Raman Lidar Measurement of the Water Vapor Profile in Alaska

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ABSTRACT

A Raman lidar system has been set up at Poker Flat Research Range (65.1N, 147.5W) as one of the remote sensing instruments of the Alaska project and has been operated on an ongoing basis. We compare Raman lidar data with radiosonde data, and examine the utility of this lidar system in water vapor mixing ratio measurement.

1. INTRODUCTION

Tropospheric clouds and water vapor play significant role in the earth radiation budget and the water vapor mixing ratio is an important meteorological parameter. Lidar can observe it continuously while the radiosonde is generally used for the intermittent measurement of profiles of the mixing ratio.

National Institute of Information and Communications Technology (NICT) promoted ‘Alaska Project’ in cooperation with Geophysical Institute of University of Alaska in United States. Multi-wavelength lidar has been set up at Poker Flat Research Range near Fairbanks, Alaska as one of the observation equipments. This lidar has Raman channels in addition to Mie lidar channels of 1064nm and 532nm. Extinction coefficient, backscattering coefficient, scattering ratio and water vapor mixing ratio are derived from Mie-Rayleigh, N_2 and H_2O Raman scattering signal.

2. INSTRUMENTS

Fig.1 shows the block diagram of the multi-wavelength lidar system. The specifications of this system are listed in Table1.

Light of both the fundamental and second harmonic wavelength of Nd:YAG laser is transmitted and H_2O Raman (660nm), N_2 Raman (607nm), Mie-Rayleigh (532nm, 1064nm) and polarization component (532nm) are simultaneously detected in 10 channels.

A telescope of a diameter of 50mm is used to receive backscattering from Haze particles. Cross polarized component is detected in one channel and parallel-polarized component is detected in two channels (for lower and upper height) in the troposphere and the stratosphere, respectively. Each system uses a 35cm telescope. A Si-Avalanche photodiode module (APD) is used for detection of 1064nm backscattering in the system for the stratosphere.

Measurements from the 12Z radiosonde launched in Fairbanks, Alaska (64.8N, 147.9W) is used to derive atmospheric density and water vapor mixing ratio for comparison with the Raman lidar measurements.

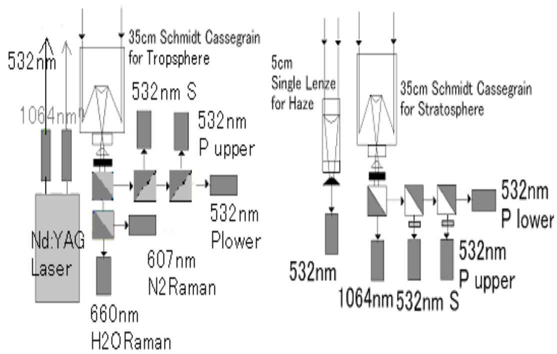

Fig.1 Block diagram of Transmitter and Receive

Table 1. Specifications of lidar system

Transmitter	
Laser	Nd:YAG (1064 nm, 532 nm)
Repetition	20 Hz
Pulse Energy	550 mJ (532nm), 600 mJ (1064nm)
Pulse width	5-7 ns
Receiver	
Telescope	355 mm (Schmidt Cassegrain) × 2 50 mm (Single Lens)
Field of view	1 mrad
Detector	APD, PMT (photon counting)
Number of channel	10 ch
Range Resolution	12 m

3. RESULT

Water vapor mixing ratio derived from lidar data was calculated from the ratio of H_2O and N_2 Raman signals. Scattering ratio R was derived from the ratio of the Rayleigh signal and N_2 Raman signal. We need extinction correction factors for atmospheric molecules and aerosol.

The extinction coefficient of atmospheric molecule was derived from atmospheric density by radiosode data [1]. We calculated the aerosol extinction coefficient according to Ansmann et al [2],

$$\alpha_{\lambda_L}^{aer}(z) = \frac{\frac{d}{dz}\left[\ln\frac{N(z)}{X_{N_2}(z)}\right] - \alpha_{\lambda_L}^{m}(z) - \alpha_{\lambda_{N_2}}^{m}(z)}{1+\frac{\lambda_L}{\lambda_{N_2}}} \quad ,(1)$$

where, $\alpha^{aer}(z)$ and $\alpha^{m}(z)$ are extinction coefficient of atmospheric gases and aerosol, N(z) is N_2 molecular number density, $X_{N2}(z)$ is range-squared N_2 Raman signal, λ_L and λ_{N2} are wavelengths of return signal and N_2 Raman signal.

