Drop size distribution measurement of ISO nozzles by shadowgraphy method

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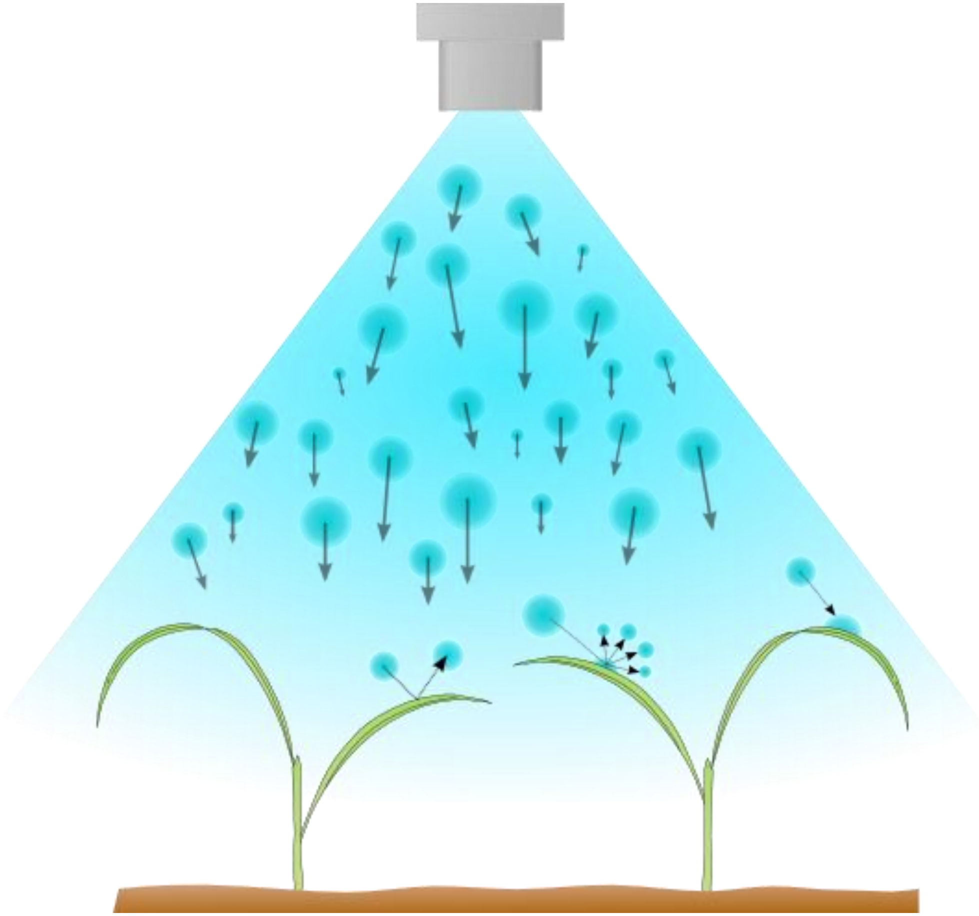
Agricultural spray application



Deposition

From the nozzle to the plant

➔ Effect of the size on droplets driftability

Retention

Droplet impacts on the plant surface

➔ Effect of the droplets energy on the retention

$$We = \frac{\rho \boxed{\boldsymbol{v}^2\ \boldsymbol{l}}}{\sigma}$$

Spray characterization techniques

- Laser diffraction spectrometry (LDS)
  - Droplet **size**
- Phase Doppler Anemometry (PDA)
  - Droplet **size and speed**
- Particle/Drop Image Analysis (PDIA)
  - Based on image analysis
  - Droplet **size and speed**

Need coherent light (laser)

