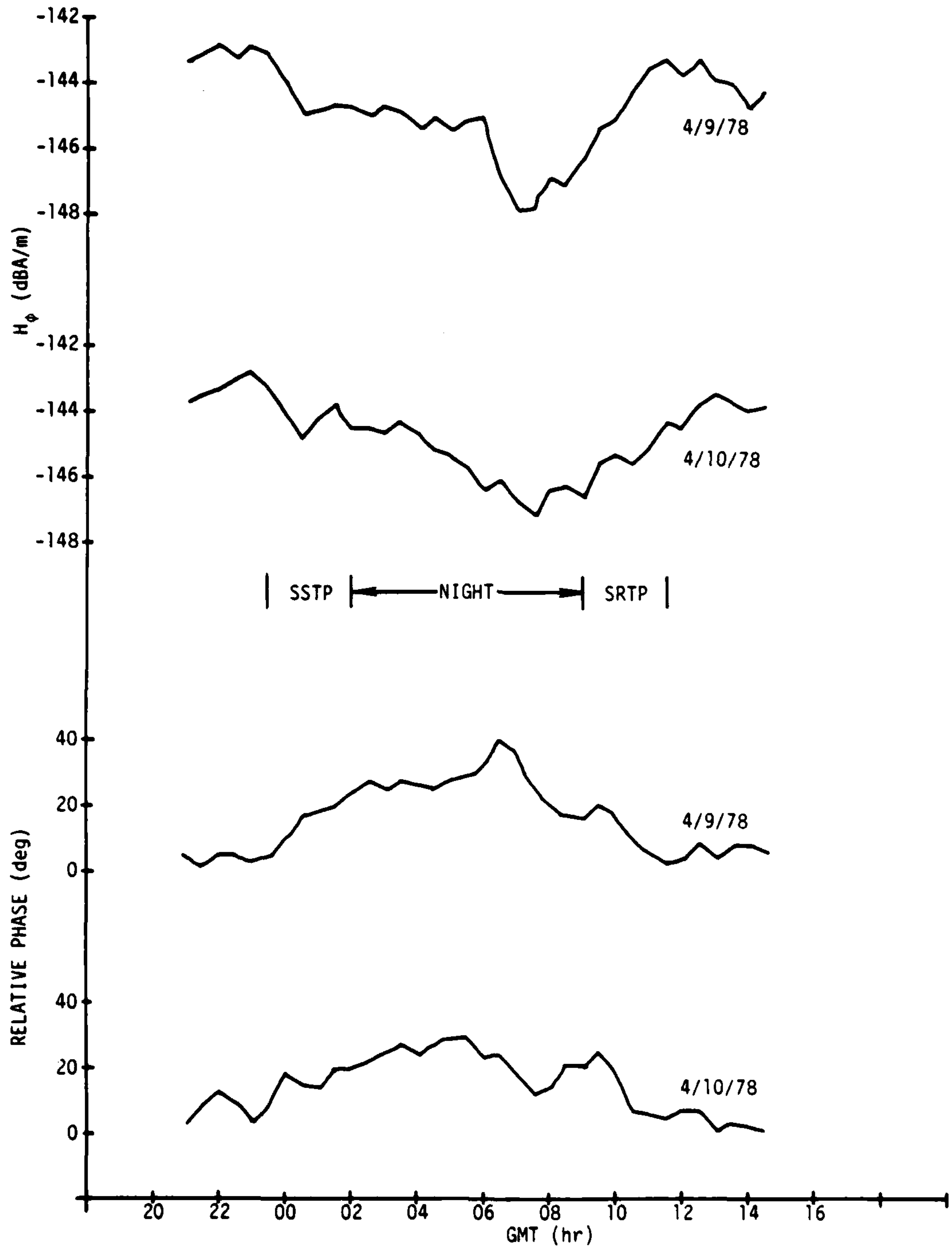

Figure B-5. Connecticut Data Versus GMT (ψ = 291 deg), 9 and 10 April 1978

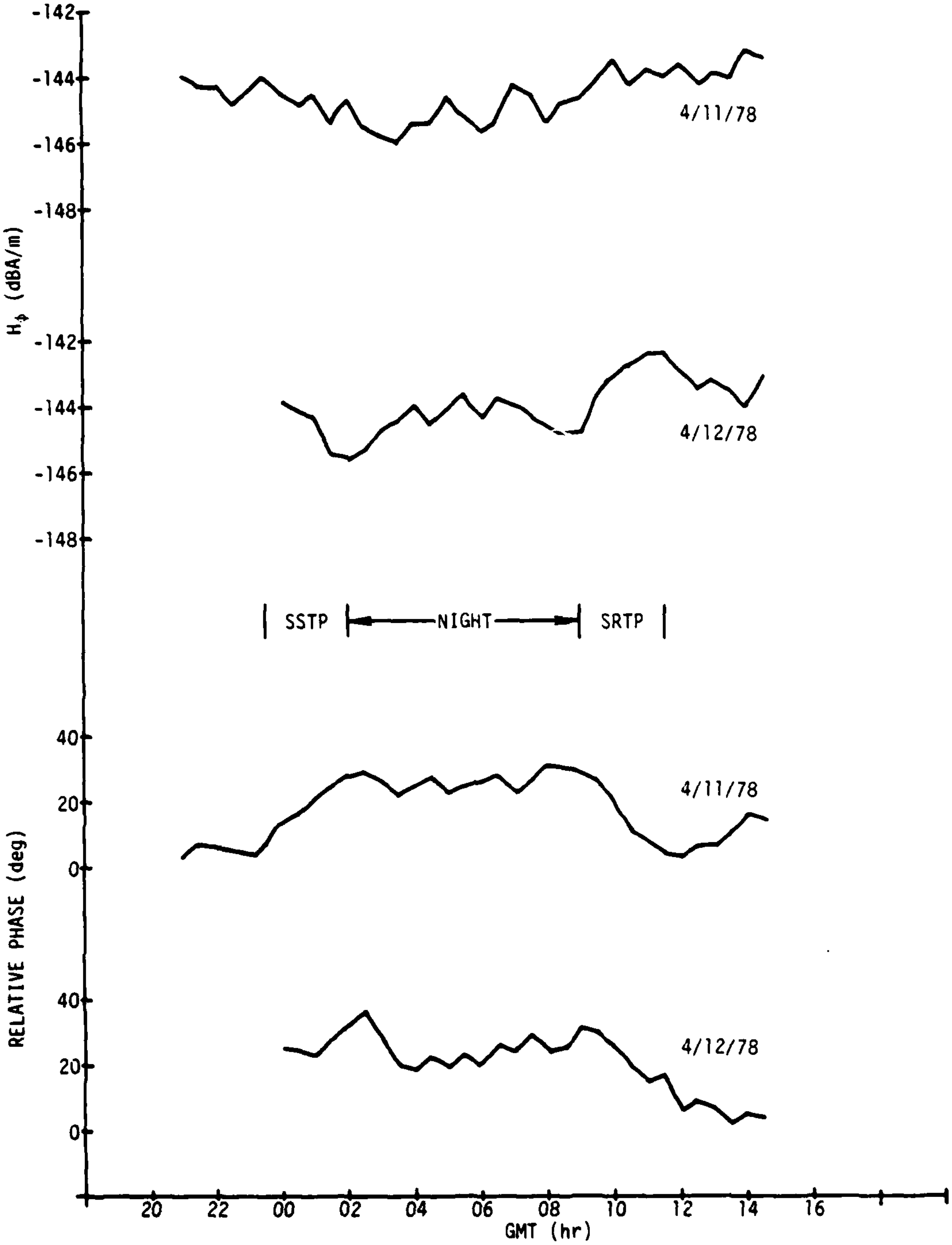

Figure B-6. Connecticut Data Versus GMT (ψ = 291 deg), 11 and 12 April 1978

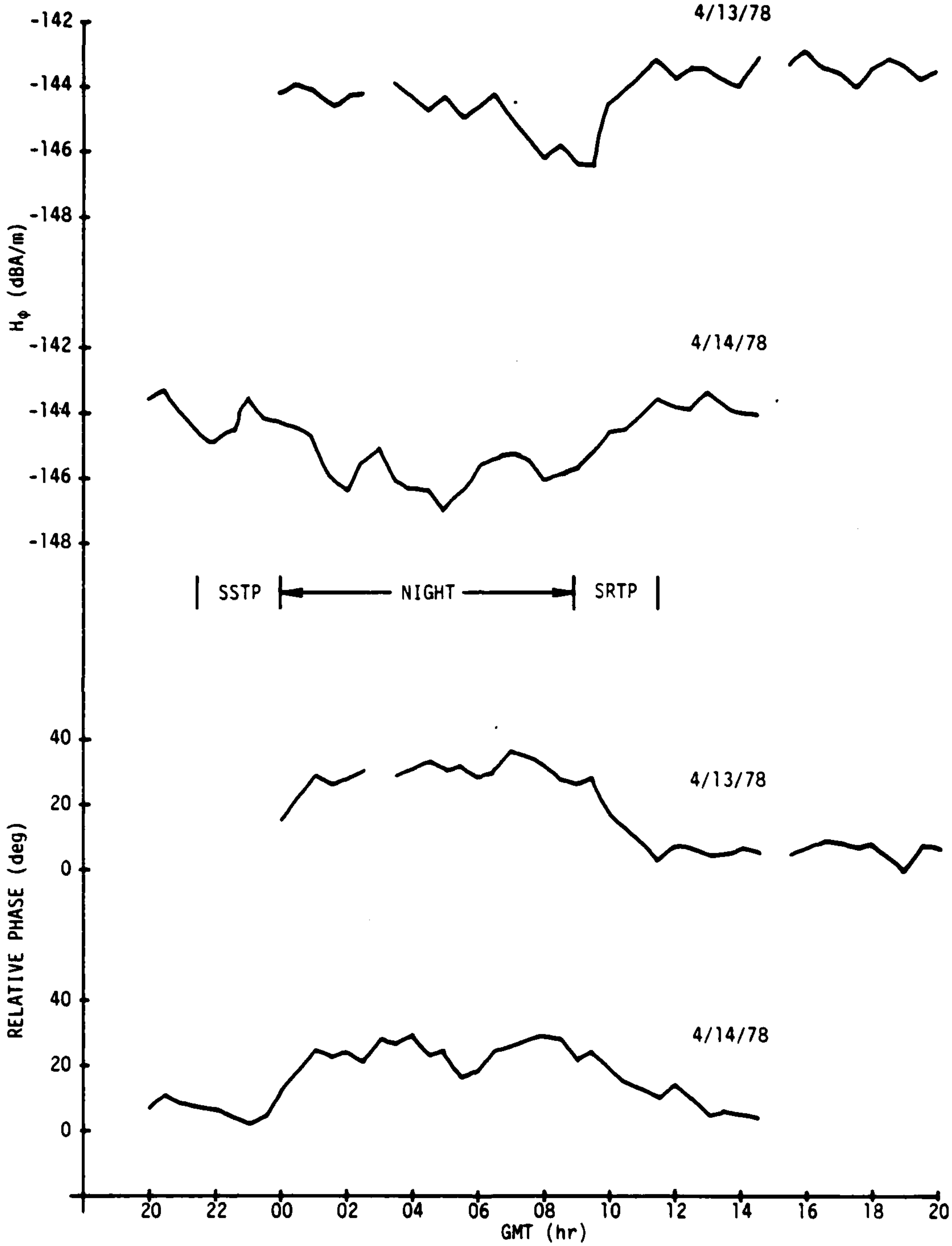

Figure B-7. Connecticut Data Versus GMT (ψ = 291 deg), 13 and 14 April 1978

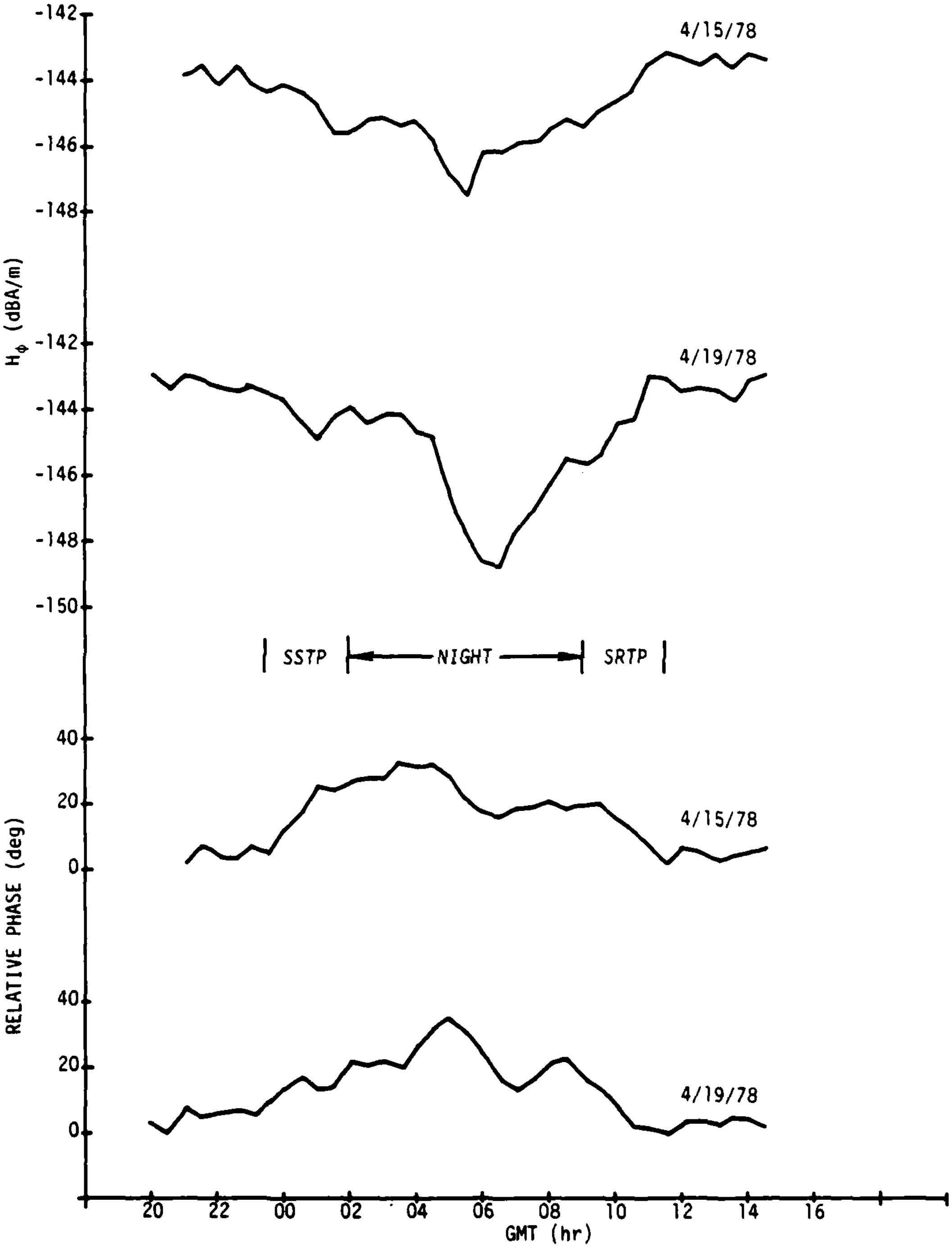

