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# NWP-application
# “Wind power in cold climates”

WindREN AB

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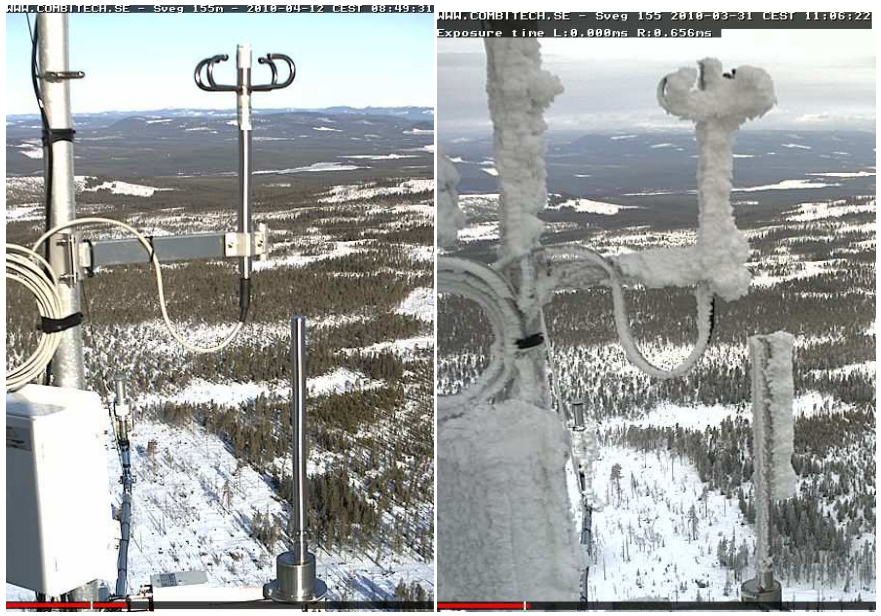
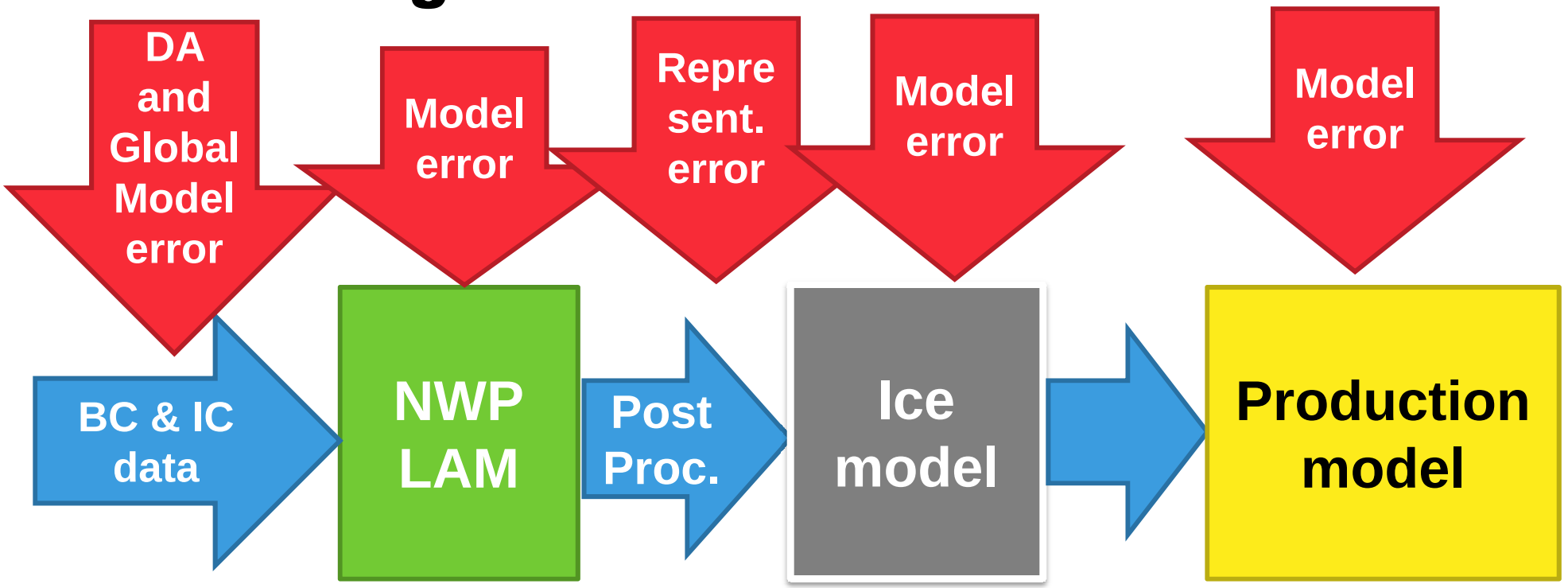
# Meteorological needs for wind power production

