MAGNETIC BAYS AT MACQUARIE ISLAND

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Summary

Polar magnetic bays are the most striking feature of magnetic records obtained by the Australian National Antarctic Research Expeditions at Macquarie Island. Negative bays are more numerous than positive bays and have greater amplitudes and durations. As a rule, negative bays commence about magnetic midnight whereas positive bays commence about 5 hr earlier. A daily reversal in direction of the bay-producing currents is indicated and the time at which this reversal takes place appears to vary with the seasons. During magnetically disturbed periods the ratio H bay amplitude to Z bay amplitude increases, indicating a northward movement of the bay-producing currents. At the same time auroras seen from Macquarie Island lie further north in the sky than usual.

I. Introduction

Since 1948 the Australian National Antarctic Research Expeditions have maintained a scientific station at Macquarie Island. A geomagnetic observatory, manned by officers of the Bureau of Mineral Resources, Geology and Geophysics, has operated there since 1950.

Macquarie Island (54·5° S., 159° E.) lies about 1° north of the southern auroral zone (cf. Bond and Jacka 1960) and the geomagnetic records are characteristic of that region. "Bay"-like indentations are prominent features on the magnetograms. In Figure 1 the record of October 24, 1954 is typical of "disturbed" periods while that of October 30, 1954 shows a less disturbed record. In the early part of this record a bay (or pair of bays) is formed by increase in the horizontal (H) and vertical (Z) components. Later in the day another bay is formed by decrease in H and Z. In the following discussion the first type (increase) will be termed a positive bay and the second type (decrease) a negative bay.

II. Characteristics of Bays

Most of the data used in this paper are from records of the sunspot-minimum year 1954. During that year 435 negative bays and 172 positive bays were recorded; their distribution throughout the year is illustrated in the histograms of Figure 2. These show that most bays are recorded at or near the equinoxes—this is of course true of magnetic disturbances in general. Negative bays are more numerous and usually have amplitudes two or three times as great as those of positive bays; in 1954 the average amplitude of negative bays was about 285 gammas. Although the beginnings and endings of many bays are poorly defined, it is possible to say that the average duration of negative bays (approximately 100 min) is roughly twice that of positive bays.

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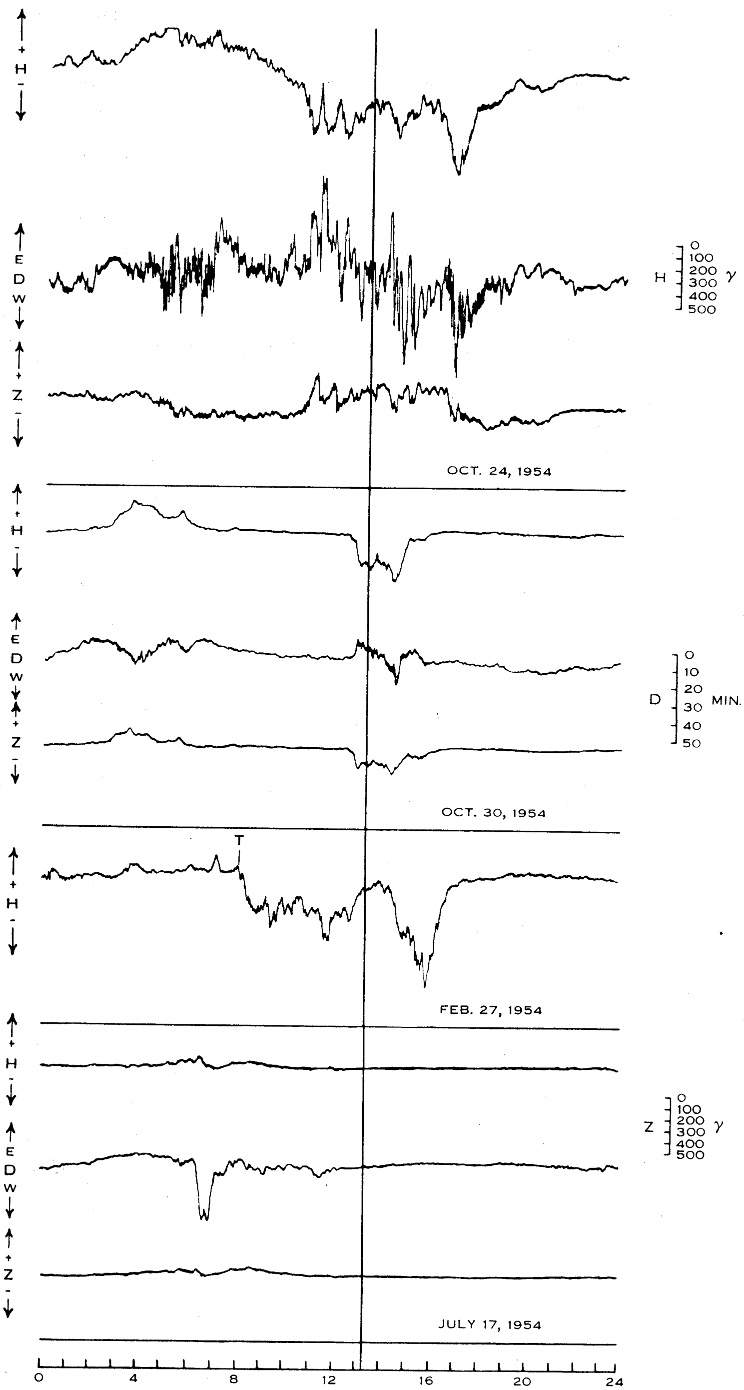

