A Dissertation for the Degree of Doctor of Science

IONOSPHERIC CONVECTION-ELECTRIC FIELD EFFECTS ON POLAR LOWER-THERMOSPHERIC WIND DYNAMICS

by

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Abstract

In this thesis, we determined the importance of the ionospheric convection electric field in the wind dynamics in the polar lower thermosphere. The ionospheric convection electric field influences the wind dynamics in the polar thermosphere, but its importance in the wind dynamics in the lower thermosphere (90–130 km in height) is not yet clearly understood. Of vital importance is to qualify the significance of the ionospheric convection electric field in order to better understand the Magnetosphere-Ionosphere-Thermosphere (MIT) coupling process. In particular, we quantitatively evaluated contributions of the ionospheric convection effects by analyzing data sets obtained during summer days. Here we report the results from two case studies mainly based on observations with European Incoherent SCATter (EISCAT) Svalbard Radar (ESR) located in Longyearbyen (78.2°N, 16.0°E in geographic coordinates, 75.2°Λ in invariant latitude). From the two case studies, we have verified that the ionospheric convection effects play an important role in the wind dynamics in summer at and above 106 km for a longer time scale (1 day or so) and at 118 km for a shorter time scale (1 hour or so).

Utilizing the ESR data from 1000 UT on 1 July 1999 to 1000 UT on 7 July 1999, we investigated the importance of ion drag on the lower thermospheric wind dynamics in the time scale of one day (i.e., the diurnal tide). The electric field exhibited a stable diurnal variation primarily occurring throughout the first 3 days of observations, while, during the latter 3 days, the diurnal variation was not clearly identified. On the basis of this difference of the electric field variation, we divided the data into two intervals with a length of 3 days each. We compared the horizontal velocities of the ions and the neutral gases. At upper heights (110–120 km) on the first 3 days, the difference between the ion and neutral motion was clearly identified. We compared the diurnal tidal amplitudes and phases of the two intervals derived from the ESR data. The amplitude of the meridional diurnal tide for the first 3 days was larger than that of the latter 3 days over the height region between 100 and 118 km. Furthermore, we compared ion drag accelerations with total accelerations (wind tendencies). We concluded that the ion drag played an important role in the diurnal variation of the lower thermospheric wind at and above 106 km during the almost geomagnetically quiet interval for July 1-7, 1999 at Longyearbyen. In addition, we compared the National Center for Atmospheric Research (NCAR) Thermosphere-Ionosphere-Mesosphere-Electrodynamics General Circulation Model (TIME-GCM) predictions with the observations. The TIME-GCM predictions also indicated that the diurnal tide is influenced by the convection electric field.

Utilizing the ESR data obtained on 16 June 2005, we investigated the importance of the ion drag and the Joule heating-induced pressure gradient effects on the lower thermospheric wind dynamics in the time scale of $\sim$1 hour. The Advanced Composition Explorer (ACE) satellite observed a southward turning in the Interplanetary Magnetic Field (IMF) at 0843 UT. At 0900 UT, the F region ion velocity and the lower thermospheric neutral wind (at 118 km height) observed with the ESR began to accelerate significantly in the westward and northwestward directions, respectively. The neutral wind was remarkably accelerated within one hour from 0900 UT, and its speed became a value of $\sim$500 m s^{-1} at 1000 UT. The wind speed was significantly higher than a typical wind speed at 118 km. We evaluated the ion drag contribution to the generation of the high-speed neutral wind. Our evaluation verifies that the ion drag force could not generate the high-speed neutral wind within such a short time ($\sim$1 hour). The result implies that the major driving force of the atmosphere was the horizontal pressure gradient force induced by the Joule heating. We deduced the contribution of the pressure gradient force based on a quantitative estimation of the Joule heating-induced pressure gradient from the ESR and the Super Dual Auroral Radar Network (SuperDARN) data. We concluded that the pressure gradient force was the most probable force in this event.

To summarize, we have found that the ionospheric convection electric field can significantly influence the lower thermospheric wind dynamics during the summer by the ion drag for a longer time scale (1 day or so) and by the Joule heating-induced pressure gradient force, in particular, for a shorter time scale (1 hour or so).