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)

Integration of downwind flux contributions in FSAM (Flux Source Area Model, Schmid (1994))
- Definition of Gaussian crosswind distribution
  \[ D_y(x, y) = \frac{1}{\sqrt{2\pi}\sigma_y(x)} e^{-\frac{1}{2} \left( \frac{y-y_0}{\sigma_y(x)} \right)^2} \]
- Introduction of Gaussian along-wind diffusion as a function of \( \sigma_u/\bar{u} \)
  \[ D_u(x, x') = \frac{1}{\sqrt{2\pi}\sigma_u(x)} e^{-\frac{1}{2} \left( \frac{x-x_0}{\sigma_u(x)} \right)^2} \]
- The 2-dimensional footprint
  \[ \text{Flux contributions downwind of the measurement system are now considered} \]
  \[ \rightarrow \text{The footprint maximum moves closer to the measurement system} \]
  \[ \rightarrow \text{Flux contributions close to the measurement system gain in importance} \]

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

Acknowledgements
- The Graswang site is part of the TERENO and ICOS-D ecosystems (Integrated Carbon Observation System, Germany) networks which are funded, in part, by the German Helmholtz Association and the German Federal Ministry of Education and Research (BMBF). This study is a contribution to the Helmholtz-Association’s climate initiative REKLIM (Topic 4 “The Land Surface in the Climate System”) which we would like to acknowledge for additional funding. The support by the Bayerischen Staatsforsten and our co-worker Elisabeth Eckart is appreciated.

Experimental verification of downwind flux contributions
Flux estimated by the model is determined and is directly compared to the measured flux

- 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