Case study on vertical variability in icing conditions in Finland

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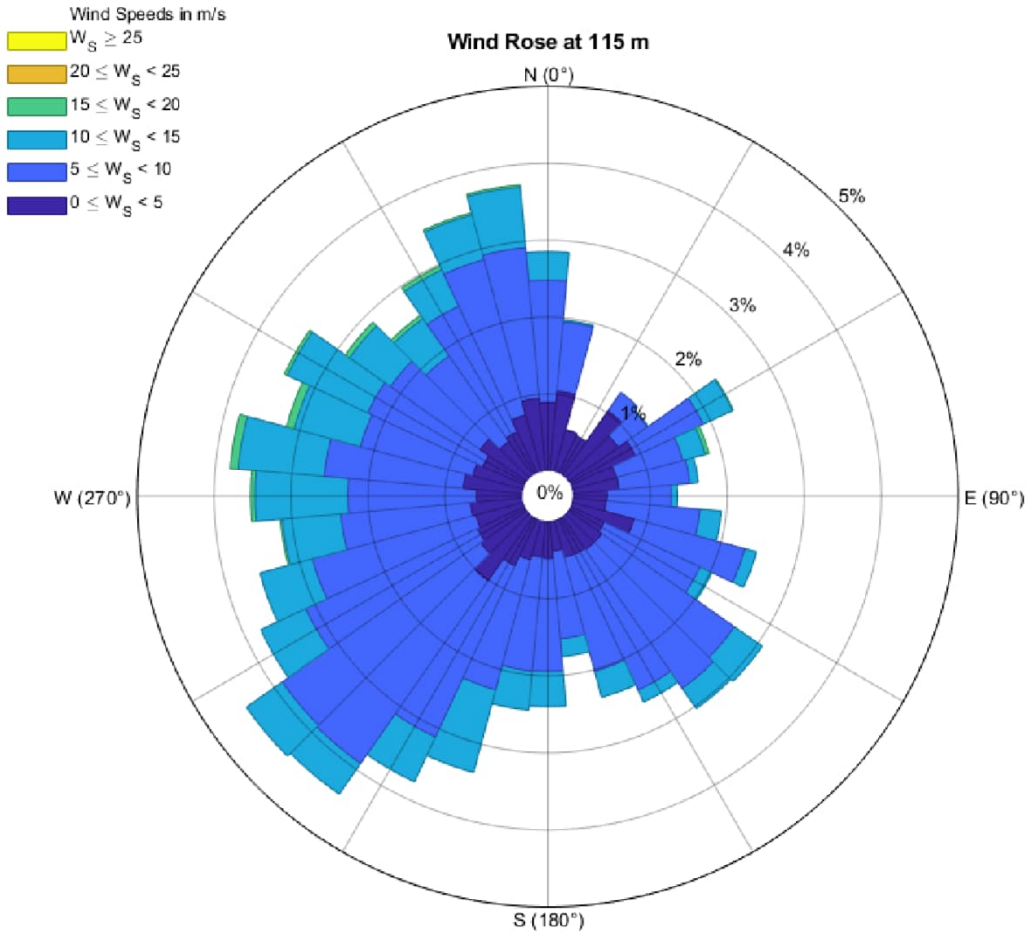
Research question

