Sensitivity Analysis of a Source Partitioning Method for H_2O and CO_2 Fluxes via Large Eddy Simulations

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1 - Introduction

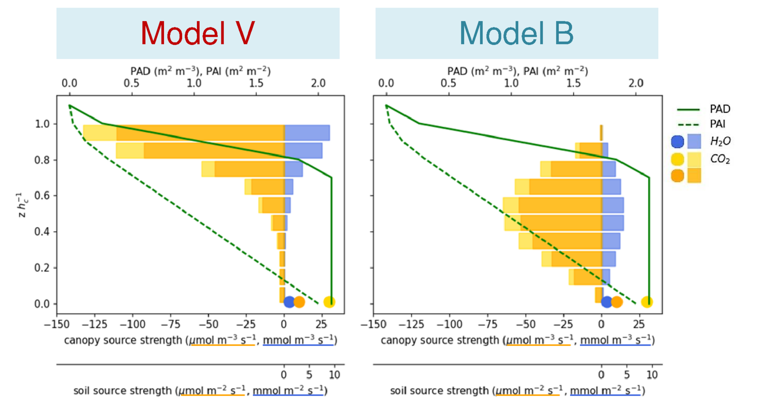
Eddy-covariance observations can only provide the *net* fluxes (of H_2O and CO_2) that emerge from plant canopies. However, for proper process understanding the contributions of transpiration, evaporation, photosynthesis, and respiration are required. Scanlon and Sahu (2008) and Scanlon and Kustas (2010) proposed a source partitioning method (**SK10**), that is based on: (1) high frequency raw data time series, (2) separate application of the flux-variance similarity theory to stomatal and non-stomatal components of the fluxes, and (3) assumptions on water use efficiency (**WUE**) on leaf-scale.

We conducted Large Eddy Simulations (**LES**) for (a) contrasting canopy source/sink distributions, (b) varying relative magnitudes of soil sources and canopy sinks/sources (*Fig.1*), and (c) contrasting plant area density (PAD) distributions (affecting turbulence). SK10 was applied to the synthetic high frequency data and the effects of canopy type (PAD distribution), measurement height, sink-source-distributions, and varying assumed WUEs were tested regarding the partitioning performance. Here we focus on one PAD distribution (uniform).

2 - Large Eddy Simulations

Model: DALES (Heus et al. 2010, Ouwersloot et al. 2016)

- Conditions: neutral
- 72 h_c x 36 h_c x 32 h_c with 720 x 360 x 144 nodes
- grid resolution: 0.1 h_c
- simulation runtime: 720 $h_c u_*^{-1}$
- field sampling: every 6 $h_c u_*^{-1}$ for last 120 $h_c u_*^{-1}$
- PAI: 2 $m^2 m^{-2}$, uniformly distributed
- 10 scalar sources in canopy and 1 soil source
- H_2O and CO_2 fields generated from scalar fields by linear scaling based on source distribution



