GLOBAL SOLAR RADIATION: COMPARISON OF SATELLITE AND GROUND BASED OBSERVATIONS

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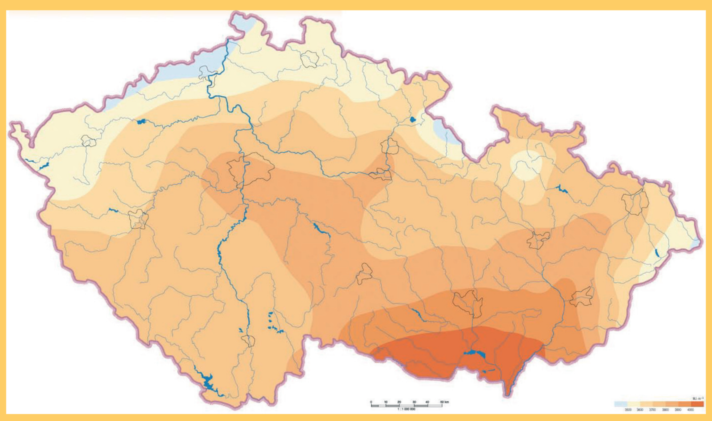
What is a global solar radiation?

Global solar radiation is the amount of solar radiation energy received on a horizontal surface during a given time. It is a sum of direct and diffuse solar radiation and it can be expressed either as an instant flux of energy in watts per square metre (W/m²) or amount of energy recorded during a time period, e.g., in MJ/m². Distribution of annual sums of global solar radiation over the Czech Republic in the long-term perspective (1961-2000) is shown below.



What is LandSAF?

Land Surface Analysis Satellite Applications Facility (LandSAF) is one of eight EUMETSAT's centres of excellence for processing satellite data. The scope of LandSAF is to increase benefit from EUMETSAT Satellites (MSG and EPS) data related to land, land-atmosphere interactions, and biospheric applications.

References

Tolasz, R., 2007: Climate Atlas of Czechia. Ceský hydrometeorologický ústav, Universita Palackého, Praha, Olomouc.

Acknowledgement

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I. Motivation - why do we focus on satellite data?

The network of ground stations monitoring global solar radiation (GLBR) in the Czech Republic is very sparse. Starting in 1984 with 11 stations, Czech Hydrometerological Institute (CHMI) currently operates 19 stations recording GLBR (Fig. 1).

- *Q: How can we get information on solar radiation at other locations?*

Higher density data on sunshine duration could help. However, when converted to GLBR, it is often strongly biased due to lack of metadata. The long-term (1961-2000) annual climatology of GLBR in the Czech Republic reveals very smooth pattern in its spatial distribution (see box in the left, reprinted from Tolasz, 2007).

- *Q: Would it look the same if more stations were available? Aren't we missing something on spatial variability?*

Annual sum of downwelling solar shortwave flux (DSSF) derived by EUMETSAT LandSAF in 2013 offer us possible answers (Fig. 2). Our goal is thus evaluate monthly sums of DSSF by comparing with GLBR at locations of CHMI stations in the year 2013.

Figure 1. CHMI stations observing global solar radiation.

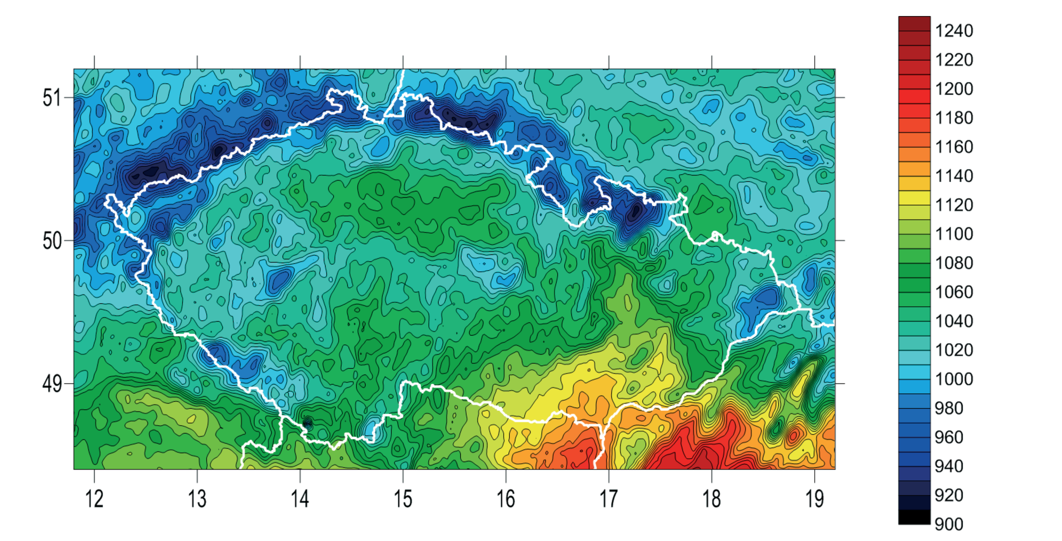

Figure 2. Annual sum of DSSF in kWh/m² in 2013. Multiply by the factor 3.6 to read values in MJ/m².

