P1.22 A STUDY OF BLOCK AVERAGING VERSUS RECURSIVE FILTERS FOR COMPUTING SCALAR EDDY COVARIANCES NEAR THE SURFACE

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1. INTRODUCTION

The eddy covariance method is widely used for measuring the vertical flux densities of heat, mass, and momentum near the surface. In some studies (e.g., Twine et al. 2000), the sum of latent and sensible heat fluxes estimated by eddy covariance has been too small to close the surface energy balance, relative to the sum of the net radiation, soil heat flux, and heat storage terms measured independently. This discrepancy might be caused or augmented by the use in the covariance calculations of mean removal procedures that suppress low-frequency contributions to the fluxes. In this work, we compared flux estimates obtained with block averaging to flux estimates calculated with recursive filters applied with various effective time constants. A likely interpretation is that block averaging yields upper limits of flux density values, while recursive filter estimates approach the "true" value from below as the effective time constants are increased.

2. INSTRUMENTATION

Two eddy covariance systems were deployed at the Walnut River Watershed in southeastern Kansas during 15-17 May 2001. The systems used sonic anemometers (Gill, Omnidirectional Model R3) with open-path infrared gas analyzers (one "ATDD" and the other "LICOR") for fast (20 Hz) synchronous measurements of wind, temperature, water vapor and CO_2. The two systems were set up side by side and 4 m apart, above a pasture with short grass. All of the sensors were placed 4 m above the ground level; the gas analyzers and the sonics were mounted 30 cm apart on a line transverse to the predominant wind direction.

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The raw data were recorded for 30-min periods. All of the data were screened for spikes, excessive noise, and unusual spectral shapes; 30-min data sets with unwanted characteristics were excluded from subsequent analysis.

Data analysis included estimation of heat, moisture, and CO_2 fluxes by using 30-min block averages or a recursive filter with effective time constants ranging from 50 s to 800 s. Coordinate rotations were performed in all cases to set the mean vertical and lateral wind components to zero.

The recursive filter was implemented in the form:

$$\tilde{x}_i = x_i + e^{-\frac{\Delta}{\tau}} \cdot (\tilde{x}_{i-1} - x_i) \qquad (1)$$
$$x_i' = x_i - \tilde{x}_i$$

Here $\tilde{x}_i$ is the moving mean (low-frequency component), x' the departure from the local mean (fluctuating part), Δ the sampling interval (0.05 s), and τ the effective time constant. The time delay and frequency response for the filter with τ set to 200 s are shown in Fig. 1.

Special attention was given to the question of choosing the proper time delay between data streams from different sensors to compensate for microprocessor-induced lags when the

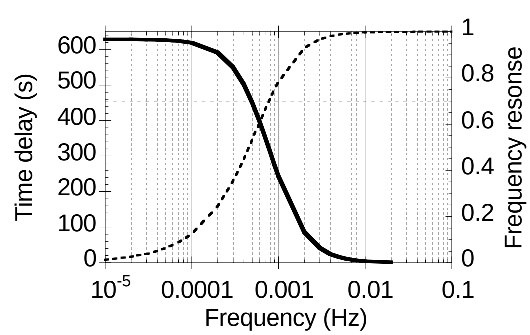

Fig. 1. Frequency response (dashed line) and group delay (solid line) for the recursive filter (1) with an effective time constant of 200 s. A "cut-off" level of 0.7 is shown with a thin dashed line.

covariances were calculated (Zeller et al. 2001). For the Gill-ATDD combination, the sonic data had to be delayed by one digitization time step (+0.05 s), while the sonic data had to be advanced by 4 steps (-0.2 s) for the Gill-LICOR combination.

3. RESULTS AND DISCUSSION

After cospectral corrections with techniques mostly described by Massman (2000), the sum of sensible and latent heat fluxes, H + λE, found by 30-min block averaging was sufficiently large to close the energy balance for both systems (Fig. 2). These flux estimates were consistently larger than the fluxes computed with the recursive filters. The differences during the daytime were usually largest for water vapor, intermediate for carbon dioxide, and smallest for heat. The differences were typically 10-18% for the recursive filter with a 50-s time constant and 5-10% with an 800-s time constant (Fig. 3).

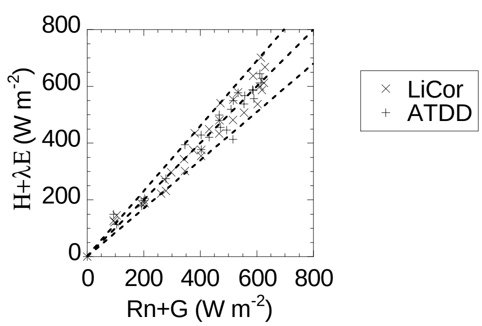

Fig. 2. Daytime energy balance components with 30-min block averaging for the eddy fluxes H and λE versus the sum of net radiation and soil heat flux, Rn + G. The dotted lines show coincidence and ±15% differences.

One interpretation of the relatively small flux estimates obtained with the recursive filter is that some contributions to the daytime fluxes from low-frequency turbulence fluctuations were removed by the filtering. Also, because the effects of the 800-s mean removal computation are roughly equivalent to block averaging over periods of 30-40 min, another mechanism seems to have contributed to the computation of smaller values with the recursive filter. That mechanism might be related to nonlinear distortions of the signals at frequencies close to the cut-off frequency of the filter, where filter group delay is rather sensitive to frequency changes (Fig. 1).

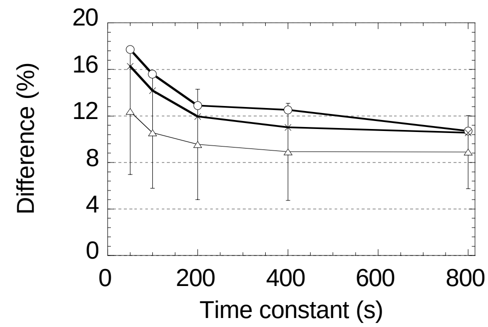

Fig. 3. Average differences among flux estimates (sensible heat: triangles; latent heat: circles; CO_2: "x" symbols) using recursive filters with time constants of 50 s to 800 s. The differences are expressed as percentages of block averaged values. Error bars represent one standard deviation from the mean (shown for sensible heat flux only).

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4. REFERENCES

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