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

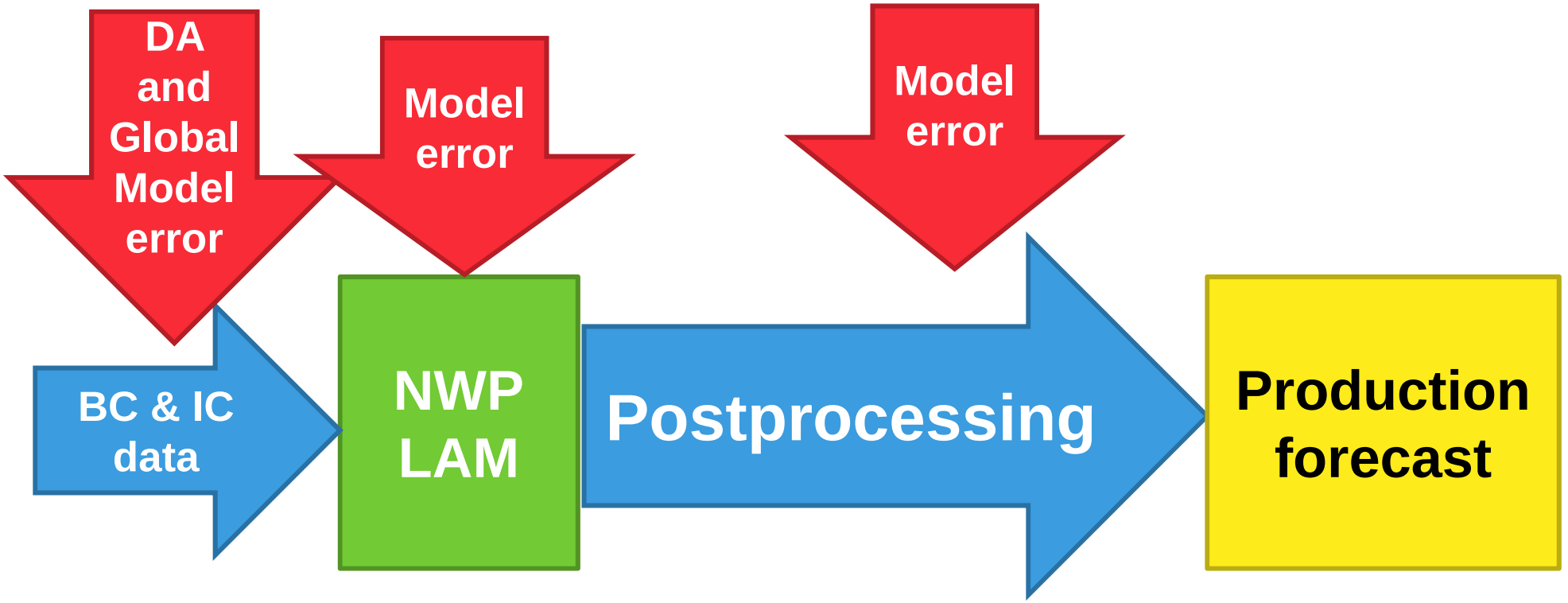


NWP needs: Observations of wind, temperature, and power production for each turbine

