

COSMIC NOISE ABSORPTION AT SOUTH POLE AND FROBISHER BAY: INITIAL RESULTS

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Abstract: A 30 MHz riometer was installed at Frobisher Bay, Canada, in July 1985 to enable conjugate studies of cosmic noise absorption (CNA) phenomena to be performed in conjunction with observations from Amundsen-Scott South Pole station. The riometer data reveal a variety of temporal associations between disturbances appearing in opposite hemispheres which are generally consistent with observations at these sites reported previously. These include events with simultaneous onsets and similar time variations, closely similar events but with onset times and absorption maxima differing by several minutes, and absorption events appearing in one hemisphere only. For the present data set, however, fluxgate magnetometer data from both locations aid in interpreting the observed phenomena. In particular, absorption events and intense electrojet currents in the dusk sector were found to occur preferentially in one hemisphere (mainly at the South Pole during the period July–September examined here). Because the magnetometer can sense the presence of electrojets far from its immediate vicinity, these cases appear to be evidence of nonconjugate electron precipitation (perhaps occurring on open field lines) or of the severe distortion of the magnetic field line topology in this local time region. Absorption in the noon sector is characterized by long-period modulations in the Pc 5–6 range.

1. Introduction

Studies of the conjugacy of auroral and ionospheric phenomena at very high latitudes are an important aspect of magnetospheric physics research. The extent to which auroral phenomena in opposite hemispheres are similar in occurrence and in the details of their temporal, spatial and spectral characteristics can be used to infer the commonality of the source(s) of the disturbances (*e.g.* BELON *et al.*, 1969; DICKINSON *et al.*, 1986; MIZERA and EVANS, 1986). At one extreme in this consideration is the question of whether sources lie on open or closed field lines.

At invariant latitudes $\Lambda \gtrsim 70^\circ$, geomagnetic field lines may be open or closed, the spatial extent in latitude of the two regions being dependent on the level of geomagnetic disturbance. Because of the different offsets of the geomagnetic and geographic poles in the two hemispheres, there are few ground locations at $\Lambda \gtrsim 70^\circ$ where conjugate measurements can be made. One such pair of stations is Amundsen-Scott South Pole station in Antarctica and Frobisher Bay in Canada ($\Lambda \approx 74^\circ$ – 75°).

This paper reports on some initial results of the comparison of 30 MHz riometer data obtained at these two locations in the interval from July to September 1985. The results of a previous study of the conjugate properties of auroral absorption events at

these two sites were reported by HARGREAVES and CHIVERS (1965). They noted that auroral absorption events had many points of similarity, but also significant differences. The advantages of the present measurements are a) the riometer operating frequencies are the same in both hemispheres; b) the data are obtained digitally at high resolution; and c) fluxgate magnetometer data from AT&T Bell Laboratories instruments at both sites are available to aid in interpreting the observed phenomena.

2. Observations

2.1. Occurrence statistics

Figure 1 is a plot of the diurnal variation of the frequency of occurrence of cosmic noise absorption at Frobisher Bay (FB) and South Pole (SP) exceeding thresholds of 0.5 and 1 dB. The data were binned in 10-min intervals and cover the time period from July 15 to September 11, 1985. The SP results are typical of the diurnal occurrence variation obtained for the entire year and indeed for all previous years (since 1982) of the SP observations. They show pre-noon and pre-midnight occurrence

