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AVERAGE HIGH LATITUDE MAGNETIC FIELD: VARIATION WITH INTERPLANETARY SECTOR AND WITH SEASON

II. COMPARISON OF DISTURBANCE LEVELS AND DISCUSSION OF IONOSPHERIC CURRENTS

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R. LANGEL
NATHAN BROWN

GODDARD SPACE FLIGHT CENTER
GREENBELT, MARYLAND

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R. Langel

Laboratory for Space Physics
NASA Goddard Space Flight Center
Greenbelt, Maryland 20771

Nathan Brown

Physics Department
University of Maryland
College Park, Maryland

GODDARD SPACE FLIGHT CENTER
Greenbelt, Maryland

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ABSTRACT

Average high latitude magnetic field data from northern observatories are examined for three ranges of magnetic disturbance level, Kp = 1- to 1+, 2- to 3+, and ≥ 4-. Except for 0-8^h MLT, 55-78° invariant latitude, during away interplanetary magnetic field sectors, the variations between season and sector have the same characteristics at all Kp ranges. Because the amplitude of sector differences is much larger at sunlit local times than in the midnight sector, it is concluded that the current system of Svalgaard (1973) is not adequate to describe the sector variations in magnetic disturbance, other current systems are discussed briefly. The disturbance morphology and seasonal variation at all Kp levels confirms the results of previous studies which indicate that latitudinally broad current systems, like S_q^p, and non-ionospheric sources are present in addition to latitudinally narrow electrojet currents. Comparison of data between Kp levels indicates that the Harang discontinuity shifts toward earlier MLT with increasing Kp level.

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II. COMPARISON OF DISTURBANCE LEVELS AND DISCUSSION OF IONOSPHERIC CURRENTS

INTRODUCTION

Studies of magnetograms from high latitude observatories have shown that the character of magnetic disturbance changes from one interplanetary sector to another (Svalgaard, 1968; Mansurov, 1969; Mansurov and Mansurova, 1970; Burch, 1973; Campbell and Matsushita, 1973), apparently due to changes in the electric field (Heppner, 1972a). The term sector refers to the direction of the interplanetary magnetic field, toward or away from the sun. Table 1 presents the results from a survey of average magnetic field disturbance at the earth's surface for Kp = 2- to 3+ by Langel (1973a, henceforth referred to as paper I). Precise definitions of auroral belt regions ("negative bay" $\doteq$ 21-8^h MLT, magnetic local time, "positive bay" $\doteq$ 13-22^h MLT, "ambiguous" $\doteq$ 9-13^h MLT) and the polar cap region are found in paper I. In addition to the results of Table 1, paper I pointed out a prominent difference in ΔZ (the vertical component of the disturbance) between the two sectors from about 9-14^h near 80° invariant latitude, ΔZ in this region is predominantly negative for away sectors and predominantly positive for toward sectors, in agreement with the previous studies cited above.

This paper extends the results of paper I to periods of Kp = 1- to 1+ and to periods of Kp $\geq$ 4- and compares results from the three Kp ranges. Data for all three Kp ranges covered the period July 1965 through June 1968. It is shown that, for the most part, the characteristics of the variations between sector and/or season remain unchanged between the various Kp levels. This indicates that such features reflect fundamental changes in magnetospheric or ionospheric configuration between seasons or sectors, independent of magnetic disturbance level.

DATA REDUCTION

As indicated in paper I, data availability varied between observatories. The number of points entering into the averages is less for the present study than for paper I and, in some cases, is very small. Averages with less than 5 points are not utilized, and averages with less than 10 points are only utilized when they do not differ widely from surrounding values. In most cases, for Kp = 1-

Table 1

Summary of Results from Average Magnetic Disturbance Patterns,
Kp: 2- to 3+

General Features

(1) The Harang discontinuity is present during all seasons and sectors.

(2) A significant Y component exists in both positive and negative bay regions.

(3) $|\Delta Z|$ is much larger to the north of the auroral belt than to the south in both the positive and negative bay regions.

Differences between seasons

(1) In the negative bay region, $|\Delta H|$ and $|\Delta Z|$ are greatest in summer and least in winter during toward sectors. During away sectors, $|\Delta H|$ is less in summar and equinox (ΔH in summer $\doteq$ ΔH in equinox) than in winter while $|\Delta Z|$ is greater in winter and summer (ΔZ in summer $\doteq$ ΔZ in winter) than in equinox.

(2) In all other regions both $|\Delta H|$ and $|\Delta Z|$ are greatest in summer and least in winter.

(3) Seasonal differences are larger in sunlit local times than in darkness.

Differences between sectors

(1) In the negative bay region both $|\Delta H|$ and $|\Delta Z|$ are greater in toward sectors than in away sectors during summer and vice versa during winter.

(2) In the positive bay region both $|\Delta H|$ and $|\Delta Z|$ are greater during toward sectors than during away sectors at all local times and during each season.

(3) Angular and magnitude differences show that the polar cap boundary is further north near dawn and further south from $10\text{-}22^h$ during toward sectors as compared with away sectors.

to 1+, more than 15 points entered each average, and in some cases more than 30 points were available. For Kp ≥ 4-, 8-13 points entered most of the averages.

As in paper I, magnetic variations are studied between seasons and interplanetary sectors for a fixed level of magnetic disturbance based on Kp, namely: Kp = 1- to 1+ and Kp ≥ 4-. Table 2 shows the average Ap for each season and sector. Within the range Kp = 1- to 1+, Ap is nearly equal for all data divisions, indicating that comparisons between these data divisions are not biased by the data selection. Ap for the range Kp ≥ 4- shows enough variation between data divisions that some caution in comparisons between data divisions is advised. As eleven of the twelve stations used in deriving Kp are in the northern hemisphere, and our analysis is for the northern hemisphere, seasonal bias due to domination of Kp by southern stations in one season and northern stations in another season is avoided. The reader is referred to paper I for further details regarding the selection and reduction of the data.

Table 2

Average Ap for the Various Data Divisions

	Away Sectors	Toward Sectors
A. Kp = 1- to 1+		
Summer	3.96	4.10
Equinox	3.85	4.01
Winter	4.00	4.00
B. Kp ≥ 4-		
Summer	34.32	34.96
Equinox	36.60	34.01
Winter	33.32	38.20

DESCRIPTION OF THE DATA

Figures 1-3 (Kp = 1- to 1+) and 5-7 (Kp ≥ 4-) show the average horizontal disturbance vectors for the three seasons. Season, in these studies, is defined relative to the dipole latitude of the sub-solar point, θ_{sun}, as follows:

