ASPECTS OF FORECASTING OF THE WIND FARM POWER OUTPUT - PRACTICAL EXPERIENCE

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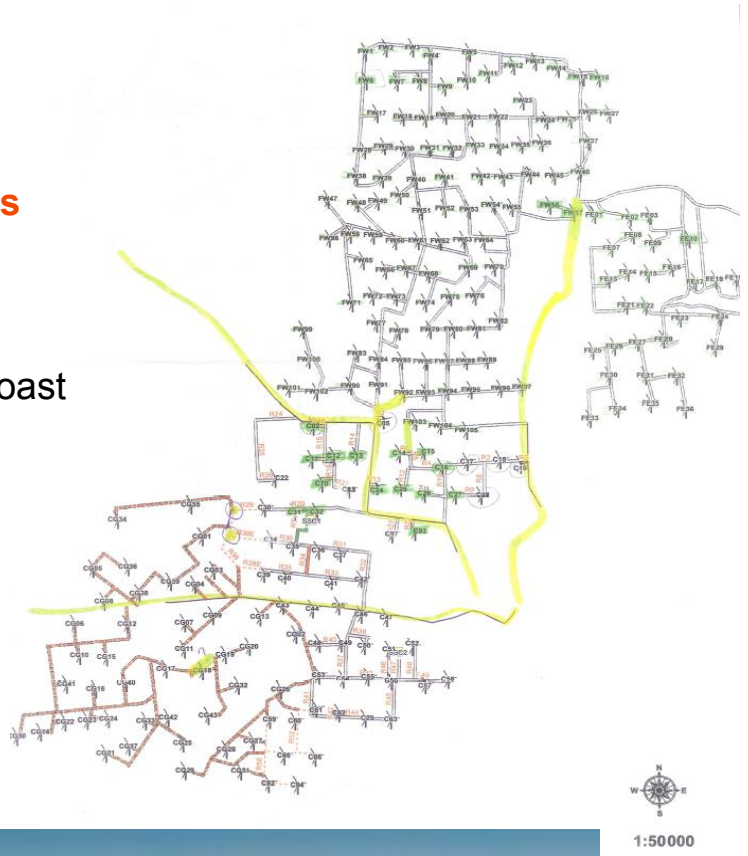
Trading

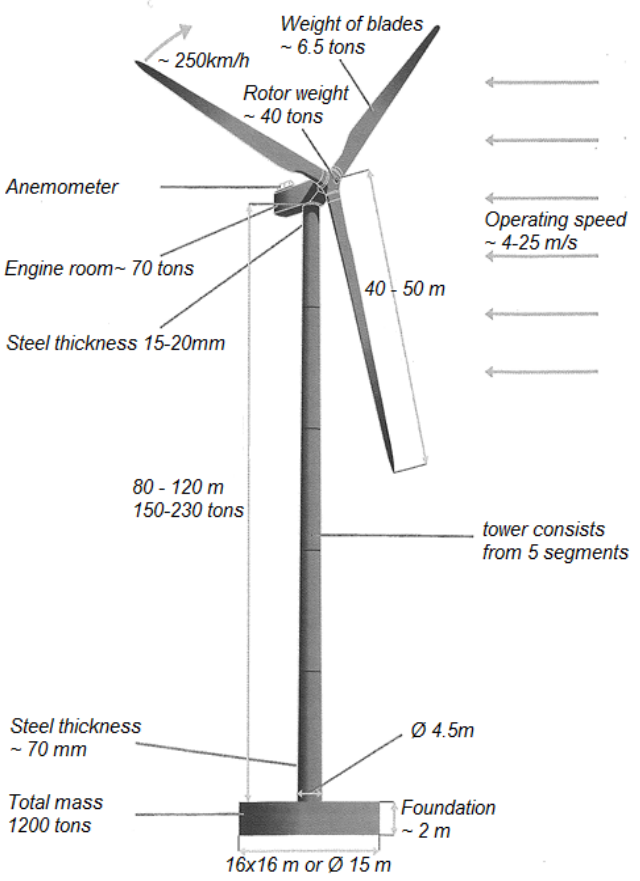
WIND POWER PLANTS. LARGEST EUROPEAN ONSHORE WIND FARM …

- Group of wind turbines in one area
- **Intermittent renewable resource X conventional sources**
- ***CEZ Fantanele & Cogealac wind farm***
  - Located in South East Romania, 15 km from Black sea coast
  - Built for 2 years, finished in December 2012
  - 240 turbines / 600 MW installed capacity
  - Seasonal pattern of utilization (20 – 30 %)
  - Size 12 x 6 km

