WESC 2025
24 - 27 JUNE | NANTES, FR

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Wind speed effects on droplet size distribution

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Background

- Wind turbine blade erosion caused by rain
- Rain + wind + high tip speed = power washer

photo: armouredge.com

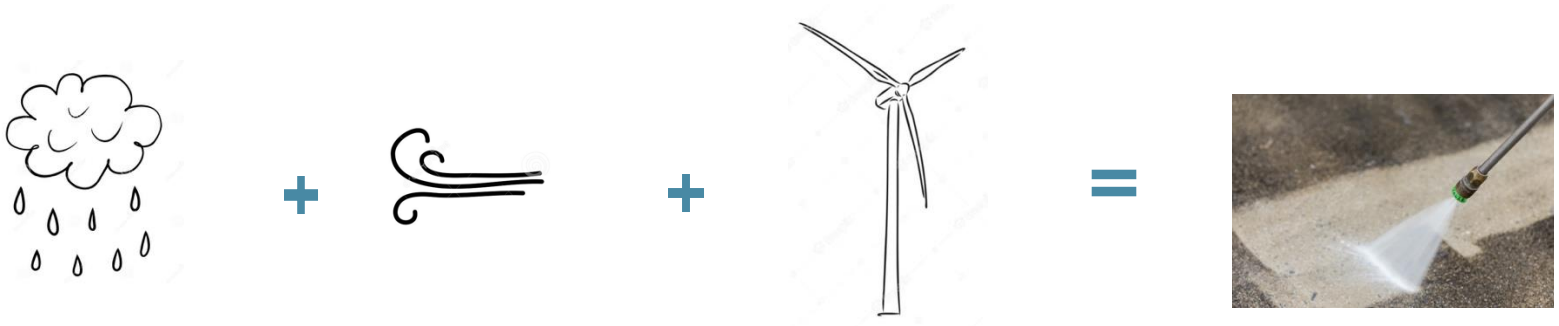

photo: powerfulgarden.com

Background

- A real wind turbine operating at high wind speed and in rain
- A video from Windmill Tech LinkedIn page ->
- Typical maximum tip speed: 70–100 m/s
- Typical terminal velocity of droplets: 0.5–7 m/s
- Impact velocity mostly determined by the tip speed

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Erosion damage modelling

- We normally need to estimate the number of impacts or the amount of impinged water on the blade
- Not directly measurable
- Rain rates are estimated with rain gauges (worldwide)
- Converted into liquid water content in the air
- The size and fall-velocity estimated with the theoretical drop-size distribution (DSD) from rain rate data

The Best distribution

- The size distribution of raindrops
- By A. C. BEST, 1950

$$1 - F = exp\left[-(x/a)^n\right]$$

$$a = A\ I^p$$

- Need for an update?
- Several studies point to a potential wind speed dependency in DSD
- High wind speed can enhance droplet breakup
- Higher wind speeds expected to shift the distribution toward smaller droplet sizes

Hypothesis

The Best DSD can be updated with a wind speed dependent variable

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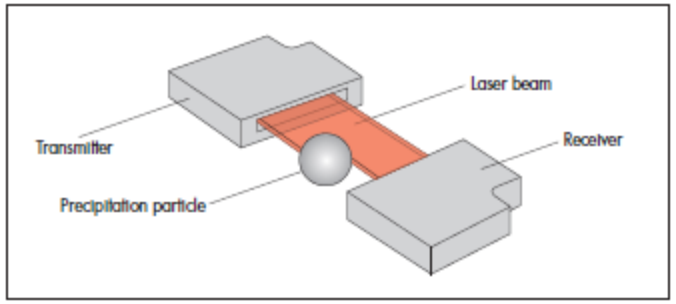
Risø meteorological mast

