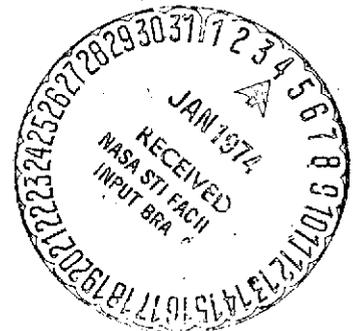


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VARIATION WITH INTERPLANETARY SECTOR OF THE TOTAL MAGNETIC FIELD MEASURED AT THE OGO-2, 4, AND 6, SATELLITES

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GODDARD SPACE FLIGHT CENTER
GREENBELT, MARYLAND

Variation with Interplanetary Sector of the Total Magnetic Field
Measured at the OGO 2, 4, and 6 Satellites

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i

Abstract

Variations in the scalar magnetic field (ΔB) from the polar orbiting OGO 2, 4, and 6 spacecraft are examined as a function of altitude for times when the interplanetary magnetic field is toward the sun and for times when the interplanetary magnetic field is away from the sun. In both cases the total field variations form a region of positive ΔB between about 22^h and 10^h MLT and a region of negative ΔB between about 10^h and 22^h MLT. This morphology is basically the same as that found when all data, irrespective of interplanetary magnetic sector, are averaged together (Langel, 1973a, b). Differences in ΔB occur, both between sectors and between seasons, which are similar in nature to variations in the surface ΔZ found by Langel (1973c). The altitude variation of ΔB at sunlit local times, together with ΔZ at the earth's surface, demonstrates that the ΔZ and ΔB which varies with sector has an ionospheric source. Langel (1973b) showed that the positive ΔB region in the dark portion of the hemisphere is due to at least two sources, the westward electrojet and an unidentified non-ionospheric source(s). Comparison of magnetic variations between season/sector at the surface and at the satellite, in the dark portion of the hemisphere, indicates that these variations are caused by variations in the latitudinally narrow electrojet currents and not by variations in the non-ionospheric source of ΔB .

INTRODUCTION

A correlation between some dynamical processes of the magnetosphere and the north-south component of the interplanetary magnetic field is predicted by models based on Dungey's (1963) field line merging theory, and has been the subject of intensive experimental investigation. Not predicted, however, was the change in character of dayside magnetic disturbance at high latitudes, depending on the interplanetary magnetic field sector (toward or away from the sun), discovered independently by Svalgaard (1968) and Mansurov (1969). It has been shown that the Y component of the interplanetary field (B_Y) is the important factor in the azimuthal sector correlation (Friis-Christensen et al., 1972); B_Y is typically > 0 during away sectors and < 0 during toward sectors. Recent field line merging models (Atkinson, 1972; Jorgensen et al., 1972; Russell, 1972; Russell and Atkinson, 1973) have attempted to describe the response of the magnetosphere to field line merging for all possible directions of interplanetary field, and have succeeded in accounting for some of the observed effects. In addition to changes in magnetic disturbance between sectors, Heppner (1972a, b) has found changes in the characteristics of electric field data from OGO-6 between sectors and has noted that there are discrepancies between the OGO-6 electric field observations and the simple predictions based on field line merging models, even the latest refinements of those models (Heppner, 1973).

Ionospheric current systems have been proposed (Berthelier, 1972; Svalgaard, 1973; Campbell and Matsushita, 1973) to account for the magnetic variations between sectors but such current systems have been inferred from surface data only. It is the purpose of this paper to examine the variations

between sectors in the magnetic field at the POGO (OGO 2, 4, and 6) satellites, which were in the altitude range 400 to 1410 km, above the ionosphere. Field variations between sectors will be delineated and compared to surface data to show that ionospheric sources are indeed responsible for those magnetic disturbances which show variations between sectors.

Previous Analysis of Satellite and Surface Disturbance. The basic morphology of the variation or disturbance in total field at the POGO (OGO 2, 4, and 6) satellites, independent of interplanetary sector, and the interpretation of that morphology in terms of sources has been previously presented by Langel (1973a, b, henceforth referred to as papers I and II). Only the total field is measured in these experiments, and the quantity analyzed is $\Delta B = |\vec{B}| - |\vec{M}|$ where $|\vec{B}|$ ($= B$) is the quantity measured, and \vec{M} is a spherical harmonic analysis (details are in paper I) of the quiet time field. Paper I describes the average characteristics of ΔB as a function of season, Kp, and altitude in terms of contours of average ΔB . Figure 1 illustrates the basic pattern of ΔB , which is positive from about 22^h to 10^h MLT (magnetic local time) and negative from about 10^h to 20^h MLT. This pattern is found at all seasons, Kp levels, and altitudes, and the two regions are denoted the positive ΔB region and the negative ΔB region respectively. In paper II it was shown that neither region can be accounted for in terms of latitudinally narrow electrojet currents as the principal source. Figure 2 summarizes the proposed source current distribution, omitting continuity in some regions where it is believed that field aligned currents may be important because conductivity gradients are expected to exceed electric field gradients (see, e.g., Heppner et al., 1971). A

latitudinally broad current in the sunlit region between about 10^h and 19 or 20^h MLT produces both the negative ΔB region and positive bays in the auroral belt. The latitudinally narrow westward electrojet from about 22^h to 8^h contributes some of the positive ΔB , particularly at low altitude, but most of the positive ΔB is shown to be extra-ionospheric in origin. The latitudinally narrow eastward electrojet is only detected in low altitude passes between 18^h and 22^h MLT.

Because, at high latitudes, ΔB corresponds most closely with ΔZ in the component data, the satellite ΔB will be compared to the surface ΔZ . In particular, Langel (1973c, henceforth referred to as paper III) and Langel and Brown (manuscript in preparation) have studied the variations in averaged surface data as a function of interplanetary magnetic sector and geomagnetic season. The time period studied in paper III was July 1965 through June 1968, which is close to the October 1965 through November 1969 period of the POGO data considered in the present paper so that surface-satellite comparisons are meaningful. Patterns of averaged surface ΔZ for summer and equinox, $K_p = 2-$ to $3+$, are shown in Figure 3, and Table 1 summarizes some of the conclusions regarding ΔZ from the surface data. Note that for purposes of this study, the positive bay (bay, here, refers to variations in the horizontal field at the earth's surface, i.e. ΔH) region is part of the negative ΔB region, and the negative bay region is part of the positive ΔB region. In addition to the sector variations in Table 1, a very prominent difference in ΔZ between sectors occurs from about 9^h to 14^h near 80° invariant latitude (Figure 3), where ΔZ is predominantly negative for away sectors and predominantly positive for toward sectors. The positive ΔZ ($+\Delta Z$) and the negative ΔZ ($-\Delta Z$) overlap differently on the dayside for the two sectors; in

the case of away sectors the $-\Delta Z$ region is to the north of the $+\Delta Z$ region, and for toward sectors it is to the south. For the summer away sector, the $-\Delta Z$ a feature near 11^h and 81° is separated from the peak of the $-\Delta Z$ region near 16^h and 75° . This feature, together with the directions of $\vec{\Delta H}$, led Langel (paper III) to suggest a localized current in this region.

