Bias-correcting simulated wind power in Austria and in Brazil from the ERA-5 reanalysis data set with the DTU Wind Atlas

"reFUEL" ERC-2017-STG 758149

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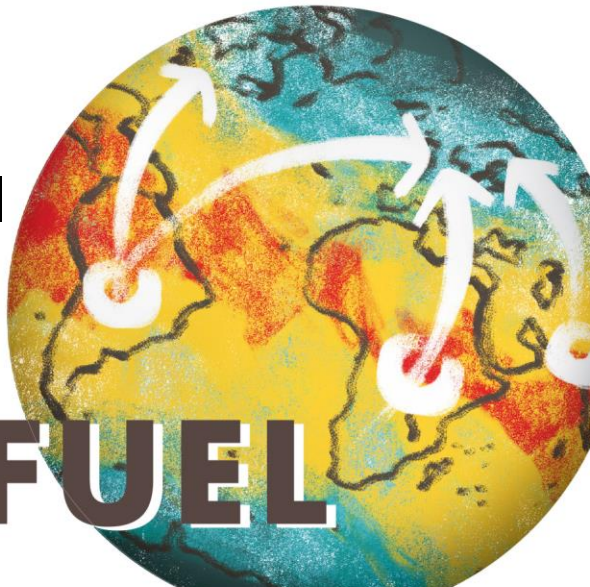
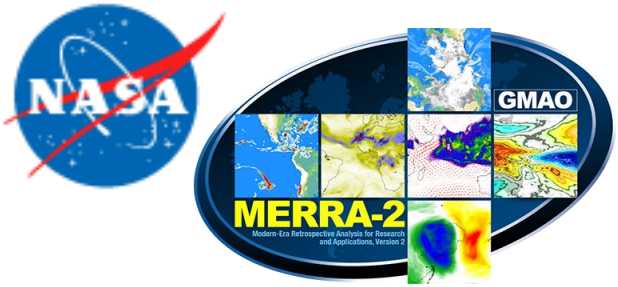
reFUEL project

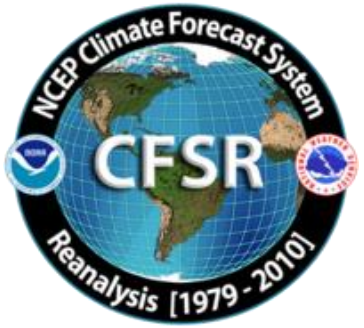
- 5 year research project at BOKU
- Funded by ERC-2017-STG 758149
- No regionalisation but globalisation of energy sector
  - New, easily tradable, low-cost *renewable fuels*
  - *Global bio-physical variability* of renewables
  - Regional differences in *land-use restrictions* associated with the expansion of energy infrastructure
- Open-source global renewable energy model
  - Energy system
  - Land-use modelling



Introduction

- Future energy systems with high shares of intermittent renewables
- Variability, different locations and sources
- Long time-series of power generation?
- → Simulation from meteorological data
  - Measurements
  - Reanalysis





ECMWF

ECMWF RE-ANALYSIS ERA

ERA

Research aim

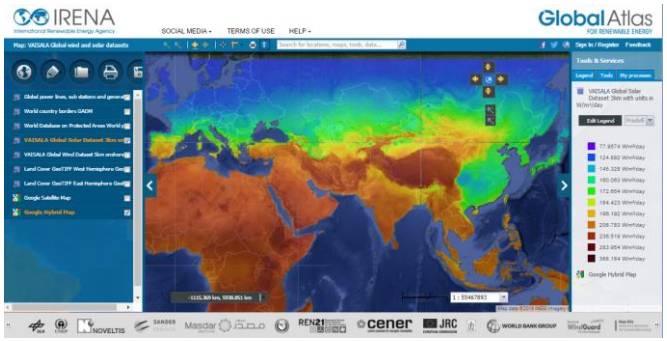
- How well are ERA5 data suited for simulation of wind power generation?
- Can the model be applied to different parts of the world or globally?
- Can the Global Wind Atlas improve simulation quality by increasing spatial resolution?

Data

- European Centre for Medium-Range Weather Forecasts
- ERA5
  - Availability
    - Global
    - Since 1979 (1950)
  - Resolution
    - Spatial: 0.25 ° x 0.25 ° (31 km x 31 km)
    - Temporal: hourly
- Reanalysis wind speeds
  - 10m, 100m
  - u-, v-direction

