

EUMETSAT Satellite Application Facility on Climate Monitoring

The EUMETSAT
Network of
Satellite
Application
Facilities



CM SAF Cloud, Albedo, Radiation dataset, AVHRR-based, Edition 1 (CLARA-A1)

Surface Radiation Products

Validation Report



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Surface Incoming Shortwave Radiation	CM-52
Surface Net Shortwave Radiation	CM-67
Surface Outgoing Longwave Radiation	CM-74
Surface Downward Longwave Radiation	CM-81
Surface Net Longwave Radiation	CM-88
Surface Radiation Budget	CM-95
Cloud Radiative Effect SW	CM-100
Cloud Radiative Effect LW	CM-101

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Applicable documents

Reference	Title	Code
AD 1	CM SAF Product Requirement Document	SAF/CM/DWD/PRD/1.7

Reference Documents

Reference	Title	Code
RD 1	Algorithm Theoretical Basis Document Surface Radiation Products CLARA-A1	SAF/CM/DWD/ATBD/GAC/RAD/1.2





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1 Executive Summary

This CM SAF report provides information on the validation of the surface radiation products from the CM SAF GAC Edition 1.0 data sets derived from AVHRR sensors onboard the series of NOAA satellites and the METOP satellite.

This report presents the validation of

Surface Incoming Shortwave Radiation [CM-52, SIS_AVHRR_global_D, Section 5.2],
Surface Net Shortwave Radiation [CM-67, SNS_AVHRR_global_DS, Section 5.3],
Surface Outgoing Longwave Radiation [CM-74, SOL_AVHRR_global_DS, Section 5.4],
Surface Downward Longwave Radiation [CM-81, SDL_AVHRR_global_DS, Section 5.5],
Surface Net Longwave Radiation [CM-88, SNL_AVHRR_global_DS, Section 5.6],
Surface Radiation Budget [CM-95, SRB_AVHRR_global_DS, Section 5.7],
Cloud Radiative Effect SW [CM-100, CFS_AVHRR_global_DS, Section 5.8],
Cloud Radiative Effect LW [CM-101, CFL_AVHRR_global_DS, Section 5.9]



from the GAC surface radiation data set available from 1982 to 2009. Three of these data sets (SIS, SOL, SDL) are validated against available reference data sets from surface measurements. For these data sets, the accuracy is defined based on the absolute bias derived from the validation with the reference data and evaluated against the accuracy requirements as given on in the product requirements document (PRD) [AD 1]. The accuracy of the remaining five data sets is estimated based on the accuracy of the input data sets using the method of error propagation.

From the eight data sets, four (SIS (daily and monthly means), SOL, SDL, and CFL) clearly fulfil the accuracy requirements as specified in the Product Requirements Document (PRD) [AD 1]. The accuracy of the CM SAF GAC SNS and CM SAF GAC CFS data sets are within the threshold accuracy requirements, while the CM SAF GAC SRB and the CM SAF GAC SNL data sets slightly exceed the threshold accuracy requirement.

Table 1: Summary of the accuracy of the CM SAF GAC surface radiation data sets.

Data Set	Threshold / Target / Optimal Accuracies in W/m2	Dataset Accuracy in W/m2
SIS	15 / 10 / 8	10
	30 / 25 / 20 (daily averages)	20
SNS	20 / 15 / 12	15
SOL	15 / 10 / 8	14
SDL	15 / 10 / 8	8
SNL	20 / 15 / 12	22
SRB	25 / 20 / 15	42
CFS	15 / 10 / 8	15
CFL	15 / 10 / 8	5

The basic accuracy requirements are defined in the product requirements document (PRD) [AD 1], and the algorithm theoretical basis document (ATBD) describes the individual parameter algorithms [RD 1].

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2 The EUMETSAT SAF on Climate Monitoring

The importance of climate monitoring with satellites was recognized in 2000 by EUMETSAT Member States when they amended the EUMETSAT Convention to affirm that the EUMETSAT mandate is also to “contribute to the operational monitoring of the climate and the detection of global climatic changes”. Following this, EUMETSAT established within its Satellite Application Facility (SAF) network a dedicated centre, the SAF on Climate Monitoring (CM SAF, <http://www.cmsaf.eu>).



The consortium of CM SAF currently comprises the Deutscher Wetterdienst (DWD) as host institute, and the partners from the Royal Meteorological Institute of Belgium (RMIB), the Finnish Meteorological Institute (FMI), the Royal Meteorological Institute of the Netherlands (KNMI), the Swedish Meteorological and Hydrological Institute (SMHI), the Meteorological Service of Switzerland (MeteoSwiss), and the Meteorological Service of the United Kingdom (UK MetOffice). Since the beginning in 1999, the EUMETSAT Satellite Application Facility on Climate Monitoring (CM SAF) has developed and will continue to develop capabilities for a sustained generation and provision of Climate Data Records (CDR's) derived from operational meteorological satellites.

In particular the generation of long-term data sets is pursued. The ultimate aim is to make the resulting data sets suitable for the analysis of climate variability and potentially the detection of climate trends. CM SAF works in close collaboration with the EUMETSAT Central Facility and liaises with other satellite operators to advance the availability, quality and usability of Fundamental Climate Data Records (FCDRs) as defined by the Global Climate Observing System (GCOS). As a major task the CM-SAF utilizes FCDRs to produce records of Essential Climate Variables (ECVs) as defined by GCOS. Thematically, the focus of CM SAF is on ECVs associated with the global energy and water cycle.

Another essential task of CM SAF is to produce data sets that can serve applications related to the new Global Framework of Climate Services initiated by the WMO World Climate Conference-3 in 2009. CM SAF is supporting climate services at national meteorological and hydrological services (NMHSs) with long-term data records but also with data sets produced close to real time that can be used to prepare monthly/annual updates of the state of the climate. Both types of products together allow for a consistent description of mean values, anomalies, variability and potential trends for the chosen ECVs. CM SAF ECV data sets also serve the improvement of climate models both at global and regional scale.

As an essential partner in the related international frameworks, in particular WMO SCOPE-CM (Sustained COordinated Processing of Environmental satellite data for Climate Monitoring), the CM SAF - together with the EUMETSAT Central Facility, assumes the role as main implementer of EUMETSAT's commitments in support to global climate monitoring. This is achieved through:

- Application of highest standards and guidelines as lined out by GCOS for the satellite data processing,
- Processing of satellite data within a true international collaboration benefiting from developments at international level and pollinating the partnership with own ideas and standards,
- Intensive validation and improvement of the CM SAF climate data records,
- Taking a major role in data set assessments performed by research organisations such as WCRP. This role provides the CM SAF with deep contacts to research organizations that form a substantial user group for the CM SAF CDRs,
- Maintaining and providing an operational and sustained infrastructure that can serve the community within the transition of mature CDR products from the research community into operational environments.

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A catalogue of all available CM SAF products is accessible via the CM SAF webpage, www.cmsaf.eu/. Here, detailed information about product ordering, add-on tools, sample programs and documentation is provided.

3 Introduction

The surface radiation data sets derived from the AVHRR GAC satellite data contain information on the shortwave and longwave radiation components as well as on the cloud forcing for both spectral regions. The shortwave surface radiation data sets (SIS, SNS) are based on the retrieval of the surface irradiance using information from the Nowcasting SAF cloud detection algorithm V2.3.1 and the satellite-derived radiances in the visible and near-infrared AVHRR satellite channels [RD 1]. The longwave surface radiation data sets rely on information obtained from the ERA-Interim reanalysis and the monthly averaged cloud fraction obtained from the CM SAF GAC data set [RD 1]. The shortwave and longwave cloud forcing and the surface radiation budget are determined directly from the corresponding surface radiation data sets.

All products are globally available as monthly averages (SIS is also available as daily averages) between 1989 and 2009 on a 0.25°-regular longitude-latitude grid.

4 Validation Data Sets

The validation of the surface radiation data sets is conducted against surface measurements from the Baseline Surface Radiation Network (BSRN) [Ohmura *et al.*, 1998]. The BSRN provides quality-controlled surface radiation measurements since 1992 at more than 40 stations worldwide. The data is distributed via the World Radiation Monitoring Center (WRMC) hosted by the Alfred Wegener Institute (AWI) in Bremerhaven, Germany (<http://www.bsrn.awi.de/>). The BSRN data are available at a high temporal resolution. For validation of the GAC surface radiation products, daily and monthly averages were calculated following the quality-control and averaging methods presented in Roesch *et al.* [2011].



5 Validation

The strategy for the validation of the CM SAF GAC surface radiation data sets follows the CM SAF Product Requirements Document [AD 1]. For the surface incoming solar radiation (SIS), the surface outgoing longwave radiation (SOL), and the surface downward longwave radiation (SDL) the accuracy of the data set is validated with available surface observations from the BSRN. For the other parameters, the accuracy is tested based on the accuracy of the input data using the method of propagation of uncertainty.

