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NWP-application
“Wind power in cold climates”

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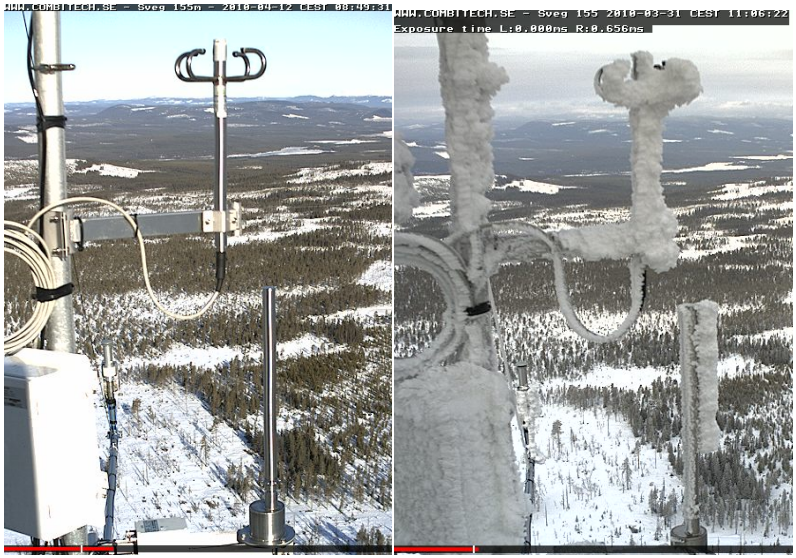
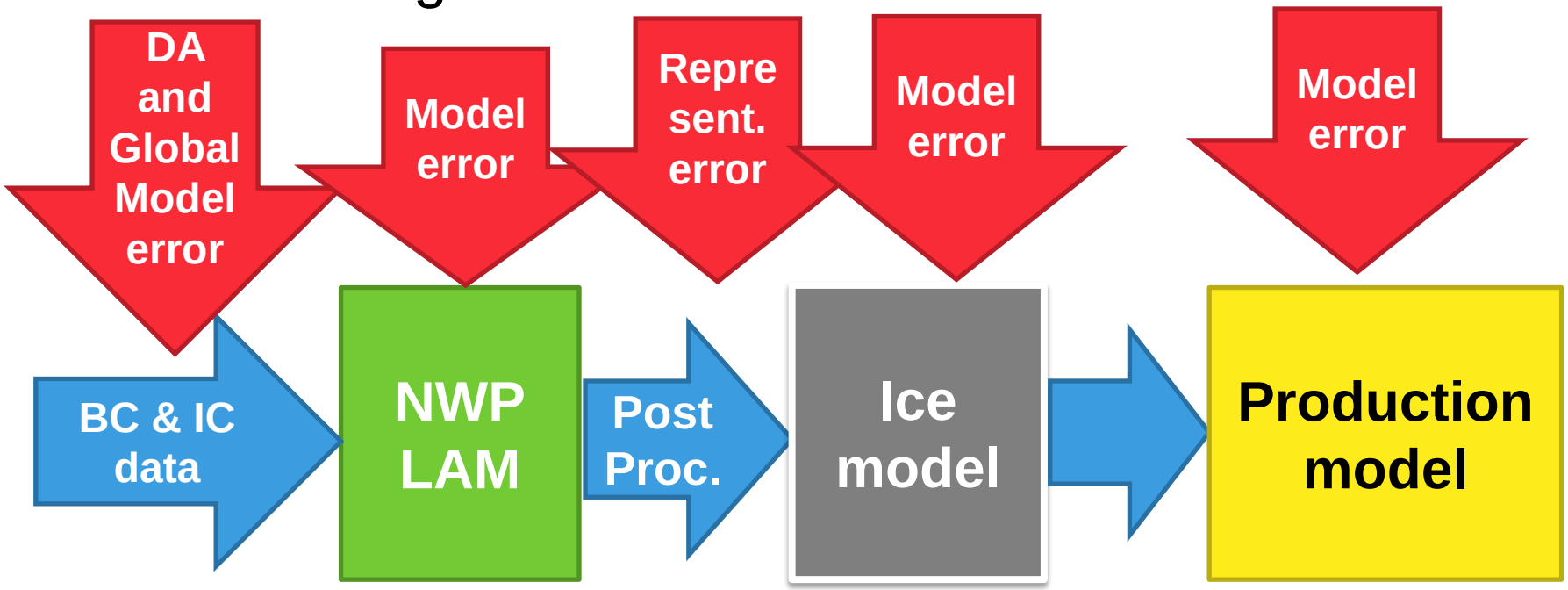
Meteorological needs for wind power production

