The challenge of detecting the liquid water content with ceilometer and Wind LiDAR

Winterwind 2024, Session Environment (8)

Sara Koller, Fabian Umbricht, Meteotest

Pekko Tuominen, Vaisala

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

IEA Task 19

IEA Ice Classification for wind energy sites

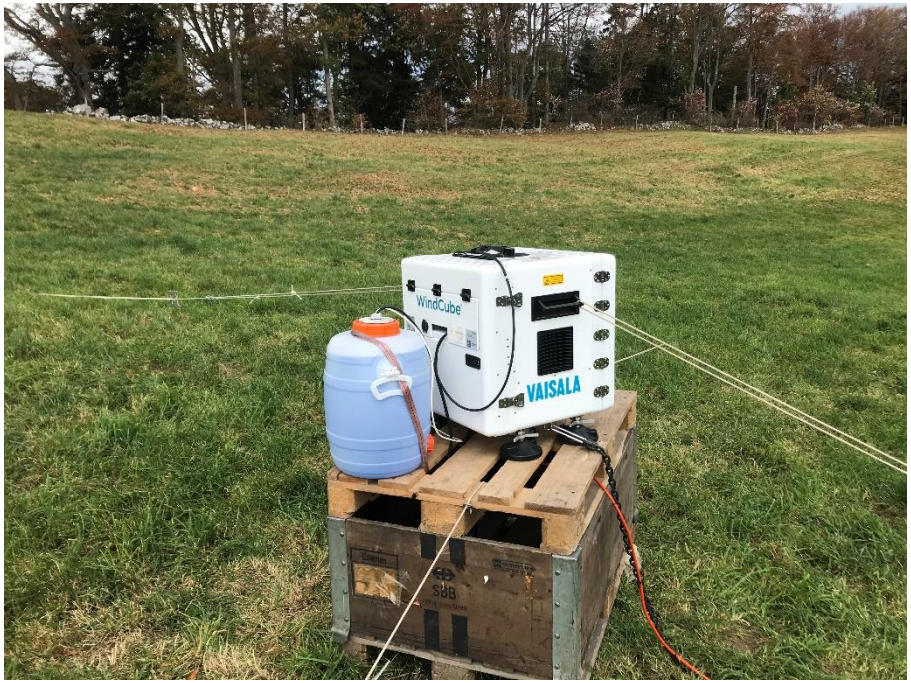
IEA Ice class	Meteorological icing	Instrumental icing	Production loss
	% of year	% of year	% of annual production
5	>10	>20	> 20
4	5-10	10-30	10-25
3	3-5	6-15	3-12
2	0.5-3	1-9	0.5-5
1	0-0.5	<1.5	0 - 0.5

Site: 100m met mast, Wind LiDAR and ceilometer

Setup met mast:

- Heated and unheated anemometers (3D-Sonic, Thies First Class)
- Temperature (100m, 10m)
- Relative humidity (100m, 10m)
- Webcam filming a sensor (80m)

Site: 100m met mast, Wind LiDAR and ceilometer



Setup Wind LiDAR:

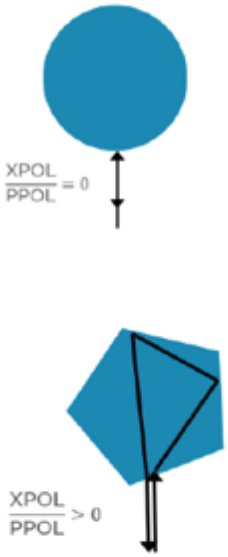
- Windcube V2.1 by Vaisala
- Oct 19, 2023 to Feb 06, 2024
- Measurement heights: 40 - 300m
- Output: Wind direction and speed at 20 heights above ground
- Side product: Carrier to Noise Ratio (CNR)

Site: 100m met mast, Wind LiDAR and ceilometer

Setup ceilometer:

- CL61 ceilometer by Vaisala
- Dec 27, 2023 to Feb 06, 2024
- Measurement interval: 5sec
- Measurement height: up to 15km (4.8m resolution)
- Output: attenuated backscatter, linear depolarization ratio, parallel-polarized backscatter, cross-polarized backscatter
- Derived results: Cloud type, cloud heights and thickness, precipitation, liquid water content (?)

