EUMETSAT Satellite Application Facility on Climate Monitoring

The EUMETSAT Network of Satellite Application Facilities

CM SAF Climate Monitoring

Product User Manual

Meteosat (MVIRI) Solar Surface Irradiance and effective Cloud Albedo Climate Data Sets

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Surface Incoming Shortwave Radiation (SIS):	**CM-54**
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1 The EUMETSAT SAF on Climate Monitoring (CMSAF)

The importance of climate monitoring with satellites was recognized in 1999 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 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). Since the start of the CM SAF in 1999 the project went through three phases, i.e., the Development Phase lasting from 1999 to 2004, the Initial Operations Phase (IOP) and the Continued Development and Operations Phase (CDOP). 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) and the Meteorological Service of Switzerland (MeteoSwiss).

After focusing on the development of retrieval schemes to derive a subset of Essential Climate Variables (ECVs) in the development phase, CM SAF delivered to its users products based on Meteosat and polar orbiter data for Europe and Northern Africa supporting NMHSs in their provision of climate services in the IOP from 2004 to 2007. During CDOP, lasting from 2007 to 2012, the product validation continued, the time series were expanded and algorithms were further improved, while the study domain was extended from the baseline area to the MSG disk for the geostationary products and to include global and Arctic coverage for the polar orbiter products. In addition, long term climate datasets from polar orbiting and geostationary satellites are being generated for climate monitoring (i.e. HOAPS, METEOSAT and AVHRR-GAC based products).

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

2 Introduction

This CM SAF Product User Manual provides relevant information to the user on the shortwave Meteosat climate data sets. The document enables the user to perform an appropriate use of the data including background information of the applied retrieval methods. The Meteosat (MVIRI) climate data sets are derived from the Meteosat First Generation satellites.

This manual describes available products including example images, gives basic algorithm descriptions and a brief overview of the accuracy. It also discusses potential difficulties affecting the scientific interpretation. Additionally, a technical description of the data including information on format as well as on access and handling tools (e.g. mapping and display tools) is provided in the final sections.

CM SAF data products are distinguished between operational monitoring products and data sets (Schulz et al. (2009)). Operational monitoring products are disseminated with appropriate timeliness for climate monitoring (8 weeks after observation at the latest) to support operational climate monitoring applications of National Meteorological and Hydrological Services. The timeliness requirement means that this type of product is not a priori suitable for monitoring of inter-annual variability and trends with high confidence. Bias errors due to e.g. sensor degradations and orbital shifts as well as inter-satellite biases are not corrected for in the operational monitoring product. However, the characterisation of relatively strong anomalies on the monthly scale should be feasible. Concerning the retrospective produced data sets, errors due to sensor degradations, orbital changes and inter-satellite biases are minimised. Those data sets are aimed at providing time series suitable for analysing variability at longer scales than inter-annual. **This Product User Manual describes exclusively the CM SAF Meteosat solar climate data sets, hence generated data sets covering a fixed period.**

Long time series are needed for climate monitoring and analysis. For this reason there is a need to employ the satellite information of the first generation of Meteosat satellites (Meteosat-2 to Meteosat-7) to generate climate information. The MVIRI instrument onboard the Meteosat First Generation satellites is equipped with 3 channels: a broadband channel in the visible, a channel in the Infrared, and a water vapour channel.

The second generation of Meteosat satellites is equipped with the Spinning Enhanced Visible and InfraRed Imager (SEVIRI) and the Geostationary Earth Radiation Budget (GERB) instrument. The GERB instrument is a visible-infrared radiometer for earth radiation budget studies. It provides accurate measurements of the shortwave (SW) and longwave (LW) components of the radiation budget at the top of the atmosphere. SEVIRI employs twelve spectral channels, which provide more information of the atmosphere compared to its forerunner. Several retrieval algorithms have been developed in order to use the additional information gained by the improved spectral information of MSG mainly for now-casting applications. However, these algorithms can not be applied to the MVIRI instrument onboard the Meteosat First Generation satellites as they use spectral information that is not provided by MFG (NWC SAF cloud algorithm, CM-SAF radiation algorithm).

MVIRI is a passive imaging radiometer with three spectral chances a visible channel covering 500-900 nm, and infra-red channel covering 5.7-7.1 microns and 10.5-12.5 microns. MVIRI comes with a spatial resolution of 2.5km for the visible and 5km for the IR channels, sub-satellite point respectively.

Hence, in order to be able to provide a long time series covering more than 20 years there is a need for a specific climate algorithm that can be applied to the satellites from the Meteosat First and Second Generation. Moreover, the retrieved climate variable must have climate quality.

The MAGICSOL method in combination with the gnu-public license version of MAGIC does meet the above mentioned requirements. The method provides the effective cloud albedo, the solar surface irradiance, and the net shortwave radiation, i.e., all components of the GCOS Essential Climate Variables (ECVs) surface radiation budget and cloud properties.

The applied Heliosat method needs only the broadband visible channel as satellite information and can therefore be applied to MFG and across different satellite generations. The application to other geostationary satellites, e.g., in the US and Asia is also possible. Hence, the Heliosat method has not only the power to provide long time series of ECVS, but also to provide ECVs, which cover the complete geostationary ring.

The Heliosat method, which is well established in the solar energy community, is the basis of the MAGICSOL method for clouds. However, modifications of the original Heliosat method are needed to meet the requirements to generate a Climate Data Set

2.1 Applicable Documents

Reference	Title	Code
AD.1.	CM SAF Product Requirement Document	SAF/CM/DWD/PRD/1.6
AD.2	Cooperation Agreement	

2.2 Reference Documents

Reference	Title	Code
RD.1	Validation Report. Meteosat (MVIRI) Solar Surface Irradiance and effective Cloud Albedo Data Sets. MVIRI_HEL	SAF/CM/DWD/VAL/MVIRI_HEL/1.0
RD.2.	Algorithm Theoretical Baseline Document (ATBD) Meteosat (MVIRI) Solar Surface Irradiance and effective Cloud Albedo Data Sets. MVIRI_HEL	SAF/CM/DWD/ATBD/MVIRI_HEL/1.0

Version history since CDOP-1

The following table list product versions according to the release history of the Meteosat climate data sets from the first release in January 2011 to the respective updated release. The version history is also available for each product on www.cmsaf.eu.

Version	Time range	Major changes
1	Jan 1983 – Jan 2005	• First version based on modified Heliosat version 1.0 • MAGIC version 0x86

3 Description of Meteosat climate data sets

The Meteosat processing provides climate data sets of effective cloud albedo, solar surface irradiance and direct irradiance. The applied method, i.e., MAGICSOL described in detail in the Algorithm Theoretical Baseline document (SAF/CM/DWD/ATBD/MVIRI_HEL), provides also information on the clear sky reflection which can be used to derive the surface albedo and the surface solar net budget. These records enable the calculation of the surface short-wave net radiation budget. The effective cloud albedo, the solar surface irradiance and the direct irradiance are available on a regular 0.03x0.03 degree grid. The spatial coverage covers the Meteosat disk up to a scanning angle of 70 degree as illustrated in Figure 3–1. The data sets are available as hourly, daily and monthly means. All MAGICSOL data sets are introduced in Table 3-1 with associated acronyms and units. Table 3-2 provides an overview about all available surface irradiance and effective cloud albedo data sets and products.

Table 3-1: *Overview of MAGICSOL data sets discussed in this PUM.*

Acronym	Product title	Unit
SIS	Surface Incoming Shortwave Irradiance	W m^{-2}
CAL	Effective Cloud Albedo	Dimensionless
SID	Direct Irradiance at surface	W m^{-2}

Table 3-2 *Overview of CM SAF surface irradiance and effective cloud albedo products and data sets.*

Acronym / Identifier	Product title	Type	Satellite & Instrument	Period & Coverage
SIS / CM-54	**Surface Incoming Shortwave Radiation**	**Data set**	**MFG MVIRI**	**1983-2005 Meteosat disk**
SIS / CM-49	ditto	Product	MSG SEVIRI/GERB	2007-today Meteosat disk
SIS / CM-48	ditto	Product	MSG SEVIRI/GERB	2005-2007 Europe
SIS / CM-50	ditto	Product	NOAA AVHRR	2005-today Europe
SIS CM-51	ditto	Product	MSG/NOAA merged	2007-today Meteosat disk & Northern Europe
CAL CM-111	**Effective Cloud Albedo**	**Data set**	**MFG MVIRI**	**1983-2005 Meteosat disk**
SID CM-106	**Direct Irradiance at Surface**	**Data set**	**MFG MVIRI**	**1983-2005 Meteosat disk**
SID CM-105	ditto	Product	MSG SEVRI/GERB	2009-today Meteosat disk

Figure 3–1 gives an overview of the processed and available area.