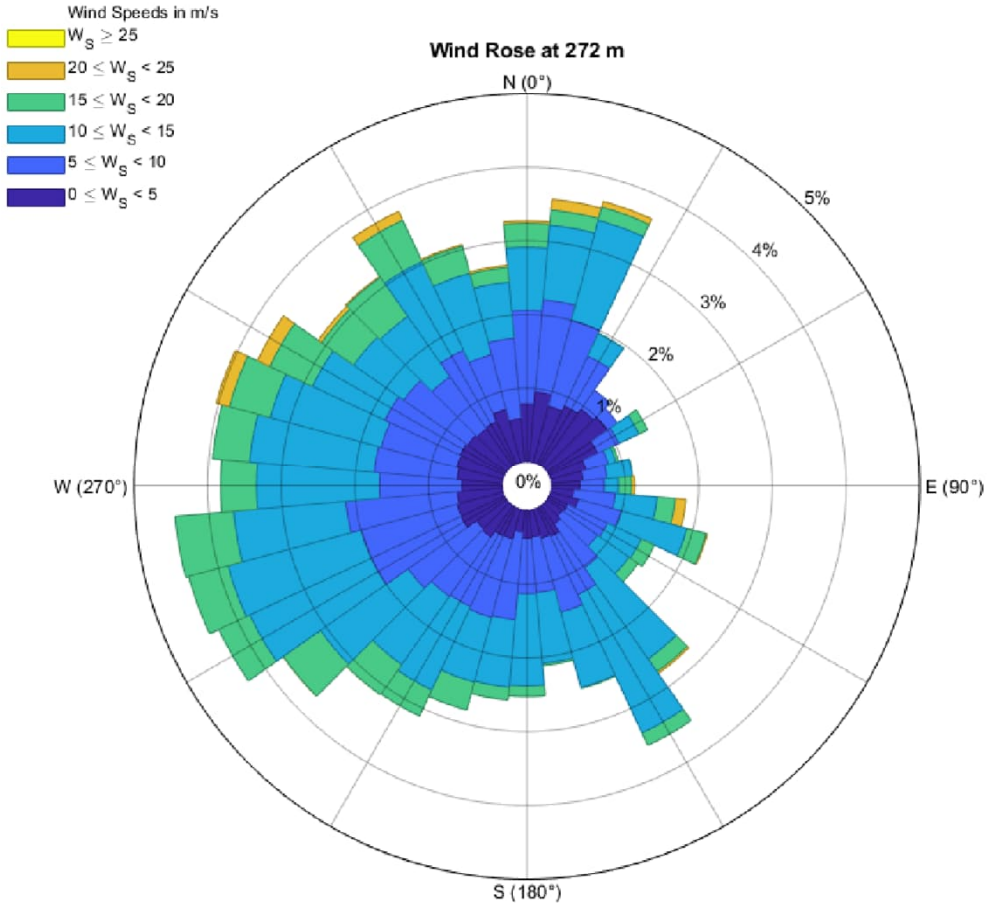
- Core questions:
  - How do icing conditions change when moving from 100 – 150 m turbines to ~250 meter turbines
  - Frequency, intensity etc.

Data outline

- 318 m mast outside Kuopio, Eastern Finland
- FMI (Finnish Met institute)
- Wind speed, direction, temperature, relative humidity and icing rate (Goodrich 0872F1) at 115m an 272m
- Main focus in icing intensity/icing rate as mm/h

