EUMETSAT Satellite Application Facility on Climate Monitoring

Product User Manual

Microwave Imager Radiance FCDR

SSM/I Brightness Temperatures

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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/2.2
RD 2	Validation Report Fundamental Climate Data Record of SSM/I Brightness Temperatures	SAF/CM/DWD/VAL/ FCDR_SSMI/1.2
RD 3	Algorithm Theoretical Basis Document Fundamental Climate Data Record of SMMR Brightness Temperatures	SAF/CM/DWD/ATBD/ FCDR_SMMR/2.2
RD 4	Product User Manual Fundamental Climate Data Record of SMMR Brightness Temperatures	SAF/CM/DWD/PUM/ FCDR_SMMR/1.2
RD 5	Algorithm Theoretical Basis Document Fundamental Climate Data Record of SSMIS Brightness Temperatures	SAF/CM/DWD/ATBD/ FCDR_SSMIS/2.2
RD 6	Product User Manual Fundamental Climate Data Record of SSMIS Brightness Temperatures	SAF/CM/DWD/PUM/ FCDR_SSMIS/1.5
RD 7	Validation Report Fundamental Climate Data Record of SMMR / SSM/I / SSMIS Brightness Temperatures	SAF/CM/DWD/VAL/ FCDR_MWIR/1.4

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I Preface

This document is structured in different logical parts, reflecting the different instrument series used to compile a Fundamental Climate Data Record (FCDR) from conical scanning microwave imagers. After a short introduction, summarizing the current status, the corresponding Product User Manuals (PUM) for the parts from the Scanning Multichannel Microwave Radiometer (SMMR) and the Special Sensor Microwave Imager/Sounder (SSMIS) are referenced here. These parts are made available as separate documents. The main part of this document focuses on the Special Sensor Microwave / Imager (SSM/I) component of the FCDR.

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.

The CM SAF data sets 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.

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 collection of CM SAF Product User Manuals (PUM) provide information on the Fundamental Climate Data Record (FCDR) of Microwave Brightness Temperatures from the conical scanning microwave sensors Special Sensor Microwave/Imager (SSM/I), Special Sensor Microwave Imager/Sounder (SSMIS) and Scanning Multichannel Microwave Radiometer (SMMR). This fourth release is a continuation of the previous release (available from CM SAF; http://dx.doi.org/10.5676/EUM_SAF_CM/FCDR_MWI/V003).

Data from the space-borne microwave imagers and sounders such as the Scanning Multichannel Microwave Radiometer (SMMR), Special Sensor Microwave/Imager (SSM/I) and the Special Sensor Microwave Imager/Sounder (SSMIS) are used for a variety of applications, such as analyses of the hydrological cycle (precipitation and evaporation) and related atmospheric and surface parameters, as well as remote sensing of sea ice, soil moisture, and land surface temperatures. Carefully calibrated and homogenised radiance data sets are a fundamental prerequisite for climate analysis, climate monitoring and reanalysis. Several National Meteorological Services and Reanalysis centres assimilate microwave radiances directly and not derived geophysical parameters. Forecast and reanalysis can thus benefit from a Fundamental Climate Data Record (FCDR) of brightness temperatures (Poli et al. 2015). The generation of Thematic Climate Data Records (TCDRs) strongly relies on the availability of FCDRs. Highest possible TCDR quality can be achieved easiest in radiance space, in turn increasing the products value for users.

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).

The HOAPS processing suite has been transferred to CM SAF in a Research to Operations activity in order to provide a sustained processing of the climate data records which is one of the main tasks of CM SAF, but not in the focus of the research group at the MPI-M / UHH. The operational processing and reprocessing of the FCDRs and TCDRs as well as the provision to the research community is maintained and coordinated by the CM SAF.

