
MeteoGroup

WRF for realistic wind farm siting

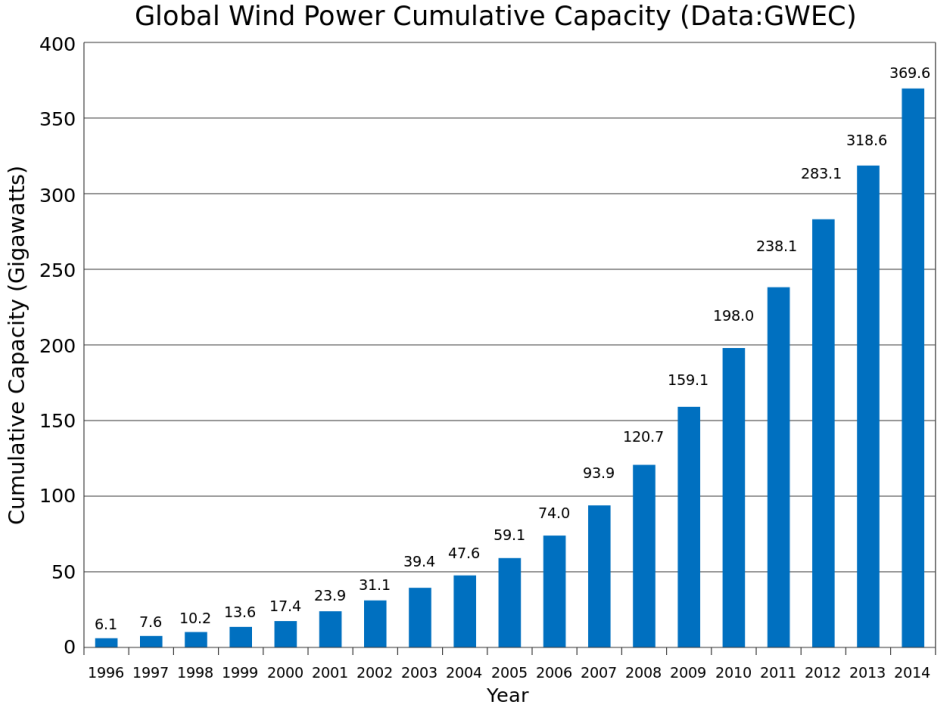
Hugo Hartmann, Wim van den Berg, Bas de Haan, Daniel van Dijke

Presentation 6A.4 – 16th Annual WRF User's Workshop, 15-19 June 2015

MeteoGroup

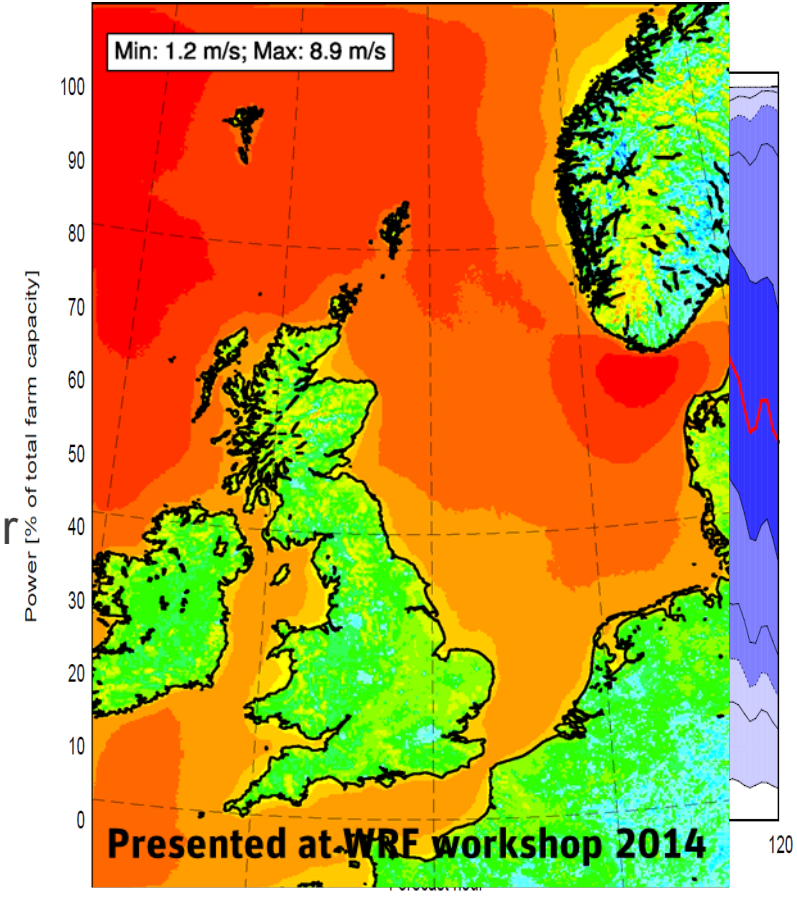
Wind energy is booming business

- Worldwide 200,000 turbines
- Nominal capacity **370 GW**
  - 150 million households (4%)
  - China 31%, EU 25%, US 18%
- Doubling every three years



