

Developing a wind and solar power data model for Europe with high spatial-temporal resolution

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Outline

- **Background/motivation**
- **Hourly wind and solar resource model**
- **Wind and PV power production calculations**
- **Validation of the wind and PV power production model**
- **Comparison with reanalysis model (6 hour resolution)**
- **Conclusions**

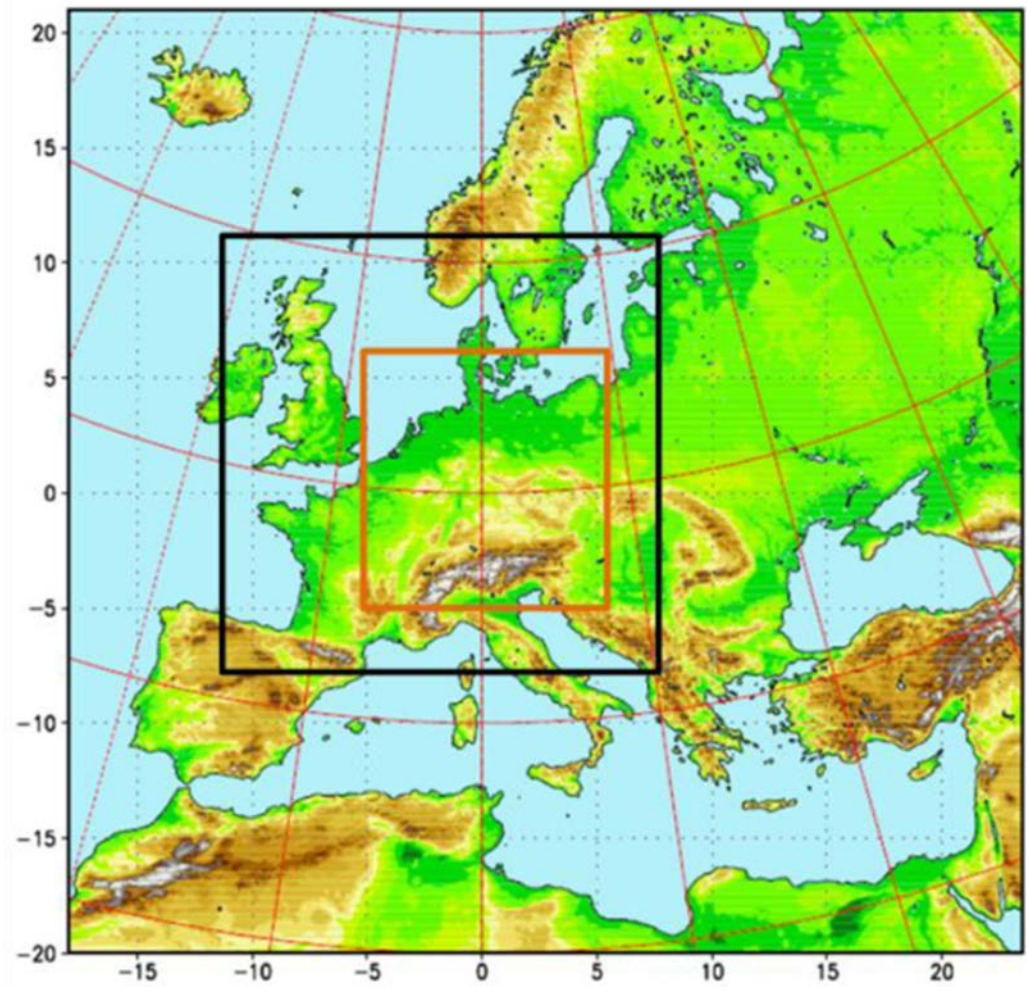
Background/motivation

- **The future European power system will probably include large shares of wind and solar resources**
- **Wind and solar resources are variable**
- **Important to understand the variability characteristics to be able to develop the future power system**
- **Useful to have a data model of wind and solar resources to be able to simulate the variability of the future power system**

Wind and solar resource model

- **Numerical weather prediction model: COSMO EU (DWD)**
- **Include both wind (2006-today), solar radiation (2011-today) and temperature**
- **Hourly resolution**
- **Spatial resolution: 7x7 km Europe and Northern Africa**
- **Further development of Aigner's PhD work**