Figure B-8. Connecticut Data Versus GMT (ψ = 291 deg), 15 and 19 April 1978

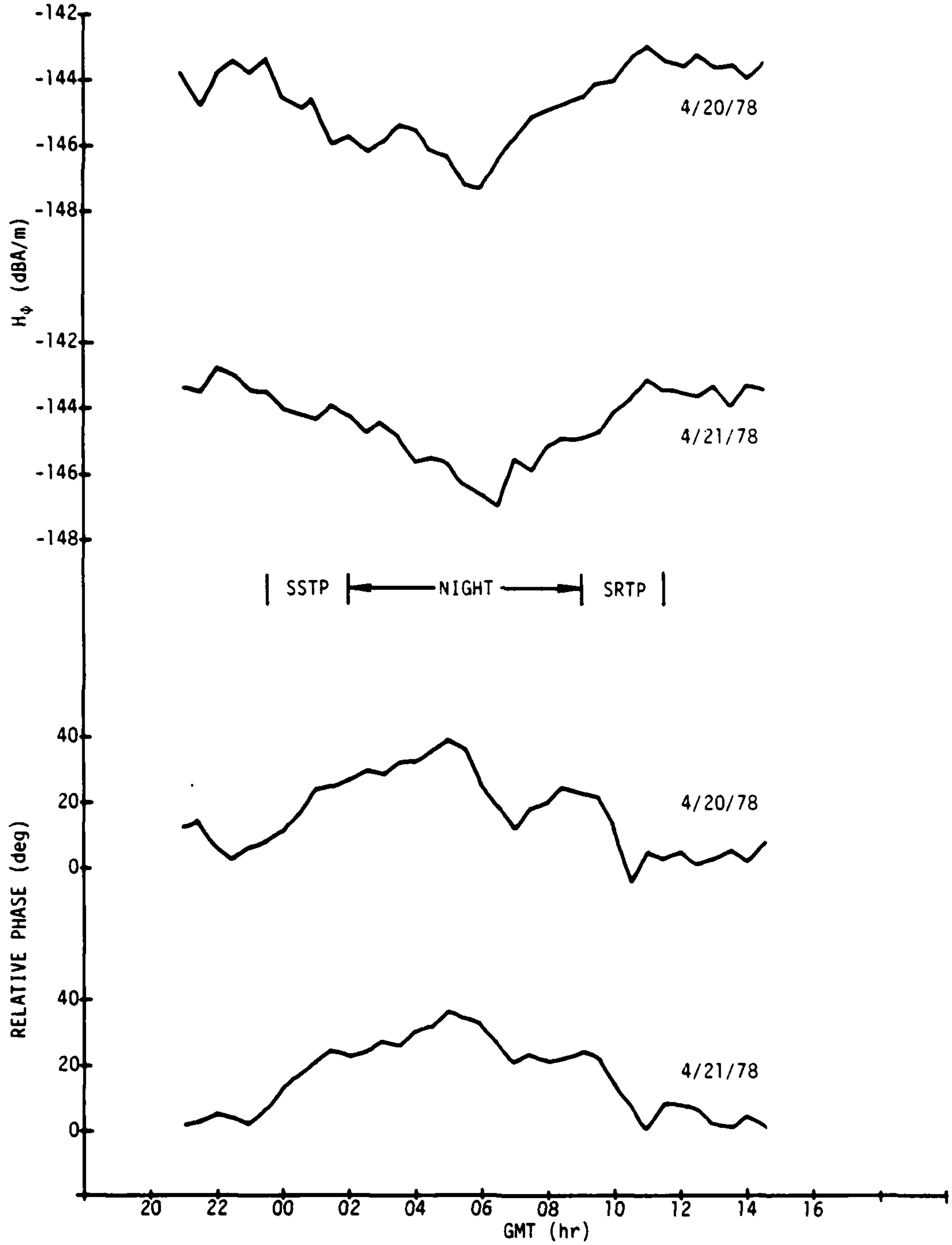

Figure B-9. Connecticut Data Versus GMT (ψ = 291 deg), 20 and 21 April 1978

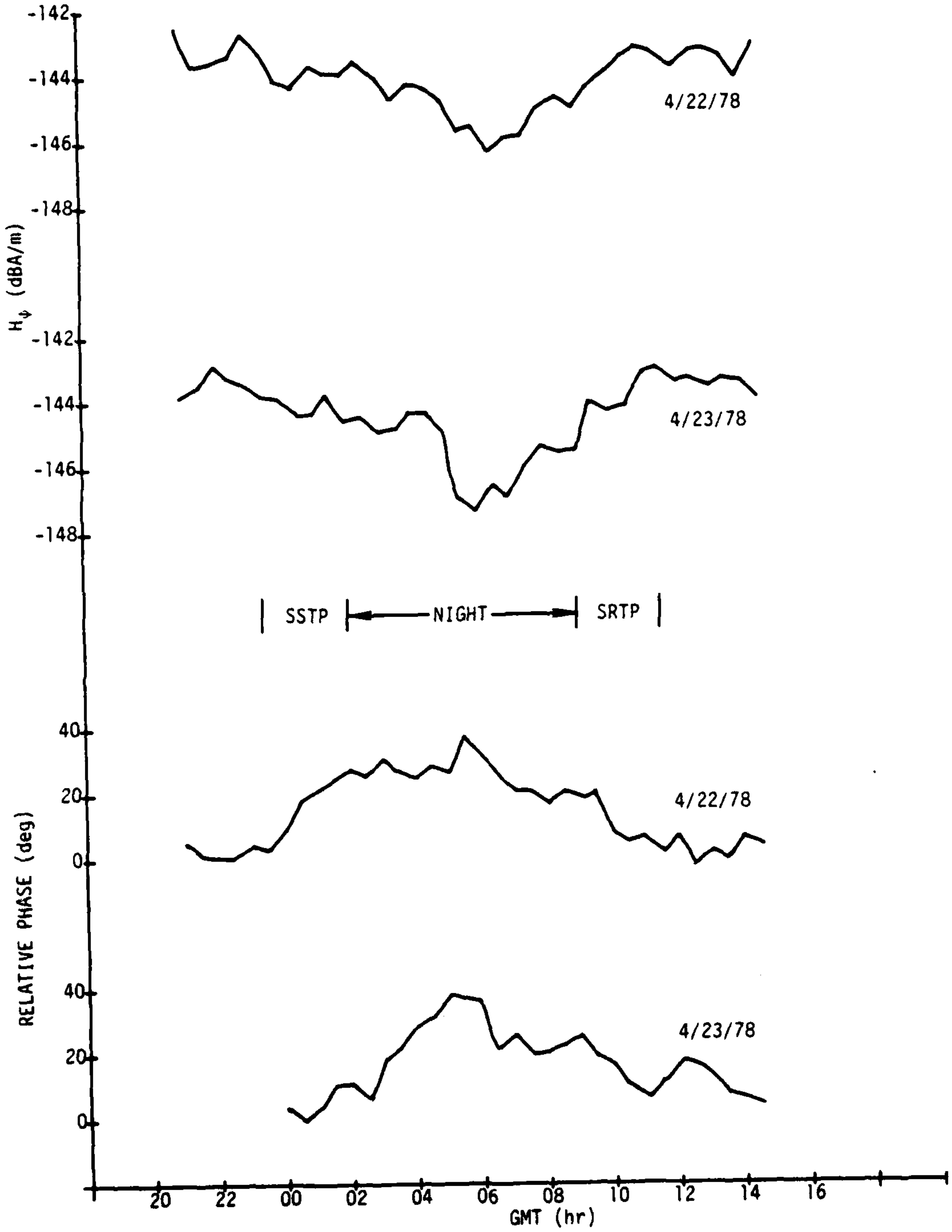

Figure B-10. Connecticut Data Versus GMT (ψ = 291 deg), 22 and 23 April 1978

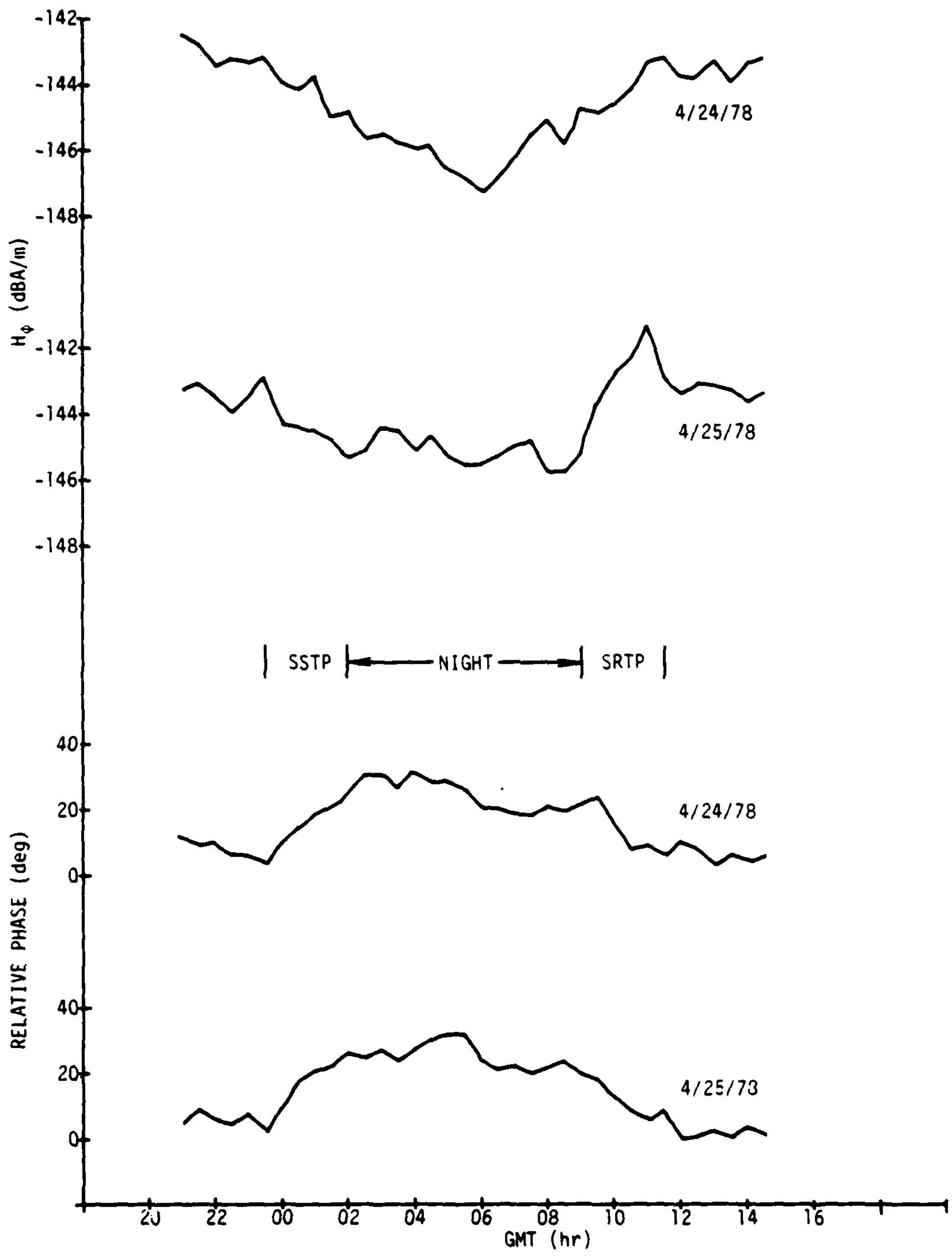

Figure B-11. Connecticut Data Versus GMT (ψ = 291 deg), 24 and 25 April 1978

