HIGHLY ACCUMULATED CO₂ AND COLD-AIR DRAINAGE WITHIN A SUBURBAN CANOPY LAYER IN WINTER NIGHT

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In this study we focused on highly accumulated carbon dioxide (hereafter CO₂) within a suburban canopy under nocturnal stably stratified conditions. The results were derived from the wintertime field measurements of the vertical profiles of CO₂, air temperature, and turbulent flows, which were conducted in a residential area (the mean height of canopy is 7.3 m) of Tokyo, Japan.

In the daytime especially under very windy condition, CO₂ concentration measured at a reference height (29-m height a.g.l.) is almost same level with background CO₂ concentration (=380 ppmv), while in the nighttime the CO₂ concentration increased. The increase of CO₂ concentration was significantly associated with the stably stratified condition. We therefore examined the ensemble mean vertical profile of CO₂ concentration using bulk Richardson number (Rb) as a stability index.

Under stably stratified conditions (Rb > 5), the CO₂ concentration above the canopy decreased with height (the difference within and above the canopy reaches 40 ppmv). On the contrary, the CO₂ concentration within the canopy kept almost same level, which indicates that the CO₂ emitted from the houses accumulated within the canopy. This was also visible in the snap-shot of height-temporal contour map of CO₂ concentration. Such behavior was not found in H₂O profile. The vertical profile of air temperature and additional observations on the surface temperature using a thermal infrared camera suggested that the cold air generated at roof level moved down to the ground level, causing the minimum of air temperature to occur at ground surface level. The effect of ‘cold air subsidence’ within the canopy is the most plausible reason for the dynamical behavior of scalars. The cold air generated at the roof-top takes down the high CO₂ emitted from ventilation fan towards the ground level. For the case of H₂O, there is no significant source of H₂O within the canopy except for the soils in the backyard. Therefore, the subsidence flow from the roof level takes the less humid air down to the ground and decreases the H₂O concentration within the canopy except the region closest to the ground.

Under unstable conditions (Rn < -1), the CO₂ concentration for the unstable case during daytime is almost homogeneous within and above the canopy, although the CO₂ flux was upward even in the daytime. The locations of the ventilating fans are usually in the middle or upper part of the canopy. Therefore, the emitted CO₂ from the houses were easily dispersed by larger turbulent mixing. The shape of the H₂O profile for the unstable case was quite different from that of CO₂. The H₂O concentration was highest near the ground and there were differences within and above the canopy. This is probably because the emission of H₂O was located in the vicinity of the ground surface. The turbulent kinetic energy within the canopy is less than that above or in the upper part of the canopy, and thus the emitted H₂O near the ground would not be well-mixed.

The present results and discussion indicate that urban micro-climate models should include both the three-dimensional turbulent flow around the building and the source distributions to accurately describe the dynamical behavior and diffusion processes of the scalars within and above urban canopies.

Keywords: Highly accumulated carbon dioxide, Tower measurement, Scalar transfer, Cold-air subsidence, source and sink