REPORT UAG-18

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Solar-Terrestrial Physics

A STUDY OF POLAR CAP AND AURORAL ZONE MAGNETIC VARIATIONS

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"A Study of Polar Cap and Auroral Zone Magnetic Variations"

by

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ABSTRACT

It is shown that the daily magnetic variation in the polar cap on moderately disturbed days is essentially identical to that of extremely quiet days, but significantly enhanced. On the basis of an extensive analysis of magnetic and auroral records, it is inferred that the particular type of magnetic variation identified as the DP-2 mode is not a new and distinct variation, but is one of the manifestations of magnetospheric substorms.

1. Introduction

It was found by Hasegawa [1939] and Nagata and Kokubun [1962] that there exists a particular type of daily magnetic variation in the polar cap, which differs from what one would expect from the dynamo theory of daily magnetic variations. The latter authors denoted this daily variation S_q^p and demonstrated that its equivalent current system resembles the SD current system, consisting of two current vortices.

Later, this daily variation was examined in great detail by Kawasaki and Akasofu [1967] and Feldstein and Zaitzev [1967]. Although their methods of analyses were different, their results (the polar plot of the distribution of magnetic vectors associated with the daily variations) were quite similar. They showed that the polar cap daily variation is essentially a daytime phenomenon and thus their results differ considerably from what was obtained by Nagata and Kokubun [1962]. They concluded also that Nagata and Kokubun's results were representative of a somewhat disturbed rather than an extremely quiet period. [For more details, see a review paper by Feldstein, 1969].

Feldstein and Zaitzev [1967] showed further that the equivalent current system for the quiet day daily variation is a single vortex located in the dayside of the polar cap. This single vortex representation appears to be somewhat oversimplified. However, the salient characteristic of S_q^p, namely, its confinement to the dayside polar cap was demonstrated in both analyses. Hereafter, by the S_q^p variation, we refer to the daily variation elucidated by Kawasaki and Akasofu [1967] or Feldstein and Zaitzev [1967], rather than that by Nagata and Kokubun [1962]. The S_q^p variation has been found to occur even during two extremely quiet days of the IQSY (ΣKp=1+, 0+) and is important in studying disturbance variations, since disturbance variations are, in general, defined as deviations from the quiet day level.

It has been proposed by Nishida et al. [1966] that there exists a distinctive type of world-wide magnetic variations which is not directly associated with enhancements of the auroral electrojet. This variation, subsequently called the DP-2 variation [Nishida, 1968a], has been found to be correlated with changes of the north-south component of the interplanetary magnetic field [Nishida, 1968b]. Nishida also showed that the equivalent current system of the DP-2 variation consists of two "vortices", one in the early afternoon sector and the other in the early morning sector. The former is more intense and covers a larger area than the latter.

It has been suggested by Axford [1969], Nishida and Kokubun [1971] and others that such a magnetic variation might be related to the convection of the magnetospheric plasma. Further, it has recently been suggested by Kokubun [1971], Nishida and Kokubun [1971] and Iijima and Nagata [1971] that the DP-2 or DP-2-like magnetic variations appear before the explosive phase of magnetospheric substorms.

Recently, it has been noted by Svalgaard [1968], Mansurov [1969] and Friis-Christensen et al. [1971] that there is a close correlation between the Z-component variations of polar cap stations and the sector structure of the interplanetary field. From these observations, it has been suggested by Mansurov [1969] and Wilhjelm and Friis-Christensen [1972] that merging can occur between an ecliptic component of the interplanetary magnetic field and the earth's field.

The purpose of this paper is to examine some of these geomagnetic disturbances in the polar cap. [See also Kawasaki and Akasofu, 1972a]. Our study is mainly based on magnetic records on the days selected by Dr. A. Nishida for the Working Group IV, Commission IV of IAGA, and also on those days examined by Nishida [1971] for his studies of the DP-2 variations. These days are called DP-2 days in this paper and are listed in Table 1.

TABLE 1

DP-2 Days

July	16, 1965
July	24, 1965
August	2, 1965
August	14, 1965
September	4, 1965
October	2, 1965
November	30, 1965
December	1, 1965
December	11, 1965

Figures 1 and 2 show the combined H-component records from the standard auroral zone stations for the DP-2 days (College, Cape Wellen, Tixie Bay, Dixon Island, Kiruna, Leirvogur, Fort Churchill, Meanook and, when available, Great Whale River). The upper and lower envelopes give, respectively, the AU and AL indices; the distance between the two envelopes gives the AE index [Davis and Sugiura, 1966].

2. The Quiet Day Daily Magnetic Variation in the Polar Cap

As the first step of our study, we combine each vector component of the magnetic records for each polar cap station for summer days listed in Table 1. Figures 3 through 12 are the results of this analysis. In the upper part of each figure, the upper and lower envelopes of the combined records of the DP-2 days are shown. It seems clear that the envelopes delineate a "daily" variation, together with short-period "fluctuations". The records of Thule are not shown here but also exhibit a "daily" variation of the same type. Added to the envelopes is the record of May 8, 1964, one of the quietest days ($\Sigma Kp=1+$) during the IQSY, which was studied by Kawasaki and Akasofu [1967]. It can be seen that the quiet day variation and the envelopes have a very similar variation, although the magnitude on the DP-2 days is a few times greater than that on May 8, 1964. In order to see more clearly the daily variation on May 8, 1964, the lower parts of Figures 3 through 12 show the same records reproduced at a greater sensitivity scale (x5). These also show the records on May 12, 1964, another quiet day ($\Sigma Kp=5-$); the daily variation is somewhat greater during the period 1200-2400 UT on May 12 than on the corresponding period of May 8 although the sum of the three-hourly Kp indices of the period 1200-2400 UT on May 12 was less than that of May 8, 1964. (The data on May 8, 1964, were digitized at 3 minute intervals whereas those of May 12, 1964, are essentially analog data; this accounts for the retention of high frequency components on the latter day). The tendency for similar variations is seen in both the X- and Y-components (or H and D) from all the polar cap stations.

One important point to be clarified in this connection is the question of whether the enhancement of the daily variation is only an apparent one resulting from the frequent occurrence of disturbances which have a life-time of the order of a few hours (such as substorm variations). We note in this connection that the S_q^p variation exists even on extremely quiet days and that it is unlikely to be due to the superposition of substorm variations, since on such quiet days the interplanetary magnetic field, is in general, fairly steady and has a northward component. On moderately disturbed days, however, it is not possible to exclude the possibility that the enhanced 24-hour component is simply an apparent one. To be more specific, it is possible that the substorm field may contain a long period variation (say 6 to 12 hours) upon which are superposed the intense fluctuations more usually identified as substorms. Thus this long period variation of the substorm field may contribute to the daily variation in one direction for a period of time at a polar cap station and, as the earth rotates, it may contribute in the opposite direction during a later period. However, it is important to note that both the upper and lower envelopes clearly delineate a 24-hour component in spite of the fact that polar magnetic substorms of differing intensities and durations occurred frequently (see Figure 1) on the superposed days.

We may infer the vector distribution of the 24-hour variation on the basis of our analysis of the S_q^p variation on May 8, 1964 [Kawasaki and Akasofu, 1967]. Note that both Kawasaki and Akasofu [1967] and Feldstein and Zaitzev [1967] showed that the S_q^p variation is very different from the SD type variation; for details of the harmonic analysis of S_q^p, see Kawasaki and Akasofu [1967].

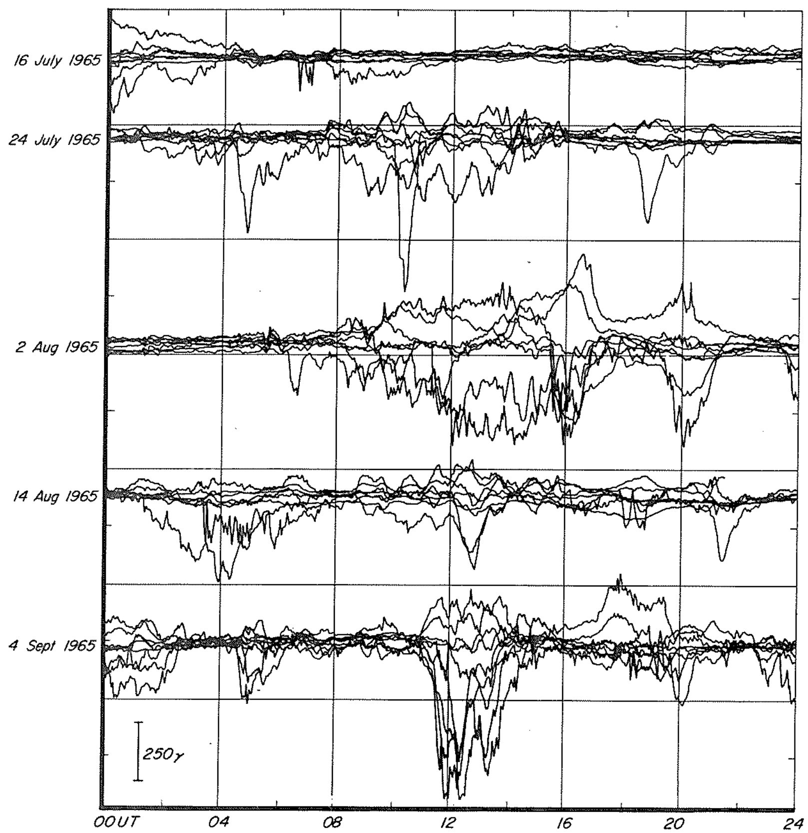


Fig. 1. Auroral electrojet indices of summer DP-2 days listed in Table 1.