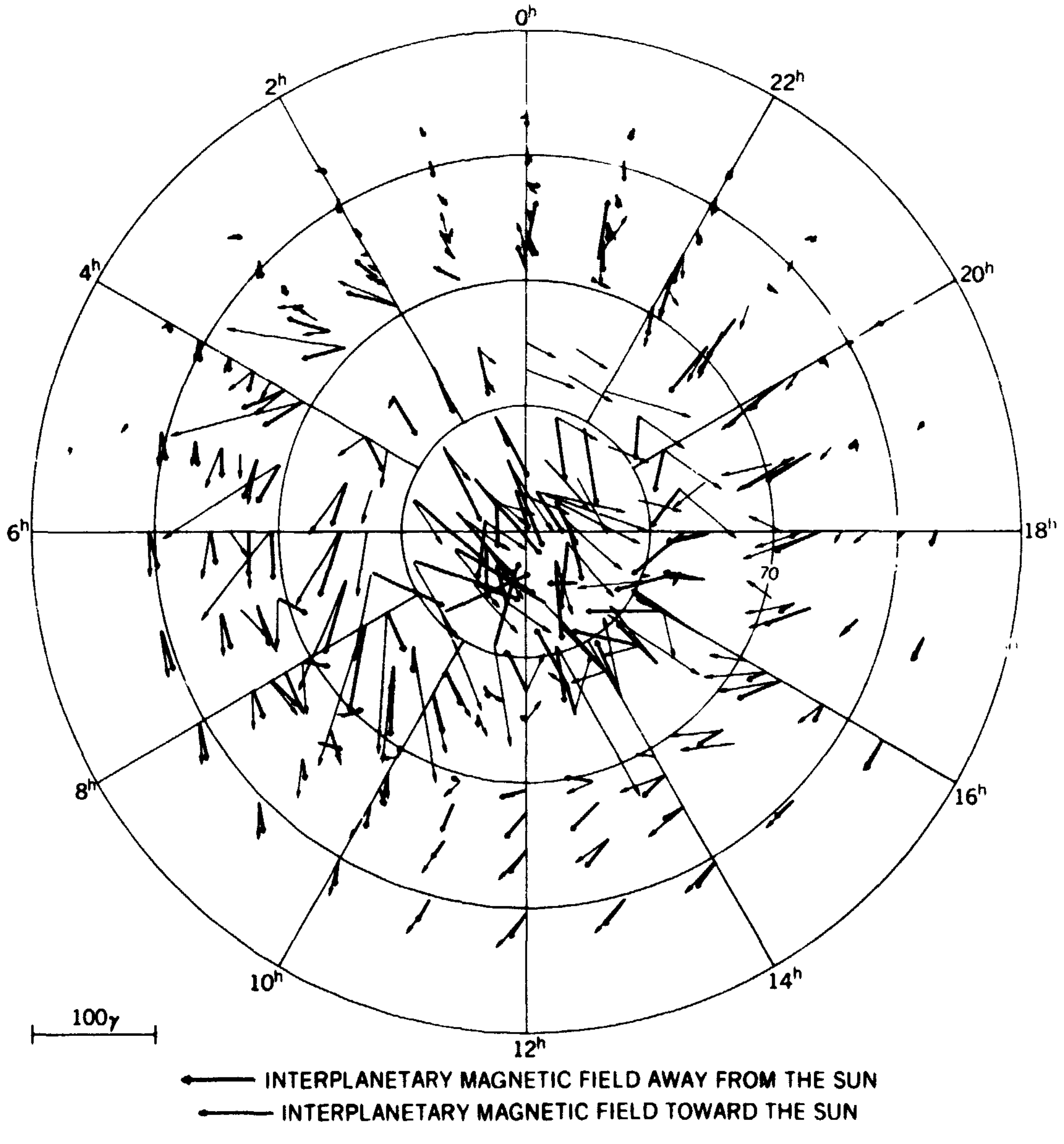

Figure 1. Average horizontal disturbance vectors at the earth's surface, Summer season, Kp = 1- to 1+, 1965-1968. Coordinates are magnetic local time and invariant latitude.