- Site planning: Climatology for wind and icing
- Maintenance and safety
- Operation
  - Power production for electrical grid
  - Noise pollution
- Trading

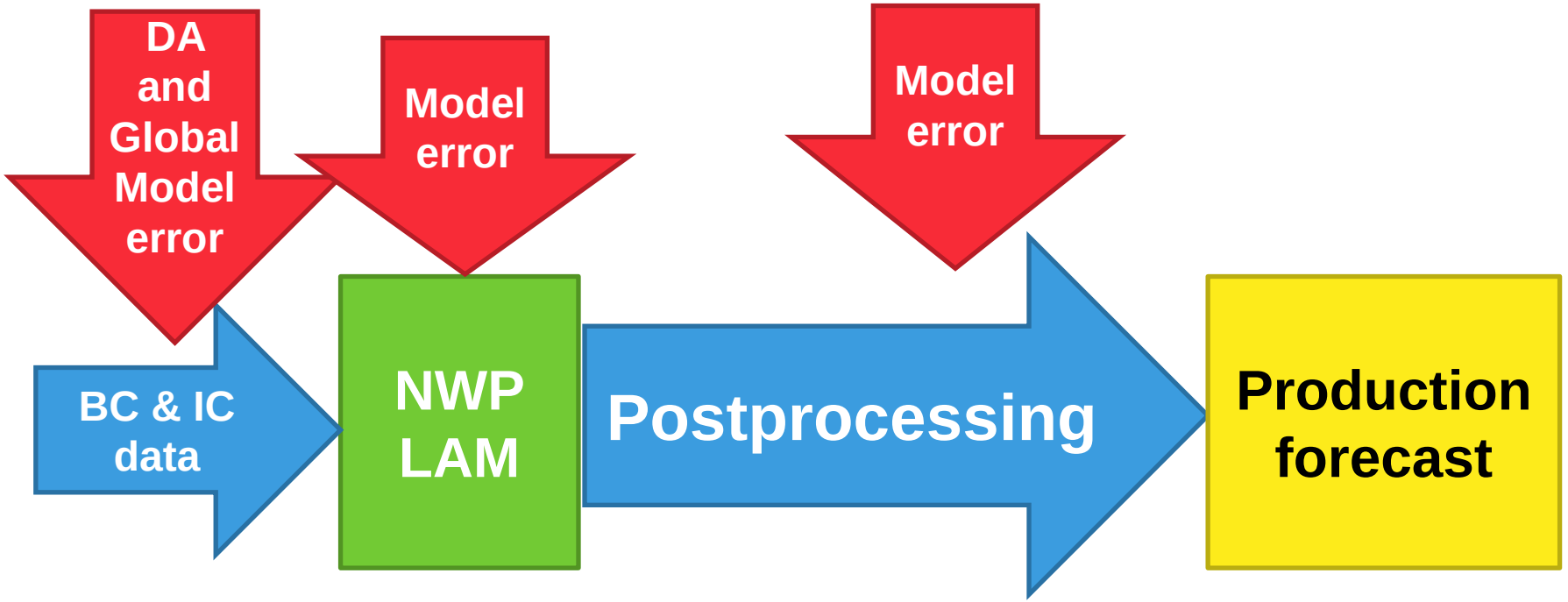


NWP needs: Observations of wind, temperature, and power production for each turbine

