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Letter to the Editor

First complementary observations by ionospheric tomography, the EISCAT Svalbard radar and the CUTLASS HF radar

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Abstract. Experimental results are presented from ionospheric tomography, the EISCAT Svalbard radar and the CUTLASS HF radar. Tomographic measurements on 10 October 1996, showing a narrow, field-aligned enhancement in electron density in the post-noon sector of the dayside auroral zone, are related to a temporal increase in the plasma concentration observed by the incoherent scatter radar in the region where the HF radar indicated a low velocity sunwards convection. The results demonstrate the complementary nature of these three instruments for polar-cap ionospheric studies.

Key words. Ionosphere · Auroral ionosphere · Polar ionosphere · Radio science (ionospheric physics)

Introduction

In this paper first results are presented from observations of the dayside auroral ionosphere over Svalbard using three complementary experimental techniques: ionospheric tomography giving an image of the spatial structure of electron density; the EISCAT Svalbard radar (ESR) yielding the temporal development of electron concentration along a fixed line of sight and the CUTLASS HF radar giving information on the convection of the plasma.

Ionospheric tomography has been used extensively at mid-and auroral latitudes to produce images of electron density. A number of successful experimental results have been reported in a special issue of *Annales Geophysicae* (**13**, 1995). Pryse *et al.* (1997) demonstrated that it was possible to create tomographic images of the polar-cap ionosphere using just two closely-spaced receivers at Longyearbyen and Ny Ålesund. Their results showed tomographic images of the cusp region at magnetic midday, and of the polar-hole in the dawn convection cell.

The ground-based receiver configuration for ionospheric tomography requires a number of stations aligned approximately in longitude, a restriction that at high

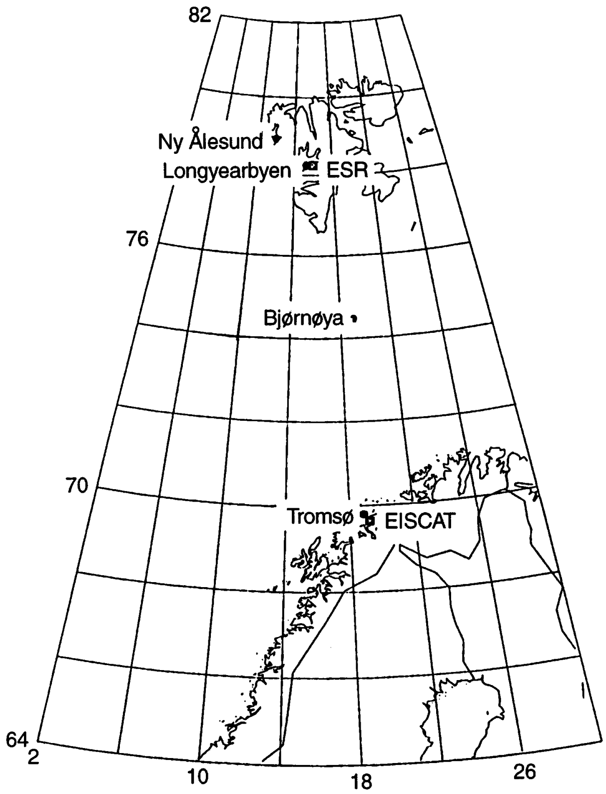


Fig. 1. Map showing the locations of the receiving stations and the EISCAT radars

latitudes must be reconciled with the sparsity of settlements providing suitable locations. Since October 1996 Navy Navigation Satellite System (NNSS) receivers have been deployed at four sites shown on the map in Fig. 1: Tromsø (69.8°N,19.0°E), Bjørnøya (74.5°N,19.0°E), Longyearbyen (78.2°N,15.7°E) and Ny Ålesund (78.9°N,12.0°E). The sites were chosen to span the region between the EISCAT radar at Tromsø (69.6°N,19.2°E) and the new EISCAT Svalbard Radar (ESR) at Longyearbyen (78.1°N,16.0°E), allowing investigations into the elec-