II. Data and validation approach

We chose 16 stations with GLBR for validation of monhtly sums of DSSF (see Fig 1; stations in Brno, České Budějovice and Holešov were omitted due to incomplete data series). The station data were compared directly with the nearest satellite grid box or group of 4 or 9 nearest grid boxes spatially averaged into a single value. Spatial resolution of LandSAF DSSF is 0.05 degrees in latitude/longitude. Tab. 1 summarizes basic information of the validation dataset including mean distances of LandSAF grid boxes to stations.

Number of stations	Altitude range [m]	Mean distance of LandSAF grid boxes including mean standard deviation [km]		
		1 grid box	4 grid boxes	9 grid boxes
16	158 - 1315	2.1 ± 0.9	3.5 ± 1.1	5.1 ± 1.8

Table 1. Basic metadata of station validation dataset and distances of LandSAF grid boxes to stations.

III. Results

There is a high correlation of monthly GLBR and DSSF data (high R^2 values) with data points centered on the 1:1 line (regression equations close to y = x), no matter whether a single or more LandSAF grid boxes are taken for comparison (Fig. 3). It points out to the high quality of the DSSF data. Mean error (DSSF minus GLBR), standard deviation of the mean error and RMSE are summarized in Tab. 2 and confirms that using the nearest grid point for evaluation is correct approach. Fig. 4 shows annual course of spatially averaged GLBR and DSSF and reveals frequent underestimation of DSSF and spatial variability (expressed by coefficient of variation) in some months, mostly in winter.

Number of grid boxes	Mean error (DSSF-GLBR) [MJ/m²]	Standard deviation of errors [MJ/m²]	RMSE [MJ/m²]
1	-8.77	16.90	362.6
4	-8.88	16.96	366.6
9	-8.44	17.05	361.9

Table 2. Error statistics derived from the comparison between monthly GLBR and DSSF on 16 stations in 2013.

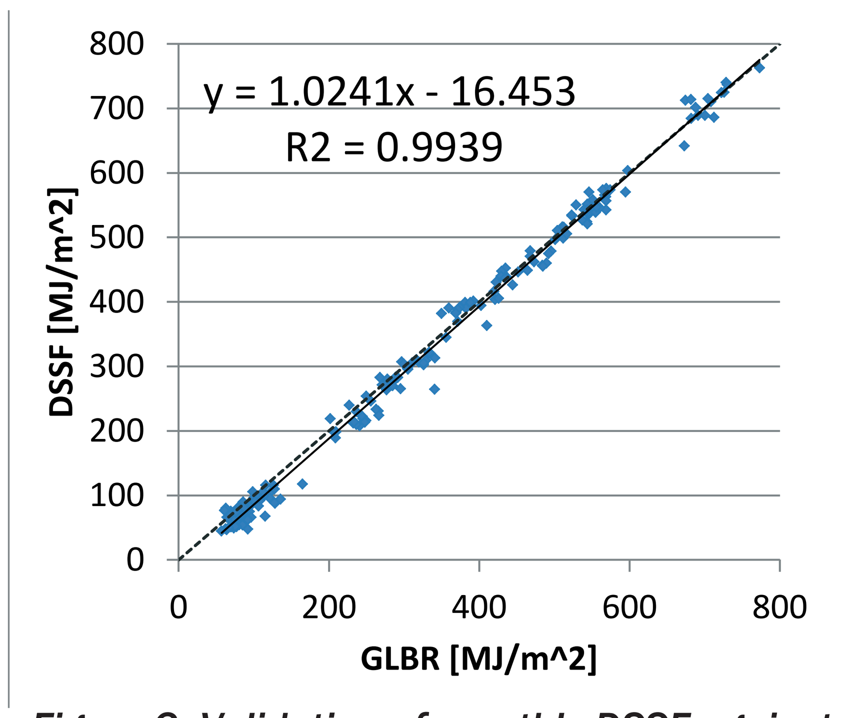

Figure 3. Validation of monthly DSSF against station GLBR.

