ACCURACY IMPROVEMENTS OF SATELLITE-DERIVED SOLAR RESOURCE BASED ON GEMS RE-ANALYSIS AEROSOLS

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Abstract

New model for operational calculation of solar irradiance from Meteosat MSG satellite data was developed and implemented by GeoModel. First version used climate averages of atmospheric parameters. This work demonstrates accuracy improvements of Direct Normal Irradiance (DNI) from implementation of new global atmospheric data with daily frequency which comes as a result of the European project GEMS. The new model better captures daily variability, especially events with extreme atmospheric load of aerosols and water vapour. Thus it reduces uncertainty of instantaneous GHI and especially DNI estimates. Main accuracy improvements were achieved in reduction of Root Mean Square Deviation (RMSD) and improved distribution functions.

Keywords: Direct Normal Irradiance, DEMS aerosols, accuracy, SolarGIS.

1. SolarGIS model and calculation of DNI products

The model is designed for operational processing of Meteosat MSG satellite data at full spatial and temporal resolution geographically covering Europe, Middle East and Africa; its innovative features are discussed in [1]. The algorithms are based on the Heliosat-2 calculation scheme and the approach of [2].

The key enhancements of the new model include: (1) multi-spectral satellite information to improve classification of snow/land/cloud signals, (2) a new algorithm to more accurate calculation of lower bound preserving diurnal variability, (3) implementation of backscatter correction (4) variable upper bound for dynamic range and cloud index calculations, (5) new clear sky model, adapted DirIndex model for calculation of DNI from Global Horizontal Irradiance, and (7) downscaling with high resolution DEM to include local variability of solar irradiance.

A new broadband simplified version of the SOLIS model [3] is implemented in calculation scheme. This model allows fast calculation of clear-sky irradiance from three input parameters characterizing the state of the atmosphere: water vapour and aerosol content and aerosol type (urban, rural, maritime and tropospheric).

Quality of the model was evaluated using high-quality ground measurements from 29 BSRN and meteorological stations over Europe and North Africa, see more in [1].

Solar radiation data are available from 2004 onwards at 15-minute or aggregated time domains, in high spatial resolution, from the SolarGIS web system (http://solargis.info).

2. GEMS Atmospheric dataset

One of the main outcomes of the European project GEMS is a new atmospheric dataset - a product of re-analysis computed by ECMWF. This dataset includes also parameters important for solar radiation models - total Aerosol Optical Depth and total Water Vapour. The data set has global coverage and is available for a period 01/2003 to 04/2009 (further to be extended within the new European project MACC). The time step of the data is 24 hours, in 12 and 24 hour forecast levels, and spatial resolution close to 1.125 arc-degree. The data is a result of new developments in the assimilation of aerosol sources and modeling within the framework of Integrated Forecast System run by ECMWF [4].

3. Improvements in DNI accuracy

Originally, two atmospheric databases representing long-term climate averages were used in the SolarGIS model: NVAP water vapour (WV) [5] and atmospheric optical depth (AOD) by [6]. Both datasets were represented by long-term monthly average values. Implementation of these datasets in the satellite model resulted in a uniform monthly clear-sky radiation values omitting any information about day-by-day variation. The effect of such clear-sky model parameterization is a distorted distribution of the DNI values with erroneous representation of extreme events such as very high or very low aerosol loads. The frequency distribution from the Valladolid (Spain) shows this effect in Fig. 1 (left).