The accuracy requirements applicable for this validation report are mainly derived from GCOS in 2004, which have been updated in December 2011. All products in the GAC surface radiation dataset fulfil the updated GCOS requirements regarding the horizontal resolution (100 km). The GCOS accuracy requirements are partly fulfilled for the surface radiation products (detailed results to be described further below); the requirements on stability have yet to be assessed.

5.1 Methodology

According to the PRD [AD 1] the validation of the CM SAF GAC SIS, SDL, and SOL data sets is based on the comparison with available surface measurements. The measures for the verification with surface measurements are the bias, the absolute bias, the bias-corrected variance, the correlation coefficient of the anomalies and the fraction of months (resp. days), which exceed the target accuracy. To account for uncertainties in the surface measurements and possible errors introduced by calculating the temporal averages from the BSRN observations, an uncertainty of 5 W/m² is assumed for the daily and monthly averages derived from the surface observations [Ohmura *et al.*, 1998]. Only those stations are considered in the validation that have more than 12 months of data between 1989 and 2009.

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The validation of the CM SAF GAC SNS, SNL, SNS, SRB, CFS, and CFL data sets are based on the accuracies of the data sets, which are used to generate these data sets. The quality of the data sets is assessed by comparisons with the specified accuracy in the PRD [AD 1].

5.2 SIS Validation

The surface incoming solar radiation data set from the CM SAF GAC Edition 1.0 is validated against surface measurements obtained within the global Baseline Surface Radiation Network (BSRN). As described in Section 4 daily and monthly averages are calculated from the high-resolution BSRN data.

In addition to the validation results presented in the following it should be noted that in the CM SAF GAC SIS data set numerous grid boxes are set to missing values. During the generation of this data set it has been found that grid boxes with less than 20 observations per day and those over bright surfaces (i.e., snow-covered and desert regions), do not fulfil the accuracy requirements. These grid boxes are set to missing data and should not be considered in the analysis of the data set.

5.2.1 Monthly Averages

The validation results for the monthly averaged CM SAF GAC SIS data set are shown in Table 2.

Table 2: Validation results for the monthly averaged CM SAF GAC SIS data set compared to BSRN surface measurements

Data set	Analyzed Months	Bias (Wm ⁻²)	Abs. Bias (Wm ⁻²)	Std. Dev. (Wm ⁻²)	Corr. Ano.	Frac. Months > 15 Wm ⁻² , %	Frac. Months > 20 Wm ⁻² , %
CM SAF, GAC	3105	-3.3	10.4	14.4	0.88	23.6	13.7

In total, 3105 monthly mean data values of the surface incoming solar radiation from 37 stations between 1992 and 2009 were used for the validation of the monthly mean CM SAF GAC SIS data set. The bias of the data set compared to the BSRN reference data is -3.3 W/m², the absolute bias is 10.4 W/m². The bias is well below the optimal accuracy of 8 W/m² as specified in the PRD [AD 1], showing the excellent quality of the data set. The absolute bias is at the target accuracy of 10 W/m² [AD 1], also providing evidence of the high quality of the monthly mean CM SAF GAC SIS data set.

Considering the uncertainty of the surface observations of 5 W/m², less than 25 % of the available monthly-averaged data values are outside the target accuracy (Table 2). The temporal correlation of the anomalies is 0.88, i.e., the data set is well suited for the detection and quantification of climate anomalies.

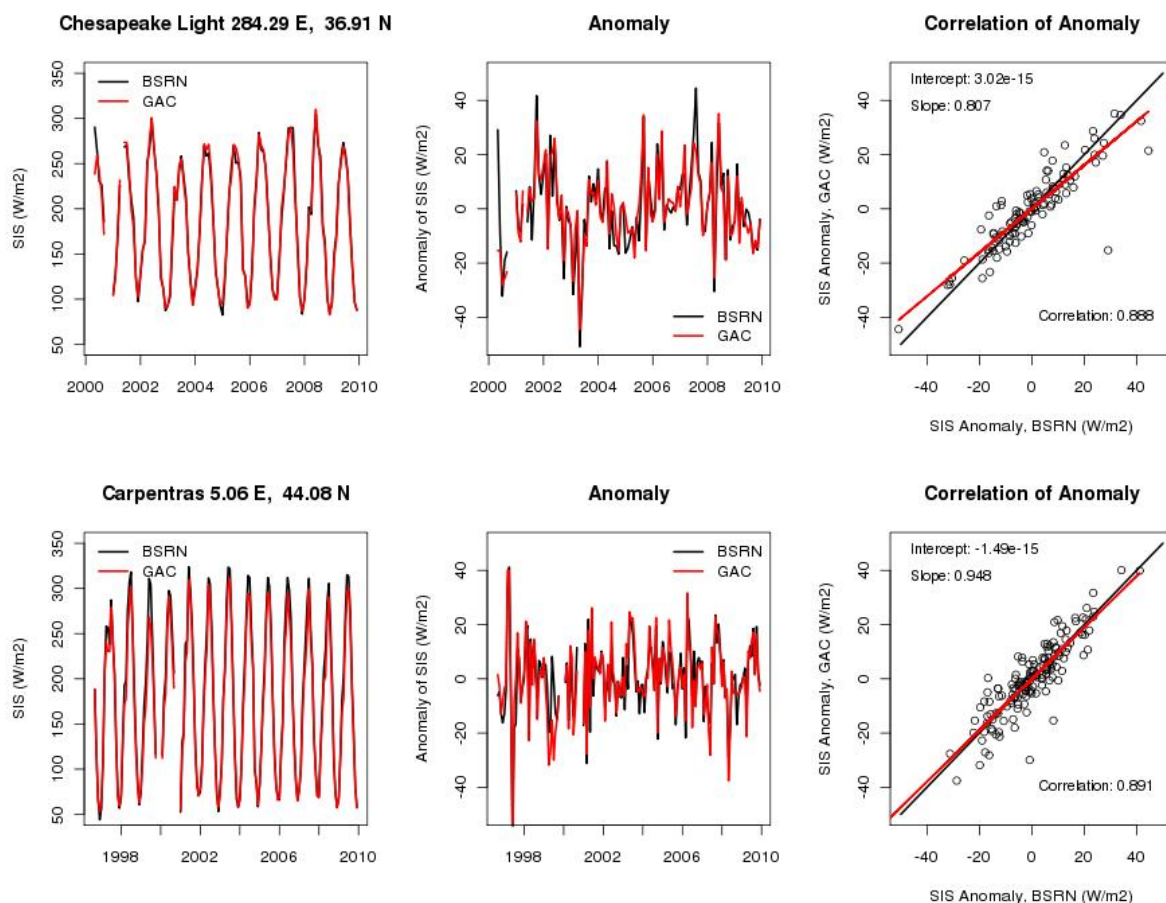


Figure 1: Analysis of the monthly time series of the CM SAF GAC SIS data set compared to monthly averaged data from BSRN for (upper row) Chesapeake Lighthouse on the US Atlantic Coast and (lower row) Carpentras, France. Shown are (left column) the time series of the monthly mean data sets, (center column) the time series of the anomalies relative to the multi-year monthly averages, and (right column) the correlation of the monthly anomalies derived from the BSRN and the CM SAF GAC SIS data set.

Figure 1 presents two examples of analysed time series. The CM SAF GAC SIS data set is compared to monthly averaged data from BSRN for Chesapeake Lighthouse on the US Atlantic Coast (upper row) and Carpentras, France (lower row). The annual cycle is dominating the variability of the surface solar radiation in both time series. The inter-annual variability is depicted by the time series of the anomalies, calculated by subtracting the mean value of the corresponding months, and mainly governed by the variability in cloud coverage. The high quality of the CM SAF GAC SIS data set is shown by the high correlation of the anomalies.

The spatial distribution of the surface stations used for the validation are shown in Figure 2 together with the multi-year mean surface solar irradiance for the month of September from the CM SAF GAC SIS data set. Only at three surface stations (Desert Rock, Nauru, and Alice Springs) the quality of the CM SAF GAC SIS data set exceeds the target accuracy. Figure 3 presents the results from the validation of the CM SAF GAC SIS data set for each of the 37 BSRN surface stations in more detail. 34 stations are well within the target accuracy. Only at Desert Rock and Alice Spring the CM SAF GAC SIS values significantly deviate from the BSRN surface observations. At most surface stations the CM SAF GAC SIS data set underestimates the surface observations. At some of the tropical stations the CM SAF GAC SIS data set overestimates the surface solar radiation as compared with BSRN measurements.