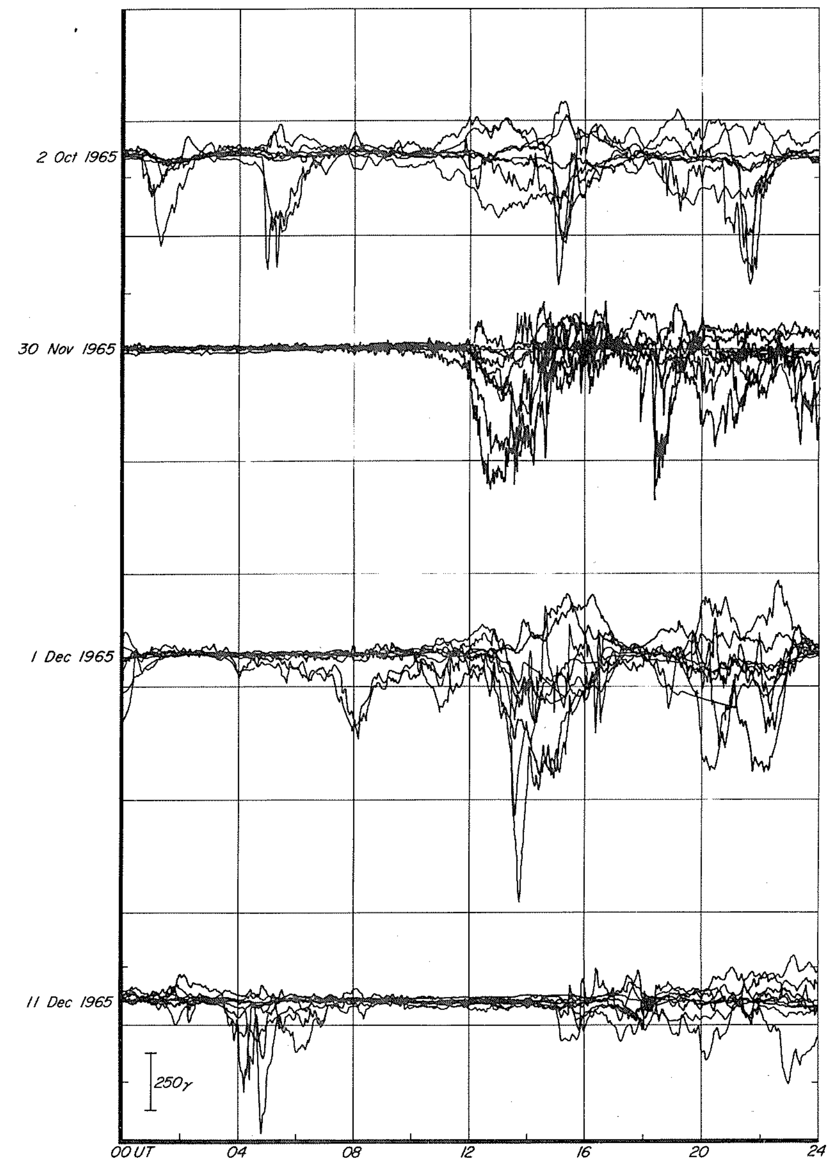


Fig. 2. Auroral electrojet indices of winter DP-2 days, listed in Table 1.

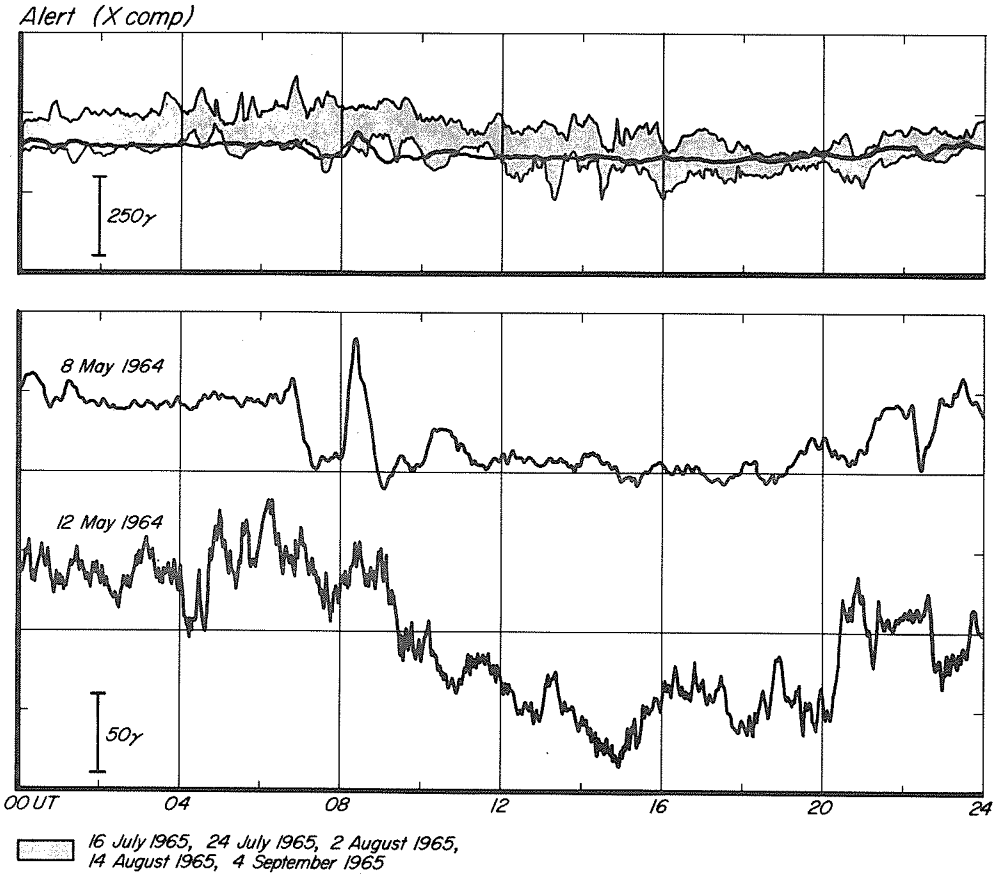


Fig. 3. Superposed records of Alert X-component on summer DP-2 days and quiet days: May 8 and May 12, 1964.

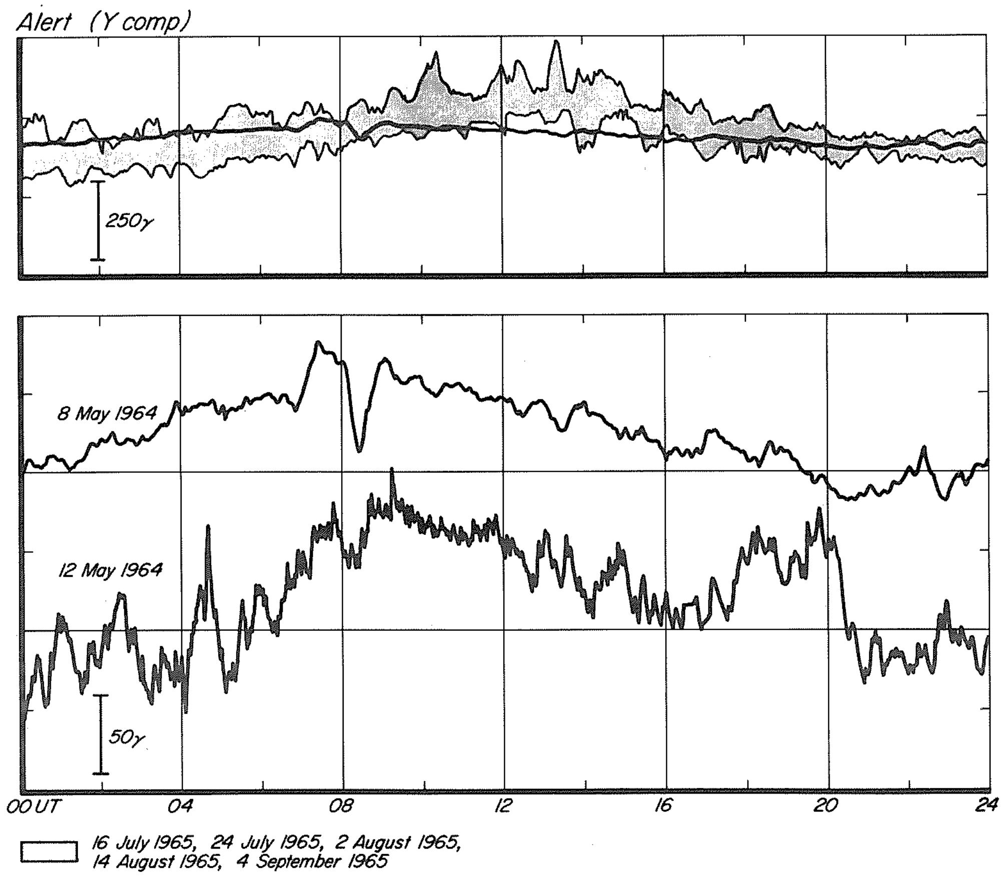


Fig. 4. Superposed records of Alert Y-component on summer DP-2 days and quiet days: May 8 and May 12, 1964.

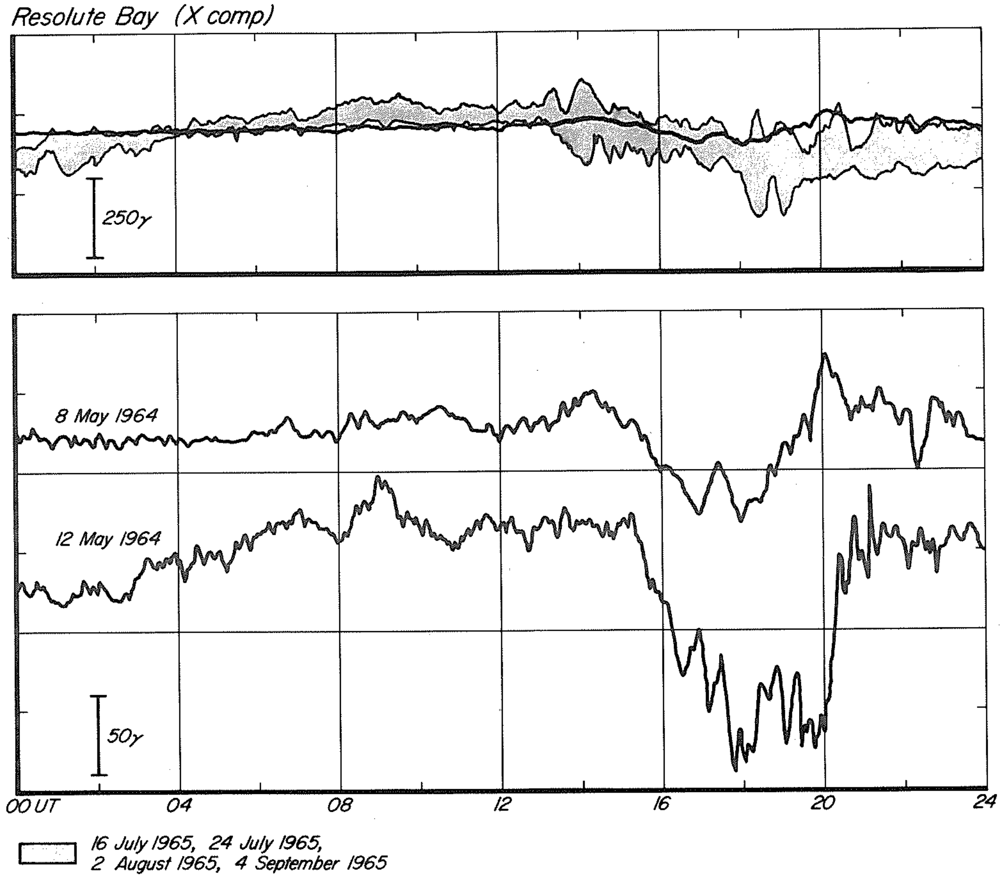


Fig. 5. Superposed records of Resolute Bay X-component on summer DP-2 days and quiet days: May 8 and May 12, 1964.