The first release of the CM SAF FCDR (Fennig et al. 2013) focussed on the SSM/I series, covering the time period from 1987 to end of 2008. In order to continue the HOAPS TCDRs beyond 2008 it was necessary to extend the underlying FCDR of microwave TBs with the SSMIS sensor family aboard the DMSP platforms F16, F17, and F18, which was accomplished with the second release of the CM SAF FCDR (Fennig et al. 2015). This combined FCDR of SSM/I and SSMIS brightness temperatures provides a consistent FCDR from 1987 to 2013.

Following requests from users of the FCDR, the third release focussed on the extension of the microwave brightness temperature data record to the earlier time period from 1978 to 1987 with observations from the SMMR on-board Nimbus 7 and the extension of the SSMIS period to 2015. However, it turned out to be a very challenging task, as it has not been possible to get hold of the original raw instrument data records. Although this data record must have eventually been transferred from the Marshall Space Flight Centre (MSFC) to the National Snow & Ice Data Center (NSIDC), it is currently not available from their archives. Instead, the Nimbus-7 SMMR Pathfinder Level 1B Brightness Temperatures data record, available from NSIDC (Njoku, 2003), was used to generate this FCDR.

The third release of the FCDR is described in Fennig et al. (2020) which also includes a decent overview of the applied methodologies.

With the fourth release of the Microwave Imager Radiance FCDR, the temporal coverage of the SSMIS has been extended to 31 December 2020 while the SMMR and SSM/I data records remain unchanged.

2.1 Practical Considerations

The CM SAF FCDR is a completely reprocessed data record, thus ensuring a maximum in homogeneity by applying a common processing scheme and inter-calibration model for all observations. Among others, known instrument issues like sunlight intrusions, moonlight intrusions, and reflector emissivity have been accounted for and the brightness temperatures have been carefully inter-calibrated to the predecessor SSM/I instrument series, allowing a seamless continuation of existing TCDRs. The inter-calibration method, developed for the SSMIS FCDR, explicitly includes all possible surface types to account for the entire natural distribution of brightness temperatures from radiometric cold scenes (rain-free ocean) to radiometric warm scenes (vegetated land surfaces). This ensures a broad range of applications of this FCDR not only for oceanic, but also for sea-ice and land surfaces.

It is important to keep in mind that the three microwave radiometers SMMR, SSM/I, and SSMIS are completely differently designed instruments and not just one sequential instrument series. While the SSMIS does provide a continuation of the basic SSM/I observed frequencies (19, 22, 37 GHz), the SMMR contains SSM/I like channels at 18 GHz, 21 GHz and 37 GHz. However, it is not expected that all instruments give identical brightness temperatures per se. A combination of all individual data records with an inter-sensor calibration can thus be defined as a FCDR for a specific frequency, spanning the complete time-period. Otherwise, also a sensor specific FCDR can be defined, providing consistent data records for one sensor type. This leads to the potential paradigm, that a FCDR can be defined in two ways:

- with a primary aim as the consistency across sensors with sensor calibration being a secondary consideration, or
- with a focus on accuracy on each sensor data record independently with consistency diagnosed rather than constraint.

In order to aim for one data set able to fulfil both paradigms, one important feature of this FCDR is the flexibility to use the same data record with or without inter-calibration. The brightness temperatures, corrected for instrument anomalies, and the inter-calibration offsets are provided as separate layers in each data file, allowing the users to individually choose whether to apply the correction (adding the offsets) or not. In this sense, the three components (SMMR, SMM/I, SSMIS) of the Microwave Imager Radiance FCDR form together the fourth release (CM-12003), defined as a combined FCDR with optimal sensor calibration and consistency.

II SMMR

The technical description and the Product User Manual of the SMMR component of this combined FCDR (R4) are available as individual, instrument specific ATBD [RD 3] and PUM [RD 4], respectively. The latest validation report [RD 7] for this release covers the SMMR and SSMIS data records.