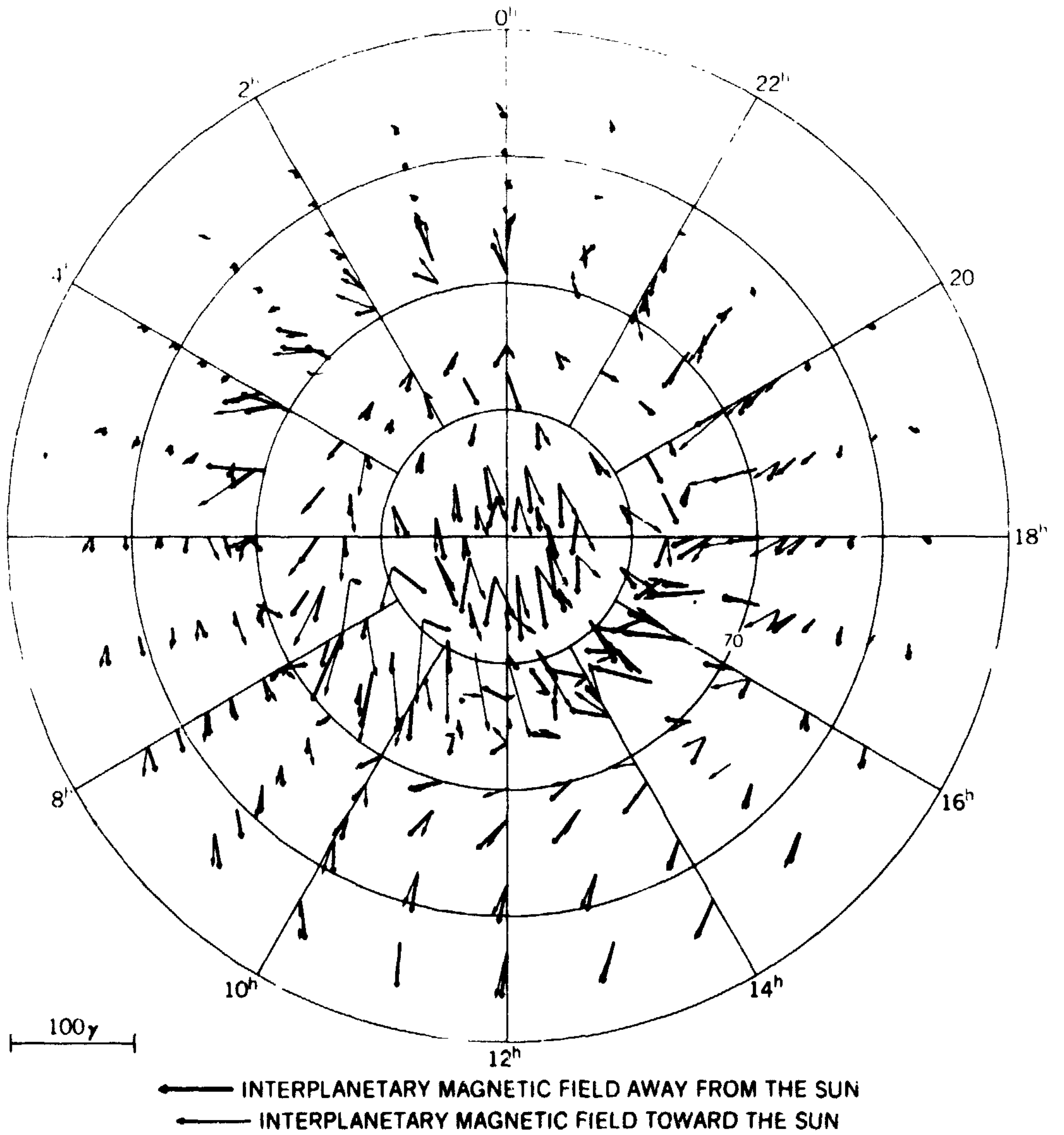

Figure 2. Same as Figure 1 Except Equinox Season

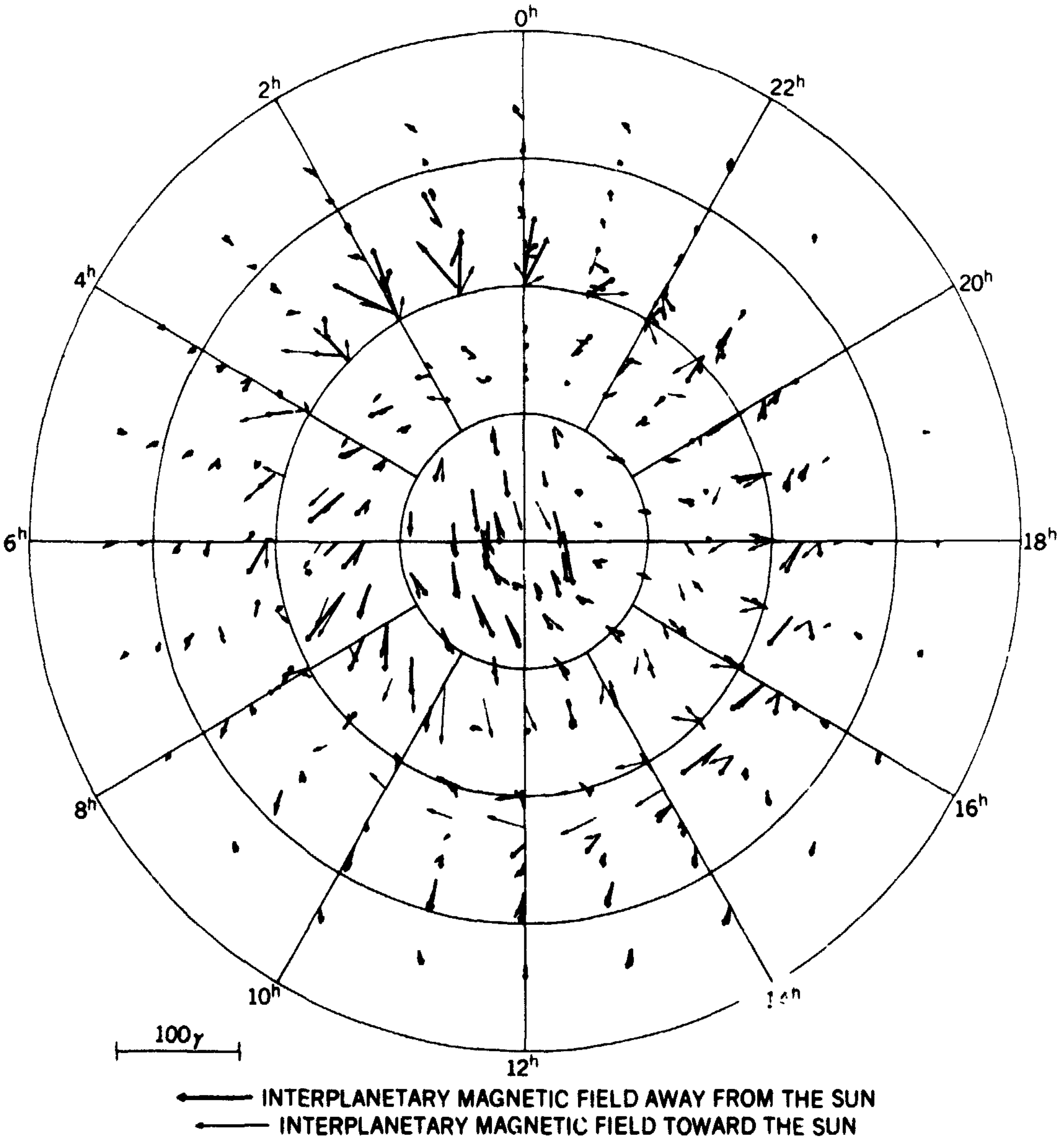

Figure 3. Same as Figure 1 Except Winter Season

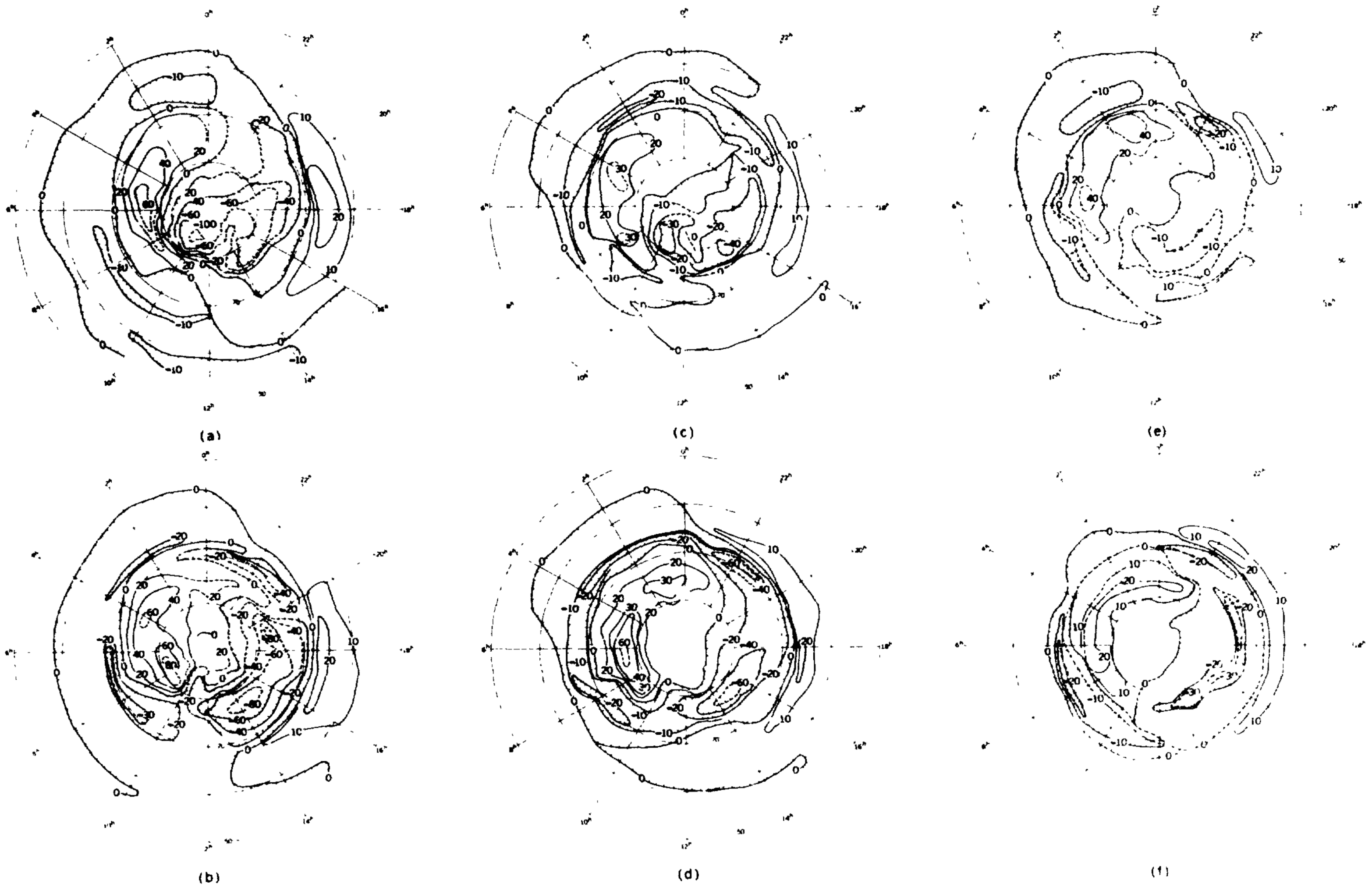

Figure 4. Contours of $\Delta Z\,(\gamma)$ at the ea surface. Data from 1965 to 1968 for Kp = 1- to 1+. Coordinates are magnetic local time and invariant latitude. (a) and (b) are