Ice Monitoring for R&D projects

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Winterwind
INTERNATIONAL WIND ENERGY CONFERENCE

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Outline

- Introduction
- Projects description and instrumentation
- Ice Characterisation
- Ice loads & Ice throw
- De-icing monitoring
- Technical challenges
- Conclusion

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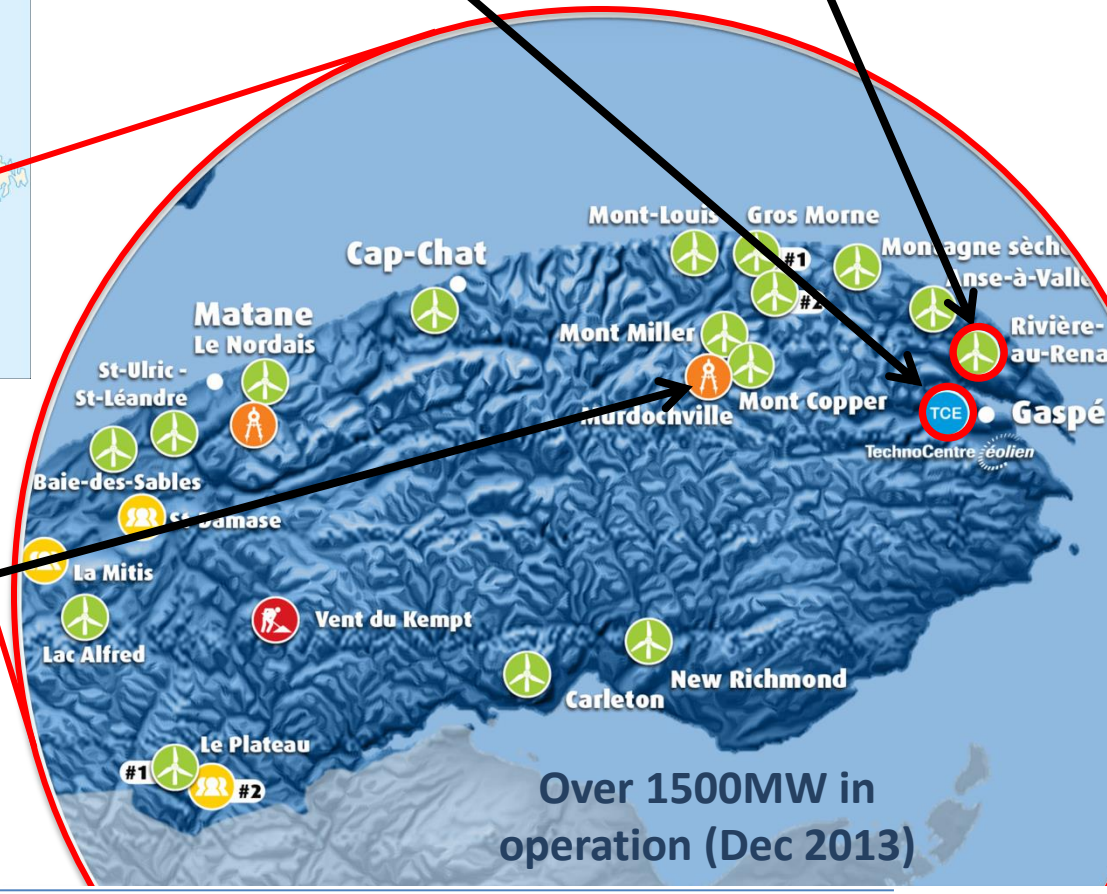

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Wind Farm / Test Site

- Two 2.05 MW Senvion MM92 CCV

SENVION
wind energy solutions

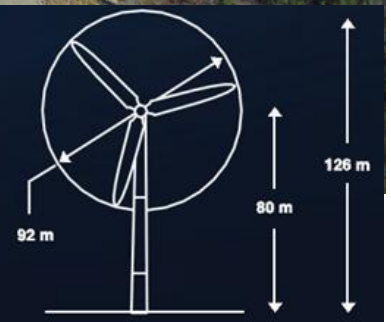
- Commissioned March 2010

Hydro Québec

- Icing (IEA Class 2-3)
- Complex terrain (IEC Class 2)
- R&D, technological transfer, technological validation, performance assessment.

