Product User Manual

Land Surface Temperature (LST)

PRODUCTS: LSA-001 (MLST), LSA-050 (MLST-R), LSA-003 (DLST), LSA-002 (ELST)

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Version 2.7	06/04/2016	Update information on EPS LST (ELST, LSA-002)
Version 2.8	27/10/2016	Changes following the ORR on EPS products: - It is now specified that only the primary Metop satellite is processed to generate ELST (LSA-002) – end of Introduction; first paragraph of section 3.2. - Further information on ELST algorithm and emissivity. - Clarification that Annex C refers to SEVIRI LST products. - Added note on the use of static emissivity for AVHRR LST (section 2.3.1, 2nd full paragraph after equation

Version 3.0	17/01/2017	Document updated to include information of MSG DLST product (LSA-003)
Issue 2	02/06/2017	Section describing processing scheme removed from PUM and transferred to the respective ATBDs.
Issue 3	03/05/2018	Added MSG LST CDR (LSA-050).
	11/12/2018	Add paragraph describing the different algorithms and applications between LSA-050 and CM SAF MVIRI & SEVIRI TCDR Editorial changes and slight rephrasing in: page 10 (2nd para), 12 (2nd para), 13 (1st and 3rd para), 14 (3rd para), 15 (1st line), 16 (2.3 Title section). Add of main results from comparison of LST-CDR with ECMWF Tskin and MODIS LST. Add clarification about slower changes observed in the DTC composite.

TABLE OF CONTENTS

List of Figures

List of Tables

1 Introduction

The Satellite Application Facility (SAF) on Land Surface Analysis (LSA) is part of the SAF Network, a set of specialised development and processing centres, serving as EUMETSAT (European organization for the Exploitation of Meteorological Satellites) distributed Applications Ground Segment. The SAF network complements the product-oriented activities at the EUMETSAT Central Facility in Darmstadt. The main purpose of the LSA SAF is to take full advantage of remotely sensed data, particularly those available from EUMETSAT sensors, to measure land surface variables, which will find primarily applications in meteorology (http:/lsa-saf.eumetsat.int).

The spin-stabilised Meteosat Second Generation (MSG) has an imaging-repeat cycle of 15 minutes. The Spinning Enhanced Visible and Infrared Imager (SEVIRI) radiometer embarked on the MSG platform encompasses unique spectral characteristics and accuracy, with a 3km resolution (sampling distance) at nadir (1km for the high-resolution visible channel), and 12 spectral channels (Schmetz et al., 2002).

The EUMETSAT Polar System (EPS) is Europe’s first polar orbiting operational meteorological satellite and the European contribution to a joint polar system with the U.S. EUMETSAT will have the operational responsibility for the “morning orbit” with Meteorological-Operational (Metop) satellites, the first of which was successfully launched on October 19, 2006. Despite the wide range of sensors on-board Metop (http://www.eumetsat.int/), most LSA SAF parameters make use of the Advanced Very High Resolution Radiometer (AVHRR) and, to a lesser extent, of the Advanced Scatterometer (ASCAT).

Several studies have stressed the role of land surface processes on weather forecasting and climate modelling (e.g., Dickinson et al., 1983; Mitchell et al., 2004; Ferranti and Viterbo, 2006). The LSA SAF has been especially designed to serve the needs of the meteorological community, particularly Numerical Weather Prediction (NWP). However, there is no doubt that the LSA SAF addresses a much broader community, which includes users from:

- Weather forecasting and climate modelling, requiring detailed information on the nature and properties of land.
- Environmental management and land use, needing information on land cover type and land cover changes (e.g. provided by biophysical parameters or thermal characteristics).
- Agricultural and Forestry applications, requiring information on incoming/outgoing radiation and vegetation properties.
- Renewable energy resources assessment, particularly biomass, depending on biophysical parameters, and solar energy.
- Natural hazards management, requiring frequent observations of terrestrial surfaces in both the solar and thermal bands.
- Climatological applications and climate change detection, requiring long and homogeneous time-series.

Table 1 - The LSA SAF set of products and respective sensors and platforms. The table covers both existing and future EUMETSAT satellites and, therefore, refers to operational products and development activities

Product Family	Product Group	Sensors/Platforms
Radiation	Land Surface Temperature (LST)	SEVIRI/MSG, AVHRR/Metop, FCI/MTG, VII/EPS-SG
	Land Surface Emissivity (EM)	SEVIRI/MSG, FCI/MTG (internal product for other sensors)
	Land Surface Albedo (AL)	SEVIRI/MSG, AVHRR/Metop, FCI/MTG, VII/EPS-SG, 3MI/EPS-SG
	Down-welling Short-wave Fluxes (DSSF)	SEVIRI/MSG, FCI/MTG
	Down-welling Long-wave Fluxes (DSLF)	SEVIRI/MSG, FCI/MTG
Vegetation	Normalized Difference Vegetation Index (NDVI)	AVHRR/Metop, VII/EPS-SG
	Fraction of Vegetation Cover (FVC)	SEVIRI/MSG, AVHRR/Metop, FCI/MTG, VII/EPS-SG, 3MI/EPS-SG
	Leaf Area Index (LAI)	SEVIRI/MSG, AVHRR/Metop, FCI/MTG, VII/EPS-SG, 3MI/EPS-SG
	Fraction of Absorbed Photosynthetically Active Radiation (FAPAR)	SEVIRI/MSG, AVHRR/Metop, FCI/MTG, VII/EPS-SG, 3MI/EPS-SG
	Gross Primary Production (GPP)	SEVIRI/MSG, FCI/MTG
	Canopy Water Content (CWC)	AVHRR/Metop, VII/EPS-SG
Energy Fluxes	Evapotranspiration (ET)	SEVIRI/MSG, FCI/MTG
	Reference Evapotranspiration (ET0)	SEVIRI/MSG, FCI/MTG
	Surface Energy Fluxes: Latent and Sensible (LE&H)	SEVIRI/MSG, FCI/MTG
Wild Fires	Fire Detection and Monitoring (FD&M)	SEVIRI/MSG
	Fire Radiative Power	SEVIRI/MSG, FCI/MTG, VII/EPS-SG
	Fire Radiative Energy and Emissions (FRE)	SEVIRI/MSG, FCI/MTG, VII/EPS-SG
	Fire Risk Map (FRM)	SEVIRI/MSG, FCI/MTG
	Burnt Area (BA)	AVHRR/Metop, VII/EPS-SG

