EUMETSAT Satellite Application Facility on Climate Monitoring

The EUMETSAT Network of Satellite Application Facilities

CM SAF
Climate Monitoring

Product User Manual

Fundamental Climate Data Record of SMMR / SSMI / SSMIS Brightness Temperatures

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Applicable documents

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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	Product User Manual Fundamental Climate Data Record of SSM/I Brightness Temperatures	SAF/CM/DWD/PUM/FCDR_SSMI/1.1
RD 3	Validation Report Fundamental Climate Data Record of SSM/I Brightness Temperatures	SAF/CM/DWD/VAL/FCDR_SSMI/1.0
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RD 5	Validation Report Fundamental Climate Data Record of SMMR / SSM/I / SSMIS Brightness Temperatures	SAF/CM/DWD/VAL/FCDR_MWI/1.4
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RD 7	Product User Manual Fundamental Climate Data Record of SMMR Brightness Temperatures	SAF/CM/DWD/PUM/FCDR_SMMR/1.1

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I Preface

I-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.

I-2 Introduction

This CM SAF Product User Manual (PUM) provides 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 third release is a continuation of the SSM/I and SSMIS FCDR (Fennig et al., 2015). As the SSM/I part remains unchanged since the first release (Fennig et al., 2013), it is included here as an integral part of this third release.

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, http://www.hoaps.org/) 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. 2011). 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 order to derive reliable long term trend estimates of the global water cycle parameters it is strictly necessary to carefully correct for all known problems and deficiencies of the SSM/I radiometers as well as to inter-calibrate and homogenise the different instruments. Moreover, all applied corrections need to be clearly documented to provide a complete calibration traceability for a Fundamental Climate Data Record (FCDR). Following these recommendations, CM SAF released a first edition of the microwave radiance FCDR comprising just the SSM/I brightness temperatures in 2013, freely available from the web user interface (http://wui.cmsaf.eu/; Fennig et al., 2013). This FCDR has already been used in the ESA CCI Sea ice project and will also be used in the upcoming reanalysis ERA5.

In order to further extend the Thematic Climate Data Records (TCDRs) like the HOAPS data record in time, the SSM/I successor instrument SSMIS has to be used from 2009 onwards. A second edition of the combined SSM/I and SSMIS FCDR has been successfully released by CM SAF in 2015 (Fennig et al., 2015), covering the time period from 1987 to 2013. The SSMIS sensors on-board F16, F17, and F18 have now been reprocessed for this third FCDR release:

- The SSMIS inter-calibration has been updated.
- Deficiencies in the reflector emissivity correction are rectified.
- The time period is extended by two additional years compared to the previous release to cover the SSMIS period until end of 2015.

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.

This third microwave radiance FCDR release now also provides data records from the Scanning Multichannel Microwave Radiometer on board Nimbus-7 for the time period from 1978 to 1987. As the original raw data records are not available, the Nimbus-7 SMMR Pathfinder Level 1B Brightness Temperatures data record, available from NSIDC (Njoku, 2003), are used to generate the SMMR FCDR.

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 first, still unchanged version of the Microwave Imager Radiance FCDR (CM-150), covering the SSM/I plus the updated SSMIS and the newly generated SMMR data records form together the third edition (CM-12002), 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 are available as individual, instrument specific ATBD [RD 6] and PUM [RD 7], respectively. The latest validation report [RD 5] for this release covers the SMMR and SSMIS data records.

III SSM/I

The SSM/I component of this combined FCDR remains unchanged compared to first release and therefore also the corresponding documents ATBD [RD 1], Product User Manual [RD 2], and Validation Report [RD 3] are still applicable to the SSM/I data record part. These documents are easily accessible from the SSM/I FCDR DOI summary webpage [http://dx.doi.org/10.5676/EUM_SAF_CM/FCDR_SSMI/V001] and at www.cmsaf.eu/docs. Access to the SSM/I data records is given also through the DOI webpage.

IV SSMIS

This part of the document focuses on the SSMIS and starts 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 SSMIS Algorithm Theoretical Basis Document [RD 4]. Basic accuracy requirements are defined in the product requirements document [AD 3]. A detailed validation of the SSMI FCDR is available in the Validation report [RD 5].

