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Performance Maps for Ice Mitigation Operational Strategies

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Outline
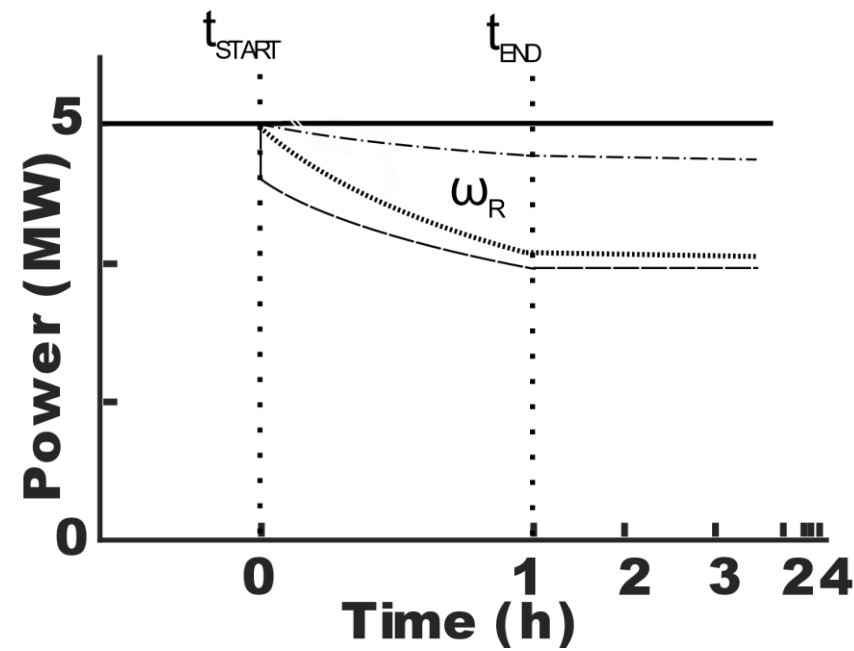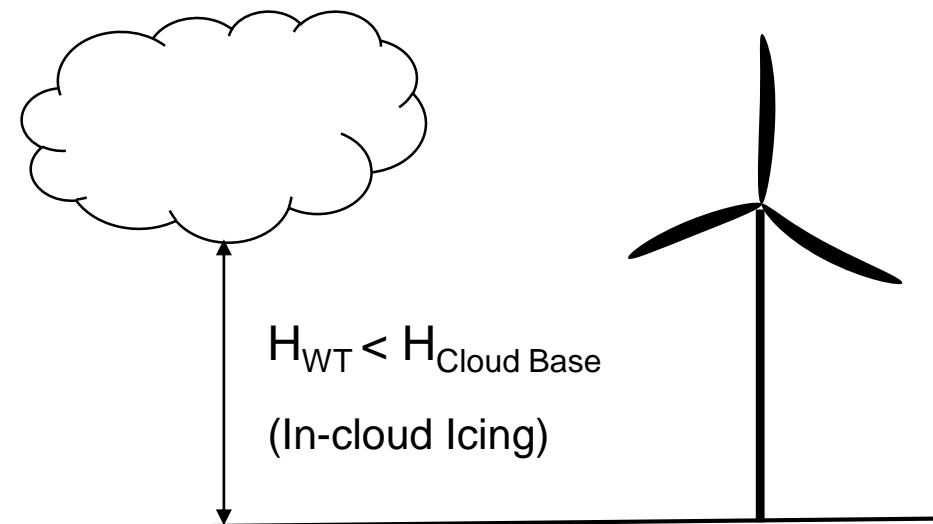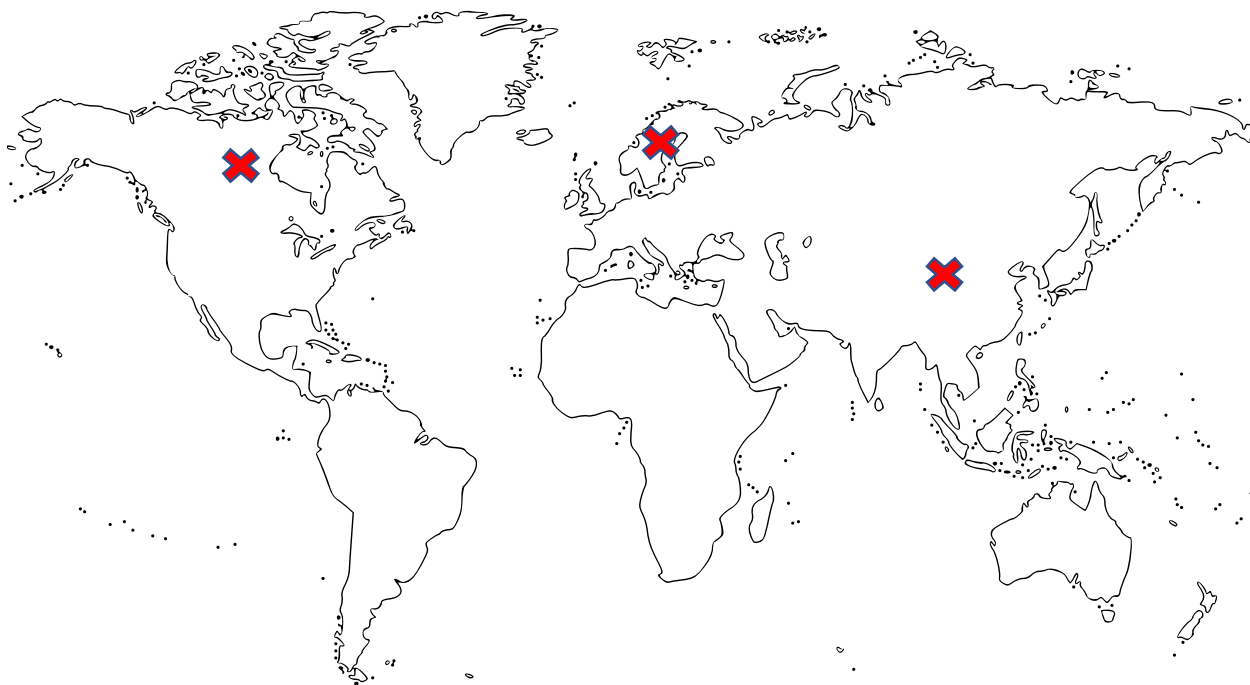
- What is the issue?

- Ice modelling strategies

- Arising questions

- Current approach

- What is a performance map?

- Performance Maps

- Advantages

What is the issue?

