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SZA dependence of the plasma density and temperatures in the polar ionosphere and magnetosphere during quiet periods

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The electron density in the polar region is one of the most important parameters in the study of acceleration of outflowing ions and plasma supply processes from the ionosphere toward the magnetosphere. However, the lack of observations, especially in an altitude range of 1000-4000 km, has made it difficult to clarify how strongly the solar radiation influences the electron density and ion acceleration. In order to quantitatively evaluate the importance of solar radiation for the electron density in the polar topside ionosphere and magnetosphere, we have investigated the solar zenith angle (SZA) dependence of the electron density profile in the polar cap during geomagnetically quiet periods. The electron density data used in the present study are obtained from 63 months of plasma wave observations by the Akebono satellite in an altitude range of 500-10,500 km in the solar maximum (monthly-averaged $F_{10.7}$larger than 170). Electron density profiles at low altitudes are well fitted by quasi-hydrostatic equilibrium functions, while those at higher altitudes are well described by power law functions. In the quasi-hydrostatic equilibrium functions, we used a constant temperature, and altitude dependence of the gravitational force and magnetic field strength are taken into account.
Clear transition of the density profile is identified at about 2000 km altitude above an SZA of about 110 degrees. The largest variation in the fitted electron density with SZA is identified at 2100 km altitude, where the electron density varies by a factor of 88 from $1.25*10^4$ cm^{-3} at an SZA of 50 degrees to $1.43*10^2$ cm^{-3} at an SZA of 130 degrees in the polar cap. Above 5800 km altitude, the variation in the fitted electron density is within a factor of 20. The electron density and scale height decrease drastically with increasing SZA in an SZA range of 90-120 degrees. The sum of the ion and electron temperatures estimated from the scale height at an SZA of 120 degrees (3600 K) is less than half of that at an SZA of 90 degrees (8200 K).
Furthermore, in order to compare the change in the ionospheric plasma temperature with that obtained by the Akebono satellite, we have investigated the SZA dependence of the electron and ion temperatures in the topside ionosphere using 19 months of data derived from EISCAT Svalbard Radar (ESR), located at an invariant latitude of 75.2 degrees, in an altitude range of 300-1100 km during geomagnetically quiet periods in the solar maximum. The electron (ion) temperature above about 300 (600) km altitude decreases most drastically with increasing SZA in an SZA range of 80-110 degrees, which is near the terminator in the ionosphere. Although the SZA range of the drastic temperature change was about 10 degrees lower than that derived by the Akebono data, the drastic decrease in the ionospheric temperatures strongly suggests the dominant role of heating and photo-ionization processes by solar radiation in determining the electron density up to about 2000 km in the polar cap during geomagnetically quiet periods. Above about 2000 km altitude, the ionospheric control of the electron density gradually diminishes with increasing altitude.

Keywords: polar wind, ion upflow, ion outflow, Akebono satellite, EISCAT radar