IV-1 The SSMIS Instrument

SSM/I sensors have been carried aboard the DMSP satellite series since 1987. Eventually, six SSM/I instruments have been successfully launched aboard the F08, F10, F11, F13, F14 and F15 spacecraft. The first SSMIS was launched in October 2003 aboard the F16 spacecraft, designed to continue the successful SSM/I observations. To date, four SSMIS instruments were launched (F16, F17, F18, F19) and one more is built and stored (F20). The F19 unfortunately failed after 10 month in orbit. Currently, there is no final decision whether the F20 will be launched or not.

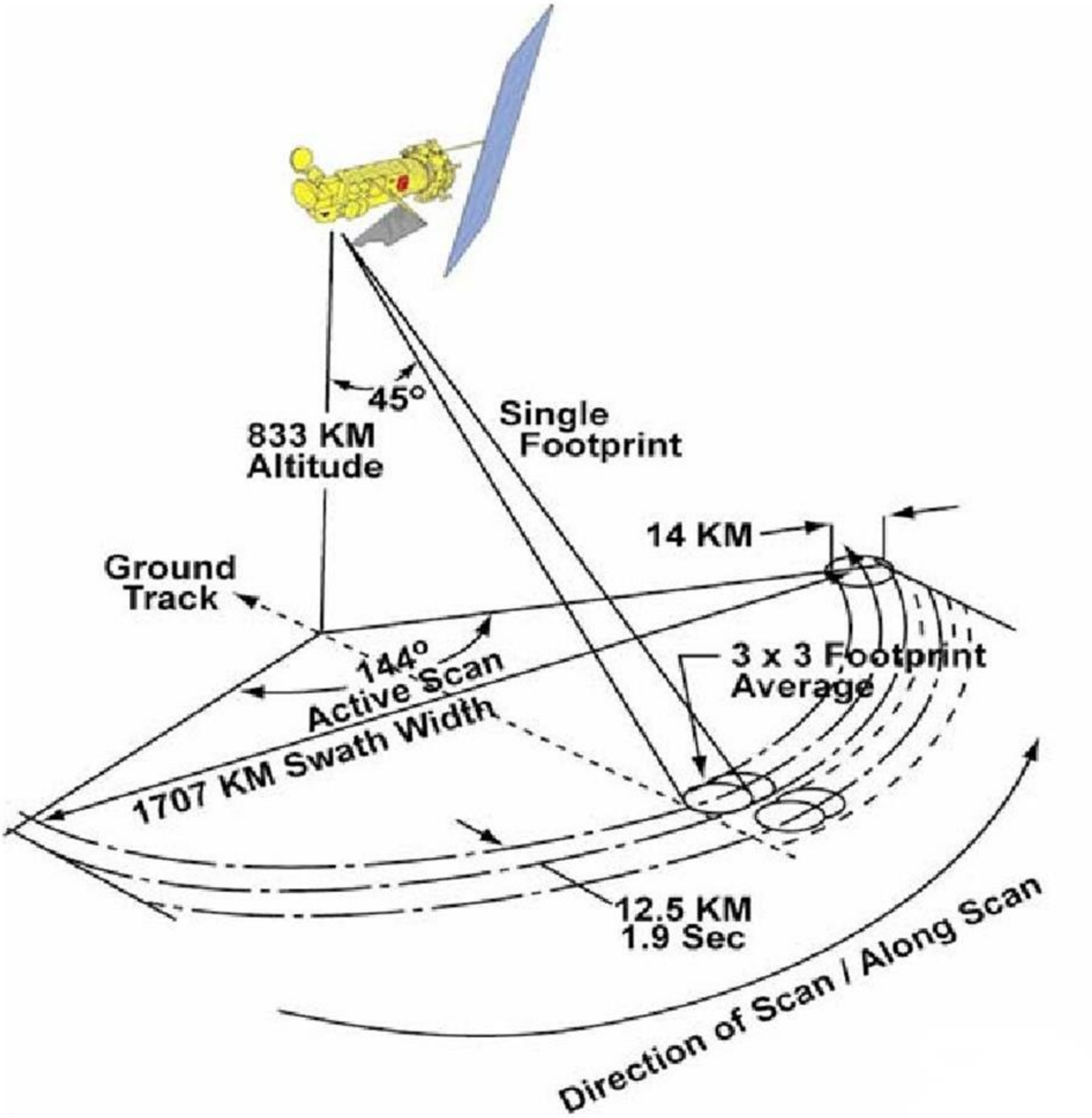

Figure 1: SSMIS scan geometry showing directions of active scan, swath width, ground track, and footprint averages (from Kunkee et al., 2008).

