DTU Library

Wind power variability and power system reserves

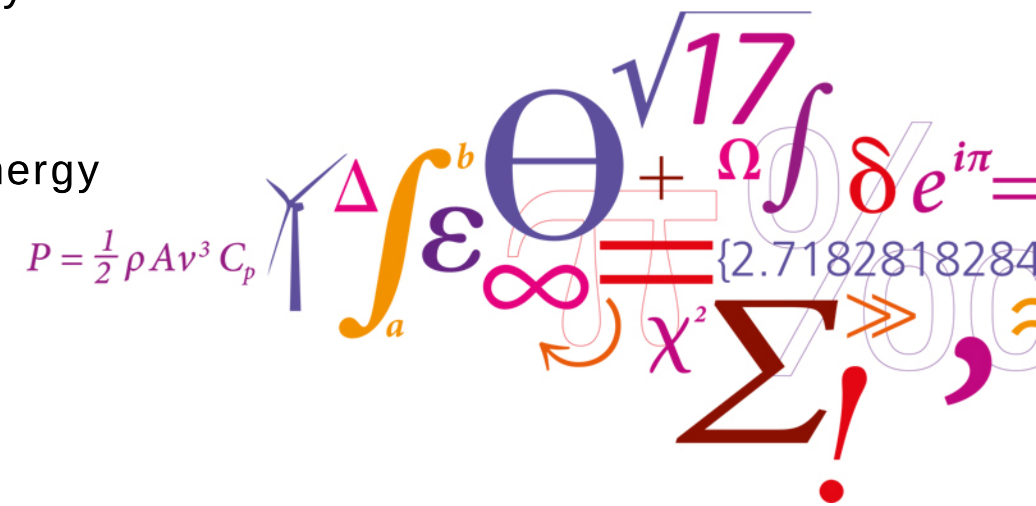
Sørensen, Poul Ejnar; Litong-Palima, Marisciel; Hahmann, Andrea N.; Heunis, Schalk; Ntusi, Marathon; Hansen, Jens Carsten

Publication date:
2016

Document Version
Publisher's PDF, also known as Version of record

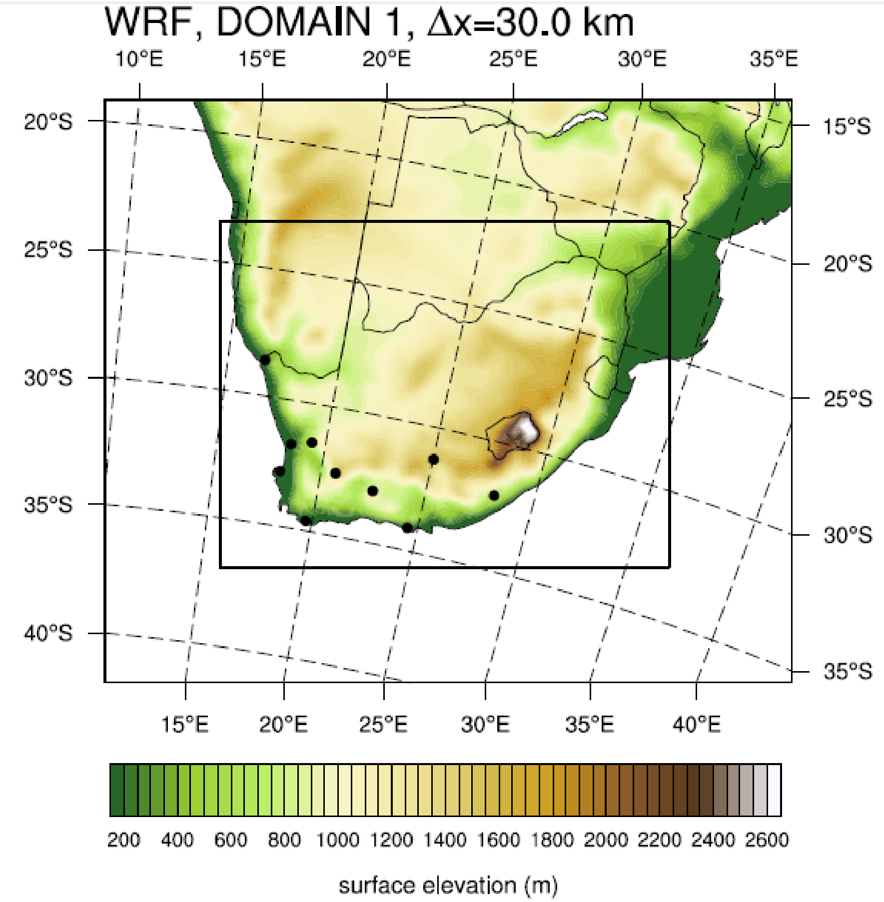
Wind Power variability and power system reserves

