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X-645-72-301

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NASA TM X- 66004

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(NASA-TM-X-66004) AVERAGE DAILY VARIATIONS IN THE MAGNETIC FIELD AS OBSERVED BY ATS-5 T.L. Skillman (NASA) Aug. 1972 55 p CSCL 03B

N72-30347

Unclas

G3/13 39481

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AUGUST 1972

GSFC

GODDARD SPACE FLIGHT CENTER
GREENBELT, MARYLAND

X-645-72-301

AVERAGE DAILY VARIATIONS IN THE MAGNETIC FIELD AS OBSERVED BY ATS-5

T. L. Skillman

August 1972

Abstract

Hourly averages of the magnetic field components are determined and analyzed using the measurements by the Magnetic Field Monitor (MFM) aboard the ATS-5 satellite. The data covering the time period of September 1969 through September 1971 are sorted and analyzed for various Kp values, geomagnetic latitude of the subsolar point, and local time. Local time variations are harmonically analyzed, and amplitudes and phases are given up to the fourth harmonic.

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I. Introduction

ATS-5, launched on August 12, 1969, was the fifth in a series of Applications Technology Satellites conceived and designed by NASA/Goddard Space Flight Center with the program objective of furthering the state of the art in application technology placing emphasis on satellite communications and meteorology. Because of excessive on-board damping during an interim spin-stabilized phase of flight, spin about an unstable axis deteriorated to an anomalously flat spin shortly after the spacecraft was positioned in the synchronous orbit. By ejecting the apogee motor casing on September 5, the spin axis was rotated to the original spacecraft axis, but was spinning in the opposite direction. The momentum removal systems were unable to slow down the spacecraft spin. Consequently, all experiments which depended on the planned gravity gradient stabilization became in-operative, and the mission was declared a failure.

Two systems capable of operating in the spinning condition were the Magnetic Field Monitor and portions of the Environmental Measurements Experiment (EME). The EME was a scientific experiment package consisting of six experiments, four of which have operated continuously since turn-on. Specifics of these experiments are listed in Table 1.

The Magnetic Field Monitor (MFM) was not on board as a scientific experiment but was to be used along with three axis torquing coils as a back-up attitude control system during launch and manuevering to the on-station position. The magnetometer sensor is mounted on the antenna boom approximately 4½ feet from the center of the spacecraft. Figure 1

TABLE 1

ATS-5 Environmental Monitor Experiments

Instrumentation	Status	Purpose	Principal Investigator
3DME-Tri-Directional Medium Energy Particle Detector	Operational	Extend the description of auroral zone phenomena involving energetic trapped radiation (protons - 30 to 250 keV; electrons - above 30 keV).	Univ. of Calif. Berkeley [F. Mozer]
ODHE-Omni-Directional High Energy Particle Detector	Operational	Study the electric and magnetic fields responsible for the acceleration of outer zone electrons (e - 0.5 to 5 MeV).	Univ. of Calif. San Diego [C. McIlwain]
3DLE-Bi-Directional Low Energy Particle Detector	Operational	Map the distribution of low-energy electrons and protons on a constant line of force (e & p-0.5 to 20 keV).	Univ. of Calif. San Diego [C. McIlwain]
SRB-Total Power Radiometer	Booms Not Extended	Measure the effects of solar radio burst at 32 discrete frequencies from 60 kHz to 3.8 MHz.	NASA-GSFC [R. G. Stone]
EF-High Impedance Voltmeter (DC/AC)	Booms Not Extended	Measure the electric field in the magnetosphere by using the spacecraft gravity gradient booms as Langmuir probes.	NASA-GSFC [T. L. Aggson]
UDLE-Uni-Directional Low-Energy Particle Detector	Operational	Long-term study of auroral particle fluxes in the vicinity of the loss cone (e - 0.5 to 50 keV; p - 1, 5, 20, 60, 1000 keV)	Lockheed Palo Alto Research Lab [R. D. Sharp]

shows the instrument perched on the boom at the top of the photograph. It is covered by an aluminized mylar thermal blanket which acts to passively control the temperature range of the sensor. The temperature encountered by the sensor was nominally near 0^{o}C varying by $\pm 5^{o}$C with the sun's position. However, the temperature dropped when the spacecraft was shadowed by the earth; for instance, during such an eclipse of maximum duration (approximately 80 minutes) the temperature dropped to -25^{o}C (see Appendix A). Figure 2 is a sketch showing the positions of the MFM sensor and electronics. The output of the magnetometer is fed into the EME telemetry system (PFM) for inclusion on each experimenter's data tapes. The prime output is on the spacecraft telemetry system (PCM) and has been recorded approximately 60% of the time since launch. For information about the magnetometer, the telemetry systems, etc., see GSFC Document X-645-70-54 entitled "ATS-E Magnetic Field Monitor Instrumentation" by T. L. Skillman dated January 1970.

ATS-5 was spin-stabilized at 77 rpm about the spacecraft Z-axis which is approximately parallel to the earth's rotational axis, and has been on station at $105^{o} \pm 1^{o}$W. longitude since September 11, 1969. The inclination of the spacecraft changed with time from the initial value of 2.5^{o} to 0.5^{o} in September 1971. Changes in the orbit inclination and right ascension of the ascending node are shown in Appendix B plot. Figure 3 illustrates the ATS-5 orbit and spin geometry. It shows the satellite in the synchronous orbit (ω = 1 rev/24 hours) at the fixed earth longitude of 105^{o}W. The spacecraft is spinning about the -Z body axis and the spin vector is pointing north. The angle, θ,

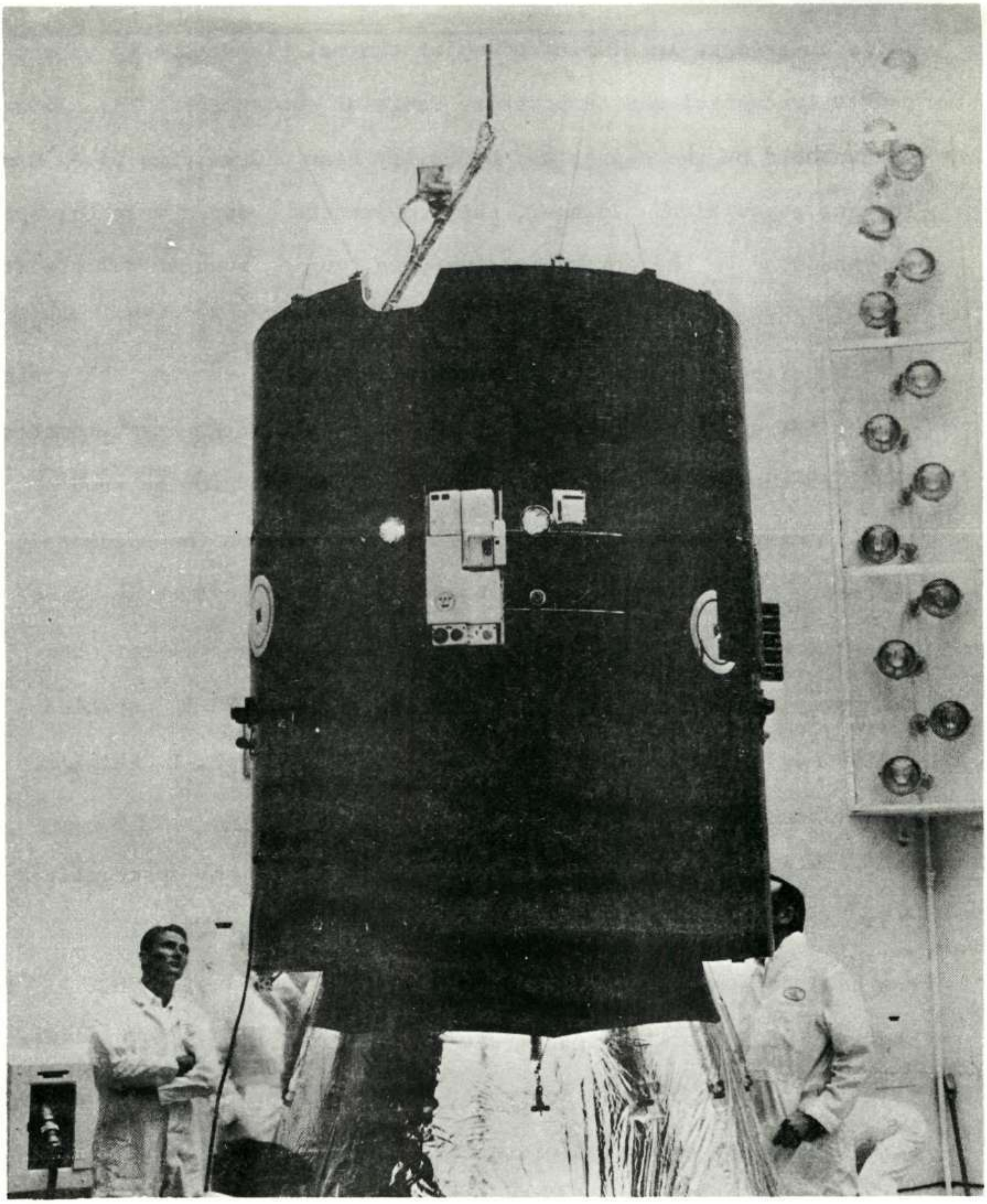

Figure 1. ATS-5 Spacecraft

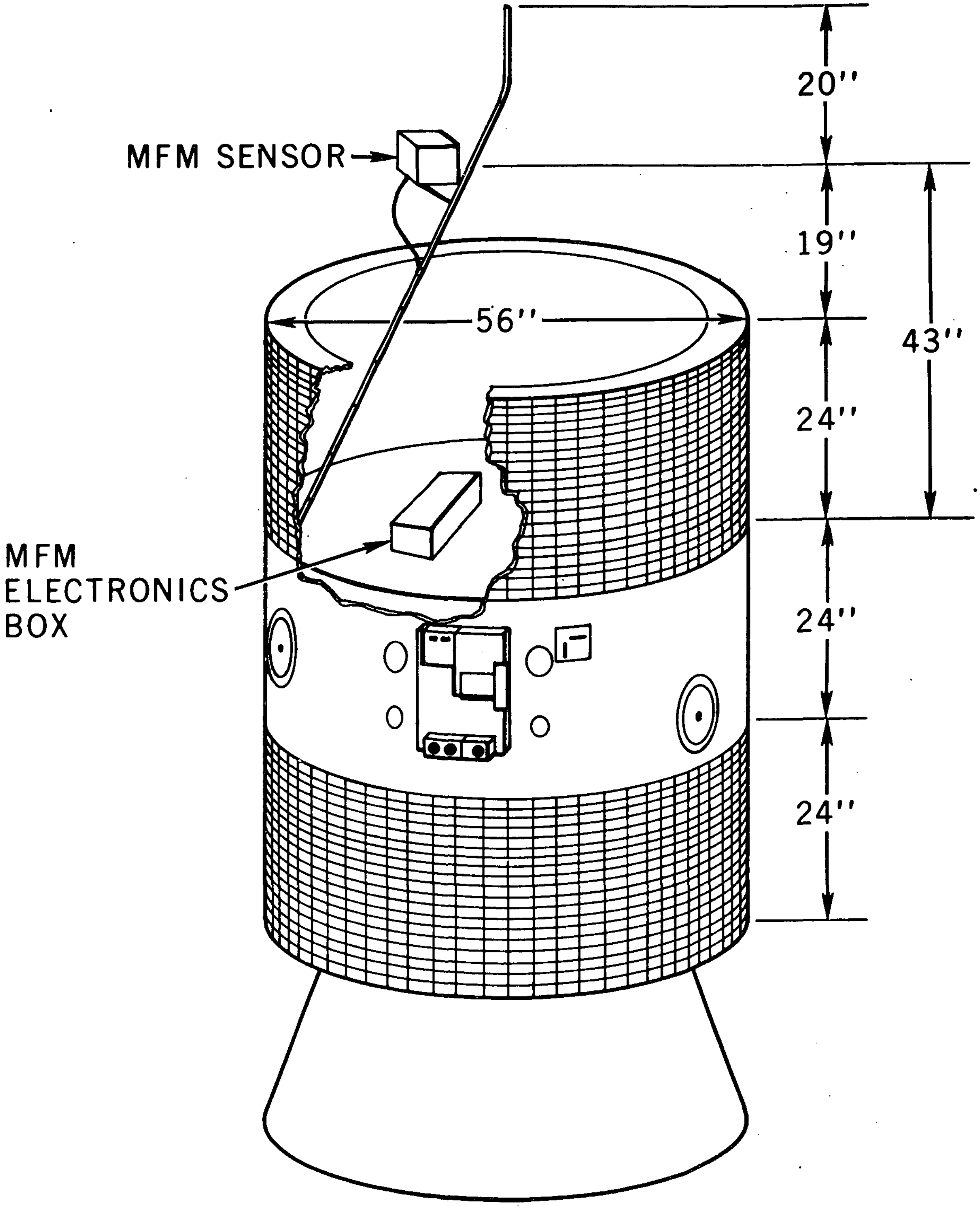

Figure 2. Sketch of the Relative Positions of the MFM Sensor and Electronics on ATS-5 Spacecraft

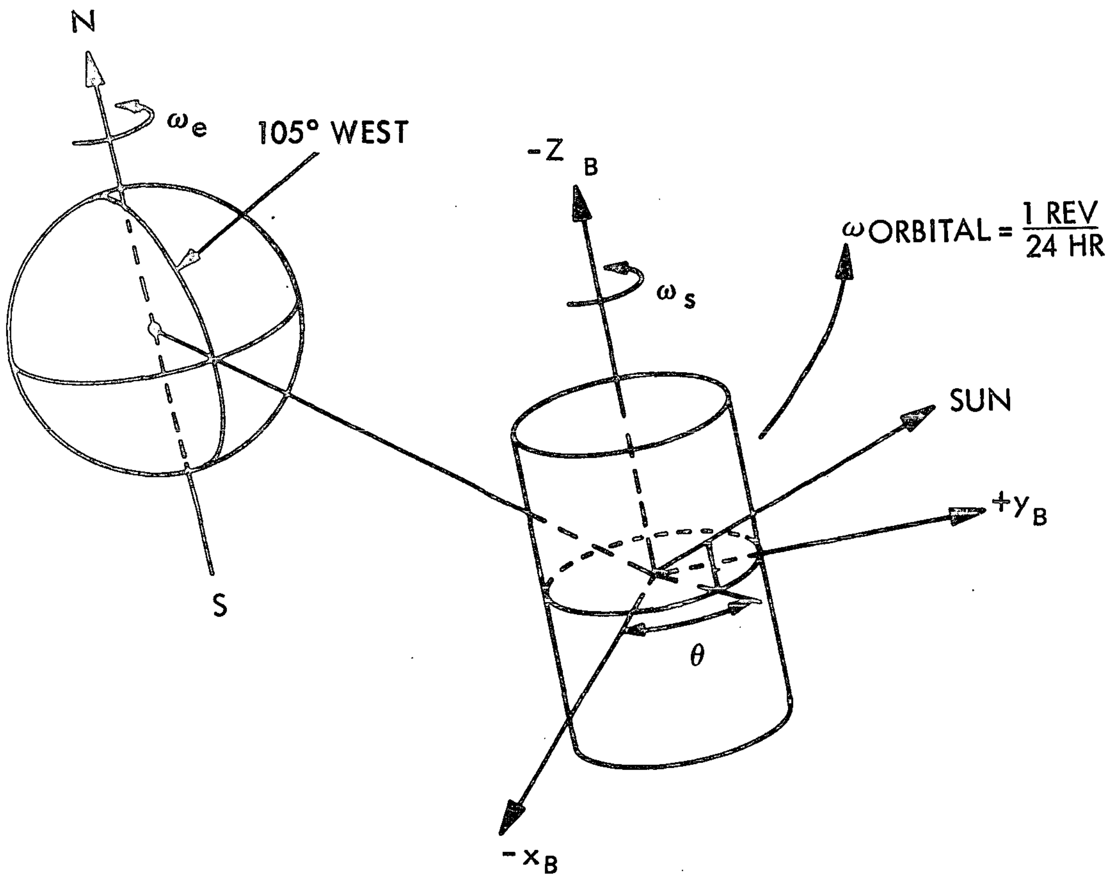

Figure 3. ATS-5 Orbit and Spin Geometry

defined by the angle between the -X body axis and the plane containing the spin axis and the spacecraft sun vector, is used in the description related to the despinning of the PCM data. The body coordinate system is the system used by General Electric, the subcontractor responsible for attitude determination of the spacecraft.

