

**High resolution forecast maps of  
production loss due to icing.**

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## **Introduction**

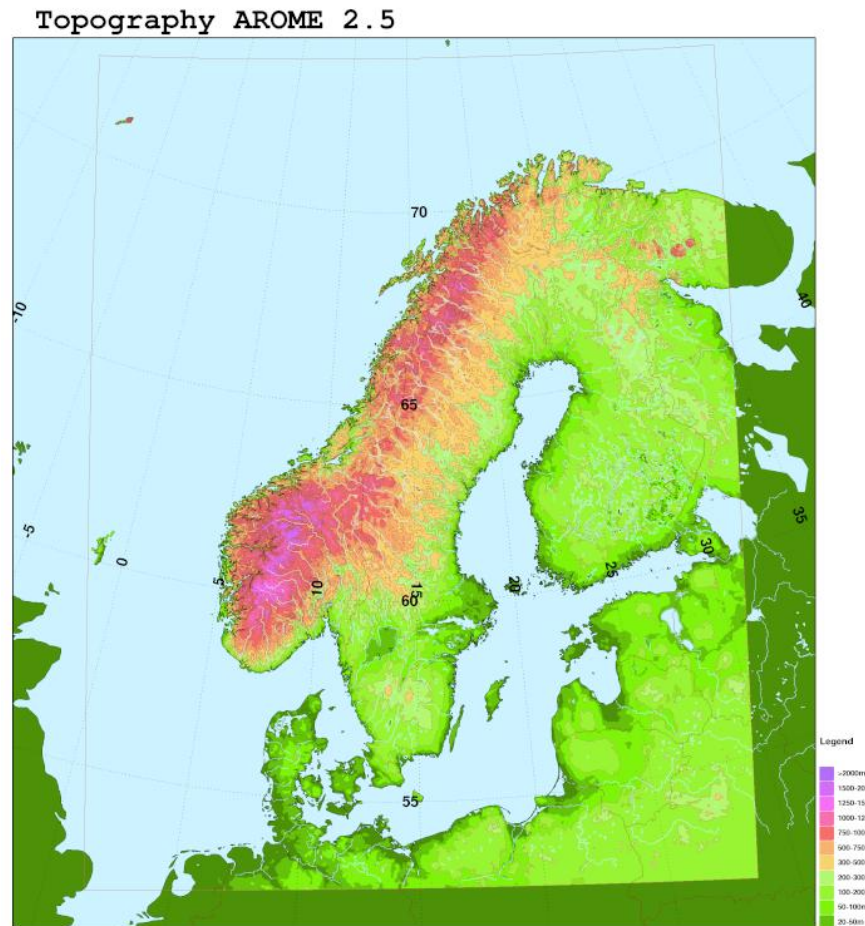
- Previously real-time forecasts of production loss due to icing mostly has been performed on individual wind turbines or wind farms.
- There also seems to be a demand for an overview picture for those who are managing many wind farms.
- Since March 2014, SMHI, together with MET Norway (yr.no), is running a new operational high resolution weather forecast model.
- This new model has a rather advanced cloud scheme that in previous projects has produced reasonable ice loads.

## Model setup

### MetCoOp Arome 38h1.2

- 2.5 km horizontal resolution
- 65 vertical levels
- Analysis every third hour
- 66-hour forecasts produced every sixth hour (00, 06, 12, 18 UTC)

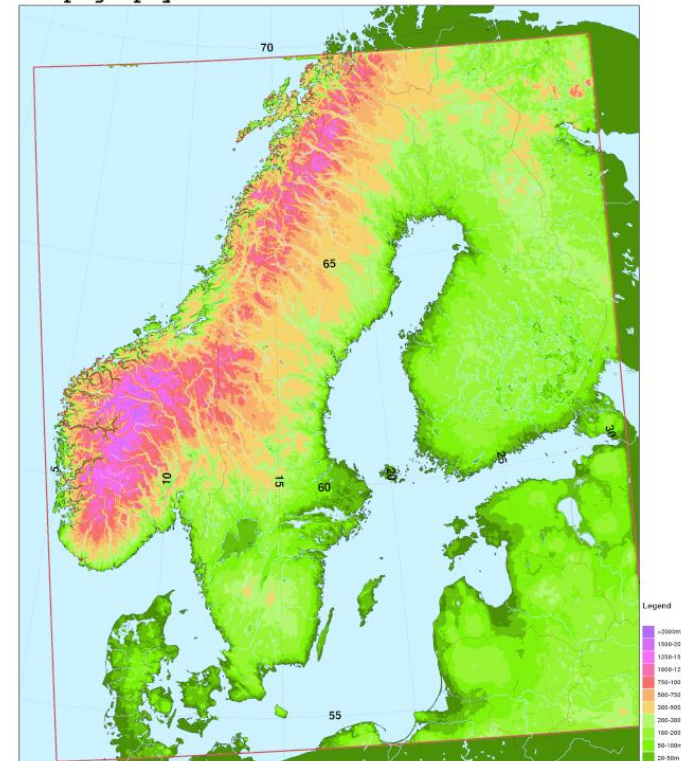
Used for operational public forecasting in Sweden and Norway.



