EUMETSAT Satellite Application Facility on Climate Monitoring

CM SAF Cloud, Albedo, Radiation dataset, AVHRR-based, Edition 2 (CLARA-A2)

Surface Radiation Products

Validation Report

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Surface Incoming Shortwave Radiation	**CM-11201**
Surface Outgoing Longwave Radiation	**CM-11251**
Surface Downwelling Longwave Radiation	**CM-11261**

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Reference	Title	Code
AD 1	CM SAF Product Requirement Document	SAF/CM/DWD/PRD/2.7

Reference Documents

Reference	Title	Code
RD 1	Algorithm Theoretical Basis Document CM SAF Cloud, Albedo, Radiation dataset, AVHRR-based, Edition 2 (CLARA-A2) Surface Radiation Products	SAF/CM/DWD/ATBD/CLARA/ RAD/2.3

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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 CLARA Edition 2.0 (CLARA-A2) data records 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-11201, SIS_AVHRR_global_D, Section 5.2],
Surface Outgoing Longwave Radiation [CM-11251, SOL_AVHRR_global_DS, Section 5.3],
Surface Downwelling Longwave Radiation [CM-11261, SDL_AVHRR_global_DS, Section 5.4], from the CLARA-A2 surface radiation data record available from 1982 to 2015. All data records (SIS, SOL, SDL) are validated against available reference data records from surface measurements. 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].
All data records fulfil the accuracy requirements as specified in the Product Requirements Document (PRD) [AD 1].

Table 1: Summary of the accuracy of the CM SAF CLARA-A2 surface radiation data records.

Data Record	Threshold / Target / Optimal Accuracies in W/m^2	Data record Accuracy in W/m^2
SIS	15 / 10 / 8 30 / 20 / 15 (daily averages)	9 18
SOL	15 / 10 / 8	14
SDL	15 / 10 / 8	8

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].

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 records is pursued. The ultimate aim is to make the resulting data records 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 records 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 records 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, variabilities and potential trends for the chosen ECVs. CM SAF ECV data records 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 record 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.

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 records derived from the AVHRR GAC satellite data contain information on the shortwave and longwave radiation. The shortwave surface radiation data records (SIS) are based on the retrieval of the surface irradiance using information from the Nowcasting SAF cloud detection algorithm PPSv2014 and the satellite-derived radiances in the visible and near-infrared AVHRR satellite channels [RD 1]. The longwave surface radiation data records rely on information obtained from the ERA-Interim reanalysis and the monthly averaged cloud fraction obtained from the CM SAF CLARA-A2 data record [RD 1].
All products are globally available as monthly averages (SIS is also available as daily averages) between 1982 and 2015 on a 0.25°-regular longitude-latitude grid.

4 Validation Data Records

The validation of the surface radiation data records is conducted against surface measurements from the Baseline Surface Radiation Network (BSRN) [*Ohmura et al.*, 1998]. The BSRN provides quality-controlled surface radiation measurements at more than 50 stations worldwide, with some stations providing data since 1992.The provided data coverage of BSRN differs between few months and more than 20 years of data. 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 CLARA-A2 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 CLARA-A2 surface radiation data records 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 record is validated with available surface observations from the BSRN. 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 CLARA-A2 surface radiation data record fulfil the updated GCOS requirements regarding the horizontal resolution (100 km).

5.1 Methodology

According to the PRD [AD 1] the validation of the CM SAF CLARA-A2 SIS, SDL, and SOL data records is based on the comparison with available surface measurements. The CLARA-A2 data are extracted at each BSRN station site using a nearest-neighbour technique. 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 (see details below). 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/m^2 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, which have more than 12 months of data between 1982 and 2015. The quality of the data records is assessed by comparisons with the specified accuracy in the PRD [AD 1].

Bias

The bias or (also called mean error) is simply the mean difference between the average of two data records, resulting from the arithmetic mean of the difference over the members of the data records. It indicates whether the data record on average over- or underestimates the reference data record.

$$\mathrm{Bias} = \frac{1}{n}\sum_{k=1}^{n}(y_k - o_k) = \bar{y} - \bar{o}$$

Mean absolute difference

In contrast to the bias, the mean absolute difference (herinafter reffered to as absolute bias) is the arithmetic average of the absolute values of the differences between each member (all pairs) of the time series. It is therefore a good measure for the mean “error” of a data record.

$$\mathrm{MAD} = \frac{1}{n}\sum_{k=1}^{n}|y_k - o_k|$$

Standard deviation

The standard deviation SD is a measure for the spread around the mean value of the distribution formed by the differences between the generated and the reference data record.

$$\mathrm{SD} = \sqrt{\frac{1}{n-1}\sum_{k=1}^{n}\left((y_k - o_k) - (\bar{y} - \bar{o})\right)^2}$$

Anomaly correlation

The anomaly correlation describes to which extend the anomalies of the two considered time series correspond to each other without the influence of a possibly existing bias. The correlation of anomalies retrieved from satellite data and derived from surface measurements allows the estimation of the potential to determine anomalies from satellite observations.

$$AC = \frac{\sum_{k=1}^{n}(y_k - \bar{y})(o_k - \bar{o})}{\sqrt{\sum_{k=1}^{n}(y_k - \bar{y})^2}\sqrt{\sum_{k=1}^{n}(o_k - \bar{o})^2}}$$

Here, for each station the mean annual cycle $\bar{y}$ and $\bar{o}$ were derived separately from the satellite and surface data, respectively. The monthly/daily anomalies were then calculated using the corresponding mean annual cycle as the reference.

Fraction of time steps above the validation target values

A measure for the uncertainty of the derived data record is the fraction of the time steps that are outside the requested target value'T'. The target values is given by the target accuracy of the respective CM SAF product, plus the non-systematic error (uncertainty) of the BSRN measurements (Ohmura et al. 1998).

$$\mathrm{Frac} = 100 \cdot \frac{\sum_{k=1}^{n} f_k}{n} \text{ with } \begin{cases} f_k = 1 & \text{if } y_k > T \\ f_k = 0 & \text{otherwise} \end{cases}$$

Thereby, the variable 'y' describes the data record to be validated (e.g., CM SAF) and 'o' denotes the reference data record (i.e., BSRN). The individual time step is marked with 'k' and 'n' is the total number of time steps.

5.2 SIS Validation

The surface incoming solar radiation data record from the CM SAF CLARA-A2is 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 CLARA-A2 SIS data record selected grid boxes are set to missing values. During the generation of this data record it has been found that grid boxes with less than 20 observations per day 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 record.

5.2.1 Monthly Averages

The validation results for the monthly averaged CM SAF CLARA-A2 SIS data record are shown in Table 2.

Table 2: Validation results for the monthly averaged CM SAF CLARA-A2 SIS data record compared to BSRN surface measurements; also included are the results from the CLARA-A1 (predecessor of CLARA-A2) SIS data record

Data record	Analyzed Months	Bias (W/m^2)	Abs. bias (W/m^2)	Std.Dev (W/m^2)	Corr. Ano	Frac. Month > 15 W/m^2
SIS, A2	6.420	--1.61	8.8	13.1	0.87	17.6
SIS, A1	3.105	-3.3	10.4	14.4	0.88	23.6

In total, 6420 monthly mean data values of the surface incoming solar radiation from 54 stations[1] between 1992 and 2015 were used for the validation of the monthly mean CM SAF CLARA-A2 SIS data record. The bias of the data record compared to the BSRN reference data is −1.61 W/m^2, the absolute bias is 8.8 W/m^2. The bias is well below the optimal accuracy of 8 W/m^2 as specified in the PRD [AD 1], showing the excellent quality of the data record. The absolute bias is at the target accuracy of 10 W/m^2 [AD 1], also providing evidence of the high quality of the monthly mean CM SAF CLARA-A2 SIS data record.
Considering the uncertainty of the surface observations of 5 W/m^2, less then 20 % of the available monthly-averaged data values are outside the target accuracy (Table 2). The temporal correlation of the anomalies is 0.87, i.e., the data record is well suited for the detection and quantification of climate anomalies.

