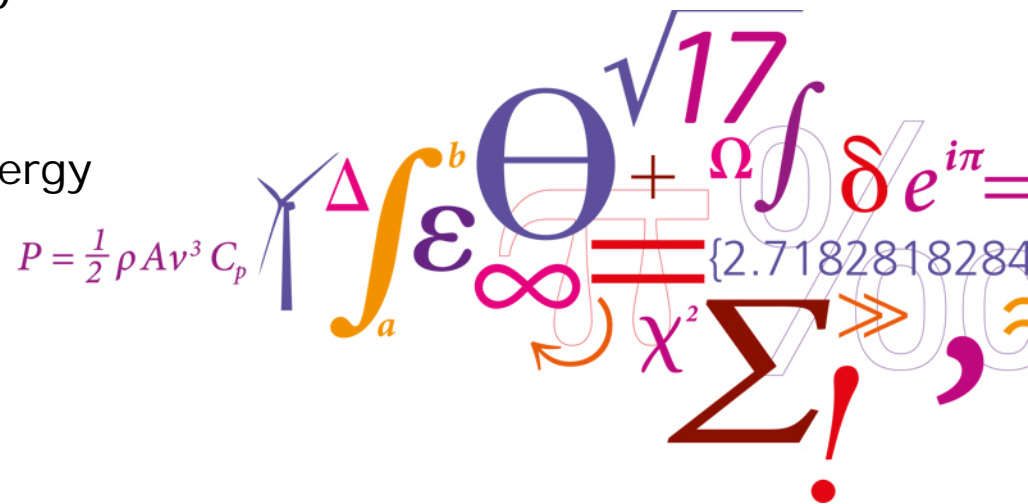


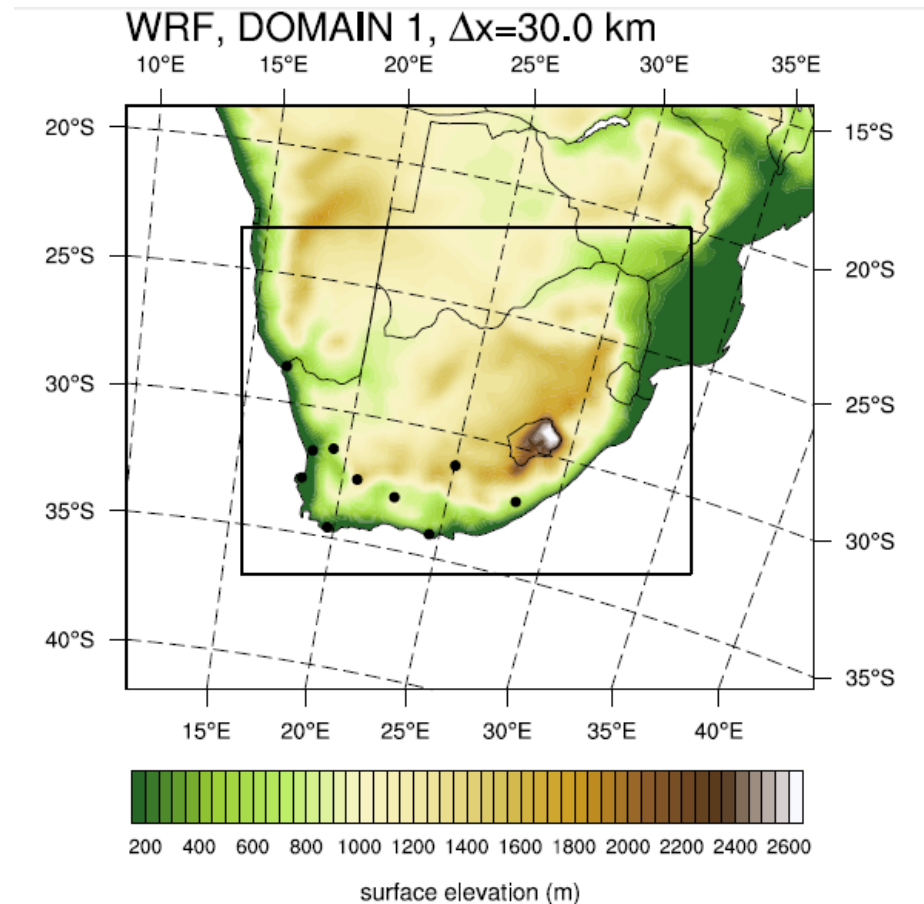
Wind Power variability and power system reserves

