Analysis of hydrometeor vertical velocities in non-drizzling to heavily drizzling stratocumulus: Simulations versus long-term observations

J. Rémillard [1,2], A. S. Ackerman [2], A. M. Fridlind [2], P. Kollias [3], E. Luke [4], and G. Tselioudis [2]

1 Columbia University in the City of New York
2 NASA National Aeronautics and Space Administration, Goddard Institute for Space Studies, New York, N.Y.
3 McGill
4 Brookhaven National Laboratory

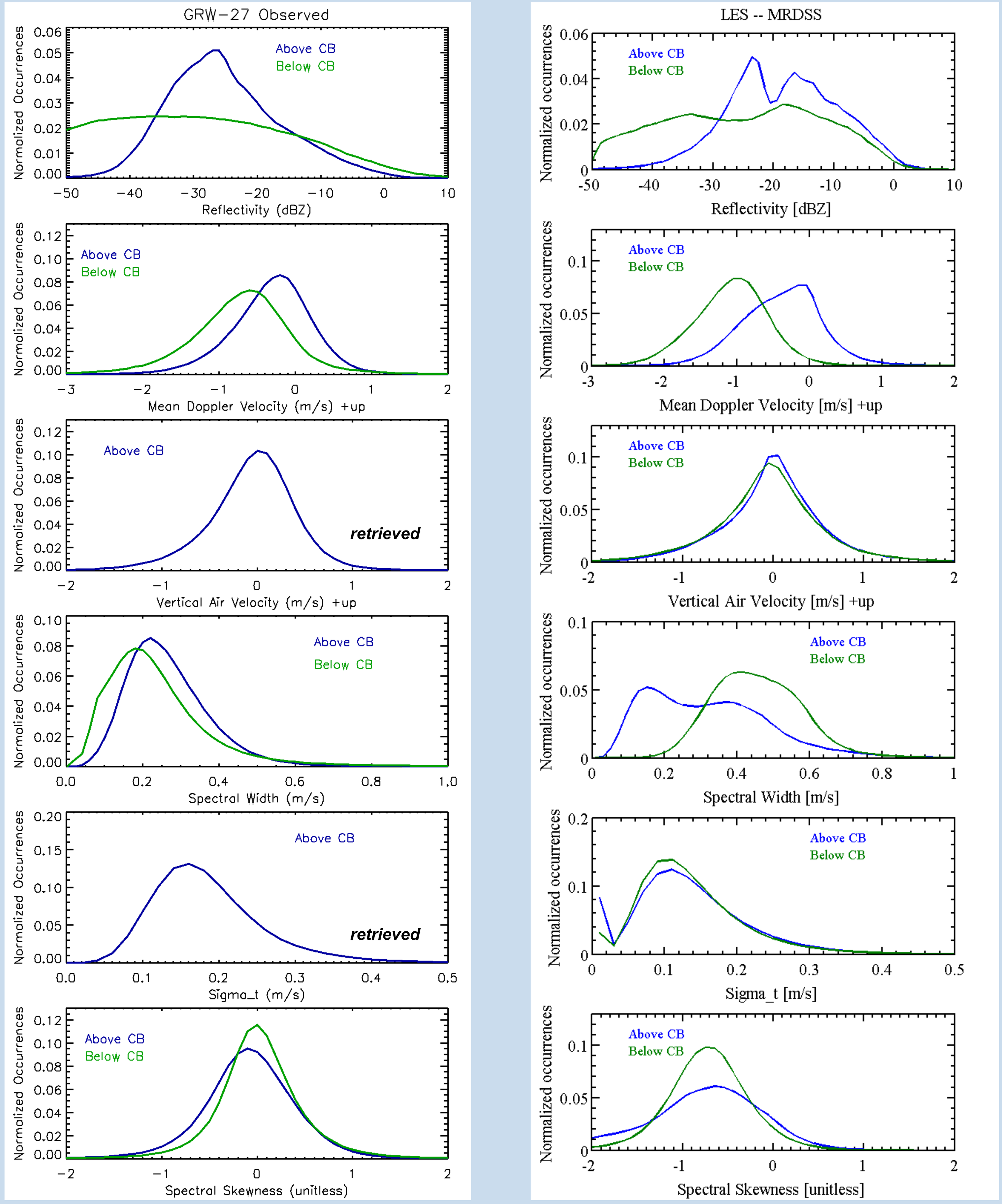
Background

In 2009–2010, the W-band profiling cloud radar deployed for the CAP-MBL campaign in the Azores sampled 27 days of marine boundary-layer clouds. Here, we compare large-eddy simulations (LES) to radar measurements and retrievals obtained during those days, to examine the fidelity of modeled drizzle properties.