II. Magnetic Field Measurements

The Magnetic Field Monitor is a triaxial fluxgate magnetometer with a range of approximately $\pm$ 500γ and a sensitivity of 1γ. The field is measured along each axis by combining a "fine" reading within a range $\pm$ 25γ and a "coarse" reading which indicates the necessary number of steps to be fed into a compensating coil in order to keep the instrument within the range of the fine scale. There are 32 steps of approximately 33γ for each axis, thereby providing a nominal range of -495γ to +525γ.

Along each axis of the fluxgate coordinate system the magnetic field component is thus determined from the following formula:

$$B = A(N - 15) + D(V - C) \tag{1}$$

where B = Magnetic field along the sensor axis in gamma

A = Constant gamma field increment for each digital compensating field (N)

N = Digital number telemetered back giving the status of current steps applied to the sensor compensating coils

D = Constant number of gamma per volt for fluxgate axis over the linear portion of its response curve

V = Output voltage from the fluxgate (nominally 0.75 to 4.25 volts)

C = Voltage (a constant) for zero magnetic field along sensor axis

Constants A, D, and C vary for different sensor axes. A calibration field of +10 gamma per axis is internally generated once every 12.02 hours for a duration of 5.63 minutes as a means of checking the magnetometer sensitivity.

The constants used for the ATS-5 magnetometer in equation (1) are as follows:

$A_x = 32.804\gamma$	$D_x = 13.49\gamma/\text{volts}$	$C_x = 2.49$ volts
$A_y = 32.942\gamma$	$D_y = 13.85\gamma/\text{volts}$	$C_y = 2.52$ volts
$A_z = 32.775\gamma$	$D_z = 13.63\gamma/\text{volts}$	$C_z = 2.55$ volts

For the "fine" output the frequency responses of the magnetometer (sensor and electronics combined) are:

PCM - approximately 100 cps at 3db

PFM - approximately .115 cps at 3db

The data sampling intervals for each axis are:

PCM - "Fine" 2.97 sec/sample

"Coarse" 95 sec/sample

PFM - "Fine" and "Coarse" 5.12 sec/sample

III. Data Reduction

Some general comments should be made about the accuracy of the measurements used in this report. First, the magnetometer was on the spacecraft as a monitor and not as an experiment. Secondly, the spacecraft was not magnetically clean, and as a result, encountered large disturbances from both A.C. and D.C. fields. The D.C. fields as measured at the GSFC Magnetic Test Facility were compensated by six auxiliary magnets with the following field modifications at the magnetometer:

	Initial Perm Field	Compensated
	X = +119.7γ	X = +21γ
(Magnetometer Coordinates)	Y = - 80.8γ	Y = +31γ
	Z = -164.0γ	Z = +109γ

The large field remaining in Z was purposely set at +109γ to insure maximum range when on-station in synchronous orbit.

D.C. offsets resulting from various spacecraft functions being turned "on" and "off" were recorded prior to flight. These corrections, some of which changed after launch, have been used to correct the data. This was accomplished in the following manner by observing the spin axis (Z) output on the plotted data. Where sudden jumps in the D.C. level were observed, the command log from the ATS-5 control center was checked to see whether or not a command had been sent to the spacecraft. If a command had been sent, the resulting shift was compared to the preflight test to see if the observed shift is consistent with the test. Typically these corrections varied from 1 to 20γ.

Corrections as observed during ground testing for a.c. fields and later verified in flight, were also applied to the data to eliminate the effects of the solar array modulation due to the spacecraft spin. These corrections were always less than 10γ.

The data used in the "hourly value" data set for the spin axis (Z) component were supplemented with data from the PFM telemetry system when not available on the PCM telemetry output. The PCM telemetry output in the spin plane (X and Y) was despun by a program developed under contract by General Electric, Valley Forge Space Center. G.E. performed this investigation as they were the spacecraft attitude control subcontractors and were completely familiar with the spacecraft and specifically with the various sensors onboard. A report of this study contract is given in G.E. document 71SD4257 dated September 15, 1971 and titled "Magnetic Data Reduction Study Contract" by J. J. Mueller and G. W. Coyne, Jr. For the details of the despinning technique we refer to this report.

The despun data were transformed to the DHV components of the magnetic field using the sun sensor output with the following assumptions:

1. The ATS-5 spacecraft is located at synchronous altitude at 105°W. longitude and 0° latitude, and is stationary in a geocentric reference frame corotating with the earth.

2. The vehicle is spinning about its -Z (G.E. body frame) axis which is aligned with the earth's spin axis, with no nutation.

This DHV system is the same as that used by Coleman and Cummings (1971) for the analysis of the ATS-1 magnetic field data, and is illustrated in Figure 4.

The North (H) component is obtained directly from the +Z magnetometer measurements. The East and outward components (D and V, respectively) are obtained from the X and Y components by the despinning technique mentioned above. It should be noted here that the East component, D, is in force unit and not in angular measure as in declination in the conventional usage of the notation D. Also note that H is the North component and not the total horizontal intensity.

IV. Analysis

Having computed the geomagnetic latitude of the subsolar point, θ^s_{gm}, for each hourly value observed, the data were sorted first by division into three categories: $\theta^s_{gm} > 10^o$, $-10^o < \theta^s_{gm} < 10^o$, and $\theta^s_{gm} < -10^o$. The grouping with θ^s_{gm} is made to investigate the dependence of the daily variations on the tilt angle of the dipole axis relative to the sun-earth direction. The data were further sorted by geomagnetic activity (Kp) into three classes: Kp = 0-1; Kp = 2-3; and Kp ≥ 4.

For each magnetic component and for each (Kp, θ^s_{gm}) group, hourly averages and standard deviations were computed for each local time hour. Here the hourly intervals are each centered at the half

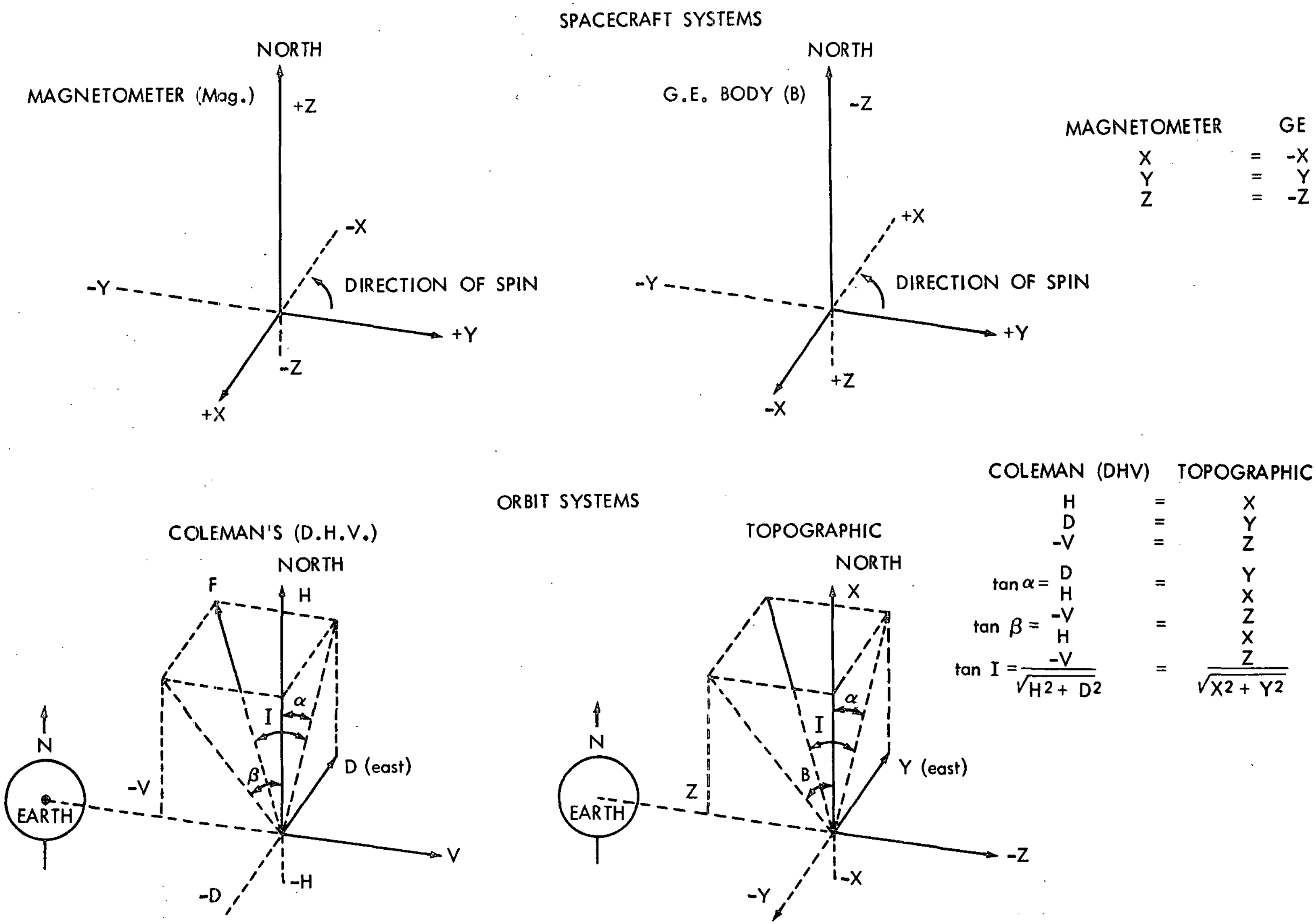

Figure 4. Various ATS-5 Coordinate Systems

hour. The hourly averages so obtained are listed in Appendix C. To indicate statistical significance of these averages, the maximum and minimum numbers of hourly data points (used in averaging) and the maximum and minimum standard deviations are given in Tables 2 through 4 for each (Kp, θ^s_{gm}) group. It should be noted that the number of data points for very disturbed conditions of Kp ≥ 4 is unavoidably small for some local hours.

Figure 5 presents the daily variations in the magnitude, F, and the H, D, and V components of the magnetic field at the ATS-5 position. To facilitate comparison of the daily variations for different θ^s_{gm} groups, classification is made first with respect to Kp, and for each Kp group three curves are drawn for the three θ^s_{gm} groups.

In Figure 6 the same data are presented in a different form; namely, division is made first according to θ^s_{gm}, and for each θ^s_{gm} group three curves are prepared for the three Kp groups to show the dependence of the daily variations on magnetic activity.

A separate diagram, Figure 7, is presented to give the daily variations in the dip angle, I, where I is computed from the formula $\tan I = -V/\sqrt{D^2 + H^2}$. The maximum and minimum values of I and the local hours at which these maxima and minima occur are listed in Table 5 together with the ranges (maximum - minimum) in the variations of I. Appendix D is two plots of angle variations determined from hourly average values for tilts in the HV and HD planes.

Each average daily variation, say f(t), is then expressed in a Fourier series as:

Table 2

Geomagnetic Subsolar Latitude $\theta_{gm}^{(s)}$. $> 10°$

Maximum and Minimum Number of Data Points and the Standard Deviation for Each Component Used for Plotting and Fourier Expansion for the Geomagnetic Subsolar Latitudes $\theta_{gm}^{(s)}$ $> 10°$.

$\theta_{gm}^{(s)} > 10°$

H

	Data Points		Standard Deviation γ	
Kp	Max. No.	Min. No.	Max. Std. Dev.	Min. Std. Dev.
0, 1	99	27	8.46	4.87
2, 3	119	33	17.95	6.34
≥4	29	6	20.18	4.31

V

0, 1	88	24	8.10	3.98
2, 3	108	26	10.64	5.12
≥4	30	2	12.51	1.00

D

0, 1	88	24	4.72	1.55
2, 3	108	27	7.50	1.99
≥4	30	2	9.28	1.50

Table 3

Maximum and Minimum Number of Data Points and the Standard Deviation for Each Component Used for Plotting and Fourier Expansion for the Geomagnetic Subsolar Latitudes $-10° \leqslant \theta_{gm}^{(s)} \leqslant 10°$.

H

	Data Points		Standard Deviation γ	
Kp	Max. No.	Min. No.	Max. Std. Dev.	Min. Std. Dev.
0, 1	64	35	9.62	6.59
2, 3	80	38	14.49	7.90
≥4	25	8	22.24	7.40

V

0, 1	52	20	10.68	3.92
2, 3	71	24	23.40	5.36
≥4	23	4	16.77	6.21

D

0, 1	52	20	6.01	2.40
2, 3	71	24	7.09	2.29
≥4	23	4	9.97	2.70

Table 4

Maximum and Minimum Number of Data Points and the Standard Deviation for Each Component Used for Plotting and Fourier Expansion for the Geomagnetic Subsolar Latitudes $\theta_{gm}^{(s)} < -10$.

