

Icing detection with LiDAR

Winterwind 2023, Session Icing (4)

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March 28, 2023



IEA Wind TCP Task 52

Large-Scale Deployment of Wind Lidar

	Theme	Working groups (active)
# 1	<i>Universal inflow characterisation</i>	(#1) Turbulence Intensity (TI) by Lidar (#2) Lidar Assisted Control (LAC)
# 2	<i>Replacing met masts</i>	(#3) Lidar in Complex Terrain (#4) Lidar in Cold Climate
# 3	<i>Connecting wind lidar</i>	(#5) Digitalization (#7) Lidar Ontology
# 4	<i>Accelerating offshore wind deployment</i>	(#6) Scanning Lidar Offshore

IEA Task 19



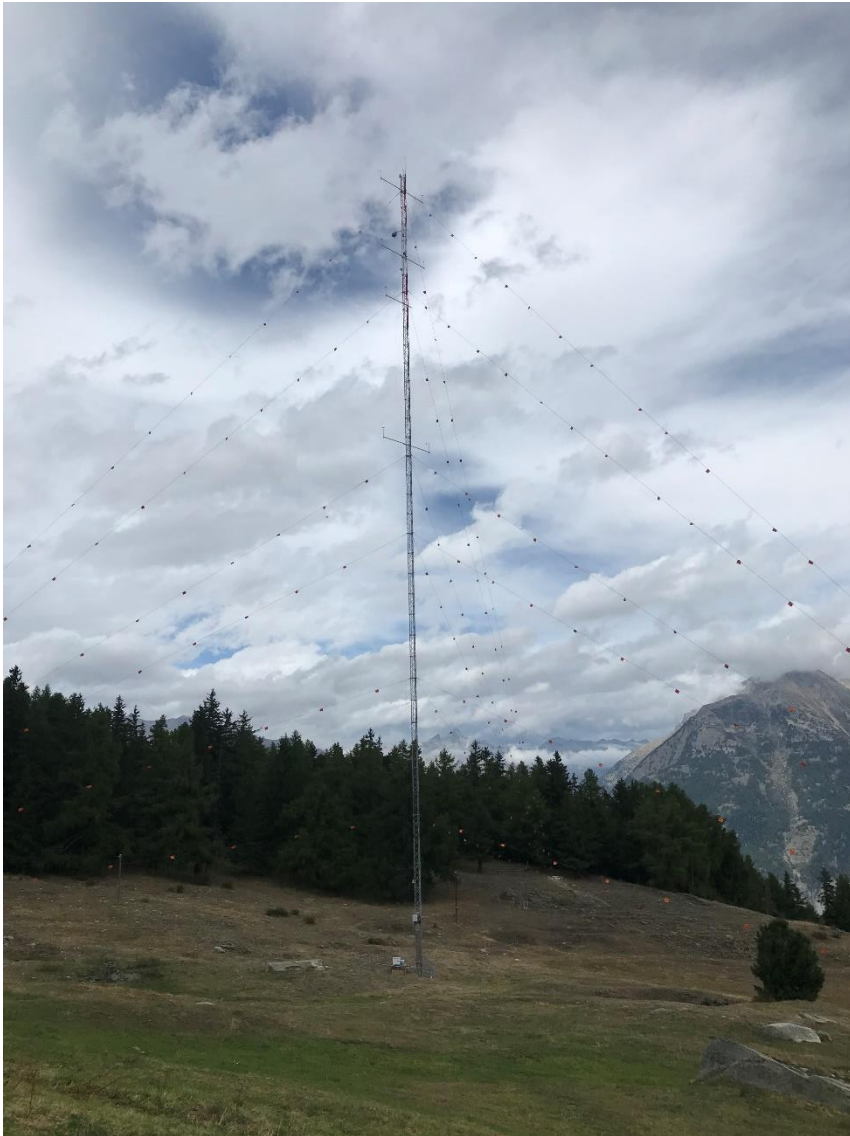
IEA Ice Classification for wind energy sites

IEA Ice class	Meteorological icing	Instrumental icing	Production loss
	% of year	% of year	% of annual production
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

Can LiDAR help us to detect icing?

(Do we need a PhD degree for this?)