→ High cost

Based on optic theory

→ Require liquid optical properties

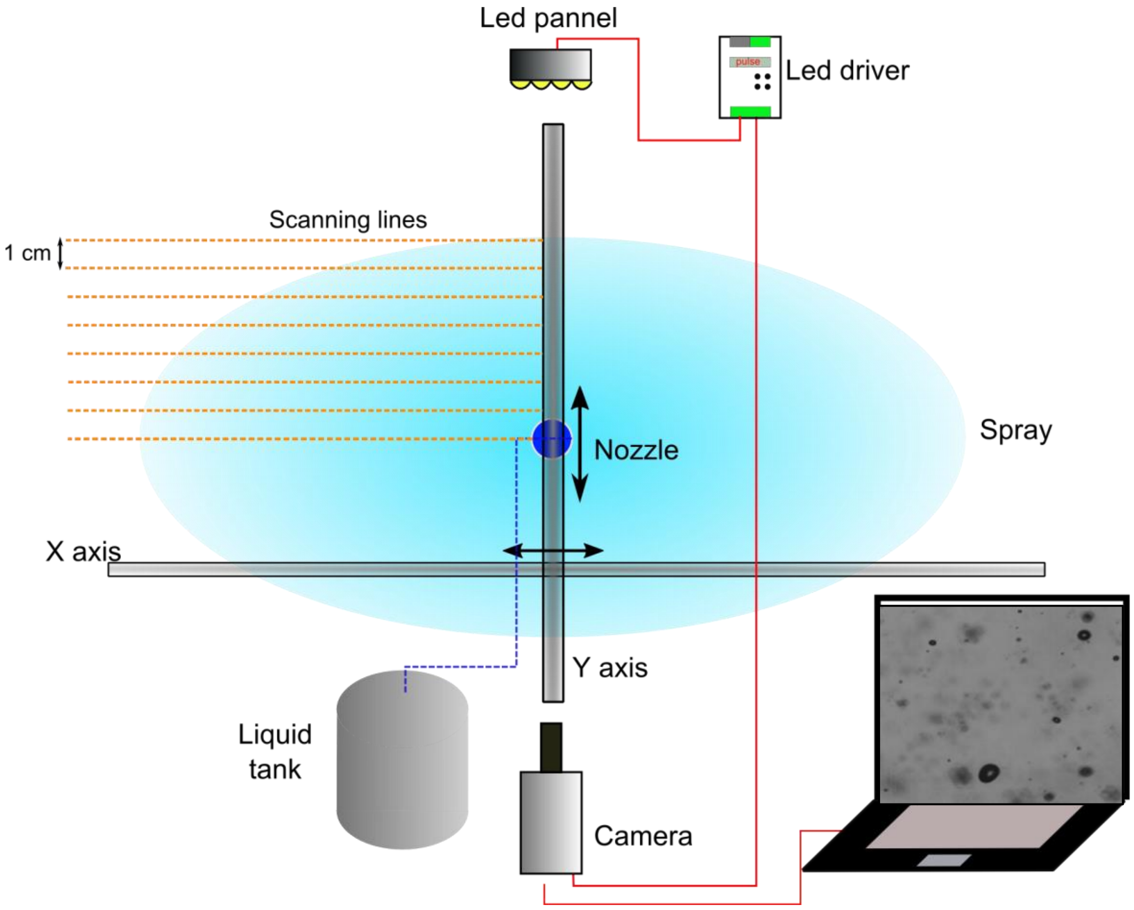
Objective

Validation of a versatile, low cost and accurate **spray characterization tool** based on high speed imaging

Method

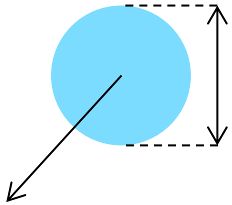
Assess the method capability to segregate nozzle class boundaries (VF/F, F/M, …)

Image acquisition set-up



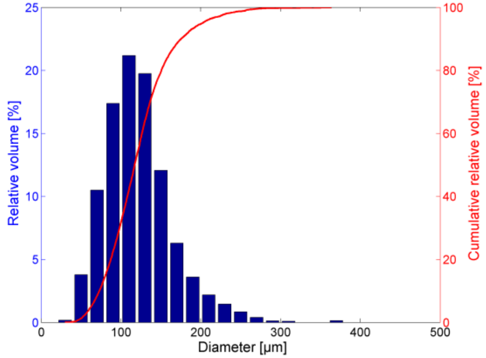
- 8-bit PIV camera
- 72 W LED panel
- Acquisition of picture in PIV mode (double frame)
- Scan of ¼ of the spray

