Evaluation of forest CO_2 flux from sonde measurement in Borneo, Malaysia

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1. Abstract

To evaluate the CO_2 flux of a tropical forest in Borneo Island forest, we collected vertical CO_2 profiles over the forest by using a CO_2 sonde in 4-6 Aug 2015. We detected the differences in vertical CO_2 profiles between dawn and daytime, and at the coast and forest sites. Then we estimated the CO_2 fluxes (μmol m^{-2} s^{-1}) at dawn and daytime of the forest from the vertical CO_2 profiles.

The CO_2 flux of Borneo's forest was very large (16.5 and -37.7 at dawn and daytime). These evaluated values were consistent with fluxes measured by the eddy-covariance method in the same region. Thus, use of the CO_2 sonde to collect observations of vertical CO_2 profiles was considered to be an effective method to verify CO_2 absorption and emission in forest area.

2. Method

2.1 Site information (Figure 1(a))

The study sites had a widespread distribution of vegetation, relatively flat land, and a low population density. The sites (forest site and coast site) are located in northeastern part of Borneo Island, Malaysia.

2.2 Equipment (Figure 1(b))

The CO_2 sonde consists of a balloon, a cutter for cutting the rope, a parachute, CO_2 sensor, two 10 L aluminum bags filled with CO_2 standard gases (approximately 380 and 430 ppm), and a radiosonde. The CO_2 sonde measured alternately outside air and two CO_2 standard gases through the elevation ascent process (Figure 1(c)). The sonde was launched at a rising speed of 2–3 m s^{-1} to an altitude of 10 km.

In addition, location information (latitude, longitude, and altitude), air pressure, temperature, and relative humidity were measured by the radiosonde.

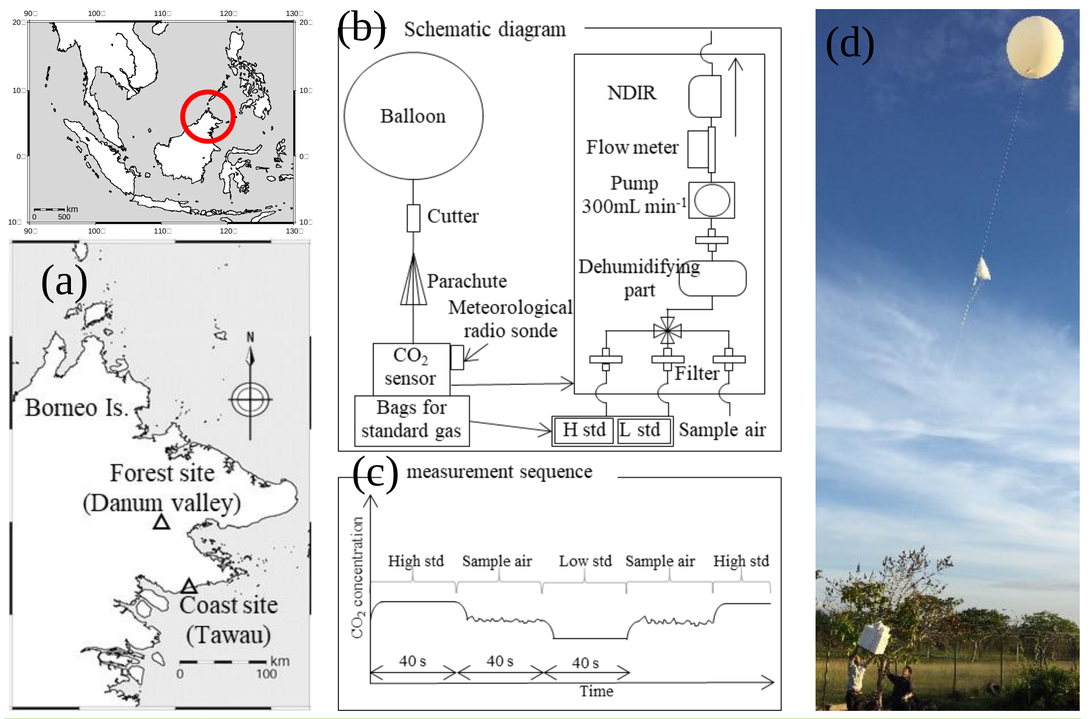

Figure 1 (a) Location of the sites, (b) Schematic diagram, (c) measurement sequence, and (d) the photo for launching CO_2 sonde

3. Results

3.1 Vertical CO_2 profiles (Figure 2)

At 07:00, CO_2 concentration inside the stably stratified planetary boundary layer (SBL) at both the coast site and the forest site on both 5 and 6 August showed a strong accumulation trend for CO_2 concentration near the ground.

