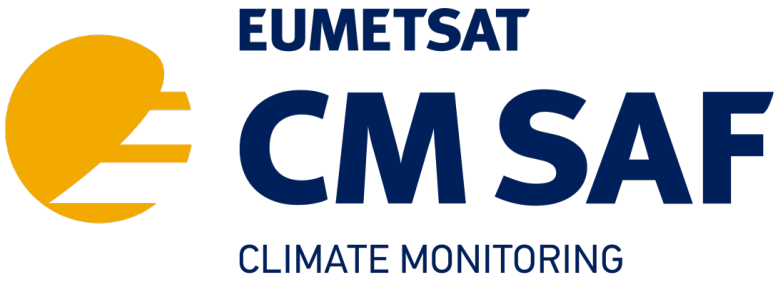
EUMETSAT Satellite Application Facility on Climate Monitoring



Product User Manual Meteosat Cloud Fractional Cover (Comet) Edition 2

DOI: 10.5676/EUM_SAF_CM/CFC_METEOSAT/V002

Cloud Fractional Cover (CFC) **CM-23012**

Reference Number:	SAF/CM/MeteoSwiss/PUM/MET/CFC/2.0
Issue/Revision Index:	2.0
Date:	06.04.2023

Document Signature Table

	Name	Function	Signature	Date
Author	Anke Tetzlaff Reto Stöckli	CM SAF Scientist Team Leader		06.04.2023
Editor	Marc Schröder	Science Coordinator		
Approval	Steering Group			
Release	Rainer Hollmann	Project Manager		

Distribution List

Internal Distribution	
Name	**No. Copies**
DWD / Archive	1
CM SAF Team	1

External Distribution		
Company	**Name**	**No. Copies**
Public		1

Document Change Record

Issue/ Revision	Date	DCN No.	Changed Pages/Paragraphs
1.0	15/08/2016	SAF/CM/MeteoSwiss/PUM/MET/CFC/2	First version submitted for DRR 2.8
1.1	09/05/2017	SAF/CM/MeteoSwiss/PUM/MET/CFC/2	Final Document based on comments from DRR 2.8
2.0	06/04/2023	SAF/CM/MeteoSwiss/PUM/MET/CFC/2.0	Second version submitted for DRR 3.9

Applicable Documents

Reference	Title	Code
AD 1	CM SAF Product Requirements Document	SAF/CM/DWD/PRD/4.1

Reference Documents

Reference	Title	Code
RD 1	Validation Report Meteosat Cloud Fractional Cover Edition 2	SAF/CM/MeteoSwiss/VAL/MET/CFC/2.0
RD 2	Algorithm Theoretical Basis Document Meteosat Cloud Fractional Cover Edition 2	SAF/CM/MeteoSwiss/ATBD/MET/CFC/2.1

Table of Contents

List of Tables

List of Figures

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 the 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 Office of the United Kingdom (UK Met Office). Since the beginning in 1999, the EUMETSAT Satellite Application Facility on Climate Monitoring (CM SAF) has developed and will continue to develop capabilities for a sustained generation and provision of Climate Data Records (CDR’s) derived from operational meteorological satellites.

In particular, the generation of long-term data records is pursued. The ultimate aim is to make the resulting data records suitable for the analysis of climate variability and potentially the detection of climate trends. The 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 the CM SAF is on ECVs associated with the global energy and water cycle.

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

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 the highest standards and guidelines as outlined by GCOS for satellite data processing,

- Processing of satellite data within a true international collaboration benefiting from developments at international level and pollinating the partnership with its own ideas and standards,

- Intensive validation and improvement of the CM SAF climate data records,

- Taking a major role in data record assessments performed by research organisations such as the World Climate Research Programme (WCRP). This role provides the CM SAF with strong 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.

2 Product Description

In this section, the Cloud Fractional Cover (CFC) data is described shortly regarding retrieval methods, information content and limitations. Validation results are also described and a short statement on recommended applications is given.

The Meteosat CFC is provided in % cloud cover (0-100%) corresponding to 0-8 okta according to the WMO specification as given in the ATBD [RD 2].