Image processing method



Diameter

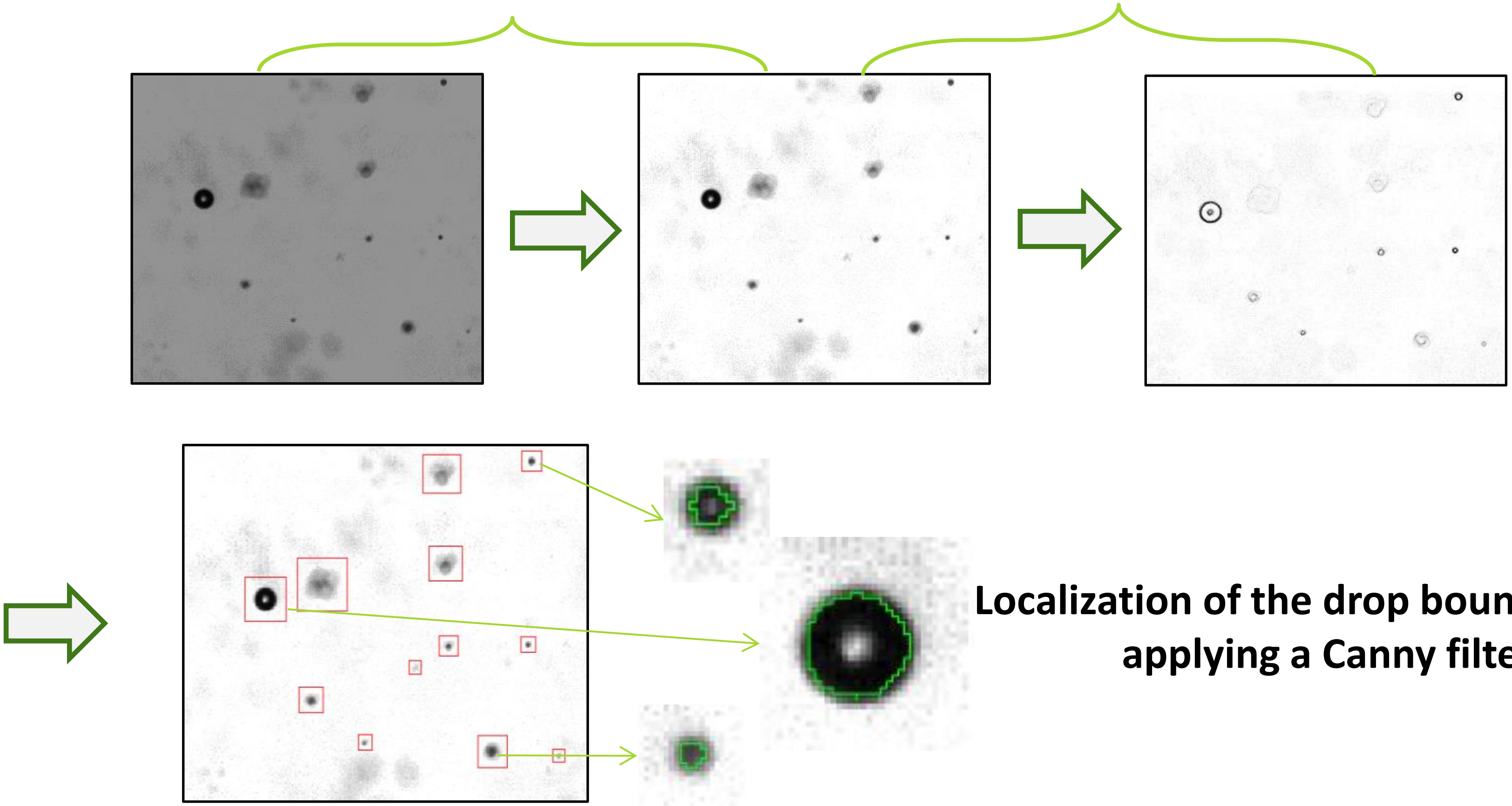
Velocity (x,y)



Overall spray characteristics is set by summing each droplet characteristic

Drops localization

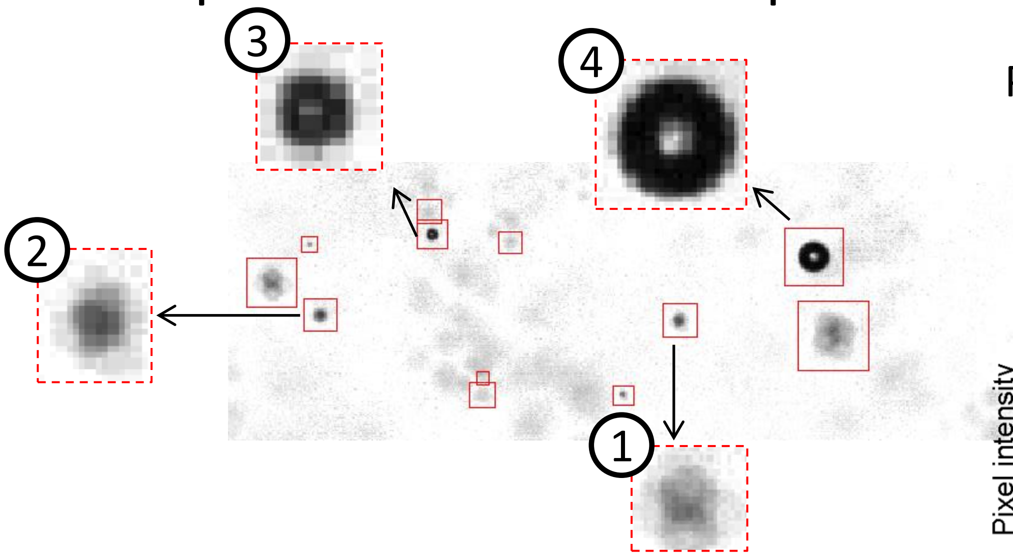
Average background subtraction **Gradient computation**



