

DIURNAL VARIATIONS OF CO₂ MIXING RATIO IN THE LOWER ATMOSPHERE BY THREE WAVELENGTH DIAL

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ABSTRACT

We have conducted the measurement of high accurate CO₂ mixing ratio profiles by measuring the temperature profiles simultaneously using the three wavelength CO₂ DIAL. The measurements of CO₂ diurnal variation in the lower atmosphere were carried out on sunny and cloudy days respectively. We find out that increasing of the CO₂ mixing ratio occurs over the altitude of about 2 km from the surface during nighttime. On the other hand, the CO₂ mixing ratio decreases over the lower atmosphere during daytime. In particular, the CO₂ mixing ratio decreases earlier on sunny days than on cloudy days after sunrise. This result suggests that CO₂ absorption by photosynthesis greatly contributes to the strength of the solar radiation.

1. INTRODUCTION

Validating and improving the global atmospheric transport model requires precise measurement of the carbon dioxide (CO₂) profile. In particular, knowledge of CO₂ diurnal variation in the lower atmosphere is important for the elucidation of sinks and sources. We have developed a ground based direct detection three wavelength 1.6 μm DIAL to achieve measurements of vertical CO₂ concentration and temperature profiles in the atmosphere¹⁻³. In the DIAL observation, the temperature dependence of the CO₂ mixing ratio due to the temperature dependence of the absorption cross section is 1.6 ppm/K near the ground and the air density in the atmosphere. This means that the difference between the model and the actual temperature profile greatly influences the accuracy of the CO₂ mixing ratio. We carried out measurements of CO₂ diurnal variations on the sunny and cloudy day. In this paper, we report on the details of CO₂ diurnal variations and the differences in CO₂ profiles due to weather.

2. CO₂ DIURNAL VARIATIONS

The CO₂ DIAL consists of an optical parametric generator (OPG) transmitter that excited by the LD pumped Nd:YAG laser. The on-line DFB seed laser onto the line center (1572.992 nm) by the wavelength control unit including CO₂ reference cell. The off-line DFB seed laser (1573.137 nm) is operated by the free-run mode. The third DFB seed laser (1573.040 nm) for the temperature measurement is operated by the offset lock system. These seed lasers were connected to an optical fiber switch, and the switching speed is 2.5 ms. The atmospheric backscatters were collected by a 250 mm telescope and was connected into the near-infrared PMT module operated with an analog mode. We realized the CO₂ concentration measurement for daytime by using the narrowband interference filter with 1.0 nm FWHM.

Atmospheric CO₂ measurements were conducted from 0.39 to 2.5 km by the three wavelength DIAL at the Hino campus of Tokyo Metropolitan University (35.7N, 139.4E). Figure 1 shows the time-height cross section of the CO₂ mixing ratio with an integration time of 30 minutes. Japan was covered with high pressure during the observation period. It was fine and the wind was weak. A CO₂ gas sensor (LI-COR, LI-7500) was installed at the our lidar laboratory. CO₂ mixing ratio between the ground and 0.39 km altitude were interpolated. The sunrise was 5:00LT and the sunset was 18:23LT.

CO₂ mixing ratios increased from 22:00 LT on 21 April to 07:00 LT on 22 April at the altitude of 1.5 km or less. On the other hand, CO₂ mixing ratios decreased during daytime (especially in the afternoon). Furthermore, the increase or decrease in CO₂ mixing ratios occurs earlier in the lower layer than in the upper layer. Diurnal variations are attributable primarily to the natural photosynthetic and respiration cycle of vegetation and soils and to anthropogenic sources in urban areas.

Figure 2 shows the time-height cross section of the CO₂ mixing ratio on 30 - 31 October, 2018. It was cloudy during DIAL measurement and the clouds were about 5 km altitude and the wind was weak. The sunrise was 6:01LT. After 10:00LT, background level increased and we could not continue the DIAL measurement. As in the case of Fig. 1, the CO₂ mixing ratio at night time increased to an altitude of 1.5 km, and the value was 410 ppm or more. However, even after 2 hours from sunrise, the decrease in CO₂ mixing ratio as shown in Fig. 1 was not measured. We consider that the weaker photosynthetic activity on cloudy days compared to sunny days is due to the difference in the decrease of the CO₂ mixing ratio after sunrise.

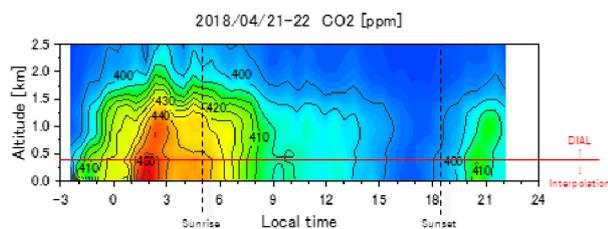


Figure 1 Time-height cross section of the CO₂ mixing ratio on 21-22 April 2018 with an integration time of 30 minutes. Between the ground and the altitude of 390 m, it is interpolated by the measurement of the ground CO₂ sensor (LI-7500) and the DIAL measurement.

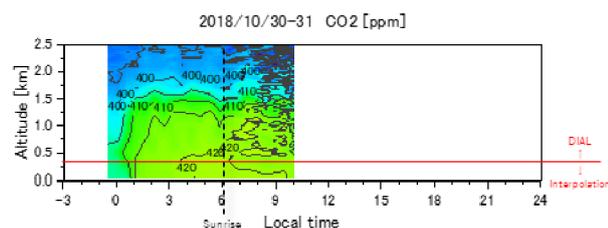


Figure 2 Time-height cross section of the CO₂ mixing ratio on 30 - 31 April 2018.

3. CONCLUSION

We have developed the three wavelengths 1.6 μm DIAL system for measurements of the CO₂ mixing ratio and the atmospheric temperature profiles in the troposphere. The CO₂ DIAL conducted measurements of a diurnal variation of CO₂ mixing ratio and temperature profile on 21-22 April 2018 and 30-31 October 2018 from 0.39 to 2.5 km altitude. We can see that the increasing of CO₂ mixing ratios occurs over the altitude of about 2 km from surface during nighttime. On a sunny day (April), the CO₂ mixing ratio decreased significantly for two hours after sunrise. On the other hand, on a cloudy day (October), the CO₂ mixing ratio did not decrease significantly even after two hours from sunrise. However, we could not continue the measurement except for four hours after sunrise due to the deterioration of the signal-to-noise ratio of increase of background radiation arising from clouds over the lidar site, so we could not know the behavior of the CO₂ mixing ratio over the entire daytime. Diurnal variations are attributable to the natural photosynthetic and respiration cycle of vegetation and soils and to anthropogenic sources in urban areas. However, we found out that CO₂ mixing ratio in the lower atmosphere attributes primarily to the photosynthesis of plants under the environment around our lidar site.

ACKNOWLEDGEMENTS

This work was financially supported by the System Development Program for Advanced Measurement and Analysis of the Japan Science and Technology Agency.

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