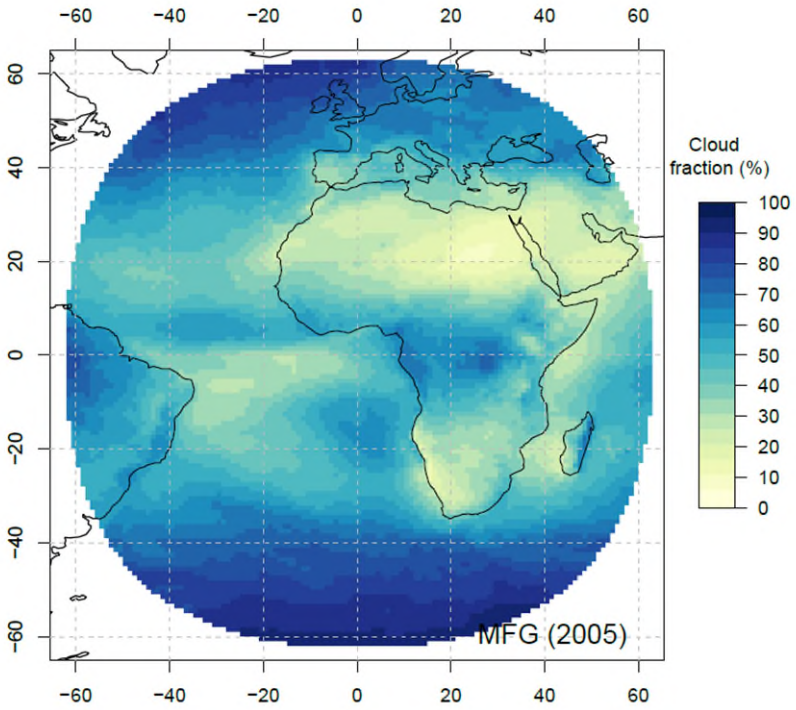


Figure 1: CFC annual mean for MFG-based in 2005.

2.1 Short Algorithm Description

This second version of the data record builds on a newly developed state-of-the-art retrieval system for only two heritage channels. It employs a cyclic generation of clear sky background fields, on continuous cloud scores and on a Bayesian cloud fraction estimation using concurrent information on cloud state and variability. The algorithm depends on well characterized IR radiances and VIS reflectances from the Meteosat Fundamental Climate Data Record (FCDR) provided by EUMETSAT.

The Cloud Fractional Cover data is based on only two heritage channels from MFG MVIRI and MSG SEVIRI. The calibrated visible and inter-calibrated infrared radiances firstly serve as input to a daily recurring parametric estimation of clear sky background fields with diurnal cycle models of brightness temperature and reflectance. These clear sky inversions are constrained by previously cloud masked reflectances and brightness temperatures. The resulting clear sky background fields together with the all sky instantaneous reflectances and brightness temperatures yield continuous cloud mask scores of pixel wise state and spatiotemporal variability. CFC is retrieved from these scores by use of a Bayesian classifier. It is based on

the conditional occurrence probability of scores and two dimensional score combinations given SYNOP observed CFC classes. The use of such two dimensional score combinations featuring both the state and variability of specific reflectance or brightness temperature features is a substantial and useful addition to the commonly used naïve Bayesian classifier [RD-2]. The use of a Bayesian classifier has the benefit of instantaneous and pixel wise CFC estimates. This means that Meteosat CFC is not built from the spatial aggregation binary cloud mask estimates as often done. The use of a Bayesian classifier also yields posterior retrieval probabilities for each CFC value.

2.2 Highlights

- Heritage: Corresponds to CFC measured at WMO/SYNOP sites
- Applicability: Instantaneous and pixel wise CFC estimates with posterior retrieval probability as part of the dataset
- Precision: Inter-calibrated input radiance time series from EUMETSAT
- Accuracy: Meets optimal CM SAF daily and monthly requirements and decadal stability. Meets those requirements for many of the individual locations.
- Resolution: 0.05 degree spatial and 30 minute temporal resolution

Improvements compared to edition 1:

- Extension back to 1983 using new Meteosat 2–7 infrared calibration
- Decreasing negative biases during winter months
- Tightening accuracy and precision requirements
- Improving on decadal stability

2.3 Limitations

- Accuracy lower during night and beyond 60 degree View Zenith Angle
- No full pixel wise CFC and CFC probability histogram provided to the user
- No additional usage of non-heritage channels for MSG due to homogeneity issues.

2.4 Validation

Averaged over all reference sites, Meteosat CFC complies with monthly optimal requirements for accuracy and precision as compared to SYNOP (see figure 2 and figure 3). Taking accuracy and precision requirements simultaneously into account – monthly optimal, target and threshold requirements are met by 20%, 61% and 80% of sites, respectively (see Figure 3, also for a graphical display of the requirements). These values are lower than in Edition 1 since accuracy and precision requirements were tightened for

Edition 2. For instance, the monthly threshold accuracy requirement was lowered from 10% to 5% and the monthly threshold precision requirement was lowered from 20% to 15%. So in absolute terms both accuracy and precision increased in Edition 2.

