MODELLING ICE ACCRETION ON A CYLINDER, SIMPLE? RIGHT?

UNIVERSITÉ LAVAL

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Paper

- More details, see paper
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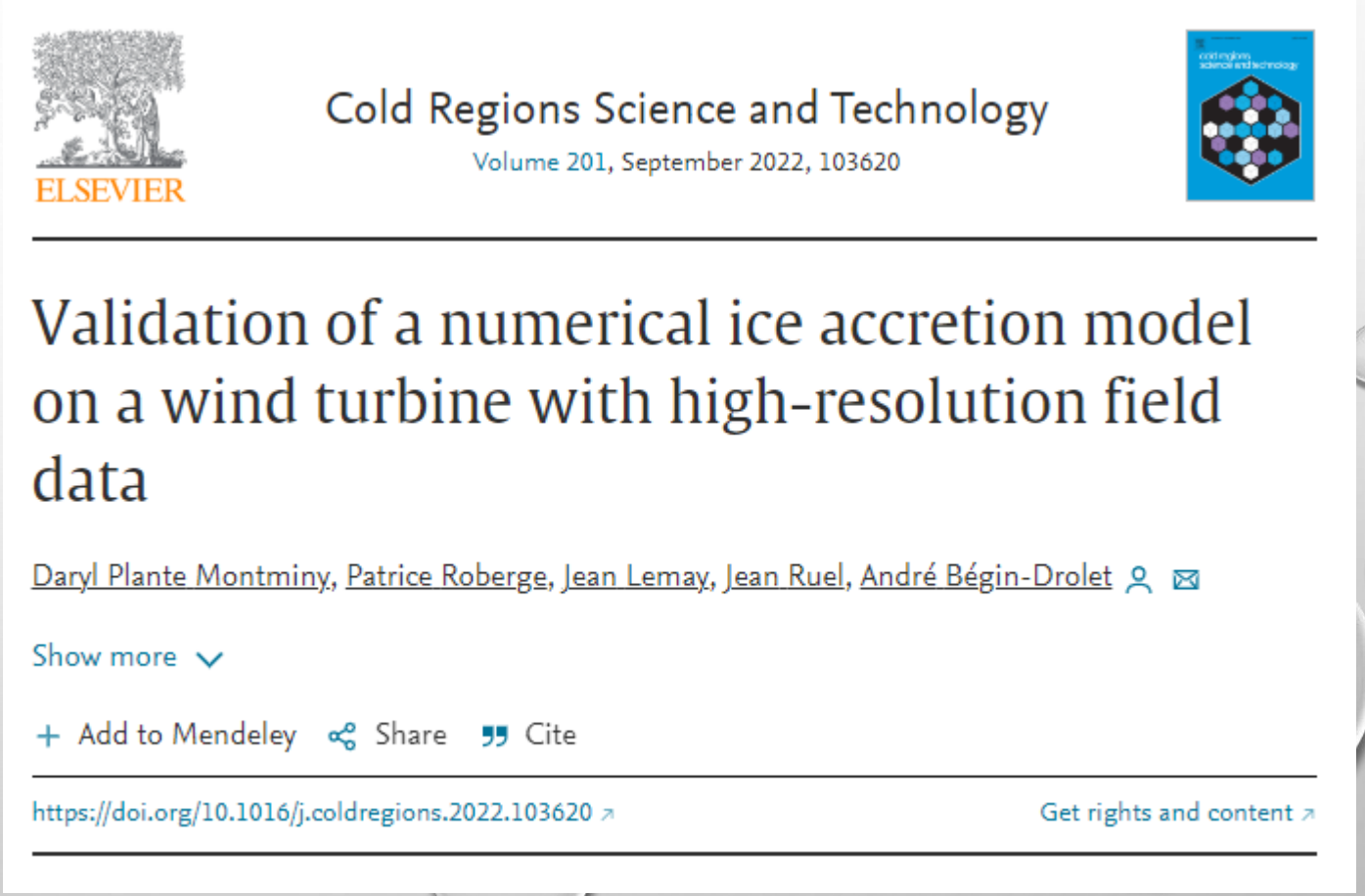

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Validation of a numerical ice accretion model on a wind turbine with high-resolution field data

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The holy grail

Meteorological data

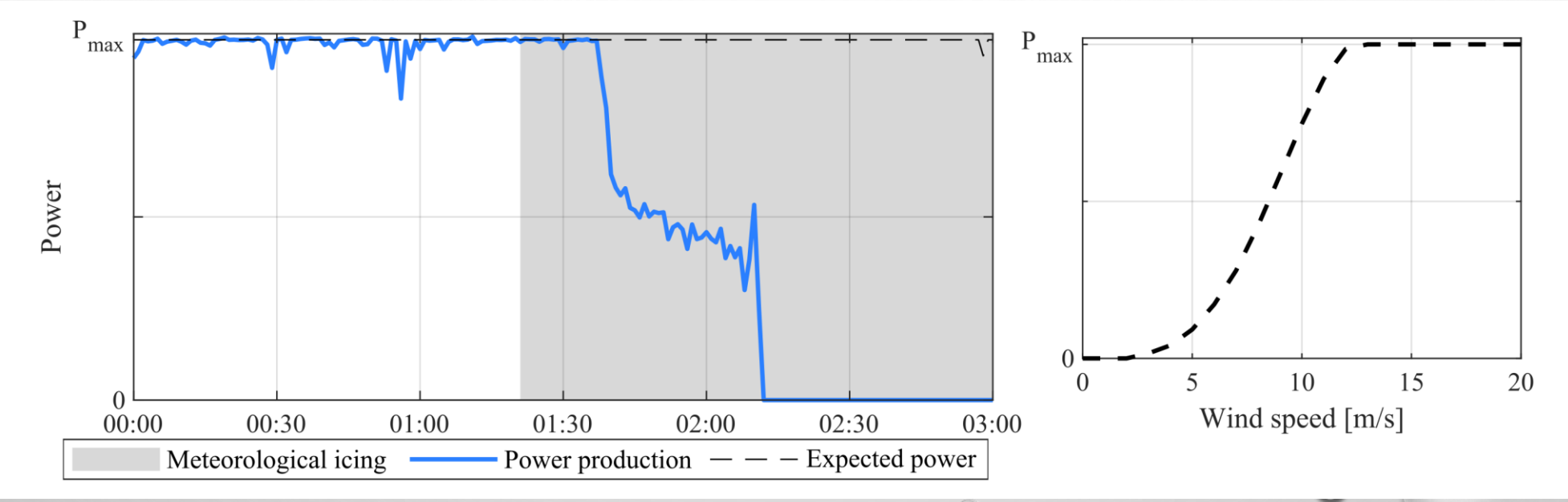
Turbine data

Computers, math and fancy stuff

Turbine performance, icing losses

Where are we so far?

Example of a real icing event



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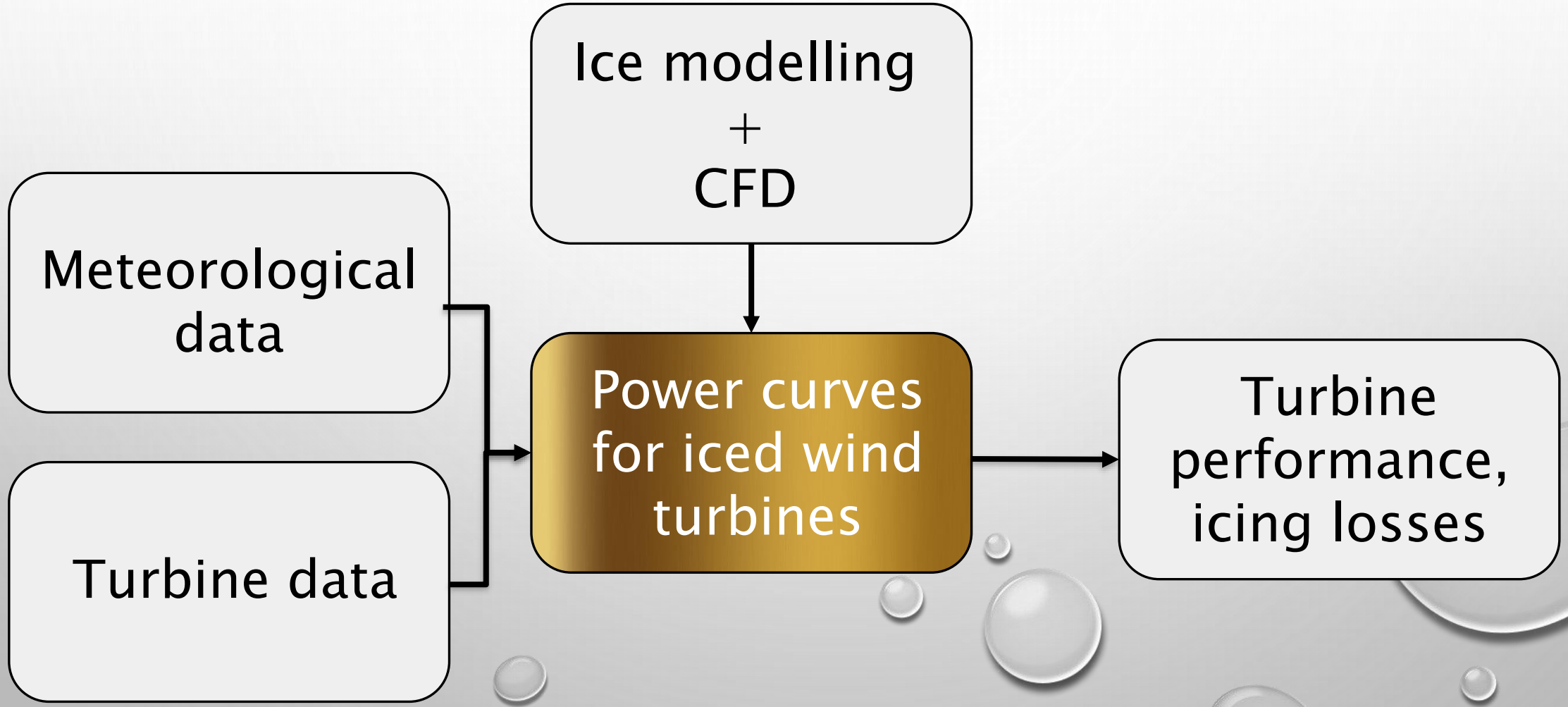
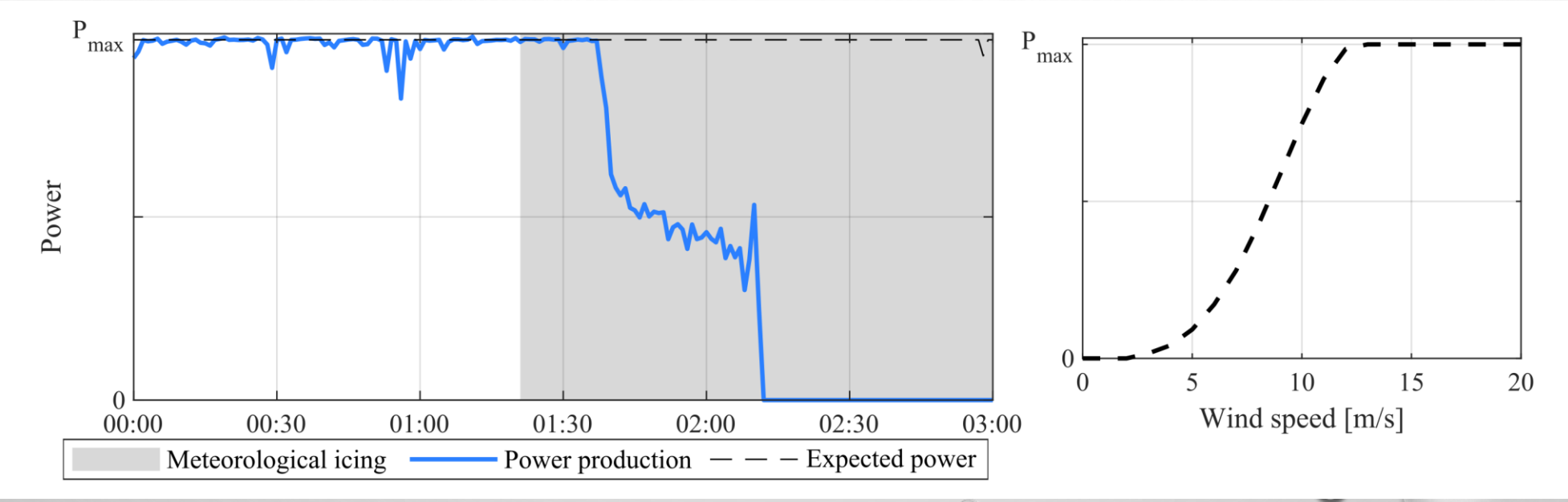
Where are we so far?