Data

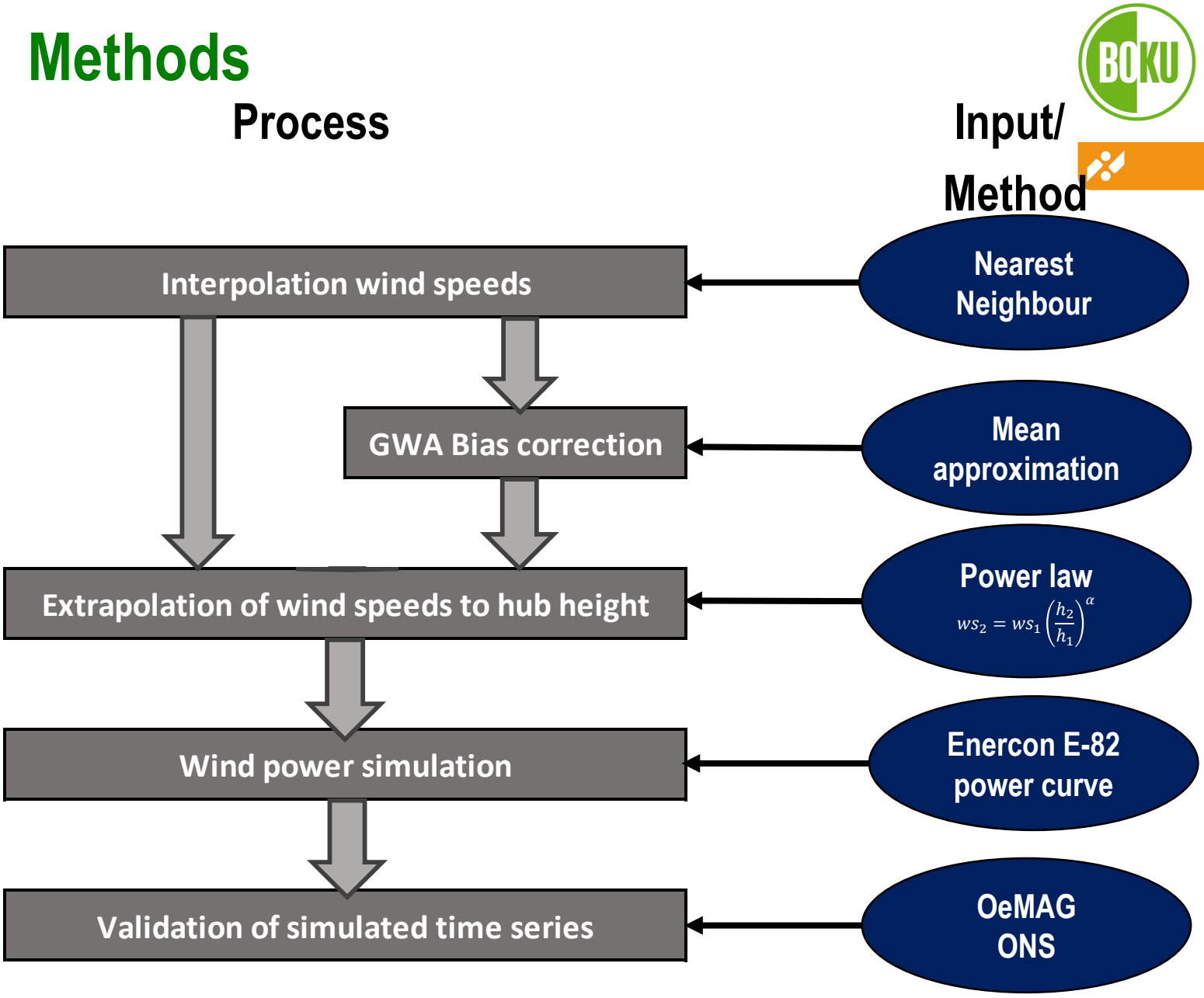
- Locations of wind power plants, commissioning dates and installed capacity
  - Austria: IG Windkraft (wind turbines)
  - Brazil: The Wind Power (wind parks)



- Global Wind Atlas (GWA)
  - Technical University of Denmark (DTU)
  - 1 km x 1 km

- Validation Data
  - Austria: OeMAG Abwicklungsstelle für Ökostrom
  - Brazil: ONS Operador Nacional do Sistema Elétrico

Methods

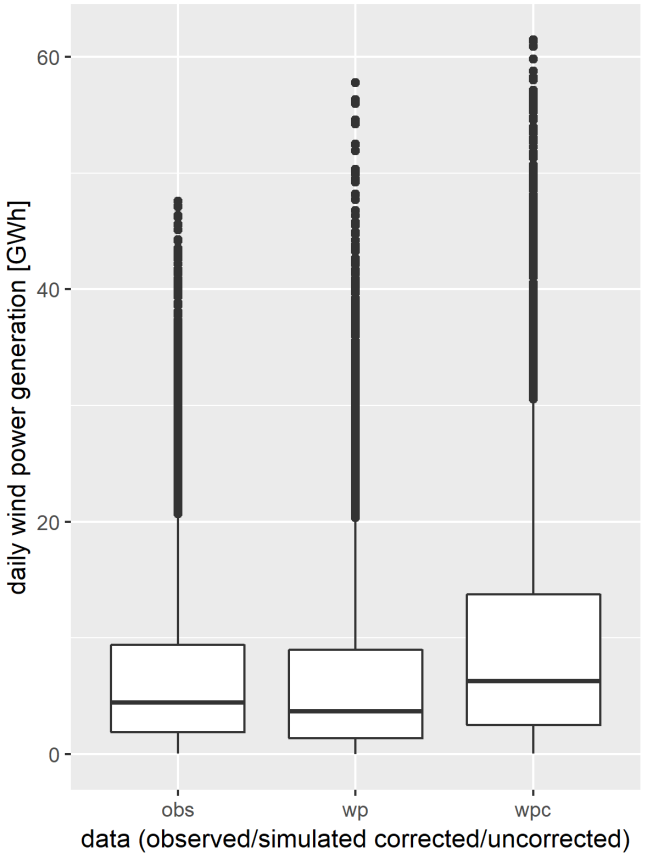

Process
Input/ Method
Interpolation wind speeds
Nearest Neighbour
GWA Bias correction
Mean approximation
Extrapolation of wind speeds to hub height
Power law
$ws_2 = ws_1\left(\frac{h_2}{h_1}\right)^{\alpha}$
Wind power simulation
Enercon E-82 power curve
Validation of simulated time series
OeMAG ONS