Poul Sørensen, DTU Wind Energy
Marisciel Litong-Palima, DTU Wind Energy
Andrea Hahmann, DTU Wind Energy
Schalk Heunis, EOH Enerweb
Marathon Ntusi, ESKOM
Jens Carsten Hansen, DTU Wind Energy



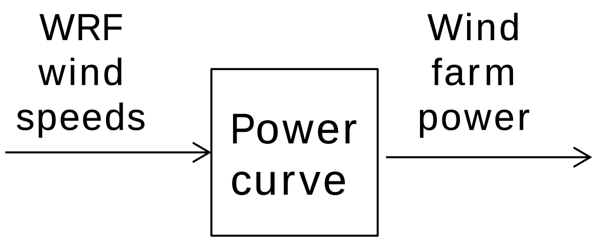
Weather Research and Forecasting (WRF)

- WRF used in the Wind Atlas of South Africa (A. Hahmann et.al.)
- New WRF run to include all South Africa
  - 1990-2014
  - Outer domain 1 Δx=30km
  - Inner domain 2 Δx=10km
  - Time resolution ΔT=1h
  - Light nudging
- Stored data
  - Wind speed (height 80m, 100 m and 125m)
  - Wind direction (same heights)
  - Air density
  - Horizontal irradiation
  - Air temperature
  - Wind speed 10m height

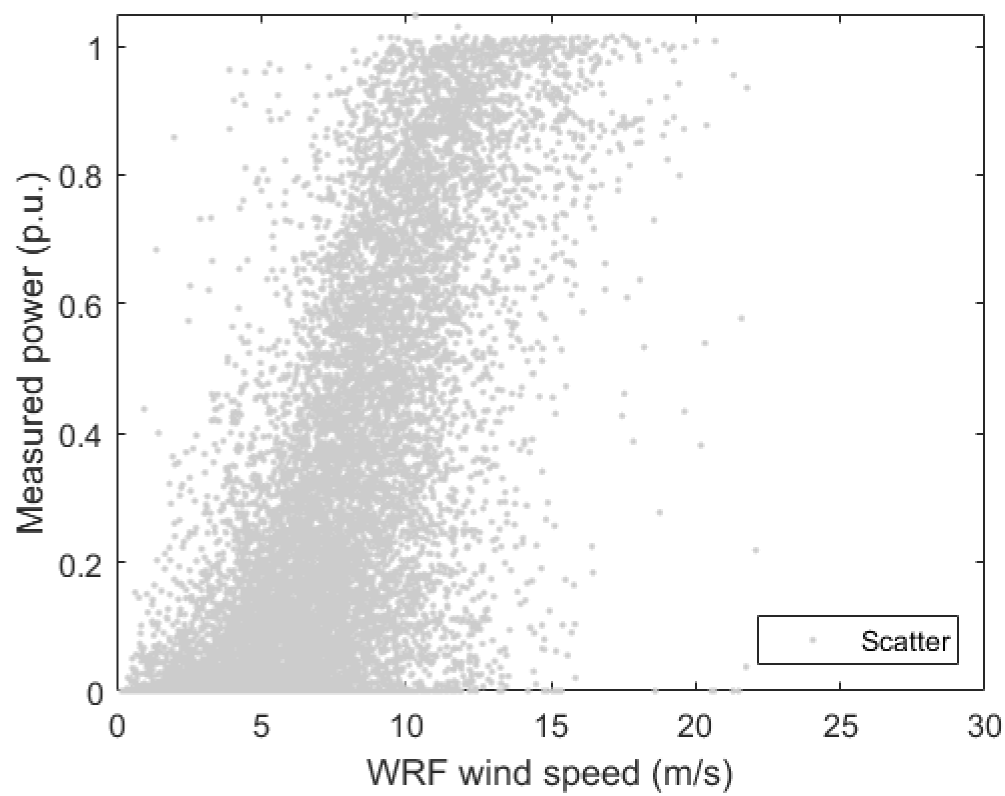


Power curve estimation using WRF wind speeds and measured power

- Power curves needed to model wind power using WRF data:



