P1.14 VALIDATION OF A SIMPLE FOOTPRINT TOOL FOR TRACE GAS FLUX MEASUREMENTS ABOVE AGRICULTURAL FIELDS

Christof Ammann*, Christoph Spirig, Albrecht Neftel
Federal Research Station Agroscope ART, Zürich, Switzerland

1. INTRODUCTION

Micrometeorological techniques like the eddy covariance technique (EC) have the advantage of detecting an average flux integrated over an upwind area with a length scale of about 100 times the measurement height. The actual position and extension of the 'footprint' of the measured flux depend on wind direction and turbulence conditions and can be estimated with the help of dedicated models (e.g. Schmid, 2002). In agricultural applications, the fields or emission areas of interest are often of limited extension or may exhibit heterogeneities. In both cases, it is crucial to evaluate what area is effectively represented by each flux measurement. This is especially important for studies intended to determine long-term budgets of trace gases.

2. METHOD

We present the 'ART footprint tool', a user-friendly tool for footprint calculations of flux measurements in the surface layer. The calculations are based on the analytical footprint model by Kormann and Meixner (2001). The footprint density function of a flux sensor is determined using readily available data from standard eddy covariance measurements. This footprint density function is integrated over defined surface areas given as quadrangular polygons representing e.g. agricultural fields (see Fig. 1).

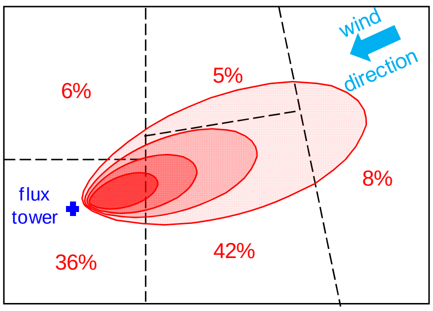

Figure 1: Illustrative example of the flux footprint contribution (red numbers) of different agricultural plots for an eddy covariance flux measurement as calculated by the present tool. The red shaded areas indicate the footprint weight function for the given wind direction.

* *Corresponding author address*: Christof Ammann, Agroscope ART, Air Pollution and Climate Group, Reckenholzstrasse 191, CH-8046 Zürich, Switzerland; e-mail: christof.ammann@art.admin.ch

The ART footprint tool and its application is documented in Neftel et al. (2008). In contrast to other similar footprint models it does not require the roughness length z_0 as an input parameter. The latter is not a measured quantity and there is no common easy way for the determination of z_0 in non-uniform terrain. Instead the model uses measured values of wind speed u, friction velocity u_*, Obukhov length L, and the standard deviation of the lateral wind component σ_v. They can be determined by a common sonic anemometer sensor.
The footprint tool was implemented in an EXCEL® spreadsheet in order to facilitate the data input and handling. It can be downloaded from the Internet at the following URL:
http://www.agroscope.admin.ch/art-footprint-tool/

3. RESULTS AND DISCUSSION

We illustrate the use and performance of the ART footprint tool in three different field applications in an agricultural environment at the Swiss FLUXNET site Oensingen (Ammann et al., 2007; 2009). Due to the limited size of the fields, a relatively low measurement height of 1.2 m was chosen for the EC flux measurements. The following three examples comprise studies of three different trace gases (CO_2, NH_3, and CH_4) and different relations between field size and footprint extension.

3.1 *CO_2 Exchange on Neighboring Fields*

EC flux measurements of CO_2 were performed over two neighboring grassland fields, one intensively managed (INT) and the other extensively managed (EXT). The experiment is described in detail by Neftel et al. (2008). Two flux towers (EC1 and EC2) were positioned in the centre of each field. Their measurements showed a contrasting CO_2 flux of the two grassland fields during the study period (Fig. 2a), because the EXT field had been cut recently. The third tower (EC3) was located on the EXT field near the border between the two fields. Its flux was influenced by both fields to a varying degree depending mainly on wind direction (Fig. 2b). The footprint fractions of the EC3 tower (Fig. 2c) as determined with the ART footprint tool were used to calculate the EC3 flux from the other two EC systems. The results in Fig. 2d show, that the flux simulated with the footprint fractions well reproduced the measured flux affected by the two fields with contrasting CO_2 exchange.

