

ICEMET-project

solves the LWC measurement

Timo Arstila, Winterwind 7.2.2017

ICEMET-project

University project
1.1.2016 – 30.6.2017
funded by TEKES and
University of Oulu



In-cloud icing

the reason for wind turbine icing

Icy weather conditions are result of

- temperature below zero
- water droplets
- relative wind speed



LWC measurement has been a challenge

There has been several methods to measure the LWC of the air

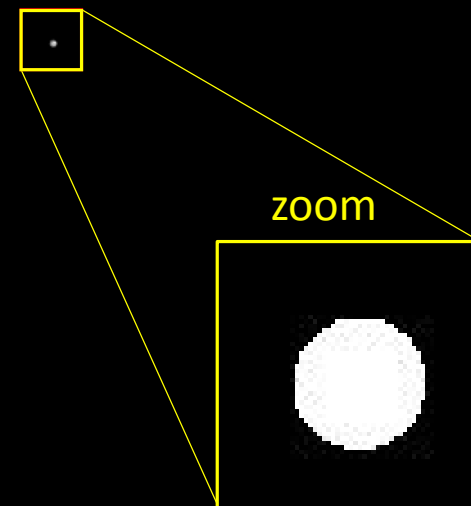
- hot wire
- mass of accumulated ice
- forward/back scattering of light
- conventional shadow imaging

Still need for fast and reliable method to measure LWC and specially together with MVD and DSD.



Computational imaging

example image for analysis



PoC test site

late winter 2016



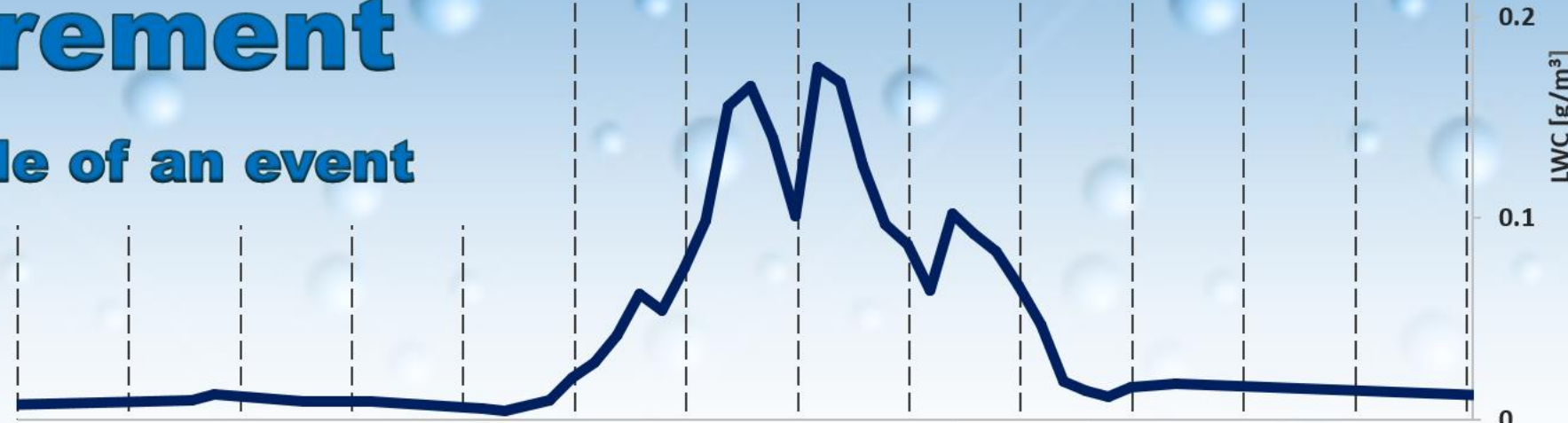
PoC-measurement results example of an event

