EUMETSAT Satellite Application Facility on Climate Monitoring

Product User Manual

Land Surface Temperature (LST) Edition 2

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Applicable Documents

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

Reference Documents

Reference	Title	Code
RD 1	Validation Report Meteosat Land Surface Temperature Edition 2	SAF/CM/MeteoSwiss/VAL/MET/LST/2.1
RD 2	Algorithm Theoretical Basis Document Meteosat Land Surface Temperature Edition 2	SAF/CM/MeteoSwiss/ATBD/MET/LST/2.1

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1 The EUMETSAT SAF on Climate Monitoring (CM SAF)

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

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

In particular, the generation of long-term data records is pursued. The ultimate aim is to make the resulting data records suitable for the analysis of climate variability and potentially the detection of climate trends. The CM SAF works in close collaboration with the EUMETSAT Central Facility and liaises with other satellite operators to advance the availability, quality and usability of Fundamental Climate Data Records (FCDRs) as defined by the Global Climate Observing System (GCOS). As a major task, the CM-SAF utilizes FCDRs to produce records of Essential Climate Variables (ECVs) as defined by GCOS. Thematically, the focus of the CM SAF is on ECVs associated with the global energy and water cycle.

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

As an essential partner in the related international frameworks, in particular WMO SCOPE-CM (Sustained COordinated Processing of Environmental satellite data for Climate Monitoring), the CM SAF - together with the EUMETSAT Central Facility, assumes the role as main implementer of EUMETSAT’s commitments in support to global climate monitoring. This is achieved through:

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

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

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

- Taking a major role in data record assessments performed by research organisations such as the World Climate Research Programme (WCRP). This role provides the CM SAF with strong contacts to research organizations that form a substantial user group for the CM SAF CDRs,

- Maintaining and providing an operational and sustained infrastructure that can serve the community within the transition of mature CDR products from the research community into operational environments.

A catalogue of all available CM SAF products is accessible via the CM SAF webpage, www.cmsaf.eu/. Here, detailed information about product ordering, add-on tools, sample programs and documentation is provided.

2 Compilation of the Meteosat LST CDR

The CM SAF LST CDR is based on 38 years of Meteosat measurements. MVIRI and SEVIRI are optical imaging radiometers mounted on the geostationary Meteosat First Generation (MFG) and Meteosat Second Generation (MSG), respectively. Meteosat satellites in operational mode are centred near 0°/0° latitude/longitude and acquire an image of a full earth disk including Europe, Africa, the Middle East and the Atlantic Ocean. MVIRI scans the full earth disk every 30 minutes with 5 x 5 km² spatial resolution at nadir in the thermal channel. SEVIRI images the full disk every 15 minutes with a horizontal resolution of 3 x 3 km² at nadir. MVIRI has three bands: a broad visible channel, a water vapour channel and a single infrared channel. SEVIRI has 12 spectral channels between 0.6 µm and 13.4 µm, which include two thermal infrared 'split-window' channels. In order to ensure the highest possible consistency for the LST CDR, the retrieval algorithms only use channels that are available or can be simulated from both sensors, i.e. the broadband visible channel and the 10.8 µm infrared channel.

The presented LST CDR spans the years 1983-2020, and is based on measurements of MFG-2, MFG-3, MFG-4, MFG-5, MFG-6, MFG-7, MSG-1, MSG-2, MSG-3 and MSG-4 (Figure 2-1). Gaps in the prime satellite were filled by a back-up satellite. Both CDRs were derived from Level 1.5 MVIRI and SEVIRI data provided by EUMETSAT.