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



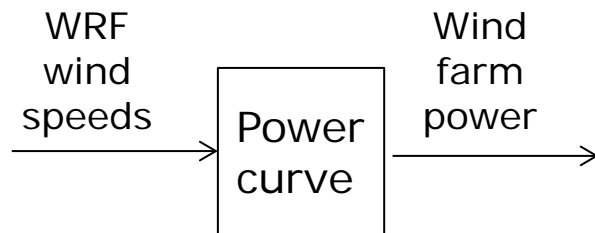
Weather Research and Forecasting (WRF)

- 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 $\Delta x=30\text{km}$
 - Inner domain 2 $\Delta x=10\text{km}$
 - Time resolution $\Delta T=1\text{h}$
 - 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

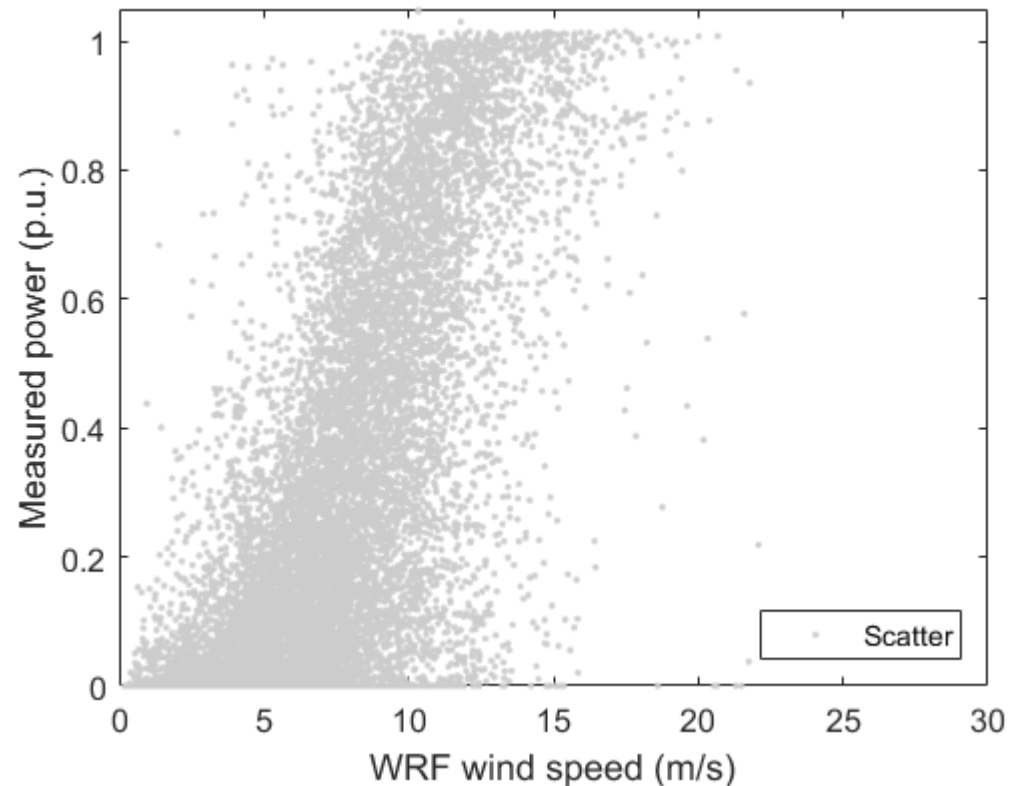


Power curve estimation using WRF wind speeds and measured power