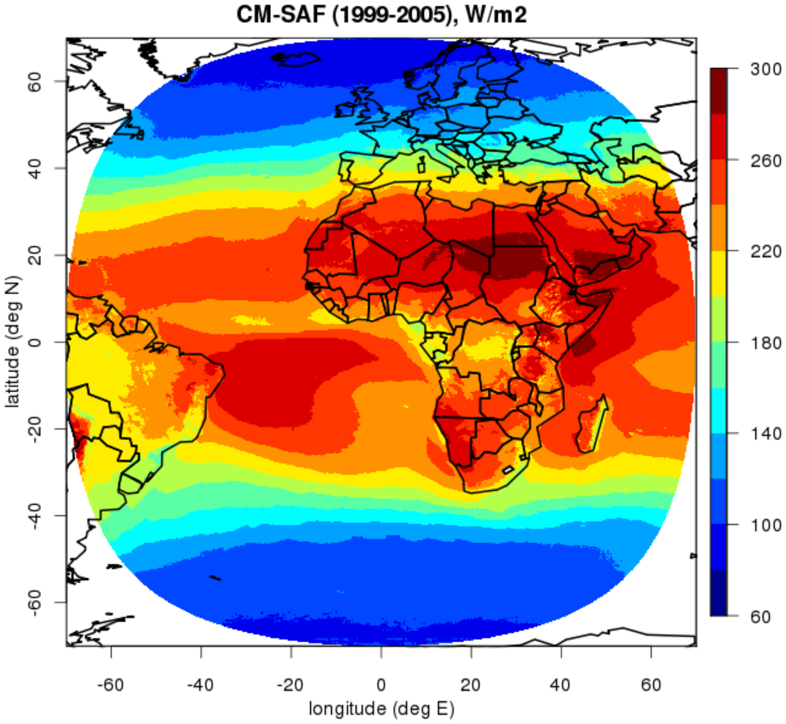


Figure 3–1 Area coverage for CM SAF Meteosat climate data sets, illustrated here for SIS.

3.1 Basic processing of Meteosat images

The processing of the MVIRI data is done in satellite projection. The results are transferred to the regular latitude-longitude-grid using the climate data operators (cdo) (https://code.zmaw.de/projects/cdo). For the retrieval of the effective cloud albedo, the Heliosat algorithm is used (Hammer et al., 2003). The original version of the Heliosat method has been modified to generate a data sets that meets climate quality. The effective cloud albedo derived with the modified Heliosat version is used in combination with the clear-sky surface radiation model MAGIC (Mueller et al.,, 2009) to derive the surface radiation products from the geostationary Meteosat satellites number 2 to 7. The derived parameters and methods are described in more detail in the following sections. The complete model (cloud and clear sky) is called MAGICSOL and described in more detail in the CM-SAF ATBD (SAF/CM/DWD/ATBD/MVIRI_HEL).

The Heliosat method does not require calibrated radiances as input, but is directly based on image counts. To consider the aging of the satellite instruments and the transitions between the satellites of the Meteosat series a self-calibration method has been developed and applied. The self-calibration methods overcomes the need for well calibrated radiances, which are not available for Meteosat First Generation. The MAGICSOL algorithm uses the satellite image information in order to retrieve the effective cloud albedo.

From the Heliosat algorithm the effective cloud albedo is derived. Together with information about the atmospheric clear sky state (water vapour, aerosols, ozone) the effective cloud albedo is used as input for the MAGIC method to calculate the direct irradiance and the solar surface irradiance.

In the following sub-sections a brief description of each individual surface radiation product is given with associated information on averaging methods, validation procedures and known limitations.

3.2 Effective Cloud Albedo (CAL)

3.2.1 Product Definition

The effective cloud albedo is defined as the amount of reflected irradiance for all sky relative to the amount of reflected irradiance for clear sky. Reflected irradiance is not transmitted to the surface. It is therefore an essential variable within the Earth's radiation budget. The effective cloud albedo is the central cloud information used to derive the solar surface irradiance within the MAGICSOL method. It is dimensionless. CAL will be provided for the Meteosat disk, covering Europe and Africa on a regular 0.03x0.03 degree latitude-longitude grid. The data set will compile monthly, daily and hourly means covering the period 1983-2005.

3.2.2 Basic Retrieval approach

The original Heliosat method is described in several publications, e.g. in Hammer et al., 2003, and Cano et al., 1986. It is used to retrieve the effective cloud albedo. The effective cloud albedo is defined as (Equation 3.1):

Equation 3.1: $$CAL = \frac{R - R_{\mathrm{sfc}}}{R_{\max} - R_{\mathrm{sfc}}}$$

Here $R_{\max}$ is a measure for the maximal cloud reflection, R_{sfc} is the clear sky reflection, dominated by the surface albedo and R is the observed irradiance. $R_{\max}$ and R_{sfc} are determined by statistical methods from the observed radiance (R) on a monthly basis. Hence all quantities are based on the observation of the reflections. No additional information (e.g., from a model) is required for the retrieval of the effective cloud albedo. The effective cloud albedo describes the amount of reflected irradiance for all sky relative to the amount for clear sky, normalised to the maximum cloud reflection .

The method for the derivation of $\rho_{\max}$ and ρ_{sfc} has been modified relative to the original Heliosat method to meet the needs for the retrieval of a climate data set. The methods are described in detail in the Algorithm Theoretical Baseline Document (ATBD: SAF/CM/DWD/ATBD/MVIRI_HEL). Here only a brief overview of the modifications is given:

- Implementation of a self-calibration method for the calculation of $\rho_{\max}$. The self calibration method uses the reflections of a stable cloud target in the Southern Atlantic Ocean to correct for changes in the reflections introduced by changes of satellites or aging of satellites. Details are discussed in the MAGICSOL ATBD [RD.2].
- Implementation of a Fuzzy logic method for the retrieval of clear sky radiances and. ρ_{sfc} The Fuzzy logic method enables a better detection of snow and subsequent a better treatment of clouds above snow. The method is an improved version (Dürr and Zelenka, 2009)) of that presented by Zelenka (2001). Further details are discussed in the Heliosat ATBD (RD.2)

3.2.3 Details on processing, gridding and averaging

Monthly, Daily and hourly means are calculated by arithmetic averaging, using Equation 3.2. .

Equation 3.2: $$CAL_{mean} = \frac{\sum_{i=1}^{n} CAL_i}{n}$$

Here i is a loop over the slots per hour for the calculation of hourly means, a loop over the hourly means for the calculation of the daily means and a loop over daily means for the calculation of monthly means. The conversion from the irregular satellite projection to the regular 0.03x0.03 degree grid is done with the climate data operators, see section 5.1 for details on the cdo tools..

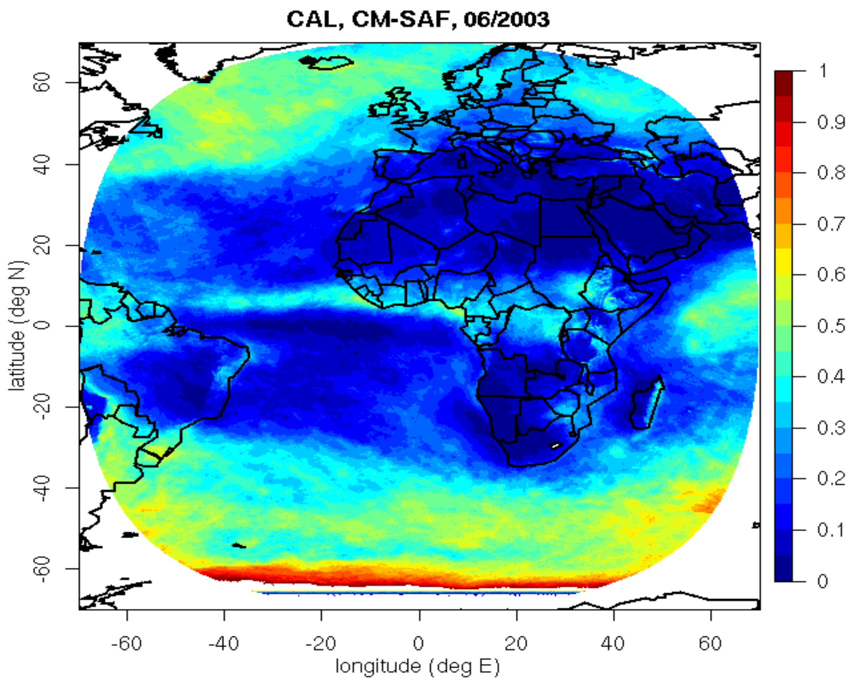
3.2.3.1 Input data

MVIRI images of the broadband channel in openMTP format. Level 1.5 rectified image data of digital counts (not radiances) are used. The respective data are called *"Rectified Image Data"* and provided by Eumetsat (EUM TD 06). Calibrated or inter-calibrated radiances are not needed by the applied MAGICSOL method, the respective issues are resolved by an implemented self-calibration method, described in more detail in the ATBD [RD.2]. This approach follows the Eumetsat recommendation given in EUM TD 05 "…it is necessary to rely to a great extent on vicarious, or external, calibration techniques in order to maintain product quality."

