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Measurements and modeling of surface–atmosphere exchange of microorganisms in Mediterranean grassland

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Supplementary Material

1 Flux Computations

The flux-gradient methodology assumes that, in the atmospheric surface layer, the flux of a certain scalar is a function of: the gradient of the said scalar measured at two heights, the delta between the measurement heights, and an appropriate eddy-diffusivity coefficient, in a manner analogous to the parametrization of molecular diffusion (see, for example, (Businger, 1986) and (Baldocchi et al., 1988))

The flux of a certain scalar (F_c) can, therefore, be represented as (Eq. (S1)):

$$F_c = -K_c \left(\frac{dc}{dz}\right), \tag{S1}$$

In Eq. (S1) K_c is the eddy-diffusivity coefficient (in $m^2\ s^{-1}$), dc represents the gradient of concentration and dz the difference between the two sampling heights. When F_c is positive, an outgoing flux is moving from the surface to the atmosphere (and the surface is, therefore, acting as a source of the scalar c), while the opposite is true if the flux is negative (and, in this case, the surface acts as a sink).

By appropriately scaling K_c on the sampling heights and a scale length, flux can be, instead, expressed as the product of a transport velocity and a difference in concentration, following the aerodynamic method ((Monin and Obukhov, 1954); (Simpson et al., 1998)) and the formulation of (Beine et al., 2003), Eq. (S2)):

$$V_c = k \frac{u_*}{ln\left(\frac{z_2}{z_1}\right) - \Psi_H\left(\frac{z_2}{L}\right) + \Psi_H\left(\frac{z_1}{z_2}\right)}, \tag{S2}$$

In Eq. (S2) k is the Von Kármán constant (assumed equal to 0.4), u_* represents friction velocity, z_1 the lowermost sampling height, z_2 the uppermost sampling height, L is the Obukhov length and ψ_H is the universal similarity function represented as Eq. (S3):

$$\Psi_H = \begin{cases} 2\ln\left[\frac{1-\sqrt{1-16\frac{z}{L}}}{2}\right] & if\ \frac{z}{L} < 0 \\ -17\left[1 - \exp\left(-0.29\frac{z}{L}\right)\right] & if\ \frac{z}{L} > 0 \end{cases}, \tag{S3}$$

In Eq. (S3) z/L is the stability parameter.

The actual height z, considered in the aforementioned computations should actually be corrected by subtracting the zero plane displacement height, roughly two-thirds of the average canopy height.

In the present work, due to the considerably short and simple canopy, z is quite insensitive to such correction.

2 Eddy- Covariance Quality Check and Relationship with Flux Gradient results

The eddy-covariance (EC) technique was used to evaluate the applicability of flux-gradient (FG) technique for the Montfavet situation during the September 2015 campaign.

EC data were elaborated with EddyPro 6 and quality-checked following Mauder and Foken (2006). The flagging methodology followed the CarboEurope IP project standards with a flag of 0 indicating best quality fluxes, a flag of 1 fluxes suitable for general analysis and a flag of 2 fluxes to be discarded. In the September campaign where EC and FG were compared 84.85% of fluxes used for comparison obtained a flag of 0, 10.6% a flag of 1 and only 4.54% a flag of 2. The linear regression between EC and FG did not significantly change when removing flag 2 fluxes. The correlation coefficient changed from 0.72 to 0.70 and slope and offset where substantially unchanged (a difference of 0.005 for the slope and of 0.019 for the offset).

A two dimensional footprint model from Kljun et al. (2015) was used to investigate the contribution of the grassland to the measured flux. One aggregated footprint per day was generated, each one spanning a domain of a 25*z meter radius around the tower (76 m) with a resolution of 2 m on both the x and y direction.

Footprint analysis showed that grassland is the main contributor to the footprint with a cumulative 50-60% contribution. Fluxes are also influenced by terrain with various roughness elements that were taken into account by choosing a conservative z0 of 0.15 m.

Footprint analysis also allows investigating potential flow distortions due to the presence of the scaffolding by comparing wind direction and quality flags. During the days between the 26th and 30th of September 2015, the main wind direction was blowing through the scaffolding before reaching the sensors. Between the 26th and the 28th of September, no matter the mainly northerly wind direction, all data had a quality flag of 0, which, from the point of view of the Integral Turbulence Test, means a deviation of less than 30% compared to what is predicted based on similarity theory. Larger errors, with discrepancies > 100%, happened only on the 1st of October, where there was a more “frontal” wind direction, where the disturbance from the scaffolding should be, in fact, less. Flag 2 fluxes were already excluded from analysis since, for microbial gradient method, they do correspond to moments where the two Burkard samplers are below the MRG and thus not providing reliable fluxes.

It is important to note that EC and FG footprints are, for stable stratification, the same when the EC measurements are made at the arithmetic mean of the highest and lowest gradient measurement heights. Conversely, for unstable stratification, the footprints match when the EC measurements are made at the geometric height of the aforementioned heights (Horst, 1999).

Given the height differences between the EC and FG systems, the FG footprints should be smaller (Horst, 1999), receiving more contribution from the grassland itself and being less influenced by external influences and roughness elements.

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