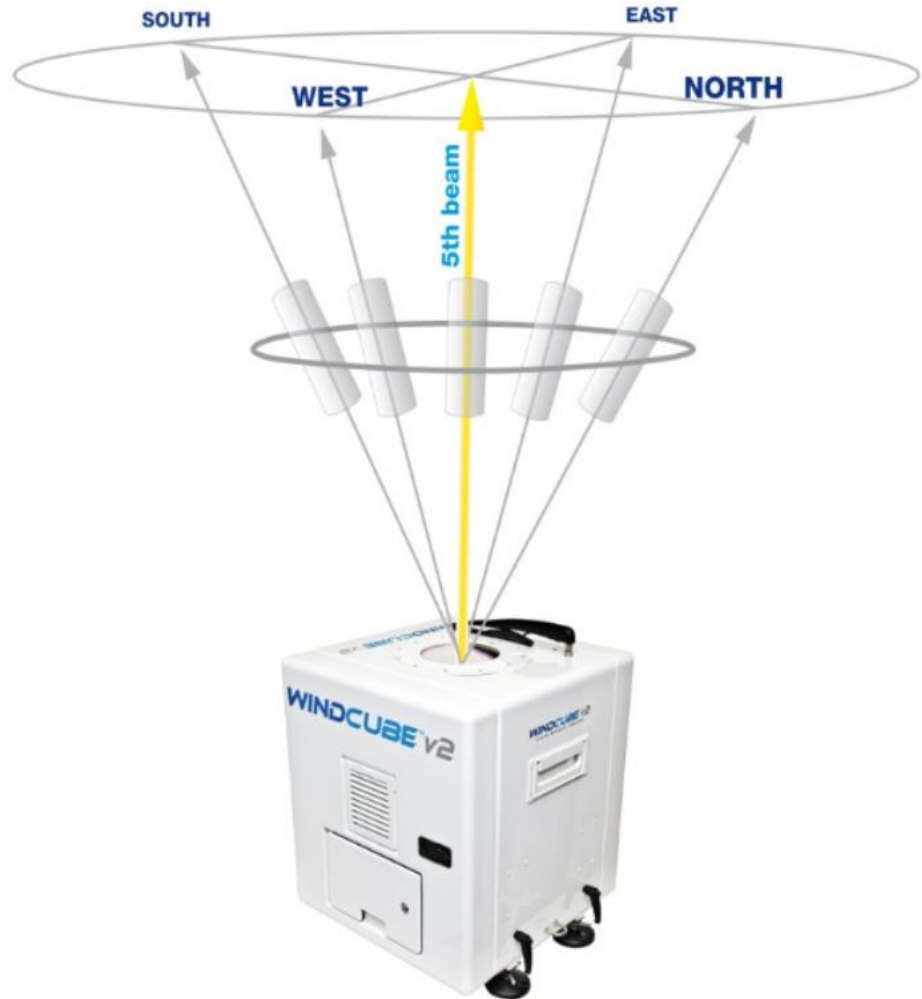
Site: met mast and LiDAR



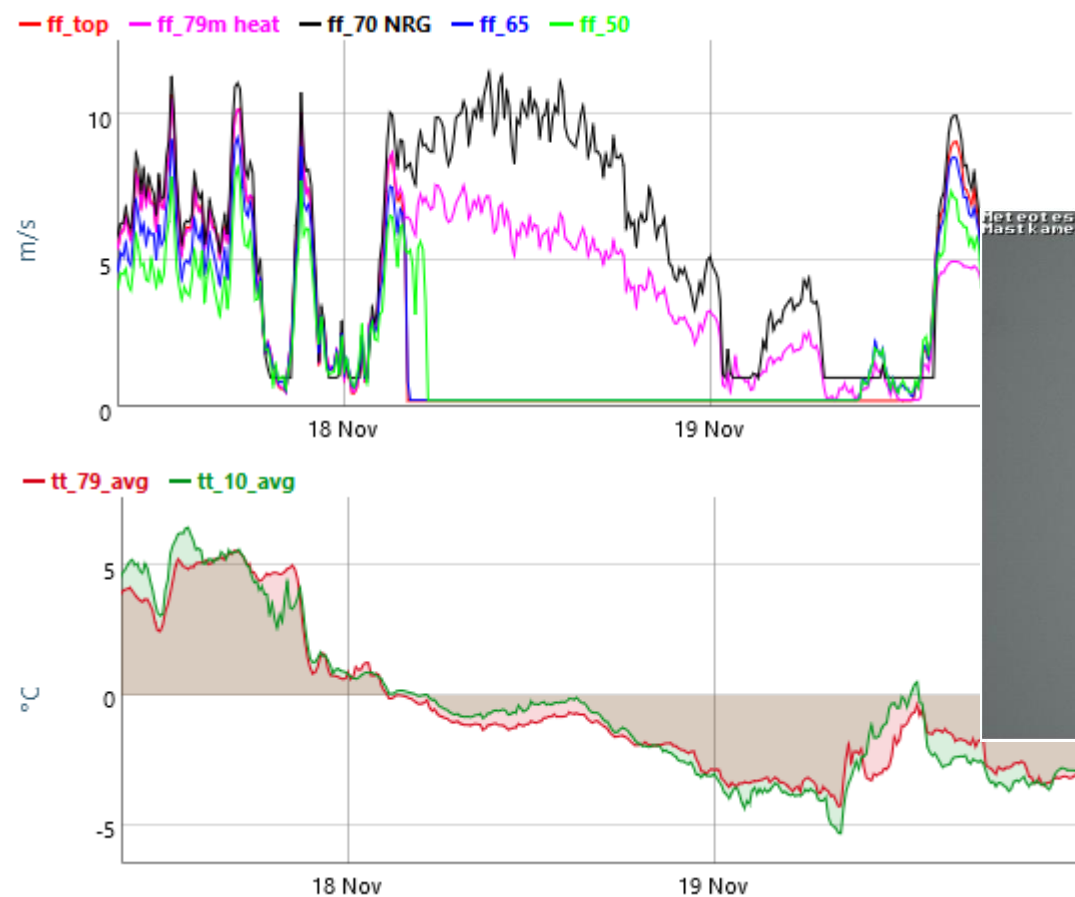
Setup:

- Heated and unheated anemometers (NRG icefree, Thies First Class)
- Temperature
- Relative humidity
- Webcam filming a sensor

