SOLAR HEATING & COOLING PROGRAMME
INTERNATIONAL ENERGY AGENCY

2014 HIGHLIGHTS

SHC Task 46
Solar Resource Assessment and Forecasting

THE ISSUE

Knowledge of solar energy resources is critical when designing, building and operating successful solar water heating systems, concentrating solar power systems, and photovoltaic systems. However, due to their dependence on weather phenomena the energy output from these technologies can be highly variable, especially in situations where storage is not available to smooth out this variability. Accurate solar resource assessment and reliable solar power forecasting are important tools not only for system design, but also for system operators in matching loads at any given time with the solar energy technologies available. Reliable solar data and data products are essential for optimizing the value of these technologies in meeting clean energy goals and lowering the overall cost of energy.

OUR WORK

Participants representing research institutions and private consultancies from around the world are engaged in Task 46 Solar Resource Assessment and Forecasting to produce information products and best practices on solar energy resources that will greatly assist policymakers as well as project developers and system operators in advancing renewable energy programs worldwide.

One main objective of this work is to examine and compare various solar energy resource databases and forecasting schemes over various time scales. Other objectives are to further understand grid integration of solar technologies under varying resource conditions, to identify best practices in solar resource measurements, to continue the improvement and accuracy of solar resource modeling, and to survey best practices leading to bankable solar resource data sets.

PARTICIPATING COUNTRIES

Australia
Austria
Canada
Denmark
France
Germany
Netherlands
Singapore
Spain
Switzerland
United States

SHC Task 46 is a five-year collaborative project with the IEA SolarPACES Programme and the IEA Photovoltaic Power Systems Programme.

Task Date	**2011-2016**
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KEY RESULTS OF 2014

Comparison of Irradiance Forecasts Based on Numerical Weather Prediction for Central and Northern Europe

The increasing contribution of fluctuating solar power to the electricity supply leads to a need for accurate solar power predictions as a basis for management and operation strategies. Therefore, a substantial research effort is currently underway on the development of irradiance and solar power prediction models, and a variety of different models are available. In order to allow for a transparent and comparable evaluation of these different models a coherent set of basic evaluation measures and procedures as well as reference data sets are currently being compiled in Task 46. A special focus is on the comparison of forecasts provided by different numerical weather prediction (NWP) models that provide different spatial and temporal resolutions, examining the models' ability to represent irradiance variability.

In 2014 the Task focused on the forecast comparison for a set of NWP based irradiance forecasting approaches for Central and Northern Europe. As a basis for the comparison, we have compiled a common ground measurement data set of hourly measured irradiance values for four countries in Europe with different climatic conditions: Denmark, Germany, Austria and Switzerland (including mountain stations). The period of evaluation is March 2013 to February 2014. The comparison includes direct model output (DMO) of different numerical weather prediction models: the Integrated Forecast System, or IFS of the European Centre for Mid-Range Weather Forecasting (ECMWF), Consortium for Small-Scale Modeling of the European Union (COSMO-EU) of the German Weather Service (DWD), the High Resolution Large Area Model (HIRLAM) for Scandinavia and RADAR Rapid Update Cycle (RUC) of the Danish Meteorological Institute (DMI). The comparison also includes forecasts based on statistical post-processing based one NWP models as input (Meteotest Global Forecast System-Model Output Statistics, or GFS-MOS). A preliminary evaluation of these forecasting approaches for 18 sites in Germany shows a considerable spread of root mean square error (rmse) values for the different methods (see Figure1). Best results for the very short-term scale up to 6 hours ahead are achieved with a MOS system integrating real-time measurements. The increase of rmse values with the forecast horizon is faster for the meso-scale model forecasts than for global model based forecasts.

An evaluation of operational NWP and cloud motion models in North America is presented in Figure 2 as a function of time horizon. These models are listed in Table 1, which also reports on performance of the optimum model mix to be operationally served in the US as part of SolarAnywhere, produced by Clean Power Research.

Table 1. Forecast models used in the North American study

Model	Spatial Resolution	Coverage	Refresh Rate	Time Resolution	Time Horizon
National Digital Forecastt Database (NDFD)	5 km	USA	3-hourly	3 hours	168 hours
Rapid Update (RAP)	13 km	North America	hourly	1 hour	18 hours
North American Mesoscale (NAM)	12 km	North America	6-hourly	1 / 3 hours *	84 hours
Global Forecast System (GFS)	~50 km	Global	6-hourly	3 / 12 hours **	384 hours
European Ctr for Medium Range Weather Forecasts (ECMWF)	~13 kn	Global	12-hourly	3 / 6 hours ***	240 hours
High Resolution Rapid Refresh (HRRR)	3 km	North America	hourly	1 hour	18 hours
Satellite cloud motion	10 km	Global****	hourly	1 hour	9 hours

** 1 hour until 36 hours ahead, 3 hours beyond ** 3 hours until 192 hours ahead, 12 hours beyond *** 6 hours until 144 hours ahead, 6 hours beyond ****currently operational in North America*