↑wind energy market = ↑ number of customers

- Asking for accurate and reliable:
  - Wind climatology data-sets
  - Real-time wind/power forecasts (incl. probabilities)
- For what?
  - Optimize trading strategy
  - Efficiently use time available in weather windows
- **PowerCast**
  - Statistical product (MOS)
  - Power model to convert wind forecast into power



MeteoGroup

Offshore wind farms North Sea

commisioned and planned

Clustering

- Local wind resource
- Operator
- Maintenance

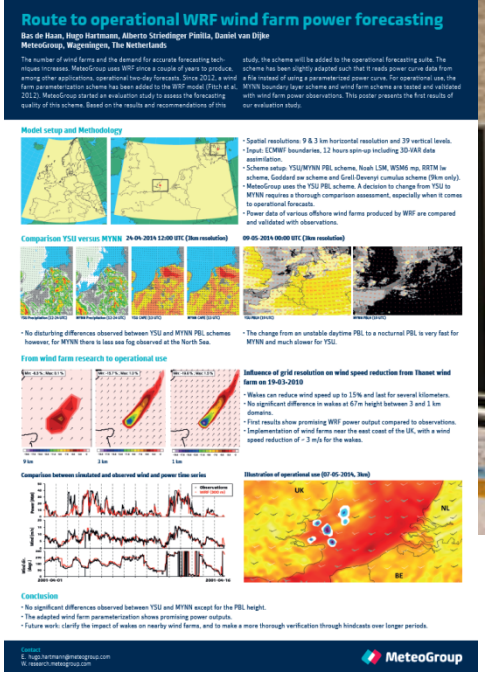
But…

- Wake effects in wind farm
- Mutual interaction

www.4coffshore.com

WRF potential in wind power forecasting

- Since WRF 3.3: Fitch et al (2012) parameterization scheme
- **How does it compare with PowerCast?**
- Preliminary results presented on a poster last year
- This presentation: verification study for the onshore wind farm “Farr” (Scotland)


Route to operational WRF wind farm power forecasting

Bas de Haan, Hugo Hartmann, Alberto Striedinger Pinilla, Daniel van Dijke
MeteoGroup, Wageningen, The Netherlands

The number of wind farms and the demand for accurate forecasting techniques increases. MeteoGroup uses WRF since a couple of years to produce, among other applications, operational two-day forecasts. Since 2012, a wind farm parameterization scheme has been added to the WRF model (Fitch et al., 2012). MeteoGroup started an evaluation study to assess the forecasting quality of this scheme. Based on the results and recommendations of this study, the scheme will be added to the operational forecasting suite. The scheme has been slightly adapted such that it reads power curve data from a file instead of using a parameterized power curve. For operational use, the MYNN boundary layer scheme and wind farm scheme are tested and validated with wind farm power observations. This poster presents the first results of our evaluation study.

Model setup and Methodology

- Spatial resolutions: 9 & 3 km horizontal resolution and 39 vertical levels.
- Input: ECMWF boundaries, 12 hours spin-up including 3D-VAR data assimilation.
- Scheme setup: YSU/MYNN PBL scheme, Noah LSM, WSM6 mp, RRTM lw scheme, Goddard sw scheme and Grell-Devenyi cumulus scheme (9km only).
- MeteoGroup uses the YSU PBL scheme. A decision to change from YSU to MYNN requires a thorough comparison assessment, especially when it comes to operational forecasts.
- Power data of various offshore wind farms produced by WRF are compared and validated with observations.

Comparison YSU versus MYNN 24-04-2014 12:00 UTC (3km resolution) 09-05-2014 00:00 UTC (3km resolution)

- No disturbing differences observed between YSU and MYNN PBL schemes however, for MYNN there is less sea fog observed at the North Sea.
- The change from an unstable daytime PBL to a nocturnal PBL is very fast for MYNN and much slower for YSU.

From wind farm research to operational use

Influence of grid resolution on wind speed reduction from Thanet wind farm on 19-03-2010

- Wakes can reduce wind speed up to 15% and last for several kilometers.
- No significant difference in wakes at 67m height between 3 and 1 km domains.
- First results show promising WRF power output compared to observations.
- Implementation of wind farms near the east coast of the UK, with a wind speed reduction of ~ 3 m/s for the wakes.