DESCRIPTION OF THE DATA

Full details regarding the POGO spacecraft, the magnetometer experiment, and data analysis are found in papers I and II and the references therein. As in paper I, the POGO data are subdivided by season, Kp, and altitude before averaging. Season is defined in terms of the dipole latitude of the sub-solar point, θ_{sun} , where $|\theta_{\text{sun}}| < 10^\circ$ is equinox, $\theta_{\text{sun}} > 10^\circ$ is northern summer, and $\theta_{\text{sun}} < -10^\circ$ is northern winter. Data subdivision by Kp was into four levels: 1) Kp = 0 to 0+, 2) Kp = 1- to 1+, 3) Kp = 2- to 3+, and 4) Kp \geq 4-. Data division by altitude was into the ranges < 550 km, 550-700 km, 700-900 km, and > 900 km. Because the number of data points entering each average is already limited, further division by interplanetary sector reduces the reliability of the averages. In addition, the lack of interplanetary data during some periods when POGO data are available results in a further reduction in the data available for averaging. For these reasons, discussion in this paper is limited to the Kp = 2- to 3+ activity range, for which the available data is a maximum. It has been found (Svalgaard, 1968; Mansurov, 1969; Mansurov and Mansurova, 1970) that variations in magnetic field pattern are anti-correlated in the northern and southern hemisphere (i.e., the "type" of disturbance which occurs in the north during away sectors occurs in the south during toward sectors, and vice versa). Examination of averages of ΔB from POGO confirm this

asymmetry, i.e., toward (away) sectors in the northern summer have the same disturbance pattern, within experimental error, as away (toward) sectors in southern summer. The same applies to the equinox and winter seasons. In order to improve the averaging process for the POGO data, northern and southern hemisphere data are combined in the present study. In this combination data from away (toward) sectors in the north is combined with data from toward (away) sectors in the south. Results are presented in terms of conditions prevailing in the north (i.e. "data from away sectors" means data from away sectors in the north and data from toward sectors in the south). Data from northern summer (winter) is combined with data from southern summer (winter), i.e. data from north and south is about 6 months out of phase. Combining the data from the northern and southern hemisphere offsets most of the reduction in the number of points entering into the averages due to subdivision by sector. Other details of the averaging process are identical to those described in paper I. The standard errors of the averages are about 10γ and 7γ respectively, for altitude < 550 km and altitudes between 700 and 900 km. Figures 4-6 show contours of ΔB for these altitude ranges for toward and away sectors in the three seasons. Comparison of Figures 4-6 with Figure 1 shows that the basic disturbance pattern is the same in all cases; both the positive and negative ΔB regions are found in the regions discussed in the Introduction. Further, comparison of Figure 5 and Figure 1, both of which are for equinox, indicates that the disturbance magnitudes near the peaks of the positive and negative ΔB regions for the data divided by sector are not greatly different from the magnitudes when all data is averaged together. Definite changes do occur between season and sector in the POGO data, however, which, upon comparison with surface data, give some insight into the source of these variations.

Seasonal Variations. Although seasonal variations do occur in the positive ΔB region for a given interplanetary sector, the magnitude of such variations is no larger than the standard error of the averages and cannot be considered significant without corroborating data. This situation is in contrast to the surface data in this region where seasonal differences of as much as a factor of two occur.

In the portion of the negative ΔB region from about 11-19^h MLT for altitudes < 550 km, and at all MLT in the negative ΔB region for altitudes 700-900 km, $|\Delta B|$ is greatest in summer and least in winter. This variation is in the same sense as that seen in POGO data not divided by sector (paper I) and in the surface $|\Delta Z|$ (e.g. paper III). Near 19-21^h at altitudes < 550 km, however, $|\Delta B|$ for away sectors in winter exceeds that in summer, with the disturbance magnitude being smallest at equinox. This region near 19-21^h in winter actually contains the peak disturbance in the negative ΔB region for altitudes less than 550 km, in contrast to the usual case (Figures 4, 5, 6b, 6d; see also paper II) in which the peak disturbance in the negative ΔB region is near 15-16^h. During winter toward sectors at altitudes less than 550 km, two peaks occur in the negative ΔB region, one near 15^h and the other near 19^h. The strength at low altitude of the disturbance near 19-21^h, compared to 15-16^h, during winter should be compared with the surface data (paper III), where ΔZ in the positive bay region (= negative ΔB region) exhibited a peak near 20-22^h which was separate from the main peak near 14-15^h in all seasons except for away sectors in summer. In the surface data, this feature is most apparent for winter.

Variations between Sectors. From Figures 4-6, it is clear that the most significant variation in ΔB between sectors is, as expected, much like the variation in surface ΔZ . In Figure 4 for away sectors the negative ΔB region extends to 8^h at 80°, while for toward sectors it extends only to about 11^h. Near 7-8^h above 80° (alt. < 550 km) for away sectors ΔB is negative ($\leq -20\gamma$ in summer), while for toward sectors ΔB is positive ($\geq 20\gamma$ in summer). The largest change occurs in the region between 80° and 86° and between 7-10^h, where the difference in average ΔB in summer reaches 100 γ at alt. < 550 km and 40 γ at altitudes between 700-900 km. At equinox the difference in average ΔB in this region reaches 20 γ and 12 γ at altitudes < 550 km and 700-900 km. In winter, differences between the two sectors from 6^h to 18^h are smaller than the standard errors of the measurements.

Between 19^h and 5^h, below about 80°, sector differences for summer are insignificant, so that sector differences for this season are a phenomena of sunlit local times.

Sector differences do occur at non-sunlit local times in winter and equinox, but their significance is not clear. The largest of these sector differences occurs at equinox in the positive ΔB region, mainly between 60 - 70° from 0 - 5^h MLT, where ΔB for away sectors is greater than ΔB for toward sectors at altitudes < 550 km and altitudes between 550 - 700 km (not shown in the figure). For altitudes above 700 km the difference is negligible. This same sector difference in this region is present in the ΔB for winter and in the surface ΔZ , but in these cases the magnitude of the differences is near the standard error of the averages. The surface data in this region in summer show that ΔZ for toward sectors is greater than ΔZ for away sectors; this difference is not apparent in the satellite data.

Some differences between sector, which are on the borderline of significance, also occur in the negative ΔB region;

- 1) In winter, near 19-20^h, $|\Delta B|$ for away sectors is greater than $|\Delta B|$ for toward sectors,
- 2) In summer, the peak magnitude of negative ΔB is greater for away sectors,
- 3) At equinox, the peak magnitude of negative ΔB is greater for toward sectors.

DISCUSSION

Ionospheric Current at Sunlit Local Times. The conclusion of paper II, that the negative ΔB region can be completely accounted for in terms of a latitudinally broad current in the sunlit portion of the hemisphere between about 13^h and 19-20^h, is still applicable when the data is divided by sector. Using the technique described in paper II, equivalent current systems for toward and away sectors are derived for summer. It is to be emphasized that only data from the negative ΔB region entered into the derivation of this current system. Figure 7 shows the resulting currents, called the HLS current (for High Latitude, Sunlit), and Figure 8 shows the ΔB at 453 km which would be caused by these currents. Comparison of Figure 8 and Figure 4 shows that the ΔB from the equivalent current reproduces the main features of the measured data.

Figure 9 shows the altitude dependence of ΔB at three locations: near the peak of the negative ΔB region for both sectors, near 1-3^h in the positive ΔB region for both sectors, and near 6-7^h in the positive ΔB region for toward sectors. Comparison with Figures 4 and 5 of paper I shows that $|\Delta B|$ in the negative ΔB region decreases with altitude in the

same fashion for each sector as for all data considered together independent of sector. The region near 2-3^h, 70-75°, corresponds to the location of the maximum disturbance in the positive ΔB region for all data independent of sector (paper I). In paper II it was found that the altitude dependence in this region did not permit explanation in terms of purely ionospheric sources. ΔB in this region (Figure 9) decreases slowly with altitude for both sectors and, in fact, is almost identical to the behavior of the maximum disturbance in the positive ΔB region found in paper I for all seasons and both hemispheres for $Kp = 2-$ to $3+$. It is concluded that the disturbance in this region is of the type shown in paper II to be due to a combination of sources, namely, the westward electrojet and a non-ionospheric source (or sources).

Near 6-7^h, 78-87°, for toward sectors, however, Figure 9 shows that ΔB falls off more rapidly with altitude than near 2-3^h. Further, comparison of Figures 4-6 for altitudes < 550 km shows that ΔB near 2-3^h is about 40-50 γ for all seasons, while near 6-7^h ΔB is near 60-63 γ in summer, 50-52 γ at equinox, and near 30 γ in winter. Thus the sunlit portion of the positive ΔB region, for toward sectors, shows an altitude and seasonal variation more like $|\Delta B|$ in the negative ΔB region than like ΔB earlier than 5^h MLT in the positive ΔB region. These characteristics indicate an ionospheric source for this portion of the positive ΔB region similar to the dashed flow lines in Figure 2. Thus dayside sector differences are ionospheric in origin.

