Probabilistic storm forecasts for wind farms in the North Sea

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KMI

Outline

1. Elia storm forecast tool
2. Past winter test periods
3. Summer updates
4. Storm Ciara (or Sabine or Elsa)
5. Future model improvements

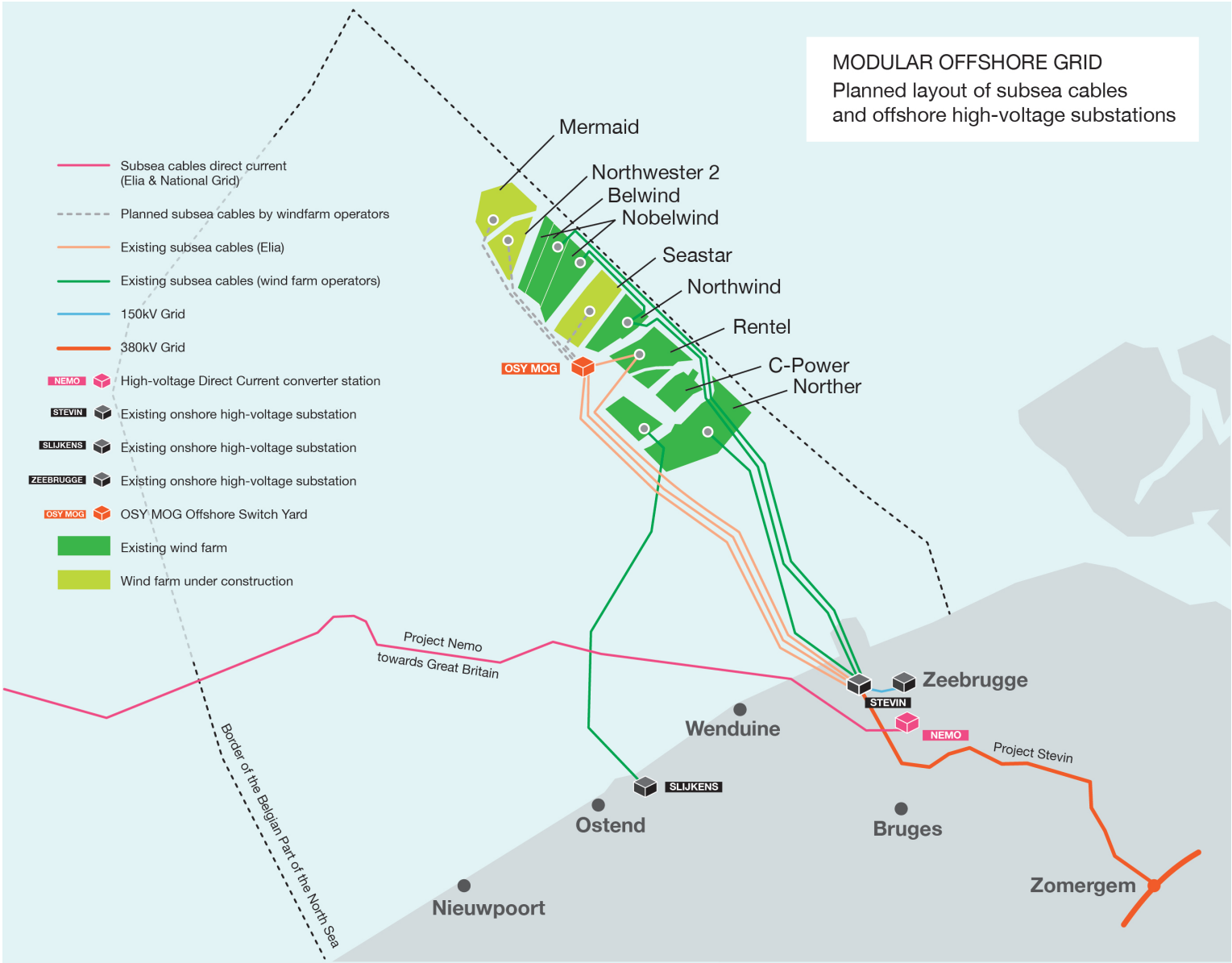
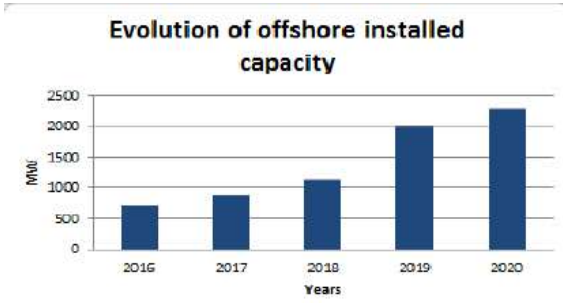


Figure: Belgian offshore wind farms (source: Elia)

Belgian offshore wind energy capacity (source: Elia)

Windfarm	Capacity (MW)	# Turbines
C-Power	325	54
Rentel	294	42
Belwind	171	56
Northwind	216	72
Nobelwind	165	50



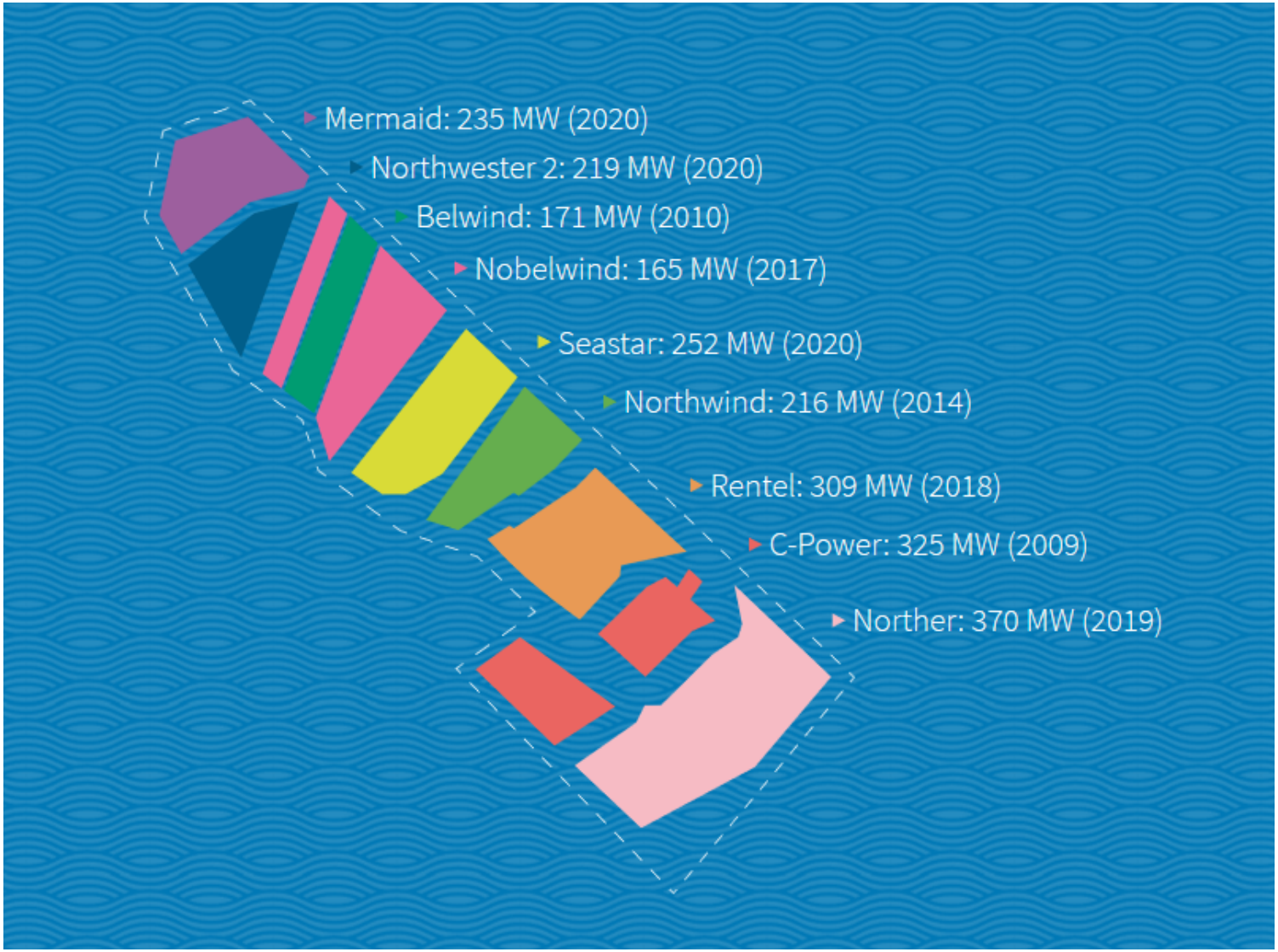


Figure: Belgian Offshore Platform (BOP)

Some facts from BOP website

- Currently **6 operational wind farms** with **1.5 GW** total installed capacity.
  - Norther became operational in summer 2019.
- Estimated by **2020: 2.2GW** total capacity which will produce an average 8 TWh annually
  - electricity consumption of 2 million families,
  - 10 % of Belgian electricity consumption.
- Operational lifetime: 20 years.
- Possible to increase to at least **4 GW** capacity **after 2020**.

KMI

Numerical weather models at the RMI

- ECMWF (9km, operational, 2 runs per day)
- ALARO (4km, operational, 4 runs per day)
- ALARO (1.3km, experimental, 4 runs per day)
- ECMWF EPS (18km, operational, 2 runs per day)
- RMI-EPS (2.5km, experimental, 2 runs per day)

$\Rightarrow$ operational products based on combination of ECMWF EPS and ALARO 4km

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NOTE: in addition our forecasters also look at other models (GFS, UKMO, AROME-MF,...)

Probabilistic storm forecasts

- Wind farms in the North Sea
- Cut-out events (between 25 m/s and 30 m/s) for transmission system operator Elia
- ALARO (4km) wind speed (15min) at turbine height
- ECMWF EPS (18km) wind speed (1h) at 100m
  NOTE: only 3-hourly data before 23 Nov 2016.

