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

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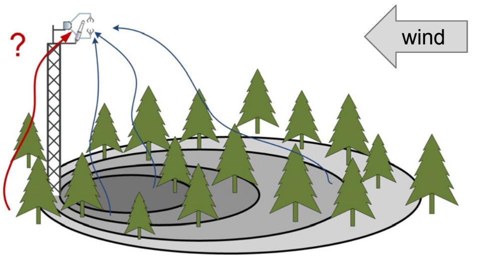
## Motivation

Do downwind sources also contribute to the measured flux?




Lagrangian footprint models predict flux contributions from downwind sources.

↕

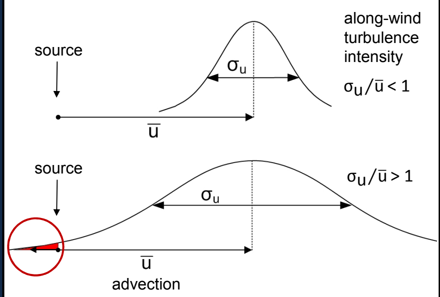
**BUT:** Most simple and computationally less intensive analytical models and (semi-) empirical parameterizations are not able to consider flux contributions from downwind sources for all stability conditions.

## Theory of downwind flux contributions

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

→ Downwind contributions are not considered

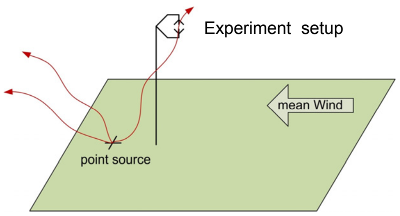
- High along-wind turbulence intensities ($\sigma_u/\bar{u}$) are responsible for downwind contributions (lower graph, red area)




## 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 m²
- Release rate: 7 l min⁻¹ continuously over one averaging period (10 minutes)
- Natural flux of methane almost zero

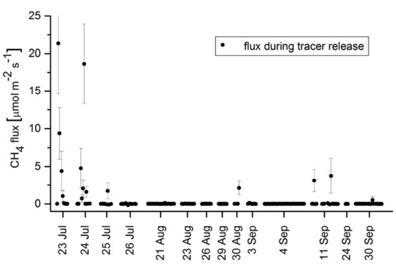
## Experimental verification of downwind flux contributions



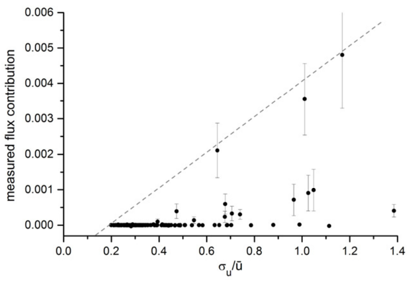

Flux estimated by the model is determined and is directly compared to the measured flux

$$\eta = Q_\eta f$$

flux estimated by footprint model — tracer release rate — footprint weighting factor

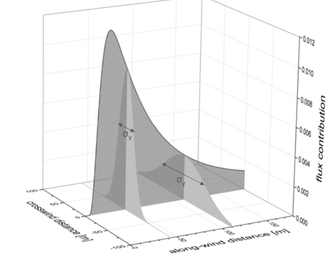



- Discontinuous time series of measured 10-minute $CH_4$ fluxes shows that flux contribution from downwind sources is measurable only occasionally




- Downwind contribution depends on along-wind turbulence intensity $\sigma_u/u$
- 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

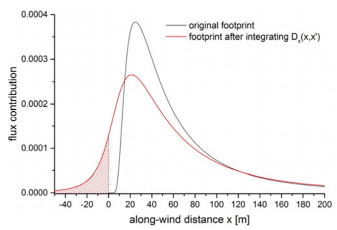
## Integration of downwind flux contributions in FSAM (Flux Source Area Model, Schmid (1994))




Definition of Gaussian crosswind distribution

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

+




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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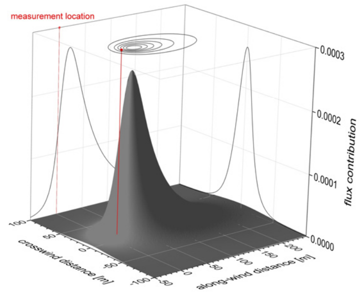


The 2-dimensional footprint

→ 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

Acknowledgements

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REKLIM Helmholtz-Verbund Regionale Klimaänderungen — TERENO Terrestrial Environmental Observatories — ICOS Integrated Carbon Observation System