- Ideal Case: 100% nominal power

- Icing Occurs: power drops

- Variability of icing losses with location

$H_{WT} < H_{Cloud\ Base}$

(In-cloud Icing)

Image by OpenClipart-Vectors from Pixabay

Ice Mitigation Strategies

- Operational Shutdown

- Anti-Icing Systems

- Protective Coatings

- Flexible Blades

- Blades Design

- Rotational Speed Modification

$\omega_M < \omega_R$

$\omega = 0s^{-1}$
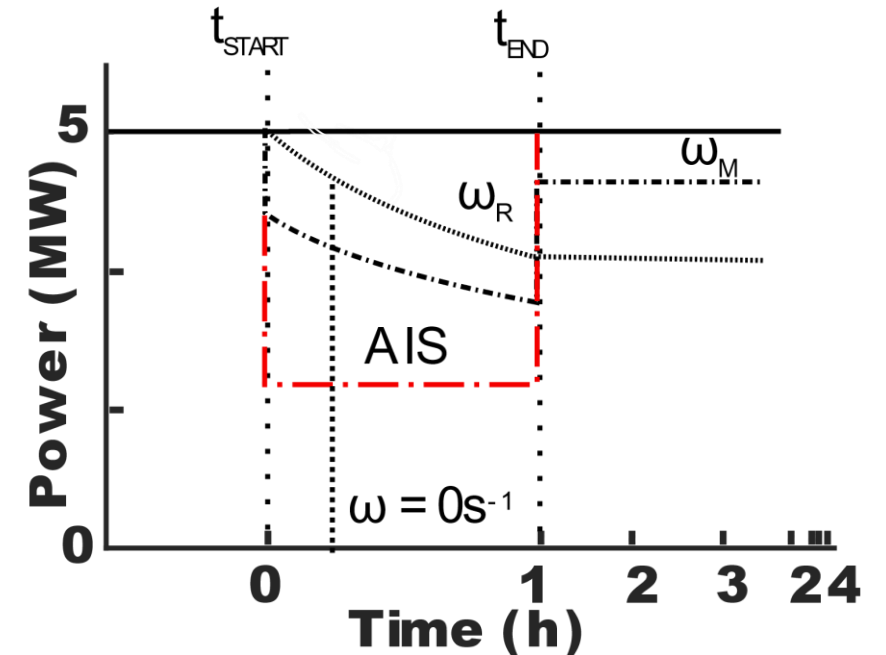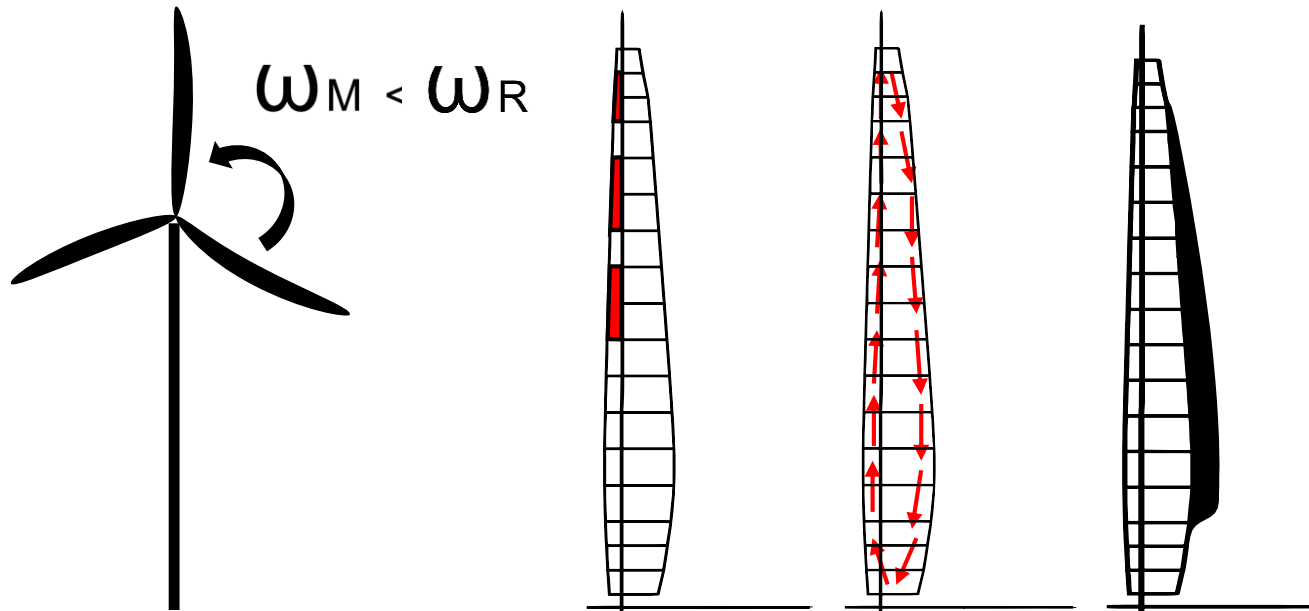
Arising Questions

- Which ice mitigation approach is the most suitable

  for my wind turbine?

- How does the ice mitigation effectiveness of different

  strategies vary and how do I compare them?

Current Approach

- Model the variation of the performance for each ice mitigation strategy

- Establish operational envelopes for each strategy as a function of icing and operational parameters