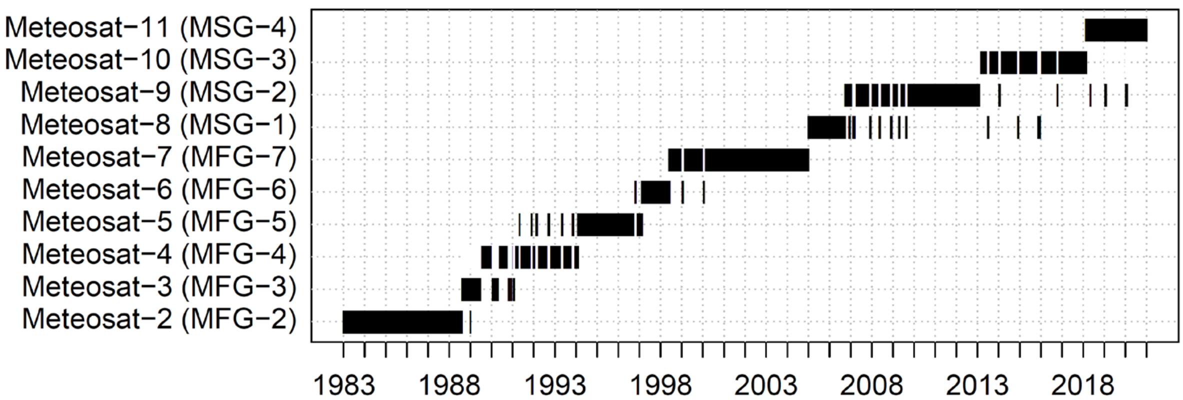

Figure 2-1: Availability of MFG and MSG measurements.

For MVIRI and SEVIRI dedicated infrared channel inter-calibration factors were provided by EUMETSAT (realease 1.0 of the Meteosat FCDR), which are based on daily inter-calibrations of MVIRI and SEVIRI with the High Resolution Infrared Radiation Sounder (HIRS) on board the National Oceanic and Atmospheric Administration (NOAA) and Infrared Atmospheric Sounding Interferometer (IASI) instrument on Metop polar orbiting platforms. The inter-calibration is carried out using the spectral response function of the respective MVIRI and SEVIRI sensor. For a more detailed instrument specification and a description of the calibration, the reader is referred to John et al. (2019).

3 Product Description

The CM SAF LST is the clear sky LST provided in K (RD 2). In a joint effort, the LSA SAF and CM SAF team have developed a single-channel LST retrieval algorithm suitable to generate LST data across Meteosat satellite generations. A consistent single-channel approach maximizes long-term and inter-satellite consistency (Scarino et al. 2013).