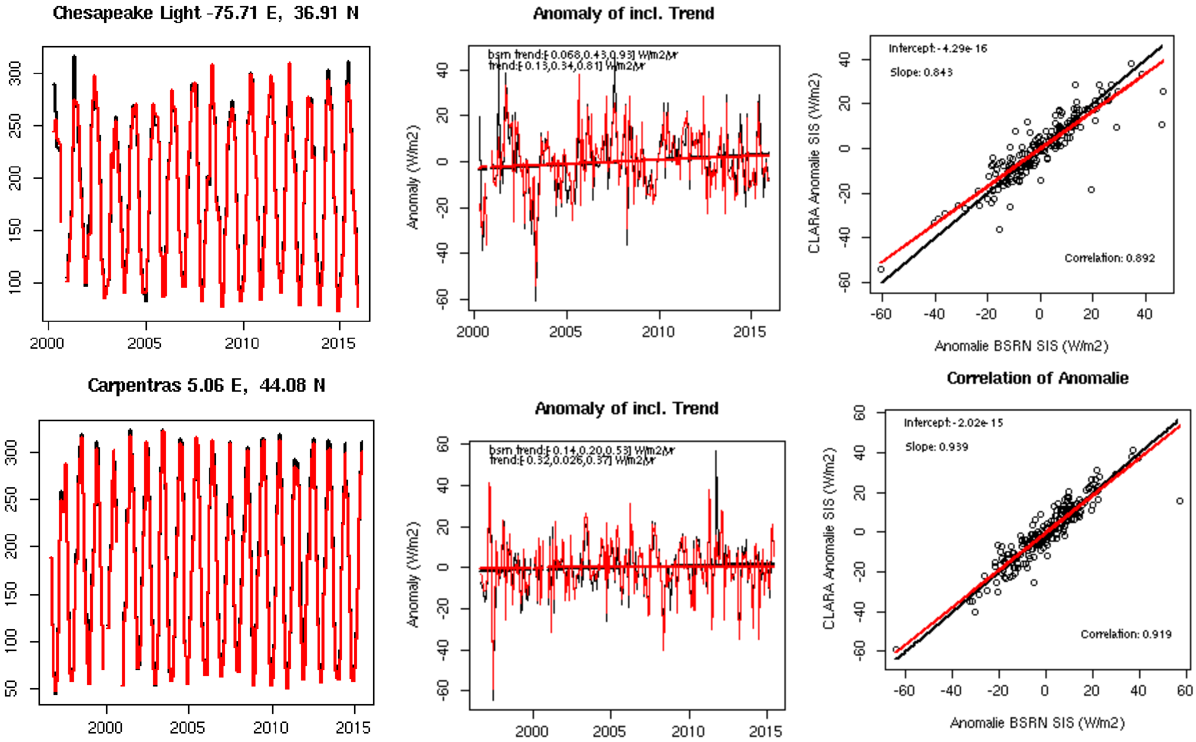


Figure 5-1: Analysis of the monthly time series of the CM SAF CLARA-A2 SIS data record compared to monthly averaged data from BSRN for (upper row) Chesapeake Lighthouse on the US Atlantic Coast and (lower row) Carpentras, France. Shown are (left column) the time series of the monthly mean data records, (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 CLARA-A2 SIS data record.

To document the performance of the CLARA-A2 SIS data record and the analysis Figure 5-1 presents two examples of analysed time series. The CM SAF CLARA-A2 SIS data record 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.

[1] The measurements from Sonnblick, Izana, and Syowa have not been considered for the general assessment of the CLARA-A2 SIS data record. The observations from Sonnblick and Izana are not considered to be representative for the area of a CLARA-A2 grid box; the bias of the CLARA-A2 SIS data record in Syowa is exceptionally large (likely due the snow-coverage of the region) introducing an unrepresentative large error of the CLARA-A2 SIS data record. The validation results from these stations are provided in the stationwise validation, see e.g., Figure 5.3

The high quality of the CM SAF CLARA-A2 SIS data record is shown by the high correlation of the anomalies.

The spatial distribution of the surface stations used for the validation are shown in Figure 5-2 together with the multi-year mean surface solar irradiance for the month of September (chosen to provide the highest data coverage) from the CM SAF CLARA-A2 SIS data record. Figure 5-3 presents the results from the validation of the CM SAF CLARA-A2 SIS data record for each of the 57 BSRN surface stations in more detail. 51 stations are within the target accuracy, while the data record exceeds the target accuracy at 6 of the 57 surface stations. 2 of these surface stations are located in the polar regions (Alert, Syowa) suggesting a general problem of accurately deriving the surface solar radiation over snow-covered surfaces and the difficulty to correctly identify these situations.. Izana (Canary Islands, Spain) and Sonnblick (Alps, Austria), two recently introduced BSRN stations, are located in highly topographically-structured terrain and the representativity of these measurements for comparison with remote-sensing data is questionable. The enhanced bias in Tamanrasset and Ilorin (both stations are located in Africa) might be explained by local aerosol loadings and/or properties, which are not correctly described in the satellite retrieval scheme.

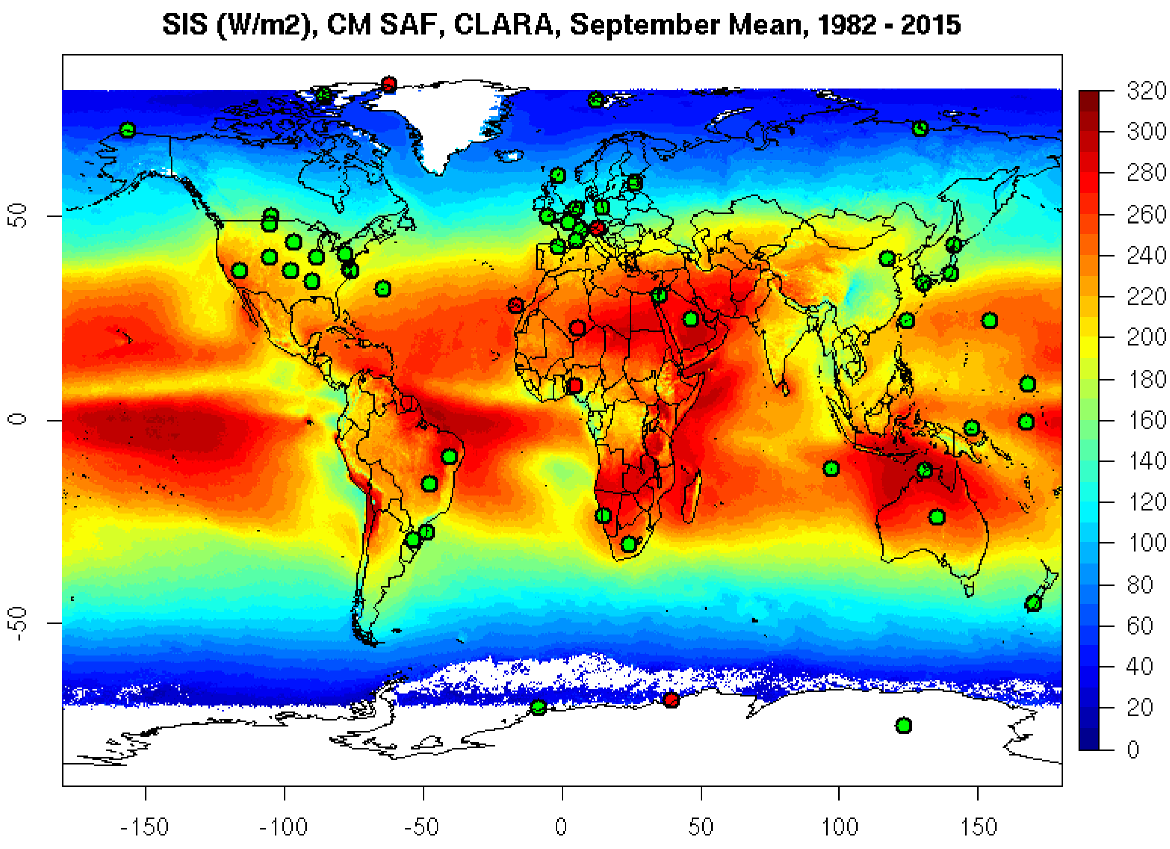


Figure 5-2: Multi-year average of the CM SAF CLARA-A2 surface solar irradiance data record for the month of September (chosen to provide the highest data coverage) and validation results obtained by comparison with available BSRN surface measurements. Green dots represent surface stations where the CLARA-A2 SIS data record is within the target accuracy, red dots correspond to surface stations, where the CLARA-A2 SIS data record does not meet the target accuracy.