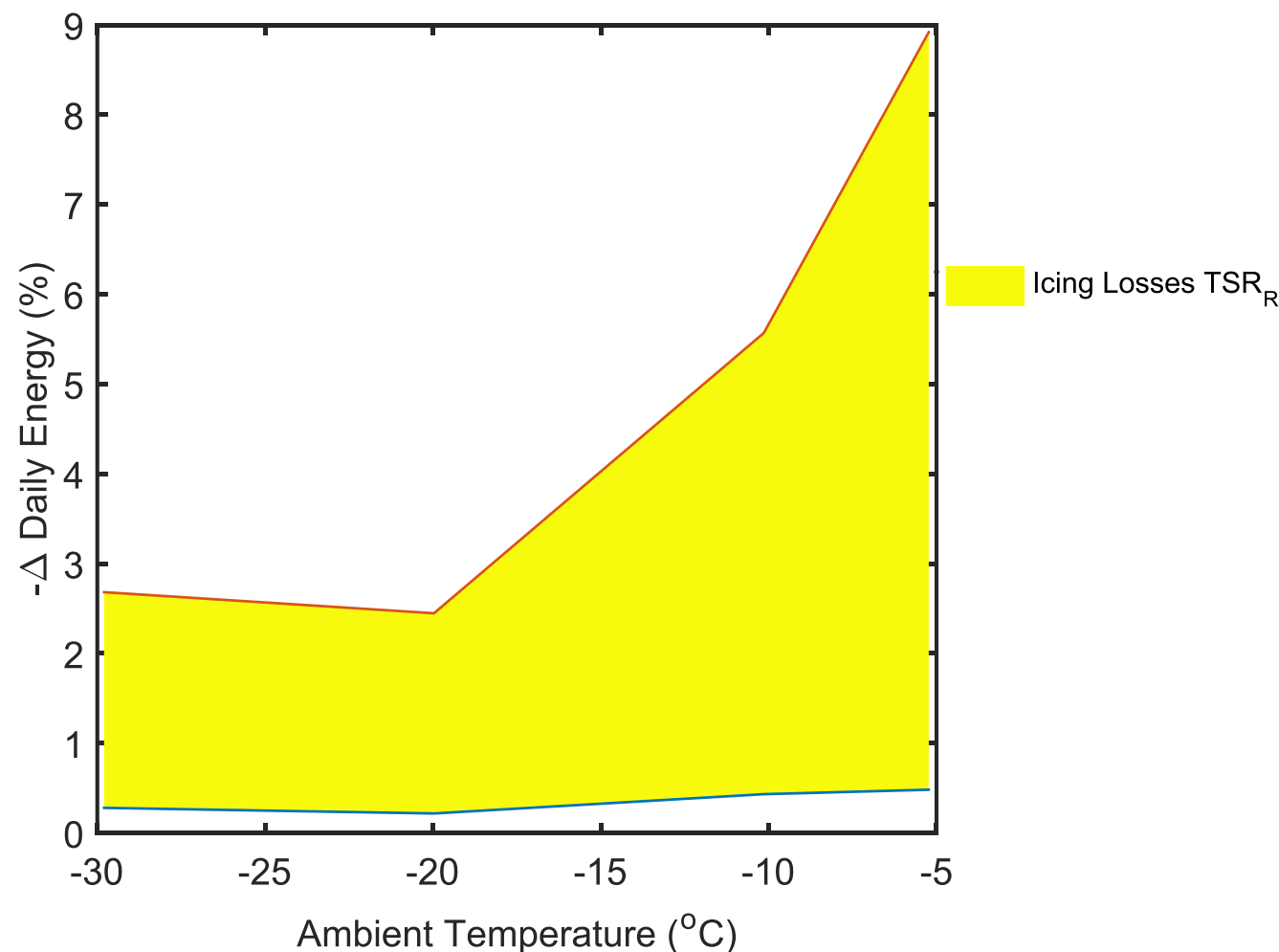- Suggest best operational strategy or set of strategies
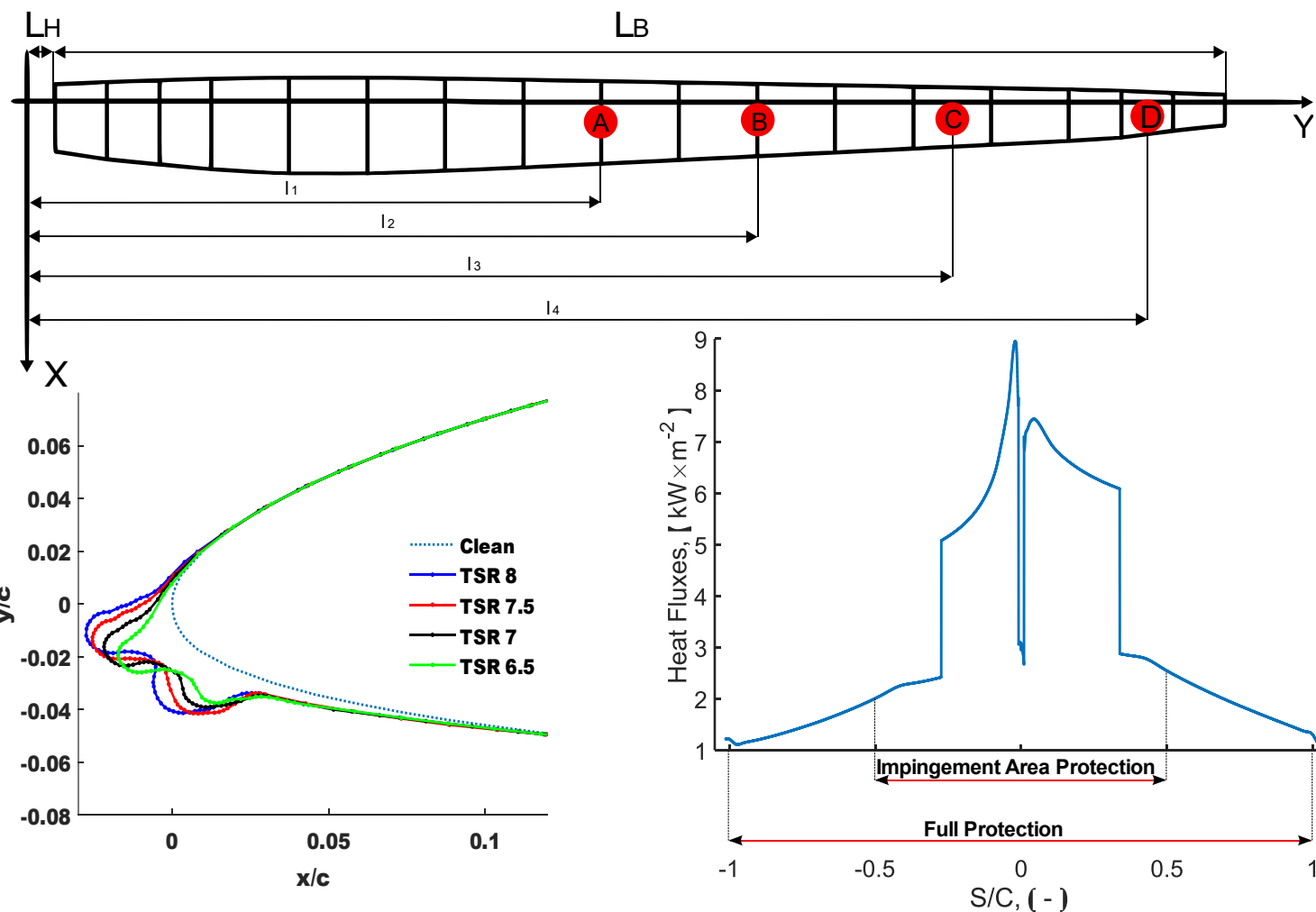
$$E_{Loss} = |E_{CLEAN} - E_{AIS/TSR,M/TSR,R/S}|/E_{CLEAN}$$

What is a performance map?

