EUMETSAT Satellite Application Facility on Climate Monitoring

Product User Manual

Fundamental Climate Data Record of SSM/I Brightness Temperatures

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Applicable documents

Reference	Title	Code
AD 1	Memorandum of Understanding between CM SAF and the Max-Planck Institute for Meteorology and Meteorological Institute, University of Hamburg	
AD 2	Cooperation Agreement	
AD 3	CM SAF Product Requirements Document	SAF/CM/DWD/PRD/2.0

Reference documents

Reference	Title	Code
RD 1	Algorithm Theoretical Basis Document Fundamental Climate Data Record of SSM/I Brightness Temperatures	SAF/CM/DWD/ATBD/FCDR_SSMI/1.3
RD 2	Validation Report Fundamental Climate Data Record of SSM/I Brightness Temperatures	SAF/CM/DWD/VAL/FCDR_SSMI/1.0

Table of Contents

List of Figures

List of Tables

1 The EUMETSAT SAF on Climate Monitoring

The importance of climate monitoring with satellites was recognized in 2000 by EUMETSAT Member States when they amended the EUMETSAT Convention to affirm that the EUMETSAT mandate is also to "contribute to the operational monitoring of the climate and the detection of global climatic changes". Following this, EUMETSAT established within its Satellite Application Facility (SAF) network a dedicated centre, the SAF on Climate Monitoring (CM SAF, http://www.cmsaf.eu/).

The consortium of CM SAF currently comprises the Deutscher Wetterdienst (DWD) as host institute, and the partners from the Royal Meteorological Institute of Belgium (RMIB), the Finnish Meteorological Institute (FMI), the Royal Meteorological Institute of the Netherlands (KNMI), the Swedish Meteorological and Hydrological Institute (SMHI), the Meteorological Service of Switzerland (MeteoSwiss), and the Meteorological Service of the United Kingdom (UK MetOffice). Since the beginning in 1999, the EUMETSAT Satellite Application Facility on Climate Monitoring (CM SAF) has developed and will continue to develop capabilities for a sustained generation and provision of Climate Data Records (CDR's) derived from operational meteorological satellites.

In particular the generation of long-term data 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 (PUM) provides information on the Fundamental Climate Data Record (FCDR) of Brightness Temperatures from the Special Sensor Microwave/Imager (SSM/I). The predecessors of this data record and the data processor suite have originally been developed at the Max-Planck Institute for Meteorology (MPI-M) and the University of Hamburg (UHH) for the Hamburg Ocean Atmosphere Parameters and Fluxes from Satellite Data (HOAPS, htpp://www.cmsaf.eu/) climatology.

HOAPS is a compilation of climate data records for analysing the water cycle components over the global oceans derived from satellite observation (Andersson et al. 2010). The main satellite instrument employed to retrieve the geophysical parameters is the SSM/I and much work has been invested to process and carefully homogenize all SSM/I instruments onboard the Defence Meteorological Satellite Program (DMSP) platforms F08, F10, F11, F13, F14 and F15 (Andersson et al. 2010). In the framework of a Research & Operations activity the HOAPS processing suite has been transferred to CM SAF. After further enhancing the processor and the intersensor-calibration method at CM SAF, this FCDR forms the basis of future TCDRs from HOAPS.

A technical description of the data sets including information on the file format as well as on the data access is provided in this document. Furthermore details on the implementation of the processing chain and individual processing steps are available in the Algorithm Theoretical Basis Document [RD 1]. Basic accuracy requirements are defined in the product requirements document [AD 2]. A detailed validation of the FCDR is available in the Validation report [RD 2].

3 The SSM/I Instrument

SSM/I sensors have been carried aboard the DMSP satellite series since 1987. Up to three radiometers have been in orbit simultaneously. An extensive description of the instrument and satellite characteristics has been published by Hollinger (1987) and Wentz (1991). Hence, only a short summary of essential information is given here. The DMSP satellites operate in a near-circular, sun-synchronous orbit, with an inclination of 98.8° at an approximate altitude of 860 km. Each day, 14.1 orbits with a period of about 102 minutes are performed. The Earth's surface is sampled with a conical scan at a constant antenna boresight angle of 45° over an angular sector of 102.4° resulting in a 1400 km wide swath on the Earth surface (Figure 1). A nearly complete coverage of the Earth by one SSM/I instrument is achieved within two to three days. Due to the orbit inclination and swath width, the regions poleward of 87.5° are not covered.

