SOLAR RESOURCE KNOWLEDGE MANAGEMENT: A NEW TASK OF THE INTERNATIONAL ENERGY AGENCY

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ABSTRACT

"Solar Resource Knowledge Management" is a new task approved by the International Energy Agency's (IEA's) Solar Heating and Cooling (SHC) Program. The concept for the task was developed over several years by an international consortium of solar resource experts who are involved in the use of weather satellite imagery for developing large-area site-time specific data and maps of the solar resource.

The goal of IEA/SHC Task36 "Solar Resource Knowledge Management" is to provide the solar energy industry, the electricity sector, governments, and renewable energy organizations and institutions with the most suitable and accurate information on solar radiation resources at the Earth's surface in easily-accessible formats and understandable quality metrics. The scope of solar resource assessment information includes historic data sets and data products derived from current satellite imagery and other means.

This paper, which follows the 2005 Annual Report submitted to the IEA/SHC, provides a status of work in achieving Task 36 objectives, and reviews initial results in the context of the needs of the solar industry, national renewable energy planning and policy development.

1. INTRODUCTION

Task 36 "Solar Resource Knowledge Management" was developed as a concept paper at a satellite-based solar resource assessment workshop in Switzerland in March 2003, and was approved at the 57th meeting of the SHC Executive Committee (ExCo) in Espinho, Portugal, 15-17 June 2005. Six countries (Canada, France, Germany, Spain, Switzerland, and the United States) and the European Union are officially participating in the task. The National Renewable Energy Laboratory serves as the Operating Agent for this task, and each of the first three co-authors of this paper lead a subtask. The lead international institutions serving as task participants are as follows:

Canada: Department of Natural Resources

European Commission: JRC (Italy); European Space Agency

France: ADEME

Germany: DLR; Hochschule Magdeburg; University of Oldenburg

Spain: CIEMAT; University of Navarro

Switzerland: Meteotest; UNIGE

U.S.: Department of Energy/National Renewable Energy Laboratory; National Aeronautics and Space Administration; State University of New York at Albany.

Many of the participants in the task have been involved in the United Nations Environment Programme's (UNEP's) Solar and Wind Energy Resource Assessment (SWERA) project, which included the development of high-resolution site-time specific solar resource maps and data for 13 countries around the world (1). Task 36 allows for the participants to continue work on many elements of the SWERA project, which is now completed.

2. GOALS, OBJECTIVES, AND APPROACH

The goal of IEA/SHC Task 36 "Solar Resource Knowledge Management" is to provide the solar energy industry, the electricity sector, governments, and renewable energy organizations and institutions with the most suitable and accurate information on solar radiation resources at the Earth's surface in easily-accessible formats and understandable quality metrics. The scope of solar resource assessment information includes historic data sets and current data products derived using satellite imagery and other means.

There are three main objectives of this Task to achieve this goal:

- To provide further standardization and benchmarking of international solar resource data sets;
- To provide improved data reliability, availability and accessibility in formats that address specific user needs;
- To integrate improved spatial and temporal coverage with customized solar resource products, including reliable short-term solar radiation forecasts and scenarios on the future availability of solar resources in a changing climate.

Achieving these objectives would reduce the cost of planning and deploying solar energy systems, improve the efficiency of solar energy systems through more accurate and complete solar resource information, and increase the value of the solar energy produced by solar systems.

3. TASK 36 APPROACH

The international institutions participating in Task 36 are addressing these objectives through a coordinated work plan that encompasses three subtasks:

Subtask A: Standardize and Benchmark Solar Resource Products to Ensure Worldwide Intercomparability and Acceptance (Subtask Leader: Dr. Hans Georg Beyer)

The objectives of this Subtask are to provide:

a) Coherence and benchmarking of models producing solar irradiance values from satellite data;
b) Accessibility and coherence of ancillary model input data such as atmospheric conditions and land surface parameters;
c) Sensitivity analyses;
d) Ground truth validations with high quality data;
e) Definition of validation protocols and measures of end-product confidence;
f) Cross-satellite platform and cross-model comparisons

Subtask B: Develop Common Structure for Archiving and Accessing Data Products (Subtask Leader: Dr. Lucien Wald)

The objectives of this Subtask are to develop and produce deliverables designed to provide:

a) Worldwide networking between distributed data centers resulting in global coverage of high-quality solar resource data;
b) Information and data exchange protocols;
c) Facilitation of reliable and fast end-user access;
d) Documentation of data products designed for specific end-user applications.