Wind power model

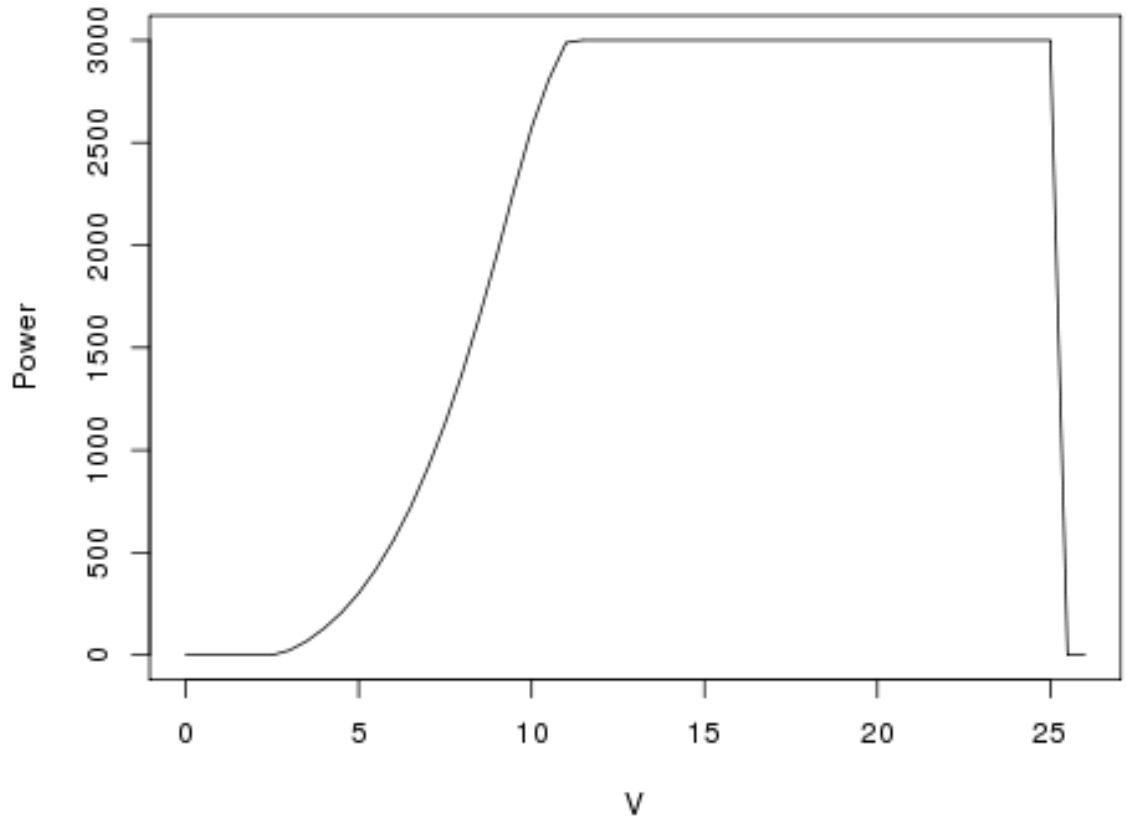


Figure: Wind power curve: a typical example

Wind power model

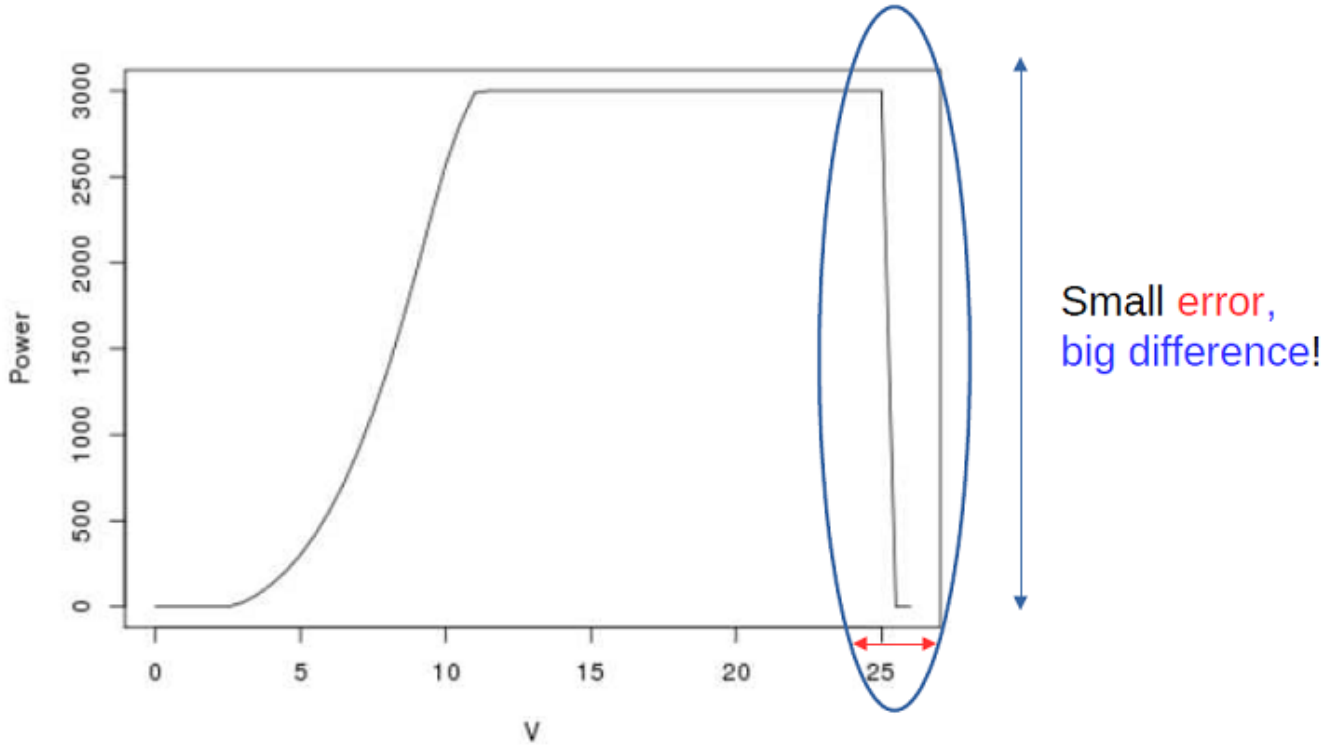
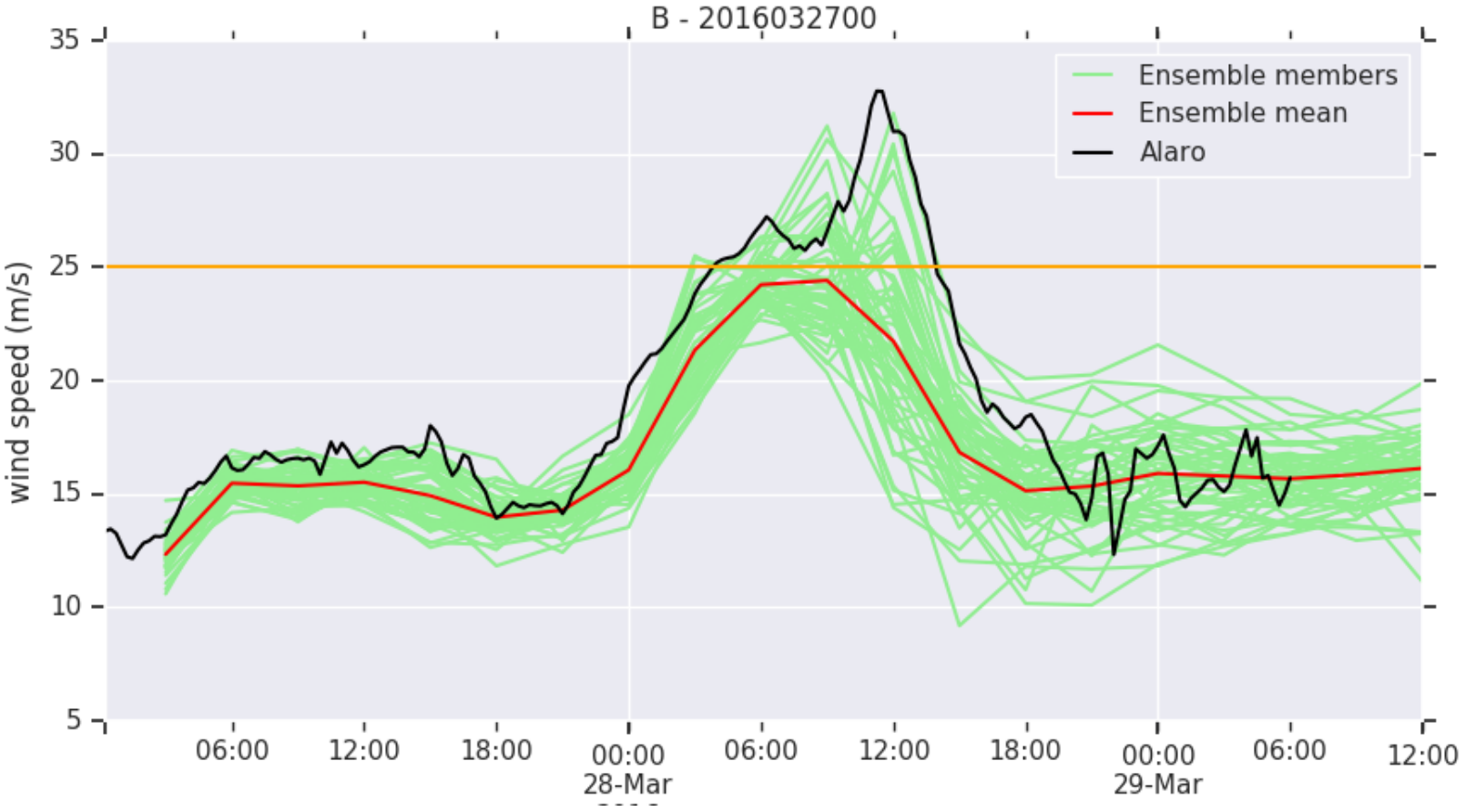


