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Using atmospheric path-tracing as a simple hemispheric simulator to test stereo camera reconstructions of 3-dimensional boundary layer cloud fields

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Measurements of shallow cumulus cloud properties at meteorological sites are of crucial importance to evaluate Large-Eddy Simulations (LES) of this cloud regime, as well as its parameterized representation in numerical weather and climate models. However, to this date, these datasets have mainly consisted of vertical, one-dimensional profile data, often sampled with remote sensing equipment such as lidar or radar. A recently explored new method for adding multi-dimensional information is to use hemispheric images from a network of multiple cameras. Such networks observe shallow cumuli in unprecedented spatial detail and at ultra-high frequency. Fisheye cameras provide a large field of view, which enables the observation of complete shallow cumulus life cycles. Camera networks can thus strongly complement the existing instruments at a site, yielding unprecedented new insights into cumulus cloud field geometry, dynamics, and evolution. One possible way to independently assess the accuracy of camera networks is to apply it to virtual cloud fields as generated with LES, acting as truth in an Observation System Simulation Experiment (OSSE). However, for this purpose virtual hemispheric camera projections of the LES cloud fields are needed.

In this study, we combine Beer-Lambert radiative transfer with an open-source Monte Carlo path-tracing code to generate such projections. The method is applied to simulate a network of multiple stereo cameras as currently installed at the Jülich Observatory for Cloud Evolution (JOYCE), Germany as part of the ongoing SOCLES project. Three-dimensional LES cloud fields for selected days are used as input. Hemispheric projections are then generated and provided to the existing algorithm for generating three-dimensional fields from actual stereo camera images. Comparing the latter to the input LES fields then allows precise error estimation. One goal is to, thus, find out how much of an arbitrary three-dimensional cloud field can, in theory, be reliably detected by a stereo camera setup. A second goal is to use this information to optimize the configuration of the stereo camera network at the site.

We find that the hemispheric path tracing projections can function well in this workflow. For the selected days we find that 81% of the reconstructable cloudy grid boxes in an LES cloud field is reconstructed by the stereo camera algorithm. Modest dependence on reconstruction tolerance is reported, while dependence on camera distance is also investigated.