Modelling icing conditions for a selection of Swedish wind farms during winter 2014/2015

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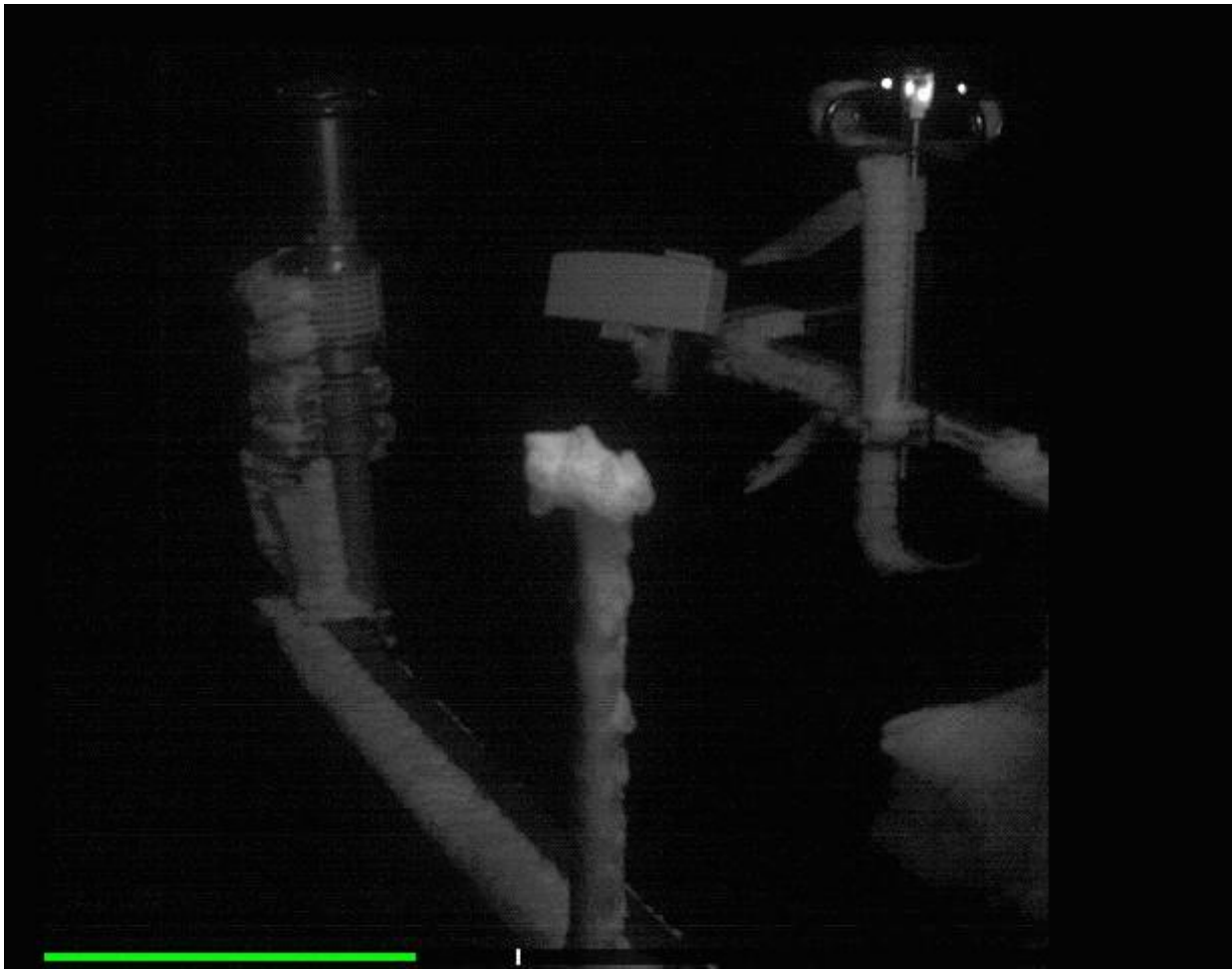
Overview

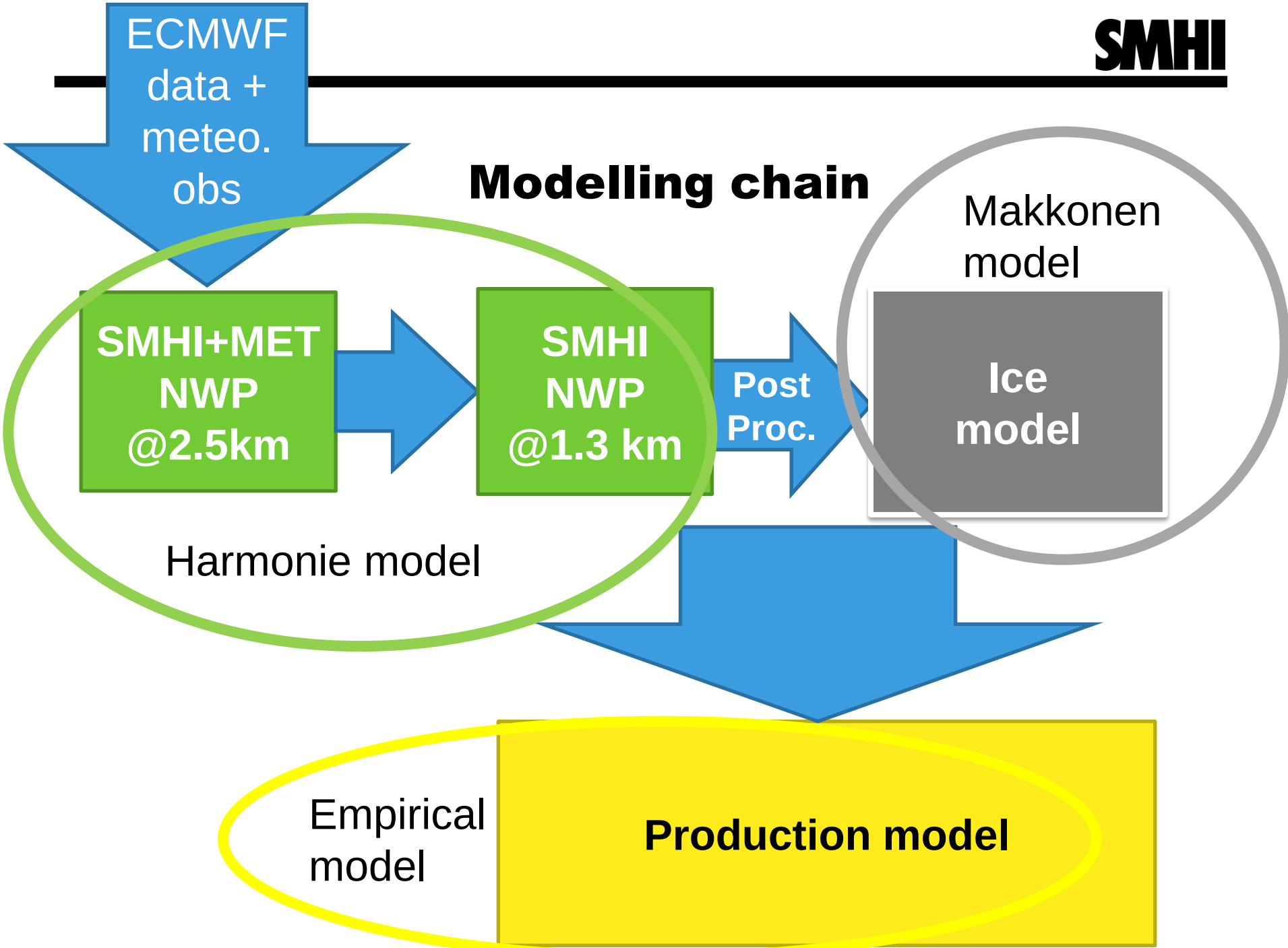
- Motivation
- Model setup
- The meteorological model HARMONIE
- Results:
  - Icing and wind power production losses during winter 14/15
  - Comparison with last years
  - Icing maps
- Conclusions

Icing is a severe problem for windpower

- Site planning
- Maintenance
- Safety
- Power production
- Noise pollution
- Trading



Hourly Webcam pictures of 2012-01-01 at a site by Combitech and provided by OX2


ECMWF data + meteo. obs
SMHI
Modelling chain
Makkonen model
SMHI+MET NWP @2.5km
SMHI NWP @1.3 km
Post Proc.
Ice model
Harmonie model
Empirical model
Production model

NWP Model setup 1/2

Harmonie/Arome 38h1.2

- Developed with 26 countries from Europe and northern Africa
- 2.5 km horizontal resolution
- Non-hydrostatic
- Model state updated 3-hourly (RUC)
- 66-hour forecasts produced every sixth hour (00, 06, 12, 18 UTC)

Used for forecasting of wind power production.