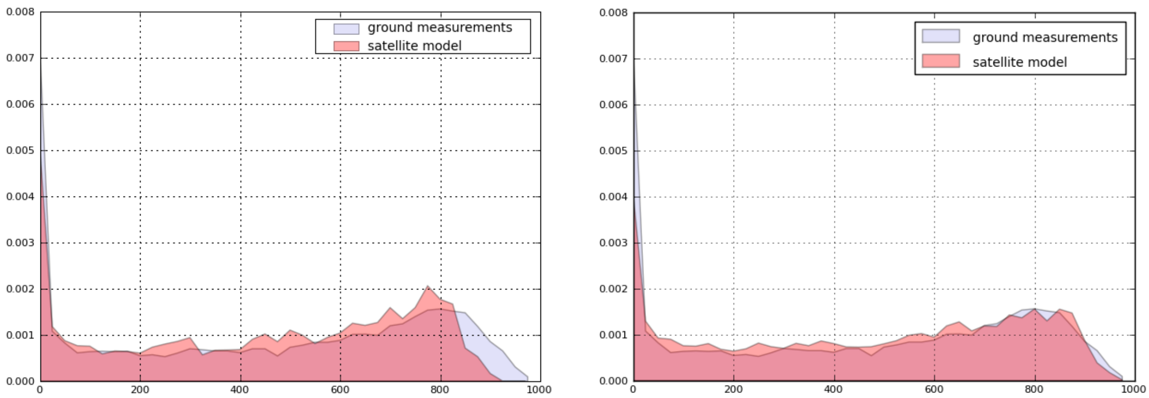

Fig. 1 Frequency distribution of DNI values [W/m^2] for Valladolid (Spain). Left: results based on the AOD and VW long-term monthly averages. Right: results based on daily values from the GEMS database

The use of *long-term averages of aerosols* results in overestimation of values below 850 W/m^2, and significant underestimation above this limit (lack of low aerosol load situations in the AOD dataset). Validation of DNI was performed for 29 sites with high-quality ground measurements. The model using long-term averaged atmospheric data gives mean bias DNI -5.4 W/m^2 (-1.6%), standard deviation of biases 8.0%, and Root Mean Square Deviation (RMSD) for hourly data is 130 W/m^2 (39.7%). Using long-term averaged atmospheric data in a well-calibrated model may still provide good average DNI values with low bias.

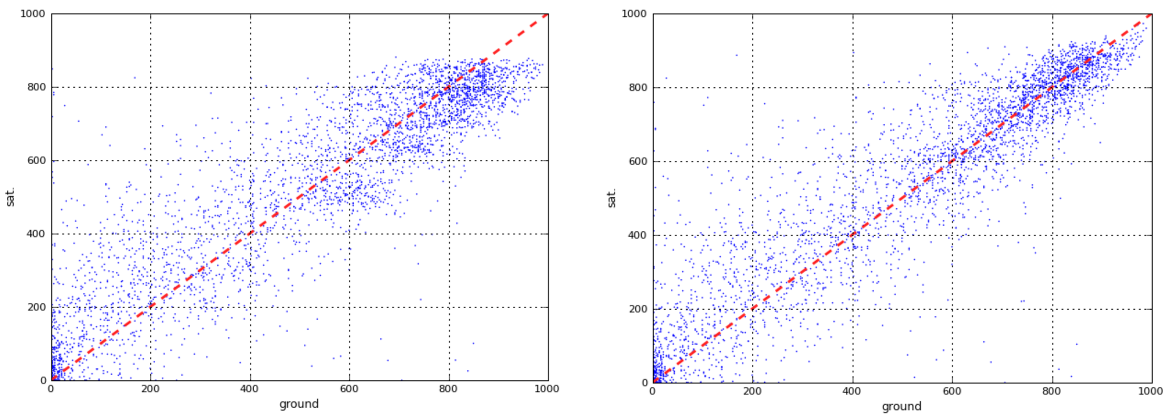

Fig. 2 DNI from satellite model compared to ground measurements (Badajos, Spain). Left: model using AOD and VW long-term monthly averages. Right: model using daily values from the GEMS database

From the viewpoint of running the operational model, the new *GEMS atmospheric dataset* better captures daily variability, especially events with extreme atmospheric load of aerosols and water vapour. Thus it reduces the uncertainty of instantaneous DNI estimates. Main accuracy improvements were achieved in reduction of RMSD and improved frequency distribution function of DNI (Fig. 1 and 2, Tab. 1). For the satellite model, based on the GEMS atmospheric dataset, the overall mean bias of DNI is -3.1 W/m^2 (-0.9%), standard deviation of biases 6.4% and RMSD for hourly values is 123 W/m^2 (35.7%).