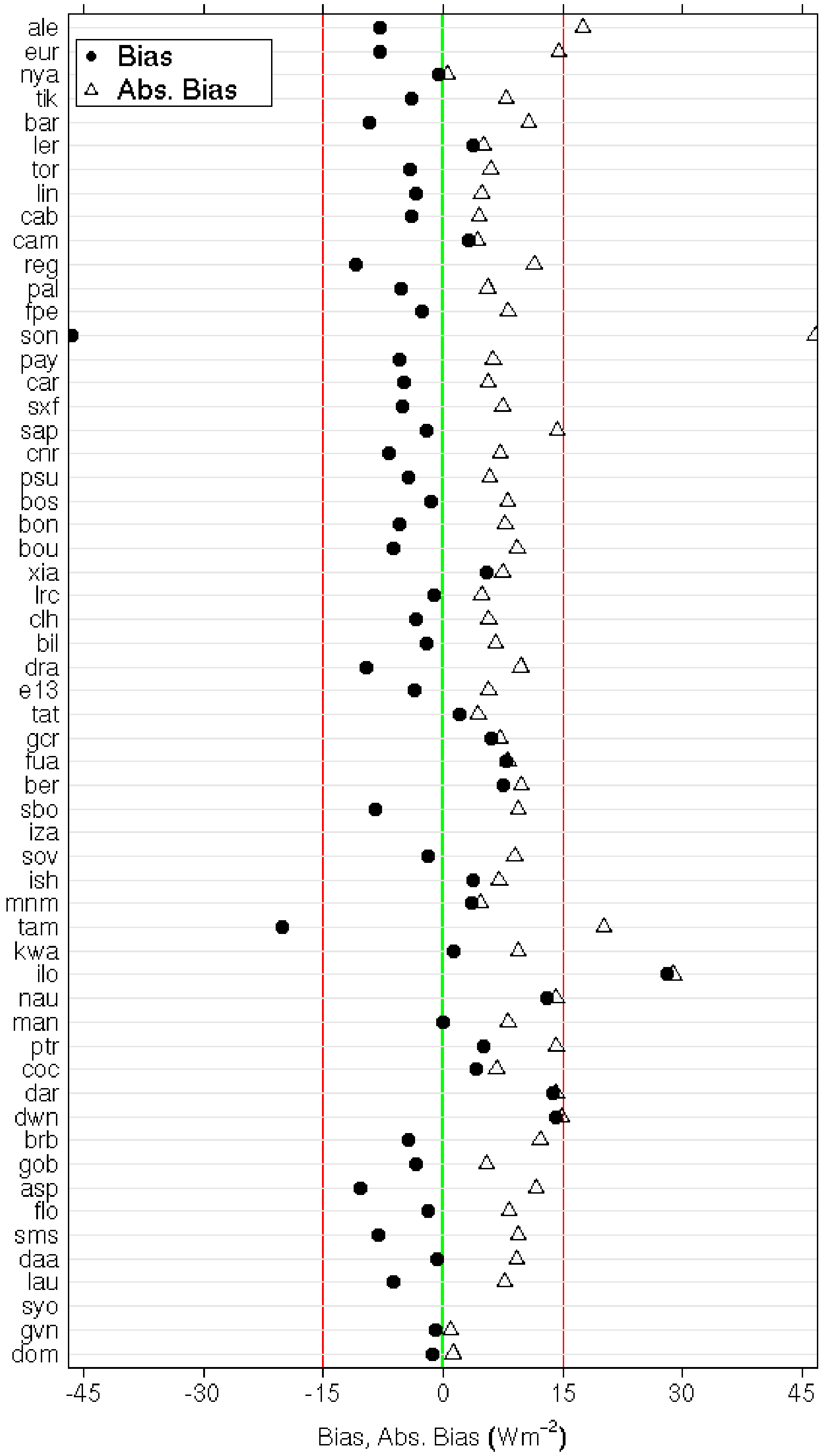


Figure 5-3: Stationwise validation results for the CM SAF CLARA-A2 SIS data record. Shown are the bias (filled dots) and the absolute bias (triangle) of the monthly mean SIS data from the CM SAF CLARA-A2 data record compared to the BSRN surface measurements. The station names are listed north-to-south and named according to their BSRN-label (see http://www.bsrn.awi.de/). The area between the red lines 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 CLARA-A2 SIS data record is within the target accuracy as defined in the PRD [AD 1].

The stability of the CM SAF CLARA-A2 SIS data record is documented by comparison with BSRN surface reference measurements. The temporal evolution of the difference between the CLARA-A2 data record and the surface measurements is used to quantify the decadal stability of the CLARA-A2 SIS data record.

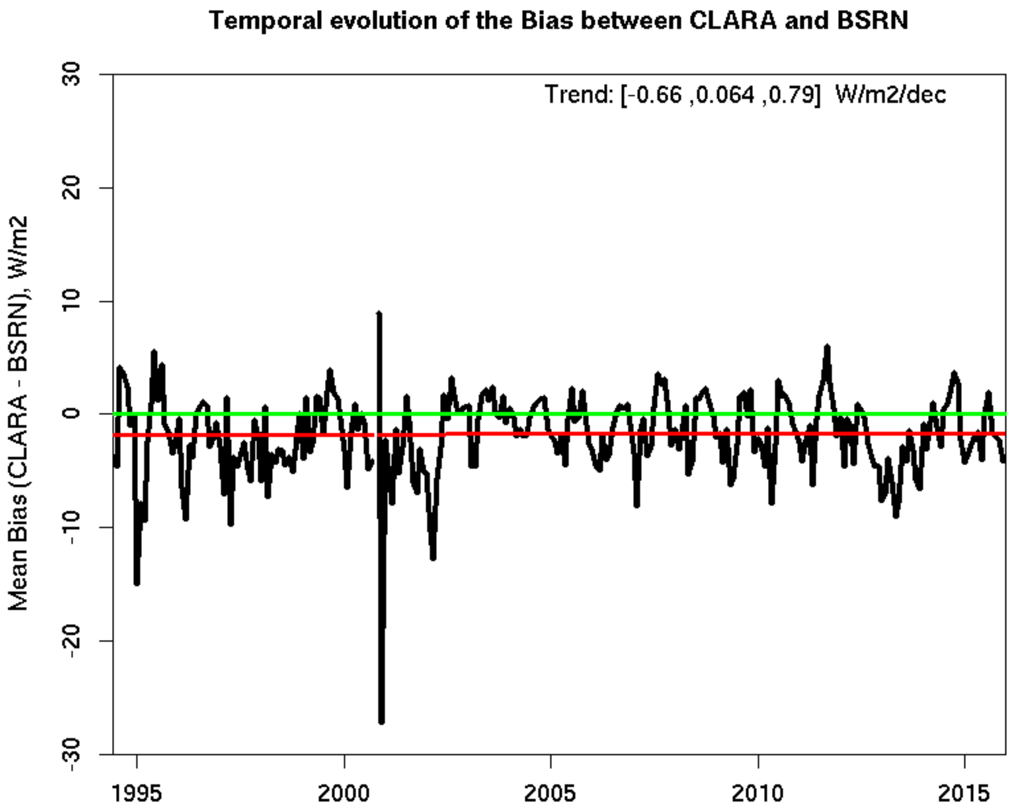


Figure 5-4: Temporal evolution of the mean bias difference between the CM SAF CLARA-A2 SIS climate data record and the BSRN surface measurements. Basis for this figure are BSRN stations used for the general assessment of the CLARA-A2 SIS data record in Table 2.

Figure 5-4 shows the temporal evolution of the mean bias difference between the CM SAF CLARA-A2 SIS climate data record and the BSRN surface references measurements. As already shown in Table 2 the bias is slightly negative and shows no significant temporal trend

