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SURFACE RENEWAL DETERMINATION OF SCALAR FLUXES OVER AN OLD-GROWTH FOREST

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1. INTRODUCTION

The surface renewal (SR) method for estimating fluxes from canopies involves high frequency measurements of scalar parameters. The high frequency data are analyzed for ramp-like characteristics and the amplitude and inverse ramp frequency are used in basic energy or mass conservation equations to estimate fluxes. In previous papers, good results were reported for estimating sensible (*H*) and latent heat (λE) flux density and CO_2 flux density (F_c) using an unfiltered, data set of 10 Hz wind speed, temperature and humidity data collected above a 65 m tall, old-growth coniferous forest at the Wind River crane site in Washington State. In this paper, we report on an extensive data set from the same site, where the data were filtered to remove data measured when the air came from a direction with inadequate fetch or through the crane.

2. MATERIALS AND METHODS

Data were collected above a 65 m tall, old-growth coniferous forest at the Wind River crane site in Washington State. High frequency (10 Hz) wind speed, temperature, humidity, and CO_2 fluctuations were recorded using a Gill 3-D sonic anemometer and Licor 6262 infrared gas analyzer mounted near the canopy top. Estimates of eddy covariance λE and F_c were corrected for density fluctuations (Webb et *al.*, 1980). Similar high frequency data were also used to determine *H*, λE, and F_c using the surface renewal method (Paw U et al., 1996; Snyder et al., 1996; Spano et al., 1997). The ramp amplitude (a) and inverse ramp frequency [$1/(d+s)$] were calculated during 30 minute sampling periods using a structure function (Van Atta, 1977) in simultaneous equations evaluated with four time lags (*r* = 2, 4, 5 and 6 s). The SR results were calibrated against EC values to determine a weighting factor (α) for uneven source and sink distribution within the canopy (Paw U et al., 1995).

3. RESULTS AND DISCUSSION

The energy balance closure from the eddy covariance system showed a discrepancy of about 17%, that is comparable to similar studies and is an evidence of the accuracy of the data set.

In Tables 1, 2 and 3, the calibration of SR values of the four time-lag calculations against EC measurements for *H*, λE and *Fc* are reported. In the case of *H*, the R^2 values were independent of time lags, with α close to 1 for r = 5 s. The R^2 values observed for λE and *Fc* are smaller than for *H* analysis. The best results were obtained for r = 2 s and r = 4 s. The bigger α factor values were for r = 5 s (λE) and r = 6 s (*Fc*).

Table 1. Regression statistics for H_{SR} vs. H_{EC}. Regressions were forced through the origin. The range of *H* was - 104 W m^{-2} to 568 W m^{-2}.

Time lag (s)	Weighting factor, α	R^2	N
2	0.39	0.73	606
4	0.40	0.73	588
5	0.94	0.72	603
6	0.61	0.73	599

Table 2. Regression statistics for λE_{SR} vs. λE_{EC}. Regressions were forced through the origin. The range of λE was - 78 W m^{-2} to 590 W m^{-2}.

Time lag (s)	Weighting factor, α	R^2	N
2	0.42	0.33	514
4	0.41	0.34	500
5	0.72	0.10	499
6	0.50	0.13	512

Table 3. Regression statistics for Fc_{SR} vs. Fc_{EC}. Regressions were forced through the origin. The range of *Fc* was - 25 μmol m^{-2} s^{-1} to 21 μmol m^{-2} s^{-1}.

Time lag (s)	Weighting factor, α	R^2	N
2	0.17	0.38	413
4	0.34	0.40	345
5	0.57	0.28	382
6	0.65	0.29	398

The comparison between EC and uncalibrated SR flux estimates indicates that the α factor might be different for daytime and nighttime fluxes. A plot of Fc_{EC} vs Fc_{SR} calculated using r=2 s and r=4 s for daytime periods are shown in Figures 1 and 2. When calibrated for daytime and nighttime, the slope and R^2 were

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improved, but the results were not as good as for *H*. For *Fc* the R^2 was about 0.59 with a RMSE = 4.3 μmol m^{-2} s^{-1}, which is about 10% of the *Fc* range (Figure 3). Results for *λE* are also improved by day and nighttime calibration (Figure 4).

