DIURNAL CHANGES IN CO_2 EXCHANGE OF A TROPICAL RAIN FOREST IN PENINSULAR MALAYSIA

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ABSTRACT

Understanding the energy/H_2O/CO_2 exchange processes is very important for evaluating the roles of tropical rain forest in climate change. The sensible heat, latent heat, and CO_2 fluxes above a tropical rain forest in Peninsular Malaysia were measured using the eddy covariance method for the year 2003. The diurnal patterns of energy, H_2O and CO_2 flux were investigated using a multi-layer model that considered patchy stomatal closure. Both bimodal and homogeneous stomatal opening distributions were simulated, and the results indicated that the observed negative relationship between CO_2 absorption under light-saturated conditions and vapor pressure deficit were not sufficiently explained by stomatal closure alone, for homogeneous stomatal opening distributions. For bimodal stomatal opening distributions, however, a greater depression in canopy photosynthesis was found with increased atmospheric vapor pressure deficit. These results strongly suggested that the depression in canopy photosynthesis was caused not only by stomatal closure limitation but also by the patchy (bimodal) stomatal behavior response to the increased atmospheric vapor pressure deficit. Thus, the midday depression in canopy photosynthesis was mainly caused by patchy (bimodal) stomatal closure.

INTRODUCTION

The diurnal changes in forest CO_2 exchange are mainly caused by changes in the light environment, but the midday depression in canopy photosynthesis suggests that factors other than light-dependency affect the carbon gain of a forest. Some researchers have attributed the midday depression in canopy photosynthesis to high evaporative demand, i.e., stomatal limitation. However, both qualitative and quantitative evaluations of stomatal limitation are needed, because not only stomatal closure reduces intercellular CO_2 concentrations; patchy stomatal closure also causes an apparent depression in photosynthetic capacity. An evaluation of the effects of patchiness in a single leaf on the gas-exchange characteristics of a whole forest is needed to accurately understand carbon sequestration at the forest level.

METHODS

A multi-layer model for CO_2 and H_2O exchange in a C_3 plant community was used to apply the findings from the leaf scale to the forest scale. This multi-layer model computes above canopy fluxes based on detailed processes characterized by the canopy structure and the biochemical processes, considering patchy stomatal behavior.

Observations were conducted at the Pasoh Forest Reserve near Simpang Pertang in Negeri Sembilan, about 140 km southeast of Kuala Lumpur, Peninsular Malaysia (2°58' N, 102°18' E). The core area (600 ha) of the reserve is a primary lowland mixed dipterocarp forest, consisting of various species of Shorea and Dipterocarpus. The continuous canopy height is approximately 35 m, although some emergent trees exceed 45 m.

Fluxes of sensible heat, water vapor and carbon dioxide were measured at a height of 54 m on an observation tower. Wind velocity and temperature were observed with a three-axis sonic anemometer (SAT-550, Kaijo). Carbon dioxide concentration was monitored with an open path CO_2/H_2O analyzer (LI-7500, Li-Cor Inc.). Data from the year 2003 were analyzed. The mean diurnal change in CO_2 storage was estimated from the vertical profile of CO_2 concentration data (Ohkubo et al.., unpublished, 2005) with a closed path CO_2/H_2O analyzer (LI-7000, Li-Cor Inc.). The measurement heights were 53, 45, 30, 20, 10, 5, 2, 1, 0.5 and 0.2 m. The measurements were made from 8-14 September and from 2-30 October 2004. The micrometeorological variables monitored at the top of the observation tower and incorporated into the model included downward and upward ranges of short-wave radiation (MR22, Eko), ranges of long-wave radiation (PIR, Eppley), ranges of PAR (LI-190SA, Li-Cor Inc.), air temperature, humidity (HMP45A, Visala), wind velocity (AC750, Makino) and rainfall.

RESULTS & DISCUSSION

Both bimodal and homogeneous stomatal opening distributions were simulated (Fig. 1). The simulations indicated that if stomata were homogeneously distributed, the negative relationship between CO_2 absorption under light-saturated conditions and vapor pressure deficit was not sufficiently explained by stomatal closure alone. However, when stomata were bimodally distributed, a greater depression in canopy photosynthesis was found with increased atmospheric vapor pressure deficit. These results strongly suggest that the depression in canopy photosynthesis is affected by both stomatal closure limitation and patchy (bimodal) stomatal behavior in response to increased atmospheric vapor pressure deficit. The diurnal changes in CO_2 flux accumulated until each layer indicated the afternoon depression in canopy photosynthesis, which was almost completely explained by the assimilation depression of leaves found >30 m above ground that was caused by bimodal stomatal closure, although the assimilation of lower leaves was not limited by bimodal stomatal closure. We conclude that the diurnal change in NEE at the Pasoh Forest Reserve could be accurately explained with the modified multi-layer model by considering patchy stomatal closure. Thus, the midday depression in canopy photosynthesis was mainly caused by patchy (bimodal) stomatal closure.

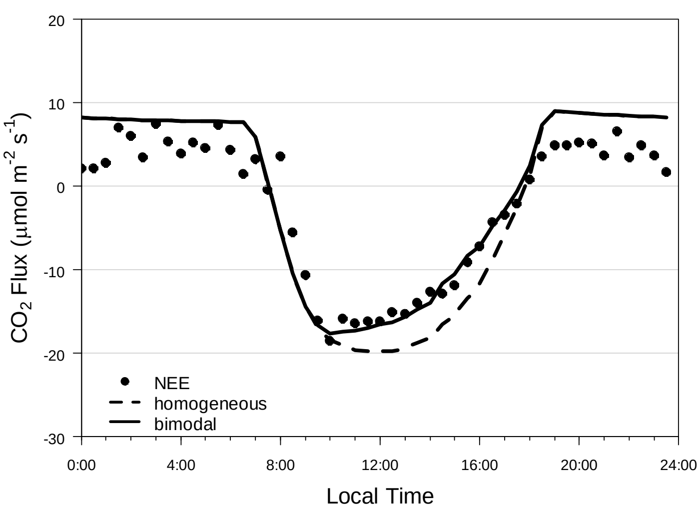

Fig. 1. Comparisons of the mean diurnal changes in the observed NEE and simulated CO_2 flux. Both homogeneous and bimodal stomatal opening distributions were simulated.