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HIGH LATITUDE MAGNETIC DISTURBANCES (A BRIEF REVIEW WITH INITIAL RESULTS FROM MOTION PICTURE PRESENTATION)

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High Latitude Magnetic Disturbances

(A Brief Review with Initial Results

From Motion Picture Presentation)

By

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I. Introduction

A comprehensive review of high latitude (i.e., auroral zone and polar cap) magnetic disturbances should treat in sequence the properties of the solar wind and interplanetary fields, their interaction with the earth's magnetic field, the mechanisms for transferring solar wind energy to the outer magnetosphere, the motions of fields, plasmas and energetic particles within the magnetosphere, the energy coupling between the outer magnetosphere and ionospheric regions, possible influences of wind generated potentials in the ionosphere, and the electro - and hydromagnetic properties of the ionosphere which eventually determine many of the characteristics of the magnetic disturbance seen by a high latitude magnetic observatory. Any attempt at this type of review in a short paper is destined to be too sketchy to be substantive and some of these topics are discussed in other papers at this symposium.

The discussion here is directed to the geomagnetic time and latitude distribution of magnetic disturbance at auroral and polar cap latitudes. This is an old topic which has assumed new status as a consequence of space measurements in recent years. Among other phenomena of known association with auroral zone magnetic disturbances, we are now aware that sudden changes in the population of low energy trapped particles are closely correlated with bay activity in the auroral zone (McIlwain, 1966; Davis and Williamson, 1966; Konradi, 1966). The importance of the topic is also evident on examination of recent theories (e.g., Axford and Hines, 1961; Dungey 1961; Piddington, 1963; Taylor and Hones, 1965) in which the basic problem is arriving at an explanation for the high latitude disturbance patterns as an eventual consequence of solar wind interaction with the magnetosphere. To various degrees the problem is usually worked backwards in the sense that conditions in the outer magnetosphere are deduced from an assumed high latitude current distribution and one then finds cause for these conditions. There have been only a few attempts at treating this, i.e., the reverse, problem quantitatively (e.g., Fejer, 1963; Taylor and Hones, 1965). This lack of quantitative treatment is not surprising considering that a number of assumptions are required which in turn cast doubt on specific results. Typical steps, not all identified with any one analysis, are: (a) the assumption of a model of the surface magnetic disturbance which in turn usually includes the additional assumption that the disturbance is invariant with time, (b) the assumption that the model disturbance is caused by ionospheric currents whose circuits lie entirely within the ionosphere, (c) the assumption, associated with (b), that magnetic field lines are also lines of electrical equipotential, (d) the assumption of a static model atmosphere for neutral and charged particles at ionospheric heights for calculation of tensor conductivities, and (e) the assumption of a magnetic field model for tracing field lines into the outer magnetosphere.

The missing link in understanding the disturbance phenomena is obviously the lack of measurements of electric fields. However, even when we have these measurements they will have to be referenced in time and location to characteristic stages of magnetic disturbance as recorded by surface observatories. Thus it is important that we have clear conceptual pictures of typical patterns or systems of magnetic disturbance at high latitudes and an equally clear understanding that these patterns are only <u>quasi-stable</u>. The most difficult concepts involve recognizing the continuous existence of patterns under highly variable conditions. These concepts, although difficult to convey in words or fixed time illustrations, are relatively easy to grasp through repeated viewing of the motion picture presentation described in Section III, below.

II. Brief Review of Disturbance Patterns

Birkeland's (1900-1913) descriptions and explanations of "polar elementary storms" coincident with auroral displays represent the first modern attempt to understand high latitude disturbances. Birkeland's "polar elementary storms" are now usually referred to as "magnetic bays" or "auroral electrojet disturbances". The changes in name do not imply any physical difference. Birkeland's concepts were necessarily simply: electrons entered the outer atmosphere from great distances and returned to distant space. Their horizontal paths along a magnetic shell while in the outer atmosphere determined the current flow causing the magnetic disturbance. Thus, he did not close the circuit within the ionosphere. Criticisms are well known but the basic concept is brought back in different forms as earlier grounds for criticism are found lacking (See, e.g., Alfvén, 1966).

Chapman's (Chapman and Bartels, 1940) harmonic analysis of magnetic storms provided a description of magnetic disturbance in terms of a system of currents forming closed circuits within the ionosphere. Although highly idealized in terms of D_{st} (symmetric about the earth's magnetic axis) and S_D (solar diurnal) parts, this idealization has been a reference system for many subsequent studies. Polar views of Chapman's $D_{st} + S_D$ and S_D systems are shown in Figure 1, A and B respectively. In more recent years various symbolisms (e.g., DS, DP, D_p, D_i, etc.) have been used to describe the non-symmetric part of a disturbance largely to escape the restrictive nature of the S_D definition. A review of disturbance classifications has been given by Chapman (1961). As different investigators do not use the same techniques in analysis but may choose to use the same symbols in speaking of the resulting current systems, considerable confusion can, and often does, result from this labelling. An obvious example is the use of the term asymmetrical D_{st}. To avoid semantic confusion here, we will ignore the usual symbolisms.

Chapman's analysis was based on averaging a large number of magnetic storms and most subsequent analyses have been carried out by various techniques of averaging as a function of local time the disturbances occurring on different days. The sampling of days and hours relative to the number of observatories used and their locations gives, as expected, variations in the resulting pattern of disturbance. The equivalent ionospheric current systems drawn to represent these patterns are accordingly different in detail. Two well known representations of this type are shown as Figures 1(C) and 1(D) from Silsbee and Vestine (1942) and Nagata (1950), respectively. More recently Nagata and Iijima (1964) have shown that current systems derived by similar averaging procedures at high southern and high northern latitudes are essentially the same which suggests a conjugate relationship in the average disturbance pattern. This is illustrated in Figures 1(E) and 1(F).

The averaging of a number of disturbances or a number of days has the obvious drawback that temporal variations in the distribution are eliminated. Also, details which persist spatially but do not occur at the identical local time each day or at identical latitudes through a range of disturbance intensities can be lost and thus ignored in subsequent physical interpretation. The smoothing becomes even more extreme when a small number of scattered observatories is used. These points are immediately evident in comparing diagrams such as those in Figure 1 with Harang's (1946) analysis of disturbances obtained by rotating in local time a set of stations which were closely spaced along a geomagnetic meridian. Even though Harang used hourly values, the fact that he did not mix widely different levels of disturbance and did use closely spaced stations, brought out the very important detail that there is an overlap in latitude between $+\Delta H$ and $-\Delta H$ disturbances near the local time of transition from positive to negative bays. This is illustrated in Figure 2.

A second category of analysis, designed to show temporal variations in the spatial distribution, has been the construction of disturbance patterns or equivalent current systems for specific hours using hourly mean values (e.g., Vestine, et al., 1947; Fukushima, 1953; Fairfield, 1963). As this has been done by rather tedious analysis, examples are limited to a small number of hours for particular disturbances. Selection of representative samples is thus a problem and some detail is lost in the one hour smoothing. There is necessarily an additional loss of detail through smoothing when current systems with ionospheric continuity are constructed from the hourly values.