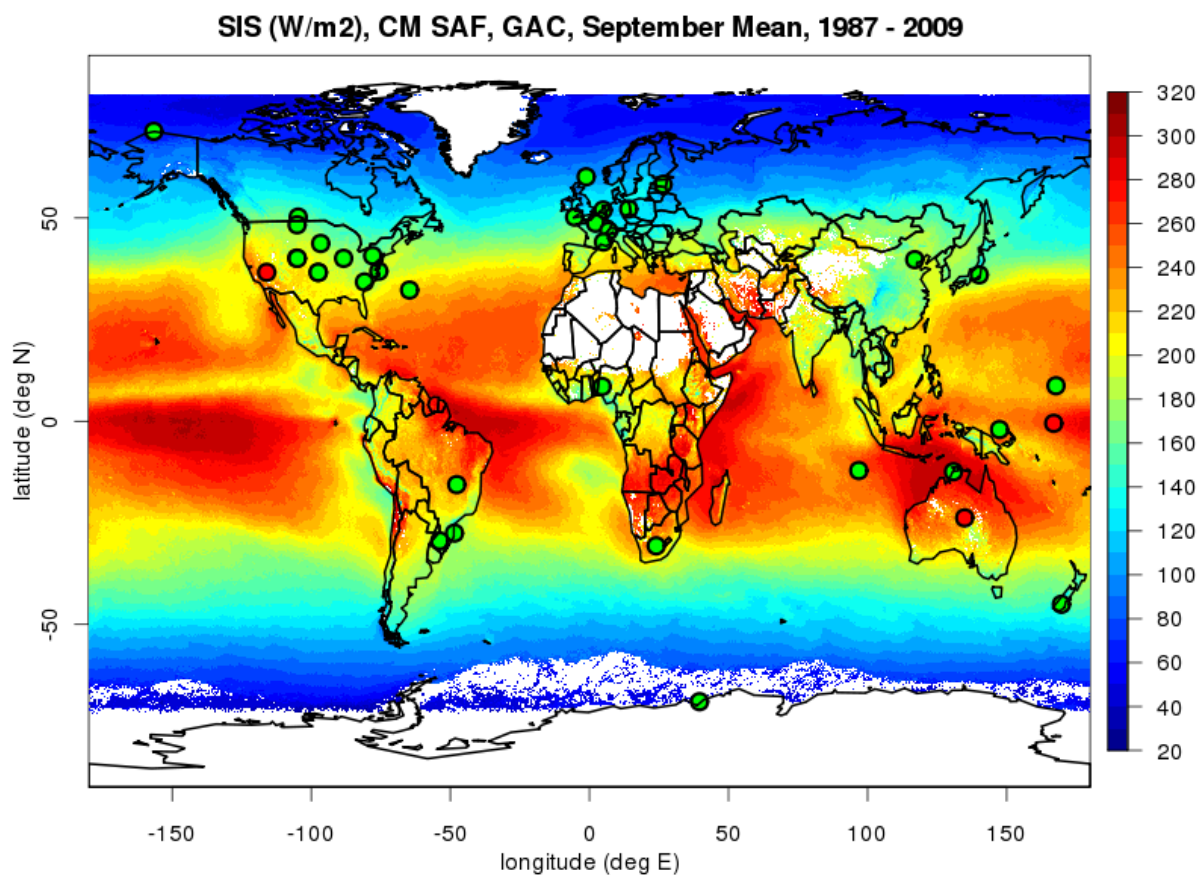


Figure 2: Multi-year average of the CM SAF GAC surface solar irradiance data set for the month of September and validation results obtained by comparison with available BSRN surface measurements. Green dots represent surface stations where the GAC SIS data set is within the target accuracy, red dots correspond to surface stations, where the GAC SIS data set does not meet the target accuracy.

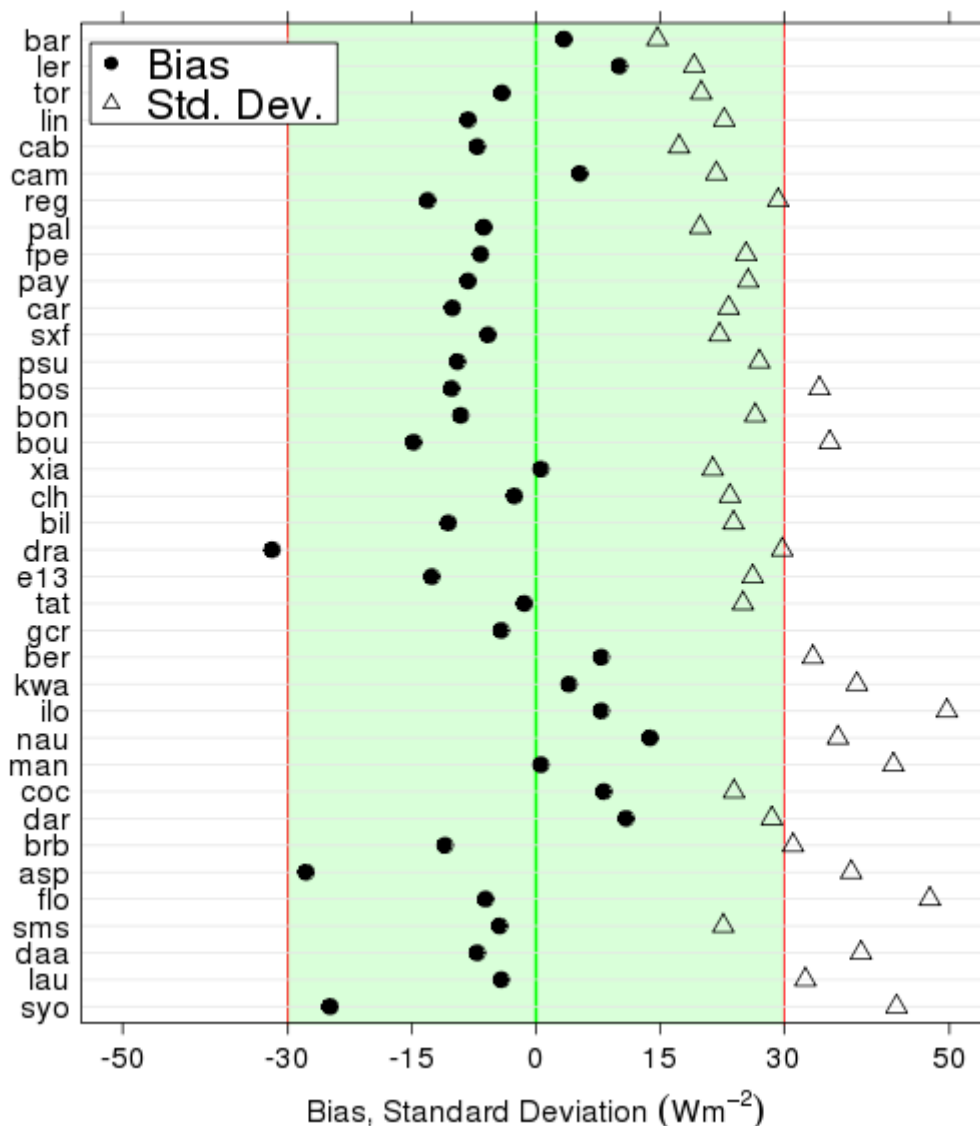


Figure 3: Stationwise validation results for the CMSAF GAC SIS data set. Shown are the bias (filled dots) and the variance (triangle) of the monthly mean SIS data from the CM SAF GAC data set compared to the BSRN surface measurements. The station names are listed north-to-south and named according to their BSRN-label (see <http://www.bsrn.awi.de/>). The green area marks the target accuracy including the uncertainty of the surface observations.

Based on the results presented here, we conclude that the monthly-averaged CM SAF GAC SIS data set is within the target accuracy as defined in the PRD [AD 1].

In addition to the validation using BSRN surface reference measurements, the CM SAF GAC SIS data set has been compared to the surface irradiance data provided by GEWEX-SRB (Stackhouse et al., 2012).