III SSM/I

This part of the document focuses on the SSM/I, starting with a brief technical description of the instrument and then provides information on the file format as well as on the data access. Details on the implementation of the processing chain and individual processing steps are available in the corresponding SSM/I Algorithm Theoretical Basis Document [RD 1]. Basic accuracy requirements are defined in the product requirements document [AD 3]. A detailed validation of the SSM/I FCDR is available in the sensor specific Validation Report [RD 2] and the complete FCDR time-series Validation Report [RD 7].

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 III-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. In addition, 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.

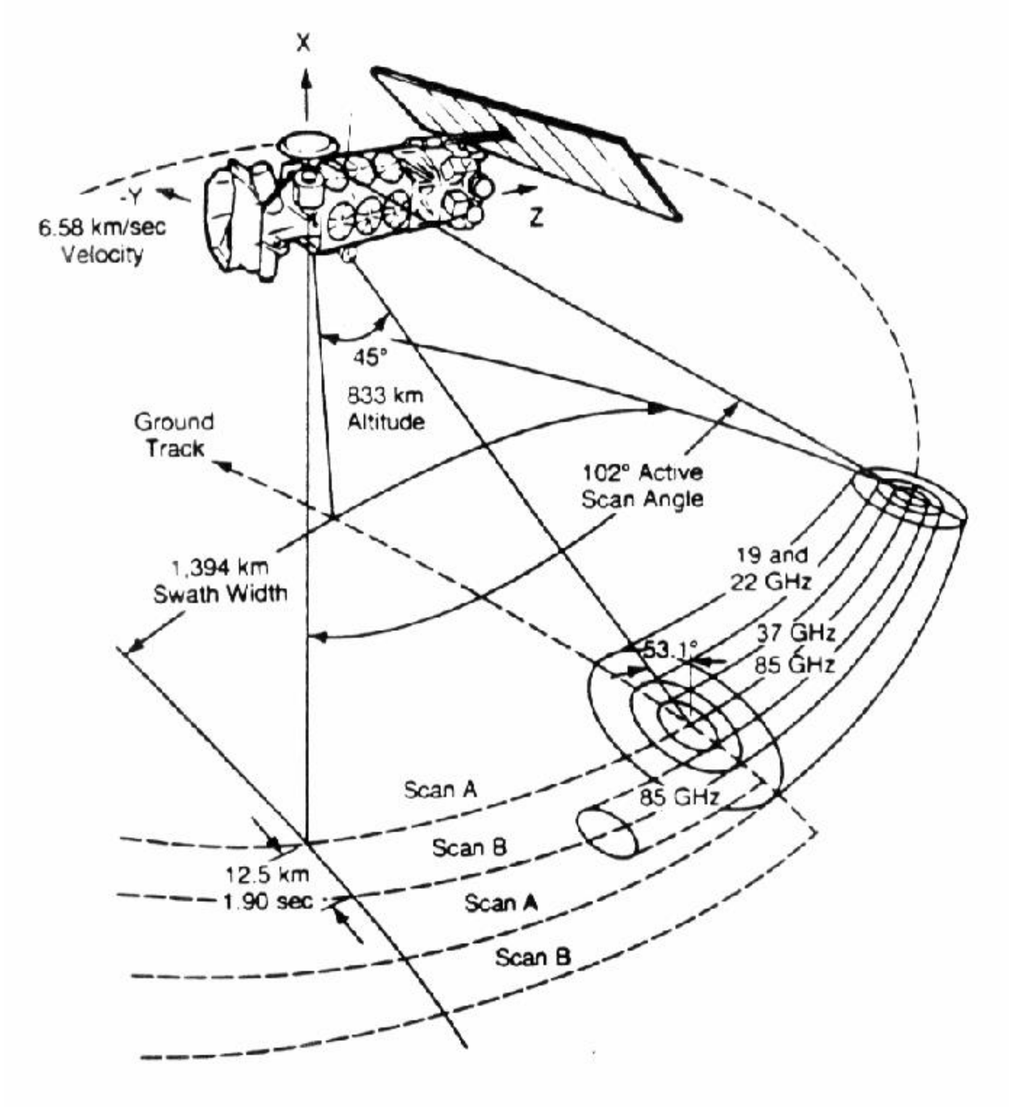

Figure III-1: SSM/I scan geometry (from Hollinger et al., 1987).

