The ESA – ENVISOLAR project: Experience on the commercial use of Earth observation based solar surface irradiance measurements for energy business purposes

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Abstract

Within the Earth Observation Market and Development (EOMD) programme at the European Space Agency (ESA) the ENVISOLAR project aims at an intensified usage of Earth Observation based information products in the solar energy industries. Existing services for investment decision, plant management, load forecasting and for science and consulting rely on high quality surface solar irradiance measurements and credible processing chains to deliver such information regularly. The ENVISOLAR consortium has identified a list of blockages preventing the increased use of Earth Observation techniques up to now. Parallel to ENVISOLAR, the EU 5. Framework project HELIOSAT-3 develops a new physically based method to derive surface solar irradiance. It is analysed how the new Heliosat-3 method helps to solve such blockages. Additionally, it is reported how ENVISOLAR intends to solve some of the blockages identified within its project duration.

Keywords: market development, investment decision services, plant management, load forecasting, irradiance time series, small and large photovoltaics, solar thermal electricity

1. The ESA EOMD program

The European Space Agency (ESA) with its Earth Observation Market and Development (EOMD) program supports the industrial usage of Earth Observation based information products. EOMD offers the opportunity to evaluate the usage of Earth observation based products and to assess the value of such products for any kind of commercial service. All activities initiated under EOMD are defined in close co-operation with industry through dedicated workshops, industry briefings and individual company feedback.

A typical EOMD consortium consists of Earth Observation data providers, market players using such satellite-based data products and selling value-added end user services and key customers using such end user services for their downstream business.

Typical EOMD work-packages include the following list of activities: build up an integrated service chain from EO provider to market player, upgrade both EO provider and market player service chains, perform a science review, set up a business plan for market player services, create example customer products, do market trials with key customers, learn from market trials and improve service chains, do again market trials, do marketing and promotion for market player services and set up and revise a business plan.

2. The ENVISOLAR project

To support the industrial use of Earth Observation information for solar energy industry needs, DLR has teamed up in the EOMD project ENVISOLAR with several sub-contractors. The consortium holds strong scientific, engineering and marketing skills on environmental information for solar plant management and a well established access to the target markets:

- DLR German Remote Sensing Data Center (D) as operational service provider responsible for atmospheric parameter data sets
- Ecole des Mines/Armines (F) and Oldenburg University (D) as operational service provider responsible for irradiance parameter retrieval using Meteosat and Meteosat Second Generation satellites

The basic activity of all EO service suppliers is the retrieval of surface solar irradiance from Meteosat and Meteosat Second Generation satellites using atmospheric information on cloud, aerosol, water vapor and ozone distribution in time and space (Fig. 1). The aim is to retrieve spectrally resolved direct and diffuse solar surface irradiance in a high temporal and spatial resolution for historical long term time series (> 10 years time series length) and in near-real-time for monitoring purposes.

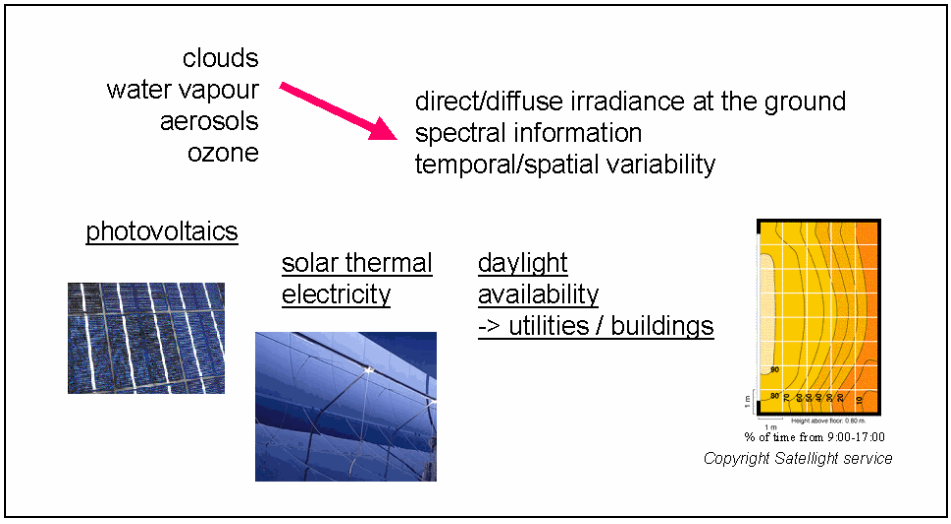

Fig. 1 Principle of solar surface irradiance retrieval and applications

Such data is used by the market players to offer the following services:

- investment decision services for solar thermal electricity, big PV, and small PV plants
- plant management services (both big PV and small PV)
- load forecasting for electric utilities
- irradiance times series for science and consulting

Both investment decision services and irradiance time series service need long-term historical data sets, while the plant management and the load forecasting service needs near real time products. A schematic overview of the inter-relationship of ENVISOLAR services and applications gives Fig. 2.