OSIsoft.

Description	Value
Number of wind turbines	2
Model	REpower MM92 CCV
Rated power / Wind turbine	2.05 MW
Frequency	60 Hz
Rotation speed	7.8 – 15 RPM
Start-up speed	3 m/s (10.8 km/h)
Shut-down speed	24 m/s (86.4 km/h)



IEC wind class: 2
Annual average wind speed: 7.9 m/s
Topography: Complex site with high turbulence, near the sea
Temperature: -30°C to +30°C
Ice conditions: Up to 40 mm of ice

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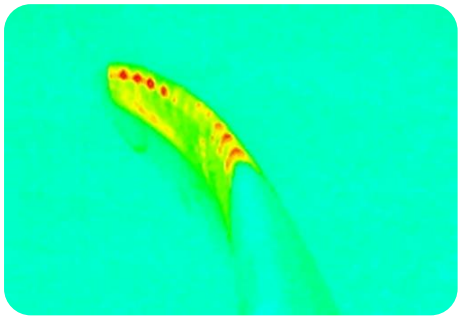
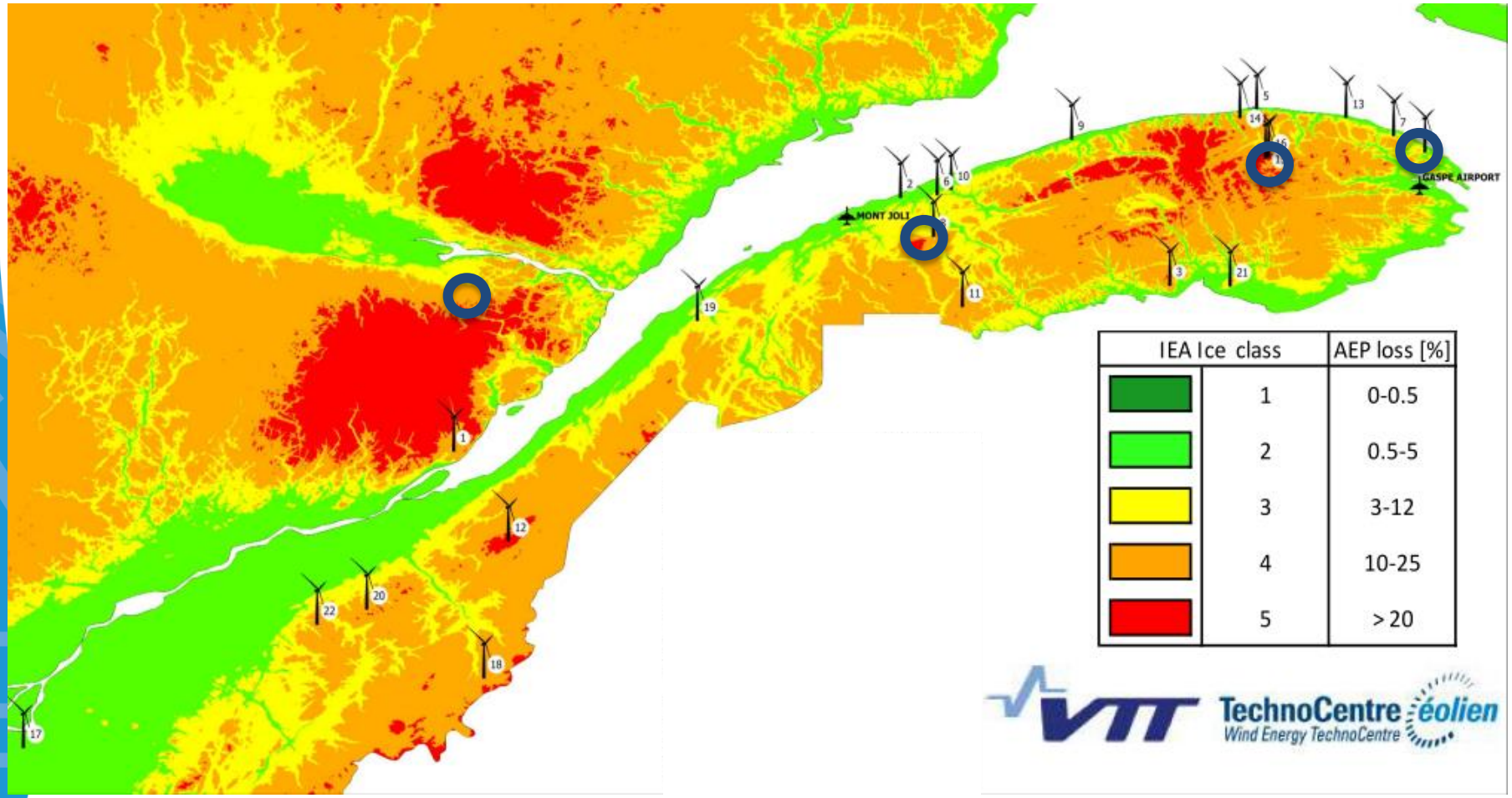
On-going projects