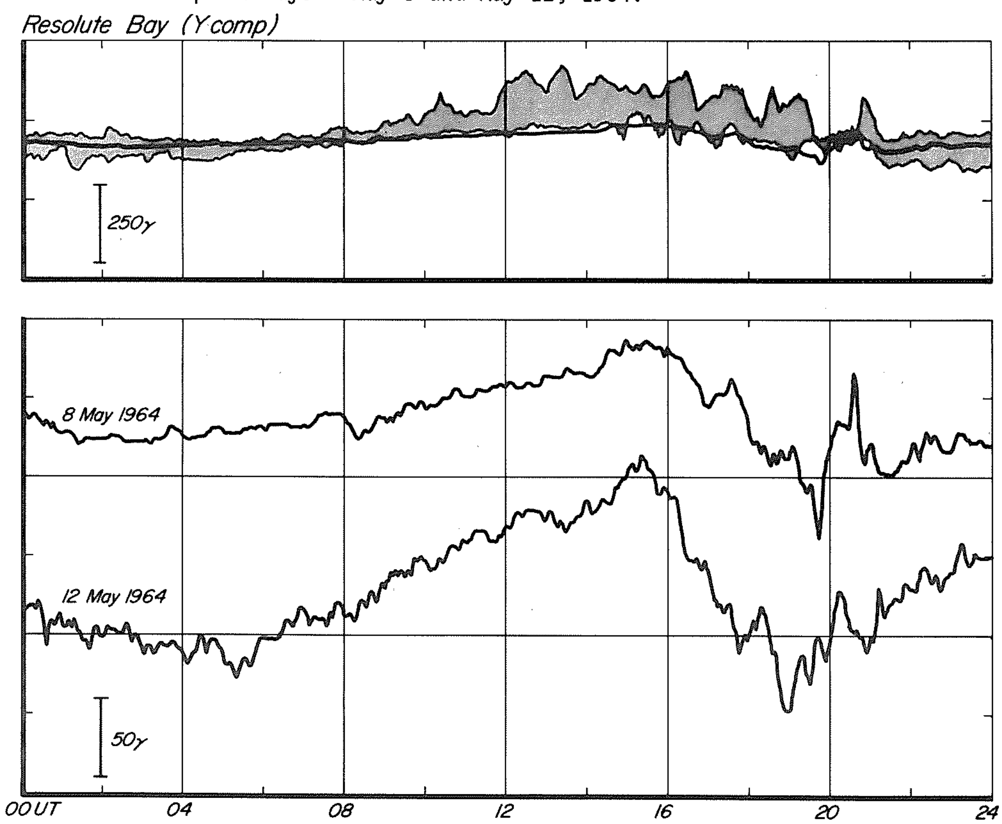


Fig. 6. Superposed records of Resolute Bay Y-component on summer DP-2 days and quiet days: May 8 and May 12, 1964.

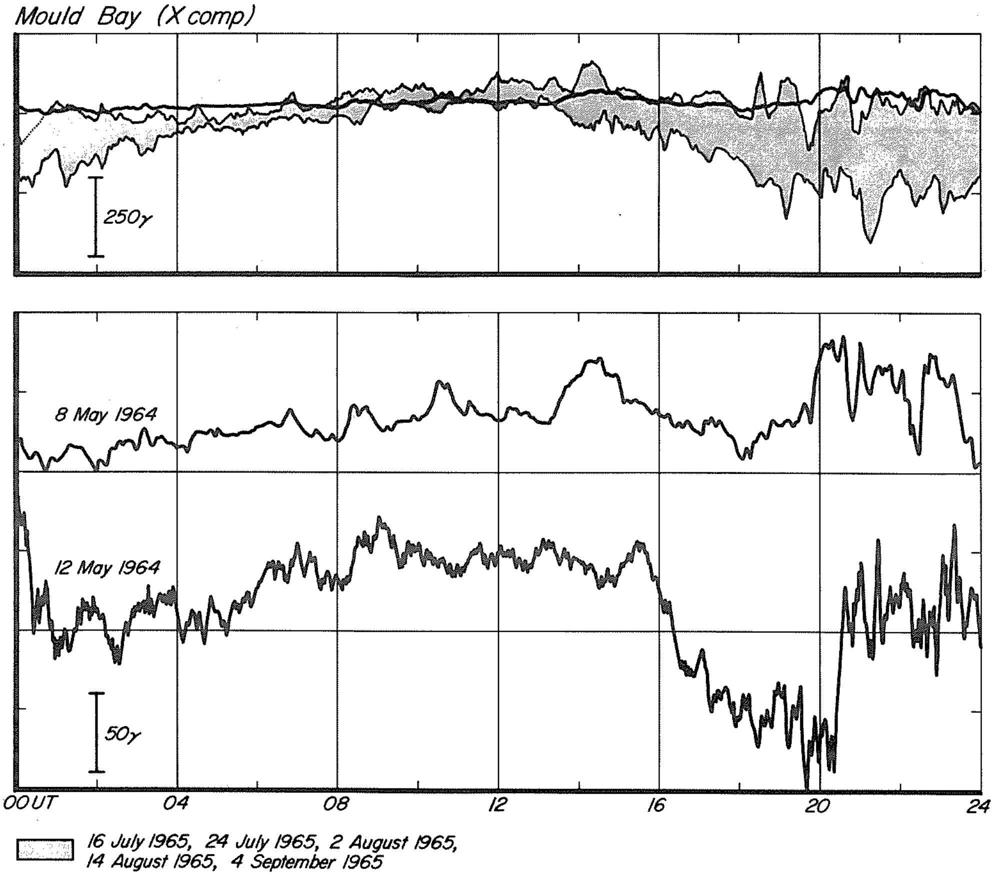


Fig. 7. Superposed records of Mould Bay X-component on summer DP-2 days and quiet days: May 8 and May 12, 1964.

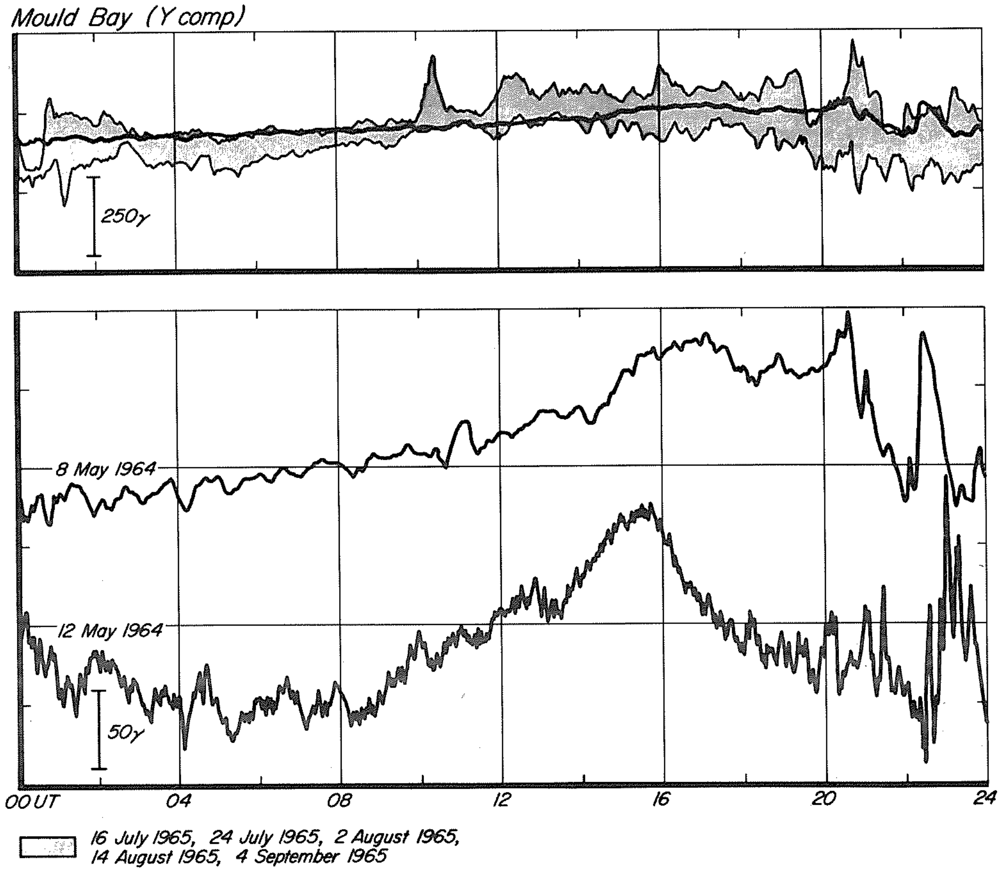


Fig. 8. Superposed records of Mould Bay Y-component on summer DP-2 days and quiet days: May 8 and May 12, 1964.

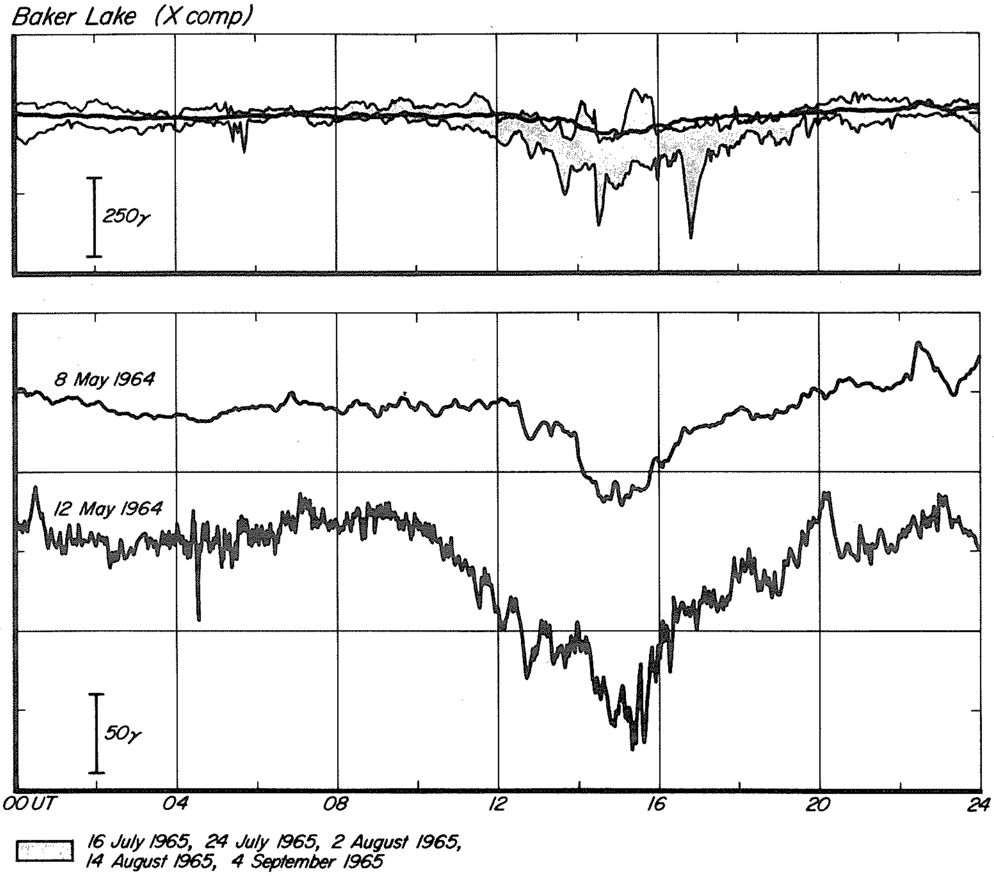


Fig. 9. Superposed records of Baker Lake X-component on summer DP-2 days and quiet days: May 8 and May 12, 1964.

