EUMETSAT Satellite Application Facility on Climate Monitoring

Product User Manual

MSG Surface Radiation Products

Edition 1

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Surface Incoming Shortwave Radiation	**CM-53**
Surface Net Shortwave Radiation	**CM-68**
Surface Outgoing Longwave Radiation	**CM-75**
Surface Downward Longwave Radiation	**CM-82**
Surface Net Longwave Radiation	**CM-89**
Surface Radiation Budget	**CM-96**
Cloud Radiative Effect SW	**CM-102**
Cloud Radiative Effect LW	**CM-103**

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

Reference Documents

Reference	Title	Code
RD 1	Validation Report Surface Radiation Products MSG Edition 1.0	SAF/CM/VAL/MSG/RAD/1.2
RD 2	Algorithm Theoretical Basis Document Surface Radiation Products	SAF/CM/ATBD/MSG/RAD/1.1

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1 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. 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, http://www.cmsaf.eu/. Here, detailed information about product ordering, add-on tools, sample programs and documentation is provided.

2 Introduction

This CM SAF Product User Manual provides information on the CM SAF surface radiation data sets derived from SEVIRI/GERB observations.
This manual briefly describes the historical development of CM SAF and the MSG surface radiation data sets. A technical description of the data sets including information on the file format as well as on the data access is provided. Further details on the implementation of the retrieval processing chain, and individual algorithm descriptions are available in the Algorithm Theoretical Basis Document [RD 2]. Basic accuracy requirements are defined in the product requirements document [AD 1]. A detailed validation of the MSG-based surface radiation parameters is available in the Validation Report [RD 1].

3 Product definitions

The CM SAF MSG surface radiation data set from SEVIRI/GERB satellite observations provides global coverage. The instantaneous SEVIRI/GERB observations are used to derive the spatio-temporal averaged data sets. The products are available as monthly averages on a regular latitude/longitude grid with a spatial resolution of 0.25° × 0.25° degrees. For the surface solar irradiance (SIS: surface incoming solar radiation) also daily averages are available. The temporal coverage of the data sets ranges from 1 January 2006 to 31 December 2011. The products covered by this document are:

Surface Incoming Shortwave Radiation: SIS – CM-53
The incoming solar radiation at the Earth`s surface in the solar spectrum
Surface Net Shortwave Radiation: SNS – CM-68
The difference between SIS and the outgoing solar radiation at the Earth´s surface
Surface Outgoing Longwave Radiation: SOL – CM-75
The radiation in the thermal spectrum emitted by the Earth`s surface. t
Surface Downward Longwave Radiation: SDL – CM-82
The radiation in the thermal spectrum received by the Earth's surface
Surface Net Longwave Radiation: SNL – CM-89
The longwave budget at the Earth's surface: SDL -- SOL
Surface Radiation Budget: SRB – CM-96
The total radiation budget at the Earth's surface: SNS + SNL
Cloud Radiative Effect SW: CFS – CM-102
The radiation effect (cooling/heating) induced by clouds relative to clear sky in the solar spectrum.
Cloud Radiative Effect LW: CFL – CM-103
The radiation effect (cooling/heating) induced by clouds relative to clear sky in the thermal spectrum.

The algorithm theoretical baselin of these products is documented in the ATBD, [RD 2]

Table 1 presents a summary of the accuracy of the different products contained in the CM SAF MSG surface radiation data set. For more information on the validation strategy and more detailed accuracy information, the reader is referred to the corresponding validation report [RD 1].
All products have been developed and evaluated with respect to requirement goals defined in the PRD [AD 1]. The finally achieved product accuracies are described in the validation report [RD 1]. Of specific interest here are requirements as outlined by the Global Climate Observing System (GCOS) community and issued by the United Nations World Meteorological Organisation (WMO) in December 2011. All products in the MSG surface radiation dataset fulfil GCOS requirements regarding the horizontal resolution (100 km). The

GCOS accuracy requirements are partly fulfilled for the surface radiation products (detailed results to be described further below); the requirements on stability have yet to be assessed.