- Collaborative Projects
  - Ice characterisation
    - Ice detection by camera monitoring
    - Icing severity and intensity assessment
  - Load Measurements
    - Ice load characterisation
    - Multi-body dynamics simulations (extreme load cases)
    - Control parameter optimisation based on icing severity
- Validation of a de-icing System
  - Instrumentation 3 turbines
  - 24/7 monitoring of icing events
  - Independent performance evaluation



Projects location



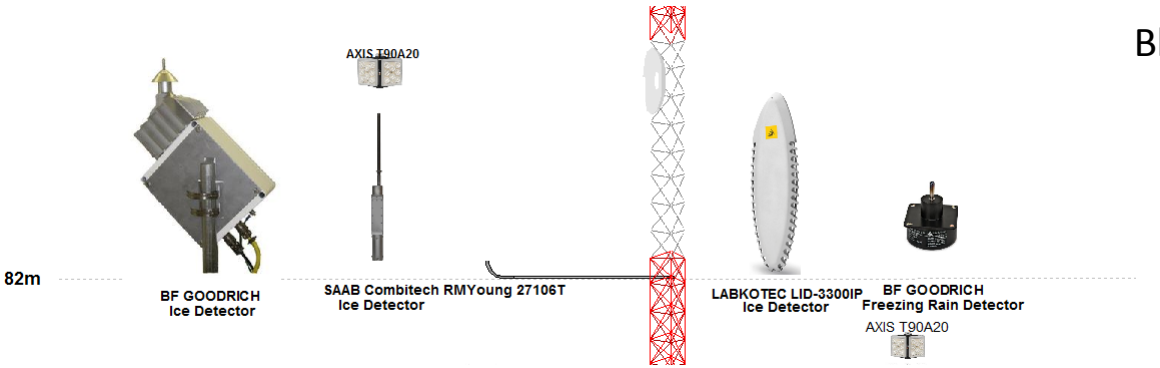
Instrumentation

- 3 wind farms, 7 wind turbines, 3 met masts,
- 20+ remote IP cameras
  - 6 wind turbines with hub mounted cameras
    - Optical cameras with IR illuminators
    - Thermal camera
  - 7 wind turbines with nacelle cameras
  - 3 met masts