Results

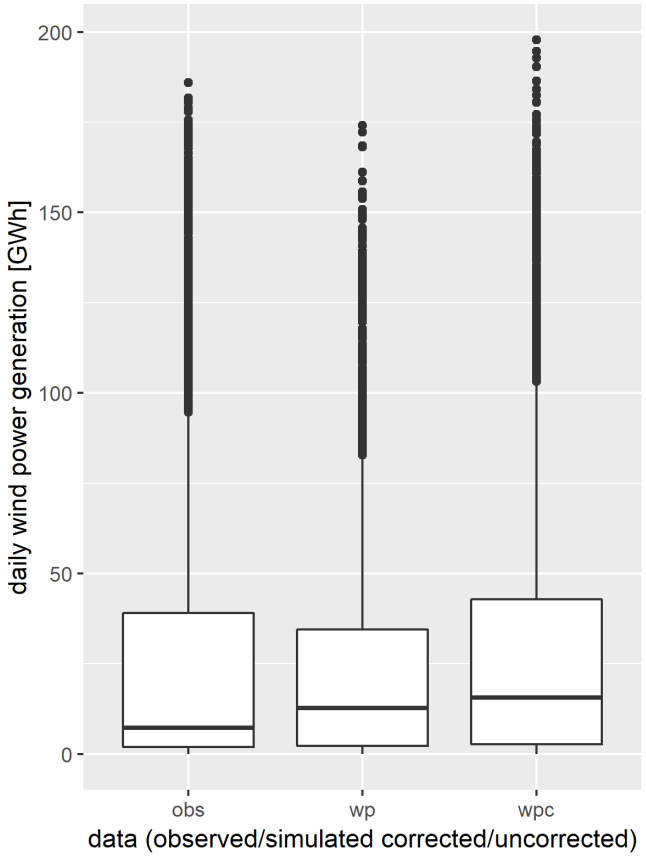
	Austria	Austria GWA	Austria observed	Brazil	Brazil GWA	Brazil observed
RMSE [GWh]	**1.80**	4.43		11.52	**9.93**	
MBE [GWh]	**-0.33**	2.85		**-1.58**	3.69	
Mean [GWh]	**6.68**	9.86	7.02	**24.68**	29.95	26.26

Results

Austria



Brazil



Comparison RMSEs Austria

	Source	Dataset	Region	Temporal resolution	rel. RMSE
without GWA	González-Aparicio et al. [29]	ECMWF[1]	Belgium	hourly	3.0%[2]
	González-Aparicio et al. [29]	MERRA	Belgium	hourly	4.5%[2]
	This study	ERA5	Austria	daily	4.90%
	González-Aparicio et al. [29]	MERRA	Ireland	hourly	6.5%[2]
	Pfenninger and Staffell [1]	MERRA	Ireland	hourly	6.65%
	González-Aparicio et al. [29]	ECMWF[1]	Austria	hourly	9.8%[2]
	Cradden et al. [32]	MERRA	Ireland	hourly	10.2%
	González-Aparicio et al. [29]	ECMWF[1]	Ireland	hourly	11.6%[2]
	González-Aparicio et al. [29]	MERRA	Austria	hourly	12.9%[2]
with GWA	González-Aparicio et al. [29]	MERRA	Belgium	hourly	4.2%[2]
	González-Aparicio et al. [29]	MERRA	Ireland	hourly	6.6%[2]
	This study	ERA5	Austria	daily	12.10%
	González-Aparicio et al. [29]	MERRA	Austria	hourly	14.0%[2]

[1] non-freely available

[2] for single years

[1] S. Pfenninger and I. Staffell: "Using bias-corrected reanalysis to simulate current and future wind power output" (2016)
[29] I. González-Aparicio et al.: "Simulating European wind power generation applying statistical downscaling to reanalysis data" (2017)
[32] L. C. Cradden et al.: "A 34-year simulation of wind generation potential for Ireland and the impact of large-scale atmospheric pressure patterns" (2017)

Comparison RMSEs Brazil

	Source	Dataset	Region	Temporal resolution	Rel. RMSE
without GWA	Olauson [11]	ERA5	Germany	hourly	2.35%
	Olauson [11]	MERRA-2	Germany	hourly	2.82%
	Pfenninger and Staffell [1]	MERRA	Germany	hourly	3.11%
	González-Aparicio et al. [29]	MERRA	Germany	hourly	3.8%[2]
	González-Aparicio et al. [29]	ECMWF[1]	Germany	hourly	4.4%[2]
	This study	ERA5	Brazil	daily	15.5%
with GWA	González-Aparicio et al. [29]	MERRA	Germany	hourly	7.3%[2]
	This study	ERA5	Brazil	daily	13.40%