A third category of analysis involves relating the magnetic disturbance pattern to the behavior of aurora. At electrojet latitudes it has been well established that the time and space distribution of positive and negative bays correlates, in detail, with: (1) stages of auroral morphology as revealed primarily by sequences of auroral forms (Heppner, 1954), and (2) the direction of auroral motion (Davis, 1962). Figure 3, Pattern I, illustrates in idealized form the most common coincident behavior of the aurora and magnetic bays. Pattern II, Figure 3, illustrates a second type of coincident behavior in which there is a disappearance of activity between the positive and negative bay sectors of the disturbance pattern. The occurrence of Pattern II is generally limited to periods of low activity. Davis' figures (given in his paper in this book, or 1963) show the directions of auroral motion associated, respectively, with eastward ($+\Delta H$) currents and westward ($-\Delta H$) currents. The lines AB in Figure 3 and AA' in Davis' figures (1963) separate the two ($+\Delta H$ and $-\Delta H$) time and space sectors of the disturbance pattern at electrojet latitudes.

The overlap in latitude between the $+\Delta H$ and $-\Delta H$ sectors that appears between 23^h and 00^h LT in Figure 3 is a typical feature of the disturbance pattern that seldom appears in studies utilizing averages. In fact, this section of the pattern may appear as a time of low disturbance because the + and $-\Delta H$ effects from currents to the south and north, respectively, will be mutually cancelling each other at an observatory situated in the center. As noted previously the overlap does appear as a major feature in Harang's diagram, Figure 2. This latitudinal overlap illustrated by Figures 2 and 3 and Davis' (1963) analysis is a particularly important stage in the disturbance pattern as it represents the condition which exists immediately preceding the event known as "auroral break-up" (i.e., the lowest latitude homogeneous are breaks into active rayed forms) which is accompanied by a sudden increase in intensity of the westward electrojet and a local time shift of the electrojet pattern. This event is also referred to as negative bay onset, auroral activation, etc.

From the detailed correlation of aurora and magnetic disturbance noted above one would logically assume that statistical patterns of auroral occurrence and magnetic disturbance would also correlate. At electrojet latitudes this expectation is borne-out. In the central polar cap region (e.g., > 80° magnetic latitude) however the correlation is apparently negative (Davis, 1963; Lassen, 1963). Feldstein (1966) has compiled statistics on the local time of occurrence of aurora and plotted the distribution on a 24 hour polar scale. The resulting distribution, which he names the "auroral oval" places the region of maximum occurrence for the noon hours near 76° magnetic latitude and for midnight hours near 67°. The term "auroral oval" appears to have the same meaning as an older term "the auroral belt" which has often been used to distinguish between this distribution and the location of the "auroral zone" which defines the latitude of most frequent occurrence without reference to local time. The change in latitude with local time of the southern edge of the auroral belt is apparent in Figure 2.

The coincidence of the auroral belt (or oval) with electrojet magnetic disturbances is well established and need hardly be mentioned further except for a recent interpretation suggested, and questioned, by Feldstein (1966) but pursued to great length by Akasofu and co-workers (Akasofu, Chapman and Meng, 1965; Akasofu, Kimball and Meng, 1965, 1966). As summarized by Akasofu (1965) positive bays in the afternoon sector are not caused by an eastward electrojet current but are instead the result of ionospheric return currents from westward electrojets at higher latitudes. In this interpretation the westward electrojet flows everywhere along the auroral oval and positive bays at auroral latitudes in the evening are a minor consequence of the westward flow at higher latitudes. Thus, by definition, in this picture there is no direct spatial association between the occurrence of aurora and the eastward current. This view directly conflicts with the observations of many individual studies some of which involved extensive statistics: e.g. Heppner's (1954) study of 95 complete and 50 partial nights at College, Alaska and Bond's (1960) investigation of 62 nights at Macquarie Island which revealed only two conflicts with the patterns typified by Figure 3 and these were cases when the aurora was rayed during the positive bay. Auroral behavior defies perfect classification so it is not difficult to find isolated or detailed exceptions in its association with magnetic disturbance. However, observational data on the presence of aurora is overwhelmingly contrary to Akasofu's interpretation. There are other arguments based on auroral morphology which also contradict this interpretation and its implications but this is a separate topic. It should be noted that the distinction between "electrojet" and "return" current is not purely semantic in that "return" here implies that there is no causative driving potential or auroral particle precipitation associated directly with the eastward current, or $+\Delta H$ disturbance. Interpreted broadly it also means that the total eastward current can never be greater than a small fraction of the integrated westward electrojet current. Or interpreted more along the lines proposed, the total eastward current is not greater than the westward current having similar alignment at slightly higher latitudes. The disturbance movies discussed in the following sections make it obvious that there are major flaws in the current system constructed by Akasofu, Chapman and Meng (1965).

III. Film Display of Disturbance Patterns

The review in Section II was directed toward the spatial distribution of disturbance patterns. Time variations in the pattern were largely ignored because only very limited information has been available. More recently magnetograms have been digitized at 2.5 minute intervals under a joint USC & GS - NASA effort. As these data can be handled by computers, analyses of time variations can be performed which previously would not have been feasible from a labor stand point. Using data in this form for seven auroral zone observatories Davis and Sugiura (1966) have defined an index for auroral electrojet activity, AE, based on the envelope of superimposed traces of the horizontal component. This envelope clearly illustrates variations in electrojet activity with universal time but is independent of the local time pattern.

For analysis of the local time pattern as a function of universal time the author has used an SC-4020 plotter to display in polar projection the disturbance vector in the horizontal plane simultaneously from 25 high latitude observatories for each 2.5 minutes of universal time for a period of 16 consecutive days in October 1957. The interval October 5-20, 1957 was chosen because: (1) the maximum number of high latitude magnetograms was available for 1957-1958, (2) a wide range of disturbance levels was available between October 5 and 20 without getting into a major storm which would make many records unreadable, and (3) for baseline determination October 5-20 included two 24 hour intervals which were the most quiet days within a four month interval. A 26th observatory, Pt. Barrow, was digitized but not used because the D trace was missing from the magnetograms on the quiet days. K_p indices for the 16 days are shown in Figure 4 to illustrate general activity levels.

Restriction of this initial study to 16 days can be best understood by examining the quantity of data involved. For the 16 days there are 9216 independent polar diagrams which means 230,400 observatory vectors or 691,200 component (i.e., D, H, or Z) scalings. The variation in the vertical component, ΔZ, is not represented in plots made to date. ΔH and ΔD (or ΔX and ΔY) determine the horizontal vector. The individual polar plots are put on 35mm film in time sequence by the SC-4020 plotter. Playback of this film gives a continuous movie of the simultaneous disturbance vectors. Movies in both geographic and geomagnetic coordinate systems have been made by this means. As expected, the vectors are better organized in geomagnetic than in geographic coordinates; i.e., the vector patterns are more stable as a function of geomagnetic local time and latitude than as a function of geographic local time and latitude. Thus, geomagnetic coordinates are used exclusively for detailed study. For movie presentation in which the speed of projection has to be matched to a viewers ability to follow changes, four frames are inserted between each two independent frames. This is accomplished by linear interpolation at 0.5 minute intervals between consecutive 2.5 minute scalings.