That sector differences are ionospheric in origin, probably due to E-region currents, is also borne out by comparison of the surface ΔZ data of Figure 3 and the satellite ΔB data of Figure 4-5. Confining attention to the sunlit portion of the hemisphere, comparison of these figures

indicates that much more structure is present in the surface data than in the satellite data, particularly for away sectors. Most notable in this respect is the presence of two peaks in the surface ΔZ for summer away sectors, near 16^h and 75° and near 12^h and 82° , and the tendency toward two such peaks at equinox. (Two such peaks are also present for summer and equinox away sectors in the unpublished $K_p = 1-$ to $1+$ data). In contrast, only one peak is evident in the average ΔB at the satellite. This indicates that the surface data is nearer to the source than is the satellite data so that the vertical distance of the satellite from the two (E-region) sources is comparable with the horizontal separation of the sources. Integration of disturbance from the two sources will cause the disturbance at the satellite to merge into one peak. Also, the one peak of ΔB at the satellite will be larger than the ΔB due to either of the sources considered alone, which may account for the fact that $|\Delta Z|$ at the surface is greater for toward than away sectors in all seasons but that $|\Delta B|$ at the satellite is greater for away than toward sectors in summer.

The eastward electrojet. An eastward electrojet has been noted at evening local times by Heppner (1954), among others, and has more recently been studied by Rostoker and Kisabeth (1973). In paper II it was pointed out that a latitudinally narrow jet-type current, of the magnitude usually noted for the eastward electrojet, would be detectable only at low altitudes by the POGO satellites. Examination of individual passes from the POGO satellites indicated that the ΔB pattern expected from a latitudinally narrow eastward electrojet is found on some passes between $18-23^h$ MLT at very low altitudes. No such passes earlier than 18^h have yet been found. In paper II

positive bays between 12-18^h (sunlit MLT) were attributed to a latitudinally broad ionospheric current and, utilizing only ΔB from the POGO experiments, equivalent current systems (HLS currents) were derived which could account for the average surface data of paper III in this MLT region. The earliest MLT shown by Rostoker and Kisabeth (1973) is in their Figure 6(a), which is a latitudinal profile of ΔH , ΔZ , and ΔD at about 19^h MLT. Comparison of this profile with the average data in Figures 3 and 5 of paper III indicates that the characteristics of this particular profile are close to the characteristics of the averages at this MLT. In particular the large negative ΔZ to the north with its peak occurring in the vicinity of the zero crossing of ΔH , and the large negative ΔD above 75° in the profile are also features of the average data. Comparison with Figures 7, 9 and 10 of paper II, which give the surface disturbance resulting from the equivalent currents of Figure 7 of the present paper, shows that these features are largely reproduced by a current system like HLS. In contrast to the profile of Figure 6(a), the other profiles of Rostoker and Kisabeth (1973) seem more consistent with a latitudinally narrower jet-type current, as expected for data nearer midnight.

This apparent dichotomy of source currents in the 12-23^h MLT region was noted earlier by Oguti (1963) and by Kamide and Fukushima (1972) who suggested two types of positive bays: 1) a broad variation in the evening sector which is controlled by ionization due to solar radiation and exhibits a large seasonal change, and 2) event-type bays in the nightside auroral region which show no seasonal variation. As already pointed out, separate peaks near 20-22^h are noted in the average surface data and in the winter averages at low altitudes in the OGO 2, 4, and 6 data. It

seems likely that these are associated with the nightside positive bays and a latitudinally narrow eastward electrojet.

Sector and Seasonal Variation in Electrojet Currents. Finally, a comparison of the surface ΔZ of Figure 3 with the satellite ΔB of Figures 4-5 for MLT between 19^h and 5^h (i.e. the dark portion of the hemisphere) again shows much more structure in the surface data than in the satellite data. Subsidiary maxima in the surface data are not often seen in the satellite data. In addition, in paper III, significant amplitude variations in ΔZ and ΔH were found both between sectors and between seasons. If such variations are present in the POGO data they are of magnitude near or less than the standard error of the averages. It is concluded that the major sector and seasonal differences in the surface data in this region are due to variations in latitudinally narrow electrojet currents and not in the non-ionospheric sources found in paper II. This accounts for the different seasonal/sector variation in amplitude between surface and satellite data because E-region currents are closer (about 115 km) to the surface data than even the lowest altitude satellite data (about 300 km above the E-region) and such ionospheric currents are not the principle source of satellite ΔB (paper II).

SUMMARY AND CONCLUSIONS

Total magnetic field data from the POGO spacecraft are utilized to obtain the average disturbance pattern in ΔB as a function of season, sector, and altitude. These patterns have the same major features as data not divided by sector studied in papers I and II. Examination of the differences in ΔB pattern with altitude, together with ΔZ at the earth's surface, demonstrates that the ΔZ and ΔB which varies between sectors has

an ionospheric source. Variations in an ionospheric current pattern require a variation in ionospheric electric field. Such variations have been found by Heppner (1972a and b) in the OGO-6 electric field data. Since these measurements were of one axis only, the detailed variations in electric potential are still unknown.

The existence of a latitudinally broad ionospheric current system in the 12^h - 18^h MLT region, the HLS current, is confirmed, and the existence of such a current in the 6-12^h MLT region during toward sectors is inferred.

Both the surface data and the satellite data also indicate the existence of latitudinally narrow electrojet currents, eastward from about 19^h to 22^h MLT and westward from about 22^h to 6^h MLT. Comparison of magnetic variations between seasons and sectors at the surface and satellite in the dark portion of the hemisphere indicates that these variations are caused by variations in the latitudinally narrow jet-type currents and not variations in the non-ionospheric source of positive ΔB found in paper II. This is consistent with the variations in average surface disturbance found in paper III and with the results of Burch (1973) who found a seasonal variation of the AU and AL indices for toward and away sectors.

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Table 1: Summary of results from average surface ΔZ , Kp: 2- to 3+.

General Feature:

$|\Delta Z|$ 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, $|\Delta Z|$ is greatest in summer and least in winter during toward sectors. During away sectors, $|\Delta Z|$ is greater in winter and summer (ΔZ in summer \doteq ΔZ in winter) than in equinox.
- (2) In the positive bay region at 20-22^h, $|\Delta Z|$ is greatest in equinox and least in winter.
- (3) In all other regions $|\Delta Z|$ is greatest in summer and least in winter.
- (4) Seasonal differences are larger at sunlit local times than in darkness.

Differences between sectors:

- (1) In the negative bay region during summer, $|\Delta Z|$ is greater in toward sectors than in away sectors, and vice versa during winter.
- (2) In the positive bay region, $|\Delta Z|$ is greater during toward sectors than during away sectors at all local times and during each season.

FIGURE CAPTIONS

- Figure 1: Average ΔB (γ) from OGO 2, 4, and 6 for $K_p = 2-$ to $3+$, northern hemisphere, and geomagnetic equinox. Coordinates are invariant latitude and magnetic local time.
- Figure 2: Conceptual drawing of proposed current sources (Langel, 1973b). The latitudinally broad current in the negative ΔB region, 11^h to 18^h MLT, is called the HLS current (High Latitude, Sunlit). Eastward and westward electrojets are shown as large arrows. The positive ΔB region, shaded, is due to a non-ionospheric source(s) in addition to the westward electrojet. Coordinates are invariant latitude and magnetic local time.
- Figure 3: Contours of average ΔZ (γ) at the earth's surface. Data from 1965 to 1968 for $K_p = 2-$ to $3+$. Coordinates are invariant latitude and magnetic local time.
- Figure 4: Average ΔB (γ) from OGO 2, 4, and 6 for $K_p = 2-$ to $3+$ and geomagnetic summer. Sector classifications are for the northern hemisphere and are reversed in the southern hemisphere.
- Figure 5: Same as Figure 4 except season is geomagnetic equinox.
- Figure 6: Same as Figure 4 except season is geomagnetic winter.
- Figure 7: Equivalent current derived from negative ΔB region data for geomagnetic summer, $K_p = 2-$ to $3+$. The current is assumed to flow at 115 km, and 10^4 amps. flows between stream lines. Coordinates are MLT and invariant latitude. This current is designated the HLS current (for High Latitude, Sunlit).
- Figure 8: ΔB (γ) at 453 km from HLS current system for geomagnetic summer, $K_p = 2-$ to $3+$. Coordinates are MLT and invariant latitude.

Figure 9: Altitude dependence of ΔB from geomagnetic summer at selected locations.