- Shows how a wind turbine's performance vary for all considered ice mitigation strategies for a given period.

- Steady State Case:
  - IewINT software
  - Qblade
  - 1-hour extreme icing event, $10ms^{-1}$

- Considered strategies:
  - No strategy ⬅
  - Modified rotational speed
  - Anti-icing
  - Operational Shutdown
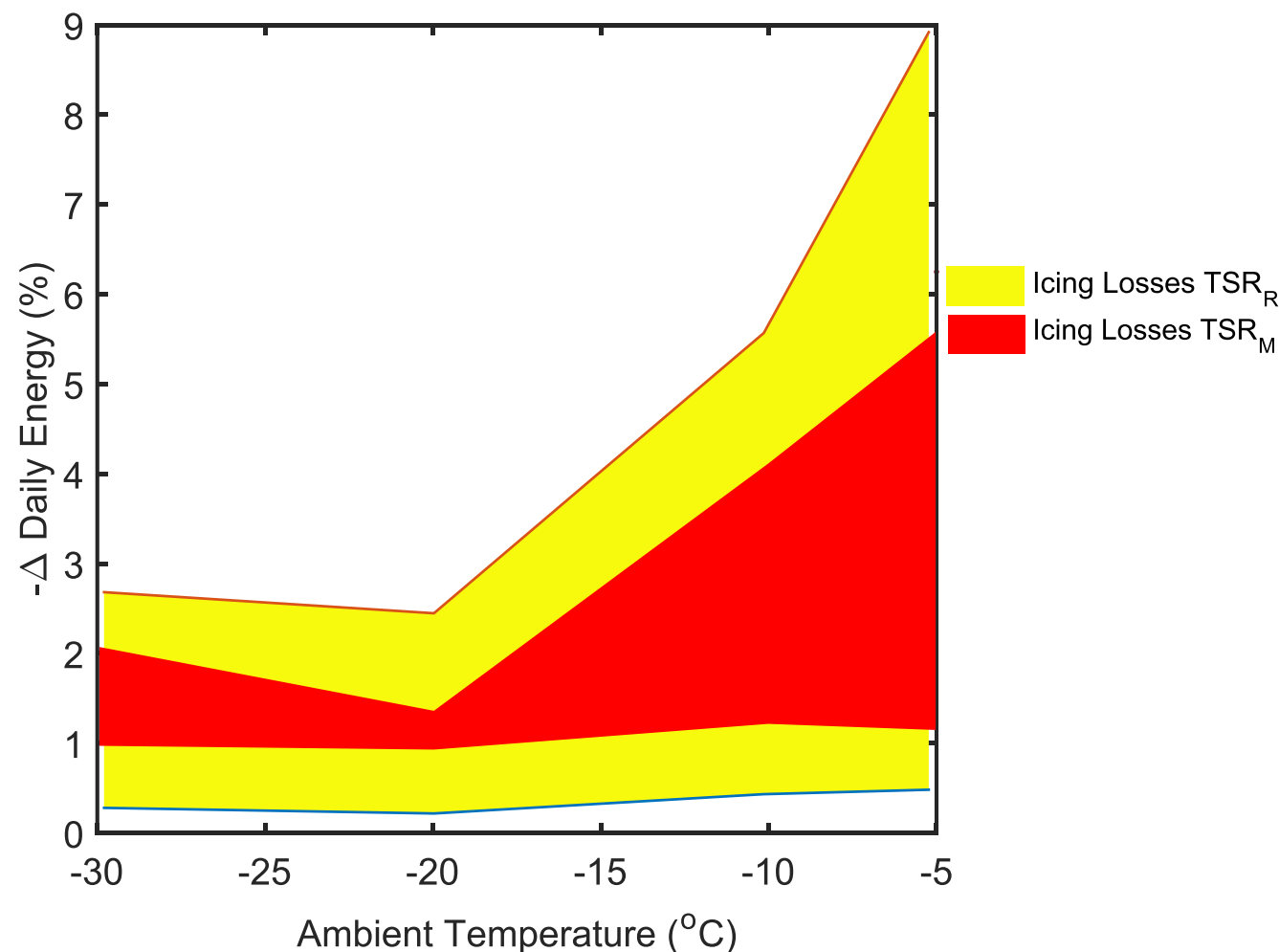
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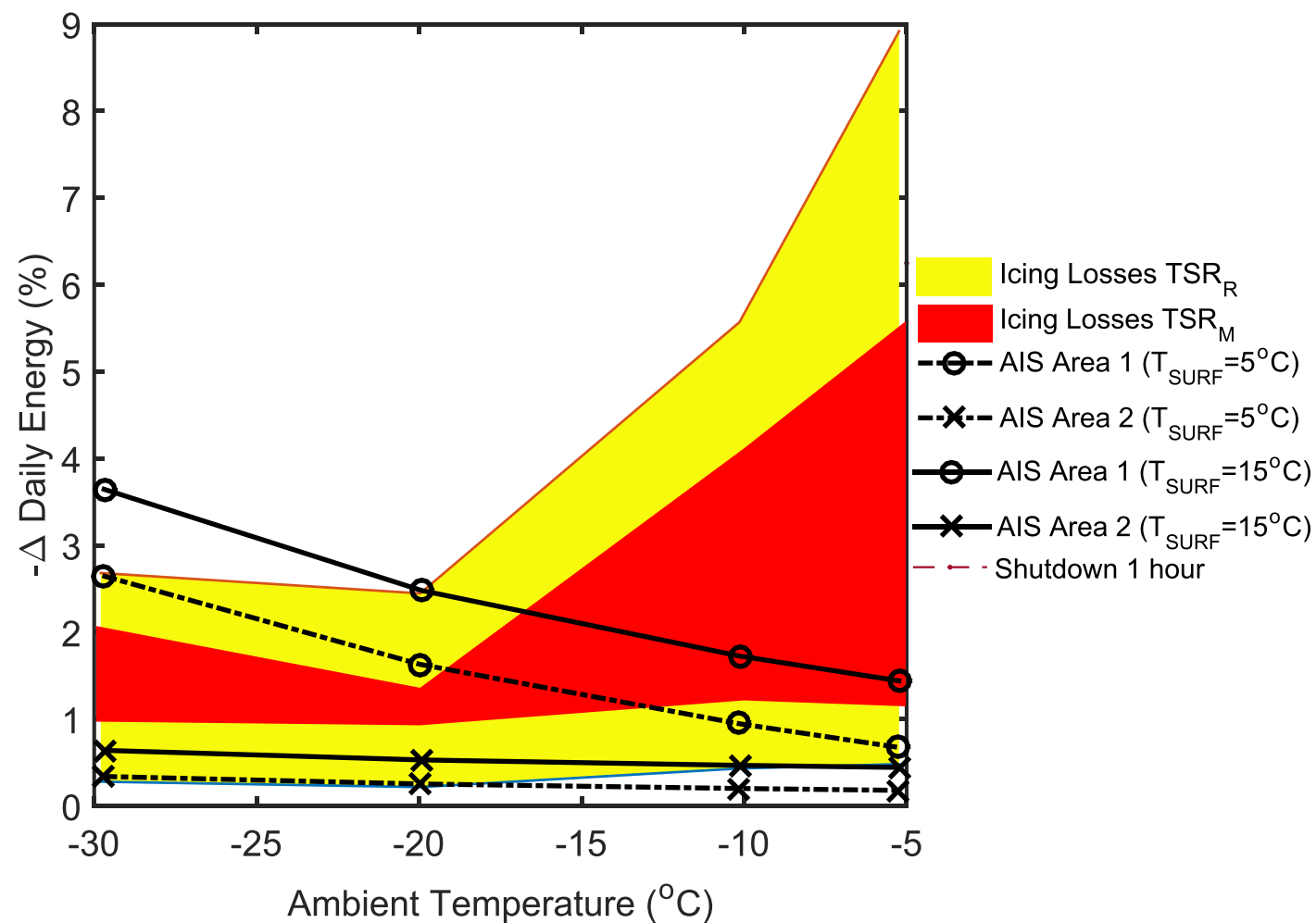