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.

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 III-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 inter-sensor 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 III-1.

With the release FCDR R3 (product_version 1.3), the internal structure of the data files had been changed to match the SMMR and SSMIS file format structure. This also implies a change from scaled integer type variables to floating point variables. This can result in small, statistically not significant, differences compared to first releases, which are caused by numerical noise.

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 1.7 (http://cf-pcmdi.llnl.gov/) and Attribute Convention for Dataset Discovery version 1.3

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* 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 III-5, Table III-6 and Table III-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

Table III-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

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, scene_channel, scene_across_track*]. The observation time of the A-scan can be calculated by subtracting 60/*rotation* (~1.9 s) from the B-scan time.

The FOV positions of the high and low resolution channels are co-registered. In order to keep the file structure comparable to the SSMIS and SMMR, the different across-track resolutions are organized in separate logical data groups. The lower resolution channels are put in the group *scene_env* and the higher resolution channels in the group *scene_img*. Each of the two scene data groups provides a set of geolocation variables and can be used independently. The scenes across track coordinates are index arrays to the global across track coordinate. The scene channel coordinates are corresponding index arrays to the global channel coordinate. The quality control flag and bit values are numbered using the global channel coordinate.

The 85 GHz channels are available in the original resolution in the data group *scene_img* and also resampled to the 37 GHz antenna pattern in the data group *scene_env*.

Calibration data records and spacecraft related variables are also available in separate logical data groups. This flexible format design allows it to provide the different microwave conical scanning instrument data in one logical format.

Brightness temperatures, inter-sensor 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* 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.

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

5.1 Data file contents

A common NetCDF file consists of groups, dimensions, variables, and attributes. These components can be used together to capture the meaning of data and relations among data. The variables are grouped into logical data groups. Global attributes are summarized in Table III-2 and possible variable attributes in Table III-3 (both in Appendix A). The following variables (thematically sorted) are available in the FCDR data files:

Global 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]

channel

Channel number
Fixed dimension [7]

scan_type

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

nchar

General character length
Fixed dimension [50]

Global variables

central_freq

Frequencies of the corresponding channel number.

polarization

Polarization of the corresponding channel number.

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']

pflag

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

tfrac

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

rev

Revolution number
dimension [*time*]

qc_scan

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

qc_channel

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

rotation

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

md5

MD5 message digest
dimension [*time, nchar*]

Data group 'platform'

This group contains spacecraft related variables.

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*]

Data group 'calibration'

This group contains calibration related variables.

nload

Cold and hot load reading number
Fixed dimension [5]

nread

General reading number
Fixed dimension [3]

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*]

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*]

Feedhorn data groups (*scene_env*, *scene_img*)

These data groups contain SSM/I FOV sensor variables. Each group is also tagged with a comment attribute to provide a list of human readable channels names.

scene_channel
Group channel coordinate (index to global *channel*)
fixed dimensions depending on group

scene_across_track
Group across track coordinate (index to global *across_track*)
fixed dimensions depending on group

lat

FOV latitude [degree_north]
dimensions [*time, scene_across_track*] or [*time, scan_type, scene_across_track*]

lon

FOV longitude [degree_east]
dimensions [*time, scene_across_track*] or [*time, scan_type, scene_across_track*]

laz

FOV local azimuth angle [degree_east]
dimension [*time, scene_across_track*] or [*time, scan_type, scene_across_track*]

eia

Earth incidence angle [degree]
dimension [*time, scene_across_track*] or [*time, scan_type, scene_across_track*]

sft

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

qc_fov

Field of view quality control [bit mask]
dimensions [*time, scene_across_track*] or [*time, scan_type, scene_across_track*]
All bits set to 0 implies acceptable data. See Table III-7 for bit meanings.