One popular path to the Holy Grail



Where are we so far?

Example of a real icing event



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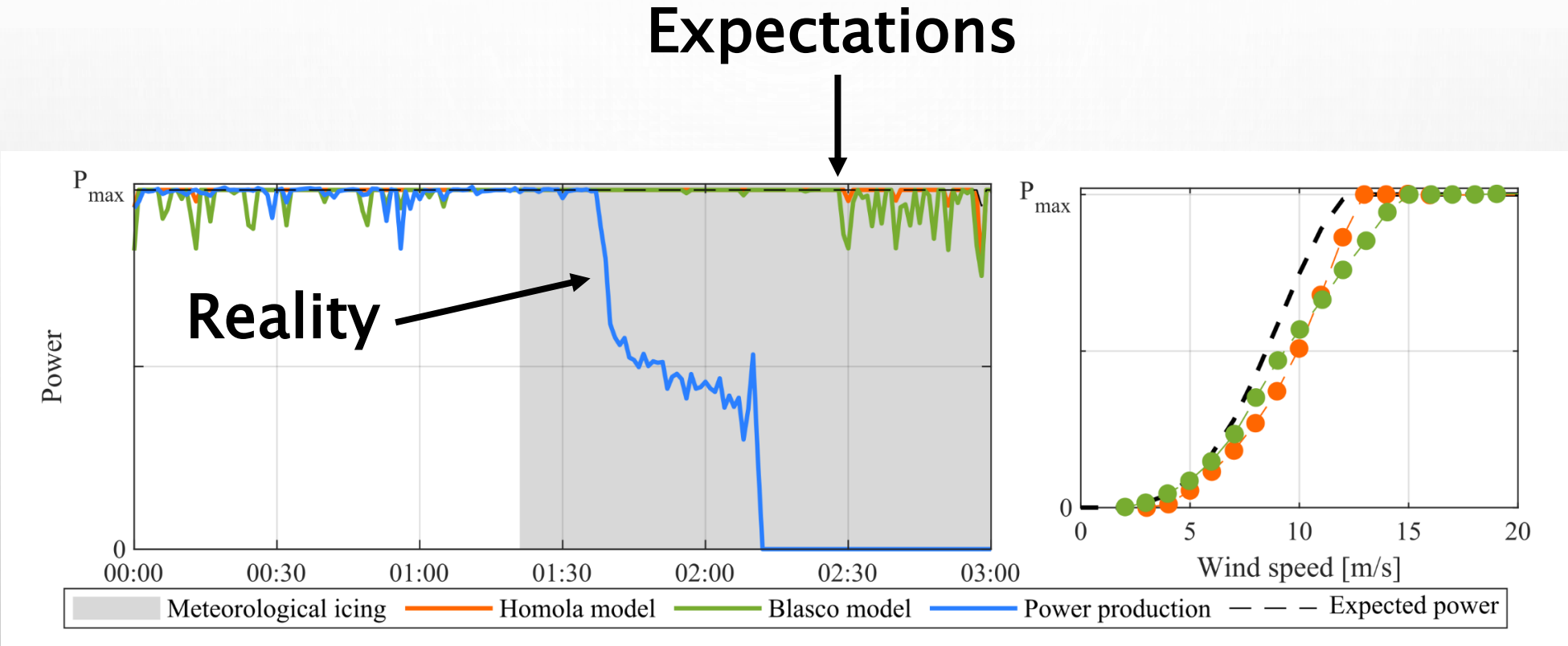
Expectation vs. reality



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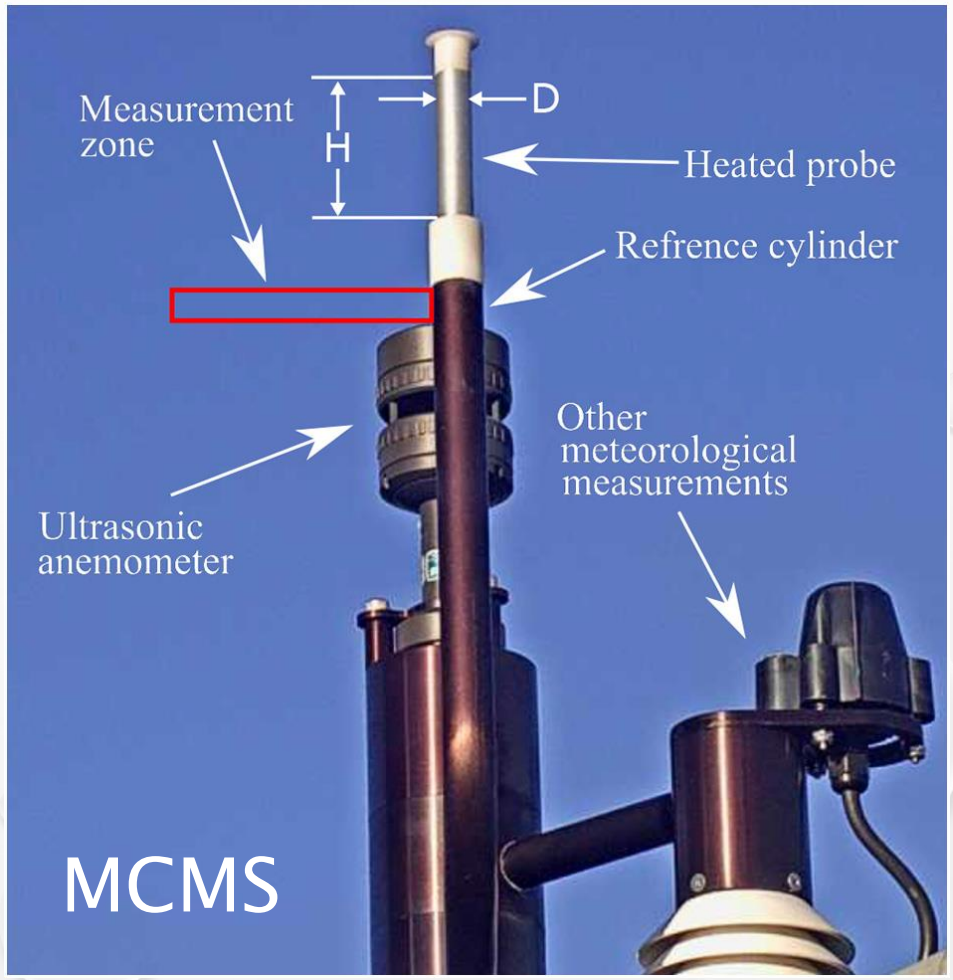
- Homola, M.C., Virk, M.S., Nicklasson, P.J., Sundsbø, P.A., 2012. Performance losses due to ice accretion for a 5 MW wind turbine. Wind Energy 15 (3), 379–389.
- Blasco, P., Palacios, J., Schmitz, S., 2017. Effect of icing roughness on wind turbine power production. Wind Energy 20 (4), 601–617.

