IceWind

Improved forecast of wind, waves and icing

Niels-Erik Clausen, DTU
Wind Energy

norden

Top-level Research Initiative
Integration of large-scale wind power

IceWind project – key figures

Title: Improved forecast of wind, waves and icing

Project period 1 September 2010 – 30 april 2015

Overall budget 22.1 mill NOK

Supported by Top-Level Research Initiative (TFI) 56%

Nordic Energy Industry and own finansing 44%

Partners: 13

Coordinator: DTU Wind Energy

4 PhD projects: Two in Iceland, one in Sweden and one in Denmark

IceWind Partners

- DTU Wind Energy (DK)
- Vestas Wind Systems (DK)
- Kjeller Vindteknikk AS (NO)
- Meteorologisk Institutt (NO)
- Statoil AS (NO)
- Oceaneering Asset Integrity (NO)
- Odfjell Wind AS (NO)
- VTT (FI)
- Uppsala University (SE)
  - Weathertech Scandinavia
- Icelandic Met Office (IS)
- University of Iceland (IS)
- Landsvirkjun (IS)
- Landsnet (IS)

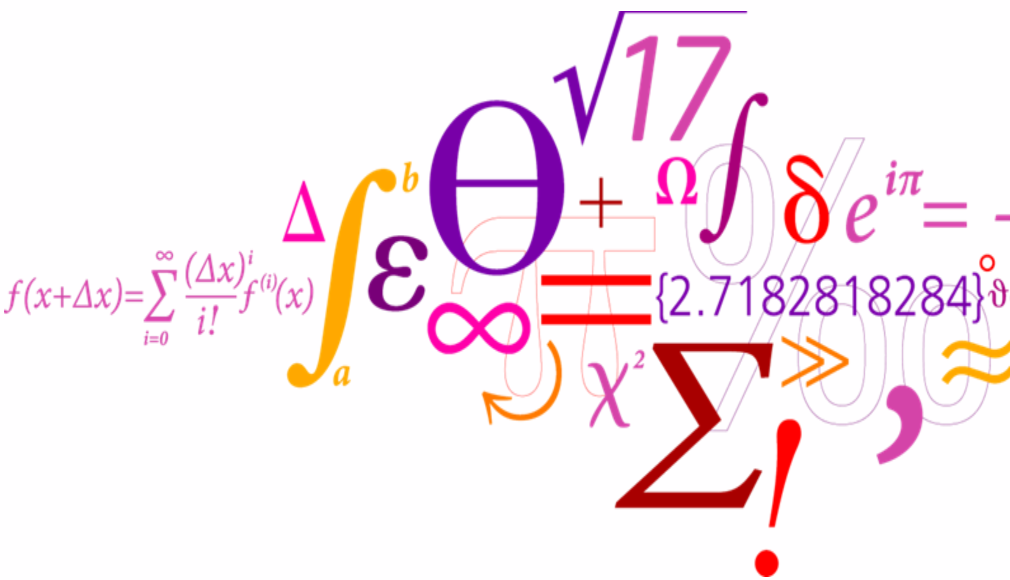
IceWind work packages

- WP 1 Icing (lead VTT, Finland)
  - Atlas of icing for Iceland and Sweden, forecast of atmospheric icing, estimate of production losses due to icing
- WP 2 Iceland (lead Icelandic met office - IMO)
  - Wind atlas of Iceland, identification of sites for wind farms, technical and market integration studies
- WP 3 Forecast and O&M (lead Oceaneering)
  - Offshore meso-scale effects of large wind farms incl. wakes, short term forecasting, maintenance strategies and availability of wind farms
- WP 4 Power and energy aspects (lead DTU Wind)
  - Spatial and temporal variability of wind resource, forecast errors and their impact on the Nordic power grid and balance market

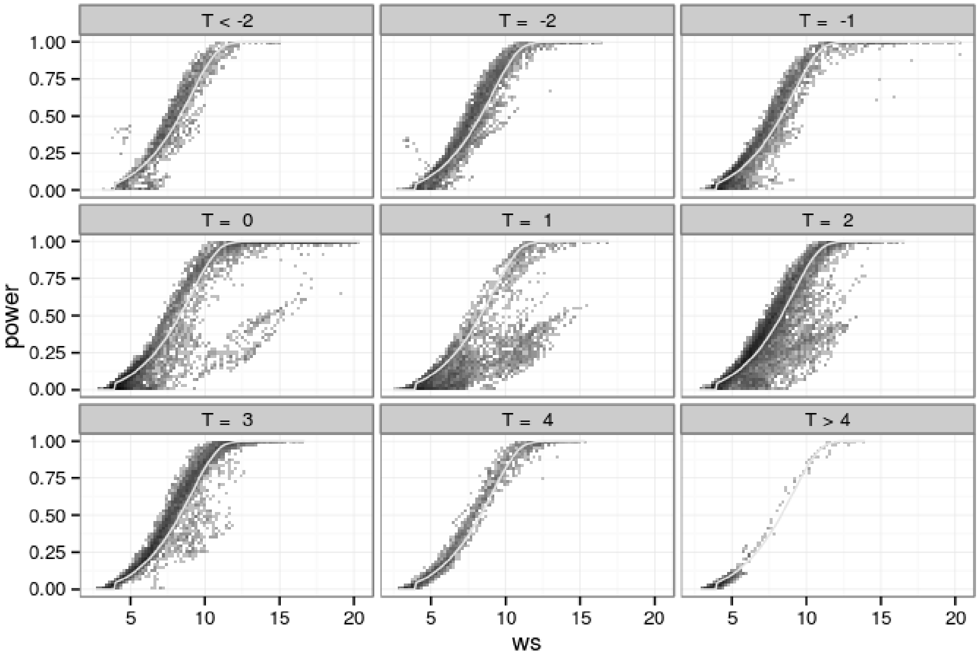
Investigation of Nacelle Temperature Measurements