The LSA SAF products (Table 1) are based on level 1.5 SEVIRI/Meteosat and/or level 1b Metop data. Forecasts provided by the European Centre for Medium-range Weather Forecasts (ECMWF) are also used as ancillary data for atmospheric correction.

The SEVIRI/Meteosat derived products are derived for the Full SEVIRI disk and distributed via EUMETCast for 4 different geographical areas within Meteosat disk (Figure 1):

- Euro – Europe, covering all EUMETSAT member states;
- NAfr – Northern Africa encompassing the Sahara and Sahel regions, and part of equatorial Africa.
- SAfr – Southern Africa covering the African continent south of the Equator.
- SAme – South American continent within the Meteosat disk.

SEVIRI full disk products are available via ftp (off-line and/or NRT).

Metop derived parameters are currently available at level 3 full globe in sinusoidal projection, centred at (0ºN, 0ºW), with a resolution of 0.01º by 0.01º, one file for daytime and another for night-time observations.

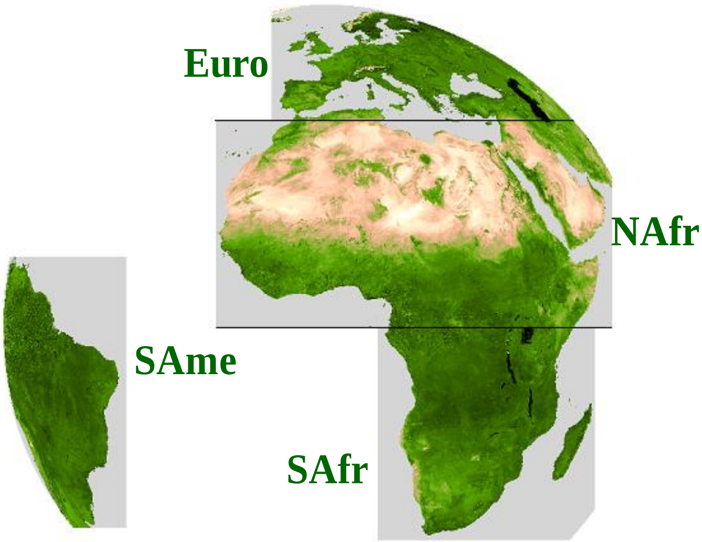

Figure 1 - The LSA SAF geographical areas.

The LSA SAF system is located at IPMA (Portugal) and VITO (Belgium) and has been designed to generate, archive, and disseminate the operational products. LSA SAF Land Surface Temperature products are coordinated by IPMA. The monitoring and quality control of the operational products is performed automatically by the LSA SAF software, which provides quality information to be distributed with the products.

The LSA SAF products are currently available from LSA SAF website (http://landsaf.ipma.pt) that contains real time examples of the products as well as updated information.

This document is one of the product manuals dedicated to LSA SAF users. The algorithm and the main characteristics of the Land Surface Temperature (LST) generated by the LSA SAF from SEVIRI and AVHRR data are described in the following sections. The characteristics of AVHRR and SEVIRI based LST products provided by the LSA SAF are described in Table 2. Further details on the LSA SAF product requirements may be found in the Product Requirements Document (SAF_LAND_IPMA_PRD) available at the LSA SAF website http://lsa-saf.eumetsat.int.

Table 2 - Product Requirements for LST, in terms of area coverage, resolution and accuracy.

LST Product	Coverage	Resolution		Accuracy (RMSE)		
		Temporal	Spatial	Threshold	Target	Optimal
MLST (LSA-001): LST_SEVIRI	MSG disk	15 min	MSG pixel resolution	4K	2 K	1K
MLST (LSA-050): LST_SEVIRI (Reprocessed)	MSG disk/ 2004-2015	15 min	MSG pixel resolution	4K	2 K	1K
ELST (LSA-002): LST_AVHRR	GLOBE	Daytime/ Night-time	1-km	4K	2 K	1K
DLST (LSA-003): DLST_SEVIRI synthesis	MSG disk	10-day	MSG pixel resolution	4K	2 K	1K

In the case of LST_AVHRR (LSA-002), at any given time, only the primary satellite is processed.

