Digital Ionosonde Observations of the Cusp/Cleft region of the Ionosphere

John MacDougall and P. T. Jayachandran
Dept. Electrical Engineering, University of Western Ontario, London, Ont., Canada N6A5B9
email: jmacdoug@uwo.ca

ABSTRACT

The ionosphere over Cambridge Bay (77^o CGM lat.) shows a number of unexpected and interesting features due to its coupling with the magnetosphere. We discuss the behaviour that occurs in 4 time intervals: (a) Noon (10-13 LMT): A relatively quiet interval showing moderate speed poleward flow. (b) Postnoon (13-19 LMT): A somewhat disturbed interval that often shows switching of convection direction related to movement of the convection reversal. (c) Nighttime (19-01 LMT): Polar cap type quiet antisunward convection. (d) Morning (01-10 LMT): A very disturbed interval that shows auroral features.

1.0 INTRODUCTION

This is study of the ionospheric behaviour as seen from Cambridge Bay (geog: 69.1^{o}N, 105.1^{o}W, 77^o CGM lat.), a 'cusp' location. We compare this behaviour with stations located further poleward. The measuring instrument is a CADI digital ionosonde [1]. In particular this study will focus on the measured ionospheric convection velocities. For the more poleward stations, Eureka (89^o CGM lat.) and Resolute Bay (83^o CGM lat.) the patterns of convection velocities tend to be very consistent and on most days just shows an orderly antisunward motion. The ionospheric convection, and pattern of behaviour, at Cambridge Bay is very different. Fig. 1 shows a Cambridge Bay sample. This figure shows (top panel) the virtual height for a frequency of 3.180 MHz, and the next 2 panels show the ionospheric horizontal velocity as azimuth and magnitude measure on the same frequency.

In this figure it is difficult to discern any antisunward convection pattern, although the relatively quiet interval from 3-6 UT does show an approximately antisunward direction. During much of the day the 'average' convection direction is not very obvious. This day is probably a bit quieter than most days at Cambridge Bay so on a typical day the Cambridge Bay convection patterns at first glance appear to be chaotic. For this reason our earlier studies concentrated on the relatively well behaved convection patterns that we observe at polar cap stations Eureka and Resolute Bay. However, the Cambridge Bay although initially appearing to be chaotic has a pattern of daily behaviour that tends to