Depolarization



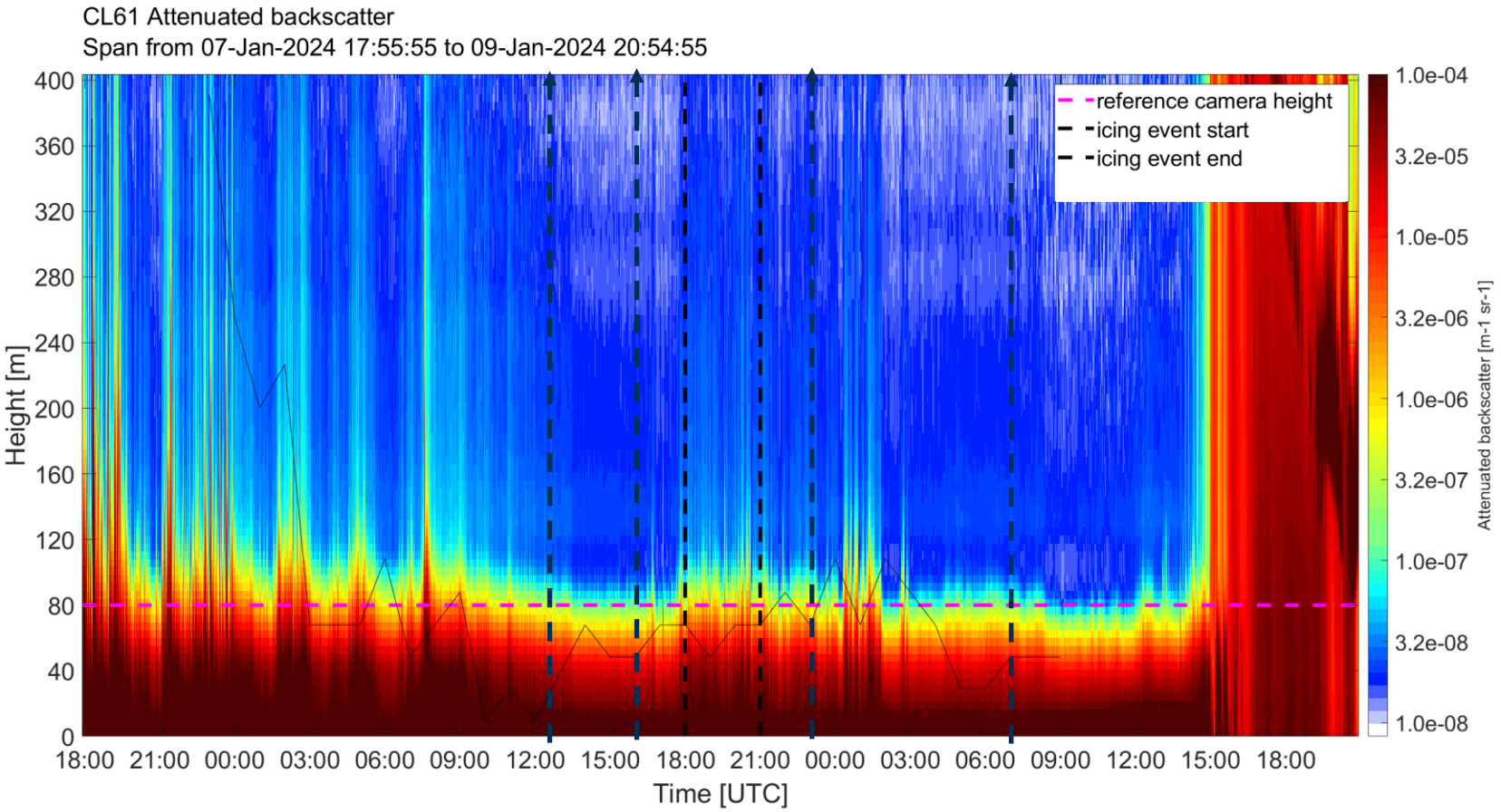
- CL61 emits linearly-polarized light
- Polarization direction of the light changes depending on the scatterer shape

