Solar power generation calculations for the European Domain

Climate Change

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Outline

- Objective of the work and addressed issues
- Approach to the calculation of the regional PV power generation
- Validation of the proposed approach

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OBJECTIVE and ISSUES ADDRESSED

CLIMATE (WP2)

River Discharge

Temperature

Rainfall

Wind Speed

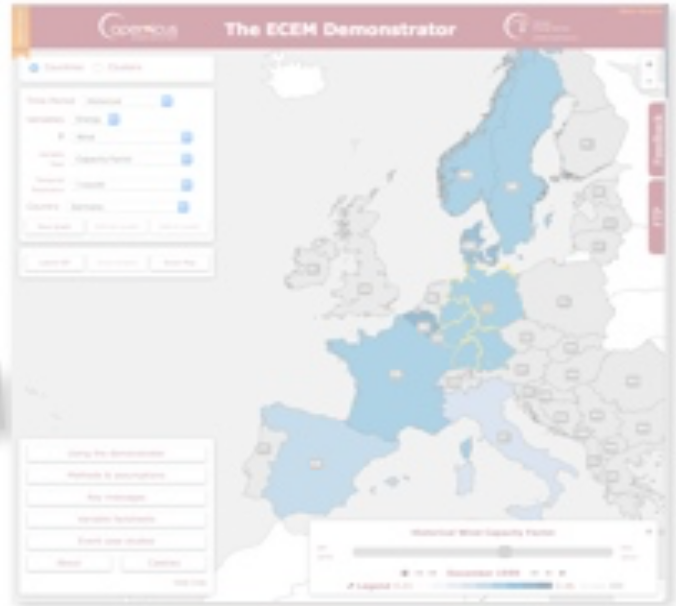
Solar Radiation

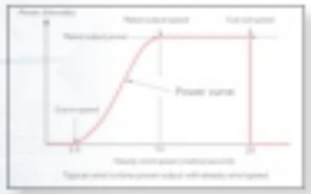
Cloud Cover

Others?

Ancillary

+ Extreme Events Case Studies





Define Models / Transfer Functions

Select / Gather relevant Datasets

- Country/Cluster Scale
- Historical Period
- Seasonal Forecasts
- Climate Projections

ENERGY (WP3)

Demand

Hydro Power

Wind Power

Solar Power

Thermal Power ?

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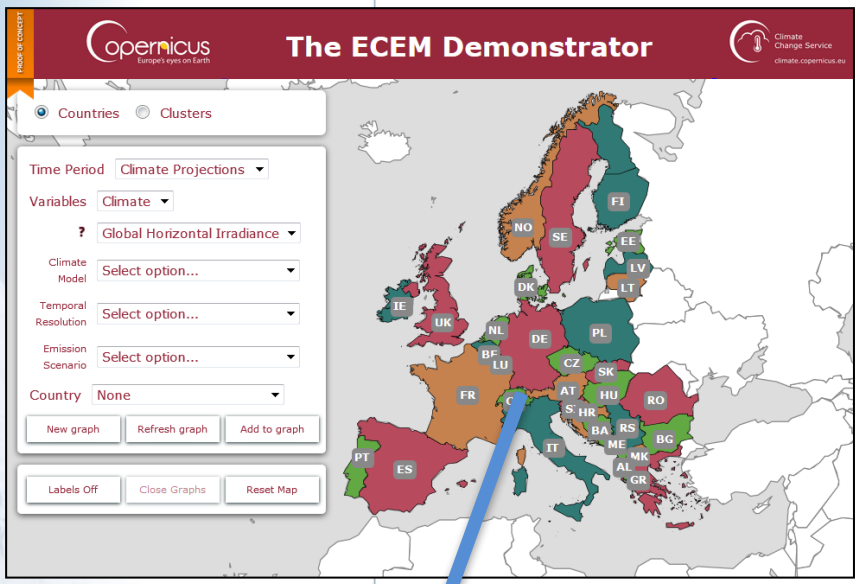
OBJECTIVE and ISSUES ADDRESSED



Goal: Calculation of the PV power generation from climate data (re-analysis and projection) for any location in Europe.

Problem: How to take the characteristics of the PV plants into consideration ?