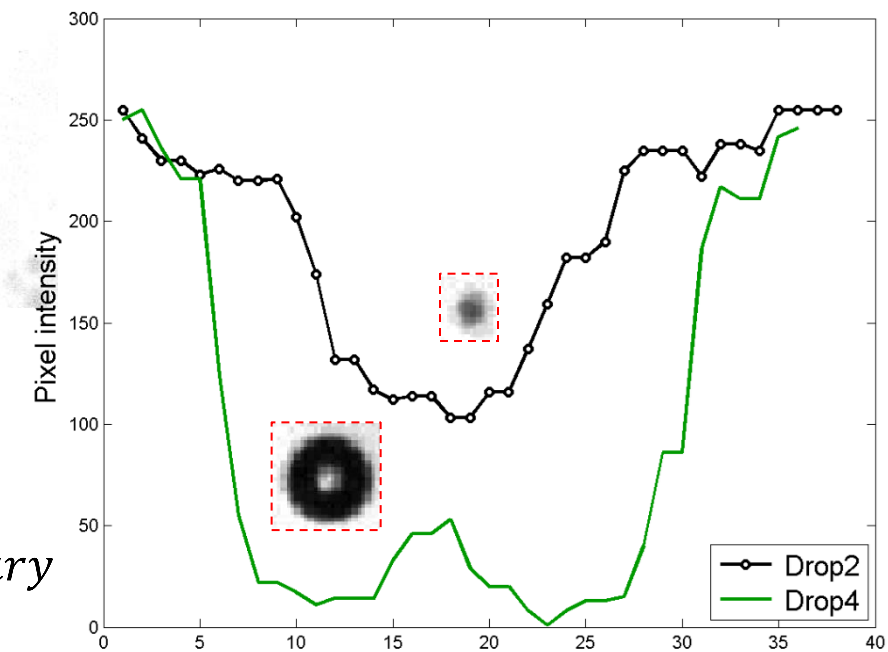
Localization of the drop boundaries by applying a Canny filter

Out of focus drops rejection

- Drop shadow boundaries present various levels of sharpness



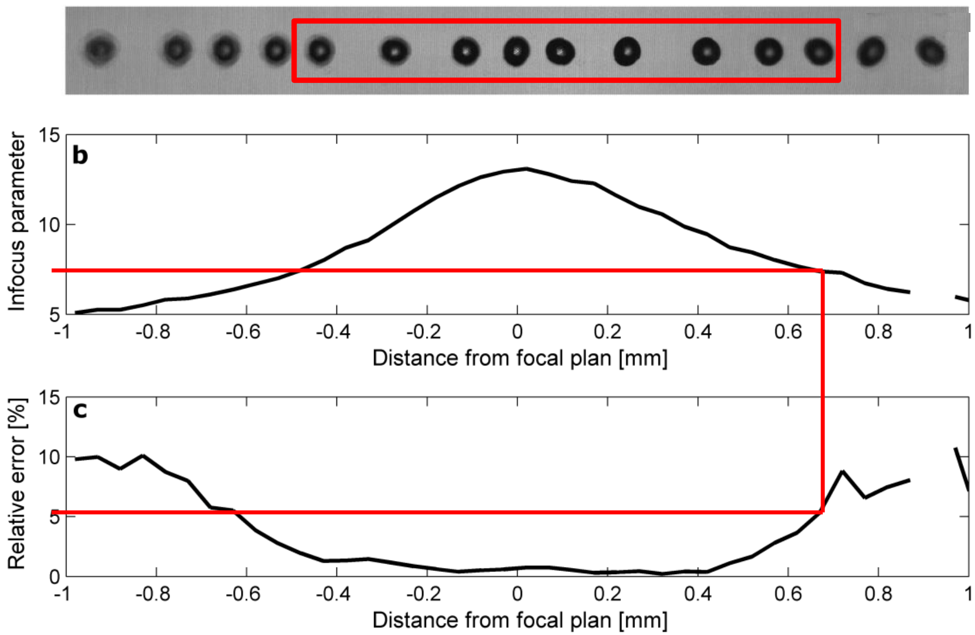
Pixel intensities accross droplet shadows