→ Spheres: Due to the symmetry the detected return signal is not depolarized

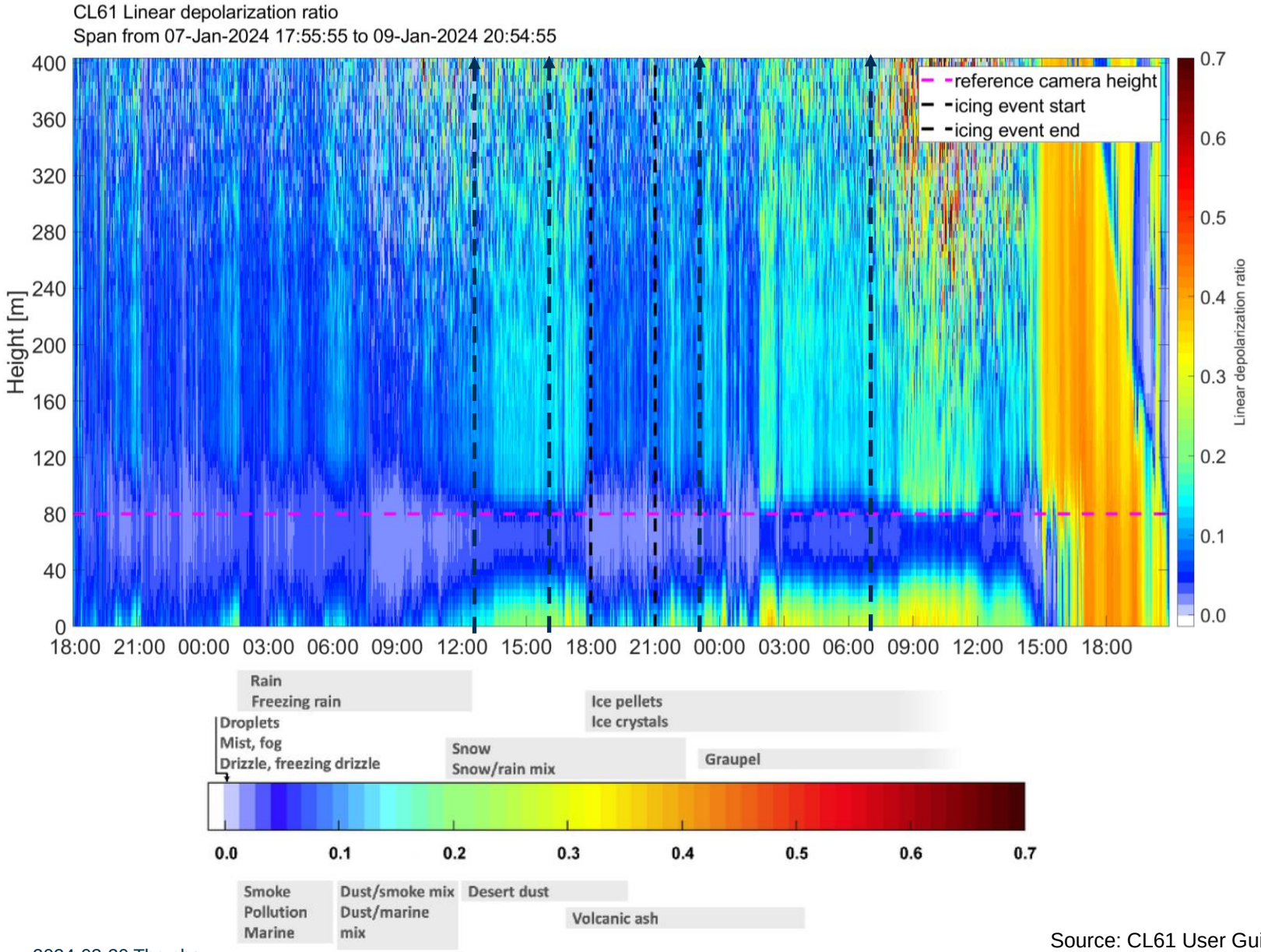
→ Non-spheres: Significant depolarization due to multiple internal reflections at solid/fluid interfaces