The target market can be divided in three main markets: (a) institutional investors, assurances and banks, and, to ensure their benefits, professional operators for solar power plants ('big' solar market), (b) private investors and their craftsmen ('small' solar market), and (c) utilities and load management software creators/operators as the utility's market.

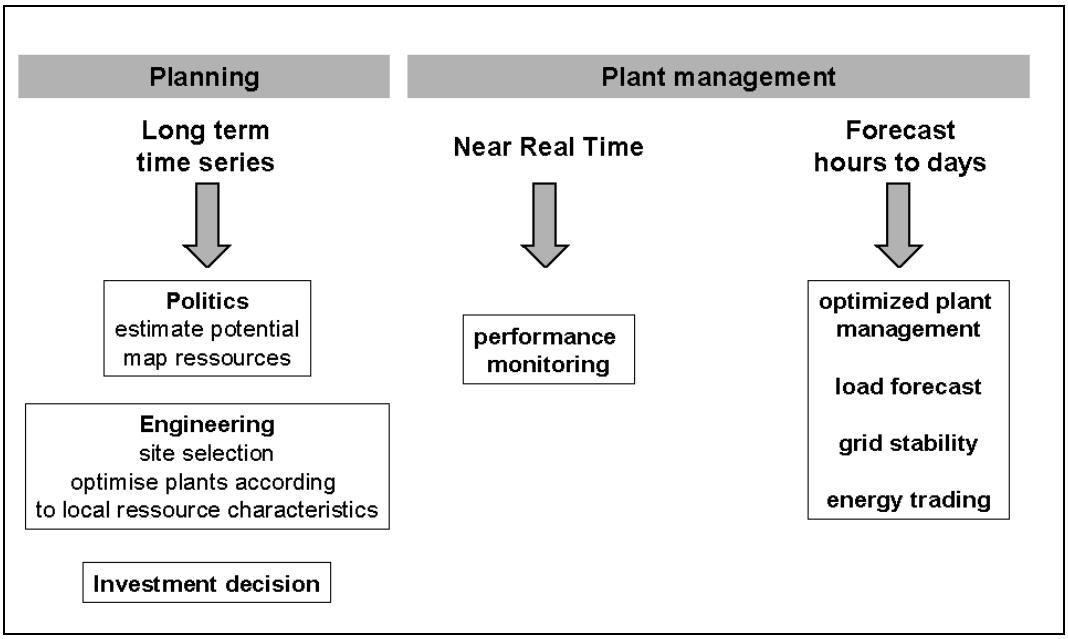

Fig.2 Structure of different ENVISOLAR services and possible applications

The group of market players providing the ENVISOLAR services to end customers consists of:

- Armines – Les Presses (F), interested especially in spectrally resolved irradiance time series for various customers. Armines - Les Presses has sold the European Solar Radiation Atlas (ESRA) for many years.
- DLR Institute of Technical Thermodynamics (D), working especially in the field of concentrating solar thermal systems. DLR-TT has developed and employed the STEPS GIS tool for siting of concentrating solar thermal power plants.
- Enecolo AG (CH), interested especially in photovoltaic system performance monitoring, load prediction for utitilies and site audit. Enecolo AG is very experienced in audit and monitoring of photovoltaics.
- meteocontrol GmbH (D), is experienced especially in simulation results for investment decisions, in performance monitoring for photovoltaic plant management, and in load prediction for utilities.

The following companies agreed to act as key customers and to assess the ENVISOLAR services: Edisun Power AG is a contracting company for renewable energies. It finances, builds and operates at present mainly photovoltaic installations. Enercity Stadtwerke Hannover AG is the public utility for the city Hannover/Germany. SAG Franchise as an umbrella organisation offering central purchase, planning and financing budgeting for craftsmen which install photovoltaic systems mainly for private owners. stromaufwärts GmbH does planning, construction and operation of grid connected and off-grid photovoltaic power plants. TECSOL S.A is a technical consultancy specialised in energetics for private and public clients.

