P4.5. CO_2 CONCENTRATION AND FLUX IN A CALIFORNIA'S OAK/GRASS SAVANNA

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1. INTRODUTION

The measurement of CO_2 concentration is important in estimating canopy carbon storage term associated with partitioning diurnal net ecosystem carbon exchange (NEE) between the atmosphere and the canopy applying eddy-covariance technique (Yang et al. 1999).

The objectives of this study is to (1) understand the features of CO_2 concentration within the canopy, including diurnal and seasonal patterns and levels, (2) compare two methods used in estimating canopy carbon storage terms – 4-height CO_2 profile measurement and 2-point eddy-covariance tower measurements, and (3) examine the influences of temperature, soil moisture, and wind speed and direction, and soil moisture on diurnal patterns of CO_2 concentration, canopy storage term, and NEE.

2. Materials and methods

2.1 *Study site*

The study was conducted in an oak/grass savanna ecosystem in the foothills of the Sierra Nevada in California, USA, located at 38.433°N, 120.967°W with elevation 177 m. The oak savanna has typical Mediterrenean climate type with significant wet and dry periods in the whole year (Figure 2). Most of precipitation falls between November to next April while few precipitation occurs during May to October. Mean annual air temperature and precipitation, determined over 30 years at nearby weather stations (Camp Pardee, california), are 16.3°C and 543.7 mm, respectively.

Overstory tree species of the ecosystem mostly consists of scattered oak trees (*Quercus douglasii*), which covers about 40% of the landscape within a kilometer of the flux tower (Kim et al. in press). The mean height of the oak stand is 7.1 m. Its mode is 8.6 m and the maximum height is 13.0 m (Kiang 2002). The understory grass is dominated by cool-season C_3 annual species. More than 95% of species are represented by *Brachypodium distachyon* L., *Hypochaeris glabra* L., *Trifolium dubium* Sibth., *Trifolium hirtum* All., *Dichelostemma volubile* A., and *Erodium botrys* Cav. The growing season for understory grass was limited in the wet season, normally from early Nov to late May. Maximum LAI during the peak growth period was only 1.1.

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The soil at the site is classified as the Auburn-Exchequer association (Soil Survey of Amador Area, California, 1965, USDA, Soil Conservation Service). The soil of the oak-grass savanna is an Auburn very rocky silt loam (Lithic haploxerepts). The soil profile is about 0.75 m deep, and overlays fractured rock. Soil texture was analyzed at Division of Agriculture and Natural Resources (DANR) Analytical Soils Laboratory, University of California-Davis. More detail site information has been given previously (Baldocchi et al. 2003; Xu and Baldocchi 2003; Xu and Baldocchi 2004).

2.2 *Data Collection*

We measured ambient CO_2 concentration profile using a low cost infrered CO_2 Analyzer (IRGA, LI-800 GasHound, Li-cor Inc., Lincoln, Nebraska, USA) at the height of 0.35, 1.8, 6.0, and 23.5 m. The system was controlled by a data-logger (CR10, Campbell Scientific, Inc., Logan, Utah, USA). For each height, 20 samples were acquired at 4 Hz within 5 s. The sampling process was repeated 16 times during each half hour period. Every half-hour average and standard deviation were recorded. A zeroing and spanning calibration sequence is performed at each day 09:00hr and 15:00hr PST.

CO_2 concentration was also measured with LI-7500 Open Path CO_2/H_2O Gas Analyzer, which was a part of eddy covariance (EC) systems. We had two eddy-covariance towers in this study site – overstory tower and understory tower. The overstory system was supported 23 m above the ground on a walk-up scaffold tower, and the understory system was mounted about 2 m above the ground on a tripod tower. The two towers consisted of a 3-D sonic anemometer (Model 1352, Gill Instruments Ltd, Lymington, England) and an open-path and fast response infrared gas analyzer (Li-7500, Li-Cor Inc., Lincoln, Nebraska, USA). The anemometer and the IRGA provide digital output of the fluctuations in wind speed in three directions (w, u, v), sonic temperature, water vapor, and CO_2 density. The raw data from each 30-min period were recorded at the rate of 10 Hz into separate files on a laptop computer.

