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Variation of the cold plasma density structure above the polar ionosphere associated with geomagnetic storms

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Plasma outflow from the polar ionosphere into the magnetosphere is one of the most important processes in the magnetosphere-ionosphere coupling in the polar region. Recent satellite observations have clarified that the plasma outflow takes an important role on the supply of plasma into the magnetosphere, the abrupt changes of the ring current ion composition and the formation process of the auroral acceleration region during geomagnetic storms. Laakso and Grard, [2002] showed that the plasma density above the polar ionosphere increased more than one order of magnitude during magnetic disturbed periods. However, these studies have not been focused on the variation during geomagnetic storms. Since the energy input and decay in the ionosphere can be identified clearly, it is important to study the density distribution during these periods in order to understand the evolution of the plasma density enhancement above the polar ionosphere. In this study, we analyzed the electron density data observed by the Akebono satellite in an altitude range from 300 to 10500 km, in order to clarify the physical process of an abrupt change of the plasma density structure during geomagnetic storms.

The electron density along the satellite path was derived using the upper cut-off frequency of the upper-hybrid resonance (UHR) and whistler mode waves observed by the PWS instrument onboard the Akebono satellite with the time resolution of 2 seconds. The upper cut-off frequencies of the UHR and whistler mode waves were used for the cases of the plasma frequency are larger than the cyclotron frequency and the plasma frequency are smaller than the cyclotron frequency, respectively. In the present data analysis, we used the data from March, 1989 to July, 1990 to perform a statistical analysis. These electron density data were sorted into two geomagnetic conditions, magnetically quiet and geomagnetic storm periods using the SYM-H index. The quiet time is defined as the period when the SYM-H index is in the range from -10 to 40 nT and the Kp index is less than 2+ for previous 3 hours. The geomagnetic storm is defined as the event with the minimum SYM-H index of less than -40 nT. The main phase of the geomagnetic storm is defined as the period when the time derivative of the SYM-H index is negative.

First, we performed the case studies for the geomagnetic storm events which occurred on 6 June, 9 June, 10 August, 26 September, and 17 November, 1989. In these events, enhancements of the plasma density were associated with the storm main phases. In the 6 June storm, the electron density enhances up to 100 times as large as the prestorm level.

Using the data from March, 1989 to July, 1990 we performed statistical analyses of the electron density during the magnetically quiet time and the storm main phase. The electron density data were sorted into bins with the size of 500 km in altitude, 5 degrees in invariant latitude and 1.5 hour in magnetic local time. The electron density data were averaged logarithmically in each bin. During the main phase, the electron density increased 3 to 10 times compared with the quiet-time distribution in the altitude range from 5000 to 10000 km and invariant latitudes higher than 65-70 degrees. However, in the altitude range from 1500 to 3500 km, the density enhancements were found only in the cusp and auroral region.

These studies indicate that a large amount of the ionospheric plasma drifts upward to the altitude region of 5000-10000 km in the magnetosphere. The density enhancement in the altitude range from 1500 to 3500 km implies the existence of the plasma source in these regions. In these regions, since the cleft ion upwelling and the auroral bulk upflow are frequently observed, these ion upflow processes would be strongly associated with this plasma density enhancement observed by the Akebono satellite.