H

	Data Points		Standard Deviation γ	
Kp	Max. No.	Min. No.	Max. Std. Dev.	Min. Std. Dev.
0, 1	92	32	9.80	6.46
2, 3	102	23	15.95	6.83
≥4	25	1	17.58	0.0

V

0, 1	86	33	11.73	3.56
2, 3	95	21	15.42	3.14
≥4	21	1	18.98	0.0

D

0, 1	86	33	3.69	0.87
2, 3	95	21	5.46	1.76
≥4	20	1	8.28	0.0

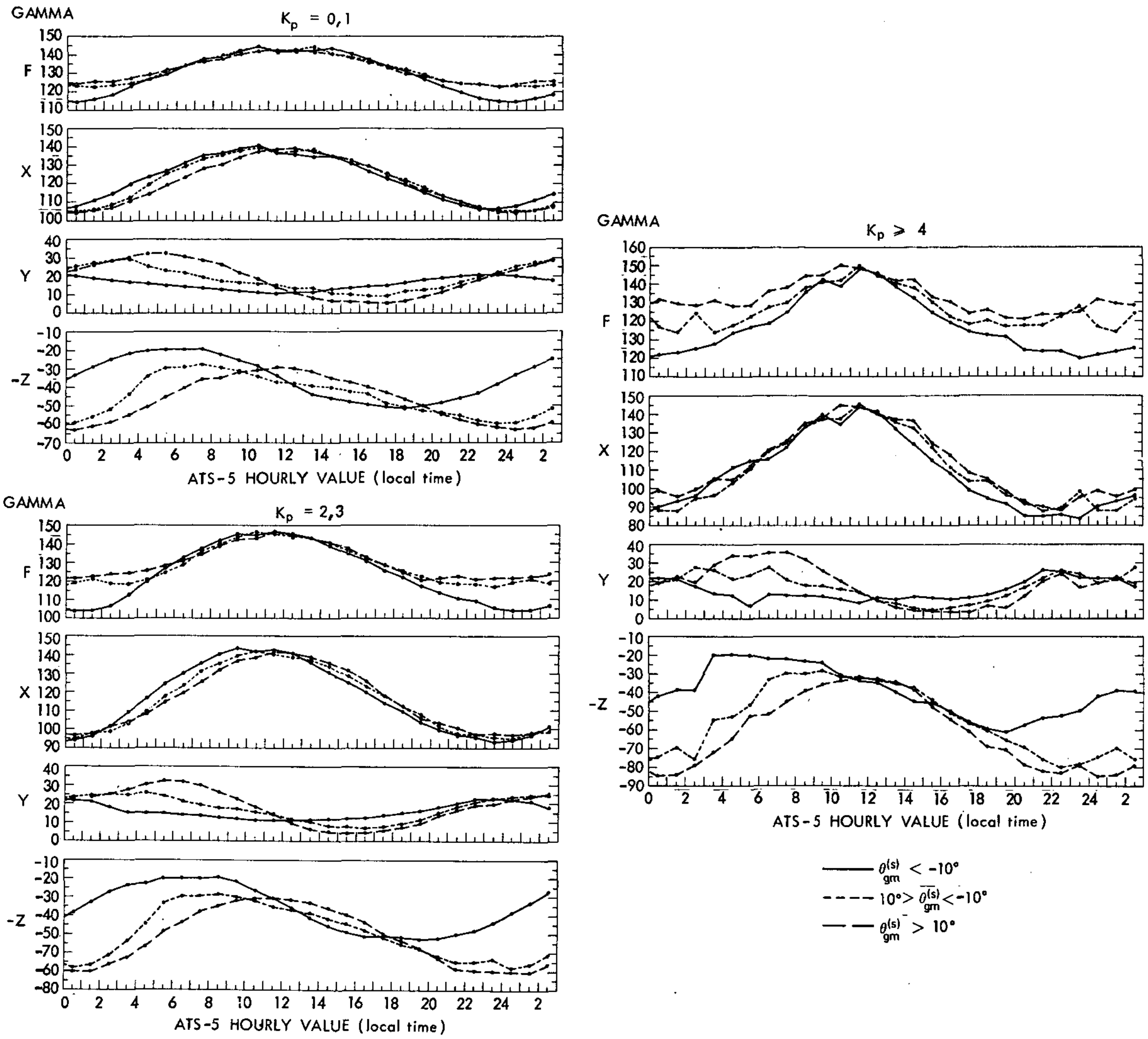

Figure 5. Daily Variations in the Magnitude of F and the X, Y, -Z Components of the Magnetic Field at ATS-5.

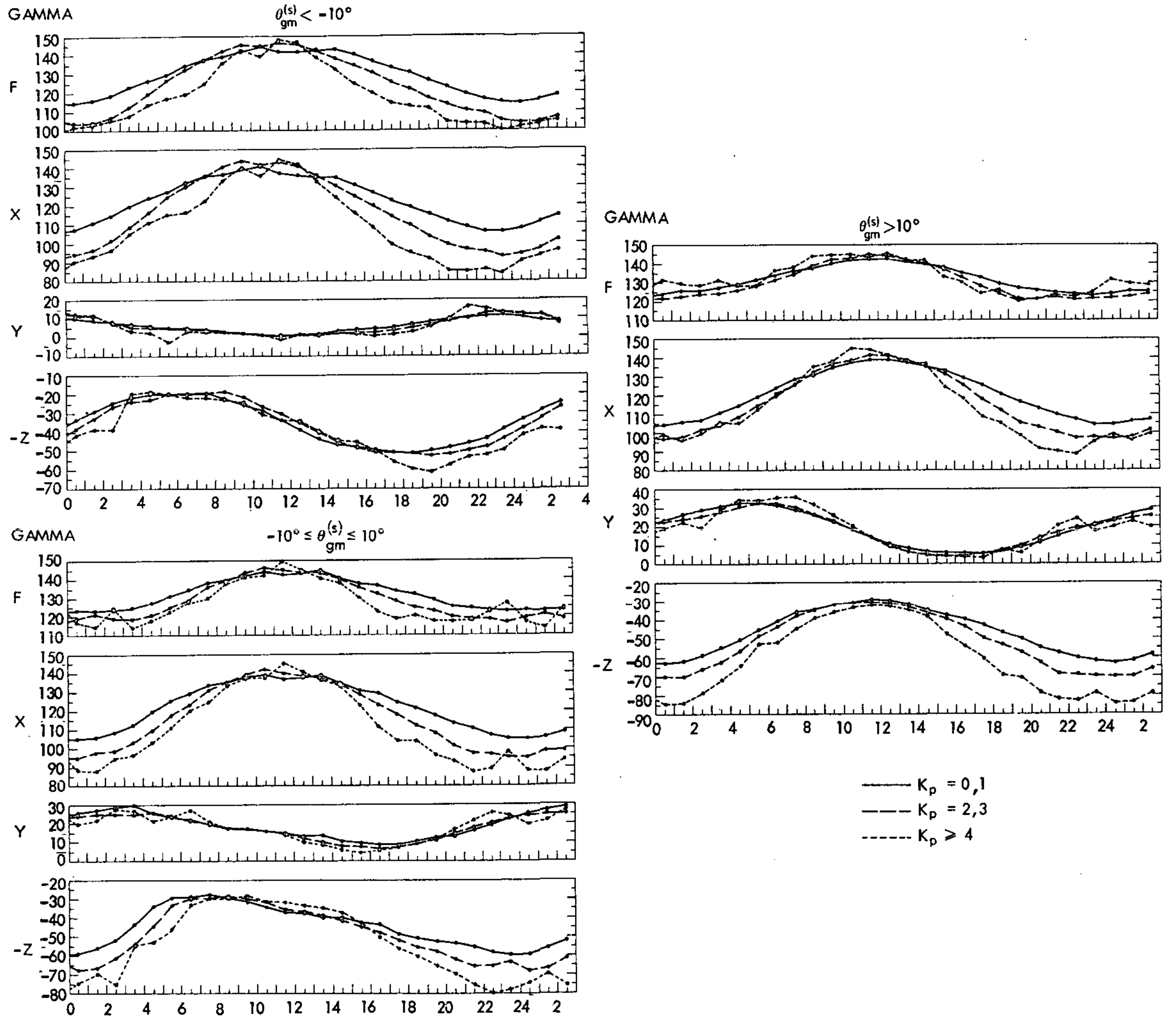

Figure 6. Daily Variations in the Magnitude of F and the X, Y, -Z Components of the Magnetic Field at ATS-5.

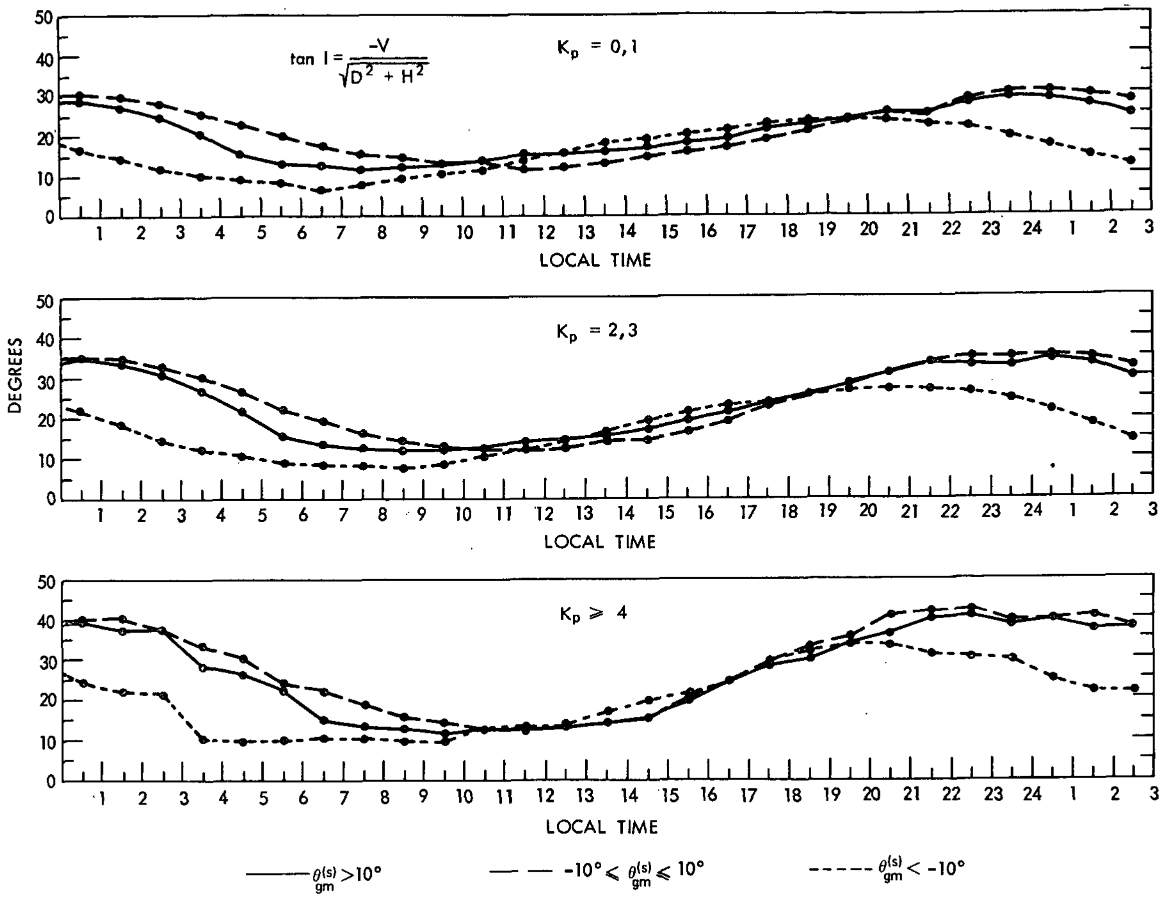

Figure 7. Daily Variations in the Dip Angle of the Magnetic Field at ATS-5

Table 5

Angle of Dip (I)

Kp = 0,1

$\theta^{(s)}_{gm}$	Maximum Angle of Dip		Minimum Angle of Dip		Total Range
	(I)°	Local Time	(I)°	Local Time	
> 10°	30.5	0.5	11.7	11.5	18.8°
-10° to +10°	28.9	23.5	11.5	07.5	17.4°
≤-10°	23.3	19.5	06.8	06.5	16.5°

Kp = 2,3

> 10°	35.1	0.5	12.1	11.5	23.0°
-10° to +10°	34.8	0.5	11.8	08.5	23.0°
<- 10°	27.2	20.5	07.6	08.5	19.6°

Kp ≥ 4

> 10°	42.2	22.5	12.5	11.5	29.7°
-10° to +10°	40.6	22.5	11.5	09.5	29.1°
<-10°	33.3	20.5	09.7	09.5	23.6°

$$f(t) = \sum_{m=0}^{9} (a_m \cos mt + b_m \sin mt)$$

$$= \sum_{m=0}^{9} C_m \cos (mt - \alpha_m)$$

where

$$C_m = \sqrt{a_m^2 + b_m^2} \qquad m = 0, 1, 2, ----$$

$$\alpha_m = \tan^{-1} b_m/a_m$$

Tables 6 through 8 give the amplitudes C_m and phases α_m for F, H, V, and D. Table 9 lists the time of maximum for the diurnal (24-hour) component of each of these elements.

In Figure 5 the daily variations for different θ_{gm}^{s} groups are presented for each Kp group. The seasonal classification therefore is made using the geometric parameter θ_{gm}^{s}, i.e. the geomagnetic latitude of the subsolar point. This classification is more precise and convenient for the study of the distortions of the magnetospheric field due to the solar wind than a classification according to the calendar season. However, the seasonal changes in the daily variations by use of the ordinary season classification are of value in certain types of statistical studies. Thus the average daily variations for the four seasons as defined below are plotted in Figure 8:

Season	Day of Year	Dates
Spring	36 to 127	Feb. 5 to May 7
Summer	128 to 218	May 8 to Aug. 6
Fall	219 to 309	Aug. 7 to Nov. 5
Winter	310 to 35	Nov. 6 to Feb. 4

Table 6

Fourier Expansion of H, D, V, and F for Geomagnetic Latitude $\theta_{gm}^{(s)}$, for the Subsolar Point > 10°, Expressed in the Form: e.g., H = $C_m \cos(mt - \alpha_m)$; C_m in Gamma, α_m in Degrees.

F

Kp = 0, 1

m	0	1	2	3	4
Cm	132.1	9.5	1.0	0.1	0.1
αm		+18°	+15°	+78°	-59°

Kp = 2, 3

m	0	1	2	3	4
Cm	130.4	11.8	3.2	0.4	0.7
αm		+23°	+25°	-81°	+28°

Kp ≥ 4

m	0	1	2	3	4
Cm	133.2	10.7	5.4	1.3	0.5
αm		+40°	+33°	-18°	-35°

H

Kp = 0, 1

m	0	1	2	3	4
Cm	121.2	17.3	0.4	0.1	0.2
αm		+11°	+82°	-50°	+48°

Kp = 2, 3

m	0	1	2	3	4
Cm	116.8	22.6	2.3	0.6	0.4
αm		+16°	+26°	+72°	+17°

Ko ≥ 4

m	0	1	2	3	4
Cm	114.5	25.4	5.3	1.6	0.9
αm		+27°	+23°	+10°	+43°

V

Kp = 0, 1

m	0	1	2	3	4
Cm	45.8	16.6	1.4	0.2	0.5
αm		+17°	-27°	-29°	+51°

Kp = 2, 3

m	0	1	2	3	4
Cm	50.6	20.9	1.2	0.8	0.7
αm		+20°	-42°	+59°	+30°

Kp ≥ 4

m	0	1	2	3	4
Cm	59.5	26.9	1.5	1.9	0.9
αm		+23°	+63°	-58°	+82°

D

Kp = 0, 1

m	0	1	2	3	4
Cm	18.5	13.2	1.4	0.8	0.5
αm		-54°	-20°	-75°	-22°

Kp = 2, 3

m	0	1	2	3	4
Cm	18.2	12.7	3.2	0.9	0.3
αm		-53°	-36°	-75°	-73°

Kp ≥ 4

m	0	1	2	3	4
Cm	18.6	13.7	5.3	2.4	1.1
αm		-62°	-37°	-65°	+7

Table 7

Fourier Expansion of H, D, V, and F for Geomagnetic Latitude, $\theta^{(s)}_{gm}$, for the Subsolar Point $-10^\circ \leqslant \theta^{(s)}_{gm} \leqslant 10^\circ$, Expressed in the Form: e.g., $H = C_m \cos(mt - \alpha_m)$; C_m in Gamma, α_m in Degrees.