Two North Pacific stratocumulus case studies are simulated using the DHARMA LES code with size-resolved (bin) micro-physics (*Ackerman et al. 2004*):

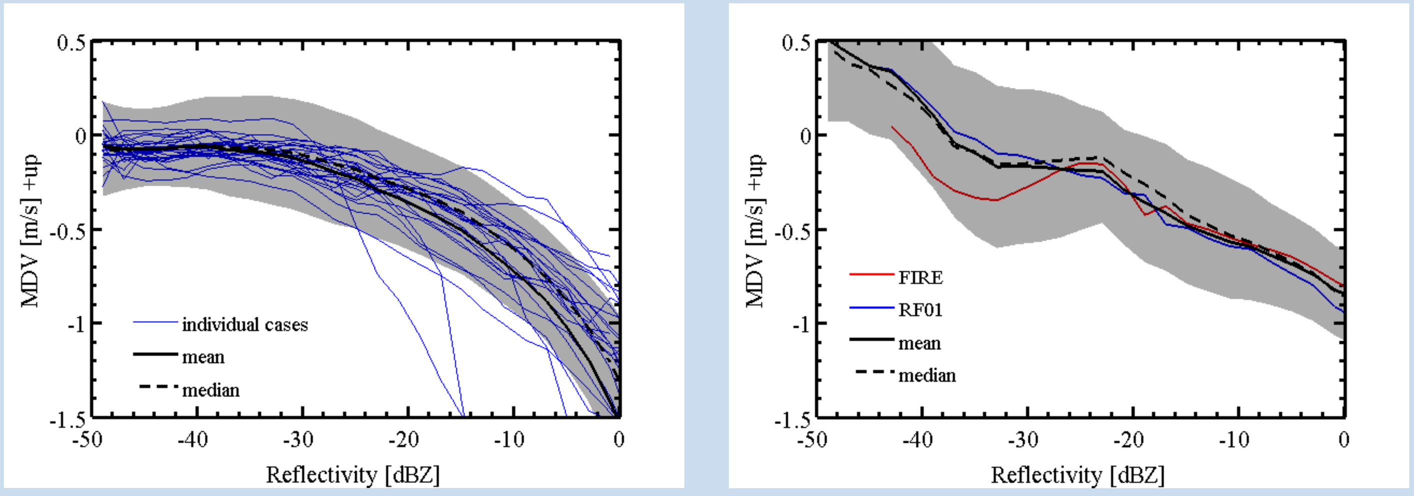
- → **FIRE**: 25 bins, CCN=75,150,600 cm^{-3}, 350-450m thick, based on FIRE-I campaign
- → **RF01**: 20 bins, CCN=40,75,150,300,600 cm^{-3}, 250-350m thick, based on DYCOMS-II campaign

The droplets bins are structured such that mass doubles between bins for FIRE, and about that for RF01. Both cases are 8-h nocturnal simulations sampled hourly, with the last 5 hours included in the following statistics. The McGill Radar Doppler Spectra Simulator (MRDSS) is applied to emulate cloud radar Doppler spectra from the LES results.