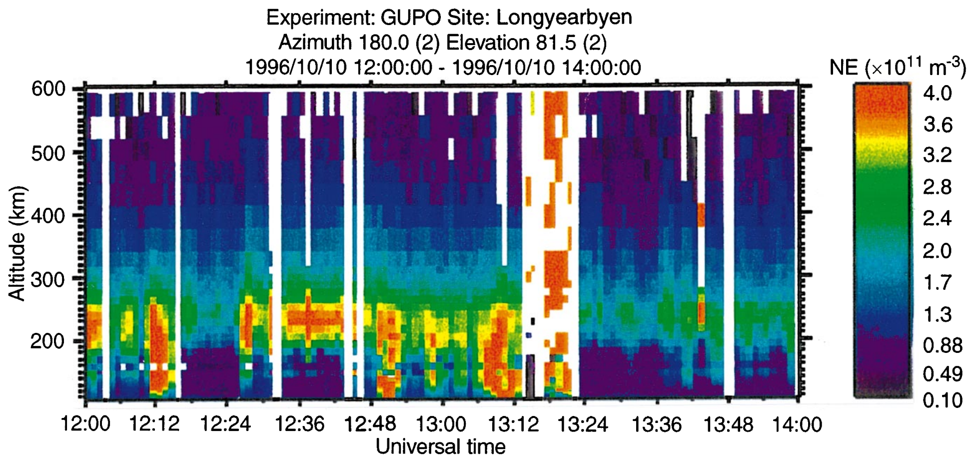


Fig. 2. Electron densities obtained from the EISCAT Svalbard radar on 10 October 1996. The enhancement in electron density occurring between 1307 and 1312 UT is of particular interest to the current study

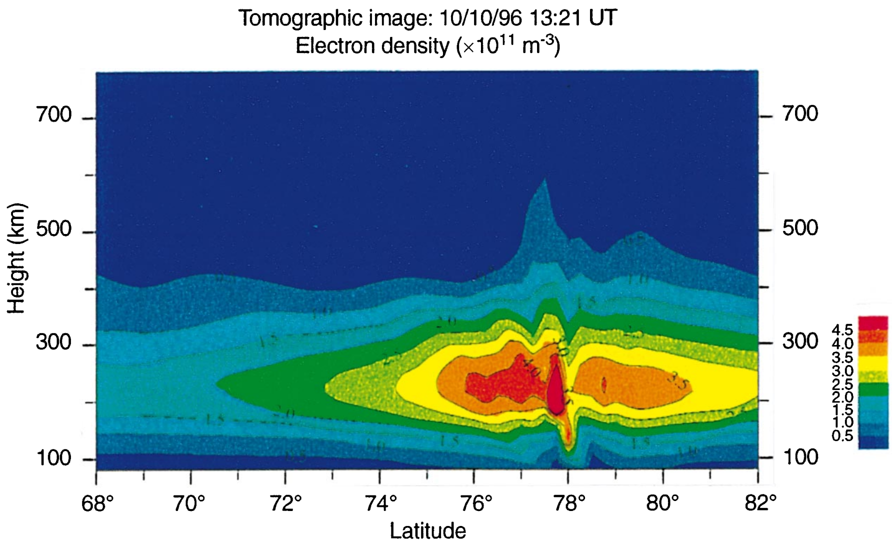


Fig. 3. Tomographic image of electron density for the satellite crossing 70°N,3°E at 1321 UT on 10 October 1996. A latitudinally narrow enhancement in electron density at 78°N in the ionosphere to the west of Svalbard is a prominent feature

tron-density distribution in the auroral and polar-cap regions of the ionosphere. In this paper initial observations are presented from this tomographic chain and from ESR. Interpretation of the results is aided by information on plasma velocities measured by the CUTLASS HF radar. This bistatic radar, with stations at Hankasalmi (62.3°N, 26.6°E) in Finland and Pykkvibær (63.8°N,20.5°W) in Iceland, can determine the convective flow of the plasma over a wide area of the high-latitude ionosphere including that of interest here (Milan *et al.*, 1997).

