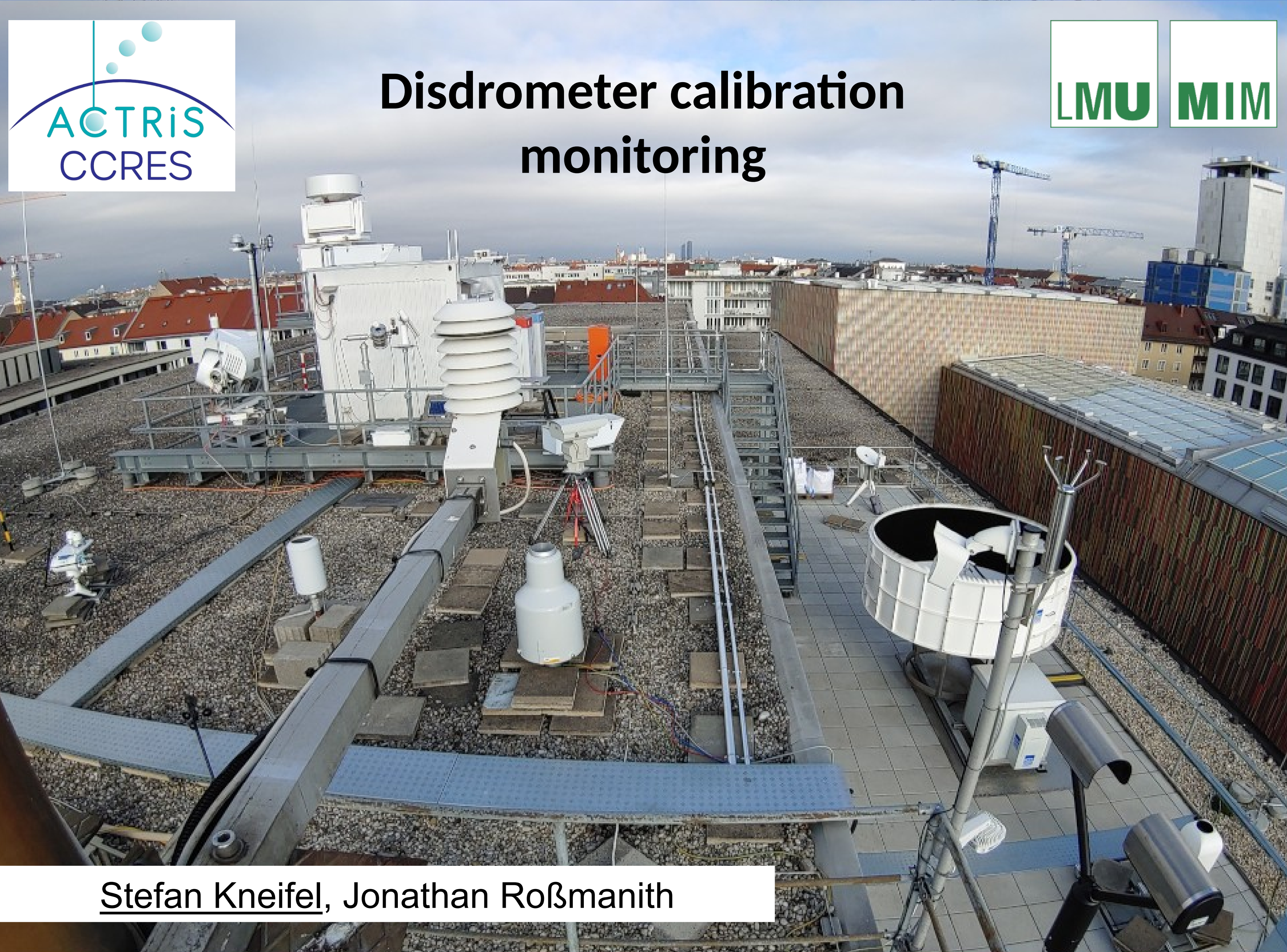
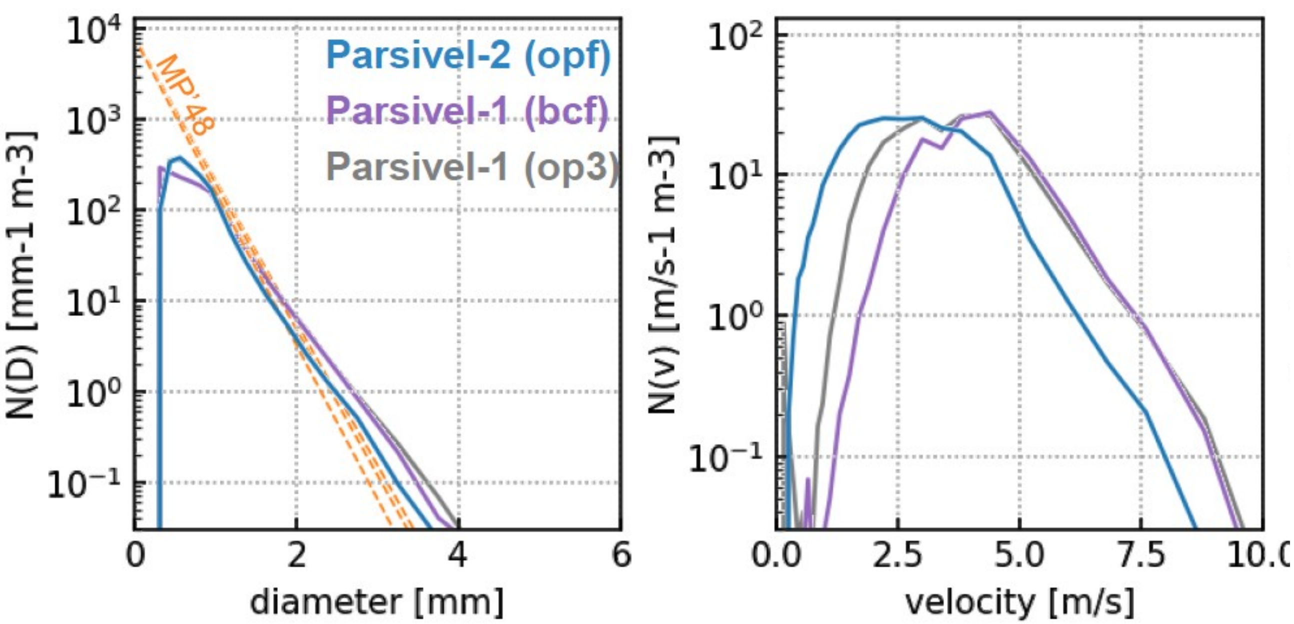
Disdrometer calibration monitoring