At 14:00, CO_2 concentration inside the convective planetary boundary layer (CBL) at the forest site on both August 4 and 5 was about 6 ppm lower than the concentration above the CBL, which suggests that the tropical rain forest can absorb CO_2 very strongly during the daytime.

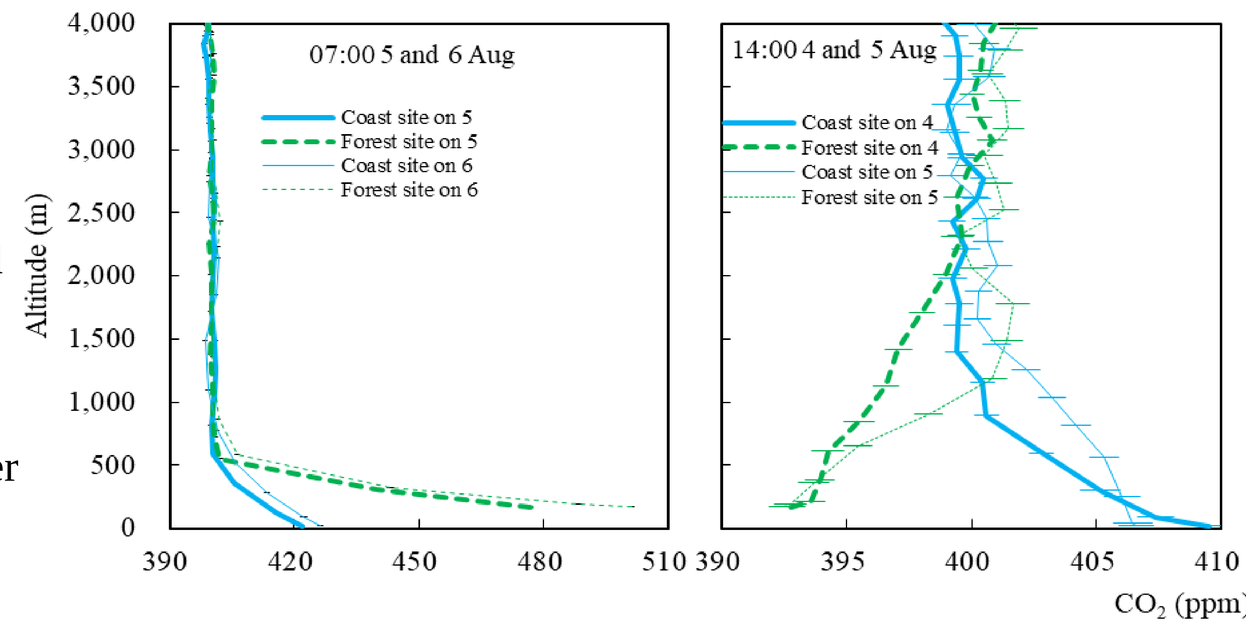

Figure 2 Vertical CO_2 profiles at 07:00 and 14:00 over the coast and forest site

3.2 Estimated CO_2 fluxes (Figure 3)

The CO_2 fluxes (μmol m^{-2} s^{-1}) in August, which were measured by the eddy-covariance method in the Amazon (Wu et al., 2016) and Pasoh in the Malay Peninsula (Kosugi et al., 2008) were compared with the forest site's CO_2 flux.

The CO_2 flux of forest site at 07:00 showed a value of 16.0 to 16.9 (ave: 16.5), and these data were within the values of CO_2 fluxes in the Amazon (ave: 5.5, min: -6.6, max: 22.9) and Malay Peninsula (ave: 4.9, min: -14.8, max: 28.1).

The values of forest site's CO_2 flux during the 14:00 (-37.7) were close to the minimum values of the CO_2 fluxes of the Amazon (ave: -13.5, min: -31.0, max: 1.3) and Malay Peninsula (ave: -17.6, min: -35.4, max: 0.2). As a result, the CO_2 flux of DMV's forest in this season is estimated to be almost the same or larger than the forest flux at the Amazon and Pasoh.

