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Ceilometer-based Rainfall Rate estimates in the framework of VORTEX-SE campaign: A discussion

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During Spring 2016 the first season of the Verification of the Origins of Rotation in Tornadoes EXperiment-Southeast (VORTEX-SE) was conducted in the Huntsville, AL environs. Foci of VORTEX-SE include the characterization of the tornadic environments specific to the Southeast US as well as societal response to forecasts and warnings. Among several experiments, a research team from Purdue University and from the University of Massachusetts Amherst deployed a mobile S-band Frequency-Modulated Continuous-Wave (FMCW) radar and a co-located Vaisala CL31 ceilometer for a period of eight weeks near Belle Mina, AL. Portable disdrometers (DSDs) were also deployed in the same area by Purdue University, occasionally co-located with the radar and lidar. The NOAA National Severe Storms Laboratory also deployed the Collaborative Lower Atmosphere Mobile Profiling System (CLAMPS) consisting of a Doppler lidar, a microwave radiometer, and an infrared spectrometer. The purpose of these profiling instruments was to characterize the atmospheric boundary layer evolution over the course of the experiment.

In this paper we focus on the lidar-based retrieval of rainfall rate (RR) and its limitations using observations from intensive observation periods during the experiment: 31 March and 29 April 2016. Departing from Lewandowski et al., 2009, the RR was estimated by the Vaisala CL31 ceilometer applying the slope method (Kunz and Leeuw, 1993) to invert the extinction caused by the rain. Extinction retrievals are fitted against RR estimates from the disdrometer in order to derive a correlation model that allows us to estimate the RR from the ceilometer in similar situations without a disdrometer permanently deployed. The problem of extinction retrieval is also studied from the perspective of Klett-Fernald-Sasano's (KFS) lidar inversion algorithm (Klett, 1981; 1985), which requires the assumption of an aerosol extinction-to-backscatter ratio (the so-called lidar ratio) and calibration in a molecular reference range. The latter is hampered by the limited dynamic range of the ceilometer under rain events, which usually makes it difficult to properly record the reference-range interval.

The RR is also compared to estimates by the FMCW radar, which provides vertical profiles of reflectivity and Doppler spectra, from which DSDs and rainfall rates can be inferred more directly. Ceilometer-derived RRs are compared with RR radar estimates for the same days in order to identify pros and cons of the proposed approach.

Following Westbrook et al. (2010), we also consider the estimation of rain rates using two-color lidar, which is limited to drizzle and low rain rates. The key to this method is that the Doppler lidar's wavelength (1.5 μm) is partially absorbed by the liquid, and thus it is a differential absorption technique.

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