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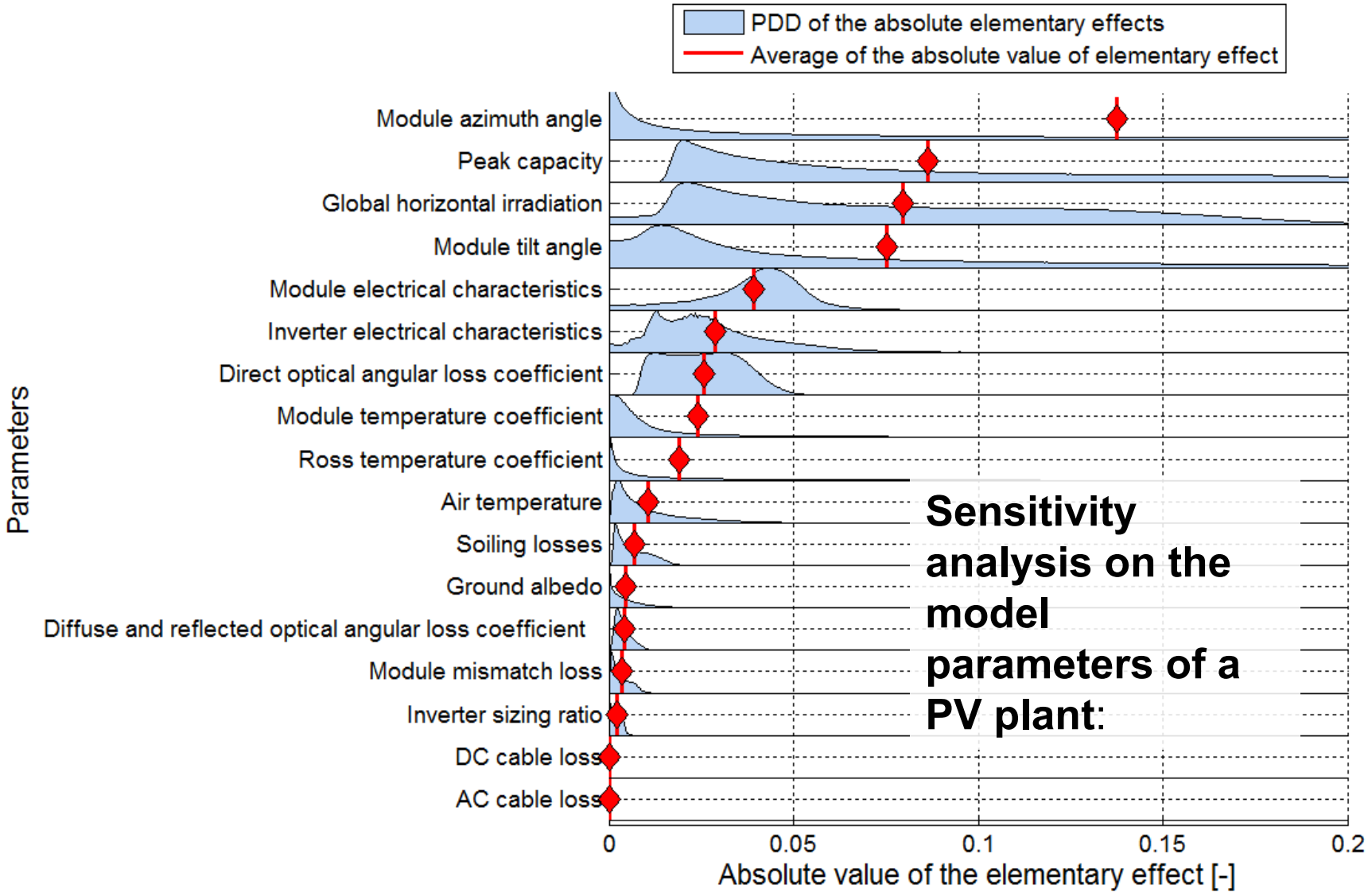
Approach- motivation



A Probabilistic Approach to the Estimation of Regional Photovoltaic Power Generation using Meteorological Data, Application of the Approach to the German Case, PhD Thesis, Yves-Marie Saint-Drenan, Kassel, August 2015