$$Sharpness \propto Gradient\ intensity\ at\ the\ boundary$$

Out of focus drops rejection

- Determination of focus parameter threshold



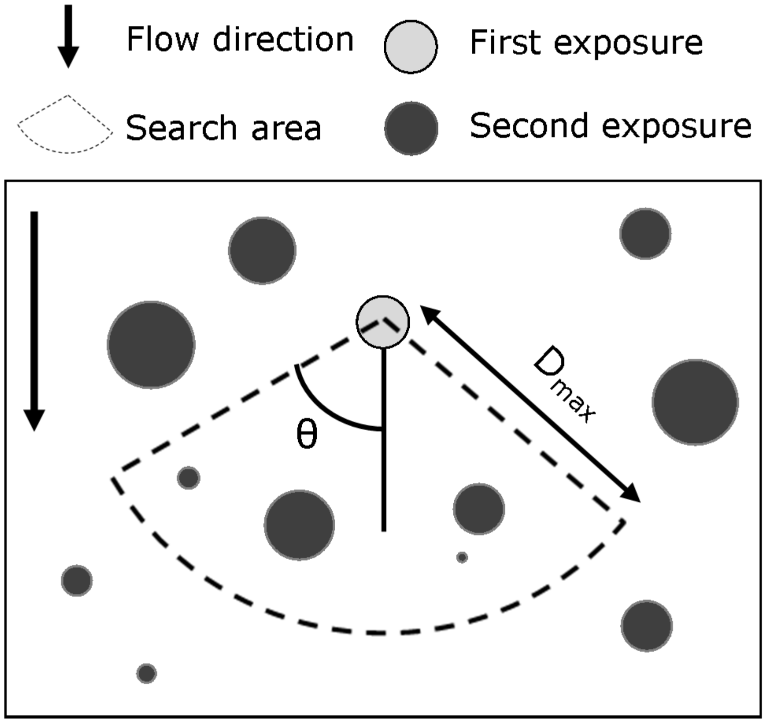
Oblique stream of monosized drops

$$Focus\ parameter = \frac{grad_{bound}}{I_{object} - I_{back}}$$

Relative error on drop diameter measurements

Velocity measurement

- Droplet tracking based on:
  - Droplet size
  - Most probable displacement

