Ice Profile Classification

Based on ISO 12494

Presented by:

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2012-02-12

WinterWind 2013

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- Introduction to TCE
- Motivation
- Methodology
  - Measurement Campaign
  - Ice profile classification using ISO 12494
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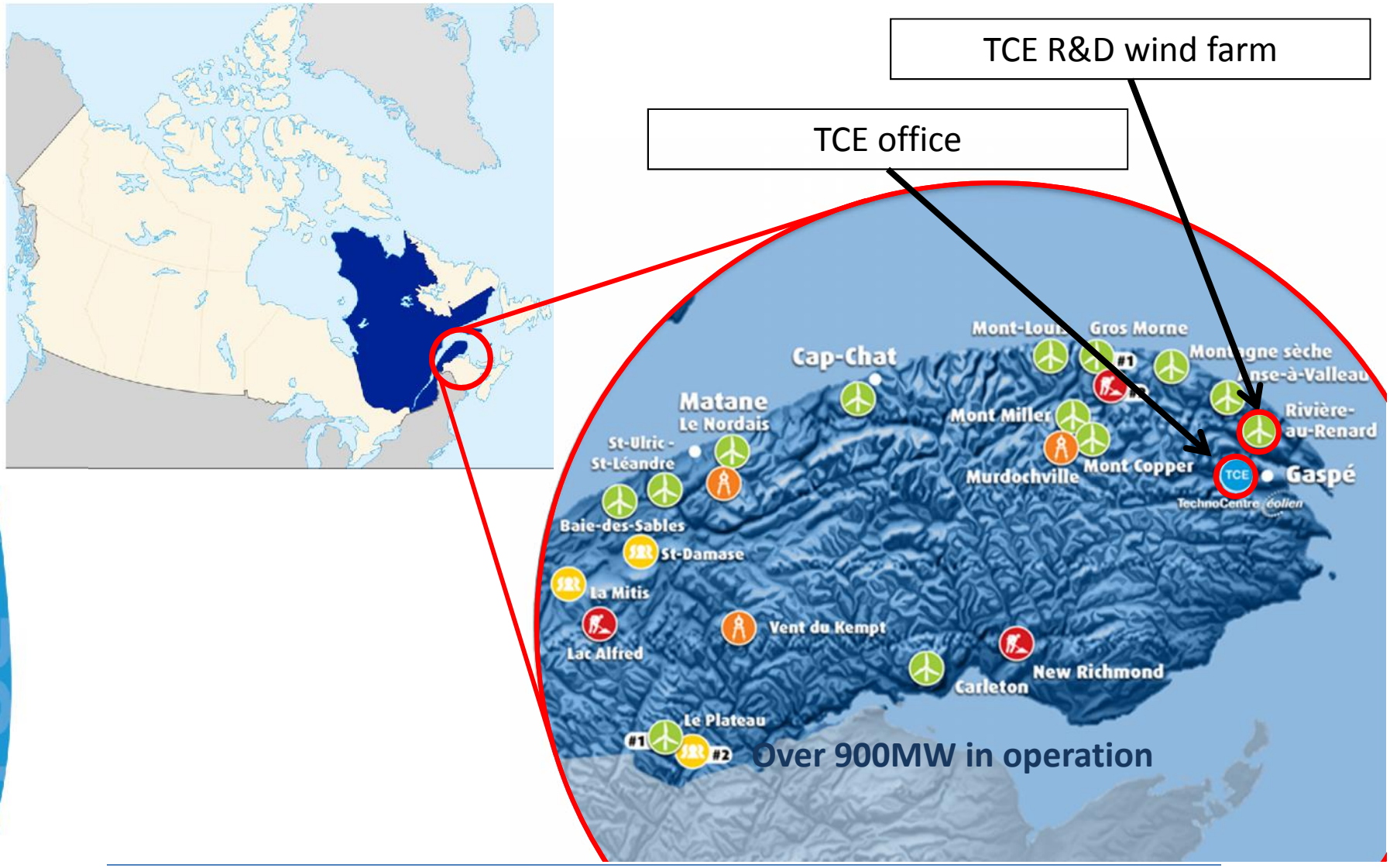
- Summary for winter 2011-2012
- Conclusions/Further work

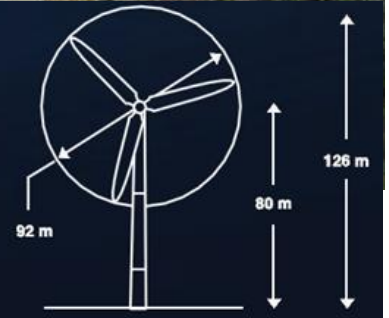
TCE infrastructure location



TCE R&D Wind Farm

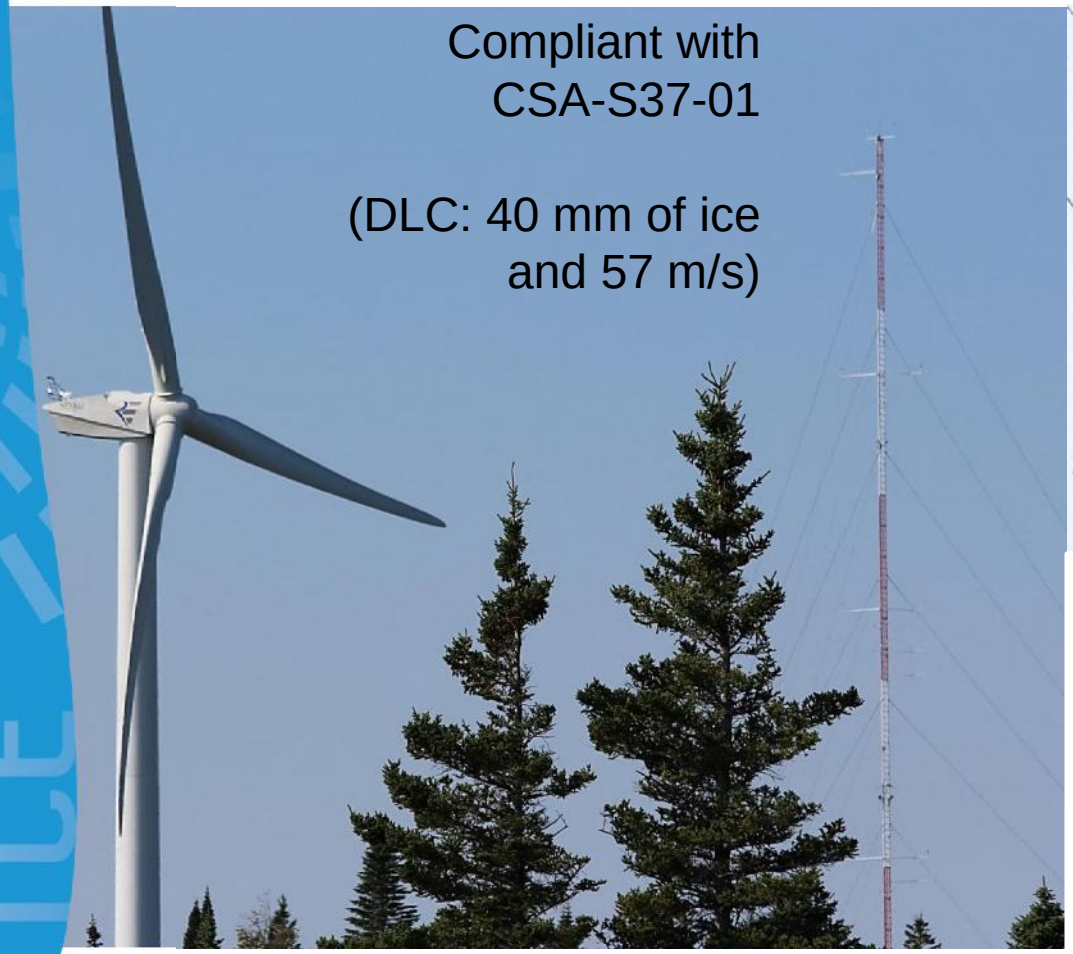
- Two 2.05 MW Repower MM92 CCV wind turbines
- Located in Riviere-au-Renard, Québec, Canada
- Icing & complex terrain
- Commissionned in March 2010
- Research, development and technology transfer projects involving northern climates and complex terrain.

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)



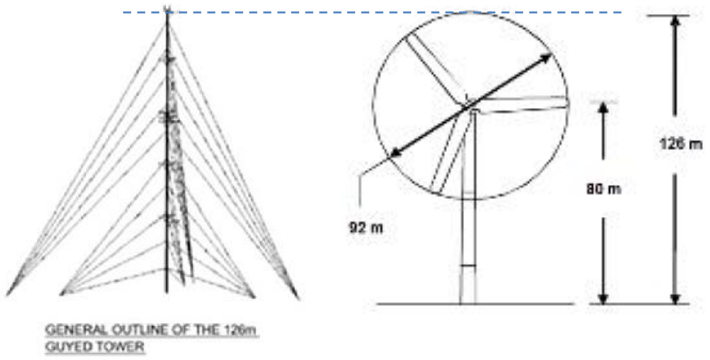
IEC wind class: 2
Annual average wind speed: 7.9 m/s
Topography: Complex site with high turbulence, near the sea
Temperature: -30°C to +30°C
Ice conditions: Up to 40 mm of ice

TCE 126m Met Mast



Compliant with
CSA-S37-01

(DLC: 40 mm of ice
and 57 m/s)

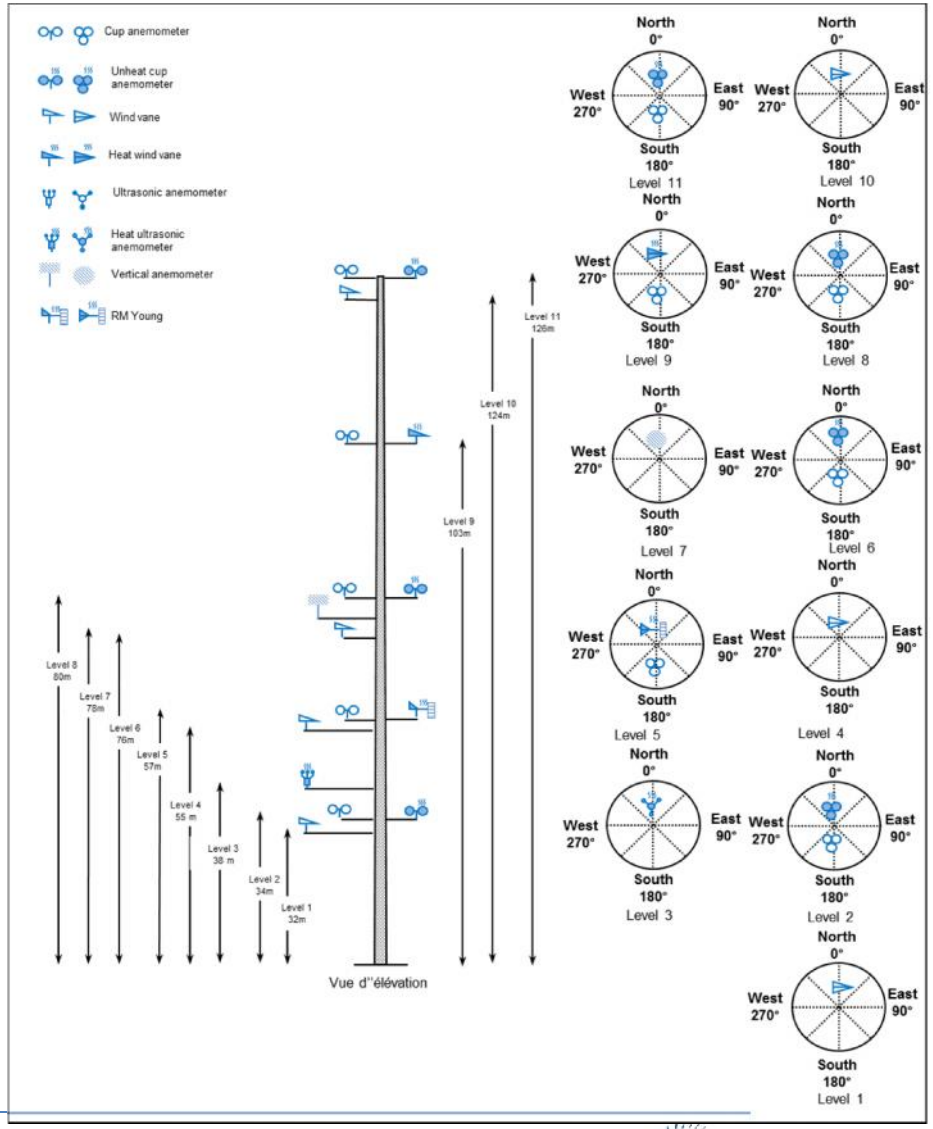


GENERAL OUTLINE OF THE 126m
GUYED TOWER

TCE 126m Met Mast

- 5 levels of unheated class 1 anemometers
- 3 levels of heated anemometers
- 2 levels of heated and unheated wind vanes
- Ceilometer to detect cloud height
- 4 levels of thermometers
- Hygrometer

