P1.13 CARBON AND ENERGY EXCHANGES AT THREE BOREAL FOREST SITES IN BERMS STUDY REGION IN 2000 AND 2001

J.H. McCaughey[1]*, A.G. Barr[2], T.A. Black[3], Z. Nesic[3], K. Morgenstern[3], T. Griffis[3], and D. Gaumont-Guay[3]
[1]Queen's University, Kingston, Ontario, [2]Meteorological Service of Canada, Saskatoon, Saskatchewan, [3]University of British Columbia, Vancouver, British Columbia

1. INTRODUCTION

The Boreal Ecosystem Research and Monitoring Sites (BERMS) program sites are located in central Saskatchewan and were formerly part of the BOREAS Southern Study Area (Sellers et al., 1997). The southern old aspen (SOA) site (53.7°N, 106° W) has an overstory of aspen (*Populus tremuloides, Michx*), average height 20 m, and an understory of mainly hazelnut (*Corylus cornuta, Marsh*), 2 m tall. The forest is about 70 years old with a stem density of 980 stems ha^{-1} and diameter at breast height (dbh) of 17 cm. At the southern old jack pine (SOJP) site, the dominant species is jack pine (*Pinus banksiana Lamb*). Understory consists of clumps of green alder (*Alnus crispa (Ait.) Pursh*) and a lichen surface carpet (*Cladina sp*). The trees are 65-70 years old, 13 m tall, with a stand density of 1190 stems ha^{-1} and a dbh of 12.9 cm . At the southern old black spruce (SOBS) site the dominant species is black spruce (*Picea mariana (Mill.) B.S.P.)*, up to 11 m high, with 10% tamarack (*Larix laricina (Du Roi) K. Kock)*, 10-16 m high, and occasional jack pine, 13 m high. The stand density is 5900 stems ha^{-1} with a dbh 7.1 cm, and the canopy is approximately 115 years old.

In this paper, we compare the sites in terms of their carbon sequestration rates, and we demonstrate the importance of phenology and springtime conditions as controls of carbon fluxes.

2. METHODS

Measurements of half-hour average CO_2, water vapour and energy (CWE) fluxes are continuously made using an automated eddy covariance (EC) system. An identical setup is used at the three sites to enhance comparability of flux values. Wind velocity and temperature fluctuations are measured with a 3-D sonic anemometer-thermometer (model R3, Gill Instruments, Lymington, UK at SOA and SOBS and model CSAT3, Campbell Scientific Inc., Logan, Utah, USA at SOJP). CO_2 and water vapor fluctuations are measured with a closed-path infrared gas analyzer (IRGA, model 6262, LI-COR Inc., Lincoln, NE, USA). The IRGA is located in a temperature-controlled enclosure and mounted on the flux tower. A heated tube, 4 m in length, is connected to the IRGA, which samples air from within 30 cm of the sonic anemometer. A diaphragm pump (model DOA-V191-AA, Gast Inc., Dayton, OH) draws the air through the IRGA at a flow rate of 10 L min^{-1}. The analogue EC signals are measured by a data acquisition system (model DAQBook /200, IOtech, Inc.) at a sampling rate of 125 Hz, digitally filtered and down-sampled at 21 Hz to a computer for on-line flux calculations. Each system is calibrated daily and operates continuously. The system is described in detail in Black et al. (2000). Continuous flux measurements at SOA started in 1996, April 20 1999 at SOBS and August 8 1999 at SOJP.

The flux tower at each site provides a platform for the EC system at its top, as well as an eight-level air-sampling system for measuring the CO_2 concentration profile. The latter provides the data to calculate the CO_2 storage in the air column beneath the EC sensors. Net ecosystem productivity (NEP) was calculated as – (F_c + $\Delta S_c/\Delta t$), where F_c is the EC flux of CO_2 above the canopy and $\Delta S_c/\Delta t$ is the change in CO_2 storage in the air column. Values of nighttime F_c missing or when $u_* <$ 0.35 m s^{-1} were replaced by values obtained from the relationship between F_c for $u_* >$ 0.35 m s^{-1} and soil temperature at the 2-cm depth at each site. These F_c values were also corrected for lack of energy balance closure (12%, 11% and 15% at SOA, SOBS and SOJP, respectively). The above relationships were also used to calculate hourly values of respiration (*R*) for the entire year. Daytime values of *R* were added to NEP to obtain hourly values of gross ecosystem photosynthesis (*P*).

