EUMETSAT CM SAF CLIMATE MONITORING

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MeteoSwiss

Product User Manual

MeteoSwiss Land Surface Temperature Data v.4.2.0

LST **Land Surface Temperature**

Document Change Record

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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/PUM/MET/LST/2.1
RD 3	Meteosat land surface temperature climate data record: Achievable accuracy and potential uncertainties	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, Remote Sens., 2015.
RD4	Heat indices for Europe derived from CM SAF satellite data: A proof of concept	Arno Cheda, Anke Tetzlaff, Josh Blannin, Elizabeth Good, Varun Sharma, Isabel Trigo, Jonas Schwab, Aku Riihela, Christian Grams, Marc Schröder, manuscript to be submitted.

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1 Product Description

Land Surface Temperature (LST) is the **r**adiative **skin temperature of the Earth's land surface**. It represents the temperature of the very top layer of the ground and is influenced by factors like the ground's emissivity, its vegetation cover and soil moisture. Land Surface Temperature has a strong diurnal cycle. During a clear sky summer day, the difference between the near surface air temperature and the land surface temperatures can be up to 20 K in Switzerland. Complementary to the near surface air temperature, it is hence an independent temperature measure to characterize climate change.

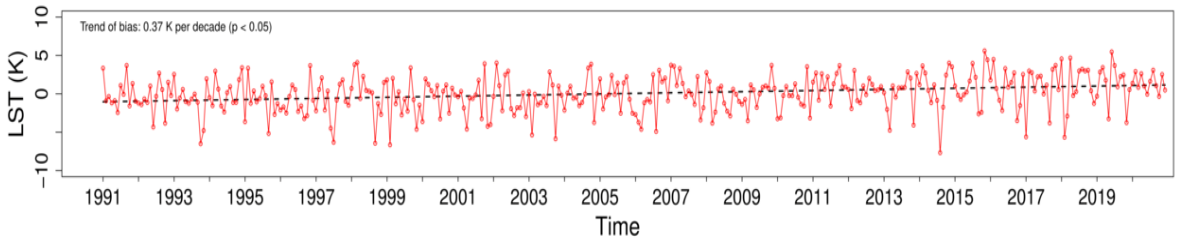

Figure 1: Land Surface Temperature (LST) anomaly time series 1991 to 2020 for Luzern extracted from the MeteoSwiss LST satellite-based climate data. The data are provided on a 0.05° latitude and longitude grid (ch05h grid).

The MeteoSwiss Land Surface Temperature (LST) climate data are based on sub-hourly satellite-based radiation measurements from the Meteosat satellites. The product is generated using the GeoSatClim software developed by MeteoSwiss in the EUMETSAT Climate Monitoring Satellite Application Facility (CM SAF) [RD2]. The MeteoSwiss Land Surface Temperature climate data are generated in near-real-time with a latency of 1 day and as long-term climate data record for the period 1991-now at a 0.05° latitude and longitude grid for entire Switzerland. The MeteoSwiss LST data are Level 3 data presented as hourly samples i.e., the data is not temporal averaged and represents the Meteosat measurement at the full hour. The data are clear sky data i.e., cloudy observations have no data values. This results in gaps in the hourly sample data.

The following parameters and ancillary data are available:

Parameter & Ancillary data	Name	Description	Period and Grid	Temporal resolution
LST_PMW	Land Surface Temperature	Clear sky skin temperature of the uppermost layer of the Earth Surface.	1991-now, ch05h, ch02	Hourly Sample
IR	Infrared Temperature	Top-of-atmosphere Meteosat Infrared Brightness Temperature measured at 10.8 micrometer wavelength.	1991-now, native Meteosat satellite grid	Instantaneous: 15 min for MSG and 30 min for MFG
SCAN_TIME	Meteosat scan time	Precise scan time per satellite pixel	1991-now, native Meteosat satellite grid	Instantaneous: 15 min for MSG and 30 min for MFG

Table 1: MeteoSwiss Land Surface Temperature and ancillary data.

1.1 Short Algorithm Description

The MeteSwiss Land Surface Temperature climate data is based on 40 years+ of Meteosat satellite 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 climate data span the years 1991-now, 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, derived from Level 1.5 MVIRI and SEVIRI data provided by EUMETSAT.