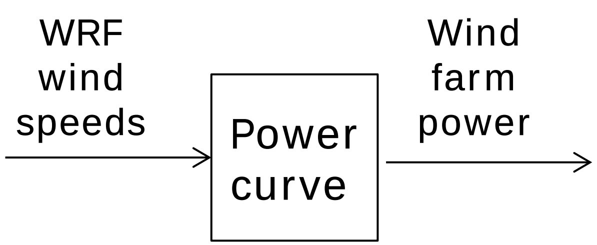
- The example shows high scatter between WRF wind speeds and generated wind farm power in same hour
- A major reason for the high scatter here is that WRF runs are only lightly ***nudged***, which ensures inclusion of mesoscale effects

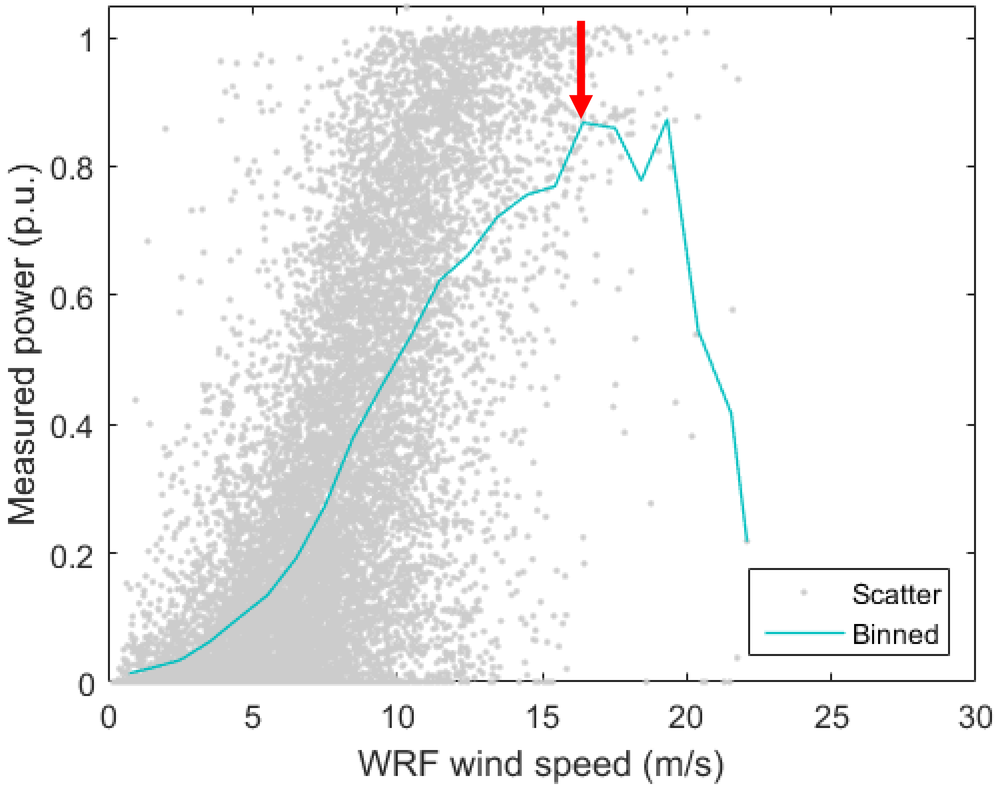


Power curve using standard method of binning

- Usually power curves are generated using method of binning (IEC 61400-12 series):
  - Bin (ws,p) data into ws intervals
  - Calculate average ws and average p in each interval