The algorithms used for the estimation of SEVIRI and AVHRR LST products within the LSA-SAF (Table 2) are based on a Generalized Split Window (GSW) that uses the difference between two adjacent window channels to correct the atmospheric absorption. Nevertheless, small adjustments have been implemented in the production chains since the start time of operations, namely, an updated treatment of emissivity, upgrades in the ECMWF forecasts, among others. In the meantime, the generation of a long-term dataset is also pursued, aiming to make these datasets suitable for climate variability and change detection studies. Consequently, a decision to reprocess the dataset was made in order to generate a SEVIRI LST Climate Data Record (CDR), for the entire period from 2004 to 2015. LSA-050 corresponds to a reprocessing of LST with a temporal sampling of 15 minutes, using the most recent version of the algorithm (v7.14.0) used for product LSA-001. Therefore, the above mentioned CDR has the advantage of being currently updated with the Near Real Time (NRT) LST product (LST-001) that uses the same algorithm version.

It is also worth mentioning that the CM SAF (http://cm-saf.eumetsat.int) also provides a number of CDRs, including a SEVIRI-based LST one. This has been developed in close collaboration with the LSA SAF and EUMETSAT Central Facility. Since the purpose in this case was to provide a long LST record covering Meteosat First and Second Generation (using MVIRI and SEVIRI instruments), a single algorithm based on a Mono-window approach and covering the period from January 1991 to December of 2015 (Duguay-Tetzlaff et al., 2015).

2 Algorithm

2.1 Overview

Land Surface Temperature (LST) is defined as the radiative skin temperature of land surface, as measured in the direction of the remote sensor. Such a directional radiometric temperature may be derived from a radiative energy balance of a surface and provides the best approximation to the thermodynamic temperature based on a measure of radiance (Norman and Becker, 1995).
LST plays an important role in the physics of land surfaces as it is involved in the processes of energy and water exchange between the surface and the atmosphere. LST is a useful product for the scientific community namely for those dealing with meteorological and climate models. Accurate values of LST are also of special interest in a wide range of areas related to land surface processes, namely hydrology, meteorology, agro-meteorology, climatology and environmental studies. A correct estimation of **Land Surface Emissivity** (**EM**) is crucial for LST retrieval from space as well as for the implementation of atmospheric correction methods.

Instruments on-board satellites provide the only means of LST observations for large areas in an operational way. The spectral radiance fields measured at the top of the atmosphere are influenced by surface parameters (such as EM and LST) as well as by the composition and thermal structure of the atmosphere. Therefore, in order to obtain LST from space it is necessary to correct the atmospheric influence and take into consideration land surface emissivity, which must be adequately known. On the other hand, the accuracy of the atmospheric corrections depends on the quality of radiative transfer models, uncertainties in atmospheric molecular absorption coefficients, aerosol absorption/scattering coefficients and errors in the atmospheric profiles.

Several algorithms have been developed during the last years to estimate LST and EM from space. Most are based on methods to determine Sea Surface Temperature (SST) that were then adapted to land surfaces. Examples of such techniques include:

- Single channel methods (Price, 1983; Duguay et al., 2015) applicable to an arbitrary single IR-channel, that rely on radiative transfer calculations based on vertical soundings from NOAA-TOVS (or EPS-HIRS-3 in the future) as well as on radiosonde data (or NWP analyses as an alternative) to estimate the atmospheric effects. It is worth noting that this methodology requires a precise description of the atmospheric structure.
- Multi-channel (split-window) approaches have been used by several authors (*e.g.* Prabhakara *et al.*, 1974, McMillin, 1975, Deschamps and Phulpin, 1980, Price, 1984, Ho *et al.*, 1986). The technique performs an atmospheric correction based on the differential absorption in IR bands. In the IR windows (around 3.7μm and from 8-13 μm), atmospheric attenuation due to water vapour may be approximated by a

linear combination of the temperatures measured in two (or more) neighbouring channels.

- Multi-angular methods that are based upon different absorption when the same scene is observed from two different viewing angles (*e.g.* Chedin *et al.*, 1982).
- Physically based methods such as the Temperature Independent Spectral Index (TISI) (Becker and Li, 1990a, Li and Becker, 1993) and the Two-Temperature methods (TTM) (Watson, 1992b; Faysash and Smith, 1999, 2000) that allow a simultaneous retrieval of EM and LST.

An accurate determination of LST is a difficult task. The spectral emissivity varies for different land cover types, assumptions of the atmospheric state are uncertain, and LST presents a high variability in time and space. Differences in soil moisture content, vegetation cover, surface cover type, texture and roughness, as well as in vegetation cover structure may significantly affect thermal emissivity (EM) and the directional distribution of the outgoing radiance. EM may also vary with the viewing angle, an effect that is more important over land than over water since the combination of surface slope and satellite scanning angle results in larger local viewing angles (Wan and Dozier, 1989; McAtee et al., 2003). Variability in atmospheric profiles over land is also increased by topography. Finally, it is worth mentioning that difficulties may arise because of the variability of both LST and EM within a pixel.