For MVIRI and SEVIRI dedicated infrared channel inter-calibration factors were provided by EUMETSAT (release 2.0 of the Meteosat FCDR), which are based on daily inter-calibrations of MVIRI and SEVIRI against 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 Land Surface Temperature retrieval from top of atmosphere clear-sky radiances is performed using the CM SAF GeoSatClim Physical LST Algorithm v2.4.0 software [**Fehler! Verweisquelle konnte nicht gefunden werden.**]. The implemented Physical Mono Window (PMW) model is as radiative transfer-based model for climatological LST retrieval from single-channel infrared measurements [RD3].

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 spectral surface emissivity is taken from the Combined ASTER and MODIS Emissivity for Land (CAMEL) database. Details on the PMW algorithm are published in the CM SAF Land Surface Temperature ATBD [RD2].

1.2 Highlights

- 40 years+ of Land Surface Temperature (LST) climate data with an hourly temporal 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.
- Atmospheric correction through the implicit use of radiative transfer models.

- Inter-calibrated input radiances from EUMETSAT to ensure a high temporal stability of the CDR.

1.3 Validation

This section provides a short summary of the CM SAF Land Surface Temperature validations [**Fehler! Verweisquelle konnte nicht gefunden werden.**]. Please not that we used the CM SAF GeoSatClim Physical LST Algorithm v2.4.0 software to process the MeteoSwiss LST data. The reference datasets used to evaluate the CM SAF LST data precision and accuracy were taken from four ground-based observation in Europe and Africa. 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:

	hourly	**monthly**
Accuracy (mean bias error)	0.6 K	0.4 K
Precision precision (bias corrected root mean square error)	1.9 K	1.0 K

Table 2: Summary of CM SAF LST accuracy as evaluated at the four KIT validation sites.

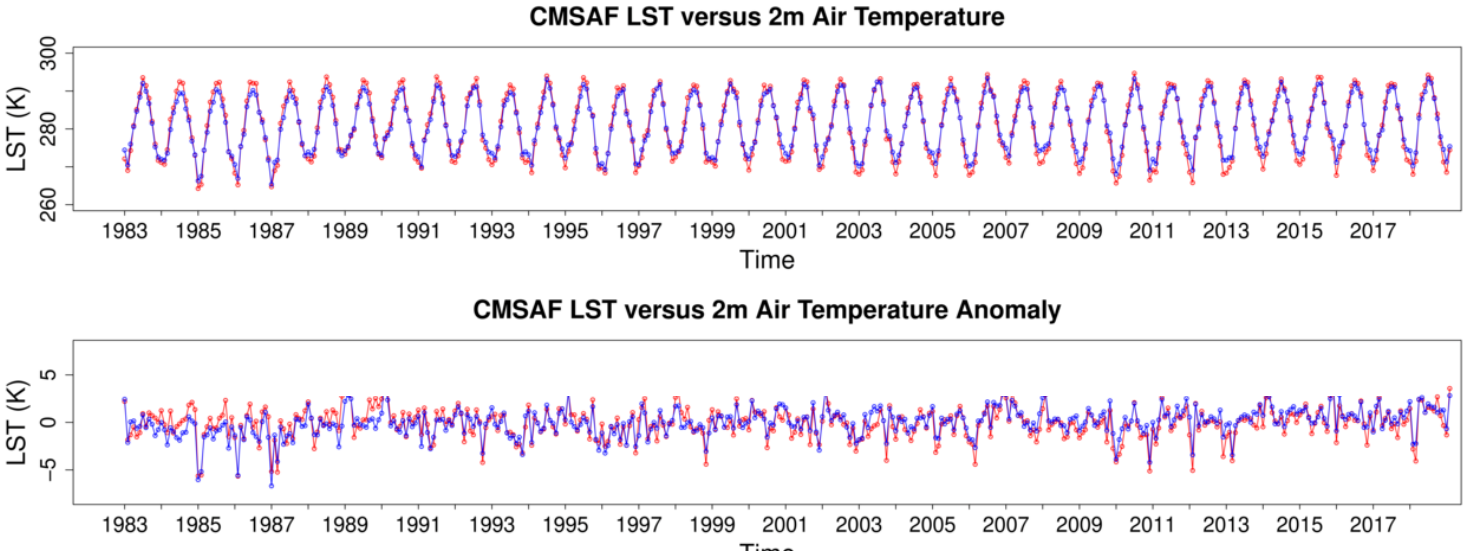

Figure 2: Monthly mean time series of the CM SAF LST (red) as compared to homogenized T2m air temperature measurements (blue) at 466 stations over Europe. Above) monthly mean air temperature, below) monthly mean air temperature anomaly (seasonal corrected).

