COMPARISON OF SOLAR RADIATION FORECASTS FOR THE USA

J. Remund[1], R. Perez[2] and E. Lorenz[3]
[1]Meteotest, Fabrikstrasse 14, 3012 Bern, Switzerland
[2]ASRC, The University at Albany, 251 Fuller Rd, Albany, NY 12203, USA
[3]University of Oldenburg, Institute of Physics, Carl von Ossietzky Strasse 9-11, 26129 Oldenburg, Germany

ABSTRACT: Global radiation short time forecast of three different models (ECMWF, NDFD and GFS/WRF) have been compared. The comparison was made for a half year period (summer 2007) at three different climates in the USA. ECMWF shows the best results, followed by NDFD and GFS/WRF. Uncertainty varies strongly from place to place. The breakeven with persistence is reached after 2-3 hours. Distributions of hourly values do differ from measured values, but are quite similar to global radiation data based on satellite data.

Keywords: global radiation, forecast models

1 INTRODUCTION

Solar radiation and PV production forecasts are becoming increasingly important as solar produced energy is growing strongly. Within the next few years the share of solar produced energy injected on power grids during peak hours will become noticeable in some areas of the world, especially where legislation encourages the deployment of increasingly large solar power plants.

Within the ongoing project IEA SHC Task 36 „Solar resource knowledge management“ (http://sunbird.jrc.it/iea-shc-task36/) three teams of experts are benchmarking their solar radiation forecast against ground truth data in the USA.

2 DATA

2.1 Compared models

The team members and their approaches to forecast global horizontal irradiance (GHI) are listed in Table 1.

Table 1: Team members and their used model.

Team	Output parameter used	Resolution	Model
New York State Univ. Albany, ASRC, USA	Cloud cover statistical model for GHI 3 h time resolution	9 km	NDFD [1]
Univ. Oldenburg EHF, Germany	Direct model output GHI (3 h time resolution enhanced to 1 h resolution)	25 km	EC-MWF [2]
Meteotest, Switzerland	Direct model output GHI 1 h time resolution	11 km	GFS/ WRF [3]

The NDFD data were based on a combination of GFS model, local area models and local human input (regional weather offices within USA).

For ECMWF the average of the 4x4 nearest grid points of global radiation forecast were used. The radiation transfer parameterization of the ECMWF model is described in [4]. Hourly values were calculated with two methods: In a first version the hourly global radiation values were calculated as a linear interpolation of the 3 hourly values. In a second version the hourly values were calculated with help of clear sky model and the clearness index [5].

For GFS/WRF the global radiation of the nearest grid point based on Dudhia [6] radiation code was used. The GFS data (1°) were upscaled with two nestings at 33 and 11 km.

At present we focus our attention on the global irradiance component with forecast ranges of up to up to 60 hours.

2.1 Data for benchmarking

Three climatically distinct locations with high quality measurements from the BSRN/SURFRAD [7] network were selected for benchmarking (Table 2).

Table 2: Data used for benchmarking.

Site	Latitude	Longitude	Altitude
Desert Rock NV	36.63°N	116.02°W	1007 m
Boulder CO	40.13°N	105.24°W	1689 m
Goodwin Creek MS	34.25°N	89.87°W	98 m

Desert Rock is an example for desert climate. Boulder is at the eastern edge of the Rocky Mountains. It’s in-between the mountainous climate and the climate of the Great Plains. Goodwin Creek in the Mississippi basin shows a more moderate and humid climate.

The period of comparison is April – September 2007.

3 METHOD

In previous comparisons we have noted that the accuracy of solar forecast models was strongly dependent upon the region and the season. However, up to now it had not been possible to systematically compare models for the same period and location. Therefore, a common time period and common set of ground truth locations have been defined as part of the IEA task.

The main validation metric is the mean bias error (mbe) and the root mean squared error (rmse). The results are also compared to the persistence (assumption of constant clearness index) and to each other. In addition, the cumulative frequency distributions of the forecasts are checked with an advanced Kolmogorov-Smirnoff test [8]. The forecasts were separated in same day, next day and 2-Day forecast.

4 RESULTS

4.1 Bias of the forecasts

The mean bias errors (mbe) are generally small (Table 3, Figure 1 and 2). Only GFS/WRF model shows higher values at Boulder and Goodwin creek (overestimation of global radiation).

