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Validation of modelled instrumental icing with mast measurements

Ville Lehtomäki, Mona Kurppa

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Validation of modelled temperature and instrumental icing with mast measurements

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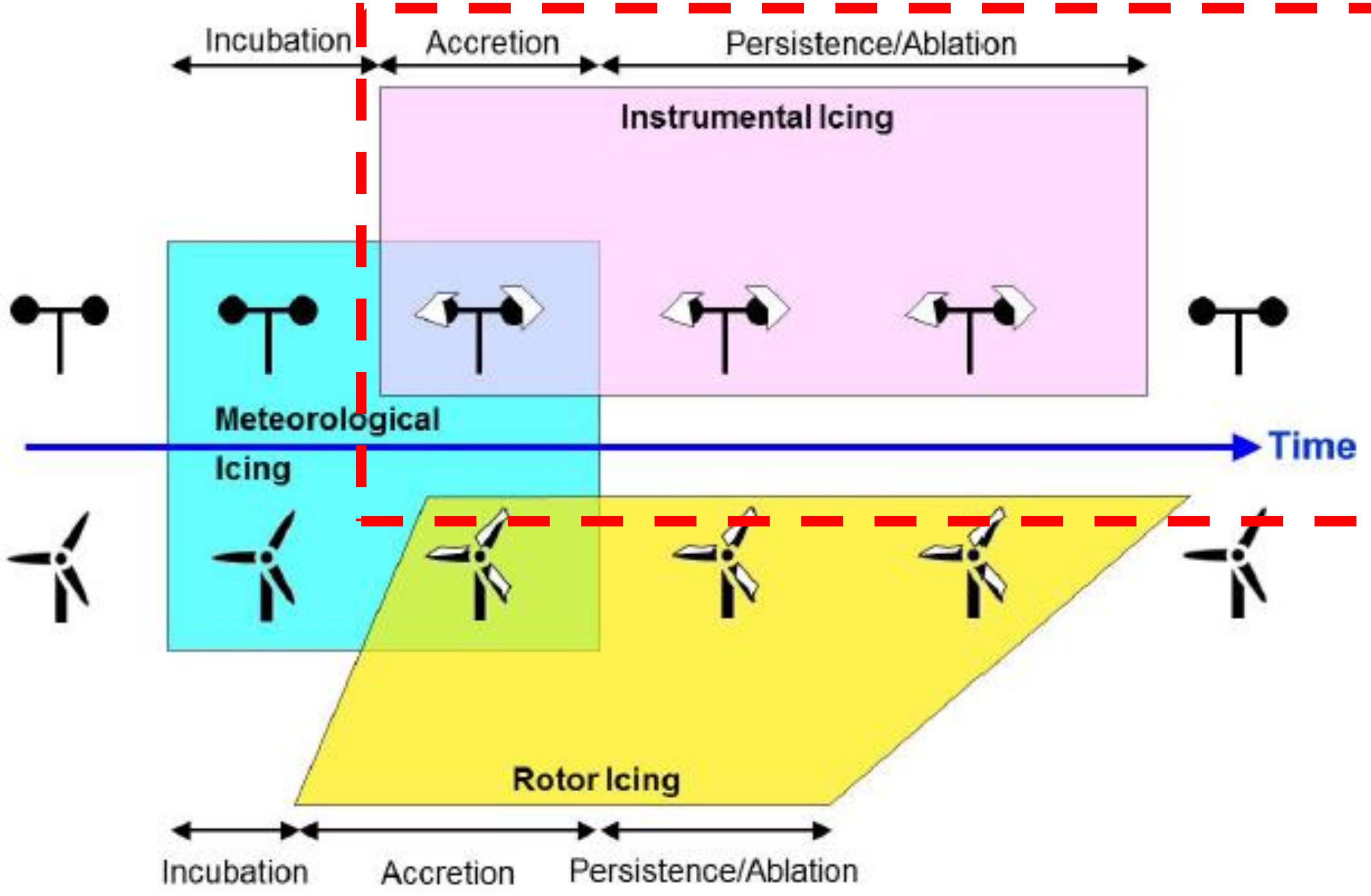
Outline

- Introduction
- Datasets
- Results
  - Temperature validation
  - Instrumental icing validation
- Summary & conclusions

