Analysis of Raindrop Size Distributions Measured During the Mid-latitude Continental Convective Clouds Experiment

Casey Pham[1] and Greg M. McFarquhar[1,2], Aaron Barnsemer[2], Andrew Heymsfield[2],
[1]University of Illinois, Urbana, IL [2]National Center for Atmospheric Research, Boulder, CO

Motivation

- Explore shapes of raindrop size distributions in mid-latitude convective clouds.
- Use data collected by cloud probes during Mid-latitude Continental Convective Clouds Experiment (MC3E).
- How do raindrop size distributions vary with rain rate?
- Is shape of raindrop size distributions invariant when normalized?

MC3E

Fig. 1: University of North Dakota Cessna Citation II Research Aircraft used for flights

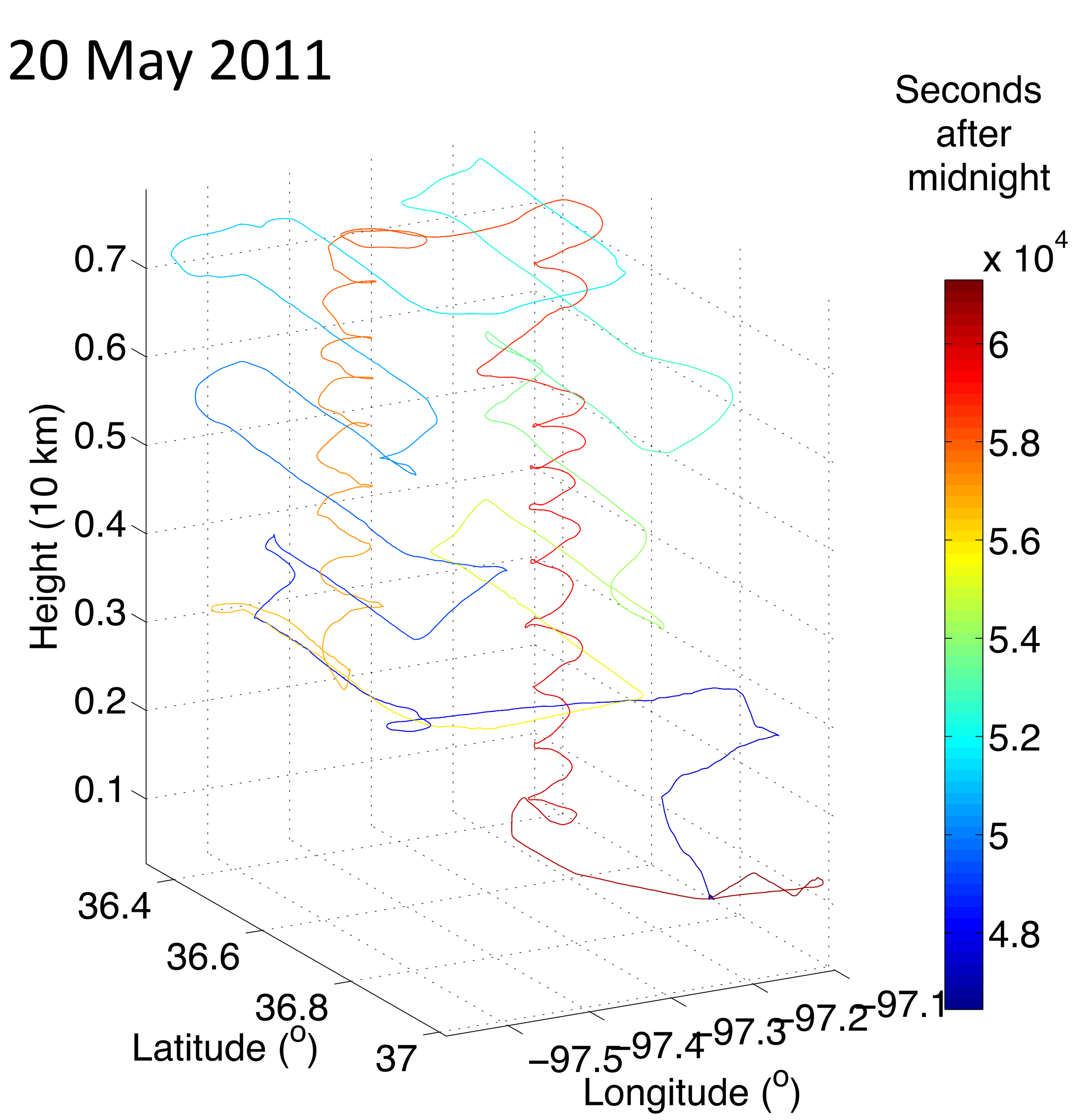


Fig.2: Flight track from 20 May, 2011

Data

- Cloud Imaging Probe (CIP)