## Model setup

- Original model data is interpolated to a 1 km grid.
- All parameters vertically adjusted to the higher resolution topography.
- Makkonen formula used to calculate icing rate and ice load.
- Model cloud water, cloud ice, rain and snow is used.
- Power loss is calculated using empirical relations between wind speed, icing rate and ice load.
- Nacelle height 100 m assumed.
- Ice load is carried over between forecasts.

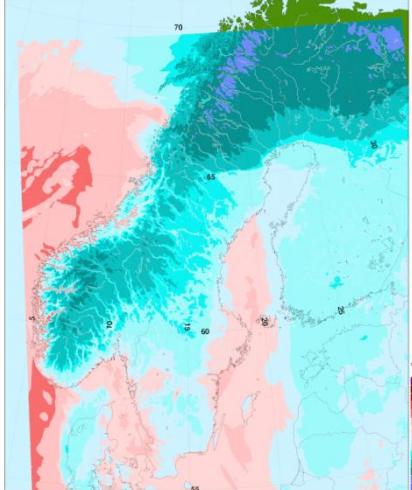
Topography Arome ICE



# Model setup

## Temperature

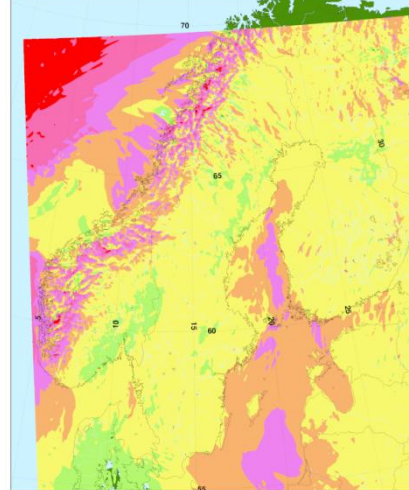
Arome 100m agl temp forecast



Fre 30 Jan 2015 00Z +12h  
giltig Fre 30 Jan 2015 12Z

## Wind speed

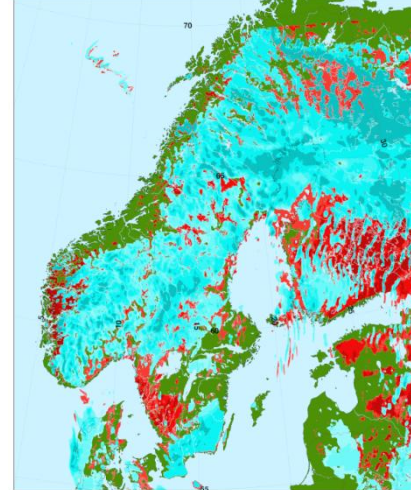
Arome 100m agl wind forecast



Fre 30 Jan 2015 00Z +12h  
giltig Fre 30 Jan 2015 12Z

## Icing rate

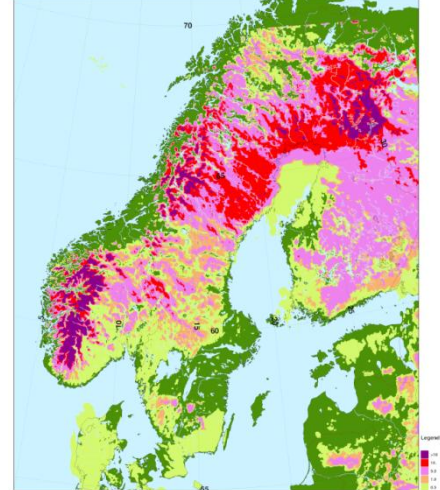
Arome diced forecast 100m agl



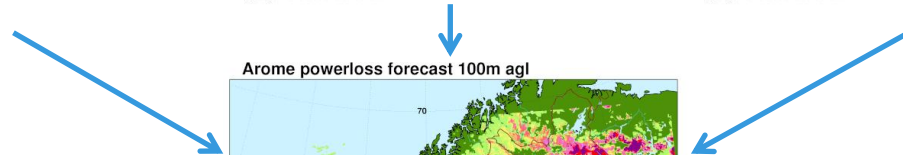
Fre 30 Jan 2015 00Z +12h  
giltig Fre 30 Jan 2015 12Z