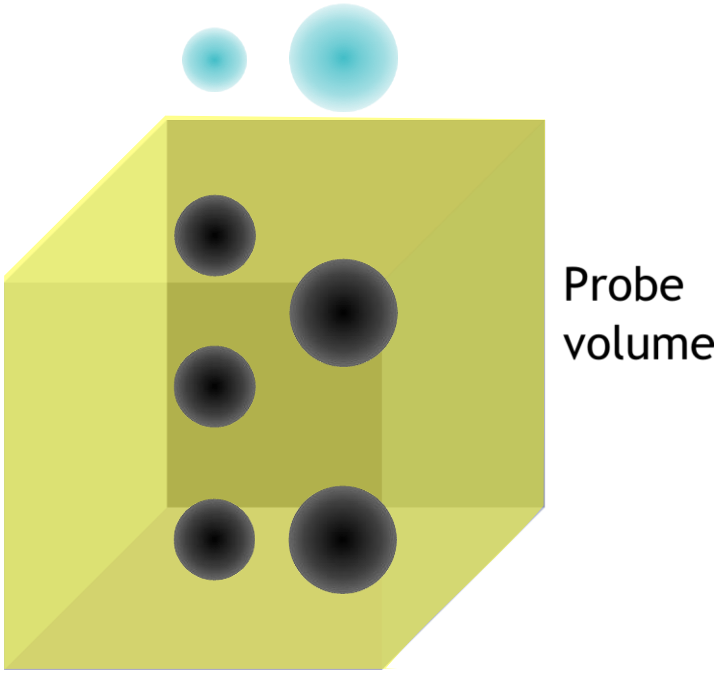


$$D_{max} = v_{max}\,\Delta t$$

θ deviation in respect to the main flow

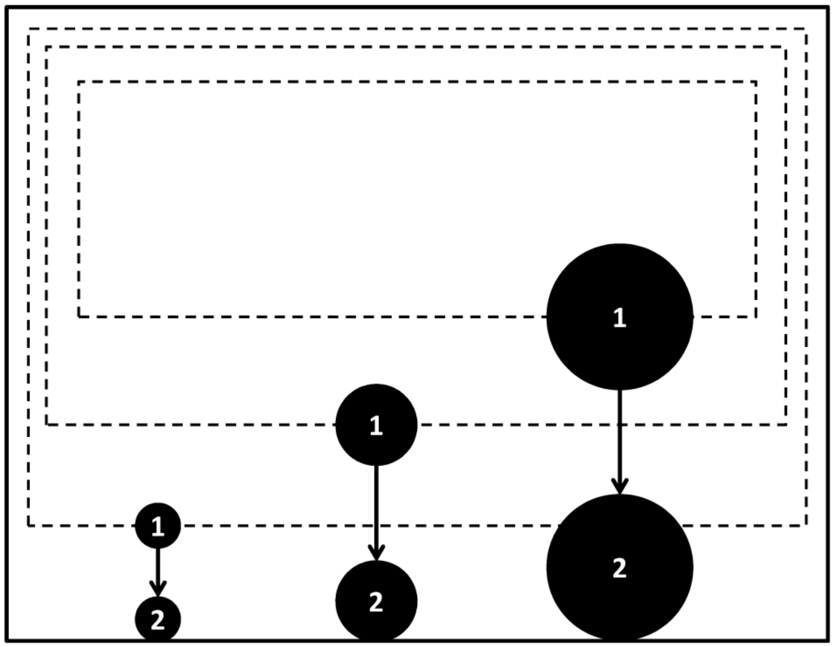
Sampling probality

Residential time



$time \searrow$ when $v \nearrow$

Size of the probe volume

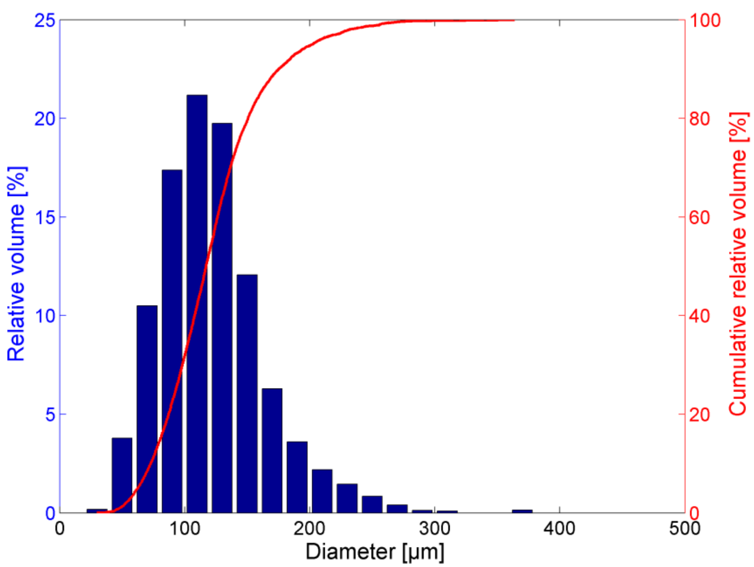


$size \searrow$ when $d \nearrow$

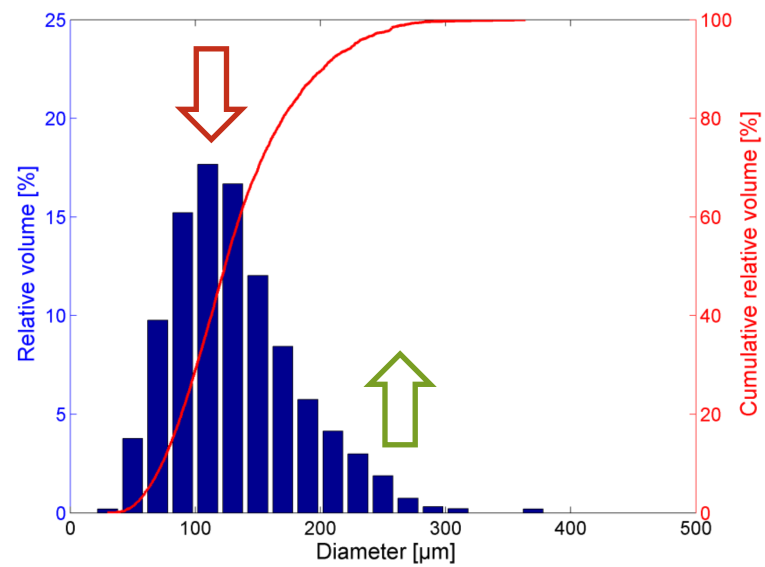
Correction of the drop size distribution