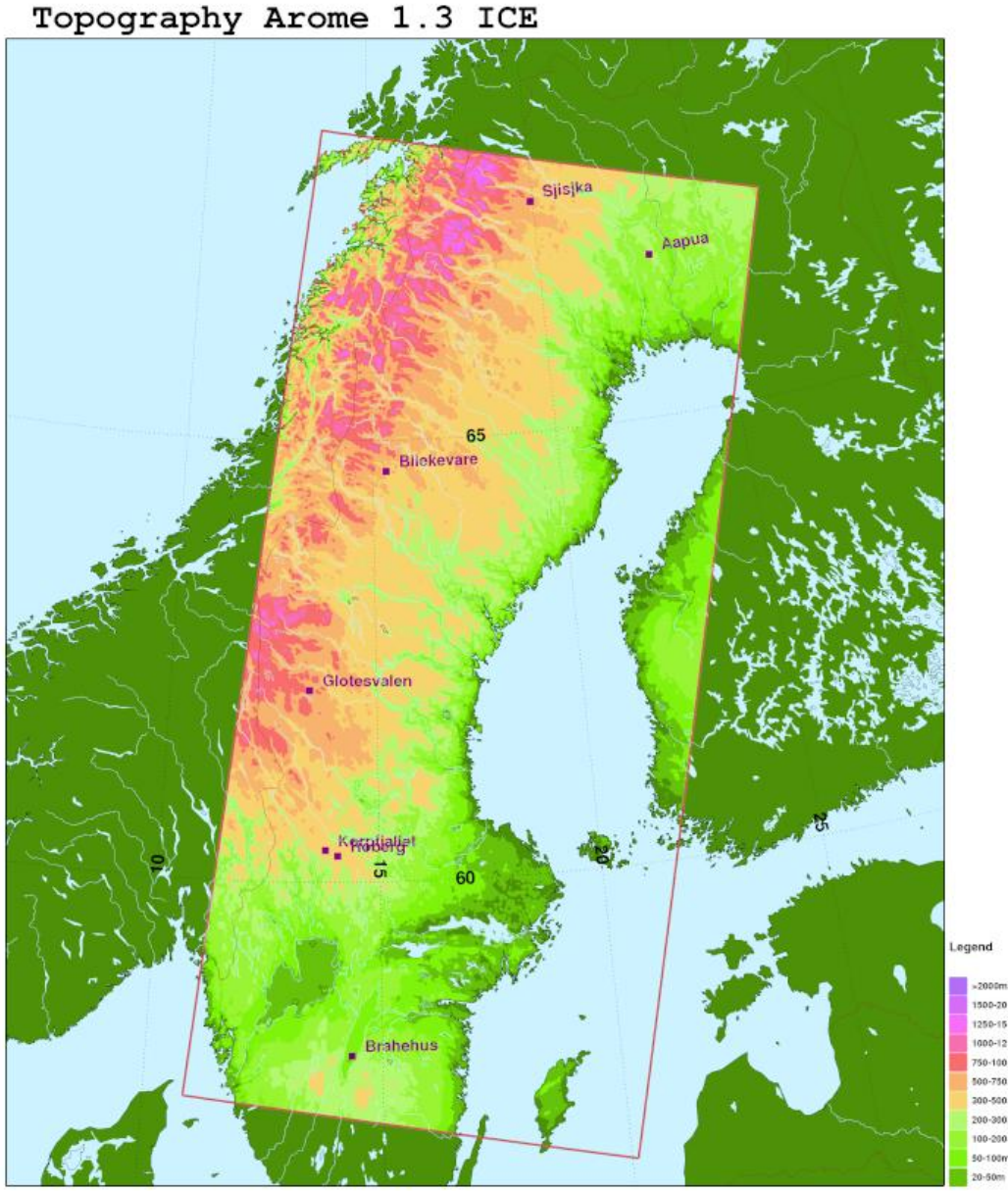
Open data:

http://opendata-catalog.smhi.se

NWP Model setup 2/2

Harmonie/Arome 38h1.2

- Using input from the official forecast @2.5 km
- Only surface state updated every sixth hour
- 18-hour forecasts produced every 12th hour (00, 12 UTC)
- Used for analysis of icing and production loss



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**

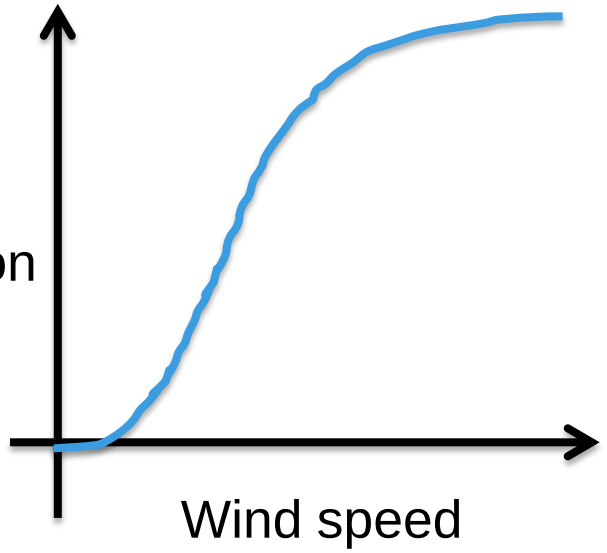
Modelling production losses

- Empirical relationship of 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



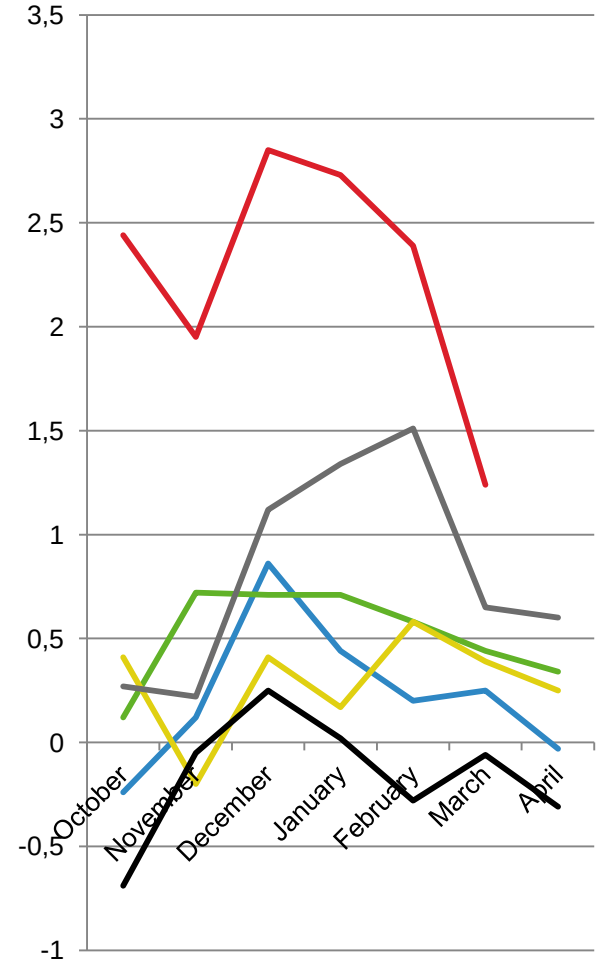
Observations for verification

- 5 sites over the domain with:
  - Wind power production data
  - Wind speed and temperature from wind turbine nacelle
- Additional 2 sites with meteorological observations of temperature and wind speed
- Icing observations at 1 site.
- Observations are collected every 10 minutes at 60-100 m above ground.

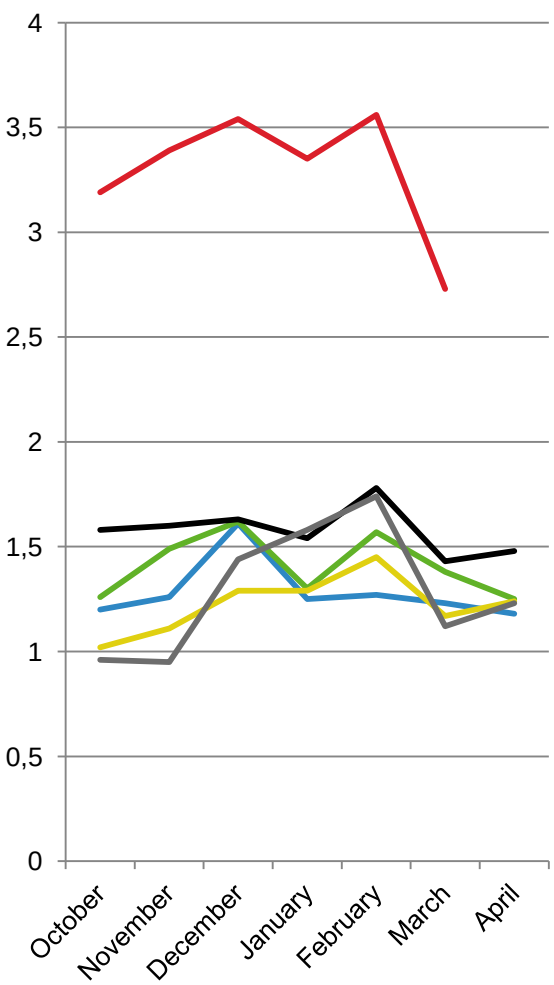
Production loss will be used as proxy for atmospheric icing.