F

Kp = 0, 1

m	0	1	2	3	4
Cm	132.5	11.0	1.1	0.6	0.6
αm		+14°	+70°	+25°	+8°

Kp = 2, 3

m	0	1	2	3	4
Cm	129.1	14.0	3.3	1.3	0.6
αm		+17°	+44°	-12°	-67°

Kp ≥ 4

m	0	1	2	3	4
Cm	128.3	10.5	8.5	3.9	2.6
αm		+14°	+66°	-12°	+43°

H

Kp = 0, 1

m	0	1	2	3	4
Cm	122.6	17.3	1.9	0.7	0.5
αm		+19°	-14°	-80°	+27°

Kp = 2, 3

m	0	1	2	3	4
Cm	116.8	23.7	1.8	1.0	0.2
αm		+21°	-90°	+33°	+11°

Kp ≥ 4

m	0	1	2	3	4
Cm	113.1	24.0	7.1	4.4	2.4
αm		+20°	+78°	-21°	+51°

V

Kp = 0, 1

m	0	1	2	3	4
Cm	44.1	14.2	4.8	2.1	0.4
αm		+50°	+13°	-50°	-45°

Kp = 2, 3

m	0	1	2	3	4
Cm	48.2	18.9	4.8	2.5	1.2
αm		+40°	-9°	-72°	+77°

Kp ≥ 4

m	0	1	2	3	4
Cm	52.6	25.1	2.5	1.8	1.5
αm		+34°	-2°	+78°	-14°

D

Kp = 0, 1

m	0	1	2	3	4
Cm	18.1	8.7	2.0	0.7	0.1
αm		-36°	-11°	+46°	+5°

Kp = 2, 3

m	0	1	2	3	4
Cm	17.1	8.9	1.3	0.8	0.5
αm		-36°	+57°	-5°	-48°

Kp ≥ 4

m	0	1	2	3	4
Cm	17.2	9.1	2.7	1.8	1.0
αm		-34°	-67°	-2°	+6

Table 8

Fourier Expansion of H, D, V, and F for Geomagnetic Latitude, $\theta_{gm}^{(s)}$, for the Subsolar Point < -10°, Expressed in the Form: e.g., $H = C_m \cos(mt - a_m)$; C_m in Gamma, a_m in Degrees.

F

Kp = 0, 1

m	0	1	2	3	4
Cm	129.6	14.5	0.8	0.8	1.0
a_m		+17°	-1°	-36°	+85°

Kp = 2, 3

m	0	1	2	3	4
Cm	124.8	21.1	2.5	0.8	0.3
a_m		+20°	-57°	-66°	+73°

Kp ≥ 4

m	0	1	2	3	4
Cm	118.8	20.8	4.5	2.1	0.5
a_m		+22°	+49°	+63°	+50°

H

Kp = 0, 1

m	0	1	2	3	4
Cm	123.0	16.5	0.6	0.5	0.9
a_m		+33°	+9°	-46°	+75°

Kp = 2, 3

m	0	1	2	3	4
Cm	117.3	25.2	2.1	0.5	0.5
a_m		+31°	-54°	-52°	+85°

Kp ≥ 4

m	0	1	2	3	4
Cm	109.5	27.1	4.5	1.7	0.9
a_m		+35°	+28°	+48°	-86°

V

Kp = 0, 1

m	0	1	2	3	4
Cm	35.3	15.8	0.9	0.7	0.8
a_m		-75°	-12°	+5°	-51°

Kp = 2, 3

m	0	1	2	3	4
Cm	36.3	17.1	1.1	0.7	0.4
a_m		-87°	-41°	-57°	-52°

Kp ≥ 4

m	0	1	2	3	4
Cm	39.1	18.5	1.0	2.0	1.6
a_m		+86°	+86°	-51°	-29°

D

Kp = 0, 1

m	0	1	2	3	4
Cm	15.7	4.6	0.5	0.4	0.3
a_m		+23°	-83°	-80°	+79°

Kp = 2, 3

m	0	1	2	3	4
Cm	15.7	5.4	1.5	0.7	0.3
a_m		+18°	+55°	+68°	-16°

Kp ≥ 4

m	0	1	2	3	4
Cm	14.9	6.3	3.1	0.7	1.8
a_m		+28°	+64°	+90°	+83°

Table 9

Local Time (hours) of Maximum Field Value (L.T.)
for First Harmonic

Kp	H	V	D	F
$\theta_{gm}^{(s)} = <-10°$				
0,1	14.2	7.0	1.5	13.1
2,3	14.1	6.2	1.2	13.3
≥4	14.4	5.8	1.8	13.5
$-10° \leq \theta_{gm}^{(s)} \leq 10°$				
0,1	13.3	15.3	9.6	12.9
2,3	13.4	14.7	9.6	13.1
≥4	13.3	14.2	9.8	12.9
$\theta_{gm}^{(s)} = >10°$				
0,1	12.7	13.2	8.4	13.2
2,3	13.1	13.3	8.4	13.5
≥4	13.8	13.6	7.9	14.7

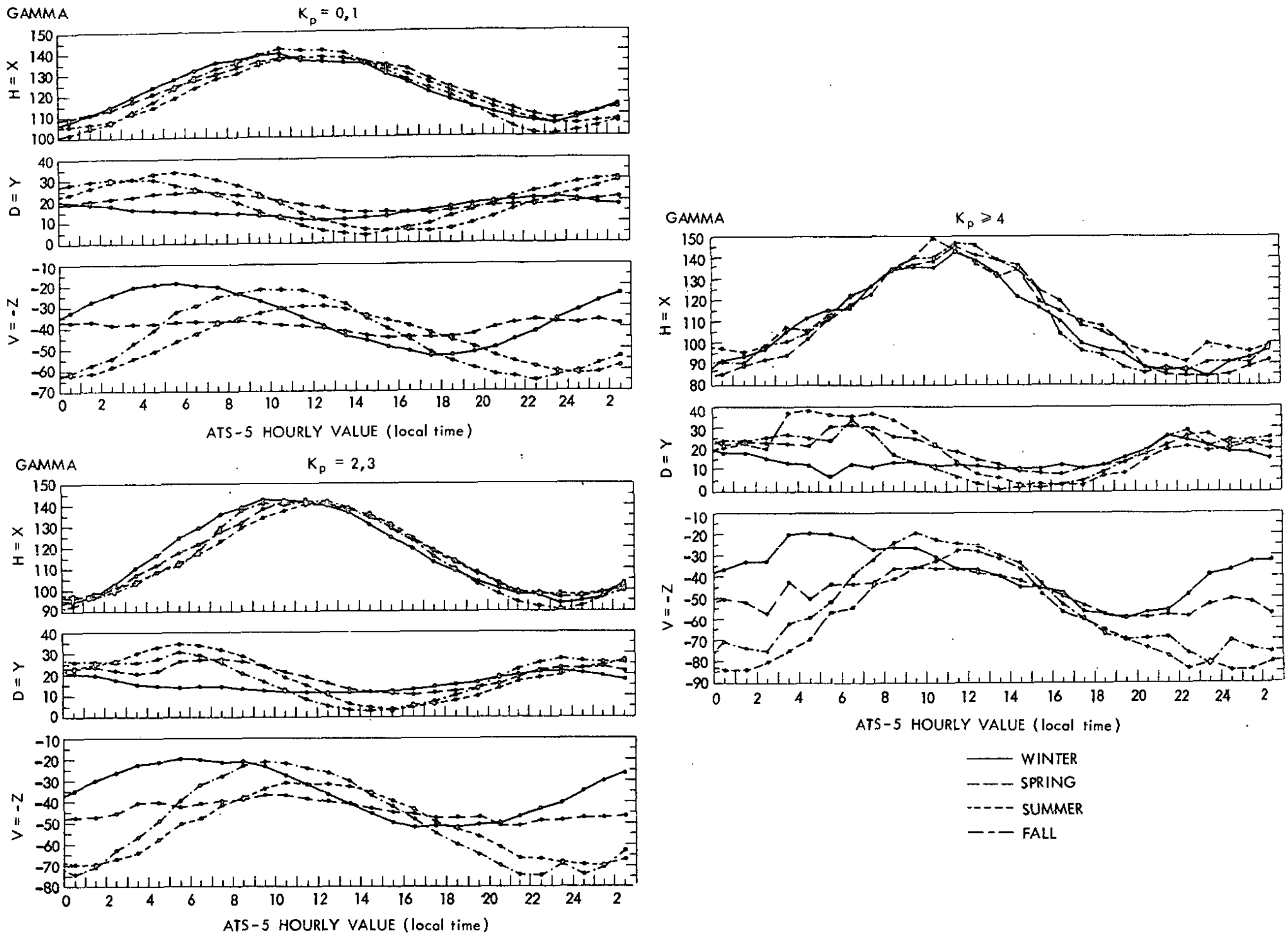

Figure 8. Daily Variations Relative to Seasons of the Year

V. Discussion

The plots in Figures 5 and 6 clearly show the effects of increased magnetic activity on the daily variations. The largest variations occur near local midnight due to the diamagnetic effects of increased plasma intensity.

The sorting of the data by geomagnetic latitude of the subsolar point emphasizes two points. First, there is an apparent change in phase in the Y (D) and -Z(V) as shown in Figure 6. Secondly, there is a significant difference in the $< -10^{o}$ trace in Figure 7 when compared with the other two θ_{gm}^{s} traces in the same plots. This difference is also evident, especially in the D and V plots in Figure 8. The position of ATS-5 is 7^{o} to 10^{o} north of the geomagnetic equator. Therefore, during the winter ($\theta_{gm}^{s} < -10^{o}$), ATS-5 is closest to the equatorial current sheet. The existence of this current sheet has been established by the Ogo 3 and 5 magnetic field observations (Sugiura 1972).

Figure 8 shows appreciable differences between spring and fall. In Figures 5 to 7 these differences are masked because the geomagnetic latitude of the sun was used for the classification of the data, thereby combining two equinoctial seasons. The presence of the annual variation seen in Figure 8 was quite unexpected, since such a variation calls for an explanation that goes beyond the geometrical configuration of the current sources relative to the sun's geomagnetic latitude. This implies that there is either a true annual variation in the solar wind conditions or a hysteresis effect in the response of the magnetosphere to the seasonal variations in the solar wind.

In order to study the apparent phase changes in D(Y) and V(-Z), the data was broken down further by the calendar seasons. This breakdown resolves the $-10^{o} \leq \theta_{gm}^{s} \leq 10^{o}$ in Figure 5 into Spring and Fall in Figure 8. The difference in these two seasonal traces is most prominent in the V(-Z) plots of Figure 8. Figure 9 is a further subdivision of the data for Kp = 0-1 for each calendar month. Gradual phase changes are apparent in both D and V. There seems to be a reversal in phase in these components near February to March. Corresponding to this phase reversal a slight, but noticeable, phase shift is observed in H.

The data was next compared with calculated field values taken from the ATS-5 Ephemeris data. The Ephermeris data includes component field values for the ATS-5 position at 10 minute intervals for a regular (geomagnetic reference field) and a distorted field model. The model for the "regular" field is determined from the GSFC/65 epoch 1965.0 of Hendricks and Cain, and represents the internal field of the earth. The "distorted field" takes into account the additional effects of the solar wind and geomagnetic tail. These calculations are from the Mead-Williams model (Williams and Mead, 1965) using a 40 gamma tail field. Figure 10 displays the computed values for four days: day 172, 1970; day 264, 1970; day 355, 1970; and day 80, 1971. These days are the equinoxes and soltices and are compared here with the observed hourly averages compiled monthly which include these dates. The observed H trace follows the shape of the Mead-Williams model fairly well, but has a more or less constant, higher field value of 5 to 25 gamma.

The D and V plots in Figure 10 show both amplitude and phase differences when compared to either of the calculated fields. These