# Modelling chain



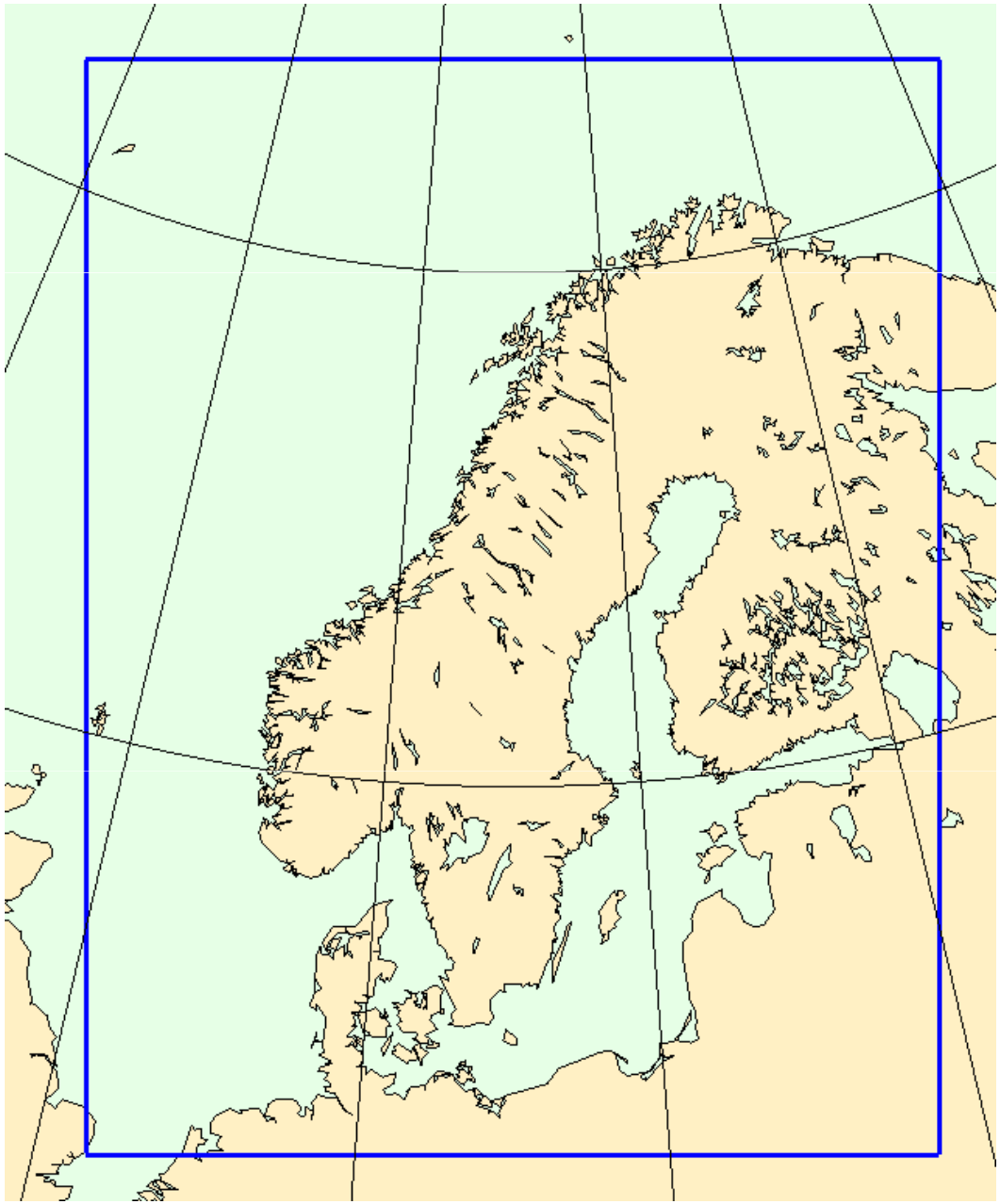
# Modelling chain




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