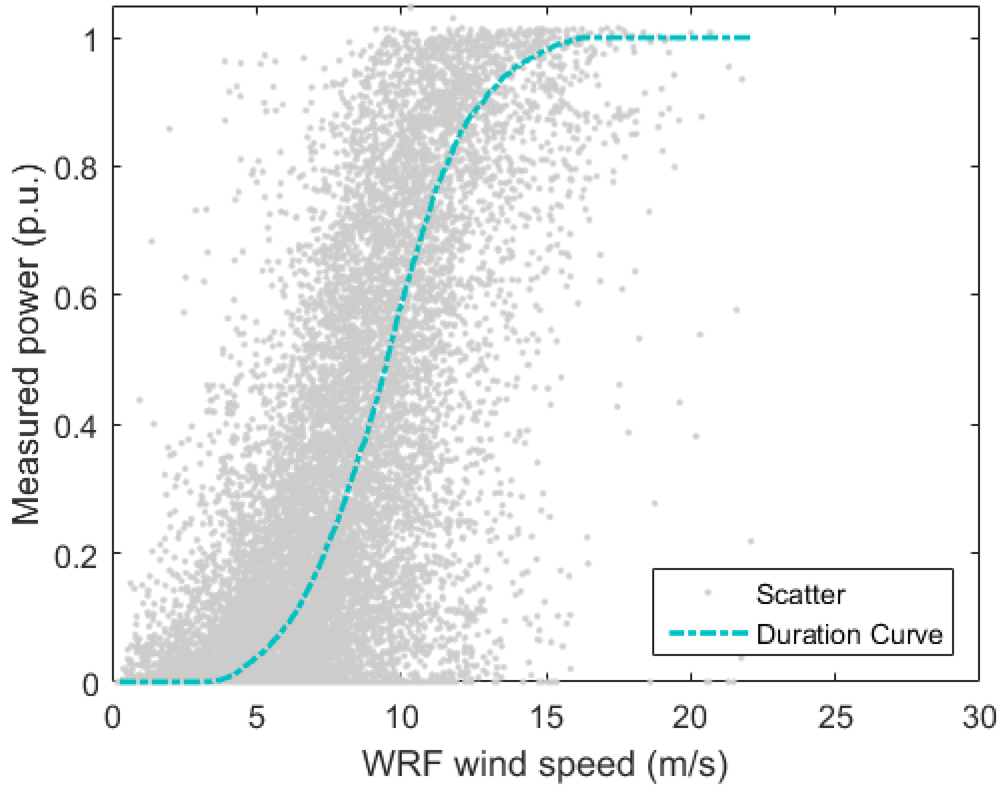
- Problem: averaging lowers maximum value and alters the wind power production





