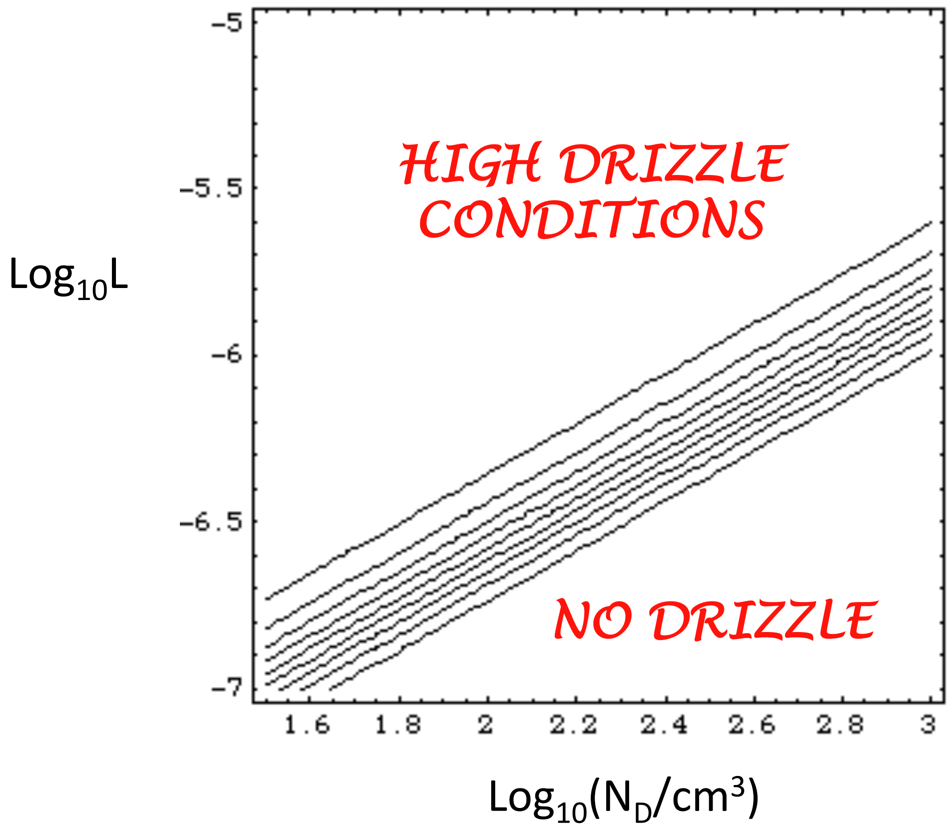
Exploring the role of turbulence in parameterization of the cloud-to-drizzle transition



T_{LDM} contours of constant drizzle rate in the transition region*

Turbulence parameter empirically assigned in LDM

N_D = droplet concentration (cm^{-3})

L = liquid water fraction (cm^3cm^{-3})

***Y. Liu, P. H. Daum & R. McGraw, GRL 32, L11811 (2005)**

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MICROPHYSICAL MODEL FOR TURBULENT CONDENSATION/EVAPORATION GROWTH

R. McGraw and Y. Liu, GRL 33, L03802 (2006)

Cloud droplets undergo diffusion-controlled growth

$$\frac{d}{dt} r^2 = k(T)(S-1)$$

$$= k(T)\left(\langle S \rangle - 1\right) + k(T)\left(S(t) - \langle S \rangle\right)$$

Drift *Diffusion*

Model for statistical properties of fluctuations in S(t)

$$\left\langle \left(S(t) - \langle S \rangle \right)^2 \right\rangle = \sigma_S^{\,2}$$

variance

$$\left\langle \left(S(t) - \langle S \rangle \right) \left(S(t+\Delta) - \langle S \rangle \right) \right\rangle = \sigma_S^{\,2} \exp(-\gamma\Delta)$$