Therefore, it is apparent that the approximate value of the instant net CO_2 flux can be calculated by the differences in CO_2 concentrations obtained from measuring the vertical CO_2 profiles along a time course such as from dawn to daytime in the tropical forest.

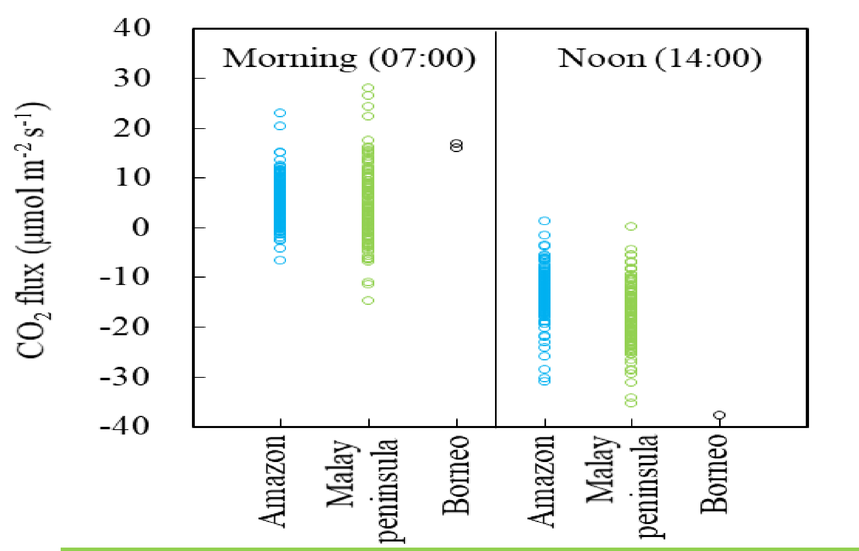

Figure 3 Comparison of the estimated CO_2 fluxes obtained in this study and in previous studies

3.3 Diurnal variations of CO_2 concentrations and wind direction (Figure 4)

CO_2 concentrations on 4–5 August at the coast site in the daytime were generally 6–10 ppm higher than the background level. Such a CO_2 built-up phenomenon at the surface level was also seen in the sonde experiment, as shown in Figure 2.

However, the CO_2 concentration on 6 August at the coast site in the daytime was similar to the background level because the oceanic air came from the ocean side. The forest site showed considerably lower concentrations on 4–6 August in daytime, thus suggesting that the tropical rain forest can strongly uptake CO_2 from the air. This concentration decrease (7–12 ppm) was almost the same as the level observed by the sonde experiment.

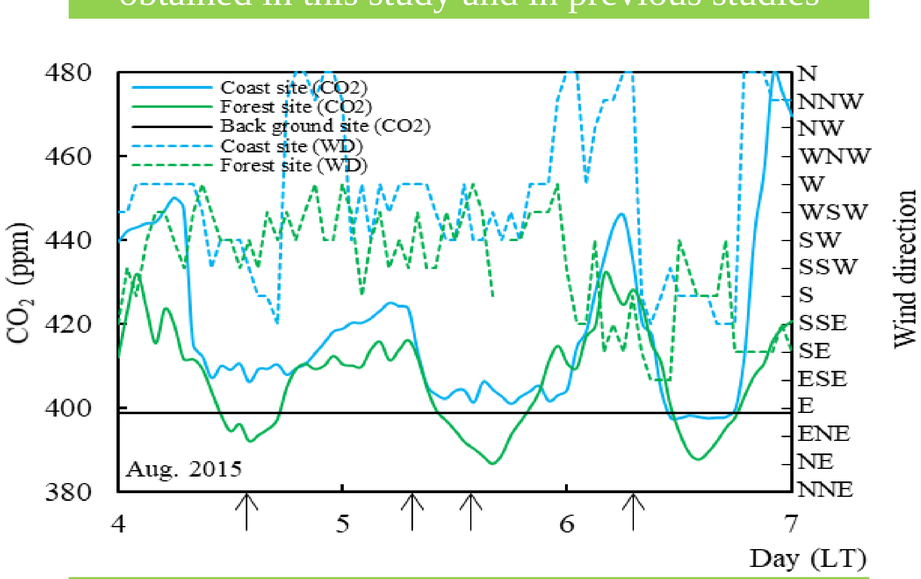

Figure 4 Diurnal variations of CO2 concentrations and wind direction at the coast site and forest site