Station	**NVAP and Remund (2008) atmospheric dataset**		**GEMS atmospheric dataset**	
	BIAS [%]	**RMSD [%]**	**BIAS [%]**	**RMSD [%]**
Badajoz (Spain)	*3.1*	*29.5*	*7.0*	*26.9*
Caceres (Spain)	-0.4	31.7	2.7	29.8
Izana (Spain)	-17.5	37.6	-1.4	30.1
Palma (Spain)	4.0	30.2	3.5	29.2
Madrid (Spain)	-2.1	26.2	-1.6	24.4
Malaga (Spain)	*8.4*	*33.9*	*12.6*	*32.3*
Murcia (Spain)	6.5	28.2	3.0	25.6
Soria (Spain)	4.9	35.3	1.6	32.4
Valladolid (Spain)	*0.3*	*28.5*	*5.3*	*27.6*
Tamanrasset (Algeria)	8.4	28.6	-4.1	23.3
Sede Boqer (Israel)	*-11.0*	*28.6*	*-11.7*	*26.9*

Tab. 1 Comparison of model results based on climate averages of AOD and WV with daily parameterisation from GEMS re-analysis

Further regional improvements in the GEMS re-analysis are needed, as the model does not capture well AOD in Sede Boqer which currently results in systematic underestimation of DNI. This is given by a combination of low resolution of the AOD dataset and complex geography of the region (Fig. 3). The similar problems may be found in other sites, such as Malaga (Bias 12%) where low resolution grid cell in the GEMS database covers complex territory which includes Mediterranean see, dense urban area of Malaga and nearby mountain ranges.

Bias within approx. ±5% is considered as acceptable due to the accuracy limits of ground instrumentation. Slightly increased bias for Badajos and Valladolid is attributed to uncertainty of ground measurements or low resolution of AOD dataset which may not fully describe the regional atmospheric conditions.

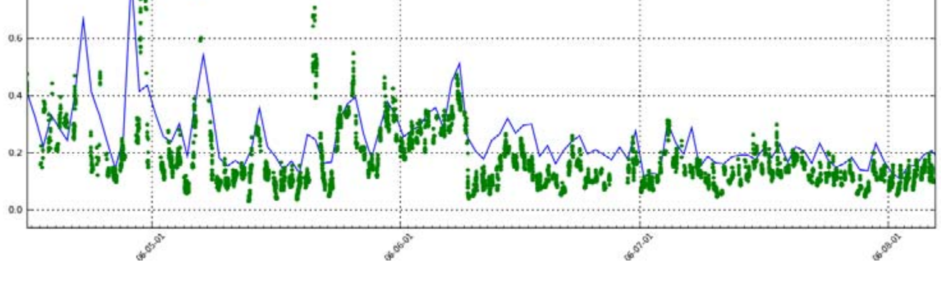

Fig. 3 Comparison of AOD670 from GEMS database (1.125 degree resolution) with ground measurements of AERONET network for Sede Boqer station.

4. Conclusions

The GEMS dataset with daily values of atmospheric parameters was implemented in the new version of the SolarGIS satellite model for DNI calculation. This dataset shows improvements over the previous version of the model which used long-term monthly climate values.

The new model implementation better captures daily variability, especially events with extreme atmospheric load of aerosols and water vapour. Thus it reduces uncertainty of instantaneous GHI and especially DNI estimates. The main accuracy improvements were achieved in reduction of Root Mean Square Deviation (RMSD) and improved distribution functions.

Further improvements of GEMS database are planned, and one of the issues to be considered is a need for reducing deviation in regions with complex geography, such as was found in Sede Boqer and Malaga.

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