Since the number of unknowns (LST and EM for each channel) is always larger than the number of independent measurements (*i.e.* number of used channels) it is not possible to retrieve both LST and spectral emissivity from passive radiometry (even performing the atmospheric corrections) without introducing further assumptions. Examples include assuming a blackbody emissivity (Prabakhara et al., 1974), deriving empirical relationships between emissivity and a vegetation index (Van de Griend and Owe, 1993), performing emissivity normalisation (Gillespie, 1985), using a reference channel (Kahle et al., 1980), spectral ratio (Watson, 1992a), alpha coefficients (Kealy and Hook, 1993), a Temperature Independent Spectral Index (TISI) (Becker and Li, 1990a, Li and Becker, 1993), the Vegetation Cover Method (VCM) (Valor and Caselles, 1996, Caselles et al., 1997), a Look Up Table (Wan and Dozier, 1996) or the TTM (Watson, 1992b; Faysash and Smith, 1999, 2000).

Studying relations between clear sky space-derived surface parameters, e.g. LST and vegetation indices, is important for global change research (Stoll, 1994; Lambin and Ehrlich, 1996) and for estimating evapotranspiration (Stisen et al., 2008). However, such studies require frequently available and spatially continuous (i.e. cloud-free) parameter fields. Sensors on-board of geostationary satellites usually have high temporal sampling rates (e.g. 15 minutes for MSG/SEVIRI), which is ideal for temporal compositing. Due to its simplicity and stability, the Maximum Value Composite (MVC) is especially popular for vegetation indices (Holben, 1986), but for LST also median and mean composites were shown to be useful (Göttsche and Olesen, 2001). Temporal compositing of surface parameters reduces large data volumes and increases the spatial continuity of parameter fields. Frequently decadal (10 day) composites are formed, which is a compromise between sufficient temporal sampling and data availability (e.g. limited by clouds). For a composite to be meaningful, the underlying surface parameter has to be stable over the compositing interval; for decadal composites, this is approximately the case for vegetation indices and for surface albedo (in the absence of rain events). In contrast, LST is highly dynamic and varies on the order of minutes. Fortunately, the diurnal temperature cycle (DTC) exhibits a stable periodicity, i.e. the fast changes of LST are mainly controlled by the regular changes in solar illumination. Therefore, performing separate compositing at fixed times of the day yields estimates of LST subject to the chosen criteria (e.g. maximum or median) at those times, e.g. at the 96 observation times of MSG/SEVIRI (Göttsche and Olesen, 2009). Slower changes (changes between different days within a month or season) observed in this composite DTC can then be assumed to reflect changes in the atmosphere or in surface parameters, e.g. vegetation and deep soil temperature.

2.2 Physics of the Problem

The retrieval of LST is based on measurements from MSG and EPS systems in the thermal infrared window (MSG/SEVIRI–channels IR10.8 and IR12.0 and Metop/AVHRR-3–channels 4 and 5). Theoretically, LST values can be determined 96 times per day from MSG, and twice per day from Metop. However, fewer observations are generally available due to cloud cover contamination.

LSA SAF LST retrievals are based on the Generalised Split-Window (GSW) algorithm (Wan and Dozier, 1996). The GSW performs corrections for atmospheric effects based on the differential absorption in adjacent IR bands and requires EM as input data; a look-up table of optimal coefficients is previously determined at individual angles covering different ranges of water vapour and air temperature near the surface. The retrieval of EM is based on the Vegetation Cover Method (VCM; Caselles *et al*., 1997; Trigo et al, 2008) that relies on the use of a geometrical model to compute an effective emissivity based on the knowledge of the Fractional Vegetation Cover (FVC), also provided by the LSA SAF.

IR radiance is strongly absorbed and scattered even by thin clouds and aerosol layers. Retrieval of LST requires identification of cloudy and partly cloudy pixels in order to separate them from cloud-free pixels. Clouds may prevent the retrieval when they totally block the signal from the surface and they may also affect the accuracy of the product when there are thin clouds and aerosols, which attenuate the signal from the surface but do not completely block it (see Table 3). LST is derived for all clear pixels, *i.e.* all situations in which scattering in the IR can be ignored. Clear sky pixels are identified through the application of the cloud mask available from the software delivered by the Nowcasting and Very Short Range Forecasting Satellite Application Facility (NWC SAF; http://nwcsaf.inm.es/). The NWC SAF developed two software packages prepared to use SEVIRI/MSG and AVHRR (onboard MetOp or NOAA) data, respectively. Availability and/or accuracy of LST may also be affected by some potential problems (already identified by the NWC SAF), namely:

- Non-detected low clouds (at night) or shadowed cloud layers (daytime); cloud edges; sub-pixel clouds; thin clouds over dark surfaces.
- Cloud free areas that are cloud masked due to very cold winter situations.

Table 3 - Retrieval of LST product according to cloud mask information.

Cloud mask information	**LST product**
Non-processed	Impossible to retrieve
Cloud free	Retrieved
Cloud contaminated (partly cloudy or semitransparent)	Impossible to retrieve
Clouds filled (opaque clouds completely filling the FOV)	Not retrieved (highly affects accuracy)
Snow/Ice contaminated*	Retrieved
Undefined (not classified due to known separability problems)	Not retrieved (may affect the accuracy)

*The information on the presence of snow/ice is obtained from the NWC SAF cloud-mask, which provides a pixel classification every 15-min. The Land-SAF provides a snow cover product, obtained through an independent procedure, which is available to users as a daily composite.