Modelling chain



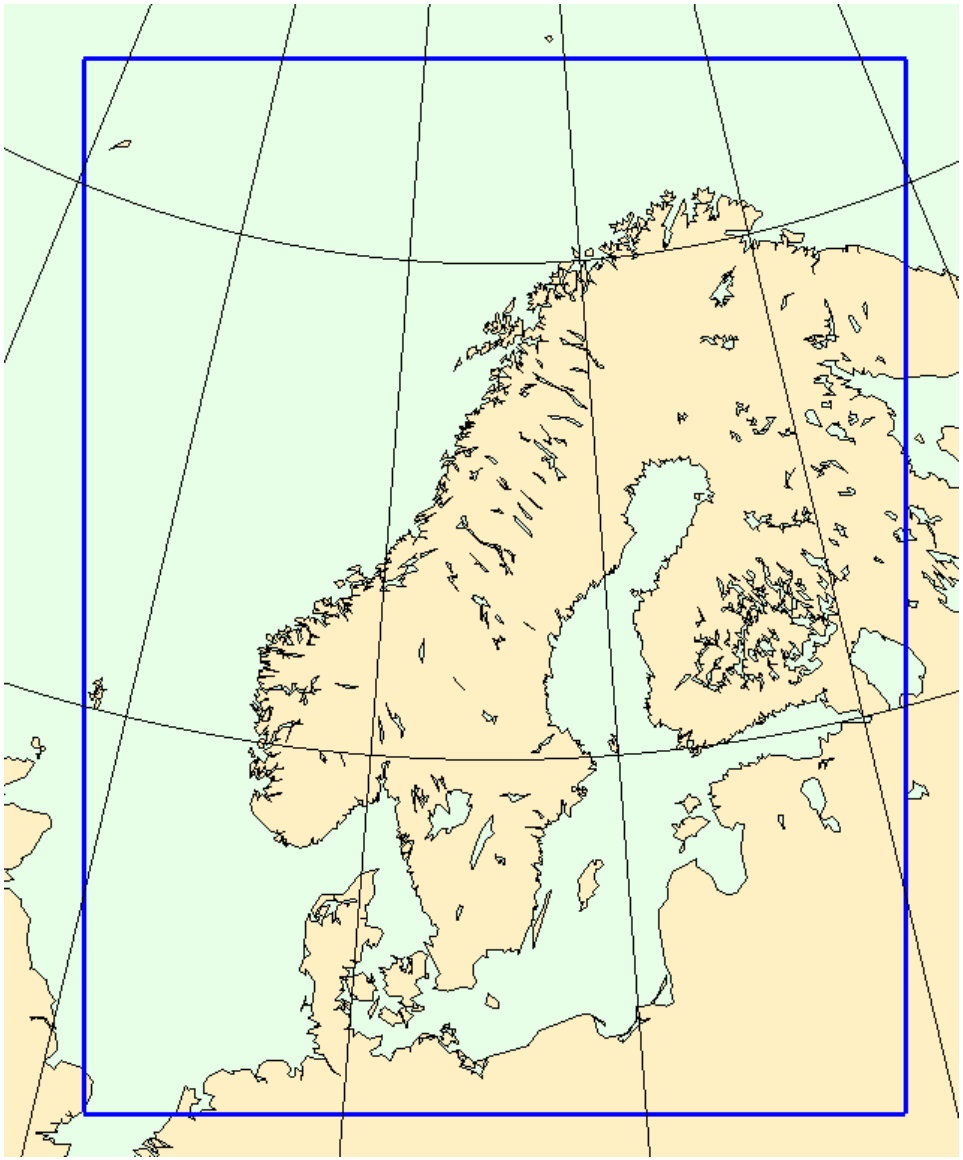
Modelling chain



However, ice product remains
difficult to verify.

NWP model

- Operational model of MetCoOp with MET Norway:
- HARMONIE-Arome cy38h1.1
- 2.5 km and 65 levels
- 3D-Var 3h-RUC
- Height adaption for wind, temperature and humidity