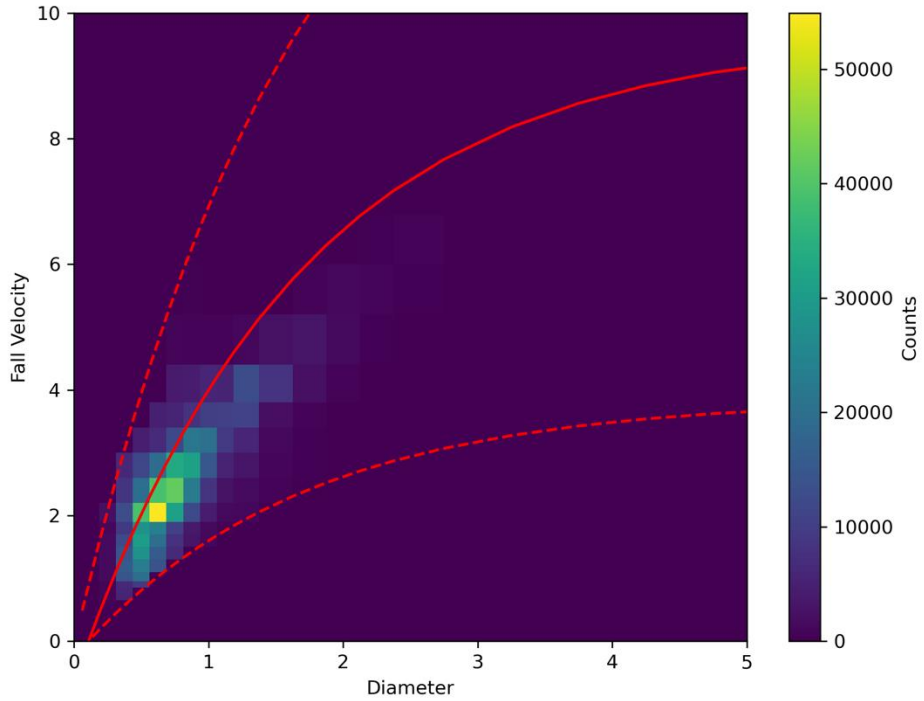
- 122 m tall tower with cup anemometers and wind vanes
- An OTT Parsivel laser-optical disdrometer at the top of the mast
- Rimco tipping bucket rain gauge
- From June 2019 – May 2023