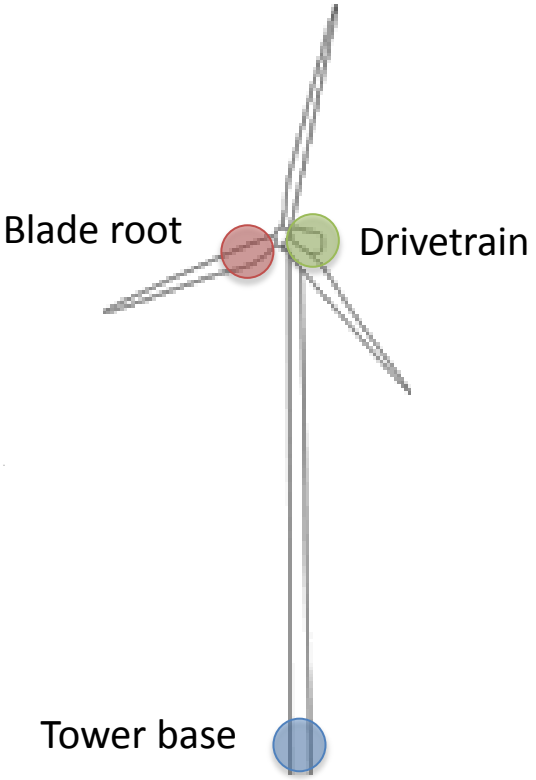
Instrumentation

- Ice detection
  - Blade surface ice detection
  - Blade eigenfrequencies variations
  - Nacelle type ice detectors

- MMV1 (RaR) ice detection bench test
  - Comparison of multiple ice detectors



- Load Measurement
  - Standard IEC load measurement
  - Extended for ice load assessment



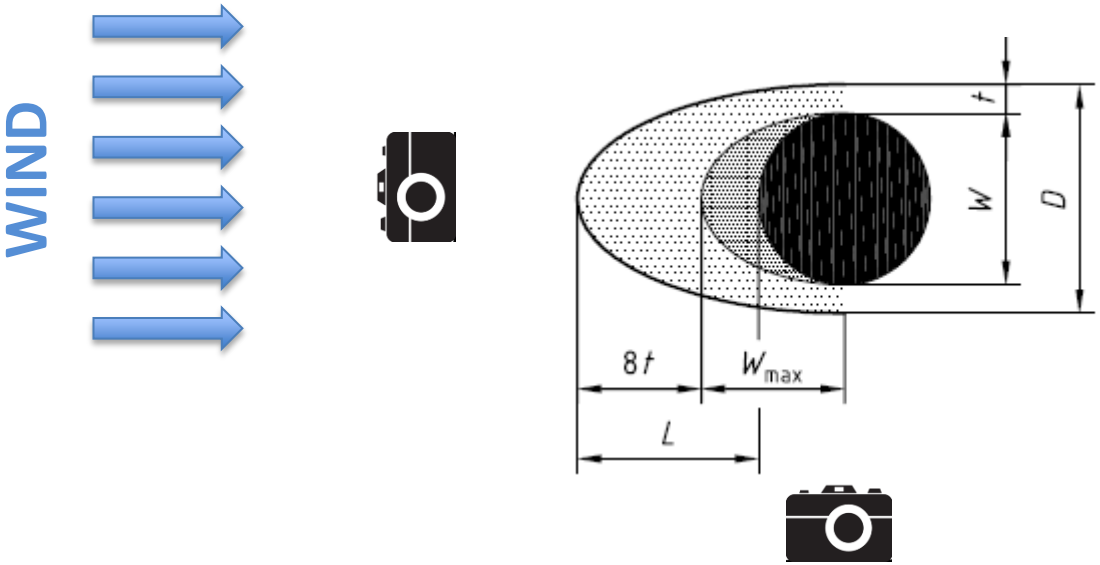
Ice Characterisation

- Timelapse Mt Needle (Murdochville)
  - Instrumental icing duration validation
  - Meteorological icing duration estimation
  - Evaluation of instruments behavior under icing