Basics: Icing event

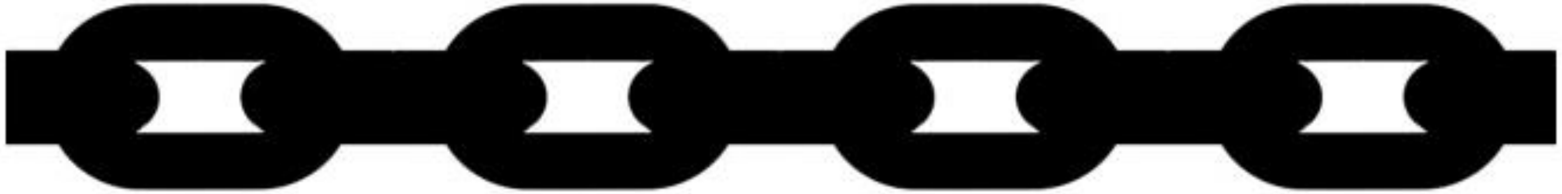


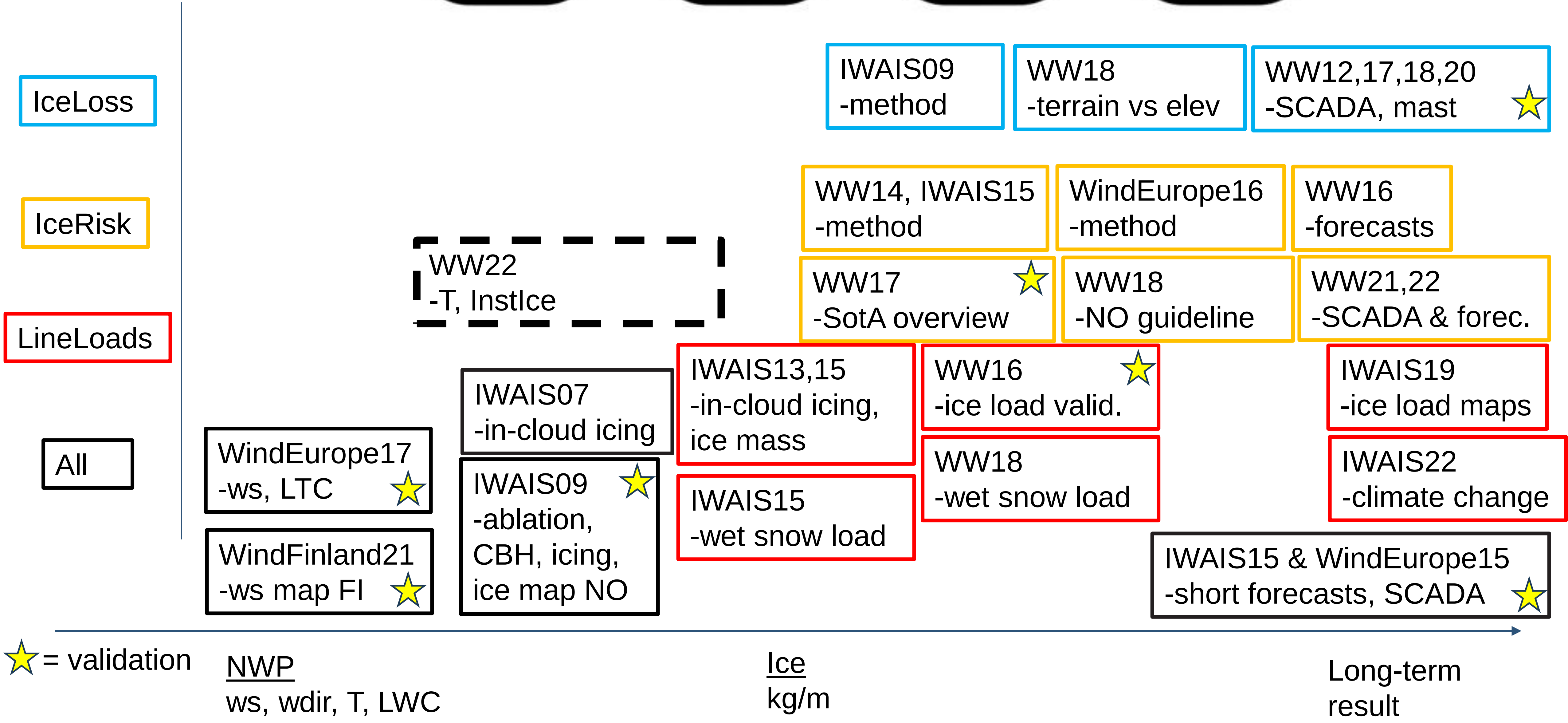
Source: IEA wind Task 19: Recommended Practices for 13. Wind Energy in Cold Climates, 2 Edition 2017

Motivation: Why is icing model validation important?