Data from all operational MFG satellites (Metoesat-2, 3, 4, 5, 6, 7) at 0,0 degree position have been used. Further details of the MVIRI input data are described in Eumetsat documentations (EUM TD 06 and EUM TD 04).

3.2.4 Product examples

Figure 3–2 provides examples of the monthly mean CAL product for June 2003 and November 2003.



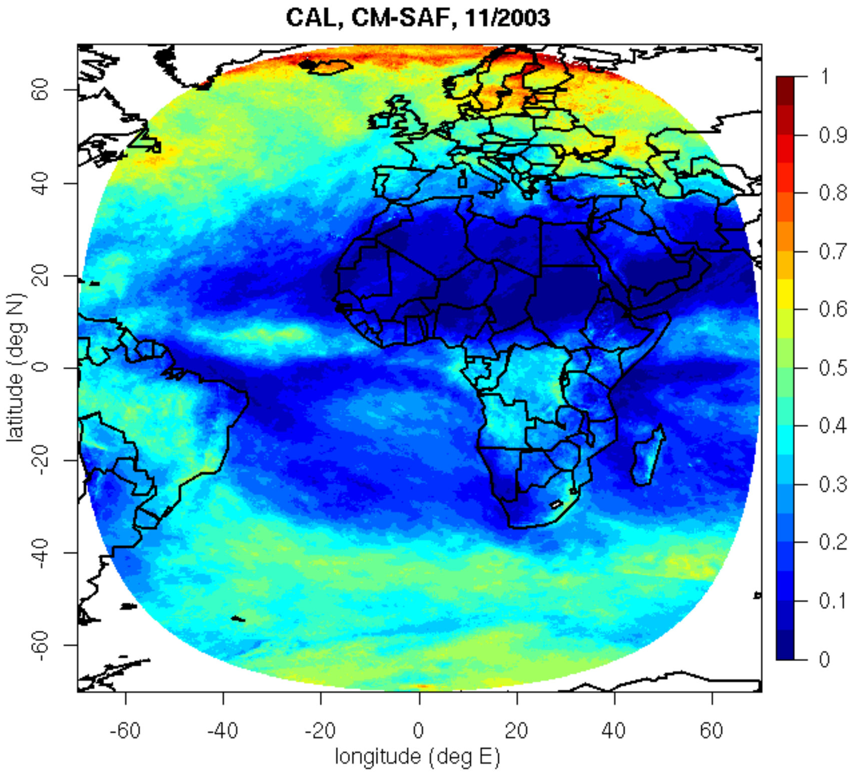


Figure 3–2 Example of the CAL monthly means for June and November 2003.

3.2.5 Validation

The Product Requirement Document (PRD) [AD.1] lists specific product requirements which have to be fulfilled by the products. The achieved accuracy for the CAL product is summarized in Table 3-3.

Table 3-3 *Accuracy achieved for CAL. The 90% limit compiles all regions, no region is excluded.*

Product	Summary on mean error (absolute)
CAL (MVIRI)	*90 % of absolute bias values below 0.1 for monthly means, 0.15 for dailymeans respectively.* *Bias below 0.15 for hourly means.* *Higher bias values occur in the Alpine and other mountainous regions, e.g. due to uncertainties in area to point comparison and errors introduced by snow coverage..*

The detailed results of the validation are presented in the CM SAF Validation Report [RD.2: SAF/CM/DWD/VAL/MVIRI_HEL]. The numbers given in Table 3-3 are worst case accuracies derived from the accuracy of SIS summarised in Table 3-4.

3.2.6 Limitations

- Below is a list of known deficiencies and limitations of the CAL CDR:
- ρ_{sfc} can only be retrieved accurately if a certain amount of clear sky cases are present within each month. In some regions and seasons, this is not always the case. In regions and periods with long-lasting clouds higher uncertainties occur. Here cloud contamination of ρ_{sfc} leads to lower values of CAL, hence to significant errors in CAL. This artefact occurs pre-dominantly for slant geometries (border of Heliosat coverage, or wintertime above a latitude of +/- 60 degrees). It is expected that the target accuracy o. 0.1 (0.15) for monthly (daily) means is not met any more in those regions and higher uncertainties might occur. The sensitivity of this artefact on CAL accuracy is discussed in more detail in the ATBD (RD.2). However, as long-lasting clouds are a pre-requisite for the occurrence of this artefact, the effect on solar irradiance is usually rather small.
- The anisotropy of the cloud reflection leads to uncertainties in the effective cloud albedo in the order of 1-2 %. An improved correction of the anisotropy effect will be included in the next release of the CAL CDR.
- The relatively high clear sky reflection over bright surfaces (snow and specific desert areas) reduces the contrast between clear sky reflection and cloudy sky reflection and leads to higher uncertainties in the calculation of CAL
- User application of the CAL CDR revealed a striping feature for the daily mean products before 1995. This corresponds to products derived from MVIRI data onboard the satellites Meteosat 2-4. For Meteosat 2 and 3 this striping is caused by disregarding the special night-time operation of the satellites (18:00-05:00UTC). During day-time the visible channel contained only half of the image (only every second line) for every even slot, whereas for the odd slots the whole image was available. The image at even slots was completed by copying the existing line onto the non-existing one. However, during night-time every image contained only half of the image which resulted in empty lines (all zero's) for the odd slots because the copying routine was only applied to the even slots. These missing lines are then used in the Heliosat algorithm leading to the striping for CAL and, consequently, for SIS and SID. The hourly mean products are only affected for the early morning and late evening hours. The fields between 07:00 and 17:00 UTC are not involved and can be used without limitations. For the other times during the day the striping is very strong. For SIS for example the mean amplitude is in the order of 40-50 W/m², and a maximum of about 70-80 W/m²is found. Therefore, the data for these time periods should not be used. The daily mean products are affected to a lesser extent as the averaging over the whole day reduced the influence of the early and late hours. However, the striping is visible. For the SIS daily mean product the mean amplitude of the stripes is in the order of 5 W/m² (maximum in the order of 20 W/m²). For Meteosat 4 the reason for the striping is not yet fully understood. It is not only limited to the early morning and late evening hours but occurs during the whole day Meteosat 4 should not have missing lines as always full images should be available. Complications might occur during the times when Meteosat 3 served as substitute for Meteosat 4 which then carried on within the processing chain. Thus, further investigations must and will be carried out. Until then the daily means from Meteosat 4 should also be handled with care.