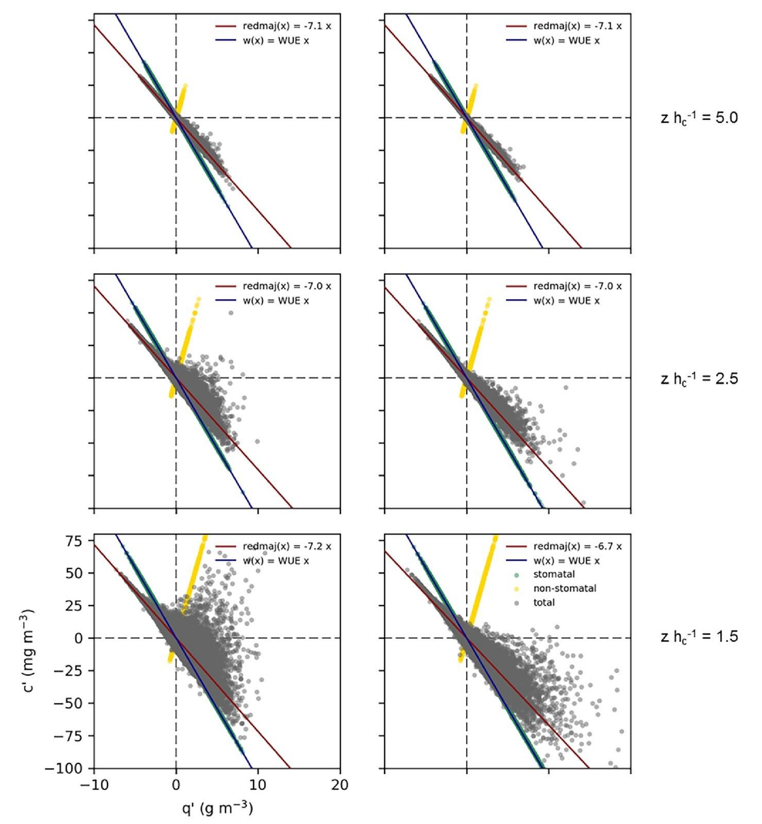


Fig.1, top: Plant area density (PAD) distribution, cumulative plant area index (PAI) and variations of sink-source-distributions used to scale the LES scalar fields (*left*: ModelV after Sellers et al. 1992, *right*: ModelB after Ney et al. 2017), each with ten canopy sinks/sources (*bars*) and one soil source (*circle*). For CO_2, two different soil sources were used, with the canopy sink adapted such that the net flux is the same.

Fig.2, bottom: Examples of sampled synthetic high frequency data of *q'* and *c'* at different 'measurement' heights for ModelV and ModelB (with the strong soil source). Differentiation between scalars originating from stomatal (*green dots*) and non-stomatal (*yellow dots*) processes. The *blue line* presents the WUE and the *red line* the reduced major axis regression between total *q'* and *c'*.