Experimental and method

The experimental system designed for recording radio signals transmitted from the NNSS satellites has been described by Kersley *et al.* (1993). The phase-coherent signals are transmitted on two frequencies, 150 and 400 MHz. The recorded signals are in the form of differential carrier phase measurements, that provide information on the total electron content along a number of ray paths as the satellite passes from horizon-to-horizon. By combining such measurements from a number of receivers, it is possible to use a tomographic algorithm to obtain the values of electron density in a latitude-height plane.

The tomographic image presented in this paper was reconstructed using the method described by Fremouw *et al.* (1992), with modifications to use a range of Chapman profiles and to allow the incorporation of hmF2 and NmF2 values from the dynasonde located at Tromsø to improve the reconstruction of the vertical profile.

Results and discussion

On 10 October 1996 the ESR radar ran for over 7 hours in the GUP0 mode, with the beam static and pointing approximately along the geomagnetic field line at an elevation of some 81°. At the time relevant to the present observations both sites of the CUTLASS radar were receiving returns from ionospheric irregularities above Svalbard. The electron densities obtained from ESR between 1200 and 1400 UT are plotted in Fig. 2. It should be noted that an unavoidable gap in the observations occurred between 1313 and 1323 UT. The F-layer peak, at an altitude of approximately 240 km, is broken by regions of enhanced electron den-

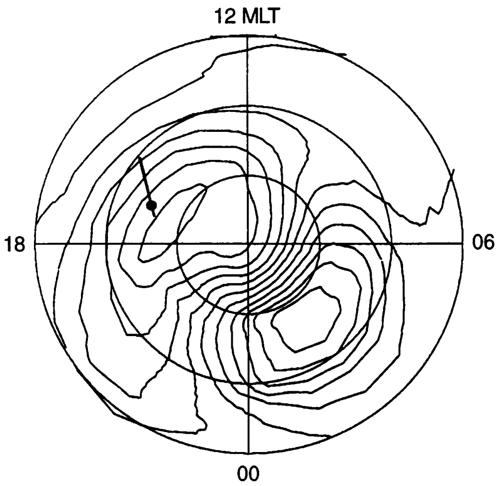


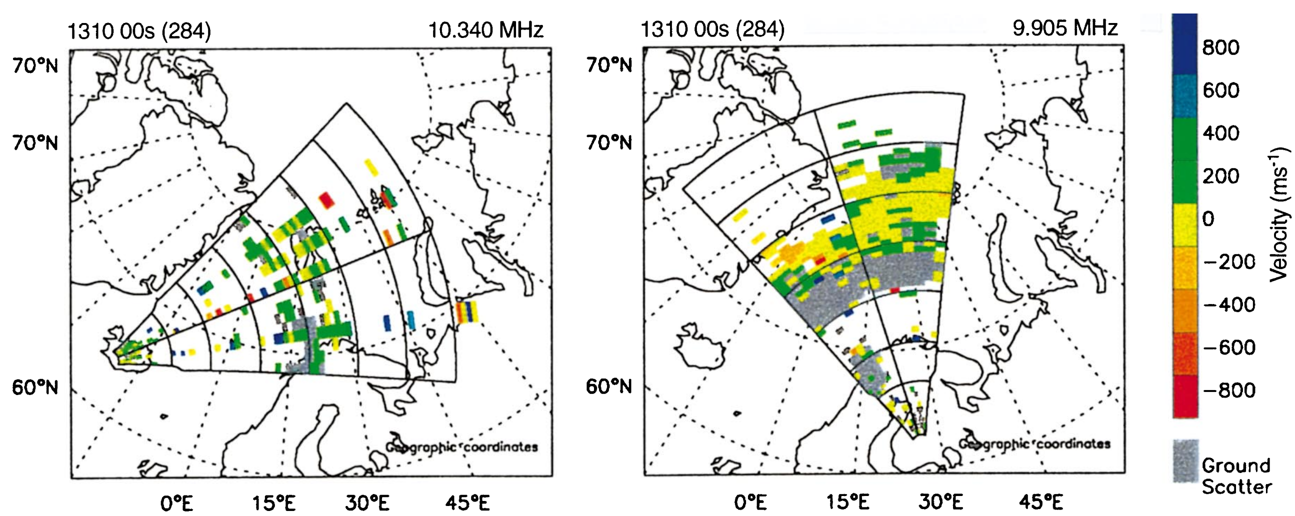
Fig. 4. IZMEM plot of electric potential for the prevalent IMF conditions on MLT/CGM co-ordinates. The section of the tomographic image and the coincident location of the feature in the image (75.0°N, 16.48 MLT) and the ESR measurements (75.0°N, 14.41 MLT) are shown