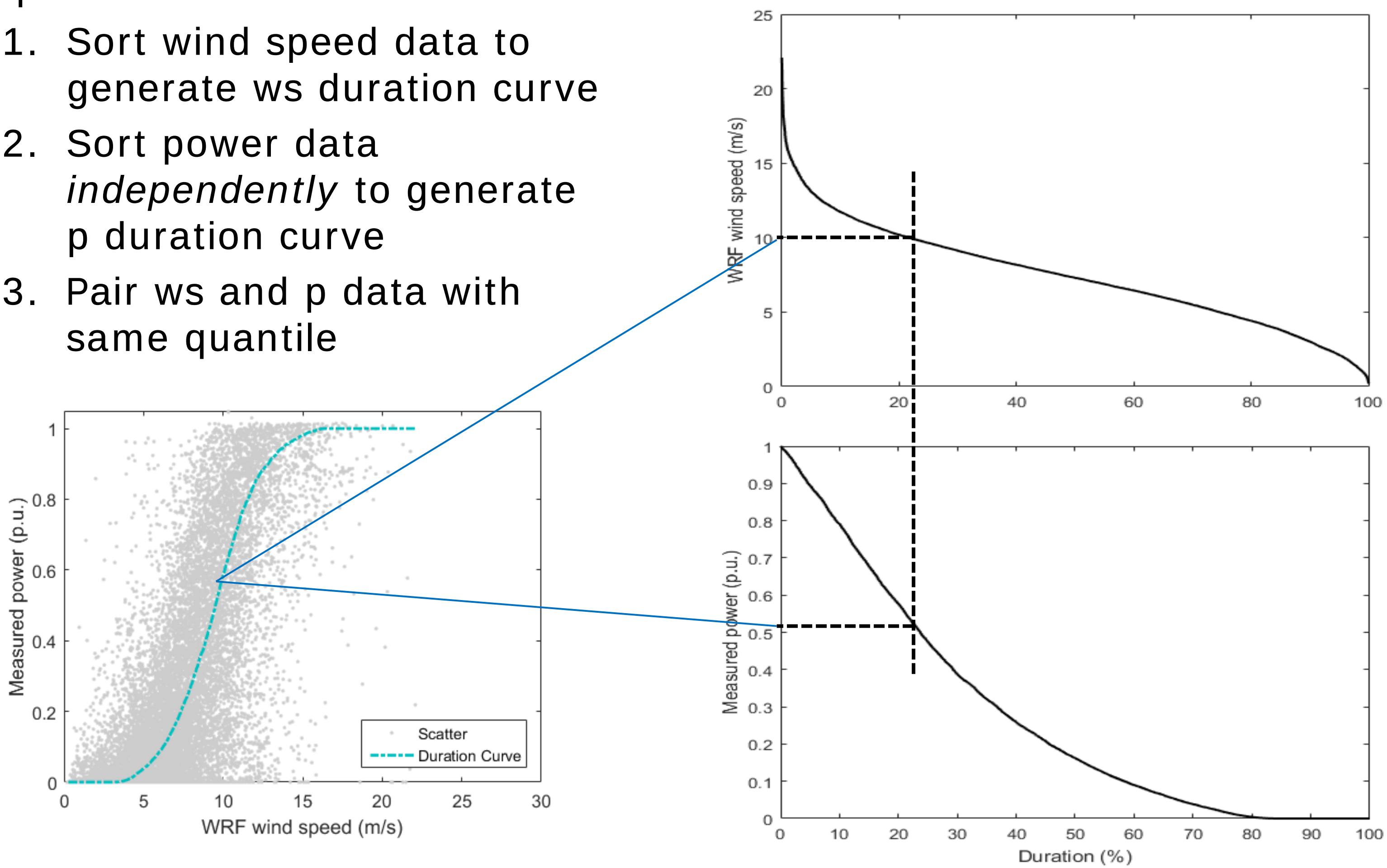
Power curves from duration curves

- Alternative method to estimate power curve:
  - ”Duration Curve” method



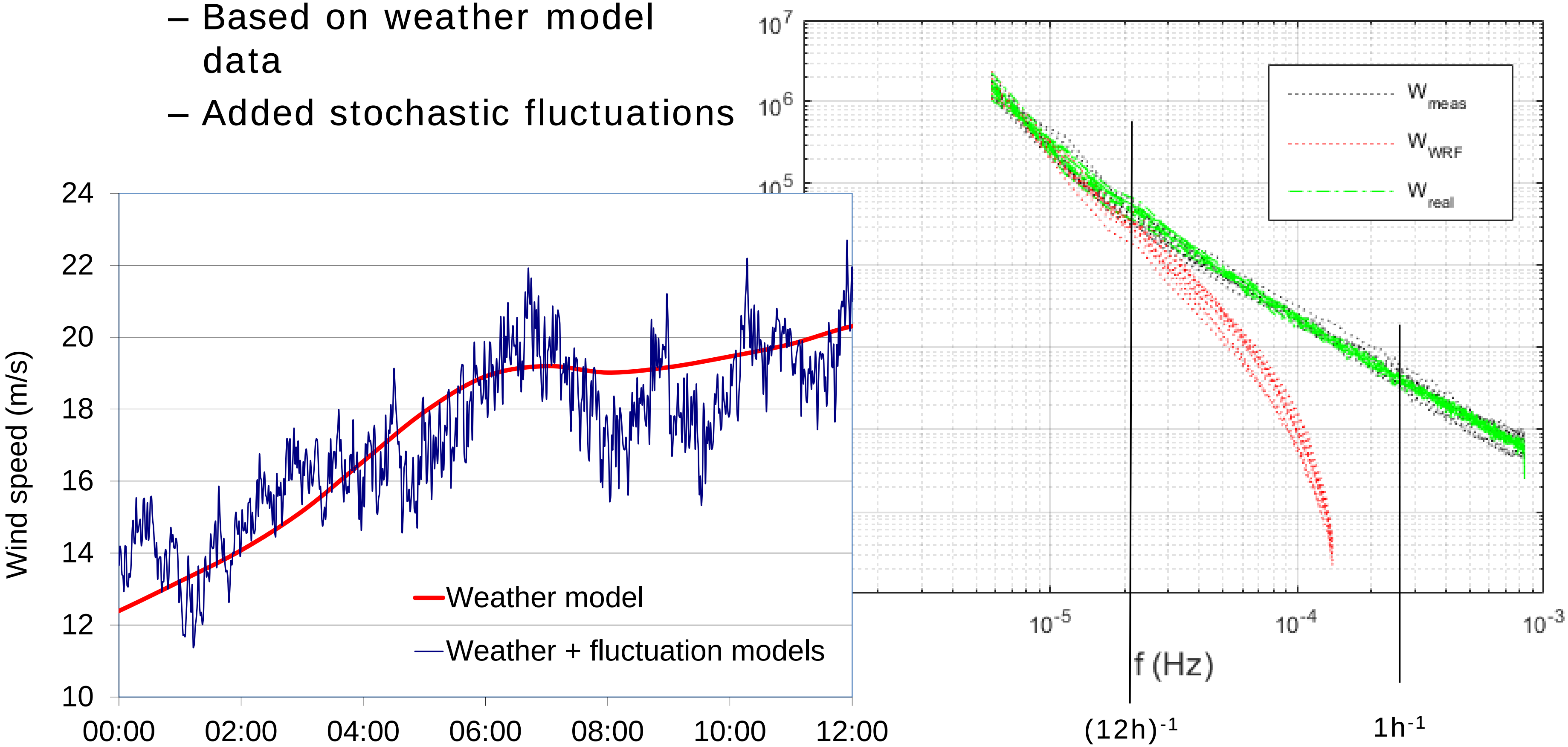
Power curves from duration curves

- Approach:
  1. Sort wind speed data to generate ws duration curve