[1] non-freely available

[2] for single years

[1] S. Pfenninger and I. Staffell: "Using bias-corrected reanalysis to simulate current and future wind power output" (2016)
[11] J. Olauson, "ERA5: The new champion of wind power modelling?" (2018)
[29] I. González-Aparicio et al.: "Simulating European wind power generation applying statistical downscaling to reanalysis data" (2017)

Comparison MBEs Austria

	Source	Dataset	Region	Temporal resolution	Rel. MBE
without GWA	González-Aparicio et al. [29]	MERRA	Belgium	hourly	-1.4%[2]
	This study	ERA5	Austria	daily	-0.9%
	Cradden et al. [32]	MERRA	Ireland	hourly	-0.79%
	González-Aparicio et al. [29]	ECMWF[1]	Belgium	hourly	0.0%[2]
	González-Aparicio et al. [29]	ECMWF[1]	Ireland	hourly	0.0%[2]
	González-Aparicio et al. [29]	MERRA	Austria	hourly	0.6%[2]
	González-Aparicio et al. [29]	MERRA	Ireland	hourly	0.6%[2]
	González-Aparicio et al. [29]	ECMWF[1]	Austria	hourly	1.0%[2]
with GWA	González-Aparicio et al. [29]	MERRA	Austria	hourly	-1.2%[2]
	González-Aparicio et al. [29]	MERRA	Belgium	hourly	-0.2%[2]
	González-Aparicio et al. [29]	MERRA	Ireland	hourly	0.9%[2]
	This study	ERA5	Austria	daily	7.8%

[1] non-freely available

[2] for single years

[29] I. González-Aparicio et al.: "Simulating European wind power generation applying statistical downscaling to reanalysis data" (2017)
[32] L. C. Cradden et al.: "A 34-year simulation of wind generation potential for Ireland and the impact of large-scale atmospheric pressure patterns" (2017)

Comparison MBEs Brazil

	Source	Dataset	Region	Temporal resolution	Rel. MBE
without GWA	This study	ERA5	Brazil	daily	-2.1%
	González-Aparicio et al. [29]	MERRA	Germany	hourly	0.7% [2]
	González-Aparicio et al. [29]	ECMWF[1]	Germany	hourly	1.6% [2]
with GWA	González-Aparicio et al. [29]	MERRA	Germany	hourly	2.9% [2]
	This study	ERA5	Brazil	daily	5.0%

[1] non-freely available

[2] for single years

[29] I. González-Aparicio, F. Monforti, P. Volker, A. Zucker, F. Careri, T. Huld and J. Badger, "Simulating European wind power generation applying statistical downscaling to reanalysis data," Applied Energy, pp. 155 - 168, 9 May 2017.

Conclusion

- ERA5 delivers satisfactory wind power simulation results
- GWA has negative impact on quality of simulation
- Results are similar in both countries
  - → Global model?
- Further research in other case study areas needed

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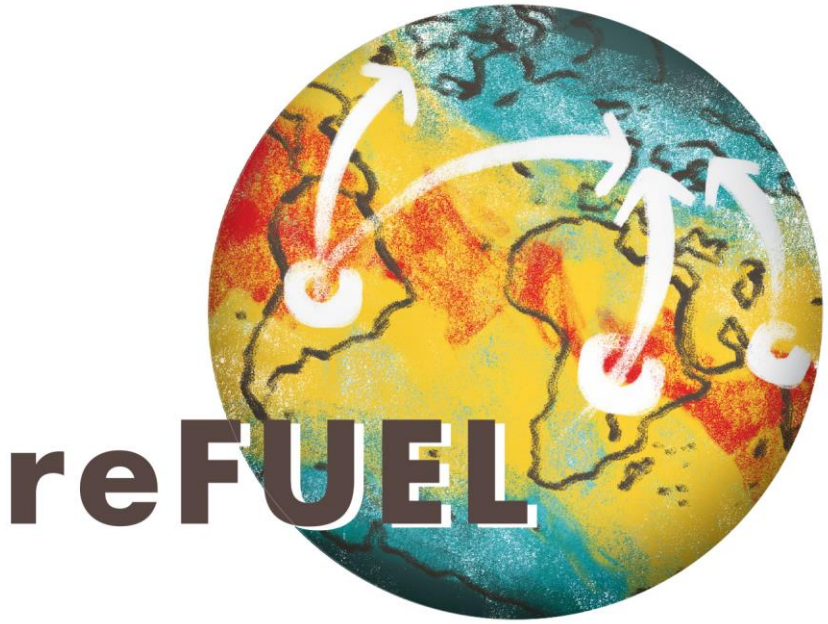

Thank you!