Figure: Wind power curve: a typical example

Cut-out event of 28 March 2016



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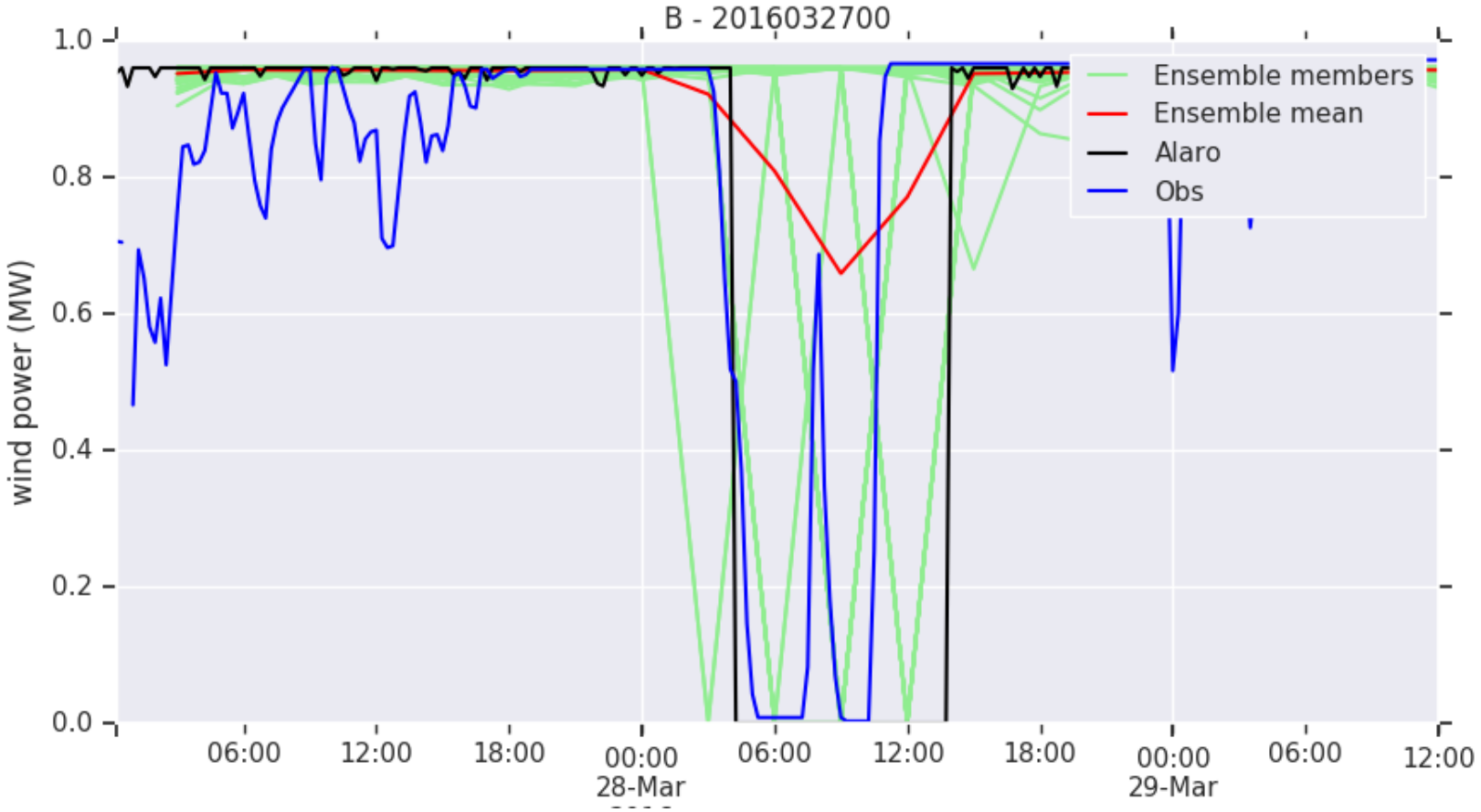
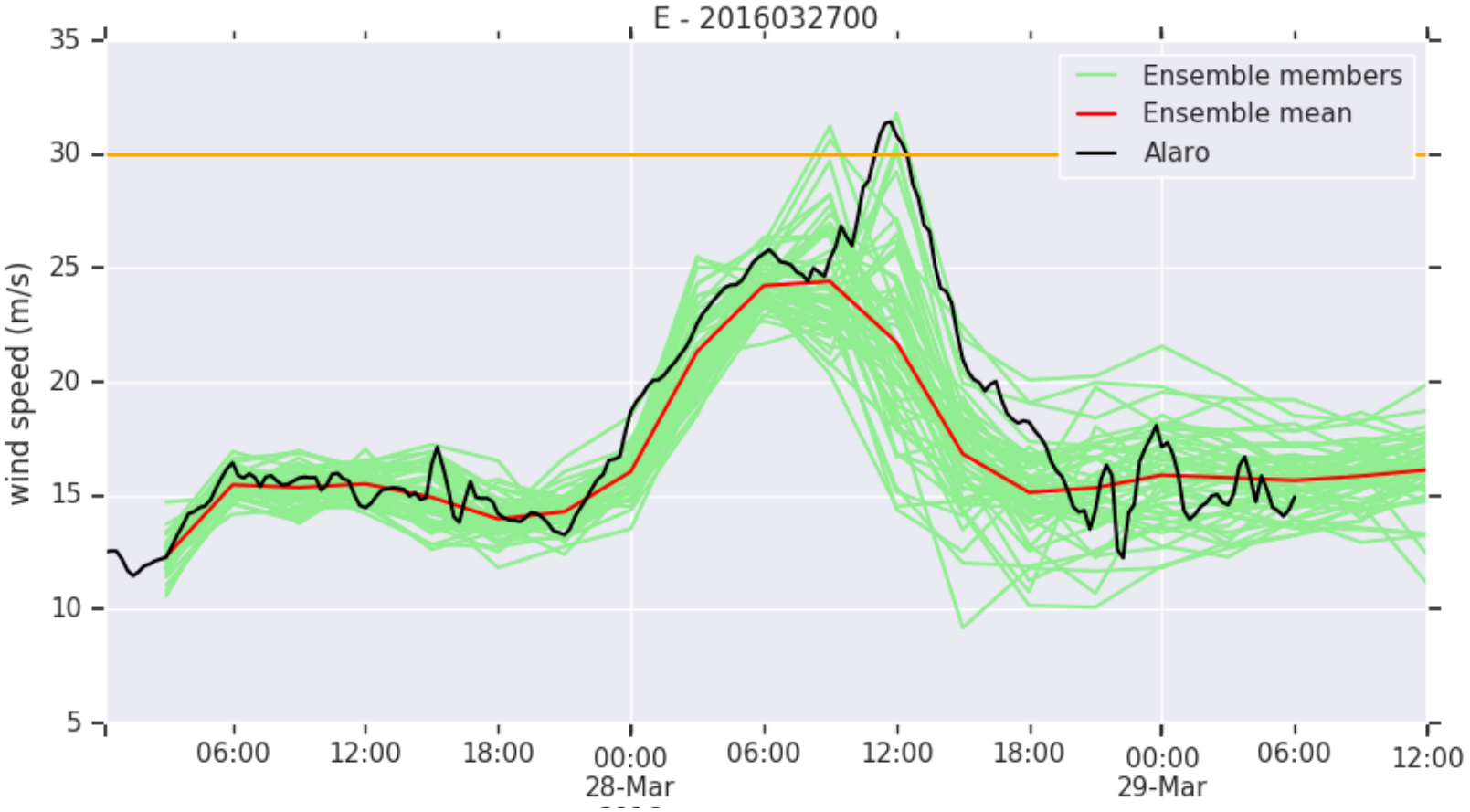
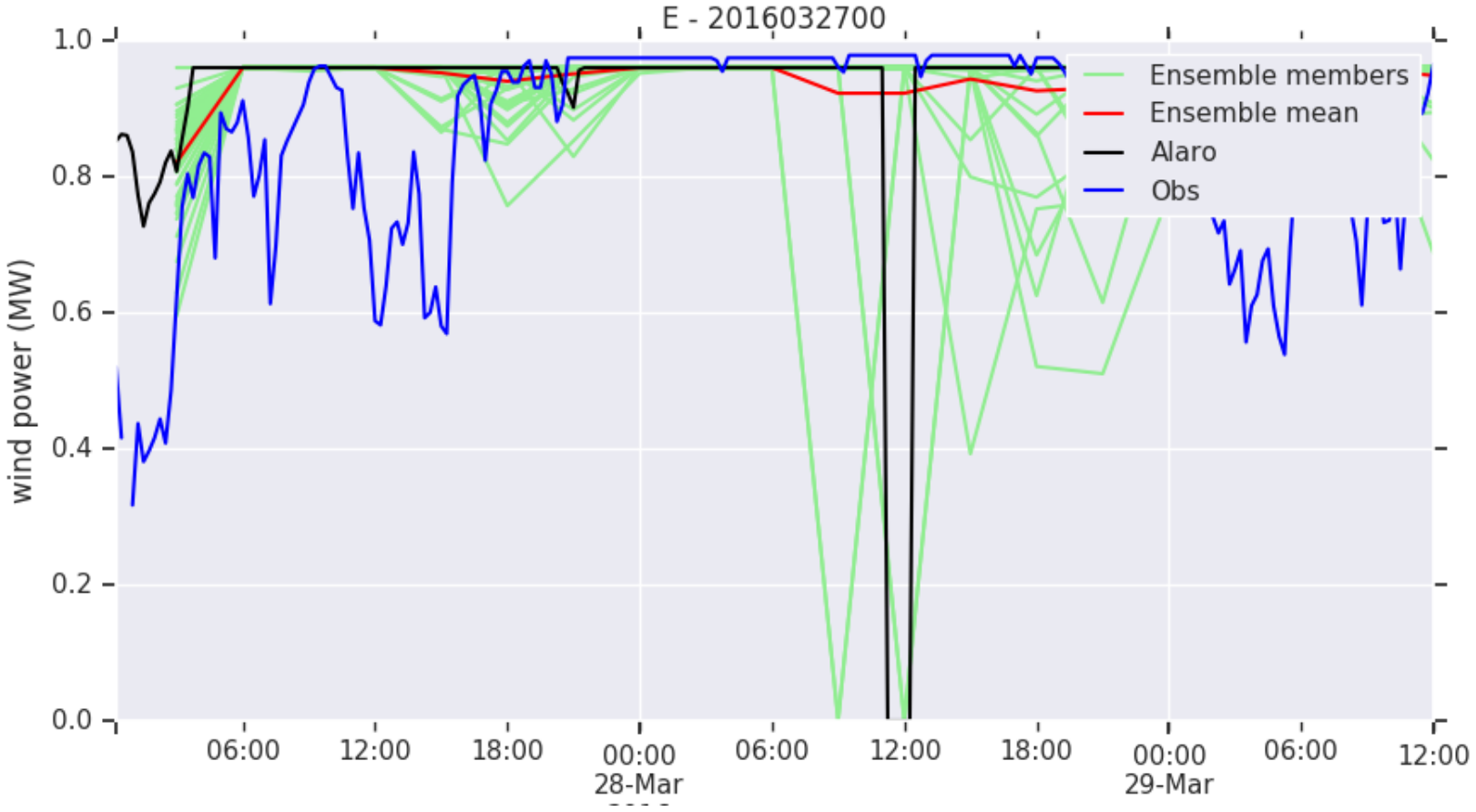