- Big temperature bias = poor icing results
- No ice = no icing loss / ice throw
- Too much ice = too much icing loss / ice throw
- Model chain: Increases confidence for icing predictions

Model chain




IceLoss
IceRisk
LineLoads
All
IWAIS09
-method
WW18
-terrain vs elev
WW12,17,18,20
-SCADA, mast
WW14, IWAIS15
-method
WindEurope16
-method
WW16
-forecasts
WW22
-T, InstIce
WW17
-SotA overview
WW18
-NO guideline
WW21,22
-SCADA & forec.
IWAIS07
-in-cloud icing
IWAIS13,15
-in-cloud icing,
ice mass
WW16
-ice load valid.
IWAIS19
-ice load maps
WindEurope17
-ws, LTC
IWAIS09
-ablation,
CBH, icing,
ice map NO
WW18
-wet snow load
IWAIS22
-climate change
IWAIS15
-wet snow load
WindFinland21
-ws map FI
IWAIS15 & WindEurope15
-short forecasts, SCADA
= validation
NWP
ws, wdir, T, LWC
Ice
kg/m
Long-term
result

A story on modelling…

All models are wrong

until proven otherwise

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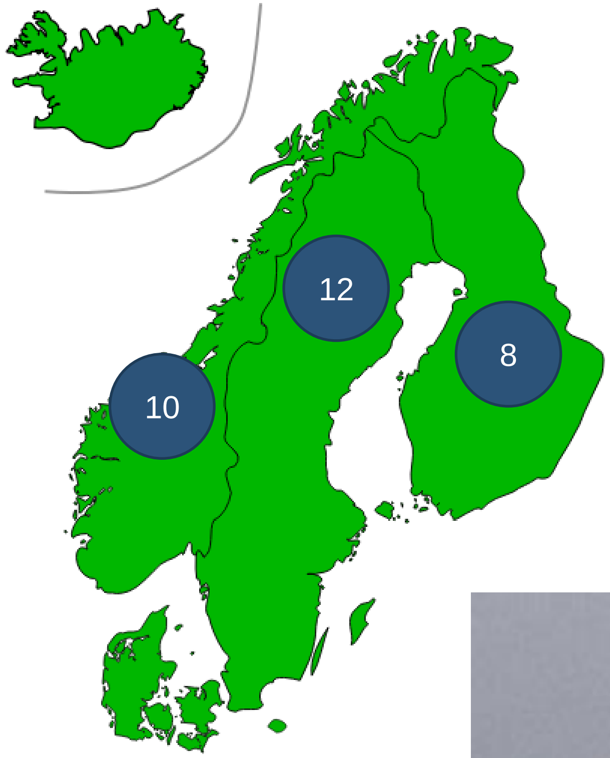
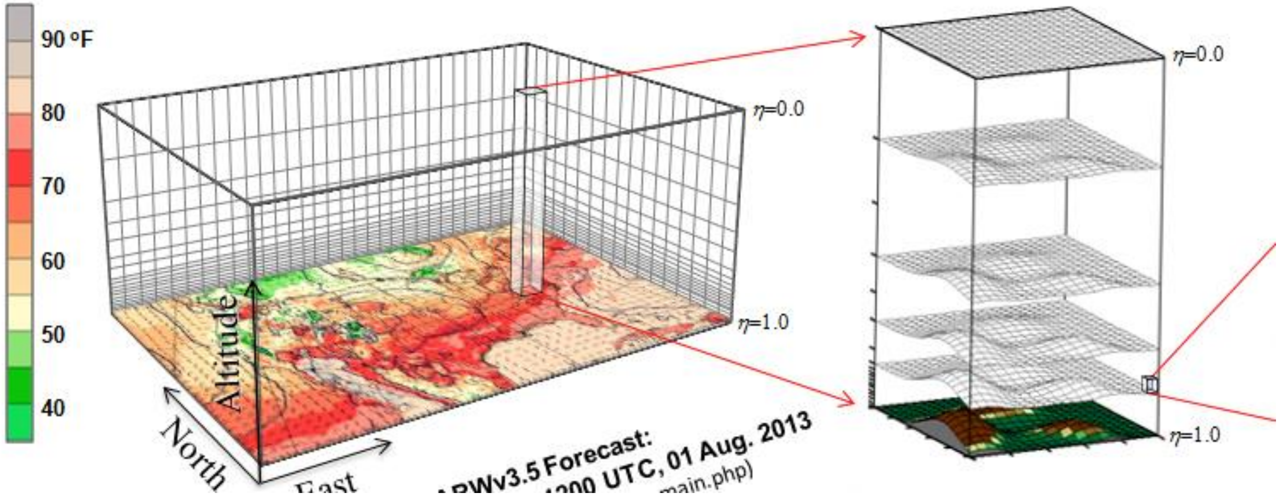
Met mast overview



