Development of a MAX-DOAS instrument employing multi-track spectroscopy for measuring tropospheric column density of NO2

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Spectroscopic analysis of the scattered sunlight observed by zenith viewing (elevation angle = 90 degrees) UV/Vis spectrometers has been widely performed to measure the stratospheric NO2 column density. By expanding this method to include analysis of the scattered sunlight collected with low elevation angles (5, 10, 20, and 30 degrees), sensitive measurements of NO2 present in the lower troposphere can be made. This configuration has been named Multi-Axis Differential Optical Absorption Spectroscopy (MAX-DOAS). Under clear conditions, the observed slant column densities of NO2 can be converted to vertical column densities using air mass factors derived from a radiative transfer model. Furthermore, vertical profiles of NO2 (with a height resolution of 1 km) can be retrieved by combining the measurements with multiple elevation angles.

We have succeeded in continuously measuring the tropospheric NO2 column densities at our institute in Yokosuka for one year from January 2005, using a preliminary MAX-DOAS instrument employing a handheld spectrometer equipped with a 1-dimensional CCD array detector. The observation was performed using a single telescope with its elevation angle sequentially changed every 6 minutes to obtain a full data set with five different elevation angles in 30 minutes. This resulted in a disadvantage that the observations with different angles were not performed simultaneously. In order to overcome this disadvantage, we have started to construct another MAX-DOAS instrument based on the multi-track spectroscopy. In this system, the scattered sunlight collected by five telescopes with different elevation angles are simultaneously introduced into a single spectrograph and are dispersed spectrally onto a 2-dimensional CCD detector. The light exiting from the telescopes is first transferred by an optical fiber bundle to the spectrograph and then enters it through a slit as five light tracks vertically separated from each other. It was confirmed that the tracks were kept separated in the spectrograph without crosstalk until they reached the CCD detector. This multi-track analysis enabled us to extract larger number of data sets not influenced by clouds, leading to more frequent measurements of the NO2 column with a higher time resolution. Additionally in the new system, a mirror can be introduced into the optical path of each telescope so that the zenith measurement can be performed periodically that can be used as a reference spectrum for each track. Moreover, we have newly employed a spectrometer with a longer focal length (300 mm) and a CCD detector that can be cooled down to -50 degrees Celsius to reduce stray light and dark current, respectively. We present the fundamental performance (stray light, wavelength resolution and shift) and the overall performance of the new system to detect the tropospheric NO2 column in comparison to the preliminary one.