To date, six SSM/I instruments have been successfully launched aboard the F08, F10, F11, F13, F14 and F15 spacecrafts. All satellites have a local equator crossing time between 5 and 10 A.M./P.M. for the descending/ascending node. The F08 had a reversed orbit with the ascending node in the morning. Also, the Earth observing angular sector of the scan on this satellite is, differently from the others, centred to the aft of the sub-satellite track. Most of the DMSP satellites have a stable orbit. The temporal variation of the equator crossing times is less than three hours for all satellites. At the end of the time period the orbits of F14 and F15 begin to decay noticeably, but are still within 2-3 hours of original time.

The SSM/I is a seven channel total power radiometer measuring emitted microwave radiation at four frequency intervals centred at 19.35, 22.235, 37.0, and 85.5 GHz. All frequencies are sampled at horizontal and vertical polarization, except for the 22.235 GHz channel, which measures only vertically polarized radiation. The channels will be referred to as 19, 22, 37, and 85 GHz hereafter and the corresponding brightness temperatures of each channel and polarization as TB19v/h, TB22v, TB37v/h, and TB85v/h.

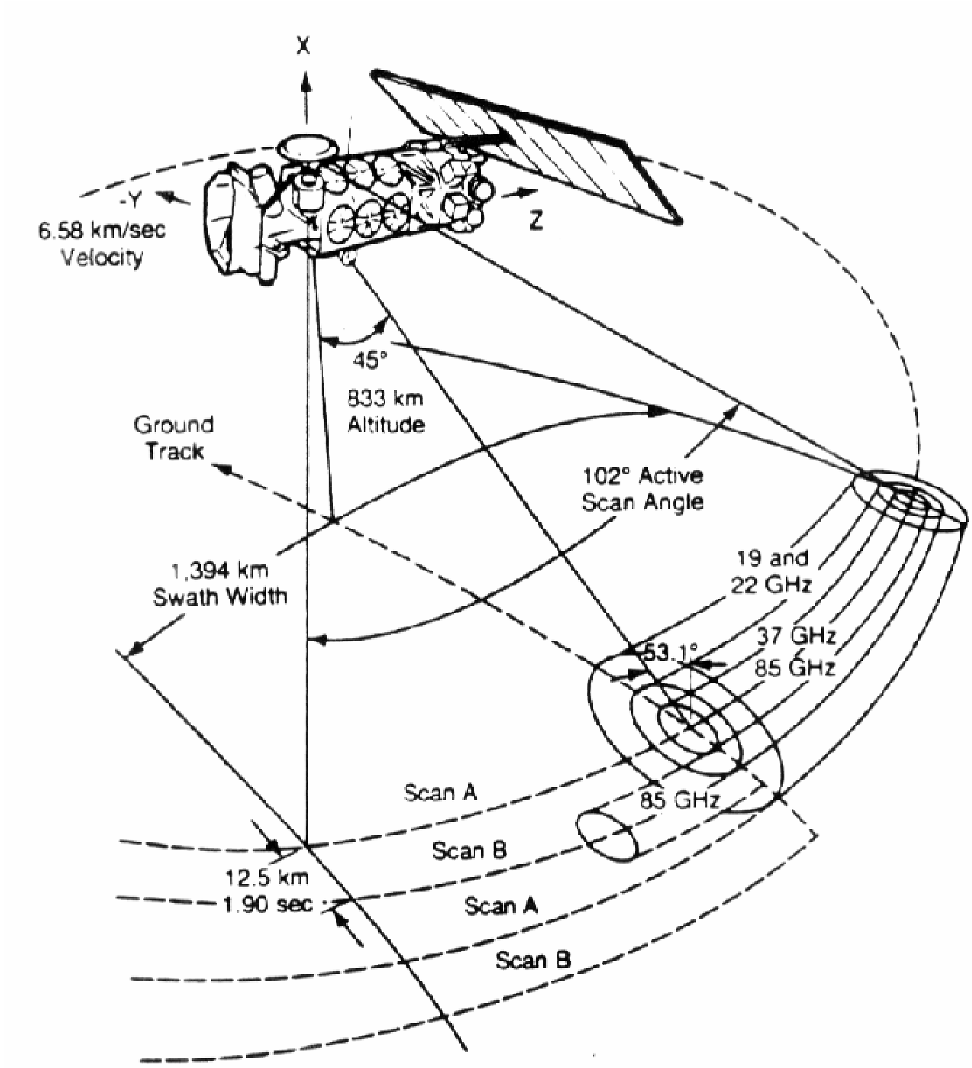

Figure 1: SSM/I scan geometry (from Hollinger et al., 1987).

The spatial resolution varies from 69 km by 43 km with a sampling frequency of 25 km for the 19 GHz channel to 15 km by 13 km with 12.5 km sampling frequency for the 85 GHz channel. The 85 GHz channels are sampled for each rotation of the instrument (A and B-scans) with a resolution of 128 uniformly spaced pixels, while the remaining channels are sampled every other scan (A-scans) with a resolution of 64 pixels (see Figure 1). A fixed cold space reflector and a reference black body hot load are used for continuous onboard two point calibration.

4 Product definition

The CM SAF FCDR from SSM/I brightness temperatures is compiled as daily collections of all observations from each sensor. All sensor specific data available in the raw data records are provided as well as additional information like quality control flags, Earth incidence angles (EIA), averaged 85 GHz brightness temperatures, incidence angle normalisation offsets and intersensor calibration offsets. The FCDR is available for the time period from July 1987 until end of 2008. A detailed list of data availability for each of the six SSM/I platforms is given in Table 1.

5 Data format description