ENVISOLAR started on 1st December 2003 and concluded its phase 1 in November 2004. Phase 2 of the project is dedicated to market trials and will take place until the end of 2006.

3. ENVISOLAR services

3.1. Services for investment decision

To optimise the financial yield, site assessment is necessary for the investor. This is provided by GIS (Geographical Information System) based services as e.g. STEPS (http://www.dlr.de/steps) or Premium Site Audits (http://www.meteocontrol.de). By such means it is possible to find the optimal location for solar power plants. With increasing plant size and therefore higher investments, the investors need better site optimisation.

On the other hand the financing of solar power plants is based largely on loans. Therefore, financial institutes and insurers expect precise audits before they give their approval for a loan to an investor. For large plants at least two site audits are required: One or two have to be provided by the investor and one is ordered by the bank itself to confirm the basic figures for the investment decision.

For the market of small solar energy systems an estimation of the expected yield is required also by the private investor to minimise the risk of loosing money and to compare the offers of different suppliers. As he does not pay for this service at this stage of the selling process, the yield estimation has to be very cost effective. The number of offers is high and therefore, access to this kind of yield estimation has to be easy and fast. An example for such a service is the Solar'Webservice offered by Meteocontrol GmbH (http://www.meteocontrol.de).

3.2 Services for plant management

To assure good benefit from the installed solar energy systems, plant monitoring must be realised for every plant. To meet the different demands, the scale of service is different. Smaller solar energy systems need low cost monitoring ("performance check"), while large solar energy systems need detailed monitoring with automatic fault detection routines (see http://www.pvsat.com). Both services aim at a reduction of down time and fast ("automated") detection of faults.

3.3 Load forecast service

Currently, load forecasting (http://www.meteocontrol.de) becomes an increasingly important issue for electric utilities. More sophisticated methodologies, which take into account several meteorological quantities including solar irradiance, are introduced. This has to guarantee that at any time utilities provide exactly the power that is needed by their customers, otherwise major grid failures as recently experienced in the USA may result. With a higher penetration of the grid by renewable energies also the production becomes strongly weather dependent. Today wind power prediction is already an urgently needed service in some European countries. In the near future also a precise prediction of solar electricity production will become necessary.

3.4 Time series for Science and Consulting

Time series, maps and statistics of irradiance, direct and diffuse components and spectral components such as illumination will be provided to the user (http://www.soda-is.com). Time series are used to calculate the yield of solar thermal and photovoltaic power plants. Furthermore, they can be used to estimate light and heat demand within buildings for architectural purposes. Time series are a semi-finished product on which all other products are built but there is also a market for raw time series. In general, planners, architects and scientists are the key customers for this sector.

4. Blockages identified

Already during the proposal writing phase the consortium members have identified the following list of blockages which prevents the use of satellite-based irradiance information in the solar energy market.

4.1 Blockages related to the products

Present algorithms to derive surface solar irradiance are based on simple empirical approaches and do not appropriately take account of the distribution of atmospheric constituents as clouds, aerosols, water vapour and ozone.

1) Quality of hourly irradiance data based on satellites needs to be improved.
2) No spectrally resolved satellite-based irradiance data is available today.
3) Some users already operate software tools and need access to complete meteorological data sets e.g. irradiance combined with temperature for solar power plants and load forecast simulations. As satellite based precursor services often does not offer this additional information, these users still use irradiance maps which are interpolated from ground measurements but offer additional information as e.g. air temperature in the same data format.
4) Load forecast is a new service, but there is no experience available concerning the accuracy.

4.2 Blockages related to the services

1) Up to now there is a fragmentation of service offers, which prevents from meeting customer's requirements.
2) Existing archives of satellite-based irradiances are restricted in terms of spatial coverage, length of time series, and temporal and / or spatial resolution. This is due to the amount of data of geostationary satellites.
3) The reliability of the Near Real Time processing chain is not sufficient.
4) There is also the need for further customer orientated software based on web services.

4.3 Blockages related to supply and distribution

1) There is a lack of suitable infrastructure for fast access to irradiance time series with high spatial resolution. This results in long delivery times unacceptable for customers who require a time series for a certain region.
2) Additionally, there is a lack of suitable infrastructure for near real time (within 24 hours) access to irradiance data.