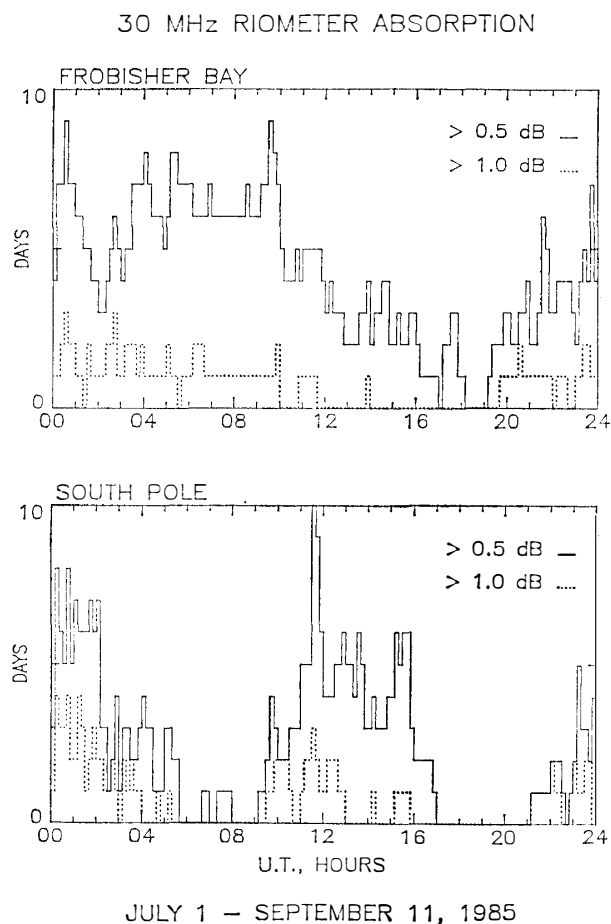


Fig. 1. Diurnal variation of the occurrence of 30 MHz cosmic noise absorption for two levels of activity. Local magnetic noon (midnight) is at 1530 UT (0330 UT). The statistical results for Frobisher Bay are biased at all local times, but particularly between 03 and 10 UT, by anomalous signal responses of instrumental origin occurring on several days.

maxima (the magnetic local time (MLT) at these stations is UT - 3.5 h) and deep minima in the early-morning and for much of the afternoon. The SP statistics also show that a higher proportion of the larger events occurs on the nightside. This result can be understood on the basis that the nightside events are caused mainly by hard electron precipitation ($E \geq 10$ keV) associated with substorms (*e.g.*, see HONES *et al.*, 1986), whereas the dayside events are influenced to some extent by the softer electron precipitation associated with the polar cusp.

Although there is a tendency for somewhat similar behavior in the occurrence statistics for FB (for example, the pre-midnight peak and afternoon minimum), the FB data contain an anomalously large contribution (compared with SP) particularly from 03 to 10 UT, but not limited to this interval. This anomalous contribution is also apparent in plots of the diurnal variation of average absorption at the two sites (not shown).

The reason for the disparity between FB and SP can be seen in the data for August 3, 1985 which are illustrated in Fig. 2. A substorm-associated absorption event of ~ 1 dB occurred at SP near 0100 UT; this event was also recorded at lower amplitude at FB. But what is unusual in the FB record is the PCA (polar cap absorption)-like absorption that began near 0200 UT and lasted until ~ 1800 UT for which there is no counterpart at SP. Such changes in the riometer signal level occurred at FB on a number of other days, mostly in the morning hours but occasionally at night, reaching peak values of ~ 0.5 –1 dB. Because there were no reported PCA events on these