The CM SAF FCDR dataset is provided as NetCDF (Network Common Data Format) files version 4 (http://www.unidata.ucar.edu/software/netcdf/). The data files are conforming to the 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.

All SSM/I FCDR product files are swath based and built following the same design principles. The record dimension of the data files is the B-scan integer time measured in seconds since 1st January 1987. Each file contains all possible scans for one complete day (~ 22749 scans) regardless of their quality and status. Missing scans are marked as missing and sensor data are set to undefined in this case.

The users are advised to read and apply the supplied quality control flags *qc_scan*, *qc_channel*, *qc_fov_lo* and *qc_fov_hi* in order to filter incorrect and erroneous observations. The quality control procedure and thresholds are described in the ATBD [RD 1]. An example how to read and apply the quality control flags is given in Appendix B. The meanings of the flags are summarized in Table 5, Table 6 and Table 7 (all in Appendix A).

To account for the higher sampling rate of the 85 GHz channels (see section 3), an additional dimension *scan_type* [A, B] is used to maintain the same record dimension as for the low resolution channels. This also keeps the file format compatible to the original NOAA/NESDIS format and results in a 4–dimensional array for the 85 GHz channel brightness temperatures: [*time, scan_type, channel_hifreq, across_track*]. The observation time of the A-scan can be calculated by subtracting 60/*rotation* (~1.9 s) from the B-scan time.

Brightness temperatures, intersensor offsets and EIA normalization offsets are archived as separate variables to allow the corrections to be added as required by the users. The brightness temperatures *tb* and *tb_hi* are the values after calibration with antenna pattern correction and along-scan correction applied. An example how to read the temperatures and apply the offsets is given in Appendix B.

The FOV positions of the high and low resolution channels are co-registered. To get the FOV position of the lower resolution channel the *across_track_lores* coordinate variable can be used as an index to the A-scan position arrays:

lat_lores = *lat*[*time, 0, across_track_lores*]

This follows the CF convention for compression by gathering and the corresponding attribute *compress* is assigned to the coordinate variable *across_track_lores*. An examples how to read the geolocation and to filter the low resolution positions is given in Appendix B.

Daily mean values, e.g. noise equivalent temperature, have a fixed dimension *date* of size 1.

Table 1: FCDR instrument data availability.

