A Multi-instrument study of spectral width boundary motion in data from the CUTLASS Finland HF radar.

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Abstract

During the interval 0200 to 0500 UT on 20th December 1998, a distinct boundary between large (>200ms^{-1}) and small (<200ms^{-1}) spectral widths was observed by the CUTLASS HF coherent radar at Hankasalmi, Finland. Such a boundary has been previously suggested to be the ionospheric footprint of the open-closed field line boundary. Both the EISCAT mainland and EISCAT Svalbard radars were observing within the area of interest during the interval. These, and several other data sets commonly available, are used to investigate the reason for the presence of this boundary and its subsequent motion. Preliminary results indicate a relationship between elevated electron temperature and large (>200ms^{-1}) spectral width in the F-region.

1. Introduction

One of the standard parameters measured by the coherent HF radars that form the SuperDARN network is the Doppler spectral width. This parameter is effectively a measure of the turbulence within the ionospheric plasma in each range cell of the radar's field of view. A distinct change in this parameter implies an alteration in the physical characteristics of the plasma being observed by such a radar.

There has been much interest recently in a feature commonly observed in the SuperDARN radars' Doppler spectral width parameter, namely a distinct latitudinal boundary located within the auroral region, between values above and below 200 ms^{-1}. The type of boundary observed in this interval has previously been linked to the ionospheric footprint of two magnetospheric boundaries. The first is that between the central and boundary plasma sheets [Lewis et al., 1997, Dudeney et al., 1998], and the second that between the open and closed field lines [Lester et al., 1999]. The latter of the two relies on the spectral width boundary being co-located with the poleward edge of the 630.0nm optical auroral emission. Data shown here indicates that this relationship is not always the case. Several other interesting features have been found including a relationship between high spectral width and elevated electron temperature.

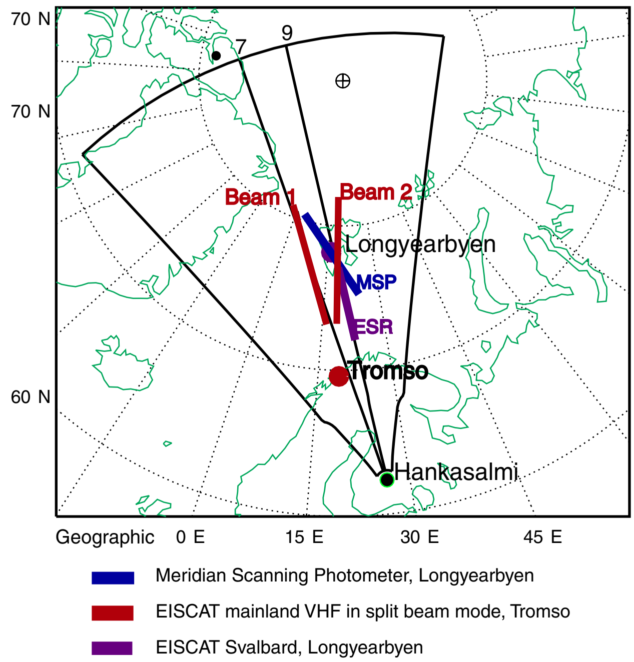

Figure 1. Geographic location of the instruments during the interval 02-05UT, 20th December 1998. The field of view of CUTLASS Finland is shown in black, with beams 7 and 9 indicated.

2. Experimental overview

The main four instruments used in this study are shown in Figure 1. The EISCAT VHF radar at Tromsø was operating in split beam mode with beam 1 directed at a geographic azimuth of 345.0° and beam 2 at an azimuth of 359.5°. Both beams were at an elevation of 30.0°.

The EISCAT Svalbard radar (ESR) was operating with an elevation of 30.0° and a geographic azimuth of 161.6° which places the ESR beam directly along beam 9 of CUTLASS Finland in terms of azimuth. The meridian scanning photometer (MSP) at Longyearbyen, Svalbard runs across the field of view of the Finland radar.