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

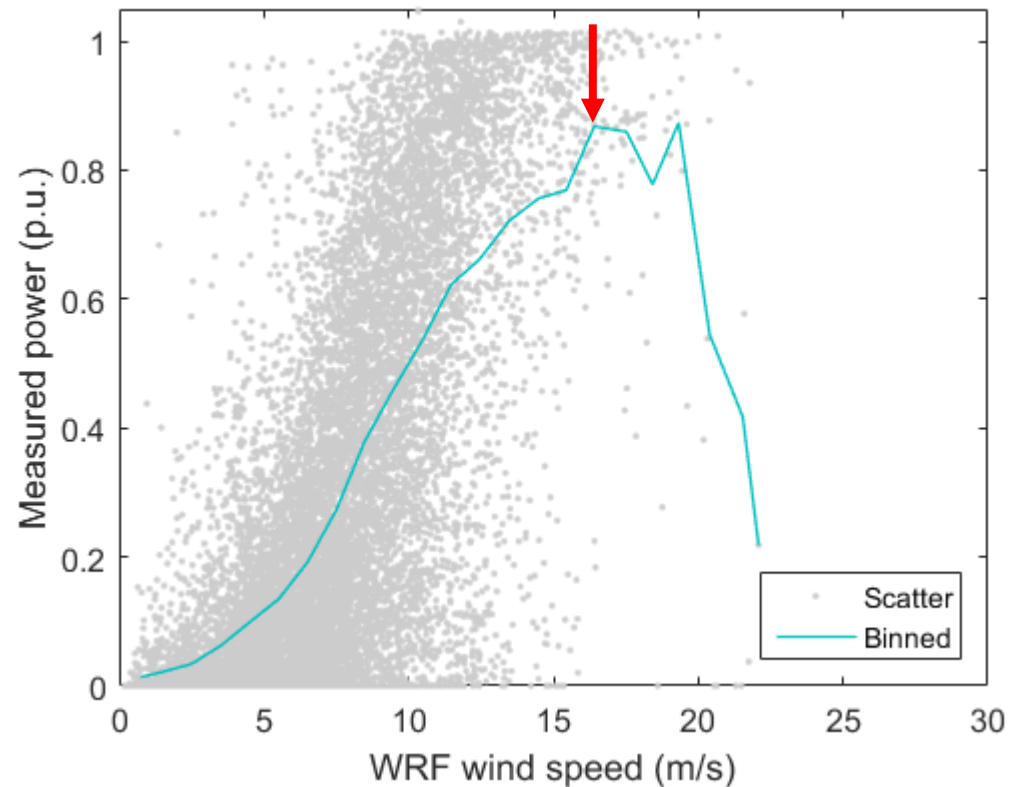
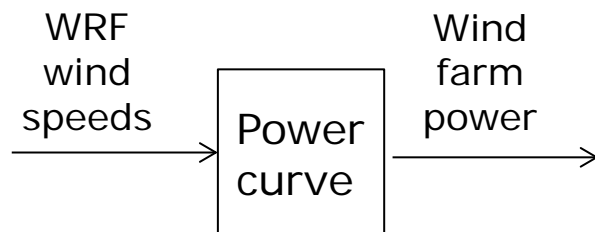


- The example shows high scatter between WRF wind speeds and generated wind farm power in same hour
- A major reason for the high scatter here is that WRF runs are only lightly *nudged*, which ensures inclusion of mesoscale effects



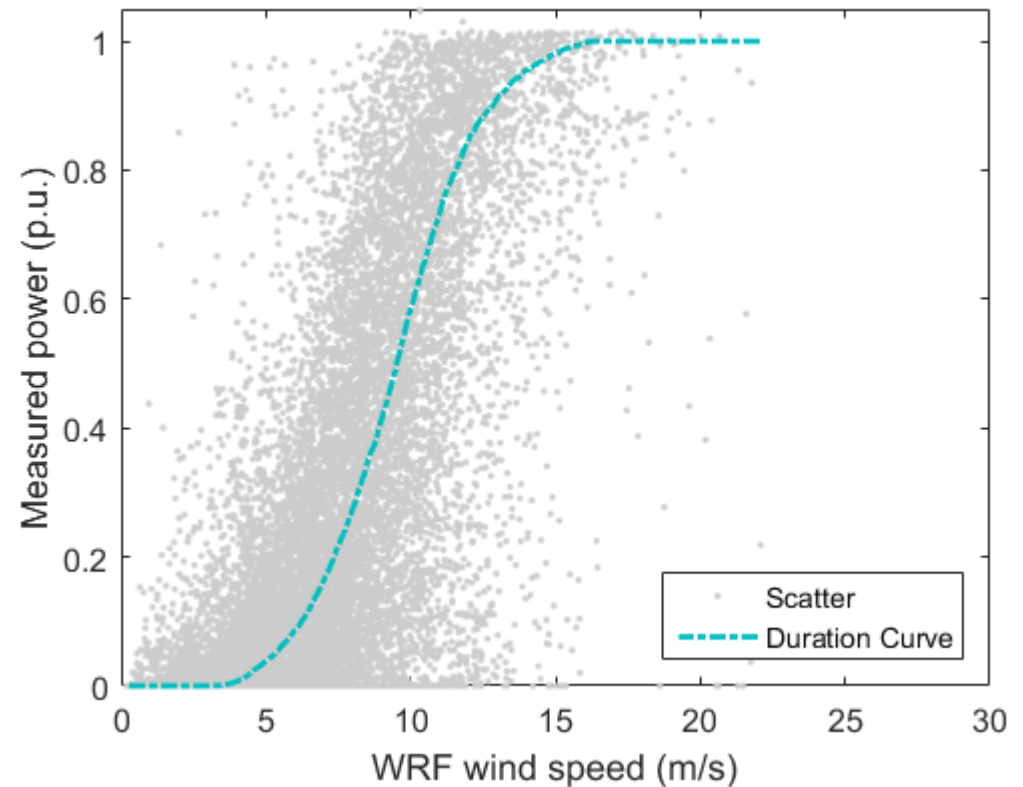
Power curve using standard method of binning