The Meteosat CFC accuracy and precision results together with the reported decadal stability <1%,fulfilling the target decadal stability requirements, demonstrate that the Edition 2 of the Meteosat CFC CDR is suitable for climate monitoring, climate model evaluation and regional climate analysis applications. The Meteosat CFC corresponds to CFC measured at WMO SYNOP sites.

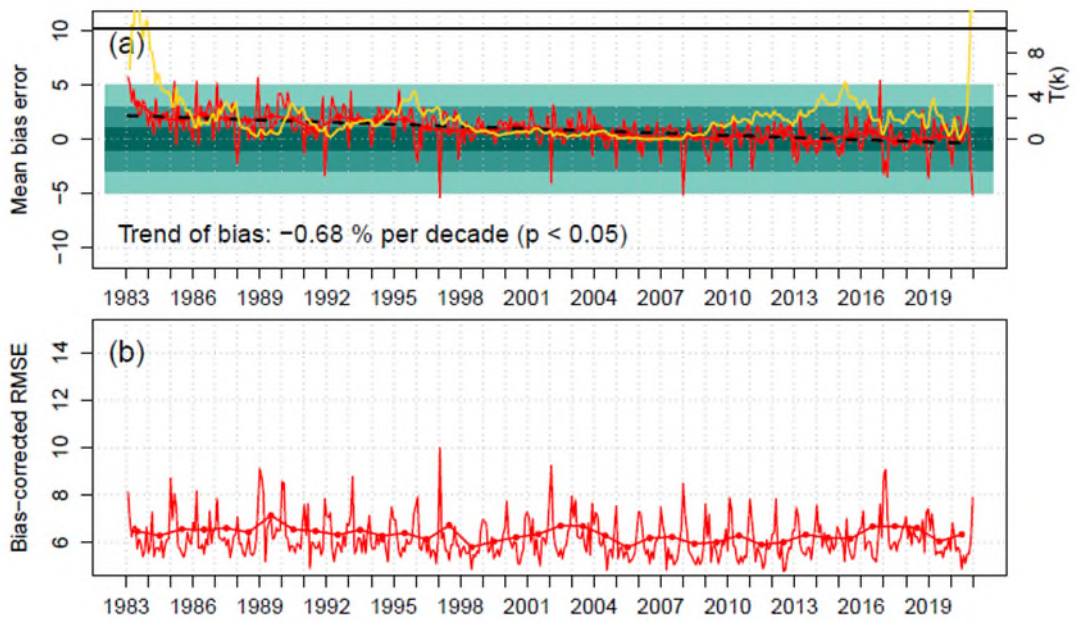


Figure 2: Mean bias error (a) and bias-corrected root mean square error (b) of Meteosat CFC as compared to SYNOP observations. Red=bias. Yellow: homogeneity test.

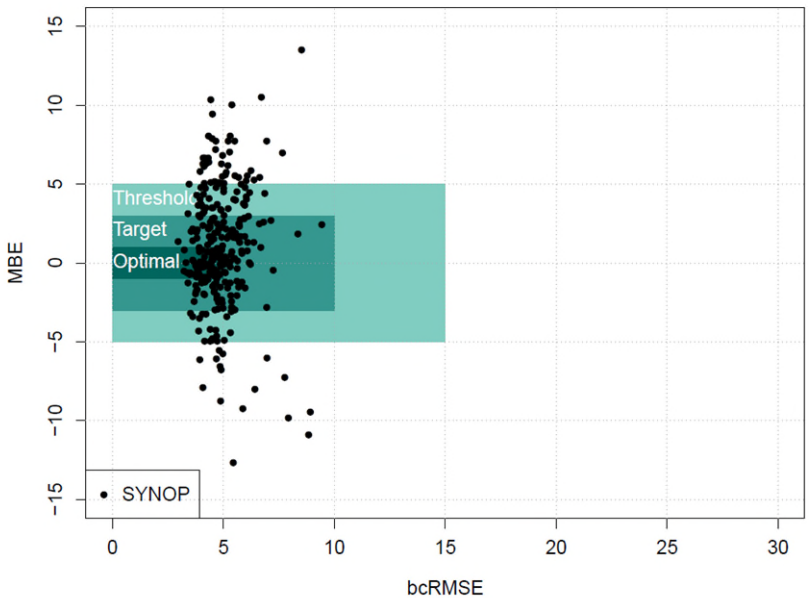


Figure 3: Performance statistics of the Meteosat CFC monthly means as compared to synoptic observations at 290 sites.