## Ice load

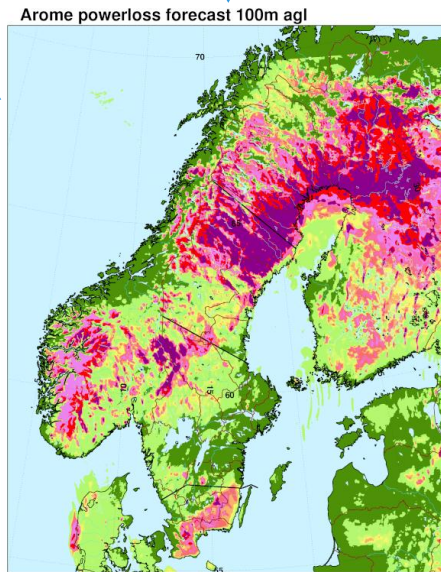
Arome iceload forecast 100m agl



Fre 30 Jan 2015 00Z +12h  
giltig Fre 30 Jan 2015 12Z



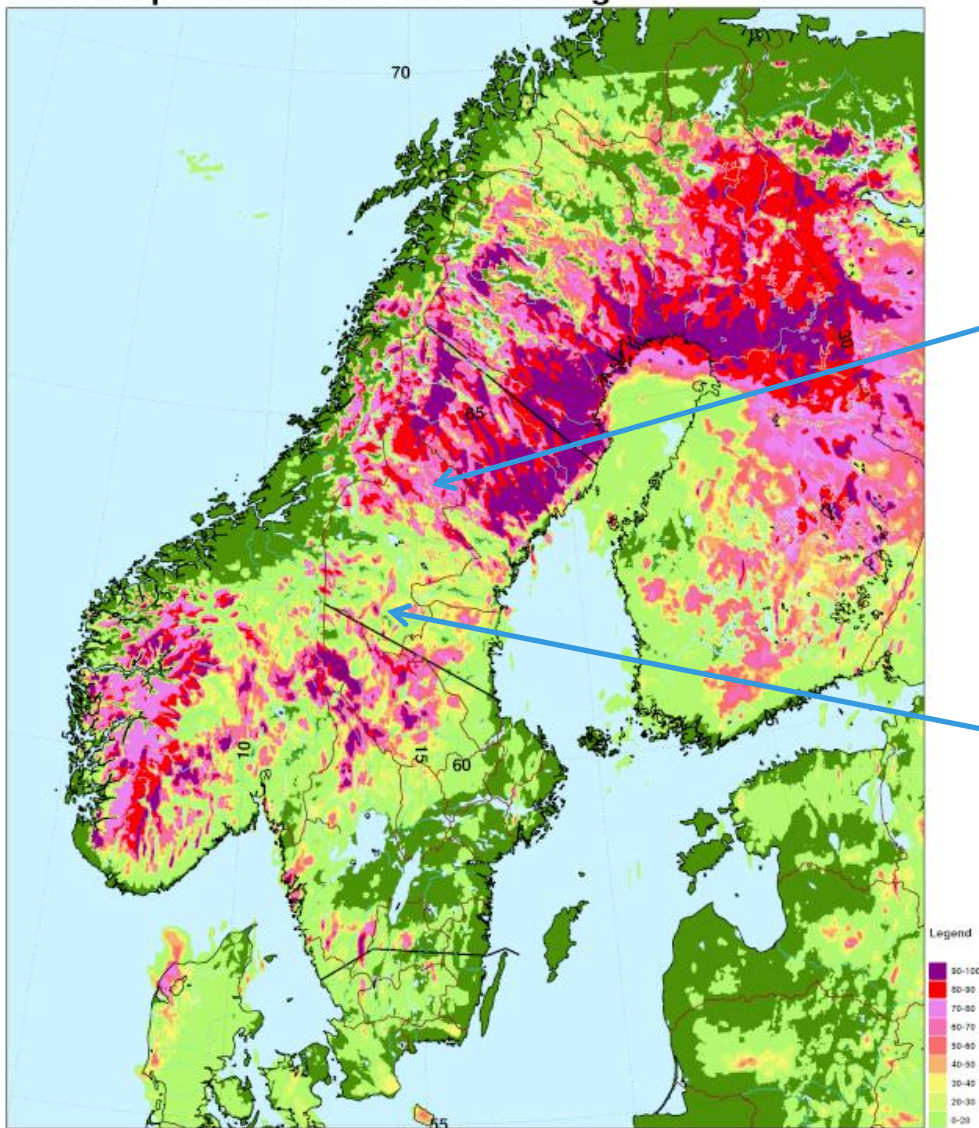
Power loss %



Fre 30 Jan 2015 00Z +12h  
giltig Fre 30 Jan 2015 12Z

# Sample maps

Arome powerloss forecast 100m agl