The meteorological model performance winter 2014/5 for wind speed

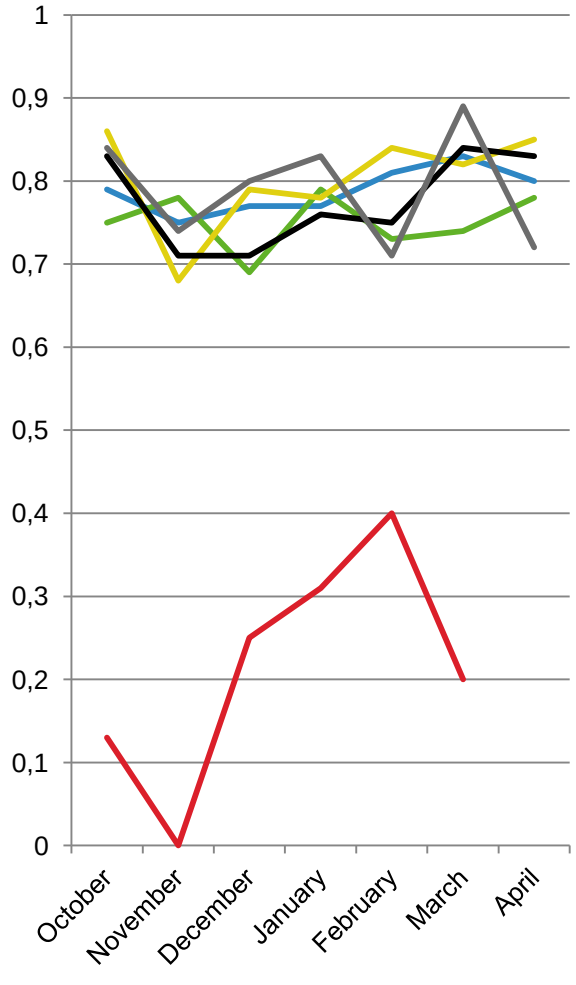
Bias in m/s

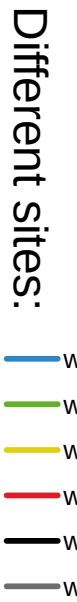


MAE in m/s

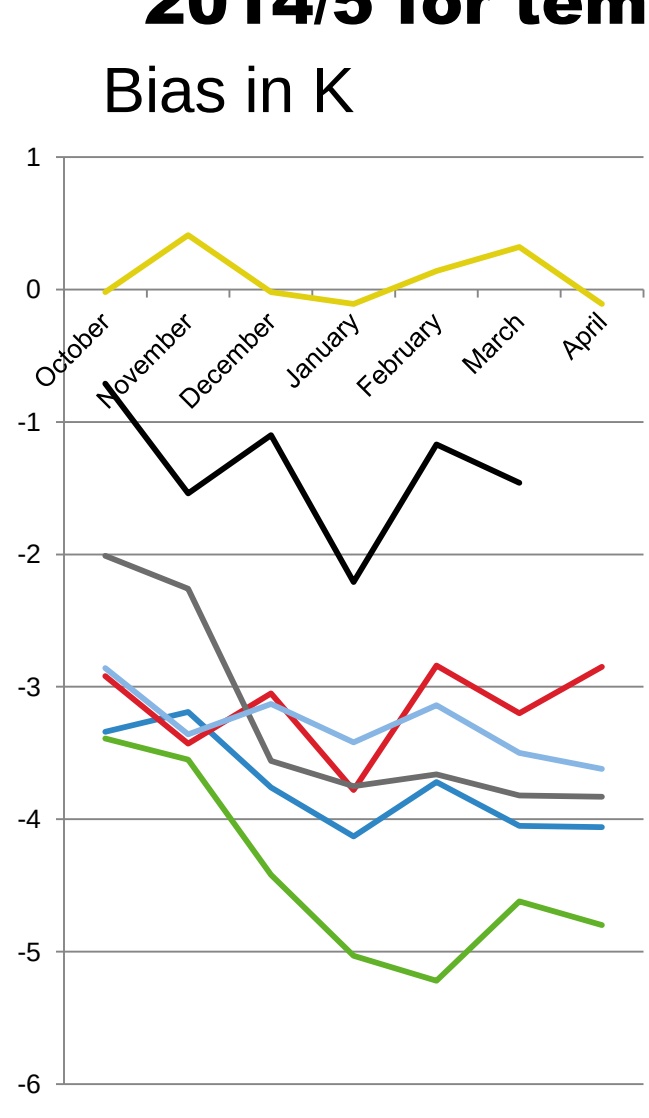


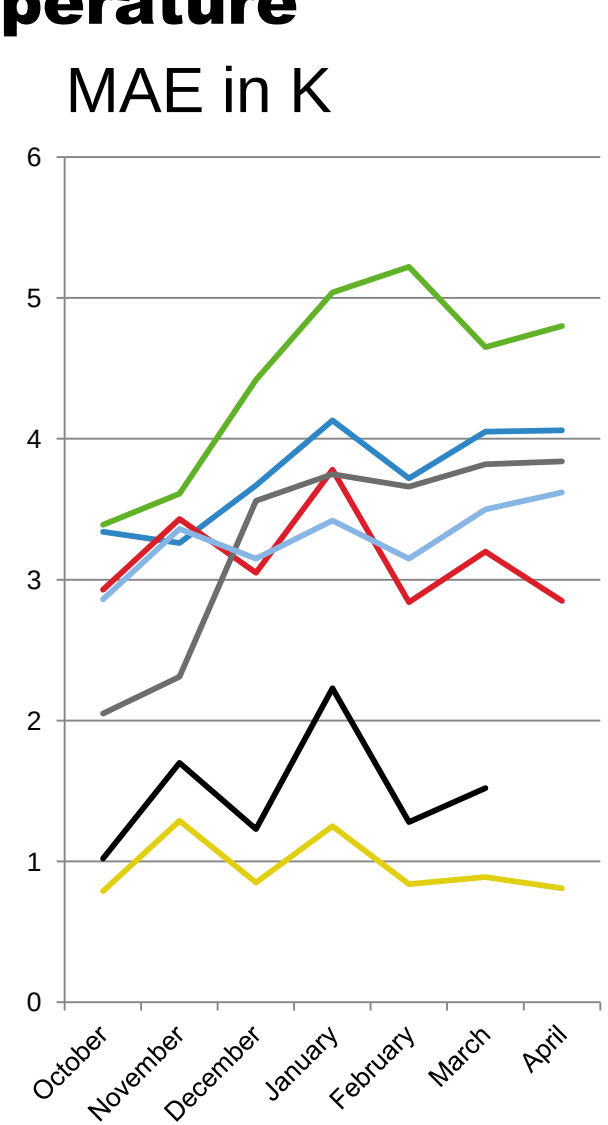
Correlation

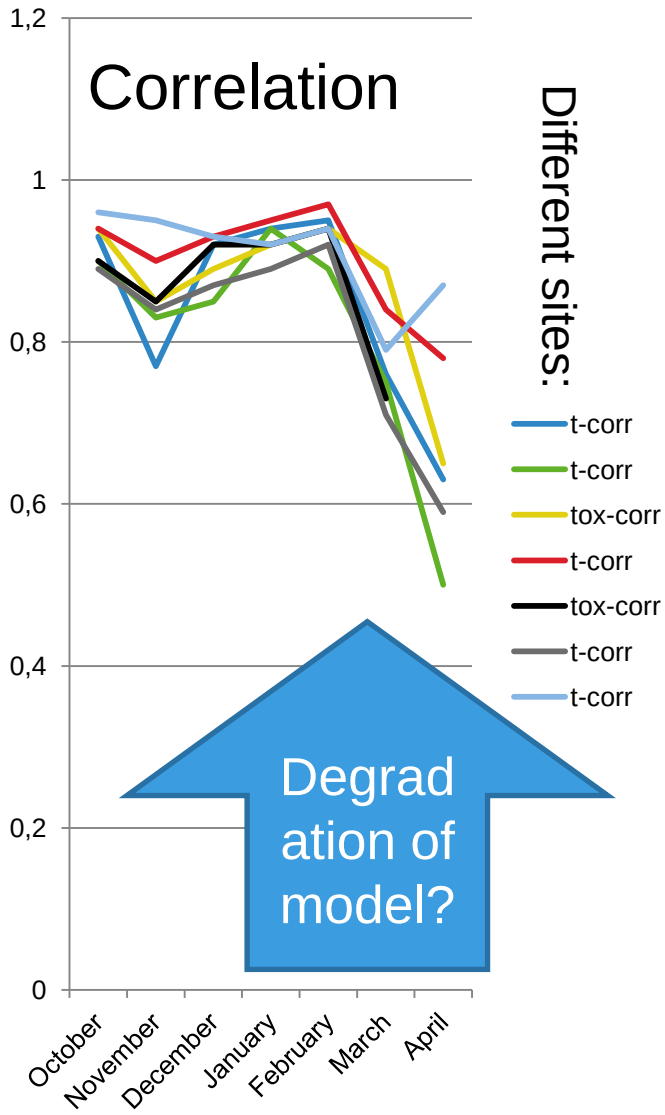




The meteorological model performance winter 2014/5 for temperature

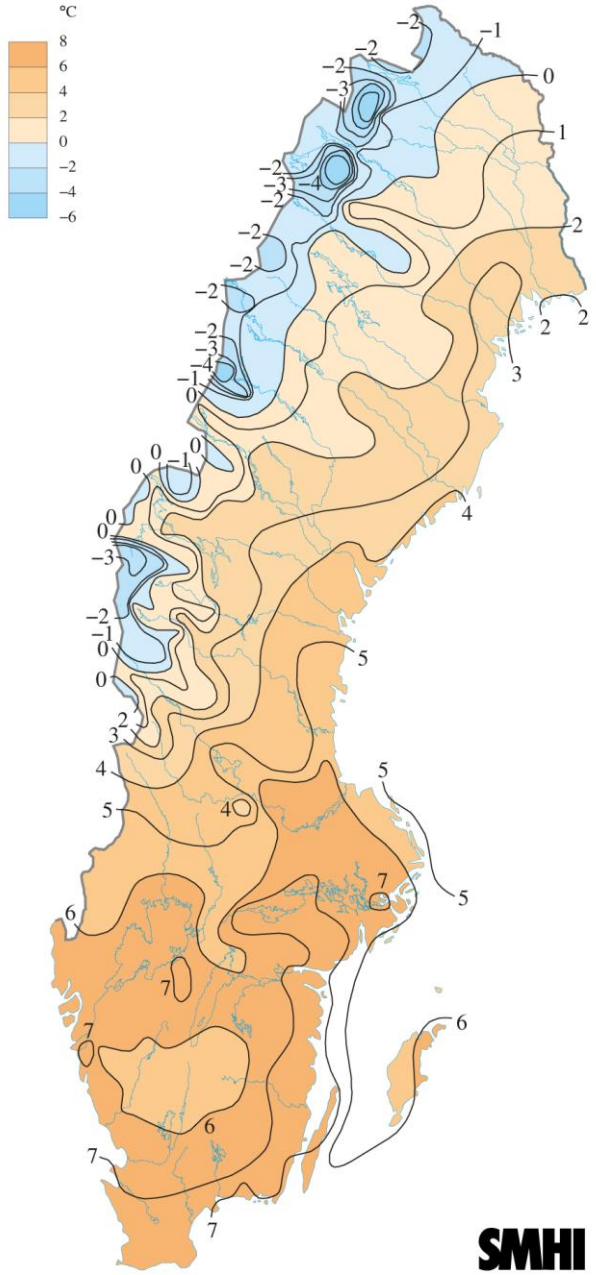