- 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**



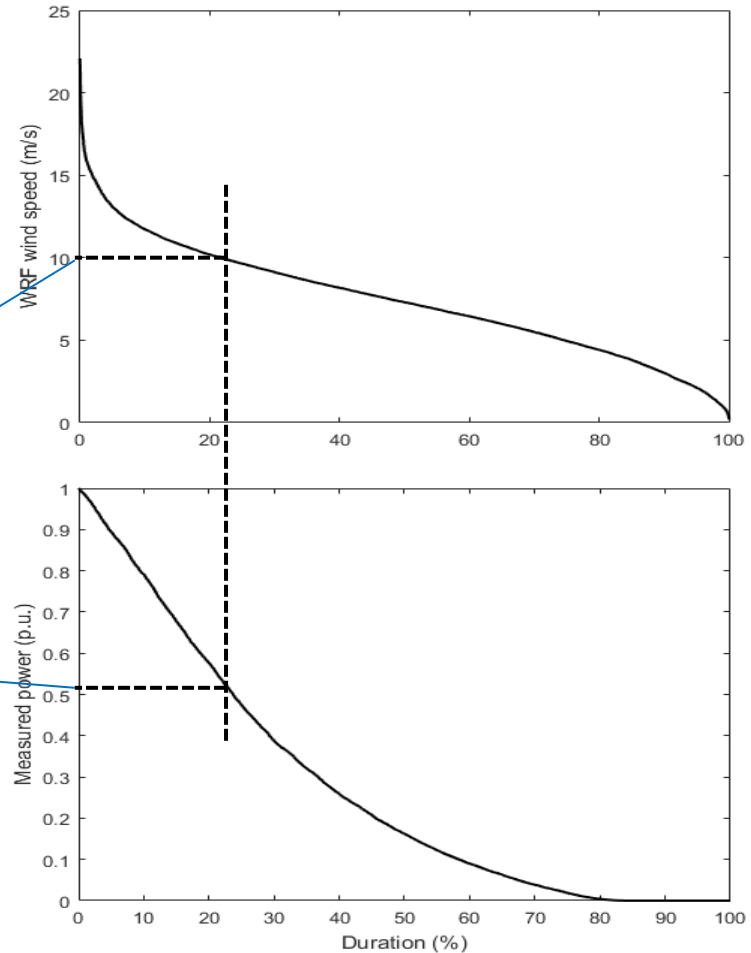
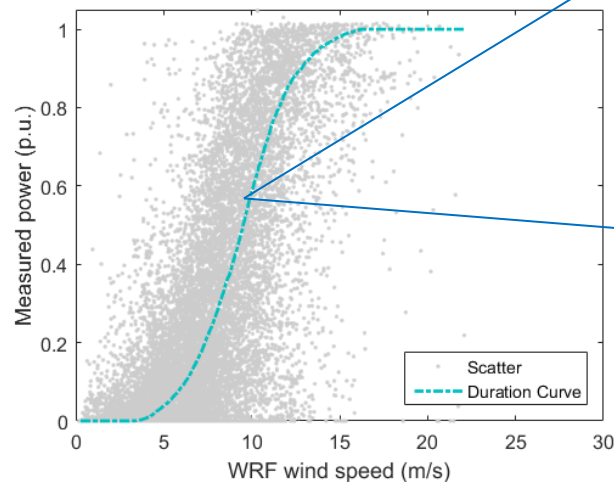
Power curves from duration curves