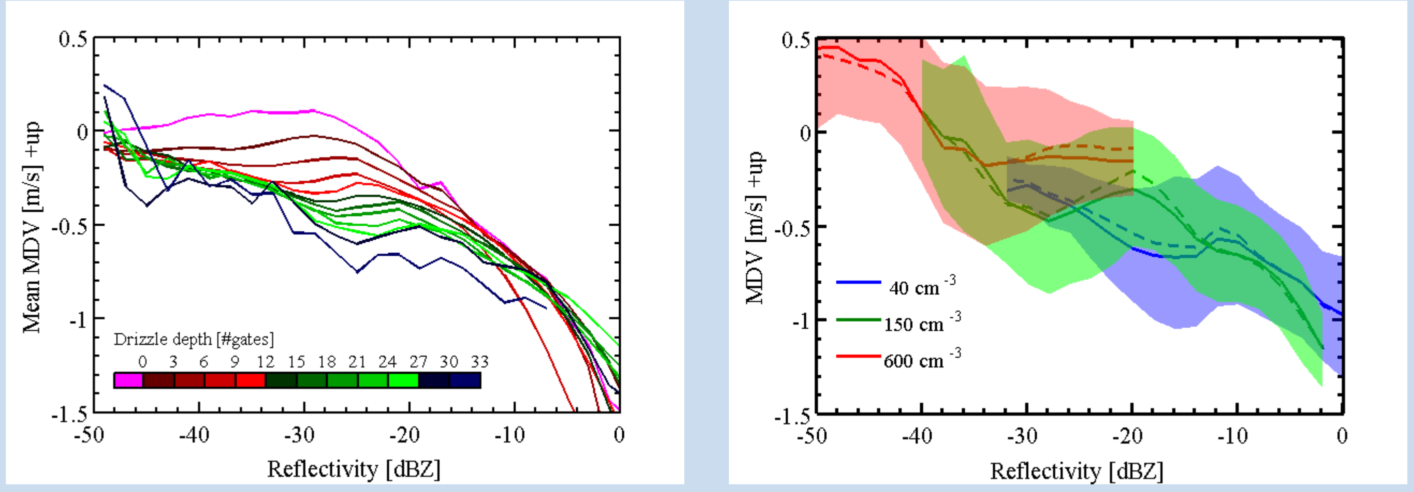


In-cloud relation between Z and MDV

Combining all the observations, a robust relation is found between the reflectivity and the Doppler velocity measured in the clouds. Reproducing it with the LES is challenging, raising some interesting properties of drizzle growth model.