2.5 Recommended Application

Meteosat CFC is useful to extend existing ground-based CFC estimates with spatial information. Meteosat CFC can be used to evaluate and improve NWP or climate model based cloud cover diurnal cycles (e.g. the timing and phase of convective cloud formation). Meteosat CFC is also useful to augment CFC from polar orbiter data with statistical information on the diurnal cycle of cloudiness in order to, for example, correct incomplete diurnal coverage or orbital drift. Meteosat CFC is also useful to cloud or clear sky screen downstream applications such as LST or Albedo retrievals. The usability of Meteosat CFC in climates with substantial snow and near surface fog has to be tested. Despite the high decadal stability, the applicability of Meteosat CFC in trend analyses has to be thoroughly evaluated and cross-checked with quality screened ground based reference time series.

3 Data format description

The CM SAF's climate monitoring CFC 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 1.7 (https://cfconventions.org/Data/cf-conventions/cf-conventions-1.7/cf-conventions.html) and NetCDF Attribute Convention for Dataset Discovery version 1.3 (http://wiki.esipfed.org/index.php/Attribute_Convention_for_Data_Discovery_1-3).

For data processing and conversion to various graphical packages input format, the 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).

The presented Meteosat CFC data is provided on a regular latitude and longitude grid. The geographic reprojection from the native Meteosat grid onto the latitude longitude grid is carried out using spatial nearest neighbour search and averaged if the destination grid cell is more than half of the size of the source grid cell (near the equator). Bilinear interpolation is used elsewhere (e.g. at high latitudes) (RD-2). Table 1 gives information on the geographical coverage.

Table 1: Characteristics of the Meteosat CFC data geographical coverage.

Lon min	Lon max	Lat min	Lat max	Spacing (lon, lat)	Projection	Datum
-65.0°	65.0°	-65.0°	65.0°	0.05°	latitude - longitude	WGS 84

The Meteosat CFC data are Level-3 data presented as hourly, daily and monthly means as outlined in Table 3.

CFC hourly means are the mean of all valid instantaneous retrievals for a given hour. A minimum of one valid instantaneous retrieval is required. For daily and monthly CFC means, we require at least four observations per day and twenty observations per month, respectively. Details on the averaging procedure can be found in the corresponding ATBD (RD-2).

Table 2: Meteosat CFC data.

	CFC
Hourly mean	X
Daily mean	X
Monthly mean	X
Monthly mean diurnal cycle	X

For each time step we provide a separate output file, which follows the naming convention:

[CFC][t][s][yyyy][mm][dd][hh][mm][002231000101MA.nc]

Where CFC is the TCDR identifier, **t** is time interval (m=monthly, d=daily, h=hourly), **s** is time statistics (m=mean, d=mean diurnal cycle), **yyyy**=year, **mm**=month, **dd**=day, **hh**=hour, **mm**=minute. The string 002231000101MA is the CM SAF specific TCDR suffix not of interest to the user. The file type identifier .nc stands for a NetCDF file.

Example for the daily mean for 1 May 2005: CFCdm2005050100000002231000101MA.nc

3.1 General Variables

Table 3: General variables.

Name	Description
lon	*geographical longitude of grid-box centre [degree_east]*
lat	*geographical latitude of grid-box centre [degree_north]*
time	*time of averaging/composite time period; in case of diurnal cycles, this vector has 24 elements [days counted from 1970-01-01]*
lon_bnds	*geographical longitude of grid-box edges [degree_east]*
lat_bnds	*geographical latitude of grid-box edges [degree_north]*
time_bnds	*time edges*
record_status	*overall status of each record (timestamp) in this file. If a record is flagged as not ok, it is recommended not to use it.*
grid_mapping	*projection parameters*
SATID	*spacecraft ID (unique number defined by MSGGS or GSDS or NORAD or COSPAR):* *19 = MFG 4, 20 = MFG 5, 21 = MFG 6, 22 = MFG 7,* *321 = MSG 1, 322 = MSG 2, 323 = MSG 3, 324 = MSG 4*

3.2 Global Attributes

Table 4: Global attributes.