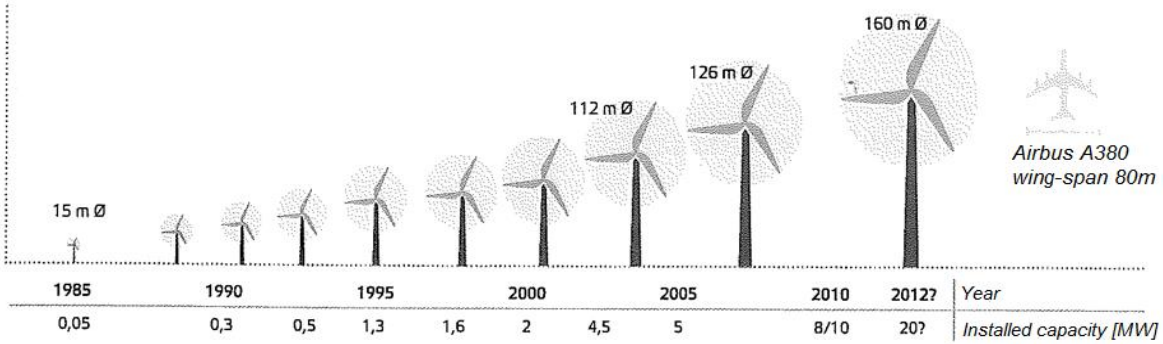


WIND TURBINES PRODUCE CLEAN ENERGY …

- More than 2 200 years old machine (windmills).
- One large turbine (2.5MW) can produce electricity to power 1,400 homes.
- Currently the largest VESTAS V164 turbine with capacity of 8MW, height 220 m and diameter 164 m, stands in Denmark.



Evolution of turbines (source: EWEA)