The IRGA was swapped out every month with a newly calibrated one. The CO_2 signal of the IRGA was calibrated against gas mixtures in air that were referenced to standards prepared by NOAA's Climate Monitoring & Diagnostics Laboratory (NOAA/CMDL). The span for the water vapor was calibrated with a dew point generator (model Li-610, Li-Cor Inc, Lincoln, Nebraska, USA). Zeros for both CO_2 and water vapor channels were calibrated with 99.99% nitrogen gas. Calibration results showed that the cumulative deviations for zero drift and span change for both CO_2 and water vapor channels over a period of one full year were less than 3% and 1%, respectively. Thus, shifts of zero and span over a month period can be considered as insignificant.

Along with the flux measurements with the eddy covariance technique, standard meteorological and soil parameters were also measured continuously with an array of sensors. Precipitation was measured with a tipping-bucket rain gauge (Texas Electronics, Texas). Air temperature and relative humidity were measured with a shielded and aspirated sensor (HMP-35 A, Vaisala, Helsinki, Finland). Soil temperature at the depths of 0.04 m were measured with four multiple-level thermocouple sensors. Soil volumetric water content was measured with frequency domain reflectometer probe (ML2x, Delta-T Devices, Burwell, Cambridge U.K.) at depths of 0.05, 0.10 and 0.20 m. All channels from meteorological and soil sensors were scanned every 5 s with data-loggers (CR10X or CR23X, Campbell Scientific Inc., Logan, UT, USA), and then 30-min mean data were stored. The 30-min mean data were also retrieved by the laptop computer used for the eddy covariance measurement. The two eddy flux systems were powered by eight 12 VDC deep cycle batteries that were charged by eight solar panels (Model SP75, Siemens) in wintertime and six panels in the rest time of the year.

2.3 *Data Analysis*

Standard micrometeorological software was used to compute carbon flux covariances from the raw data. Computations included spike removal, coordinate rotation and application of standard gas laws. For more detail information on data processing, readers are referred to Baldocchi et al. (1988) and Baldocchi (2003).

For long-term and continuous measurements, data gaps due to missing observations and rejected after quality control are unavoidable and must be filled to obtain the information on the annual sum of the carbon flux data for the ecosystem. We used the following approaches to fill gaps or to replace rejected data points. For small gaps (less than an hour), simple interpolation method was used. Larger blocks of missing data during the growing season were filled by using mean diurnal variations (Falge et al. 2001).

Canopy CO_2 storage ($F_{storage}$) was computed based on the CO_2 concentration from open path IRGAs of overstory and understory EC system.

$$F_{storage} = \hat{\rho} \sum \frac{\Delta c}{\Delta t} \Delta z \qquad (1)$$

where $\hat{\rho}$ is air molar density, mol m^{-3}; Δc is the difference of CO_2 concentration between overstory and understory IRGAs over a Δt period (i.e., 1800 s) at the measurement height z; Δz is half the height difference between the above and below.

3. Results and Discussions

CO_2 concentration showed significant diurnal pattern, and the diurnal variation was changeable in seasons.

Annual mean CO_2 concentration was 402.4±16.3, 397.8±13.3, 393.4±10.7, and 388.8±9.0 ppm at the height 0.35, 1.8, 6.0, and 23.5 m, respectively.

Daily mean and maximum of CO_2 concentration appeared to be exponentially related to the height (R^2 = 0.99), while daily minimum of CO_2 was stable around 378 ppm at all height in a course of year.

Comparing with canopy carbon storage term estimated with the 4-layer profile data, carbon storage term was overestimated 31% if only the 2-point CO_2 concentration was applied.

We also examined the influences of temperature, wind speed and direction, and soil moisture on diurnal patterns of CO_2 concentration, canopy storage term, and NEE.

The results suggested that canopy storage term was a considerable source of uncertainty in partitioning NEE. Our study provided a basic understanding on the relationships between atmospheric CO_2 concentration and NEE in an individual site and will be useful in modeling regional CO_2 concentration and NEE.

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