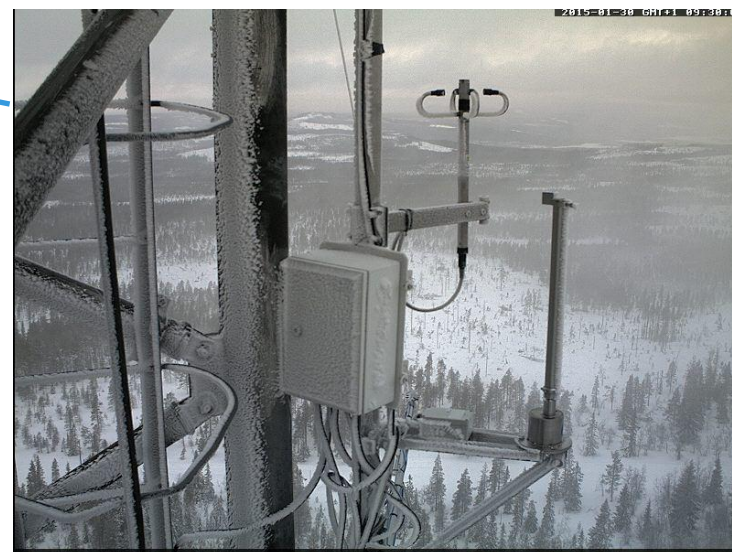


Fre 30 Jan 2015 00Z +09h  
giltig Fre 30 Jan 2015 09Z

Tåsjö 100m



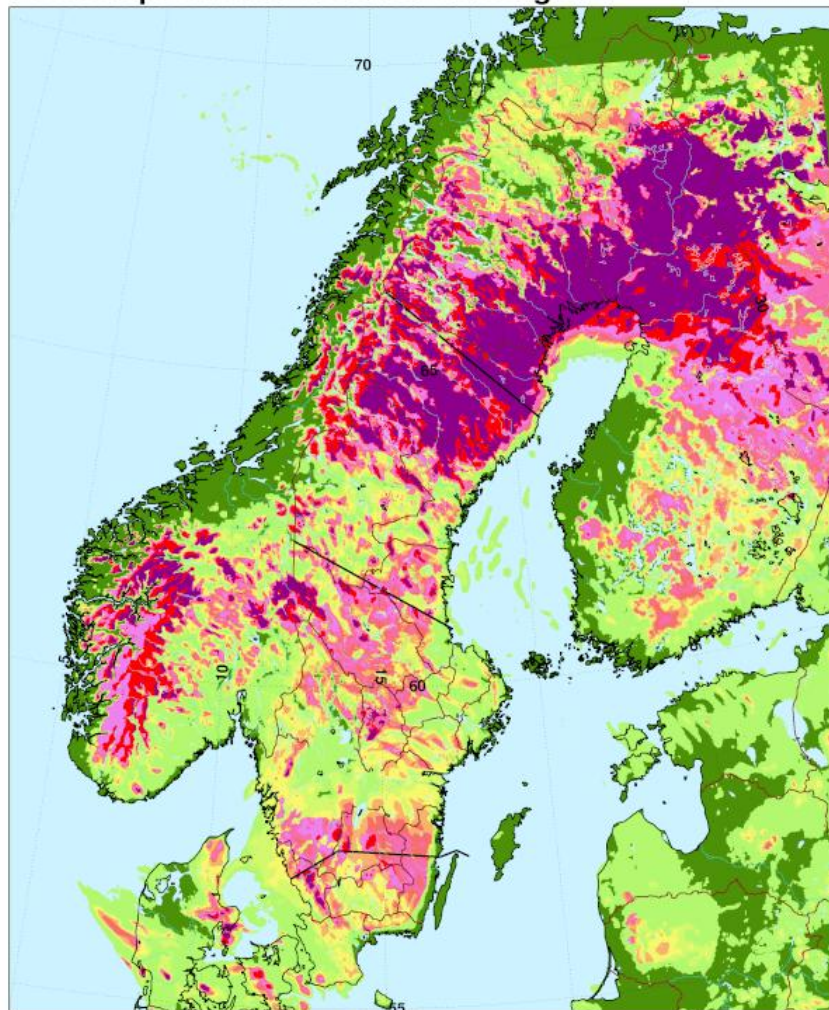
Sveg 70m



# Sample maps

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

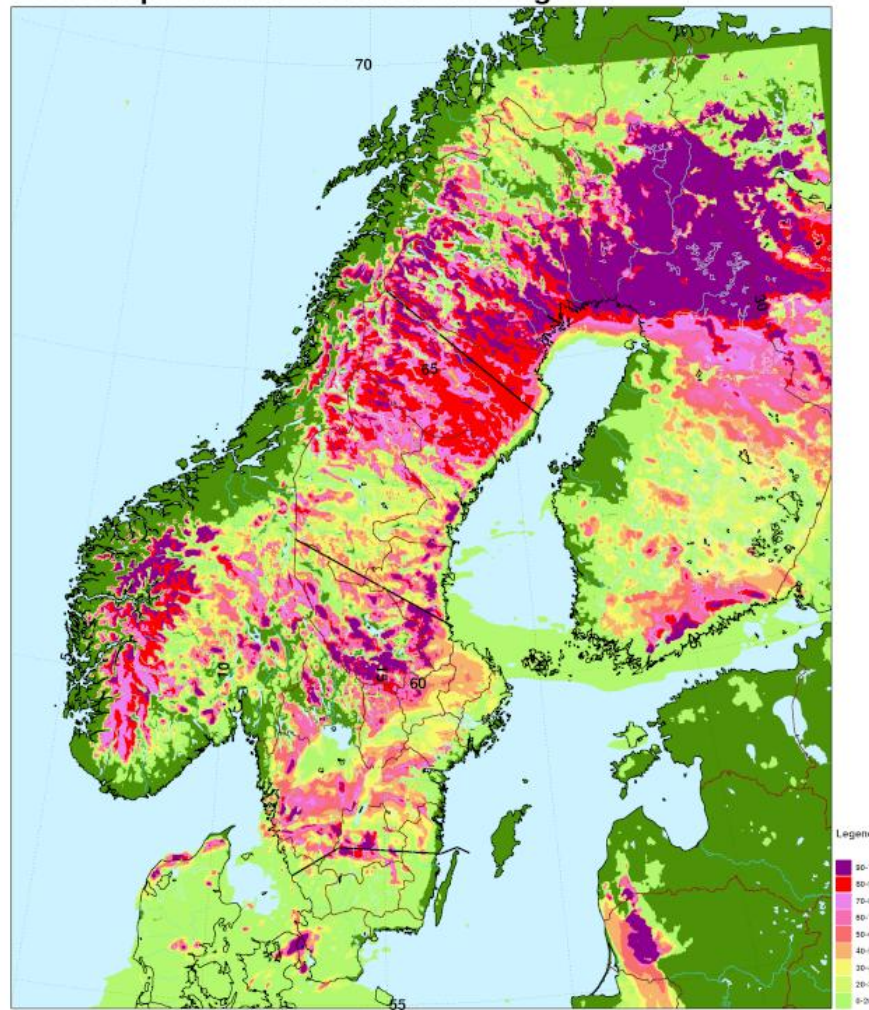
Arome powerloss forecast 100m agl