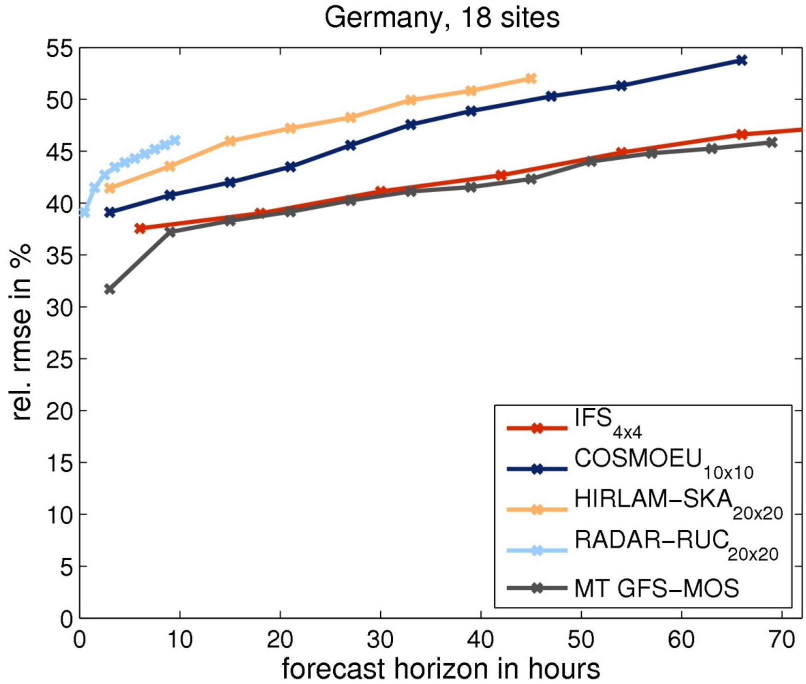


Figure 1: Relative rmse of irradiance predictions for different approaches in dependence on forecast horizon. Forecasts are derived as averages of 4x4 grid points for IFS of ECMWF, of 10x10 grid points for COSMO-EU of DWD, and as 20x20 grid points for DMI's HIRLAM-Scandinavia and RADAR-RUC, in order to evaluate the models on a similar spatial scale (~60km x 60km).

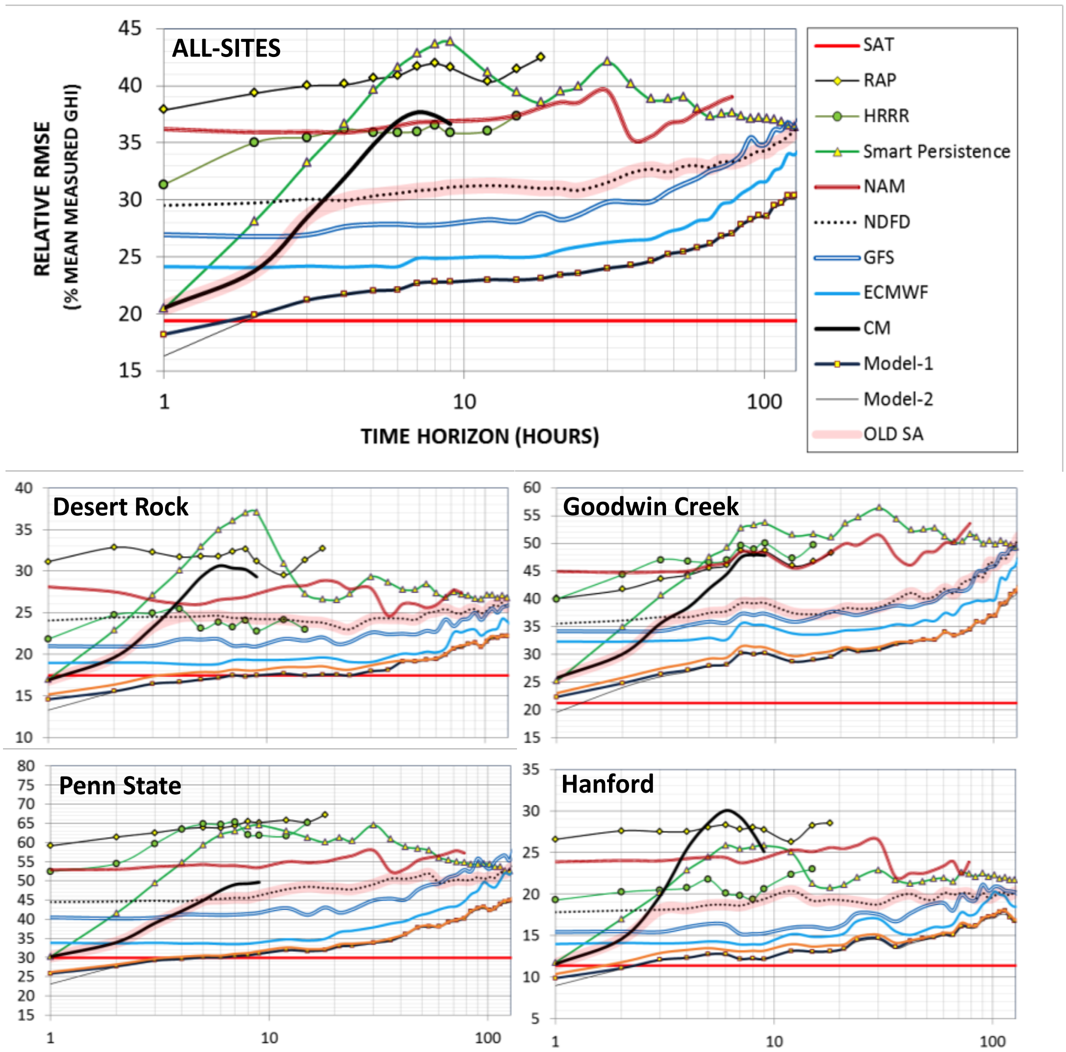
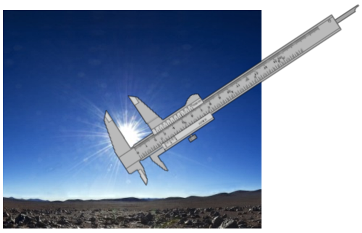


