SOLAR HEATING & COOLING PROGRAMME
INTERNATIONAL ENERGY AGENCY

2015 HIGHLIGHTS

SHC Task 46
Solar Resource Assessment and Forecasting

THE ISSUE

Knowledge of solar energy resources is critical when designing, financing, 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 and operation, but also for system financing.

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 Kingdom

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

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KEY RESULTS OF 2015

Comparison of Irradiance Forecasts for La Reúnion Island Based on Numerical Weather Prediction Models

As the deployment of variable solar energy technologies expands, it is increasingly important to develop accurate solar power prediction methodologies to effectively operate these systems in the electricity grid. Substantial research 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, one of the major efforts of Task 46 has been to develop a coherent set of basic evaluation measures and procedures so that different forecasting schemes applied to different regions can be benchmarked. 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, and results of these studies were summarized in last year's Task 46 Highlights. In 2015, these studies extended to La Reúnion Island, a tropical island located in the Indian Ocean. The Island is experiencing rapid growth in the use of grid-connected Photovoltaic (PV) energy and solar hot water systems. In 2013 PV exceeded 25% of the total installed power in the island, and at least one occasion PV power output exceeded 30% of the total power output from the island. Thus, solar power forecasting is becoming increasingly important to the local utility to be able to manage the net load which is impacted by the variable power coming into the grid from PV systems.

The Laboratory PIMENT at the University of La Reúnion, working in collaboration with other Task 46 experts, is developing various day-ahead forecasting methods for La Reúnion. Their approach is based on the Global Horizontal Insolation (GHI) forecast provided by the European Center for Midrange Weather Forecasting (ECMWF). The hourly forecasts were tested against hourly data obtained at a solar monitoring station located in the town of Saint Pierre, a high solar resource site in the southern part of the Island. Two years of data were used: 2012 data were used as "training" as part of a scheme to improve the forecasts using Neural Networks (NN), and 2013 data were used for validation. The two main metrics for comparing the forecasts with actual data were the Mean Bias Error (MBE) and the Root Mean Square Error (RMSE).

Without making any adjustments to the GHI forecasts coming from the ENMWF it was found that the forecasts underestimated the actual solar resource under clear and partly cloudy conditions, and slightly overestimated the actual measurements under overcast conditions. There was a fair amount of scatter in the outcomes, with an RMSE of about 30%. So the researchers undertook a couple of studies to improve the forecasts. One was to update the forecasts using a method known as Model Output Statistics during the post processing of the forecasts. Methods such as spatial aggregation and temporal interpolation of model outputs were investigated. Furthermore, bias removal techniques based on the clear-sky index and the cosine of the zenith angle, using both MOS and NN methods, were undertaken to better calibrate the model output to local conditions.

The results show that these MOS and NN post-processing schemes improved the model outputs primarily through the method of bias removal techniques; the spatial aggregation and temporal interpolation schemes contributed little to the model improvements. As seen in Figure 1 as well as Table 1, the biases were essentially eliminated using post-processing methods, although there was little improvement in the RMSE. The RMSE is, however, substantially higher if just "persistence" forecasting was used, rather than the NWP model outputs.

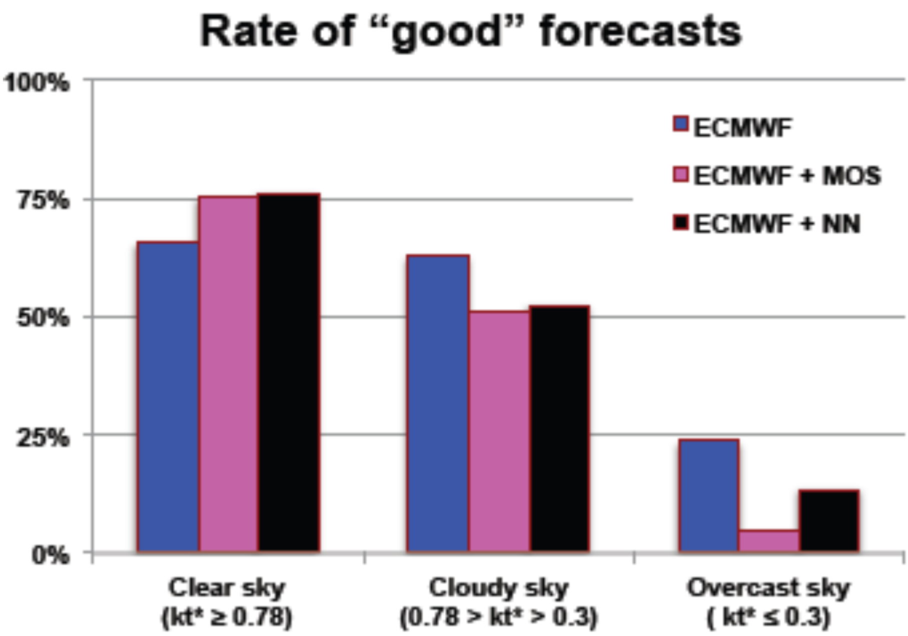

Figure 1. Results of day-ahead GHI forecasts based on NWP forecast models results from the ECMWF, at Saint Dennis, La Reúnion Island, where the raw output as well as outputs modified by MOS and NN post-processing are examined. kt represents the clear-sky index.