  2. Sort power data *independently* to generate p duration curve
  3. Pair ws and p data with same quantile

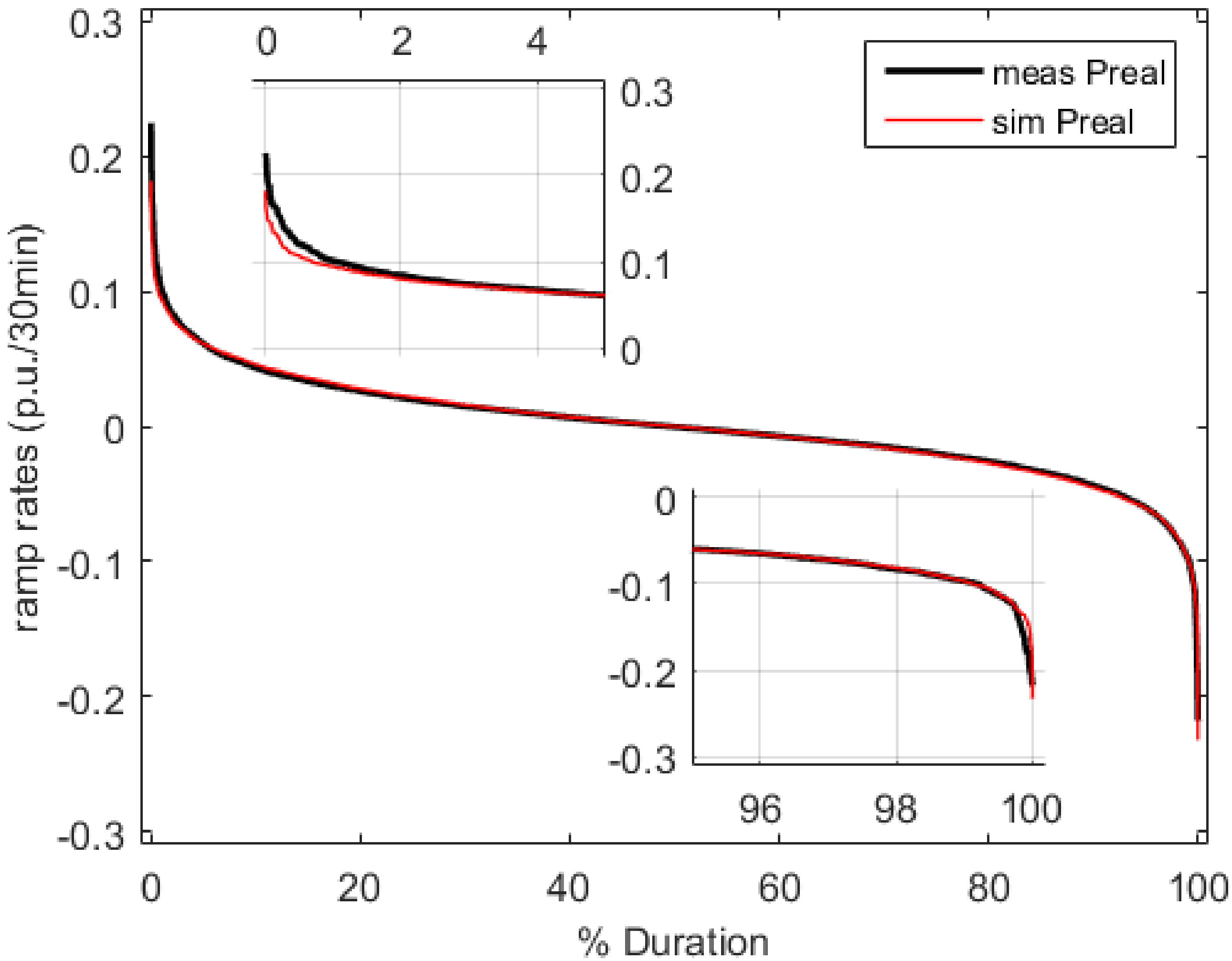


CorWind – Simulation of long term wind speed fluctuations

- Basic CorWind idea
  - Based on weather model data
  - Added stochastic fluctuations



