Benchmark study of Icing Forecasts
Do they add value?

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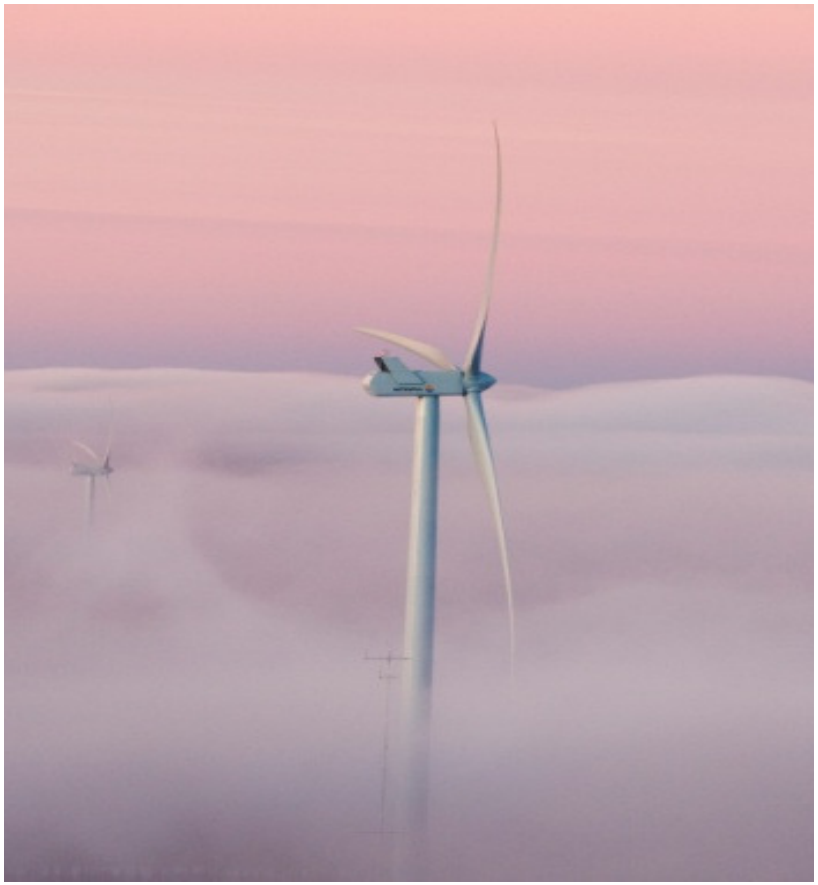
Outline

- Background / project motivation
- Description of benchmark study
- Icing during benchmark period
- Performance of day ahead icing forecasts for Power
- Performance of day ahead categorical icing forecasts
- Conclusions



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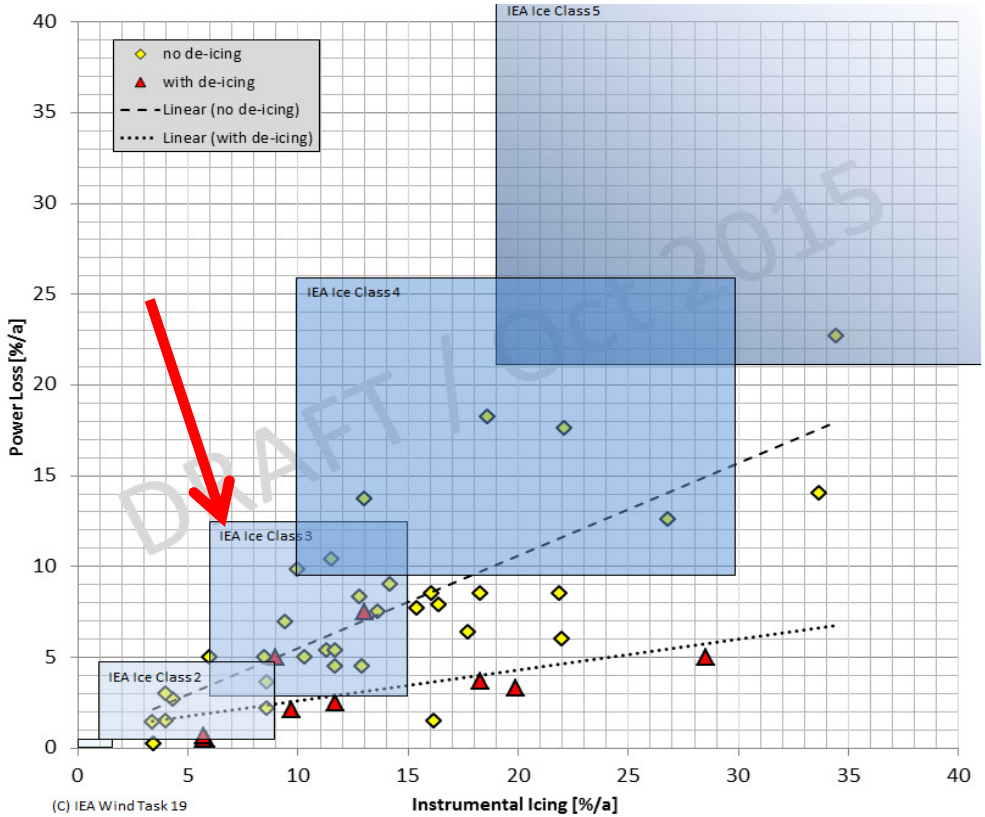
Background: Stor-Rotliden Wind Farm

- IEA Ice Class 3 Site with 40 Vestas V90 Wind Turbines (No de/anti-icing)
- Large imbalance costs observed during winters (2010-2015)
- Poor planning reported by O&M maintenance staff → standard weather forecasts do not report icing events



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Project Motivation

- Recent development of icing models – production loss models
  - Max. 5 years, have matured since.
  - Capture reasonably well magnitude of losses in prognosis mode
  - Only isolated studies of performance for icing forecasts
  - No independent icing forecast model benchmark (blind test) done so far

- Aim of the study:
  - Analyse day-ahead icing forecast performance during winter at Stor-Rotliden
  - Analyse the skill of deterministic/categorical icing forecast
  - Characterise icing forecast variability
  - Potential for being used operationally?