Subtask C: Improve Techniques for Solar Resource Characterization and Forecasts (Subtask Leader: Dr. Richard Meyer)

The objectives of this Subtask are to develop and produce deliverables designed to provide:

a) Short-term (hours) to medium-term (days) solar resource forecasting;
b) Analysis of long-term variability of solar resources;
c) Improved exploitation of existing satellite resources (e.g. very high spatial resolution for plant micro siting);
d) Adaptation of resource assessment techniques to the capabilities of new generations of satellites;

e) New methods for improved products, such as spectrally- or angular-resolved information.

4. TASK STATUS

Since the official start of the five-year Task on July 1, 2005, several informal meetings among various task participants have taken place, including a side meeting during the Solar World Congress in Orlando in August 2005. During these meetings, participants made a decision to hold the first Task Experts Meeting in DLR-Oberpfaffenhofen, Germany, November 16-18, 2005. Approximately 22 Task Participants attended the Experts Meeting, including representatives from all participating countries (and the EU) except Canada. In addition, there was guest representation from Brazil, Task 2 of the Photovoltaic Power Systems (PVPS) Implementing Agreement, and the European Space Agency. Substantive planning for each of the three major subtasks took place at this meeting. A Second Experts Meeting was scheduled to be held in Denver on July 6-7, 2006 in advance of the Solar 2006 Conference.

The following sections summarize the current plans and scope of each subtask.

4.1 Subtask A: Standardization and Benchmarking of Solar Resource Products

This subtask focuses on key activities designed to benchmark the various satellite-derived solar resource assessment methodologies being carried out by various institutions around the world. Several key activities are underway:

- Identifying high quality surface broadband and spectral solar measurement data sets
- Establishing in greater detail the measures of model quality
- Establishing model benchmarking measures
- Applying benchmarking procedures to products in Subtask C
- Producing a data user handbook

4.2 Subtask B: Common Structure for Archiving and Accessing Data Products

This subtask is dedicated to developing an approach where data from the data providers are made available to customers through "brokers" (see Figure 1). The broker offers customers unique access to an ensemble of information supplied by providers, as shown in the Figure. Thus, the broker is taking care of the relationship with its customers on the one hand, and with its providers on the other hand.

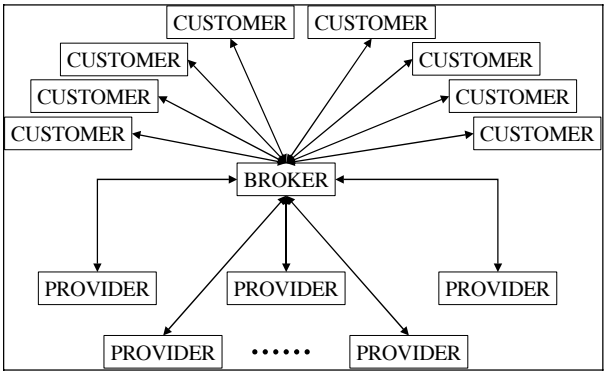

Fig. 1: Structure of the information system

Subtask B will deliver software, metadata, guidelines, documentation, and technology transfer procedures to providers and brokers. Out of this, a prototype information system will be developed and demonstrated. It will be used to raise awareness and show to brokers, providers, and customers what can be achieved, at what expenses and which benefits can be drawn for each community.

Given that the domain of web services is evolving quite fast, it is believed that in five years, there will be enough interest, commercial or not, for the installment of several brokers. If this is the case, the prototype set up by subtask B will disappear, having successfully fulfilled its role.