WinterWind 2015

Neil Davis,
Andrea Hahmann,
Niels-Erik Clausen,
and Mark Žagar



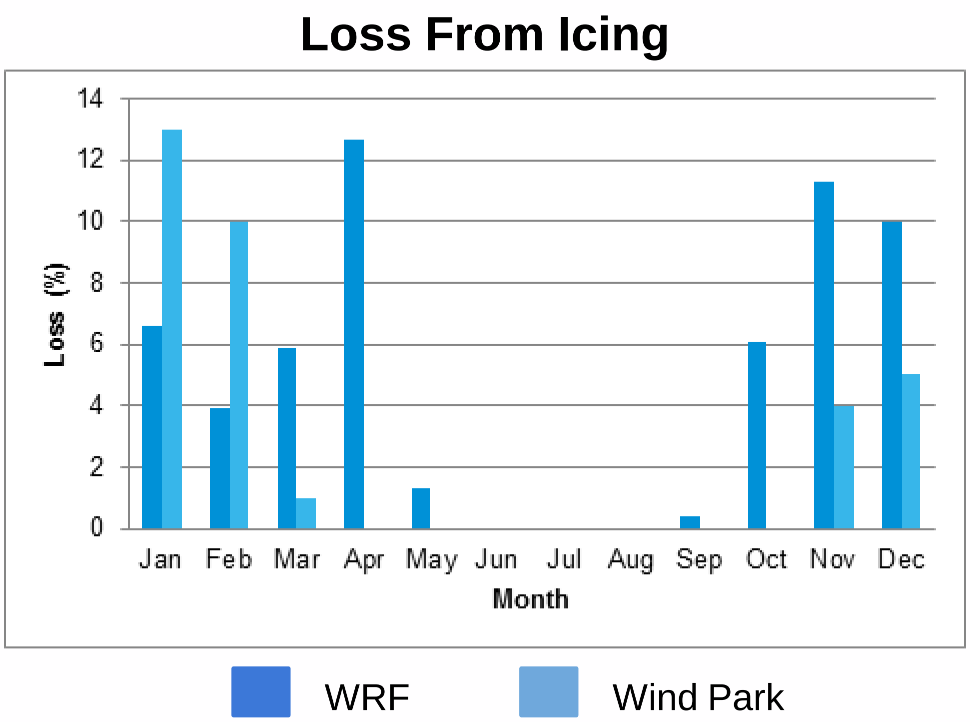
Motivation #1
Identifying Ice



- Non-iced points are needed for fitting power curve
- Many turbines show “icing” signal above 0℃

Motivation #2
Forecasting Icing

- Large differences in ice forecasts in Spring and Fall
- Unknown if model error or observational error



Study Setup

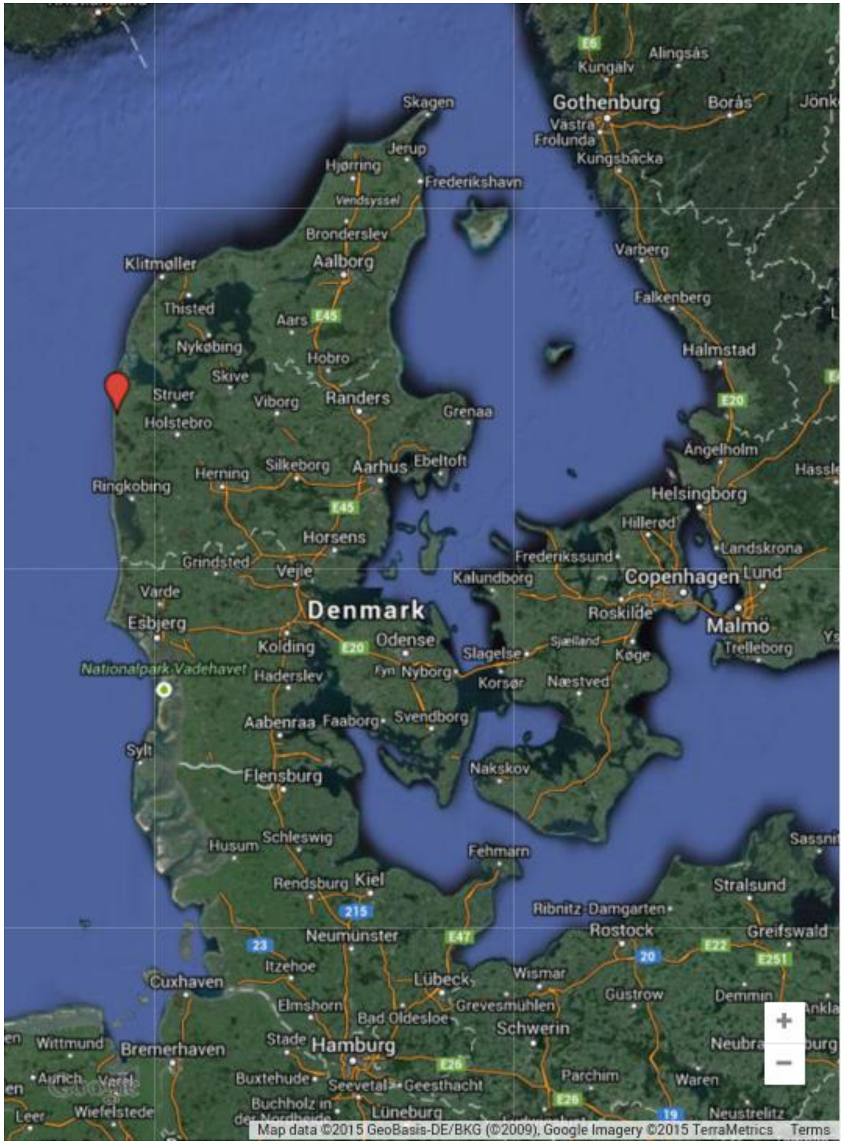
- Find evaluation site
  - Known good mast measurements
  - Multiple turbines
  - At least 1 year of record
- Compare different mast measurements
- Compare mast with nacelle measurements
- Compare mast and nacelle measurements against meteorological model results