4.4 Blockages related to benefits & costs

1) In parallel to the ENVISOLAR services there are cost free or low cost sources with coarse resolution and low quality available. They are mainly interpolated from ground data and satellite based data sets for climatology purposes or from NWP models. Therefore, it is important to raise awareness of the value of high quality and high resolution data.
2) ‚Service versus investment': Customers have to decide between paying an on-going satellite-based service or investing once for a ground-based measurement device at their plant and maintaining it.
3) The solar industry is both price and quality sensitive. Certain customers planning large investments and needing bankable audits are used to expensive ground measurements and therefore, they are willing to pay for high quality data. But on the other hand the quality of satellite-based data has to be comparable to ground measurements. Other customers as e.g. privat home owners with lower demands on quality will be much more price sensitive but accept lower quality as well.

4) One group of customers uses irradiance time-series embedded in plant sizing software, which does not take the geographical coordinates of the planned site into account. These users seem to be unaware of the atmospheric variability and its influence on the result of their simulations.

4.5 Blockages related to customers

1) Lack of awareness in the energy industry of the benefits of satellite data (e.g. consistent and grid-average data sets over large regions).
2) Lack of demonstration of EO capability on practical trial cases relevant for the solar industry.
3) Missing awareness how reliable the Meteosat satellite group is.

5. Benefits of the new Heliosat-3 method

5.1 The new Heliosat-3 method

Within the European Commision, 5th framework project HELIOSAT-3 a new method is currently under development. It is physically based and uses cloud physical parameters together with aerosol, water vapour and ozone concentration directly to retrieve surface solar irradiance. The Heliosat-3 method aims at eliminating several of the shortcomings in the existing schemes and exploiting the capabilities of the new generation of European meteorological satellites (Meteosat Second Generation (MSG), now Meteosat-8, and METOP).

Up to now, based almost exclusively on the visible among the 3 available channels, cloudiness has been retrieved as a mixture of cloud amount and cloud opacity. The Meteosat-8 SEVIRI, with its carefully selected 12 spectral channels, allows not only a much more precise characterisation of clouds, but also retrieval of atmospheric water vapour, ozone and, partly, aerosols. Knowledge of these components allows considering use of real-time radiative transfer modelling (RTM) for solar irradiance estimates. However, this is not as straightforward at it may seem at the first glance.

Spatial resolution in the high resolution visible (HRV) channel is now 1 km at nadir instead of 2.5 km and 3 km instead of 5 km in the other visible and infrared channels, respectively, while the repeat cycle is 15 instead of 30 minutes. This means that for covering Europe, about 3 millions pixels ought to be processed every 15 minutes. Heliosat-3 makes operational use of integrated RTM calculations possible by introducing an ingenuous parameterisation of the diurnal variation of global irradiance (Mueller *et al*., 2004). Integrated calculations are much more flexible and efficacious than use of pre-calculated look-up tables. Furthermore, the selected RTM allows retrieval of spectrally resolved irradiances.

Additionally, it should be stressed that use of water vapour and aerosols instead of turbidity factors in radiative transfer calculations allows a more realistic estimate of direct beam and diffuse (sky) irradiances, both elements being essential to many solar energy applications.

Current distributions of daily column water vapour can be extracted from the TIROS Operational Vertical Sounder (TOVS) measurements performed by the NOAA polar orbiters and are available at the World Data Centre for Remote Sensing at DLR on an interpolated grid with 0.5^{o} (55 km) mesh width. Derivation of substantially better spatially resolved data from Meteosat-8 SEVIRI is also now available for Heliosat-3 (Schroedter-Homscheidt et al., 2004).

Current distributions of daily total column ozone are derived from the Global Ozone Monitoring Experiment (GOME) onboard of the ERS-2 satellite, from the NASA Total Ozone Mapping Spectrometer (TOMS) and from SCIAMACHY onboard of ENVISAT. GOME and SCIAMACHY data are processed at the DLR Remote Sensing Data Centre (DFD) in near-real time. All three data sets can be interpolated according to their characteristic time frequency in order to yield 0.5^{o} resolution (55.5 km) ozone column maps (http://wdc.dlr.de) (Schroedter-Homscheidt et al., 2004).

Earth Observation based determination of aerosol optical depth (AOD) and aerosol type is a developing field. A synergetic retrieval method (SYNAER, Holzer-Popp et al., 2002a und b) exploiting a spectrometer and radiometer combination has been developed and validated at DLR-DFD with GOME and ATSR-2, both onboard ERS-2. Extension of SYNAER to the SCIAMACHY and AATSR combination onboard ENVISAT is currently being developed. Another source of data could originate from the MISR and MODIS instruments onboard EOS-TERRA and AQUA, respectively and in future from the operational METOP programme. Currently, however, AOD and aerosol type still must be extracted from climatological data collections. The backup climatology for Heliosat-3 was produced by means of the SYNAER method based on GOME/ATSR-2 and of the Global Aerosol Data Set (GADS) OPAC database. It contains

14 months (July 1997 to August 1998) and covers Europe and Africa on a 5° grid. A Linke turbidity climatology, interpolated on a 5 minutes of arc grid is available at www.helioclim.net/-linke/index.html, and recently Cros et al. (2004) have merged both by means of data fusion techniques. Needless to say that the backup climatology is going to be progressively supplemented and, eventually be replaced by daily estimates as soon near-real-time processing of aerosol data will become operational.