3 - Source Partitioning Method

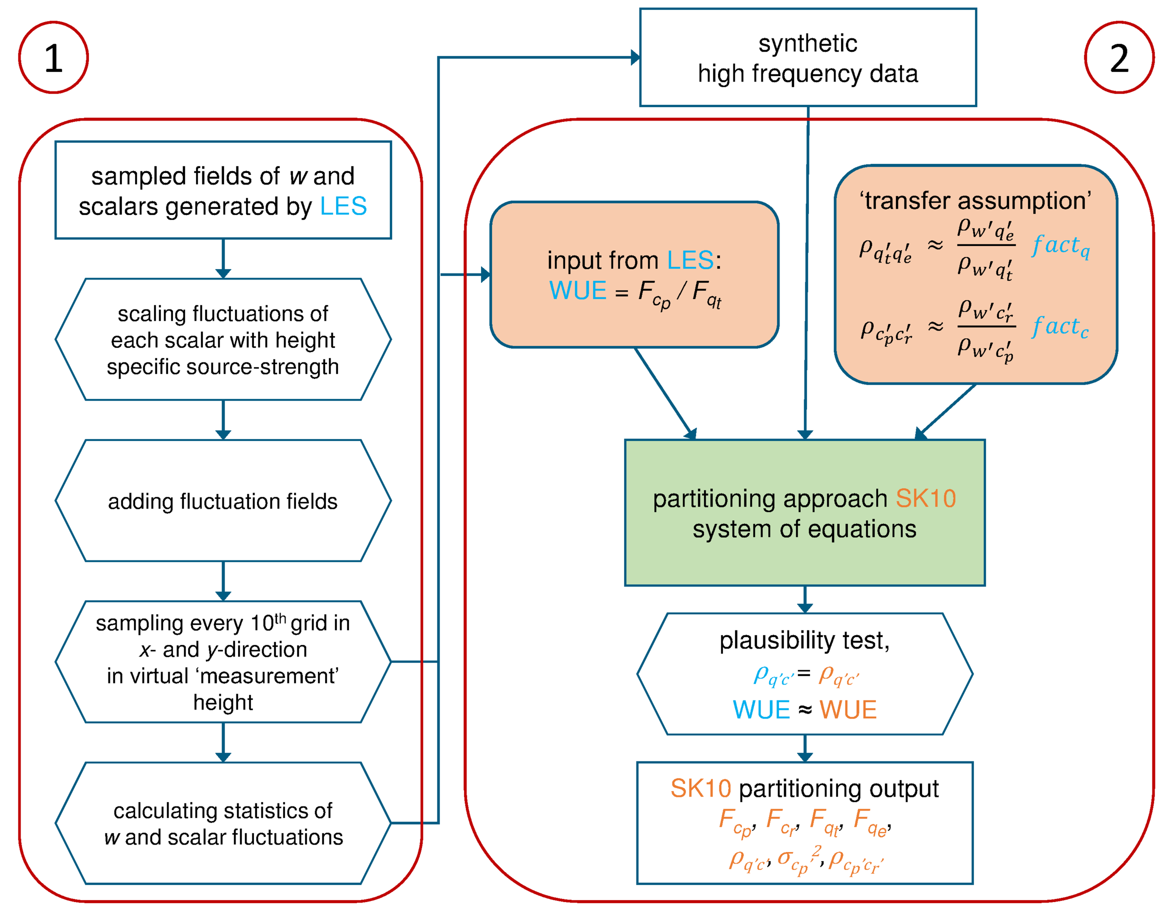


Fig.3: Method: (1) generation of synthetic high frequency data with LES, (2) application of SK10 to derive the contributions to the fluxes of CO_2 and H_2O.
(c_p: CO_2 related to photosynthesis, c_r: CO_2 related to soil respiration, F_x: flux of *x*, h_c: canopy height, q_e: H_2O related to evaporation, q_t: H_2O related to transpiration, u_*: friction velocity at canopy top, *z*: height above soil surface)

4 - Results

- SK10 was able to approach the correct partitioning only for the strong soil source and observations within the roughness sublayer (maximum decorrelation) (*Fig.4 top*). The partitioning was sensitive to the parameterization of $\rho_{c_p'c_r'}$ (transfer assumption, *Fig.5*). Replacing a parameterized $\rho_{c_p'c_r'}$ with observed values (correcting the transfer assumption), the partitioning results improved and were realistic up to $z \approx 3h_c$ (*Fig.4 bottom*).
- The partitioning results were very sensitive to the assumed WUE. This sensitivity was strongly modified by the quality of the estimation of the correlation $\rho_{c_p'c_r'}$ (*Fig.6*).