sities extending to lower altitudes. Several enhancements in the density were particularly intense, at around 1212, 1250 and 1308 UT, when densities in excess of 4.0×10^{11} m^{-3} were seen even at the lowest altitude of measurements by the radar. The enhancement observed between 1307 and 1312 UT is of particular interest as it was close in time to an NNSS satellite pass.

The tomographic image shown in Fig. 3 is for a southbound stallite pass that crossed 70°N at a longitude of 3°E at 1321 UT on 10 October 1996. The height of the F-layer peak is in general agreement with that found by ESR. At 78°N a latitudinally narrow enhancement in electron density can be seen to extent down to altitudes below the F-layer peak. This field-aligned structure has the characteristic ionospheric signatures of a discrete auroral arc in the post-noon sector of the dayside auroral zone, of the kind studied by Moen *et al.* (1997). The plasma circulation in the polar-cap ionosphere driven by the solar wind is such that a magnetic local time (MLT) and corrected geomagnetic latitude (CGM) framework is more appropriate to relate the features in tomographic images to measurements from other instruments. The enhancement in the ESR measurements at 1308 UT and the narrow feature in the tomographic image to the west of Svalbard have been converted to positions on the MLT/CGM plot shown in Fig. 4. Also shown in Fig. 4 is a plot of electric potential estimated from the IZMEM model for the prevalent IMF conditions measured by the WIND satellite (By +2.8 nT, Bz –0.8 nT). The IZMEM plot shows that the spatial structure seen on the tomographic image and the temporal density enhancement measured by the radar are located on sunward-convecting field lines in the post-noon sector. The feature imaged by tomography is coincident in MLT/CGM with that seen by ESR. It is possible that the feature imaged by ionospheric tomography is that observed by the ESR at 1308 UT, provided that the plasma convection velocities are low. Line-of-sight velocity measurements from the CUTLASS radar are displayed in Fig. 5. The left plot shows measurements from Iceland and the right plot measurements from Finland. Negative velocities are away from the radar. Although there was not sufficient spatial overlap to combine the measurements to obtain vector velocities, the line-of-sight velocities from both radars over Svalbard are less than 200 m s^{-1}. In addition, the velocities are predominantly away from the Finland radar and towards the Iceland radar, in agreement with the interpretation that the same feature in the weak sunward convective flow was being observed by both ESR and tomography.

These first results demonstrate the potential of multi-instrument studies in the high-latitude ionosphere, where measurements of electron density from the ESR provide information on the temporal changes in the plasma density at one location, ionospheric tomography shows the spatial distribution of electron density over an extended region of latitude and the CUTLASS radar measures plasma convection velocities.

Fig. 5. CUTLASS velocity components for the Iceland radar (*left*) and the Finland radar (*right*). Negative velocities are away from the radars



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