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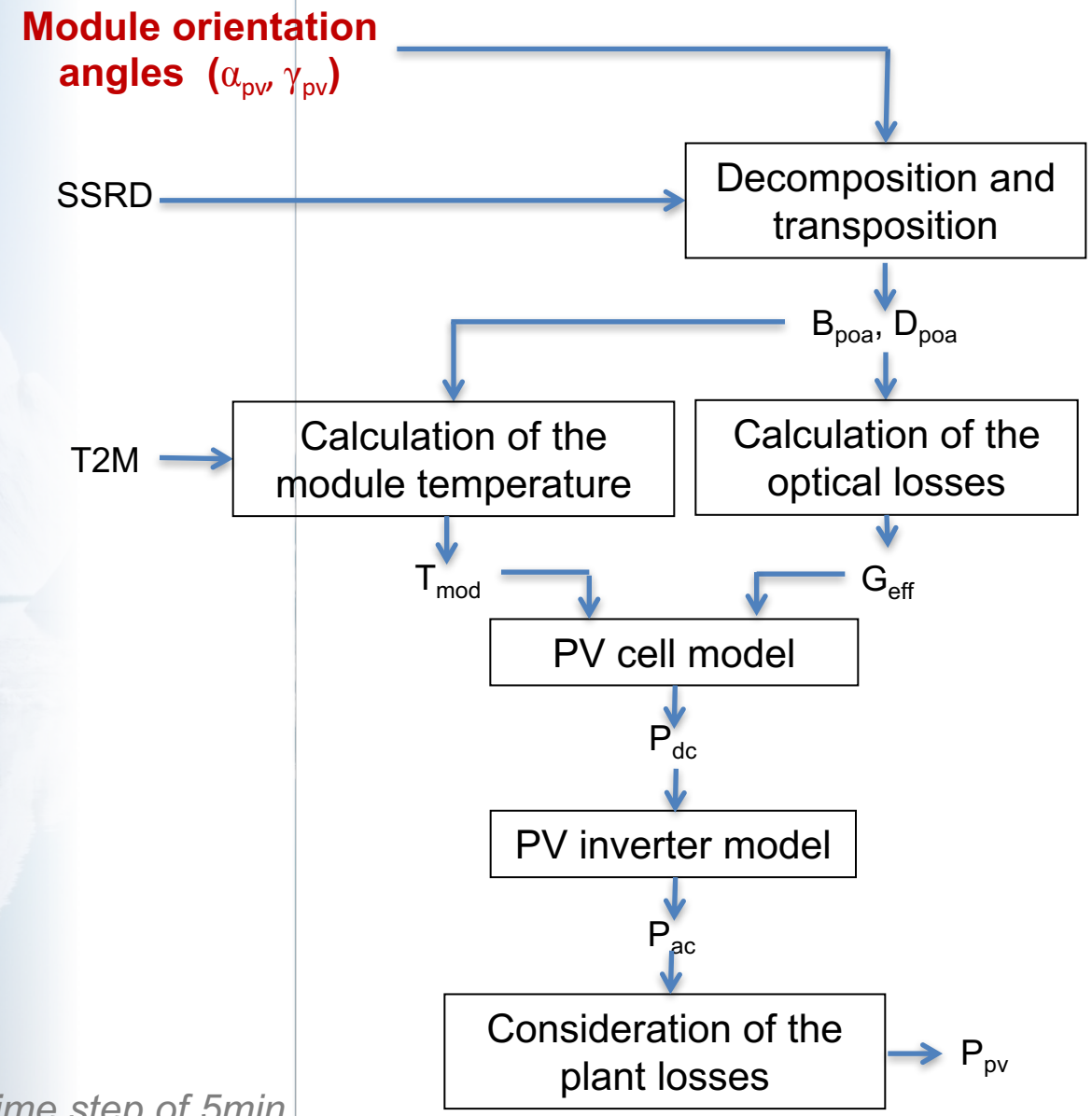
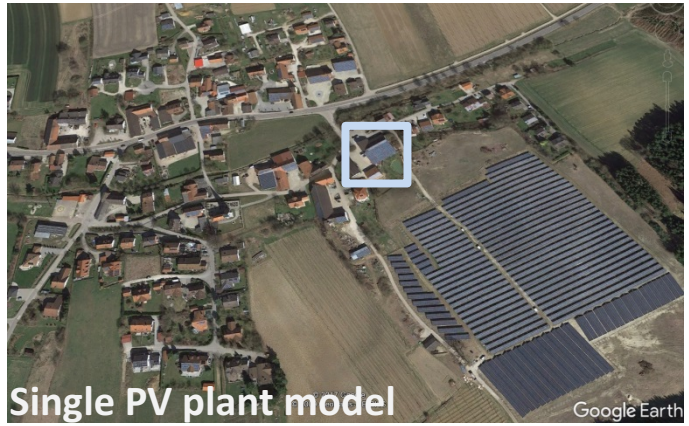
Approach- model selection (1/2)





All parameters set to reference values except the module orientation angles.