The CM SAF LSTs have an excellent agreement with homogenized station-based air temperature measurements in Europe (Figure). We observe a decadal trend in bias between the Land Surface Temperature minus T2m air temperature anomalies of 0.1K/decade for the period 1999 to 2020, which reflects the high temporal stability of the land surface temperature climate data record. For Europe (1999 to 2019) significant trends in CM SAF LST data of 0.37 K/decade are obtained, which match the station-based T2m trends of 0.34 K/decade within 0.03 K/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 0.05 K/decade in Europe.

Recommended Application

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 modelling

Validation of regional model reanalysis such as the new 1 km ICON Reanalysis Light

LST can be also used as input for weather prediction models to constrain the skin temperature estimates

Agriculture and water management

Crop health and stress: LST data can identify stress in crops due to water shortages, allowing for early intervention with irrigation

Phenology and development: LST data can be used to calculate metrics like Growing Degree Days (GDD), which are used to predict crop development rates.

Climate and environmental monitoring

Urban heat islands (UHIs): LST is used to monitor UHIs and understand their impact on micro-climates for major agglomeration zones in Switzerland

Drought monitoring: It is a key input for monitoring drought conditions and assessing their severity (e.g. Swiss drought monitoring; https://www.trockenheit.admin.ch/en/factors/vegetation/vegetation-health-index-vhi)

Land use/land cover change LST data helps to understand how changes in land use in Switzerland affect the climate and energy balance.

Heatwaves: Satellite LST is used to monitor extreme heat events and to establish heat indices [RD4]

Energy balance

LST is an important parameter for understanding the energy balance between the land surface and the atmosphere in particularly in Swiss mountain regions where ground measurements are sparse

2 Data format description

The MeteoSwiss's climate monitoring radiation 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 1.8 (https://cfconventions.org/Data/cf-conventions/cf-conventions-1.8/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, MeteoSwiss recommends the usage of the climate data operators (CDO), available under GNU Public License (GPL) from MPI-M (http://www.mpimet.mpg.de/~cdo).

2.1 Spatial gridding

The presented MeteoSwiss Radiation Data are 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 a spatial nearest neighbour search. Please note that, with the selected grid, we more or less represent the native grid resolution which is about about 0.03° for the SEVIRI sensor and about 0.05° for the MVIRI sensor over Switzerland. With the ch05h time series back to 1991 we provide a true climate time series over the 0.05° MVIRI and 0.03° SEVIRI period which is not altered by downscaling artifacts. We have therefore decided for the 0.05° MVIRI grid resolution.

Lon min	Lon max	Lat min	Lat max	Spacing (lon, lat)	Projection	Datum
5.025	10.975	45.025	48.975	0.05°	latitude - longitude	WGS 84

Table 6: Characteristics of the MeteoSwiss LST Data geographical coverage.

Hence, we provide the highest possible spatial resolution as observed by the satellite sensor for each time series. Table 6 gives information on the geographical coverage. The 0.05° data are slightly larger than Switzerland and also cover those regions outside Switzerland which are relevant for the Swiss hydrological catchment.

2.2 Temporal aggregation

The MeteoSwiss LST Data are Level-3 presented as hourly samples. Re-projected, instantaneous fields from the full hour (e.g. 12:00) are provided i.e. the data are not averaged. This is done as LST has a strong diurnal cycle with gaps due to cloud coverage. The spatial and temporal aggregation is conducted using the GeoSatClim re-projection and aggregation tools.

2.3 File naming and packing

Hourly sample data are packed into monthly files to simply the data transfer, which follows the naming convention:

[satellite].[variable].[t]_[region].lonlat_[yyyy][mm]01000000.nc

Where satellite is the satellite identifier (msg, mfg), variable is the radiation component (LST), t is time interval (h=hourly), region (ch05h), yyyy=year, mm=month.

Example Surface Outgoing Longwave Radiation (LST) data for September 2025 for the ch05h grid:

msg.LST.H_ch05h.lonlat_20250901000000.nc (720 hourly mean steps in one file)

2.4 General Variables

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

Table 7: General Variables.

