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Riometer absorption morphology at Davis and Casey stations

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RIOMETER ABSORPTION MORPHOLOGY AT DAVIS AND CASEY STATIONS

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ABSTRACT

The variations of 30 MHz riometer signals at the high latitude stations of Davis (geographic coordinates 68.6°S, 78.0°E; invariant latitude 74.5°S) and Casey (geographic coordinates 66.2°S, 110.4°E; invariant latitude 80.6°S) are investigated. The general variation in ionospheric absorption at these stations is investigated for normal conditions and specifically for some disturbed periods. The quiet day diurnal variation of the riometer signal at both stations has a quasi-sinusoidal shape. At both stations, the quiet day signal is larger in winter than in summer. Some absorption events at both stations are closely related to auroral substorms. However the Davis events generally commence at an earlier magnetic local time, last longer and have a larger maximum absorption amplitude than the associated Casey events. Both stations show an increase in average absorption around local magnetic noon. This may be an absorption signature of the passage of the magnetospheric cusp over these high latitude stations. These magnetic midday events were generally of lower absorption amplitude than the events observed around magnetic midnight.

1. INTRODUCTION

1.1 GENERAL

The riometer (Relative Ionospheric Opacity METER) technique has achieved wide usage since its introduction by Little and Leinbach (1959). A riometer, a VHF receiver with a wide angle antenna, is used to receive cosmic radio noise from radio sources (primarily of galactic origin) within its beam. The variation in the received signal due to absorption of the incident radiation by the ionosphere is used to investigate the effect on the ionosphere. Advantages of the riometer are that the incoming signal has a very stable sidereal variation and that its operation is not limited by lower atmospheric conditions.

The riometer is a useful and economic tool for an ionospheric observatory. It can be used in association with radio, magnetic and optical techniques to investigate the influence of solar variability upon the Earth's upper atmosphere.

Riometer data, recorded at Davis and Casey stations, Antarctica, during the low solar activity years 1985 and 1986 are investigated in this report. In some cases magnetometer data are also presented.

1.2 SITE CHARACTERISTICS

Due to the interaction of solar radiation and the solar wind with the upper atmosphere and the geomagnetic field, different regions and altitudes of the upper atmosphere exhibit different properties. The magnetosphere and ionosphere are divided into regions on the basis of general characteristics of the plasma and the magnetic field in that region. At high latitudes, the projections onto the upper atmosphere of the magnetotail and the magnetospheric cusp define the auroral oval, polar cap and cusp region.

Davis and Casey have similar geographic latitudes, but significantly different geomagnetic invariant latitudes. The geographic latitude defines the diurnal and seasonal variation in solar radiation received at a site. The geomagnetic invariant latitude, and the variable solar activity define the particle precipitation regions that influence a site. Parameters of the Casey and Davis stations are shown in Table 1.

	Casey	Davis
Geographic co-ordinates	66.20°S, 110.35°E	68.60°S, 78.00°E
Invariant co-ordinates	80.64°S, 85.29°E	74.48°S, 29.60°E
L value	37.8	14.0
Magnetic local time (approximate)	UT + 6.60	UT + 2.58

Table 1. Casey and Davis site parameters.

Under typical solar conditions, Davis is located in the polar cap near the inner boundary of the auroral oval at local magnetic midnight, and on the equatorward edge of the cusp region at local magnetic noon. For similar conditions, Casey would be located in the polar cap at local magnetic midnight and on the poleward edge of the cusp region at local magnetic noon. As solar conditions become more disturbed, the auroral oval becomes more extensive and expands equatorward, altering the regions which influence these sites.

1.3 EQUIPMENT

The receiver used at Casey is a commercially produced La Jolla science instrument with an operating frequency of 30.0 MHz. The antenna is a vertically directed broad beam with the 3 dB points located approximately 42° off-vertical. The data were recorded on a chart running at 5 cm hr^{-1}. Also at Casey, a fluxgate magnetometer is used to measure the magnetic field Z component.

The Z component magnetic field strength is recorded on chart at 6 cm hr^{-1}.

The riometer at Davis is an Antarctic Division constructed receiver (Bird et al. 1974). The operating frequency is 30.1 MHz and the data are recorded on chart at 10 cm hr^{-1}. The antenna, which is of identical structure to the Casey unit, was incorrectly connected during the period of analysis covered by this report. The effect of this is discussed in section 1.4. Also at Davis, a fluxgate magnetometer measures the X (geographic north), Y (geographic east) and Z (vertical) components of the magnetic field. These data are recorded on chart at 10 cm hr^{-1}.

1.4 THE CHART ANALYSIS

The riometer data scaled cover the period 1 January 1985 to 30 November 1986 for Casey and for the entire 1985 year at Davis. At Casey, interference from local transmitters, wind static during blizzard conditions and some instrument problems led to intermittent data loss. The only significant data loss was between 25 January 1985 and 28 February 1985 when the instrument was incorrectly operated.

At Davis it was found that noise from the operation of the LSI 11/02 computer located in the same room as the riometer receiver caused significant interference. This made it difficult to compute the quiet day curve (QDC) when the computer was heavily used between June and November 1985. An event analysis was still possible during this period.

A further problem with the Davis data was that the antenna was not correctly connected. This resulted in the antenna being directed in an off-vertical direction. The Davis dipoles run parallel to a line pointing 7° west of geographic north. The off-vertical direction of the antenna beam resulted from the western dipole not being connected (the connector was poorly constructed and did not mate appropriately). This non-connection is expected to tip the antenna beam perpendicular to the dipole alignment. With a vertical antenna, a QDC maximum is expected at approximately 1630 local sidereal time (LST). The Davis riometer with its mis-connected antenna yielded a QDC maximum at approximately 1400 LST. This implies, to a first order approximation, that the antenna was preferentially sampling a region approximately 77 km from Davis on a line from Davis 7° north of east. Looking at an invariant coordinates map (Boyd 1983), this roughly corresponds to a region with an invariant latitude 0.7° higher than Davis (i.e. 75.2°S as opposed to 74.5°S) and a magnetic time approximately 8 minutes earlier than Davis. No account has been taken of these variations, except for this discussion, in presenting the Davis data.

Principally two forms of chart analysis were undertaken. One involved routine scaling at fixed times and the other focused on absorption events.

The routine scaling consisted of measurements every half hour in universal time (UT). Figure 1 shows a riometer trace incorporating an absorption event. The half hourly values scaled are marked. The absorption event is incompletely described by this scaling but the routine nature of this form of scaling enables an evaluation of average absorption values. This is because the values scaled are selected without knowledge of the occurrence of an event. It is from these half hourly scalings that the computer determined QDCs and absorption variations are calculated. Daily calibration signals were measured to correct for chart alignment and system linearity. Figure 2 shows the average calibration currents versus chart value for the Davis and Casey riometers. The Casey riometer is slightly non-linear. This non-linearity was roughly corrected by linearly interpolating between points on the calibration curve.

Event scaling involved identifying and classifying absorption events as described in section 3.1. Parameters scaled for each event were start time, stop time and the maximum absorption amplitude. This scaling allows us to investigate the diurnal occurrence of different types of events, their duration and their relative amplitude. For this form of analysis we only consider the maximum absorption amplitude of the event. The estimation of the maximum absorption amplitude was not done with reference to QDCs but directly from the chart record. This means that an absorption event may be mis-scaled as a short-term event when it is really a deeper long-term event. The event scaling was not referred to a QDC because of the extra time the scaling would have taken. Mis-scaled events are estimated to be rare. Events with a maximum absorption amplitude in excess of 0.3 dB were scaled. For the absorption event depicted in Figure 1 the event scaling points are marked.

2. THE DIURNAL AND SEASONAL VARIATION OF THE RIOMETER SIGNAL LEVEL

2.1 DETERMINING A QUIET DAY CURVE

A riometer receives the integrated VHF radiation within its receiver bandwidth from radio sources within its antenna beam. Solar radiation at this frequency is negligible except at times of solar activity. When this occurs the increased emissions are extremely unstable and easily discernable positive excursions, if they are not confused with HF transmission interference. Under quiet conditions, the riometer reaches a maximum when the galactic centre is in the beam. Because of the Earth's annual revolution around the Sun, the sidereal day, which determines when the same sources are in the antenna beam, is approximately 4 minutes shorter than the solar day. The characteristics of a riometer absorption event are measured relative to a quiet value at a similar sidereal time. The determination of a QDC, obtained from the riometer trace under quiet atmospheric conditions, is the starting point for an analysis of riometer data.

The riometer is principally a device for examining particle precipitation effects on the ionosphere, however the 'quiet' ionosphere which exists due to solar radiation causes some attenuation of the stellar signal received at the site. The inclination of the Earth's rotation axis with respect to the plane of its orbit around the Sun results in a seasonal variation of the background ionosphere effect. Because of the resultant variation in the level of background absorption, the riometer QDCs against which absorption levels are measured are generally determined for periods of less than a season. Often a period of one month is chosen. The variation in QDCs determined for different seasons of the year are a measure of the variation to the background level of ionospheric absorption.

Many methods have been proposed and used to determine riometer QDCs. Because absorption will only result in a decrease in the signal received by a riometer, most methods rely on splitting the received signal strengths into sidereal time bins and then picking some near top value recorded in each bin. To reduce the influence of any interference in the determination of the QDC, the point chosen from each bin is generally selected by eye, thus rejecting obvious noise values, or by some percentage criterion. Krishnaswamy et al. (1985) advocated the Inflection Point Method (IPM). This involves selecting as the QDC value from a sidereal time bin, the point of most rapid descent of a histogram generated from data in that bin. A smooth curve is then fitted through these points. This is the method which we have adopted to generate QDCs from our half hourly sampled data. Discussions of the advantages of this method are contained in Krishnaswamy et al. (1985).

2.2 SIDEREAL AND SEASONAL VARIATION IN THE QUIET DAY CURVE

In Figure 3, QDCs determined for Davis and Casey for December 1985 are shown. The solid lines represent the QDC determined by the IPM. The dots are the individual half hourly scaling values arrayed in LST. The QDCs at both stations have a smooth single peak sidereal variation. The Casey curve reaches a maximum near 1630 LST, when the Milky Way is overhead, and a minimum near 0330 LST. The Davis curve peaks near 1400 LST, indicating that the antenna is skewed approximately 40° to the east of vertical.

The monthly QDC values for Casey from March 1985 to January 1986 for 0400, 1100, 1600 and 2000 LST are plotted in Figure 4. In general terms, for all times, the QDC value is higher in winter than in summer. This is likely to be caused by the marked seasonal variation in the solar radiation incident on the Antarctic ionosphere.

3. SOME CHARACTERISTICS OF IONOSPHERIC ABSORPTION IN THE POLAR CAP AND CUSP REGIONS

3.1 CLASSIFICATION OF IONOSPHERIC ABSORPTION

All ionospheric disturbances can be traced back to a solar origin. With increasing solar activity X-ray and EUV fluxes increase, directly influencing the ionosphere. At a later time, charged particles and an intensified solar wind from the same disturbance may batter the magnetosphere resulting in increased energetic particle precipitation at high latitudes. An individual solar event will affect the ionosphere differently at different locations and at different times.

We attempt to classify absorption events in the following manner (as per Murray and Wilkinson 1983).

3.1.1 Solar flare absorption (SFA)

When a strong solar flare occurs, the flux of solar X-rays incident on the ionosphere increases significantly within minutes of the flare. This results in a strongly ionised D region in the sunlit hemisphere and increased absorption of VHF waves. The riometer signal of these events is often accompanied by solar VHF noise spikes. This type of event may also be referred to as a short wave fade-out. Figure 5 shows an example of SFA recorded at Macquarie Island in 1985.

3.1.2 Polar cap absorption (PCA)

Within 10 minutes to a few hours of an intense solar event, the energetic particles ejected by the flare reach the Earth and are guided to the polar regions by the Earth's magnetic field. The result is enhanced ionisation in the D region and intense absorption of HF signals. Principally solar protons are responsible for PCA events. PCA events often persist for a number of days. Figure 15 shows some PCA events recorded at Casey and Davis during the study period.