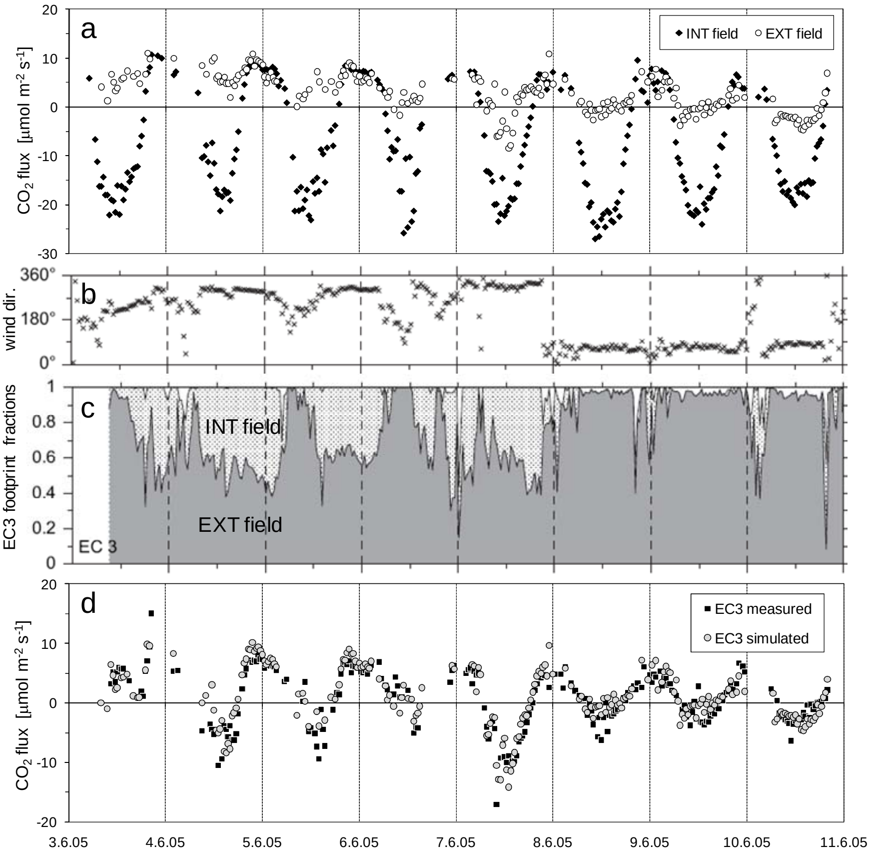

Figure 2: Eight-day period with data of (a) measured CO_2 fluxes for the neighboring INT and EXT fields, (b) wind direction, (c) footprint contribution of INT and EXT field to the EC3 flux; (d) comparison of measured and footprint fraction derived EC3 flux.

3.2 *NH_3 Emission from Freshly Spread Slurry*

EC flux measurements of NH_3 were performed over a wheat stubble field in summer 2009 using an electron transfer reaction mass spectrometer eTR-MS (Sintermann et al., 2010; Spirig et al., 2010) during and after slurry application. The cattle slurry was broadcast using a tank trailer with a splash plate. Since the slurry tank had to be refilled several times, the slurry was spread sequentially on six tracks (Fig.3) at time intervals of about 25 min.

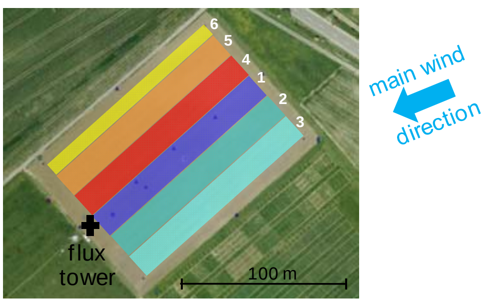

Figure 3: Aerial photograph of the measurement field with indication of the six slurry application tracks (colored; numbers indicate application sequence).

In this way, a relatively complex NH_3 emission pattern was produced in the footprint of the flux tower. The footprint contribution of the individual track areas calculated with the ART footprint tool are plotted in Fig. 4.

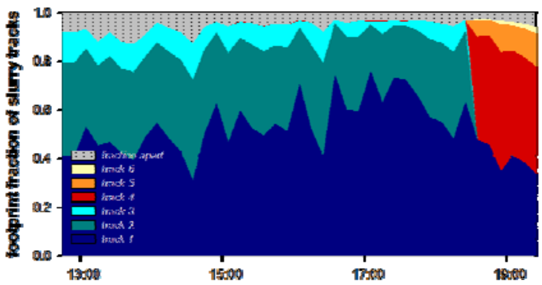

Figure 4: Footprint fractions FP_i of the slurry application tracks (see Fig. 3) during six hours after the begin of slurry spreading at 12:40 LT on 6 August 2009.