Going back to basics

- First step: accurately model ice accretion on a wind turbine nacelle
- How?
  With LEWICE (commercial ice accretion software)
- Whats new?
  Feeding field data inputs and validating with images



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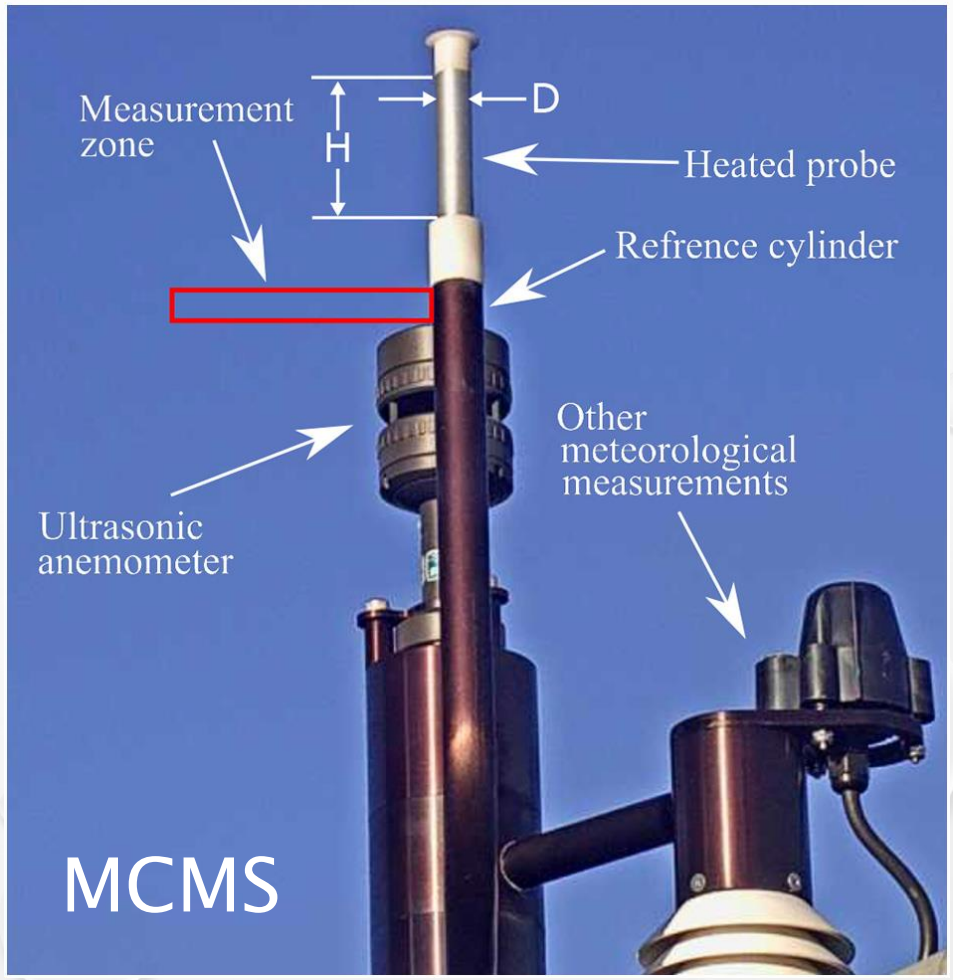
Methodology

- Meteorological Conditions Monitoring Station (MCMS)
- Reference Cylinder (ø19.5 mm)
- Photo every 15 minutes
- Software to extract ice thickness



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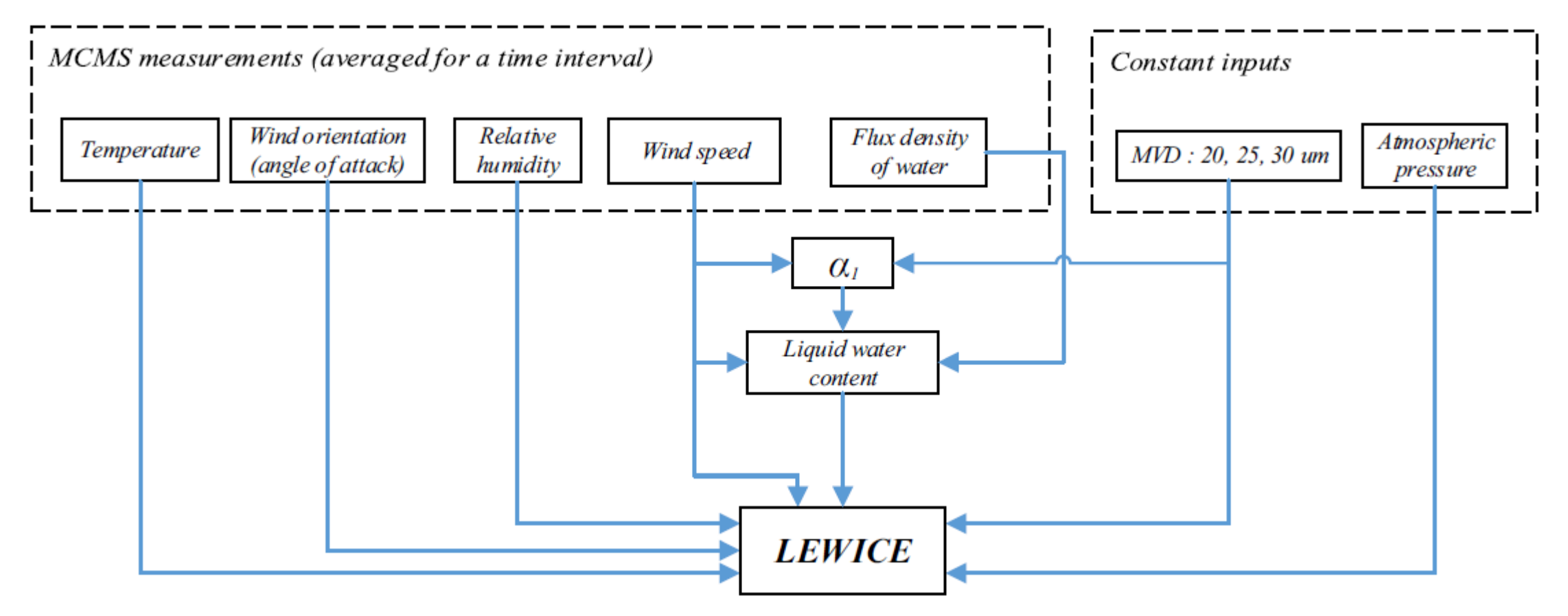
Model setup