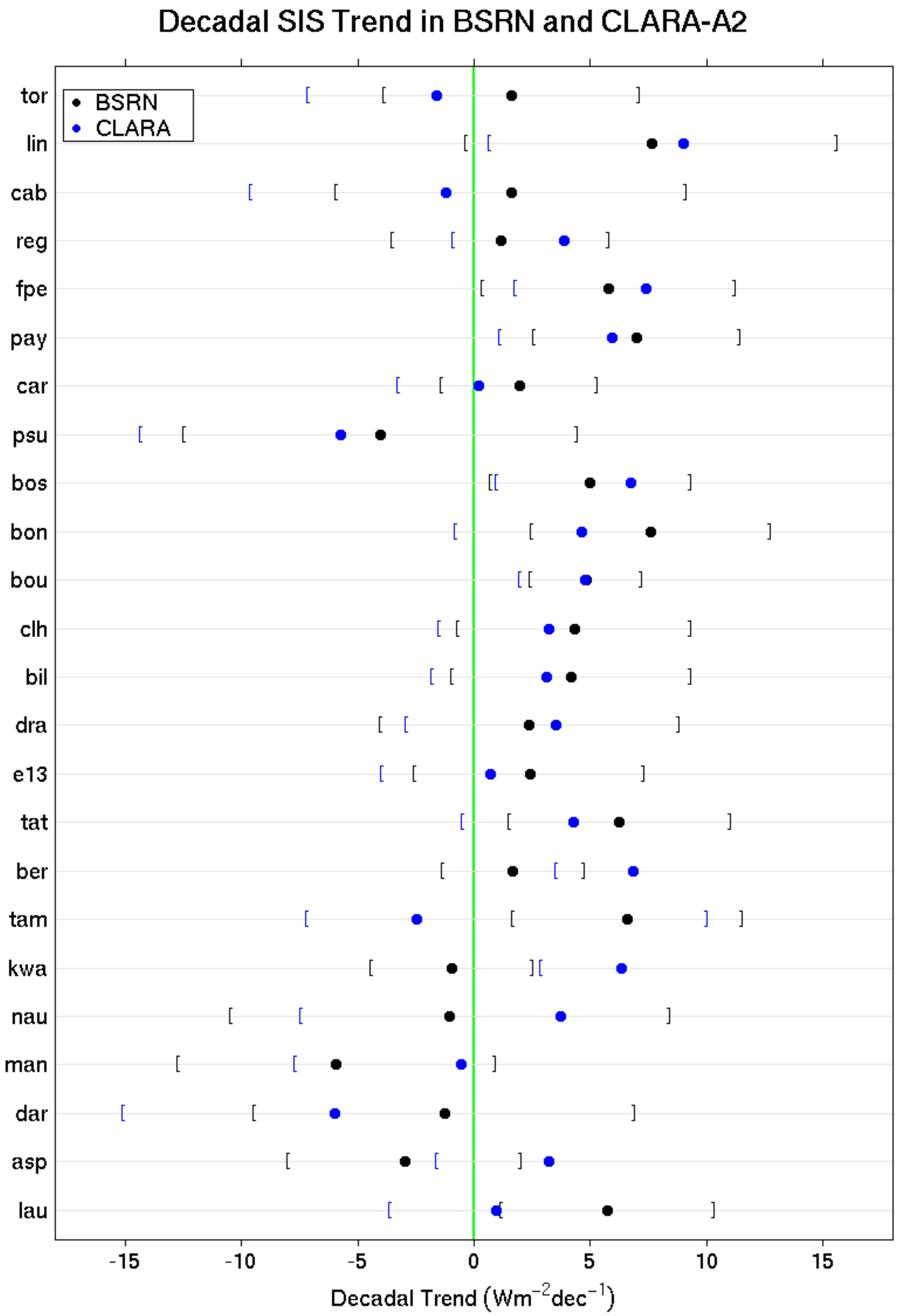


Figure 5-5 Comparison of decadal trends incl. their statistical uncertainty of the CM SAF CLARA-A2 SIS climate data record and BSRN surface measurements at BSRN sites with at least 10 years of overlapping data.

Figure 5-5 shows the decadal trends incl. their statistical uncertainty for the BSRN stations with more than 10 years of common data from the CM SAF CLARA-A2 SIS data record and the surface measurements. There is a tendency of the CLARA-A2 SIS data record to show smaller trends than the BSRN measurements. Within the range of uncertainty the CLARA-A2 SIS data record agrees with the surface reference data at almost all locations; only in Kwajalein (kwa) the trend estimates are different. For both data records there are positive trends at most locations, some of these trends are statistically significant. No significant negative trend in the surface irradiance is detected in both data records.

Overall, we conclude that the CM SAF CLARA-A2 SIS climate data record fulfils the requirement on decadal stability.

5.2.2 Daily Averages

For the surface incoming solar radiation also daily-averaged data are provided by CM SAF as part of the CM SAF CLARA-A2 surface radiation climate data record. The validation of the daily mean CM SAF CLARA-A2 SIS data record is also conducted by comparison with the surface measurements from the BSRN surface network. The target accuracy defined for the daily-averaged data is 20 W/m^2 [AD 1]. The results of the validation of the CM SAF CLARA-A2 data record of the daily mean surface incoming solar radiation are provided in .

Table 3: Validation results for the daily averaged CM SAF CLARA-A2 SIS data record compared to BSRN surface measurements; also included are the results from the CLARA-A1 (predecessor of CLARA-A2) SIS data record

Data record	Analyzed Days	Bias (W/m^2)	Abs. bias (W/m^2)	Std.Dev (W/m^2)	Corr. Ano	Frac. Month > 25 W/m^2	Frac. Month > 30 W/m^2
SIS, A2	181.649	-1.7	18.6	27.7	0.90	25.0	19.5
SIS, A1	96,237	-4.7	22.9	34.3	0.85	25.5	20.8

More than 180.000 daily-averaged data values are considered for the validation of the daily mean CM SAF CLARA-A2 SIS data record. The bias is slightly negative consistent with the result from the monthly mean analysis. The absolute bias is below the target accuracy of 20 W/m^2. About 20 % of the daily mean values deviate to more than 30 W/m^2 (corresponding to the threshold accuracy) from the reference data record. Figure 5-55-5 presents more detailed results from the validation of the daily-averaged CM SAF SIS CLARA-A2 data record for each of the 57 BSRN surface stations. The results of the station-by-station daily validation analysis correspond to analysis of the monthly accuracy of the CLARA-A2 SIS data record.

Overall the accuracy of the daily mean CM SAF CLARA-A2 SIS data record fulfils the accuracy requirement as stated in the PRD [AD 1].

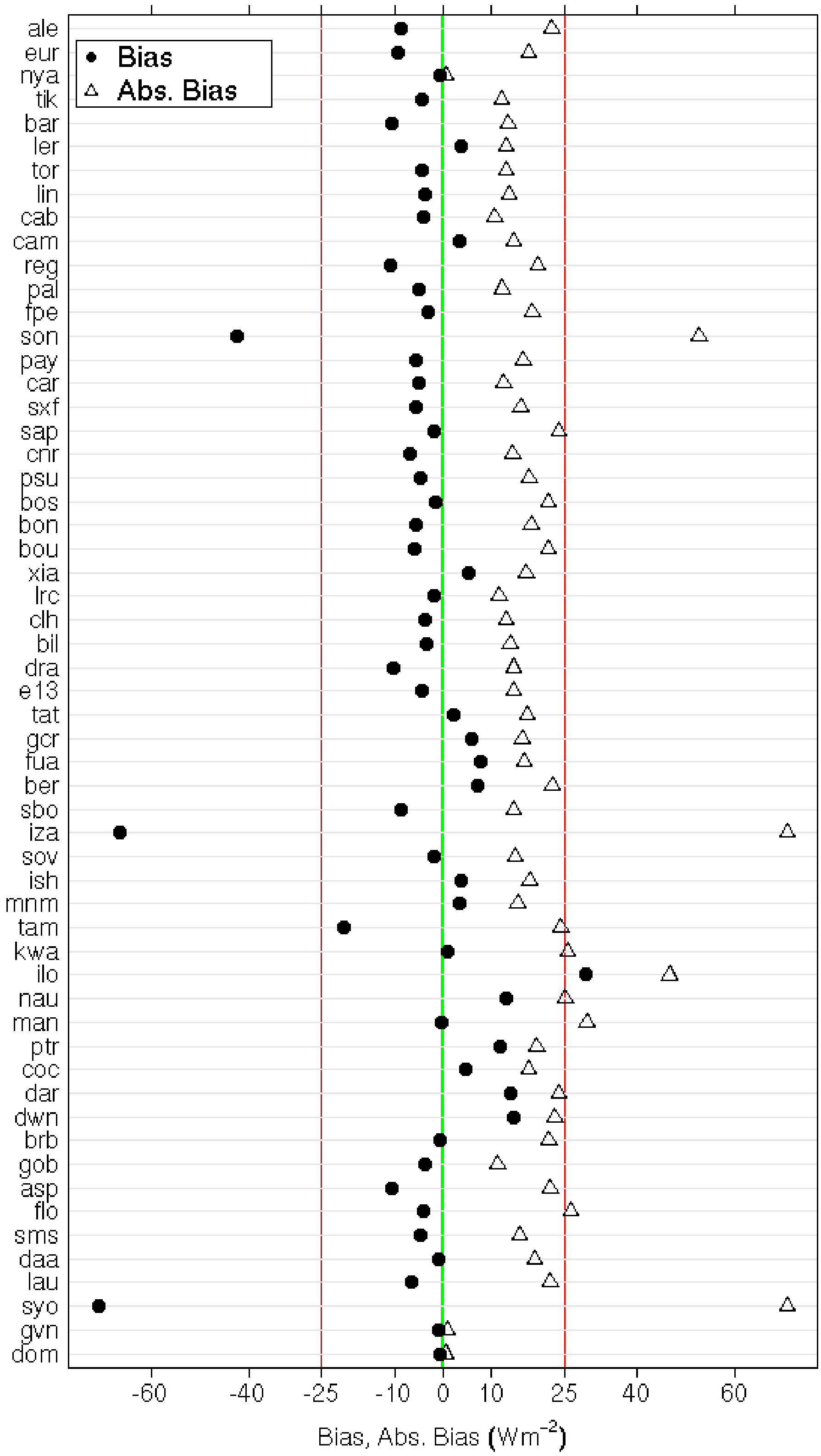


Figure 5-6: Stationwise validation results for the daily mean CM SAF CLARA-A2 SIS data record. Shown are the bias (filled dots) and the absolute bias (triangle) of the daily mean SIS data from the CM SAF CLARA-A2 data record compared to the BSRN surface measurements. The station names are listed north-to-south and named according to their BSRN-label (see http://www.bsrn.awi.de/). The area between the red lines marks the target accuracy including the uncertainty of the surface observations.