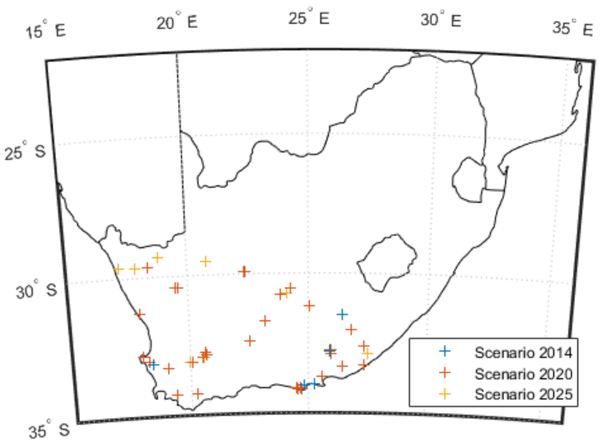
Validation: 30 minutes ramp rate sim and meas system level (8 wind farms)



Simulation cases

- Cases
  - 2014 Reference (Past) case
  - 2020 Planned development case.
  - 2025 Future case to be considered in the grid development plans.

- 5% of electricity from wind in 2025

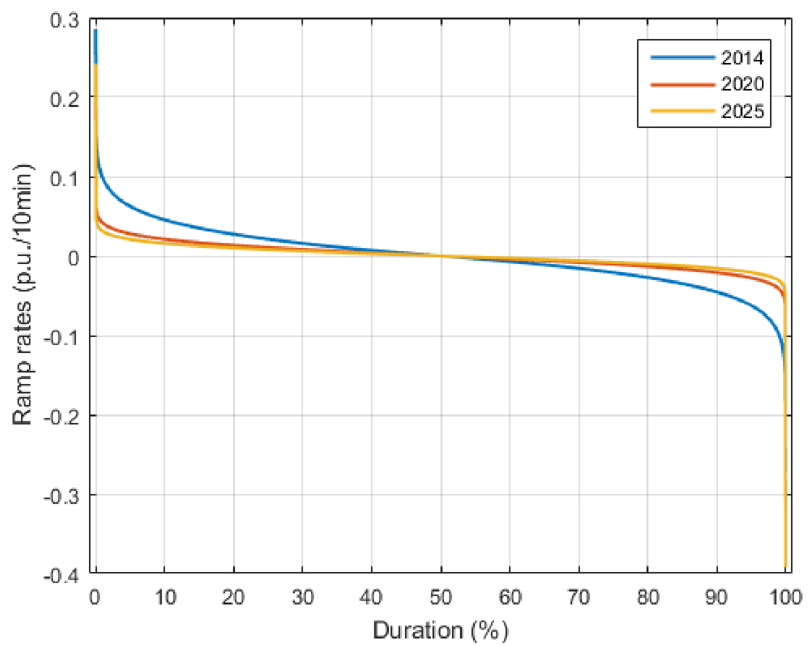


Variable	2014	2020	2025
Installed wind capacity [MW]	460	3800	7400
Wind capacity factor [%]	26.2	31.4	30.5
Consumption [TWh/y]	231	356	404
Penetration [%]	0.5	2.9	4.9

Wind power ramp rate statistics

- Relative (per-unit vs. installed wind power capacity) ramp rates decrease with increasing capacities
  - Biggest change between 2014 and 2020

- Reason: spatial smoothening



Case year	2014	2020	2025
Mean absolute ramp rate [p.u./10 min]	0.028	0.013	0.010

Reserves in ESKOM power system

- Different reserve categories reserves (SA grid code):
  - Instantaneous reserves – Used to arrest the frequency at acceptable limits following a contingency [max 10 s activation – min 10 min duration]
  - Regulating reserves – Used for second-by-second balancing of supply and demand, and under AGC control [max 10 min activation – min 1 h duration].
  - 10-minute reserves – To balance supply and demand for changes between the Day ahead market and real-time, such as load forecast errors and unit unreliability [max 10 min activation – min 2 h duration].
  - Emergency reserves – Used when the interconnected power system (IPS) is not in a normal condition, and to return the IPS to a normal condition while slower reserves are being activated [max 10 min activation – min 2 h duration].
  - Supplemental reserves – Used to ensure an acceptable day-ahead risk [max 2-6 h activation – min 2 h duration].