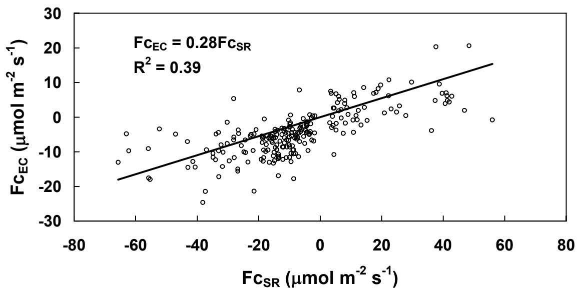

Figure 1. Uncalibrated half-hour Fc_{EC} vs. Fc_{SR} using the time lag r=2 s from data collected during May and June.

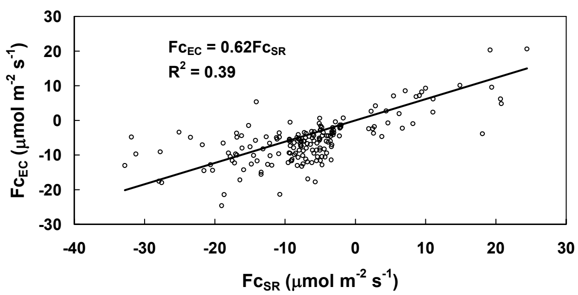

Figure 2. Uncalibrated half-hour Fc_{EC} vs. Fc_{SR} using the time lag r=4 s from data collected during May and June.

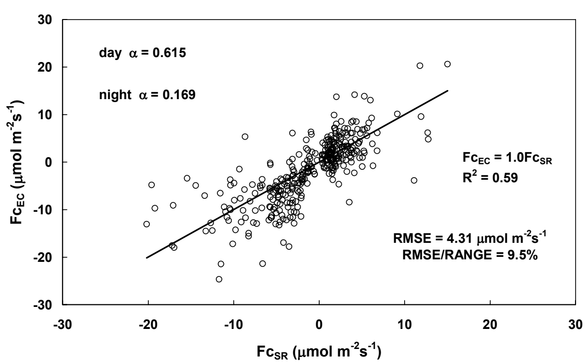

Figure 3. Half-hour Fc_{EC} vs. Fc_{SR} using the time lag r=4 s from data collected during May and June 1999and weighting factors for daytime and nighttime periods.

4. CONCLUSIONS

Based on these experiments, the SR method provides a simple, low-cost method to estimate scalar fluxes without the need to measure stability or wind speed. The SR method offers a possible alternative for estimating *H*, λ*E*, and F_c when the α weighting factor is known. Therefore, the SR method can be used to estimate scalar fluxes during periods with missing data or when more expensive equipment is unavailable. More work is needed to filter or smooth the EC estimates before calibrating the SR data. The SR methods offers a possible alternative for estimating H,, when the alpha weighting factor is known, although it exhibits larger errors for F_C and *λE* than *H*.

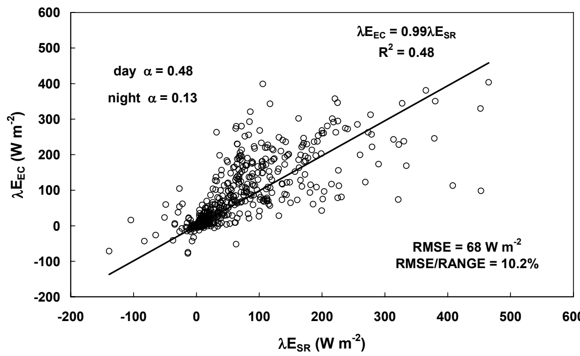

Figure 4. Half-hour λE_{EC} vs. λE_{SR} using the time lag r=4 s from data collected during May and June 1999. Data were corrected using daytime and nighttime α factors.

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