Benchmarking of different approaches to forecast solar irradiance

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Introduction

Power generation from photovoltaic systems is highly variable due to its dependence on meteorological conditions. An efficient use of this fluctuating energy source requires reliable forecast information for management and operation strategies. Due to the strong increase of solar power generation the prediction of solar yields becomes more and more important. As a consequence, in the last years various research organisations and companies have been developing different methods to forecast irradiance as a basis for respective power forecasts. For the users of these forecasts it is important that standardized methodology is used when presenting results on the accuracy of a prediction model in order to get a clear idea on the advantages of a specific approach. In this paper we introduce a benchmarking procedure developed within the IEA SHC task 36 “Solar Resource Knowledge Management” to asses the accuracy of irradiance forecasts. Different approaches of forecasting are compared.

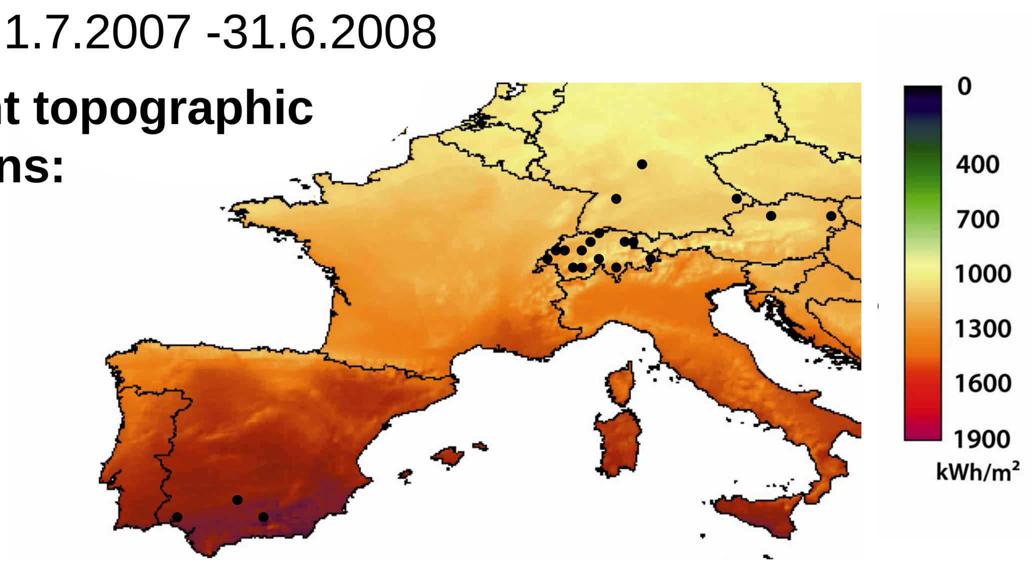
Ground measurement data

A common ground measurement data set is important for the comparison of different methods, because site and period may significantly influence the performance of a given forecasting system.

Period of evaluation: 1.7.2007 -31.6.2008

Regions with different topographic and climatic conditions:

- Southern Germany
- Switzerland
- Austria
- Southern Spain



Map of mean yearly irradiation sum (1995-2004) with location of ground measurement stations.

Accuracy assessment

Root mean square error

$$rmse = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(I_{forecast,i} - I_{measured,i})^2}$$

describes the uncertainty of the forecast.

The evaluation is performed for hourly values (only day values).

Comparison to a trivial reference model:

Persistence: “cloud situation stays the same as the previous day”