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



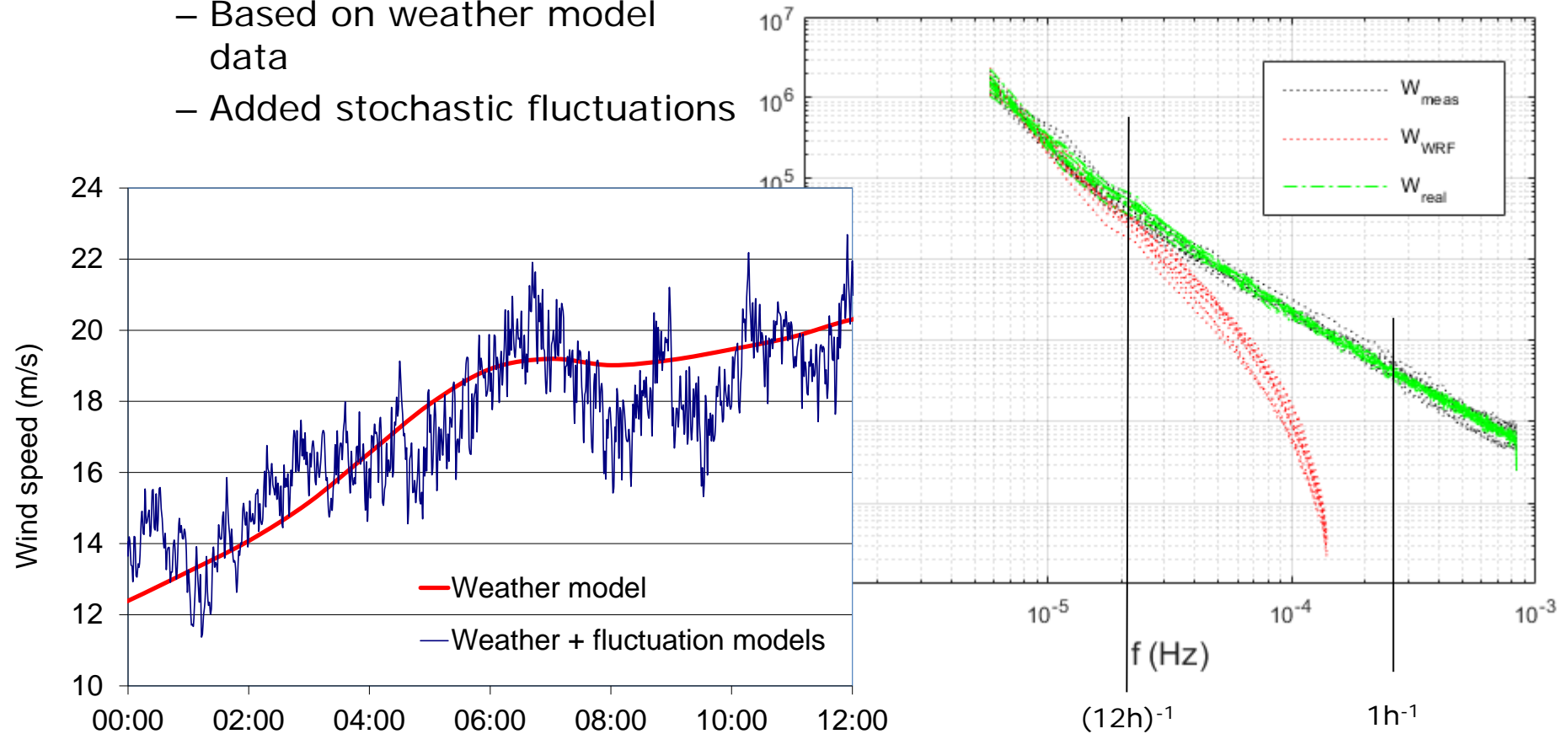
Power curves from duration curves

- 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

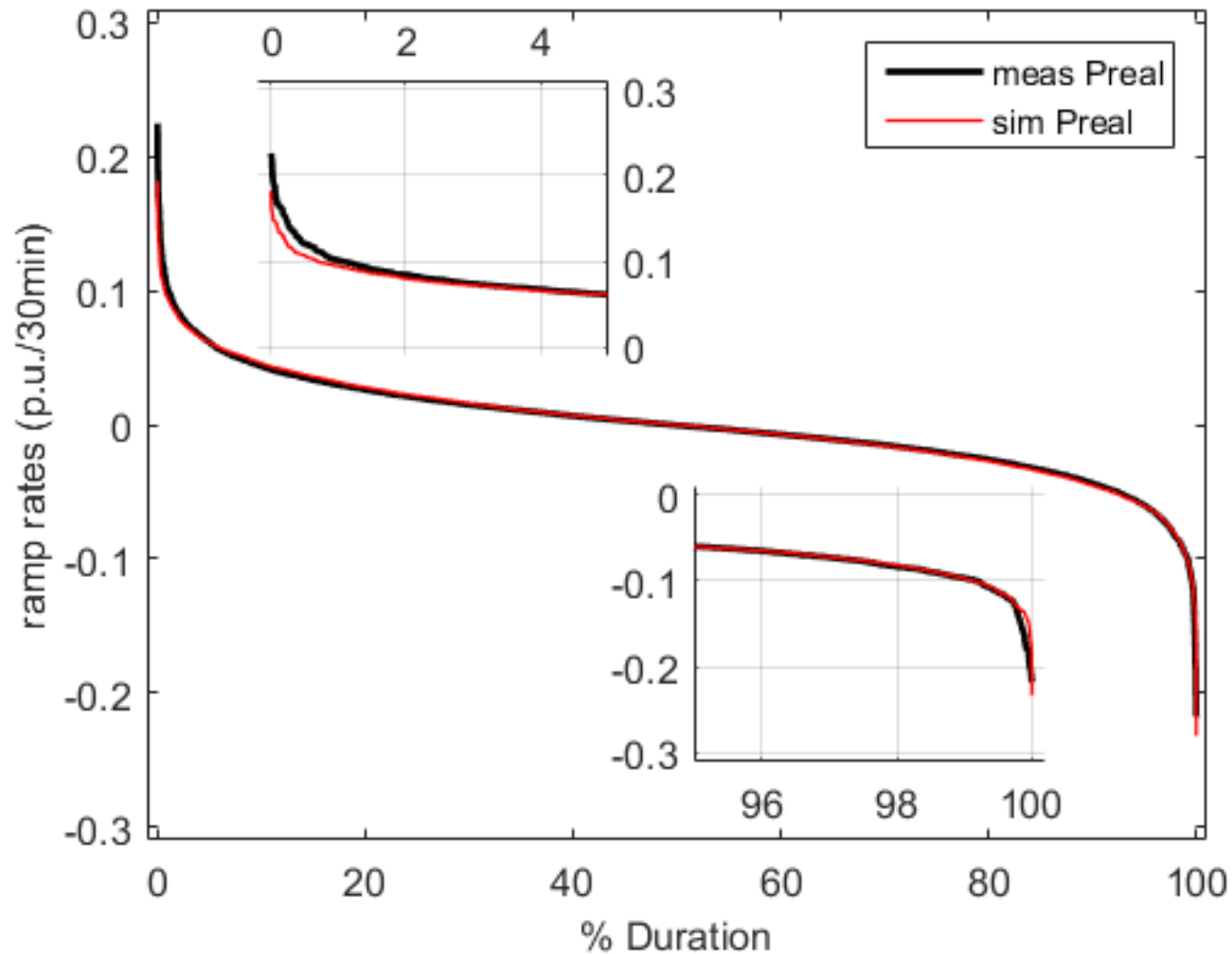


CorWind – Simulation of long term wind speed fluctuations

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



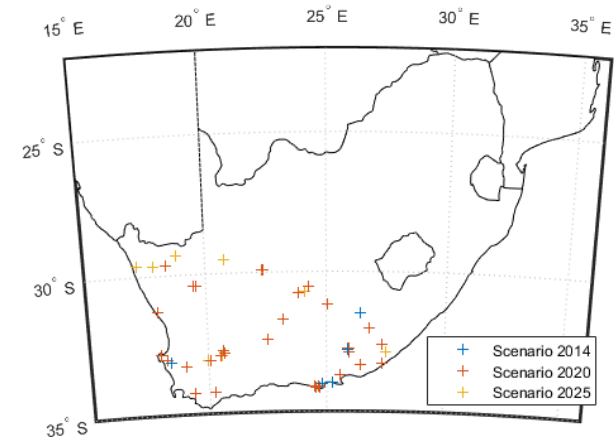
Validation: 30 minutes ramp rate sim and meas **system level** (8 wind farms)