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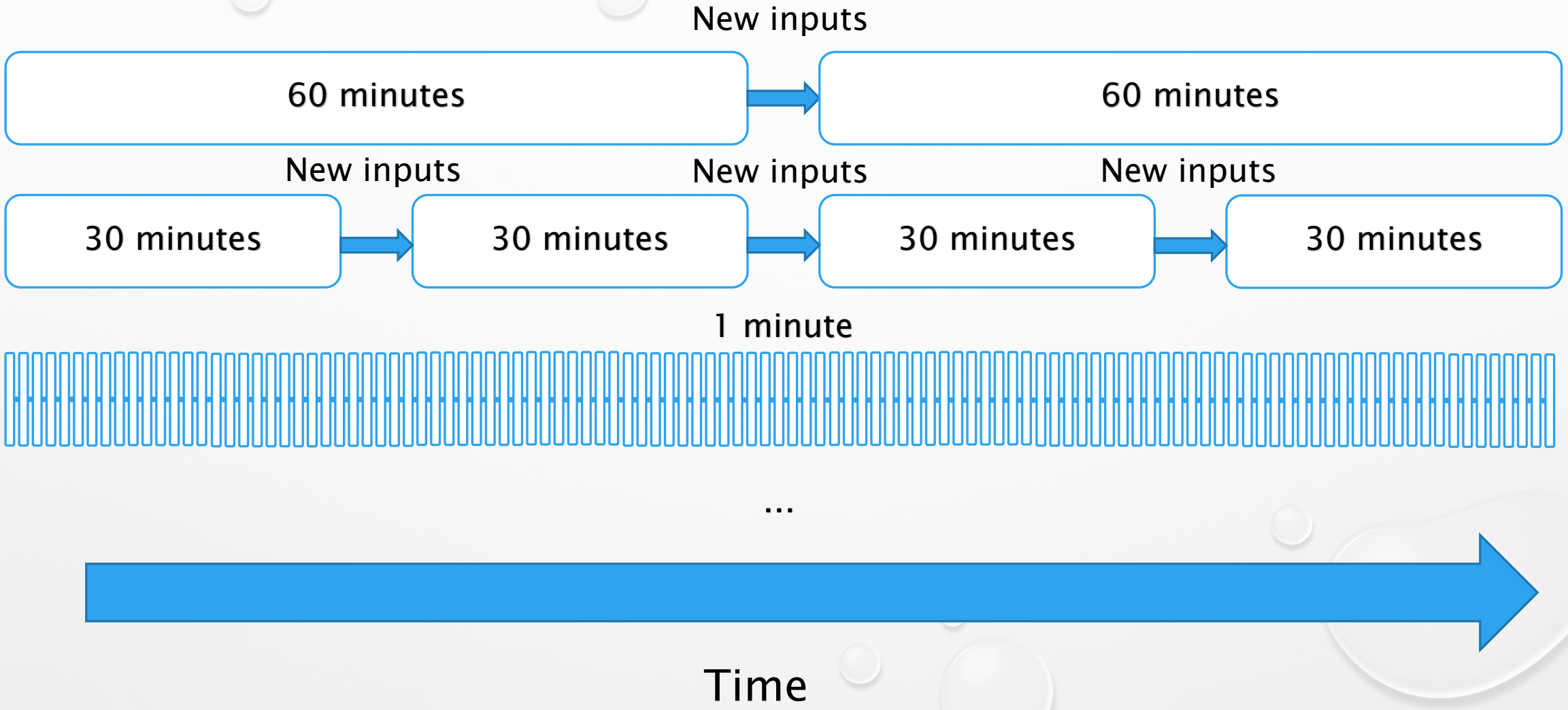
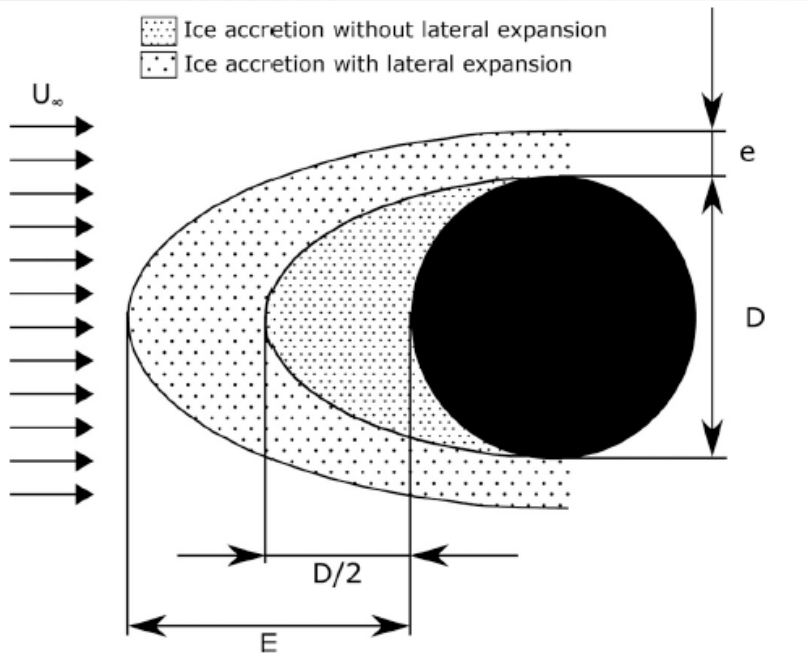
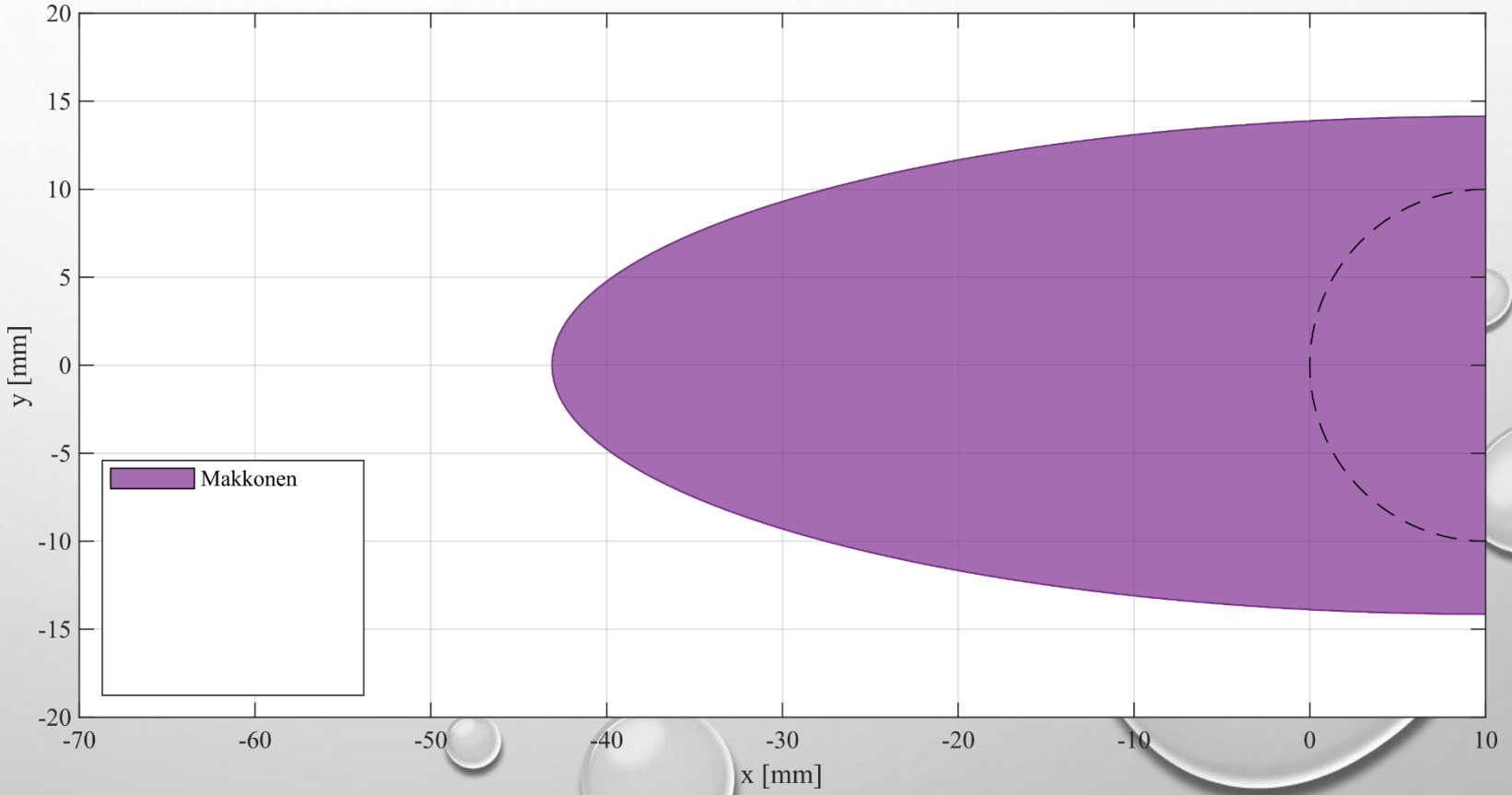
Time step


New inputs
60 minutes
60 minutes
New inputs
New inputs
New inputs
30 minutes
30 minutes
30 minutes
30 minutes
1 minute
...
Time

Influence of the time step



Roberge et al. (2021) In situ estimation of effective liquid water content on a wind turbine using a thermal based sensor. Cold regions science and technology. Adapted from ISO-12494



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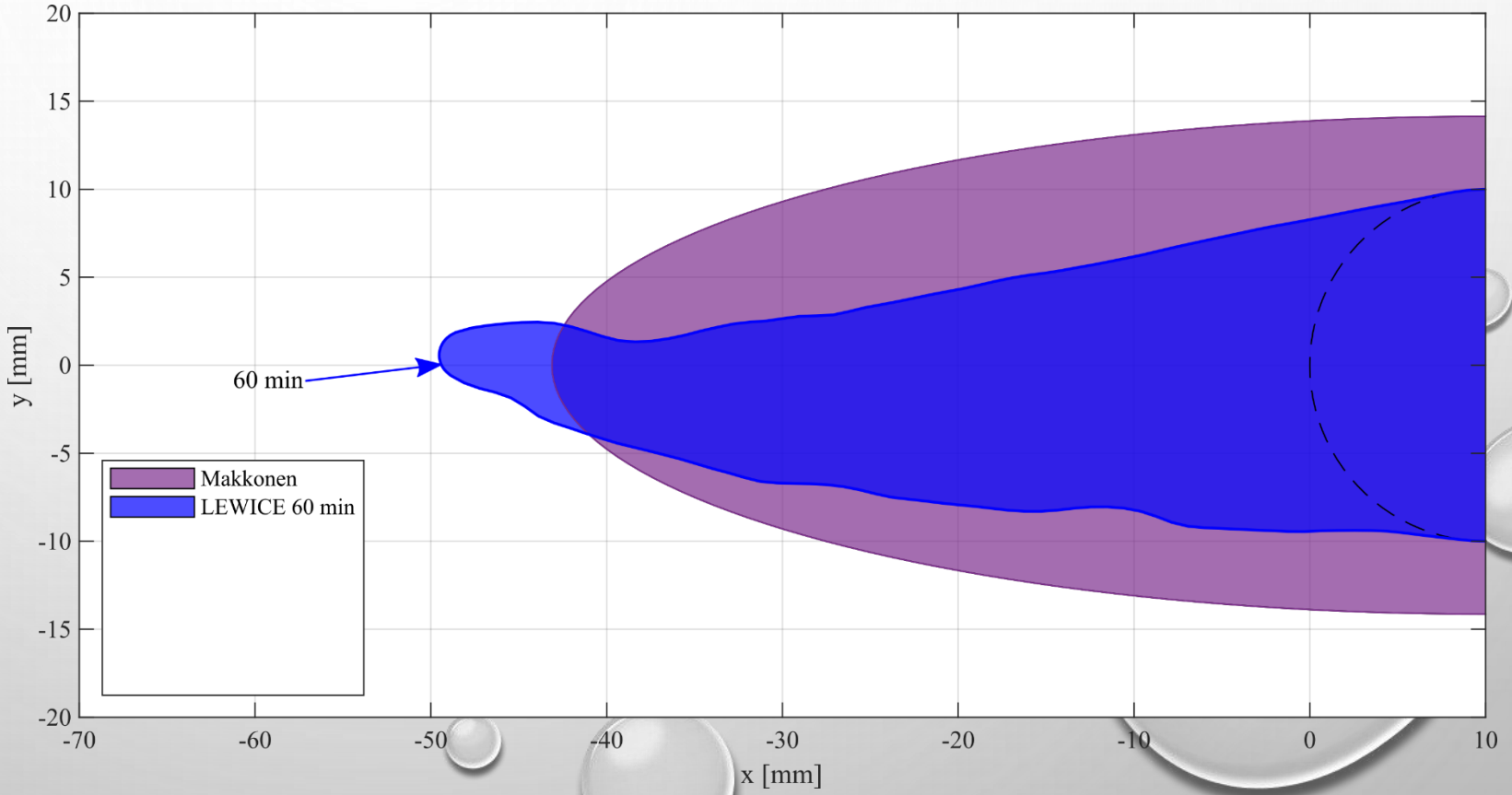
Influence of the time step