$$P_{pv,i}=f_{pv}(\alpha_{pv,i}, \gamma_{pv,i}, SSRD, T2M)$$

Time step of 5min for the calculation

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Approach- model selection (2/2)

$$P_{pv} = \frac{1}{\sum_i C_i} \sum_i C_i \, P_{pv,i}$$

with

C_i peak capacity of the ith plant

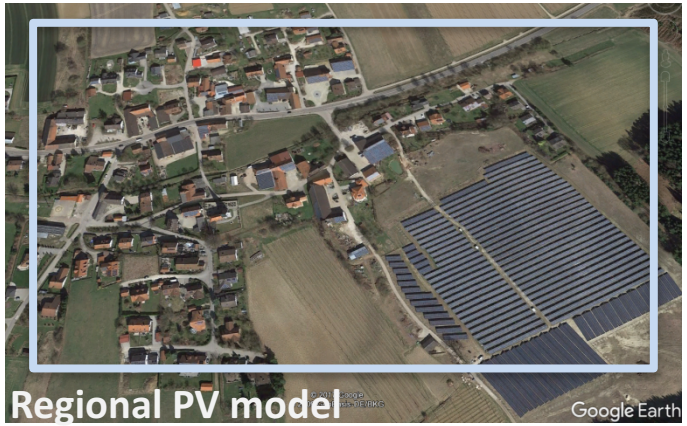
$P_{pv,i}$ specific power of the ith plant

$$P_{pv,i} = f_{pv}(\alpha_i, \gamma_i, SSRD, T2M)$$

$$P_{pv} = \sum_{i,j} \rho(\alpha_i, \gamma_j) \, f_{pv}(\alpha_i, \gamma_j, SSRD, T2M)$$

with

$\rho(\alpha_i, \gamma_j)$ share in capacity of plants with an orientation (α_i, γ_j)



We need to estimate the distribution function for any location in Europe

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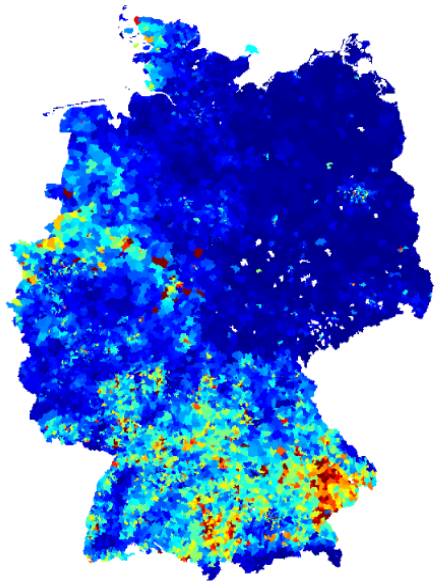
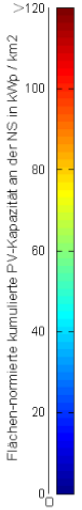
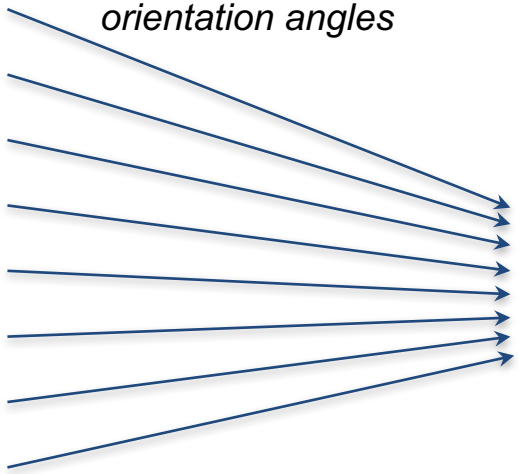
Approach- model parameter estimation

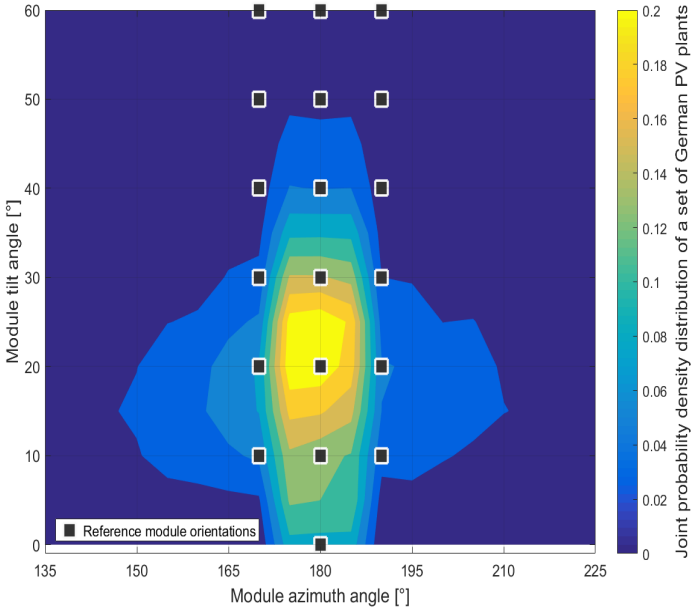
Estimation of the distribution function $\rho(\alpha,\gamma)$