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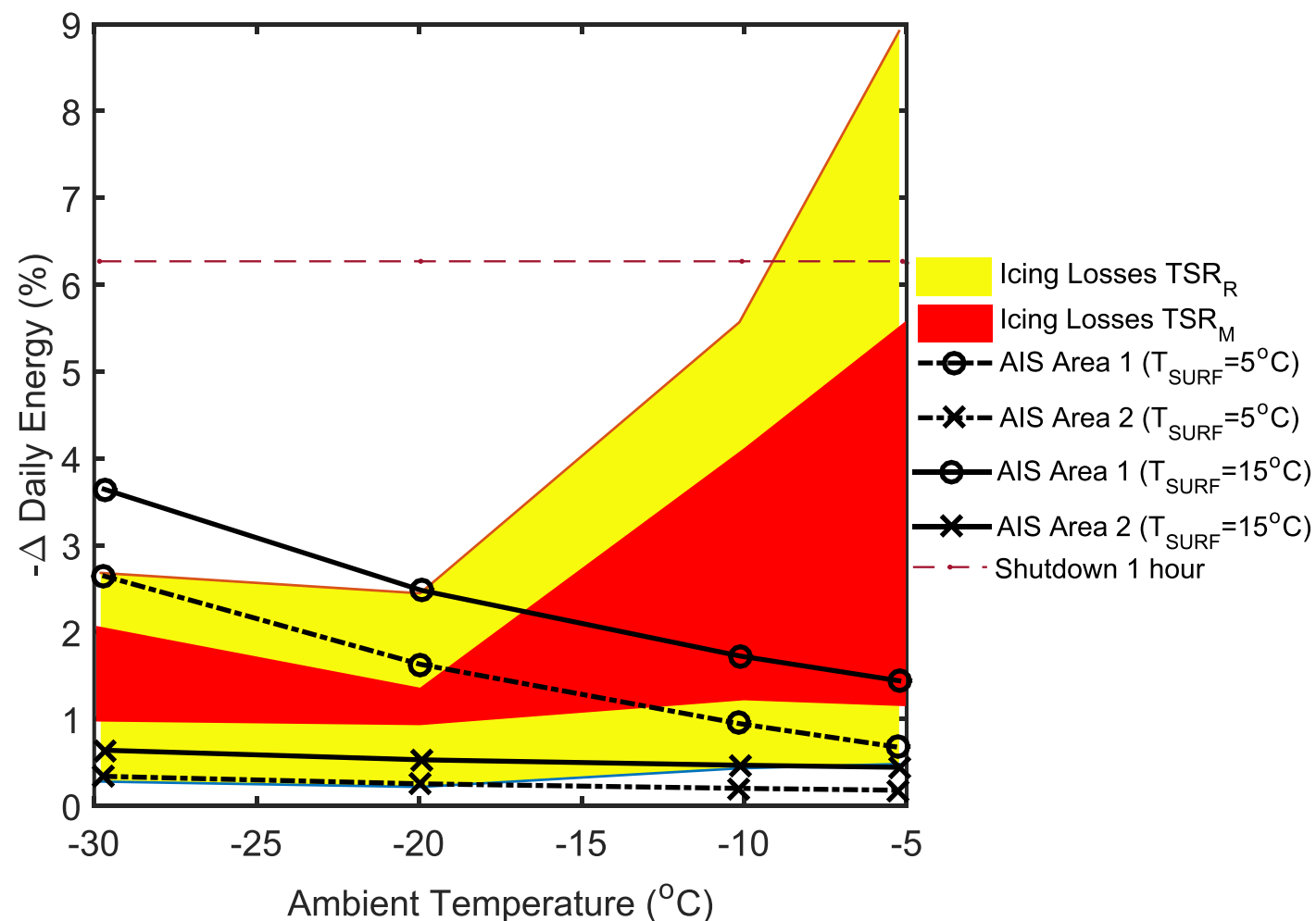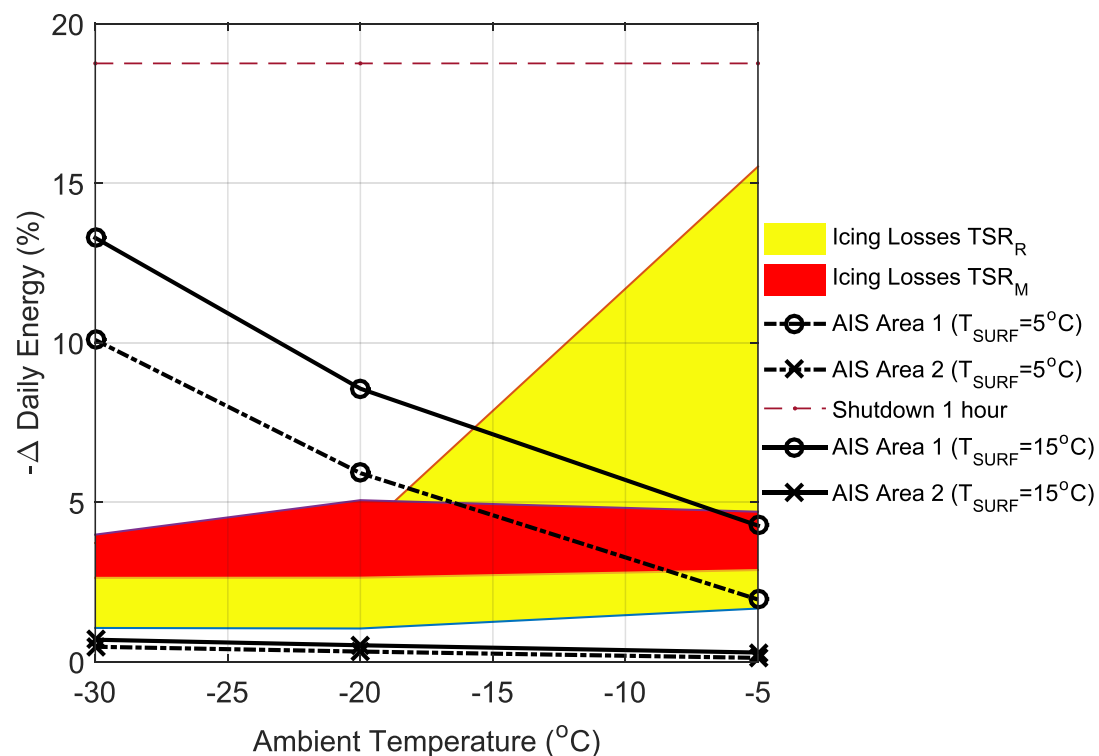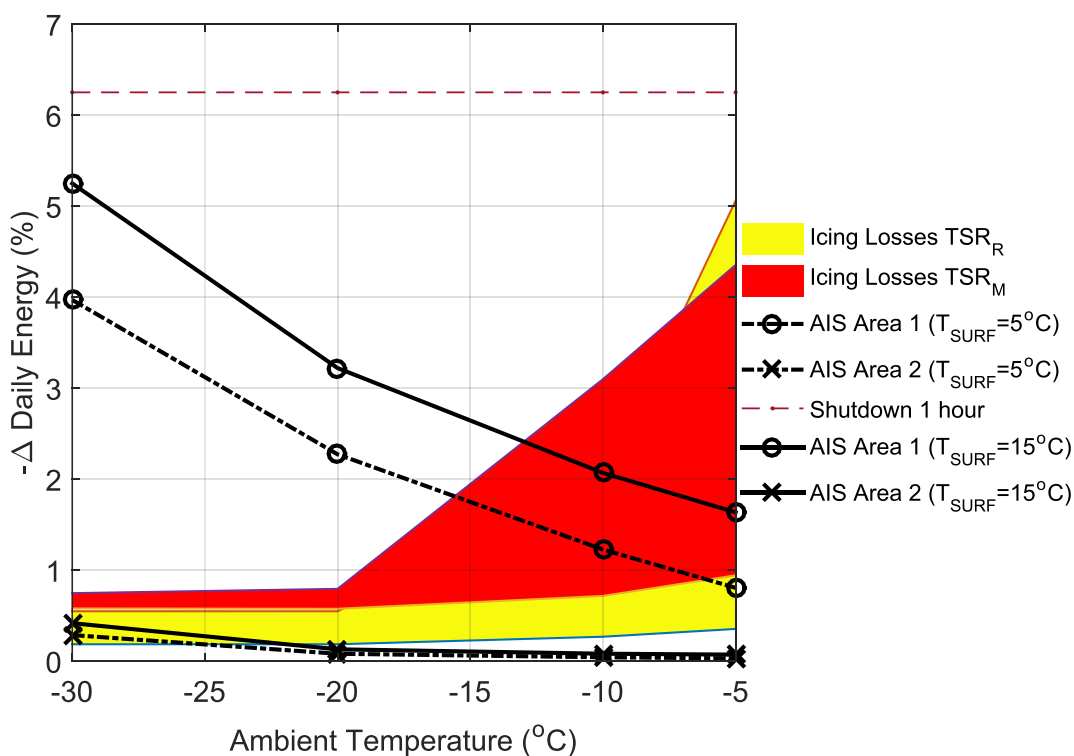
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Legend:
- Icing Losses TSR_R
- Icing Losses TSR_M
- AIS Area 1 ($T_{SURF}=5^oC$)
- AIS Area 2 ($T_{SURF}=5^oC$)
- AIS Area 1 ($T_{SURF}=15^oC$)
- AIS Area 2 ($T_{SURF}=15^oC$)
- Shutdown 1 hour