- Wind orientation changes quickly
- Averaging out wind turbulence



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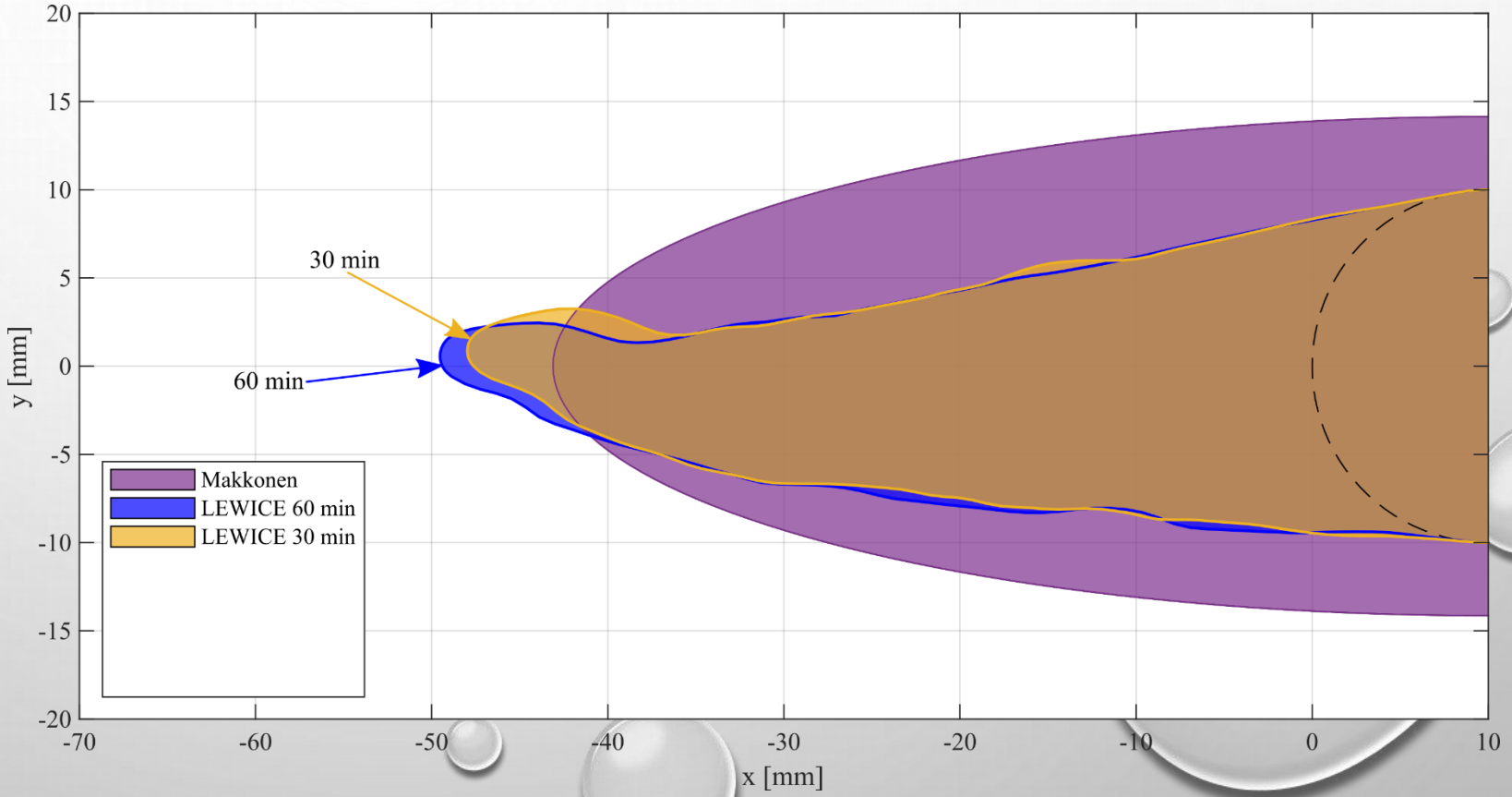
Influence of the time step

- Wind orientation changes quickly
- Averaging out wind turbulence
- More resolution, more calculations



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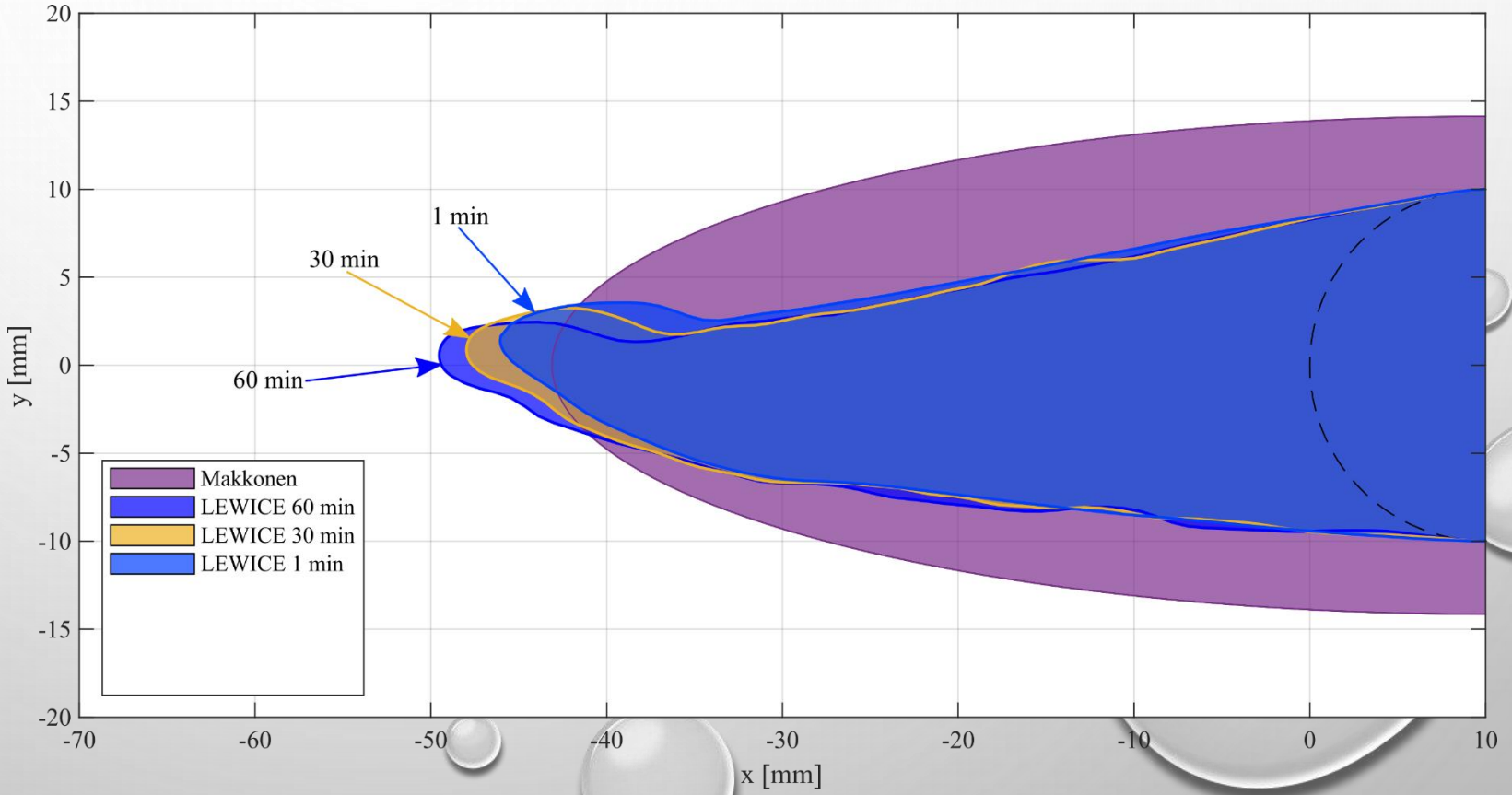

