Simultaneous Millimeter-wave Multi-line Observation at Syowa: Results in the First Year of Regular Observation

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Since 2012, we have been conducting steady observations of nitric oxide (NO) and ozone using a ground-based millimeter-wave spectrometer at Syowa in order to study the influence of energetic particle precipitation, EPP, on the composition of the middle atmosphere in the polar region. Millimeter-wave spectroscopy is almost the only ground-based remote sensing method that can observe temporal changes of atmospheric composition above the mesosphere through day and night. So, this is one of the most suitable ways to observe the atmospheric response to EPP. However, the instantaneous frequency coverage, which was 1 GHz at that time, was too narrow to observe both NO and ozone simultaneously. To obtain more comprehensive view of the EPP related molecules, we have developed a multi-frequency millimeter-wave spectrometer that enables simultaneous observation of 230 GHz, 247 GHz, and 250 GHz frequency-bands by using a newly developed waveguide-type frequency multiplexer by ourselves and a 2.5 GHz band FFT digital spectrometer. In July 2022, we started steady operation of the simultaneous multi-line observation for NO, ozone, CO, NO_2, and HO_2.

Two ozone rotational transition lines, six NO hyperfine structure lines, and one CO rotational transition line were significantly detected by with the multi-frequency millimeter-wave spectrometer, and physical quantities such as column density and/or vertical distribution of volume mixing ratio are derived from these data. Particularly for the column density of NO, whose line intensity is two orders of magnitude weaker than the ozone line, the random error caused by noise in the spectral data was reduced by averaging the column densities derived from the six hyperfine structure lines weighted by error. This is a remarkable progress from the previous observations that provided only daily averages, since now we can obtain 12- or 6-hour time-resolution column density data. No significant emission lines of HO_2 and NO_2 have been detected above the sensitivity limit so far.

Data analysis is still underway but suggesting some interesting results. For example, time series in NO column density from September to the end of October 2022 show several rapid increases due to electron precipitation, and it is likely that the differences in the durations of subsequent decay reflect the effects of photochemistry. In the data between 20 and 30 March, 2023, the NO response appears to be different due to different causes such as auroral activity, CME, and high-speed solar wind. For ozone data, data analysis algorithm is developing in collaboration with a group at Tohoku University, and the stability and reliability of retrieved vertical distributions and column densities are being evaluated through comparisons with data obtained from other instruments.

In the symposium, we will report in detail the results obtained by the simultaneous multi-line observations over the past year.