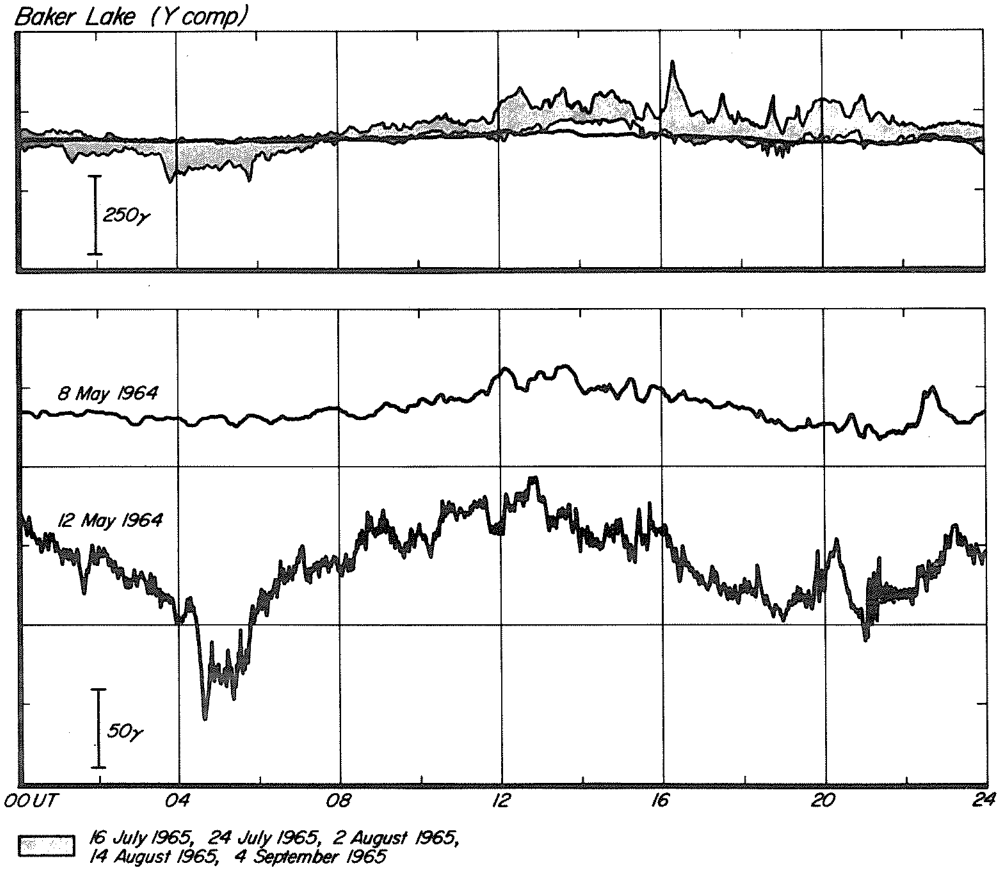
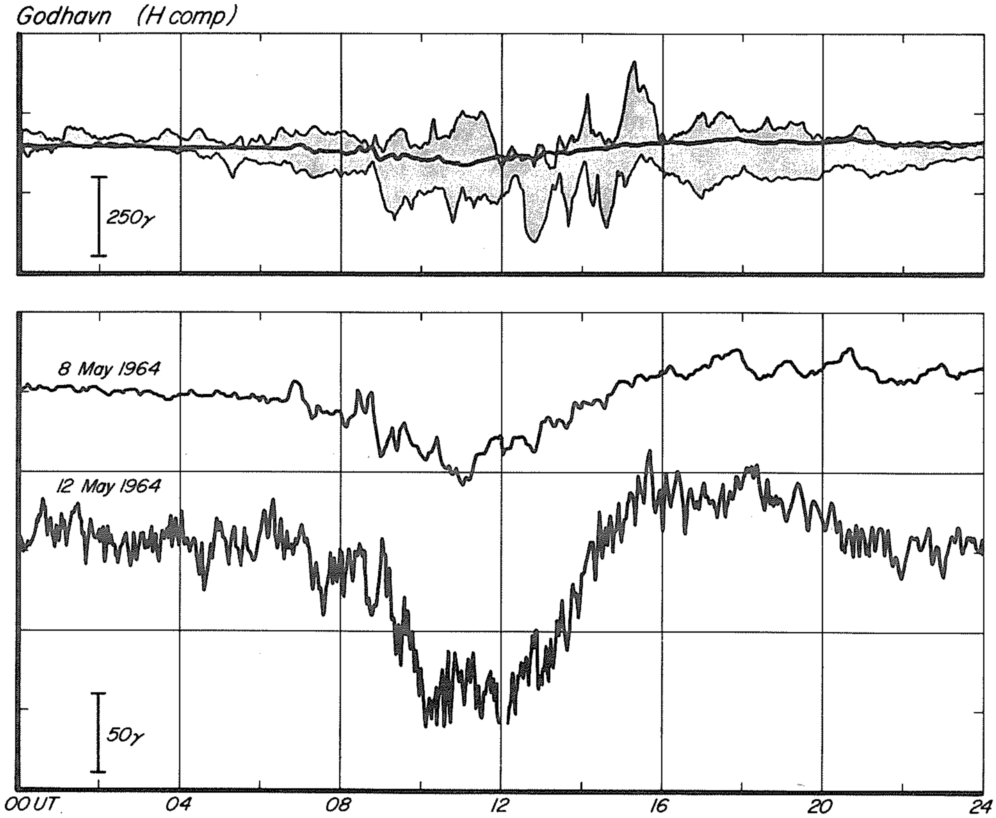
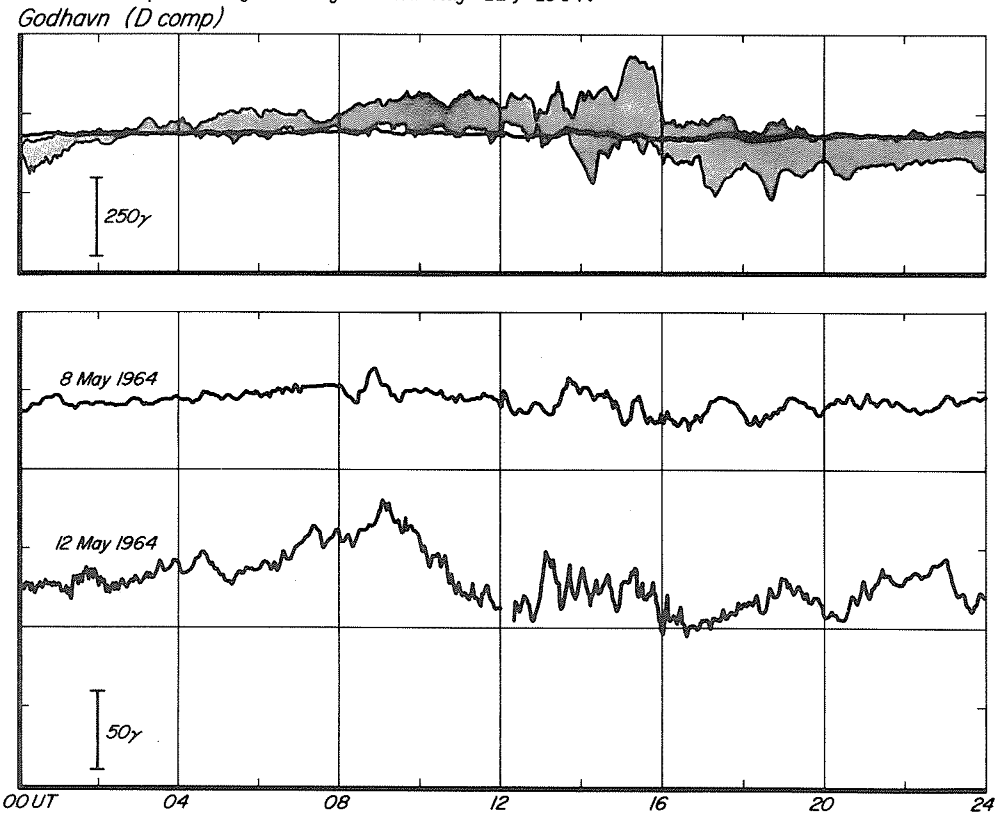


Fig. 10. Superposed records of Baker Lake Y-component on summer DP-2 days and quiet days: May 8 and May 12, 1964.



16 July 1965, 24 July 1965, 2 August 1965, 14 August 1965, 4 September 1965

Fig. 11. Superposed records of Godhavn H-component on summer DP-2 days and quiet days: May 8 and May 12, 1964.



16 July 1965, 24 July 1965, 2 August 1965, 14 August 1965, 4 September 1965

Fig. 12. Superposed records of Godhavn D-component on summer DP-2 days and quiet days: May 8 and May 12, 1964.

3. Relationships between the Field of the DP-2 Variations and Polar Magnetic Substorm Field

It has been proposed by Nishida [1968a, b, 1971] that many short-period geomagnetic fluctuations on moderately disturbed days are distinct from polar substorm fields. We have made an extensive re-examination of this particular point by analyzing both auroral zone and polar cap magnetic records. Figures 13 through 21 summarize the results of this analysis. In each of the figures, the interplanetary magnetic field angle θ observed by IMP 3, the AU and AL indices and both the X-and Y-(or H and D) component records of several polar cap stations are plotted. Following Nishida, the interplanetary records have been shifted approximately 20 minutes later in time with respect to the ground records to obtain the best correlation with the polar cap data. Arnoldy [1971] has shown that the auroral electrojet index (AE) is best correlated with the southward-directed field B_S in the solar magnetospheric coordinate system integrated over the hour preceding the hourly average of AE; we have used the interplanetary magnetic field angle θ in solar ecliptic coordinates in the analysis of this section, since in most of the cases studied here the variations in θ are clearly related to those in B_S.

According to Nishida [1968a, b, 1971], the major characteristics of the DP-2 variations which distinguish them from magnetic substorm variations are that (a) they are not coherent with polar magnetic substorms, (b) they can occur in the absence of polar magnetic substorms, (c) they have a lifetime of about one hour and (d) they are observed world-wide. In Figures 13 through 21, some of the variations shaded are the same as those identified as DP-2 variations by Nishida [1971].

In this section we wish to show that many of the variations which have DP-2 like characteristics or have been previously identified as DP-2 are, in fact, associated with polar magnetic substorms, that is, they are coherent with changes in the auroral electrojet. Figures 13 through 16 are particularly good examples of such coherency. Most of the shaded variations on August 2, 1965 (Fig. 14), August 14, 1965 (Fig. 15) and December 1, 1965 (Fig. 16) in the Alert Y-records have been previously identified as DP-2 [Nishida, 1971]. It is clear the polar cap variations that have been shaded occur in association with the shaded variations in the electrojet indices. Thus, in these examples the variations described as DP-2 are actually coherent with the occurrence of polar magnetic substorms as inferred from the electrojet indices.

Although changes in the interplanetary magnetic field angle θ are often best-correlated with the Alert Y-component records from about 1000 UT to 1700 UT, it is readily apparent in Figures 13 through 21 that such changes are sometimes better correlated with the Alert X-component or with the components of other polar cap stations at other UT hours. Figures 15, 17, 18, 19 and 20 show examples of these correlations between 0000 UT to 1000 UT. These examples suggest that the current system which is responsible for the variations observed in the polar cap is fixed with respect to the sun.