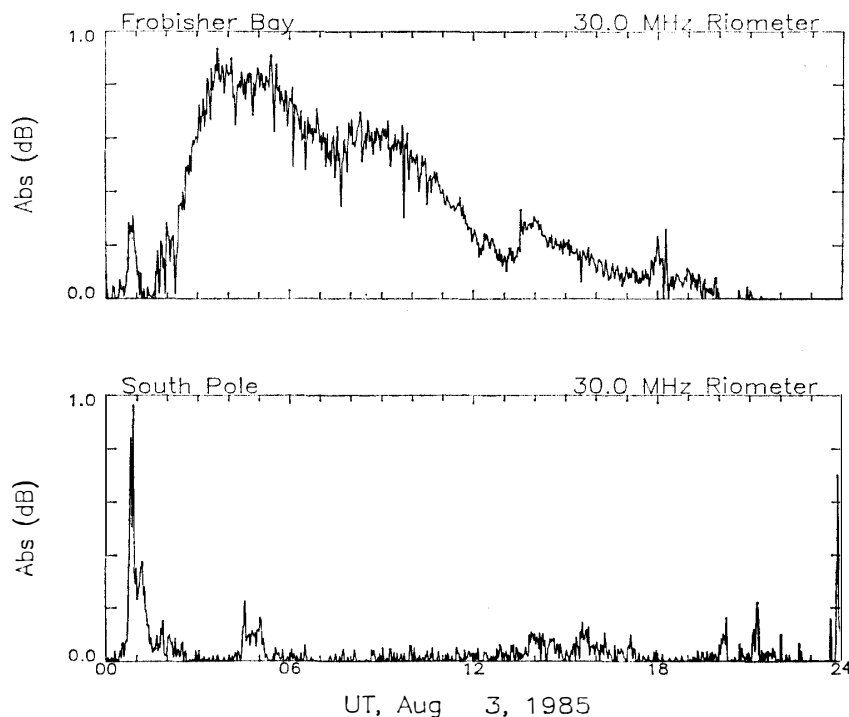


Fig. 2. An example of the suspected data artifact recorded at Frobisher Bay on several days. The South Pole and Frobisher Bay riometers both respond to an auroral absorption event maximizing shortly before 01 UT, but only Frobisher Bay experiences the signal decrease (*i.e.*, absorption) which lasts for most of the day.

occasions nor were there any satellite-recorded solar particle increases that could obviously account for the effect, this response is thought to be instrumental in origin (indeed, replacement of the receiver with another instrument in late-1986 seems to have eliminated the effect).

The effect of this anomalous contribution is to render meaningless the significance of any statistical comparison between SP and FB data presented in Fig. 1. However, because the majority of the FB data during the period of observations covered here were free of such behavior, it is possible to compare individual auroral absorption events, as is discussed below.

2.2. Event comparison

The comparison of individual events for data intervals not containing the anomalous FB response exhibits a wide variety of relationships. This is illustrated in Figs. 3 through 6, which show typical examples of the FB and SP data divided into four time sectors: 00–06 UT (Fig. 3) which includes events within ± 3 hours of local magnetic midnight; 06–12 UT (Fig. 4); 12–18 UT (Fig. 5) which includes events within ± 3 hours of local magnetic noon; and 18–24 UT (Fig. 6).

2.2.1. 00–06 UT. The midnight sector (Fig. 3)

Events in this sector typically have sharp onset and relatively short duration (≤ 30 min). Previous analysis of SP data (HONES *et al.*, 1986) has shown that these occur-