2.3 Description of the Algorithm

2.3.1 VCM

Estimation of EM for IR SEVIRI bands, as well as for the corresponding channels on AVHRR (channels 4 and 5) relies on the VCM approach (Caselles and Sobrino, 1989, Valor and Caselles, 1996, Caselles *et al.*, 1997). Considering flat surfaces and neglecting the term related to the radiation that indirectly reaches the sensor by means of internal reflections, the pixel effective emissivity may be obtained by combining the vegetated area and exposed soil as follows:

$$\varepsilon_{i,pixel} = \varepsilon_{i,v} FVC + \varepsilon_{i,g} (1 - FVC) \quad (1)$$

where $\varepsilon_{i,v}$ and $\varepsilon_{i,g}$ are respectively the vegetation and ground band-EM on channel *i* and FVC is the fractional vegetation cover.

Estimation of emissivity involves both static and dynamical information. The International Geosphere Biosphere Programme (IGBP) conventional land cover classification was adopted and consists of a global classification with 17 classes. However, the MODIS land cover product may be used as an alternative. The MODIS product identifies the same 17 IGBP classes and is available four times per year, allowing taking into account the annual changes in land cover.

Changes on emissivity pixel values for SEVIRI channels are mostly driven by LSA SAF SEVIRI-based FVC product. The emissivity values used for AVHRR channels make use of an identical procedure, however these will remain static until the AVHRR FVC product is implemented. Dynamic information on snow cover, provided by cloud mask (NWC SAF) and by the H-SAF snow cover products, is crucial to insure a correct estimation of emissivity in pixels covered by snow. Dynamic information on snow cover is provided for both sensors (AVHRR/Metop and SEVIRI/MSG).

Information on emissivity data was obtained from John Hopkins University (JHU) spectral reflectance library and from the Moderate Resolution Imaging Spectrometer – University of California, Santa Barbara (MODIS-UCBS) spectral reflectance library. Both libraries provide reflectance measurements for a wide range of natural and manmade materials. As described in Peres and DaCamara (2005), the assignment of laboratory measurements to IGBP surface types was performed using about 50 surface materials that were individually used or combined in order to characterise the 17 IGBP land cover classes. Combination of vegetation and ground types for the 17 IGBP classes is based on a land cover class description that was adapted from Belward and Loveland (1996). It is worth noting that Permanent Wetlands, Snow and Ice and Water are the only classes that remain unchanged with respect to changes in surface vegetation. Pixels identified as covered by snow and ice will have its original class changed to snow and ice classes. A thoroughly assessment of EM uncertainties associated to the VCM under use at the LSA SAF, and impacts on the LST product are described in Trigo et al. (2008) and in Freitas et al. (2009).

2.3.2 Generalised Split-Windows

Split-window methods for deriving SST in clear sky conditions have proven to be very efficient and are operational at NOAA. However, the application of split-window methods over land implies the a priori knowledge of surface spectral emissivity. In addition, the vertical structure of boundary layer is more complex over land than over water and in particular the near surface air temperature over land may be very different from LST. Becker and Li (1990b) have shown that it is theoretically possible to extend split-window methods to retrieve LST when the surface temperature is expressed as a linear combination of the brightness temperatures measured in two adjacent channels using coefficients that depend on spectral emissivities but not on atmospheric conditions. Based on Becker and Li's (1990b) local split-window algorithm, Wan and Dozier (1996) proposed a viewing angle dependent split-window algorithm to derive LST from AVHRR and MODIS data that has been adapted to SEVIRI and AVHRR-3 data (Madeira, 2002; Freitas et al., 2010). LST (T_s), is obtained from the following equation:

$$T_s = (A_1 + A_2 \frac{1-\varepsilon}{\varepsilon} + A_3 \frac{\Delta\varepsilon}{\varepsilon^2}) \frac{T_{10.8} + T_{12.0}}{2} + (B_1 + B_2 \frac{1-\varepsilon}{\varepsilon} + B_3 \frac{\Delta\varepsilon}{\varepsilon^2}) \frac{T_{10.8} - T_{12.0}}{2} + C \qquad (2)$$

where $T_{10.8}$ ($\varepsilon_{10.8}$) and $T_{12.0}$ ($\varepsilon_{12.0}$) are the brightness temperatures (emissivities) of 10.8 and 12.0 µm MSG/SEVIRI infrared channels respectively; $\varepsilon = 0.5(\varepsilon_{10.8} + \varepsilon_{12.0})$ and $\Delta\varepsilon = \varepsilon_{10.8} - \varepsilon_{12.0}$. The same algorithm is applied to AVHRR/Metop LST, where $T_{10.8}$ $(\varepsilon_{10.8})$ and $T_{12.0}$ ($\varepsilon_{12.0}$) correspond to channel 4 and channel 5 brightness temperatures (emissivities), respectively.

The first step of the GSW algorithm (Figure 2) is the definition of ranges to be considered in the GSW development. These ranges must be wide enough to cover the observed range of atmospheric properties, surface temperature, surface emissivity and sensor viewing angles (Martins et al, 2016). Accordingly, accurate atmospheric radiative simulations using MODTRAN4 (Berk et *al*., 2000) were performed as described below.