As a result of this approach, the following activities will be undertaken:

- Evaluation of the legal aspects (data rights, etc.) of the prototype system
- Identification of users requirements
- Determination of data exchange protocols and metadata
- Development of the data dissemination prototype
- Networking of resource providers
- Use of prototype by users
- Automatic access by commercial applications
- Example application of the prototype system using solar micro-siting in Geographic Information Systems (GIS).

4.3 Subtask C: Improved Techniques for Solar Resource Characterization and Forecasting

During the first Task Experts Meeting the work plan for Subtask C was substantially revised and simplified, based on the feedback from the task participants The eight

activities proposed in the original work plan have been synthesized into four activities, based on priorities and availability of resources for the task. These activities, in order of priority, are:

- Improving satellite data retrieval method
- Conducting long-term climatological analysis
- Developing procedures for forecasting solar energy resources
- Developing procedures for micro-siting of solar technologies

The first activity, "improving satellite data retrieval methods," will focus on improving the input data describing the state of the atmosphere, which in turn will improve radiative transfer calculations by solar radiation models. Further, better data on ground reflectivity will help improve the solar radiation retrievals. The approach will also include acquisition or derivation of better aerosol and water vapor data from satellites. For example, Figure 2 shows that aerosol optical depth data can be highly variable in time and space (2). Model results can be significantly improved by using the improved aerosol data sets as exemplified in Figure 1.

In the course of work on Subtask C, new retrievals utilizing the new Meteosat Second Generation (MSG) satellite series will be further developed and tested. Improvements also are expected for snow detection, because snow is often misinterpreted by satellite sensors as clouds, therefore causing errors in the solar irradiance predictions. Further, this activity includes improved spectral and angular solar radiation products.

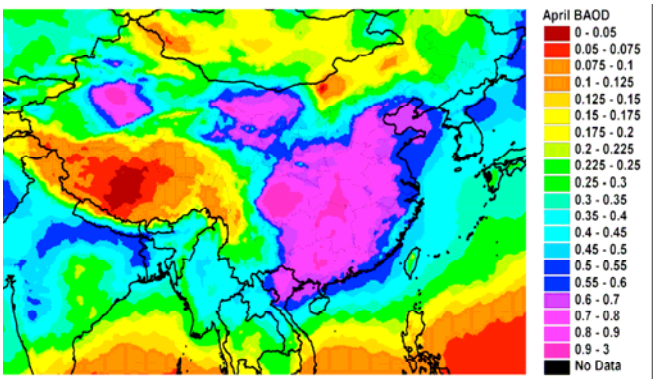

Figure 2: Example of high spatial resolution aerosol optical depth data. (2).

The "Forecasting of Solar Resources" activity includes "Now casting" (up to 3 hour predictions) and near-term (up to 72-hour) solar forecasts. The activity may also include "mid-term" (several days to several weeks) forecasting as an option.

For forecast horizons up to 3 days, several approaches to derive solar irradiance forecasts from global numerical weather predictions will be investigated. For an enhanced modeling of local effects, mesoscale models will be applied.

Some numerical weather prediction models, e.g. the global European Community Medium-Range Weather Forecast (ECMWF) model or the mesoscale model MM5, directly provide forecasts of solar irradiance. These forecasts will be analyzed and further enhanced. Figure 3 presents example evaluations for different irradiance forecasts; derived from MM5, the ECMWF model and a model output statistic (MOS) forecast system (3).

Furthermore methods for forecasting solar irradiance based on predicted cloud properties by numerical weather prediction models will be developed or further improved and tested. Statistical methods will be considered as well as methods based on radiative transfer modeling and a combination of both approaches. Figure 4 shows an example of recent results in parameterized short term forecasting (4,5).

Additional aerosol forecasting will enhance the quality of solar resource predictions, and now casting of solar irradiance will be based on motion vectors derived from satellite images.