Temperature -12 °C
 Wind speed 7 m/s

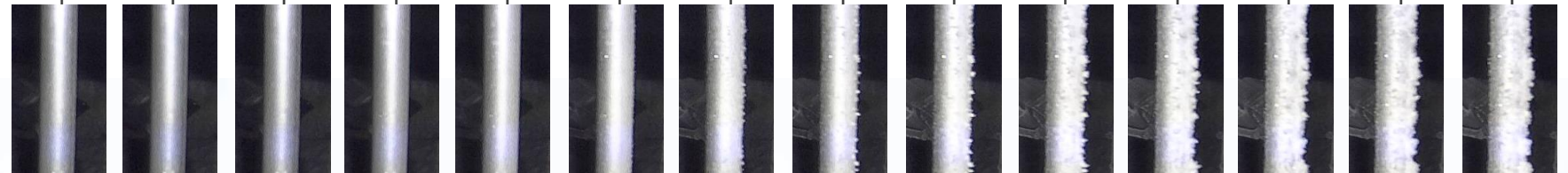
17.3.2016

LWC

Time



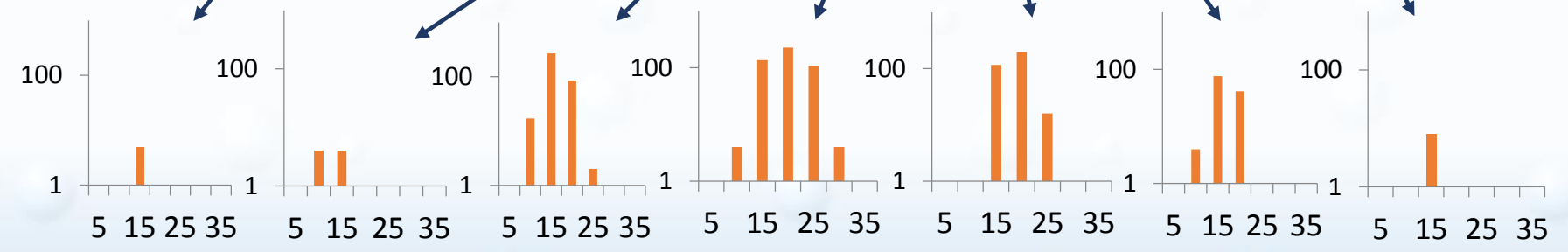
30 mm rod



MVD



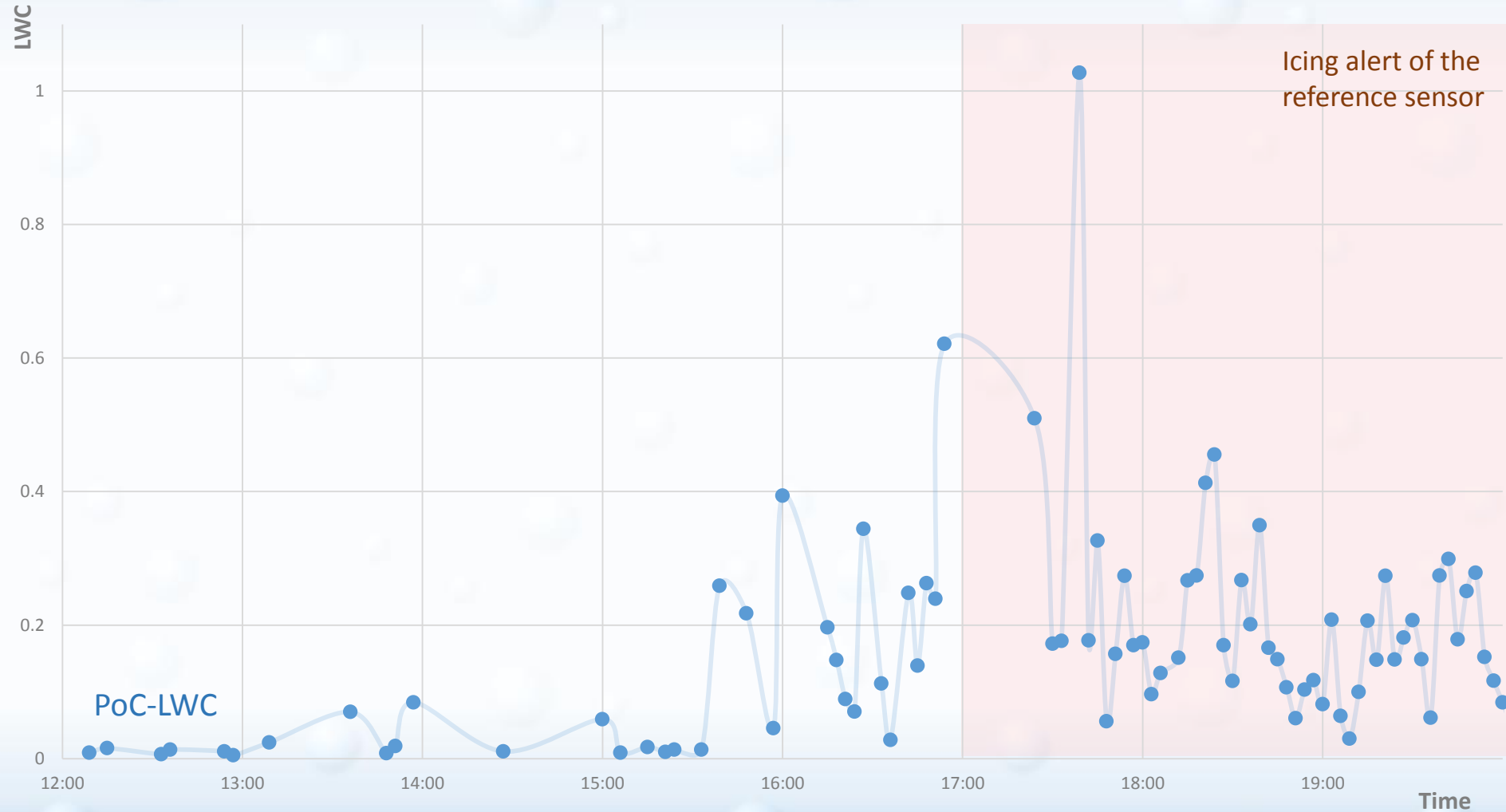
DSD (log)