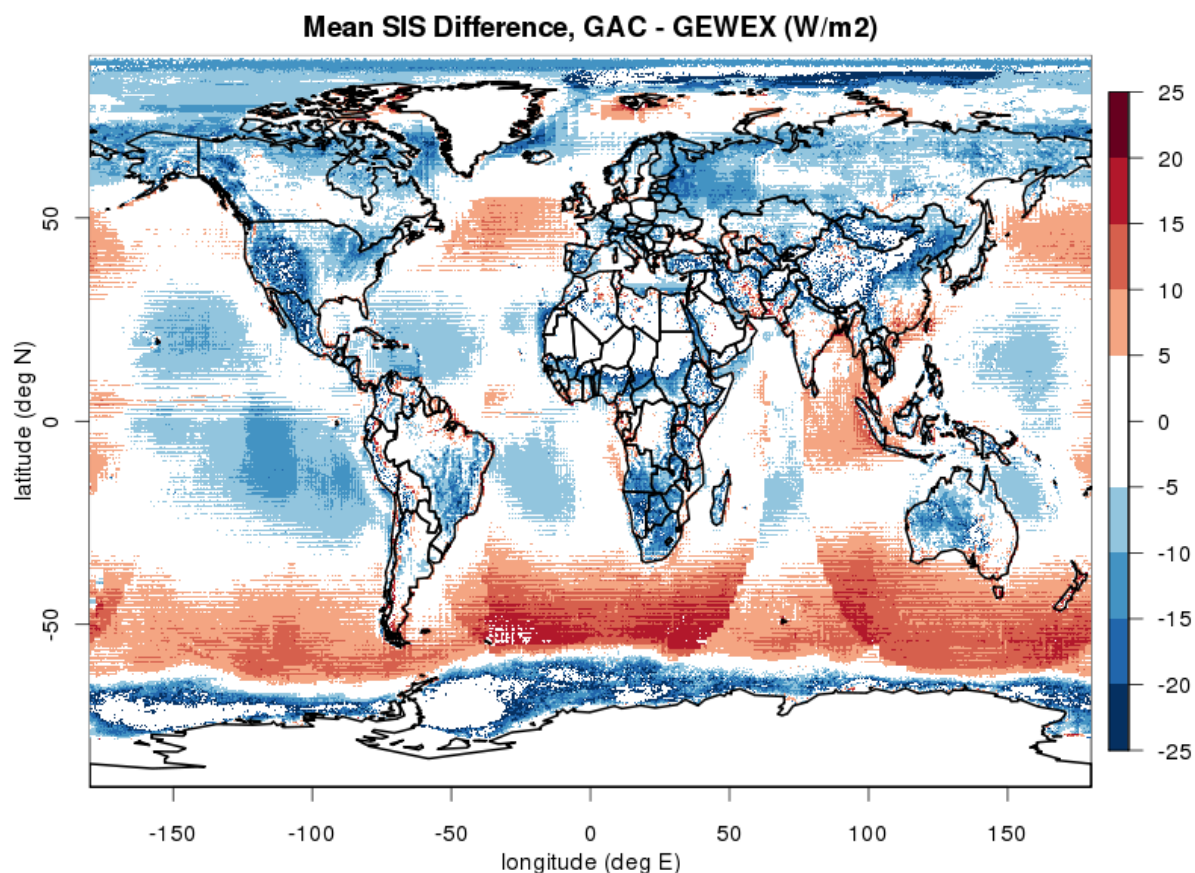


Figure 4: Mean Difference between the CM SAF GAC SIS data set and the surface irradiance provided by GEWEX-SRB.

Figure YY presents the mean bias between the monthly mean CM SAF GAC SIS data set and the GEWEX-SRB data set. The well-known feature of the inconsistency of the GEWEX-SRB data set at the transition zones between the geostationary satellites (e.g., Evan et al., 2007) is the most striking feature in this comparison. These artificial inconsistencies are introduced by the application of the ISCCP radiance and cloud information in the generation of the GEWEX-SRB data set. The use of AVHRR data only in the generation of the CM SAF GAC data sets prevents such unrealistic features in the data. The CM SAF GAC SIS data sets trends to have lower values of the solar surface irradiance over land and parts of the tropical ocean region. The mean difference between these two data sets is -2 W/m².

5.2.2 Daily Averages

For the surface incoming solar radiation also daily-averaged data are provided by CM SAF from the AVHRR GAC data. The validation of the daily mean CM SAF GAC SIS data set is also conducted by comparison with the surface measurements from the BSRN surface network. The target accuracy defined for the daily-averaged data is 25 W/m² [AD 1]. The results of the validation of the CM SAF GAC data set of the daily mean surface incoming solar radiation are given in Table 3.

Table 3: Validation results for the daily-averaged CM SAF GAC SIS data set compared to BSRN surface measurements.

Data set	Analyzed Days	Bias (Wm ⁻²)	Abs. Bias (Wm ⁻²)	Std. Dev. (Wm ⁻²)	Corr. Ano.	Frac. Days > 30 Wm ⁻² , %	Frac. Months > 30 Wm ⁻² , %
CM SAF, GAC	96,237	-4.7	22.9	34.3	0.85	25.5	20.8

Nearly 100,000 daily-averaged data values are considered for the validation of the daily mean CM SAF GAC SIS data set. The bias is slightly negative consistent with the result from the monthly mean analysis. The absolute bias is below the target accuracy of 25 W/m². About 25 % of the daily mean values deviate to more than 30 W/m² (corresponding to the target accuracy plus the uncertainty of the surface observations) from the reference data set. The spatial distribution of the surface stations used for the validation are shown in Figure 5 together with the daily mean surface solar irradiance from the CM SAF GAC SIS data set for 1 July 2009. Figure 6 presents more detailed results from the validation of the daily-averaged CM SAF SIS GAC data set for each of the 37 BSRN surface stations.

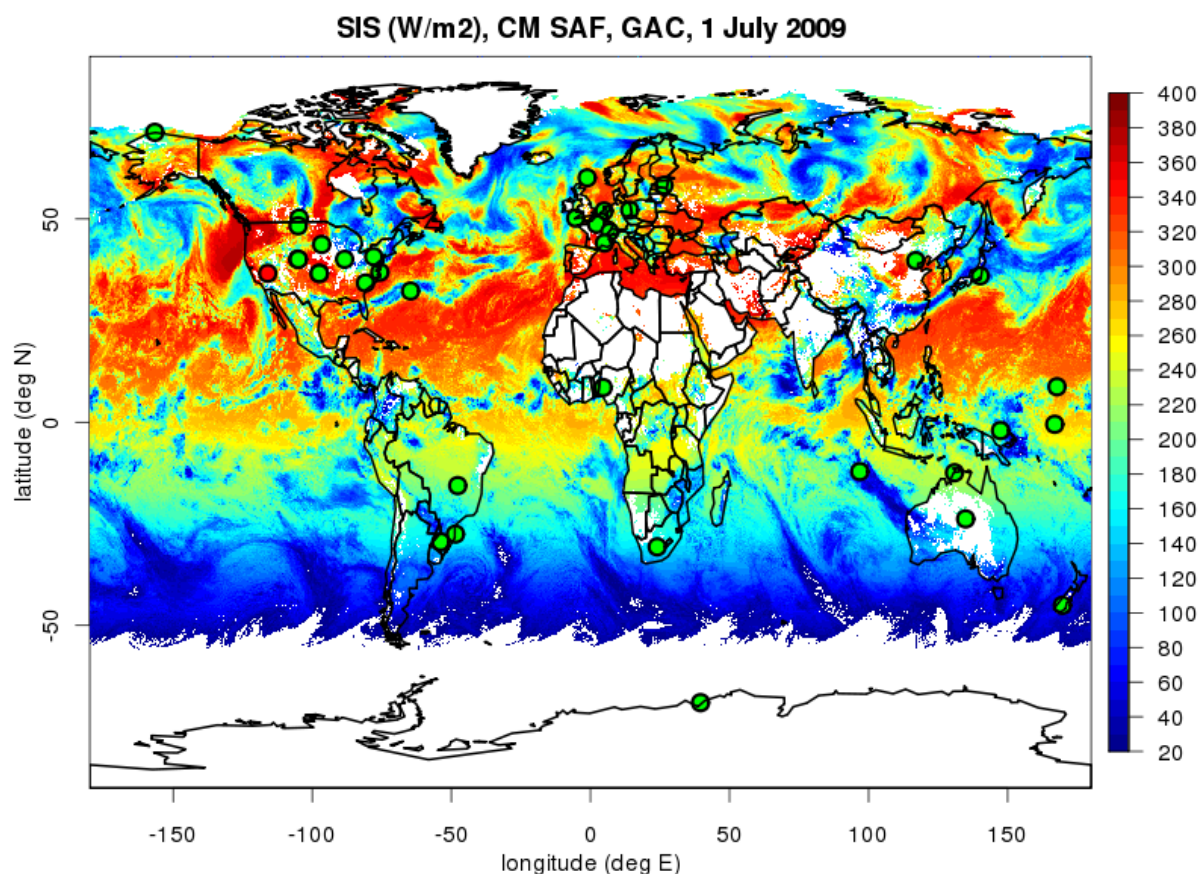


Figure 5: Daily mean from 1 July 2009 of the CM SAF GAC SIS data set (colour coding) and validation results obtained by comparison with available BSRN surface measurements. Green dots represent surface stations where the CM SAF GAC SIS data set is within the target accuracy, red dots correspond to surface stations, where the CM SFA GAC SIS data set does not met the target accuracy.