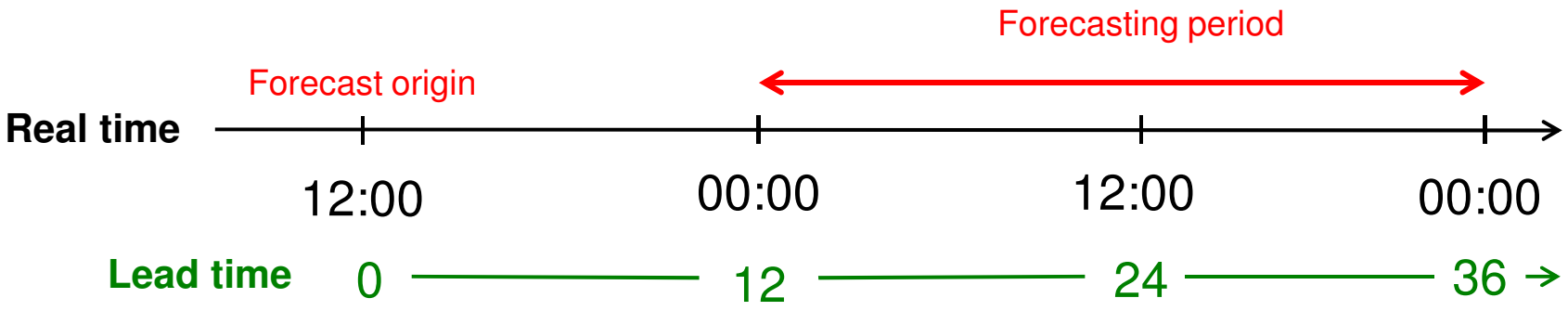
Description of Benchmark study (1/3)

- **PARTICIPANTS:**
  - 6 different icing forecasts provided by different suppliers → Type A
  - 1 standard forecast output ('ensemble forecast') → Type B
  - 3 Baseline models

	Type A	Type B	Baseline models
Icing Modelling	Physical + Statistical	Purely Statistical	Purely Statistical
Number	6	1	3
Features	- Modelled prod. losses - Icing warnings	- No modelled prod. losses - Can be an ensemble - No icing warnings	- Simple models - Based on SCADA data - Provide Skill threshold

Description of Benchmark study (2/3)

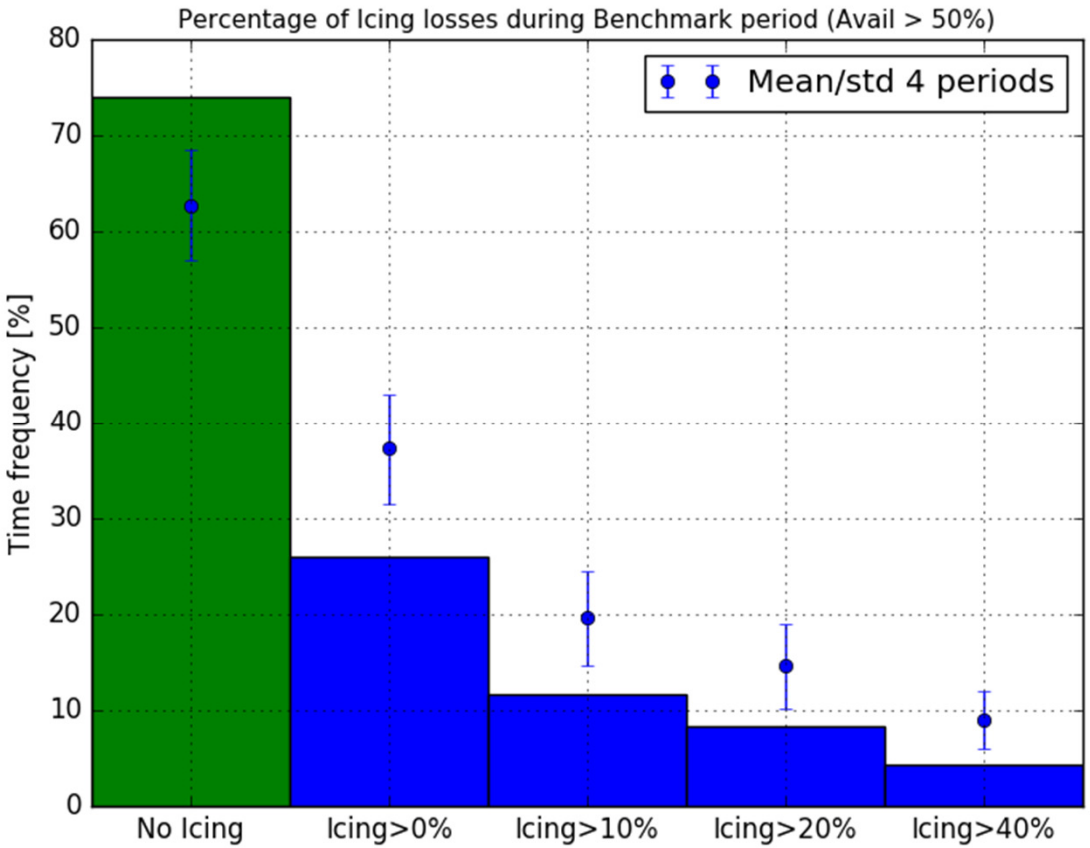
- **Some definitions**:
  - Forecast origin: Time at which forecast is issued to TSO (12-noon).
  - Forecasting period: Period of hours forecasted
  - Lead time: Time difference between forecasting period and forecast origin.