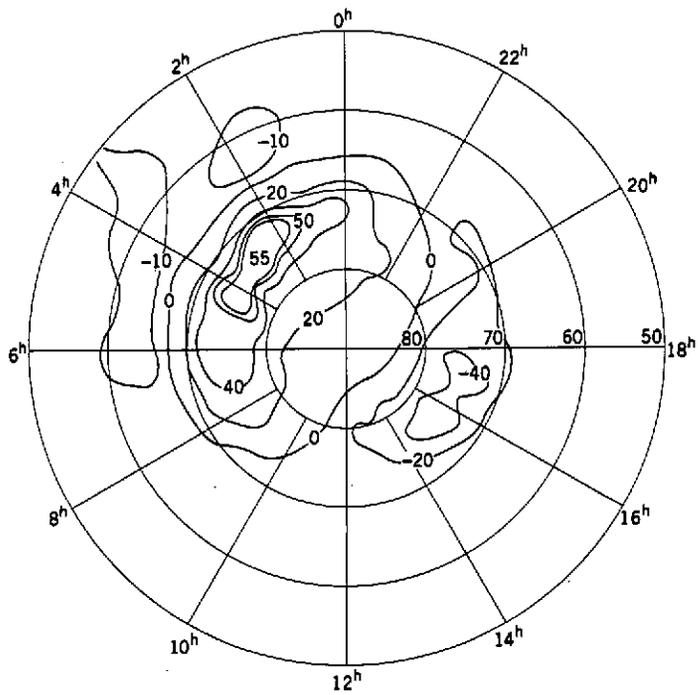
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ALT < 550 km



