Wind Power Forecasting in Complex Terrain and Extreme Weather Conditions

5 June - 2019 Meteorology & market design for grid services workshop

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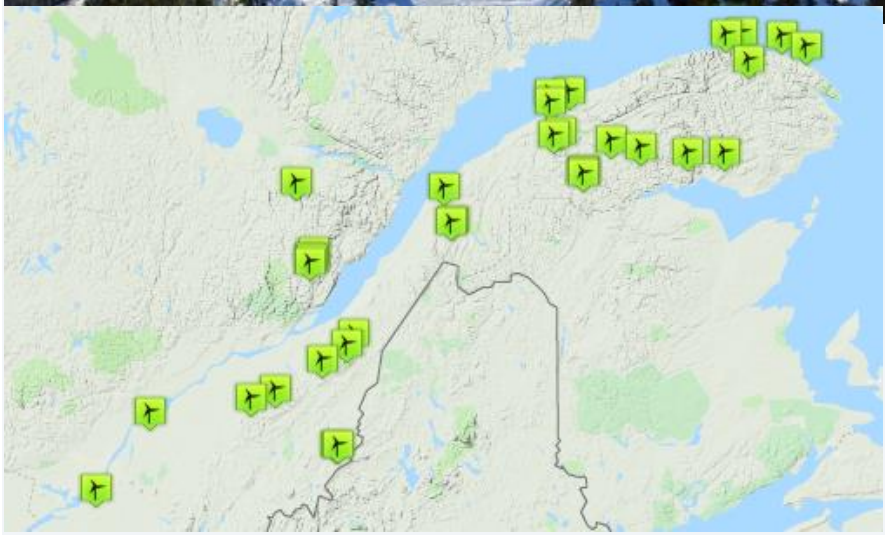
When wind power forecasting becomes difficult

Challenges in extreme conditions

- Effect of precipitation when dust and sand have decreased output with up 15%
- Risk of cut-out at high wind speed
- Risk of steep ramps when weather patterns are changing
- Effect of complex terrain (mountains) which is not captured adequate in weather models
- Icing on wind turbines
- ….and more



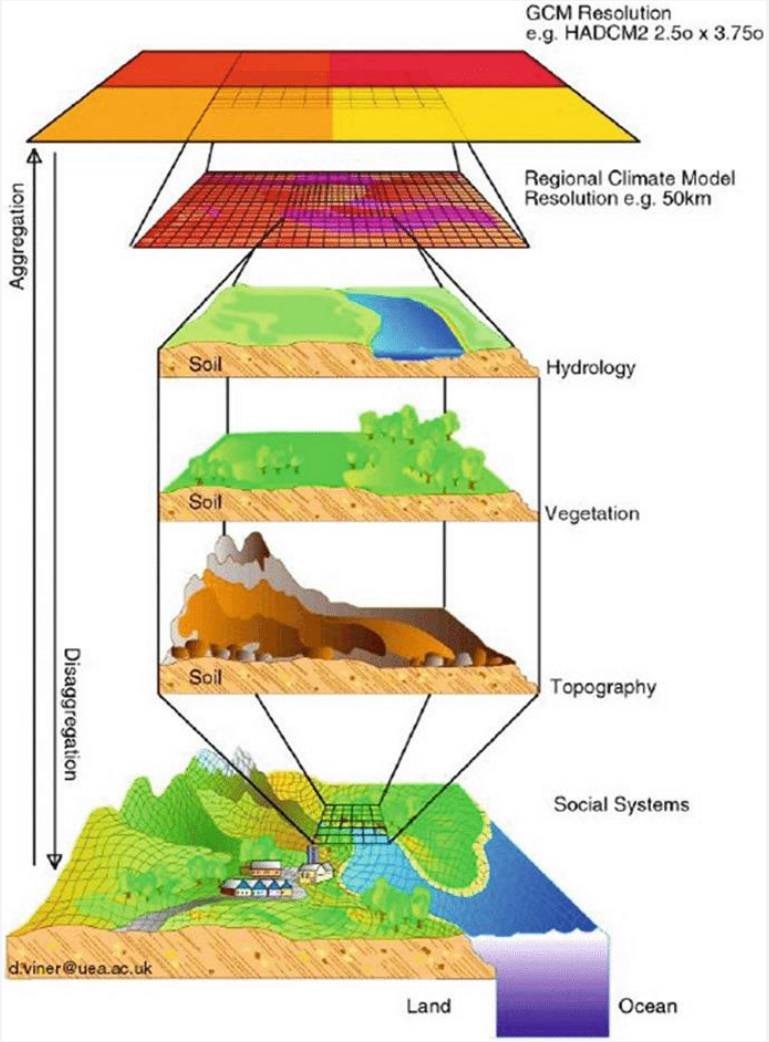
Wind speed downscaling in complex terrain

Why use downscaling?