ca. 35 000 PV plant orientation angles





$$\rho(\alpha,\gamma) \approx \left[\frac{1}{\sqrt{2\pi\sigma_\alpha^2}} exp\left(-\frac{(\alpha-\mu_\alpha)^2}{2\sigma_\alpha^2}\right)\right]\left[\frac{1}{\sqrt{2\pi\sigma_\gamma^2}} exp\left(-\frac{(\gamma-\mu_\gamma)^2}{2\sigma_\gamma^2}\right)\right]$$

μ_α=180°

σ_α=19.3°

μ_γ=0.7 γ_{opt}

σ_γ=10.8°

γ_{opt}: optimal tilt angle

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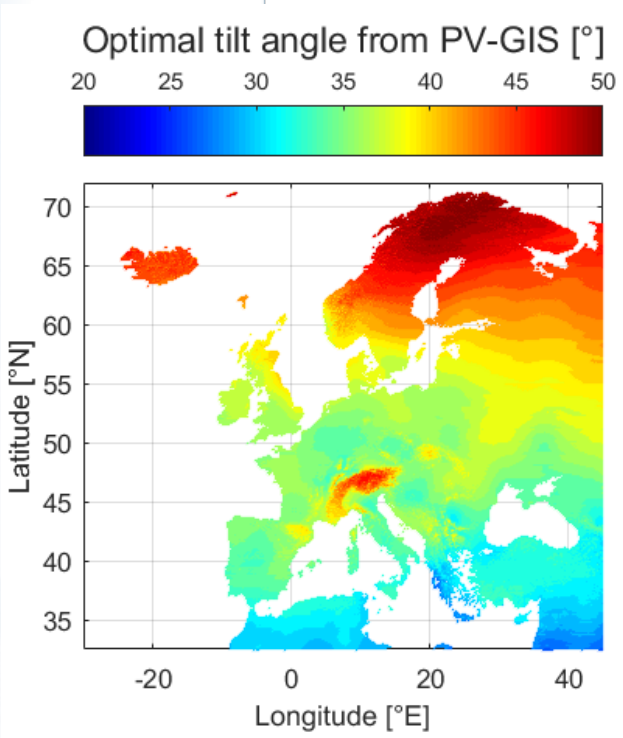
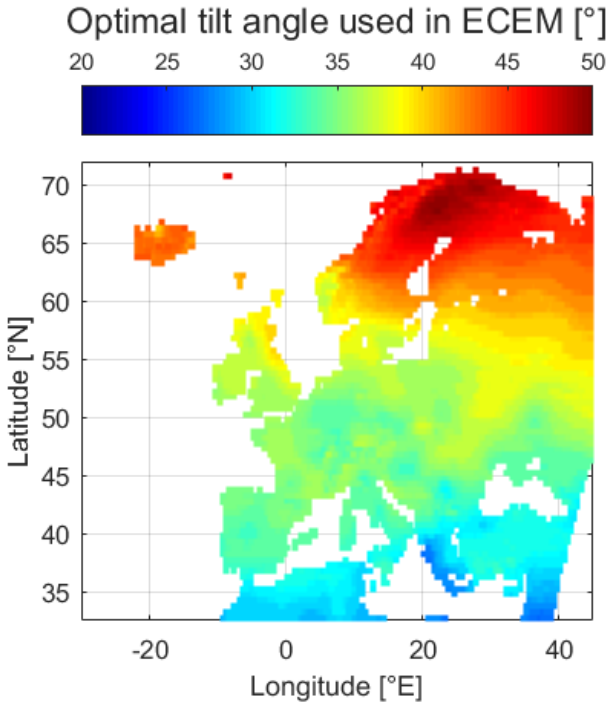
Approach- model parameter estimation

Choice of the optimal tilt angle dataset





The optimal slope dataset prepared by PV-GIS has been chosen.