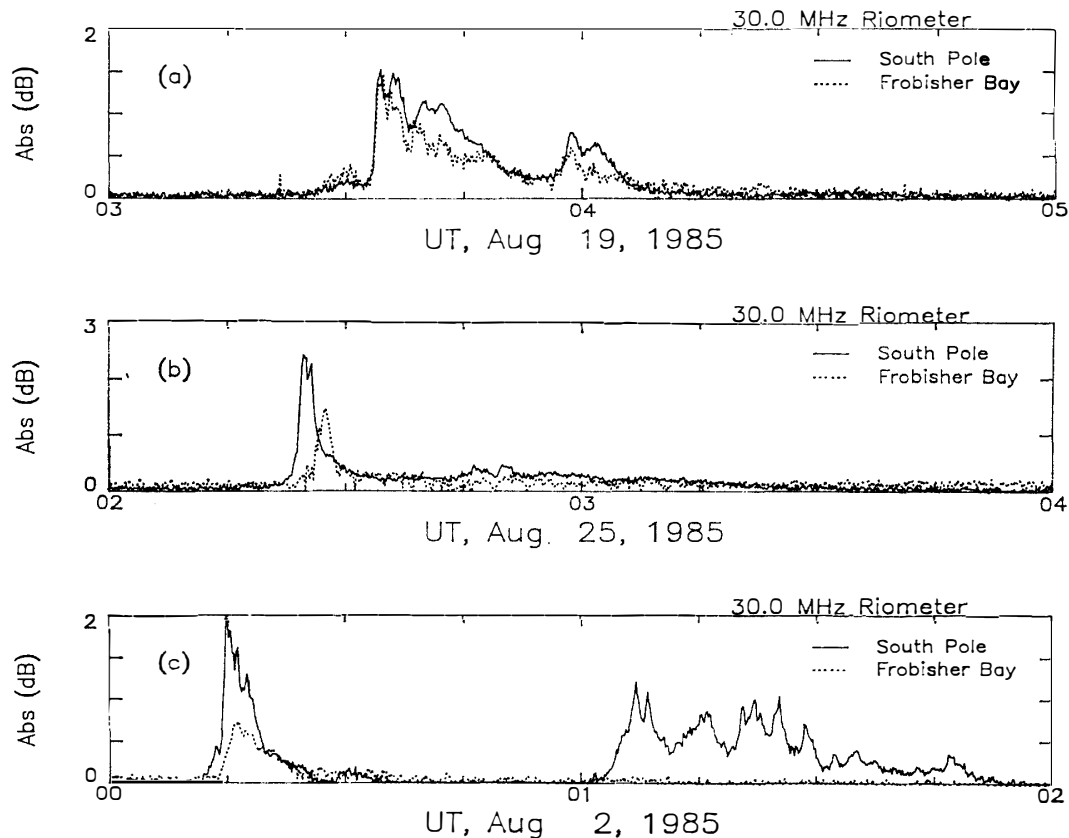


Fig. 3. Examples of absorption events in the midnight sector. Local midnight is at 0330 UT.

rences are associated with the poleward and/or westward surge of auroral activity into the polar cap following the expansive phase of magnetic substorms.

Often these disturbances are evident in both hemispheres with near-simultaneous onset and similar temporal details, as in panel (a). Sometimes the onset and time of maximum absorption of generally similar events occur several minutes later in one hemisphere, as in panel (b). Almost invariably in such cases, the event occurs pre-midnight and SP records it first, suggesting that FB is located poleward and/or to the west of the SP conjugate point. When similar events do occur in both hemispheres, the absorption is generally higher at SP.

A much rarer occurrence in this local time sector is the event that is restricted to one hemisphere only, as for example the absorption observed at SP between 01 and 02 UT in panel (c) in the absence of any corresponding activity at FB. Examination of the fluxgate magnetometer recordings at the two sites reveals that there is a similar asymmetry in the ionospheric horizontal electrojet current flow. Such cases are discussed further in connection with Figs. 6 and 7.

2.2.2. 06–12 UT. The dawn sector (Fig. 4)

Examples in this sector show that the onset of absorption is more gradual than in the midnight region and occurs at about the same time in both hemispheres. Activity is of longer duration (≥ 1 h) and there can be substantial differences in both amplitude (SP usually greater than FB) and time variation.