5.3 SOL Validation

The validation of the CM SAF CLARA-A2 surface outgoing longwave radiation data record is conducted by comparison with surface measurements obtained within the BSRN network [AD 1]. Only 12 stations provide observations of SOL suitable for the validation of the CM SAF CLARA-A2 SOL data record. It has to be kept in mind that the upward longwave flux is strongly influenced by the fine scale structure of the earth's surface. The downward looking sensors at a BSRN station have typically afield of view of only a few m^2, usually over short grass or concrete. Thus, this might reduce the representativeness of a BSRN station for a 0.25° CLARA-A2 grid box, which introduces additional uncertainties in the comparisons. Table 3 provides the results of the validation.

Table 3: Validation results for the monthly averaged CM SAF CLARA-A2 SOL data record compared to BSRN surface measurements; also included are the results from the CLARA-A1 (predecessor of CLARA-A2) SOL data record

Data record	Analyzed Months	Bias (W/m^2)	Abs. bias (W/m^2)	Std.Dev (W/m^2)	Corr. Ano	Frac. Month > 15 W/m^2	Frac. Month > 20 W/m^2
SOL, A2	1680	2.9	13.7	18.1	0.74	31.6	23.0
SOL, A1	1270	5.8	13.8	17.9	0.71	34.6	24.8
SOL, ERA	1680	1.9	14.1	17.3	0.78	39.2	21.2

The bias is about 3 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 then 32 % of the considered months exceed the target accuracy. Figure 5-6 provides the bias and absolute bias from the validation of the CM SAF CLARA-A2 SOL data record for each of the 12 BSRN surface stations. Nine stations are within the target accuracy, while the data record exceeds the target accuracy at three of the surface stations. The results show that the accuracy of CLARA-A2 SOL is lower over bright surfaces, such as deserts (Gobabeb, gob) or snow (Neumayer station, gvn).

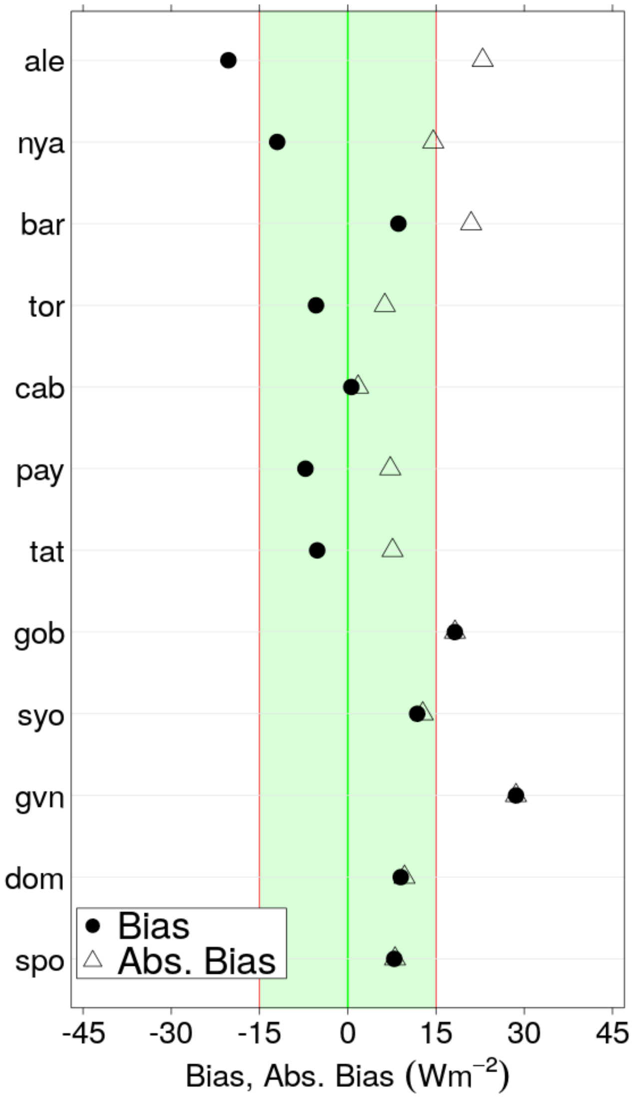
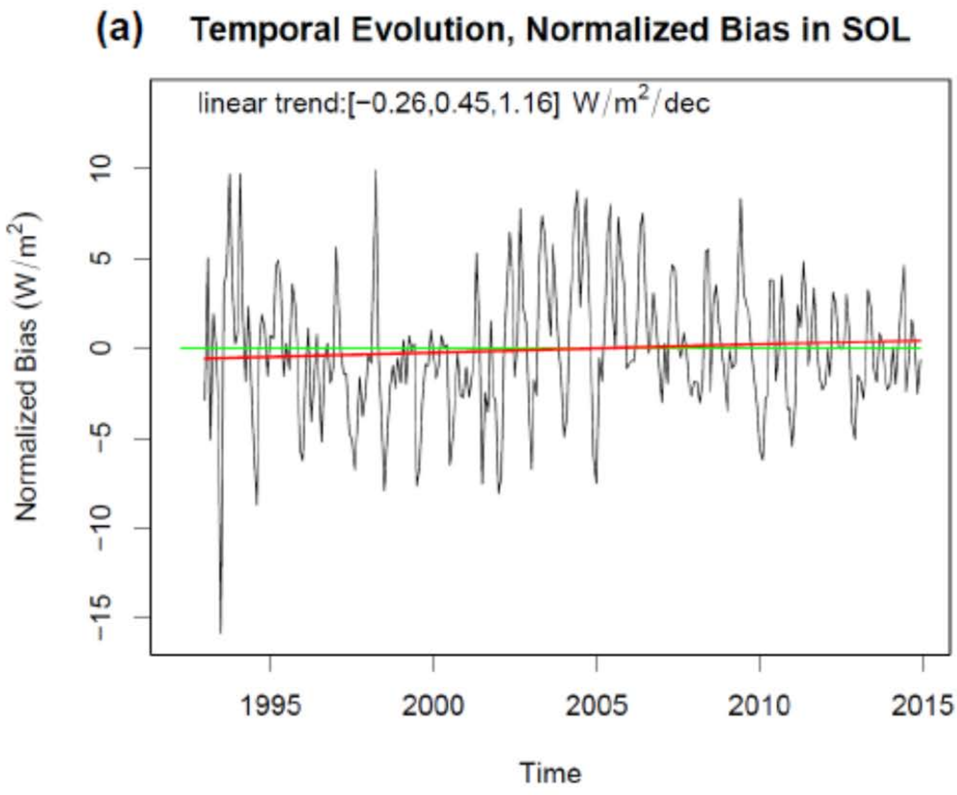


Figure 5-7: presents more detailed results from the validation (bias and standard variation) of the CM SAF CLARA-A2 SOL data record for each of the 12 BSRN surface stations

Overall the accuracy of the monthly mean CM SAF CLARA-A2 SOL data record fulfils the accuracy requirement as stated in the PRD [AD 1].
The stability of the CLARA-A2 SOL climate data record is demonstrated by a low trend in the difference between CLARA-A2 SOL and corresponding BSRN station data (see Fig. 5-7). Figure 5-8 shows that the trends in the SOL data of CLARA-A2 and BSRN are in most cases very similar.