The COSMO- EU Model



Calculation of wind speed velocity at hub height

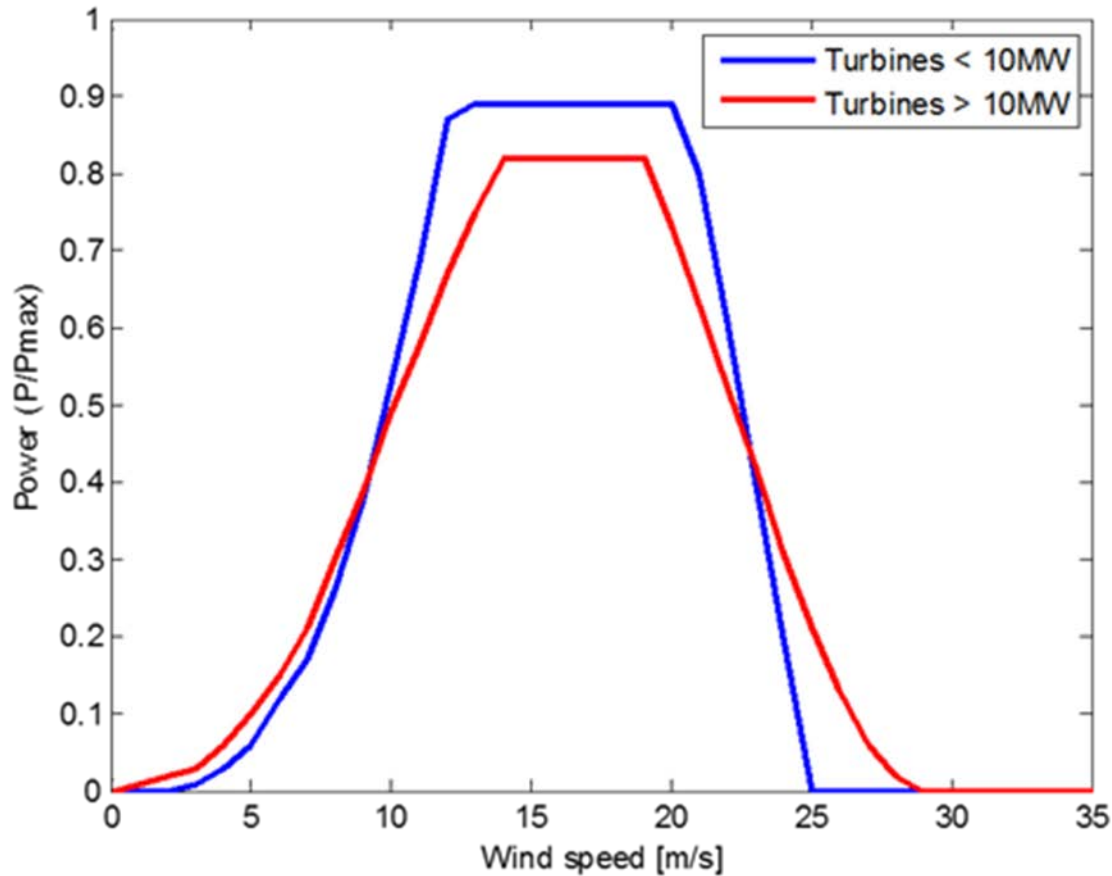
$$H_f = \log_{10}(h_{ref} / z_0) / \log_{10}(h_{mes} / z_0)$$

$$V_H = H_f \cdot V_M$$

where:

- H_f : Scaling factor
- h_{ref} : Reference hub height
- Z_0 : Surface roughness
- h_{mes} : Measurement height – 10 meters
- V_M : Wind velocity
- V_H : Wind speed velocity at hub height

Power curves used in COSMO simulations



Calculation of PV power production

$$I_{tot,p} = I_{direct,p} \cos(\theta_p) + I_{diff,p} \frac{1 + \cos(\alpha)}{2} + (I_{direct,p} + I_{diff,p}) \frac{1 - \cos(\alpha)}{2}$$

$$P_{prod,p} = I_{tot,p} cap_p \eta_{ref} [1 + \varepsilon (T_p - T_{ref})]$$

where:

$I_{tot,p}$: Total irradiance on panel p [W/m^2]

$I_{direct,p}$: Direct irradiance on panel p [W/m^2]

$I_{diff,p}$: Diffuse irradiance on panel p [W/m^2]

RE Reflection coefficient

α Tilt angle between the normal of the horizontal surface and the normal of the tilted surface.

θ_p Angle between the normal to the tilted panel and the sun's ray

$P_{prod,p}$: Total panel production

cap_p : Installed capacity of panel p

η_{ref} : Reference efficiency, how much of the generator power in the PV panel that reaches the grid

