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Boundary layer coherent structures and circulations viewed through collocated wind lidar and cloud radar profiling

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The horizontal resolution of weather models is increasing, which demands a careful consideration of momentum and energy transport carried across different scales. Deep convective transport and even shallow convective transport, which were previously parameterized, are now resolved, while turbulence remains parameterized. Can observations help constrain the transport by turbulence, coherent structures associated with convection and mesoscale circulations coupled to organized cloud systems?

Using a novel experimental setup for deriving high-resolution continuous wind profiles across the boundary layer, our objective is to provide a fresh view on the variability in horizontal and vertical wind in the presence of a range of (shallow) cloud systems over land, as well as to derive the wind variance and momentum fluxes, and a quantitative assessment of the relevant scales.

The experimental dataset is collected during the Tracing Convective Momentum Transport in Complex Cloudy Atmospheres experiment (CMTRACE). The field campaign occurred at the experimental Cabauw site (The Netherlands) between 13.09.2021 and 03.10.2021 and between 16.05.2022 and 13.06.2022. For this experiment, a cloud radar and wind lidar were operated at 75 degrees elevation, providing horizontal and vertical wind observations within and below the cloud layer. The combined lidar-radar's wind profiles have a vertical resolution of 50 m and a temporal resolution of ~1.5 minutes (which is representative of a horizontal scale of 450 - 1800 m). During CMTRACE, a large variety of cloud regimes were sampled, from non-precipitating shallow convection to deep convective clouds and stratiform clouds.

The observations reveal both coherent thermals (up and downdrafts) and mesoscale divergence and convergence patterns. The scale growth of horizontal momentum variance and flux is well explained by vertical velocity variance, whereby larger vertical velocity variance corresponds to a larger contribution of scales < 35 km to total momentum variance and flux. Additionally, precipitation is shown to separate days on which larger mesoscales contribute to horizontal momentum flux, and the presence of larger cloud structures is confirmed using cloud spatial statistics as viewed from satellite. In an outlook, the representation of these different flows in large-eddy simulation and regional weather hindcasts from the Dutch weather model HARMONIE is evaluated.

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