N=30 met masts	Range
Measurement period	2004-2021
Measurement dur.	1-10 years
Elevation	30-700 m ASL
Height	80-140 m AGL

Simulation model



WRF mesoscale weather model

- Weather Research and Forecast v3.8.1
- 4 x 4 km (1 x 1 km ws, wdir, LWC adjustment)
- Thompson cloud microphysics
- ISO 12494 ice accretion + ice ablation model

Hindcasts = long-term history

- Hindcasts are carried out to create historical data
- Hourly data from 1979 until recently
- Updated on a daily or monthly basis
- Used at KVT since 2006

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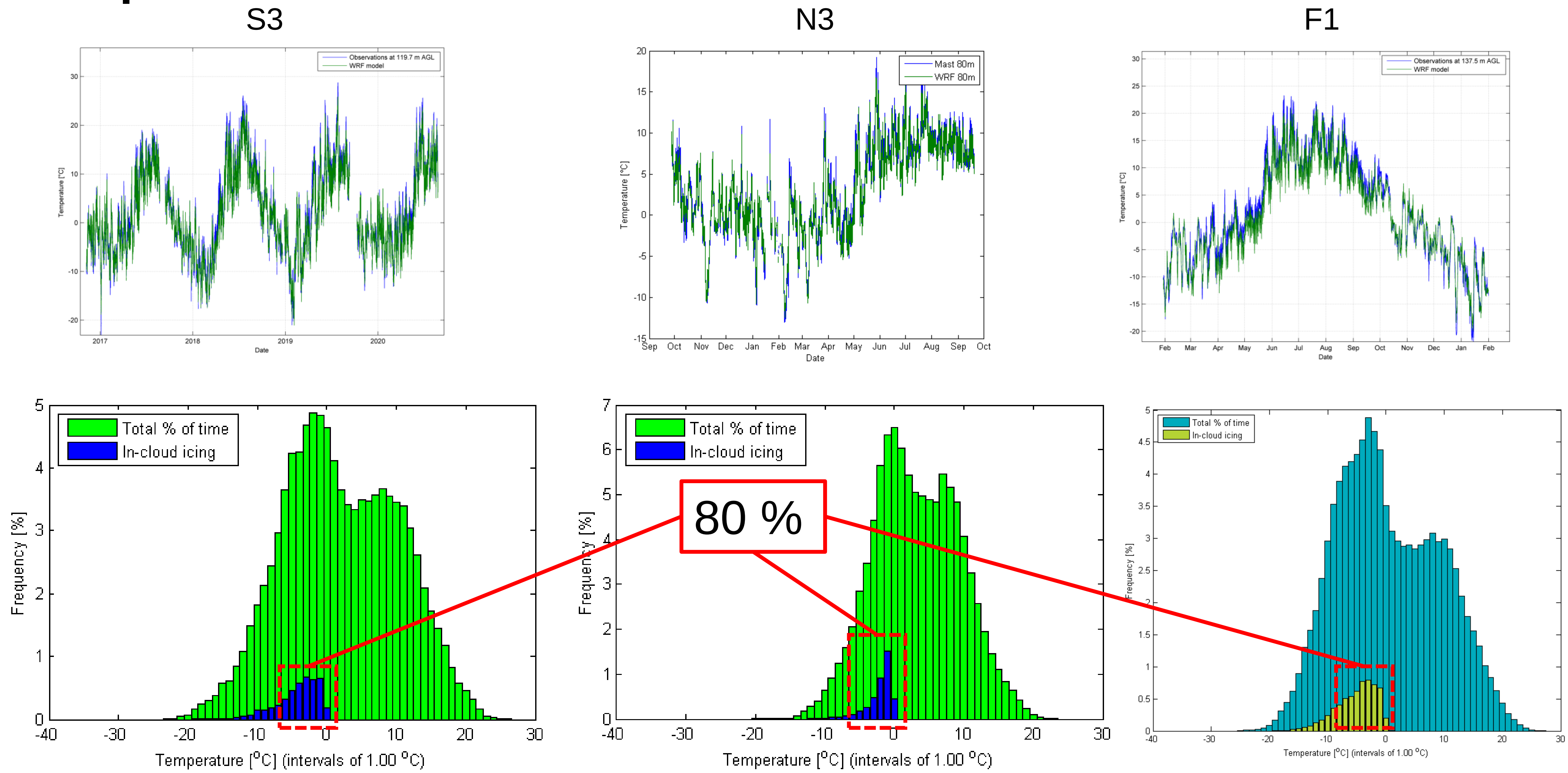
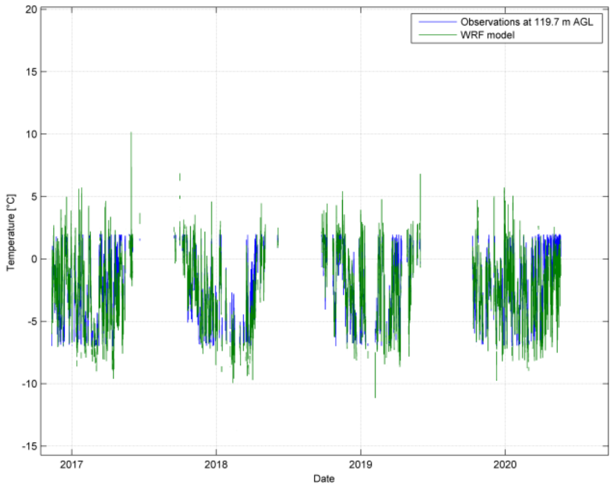
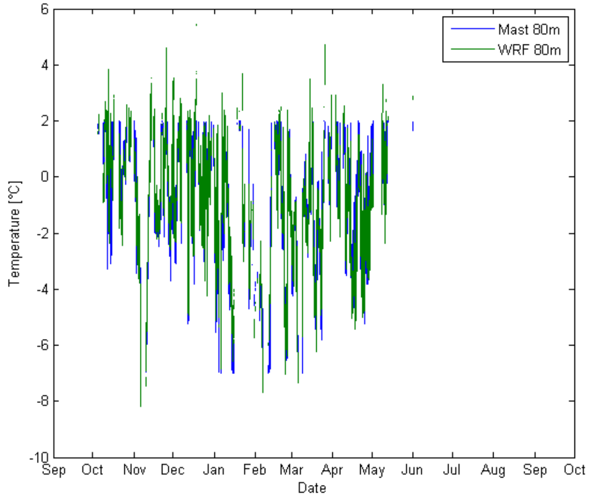
Temperature validation