DMSP platform	Launch date	Record start	Record end
F08	1987-06-18	1987-07-09	1991-12-18
F10	1990-12-01	1991-01-07	1997-11-14
F11	1991-11-28	1992-01-01	1999-12-31
F13	1995-03-24	1995-05-03	2008-12-31
F14	1997-04-04	1997-05-07	2008-08-23
F15	1999-12-12	2000-02-28	2006-07-31

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. Global attributes are summarized in Table 2 and possible variable attributes in Table 3 (both in Appendix A). The following variables (thematically sorted) are available in the FCDR data files:

Coordinate variables

date
Validity date [days since 1987-01-01 00:00:00 UTC]
Fixed dimension [1]

time
B-Scan start time [seconds since 1987-01-01 00:00:00 UTC]
Record dimension

across_track
FOV across track position of high resolution channels
Fixed dimension [128]

across_track_lores
FOV across track position of low resolution channels
Fixed dimension [64]
compress = *across_track*

channel
Channel number
Fixed dimension [7]

channel_hifreq
Channel number of high frequency channels
Fixed dimension [2]
compress = *channel*

scan_type
High resolution scan type [A, B]
Fixed dimension [2]

nload
Cold and hot load reading number
Fixed dimension [5]

nread
General reading number
Fixed dimension [3]

ndigest
MD5 Hash length
Fixed dimension [16]

Explanatory variables

channel_name
String representation of the corresponding channel number.
['V19', 'H19', 'V22', 'V37', 'H37', 'V85', 'H85']

scan_type_name
String representation of the corresponding scan type.
['A', 'B']

Daily mean statistical variables

rotation
instrument rotational speed [rpm]
dimension [*date*]

hotc_var
variance of hot load reading [count^2]
dimensions [*date, channel*]

colc_var
variance of cold load reading [count^2]
dimensions [*date, channel*]

trhl_var
variance of hot load temperature [K^2]
dimension [*date*]

nedt
noise equivalent temperature [K]
dimensions [*date, channel*]

Quality control variables

qc_scan
Scanline quality control [bit mask]
dimensions [*time*]
All bits set to 0 indicates normal condition. See Table 5 for bit meanings.

qc_channel
Channel quality control [bit mask]
dimensions [*time, channel*]
All bits set to 0 indicates normal condition. See Table 6 for bit meanings.

qc_fov_lo
Field of view quality control, low-resolution [bit mask]
dimensions [*time, across_track_lores*]
All bits set to 0 implies acceptable data. See Table 7 for bit meanings.

qc_fov_hi
Field of view quality control, high-resolution [bit mask]
dimension [*time ,scan_type, across_track*]
All bits set to 0 implies acceptable data. See Table 7 for bit meanings.

pflag

Processing Flag [bit mask]
dimension [time]
See Table 4 for bit meanings.

Geolocation variables

tfrac

B-scan micro seconds [10^-6 s]
dimension [*time*]
To get the exact scan time add this to *time*.

lat

FOV latitude [degree_north]
dimensions [*time*, *scan_type*, *across_track*]

lon

FOV longitude [degree_east]
dimensions [*time*, *scan_type*, *across_track*]

laz

FOV local azimuth angle [degree_east]
dimension [*time*, *across_track*]

sft_lo

FOV surface type for low resolution channels
dimensions [*time*, *across_track_lores*]
Possible types are: water (0), land (1), coast (2), sea_ice (11), sea_ice_edge (12)

sft_hi

FOV surface type for high resolution channels
dimensions [*time*, *scan_type*, *across_track*]
Possible types are: water (0), land (1), coast (2), coast2 (3), sea_ice (11), sea_ice_edge (12)

rev

Revolution number
dimension [*time*]

salt

Altitude of spacecraft [km]
dimension [*time*]

slat

Latitude of spacecraft sub satellite point [degree_north]
dimension [*time*]

slon

Longitude of spacecraft sub satellite point [degree_east]
dimension [*time*]

eia

Earth incidence angle [degree]
dimension [*time*, *across_track*]