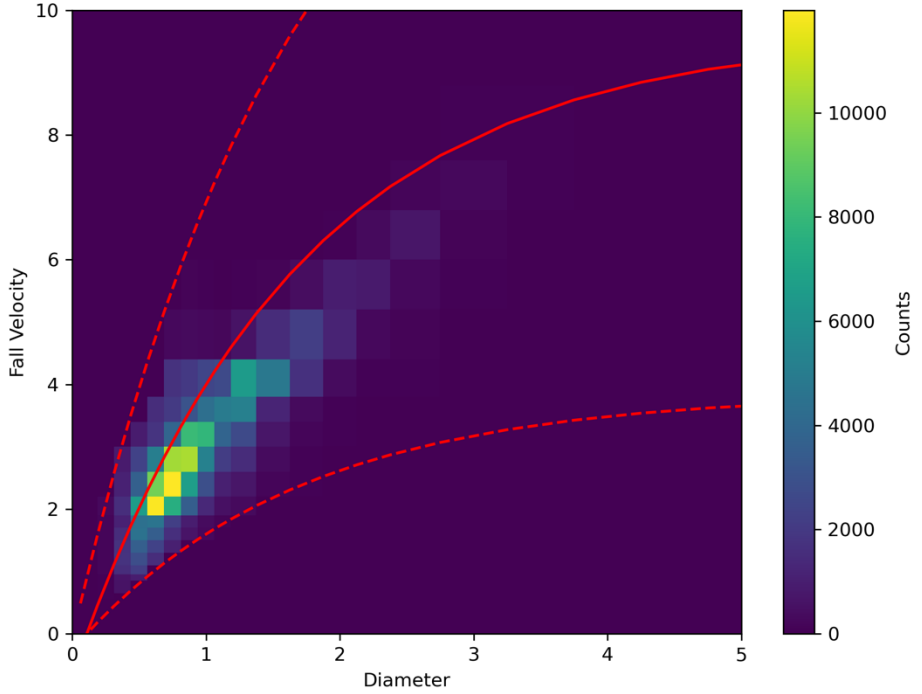


Droplet size-velocity histograms

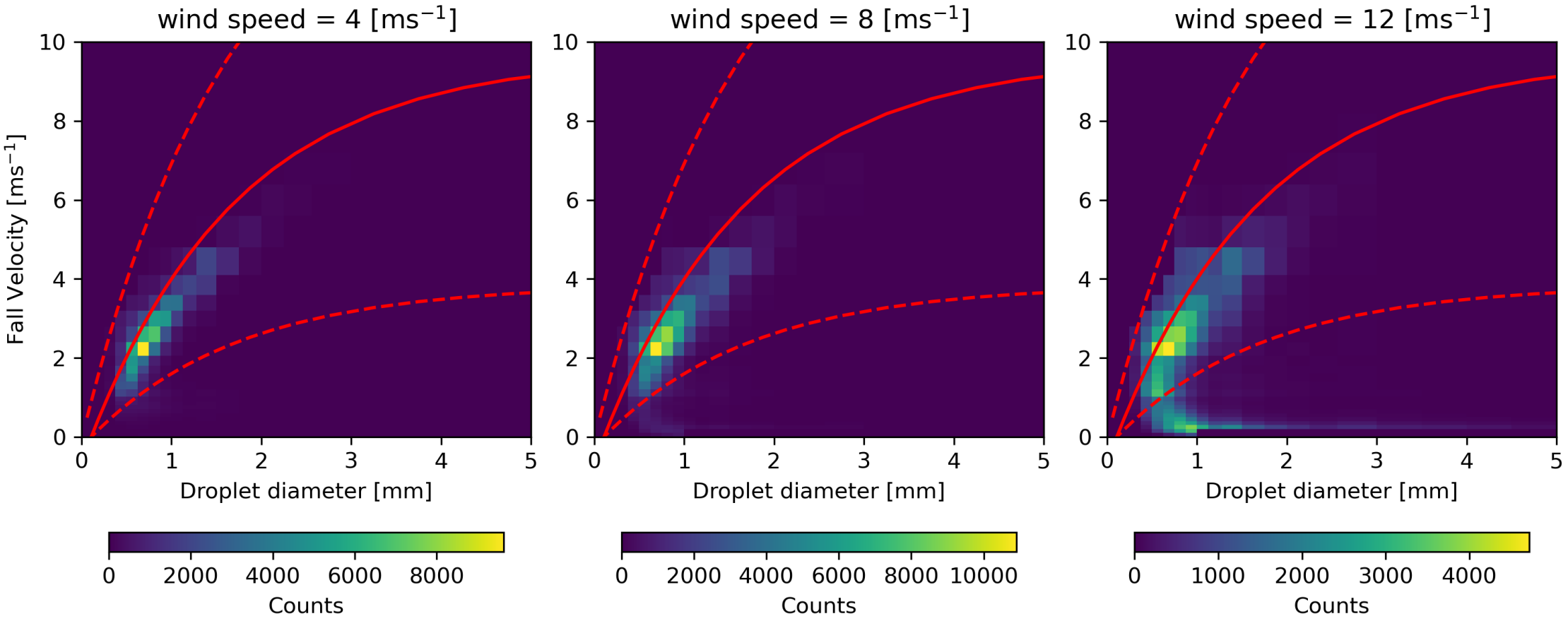
Theoretical curve for terminal fall speed vs. drop diameter, Atlas et al. 1973

