EUMETSAT Satellite Application Facility on Climate Monitoring

Validation Report

Meteosat Surface Radiation - Daylight

Edition 1

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Daylight, DAL **CM-110**

Daylight, DAL **CM-109**

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Applicable documents

Reference	Title	Code
AD 1	CM SAF Product Requirement Document	SAF/CM/DWD/PRD/2.0

Reference Documents

Reference	Title	Code
RD 1	Algorithm Theoretical Basis Document	SAF/CM/DWD/ATBD/DAL/1.1

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1 Executive Summary

This CM SAF report provides information on the validation of the spectrally resolved surface radiation of the CM SAF Meteosat Edition 1.0 data sets derived from SEVIRI/GERB and MVIRI sensors onboard of first and second generation Meteosat satellites.
This report presents the validation of the **products**

Daylight, DAL – CM-110 from SEVIRI
Daylight, DAL – CM-109 from MVIRI

available from 1983 to 2011.
The data set is validated against available reference data sets from surface measurements. For DAL, only data from the station Lyon has been available for the validation. For this data sets, the accuracy is defined based on the 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]
Based on the validation results it can be expected that the daylight (DAL) data set fulfill the accuracy requirements as specified in the Product Requirements Document (PRD) [AD 1]. No contrary hints have been found so far.

Table 1: Summary of the accuracy of the CM SAF MSG daylight. The accuracy is in the order of the measurement uncertainty.

Data Set	Threshold / Target / Optimal Accuracies in W/m2	Dataset Accuracy
DAL	10 / 7 / 5	< 3 W/m³

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 (CM SAF)

The importance of climate monitoring with satellites was recognized in 2000 by EUMETSAT Member States when they amended the EUMETSAT Convention to affirm that the EUMETSAT mandate is also to “contribute to the operational monitoring of the climate and the detection of global climatic changes". Following this, EUMETSAT established within its Satellite Application Facility (SAF) network a dedicated centre, the SAF on Climate Monitoring (CM SAF, http://www.cmsaf.eu).
The consortium of CM SAF currently comprises the Deutscher Wetterdienst (DWD) as host institute, and the partners from the Royal Meteorological Institute of Belgium (RMIB), the Finnish Meteorological Institute (FMI), the Royal Meteorological Institute of the Netherlands (KNMI), the Swedish Meteorological and Hydrological Institute (SMHI), the Meteorological Service of Switzerland (MeteoSwiss), and the Meteorological Service of the United Kingdom (UK MetOffice). Since the beginning in 1999, the EUMETSAT Satellite Application Facility on Climate Monitoring (CM SAF) has developed and will continue to develop capabilities for a

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

Another essential task of CM SAF is to produce data sets that can serve applications related to the new Global Framework of Climate Services initiated by the WMO World Climate Conference-3 in 2009. CM SAF is supporting climate services at national meteorological and hydrological services (NMHSs) with long-term data records but also with data sets produced close to real time that can be used to prepare monthly/annual updates of the state of the climate. Both types of products together allow for a consistent description of mean values, anomalies, variability and potential trends for the chosen ECVs. CM SAF ECV data sets also serve the improvement of climate models both at global and regional scale.
As an essential partner in the related international frameworks, in particular WMO SCOPE-CM (Sustained COordinated Processing of Environmental satellite data for Climate Monitoring), the CM SAF - together with the EUMETSAT Central Facility, assumes the role as main implementer of EUMETSAT's commitments in support to global climate monitoring. This is achieved through:

- Application of highest standards and guidelines as lined out by GCOS for the satellite data processing,
- Processing of satellite data within a true international collaboration benefiting from developments at international level and pollinating the partnership with own ideas and standards,
- Intensive validation and improvement of the CM SAF climate data records,
- Taking a major role in data set assessments performed by research organisations such as WCRP (World Climate Research Program). 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 daylight radiation data set derived from the Meteosat satellite data contain information on the illuminance received by humans eye. The daylight data sets (DAL) is based on the retrieval of the surface illuminance using the effective cloud albedo derived from the RMIB top of atmosphere albedo or from the MVIRI HRV channel [RD 1]. **DAL is available as monthly averages and daily averages between 1983 and 2011 on a 0.05°-regular longitude-latitude grid.**

4 Validation Data Sets

The validation of the surface radiation data sets is conducted against surface measurements from the IDMP station in Lyon. IDMP stands for International Daylight Measurement Programme. It was set up in 1991, by the Commission Internationale de l'Eclairage (International Lighting Commission) based in Vienna, Austria.- (http://www.cie.co.at/cie/home.html, ciecb@ping.at). Only 3 stations are located in the Meteosat disk region. From these stations data has been only available from Lyon.