Høvsøre Test Site

- Western Denmark
- Run by DTU Wind Energy

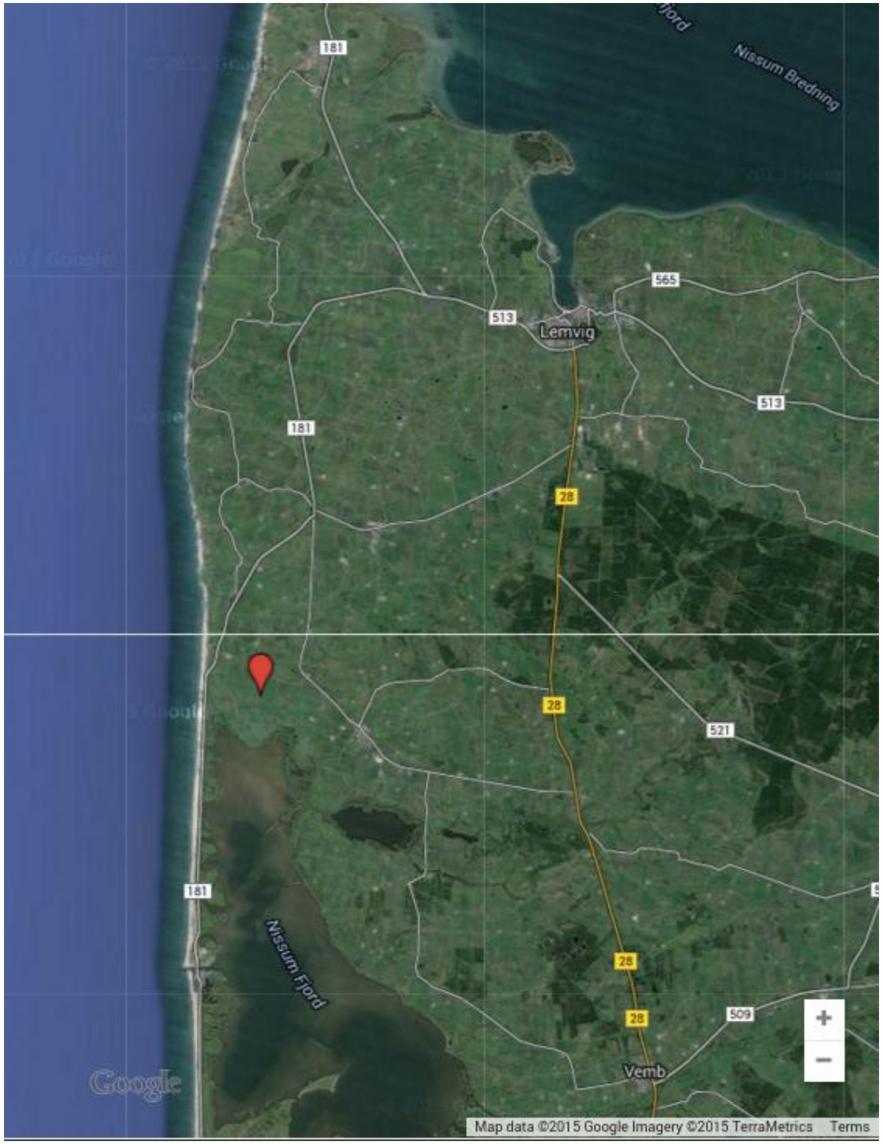
Høvsøre Test Site

- Western Denmark
- Run by DTU Wind Energy



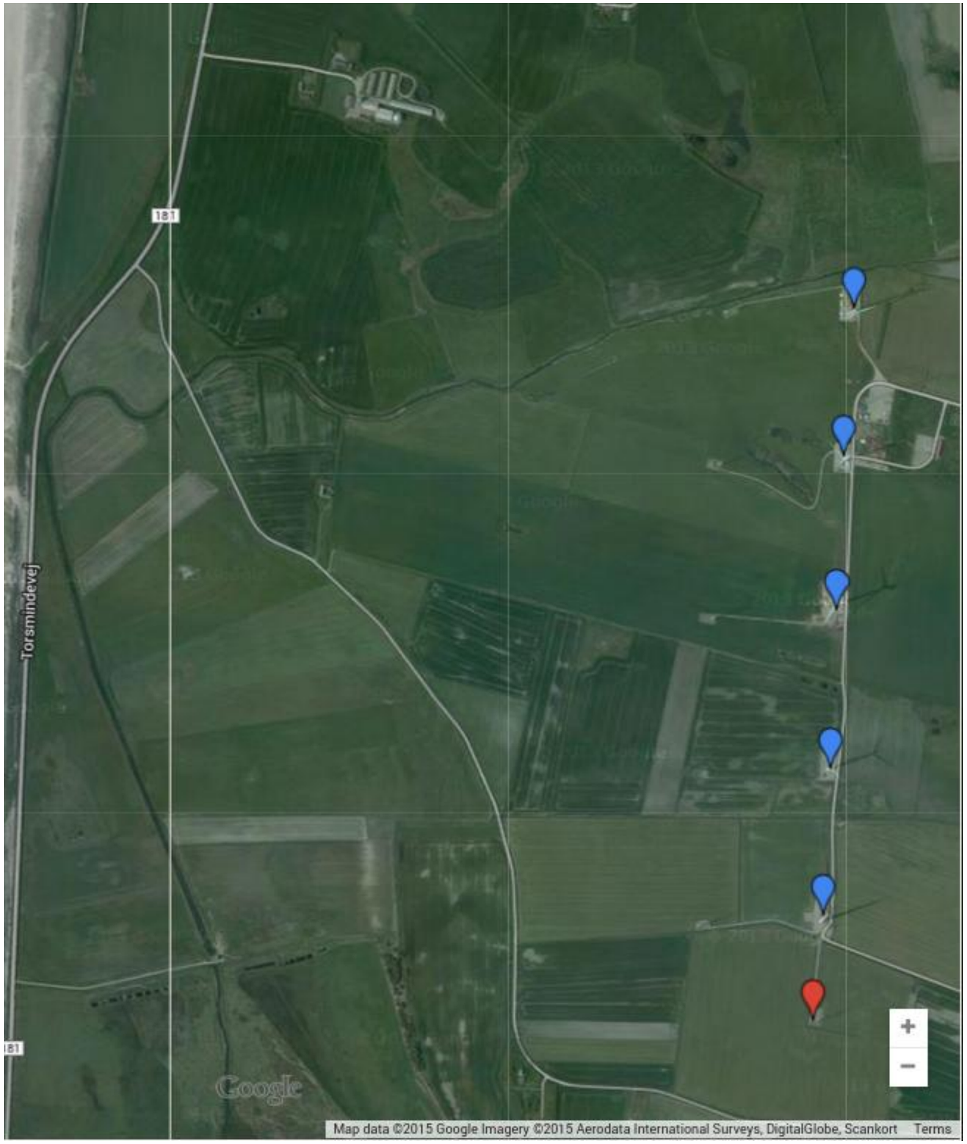
Høvsøre Test Site

- Western Denmark
- Run by DTU Wind Energy



Høvsøre Test Site

- Western Denmark
