Spatial and temporal variability of the raindrop size distribution at small scale.

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rain = large number of drops with ≠ size, shape, position, concentration, ...

Statistical approach to summarize info: \( \text{(Rain)Drop Size Distribution (DSD)} \).

\[ N(D) = \text{concentration of drops with a diameter between } D \text{ and } D+dD \text{ in the sample volume.} \]

Many rain bulk variables related to DSD:

\[
N_t = \int_{D_{\text{min}}}^{D_{\text{max}}} N(D) \, dD.
\]

\[
D_0 \quad / \quad \int_{D_{\text{min}}}^{D_0} N(D) \, D^3 \, dD = \int_{D_0}^{D_{\text{max}}} N(D) \, D^3 \, dD.
\]

\[
R = 6\pi \times 10^{-4} \int_{D_{\text{min}}}^{D_{\text{max}}} N(D) \, v(D) \, D^3 \, dD.
\]
Rainfall (and hence DSD) is variable in space and time.

- **Temporal** variability: → Uijlenhoet et al, JHM 2003; Lee and Zawadzki, 2005; ...

- **Spatial** variability:
  → small-scale DSD variability is poorly documented.  
    *Miriovsky et al, 2004* → instrumental effect vs natural variability of DSD.  
    *Lee et al, 2009* → limited spatial distribution of instruments.

Need a network of disdrometers of the same type.
II. Experimental set up

Instrument:

- Optical disdrometer **OTT-Parsivel**.
- Sampling area ~ 54 cm².
- DSD:
  - drop diameters: 0.2 → 26 mm [32 classes]
  - velocities: 0 → 22 m s⁻¹ [32 classes]

**Sampling uncertainty** associated with Parsivel measurements:

- 2 collocated Parsivels + 2 TB rain gauges.
- Duration: **15 months**.
- Limited bias (8%) Parsivels-TB rain gauges.
- Sampling uncertainty ($\sigma_\omega$): $N_t$, $D_0$, $R$, $Z_h$ & $Z_{dr}$.
- $\sigma_\omega \rightarrow f(M,\Delta t)$. 

J. Jaffrain, A. Berne, IPC 2010.
A network of 16 Parsivels has been designed and set up ($\Delta t = 30s$).
III. Method and Data set

Absolute and relative variability of the considered moment $m$ is quantified as the standard deviation & coefficient of variation between the 16 stations:

$$\bar{m}_t = \frac{1}{16} \sum_{i=1}^{16} m_{i,t}$$

$$\sigma_{m,t} = \sqrt{\frac{1}{16} \sum_{i=1}^{16} (m_{i,t} - \bar{m}_t)^2}$$

$$CV_{m,t} = \frac{\sigma_{m,t}}{\bar{m}_t}$$

**Sampling uncertainty:**

$\sigma_{\omega,i} \rightarrow$ from one Parsivel.

$\sigma_{\omega}$ associated with the combination of 16 stations?

Stochastic simulation approach:

For each station $i$ (i=1,...,16) at time step $t$.

$\hat{m}_{i,t} \sim \mathcal{N}(m_{i,t}, \sigma^2_{\omega,i})$

For each station $i$, 500 simulations.

$$\{\hat{\sigma}_{m,t}\} \quad \text{and} \quad \{\hat{CV}_{m,t}\}$$

$$((Q_{90} - Q_{10})\hat{\sigma}_{m,t}) \quad \text{and} \quad ((Q_{90} - Q_{10})\hat{CV}_{m,t})$$
III. Method and Data set

Rainy periods with $R \geq 10 \text{ mm h}^{-1}$ → considered as “convective”.

Conv $\sim 1.5$ h
Strati $\sim 42$ h

2 months with convective and stratiform events: 2009-08-24 → 2009-10-23.

Total amount $\sim 110$ mm
Evolution of the variability in time (at event scale).

Observed variability explained by the uncertainty (2 months):

- $N_t \sim 0.00 \%$
- $D_0 \sim 0.04 \%$
- $R \sim 0.14 \%$
IV. Spatial variability

\[ \bar{\sigma}_M \]

\[ C\bar{V}_M \]

<table>
<thead>
<tr>
<th></th>
<th>ALL</th>
<th>Convective</th>
<th>Stratiform</th>
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<tbody>
<tr>
<td>( N_t )</td>
<td>30.3</td>
<td>83.2</td>
<td>28.5</td>
</tr>
<tr>
<td>( D_0 )</td>
<td>0.14</td>
<td>0.19</td>
<td>0.14</td>
</tr>
<tr>
<td>( R )</td>
<td>0.7</td>
<td>4.7</td>
<td>0.5</td>
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<thead>
<tr>
<th></th>
<th>ALL</th>
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<th>Stratiform</th>
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</thead>
<tbody>
<tr>
<td>( N_t )</td>
<td>19.9 %</td>
<td>14.6 %</td>
<td>20.1 %</td>
</tr>
<tr>
<td>( D_0 )</td>
<td>10.4 %</td>
<td>9.6 %</td>
<td>10.5 %</td>
</tr>
<tr>
<td>( R )</td>
<td>29.4 %</td>
<td>25 %</td>
<td>29.5 %</td>
</tr>
</tbody>
</table>
IV. Spatial variability

- $\sigma_m \rightarrow \sigma_m$.
- Highest CV $\rightarrow$ weak $m$ values.
- $\text{CV(strati)} > \text{CV(conv)}$. 

![Graphs showing spatial variability](image-url)
Conclusion:

- **Significant variability at small scale**, i.e., within the weather radar pixel.

- Different behaviors between convective and stratiform type:
  \[ \sigma(\text{stratiform}) < \sigma(\text{convective}) \]
  \[ \text{CV}(\text{stratiform}) > \text{CV}(\text{convective}) \]

Further works:

- Investigate variability of the DSD over a larger data set (11 months at 30 s).

- Quantify the effect of such variability on radar rainfall retrieval \((Z-R, R-k_{dp})\).

- Spatial and temporal **structure of DSD** within the radar pixel scale (Geostatistics).
Thank you for your attention.

Any questions?