- In complex terrain NWPs* do not capture the wind speed with adequate precision
- Leading to “lower than normal” wind power generation forecast precision
- An alternative to resource intensive/expensive meso scala modelling

How to perform downscaling

- Based on data-mining/deep-learning techniques
- Based on NWPs grid around farm
- Data-mining on a large set of candidate parameters from a number of NWPs
- Principle component analysis used to identify and prioritize parameters



NWP: Numerical Weather Prediction

Wind speed downscaling in complex terrain

Analyzed & categorized per farm, month & NWP

	AAV			BDS			CAR			SUL		
	GEM (1)	ECM (2)	GFS (3)	GEM (1)	ECM (2)	GFS (3)	GEM (1)	ECM (2)	GFS (3)	GEM (1)	ECM (2)	GFS (3)
07.15	+++	+++	+++	+	+	=	++	++	+++	+	+	++
08.15	++	+++	+	++	++	+++	+++	++	+++	++	+	++
09.15	+++	+++	++	++	++	++	+++	++	+++	++	=	+++
10.15	++	+	++	+	+	++	++	+	+	+	=	+++
11.15	++	++	+	+	++	+	++	+	+	+	=	++
12.15	++	+	+	+	=	+	+	+	++	=	=	++
01.16	+	+	+	+	++	++	++	+	+	+	+	+

	MLO			MSE			GMO			LPL		
	GEM (1)	ECM (2)	GFS (3)	GEM (1)	ECM (2)	GFS (3)	GEM (1)	ECM (2)	GFS (3)	GEM (1)	ECM (2)	GFS (3)
07.15	+++	+	++	+++	++	+++	+++	+	+++	++	++	+++
08.15	+++	=	+++	+++	+	+	++	++	+	+++	++	+++
09.15	++	+	+++	++	+	++	++	+	++	+++	++	+++
10.15	++	+	+++	++	=	++	++	++	+++	+	=	++
11.15	+++	++	+++	++	+	++	++	++	+++	+	+	++
12.15	++	+	++	+	+	++	+	++	++	+	=	+++
01.16	++	+	+++	+	=	++	+	+	++	++	+	+++

	SRB			SRE			LAL			MDS		
	GEM (1)	ECM (2)	GFS (3)	GEM (1)	ECM (2)	GFS (3)	GEM (1)	ECM (2)	GFS (3)	GEM (1)	ECM (2)	GFS (3)
07.15	++	++	++	++	=	-	++	++	=	+++	++	+++
08.15	++	++	++	++	=	-	+++	+	+	+++	++	++
09.15	+++	++	+++	+++	-	-	+++	=	++	+++	++	+++
10.15	+++	++	+++	=	+	=	++	=	=	+++	++	++
11.15	++	++	+++	+	=	-	++	=	+	++	++	+
12.15	+++	++	+++	=	=	=	=	=	+	+++	++	++
01.16	++	++	+++	+	+	+	++	+	++	++	+	++

	NRI			DLE			SB2			VDE		
	GEM (1)	ECM (2)	GFS (3)	GEM (1)	ECM (2)	GFS (3)	GEM (1)	ECM (2)	GFS (3)	GEM (1)	ECM (2)	GFS (3)
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10.15	++	=	++	++	=	+	++	+	++	++	+	+
11.15	+++	++	+	=	+	+	+	+	++	+	+	+
12.15	+	+	+	+	++	++	++	++	++	+	+	++
01.16	++	++	+	=	++	++	+	+	++	++	+++	+++

Reduction of forecast error

- -: -2.5% to -0.5%
- =: -0.5% to 0.5%
- +: 0.5% to 2.5%
- ++: 2.5% to < 5.0%
- +++: >5.0%

Perform well on all farms except two:

- Open terrain, where the benefits are limited
- Small tree-covered hill – well-performing already

Challenges

- A black box is a black box
- Can identify correlations, which can not be explained physically
- NPW model changes can result in sudden performance degradation
- Very CPU intensive
- Requires 6-12 months of historical data
- Requires a good dataset from the farms

V02 to address some of these challenges!