In Figure 15, there is a prolonged period of August 14, 1965 during which the interplanetary field remained southward; the AL index indicates there also existed a prolonged period of polar magnetic substorms. During this interval, the angle θ of the interplanetary field remained fairly constant, yet the Alert-X record exhibited considerable variation. However, it can be seen from an examination of the solar ecliptic magnetic field component Zse (see Figure 23) that the southward-directed field did indeed follow closely the Alert X-component. On the other hand, the Alert X-component exhibits time-variations of the DP-2 type which are not precisely correlated with those of the electrojet indices. The significance of such non-coherent cases will be discussed in Section 4.

Figure 17 shows an example on July 16, 1965 during which the Alert X-component correlates with the interplanetary record but there is little or no correlation with the electrojet indices from 0000 UT to 0800 UT. This period is, however, a period of enhanced electrojet activity. From about 1200 UT to 1800 UT, although the interplanetary magnetic field remained southward there is an apparent absence of polar magnetic substorms. It is seen that there are variations of the DP-2 type most easily seen in the Resolute Bay and Mould Bay records during this interval. Thus, the absence of activity in the electrojet indices coupled with the correlation between the polar cap and interplanetary changes between 1200 and 1800 UT on July 16, 1965 might indicate this is a case of the occurrence of a "pure" DP-2 mode. However, an examination of the Point Barrow magnetogram during this interval shows there occurred a period of negative bays with a maximum deviation of about 180 gammas. Thus, these changes also appear to be substorm-associated.

Figures 18 through 20 are further examples of the correlation between polar cap changes, the AL index and the interplanetary magnetic field angle θ. Most of the variations shaded have obvious counterparts in the auroral records. The changes shaded between 0000 and 0300 UT on December 11, 1965 (Figure 20) are seen in all the records; however, an examination of the magnetograms of several world-wide stations indicate these variations are actually si's and thus not necessarily substorm-related. There can be no doubt, however, that the polar cap and interplanetary field variations between 0300 and 0700 UT are related to the substorm changes which occurred simultaneous to them.

Finally, Figure 21 shows a case in which the onset of DP-2-like variations in the polar cap coincides with the growth of the auroral electrojet. The shaded portions of the Alert and interplanetary records exhibit coherence and thus may be identified as DP-2 variations in the sense of previous investigations. However, the fact that the onset of the polar cap variations coincides with the growth of the electrojet strongly suggests that there is a close relationship between the two types of variations. Indeed, the shaded Alert and AL variations are quite similar. Moreover, the interval starting at about 1200 UT, November 30 and ending at 0300 UT, December 1, 1965 (see Figure 16) during which DP-2-like variations were observed in the polar cap coincides precisely with a period of occurrence of numerous substorms.

Thus, it is concluded from the comparison of auroral electrojet indices and polar cap magnetic changes given in this section that many of the polar cap variations identified as DP-2 are actually manifestations of polar magnetic substorms and hence cannot be ascribed to a current system distinct from that of substorms.

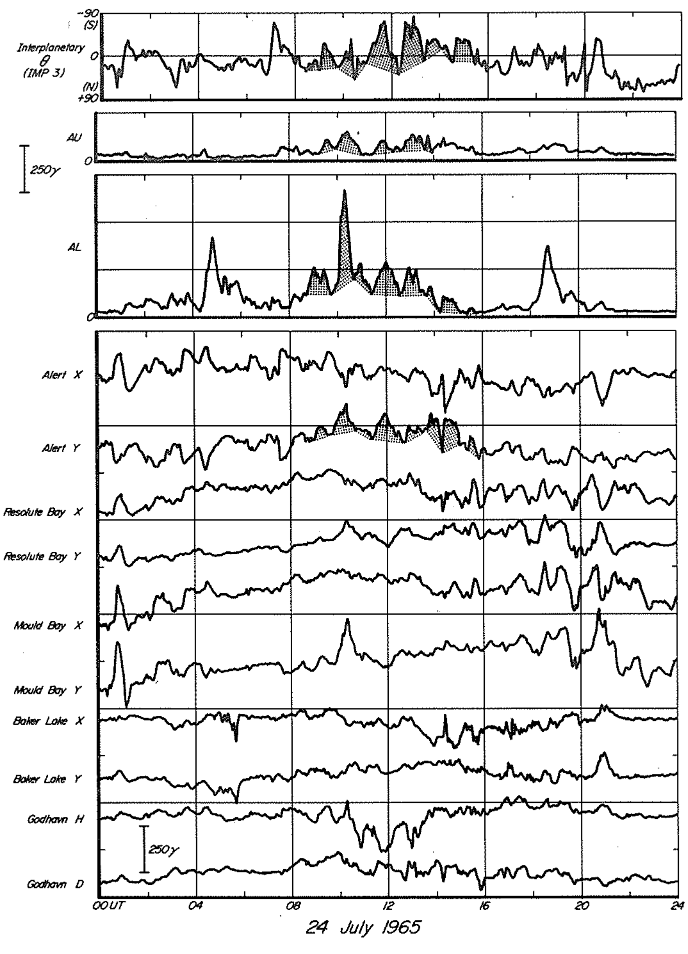


Fig. 13. Polar cap magnetic records, auroral electrojet indices and interplanetary magnetic field angle θ on July 24, 1965.

Note the shift in time of the interplanetary record to obtain the best correlation with ground data.

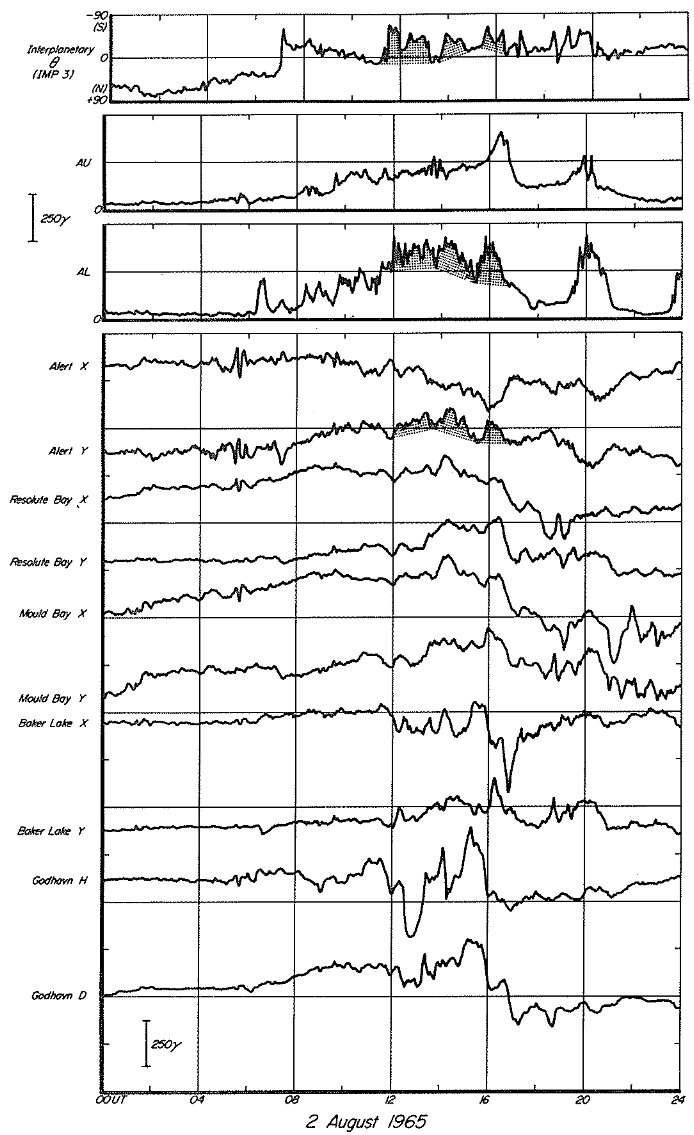


Fig. 14. Polar cap magnetic records, auroral electrojet indices and interplanetary magnetic field angle θ on August 2, 1965.

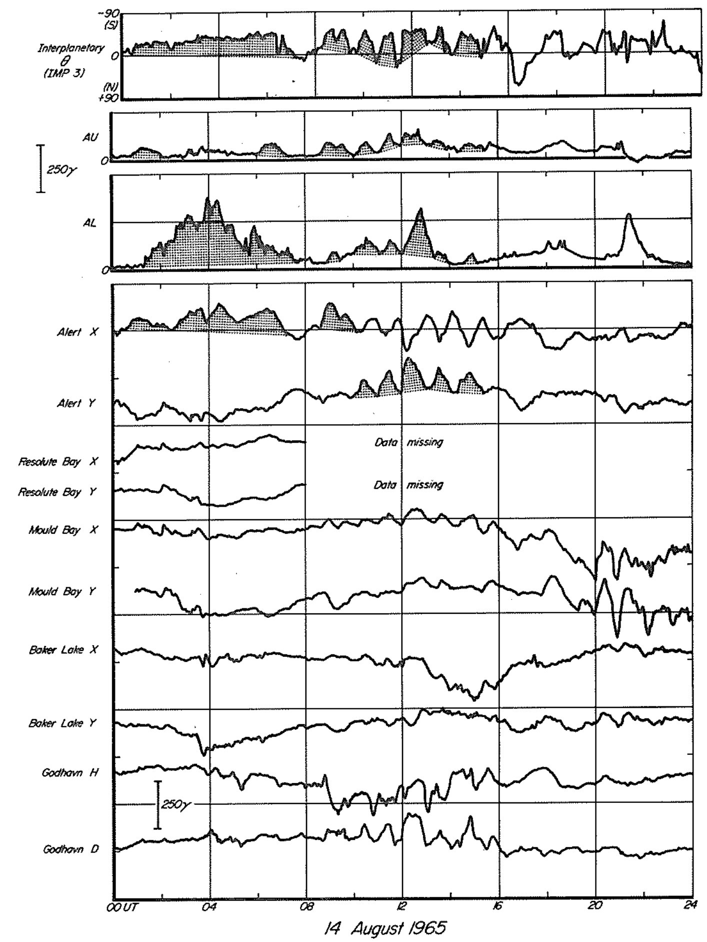


Fig. 15. Polar cap magnetic records, auroral electrojet indices and interplanetary magnetic field angle θ on August 14, 1965.