Stefan Kneifel, Jonathan Roßmanith

Motivation: Why calibrating disdrometers?

Parsivel-1 and Parsivel-2
22 September 2023 03:00 – 12:00 (9:00 hour



Parsivel-2 (opf)

	OTT	matrix
Ntot	205	205
RR	1.27	1.27
Z	26.15	25.64

Parsivel-1 (bcf)

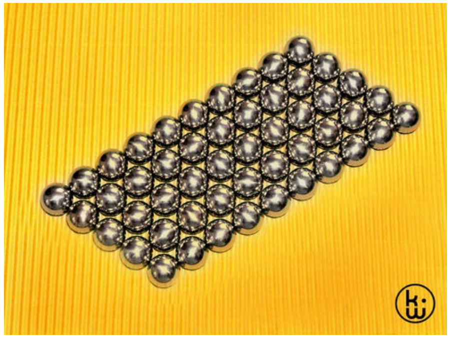
	OTT	matrix
Ntot	184	196
RR	1.68	1.63
Z	28.15	27.98

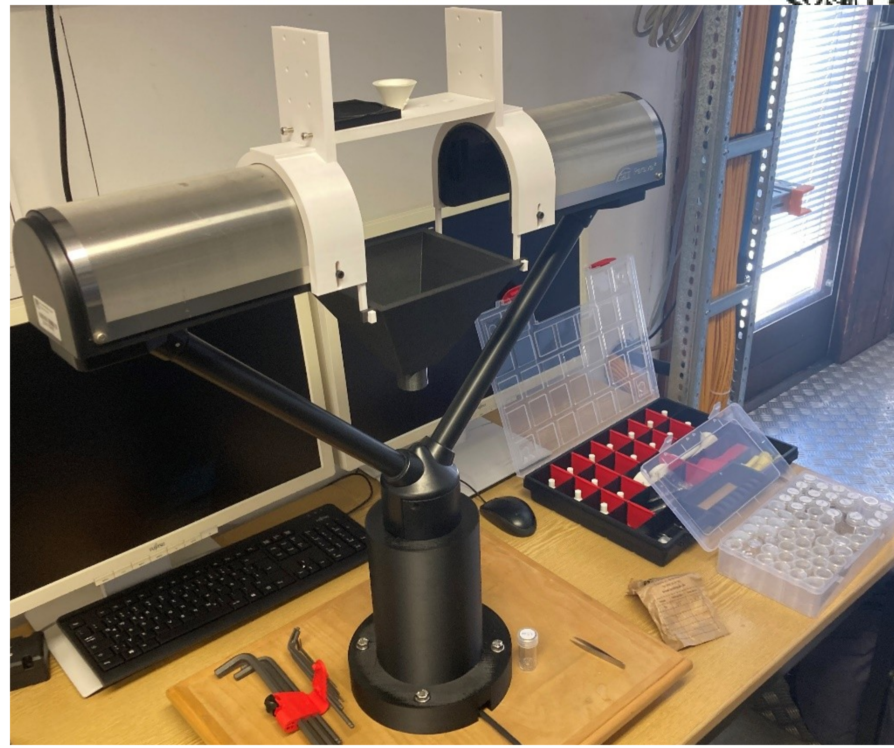
Parsivel-1 (op3)

	OTT	matrix
Ntot	218	224
RR	1.90	1.82
Z	28.93	28.67

Courtesy Martin Hagen, DLR

The laboratory setup





- Stainless steel spheres
- Diameter 0.3 - 5.0 mm
- Accuracy 10 µm
- Costs: ca. 22€ for 100 spheres

(https://www.sturm-kugellager-shop.de)

- Also PP and Polyacetal spheres
- Density closer to ice
- smaller diameter range, less accurate, slower fall speed

- 3D printed mobile dropping device
- Utilizes Parsivel mounting
- Allows testing of various configurations

The laboratory setup

3D printed funnel has thread for attaching plastic tubes to auto-matically collect spheres.

Spheres with d<1mm quite hard to handle!

Dropping device also provides a tool to make sure that laser band is well aligned.

Change from default „Matrix-mode“ into event mode

Important: Parsivel has to be set into „event mode“ in order to output measured size and fall speed directly

Description Parsivel² output - field 61

The output of field 61 is possible with Parsivel² devices and firmware version V2.10.0 or higher. You can download the firmware on our home page www.ott.com (register and log in to myOTT). The firmware update can be done easily with the software ASDO. Please check the manual for details.