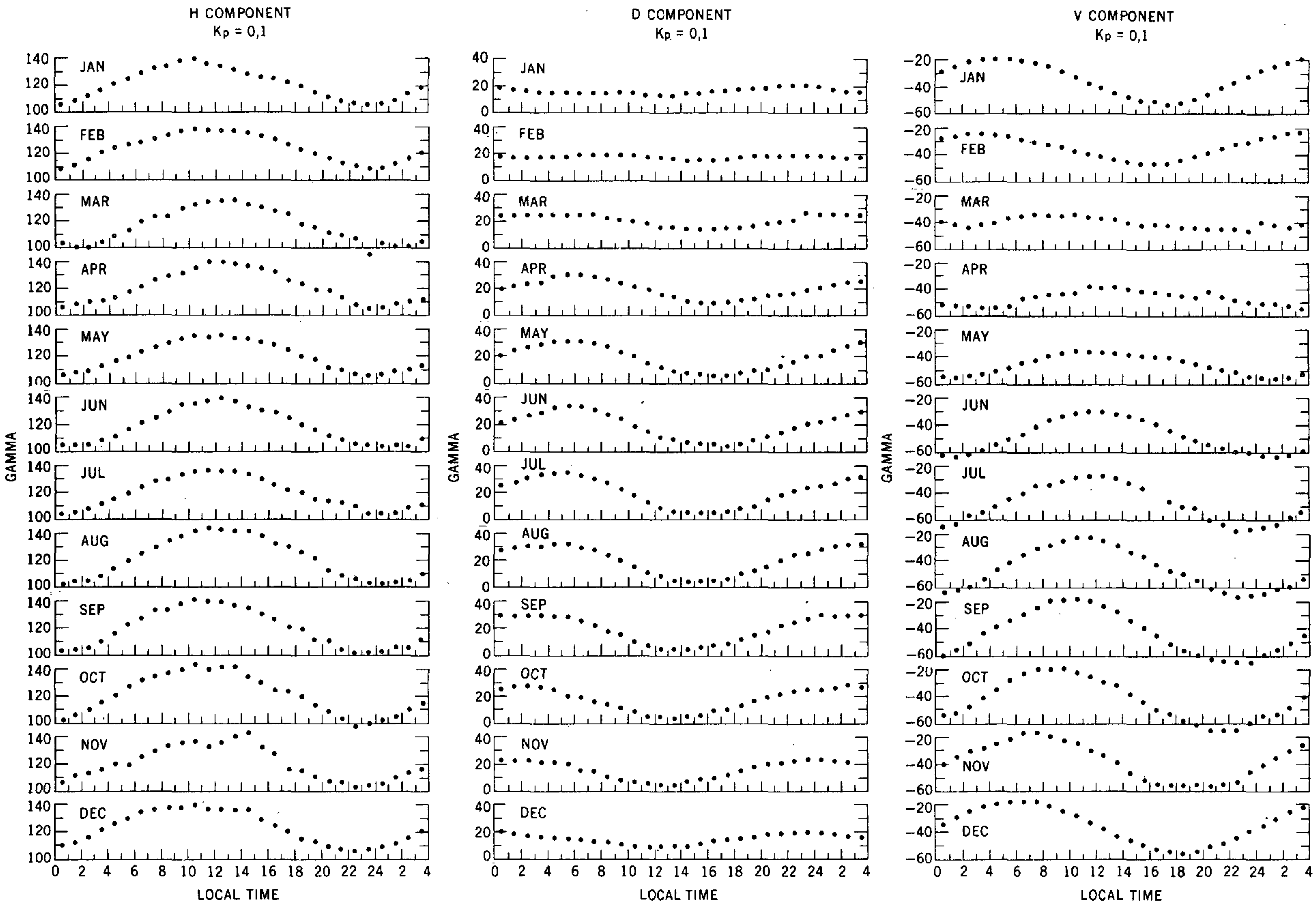

Figure 9. Daily Variations (H, D, V) separated by Calendar Months

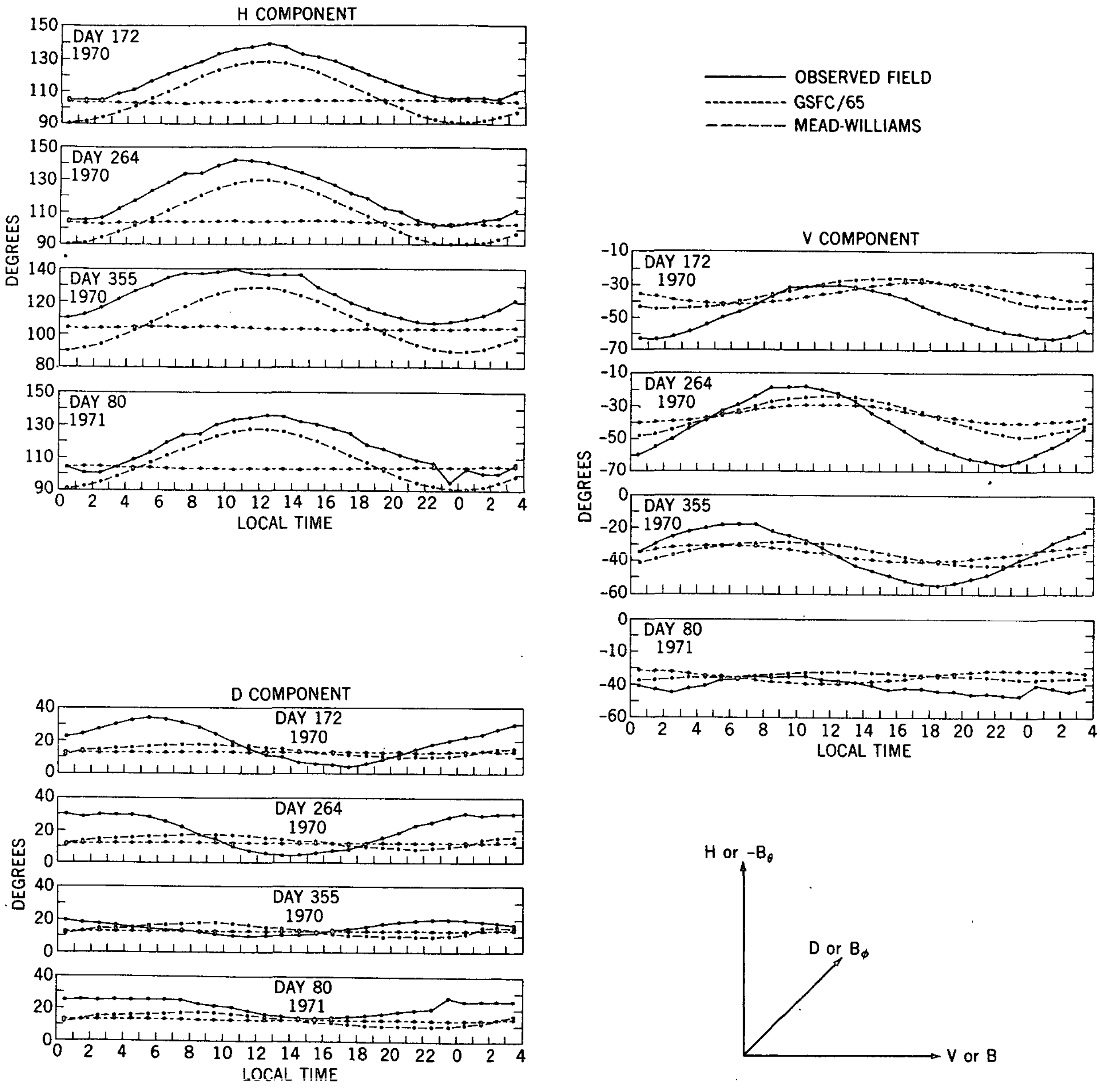

Figure 10. Comparisons of ATS magnetic fields and computed theoretical fields

differences between the measured and calculated field values are taken to be due to the equatorial current sheet. It should be noted that the phase changes in the calculated fields for the various days are probably due to changes in the geomagnetic latitude of the satellite because of the orbit inclination.

Figure 11 shows the variation of geomagnetic latitude of ATS-5 with season and local time. It should be stressed again the importance of geomagnetic latitude variations on satellite measurements even when the satellite is in a nominal synchronous equatorial orbit such as the ATS satellites.

In summary, the present study of the daily variations in the magnetic field as observed by ATS-5 suggests a need for an improved magnetospheric field model that takes into account the recent finding of the equatorial current sheet. The existence of the annual change, as indicated in the spring-fall asymmetry, in the daily variation of the magnetic field at the synchronous orbit should be studied further. Comparison of the present results with the OGO 3 and 5 observations will be made in a separate report.

Acknowledgements

I wish to thank Dr. M. Sugiura for his assistance in this work and Dr. B. Ledley for his discussions and suggestions. I wish to also acknowledge the help received from Mr. H. Gillis for his programming for the ATS-5 data reduction and Mr. L. Moriarty and R. Estes for their programming assistance relative to data analysis.

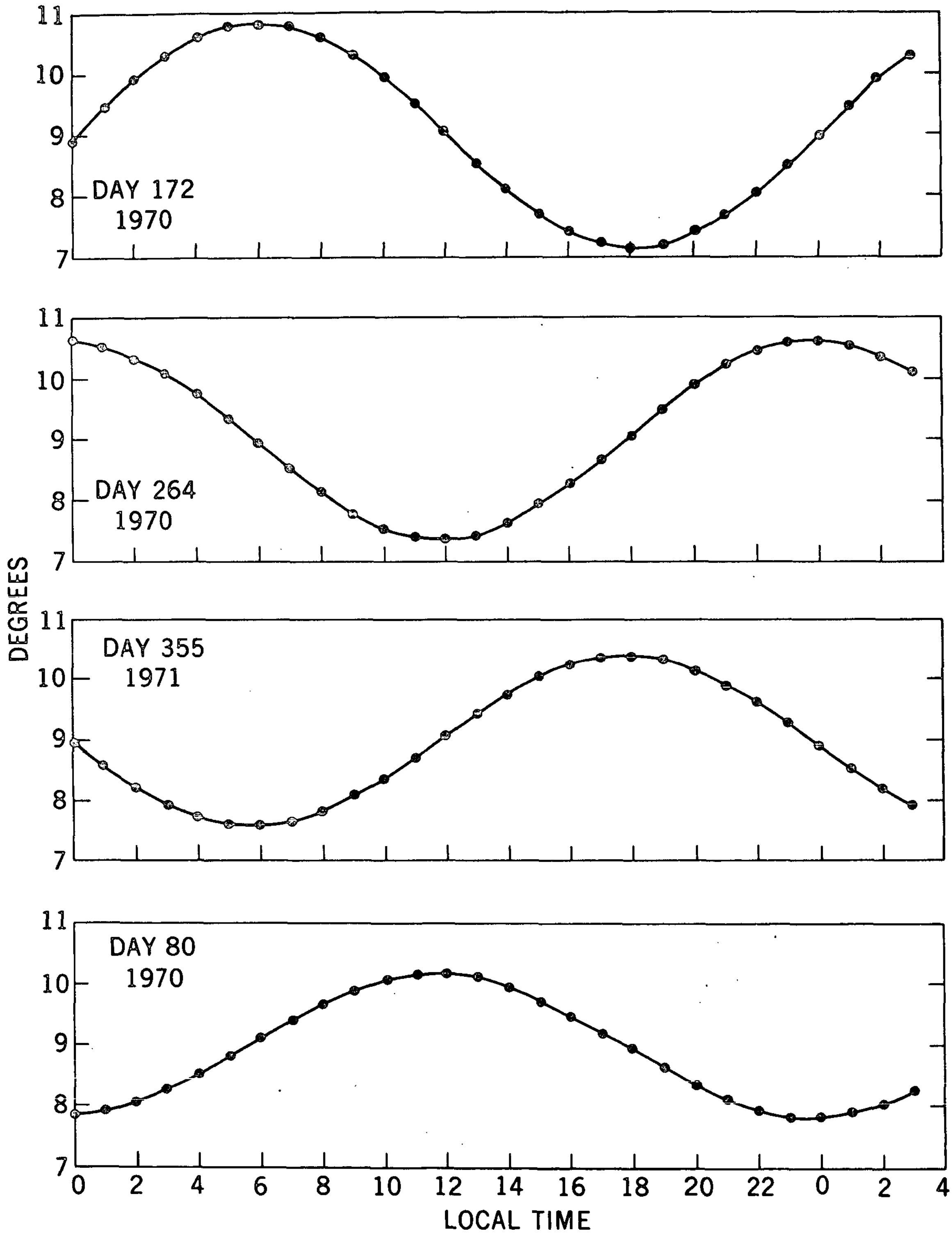

Figure 11. ATS-5 Geomagnetic Latitude

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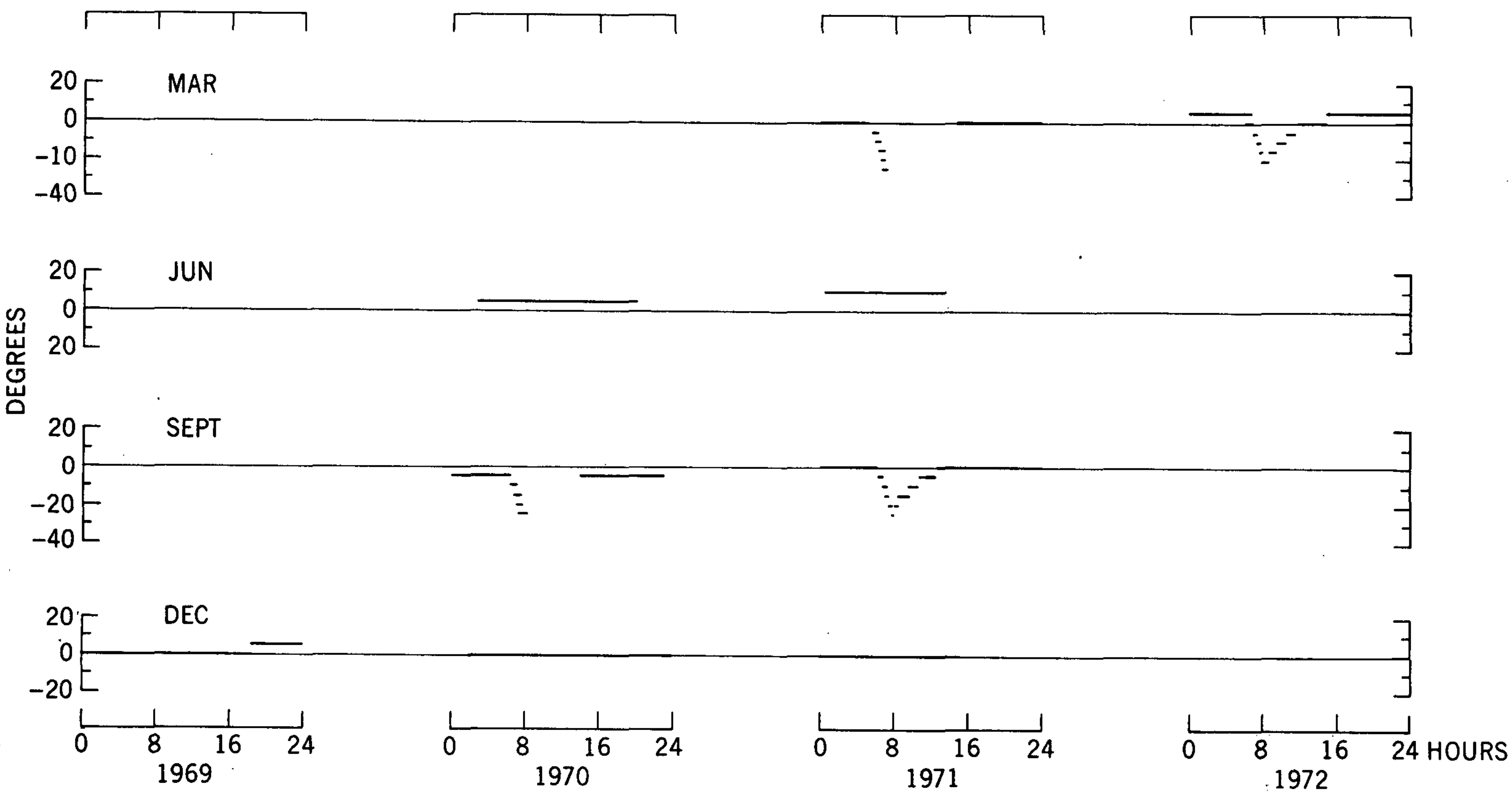
Appendix A