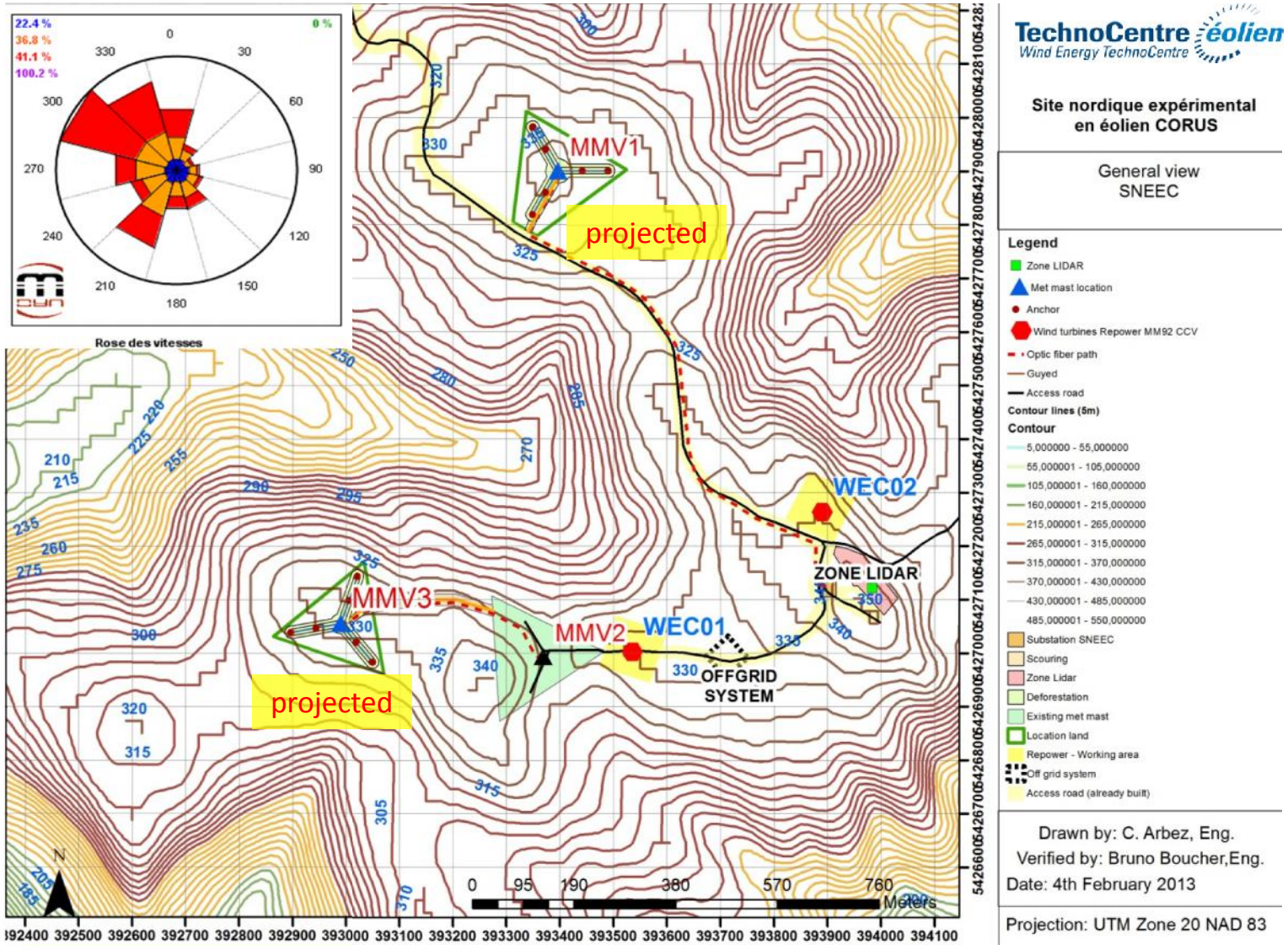
1Hz data acquisition in Osisoft PI



TCE Micro Grid

TCE Micro Grid

Infrastructure Topographic Layout



Objective/Motivations

What:

- *Quantify ice load during different icing events*

Why:

- *To validate and/or improve theoretical ice accretion models*
- *To correlate with meteorological measurements, production loss and ice induced vibration*
- *To evaluate the performance of anti-icing and de-icing technologies*

Ice Measurement Campaign

- Ongoing since October 2011
- Intended to continue until at least winter 2013-2014

- **Observations during icing events**
- **Remote Cameras**
- **Ice throw**
- **Meteorological and production data**

Observations - Blades

- Pictures taken from the ground

23 days of observed ice on blades (Winter 2011-2012)

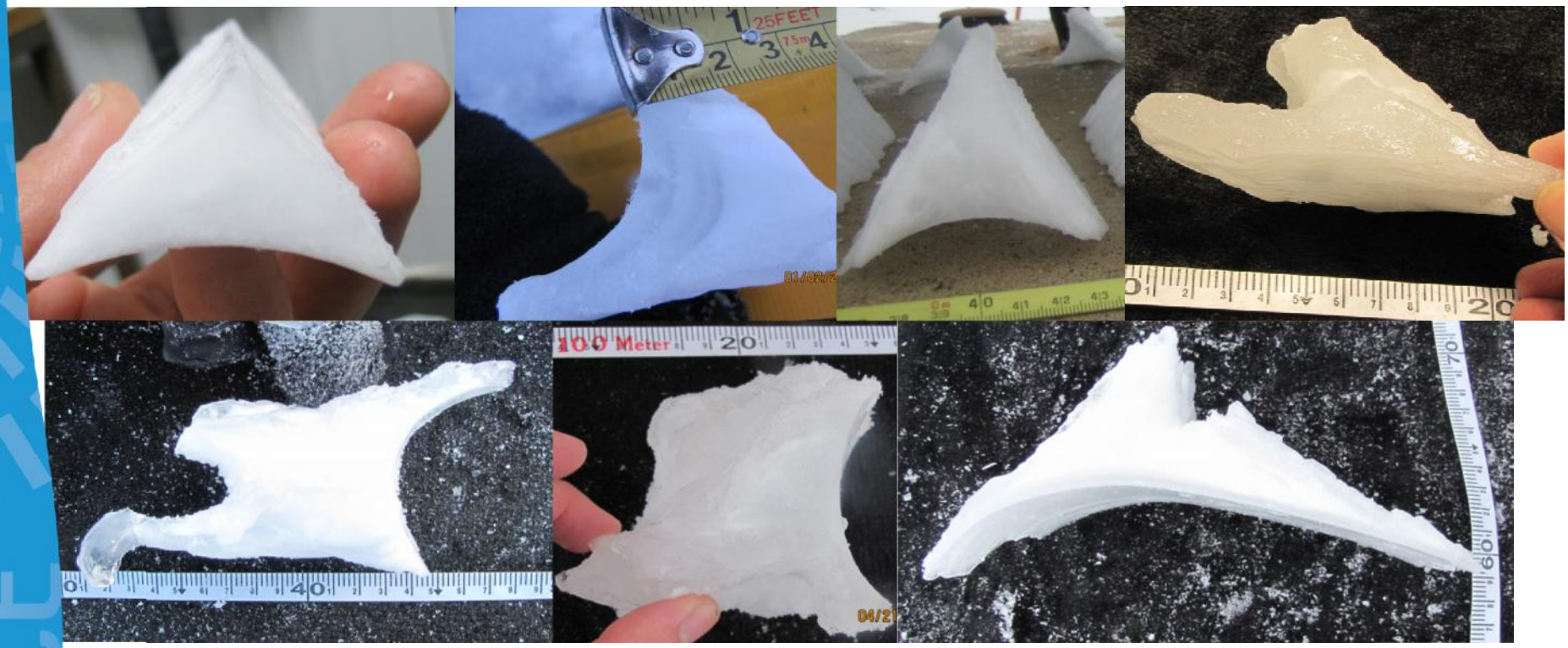
Observations – Nacelle Weather Mast

- Remote Camera on Nacelle – 5 min intervals

800+ hours of icing on nacelle weather mast (Winter 2011-2012)

Ice throw

- Shape, size, weight, distance from tower



- 150+ fragments of ice from blades collected to date

Estimating Ice Load using ISO 12494

- ISO 12494 – for RIME
  - Ice Class (IC) for Rime (R) scale 1 to 10 according to kg/m of ice on structure, shape and dimensions of ice varies depending on structure size and shape

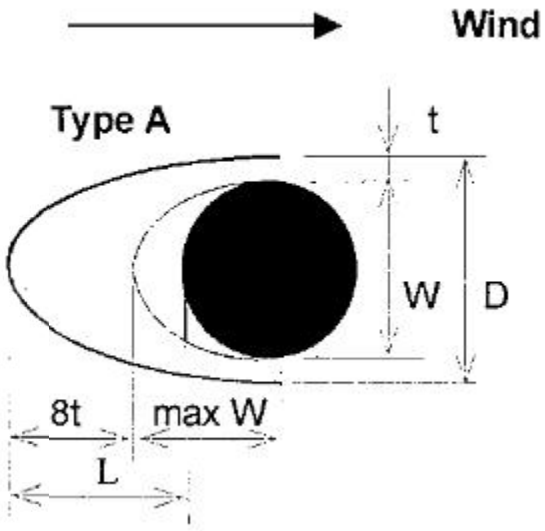


Table 5 — Ice dimensions for vane shaped accreted ice on bars, types A and B
(Valid only for in-cloud icing; density of ice = 500 kg/m^3)

Cross sectional shape of bars: Types A and B									
Object width, mm		10		30		100		300	
IC	Ice mass	Ice vane dimensions, mm							
	m, kg/m	L	D	L	D	L	D	L	D
R1	0,5	54	22	34	35	13	100	4	300
R2	0,9	78	28	54	40	23	100	8	300
R3	1,6	109	36	82	47	41	100	14	300
R4	2,8	150	46	120	56	67	104	24	300
R5	5,0	207	60	174	70	106	114	42	300
R6	8,9	282	79	247	88	165	129	76	300
R7	16,0	384	105	348	113	253	151	136	300
R8	28,0	514	137	478	146	372	181	217	317
R9	50,0	694	182	656	190	543	223	344	349
R10	To be used for extreme ice accretions								

Estimating Ice Load using ISO 12494

- ISO 12494 – for GLAZE (Freezing Rain)
  - Ice Class (IC) for Glaze (G) scale 1 to 6 according to ice thickness

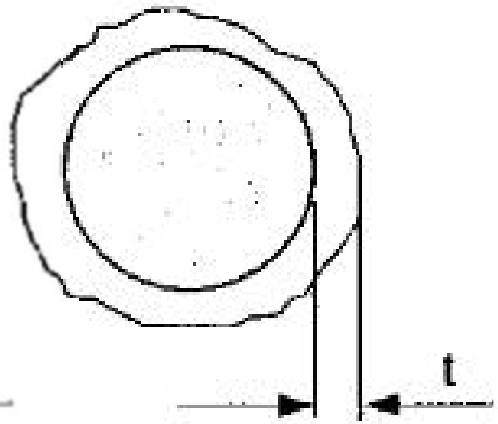
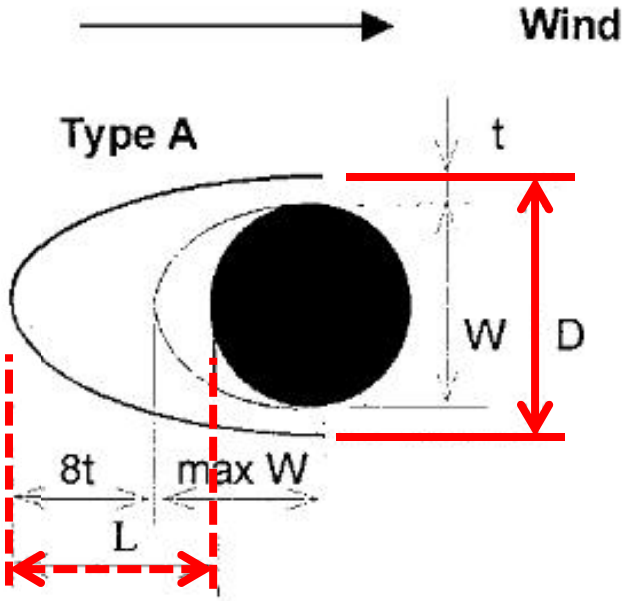