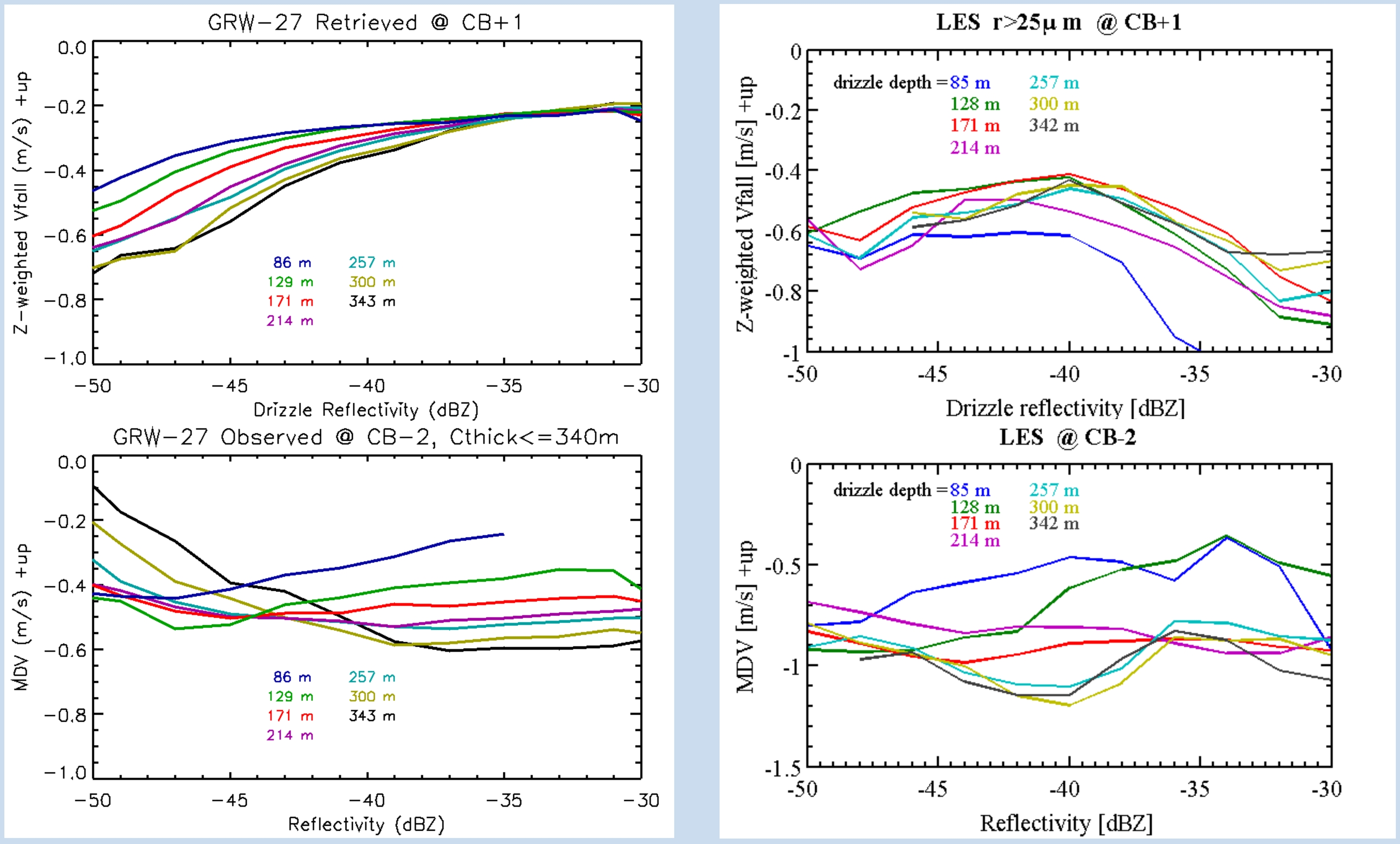


When separating the simulations by CCN numbers, a wiggle appears in the curves. Similarly, segregating the observations by the drizzle depth below CB, a gradual shift appears in the relation, although much weaker.



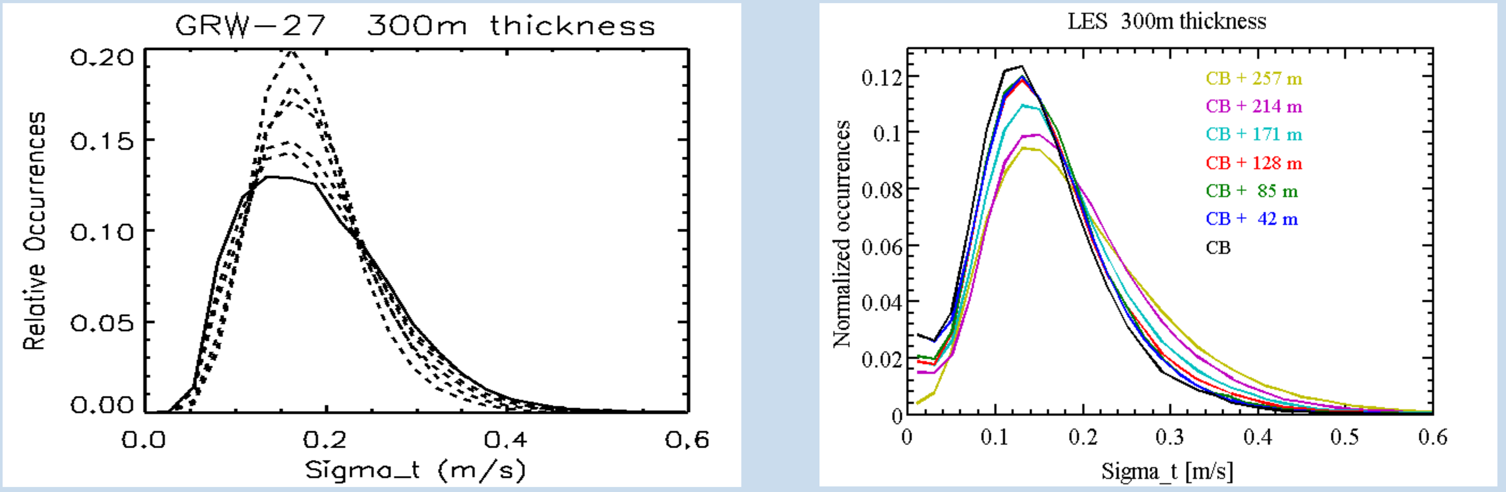
MDV and D⁶-weighted fall speeds for drizzle

Investigation of the above relation in the observations brought forward further interesting behaviors. Here, we look at drizzle properties retrieved just above CB and measured below CB. At both levels, in shallow drizzle events, hydrometeor vertical velocities become increasingly more downward as reflectivity decreases. This could be an effect of size-sorting.