  - Measures particles with maximum dimension (D) between 30 and 920 μm
- Two-Dimensional Cloud Imaging Probe (2DC)

  - 25 μm-1.6 mm
- High Volume Precipitation Spectrometer (HVPS)

  - 150 μm-1.9 cm
- Probe data processed at National Center for Atmospheric Research to generate size distributions covering all particle sizes, merging data from the 2DC (or CIP when 2DC measurements are not available) and HVPS using 1 mm dimension to transition between probes.
- Range: 50 μm to 3 mm
- Resolution: 1s

Methods

- Analyze data with temperatures greater than 5° C to include only raindrops.
- Calculate rain rate of size distributions.

$$R = \sum N(D) D^3 V_t(D) \frac{\pi}{6} dD$$

  - Terminal Velocity

$$V_t = 970.5208[1 - e^{(-\frac{D}{0.177})^{1.147}}]$$

- Normalization scaling parameter as outlined by Testud et al. (2000).

$$N_0^* = \frac{4^4}{\pi \rho_w} \frac{LWC}{D_m^4}$$

  - Liquid Water Content

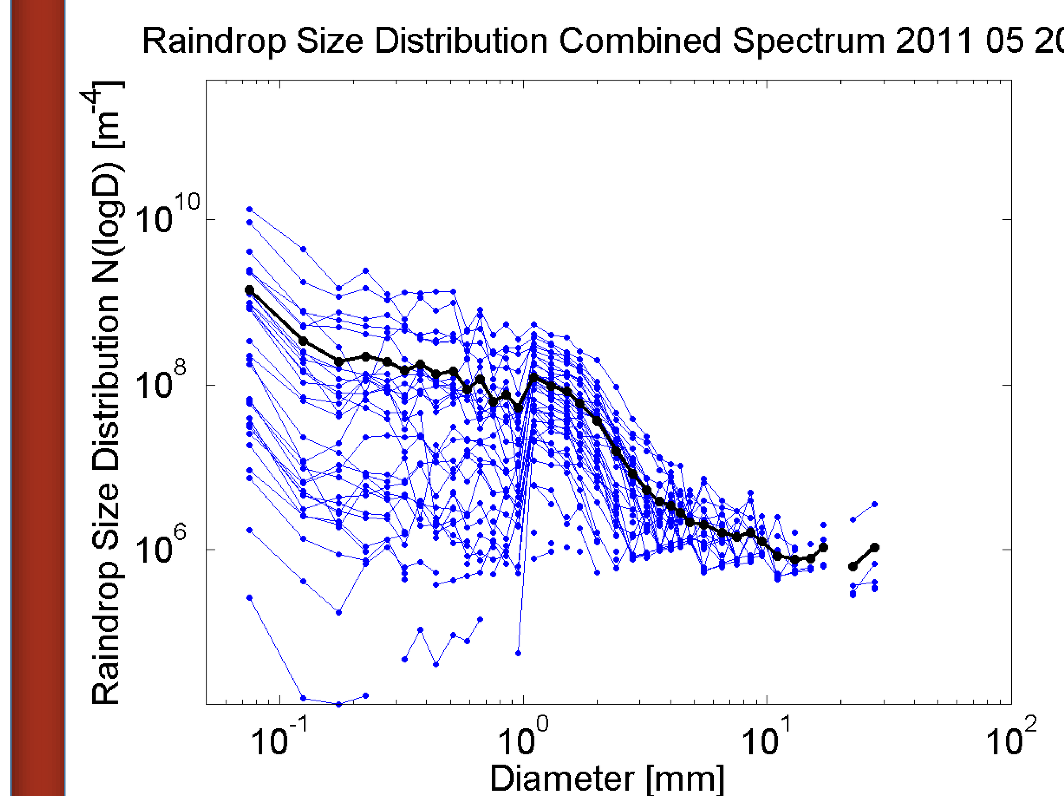
$$LWC = \frac{\pi \rho_w}{6} \int_0^\infty N(D) D^3 dD$$