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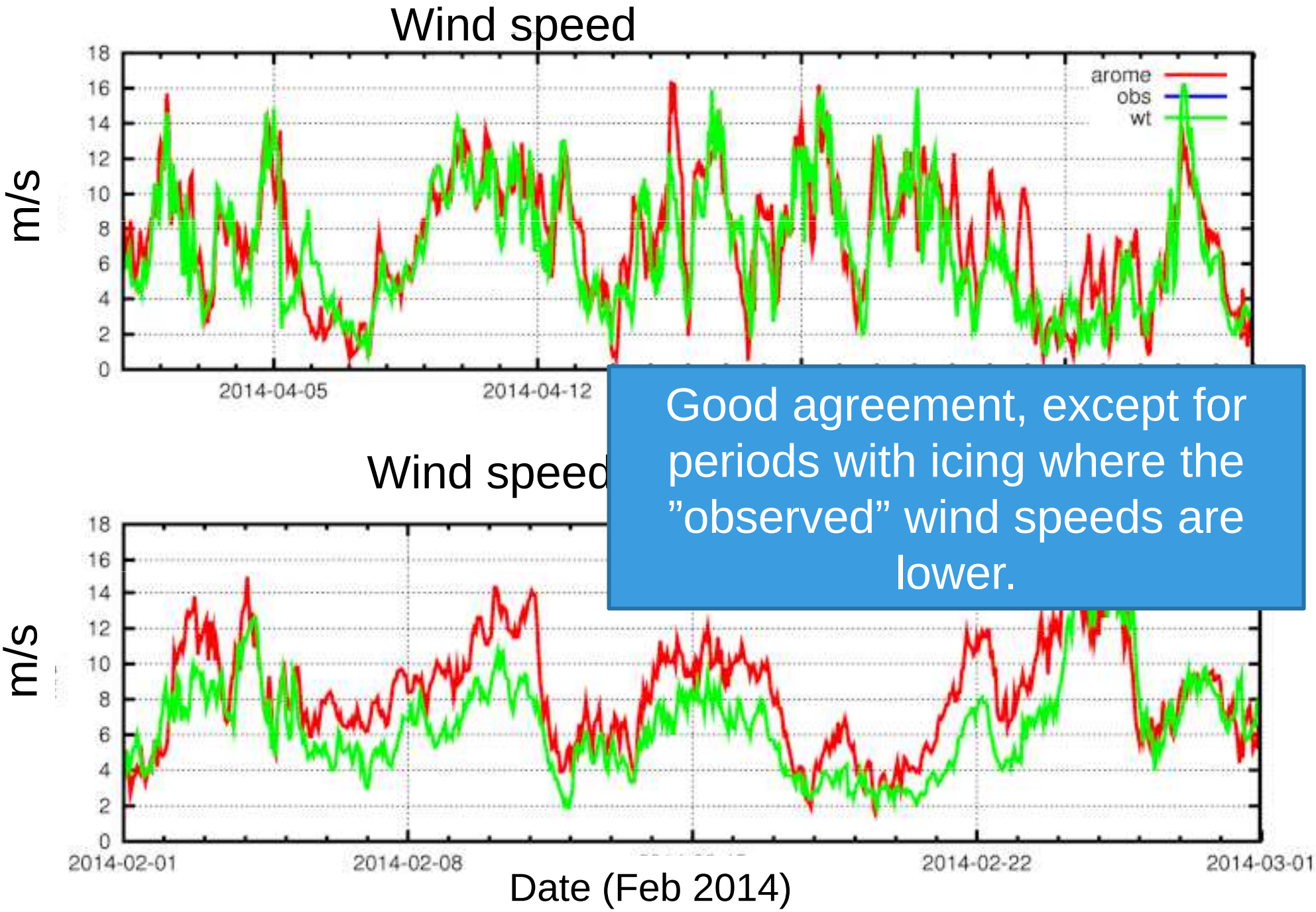



Good agreement, except for periods with icing where the ”observed” wind speeds are lower.