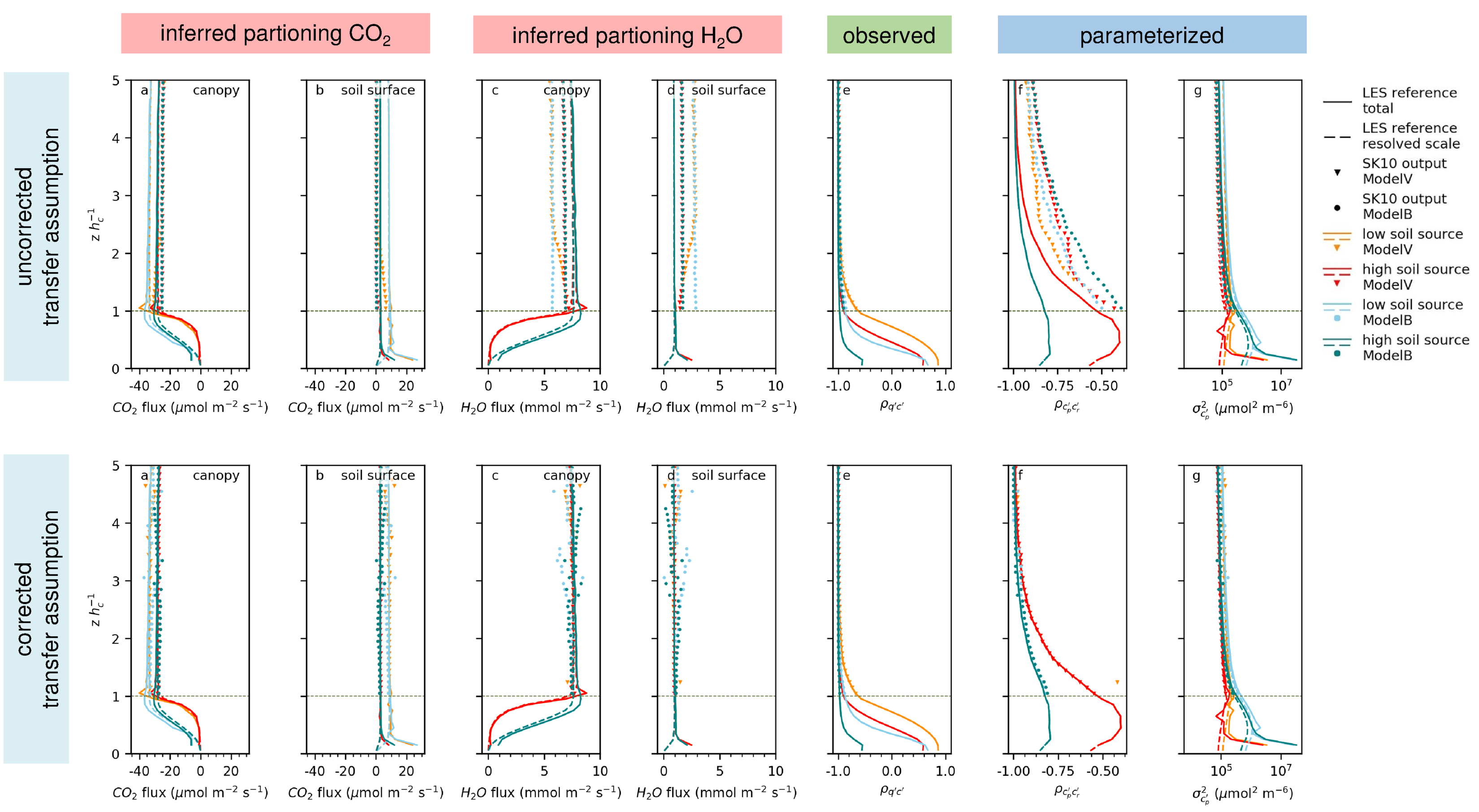


Fig.4: Vertical profiles of *inferred* H_2O and CO_2 flux components, *observed* $\rho_{q'c'}$ and *parameterized* $\rho_{c_p'c_r'}$ and $\sigma_{c_p'}^2$ for four sink-source-distributions (ModelV or ModelB, low or high soil source). *Top:* the partitioning results of SK10 with the original parametrization for $\rho_{c_p'c_r'}$; *bottom:* partitioning results with correction to the transfer assumption.

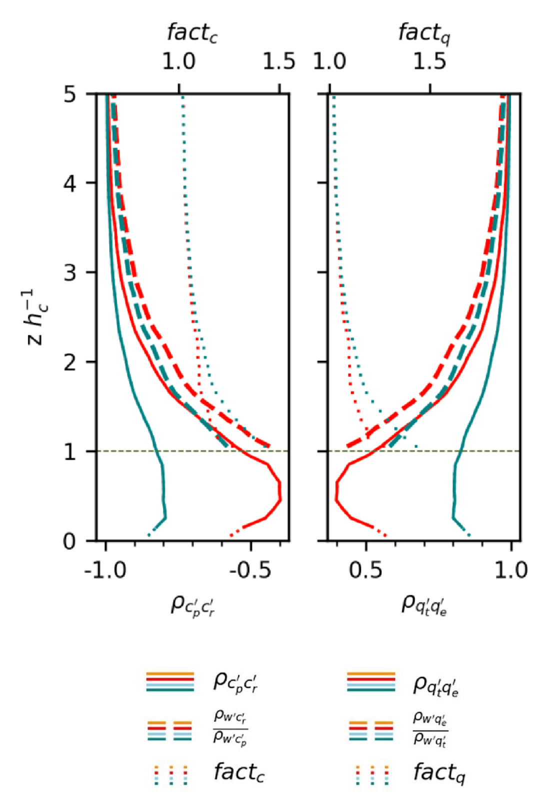


Fig.5: Comparison of real and parameterized correlation coefficients $\rho_{c_p'c_r'}$ and $\rho_{q_t'q_e'}$ (transfer assumption) and the corresponding correction factors ($fact_q$, $fact_c$).

