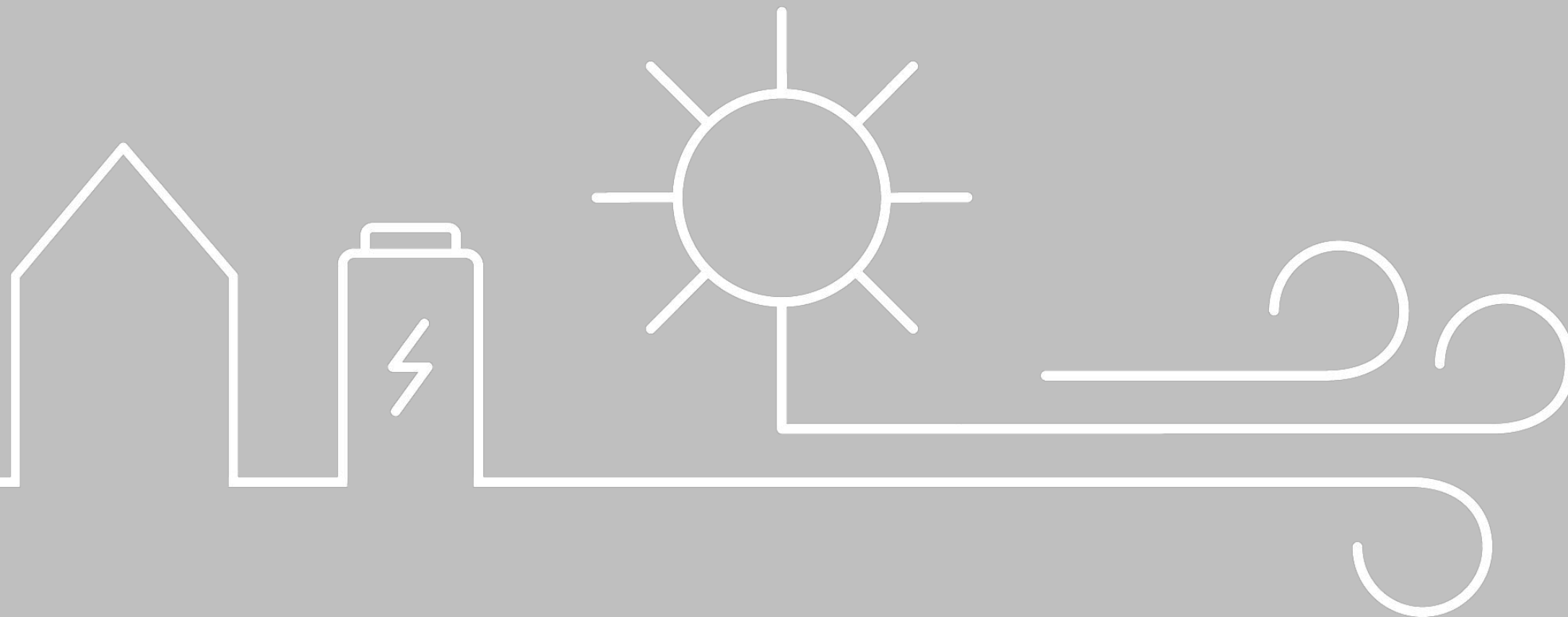




Be part of the solution with us

Return on experience

Working on a wind farm in icing conditions



Charles Godreau
April 21, 2021

OPTIMIZE YOUR RENEWABLE ENERGY PROJECTS

Nergica is a Canadian centre of applied research that stimulates innovation in the renewable energy industry through research, technical assistance, technology transfer and technical support for businesses and communities.



Solar power



Wind power



Renewable energy
integration

Our research site

Rivière-au-Renard, Quebec, Canada

~1200 hours of icing per year

In operation since 2010

Two 2 MW wind turbines

**Two fully-instrumented
126 m met masts**

**One real-time microgrid simulation and
prototyping platform (OPAL-RT)**

One 230 kW microgrid
comprising small wind turbines,
diesel generators, solar panels and
energy storage systems

Two lidars

16 kW of solar PV panels

**One powerful data processing and
archiving system
(OSIsoft PI system)**

The challenge



How do we ensure the realisation of R&D projects and wind turbine maintenance during icing events?

When is it best to go on site?

How can we assess if it is safe to approach an iced turbine?

A two stage solution

Before the event

Weather forecast

Wind farm specific forecast

Icing forecast

When on site

Icing assessment

Monitoring ice stability conditions

Approaching the turbine

Following an industry reference



Canadian Renewable
Energy Association
WIND, SOLAR, STORAGE.

Association canadienne
de l'énergie renouvelable
ÉOLIEN, SOLAIRE, STOCKAGE.

Canadian Renewable Energy Association
Operations & Maintenance

Best Practices for Wind Farm Icing and Cold Climate Health & Safety

June 2020 Edition

Available at

<https://renewablesassociation.ca/operations-and-maintenance/>

Outlines practices and procedures to assist with the safe operation and maintenance of wind power generation facilities in cold climates.

- Icing and cold temperature physical conditions
- Hazard definitions
- Best practices sorted by wind farm location
- Decision tree

Before the event – Assess the impacts and risks

Public weather service forecasts

Freely available

Provided “as is”, requires assessment

Icing prone conditions:

