

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

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Events

Work Plan and Deliverables

IEA Wind TCP Task 52

Large-Scale Deployment of Wind Lidar

	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 Wind Home

Task 52

Participation

2024-03-20 The challenge of detecting the liquid water content with ceilometer and Wind LiDAR



3



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





5

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



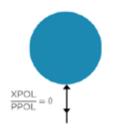


Setup ceilometer:

- 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, parallelpolarized backscatter, crosspolarized backscatter
- Derived results: Cloud type, cloud heights and thickness, precipitation, liquid water content (?)

Depolarization







7

- 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





-10

06 Jan



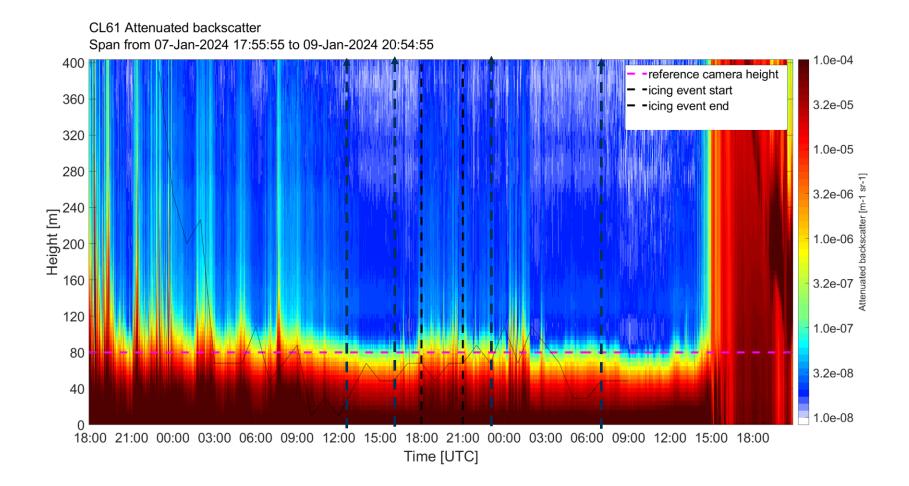
08 Jan

10 Jan

12 Jan

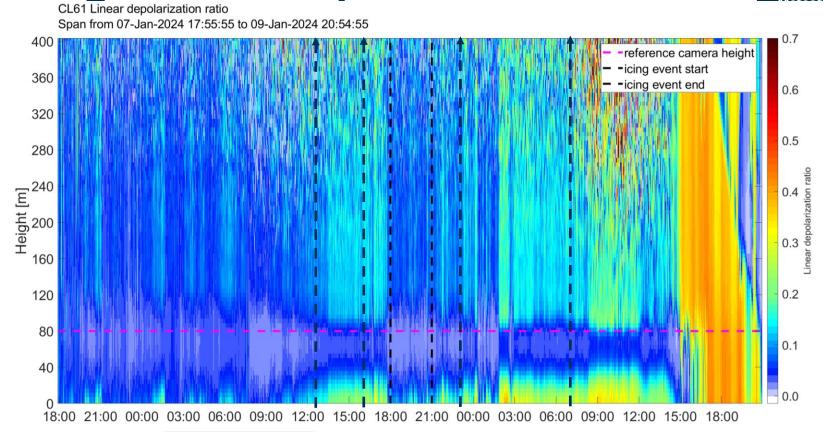
Icing events: Attenuated backscatter

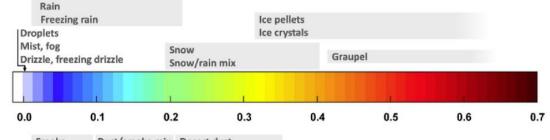
Meteotest



9

Icing events: Depolarization ratio





 Smoke
 Dust/smoke mix
 Desert dust

 Pollution
 Dust/marine
 Volcanic ash

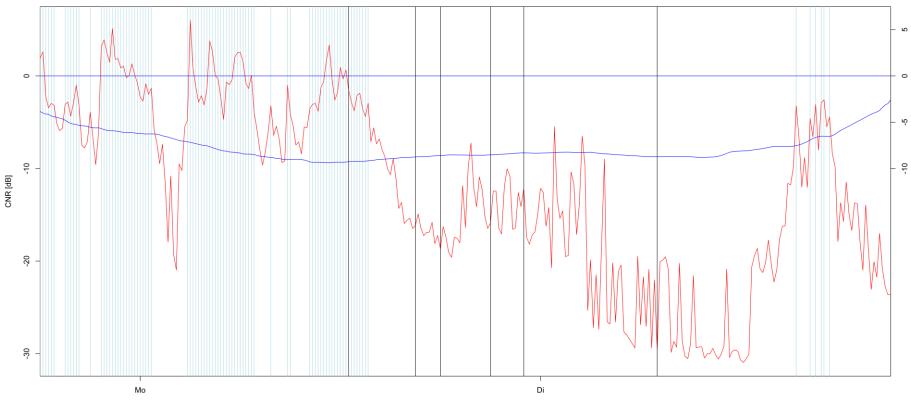
 Marine
 mix
 Volcanic ash

Source: CL61 User Guide, Vaisala

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Icing events: Wind LiDAR





Temperature below 0°C

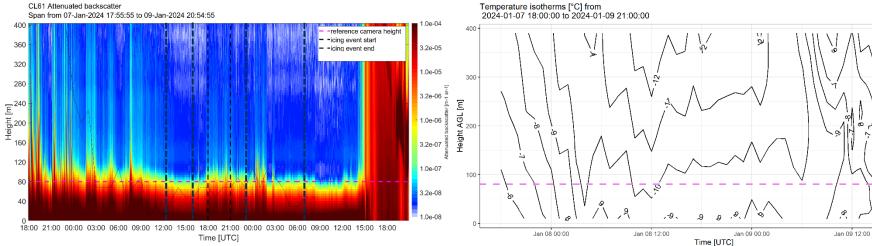
CNR > -5dB

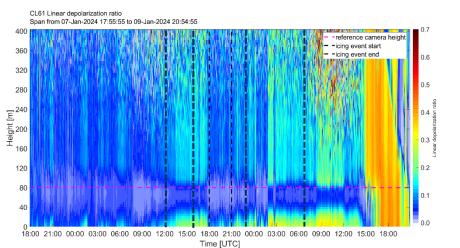
11

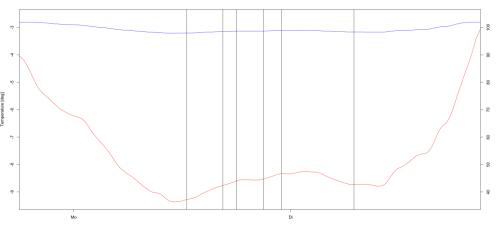
 \rightarrow clouds with supercooled water droplets?

Icing events



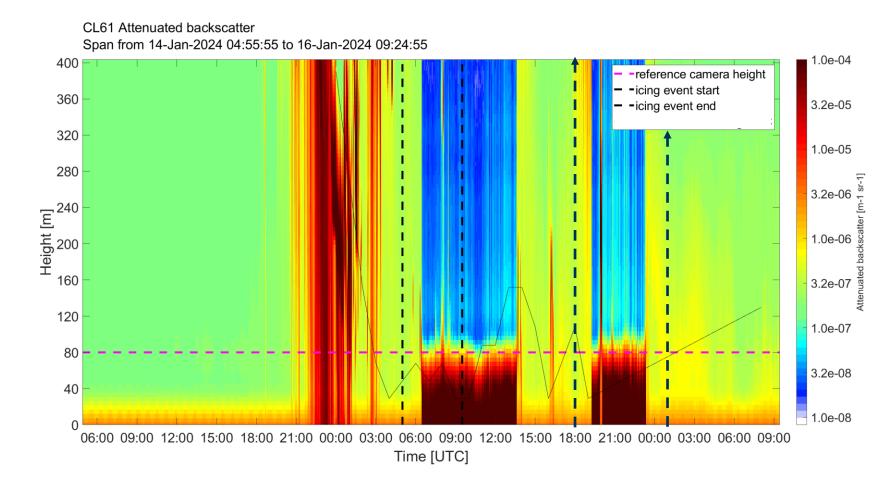




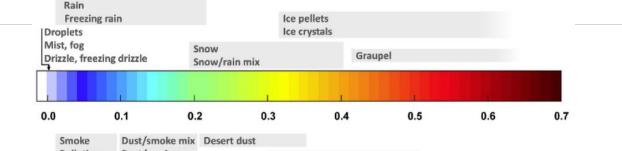


Time [UTC]