3.1.3 Auroral absorption (AA)

From 1 to 3 days after the initial solar disturbance, an intensified solar wind and associated shock waves may batter the magnetosphere generating a magnetic storm. Fluctuations in this battering may result in a series of auroral substorms which precipitate energetic particles, principally electrons, into the auroral regions at high latitudes. These result in often abruptly initiated, short duration (with respect to SFA and PCA), absorption events. Figure 6 shows an AA event, and the associated H component magnetograph, recorded at Davis on 26 April 1985.

We may also classify absorption events in terms of their appearance on the riometer chart records.

The following classifications are made:

3.1.4 Sudden cosmic noise absorption (SCNA)

Figures 1 and 6 show examples of SCNA events. SCNAs are events which reach a sharp absorption maximum shortly after the event commences and then gradually recover. SFA and some AA events are classified as SCNA. For the purpose of this analysis, SCNA events may occasionally be referred to as type A absorption events.

3.1.5 Gradual cosmic noise absorption (GCNA)

Figure 7 shows two examples of a GCNA event. GCNA events do not have a dominating abrupt start but still exhibit fluctuations in absorption level. Weak AA events belong to this classification. We may refer to these events as type B absorption events.

3.1.6 Slow cosmic noise absorption (SLCNA)

The events shown in Figure 15 are long duration SLCNA events. Figure 8 shows a brief SLCNA event. A SLCNA event is smoothly varying (relative to other absorption events) from the beginning to the end of the event. PCA events are classified as SLCNA. Daytime AA events may have a SLCNA form. We may refer to these events as type C absorption events.

3.2 EVENT ANALYSIS

Auroral absorption events were classified as type A, B or C according to the descriptions in sections 3.1.4, 3.1.5 and 3.1.6. The start time, end time and maximum absorption amplitude were also noted (see section 1.4). The minimum classifiable maximum absorption amplitude was 0.3 dB. There is a striking difference between the number, type and also the time distribution of the absorption events recorded at Casey and Davis.

The mean maximum absorption amplitude for the 305 events observed at Davis for 1985 was 1.40 dB. Sixty-four events (21%) were classified as type A, 137 (45%) as type B and 103 (34%) as type C.

At Casey the analysis period was significantly longer, from 1 March 1985 to 30 November 1986, however only 37 AA events were observed. The mean maximum absorption amplitude of these events is 0.87 dB. Three (8%) type A events, 9 (24%) type B events and 25 (68%) type C events were observed.

3.3 THE SEASONAL VARIATION IN EVENTS RECORDED AT DAVIS AND CASEY

At Davis, absorption events are generally more common in winter than in summer, both in terms of the percentage of time for which events are recorded (calculated as the total time during the month for which absorption events were in progress divided by the total time during the month, see Figure 9), and the average absorption value. The average absorption value is calculated as the sum of the products of the maximum absorption amplitude by the time duration of the event for all events in the month divided by the amount of time in the month (Figure 10).

In Figures 9 and 10, it is shown that a winter peak in absorption activity occurs for the total of events recorded and specifically for both A and B types. Type C events do not show a winter occurrence peak. Type C events are perhaps a little more common in spring and summer than in autumn and winter, however this variation may not be significant.

So few events were recorded at Casey that a split in terms of types would not be significant. The total number of events per month does however show a winter peak (Figure 11).

In Figures 9, 10 and 11 the average monthly Ap value and the monthly total of observed solar flares are also shown. The effect of flares is not as marked on the absorption event occurrence at Casey as it is at Davis. The X class flare in February 1986 may however have affected the distribution recorded at both stations.

The association of increased absorption at Davis with flare activity is probably due to the close location of this station to the midnight auroral oval and the increased particle precipitation in this region following solar activity. Casey is apparently too far inside the auroral oval to be affected in this manner, except following X class flare activity. If absorption events are principally associated with particle precipitation events in the auroral oval, then this may account for the large disparity between the number of events observed at Davis and Casey.

The winter peak in absorption activity, which is more obvious at Casey, must have a separate explanation. The effect of increasing the solar wind on the location of the auroral oval is to push the daytime cusp to higher latitudes and the midnight oval to lower latitudes than would otherwise be the case. On average, because of the inclination of the Earth's rotation axis to the ecliptic, the angle of attack between the solar wind and the geomagnetic field will vary between winter and summer. Because of this we would expect the shift in the auroral oval to be larger in summer than in winter. Thus the winter auroral oval would be, on average, closer to both Davis and Casey in winter.

For a station whose invariant latitude places it equatorward of the auroral zone, this argument would predict a summer maximum for absorption events. This is the result obtained by Rosenberg and Dudeney (1986) for Siple station. Siple station has an invariant latitude of 60.4°S, placing it generally equatorward of the auroral oval.

3.4 THE DIURNAL VARIATION OF RIOMETER ABSORPTION AT DAVIS AND CASEY

Figure 12 shows the diurnal occurrence of the 305 AA events recorded at Davis. The data are also split into type A, B and C events. There are two principal diurnal peaks in absorption activity. A major peak occurs between 1930 and 2200 UT, and a minor peak between 730 and 1000 UT. These correspond with magnetic midnight (approximately 2125 UT) and magnetic noon (approximately 9025 UT) at Davis. Other features are the sharp decline in absorption events following both peaks and the more gradual increase leading up to the peaks. Also notable is the almost total absence of events between 1200 and 1600 UT (corresponding to approximately 1430 to 1830 MLT). Following the peak in activity at magnetic midnight a significant level of absorption activity is maintained leading up to the magnetic noon activity peak.

Type A events are clustered around magnetic midnight. Type B events show a predominantly magnetic midnight occurrence with a slight occurrence in the magnetic morning and noon hours. Type C events are more prominent at and leading up to magnetic noon but still have a significant occurrence level at magnetic midnight.

Figure 13 shows a diurnal plot, for all event types, of the sum of the product of the maximum absorption and duration of each event divided by the total number of observation minutes in that time bin. It is a very rough estimation of average absorption. The notable features of this are that the magnetic noon feature become less significant, indicating a low absorption level for these events, and that the magnetic midnight peak shifts significantly to earlier hours. The peak is between 1900 and 2000 UT (approximately 2130 and 2230 MLT) indicating that larger absorption events occur significantly earlier in the evening than most of the magnetic midnight absorption events.

Only 37 absorption events were recorded at Casey, so the half hourly scaled values were used to investigate the diurnal variation of absorption at this site. Figure 14 shows the percentage of values in each half hour bin which exceed a 0 dB (Figure 14a) and 1 dB (Figure 14b) threshold. Magnetic midnight at Casey is at approximately 1724 UT and magnetic noon at 524 UT.

The events exceeding 0 dB show a minor midday peak and then a broad peak between 11 UT (1936 MLT) and 24 UT (624 MLT) surrounding magnetic midnight. The most dominant feature is a 'dip' between 730 UT and 930 UT. When the data are restricted to absorption events in excess of 1.0 dB, then the midday peak shifts to 400 UT (1039 MLT) and there are minor peaks about 11 UT (1936 MLT) and 22 UT (536 MLT) with a minimum between 1500 UT (2124 MLT) and 1930 UT (206 MLT).

Casey absorption events are few in number and the associated peaks in activity are minor. The magnetic midday peak, which for large absorption events is dominant, is likely associated with the passage of the cusp. The twin peaks surrounding magnetic midnight may be associated with poleward surges when the oval is closest to Casey.

4. DISCUSSION

4.1 THE RELATIONSHIP BETWEEN SOLAR FLARES AND IONOSPHERIC ABSORPTION

Following solar flare activity there may be an increase in the amount of ionospheric absorption activity. This can be seen in Figures 9 and 10 where the Davis April absorption peak appears associated with flare activity in that month.

In a burst of solar activity, M class flares occurred on 3, 4, 5, 7 and 11 (2 flares) February 1986 (Table 2). The more intense X class flares occurred on 4 and 6 February. Figure 15a shows the absorption recorded at Casey from 4 to 12 February. In April 1985 an M class flare was observed on the 23rd and an X class flare on the 24th. Figures 15b and 15c show the absorption records for Casey and Davis for the period 23 April to 1 May. Both periods resulted in PCA events. One apparent characteristic of PCA events is that the absorption is larger in the daylight hours than at night. The PCA events commence within a day of the X class flare, but in the case of the February 1986 event the absorption maximises 3 days after the second X class flare and for the April 1985 event the maximum absorption is reached after 2 days.

DATE	Class M	Class X	Fadeout possible on daylight circle (UT)
20/1/85	1		2041-2113
21/1/85	6		0340-0408, 0503-0532, 1350-1436, 1514-1549, 1640-1713, 2127-2155
		1	2350-0043
23/1/85	1		0721-0846
22/4/85	1		1637-1651
24/4/85		1	0845-1002
2/5/85	1		0741-0753
13/5/85	1		0904-0948
2/7/85	1		2103-2150
9/7/85	1		0126-0227
26/10/85	1		0352-0441
3/2/86	1		2034-2115
4/2/86		1	0732-0805
	1		1018-1054
5/2/86	1		1232-1321
6/2/86		1	0618-0707
7/2/86	2		0328-0413, 2259-2345
13/2/86	1		0102-0419
14/2/86	1		0902-1028
15/2/86	2		1016-1300
3/3/86	1		1242-1257
5/3/86	1		0706-0820
24/4/86	3		0034-0055, 0340-0403, 0603-0707
4/5/86	1		0939-1039
19/10/86	1		0000-0118

Table 2. Solar flare activity during 1985 and 1986. Data were obtained from IPS Radio and Space Services, Solar-Geophysical Summary.

The April 1985 event shows that the PCA event persisted for longer at Casey than at Davis. Absorption levels are still high on 30 April at Casey, while they have essentially returned to zero by 29 April at Davis. The mean absorption for each day is also larger at Casey than at Davis. This is likely to be related to the location of the stations; Casey is within the polar cap while Davis is on the edge of the polar cap.

4.2 THE RELATIONSHIP BETWEEN IONOSPHERIC ABSORPTION AND MAGNETIC STORMS

For Casey data, whenever there is an absorption event there is an associated magnetic signature. The reverse is not always the case. On many occasions large magnetic bays were observed but little or no absorption was observed. Absorption events were more likely to occur when the Z magnetometer trace reverses direction indicating that the current system had passed overhead of the station. Generally as the level of magnetic activity increases, the probability of, and amplitude of, absorption events increase. Using the extensive event data set from Davis, for each day for which an absorption event was recorded, the maximum amplitude was associated with the Ap (a global measure of the level of sub-auroral magnetic activity) for that day. In this manner the maximum absorption, A, was related to the Ap value as follows

$$A \text{ (in dB)} = 0.035 \times (Ap-6.5) + 1.2$$

Table 3 shows the data used to derive this relation. The standard deviations of each bin indicate that the usefulness of the relation is limited.

It is also true for the Davis data that when there is an absorption event, there is associated magnetic activity. Again the reverse does not necessarily follow.

4.3 THE RELATIONSHIP BETWEEN ABSORPTION EVENTS AT DAVIS AND CASEY

Events recorded at Casey are often associated with an earlier absorption event at Davis. In Table 4 we have listed the 23 events recorded between 1 March 1985 and 1 March 1986 and the closest associated event at Davis. For 13 of the events the maximum absorption of an event at Davis occurred within 21 minutes of the maximum absorption of an event at Casey. In only one case did the Casey event maximum occur before the Davis event maximum. This result most likely follows from those times when the poleward expansion of

Ap	A(in dB)	σ(n dB)
< 10	1.18	0.72
10-19	1.52	1.08
20-29	1.84	1.63
≥ 30	2.19	1.49

Table 3. Davis 'event' data. For days when an event was recorded, the maximum absorption for that day was associated with the Ap for that day. The mean and standard deviation (in dB) for a range of Ap values are tabulated.

the auroral oval, during an auroral substorm, reaches as far poleward as Casey. Casey has an invariant latitude of 80.6°S; Davis has an invariant latitude of 74.5°. Magnetic midnight occurs approximately 4 hours earlier at Casey. Davis and Casey are 1390 km apart. Also shown in Table 4 are the auroral surge propagation speeds implied. These range from 0.64 km s^{-1} to 7.72 km s^{-1}.