Calibration and sensor state variables

slope
Calibration slope [K/count]
dimensions [*time*, *channel*]

offset
Calibration offset [K]
dimensions [*time*, *channel*]

trhl
Hot load temperature [K]
dimensions [*time*, *nread*]

trfr
Forward radiator temperature [K]
dimension [*time*]

trrf
R.F. mixer temperature [K]
dimension [*time*]

hotc
Hot load reading [count]
dimensions [*time*, *scan_type*, *channel*, *nload*]

colc
Cold load reading [count]
dimensions [*time*, *scan_type*, *channel*, *nload*]

rvolt
Reference voltage
dimensions [*time*, *nread*]

agc
Automatic gain control setting
dimensions [*time*, *scan_type*, *channel*]

md5
MD5 message digest
dimension [*time*, *ndigest*]

Sensor data variables

tb
Brightness temperature [K]
dimensions [*time*, *channel*, *across_track_lores*]

ical
Brightness temperature intercalibration offset [K]
dimensions [*time*, *channel*, *across_track_lores*]

eia_norm
Brightness temperature earth incidence angle normalization offset [K]
dimensions [*time*, *channel*, *across_track_lores*]

tb_hi

Brightness temperature, 85 GHz [K]
dimensions [*time*, *scan_type*, *channel_hifreq*, *across_track*]

ical_hi

Brightness temperature intercalibration offset, 85 GHz [K]
dimensions [*time*, *scan_type*, *channel_hifreq*, *across_track*]

6 Assumptions and Limitations

The intersensor calibration method used here to homogenize the SSM/I brightness temperature time series does not account for an absolute radiometric offset. The reference target is the SSM/I aboard DMSP F11, which means that any absolute offset in the F11 TBs will be transferred to the other radiometers. However, one reason to choose the F11 as the reference target was a good performance when validating against collocated in-situ wind speed measurements from buoy observations (Andersson et al., 2010). This should at least minimize the remaining absolute error in the brightness temperature data record.

The intersensor calibration is determined over ocean, sea-ice and cold scenes over land because of a lower variability, smaller diurnal cycle and better behaved error characteristics. Due to this restriction, not the complete range of possible TBs is covered for all channels. It is assumed that the inter-sensor differences can be characterized as a linear problem and the derived correction coefficients can be used over warm land as well (see Validation Report [RD 2]).

The incidence angle normalisation TB offsets are only available over water. Geophysical retrievals over land and ice should always account for varying EIAs within their procedures.

During the time period from April 1988 to December 1991, the 85 GHz channel on DMSP F08 were defective. A replacement algorithm has been developed to estimate the 85 GHz measurements from the lower frequencies. However, this reconstruction is limited to the variability observed in the lower frequencies and can not fully recover the missing 85 GHz channel characteristics. Over land and ice surfaces this general approach is not applicable due to the strongly varying surface emissivity.

7 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 the 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.

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/).

7.1 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 note the copyright disclaimer given in section 9). 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.

7.2 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 (http://www.cmsaf.eu/) or the home page of the Web User Interface (http://wui.cmsaf.eu/).

7.3 User Problem Report

Users of CM SAF products and services are encouraged to provide feedback on the CM SAF products and services to the CM SAF team. Users can either contact the User Help Desk (see section 7.2) or use the "User Problem Report" page. A link to the "User Problem Report" is available either from the CM SAF home page (http://www.cmsaf.eu/) or the Web User Interface (http://wui.cmsaf.eu/).

7.4 Service Messages / log of changes

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

8 Feedback

8.1 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).

8.2 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).

8.3 User Workshops

CM SAF is organizing training workshops on a regular basis 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 (http://www.cmsaf.eu/) to get the latest news on upcoming events.

9 Copyright and Disclaimer

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

9.1 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.***

9.2 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.

9.3 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.

