Signatures of space weather processes in the northern polar ionosphere: Radio Tomography and the CTIP model

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Abstract

The Coupled-Thermosphere-Ionosphere-Plasmasphere (CTIP) model was run for 13th December 2001 to coincide with a period of stable interplanetary magnetic field (IMF; By –ve, Bz –ve). The results show a tongue of photo-ionization being carried from its dayside source over the pole and into the nightside where it is further carried around into the pre-dawn sector but also that this behaviour is UT dependent. When this is compared to radio tomography images both from the Scandinavian and UK chains of receivers, the predicted enhancements in the midnight-dawn sector are present. The convection pattern used in the model run is backed up by CUTLASS measurements, EISCAT measurements show that the plasma observed is high altitude and further runs of the model with the precipitation turned off also produced these nightside enhancements.

Introduction

CTIP Model

The high-latitude ionosphere is to varying degrees influenced by solar EUV radiation, particle precipitation, electrodynamic drift, diffusion, thermospheric winds and temperature-sensitive chemical reactions. The CTIP model incorporates all these factors and can then be used to investigate the interplay between them and help to interpret the densities observed in the radio tomography. The most influential controllable inputs are those of the electric potential pattern, taken from Millstone Hill (Foster et al, *GRL* 13, 1986) and the precipitation energy input according to the classification of DMSP satellite measurements by Hardy et al. (*JGR* 90, 1985) and set by Kp.

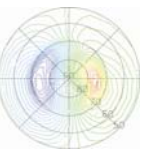
Radio Tomography

Radio Tomography is an established technique utilizing the phase-coherent signals from polar-orbiting satellites to image the spatial distribution of the ionospheric plasma.

Satellite signals from the Navy Ionospheric Monitoring System (NIMS) were monitored by UWA at two chains of receivers; one in Scandinavia and the other running through the UK. The total electron content (TEC) was measured along a large number of intersecting satellite-to-receiver ray paths. Inversion of the data yields the electron density distribution over a latitude-altitude plane (Pryse, *Surveys in Geophysics* 24, 2003 and references therein).

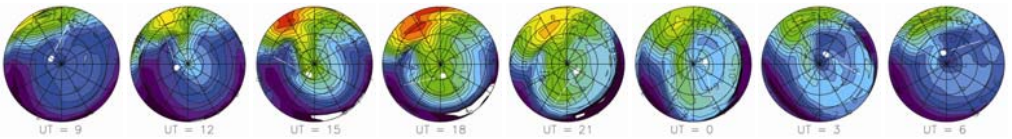
CTIP Model Results

The CTIP model was run for day 347 (13th December) 2001, under the following conditions: F10.7 = 230, Kp = 2, Millstone Hill electric potential pattern 33 (shown on the right, units in kV) - representative of the geomagnetic conditions at the time.



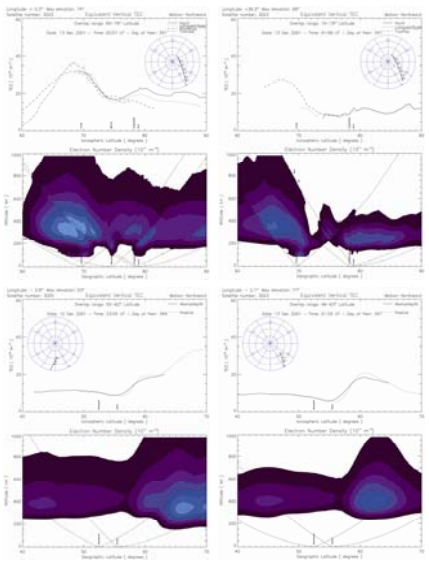
The polar plots below show the ion density output from the model at 350 km altitude on a MLAT vs. MLT grid at three hour intervals. Magnetic noon is at the top of each figure and the latitude scale is in increments of 10 degrees. The white line represents the 18 degree geographic meridian between 65 and 85 latitudes as an approximate position of the Scandinavian chain. The sequence begins at 9UT, when Scandinavia is near magnetic noon.

The photo-ionisation on the dayside is apparent in each figure. Another prominent feature in this sequence is the tongue of ionisation that is carried from the dayside over the pole towards the nightside. Its effect maximises around 18 to 21 UT when Scandinavia is in the magnetic midnight sector- this UT dependence is due to the offset between the geographic and geomagnetic poles. Close inspection of the figures for 21 and 0 UT reveal the tongue to be drawn towards the dawn at auroral latitudes.



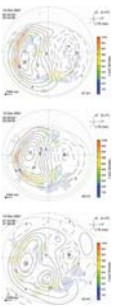
Observational Results: Radio Tomography

Radio tomography images provide observational support for the modelled tongue of ionisation (TOI) in the post-midnight sector. The top row of reconstructions are from the Scandinavian chain and reveal a clear density enhancement at the lower latitudes of the field of view with a magnitude that decreases with increasing displacement from magnetic midnight. We interpret this enhancement as being a cut through the TOI. Also shown in the upper panel of each figure is the equivalent vertical total electron content from each station and the trajectory of the satellite pass, projected at 350 km altitude on a MLT-MLAT polar grid, with geographic latitudes also marked. The colours used in the images below match those in the plots of the model run above.



The density enhancement is also observed at the higher latitudes of the field-of-view in reconstructions from the UK tomography chain, where it clearly forms the poleward wall of the post-midnight main trough. The decrease in the maximum density as the observations approach dawn are also evident in the lower latitude observations, reflecting decay by recombination.

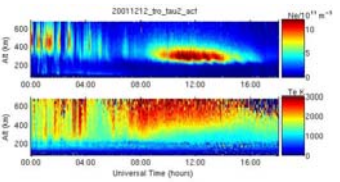
Further Support 1. Electric Potential



SuperDARN electric potential plots for the time period of interest generally support the choice of electric potential input into the model, which was based upon the IMF conditions. The three examples shown here are for the times of the Scandinavian reconstructions. These show cross-polar potentials of 50-60 kV, which is only slightly less than that in the pattern chosen for the model run.

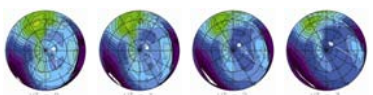
Further Support 2. High Altitude Long-Lived Plasma

Results from the mainland EISCAT UHF radar (field-aligned) show very high densities in the first three hours of 13th December 2001 at altitudes in excess of 400 km. Striations of increased electron temperature indicate that sporadic precipitation occurs during the time interval of interest however, close inspection reveals that the increased Te is broadly correlated with increased densities at E-region heights and it is very unlikely that the precipitation would cause such increased densities at the very high altitudes of interest in this study. This figure also shows the Scandinavian dayside photo-ionisation to show the contrast between the two sets of ionisation.



Further Support 3. Model

To confirm the presence of photo-ionisation in the nightside, the precipitation was switched off in a further model run.



The output revealed that the tongue of ionisation is still present and at only slightly reduced density values supporting the interpretation that photo-ionisation is the source of the tongue seen on the nightside.

Conclusions

The CTIP model predicts a UT dependent tongue-of-ionisation which brings photo-ionisation from the dayside into the nightside European sector. Radio tomography confirms these enhanced densities at the expected latitudes; the figures to the right show the trajectories of the satellite passes with the enhancements marked alongside the model results for 2 UT. It is expected that precipitation would play an important role in producing densities seen in the nightside at these latitudes. However, in this case it appears that it is the convection of dayside plasma that is the main mechanism responsible for the large scale F-region electron density structure that forms the poleward wall of the main midnight trough.