ε : Solar radiation coefficient

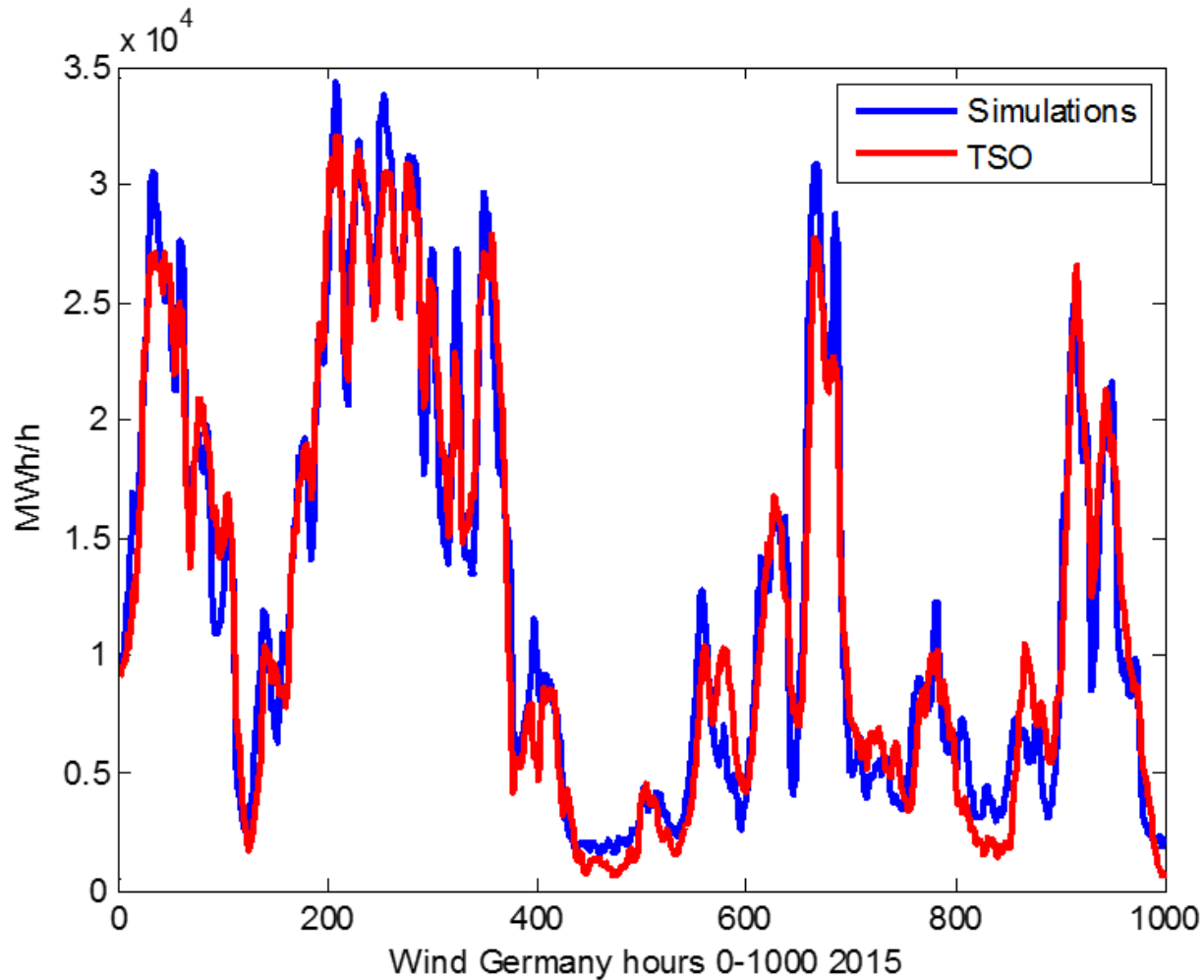
T_p : Ambient temperature for panel p

T_{ref} : Reference temperature 25 ° Celcius

Wind and PV power production model

- **Installed wind capacity: "The Wind Power"**
- **Installed PV capacities: regional capacities**
 - **Denmark: PV production for 500 geographical locations**
 - **Germany more than 1.500.000 (EEG Anlagenstammdaten) PV plants aggregated to 660 regions**
 - **Spain: 15 regions (Red Electrica)**

Validation of the wind production model



COSMO based simulations

VALIDATION OF WIND POWER 2015

	Total production [TWh/year]	MAE relative TSO [MWh/h]	MAE /installed capacity [%]	RMSE relative TSO	RMSE/ installed capacity [%]
DK TSO	14.1				
Simulations	14.4	278	5.5	358	7.1
GE TSO	83.6				
Simulations	83.2	2198	4.9	2789	6.2
Spain TSO	48.4				
Simulations	48.2	1364	5.9	1755	7.6

MAE – Mean Absolute Error

RMSE – Root Mean Square Error

COSMO based simulations (2014)

VALIDATION PV POWER PRODUCTION

	Total production [TWh/year]	MAE relative TSO [MWh/h]	MAE /installed capacity [%]	RMSE relative TSO	RMSE/ installed capacity [%]
DK TSO	0.6				
Simulations	0.6	23.7	3.9	46.2	7.6
GE TSO	32.6				
Simulations	29.2	883	2.4	1659	4.5
Spain TSO	8				
Simulations	6.6	244	5.5	415	9.3

