6.8 METEOROLOGICAL AND ECOPHYSIOLOGICAL CONTROLS ON THE CARBON BALANCES OF THREE OLD GROWTH BOREAL FORESTS

Timothy J. Griffis[1*], T. Andrew Black[1], Kai Morgenstern[1], Gordon B. Drewitt[1], David Gaumont-Guay[1], Elyn H. Humphreys[1], Allan G. Barr[2], Zoran Nesic[1], Edward H. Hogg[3], J. Harry McCaughey[4]

[1] University of British Columbia, Vancouver, British Columbia, Canada; [2] Climate Research Branch, Meteorological Service of Canada, Saskatoon, Saskatchewan, Canada; [3] Canadian Forest Service, Edmonton, Alberta, Canada; [4] Department of Geography, Queen's University, Kingston, Ontario, Canada

1. INTRODUCTION

Continuous measurements of annual carbon exchange in 2000 and 2001 were made at three southern old growth boreal forests using eddy covariance (EC) and chambers as part of the Boreal Ecosystem and Monitoring Sites (BERMS) program. The objectives of this research were to: 1) estimate respiration (*R*) using independent analyses of nighttime EC data and biotic chamber measurements; 2) examine the influence of synoptic meteorology and landscape heterogeneity on estimating *R* and photosynthesis (*P*), and 3) compare the ecophysiological characteristics and differences in *NEP* among these forest types.

2. METHODS

2.1 Study Sites

The three forest types included aspen (*Populus tremuloides*), black spruce (*Picea mariana*) and jack pine (*Pinus banksiana*). The study sites were established in 1993 as part of the Boreal Ecosystem-Atmosphere Study (BOREAS) and are defined as southern old aspen (SOA), southern old black spruce (SOBS), and southern old jack pine (SOJP) (Sellers et al., 1997). Each of the sites is located in northern Saskatchewan, Canada, and is subject to the same synoptic meteorological conditions. Flux measurements have continued since 1996 under the BERMS Program, an initiative of the Meteorological Service of Canada.

2.2 Eddy Flux Measurements

Wind velocity and temperature fluctuations were measured with a 3D sonic anemometer-thermometer (model R3, Gill Instruments, Lymington, UK at SOA and SOBS; model CSAT3, Campbell Scientific Inc., Utah, USA at SOJP) mounted above the forest on scaffold towers. CO_2 and water vapour fluctuations were measured with a closed-path infrared gas analyzer (IRGA, model 6262, LI-COR Inc., Lincoln, NE, USA). The IRGA was located in a temperature-controlled enclosure and mounted on the canopy tower within 3 m of the sonic anemometer. A heated tube, 4 m in length, was connected to the IRGA, which sampled air from within 30 cm of the sonic anemometer. A diaphragm pump pulled the air through the IRGA at a flow rate of 10 L min^{-1}. The analogue EC signals were 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 (see Chen et al., 1999 for a detailed description of the eddy covariance system and flux calculations). CO_2 fluxes were storage corrected using an 8-level CO_2 concentration profile system at SOA and SOBS. The CO_2 concentration measured at the height of the sonic anemometer was used for storage correction at SOJP.

2.3 Automated Soil Chamber Measurements

An automated non-steady state soil chamber system (6 chambers) was installed at SOA and SOBS during summer 2000. After lid closure, each chamber was sampled 5 times per minute over a 5-minute interval allowing one complete cycle of measurements to be made every thirty minutes. CO_2 concentration change in each chamber was detected using an IRGA. The chamber geometric volume was corrected for changes in temperature, pressure, small leaks, and adsorption of CO_2 to chamber walls, tubing, vegetation and litter. The effective volume was typically 25% larger than the geometric volume. Soil CO_2 efflux was computed from the change in CO_2 concentration within 1 minute of lid closure to reduce gradient suppression of the efflux.

3. RESULTS

3.1 Spatial Heterogeneity in EC Respiration

The largest EC *R* fluxes were observed for southwest winds. Warm summer air temperatures were associated with this synoptic flow. Fig. 1. illustrates the relatively large uncertainty associated with the parameter estimates of the annual *R* vs. soil temperature relationships for 4 different wind directions (NE, SE, SW, NW). For comparison, soil respiration measured using the chamber system, at SOA and SOBS is also plotted (open circles and dashed lines). The soil CO_2 efflux at SOA and SOBS was within the uncertainty of the EC estimates, but was relatively large in comparison.