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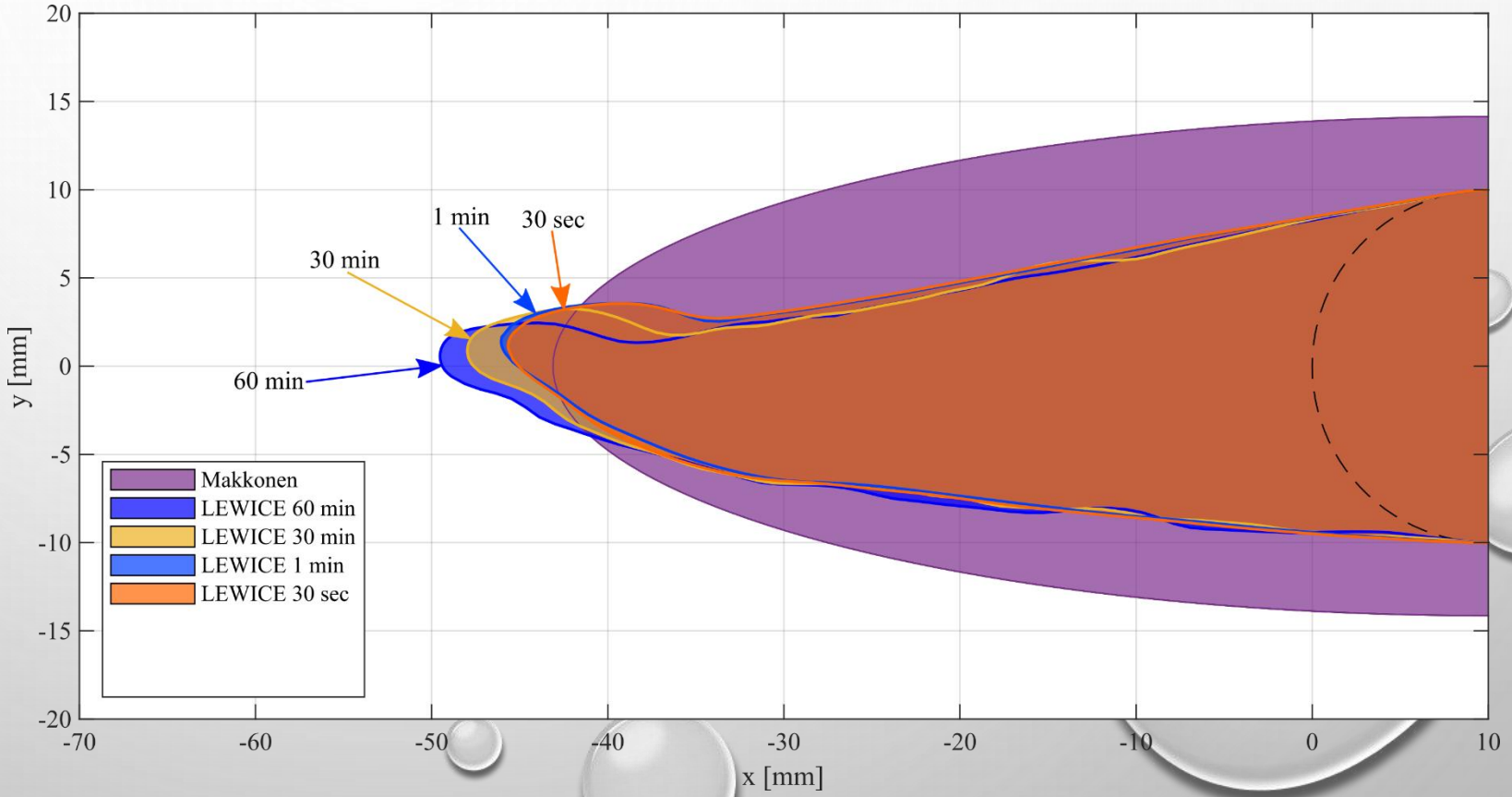

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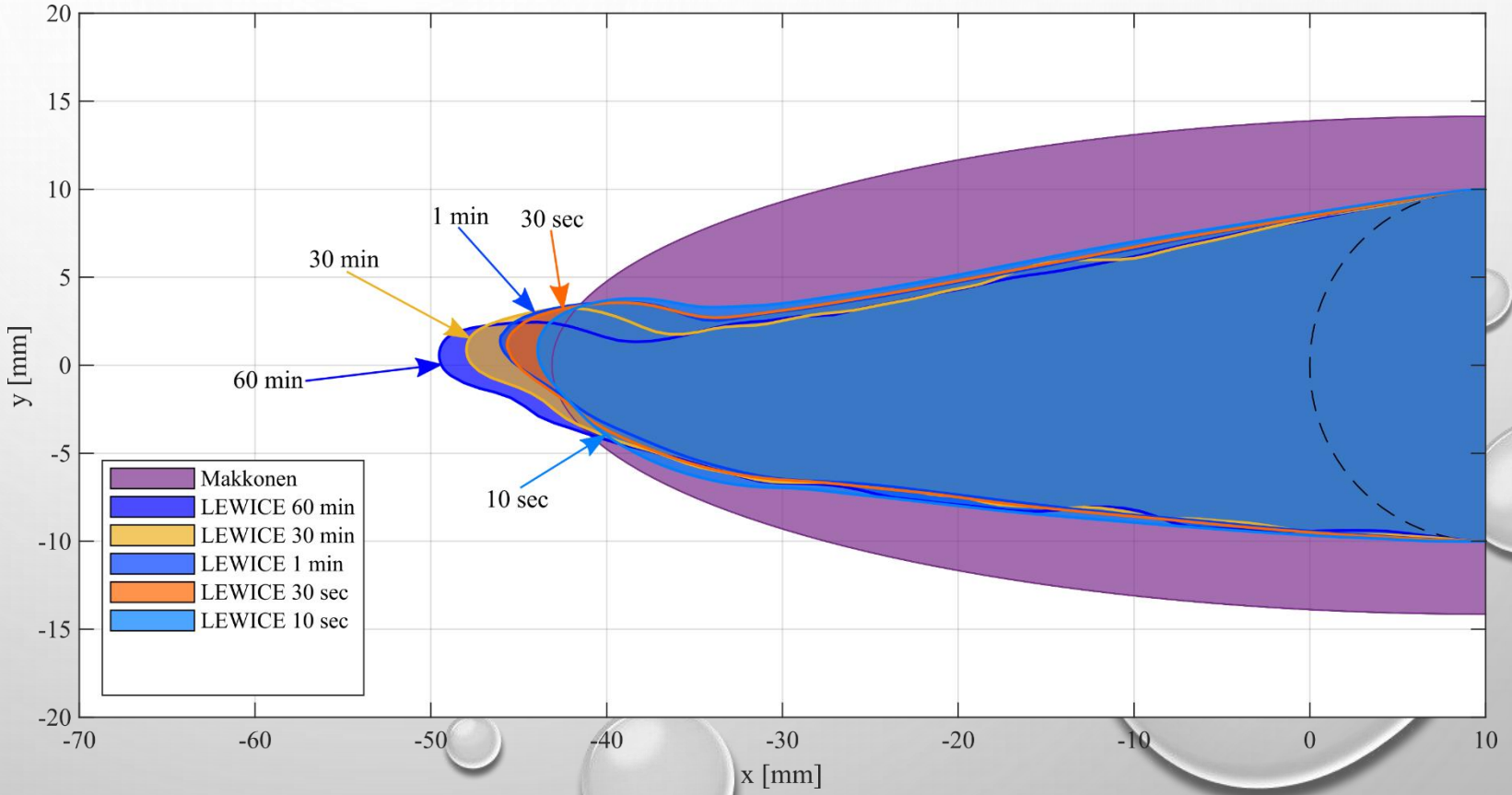

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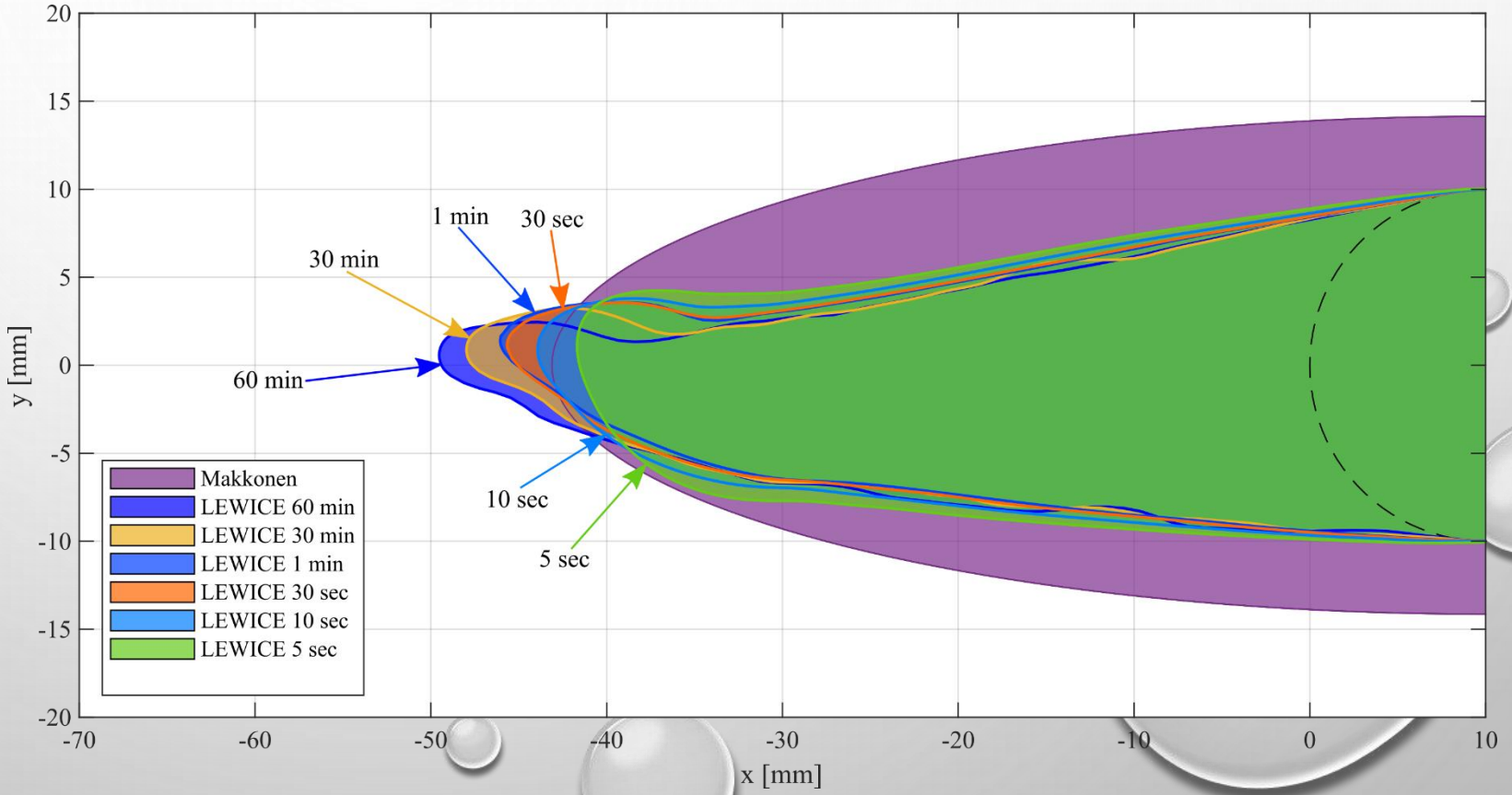