700 km < ALT < 900 km

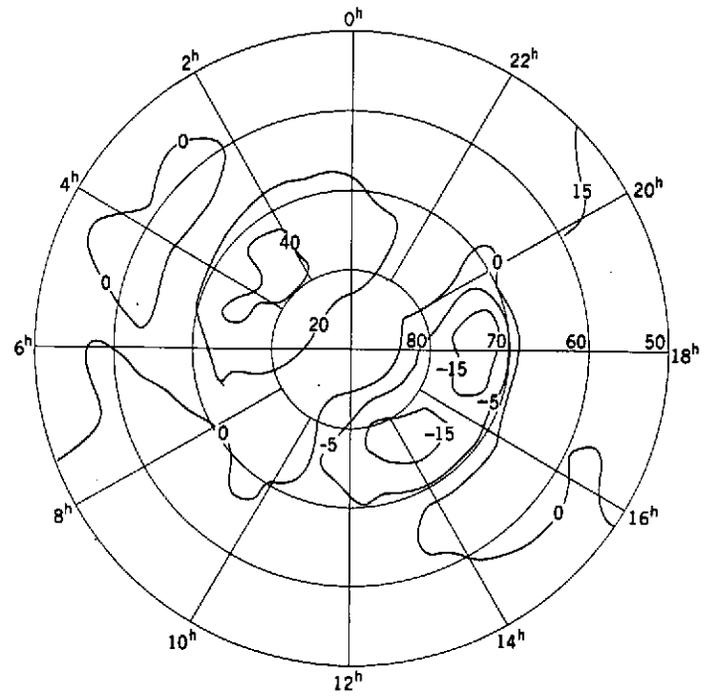


Figure 1

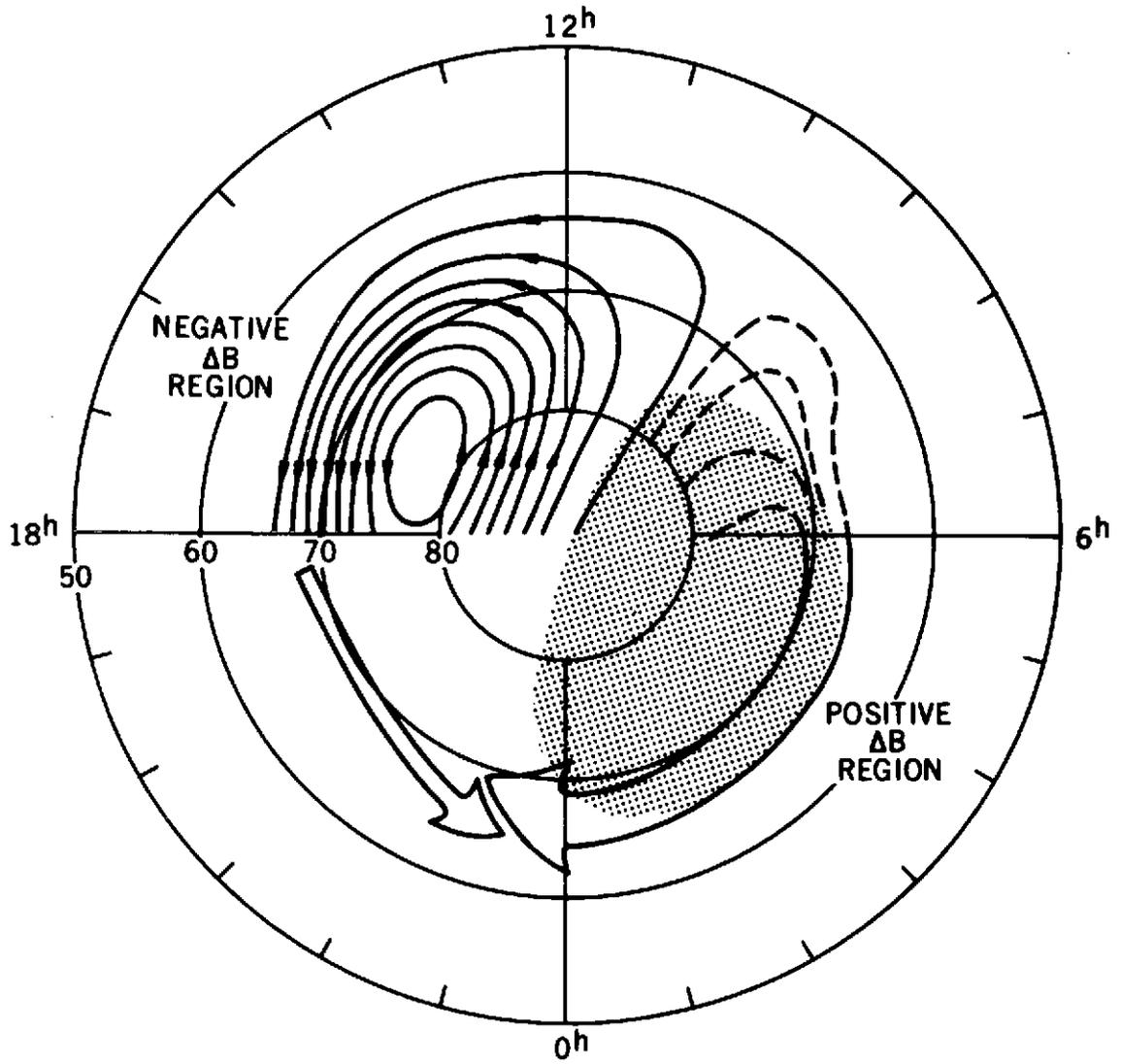


Figure 2

IP MAGNETIC FIELD AWAY FROM THE SUN

IP MAGNETIC FIELD TOWARD THE SUN

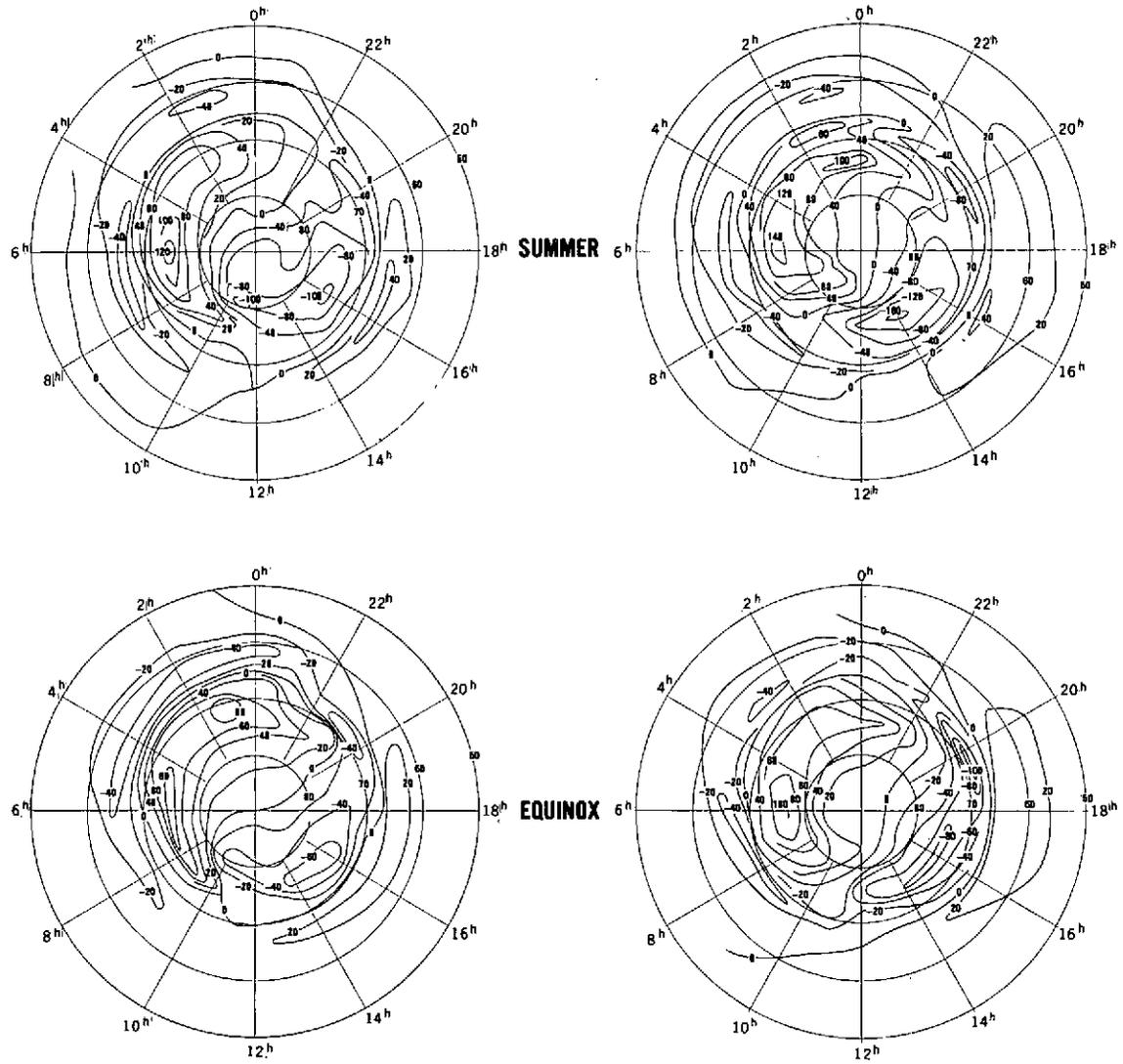
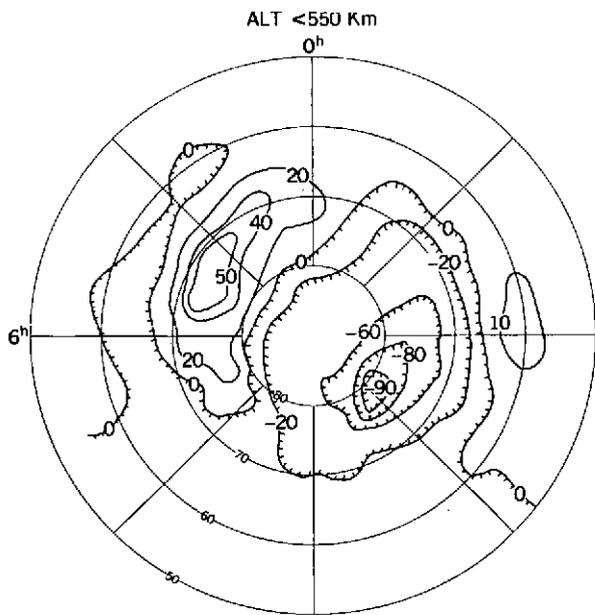
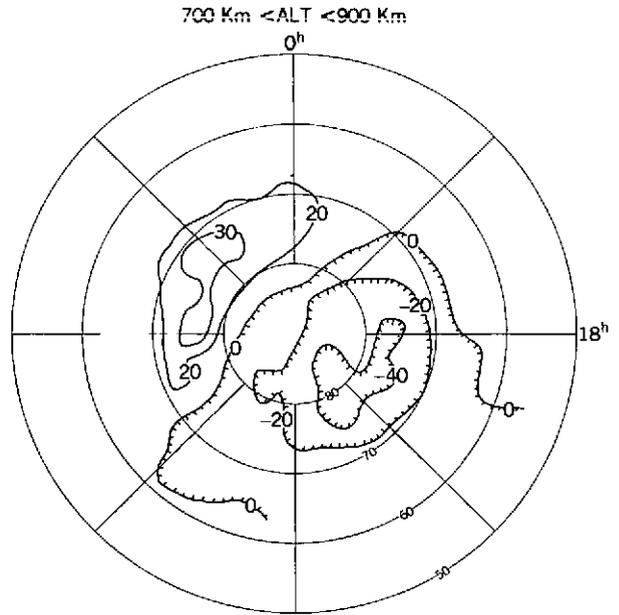


Figure 3

INTERPLANETARY MAGNETIC FIELD AWAY FROM THE SUN

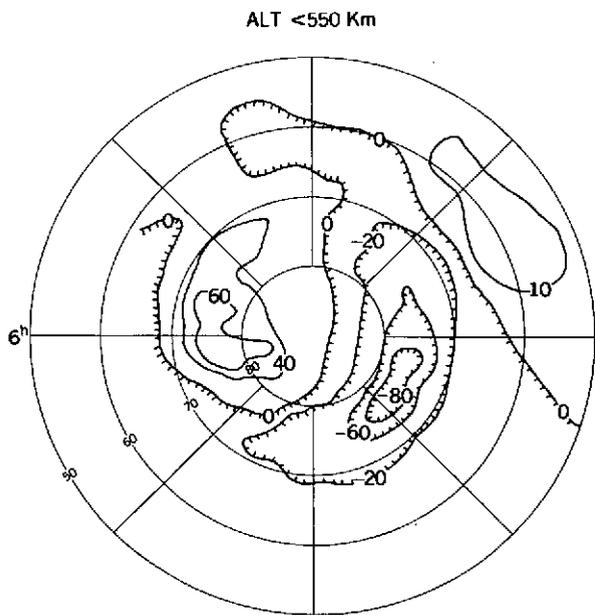


(A)

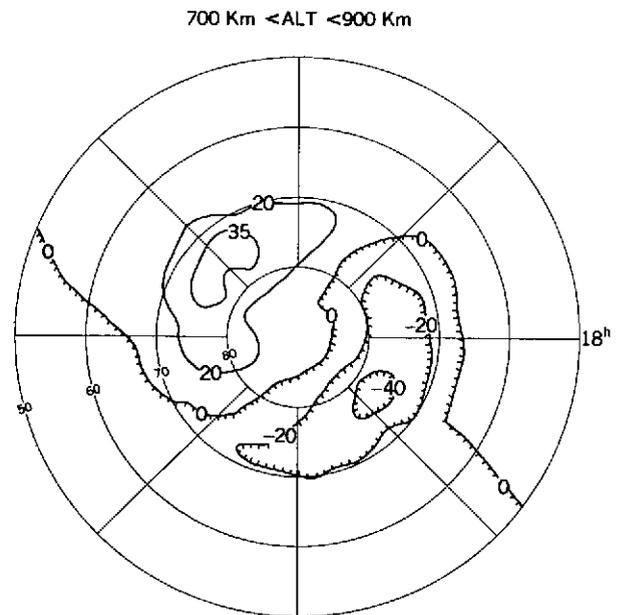


(B)

INTERPLANETARY MAGNETIC FIELD TOWARD THE SUN



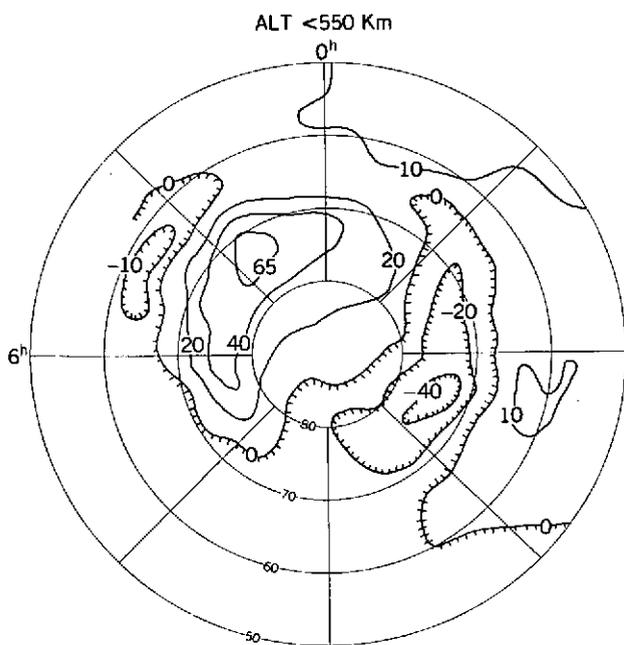
(C)