for summer, (c) and (d) are for equinox, and (e) and (f) are for winter. (a), (c), and (e) are for away sectors and (b), (d), and (f) are for toward sectors. Dashed lines indicate regions of sparse data; the position and level of these contours are of greater uncertainty than for the solid lines.

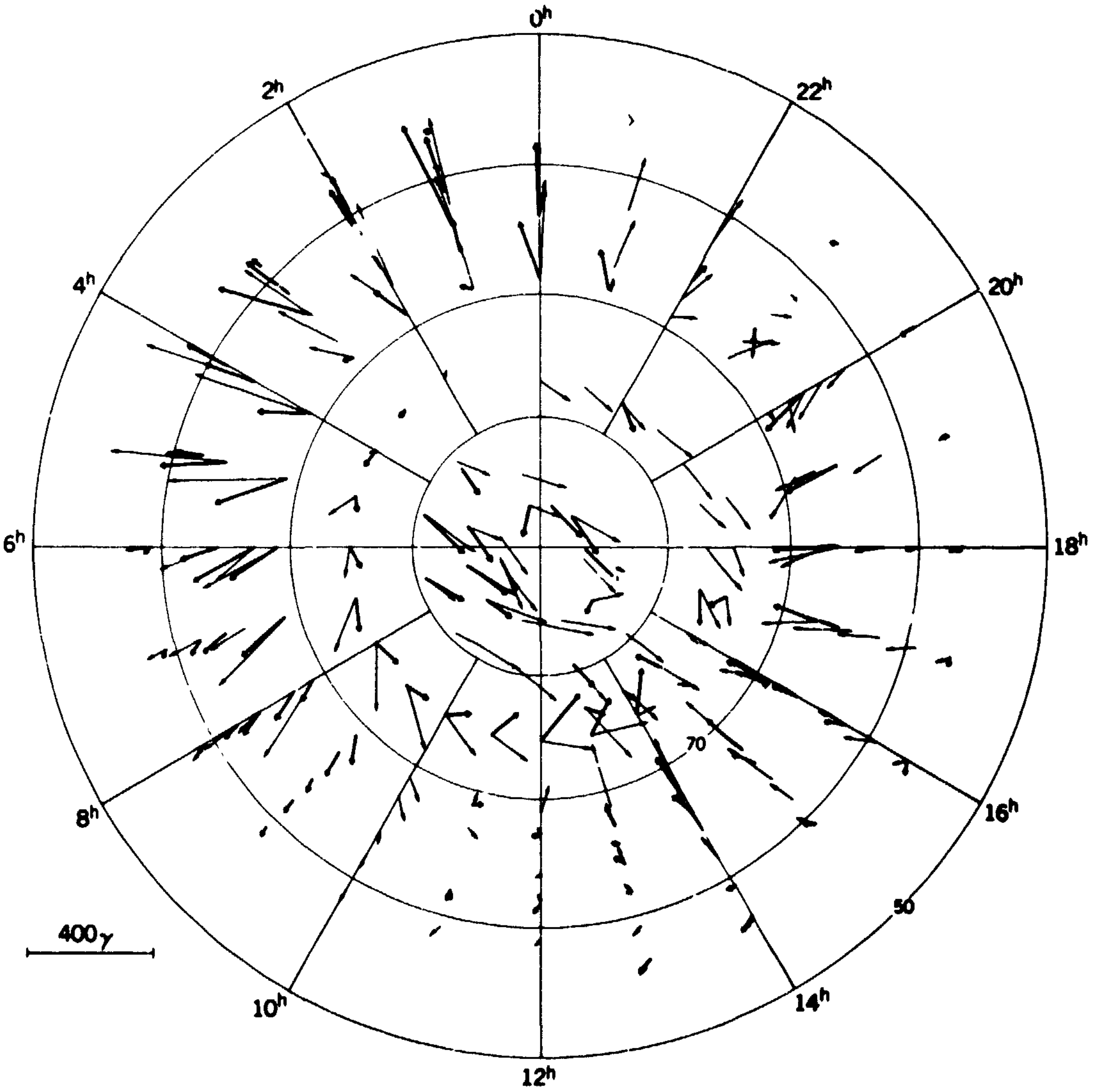

Figure 5. Same as Figure 1 Except Kp $\geq$ 4- (Summer)