The three sites have a complete and similar suite of climate measurements. The four components of the radiation balance are independently measured to determine the net radiation as the summation of the up- and downwelling shortwave and longwave components.

In-canopy air temperature and relative humidity are measured at four levels at SOA, three levels at SOBS and five levels at SOJP. These data are used to calculate stored sensible and latent energy in the trunk space. To calculate energy stored in the biomass at SOA and SOJP, two trees at each site have been selected for measurement of tree bole temperature with thermocouples at three levels; 2, 8 and 14 m. At SOA, thermocouples are placed at 2, 4 and 8 cm away from the outer bark of one tree towards the centre. Soil temperature is measured at 2, 5, 10, 50 and 100 cm with thermocouples using two replications at each site. The temperature change above the soil heat flux plates (the first 10 cm at SOBS and SOJP, and the first 3 cm at SOA) is used to calculate heat storage above the plates.

A profile of soil moisture sensors (model CS615, Campbell Scientific Inc., Logan, Utah) are installed in two locations at each site (6 levels down to 120 cm at SOA and SOBS and down to 150cm at SOJP).

3. RESULTS AND DISCUSSION

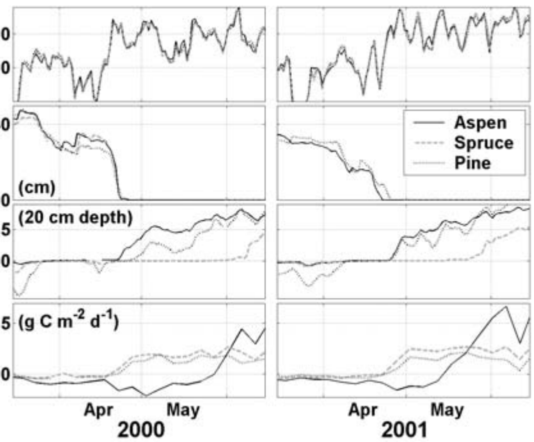
Figure 1 shows the annual cycles of NEP along with photosynthesis (P) and respiration (R) fluxes for the

*Corresponding author address: J. Harry McCaughey, Queen's University, Dept. of Geography, Kingston, Ontario, Canada K7L 3N6.
e-mail: mccaughe@post.queensu.ca

three sites. The annual totals of NEP for 2000 are 120, 28 and 72 g C m^{-2} for SOA, SOBS and SOJP, respectively. As expected, the aspen site shows the largest annual sequestration. Both conifer sites show a decrease in the NEP in July as a result of the peaking of the respiration loss and a relatively flat curve of photosynthesis. In the winter, the aspen system shows a stronger carbon efflux especially following thawing of the soil in the spring but before the flushing of the leaves, when a significant increase in the respiration loss is evident. This phenological control is absent for conifer sites which begin to photosynthesis as soon as the snow melts in the spring. Both SOBS and SOJP show a very rapid rise of photosynthesis at this time when the respiration loss from the cold soils is very small (see the pattern in April for both sites in Figure 1). A similar analysis is ongoing for 2001.

A more detailed view of the differences between the three sites in the spring is demonstrated in Figure 2. In the top panel, the air temperatures at the sites are quite similar and both years show the same behaviour, with temperatures negative or close to zero until mid- to late April followed by a rapid rise to about +10°C. The depth of snow shows no large differences between sites in either year. However, the melt rate is more rapid in 2000 as a result of the very sharp transition from sub-zero to positive values of air temperature in mid April. The soil temperature at 20 cm distinguishes the three sites very strongly. Jack pine and aspen thaw before black spruce, and in both years the increase in soil temperature following thaw at aspen is greater than at jack pine until flushing of the aspen canopy. This more rapid increase in soil temperature leads to the greater respiration loss at SOA (Figure 1) At SOBS the waterlogged soil at 20 cm remains frozen through May and then the temperature increases rapidly. At both conifer sites, the NEP traces in late April and May are positive and similar in shape with the pine values being slightly smaller as a result of soil respiration loss being larger from the warmer soil.

Figure 2. Conditions at the BERMS sites during the spring transition in 2000 and 2001



4. REFERENCES

Black, T.A., Chen, W.J., and A.G. Barr, et al., 2000: Increased caron sequestration by a boreal deciduous forest in years with a warm spring. *Geophys. Res. Lets.*, 27, 1271-1274.

Sellers, P.J., et al., 1997: BOREAS in 1997. *J. Geophys.Res.,*102, 28,731-28,769.

Figure 1. Annual variation of NEP, gross photosynthesis and respiration at the BERMS sites in 2000.