Fig. 1.—Tracings of Macquarie Island magnetograms. Scales of H, D, and Z variations are given on the right. The vertical line indicates the time (13·4 hr G.M.T.) of local midnight. For comment refer to text.

The amplitudes of all 1954 bays were plotted against their durations, to find whether these two quantities were related. Apart from the fact that most positive bays have amplitudes less than 80 gammas and durations less than 50 min, no trends could be discerned.

Figure 3 shows the variation through the year of monthly mean and extreme range of commencement times of bays recorded in 1954 ; there is an obvious grouping of the commencement times of negative bays around "magnetic midnight" (as defined by McNish (1936)). Almost all positive bays occur before magnetic midnight and most of them occur several hours before magnetic midnight. Although these diagrams suggest that there is considerable overlapping between the commencement times of negative and positive bays, it is

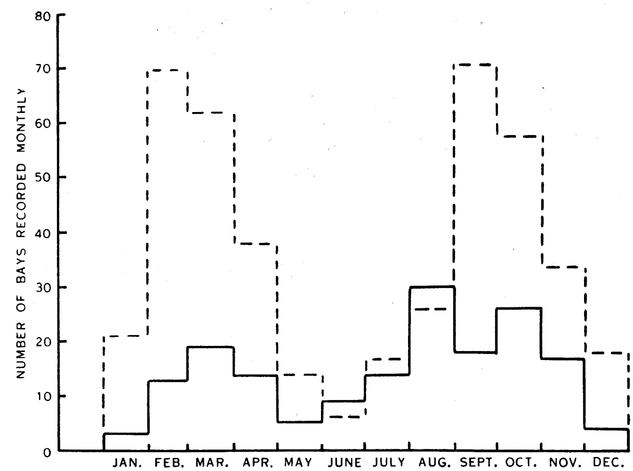

Fig. 2.—Variation of frequency of occurrence of bays in the H magnetograms through 1954 at Macquarie Island. The dashed line refers to negative bays, the full line to positive bays.

usually found that on individual days there is no overlapping ; all bays before a certain time are positive and all bays after that time are negative. For example, on the magnetogram of February 27, 1954 (Fig. 1) there is a sudden reversal of the direction of disturbances from positive to negative at the time marked "T". The transition is not always sudden but it is possible on about a quarter of all days to pick such a transition time by inspection of the records.

Several exceptions to this rule were recorded in the sunspot maximum period 1957–58 ; during large positive disturbances on stormy days a pronounced negative bay lasting about 1 hr sometimes occurred at about 7 or 8 hr G.M.T., some time before the general change-over to negative bays. Only one such case was observed during 1954.

Figure 4 illustrates the pattern of variation of transition times throughout the sunspot minimum year 1954 and the sunspot maximum year 1957–58. There appears to be a marked seasonal effect ; the transition from positive to negative bays is a few hours earlier at the equinoxes than at the solstices. In the data of 1954 the individual points cluster closely about the monthly mean ; in 1957–58 the scatter is much greater but the seasonal variation of monthly means is comparable.