* Corresponding author address: Timothy J. Griffis, Univ. of Minnesota, Dept. of Soil, Water & Climate, St. Paul, MN 55108; e-mail: tgriffis@soils.umn.edu

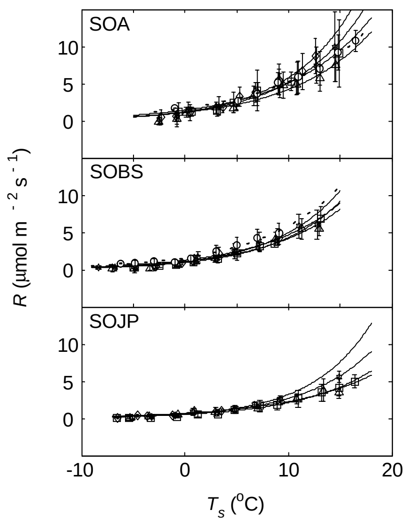

Fig. 1. Effect of wind direction on the relationship between *R* and soil temperature at 2 cm

3.2. Scaling Chamber Respiration

R was scaled up using chamber fluxes of soil respiration and published algorithms (Ryan et al., 1997; Lavigne et al., 1997) for autotrophic respiration. Scaled up annual *R* at SOA, SOBS and SOJP was 1850, 1615 and 770 g C m^{-2} y^{-1}, respectively (Fig. 2). The corresponding EC estimates of *R* were 36%, 44% and 23% less than the scaled up values. Given the large uncertainty in EC (long dashes) and chamber (short dashes) *R* estimates, the differences may not be significant.

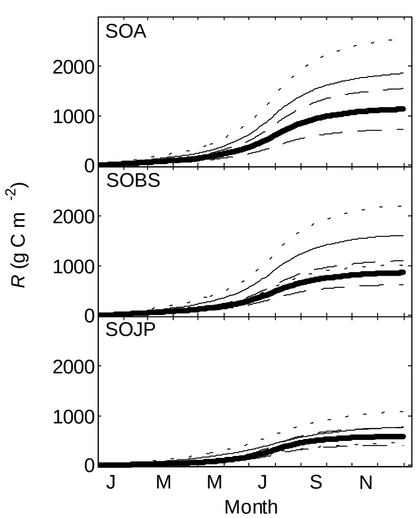

Fig. 2. Cumulative *R* estimated using biotic chambers (thin line) and EC (thick line)

3.3 Annual Carbon Balances

NEP totals for 2000 corrected for energy balance closure were 120, 28 and 72 g C m^{-2} y^{-1} for SOA, SOBS, and SOJP, respectively (Fig. 3). *NEP* was greater at SOA due to higher photosynthetic capacity. Photosynthesis was similar at SOBS and SOJP, but *R* was greater at SOBS resulting in lower *NEP*.

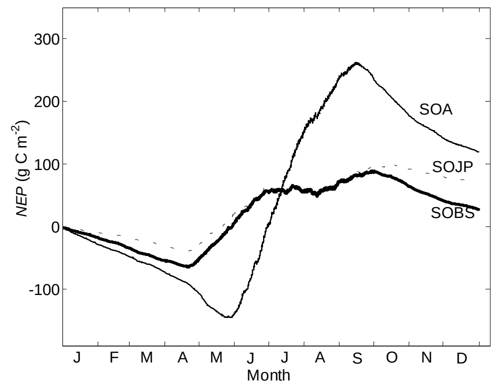

Fig. 3. Seasonal pattern of cumulative *NEP* in 2000

4. DISCUSSION AND CONCLUSIONS

Landscape heterogeneity did not have a significant effect on EC estimates of *R*. Southwest winds resulted in the largest *R* values due to warm air advection. Scaled up chamber *R* at each of the sites was greater than the EC estimates. CO_2 storage under weak turbulent conditions did not consistently account for the expected biotic flux indicating heterogeneity or circulation of stored canopy CO_2. Analysis of the mean vertical wind speed, following Lee (1998), suggested pronounced subsidence when net radiation was strongly negative. Subsidence and cold air drainage could be responsible for the lower EC *R* estimates.

5. REFERENCES

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