Orographic effects on optimal slope have been removed.

The dataset has been projected on the raster used for the energy variable calculations.

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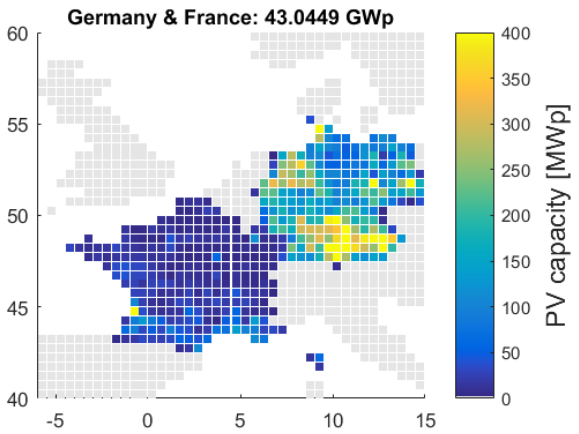
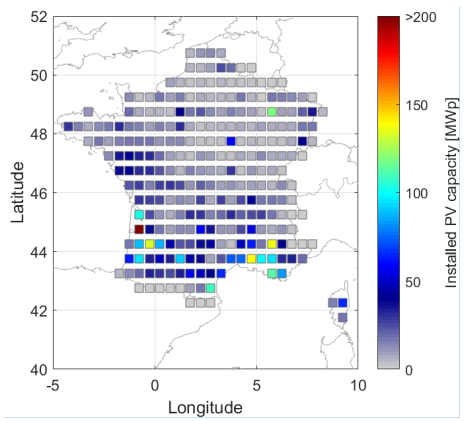
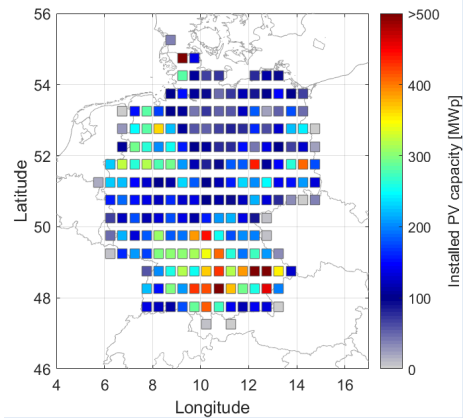
Validation: dataset used







Country	France	Germany
Time period	01/01/2014 – 31/12/2014	01/01/2014 – 31/12/2014
Installed capacity	6.2 GW_p	36.9 GW_p
Input meteorological data	3-hourly ERA-interim data (SSRD, T2M)	3-hourly ERA-interim data (SSRD, T2M)
Reference PV power data	30-min estimates from RTE aggregated in a 3-hourly country-wide capacity factor (W/W_p)	15-min estimates from four TSOs aggregated in a 3-hourly country-wide capacity factor (W/W_p)