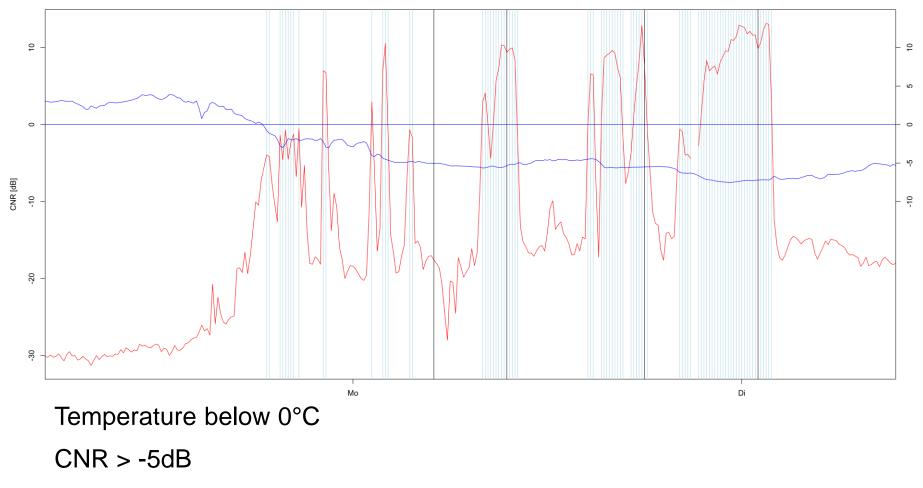
Icing events: Depolarization ratio CL61 Linear depolarization ratio Span from 14-Jan-2024 04:55:55 to 16-Jan-2024 09:24:55 0.7 400 reference camera height - icing event start 360 - icing event end 0.6 320 0.5 280 Einear depolarization ratio Height [m] 160 160 120 0.2 80 0.1 40 0.0 0 06:00 09:00 12:00 15:00 18:00 21:00 00:00 03:00 06:00 09:00 12:00 15:00 18:00 21:00 00:00 03:00 06:00 09:00



Smoke Dust/smoke mix Desert dust Pollution Dust/marine Volcanic ash Marine mix

Icing events: Wind LiDAR



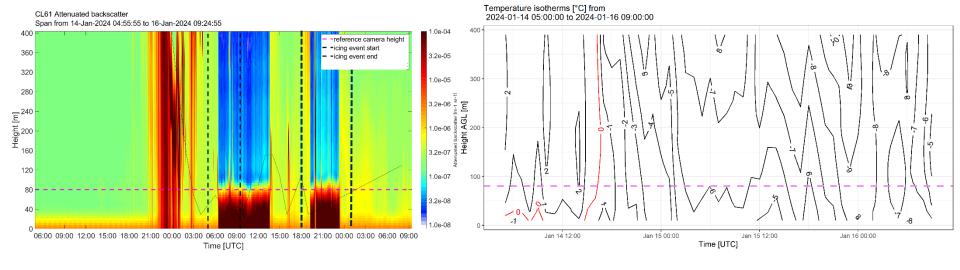


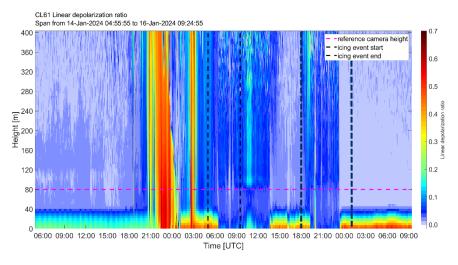
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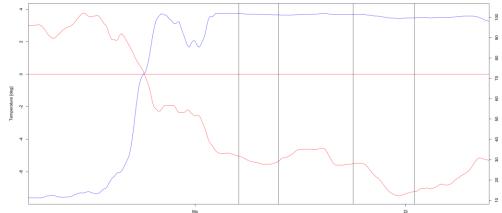
15

Icing events









Conclusion



- Ceilometer measurements look very promising
- Icing detection with Wind LiDAR measurements... long way to go still
- Next steps:
- \rightarrow Target classification (aerosols, droplets, ice, drizzle, etc.)
- \rightarrow Mean volumetric diameter
- \rightarrow Liquid water content





Thank you for your attention!