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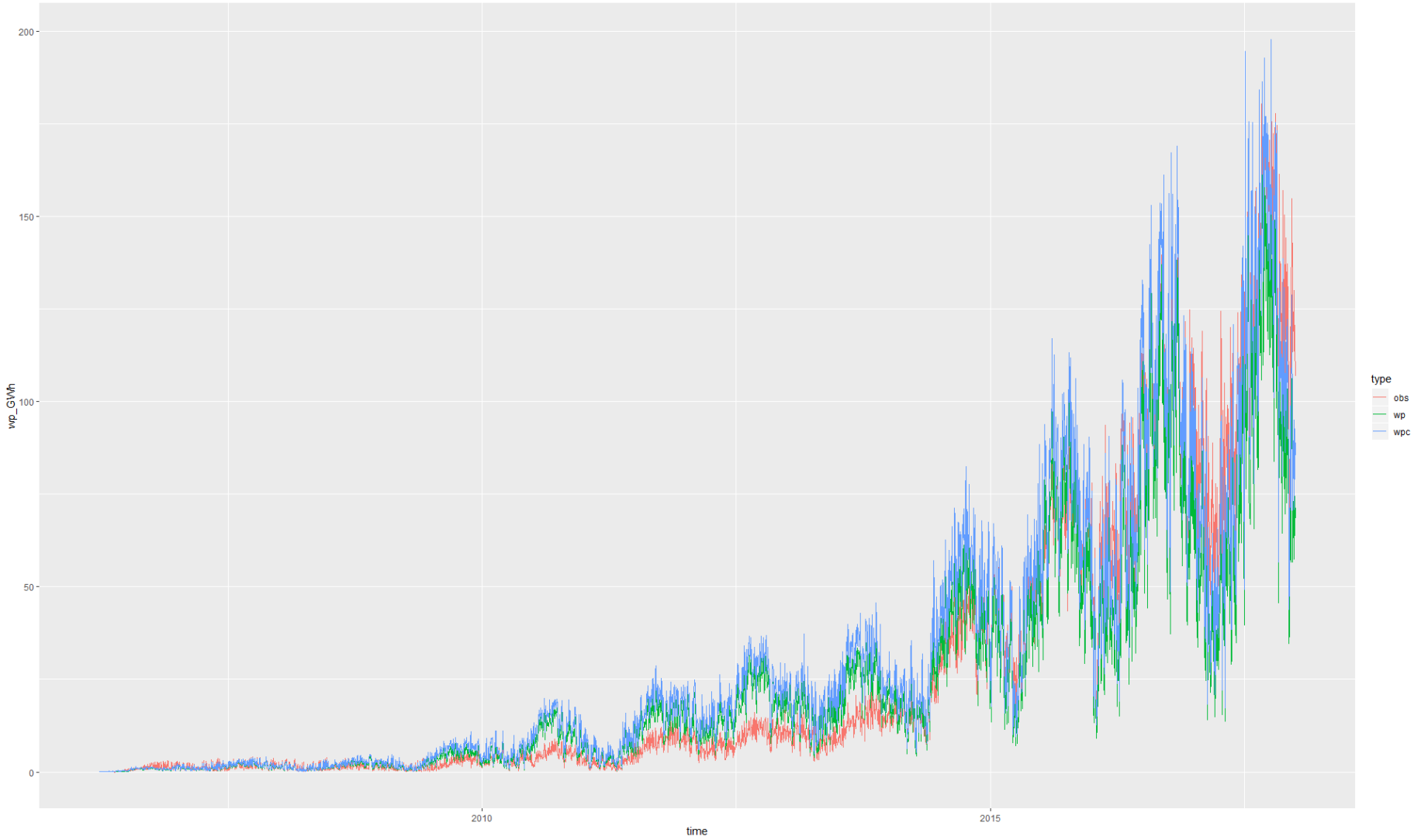
Installed Capacities