61	List of all particles detected (including size and particle speed)	13	00.000;00.000	0.200 … 25.000; 0.20 … 20.000	mm;m/s

Python code available which

- Sets Parsivel into event mode and defines desired output format
- Logs output into csv-file

Re-calculating sphere diameter

Important Note:

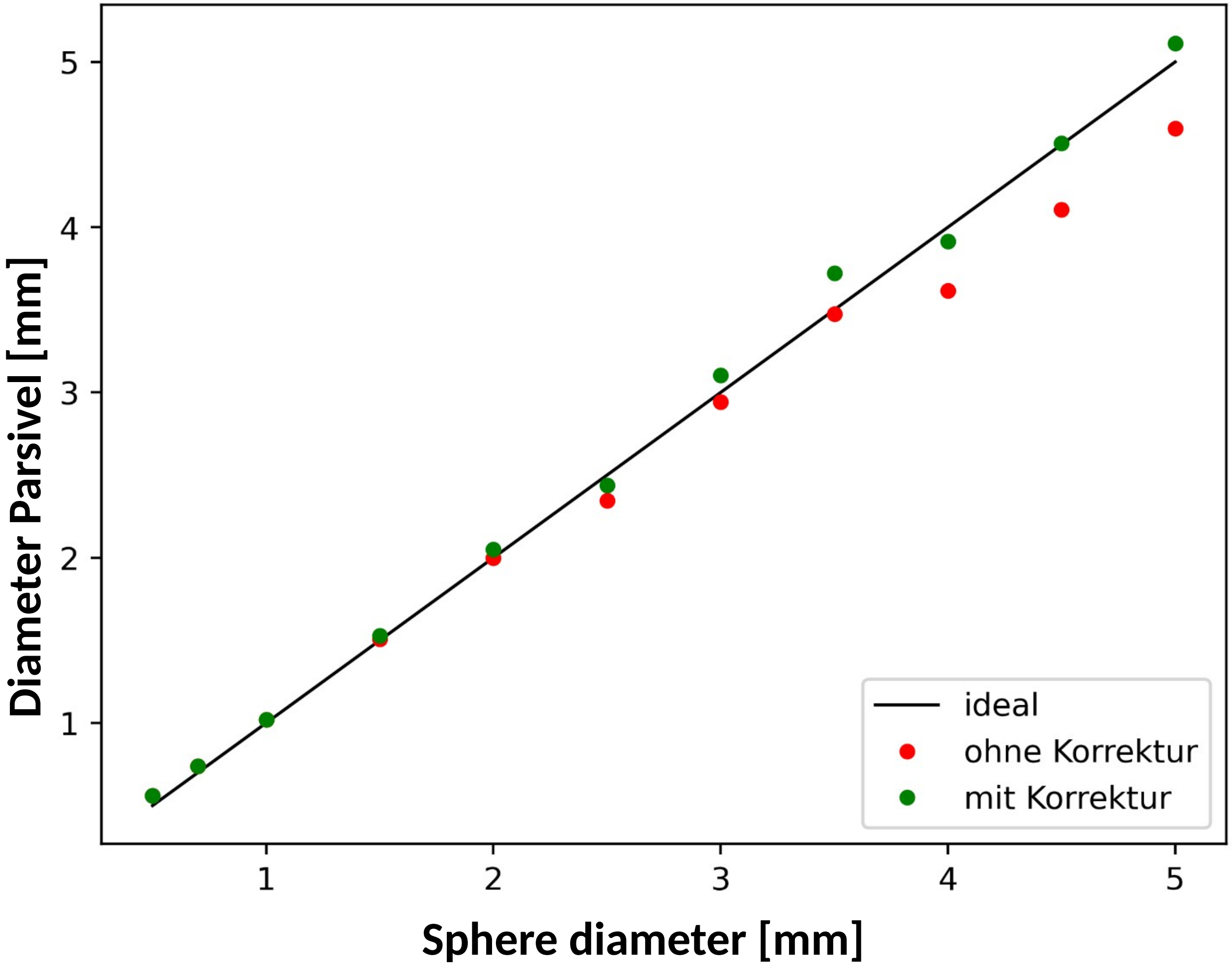
- Parsivel assumes internally, that it measures ellipsoidal rain drops with size dependent aspect ratio
- Those are converted into **equivolume sphere diameters D_{eq}**
- This conversion needs to be undone before comparison
- Unclear if this relation has been changed over time

$$a_r^{\mathrm{PAR}} \equiv \begin{cases} 1 & D_{\mathrm{eq}}^{\mathrm{PAR}} \le 1\,\mathrm{mm} \\ 1.075 - 0.075 D_{\mathrm{eq}}^{\mathrm{PAR}} & 1\,\mathrm{mm} < D_{\mathrm{eq}}^{\mathrm{PAR}} < 5\,\mathrm{mm}, \\ 0.7 & D_{\mathrm{eq}}^{\mathrm{PAR}} \ge 5\,\mathrm{mm} \end{cases} \quad (1)$$

$$\mathrm{WHD}_{\mathrm{retr}}^{\mathrm{PAR}} \equiv \frac{D_{\mathrm{eq}}^{\mathrm{PAR}}}{(a_r^{\mathrm{PAR}})^{1/3}}, \quad (4)$$

from Battaglia et al., JTECH, 2010 (https://doi.org/10.1175/2009JTECHA1332.1 .)