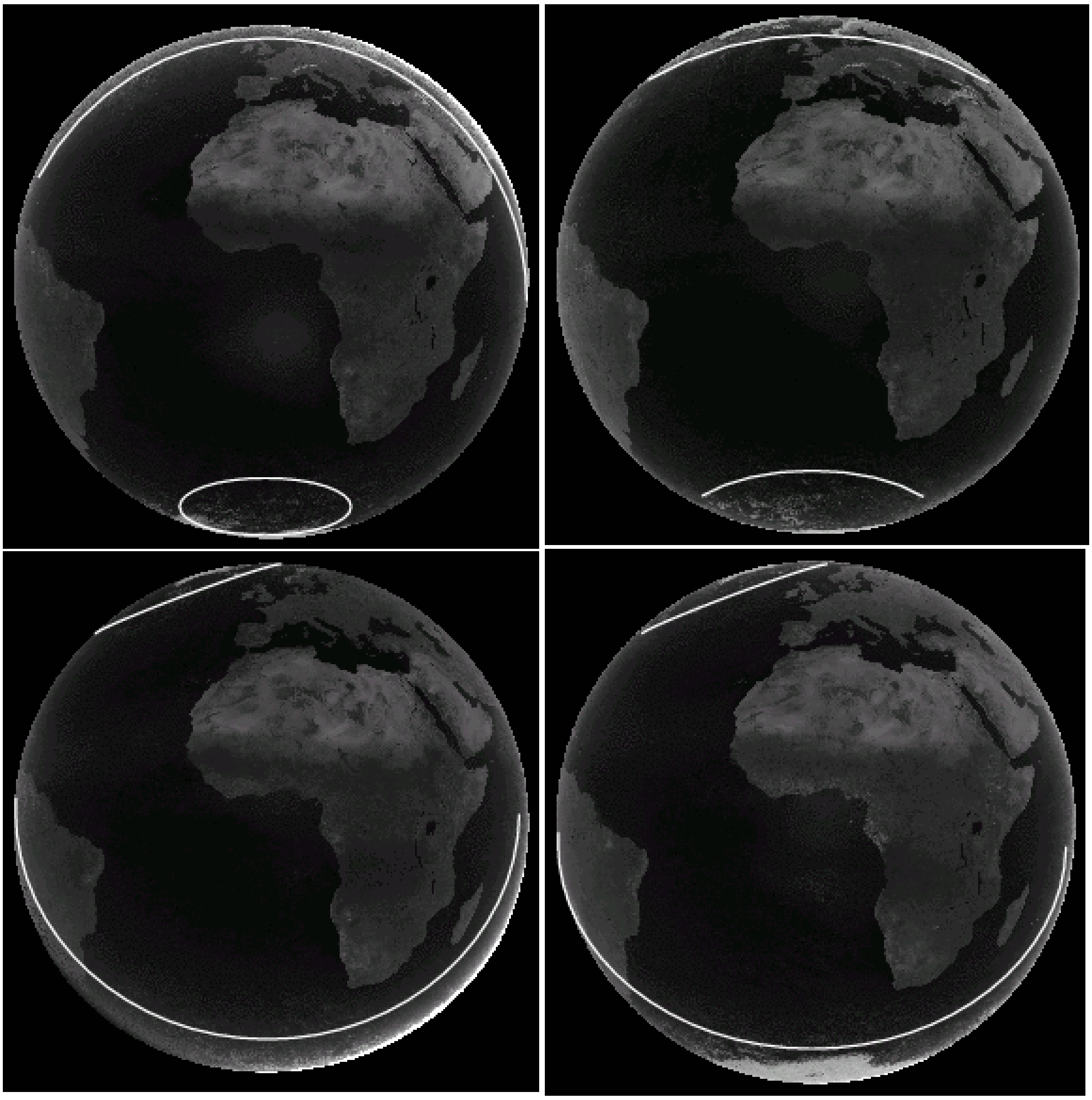


Figure 3–3: Examples of ρ_{sfc} images, here for 2000 ,12 GMT, from top left to bottom right, December, March, June and September. The white speckle patterns beyond the white lines close to the border of the disk are due to significant cloud contamination of ρ_{sfc}. However, close to the poles, some white regions are not an artefact but due to ice (Greenland & Arctic in the September image). Cloud contamination occurs also in a small band around sunrise and sunset at the East and West border of the disk, respectively. However, the core of the Meteosat disk is almost not affected.

3.3 Surface Incoming Solar Radiation (SIS)

3.3.1 Product definition

The surface incoming solar (SIS) radiation is the radiation flux (irradiance) reaching a horizontal plane at the Earth surface in the 0.2 - 4 µm wavelength region. It is expressed in Wm^{-2}.

3.3.2 Basic Retrieval approach

The surface incoming solar radiation (SIS) is retrieved using the Heliosat method. The Heliosat method is based on the conservation of energy. As a consequence the basic relation between the solar irradiance and the effective cloud albedo is as follows:

Equation 3.3: $$SIS = SIS_{CLS} * (1 - CAL)$$

Here, SIS is the solar surface irradiance, SIS_{CLS} the clear sky irradiance and CAL is the effective cloud albedo, also called cloud index n in former publications (e.g., Cano, 1986) . For effective cloud albedo values above 0.8 the above equation is modified in order to consider the saturation and absorption effects within optically thick clouds. The modification of the equation for small and large values of CAL is based on ground measurements and is described in detail in the ATBD [AD3] and given in the Appendix, Section 7.3, of this document.

When CAL is known, SIS can be calculated from the clear-sky solar irradiance. The algorithm to calculate the clear-sky solar surface irradiance uses RTM based LUTs for the calculation of SIS_{CLS} .

The radiative transfer model (RTM) libRadtran (Mayer and Kylling, 2005) was used for the generation of the LUT. The LUT contains SIS values for a wide range of atmospheric states and 24 spectral bands. The SIS value for the actual atmospheric state is then calculated by interpolation between the states. The atmospheric states cover different values for water vapour, ozone, aerosol optical depth, aerosol single scattering albedo, and asymmetry parameter. Several aerosol types were included (Hess et al., 1998). Additionally, Modified Lambert Beer (MLB)-LUTs are used (Mueller et al, 2004). A specific aerosol optical thickness and aerosol type can be assigned to each pixel depending on the provided aerosol background map. Two different background aerosol maps are available and currently the one after Kinne et al. 2006 is used. Water vapour amounts (monthly means) are taken from ERA-40 and ERA-interim reanalysis. The interpolation between the LUTs is done with a linear interpolation scheme.

3.3.3 Details on processing, gridding and averaging

Daily averages are calculated following a method by Möser (1983) (also published in Diekmann et al., 1988), see Equation 3.4.

Equation 3.4, calculation of SIS means: $$SIS_{DA} = SIS_{CLSDA} \frac{\sum_{i=1}^{n} SIS_i}{\sum_{i=1}^{n} SIS_{CLS\,i}}$$

SIS_{DA} is the daily average of SIS. SIS_{CLSDA} is the daily averaged clear sky SIS, SIS_i the calculated SIS for satellite image *i* and SIS_{CLS_i} the corresponding calculated clear sky SIS. n is the number of images available during a day.

The applied equation for averaging accounts for data gaps (missing values) and zero values. However, the larger the number of available images per day, the better the daily cycle of cloud coverage can be resolved, increasing the accuracy of the daily average of SIS. A minimum number of three available pixels per day is required to derive the daily mean for this specific pixel. The monthly average is calculated from the daily means of this month on pixelbasis as arithmetic mean with a required number of 20 existing daily means. The hourly means are calculated as arithmetic average using Equation 3.2. The conversion from the irregular satellite projection to the regular 0.03x0.03 degree grid is done with the climate data operators, see section 5.1 for details of the cdo tools.

3.3.4 Input data

- CAL from MVIRI processing, available for each pixel in satellite resolution.
- Total water vapour from the ERA-interim Reanalysis have been used from 1989 onwards. Up to 1989 ERA Reanalysis data have been used (Uppalla et al., 2005 anmd Betts et al. 2009). Monthly means on 0.5x0.5 degree latitude-longitude grid. The pixel value is derived by spatial interpolation and assignment of the respective monthly mean.
- Ozone content, climatological value from MPI standard profiles (Krämer et al., 2003).
- Lookup tables.
- Surface albedo from SARB/CERES (see section 7.2 for details), only needed for the clear sky model.
- Aerosol climatology after Kinne et al. 2006 is used. Monthly long term means on 1x1 degree latitude-longitude grid. The pixel value is derived by spatial interpolation and assignment of the respective monthly mean.

3.3.5 Product examples

Figure 3–4 provides examples of the monthly mean SIS product for June 2003 and January 2003.