An extensive description of the instrument and satellite characteristics has been published by Kunkee et al. (2008). 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 833 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 144° resulting in a 1700 km wide swath (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. All satellites have a local equator crossing time between 5 and 8 A.M./P.M. for the descending/ascending node.

The SSMIS integrates the imaging capabilities of the SSM/I sensor with the cross-track microwave sounders Special Sensor Microwave Temperature SSM/T and Special Sensor Microwave Humidity Sounder, SSM/T-2 into a single conically scanning 24-channel instrument. The sensor characteristics are summarized in Table 8.

The SSM/I like frequencies are centred at 19.35, 22.235, 37.0, and 91.35 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 91 GHz hereafter and the corresponding brightness temperatures of each channel and polarization as TB19v/h, TB22v, TB37v/h, and TB91v/h.

The spatial resolution varies from 74 km by 47 km with an along-scan sampling frequency of 25 km for the 19 GHz channel to 15 km by 13 km with 12.5 km along-scan sampling frequency for the 91 GHz channel. All channels are sampled for each rotation, resulting in an along-track sampling of 12.5 km with a resolution of 180 uniformly spaced pixels. The channels 12-16 are averaged on-board to an along-scan resolution of 90 pixels (see Figure 1). A fixed cold space reflector and a reference black body hot load are used for continuous on-board two point calibration (see RD 2). A detailed description of the SSMIS is given by Kunkee et al. (2008).

IV-2 Product definition

The CM SAF FCDR from SSMIS brightness temperatures consists of 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 SSMIS FCDR is available for the time period from November 2005 until end of 2015. A detailed list of data availability for each of the three SSMIS platforms is given in Table 1.

The SSMIS FCDR daily data files provide all available 24 SSMIS channels (see Table 8) in their native resolution and sampling. During the reprocessing procedures, detected instrument issues, namely sunlight intrusions, moonlight intrusions, and reflector emissivity, are corrected for all channels and new geolocations are computed for all feedhorns (see RD 4). Only the SSM/I-like channels are then inter-calibrated to the selected reference instrument. This inter-calibration offset is available as an additional layer in the data files. However, the non-SSM/I channels are not inter-calibrated and thus inter-calibration offsets are not provided.

IV-3 Data format description

The CM SAF FCDR 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 1.6 (http://cf-pcmdi.llnl.gov/) and NetCDF Attribute Convention for Dataset Discovery version 1.3.

All SSMIS FCDR product files are swath based and built following the same design principles. The record dimension of the data files is the scan integer time measured in seconds since 1st January

Table 1: SSMIS FCDR instrument data availability at CM SAF.

DMSP platform	Launch date	Record start	Record end
F16	2003-10-18	2005-11-01	2015-12-31
F17	2006-11-04	2006-12-14	2015-12-31
F18	2009-10-18	2010-03-08	2015-12-31

1987. Each file contains all possible scans for one complete day (~45505 scans) regardless of their quality and status. Missing scans are marked as missing and all 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 4]. 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 different sampling rate and alignment of the six SSMIS feedhorns, each feedhorn is available as a separate logical data group (see also Table 8). Each of the six scene data groups provides a set of geolocation variables and can be used independently. The scenes across scan coordinates are index arrays to the global across scan 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.

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. Only the SSM/I related channels are inter-calibrated. The other SSMIS channels are provided without inter-calibration offsets. The brightness temperatures *tb* are the values after intrusion correction and 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 91 GHz channels are available in the original resolution in the data group *scene_img2* and also resampled to the 37 GHz antenna pattern in the data group *scene_env2*. Additionally available are 85 GHz channel data in the data group *scene_env2* for water surface type to provide backward compatibility to the SSM/I FCDR.

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

IV-3.1 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 2 and possible variable attributes in Table 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

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

across_track

FOV across track position
Fixed dimension [360]

channel
Channel number
Fixed dimension [26]

nread
General reading number
Fixed dimension [3]

nchar
General character length
Fixed dimension [50]

Global variables

central_freq, channel_if1, channel_if2
(Intermediate) frequencies of the corresponding channel number.

polarization
Polarization of the corresponding channel number.

channel_name
String representation of the corresponding channel number.