Comparison to reference sensor

PoC-sensor vs. icing sensor

Cloud event 14.3.2016



ICEMET-sensor

winter 2016 - 2017

Specifications

- height 53 cm
- weight 8 kg
- sample volume 0,5 cm³
- sampling frequency up to 35 Hz
- heating power up to 500 W
- resolving power 3 μm



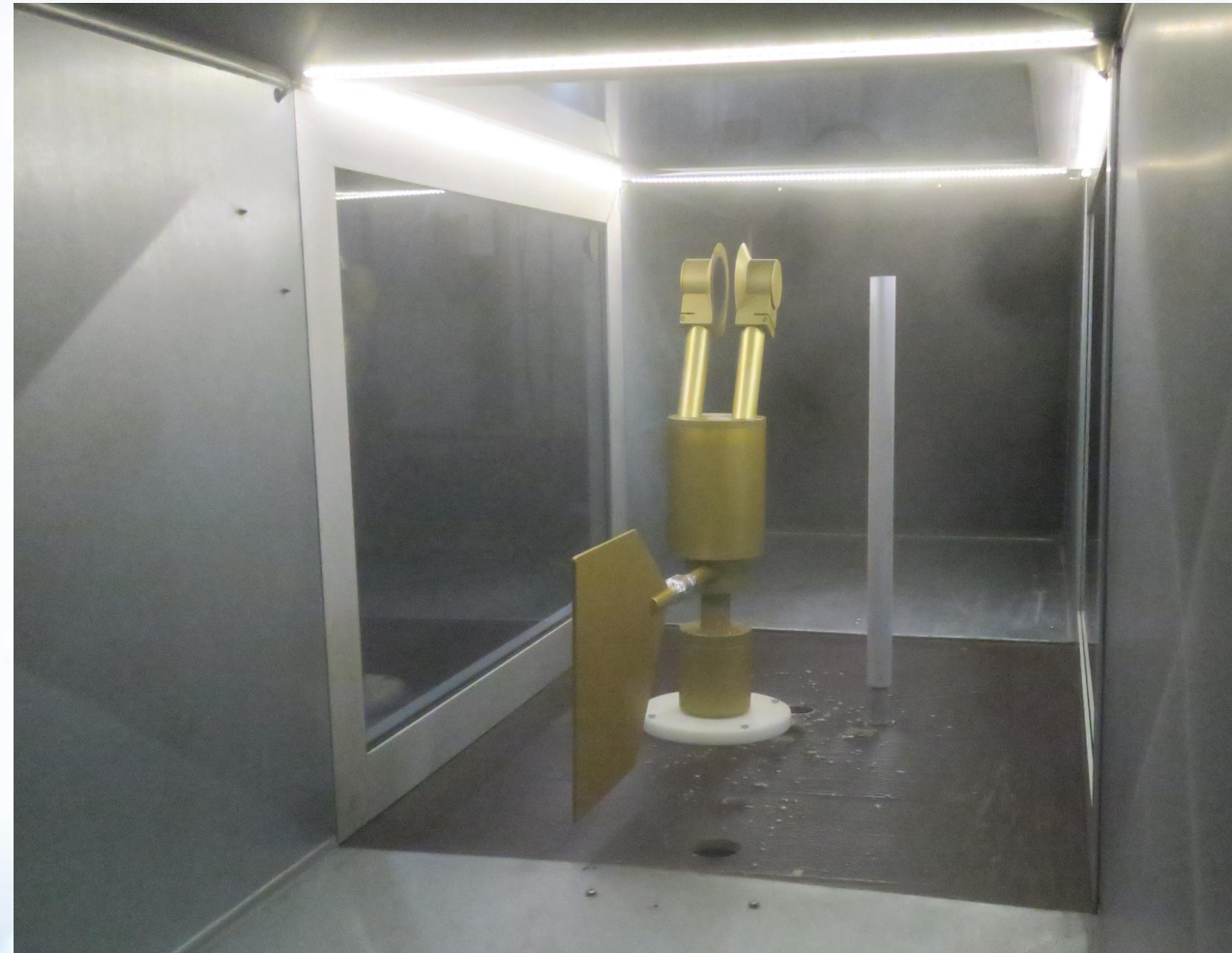
Wind tunnel tests

VTT, Espoo, 13.-14.10.2016

Test conditions

- Temperatures -5 °C and -15 °C
- Wind speeds 4 m/s, 7 m/s, 10 m/s
- LWCs 0,1 g/m³, 0,2 g/m³, 0,4 g/m³

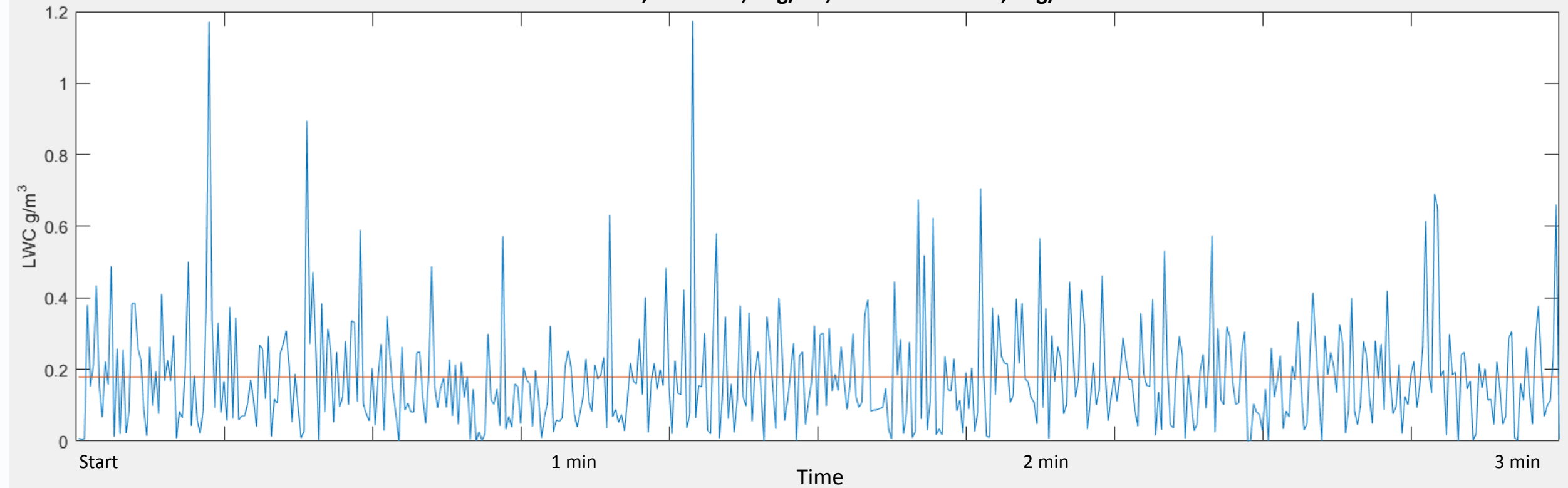
Reference measurement:
standard 30 mm icing rod.