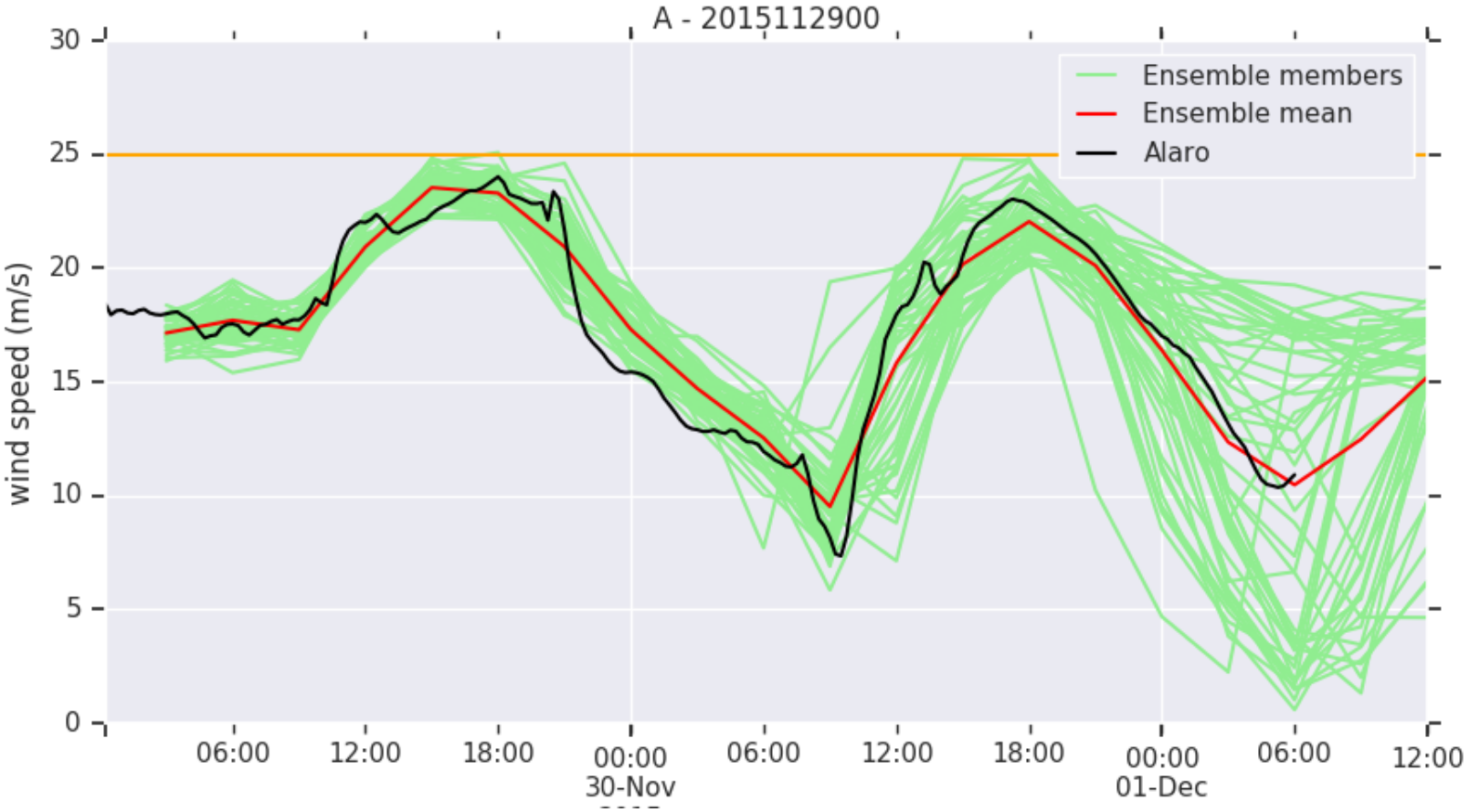
False alarm for 28 March 2016



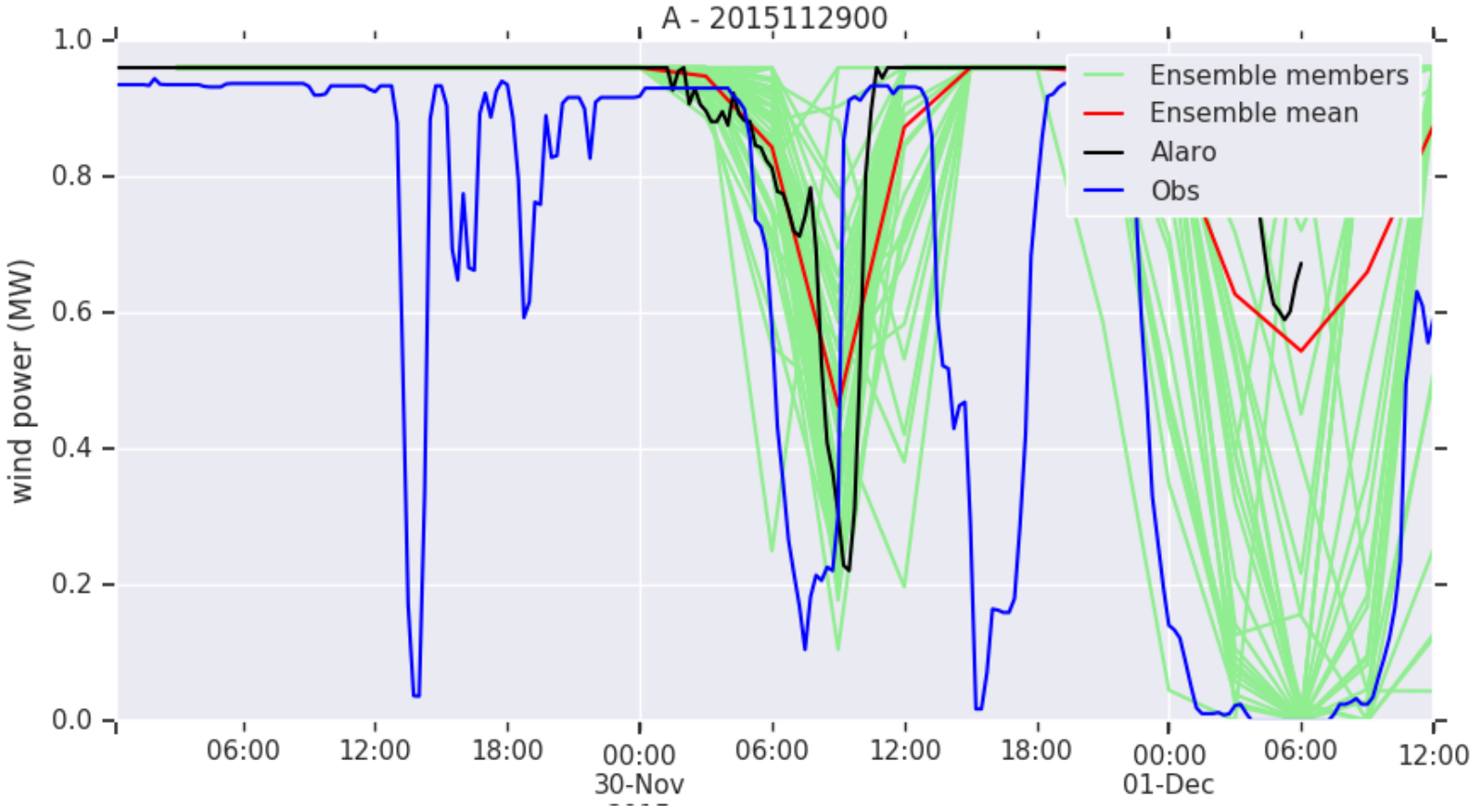
False alarm for 28 March 2016



Near misses for 29-30 November 2015



Near misses for 29-30 November 2015



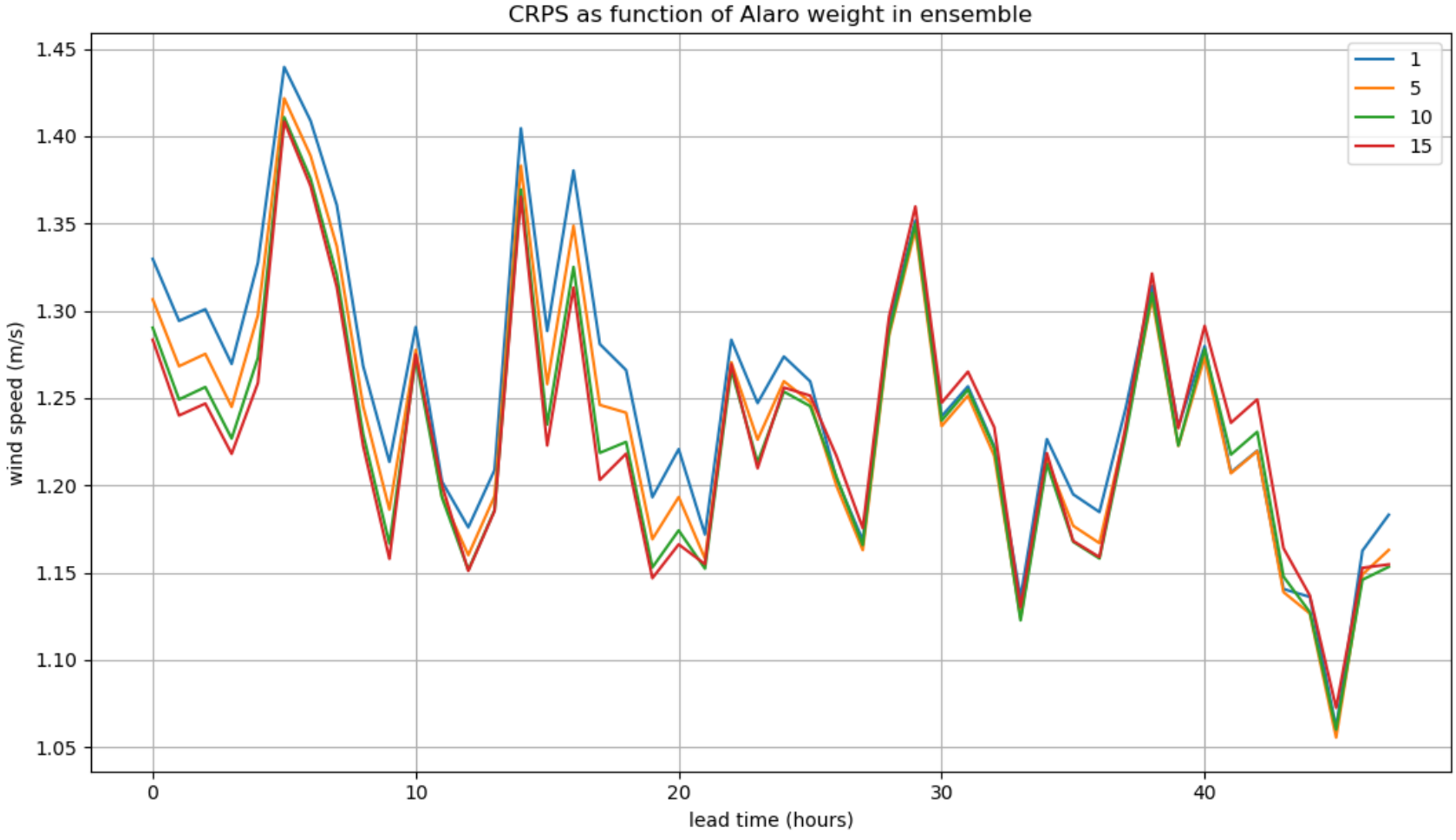
Verification: hits, misses and false alarms