Site: met mast and LiDAR



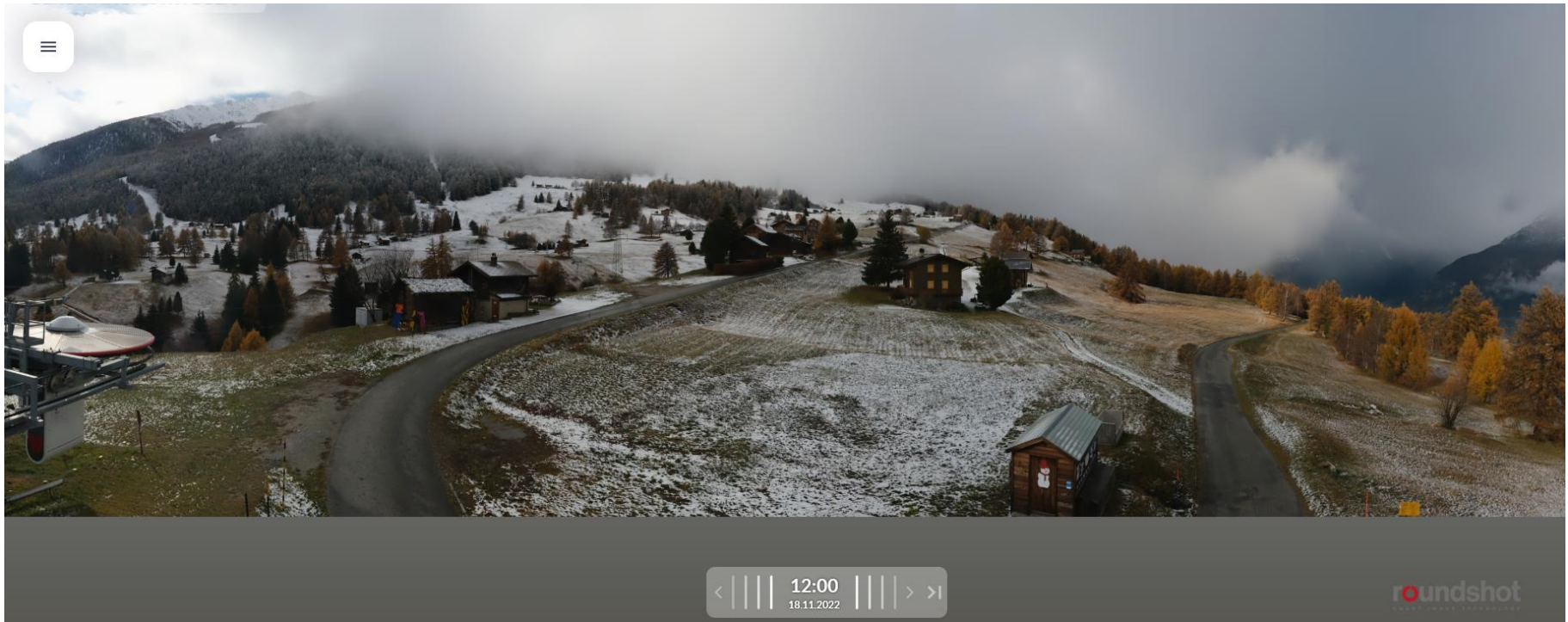
Icing event (1)



