Experimental verification of downwind flux contributions and its integration in an existing flux footprint model

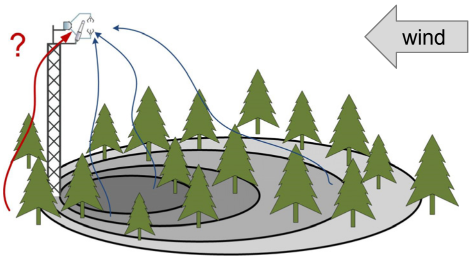
K. Heidbach, H.P. Schmid

Karlsruhe Institute of Technology, Institute of Meteorology and Climate Research (IMK-IFU), Garmisch-Partenkirchen, Germany

Contact: katja.heidbach@kit.edu

Motivation

Do downwind sources also contribute to the measured flux?



Lagrangian footprint models predict flux contributions from downwind sources.

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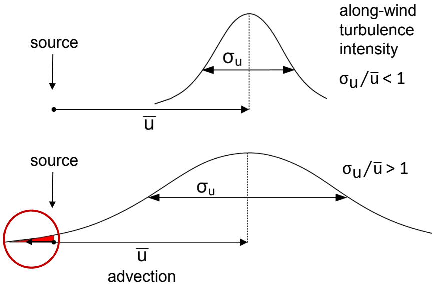
BUT: Most simple and computationally less intensive analytical models and (semi-) empirical parameterizations are not able to consider flux contributions from downwind sources for all stability conditions.

Theory of downwind flux contributions

- Up to now, analytical models only include the mean wind velocity $\bar{u}$

→ Downwind contributions are not considered

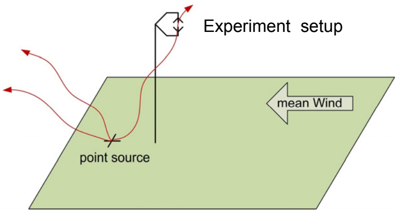
- High along-wind turbulence intensities ($\sigma_u/\bar{u}$) are responsible for downwind contributions (lower graph, red area)



Evaluation site "Graswang", Germany

- Tracer experiments at the TERENO-grassland site in Graswang, southern Germany (47.57° N, 11.03° E; 870 m a.s.l.), located on a flat valley bottom (~1 km wide), flanked by steep sides
- Surface source of methane of ~1 m^2
- Release rate: 7 l min^{-1} continuously over one averaging period (10 minutes)
- Natural flux of methane almost zero

Experimental verification of downwind flux contributions



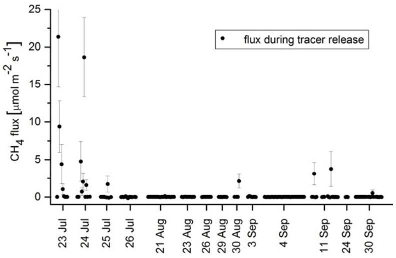
Flux estimated by the model is determined and is directly compared to the measured flux

$$\eta = Q_\eta f$$

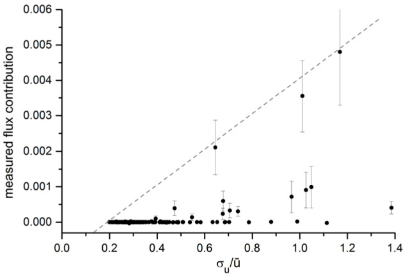
flux estimated by footprint model

tracer release rate

footprint weighting factor

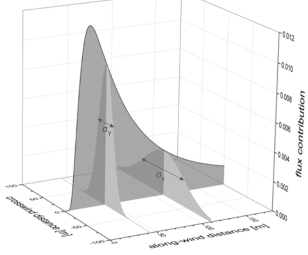


- Discontinuous time series of measured 10-minute CH$_4$ fluxes shows that flux contribution from downwind sources is measurable only occasionally



- Downwind contribution depends on along-wind turbulence intensity σ_u/u
- Dashed line indicates a rough boundary up to which downwind contributions of various extents are possible while above that boundary values become more and more unlikely

Integration of downwind flux contributions in FSAM (Flux Source Area Model, Schmid (1994))



Definition of Gaussian crosswind distribution

$$D_y(x,y) = \frac{1}{\sqrt{2\pi}\sigma_y(x)} e^{-\frac{1}{2}\left(\frac{y}{\sigma_y(x)}\right)^2}$$

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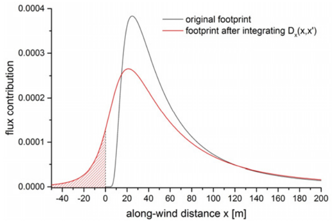

Introduction of Gaussian along-wind diffusion as a function of $\sigma_u/\bar{u}$

$$D_x(x,x-x') = \frac{1}{\sqrt{2\pi}\sigma_x(x)} e^{-\frac{1}{2}\left(\frac{x-x'}{\sigma_x(x)}\right)^2}$$

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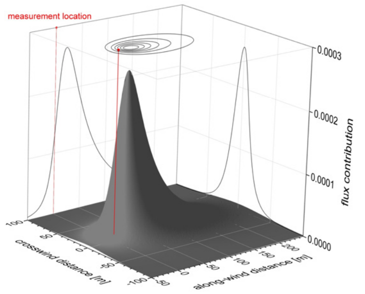
The 2-dimensional footprint



→ Flux contributions downwind of the measurement system are now considered

→ The footprint maximum moves closer to the measurement system

→ Flux contributions close to the measurement system gain in importance

Reference

Schmid, H. P., 1994. Source Areas for Scalars and Scalar Fluxes. Boundary-Layer Meteorology, 67, p. 293-318

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