The simulations are performed for the database of global profiles of temperature, moisture, and ozone compiled by Borbas et al. (2005) for clear sky conditions, and referred to as SeeBor. The database contains over 15,700 profiles taken from other datasets, such as NOAA88 (Seemann et al, 2003), TIGR-like (Chevallier et al., 2000), and TIGR (Chedin et al., 1985), that are representative of a wide range of atmospheric (clear sky) conditions over the whole globe. In addition, surface parameters such as skin temperatures (Tskin) and a landcover classification within the International

Geosphere-Biosphere Programme ecosystem categories (IGBP; Belward, 1996) are assigned to each profile. Skin temperature over land surfaces corresponds to LST in SeeBor and is estimated as a function of 2m temperature (T2m), and solar zenith and azimuth angles (Borbas et al., 2005). The SeeBor database described above was split into two subsets – one used for the calibration of the LST GSW, and an independent one used for verification of the fitted algorithm. The criteria to build the calibration databases for SEVIRI and for AVHRR LST algorithms are described in the respective ATBD (ATBD_MLST and ATBD_ELST).

The second step (Figure 2) consists of computing the optimal GSW coefficients by separating the ranges of atmospheric water vapour column, tropospheric temperature and the surface temperature (daytime and night time) into tractable sub-ranges. The coefficients were determined by means of separate regression analysis performed on the simulated data in each range for individual viewing angles (see e.g., Martins et al., 2016).

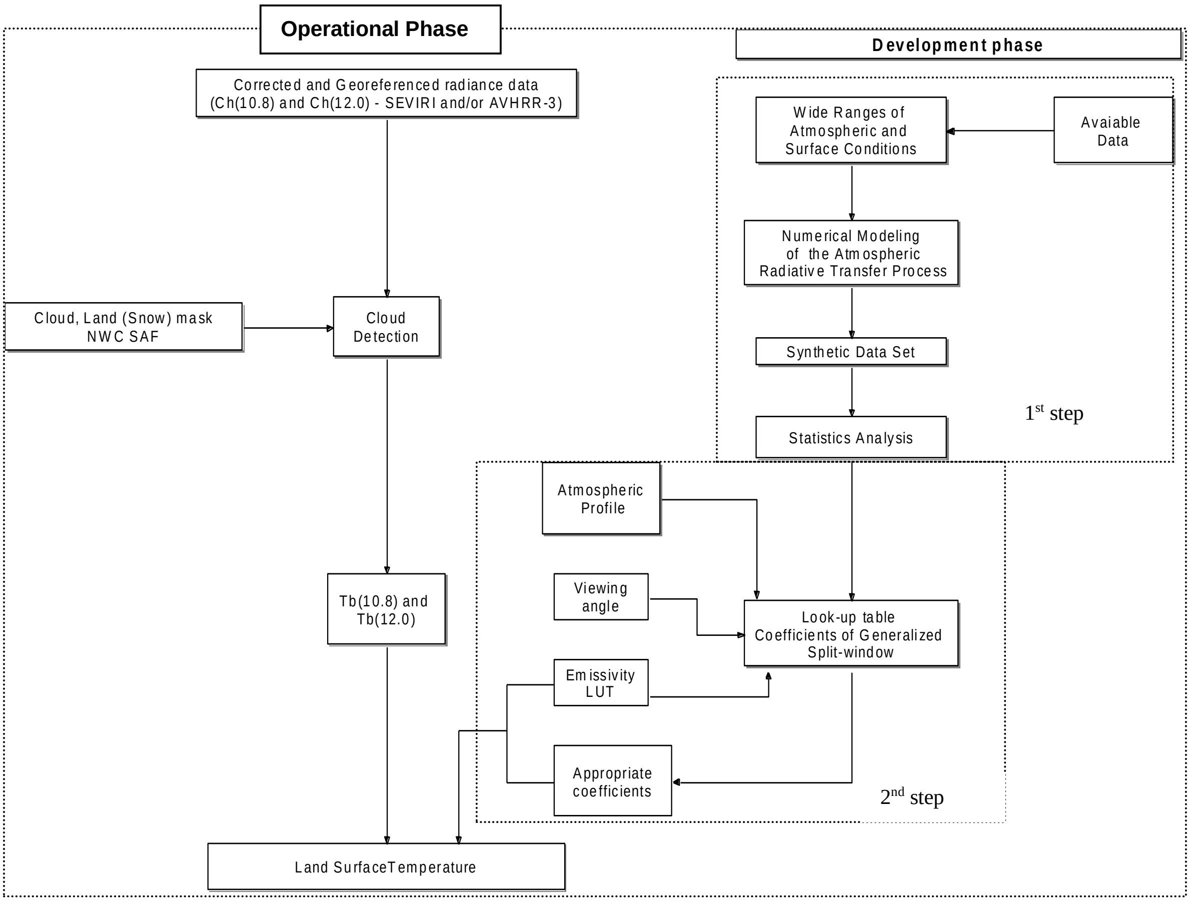

Figure 2 - Flow diagram of the GSW.

The MODTRAN4 simulations of top-of-atmosphere (TOA) brightness temperatures were performed for split-windows channels available from SEVIRI/MSG and AVHRR-3/MetOp, using the respective response functions. These simulations allowed the estimation of two different LUT for the GSW algorithm – LUT_SEVIRI and LUT_AVHRR – that are then used in the SEVIRI/MSG and AVHRR/MetOp processing chains, respectively.