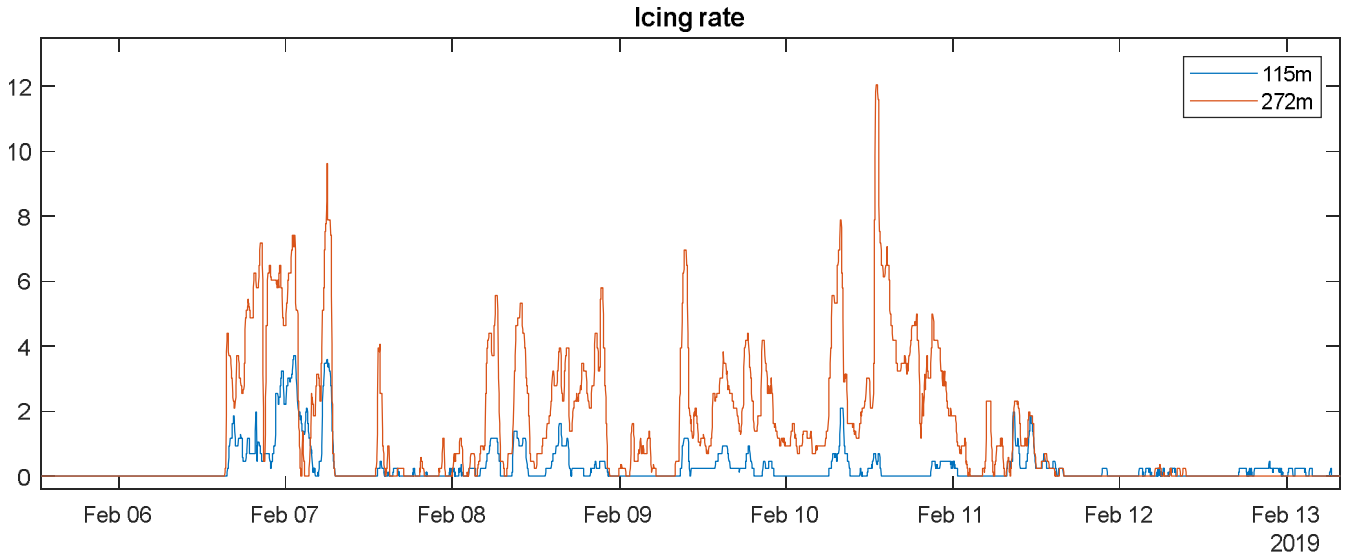
Wind, full dataset





Icing rate signal

- The alarms are not simultaneous, there are events that are visible in one sensor and not the other
- There is more icing on the higher measurement level and the absolute values of the sensor signal are higher



Hit rate

- There is some amount of overlap, but there are significant number of events where only one sensor gives any alarms.