$$Sampling\ probability \propto \frac{PV_{size}}{v_d}$$

$$Correction\ Factor = \frac{v}{(FOV_{cor}\ DOF)}$$



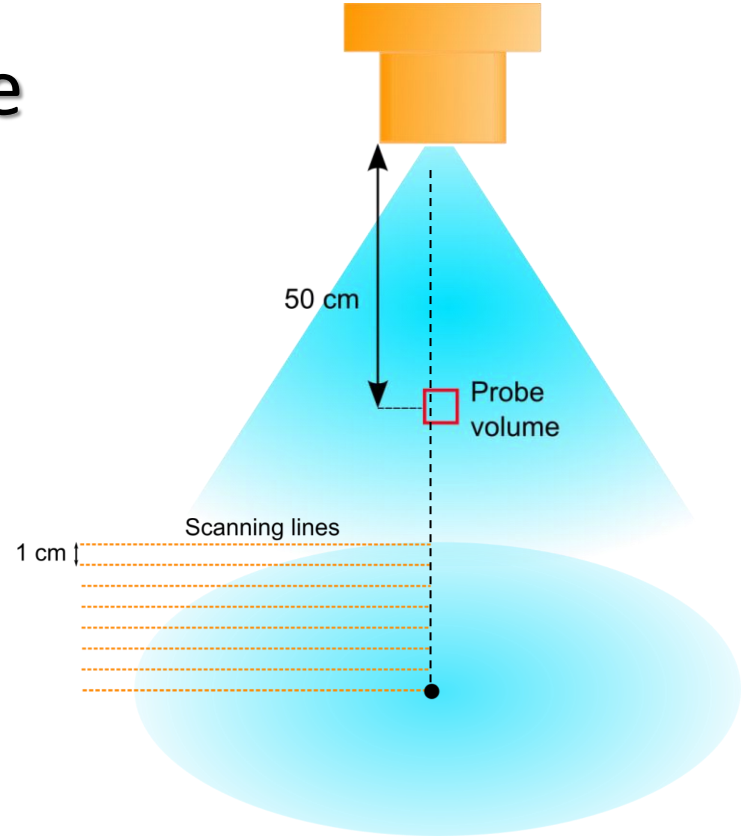
Correction



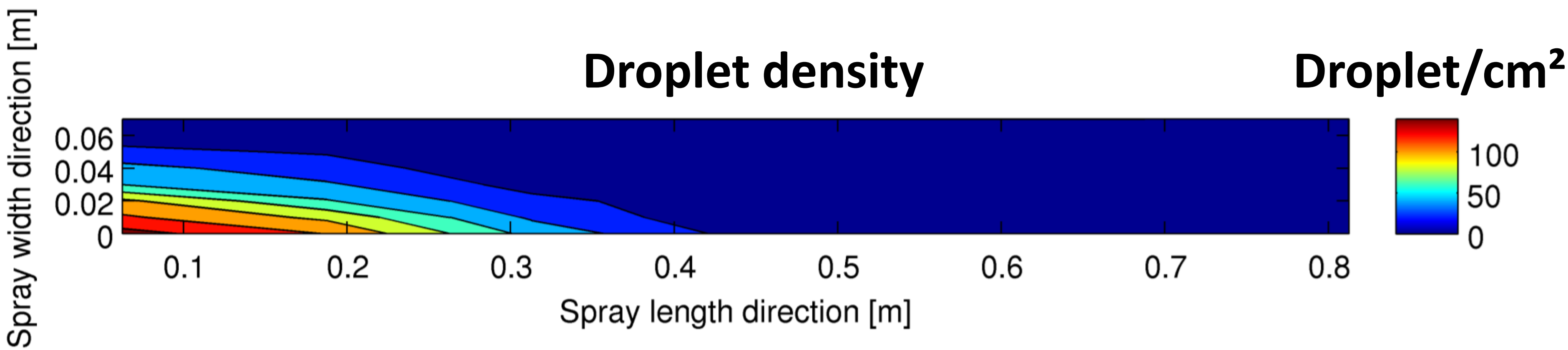
Measurements

- Scan of 6 nozzles defining the droplet size class boundaries

Class boundary	Nozzle type	Pressure (bar)
VF/F	TeeJet TP 110 01	4.5
F/M	TeeJet TP 110 03	3.5
M/C	TeeJet TP 110 06	2.5
C/VC	TeeJet TP 80 08	2.5
VC/XC	TeeJet TP 65 10	1.5
XC/UC	TeeJet TP 65 15	1.5