autocorrelation

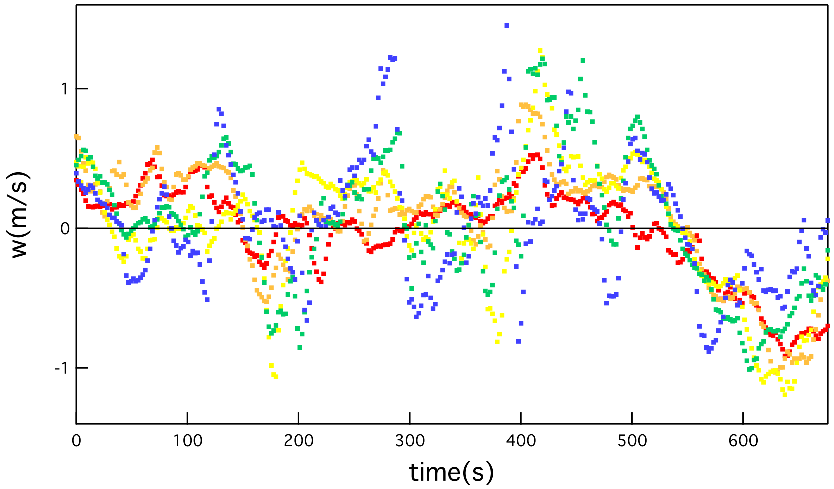
If Gaussian ⇨ *Brownian motion along the growth coordinate $z=r^2$*