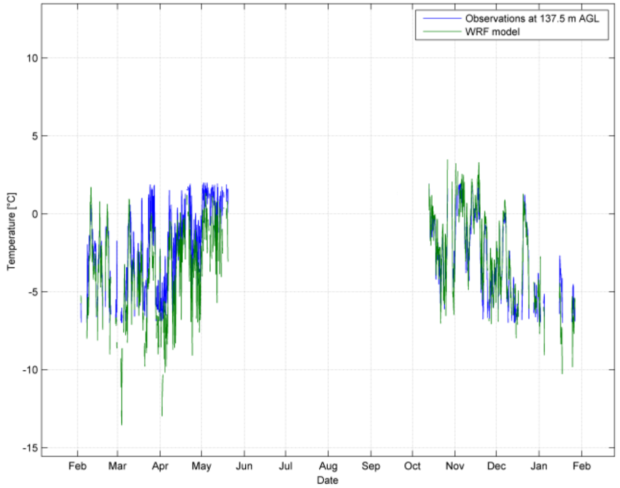


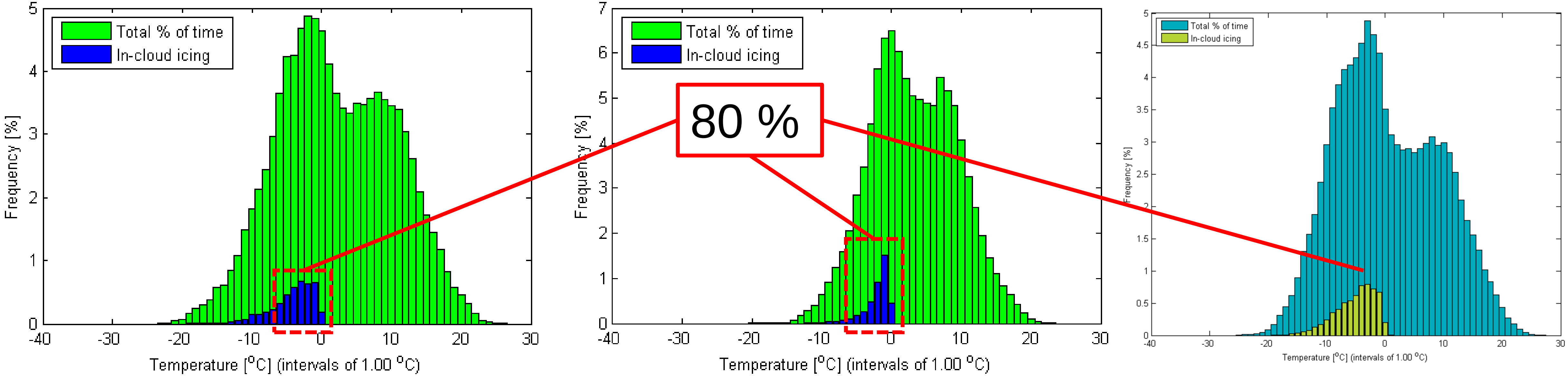
Temperature validation: -7 °C ≤ T ≤ + 2°C