  - Mean Volume Diameter

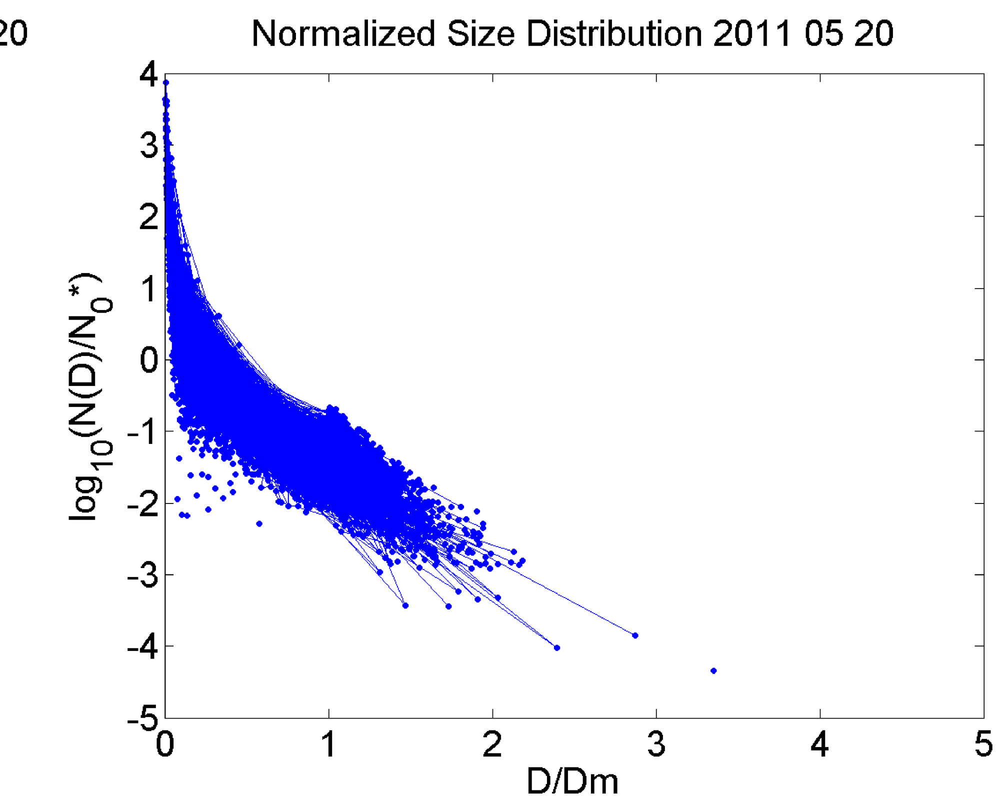
$$D_m = \frac{\int_0^\infty N(D) D^4 dD}{\int_0^\infty N(D) D^3 dD}$$

- Plot normalized size distributions by dividing size distribution N(D) by N_0*, against normalized diameter D/D_m.