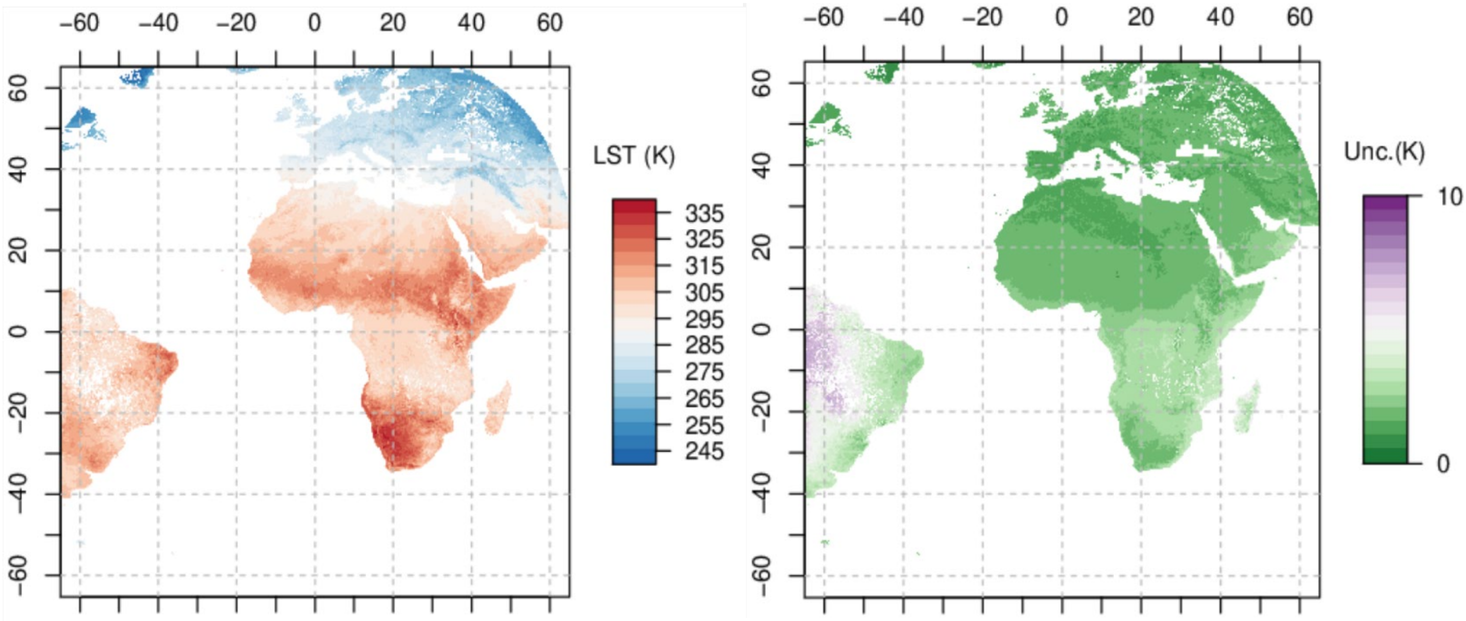

Figure 3-1: Example CM SAF LST data 2005/01 12:00 am (monthly diurnal cycle). Left) LST data. Right) uncertainty.

The CM SAF LST data are Level-3 data presented as hourly samples and monthly mean diurnal cycle composites. An example of the CM SAF LST monthly diurnal cycle data is provided in figure 3.1. The monthly diurnal cycle data contain 24 time slots for every hour of the day. The data is land-only. Ocean and sea are excluded, but lakes including the Caspian sea are included. The data are clear sky data i.e. cloudy observations are not gap filled. This results in gaps in the hourly sample data. Over the tropics and in Northern Europe in winter gaps due to persistent cloud coverage are also present in the monthly data (see Figure 3-1). Uncertainties are provided as ancillary fields for every pixel (Figure 3-1 right).

In this section, the CM SAF LST CDR is shortly described regarding retrieval methods, information content and limitations. Validation results are also described for each presented product. A short statement on recommended applications is given at the end of each product description.

3.1 Short Algorithm Description

The CM SAF LST retrieval is performed using the GeoSatClim Physical LST Algorithm v2022 (RD 2). The implemented Physical Mono Window (PMW) model is an adapted version of the radiative transfer-based model proposed by Heidinger et al. (2013) for climatological LST retrieval from single-channel infrared measurements. A detailed description of the implemented PMW model is provided in Duguay-Tetzlaff et al. (2015).

Radiative transfer models can be used to estimate the upward and downward atmospheric path radiance ($L^{\uparrow}_{11\mu m}$, $L^{\downarrow}_{11\mu m}$) and the atmospheric transmittance ($\tau_{11\mu m}$) in the thermal infrared for a specific atmospheric profile. The radiance $L_{11\mu m}$ recorded in Meteosat 11μm channel can be written as:

$$L_{11\mu m}=\varepsilon_{11\mu m}\, B_{11\mu m}(LST)\tau_{11\mu m}+L^{\uparrow}_{11\mu m}+L^{\downarrow}_{11\mu m}\,(1-\varepsilon_{11\mu m})\tau_{11\mu m} \qquad (1)$$

where $\varepsilon_{11\mu m}$ is the land surface emissivity. The calibrated Planck function $B_{11\mu m}$ (LST) provides the radiance emitted by blackbody at a specific LST.