2.4 Error Budget Estimates

The Land-SAF LST products (both derived from SEVIRI/Meteosat and AVHRR/MetOp) are distributed to users along with a quality flag and an uncertainty (or error bar) estimated on a pixel-by-pixel basis. The computation of LST uncertainty takes into account the uncertainties of the generalized split-window algorithm, which heavily depend on the total optical path between the sensor and the surface, essentially determined by the viewing geometry and the total water vapour content in the atmosphere. On top of that, LST uncertainty estimates consider the propagation of input errors, namely: (i) sensor noise; (ii) uncertainties in surface emissivity; and (iii) expected forecast errors in total column water vapour.
A detailed analysis of error statistics may be found in the ATBD_MLST (http:/landsaf.ipma.pt) or in Freitas et al. (2010), in the case of SEVIRI-based LST. As an example, Figure 3 summarizes the distribution of LST uncertainties within four classes of atmospheric water vapour. The analysis of the uncertainty in AVHRR/Metop LST may be found in the ATBD_ELST.

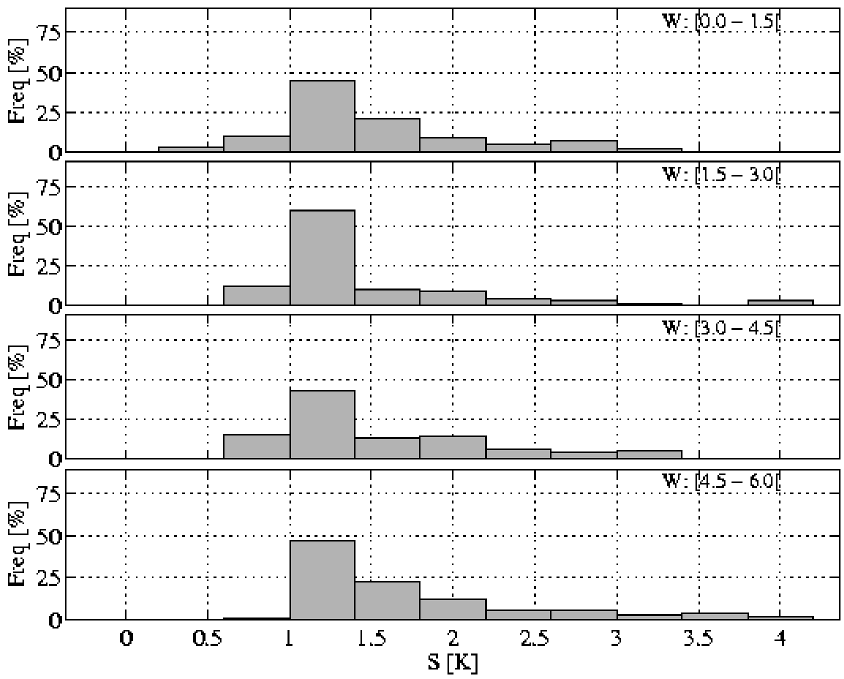

Figure 3 - Histograms of LST uncertainties [K] taking into account algorithm uncertainties and propagation of input errors. The results are displayed by four classes of total column water vapour, from top to bottom: < 1.5cm; 1.5 – 3.0 cm; 3.0 – 4.5 cm; and ≥ 4.5 cm.

2.5 10-daily LST Synthesis: The DLST product (LSA-003)

The LSA SAF DLST product provides a synthesis of the daily cycle, which is captured by SEVIRI 15-minute LST product (LSA-001), over 10-day periods. Users are offered the following options for 10-daily LST composites:

(i) Maximum and Median LST (LSA-003A) within the compositing period of 10 days, per time-slot, leading to a maximum/median value every 15 minutes.

(ii) Thermal Surface Parameters 'TSP' (LSA-003B) that summarize maximum and median diurnal temperature cycles given by the LSA-003A products (Göttsche and Olesen, 2009).

The latter assumes that the diurnal cycle of LST under clear sky conditions may be described by the following model:

$$\begin{aligned} T_1(\theta) &= T_0 + T_a \cdot \cos(\theta_z) \cdot \frac{e^{\tau(m_{\min} - m(\theta_z))}}{\cos(\theta_{z,\min})} & \theta < \theta_s \\ T_2(\theta) &= (T_0 + \delta T) + \left[T_a \cdot \cos(\theta_{zs}) \cdot \frac{e^{\tau(m_{\min} - m(\theta_{zs}))}}{\cos(\theta_{z,\min})} - \delta T \right] \cdot e^{\frac{-12h}{\pi k}(\theta - \theta_s)} & \theta \geq \theta_s \end{aligned} \quad (3)$$

Where T_1 and T_2 correspond to LST during the daytime and night-time part of the diurnal cycle, respectively; θ and θ_s are the hour angles w.r.t. thermal noon at times t and t_s, respectively, while θ_z and θ_{zs} are the corresponding solar zenith angles. The smallest zenith angle $\theta_{z,min}$ occurs at hour angle $\theta = 0$ when the modelled LST reaches its maximum T_{max}. m is a function describing the relative air mass. The model parameters are presented in Figure 4 and identified in Table 4. Further details on the TSP algorithm are provided in the LSA SAF DLST (LSA-003) ATBD and in (Göttsche and Olesen, 2009).

Table 4 - Thermal Surface Parameters (TSP) included in product LSA-003B.