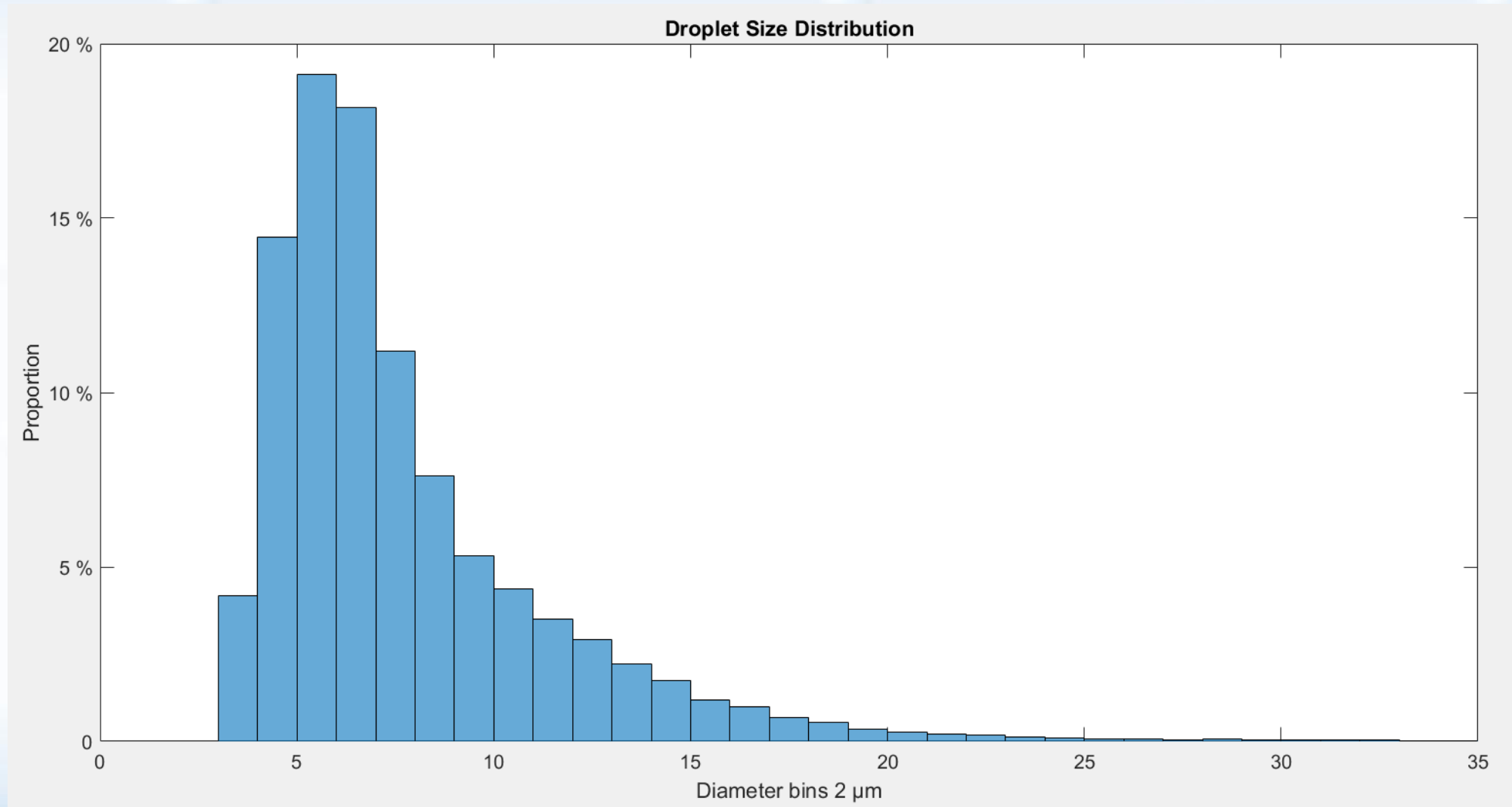
Preliminary results from wind tunnel

LWC