Meteorological icing: Nov 18, 2022 04.10 – 09.50 CET

Instrumental icing: Nov 18, 2022 04.10 – Nov 19, 2022 09.50 CET

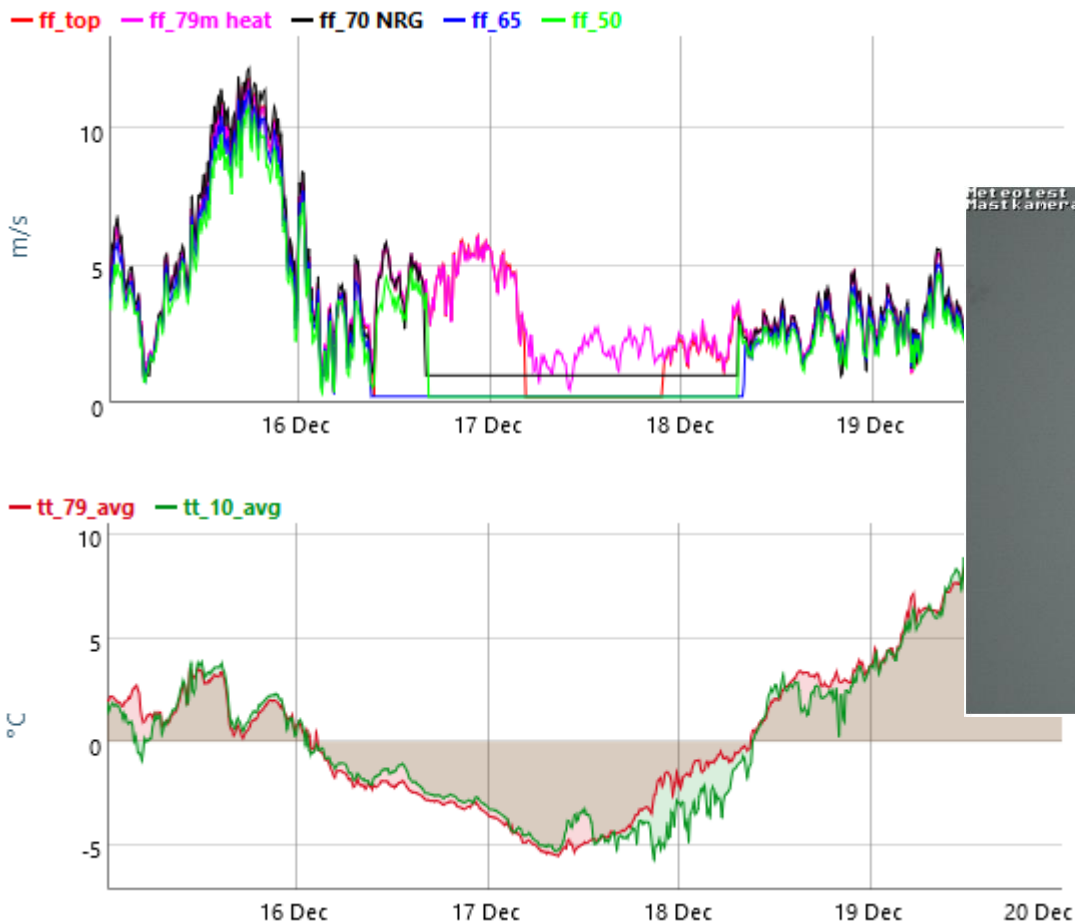
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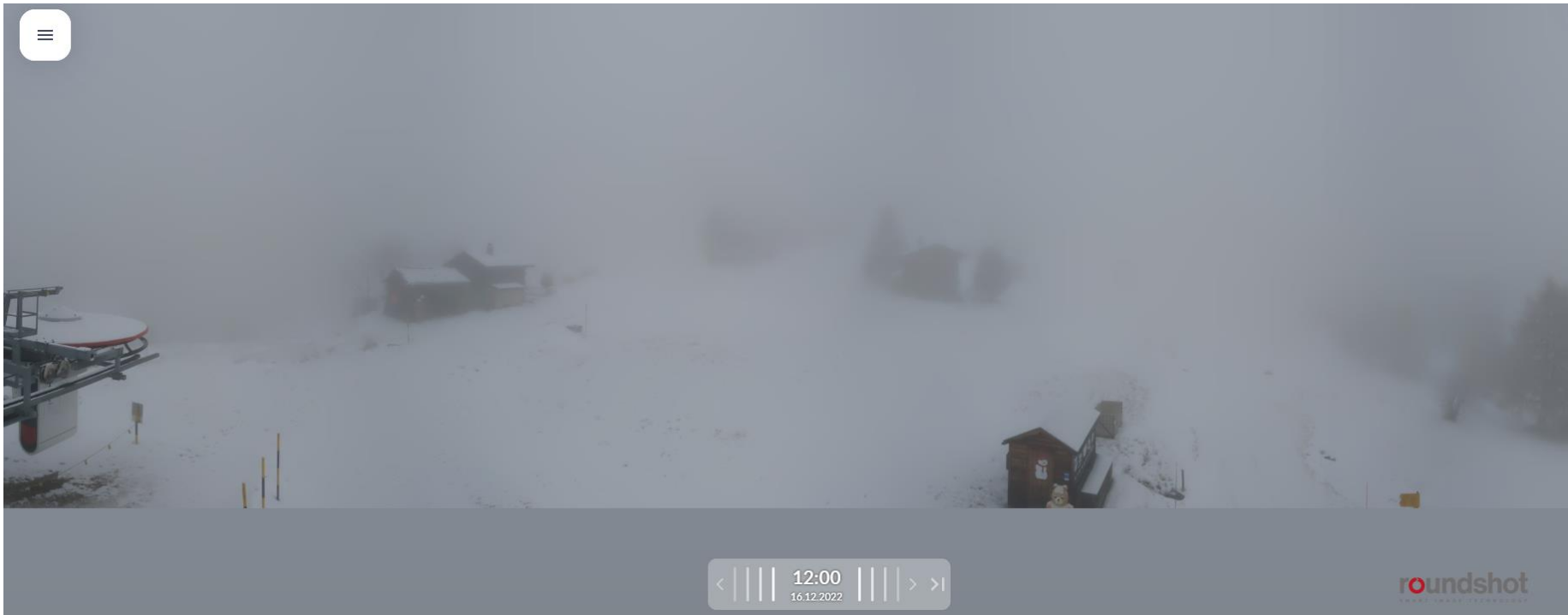
Icing event (2)



Meteorological icing: Dec 16, 2022 14.30 – 17.30 CET

Instrumental icing: Dec 16, 2022 14.30 – Dec 18, 2022 08.00 CET

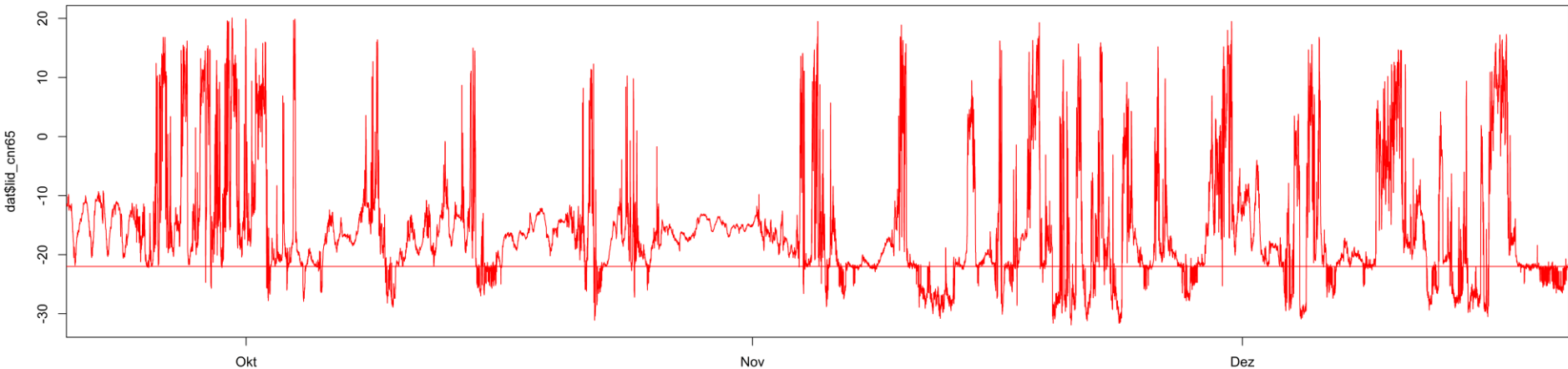
Icing event (2)