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

Data Set	Threshold / Target / Optimal Accuracies in W/m2	Dataset Accuracy in W/m2
SIS	15 / 10 / 8 25 / 20 / 15 (daily averages)	<8 <20
SNS	20 / 15 / 12	<15
SOL	15 / 10 / 8	<10
SDL	15 / 10 / 8	<10
SNL	20 / 15 / 12	<15
SRB	25 / 20 / 15	<16
CFS	15 / 10 / 8	<10
CFL	15 / 10 / 8	<10

3.1 Parameter Retrievals

Here a brief overview of the retrieval methods used to generate the CM SAF MSG surface radiation data sets is given. More detailed information can be found in the ATBD [RD 2].

3.1.1 Surface incoming shortwave radiation

The retrieval of the surface incoming solar radiation is based on the method presented in *Mueller et al.,* (2009). As auxiliary data sources, the integrated water vapour from the ERA-Interim data set (*Dee et al.,* 2011), aerosol information from the Kinne data base (Kinne *et al.,* 2005) and the surface albedo from the SARB/CERES team (http://www-surf.larc.nasa.gov/surf/) are used.

The effective cloud albedo derived with the MAGICSOL method [RD 2] is used to treat the effect of clouds on the clear sky solar irradiance. For clear-sky pixels, no additional satellite information is required to calculate the surface incoming solar radiation using the Mesoscale Atmospheric Global Irradiance Code (MAGIC, http://gnu-magic.sourceforge.net/). The temporal averaging of the instantaneous retrieval results on the pixel level is conducted following the method of *Möser and Raschke* (1984), which takes into account the diurnal cycle of the solar radiation. At least 20 instantaneous observations need to be available for each pixel in order to calculate the daily average; monthly averages are only generated when at least 20 valid daily mean values are available.

More details on the retrieval and the specific limitations are given in the ATBD [RD 2]. The overall accuray of the CM SAF MSG SIS data set has been estimated to be better than 8 W/m^2 for the monthly mean data and better than 20 W/m^2 for the daily averages. Further information on the accuracy of the product is contained in the validation report [RD 1].