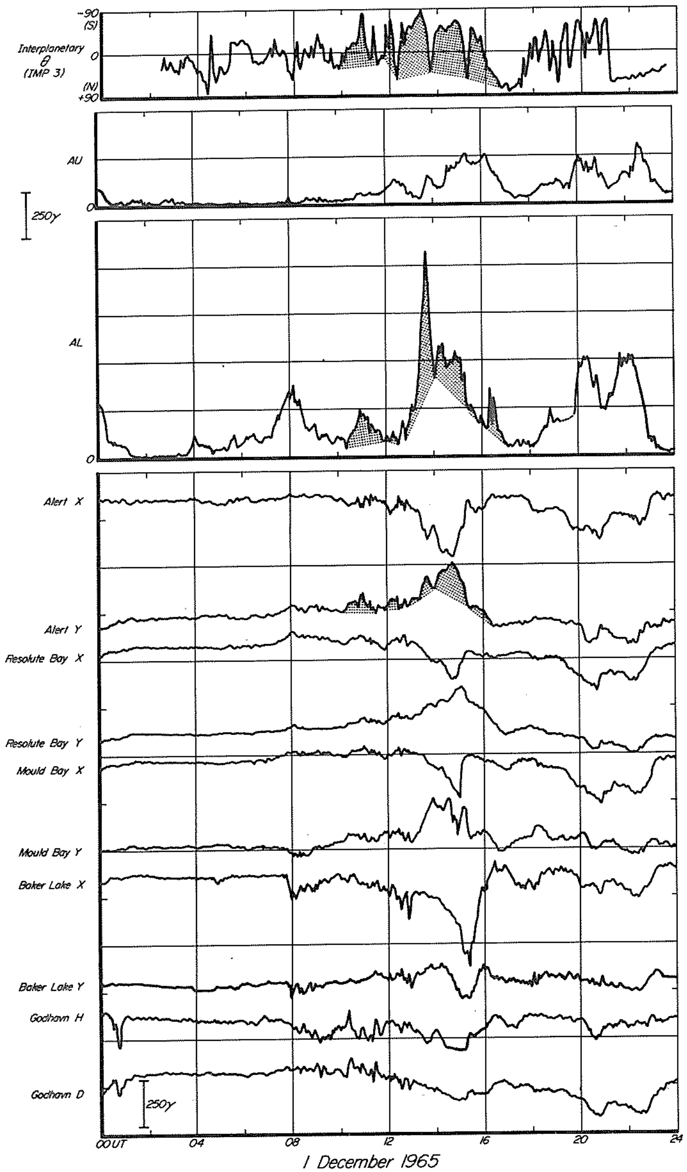


Fig. 16. Polar cap magnetic records, auroral electrojet indices and interplanetary magnetic field angle θ on December 1, 1965.

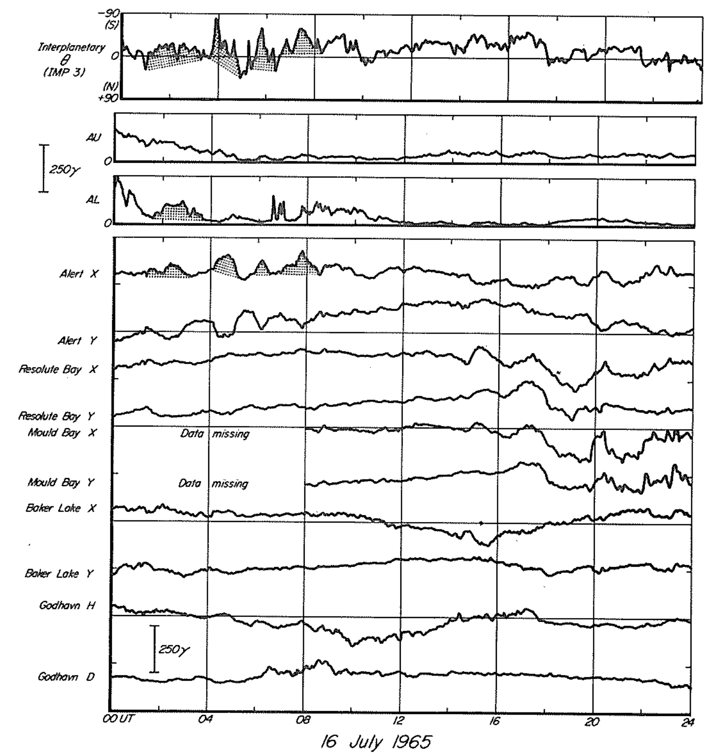


Fig. 17. Polar cap magnetic records, auroral electrojet indices and interplanetary magnetic field angle θ on July 16, 1965.

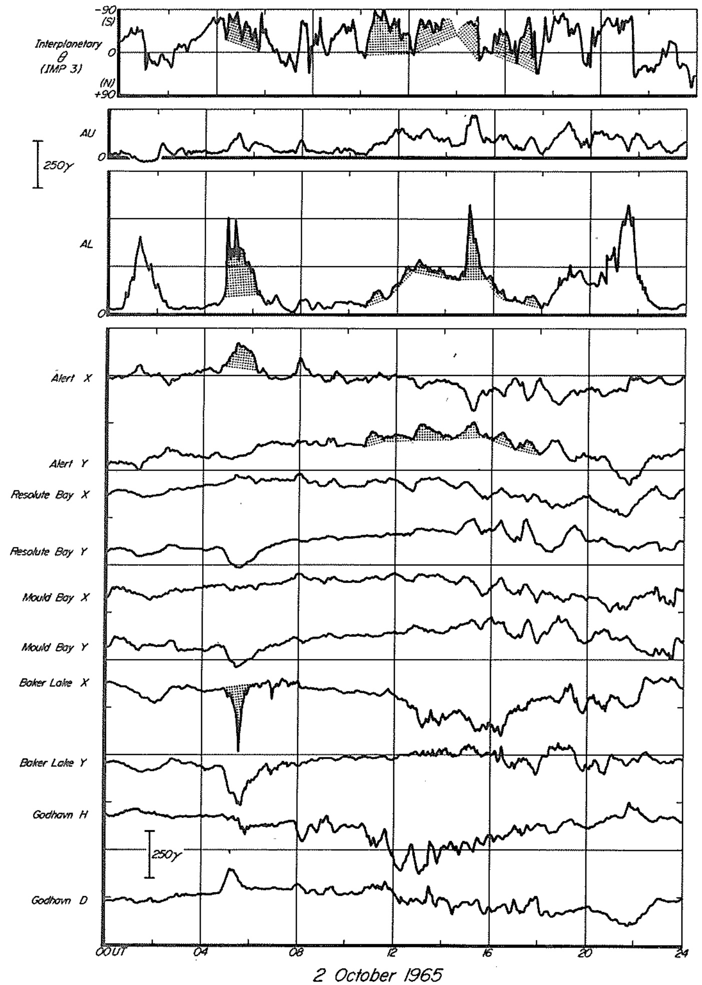


Fig. 18. Polar cap magnetic records, auroral electrojet indices and interplanetary magnetic field angle θ on October 2, 1965.

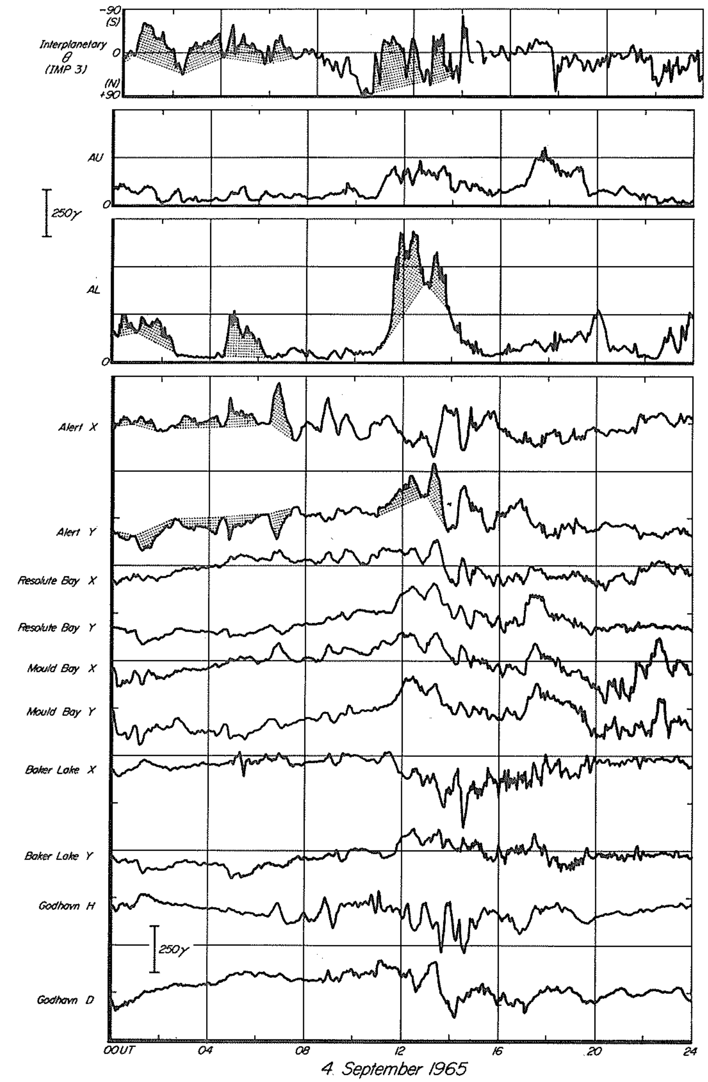


Fig. 19. Polar cap magnetic records, auroral electrojet indices and interplanetary magnetic field angle θ on September 4, 1965.