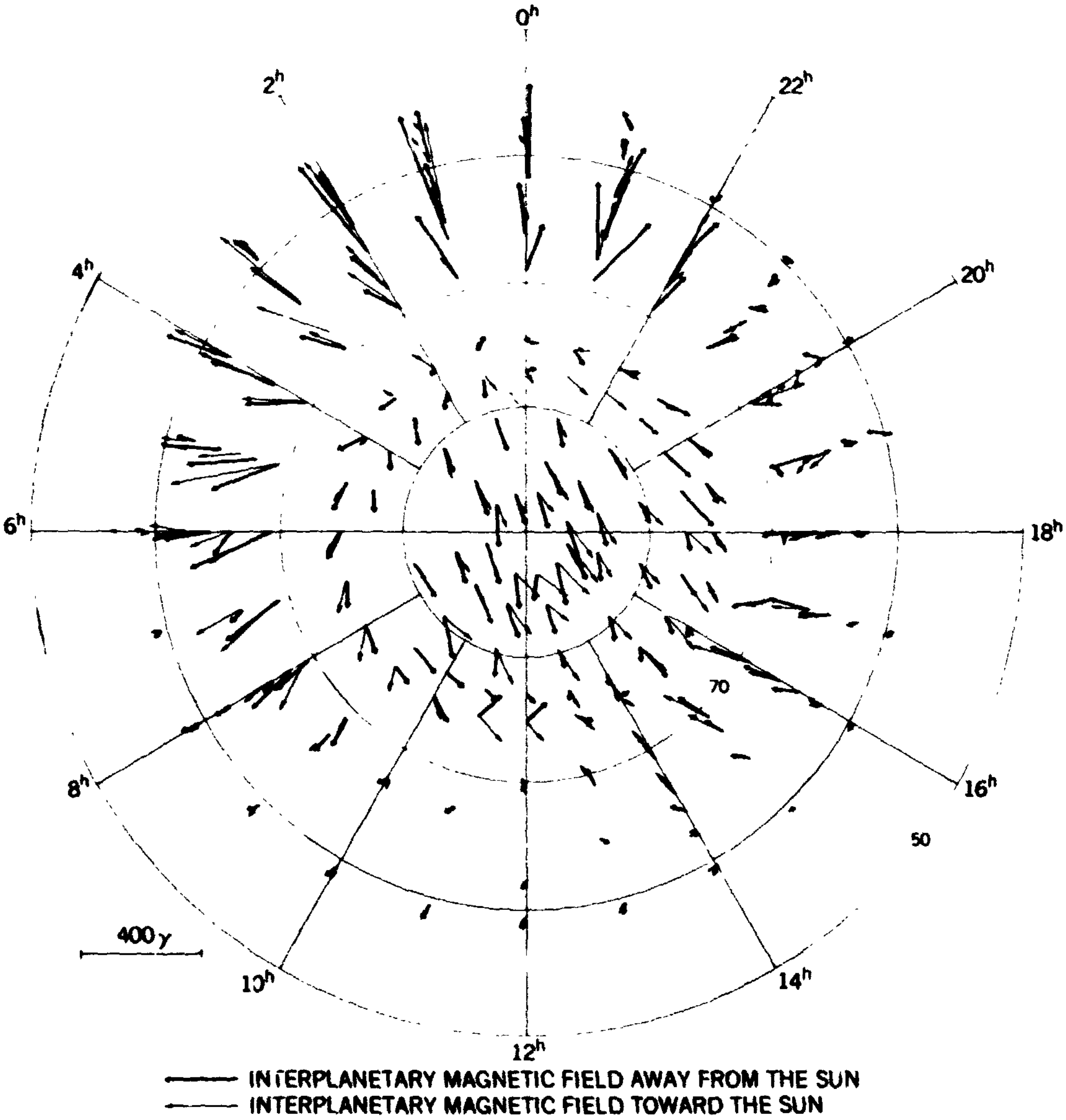

Figure 6. Same as Figure 2 Except Kp ≥ 4- (Equinox)

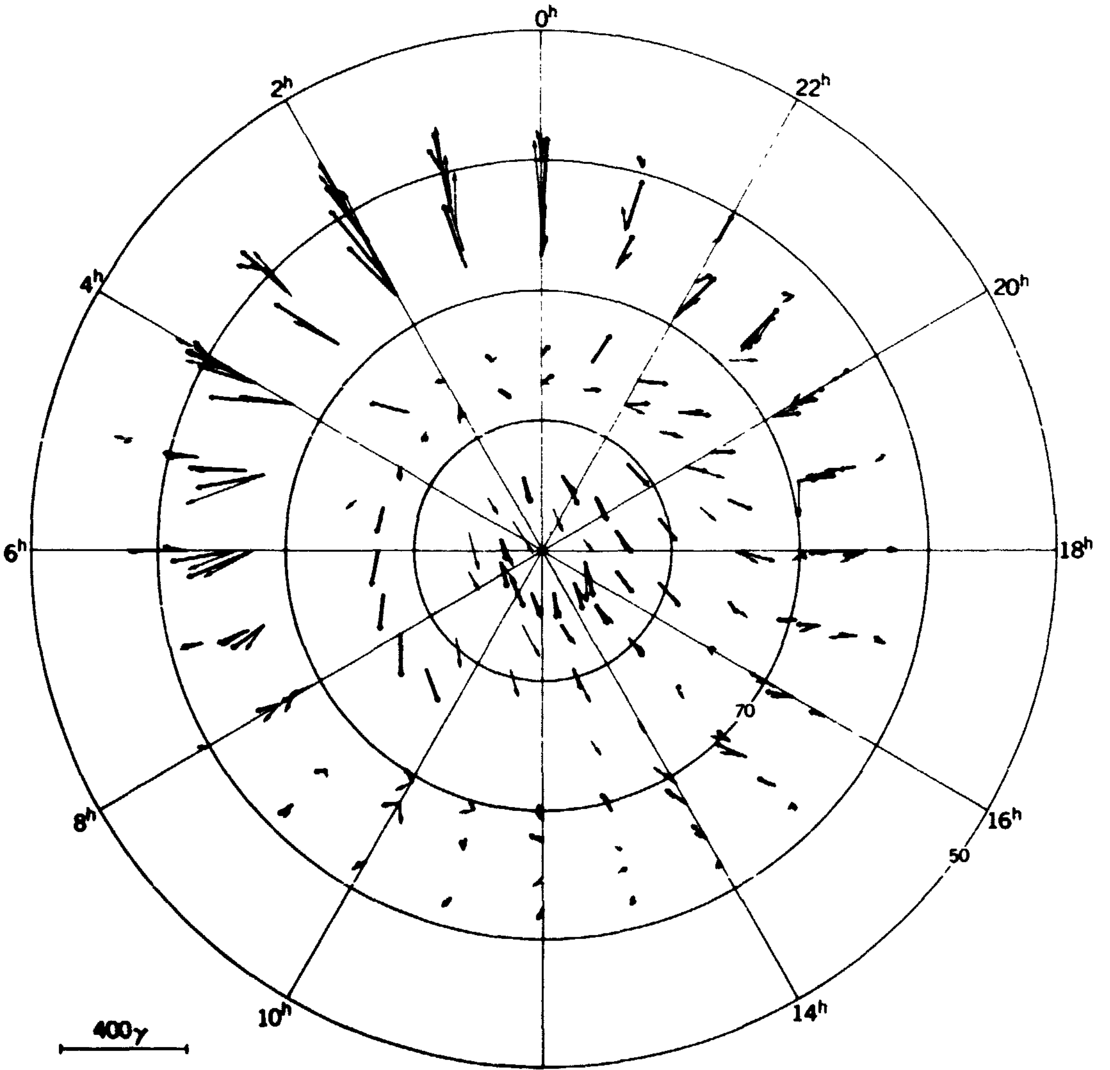

Figure 7. Same as Figure 3 Except Kp ≥ 4- (Winter)