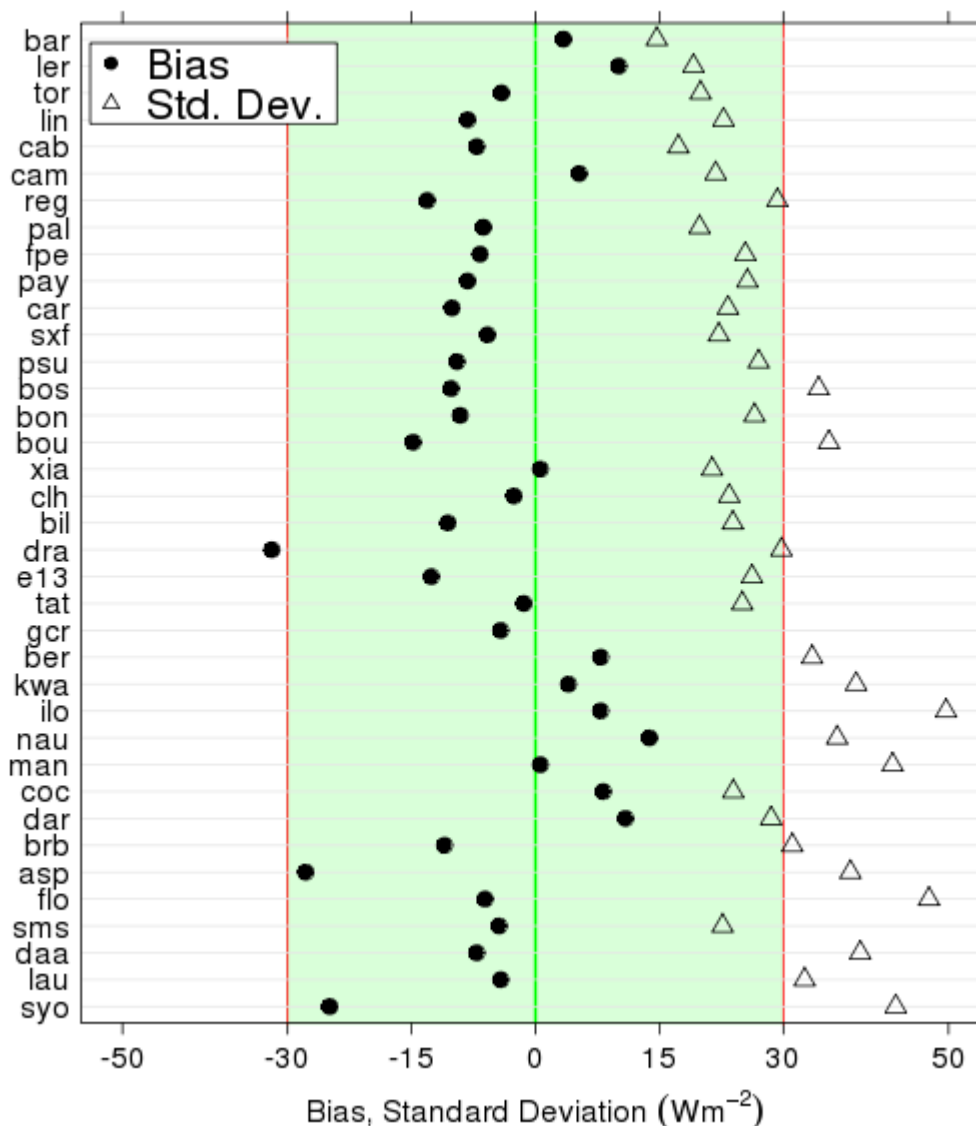


Figure 6: Stationwise validation results for the daily mean CMSAF GAC SIS data set. Shown are the bias (filled dots) and the variance (triangle) of the daily mean SIS data from the CM SAF GAC data set compared to the BSRN surface measurements. The station names are listed north-to-south and named according to their BSRN-label (see <http://www.bsrn.awi.de/>). The green area marks the target accuracy including the uncertainty of the surface observations.

Only at one surface station (Desert Rock) the CM SAF GAC SIS data set exceeds the target accuracy for daily means. At 36 stations distributed throughout the world, the CM SAF GAC data set of the daily mean surface incoming solar radiation fulfils the accuracy requirements. Overall the accuracy of the daily mean CM SAF GAC SIS data set fulfils the accuracy requirement as stated in the PRD [AD 1].

5.3 SNS Validation

The accuracy of the CM SAF GAC data set of the surface net solar radiation is determined based on the accuracy of the monthly mean SAL and SIS data sets [AD 1]. The accuracy of the monthly mean CM SAF GAC SIS data set has been determined to be within 15 W/m²; the accuracy of the SAL data set is 10 % [AD 1].

The surface net shortwave radiation budget is calculated from the CM SAF GAC data sets of the surface incoming solar radiation (SIS) and the surface albedo (SAL) [RD 1]. Using

Equation E4 in the ATBD [RD 1] and applying the propagation of uncertainty method, the uncertainty in SNS can be estimated by:

$$\Delta SNS = \frac{\partial SNS}{\partial SIS} \Delta SIS + \frac{\partial SNS}{\partial SAL} \Delta SAL = (1 - SAL) \Delta SIS + SIS \Delta SAL \quad (\text{Eq. 1})$$

The accuracy is derived on a monthly basis using the uncertainties of SAL ($\Delta SAL = 25\%$) and a fixed value for the uncertainty of SIS ($\Delta SIS = 15 \text{ W/m}^2$). The spatial distribution of the temporal average of the uncertainty associated with the SNS data set is shown in Figure 7. In most regions the accuracy is close to the target accuracy (15 W/m^2) and always within the threshold accuracy of 20 W/m^2 . The temporally- and spatially-averaged accuracy of the CM SAF GAC SNS data set is 15.4 W/m^2 . The accuracy over ocean surfaces is slightly higher than over land surface, because of the relatively low surface albedo over the ocean. Overall we conclude that the CM SAF GAC SNS data set is within the threshold accuracy requirement.

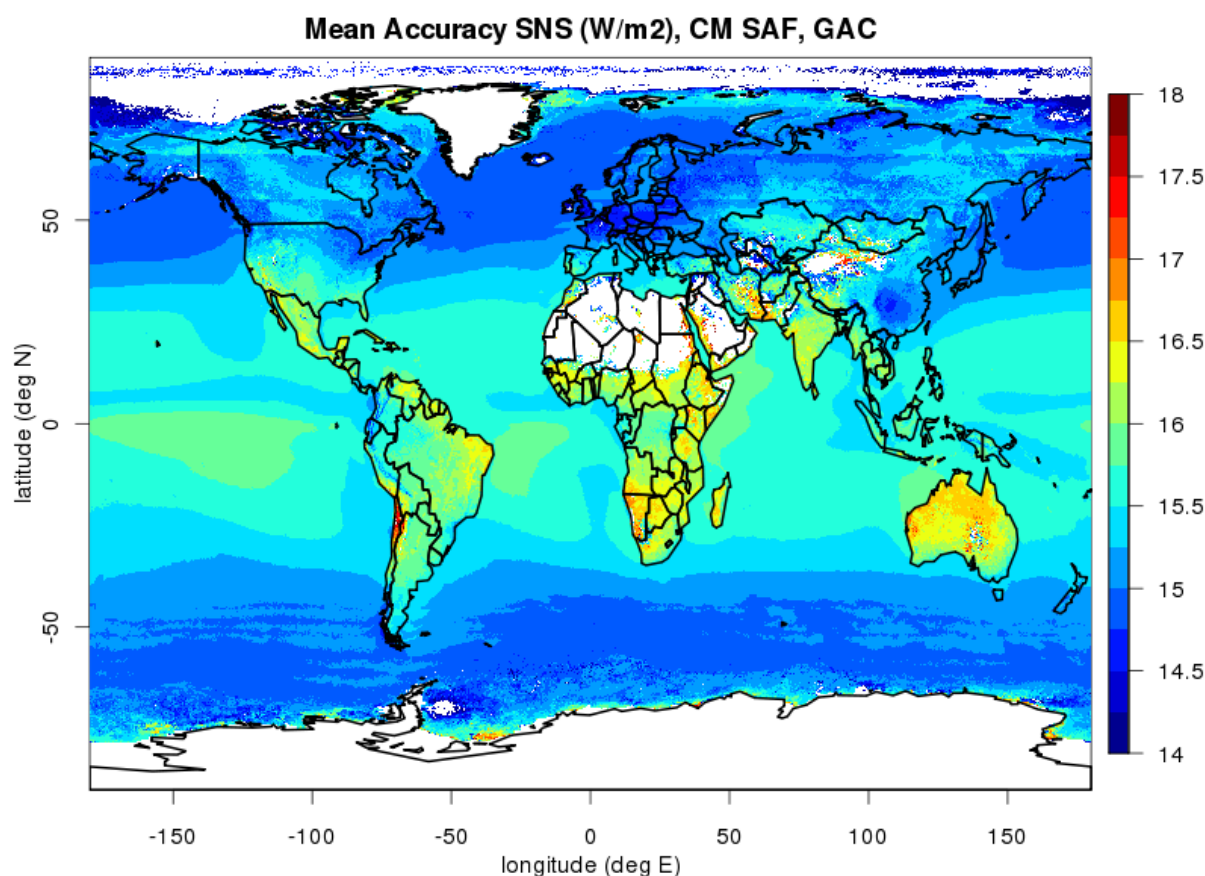


Figure 7: Temporally-averaged accuracy of the CM SAF GAC solar surface net radiation data set.

5.4 SOL Validation

The validation of the CM SAF GAC surface outgoing longwave radiation data set is conducted by comparison with surface measurements obtained within the BSRN network [AD 1]. Only 8 stations provide observations of SOL suitable for the validation of the CM SAF GAC SOL data set. Table 4 provides the results of the validation.


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Table 4: Validation results for the monthly-averaged CM SAF GAC SOL data set compared to BSRN surface measurements.