8 meteorological icing events

Icing events: Attenuated backscatter

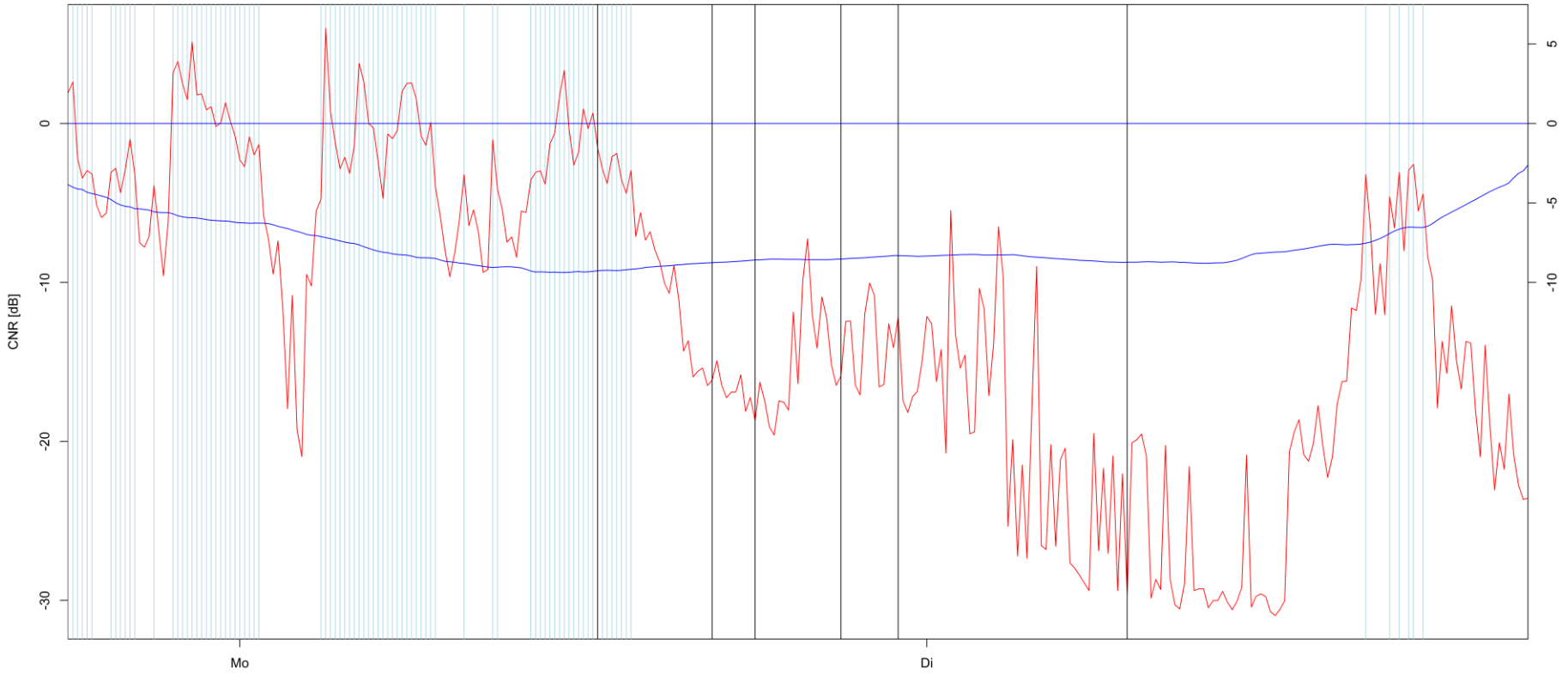


Icing events: Depolarization ratio



Source: CL61 User Guide, Vaisala

Icing events: Wind LiDAR