From the time of application (t_0), the slurry exhibited a fast exponential decay of the ammonia emission E_{NH_3} of the general form:

$$E_{NH_3}(t-t_0) = F_1 \cdot \exp\left(-\frac{t}{\tau_1}\right) + F_2 \cdot \exp\left(-\frac{t}{\tau_2}\right) \quad (1)$$

It was assumed that all six tracks had the same temporal behavior and thus the ammonia flux at the position of the EC system could be written as the sum of the emission from each track adjusted for the individual application time (t_{0i}) and weighted with the corresponding footprint fractions FP_i (see Fig. 4):

$$F_{EC}(t) = \sum_{i=1}^{6} FP_i(t) \cdot E_{NH_3}(t - t_{0i}) \qquad (2)$$

This function was fitted to the respective EC flux measurements (see Fig. 5) by adjusting the four constants F_1, F_2, τ_1, τ_2 in Equation 1. In this way, the emission from the individual tracks with time scales τ_1 = 31 min. and τ_2 = 141 min. were derived.

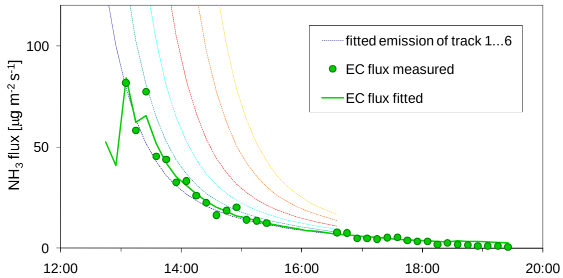

Figure 5: Temporal development of NH_3 emissions of the six slurry application tracks and the resulting EC flux average emission of the entire field.

3.3 *Artificial CH_4 Release Grid*

EC flux measurements of CH_4 were performed over a short-cut grassland using a Quantum Cascade Laser Spectrometer QCLAS in spring 2009. On the field with negligible natural CH_4 exchange, an artificial flux generation system (gas release grid) was built to mimic a limited area source of methane. The uniform release of gas across the grid was achieved by using identical flow orifices placed at equidistant intervals.

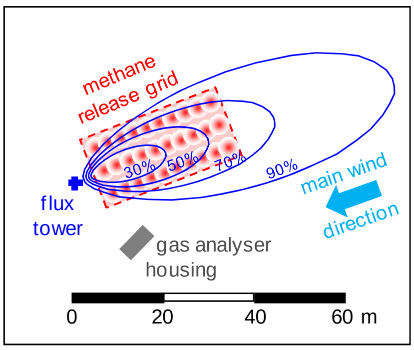

Figure 6: Schematic illustration of the field measurement setup. Blue curves indicate extension of respective integral footprint contribution.

The experiment is described in detail by Tuzson et al. (2010). The grid of about 300 m^2 was placed within the main footprint area (blue isolines) of the EC system. The measured EC flux was corrected for the limited footprint fraction covered by the gas release grid. Outside the grid, the CH_4 flux was supposed to be zero. The maximum footprint fraction of the emission grid under optimum wind direction was about 60%. Fig. 7 shows the comparison of produced gas release (two different levels) and the corrected flux measurements. The EC fluxes corrected with the footprint tool were able to reproduce the artificial emission rates to a satisfying degree.

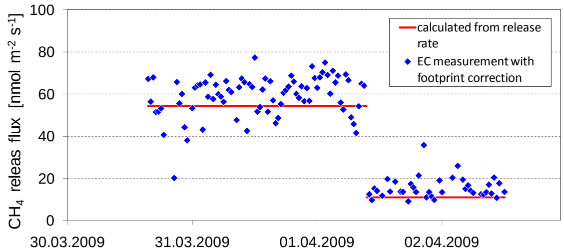

Figure 7: CH_4 emission flux for the release grid area (rectangular red area in Fig. 6) as calculated from the controlled gas release rate and as derived from the EC flux measurement with footprint correction

4. CONCLUSIONS

All three applications indicated a good performance of the simple ART footprint tool. This shows the suitability of the tool as a routine quality check for field experiments and flux monitoring stations influenced by distinct surface areas with differing vegetation covers, growth states, and/or land-use.

Acknowledgements

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