Observations vs model

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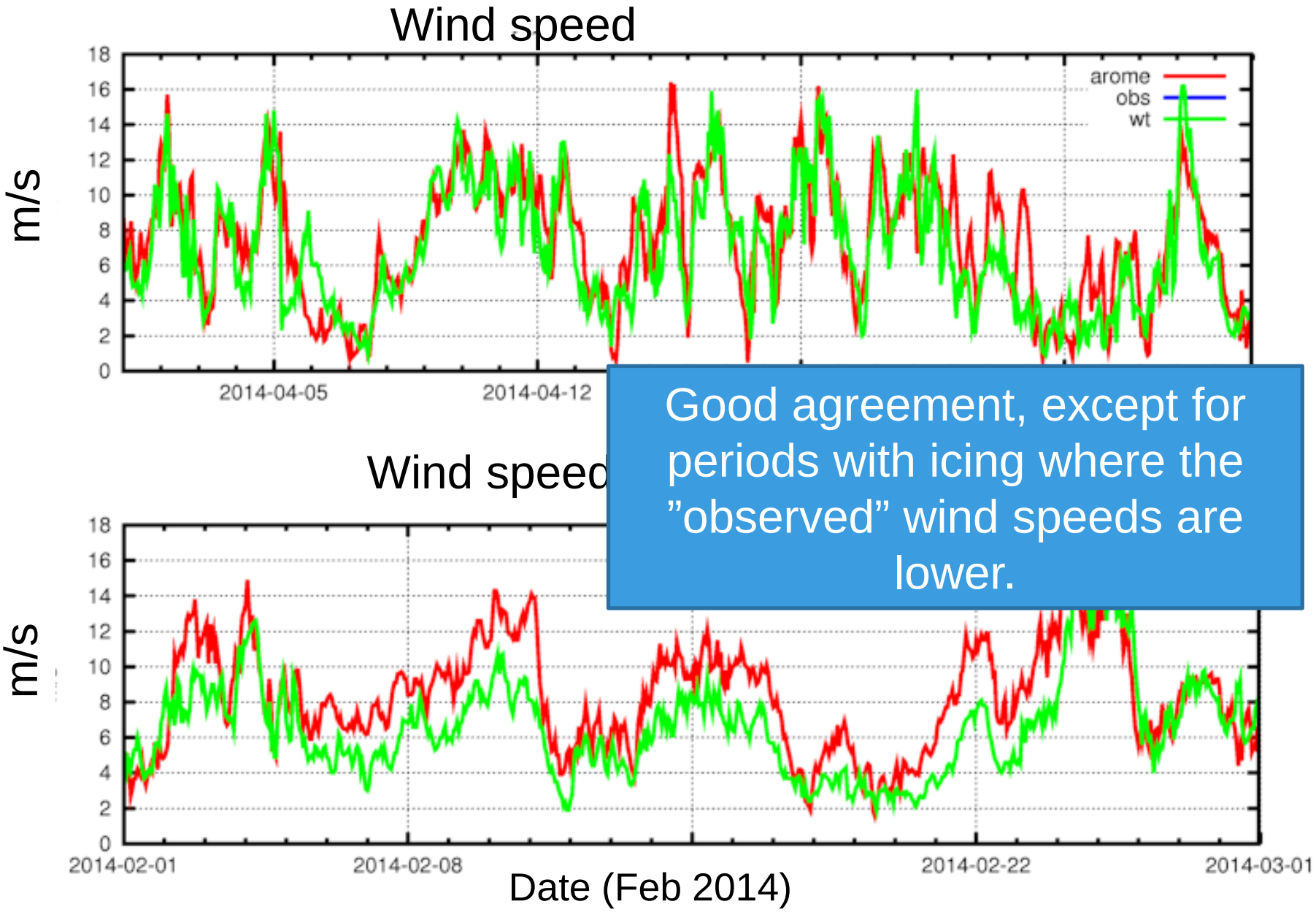


Good agreement, except for periods with icing where the ”observed” wind speeds are lower.

Verification of the production forecasts

- March – April 2014
- Using 06UTC run and forecast for next day
- Only very modest icing
- Assumption: all turbines are working.

Station	Approx. Ideal production	Bias	Std dev	Correla-tion
1	500 MWh	16 MWh	24 MWh	0.9
2	700 MWh	70 MWh	171 MWh (?)	0.9
3	500 MWh	106 MWh	172 MWh	0.54
4	500 MWh	21 MWh	29 MWh	0.9
5	800 MWh	66 MWh	59 MWh	0.9
6	600 MWh	70 MWh	50 MWh	0.9

Ice and standstill!

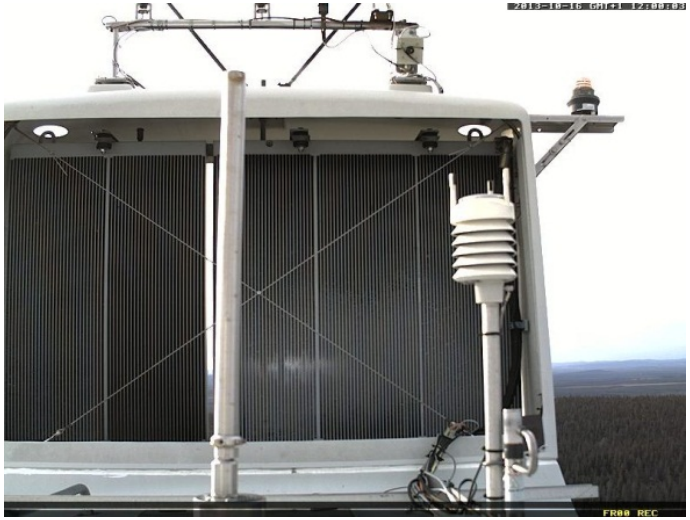
Modelling the ice load

- Makkonen Model (2000)
- Developed for ice growth on cylinder
- Additionally:
  - flux of precipitation
  - Sublimation, melting
  - shedding