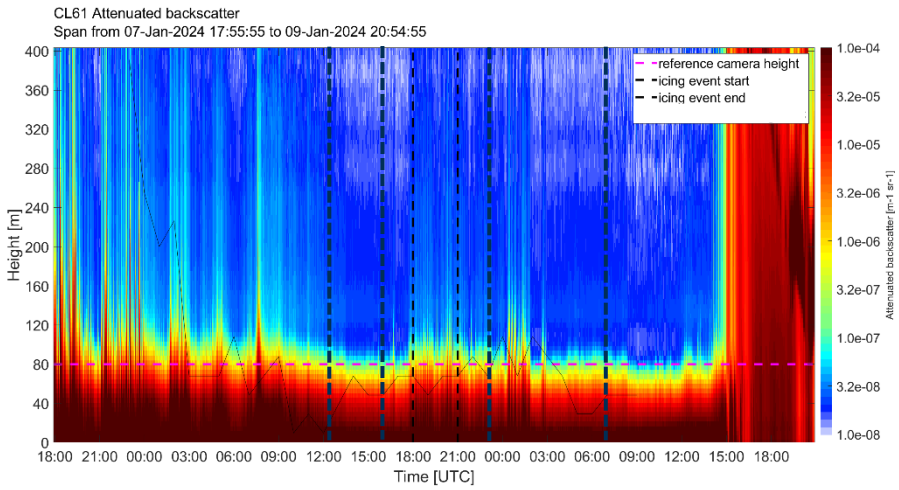


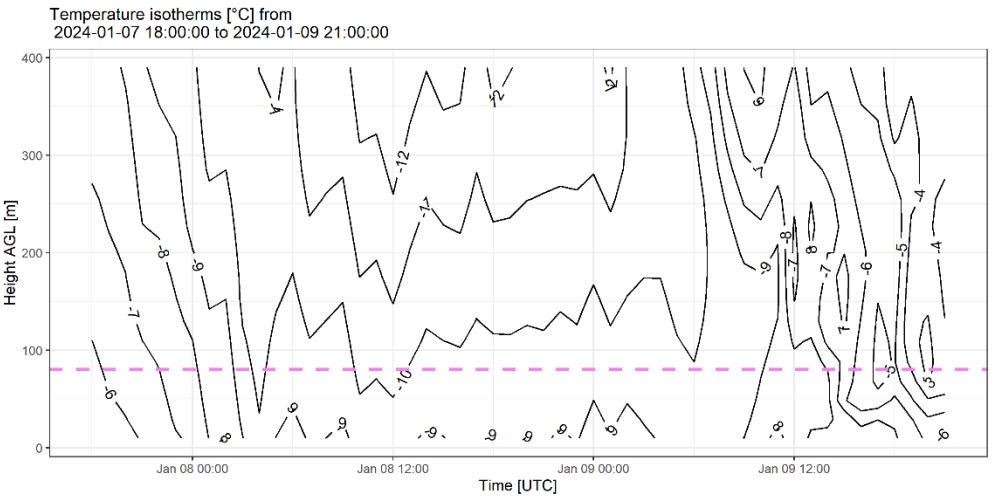
Temperature below 0°C

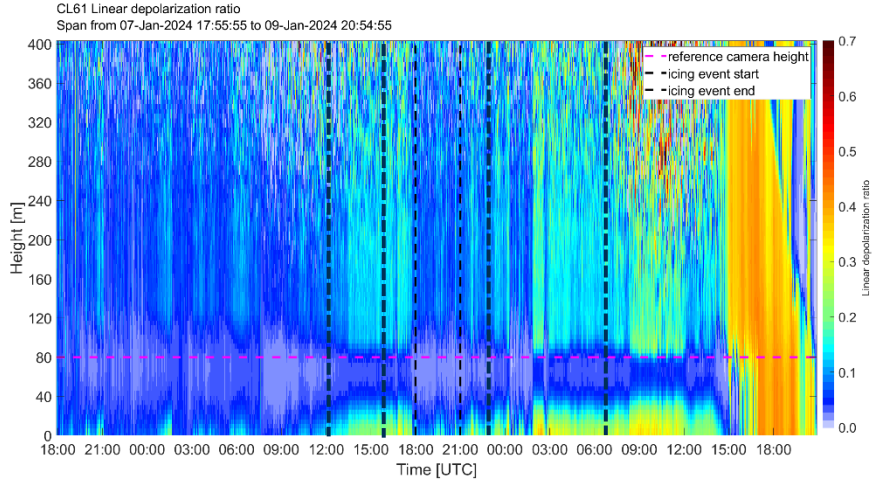
CNR > -5dB

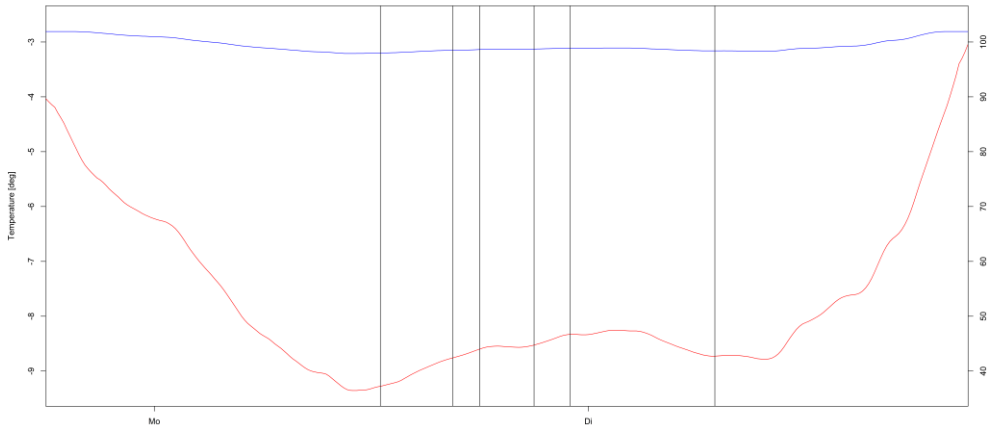
→ clouds with supercooled water droplets?

