Temperature diagnostics for the winter mesopause region estimated from N_2^+ (0,0) Meinel band at 1.1 µm observed by the NIRAS-2 and the NIRAC

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Dayside aurora and polar patches are the key phenomena for understanding of the dayside magnetosphere-ionosphere-atmosphere coupling process. These phenomena are being monitored by ground-based optical instruments in high latitude region corresponding to polar cap and cleft, but the observations are done at limited geographic location and in limited season for avoiding strong photon intensity of sky background. Alternatively, active/passive radio remote sensing such as HF/VHF/UHF radar, GNSS and LF wave receiver are effective, but spatial and temporal resolutions by those measurements are not sufficient in comparison to optical measurements.

We present simultaneous observations of N_2^+ Meinel (0,0) band (hereafter, N_2^+ (M)) aurora by cutting-edge short wavelength infrared (SWIR) imaging spectrograph (NIRAS-2) and monochromatic camera (NIRAC) installed at Kjell Henriksen Observatory (78°N, 16°E). NIRAS-2 is a 2-D imaging spectrograph with a fast optical system at spectral resolutions for twilight/daytime aurora measurements from the ground. It is designed for SWIR wavelengths from 1.1 to 1.3 microns in which sky background intensity is weaker than in visible subrange. In addition, NIRAC have been developed focusing on aurora emissions of N_2^+ (M). The N_2^+ (M) is about two orders brighter than N_2 1st negative band at 427.8 nm (Remick et al. 2001). Total optical system is fast (*F*-number 1.5) and its FOV (84° x 68°) is slightly wider than that of the NIRAS-2. Thus, the NIRAC is used as a twin instrument to the NIRAS-2 to help in interpreting meridional scan data obtained from the NIRAS-2.

On January 21 2023, N_2^+ (M) intensification of associated with a band-shape aurora structure was observed by the NIRAS-2 and the NIRAC at temporal resolutions of 30 seconds and 20 seconds, respectively. Additionally, the European incoherent scatter Svalbard Radar (ESR) also observed electron density variations at the same time. Electron density measured at altitude ranges from 100 km 120 km changed in the same way as N_2^+ (M) intensity, which implies that a primary source of N_2^+ (M) emissions is direct collisions of N_2 by precipitating electrons penetrating down to around 100 km altitude (up to 10 keV).

The observed N_2^+ (M) spectrum show fine structures due to N_2^+ rotational motions and it was successfully reproduced by common molecular models for diatomics and non-linear least squares fitting. The estimated N_2^+ rotational temperature with 30-sec cadences mostly ranges from 200 to 300 K, which agrees with NRLMSIS 2.1 at 100 and 110 km altitude, respectively. During a period where strong aurora intensification was seen, the rotational temperature was about 160 K with an error of 15 K (1-sigma). In addition, the ESR demonstrated that a peak altitude of electron density also got down to 100 km. These results are consistent with that a center altitude of N_2^+ (M) emission layer gets lower associated with more energetic particle precipitations. In this study, further analysis results based on the above case study and several similar events will be presented.

References

Remick, K. J., R. W. Smith, and D. Lummerzheim (2001), The significance of resonant scatter in the measurement of N_2^+ first negative 0-1 emissions during auroral activity, J. Atmos. Sol. Terr. Phys., 63, 295.