The atmospheric path radiances ($L^{\uparrow}_{11\mu m}$, $L^{\downarrow}_{11\mu m}$) and the atmospheric transmittance ($\tau_{11\mu m}$) in Eq. (1) was estimated using the Radiative Transfer for TOVS (RTTOV) radiative transfer model. The atmospheric temperature and moisture profiles required for the radiative transfer runs are taken from ECMWF ERA5 profiles. The surface emissivities are taken from the Combined ASTER and MODIS Emissivity for Land (CAMEL) database.

The retrieval also includes a simple uncertainty characterization for hourly samples. Potential LST uncertainties were assessed through the use of a synthetic validation database. The validation data base was constructed from radiative transfer simulations. The LST uncertainty, S_{LST} , is composed of three components: 1) radiometric noise, 2) uncertainty in surface emissivity and 3) uncertainty in NWP profiles. All error sources are considered to be independent:

$$S_{LST} = \sqrt{S^2_{noise} + S^2_{emissivity} + S^2_{NWP}}$$

For the sensor noise we assumed a uniform random distribution within the interval [-0.3 K, 0.3 K] for SEVIRI and [-1.3 K, 1.3 K] for MVIRI. Emissivity uncertainties are assumed to range between [-0.04 and 0.04] depending on the surface type. The impact of atmospheric profile errors on retrieved LST values were estimated by replacing the profiles at hour h by the corresponding ones at hour h+6. Please note that those uncertainties cannot be propagated in time and space as spatial and temporal correlation scales are missing. A spatial and temporal uncertainty characterization is planned for the next release.

Details on the PMW algorithm and the uncertainty characterization are published in the CM SAF LST ATBD (RD-2).

3.2 Highlights

- 38 years of LST TCDR with an hourly temporal and 0.05° x 0.05° spatial resolution.
- Climatological LST observations are provided at the same time step as Numerical Weather Prediction (NWP) and climate models.
- Single channel LST method across all Meteosat satellite generations to ensure climatological consistency.

- Sensor differences (spectral response) are handled directly within the radiative transfer-model through an accurate physical approach.
- Accurate atmospheric correction through the implicit use of radiative transfer models.
- Physical retrieval approach which is independent from a training data base.
- LST estimates with pixel wise uncertainty estimates.
- Inter-calibrated input radiances from EUMETSAT to ensure a high temporal stability of the CDR.

3.3 Limitations

- Dependency on external NWP and surface emissivities to estimate the atmospheric state and the surface properties.
- The PMW model is likely to be inaccurate in regions with heavy atmospheric water vapour loading (total column water vapour > 45 kg/m^2) and at high satellite viewing angles (> 60°) (RD 1).
- Viewing angle effects due to roughness and structure of land surface are not handled in the presented algorithm.
- The PMW model is highly sensitive to errors in cloud masking.

3.4 Validation

This section provides a short summary of the CM SAF LST CDR validations. Details are summerized in the CM SAF validation report (RD 1).

This CM SAF Product Validation Report provides information on the quality of the CM SAF Meteosat Land Surface Temperature (LST) Climate Data Records (CDRs) derived from the Meteosat Visible and InfraRed Imager (MVIRI) on board the Meteosat First Generation (MFG) and the Spinning Enhanced Visible and InfraRed Imager (SEVIRI) observations on board the Meteosat Second Generation (MSG) satellites. The covered time of the presented CDRs ranges from January 1983 to December of 2020.