$$\frac{Dm}{dt} = \alpha_1 \alpha_2 \alpha_3 wAV - Q$$

α_1 = collision efficiency.
α_2 = sticking efficiency.
α_3 = accretion efficiency
***w*A*V* = Flux of water droplets**

Measuring of ice load



Measuring ice load is not simple. Different techniques, but no one has proven to be totally reliable. Harsh environment.

“Results of the Vindforsk project V-363 with report “Experiences of different ice measurements methods” indicate that no technique and no instrument for measuring ice load or ice accretion can be trusted in every icing situation.”

Observations vs. model

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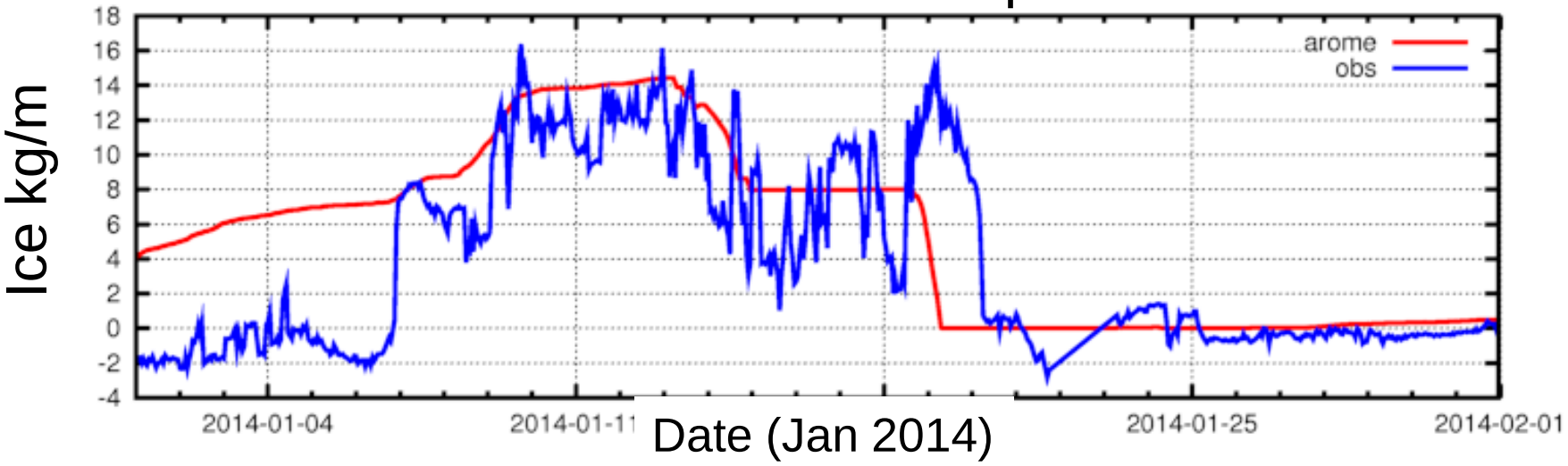
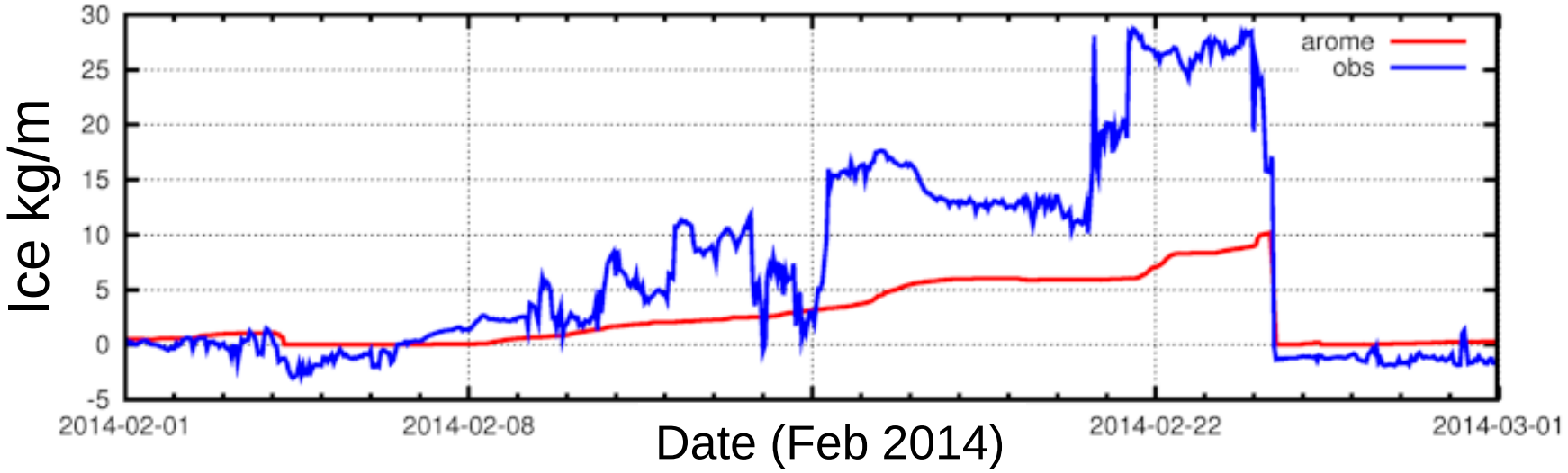
Iceload for one wind park





