Abstract, Contributions by Olaf Menzer to the AmeriFlux Management Project

Mapping AmeriFlux footprints: Towards footprint model processing across a network of flux tower sites

In this research project, I addressed the feasibility and challenges of footprint model application across a wide range of biomes within the AmeriFlux network. Footprint models provide source calculations to attribute ecosystem fluxes to specific surface areas. Such calculations are needed for data synthesis studies and can support flux up-scaling to larger regions, for example, when combined with remote sensing data. However, flux footprints are not currently being routinely processed; different approaches exist but have not been standardized yet. In part, this is due to varying instrumentation and data processing methods at the site-level, resulting in heterogeneous data sets. The goal of this work was to evaluate tower footprint models across different sites, aiming at a future AmeriFlux product to be generated at the network level.

My key contributions to this project included data assimilation and processing, footprint model evaluation using statistical and visualization techniques, as well as the implementation of parallelized processing routines. First, the data processing involved inquiring for specific footprint model input variables not currently in the database and directly contacting principal investigators. This was crucial to understand site specific parameters, and also to formulate which meta data will be needed for the implementation of standardized processing routines. I summarized which variables commonly collected at flux tower sites will be needed as model input. In turn, this lead to the decision to include variables such as the variance of the cross wind speed in future releases of the data base. In addition, reaching out to the scientific community resulted in several new sites joining the AmeriFlux network.

Next, I evaluated the following two different models to compute flux footprints. The model by Kormann & Meixner (2001) calculates an analytical solution of the advection-diffusion equation in the surface layer. It uses an exponential mean wind profile, an eddy diffusivity and Monin Obukhov similarity theory. By comparison, the model by Kljun et al. (2004) is a parameterisation of model calculations from a three-dimensional Lagrangian particle dispersion over a range of atmospheric stratifications from advective to stable. Both models can estimate crosswind integrated (one-dimensional) and crosswind distributed (two-dimensional) representations of the theoretical footprint functions.

After the footprint model code was integrated into a processing framework, I implemented a parallelization of the footprint calculations which was important to speed up the evaluation of several tower sites in synthesis. Preliminary results for six AmeriFlux and two ICOS sites show reasonable agreement among the different footprint models for daytime unstable atmospheric conditions, and larger differences during nighttime stable conditions. Overall, there was higher variability in footprint estimates at night compared to daytime, predominantly during winter. Along with providing a summary report to the participating investigators, I produced animated maps in video format that show the progression of the crosswind distributed footprints for several years of data and can be used for data interpretation within the AmeriFlux database. One of the principal investigators directly forwarded these maps to the forest service, showing where flux source areas are predominantly located at his site, in the hope for the re-assessment of a planned logging of trees.

I presented preliminary results of this study at the American Geophysical Union (AGU) Fall Meeting in December 2014 and at the North American Carbon Program (NACP) Principal Investigator Meeting in January 2015. At the NACP meeting, I also presented the work as an example case study during a breakout session on interoperability and synergy effects between research networks.