X-axis: Ambient Temperature (^oC)
Y-axis: $-\Delta$ Daily Energy (%)

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Performance Maps

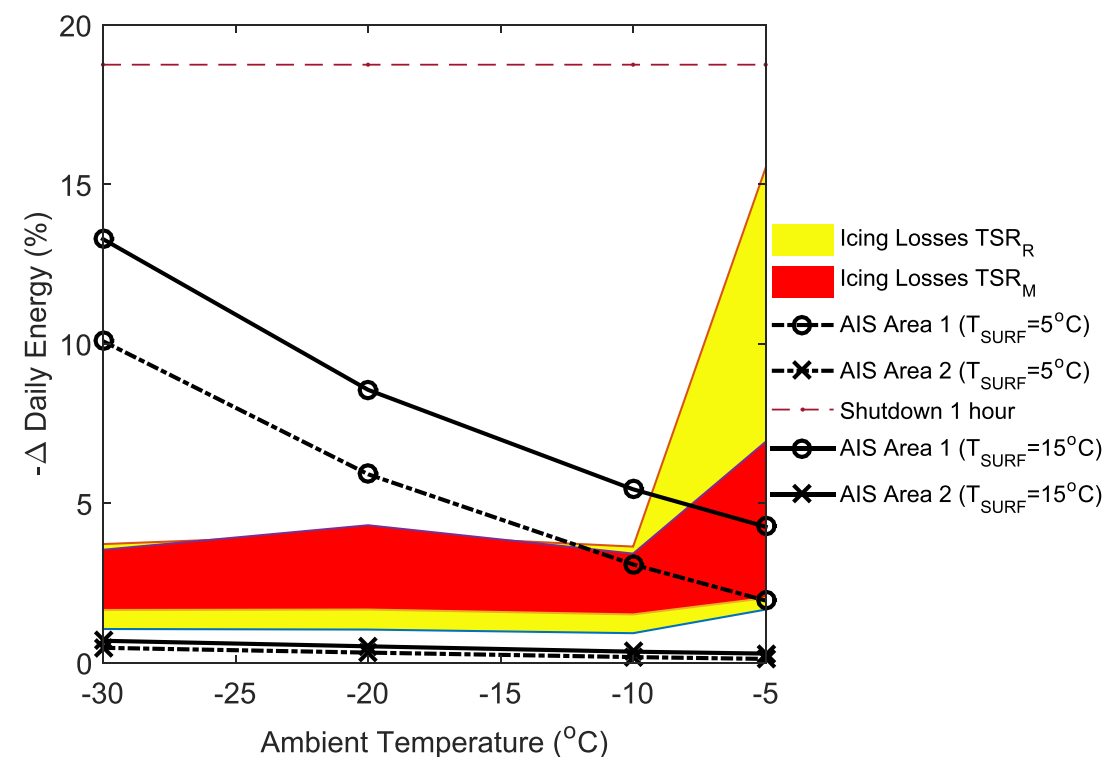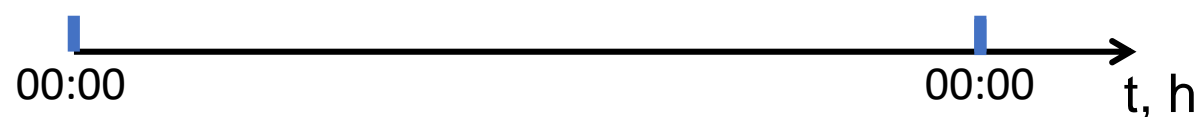- Reduced wind speed same icing parameters and ice duration
- Same wind speed, milder icing parameters and 4-hour long event