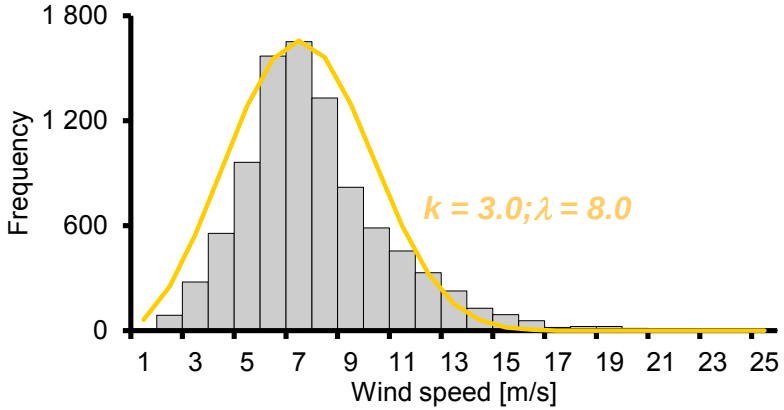


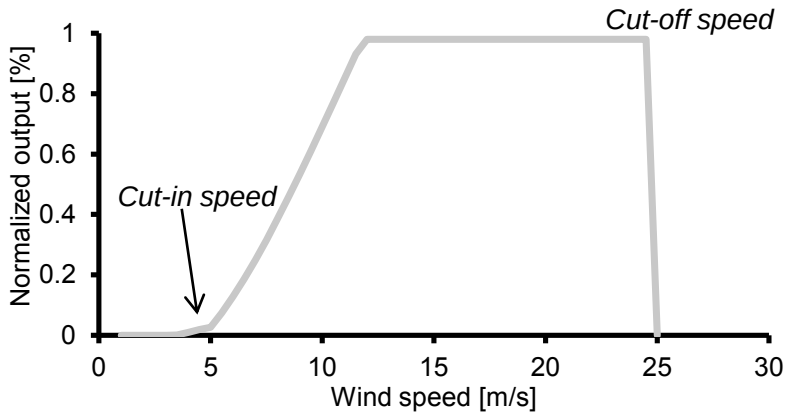
PHYSICS OF WIND …

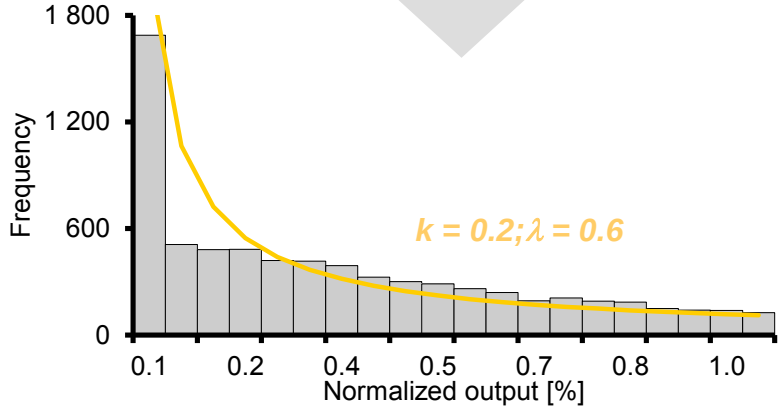
- Wind speed is a fundamental atmospheric variable.
- Velocity distribution often matches the Weibull shape defined as (k… shape parameter, λ…scale parameter):

$$f(x;\lambda;k) = \frac{k}{\lambda}\left(\frac{x}{\lambda}\right)^{k-1} e^{-(x/\lambda)^k}; x \geq 0$$

- Extract kinetic energy from the flow of wind into electrical power.
- Wind power is defined as ~ v^3