Figures 5-8 contain examples of individual frames. The heavy line passing through the center of each plot is the geomagnetic noon-midnight meridian. The long end of this line points toward the sun and thus denotes the noon meridian. In the lower right-hand corner of Figure 5 geomagnetic times 0^h, 6^h, 12^h, 18^h and geomagnetic longitudes 0°, 90°, -90°, 180° are illustrated together with numbers identifying the observatories which are listed in Table I. Dotted lines are circles of constant geomagnetic latitude in 10° intervals. In Figures 6-8 the coordinates have been rotated by 90° or 180° such that noon is near the bottom of each figure. The scale of the disturbance vector length is 100 gammas = 10° latitude in all cases.

IV. Discussion Related to Initial Analysis of Disturbance Film

A viewer of the movie described above can form his own general impressions. However, it is only through repeated viewings and careful examination of successive frames that these impressions become at all quantitative. To date the author has studied primarily the major features. Thus, analyses of many details (e.g., time differences between the appearance of change at different stations, etc.) will have to be given in subsequent reports. Some initial impressions and conclusions are given below:

(A) Circuit closure: The pattern of disturbance vectors at any one time gives the general impression that systems of closed ionospheric currents could be drawn compatible with the observed disturbances. However, on closer examination the following points are apparent. (1) There is not an adequate number and distribution of observatories to permit such constructions to be accurate and even qualitative representation may often hinge on being able to place currents where there are not any observatories to confirm or deny the construction. This is particularly true at auroral latitudes where the disturbance is locally concentrated. In polar cap regions the disturbance is often highly uniform and it is reasonable at these times to assume that the central polar cap disturbance is adequately represented by the available observatories. (2) For specific periods of time, which are not infrequent, there are good reasons for questioning closure in the ionosphere. The most obvious situation of this type is when a relatively stable pattern of disturbance is present and a distinct group of observatories, all showing either $+\Delta H$ or $-\Delta H$, suddenly or gradually undergo a significant change in the level of disturbance without change in sign while at the same time there is no significant change in the disturbance at other observatories. Any attempt to maintain circuit continuity in the ionosphere as a function of time through this sequence is necessarily dependent on adjustments to the current system only in the region of change and those regions which are unobserved. Belief in complete ionospheric closure at these times would appear to be based more on faith than on logic. (3) More generally from repeated viewings one recognizes that the major sectors of the pattern (i.e., the positive and negative bay auroral disturbances and the polar cap disturbance) are not disturbed proportionally at different times. Thus, although all sectors tend to be either disturbed or quiet for the same periods, the relative and combined intensities of positive and negative bays often vary greatly while the polar cap disturbance level remains relatively stable. Explanation of the various combinations of relative intensity could be sought in terms of closure at lower latitudes which are not represented in the film.

This again invokes the unknown in assuming a closed ionospheric system. (4) For the same reasons as (1) above, current systems which do not close completely in the ionosphere could be constructed compatible with the observed disturbances.

(B) Biased Distributions: Related to item (1) under (A) above it is apparent that any analysis which is based on the universal time period 20^h to 01^h will de-emphasize and in many cases completely miss the presence of $+\Delta H$ positive bay activity at auroral latitudes, and any analysis based on the period 01^h to 04^h is likely to de-emphasize, but not miss, the $-\Delta H$ negative bay activity. This is a direct consequence of the lack of stations below 70^o Mag. Lat. in the Atlantic region. It is interesting to note that Vestine, et al's, (1948) diagrams at two hour intervals illustrating positive bay activity disappearing during progression of a storm show this disappearance at 22^h and 00^h UT. Similarly, Silsbee and Vestine's (1942) widely quoted current diagram shown in Figure 1(C) is based on 3 hour averages centered at 21^h, 00^h, and 03^h UT. As this puts maximum weight on the UT period 20^h to 01^h it is not surprising that the diagram shows a relatively insignificant positive bay sector.

(C) Return Current Question: As noted in Section II Akasofu, et al (1965, 1966) attribute $+\Delta H$ disturbances at auroral latitudes in the afternoon, or evening, hours to return currents from the westward electrojet whose circuit is extended from the early morning hours to the afternoon hours at latitudes slightly greater than those of the $+\Delta H$ disturbance. The following observations from the disturbance film are contrary to this return current interpretation. (1) Periods do exist in which the general level of $+\Delta H$, positive bay, activity is greater than the $-\Delta H$, negative bay, activity. (2) It is quite common to observe $+\Delta H$ disturbances over extended areas in the evening hours which are considerably stronger than $-\Delta H$ disturbances over similar areas at adjacent higher latitudes. (3) At lower latitudes, e.g. $\leq 55^o$, in the same time sector as the $+\Delta H$ disturbance the disturbance is most commonly negative. (4) The $+\Delta H$ disturbance in many cases remains relatively stable while there are large excursions in the negative bay, $-\Delta H$, disturbance. Relative to (B) above it should also be noted that Akasofu, Chapman, and Meng (1965) have selectively used diagrams for 24^h UT from Vestine (1948) and for 21^h15^m from Fukushima (1953) as support for their interpretation.

(D) Repetition of Pattern at the Same UT on Successive Days: The film presentation, or examination of magnetograms, makes one conscious of the great variability of high latitude disturbance levels as a function of UT and date. The film also conveys an impression of irregular movements of the pattern with local time. Although such movements take place, as discussed in (E) below, much of this impression is caused by changes in intensity and small shifts in latitude accompanying intensity changes rather than a movement of the configuration in magnetic local time. One test of pattern stability is its repeatibility from day to day. Examples of repetitious behavior of bays on successive days have been given in the past for specific observatories (Chree, 1913; Wells, 1947; Heppner, 1954). The film permits one to examine this type of stability for the complete pattern in detail. Taking the identical UT on successive days is an extreme test which apriori the author thought would show general agreement but not detailed agreement. It has become apparent however that detailed correspondence between successive days frequently exists. Figure 5 shows the disturbance vectors at 15^h40^m UT on 7 successive days in which the 3-hour Kp values for 15^h- 18^h range from 2^+ to 5^+. The degree of detailed correspondence in the vector configurations is obvious. To illustrate that the repeatibility is not a peculiar properly of this UT, an example of two consecutive days is given for 03^h40^m UT in Figure 6. It should be noted that although these are selected examples they are not the findings of a careful selection. A large number of examples of equally detailed repetition could be extracted from the film.

(E) Pattern Movements in Geomagnetic Time: The previous subsection, (D) above, emphasized the stability of the disturbance vector pattern. However, we know quite well from previous studies that the pattern is not completely fixed in geomagnetic time or in any other known time scale even when we take into account possible false impressions caused by latitude shifts. Space will not permit a general discussion here but some generalization on movements of the + to -ΔH discontinuity in magnetic local time as seen in movie form is important. The first generalization is that this discontinuity persists most of the time within a sector of several hours near 22^h magnetic local time. It is thus convenient to visualize a pattern fixed in magnetic local time (i.e., relative to the sun) and examine deviations from the fixed position. When this is done it is rather surprising to find that for the majority of time the transition from + to -ΔH disturbance progresses rather smoothly successively from one observatory to the next as the earth rotates relative to the fixed position. This is essentially just a restatement of the stable condition subject to the observatory distribution which does not permit distinction between a smooth transition and irregular, small time jump, transitions over hour angles less than the east-west separation of successive observatories. This apparent smooth transition is usually interrupted several or more times per day by discrete jumps in which the discontinuity shifts suddenly (e.g., within 10 or 20 minutes) to an earlier geomagnetic local time. However it is apparent that these sudden jumps are in most cases confined to time sectors less than 3 hours; that is, they do not extend far enough back in local time to wipe out the positive bay sector. Figure 7 between 8:40 and 09:00 UT illustrates a small jump for the case of a weak disturbance. Following such sudden shifts to earlier local time the discontinuity in geomagnetic local time gradually returns to roughly the same time zone where it was located prior to the shift. This is an interesting feature in that the return to the previous location appears to progress approximately at the earth's rate of rotation. If correct, this implies that one cannot visualize the pattern entirely in terms of position relative to the sun (i.e., local time) but must also allow for the possibility that the pattern to some degree rotates with the earth and becomes interrupted when it rotates into the time zone of the + to -ΔH discontinuity.

