OBSERVATIONS OF THE LOWER-TROPOSPHERIC TEMPERATURE PROFILES USING THREE WAVELENGTH CO_2-DIAL

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ABSTRACT

The eye-safe lower-tropospheric temperature profiler with three wavelength differential absorption lidar (DIAL) technique which can perform the continuous temperature profile observation through daytime and nighttime is conducted. The DIAL consists of a Nd:YAG laser pumped an OPG tuned around 1573 nm of an CO_2 absorption line with 2 mJ/pulse at 400 Hz repetition rate and a receiving telescope of 25cm diameter. In this paper, we show the result of continuous temperature profile observations over 25 hours from 0.39 to 2.5 km altitude in the lower-troposphere. We can see temporally the generation and disappearance of the temperature inversion layers in the planetary boundary layer.

1. INTRODUCTION

Continuous observations of the temperature profile of lower-troposphere are important for studies in the atmospheric science. The lidar is the most effective instruments for temperature profiling with high temporal and spatial resolutions. Different lidar techniques for measuring the atmospheric temperature profile have been developed, namely the rotational Raman lidar (RRL), the high-spectral resolution lidar (HSRL) technique and the DIAL[1]. In lower-troposphere observation, achievement of the high rejection rate for the Mie scattering signal is difficult for the RRL and the HSRL. In daytime observation, as the solar background noise is higher in UV and visible wavelength, high power laser is required.

The 1.6 μm CO2 absorption band has the reasonable absorption intensity for DIAL observations in the troposphere[2-4]. We added a third wavelength for temperature measurement to the conventional two-wavelength DIAL. In addition to λ_{on} (1572.992 nm) and λ_{off} (1573.137 nm), the third wavelength λ_T (1573.040 nm) for temperature measurement is adopted to the off-center absorption line. Temperature profiles by the DIAL technique can be obtained from the ratio of receiving signals λ_T and λ_{on}.

$$\frac{S_T(z)}{S_{on}(z)} = \frac{E_T}{E_{off}} exp\left\{-2\int_0^z n_{co2}(Z)\Delta\sigma dZ\right\} \quad (1)$$

$$\Delta\sigma = \sigma_{on}(T,z) - \sigma_T(T,z) \quad (2)$$

The atmospheric temperature $T(z)$ is calculated from the CO_2 density $n_{CO2}(z)$ which obtained from conventional DIAL technique and the differential absorption cross section $\Delta\sigma$.

2. TEMPERATURE OBSERVATIONS

This DIAL system is composed of an optical parametric generator (OPG) transmitter excited by a laser-diode pumped Nd:YAG laser. The partial power of λ_{on} and λ_T injection seeders were as split off and directed through wavelength-controlled units, respectively. Three injection seeders, which are DFB lasers, are connected to an optical fiber switch. The output seeder wavelength is switched for every shot in turn of λ_{on}, λ_{off} and λ_T. The atmospheric backscatters are collected by 25 cm diameter telescopes and bandwidth of the interference filter is 1 nm FWHM. The optical receiver includes a near-infrared PMT operating in the analog mode.

Atmospheric temperature observations were conducted from 0.39 to 2.5 km by the three wavelength DIAL in 21 - 22 April 2018 at the Hino campus of Tokyo Metropolitan University (35.7N, 139.4E). It was covered with high pressure during the observation period, it was fine and the wind was weak. Figure 1 shows temperature profiles with an integration time of 30 minutes. Temperatures between the ground and 0.39 km of the DIAL minimum altitude were interpolated. There is the stable boundary layer at 0.75 km altitude and the inflection point of the temperature gradient at an altitude of 1.5 km until 6:00 LT. The temperature on the ground is lower than 0.39 km altitude between 2:00LT and 6:00LT. The surface inversion layer is appearing in this time. After sunrise (5:00 LT), the surface temperature increased, and the inversion layers disappeared. After sunset (18:23 LT), an inversion layer was formed again at an altitude of 0.6 km. Typical diurnal variations of temperature profiles in fine weather were observed in detail.

3. DISCUSSION AND CONCLUTION

We have developed three wavelengths 1.6 μm DIAL system for measurements of the atmospheric temperature profiles with the CO_2 mixing ratio in the lower-troposphere. This DIAL conducted measurements of a diurnal variation of temperature profile on 21 - 22 April, 2018 from 0.39 to 2.5 km altitude. At an altitude of 1.5 km or less, the inflection point of the temperature gradient and the existence of a clear inversion layer were observed. Usually nocturnal surface inversion layer height is lower than 100 m, but observed inversion layer height is higher than this. This result will be explained following mechanism. Our observation site is located at the west edge of the Kanto plain. The north and west boundaries of the plain consist of high mountains while the other sides face the Pacific Ocean. Numerical results show cold air accumulation in the western parts of the plain[5]. The accumulated cold air generated a deep surface inversion layer.

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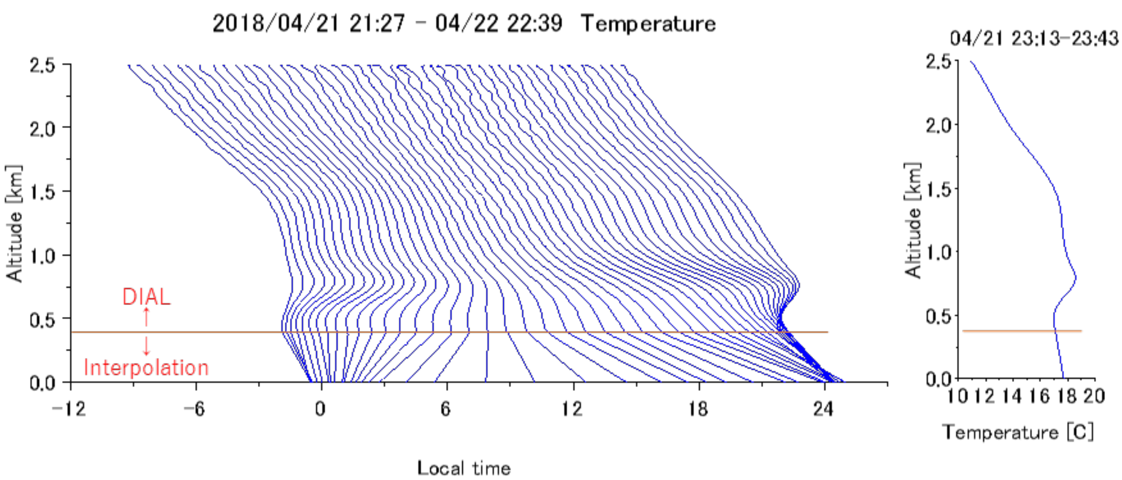

Figure 1 Atmospheric temperature profiles with an integration time of 30 minutes obtained from three wavelength CO_2 DIAL on 21-22 April 2018.