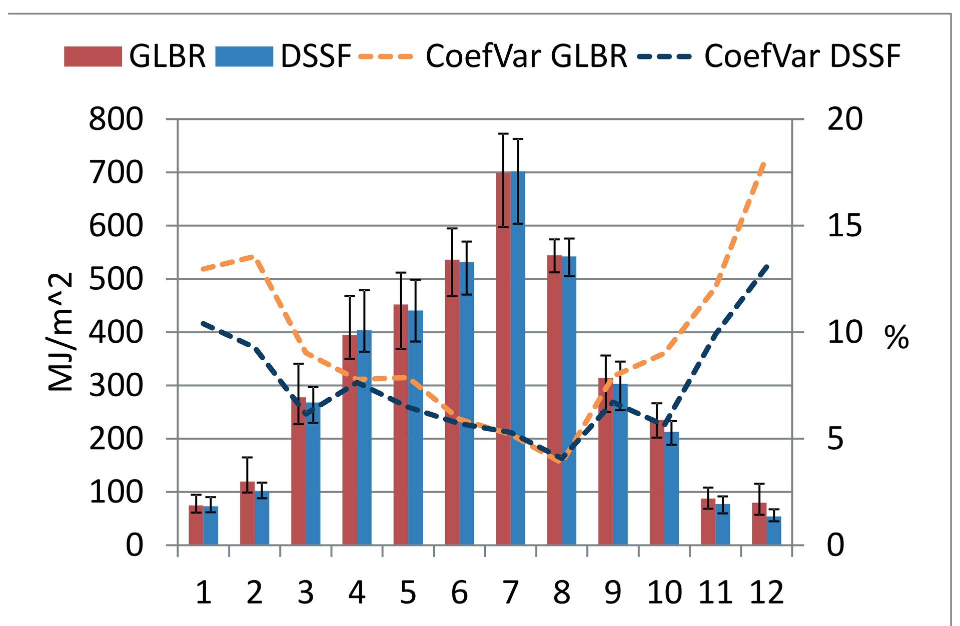

Figure 4. Annual course of spatially averaged GLBR and DSSF. Error bars indicate maximum and minimum value at individual stations. Spatial variability for both series is expressed in the form of coefficient of variation.

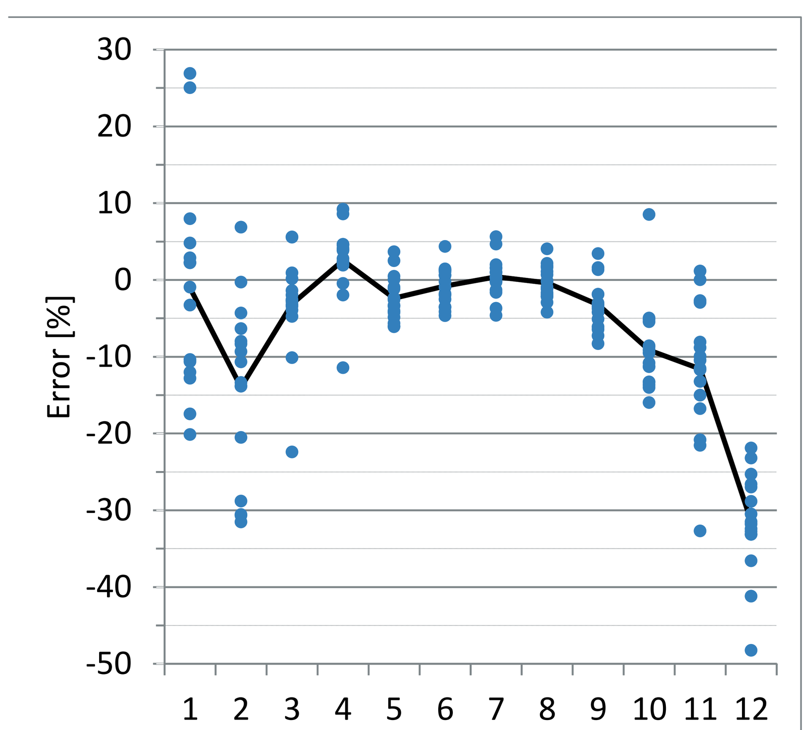

Figure 5. Annual course of relative error, (DSSF-GLBR)/GLBR, for 16 stations. Mean relative error highlighted in black.

Error of monthly DSSF for individual stations is usually within ± 30 MJ/m². While in summer months this corresponds to ± 5% of relative error (computed as DSSF-GLBR/GLBR), in winter half-year relative errors can exceed ± 20% (Fig. 5). A magnitude of error doesn't depend on distance between station and grid point(s) (not shown). Annual mean error and RMSE for stations show a dependence on altitude, with more elevated stations having higher negative annual mean error (Fig. 6).

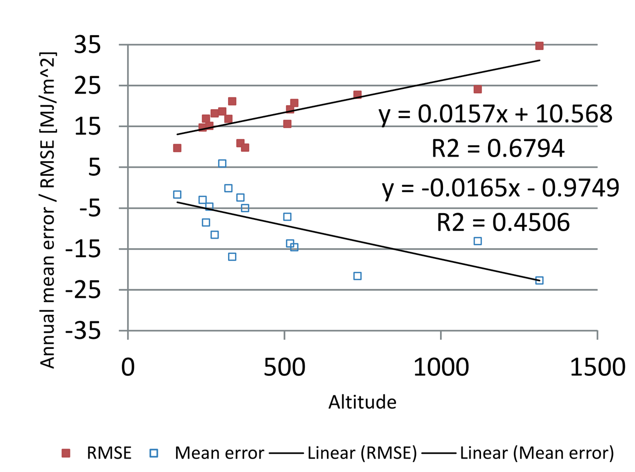

Figure 6. Dependence of temporal mean error and RMSE on altitude of stations.

IV. Conclusion and outlooks

Based on this very first evaluation, LandSAF DSSF seems to be perspective source of information on global solar radiation on monthly time scale. Evaluation of longer time series and finer time scales is our next step, along with more detailed investigation of error sources in both, DSSF and GLBR data.