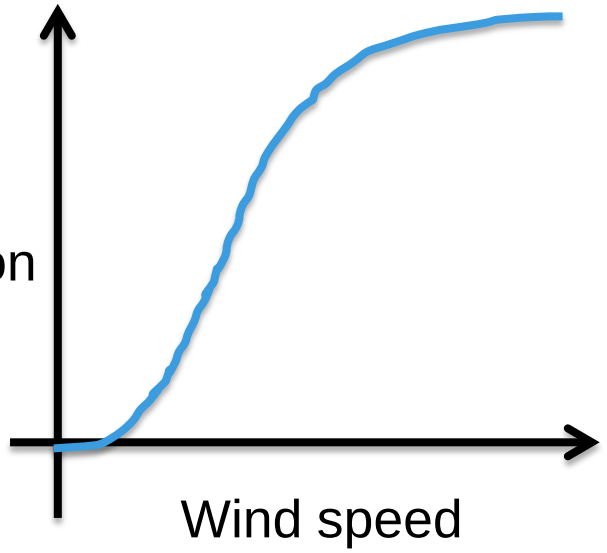
Modelling production losses

- Empirical relationship of modelled ice growth, ice load, and wind speed.
- Seasonally varying effect curves for each turbine from observed wind speed and power production.
- Assumption: All turbines are working.
- +18h- to +42h-forecast data from 06UTC-runs