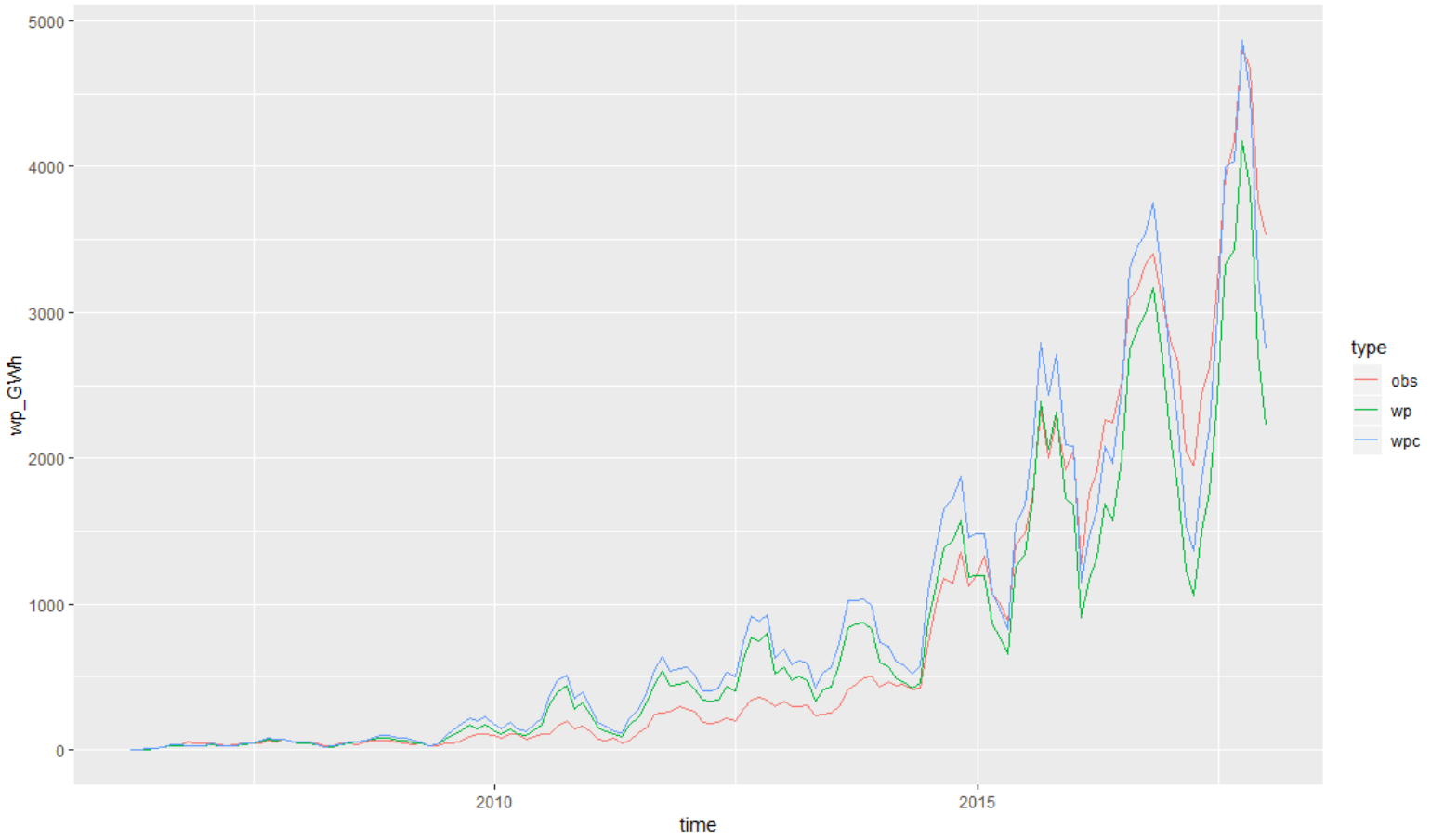
Author	Country	Capacity [GW]	Timespan
Pfenninger and Staffell [1]	Germany	31.5[1]	2015
Pfenninger and Staffell [1]	Ireland	2.4[1]	2015
Olauson [11]	Germany	43-48	2016
González-Aparicio et al. [29]	Austria	2.0	2015
González-Aparicio et al. [29]	Belgium	2.2	2015
González-Aparicio et al. [29]	Germany	43.4	2015
González-Aparicio et al. [29]	Ireland	2.4	2015
Cradden et al. [32]	Ireland	0.1-2.2	2001-2014
This study	Austria	1.5	2003-2017
This study	Brazil	3.1	2006-2017