Temperature close to 0 °C

Precipitations

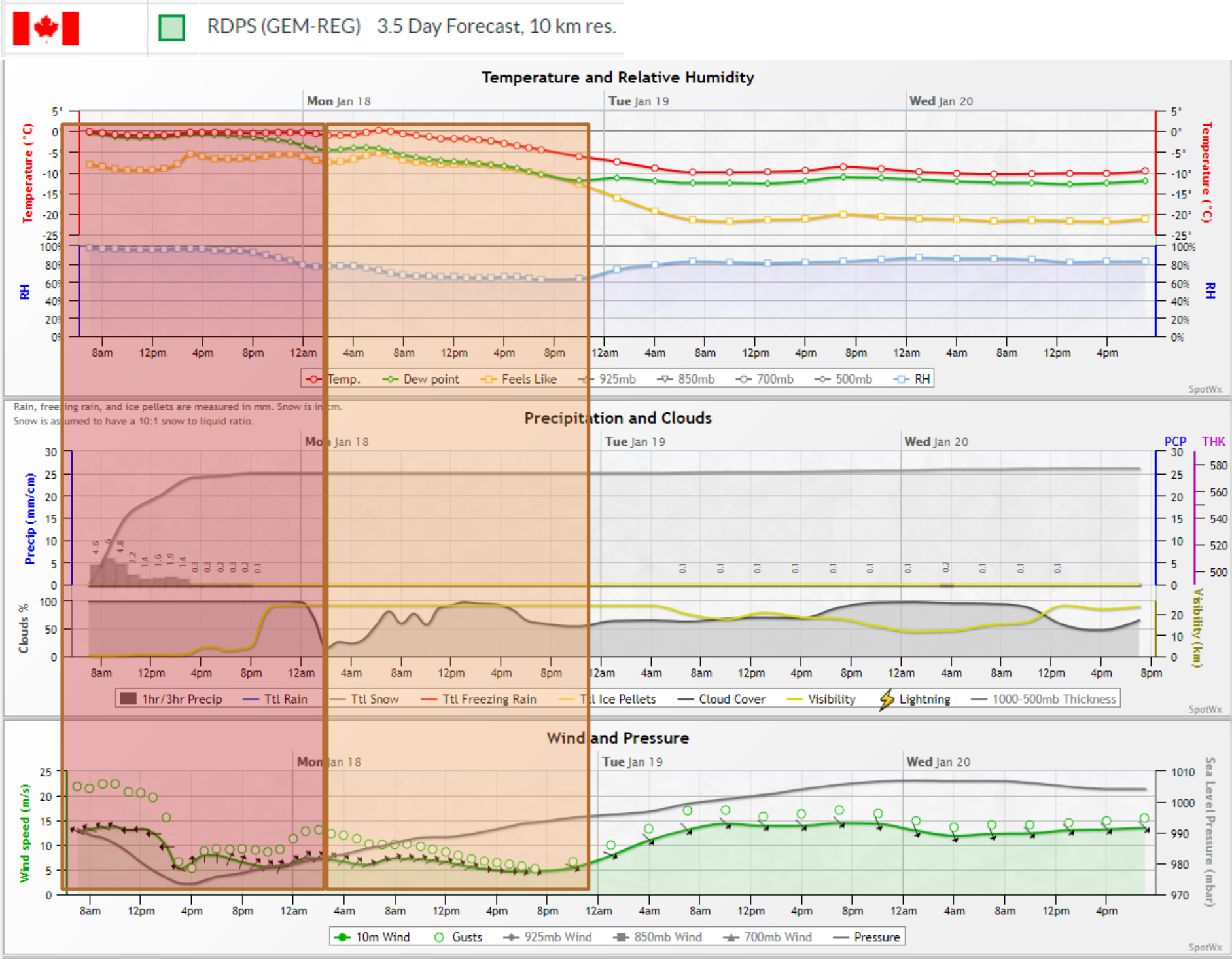
High winds

Potential candidate for on-site intervention:

Temperature close to 0 °C

No Precipitation

Low winds



<https://spotwx.com/>

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Before the event – Assess the impacts and risks

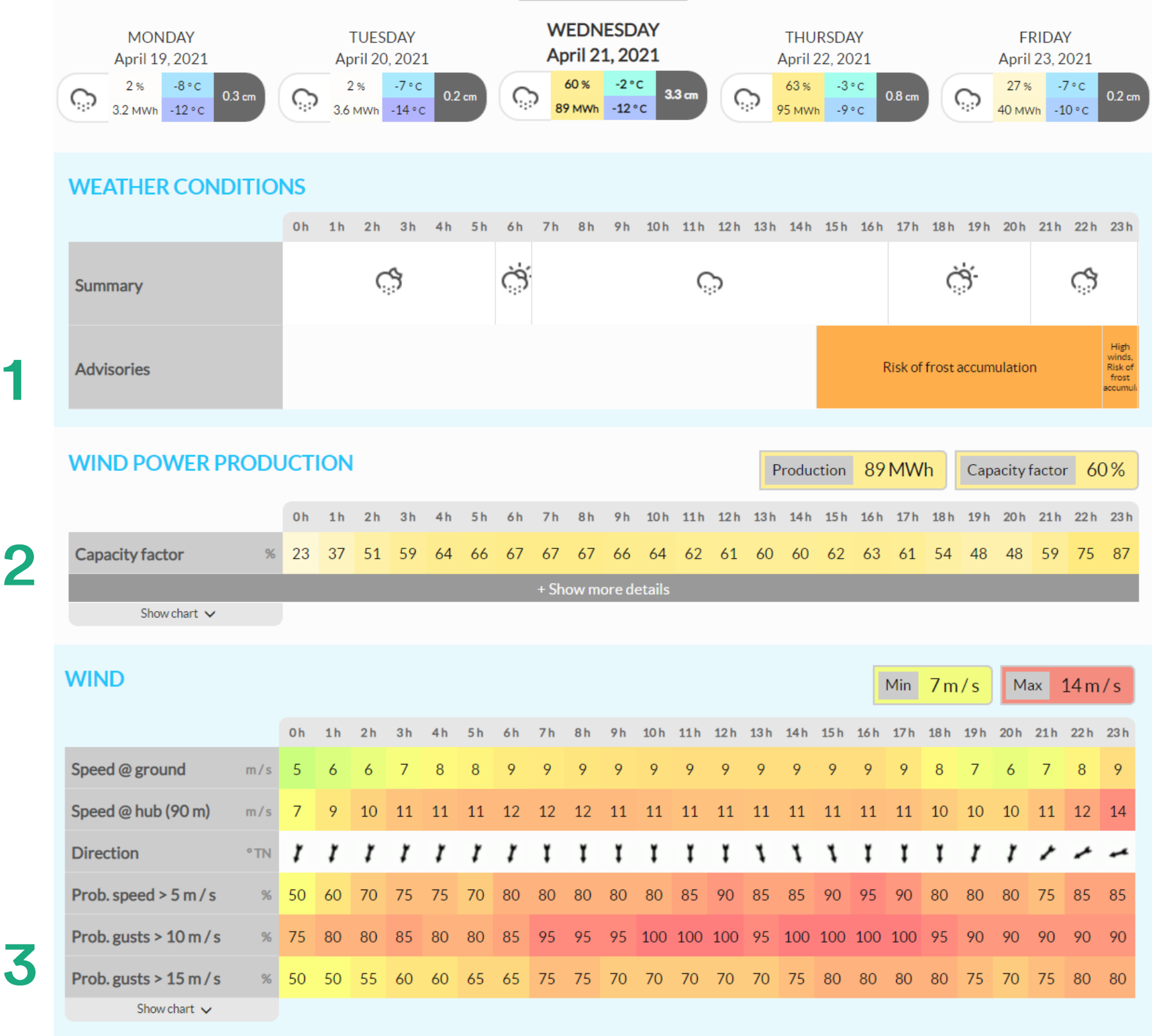
Wind farm specific forecast

Several companies provide services to ease site managers decision making

1- Health and safety risk advisories

2- Capacity factor

3- High wind probability



Before the event – Assess the impacts and risks

Wind farm specific forecast

4- Temperature, including wind chill

5- Precipitation

6- Frost indicator

4

TEMPERATURE																									
		0h	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	12h	13h	14h	15h	16h	17h	18h	19h	20h	21h	22h	23h
Temperature	°C	-11	-12	-12	-12	-11	-11	-10	-10	-10	-9	-9	-8	-8	-7	-6	-6	-5	-5	-4	-3	-3	-2	-2	-3
Feels like	°C	-19	-20	-21	-21	-21	-20	-20	-20	-19	-19	-18	-17	-17	-16	-15	-15	-14	-13	-11	-10	-9	-9	-10	-10
Relative humidity	%	85	85	85	85	86	86	86	86	86	87	87	87	87	88	88	89	90	91	92	93	93	92	91	90
Dew point	°C	-13	-14	-14	-14	-13	-13	-12	-12	-11	-11	-10	-10	-9	-9	-8	-7	-7	-6	-5	-4	-4	-4	-4	-4
Show chart		▼																							

5

PRECIPITATION

Snow3.3 cm

		0h	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	12h	13h	14h	15h	16h	17h	18h	19h	20h	21h	22h	23h	
Prob. of precipitation	%	40	40	40	40	40	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	20	20	20	20	
Accumulation	cm						0.1	0.1	0.1	0.3	0.3	0.3	0.3	0.3	0.3	0.2	0.2	0.2	0.2	0.2	0.2					
Precipitation type		Light snow possible					Light snow														Light snow possible					
Frost indicator	x10 %															1	2	4	6	8	6	5	4	4	4	5