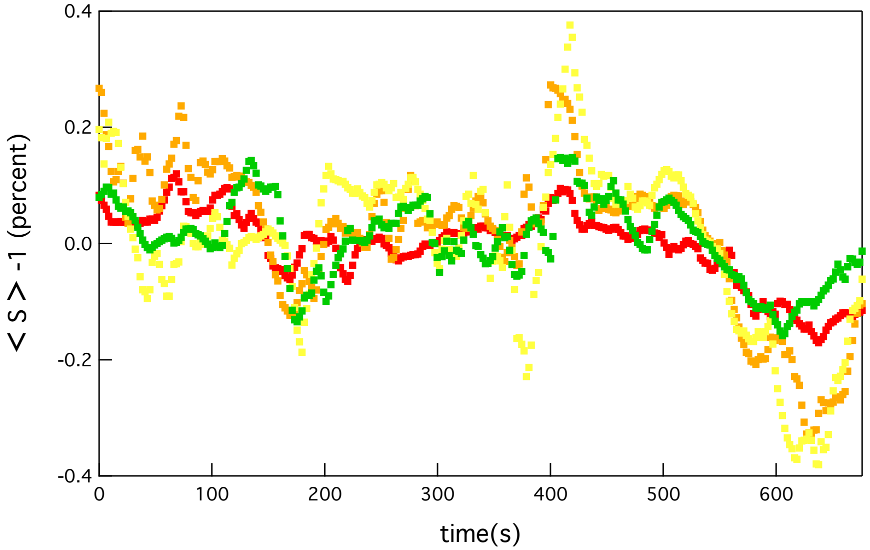
DOPPLER RADAR MEASUREMENTS AND IMPLICATIONS FOR DRIZZLE FORMATION

R. McGraw, E. Luke, and P. Kollias (in preparation)

The W-band (95GHz) ARM Cloud Radar

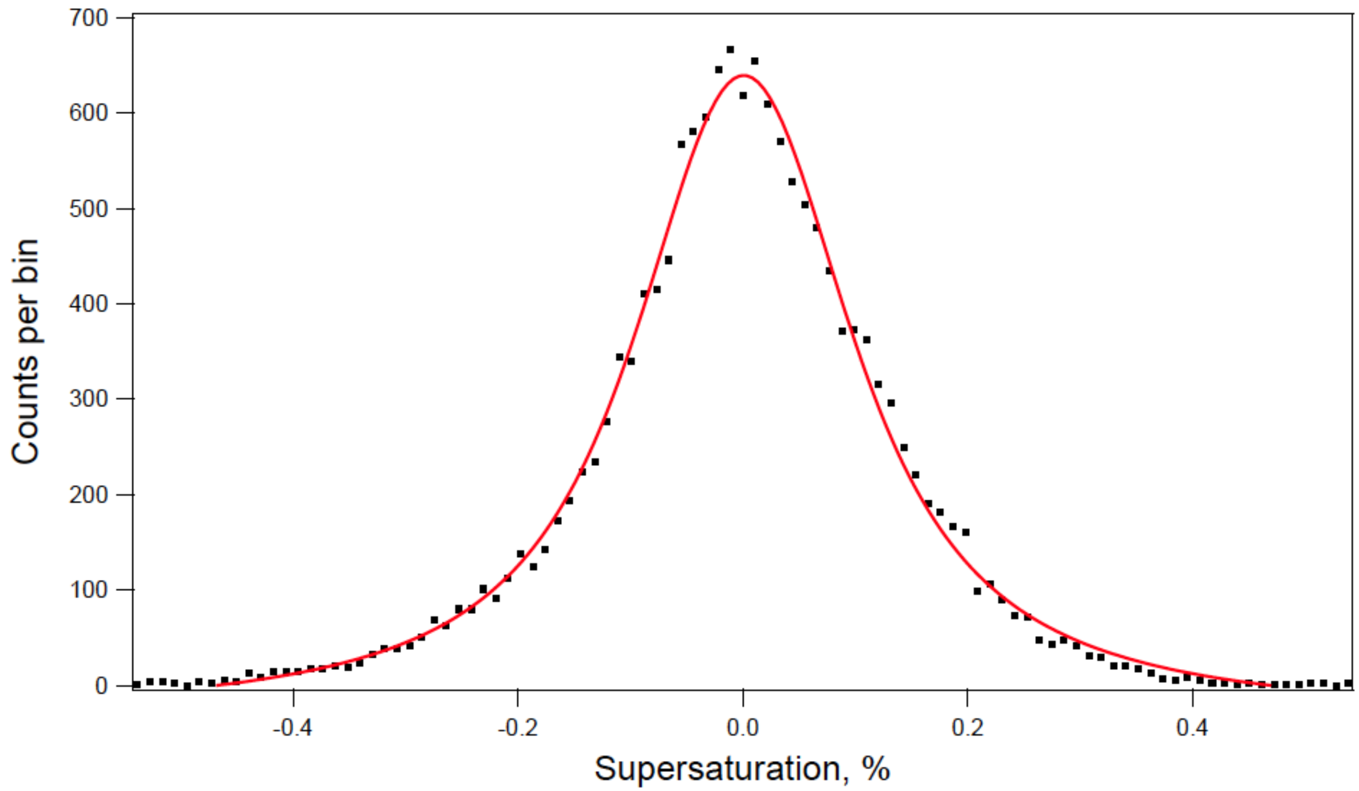
$$\langle S \rangle - 1 = \frac{d \ln L}{dz} \frac{w}{\pi k(T)} \left(\frac{L}{N_D} \right)^{2/3}$$





VOCALS *IN-SITU* MEASUREMENTS (G-1)

Marine stratus cloud: sampling distance = 2.5m; number of samples = 16000



black points: binned measurements from G. Senum *red curve: fit to Voight distribution*

$$S - 1 = \frac{d\ln L}{dz}\,\frac{2}{3}\,\frac{w}{k(\mathrm{T})}\,\frac{\mu_3}{\mu_1}$$