The sudden shifts discussed above are accompanied by increases in negative bay intensity and are undoubtedly associated with auroral break-ups. A more complete discussion of the time morphology of these events and other features is beyond the scope of this presentation.

(F) <u>Other Comments</u>:

1. Although intensity vs. location in pattern has been largely ignored in the above discussion, one feature that appears consistently which has apparently not been noted previously should be mentioned. This is the persistence of the positive bay (+ΔH) disturbance for

sometime after a negative bay has largely decayed followed an active period. Figure 8 is a typical example. Figure 7 also gives some indication of this behavior although in this case there is also a local time shift in the region of maximum negative bay activity.

2. Examination of Figures 5-8 illustrates the nearly identical behavior of the polar cap disturbance at Thule and Resolute Bay. This is a general condition which appears to become invalid only during quiet times or periods of weak disturbance. The disturbance at Godhavn often, but not always, duplicates that of Thule and Resolute Bay. These features have previously been noted by Fairfield (1963). An additional feature of this stable polar cap behavior is that the perpendicular to the Thule and Resolute Bay disturbance vector consistently intersects the nighttime electrojet region either at the $+\Delta H$ to $-\Delta H$ local time discontinuity or to the positive bay ($+\Delta H$) side of this discontinuity within several hours of the local time at the discontinuity.

3. Considerable insight into disturbance and auroral mechanisms might be obtained if one could determine the local time and latitude where a disturbance begins at high latitudes. It has frequently been implied that a disturbance begins with the sudden onset of a negative

bay. This is a misleading concept. Both the film, discussed above, and auroral studies (e.g., Heppner, 1954) show that the sudden onset or rapid growth of a negative bay is a feature which occurs within a previously existing disturbance pattern. One must thus look at the transition from very quiet periods to disturbed periods if a point of origin is to be found. The initial study of the film has not revealed a point of origin; in fact the impression is obtained that there is usually a slow growth not particularly confined to either the polar cap or a given sector. This point, and others, will be treated in greater detail following future more detailed studies with the film technique.

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Figure Captions

Figure 1 High latitude current systems: Chapman (A) and (B), Silsbee and Vestine (C), Nagata (D), Nagata and Iijima (E) and (F) (See text).

Figure 2 Contours of equal disturbance of the horizontal component from Harang (1946): solid lines for $+\Delta H$, light dashed lines for $-\Delta H$. Time designated is local standard time which is roughly 1 to 1.5 hours earlier than geomagnetic local time for the meridians studied.

Figure 3 Idealized patterns of simultaneous auroral activity and magnetic disturbance from Heppner (1954). Time designated is local standard time which is approximately 1.5 hours later than geomagnetic local time for region studied.

Figure 4 Kp indices for period covered in film study.

Figure 5 Disturbance vectors at 15:40 UT on 7 consecutive days (See Table 1 for observatory identification).

Figure 6 Disturbance vectors at 03:40 UT on two consecutive days.

Figure 7 Disturbance vectors at 20 min. intervals 08:00 to 09:00, October 10, 1957.

Figure 8 Disturbance vectors at 20 min. intervals 09:20 to 11:00, October 12, 1957.

Table I

	Observatories	Geomagnetic Latitude °N
1.	Thule	88.0
2.	Resolute Bay	82.9
3.	Godhavn	79.8
4.	Murchison Bay	75.3
5.	Baker Lake	73.7
6.	Tikhaya Bay	71.1
7.	Julianehaab	70.8
8.	Reykjavik	70.2
9.	Yellowknife	69.0
10.	Churchill	68.7
11.	Cape Chelyuskin	66.3
12.	Kiruna	65.3
13.	College	64.7
14.	Murmansk	64.1
15.	Dixon Island	63.0
16.	Lerwick	62.5
17.	Cape Wellen	61.8
18.	Meanook	61.8
19.	Tixie Bay	60.4
20.	Sitka	60.0
21.	Nurmijarvi	57.9
22.	Agincourt	55.0
23.	Victoria	54.1
24.	Srednikan	53.2
25.	Yakutsk	51.0