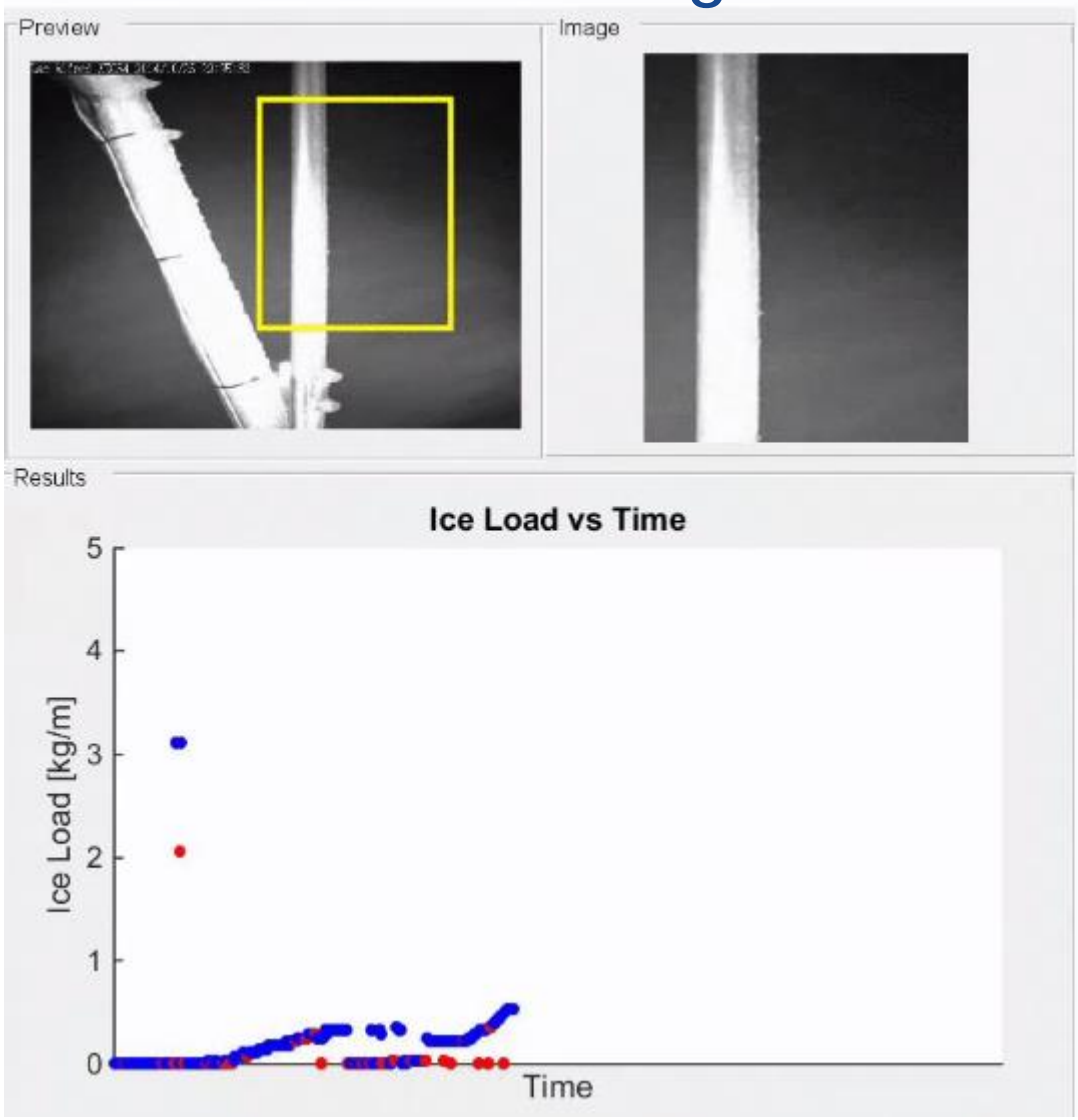
Ice Characterisation

Camera monitoring to the next level:

- Estimation of ice load based on ISO12494 standard
- Assume an elliptical ice profile for rime ice and 600kg/m^3
- Assume a constant thickness of ice for glaze and 900kg/m^3