S3	N3	F1

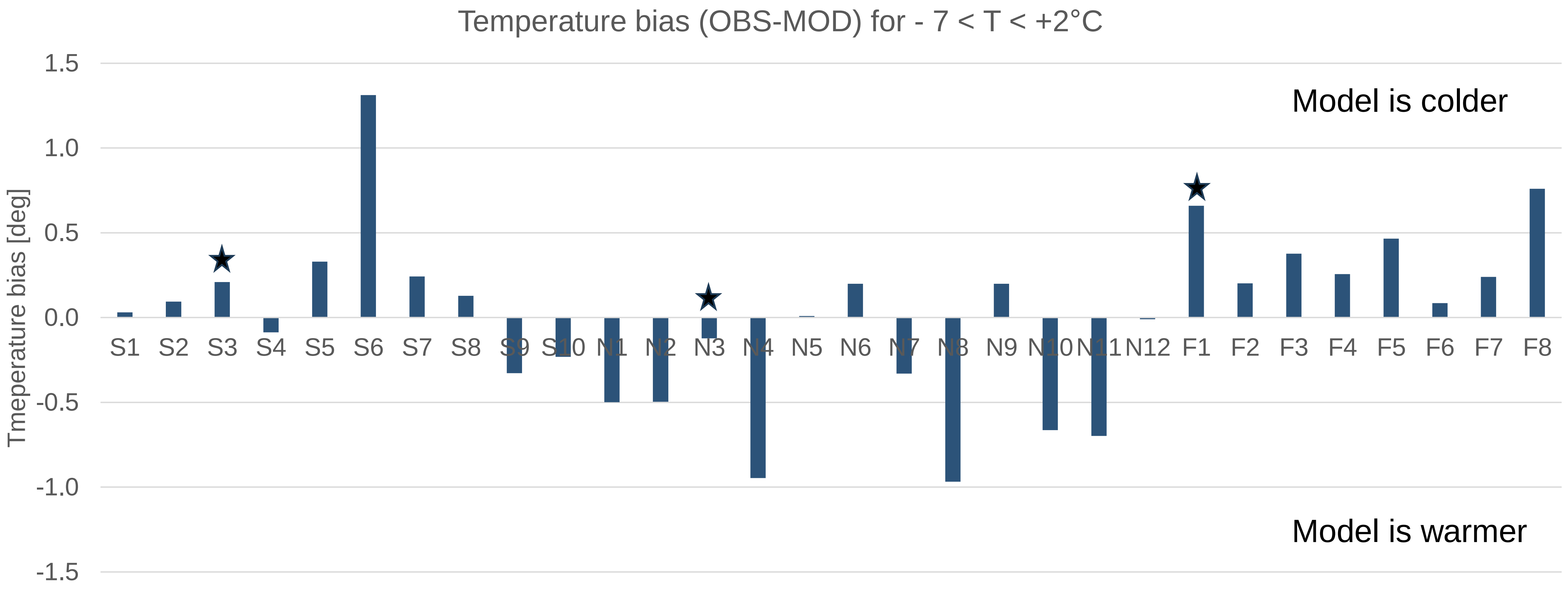








Temperature validation: model bias



±0.2 °C is typical measurement uncertainty

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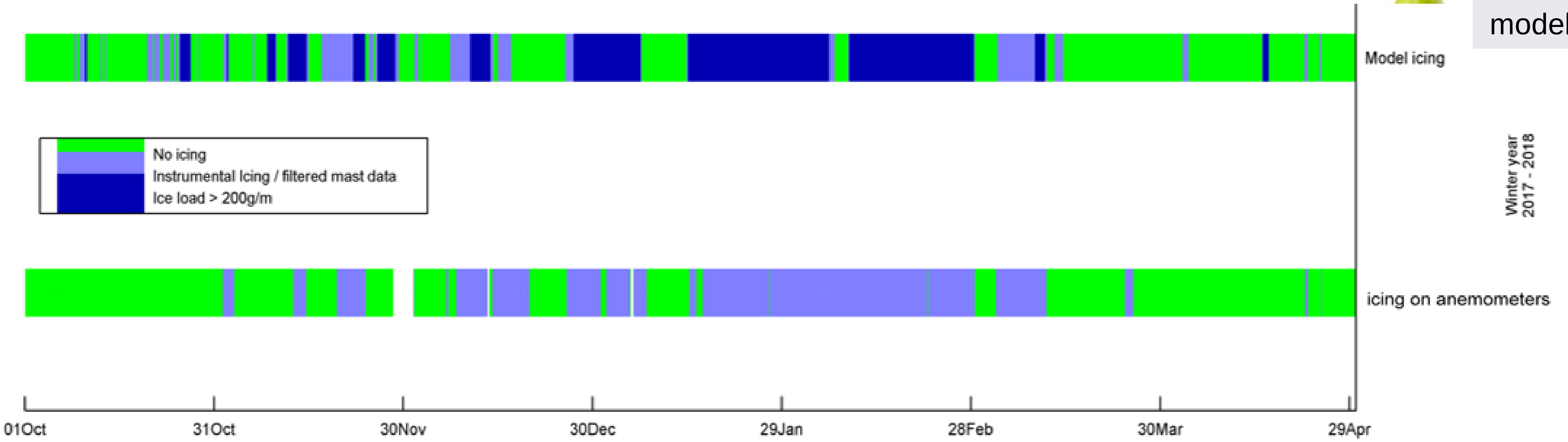