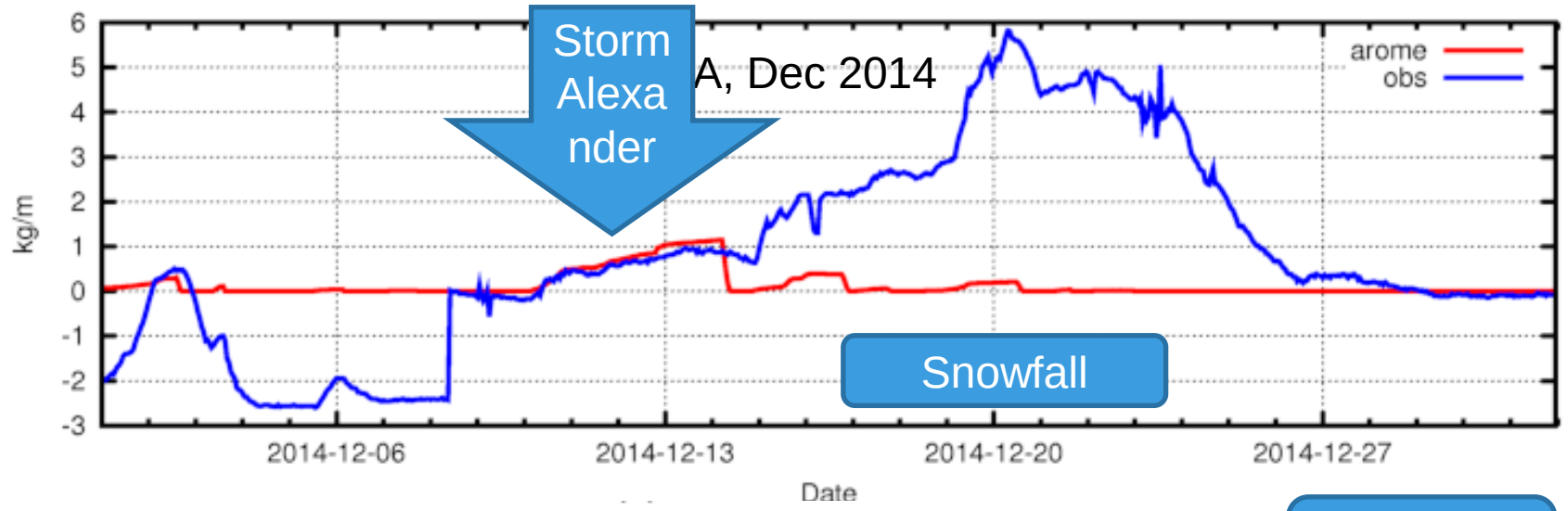


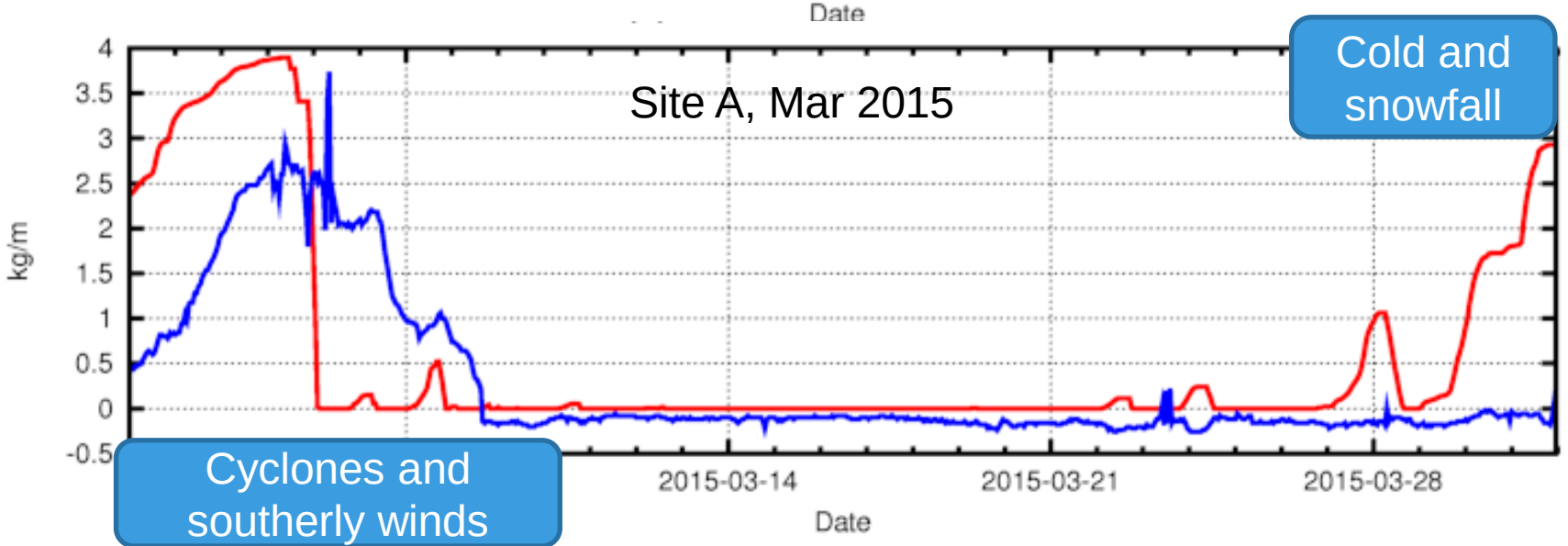
Swedish Winter 2014/5

- Oct 2014 – Mostly mild and rich on precipitation
- Nov 2014 - Mild and cloudy in South but sunny in North
- Dec 2014 – Mixed with emphasis on mild
- Jan 2015 – In general mild and rich on precipitation
- Feb 2015 – Mild winds yielded early spring
- Mar 2015 – Spring warmth was partly reduced
- Apr 2015 – Active low pressure traffic over Norwegian Sea