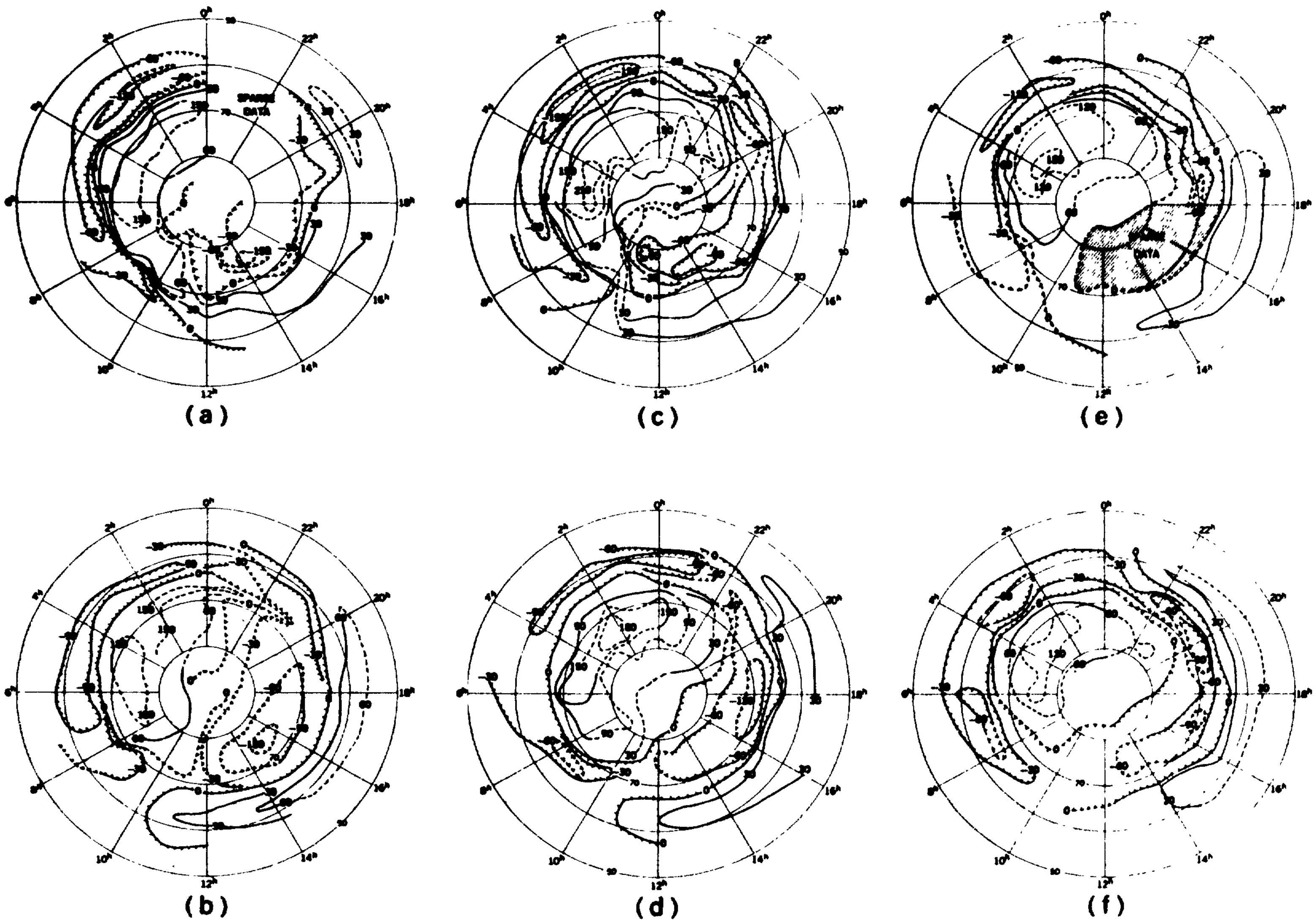

Figure 8. Same as Figure 4 Except Kp $\geq$ 4-

$|\theta_{sun}| < 10°$ is equinox, $\theta_{sun} > 10°$ is (northern) summer, and $\theta_{sun} < -10°$ is (northern) winter.

Vectors from both sectors are drawn on each figure to facilitate comparison. Corresponding contours of ΔZ are shown in Figures 4 and 8. Invariant latitude and magnetic local time are used throughout this paper. Tables 3 and 4 contain a summary of the maximum amplitude of horizontal disturbance at particular magnetic local times within the various regions and a comparison of these amplitudes between seasons. An asterisk indicates a sparsity of data points. For Kp = 1- to 1+, the statistics for ΔH comparisons near 0–2^h in the negative bay region are poor, so the results in this region should be viewed with caution. For Kp $\geq$ 4- the statistics are marginal in several regions so only trends will be discussed. Amplitude differences between the various data divisions occur at most local times although, in general, these differences are greatest near noon and least near midnight. Because of the great scatter in the data entering into each average and the occurrence of regions of sparse data, amplitude differences will be discussed only in terms of trends.

At latitudes below about 68° during sunlit local times, the horizontal vectors for Kp = 1- to 1+ clearly show the effects of the Sq current system. This is also true for the Kp = 2- to 3+ and Kp $\geq$ 4- data but is more apparent at Kp = 1- to 1+ because the auroral belt and polar cap disturbance is smaller.

As noted in the introduction, most of the data features for Kp = 1- to 1+ and Kp $\geq$ 4- are the same as those found in paper I for Kp = 2- to 3+. Of the results in Table 1, all of the general features, items (2) and (3) under "Differences between seasons", and all of the "Differences between sectors" are the same for all disturbance levels. In paper I, a separate negative ΔZ peak near 11^h and 81°, near the dayside cusp location, was noted for away sectors during summer. A localized dayside current was postulated to account for this peak in ΔZ, and for $\Delta \vec{H}$ in this region. For Kp = 1- to 1+ this separate peak is apparent at both summer and equinox, and for Kp $\geq$ 4- it is apparent for equinox (data for part of this region are not available for summer).

Regarding item (1) under differences between seasons in Table 1, the results for toward sectors for Kp = 1- to 1+ and Kp $\geq$ 4- are the same as in Table 1. For away sectors, however, the seasonal differences in away sectors are somewhat confused. Some differences between the midnight and dawn regions are apparent, so these regions are considered separately. Table 5 summarizes the results. For the two lower Kp ranges there is a tendency for disturbance levels near 0–3^h to be greatest in winter and least in summer and a tendency for disturbance levels near 5–7^h to be greatest in summer and least in equinox. (Note that ΔZ and $\Delta \vec{H}$ do not always vary in the same manner.) For Kp $\geq$ 4-, the

Table 3

Comparison of Horizontal Disturbance as Function of Season and Interplanetary Sector; Kp = 1- to 1+