Table 4: mean bias errors of one day forecast

Site	NDFD [W/m²] ([%])	ECMWF Version 2 [W/m²] ([%])	GFS/ WRF [W/m²] ([%])
Desert Rock NV	10 (2)	15 (3)	13 (2)
Boulder CO	12 (3)	43 (11)	85 (19)
Goodwin Creek MS	-17 (-4)	24 (6)	82 (18)

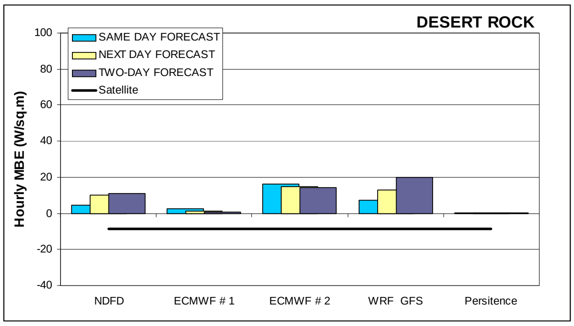

Figure 1: mbe of radiation forecast models at Desert Rock NV.

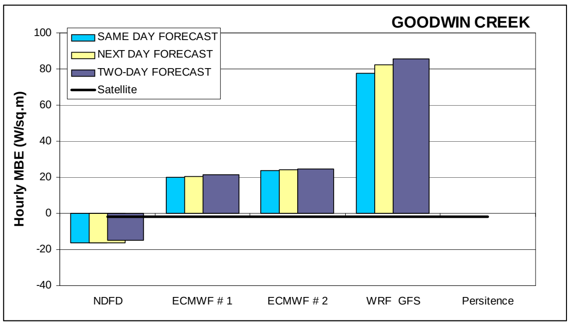

Figure 2: mbe of radiation forecast models at Goodwin Creek MS.

4.2 Uncertainty of forecast

As the main uncertainty measure the root mean squared error (rmse) is used. The rmse varies strongly from site to site. The forecast at Boulder show clearly the highest and Desert Rock the smallest uncertainties (Table 4 and Figure 3) .The uncertainty grows only slightly from day to day.

Table 4: rmse of one day forecast

Site	NDFD [W/m²] ([%])	ECMWF Version 2 [W/m²] ([%])	GFS/ WRF [W/m²] ([%])
Desert Rock NV	96 (18)	87 (18)	105 (18)
Boulder CO	167 (41)	162 (40)	223 (50)
Goodwin Creek MS	149 (36)	136 (32)	190 (41)

The large share of sunny hours at Desert Rock facilitates the forecast. For Boulder, lying at the border of two different climate regimes, forecasting is much more difficult. An enhancement of the spatial resolution to 2-5 km could enhance the quality at this site. ECMWF Version 2 shows the best results, followed by NDFD. GFS/WRF model shows approximately 25% higher uncertainties mainly at Boulder and Goodwin Creek MS.

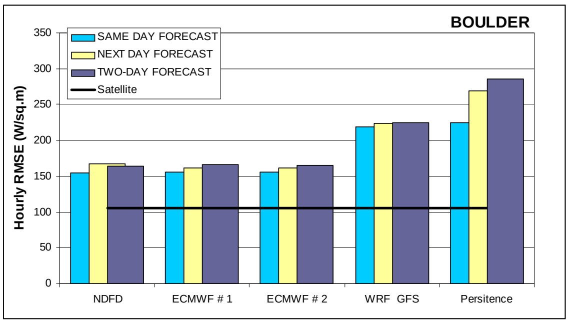

Figure 3: Uncertainty of radiation forecast models at Boulder CO.

4.3 Comparison to persistence

The breakeven of persistence is reached after 2-4 hours (Fig. 4). The breakeven is dependent on the uncertainty. For ECMWF and NDFD this value is reached at 2 hours for GFS/WRF at 3 hours.