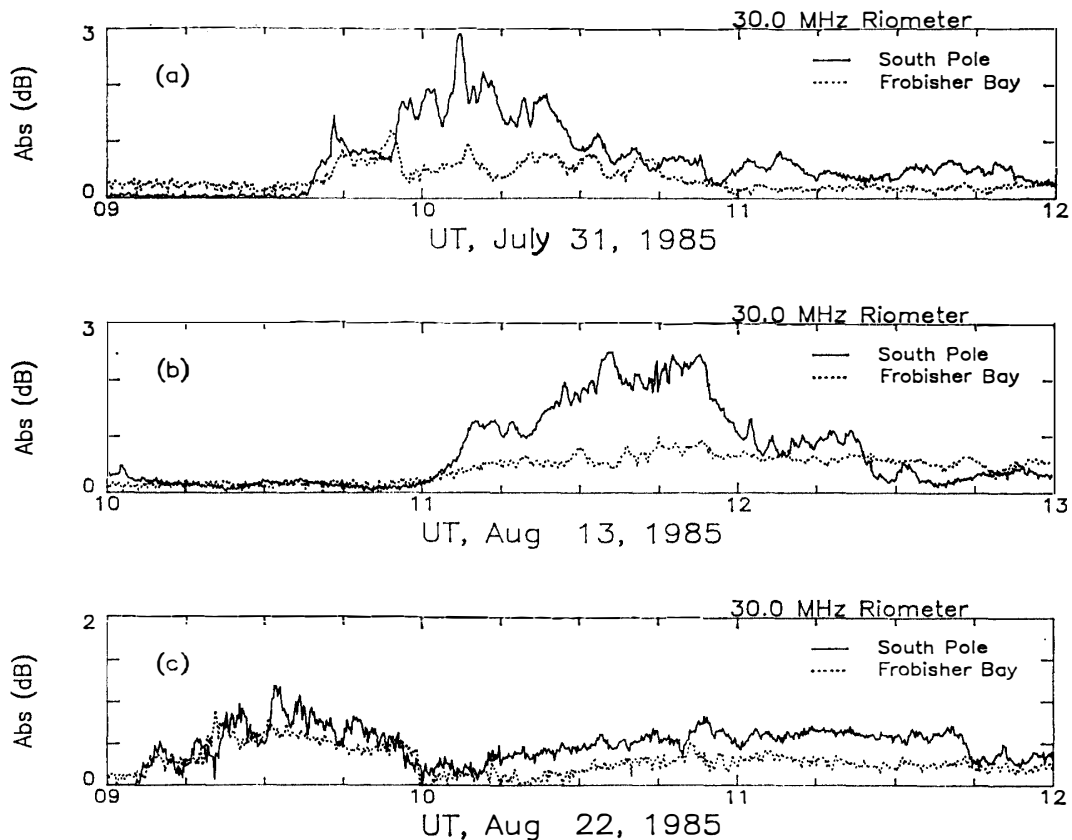


Fig. 4. Examples of absorption events in the dawn sector. Local dawn is at 0930 UT.

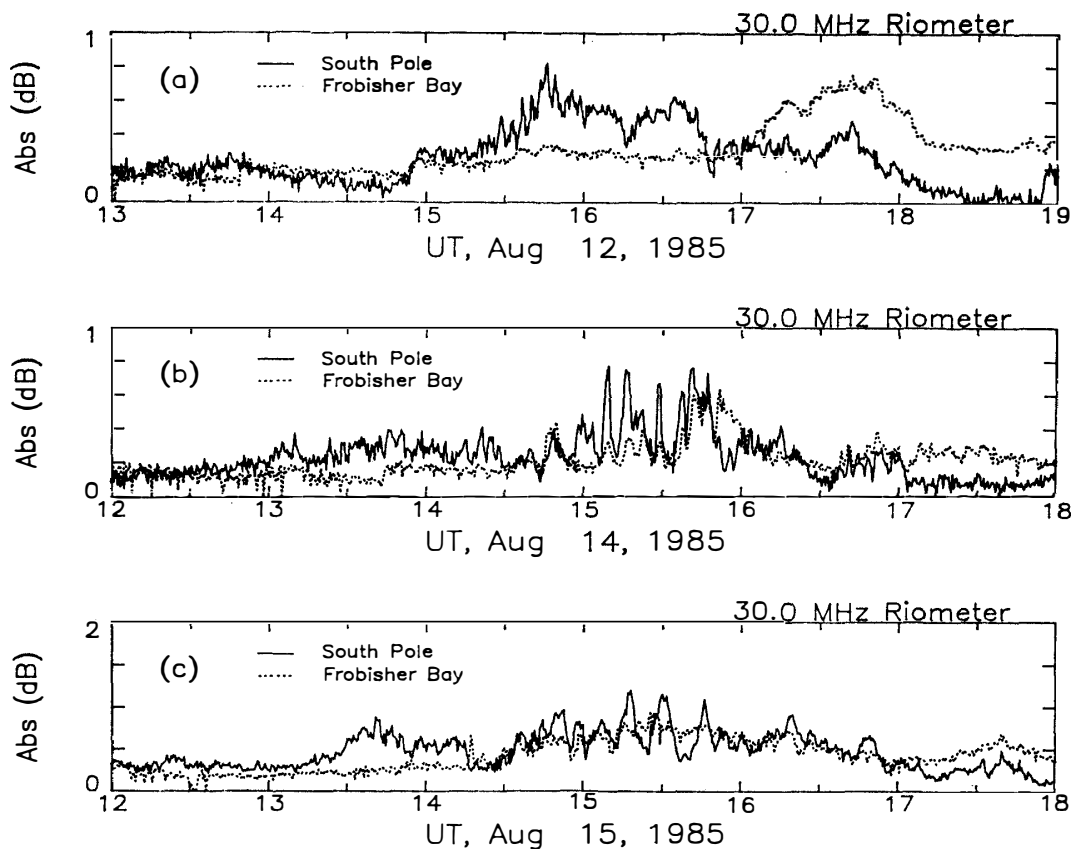


Fig. 5. Examples of absorption events in the noon sector. Local noon is at 1530 UT.

2.2.3. 12–18 UT. The noon sector (Fig. 5)

Absorption events in the noon sector typically last for several hours and occur at both SP and FB with generally similar characteristics. The SP absorption is larger throughout most events, but this asymmetry can switch within a given event from southern- to northern-hemisphere dominance, as in panel (a) near 17 UT. The most distinguishing feature is the appearance of long-period Pc 5-type variations (5–15 min) that are most clearly evident in the SP data in the events examined thus far. However, there can be some quite good temporal association, as, for example, in panel (b) between 15 and 16 UT.