Daily values of the inputs on 50 x 50 to 100 x 100 km grids appear as acceptable for implementing Heliosat-3 operationally. Variation of total column content and of aerosol optical depth within the time frame of a day is predominantly less than fluctuation of cloudiness within the same time. Computing time limitations hardly allow claiming for finer meshes. Thus, running the clear-sky module on a coarser grid and modulating its results with cloudiness at pixel resolution for all pixels in a mesh is definitely a fair trade. Fig. 3 gives a scheme of the Heliosat-3 principle of combining high resolution cloud information with clear sky parameters like aerosols, water vapour and ozone.

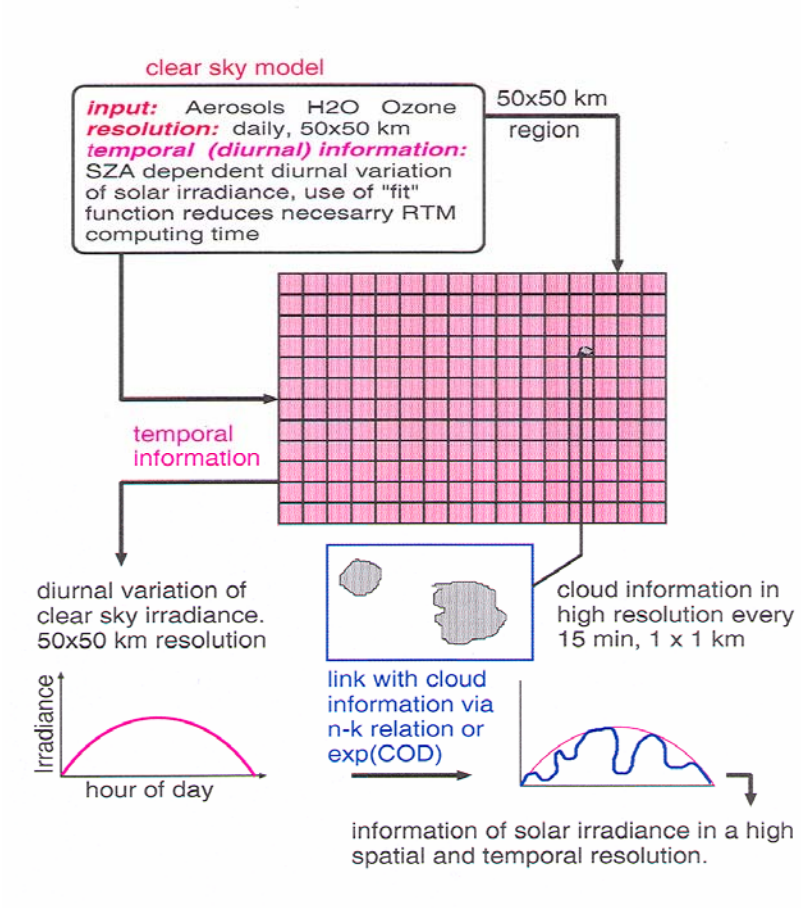

Figure 3: Spatial and temporal linkage between clear-sky and all-skies irradiance retrievals (Fig. 1 of Mueller *et al*., 2004).

5.2 Heliosat-3 answers to blockages related to the products

The new algorithm version Heliosat-3 combines satellite-based atmospheric retrieval methods for clouds with state-of-the-art retrieval schemes for aerosols, water vapour and ozone. Deriving physically parameters as optical thickness or concentrations allows the usage of radiative transfer models explicitely in the irradiance calculation. Taking more detailed information about aerosols, water vapour and ozone into account improves the quality of irradiance data.

Meteosat Second Generation provides 4 images per hour instead of 2 images per hour which have been offered by the Meteosat satellites. Averaging these 4 images per hour represents the hourly average and also the variability inside one hour better.