Icing events

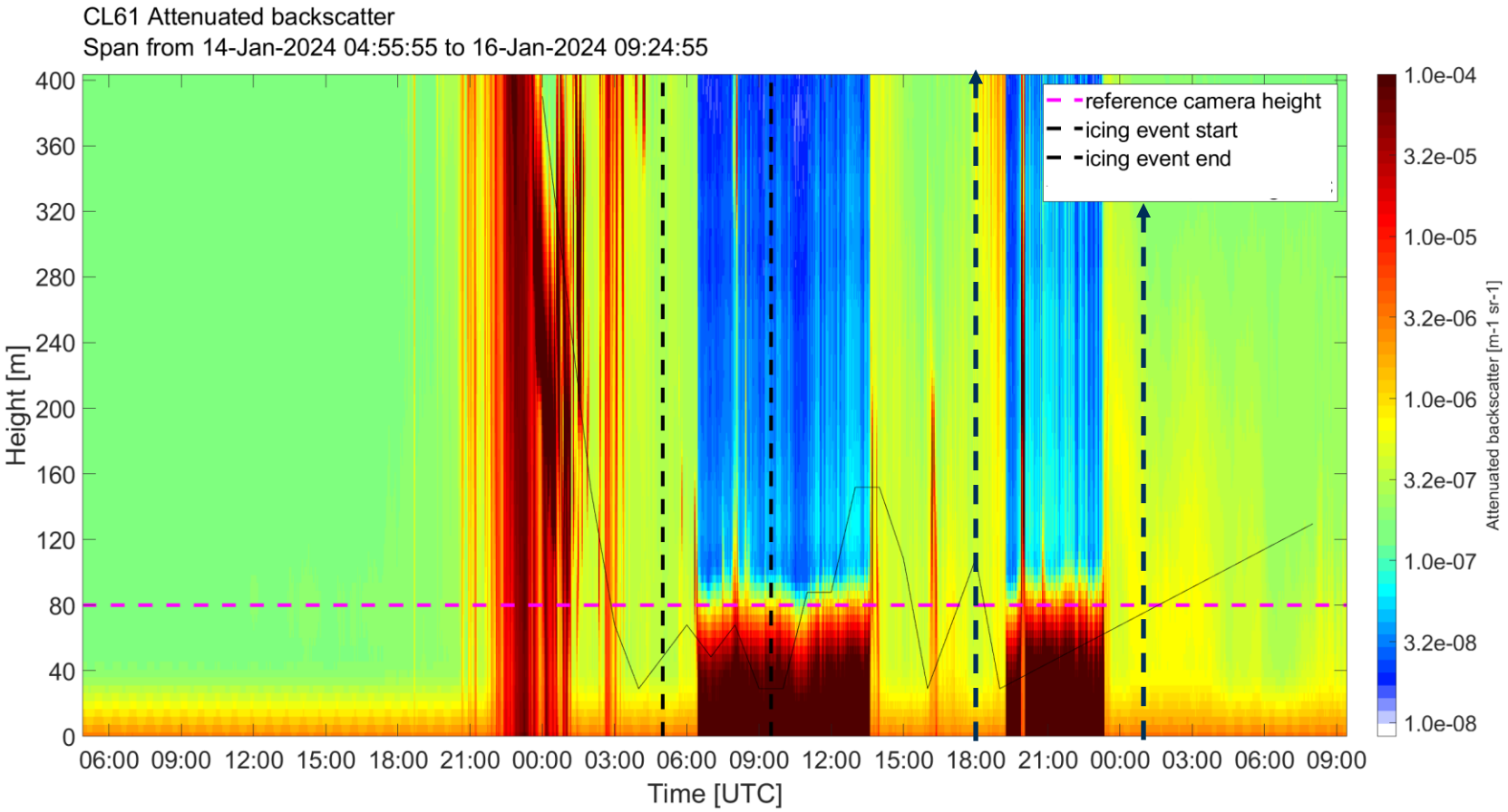




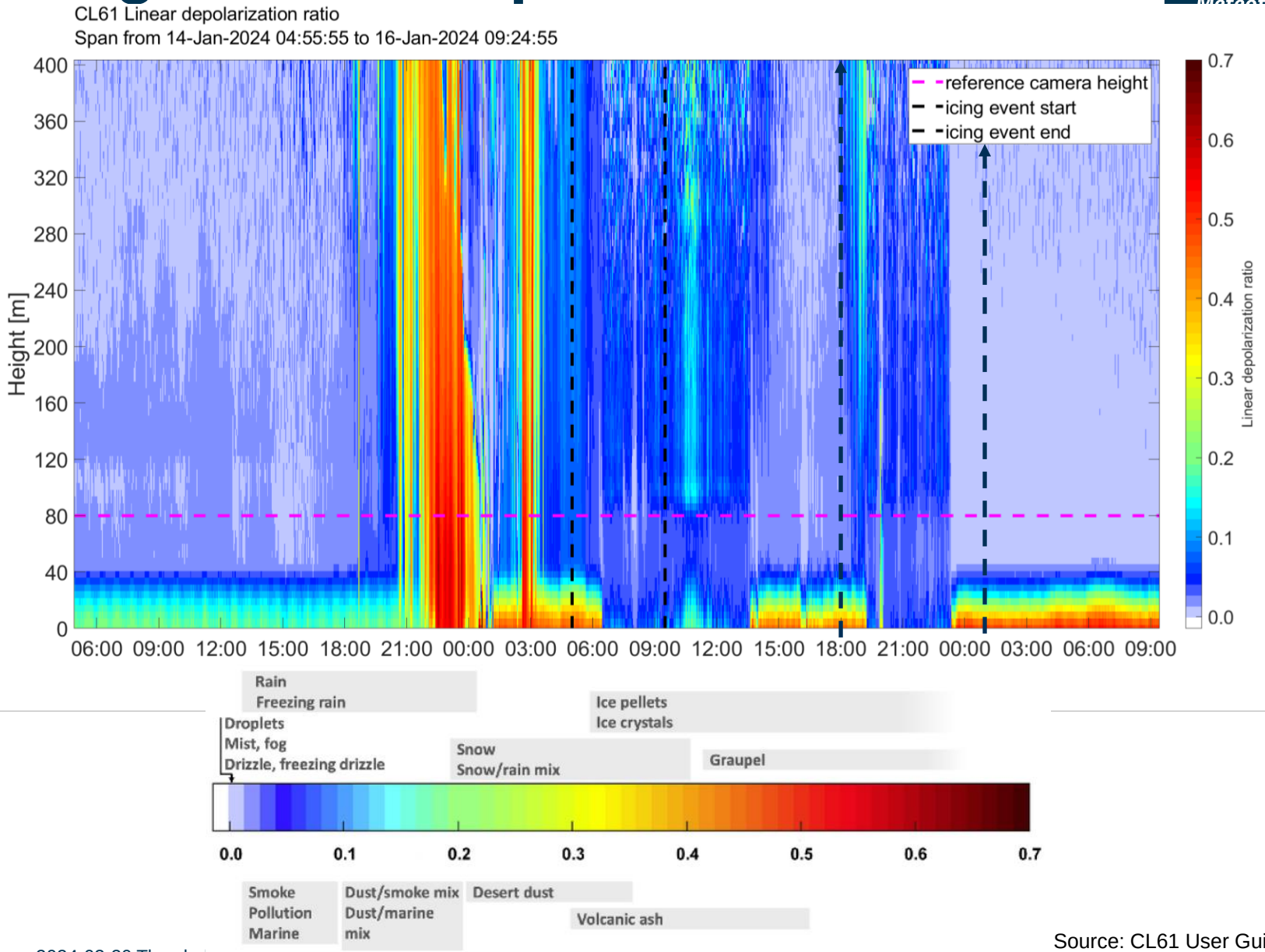




Icing events: Attenuated backscatter

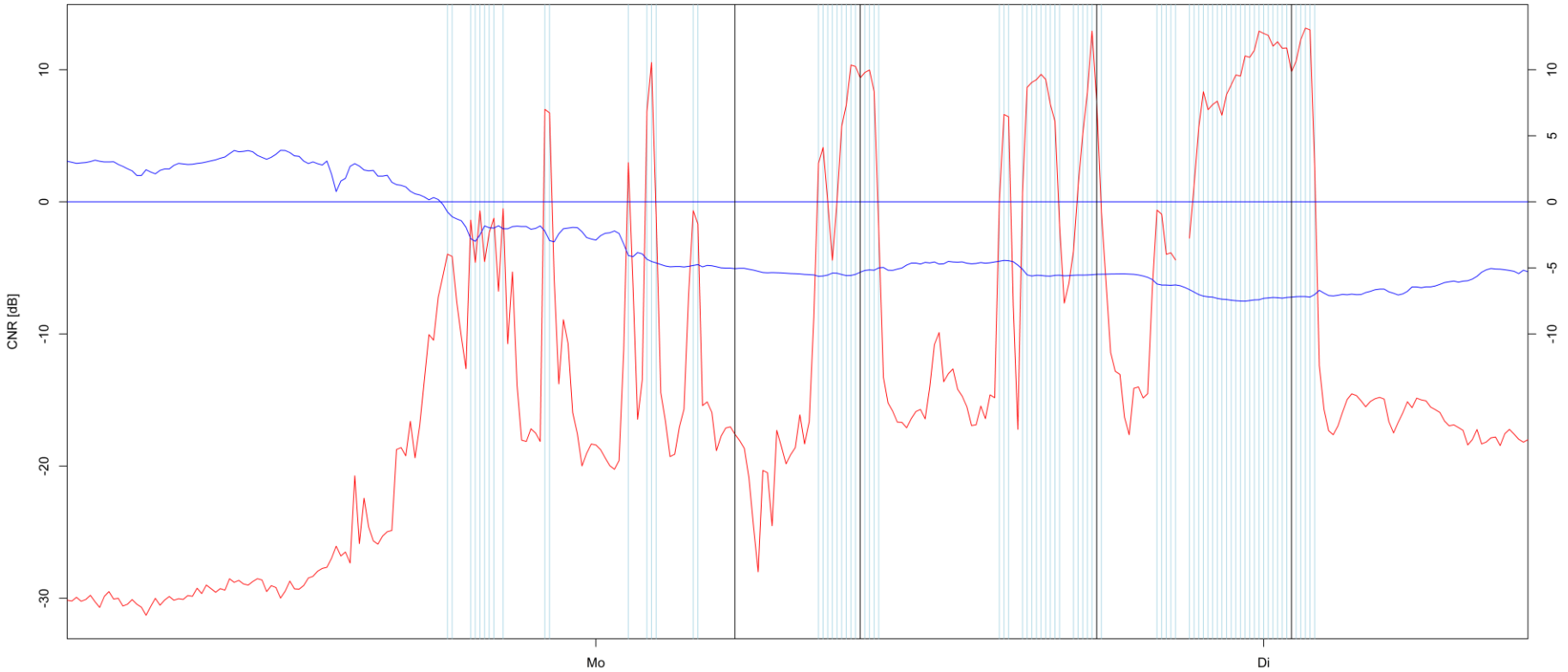


Icing events: Depolarization ratio



Source: CL61 User Guide, Vaisala