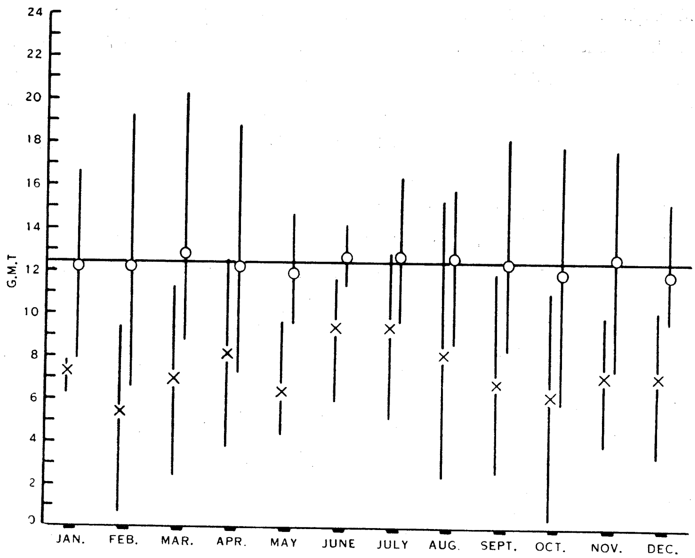

Fig. 3.—Variation of commencement times of bays in the H magnetograms through 1954 at Macquarie Island. Circles denote monthly means for negative bays, crosses for positive bays ; the vertical lines indicate the extreme range of commencement times. The horizontal line is at " magnetic midnight ".

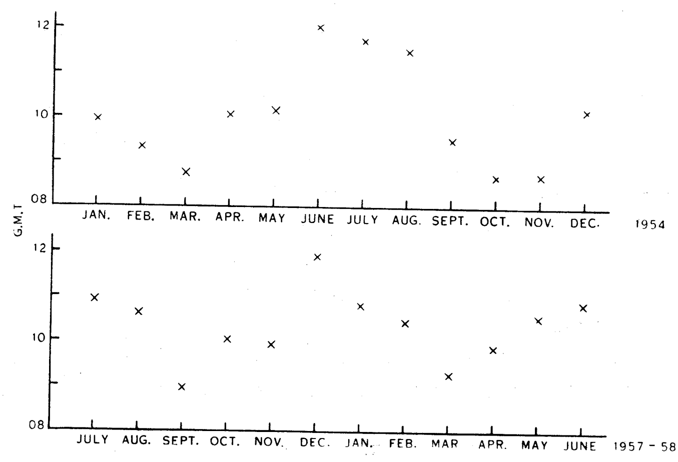

Fig. 4.—Variation through the years 1954 and 1957–58 of monthly mean times of transition from positive to negative bay activity in the H component at Macquarie Island.

It was thought that the transition times might be related to the degree of magnetic storminess and that the apparent seasonal effect might result from the larger number of disturbed days near the equinoxes. This could be so if the transitions occurred earlier on disturbed days than on quiet days. To test this possibility transition times were plotted against the daily K-index sums; this was done separately for equinoctial and solstice months. The plot for solstice (or other than equinoctial) months in 1954 shows some tendency for the points to form an elongated group, suggesting a correspondence between K sum and transition times. However, this tendency is not repeated in the plot for the equinoctial months of 1954, nor does it appear in either of the plots for the period July 1957 to June 1958. It seems probable then that there is a real seasonal variation in transition times.

So far this part of the paper has been concerned with magnetic bays which are evident on the H and Z component traces. Such bays are invariably accompanied by declination (D) component disturbances, but these are generally oscillatory in character and not of simple bay shape. The record of July 17, 1954 (Fig. 1) shows a different type of bay. It is evident that there is little disturbance on either H or Z but there is a pronounced negative bay in the declination component D. In 1954 about 80 such bays were recorded. All of these were negative (i.e. the westerly declination increased) and all occurred in the intervening period between the times when positive H, Z bays and negative H, Z bays were most common.

From the foregoing facts about magnetic bays at Macquarie Island it is possible to draw a number of fairly definite conclusions. It is clear from the reversal in bay sign that the bay-producing currents flowing near the southern auroral zone change direction from eastward to westward in the early evening of each day and that about this time currents often flow northward over the recording station producing bays in declination only.