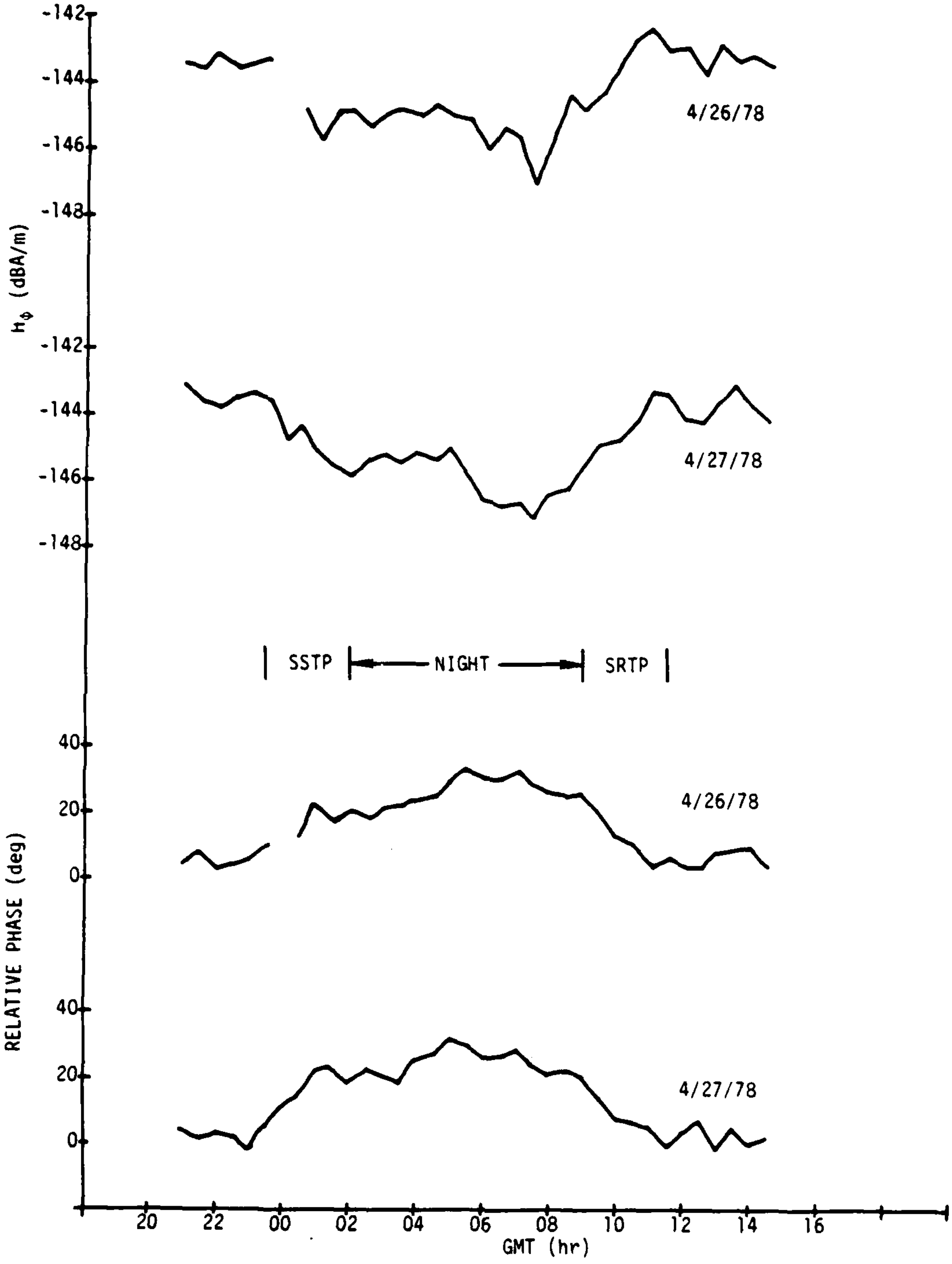

Figure B-12. Connecticut Data Versus GMT (ψ = 291), 26 and 27 April 1978

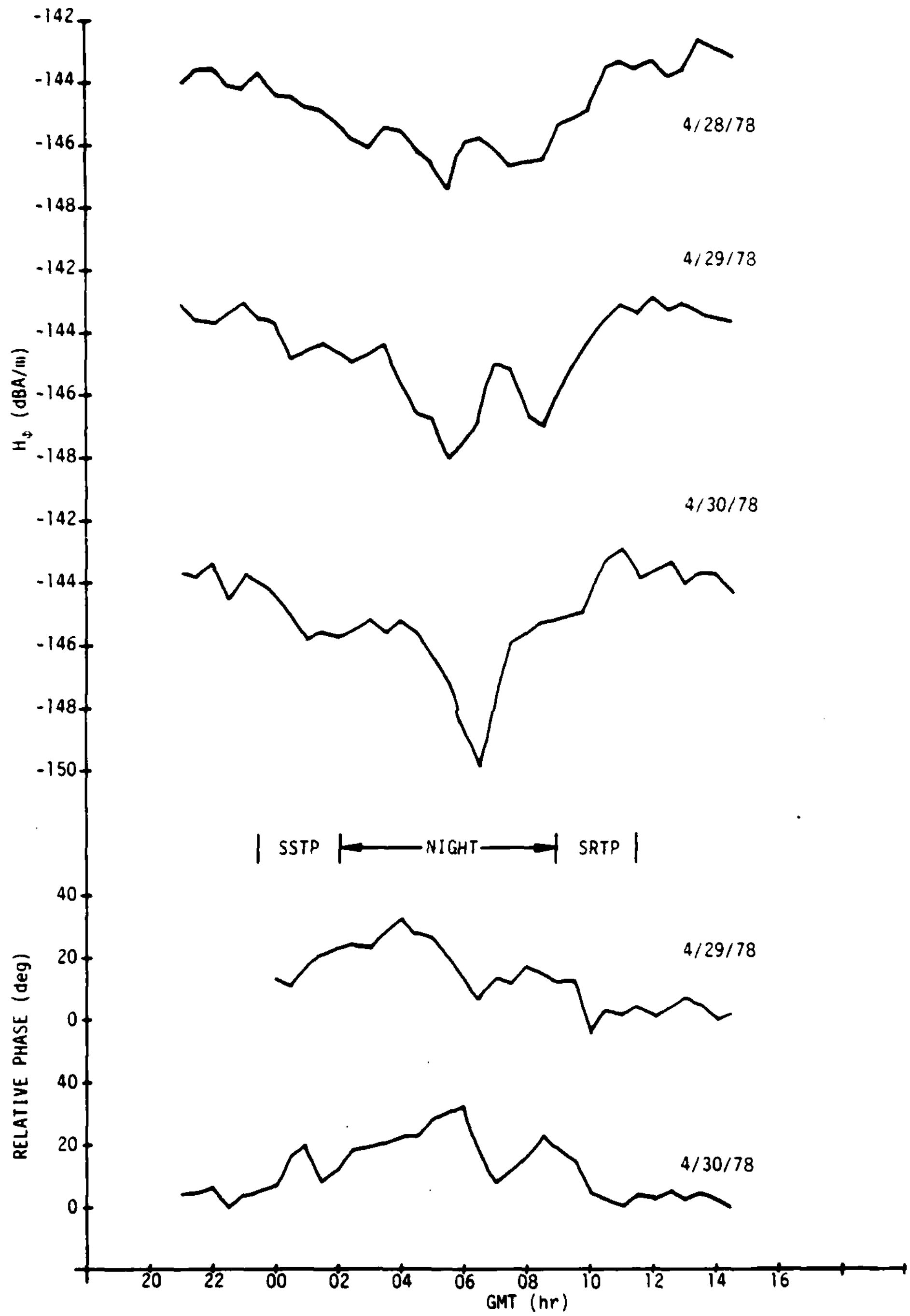

Figure B-13. Connecticut Data Versus GMT (ψ = 291 deg), 28 Through 30 April 1978

Appendix C

CONNECTICUT DAILY DATA, MAY 1978

Daily plots of Connecticut signal strength (both amplitude and relative phase) versus GMT for May 1978 are given in this appendix as figures C-1 through C-12.