	CASEY			DAVIS			DIFFERENCE	
Date	Duration	MAT	A	Duration	MAT	A	TIME	SPEED
26/3/85	2200-2313	2203	0.50	2150-2240	2155	1.2	8	2.88
28/4/85	0010-0045	0023	0.56	2356-0330	0020	4.23	3	7.22
26/5/85	1912-2100	1922	0.23	1900-1930	1914	1.63	8	2.88
6/6/85	1612-1700	1624	1.27	1600-1718	1607	2.07	17	1.36
9/6/85	2015-2100	2037	0.60	2000-2048	2001	1.85	36	0.64
	2212-2250	2220	0.68	2207-2300	2227	2.70	-7	-3.31
10/6/85	1927-2000	1933	0.50	1830-2312	1839	3.27		
26/6/85	1906-1953	1931	1.19	1848-2154	1910	7.57	21	1.10
5/7/85	2035-2100	2041	0.43	2010-2045	2022	2.34	19	1.22
8/7/85	1840-1922	1854	0.99	1832-1900	1839	2.47	15	1.54
20/8/85	1540-1630	1546	0.68					
22/8/85	1727-1818	1743	1.20	1630-1800	1645	1.51		
27/8/85	1740-1850	1755	0.50	1836-2018	1842	3.65		
		1842	0.60					
14/9/85	1335-1418	1351	0.46	0600-0930	0747	0.51		
15/9//85	1940-2000	1945	0.52	1924-1955	1928	1.64	17	1.36
16/9/85	1713-1743	1723	0.40					
5/10/85	1710-1800	1718	0.75					
	2011-2047	2026	0.43	1950-2045	2005	1.10	21	1.10
27/11/85	0448-0612	0515	0.23					
7/2/86	1711-1741	1720	0.78	1700-1755	1706	2.80	14	1.65
	2124-2200	2131	0.67	2108-2300	2114	2.91	17	1.36
8/2/86	2049-2240	2051	6.65	2045-2200	2047	8.86	4	5.79

MAT = Maximum Absorption Time (UT)
A = Maximum Absorption (dB)

Table 4. Associated absorption events at Casey and Davis event. The time difference between the occurrence of the maximum absorption levels and the implied speed between the two stations are also indicated.

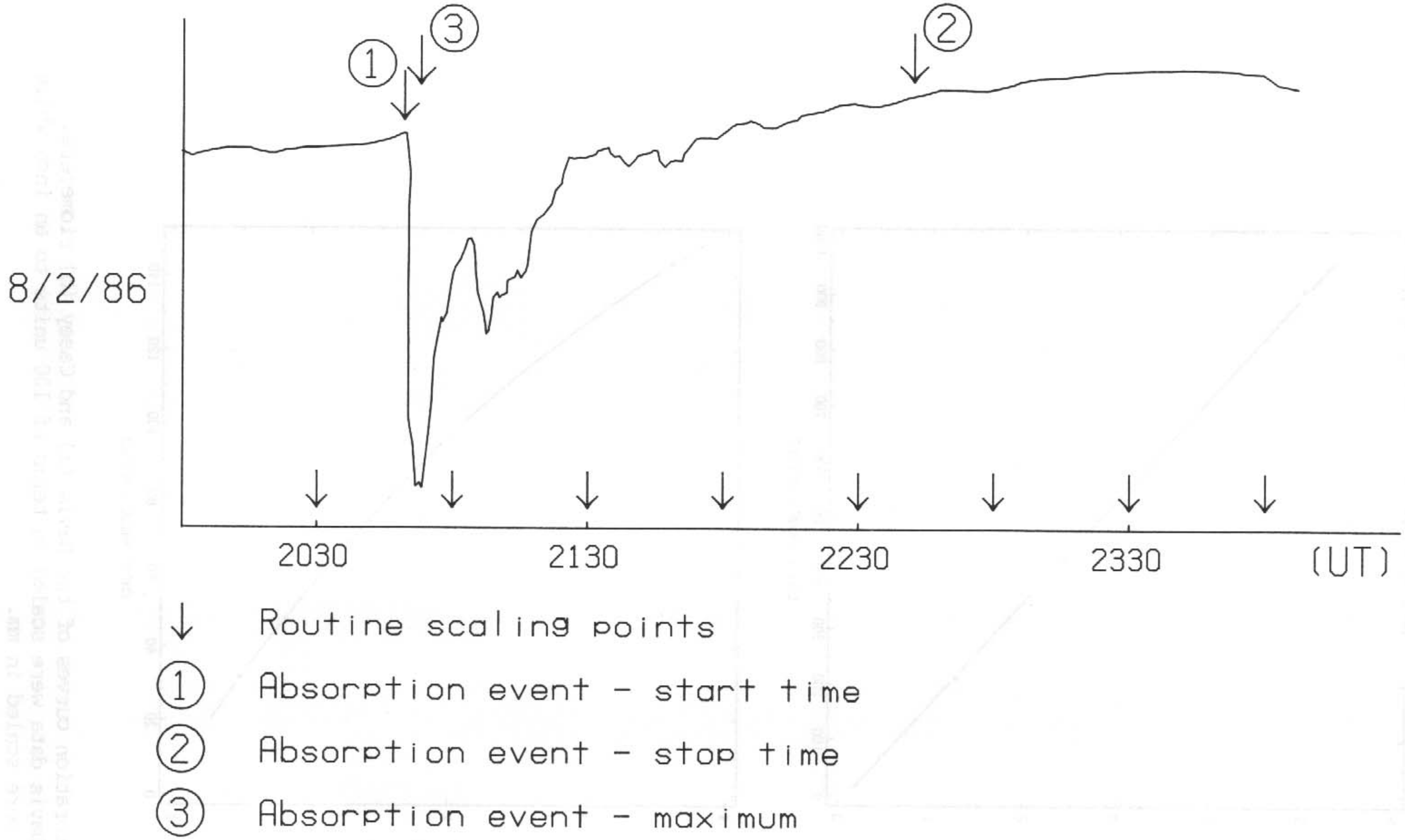


Figure 1. Casey riometer record showing 'routine' and 'event' scaling points.

(a)

(b)

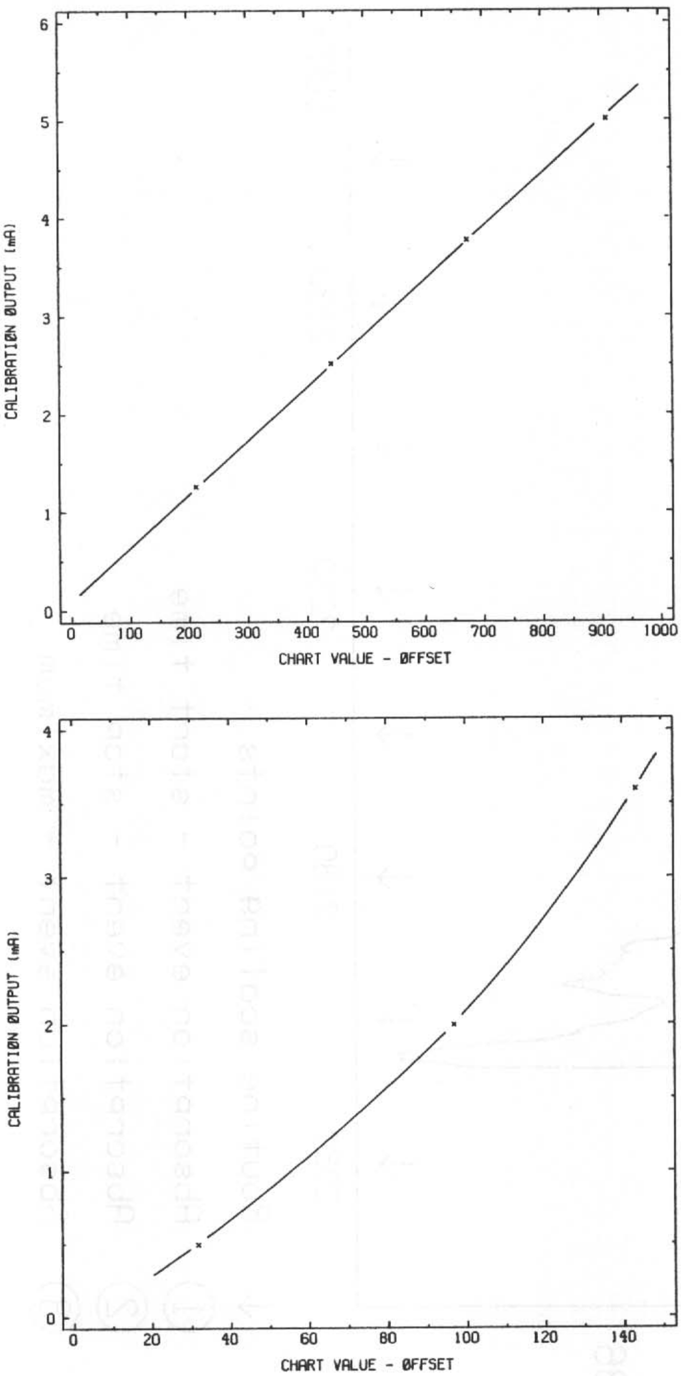


Figure 2. Calibration curves of the Davis (a) and Casey (b) riometers. Note that the Davis data were scaled in terms of 100 units to an inch while the Casey data were scaled in mm.