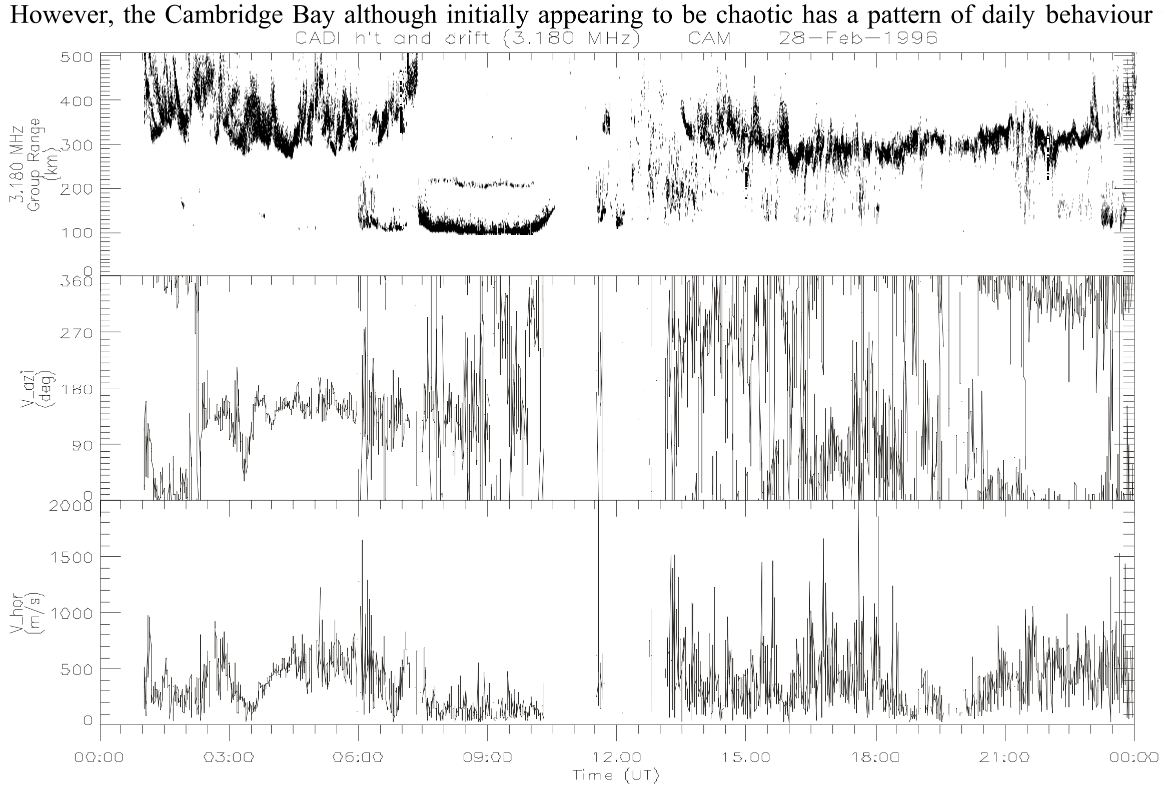

Fig. 1. Ionospheric convection as observed from Cambridge Bay, Feb 28, 1996.

repeat from day-to-day. In this paper we will briefly describe the daily sequence of behaviour that is seen at Cambridge Bay, and then we will investigate the portions of the daily sequence in more detail.

2.0 Cambridge Bay Daily Behaviour Sequence

The sequence of daily behaviour, dividing the day into 4 intervals, is:-

- 18-21 UT (10-13 LMT) midday cusp: relatively quiet approximately antisunward convection at moderate speed. Few signs of precipitation events.
- 21-3 UT (13-19 LMT) postnoon convection reversal region. Much switching of convection direction depending on station location relative to the convection reversal. Precipitation events commonly seen.
- 3-9 UT (19-1 LMT) nighttime antisunward convection region. Usually relatively unstructured antisunward convection, although pattern is frequently obscured by sporadic E. Few signs of precipitation.
- 9-18 UT (1-10 LMT) prenoon convection reversal region. This interval is even more disturbed than in the postnoon. There are frequent fluctuations of the convection along with precipitation events. As noon is approached the behaviour usually becomes somewhat less disturbed, and the convection direction depends on whether one is equatorward or poleward of the convection reversal.

The reference to precipitation events may puzzle some readers since the digital ionosonde clearly does not measure either the optical or particle signatures of precipitation. However, the ionospheric signatures of precipitation are easily seen if the precipitation produces ionization densities whose plasma frequency is comparable with the ionosonde measuring frequency. In the top panel of Fig. 1 the vertical streaks descending from F Region down to the E region show some sort of precipitation. Longer lived precipitation events produce a V-shaped pattern in the E region as the event passes over the station, and several such events can also be seen in Fig. 1.

2.1 The midday cusp

Surprisingly the cusp time interval from ~18-21 UT (10-13 LMT) is much less disturbed than the prenoon and postnoon and intervals. A dramatic example that illustrates this behaviour is shown in Fig. 2.

In Fig. 2, top panel, there is a clear interval 19-21 UT with strong precipitation on either side. Note that this figure shows the convection as separate EW and NS components in the middle and lowest panels, rather than as azimuth and speed. The 19-21 UT time interval coincides with the midday cusp interval shown by various studies such as [2]. We commonly see this interval, usually between ~18-21 UT where particle precipitation is absent. As seen in Fig. 2, the convection measurements during this interval are usually well behaved so that we can easily estimate the amount of flux being convected into the pole during this interval. What we calculate is the potential across this cusp interval by integrating the eastward electric field across the gap. It is of interest to compare this calculated 'cusp' potential with the cross polar cap potential.