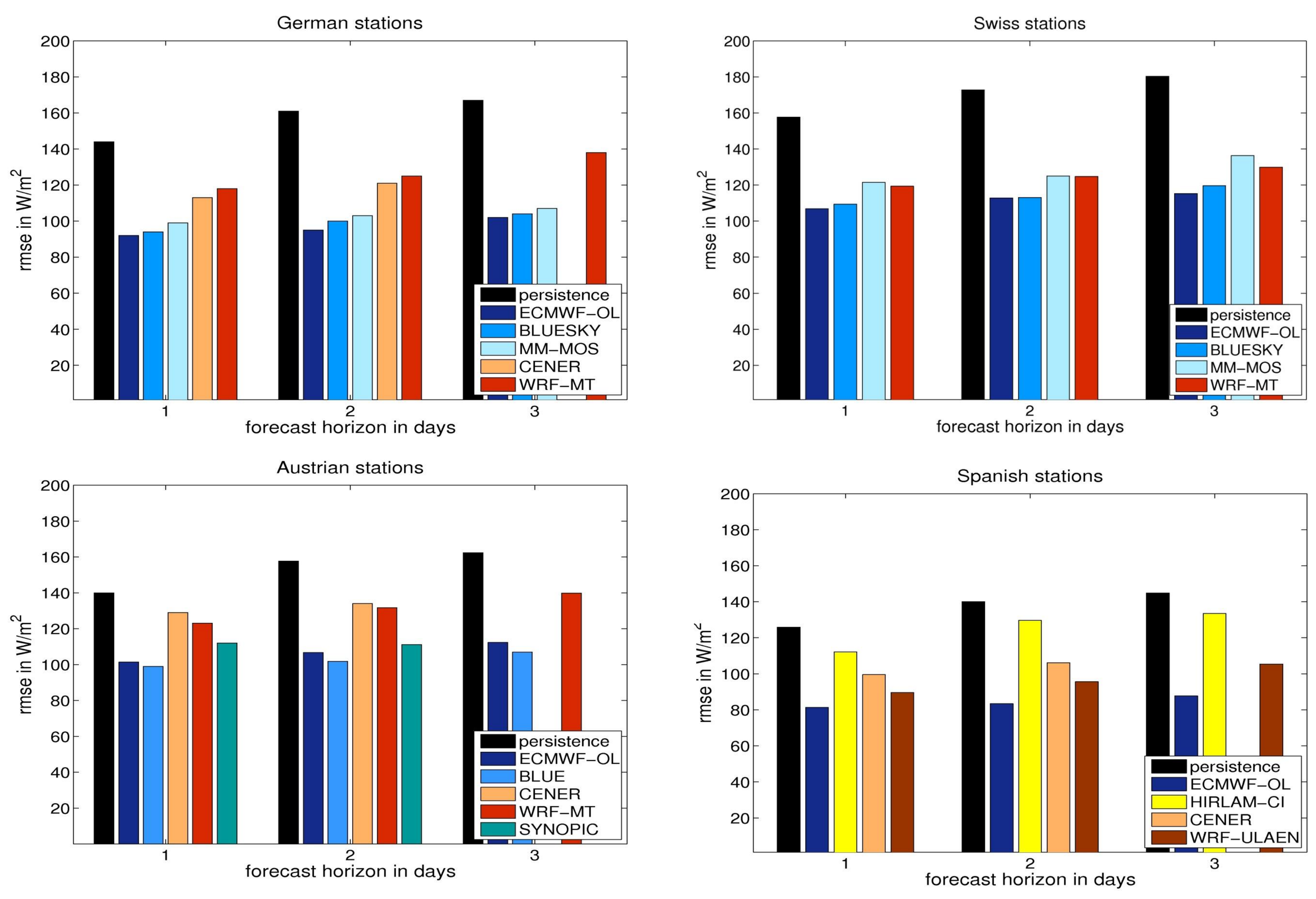
Forecasting approaches

Team & abbreviation	Approach	Numerical Weather prediction model with spatial and temporal resolution	
1) University of Oldenburg, Germany, ECMWF-OL	Statistical post processing in combination with a clear sky model	ECMWF* - 0.25°x 0.25° - 3 hours	Global model with post processing
2) Bluesky, Austria a) SYNOP b) BLUE	a) Synoptic cloud cover forecast by meteorologists ´b) BLUE: statistic forecast tool	for b) GFS+ - 1° x 1° and 0,5°x 0.5° - 3 hours and 6 hours	
3) Meteocontrol, Germany MM-MOS	MOS (model Output Statistics) by Meteomedia GmbH	ECMWF* - 0.25°x 0.25° - 3 hours	
4) Cener, Spain CENER	Post processing based on learning machine models	Skiron^x/GFS+ - 0.1°x 0.1° - 1 hour	Mesoscale models with postprocessing
5) Ciemat, Spain HIRLAM-CI	Bias correction	AEMET-HIRLAM^x - 0.2°x 0.2° - 1 hour	
6) Meteotest, Switzerland, WRF-MT	Direct model output of global horizontal irradiance (GHI) averaging of 10x10 model pixels	WRF^x/GFS+ : - 5 km x 5 km - 1 hour	Mesoscal models
7) University of Jaen, Spain WRF-UJAEN	Direct model output of GHI	WRF^x/GFS+ - 3 km x 3 km - 1 hour	

*ECMWF: European Centre for Medium-Range Weather Forecasts, + GFS: Global Forecast System
^x WRF, Skiron, AEMET-HIRLAM: mesocale numerical weather prediction models

Overall results for the different regions

- All forecast methods are clearly better than persistence.
- Approaches using a global model in combination with post processing show best results.
- WRF forecasts, even without post processing using historic ground data, perform better than the other mesoscale models.
- For southern Spain with a lot of sunny days forecast accuracy is higher than in Central Europe.