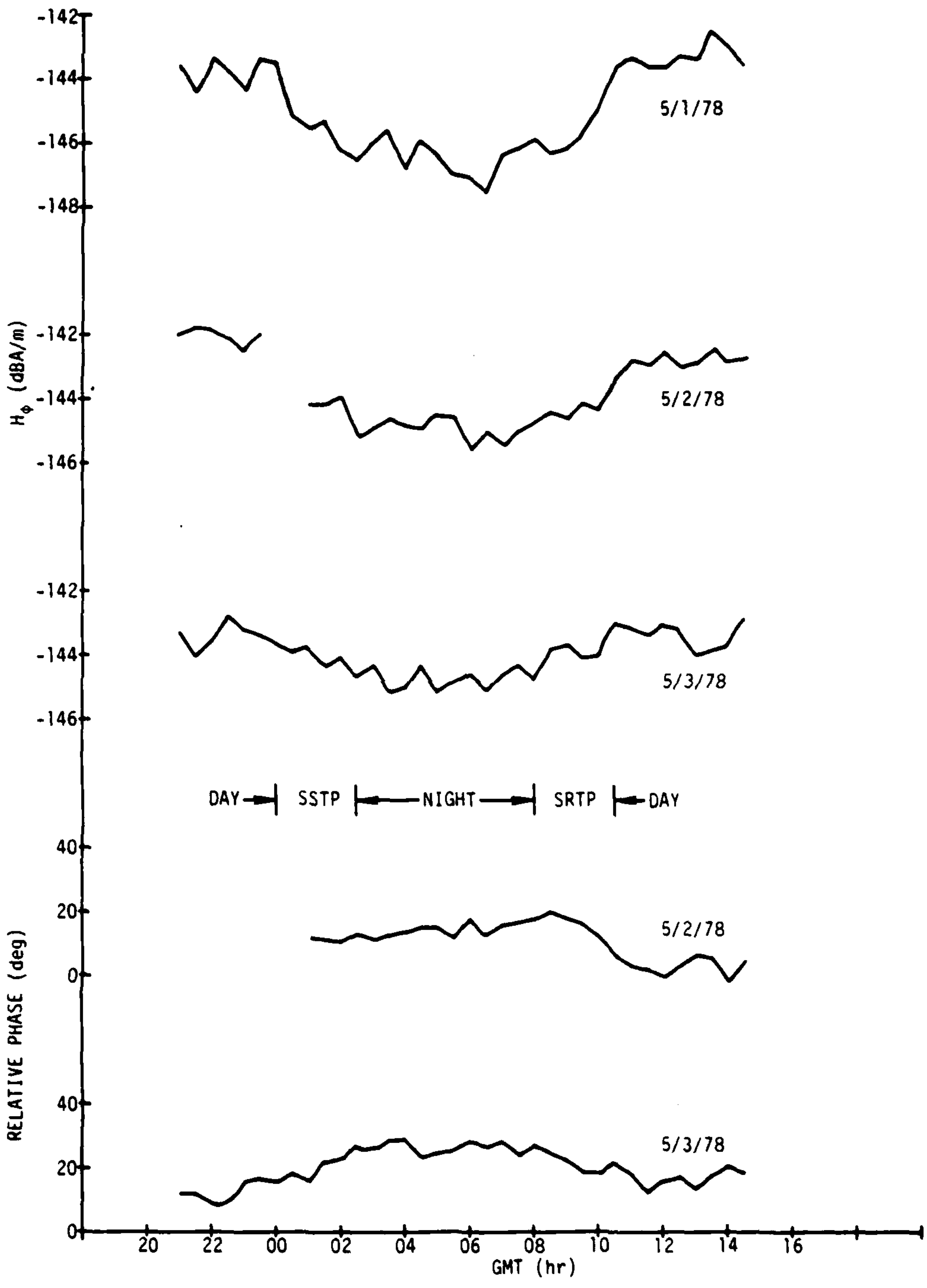

Figure C-1. Connecticut Data Versus GMT (ψ = 291 deg), 1 Through 3 May 1978

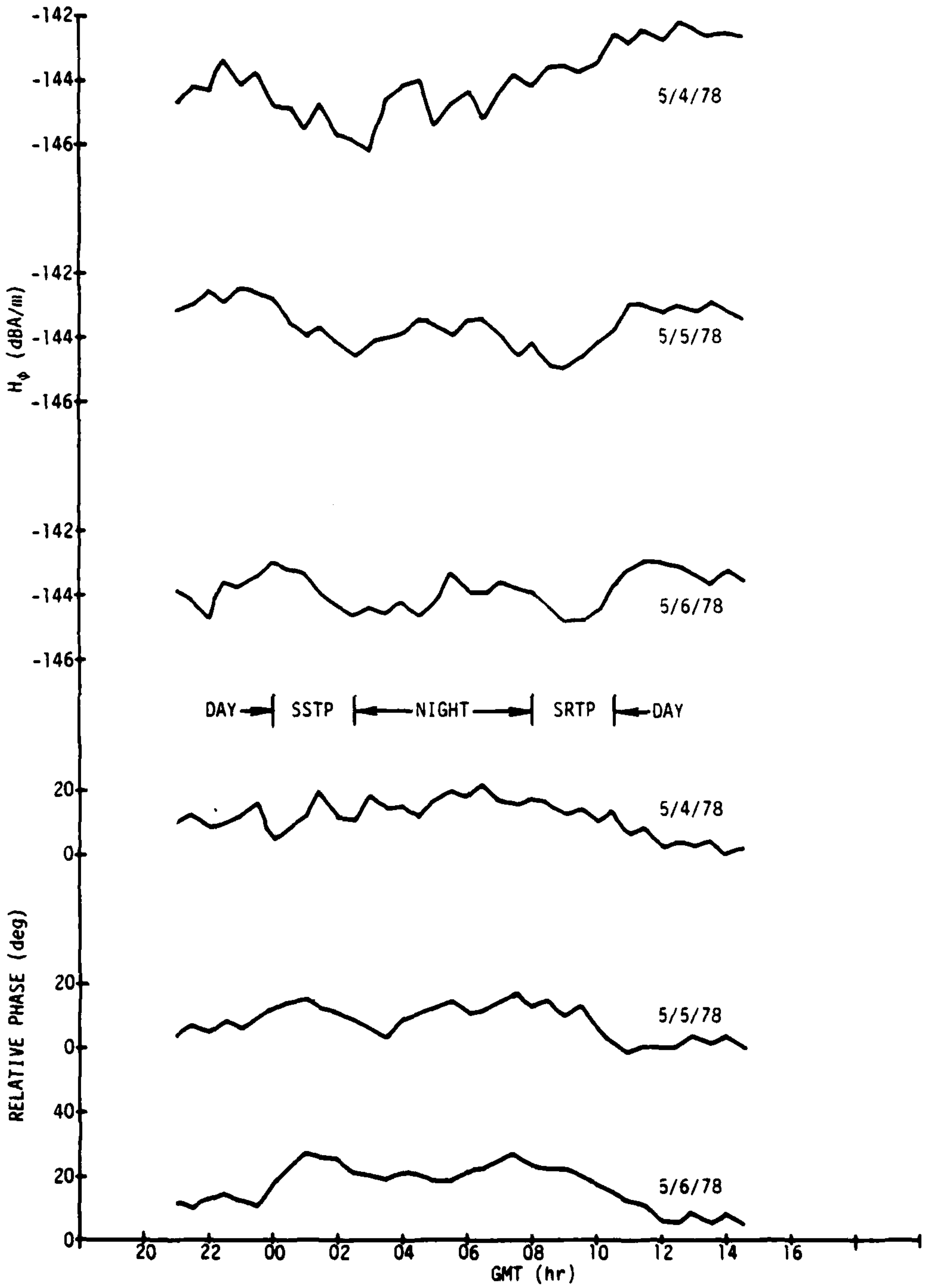

Figure C-2. Connecticut Data Versus GMT (ψ = 291 deg), 4 Through 6 May 1978

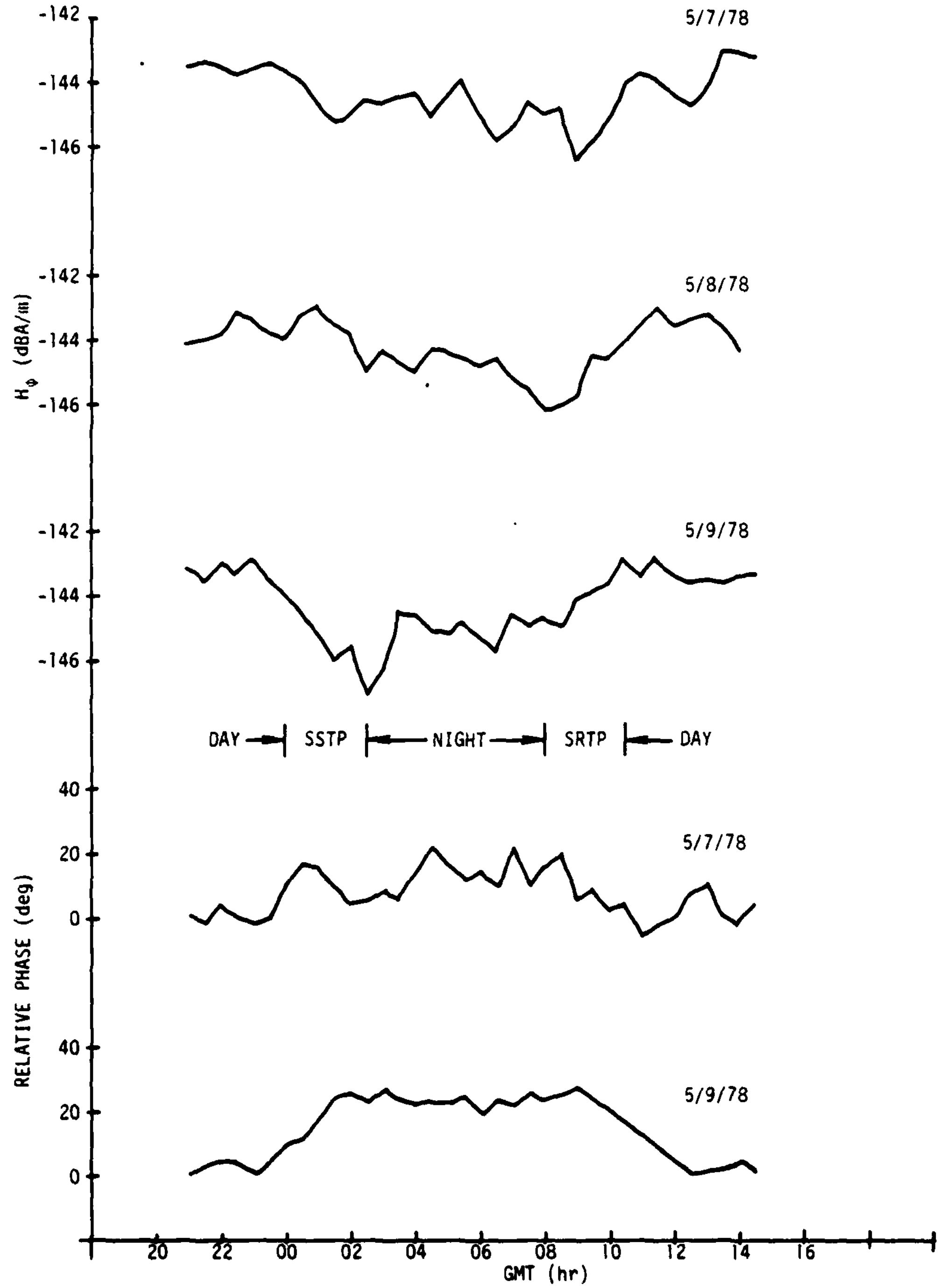