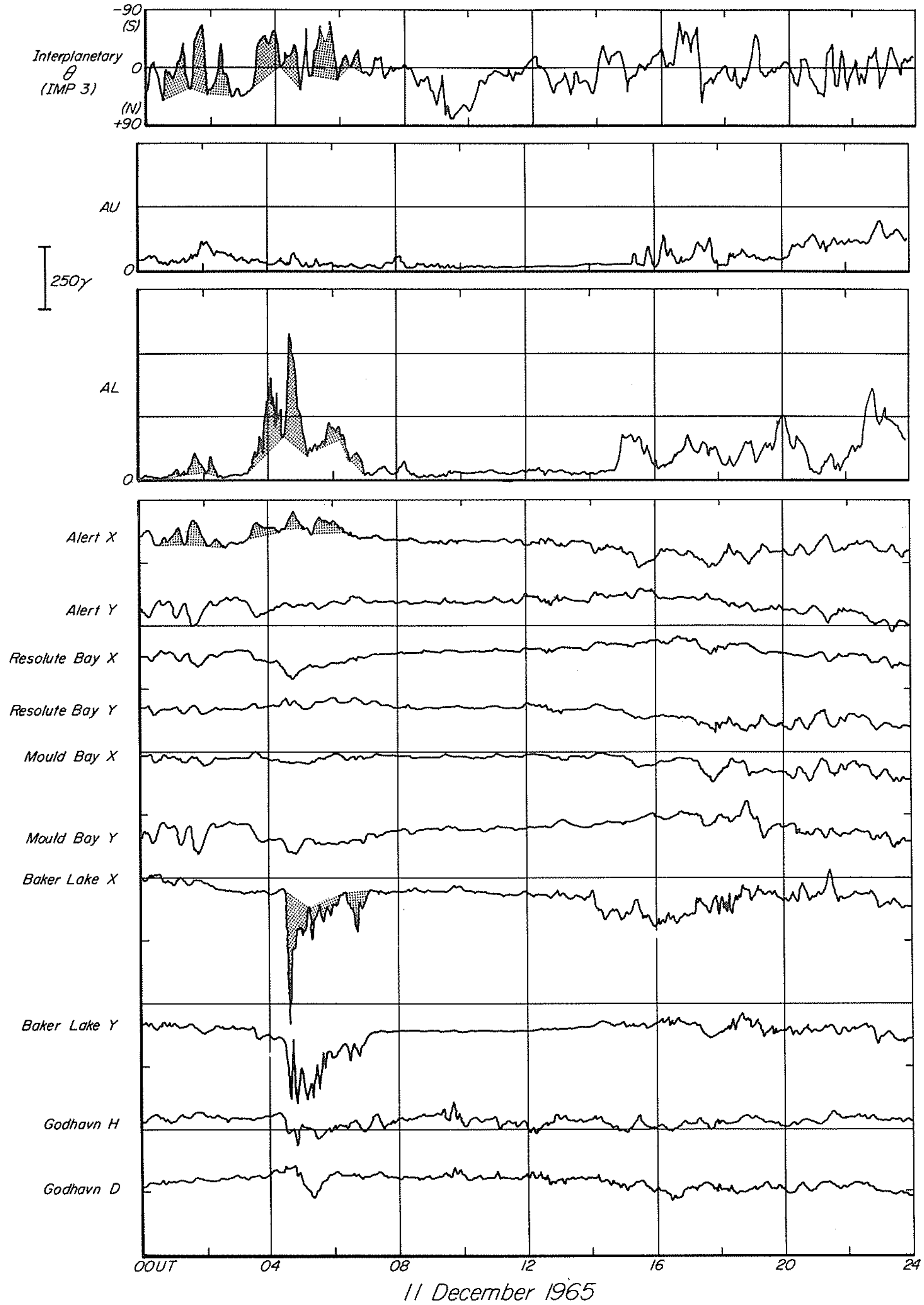


Fig. 20. Polar cap magnetic records, auroral electrojet indices and interplanetary magnetic field angle θ on December 11, 1965.

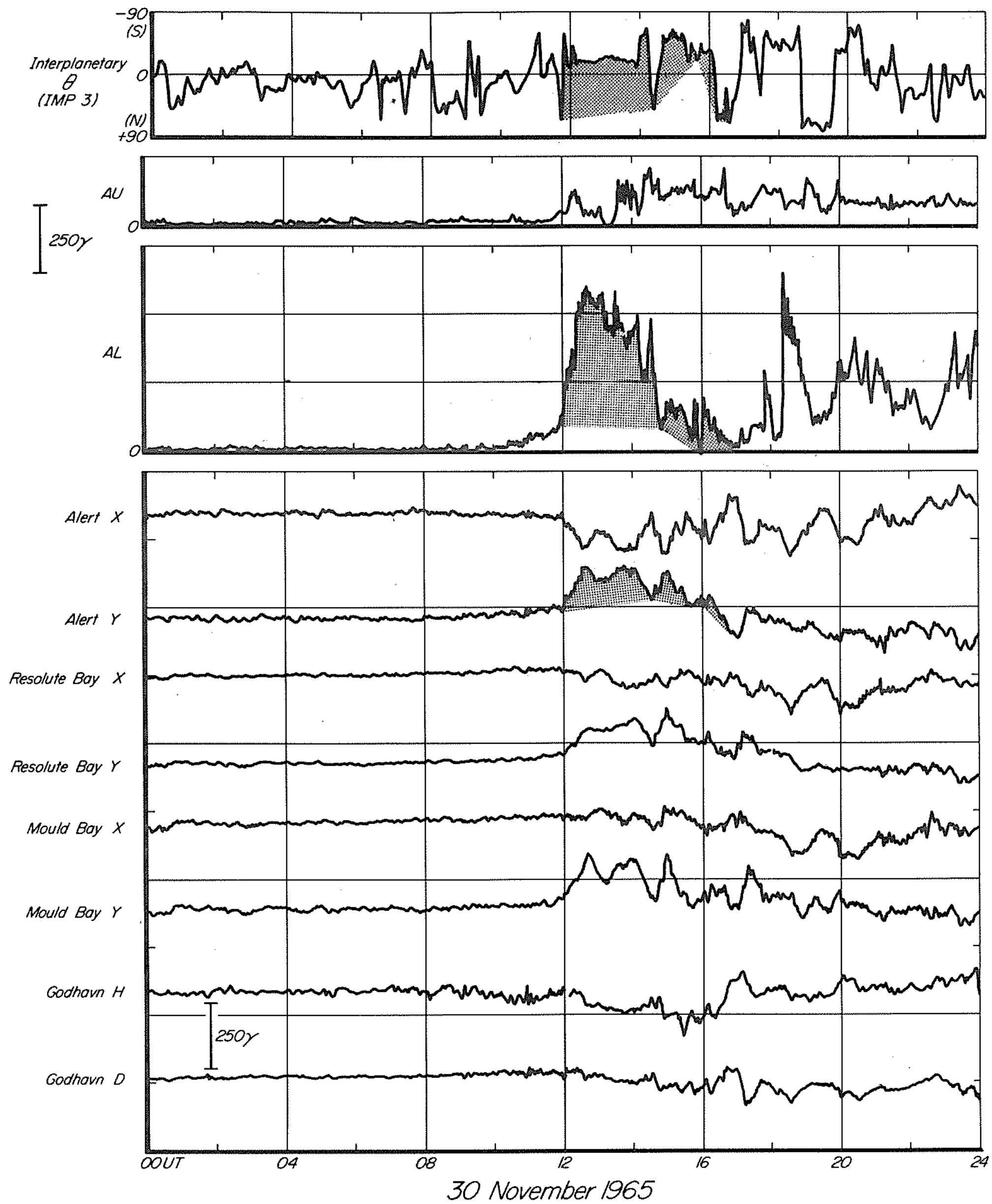


Fig. 21. Polar cap magnetic records, auroral electrojet indices and interplanetary magnetic field angle θ on November 30, 1965.

4. Significance of Non-coherent Variations of DP-2 and Auroral Electrojet Indices

In the previous Section, we showed numerous examples of close correlations between DP-2-like changes and the occurrence of polar magnetic substorms. Further, in these examples, it can clearly be seen that whenever the electrojet indices indicate that polar magnetic substorms are occurring the polar cap records tend to be DP-2-like. However, the converse is not always true. That is, DP-2-like polar cap changes are not always accompanied by enhancements of the auroral electrojet indices. Furthermore, often there does not exist a one-to-one correspondence between polar cap changes and the variations in the electrojet indices (although the duration of the activity can be identical). Thus, one might be led to believe that (because of the lack of coherency with substorm fields or the occurrence of polar cap DP-2 type variations in the apparent absence of substorms) some polar cap variations are distinct from substorm fields. That is, that there could indeed be a "pure" DP-2 mode. But, in fact, such a conclusion is based on the misconception that a single station or the auroral electrojet indices, for that matter, can accurately monitor the growth and decay of polar magnetic substorm fields.

It is well known that the auroral electrojet is a rather dynamic phenomenon as evidenced by the accompanying auroral displays. Not only does the intensity of the currents in the electrojet and its associated circuit vary in time, but also their configurations and locations with respect to the observing stations. It is impossible from the ground observations of the auroral zone stations alone to separate the spatial from the temporal development of the auroral electrojet.

It is clear from this that the time development of the substorm current does not necessarily closely follow the development of the field observed at an auroral zone station.

In this connection, it should be noted that the AE (or AL) index is too crude to define the growth and expansive phases of substorms. Akasofu [1960] showed that an intensification or a decay of the H-component records at a single station may only be an apparent one due solely to rapid north-south motions of the electrojet toward or away from the station. Further, even if there were no longitudinal and latitudinal motions of the electrojet with respect to the sun, because of the rotation of an observing station underneath the time-developing electrojet, the time-development of the field observed at the station can differ significantly from the actual one.

It should also be noted that the variations identified as DP-2 occur during periods of weak to moderate magnetic activity and near local noon for the polar cap stations. For the polar cap stations used in the present and previous investigations, local noon occurs when the midnight portion of the auroral oval is located in the Siberian sector. Unfortunately, during weak to moderate activity, it is likely that the midnight portion of the oval is located north of the Siberian coastline in the Arctic Ocean where little or no data are available. Consequently, it is not surprising that the auroral electrojet indices sometimes show little or no correlation with DP-2 variations.

Thus, it is not valid to conclude on the basis of a comparison of the variations of the presently available electrojet indices and the polar cap magnetic records alone that the polar cap variations are unrelated to polar magnetic substorms.

5. Relationships with Auroral Substorms

For further evidence to support the conclusions in the last two sections we have examined auroral displays during DP-2 variations.

Here we show an example of auroral activity during the DP-2 variations on October 2, 1965, which was examined in Section 3 (see Fig. 18). Figure 22 shows selected all-sky camera photographs taken from College during the DP-2 variations. It is quite clear in this example that all the major features of auroral substorms, such as westward traveling surges (1130-1147 UT), the subsequent poleward motion (1150-1240 UT) and the eastward drifting inverted Ω bands (1405-1416 UT) are present. Thus, the magnetic disturbances between 1000 and 1420 UT should not be identified as a new type of magnetic disturbance, but rather as the effect of polar magnetic substorms in the polar cap. This example is enough to indicate that it is difficult to define different types of magnetic variations on the basis of magnetic records alone; for many other such examples, see Akasofu and Snyder [1972].

6. Relationship of Interplanetary Magnetic Field Changes to Z-component Polar Cap Magnetic Variations

Svalgaard [1968], Mansurov [1969] and Friis-Christensen et al. [1971] have shown that there is a clear relationship between variations of the sector structure of the solar wind and the Z-component variations at polar cap stations. Friis-Christensen et al. [1972] showed from hourly values that the correlation is actually better for the Y-component (the component perpendicular to the sun-earth line) of the interplanetary field rather than the sector structure.