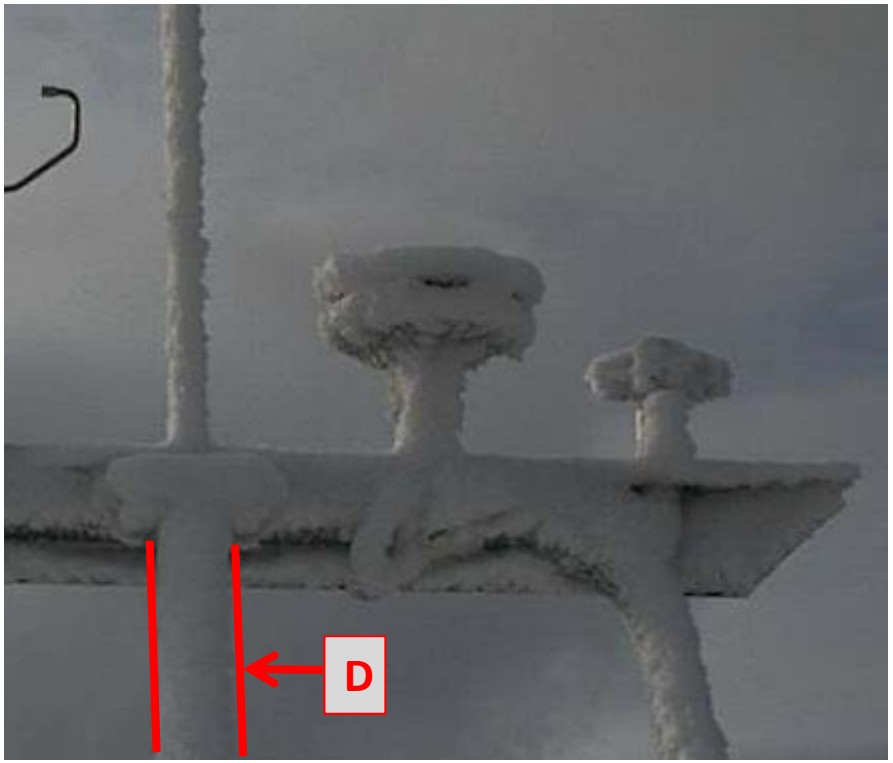
Table 3 — Ice classes for glaze (ICG) (density of ice = 900 kg/m^3)

Ice class (IC)	Ice thickness t mm	Masses for glaze, m, kg/m			
		Cylinder diameter, mm			
		10	30	100	300
G1	10	0,6	1,1	3,1	8,8
G2	20	1,7	2,8	6,8	18,1
G3	30	3,4	5,1	11,0	28,0
G4	40	5,7	7,9	15,8	38,5
G5	50	8,5	11,3	21,2	49,5
G6	To be used for extreme ice accretions				

Nacelle Weather Mast Load Classification

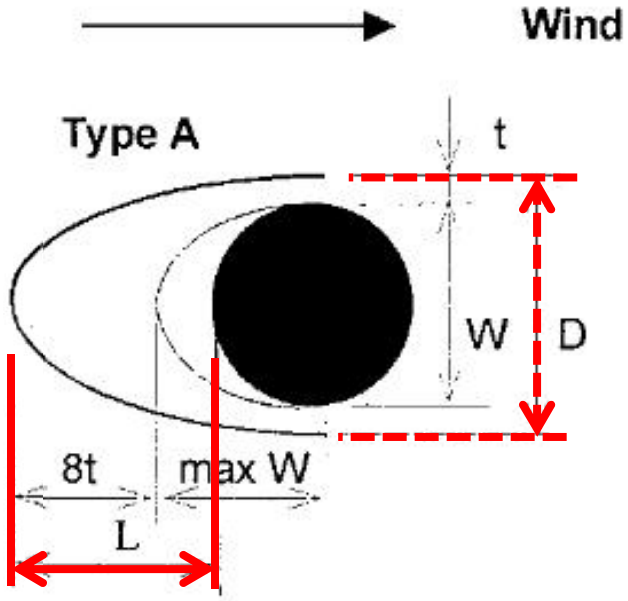
- Weather mast ice load estimation
  - “D” measured,
  - “L” estimated, higher error but more data

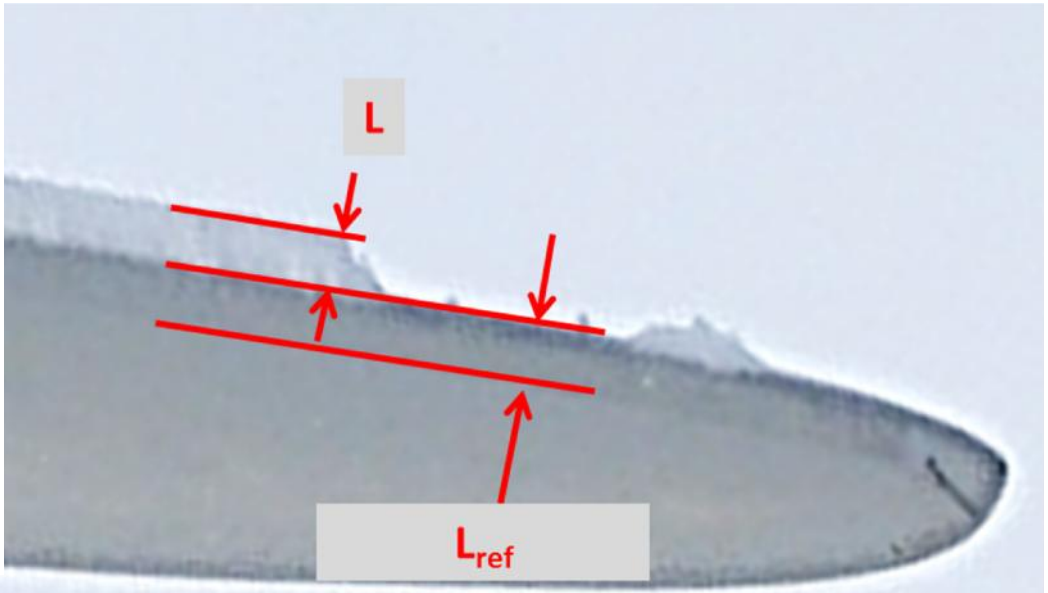




Blade Ice Load Classification

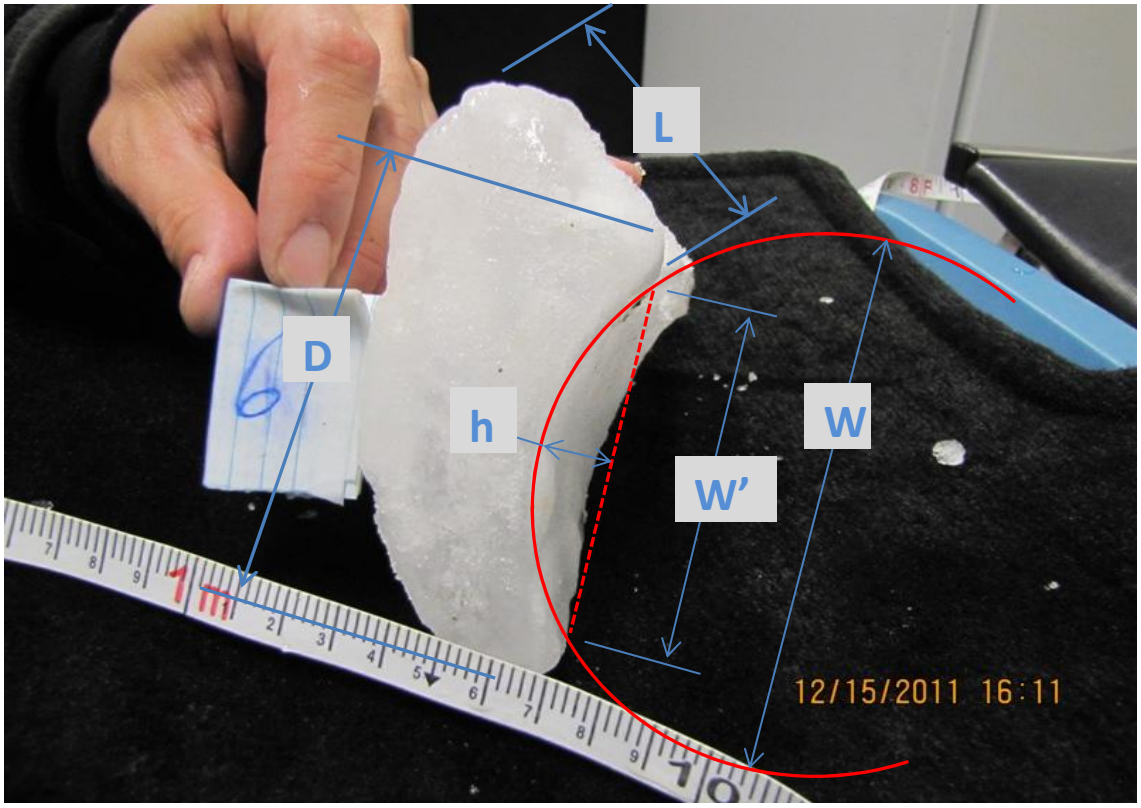
- Blade ice load estimation
  - “L” measured
  - “D” estimated
  - Limited amount of pictures covering the duration of an icing event.





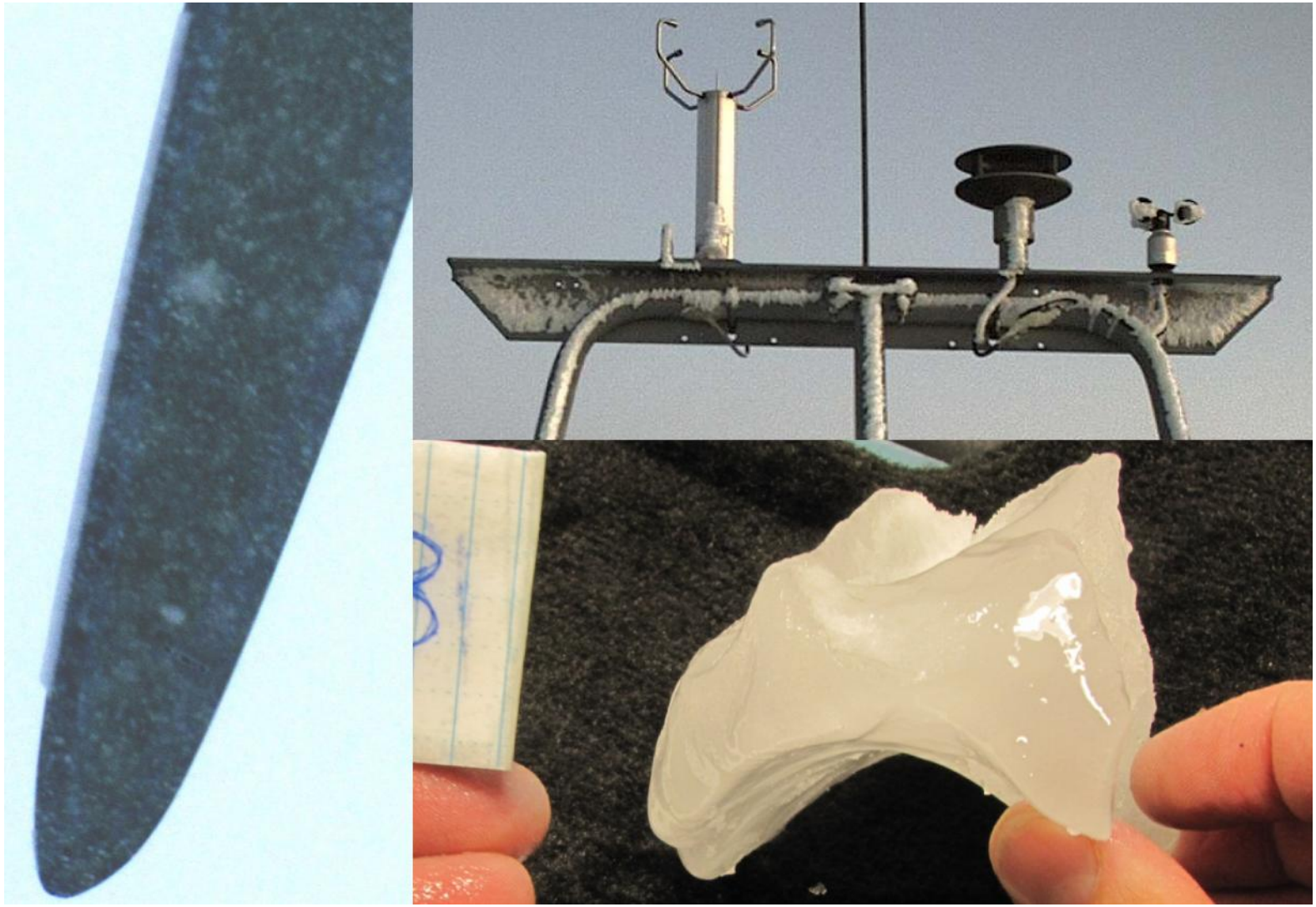
Ice throw Load Classification

- Used to validate blade ice load
  - More accurate measurement
  - Precise time of ice shed unknown

