Molecular ion upflow observed by EISCAT in conjunction with Arase during the September 7, 2017 magnetic storm

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Molecular ions (O_2^+/NO^+/N_2^+) originated from the ionosphere have been observed in the magnetosphere [e.g., Klecker et al., 1986; Christon et al., 1994]. Recently, the Arase satellite also observed the molecular ions even in the small geomagnetic disturbance periods [Seki et al., 2019]. However, it is not revealed how these molecular ions are transported from the ionosphere, especially in the low-altitude ($<$~300 km) region where molecular ions are abundant. It is considered that some heating mechanisms such as ion frictional heating, ion resonance heating, and local plasma instabilities cause the ion upflow and transport molecular ions upward. The previous study of Peterson et al. [1994], on one hand, reported that these mechanisms cannot create ion upflows fast enough to overcome the loss of molecular ions by chemical reactions and transport them into the high-altitude ionosphere where the ion outflows usually take place. Therefore, it is necessary to reveal what mechanism causes molecular ion upflows. In this study, we aim at the observational assessments of molecular ion upflow mechanisms in the low-altitude ionosphere based on a conjugate observation by the 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 the strong ion pressure gradient. We also estimated the flux decrease of molecular ions due to dissociative recombination. The O_2^+ (NO^+) flux decreased to ~1 (~0.001) % at 350 km compared with 280 km. The estimated upflow flux of O_2^+ (NO^+) at 350 km is at least ~10^{10} (~10^7) m^{-2} s^{-1}. 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.

Reference:

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