  - Baseline models:
    - Persistence: Power at Forecast origin = Power during Forecasting period
    - Climatology: Mean Power of last week = Power during Forecasting period
    - Weekly Diurnal: Hourly Mean Power of the past week = Hourly Power in F. period

Description of Benchmark study (3/3)

- Period of study and icing severity:
  - Production losses due to icing computed using IEA T19 Ice Loss Method [1]
  - Less icing than average during same period on the past 4 years



Period of study

(15/02/2015 – 13/05/2015)
(10-10-2015 – 25/01/2016)
~ 6.5 months

[1] www.ieawind.org/task_19

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Performance of day ahead icing forecasts for Power

- **Approach:** Data filtering strategy focused on icing severity
  - Applying 5 different data filters
  - Analysis of NMAE, NRMSE and NBE
  - Overall Performance and over leadtime

Selection name	Per. Production losses [%]	Availability [%]
All	>= 0	>50
Icing>0	> 0	>50
Icing>10%	> 10	>50
Icing>20%	> 20	>50
Icing>40%	> 40	>50

- Data corrections:
  - Power data → hourly averaged & normalized with Available Power Cap.
  - Forecasts → Corrected to account for availability

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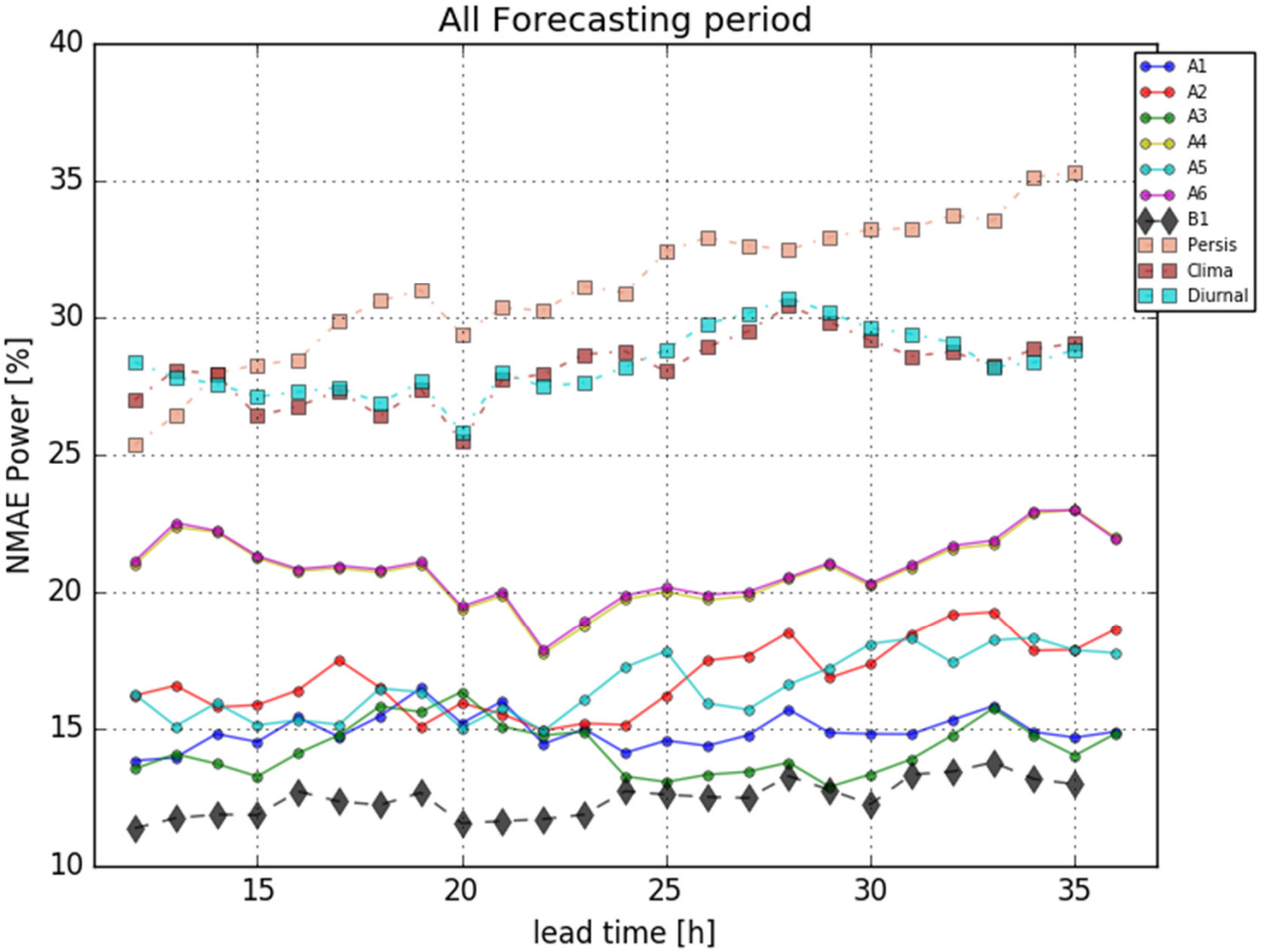
Results for NMAE (’All’)