Re-calculating sphere diameter

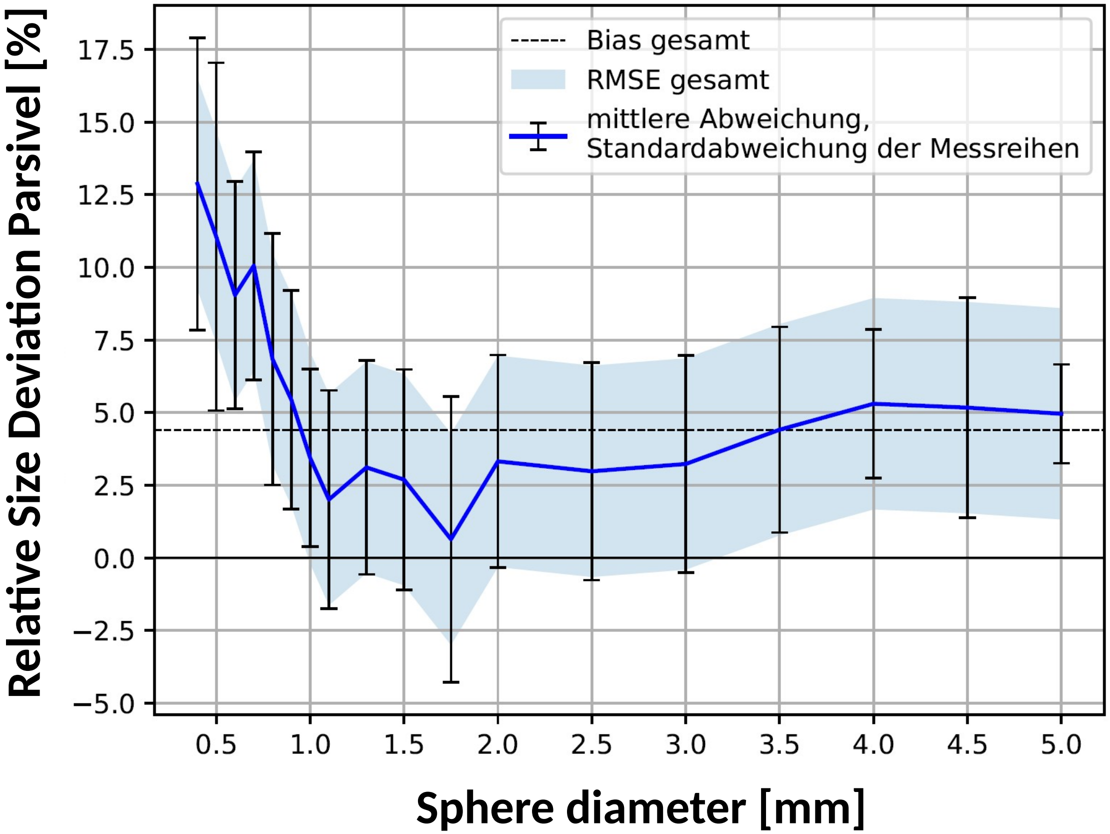


Red: No correction for ellipsoid assumption

Green: Inlcuding correction

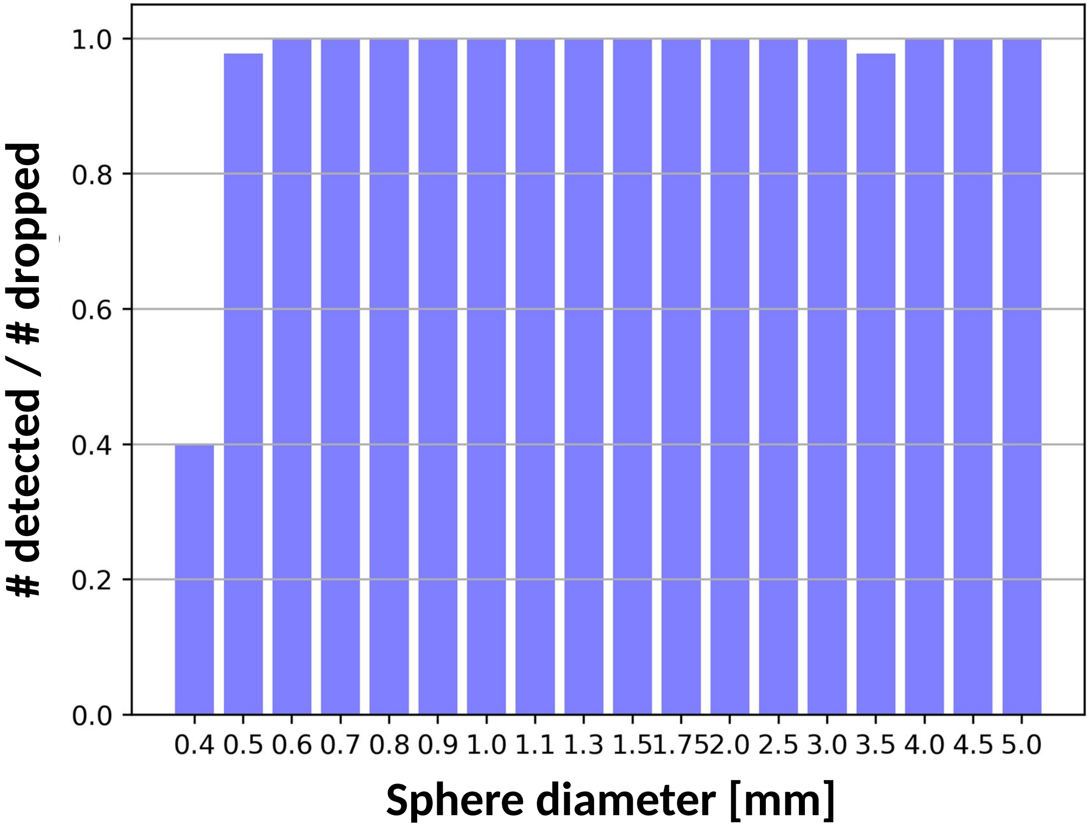
Hands On Training

Size calibration results and their potential impact