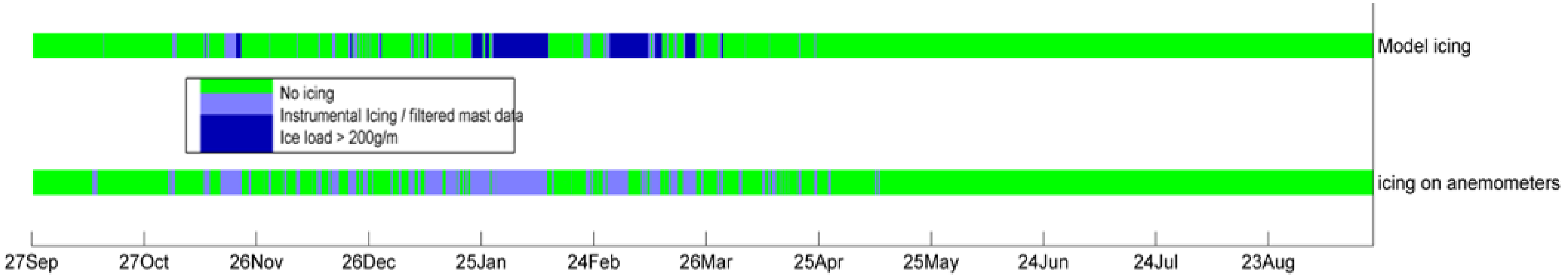
Instrumental icing validation

	Instrumental icing
Met mast	Non-heated cup vs heated sonic Statistical ratio & T < 3°C
WRF model	ISO 12494 method Ice mass > 10 g/m