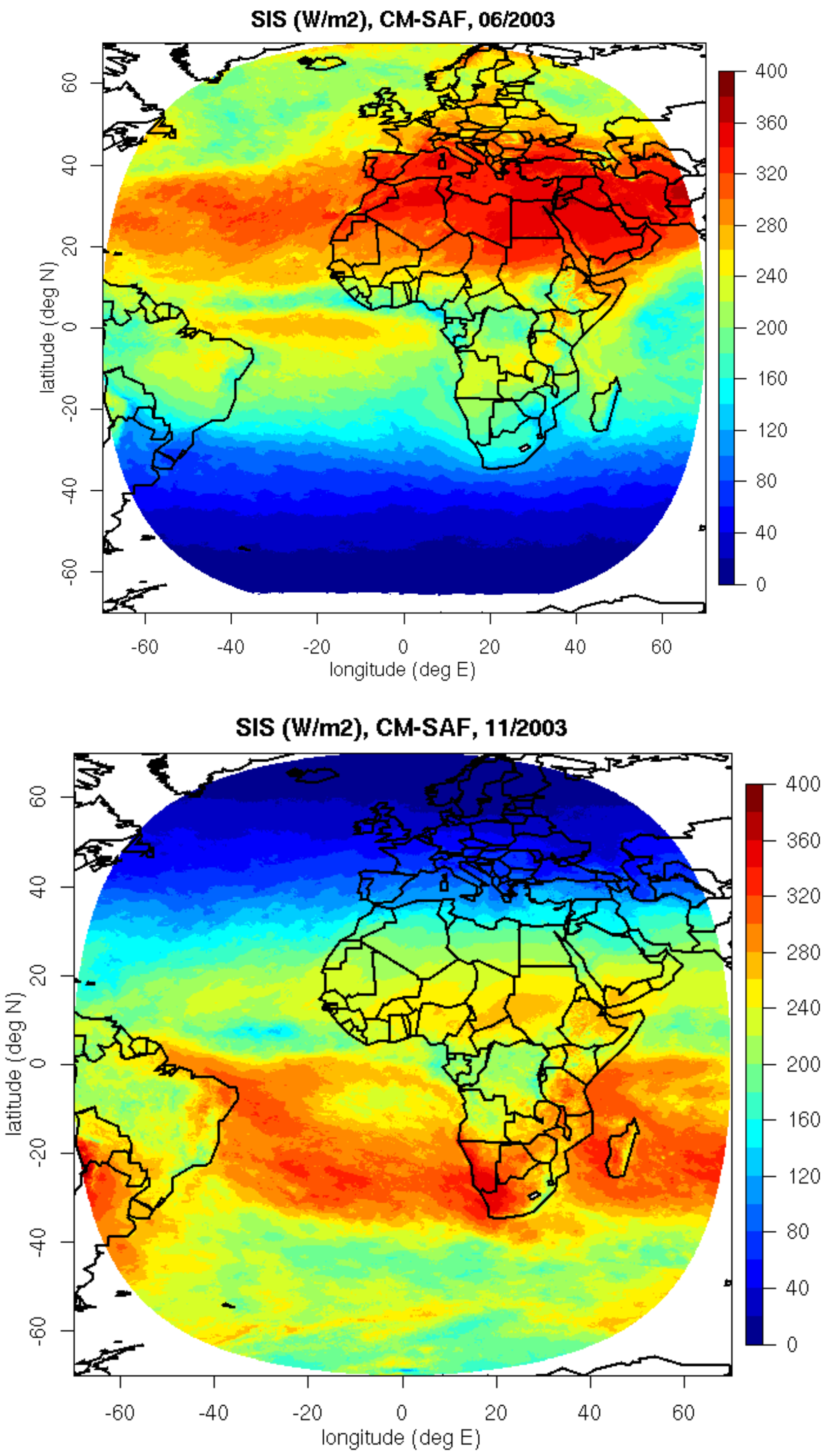


Figure 3–4 Example of the SIS monthly mean products for June and November 2003.

3.3.6 Validation

The Product Requirement Document (PRD) [AD.1] lists specific product requirements which have to be fulfilled by the products. The achieved accuracy for the SIS product are shown in Table 3-4.

Table 3-4 *Accuracy achieved for SIS. The 90% limit includes all regions, no region is excluded.*

Product	Summary on mean error (absolute)
SIS for MVIRI	*Man Absolute Bias below 10 W/m² and 90 per cent of absolute bias values below 10 W/m² (+ uncertainty of ground based measurements) for monthly means, 20 W/m² for daily means respectively.* *10 W/m² Mean Bias for hourly means and 10% Mean Absolute Deviation for monthly mean diurnal cycle.* *Higher bias values occur in the Alpine and other mountainous regions, e.g. due to uncertainties in area to point comparison and snow coverage.*

The detailed results of the validation are presented in the CM SAF Validation Report [RD.2: SAF/CM/DWD/VAL/MVIRI_HEL]. Here the main validation results are given in Table 3-5.

Table 3-5: *Summary of validation results for SIS: N Number of comparisons. MAB: mean of absolute bias values for monthly/daily means. SD: standard deviation. AC: Correlation of anomalies: Fraction of cases (months/days) with an accuracy outside of 10 W/m² (monthly means) and 20 W/m² (daily means). Basis of the results has been the comparison with 12 BSRN stations.*

SIS	N	Bias [W/m^2]	MAB [W/m^2]	SD [W/m^2]	AC	$Frac_{mon}$ > target accuracy [%]
Monthly Means	878	4.24	7.76	8.23	0.89	10.71
Daily means	29790	4.41	15.05	23.36	0.92	16.32

The bias in the Alpine region depends strongly on the region of interest which is discussed in detail in Dürr et al., (2010).

3.3.7 Limitations

Below is a list of known deficiencies and limitations of the SIS product:

- The high clear-sky reflection over bright surfaces (e.g., desert regions) reduces the contrast between clear-sky reflection and cloudy-sky reflection. This leads to higher uncertainties in CAL and errors in the calculation of SIS. The new method for the retrieval of the clear sky reflection (Fuzzy logic approach) improves the accuracy of SIS over bright surfaces, but still the accuracy is significantly lower for snow covered surfaces.
- In regions with long-lasting cloud cover the Fuzzy Logic approach detects snow cover. This results in an underestimation of the effective cloud albedo and errors in the solar irradiance.
- The accuracy of aerosol information is not well defined in several regions of the world due to missing ground measurements. Any uncertainty in the aerosol information affects the accuracy of SIS, especially in regions that are dominated by

cloudfree sky. For the current Heliosat data set a climatology has been used. Monthly, daily and hourly variations in the aerosol optical depth are therefore not considered.

- User application of the SIS CDR revealed a striping feature for the daily mean products before 1995. This corresponds to products derived from MVIRI data onboard the satellites Meteosat 2-4. For Meteosat 2 and 3 this striping is caused by disregarding the special night-time operation of the satellites (18:00-05:00UTC). During day-time the visible channel contained only half of the image (only every second line) for every even slot, whereas for the odd slots the whole image was available. The image at even slots was completed by copying the existing line onto the non-existing one. However, during night-time every image contained only half of the image which resulted in empty lines (all zero's) for the odd slots because the copying routine was only applied to the even slots. These missing lines are then used in the Heliosat algorithm leading to the striping for CAL and, consequently, for SIS and SID. The hourly mean products are only affected for the early morning and late evening hours. The fields between 07:00 and 17:00 UTC are not involved and can be used without limitations. For the other times during the day the striping is very strong. For SIS for example the mean amplitude is in the order of 40-50 W/m², and a maximum of about 70-80 W/m²is found. Therefore, the data for these time periods should not be used. The daily mean products are affected to a lesser extent as the averaging over the whole day reduced the influence of the early and late hours. However, the striping is visible. For the SIS daily mean product the mean amplitude of the stripes is in the order of 5 W/m² (maximum in the order of 20 W/m²). For Meteosat 4 the reason for the striping is not yet fully understood. It is not only limited to the early morning and late evening hours but occurs during the whole day Meteosat 4 should not have missing lines as always full images should be available. Complications might occur during the times when Meteosat 3 served as substitute for Meteosat 4 which then carried on within the processing chain. Thus, further investigations must and will be carried out. Until then the daily means from Meteosat 4 should also be handled with care.

3.4 Direct irradiance (SID)

3.4.1 Product definition

The direct irradiance (SID) is the radiation flux (irradiance) reaching a horizontal plane at the Earth surface in the 0.2 - 4 µm wavelength region directly without scattering. It is expressed in W m^{-2}.

3.4.2 Algorithm outline

3.4.2.1 Clear sky.

The algorithm for the calculation of SID under clear-sky conditions is described in detail in Mueller et al., 2009 and also documented in the public license gnu-MAGIC project, http://sourceforge.net/projects/gnu-magic. It is a fast method to calculate solar irradiance (including the direct irradiance) for large areas, which uses an eigenvector hybrid LUT approach for the fast and accurate calculation of SID. The aerosol optical thickness and type is assigned to each pixel depending on the provided aerosol map. Two different aerosol maps are available and currently the one after Kinne et al 2006 is used. Monthly means of water vapour amounts are taken from the ERA-40 and ERA-interim reanalysis. The interpolation within the LUTs is done with a linear interpolation scheme. The atmospheric input and interpolation routine is identical for SIS and SID, with exception of a background surface albedo map, which is not needed for SID.

3.4.2.2 Cloudy sky situations.

For the consideration of clouds on the clear sky irradiance a formula of Müller et al. (2009) is used, which describes the relation of the direct irradiance (all sky) SID_{allsky} to that of the clear sky direct irradiance SID_{clear} (Equation 3.5).