Data set	Analyzed Months	Bias (Wm^{-2})	Abs. Bias (Wm^{-2})	Std. Dev. (Wm^{-2})	Corr. Ano.	Frac. Months > 15 Wm^{-2} , %	Frac. Months > 20 Wm^{-2} , %
CM SAF, GAC	1270	5.8	13.8	17.9	0.71	34.6	24.8

The bias is about 6 W/m^2 , the absolute bias is about 14 W/m^2 , which is within the target accuracy considering the uncertainty of the surface observations. Less than 35 % of the considered months exceed the target accuracy.



Figure 8: presents more detailed results from the validation (bias and standard variation) of the CM SAF SOL GAC data set for each of the 8 BSRN surface stations

Overall the accuracy of the monthly mean CM SAF GAC SOL data set fulfils the accuracy requirement as stated in the PRD [AD 1].

5.5 SDL validation

The validation of the surface downwelling longwave radiation is done by comparison with surface measurements obtained within the BSRN network. In total, data from 44 stations are used for the validation. The validation results are shown in Table 5.

Table 5: Validation results for the monthly-averaged CM SAF GAC SDL data set compared to BSRN surface measurements.

Data set	Analyzed Months	Bias (Wm^{-2})	Abs. Bias (Wm^{-2})	Std. Dev. (Wm^{-2})	Corr. Ano.	Frac. Months > 15 Wm^{-2} , %	Frac. Months > 20 Wm^{-2} , %
CM SAF, GAC	5314	-3.7	8.3	10.4	0.82	16.5	7.4
ERA-I	5364	-6.1	9.2	10.6	0.85	19.7	11.7

The bias of the CM SAF GAC SDL data set is slightly negative (-3.7 Wm^{-2}), the absolute bias is close to the optimal accuracy of 8 Wm^{-2} [AD 1], showing the high quality of the CM SAF GAC SDL data set. Less than 17 % of the available monthly mean values exceed the target accuracy, considering an uncertainty of the monthly-averages derived from the surface observations of 5 Wm^{-2} . The corresponding validation results obtained for the ERA-Interim data set are also reported in Table 5 showing the improved quality of the CM SAF GAC SDL data set due to the application of the satellite-derived cloud information and the topography correction.

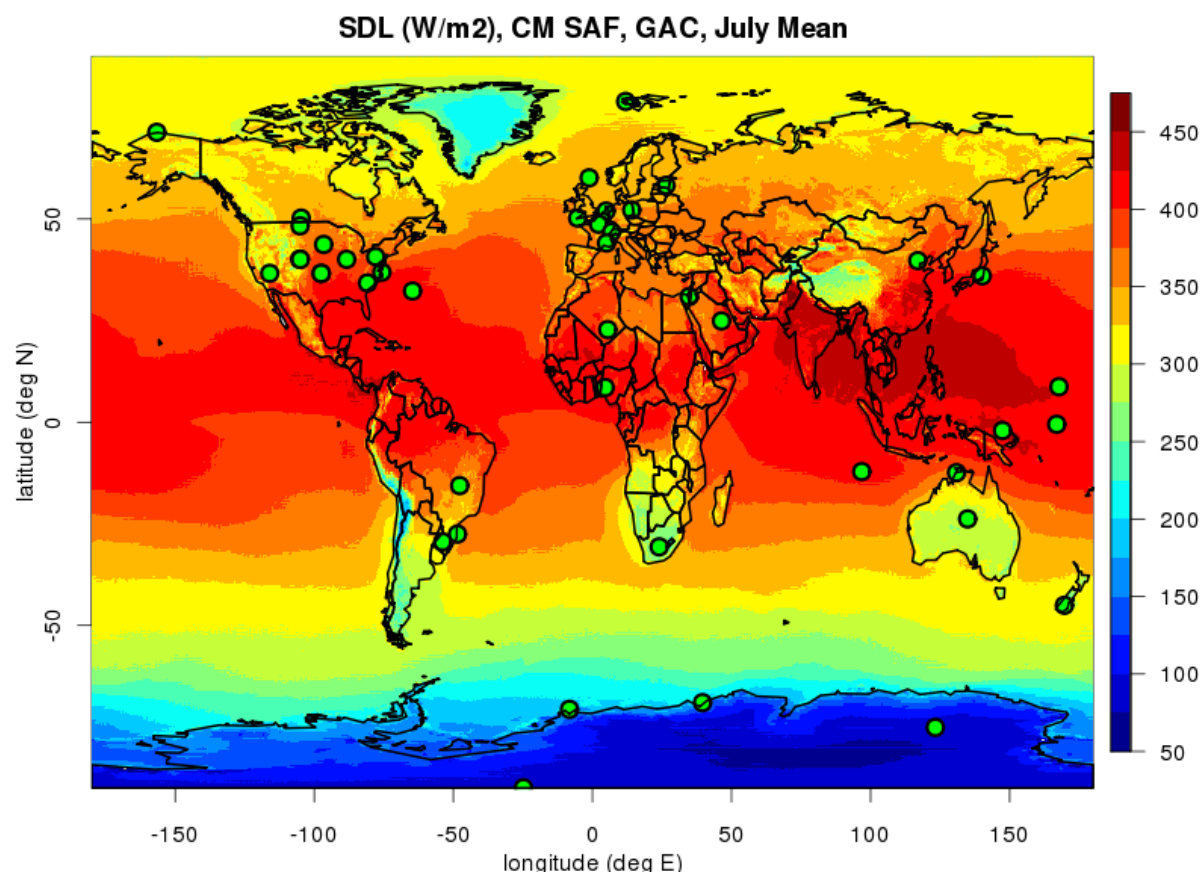


Figure 9: Multi-year mean of July from the CMSAF GAC SDL data set. Green dots correspond to BSRN surface stations, where the CM SAF GAC SDL data set fulfils the accuracy requirements.

The spatial distribution of the surface stations used for the validation are shown in Figure 9 together with the multi-year mean for the month of July from the CM SAF GAC SDL data set. At all stations the quality of the CM SAF GAC SDL data set is within the target accuracy. Figure 10 presents more detailed results from the validation (bias and variance) of the CM SAF SDL GAC data set for each of the 44 BSRN surface stations.

Based on the results presented here, we conclude that the monthly mean CM SAF GAC SDL data set is within the target accuracy as defined in the PRD [AD 1].