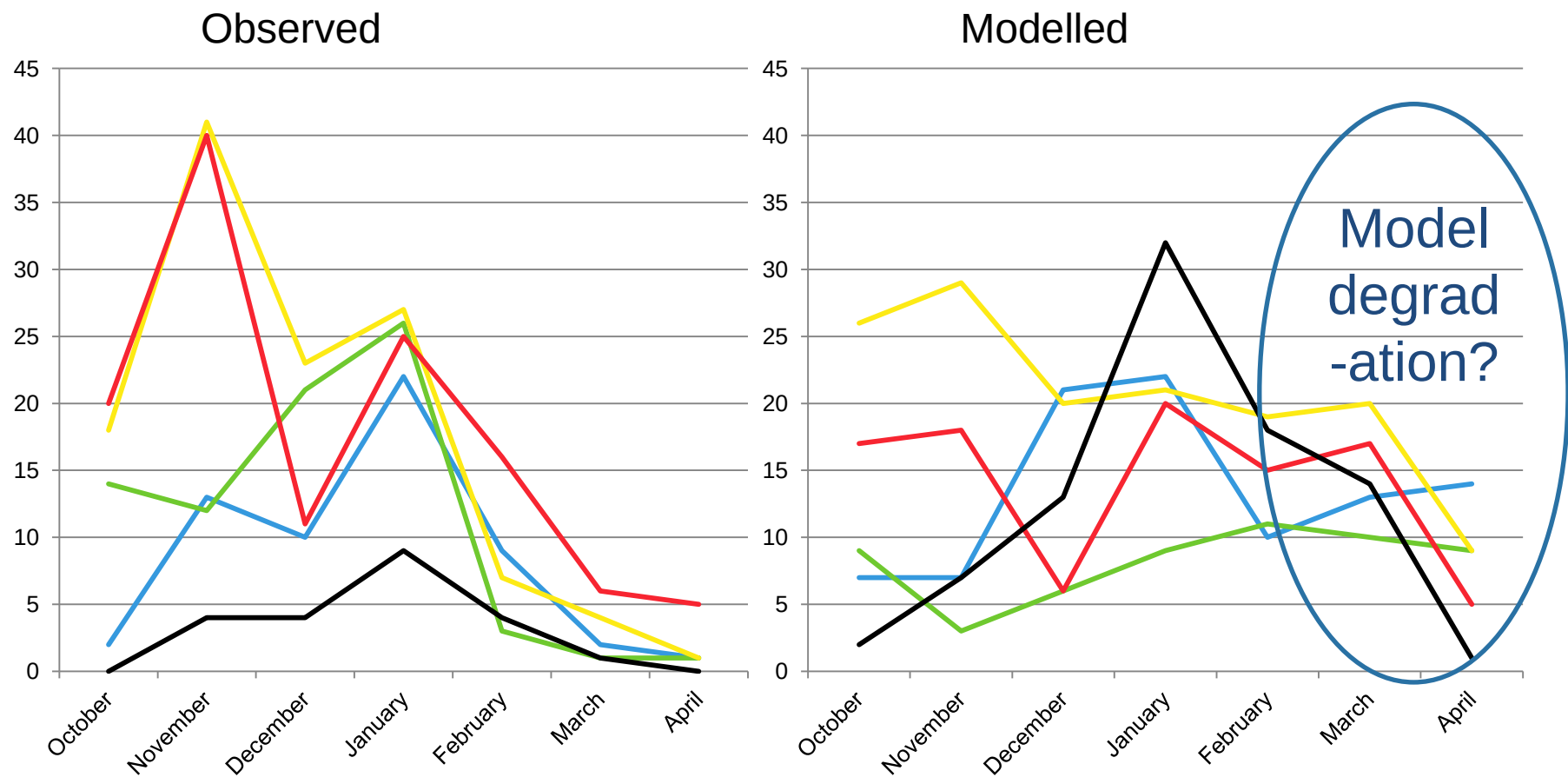
Icing on wind turbines during 2014/5





Production loss during winter 2014/5

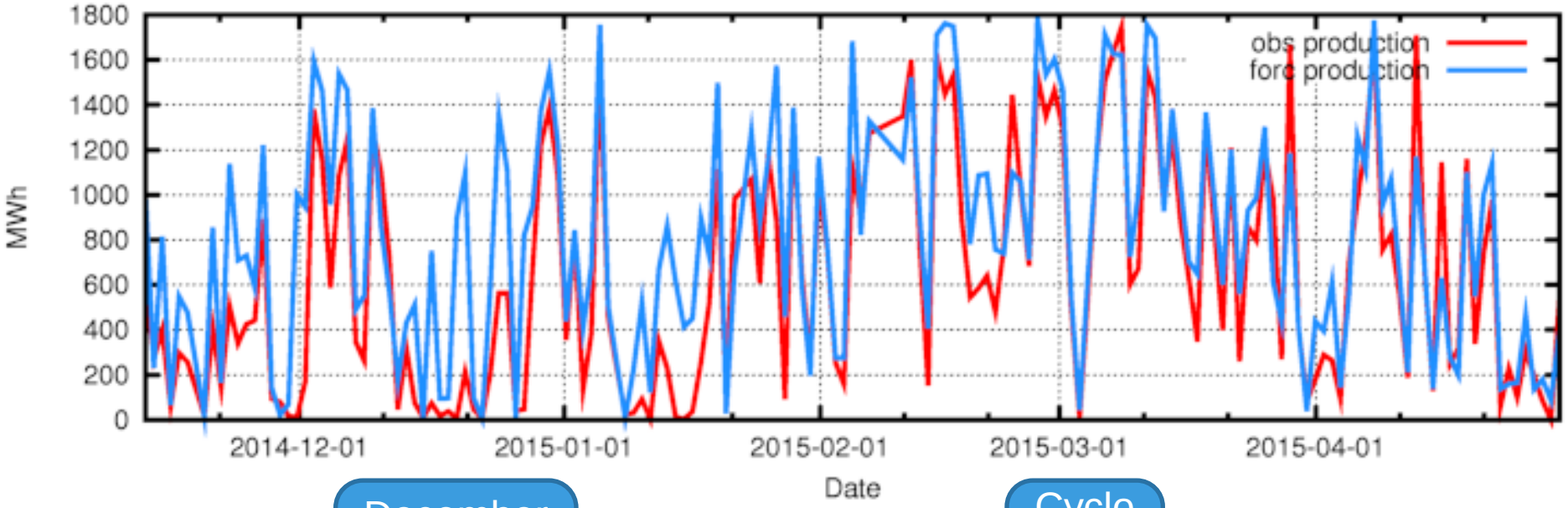
Production loss in % for 5 sites



It is assumed that all turbines are running and no de-icing is present.