Show chart

6

- Frost indicator :
✓ Hoarfrost
✓ Rime Ice
✓ Freezing Rain



wpred <http://www.wpred.com/>

Before the event – Assess the impacts and risks

Icing forecast

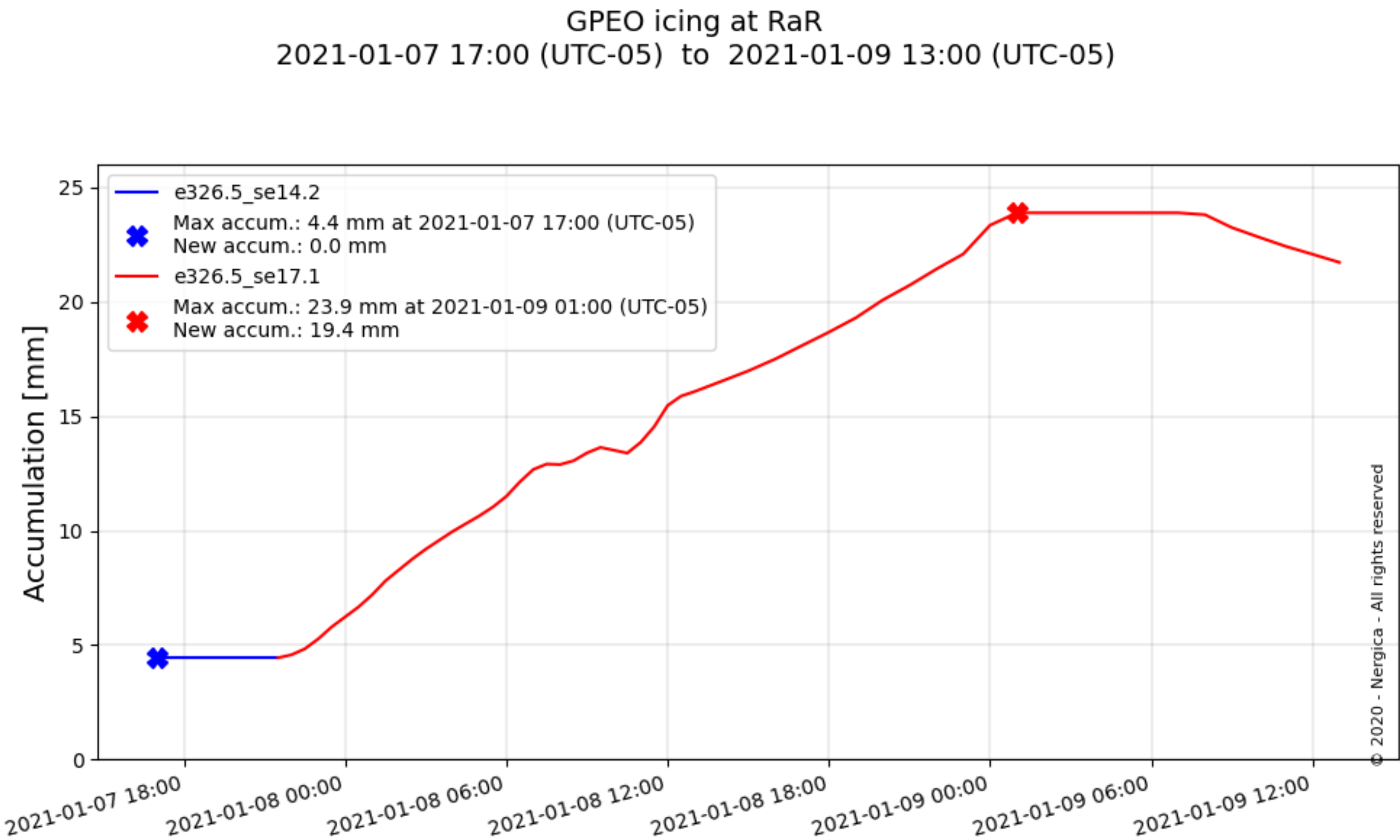
GPEO: Nergica icing model

48 h forecast

30 minutes interval

Indicates icing severity

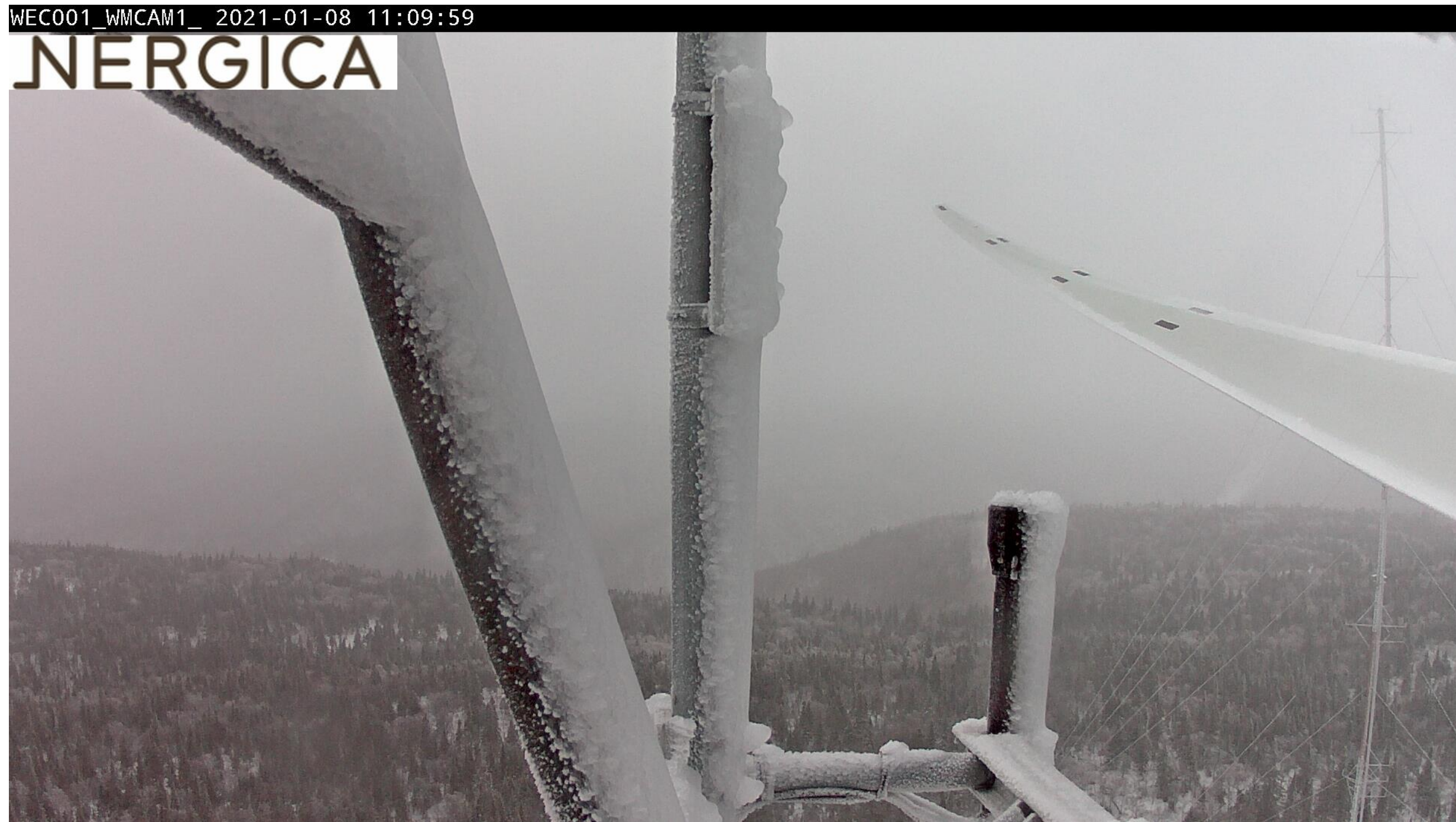
Automated alerts sent to site manager and technicians