2.2.4. 18–24 UT. The dusk sector (Fig. 6)

The events in this sector have many of the same features described earlier for events in the midnight sector; *i.e.*, rapid onset, short duration, and large amplitude. It is likely that these events also arise from substorm expansions of auroral activity into the polar cap. The typical situation in the dusk sector is exemplified by panels (a) and (b) which show large absorption events occurring at SP only. Panel (c), where there is evidence of absorption at both sites and, in particular, where the absorption at FB is dominant, is extremely rare in the data set examined (it was, in fact, the only example found).

Cases (a) and (b), and the similar event described earlier in connection with Fig. 3c, suggest an apparent lack of conjugacy. It should be noted, however, that the

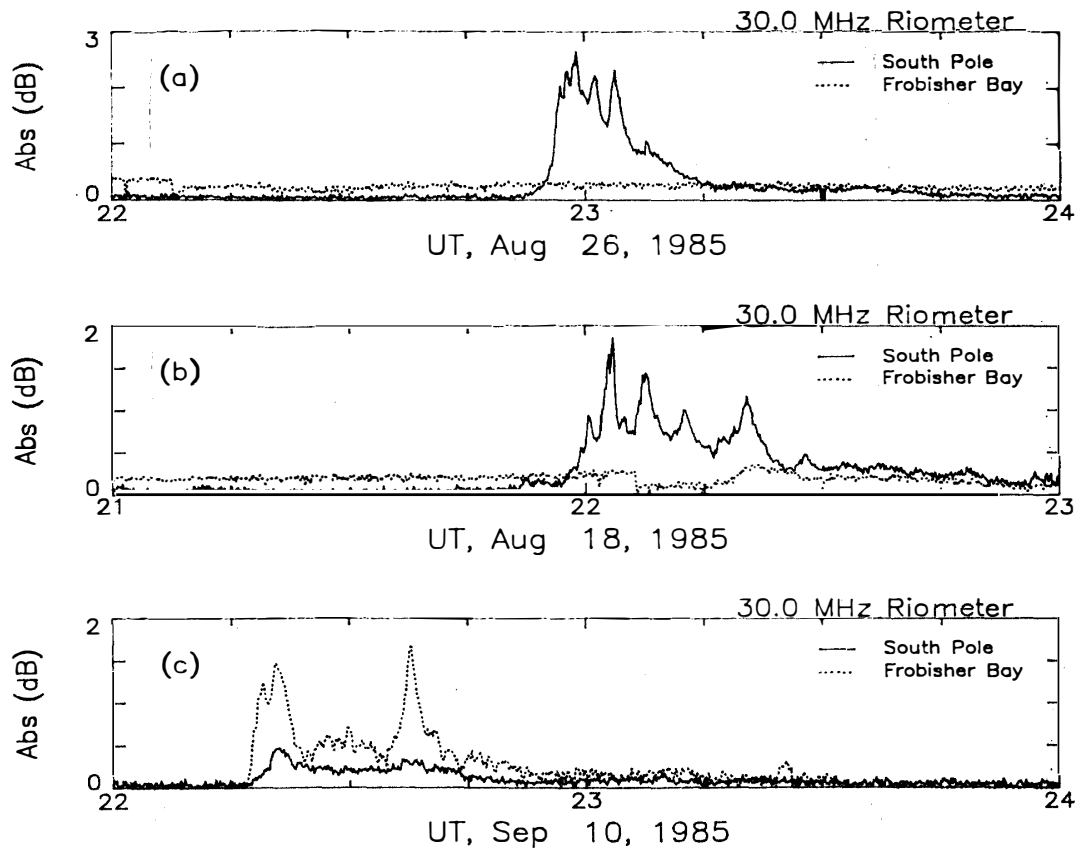


Fig. 6. Examples of absorption events in the dusk sector. Local dusk is at 2130 UT.

zenith-directed riometer fields of view correspond to an area of ~ 115 km diameter at 100 km height. Since the auroral structures are likely to be discrete arcs of much narrower extent, could the apparent lack of conjugacy be caused by the precipitation region in the north being located just outside the field of view of the FB riometer?