Appendix A

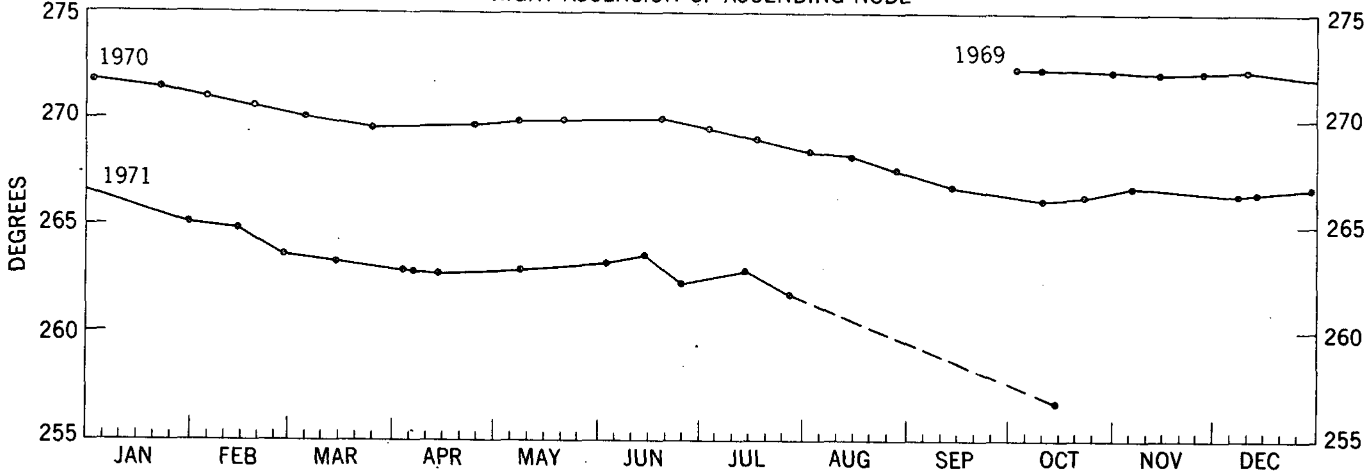
ATS-5 Magnetometer Sensor Temperature



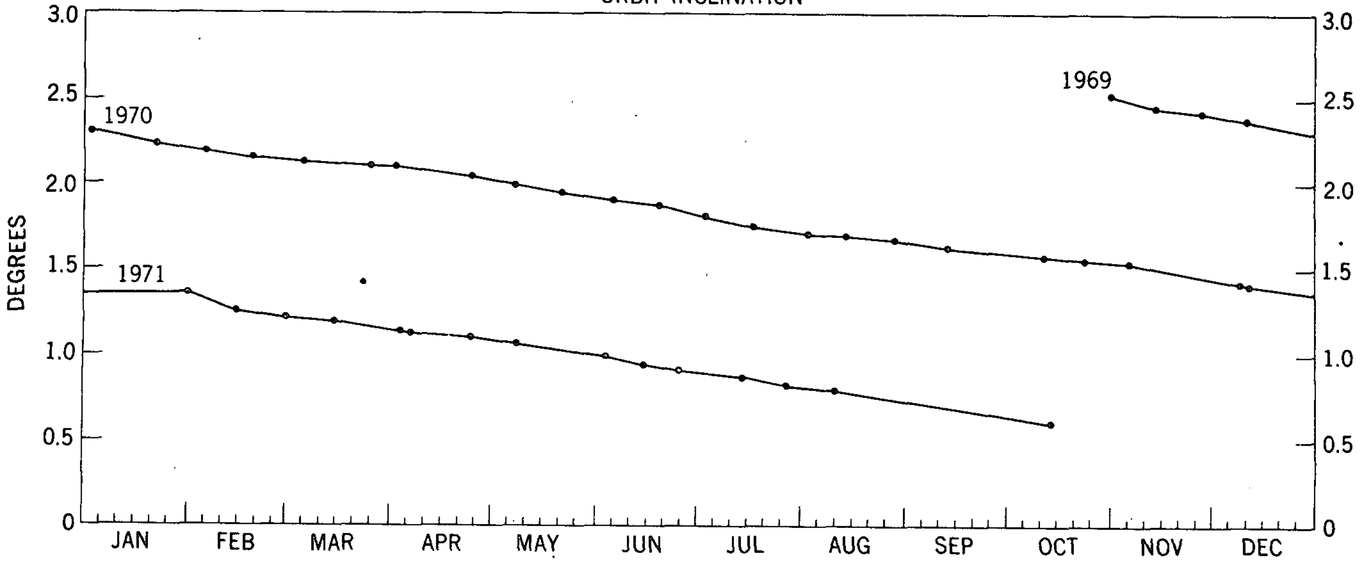
Appendix B

Appendix B

RIGHT ASCENSION OF ASCENDING NODE



ORBIT INCLINATION



Appendix C

Geom. Sun Lat. less than or equal -10 Deg

GEOM. SUN LAT. LESS THAN OR EQUAL -10 DEG

H COMPONENT

KP IS 0 OR 1

LOCAL TIME	NUMBER OF SAMPLES	AVERAGE(GM)	STANDARD DEVIATION
0.5	87	107.5	9.23
1.5	81	110.8	8.57
2.5	77	114.4	7.61
3.5	60	119.8	6.90
4.5	48	123.9	6.46
5.5	44	127.0	7.45
6.5	39	131.9	7.62
7.5	34	135.5	7.92
8.5	34	136.5	8.34
9.5	32	138.9	8.52
10.5	32	140.7	8.87
11.5	34	137.0	9.31
12.5	39	135.9	9.80
13.5	35	134.6	8.46
14.5	48	134.9	8.62
15.5	70	130.9	8.85
16.5	85	126.8	8.15
17.5	80	122.3	7.50
18.5	79	119.1	7.22
19.5	84	115.0	8.00
20.5	87	111.3	7.98
21.5	92	108.4	8.99
22.5	91	106.0	9.43
23.5	88	106.2	9.23

KP IS 2 OR 3

LOCAL TIME	NUMBER OF SAMPLES	AVERAGE(GM)	STANDARD DEVIATION
0.5	77	94.2	13.44
1.5	66	96.7	13.98
2.5	59	101.6	10.97
3.5	41	108.9	7.35
4.5	32	116.6	6.83
5.5	27	124.3	11.77
6.5	25	130.0	15.95
7.5	23	135.5	9.62
8.5	26	140.3	10.82
9.5	23	143.4	12.15
10.5	23	141.5	13.16
11.5	31	142.8	12.36
12.5	37	140.8	12.46
13.5	40	135.9	12.37
14.5	37	130.1	10.61
15.5	50	124.9	10.06
16.5	67	119.8	10.21
17.5	84	113.9	9.27
18.5	91	109.6	9.67
19.5	102	103.3	10.88
20.5	97	99.5	9.84
21.5	95	96.7	9.94
22.5	97	95.5	15.63
23.5	81	92.8	13.10

KP IS GREATER THAN 3

LOCAL TIME	NUMBER OF SAMPLES	AVERAGE(GM)	STANDARD DEVIATION
0.5	16	90.3	8.09
1.5	14	93.2	12.92
2.5	9	96.2	11.52
3.5	3	105.0	7.12
4.5	3	111.3	5.44
5.5	1	115.0	0.0
6.5	2	116.0	7.00
7.5	2	122.0	9.00
8.5	4	133.3	9.78
9.5	3	140.0	7.79
10.5	4	135.0	15.28
11.5	2	144.0	4.00
12.5	3	141.7	5.44
13.5	4	132.3	2.77
14.5	7	124.0	11.20
15.5	10	115.4	9.02
16.5	13	108.2	14.28
17.5	21	99.1	17.58
18.5	21	94.9	15.36
19.5	25	92.1	15.27
20.5	24	85.1	14.36
21.5	21	84.8	15.67
22.5	22	85.8	11.15
23.5	14	83.7	10.05

GEOM. SUN LAT. LESS THAN OR EQUAL -10 DEG

V COMPONENT

KP IS 0 OR 1

LOCAL TIME	NUMBER OF SAMPLES	AVERAGE (GM)	STANDARD DEVIATION
0.5	81	-33.3	9.16
1.5	75	-28.9	7.59
2.5	64	-24.7	4.69
3.5	50	-21.8	4.05
4.5	41	-20.1	3.99
5.5	41	-19.4	3.88
6.5	35	-19.8	4.35
7.5	34	-19.3	4.39
8.5	34	-22.4	4.07
9.5	33	-25.7	4.21
10.5	33	-28.8	4.08
11.5	35	-33.6	3.77
12.5	40	-39.0	4.13
13.5	39	-44.0	3.61
14.5	46	-45.9	3.56
15.5	62	-48.0	4.06
16.5	74	-49.5	4.54
17.5	70	-50.9	5.39
18.5	69	-51.5	6.28
19.5	74	-50.1	7.45
20.5	79	-48.5	8.78
21.5	85	-46.1	10.32
22.5	85	-43.3	11.73
23.5	86	-38.4	10.43

KP IS 2 OR 3

LOCAL TIME	NUMBER OF SAMPLES	AVERAGE (GM)	STANDARD DEVIATION
0.5	68	-38.1	12.61
1.5	55	-32.8	10.51
2.5	47	-27.1	5.08
3.5	31	-23.4	3.17
4.5	30	-22.5	3.86
5.5	26	-19.8	4.68
6.5	24	-19.5	5.11
7.5	21	-19.9	4.81
8.5	25	-18.9	3.14
9.5	23	-21.7	4.49
10.5	24	-26.3	4.87
11.5	33	-30.4	5.15
12.5	36	-35.4	5.04
13.5	39	-40.7	6.25
14.5	40	-45.3	4.65
15.5	49	-48.8	4.21
16.5	65	-51.0	4.78
17.5	76	-50.8	6.55
18.5	80	-51.5	8.37
19.5	95	-52.5	10.91
20.5	84	-51.9	12.83
21.5	85	-49.9	14.20
22.5	91	-48.0	15.42
23.5	75	-43.6	13.87

KP IS GREATER THAN 3

LOCAL TIME	NUMBER OF SAMPLES	AVERAGE (GM)	STANDARD DEVIATION
0.5	11	-41.9	13.10
1.5	9	-33.7	13.71
2.5	9	-39.0	18.98
3.5	2	-20.0	0.0
4.5	2	-19.5	0.50
5.5	1	-20.0	0.0
6.5	2	-22.0	4.00
7.5	2	-22.0	5.00
8.5	3	-23.0	3.56
9.5	2	-24.0	1.00
10.5	3	-30.7	5.44
11.5	2	-33.5	1.50
12.5	4	-34.3	5.63
13.5	5	-39.8	6.62
14.5	6	-44.5	2.99
15.5	10	-45.4	4.96
16.5	12	-50.0	6.15
17.5	17	-55.9	9.33
18.5	18	-59.3	8.85
19.5	21	-61.2	10.68
20.5	19	-57.4	14.39
21.5	18	-53.3	17.24
22.5	19	-52.2	13.91
23.5	11	-49.7	18.70

GEOM. SUN LAT. LESS THAN OR EQUAL -10 DEG
D COMPONENT

KP IS 0 OR 1

LOCAL TIME	NUMBER OF SAMPLES	AVERAGE(GM)	STANDARD DEVIATION
0.5	81	20.2	3.61
1.5	75	18.8	3.69
2.5	64	17.9	2.86
3.5	50	16.9	2.12
4.5	41	16.1	1.34
5.5	41	15.1	1.20
6.5	35	14.5	0.87
7.5	34	13.8	1.26
8.5	34	12.9	1.92
9.5	33	12.1	1.81
10.5	33	11.2	2.30
11.5	35	10.6	2.28
12.5	40	11.3	2.70
13.5	39	11.4	2.57
14.5	46	12.9	2.85
15.5	62	13.5	2.89
16.5	74	14.4	2.73
17.5	70	15.0	2.60
18.5	69	16.4	2.32
19.5	74	17.8	2.24
20.5	79	19.0	2.21
21.5	85	20.2	2.73
22.5	85	21.0	3.21
23.5	86	21.0	3.56

KP IS 2 OR 3

LOCAL TIME	NUMBER OF SAMPLES	AVERAGE(GM)	STANDARD DEVIATION
0.5	68	22.2	5.37
1.5	55	21.3	5.37
2.5	47	18.1	3.99
3.5	31	15.5	2.43
4.5	30	15.1	2.65
5.5	26	14.9	2.56
6.5	24	14.1	1.76
7.5	21	13.8	1.92
8.5	25	12.6	2.30
9.5	23	11.9	2.07
10.5	24	11.2	2.08
11.5	33	11.1	2.54
12.5	36	11.2	3.00
13.5	39	11.4	3.01
14.5	40	11.8	3.14
15.5	49	12.2	2.92
16.5	65	12.4	2.75
17.5	76	13.6	2.97
18.5	81	15.0	2.83
19.5	95	16.2	2.71
20.5	84	18.2	3.00
21.5	85	20.2	3.59
22.5	91	22.5	4.91
23.5	75	22.9	5.46

KP IS GREATER THAN 3

LOCAL TIME	NUMBER OF SAMPLES	AVERAGE(GM)	STANDARD DEVIATION
0.5	11	21.8	6.87
1.5	9	21.7	6.43
2.5	8	17.4	4.53
3.5	2	13.5	1.50
4.5	2	12.5	1.50
5.5	1	7.0	0.0
6.5	2	13.0	1.00
7.5	2	12.5	0.50
8.5	3	12.3	1.25
9.5	2	12.0	1.00
10.5	3	10.7	0.47
11.5	2	8.5	1.50
12.5	4	11.3	3.42
13.5	5	10.6	3.50
14.5	6	12.0	2.00
15.5	10	11.3	2.41
16.5	12	10.5	3.66
17.5	18	11.3	2.77
18.5	18	12.8	2.65
19.5	20	15.8	3.17
20.5	19	19.7	5.54
21.5	18	26.2	5.63
22.5	20	25.1	6.09
23.5	11	22.3	8.28

GEOM. SUN LAT. GREATER THAN -10 DEG BUT LESS THAN OR EQUAL 10 DEG
H COMPONENT

KP IS 0 OR 1

LOCAL TIME	NUMBER OF SAMPLES	AVERAGE(GM)	STANDARD DEVIATION
0.5	52	105.1	7.41
1.5	53	105.8	7.90
2.5	43	108.4	6.59
3.5	37	112.4	7.18
4.5	41	119.8	7.40
5.5	48	125.7	7.49
6.5	52	129.4	7.35
7.5	56	133.8	8.18
8.5	57	135.4	7.58
9.5	63	138.0	8.64
10.5	64	139.3	9.53
11.5	52	136.9	9.33
12.5	56	137.4	9.23
13.5	50	138.5	9.62
14.5	52	134.3	9.06
15.5	44	130.7	7.66
16.5	35	129.1	6.95
17.5	38	124.3	7.70
18.5	42	121.6	7.20
19.5	39	117.6	7.04
20.5	49	113.1	8.22
21.5	48	110.3	7.71
22.5	51	107.1	7.63
23.5	49	105.2	7.52

KP IS 2 OR 3

LOCAL TIME	NUMBER OF SAMPLES	AVERAGE(GM)	STANDARD DEVIATION
0.5	68	94.9	9.27
1.5	70	98.0	9.12
2.5	62	98.9	9.27
3.5	47	103.0	10.05
4.5	50	109.4	9.42
5.5	40	117.7	8.96
6.5	38	123.1	8.80
7.5	43	131.3	13.95
8.5	40	135.3	12.09
9.5	49	139.4	14.22
10.5	51	142.0	14.49
11.5	52	140.1	10.81
12.5	59	138.7	8.85
13.5	55	137.5	8.12
14.5	54	133.8	7.90
15.5	57	128.3	8.68
16.5	58	123.2	10.05
17.5	68	117.6	8.69
18.5	74	112.0	10.24
19.5	90	108.0	10.99
20.5	72	101.4	10.18
21.5	76	97.5	9.47
22.5	76	97.1	10.21
23.5	59	95.6	10.63

KP IS GREATER THAN 3

LOCAL TIME	NUMBER OF SAMPLES	AVERAGE(GM)	STANDARD DEVIATION
0.5	14	88.2	11.10
1.5	16	87.8	7.40
2.5	8	94.5	9.99
3.5	10	96.5	7.93
4.5	9	103.1	9.85
5.5	14	110.9	8.55
6.5	12	120.3	10.18
7.5	12	124.7	10.73
8.5	20	133.4	9.42
9.5	25	137.2	11.30
10.5	20	137.6	11.53
11.5	19	145.7	11.32
12.5	18	140.5	9.53
13.5	13	136.0	9.98
14.5	15	132.8	11.35
15.5	16	122.5	17.71
16.5	15	111.5	18.26
17.5	24	103.8	22.24
18.5	25	104.1	15.08
19.5	24	96.5	13.88
20.5	21	93.3	12.10
21.5	20	92.6	12.96
22.5	25	89.4	9.73
23.5	15	98.3	13.40