The reference datasets used to evaluate the CM SAF LST data precision and accuracy were taken from four ground-based observation. The validation sites are located in different climate zones and include a wide range of atmospheric conditions for different land surfaces. The evaluation scores and their compliance with the target requirements of accuracy and precision are:

Table 3-1: Summary of CM SAF LST accuracy (mean bias error) and precision (bias corrected root mean square error), as evaluated at the four KIT validation stations, and compared to target requirements (threshold, target, optimal).

	hourly	monthly
Accuracy	0.6 K	0.4 K
Precision	1.9 K	1.0 K

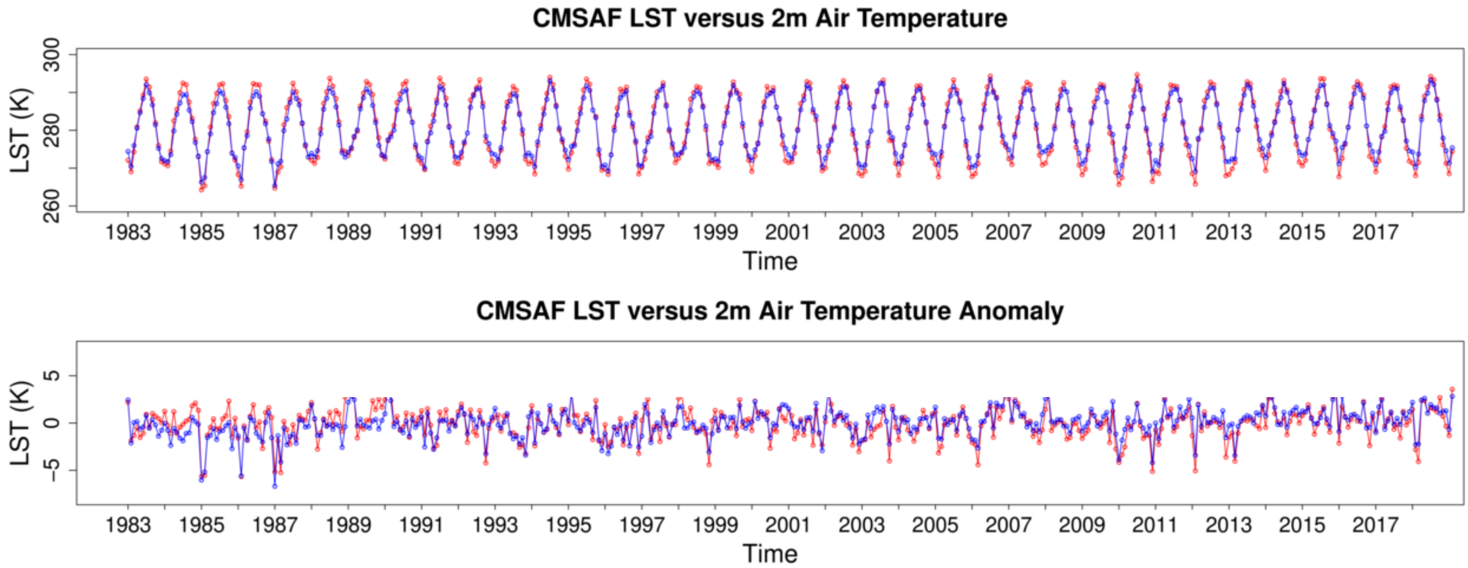

Figure 3-2: Monthly mean time series of the CM SAF LST (red) as compared to homogenized T2m air temperature measurements (blue) at 466 stations over Europe. Above) monthly mean air temperature, below) monthly mean air temperature anomaly (seasonal corrected).

The CM SAF LSTs have an excellent agreement with homogenized station based air temperature measurements in Europe (Figure 3-2). Good et al. (2022) have outlined that satellite-based LST data are highly correlated with air temperatures in anomaly space and can be used to assess warming trends over land if the required homogeneity is assured. We observe a decadal trend in bias between the CM SAF minus EUSTACE T2m air temperature anomalies of -0.1K/decade for the period 1999 to 2019, which reflects the optimal stability requirement. For Europe (1999 to 2019) significant trends in CM SAF LST data of 0.37 K/decade are obtained, which match the station-based T_{2m} trends of 0.34 K/decade. For the period 1983 to 1998 we observe some instability in the order of -0.5K/decade. A comprehensive evaluation against ESAs Land Surface Temperature Climate Change Initiative (CCI) Moderate Resolution Imaging Spectroradiometer (MODIS) LSTs (2003-2018) shows that instabilities are in the order of -0.1 K (optimal requirement) to 0.8 K (threshold requirement) for regions outside of Europe.