We wish to show in this section that the variations described by Nishida and Svalgaard are related. Figure 23 gives the interplanetary magnetic field components Yse and Zse (bold traces), the

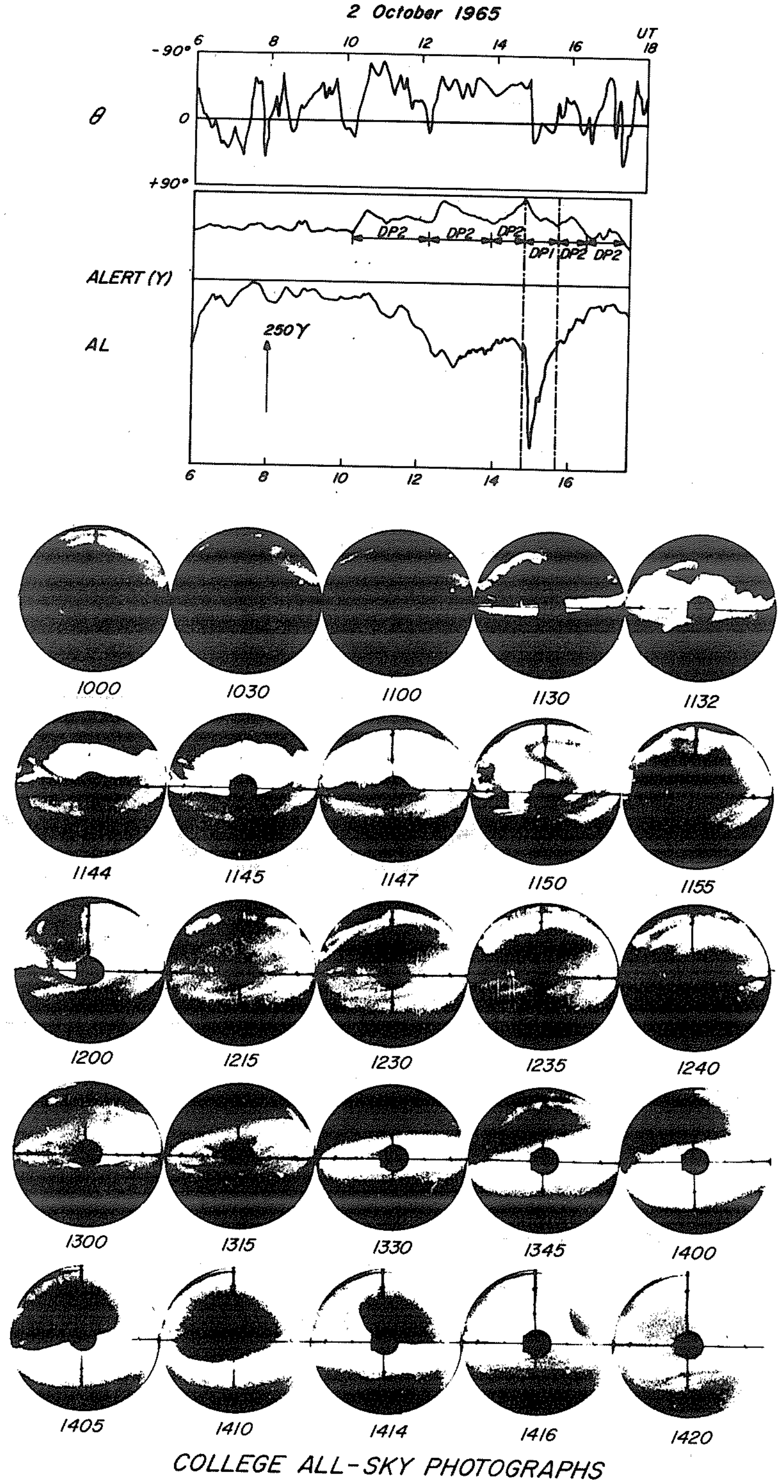


Fig. 22. College all-sky camera photographs during DP-2 variations at Alert on October 2, 1965. The AL index and the interplanetary magnetic field angle θ are also shown.

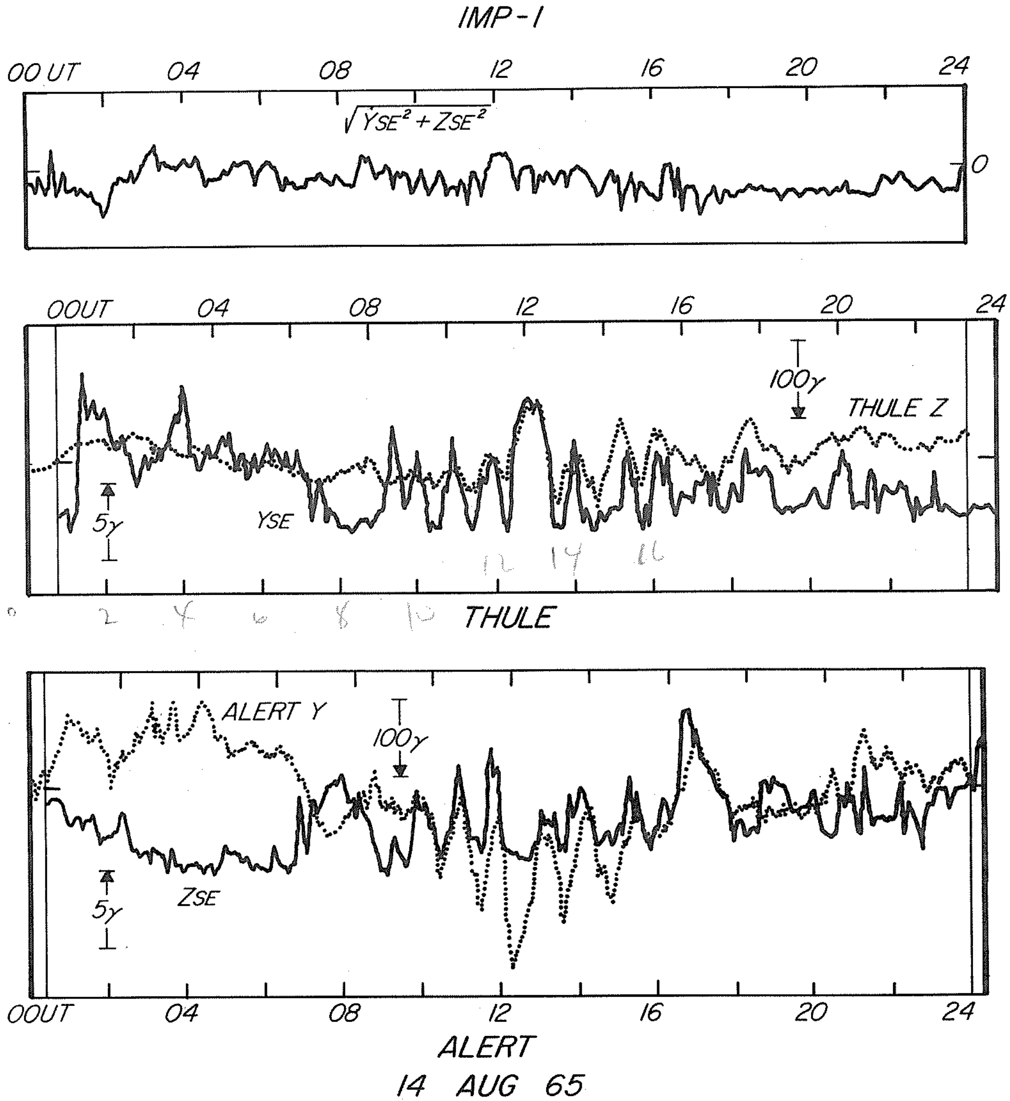


Fig. 23. Magnitude of interplanetary magnetic field component in Yse-Zse plane in solar-ecliptic coordinates and a comparison of Yse and Zse (solid lines) with the Thule Z-component, and Alert Y-component (dotted lines), respectively, on August 14, 1965.

magnitude $\sqrt{Yse^2 + Zse^2}$ of the field component in the Yse - Zse plane, and the Z-component of Thule and the Y-component of Alert (dashed traces) on August 14, 1965. As in previous figures, the interplanetary components have been shifted in time. It is quite clear that variations of the Z-component of Thule (plotted positive downward) and the interplanetary field component Yse are well-correlated between 1000 to 1800 UT; further, the variations of the component Zse are well-correlated with those of the Alert Y-component (plotted positive downward) also during the same interval. However, as was indicated in Section 3 (see Fig. 15), the variations of the southward component of interplanetary magnetic field were correlated fairly well with the auroral electrojet indices during this interval. Thus, as might be expected, the Z-variations over the polar cap also appear to be substorm-associated. A more detailed study of the polar cap Z-component variations and its relationship to the interplanetary field may be found in Kawasaki and Akasofu [1972b].

Actually, one should not discuss variations of the various components of the interplanetary and ground magnetic fields separately as can be seen in Figure 23. The magnitude $\sqrt{Yse^2 + Zse^2}$ remained relatively constant, but the components Yse and Zse varied up to ±5 gammas during the interval 1000 to 1800 UT. Thus, in this example the variation of the vector in the Yse-Zse plane can be represented by an oscillation of the vector which changed little in magnitude. It should be emphasized that the variation appears to be an oscillation to and fro through some preferred direction rather than a full rotation.

7. Discussions and Conclusions

The following conclusions may be drawn from our present, earlier and some other related studies:

(i) The S_q^p variation exists even during extremely quiet days [Kawasaki and Akasofu, 1967; Feldstein and Zaitzev, 1967].

(ii) The S_q^p variation is significantly enhanced on days when substorms occur frequently.

(iii) Fluctuations of lifetime of order 1 hour are superposed on the enhanced S_q^p variation. Some of these fluctuations were identified as the DP-2 variation by Nishida [1968a]. Our magnetic studies indicate that it is not necessary to invoke this new type of magnetic variation, the DP-2 disturbance field, which is distinct from the substorm field. The proposed DP-2 field is fairly coherent with the substorm field.

(iv) Typical features of auroral substorms are observed during the DP-2 variations, defined by Nishida. Thus, his DP-2 variations are associated with magnetospheric substorms and are not distinct from them.

(v) The DP-2 variations of Nishida and the variations described by Svalgaard are related. A single current system or mechanism is responsible for both types of variations. It may thus be inferred from the examples studied in this report, that the variations observed in the polar cap are associated with substorms. [For further details see Kawasaki and Akasofu, 1972b].

(vi) It should not be assumed that the substorm fields are well known. We are still quite uncertain about the geometry of the substorm current system and its variations during the life time of substorms. With the presently existing network of polar magnetic observatories, it is difficult to distinguish one type of disturbance from another. In particular, the auroral oval is not a fixed pattern. For example, the auroral oval tends to contract poleward during quiet periods. The initial indications of "isolated" substorms may occur far poleward of the usual oval location [Akasofu _et al_., 1971], causing only minor magnetic disturbances along the auroral oval.

Thus, small AE indices during an early phase of a substorm or during an isolated substorm (which occurs during otherwise quiet periods) could be due to the fact that an auroral substorm is in progress along the contracted oval, well poleward of the auroal zone [Akasofu and Snyder, 1972].

(vii) It is thus difficult to monitor accurately the growth and decay of the auroral electrojet activity by only several auroral zone stations as is presently done; one would need a large number of closely-spaced meridian chains of stations for this purpose. Akasofu [1960] showed also that the H-component variation as a function of time should not be taken to be proportional to the variation of the intensity of the auroral electrojet; an apparent intensification of negative bays could be partly due to a rapid approach of this jet to the observing station, and an apparent decay of negative bays could be partly due to a rapid recession of the jet from the station. It is also not difficult to show that the observed "time variation" of negative bays at auroral zone stations (which move under the jet as the earth rotates) can be very different from the true time variation of the jet intensity as a function of time.

In brief, care is required in examining relationships between certain polar cap phenomena and auroral zone magnetic records. The presently available AE index is also too crude to define the growth phase and the expansive phase of substorms [Akasofu and Snyder, 1972].

(viii) The study of Onwumechilli, Kawasaki and Akasofu [1972] indicates that it is not a simple matter to define the baselines of the DP-2 variations along the magnetic dip equator.

(ix) It has been found by Heikkila and Winningham [1971] and Frank [1971] that there is a continuous flux of magnetosheath electrons into the midday part of the oval. In addition there is a permanent E layer along the midday part of the oval [Buchau et al., 1972]. Thus, the conductivity distribution for the dynamo theory even on extremely quiet days should be modified to take into account the existence of a conductive strip along the auroral oval.

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