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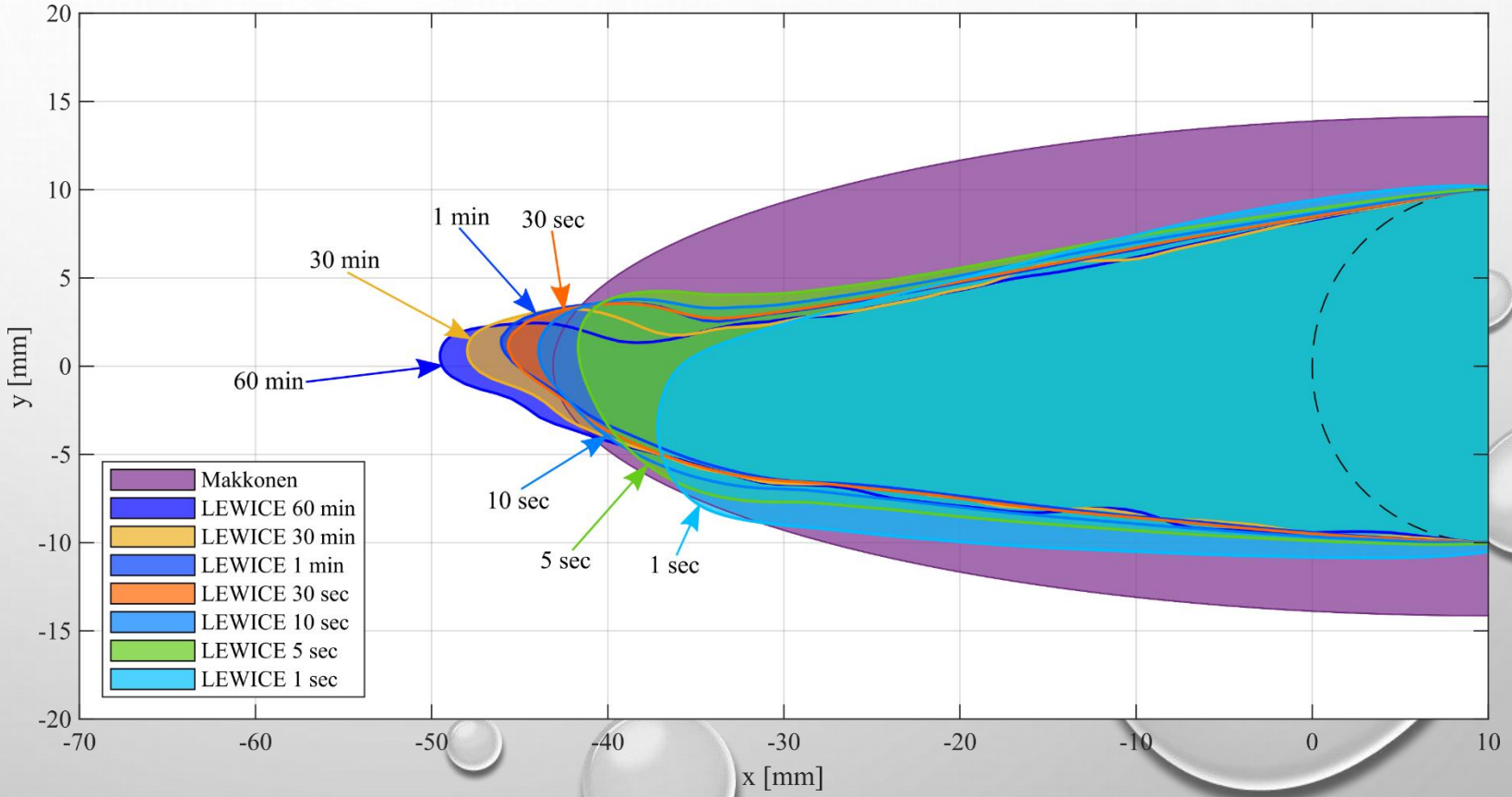
Influence of the time step

- Longer time step, slender shape
- Small time step, closer to Makkonen
- More resolution, more calculations
- Trade-off 1 min



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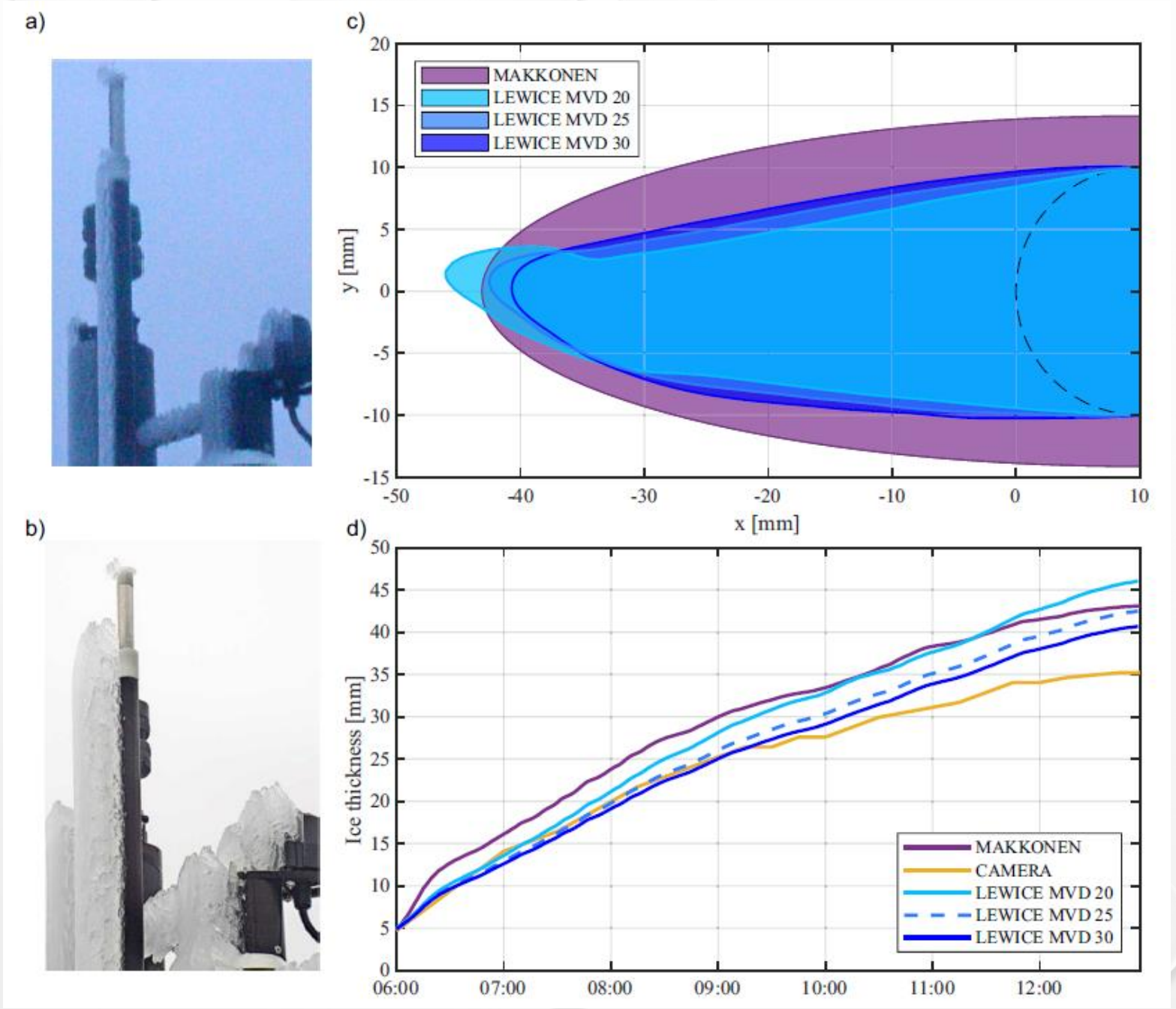
Event #1



- Glaze ice
- Accretion efficiency?
- Effect of MVD
- Ice thickness diverges at the end
- Round shape

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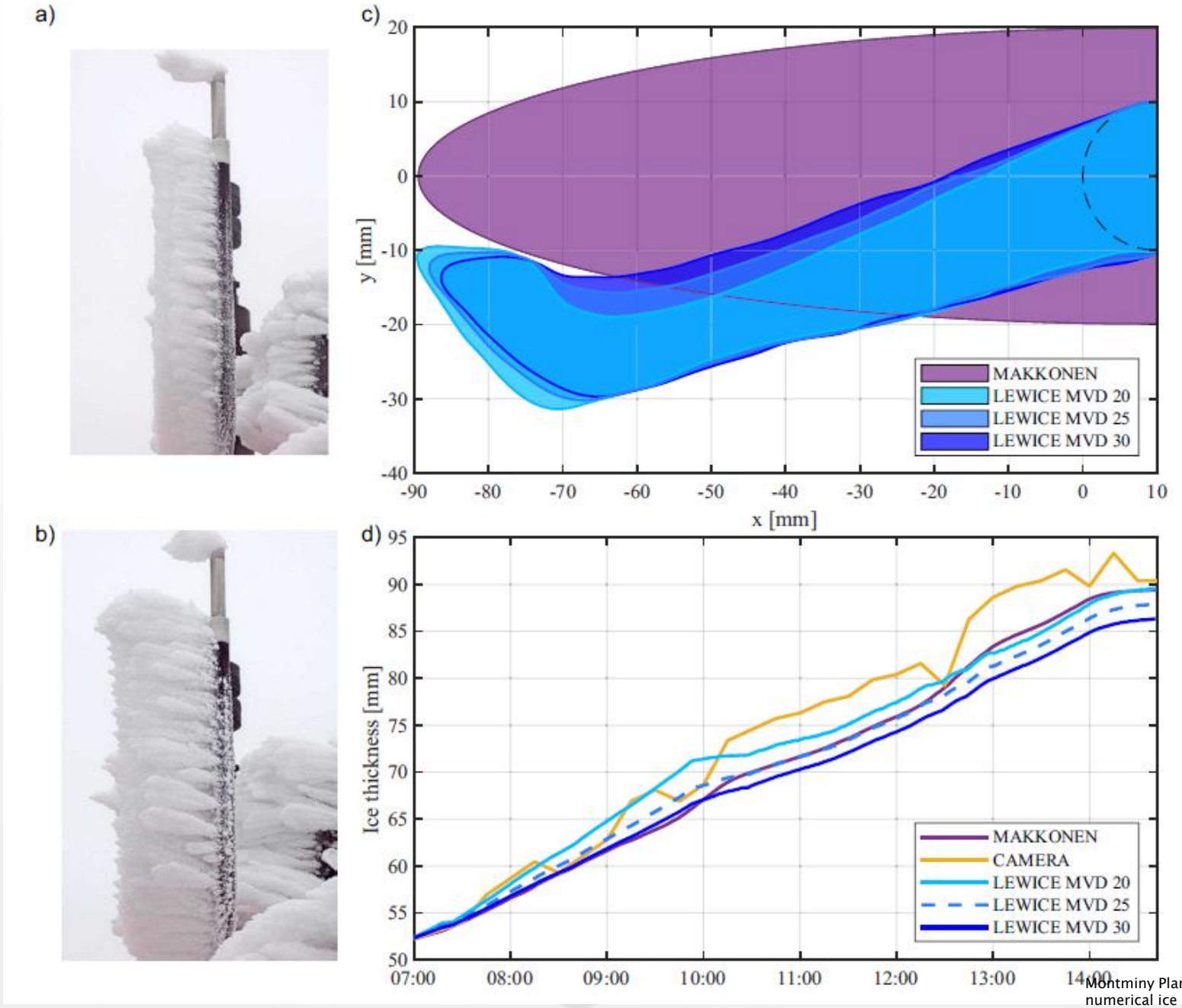
Event #3