$$V = 965 - 1030\, e^{-6D}$$

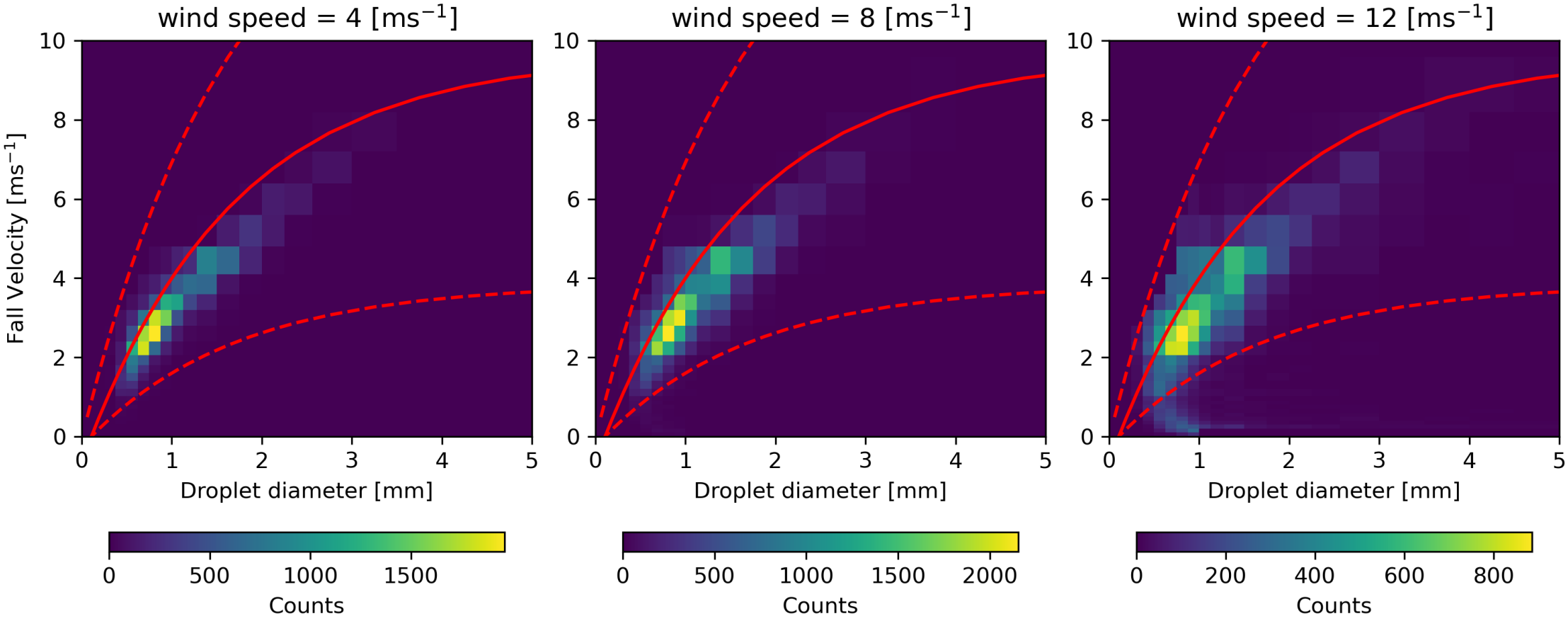




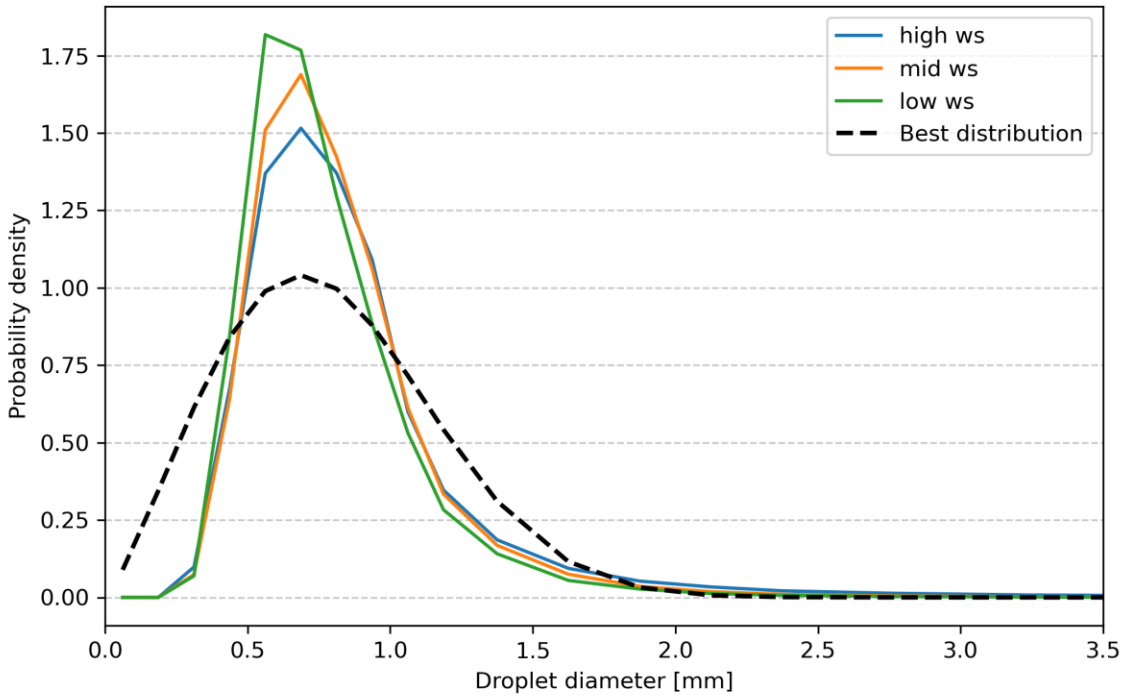
WS dependent Droplet size-velocity histograms