3.5 Recommended Application

Recommended applications for the CM SAF LST CDR are specified the CM SAF Product Requirements Document (AD 1). The Physical LST addresses all users, which are interested in high precision and climatological consistent LST products and which require consistent instantaneous climate data records.

LST is a key indicator of the Earth surface energy budget, is widely required in applications of hydrology, meteorology and climatology. It is of fundamental importance to the net radiation budget at the Earth's surface and for monitoring the state of crops and vegetation, as well as an important indicator of both the greenhouse effect and the energy flux between the atmosphere and earth surface. The product is of particular interest for e.g.:

- Regional climate model validation
- Satellite-based estimates of 2m air temperatures at a high spatial resolutions
- Climate studies on temperature anomalies
- LST analysis in the context of droughts
- Surface radiation budget

The product validation (RD 1) suggest that CM SAF LST data can be used to analyse temperature anomalies for the new WMO 1991-2020 norm period. We have observed a high correlation (R>0.9) between temperature anomalies retrieved from other satellite data or T2m air temperatures and CM SAF LSTs for all regions including desert areas (RD 1).

The validation (RD 1) against homogenised EUSTACE air temperature measurements suggests that CM SAF LST data can be used to assess warming trends in Europe from 1999 onward. For trend analysis outside of Europe the stability of the CM SAF LST CDR has to be thoroughly evaluated and cross-checked with quality-screened ground-based reference time series. Trend analysis before 1999 or trend analysis in desert regions cannot be recommended as the required homogeneity is not assured (RD 1).

The validation (RD 1) also outlined that the LSA SAF and CM SAF LSTs are well aligned for VZAs below 60° outside of desert regions. Depending on the requires accuracy and precision of the application, LSA SAF and CM SAF LST data may be used in conjunction.

The usability of the CM SAF LST in subtropical to tropical climate and at very high satellite viewing angles has to be tested.

4 Data format description

The CM SAF's climate monitoring SRB products are provided as NetCDF (Network Common Data Format) files (http://www.unidata.ucar.edu/software/netcdf/). The data files are created following NetCDF Climate and Forecast (CF) Metadata Convention version 1.7 (https://cfconventions.org/Data/cf-conventions/cf-conventions-1.7/cf-conventions.html) and NetCDF Attribute Convention for Dataset Discovery version 1.3 (http://wiki.esipfed.org/index.php/Attribute_Convention_for_Data_Discovery_1-3).

For data processing and conversion to various graphical packages input format, the CM SAF recommends the usage of the climate data operators (CDO), available under GNU Public License (GPL) from MPI-M (http://www.mpimet.mpg.de/~cdo).

The presented CM SAF LST data is provided on a regular latitude and longitude grid. The geographic reprojection from the native Meteosat grid onto the latitude longitude grid is carried out using spatial nearest neighbour search and averaged if the destination grid cell is more than half of the size of the source grid cell (near the equator). Bilinear interpolation is used elsewhere (e.g. at high latitudes) (RD 2). Table 4-1 gives information on the geographical coverage.

Table 4-1: Characteristics of the Meteosat SRB data geographical coverage.

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

The CM SAF LST data are Level-3 data presented as hourly and monthly mean diurnal samples. The CM SAF LST hourly data are provided as hourly samples, i.e. instantaneous data at the full hour and not calculate a mean (e.g. 12:00 and 13:00). The monthly LST diurnal cycle composites are aggregated from all available hourly means. Details on the averaging procedure can be found in the LST ATBD (RD 2).