Then the event hits



Then the event hits



Then the event hits

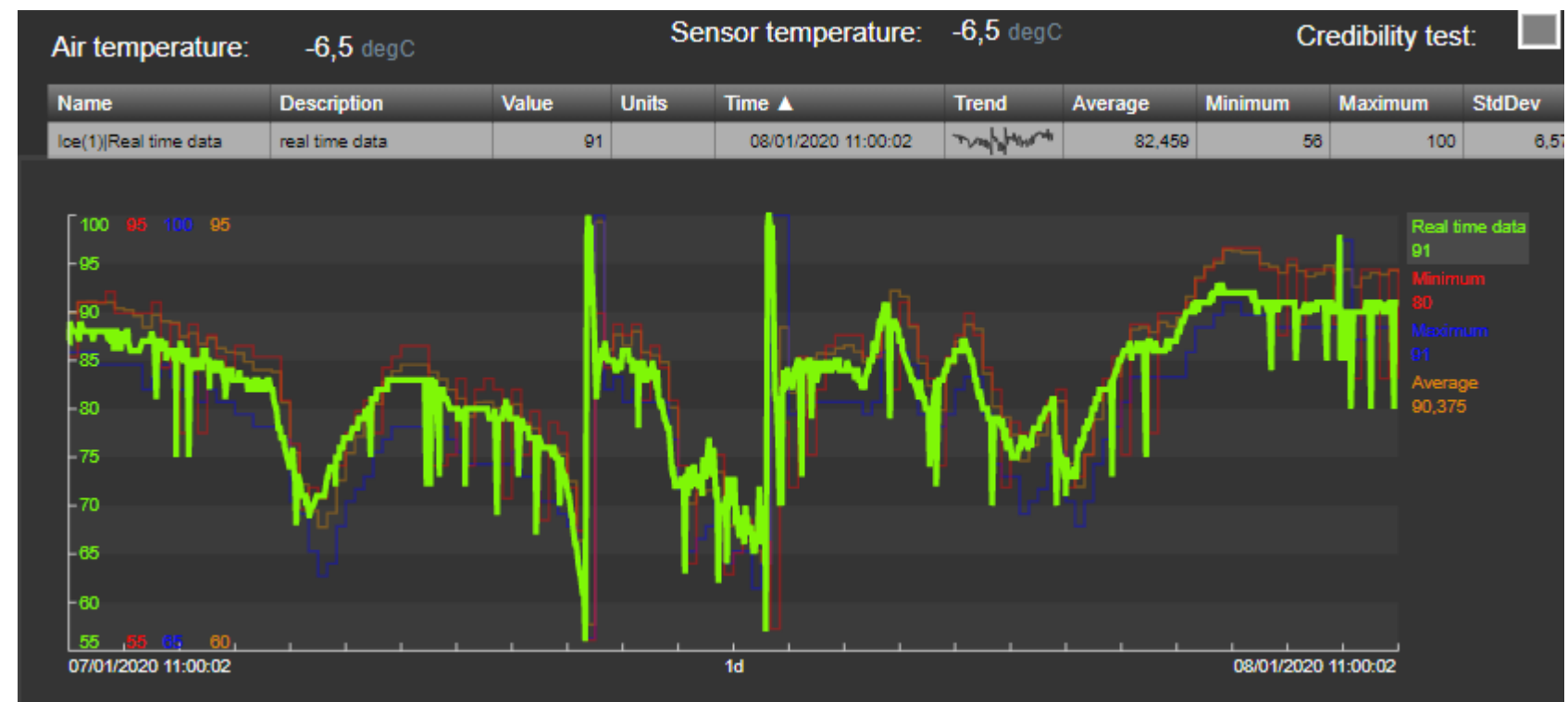
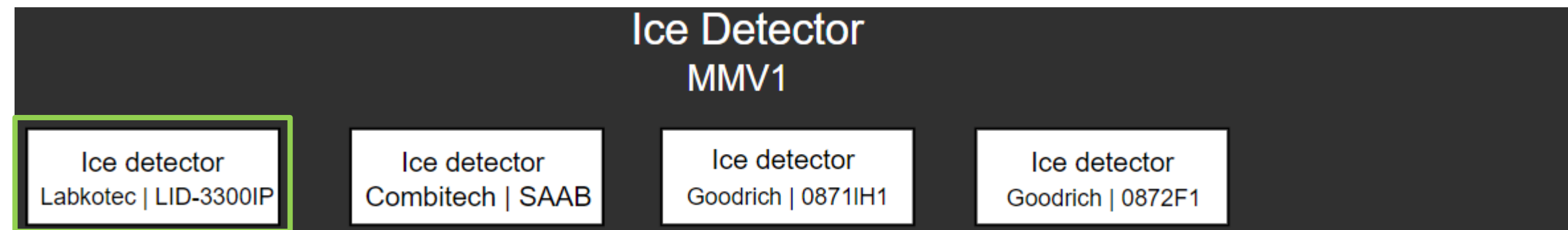
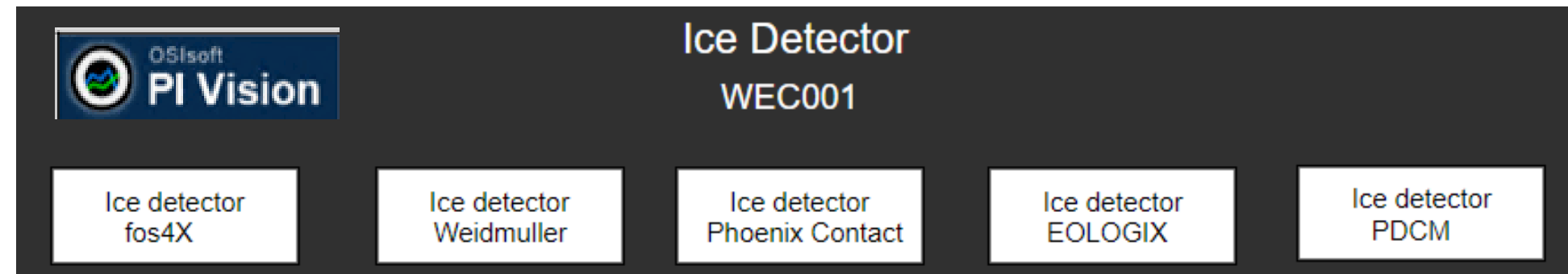


After the event – Icing assessment

Several ice detection systems tested at Nergica's site.

All signals integrated into OSIsoft PI Vision.

Cold climate adapted wind turbines can also indicate the presence of icing.