Fre 30 Jan 2015 00Z +24h  
giltig Lör 31 Jan 2015 00Z

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

Arome powerloss forecast 100m agl



Fre 30 Jan 2015 00Z +36h  
giltig Lör 31 Jan 2015 12Z



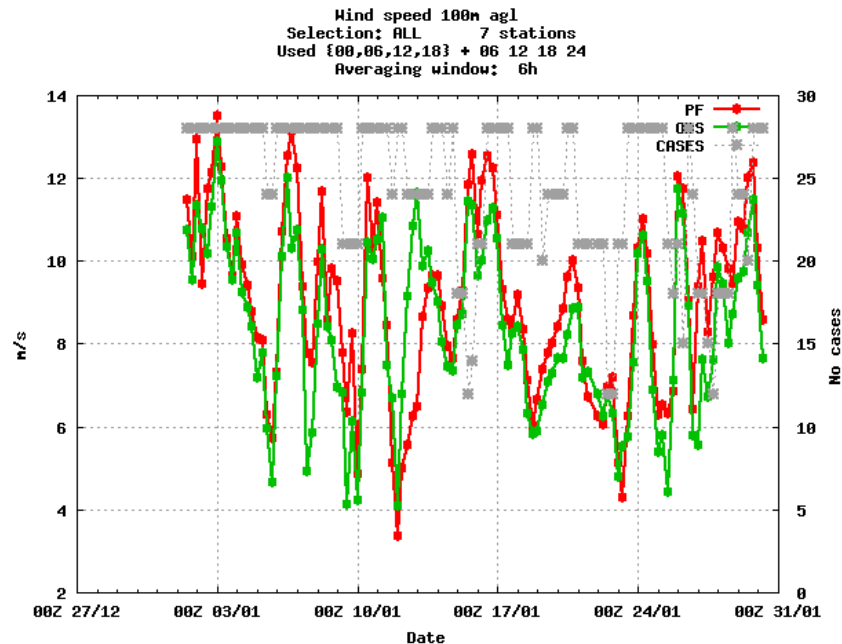
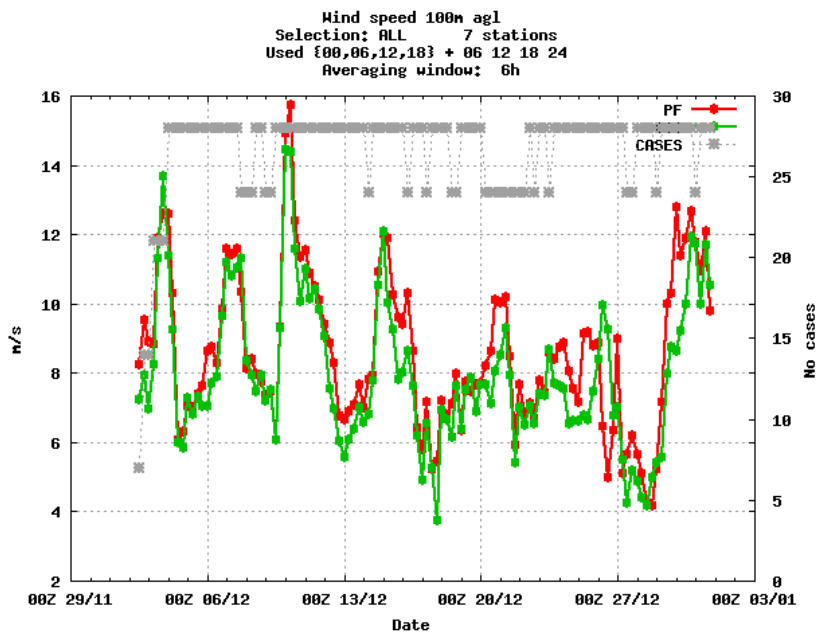
## **Preliminary verification**