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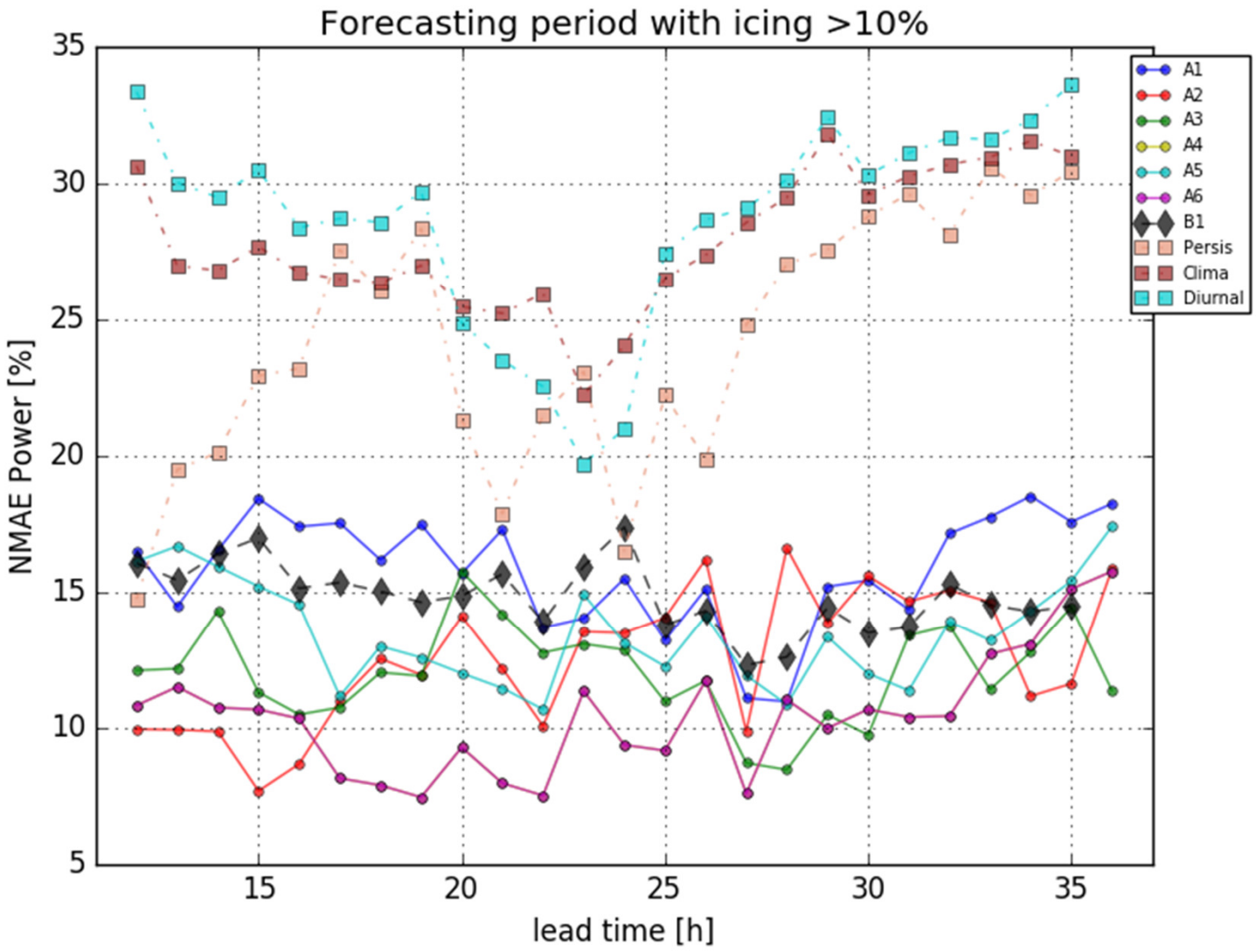
Results for NMAE (Icing>10%)



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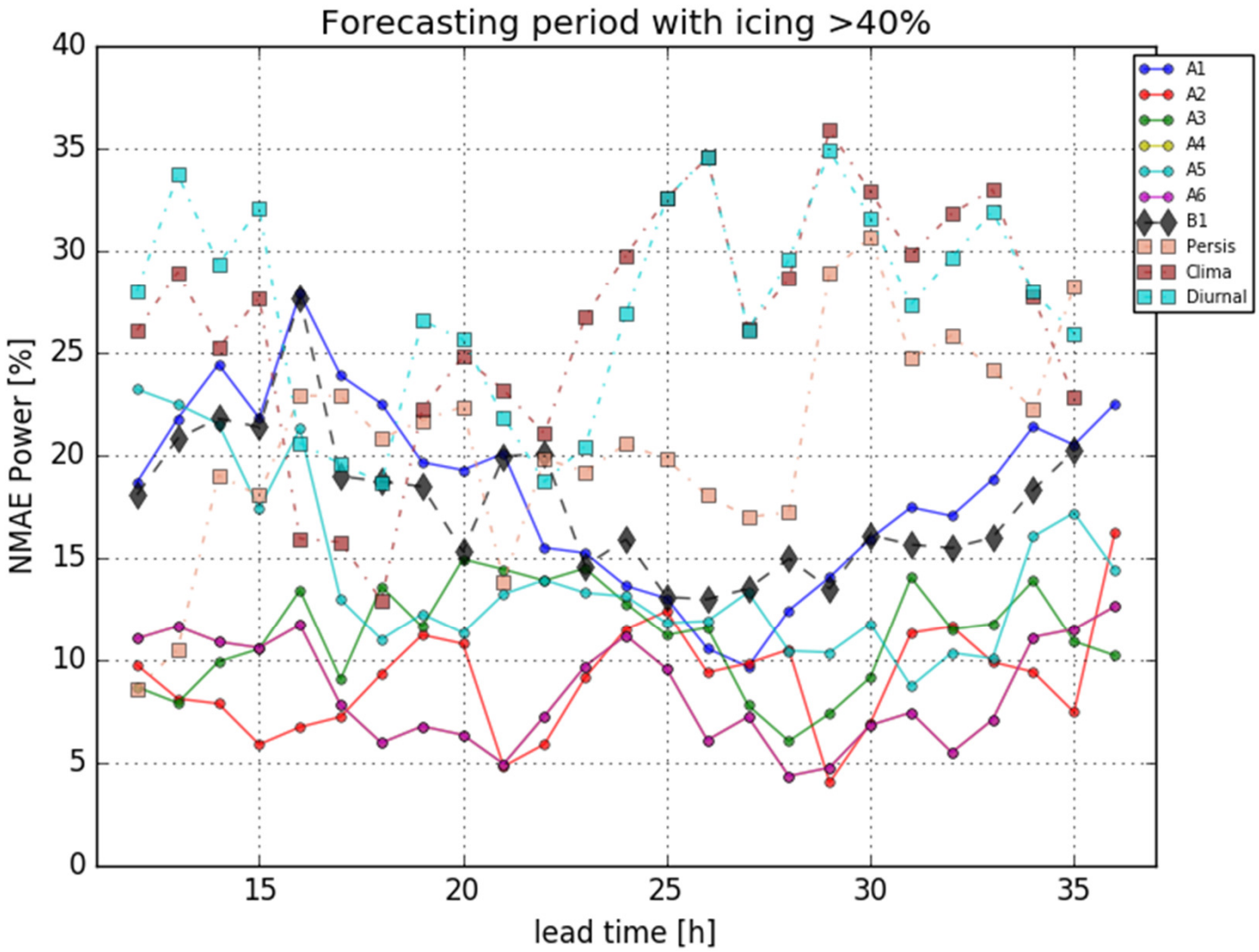
Results for NMAE (Icing>40%)