Comparison between simulated and observed wind and power time series

Illustration of operational use (07-05-2014, 3km)

Conclusion

- No significant differences observed between YSU and MYNN except for the PBL height.
- The adapted wind farm parameterization shows promising power outputs.
- Future work: clarify the impact of wakes on nearby wind farms, and to make a more thorough verification through hindcasts over longer periods.

Contact
E. hugo.hartmann@meteogroup.com
W. research.meteogroup.com

MeteoGroup

http://www.mmm.ucar.edu/wrf-workshop-0

MeteoGroup

Farr wind farm (RWEInnogy UK)

Location: South of Inverness, Scotland

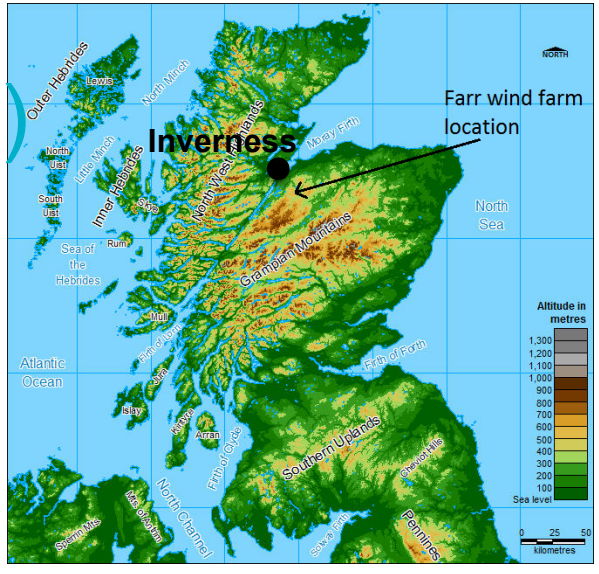
Height: 400-500 m above sea level

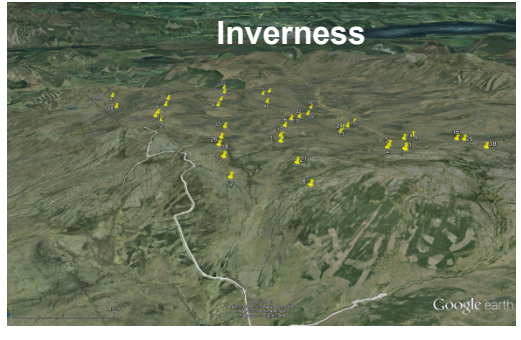
Turbines: 40 Siemens SWT-2.3-82

Cut-in/out speed: 3-5 / 25 m/s

Hub height: 60 m

Spacing: 300-500 m

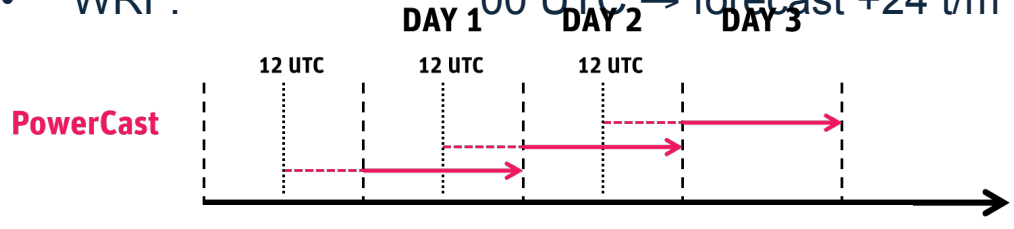


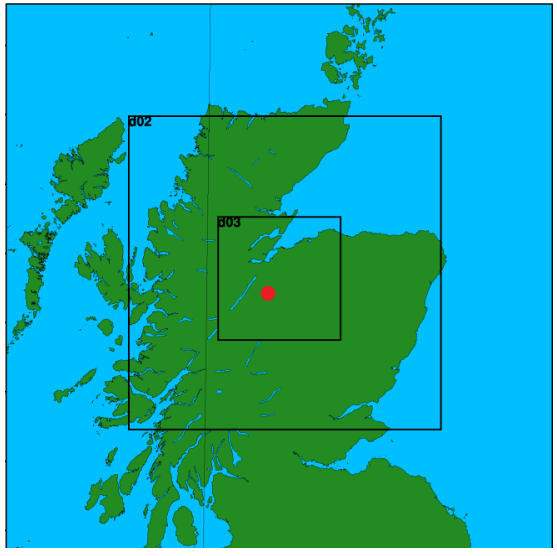