- Is performed against seven wind farms.
- Verified variables:
  - Wind speed
  - Temperature
  - Power production loss
- Observed power production loss is calculated by a comparison of observed power and a potential power that is derived from observed nacelle wind speed and observed power curves.
- Three of the seven farms have de-icing capabilities.
- Two months of data.

# Verification wind speed

December 2014

January 2015



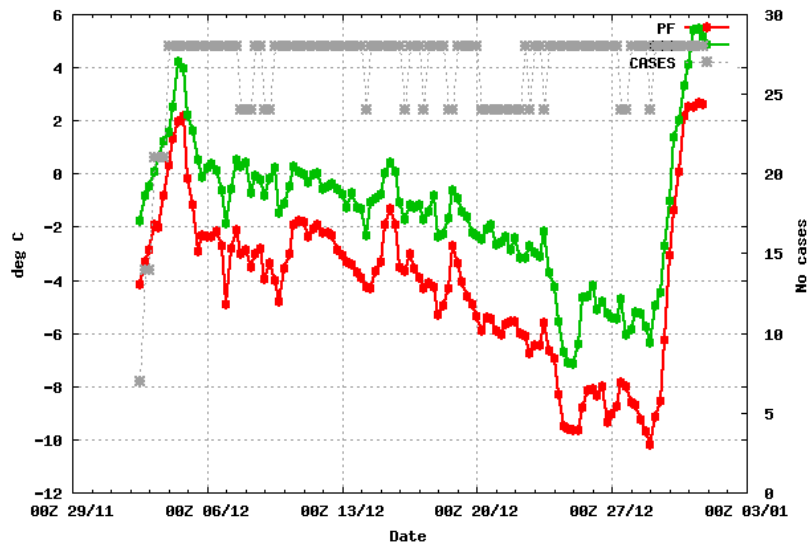
Red = forecast wind speed  
Green = observed wind speed

~ 0.5 m/s positive bias, STDV 2-2.5 m/s

# Verification temperature

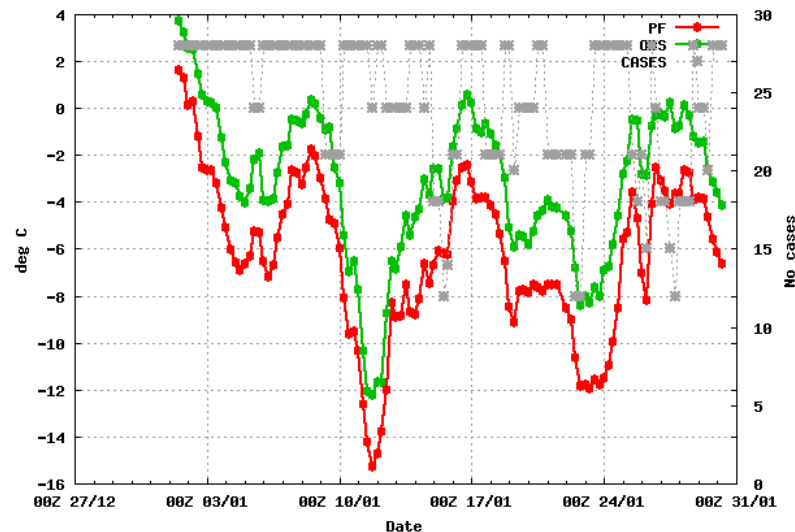
## December 2014

Temperature 100m agl  
Selection: ALL 7 stations  
Used {00,06,12,18} + 06 12 18 24  
Averaging window: 6h



