# 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 suggested 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, $\Delta zj$ 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 ($\sigma_w$) and Lagrangian length scale ($T_L$), required to calculate the dispersion matrix (Figure 1). Atmospheric stability corrections[2] were applied to the profiles of $T_L$ and $\sigma_w$.

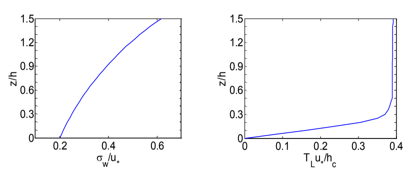


Figure 1 – Normalized profiles of Lagrangian time scale ($T_L$) and standard deviation of vertical wind velocity ($\sigma_w$) calculated using parameterization of turbulence statistics.

### 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).

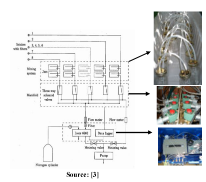


Figure 2 – Multiport sampling system used to measure concentration profiles of $CO_2$ and $H_2O$

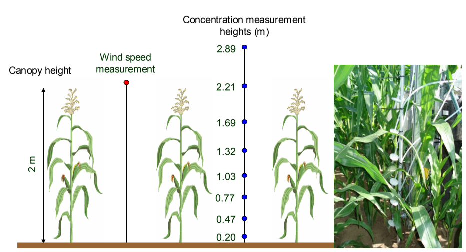


Figure 3 – Measurement heights.

- The total flux derived from the WT analysis was compared to $CO_2$ and latent heat fluxes measured using the eddy covariance method above the corn canopy.
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- The soil respiration inferred by the WT analysis was compared to the ecosystem respiration, obtained from the fitted relationship between night-time eddy covariance fluxes and soil temperature at 5 cm depth ($R^2 = 0.84$).

## RESULTS

- The derived source strength profiles (Fig. 4) seem to be physically plausible considering concentration profile shapes (data not shown).
- The WT analysis net flux presented good correlation with the total flux provided by the eddy covariance (Fig. 5). However it showed poor correlation with ecosystem respiration when used to estimate the soil respiration (Fig. 6).
- The WT analysis presented better correlation with eddy covariance measurements when the atmosphere was unstable (Tab. 1).
- The accuracy of the estimates of the net flux by WT analysis was in general reduced when corrections for atmospheric stability were applied.

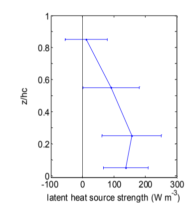


Figure 4 – Ensemble average sources strengths from 13 to 15 hour and error bar (± standard deviation) of latent heat (left) and $CO_2$ (right) estimated using the WT analysis with TSL parameterization

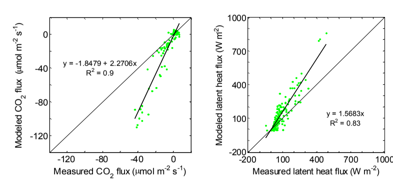


Figure 5 – Comparison between measured $CO_2$ flux and estimated flux using the WT analysis with different turbulence statistics parameterizations under different conditions of stability of the atmosphere.

Table 1 – Statistical coefficients of the relationship between latent heat flux obtained by the eddy covariance method and WT analysis 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, $\mathbf{R^2}$ is the coefficient of the determination and **d** is the Willmott agreement index which expresses the accuracy of the estimates.

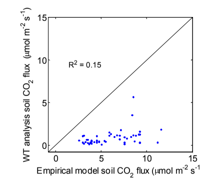


Figure 6 – Comparison between estimated $CO_2$ fluxes using and empirical model based on soil temperature and $CO_2$ fluxes estimated using WT analysis with

## CONCLUSIONS

- The WT analysis has potential to be used long-term to infer source and sinks of scalars (e.g. sensible heat, $CO_2$, $H_2O$ etc) in plant canopies.
- The current corrections for atmospheric stability need to be improved in order to be used with the WT analysis.
- Further ongoing studies will also try to derive parameterizations of the Lagrangian time scale and standard deviation of vertical wind velocity that are more suitable for the canopy used in the study.

[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.