10 References

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11 Glossary

ATBD	Algorithm Theoretical Baseline Document
CM SAF	Satellite Application Facility on Climate Monitoring
DMSP	Defense Meteorological Satellite Program
DWD	Deutscher Wetterdienst (German MetService)
ECV	Essential Climate Variable
EIA	Earth Incidence Angle
EPS	European Polar System
EUMETSAT	European Organisation for the Exploitation of Meteorological Satellites
FCDR	Fundamental Climate Data Record
FMI	Finnish Meteorological Institute
FOV	Field of view
GCOS	Global Climate Observing System
GLOBE	The Global Land One-kilometer Base Elevation
HOAPS	The Hamburg Ocean Atmosphere Fluxes and Parameters from Satellite data
IOP	Initial Operations Phase
KNMI	Koninklijk Nederlands Meteorologisch Institut
MSG	Meteosat Second Generation
NASA	National Aeronautics and Space Administration
NESDIS	National Environmental Satellite, Data, and Information System
NOAA	National Oceanic & Atmospheric Administration
PRD	Product Requirement Document
PUM	Product User Manual
QC	Quality Control
RMIB	Royal Meteorological Institute of Belgium
SAF	Satellite Application Facility
SMHI	Swedish Meteorological and Hydrological Institute
SSM/I	Special Sensor Microwave Imager
SSMIS	Special Sensor Microwave Imager Sounder
TA	Antenna Temperature
TB	Brightness Temperature
TDR	Temperature Data Records

12 Appendix A

Table 2: Global NetCDF attributes.

Name	Description
title	dataset title
summary	short description of the data file content
Conventions	conventions followed, "CF-1.5" for all files
Metadata_Convention	conventions followed, "Unidata Dataset Discovery v1.0" for all files
netcdf_library_version	NetCDF library version used
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
identifier_product_doi	Digital Object Identifier (DOI)
source	original data source
cdm_data_type	data type, “swath” 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]
geospatial_lat_units	latitude attributes unit
geospatial_lat_min	latitude bounding box minimum
geospatial_lat_max	latitude bounding box maximum
geospatial_lon_units	longitude attributes unit
geospatial_lon_min	longitude bounding box minimum
geospatial_lon_max	longitude bounding box maximum
revolution_coverage_start	revolution coverage start of the data [revolution since launch]
revolution_coverage_end	evolution coverage end of the data [revolution since launch]
platform	platform name [e.g. “DMSP 5D-3/F13”]
platform_identifier	platform sequential number [e.g. 13]
wmo_satellite_identifier	WMO code: satellite identifier
sensor	sensor name, “SSM/I”
wmo_instrument_identifier	WMO code: instrument identifier
scanlines_count	total number of scan-lines in the data file
scanlines_missing_count	number of missing scan-lines in the data file
scanlines_coverage_percent	fraction of available scans in the data file
dataset_version	FCDR version number
date_created	date on which the data was created [ISO8601 date]
date_modified	date on which the data was modified [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.
flag_masks	list of bit fields expressing Boolean or enumerated flags
flag_meanings	descriptive words for each flag value
cbtf_parameter_id	unique internal parameter ID
Compress	Records dimensions which have been compressed by gathering.

Table 4: Processing flag bit meanings [*pflag*]

Bit	Meaning	Description
1	calibration_coldload_intrusion	Cold load intrusion detected and corrected.
2	calibration_hotload_intrusion	Hot load intrusion detected and corrected.
3	TB85_lores_synthesized	F08 85 GHz channel lores TBs replaced by synthesized values.

Table 5: Scanline quality control bit meanings [*qc_scan*]

Bit	Meaning	Description
1	missing	Complete scanline is missing in raw data record.
2	geolocation_error	Geolocation is erroneous.
3	calibration_temperature_error	Calibration temperature readings are erroneous.

Table 6: Channel quality control bit meanings [*qc_chan*]

Bit	Meaning	Description
1	calibration_hotload_error	Hot load readings erroneous.
2	calibration_coldload_error	Cold load readings erroneous
3	calibration_agc_error	Gain control settings are erroneous.
4	out_of_bounds_error	Too many FOVs are out of bounds.

Table 7: FOV quality control bit meanings [*qc_fov_lo*, *qc_fov_hi*]

Bit	Meaning	Description
1	TB_V19_out_of_bounds	TB at 19 GHz vpol is out of bounds.
2	TB_H19_out_of_bounds	TB at 19 GHz hpol is out of bounds.
3	TB_V22_out_of_bounds	TB at 22 GHz vpol is out of bounds.
4	TB_V37_out_of_bounds	TB at 37 GHz vpol is out of bounds.
5	TB_H37_out_of_bounds	TB at 37 GHz hpol is out of bounds.
6	TB_V85_out_of_bounds	TB at 85 GHz vpol is out of bounds.
7	TB_H85_out_of_bounds	TB at 85 GHz hpol is out of bounds.