# 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!

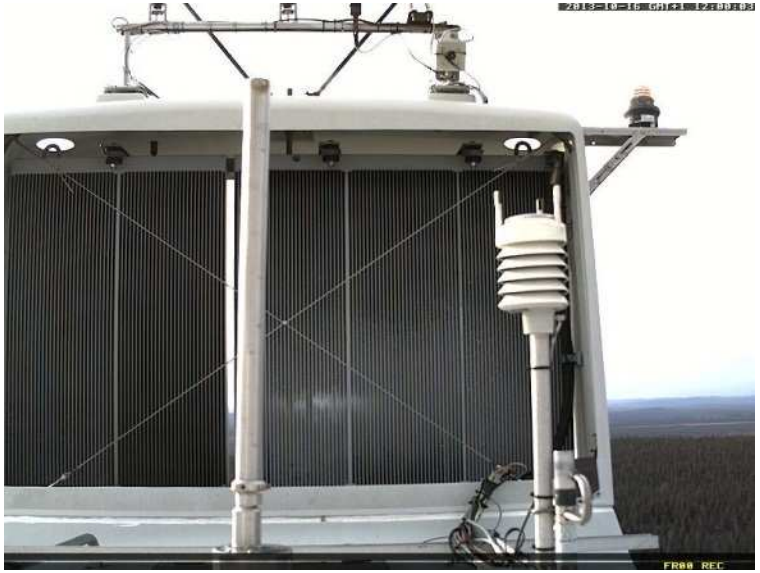
# Modelling the ice load

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

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

**$\alpha_1$ = collision efficiency.**
**$\alpha_2$ = sticking efficiency.**
**$\alpha_3$ = 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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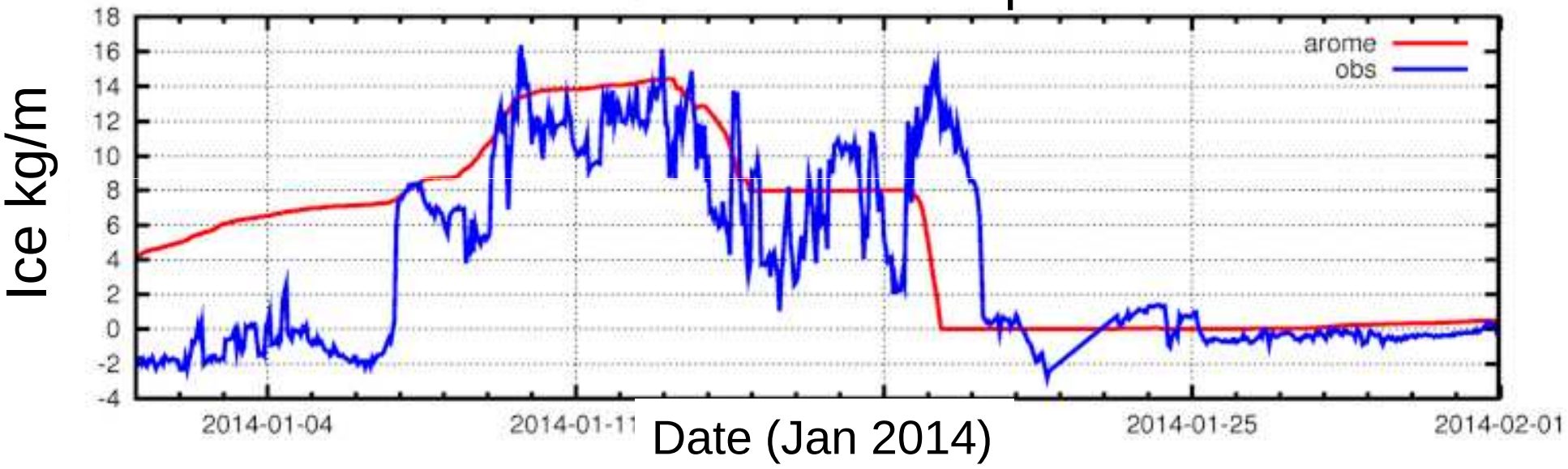
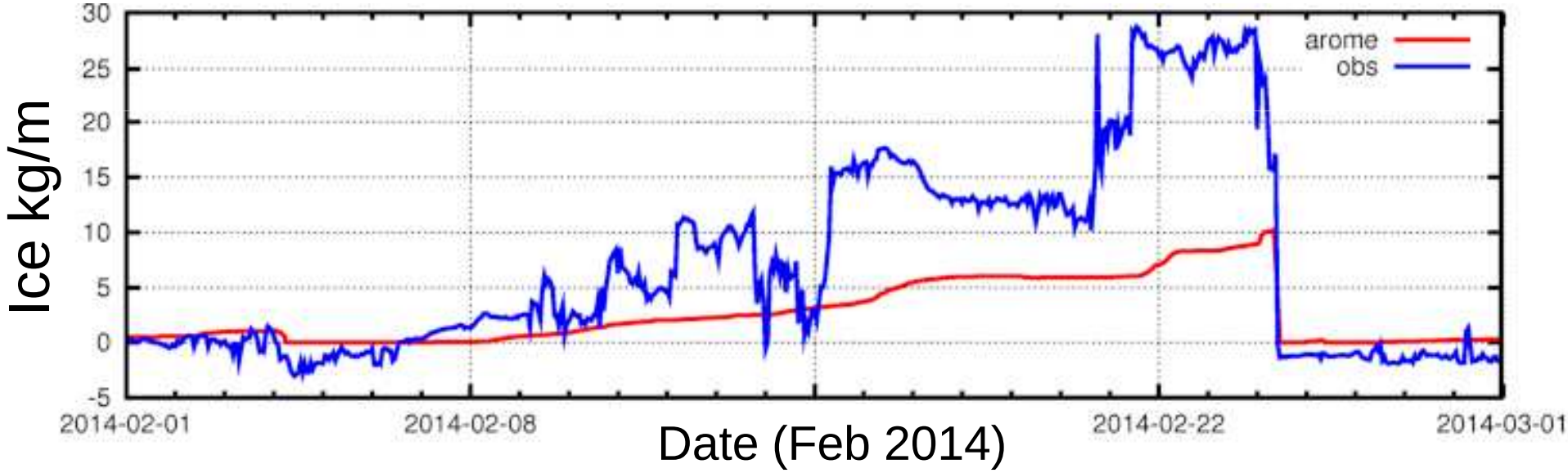
## Iceload for one wind park