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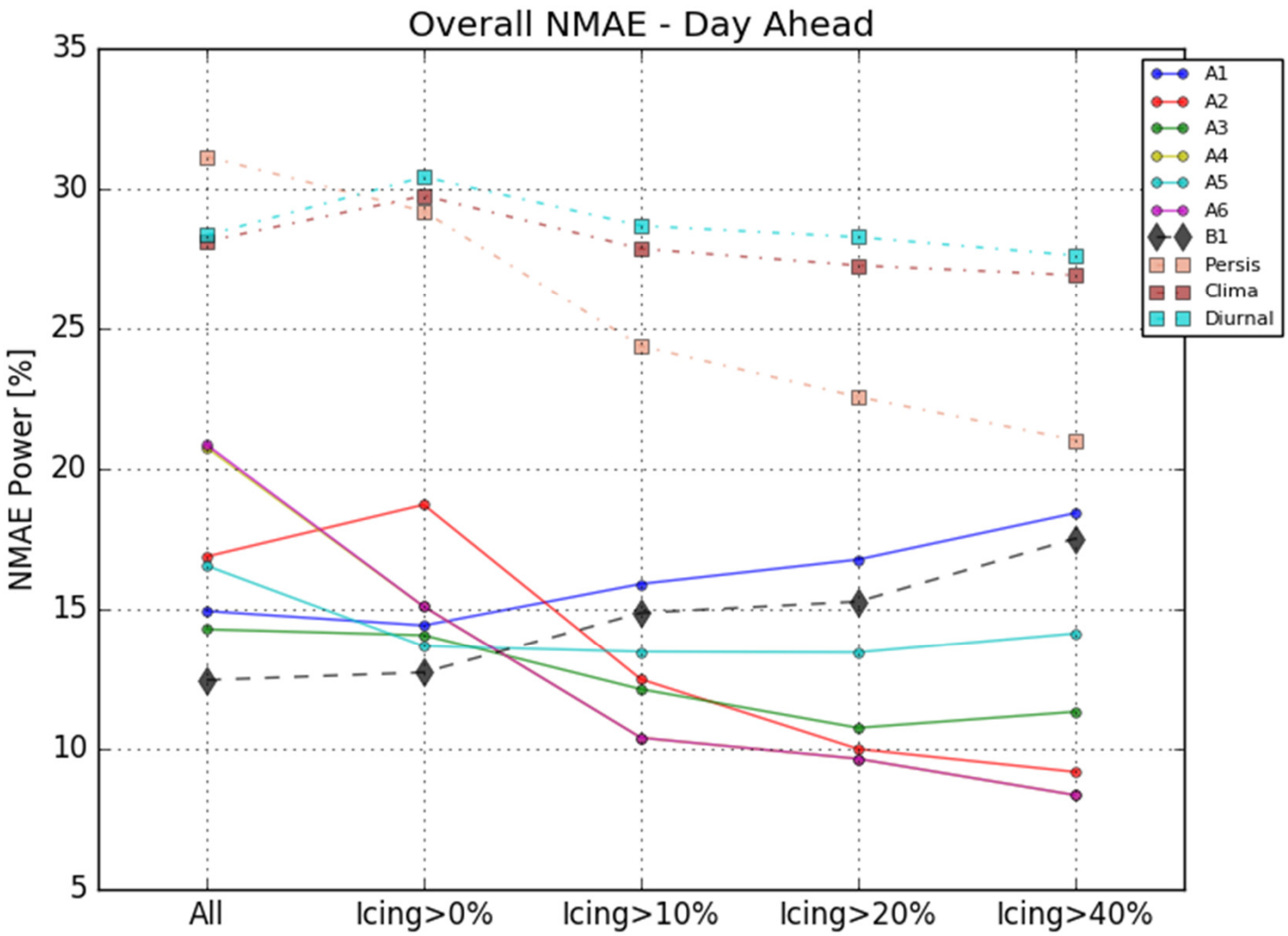
Summary of overall NMAE during Icing