Meteorological icing: Dec 16, 2022 14.30 – 17.30 CET

Instrumental icing: Dec 16, 2022 14.30 – Dec 18, 2022 08.00 CET

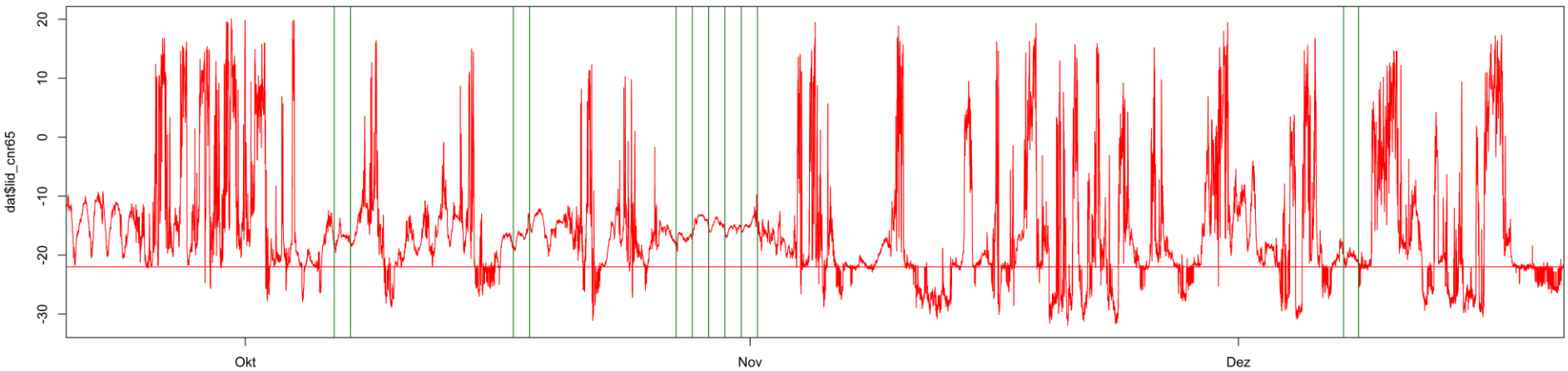
Carrier to Noise Ratio (CNR)



Diagnostic of signal strength

Threshold: -22dB

Carrier to Noise Ratio (CNR)