		Negative Bay Region							Positive Bay Region					Ambiguous Region				Polar Cap Region					
Geomagnetic Local Time		1^h	2^h	3^h	4^h	5^h	6^h	7^h	15^h	16^h	17^h	18^h	20^h	8^h	9^h	10^h	11^h	1^h	5^h	9^h	13^h	17^h	21^h
A. Disturbance Amplitude (gammas)																							
Season	**Sector**																						
Equinox	**Away**	30	30	32	40	86	24	28	44	62	40	30	15	60	44	24	8	36	32	38	48	38	32
Equinox	**Toward**	36	38	45*	58*	54	40	54	50	50	50	54	54	60	64	65	64	34	48	36	34	34	35
Summer	**Away**	20*	42*	36	36	34	54	60	46	60	52*	54*	36*	70	56	30*	—	50	68	38*	—	40	38*
Summer	**Toward**	26*	50*	98*	112	110	88	94	60	50	52	66	62	116	110	48*	80	68	54	60	66	58	50
Winter	**Away**	46	56*	28*	28*	36	34	46	10*	8*	17*	20*	34	36	28*	114*	15*	20	25	10*	14	20	25
Winter	**Toward**	48	28	48	50	34	36	46	22	22	26	25	36	30	42	46	30	14	22	16	18	14	28
B. Ratio of Seasons																							
Summer/Winter																							
Away		.43*	.75*	1.3*	1.3*	.94	1.6	1.3	4.6*	7.5*	3.0*	2.7*	1.05	1.9	2.0*	2.1*	—	2.5	2.7	3.8*	—	2.0	1.5*
Toward		.54*	1.8*	2.0*	2.2	3.2	2.4	2.0	2.7	2.3	2.0	2.6	1.7	3.9	2.6	1.04*	2.7	4.8	2.4	3.8	3.7	4.1	1.8
Equinox/Winter																							
Away		.65	.53*	1.1*	1.4	2.4	.7	.61	4.4*	7.8*	2.4*	1.5*	.44	1.7	1.6*	1.7	.53*	1.8	1.3	3.8*	3.4	1.9	1.3
Toward		.75	1.4	.94*	1.2	1.6	1.1	1.2	2.3	2.3	1.9	2.2	1.5	2.0	1.5	1.4	2.1	2.4	2.2	2.3	1.9	2.4	1.3
Summer/Equinox																							
Away		.67	1.4*	1.1	.9	.4	2.3	2.1	1.0	1.0	1.3	1.8	2.4	1.2	1.3	1.3	—	1.4	2.1	1.0*	—	1.0	1.2
Toward		.72*	1.3*	2.2*	1.9*	2.0	2.2	1.7	1.2	1.0	1.0	1.2	1.1	1.9	1.7	.74*	1.3	2.0	1.1	1.7	1.9	1.7	1.4

*Indicates sparcity of data points.

Table 4

Comparison of Horizontal Disturbance as Function of Season and Interplanetary Sector; Kp ≥ 4-

		Negative Bay Region							Positive Bay Region					Ambiguous Region				Polar Cap Region					
Geomagnetic Local Time		1^h	2^h	3^h	4^h	5^h	6^h	7^h	15^h	16^h	17^h	18^h	20^h	8^h	9^h	10^h	11^h	1^h	5^h	9^h	13^h	17^h	21^h
A. Disturbance Amplitude (gammas)																							
Season	**Sector**																						
Equinox	**Away**	380	360	240	240	225	280*	210*	120	135	140	120	60	80	130	90	90	100	150	90	100	120	110
Equinox	**Toward**	320	260	325	200	360*	230*	250*	160	190	140	110	90	110*	80*	80*	120•	90	85*	90	120	160•	120
Summer	**Away**	300*	250*	300*	180	230	220	190*	150*	180*	200*	220*	160*	90*	80*	—	—	100*	120	100*	100*	—	130*
Summer	**Toward**	280*	260	250	380	360	270	300*	200*	170	190	240	170*	200*	200*	160*	140•	110	150	190	175*	150•	170
Winter	**Away**	220	290	240	260	210	225	120	100*	80*	70	70	20	130*	110*	—	—	80	70	90	85	110	80
Winter	**Toward**	170	165	170	230	250*	190	85	80	70	80	100	80	—	—	—	—	80	90	60	80	120•	80*
B. Ratio of Seasons																							
Summer/Winter																							
Away		1.4*	.86*	1.2*	.7	1.1	.98	1.6*	1.5*	2.2*	2.8*	3.1*	8.0*	.69*	.73*	—	—	1.2*	1.7	1.1*	1.2*	—	1.6*
Toward		1.6*	1.6	1.5	1.6	1.4*	1.4	3.5*	2.5*	2.4	2.4	2.4	2.1*	—	—	—	—	1.4	1.7	3.2	2.2*	1.2*	2.1*
Equinox/Winter																							
Away		1.7	1.2	1.0	.92	1.1	1.2*	1.7*	1.2*	1.7*	2.0	1.7	3.0	.61*	1.2*	—	—	1.2	2.1	1.0	1.2	1.1	1.4
Toward		1.9	1.6	1.9	.87	1.4*	1.2*	2.9*	2.0	2.7	1.7	1.1	1.1	—	—	—	—	1.1	.94*	1.5	1.5	1.3*	1.5•
Summer/Equinox																							
Away		.79*	.69*	1.2*	.75	1.0	.79•	.90*	1.2*	1.3*	1.4*	1.8*	2.7*	1.1*	.61*	—	—	1.0*	.8	1.1*	1.0*	—	1.2*
Toward		.87*	1.0	.77	1.9	1.0*	1.2*	1.2*	1.2*	.89	1.4	2.2	1.9*	1.8*	2.5*	2.0•	1.2•	1.2	1.8*	2.1	1.5*	.94•	1.4

*Indicates sparcity of data points.

Table 5

Seasonal Variation in the Negative Bay Region During Away Sectors

S, E, and W Denote $\lvert\Delta B\rvert$ for Summer, Equinox and Winter Respectively		
Kp Range	ΔZ	ΔH
$0\text{-}3^h$ Magnetic Local Time		
1- to 1+	W > S* ≐ E	W > S > E
2- to 3+	W ≐ E > S	W > S ≐ E
$\geq$ 4-	E* ≐ S* > W*	E* > S* ≐ W*
$5\text{-}7^h$ Magnetic Local Time		
1- to 1+	S > W* > E*	S > W ≐ E
2- to 3+	S ≐ W > E	W* > S > E
$\geq$ 4-	E* > S* > W	S* ≐ E* ≐ W

*Indicates a region of some uncertainty.

tendency is for equinox to be most disturbed and winter least disturbed. Reasons for these differences between disturbance levels are not apparent.

At $20\text{-}22^h$, $|\Delta Z|$ in the positive bay region for Kp = 1- to 1+ shows a peak which is separate from the main peak near $14\text{-}15^h$ in all seasons, except for away sectors in summer. Such a feature was also noted in the Kp = 2- to 3+ data and can be seen in winter, toward sectors, in the Kp $\geq$ 4- data. The seasonal variation of $|\Delta Z|$ in this region differs from that at $13\text{-}20^h$ MLT in that at $20\text{-}22^h$ $|\Delta Z|$ is greatest in equinox and least in winter (Kp = 1- to 1+) or summer (Kp $\geq$ 4-, toward sector), whereas at $13\text{-}20^h$ $|\Delta Z|$ is greatest in summer and least in winter. This difference in $|\Delta Z|$ variation with season from that noted at earlier MLT is also present in the Kp = 2- to 3+ data of paper I, but was not considered statistically significant because of sparsity of data and poor station distribution. These same shortcomings are also present in the present data but because the feature is present to some extent at all disturbance levels it is possible that it is real. A separate peak in ΔH is not discernible in our data for this region.