[1] only sufficiently available data

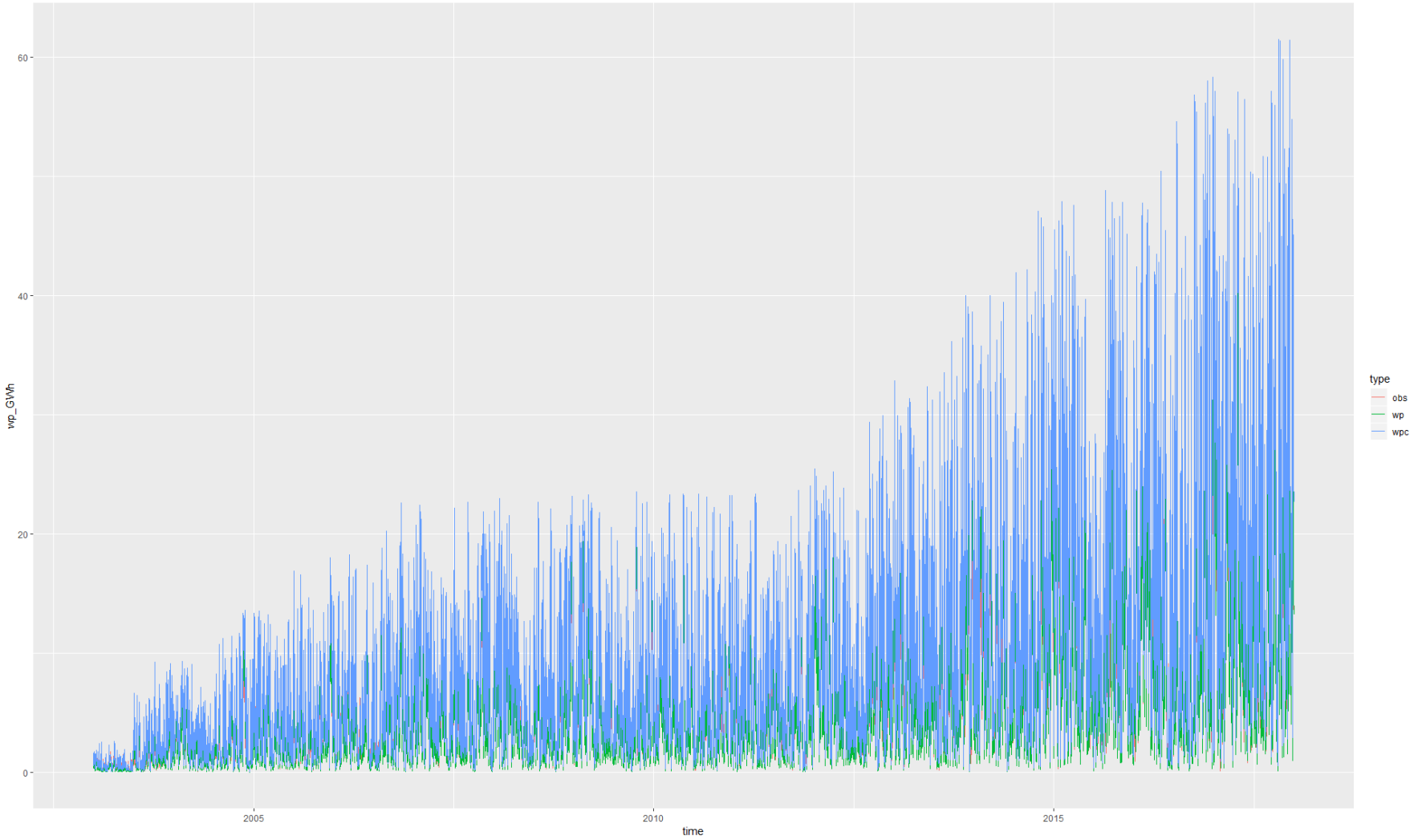
Daily wind power Brazil



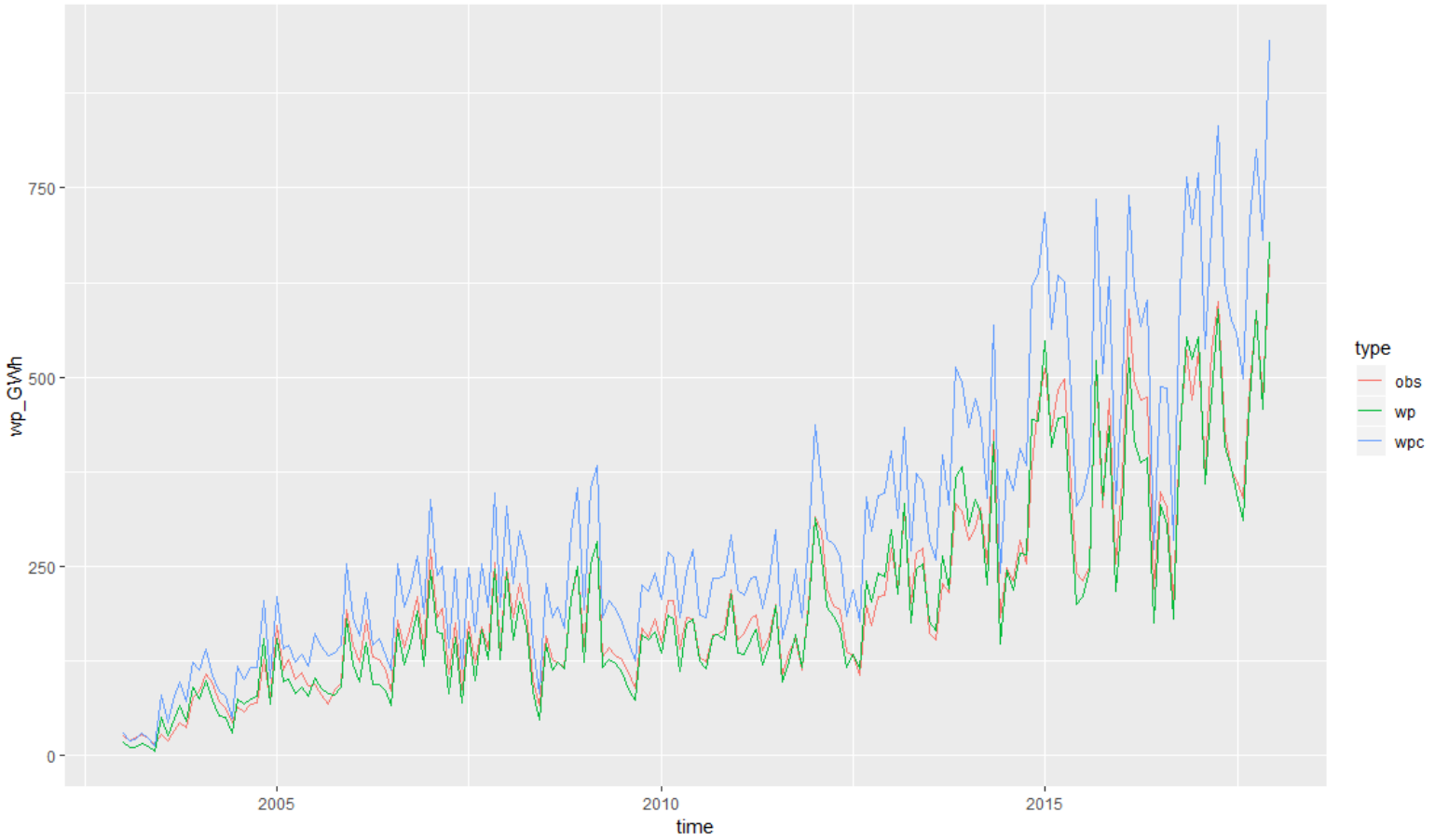
Monthly wind power Brazil



Daily wind power Austria



Monthly wind power Austria



MERRA-2 vs ERA5

and the role of the Global Wind Atlas

Data

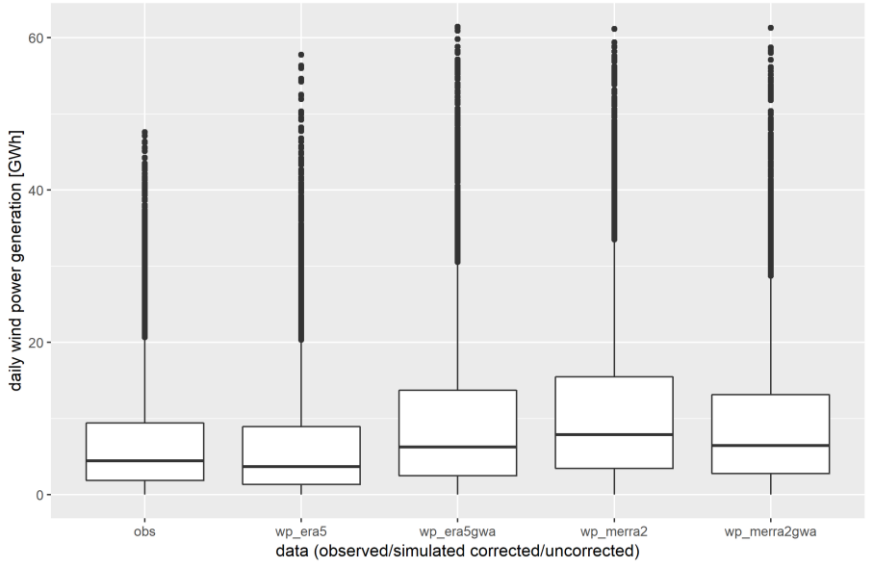
- MERRA-2 reanalysis (50 x 50 km, 1-hourly)
- ERA5 reanalysis (31 x 31 km, 1-hourly)
- Global Wind Atlas (1 x 1 km, yearly average 2015)

- Time span:
  - Austria 2003 – 2017