Figure C-3. Connecticut Data Versus GMT (ψ = 291 deg), 7 Through 9 May 1978

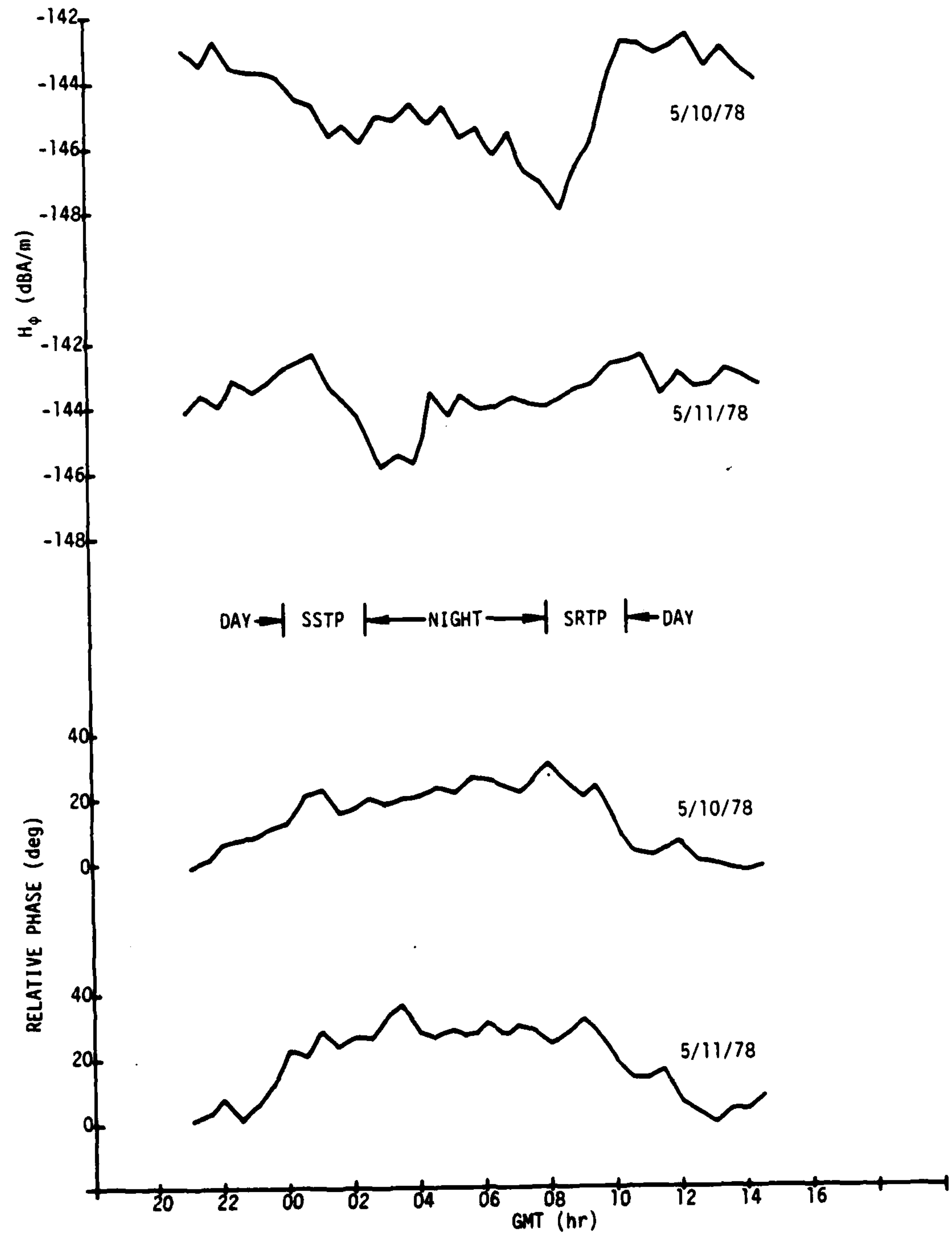

Figure C-4. Connecticut Data Versus GMT (ψ = 291 deg), 10 and 11 May 1978

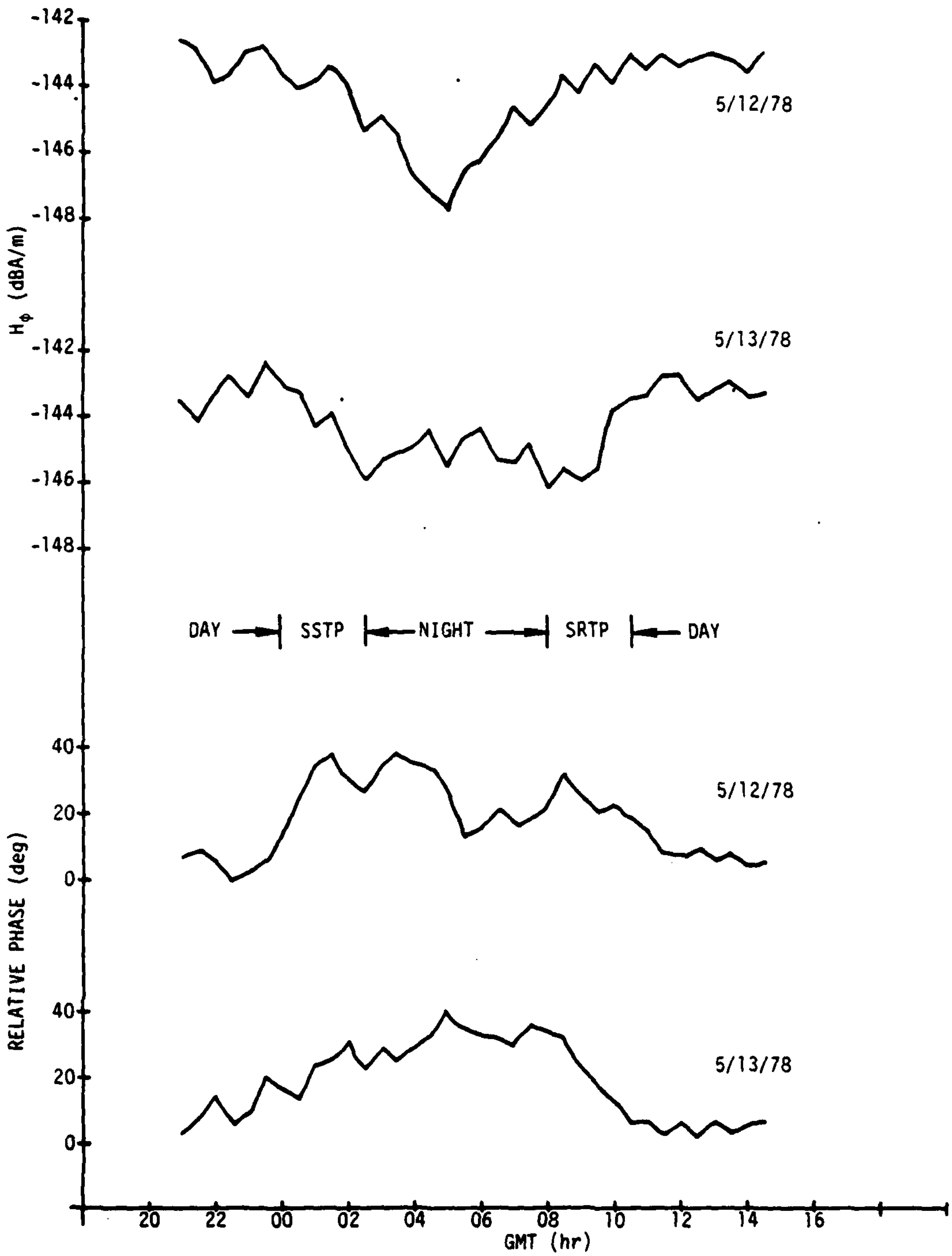

Figure C-5. Connecticut Data Versus GMT (ψ = 291 deg), 12 and 13 May 1978