Equation 3.5: $SID_{allsky} = SID_{clear} * \left((1-CAL) + 0.38 \cdot CAL)\right)^{2.5}$

where CAL is the effective cloud albedo. This formula is an adaptation from the diffuse model of Skartveith et al. (1998). The direct irradiance is zero for CAL values above 0.6 regarding the applied Equation 3.5

3.4.3 Details on processing, gridding and averaging

The calculation of the direct surface irradiance (SID) takes place on MVIRI pixel basis using all available MVIRI images. The daily average SID is calculated by arithmetic averaging:

$$SID_{DA} = \frac{\sum_{i=1}^{n} SID_i}{n} \qquad (2)$$

SID_{DA} is the daily average of SID and SID_i *is* the SID for satellite image *i*. n is the number of images available during a day.
The monthly average SID is calculated from the daily means on pixel basis as the arithmetic mean (Equation 3.2) if at least 20 daily means per month are available. Hourly means are also calculated by arithmetic averaging The conversion from the irregular satellite projection to the regular 0.03x0.03 degree grid is done with the climate data operators, see section 5.1 for details of the cdo tools.

3.4.4 Input data

The input is identical to that of SIS with exception of the background surface albedo map which is not needed for SID.

- CAL from MVIRI processing, available for each pixel in satellite resolution.
- Total water vapour from the ERA-interim Reanalysis have been used from 1989 onwards. Up to 1989 ERA Reanalysis data have been used. Monthly means on 0.5x0.5 degree latitude-longitude grid. The pixel value is derived by spatial interpolation and assignment of the respective monthly mean.
- Ozone content, climatological value.
- Lookup tables.
- Aerosol climatology after Kinne et al. 2006 is used. Monthly long term means on 1x1 degree latitude-longitude grid. The pixel value is derived by spatial interpolation and assignment of the respective monthly mean.

3.4.5 Product examples

Figure 3–5 provides examples of the monthly mean SID product for June 2003 and January 2003

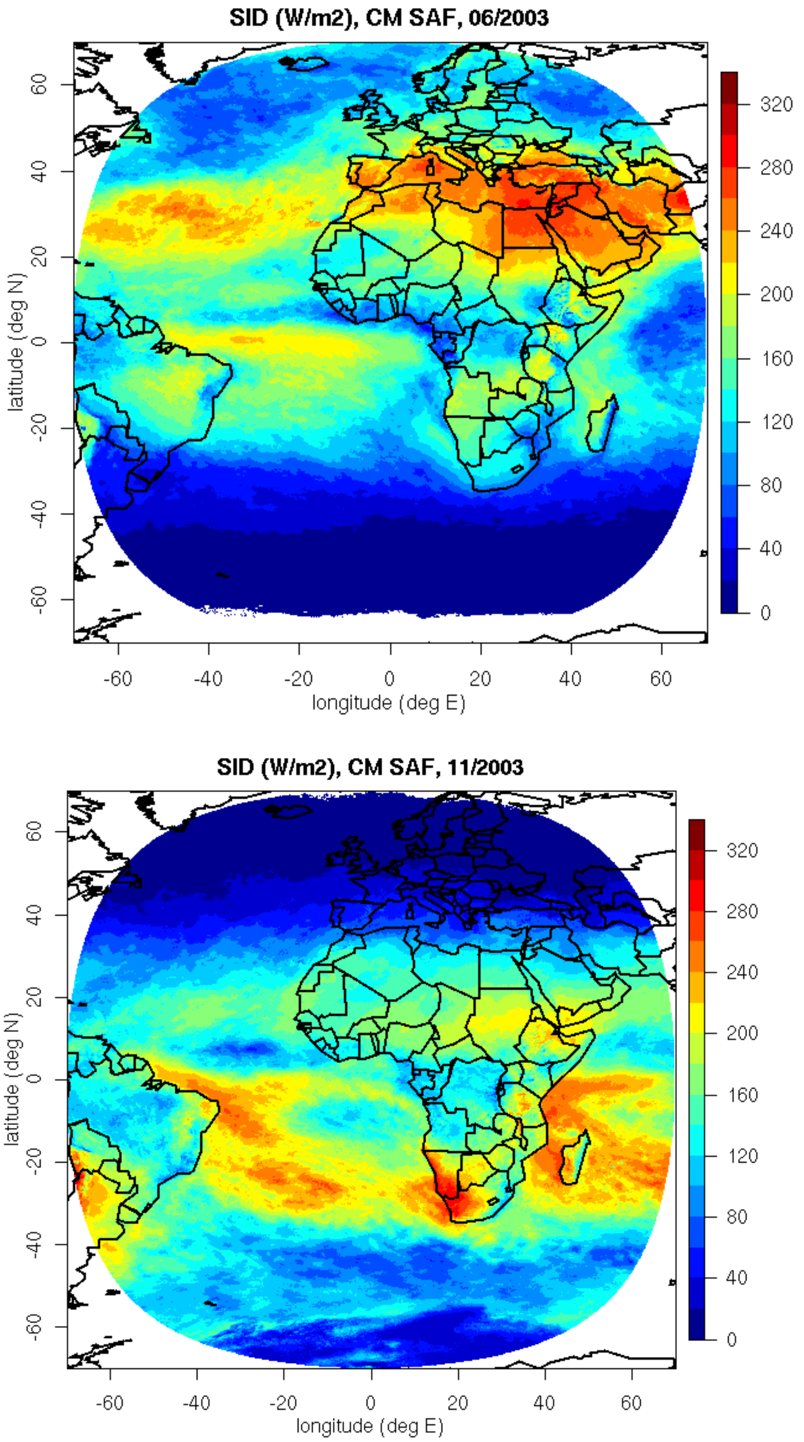


Figure 3–5 Example of the SID monthly mean products for June and November 2003.

3.4.6 Validation

The Product Requirement Document (PRD) [AD.1] lists specific product requirements which have to be fulfilled by the products. The achieved accuracy for the SID product are shown in Table 3-6 and

Table **3-7**.

Table 3-6 *Accuracy achieved for SID. The 90% limit includes all regions, no region is excluded.*

Product	Requirements on mean error (absolute)
SID for MVIRI	*MAB (Mean Absolute Bias) and 90 per cent of absolute bias values below 15 W/m² (+ uncertainty of ground based measurements) for monthly means, 25 W/m² for daily means respectively.* *Bias of 15 W/m² for hourly means.* *Higher bias values occur in the Alpine and other mountainous regions, e.g. due to uncertainties in area to point comparison and snow coverage..*

The detailed results of the validation are presented in the CM SAF Validation Report [RD.2: SAF/CM/DWD/VAL/MVIRI_HEL].

Table 3-7: *Summary of validation results for SID: N Number of comparisons. MAB: mean of absolute bias values for monthly/daily means. SD: standard deviation. AC: Correlation of anomalies: Fraction of cases (months) with an accuracy outside of 15 W/m² (monthly means) and 25 W/m² (daily means). Basis of the results has been the comparison with 12 BSRN stations.*

SID	N_{mon}	Bias [W/m^2]	MAB [W/m^2]	SD [W/m^2]	AC	$Frac_{mon}$ > target accuracy
Monthly means	805	0.89	11.0	15.67	0.83	15.4
Daily means	26614	0.74	20.73	31.74	0.89	23.42

The bias in the Alpine region depends strongly on the region of interest which is discussed in detail in Dürr et al., (2010).

3.4.7 Limitations

Below is a list of some of known deficiencies and limitations of the SID product (see SIS Limitations)

- The relatively high clear sky reflection over bright surfaces reduces the contrast between clear sky reflection and cloudy sky reflection. This leads to higher uncertainties and errors in the calculation of CAL and subsequent of SID. The new approach (Fuzzy logic) for the retrieval of clear sky reflection improves the accuracy of SID over bright surfaces but the accuracy is still significantly lower over snow surfaces.

