SOLEMI: A NEW SATELLITE-BASED SERVICE FOR HIGH-RESOLUTION AND PRECISION SOLAR RADIATION DATA FOR EUROPE, AFRICA AND ASIA

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Abstract – Solar Energy Mining (SOLEMI) is a new service set up by the DLR (Deutsches Zentrum für Luft- und Raumfahrt) providing high-quality irradiance data for the solar energy community. The service is mainly based on Meteosat-data, from which solar radiation maps with a nominal resolution of 5 km and hourly time-series can be derived for almost half of the Earth's surface: the field of view given by Meteosat-7 placed at 0° longitude and additionally Meteosat-5 placed at 63°E over the Indian Ocean is provided. Thus, for the first time high-resolution radiation data become available for most parts of Asia. Fast access to the complete Meteosat-7 region at full resolution is also a novelty. Besides Europe, this now offers access to solar radiation data all over Africa and also the Northeast of Brazil. Different to other schemes for derivation of solar radiation from Meteosat the cloud detection scheme of SOLEMI makes use of the visible and the infrared channel. Modeling of the daily variation of the background brightness temperature improves detection of thin cirrus clouds, which are hard to recognize in the visible channel. SOLEMI will provide operational access to quality-controlled homogenized long-term time-series of large regions within the view of both satellites. This is achieved by user-optimized storing of the data in a fast mass archive.

1. INTRODUCTION

Planning of great solar systems today often still suffers from the availability of reliable solar radiation data. This is valid especially for many developing countries, which often have favorable conditions for solar energy use. Generally, solar radiation measurements are scarce and expensive. Production of a representative time-series is a long-term activity, which needs good logistics and technical know-how for set up and data analysis.

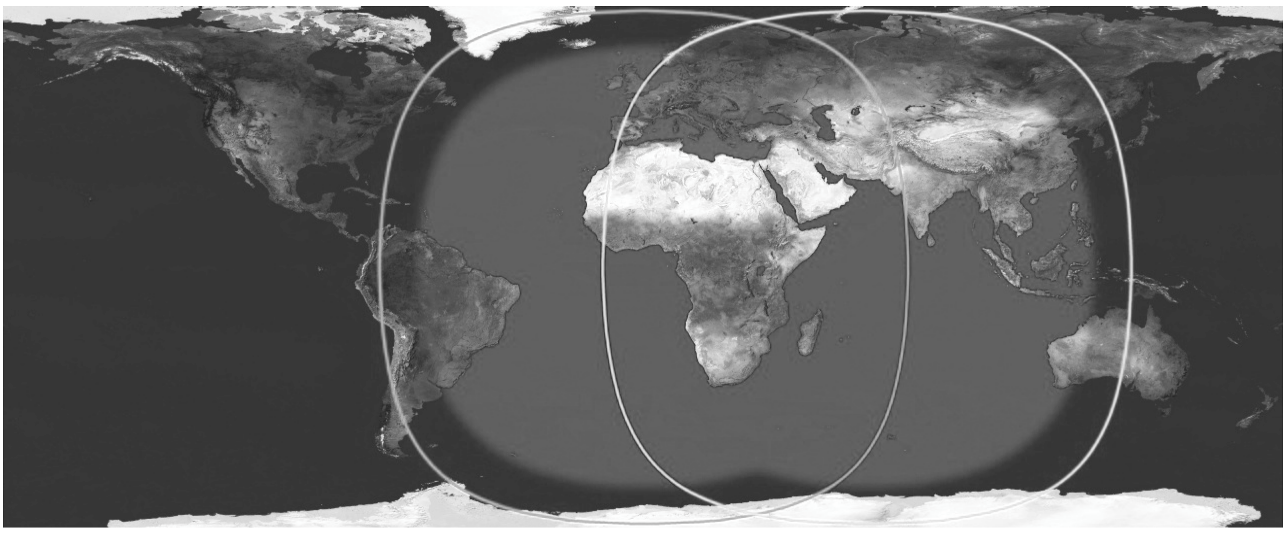

Figure 1: *World map with the areas offered by SOLEMI. The solar irradiance data is based on Meteosat positioned a 0° (dark gray line) and at 63° East (light gray line). The brightened area marks the quantitatively usable area.*