Forecasting production loss

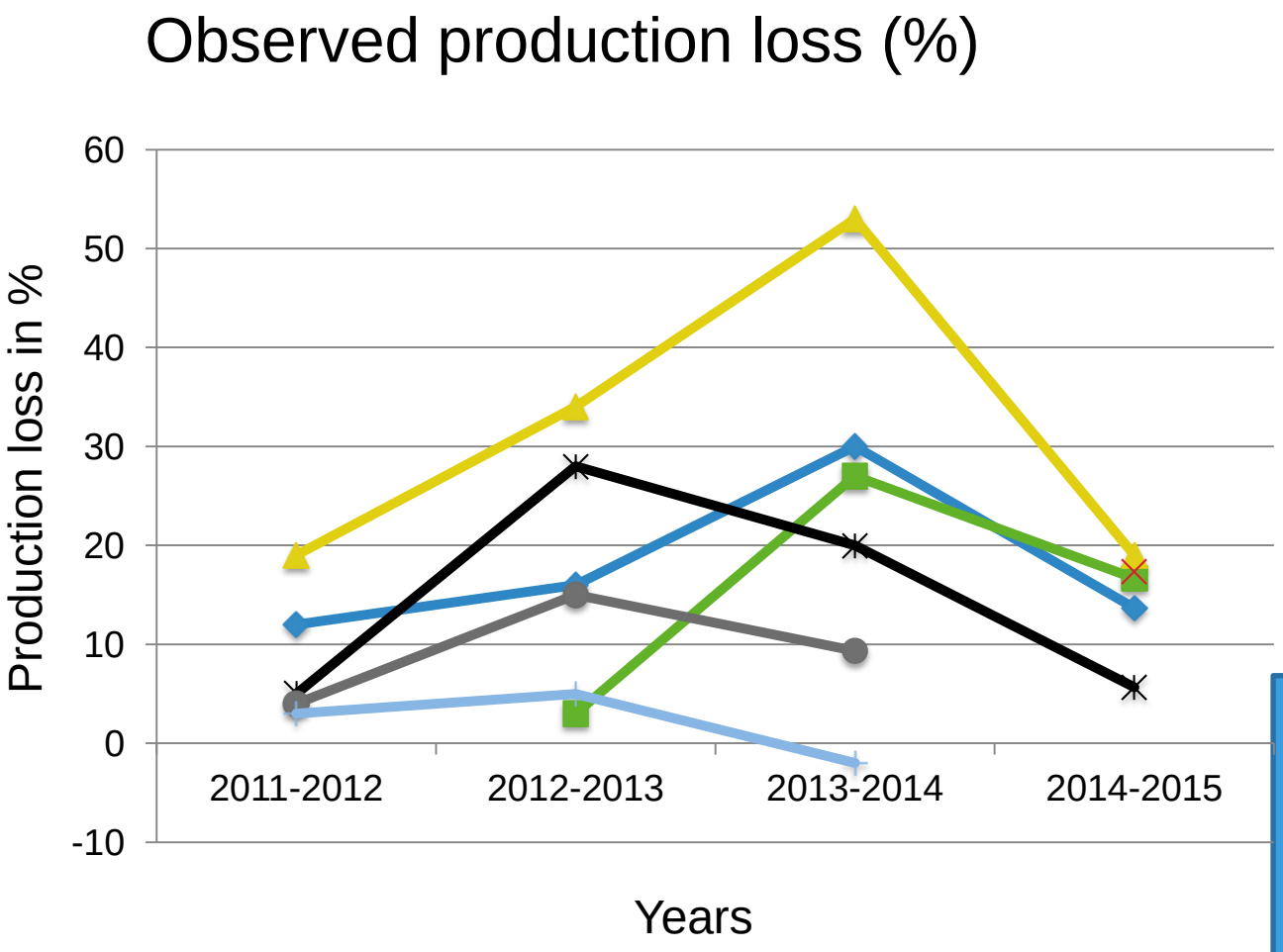
Site A, observed and forecasted daily power production



December with snowfall

Cyclones and southerly winds

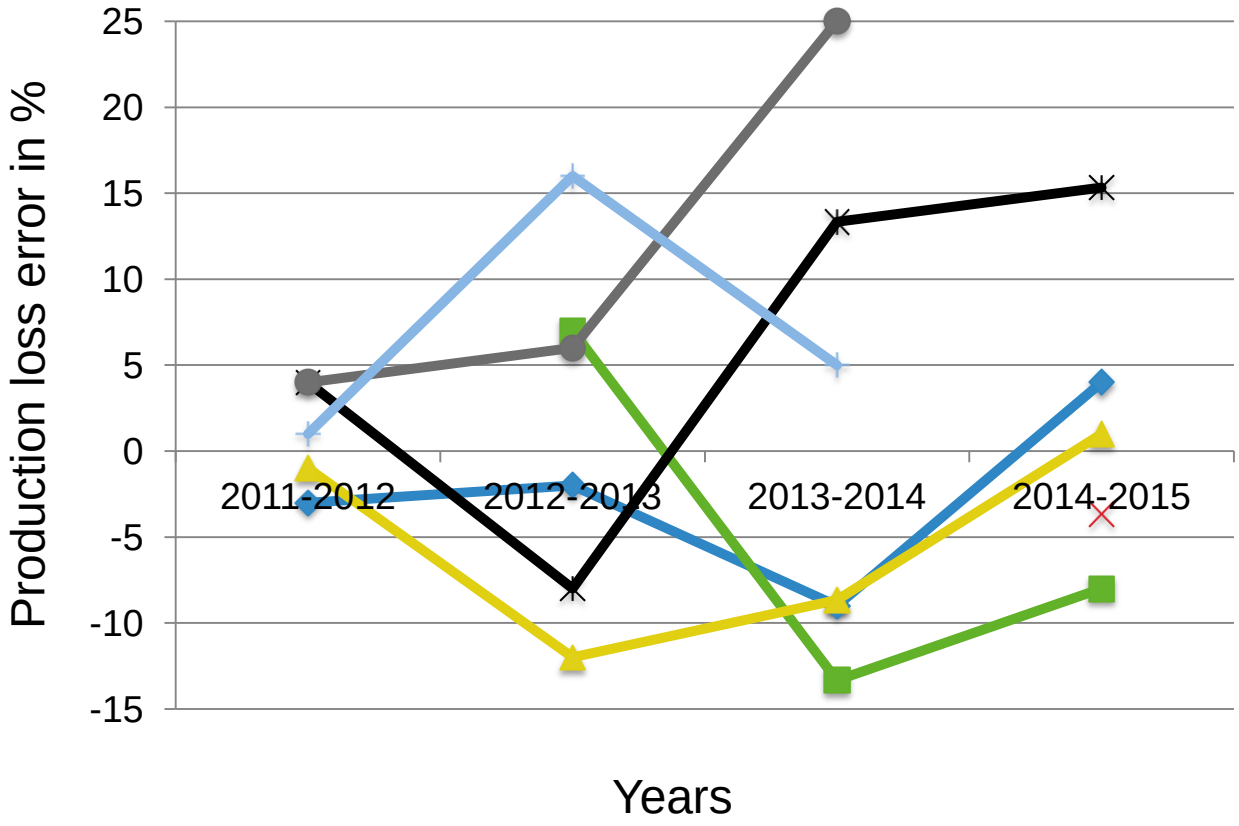
Comparison of the last 4 winters



Averaged for Dec-Feb, except for 2011-2012, Oct-Apr

Comparison of the last 4 winters

Error between modelled and observed production loss (%)