Table 2: The table provides information about the used surface measurements.

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Station Location:
Vaulx-en-Velin, France.
Latitude: 45°47' N
Longitude: 4°56' E
Height above sea level: 170 m.
Local Time: GMT+1

Code: FRA2
Type: General class.
Operation:
Started in September 1991.

Server : http://idmp.entpe.fr/vaulx

Daylight is not measured operationally by national weather services or research institutes. Hence, measurements are very seldom. The Lyon daylight data cover several years and are specified in Table 2. The data set is quality checked by the institutes that carried out the measurements.

4.1 Station Details:

The station is located 170m above sea level at Vaulx-en-velin (France), Latitude/Longitude of 45°47` N and 4°56`. Local Time GMT+1 The sampling and recording interval of the data is 1mn. The Illuminance Measuring Unit BAP 30 FCT for Outdoor Installation (LMT BAP 30 FCT) from LMT Lichtmesstechnik GmbH Berlin is used. The shadow band for the diffuse illuminancs has a radius of 27.5 cm and a width of 5.4 cm.

For vertical illuminances, a half hemisphere obstruction was made with a black honeycomb material. South Vertical Illuminance and Global Horizontal Irradiance sensors have been calibrated in October 1991 with an Optronic Lab tungsten halogen lamp at the CSTB in Nantes, France. Another calibration of the South Vertical Illuminance sensor has been performed at the British Research Establishment in September 1992. In 1993, all illuminance and irradiance sensors have been compared to IEA task 17 E relative calibration sensors.

Site surroundings:
Vaulx-en-Velin is located on the east part of Lyon Urban Community which represents 1.5 Million inhabitants. Within a 5 km radius of the station, the environment is 70% urban and suburban housing and 30% farm land and recreational fields. The Geneva freeway A42 and the highway N383 going around Lyon are only 2 kms away.

Climate characteristics:
Climate is moderate maritime on the border of a Mediterranean climate zone. Average temperature in January is 2°C and in July 21°C. Average annual sunshine duration is 2100 hours. The average number of foggy days in the year is 55 mostly in winter. The closest weather station is located 5 km away in Bron.

5 Validation

The strategy for the validation of the CM SAF MSG surface radiation data sets follows the CM SAF Product Requirements Document [AD 1]. For daylight (DAL) the accuracy of the data set is validated with available surface observations.
The accuracy requirements applicable for this validation report are following user needs, consolidated within the PCR-4 process.

5.1 Methodology

According to the PRD [AD 1] the validation of the CM SAF DAL data set is based on the comparison with available surface measurements. The main measures for the verification with surface measurements are the bias and the absolute bias. To account for uncertainties in the surface measurements and possible errors introduced by calculating the temporal averages from surface observations, an uncertainty of 5-8 % is assumed for daylight derived from the surface observations. Please note that the station is located in the city which reduces the available daylight in comparison with flat and open terrain. The quality of the data sets is assessed by comparisons with the specified accuracy in the PRD [AD 1]

5.2 Validation results

The validation results for the monthly averaged CM SAF MSG SIS data set are shown in Table 3 and Figure 1

Table 3: Validation results for the monthly averaged CM SAF DAL data set compared to surface measurements.

Station	Mean [W/m²]	N	Bias [W/m²]	Absolute Bias [W/m²]	Cor	Frac. Months Acc>7 W/m²	Frac. Months Acc>5 W/m²
Lyon	19	141	1.95	2.0	0.92	0.0	0.0