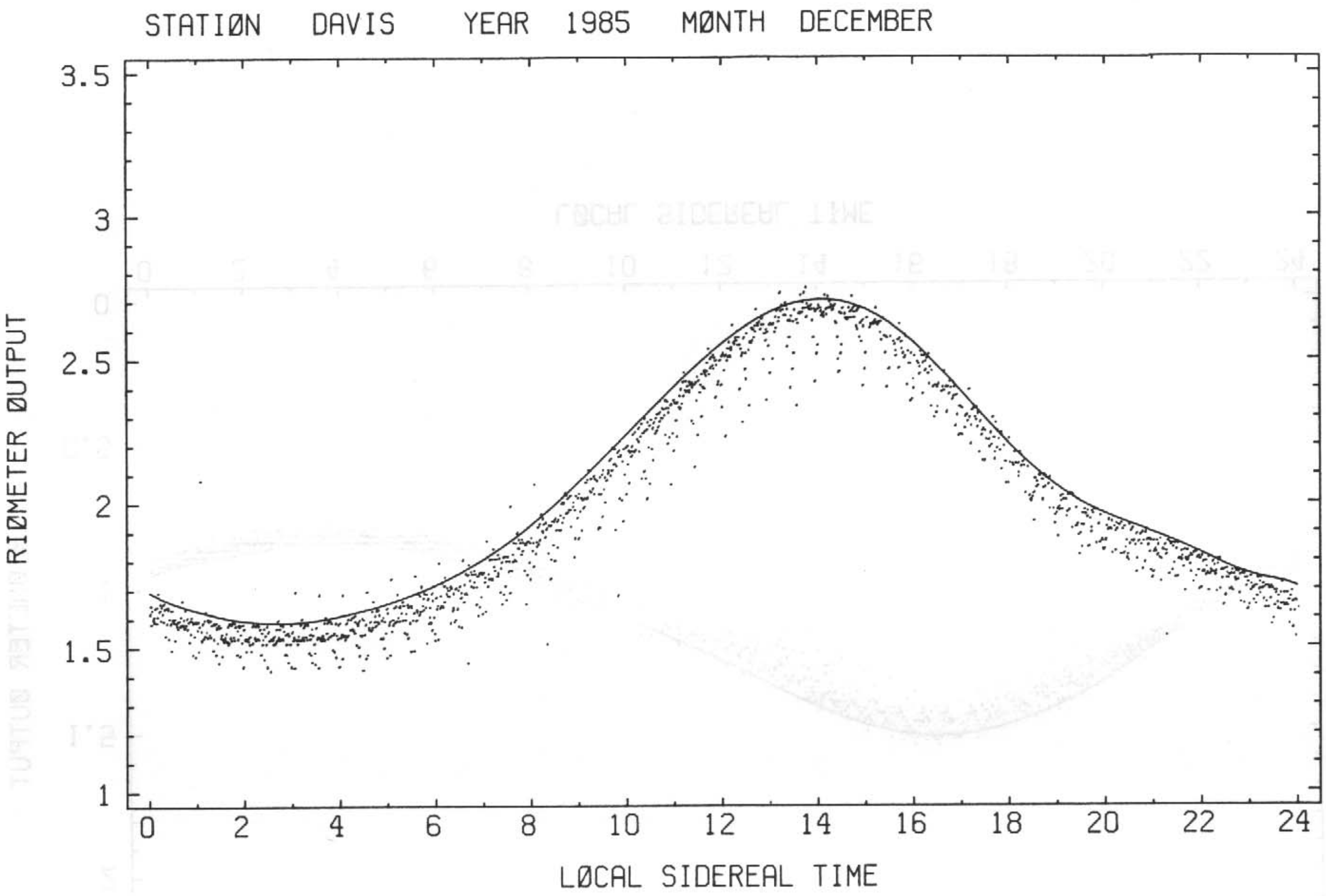
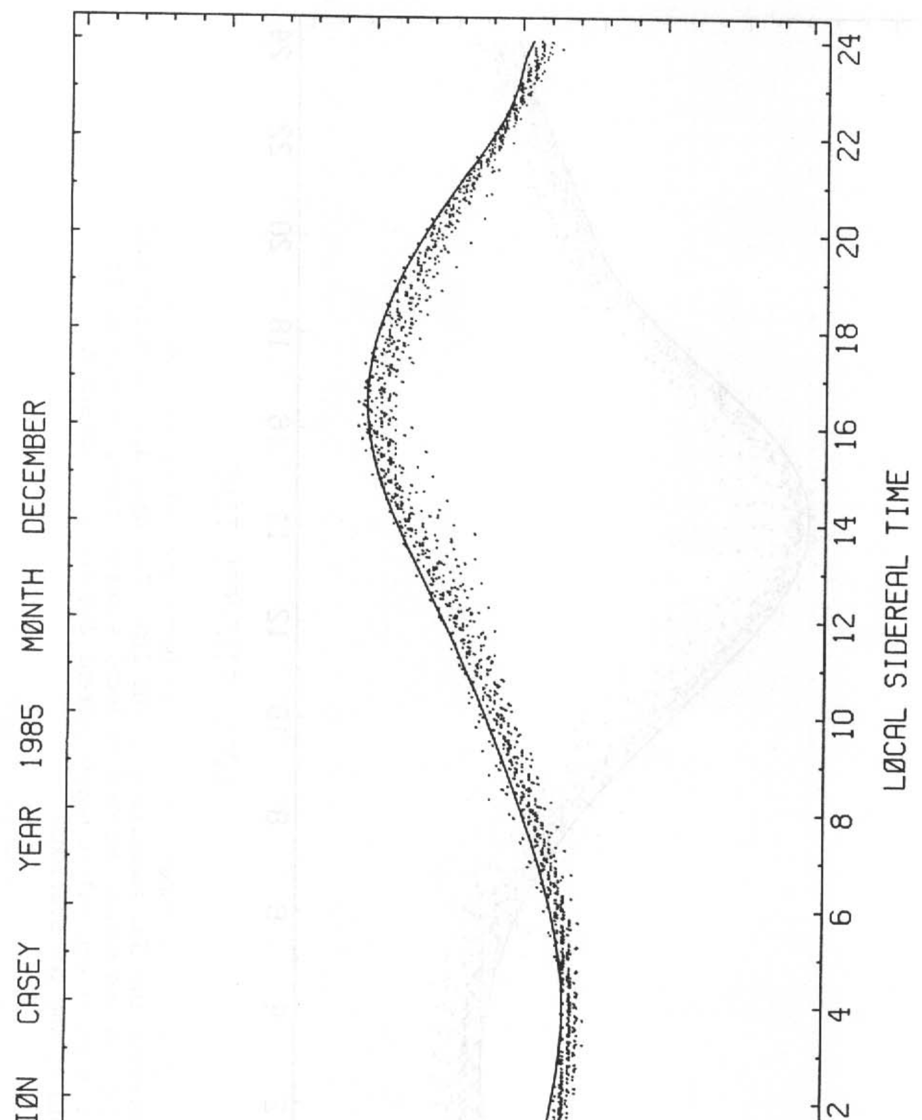


Figure 3. QDCs for December 1985 for (a) Davis and (b) Casey. The solid lines represent the QDC determined by the IPM. The dots are the individual half hourly scaling values arrayed in local sidereal time. The riometer output is in mA of equivalent noise current and are not absolutely comparable at the two stations.


STATIØN CASEY YEAR 1985 MØNTH DECEMBER
RIØMETER ØUTPUT
LØCAL SIDEREAL TIME

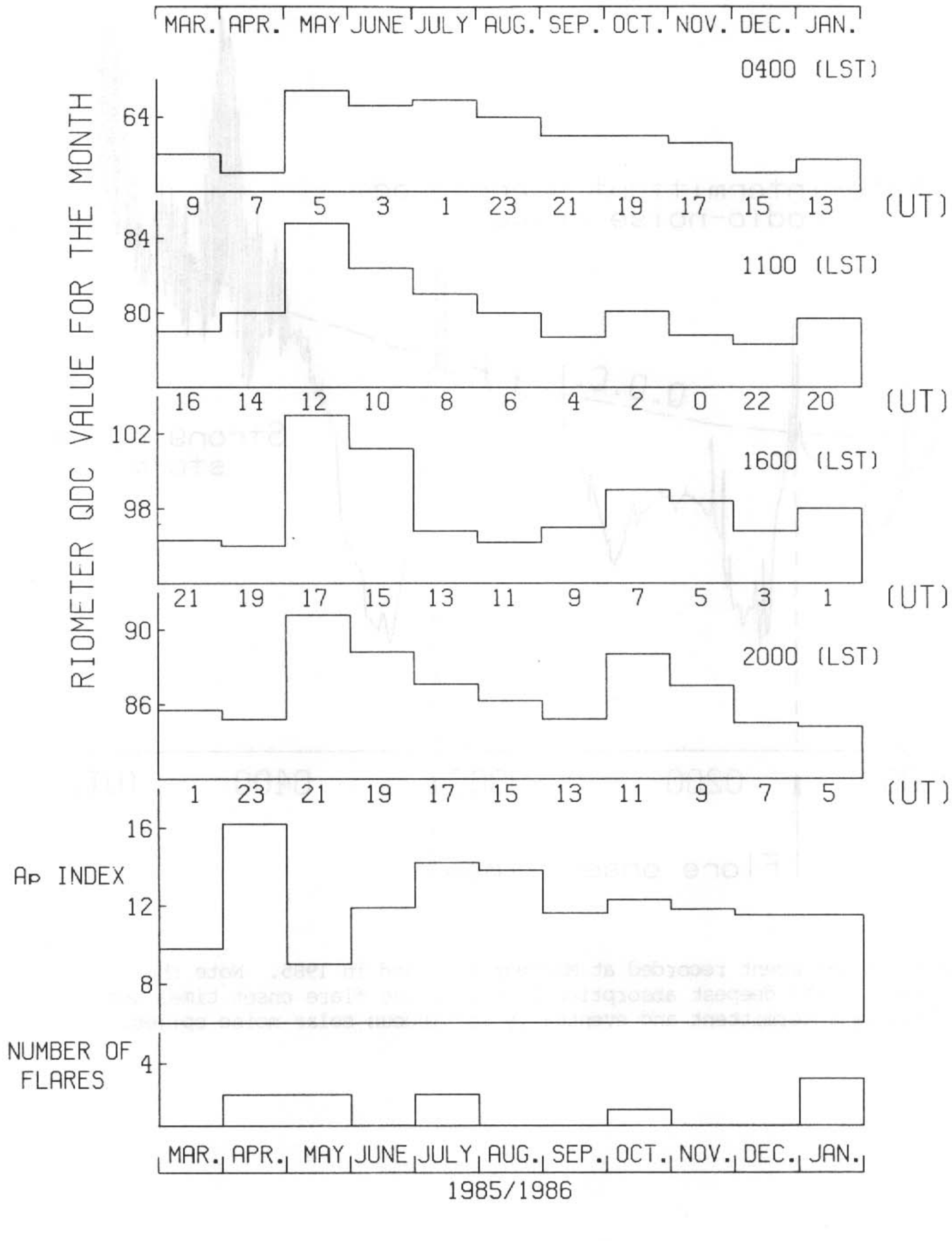


Figure 4. Monthly QDC values for 04, 11, 16 and 20 LST for Casey. The riometer QDC values are in 'arbitrary chart units'. The approximate UT associated with each LST for each month is noted below each histogram. The bottom two histograms show the average A_p value for each month and the number of solar flares reported in each month.

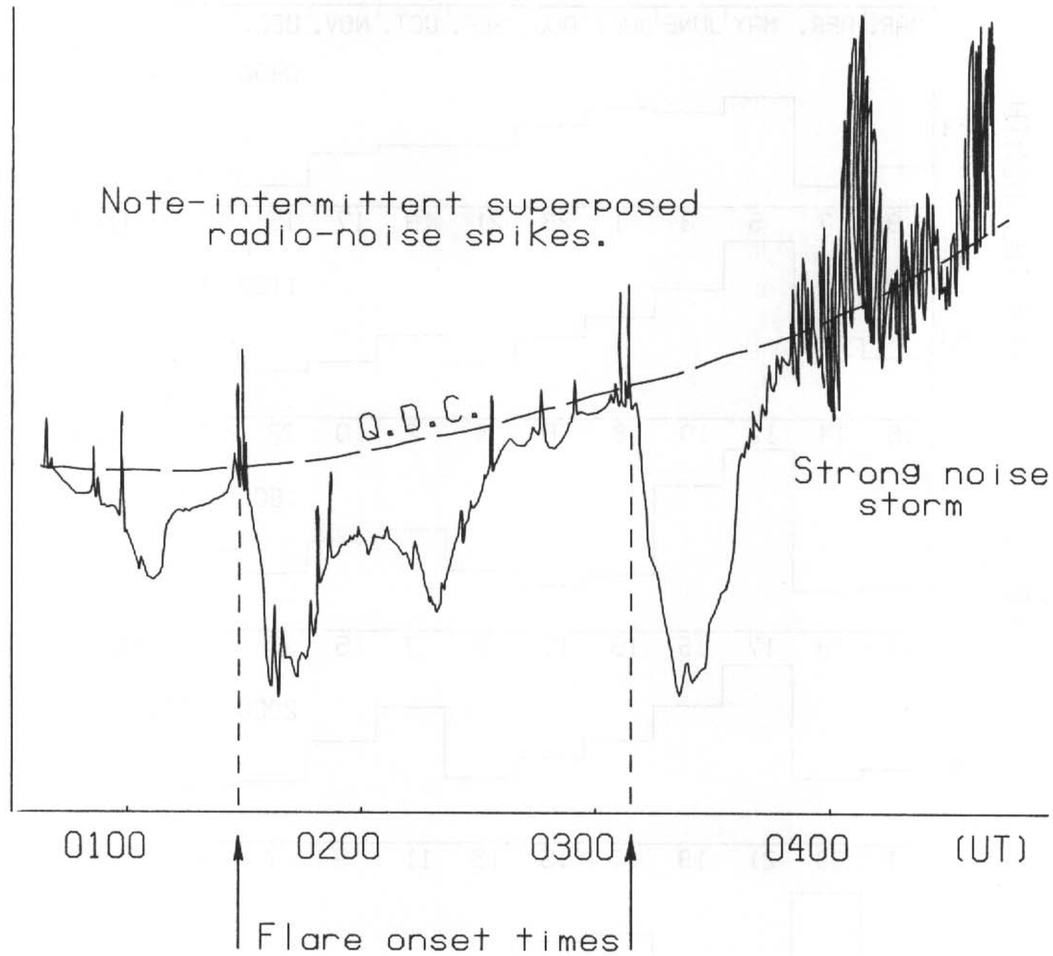


Figure 5. A SFA event recorded at Macquarie Island in 1985. Note the association of the deepest absorption bays with the flare onset times and the initially intermittent and eventually continuous solar noise spikes.