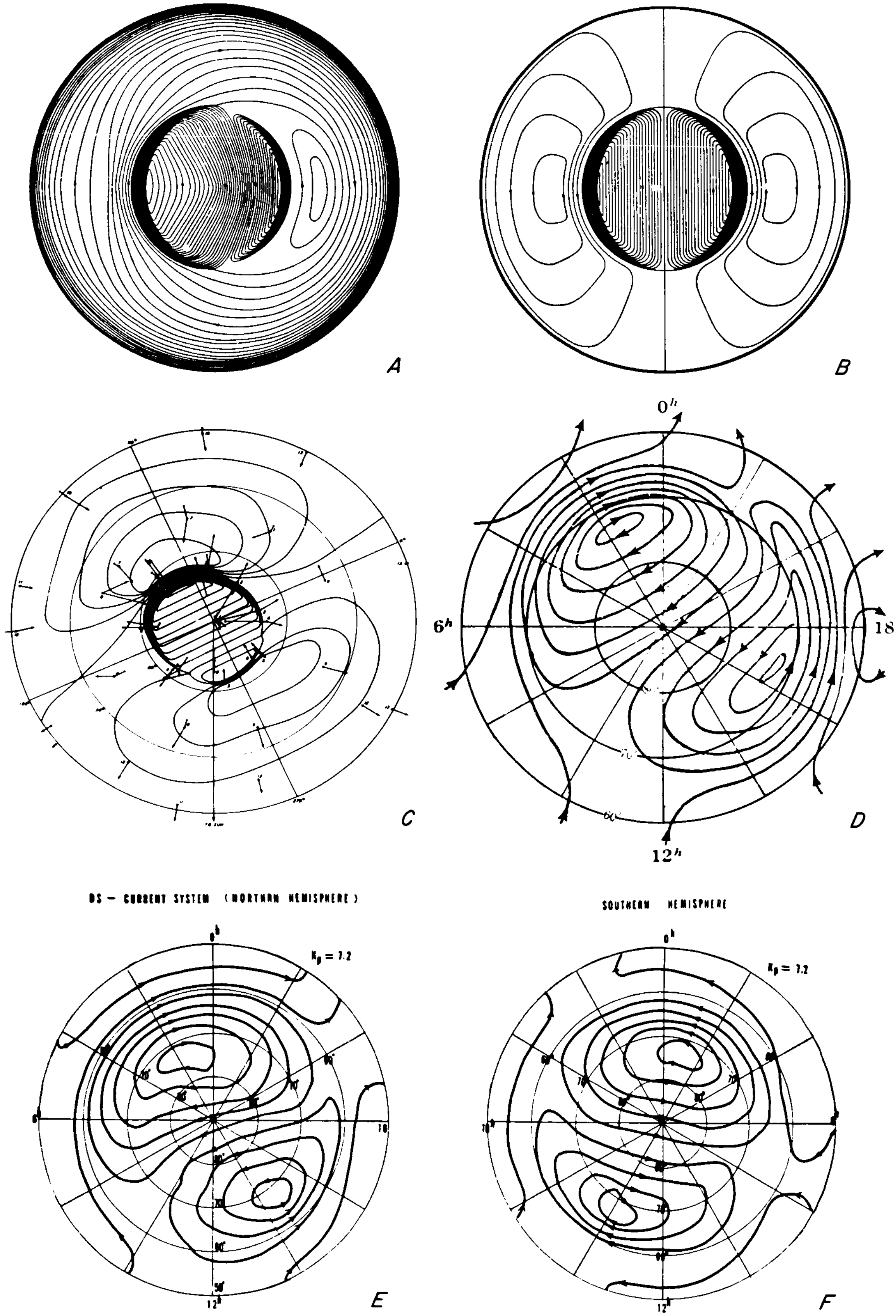

A
B
0h
6h
18h
12h
C
D
DS — CURRENT SYSTEM (NORTHRN HEMISPHERE)
SOUTHERN HEMISPHERE
Kp = 7.2
Kp = 7.2
E
F

FIGURE 1

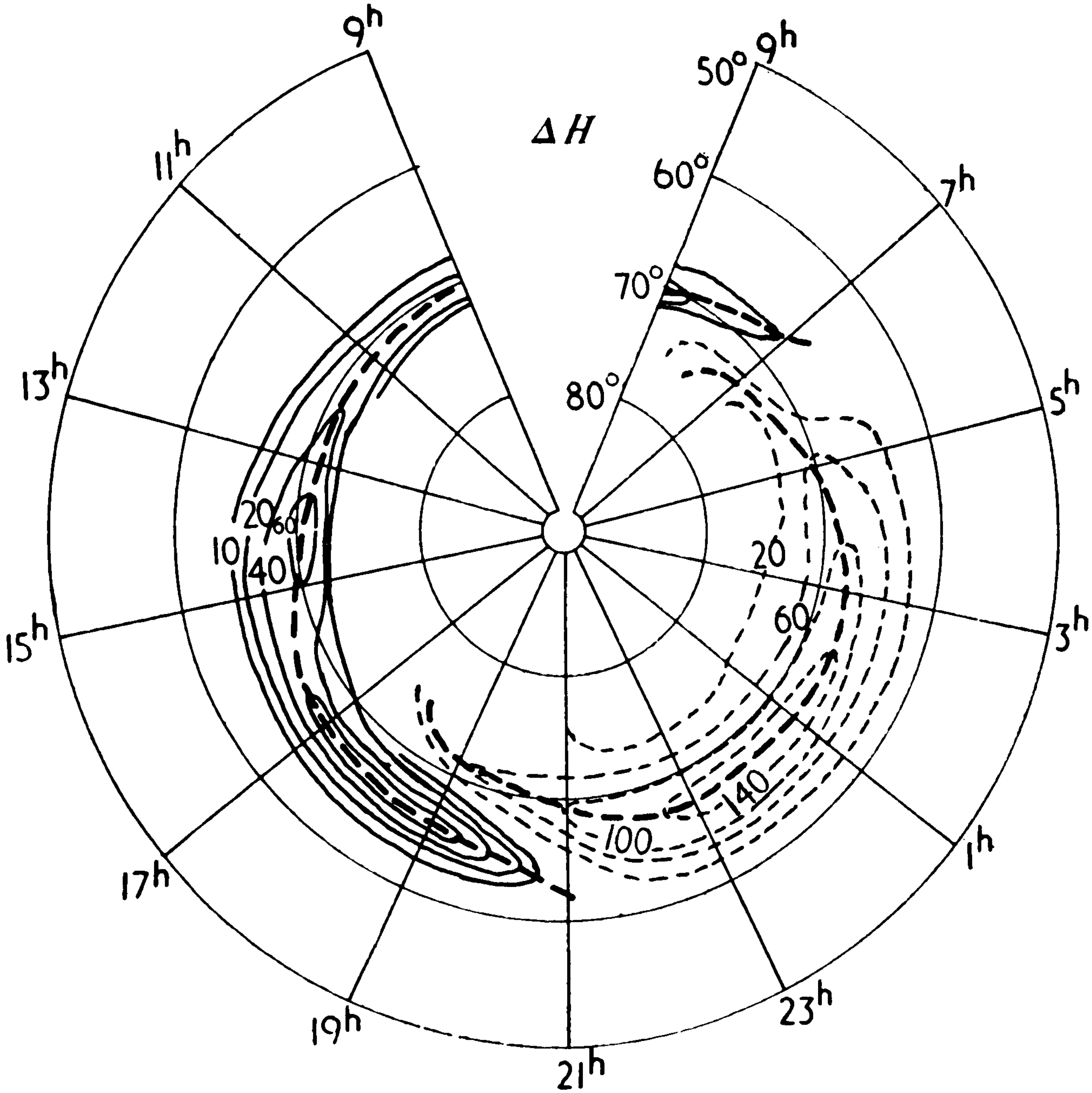
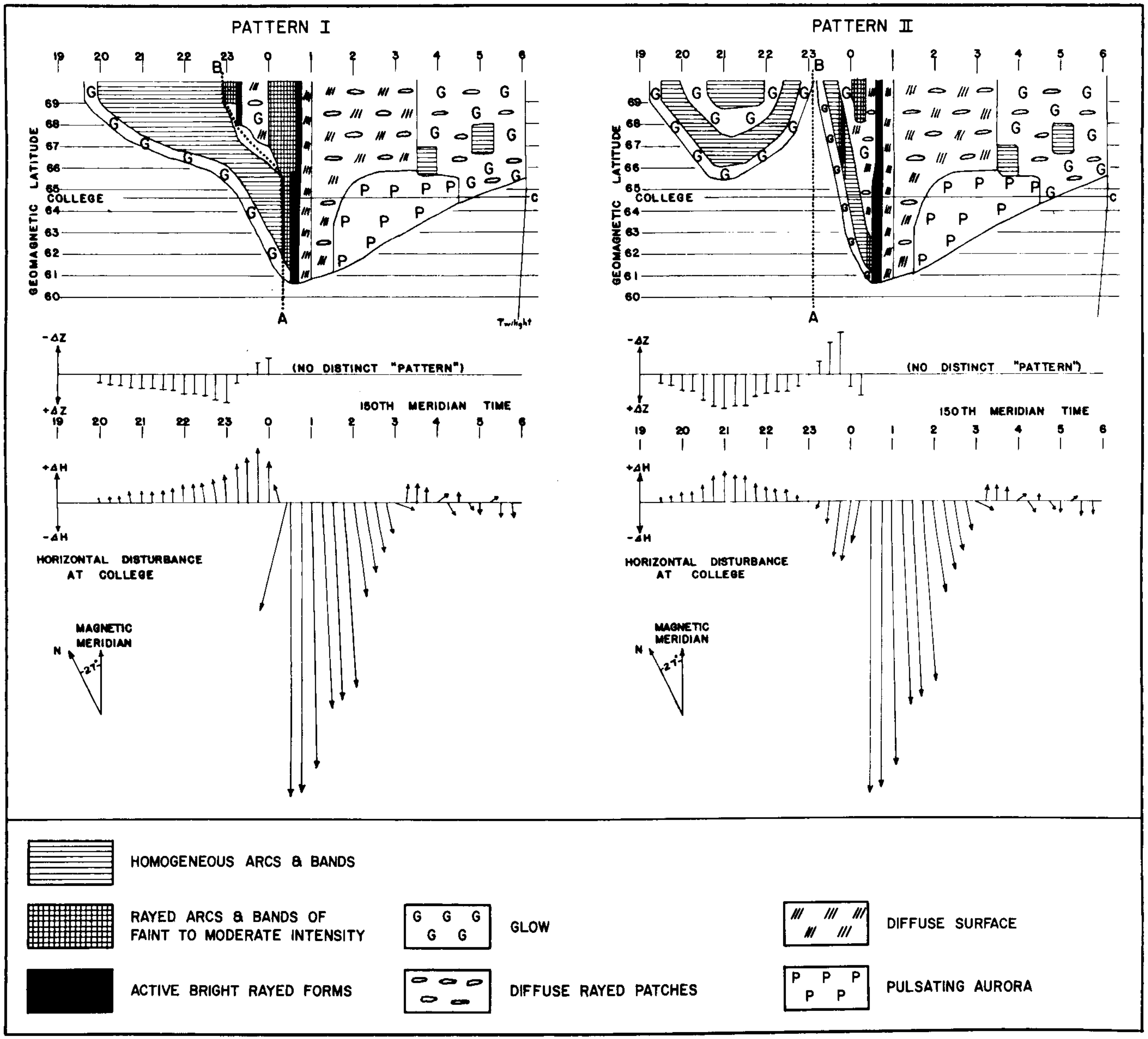

