6.7 EDDY COVARIANCE AND CHAMBER MEASUREMENTS OF CARBON DIOXIDE FLUXES FROM THE FOREST FLOOR OF A CLOSED-CANOPY DOUGLAS-FIR FOREST

Gordon Drewitt[a*], E. R. Humphreys[a], T. A. Black[a], G. Ethier[b], and Z. Nesic[a], K. Morgenstern[a], M. Novak[a]
[a] University of British Columbia, Vancouver, BC, Canada. [b] University of Victoria, Victoria, BC, Canada

1. INTRODUCTION

Soils play a major role in the carbon cycle of forest ecosystems (e.g. Raich and Schlesinger, 1992). Inputs into the soil carbon pool include litterfall and transport through roots while the most important removal mechanism is respiration by roots and microorganisms. In order to gain a better understanding of carbon turnover and storage in an ecosystem, it is crucial to examine the relative importance of soils and their role in short and long term carbon sequestration.

This study compares the results of two different methods of measuring CO_2 exchange from the forest floor of a 54 y-old (in 2000) Douglas-fir stand that is part of the Ameriflux network. An automated soil chamber system was run continuously at the site over a period of 8 months from early spring to late fall of 2000. In September and October of the same year, CO_2 flux was measured by eddy covariance (EC) above the forest floor. These independent measurements provide a means of examining the spatial and temporal variability of CO_2 flux from the forest floor and allow us to take advantage of the merits of both methods. Comparing these below-canopy measurements with the continuous, above-canopy EC fluxes provides insight into the relative importance of the forest floor contribution to the total ecosystem respiration at this site.

2. METHODS

The study site was located on the east coast of Vancouver Island, B.C., Canada (49°52'N, 125°20'W) at an elevation of 300 m on a 5 to 10° NE-facing aspect. The stand was quite dense (1150 trees ha^{-1}, mean DBH = 29 cm) and had an average height during this study of approximately 33 m. The one-sided leaf area index was 6.7 m^2 m^{-2} with most of the branches concentrated in the upper canopy layers. The forest understory vegetation was very sparse (LAI = 0.5 m^2 m^{-2}) with the main species being Oregon grape (*Berberis Nervosa*), salal (*Gaultheria shallon*) and Vanilla-leaf deer foot (*Achlys triphylla*). The forest floor was covered by a 1 to 5 cm thick mat of moss and large amounts of coarse woody debris. The soil was a humo-ferric podzol with an LFH layer between 1 to 10 cm thick. The site is part of the Ameriflux Network and was set up in 1997 to measure all relevant climatological variables and turbulent fluxes of CO_2 as well as sensible and latent heat above the canopy.

In April 2000, an automated chamber system was installed to measure CO_2 fluxes directly from the forest floor (Drewitt et al., 2002). The chambers were fabricated from round Plexiglas forms 50 cm in diameter and each consisted of a collar, inserted in the upper 2-3 cm of the soil, to which was attached a hinged, cylindrical lid. An electric motor controlled by a 21X datalogger (Campbell Scientific Inc. (CSI), Logan UT, USA) and microprocessor system opened and closed the lid when required. Air inside the chambers was circulated through a closed loop manifold system and CO_2 concentration was measured with a LI-6262 infra red gas analyzer (LI-COR Inc, Lincoln, NE, USA). During a flux measurement, the chamber lid closed for five minutes and the rate of CO_2 increase inside the chamber headspace was measured and recorded. The rate of CO_2 increase was then used to calculate the flux of CO_2 from the soil enclosed by the chamber. A total of six chambers were operated continuously between April and December 2000. A calibration system, similar to the one described in Goulden and Crill (1997) was used to continuously monitor the performance of the chambers and evaluate the plumbing system for leaks and adsorption of CO_2.

In September and October 2000, an EC system was installed at a height of 2.5 meters above the forest floor to measure CO_2 and H_2O fluxes. The sonic anemometer was a CSAT-3 (CSI) and the gas analyzer used was a LI-6262 (LI-COR). The flow rate through the gas analyzer was maintained at 8 L min^{-1}. All signals were recorded at 20.83 Hz with a 16 bit A/D data acquisition system (Model DaqBook 200, Iotech, Cleveland, OH, USA). Net radiation below the canopy was estimated from a combination of below canopy solar radiation and canopy air temperature profile measurements (Black et al., 1991).

3. RESULTS AND DISCUSSION

CO_2 fluxes measured during the two month comparison study were variable between the six chambers. The lowest average flux from a chamber over the period was 4.6 ± 0.6 (S.D.) μmol m^{-2} s^{-1}, while the highest average flux from another chamber was 10.8 ± 2.0 μmol m^{-2} s^{-1}. The average flux measured over the two months from all six chambers was 7.3 ± 1.2 μmol m^{-2} s^{-1}. The chamber flux measurements revealed varying degrees of sensitivity to temperature and were usually most highly correlated with the 5-cm depth soil temperature. Moss photosynthesis inside the chambers was negligible in four of the six chambers and decreased daytime respiration fluxes only slightly in the other two chambers. Soil volumetric water content was generally found to have very little effect on chamber measurements of CO_2 fluxes during this study.