GEOM. SUN LAT. GREATER THAN -10 DEG BUT LESS THAN OR EQUAL 10 DEG
V COMPONENT

KP IS 0 OR 1

LOCAL TIME	NUMBER OF SAMPLES	AVERAGE(GM)	STANDARD DEVIATION
0.5	52	-59.2	9.07
1.5	48	-56.0	6.58
2.5	31	-51.8	4.78
3.5	20	-43.6	3.92
4.5	22	-33.5	6.16
5.5	26	-29.2	5.07
6.5	35	-29.1	6.93
7.5	38	-27.6	6.57
8.5	44	-29.3	9.20
9.5	50	-31.2	9.37
10.5	49	-34.1	9.08
11.5	45	-37.0	7.45
12.5	48	-37.5	8.12
13.5	38	-39.7	7.80
14.5	37	-40.1	6.65
15.5	33	-42.3	6.36
16.5	26	-43.7	4.35
17.5	30	-48.6	5.09
18.5	36	-50.6	7.05
19.5	34	-52.4	8.09
20.5	43	-53.6	9.60
21.5	41	-55.2	9.95
22.5	48	-58.2	10.68
23.5	50	-59.4	9.04

KP IS 2 OR 3

LOCAL TIME	NUMBER OF SAMPLES	AVERAGE(GM)	STANDARD DEVIATION
0.5	53	-68.0	12.82
1.5	57	-66.5	12.02
2.5	41	-61.1	12.45
3.5	26	-53.4	13.69
4.5	24	-44.0	11.26
5.5	25	-32.9	6.57
6.5	24	-29.3	5.43
7.5	34	-29.5	10.26
8.5	29	-28.4	7.82
9.5	40	-29.9	8.11
10.5	42	-31.6	8.34
11.5	43	-35.1	9.53
12.5	47	-36.6	7.54
13.5	38	-38.5	6.93
14.5	48	-41.5	5.95
15.5	51	-44.7	5.75
16.5	48	-47.8	5.36
17.5	61	-51.6	5.82
18.5	66	-55.2	8.79
19.5	71	-57.4	9.61
20.5	60	-61.8	11.94
21.5	64	-65.0	12.54
22.5	63	-65.0	12.05
23.5	51	-63.2	23.40

KP IS GREATER THAN 3

LOCAL TIME	NUMBER OF SAMPLES	AVERAGE(GM)	STANDARD DEVIATION
0.5	5	-74.4	8.31
1.5	4	-69.5	8.38
2.5	4	-75.5	13.74
3.5	6	-54.3	13.12
4.5	6	-52.8	16.77
5.5	9	-46.4	13.51
6.5	7	-32.9	6.98
7.5	11	-29.7	10.88
8.5	18	-29.8	9.41
9.5	23	-28.2	9.10
10.5	18	-31.5	8.87
11.5	15	-31.8	9.25
12.5	15	-33.4	8.31
13.5	12	-34.8	7.55
14.5	17	-37.2	6.23
15.5	16	-43.5	6.21
16.5	17	-50.5	6.84
17.5	19	-56.5	8.27
18.5	19	-60.2	11.16
19.5	17	-65.4	11.28
20.5	12	-69.4	14.29
21.5	12	-75.4	8.12
22.5	13	-79.9	6.96
23.5	5	-78.2	12.35

GEOM. SUN LAT. GREATER THAN -10 DEG BUT LESS THAN OR EQUAL 10 DEG

D COMPONENT

KP IS 0 OR 1

LOCAL TIME	NUMBER OF SAMPLES	AVERAGE(GM)	STANDARD DEVIATION
0.5	52	25.7	5.04
1.5	47	27.2	5.02
2.5	31	28.8	3.61
3.5	20	29.8	3.82
4.5	22	25.2	5.18
5.5	26	23.1	4.80
6.5	35	22.0	4.36
7.5	38	19.3	3.62
8.5	44	17.4	2.97
9.5	50	16.9	4.12
10.5	49	16.1	4.32
11.5	45	15.2	4.93
12.5	48	13.3	6.01
13.5	38	13.7	5.49
14.5	37	10.9	5.51
15.5	33	9.9	4.90
16.5	26	9.0	3.56
17.5	30	9.0	2.40
18.5	36	10.8	2.45
19.5	34	12.4	2.64
20.5	43	13.7	2.96
21.5	41	16.8	3.78
22.5	48	19.6	4.44
23.5	49	22.1	4.35

KP IS 2 OR 3

LOCAL TIME	NUMBER OF SAMPLES	AVERAGE(GM)	STANDARD DEVIATION
0.5	53	23.8	5.58
1.5	56	24.7	6.61
2.5	42	25.0	7.07
3.5	26	24.8	7.09
4.5	24	26.0	5.97
5.5	25	24.5	4.55
6.5	24	21.4	4.12
7.5	34	19.7	4.53
8.5	29	17.8	4.20
9.5	40	17.5	4.77
10.5	42	15.8	4.91
11.5	43	14.4	5.71
12.5	47	11.9	6.25
13.5	38	10.2	6.19
14.5	48	8.1	5.35
15.5	51	7.8	4.58
16.5	48	6.9	3.60
17.5	61	7.5	2.29
18.5	65	9.2	2.51
19.5	71	11.3	3.28
20.5	60	14.9	4.55
21.5	64	18.1	5.42
22.5	62	20.8	5.98
23.5	50	22.7	5.64

KP IS GREATER THAN 3

LOCAL TIME	NUMBER OF SAMPLES	AVERAGE(GM)	STANDARD DEVIATION
0.5	5	19.6	9.97
1.5	5	21.6	8.33
2.5	4	27.8	5.12
3.5	6	26.5	6.63
4.5	6	21.5	6.42
5.5	9	23.7	6.77
6.5	7	27.6	5.10
7.5	11	20.9	6.14
8.5	18	17.9	4.46
9.5	23	17.7	5.13
10.5	18	16.1	5.17
11.5	15	14.9	6.06
12.5	15	10.7	5.99
13.5	12	8.7	5.88
14.5	17	6.1	4.84
15.5	17	4.9	3.98
16.5	18	6.1	3.59
17.5	19	7.3	2.83
18.5	19	9.8	2.70
19.5	17	12.5	2.97
20.5	12	17.0	5.34
21.5	12	22.0	6.08
22.5	13	26.2	5.83
23.5	5	24.2	3.92

GEOM. SUN LAT. GREATER THAN 10 DEG

H COMPONENT

KP IS 0 OR 1

LOCAL TIME	NUMBER OF SAMPLES	AVERAGE(GM)	STANDARD DEVIATION
0.5	50	104.3	7.48
1.5	61	106.0	6.57
2.5	80	106.8	7.04
3.5	85	110.8	5.87
4.5	99	114.2	5.71
5.5	86	119.1	5.67
6.5	96	123.7	6.02
7.5	99	128.3	6.77
8.5	86	130.6	7.16
9.5	89	134.8	7.46
10.5	85	137.4	7.92
11.5	81	138.7	8.32
12.5	75	139.1	8.46
13.5	72	137.3	7.35
14.5	59	135.3	7.56
15.5	56	132.8	7.96
16.5	46	129.1	7.02
17.5	44	125.6	7.13
18.5	39	120.6	5.78
19.5	36	116.5	6.54
20.5	27	113.1	5.39
21.5	28	109.8	4.87
22.5	30	107.2	5.64
23.5	40	104.3	8.41

KP IS 2 OR 3

LOCAL TIME	NUMBER OF SAMPLES	AVERAGE(GM)	STANDARD DEVIATION
0.5	53	97.0	7.90
1.5	61	97.7	7.70
2.5	74	101.6	8.12
3.5	71	104.1	7.98
4.5	80	108.4	7.87
5.5	106	114.3	7.87
6.5	116	119.6	7.87
7.5	119	125.4	8.83
8.5	108	132.0	10.32
9.5	109	136.9	11.14
10.5	109	138.4	17.95
11.5	107	141.2	11.27
12.5	102	141.0	12.30
13.5	93	138.5	11.39
14.5	94	135.8	11.43
15.5	91	131.4	11.11
16.5	74	125.4	11.18
17.5	56	117.8	11.25
18.5	53	112.1	9.70
19.5	41	105.6	7.86
20.5	38	103.2	8.25
21.5	43	100.5	8.20
22.5	38	97.3	9.80
23.5	40	97.7	6.34

KP IS GREATER THAN 3

LOCAL TIME	NUMBER OF SAMPLES	AVERAGE(GM)	STANDARD DEVIATION
0.5	15	99.1	9.02
1.5	19	95.9	7.73
2.5	20	99.6	8.68
3.5	16	105.6	8.37
4.5	15	104.9	6.01
5.5	25	112.2	8.81
6.5	27	121.0	11.92
7.5	28	125.6	10.92
8.5	19	135.2	15.96
9.5	21	138.0	18.30
10.5	20	145.0	20.18
11.5	29	144.1	15.62
12.5	27	141.4	14.28
13.5	17	137.4	14.35
14.5	25	136.8	14.27
15.5	26	124.2	15.45
16.5	20	118.5	12.14
17.5	15	108.4	14.58
18.5	13	105.2	11.96
19.5	10	98.7	10.47
20.5	6	91.5	9.91
21.5	6	90.2	7.60
22.5	6	88.3	4.31
23.5	12	95.3	8.13

GEOM. SUN LAT. GREATER THAN 10 DEG
V COMPONENT

KP IS 0 OR 1

LOCAL TIME	NUMBER OF SAMPLES	AVERAGE (GM)	STANDARD DEVIATION
0.5	45	-62.9	5.14
1.5	55	-61.8	6.88
2.5	57	-58.8	5.22
3.5	56	-54.3	5.41
4.5	71	-50.3	6.68
5.5	59	-45.1	7.03
6.5	78	-40.3	7.43
7.5	88	-35.6	7.75
8.5	74	-34.3	8.04
9.5	78	-31.8	8.10
10.5	76	-30.4	7.87
11.5	75	-28.9	7.16
12.5	71	-29.8	6.06
13.5	74	-31.7	5.18
14.5	54	-35.0	3.98
15.5	53	-37.5	4.05
16.5	43	-39.8	4.09
17.5	36	-42.8	5.10
18.5	31	-46.6	6.03
19.5	29	-50.0	5.49
20.5	24	-54.7	5.98
21.5	25	-57.4	5.74
22.5	25	-60.1	6.47
23.5	36	-61.8	7.07

KP IS 2 OR 3

LOCAL TIME	NUMBER OF SAMPLES	AVERAGE (GM)	STANDARD DEVIATION
0.5	41	-70.1	8.94
1.5	46	-70.1	9.32
2.5	45	-66.2	9.69
3.5	40	-62.3	8.33
4.5	47	-56.4	8.24
5.5	74	-48.2	8.39
6.5	100	-43.5	10.01
7.5	108	-37.5	9.82
8.5	96	-34.9	9.65
9.5	97	-31.8	9.18
10.5	93	-30.5	7.78
11.5	88	-30.4	7.47
12.5	96	-31.2	6.60
13.5	92	-32.8	6.19
14.5	81	-36.0	5.12
15.5	76	-39.3	5.53
16.5	69	-43.3	6.00
17.5	46	-49.9	7.13
18.5	43	-53.0	7.89
19.5	34	-57.1	8.05
20.5	34	-62.5	8.00
21.5	26	-68.6	10.47
22.5	29	-69.3	10.64
23.5	27	-69.7	9.82

KP IS GREATER THAN 3

LOCAL TIME	NUMBER OF SAMPLES	AVERAGE (GM)	STANDARD DEVIATION
0.5	5	-84.6	6.47
1.5	5	-94.0	2.97
2.5	4	-79.0	11.94
3.5	2	-72.0	3.00
4.5	4	-64.8	12.46
5.5	13	-52.6	10.89
6.5	21	-51.9	12.51
7.5	21	-44.7	11.48
8.5	16	-38.9	11.02
9.5	20	-35.7	10.12
10.5	21	-33.3	8.19
11.5	30	-32.0	7.94
12.5	27	-32.5	8.95
13.5	17	-34.4	7.01
14.5	21	-38.0	7.19
15.5	23	-47.4	8.85
16.5	18	-54.0	9.04
17.5	13	-60.4	13.34
18.5	10	-69.2	8.36
19.5	8	-70.6	10.83
20.5	2	-78.5	7.50
21.5	2	-82.0	1.00
22.5	2	-83.0	1.00
23.5	5	-78.8	8.42

GEOM. SUN LAT. GREATER THAN 10 DEG
D COMPONENT

KP IS 0 OR 1

LOCAL TIME	NUMBER OF SAMPLES	AVERAGE(GM)	STANDARD DEVIATION
0.5	46	23.3	3.23
1.5	54	26.5	4.72
2.5	57	28.8	3.93
3.5	56	30.5	4.01
4.5	71	32.4	3.41
5.5	59	32.7	3.04
6.5	78	31.2	3.43
7.5	88	28.7	3.71
8.5	73	26.3	3.57
9.5	78	22.3	3.72
10.5	76	18.5	3.62
11.5	75	13.9	3.75
12.5	71	10.7	3.35
13.5	73	8.2	4.57
14.5	54	6.7	4.65
15.5	53	6.1	4.36
16.5	43	5.9	4.43
17.5	36	5.4	2.15
18.5	31	6.7	1.77
19.5	29	8.9	1.55
20.5	24	11.3	1.76
21.5	25	14.9	1.55
22.5	25	18.1	2.23
23.5	36	21.1	2.72

KP IS 2 OR 3

LOCAL TIME	NUMBER OF SAMPLES	AVERAGE(GM)	STANDARD DEVIATION
0.5	41	22.9	5.85
1.5	46	24.0	5.19
2.5	45	25.5	6.37
3.5	40	27.9	7.10
4.5	48	30.6	6.31
5.5	74	32.6	4.10
6.5	100	32.2	4.05
7.5	108	30.1	4.08
8.5	96	26.7	4.58
9.5	97	23.0	4.71
10.5	93	18.5	4.59
11.5	88	14.3	5.01
12.5	95	9.7	4.19
13.5	81	6.3	3.29
14.5	80	5.0	2.94
15.5	76	4.1	2.36
16.5	69	4.6	1.99
17.5	46	5.8	2.43
18.5	42	7.5	2.28
19.5	34	9.7	2.71
20.5	34	13.9	4.10
21.5	27	16.9	5.03
22.5	30	19.4	7.50
23.5	29	20.0	5.14

KP IS GREATER THAN 3

LOCAL TIME	NUMBER OF SAMPLES	AVERAGE(GM)	STANDARD DEVIATION
0.5	6	19.7	7.67
1.5	6	22.7	7.65
2.5	4	19.3	9.28
3.5	2	29.0	8.00
4.5	3	34.3	3.86
5.5	14	33.8	6.67
6.5	21	35.7	5.95
7.5	21	35.9	4.94
8.5	16	32.0	6.45
9.5	20	26.1	6.01
10.5	21	20.3	6.15
11.5	30	14.5	5.98
12.5	27	10.2	5.33
13.5	17	6.4	5.38
14.5	21	4.9	3.74
15.5	23	4.6	3.52
16.5	17	3.9	4.34
17.5	13	3.5	8.46
18.5	10	7.4	7.45
19.5	8	5.9	5.25
20.5	2	12.5	2.50
21.5	2	20.5	2.50
22.5	2	24.5	1.50
23.5	4	17.0	4.30

DATA NOT SEPARATED ACCORDING TO GEOM. SUN LAT.