ΔH
9h
11h
13h
15h
17h
19h
21h
23h
1h
3h
5h
7h
9h
50°
60°
70°
80°
10
20
40
60
20
60
100
140

FIGURE 2



PATTERN I
PATTERN II
GEOMAGNETIC LATITUDE
COLLEGE
Twilight
(NO DISTINCT "PATTERN")
150TH MERIDIAN TIME
HORIZONTAL DISTURBANCE AT COLLEGE
MAGNETIC MERIDIAN
HOMOGENEOUS ARCS & BANDS
RAYED ARCS & BANDS OF FAINT TO MODERATE INTENSITY
ACTIVE BRIGHT RAYED FORMS
GLOW
DIFFUSE RAYED PATCHES
DIFFUSE SURFACE
PULSATING AURORA

FIGURE 3

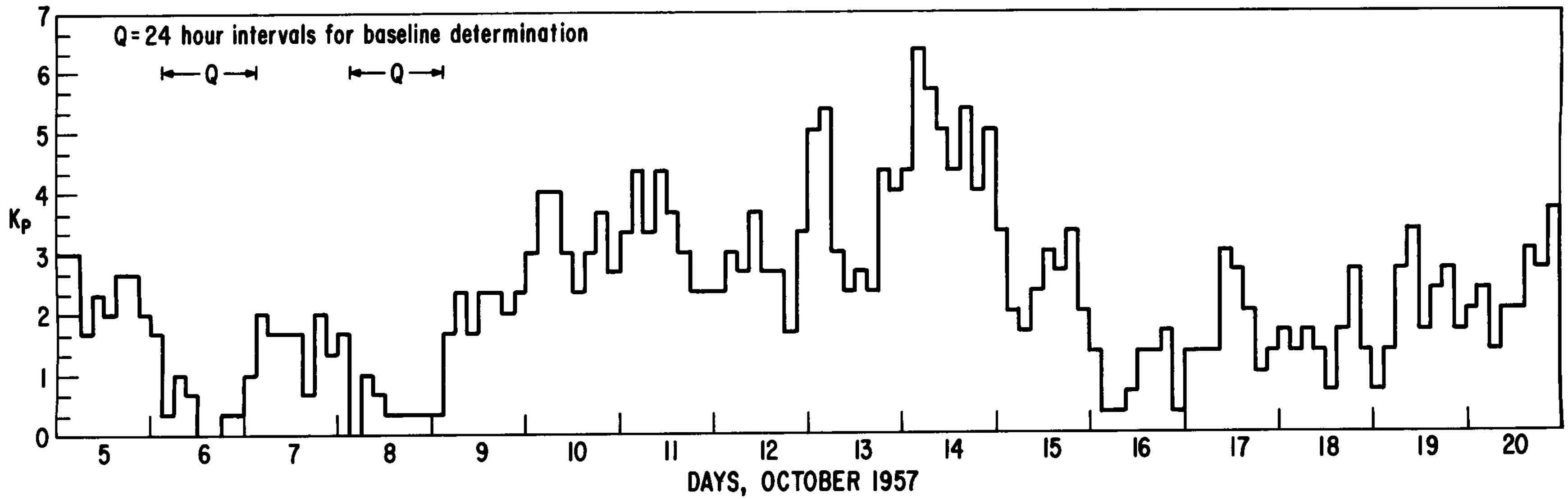

Q=24 hour intervals for baseline determination
Q
Q
Kp
0
1
2
3
4
5
6
7
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
DAYS, OCTOBER 1957