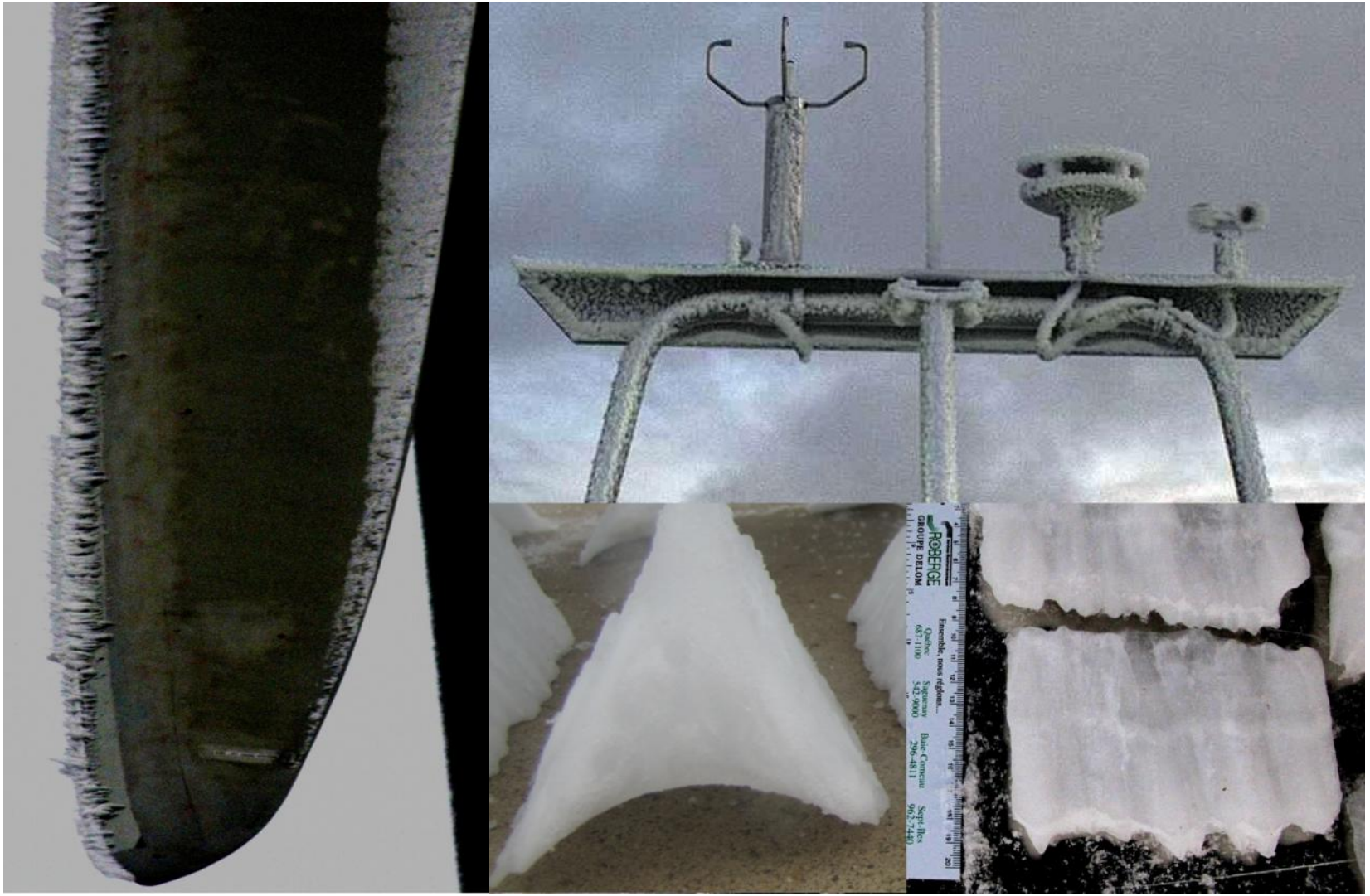


Ice Class Rime 1 (ICR1) – 0 to 0.5 kg/m

Ice Class Rime 2 (ICR2) – 0.5 to 0.9 kg/m

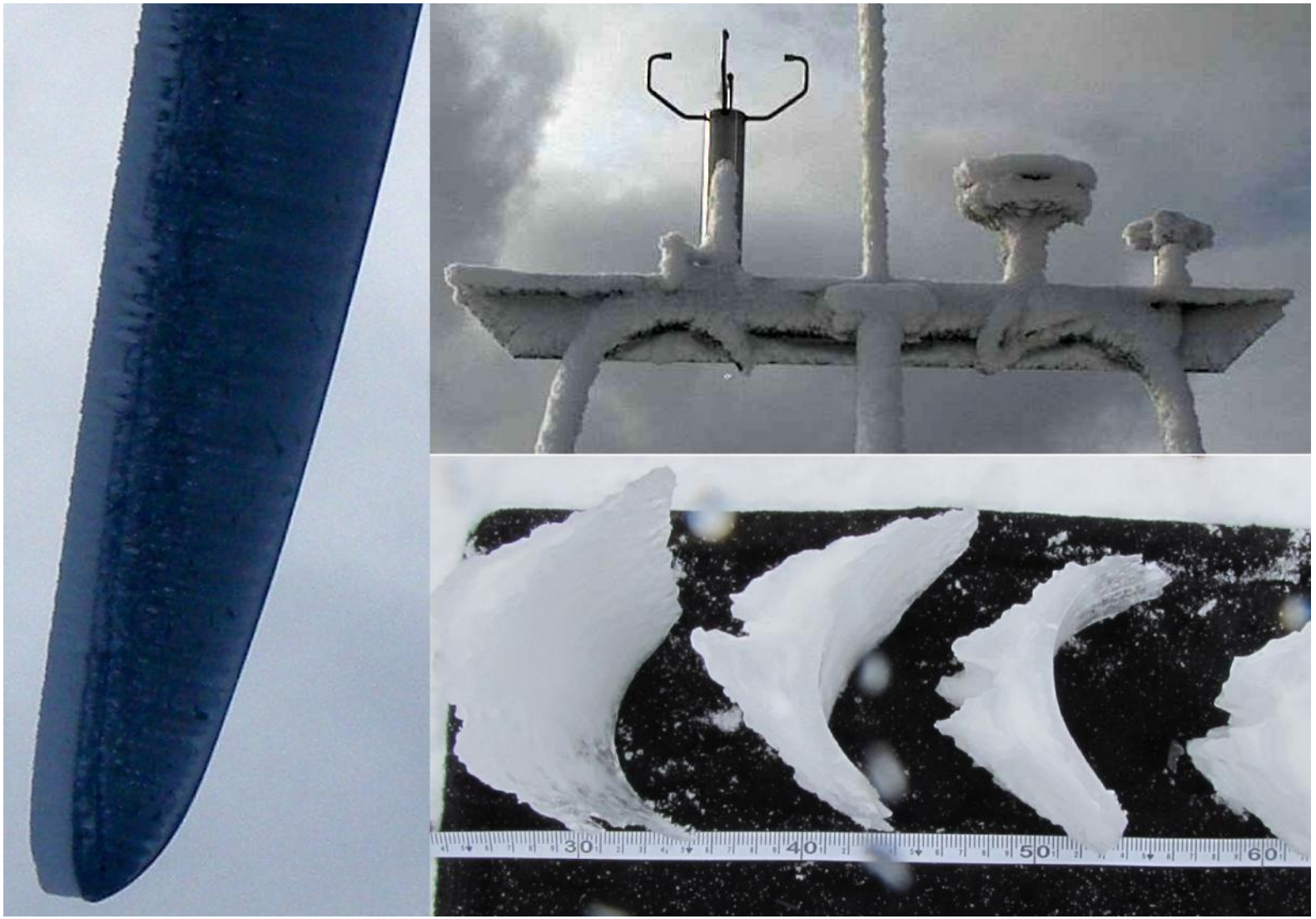


Ice Class Rime 3 (ICR3) – 0.9 to 1.6 kg/m



Ice Class Rime 4 (ICR4) – 1.6 to 2.8 kg/m

Ice Class Rime 5 (ICR5) – 2.8 to 5.0 kg/m

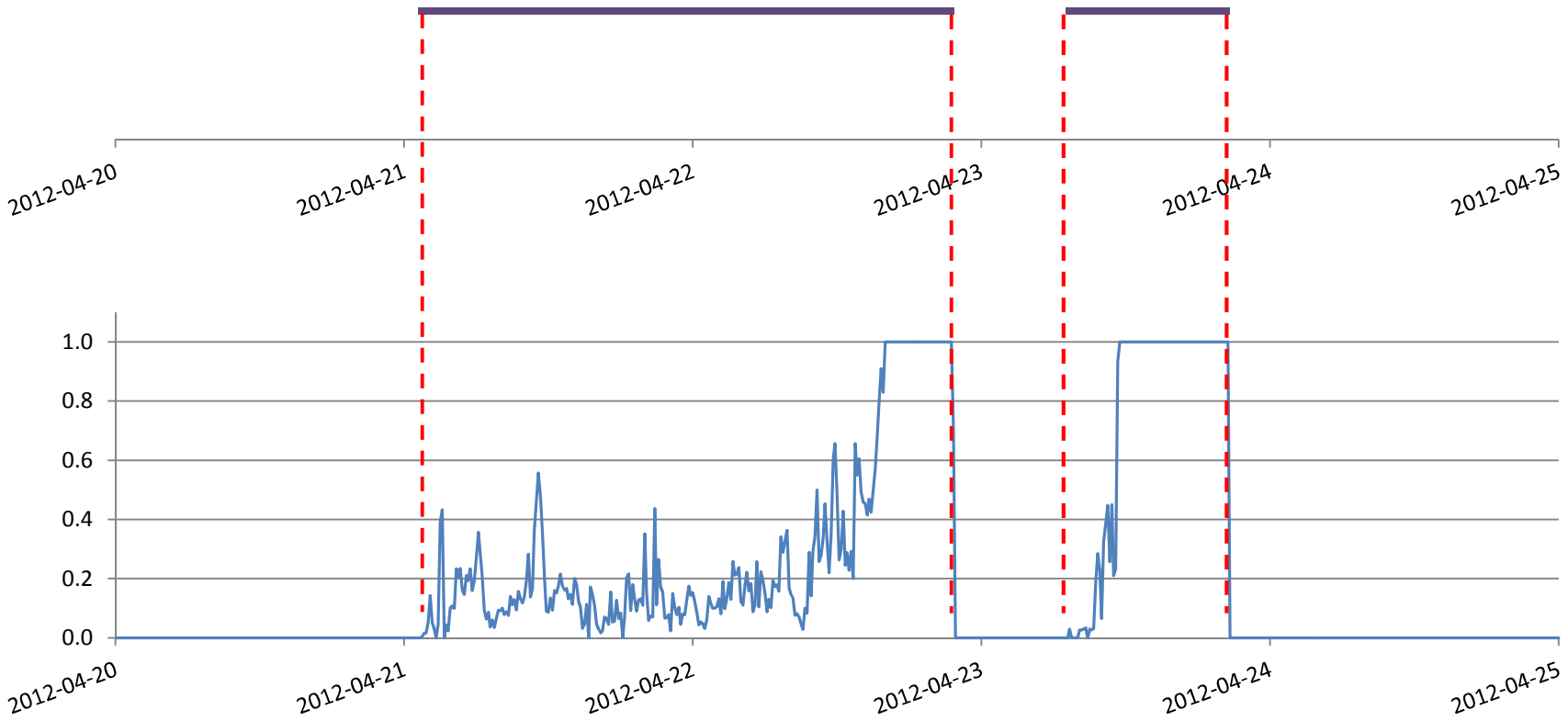


Example Icing Event

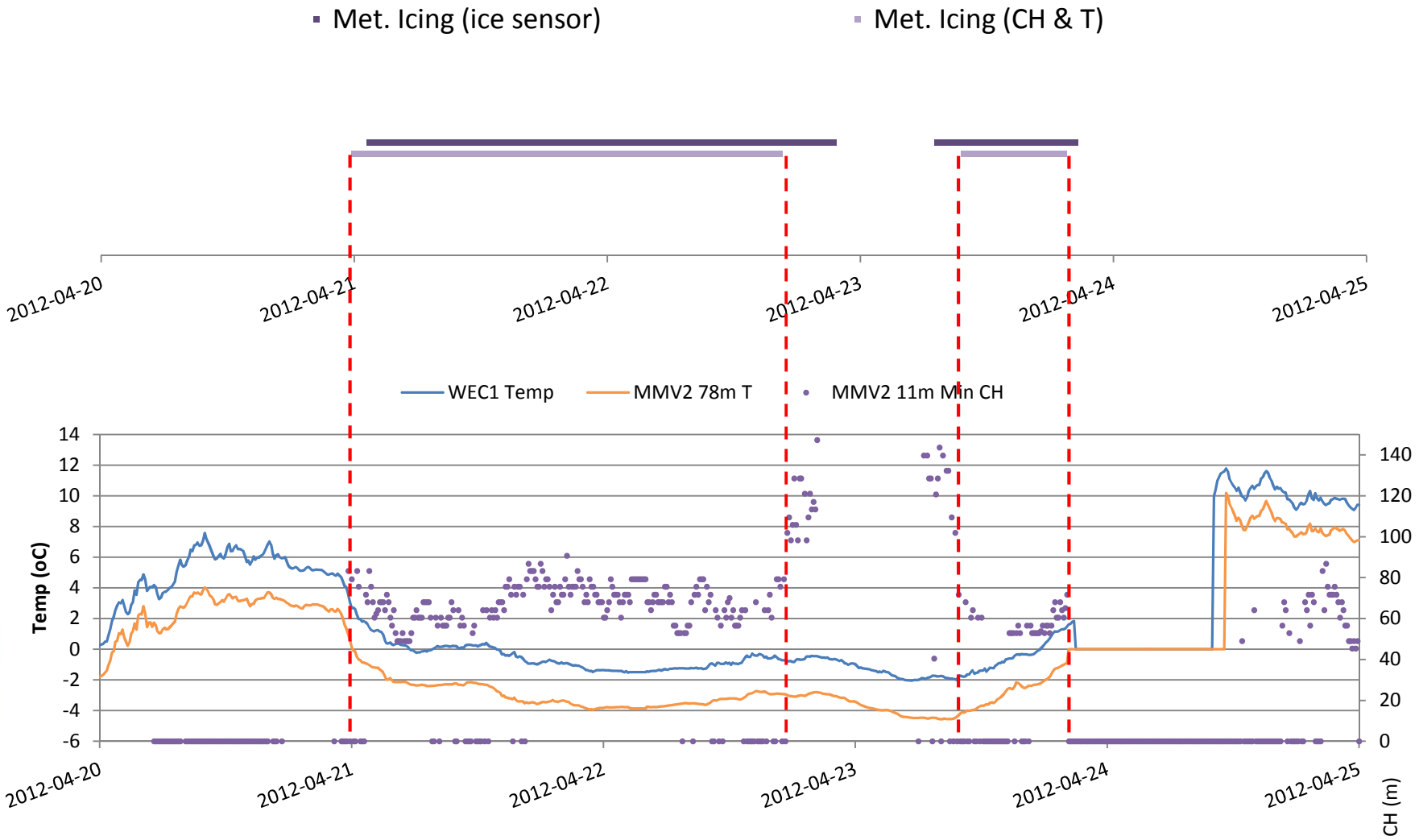
- April 21 to 23, 2012
- Rime, ICR3 to ICR5