- Run by DTU Wind Energy



- 5 turbine test stands (blue)
- 114-m met mast (red)

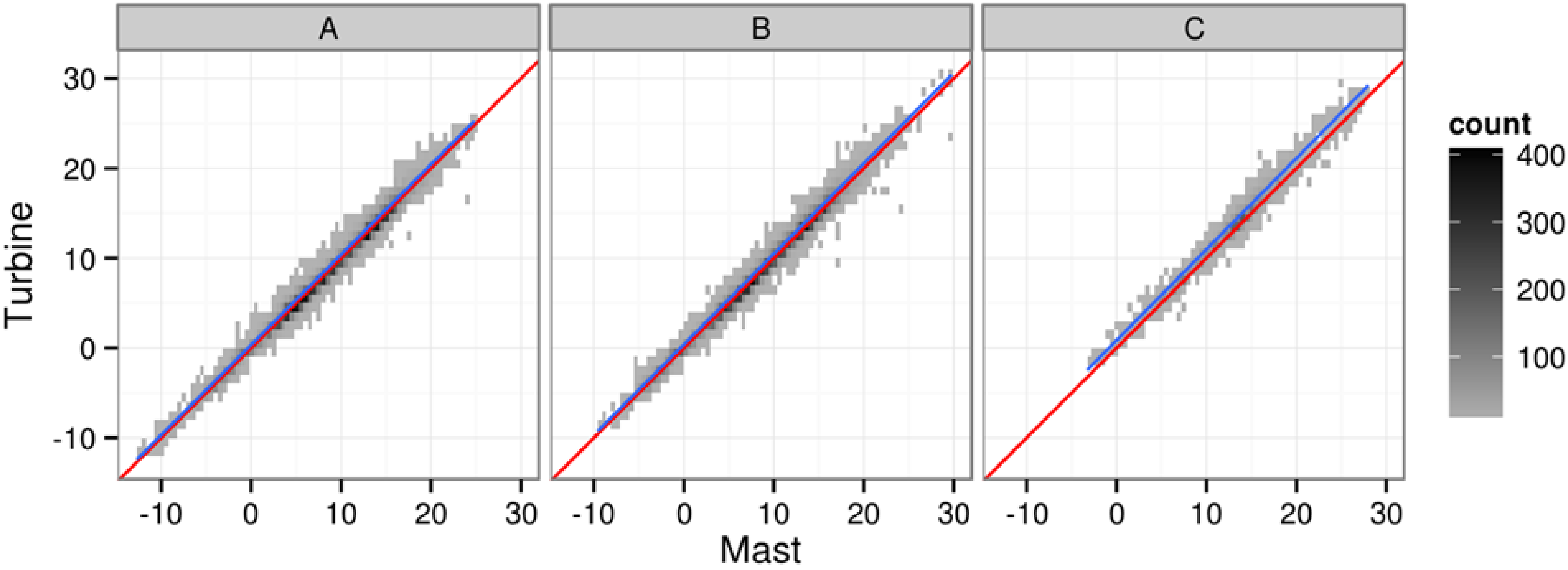
Høvsøre Met Mast

- 116-m high mast
- Temperature
  - 2-m
  - 100-m
- Temperature difference
  - 2-m to 60-m
  - 2-m to 100-m
- Good agreement between 60-m and 100-m temperatures