In answer to this question, if similarly intense electron precipitations were occurring in both hemispheres, but just outside the field of view of the riometer in one hemisphere, then fluxgate magnetometers at both sites should show comparable evidence of the intense electrojets that would undoubtedly be flowing. Figure 7 presents the three orthogonal components (H , D , Z) of the magnetic variations recorded at SP and FB for the event of August 26, 1985 (panel (a) of Fig. 6). Corresponding components at the two locations are plotted to the same amplitude scale. Comparing Figs. 6a and 7 shows that the ionospheric absorption event at SP was accompanied by a large magnetic perturbation, ~ 800 nT negative bay in the H -component, caused by a westward electrojet that was centered approximately above SP shortly after 2300 UT. However, there is no evidence of a corresponding electrojet within 5° of FB, the approximate range of the magnetometer measurement given the observed responses and assuming comparable thin horizontal line currents flowing at 100 km height. Similar magnetometer responses were obtained for all other cases where absorption was recorded in one hemisphere only.

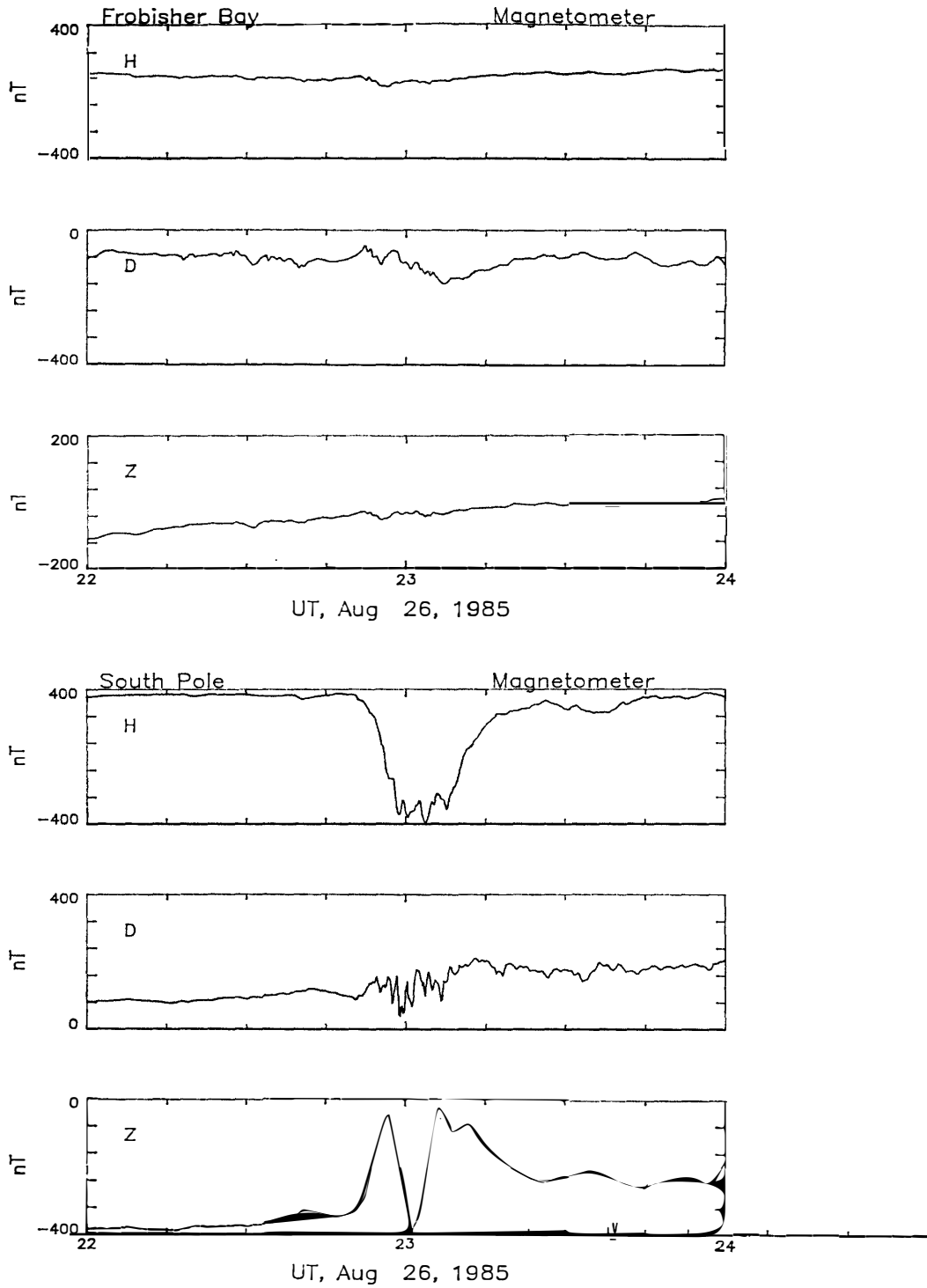


Fig. 7. Fluxgate magnetometer data for the event shown in Fig. 6a. Intense electrojet currents flow only near the station (South Pole) where the absorption event occurs.

3. Summary and Conclusions

Initial results of a comparison of 30 MHz riometer absorption observations ob-

tained at Frobisher Bay, Northwest Territories, Canada and South Pole, Antarctica, nominally conjugate locations, have been presented.

Occurrence statistics for the South Pole data set in the interval July–September 1985 reveal a two-peaked distribution, with maxima appearing in the pre-noon and pre-midnight hours. The observed distribution is similar to the distributions found for South Pole and Frobisher Bay by HARGREAVES and CHIVERS (1965). Unfortunately, the Frobisher Bay statistics for the period of observations considered in this paper suffer from the contribution of anomalous signal responses of instrumental origin, thus making them unsuitable for comparison with the South Pole statistics. However, it has been possible from visual examination to compare individual auroral absorption events.

Individual events representative of the absorption activity occurring in four local time sectors were illustrated for time intervals when the FB data were not compromised by anomalous behavior. It was noted that with few exceptions the absorption recorded at SP exceeded the absorption at FB in all local time sectors. This result also agrees with the findings of HARGREAVES and CHIVERS (1965) for the time of year examined.