Meteorological Icing (Ice Sensor)

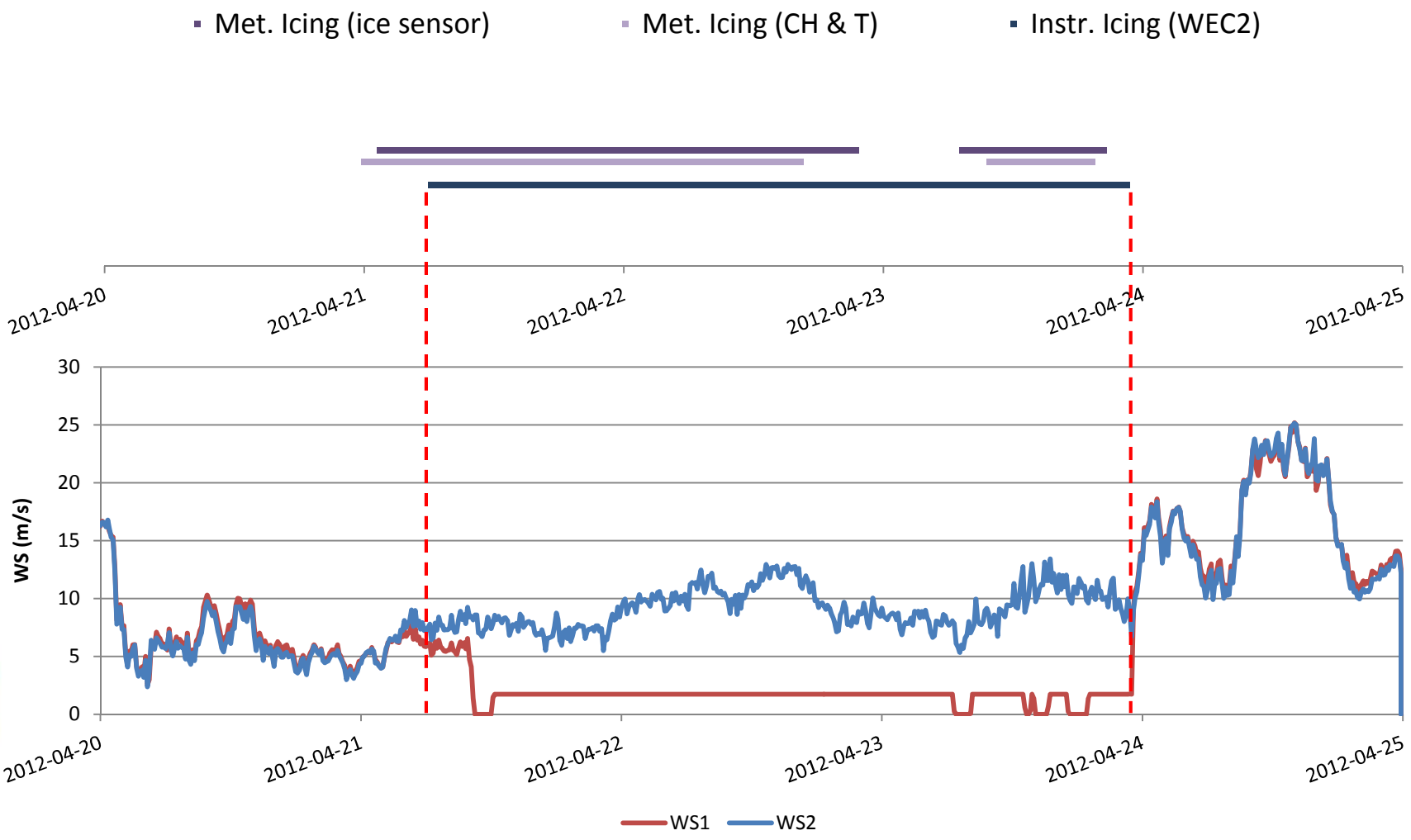
- Met. Icing (ice sensor)



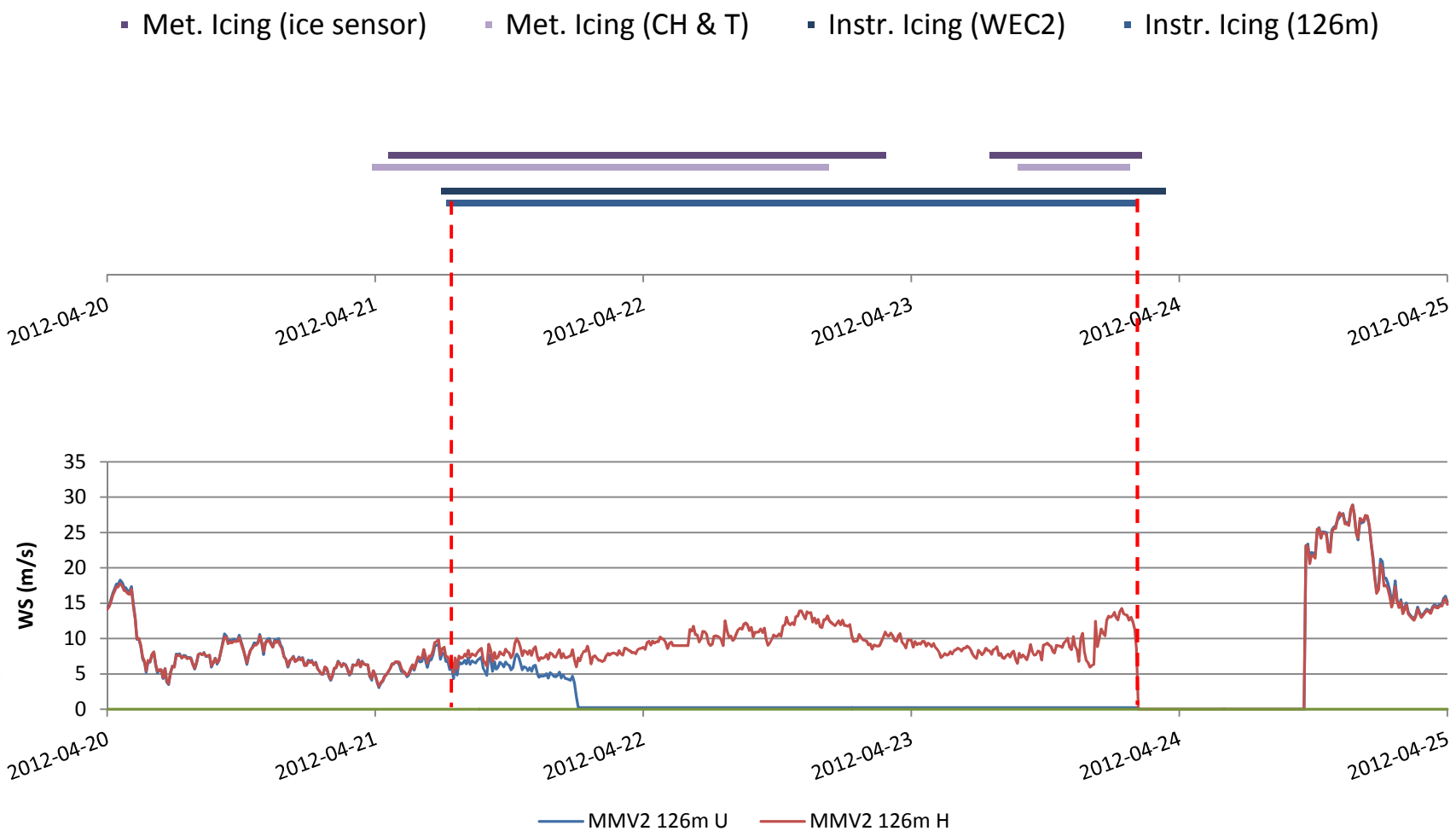
Met. Icing (Cloud Height & Temp.)



Instrumental Icing (WEC unheated anemo)

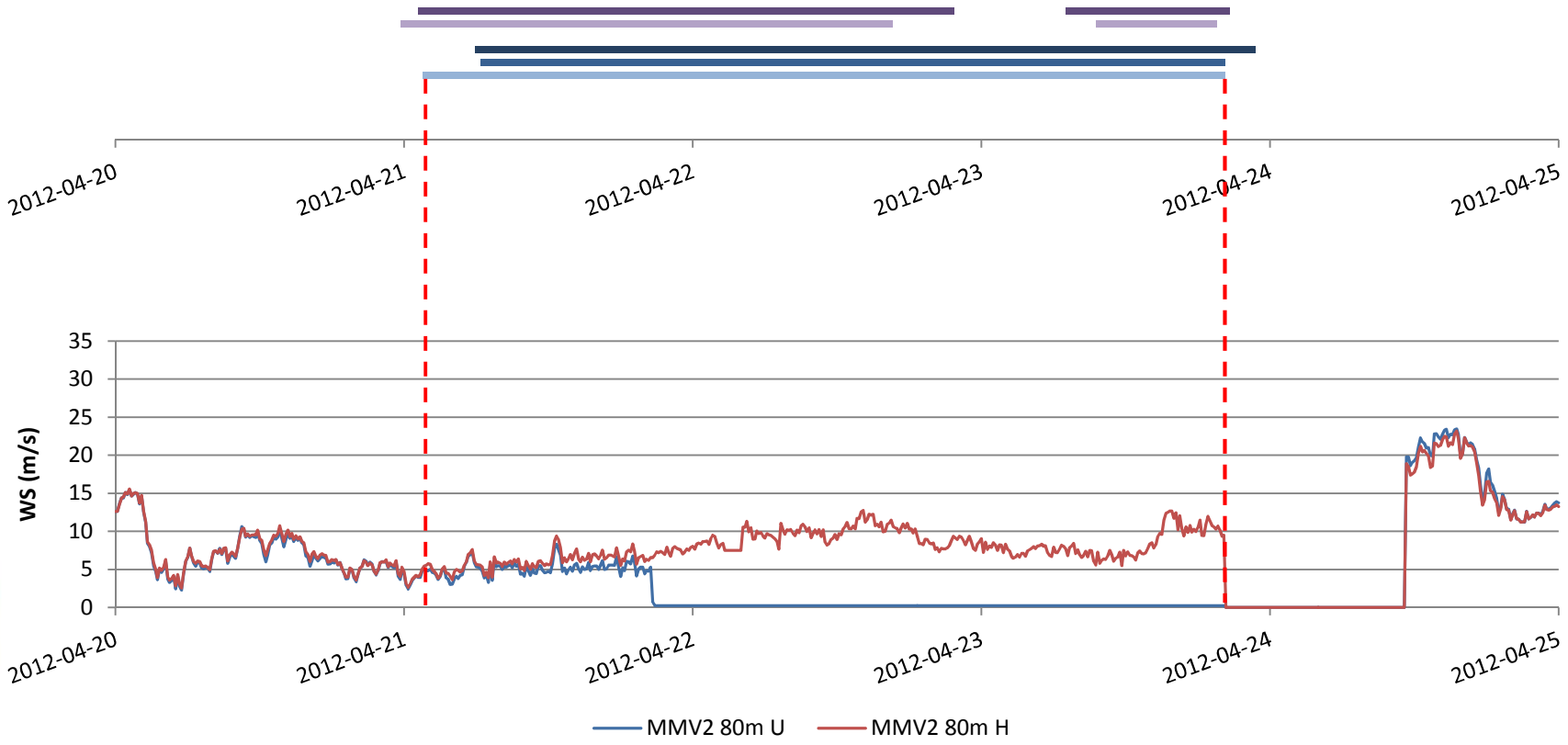


Instr. Icing (MMV2 126m unheat anemo)



