Reconstruction of the drizzle mode of the raindrop size distribution: an approach using double-moment normalisation

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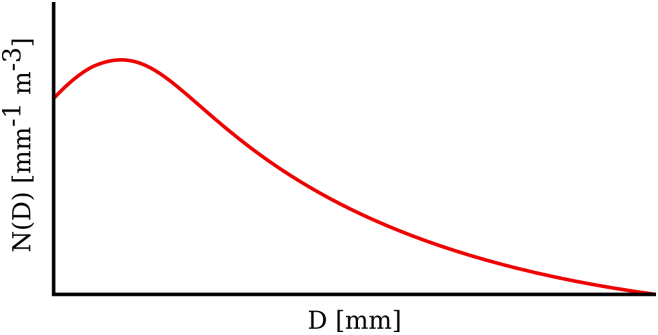
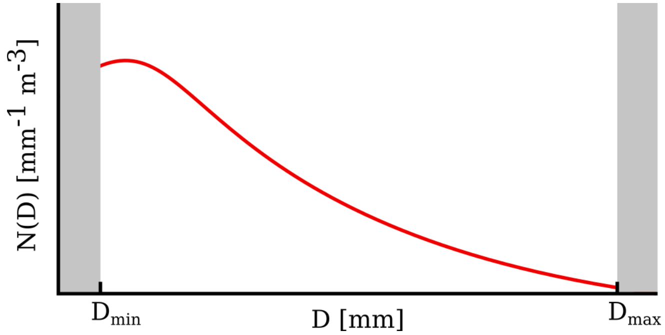
Measuring the DSD

$$N(D) \quad [\mathrm{mm}^{-1}\ \mathrm{m}^{-3}]$$



Measuring the DSD

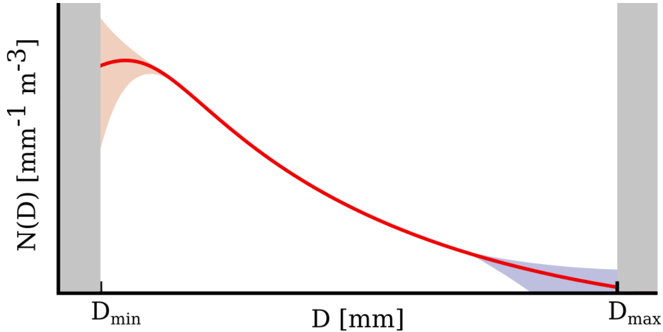
$$N(D) \quad [\mathrm{mm}^{-1}\ \mathrm{m}^{-3}]$$



- Min and max measurable size $\rightarrow$ truncation.

Measuring the DSD

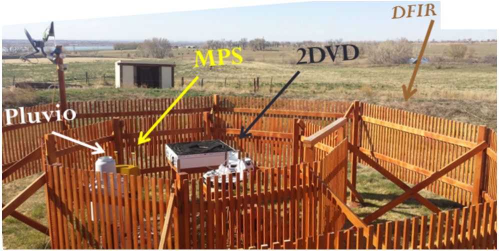
$$N(D) \quad [\mathrm{mm}^{-1}\ \mathrm{m}^{-3}]$$



- Min and max measurable size $\rightarrow$ truncation.
- Uncertainty in small (sensitivity) and large (sampling) drops concentrations.

MPS+2DVD for larger size range

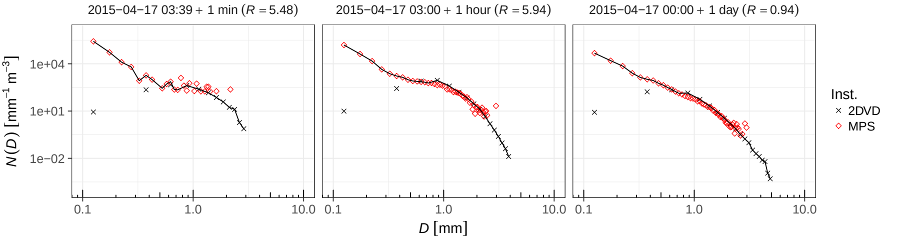
- **Thurai and Bringi, JAMC, 2017**.
- Meteorological Particle Spectrometer (MPS).
- 2D-video-disdrometer (2DVD).



	MPS	2DVD
Drop size resolution [mm]	0.05	$\sim$0.2 (we use 0.25)
Minimum D [mm]	0.1	$\sim$0.1 (0.3 in practice)

- MPS+2DVD $\rightarrow$ 0.1 mm to 10 mm with high resolution for small drops.
- Incomplete DSDs (2DVD only) versus complete DSDs (combined).

Drizzle mode and shoulder region

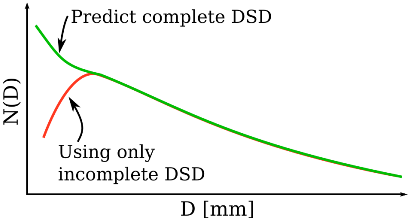


- Drizzle mode for D below 0.5−0.7 mm.
- Shoulder region for D between ∼0.7−1.2 mm.
- Rain mode for D above ∼1.2 mm.