The new algorithm version HELIOSAT-3 uses radiative transfer calculations instead of empirical relations. Therefore, it is able to produce spectrally resolved irradiance products with 20 wavelengths between 0.24 and 4 μm. Fig. 4 shows the difference between broadband and spectrally resolved irradiance products schematically.

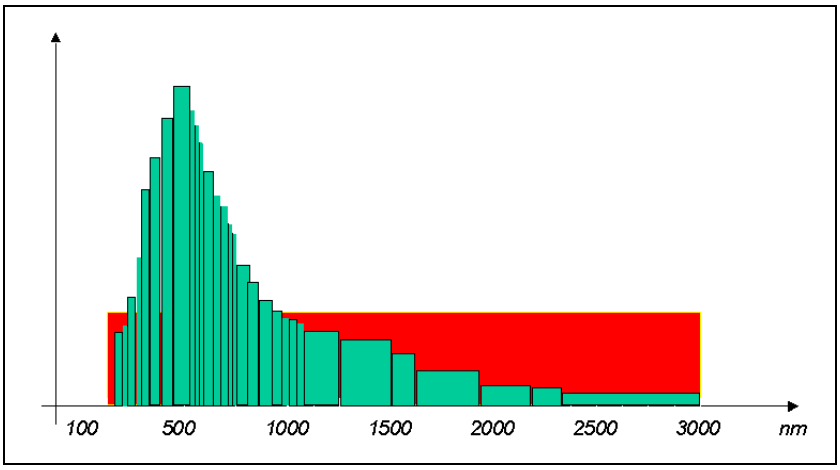

Fig. 4 Schematic view on spectrally resolved Heliosat-3 irradiance products

Information as air temperature is difficult to retrieve from satellites, but can be derived from weather prediction models in good quality. The market players will add this further parameter to the service in their value adding chain.

6. Benefits of the ENVISOLAR project

6.1 ENVISOLAR answers to blockages related to the services

Providers of several precursor services as the European Solar Radiation Atlas (ESRA, 2000), PV-SAT (http://www.pvsat.com), Safer'Sun (http://www.meteocontrol.de), SoDa (http://www.soda-is.com), STEPS (http://www.dlr.de/steps), or SWERA (http://swera.unep.net) have now teamed up for this EOMD activity in order to combine and adjust their activities. The rather costly way of producing basic irradiance parameters will be brought in line. These basic irradiance parameters are then used in the market players value adding chain specific to his individual customer structure.

During this project the long-term and large data set oriented archive facility at DLR will be included in the processing chain. To face the blockage of poor availability of long-term solar irradiance data set the service Solar Energy Mining (SOLEMI) is set up at DLR. SOLEMI will cover the full set of Meteosat First Generation data since 1983 and will be continued by MSG (see also http://www.solemi.com and Meyer et al., 2004).

It is planned to build up redundancies in data reception (e.g. two MSG antenna systems at DLR and one at Oldenburg University) and processing facilities at DLR, Ecole des Mines and Oldenburg University. Additional investments to improve the stability of the NRT chain will be done at Oldenburg University (special hardware, employment of dedicated IT specialist). Fig. 6 shows the improved technical infrastructure for automatic acquisition monitoring e.g. at DLR and automatic quality monitoring at University of Oldenburg. An important detail for high data availability is that archived data are fully kept redundant on different media types of which the backup copy is kept at a different site.

New software tools as specific web services at the market player sites will be developed which are feasible to supply different customer requirements (see e.g. fig. 7).