- The total icing time is larger at higher altitude as expected, but not by much.
- Here the definition of icing is icing rate > 0 mm/h

Icing (% of total dataset)				
		115m		TOTAL 272 m
		ON	OFF	
272m	ON	6 %	8 %	14%
	OFF	3 %	83 %	
	TOTAL 115 m	9 %		

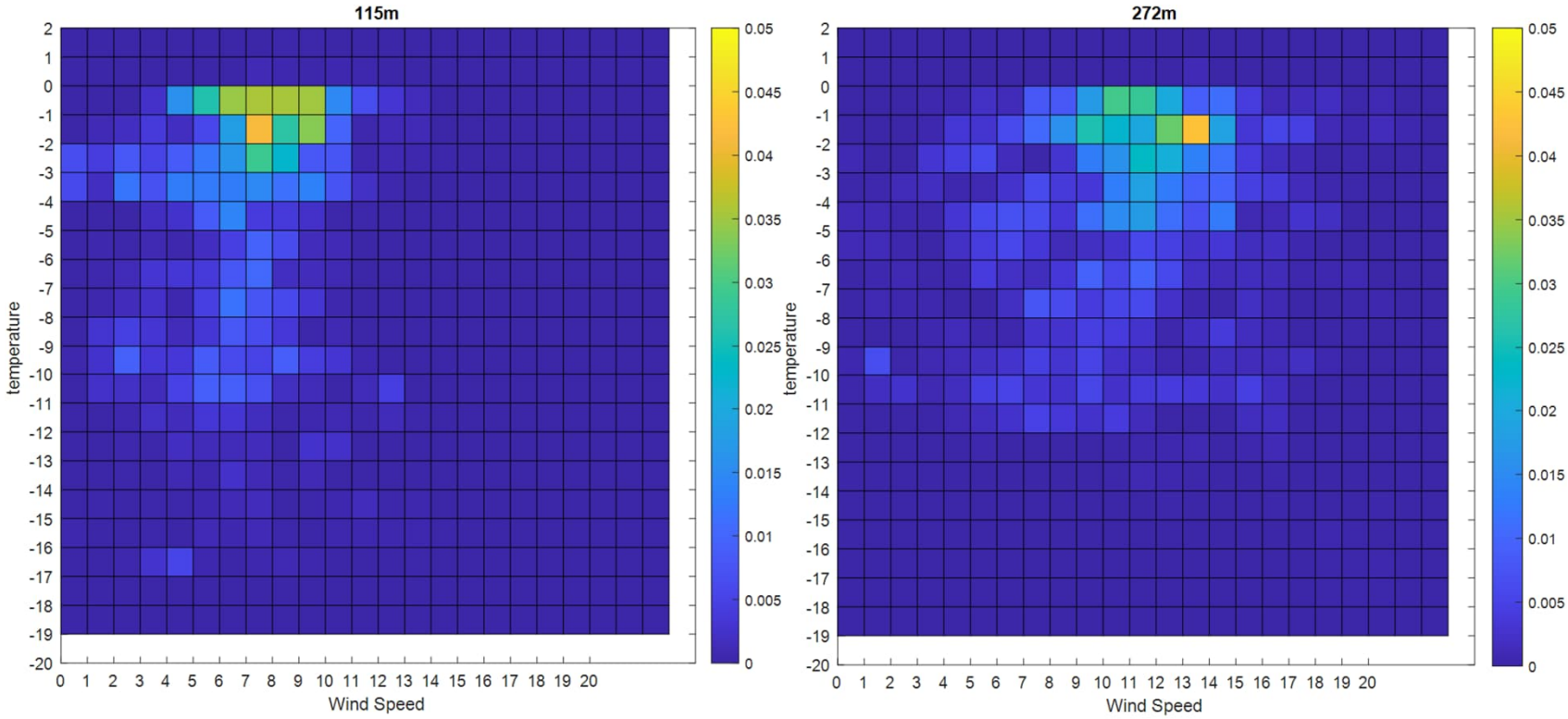
IEA Ice Classification[1]