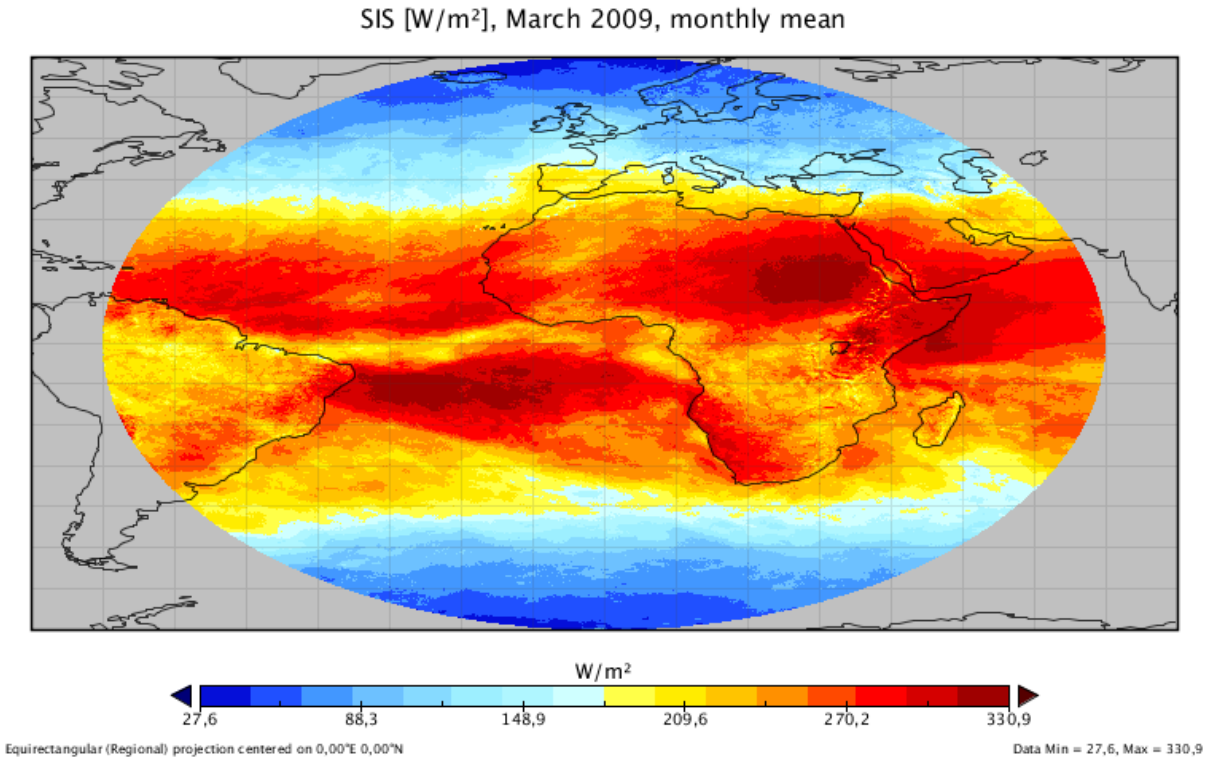

Figure 1: Example of the CM SAF MSG surface solar irradiance data set for the month of March 2009.

Figure 1 presents an illustrative example of the CM SAF MSG SIS data set. Shown is monthly mean of the surface solar irradiance for March 2009.

3.1.2 Surface net shortwave radiation

The surface net shortwave radiation is calculated directly from the surface incoming shortwave radiation and the surface albedo using the monthly averages derived from the CM SAF MSG data sets.
More details on the algorithm and the specific limitations are given in the ATBD [RD 2]. The overall accuracy of the CM SAF MSG SNS data set has been estimated to be better than 15 W/m^2. Further information on the accuracy of the product is contained in the validation report [RD 1].

3.1.3 Surface outgoing longwave radiation

The surface outgoing longwave radiation is calculated based on monthly-averaged data from the ERA-Interim reanalysis (*Dee et al.,* 2011). The reanalysis data is corrected to account for differences in the terrain elevation between the ERA-Interim data set and the 0.05° grid of the CM SAF MSG data set.
More details on the algorithm and the specific limitations are given in the ATBD [RD 2]. The overall accuracy of the CM SAF MSG SOL data set has been estimated to be better than 10 W/m^2. Further information on the accuracy of the product is contained in the validation report [RD 1].

3.1.4 Surface downward longwave radiation

The surface downward longwave radiation is derived by correcting the monthly-averaged downward longwave surface radiation from the ERA-Interim reanalysis with the CM SAF MSG CFC data set and topographic information. A cloud correction factor (CCF) to account

for the impact of cloud coverage on the surface downwelling longwave radiation is calculated for each month based on ERA-Interim data. The monthly mean surface downward longwave radiation is calculated from the clear-sky surface downward longwave radiation from ERA-Interim considering the cloud effect, which is derived from the CCF and the CM SAF MSG CFC data set.
More details on the algorithm and the specific limitations are given in the ATBD [RD 2]. The overall accuracy of the CM SAF MSG SDL data set has been estimated to be better than 10 W/m^2. Further information on the accuracy of the product is contained in the validation report [RD 1].