Clear sky events: $\text{CNR} < -5\text{dB}$

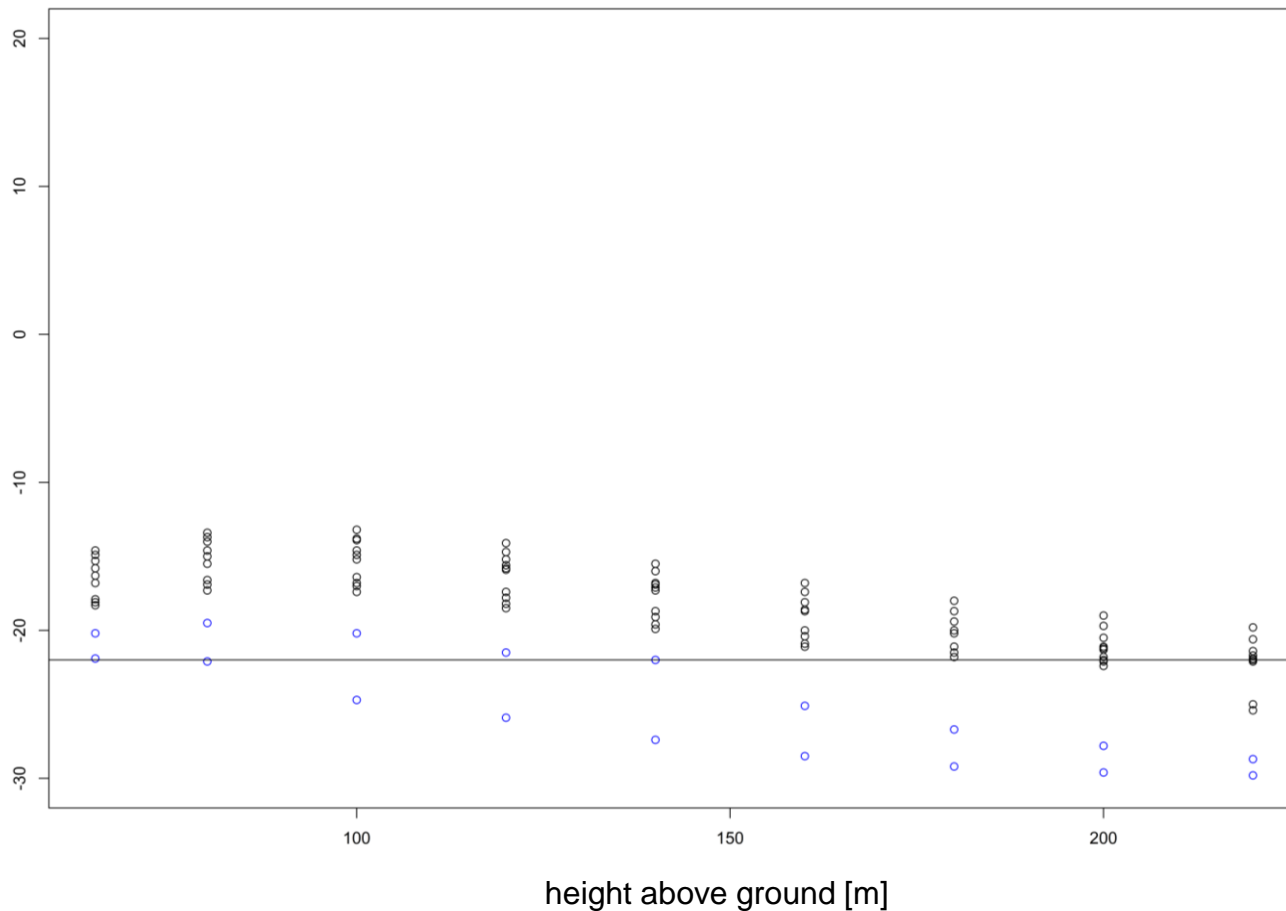
Clear sky events

Oct 7, 12pm: CNR: -18.1dB

Oct 21st, 12pm: CNR: -15.8 dB



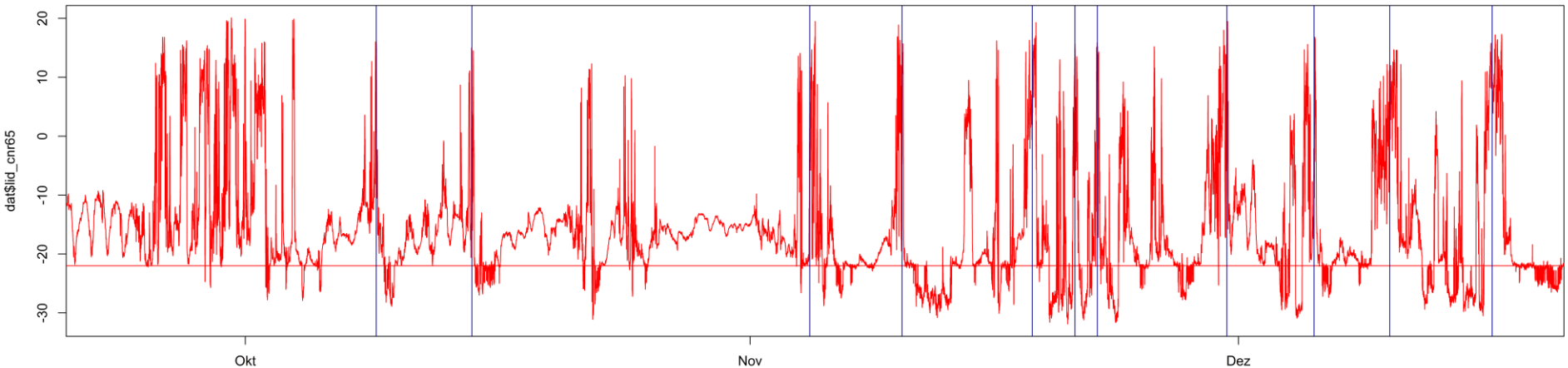
Clear sky CNR profiles



Clear sky events with temperatures above 0°C

Clear sky events with temperatures below 0°C

Carrier to Noise Ratio (CNR)