IEA Ice Class	Duration of Meteorological Icing [% of Year]	Duration of Instrumental Icing [% of Year]	Production Loss [% of AEP]
5	>10	>20	>20
4	5-10	10-30	10-25
3	3-5	6-15	3-12
2	0.5-3	1-9	0.5-5
1	0-0.5	<1.5	0-0.5

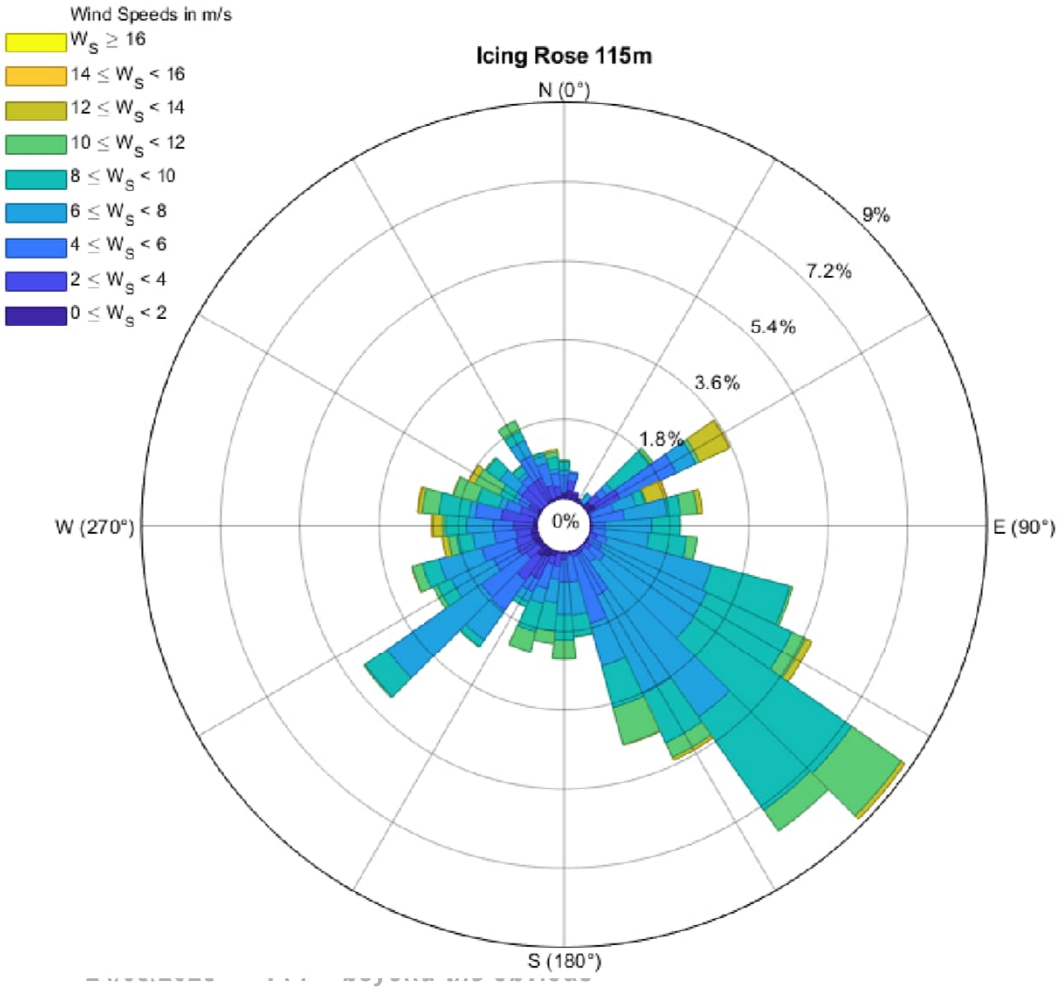
[1]: IEA Wind Recommended Practices for wind energy projects in cold climates edition 2011