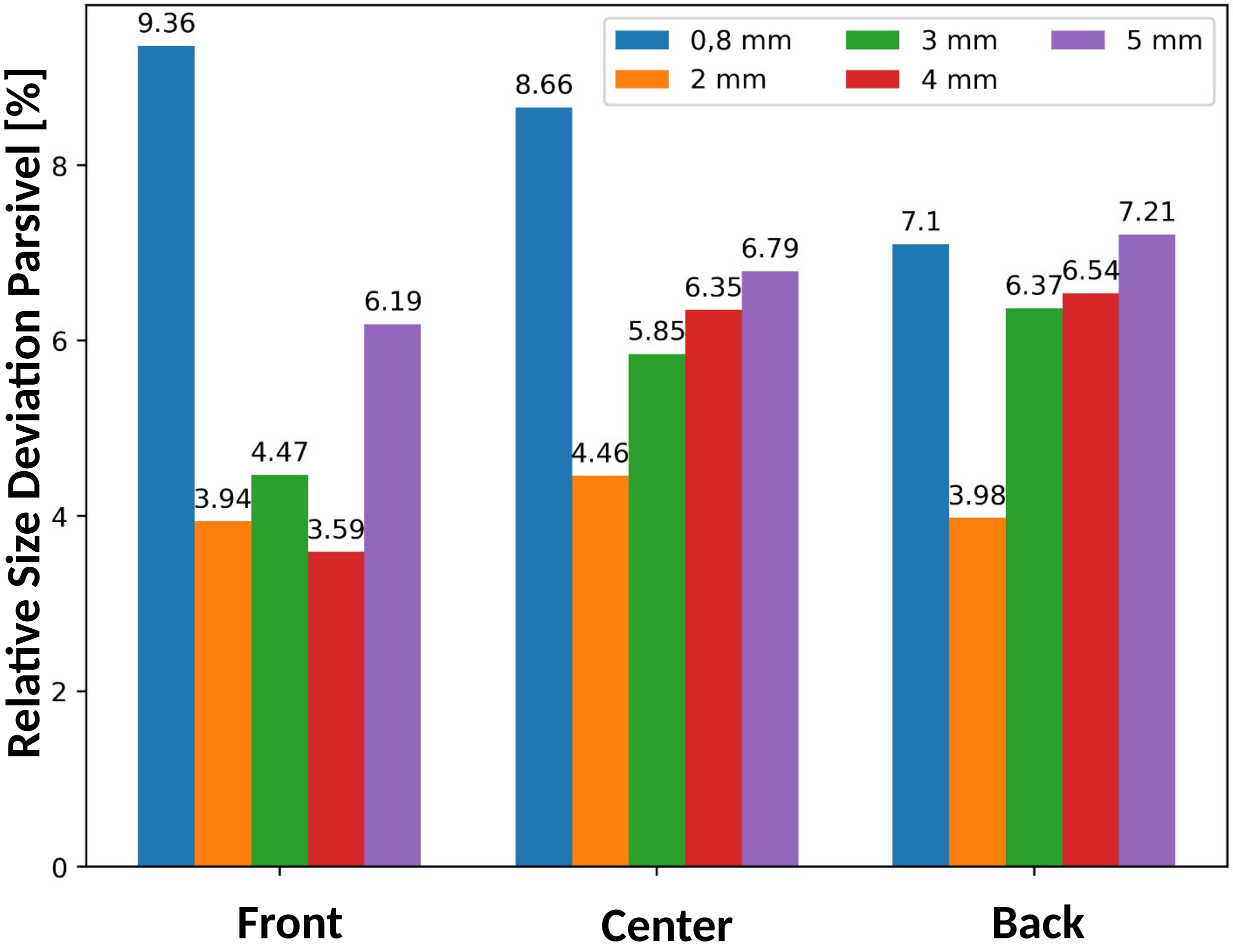
- **Systematic overestimation** of size by LMU Parsivel-2
- <u>Example calculation for Z</u>
- 3.5 mm drop => 32.6 dBZ
- 3.5mm + 5% = 3.675mm => 33.9 dBZ
- **ca. 1.3 dB in Z (Rayleigh)**