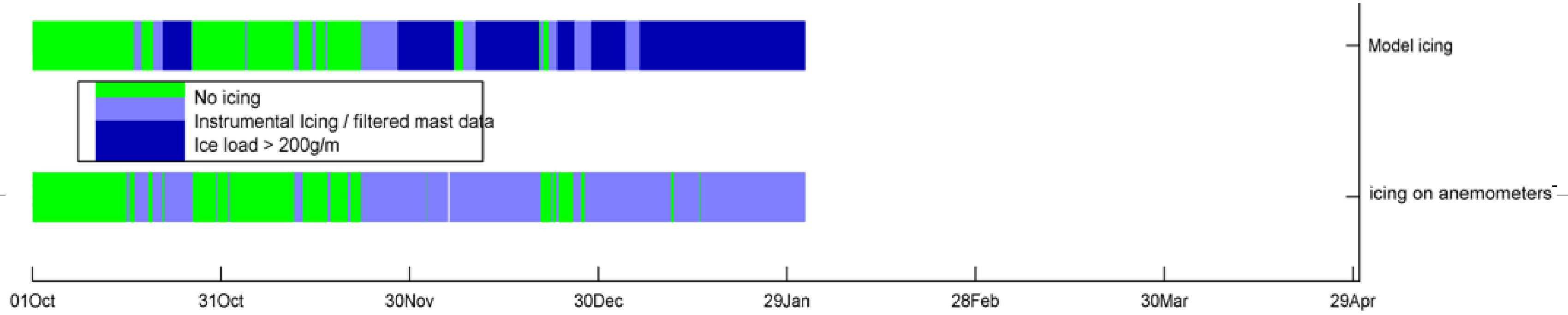
S3



N3



F1



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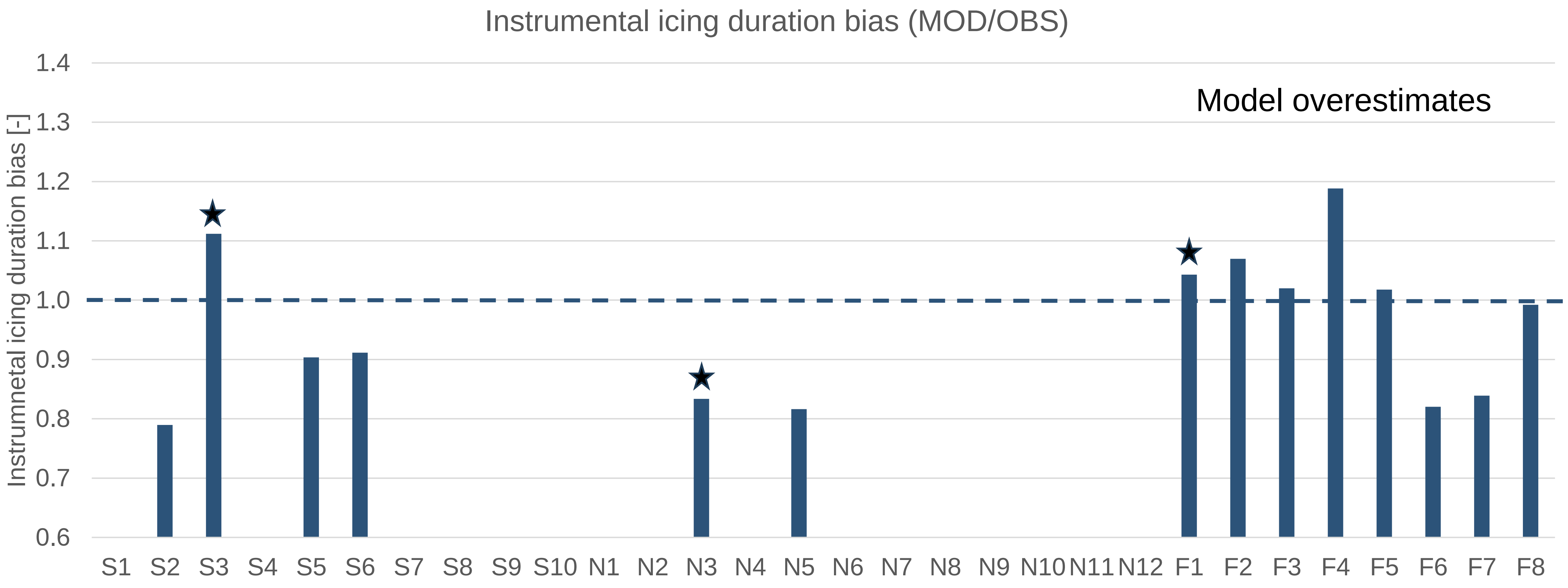
Instrumental icing validation: model bias



Validation statistics

	Temperature (OBS-MOD)	InstIce (MOD/OBS)
Min	-0.97 °C	0.79
Max	+1.31 °C	1.19
Mean	+0.01 °C	0.95
Std	0.49 °C	0.12
ALL: Mean ± unc	+0.01 ± 0.49 °C	0.95 ± 0.12
NO: Mean ± unc	-0.36 ± 0.40 °C	0.82 ± -
SE: Mean ± unc	+0.17 ± 0.43 °C	0.93 ± 0.12
FI: Mean ± unc	+0.38 ± 0.22 °C	1.00 ± 0.11

- ALL Temp bias within measurement uncertainty, 5 % underprediction on InstIce duration
- Sweden shows best Temp performance and is within measurement uncertainty
- Finland shows best InstIce performance
- Interesting: NO has warm Temp bias but underpredicts InstIce (small sample)

±0.2 °C is typical measurement uncertainty

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Summary

- All models are wrong until proven otherwise!
- Temperature model validation:
  - N=30 mast statistics (mean ± std): 0.01 ± 0.49 °C
  - Country specific behavior seen: SE & FI colder that NO
- Instrumental icing model validation:
  - N=14 mast statistics (mean ± std): 0.95 ± 0.12
  - Country specific behavior seen: SE & FI better than NO

Conclusions

- A model chain validation approach is important for:
  - Future model development
  - Increase confidence in final goal: icing loss and ice throw estimates
- Icing loss uncertainties can be reduced if model Temp & InstIce performance is adequate
- Next steps:
  - Analyse more masts in NO to get better statistics
  - Validate modelled ice load with new mast webcams
  - Model calibration method using met mast?
  - Validate new WRF model runs, better performance?

Thank you!

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