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

rev
Revolution number
dimension [*time*]

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.

pflag
Processing Flag [bit mask]
dimension [time]
See Table 4 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*]

saz
Spacecraft solar azimuth angle [degree]
dimension [time]

szen
Spacecraft solar zenith angle [degree]
dimension [*time*]

beta
Spacecraft beta angle [degree]
dimension [*time*]

ecliptic
angular position of the spacecraft measured along its orbit from the point of closest approach to the sun [degree]
dimension [*time*]

ecl_entry
Angle from Earth eclipse entry [degree]
dimension [*time*]

ecl_exit
Angle from Earth eclipse exit [degree]
dimension [*time*]

Data group 'calibration'

This group contains SSMIS calibration related variables.

ssmis_channel
Group channel coordinate (index to global *channel*)
fixed dimensions [24]

mux_sensor
Multiplexer housekeeping sensor names
dimensions [*mux, nchar*]

mux_house
Multiplexer housekeeping temperatures [K]
dimensions [*time, mux*]

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

offset
: Calibration offset [K]
dimensions [*time*, *ssmis_channel*]

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

tarm
: Main Arm/Rim Joint temperature [K]
dimension [*time*]

trefl
: Reflector temperature (interpolated) [K]
dimension [*time*]

hotc
: Hot load reading [count]
dimensions [*time*, *ssmis_channel*]

colc
: Cold load reading [count]
dimensions [*time*, *ssmis_channel*]

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

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

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

nedt
: noise equivalent temperature [K]
dimensions [*date*, *ssmis_channel*]

Feedhorn data groups

These data groups contain SSMIS FOV sensor variables. Table 8 lists the available data groups with the corresponding channels. Each feedhorn 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*]

lon

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

laz

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

eia

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

sft

FOV surface type for imager and environmental scenes.
dimension [*time, 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*]
All bits set to 0 implies acceptable data. See Table 7 for bit meanings.

tb

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

ical

Brightness temperature inter-calibration offset [K]
Only in SSM/I related groups (*scene_img2, scene_env1, scene_env2*)
dimensions [*time*, *scene_channel*, *scene_across_track*]

eia_norm

Brightness temperature earth incidence angle normalization offset [K]
Only in environmental data groups (*scene_env1*, *scene_env2*)
dimensions [*time*, *scene_channel*, *scene_across_track*]

IV-4 Assumptions and Limitations

Although the physical background of systematic errors due to the reflector emission are identified, it is not possible to fully correct for it. The main sources of uncertainty are the correct determination of the reflector emissivity after launch and additionally, in case of the F16, the estimation of the reflector temperature.

The inter-sensor calibration method used to homogenize the SSMIS brightness temperature time series does not account for an absolute radiometric offset. The reference target is the SSM/I aboard DMSP F13, which itself is inter-calibrated to the SSM/I F11 and acts as a transfer standard, 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. This should at least minimize the remaining absolute error in the brightness temperature data record.

The inter-sensor calibration is mainly determined over ocean, sea-ice and cold scenes over land because of a lower variability, smaller diurnal cycle and better behaved error characteristics. Observations over warm land scenes can only be utilized in terms of polarisation differences for the inter-sensor calibration procedure, in order to minimize the influence of the diurnal cycle. Therefore the quality of the inter-calibration is expected to be better over ocean than over land. Also, it is assumed that the inter-sensor differences can be characterized as a linear problem and the derived correction coefficients can be used over land and ice as well. This assumption has been proved for the SSM/I FCDR [RD 1].

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.

The SSMIS does not continue the 85 GHz channel but provides a 91 GHz channel. Although both frequencies show very similar characteristics, it is not feasible to provide synthetic 85 GHz channels over all surface types for the SSMIS due to the strongly varying surface emissivity of sea-ice and land surfaces. However, the FCDR provides a synthetic 85 GHz channel over water only, estimating the 85 GHz measurements from a linear combination of the 91 GHz channels. However, this reconstruction is limited to the natural variability of liquid water observed at 91 GHz and can not fully recover the missing 85 GHz channel characteristics. The main uncertainty is caused by a different scattering signal of the liquid water droplets, which depends on the frequency and the droplet size, because with increasing frequency, a significant scattering signal is already observed for smaller droplets.

