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Calculation method of flux measurements by static chambers

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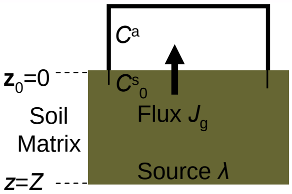
Introduction

There are several studies given in the literature for calculating fluxes by static chambers. They are all based on the diffusion and mass balance equation. The models are based on different assumptions. However, they all Indicate that the fluxes are not constant within the closure time.



1D diffusion equation

$$\frac{\partial C}{\partial t} = D\frac{\partial^2 C}{\partial z^2} + \lambda(z)$$

Mass balance equation

$$F_c = \frac{V}{A}\frac{dC^a}{dt}\bigg|_{t=0}$$

Researcher	C^a	C^s_0	J_g	λ
De Mello and Hines (1994)	$C^a(0)=C_{air}$	Constant	$J_g(t)$	Constant
Gao and Yates. (1998)	$C^a(0)=0$	Constant	$J_g(t)$	Constant
Conen and Smith (2000)	$C^a(0)=C_{air}$	$C^s_0(t)$	$J_g(t)$	Constant
Livingston et al. (2006)	$C^a(t)=C^s_0(t)$ $C^a(0)=C^s_0(0)$	$C^s_0(t)$	$J_g(t)$	$\lambda(z)$

Theoretical model

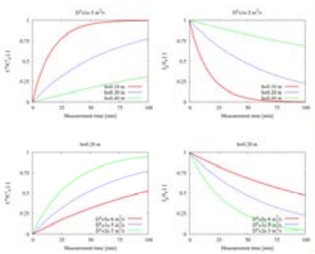
Based on Gao and Yates (1998)

$$C^a(t) = C^s_0\left[1 - \exp\left(-\frac{h_{tc}}{V/A}t\right)\right]$$

$$J_g(t) = h_{tc}C^s_0\exp\left(-\frac{h_{tc}}{V/A}t\right)$$

$$F_c = J_g(0) = h\frac{dC^a}{dt}\bigg|_{t=0}$$

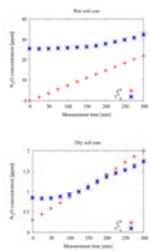
$$F_c = h_{tc}C^s_0 \qquad \text{With } h_{tc} = \frac{D^a}{h}$$



Theoretical model

Based on Conen and Smith (2000)

$$J_g(t) = h_{tc}\left(C^s_0(t) - C^a(t)\right), \quad h_{tc} = \frac{D}{h} = \frac{D^a\theta^{4/3}}{h}$$



Schematic representation

θ [%]	D [m²/s]	h [m]	r^2 *	J_m ** [%]
20	1.7×10^{-6}	0.05	0.9978	72
20	1.7×10^{-6}	0.10	0.9994	84
20	1.7×10^{-6}	0.20	0.9998	92
20	1.7×10^{-6}	0.30	0.9999	94
10	0.7×10^{-6}	0.10	0.9999	93
5	0.3×10^{-6}	0.10	1	97

* Of linear regression, concentration over time

** $J_m=J_g(300\ \text{min})/J_0$

Comparison of two models

Kroon et al. (2008)

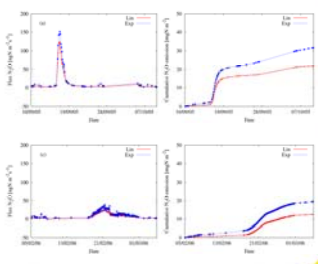
Linear

$$c^a(t) = a + bt$$

versus

De Mello and Hines (1994)

$$C^a(t) = C^s_0 - (C^s_0 - C^a_{t=0})\exp\left(-\frac{h_{tc}}{V/A}t\right)$$



Conclusions

- The linear method underestimates the flux even for short measurement times and without leakage of the chamber.
- Using an incorrect method leads to a systematic underestimation which is very significant even in comparison with the spatial and temporal variation.
- The quality of the flux estimation is dependent on the used model, the amount of measurement points, measurement time, air porosity and chamber height.
- Non-linear methods should be compared for each data set using a goodness-of-fit to choose the most appropriate method.

References: Conen and Smith, Eur J Soil Sci, 2000; De Mello and Hines, J Geophys Res, 1994; Gao and Yates, J Geophys Res, 1998; Hutchinson and Mosier, Sci Soc Am J, 1981; Kroon et al., Nutr Cycl Agroecosyst, 2008.

Available models online: http://biogeo.botanik.uni-greifswald.de/index.php?id=264 (Kutzbach et al., BG, 2007); http://arsagsoftware.ars.usda.gov (Livingston et al., Soil Sci Soc Am J, 2006)

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