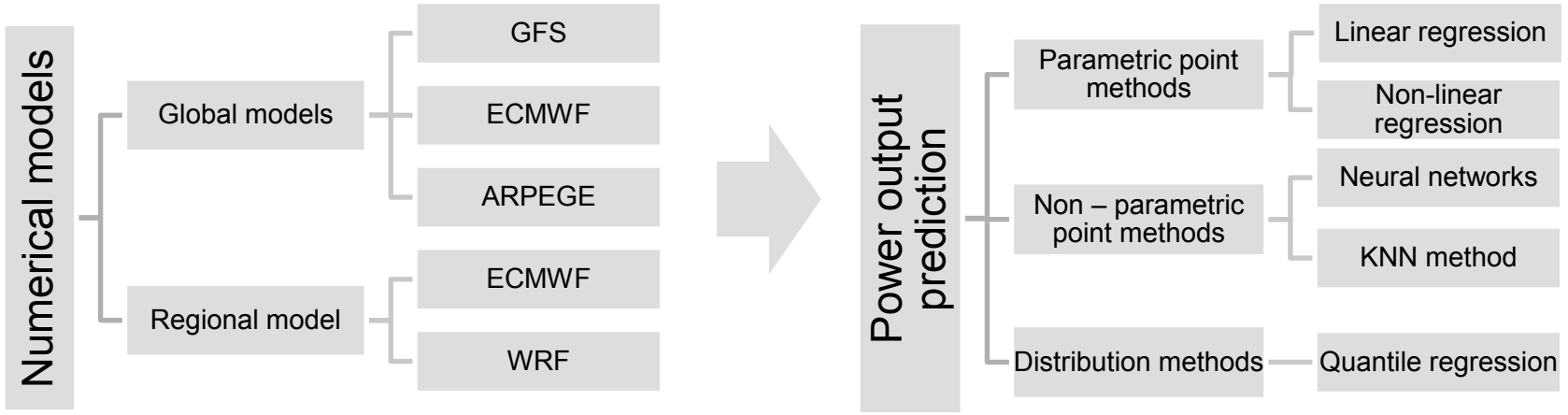




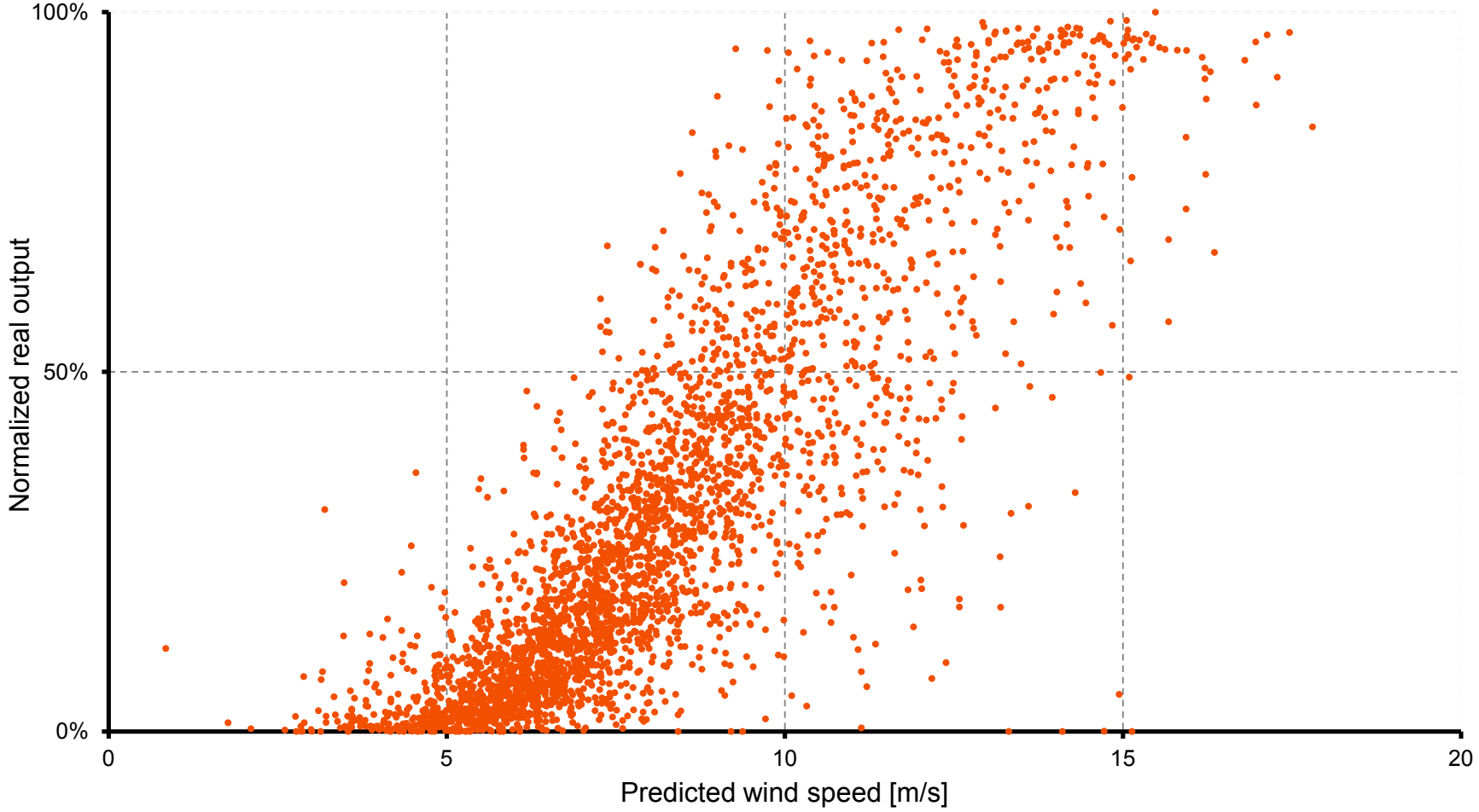
METEOROLOGICAL SERVICE IS A MUST FOR WIND FARM OPERATORS

- ***General meteorological predictions***
  - Temperatures and humidity – icing
  - Storms and lightning
  - Low and extreme wind speeds
- ***Wind power output***
  - **Electricity cannot be stored**
  - Day-ahead and intraday nomination
  - Hedging
  - Assess of the wind farm