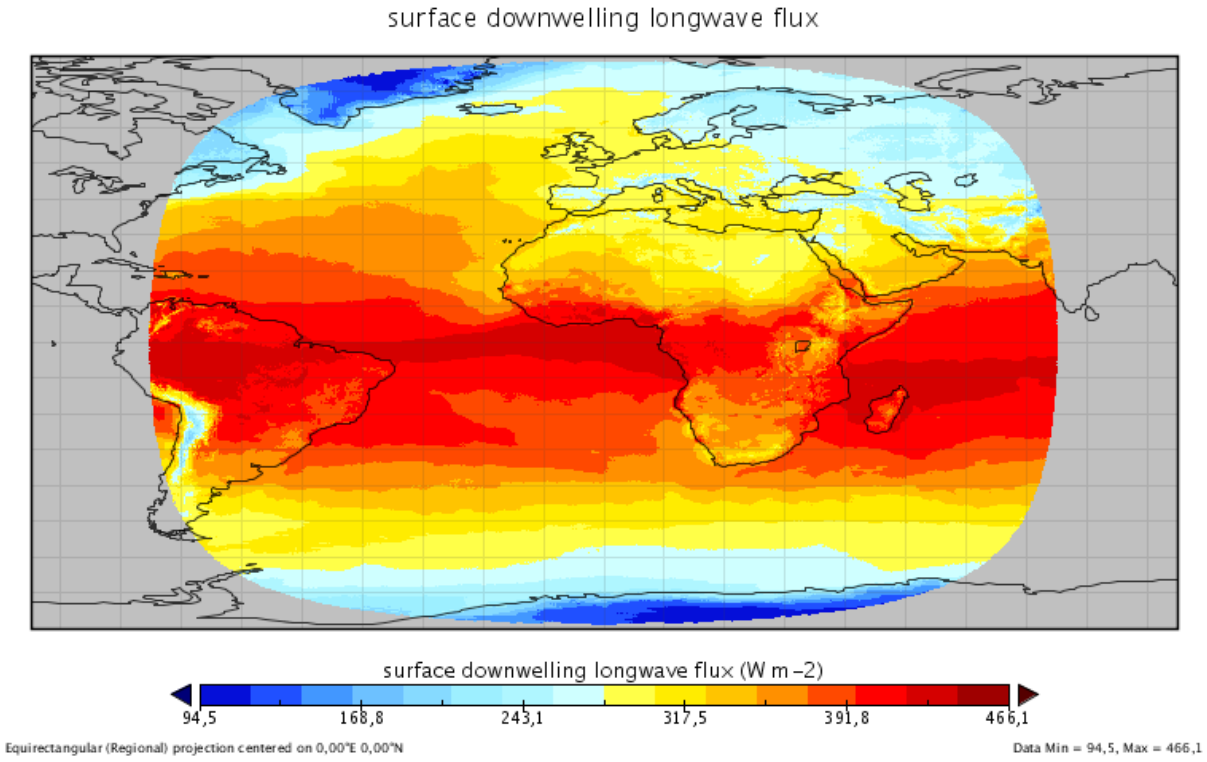

Figure 2: Example of CMSAF MSG SDL data, monthly mean for March 2009.

Figure 2 presents an illustrative example of the CM SAF MSG SDL data set. Shown is the monthly mean of the surface longwave downwelling radiation for March 2009.

3.1.5 Surface net longwave radiation

The surface net longwave radiation is derived as the sum of the surface downward longwave radiation and the surface outgoing longwave radiation, which corresponds to the definition of the surface net longwave radiation.
More details on the algorithm and the specific limitations are given in the ATBD [RD 2]. The overall accuracy of the CM SAF MSG SNL data set has been estimated to be better than 15 W/m^2. Further information on the accuracy of the product is contained in the validation report [RD 1].

3.1.6 Surface radiation budget

The monthly-averaged surface radiation budget is derived as the sum of the CM SAF MSG data sets of the surface net shortwave radiation (SNS) and the surface net longwave radiation (SNL), which corresponds to the definition of the surface radiation budget.
More details on the algorithm and the specific limitations are given in the ATBD [RD 2]. The overall accuracy of the CM SAF MSG SRB data set has been estimated to be better than 16

W/m^2. Further information on the accuracy of the product is contained in the validation report [RD 1].

3.1.7 Cloud radiative effect SW

The surface shortwave cloud radiation effect is derived from the monthly-averaged data sets of the surface incoming shortwave radiation and the surface albedo, and the monthly-averaged clear-sky surface downward shortwave radiation. The latter is derived in the processing of the surface incoming solar radiation.
More details on the algorithm and the specific limitations are given in the ATBD [RD 2]. The overall accuracy of the CM SAF MSG CFS data set has been estimated to be better than 10 W/m^2. Further information on the accuracy of the product is contained in the validation report [RD 1].

3.1.8 Cloud radiative effect LW

The monthly mean surface longwave cloud radiation effect is determined as the product of the cloud correction factor and the cloud fraction determined by CM SAF MSG.
More details on the algorithm and the specific limitations are given in the ATBD [RD 2]. The overall accuracy of the CM SAF MSG CFL data set has been estimated to be better than 10 W/m^2. Further information on the accuracy of the product is contained in the validation report [RD 1].

