APPROACHES TO FOOTPRINT MODEL VALIDATION BASED ON NATURAL TRACERS

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Motivation

Footprint models have become an important and widely accepted tool for the determination of the spatial context of micrometeorological measurements. Knowledge about the source area of an instrument is useful for both selecting suitable experiment sites, and for performing post-field data quality control to interpret the measurements correctly. Many different footprint models with a varying level of sophistication have been developed during the last decade, most of them either implemented as analytic or Lagrangian stochastic algorithms. A comparison of these models is necessary to highlight differences between them, and to validate their accuracy.

Footprint models

The footprint models to be compared in the study presented are the analytic flux source area model (FSAM) by SCHMID (1994, 1997), and the THOMSON (1987) Lagrangian stochastic (LS) trajectory model as parameterised by RANNIK et al. (2003). Both models are restricted to surface layer scaling and a constant flux layer. To save computation time and to adapt it to field scale studies, the Lagrangian stochastic model was simplified so that both models neglect canopy effects, assume only sources at the ground, and require horizontally homogeneous flow. The **main differences** between the models concern

	FSAM	Lagrangian stochastic model
Diffusion modelling	K-Theory, Eulerian advection diffusion equation	Tracking of $5 \cdot 10^4$ particles with user defined flow statistics and profiles
Diffusion directions	Vertical, crosswind	Vertical, crosswind, alongwind

Comparison approaches

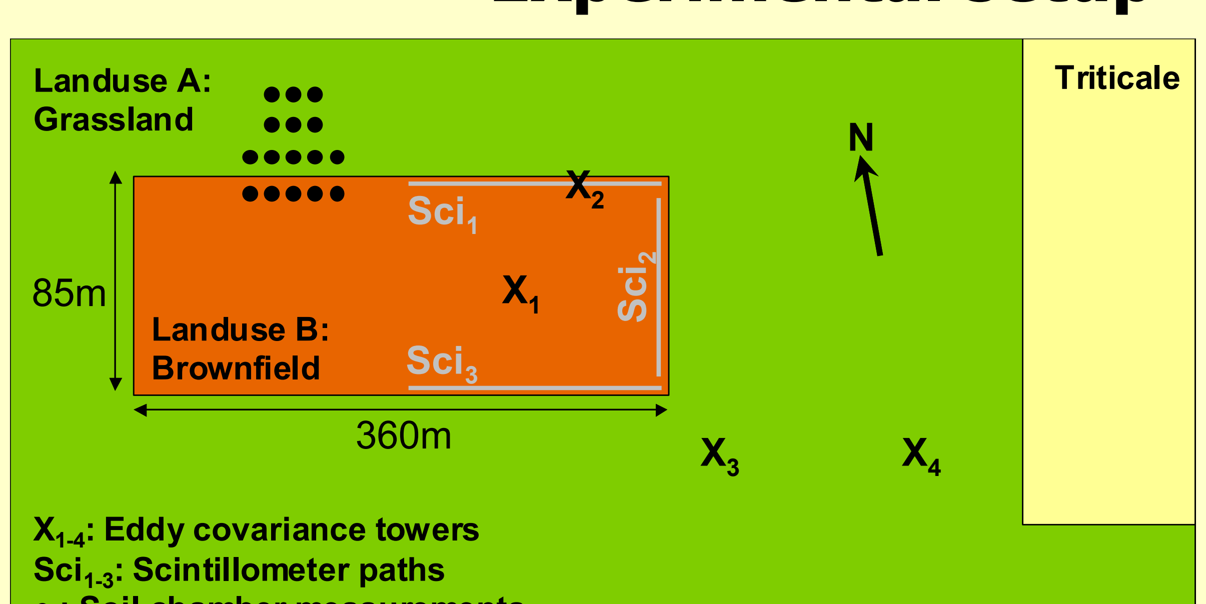
Our approach to use natural tracers for footprint evaluation studies is to operate several measurements simultaneously at different positions in an environment of clearly defined heterogeneity. It is expected that varying flux differences can be explained by the composition of land use types in the source area of the measurement positions as calculated by the footprint models, and that this correlation can be used as an indicator for the performance of the specific model. We concentrate on **2 major approaches**:

- Correlation analysis for **flux differences vs. land use differences** for a specific combination of measurement positions.
- Comparison of **measured fluxes vs. modelled fluxes** for a position with mixed fetch. The modelled fluxes will be determined using the land use composition in the fetch and **reference fluxes** for each specific land use type.