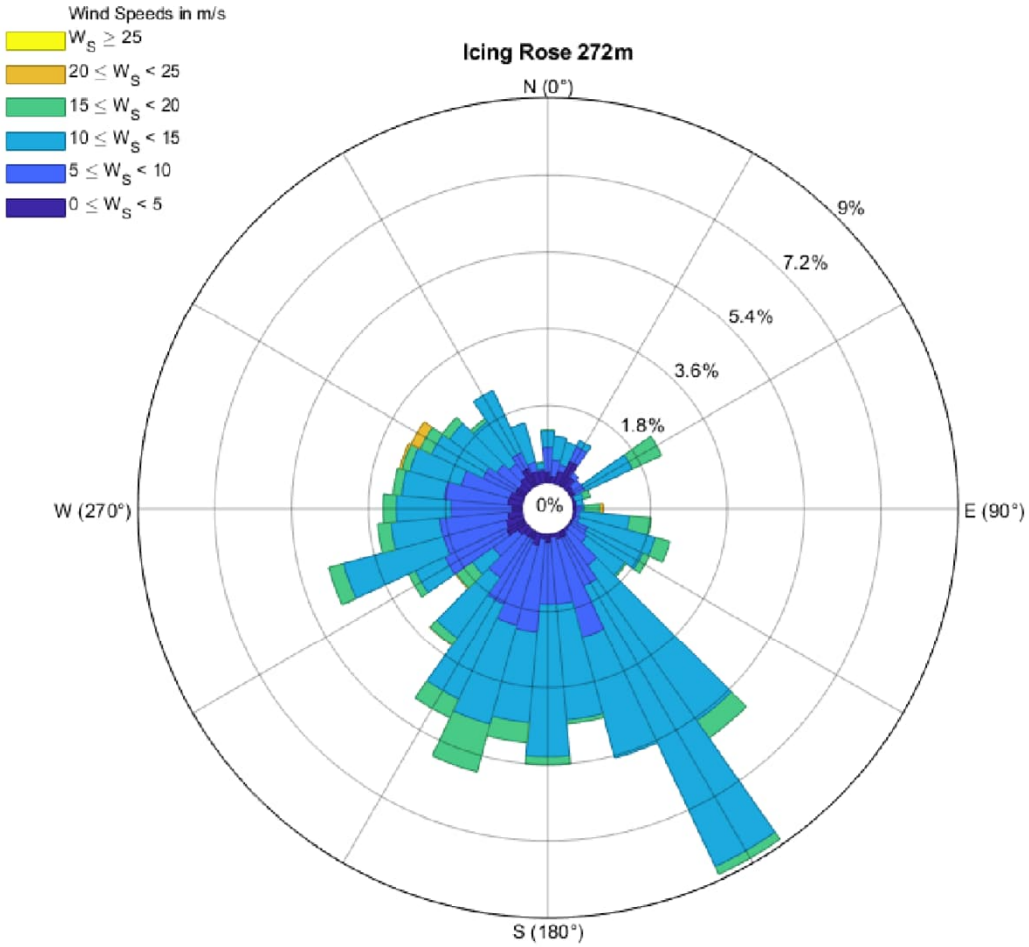
Conditions during icing

- Icing event distribution vs temperature and wind speed



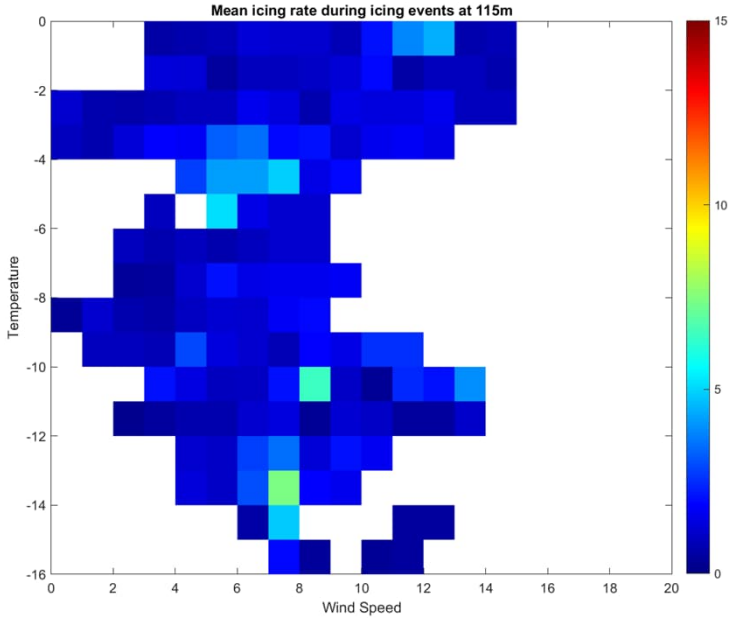
Wind, during icing

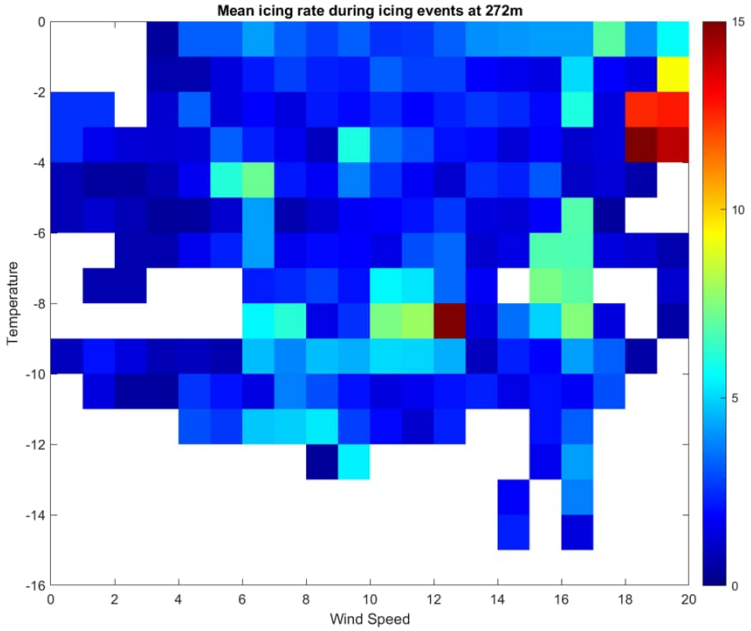




Signal strength

- Controlling for wind speed and temperature icing signal values are higher at higher altitude
- Plots during events where both sensors are active