Name	Description
title	*geosatclim (processing software)*
summary	*This file contains time-space aggregated Thematic Climate Data Records (TCDR) produced by geosatclim within the Satellite Application Facility on Climate Monitoring (CM SAF)*
id	*DOI:10.5676/EUM_SAF_CM/CFC_METEOSAT/V002*
variable_id	*CFC*
product_version	*2.6*
creator_name	*EUMETSAT/CMSAF*
creator_email	*contact.cmsaf@dwd.de*
creator_url	*http://www.cmsaf.eu*
institution	*Federal Office of Meteorology and Climatology MeteoSwiss*
project	*Satellite Application Facility on Climate Monitoring (CM SAF)*
references	*https://doi.org/10.5676/EUM_SAF_CM/CFC_METEOSAT/V002*
keywords	*EARTH SCIENCE > ATMOSPHERE > CLOUDS > CLOUD PROPERTIES > CLOUD FRACTION*
keywords_vocabulary	*GCMD Science Keywords, Version 8.6*
Conventions	*CF-1.7, ACDD-1.3*
standard_name_vocabulary	*Standard Name Table (v28, 07 January 2015)*
date_created	*creation date*
time_coverage_start	*starting date*
time_coverage_end	*ending date*
time_coverage_duration	*time duration*
time_coverage_resolution	*time resolution*
geospatial_lon_units	*degrees_east*
geospatial_lon_min	*-65*
geospatial_lon_max	*65*
geospatial_lon_resolution	*0.05 degree*
geospatial_lat_units	*degrees_north*
geospatial_lat_min	*-65*
geospatial_lat_max	*65*
geospatial_lat_resolution	*0.05 degree*
licence	*The CM SAF data are owned by EUMETSAT and are available to all users free of charge and with no conditions to use. If you*

	wish to use these products, EUMETSAT\'s copyright credit must be shown by displaying the words \"Copyright (c) (2022) EUMETSAT\" under/in each of these SAF Products used in a project or shown in a publication or website. *\n,* *Please follow the citation guidelines given at https://doi.org/10.5676/EUM_SAF_CM/CFC_METEOSAT/V002 and also register as a user at http://cm-saf.eumetsat.int/ to receive latest information on CM SAF services and to get access to the CM SAF User Help Desk.*
platform	*MFG or MSG*
platform_vocabulary	*GCMD Platforms, Version 8.6*
instrument	*MVIRI or SEVIRI*
instrument_vocabulary	*GCMD Instruments, Version 8.6*

3.3 Variables

CFC (time, lat, lon)

field containing the CFC values given in percent

(mean hourly for hourly files, mean daily value for daily files, mean monthly value for monthly files, monthly mean for each hour of the day for monthly diurnal cycle files)

PCFC (time, lat, lon)

field containing the retrieval probability for CFC given in percent

CFC_NUMO (time, lat, lon)

field containing the number of valid observations

Table 5: Meteosat CFC product variables.

Parameter	Unit	Valid range	Type	Scale	Offset	Fill Value
CFC	%	[0,100]	byte	1.0	0.0	-127
PCFC	%	[0,100]	byte	1.0	0.0	-127
CFC_NUMO	1	[0,X]	byte	1.0	0.0	-127

4 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 of how to use it for product search and ordering is given. The user is referred 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 the CM SAF and the CM SAF products are available from the CM SAF home page (http://www.cmsaf.eu).

4.1 Product ordering process

The internet address http://wui.cmsaf.eu allows direct access to the CM SAF data ordering interface. On this webpage a detailed description of how to use it for product search and ordering is given. The user is referred 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 the CM SAF and the CM SAF products are available from the CM SAF home page (http://www.cmsaf.eu).

4.2 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).

4.3 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 6.2) 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).

4.4 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. 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.

4.5 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. 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.

5 Feedback

5.1 User feedback

Users of the CM SAF products and services are encouraged to provide feedback on the CM SAF product and services to the CM SAF team. CM SAF is 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.

The EUMETSAT CM SAF is a 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).

5.2 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).

5.3 User Workshops

The CM SAF organises training workshops on regular basis in order to facilitate the use of our data. Furthermore, through our regular (approximately every four years) user's workshop our product baseline is revisited. 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.

6 Copyright and Disclaimer

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

6.1 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.***

6.2 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 by using data from EUMETSAT's Satellite Application Facility on Climate Monitoring (CM SAF)". It is highly recommended to identify the product version used clearly. 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 record is provided on the title page of this document.

6.3 Re-distribution of CM SAF data

Please do not re-distribute CM SAF data to third parties. The use of the CM SAF products is granted free of charge to every interested user, but an essential interest exists 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 user needs and requirements. Each new user shall register at CM SAF in order to retrieve the data.