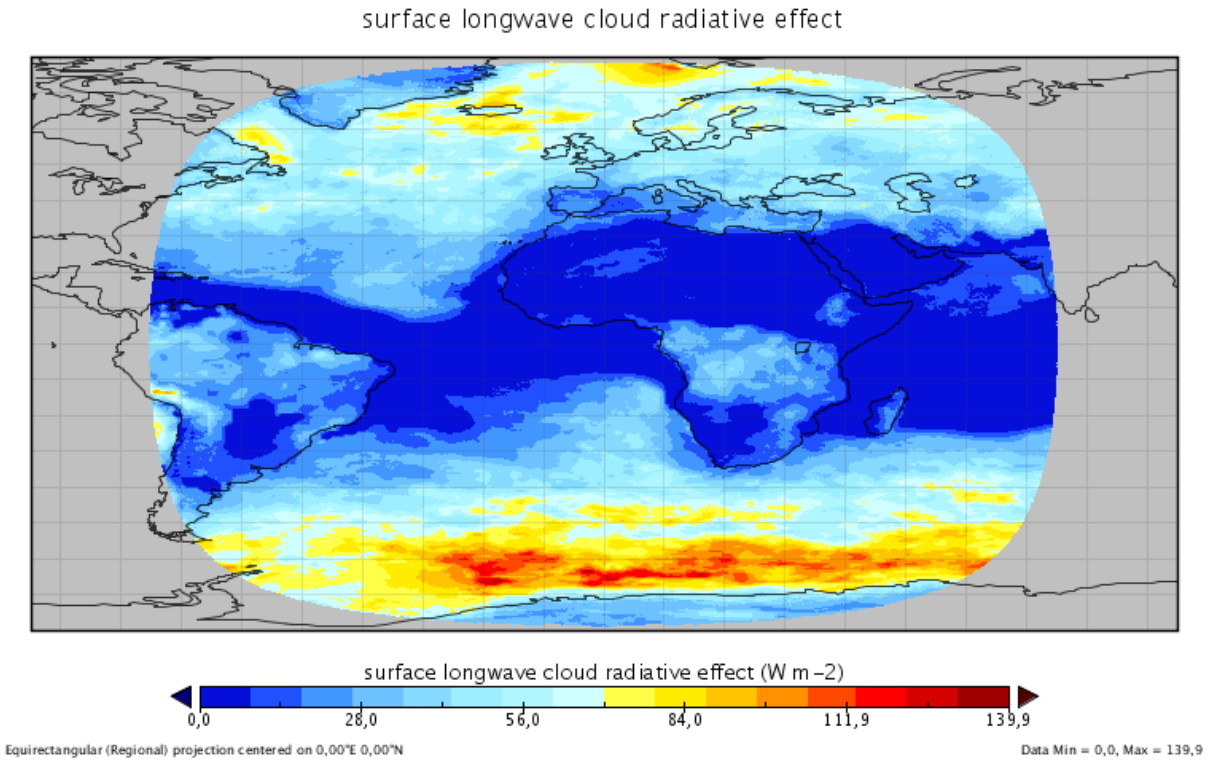

Figure 3: An example of the surface longwave cloud radiative effect. Monthly mean March 2009.

Figure 3 presents an illustrative example of the CM SAF MSG CFL data set. Shown is the monthly mean for March 2009.

3.2 General limitations of the CM SAF MSG surface radiation data set.

Here, general limitations of the application of the CM SAG MSG surface radiation data sets are presented. More specific limitations and shortcomings for each data set can be found in the ATBD [RD 2].

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- Over snow the uncertainty might be higher than the extimated accuracies for all data sets due to limitation in the detection of clouds over snow.
- The uncertainty of SID in desert and biomass regions might be higher due to heavy aerosol load.

3.3 Recommended applications:

All radiation data sets are dedicated for climate monitoring and analysis as well as for validation of climate models and reanalysis data. SIS and SID are useful for solar energy applications in addition.

4 Outlook

Future tasks will involve the improvement of the retrieval algorithm of the surface incoming solar radiation with respect to the surface albedo limitation. The time-varying surface albedo from the CM SAF MSG SAL data set will be used to improve the quality and the availability of the surface solar radiation data sets in the next release currently scheduled for 2014.
Further evaluations of the data sets will be conducted. These evaluations will also be extended to provide information on the long-term stability of the data sets.