2.5 Global Attributes

Name	Description
institution	Data produced at Federal Office of Meteorology and Climatology MeteoSwiss
title	Satellite-based Climate Data Record of MeteoSwiss
summary	This file contains Climate Data using the software GeoSatClim from the Satellite Application Facility on Climate Monitoring (CM SAF)

id	not assigned
variable_id	NA
product_version	*4.2.0*
creator_name	not assigned
creator_email	not assigned
creator_url	www.meteoswiss.admin.ch
institution	*Federal Office of Meteorology and Climatology MeteoSwiss*
project	*Satellite Application Facility on Climate Monitoring (CM SAF)*
references	Information on the data is available at https://www.meteoswiss.admin.ch/climate/the-climate-of-switzerland/spatial-climate-analyses.html
Conventions	CF-1.8, 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	*Minimum longitude*
geospatial_lon_max	*Maximum longitude*
geospatial_lon_resolution	*Grid spacing in °*
geospatial_lat_units	*degrees_north*
geospatial_lat_min	*Minimum longitude*
geospatial_lat_max	*Maximum longitude*
geospatial_lat_resolution	*Grid spacing in °*
licence	*The GeoSatClim product ("Climate Product") is subject to the Federal Office of Meteorology and Climatology MeteoSwiss Data Policy. By accessing or using the Climate Product, users agree to comply with the terms outlined in Policy, including the following attribution: "Source MeteoSwiss". The Climate*

	Product was generated using the EUMETSAT software GeoSatClim provided through the Climate Monitoring Satellite Application Facility (CM SAF). The Climate Product contains modified EUMETSAT Meteosat data since 1991, as well as additional data and products obtained from the European Centre for Medium-Range Weather Forecasts (ECMWF), NASA's Combined ASTER and MODIS Emissivity over Land (CAMEL) emissivity data, and CMIP6 aerosol data and elevation data from the SwissTopo DHM25 as ancillary fields.
platform	*MFG or MSG*
platform_vocabulary	*GCMD Platforms, Version 8.6*
instrument	*MVIRI or SEVIRI*
instrument_vocabulary	*GCMD Instruments, Version 8.6*

Table 8: Global attributes.

2.6 Variables

[Parameter] (time, lat, lon)

field containing the parameter values. For a detailed description see table 1.

Parameter	Unit	Valid range	Type	Scale	Offset	Fill Value
LST	K	[220,350]	float	1.0	0.0	9.96921e+36
IR	K	[220,350]	float	1.0	0.0	9.96921e+36
SAA	degree	[0,360]	float	1.0	0.0	9.96921e+36
SZA	degree	[0,180]	float	1.0	0.0	9.96921e+36

Table 9: Parameters with specifications of the MeteoSwiss LST Data. For a detailed description please refer to table 1.

3 Feedback

3.1 User feedback

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

Please provide your feedback to our customer service (e-mail kundendienst@meteoswiss.ch).

3.2 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 to our staff or via our customer service (e-mail address kundendienst@meteoswiss.ch).

4 Copyright and Disclaimer

The user of the MeteoSwiss LST Data agrees to respect the following regulations:

4.1 Copyright

This GeoSatClim products ("MeteoSwiss LST Data") are subject to the Federal Office of Meteorology and Climatology MeteoSwiss Data Policy. By accessing or using this Climate Product, users agree to comply with the terms outlined in Policy, including the following attribution: “Source MeteoSwiss”. The Climate Products were generated using the EUMETSAT software GeoSatClim provided through the Climate Monitoring Satellite Application Facility (CM SAF). The Climate Products contain modified EUMETSAT Meteosat data since 1991, and are also based on additional data and products obtained from the European Centre for Medium-Range Weather Forecasts (ECMWF), NASA's Combined ASTER and MODIS Emissivity over Land (CAMEL) emissivity data, and CMIP6 aerosol data and elevation data from the SwissTopo DHM25 as ancillary fields.”

4.2 Acknowledgement and Identification

When exploiting the MeteoSwiss LST Data you are kindly requested to acknowledge this contribution accordingly and make reference to MeteoSwiss and the CM SAF, e.g., by stating “The work performed was done by using data from MeteoSwiss generated with the software GeoSatClim from EUMETSAT’s Satellite Application Facility on Climate Monitoring (CM SAF)”. It is highly recommended to identify the product version used clearly.

4.3 Re-distribution of CM SAF data

Please do not re-distribute the MeteoSwiss Radiation Data to third parties. The use of the MeteoSwiss products is granted free of charge to every interested user, but an

essential interest exists to know how many and what users MeteoSwiss has. This helps to ensure of the MeteoSwiss operational services as well as its evolution according to user needs and requirements.