Likely that common disdrometers do not capture the drizzle mode.
Our aim: reconstruct the drizzle mode using well-captured moments.

Drizzle mode reconstruction ingredients

Aim: estimate complete DSD from incomplete measurements.



Double-moment normalisation of the DSD needs:

- Two well-measured moments of the DSD.

  → Incomplete DSDs measure higher order moments well.

- A representative shape function.

  → Fit to complete DSDs; generalised gamma [Thurai JAMC 2018].

Double-moment DSD normalisation

- We use approach of Lee et al, JAM, 2004.
- DSD as combination of two DSD moments and a "shape" function $h(x)$:

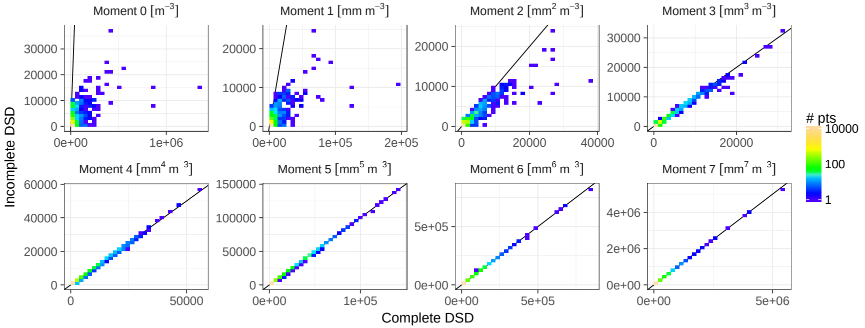
$$M_n = \int_{D_{\min}}^{D_{\max}} D^n N(D) dD.$$

$$N(D) = M_i^{(j+1)/(j-i)} M_j^{(i+1)/(i-j)} h(x).$$

- i and j are arbitrary moment orders.
- x is a double normalised diameter, so $x = D M_i^{1/(j-i)} M_j^{-1/(j-i)}$.
- $h(x)$ is assumed to stay invariant (see Lee JAM 2004, Lee JAMC 2007, Raupach JAMC 2017, Thurai JAMC 2018).

Which moment orders are measured accurately?

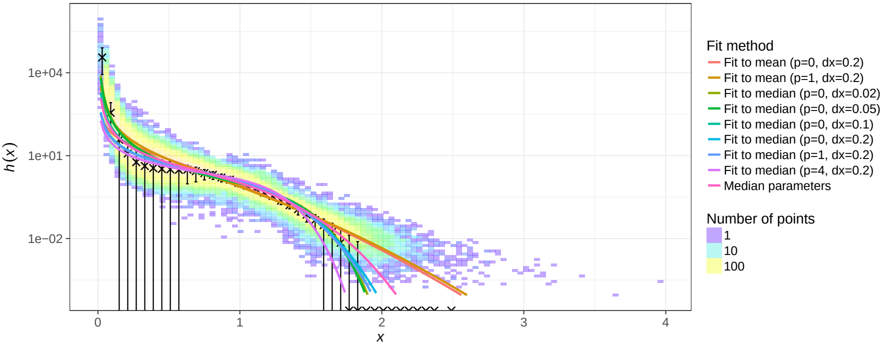
- Incomplete versus complete moments.



- We chose to use moment orders **three** and **six**.

Training a generalised gamma model for $h(x)$

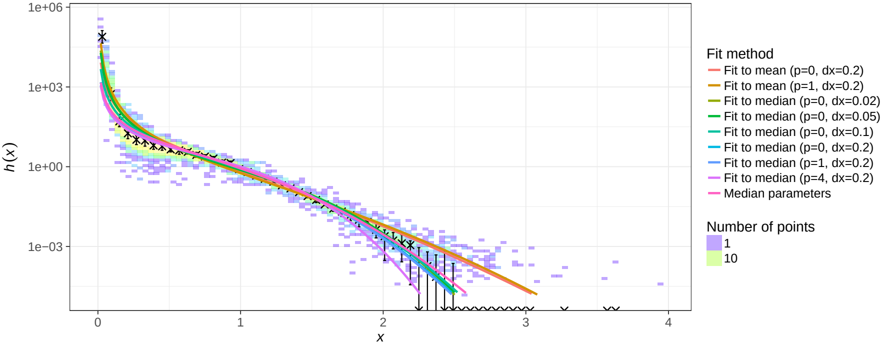
- Two parameters, scale $c > 0$ and shape μ (unconstrained).
- Fitted to $h(x)$ for each **one-minute** DSD.
  (n^p is the weight of the median corresponding to n values, dx is the class width)



- Sampling effects affect mean and median.