Detection rate

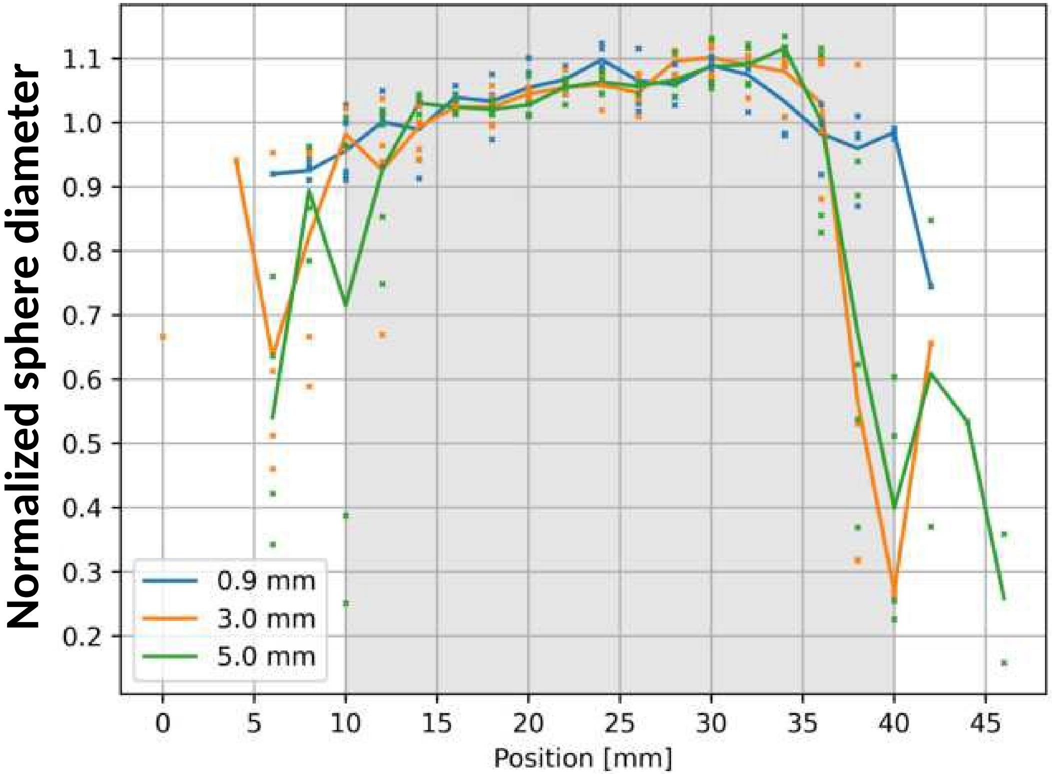


- Smallest detected diameters (0.4mm) **are strongly undercatched**
- Almost 100% detection rate for larger diameters
- 0.3mm spheres were NOT detected at all!
- Manual states: 0.2…5mm

Size bias dependent on dropping position?



Size bias dependent on dropping position?



- Size bias relatively insensitive to where the sphere falls through the laser band