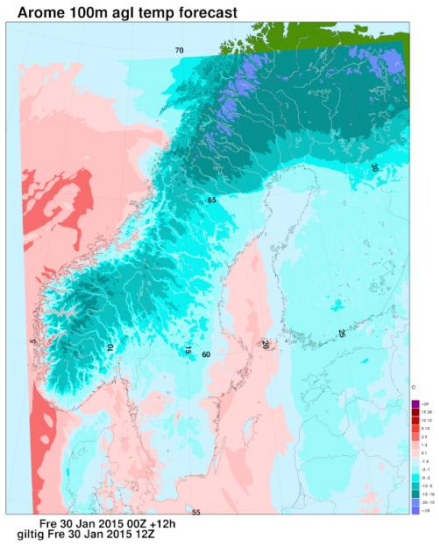


Averaged for Dec-Feb, except for 2011-2012, Oct-Apr

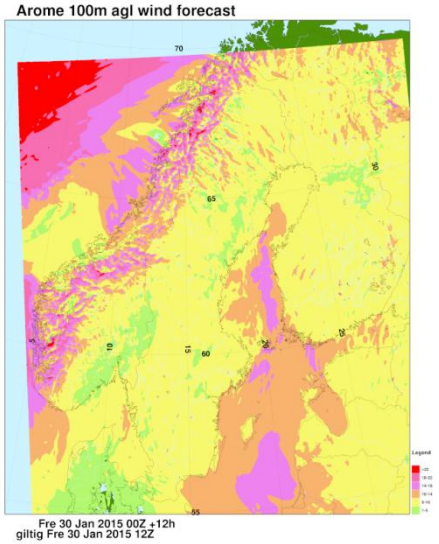
Model setup for icing maps

SMHI

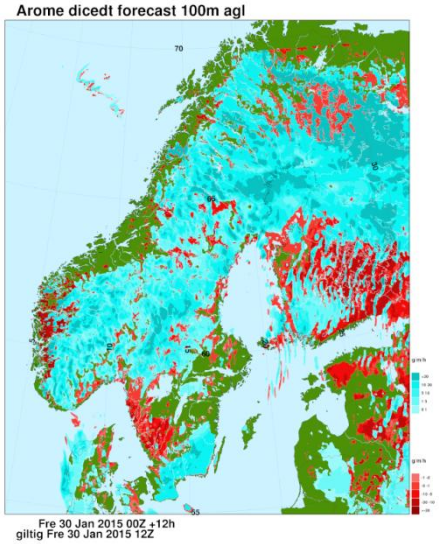
Temperature



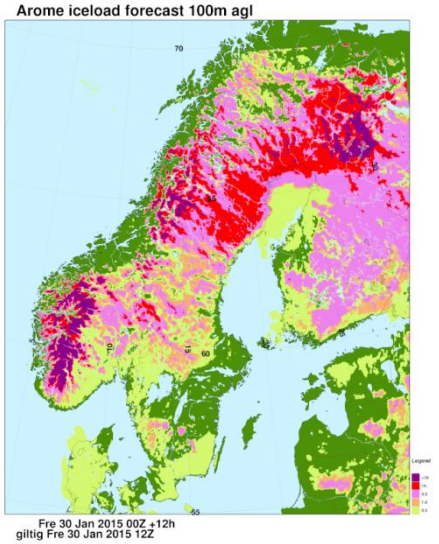
Wind speed



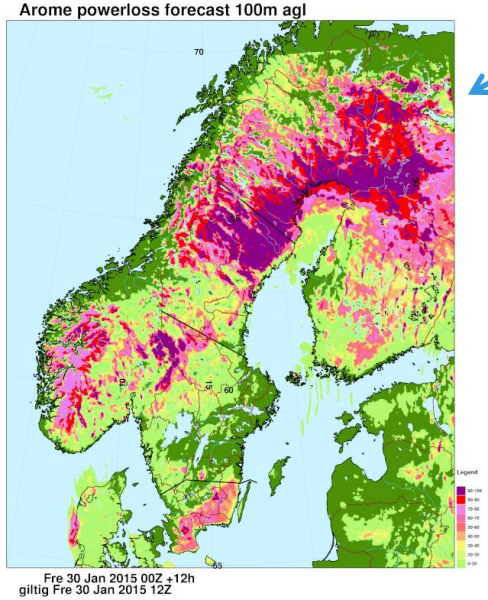
Icing rate



Ice load

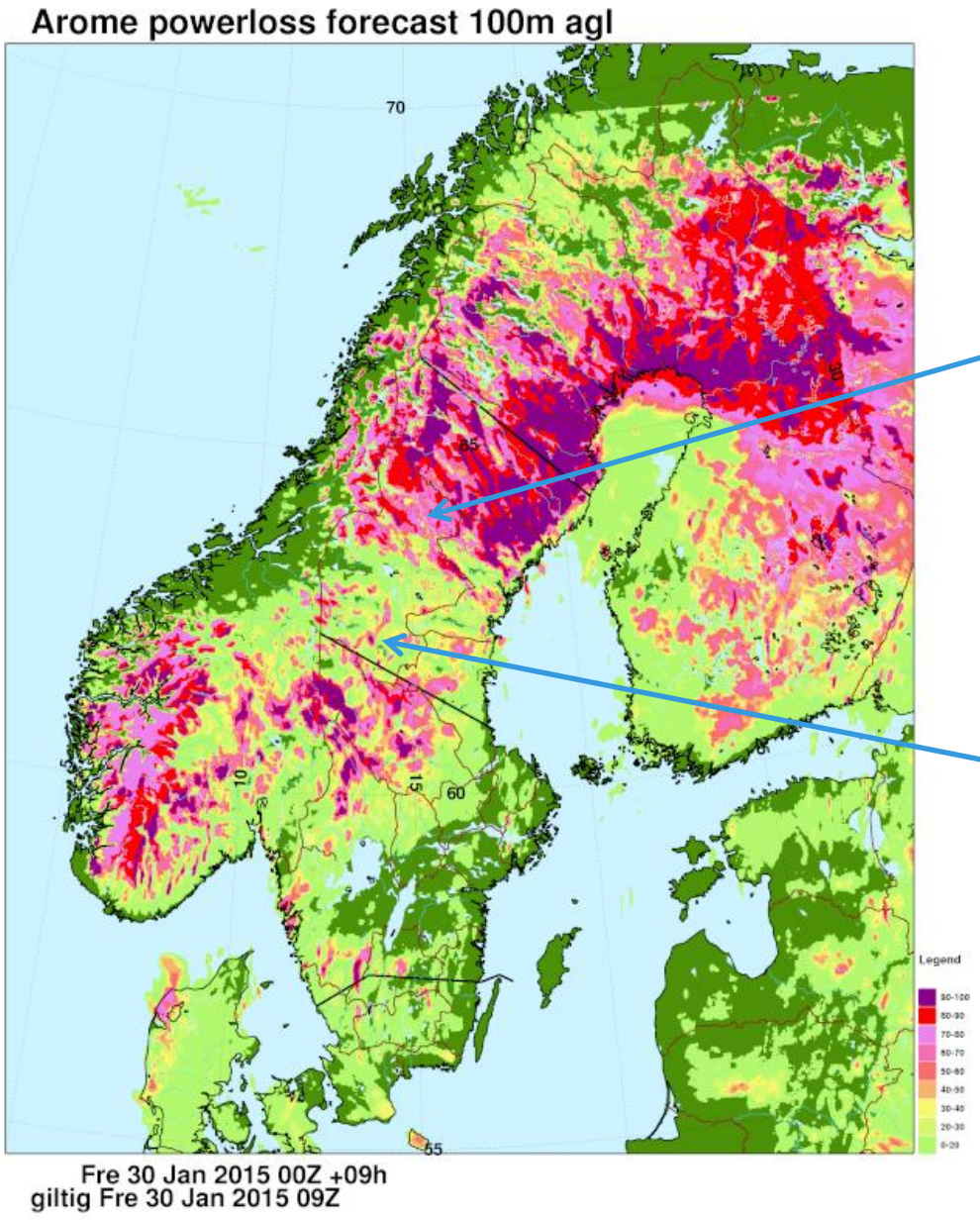


Power loss %



Sample maps

SMHI



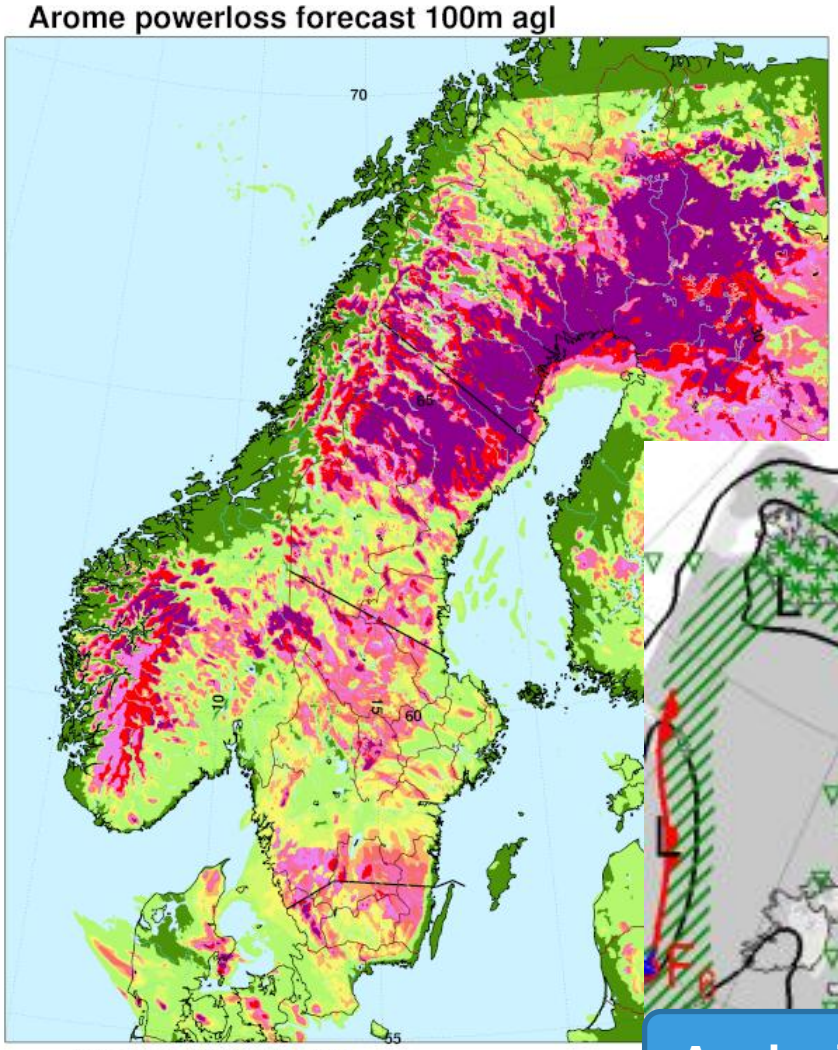
Tåsjö 100m

Sveg 70m

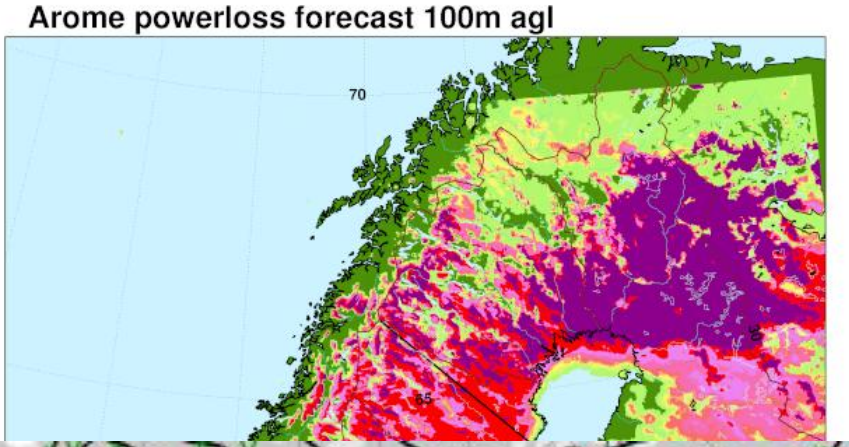
Sample maps

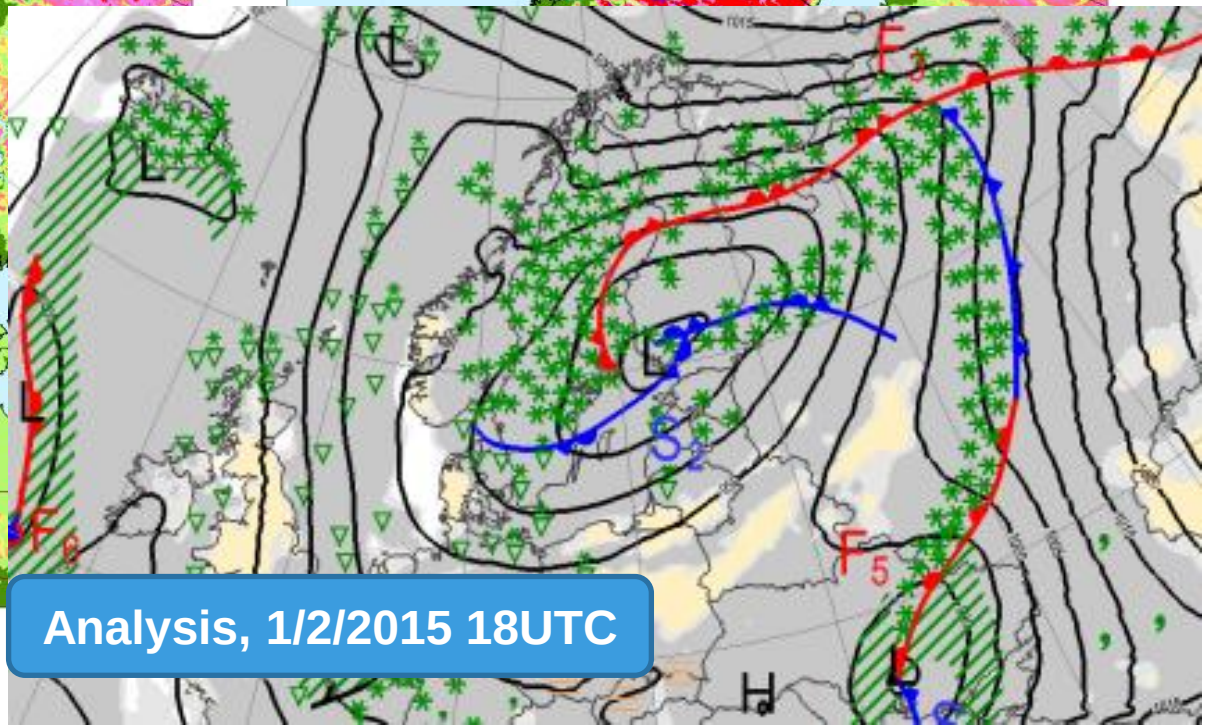
SMHI