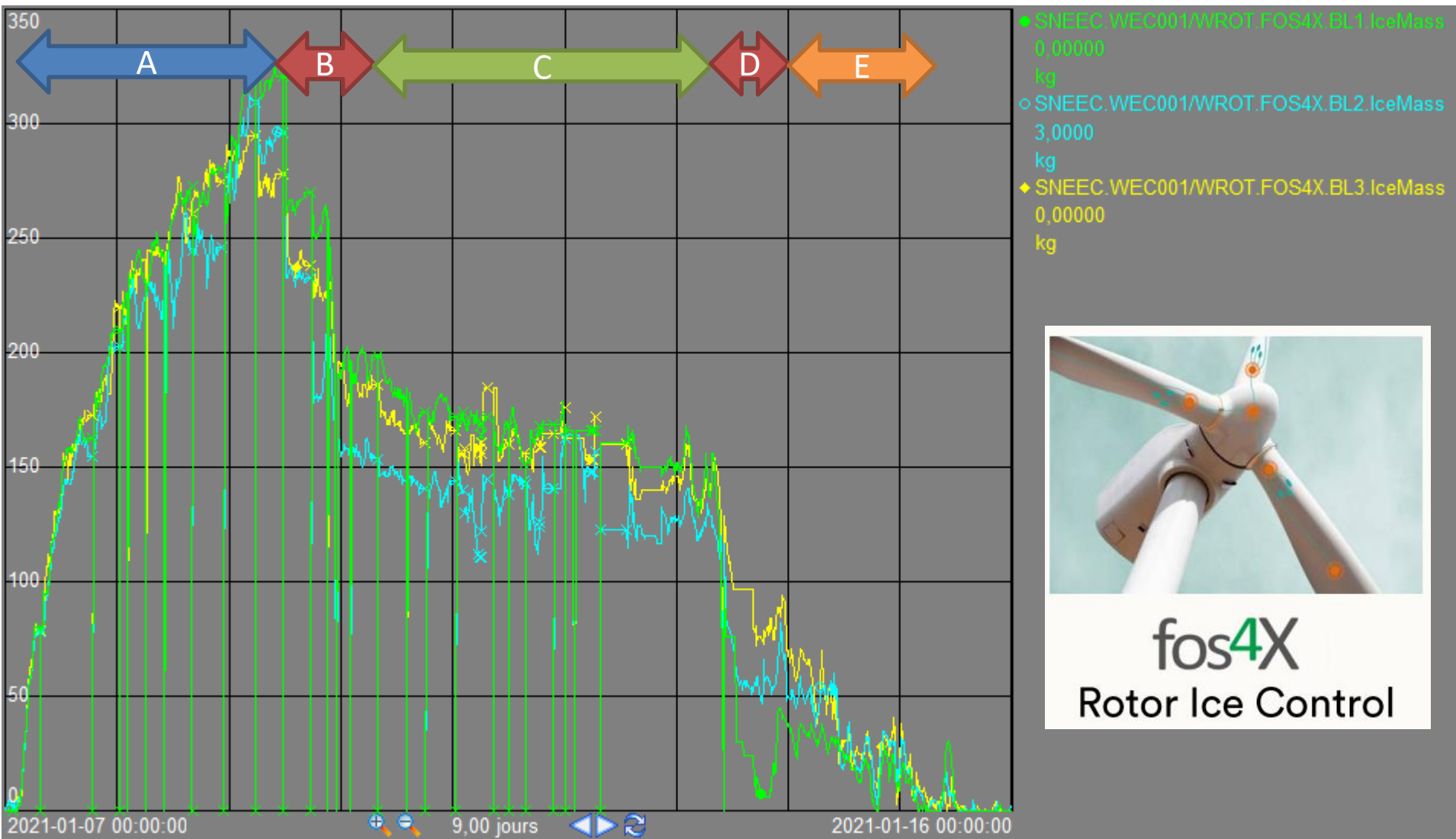
← Meteorological icing →

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After the event – Monitoring ice shed

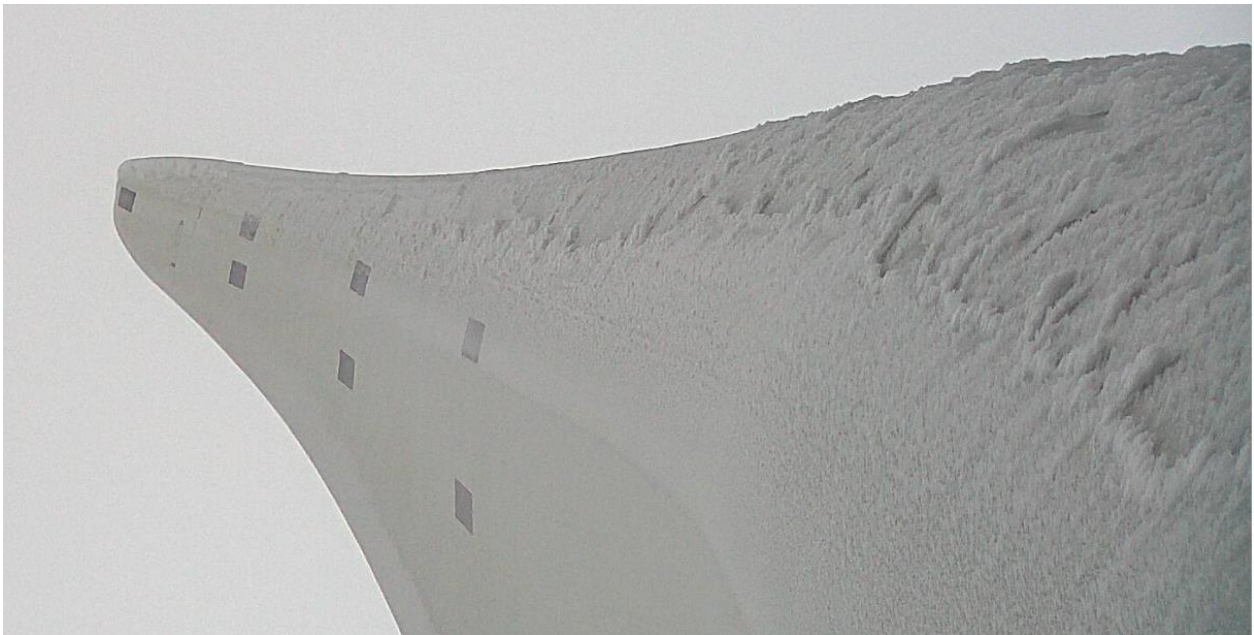
Icing event on Nergica site

- From Jan. 7, 2021 to Jan. 15 2021 (9 days)
- ~300 kg/blade at peak on on Jan. 9 at 7:00



Data collected in OSIsoft PI with fos4x ice detection system (Ice mass per blade)

Phase	Description	Start	End	Duration
A	Ice accretion	2021-01-07 03:46	2021-01-09 06:00	50,2 h
B	Fast ice shed	2021-01-09 11:10	2021-01-10 01:43	14,5 h
C	Icing persistence	2021-01-10 02:00	2021-01-13 06:35	76,6 h
D	Fast ice shed	2021-01-13 06:35	2021-01-13 13:18	6,7 h
E	Slow ice shed	2021-01-13 13:18	2021-01-15 06:10	40,8 h



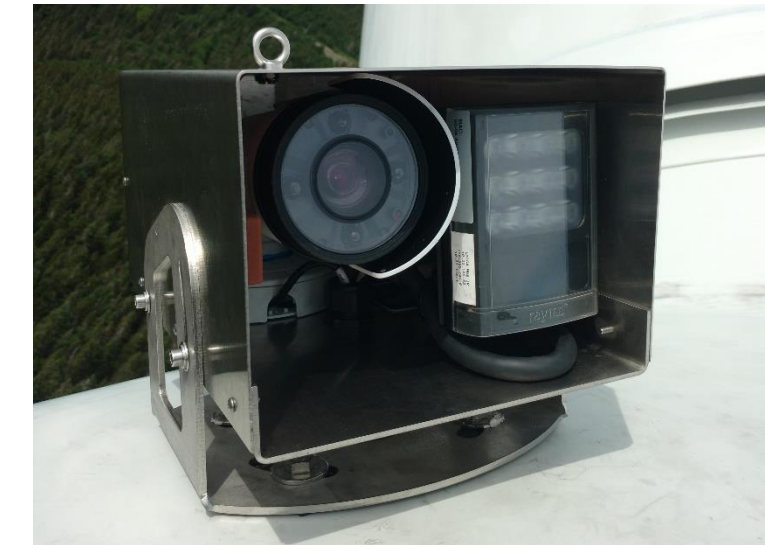
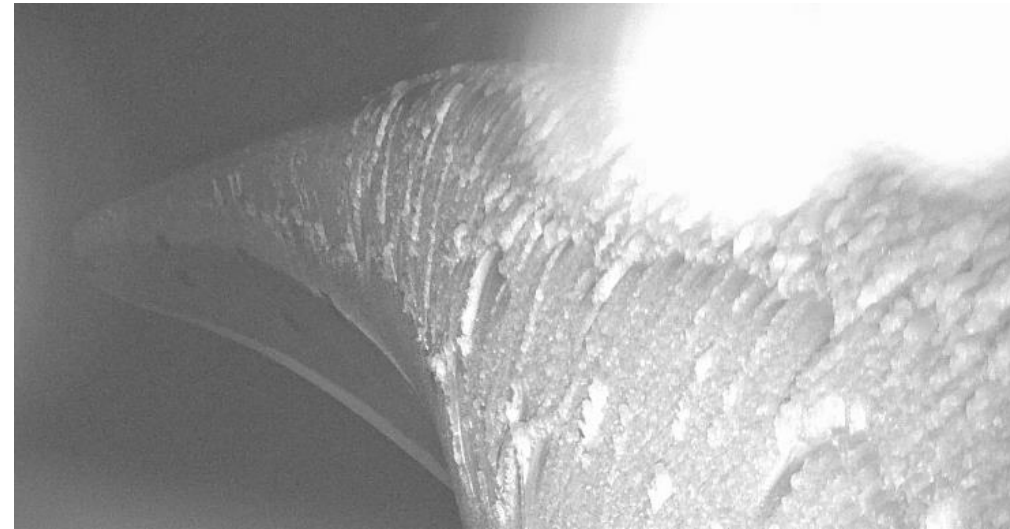
Blade 1 at 7:04 on Jan. 9, 2021

