Applying a Lagrangian Dispersion Analysis to Infer Carbon Dioxide And Latent Heat Fluxes in a Corn Canopy

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INTRODUCTION

Conventional micrometeorological techniques are generally not suitable to infer scalar source/sink distributions and fluxes inside plant canopies. Lagrangian dispersion methods have been used as an alternative to separate ecosystem component contributions for the total flux. However this method has not been tested for long periods under field conditions.

The objective of this study was to apply a Lagrangian dispersion analysis[1] (WT analysis) to infer source/sinks distributions of CO_2 and latent heat in a corn field and to assess the sensitivity of the analysis to different conditions of atmospheric stability.

METHODOLOGY

WT Lagrangian analysis

The differential form of the WT Lagrangian analysis is given by:

$$\left.\frac{dC}{dz}\right|_i = \sum_{j=1}^{m} M_{ij} S_j \Delta z_j$$

where i and j are the concentration (C) and source (S) layer indices, respectively, Δz_j is the thickness of the source layer j and M is the dispersion matrix.

A parameterization of turbulence statistics (hereafter TSL[2]) was used with wind speed to estimate the standard deviation of vertical wind velocity and Lagrangian length scale, required to calculate the dispersion matrix (Figure 1).

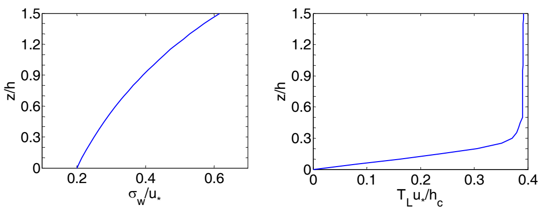

Figure 1 – Normalized profiles of Lagrangian time scale (T_L) and standard deviation of vertical wind velocity (σ_w) calculated using parameterization of turbulence statistics.

Field experiment

- The experiment was carried out in a corn field at the Elora Research Station, Ontario, Canada during the field season in 2007.
- CO_2 and water vapour mixing ratios were measured using an infrared gas analyzer (Li-6262, Li-Cor Inc., Lincoln, NE, USA) Total flux derived from WT analysis was compared to CO_2 and latent heat fluxes measured using the eddy covariance method placed above the canopy.

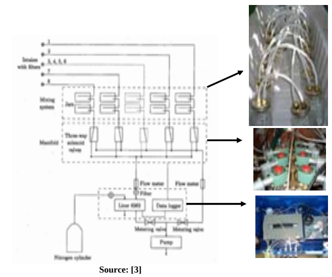

Figure 2 – Multiport sampling system used to measure concentration profiles of CO_2 and H_2O

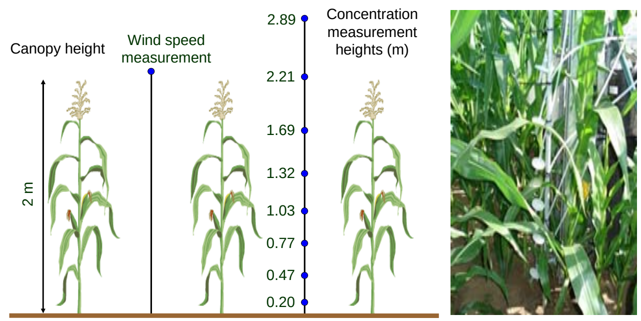

Figure 3 – Measurement heights.

- Total flux derived from WT analysis was compared to CO_2 and latent heat fluxes were measured using the eddy covariance method placed above the canopy.

RESULTS AND DISCUSSION

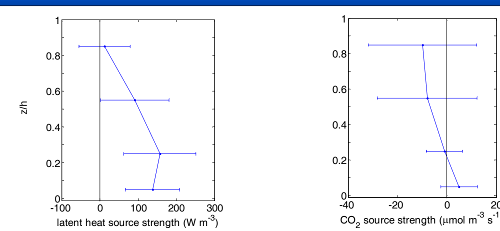

Figure 4 – Ensemble average sources strengths from 13 to 15 hour and error bar (± standard deviation) of latent heat (left) and CO_2 (right) estimated using the WT analysis with TSL parameterization

- Further ongoing studies will compare soil flux inferred by WT analysis to soil respiration measurements and will also try to derive parameterizations more suitable for the canopy used in the study.
- The derived source strength profiles seem to be physically plausible considering concentration profile shapes (data not shown) which demonstrates that WT analysis might be used to partition ecosystem total flux between soil and plants (Figure 4).
- Although it was not possible to check the flux contributions from each ecosystem component, WT analysis presented good correlation with the total flux provided by the eddy covariance.
- The WT analysis presented better correlation with eddy covariance measurements when the atmosphere was unstable.

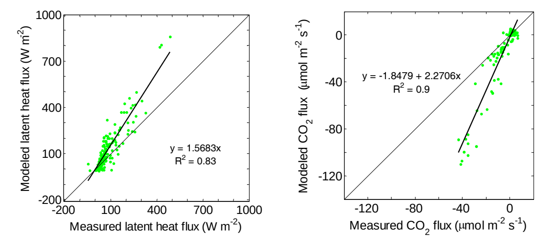

Figure 5 – Comparison between measured CO_2 flux and estimated flux using the WT analysis with different turbulence statistics parameterizations under different conditions of stability of the atmosphere.

Table 1 – Statistical coefficients of the relationship between latent heat flux obtained by the eddy covariance method and WT analyzes using TSL parameterization with and without atmospheric stability corrections for different conditions of stability of the atmosphere: ustable ($h/L \leq -0.1$), neutral ($-0.1 < h/L > 0.1$) and stable ($z/L \geq 0.1$).

Stability correction	Stability condition	Latent Heat			CO_2		
		n	R^2	d	n	R^2	d
uncorrected	unstable	100	0.86	0.91	102	0.90	0.94
uncorrected	neutral	32	0.76	0.92	33	0.78	0.71
uncorrected	stable	32	0.55	0.82	32	0.16	0.36
corrected	unstable	100	0.84	0.81	102	0.93	0.78
corrected	neutral	32	0.77	0.92	33	0.79	0.67
corrected	stable	31	0.54	0.65	31	0.15	0.39

n is the number of observations, **R^2** is the coefficient of the determination and **d** is the Willmott agreement index which expresses the accuracy of the estimates.

[1]Warland JS, Thurtell GW (2000) A Lagrangian Solution to the Relationship Between a Distributed Source and Concentration Profile. *Boundary-Layer Meteorology* **96** 453-471.

[2]Leuning, R. (2000). Estimation of scalar source/sink distributions in plant canopies using Lagrangian dispersion analysis: Corrections for atmospheric stability and comparison with a multilayer canopy model. **96**(1-2), 293-314.

[3]Qiu, GW. (2006) Development and testing of Lagrangian models of scalar dispersion in canopies. Ph.D. Dissertation. University of Guelph, Guelph, ON, Canada: 2006. 121p.