24-hour forecast, valid Sat 31/1 00UTC



36-hour forecast, valid Sat 31/1 12UTC

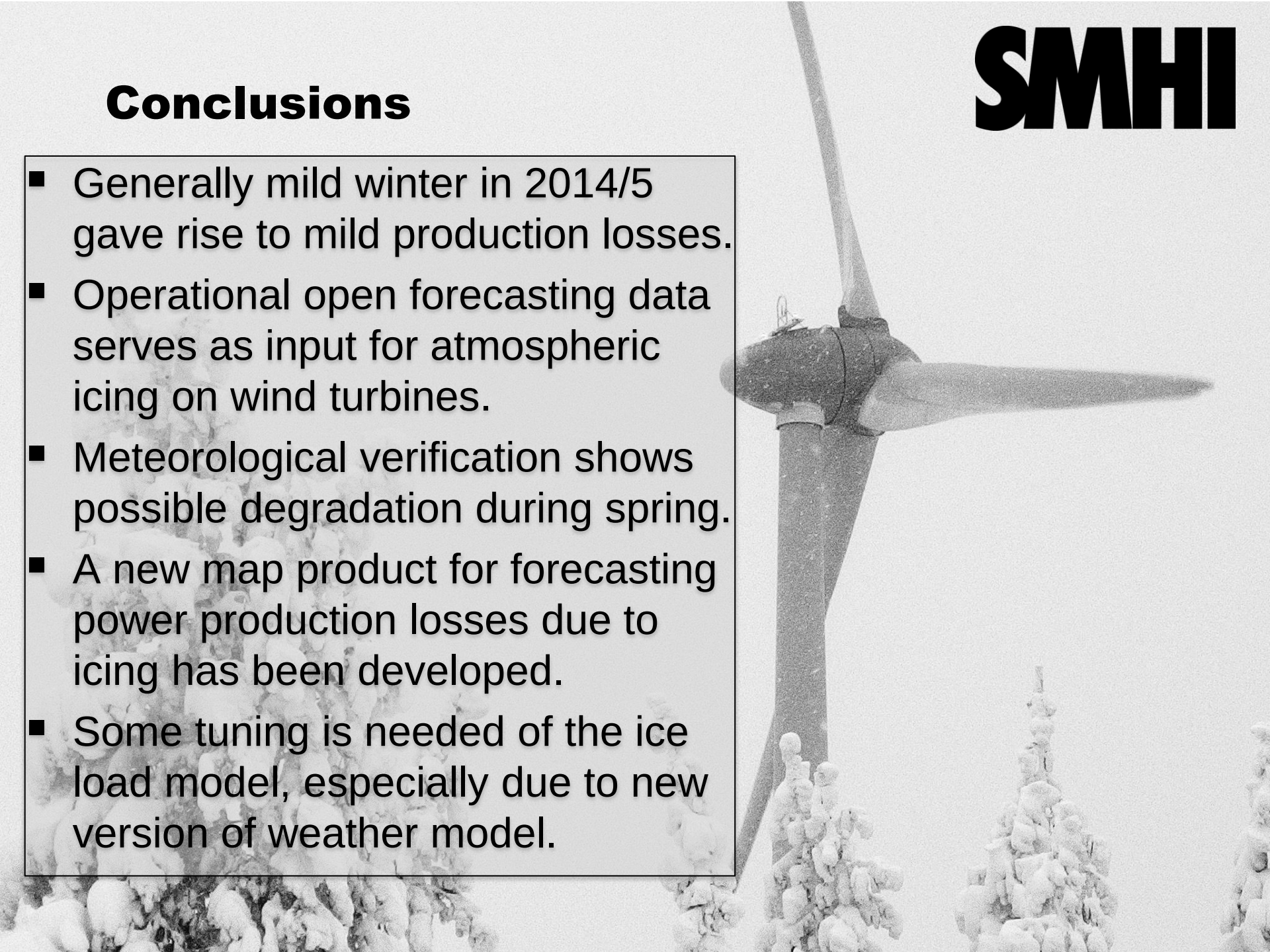




Analysis, 1/2/2015 18UTC

Conclusions

- Generally mild winter in 2014/5 gave rise to mild production losses.
- Operational open forecasting data serves as input for atmospheric icing on wind turbines.
- Meteorological verification shows possible degradation during spring.
- A new map product for forecasting power production losses due to icing has been developed.
- Some tuning is needed of the ice load model, especially due to new version of weather model.




Thank you!
clustervision
Bifrost@NSC