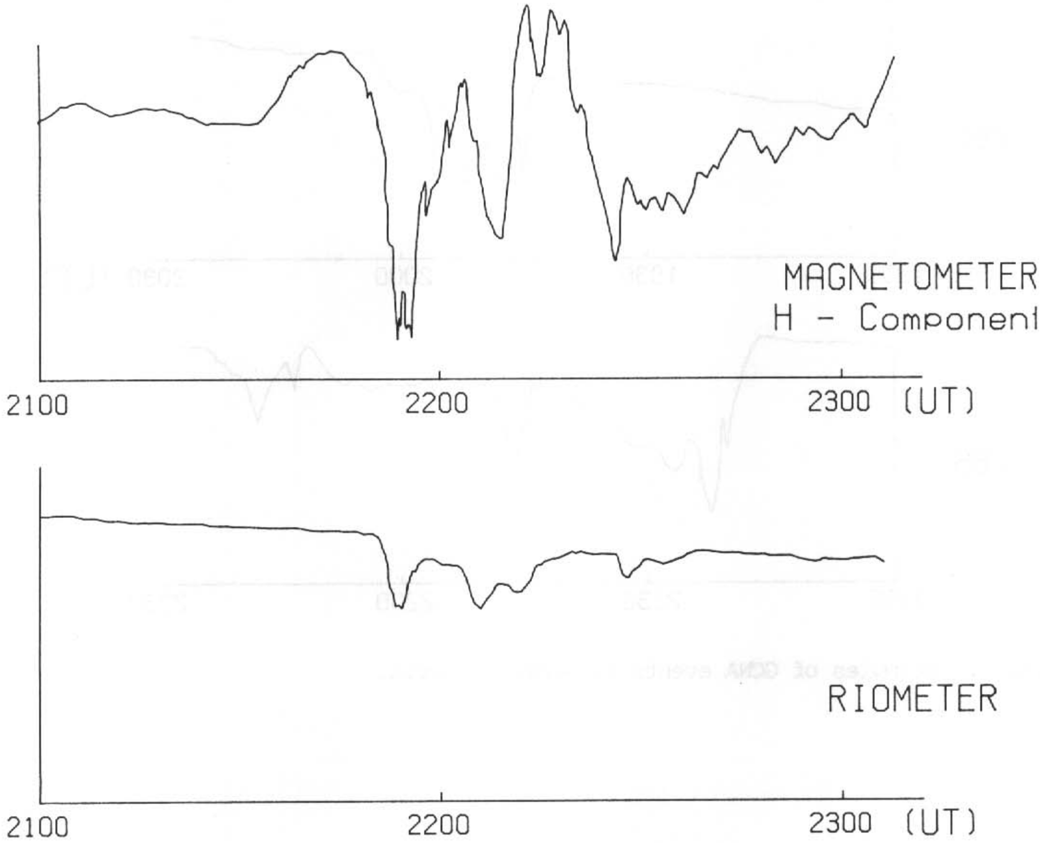


Figure 6. An AA event recorded at Davis between 21 UT and 23 UT on 26 April 1985. The H component magnetic field variation for the same period is also shown.

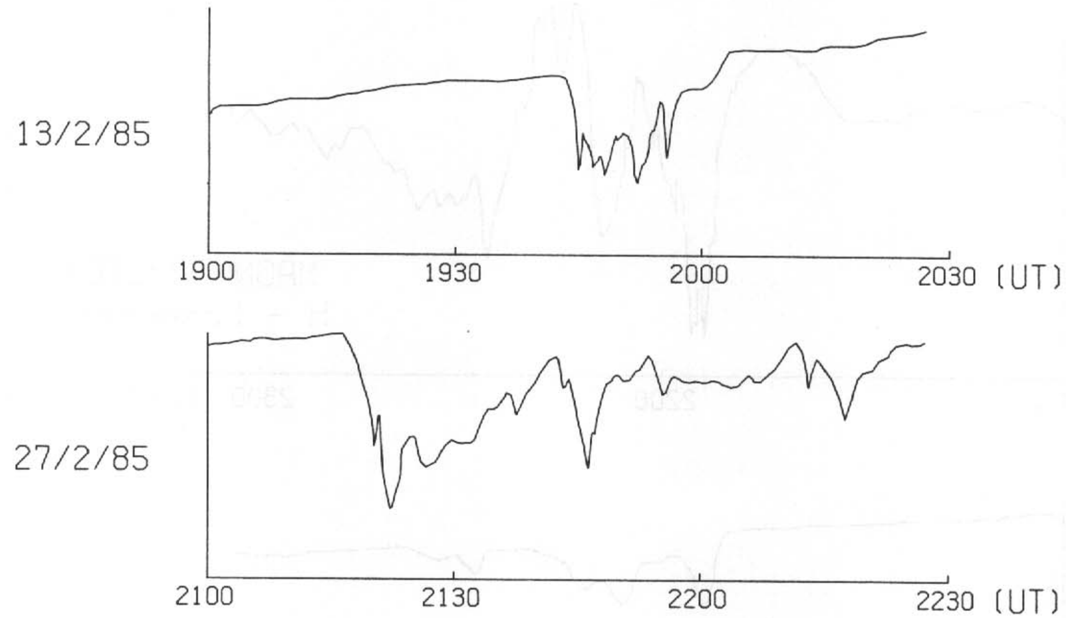


Figure 7. Examples of GCNA events recorded at Davis.

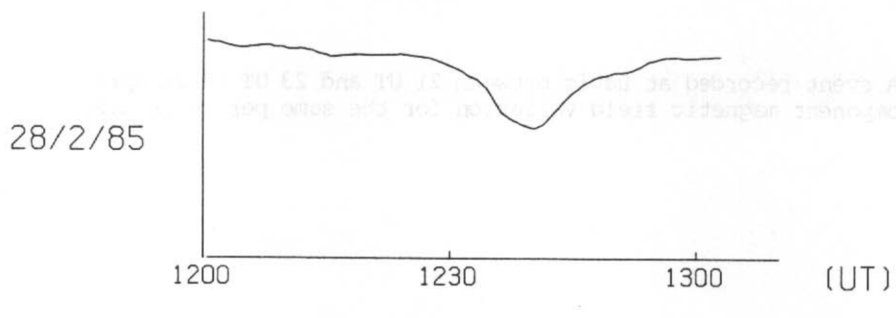


Figure 8. An example of a brief SCNA event. (Figure 15 shows examples of long duration SCNA events.)

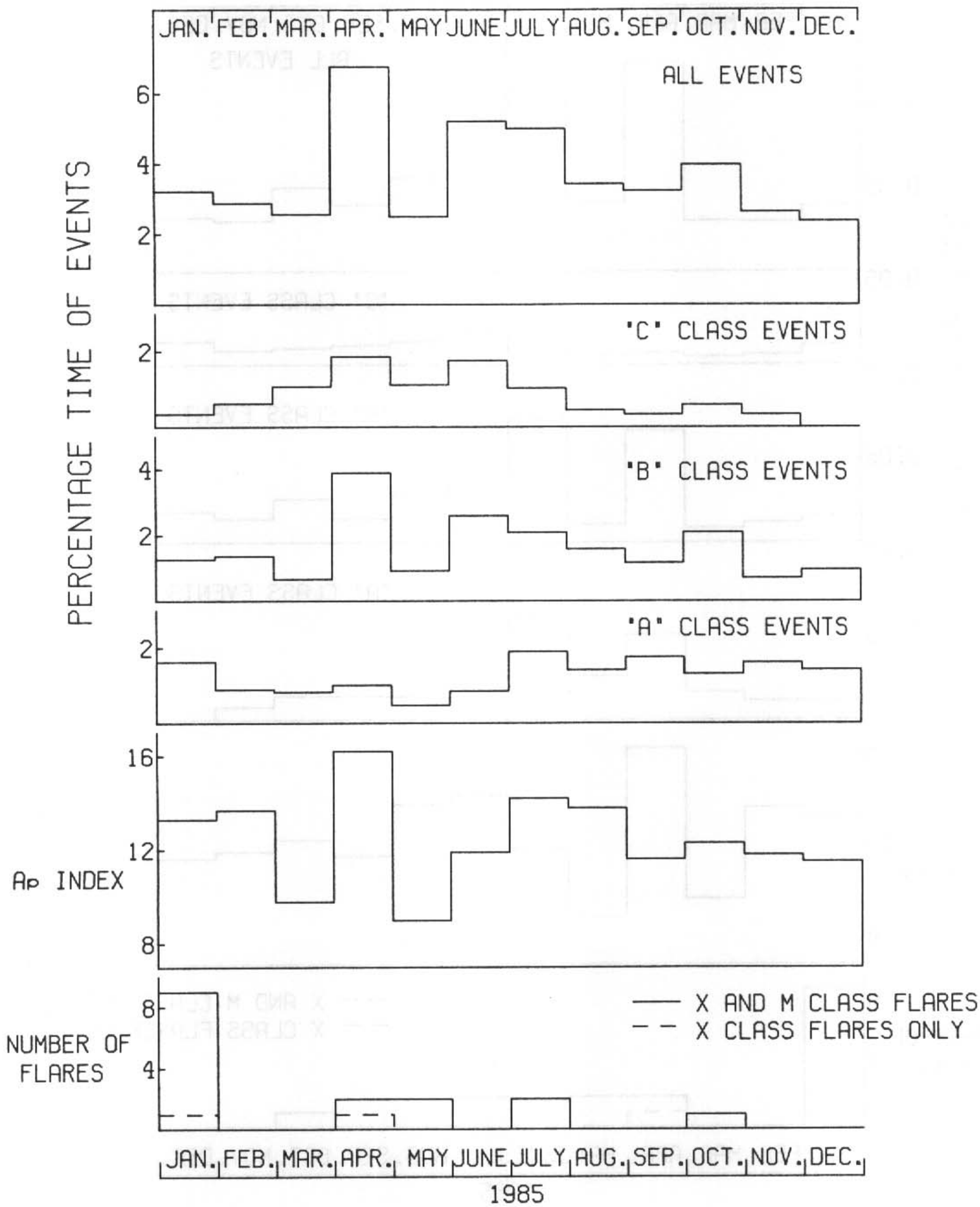


Figure 9. Davis, 1985. The average time for which absorption events are recorded for type A, B and C events calculated as the percentage of time for which absorption events were in progress divided by the total time during the months. The average Ap index and the monthly total of observed solar flares are shown for comparison.