- In regions with cloud cover lasting over longer time the Fuzzy Logic approach detects snow cover. This in turn leads to an underestimation of the effective cloud albedo and errors in the solar irradiance.
- The accuracy of aerosol information is not known in several regions of the world due to missing ground measurements.
- SID is quite sensitive to the AOD (aerosol optical depth) in clear sky situations, which introduces a certain amount of uncertainty as the accuracy of monthly AOD can only be expected to be +/- 0.1. More over, for the current Heliosat data set a climatology has been used. Monthly, daily and hourly variations in the aerosol optical depth are therefore not considered, which increases the uncertainty in daily and hourly values significantly. However, due to missing ground based measurements it is not evident nor proven that information about the temporal variation of aerosols gained from satellite would perform significantly better for the generation of a long term data sets of monthly and daily means than a best-of aerosol climatology. Indeed, Kinne et al. (Kinne et al., 2006) discussed the limited accuracy of aerosol information retrieved from satellites. More over, dynamic aerosol information with appropriate coverage does not exist for the complete period of the Heliosat data set. Hence, uncertainties in SID introduced by uncertainties in the AOD are mainly related to the lack of accurate and homogeneous input alternatives of aerosol information (especially over land) with high spatial and temporal resolution. However, due to the relative large sensitivity of SID on aerosol optical depth the limited accuracy of the aerosol information is a significant reason for the lower accuracy of SID relative to SIS.
- User application of the SID CDR revealed a striping feature for the daily mean products before 1995. This corresponds to products derived from MVIRI data onboard the satellites Meteosat 2-4. For Meteosat 2 and 3 this striping is caused by disregarding the special night-time operation of the satellites (18:00-05:00UTC). During day-time the visible channel contained only half of the image (only every second line) for every even slot, whereas for the odd slots the whole image was available. The image at even slots was completed by copying the existing line onto the non-existing one. However, during night-time every image contained only half of the image which resulted in empty lines (all zero's) for the odd slots because the copying routine was only applied to the even slots. These missing lines are then used in the Heliosat algorithm leading to the striping for CAL and, consequently, for SIS and SID. The hourly mean products are only affected for the early morning and late evening hours. The fields between 07:00 and 17:00 UTC are not involved and can be used without limitations. For the other times during the day the striping is very strong. For SIS for example the mean amplitude is in the order of 40-50 W/m², and a maximum of about 70-80 W/m²is found. Therefore, the data for these time periods should not be used. The daily mean products are affected to a lesser extent as the averaging over the whole day reduced the influence of the early and late hours. However, the striping is visible. For the SIS daily mean product the mean amplitude of the stripes is in the order of 5 W/m² (maximum in the order of 20 W/m²). For Meteosat 4 the reason for the striping is not yet fully understood. It is not only limited to the early morning and late evening hours but occurs during the whole day Meteosat 4 should not have missing lines as always full images should be available. Complications might occur during the times when Meteosat 3 served as substitute for Meteosat 4 which then carried on within the processing chain. Thus, further investigations must and will be carried out. Until then the daily means from Meteosat 4 should also be handled with care.

3.5 Planned improvements:

- Improvement of atmospheric input

  a. Higher spatial and temporal resolution of aerosol climatology/information in order to account better for spatial and temporal variations.
  b. Study to investigate the effect of a higher temporal resolution of water vapour, e.g. the use of daily means instead of monthly means
  c. Evaluation and improvement of monthly aerosol fields in order to replace the used aerosol climatology. It is expected that updated aerosol information will enhance the accuracy of the data set especially in desert regions

- Calculation of an artificial HRV channel for MSG by combination of VIS006 and VIS008 channel for MSG in order to improve the homogeneity for the MFG MSG transition of the data set.
- Improvement of algorithms.

  d. Implementation of a correction of broken clouds effect for direct beam irradiance.
  e. Optimisation of clear sky reflection retrieval in order to minimise cloud contamination.

- Analysis and evaluation of benefits and drawbacks of modifications with minor or regional effect on accuracy.

  f. Incorporation of the Infrared channel in the Heliosat algorithm in order to provide better detection potential for clouds over bright surfaces (snow)
  g. Cloud Parallax correction that accounts for horizontal shifts of high clouds due to the satellite viewing geometry (can be around 10 km for 10 km high clouds at 45 degree latitude, would possibly correct some of the errors in high latitude stations).
  h. Application of Meteosat First Generation visible channel calibration coefficients, yet to be generated by GSICS and comparison of these coefficients to the HELIOSAT self calibration method.
  i. Detection of cloud shadows. With the classical HELIOSAT, cloud shadows receive a low cloud index value since they are dark, and thus the global radiation for these areas will be at maximum. This could potentially remove some of the remaining bias and spread

4 Data description

This section describes the output formats for the surface radiation parameters. Each surface radiation parameter is gridded onto a regular lat-lon grid with a size of 0.03x0.03°. The time resolution ranges from hourly mean values (=instantaneous), daily mean values, to monthly mean values.

4.1 Product Names

Product types are:

- Surface incoming solar radiation (SIS), also known as global irradiance
- Surface incoming direct radiation (SID), also known as direct irradiance
- Effective cloud albedo (CAL), also known as cloud index.

Time resolution:

- Daily mean value

- Monthly mean value
- Hourly mean (instantaneous) values

4.2 Data Format and Ordering

CM SAF's climate monitoring products of surface radiation are provided as netCDF (Network Common Data Format, http://www.unidata.ucar.edu/software/netcdf/) files. The netCDF software functions as an I/O library, callable from C, FORTRAN, C++, Perl, or other language for which a netCDF library is available. The library stores and retrieves data in self-describing, machine-independent datasets. Each netCDF dataset can contain multidimensional, named variables (with differing types that include integers, reals, characters, bytes, etc.), and each variable may be accompanied by ancillary data, such as units of measure or descriptive text .
A netCDF consists of dimensions, variables, and attributes.. These components can be used together to capture the meaning of data and relations among data. The dimensions of the CM SAF radiation CDRs are longitude, latitude and time (see Table 7-1). Each netCDF file contains one variable (SIS, SID or CAL) at the given time resolution (hourly, daily or monthly means) together with the data values for the dimensions (see Table 7-2). The variables as well as the dimension variables are accompanied by attributes following the netCDF Climate and Forecast (CF) Metadata Convention 1.4 (http://cf-pcmdi.llnl.gov/). The attributes that are included in the CM SAF surface radiation datasets are listed in Table 7-3.
All data sets are provided in separated files, one file for each time step. The data sets covers monthly, daily and hourly values. Below a list of relevant product acronyms ($product) and acronyms for the averaging period ($mean):
SIS: Surface Incoming Shortwave Radiation**.** Also called solar surface irradiance
SID: Direct Irradiance at surface
CAL: Effective cloud albedo

mm: Monthly mean
dm: Daily mean
hm: Hourly mean

Ordered files will follow the following naming convention
$Product$mean$Year$MonthDayHour$Version
Further details on the naming are given in the Web User Interface and the naming convention document available at the CM-SAF web page: www.cmsaf.eu -> Data access -> "Naming convention" item.

4.3 Data ordering via the Web User Interface (WUI)

User services are provided through the CM SAF homepage www.cmsaf.eu. The user service includes information and documentation about the CM SAF and the CM SAF products, information on how to contact the user help desk and allows to search the product catalogue and to order products.

On the main webpage, a detailed description how to use the web interface for product search and ordering is given. We refer the user to this description since it is the central and most up to date documentation. However, some of the key features and services are briefly described in the following sections.

Copyright note:

All intellectual property rights of the CM SAF products belong to EUMETSAT. The use of these products is granted to every interested user, free of charge. If you wish to use these products, EUMETSAT's copyright credit must be shown by displaying the words "copyright (year) EUMETSAT" on each of the products used.

4.3.1 Product ordering process

You need to be registered and logged in to order products. A login is provided upon registration, all products are delivered free of charge. After the selection of the product, the desired way of data transfer can be chosen. This is either via a temporary ftp account (the default setting), or by CD/DVD or email. Each order will be confirmed via email, and the user will get another email once the data have been prepared. If the ftp data transfer was selected, this second email will provide the information on how to access the ftp server.

4.3.2 Data volume:

The data amount depends on the data request of the user, in detail on the size of the selected region and the duration of the covered time period. The user will be informed about the data volume of his request within the WUI ordering process Below the maximum values for one parameter covering the complete Meteosat disk and time period are given:

Monthly Means: 3.5 GB

Daily Means: 100 GB

Hourly means: 2.5 TB

4.4 Contact User Help Desk staff

In case of questions the contact information of the User Help Desk (e-mail address contact.cmsaf@dwd.de, telephone and fax number) are available via the CM SAF main webpage (www.cmsaf.eu) or the main page of the Web User Interface.

4.5 Feedback/User Problem Report

Users of CM SAF products and services are encouraged to provide feedback on the CM SAF product and services to the CM SAF team. Users can either contact the User Help Desk (see chapter 4.3.2) or use the “User Problem Report” page. A link to the “User Problem Report” is available either from the CM SAF main page (www.cmsaf.eu) or the Web User Interface main page.

4.6 Service Messages / log of changes

Service messages and a log of changes are also accessible from the CM SAF main webpage (www.cmsaf.eu) and provide useful information on product status, versioning and known deficiencies.