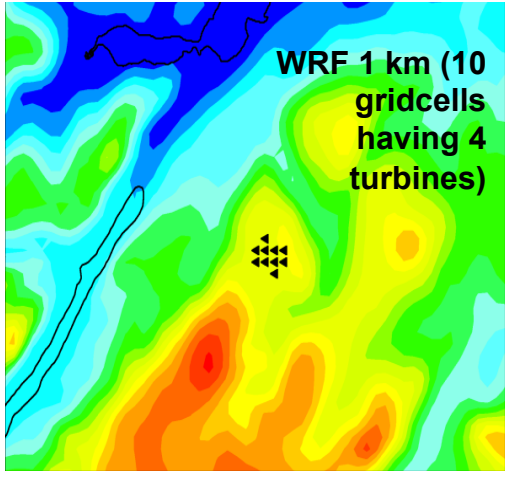
MeteoGroup

Set-up WRF hindcast

- Period: Sept. 1, 2013 → Jan. 31 2014
- WRF version: 3.3.1
- WRF domains: 9, 3 and 1 km
- No. turb./grid cell: 40, 13, 4
- Physics: **MYNN**, Noah, WSM6, RRTM, Goddard, Grell-Devenyi (9km)
- Input data: ERA-Interim 0.75°
- Comparison:
  - PowerCast: 12 UTC → forecast +12 t/m +36
  - WRF: 00 UTC → forecast +24 t/m +48



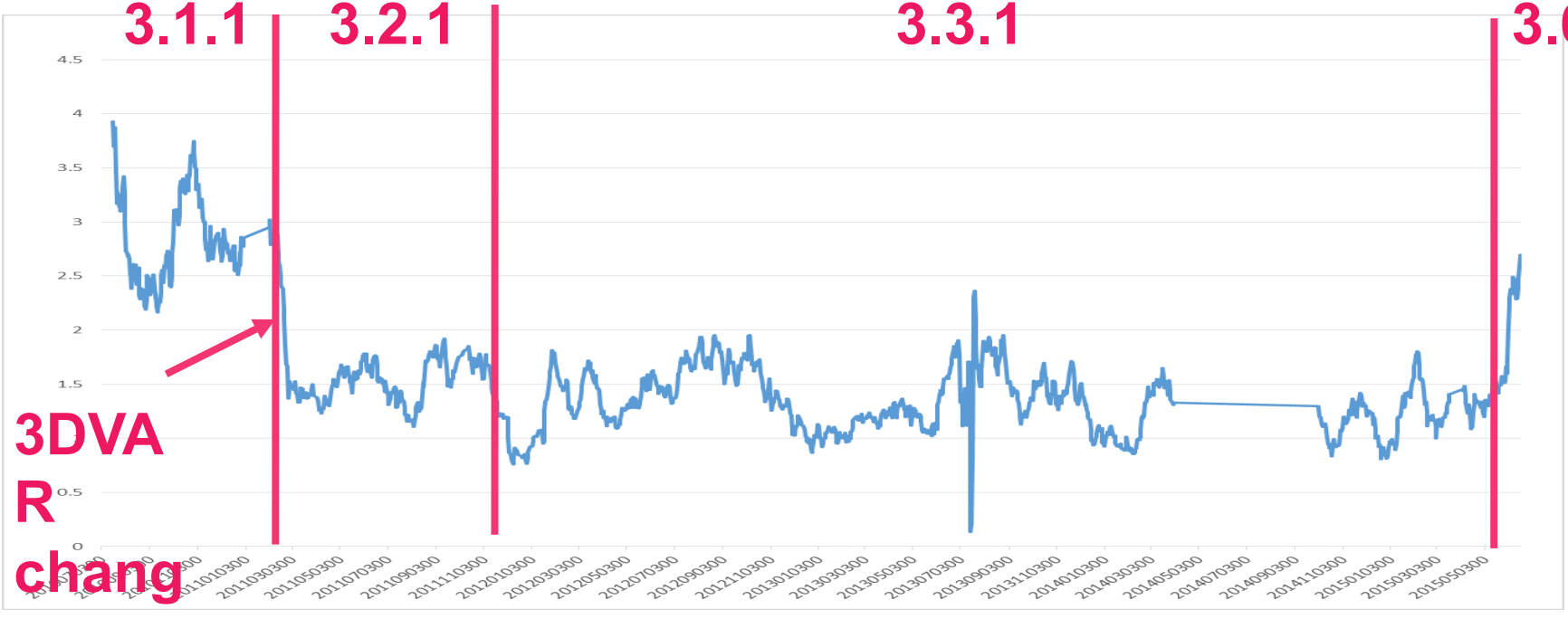




MeteoGroup

WRF verification 3.1.1 - 3.2.1 – 3.3.1 – 3.6.1

Running MAE temperature (30 days average)



- No significant improvement among versions (apart from 3.6.1?)
- Change from 6 to 12 hours 3DVAR does improve

MeteoGroup

Results

RMSE - September 2013

Wind (m/s)	WRF 9km	WRF 3km	WRF 1km
September	3.8	3.7	3.1

- RMSE is based on “farm average” wind speed (subsequent slides also “total farm power”)

- Expected behavior: ↑ horizontal resolution = ↓ RMSE
- MAE shows similar behavior