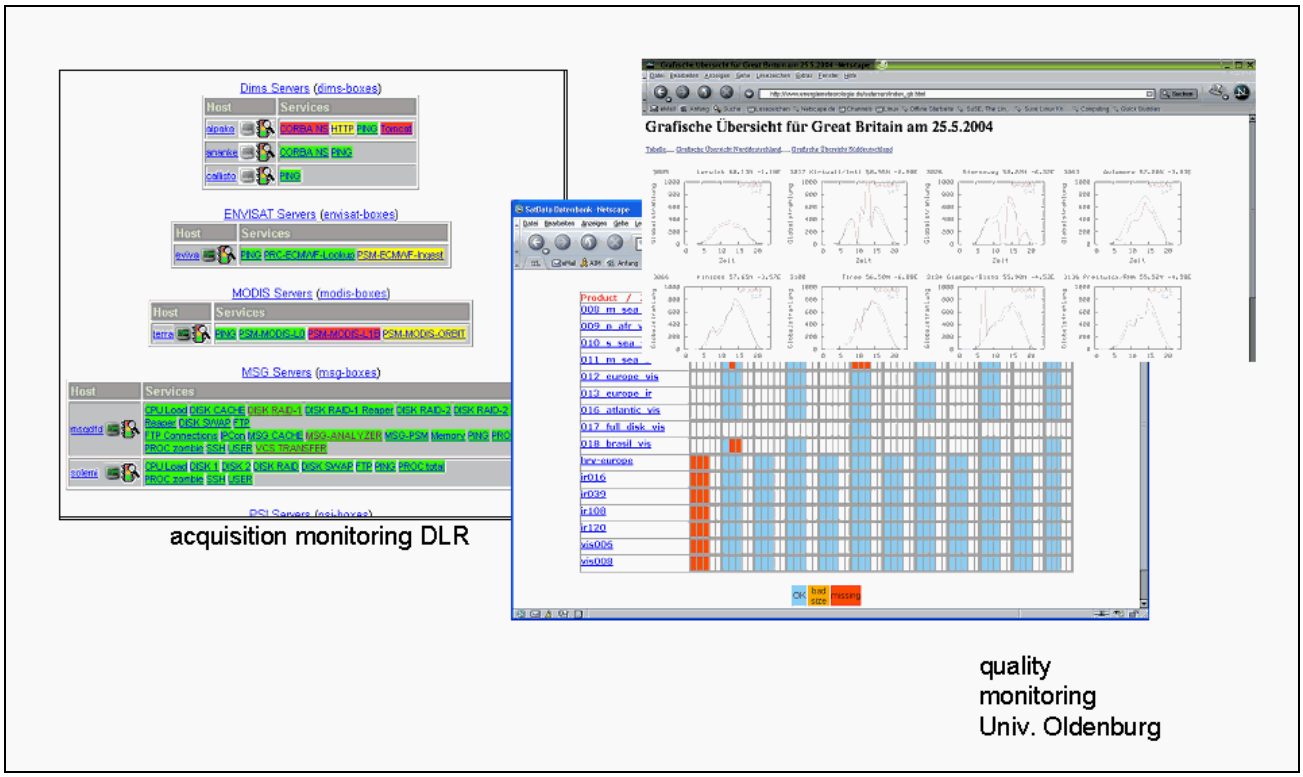

Fig. 6 Automatic monitoring tools as developed within the frame of ENVISOLAR

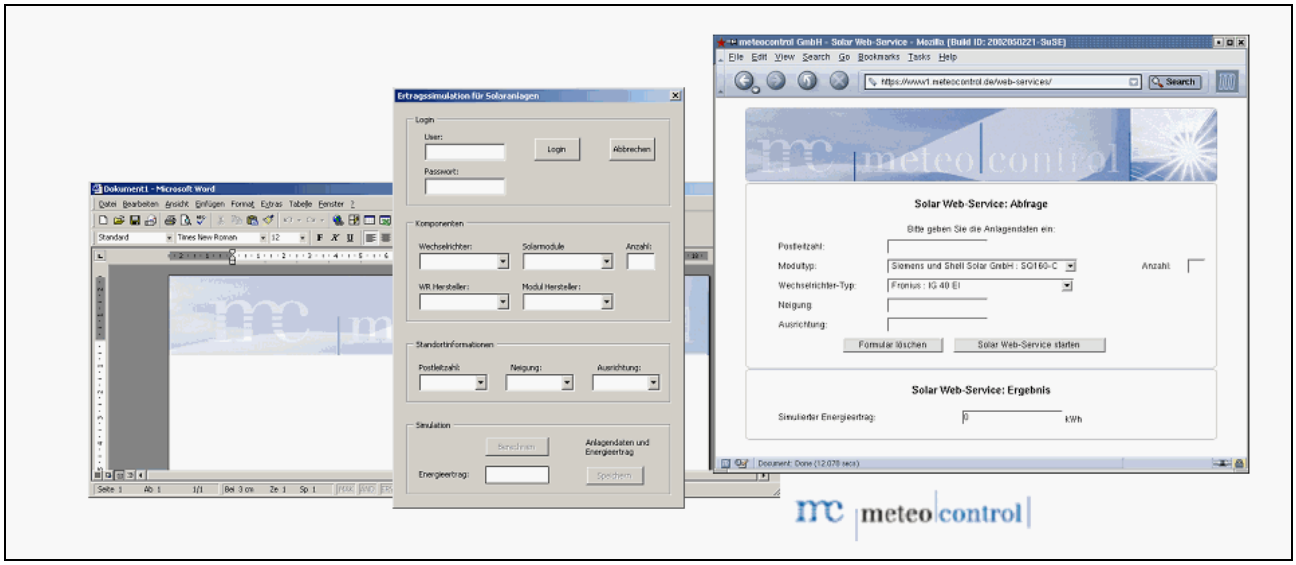

Fig.7 Examples for new web services at the market player Meteocontrol GmbH

6.2 Answers to blockages related to supply and distribution

The long-term archive structure for Meteosat data at DLR is under revision at the moment in order to guarantee fast access to long term time series in full Meteosat resolution. The data structure is changed from a full-disk image-wise access towards an access on time series of tiles. This technology will also be used in this EOMD activity in order to assure fast access to full resolution time series.

Redundancies in the receiving and processing systems will help to improve the Near Real Time reliability.

6.3 Answers to blockages related to benefits & costs

Phase 2 of the ENVISOLAR project will be dedicated to quantification of the value of high quality irradiance data in high spatial, temporal and spectral resolution for the customer. Several market trials together with the key customers involved in the consortium will be conducted. Based on these results, marketing will be focused on to show the advantage of an ongoing, monitored and controlled professional service with higher spatial resolution.

Market player services have to adapt for different groups of customers and offer medium quality products at low costs in parallel to high quality products at higher costs. This is justified by different efforts in obtaining the data and securing their quality.

The spatial and temporal (year to year) variability of the solar irradiance field will be made aware to users via training and promotional activities. The need of site specific long term data for precise high quality planning will also be analysed in further detail.

Additionally, the market players will offer irradiance time series in the relevant data format. So, the customer can stay to his known software, but also use a suitable time series file for the location he wants to analyse.

6.4 Answers to blockages related to customers

Marketing will be focused on to show the advantage of an ongoing, monitored and controlled professional service with higher spatial resolution. Key customers (Edisun Power AG, Enercity Stadtwerke Hannover AG, SAG Franchise, stromaufwärts GmbH, TECSOL S.A**)** act as partners in the consortium. Pre-commercial trials will be conducted with them and further key customers such as utilities, PV system suppliers, banks and large industry associations.

To show the reliability of geostationary satellites, information material about the Meteosat satellites will be provided. Especially, the backup system of the Meteosat satellites is emphasized and ENVISOLAR will also provide typical statistics of missing images and image errors showing the reliability of the services.