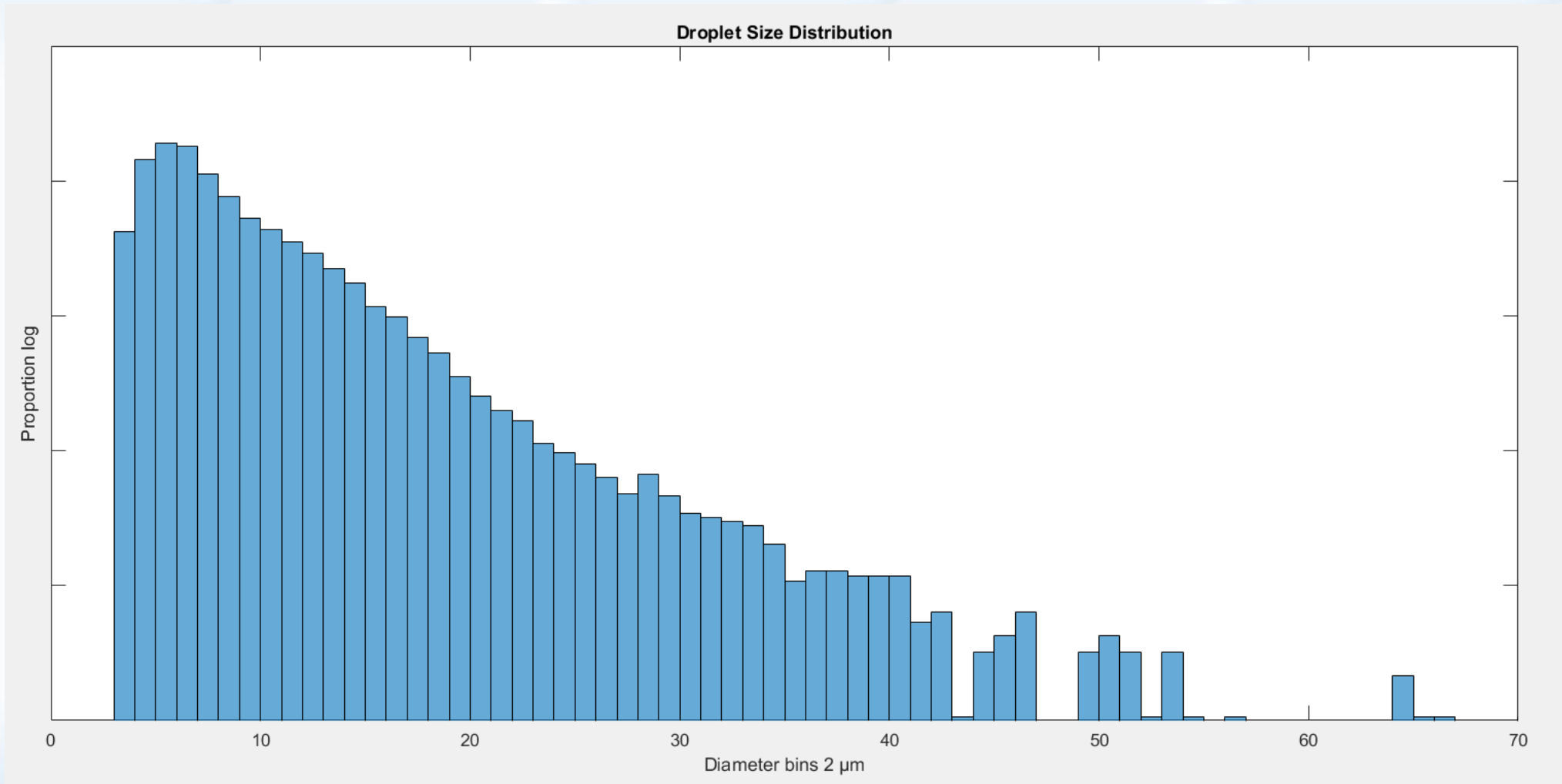
LWC vs. time, mean = 0,18 g/m³, reference rod = 0,17 g/m³