While the synthetic SSMIS 85 GHz channels are inter-calibrated to the corresponding SSM/I channels on F11, the 91 GHz channels are only inter-calibrated within the SSMIS series of instruments using F18 as reference.

IV-5 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/).

IV-5.1 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 IV-7). 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.

IV-5.2 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/).

IV-5.3 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 IV-5.2) 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/).

IV-5.4 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.

IV-6 Feedback

IV-6.1 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).

IV-6.2 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).

IV-6.3 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.

IV-7 Copyright and Disclaimer

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

IV-8 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.***

IV-8.1 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.

IV-8.2 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.

IV-9 References

Andersson, Axel; Bakan, Stephan; Fennig, Karsten; Grassl, Hartmut; Klepp, Christian-Phillip; Schulz, Joerg: Hamburg Ocean Atmosphere Parameters and Fluxes from Satellite Data - HOAPS-3 - monthly mean., electronic publication, World Data Center for Climate, doi:10.1594/WDCC/HOAPS3_MONTHLY, 2007a.

Andersson, Axel; Bakan, Stephan; Fennig, Karsten; Grassl, Hartmut; Klepp, Christian-Phillip; Schulz, Joerg: Hamburg Ocean Atmosphere Parameters and Fluxes from Satellite Data - HOAPS-3 - 5-days mean., electronic publication, World Data Center for Climate, doi:10.1594/WDCC/HOAPS3_PENTAD, 2007b.

Andersson, Axel; Bakan, Stephan; Fennig, Karsten; Grassl, Hartmut; Klepp, Christian-Phillip; Schulz, Joerg: Hamburg Ocean Atmosphere Parameters and Fluxes from Satellite Data - HOAPS-3 - twice daily composite., electronic publication, World Data Center for Climate, doi:10.1594/WDCC/HOAPS3_DAILY, 2007c.

Andersson, Axel, Fennig, Karsten, Klepp, Christian-Phillip, Bakan, Stephan, Graßl, Hartmut, and Schulz, Jörg: The Hamburg Ocean Atmosphere Parameters and Fluxes from Satellite Data – HOAPS-3, Earth Syst. Sci. Data, 2, 215-234, doi:10.5194/essd-2-215-2010, 2010.

Fennig, Karsten; Andersson, Axel; Bakan, Stephan; Klepp, Christian-Phillip; Schröder, Marc: Hamburg Ocean Atmosphere Parameters and Fluxes from Satellite Data - HOAPS 3.2 - Monthly Means / 6-Hourly Composites. Satellite Application Facility on Climate Monitoring. Doi:10.5676/EUM_SAF_CM/HOAPS/V001, 2012.

Fennig, K.; Andersson, A.; Schröder, M. (2013): Fundamental Climate Data Record of SSM/I Brightness Temperatures. Satellite Application Facility on Climate Monitoring. DOI:10.5676/EUM_SAF_CM/FCDR_SSMI/V001.

Fennig, K.; Andersson, A.; Schröder, M. (2015): Fundamental Climate Data Record of SSM/I / SSMIS Brightness Temperatures. Satellite Application Facility on Climate Monitoring. DOI:10.5676/EUM_SAF_CM/FCDR_MWI/V002.

Kunkee, D.B., Poe, G.A., Swadley, S.D., Hong Y., Wessel J.E., and Uliana E.A.: Desgin and Evaluation of the First Special Sensor Microwave Imager/Sounder, IEEE Trans. Geosci. Remote Sens., 46, 863-883, 2008.

Njoku, E. G. (2003): Nimbus-7 SMMR Pathfinder Brightness Temperatures, Version 1., Boulder, Colorado USA. NASA National Snow and Ice Data Center Distributed Active Archive Center. DOI:10.5067/7Y1XWXT07HH8.

IV-10 Glossary

ATBD	Algorithm Theoretical Baseline Document
CM SAF	Satellite Application Facility on Climate Monitoring
CDOP	Continuous Development and Operations Phase
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
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
SMMR	Scanning Multichannel Microwave Radiometer
SSM/I	Special Sensor Microwave Imager
SSMIS	Special Sensor Microwave Imager Sounder
TA	Antenna Temperature
TB	Brightness Temperature
TDR	Temperature Data Records

IV-11 Appendix A

Table 2: Global NetCDF attributes.