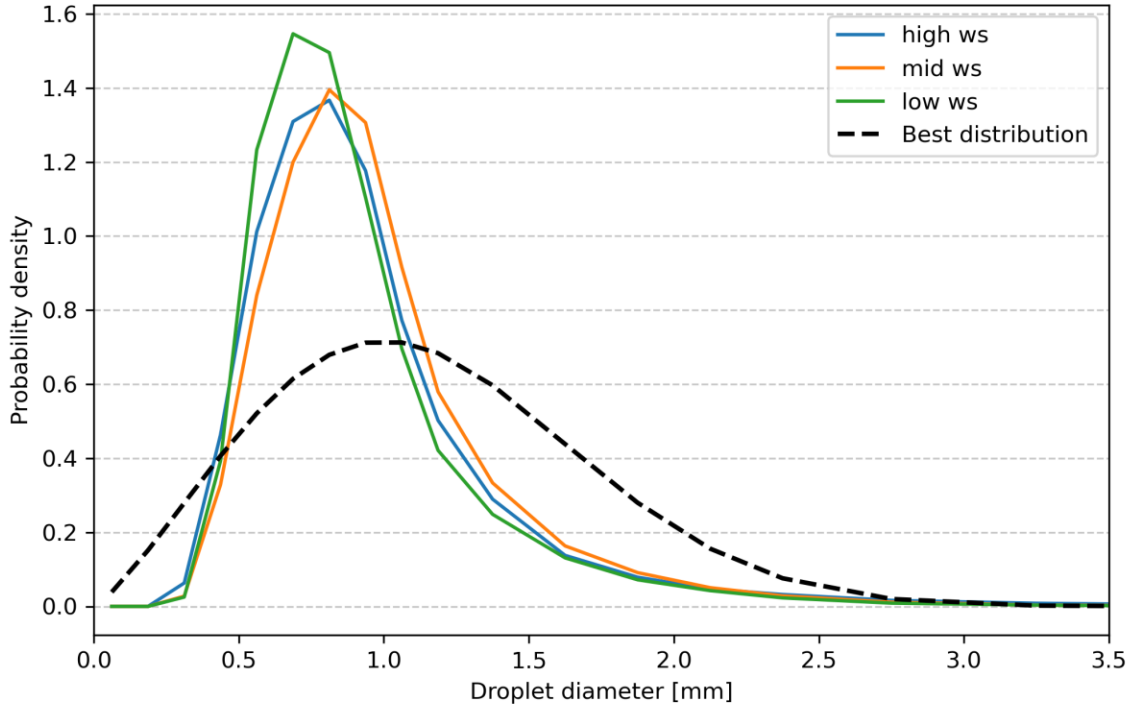


WS dependent Droplet size-velocity histograms



Marginal drop size distributions





Conclusions

- We can neither reject or confirm our hypothesis
- We observe a shift from the theoretical curve for terminal fall speed
- At and above 8 m/s the disdrometer doesn't measure accurately, the spread is higher, and more errors occur
- As it is important for wind turbine blade erosion modeling to know the DSD at high wind speeds, other instruments should be used for these measurements
- The Best DSD needs and update and the wind speed dependence with new reliable DSD measurements in different wind and climate conditions

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