Wind Speed of 7ms⁻¹, t_{ICE} = 1 hour

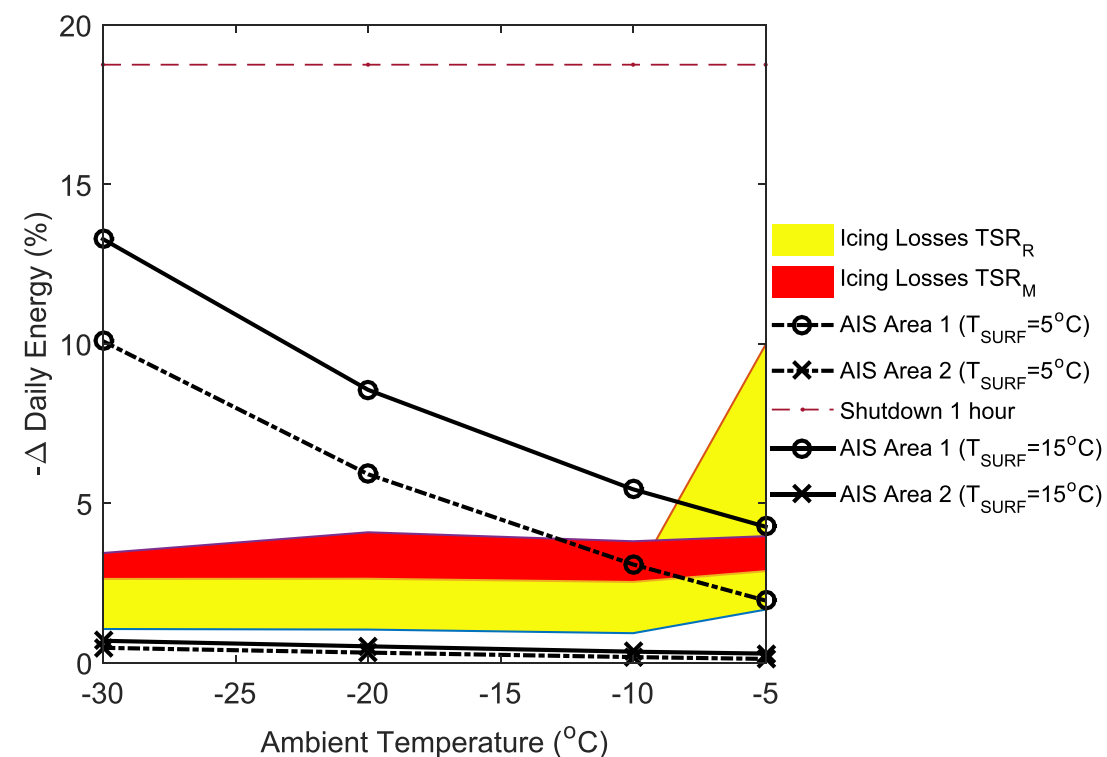Wind Speed of 10ms⁻¹, t_{ICE}= 4h hours

Performance Maps

- Importance of ice reduction algorithms and modelling for 4-hour long icing event

- If icing event starts at 00:00h– Lost Energy is **6.7**%, TSR_M for >-10°C, AIS for > -5°C ⬅

- If icing event starts at 12:00h-Lost Energy is **3.4**%, TSR_M for >-5°C, AIS for > -5°C