For each time step a separate output file is provided, which follows the following naming convention:

LTPtsyyyymmdd hh mm001231000101MA.nc

with **t** is time interval (m=monthly, i=instantaneous), **s** is time statistics (in=instanteneous, d=mean diurnal cycle), **yyyy**=year, **mm**=month, **dd**=day, **hh**=hour, **mm**=minute, 001231000101MA= fix CMSAF classifier

4.1 General Variables

Table 4-2: General Variables.

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

4.2 Global Attributes

Table 4-3: Global attributes.

Name	Description
title	*geosatclim (processing software)*
summary	*This file contains time-space aggregated Thematic Climate Data Records (TCDR) produced by geosatclim within the Satellite Application Facility on Climate Monitoring* (CM SAF)
id	*DOI:10.5676/EUM_SAF_CM/SRF_METEOSAT/V001*
variable_id	*SRB*
product_version	*2.6*
creator_name	*EUMETSAT/CMSAF*
creator_email	*contact.cmsaf@dwd.de*
creator_url	*http://www.cmsaf.eu*

institution	*Federal Office of Meteorology and Climatology MeteoSwiss*
project	*Satellite Application Facility on Climate Monitoring* (*CM SAF*)
references	*https://doi.org/10.5676/EUM_SAF_CM/SRF_METEOSAT/V001*
keywords	*EARTH SCIENCE > ATMOSPHERE > RADIATION > SURFACE RADIATION BUDGET*
keywords_vocabulary	*GCMD Science Keywords, Version 8.6*
Conventions	*CF-1.7, ACDD-1.3*
standard_name_vocabulary	*Standard Name Table (v28, 07 January 2015)*
date_created	*creation date*
time_coverage_start	*starting date*
time_coverage_end	*ending date*
time_coverage_duration	*time duration*
time_coverage_resolution	*time resolution*
geospatial_lon_units	*degrees_east*
geospatial_lon_min	*-65*
geospatial_lon_max	*65*
geospatial_lon_resolution	*0.05 degree*
geospatial_lat_units	*degrees_north*
geospatial_lat_min	*-65*
geospatial_lat_max	*65*
geospatial_lat_resolution	*0.05 degree*
licence	*Disclaimer.*
platform	*MFG or MSG*
platform_vocabulary	*GCMD Platforms, Version 8.6*
instrument	*MVIRI or SEVIRI*
instrument_vocabulary	*GCMD Instruments, Version 8.6*

4.3 Variables

LST_PMW (time, lat, lon)

Field containing the Physical LST values given in K (hourly sample for hourly files, monthly mean for each hour of the day for monthly diurnal cycle files)

LSTERROR_PMW (time, lat, lon)

Field containing the estimated LST retrieval uncertainty given in K

NUMO (time, lon, lat)

Total number of valid observations counted during the averaging period (not available for the hourly product)

Table 4-4: CM SAF LST CDR product variables.

Parameter	Unit	Valid range	Type	Scale	Offset	Fill Value
LST_PMW	K	[193,353]	short	0.01	250	-32767
LSTERROR_PMW	K	[0,15]	byte	0.05	5.0	-127
NUMO	-	[0,31]	byte	1	0	-127

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 of how to use it for product search and ordering is given. The user is referred to this description since it is the central and most up to date documentation. However, some of the key features and services are briefly described in the following sections.

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

5.1 Product ordering process

The internet address http://wui.cmsaf.eu allows direct access to the CM SAF data ordering interface. On this webpage a detailed description of how to use it for product search and ordering is given. The user is referred to this description since it is the central and most up to date documentation. However, some of the key features and services are briefly described in the following sections.

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

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

5.3 User Problem Report

Users of CM SAF products and services are encouraged to provide feedback on the CM SAF product and services to the CM SAF team. Users can either contact the User Help Desk (see 6.1) or use the "User Problem Report" page. A link to the "User Problem Report" is available either from the CM SAF home page (www.cmsaf.eu) or the Web User Interface home page (http://wui.cmsaf.eu).