Icing stability

2021-01-09 11:04



2021-01-10 01:54



Nergica hub camera system

2021-01-10 07:24



2021-01-11 06:44



2021-01-12 07:24



2021-01-13 06:44



2021-01-13 08:44



2021-01-13 12:14

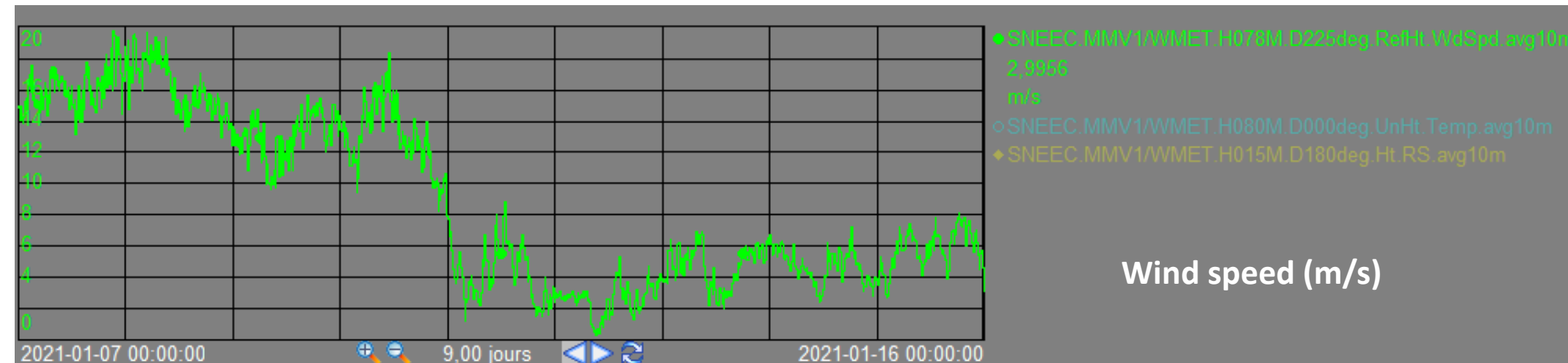


2021-01-14 07:54



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Icing stability conditions

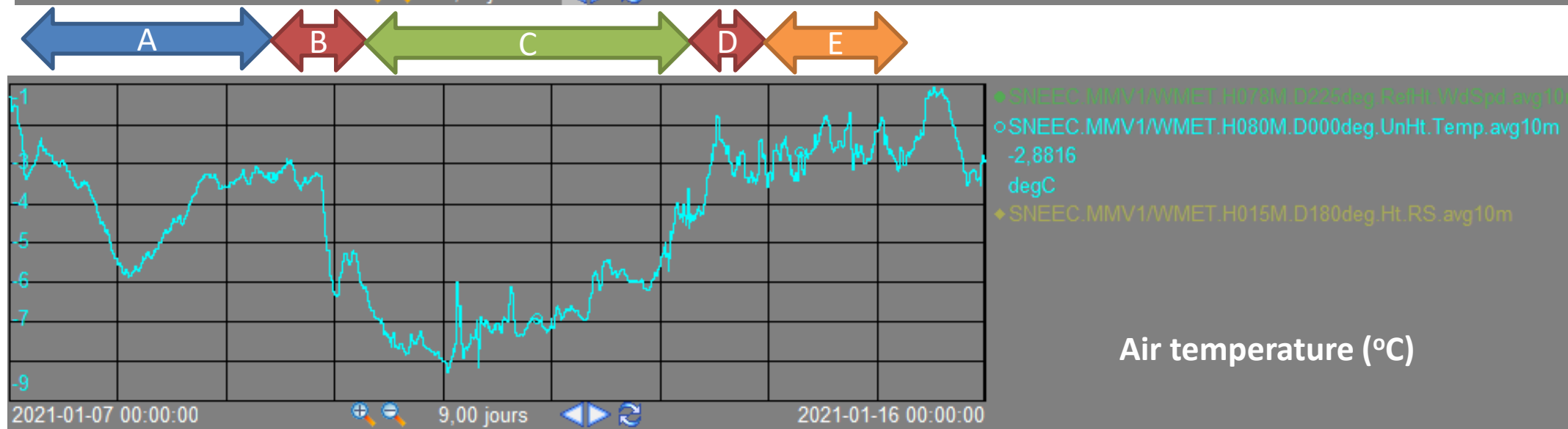


B : Ice fall 1

Warmer temperature: Around -3 °C

Strong winds: Around 13 m/s

Low solar radiation: About 150 W/m²

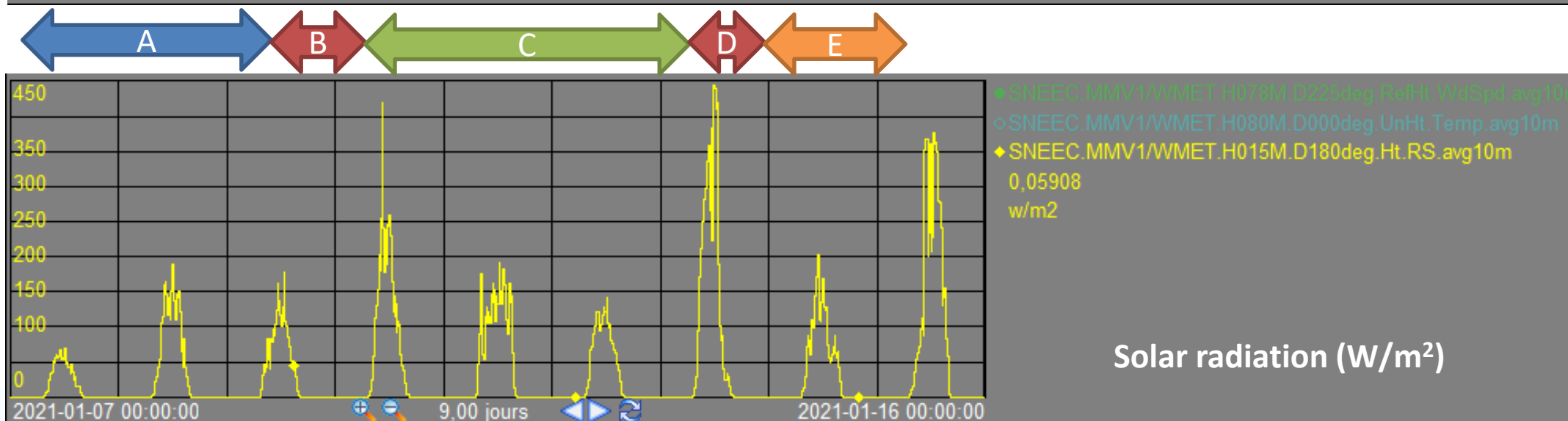


C : Persistence

Colder temperature: Around -7 °C

Lower winds: Close to 4 m/s

Low to moderate solar radiation: between 150 et 250 W/m²



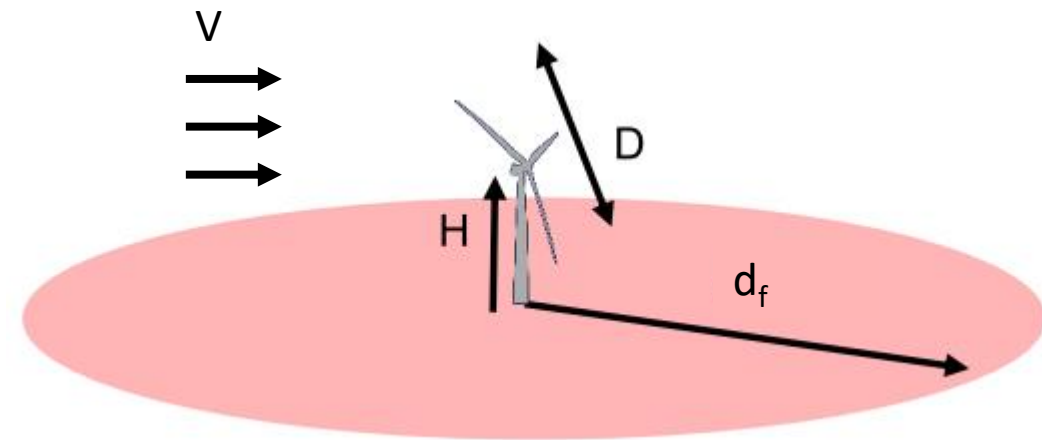
D : Ice fall 2

Warmer: Peak at -2°C

Low winds: Around 4 m/s

High solar radiation: Peak at 450 W/m²

Approaching the turbine



Maximum ice fall distance

$$d_f = \frac{\frac{D}{2} + H}{15} * V$$

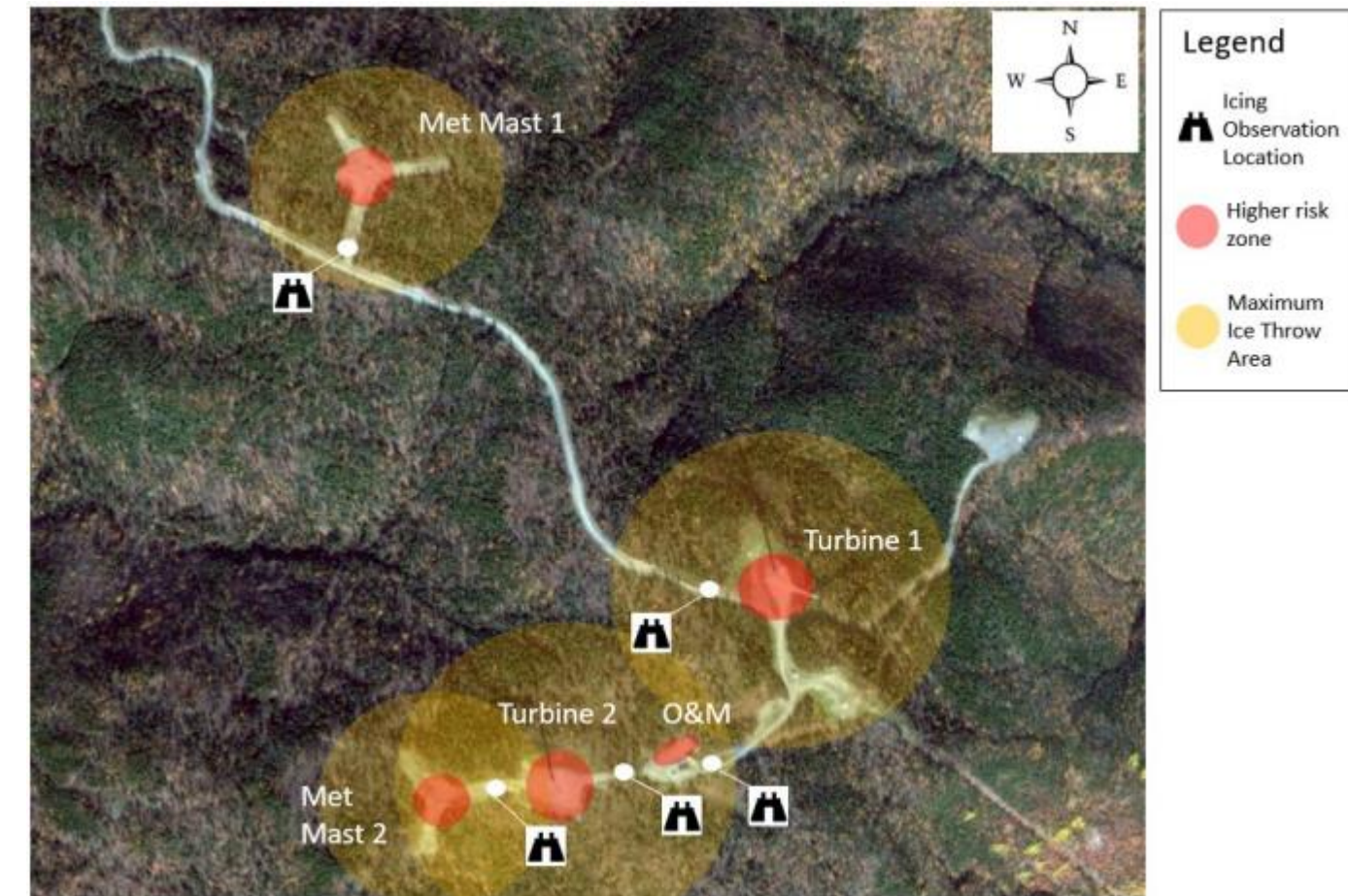
d_f = Maximum falling distance (m)

D = Rotor diameter (m)

H = Hub height (m)

V = Wind speeds at the hub's height (m/s)

A more detailed analysis and an advanced simulation may allow the maximum falling distance to be made smaller.



Icing assessment locations on Nergica site

1. Stop turbine remotely
2. Go to icing assessment location
3. Follow ice fall risk assessment procedure
4. Only if ice is stable, follow turbine approach procedure (details in appendix)

When working on a wind farm in icing conditions

Before the event

Look at the forecast

Be flexible

If possible, select days that have the lowest HSE risks and least impact on energy production

Be mindful of ice shed prone conditions

When on site

**Gather information on icing conditions:
Turbine state, ice detectors, cameras,
binoculars**

**Watch for ice shed accelerators: strong
winds, air temperature close to 0°C, high
solar radiation**

**Follow ice fall risk assessment and
turbine approach procedures**

**Communicate, build team trust and stay
safe!**

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Let's connect!