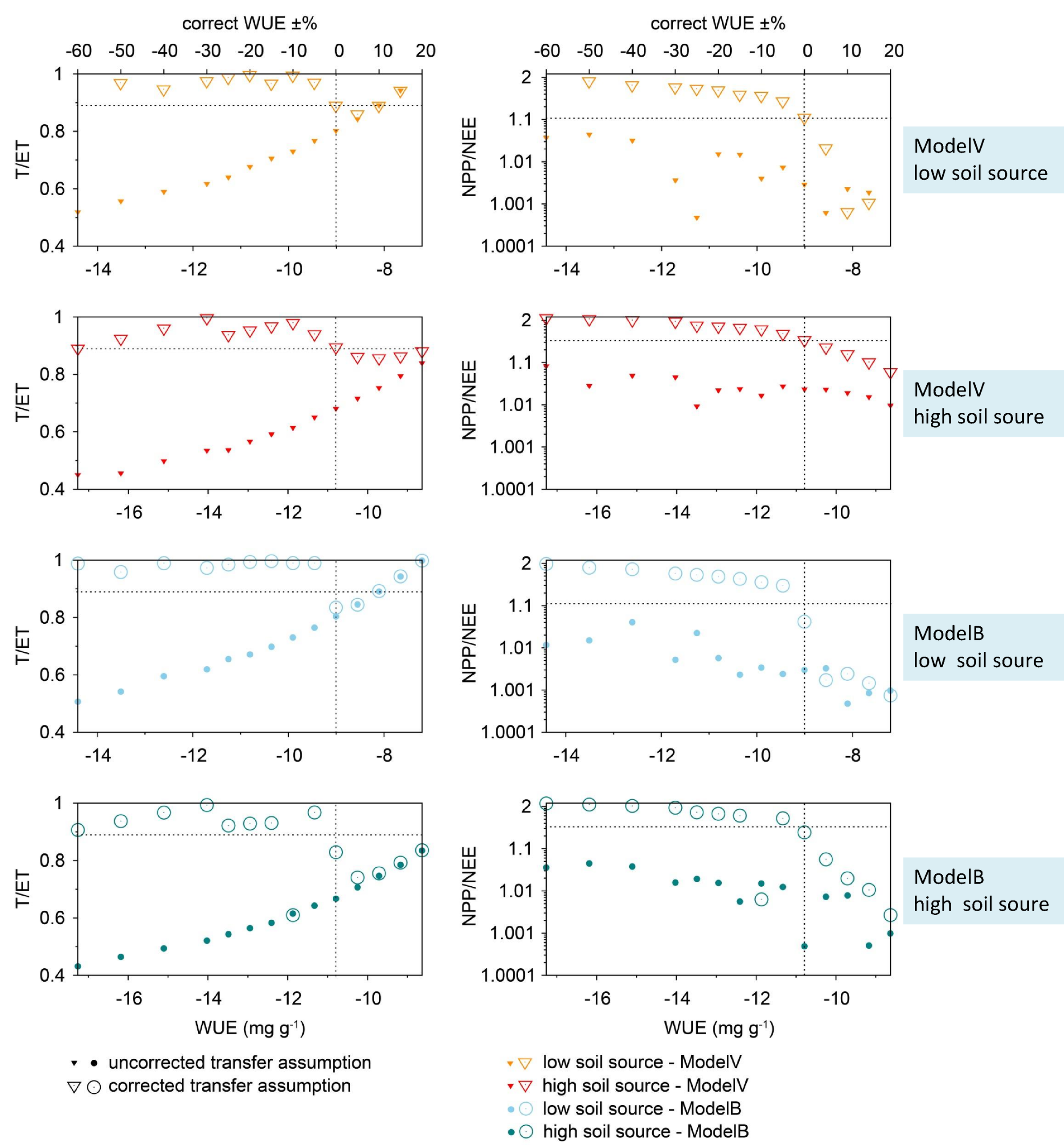


Fig.6: Results of partitioning fractions for H_2O (T/ET, *left*) and CO_2 (NPP/NEE, *right*) fluxes in relation to the input WUE at a 'measurement' height of 2.5 h_c with corrected and uncorrected transfer assumption. The true known imposed partitioning factors and WUE input are indicated by the dashed lines (T: transpiration, ET: evapotranspiration, NPP: net primary production, NEE: net ecosystem exchange).

5 - Conclusions

For a satisfying performance of SK10, a certain degree of decorrelation of *q'* and *c'* was needed: (1) enhanced by a clear separation between soil sources and canopy sinks/sources, (2) for observations within the roughness sublayer.

However, due to violation of the transfer assumption, the known true input WUE did not yield the known true input partitioning. This could only be achieved after introducing correction factors for the transfer assumption. However, it is unclear whether the profiles of these correction factors are universal and could be applied to field observations.

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