5 Data format description

CM SAF‘s climate monitoring MSG surface radiation products are provided as NetCDF (Network Common Data Format) files (http://www.unidata.ucar.edu/software/netcdf/). The data files are created following NetCDF Climate and Forecast (CF) Metadata Convention version 1.5 (http://cf-pcmdi.llnl.gov/) and NetCDF Attribute Convention for Dataset Discovery version 1.0.
For data processing and conversion to various graphical packages input format, CM SAF recommends the usage of the climate data operators (CDO), available under GNU Public License (GPL) from MPI-M (http://www.mpimet.mpg.de/~cdo).

5.1 Data file contents

A common NetCDF file consists of dimensions, variables, and attributes. These components can be used together to capture the meaning of data and relations among data. All CM SAF MSG surface radiation products files are built following the same design principles.

Each data file contains the following coordinate variables:

time
: start of averaging/composite time period
[days counted from 1970-01-01]

time_bnds
: two-dimensional array defining the averaging/composite time period
[days counted from 1970-01-01]

latitude
: geographical latitude of grid-box centre [degree_north]

longitude
: geographical longitude of grid-box centre [degree_east]

Each data file contains a subset of the following 3-dimensional variables:

sis, sns, sol, sdl, snl, srb, cfs, cfl
parameter grid box mean value, the name depends on the parameter

Each file extracted from the CM SAF database has one record of the dimension (time, lat, lon) with the time dimension as the record dimension. This allows it to concatenate the individual records into an aggregated file. Possible global and variable attributes are summarized in Table 2 and and Table 3.

6 Data ordering via the Web User Interface (WUI)

The internet address http://wui.cmsaf.eu allows direct access to the CM SAF data ordering interface. On this webpage a detailed description how to use it 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.

Further user service including information and documentation about CM SAF and the CM SAF products are available from the CM SAF home page (http://www.cmsaf.eu).

6.1 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 (Please not the copyright disclaimer given in section 4.1). 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.

6.2 Contact User Help Desk staff

In case of questions the contact information of the User Help Desk (e-mail address contact.cmsaf@dwd.de) are available via the CM SAF home webpage (www.cmsaf.eu) or the home page of the Web User Interface (http://wui.cmsaf.eu).

6.3 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 section 2.2) or use the “User Problem Report” page. A link to the “User Problem Report” is available either from the CM SAF home page (www.cmsaf.eu) or the Web User Interface home page (http://wui.cmsaf.eu).

6.4 Service Messages / log of changes

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

7 Feedback

7.1 User feedback

Users of CM SAF products and services are encouraged to provide feedback on the CM SAF product and services to the CM SAF team. We are keen to learn of what use the CM SAF data are. So please feedback your experiences as well as your application area of the CM SAF data.

EUMETSAT CM SAF is an user driven service and is committed to consider the needs and requirements of its users in the planning for product improvements and additions. Please provide your feedback e.g. to our User Help Desk (e-mail address contact.cmsaf@dwd.de).

7.2 Specific requirements for future products

Beside your general feedback you are cordially invited to provide your specific requirements on future products for your applications. Please provide your requirements e.g. to our staff or via our User Help Desk (e-mail address contact.cmsaf@dwd.de).

7.3 User Workshops

CM SAF is organizing on regular basis training workshops in order to facilitate the use of our data. Furthermore through our regular (approximately every four years) user's workshop we revisit our product baseline. Your participation in any of these workshops is highly appreciated. Please have a look at on the CM SAF home web page (www.cmsaf.eu) to get the latest news on upcoming events.

8 Copyright and Disclaimer

The user of CM SAF data agrees to respect the following regulations:

8.1 Copyright

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 in publications, presentations, web pages etc., ***EUMETSAT's copyright credit must be shown by displaying the words "copyright (year) EUMETSAT" on each of the products used.***

8.2 Acknowledgement and Identification

When exploiting EUMETSAT/CM SAF data you are kindly requested to acknowledge this contribution accordingly and make reference to the CM SAF, e.g. by stating "The work performed was done (i.a.) by using data from EUMETSAT's Satellite Application Facility on Climate Monitoring (CM SAF)". It is highly recommended to clearly identify the product version used. An effective way to do this is the citation of CM SAF data records via the digital object identifier (doi). All information can be retrieved through (http://www.cmsaf.eu/DOI).