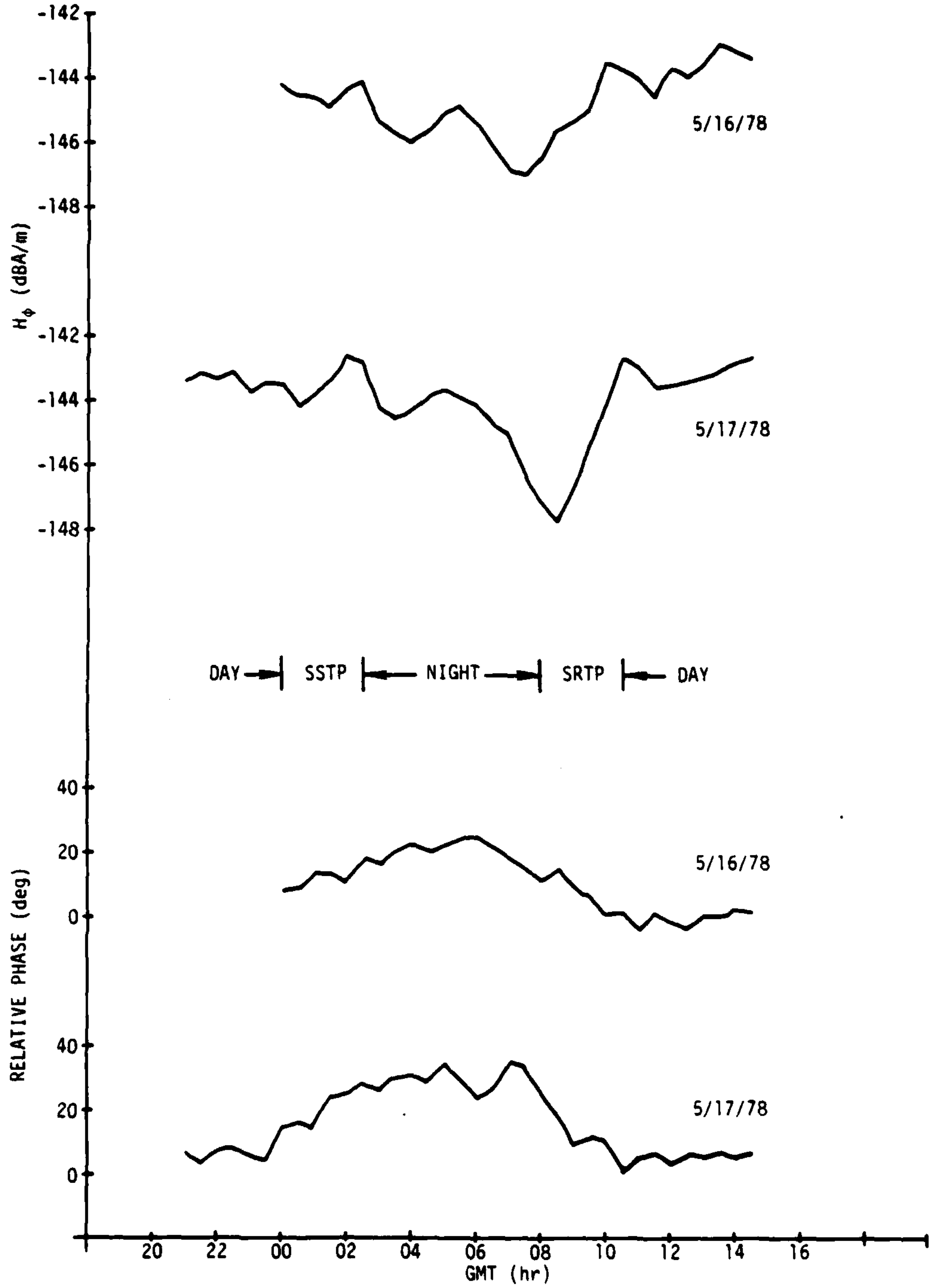

Figure C-6. Connecticut Data Versus GMT (ψ = 291 deg), 16 and 17 May 1978

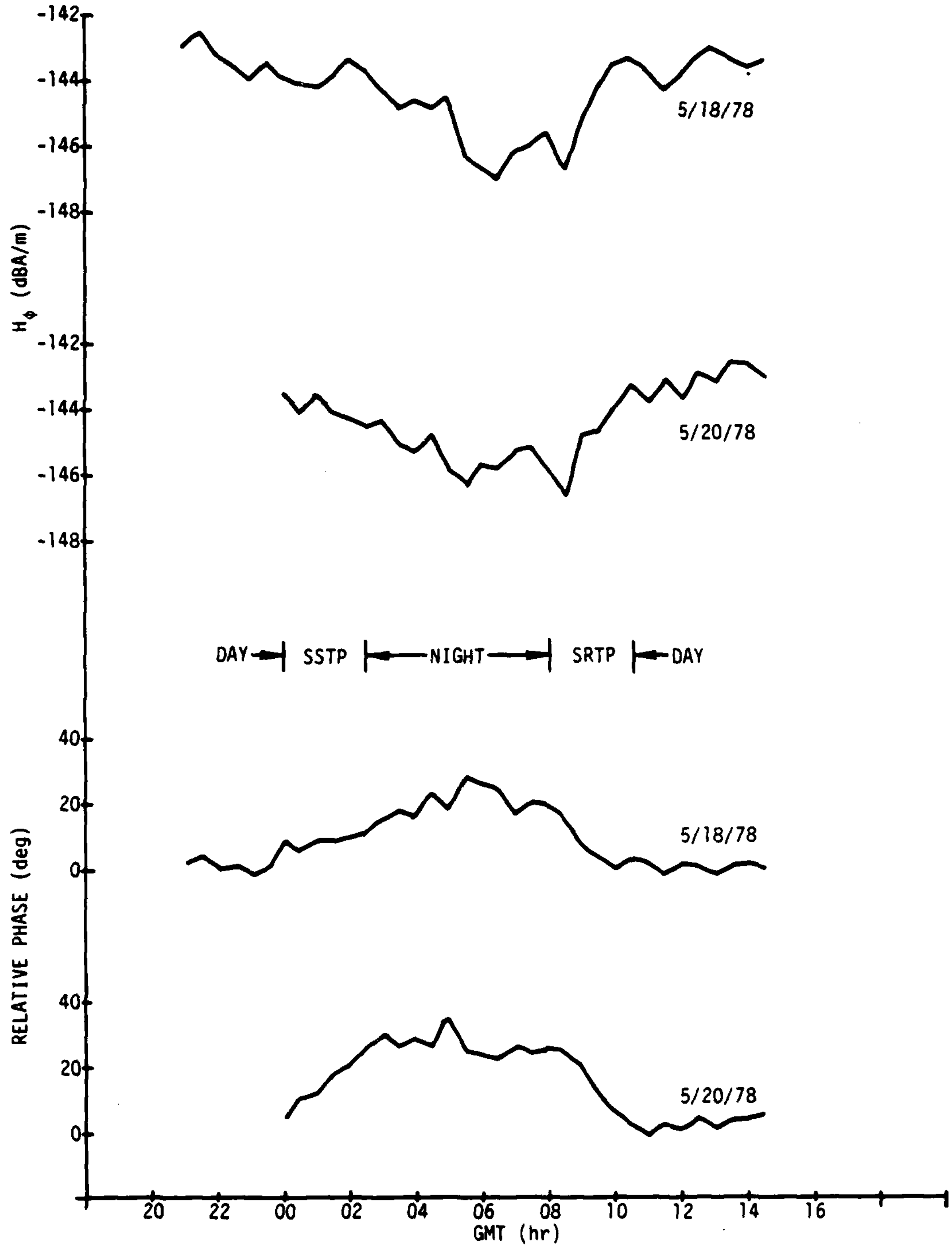

Figure C-7. Connecticut Data Versus GMT (ψ = 291 deg), 18 and 20 May 1978

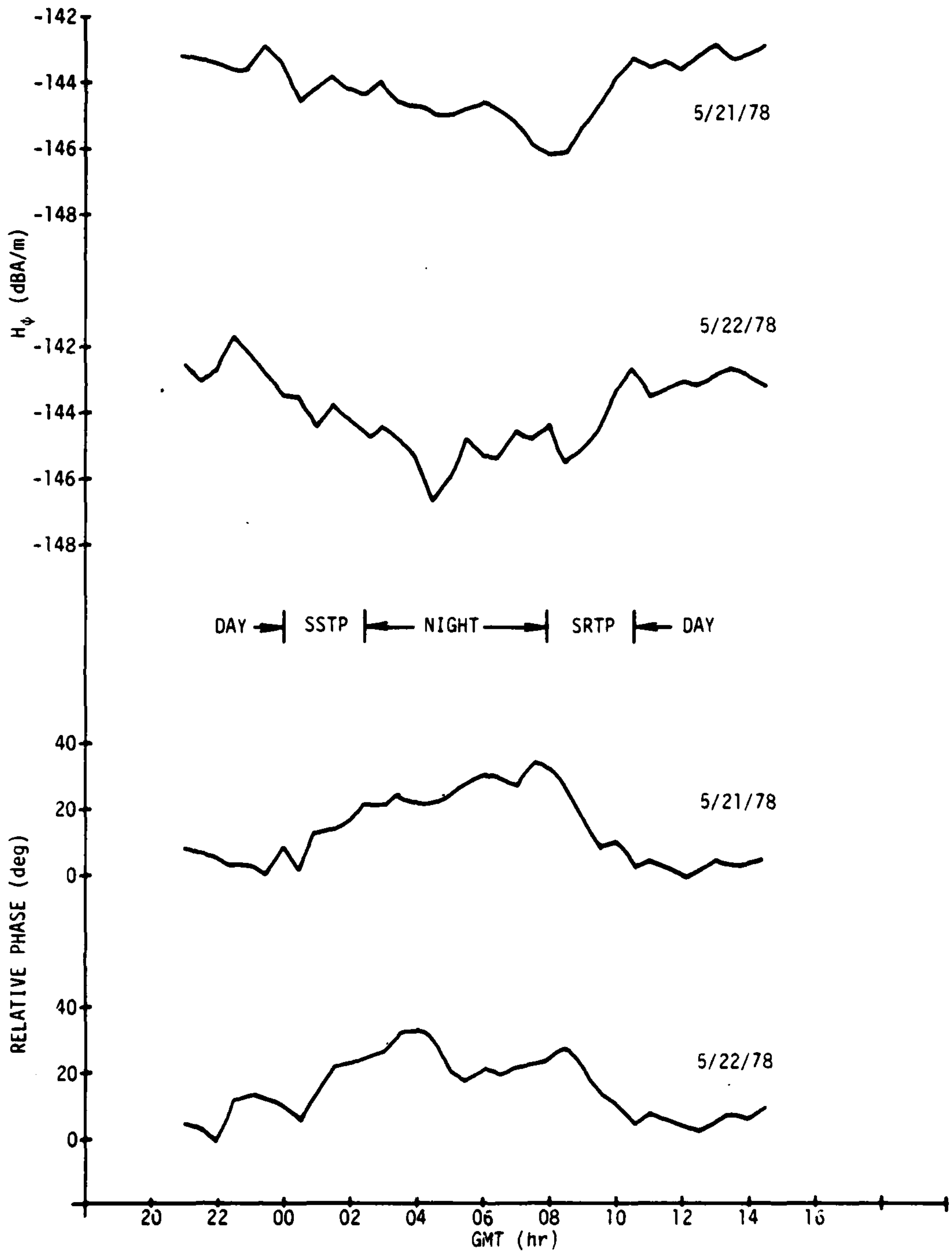