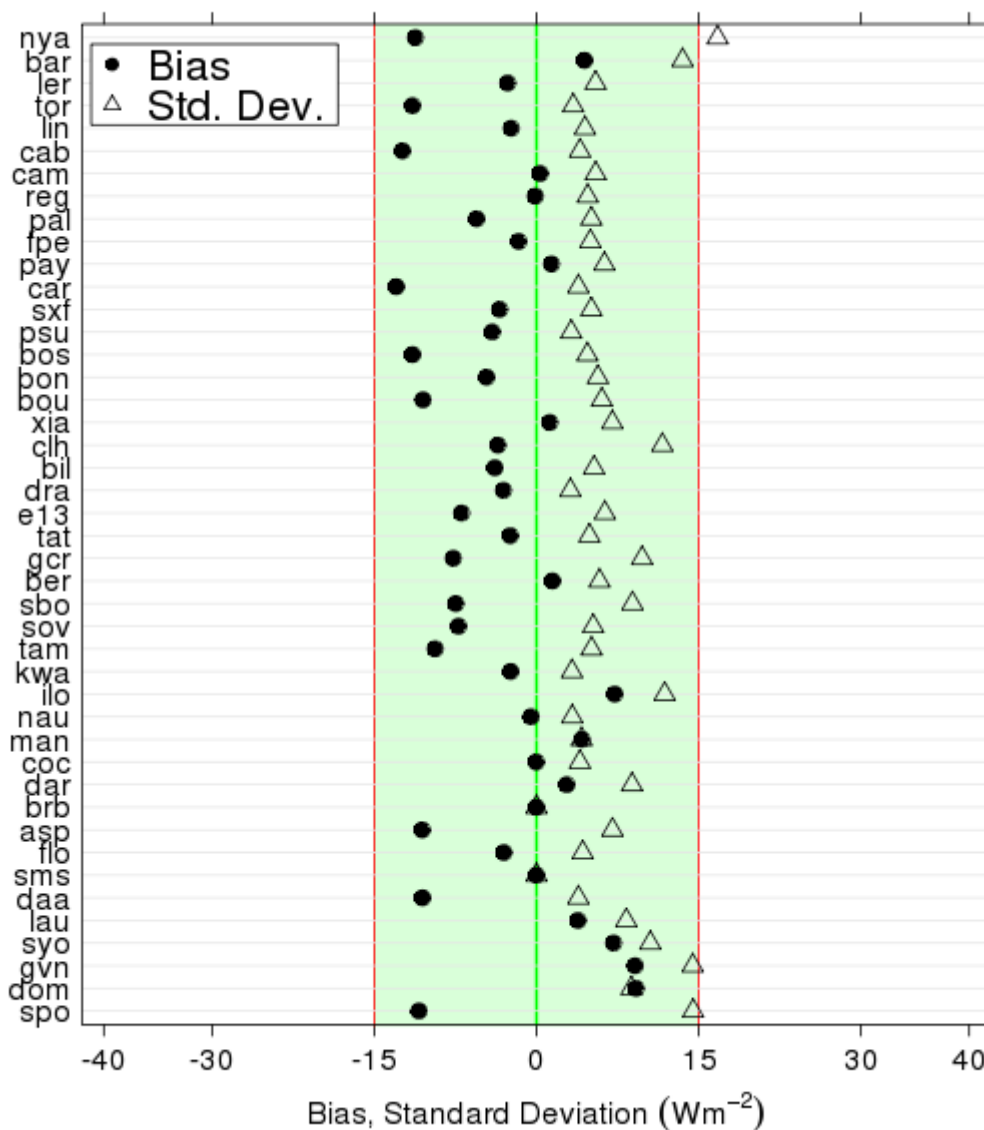



Figure 10: Stationwise validation results for the monthly mean CMSAF GAC SDL data set. Shown are the bias (filled dots) and the variance (triangle) of the monthly mean SDL data from the CM SAF GAC data set compared to the BSRN surface measurements. The station names are listed north-to-south and named according to their BSRN-label (see <http://www.bsrn.awi.de/>). The green area marks the target accuracy including the uncertainty of the surface observations.

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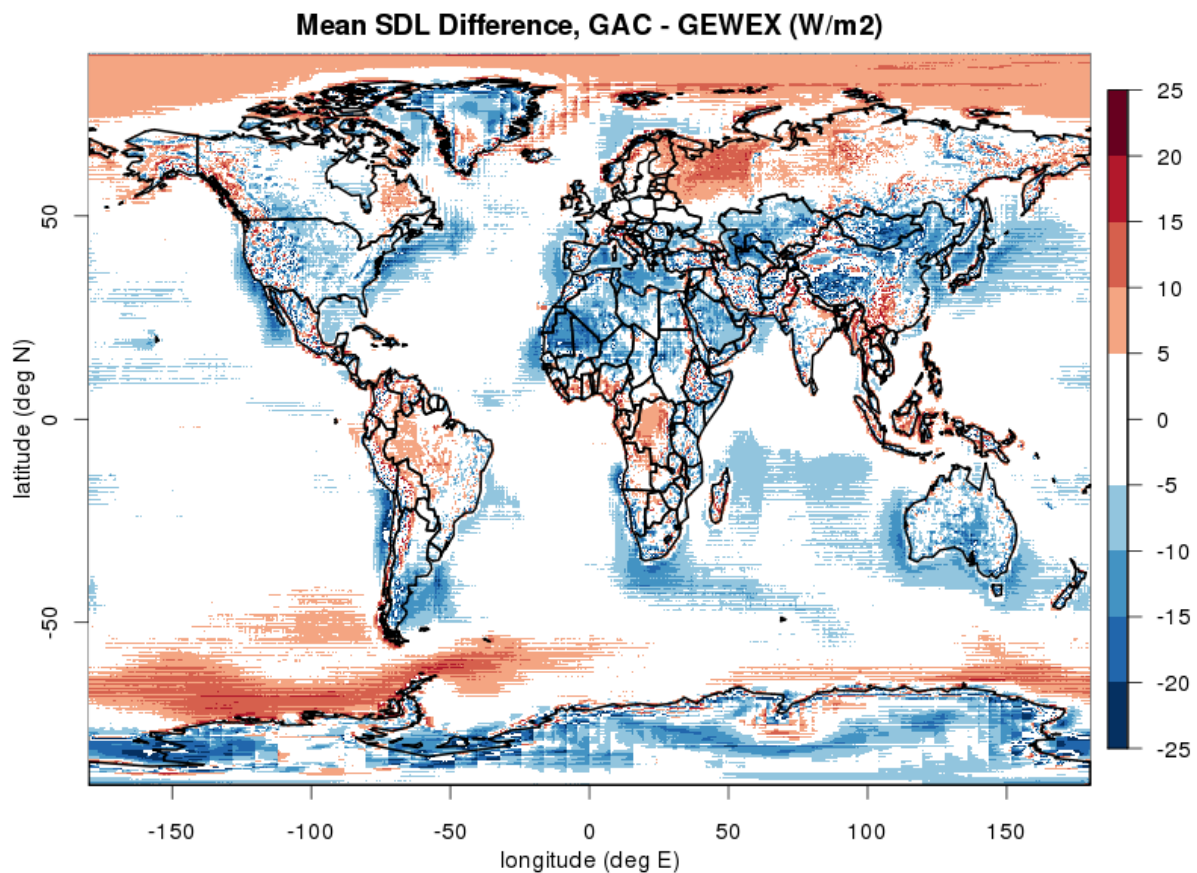




Figure 11: Mean Difference between the CM SAF GAC SDL data set and the surface downwelling longwave radiation provided by GEWEX-SRB.

Figure 11 presents the mean bias between the monthly mean CM SAF GAC SDL data set and the surface downwelling longwave radiation from the GEWEX-SRB data set. The inconsistency of the GEWEX-SRB data set at the transition zones between the geostationary satellites is not as obvious as in Figure YY for the surface solar irradiance, but can also be seen here in the Central Indian Ocean. The mean difference between these two data sets is -2 W/m². Larger differences occur over mountainous regions, e.g., the Himalaya, where the higher spatial resolution of the CM SAF GAC SDL data set allows an improved representation of the topography.

5.6 SNL validation

The accuracy of the CM SAF GAC SNL data set is assessed on the basis of the validation of the SOL and SDL data sets. According to the method of error propagation the accuracy of SNL is the sum of the accuracy of the SOL and SDL data sets. The accuracy of the CM SAF GAC SOL data set is estimated to be around 14 W/m², while the accuracy of the CM SAF GAC SDL data set can be considered to be in the order of 8 W/m², resulting in an accuracy of 22 W/m² for the CM SAF GAC SNL data set.

The uncertainty of the calculated accuracy of the SNL data set is related to the uncertainty of the accuracies of the CM SAF GAC SOL and SDL data sets. The uncertainties of the BSRN surface observations used for the validation of the SOL and SDL data sets of 5 W/m² result in comparable uncertainty of the accuracy estimates of the corresponding CM SAF GAC data sets. Hence, the uncertainty of the accuracy derived by this method for the CM SAF GAC SNL data set is 10 W/m². Taking this uncertainty into account, the accuracy of the CM SAF GAC SNL data is just within the threshold accuracy defined in the PRD [AD 1].

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5.7 SRB validation

The accuracy of the CM SAF GAC SRB data set is assessed on the basis of the validation of the SNS and SNL data sets. According to the propagation of error method, the accuracy of SRB is the sum of the accuracy of the SNS and SNL data sets. The accuracy of the SNS data set is estimated to be around 20 W/m², while the accuracy of the SNL data set can be considered to in the order of 22 W/m², resulting in an accuracy of 42 W/m² for the CM SAF GAC SRB data set. This value exceeds the threshold accuracy of 25 W/m² defined in the PRD [AD 1], even when considering some uncertainty in the calculation of the accuracy of SRB.

5.8 CFS Validation

The accuracy of the CMSAF GAC CFS data set is validated using the propagation of error method based on the equation to calculate CFS. Following Equation Eq. 14 from the ATBD of the CM SAF GAC Surface Radiation products [RD 1], the accuracy of CFS can be calculated using the following equation:

$$\Delta CFS = \frac{\partial CFS}{\partial (SIS - SIS_{cls})} \Delta (SIS - SIS_{cls}) + \frac{\partial CFS}{\partial SAL} \Delta SAL =$$

$$(1 - SAL) \Delta (SIS - SIS_{cls}) + (SIS_{clr} - SIS) \Delta SAL \quad (\text{Eq. 2})$$

The uncertainty of the difference between all-sky and clear-sky surface irradiance can be assumed to be in the same order as the uncertainty in the all-sky surface solar radiation, i.e., 15 W/m². The uncertainty of the CM SAF GAC CFS data set is calculated for every month. The spatial distribution of the temporally-averaged accuracy of the CM SAF GAC CFS data set is shown in Figure 12. Over wide areas, especially over the oceans, the accuracy is within the threshold accuracy of 15 W/m² [RD 1]. The mean accuracy is 14.3 W/m². Only for one month in the time series, the spatially-averaged accuracy exceeds the threshold accuracy of 15 W/m² by 0.1 W/m².