Applying the calibration method to disdrometers at TU Delft

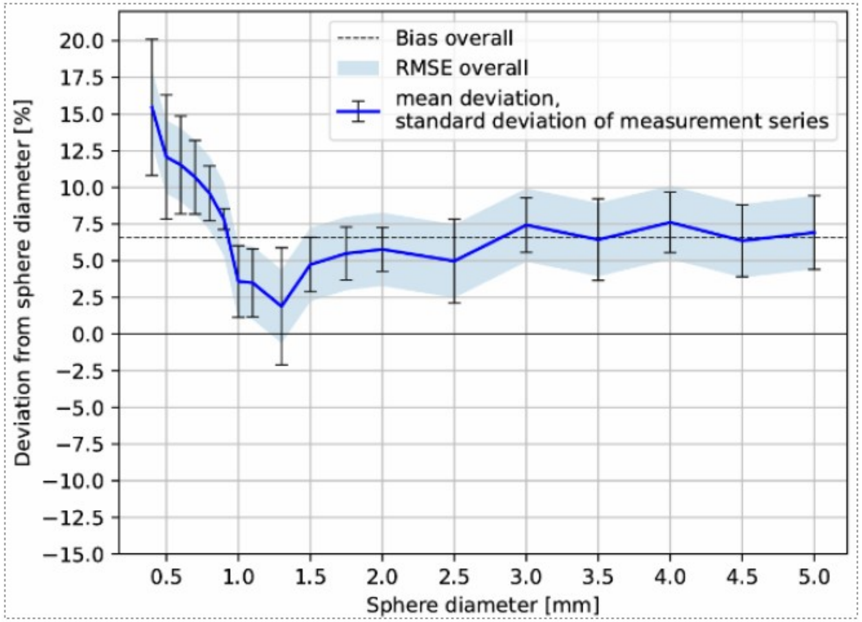


Figure 1: calibration results PAR010 before cleaning

Applying the calibration method to disdrometers at TU Delft

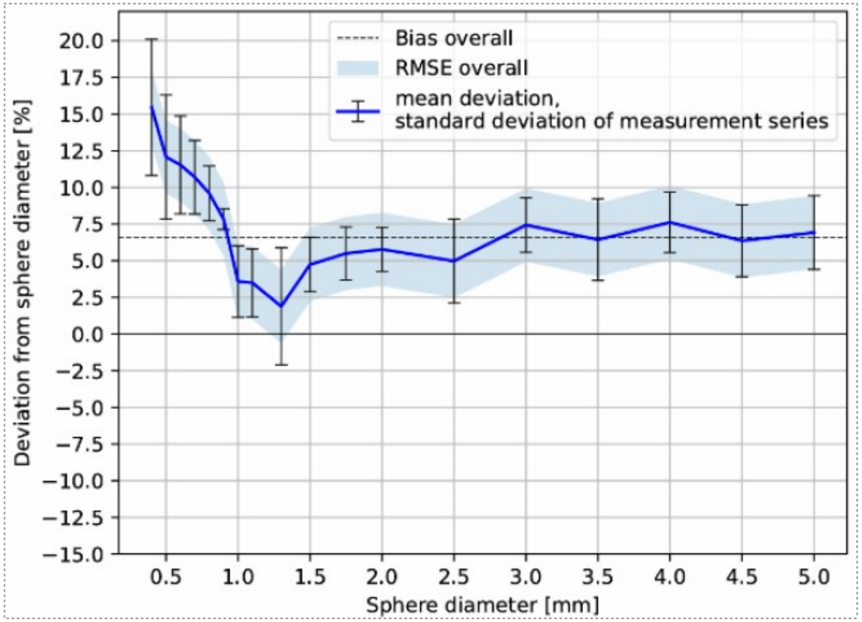


Figure 1: calibration results PAR010 before cleaning

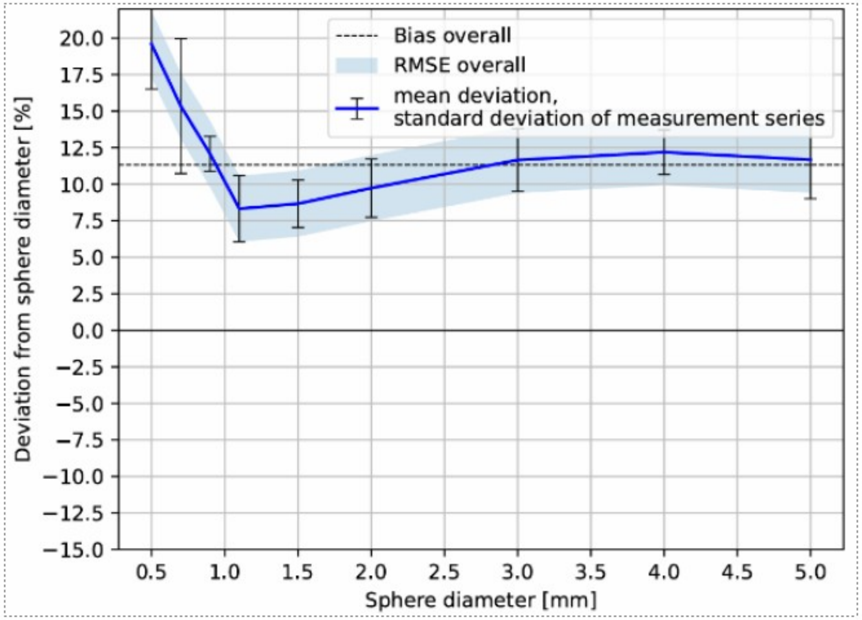
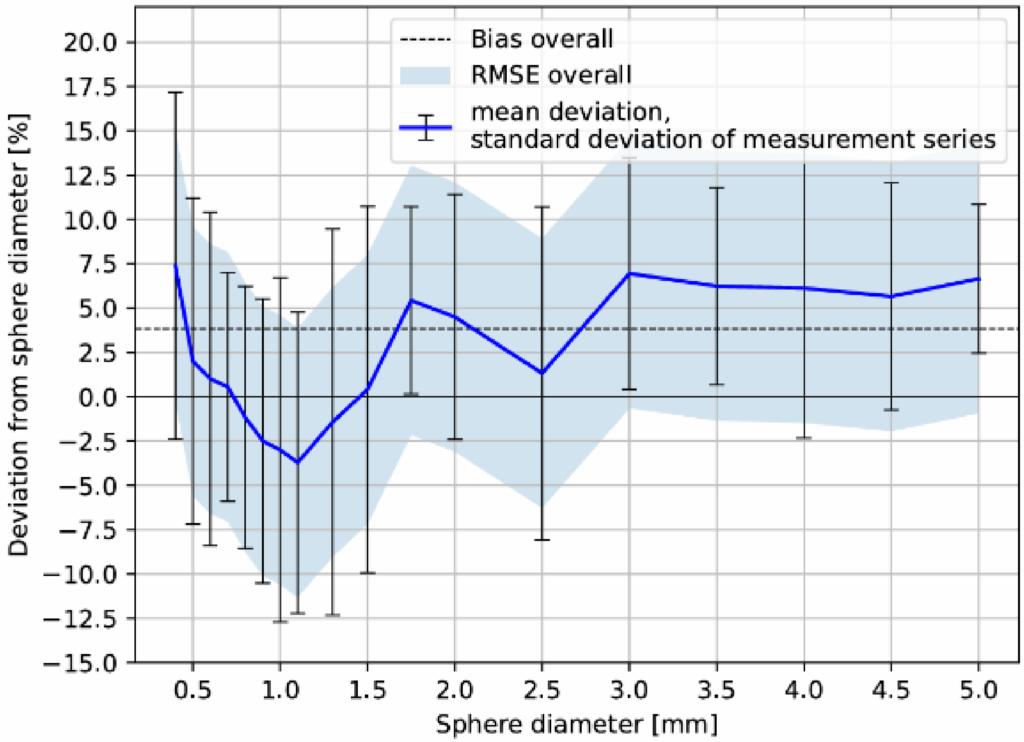


Figure 2: calibration results PAR010 after cleaning

Applying the calibration method to disdrometers at TU Delft



- Calibration setup adapted to Theis disdrometer (thanks to TU Delft technicians!)
- Smaller overestimation but still similar „shape“

Are steel spheres the correct calibration target?