Figure C-8. Connecticut Data Versus GMT (ψ = 291 deg), 21 and 22 May 1978

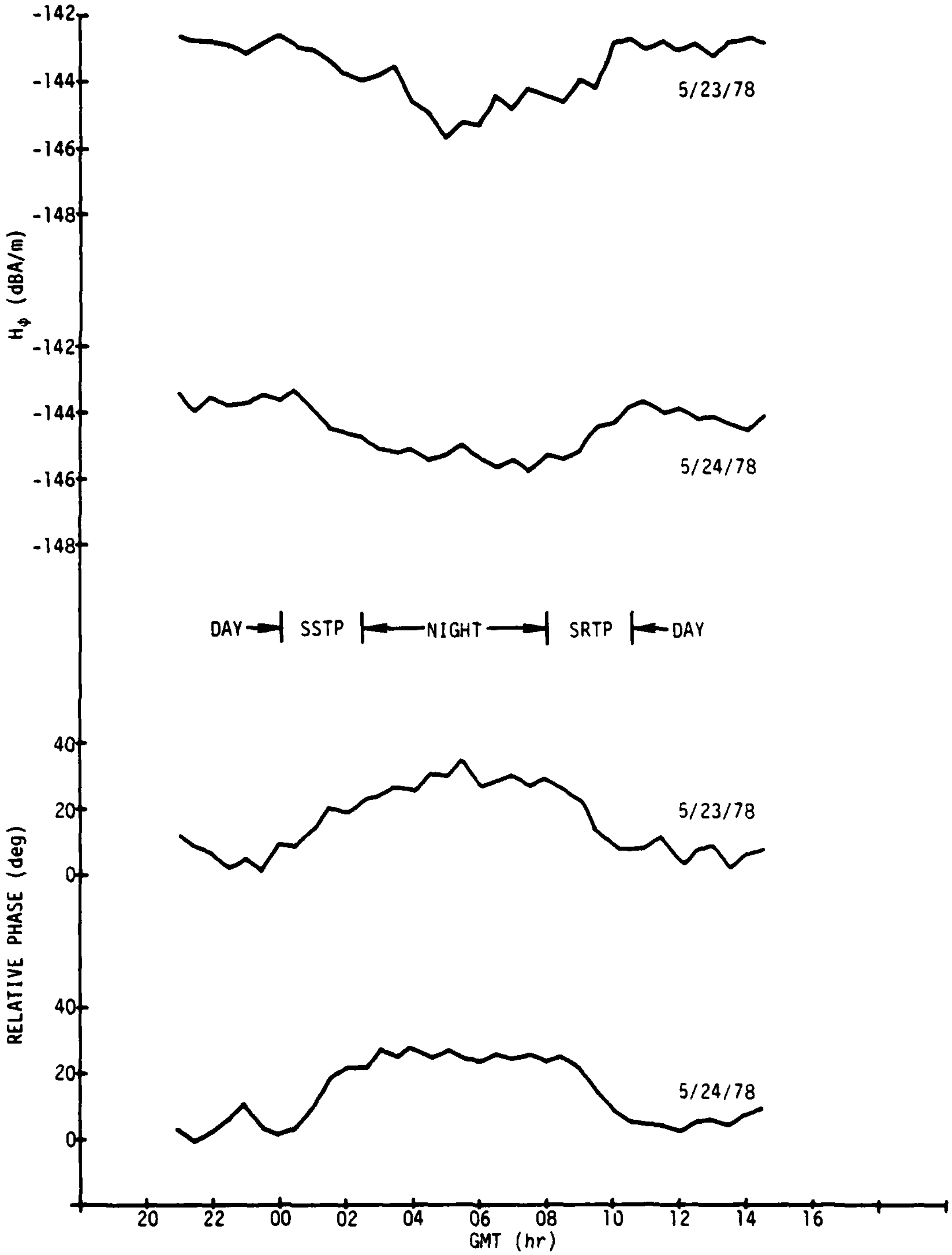

Figure C-9. Connecticut Data Versus GMT (ψ = 291 deg), 23 and 24 May 1978

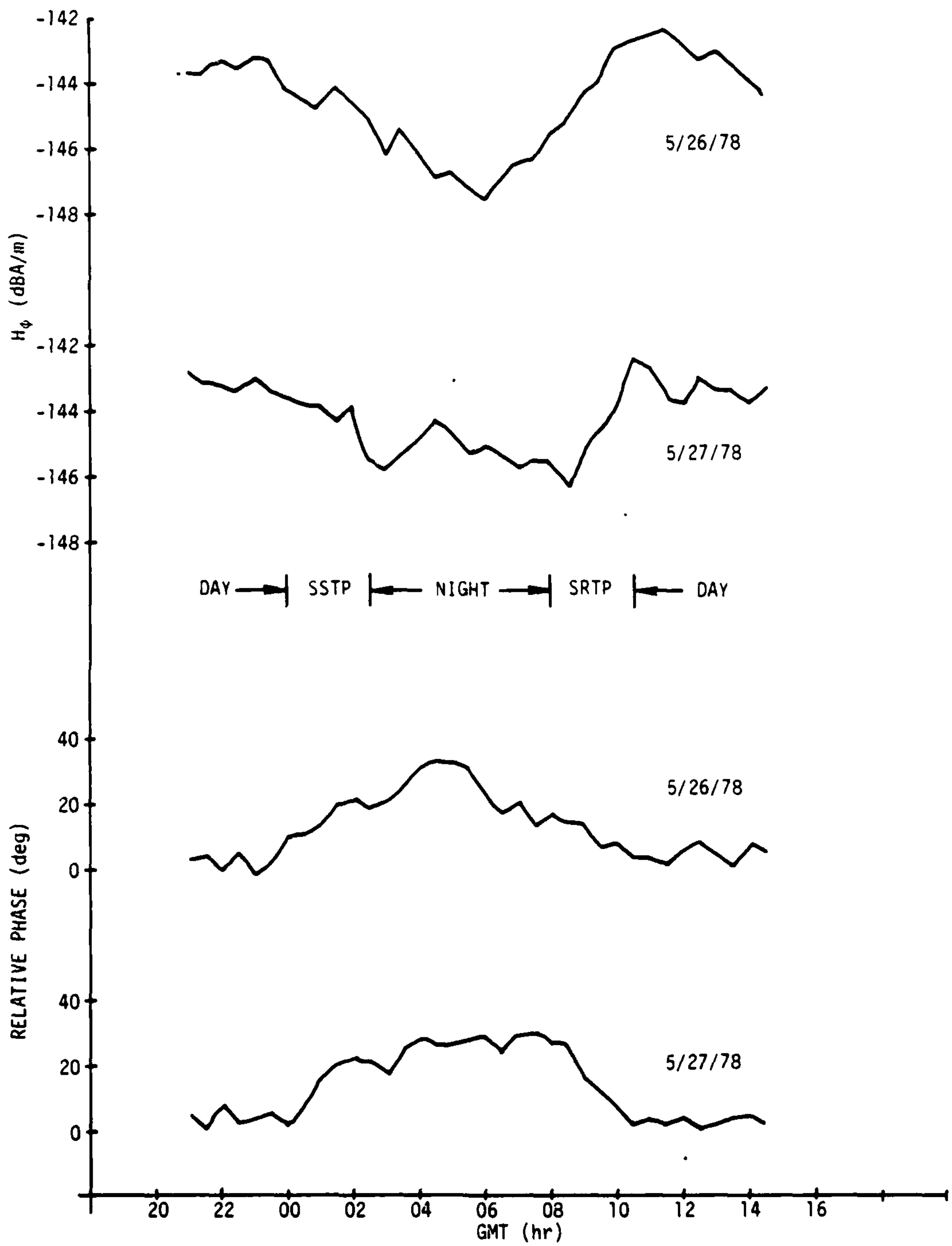

Figure C-10. Connecticut Data Versus GMT (ψ = 291 deg), 26 and 27 May 1978