Test Turbines

Turbine	Hub Height	Dates	Duration
A	106.4	2011-06 to 2013-05	1 year 11 months
B	80	2012-03 to 2014-02	11 months
C	80	2014-05 to 2015-01	8 months

Mast temperature comparison

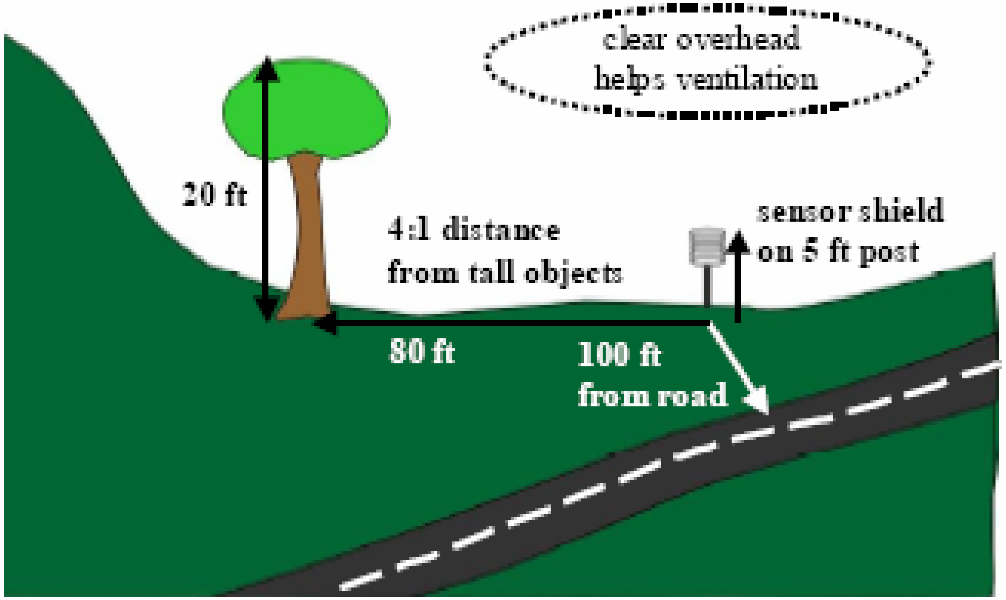


Comparison Statistics

turbine	MB	RMSE	Cor_R	slope
A	0.39	0.81	0.99	1.00
B	0.46	0.88	0.99	1.01
C	1.02	1.28	0.99	1.01

Potential Causes

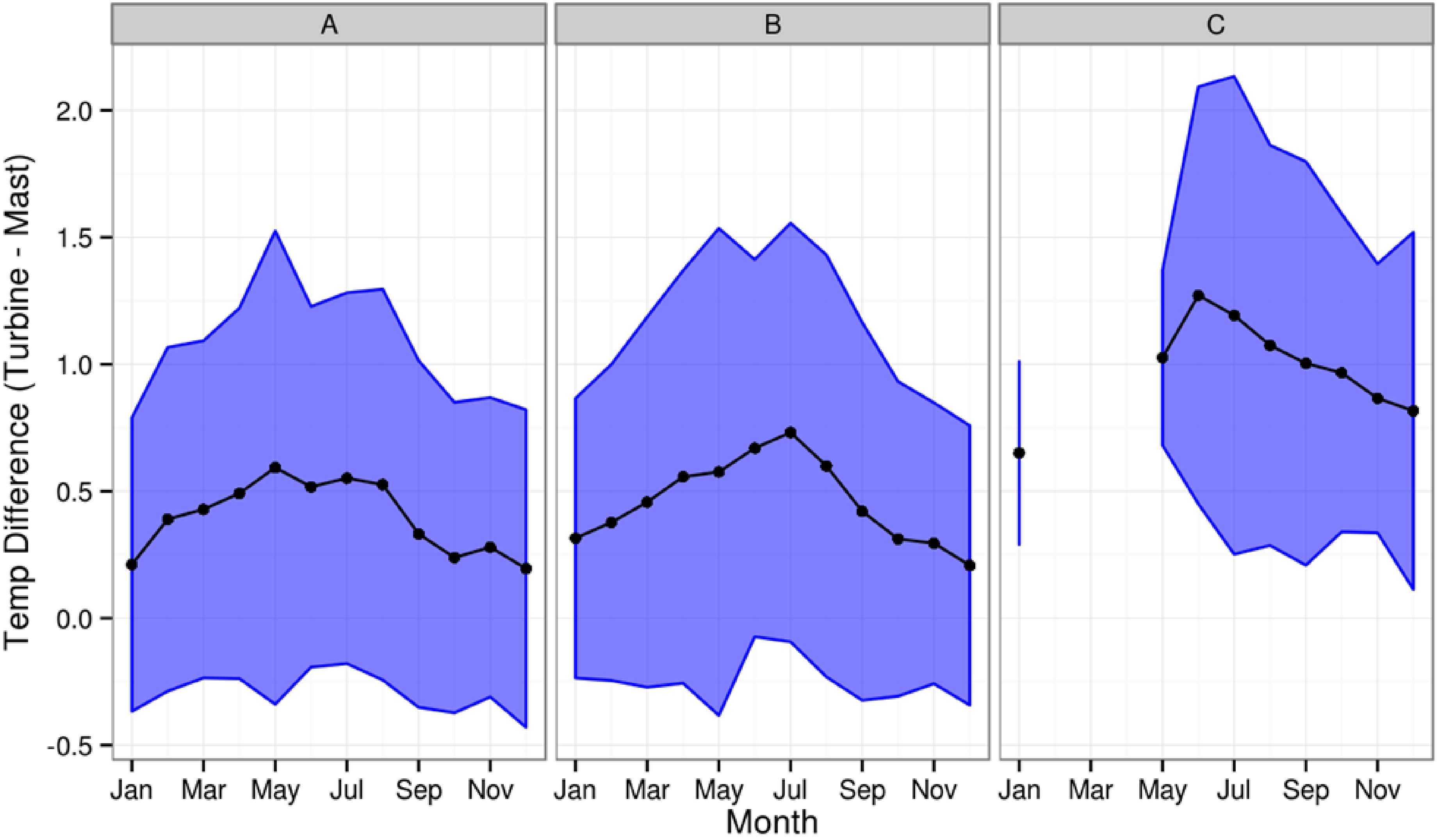
- Heat leakage
- Improper shielding
- Calibration offset