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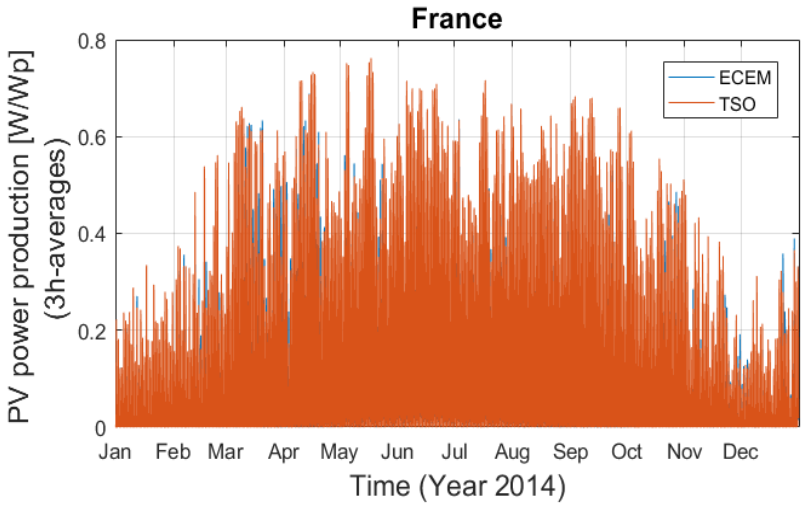
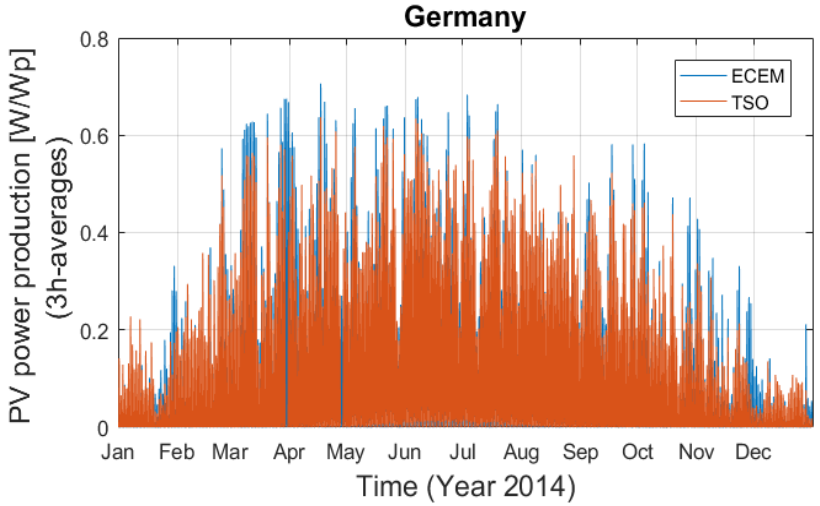
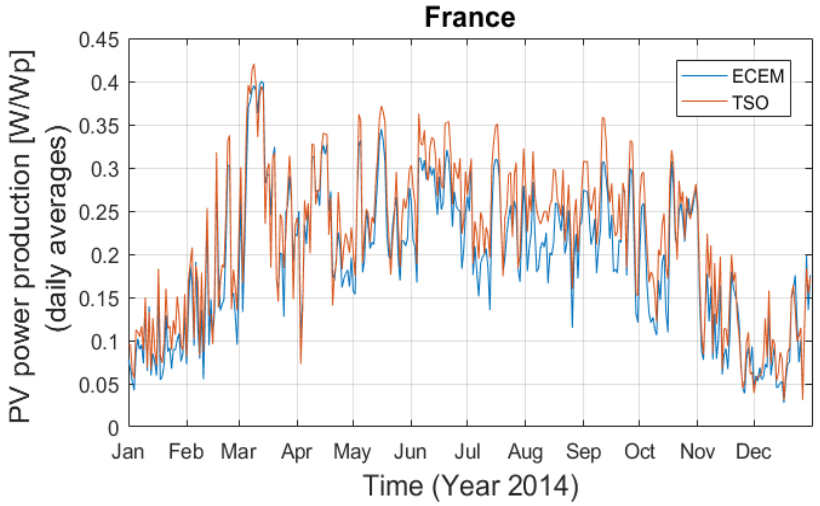
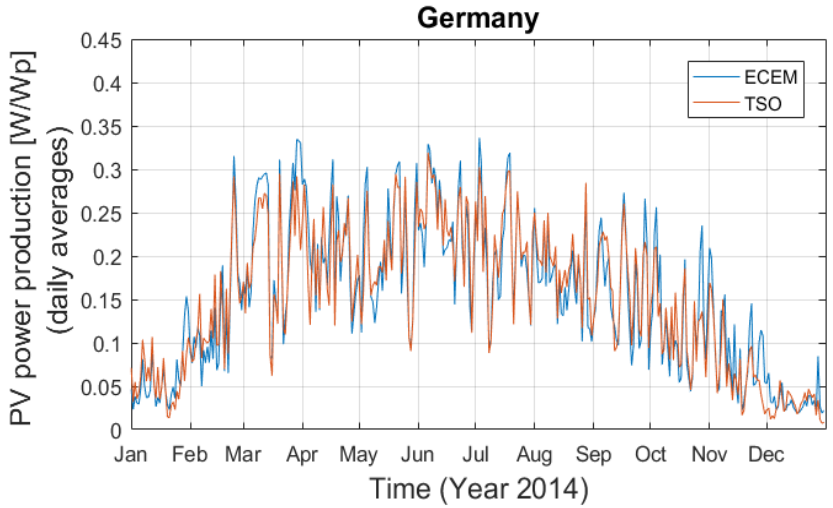
Validation: Comparison of the time series