The CUTLASS radar at Hankasalmi in Finland was running a discretionary mode in which beam 5 was returned to after each beam in the scan. The dwell time on each radar beam was 3 seconds. Thus a full scan was 2 minutes and beam 5 had a temporal resolution of 6s.

For interplanetary magnetic field data, the WIND spacecraft has been used. During the interval WIND was located at ~($40R_E$, $-60R_E$, $10R_E$) in GSM coordinates.

3. Observations

CUTLASS data

The Doppler spectral width, line of sight velocity and backscatter power from Hankasalmi are shown in the bottom three panels of Figure 2. A significant amount of F-region backscatter is observed from 0200 to 0500 UT.

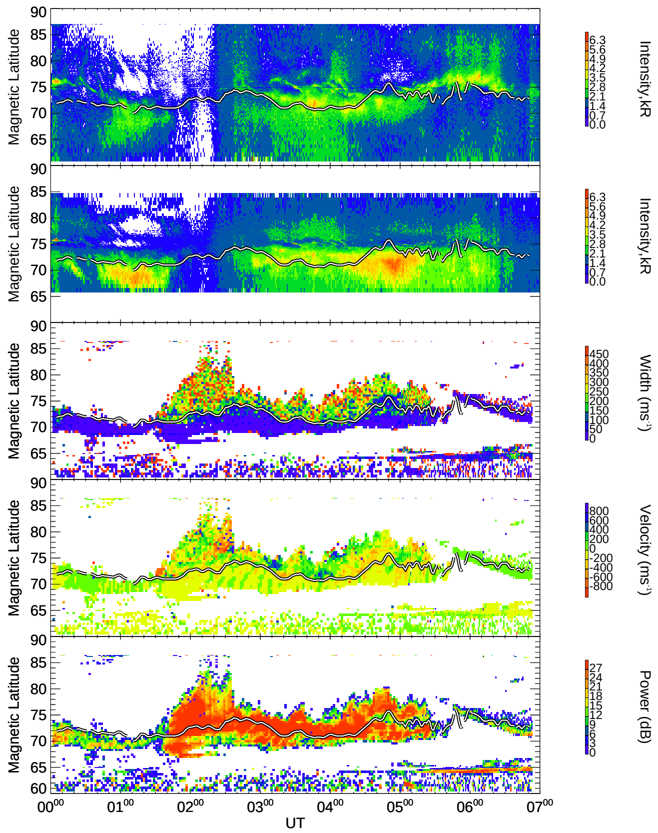

Figure 2. Top 2 panels from MSP at Longyearbyen – panel 1, 630.0nm, panel 2 557.7nm. Bottom 3 panels from CUTLASS Finland.

The F-region backscatter power is consistently high throughout the interval 0200 to 0500 UT, at or above 27dB. The position of the poleward edge of the F-region backscatter moves between 73° and 84° magnetic latitude whereas the equatorward edge remains fairly stable between 67° and 69° magnetic latitude.

In the Doppler spectral width data there is an area of low spectral width (<200ms^{-1}) equatorward of a large area of high (>200ms^{-1}) and variable spectral width. There is a distinct boundary between these two regions, this is shown by the white line in panel 3 of Figure 2. This boundary has been overlayed on all the other panels of Figure 2 for comparison.

The line of sight velocity data indicates the highest velocities are at the poleward edge of the F-region backscatter, and that these velocities are directed towards the radar (in blue). Two strong bursts of flow towards the radar occur at 0310 UT and 0350 UT.

There is evidence for wave activity in the line of sight velocity data, from 0210 UT to 0400 UT between 69° and 74° magnetic latitude. The period of the wave is approximately 10 minutes, frequency 2mHz. A wave of this frequency is also observed by the magnetometers of the IMAGE chain at this time. The amplitude observed by the magnetometers falls noticeably between the stations at Hopen Island (73° magnetic latitude) and Longyearbyen (75° magnetic latitude). It is likely that this wave is a field line resonance, in which case a lower limit in latitude for open field lines can be estimated to be around 74°.