- Rime ice
- Weird shape
- Change in orientation, mid-event
- Limit of validity of LEWICE

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Summary

- Smallest average RMSE -> 25 µm MVD model (4.23 mm)
- Smallest errors on the final ice thickness -> 20 µm MVD model (6.04 mm)

RMSE	Makkonen		MVD 20		MVD 25		MVD 30	
	[mm]	[%]	[mm]	[%]	[mm]	[%]	[mm]	[%]
Event 1	5.45	15.5	5.34	15.2	3.24	9.2	2.30	6.5
Event 2	9.42	13.0	4.60	6.4	2.36	3.3	5.48	7.6
Event 3	3.49	3.9	2.94	3.3	4.02	4.4	5.14	5.7
Event 4	6.76	36.0	2.62	14.0	1.75	9.3	1.26	6.7
Event 5	1.40	6.3	1.45	6.5	0.43	1.9	1.12	5.0
Event 6	3.88	8.8	4.26	9.7	5.76	13.1	6.63	15.1
Event 7	9.27	12.5	6.86	9.3	10.46	14.2	12.39	16.8
Event 8	1.66	5.0	7.57	22.6	5.80	17.3	4.83	14.4
Average	5.17	12.6	4.45	10.9	4.23	9.1	4.89	9.7

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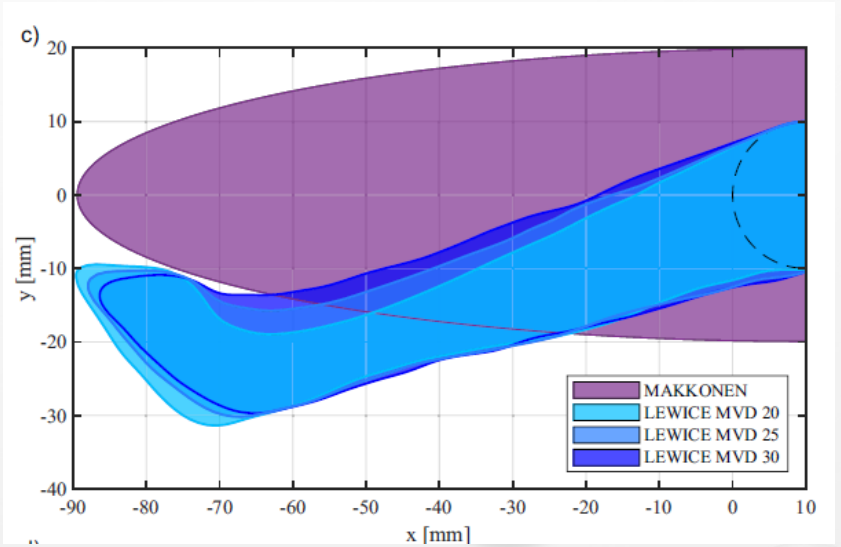
However…

- Ice thickness underestimated by most of the models for rime ice (events #2, 3, 5, 6 & 7)
- Overestimated during glaze and mixed ice accretion (events #1, 4 & 8)
- Weird ice shapes
- Limitations of LEWICE



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Conclusions

- **Still a long way to go!**
- Choice of time-step for inputs had a greater impact on ice shape than MVD
- Change in temperature, wind orientation, wind speed, LWC
- Challenge! Publicly available meteorological data

Contact information

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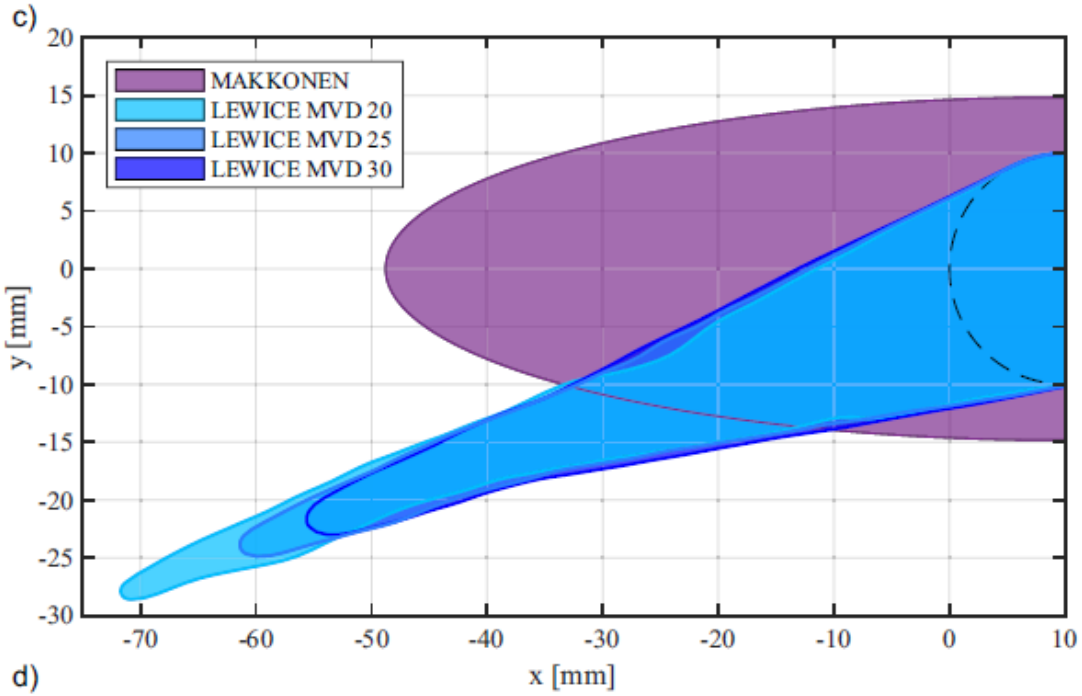
MERCI
THANK YOU
TACK

Event #2

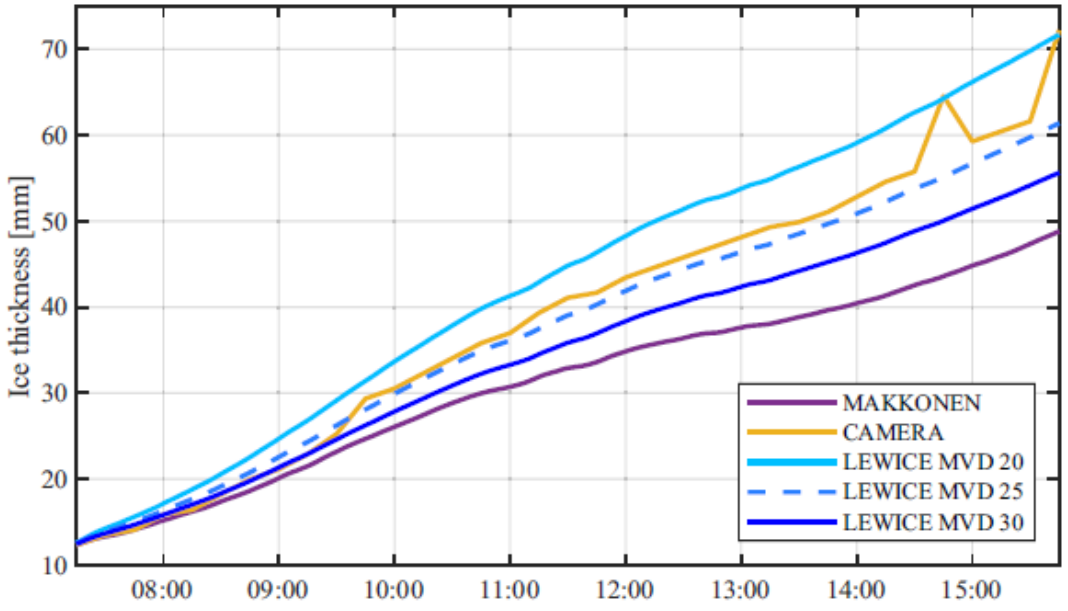
a)

b)

c)



d)



- Rime ice
- Pointy shape
- Offset in orientation
- Close to MVD = 25µm