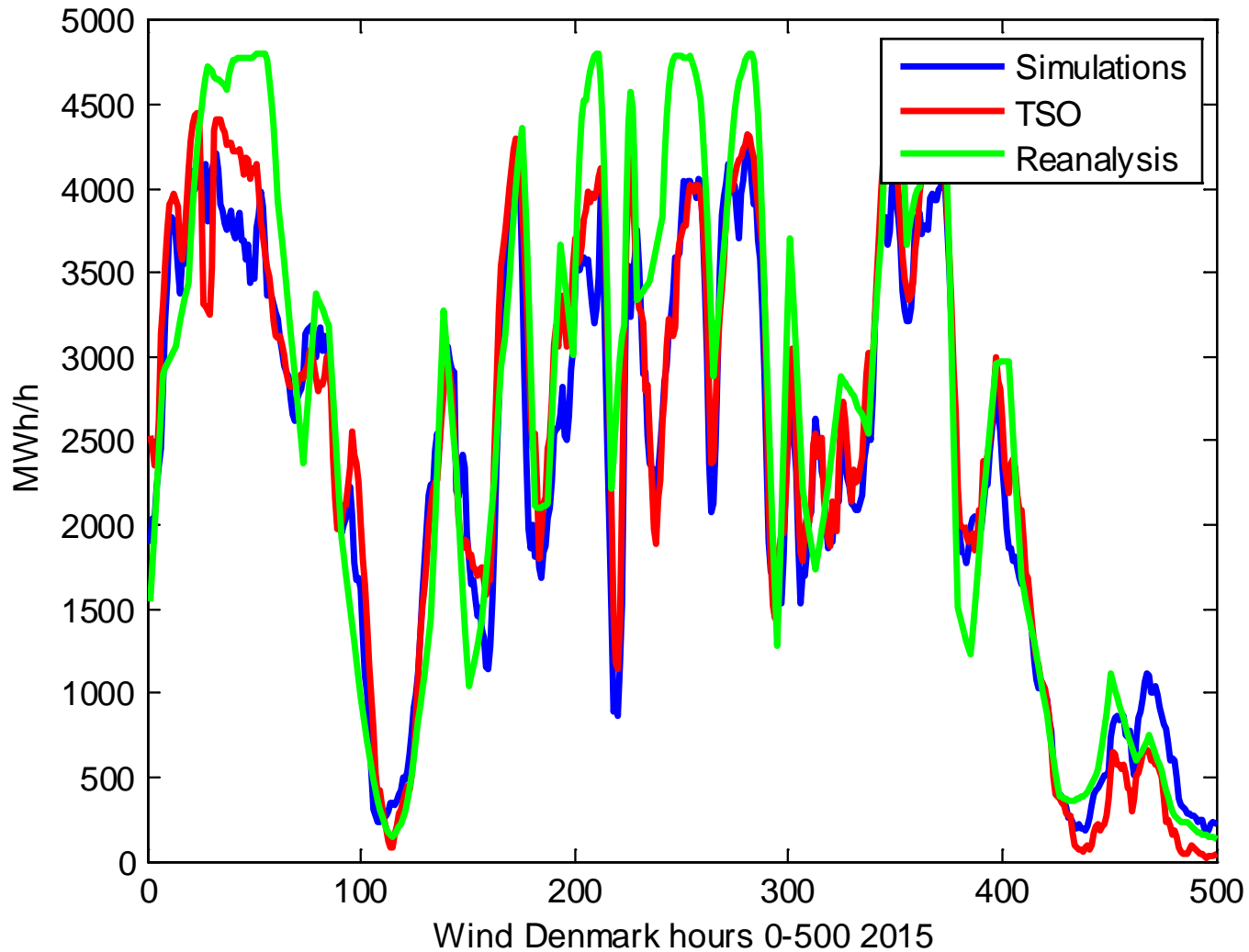
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RMSE – Root Mean Square Error

Comparison with Renalaysis data

- Renalaysis data from the NOAA/OAR/ESRL PSD Boulder, USA
- Reanalysis wind data
 - Temporal resolution 6 hours
 - Spatial resolution of 2.5 degrees in latitude and longitude
 - Hourly values calculated by linear interpolation of 6-hourly values
- Reanalysis radiation data
 - Daily average values from 1948
 - Spatial resolution 1.875° longitude and ca 1.904° latitude.
 - Hourly values based on time of year and day, latitude/longitude

Comparison wind power production DK (TSO), COSMO and Renalysis simulations



Conclusion

- **Both COSMO and Reanalysis simulations follow the real production curve closely**
- **Simulations based on COSMO EU data are more accurate than Reanalysis simulations**
- **Higher accuracy for Germany and Denmark than for Spain for both COSMO and Reanalysis wind power simulations**
- **Probably possible to improve results by e.g more advanced modelling of power curves.**