Table 1. Results of day-ahead GHI forecasts at Saint Dennis, La Reúnion Island, for forecast model results from the ECMWF for both the raw model output as well as output using MOS and NN post-processing schemes. "Persistence" represents a day-ahead kt forecast based on a kt day before observation.

	ECMWF	ECMWF+MOS	ECMWF+NN	Persistence*
MBE	-3,99 %	0,96%	0,81%	0,77%
RMSE	29,9 %	29,3%	28,9%	39,5%

Further forecast benchmarking studies will continue under Task 46 as well as future tasks, examining schemes designed for islands such as La Reúnion but also for other areas such as southern Europe and North America. These studies will continue to make use of NWP data and will also include other exogenous data such as cloud height and cloud speed and direction as part of the post-processing schemes. More information about this work can be found in: Lauret, Philippe, Elke Lorenz, and Mathieu David, 2016: Solar Forecasting in a Challenging Insular Context. *Atmosphere* **2016**, 7(2), 18; doi:10.3390/atmos7020018.

Survey Paper on Producing Bankable Solar Data Sets through Site Adaptation

When solar resource data are submitted to a financial institution to obtain financing for a project, the institution is interested in the "bankability" of the data; i.e.: What is the uncertainty of the data, and how does this uncertainty translate to the risk of funding a project where the expected long-term output is not precisely known? In order to reduce financial risk, it may be necessary to have long-term high quality measurements directly at the proposed site. However this approach is often unattainable or impractical since this requires several years of quality measurements before a long-enough record has been secured to capture expected interannual variability. Another option would be to develop a long-term set of solar resource data derived from satellite or NWP models. However, despite the longer data record, these models typically have higher uncertainty than what can be achieved from high quality ground measurements. So a third method is being developed where a short-term set of high quality ground data is merged with a long-term set of model-derived data to produce a long-term data set with the lowest uncertainty. This method is known as Site Adaptation, and Task 46 experts have recently published an article surveying techniques available to produce these adapted data sets using several different methods.

One "physically-based" method involves correcting satellite-derived data by adjusting the atmospheric input data so that the new results better match the ground-based data. A particularly important data input, especially for correcting DNI data, is atmospheric aerosol information derived from either ground measurements or satellite observations.

A second "statistical-based" method involves removing the biases in satellite-derived data using either linear or non-linear methods. Typically these methods rely on at least a short period of time (e.g. 9-12 months) when there are concurrent ground measurements with the satellite data record; in cases where this is not the case, some regional site adaptation approaches have also been suggested.

A fairly common statistical site adaptation approach has been to combine the cumulative frequency distribution of ground measurements with the satellite observations, as shown in Figure 2.

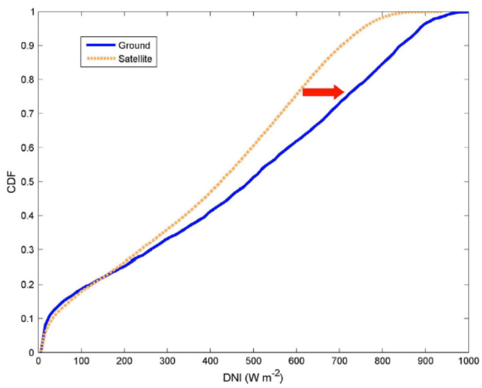

Figure 2. Site adaptation based on fitting two cumulative frequency distribution functions.

An alternative to this statistical method of combining cumulative frequency distributions is to correct the input parameters to the models of the satellite-derived data set.

There are two other possible methods for site adaptation reviewed in the report. One is known as "Measure-Correlate-Predict" (MCP), a method that has been in use for a long time to finance wind projects, but so far has received only limited use in solar projects. This method can be used with either satellite-derived or reanalysis data, and is based on establishing a relation between a short term measured and model-derived data set (even as simple as a ratio) and applying this relationship to the long-term modeled data. A second method involves the improvement of satellite-derived data by combining the results with the output of a NWP model.

In summary, the article highlights that accurate solar resource information is important for effective financing of solar projects, especially those of a large scale. Satellite-derived solar data is very useful for site prospecting and selection, and for undertaking preliminary feasibility of the performance of a proposed project. However, satellite data typically have higher uncertainties than high quality ground measurements, so the long-term satellite record can be improved even when only short-term measurements are available through various Site Adaptation methods. To learn more about these procedures, please see the full article: Preliminary survey on site-adaptation techniques for satellite-derived and reanalysis solar radiation datasets. Polo, J., S. Wilbert, J.A. Ruiz-Arias, R. Meyer, C. Gueymard, M. Suri, L. Martín, T. Mieslinger, P. Blanc, I. Grant, J. Boland, P. Ineichen, R. Escobar, A. Troccoli, M. Sengupta, K. P. Nielsen, D. Renne, N. Geuder, and T. Cebecauer, 2016. *Solar Energy* 132:25-37, 2016. http://www.sciencedirect.com/science/article/pii/S0038092X16001754.