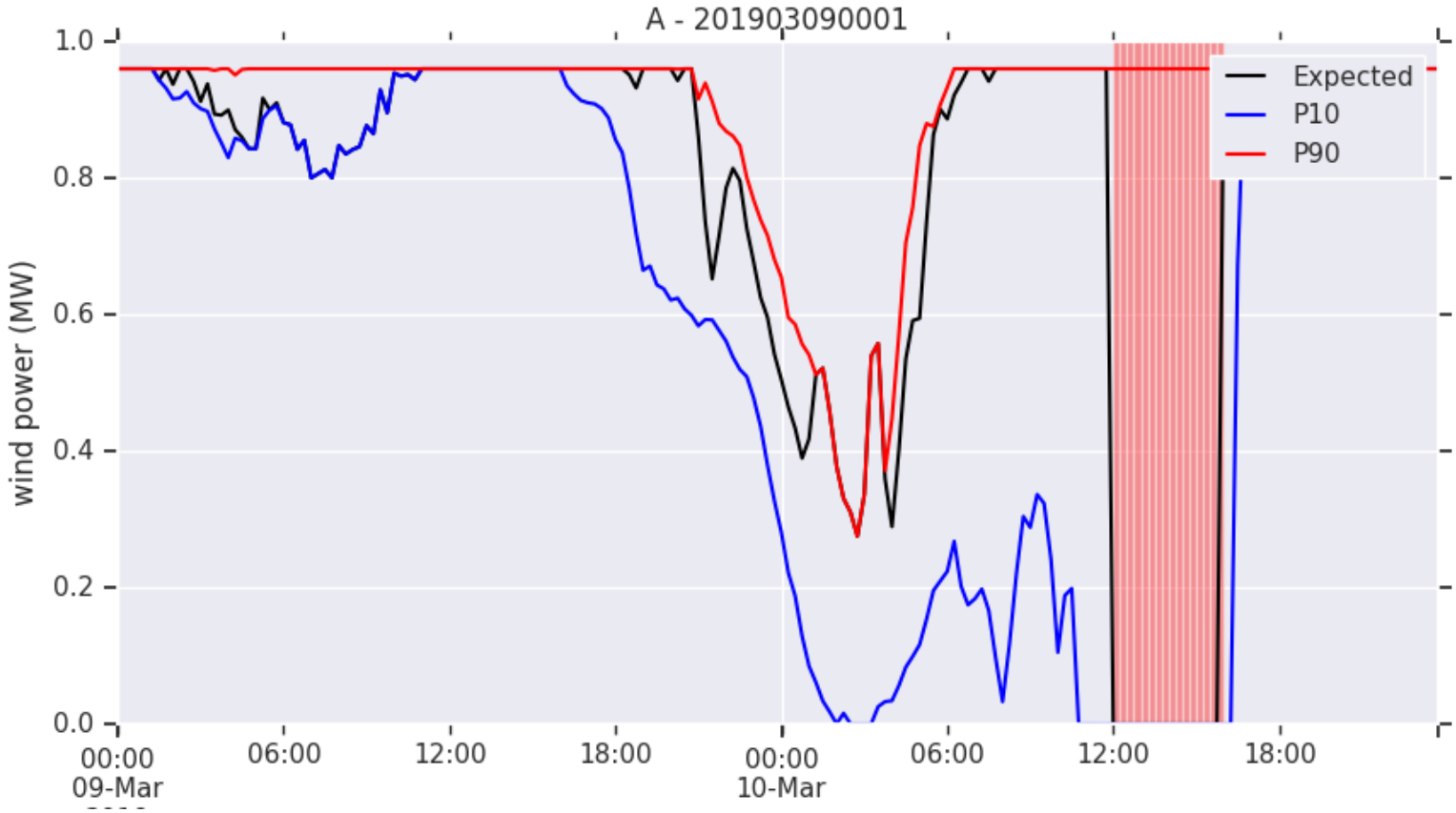
- For moderate and extreme storms, leading to cut-out events.
- 1 September 2015 - 31 March 2016
  - reruns for 7 month historical period
  - 5 hits, 3 misses, 0 false alarms
- 1 November 2018 - 14 March 2019
  - real time forecasts in test period
  - 1 hit, 0 misses, 2 false alarms

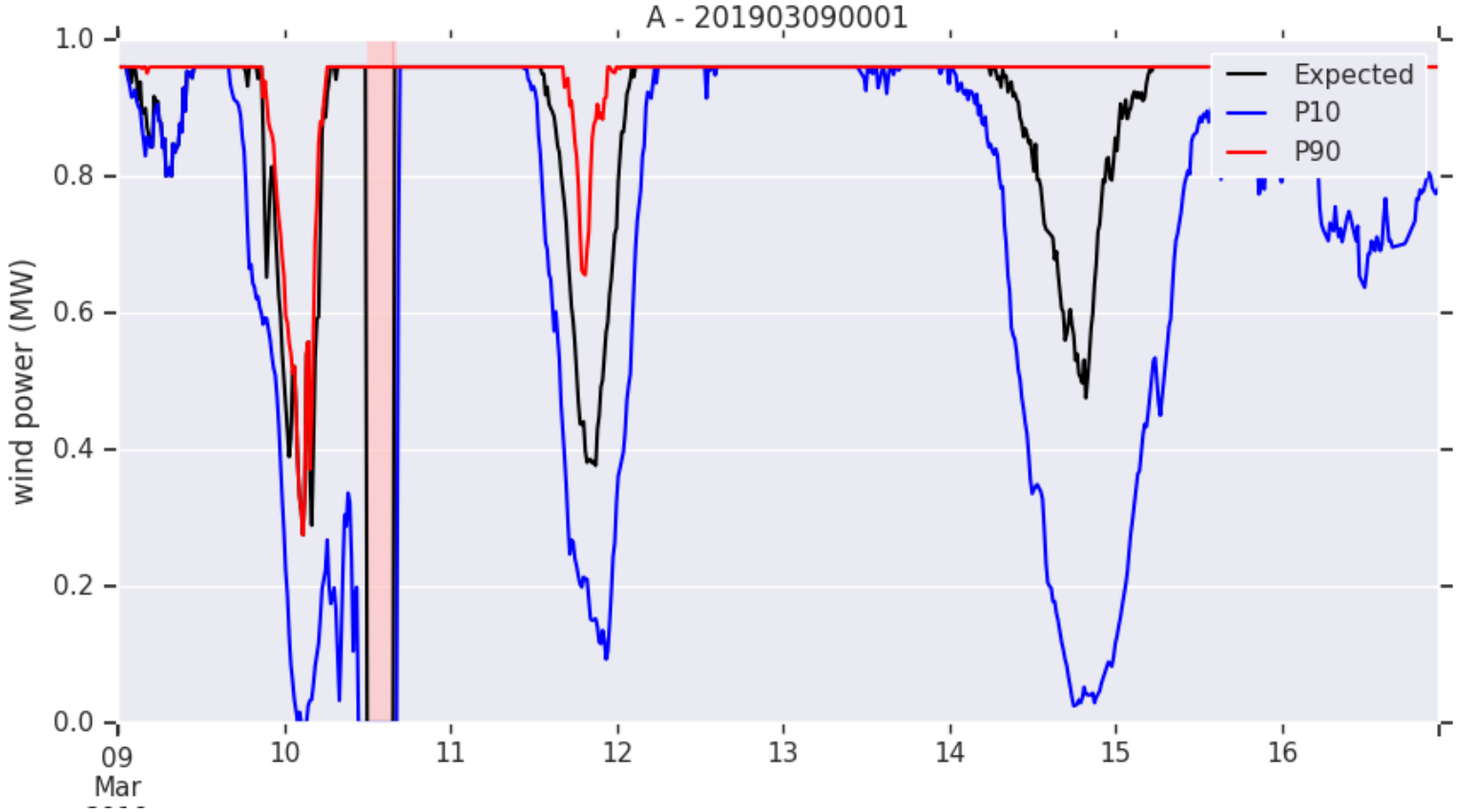
Summer updates

Elia storm forecast tool

- Forecasts up to 7 days
- P10-P90: adding ALARO to ECMWF ensemble
  - ALARO 'worth' about 15 ensemble members (first 24h)
- Expected forecast: ALARO in first 48h
  - ECEPS median after 60h
  - Weighted average of ALARO and ECEPS median in between


CRPS as function of Alaro weight in ensemble
wind speed (m/s)
lead time (hours)
1.45
1.40
1.35
1.30
1.25
1.20
1.15
1.10
1.05
0
10
20
30
40
1
5
10
15


A - 201903090001
wind power (MW)
1.0
0.8
0.6
0.4
0.2
0.0
Expected
P10
P90
00:00
09-Mar
06:00
12:00
18:00
00:00
10-Mar
06:00
12:00
18:00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wind power (MW)
1.0
0.8
0.6
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09
Mar
10
11
12
13
14
15
16
Expected
P10
P90

Storm Ciara (or Sabine or Elsa)

Cut-out event of 9 February 2020

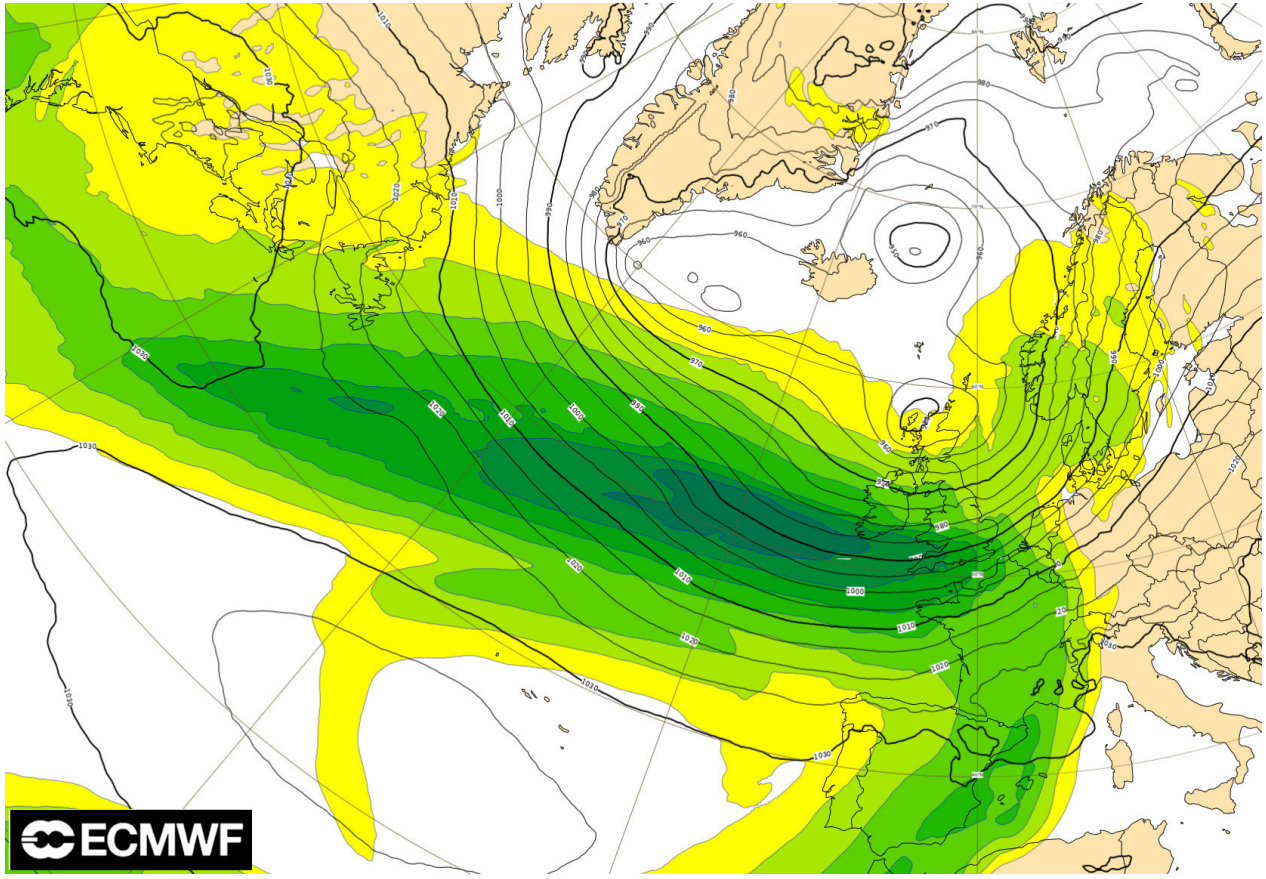


Figure: MSLP on Sunday 9 February at 12h UTC (source: ECMWF): isobars close together, heavy winds

Storm Ciara (or Sabine or Elsa)