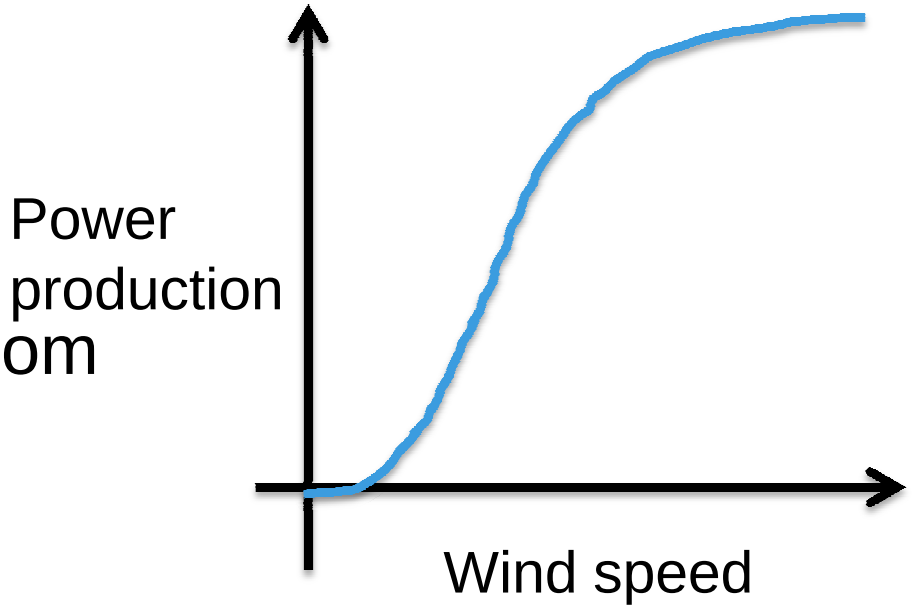
# Modelling production losses

- 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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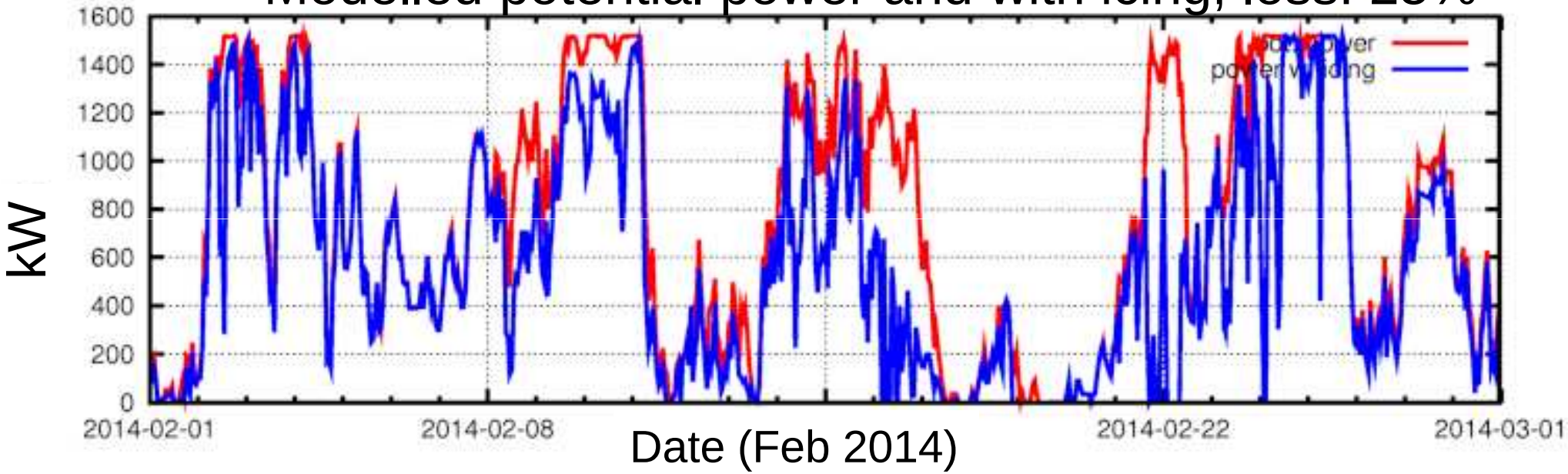