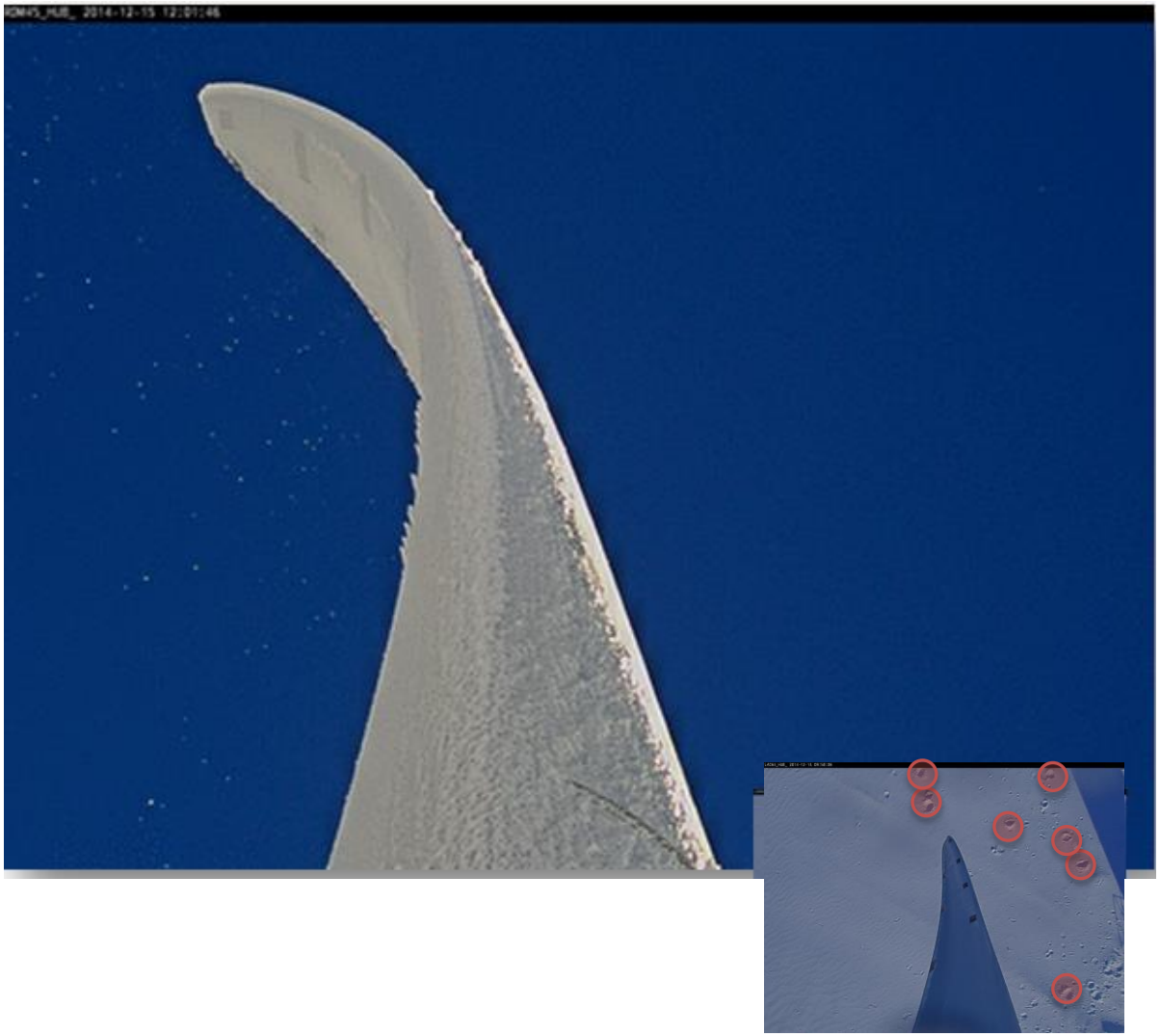


Ice load monitoring on reference tube



- Filtering based on SNR
- Efficient in low level contrast
- Need minimal visual on the tube
- Can be used in live monitoring

Blade Ice loads monitoring



Picture from optical hub camera with IR

Available Information

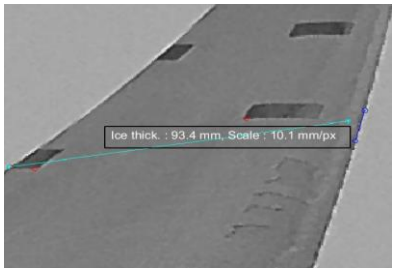
- *Total ice load variation*
- *Rotor mass imbalance (with 3 cams)*
- *Ice shed or ice throw period*
- *Orientation of nacelle during ice throw*

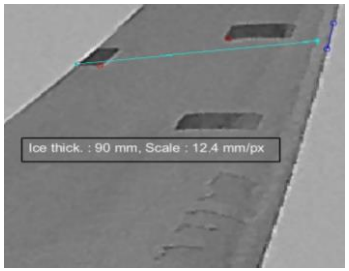
Analysis

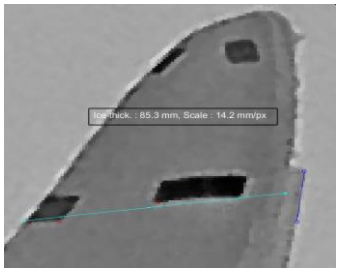
- *Ice load and imbalance modelisation*
- *Ice throw model validation*