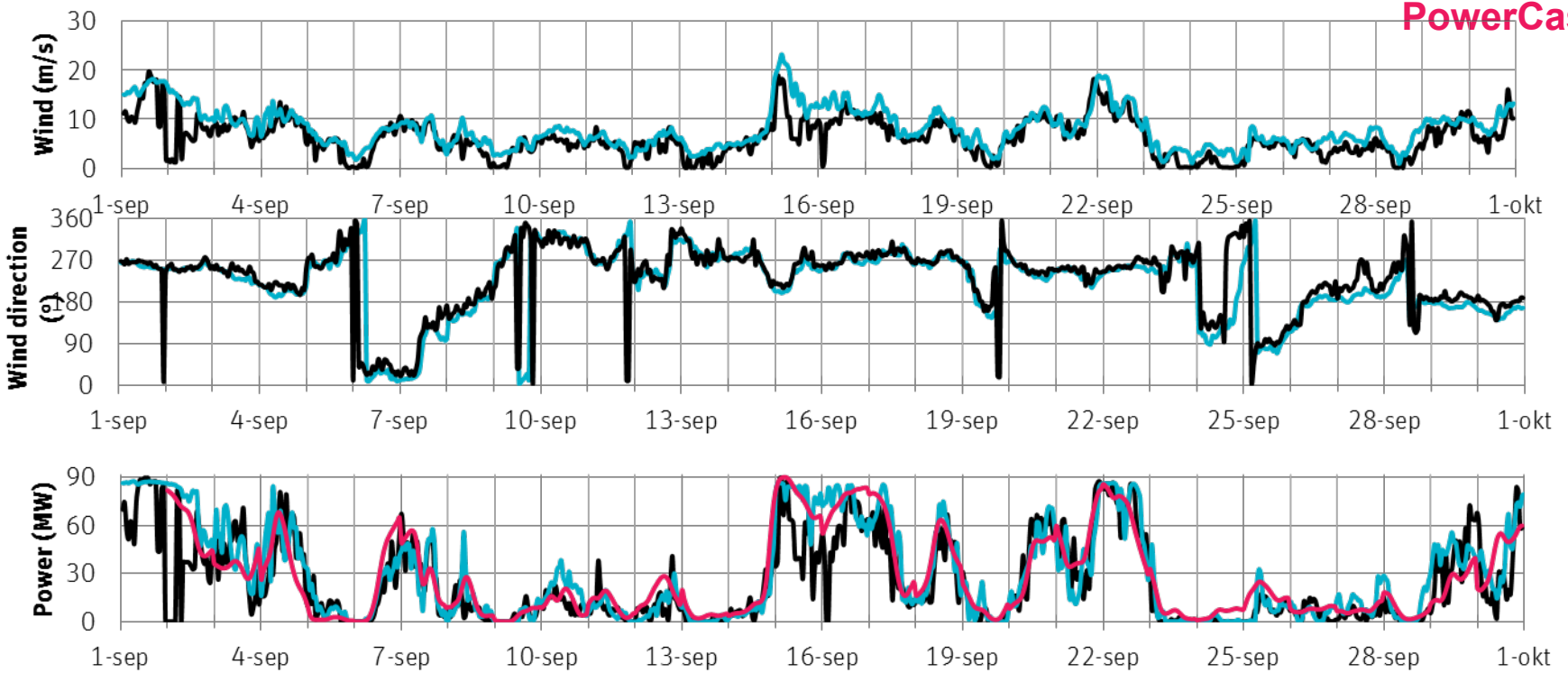
Results

Time series - September 2013

Observations

WRF 1km

PowerCast



MeteoGroup

Results

RMSE – All months

Wind (m/s)	WRF 9km	WRF 3km	WRF 1km
September	3.8	3.7	3.1
October	3.7	3.3	2.8
November	3.1	3.7	3.5
December	7.5	8.0	7.6
January	3.8	3.5	3.0
Average	4.4	4.5	4.0

- What happens in November / December?
- High power RMSE in December / January, both in WRF and PowerCast
- RMSE WRF 1 km close to that of PowerCast