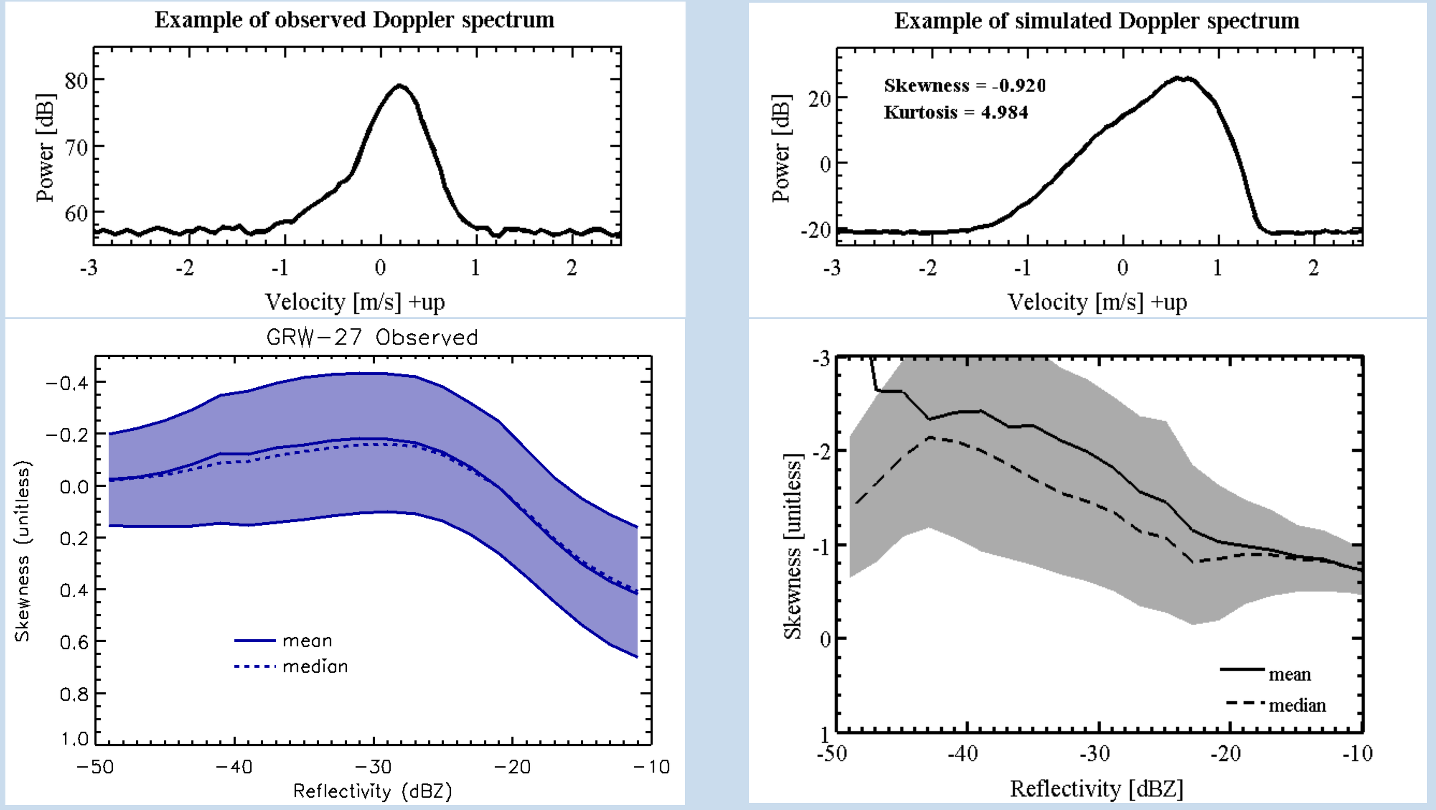
In-cloud turbulence

Retrievals of turbulence broadening in the observations are possible inside lightly drizzling clouds where the spectral cloud peak is detectable (*Luke and Kollias 2013*). For the LES, this term is directly computed by the MRDSS using the simulated eddy dissipation rate. Its dependence on height above CB is shown here for 300m-thick observed and simulated clouds. The agreement is encouraging.



Higher moments *(very preliminary)*

Work is under way to compare the full radar Doppler spectra emulated from the LES results to the observed ones. To get there, higher spectral moments such as the skewness can be compared. This quantity measures the asymmetry of the peak, with positive/negative values representing a peak with more power in its right/left side. There appears to be a lack of positive skewness in the spectra simulated inside the cloud, which needs to be investigated.



References

Ackerman, A.S., M.P. Kirkpatrick, D.E. Stevens, and O.B. Toon, 2004: *Nature*, **432**, 1014–1017.

Luke, E., and P. Kollias, 2013: *J. Atmos. Oceanic Technol.*, **30**, 1656–1671.

Contact: jr3343@columbia.edu