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Nocturnal boundary layer budgets of carbon dioxide enabled by unmanned aircraft

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At night, stable stratification near the surface is frequently observed over land, making it difficult to measure fluxes by means of the eddy covariance technique. Boundary layer budgets are a promising alternative for the quantification of surface-atmosphere trace gas fluxes under stable conditions. However, the nocturnal boundary layer (NBL) budget method requires knowledge of a tracer's concentration over the full vertical extent of the stable boundary layer, which has been challenging to acquire in the past. We show that unmanned aerial vehicles (UAVs) can be used to reduce the experimental effort. In July 2016 we carried out a preliminary study in a rural area in southern Germany as part of the ScaleX campaign. We profiled the NBL repeatedly using a custom-built carbon dioxide analyser that was carried by a multicopter. The budgets created from these data yield carbon dioxide fluxes that are plausible in comparison to other flux measurements at the site. We demonstrate how Lagrangian transport modelling can be employed to calculate the footprint of these NBL budgets.