* *Corresponding author address*: G. B. Drewitt, Univ. of British Columbia, Faculty of Agricultural Sciences, 266B-2357 Main Mall, Vancouver, B.C., Canada, V6T 1Z4 email:gdrewitt@interchange.ubc.ca

Turbulence measurements 2.5 m above the forest floor were characterized by low wind velocities (average $\overline{u}$ = 0.28 ± 0.23 m s^{-1}), relatively low friction velocities (average u_* = 0.06 ± 0.04 m s^{-1}) and very high values of longitudinal turbulence intensity (average $\sigma_u/\overline{u}$ =1.23 ± 1.79). Above the canopy, a diurnal wind direction regime was commonly observed with upslope and downslope winds during the day and night, respectively. In contrast, below the forest canopy the winds were downslope during both day and night. Potential temperature profiles obtained below the forest canopy revealed generally stable conditions during the daytime and unstable or neutral conditions at night. Energy fluxes below the canopy were very low and showed poor energy budget closure (Fig. 1).

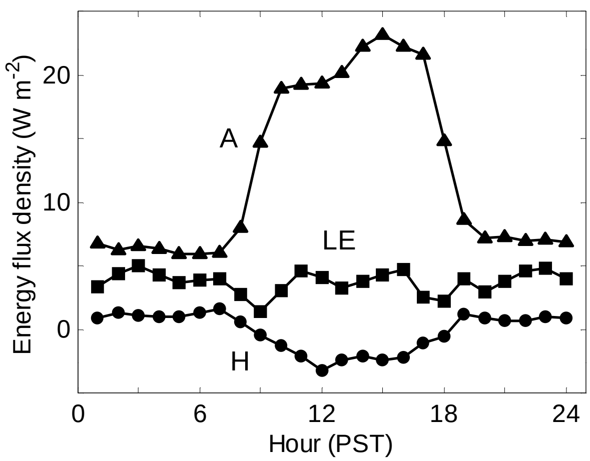

Figure 1. Average 24-hour course of energy flux densities 2.5 m above the forest floor between Aug 26 and Oct. 23, 2000: available energy, A, (net radiation – soil heat flux – biomass heat storage), latent heat, LE and sensible heat, H.

About 80 % of the below-canopy EC data were suspect because of the very low wind velocities resulting in horizontally inhomogeneous turbulence. Data cleaning procedures based on criteria of turbulent conditions resulted in the rejection of almost 90% of the below-canopy CO_2 flux measurements. The remaining half-hourly below-canopy EC CO_2 fluxes were quite variable and, unlike the chambers, showed only a weak relationship to temperature.

Comparison of CO_2 fluxes from EC and soil chambers show a large amount of scatter (Fig. 2). EC fluxes under nighttime, high wind speed conditions were about 60% of chamber fluxes. In contrast, other researchers have reported general agreement between the two methods (e.g. Janssens et al., 2001). Horizontal gradients of CO_2 measured above the forest floor at our site indicate that respired CO_2 from the soil may be escaping undetected by EC due to both horizontal and vertical advection.

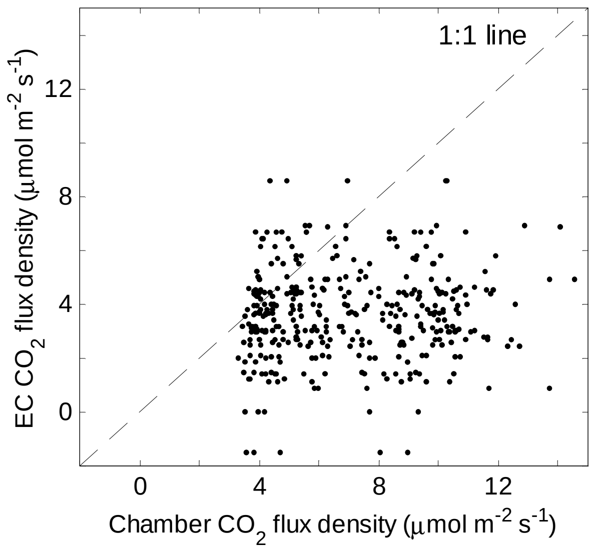

Figure 2. Chamber and eddy covariance measurements of CO_2 flux selected from nighttime high wind velocity conditions (> 0.25 m s^{-1}) between Sept–Oct, 2000.

5. SUMMARY AND CONCLUSIONS

1) Forest floor CO_2 fluxes measured by chambers at this second growth Douglas-fir stand are high and dominate ecosystem respiration.
2) The magnitude of CO_2 fluxes measured by EC are approximately 60% of those obtained from chamber measurements.
3) The closed, dense canopy of this particular stand and sloping terrain result in questionable eddy covariance measurements of fluxes and suggest the presence of significant horizontal and vertical advective fluxes.

4. REFERENCES

Black, T. A., J.-M. Chen, X. Lee, R. M. Sagar, 1991: Characteristics of shortwave and longwave irradiances under a Douglas-fir forest stand. Can. J. For. Res. 21:1021-1028.

Drewitt, G.B., T. A. Black, Z. Nesic, E.R. Humphreys, E.M. Jork, R. Swanson, G. J. Ethier, T. Griffis, K. Morgenstern, 2002: Measuring forest floor CO_2 fluxes in a Douglas-fir forest. Agricultural and Forest Meteorology (in press).

Goulden, M. L., P. M. Crill, 1997: Automated measurements of CO_2 exchange at the moss surface of a black Spruce forest, Tree physiology, 17:537-542.

Janssens, I. A, A. S. Kowalski, R. Ceulemans, 2001: Forest floor CO_2 fluxes estimated by eddy covariance and chamber-based model. Agricultural and Forest Meteorology 106: 61-69.

Raich, J. W., W. H. Schlesinger, 1992: The global carbon dioxide flux in soil respiration and its relationship to vegetation and climate. Tellus 44B: 81-99.