To test the evaluation approaches outlined above, the following **experimental setups** have been employed for comparison studies:

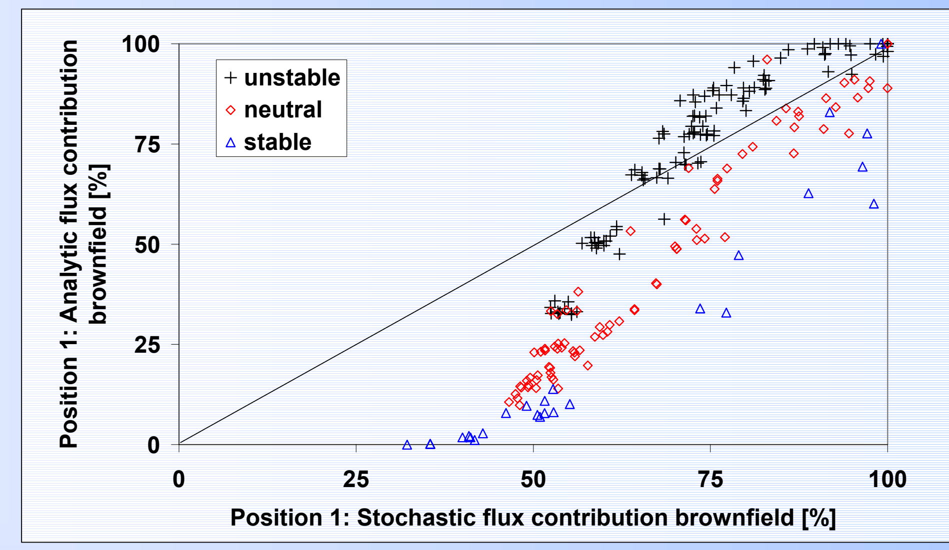
- Comparison of sensible heat flux data of simultaneous **eddy covariance measurements** (EC) at four different positions with varying fetch conditions.
- Comparison of sensible heat flux data of 3 simultaneous Scintillometer **line source measurements** (Sci) with varying fetch conditions.
- Comparison of CO_2-fluxes measured with a single eddy covariance complex with soil respiration data obtained with a **closed soil chamber system**.

Experimental setup



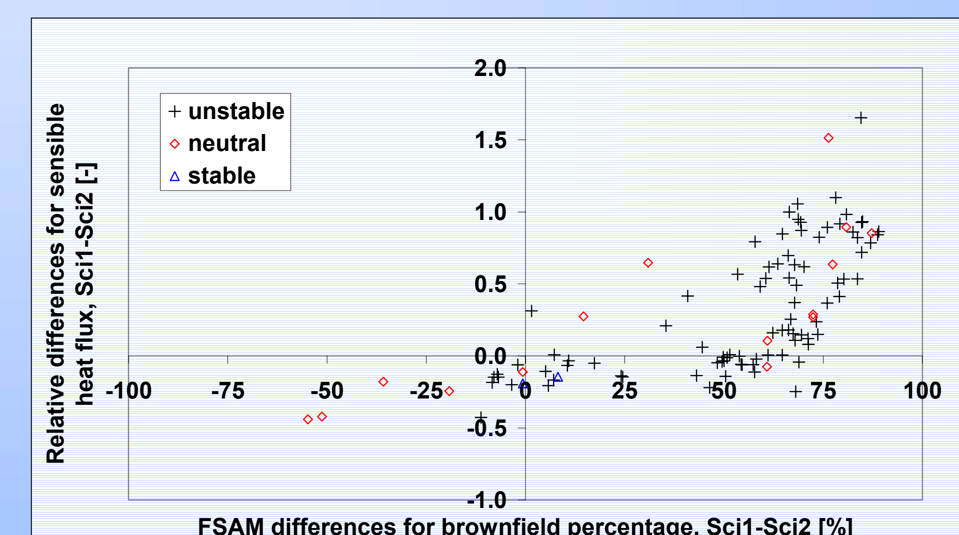
The measurements were performed at the boundary layer field site GM Falkenberg (Meteorological Observatory Lindenberg, German Meteorological Service) in the 2. Special Observation Period (SOP2) of the VERTIKO project.