MSP data

The optical data for two wavelengths (630.0nm and 557.7nm) taken from Longyearbyen, Svalbard is shown in Figure 2, panels 1 and 2. These have been plotted on a magnetic latitude axis assuming an altitude for the emission (250km for 630.0nm and 110km for 557.7nm).

The 630.0nm emission takes the form of a narrow band of high intensity approximately 5° wide. The 557.7nm emission however has a constant poleward edge at 73° magnetic latitude with a variable structure equatorward of this.

There are several equatorward arcs evident at both wavelengths between 0300 and 0400 UT. There is also a general poleward motion in the 630.0nm emission starting at 0500 UT as the CUTLASS backscatter starts to disappear.

Incoherent scatter data

Figure 3 shows the incoherent radar data from ESR. Although not shown here, the data from the EISCAT VHF beams show very similar results to that from the ESR. It is evident from Figure 2, panel 4 and Figure 3, panel 2, that the line of sight ion velocities from the incoherent radars agree well with the irregularity drift velocities observed by CUTLASS Finland. (Note that all the data shown has the same colour scale for the velocity but that the range of magnetic latitudes shown is different from Figure 2). This is consistent with previous results that F-region irregularities travel with the ambient plasma flow [Davies et al., 2000]. One can observe the same wave as seen from Hankaslami and the same flow bursts. In addition, there were strong flows at 0030UT where CUTLASS Finland observed no backscatter.

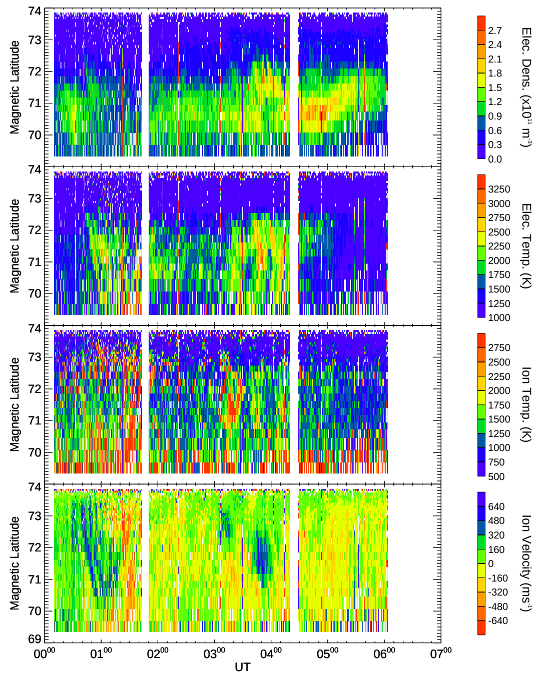

Figure 3. Data from EISCAT Svalbard Radar, 20th December 1998.

Also notice that the elevated and highly structured F-region electron temperature observed by the ESR coincides with the high spectral width observed by CUTLASS Finland at 0130 and 0400 UT. This indicates that there is electron precipitation co-located with the high values of spectral width.

Interplanetary conditions

The z component of the interplanetary magnetic field (B_z) is variable and northwards from 0030 UT until 0225 UT, then remains southward until 0300. It remains northward until 0340UT when it becomes variable until past 0500 UT.

The y component (B_y) is positive until a sudden, large jump from +6nT to –6nT at 0220UT. It is variable after this until another extended period of positive values begins at 0435UT.

The time delay from the satellite to the ionosphere has been calculated at 10 minutes.

4. Discussion

A previous case study [Lester et al., 1999] found a Doppler spectral width boundary co-located with the poleward edge of the 630.0nm optical auroral emission. This edge has been identified as the ionospheric footprint of the open-closed field line boundary using satellite data [Blanchard et al., 1995]. Figure 4 illustrates a comparison similar to that done by Lester et al. (1999) for a different interval. Clearly, the spectral width and poleward edge of the 630.0nm emission are not at