Absorption events occurring in the dusk and midnight sectors, when SP and FB are in the polar cap, were characterized by rapid onset, large amplitude and short duration ($\lesssim 30$ min). These features are consistent with the rapid surge of intense discrete auroral precipitation arcs into the polar cap following substorm expansions (*e.g.*, HONES *et al.*, 1986). In the dusk sector such events were almost exclusively recorded at SP. The absence of a corresponding precipitation signature in the vicinity of FB (*i.e.*, within approximately 5°) was confirmed by fluxgate magnetometer measurements. These measurements showed that significant electrojet currents were present only at the location where the precipitation was observed.

These cases appear to be evidence of nonconjugate electron precipitation (perhaps occurring on open field lines) or of severe distortion of the magnetic field line topology in this local time sector. Events of this kind also occurred in the midnight sector, but there it was more common to observe absorption in both hemispheres often with simultaneous onsets and similar temporal details. Closely similar absorption events with several minutes difference between their onset times and absorption maxima were also noted.

Absorption events in the dawn and noon sectors are observed at the same time in both hemispheres and are characterized by gradual onsets, lower amplitudes (than the nightside events), and durations of up to several hours. These features are consistent with the closer proximity of SP and FB to the auroral oval as the stations traverse the dayside. Long-period modulations of the absorption in the Pc 5–6 range, possibly associated with ULF hydromagnetic waves, were particularly evident in the noon sector.

Under appropriate conditions, both SP and FB are expected to traverse the polar cusp near local noon. At such times, significant cosmic noise absorption would not be expected because the energies of precipitated electrons in the cups are too low (\sim few hundred eV) to enhance the *D*- and *E*-region ionization. Occasionally, a marked decrease and recovery of pre-existing absorption occurs that may be indicative of a

station's passage through the cusp. The examples presented, however, do not appear to contain this signature and thus may reflect only disturbances occurring on field lines connected to the dayside auroral oval.

Examination of a much larger data set is required in order to determine whether seasonal effects previously reported by HARGREAVES and CHIVERS (1965) are evident in the occurrence statistics and event comparisons. Additionally, more comprehensive comparisons of the riometer and fluxgate magnetometer data will provide more information about the hemispheric asymmetry of nightside electron precipitation and electrojet currents, as well as on the possible relationship of dayside long-period absorption modulations to hydromagnetic waves.

Acknowledgments

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