Cut-out event of 9 February 2020

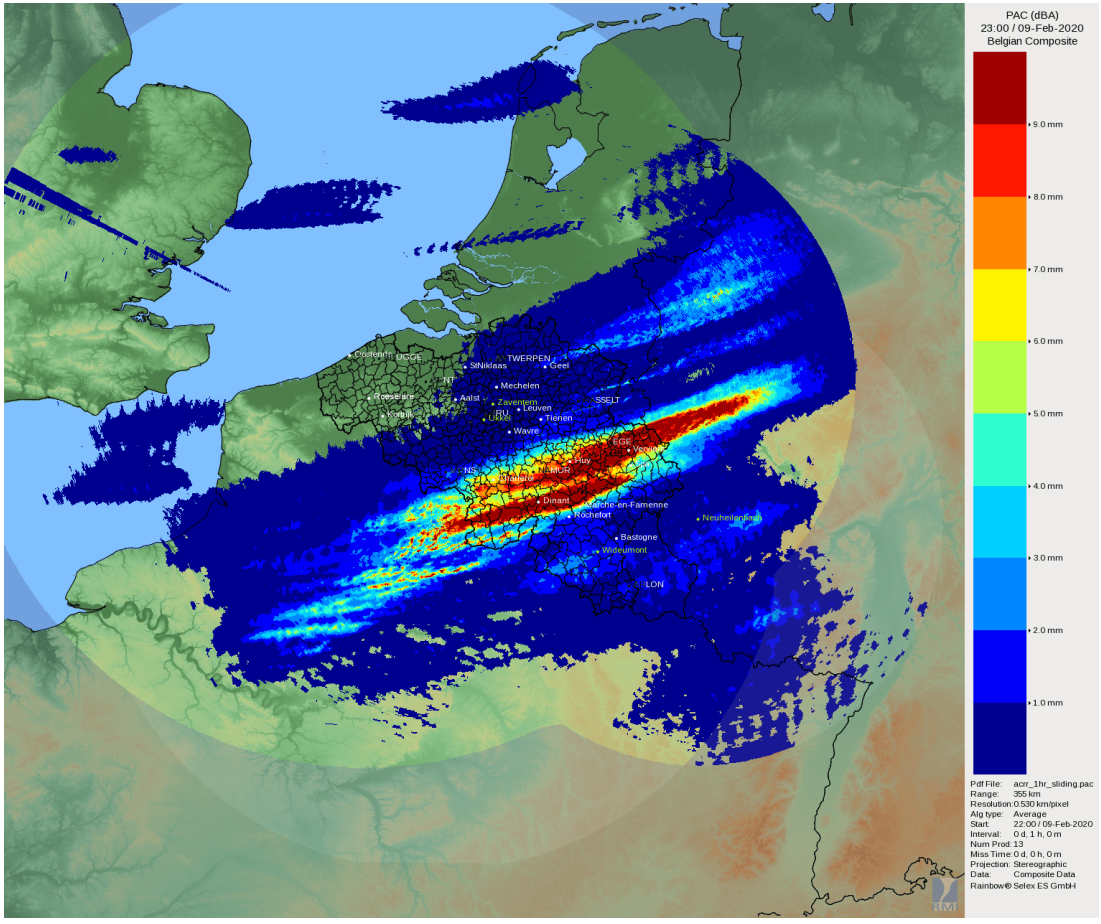
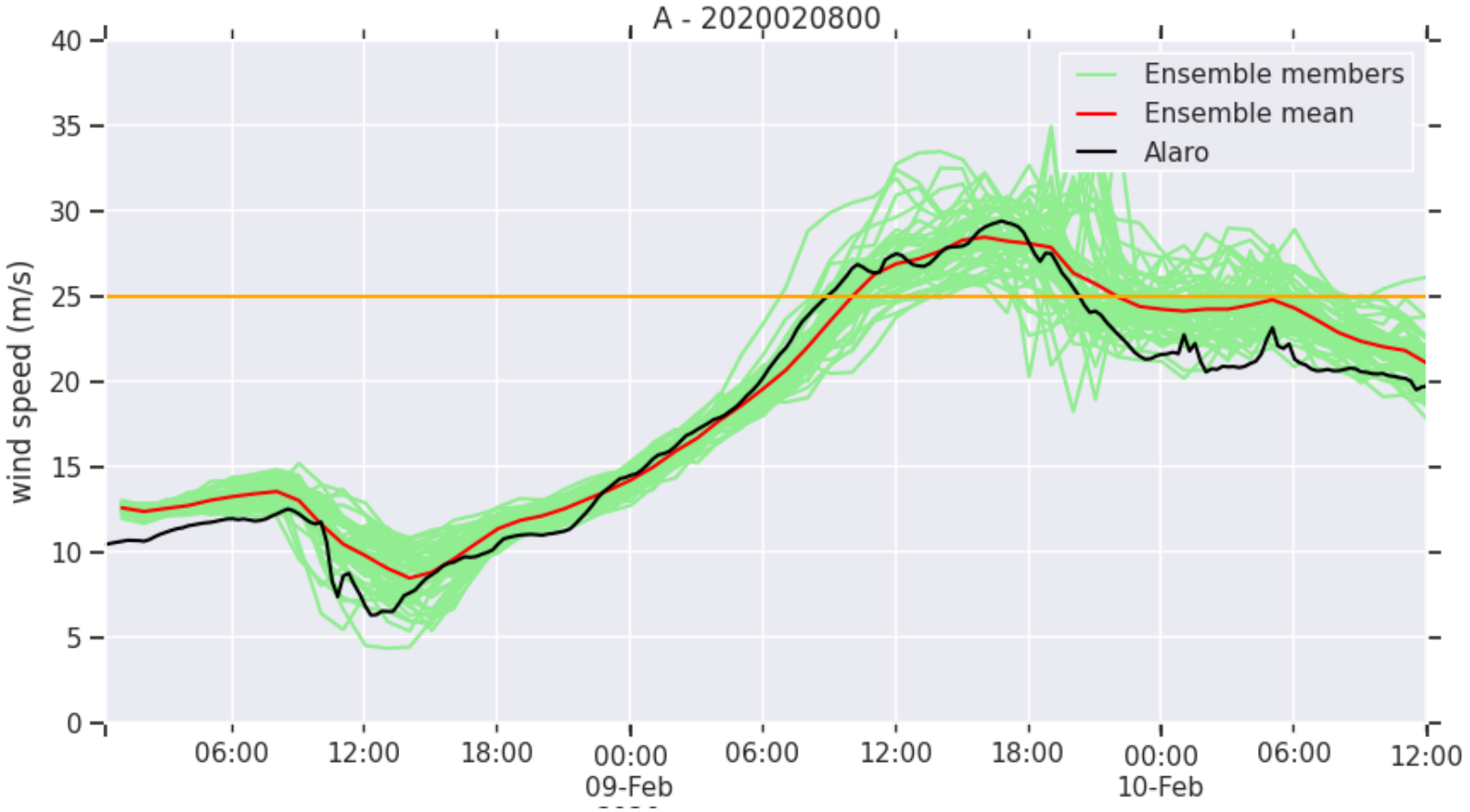
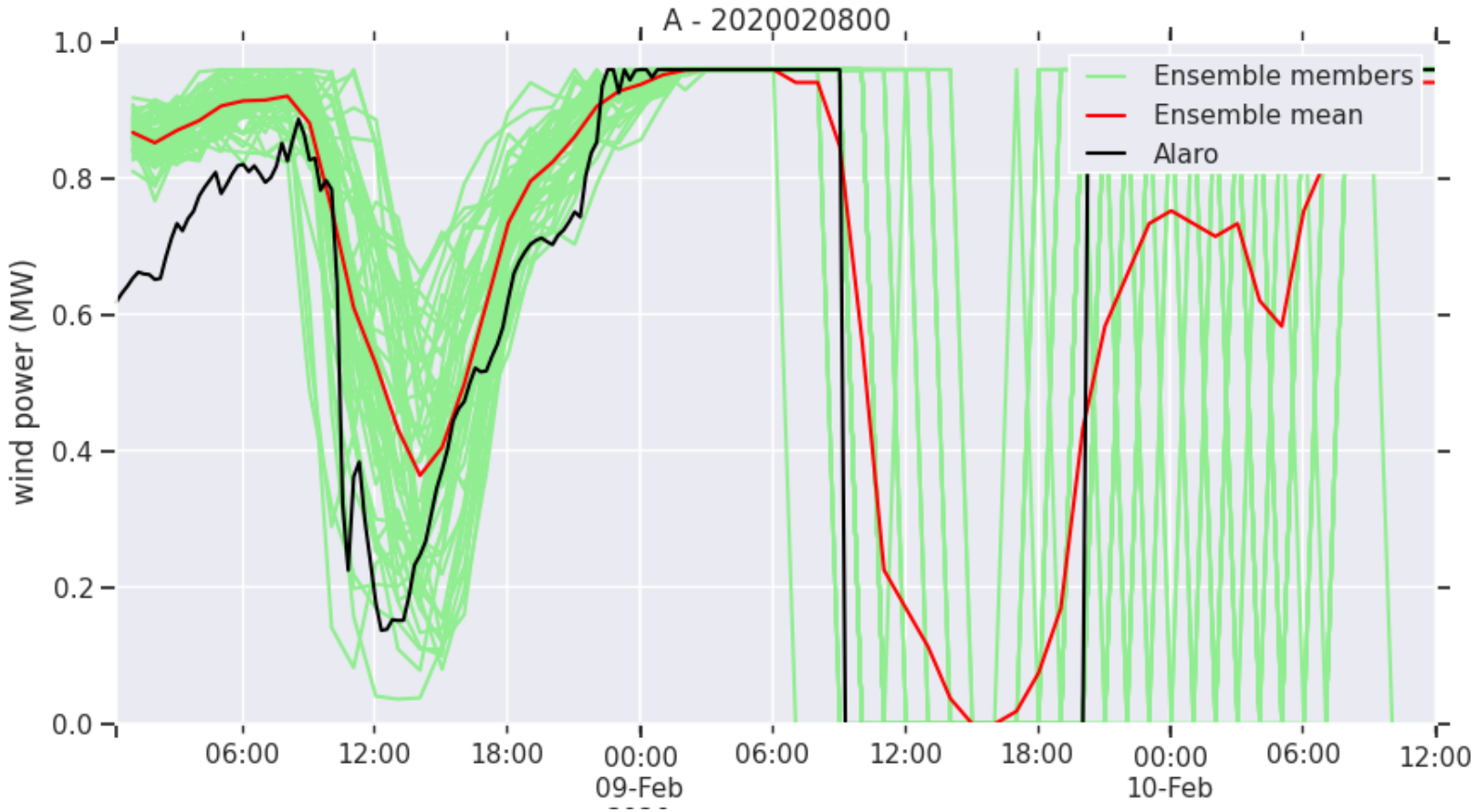


Figure: Radar images of the precipitation on Sunday 9 February at 23h UTC (source: RMI)

Cut-out event of 9 February 2020



Cut-out event of 9 February 2020



Future model improvements

Short-term

- Retuning wind power curves with historical wind power (and speed) observations
- Calibration wind speed forecasts with historical wind speed observations

