Molecular ion supply mechanisms from the low-altitude ionosphere to magnetosphere observed by EISCAT and Arase(ERG)

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Molecular ions (O_2^+/NO^+/N_2^+) in the magnetosphere have been observed during magnetic storms [Peterson et al., 1994; Klecker et al., 1986]. These molecular ions are considered to originate from the Earth’ s ionosphere. It is considered that they have been transported upward by some heating processes in the ionosphere. However, due to the larger mass than atomic ions (O^+), the molecular ions usually exist only in the low-altitude ionosphere below 300 km altitude. It is hence difficult to transport these molecular ions by overcoming loss by chemical reactions to the high-altitude ionosphere where the ion upflow and outflows usually take place [Peterson et al., 1994]. Therefore, it is necessary to reveal what mechanism causes molecular ion upflow during the magnetic storms. In this study, we aim at the observational assessments of the supply processes of the molecular ions from the low-altitude ionosphere to the magnetosphere based on conjugate observations by EISCAT radar and the Arase (ERG) satellite.

The EISCAT radar and the Arase (ERG) satellite have the conjunction event during the large magnetic storm with the minimum Dst of -124 nT on September 8, 2017. During the event, the Arase satellite was located in the dusk-side inner magnetosphere and observed molecular ions in the energy range of 12-180 keV/q. The EISCAT radar simultaneously observed the ion upflow (with the upward velocity of ~50-150 m/s) from the low-altitude ionosphere (~250-400 km) together with strong ion heating (>2000 K). The convective electric field was also enhanced by a factor of 2 in the same region. We estimated each term in the equation of motion for ions. The result indicates that the ion upflow reached stable equilibrium because the upward ion and electron pressure gradients are balanced with the downward gravitational force. It is suggested that the ion upflow can take place from the low-altitude ionosphere due to strong ion pressure gradient. We also estimated the flux decrease of molecular ions due to dissociative recombination. The flux decreased to ~1 % at 350 km compared with 280 km. The estimated upflow flux of molecular ions at 350 km is $>10^{10}$ m^{-2} s^{-1} . Comparison between distribution functions observed by Arase satellite and EISCAT radar suggests that acceleration by 3 orders of magnitudes is necessary during the outflow process. These results indicate that the strong ion frictional heating during magnetic storms enabled molecular ions to be transported upward from the low-altitude ionosphere and provide a source of molecular ion outflows into the magnetosphere.

Keywords: Molecular ion, EISCAT radar, Arase (ERG) satellite, Ion upflow, Ionospheric heating