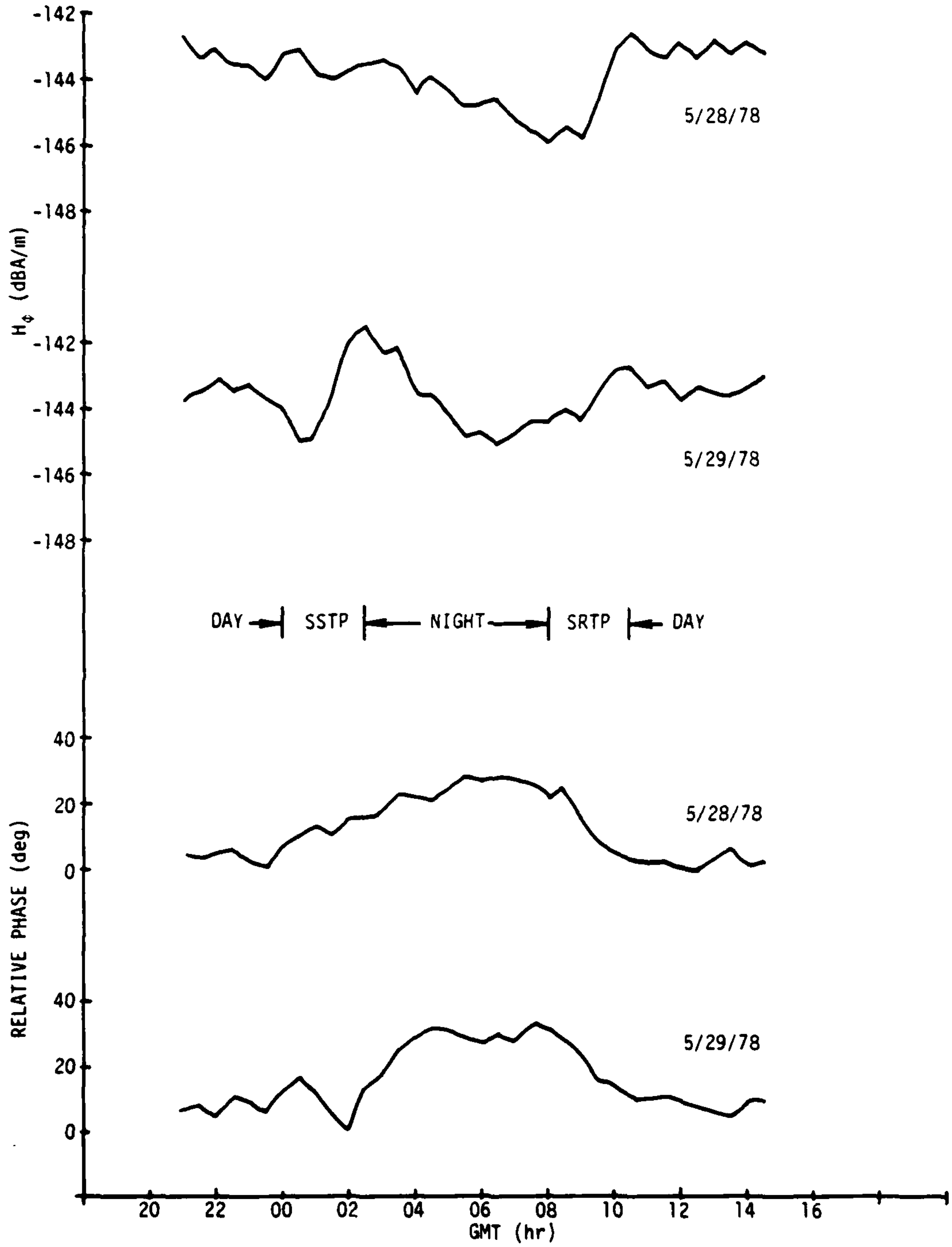

Figure C-11. Connecticut Data Versus GMT (ψ = 291 deg), 28 and 29 May 1978

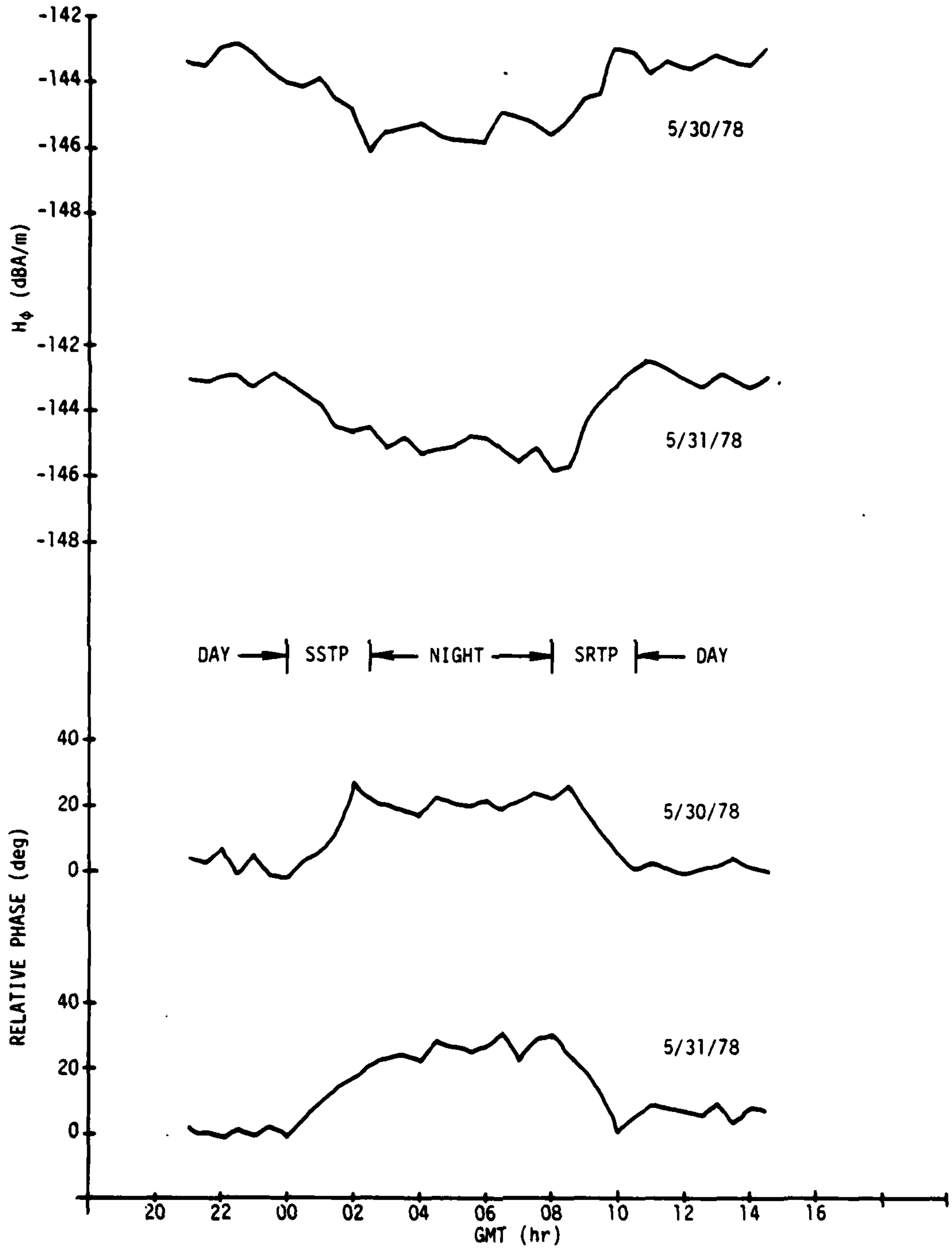

Figure C-12. Connecticut Data Versus GMT (ψ = 291 deg), 30 and 31 May 1978

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