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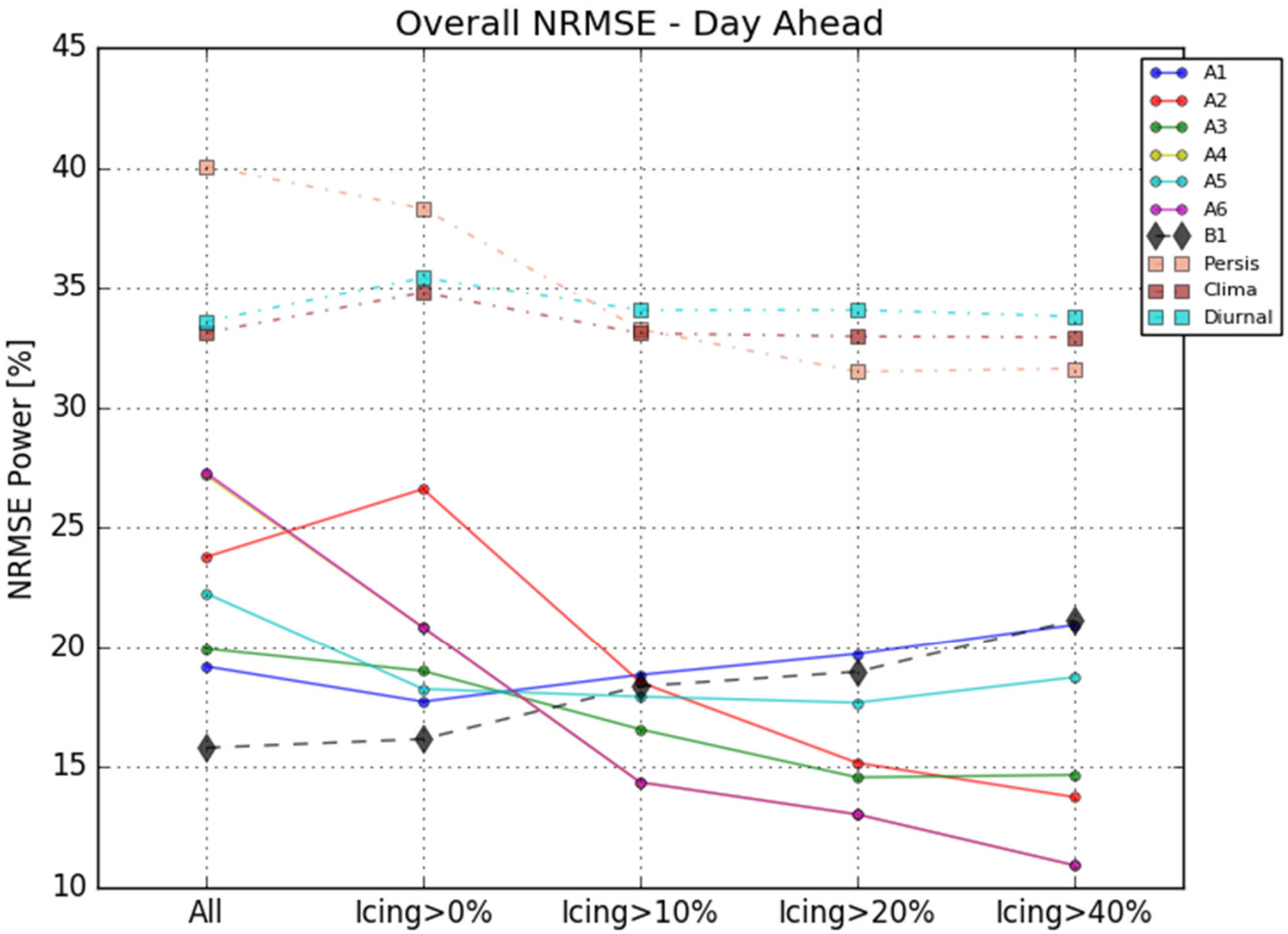
Summary of overall NRMSE during Icing