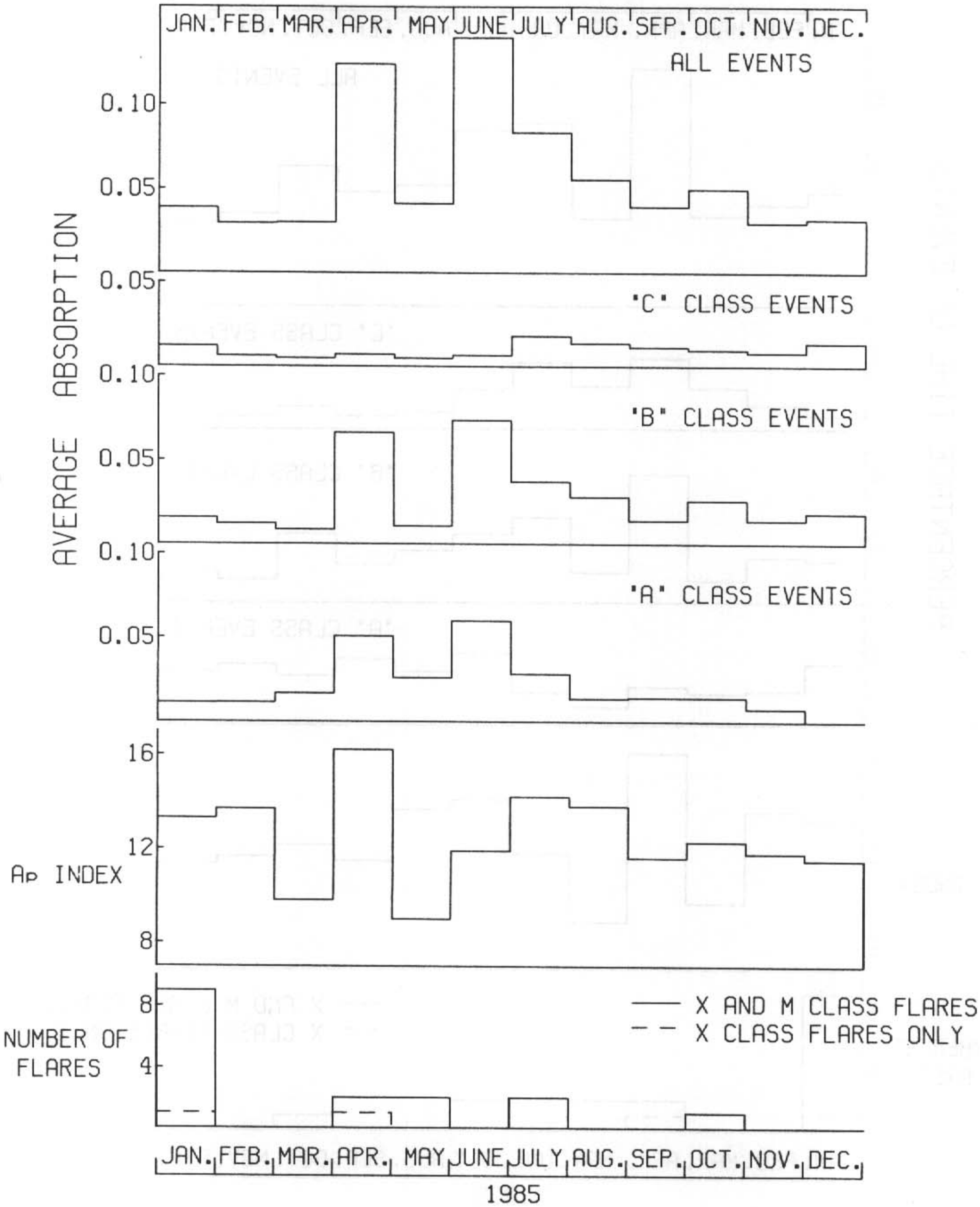


Figure 10. Davis, 1985. The average monthly absorption value determined as the sum of the products of the maximum absorption amplitude by the time duration of the event for all events in the month, divided by the amount of time in the month. The average Ap index and the monthly total of observed solar flares are also shown.

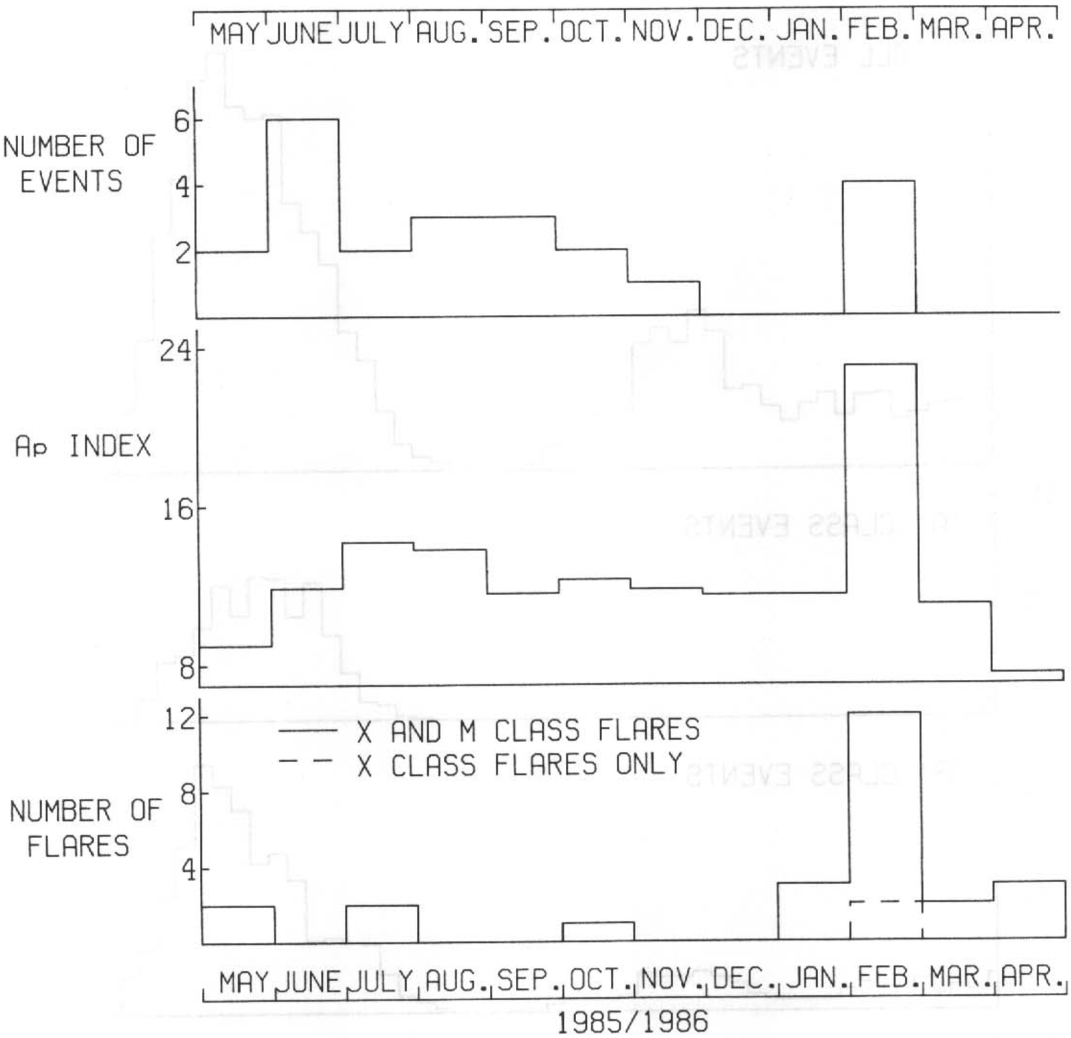


Figure 11. The monthly total of absorption events (all types) recorded at Casey for the period May 1985 to April 1986. The average Ap index and the monthly total of observed solar flares are also shown.

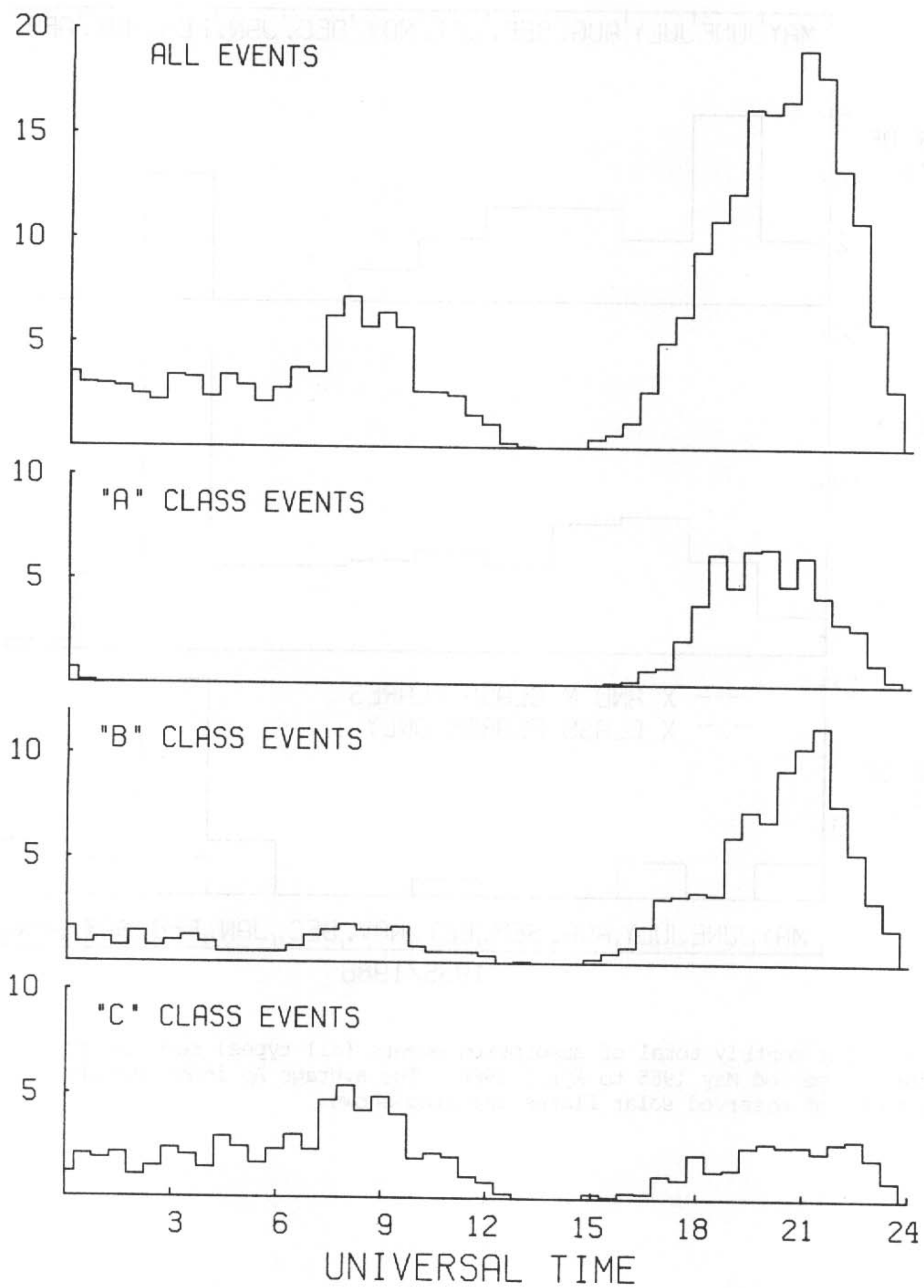


Figure 12. The diurnal occurrence of AA events at Davis. A histogram for all events is presented along with individual histograms for class A, B and C events.