Deriving solar radiation at the Earth's surface from satellites gives the chance to offer comparable data for extensively wide regions with a reasonable effort. Most geostationary weather satellites are operational since the early 1980's and provide data with half-hourly resolution. Availability of continuous long-term series of satellite data enables retrospective analysis of solar radiation data for sites far off any reference measurement. Great areas, e.g. whole countries may be analyzed at once and quality of this data is more comparable than individual measurements at the ground. Such consistent, data sets with blanket coverage allow for detailed analysis of solar energy potentials, e.g. by means of the GIS-based STEPS analysis system for ranking of solar thermal power stations (Brösamle et al., 2001).

For Europe several satellite-based radiation data sets are already available (e.g. Rigollier et al., 2001). Basically these schemes are designed to derive global horizontal radiation (GHI). Direct normal irradiance (DNI) then is retrieved by statistical approaches like Perez et al. (1992) or Olseth. and Skartveit (2001) that separate GHI into diffuse and beam radiation. DNI-data estimated by this procedures therefore have less accuracy than GHI-data. But especially planning of solar thermal power stations requires direct radiation. The high investments sums involved in this technology need very high accuracy for planning. Thus, the new service presented here „Solar Energy Mining" (SOLEMI) primarily focuses to provide high-precision DNI data. For this purpose the scheme of Schillings et al (2003a) is applied, which directly derives DNI from satellite data. For representative annual averages it is required to analyze a long-term time-series. SOLEMI therefore aims to offer a time-series based on more than 10 years of high resolution Meteosat-data.

Many of the interesting sites for solar thermal power stations are situated outside of Europe. SOLEMI provides data for regions as wide as possible: The field of view of the 'classical' Meteosat-satellites at the geostationary Prime meridian position (see figure 1) covers besides Europe, all of Africa, the Eastern part of Brazil and the Arabian Peninsula. SOLEMI additionally archives data for the Meteosat-East position. Since July 1998 Meteosat-5 operates at 63°E over the Indian ocean. This additionally enables to produce data for a large part of Asia.

2. METHOD

For derivation of the direct normal irradiance the method of Schillings et al. (2003a) is applied. Meteosat-data are used to derive the impact of clouds on DNI. Influence of other atmospheric constituents is calculated according to the clear-sky parameterization model developed by Bird (1981) and modified by Iqbal (1983). Instead of using a general turbidity index like most other procedures we treat each important constituent separately. The influence of the various constituents on DNI is visualized in fig. 2.

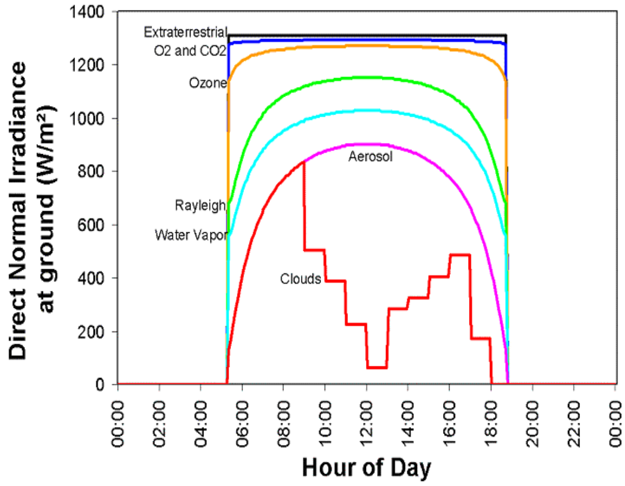

Figure 2: *Example of the hourly variation of solar irradiance for true solar time during one day. The plot separates the influence of the different atmospheric constituents on direct normal irradiance. Clouds have strongest impact and show the highest temporal and spatial variability.*

