Sodium density depletion during electron density enhancements by auroral particle precipitation

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The neutral sodium layer, generally distributed at altitudes from 80 to 110 km, is sustained by a balance between meteor absorption, diffusion, and chemical reactions. One of the interesting subjects is relationship between sodium density variation and auroral precipitation.

At the topside of the sodium layer, chemical reactions including molecular ions are the primary agent for controlling the density of neutral sodium. Previous studies have implied that neutral sodium in the lower E region can be depleted by ionization through the charge transfer reaction with molecular ions produced by the auroral particle precipitations. To date, however, this mechanism has not yet been evaluated by combining simultaneous observations of neutral sodium and ambient electron density. In the present study, for more detailed understanding, we have examined the suggested sodium ion chemical reactions based on the quantitative comparison for temporal variation of the sodium density and the reaction rates estimated from the theoretical chemistry model.

On 25 January 2012, the EISCAT VHF radar and an all-sky imager (ASI) were operated simultaneously, together with the sodium lidar at the EISCAT Tromsø site (69.6°N, 19.2°E). The ASI captured an extended period of pulsating auroras (PsA) in the post-midnight to morning sector. The EISCAT VHF radar observed intense ionization at altitudes below 100 km probably due to precipitation of high-energy electrons response for PsA. During this interval, the lidar detected characteristic depletion of sodium density from 97 to 100 km in close association with the occurrence of PsA. To evaluate the process causing the sodium depletion, the depletion rates were estimated from the lidar measurement and compared with those theoretically calculated based on the charge transfer reaction with NO^+ and O_2^+. The mean observed depletion rate is about 2×10^6 $m^{-3}s^{-1}$. The observed depletion rates showed a good agreement with the theoretical depletion rates; this agreement indicates that the sodium density was depleted by the charge transfer reactions of NO^+ and O_2^+ created by precipitation of PsA electrons. This result further indicates that precipitation of high-energy magnetosphere electros into the lower ionosphere significantly affects the chemistry of mesospheric neutral species.