5.4 Service Messages / log of changes

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

6 Feedback

6.1 User feedback

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

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

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).

6.3 User Workshops

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

7 Copyright and Disclaimer

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

7.1 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.***

7.2 Acknowledgement and Identification

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

7.3 Re-distribution of CM SAF data

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

8 References

Duguay-Tetzlaff, A., V. A. Bento, F. M. Göttsche, R. Stöckli, J. P. A. Martins, I. Trigo, F. Olesen, J. S. Bojanowski, C. da Camara and H. Kunz, Meteosat land surface temperature climate data record: Achievable accuracy and potential uncertainties, Remote Sens., 2015.

Good, E.J., Aldred, F.M., Ghent, D.J., Veal, K.L., Jimenez. An Analysis of the Stability and Trends in the LST_cci Land Surface Temperature Datasets Over Europe. EARTH AND SPACE SCIENCE, 2022, 9(9), e2022EA002317.

Heidinger, A.; Laszlo, I.; Molling, C.; Tarpley, D. Using SURFRAD to verify the NOAA Single-Channel Land Surface Temperature Algorithm. Journal of Atmospheric and Oceanic Technology, 2013.

John, V.O., Tabata, T., Rüthrich, F., Roebeling, R., Hewison, T., Stöckli, R., Schulz, J. On the Methods for Recalibrating Geostationary Longwave Channels Using Polar Orbiting Infrared Sounders. Remote Sens. 2019, 11, 1171.

Scarino, B., P. Minnis, R. Palikonda, R. Reichle, D. Morstad, C. Yost, B. Shan and Q. Liu, Retrieving clear-sky surface skin temperature for numerical weather prediction applications from geostationary satellite data, Remote Sensing, 5, 2013.

9 Glossary

ATBD	Algorithm Theoretical Baseline Document
AVHRR	Advanced Very High Resolution Radiometer
BC-RMS	Bias-Corrected RMS
CDO	Climate Data Operators
CDR	Climate Data Records
CM SAF	Satellite Application Facility on Climate Monitoring
DRR	Delivery Readiness Review
DWD	Deutscher Wetterdienst (German MetService)
ECMWF	European Centre for Medium Range Forecast
ECV	Essential Climate Variable
ERA-5	ECMWF Re-Analysis dataset
EUMETSAT	European Organisation for the Exploitation of Meteorological Satellites
EUSTACE	EU Surface Temperatures for All Corners of the Earth
FCDR	Fundamental Climate Data Record
FMI	Finnish Meteorological Institute
GCOS	Global Climate Observing System
GFCS	Global Framework of Climate Services
GOES	Geostationary Operational Environmental Satellite
HIRS	High Resolution Infrared Radiation Sounder
KNMI	Royal Meteorological Institute of the Netherlands
LSA SAF	Land Surface Analysis Satellite Applications Facility
LST	Land Surface Temperature
LTP	Physical Land Surface Temperature
MVIRI	Meteosat Visible and InfraRed Imager
MeteoSwiss	Meteorological Service of Switzerland
MSG	Meteosat Second Generation
MFG	Meteosat First Generation
NOAA	National Oceanic and Atmospheric Administration
NWP	Numerical Weather Prediction
PMW	Physical Mono-Window Model
PRD	Product Requirement Document
PUM	Product User Manual
RMIB	Royal Meteorological Institute of Belgium
RMS	Root mean square difference
RTTOV	Radiative Transfer for TOVS
SEVIRI	Spinning Enhanced Visible and InfraRed Imager
SMHI	Swedish Meteorological and Hydrological Institute
SZA	Solar Zenith Angle
T2m	2m air temperatures
UK MetOffice	Meteorological Service of the United Kingdom
VZA	Viewing Zenith Angle
WCRP	World Climate Research Program
WMO SCOPE CM	Sustained COordinated Processing of Environmental satellite data for Climate Monitoring