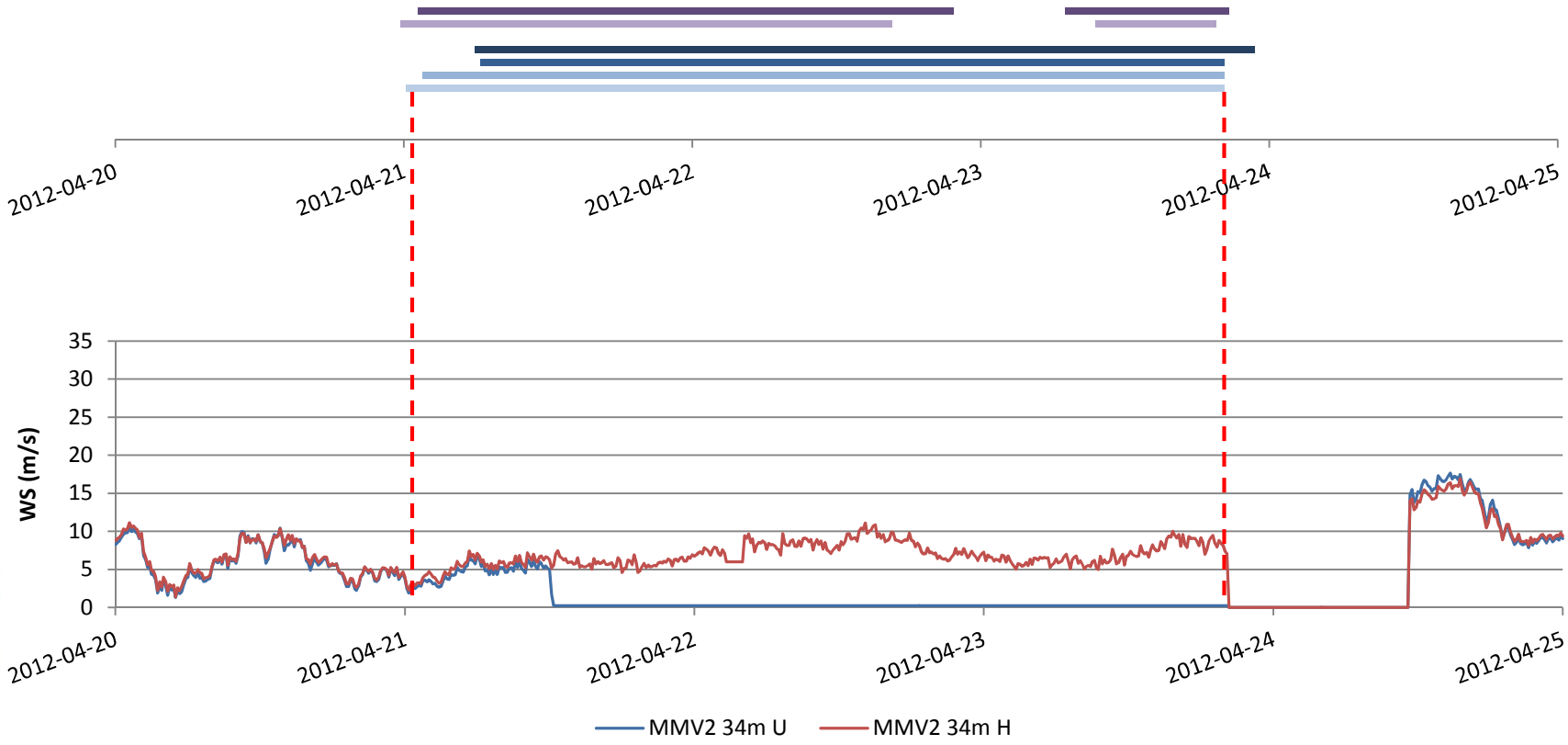
Instr. Icing (MMV2 80m unheat anemo)

- Met. Icing (ice sensor)
- Met. Icing (CH & T)
- Instr. Icing (WEC2)
- Instr. Icing (126m)
- Instr. Icing (78m)

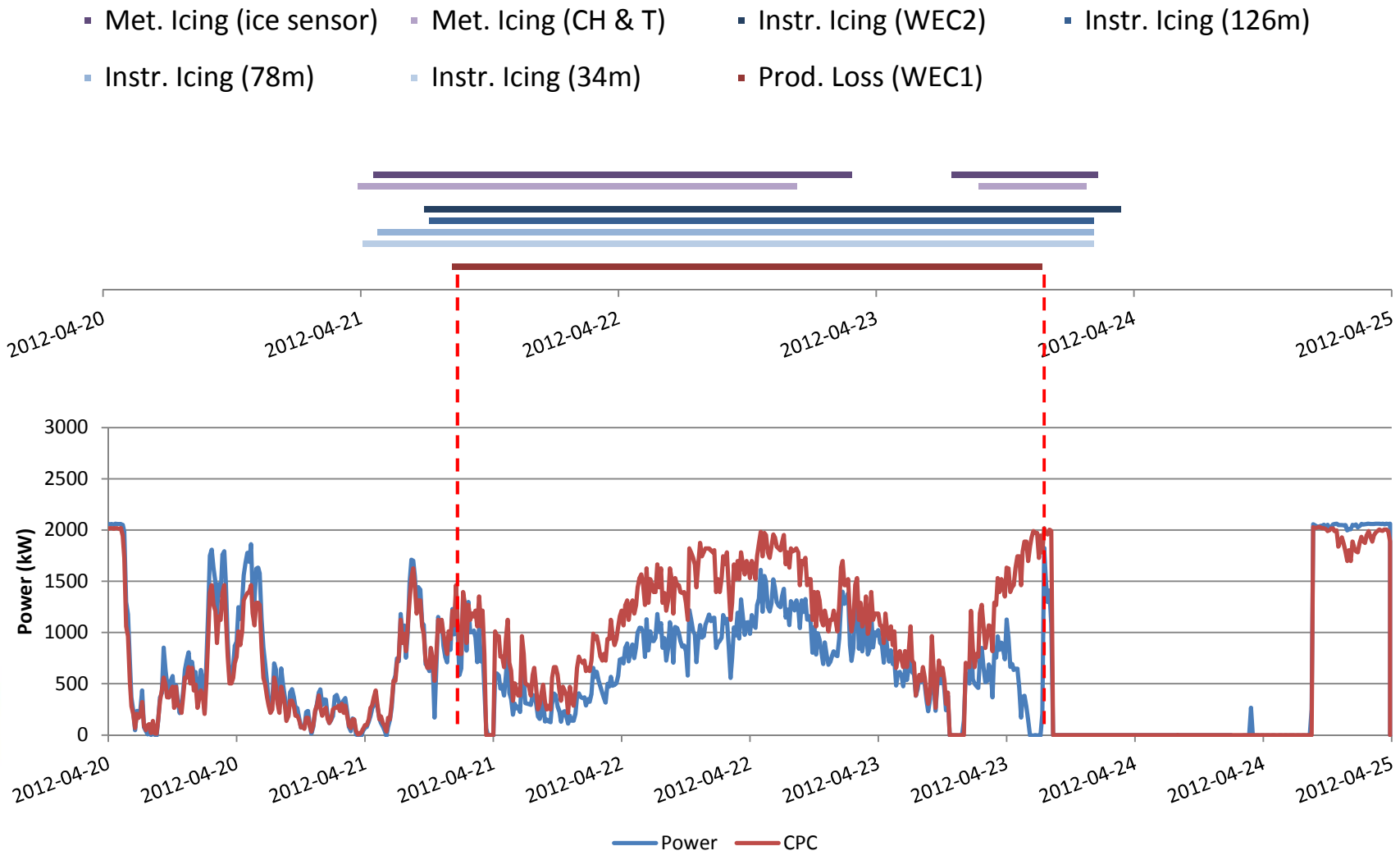


Instr. Icing (MMV2 34m unheat anemo)

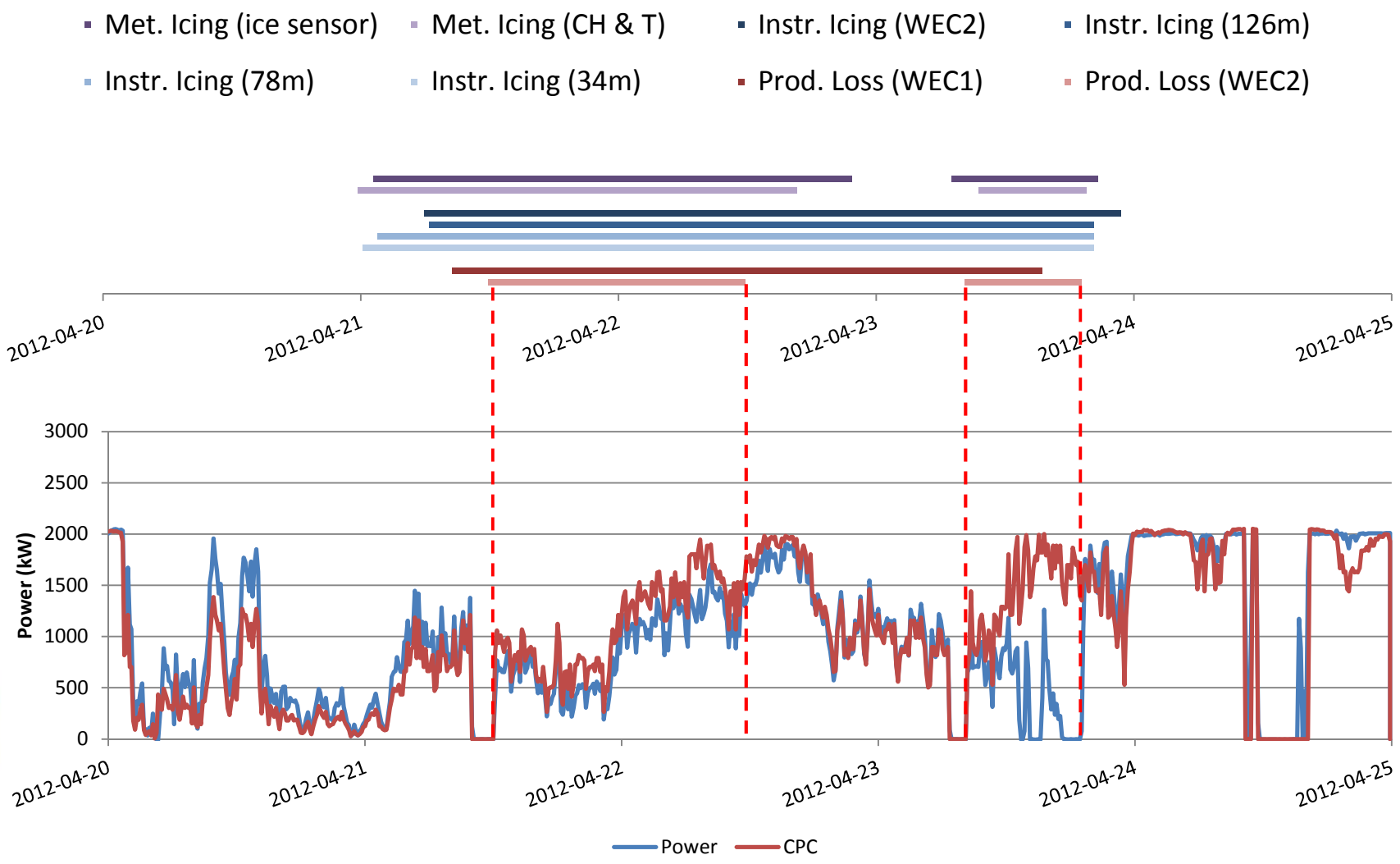
- Met. Icing (ice sensor)
- Met. Icing (CH & T)
- Instr. Icing (WEC2)
- Instr. Icing (126m)
- Instr. Icing (78m)
- Instr. Icing (34m)