IONOSPHERIC CURRENTS AND EQUIVALENT CURRENTS

Several attempts have been made to derive ionospheric currents which could cause the magnetic variations in the polar cap, some of which are reviewed by Sumaruk and Feldstein (1973). Caution is needed when comparing these current systems as two methods of analysis are utilized. Svalgaard (1973), for example, divides the observatory data into three classes: all days, days when the interplanetary field is clearly toward the sun, and days when the interplanetary magnetic field is clearly away from the sun. Data from the first class gives a regular, nearly sinusoidal, diurnal variation and is assumed by Svalgaard to be a real phenomena associated with activity outside the central polar cap. Variations associated with sector polarity are assumed to be superposed on this simple diurnal variation. Other analyses (the present paper; paper I; Sumaruk and Feldstein, 1973) do not assume such a superposition but rather analyze the entire magnetic variation for each sector separately. Current systems derived by the two methods are considerably different. The situation is rendered still more confusing when some authors do not specify which approach they have used in arriving at current patterns.

The magnetic variations determined by Sumaruk and Feldstein (1973) are very much like those found in paper I for summer. They derived a more detailed current system which seems consistent with the data of the present paper and of paper I. The method they used to derive the current system is not given. From an analysis of both satellite and surface data, Langel (1973c) concluded that the source of the magnetic disturbance which varies between sectors is in the ionosphere. His sketch of the probable current pattern is like that given in Figure 6 of paper I on the basis of surface data only. This pattern has many features in common with the currents drawn by Sumaruk and Feldstein but omits the condensation of current into spatially narrow jet-type currents contained in their analysis. In the present authors opinion, it is important to realize that all such current systems are equivalent currents which have not been shown to be real and that, even with satellite data, the presently available data does not permit a precise delineation of the real currents.

Various workers (e.g. Mansurov and Mansurova, 1971) have proposed different forms of zonal currents to account for variations between sectors. Perhaps the most well developed of these is that of Svalgaard (1973). Although not emphasized, the derivation of Figure 7 in paper I is equivalent to the procedure of Svalgaard. Further, comparison of Figure 7 and Table 2 of Svalgaard with Figure 7 of paper I indicates that the major features of the variations at Resolute Bay and Mould Bay are the same in the two analyses. Svalgaard utilizes his averages at 1800 UT to derive a circulating ionospheric Hall current which could cause the magnetic variations at that UT. Upon comparison with the data from the appropriate MLT in Figure 7 of paper I, it is found that the relative magnitudes of the disturbance at the stations Alert, Resolute Bay, Mould Bay and Godhavn are in reasonable agreement between the two studies. However, the current system proposed by Svalgaard cannot account for the overall average pattern found in paper I. Two possibilities exist, either the average pattern of paper I is not representative of the disturbance at any particular UT or the amount of data used by Svalgaard is not sufficient to define a current system. Only five stations at one UT entered into Svalgaard's current system derivation. Further, Svalgaard's Figure 7 indicates that, except at Resolute Bay during toward sectors, the peak of the horizontal disturbance is at a later UT than 1800 UT, in agreement with the results of paper I. For these reasons it is believed that the amount of data used by Svalgaard is insufficient to construct a definitive current system.

Both in paper I and in the present paper the notions of ionospheric current systems and of the superposition of a current system associated with sector polarity upon an average current system have not been emphasized because evidence for the physical reality of these notions is lacking. This is particularly true in view of the results of Heppner et al. (1971) who measured the electric fields in the dark portion of the polar cap, near twilight, by barium releases. It was found that the simultaneous surface magnetic field disturbance could not have resulted from any combination of overhead ionospheric Hall and Pedersen currents.

DISCUSSION

The survey of average high latitude magnetic disturbance for periods of slight disturbance and periods of large disturbance presented in Figures 1-8 suffers from the same shortcomings as the survey for moderately disturbed conditions presented in paper I. The available distribution of magnetic stations is not adequate for a comprehensive analysis, and the average pattern is not necessarily representative of an "instantaneous" disturbance pattern.

Most of the discussion in paper I applies to the present data and will not be repeated. That most seasonal and sector differences remain unchanged between Kp ranges indicates that such features reflect fundamental changes in magnetospheric or ionospheric configuration between seasons or sectors, independent of magnetic disturbance level.

The seasonal variation in the positive bay region (most disturbed in summer, least in winter) was first noted by Stagg (1935) and later investigated by Meng and Akosofu (1968). The present study shows, for all Kp ranges, that the greatest seasonal differences in the average disturbance occur at earlier MLT, a feature also noted by Meng and Akasofu (1968) for data from individual events. Noting that the seasonal change in S_q^p is very much like the seasonal change in positive bay intensity found by Meng and Akasofu. Kokubun (1971) suggested that the eastward current causing positive bays is more like S_q^p than like an electrojet, i.e. broad in latitudinal extent rather than a latitudinally narrow jet, and with conductivity controlled by solar radiation rather than by particle precipitation. This is essentially the same conclusion drawn by Langel (1973b) for sunlit local times.

A general feature of ΔZ for both the present data and for Kp = 2- to 3+ is that it is much larger to the north of the auroral belt than to the south in both the positive and negative bay regions. Langel (1973b) noted a similar feature in total magnetic field variations (ΔB) on the OGO 2, 4, and 6 (POGO) spacecraft. The interpretation for the positive bay region (Langel, 1973b) is that both ΔZ and ΔB from $13-18^h$ MLT are due to a latitudinally broad ionospheric current rather than a latitudinally narrow electrojet current. For the negative bay region it is claimed that the large poleward ΔZ and ΔB are partly caused by a non-ionospheric source of positive ΔZ. ΔB at the POGO has also been studied as a function of sector for Kp = 2- to 3+, including a comparison with surface ΔZ (Langel, 1973c). It was concluded that the ΔZ and ΔB which varies with sector has an ionospheric source. This conclusion is supported by the present study. In particular, seasonal differences in <u>all</u> regions are larger in sunlit local times than in darkness, implying that the amplitude of the magnetic variations is enhanced at times when the ionospheric conductivity due to solar radiation is increased. The influence of solar local time on high latitude magnetic disturbance is discussed by Svalgaard and Langel (manuscript in preparation).

Comparison of both $\Delta\vec{H}$ and ΔZ between Kp = 1- to 1+ and Kp $\geq$ 4-, for the same season and sector, clearly indicates that the equatorward boundary of both the positive and negative bay regions is shifted 5-8° equatorward for the higher Kp range. In those regions where the observatory coverage is adequate, most notably from $14-18^h$, the polar cap-auroral belt boundary undergoes a similar shift. These shifts are expected because the auroral belt is known to expand equatorward during periods of larger disturbance. Heppner (1972b) has pointed out that, near the Harang discontinuity, the negative bay magnitude is generally considerably greater than the positive bay magnitude and that this results in a bias in averaged data such that the averaged data will indicate that the discontinuity is at lower latitudes and earlier MLT than is seen in most individual disturbances. Nevertheless, it is possible to conclude from examination of the $\Delta\vec{H}$ averages that the MLT of the discontinuity shifts to earlier MLT as Kp increases. This is also apparent in Harang's original figures (Harang, 1946). A change in the morphology of the Harang discontinuity implies a change in the magnetospheric convection pattern. From the data presented in this paper it is not possible to give details regarding changes in convection. Low altitude electric field measurements from the OGO-6 spacecraft also show the MLT shifts and a detailed study of the discontinuity location is in preparation (Maynard, 1973, manuscript in preparation).

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