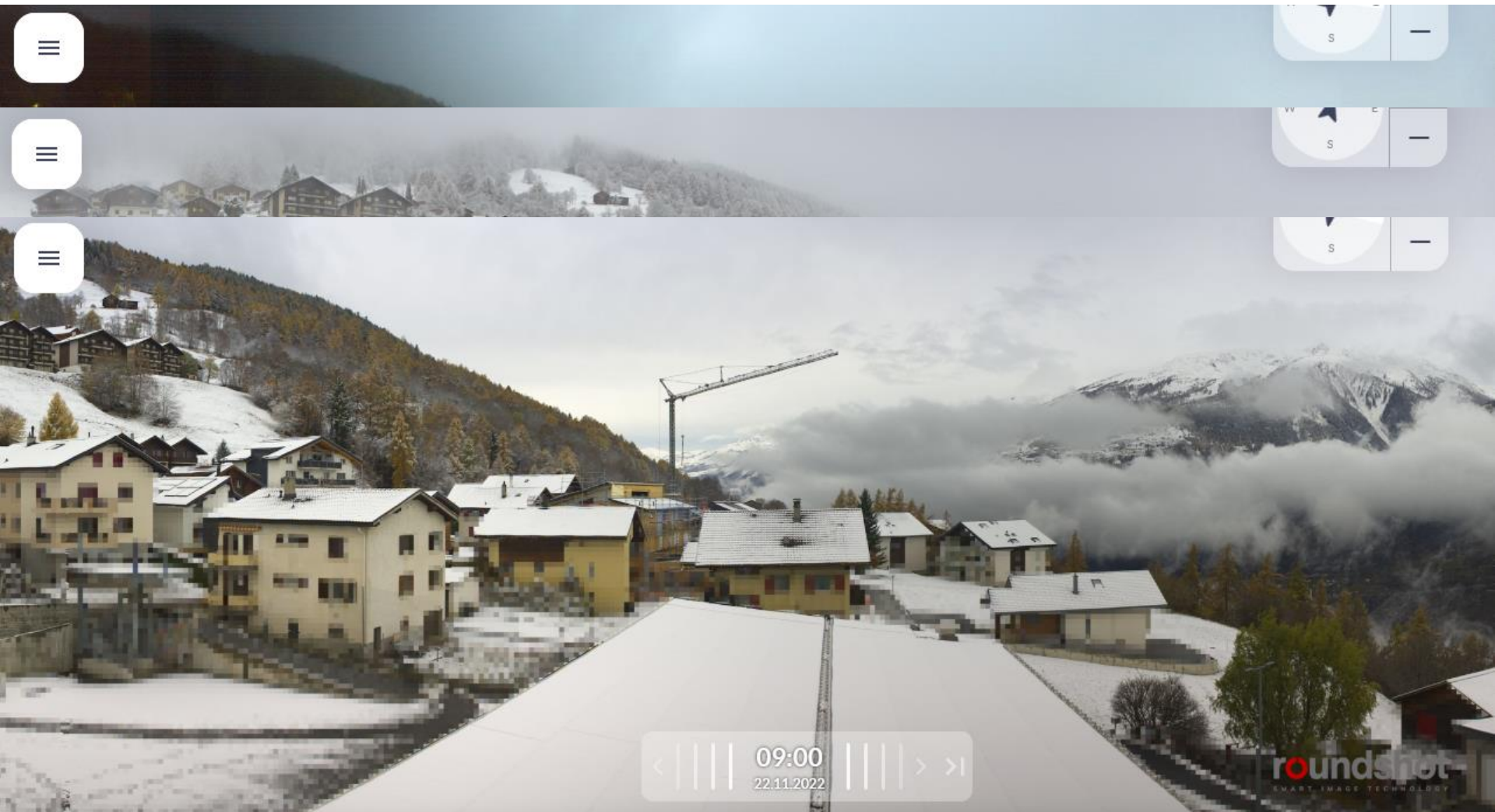
Cloudy sky events: $\text{CNR} > -5\text{dB}$

Cloudy sky events



Nov 4, 5pm:

CNR: 7.8dB



Cloudy sky CNR profiles

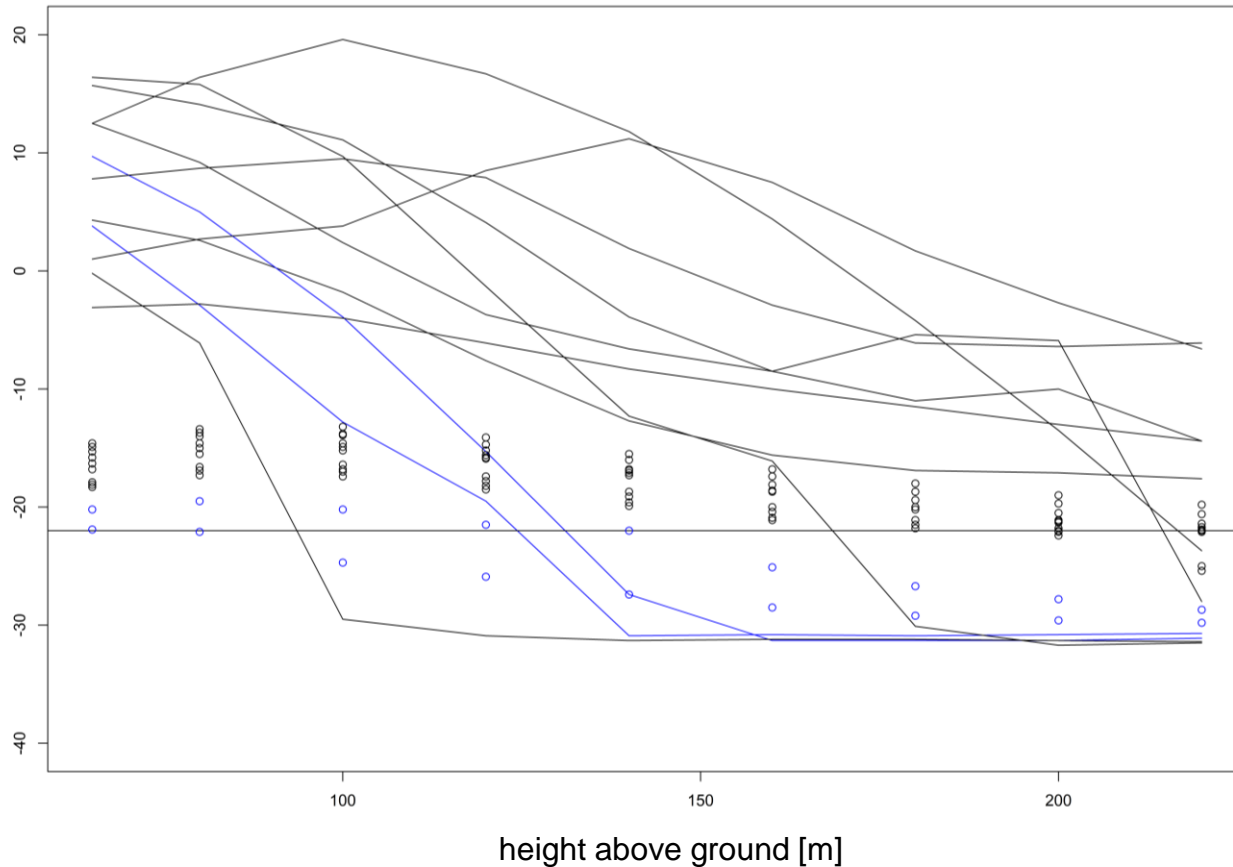


Clear sky events without meteorological icing

Clear sky events with meteorological icing

Clear sky events with positive temperatures

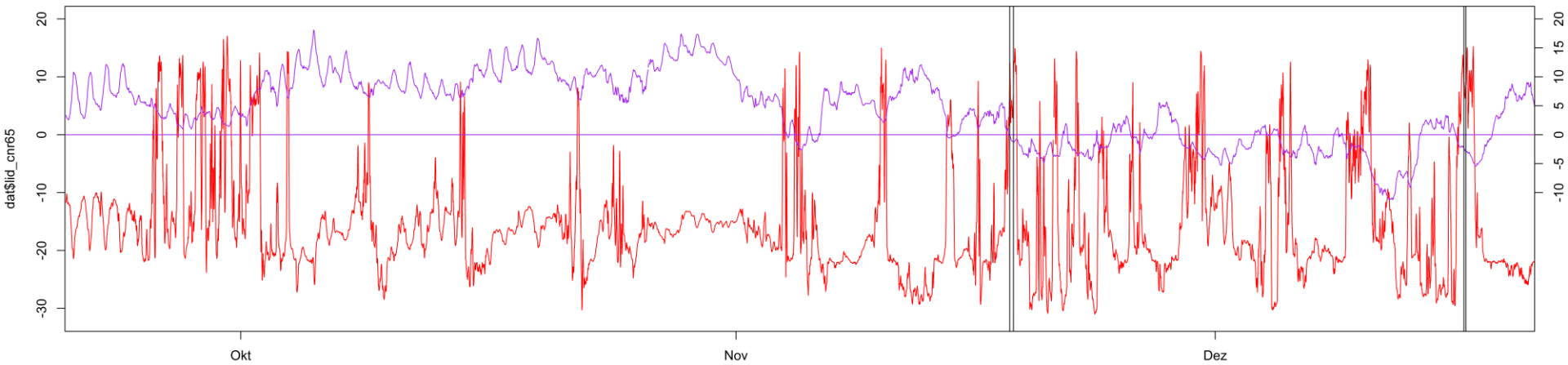
Combined CNR profiles



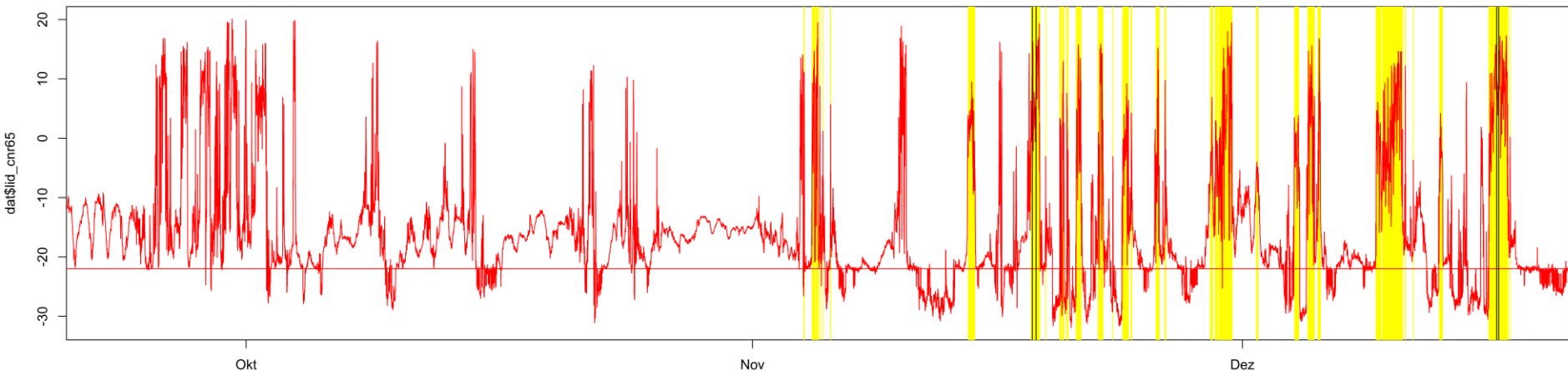
Lines: cloudy sky events, points: clear sky events

Blue line: met icing, blue points: clear sky below 0°C

CNR and temperature



Icing detection



Yellow: events $t_t < 0^\circ\text{C}$ and $\text{CNR} > -5\text{dB}$

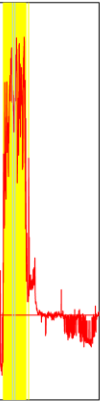
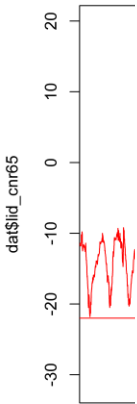
Black: meteorological icing events

→ **6.86% detected icing vs 0.41% real meteorological icing**

Icing detection

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Yellow: events $t_t < 0^\circ\text{C}$ and $\text{CNR} > -5\text{dB}$

Black: meteorological icing events

→ **6.86% detected icing vs 0.41% real meteorological icing**

Can LiDAR help us to detect icing?

(Do we need a PhD degree for this?)

Yes and no

Thank you for your attention!