Scheme of forecasting the power output

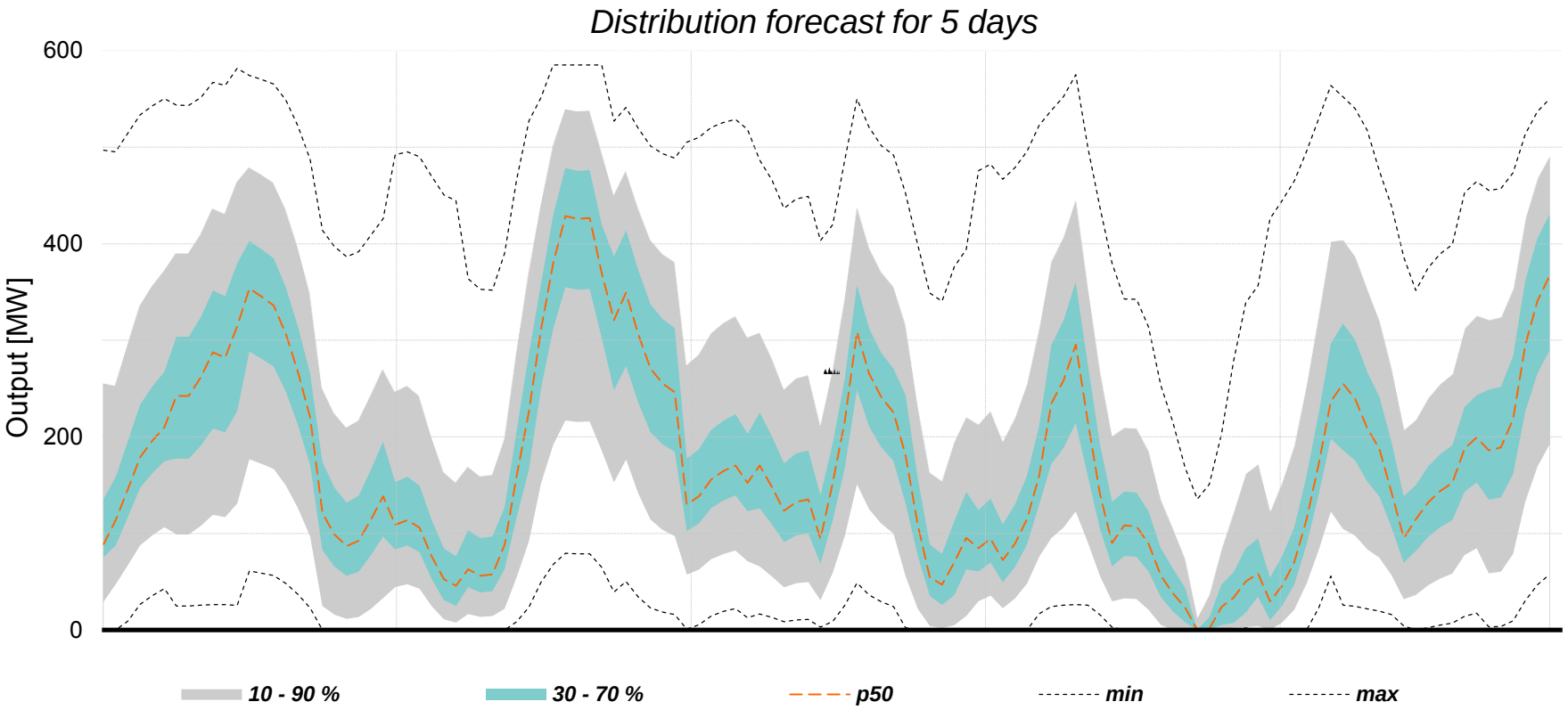


DEPENDENCE OF PREDICTED WIND SPEED ON POWER OUTPUT IS NON-TRIVIAL



QUANTILE REGRESSION HELPS FIND OUT PROBABILITIES OF THE OUTPUT

- Point forecast **X** distribution forecast: quantile regression just one of the techniques
- Koenker, R., and Bassett, G. W. Regression Quantiles, Econometrica, 1978, 46, 33-50.
- Parameter estimation for the linear function – is the problem of linear optimization



INTRADAY ALLOWS HIGHER ACCURACY WITH USAGE OF REAL DATA

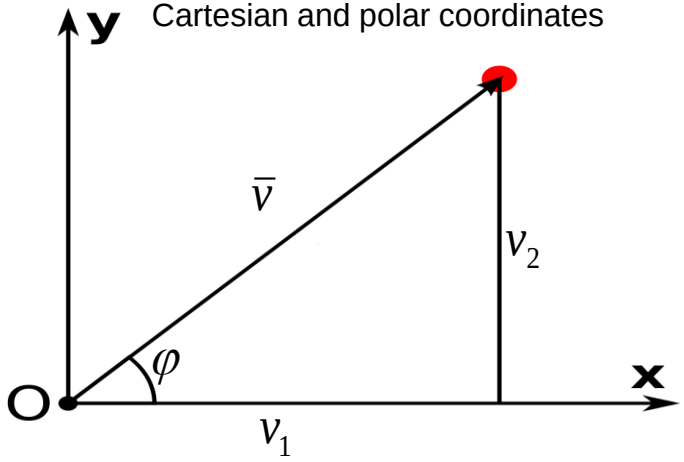
- ***Output prediction has its own limits due to numerical models accuracy!***
- Autoregression might help improving prediction on short time interval
- Usage of the Intraday AR forecast with respect to trading windows