(a) Temporal Evolution, Normalized Bias in SOL
linear trend:[−0.26,0.45,1.16] W/m²/dec
Normalized Bias (W/m²)
10
5
0
−5
−10
−15
1995
2000
2005
2010
2015
Time

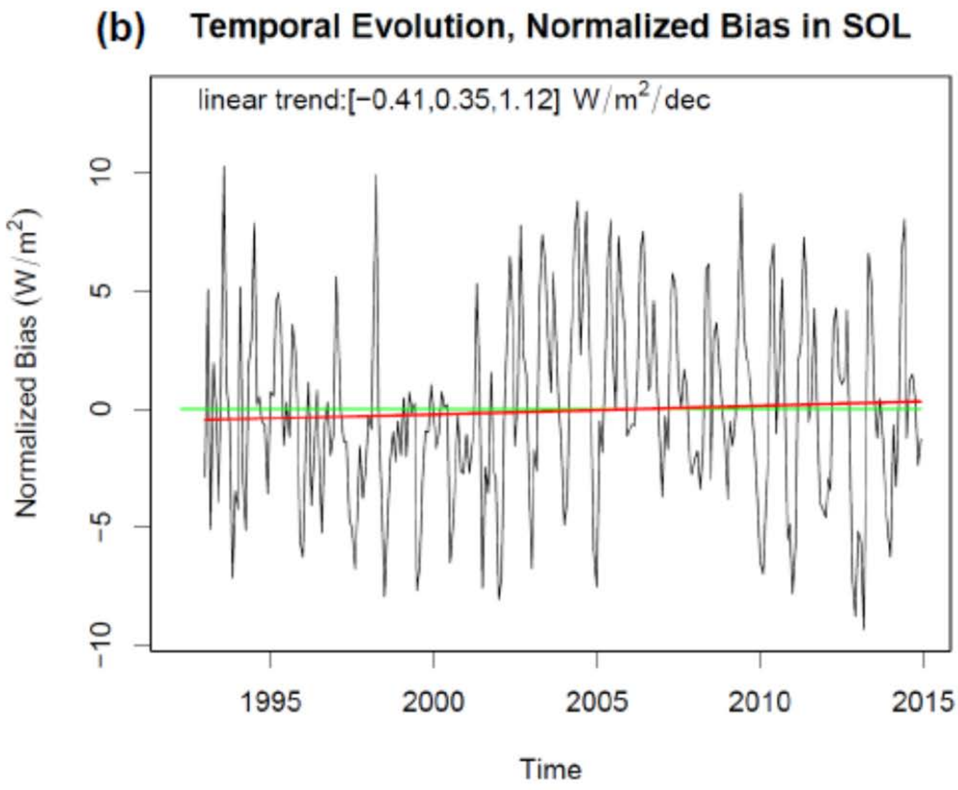

(b) Temporal Evolution, Normalized Bias in SOL
linear trend:[−0.41,0.35,1.12] W/m²/dec
Normalized Bias (W/m²)
10
5
0
−5
−10
1995
2000
2005
2010
2015
Time

Figure 5-7: Temporal evolution of the mean bias difference between the CM SAF CLARA-A2 SOL climate data record and the BSRN surface measurements. Basis for Fig. 5-7a are BSRN stations as used in Fig. 5-6, and for Fig. 5-7b only the BSRN stations with more than 10 years of data are used.

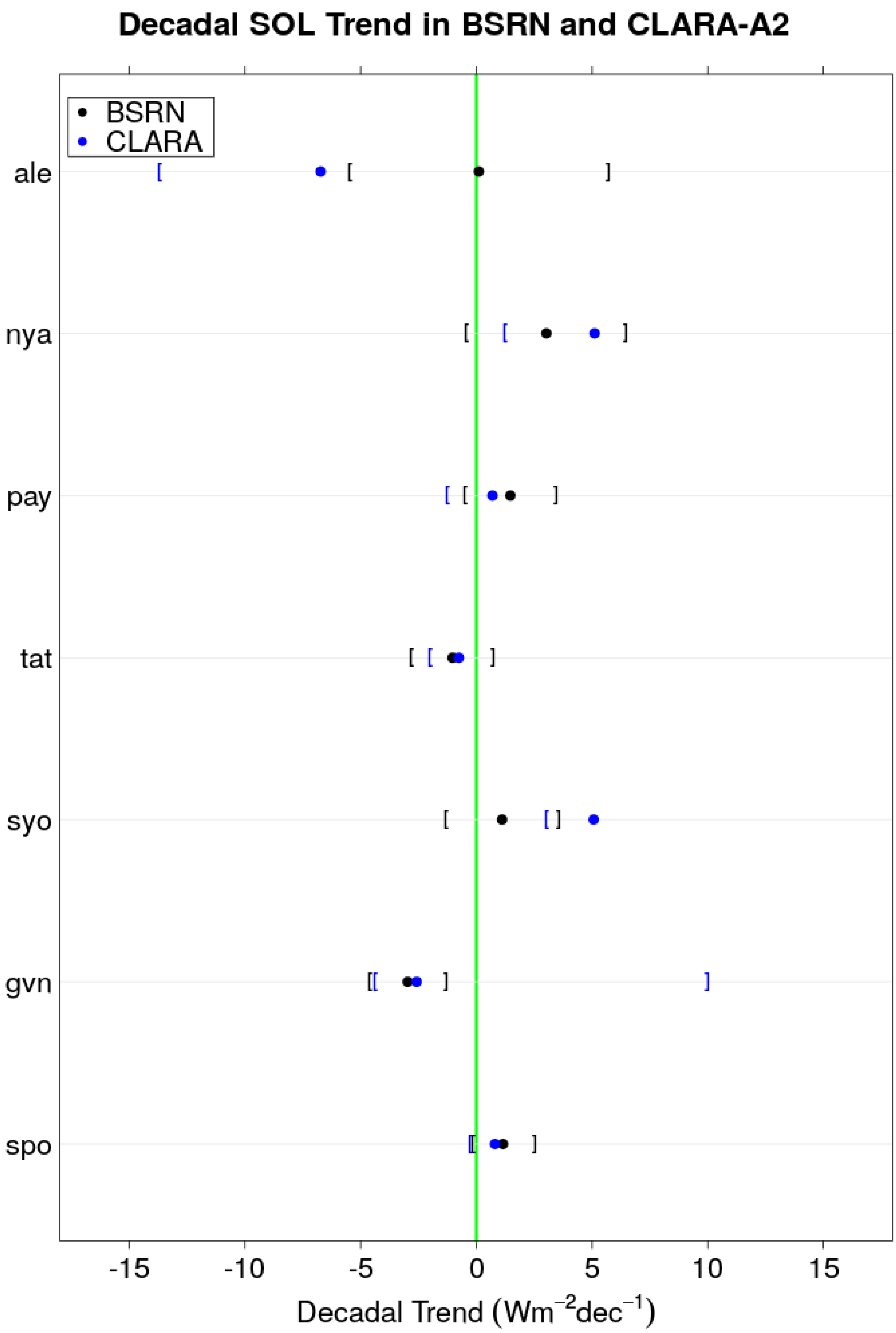


Figure 5-8: **Comparison of decadal trends of CM SAF CLARA-A2 SOL climate data record and BSRN surface measurements at BSRN sites with at least 10 years of data.**

5.4 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 52 stations are used for the validation. The validation results are shown in Table 4.

Table 4: Validation results for the monthly averaged CM SAF CLARA-A2 SDL data record compared to BSRN surface measurements; also included are the results from the CLARA-A1 (predecessor of CLARA-A2) SDL data record

Data record	Analyzed Months	Bias (W/m^2)	Abs. bias (W/m^2)	Std.Dev (W/m^2)	Corr. Ano	Frac. Month > 15 W/m^2	Frac. Month > 20 W/m^2
SDL, A2	7302	-4.7	7.9	9.4	0.84	13.7	6.1
SDL, A1	5314	-3.7	8.3	10.4	0.82	16.5	7.4
SDL, ERA	7302	-6.4	9.4	10.8	0.84	20.5	11.9

The bias of the CM SAF CLARA-A2 SDL data record is slightly negative (−4.7 W/m^2), the absolute bias is close to the optimal accuracy of 8 W/m^2 [AD 1], showing the high quality of the CM SAF CLARA-A2 SDL data record. Less than 14 % of the available monthly mean values exceed the target accuracy, considering an uncertainty of the monthly-averages derived from the surface observations of 5 W/m^2. The corresponding validation results obtained for the ERA-Interim data record are also reported in Table 5 showing the better agreement of the CM SAF CLARA-A2 SDL data record compared to BSRN data. Thus, the downscaling of ERA-Interim by the application of higher resolved CLARA-A2 cloud information and a topography correction gives a high quality data record, which can be used consistently for radiation budget analysis.

