UV Raman lidar for profiling atmospheric water vapor

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Measurements of the atmospheric water vapor over all timescales and extensive spatial regions are essential for studies of air quality, local weather, and climate change. The Raman lidar is a laser-based remote sensing instrument that is used for profiling the water vapor mixing ratio, the atmospheric temperature, and several cloud- and aerosol-related quantities. Raman lidar applications are based on the measurements of the weak inelastic scattering of light by molecules with frequency shift characteristics, as a function of the range. Since 2000, we have developed several Raman lidar systems for measuring water vapor. One such system is the lidar installed at Shigaraki MU Radar Observatory, Japan; it is designed for high-sensitivity water vapor measurements at an altitude range of 1.5–10 km with a high-power laser and a large telescope. Other systems include the portable Raman lidar that can be transported using a one-box-type vehicle and used for studying the distribution of the water vapor in the lower troposphere in various observation fields such as volcanoes and forests. These Raman lidar systems use a visible laser wavelength because of the quality limitations of optical components such as narrow-band interference filters, although the visible laser wavelength is not always safe for human eyes.

In atmospheric measurements using a laser-based system, the prevention of damage to human eyes caused by the transmitted laser radiation is an important issue. With regard to eye safety, the UV laser has an advantage over the wavelengths in the visible because the maximum permitted exposure is larger by 3–4 orders of magnitude in the UV region than in the visible region. Recently, the improved performance of UV optical components has led to the development of better UV Raman lidar systems; the system is as highly sensitive and cost effective as the visible system. Additionally, UV lidars may achieve better daytime performances than visible systems because of the reduced sky background. Hence, we have developed a water vapor Raman lidar using a UV laser. This UV Raman lidar is equipped with a 25-cm receiving telescope at a Nd:YAG laser wavelength of 354.7 nm and is used for measuring the light separated into an elastic backscatter signal and vibrational Raman signals of nitrogen and water vapor at wavelengths of 354.7, 386.8, and 408.0 nm, respectively. An example of the water vapor mixing ratio profile obtained using the developed UV Raman lidar and a radiosonde at nighttime at Uji, Kyoto, is depicted in Fig. 1. The trends shown by the lidar and the radiosonde agree well up to 7 km for a height and time resolution of 108 m and 30 min, respectively. This UV Raman lidar is suitable for measuring the atmospheric water vapor in highly populated areas and near the earth's surface. The fact that the UV lidar poses less danger to the human eye may make it favorable for use as a scanning system. This UV system has been used for continuous water vapor measurements in the urban area for validating the ground-based GPS (GNSS) meteorological observations. Moreover, we plan to use the UV lidar for simultaneous measurements with tethered balloon profiling for trace gases and aerosols in order to elucidate the properties of the minor atmospheric constituents of the earth's surface layer.

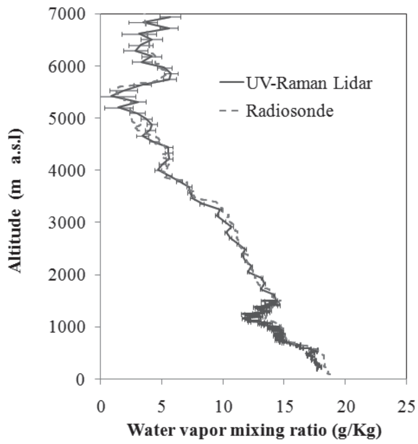

Figure 1. Water vapor mixing ratio profiles from the UV Raman lidar and the radiosonde at Uji, Kyoto, at 00:00–00:30 JST on July 9, 2011. Height resolution is 11 m for 200–1500 m and 108 m for 1500–7000 m. Error bars show the statistical uncertainty due to signal noise. The radiosonde was started at 00:00 JST.

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