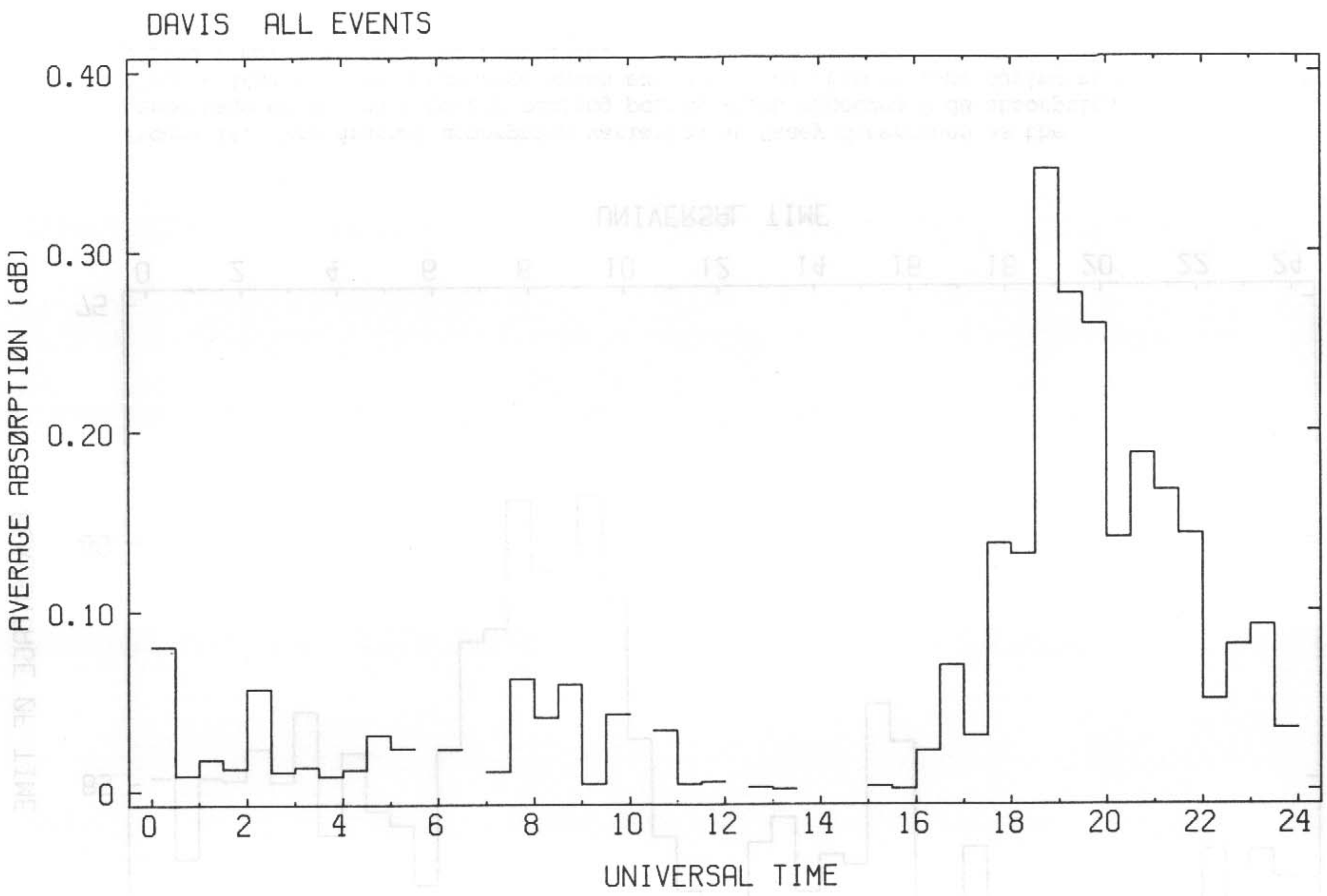


Figure 13. The average diurnal absorption variation at Davis determined inclusively of all events types, as the sum of the product of the maximum absorption and duration of each event divided by the total number of observation minutes in that time bin.

(a)

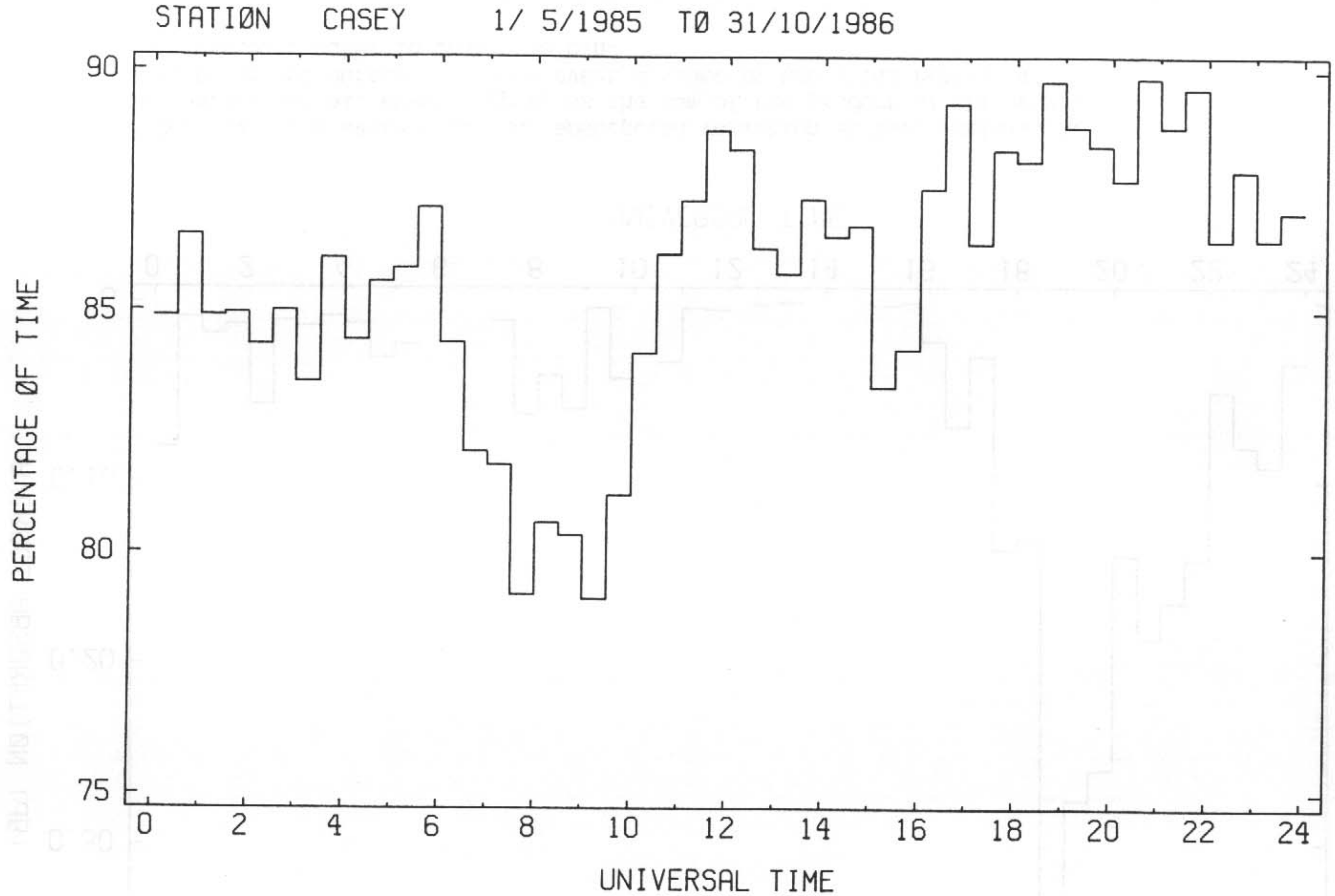
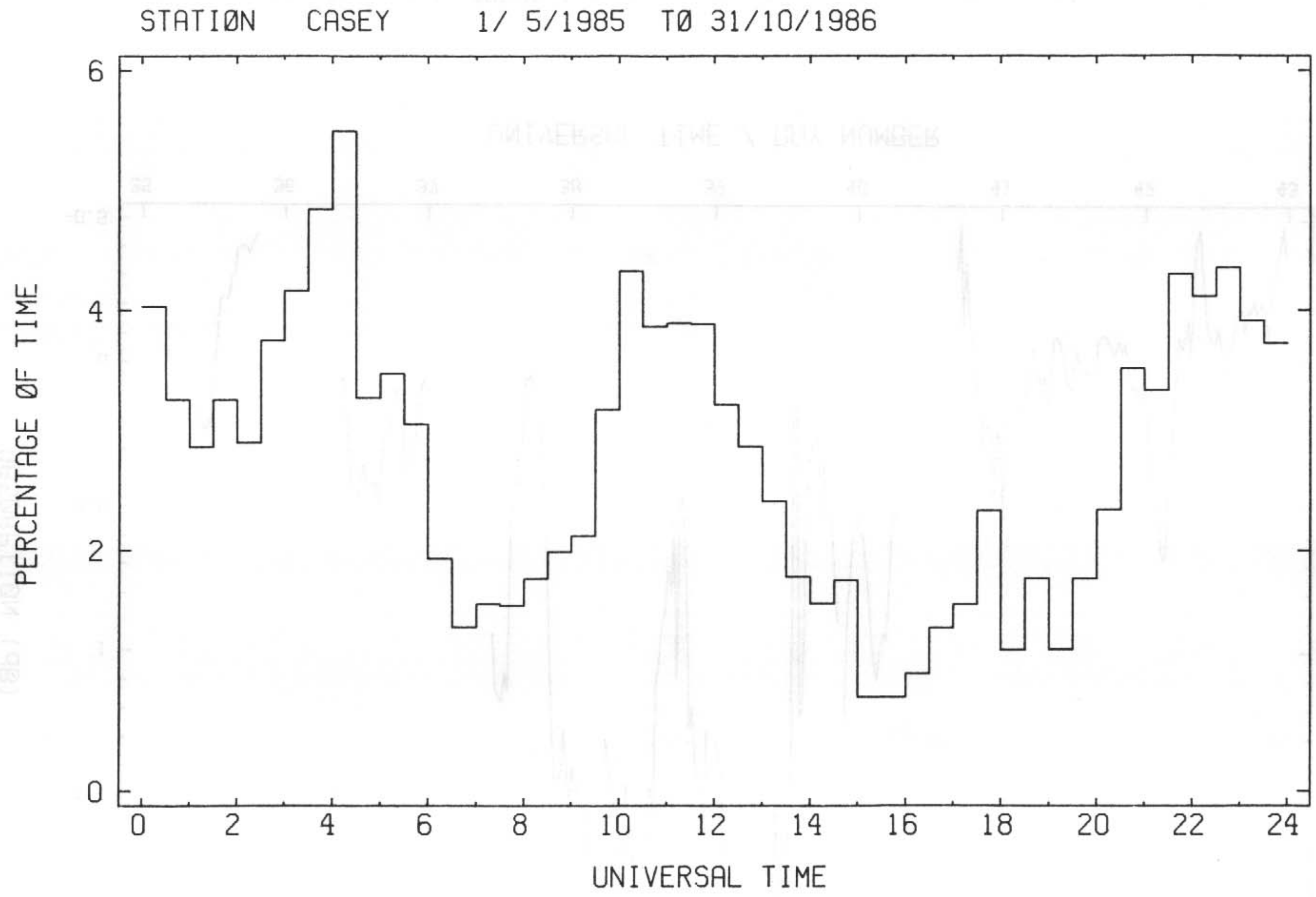


Figure 14. The diurnal absorption variation at Casey determined as the percentage of the half hourly scaling points which exceeded 0 dB absorption (Figure 14a) and the percentage which exceeded 1 dB (Figure 14b) during the period 1 May 1985 to 31 October 1986.

(b.)