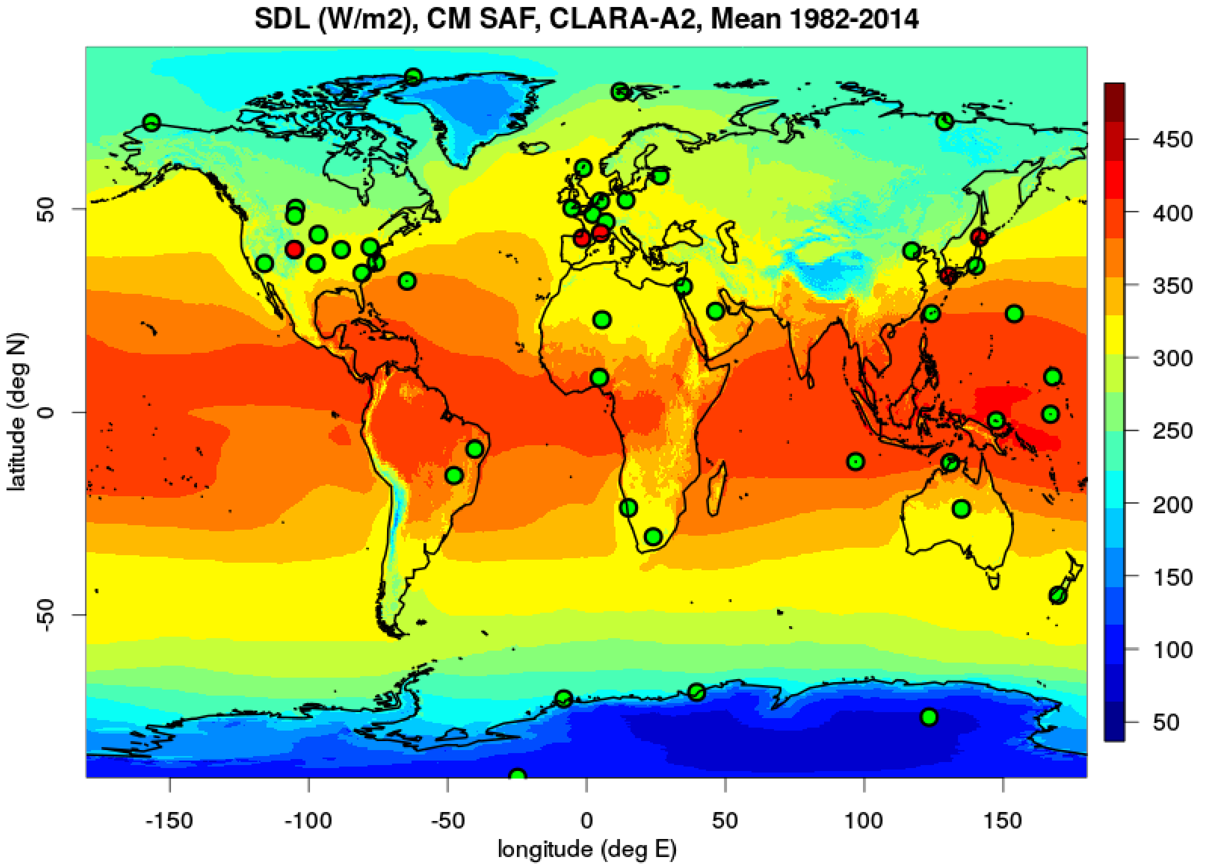


Figure 5-9: Multi-year mean of the CM SAF CLARA-A2 SDL data record. Green dots correspond to BSRN surface stations, where the CM SAF CLARA-A2 SDL data record fulfils the accuracy requirements.

The spatial distribution of the surface stations used for the validation are shown in Figure 5- together with the multi-year mean for the month of July from the CM SAF CLARA-A2 SDL data record. Except for five stations in the mid-latitudes, the quality of all the CM SAF CLARA-A2 SDL data record is within the target accuracy. Figure 5- presents more detailed results from the validation (bias and variance) of the CM SAF SDL CLARA-A2 data record for each of the 52 BSRN surface stations.

Based on the results presented here, we conclude that the monthly mean CM SAF CLARA-A2 SDL data record is within the target accuracy as defined in the PRD [AD 1].

The stability of the CLARA-A2 SDL climate data record is demonstrated by a low trend in the difference between CLARA-A2 SDL and corresponding BSRN station data (see Fig. 5-11). Figure 5-12 shows that the trends in the SDL data of CLARA-A2 and BSRN are in most cases very similar.

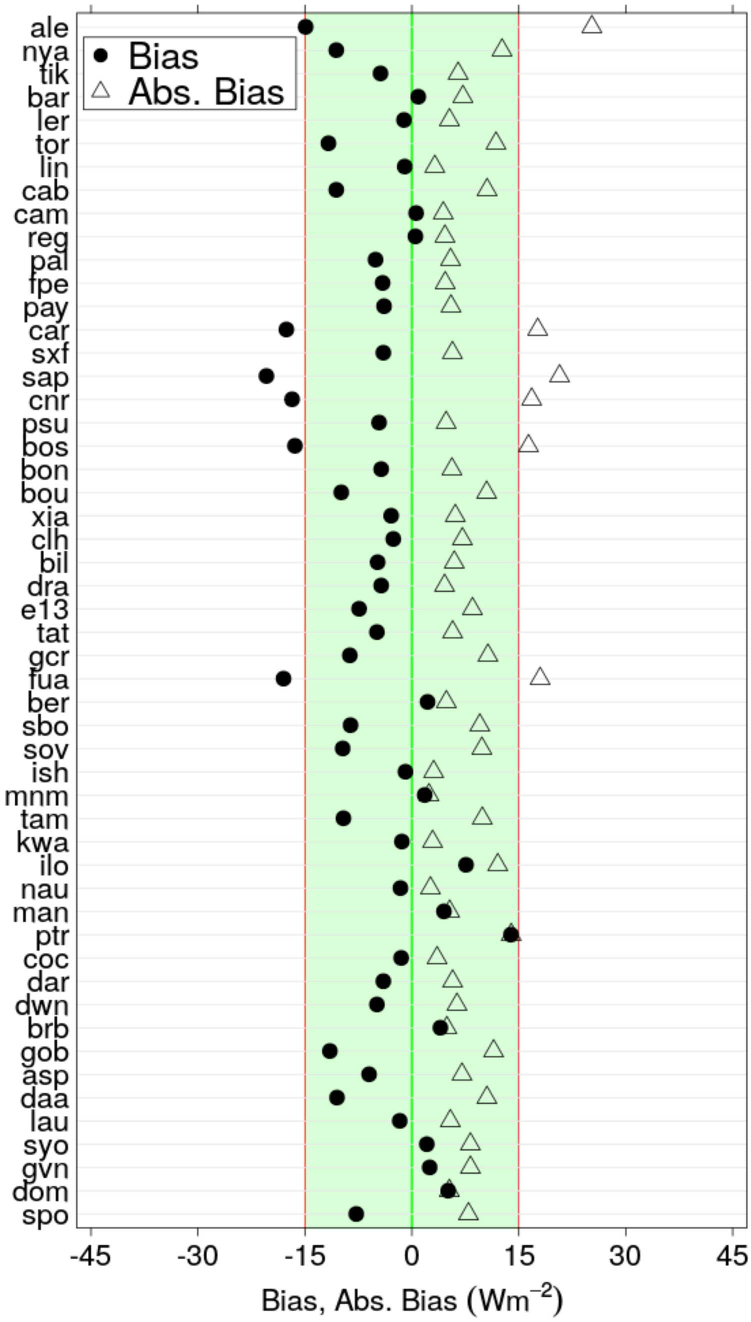
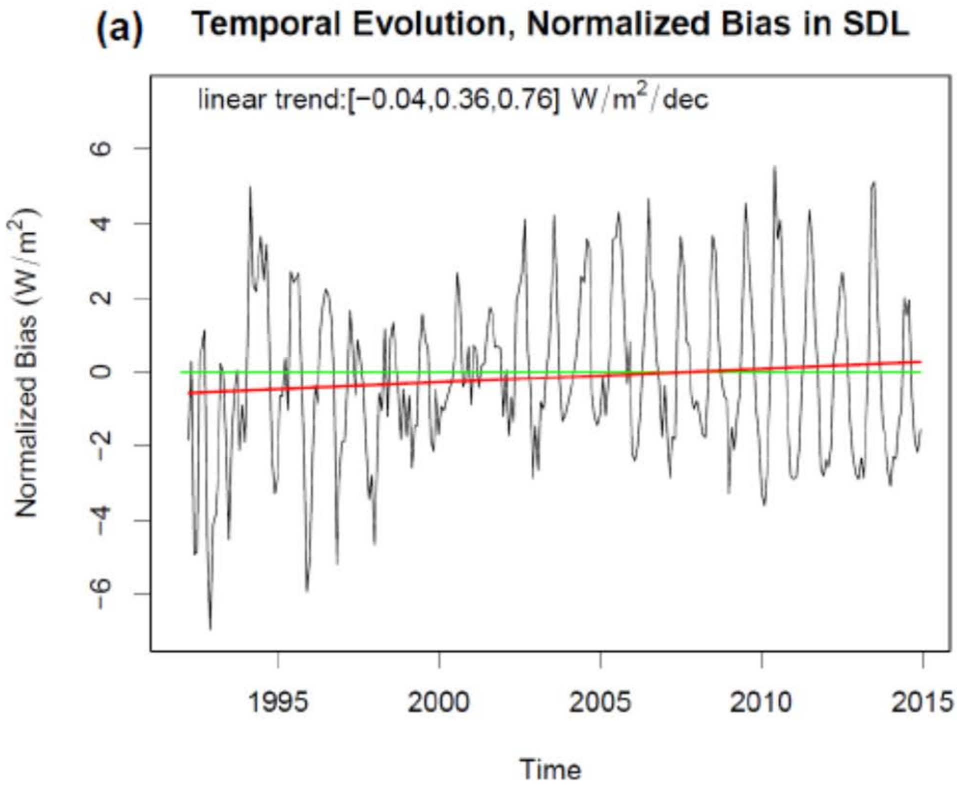


Figure 5-10: Stationwise validation results for the monthly mean CM SAF CLARA-A2 SDL data record. Shown are the bias (filled dots) and the variance (triangle) of the monthly mean SDL data from the CM SAF CLARA-A2 data record compared to the BSRN surface measurements. The station names are listed north-to-south 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.