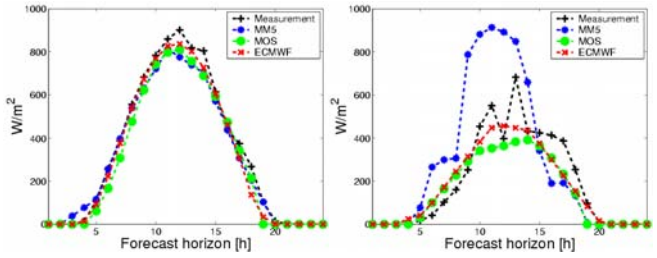

Figure 3: Comparison of different forecast approaches to ground measured irradiance for two test days (June 9 and 16, Germany). 3)

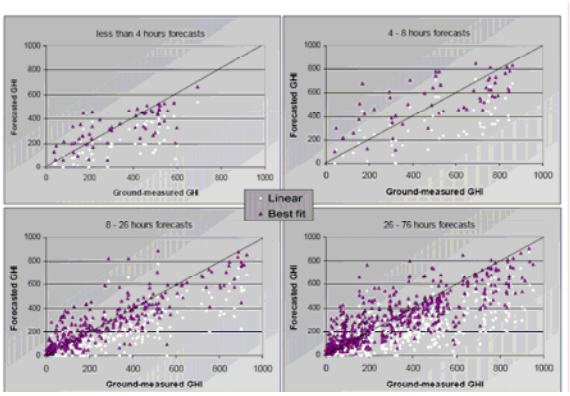

Figure 4: Examples of forecast vs. ground-based irradiance measurements (4,5).

4.4 Collaboration with Other IEA Tasks and Industry

Task 36 has also been designated as a collaborative task, at the "minimal" level, with two other IEA Implementing Agreements: the Photovoltaic Power Systems (PVPS) agreement, and the Solar Power and Chemical Energy Systems (Solar PACES) agreement. With respect to this latter agreement, the SolarPACES ExCo has welcomed Task 36 as a collaborative task with the IEA Solar Heating & Cooling Programme, and Task 36 has been incorporated as Task 5 in the SolarPACES programme.

Task 36 has strong links with industry. Two small companies are directly participating in the task. The audience for the results of Task 36 includes the technical laboratories, research institutions, and universities involved in developing solar resource data products. More importantly, data users, such as energy planners, solar project developers, architects, engineers, energy consultants, product manufacturers, building and system owners and managers, and utility organizations, are the ultimate beneficiaries of the research, and will be informed through targeted reports, presentations, web sites, handbooks and journal articles.

5. NEXT STEPS

A Second Task Experts Meeting is to be held in Denver on July 6-7, 2006, just prior to the Solar 2006 Conference. Based on the anticipated outcomes of this and the first Experts Meeting, the following activities are planned over the next year:

5.1 Subtask A

Selected ground station data sets will be subject to a common formatting and quality control (QC) procedure. Prototypes of formats and QC were planned by March 2006 and to be discussed at the Second Experts meeting.

A proposal for first order quality (MBE, RMSE) and second order quality (match of distributions, temporal correlations) should be available for the Second Experts meeting. A proposal for the preparation of data sets used for benchmarking, subject to appropriate thresholds, should also be presented at the next Experts meeting.

Existing solar radiation products shall be analyzed using the outcome of this activity on establishing measures of data quality. Products analyzed include Meteonorm, Satel-light, Helioclim, Solemi and the Surface Solar Energy (SSE) data sets. This activity will start after the Second Experts meeting.

Finally, preparation of a User's Handbook will begin.

5.2 Subtask B

A report will be prepared that will serve as a guide for the stakeholders of an information system (customers, broker, providers). The report will contain:

- A presentation of subtask B, its motivations, its overall objectives and sketches of the information system (actors, main technologies);
- The roles and responsibilities of the actors, including legal aspects, property rights and ethical aspects (equal treatment of suppliers by a broker) in their relationships;
- Elements that support the belief that the outcomes of subtask B will be exploited by the solar energy community and for its benefits.