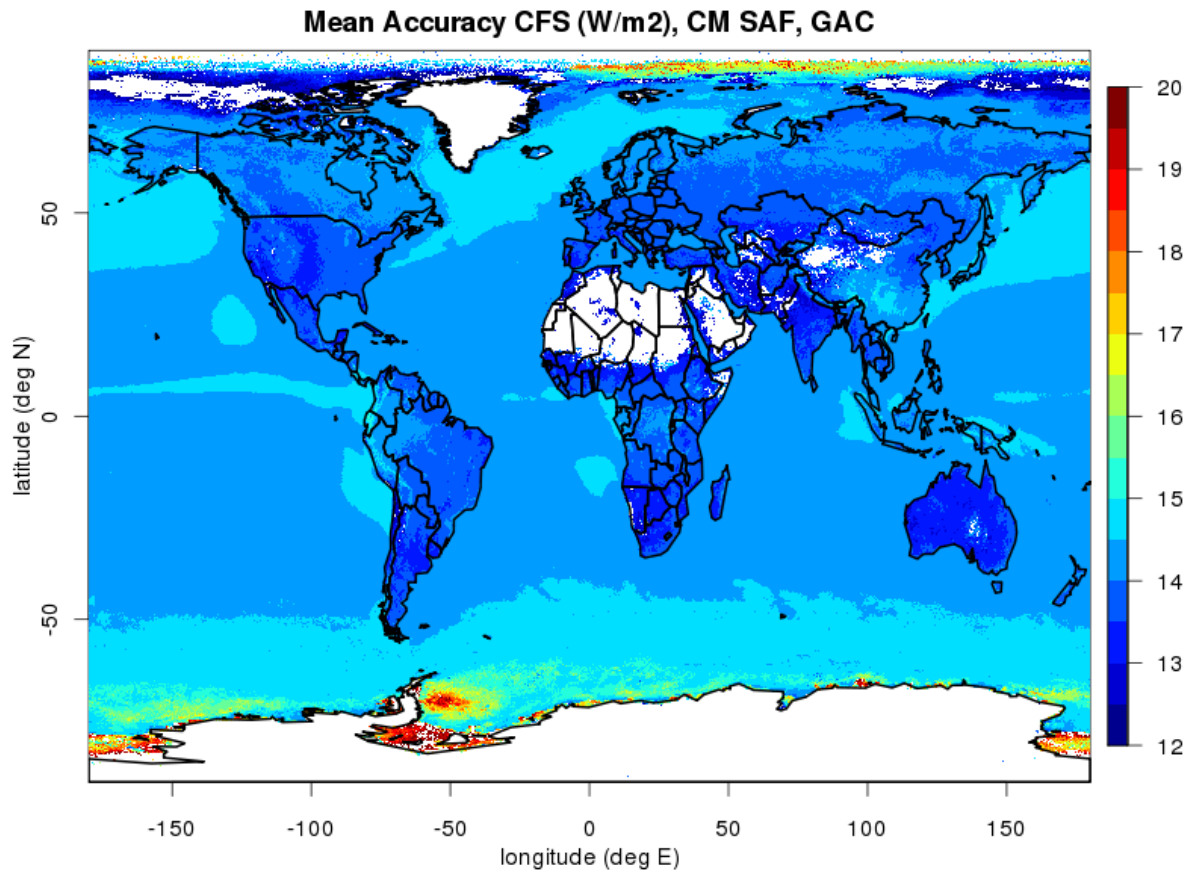


Figure 12: Spatial distribution of the temporally-averaged accuracy for the CM SAF GAC CFS data set.

5.9 CFL Validation

The CM SAF GAC CFL data set is validated based on the validation of the CFC data set. Since the cloud correction factor is derived directly from the ERA-Interim reanalysis data set we calculate the uncertainty of the CM SAF GAC CFL data set based on the accuracy of the CM SAF GAC CFC data set, which has an accuracy of about 10 % (absolute). The uncertainty of the CM SAF GAC CFL data set can then be derived using

$$\Delta CFL = \frac{\partial CFL}{\partial CFC} \Delta CFC = CCF \times \Delta CFC \quad (\text{Eq. 3})$$

The spatial distribution of the accuracy of the CFL data set is shown in Figure 13. In most regions the accuracy of the CFL data set is well below the optimal target accuracy of 8 W/m².

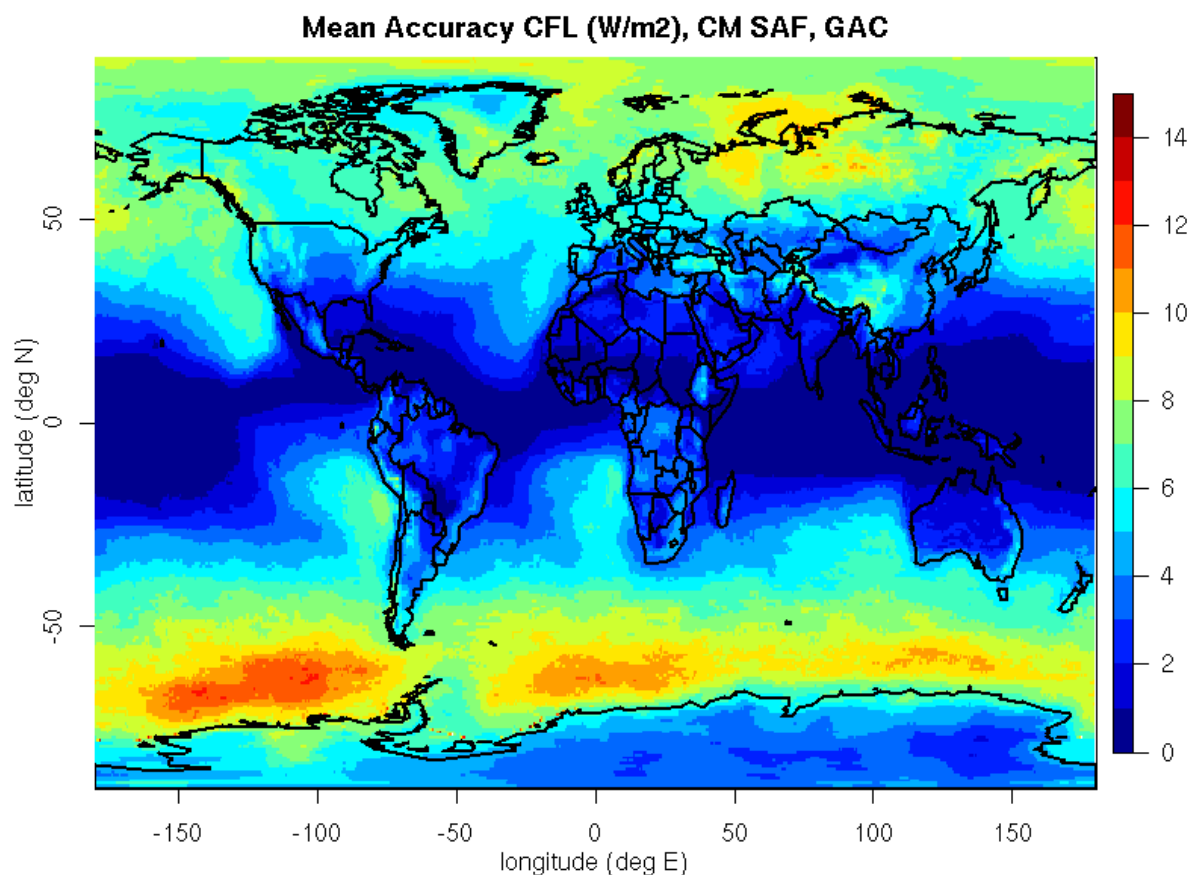


Figure 13: Spatial distribution of the temporally mean accuracy of the CFL data set.



The threshold accuracy of 15 W/m² is never exceeded; the mean accuracy is 4.1 W/m². We conclude that the CM SAF GAC CFL data set fulfils the accuracy requirements as specified in the PRD [AD 1].

6 Conclusions

We presented the validation of the CM SAF GAC Surface Radiation data sets based on the requirements as defined in the CM SAF PRD [AD 1]. From the 8 different data sets, four (SIS (daily and monthly means), SOL, SDL, and CFL) clearly fulfill the optimal or target accuracy requirements. The accuracy of the CM SAF GAC SNS and CM SAF GAC CFS data sets are close to the threshold accuracy requirements, while the CM SAF GAC SRB and the CM SAF GAC SNL data sets exceed the threshold accuracy requirements.

The suitability of these data sets for climate applications depends strongly on the specific application. The general accuracy of the data sets has been shown by validation with reference measurements and by uncertainty assessments. The data sets of the surface shortwave radiation quantities (SIS, SNS, CFS) have been shown to have a high quality and are mainly derived from satellite observations. The quality of the up- and downwelling longwave surface fluxes is also within the expectations, however, since these data sets use substantial information from reanalysis and should not be used for the validation of reanalysis and other model-derived data sets. Due to the error propagation, the accuracy of the net longwave radiation and the total surface radiation might exceed the target accuracy and without further validation with reference measurements these data should be used with care.

Please note, that the temporal stability and homogeneity of these data sets have not yet been fully evaluated. While all possible measures have been taken in the generation of these

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data sets, artificial shifts or trends in the final data sets cannot be excluded. Application of these data sets for the analysis of temporal changes / trend is recommended only after a careful evaluation of the temporal behaviour of these data sets.

7 References

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