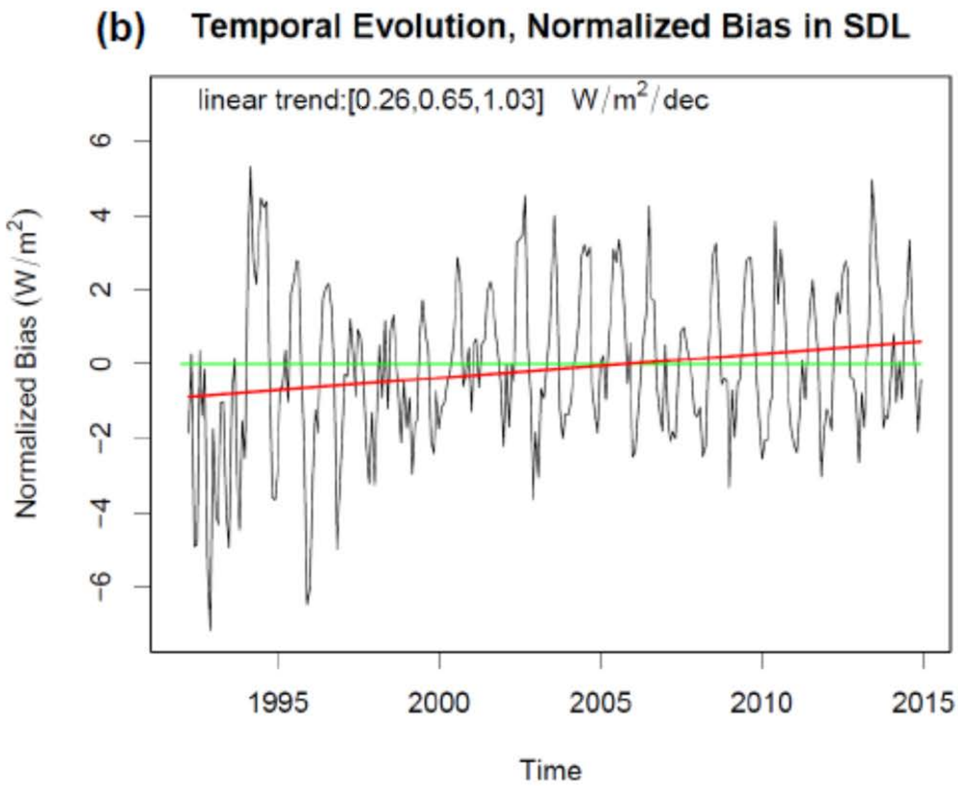


Figure 5-11: Temporal evolution of the mean bias difference between the CM SAF CLARA-A2 SDL climate data record and the BSRN surface measurements. Basis for Fig. 5-11a are BSRN stations as used in Fig. 5-10, and for Fig. 5-11b only the BSRN stations with more than 10 years of data are used.

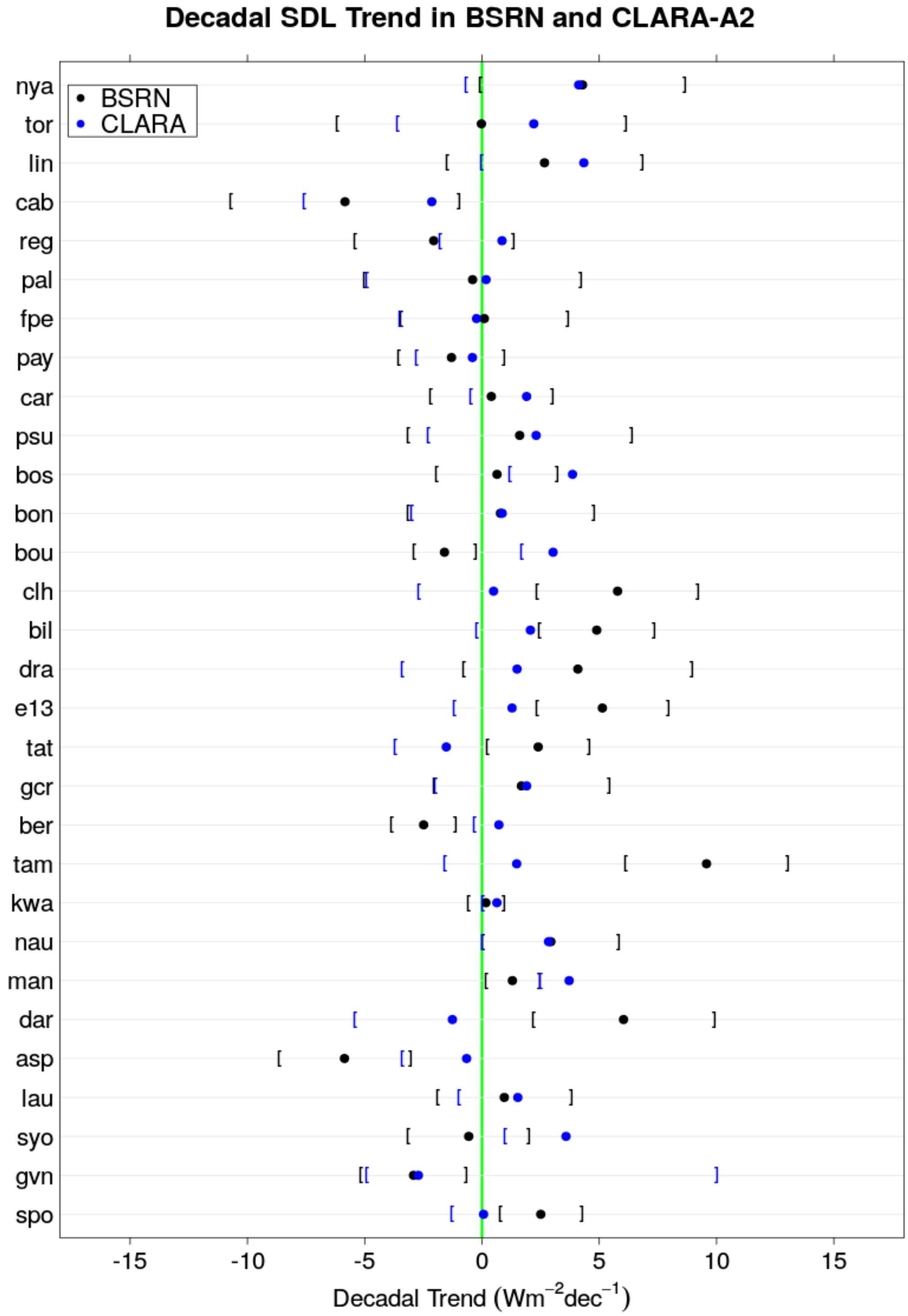


Figure 5-12: Comparison of decadal trends of CM SAF CLARA-A2 SDL climate data record and BSRN surface measurements at BSRN sites with at least 10 years of data.

6 Conclusions

We presented the validation of the CM SAF CLARA-A2 Surface Radiation data records based on the requirements as defined in the CM SAF PRD [AD 1]. All data records fulfil the optimal or target accuracy requirements.

The suitability of these data records for climate applications depends strongly on the specific application. The general accuracy of the data records has been shown by validation with reference measurements and by uncertainty assessments. The SIS data record has been shown to have a high quality and is mainly derived from satellite observations. The quality of the up- and downwelling longwave surface fluxes is also within the expectations, however, these data records use substantial information from reanalysis and should not be used for the validation of reanalysis and other model-derived data records.

7 References

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