  - Brazil 2006 – 2017 (for MERRA Aug 2017)

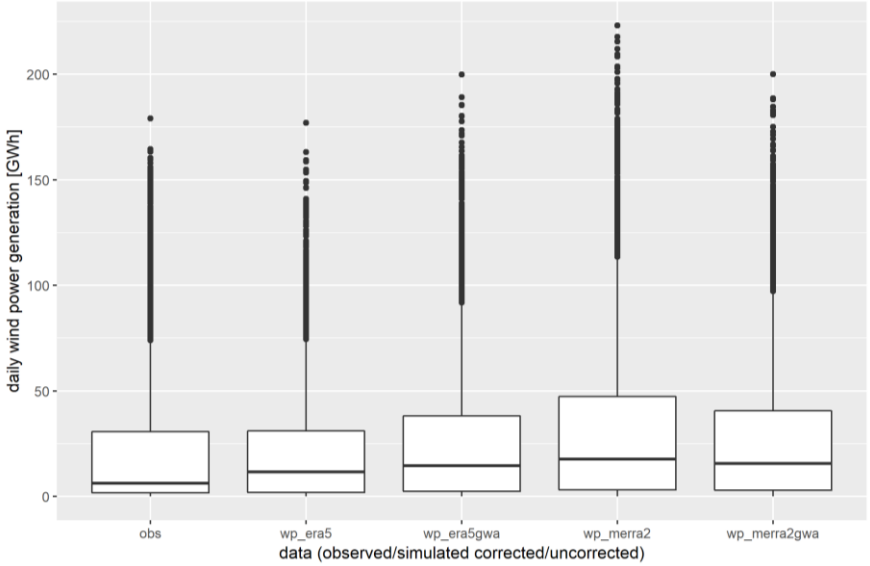
- Validation:
  - Austria: ÖmAG (quarter-hourly)
  - Brazil: ONS (daily)

Results

Austria



Brazil



Results

Austria

	ERA5	ERA5 GWA	MERRA-2	MERRA-2 GWA	obs
cor	0.98	0.98	0.95	0.95	
RMSE	1.8	4.43	6.09	4.41	
MBE	-0.33	2.85	4.27	2.71	
mean	6.68	9.86	11.28	9.72	7.02

Brazil

	ERA5	ERA5 GWA	MERRA-2	MERRA-2 GWA	obs
cor	0.96	0.97	0.98	0.98	
RMSE	9.84	9.9	15.64	9.7	
MBE	-0.21	4.67	11.16	6.03	
mean	22.43	27.31	33.8	28.67	22.64