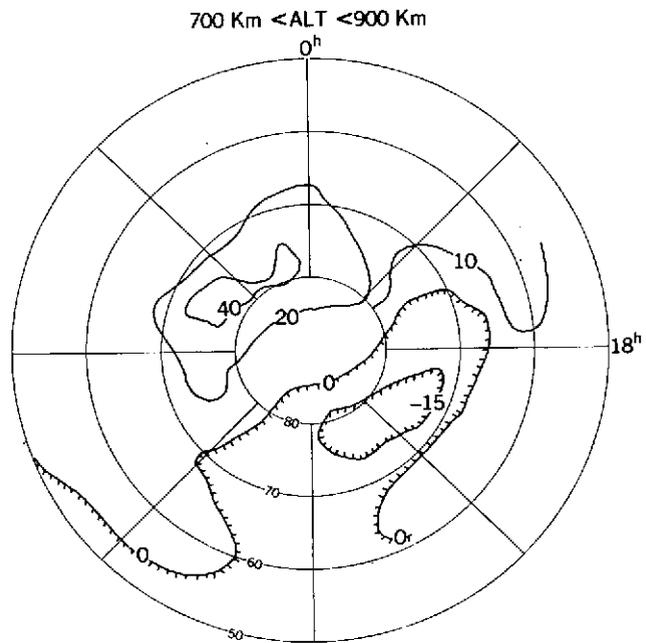
(D)

Figure 4

INTERPLANETARY MAGNETIC FIELD AWAY FROM THE SUN

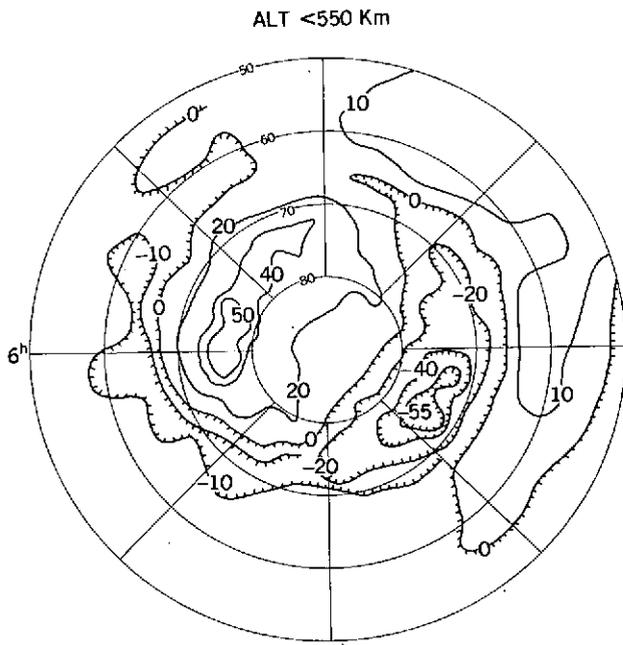


(A)

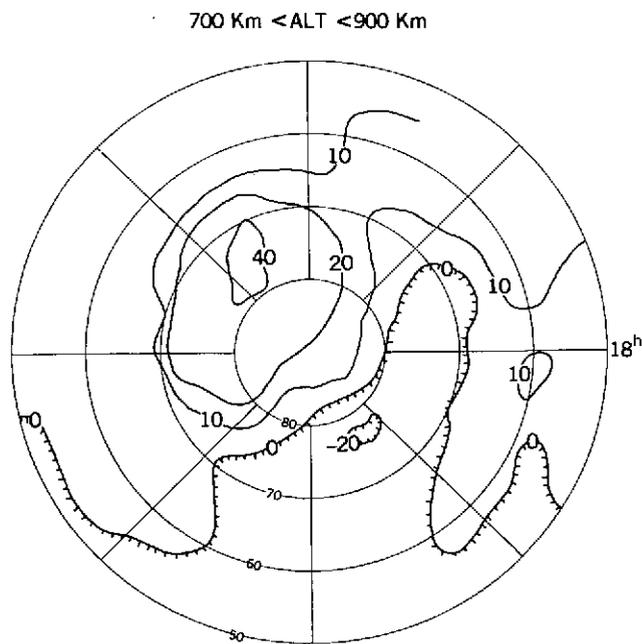


(B)

INTERPLANETARY MAGNETIC FIELD TOWARD THE SUN



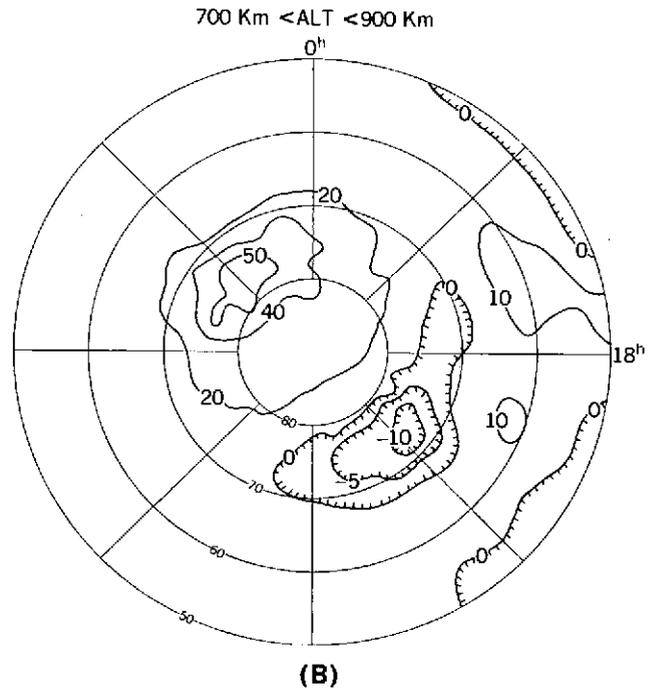
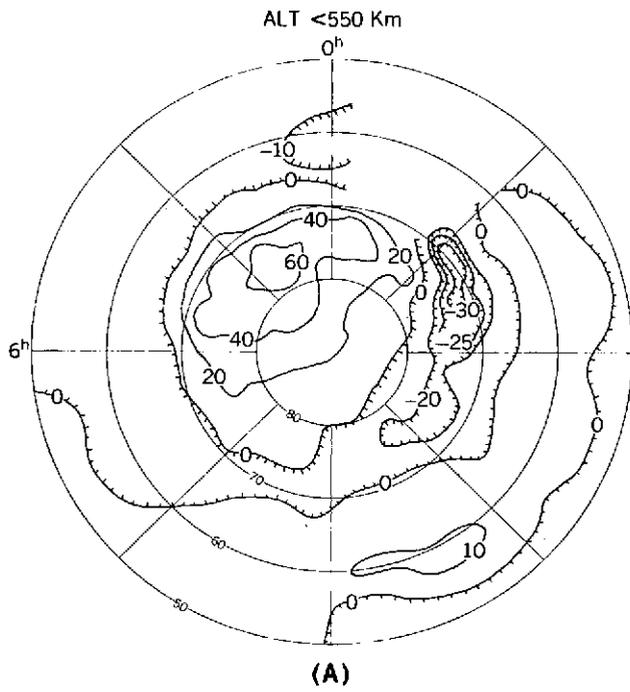
(C)



(D)