- If icing event starts at 18:00h-Lost Energy is **1.7**%, TSR_M leads to no changes, AIS for > -5°C
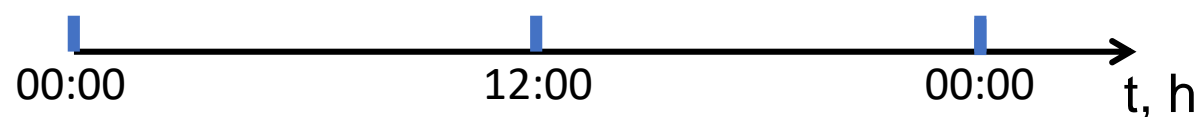
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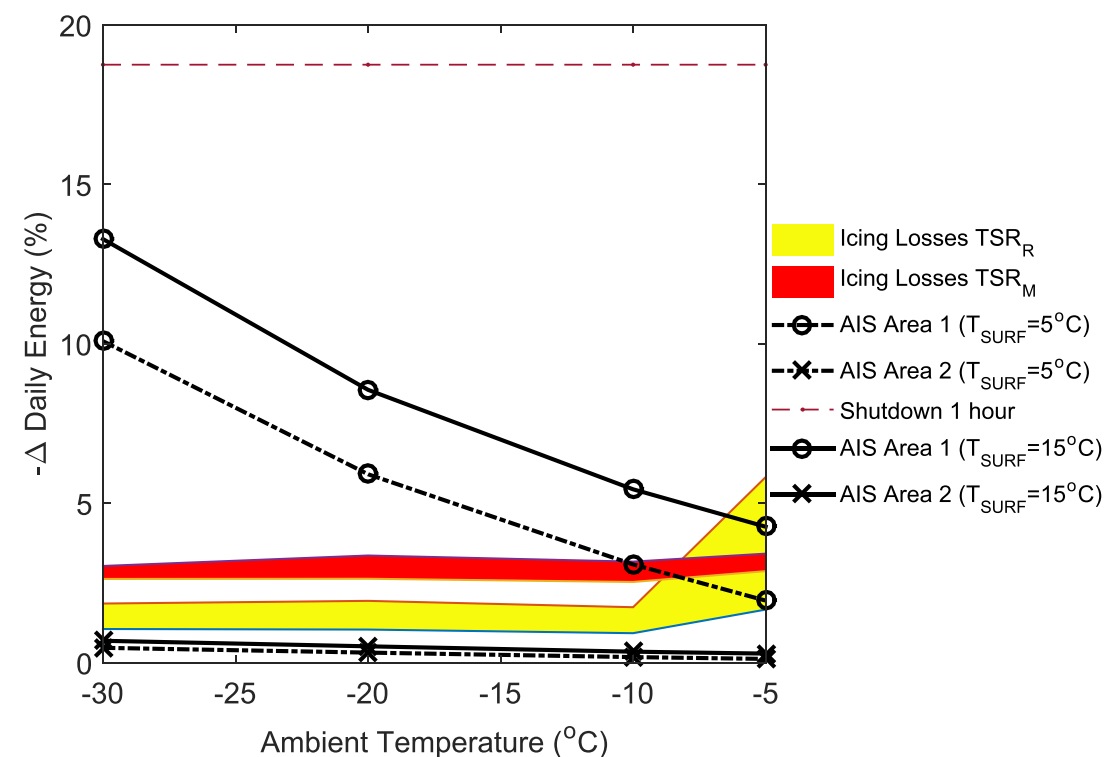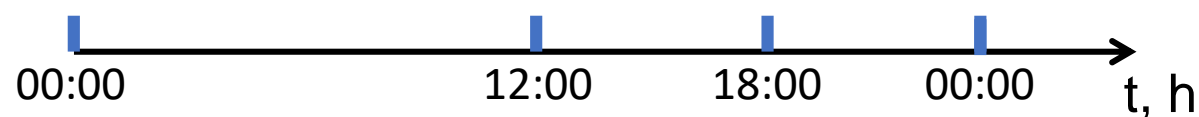
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29/01/2020

Sensitivity to Modelling Input

NACA 64-618 performance degradation due to icing for two Re numbers

- XFoil can overpredicts losses

- Fluent k-w SST turbulence model provides closer estimates

- For operational Re numbers XFoil and Fluent are in 50% agreement. (Unfavourable geometry for XFoil)

- For smoother shapes XFoil performs better and provides more consistent results than for a abrupt ice shapes

Re 160,000
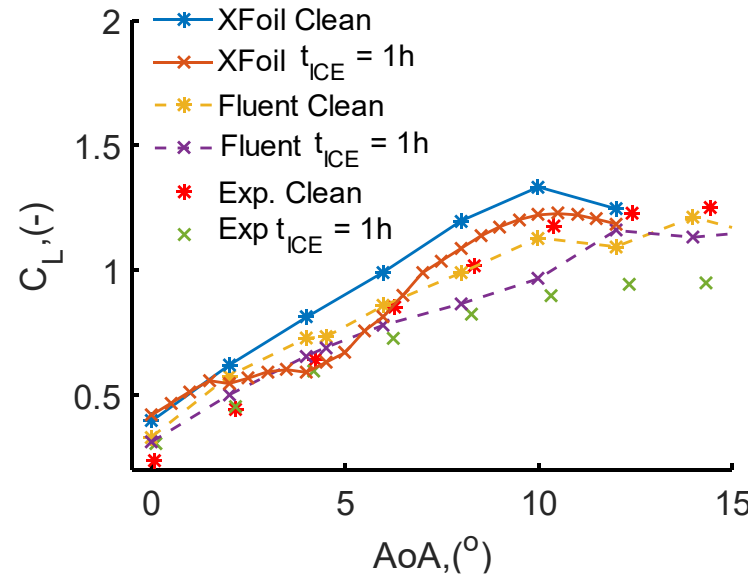
Re 6,000,000

$C_{L4.5°}$	Clean	t_{1h}	$-\Delta$, %
Exp.	0.64	0.62	3.13
Fluent	0.73	0.689	5.62
XFoil	0.84	0.629	25.12
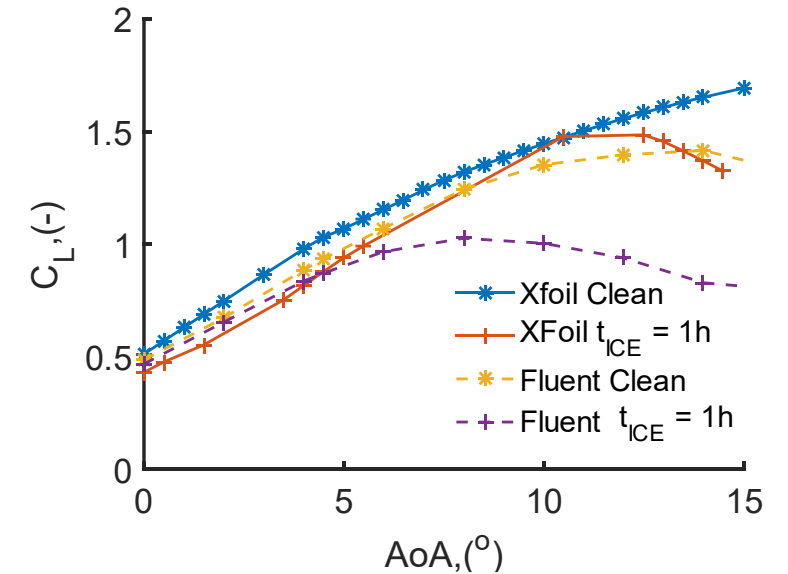
$C_{L4.5°}$	Clean	t_{1h}	$-\Delta$, %
XFoil	1.03	0.877	15
Fluent	0.934	0.840	10

Advantages

- Every ice mitigation strategy can be considered

- Eased comparison of different strategies

- Graphs can be represented in 3D showing the envelopes of operation by including variation in wind speed

- Margins between icing losses and different strategies can be used for defining areas of interest for higher fidelity analysis

- Limiting value can be used for optimisation procedures

- Different tools for analysis can be combined to convey such analysis

- The current method provides fast preliminary results

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Thank you!

Tack så mycket!