WEC1 Production Loss

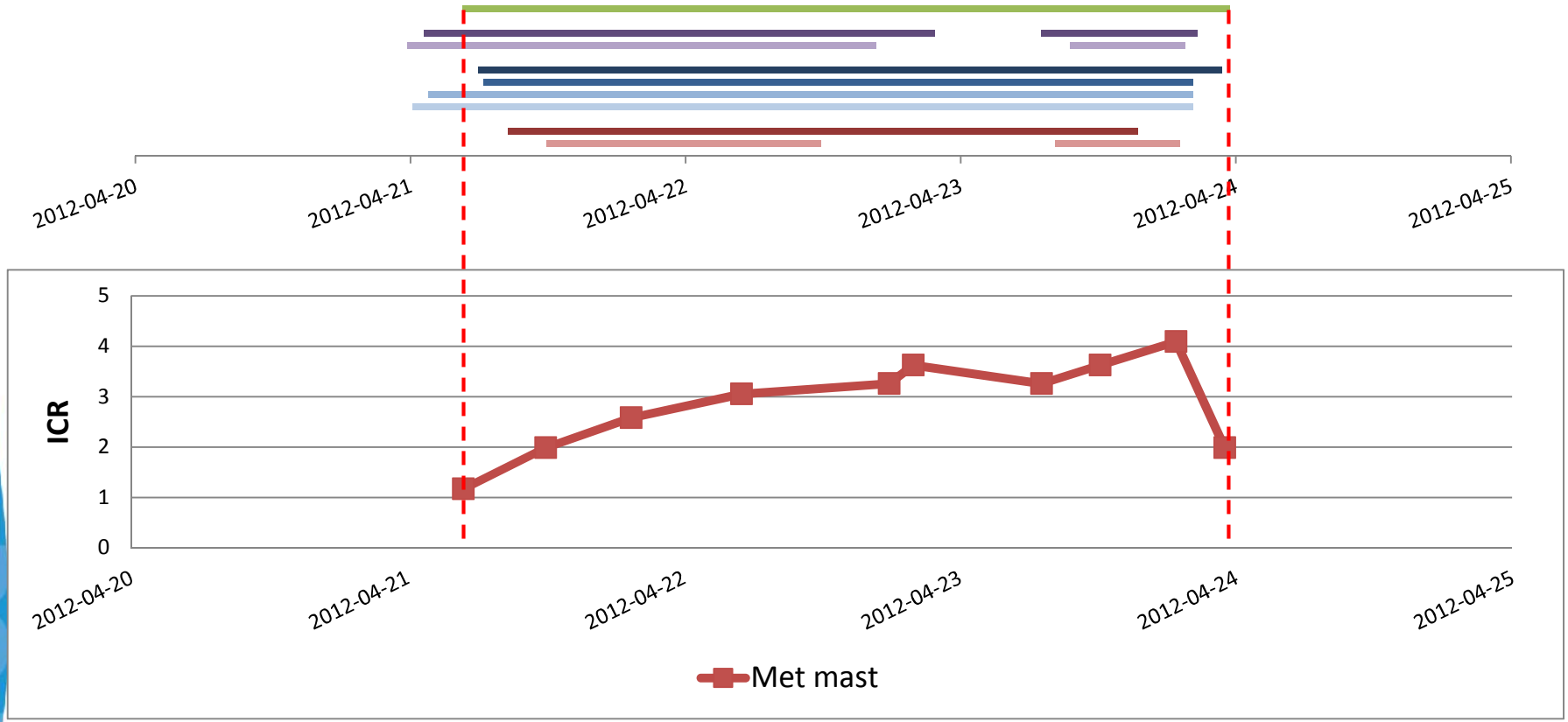


Production Loss (WEC2)

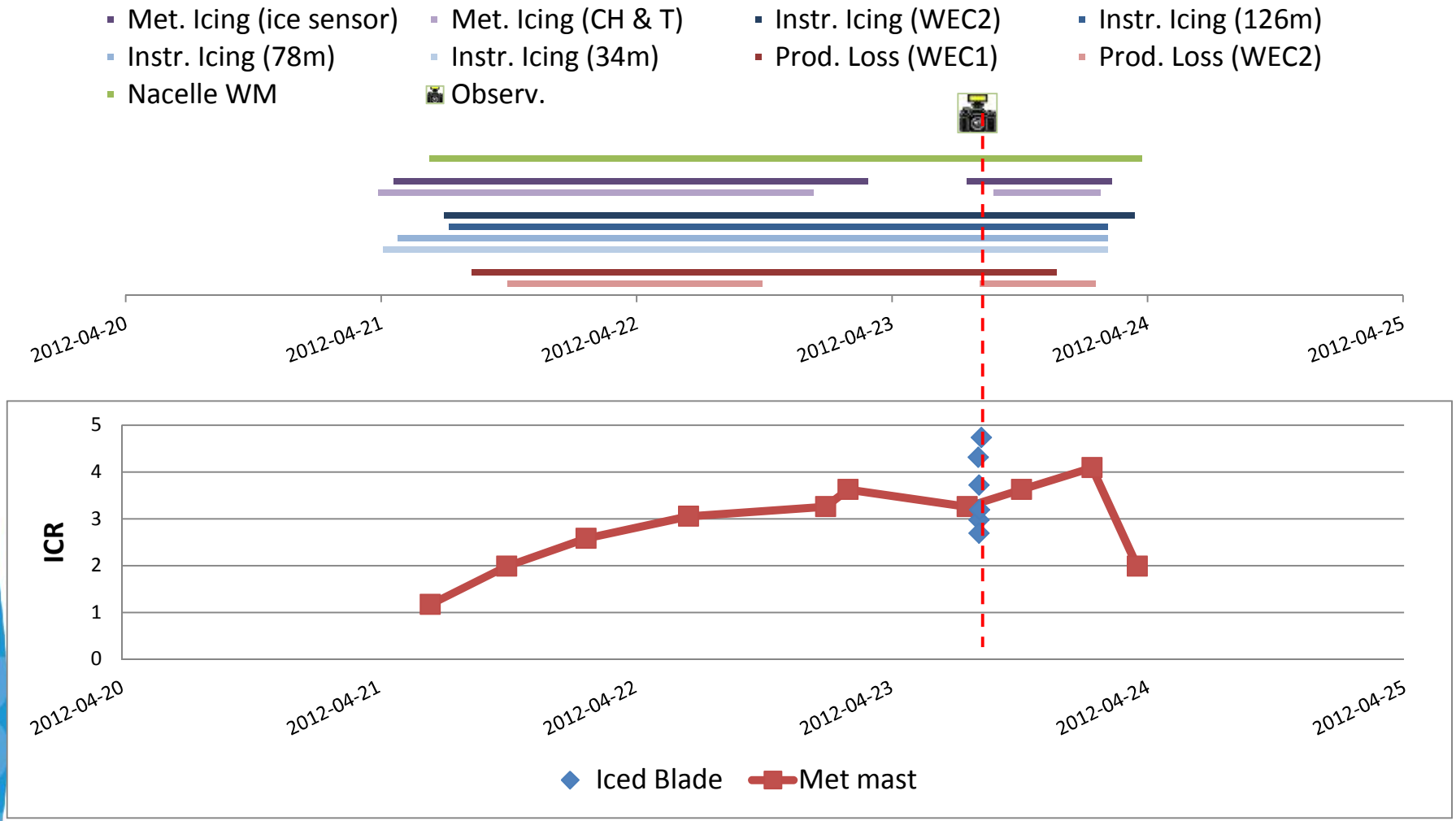


Nacelle Weather Mast Ice Load

- Met. Icing (ice sensor)
- Met. Icing (CH & T)
- Instr. Icing (WEC2)
- Instr. Icing (126m)
- Instr. Icing (78m)
- Instr. Icing (34m)
- Prod. Loss (WEC1)
- Prod. Loss (WEC2)
- Nacelle WM