Figure 5

INTERPLANETARY MAGNETIC FIELD AWAY FROM THE SUN



INTERPLANETARY MAGNETIC FIELD TOWARD THE SUN

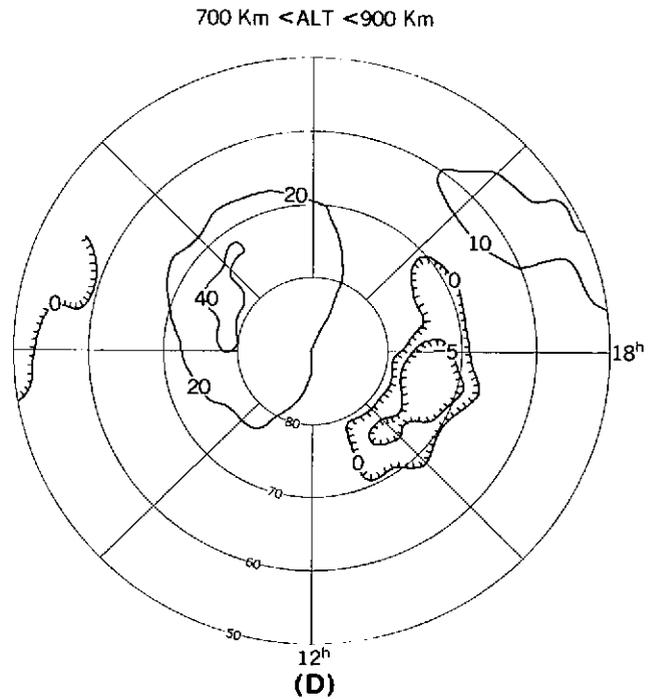
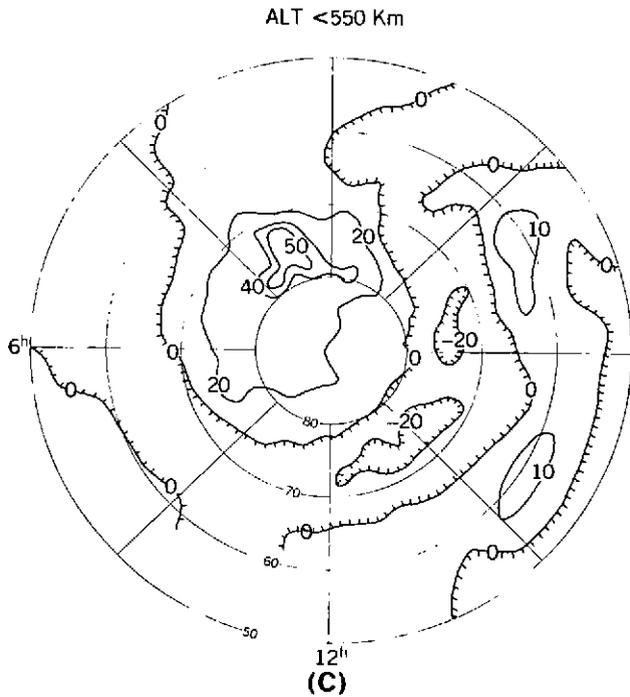
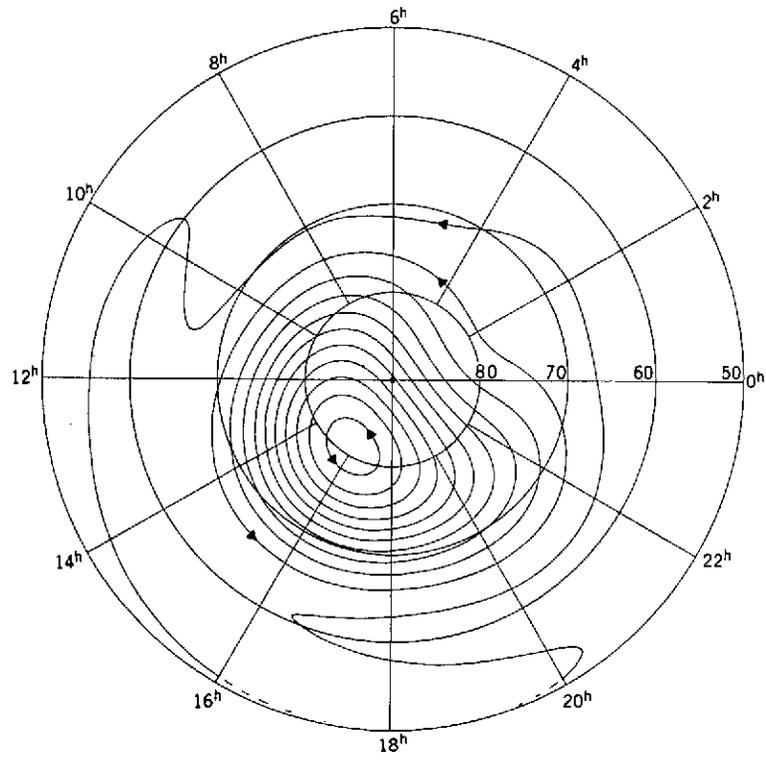


Figure 6

INTERPLANETARY MAGNETIC FIELD
AWAY FROM THE SUN



INTERPLANETARY MAGNETIC FIELD
TOWARD THE SUN

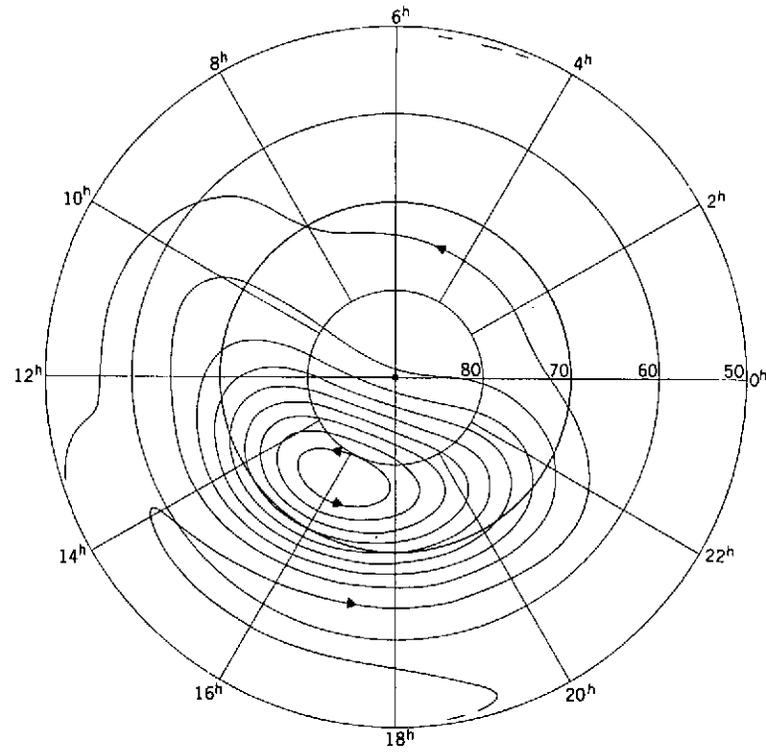
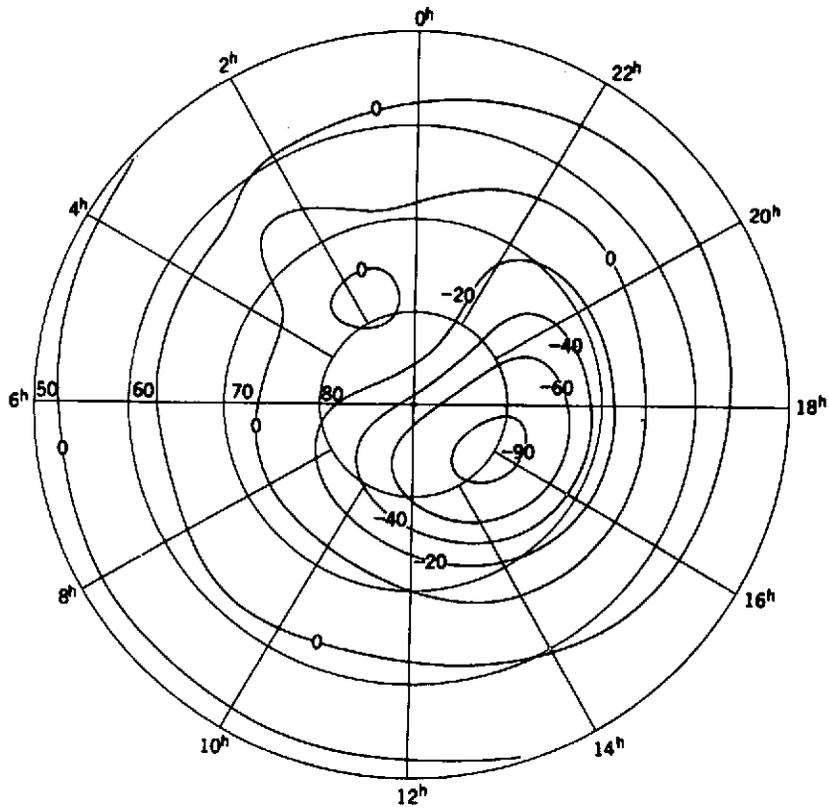