12.4 Verifying particle size measurements

If there is any doubt in relation to the plausibility of the measurement values determined by the OTT Parsivel^2, you can perform an approximate verification in the field (or in a laboratory). Reference spheres (e.g. steel spheres) with known diameters are required here; alternatively, a reference drop dispenser is used.
The reference spheres must fall through the centre of the laser strip within a measurement interval of 60 seconds. (Reference spheres falling through the edge of the laser strip must be avoided.)

Example:
In each case, 15 steel spheres (Ø: 1, 2.5 and 4 mm) fall individually, from a height of 0.25 m, through the centre of the laser strip. The list 1) that is output must contain all 30 objects and their respective classes for both the diameter and the particle speed. The particle speed is approx. 2.21 m/s.
(Resulting classes: diameter: 9, 15/16, 18/19; particle speed: 16)

1) measurement value number 31, see Chapter 11.2

!

Please note:

- Such verification is representative only when using a device to precisely specify the particle speed and the falling path (centre of the laser strip).
  In addition, a collecting device must be used below the sensor heads to prevent damage to the struts and base of the OTT Parsivel^2.
- This method of verification permits only an approximate statement.
  In case of doubt, we recommend inspecting the OTT Parsivel^2 in the factory.
  A precision test stand is available for this purpose. The results are documented in an acceptance test certificate (FAT; Factory Acceptance Test).

- The Parsivel manual explicitly recommends steel spheres for checking calibration!

Are steel spheres the correct calibration target?

Experiments with glass spheres

Motivation:

- Glass spheres might better represent a water drop, since they are transparent
- There might be a bright spot of light passing through the glass sphere
- Since Parsivel only measures the maximum voltage drop on the photo diode for estimating size, a missing of the bright spot (as for steel sphere) might cause an overestimation of the size

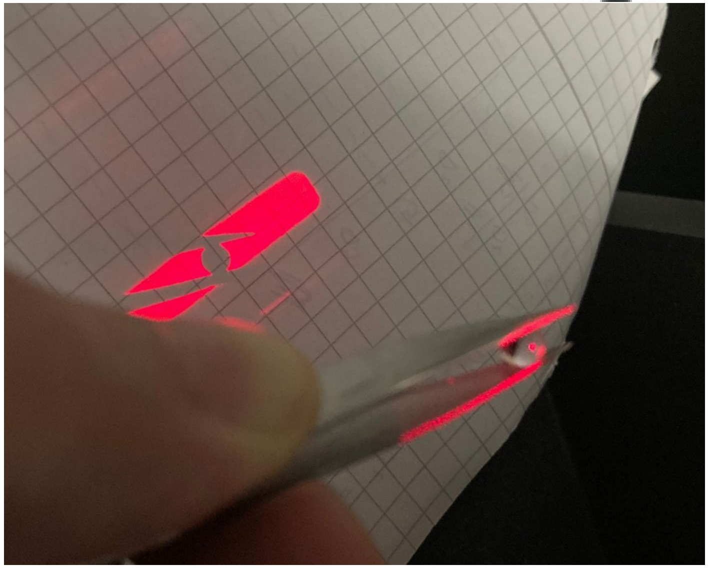
Experiment:

- Throw similar sizes (3.2mm) glass and steel spheres through Parsivel and investigate whether the offset changes

Are steel spheres the correct calibration target?

Experiments with glass spheres

Results:



- Glass and steel spheres show **very similar offset (ca. 5%)**
- There is only a bright spot if you are very close (few mm) to the glass sphere. If you go 1cm away, the glass sphere produces the same shadow as a steel sphere!
- The **difference of material (steel vs. glass) cannot explain the observed overestimation in size of the Parsivel**

Next steps:

- Test whether the size overestimation observed in the event mode is also visible in the default mode (Matrix output)
- A sphere with diameter close to the size bin edges should then assigned to the next higher size bin

Experiments with water drops

(a) Whole setup (b) Bottle with drip chamber (c) Hole plate with end of tubing and collector bottle

- Drops (>2mm) generated with medical cannulas of different diameter
- The total volume measured by Parsivel should match the total volume we drop
- Do we get the same bias as estimated with the steel sphere calibration?
- Tested event mode and standard Matrix-mode

Experiments with water drops

- Overestimation of drops (volume) consistently also found with water drops
- Similar values for Matrix and event mode
- Almost 100% detection rate of Parsivel

- Challenge of water drop experiments:
  - Drops don‘t reach their equilibrium free-fall shape (aspect ratio correction wrong)
  - Without cannula, large and small drops are produced

Ongoing work

- Use the calibration curve and provide a method how to correct the regularly meausred M-Matrix by Parsivel

- Compare various disdrometers (Parsivel 1 or 2, Thies, 2DVD, Pluvio) in real rain cases

Backup Slides

Conclusions and Discussion

- For all Parsivel-2, we find systematic overestimation of size (5-10%)
- Using glass instead of steel spheres does not alter results
- Performing calibration outside the lab is not feasable (wind)

Important open questions:

- Are we doing the calibration correctly?
- Can we find the size overestimation also when we run Parsivel in the **standard binned Matrix-mode** (currently under investigation at LMU)?
- Is the size overestimation maybe internally corrected by the OTT software for the final products (N(D), M-Matrix, RR)?

Other things to work on

- Check Parsivel-1 and older Parsivels which can be expected to be much worse (e.g. degrading laser, older software, etc.)
- If we find overestimation also in the default products (M-Matrix), we need to develop correction function based on event-mode calibration
- Get into contact with OTT and Theis to get advice and more details (e.g., exact formula used for equivolume diameter calculation)
- Connect to other groups which analyzed Parsivel measurement accuracy