Simulation cases

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

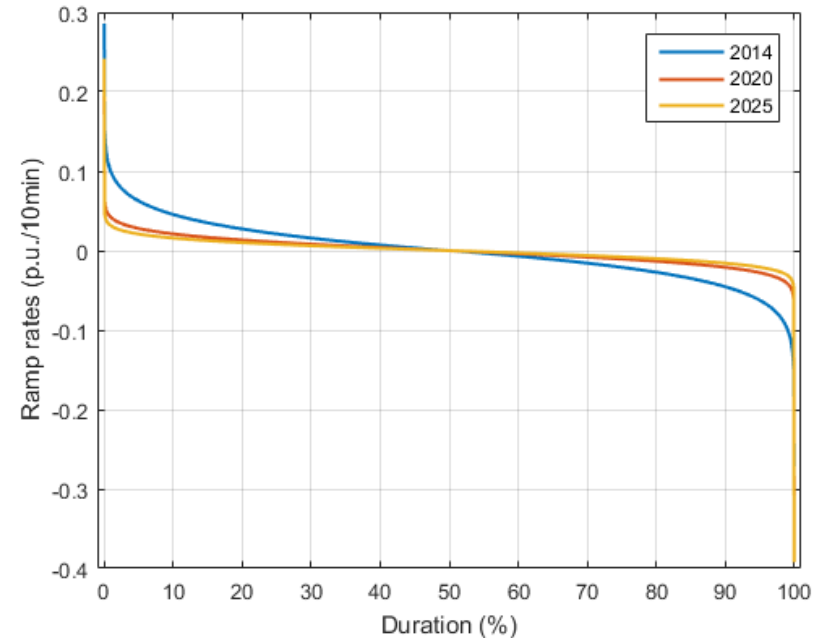
- 5% of electricity from wind in 2025



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 smoothing



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	2016/17	2017/18	2018/19	2019/20
		MW	MW	MW	MW	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

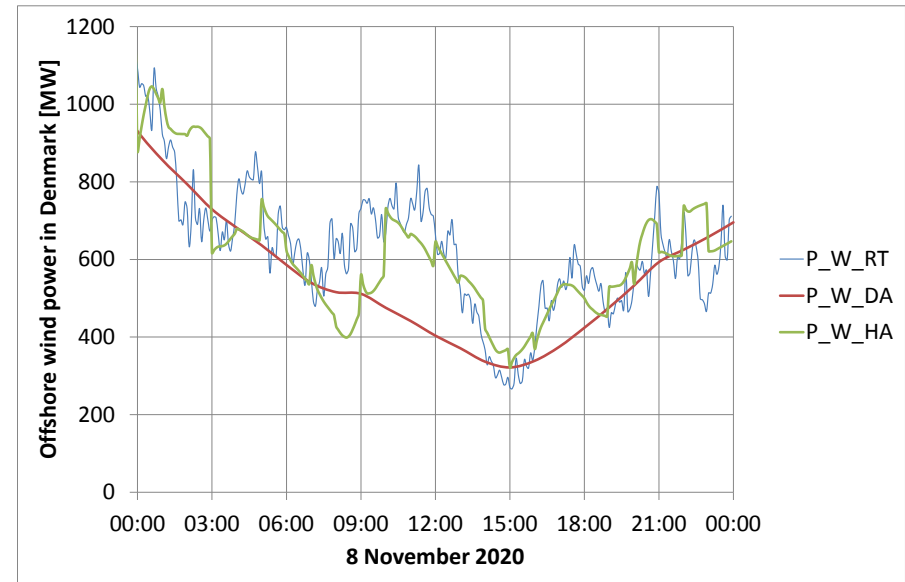
- With wind power in system, regulating reserves should cover variations of

$$\text{residual load} = \text{consumption load} - \text{wind generation}$$
- 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
Installed [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 smoothing*.
 - 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.