N_2^+ resonant scattering light observation in the sunlit topside ionosphere with the auroral spectrograph

Yu Endo(1), Takeshi Sakanoi(1), and Yasunobu Ogawa(2)

(1) Planetary Plasma and Atmospheric Research Center, Graduate School of Science, Tohoku University, S313, Joint building C, Graduate School of Science, 6-3, Aoba, Aramaki-aza, Aoba-ku, Sendai, Miyagi, 980-8578

(2) National Institute of Polar Research, 10-3, Midori-tyo, Tachikawa, Tokyo, 190-8518

We report the ground-based optical remote-sensing of molecular ion upflow by measuring 427.8 nm N_2^+ resonant scattering in the sunlit topside ionosphere. *Störmer* [1955] has summarized his work on sunlit aurora from 1918 to 1943. He observed the sunlit aurora extending to 700-1100 km altitude and the strong emission from N_2^+. *Bates* [1949] suggested the N_2^+ emission at 427.8 nm is resonant scattering in the sunlit region. Recently, satellite data showed N_2^+ emission at the high altitude in the range from 400 to about 1,000 km. MSX satellite observed first the N_2^+ emission probably caused by N_2^+ upflow from the topside ionosphere [*Romick et al.*, 1999]. Ion upflow is essential for the source of ion outflow observed in the magnetosphere. O^+ ion upflow happens mainly during geomagneticaly disturbed conditions [*Moen et al.*, 2004, *Abe et al.*, 1993]. Furthermore, the heavier molecular ions which mainly exist in the E-region were also measured at about 10,000 km altitudes [*Yau et al.*, 1993]. However, the mechanism of these molecular ion upflow is uncertain. Now, we think that N_2^+ created by the charge exchange between N_2 and O^+ in F-region are upflowing during geomagnetically disturbed condition. Thus, we focus on N_2^+ 427.8 nm emission caused not by auroral precipitating electrons but by resonant scattering in the sunlit topside ionsphere associated with N_2^+ upflow using the data taken by Aurora Spectrograph (ASG) at Longyearbyen, Svalbard (geographic latitude : 75.2 deg and geographic longitude : 16.04 deg) for 13 years.

The ASG consists of a fish-eye lens, slit, grism and a cooled CCD detector which covers the wavelength range of 420-730 nm with a 2.0 nm spectral resolution and field of view of 180° along the magnetic meridian. The ASG have been operating since 2000, but measuring N_2^+ emission 427.8 nm since 2004. The preceding study figured out that there is a high probability that the N_2^+ outflow occurs in geomagnetically disturbed condition (Kp > 4) [*Mizuno et al.*, 2005]. Therefore, we analyzed the 65 events during from 2004 to 2016 which the sun does not illuminate the ground and the Kp indices were greater than 4 for more than 9 hours. Then, if a single aurora arc appears in the geomagnetically southward direction, we can regard the auroral distribution as the auroral height profile. In this case, we can roughly assume the emission height with the simultaneous 557.7 and 630.0 nm emission. The oxygen emission at 557.7 nm is considered to be caused only by precipitating electrons, and if the 427.8 nm emission is distributed higher (larger elevation angle) than 557.7 nm, this 427.8 nm emission is resonant scattering light. We found 5 events in this cases of all 65 events. The Kp indices of these events are 4-, 2+, 3+, 4-, 6-, 5, and we found that there were two cases which are during geomagnetically disturbed conditions and not disturbed ones. Around 0700 UT on December 21, 2014 (Kp=2+), the maximum 427.8 nm emission is 400 R and Dst indice is -10 nT (an hour before the 427.8 nm observation). Then, the 427.8 nm emission peak is assumed to be at 380 km if the 630.0 nm emission peak is considered to be at 250 km. While, around 0100 UT on December 21, 2015, a geomagnetic storm occurred (Dst indice is -150 nT), and N_2^+ emission was observed at intensity of 800 R. Then, N_2^+ emission peak is 340 km and the emission at intensity more than 200 R extended up to 1,000 km and more. Of all 5 events, the N_2^+ emission peak is in 300~400 km in 4 events, the altitudes which the intensity are less than 200 R are higher increasing the activity of geomagnetism. This result suggests that N_2^+ is produced in the lower F-region and then upflowing with the geomagnetic activity. This is consistent with the preceding study.