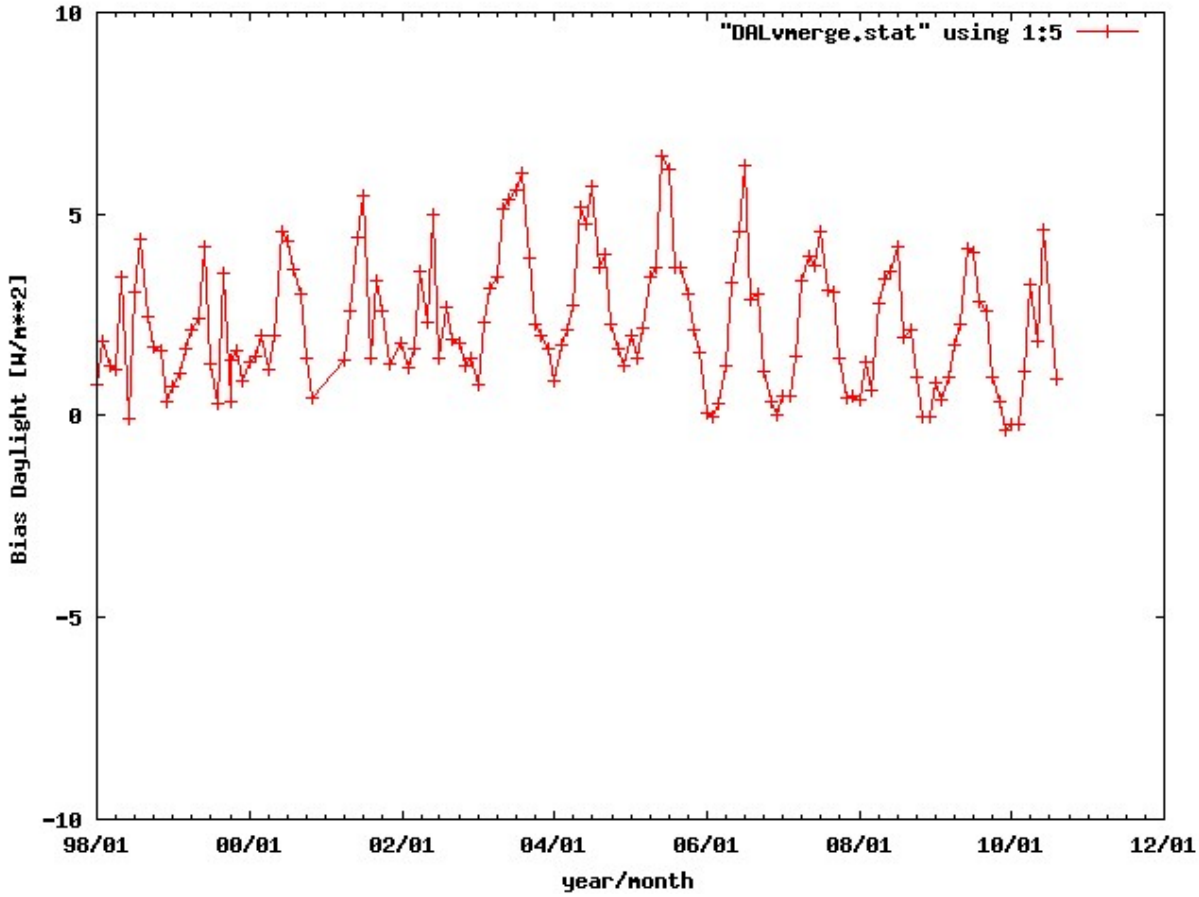

Figure 1: Bias of the satellite derived daylight data set for the comparison at the station Lyon.

The comparison with the surface measurements shows evidence for the ability of the method to provide daylight on horizontal surfaces accurately. However, there is a significant positive bias apparent. As the station is located in the city of Lyon part of the bias might be due to reduction of the horizon compared to flat and open terrain. Additionally, the station has been calibrated in 1993, which might also by due to shortcomings in the calibration. Only irradiance and the south South Vertical Illuminance sensor has been calibrated, all other illuminance and irradiance sensors have been compared to IEA task 17 E relative calibration sensors. There are no significant difference in the bias values for MVIRI and SEVIRI/GERB based data showing evidence of a certain homogeneity concerning the transition of the satellite generations.

5.3 Limitations.

- Over snow the uncertainty of daylight might be significantly higher than the estimated accuracies
- 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 DAL.
- In regions with long-lasting cloud cover the detection of a minimum which constitutes a clear sky situation might fail. This results in an underestimation of the effective cloud albedo and errors in DAL.

- The accuracy of aerosol information is unknown in several regions of the world due to missing ground measurements. Any uncertainty in the aerosol information affects the accuracy of DAL, especially in regions that are dominated by cloudless sky.
- The restriction of the validation to a comparison at one station limits the conclusiveness of the validation results. However, DAL is retrieved with the same physical method as the broadband solar surface irradiance. Hence, the DAL validation results demonstrate that the adaptation of the method is performed well. Hence, the SIS validation results supplements the validation of DAL.

6 Conclusions

We presented the validation of the CM SAF MSG daylight radiation data set based on the requirements as defined in the CM SAF PRD [AD 1]. The data set fulfils the target accuracy requirements very well and is within the optimal requirement at the given site. The method is close to the MAGICSOL method applied for the SEVIRI and MVIRI solar radiation data sets. This data sets have been proven to perform well at many surface stations. These validations provides additional evidence for the quality of the daylight data set. Apparent differences between satellite derived daylight and surface measurements might be at least partly due to the location of the sensors.