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Project Manager, Research and Innovation

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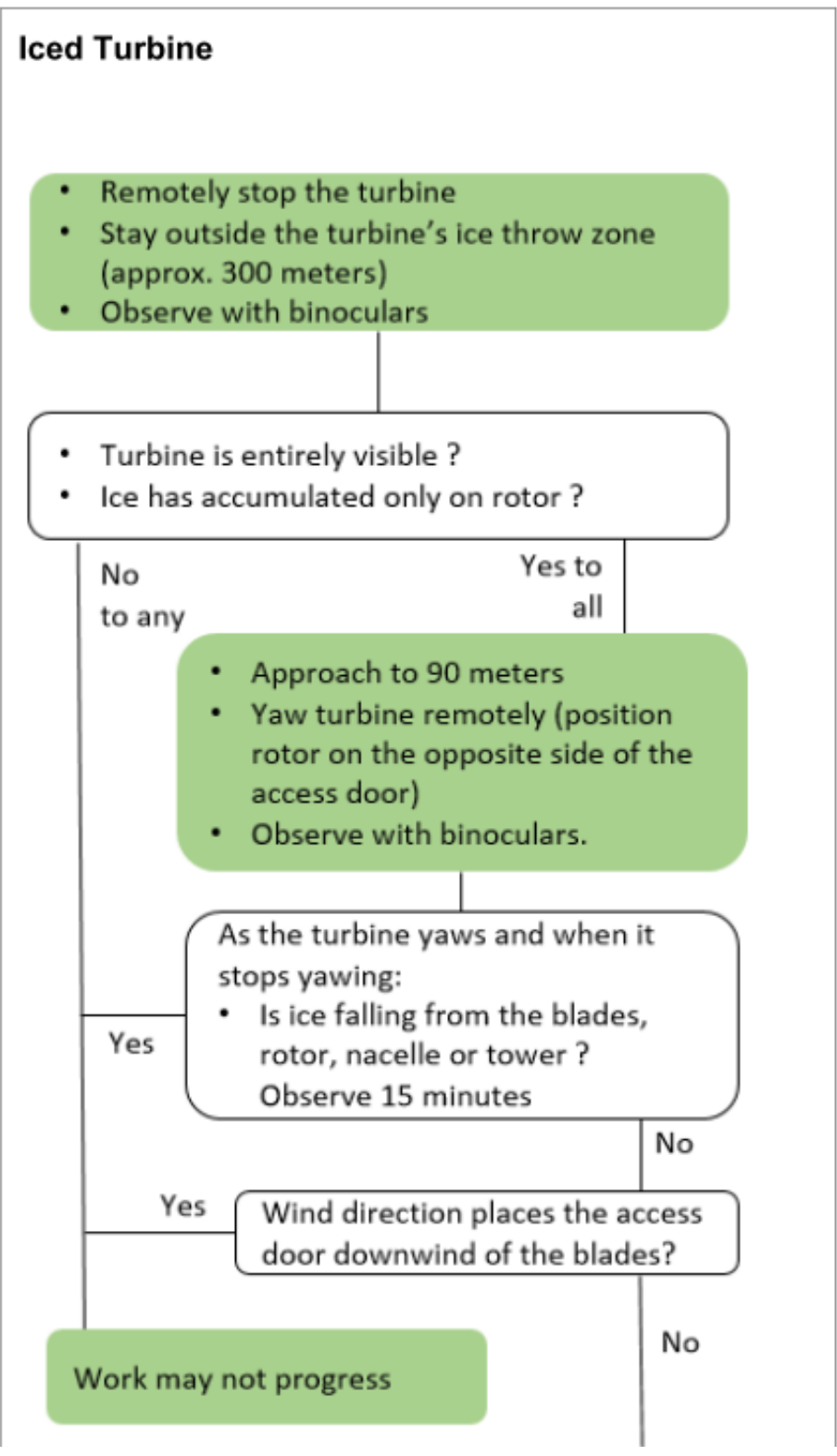
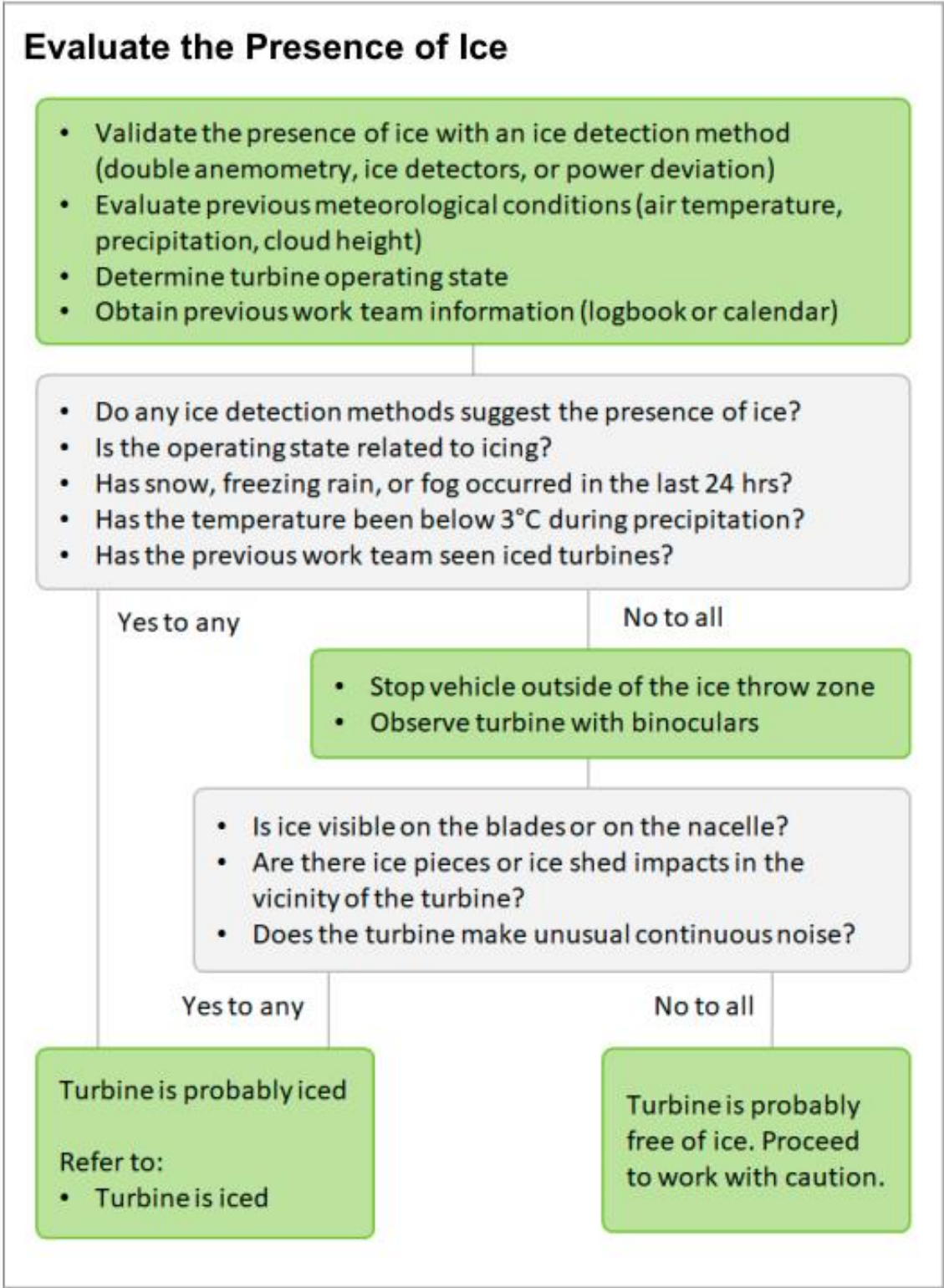
LinkedIn

linkedin.com/in/charles-godreau/

Web

nergica.com/en/

Appendix 1 : Iced turbine approach – Best practices for wind farm icing and cold climate health and safety



Turbine may be entered – BE CAREFUL

- Stay away from the blades
- Do not approach alone
- Name a spotter within the team that continuously observe for shedding ice
- Get as close as possible with the vehicle
- Continuously observe for shedding ice
- Deploy ice protection device if applicable
- One person should leave the vehicle and ensure that the way is safe and clear for the others (leave door open)
- Minimize the amount of time outside
- Once everyone is inside, drive vehicle back to parking area immediately
- Repeat the same steps to exit the turbine