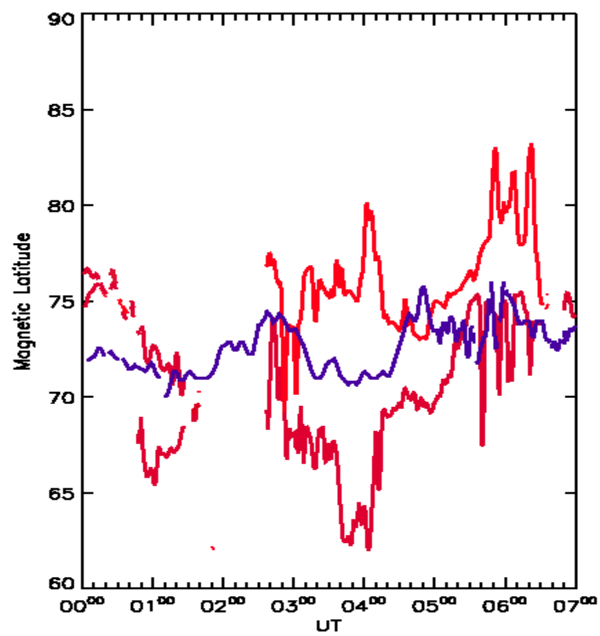

Figure 4. 2.5kR contours of 630.0nm optical emission are shown in red. 200ms^{-1} spectral width boundary shown in blue.

the same latitude for the interval 0200 to 0500 UT. Furthermore, there is no clear trend in which the two boundaries follow each other, which would be the case if the height of the 630.0nm emission was not 250km as assumed.

A comparison has been made between the electron temperature observed by the incoherent scatter radars and the Doppler spectral width observed by CUTLASS Finland. This is expressed in the form of a scatter plot for each incoherent radar beam available (Figure 5).

Only data between 71° and 72° magnetic latitude has been used to ensure that purely F-region scatter is compared. As can be seen from Figure 5 the results show that although a high spectral width implies a high electron temperature, the reverse is not the case. Clearly further data is required to see if this is indeed the case.

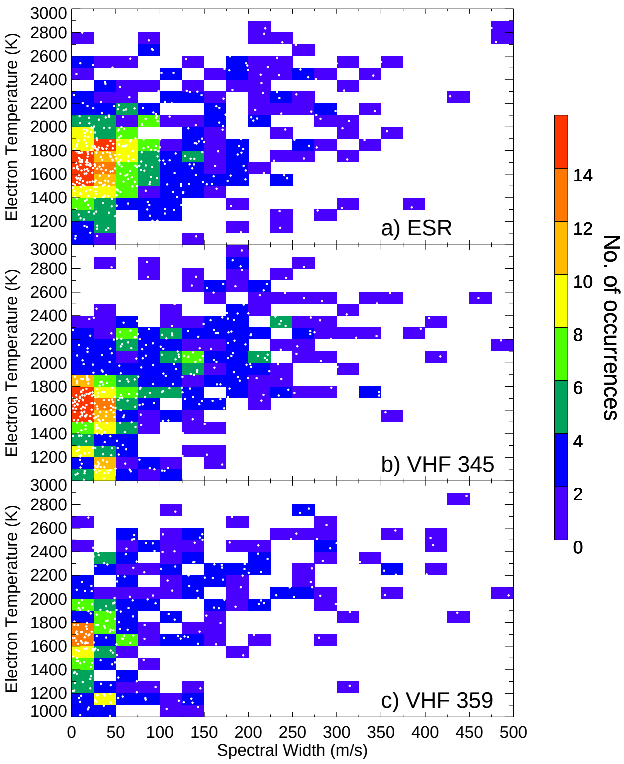

Figure 5. Scatter plots of electron temperature from the incoherent scatter radar beams plotted against spectral width from CUTLASS Finland. Range of data restricted to 71°-72° magnetic latitude.

5. Conclusions

Contrary to previous case studies, the spectral width boundary for this data set is not co-located with the poleward edge of the 630.0nm optical auroral emission during this interval. It follows that the spectral width boundary is not a reliable means of finding the ionospheric footprint of the open-closed field line boundary.

There is, however, a clear relationship between high spectral width and high electron temperature in the F-region during this interval. Further data needs to be looked at to define this relationship more specifically and identify its physical cause.

Acknowledgements

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