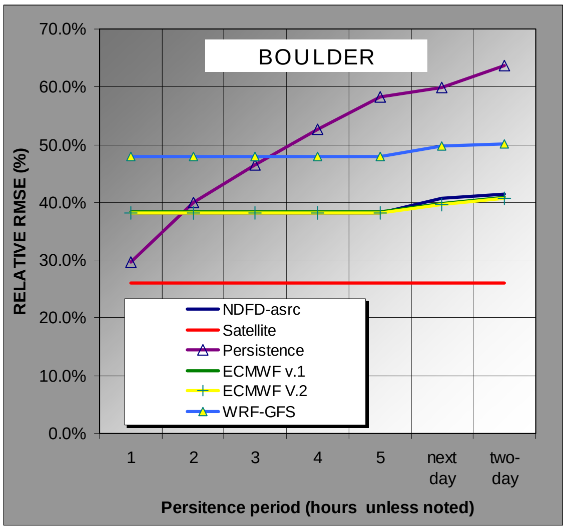

Figure 4: Relative rmse and persistence of radiation forecast models at Boulder CO.

4.4 Distribution tests

All models show statistical differences to measured distributions (Table 5 and Figure 5). Generally the forecast outputs are more similar to radiation data based on satellite data as data based on ground measurements. This can be partly explained as both satellite and forecast data are mean values for a certain grid area and ground measurements are including the information for a certain point.

ECMWF Version 2 has the lowest discepancies and GFS/WRF the biggest.

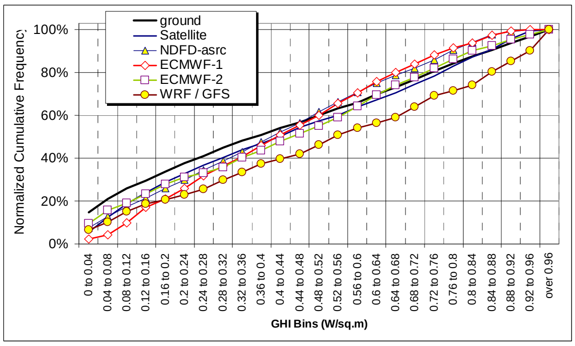

Figure 5: Comparison of cumulative distributions at Goodwin Creek MS (Kolmogorov-Smirnov-Test).

Table 5: KS-Test of one day forecast: Portion of values over critical value.

Site	NDFD [ ]	ECMWF Version 2 [ ]	GFS/ WRF [ ]
Desert Rock NV	0.429	0.017	0.476
Boulder CO	0.991	0.640	2.258
Goodwin Creek MS	0.558	0.406	2.154

5 CONCLUSIONS

ECMWF Version 2 performs best overall (3-hourly model with physical model interpolation). The uncertainty of NDFD is not much greater and not bad for a 3-hourly cloud cover model. GFS/WRF is not as good as other two models. It could possibly be improved with a better radiation model and a statistical post processing eliminating the bias.

The persistence breakeven is for all models lower than 3 hours. The persistence with cloud-motion will lengthen the breakeven to 3-4 hours.

The work within the IEA task will continue until 2009. Further test areas will include southern Germany, Switzerland and Austria as well as southern Spain (time period of one year).

Other solar components such as PV-production and direct normal irradiance will be included, as well as additional models from other expert teams including Ciemat (Spain), University of Jaen (Spain), Meteocontrol (Germany), and Blueskywetter (Austria).

5.3 References

[1] National digital forecast database (NDFD) of NOAA (http://www.weather.gov/ndfd/).

[2] Global model of the European Centre for Medium-Range Weather Forecasts (ECMWF, http://www.ecmwf.int).

[3] Weather research and forecasting (WRF) model (http://www.wrf-model.org) with 1° input of Global Forecast System (GFS) model.

[4] Morcette J.-J. (2000): Radiation Transfer, Meteorological Training Course Lecture Series. In: Meteorological Training Course Lecture Series, ECMWF, Reading UK, http://www.ecmwf.int/newsevents/training/lecture_notes/LN_PA.html.

[5] Lorenz E., Hurka J., Heinemann D., Beyer H.G. (2008): Irradiance forecasting for the power prediction of grid connected Photovoltaic systems. Special Issue "GEOSS: Benefits of Earth Observations for Renewable Energies", in review, 2008.

[6] Dudhia, J,, Numerical study of convection observed during the Winter Monsoon Experiment using a mesoscale two-dimensional model. J. Atmos. Sci., 46, 3077-3107, 1989.

[7] Surface radiation network (surfrad): http://www.srrb.noaa.gov/surfrad/

[8] Espinar B., L.Ramírez, A.Drews, H.G.Beyer, L.F.Zarzalejo, J.Polo, L.Martín, Analysis of different error parameters applied to solar radiation data from satellite and German radiometric stations, accepted for publication in Solar Energy, 2008.