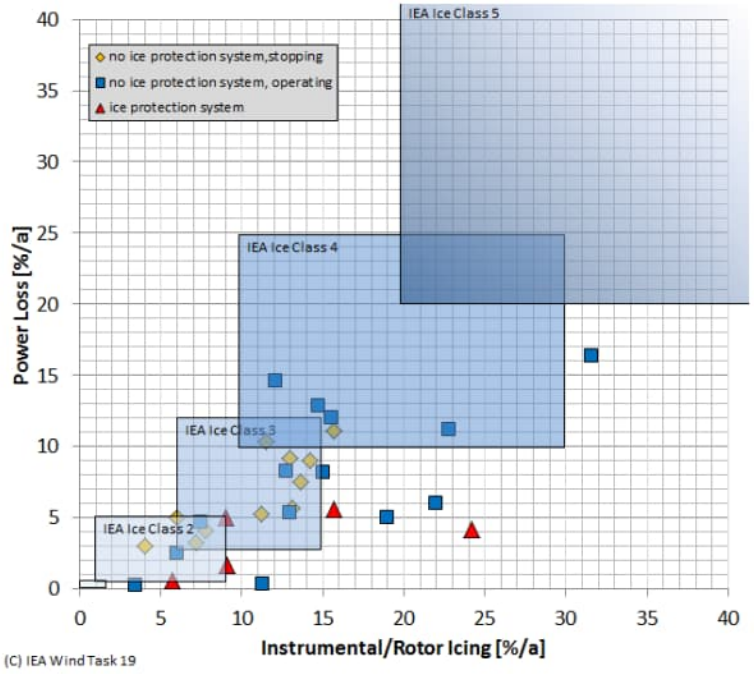


VTT World icing atlas

- WIceAtlas (vtt.fi)
- Built using open data, based on weather observations
  - Estimate meteorological icing conditions based on measeured cloud base height.
- Calibrated against observations from wind power plants
- Used as background for consulting projects for site selection and site planning
  - There’s a more accurate, higher resolution internal version that VTT use
  - Public version that’s quite rough

Wiceatlas hit rate [2]

«Long term averages» (N=30)