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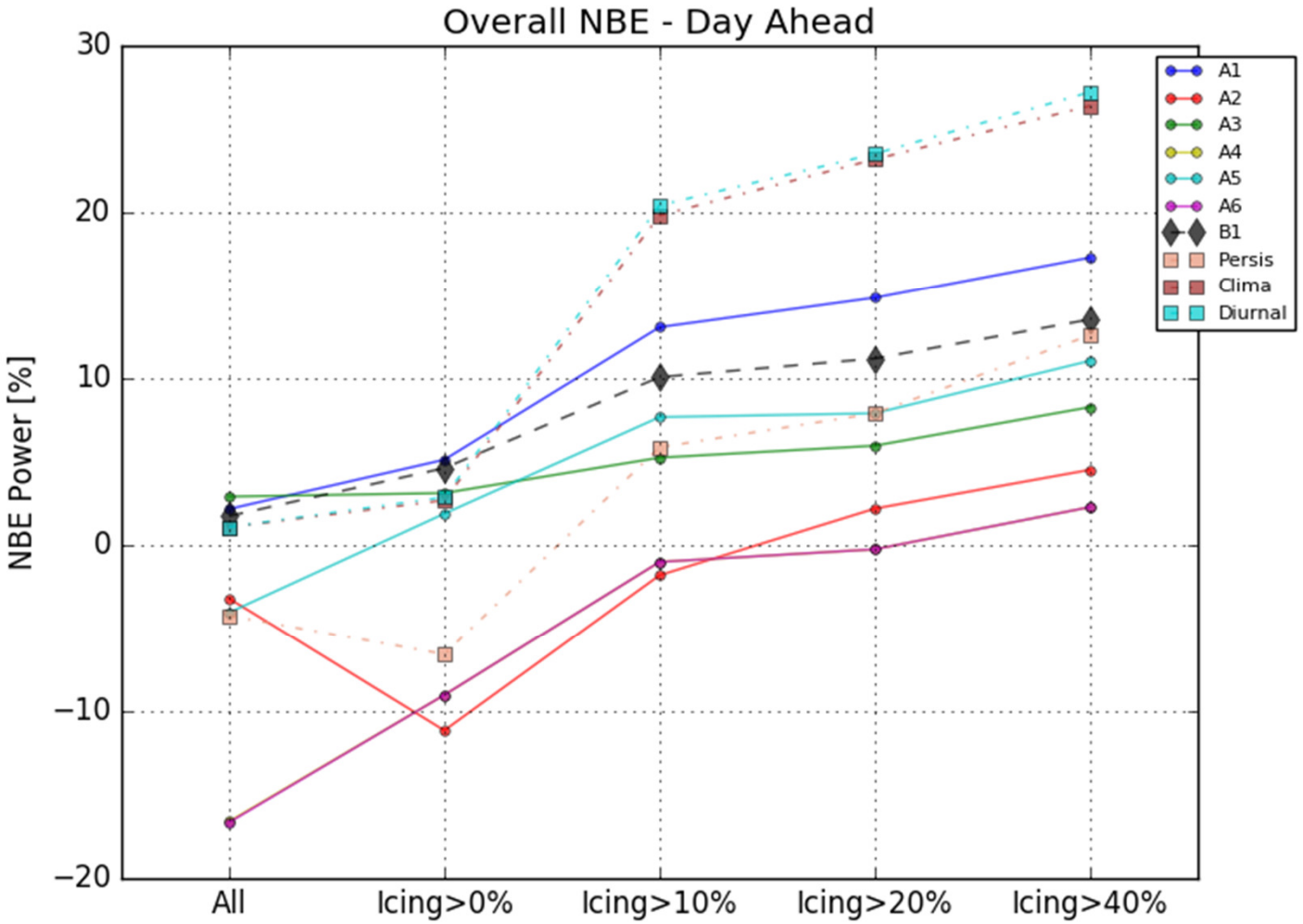
Summary of overall NBE during Icing

- Forecasts still tend to be positivily bias (overestimation of power) during icing



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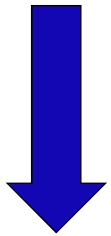
Conclusions (1) : Icing Forecasts for power – day ahead

- Icing forecast perform better when we know there will be icing during the coming day
- Focus: Finding the best proxy for determining possible icing conditions for the next day
- Strategy: Minimize false alarms and being Conservative



There is potential for using icing forecasts operationally

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Performance of day ahead categorical icing forecasts

- Goal: Evaluate correct detection of ice during all forecasting period (Icing – No Icing)

Event forecast	Event observed		
	Yes	No	Marginal total
Yes	a	b	a + b
No	c	d	c + d
Marginal total	a + c	b + d	a + b + c + d = n

a = hit
b = false alarm
c = miss
d = correct non-event

H = a / (a + c) = hit-rate
F = b / (b + d) = false alarm rate

Hanssen Kuipper Skill Score (KSS)
KSS = H - F

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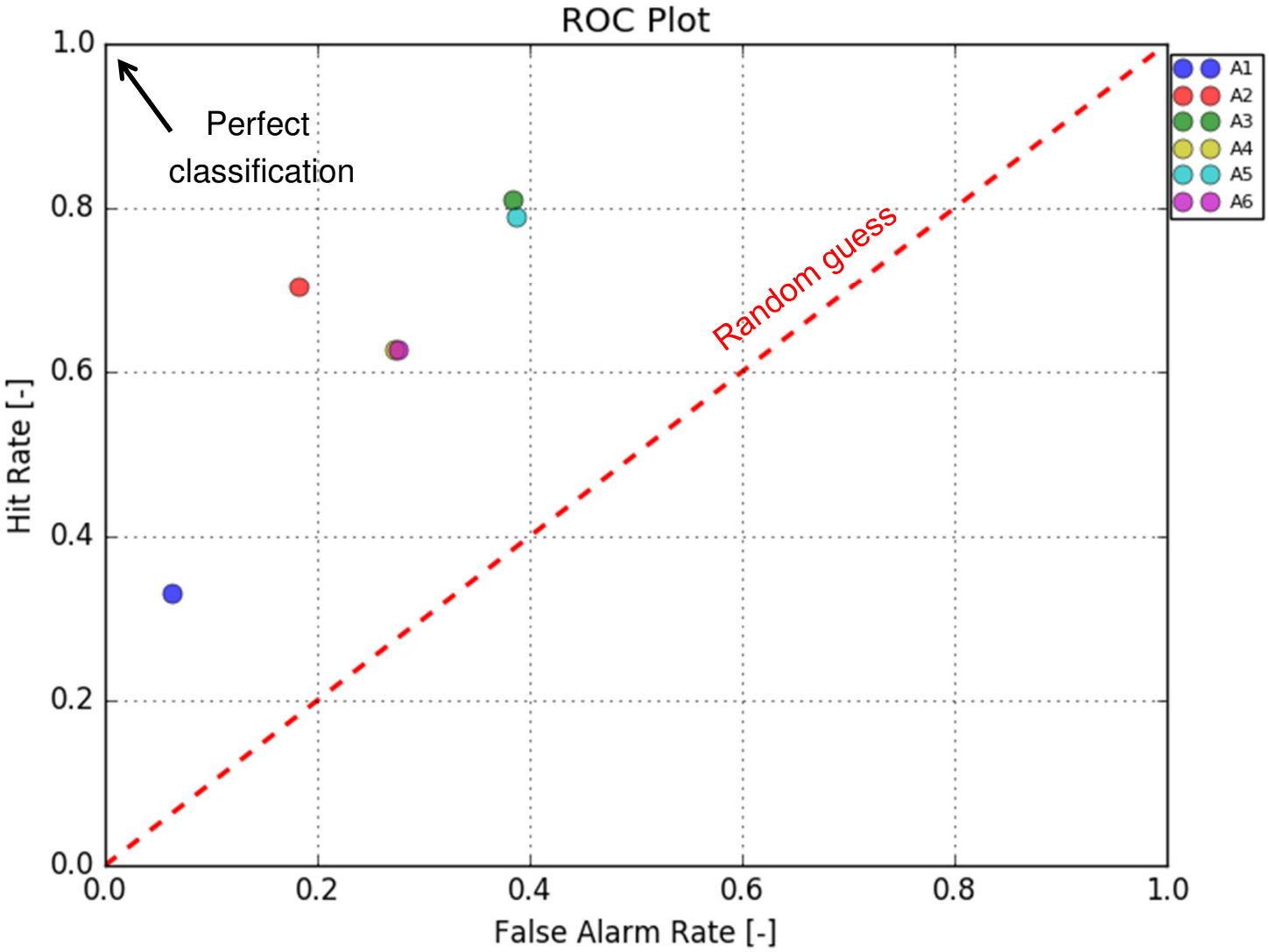
Results: Categorical Icing Forecasts