The backscattering coefficient is derived from scattering ratio R [3]. We normalized R by assuming scattering ratio to be 1 in the altitude where the Rayleigh signal is the dominant component of the lidar signal (The data normalized at about 30km).

Fig.2 shows comparison between lidar and radiosonde measurements of the water vapor mixing ratio, scattering ratio, and depolarization ratio. The profiles of water vapor mixing ratio from lidar data agree very well with those from the radiosonde under a variety of atmospheric conditions. The lidar data was averaged for 30 minutes, and range resolution was 120m. The depolarization ratio was normalized to 0.71% at about 30km, which was obtained by responsibility correction using incandescent lamp. The identification of scattering object can be done by comparing water vapor mixing ratio, scattering ratio, and depolarization ratio.

Each profile of water vapor mixing ratio in Fig.3 is averaged during one hour. Profiles apparently show the time variation of water vapor during one night

4. CONCLUSIONS

We derived water vapor mixing ratio, extinction coefficient, scattering ratio and backscattering coefficient from data obtained by multi-wavelength lidar in Alaska. The comparison of the radiosonde and lidar water vapor measurements confirms that the lidar can accurately measure water vapor in the troposphere under a variety of conditions. A similar system is planned to be installed at NICT in Koganei, and the water vapor mixing ratio is scheduled to be observed also in Japan in the future.

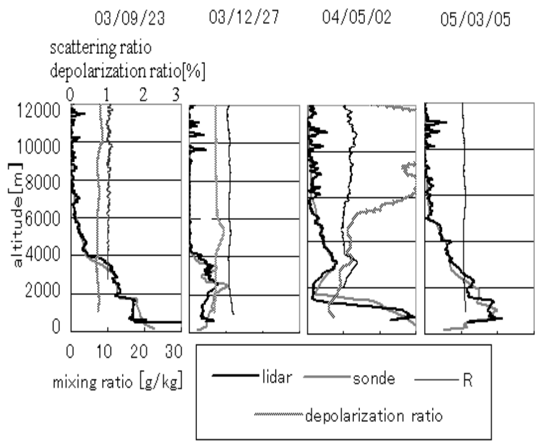

Fig.2 Height profile of water vapor mixing ratio, scattering ratio, and depolarization ratio

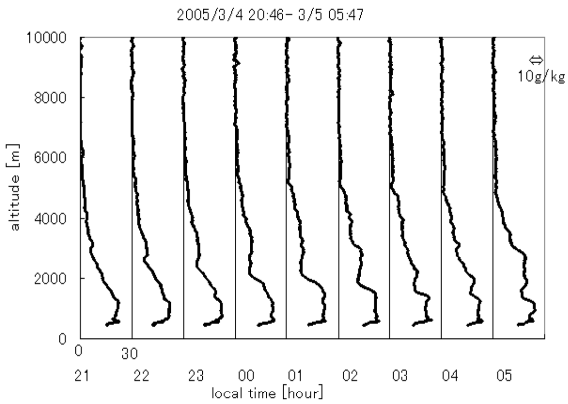

Fig.3 Time variation of water vapor mixing ratio

REFERENCE

1.Bucholtz A., Rayleigh-scattering calculations for the terrestrial atmosphere, *Appl. Opt*., 34, 2765-2773, 1995.

2.Ansmann A., Riebesell M., and Weitkamp C., Measurement of atmospheric aerosol extinction profiles with a Raman lidar, *Opt. Lett*., 15, 746-748, 1990.

3.Whiteman D. N., Melfi S. H., and Ferrare R.A., Raman lidar system for the measurement of water vapor and aerosols in the Earth's atmosphere, *Appl. Opt.* 31, 3068-3082, 1992.