FIGURE 4

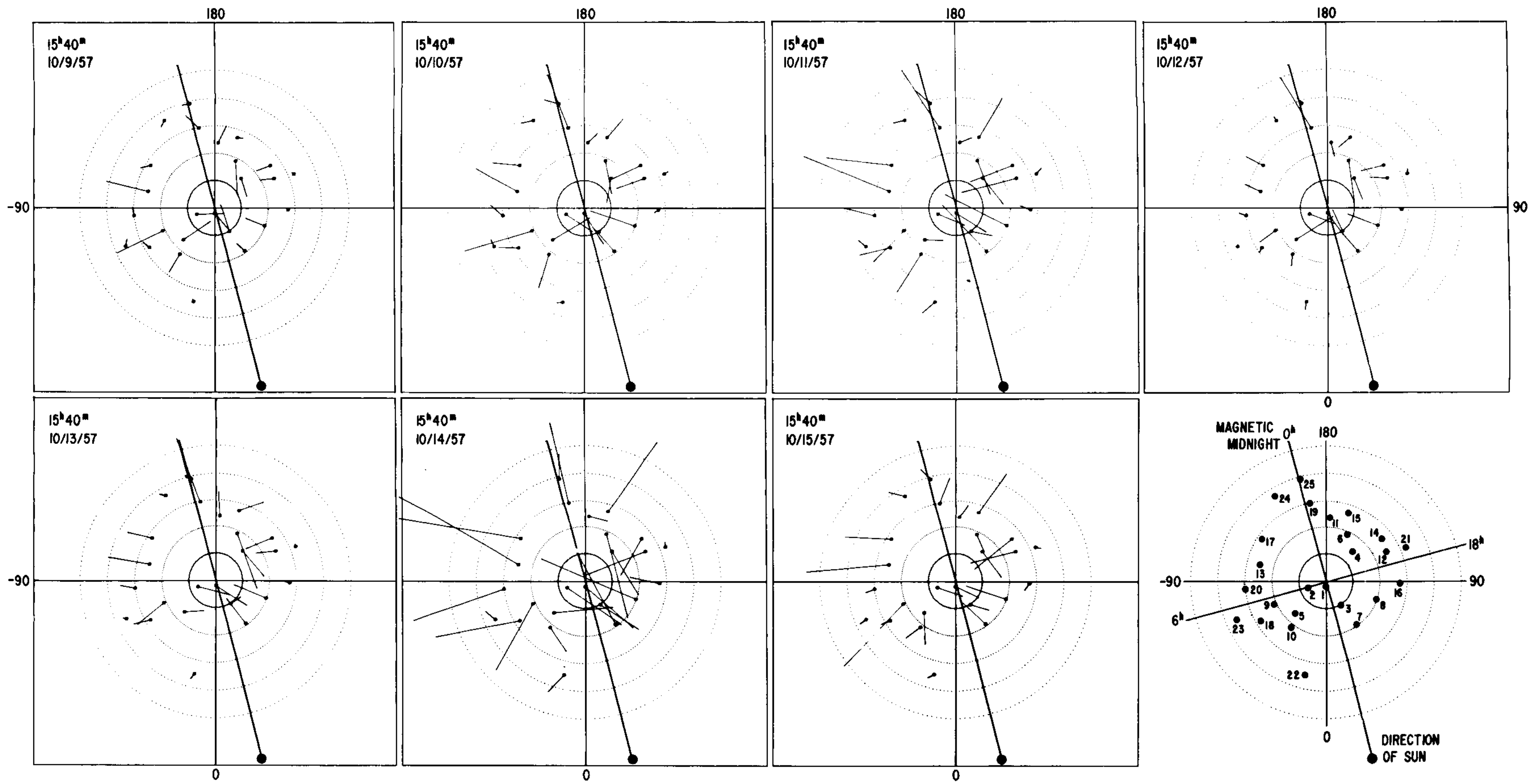

15h40m
10/9/57
15h40m
10/10/57
15h40m
10/11/57
15h40m
10/12/57
15h40m
10/13/57
15h40m
10/14/57
15h40m
10/15/57
180
-90
90
0
MAGNETIC MIDNIGHT 0h
18h
6h
DIRECTION OF SUN