Wind speed

Ice growth

10	5	0
50	25	10
100	100	90



Model vs observations

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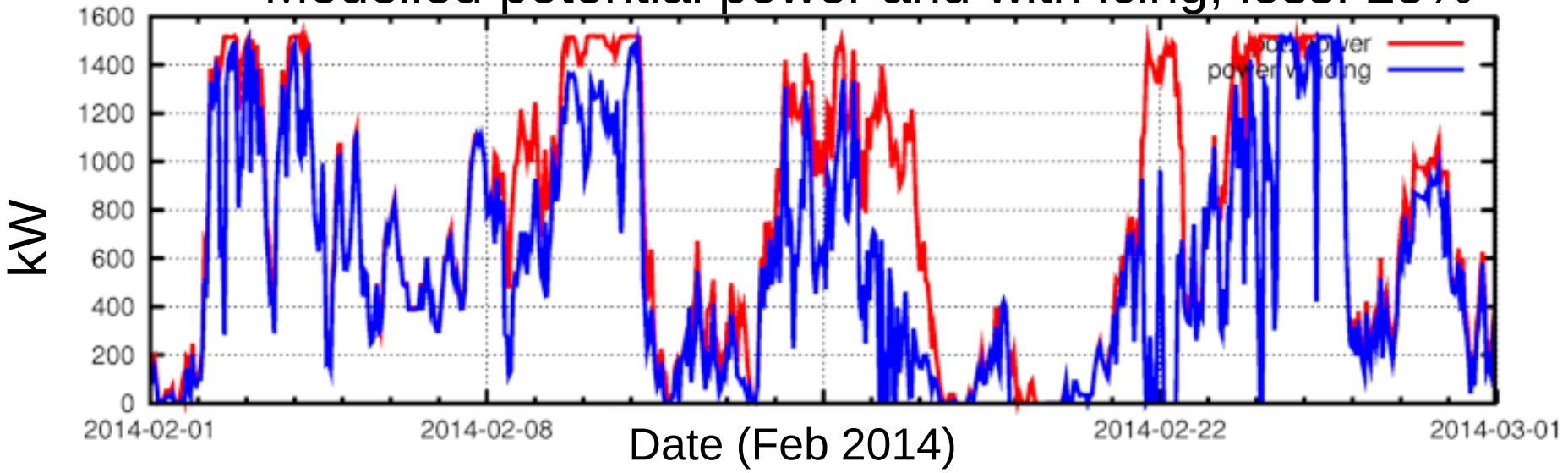
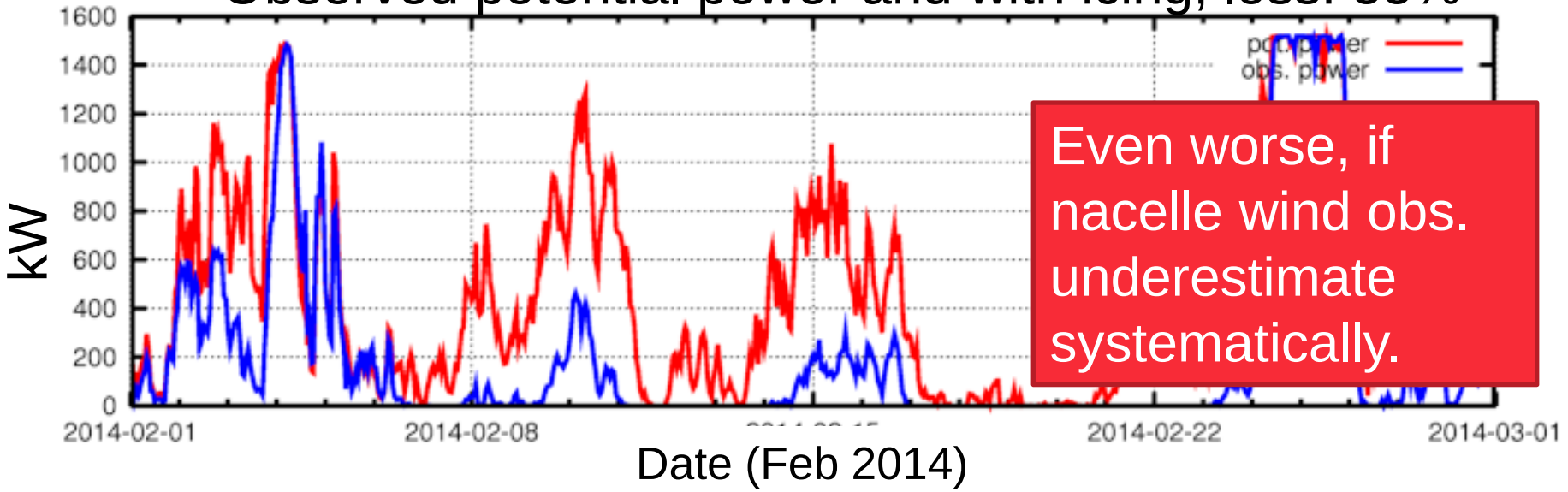
Modelled potential power and with icing, loss: 25%



Observed potential power and with icing, loss: 55%



Even worse, if nacelle wind obs. underestimate systematically.

Season of observed and modelled production losses

Month	Ice hours	Ideal model power prod (MWh)	Model loss with ice (%)	Ideal power prod from obs wind (MWh)	Obs loss (%)
October	35	505	5	521	1
November	99	617	7	487	7
December	221	821	24	683	9
January	278	756	38	706	69
February	433	605	71	515	81
March	209	758	22	675	14
April	52	509	5	418	4

Summary

- Icing on wind turbines plays an important role for production and safety.
- High-resolution NWP forecasts for ice-free wind power production are useful.
- Ice load observations are not reliable, so verification of icing model is difficult.
- Modelled production losses shows useful information, but need improvement.
- Outlook: PhD-project on quantifying the uncertainties for production losses with a meso-scale EPS

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Thank you!