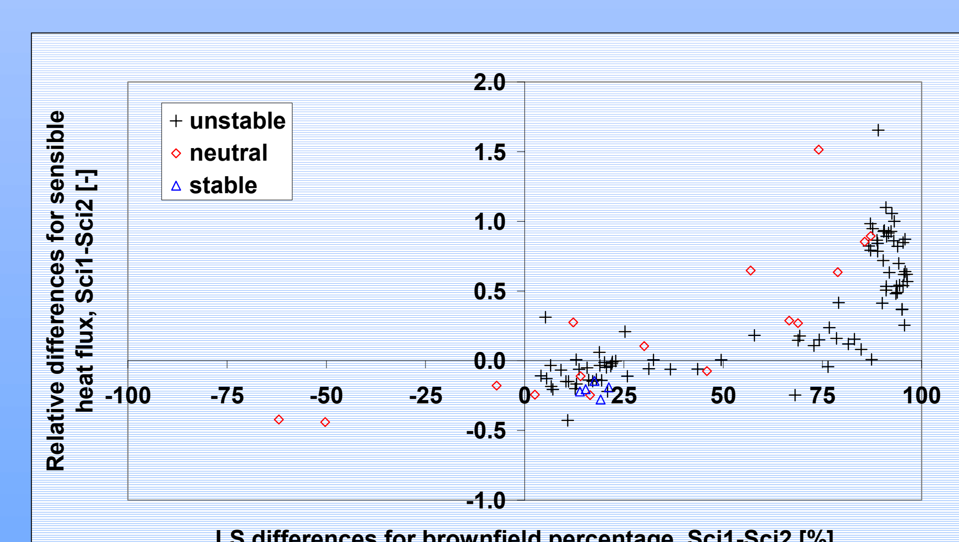
Model impact on the land use evaluation



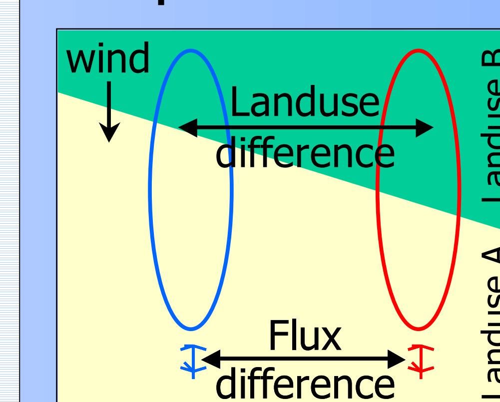
The different characteristics of the footprint models used have a significant impact on the computed land use composition in the source area. The LS model produces source weight functions with peaks closer to the tower, so that for the EC position 1 especially in stable stratification the flux contribution of the brownfield area is higher compared to the analytic model.