STATIØN CASEY 1/ 5/1985 TØ 31/10/1986
PERCENTAGE ØF TIME
0
2
4
6
0 2 4 6 8 10 12 14 16 18 20 22 24
UNIVERSAL TIME

(a)

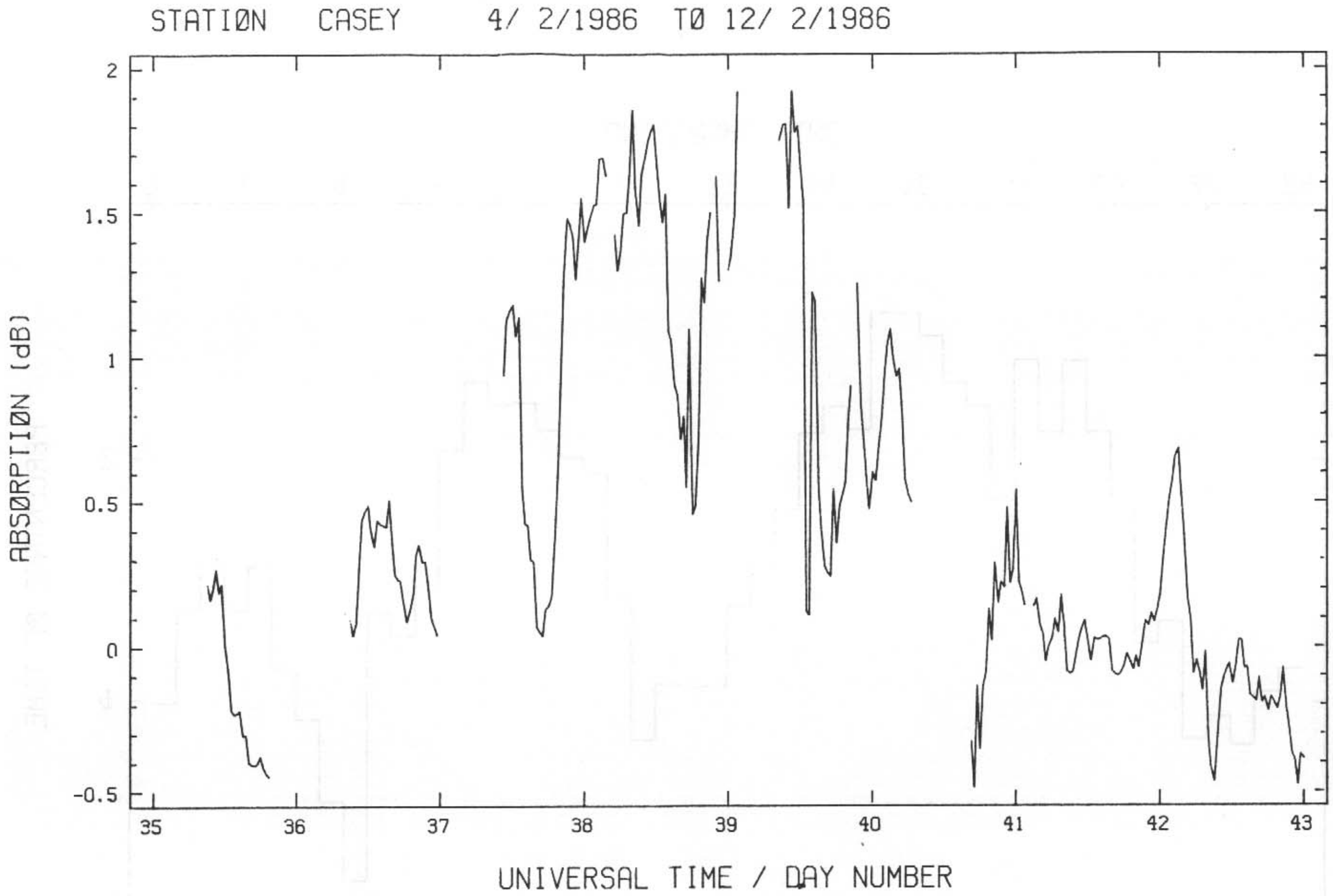
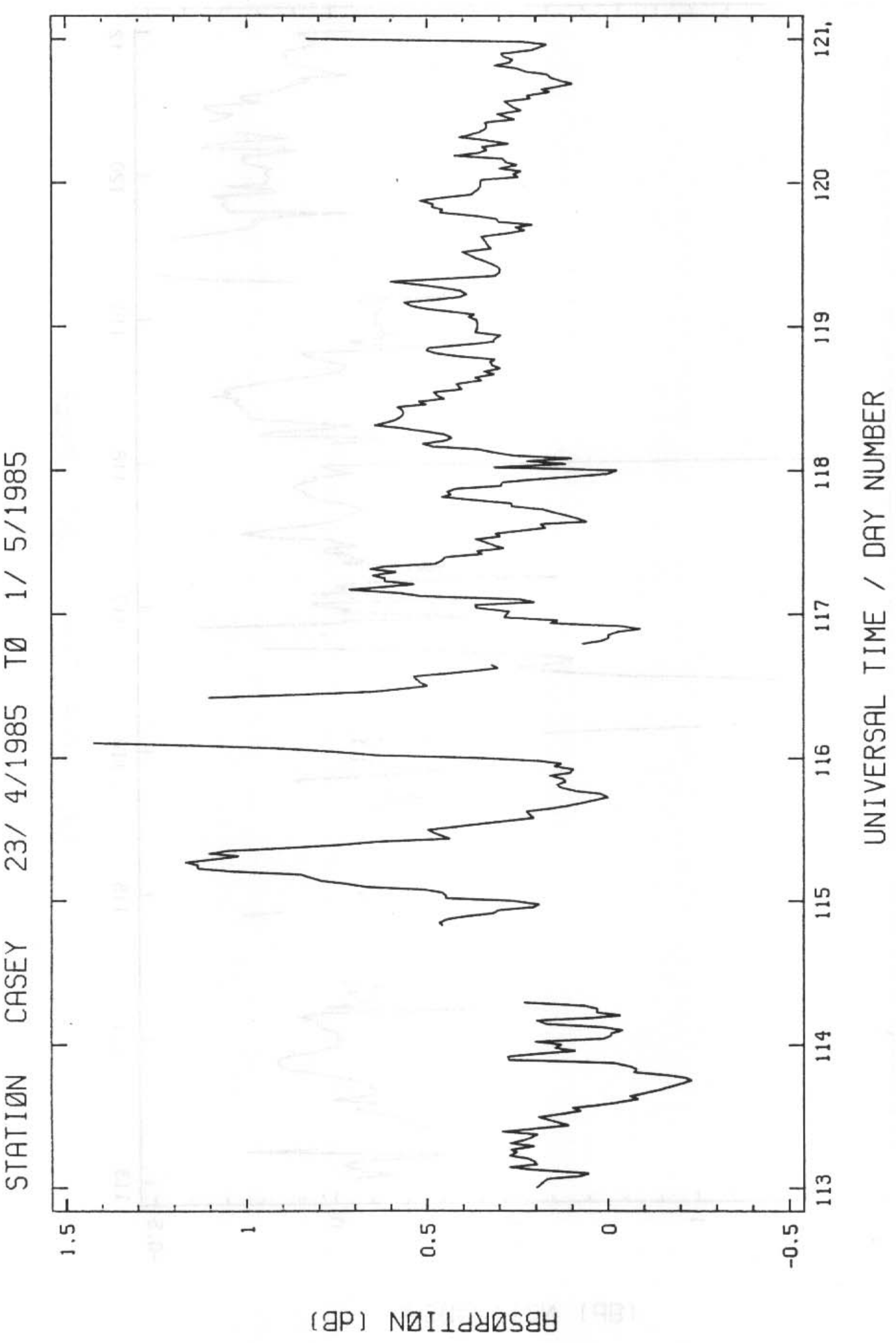
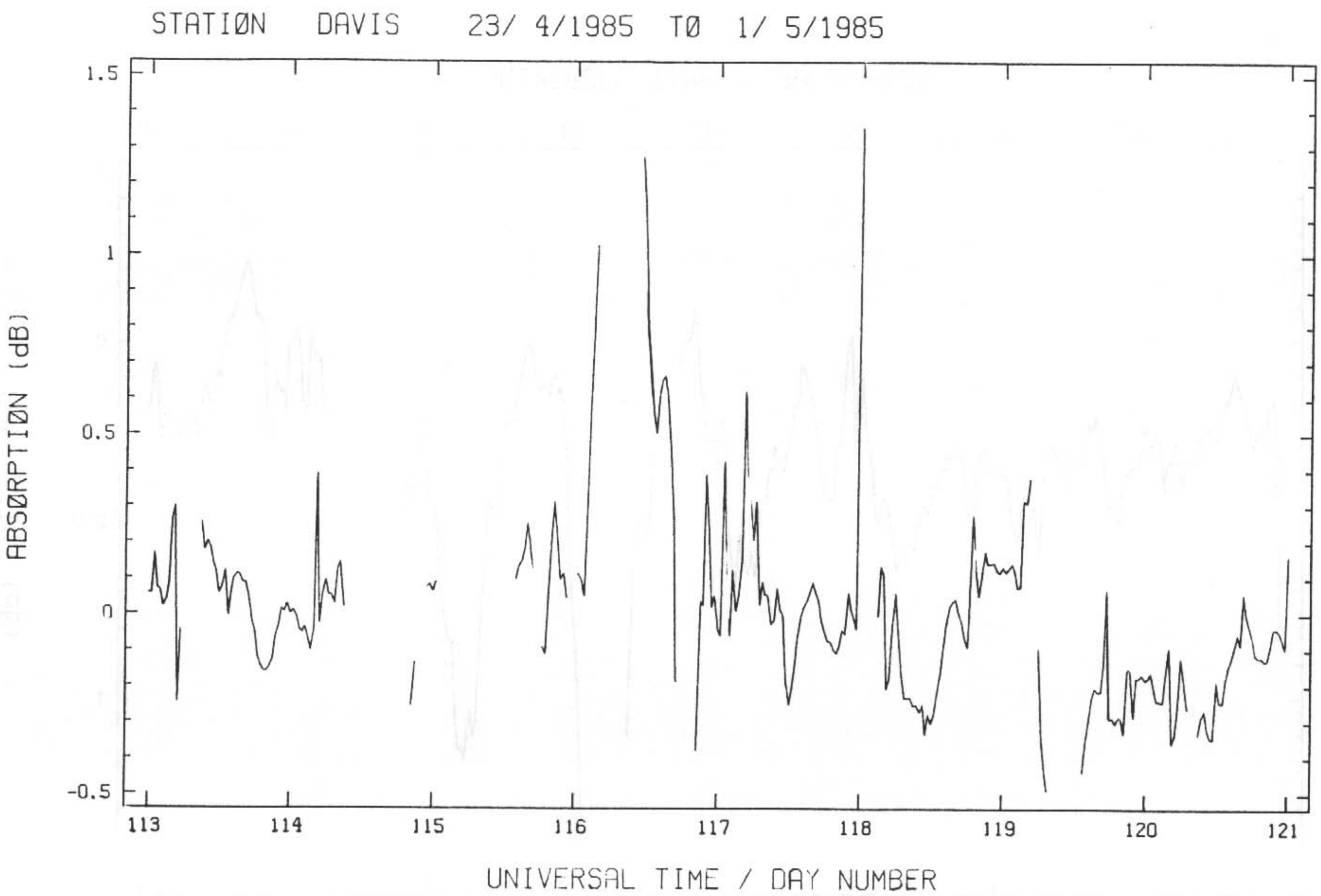


Figure 15. The absorption activity recorded at Casey and Davis following a period of solar activity. PCA events were recorded during both periods.


STATIØN CASEY 23/ 4/1985 TØ 1/ 5/1985
ABSØRPTIØN (dB)
1.5
1
0.5
0
-0.5
113
114
115
116
117
118
119
120
121
UNIVERSAL TIME / DAY NUMBER

(b)

(c)


STATIØN DAVIS 23/ 4/1985 TØ 1/ 5/1985
1.5
1
0.5
0
-0.5
ABSØRPTIØN (dB)
113
114
115
116
117
118
119
120
121
UNIVERSAL TIME / DAY NUMBER

ACKNOWLEDGMENTS

This paper has been made possible by the friendship and co-operation within Antarctic expeditions and between Australian and Chinese scientists. The authors wish to express their appreciation to the governments of their respective countries for providing the support necessary for co-operative research. They are also grateful for assistance specific to this project, particularly from Dr David Watts who developed the computer programs to generate the plots from the riometer data and Ms Gina Price who prepared most of the diagrams.

REFERENCES

Bird, I.G., Morton, B.R. and Williams, H.A. (1974). The riometer: a state-of-the-art design. Proceedings of the IREE. Pp. 133-138.

Boyd, J.S. (1983). Invariant geomagnetic co-ordinates for epoch 1977.25. ANARE Research Notes Number 19. Antarctic Division, Kingston.

Krishnaswamy, S., Detrik, P.L. and Rosenberg, T.J. (1985). The inflection point method of determining riometer quiet day curves. Radio Science 20:123-136.

Little, C.G. and Leinbach, H. (1959). The riometer - a device for the continuous measurement of ionospheric absorption. Proceedings of the IREE 47:315-320.

Murray, A.J. and Wilkinson, P.J. Riometer notes: Internal report, IPS Radio and Space Services.

Rosenberg, T.J. and Dudeney, J.R. (1986). The local time, substorm and seasonal dependence of electron precipitation at L = 4 inferred from riometer measurements. Journal of Geophysical Research 91:12032-12040.