For each atmospheric parameter we try to implement the most suitable and validated long-term data set. Today we obtain atmospheric water vapor from the NOAA-NCEP (National Oceanic and Atmospheric Administration - National Centers for Environmental Prediction) NCDC-data (National Climatic Data Center), which is based on reanalysis of a global weather model. Impact of aerosols is taken from NASA-GISS (National Aeronautics and Space Administration – Goddard Institute for Space Studies) GACP-data (Global Aerosol Climatological Project). Influence of ozone is accounted for by satellite data from the TOMS-sensor (Total Ozone Mapping Spectrometer). From these data set the transmission of the cloud-free atmosphere is calculated.

Strongest influence especially to the beam radiation have clouds. Different to other methods the SOLEMI cloud parameterization scheme is a two-channel procedure, which uses the visible channel of Meteosat (0.45 µm to 1 µm) but also the infrared channel (10.5 µm to 12.5 µm.). The additional application of the infrared channel allows for improved cloud detection at sunrise and sunset, when low sun elevation often leads to unusual reflections. The infrared channel also has a higher sensitivity for the extremely cold high ice clouds. Both effects are of special importance for the calculation of direct normal irradiance.

3. AVAILABILTY AND QUALITY

By use of the DLR mass data archive at DFD (Deutsches Fernerkundungs-Datenzentrum – German Remote Sensing Data Center), which also houses the World Data Center for Remote Sensing of the Atmosphere it is possible to archive all data in full spatial and temporal resolution. Archive organization and processing under the Data and Information Management System (DIMS) allows fast access to many years of data. The operational high performance computing environment offers rapid processing, high availability and good quality assurance.

Today a five year data set is available for Meteosat at 0°. It is planned to elongate these data for more than 10 years. The now available one year data set for Meteosat East is in the process of completion back to the first measurements in 1998.

The derived DNI data is validated against a full year of high-quality direct radiation measurements in Saudi-Arabia (Schillings et al., 2003b). On average over the eight evaluated measurement sites (see figure 3) in this region the mean bias error is +4 %, with a standard deviation of +/- 8% for the yearly sum. Of course, the root mean square errors for shorter time intervals increases, but the small bias error of the annual mean is convincing and shows that these data are a good base for planning purposes.

