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Development of a scanning Raman lidar for observing the spatio-temporal distribution of water vapor

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Water vapor and aerosol particles are important atmospheric constituents that play a key role in the atmospheric processes such as thermodynamics, radiative forcing, cloud physics, and chemistry. Atmospheric constituents near the surface are highly variable spatially and temporally, because of the complex turbulent flow over the surface. It is required to innovative techniques for observing the distributions of atmospheric constituents with good spatio-temporal resolution. We have newly developed a scanning Raman lidar to measure the spatio-temporal distributions of the water vapor and aerosol particles near the surface, which is useful to study the detailed behavior of meteorological phenomena as well as interactions of aerosol particles with water vapor.

Considering the eye-safe operation in urban districts, we employed the UV laser of 355 nm. We developed a scanning mirror system which comprises with highly reflective mirrors and a rotational stage. By use of the program-controlled rotational stage, vertical scan into any zenith direction can be operated with a maximum speed of 1.8 deg./s. Differences between the temporal variations of water vapor mixing ratio by the scanning Raman lidar and those by the conventional lidar for observing a vertical point are less than 2.5 %. It is indicated that the developed system can measure water vapor correctly though the scanning system is attached.

We have demonstrated the potential of the scanning Raman lidar in the forest region at the Shigaraki MU observatory in August and October, 2012. We performed a vertical scan in a zenith sector of 48 deg. with a constant step width of 1.5 deg. The temporal resolution of each pointing direction was 30 s. In this observation, we found that water vapor mixing ratio within the surface boundary layer varied in a range of 13.5 - 16.5 g/kg within the range of 400 m. It is suggested that the spatial variations are highly sensitive under the different topography. During the vertical plane measurements with the wide range scanning, it is found that the thickness of the atmospheric boundary layer changes into the range of about 200m according to the observed directions. During the high spatial and temporal resolution measurements with the continuous scanning at a constant speed, a single cross-sectional distribution can be acquired every 90 s; this indicates the possibility of understanding the cloud formation and modification processes via continuous observations. Scanning Raman lidar has an advantage of obtaining a detailed structure that is difficult to gather from other instruments.

Keywords: lidar, water vapor, aerosol