Highly accurate analytical footprint model for general stratification of the atmosphere

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The flux footprint (or so-called source area) is the zone of the surface that contributes to a measured vertical flux (e.g. of water vapor or carbon dioxide) between the ground and the atmosphere: Footprint models are then used to derive location and size of the source area and for interpretation of flux-tower measurements, in particular to estimate the contribution of passive scalar sources to these measured fluxes, and to combine measured fluxes with remotely sensed data.

Existing footprint models are of two types: either they derive from the solution of an advection-diffusion differential equation or they result from a parameterization based on numerical simulations performed with a Lagrangian stochastic particle dispersion model. Models of the first type are essentially based on the hypothesis of power-law profiles of the mean wind speed \( u(z) \) and eddy diffusivity \( K(z) \). Our objective was to suppress this constraint and to build a footprint model for any type of profile, in particular Monin-Obukhov surface-layer profiles.

The model was developed in the frame of the K-theory. Homogeneous conditions were assumed in the horizontal plane and the alongwind diffusion term was neglected with respect to the advection term. A semi-analytical tool has been developed to cope with any type of atmosphere stratification. Applying a dedicated quadrupole method, the boundary layer is divided into a series of sublayers and an extended power law model is applied in each of them (10 to 15 sublayers are enough to reach an error of less than 0.1%, whatever the atmosphere stability).

In the end, a highly accurate estimation of the footprint can be obtained very quickly for any profile of wind speed and eddy diffusivity.