H COMPONENT

KP IS 0 OR 1

LOCAL TIME	NUMBER OF SAMPLES	AVERAGE(GM)	STANDARD DEVIATION
0.5	189	106.0	8.44
1.5	195	107.9	8.17
2.5	200	110.1	7.98
3.5	182	114.1	7.66
4.5	188	117.9	7.56
5.5	178	122.8	7.60
6.5	187	127.0	7.62
7.5	189	131.2	8.05
8.5	177	133.3	7.98
9.5	184	136.6	8.27
10.5	181	138.7	8.78
11.5	167	137.8	8.89
12.5	170	137.8	9.13
13.5	157	137.1	8.50
14.5	159	134.9	8.40
15.5	170	131.5	8.32
16.5	166	127.9	7.70
17.5	162	123.7	7.58
18.5	160	120.1	6.97
19.5	159	116.0	7.54
20.5	163	112.1	7.74
21.5	168	109.2	8.12
22.5	172	106.6	8.38
23.5	177	105.5	8.64

KP IS 2 OR 3

LOCAL TIME	NUMBER OF SAMPLES	AVERAGE(GM)	STANDARD DEVIATION
0.5	198	95.2	10.86
1.5	197	97.4	10.66
2.5	195	100.7	9.50
3.5	159	105.0	8.81
4.5	162	110.3	8.77
5.5	173	116.7	9.53
6.5	179	121.8	10.25
7.5	185	128.0	10.99
8.5	174	134.0	11.22
9.5	181	138.4	12.37
10.5	183	139.8	16.59
11.5	190	141.1	11.37
12.5	198	140.3	11.46
13.5	188	137.7	10.77
14.5	185	134.1	10.58
15.5	198	128.8	10.53
16.5	199	122.8	10.80
17.5	208	116.2	9.84
18.5	218	111.0	9.95
19.5	223	105.4	10.65
20.5	207	100.8	9.79
21.5	204	97.6	9.59
22.5	211	96.4	12.96
23.5	190	94.8	11.27

KP IS GREATER THAN 3

LOCAL TIME	NUMBER OF SAMPLES	AVERAGE(GM)	STANDARD DEVIATION
0.5	45	92.6	10.53
1.5	49	92.5	10.04
2.5	37	97.7	9.96
3.5	29	102.4	9.17
4.5	27	105.0	7.83
5.5	40	111.8	8.64
6.5	41	120.5	11.29
7.5	42	125.1	10.81
8.5	43	134.2	12.79
9.5	49	137.7	14.59
10.5	44	140.8	16.81
11.5	50	144.7	13.84
12.5	48	141.1	12.28
13.5	34	136.3	12.02
14.5	47	133.6	13.69
15.5	52	122.0	15.57
16.5	48	113.5	15.50
17.5	60	103.3	19.28
18.5	59	101.1	15.28
19.5	59	95.0	14.23
20.5	51	89.2	13.58
21.5	47	88.8	14.21
22.5	53	87.8	10.07
23.5	41	92.4	12.66

DATA NOT SEPARATED ACCORDING TO GEOM. SUN LAT.

V COMPONENT

KP IS 0 OR 1

LOCAL TIME	NUMBER OF SAMPLES	AVERAGE(GM)	STANDARD DEVIATION
0.5	179	-48.5	15.19
1.5	178	-46.4	16.69
2.5	152	-43.0	16.69
3.5	126	-39.9	15.90
4.5	134	-38.3	14.70
5.5	126	-33.5	12.84
6.5	148	-32.8	10.86
7.5	160	-30.2	9.48
8.5	152	-30.2	9.05
9.5	151	-30.4	8.27
10.5	158	-31.2	7.93
11.5	155	-32.3	7.53
12.5	159	-34.5	7.62
13.5	151	-36.9	7.76
14.5	137	-40.0	6.63
15.5	148	-43.0	6.59
16.5	143	-45.5	6.14
17.5	136	-48.3	6.24
18.5	136	-50.1	6.72
19.5	137	-50.7	7.32
20.5	146	-51.0	9.08
21.5	151	-50.5	10.82
22.5	158	-50.5	13.26
23.5	172	-49.4	14.52

KP IS 2 OR 3

LOCAL TIME	NUMBER OF SAMPLES	AVERAGE(GM)	STANDARD DEVIATION
0.5	162	-56.0	19.27
1.5	158	-55.8	20.02
2.5	134	-50.9	20.00
3.5	97	-47.5	19.17
4.5	101	-43.4	16.58
5.5	125	-39.2	13.73
6.5	148	-37.3	12.85
7.5	163	-33.5	11.24
8.5	150	-31.0	10.41
9.5	160	-29.9	9.08
10.5	159	-30.2	7.76
11.5	164	-31.6	7.95
12.5	179	-33.5	7.03
13.5	159	-36.1	7.30
14.5	169	-39.7	6.53
15.5	176	-43.5	6.59
16.5	182	-47.2	6.36
17.5	183	-50.8	6.50
18.5	189	-53.1	8.57
19.5	200	-55.0	10.30
20.5	178	-57.2	12.79
21.5	175	-58.2	15.43
22.5	183	-57.2	16.51
23.5	153	-54.7	20.45

KP IS GREATER THAN 3

LOCAL TIME	NUMBER OF SAMPLES	AVERAGE(GM)	STANDARD DEVIATION
0.5	21	-59.8	21.93
1.5	18	-58.1	22.72
2.5	16	-58.1	25.10
3.5	10	-51.0	19.80
4.5	12	-51.3	20.55
5.5	23	-48.8	13.60
6.5	30	-45.5	14.99
7.5	34	-39.5	13.62
8.5	37	-33.2	11.18
9.5	45	-31.4	10.18
10.5	42	-32.3	8.39
11.5	47	-32.0	8.23
12.5	46	-33.0	8.52
13.5	34	-35.3	7.39
14.5	44	-38.5	6.83
15.5	49	-45.7	7.57
16.5	47	-51.7	7.82
17.5	49	-57.3	10.36
18.5	47	-61.8	10.58
19.5	46	-64.4	11.45
20.5	33	-63.1	15.63
21.5	32	-63.4	18.02
22.5	34	-64.6	17.95
23.5	21	-63.4	21.05

DATA NOT SEPARATED ACCORDING TO GEOM. SUN LAT.

D COMPONENT

KP IS 0 OR 1

LOCAL TIME	NUMBER OF SAMPLES	AVERAGE(GM)	STANDARD DEVIATION
0.5	179	22.6	4.63
1.5	176	23.4	5.92
2.5	132	24.2	6.39
3.5	126	25.0	7.36
4.5	134	26.2	7.92
5.5	126	25.0	8.34
6.5	148	25.1	7.73
7.5	160	23.3	7.08
8.5	151	20.7	6.42
9.5	161	18.5	5.36
10.5	158	16.2	4.57
11.5	155	13.5	4.22
12.5	159	11.6	4.36
13.5	150	10.4	4.99
14.5	137	9.9	5.16
15.5	148	10.0	5.10
16.5	143	10.8	5.14
17.5	136	11.1	4.81
18.5	136	12.7	4.61
19.5	137	14.6	4.31
20.5	146	16.2	3.98
21.5	151	18.4	3.61
22.5	158	20.1	3.67
23.5	171	21.3	3.69

KP IS 2 OR 3

LOCAL TIME	NUMBER OF SAMPLES	AVERAGE(GM)	STANDARD DEVIATION
0.5	162	22.9	5.61
1.5	157	23.3	5.99
2.5	134	22.7	6.82
3.5	97	23.1	8.06
4.5	132	24.9	9.53
5.5	125	27.3	9.10
6.5	148	27.5	8.03
7.5	163	25.8	7.37
8.5	150	22.6	7.07
9.5	160	20.0	6.04
10.5	159	16.7	5.10
11.5	164	13.7	5.00
12.5	178	10.6	4.75
13.5	158	8.5	4.73
14.5	168	7.5	4.70
15.5	176	7.4	4.70
16.5	132	8.0	4.41
17.5	183	9.6	4.32
18.5	188	11.3	4.20
19.5	200	13.4	4.03
20.5	178	16.2	4.23
21.5	176	18.9	4.75
22.5	183	21.4	5.88
23.5	154	22.3	5.57

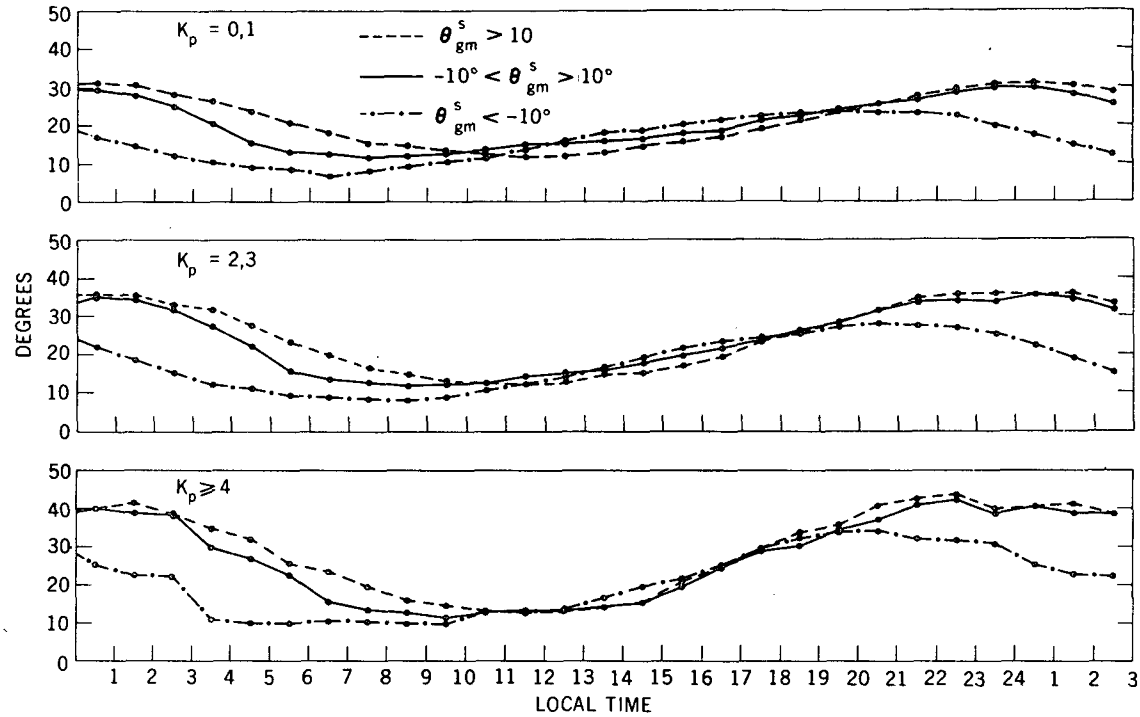
KP IS GREATER THAN 3

LOCAL TIME	NUMBER OF SAMPLES	AVERAGE(GM)	STANDARD DEVIATION
0.5	22	20.7	7.97
1.5	20	21.9	7.33
2.5	16	20.4	7.53
3.5	10	24.4	8.38
4.5	11	23.4	9.12
5.5	24	28.9	9.34
6.5	30	32.3	8.30
7.5	34	29.7	9.67
8.5	37	23.5	9.19
9.5	45	21.2	7.08
10.5	42	17.8	6.21
11.5	47	14.4	6.02
12.5	46	10.4	5.43
13.5	34	7.8	5.56
14.5	44	6.3	4.66
15.5	50	6.0	4.38
16.5	47	6.4	4.66
17.5	50	7.7	5.82
18.5	47	10.5	4.66
19.5	45	12.8	5.03
20.5	33	18.3	5.67
21.5	32	24.3	6.08
22.5	35	25.5	5.85
23.5	20	21.7	7.17

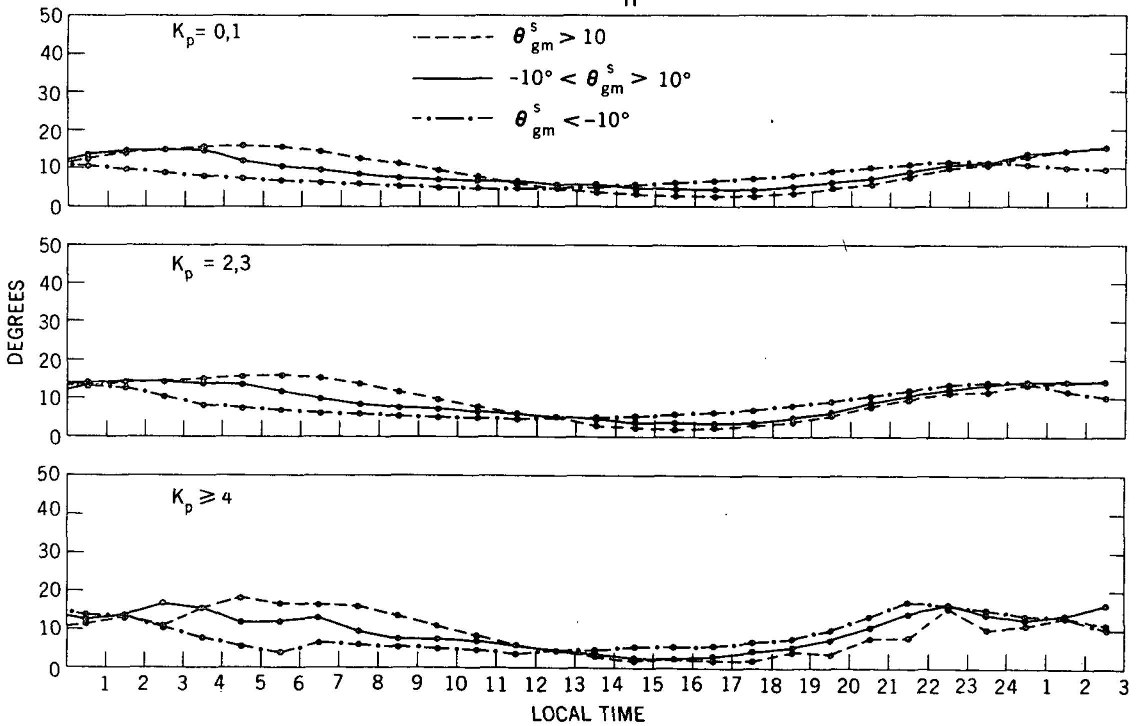
Appendix D

Appendix D
ATS-5 Tilt Angles

$\text{TAN B} = \frac{-V}{H}$



$\text{TAN } \alpha = \frac{D}{H}$



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