7. Conclusions

ENVISOLAR offers the possibility to extend existing precursor services based on solar surface irradiance information derived from satellites. It also allows to analyse blockages preventing the energy industries from usage of such information products and to work on the removal of such blockages.

ENVISOLAR aims at the usage of the operational meteorological satellite programmes Meteosat Second Generation (MSG) and the European Polar System (EPS) with its METOP satellites. Having such operational satellites with their extensive reliability and availability is the basis for the development of value added services like the ENVISOLAR services for investment decision, plant management, load forecasting and time series for science and consulting.

Additionally, information on the atmospheric composition – especially clouds, aerosols, water vapour and ozone concentrations- needs to be made available in near real time and with high availability and reliability. Only such basic information allows the development of the ENVISOLAR value added services on a commercial basis.

On the other hand, such basic information on atmospheric parameters has only a negligible commercial value itself. It helps the solar energy industries as input data set, but the costs to generate such data are probably larger than their value as ‘just input data’. Therefore, we recommend to provide such basic information on atmospheric parameters on a regular basis to the value adding industries as e.g. the market players involved in the ENVISOLAR project. This would increase the competitiveness of European industries in the field of solar energy.

Besides the development of commercial services for solar energy industries within the EOMD program, ENVISOLAR helps to increase the usage of solar energy itself. This meets the requirements set up by a group of policy drivers like the Kyoto protocol concerning the reduction of greenhouse gases, the EU green paper ‘Towards a European Strategy for the Security of Energy Supply’ from the year 2000, the EU white paper ‘Energy for the future: Renewable Sources of Energy’ from 2001, and the EU ‘Directive on the promotion of electricity produced from renewable energy sources’ decided on in 2001. Answering these requirements, there is a public interest to provide geospatial information as e.g. atmospheric and land parameters for solar energy purposes on a regular basis. This includes historical information for planning purposes as well as near-real time information for monitoring and forecasting in the daily operations of renewable energy plants. The Global Monitoring of Environment and Security (GMES) initiative might be the right umbrella for such an activity.

8. Acknowledgements

The ENVISOLAR project is funded by the European Space Agency (ESA) under contract no. 17734/03/I-IW.

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