5 Tools and Auxiliary data

This section describes currently available tools to read, display, re-project and modify the CM SAF products. All tools and auxiliary data shortly described here, are accessible from the CM SAF main webpage (www.cmsaf.eu).
All tools and auxiliary data described are free of charge. They come with no warranty and are based on best effort basis. When encountering problems, please contact the User help desk (Section 4.3.2).

5.1 Climate data operators (CDO)

To allow easy access to CM SAF datasets the possibility to import CM SAF data has recently been integrated into the ‚climate data operators' (CDO) which is a well-established conversion tool in the climate modelling community (https://code.zmaw.de/projects/cdo).
This package was originally developed for processing and analysis of data produced by a variety of climate and numerical weather prediction models (e.g. for file operations, simple statistics, arithmetic, interpolation or the calculation of climate indices). Besides the conversion between different file formats, cdo offers possibilities for pre-processing the data for validation studies, especially interpolation to other grid types and selection of regions, including methods for interpolation of non-continuous datasets such as e.g. cloud types.
The CM SAF Meteosat climate data sets are provided on a regular latitude longitude grid, whereby the latitude and longitude are given and described in the netCDF-files. CDO employs this information for spatial operations on these final products. A link to this tools is available on the CM SAF web site (www.cmsaf.eu).
Please refer to the CDO-manual for detailed instructions how to import and process CM SAF products.

5.2 R scripts for data analysis and visualization (GUI)

The statistical package R is a free software environment for statistical computing and graphics (http://www.r-project.org/). CM SAF provides scripts and software written in R to support climate analysis and visualisation of the CM SAF Meteosat CDRs.. The respective tools are accessible from www.cmsaf.eu and allow, after installation, to read, analyse and visualise the cloud and radiation products. These tools are free of charge and come as they are.
CM SAF is interested in your experiences with the tool and encourage you to report all observed problems to the user help desk (Section 4.3.2).

5.3 Auxiliary Data

This section gives an overview of available auxiliary datasets which will be helpful for further processing and interpretation of CM SAF products. All auxiliary datasets are accessible via the webpage www.cmsaf.eu in the folder 'Data Access'. Table 5-1 lists the available auxiliary datasets and their respective coverage.

Table 5-1 *Table of available auxiliary datasets. AOD=Aerosol Optical Depth, ssa=single scattering albedo, gg=asymmetry parameter, the aerosol data is available as ASCII files from the CM-SAF web page in the menu >add on products<.*

Region	Surface albedo [-]	Aerosols [AOD,ssa,gg]	Water vapour [mm]
CMSAF full disc area ("MA") (MVIRI)	X	X	x
Global ("GL").		x	x

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7 Appendix

7.1 Appendix A: Description of the netCDF file format

The netCDF metafile definitions follows the cf 1.4 convention, please see http://cf-pcmdi.llnl.gov/ for details

Table 7-1: *Dimensions in the netCDF files*

Dimension	Size	Description
Lon	4667	Longitude
Lat	4667	Latitude
Time	1	Time

Table 7-2: *Variables in the netCDF file*

Variable	Type	Dimension	Description
Lat	float	(lat)	Longitude [°E]
Lon	flot	(lon)	Latitude [°N]
Time	float	(time)	Time [days since beginning of year]
SIS, SID or CAL	short	(lon,lat,time)	Radiation variable or Effective Cloud Albedo

Table 7-3: *Variable attributes in the netCDF files*

Attribute name	Type	Description
units	string	the units of the variable
long_name	string	a more descriptive variable name
standard_name	string	a pre-defined variable name according to the standard name table in order to enable users of data from different sources to determine whether quantities were in fact comparable
coordinates	string	identifies the coordinate variables
_FillValue	same as variable	This value is considered to be a special value that indicates undefined or missing data; it is used to pre-fill disk space allocated to the variable.
missing_value	same as variable	deprecated, included for backward compatibility, describes the same as the [_FillValue]
scale_factor	short or float	the data has to be multiplied by this number; see also [add_offset]
add_offset	short or float	this number has to be added to the data if both [scale_factor] and [add_offset] attributes are present, the data is first scaled and then the offset is added
comment	string	Miscellaneous information about the data or methods used to produce it.
references	string	References that describe the data or methods used to produce it.

All data sets are provided in separated files, one file for each time step. The data sets covers monthly, daily and hourly values. Below a list of of relevant product acronyms ($product) and acronyms for the averaging period ($mean):
SIS: Surface Incoming Shortwave Radiation**.** Also called solar surface irradiance
SID:Direct Irradiance at surface
CAL: Effective Cloud Albedo

mm: Monthly mean
dm: Daily mean
hm: Hourly mean.

Ordered files will follow the following naming convention:

$Product$mean$Year$MonthDayHour$Version

Further details on the naming are given in the Web User Interface and the naming convention document available at the CM-SAF web page: www.cmsaf.eu -> Data access -> “Naming convention” item.

7.2 Appendix B: SARB/CERES albedo

http://www-surf.larc.nasa.gov/surf/pages/bbalb.html
The albedo is calculated in a two step process. The first step is to determine scene type for a given 10 minute region. The SARB group uses the 17 scene types as specified by the International Geosphere/Biosphere Programme, plus "Tundra", "Sea Ice" and "Fresh Snow" scenes. Each has an associated spectral albedo curve between 0.2 and 4.0 micrometers. These spectral curves are integrated to give a broad band albedo for the region

7.3 Appendix C: Complete equations for the effective cloud albedo - solar irradiance relation.

The effective cloud albedo is related to the solar irradaince via the clear sky index. The clear sky index is defined as:

$$k=SIS/\ SIS_{CLS}$$

Here SIS_{CLS} is the solar irradiance for cloud free skies. The relation between the effective cloud albedo CAL and the clear sky index is mainly given by:

$$k = 1\text{-}CAL$$

This relation is defined by physics, in detail by the law of energy conservation (Dagested, 2005). However, above a CAL value of 0.8 empirical corrections are needed in order to consider:

- The effect of statistical noise, which could lead to CAL values above 1 and below 0 (occurs very seldom, however have to be considered).
- The effect of saturation occurring in optical thick clouds.

In this regions the n-CAL relation was determined from the statistical regression using the ground-based measurements at European sites and fitted to get the best performance at all the ground sites. The equations given below provide the complete n-CAL relation for all possible CAL values. It is important to note that the empirical fit has been performed in the 80s and used since then without refitting.

$$CAL < -0.2, \quad k=1.2 ,$$
$$-0.2 \le CAL \le 0.8, \quad k = 1 - CAL ,$$
$$0.8 < CAL \le 1.1, \quad k = 2.0667 - 3.6667 * CAL + 1.6667 * CAL^2 ,$$
$$1.1 < CAL , \quad k = 0.05 .$$

As a consequence of the definition of the clear sky index, the surface solar irradiance for the full-sky situation (G) is given by,

$$SIS = k * SIS_{CLS} ,$$

where SIS_{CLS} is the clear-sky surface solar irradiance calculated using the MAGIC code (Mueller et al., 2004, 2009).

8 Glossary – List of Acronyms in alphabetical order

Abbreviation	Explanation
AVHRR	Advanced Very High Resolution Radiometer
AOD	Aerosol Optical DEpth
BSRN	Baseline Surface Radiation Network
CAL	Effective Cloud Albedo
CDOP	Continuous Development and Operational Phase
CDR	Climate Data Record
CM SAF	Satellite Application Facility on Climate Monitoring
DWD	Deutscher Wetterdienst
ECMWF	European Centre for Medium-Range Weather Forecast
ECV	Essential Climate Variable
ERA	ECMWF ReAnalysis
FD	Flux dataset (ISCCP)
FRAC	Fraction of days larger than the target value.
GADS/OPAC	Global Aerosol Data Set / Optical Properties of Aerosols and Clouds
GCOS	Global Climate Observing System
GERB	Geostationary Earth Radiation Experiment
GEWEX	Global Energy and Water Cycle Experiment
ISCCP	International Satellite Cloud Climatology Project
K	Clear sky index
LUT	RTM based Look-Up-Table
MAB	Mean of absolute bias values over several days or months
MVIRI	Meteosat Visible-InfraRed Imager
NCEP	National Centers for Environmental Prediction
NOAA	National Oceanic and Atmospheric Administration
RTM	Radiative Transfer Model
SD	Standard deviation
SID	Surface Incoming Direct radiation, commonly called direct irradiance
SIS	Surface Incoming Solar radiation, commonly called global irradiance or surface solar irradiance
SZA	Solar Zenith Angle
SSA	Single Scattering Albedo