Fluxes differences vs. land use differences



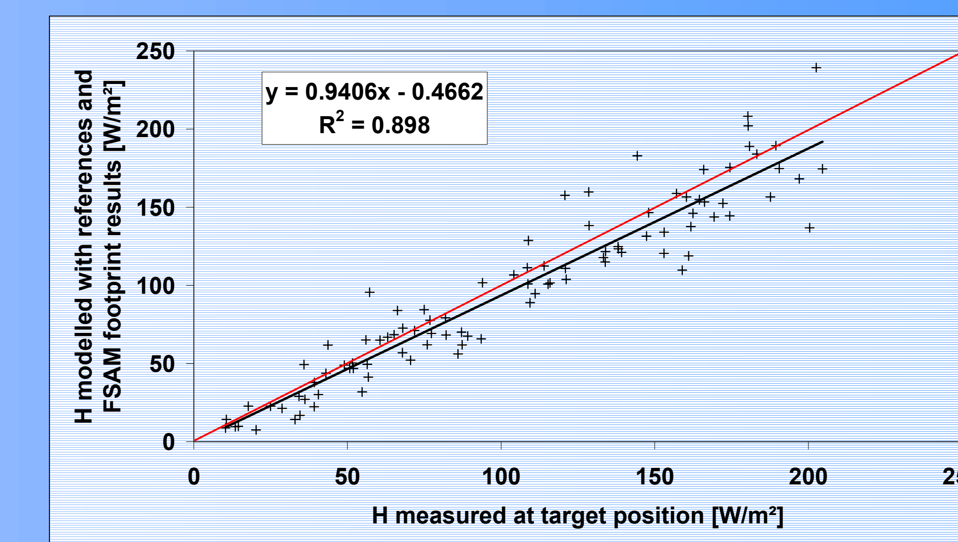


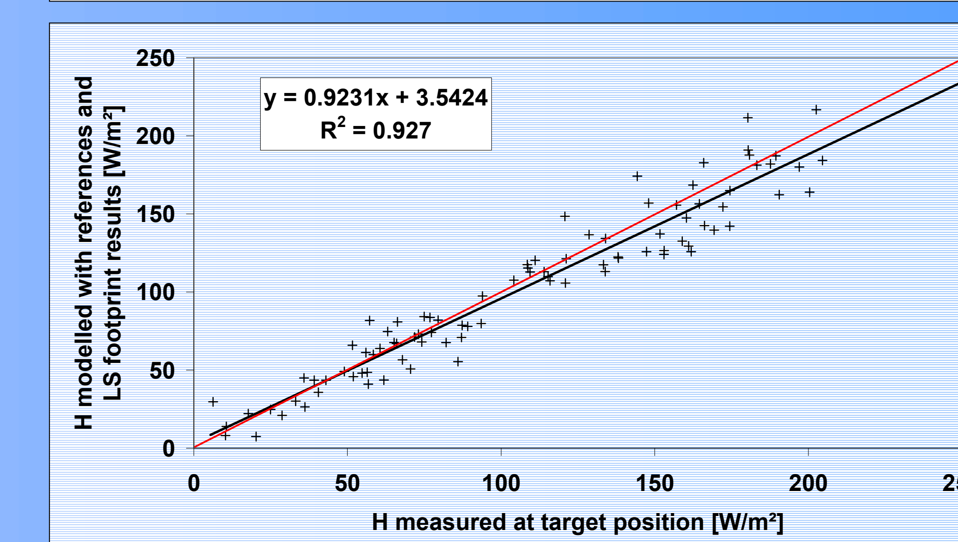
Concept:



A comparison of fluxes and land use results is shown on the left for the scintillometer paths 1 and 2. For both the analytic FSAM and the Lagrangian stochastic model it was found that high relative flux differences correspond with high flux percentage differences of the brownfield area. However, the scatter is so large that a statistical evaluation is not possible, so that this kind of comparison does not allow for a thorough model validation.

Measured fluxes vs. modelled fluxes





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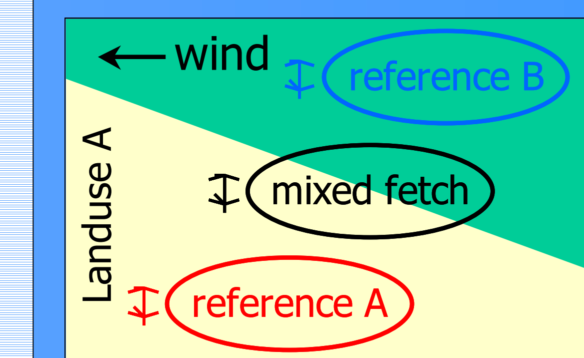

This approach is interpreted statistically by fitting a linear regression line to the comparison of fluxes measured at the mixed fetch position and modelled using the references and the footprint results. In the examples shown in the figures on the left, which were obtained with data of the 4 eddy covariance stations, the Lagrangian stochastic model produces a data set with a slightly better correlation than the analytic FSAM, as indicated by the stability index R^2. A similar result could be obtained for the Scintillometer data.

Footprint model validation results

In general, both footprint models tested allow to compute a land use composition in the source area that agrees with the fluxes measured at the specific position. However, although the differences found are only small, the analyses performed indicate that **the Lagrangian stochastic model allows to produce results that correlate slightly better** with the measurement data than the analytic FSAM. The results obtained are compromised by scatter induced by the non-uniform instrumentation, and thus could be further improved by a modified experimental setup.

Conclusions for future studies

Studies using natural tracers clearly have the potential to serve as an accurate validation instrument for the performance of footprint models. Therefore they provide a practical and cheap alternative to the more complicated tracer experiments. For future studies, the following findings of the analyses presented should be considered:

- **Instrumentation**: The comparison of data derived by a closed soil chamber system with eddy covariance measurements proved to be unsuitable for this approach due to large systemic differences between both techniques. Using several eddy covariance towers, a uniform instrumentation should be chosen to avoid additional scatter. Scintillometers provide a very good data base due to the high correlation between individual sensors.
- **Approach:** A comparison of measured fluxes at a mixed fetch position with modelled fluxes derived by footprint results and reference fluxes gives the most suitable validation results.
- **Experimental setup:** The site should be composed of 2 types of land use with significant differences in heat flux characteristics and similar roughness. If possible, the mixed fetch position should be a profile mast with uniform sensors at different heights.

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VERTIKO

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