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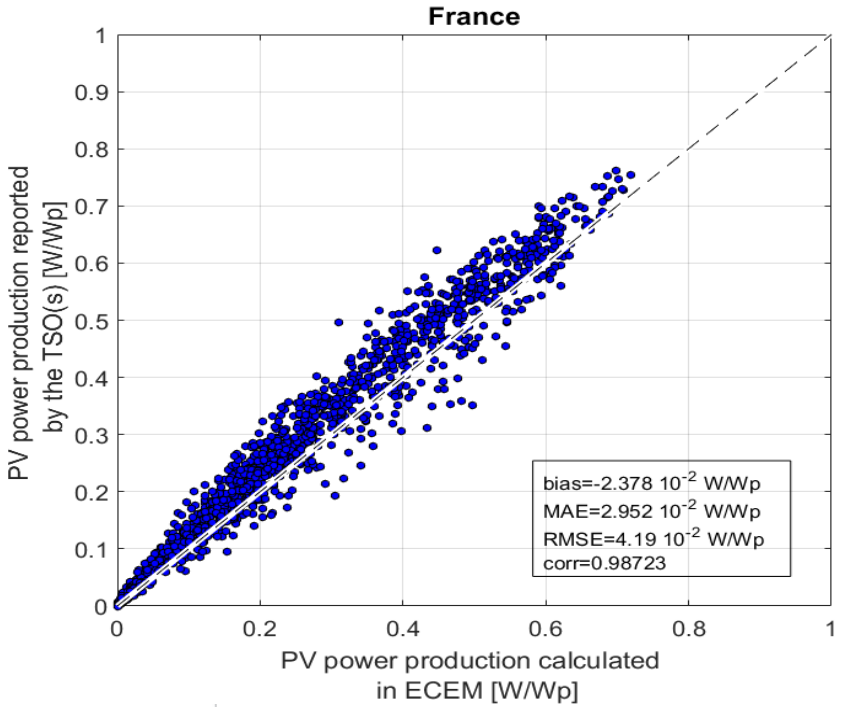
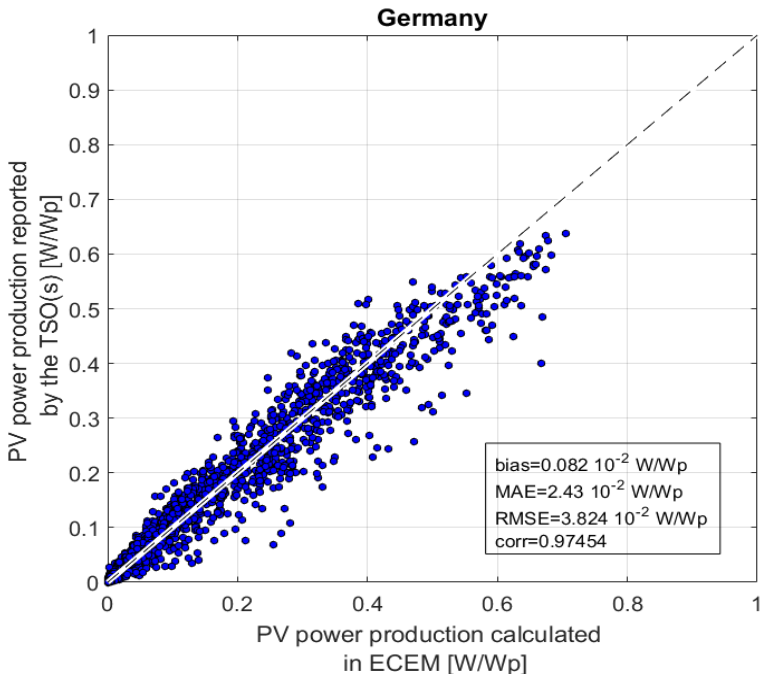
Validation: Scatter plots and error metrics





	France (Year 2014)	Germany (Year 2014)
Number of data	1831	1814
Bias	-2.4 %	0.1 %
MAE	3.0 %	2.4 %
RMSE	4.2 %	3.8 %
Correlation	0.99	0.97

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Conclusion

- We proposed an approach for calculating the PV capacity factor in Europe.
- Apart from the optimal slope, no PV plant parameter is needed to implement the proposed model. Existing databases such as PV GIS can be used for determining the optimal slope.
- A first validation with TSO data shows that the model yields satisfactory results for Germany and France.
- The proposed approach has been implemented for 33 EU countries and 99 regions with the ERA-interim data (1979-2016) and 12 CORDEX members (1979-2050)
- A free access to the resulting capacity factors is available on the ECEM demonstrator:

  http://ecem.climate.copernicus.eu/demo

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Thank You

University of East Anglia

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University of Reading

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