tb

Brightness temperature [K]
dimensions [*time, scene_channel, scene_across_track*] or
[*time, scan_type, scene_channel, scene_across_track*]

ical

Brightness temperature inter-calibration offset [K]
dimensions [*time, scene_channel, scene_across_track*] or
[*time, scan_type, scene_channel, scene_across_track*]

Only in data group 'scene_env'

eia_norm

Brightness temperature earth incidence angle normalization offset [K]
dimensions [*time, scene_channel, scene_across_track*]

6 Assumptions and Limitations

The inter-sensor calibration method used here to homogenize the SSM/I brightness temperatures (see RD 1) 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 inter-sensor 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 where 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 cannot 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 https account (the default setting), or email. Each order will be confirmed via email, and the user will get another email once the data have been prepared. If the https data transfer was selected, this second email will provide the information on how to access the https 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 from either 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:

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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 III-2: Global NetCDF attributes.

Name	Description
title	dataset title
summary	short description of the data file content
Conventions	conventions followed, "CF-1.7,ACDD-1.3 " for all files
netcdf_library_version	NetCDF library version used
institution	institution where the data was produced
project	The name of the project responsible for originating this data.
creator_name	Creator institution of this data.
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
id	Digital Object Identifier (DOI)
source	original data source
cdm_data_type	data type, “swath” for all files
keywords_vocabulary	Controlled vocabulary used for keywords.
keywords	A comma-separated list of key words.
standard_name_vocabulary	The name and version of the controlled vocabulary from which variable standard names are taken.
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_vocabulary	Controlled vocabulary used for platform.
platform	platform name [e.g. “DMSP 5D-3/F13”]
platform_identifier	platform sequential number [e.g. 13]
wmo_satellite_identifier	WMO code: satellite identifier
instrument_vocabulary	Controlled vocabulary used for instrument.
instrument	Instrument name, e.g. “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
product_version	FCDR version number
format_version	NetCDF layout 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 III-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
_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
compress	Records dimensions which have been compressed by gathering.

Table III-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 III-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.
4	possible_smoothed_calibration interference	Calibration can be affected by smoothing in Level 1a data
5	all_tb_values_missing	Scanline is available but all TBs are undefined

Table III-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 III-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 inter-calibration offsets. This is not a valid source code but should assists in writing reading procedures.

Read and apply inter-sensor calibration offsets

```
; Read, scale, and apply lores offsets
Tb          = netcdf_read ('tb')
Ical        = netcdf_read ('ical')
Pos         = where (ical eq ical@_FillValue or tb eq tb@_FillValue)
ical[pos]   = NAN
tb[pos]     = NAN
tb          = tb + ical
```

Read and apply EIA normalization offsets

```
; Read, scale, and apply EIA offsets
eoff        = netcdf_read ('eia_norm')
pos         = where (eoff eq eoff@_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)
; scene_env
tb[pos,*,*]     = NAN
; scene_img
tb[pos,*,*,*] = NAN

; Read and apply qc_channel flag to lores tbs
chn     = netcdf_read ('scene_channel')
qc      = netcdf_read ('qc_channel')
pflag   = netcdf_read ('pflag')
for c=0, dimsize(chn)-1 do
  qcc          = qc[*,chn[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 = netcdf_read ('scene_channel')
for c=0, dimsize(chn)-1 do
   pos                  = where (qc[*,chn[c]] ne 0)
   tb_hi[pos,c,*,*]     = 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')
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 = netcdf_read ('qc_fov')
for t = 0, dimsize(time)-1
   posA                 = where (qc_fov[t,0,*] ne 0)
   posB                 = where (qc_fov[t,1,*] ne 0)
   tb[t,0,*,posA]       = NAN
   tb[t,1,*,posB]       = NAN
endfor
```

IV SSMIS

The technical description and the Product User Manual of the SSMIS component of this combined FCDR (R4) are available as individual, instrument specific ATBD [RD 5] and PUM [RD 6], respectively. The latest validation report [RD 7] for this release covers the SMMR and SSMIS data records.