Icing events: Wind LiDAR



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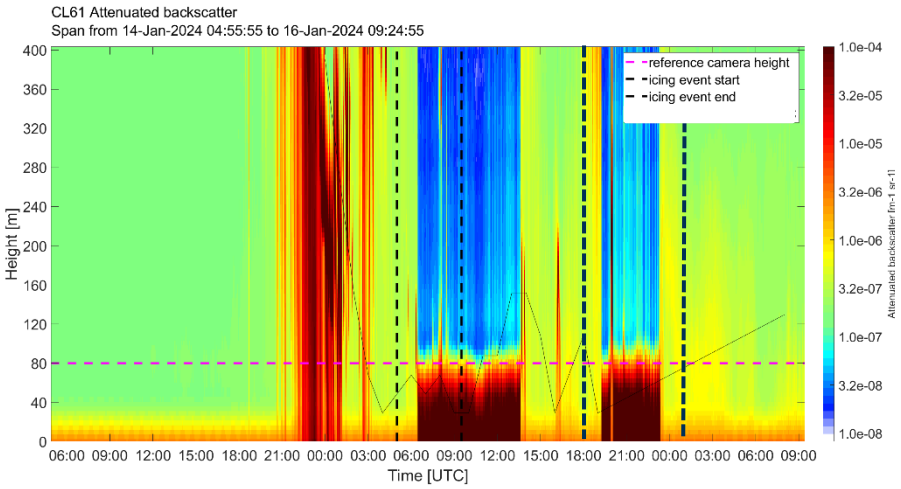
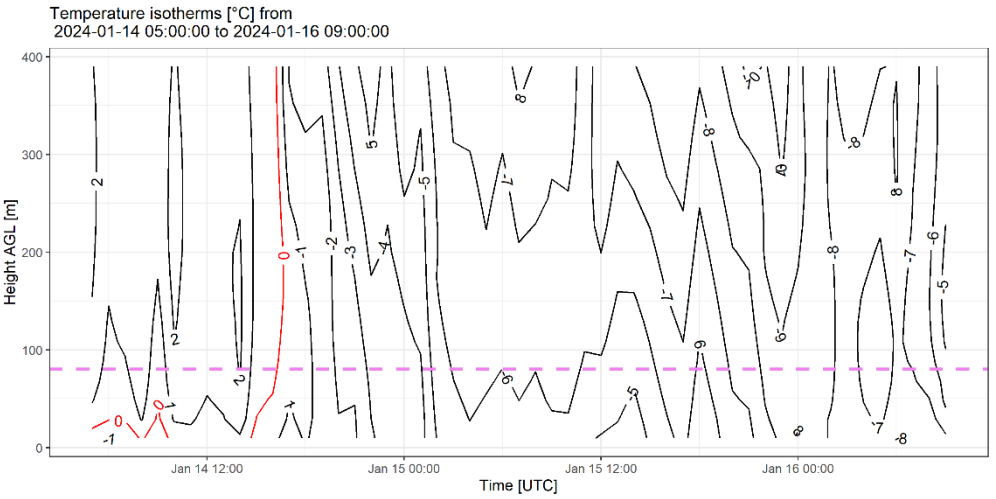
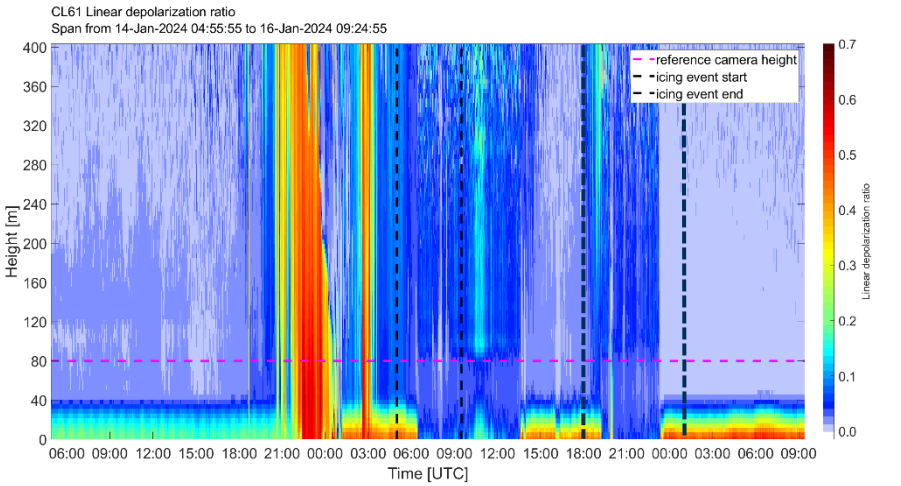
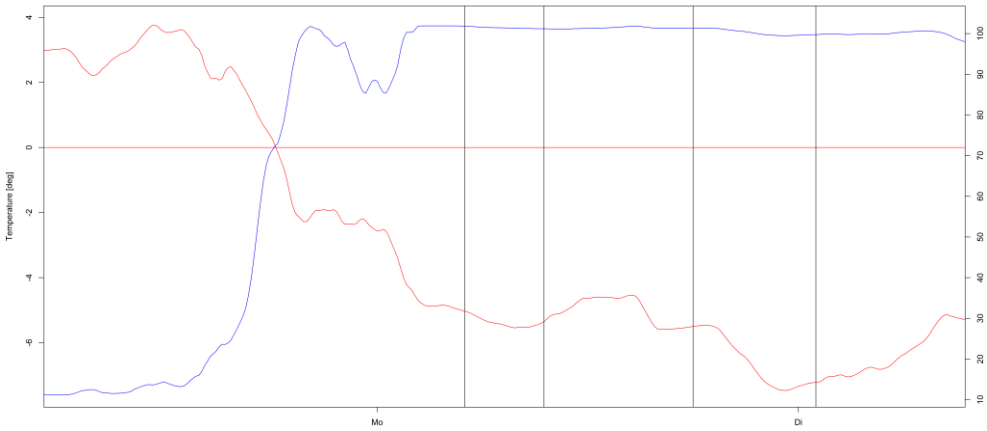
Icing events









Conclusion

- Ceilometer measurements look very promising
- Icing detection with Wind LiDAR measurements… long way to go still
- Next steps:

→ Target classification (aerosols, droplets, ice, drizzle, etc.)

→ Mean volumetric diameter

→ Liquid water content

Thank you for your attention!