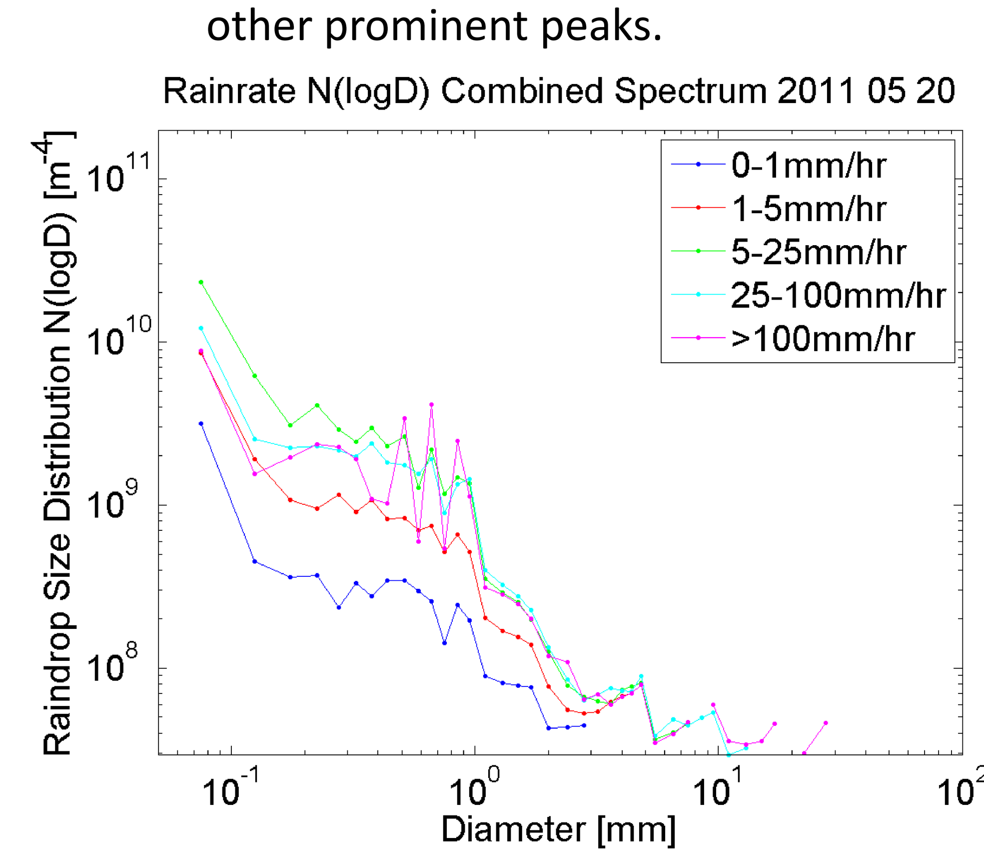
Analysis



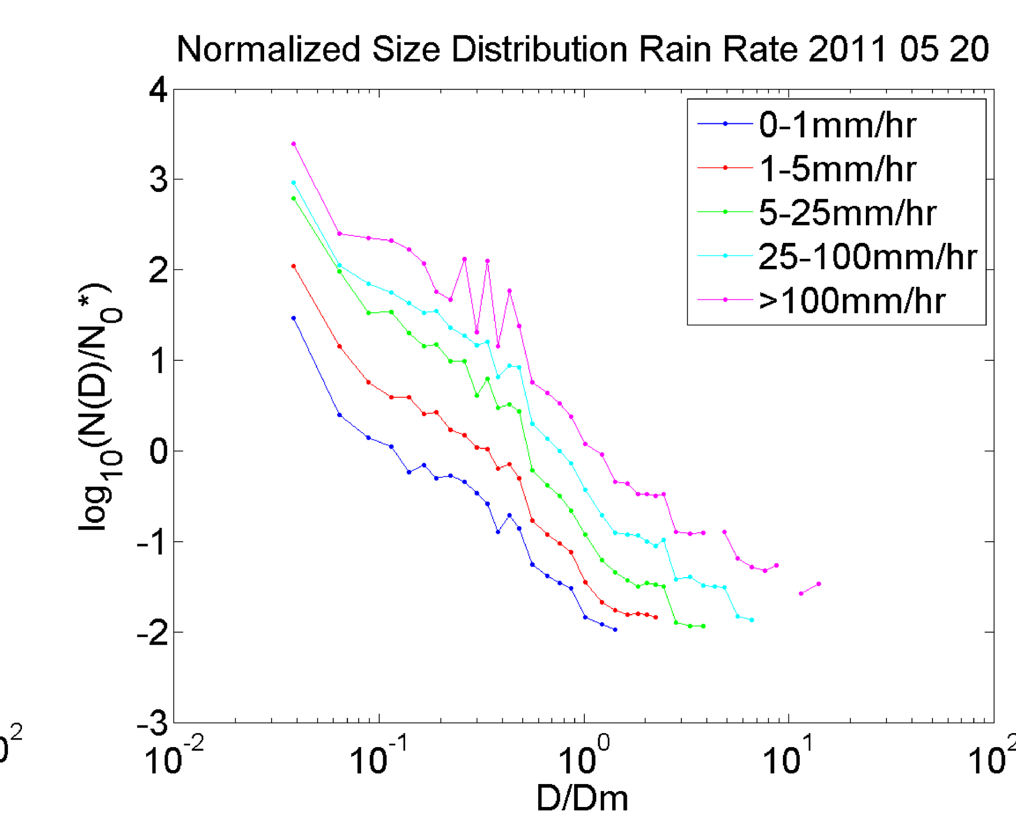
- Size distributions plotted using N(logD) to better see any peaks in size distribution.
- Peak at D=1 mm may be associated with transition between probes; no other prominent peaks.



- Normalized distributions obtained by as $N(D)/N_0$*
- Working to determine if normalized size distributions have invariant shape.



- Some variation in size distribution with rain rate, but less so at higher rain rates.



- Can see much clearer variation in size distributions, with higher rain rates having higher concentrations and larger drops.

Conclusions

- Normalized raindrop size distributions do appear to vary with rain rate.
- High rain rates have not only higher concentrations, but also larger drop sizes.
- Normalization of raindrop size distributions can be applied to data from MC3E.

Future Work

- Examine contribution of other environmental factors to size distributions.
- Investigate variation in normalized size distributions between flights.
- Determine if normalized size distributions have invariant shape and can be characterized.