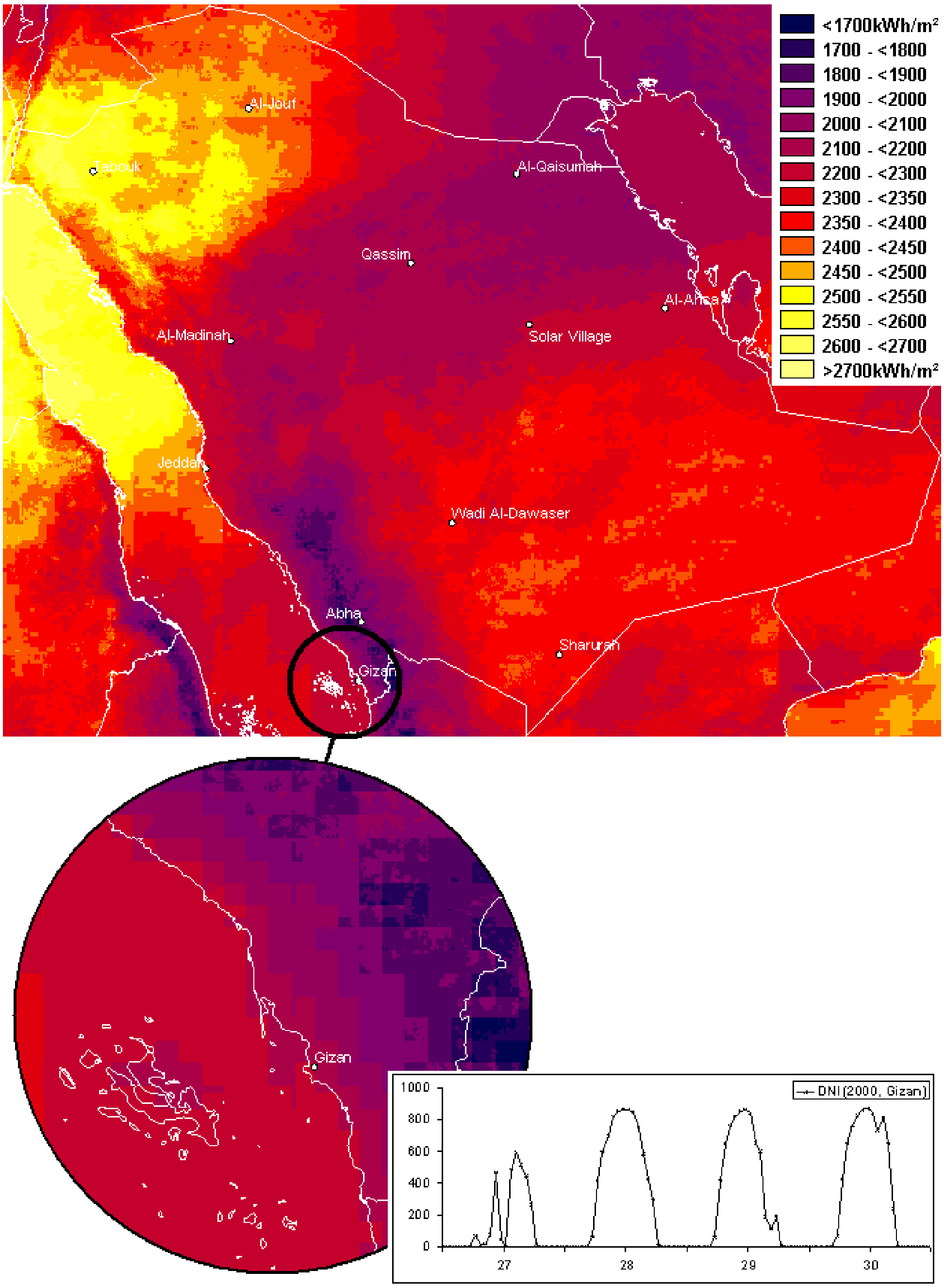

***Figure** 3: Map of the annual sum of DNI in kWh/m² for the year 2000 for the area of Saudi Arabia. An hourly time series in W/m² can be extracted for each pixel. Four days in April 2000 for the location Gizan are shown as example.*

4. CONCLUSIONS AND OUTLOOK

The service 'Solar Energy Mining' is based on approved global long-term data of the atmospheric constituents relevant for absorption and scattering of solar radiation. Together with cloud information retrieved from high resolution Meteosat data now direct normal irradiance can be provided for the full view of the two operational satellites Meteosat-7 at 0° and Meteosat-5 at 63°E based on 5 km nominal resolution. Meteosat-5 data cover such auspicious regions as India, Pakistan or China. Other promising countries at the Saudi Arabian Peninsula may be also analyzed by Meteosat-7 but Meteosat-5 there provides even better viewing conditions. Validation of the currently used algorithm by eight sites spread over Saudi Arabia gives an average mean bias error of 4%. Thus, SOLEMI can be regarded as a powerful service for concentrating solar energy at a plenitude of interesting sites worldwide.

In the future also an algorithm for global radiation, e.g. on base of the HELIOSAT-method (Hammer et a. 2003) will be implemented. This allows to use the high availability and quality of SOLEMI also for non-concentrating solar energy technologies. Resolution then should be improved using the original 2,5 km data of the Meteosat visible channel. In the next two years SOLEMI will be improved towards a fully operational customer-driven system. The final data set should cover more than 20 years of data from the Meteosat 0°-position. After the new Meteosat Second Generation gets operational it is planned to interface these data with the SOLEMI time-series. For Meteosat-East a period of seven years could be reached, if the satellite continues its service until end of the year 2005 as it is currently planned by EUMETSAT. More and current information can be found at the SOLEMI website http://www.solemi.com.

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