Preliminary results from wind tunnel DSD

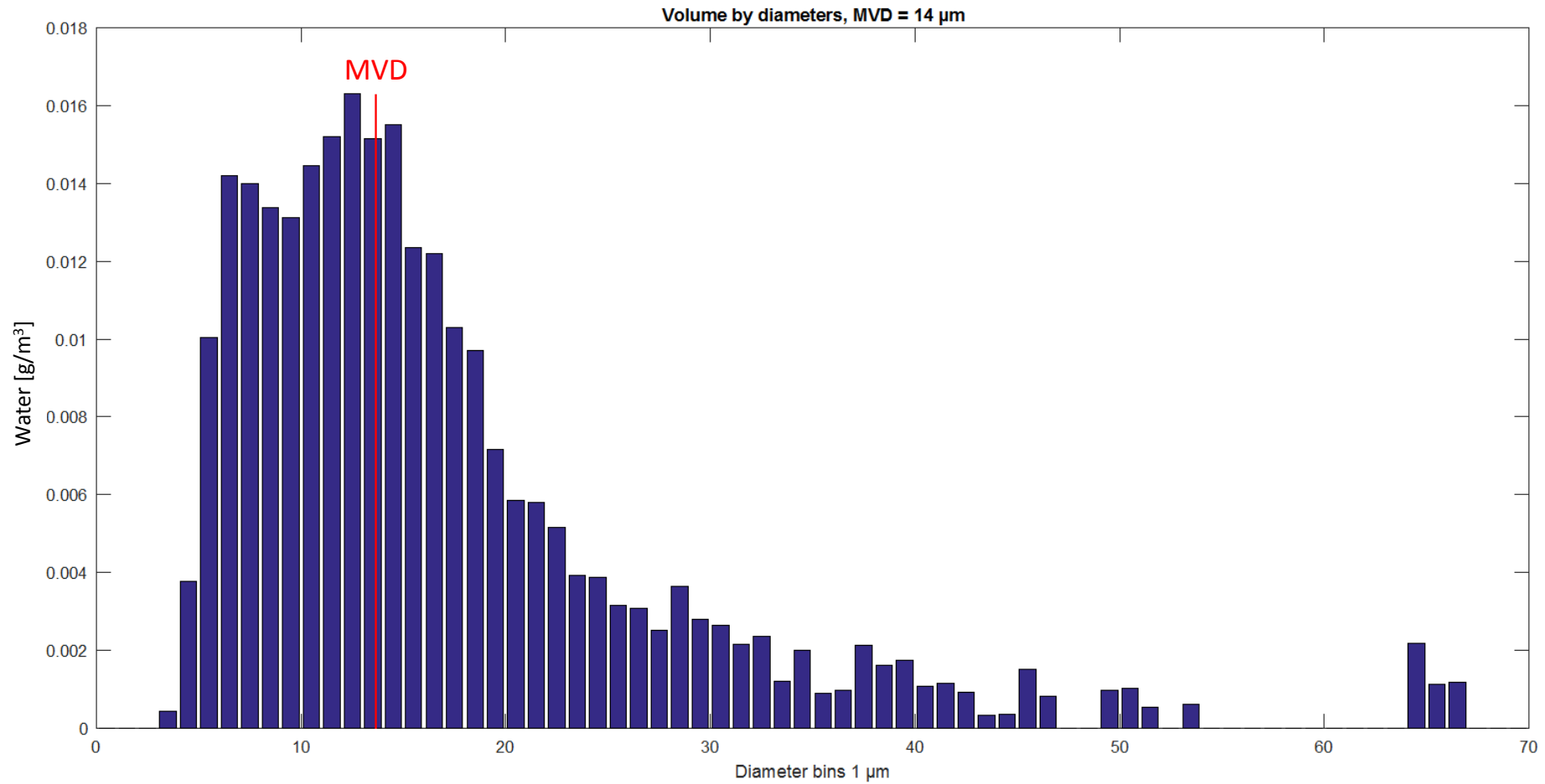


Preliminary results from wind tunnel DSD



Preliminary results from wind tunnel

MVD

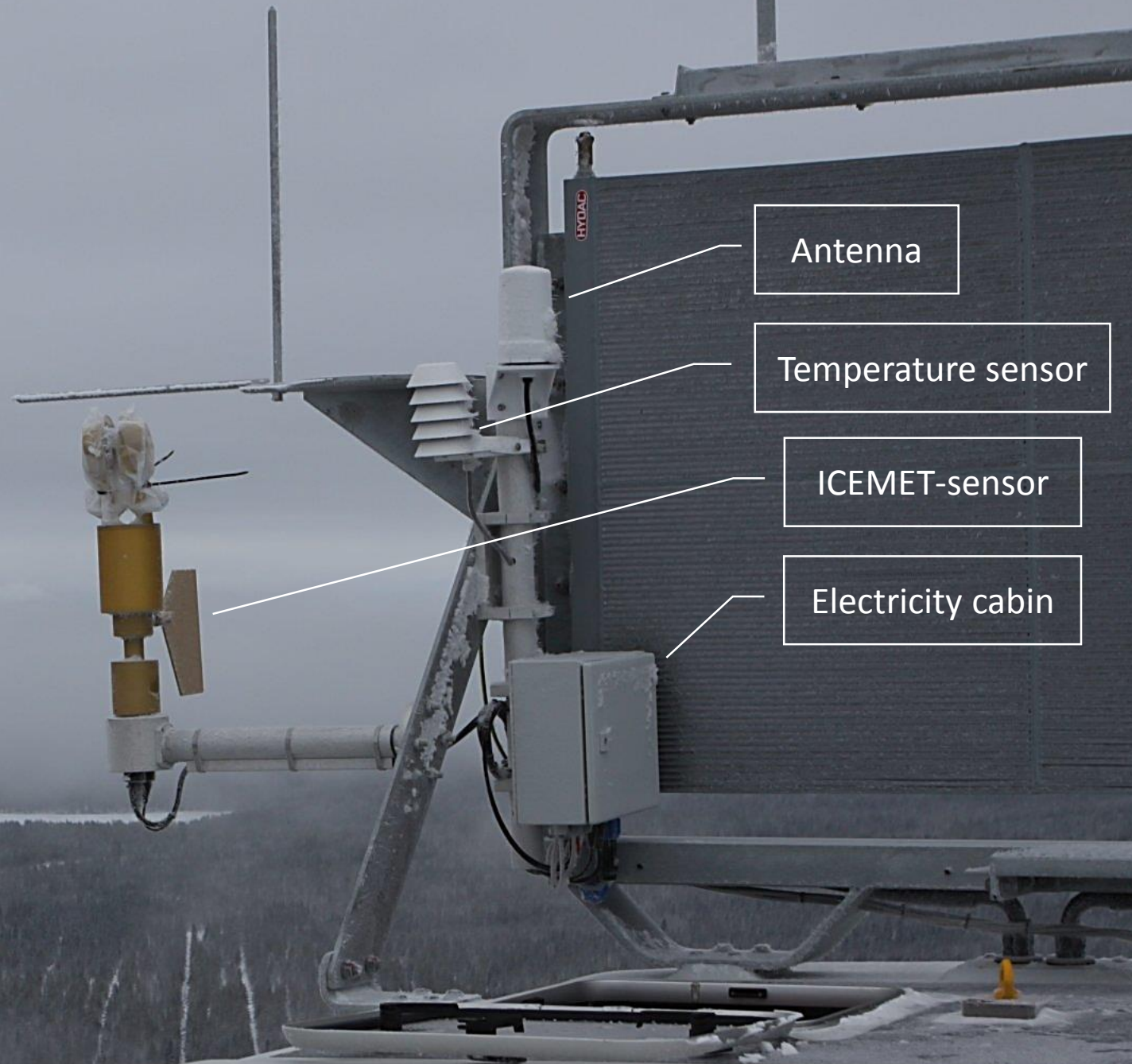


Pilot campaign

late winter 2017



Pilot setup at Peuravaara



Antenna

Temperature sensor

ICEMET-sensor

Electricity cabin

Conclusions and future

ICEMET-sensor is able to measure

- LWC, MVD and DSD with highest accuracy and reliability
- with shortest response time

ICEMET-sensor will be available for measurements starting from the winter 2017 – 2018 in

- wind turbines
- masts
- power lines
- as reference sensor



Acknowledgments

Project team:



Ville Kaikkonen



Timo Arstila



Timo Kananen



Katri Kukkola



Jaakko Hakala



Anssi Mäkyne

Funders:



Cooperators:



Steering group: ten front line experts from Finnish industry and research.

ICEMET-project

www.oulu.fi/icemet

Thank you for your attention