What is the best analytical fit to drop spectra in drizzling stratocumulus?

Yefim L. Kogan, Zena N. Kogan, and David B. Mechem

Cooperative Institute for Mesoscale Meteorological Studies, The University of Oklahoma, Norman, OK

Motivation and Objective

❖ Remote sensing microphysical retrieval and cloud microphysics parameterizations rely on a knowledge of the shape of cloud drop size distributions (DSD). These are often approximated by Gamma, lognormal, or, more specifically by Khrgian-Mazin, Marshall-Palmer type distributions.

❖ We ask the question which functional form approximates best the drop size distributions in drizzling stratocumulus?

❖ Specifically, we evaluate the accuracy of lognormal and Gamma-type distributions in approximating higher moments of the DSDs based on datasets generated in simulations with LES explicit microphysics model.

Description of Data

The study is based on the CIMMS LES model with explicit size-resolving microphysics.

We simulated several cases of stratocumulus clouds observed during the ASTEX field experiment.

The simulations represent cloud layers with different intensities of drizzle in the cloud (Fig. 1) and provided over 19,200 DSDs for each case.

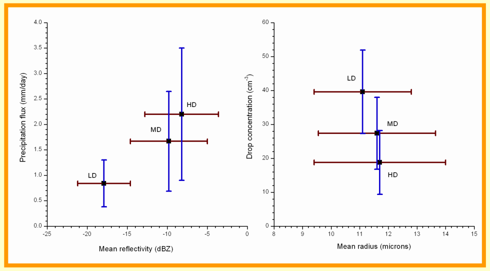

Fig 1. Mean and standard deviation of drop spectra parameters for light (LD), moderate (MD) and heavy (HD) drizzling cases.

Method

The three parameter lognormal fit (*L-fit*) is:

$$n(r) = \frac{N}{\sqrt{2\pi}\, r\sigma} \exp\left[-\frac{1}{2}\left(\frac{\ln r - \ln r_m}{\sigma}\right)^2\right]$$

where r_m is the modal radius, N concentration, and σ logarithmic drop spectrum width.

The three parameter Gamma fit (*G-fit*) is:

$$n(r) = \frac{N}{\Gamma(\alpha+1)\beta^{\alpha+1}} r^{\alpha} \exp\left(-\frac{r}{\beta}\right)$$

where parameters are N, α and β. $\Gamma(x)$ is the gamma function.

The three parameters defining each fit are expressed through the 0th, 1st and 2nd moments of the LES derived DSDs. The 4th and 6th moments of the fit are then compared with corresponding moments of the DSD from the LES dataset. Note that in Sc these moments represent drizzle flux and reflectivity.

Depending on drizzle intensity, drop spectra in Sc may exhibit one or two modes, with the 1st mode representing cloud (r<25µm) and the 2nd drizzle drops (r>25µm).

We, therefore, consider two fit types. The unimodal fit is defined by three parameters expressed through moments of the DSD integrated *over the whole drop size range*.

The bimodal fit is a sum of two fits defined by three parameters expressed through partial moments integrated over the *cloud drop* sizes, and another three through moments integrated over the *drizzle drop* sizes.

The number of parameters can be reduced from 6 to 4 by assuming a fixed drop spectrum width for cloud and drizzle drops. These 4 parameters can be matched to 4 predictive variables of a two-moment cloud microphysical parameterization.

Results

Unimodal analytical fits

In the LD case (Fig 2) the rain rate is rather well approximated by a unimodal *L-fit*, although the reflectivity is overestimated.

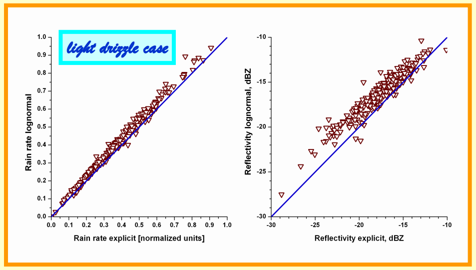

Fig. 2. Approximation of rain rate and radar reflectivity by a unimodal L-fit.

For the HD case (Fig 3), the unimodal fits fail to capture contribution from the tail of the spectrum; thus, rain rate and radar reflectivity are significantly underestimated by either an *L-fit* (left), or a *G-fit* (right panels).

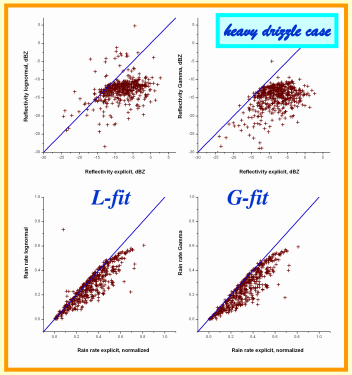

Fig. 3. Rain rate and radar reflectivity approximated by a unimodal fit.

Bimodal analytical fits

Fig 4 shows the performance of bimodal fits in the heavy drizzle case. The comparison between Figs 4 and 3 reveals that:

1) bimodal fits result in significantly smaller bias relative to the unimodal fits, and

2) the bimodal *G-fits* have a substantially reduced scatter and a much smaller error envelope (mean ± standard deviation) than *L-fits*.

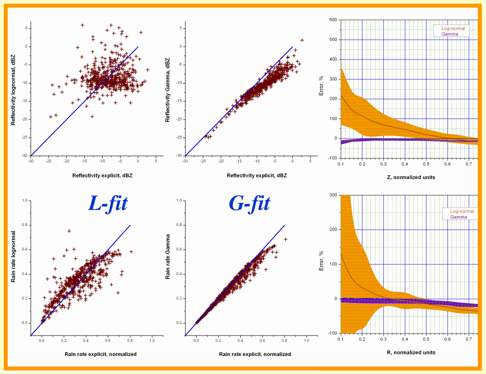

Fig. 4. Rain rate and radar reflectivity approximated by bimodal *L-* (*left*) and *G-fits (central panels)*. Right panels show errors of approximation of normalized rain rates *R* and radar reflectivity *Z*. Radar reflectivity range (-35, +5) dBZ was linearly transformed into (0, 1) interval.

Conclusions

❖ The fidelity of lognormal and Gamma type analytical fits for approximation of higher moments of drop spectra in drizzling stratocumulus was evaluated based on dataset obtained in simulations with CIMMS LES explicit microphysics model

❖ We found that bimodal fits are significantly more accurate than unimodal

❖ The Gamma-type bimodal fits represent rain rates and radar reflectivities much more accurately than lognormal fits.

Acknowledgments. This research was supported by the Office of Science (BER), U.S. Department of Energy, Grant No. DE-FG02-05ER64062 and by the Office of Naval Research, DOD.