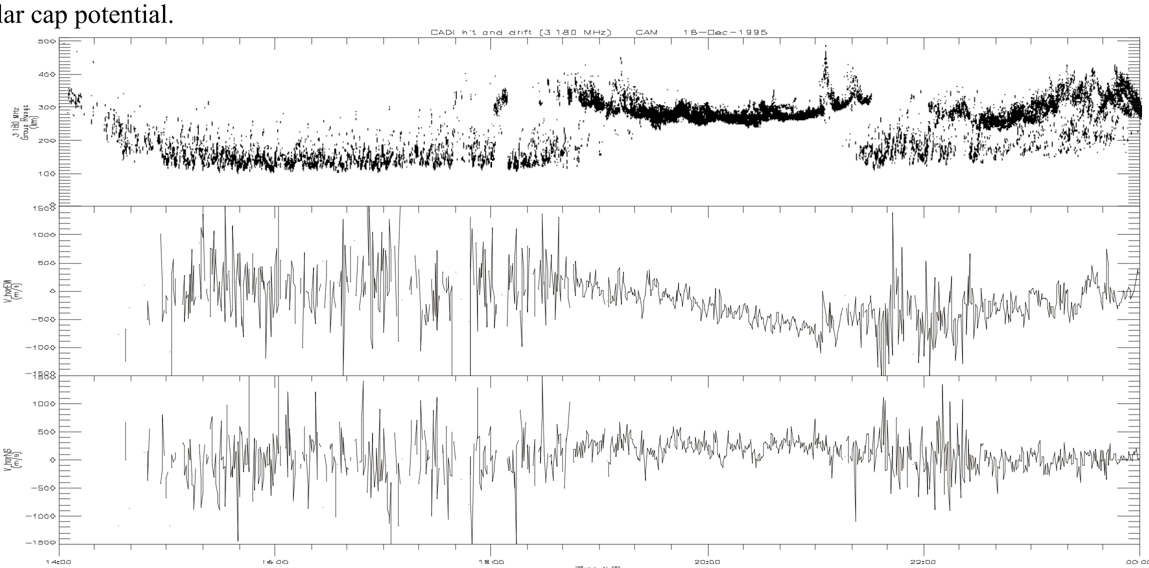

Fig. 2. Midday ionospheric measurements from Cambridge Bay, 1995 Dec 18.

To calculate the potential we selected days when IMF By and Bz remained relatively constant (preferably <±2 nT variation) throughout the entire daytime period. This necessarily made our data set relatively small and gave only 18 samples over the approximately 1 year period used for this study. For each sample we calculated the integrated eastward electric field from 18-21 UT. The result is shown in Fig. 3.

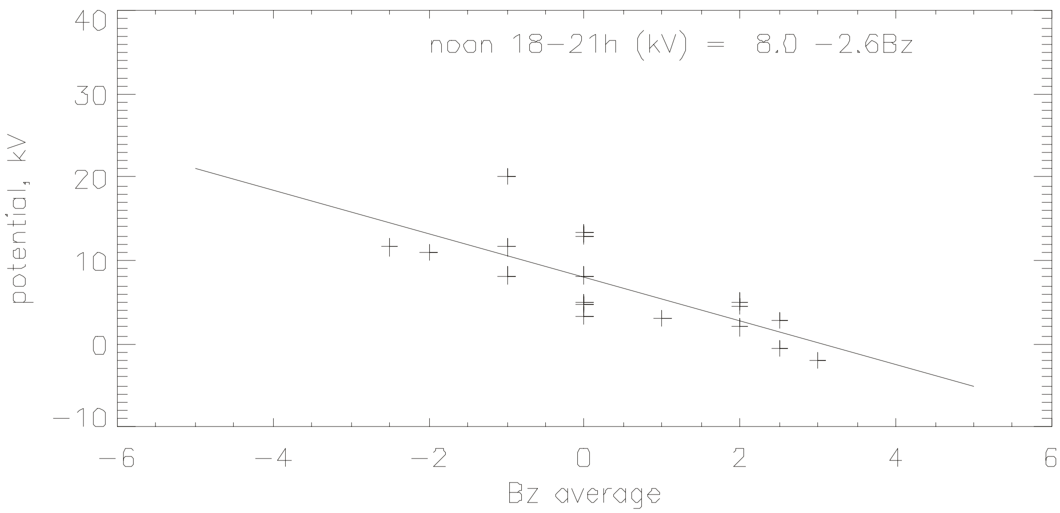

Fig. 3. Integrated 18-21 UT potentials as a function of IMF Bz

The equation of the fitted line is given on the fig.. As expected the potential decreases with increase of B_z (more northerly B_z), and for B_z greater than ~2.5 nT the direction of flow during this noon time interval is reversed (potential becomes negative). What is surprising is that this midday gap potential is only about 1/3 of the cross polar cap potential [3]. This is at variance with some models of the polar cap convection patterns such as [4] that show all the polar cap potential appearing across the midday gap. However, our result is consistent with most measured average polar cap convection patterns [5 - 8] that do not show that the flow entering the polar cap passes through a relatively small midday gap. We are currently studying, in more detail, the dayside influx to the polar cap.

