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Urban boundary layer structure of Stuttgart observed by ground-based remote sensing

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The awareness of the impacts of air quality on human health have led to regulatory measures that aim to reduce particulate matter concentrations in Europe's major metropolitan areas. In Stuttgart, Germany, the air quality thresholds prescribed by law are often exceeded at street level, as the town's situation in a bowl-shaped basin furthers the accumulation of pollutants during weak-wind conditions. The current measures include a public alarm system ('Feinstaubalarm') that is intended to stimulate motor vehicle drivers into using public transport. However, if the voluntary actions to reduce emissions show ineffective, then traffic limitations may need to be enforced in the most affected areas. The alarm is set based on weather forecast and an air quality monitoring network at street level. The required forecasting skill to assess street level air quality in separate city areas would require precisely operating model chains in order to resolve the processes and surface-atmosphere interactions involved, which in turn depend on detailed knowledge of the (vertical) structure and the evolution of the urban atmospheric boundary layer (ABL) in such complex conditions.

We aim to elucidate patterns of vertical structure development of the ABL in complex, urban, non-idealized conditions. Three-dimensional observations of the ABL were collected in the City Centre of Stuttgart between February and August of 2017, as part of a Federal Ministry of Education and Research (BMBF) initiative on Urban Climate Under Change ($[UC]^2$). A laser ceilometer and a network of three scanning Doppler lidar systems were deployed on roof tops in the city centre, providing continuous observations of the cloud base, the mixing-layer height and vertical/horizontal profiles of the wind field in a 1 km^3 domain. We discuss results of the contrasting evolution of vertical structure patterns between typical winter and summer days as well as the limitations of the tripple Doppler Lidar application. The findings highlight the influence of topography and spatial variability in the urban built-up form on the flow field in the ABL and the development of local circulations in a complex urban setting.