This report will serve as a guide for the stakeholders of an information system (customers, broker, providers).

A User Requirements Survey is currently under development, and will soon be made available to a wide range of stakeholders through a central website, and links to this survey will be provided on websites hosted by the Task 36 participating institutions The survey seeks input from data users on a variety of aspects of the data requirements including:

- Economic assessment
- Education
- Resource assessment
- Monitoring systems / maintenance
- Prediction of performance
- Forecasts
- Research activities

Based on the outcomes of the user survey, a limited series of data types available in several databases having different properties but with some redundancy will be suggested. Metadata will be used to describe these databases.

5.3 Subtask C

Several activities in Germany and the US will be undertaken to develop solar radiation forecasts. These will focus on the time range from now casting (several hours ahead) to short-term forecasting up to two days.

Significant effort will be undertaken to further improve solar radiation retrievals using the Meteosat Second Generation satellite. Snow detection procedures shall also be improved in Europe based on the findings in references 4 and 5.

Analysis of long-term variability of solar resources will proceed through inter-comparisons of various long-term data sets to determine the significance of changes in the available solar resources in the last decades, which have been observed for several regions in the world. This work will benefit from improvements made to derive solar irradiance from satellite data with greater accuracy and from further completion of satellite archives.

A feasibility study for solar micro siting will soon be conducted. The study will determine what kind of algorithms could handle the 3D problem, what kind of remote sensing data sets are required as input for proper results and how such new methods could be validated through dense ground-based measurement networks.

5.4 Outreach to the Global Earth Observation System of Systems

In December 2005 a Task 36 letter of introduction was sent to the Secretariat of the Global Earth Observation System of Systems (GEOSS) headquarters office at the World Meteorological Organization in Geneva. The letter suggests possible ways that the Task supports the GEOSS goals. It also explores mechanisms for participation in some joint IEA/GEOSS activities. Members of the task are contributing to the "Renewable Energy Community of Practice" (including co-chair activities) reporting to the GEOSS User Interface Committee. One member of Task 36 is the IEEE delegate to the GEOSS User Interface Committee. It is expected that some of the Task 36 activities will be directly in line with GEOSS objectives.

6. SUMMARY AND CONCLUSION

Task 36 focuses on the development, validation, and access to solar resource information derived from surface-based and satellite-based platforms. The task investigates benchmarking and data quality assessment procedures for data products and validation data sets, examines means by which the data can be made easily available to users through various web-based hosting schemes, and conducts studies on improving the input data sets and algorithms from which satellite-derived products are produced, including the investigation of short term forecasting and past and future climatic variability of the solar resource. Researchers interested in participating in Task 36, and whose countries are official members of the IEA/SHC, should contact the Operating Agent or the Subtask Leaders.

7. ACKNOWLEDGMENTS

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8. REFERENCES

(1) Renné, D., George, R., Marion, B., Perez, R., Schillings, C., Triieb, F., Meyer, R., Pereira, E., Martins, F., de Abreu, S. L., Colle, S., Vibradas, M., Stackhouse, P., Gueymard, C., Results of the Solar Resource Assessments in the UNEP/SWERA Project, Proceedings, Solar World Congress 2005, Orlando, FL, August 2005.

(2) Gueymard, C. and R. George, Gridded aerosol optical depth climatological datasets over continents for solar radiation modeling, Proc. Solar World Congress, International Solar Energy Society, 2005

(3) Girodo, M., PhD thesis Oldenburg University 2006, in progress

(4) Perez, R., P. Ineichen, K. Moore, M. Kmiecik, C. Chain, R. George and F. Vignola, A New Operational Satellite-to-Irradiance Model. Solar Energy 73, 5, 307-317, 2002

(5) Perez, R., M. Kmiecik, S. Wilcox, P. Stackhouse. Deriving Long Term High Resolution Solar Irradiances from Low Resolution Archives via Microstructure Patterning; to be published in the Proceedings Solar 2006, Denver, CO, July 2006.