Training a generalised gamma model for $h(x)$

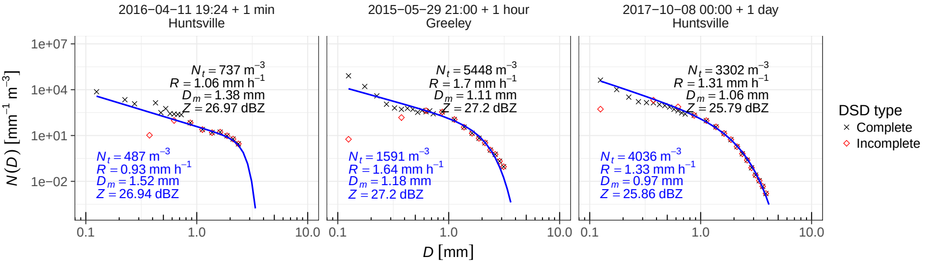
- Two parameters, scale $c > 0$ and shape μ (unconstrained).
- Fitted to $h(x)$ for each **one-hour** DSD.
  (n^p is the weight of the median corresponding to n values, dx is the class width)



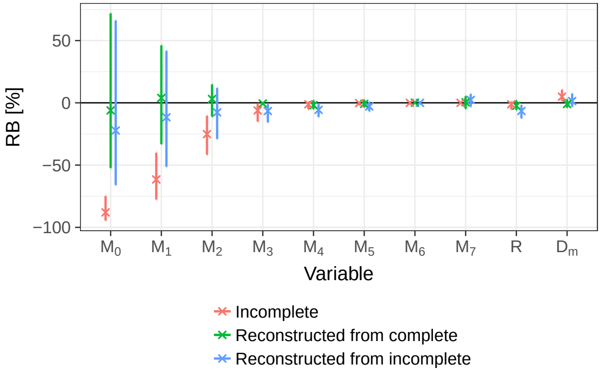
- Sampling effects → model differs by time resolution.

Reconstructed DSD examples

- DSD moments 3 and 6 from **incomplete** DSDs.
- A double-moment normalised model of the **complete** DSD.
- **Reconstructed** DSDs are the double-moment combination.



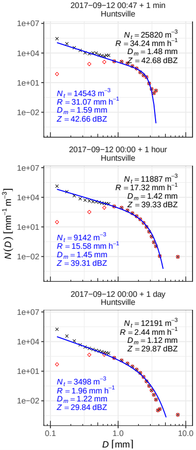
Reconstruction performance

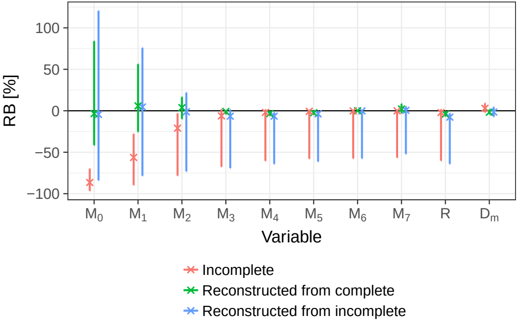


- Reconstruction helps correct bias in the lower-order moments.
- Greater error spread due to residual variability in $h(x)$.
- Higher-order moments are not significantly damaged.

Independent hurricane data

- Outer bands of Hurricane Irma, Huntsville, 11–12 September 2017.
- Rain (at times) number controlled, not drop-size controlled [Thurai 2017].
- We kept this data separate and tested the reconstruction on it.





Conclusions

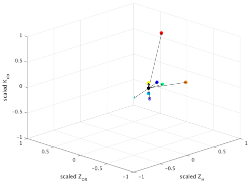
- Commonly used disdrometers likely miss the DSD “drizzle mode”.
- The drizzle mode can be reconstructed, using
  - Double-moment normalisation of Lee JAM 2004,
  - Moments three and six, well measured even in incomplete DSDs, and
  - A generalised gamma shape function $h(x)$, trained on complete DSDs.
- Reduces bias on low-order moments, does not significantly damage higher-order moments, and improves performance for **light rain** over a previous DSD correction.

Future work

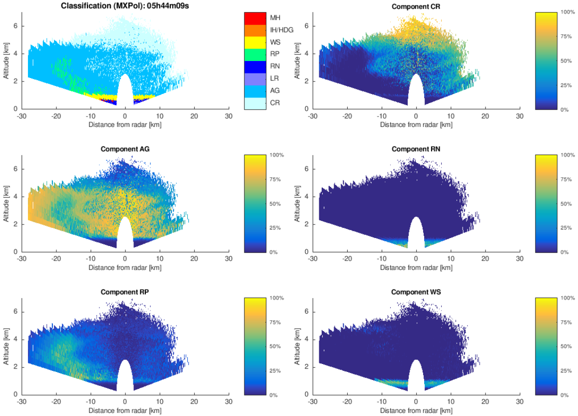
- Investigate the possible links between residual $h(x)$ variability and dominant microphysics.
- Alternative functional form for $h(x)$ model to correspond to a true pdf.
- We need more MPS+2DVD data!

De-mixing hydrometeor classification

Use distance from given polarimetric pixel to centroids.



Performances evaluated using a collocated MASC instrument.



Besic et al., AMT, 2016 ; Besic et al., AMT, 2018

Thank you

Rain (and drizzle?) over Lake Geneva