2.1 The Postnoon Convection Reversal Region

During the interval from about 21 to 3 UT the convection patterns are usually somewhat disturbed, and often show precipitation. We had not expected this behaviour since most pictures of the polar cap [6] indicate that Cambridge Bay at 77^{o} magnetic latitude should be well inside the polar cap at this time, and relatively far poleward of the convection reversal. We have examined the 'mean' convection directions during this postnoon interval because, although the convection was often disturbed, it usually showed a convection direction that was compatible with the station being either poleward or equatorward of the convection reversal. (See Fig. 1 for instance.)

We studied the convection direction as a function of the IMF B_z and found that for B_z < -1 nT the average convection direction was usually approximately eastward, whereas for B_z > -1 nT the average direction was usually approximately westward. This behaviour is easily explained as simply the equatorward motion of the convection reversal as Bz becomes more negative.

As well as the directional variation dependence described above, this postnoon interval also shows some less regular behaviour. We often see the convection direction switching back and forth by ~180^{o}, presumably as the convection reversal moves back and forth across the station. This and other forms of instability are common in this time sector. Unfortunately the digital ionosonde just gives a picture of what is happening in the near overhead region. Therefore it is not possible to be certain that the variations are due to the motion of the convection reversal with respect to Cambridge Bay. It is expected that the convection reversal region may show Kelvin-Helmholtz instabilities so the observed variations could be due to Kelvin-Helmholtz 'waves' displacing the convection reversal.

2.3 The Nighttime Interval.

The interval from 03-09 UT (19-01 LMT) usually shows 'normal antisunward polar cap convection at Cambridge Bay. The convection measurements, which preferably use the F region ionospheric reflections, are frequently interrupted by the sporadic E that is common in this time segment. Apart from the Es this time segment shows the same behaviour as is seen at the polar cap stations Eureka and Resolute Bay, which we have described in earlier publications [3, 9]. Therefore we will not further describe this time segment in this paper.

2.4 The Dawn Time Segment

The long time segment from 09-18 UT usually shows extremely disturbed behaviour. This can be seen in Fig. 1. In this figure, starting from the end of the E_s patch near 12 UT up to ~18 UT there is a continuing interval of disturbed convection and precipitation. Sometimes the precipitation becomes so intense that it forms an auroral E region as seen in the prenoon interval of Fig. 2. Near to noon the average convection direction can usually be seen (somewhat less disturbed) and the convection direction is compatible with the station being either poleward or equatorward of the convection reversal. Once again we find that the switchover of convection for the station being relatively poleward or equatorward of the convection reversal takes place for IMF B_z about –1 nT.

As well as this regular convective variation depending on station location relative to the convection reversal, this interval shows a great deal of irregular convective disturbance, along with many signs of precipitation. The station location should usually put it far poleward of auroral activity in this time sector so the amount of disturbance that we see is unexpected. This sector is of course where most of the Poleward Moving Auroral Forms (PMAF) activity is located [10 – 12] and a comparison of digital ionosonde auroral events with a list of the optical PMAF events at Cambridge Bay (Shiokawa, personal communication) showed that the PMAFs can easily be seen on the digital ionosonde recordings. However PMAF events seem to occur much less frequently than the almost daily disturbance events that we see in this time sector. We are investigating, in more detail, the disturbance events in this time sector.

3.0 CONCLUSIONS

The ionosphere over Cambridge Bay shows a number of unexpected and interesting features that reveal the complex nature of the interaction of the magnetosphere with the ionosphere in the polar cap boundary region. We will not list here all the various phenomena that were described briefly in this paper. We are currently pursuing a number of studies of the observable Cambridge Bay ionospheric-magnetospheric interaction effects.

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