Figure 7

**INTERPLANETARY MAGNETIC FIELD
AWAY FROM THE SUN**



**INTERPLANETARY MAGNETIC FIELD
TOWARD THE SUN**

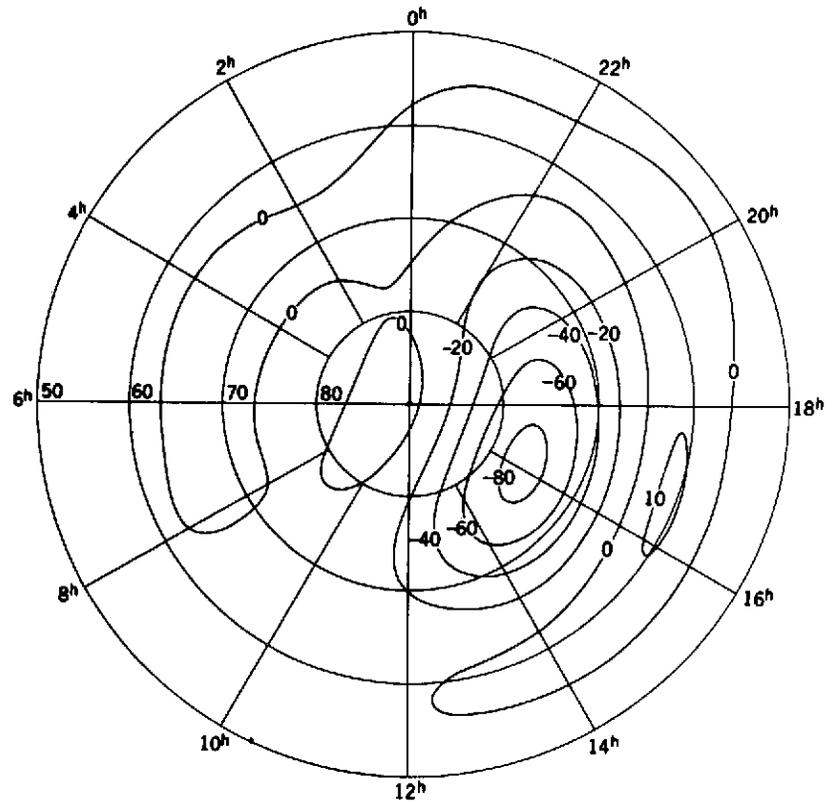


Figure 8

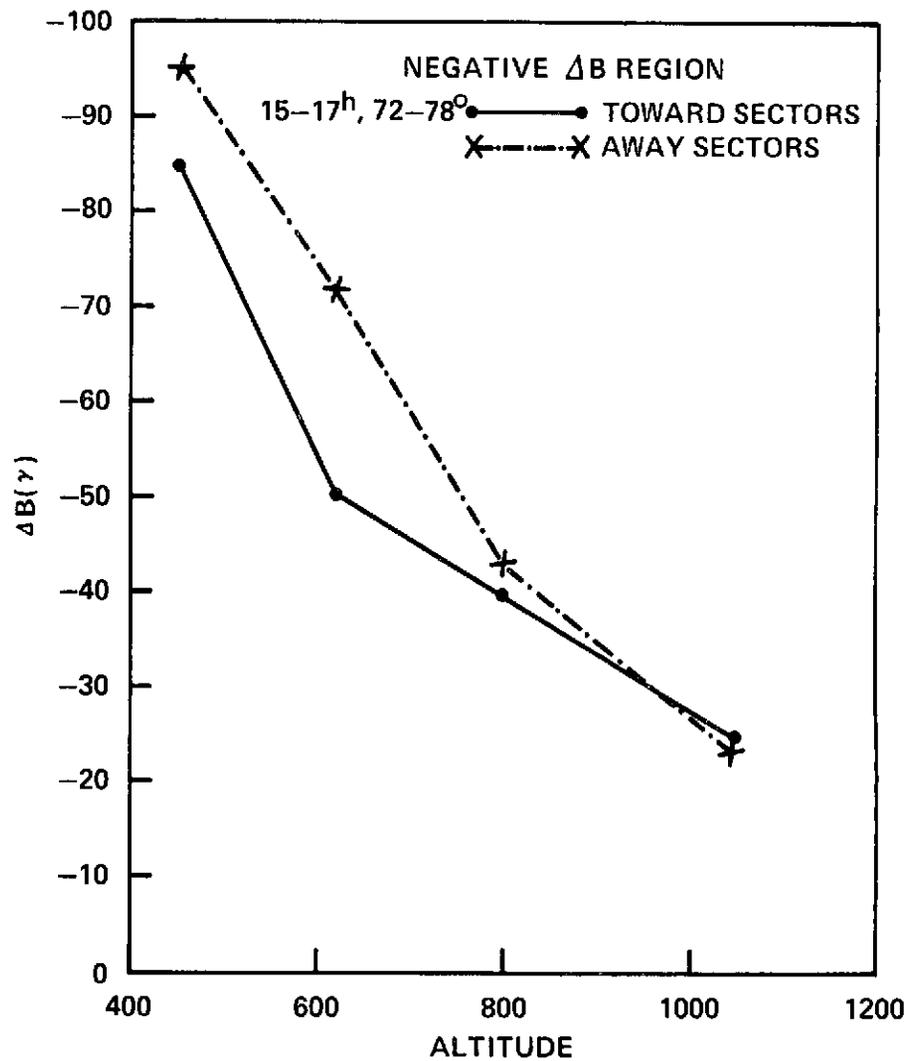
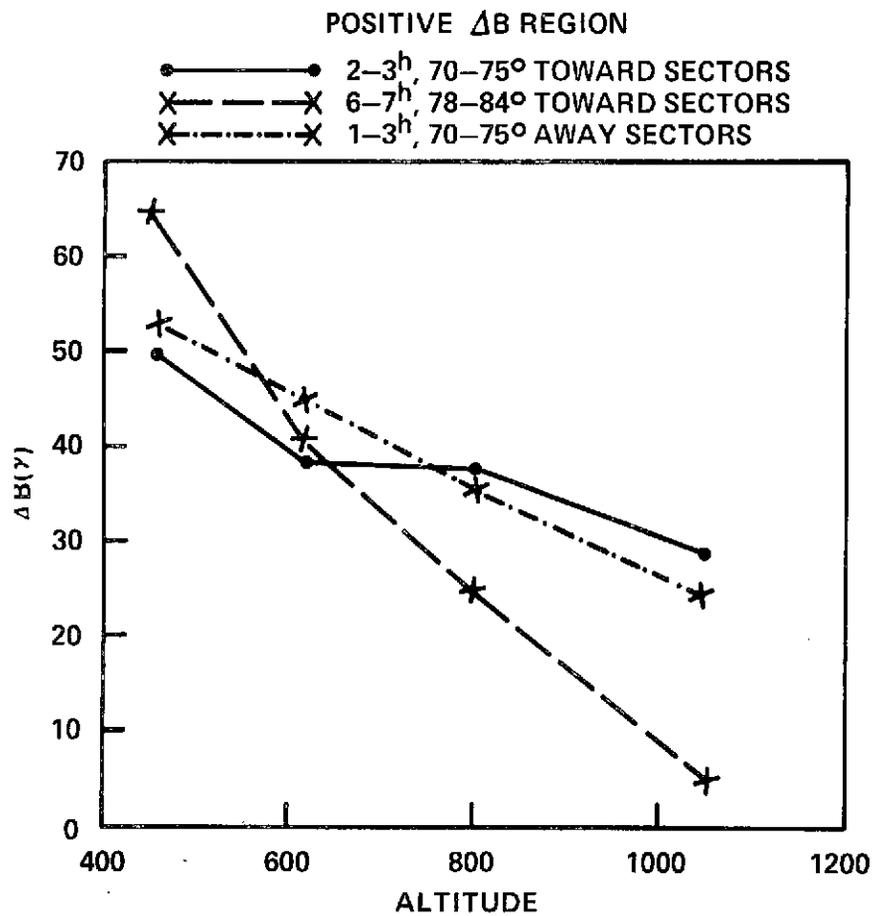


Figure 9