Figure 2: Relative rmse as a function of time horizon for global and regional models in the US. CM stands for satellite-based cloud motion forecasts. SAT is a reference satellite model RMSE (not a forecast). Model-1 is the optimum operational mix. Model-2 includes ground-based measurements when available. OLD SA is the previous version of SolarAnywhere (produced by Clean Power Research).

Consensus Paper on Direct Normal Irradiance Definitions and Applications



The direct normal irradiance (DNI) is of particular relevance to concentrated solar technologies, including concentrating solar thermal plants and concentrated photovoltaic systems. Following various standards from the International Organization for Standardization (ISO), the DNI definition is related to the irradiance from a small solid angle of the sky, centered on the position of the sun. Half-angle apertures of pyrheliometers measuring DNI have varied over time, up to 10°. The current recommendation of the World Meteorological Organization for this half-angle is 2.5°. Solar concentrating collectors have an angular acceptance function that can be significantly narrower, especially for technologies with high concentration ratios.

The disagreement between the various interpretations of DNI, from the theoretical definition used in atmospheric physics and radiative transfer modeling to practical definitions corresponding to specific measurements or conversion technologies is significant, especially in the presence of cirrus clouds or large concentration of aerosols. Under such sky conditions, the circumsolar radiation—i.e. the diffuse radiation coming from the vicinity of the sun—contributes significantly to the DNI ground measurement, although some concentrating collectors cannot utilize the bulk of it.

These issues have been discussed within a panel of international experts in Task 46. Following these discussions, a peer-reviewed collaborative paper was published in *Solar Energy*, available in Open Access. The terms of reference related to DNI are specified here. The important role of circumsolar radiation is evidenced, and its potential contribution is evaluated for typical atmospheric conditions. Blanc, P., B. Espinar, N. Geuder, C. Gueymard, R. Meyer, R. Pitz-Paal, B. Reinhardt, D. Renné, M. Sengupta, L. Wald and S. Wilbert, 2014. Direct Normal Irradiance Related Definitions and Applications: The Circumsolar Issue. Solar Energy, 110: 561–577. doi:10.1016/j.solener.2014.10.001. (access: http://linkinghub.elsevier.com/retrieve/pii/S0038092X14004824)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Solar Energy

Volume 110, December 2014, Pages 561–577

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Direct normal irradiance related definitions and applications: The circumsolar issue

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Highlights

- Review of existing definitions related to direct normal irradiance (DNI).
- Review of applications and measurement techniques of DNI.
- Expert consensus on clear definitions and terminology related to DNI.
- Important role of circumsolar radiation in DNI.

Best Practices Handbook

A final deliverable of SHC Task 36: Solar Resource Knowledge Management, published by U.S. NREL

The U.S. National Renewable Energy Laboratory (NREL) has just published the report "Best Practices Handbook for the Collection and Use of Solar Resource Data for Solar Energy Applications" (NREL/TP-5D00-63112, February 2015). The report provides information on current best practices in measuring and modeling the solar resource, and in using the data to support solar energy pre-feasibility assessments, due-diligence, and operations. Many Task 46 participants have contributed to this report, and a considerable amount of information developed under the Task 46 predecessor, Task 36: Solar Resource Knowledge Management, is incorporated into the report. Thus, the NREL publication also serves as the final deliverable of Task 36. This Best Practices Handbook updates a previous publication released by NREL in September 2010 titled "CONCENTRATING SOLAR POWER: Best Practices Handbook for the Collection and Use of Solar Resource Data" (NREL/TP-550-47465). The new handbook serves as a valuable technical resource for developers of all solar technologies, including solar heating and cooling technologies. The full report can be found at http://www.nrel.gov/docs/fy15osti/63112.pdf.