Calibration with historical wind speed

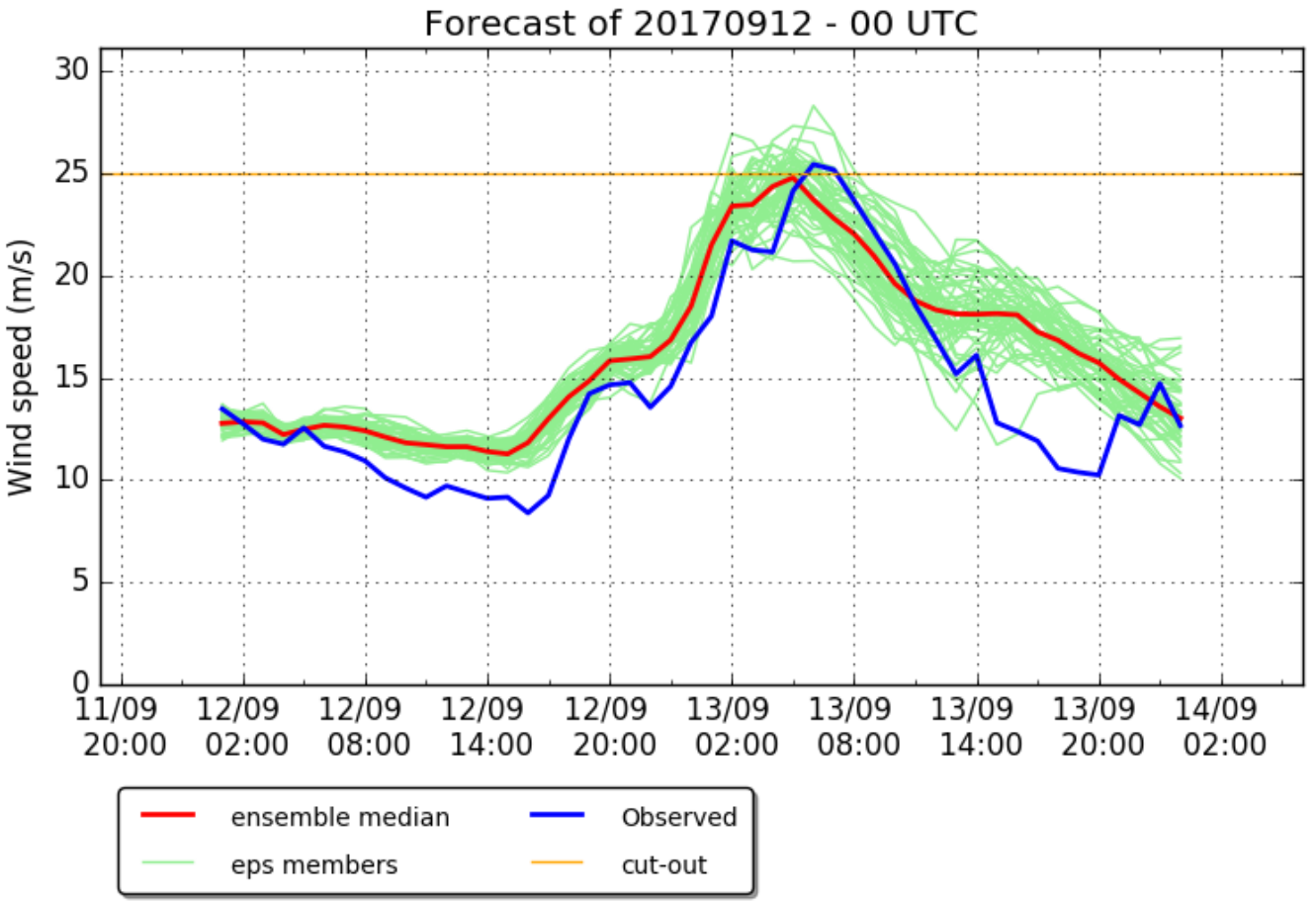


Figure: Raw ensemble forecast

Calibration with historical wind speed

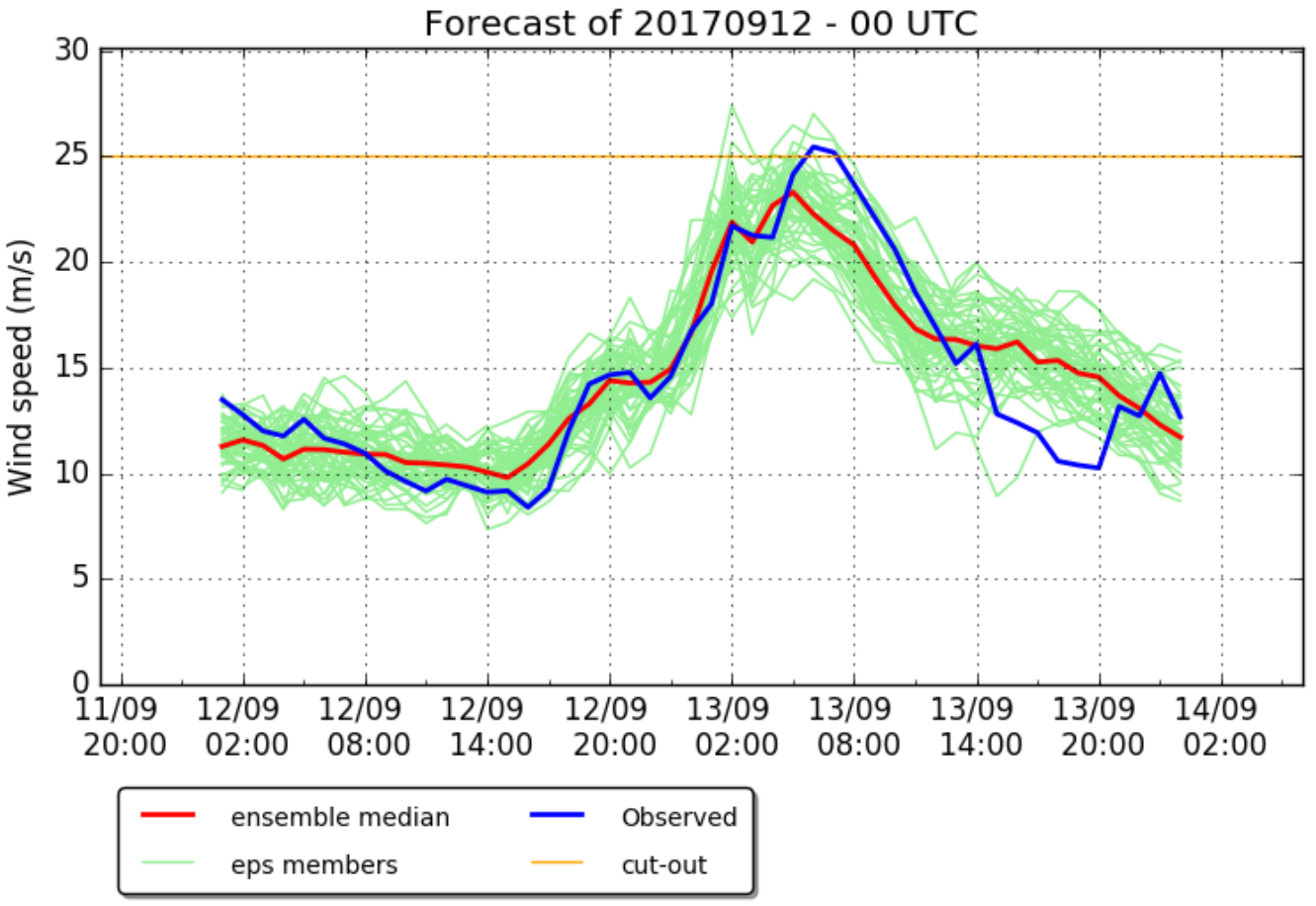


Figure: Calibrated ensemble forecast

Calibration with historical wind speed

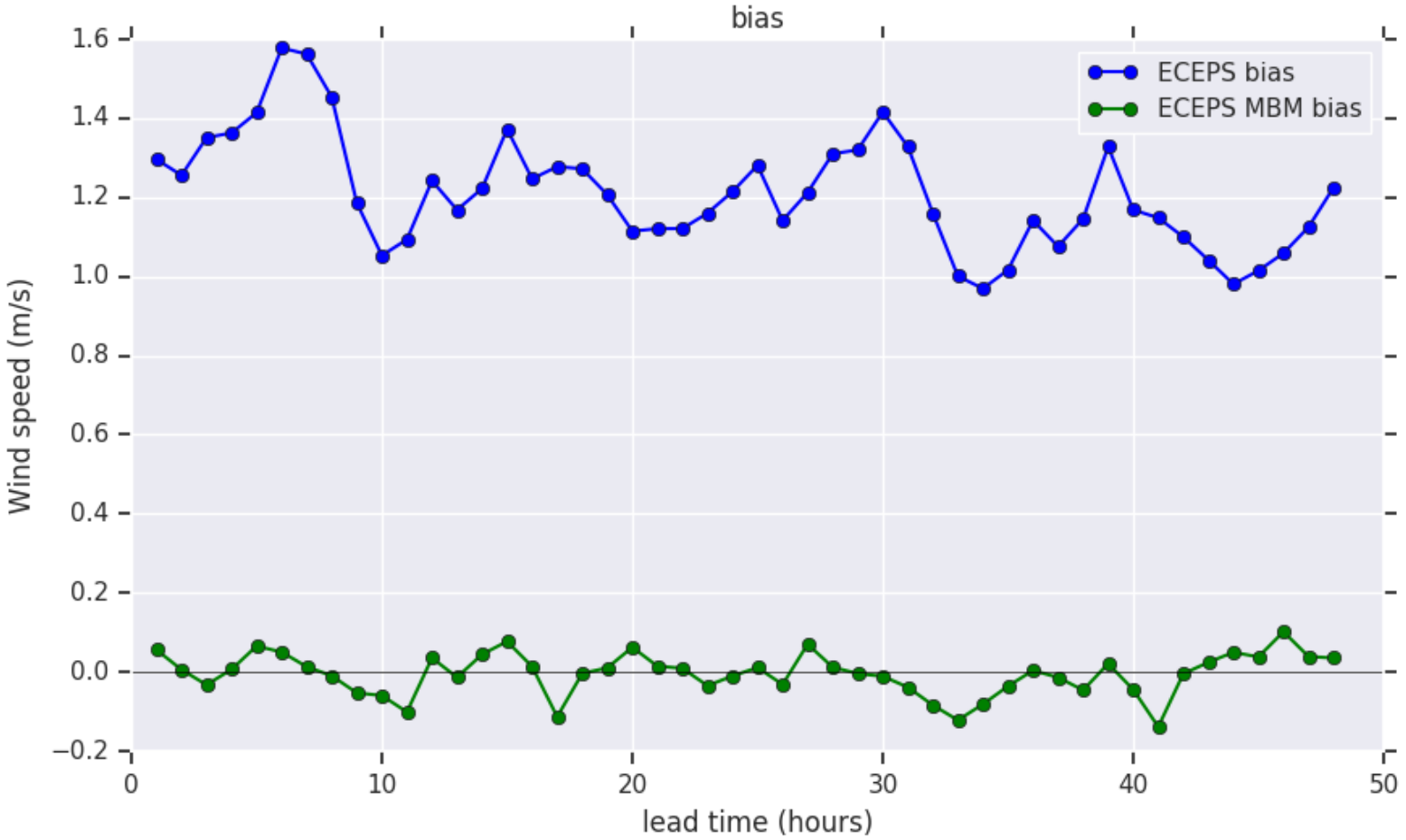


Figure: Bias of raw and calibrated ensemble

Calibration with historical wind speed

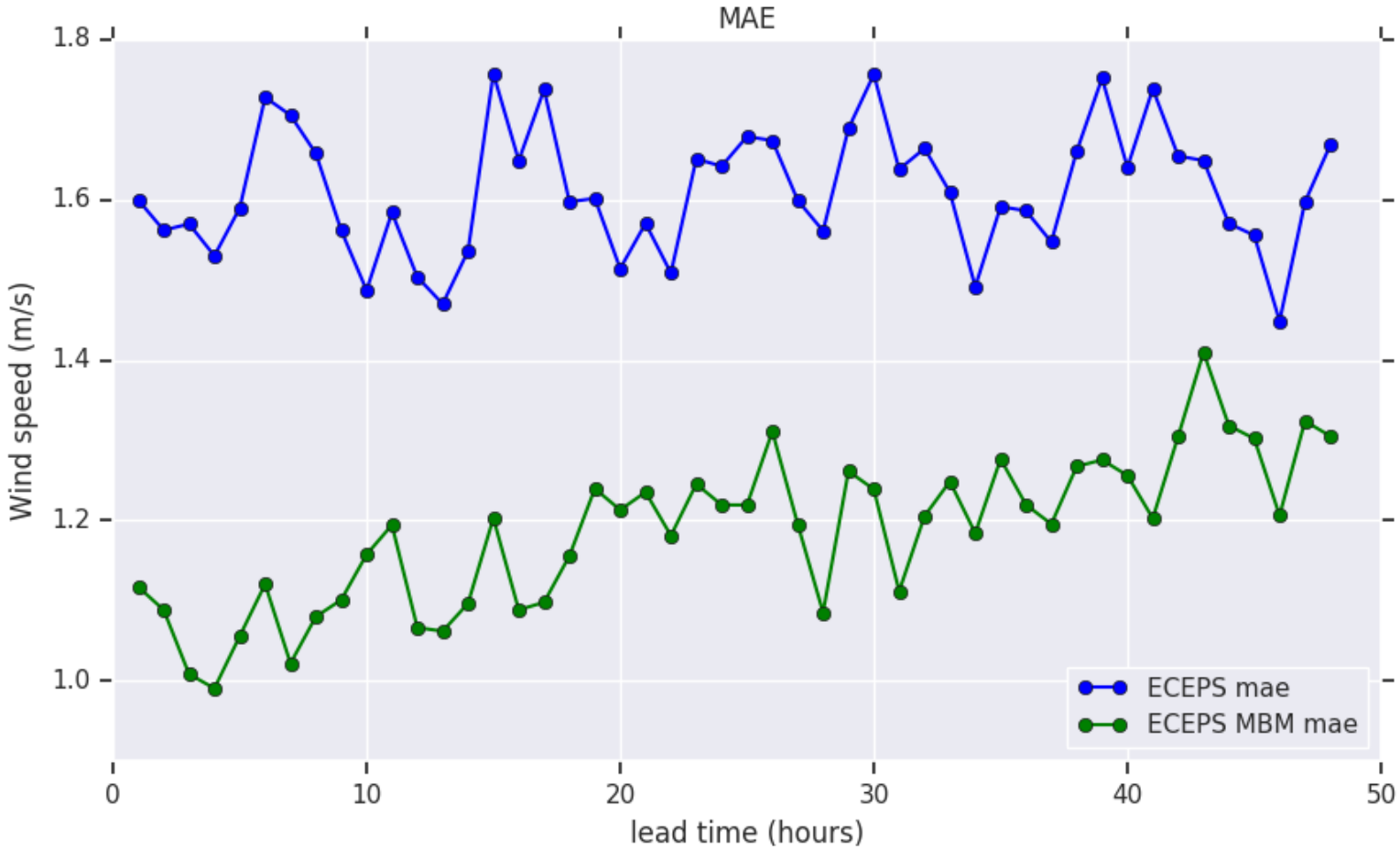


Figure: MAE of raw and calibrated ensemble