These facts may be explained qualitatively by several different theories (e.g. Maeda 1957) which postulate that currents are due to an excess of ions of one sign carried along in some way by ionospheric winds. It appears that the bay-producing current system rotates so that it presents the same general pattern as viewed from the Sun. This could result from a wind pattern fixed relative to the Sun while bay-producing ionization takes place in bursts, giving rise to considerable variation in current intensity. The normal diurnal variation may be produced by less intense but more regular ionization operating in conjunction with the same wind system. The large excess of negative bays over positive bays indicates a preponderance of bay-producing ionization on the night side of the Earth. The apparent seasonal variations in the change-over times from positive to negative bays suggests that magnetic bay studies may make useful contributions to the understanding of upper atmospheric wind systems.

III. Correlation between Bays and Auroras

It has long been recognized that the polar bay type of magnetic disturbance is often accompanied by visible aurora. Some aspects of the relation between the two phenomena have been investigated.

The magnetic records and records of auroral observations for the year 1954 were studied closely to determine whether simultaneous onset of magnetic bays and the auroras generally occurred. Of 77 nights on which the sky was clear and it was possible to decide whether the first bay activity coincided with the first auroral activity, good agreement was noted on 35 nights. On 16 more nights there was agreement in the absence of both magnetic and auroral activity; as absence of activity is comparatively rare in each phenomenon the probability of chance coincidence is low. Of the remaining 26 nights 14 would have shown agreement but for the observation of auroral glow at a time when there was no magnetic bay activity. Glows are frequently the upper limits of very distant auroras so that the magnetic effects of currents associated with them may be very weak; these cases cannot be regarded as conclusive.

Summarizing these findings:

Bays and auroras commenced together	35 nights
Neither was recorded all night	16
Results inconclusive	14
Only one recorded, or times disagree	12
Total	77

It is clear that in most cases magnetic bays and auroras do commence at about the same time.

Once bays have begun, magnetic fluctuations are usually so frequent that further correlation with the auroras is more difficult. It seems likely that a burst of ionization impinging on the ionosphere in the auroral zone produces the visible aurora and at the same time creates the condition in the ionosphere necessary for a bay, which commences simultaneously with or soon after the visible aurora. Arcs and bands are the auroral forms most frequently associated with the commencement of bays.

Observations at Macquarie Island also demonstrate that the bay-producing currents and the aurora are more or less coincident in space. On most days the Z component trace closely resembles the H component trace, as for example on October 31, 1954 (Fig. 1). Easterly or westerly currents several degrees polewards of the recording station would account for this. However, on many magnetically disturbed days the H and Z traces are observed to be quite dissimilar: a general increase in the value of the H component may be accompanied by a general decrease in the value of the Z component or vice versa. These effects would be caused by easterly or westerly currents situated equatorwards of the recording station. For example, on the magnetogram for October 24, 1954 (Fig. 1) a positive bay or series of bays between about 5 and 10·5 hr is accompanied by depressed values in Z. After 10·5 hr a series of pronounced negative H bays occurs and is accompanied by generally increased values of Z lasting until about 17·5 hr, after which H disturbances again tend to be positive and Z disturbances negative.

It may be noted that, although the Z component trace shows an average increase between 10·5 and 17·5 hr, it exhibits small variations which correspond in form and sign to bays in H. This suggests the continued presence of a varying current located polewards from the recording station in addition to a current situated equatorwards from the station.

In 1954 there were 15 days on which the Z trace remained neutral or became generally positive during negative H bays. All except one of the 15 days were very disturbed magnetically and, during all on which the night sky was clear, auroras were observed overhead or to the north of the island, rather than only to the south as was normal. Moreover, these 15 days include the times when all the most brilliant auroral displays of the year were seen.

These observations at Macquarie Island strongly support the view that magnetic bay-producing currents and the aurora are closely related in both time and space.

IV. Acknowledgments

The author wishes to thank the Bureau of Mineral Resources, Geology and Geophysics of the Department of National Development, for permission to use data from the magnetic observatory at Macquarie Island. Thanks are due also to the Antarctic Division of the Department of External Affairs for supplying auroral data.

V. References

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