13 Appendix B

The following pseudo code can be used as a reference to read the valid brightness temperatures and to apply the intercalibration offsets. This is not a valid source code but should assists in writing reading procedures.

Read and scale brightness temperatures

```
; Read and scale lores TBs
tbi     = netcdf_read ('tb')
tb      = float(tbi) * tbi@scale_factor + tbi@add_offset
pos     = where (tbi eq tbi@_FillValue)
tb[pos] = NAN

; Read and scale hires TBs
tbi        = netcdf_read ('tb_hi')
tb_hi      = float(tbi) * tbi@scale_factor + tbi@add_offset
pos        = where (tbi eq tbi@_FillValue)
tb_hi[pos] = NAN
```

Read and apply intersensor calibration offsets

```
; Read, scale, and apply lores offsets
ici       = netcdf_read ('ical')
ical      = float(ici) * ici@scale_factor + ici@add_offset
pos       = where (ici eq ici@_FillValue)
ical[pos] = NAN
tb        = tb + ical

; Read, scale, and apply hires offsets
ici       = netcdf_read ('ical_hi')
ical      = float(ici) * ici@scale_factor + ici@add_offset
pos       = where (ici eq ici@_FillValue)
ical[pos] = NAN
tb_hi     = tb_hi + ical
```

Read and apply EIA normalization offsets

```
; Read, scale, and apply EIA offsets
eoffi     = netcdf_read ('eia_norm')
eoff      = float(eoffi) * eoffi@scale_factor + eoffi@add_offset
pos       = where (eoffi eq eoffi@_FillValue)
eoff[pos] = NAN
pos       = where (finite(eoff) and finite(tb))
tb[pos]   = tb[pos] + eoff[pos]
```

Read and apply quality scanline and channel control flags

```
; Read and apply qc_scan flag
qc                = netcdf_read ('qc_scan')
pos               = where (qc ne 0)
tb[pos,*,*]       = NAN
tb_hi[pos,*,*,*] = NAN

; Read and apply qc_channel flag to lores tbs
chn   = netcdf_read ('channel')
qc    = netcdf_read ('qc_channel')
pflag = netcdf_read ('pflag')
for c=0, dimsize(chn)-1 do
   qcc          = qc[*,c]
   if ((c ge 5) and (pflag and 4)) then qcc = 0     ; test bit 3 of pflag (85GHz F08)
   pos          = where (qcc ne 0)
   tb[pos,c,*] = NAN
end for
```

```
; Read and apply qc_channel flag to hires tbs
chn_hi = netcdf_read ('channel_hifreq')
for hc=0, dimsize(chn_hi)-1 do
   c                 = chn_hi[hc]
   pos               = where (qc[*,c] ne 0)
   tb_hi[pos,hc,*,*] = NAN
end for
```

Read and apply FOV control flags

Here we set all TBs at one FOV to undefined if one channel is out of bounds.

```
; Read and apply qc_fov_lo flag
time = netcdf_read ('time')
qc   = netcdf_read ('qc_fov_lo')
for t = 0, dimsize(time)-1
   pos         = where (qc[t,*] ne 0)
   tb[t,*,pos] = NAN
endfor

; Read and apply qc_fov_hi flag
qc_fov_hi = netcdf_read ('qc_fov_hi')
for t = 0, dimsize(time)-1
   posA              = where (qc_fov_hi[t,0,*] ne 0)
   posB              = where (qc_fov_hi[t,1,*] ne 0)
   tb_hi[t,0,*,posA] = NAN
   tb_hi[t,1,*,posB] = NAN
endfor
```

Read geolocation and select lores FOVs

```
lati     = netcdf_read ('lat')
loni     = netcdf_read ('lon')
lores    = netcdf_read ('across_track_lores')
lat      = float(lati) * lati@scale_factor + lati@add_offset
lon      = float(loni) * loni@scale_factor + loni@add_offset
pos      = where (lati eq lati@_FillValue or loni eq loni@_FillValue)
lat[pos] = NAN
lon[pos] = NAN
lat_lo   = lat[*,0,lores]
lon_lo   = lon[*,0,lores]
```