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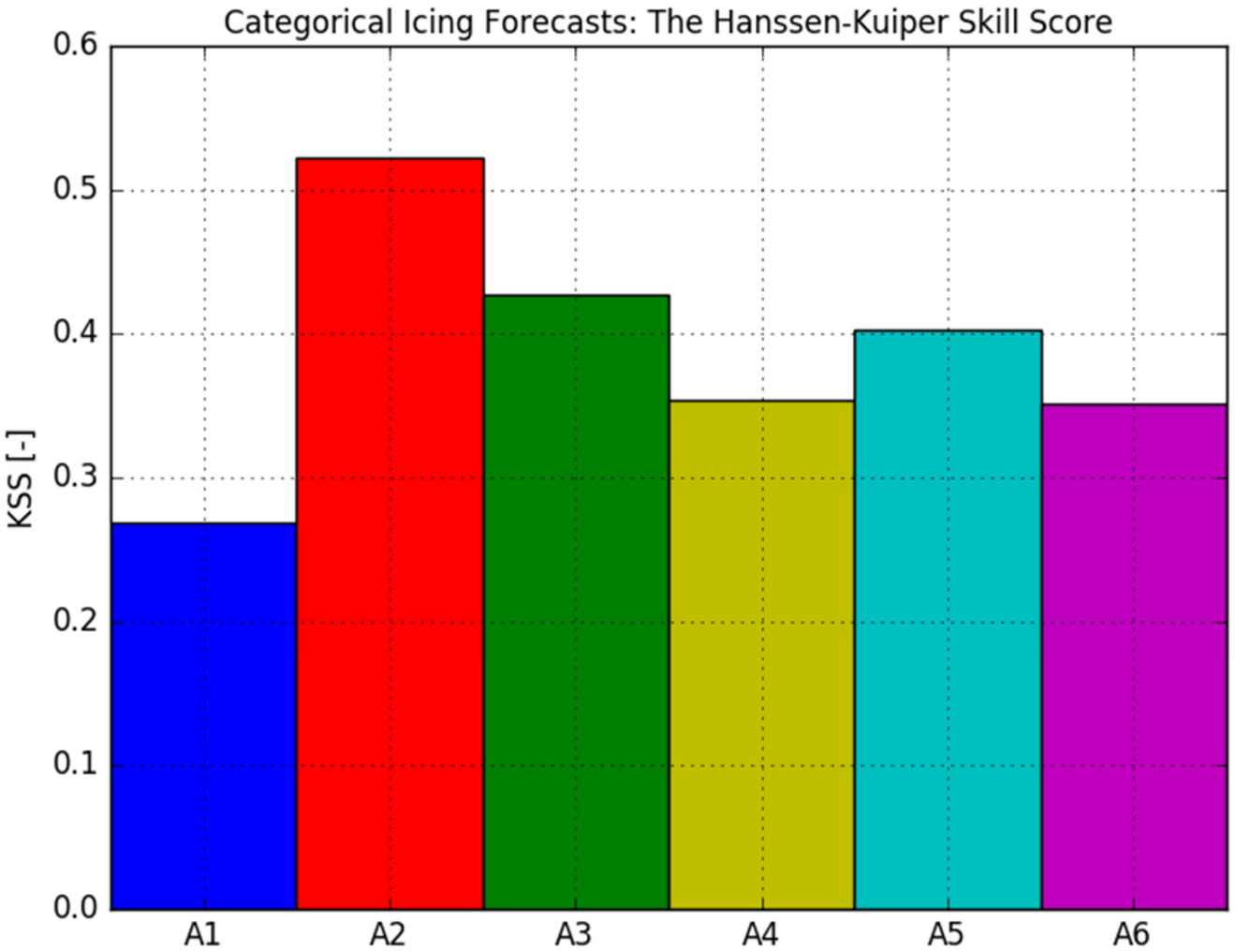
Results: Categorical Icing Forecasts



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Conclusions (2): Categorical icing forecast

- Icing forecasts have ‘some’ skill in determining icing conditions
  - They are still not perfect!

- Somewhat large variability between models
  - False alarm rate ranging from **7% to 39%**
  - Hit rate ranging from **33% to 81%**

- Efforts still to be made for determining the best possible proxy for icing
  - A Probabilitic approach seems the most reasonable
  - Essencial for finding the best weighing strategy for forecasting Power

THANK YOU FOR YOUR ATTENTION !

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