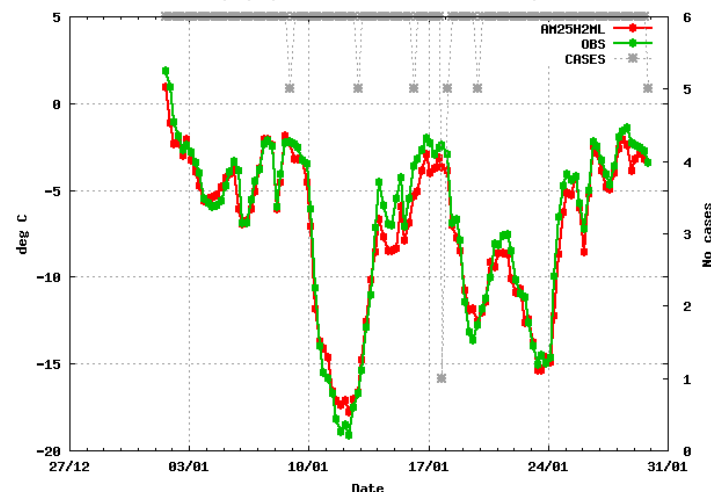
## January 2015

Temperature 100m agl  
Selection: ALL 7 stations  
Used {00,06,12,18} + 06 12 18 24  
Averaging window: 6h



## Tåsjö 100m January 2015

Station: Tåsjo\_100  
Temperature  
At {00,06,12,18} + 07 08 09 10 11 12 Window: 6h



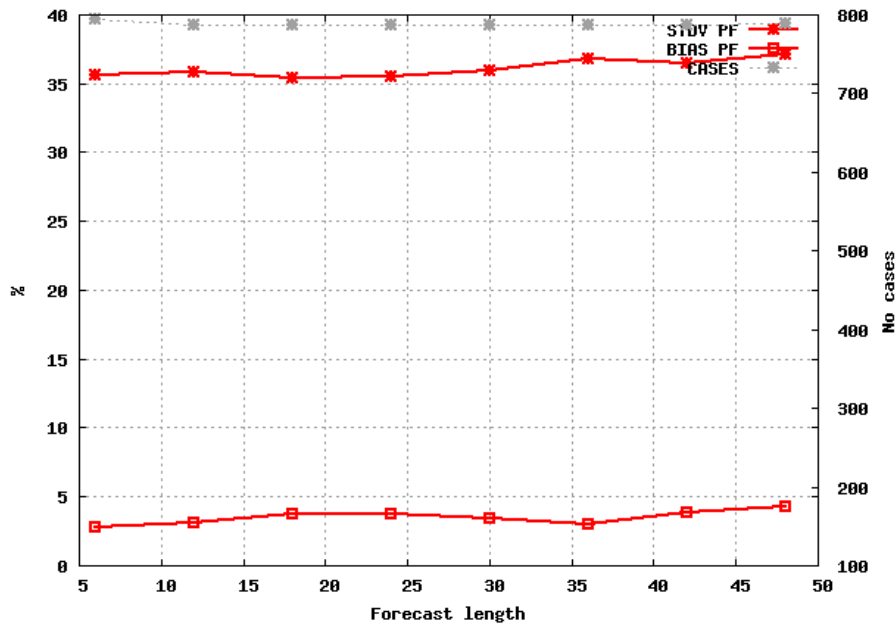
Red = forecast temperature  
Green = observed temperature

Clear negative bias, very good correlation.  
Nacelle temp too warm?  
Compare with Tåsjö 100m.

# Verification power production losses

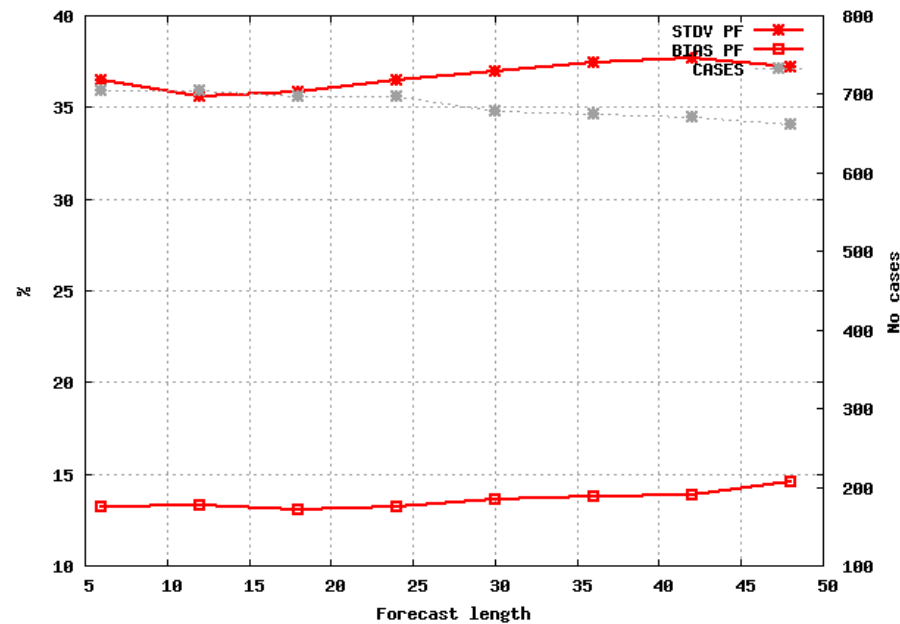
December 2014

Selection: ALL using 7 stations  
Production loss Period: 201412  
Hours: {00,06,12,18}