L and μ_k from CAPS probe
w from gust probe
k(T) from Pruppacher and Klett

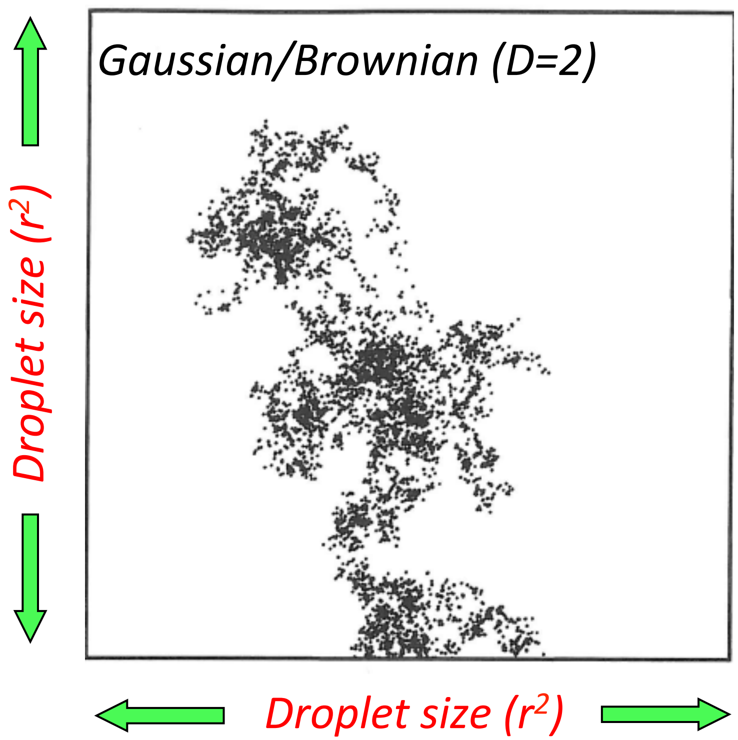
IMPLICATIONS FROM THE VOIGHT DISTRIBUTION

The convolution: $$f_{Voight}(\delta S) = f_{Gauss} \circ f_{Cauchy}(\delta S)$$

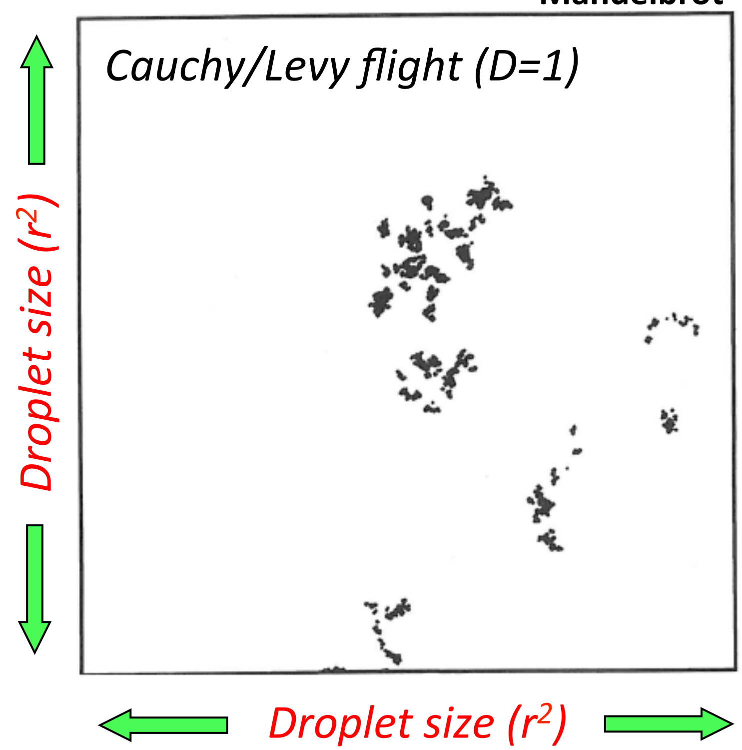
$$\Leftrightarrow \quad \delta S_{Voight} = \delta S_{Gauss} + \delta S_{Cauchy}$$

Implies a supersaturation/<u>droplet growth velocity</u> decomposition into frequent short steps (Brownian) followed by the occasional much longer flight (Levy)

Mandelbrot



Mandelbrot



Future Directions

- Field validation of KP drizzle model and LDM: *Validation requires co-located datasets of cloud droplet number concentration, cloud liquid water content, and drizzle threshold* *Drizzle threshold should match the LDM threshold line*

  - *Slope and linearity would confirm the theory*
  - *Intercept would give the turbulence parameter*

2. Datasets containing *co-located vertical velocity, gradient of liquid water content with height, and cloud droplet number concentration* would give another path to the turbulence parameter – compare the two approaches for consistency

   - Compare remote and gust-probe measurements of w and inferred supersaturation