CHALLENGES WITH MODEL SPECIFICATION

- ***Periodical variables:***
  - Problem with singularity
  - Transition between Cartesian and polar coordinates
  - Define wind speed and wind direction in Cartesian coordinates v_1 and v_2 :

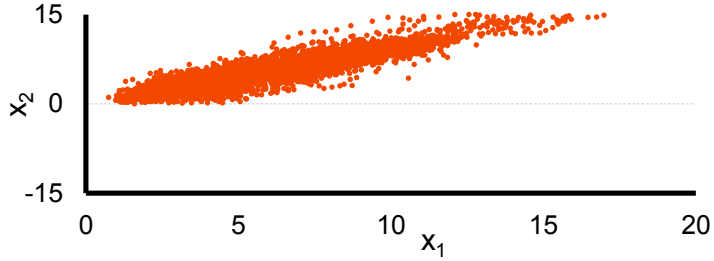
$$v_1 = \bar{v}\cos\varphi \;\; ; \; v_2 = \bar{v}\sin\varphi$$

Cartesian and polar coordinates

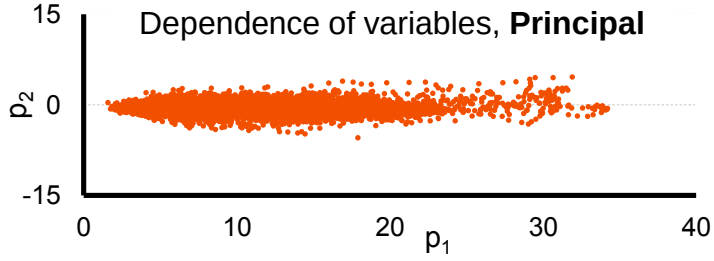


- ***Decrease number of variables:***
  - Principal component analyses
  - PCA "squeezes" as much as possible information into the first principal components
  - E.g. predicted wind speeds from several numerical models, 1st principal component contains 96% of variability

Dependence of variables, **Cartesian**

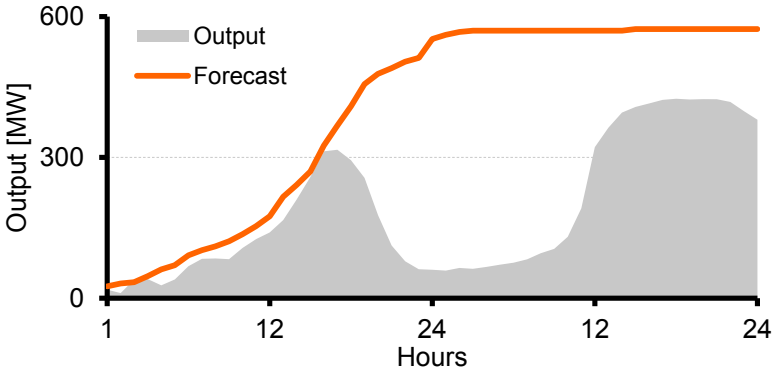


Dependence of variables, **Principal**

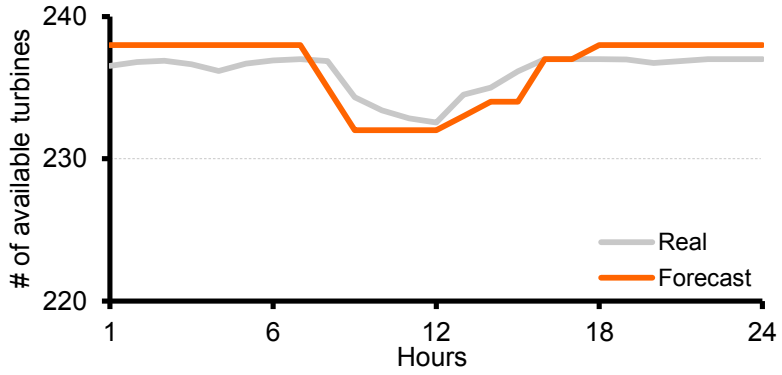


CHALLENGES WITH OPERATING THE MODEL

- ***Icing***
  - Often followed by huge wind speeds.



- ***Unavailability***
  - Discrepancy between real and forecasted availability can destroy forecast…



- ***Speed of data availability***
  - Earlier data can improve accuracy but in physical limits.


Thank you