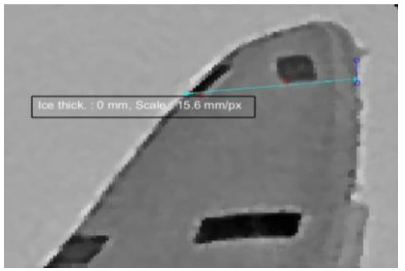
Blade Ice loads measurement

- Ice tickness measured in 4 places (ref markers) on typical hub camera image of iced blade



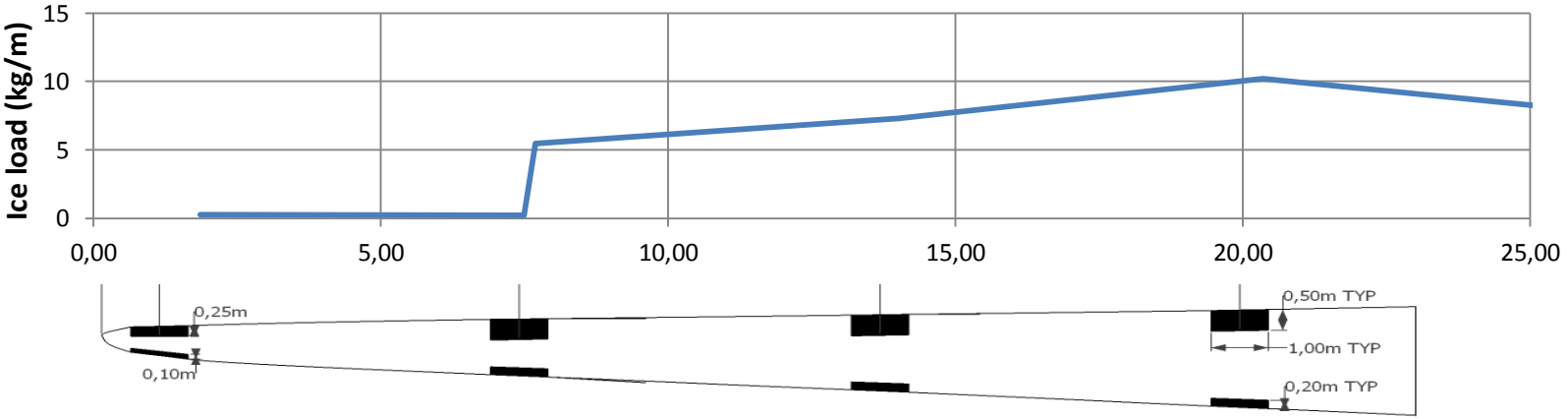






M1=93mm M2=90mm M3=85.3mm M4=4mm

- Ice load distribution on entire blade (**Total ~220kg**)



