Observing Warm Clouds in 3D Using ARM Scanning Cloud Radars and a Novel Ensemble Method

Research Highlight

Boundary-layer clouds make a significant contribution to the planetary albedo and thus are fundamentally important to the Earth's radiation budget. Due to their complex turbulent structures, coupled with a strong susceptibility to aerosol, they remain a key source of uncertainty in climate projections. While Atmospheric Radiation Measurement Climate Research Facility (ARM)'s long-term observations from vertically pointing radar have been invaluable for observing detailed processes for boundary-layer clouds and improve their representation in models, elucidating the 3D structure of clouds from just a profile view is difficult. To tackle this problem, ARM now has a collection of scanning cloud radar strategically positioned at observation sites across the world.

To take full advantage of these new scanning radar measurements, researchers at the University of Reading have developed a novel ENsemble ClOud REtrieval (ENCORE) method to provide 3D fields of cloud water content and droplet size in both overcast and broken cloud conditions. As illustrated in Figure 1, ENCORE involves three key components: 1) reconstruction of 3D radar reflectivity where scans are made perpendicular to the wind; 2) synergy between radar reflectivity and shortwave radiances over a focused area dubbed "supercolumns," using an ensemble optimal estimation approach and 3D radiative transfer; and 3) match-up between donors within the supercolumns and recipients outside the supercolumns. Uncertainty due to measurement error in overhead clouds is about 20 percent in cloud water content and 6 percent in cloud effective radius from an evaluation using large eddy simulations.

Using ARM Mobile Facility measurements at the Azores in 2009, Figure 2 shows 3D cloud retrievals for overcast stratocumulus and challenging shallow cumulus. The track of radiances for both cases is along y-axis at 2.5 km, with the clouds passing along the x-axis from positive to negative. For the stratocumulus case, ENCORE shows good agreement with independent retrievals of liquid water path (LWP) along the radiance track from the two-channel microwave radiometers with an error of 20 gm^{-2}, which is comparable to retrieval uncertainty. Interestingly, for the shallow cumulus case, microwave radiometers have difficulty in capturing such clouds that have low water path and highly heterogeneous structure. This highlights that the introduction of the new scanning radars can greatly enhance cumulus observations.

These new observations open the door to many new lines of research and ultimately will help unravel the influence of aerosol on clouds in both a macrophysical and microphysical sense. They will also give insight to the 3D radiative properties of boundary-layer clouds.

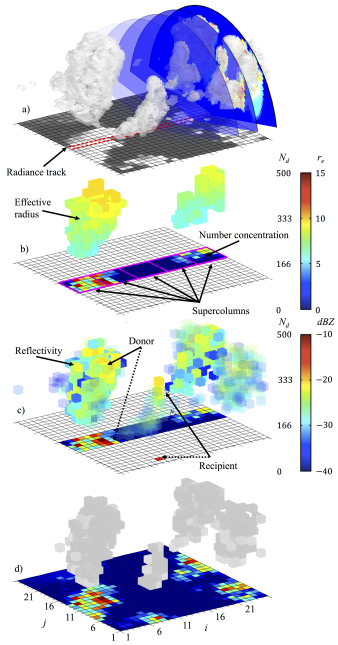

Figure 1. Diagram showing the main steps of the ENsemble ClOud REtrieval method (ENCORE). a) Gathering of radiance (red dashed lines) and radar reflectivity (hemispherical slices) observations, b) retrieved drop number concentration and effective radius within each supercolumn (magenta boxes), c) reflectivity matching of donor columns (solid) to recipient columns (translucent), and d) completed retrieval.

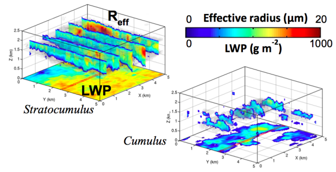

Figure 2. Example of retrieved 3D cloud properties in two different cloud types over the Azores.

Reference(s)

Fielding MD, J Chiu, RJ Hogan, and G Feingold. 2014. "A novel ensemble method for retrieving properties of warm cloud in 3-D using ground-based scanning radar and zenith radiances." Journal of Geophysical Research – Atmospheres, 119(18), doi:10.1002/2014JD021742.

Contributors

Mark D. Fielding, *University of Reading*

Working Group(s)

Cloud Life Cycle, Cloud-Aerosol-Precipitation Interactions