7 References

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Müller R. (2012), “Solar Irradiance, Global Distribution", in Encyclopedia of Sustainable Science and Technology, 9699-9729, Springer 2012, ISBN 978-0-387-89469-0.

Mueller, R., C. Matsoukas, A. Gratzki, H. Behr, and R. Hollmann (2009), The CM-SAF operational scheme for the satellite based retrieval of solar surface irradiance - A LUT based eigenvector hybrid approach, *Remote Sensing of Environment, 113*(5), 1012-1024.

8 Glossary

AVHRR: Advanced Very High Resolution Radiometer
AOD: Aerosol Optical Depth
CAL: Effective cloud albedo
COT: Cloud optical depth
DAL: Daylight
GADS/OPAC: Global Aerosol Data Set / Optical Properties of Aerosols and Clouds
GERB: Geostationary Earth Radiation Experiment
K: Clear sky index.
LUT: Look-up table
MVIRI: Meteosat Visible-InfraRed Imager
NOAA: National Oceanic and Atmospheric Administration
NCEP: National Center for Environmental Prediction
RTM: Radiative Transfer Model
SID: Surface Direct Irradiance (beam).
SIS: Solar Surface Irradiance
SZA: Sun Zenith Angle
SSA: Single Scattering Albedo

9 Appendix:

9.1 Statistical Measures

Bias: The bias (or mean error) is simply the mean difference between the two considered datasets. It indicates whether the dataset on average overestimates or underestimates the reference dataset (e.g., ground measurement denoted as o).

$$\text{Bias} = \frac{1}{n}\sum_{k=1}^{n}(y_k - o_k) = \bar{y} - \bar{o} \tag{23}$$

Relative Bias: is the Bias divided by the absolute value of the reference.

$$\text{Bias} = \frac{\bar{y} - \bar{o}}{\bar{o}} \tag{24}$$

Standard deviation (SD): 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 dataset.

$$\text{SD} = \sqrt{\frac{1}{n-1}\sum_{k=1}^{n}\left((y_k - o_k) - (\bar{y} - \bar{o})\right)^2} \tag{25}$$

Root Mean Square Deviation: The root-mean-square deviation (RMSD) or root-mean-square error (RMSE) results from the bias and the standard deviation and is defined as follows. It measures beside the bias also the scatter of the data.

$$\text{RMSE} = \sqrt{BIAS^2 + SD} \tag{26}$$

Relative Root Mean Square Error: is the RMSE divided by the absolute value of the reference data set.

$$\text{RMSE} = \frac{\sqrt{BIAS^2 + SD}}{\bar{o}} \tag{27}$$

9.2 DAL PRD 2.0 entries

CM-109	Daylight		DAL SEVIRI DS
Type	Dataset		
Applications and users	* Climate Research * NMHSs * Government agencies * Private Sector * Public Sector		
Characteristics and Methods	Daily Mean Monthly Mean		
Comments	time series from 2004-2009		
Generation frequency	N/A		
Input satellite data	SEVIRI/GERB		
Dissemination			
Format	Means	Type	
netcdf CF	FTP	offline	
Accuracy			
Threshold	Target	Optimal	
lux equivalent to 10 W/m^2	lux equivalent to 7 W/m^2	lux equivalent to 5 W/m^2	
Verification method	comparison with in-situ measurements		
Coverage, resolution and timeliness			
Spatial coverage	Spatial resolution	Vertical resolution	Timeliness
Meteosat disk	$(0.05°)^2$		N/A

CM-110	Daylight		DAL MVIRI DS
Type	Dataset		
Applications and users	* Climate Research * NMHSs * Government agencies * Private Sector * Public Sector		
Characteristics and Methods	Daily Mean Monthly Mean		
Comments	time series from 1983-2005		
Generation frequency	N/A		
Input satellite data	MVIRI		
Dissemination			
Format	Means	Type	
netcdf CF	FTP, CD-ROM	offline	
Accuracy			
Threshold	Target	Optimal	
lux equivalent to 10 W/m^2	lux equivalent to 7 W/m^2	lux equivalent to 5 W/m^2	
Verification method	comparison with in-situ measurements		
Coverage, resolution and timeliness			
Spatial coverage	Spatial resolution	Vertical resolution	Timeliness
Meteosat disk	Meteosat Pixel Resolution		N/A