Simultaneous observations of a low-altitude ion upflow by the EISCAT radar and molecular ions in the ring current by the Arase (ERG) satellite

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Molecular ions ($O_2^+/NO^+/N_2^+$) originating from the ionosphere have been observed in the magnetosphere during the magnetic storms [e.g., Klecker et al., 1986; Christon et al., 1994] and also recently observed by Arase satellite even during weak geomagnetic disturbance periods [Seki et al., 2019]. It suggests that the molecular ions are commonly supplied from the ionosphere. However, it is not revealed how these molecular ions are transported from the low-altitude (<300 km) ionosphere where molecular ions usually exist. These molecular ions are considered to be transported upward by some heating mechanisms such as ion frictional heating, particle precipitations and local plasma instabilities. However, previous observations indicate that those mechanisms are not efficient enough to transport molecular ions by overcoming loss due to the dissociative recombination [Peterson et al., 1994].

In this study, we aim at quantitative assessment of the ion upflow process for the molecular ions from the low-altitude ionosphere based on the simultaneous observations by the EISCAT radar and the Arase (ERG) satellite on September 8, 2017. During the magnetic storm started from September 7, 2017, the Arase (ERG) satellite observed molecular ions ($O_2^+/NO^+/N_2^+$) in the ring current. The EISCAT radar simultaneously observed the ion upflow (~50-150 m/s) in the low-altitude (250-350 km) ionosphere together with strong ion heating (>2000 K) during the main phase around the second Dst minimum of the storm. The convective electric field derived from the electron heating observed by EISCAT around 110 km altitude was also enhanced by a factor of 2. The observations suggest that the additional ion heating at the low-altitude ionosphere helped to cause the fast upflow and transport molecular ions upward. We also estimated flux decrease of molecular ions (O_2^+/NO^+) from 280 to 350 km altitudes due to the dissociative recombination. It was about two orders of magnitude without any production processes. These results suggest that the low-altitude ion upflow caused by the ion frictional heating enables molecular ions to escape to space against rapid loss by the dissociative recombination.

References

[1] Klecker et al., Discovery of energetic molecular ions (NO+ and O2+) in the storm time ring current, Geophys. Res. Lett., Vol. 13, 632-635, 1986.

[2] Peterson et al., On the sources of energization of molecular ions at ionospheric altitudes, J. Geophys. Res., Vol. 99, 23257-23274, 1994.

[3] Christon et al., Energetic atomic and molecular ions of ionospheric origin observed in distant magnetotail flow-reversal events, Geophys. Res. Lett., Vol. 21, 3023-3026, 1994.

[4] Seki et al., Statistical Properties of Molecular Ions in the Ring Current Observed by the Arase (ERG) Satellite, Geophys. Res. Lett., Vol. 46, doi:10.1029/2019GL084163, 2019.