MeteoGroup

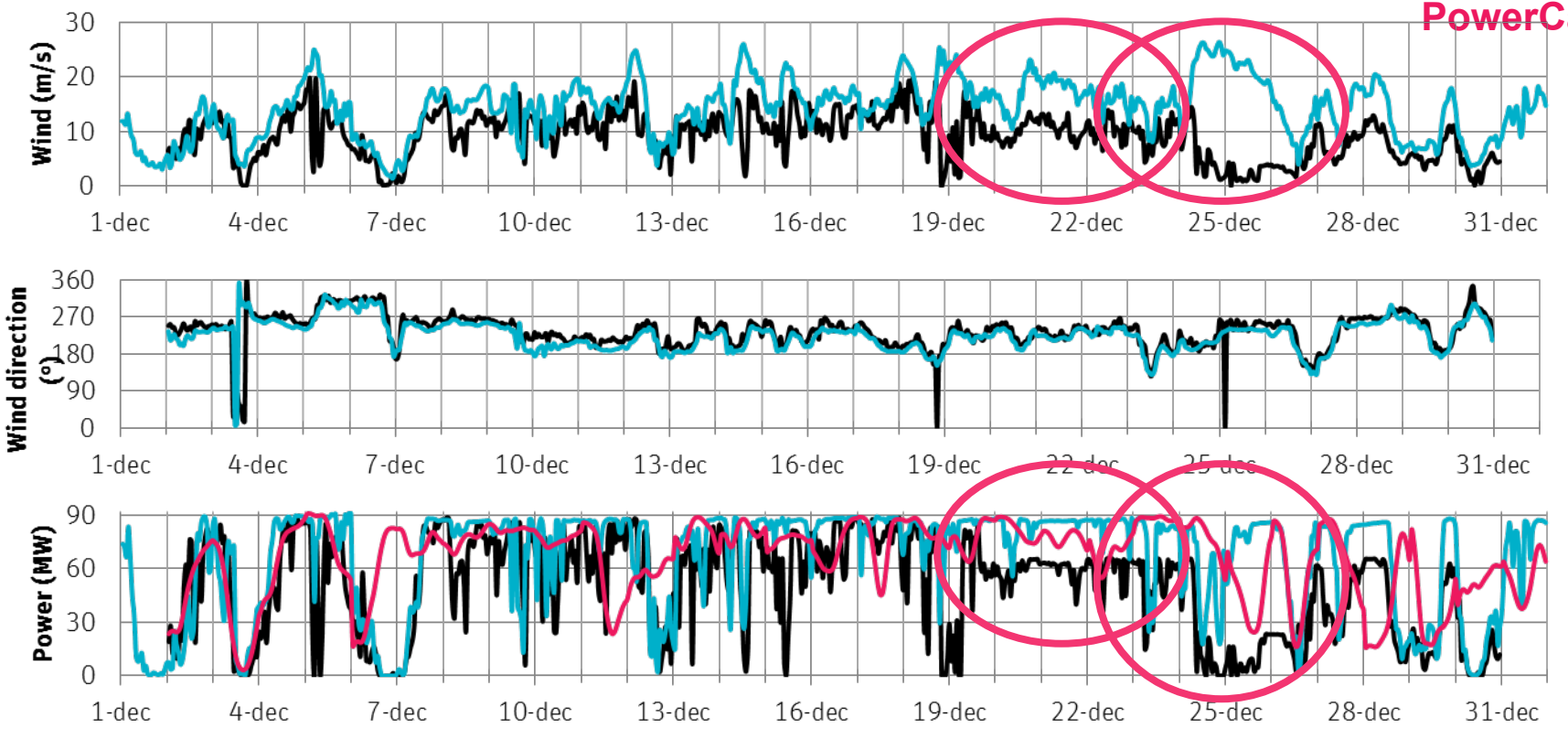
Results

Time series - December 2013

Observations

WRF 1km

PowerCast



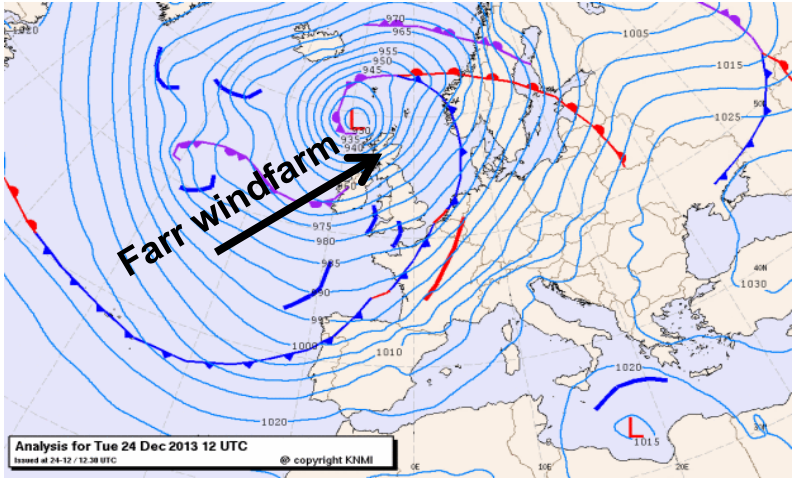
Observation data questionable (metadata not available) → RMSE december unreliable