NWP: Numerical Weather Prediction

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Icing on wind turbines

The issue with icing on turbines is…

- Significantly reduce output in part of the year for customers in North America & Scandinavia
- Does not only effect the period itself, but will also impact model calibration and forecast accuracy in a period after the event
- Not many turbines have ice detection equipment - and it is expensive

…that forecasting is difficult…

- Analysis show that forecasting yields too many falls positive and get the timing wrong
- Standard weather models do not capture enough details to model icing event
- Applying meso scala models tuned for ice forecasting does not improve things much
- Local conditions are just really complicated to model and therefore also to predict

Icing on wind turbines

…so we took a different approach

- Online detection of icing & estimation of effect
- Forecast magnitude and duration of event
- Post-processing of power forecast to predicted icing effect

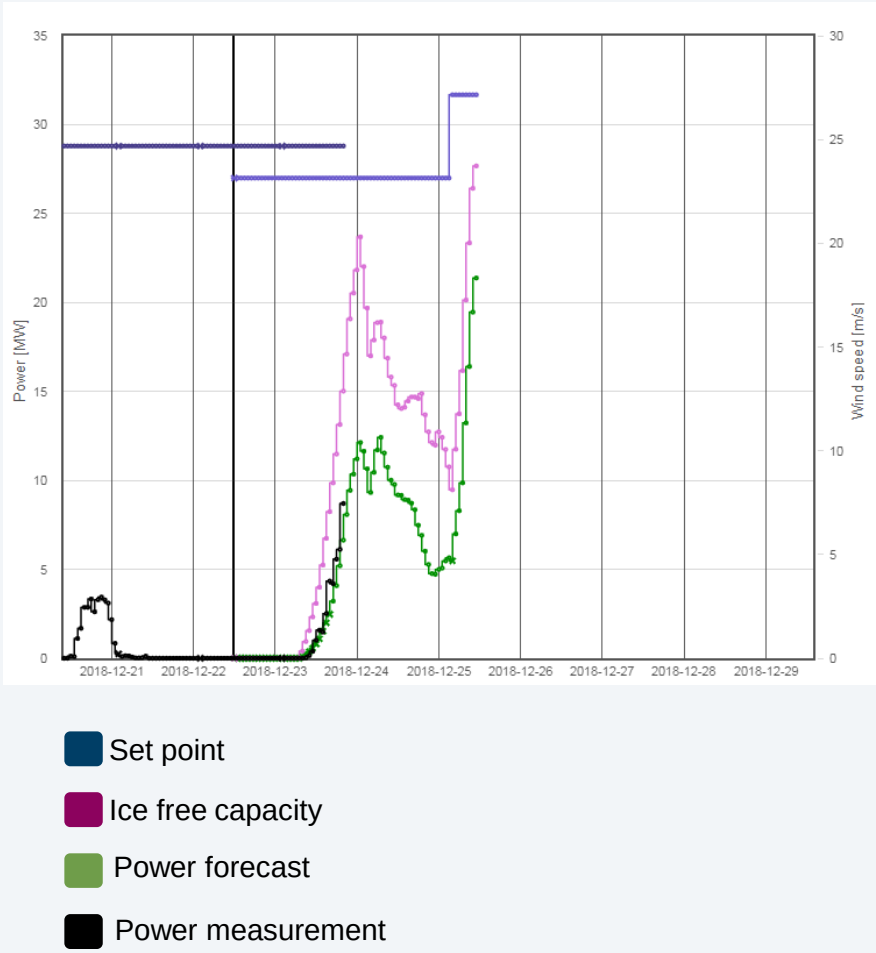
V01 - 2013

- Tracking “status” of farm and if threshold met, classify as icing event
- Evaluate individual event without taking uncertainty into account
- Noise in bottom and top of power curve

V02 - 2019

- Introduction of state space model
- Uncertain events only get small weights
- Fine tuning of weights for fundamental model and real time calibration model

Icing event and subsequent ramp up



Questions and contact information

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