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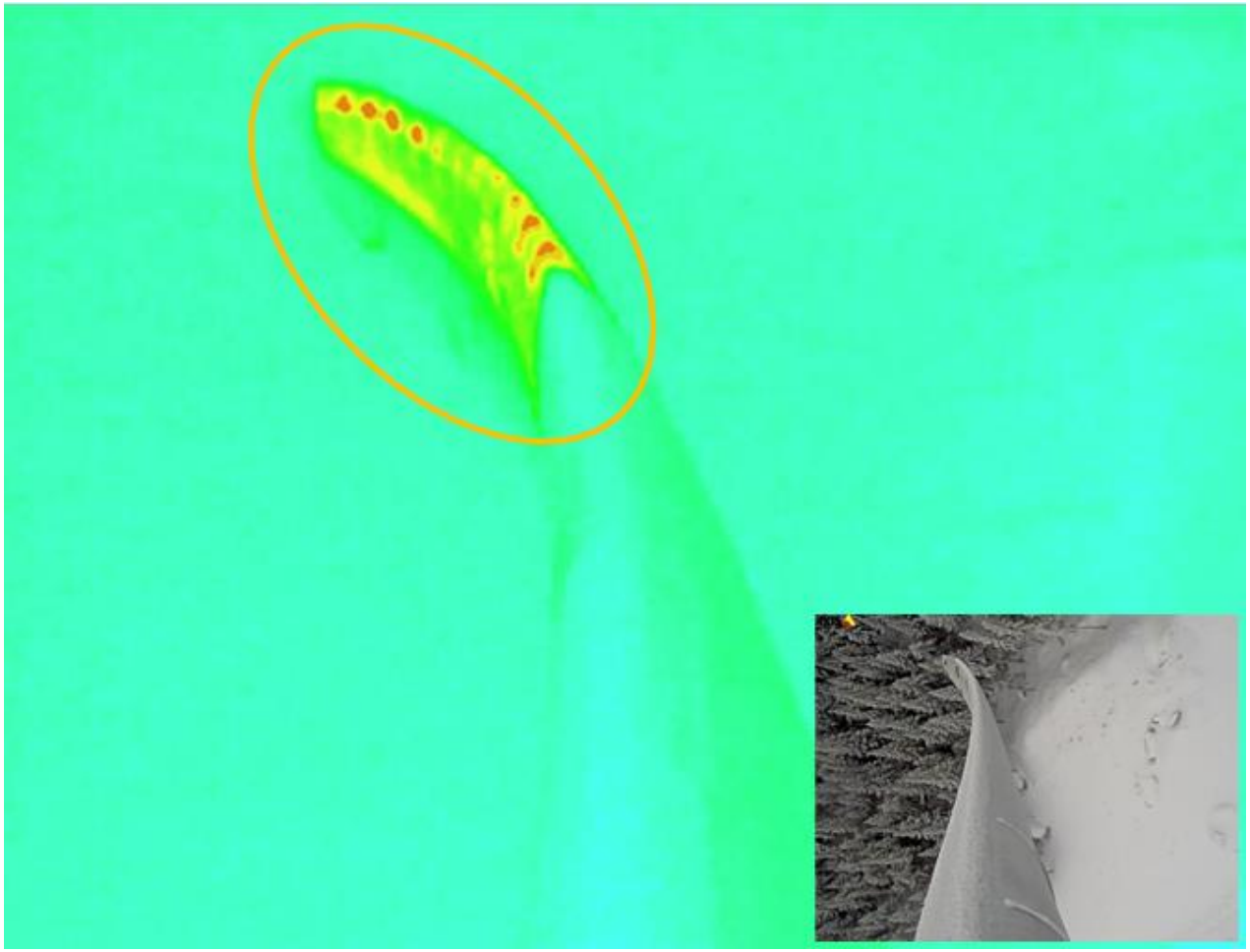
De-icing monitoring

Picture from optical hub camera

<u>Ice load from test blade</u>

- Before deicing:
  - M1=0,29 kg/m
  - M2=5,5 kg/m
  - M3=7,3 kg/m
  - M4=10,2 kg/m
- After deicing
  - M1=0 kg/m
  - M2=0 kg/m
  - M3=0 kg/m
  - M4=10,2 kg/m

De-icing monitoring



Picture from thermal hub camera

Ice load from nacelle

Avg rate: 0,35 kg/h/m

Peak load: 4,91 kg/m

Weather condition

Precipitation: ~ 2mm/h

Wind speed: ~ 5m/s

Temp.: -4°C

Result

- **Complete heated area (20m) ice free**

Technical challenges

- Camera positioning
- Image quality: problem with fog and ice in the lens
- Camera ice shield (ice protection vs ventilation)
- Bright flash during icing event with illuminator at night
- Camera settings (zoom, focus, IR intensity)
- Increase the precision of ice measurements on blades
- Image storage

Conclusions

- Image monitoring provides valuable information for R&D projects
  - Validation of de-icing system efficiency
  - Evaluate the performance of other instruments
- Image analysis can be use as an ice detector for icing intensity and severity assessment on simple object
- Hub camera pictures can be used to estimate the ice loads on the blades
- Still room for improvement!!!

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Thank you