Blade Ice Load

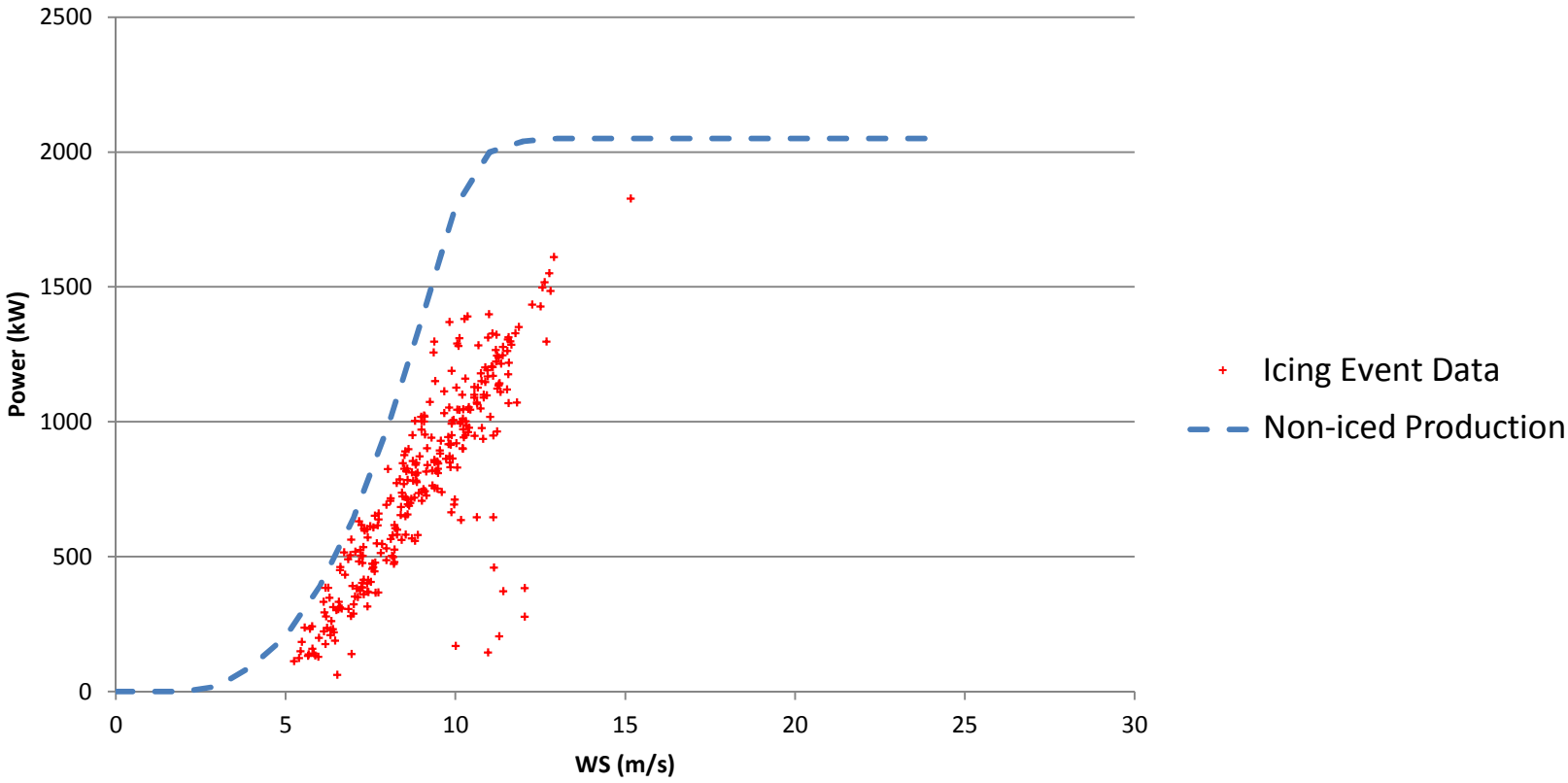


Example Icing Event

- April 21 to 23, 2012
- Rime, ICR3 to ICR5

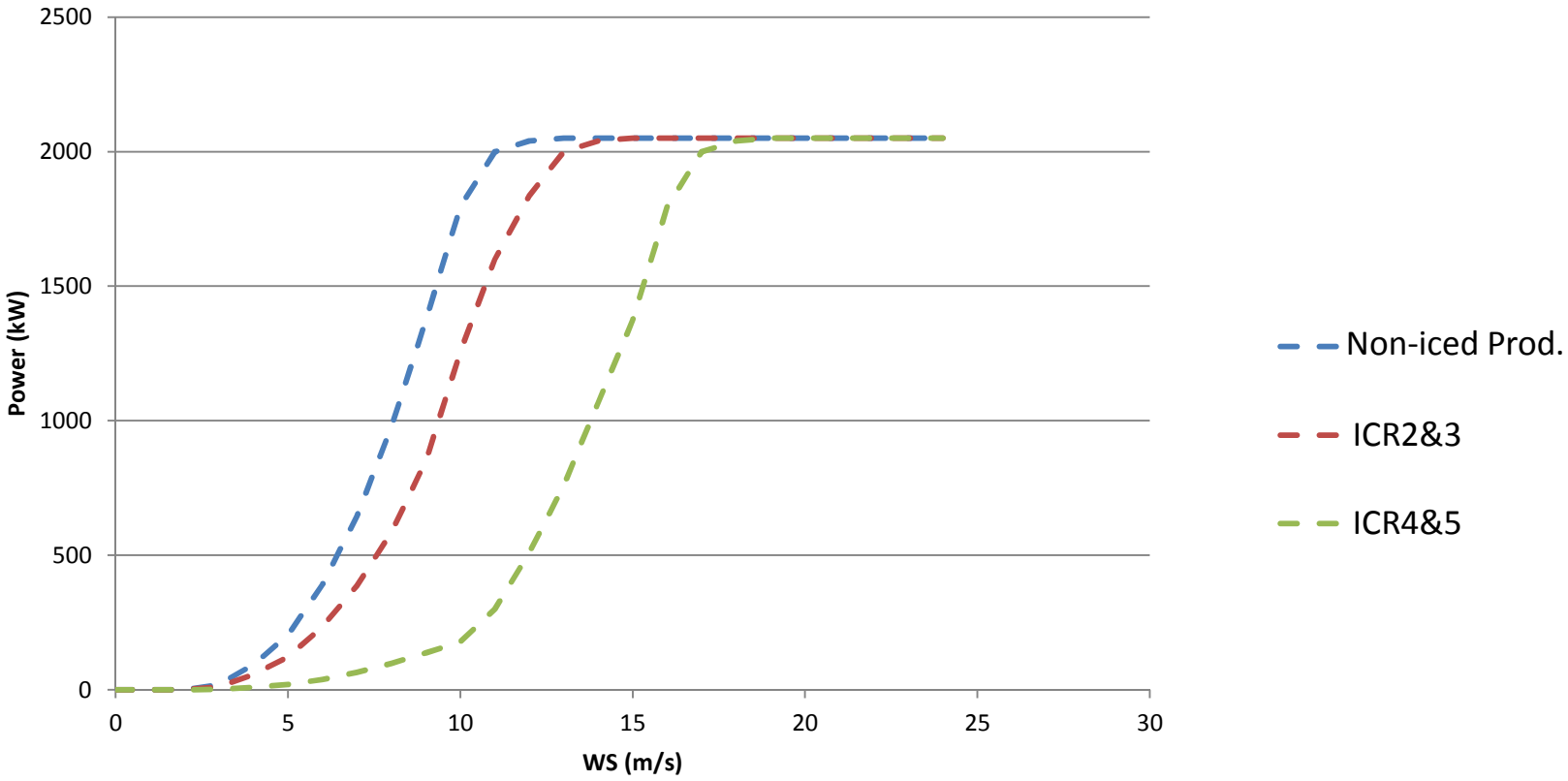
Power Curve

- Production loss during april 20-23 icing event



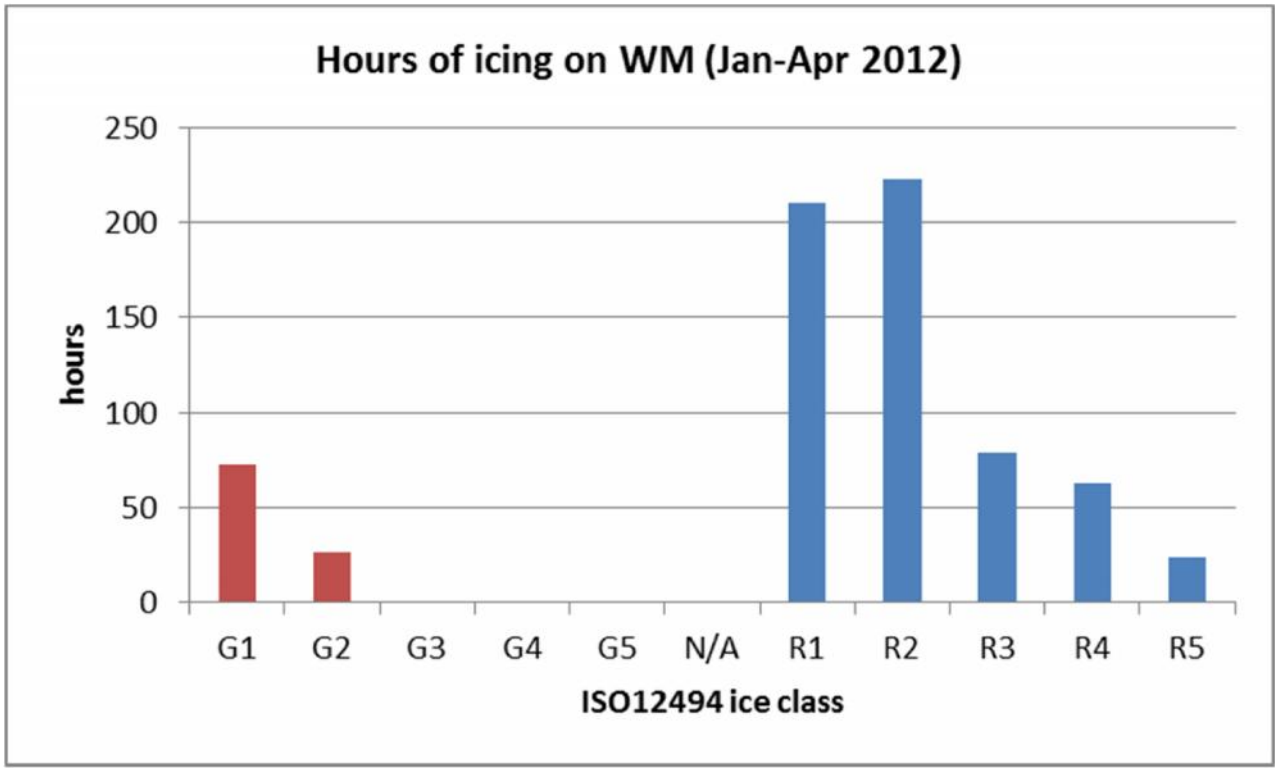
Power Curve

- Power curve estimations based on ice classification and production losses of all icing events in Winter 2011-2012



Nacelle Weather Mast Load Classification

- Weather mast occurrence of icing severity over the course of the winter



Winter 2011-2012 in numbers

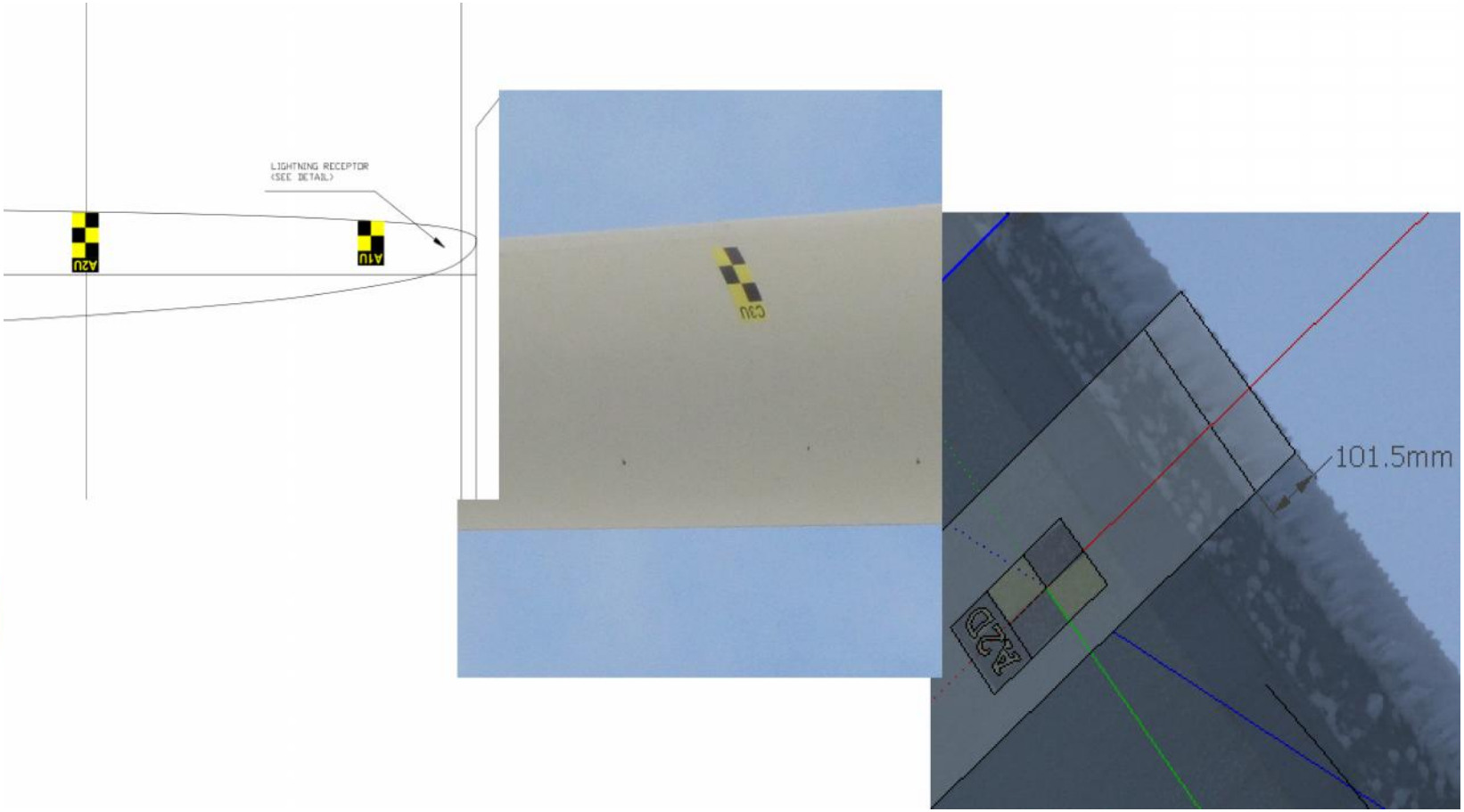
Meteorological Icing	~200 hours
Instrumental Icing	~400 hours
Nacelle WM icing	800+ hours
Ice observed on blades	23 days
Production Loss	~140 hours
Production Loss (% AEP)	~1.5%
Hours of ICR2&3	~300 hours
Hours of ICR4&5	~100 hours
Hours of Glaze	~100 hours

Conclusions

- Improved understanding of the severity of icing events
- Measurement Campaign database can be used to validate simulation models (e.g. weather, ice accretion)
- Methodology can be applied to assessing performance of ice protection technologies
- Nacelle weather mast ice severity correlates to blade icing severity
- Duration of weather mast icing generally much longer than blade icing
- How to make measurement of icing severity on blades could be more accurate and more frequent?

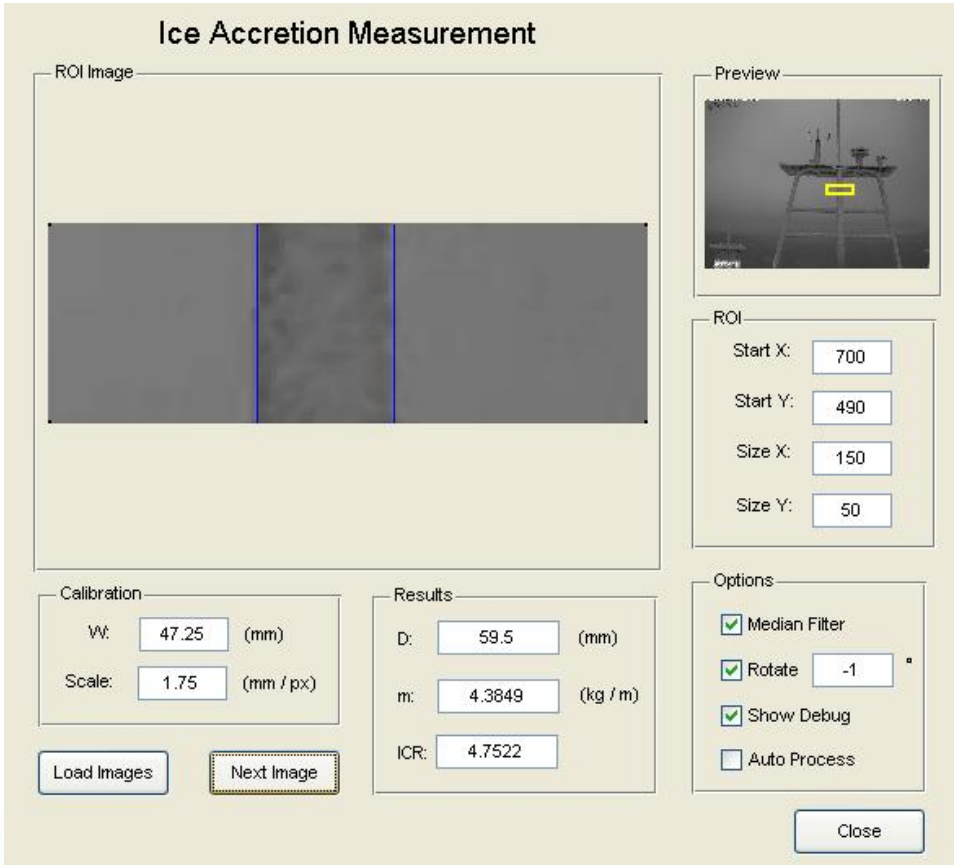
Checker board tape

- In order to get a better estimation of blade ice load and position along span of blade

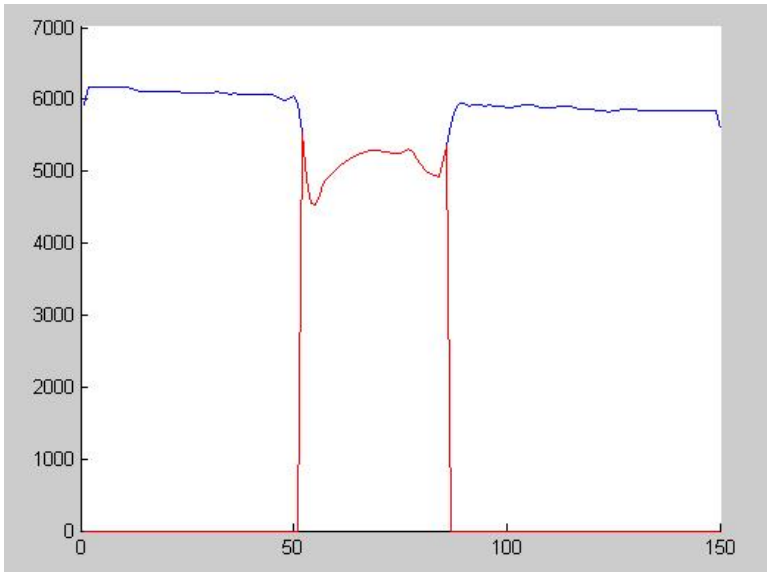


Hub Camera

Ongoing – Automation of Image Analysis



ICR= 5



In Collaboration with:

CRVI
Centre de Robotique et de Vision Industrielles

References

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ISO 12494:2001, Atmospehiric Icing of Structures, International Organisation for Standardization, 2001


Thank you, Tack, Danke, Merci!

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