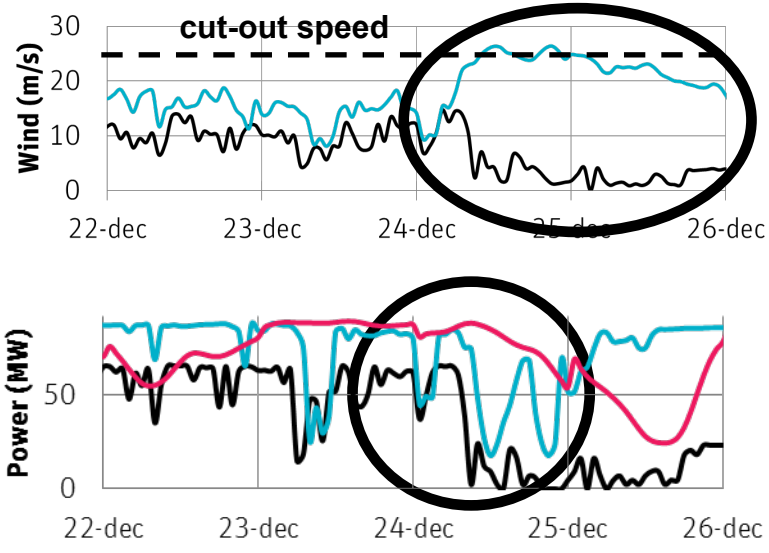
What happens on December 24/25?

MeteoGroup

Results

Analysis of Christmas storm (December 24, 12 UTC)





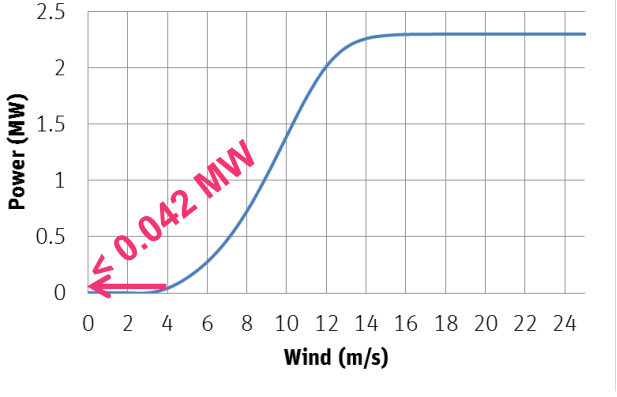
- Again: questionable wind observations…
- PowerCast: Statistical method underestimates high wind speed, cut-out wind speed not exceeded
- WRF: Better in extremes; wind speed exceeds cut-out speed → power drops

MeteoGroup

Results

Skill extreme events: contingency tables / Hanssen-Kuipers score

- Event: **< ~cut-in speed** (< 0.042 MW)
- Evaluated with: Hansen-Kuipers score
  - Hit rate – False alarm rate
  - Score = 1 is perfect skill



September 2013		Observations	
		< 0.042 MW	> 0.042 MW
WRF 1km	< 0.042 MW	97	24
	> 0.042 MW	51	524

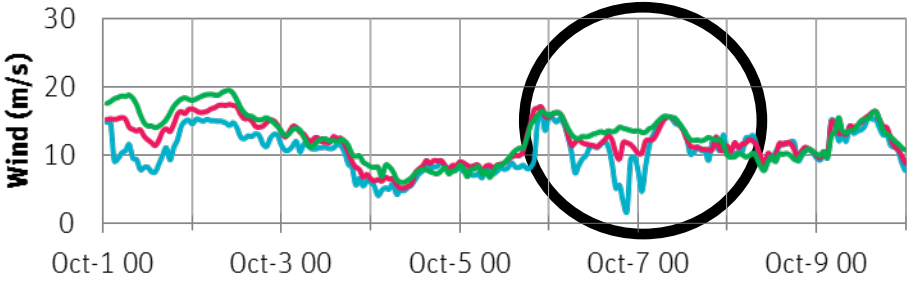
September 2013		Observations	
		< 0.042 MW	> 0.042 MW
PowerCast	< 0.042 MW	35	9
	> 0.042 MW	113	539
Hanssen-Kuipers		0.22	

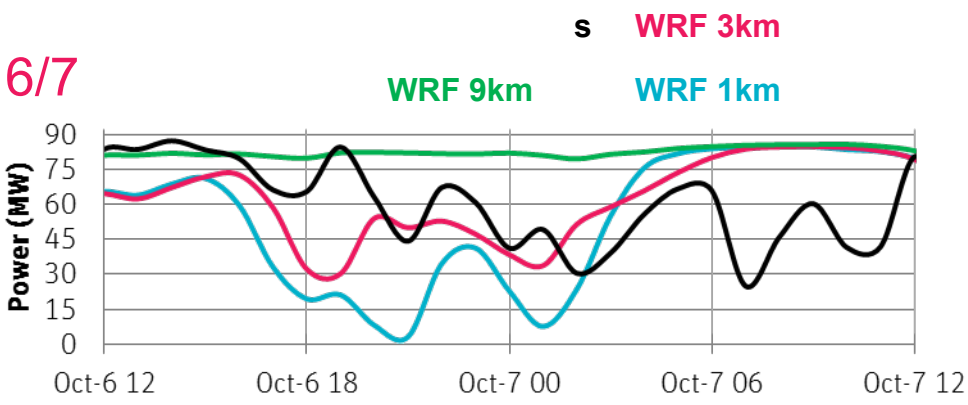
- WRF has a better skill for extreme events (here: turbine cut-in speed/ power)