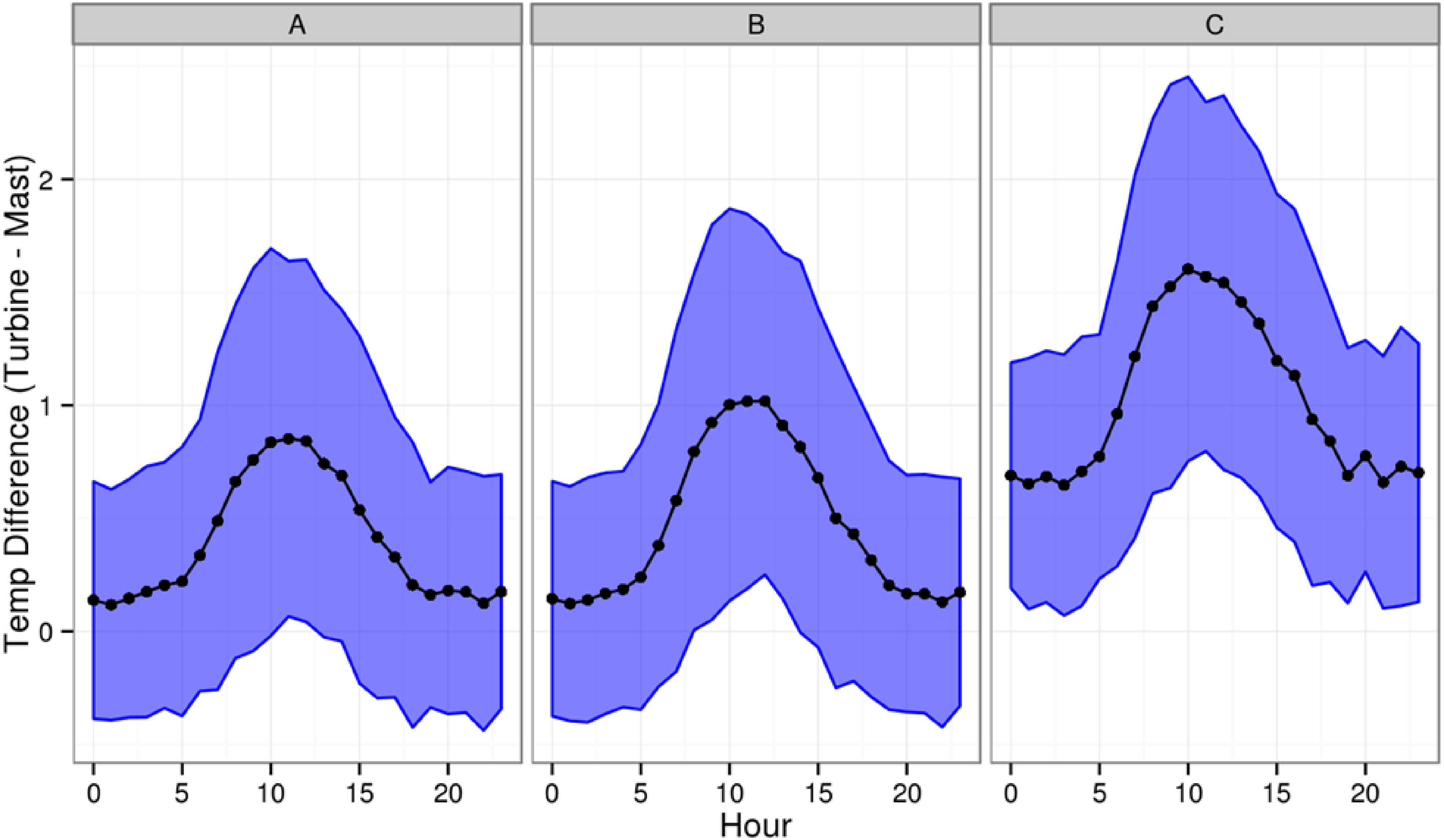
Suggestions for thermometer placement for personal weather stations.