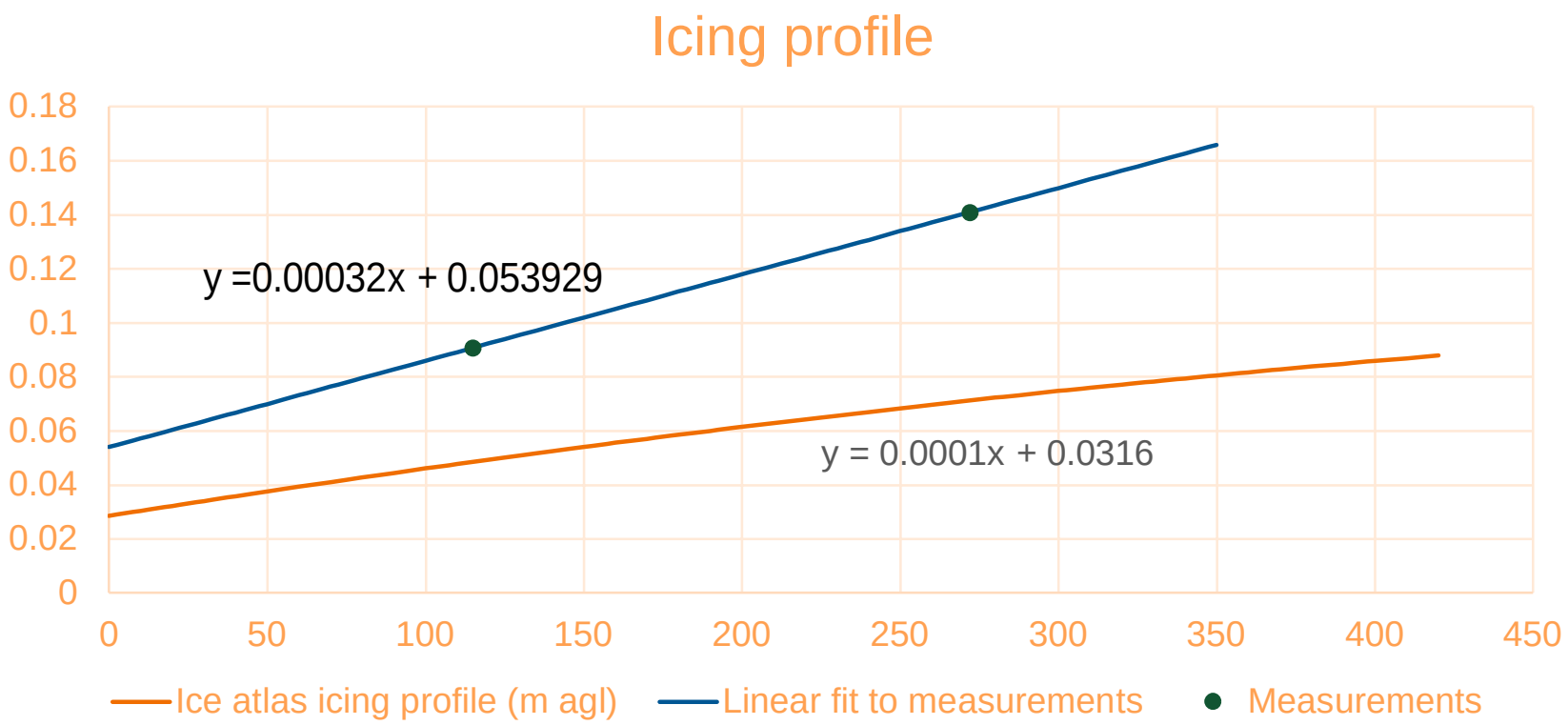


07.02.2017

IEA Ice Classes (N=72)

Mapped Ice Class \ Measured Ice Class	1	2	3-5
3-5		1	33
2		17	17
1	2	2	

Icing profile



Conclusions

- There is an amount of correlation between the two icing measurements: no icing at 115m will most likely mean no icing at 272m as well.
- The icing rates are higher at the higher altitude
- Icing more frequent at higher altitude
- the amount of ice that would actually accrete on a structure at 272 is significantly higher.
  - Higher wind speeds on average during the same events
  - Higher Liquid water content

Conclusions, cont.

- Larger wind turbines will experience more frequent icing than current ones
- Icing intensity higher
- Wind speed higher

➔mitigation harder

➔Blade heating power requirements higher

➔Event impact seen faster, losses might also increase [3]

beyond

the obvious

References

1. IEA Wind Recommended Practices for wind energy projects in cold climates edition 2011
2. R. Cattin "Blind Icing Map Validation", WinterWind, Skellefteå, 2017 http://windren.se/WW2017/7_2_09_Cattin_IEA_Task_19_-_Blind_icing_map_validation_Pub_v2.pdf
3. Gregow, E., B. Bernstein, I. Wittmeyer, and J. Hirvonen, 2015: LAPS–LOWICE: A Real-Time System for the Assessment of Low-Level Icing Conditions and Their Effect on Wind Power. *J. Atmos. Oceanic Technol.*, **32**, 1447–1463, https://doi.org/10.1175/JTECH-D-14-00151.1.