The DOI for this data set is provided on the title page of this document.

8.3 Re-distribution of CM SAF data

Please do not re-distribute CM SAF data to 3rd parties. The use of the CM SAF products is granted free of charge to every interested user, but we have an essential interest to know how many and what users the CM SAF has. This helps to ensure of the CM SAF operational services as well as its evolution according to users needs and requirements. Each new user shall register at CM SAF in order to retrieve the data.

9 References

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Hess, M., P. Koepke, and I. Schult (1998), Optical properties of aerosols and clouds: The software package OPAC, *Bulletin of the American Meteorological Society, 79*(5), 831-844.

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10 Netcdf conventions

Table 2: Global NetCDF attributes.

Name	Description
Title	dataset title
Conventions	conventions followed, "CF-1.5" for all files
Metadata_Convention	conventions followed, "Unidata Dataset Discovery v1.0" for all files
institution	institution where the data was produced
creator_url	URL contact information for the creator of the data
creator_email	email contact information for the creator of the data
references	references that describe the data or methods used to produce it
source	original data source
cdm_data_type	data type, “grid” for all files
filename	original filename
time_coverage_start	temporal coverage start of the data [ISO8601 date]
time_coverage_end	temporal coverage end of the data [ISO8601 date]
time_coverage_duration	temporal coverage duration of the data [ISO8601 duration]
geospatial_lat_units	latitude attributes unit
geospatial_lat_resolution	latitude grid resolution
geospatial_lat_min	latitude bounding box minimum
geospatial_lat_max	latitude bounding box maximum
geospatial_lon_units	longitude attributes unit
geospatial_lon_resolution	longitude grid resolution
geospatial_lon_min	longitude bounding box minimum
geospatial_lon_max	longitude bounding box maximum
cmsaf_major_version_number	CM SAF major release version
cmsaf_minor_version_number	CMSAF minor release version
processed_satellite	satellites processed for this mean
processed_orbit_node	satellite orbit nodes processed for this mean "ascending, descending" for all files
cmsaf_parameter_id	CM SAF product identifier
cmsaf_parameter_code	CM SAF product name
intercalibration	intercalibration version applied
date_created	date on which the data was created [ISO8601 date]
history	provides an audit trail for modifications to the original data

Table 3: Attributes assigned to variables.

Name	Description
long_name	long descriptive name
standard_name	standard name that references a description of a variable's content in the CF standard name table
units	physical unit [udunits standards]
C_format	format string that should be used for C applications to print values for this variable, applies to the scaled (internal) type and value
FORTRAN_format	format string that should be used for FORTRAN applications to print values for this variable, applies to the scaled (internal) type and value
valid_min	smallest valid value of a variable
valid_max	largest valid value of a variable
scale_factor	The data are to be multiplied by this factor after it is read.
add_offset	This number is to be added to the data after it is read. If scale_factor is present, the data are first scaled before the offset is added.
_FillValue	This number represent missing or undefined data. Missing values are to be filtered before scaling.
missing_data	This number represent missing or undefined data. Missing values are to be filtered before scaling. Contains the same value as the _FillValue-attribute.
cell_methods	method used to derive data that represents cell values following the CF Convention

11 Glossary.

AVHRR: Advanced Very High Resolution Radiometer
AOD: Aerosol Optical Depth
CAL: Effective cloud albedo
CFS Cloud Radiative Effect Shortwave
CFL Cloud Radiative Effect Longwave
COT Cloud optical depth
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
SEVIRI: Spinning Enhanced Visible and InfraRed Imager
NOAA: National Oceanic and Atmospheric Administration
NCEP: National Center for Environmental Prediction
RTM: Radiative Transfer Model
SIS: Surface Incoming Shortwave Radiation
SNS Surface Net Shortwave Radiation
SOL: Surface Outgoing Longwave Radiation
SDL: Surface Downward Longwave Radiation
SNL: Surface Net Longwave Radiation
SRB: Surface Radiation Budget
SZA: Sun Zenith Angle
SSA: Single Scattering Albedo