FIGURE 5

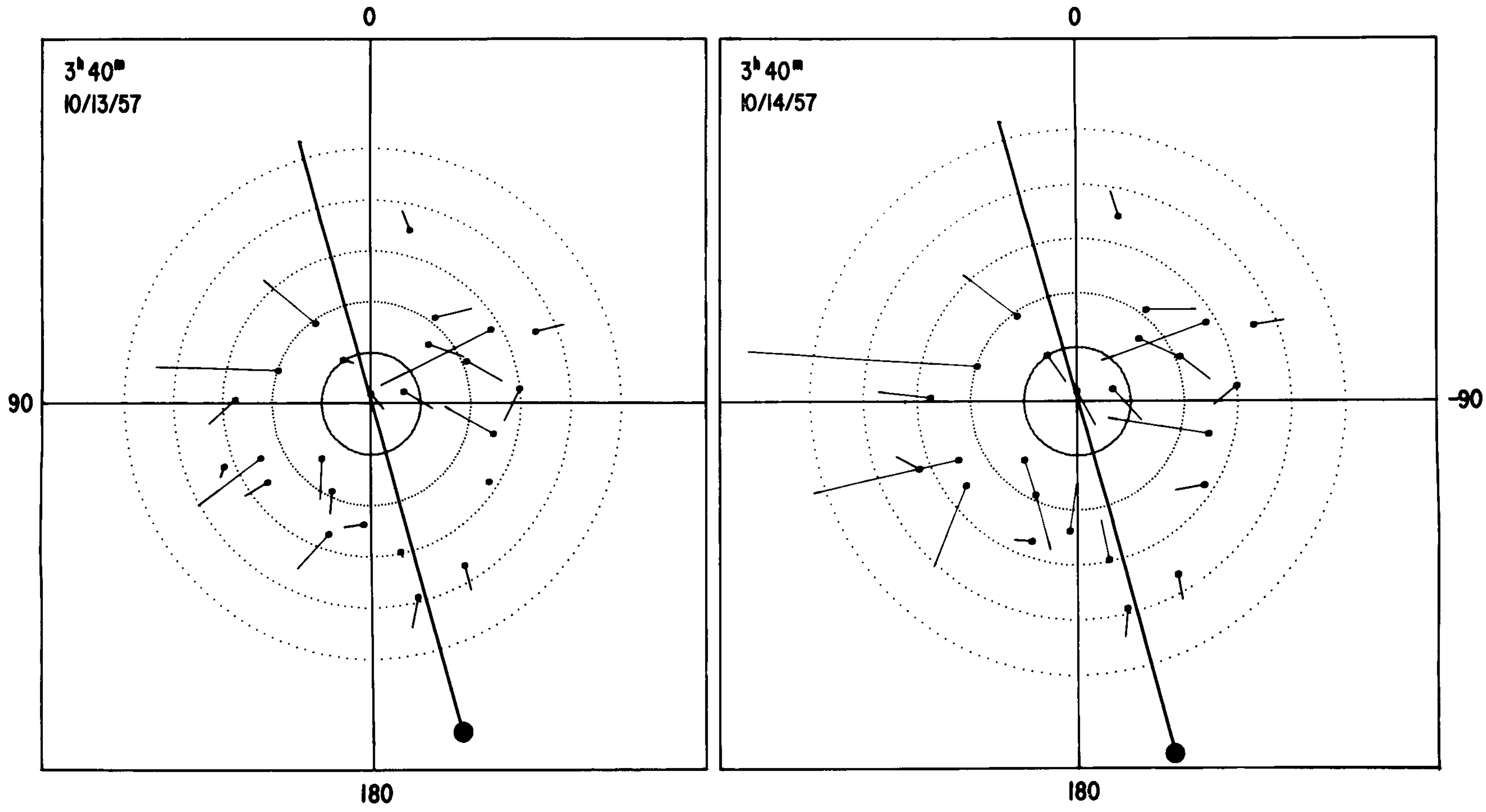
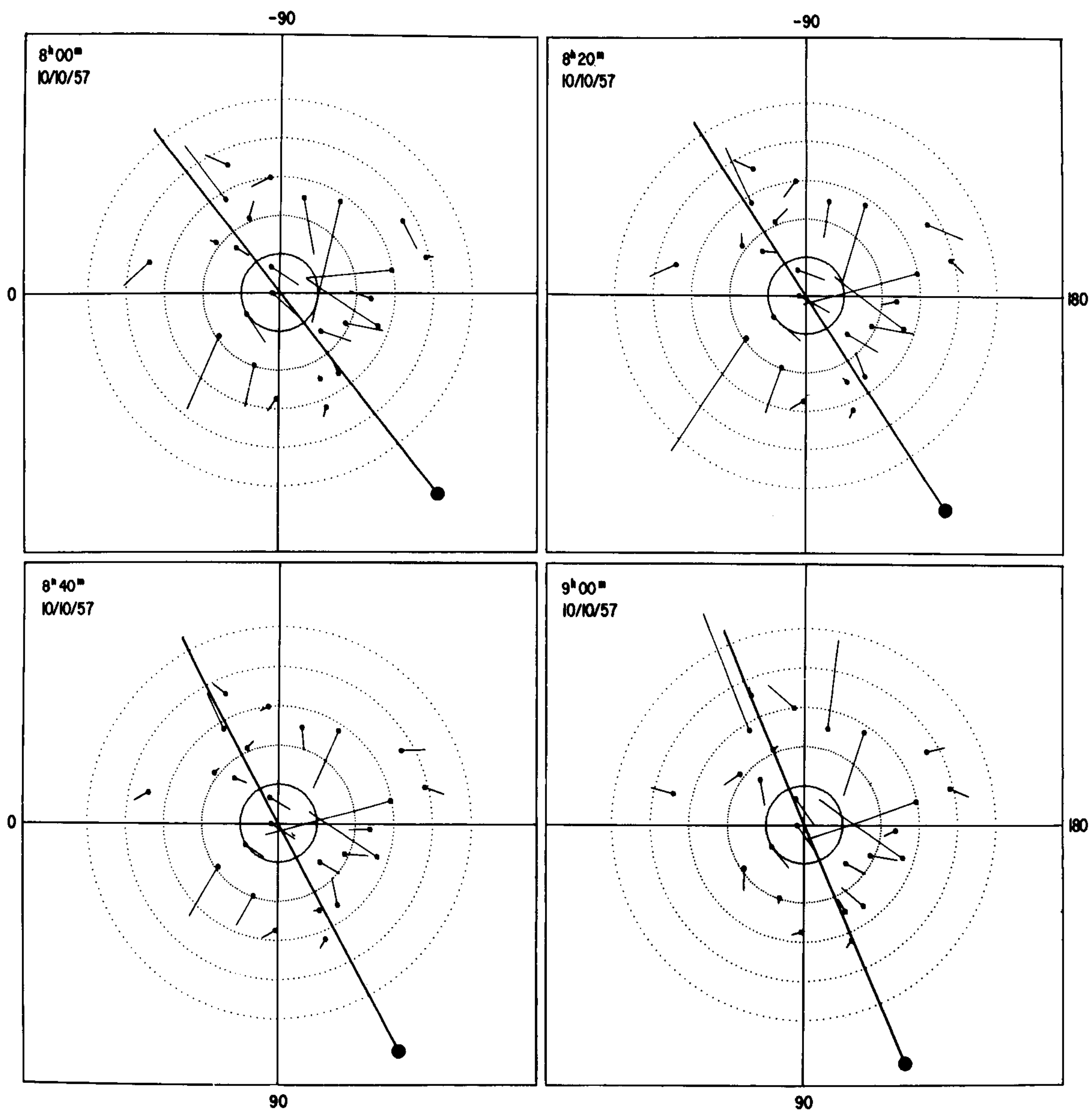
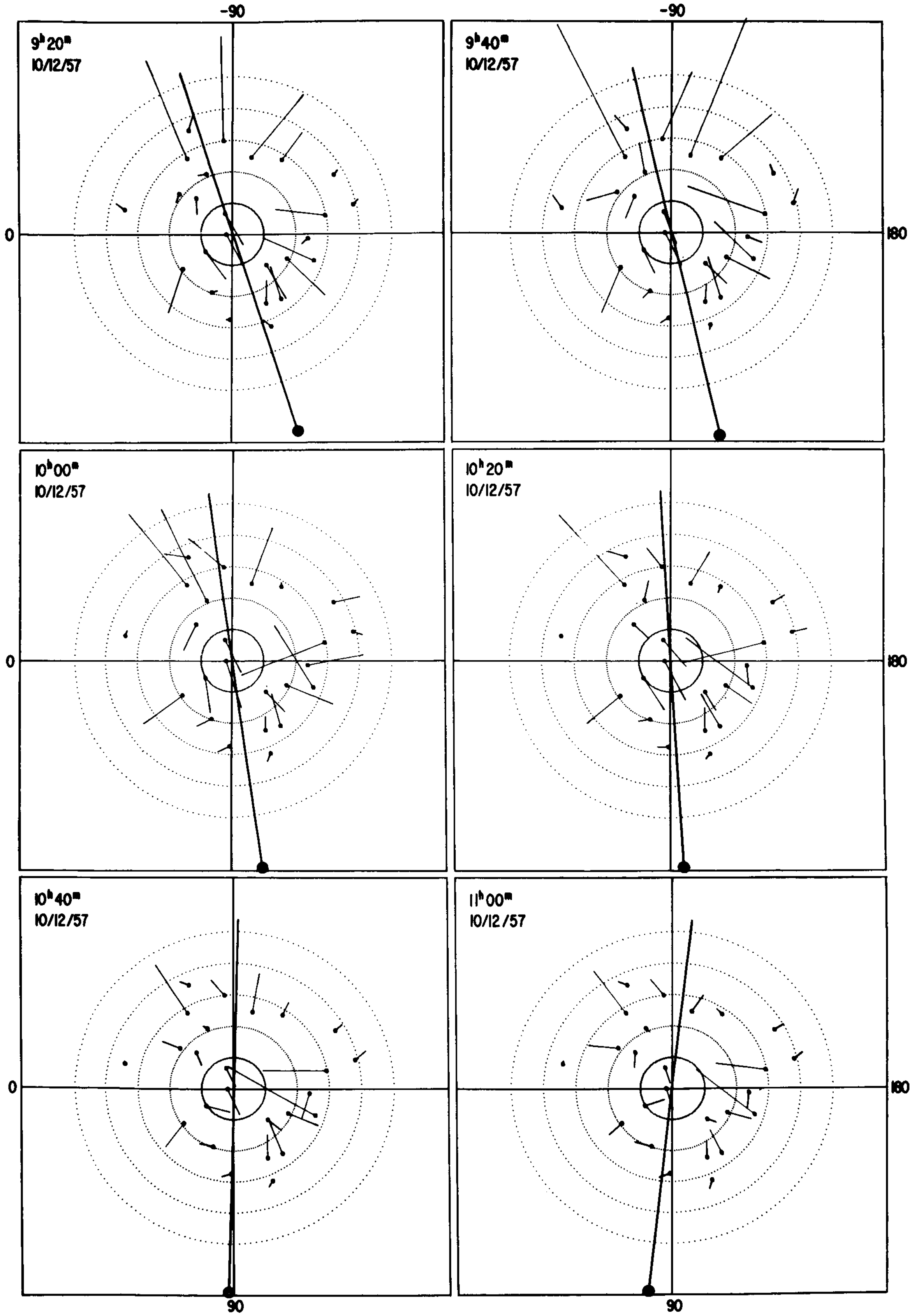


FIGURE 6



-90
-90
8^h00^m
10/10/57
8^h20^m
10/10/57
0
180
8^h40^m
10/10/57
9^h00^m
10/10/57
0
180
90
90

FIGURE 7



-90
-90
9h20m
10/12/57
9h40m
10/12/57
0
180
10h00m
10/12/57
10h20m
10/12/57
0
180
10h40m
10/12/57
11h00m
10/12/57
0
180
90
90

FIGURE 8