Calibration with historical wind speed

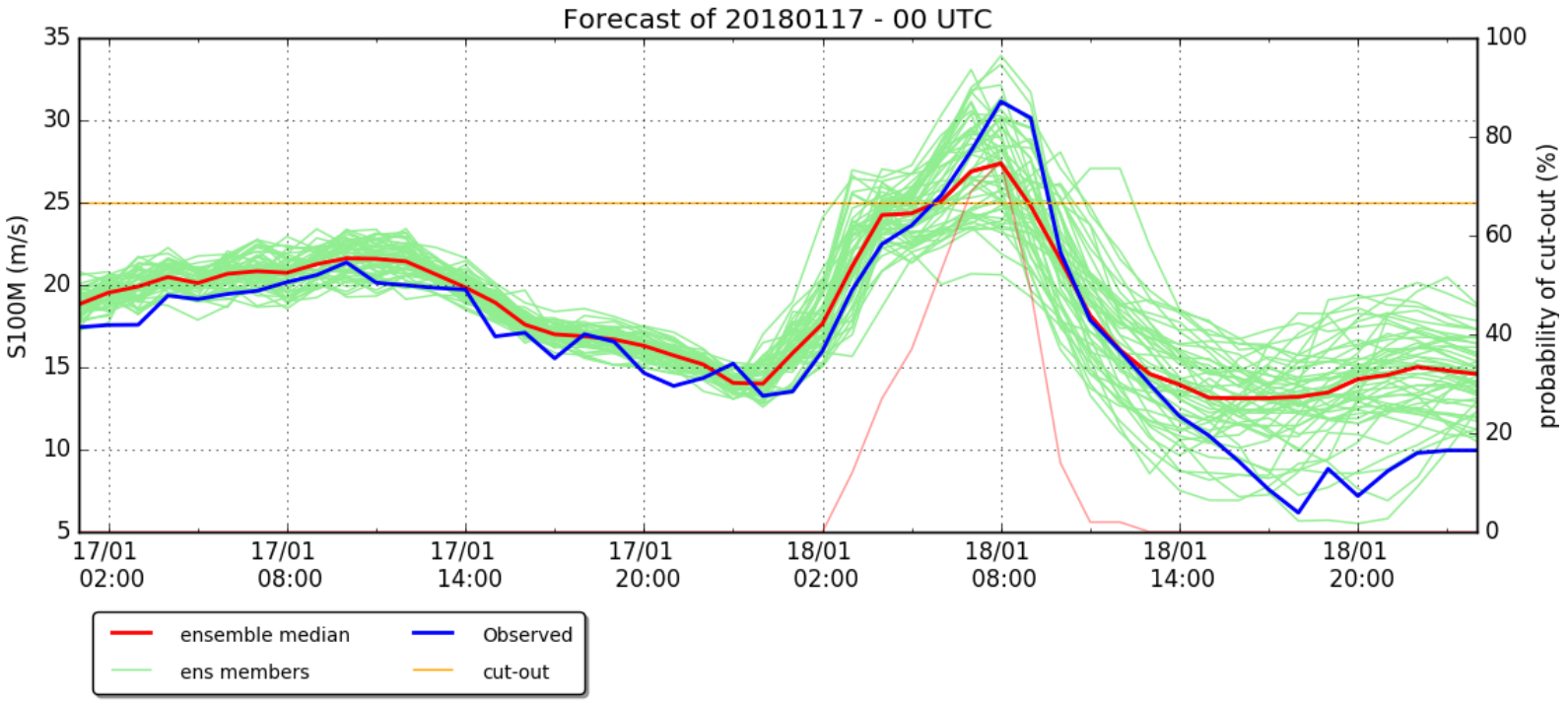


Figure: Cut-out event: raw ensemble forecast

Calibration with historical wind speed

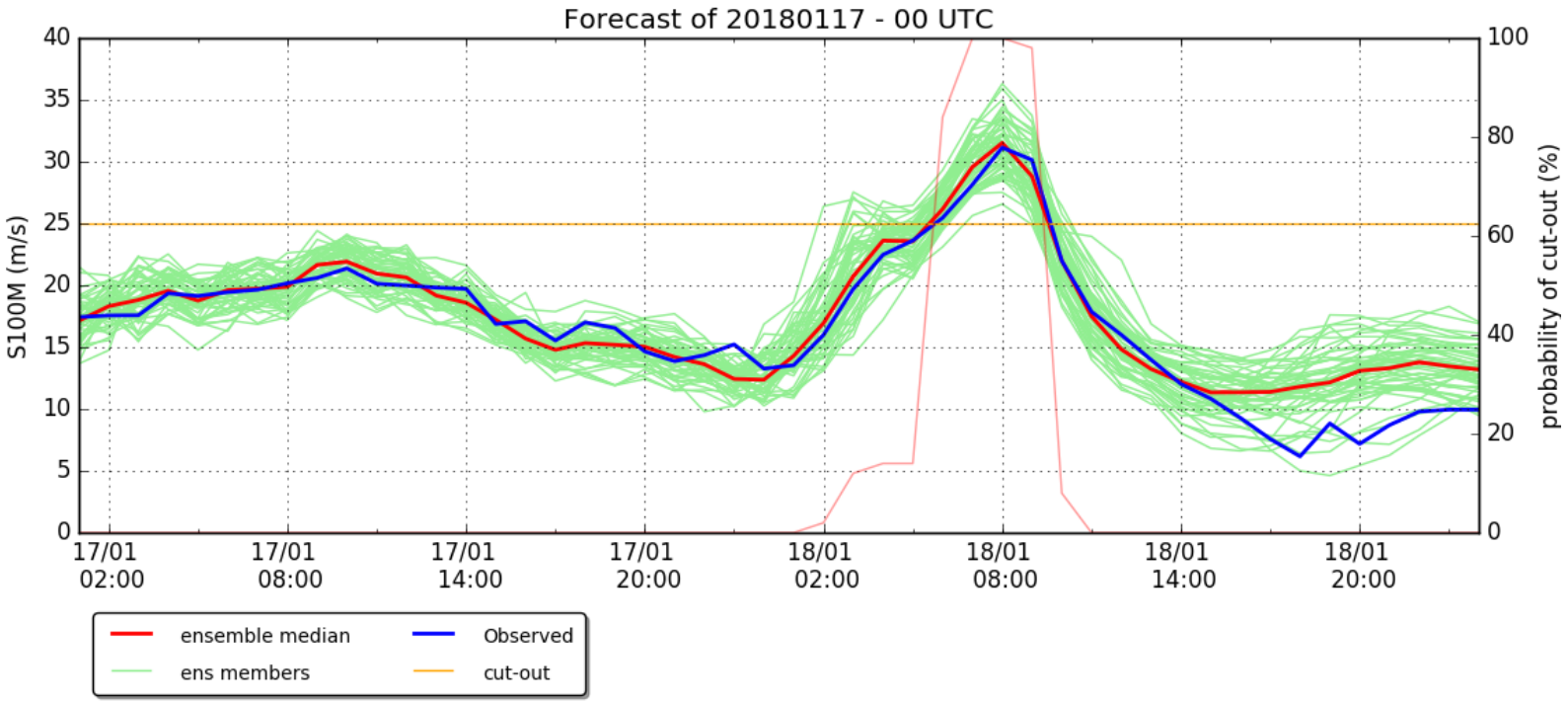


Figure: Cut-out event: calibrated ensemble forecast

Future model improvements

Long-term

- Use of wind direction?
- (Maybe also wind gusts?)
- More detailed spatial modeling of the wind farms?
- Wake effects? Influence of other turbines and wind farms.

THANK YOU