SA regulating reserves requirements

- SA Ancillary Services Technical Requirements 2015/16 – 2019/20. Rev. 1 ESKOM 28-10-2014
  - ***Regulating reserves*** should be ***sufficient to cover the genuine load variations*** within the hour

Table 2: Regulating up and down reserve requirements

Reserve	Period	2015/16 MW	2016/17 MW	2017/18 MW	2018/19 MW	2019/20 MW
Regulating up	Summer (Pk/off pk)	450	450	500	500	550
	Winter (Pk/off pk)	550	550	600	600	650
Regulating down	Summer (Pk/off pk)	450	450	500	500	550
	Winter (Pk/off pk)	550	550	600	600	650

Influence of wind on regulating reserves requirements

- With wind power in system, regulating reserves should cover variations of

  residual load = consumption load – wind generation

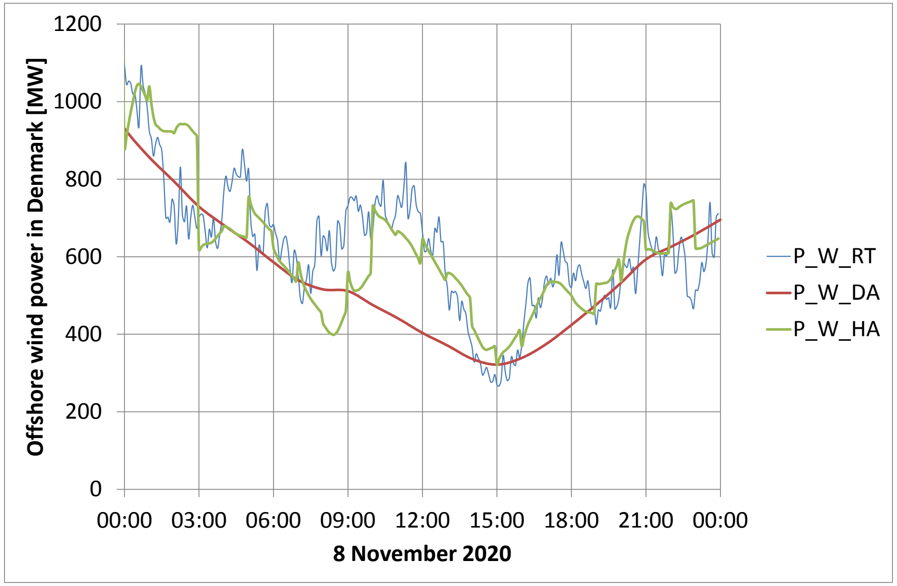
- This increases variations compared to system without wind

- With South African wind penetration cases, the ***increase is very small***:

Variable	Season	2014	2020	2025
Consumption variations [MW]	Summer	400	550	700
	Winter	500	650	800
Wind variations [MW]	-	29	106	155
Wind penetration	-	0.5	2.9	4.9
Total variations [MW]	Summer	401	560	717
	Winter	501	659	815
Increase due to wind [%]	Summer	0.3	1.8	2.4
	Winter	0.2	1.4	1.9

Using HA forecast to update planned production

- The Danish TSO Energinet.dk uses ***forecasts*** to balance power system before hour of operation
- CorWind can simulate wind power forecasts in addition to real time wind power generation
- Similar hour-ahead balancing in South Africa would ***reduce*** the real time error to be balanced with ***expensive automatic*** regulating reserves (see table)



Case year	2014	2020	2025
Insalled [MW]	460	3800	7400
Day-ahead error [MW]	35	179	318
Hour-ahead error [MW]	25	118	200
Error reduction [MW]	10	61	118

Conclusions

- The presented work is a ***pilot application*** of the ***CorWind*** methodology to ***simulate correlated wind power*** time series and apply the simulations to ***assess the need for reserves***.
- The main conclusions of the work are that
  - ***Ramp rates*** of simulated wind power time series are ***validated*** against measured time series
  - The ***normalized ramp rates*** of wind power will be reduced significantly from 2014 to 2020 because of the ***spatial smoothening***.
  - With the moderate ***5 %*** wind power penetration in 2025, the ***impact*** of wind power fluctuations on need for regulating reserves is ***quite small***.
  - ***Hour-ahead balancing*** would lead to significant ***reduction*** of the need for ***expensive (automatic)*** regulating reserves caused by wind power forecast errors.