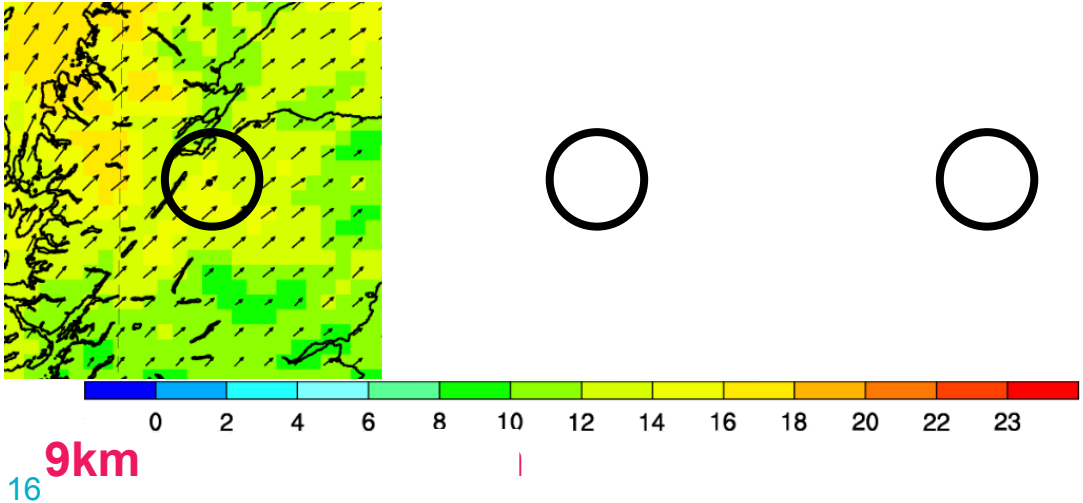
MeteoGroup

Results

Resolution effect: analysis October 6/7







- WRF 1km: Too much shielding?

MeteoGroup

Results

Resolution effect: analysis October 6/7

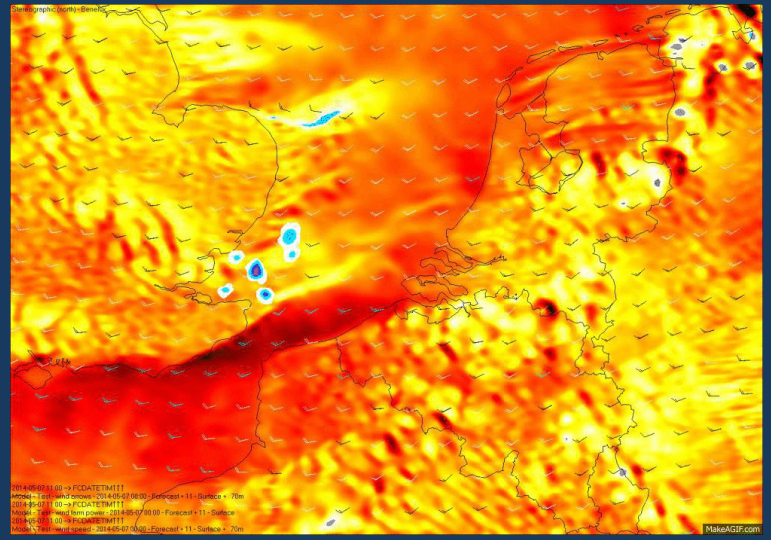
Is WRF modelling the wind speed variation correctly in rugged terrain?

MeteoGroup

Conclusions

- In general: WRF 1km power forecast quality (RMSE) is comparable to PowerCast
- Pay attention to the quality of the wind farm observations, availability of metadata (e.g. turbine switch-on/off, maintenance) is crucial
- WRF is better in capturing extreme events (high/low wind speeds) compared to the statistical PowerCast product
- Increasing resolution does not always improve the forecast; is WRF modelling the wind speed variation correctly in rugged terrain?

Wind farm scheme incorporated in MeteoGroup's operational WRF 3.6.1 forecasts…



MeteoGroup

Thank you, questions?

Contact
E. hugo.hartmann@meteogroup.com
W. research.meteogroup.com