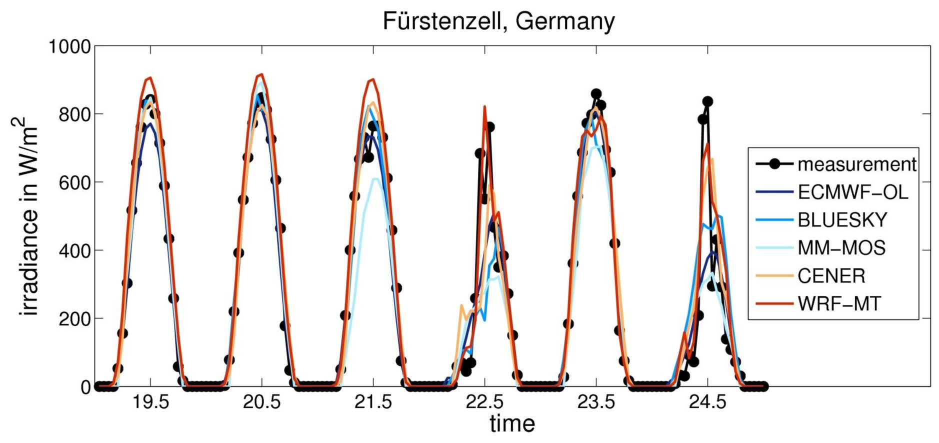
Rmse for the first, second, and third forecast day for stations from Germany (I_{mean}=227 W/m²), Switzerland (I_{mean}=267W/m²), Austria (I_{mean}=222W/m²), and Spain (I_{mean}=391W/m²).

Detailed evaluation: selected results

Time series of predicted and measured irradiances

Illustration of forecast accuracy for different weather conditions:

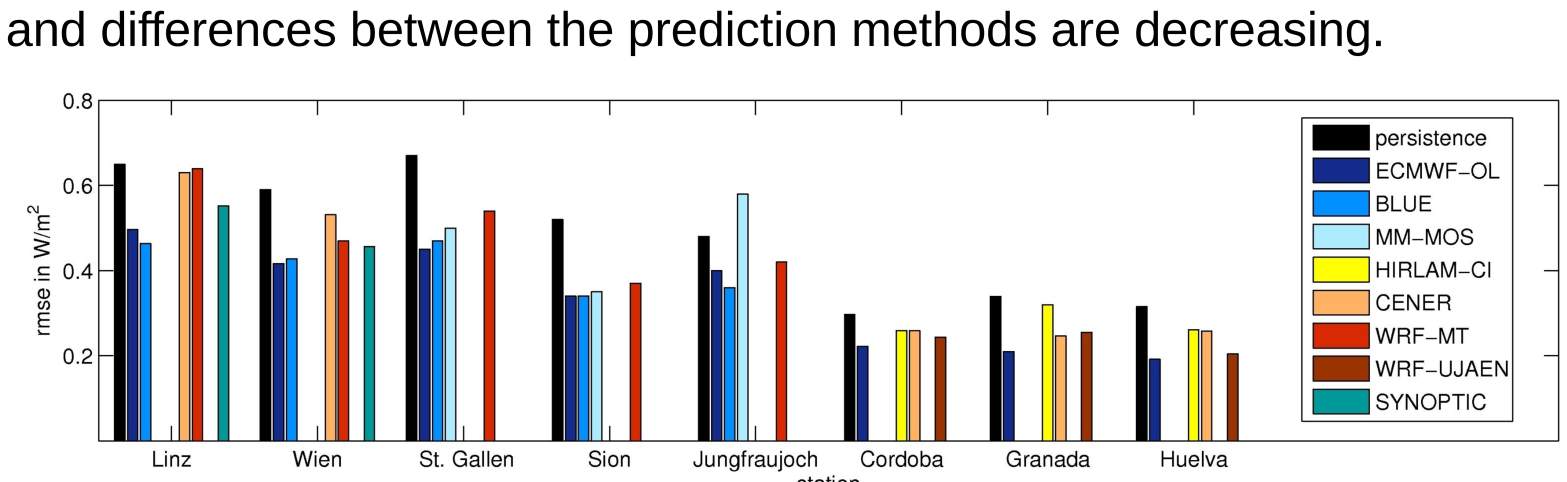
- good agreement of prediction and measurement for clear sky days
- large deviations between measurement and forecast for variable clouds



Comparison of measured and predicted irradiances (first forecast day), six days in May 2007.

Evaluation per station

- Influence of topography: for mountain stations large difference between the forecasting methods may occur.
- Influence of climate: with increasing share of sunny days, rmse values and differences between the prediction methods are decreasing.



Relative rmse for the first forecast day for selected stations. Normalisation is performed with respect to mean ground measured irradiance.

Summary

A procedure of benchmarking irradiance forecasts was presented and applied to seven different forecasting algorithms.

We have shown, that all proposed methods perform significantly better than persistence. A strong dependency of the forecast accuracy on the climatic conditions is found. For Central European stations the relative rmse ranges from 40% to 60%, for Spanish stations relative rmse values are in the range of 20% to 35%. At the current stage of research, irradiance forecasts based on global model numerical weather prediction models in combination with post processing show best results.

There is ongoing development of the methods to predict irradiance by the IEA task 36 members. Accordingly, evaluation and comparison of the forecasts will be continued.