http://wiki.wunderground.com/index.php/PWS_-_Siting

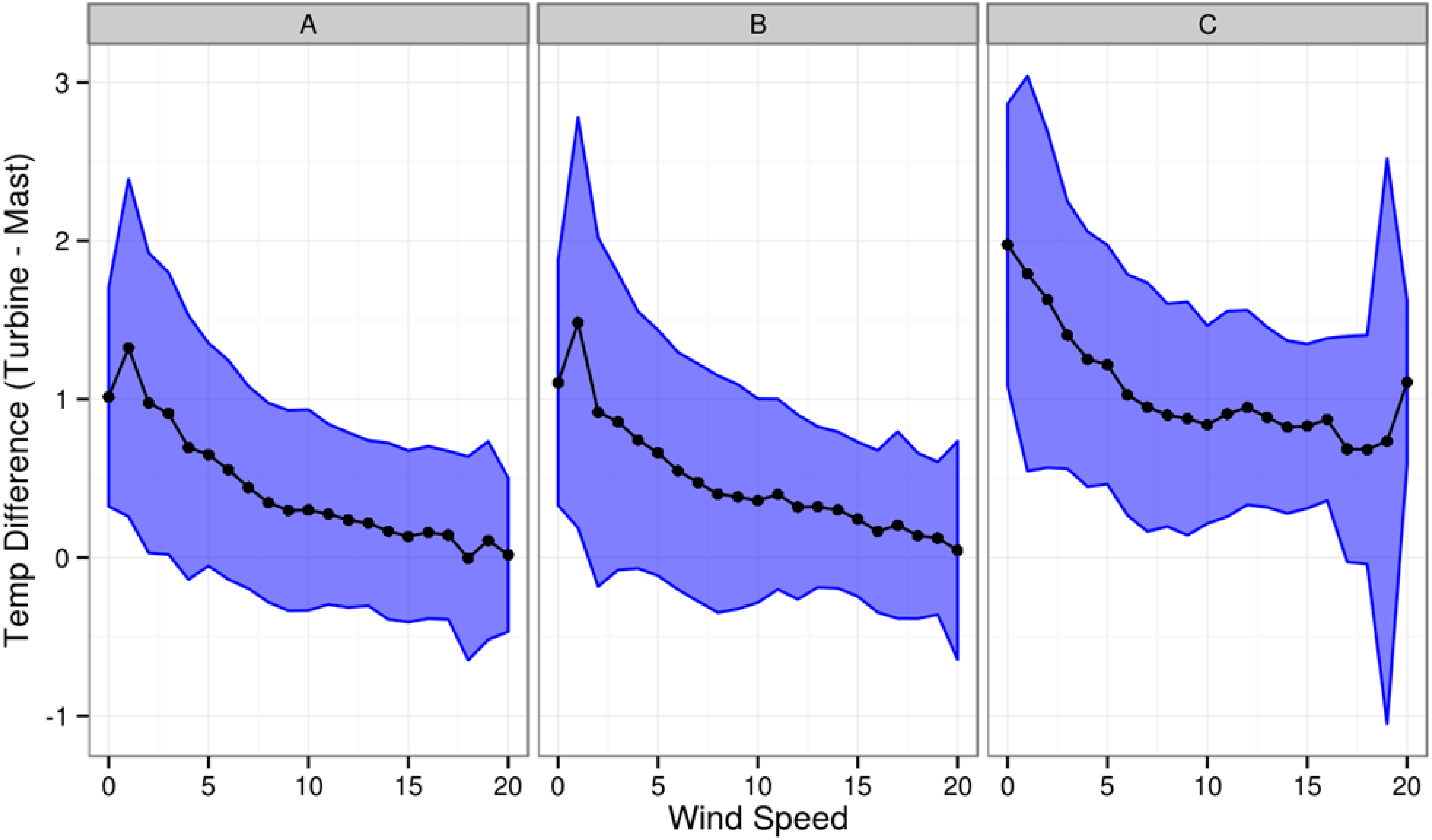
Seasonal Bias



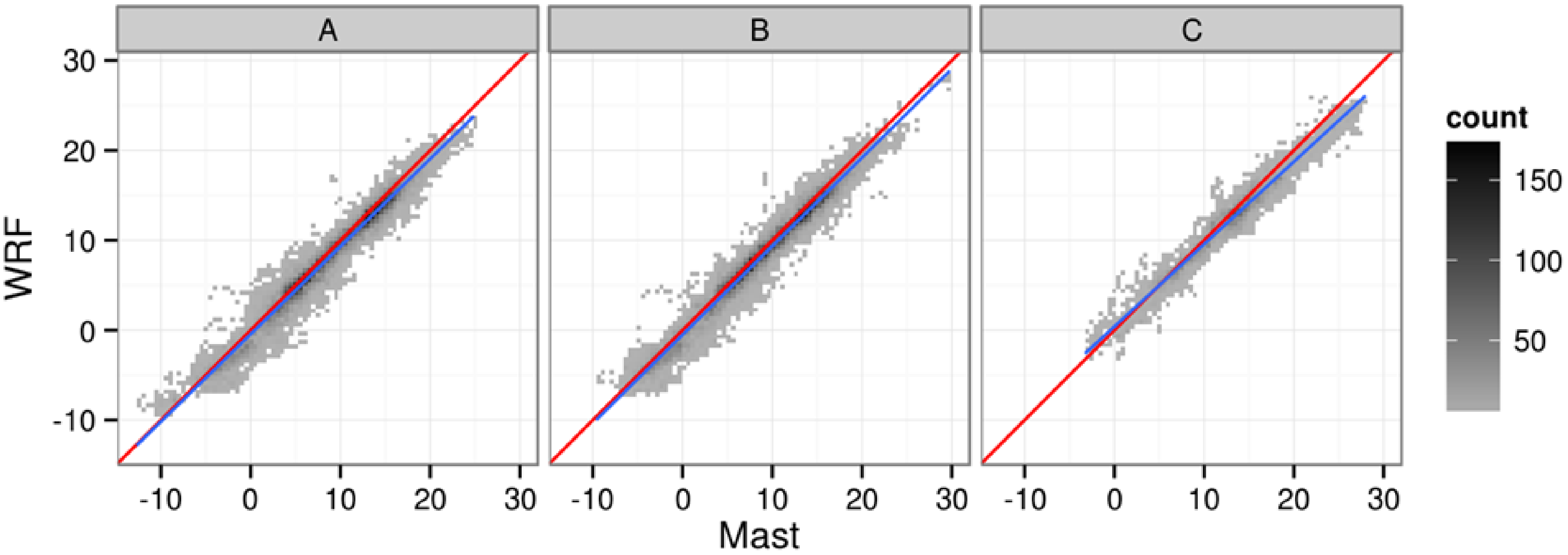
Diurnal Bias



Bias with Wind Speed



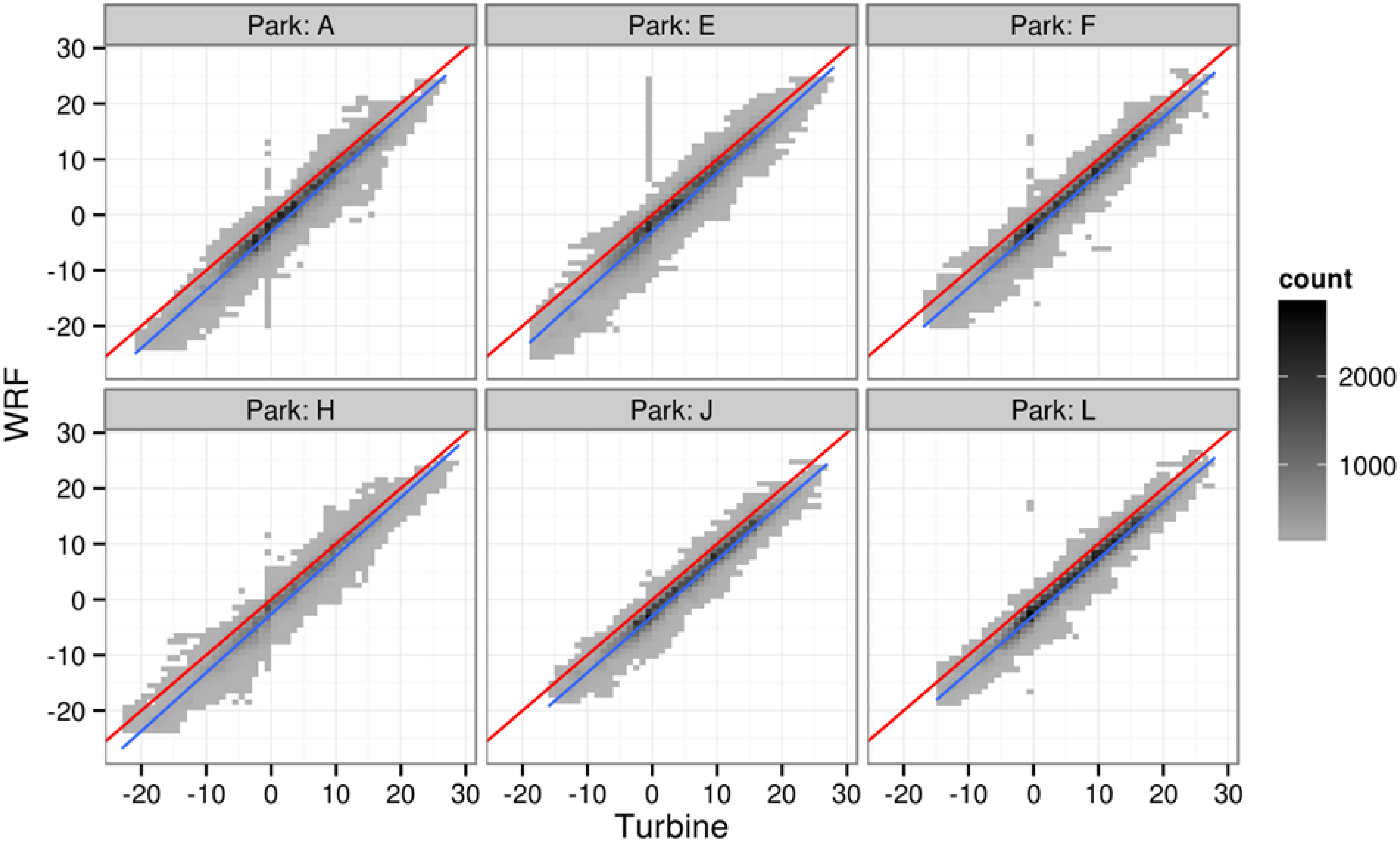
WRF model bias



WRF model bias

turbine	MB	RMSE	Cor_R	slope
A	-0.64	1.36	0.98	0.97
B	-0.63	1.33	0.98	0.99
C	-0.62	1.37	0.98	0.92

WRF vs Turbine 2 year study



Summary

- Turbine
  - Significant bias was found both between certain nacelle measurements and mast measurements as well as between WRF model output and both nacelle and mast measurements
  - Seasonal change in bias was approximately 1℃
  - Diurnal pattern suggests solar heating of the thermometer
  - At higher wind speeds bias decreased

- WRF
  - Bias changes with temperature
    - Cold bias at warm temperatures
    - Small bias at cooler temperatures
  - Cold bias in WRF vs mast enhances warm nacelle bias for icing studies
    - WRF data should be corrected for nacelle bias

This work was supported financially by the Top-Level Research Initiative (TFI) project, Improved forecast of wind, waves and icing (IceWind), Vestas, and the Nordic Energy Industry.