January 2015

Selection: ALL using 7 stations  
Production loss Period: 201501  
Hours: {00,06,12,18}

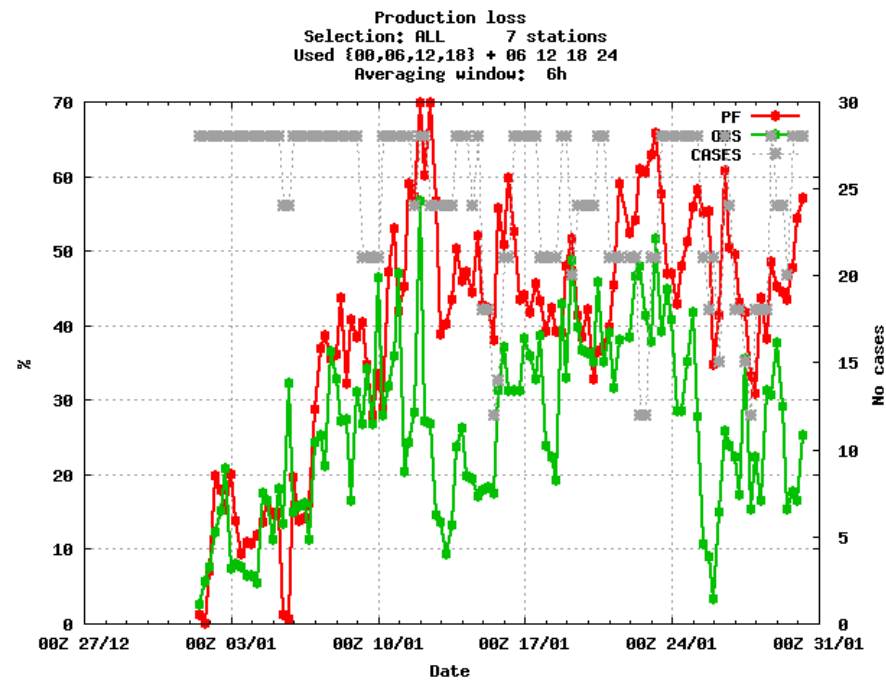
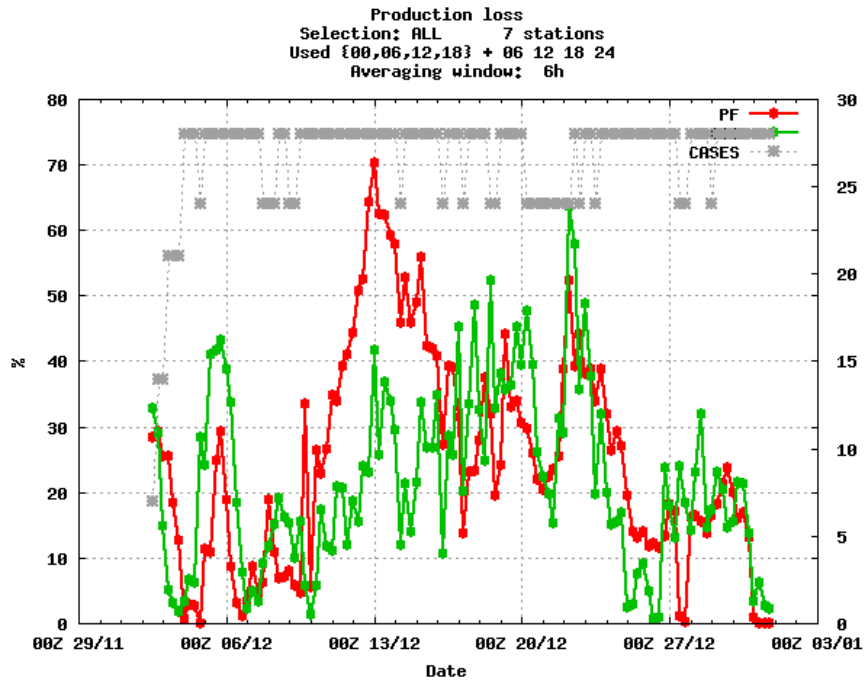


Bias and standard deviation for production loss:

- Not much quality degradation with forecast length.
- Positive bias, higher in January.

December 2014

January 2015



Time series of observed (green) and forecasted (red) production losses

- Apart from a week around the 13th good correspondence for December.
- Rather good first two weeks of January, but after that the forecasts have been a bit pessimistic.

## **Summary**

- A new product for forecasting power production losses due to icing has been developed.
- It relies on output from the joint Sweden/Norway operational forecast model.
- The model data is adapted to a 1 km horizontal resolution, taking a more detailed topography into account.
- Reasonable quality of the wind speed and temperature forecasts.
- Production loss forecast a bit too pessimistic.
- Some tuning is needed of the ice load model.

**Thank you**

**Any questions??**