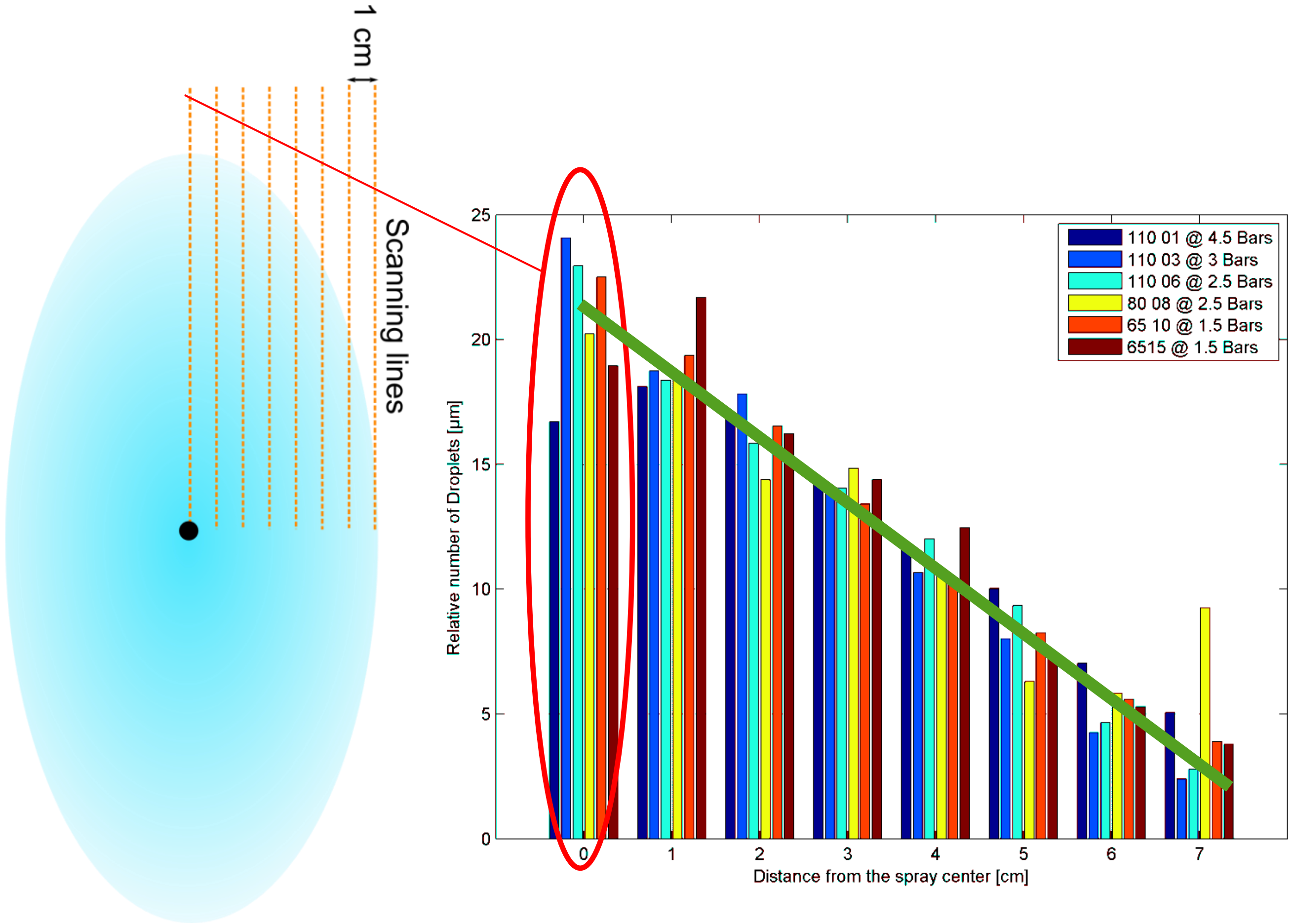
Spatial distribution of the droplets



110 03 @ 3 Bars

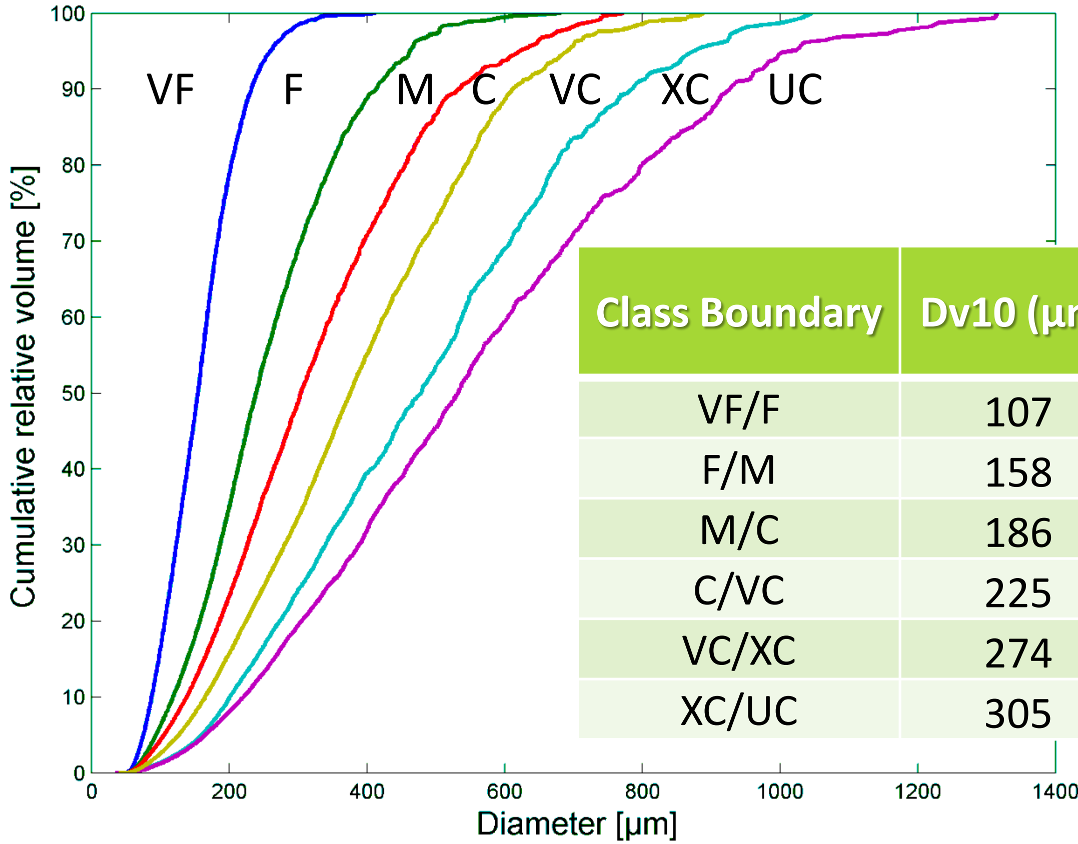
- Highest droplet density at the spray center
- Ellipsoidal shape (~1-10 for the 110 03)

Spatial distribution of the droplets



- Linear decrease of the droplet density with the distance to the spray center
- Weak effect of the nozzle
- Less than 5% of the droplet measured in the last scanning line

Cumulative drop size distribution



Class Boundary	Dv10 (µm)	Dv50 (µm)	Dv90 (µm)	Droplet count
VF/F	107	**154**	232	95398
F/M	158	**239**	414	46756
M/C	186	**304**	532	39947
C/VC	225	**375**	612	28817
VC/XC	274	**479**	786	15552
XC/UC	305	**532**	927	20084

Conclusions

- An image processing method has been presented
- The spatial analysis of the data showed that the scanning method is appropriate for flat fan sprays
- The imaging method is able to segregate the droplet size class boundaries

Further work

- Computation of the flow rate by integrating the measurements over the spray