Name	Description
title	dataset title
summary	short description of the data file content
Conventions	conventions followed, "CF-1.6,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 this data
creator_email	email contact information for the creator of this 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
platform_identifier	platform sequential number [e.g. 16]
wmo_satellite_identifier	WMO code: satellite identifier
instrument_vocabulary	Controlled vocabulary used for instrument.
intrument	Instrument name, “SSMIS”
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.
tdr_software_rev_num	Level1 TDR software revision 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
FORTRAN_format	format string that should be used for FORTRAN applications to print values for this variable
valid_min	smallest valid value of a variable
valid_max	largest valid value of a variable
_FillValue	This number represent missing or undefined data.
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 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.
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 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.
5	defective	Channel is defective.

Table 7: FOV quality control bit meanings [*qc_fov*].

Bit	Meaning	Description
1	TB_CHN01_out_of_bounds	TB in channel 1 is out of bounds.
2	TB_CHN02_out_of_bounds	TB in channel 2 is out of bounds.
3	TB_CHN03_out_of_bounds	TB in channel 3 is out of bounds.
X	TB_CHNX_out_of_bounds	TB in channel X is out of bounds.
24	TB_CHN24_out_of_bounds	TB in channel 24 is out of bounds.

IV-12 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

```
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 but only apply when defined
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)
tb[pos,*,*]     = NAN

; Read and apply qc_channel flag (set flagged values to undefined)
chn   = netcdf_read ('scene_channel')
qc    = netcdf_read ('qc_channel')
for c=0, dimsize(chn)-1 do
   pos          = where (qc[chn[c] ne 0)
   tb[pos,c,*]  = NAN
end for
```

Read and apply FOV control flags

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

```
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 FOV control flags, but exclude unused channels

Here we exclude the synthesized 85 GHz channels, which are only defined over water type.

```
time = netcdf_read ('time')
qc   = netcdf_read ('qc_fov')

; remove the 85GHZ bits from the qc
; | , & , ~  are bit operators for BIT OR, BIT AND, BIT NOT
qc85 = BIT(25) | BIT(26)                    ; or qc85 = 16777216 | 33554432
qc   = qc & (~qc85)

; now just test if the flag is 0
for t = 0, dimsize(time)-1
   pos          = where (qc[t,*] ne 0)
   tb[t,*,pos]  = NAN
endfor
```

IV-13 Appendix C

Table 8: SSMIS Receiver channel characteristics. SSM/I like channels are 12 to 18.

Data group	Channel Number	Frequency [GHz]	Polari-sation	Passband [MHz]	NEΔT [K]	Integration Time [ms]
scene_las (Lower Air Sounding Scene)	1	50.300	h*	400	0.4	12.6
	2	52.800	h*	400	0.4	12.6
	3	53.596	h*	400	0.4	12.6
	4	54.400	h*	400	0.4	12.6
	5	55.500	h*	400	0.4	12.6
	6	57.290	rc	350	0.5	12.6
	7	59.400	rc	250	0.6	12.6
	24	60.793±0.358±0.050	rc	30.0	0.7	12.6
scene_img1 (Imager Scene 1)	8	150.000	h	1500	0.88	4.2
	9	183.310±6.6	h	1500	1.2	4.2
	10	183.310±3.0	h	1000	1.0	4.2
	11	183.310±1.0	h	500	1.25	4.2
scene_env1 (Environ-mental Scene 1)	12	19.350	h	400	0.7	8.4
	13	19.350	v	400	0.7	8.4
	14	22.235	v	450	0.7	8.4
scene_env2 (Environ-mental Scene 2)	15	37.000	h	1500	0.5	8.4
	16	37.000	v	1500	0.5	8.4
scene_img2 (Imager Scene 2)	17	91.655	v	1500	0.9	4.2
	18	91.655	h	1500	0.9	4.2
scene_uas (Upper Air Sounding Scene)	19	63.283±0.285	rc	1.5	2.38	25.2
	20	60.793±0.358	rc	1.5	2.38	25.2
	21	60.793±0.358±0.002	rc	1.5	1.75	25.2
	22	60.793±0.358±0.005	rc	3.0	1.0	25.2
	23	60.793±0.358±0.016	rc	8.0	0.6	25.2

(*) These channels are incorrectly assigned v-pol on SSMIS F16.