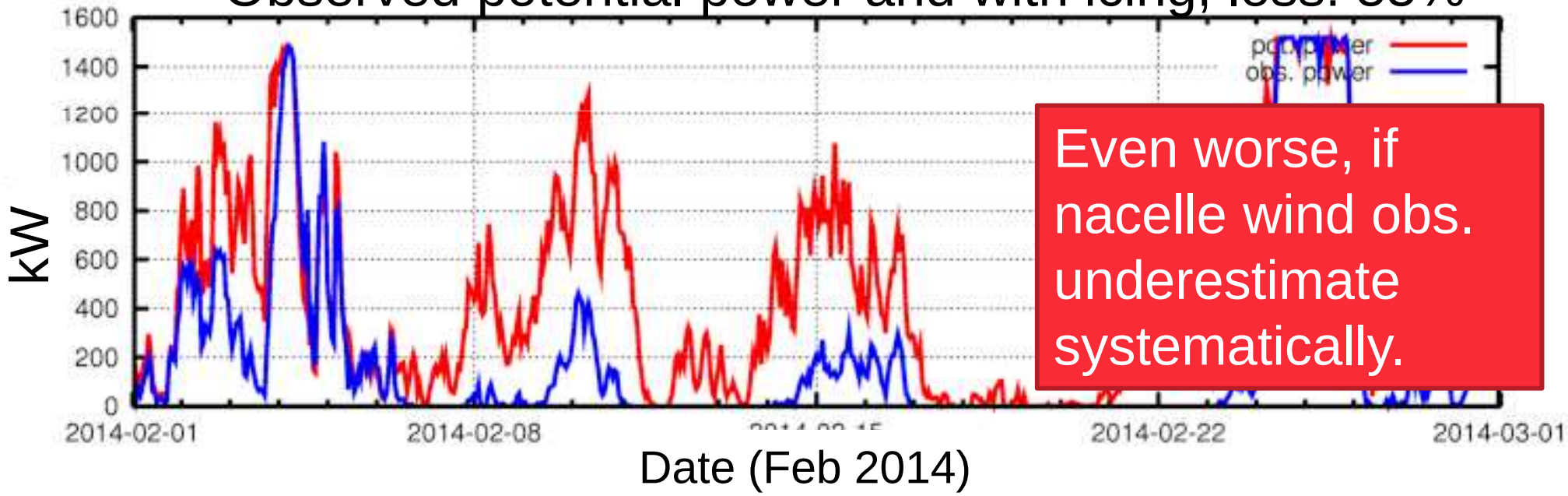
Modelled potential power and with icing, loss: 25%




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

# Thank you!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