Parameter (eq. 3)	**Identification in LSA-003B**	**Meaning**
T_o [°C]	T0	minimum temperature
T_a [°C]	Ta	temperature amplitude $(= T_{max} - T_0)$
t_m [solar time]	tmax	time of the maximum
t_s [solar time]	tdec	start of the attenuation function
δT [°C]	dT	$T_o - T(t \rightarrow \infty)$, where t is time
k [hh:mm]	att	attenuation constant (via continuity constraint)
τ [–]	tot	total optical thickness (TOT)

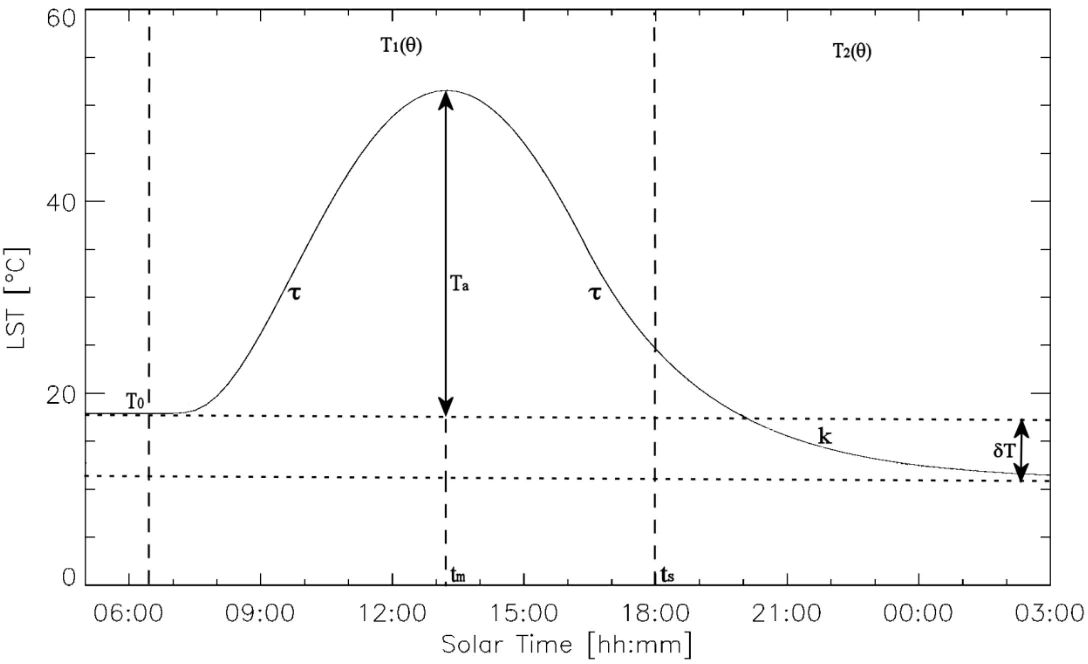

Figure 4 Model parameters and fit of the DTC model (solid line, eq. (3)) to sample LST (data omitted for clarity). The "daytime" part T1 (sunrise to start of attenuation function at ts) and the "night-time" part T2 (ts to end, here 03:00h) of the model is indicated by broken vertical lines

Individual median and maximum composite LST have the same uncertainty as the input MLST (LST-001), since they represent single (or two) MLST values. Assuming that the DTC model correctly describes the thermal behaviour of the land surface and a random scatter of composite LSTs around their true values, the simultaneous fitting of a time series of LST composites will reduce uncertainty considerably, similar to averaging. However, this improvement in uncertainty is difficult to quantify, since 'true' maximum and median LST at any given time are usually unknown.

3 Data Description - SEVIRI/Meteosat LST Products: NRT LSA-001 (MLST) and CDR LSA-050 (MLST-R)

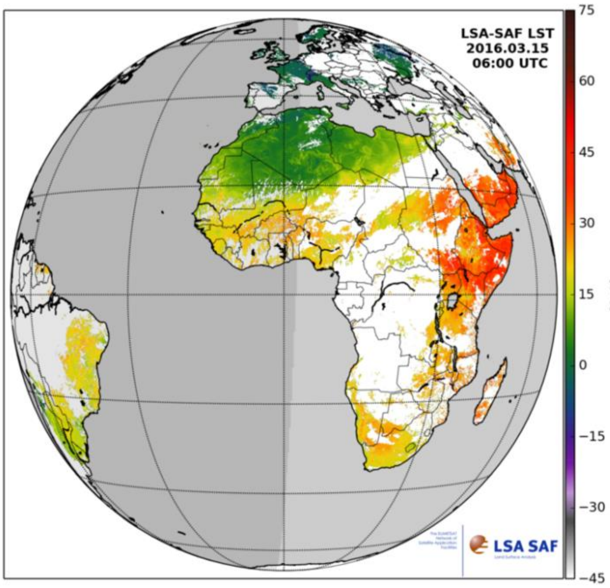

Figure 5 SEVIRI LSA SAF LST Product LSA-001.

3.1 Overview – SEVIRI Near Real Time LST (MLST) Product LSA-001

The LSA SAF SEVIRI/MSG chain processes the whole SEVIRI disk, although products distributed via EUMETCast are available for the four geographical areas, described in Table 5 (and in Figure 1). The projection and spatial resolution correspond to the characteristics of Level 1.5 MSG/SEVIRI instrument data. Information on geo-location and data distribution is available at the LSA SAF website:
http://lsa-saf.eumetsat.int.
Data users have access to the following data:

- A dataset containing the LST field;
- A quality control information field;
- A dataset containing the LST uncertainty estimates.

The data are coded in HDF5 format. The HDF5 files in LSA SAF system have the following structure:

- A common set of attributes for all kind of data, containing general information about the data (including metadata compliant with U-MARF/EUMETSAT Data Centre requirements);
- A dataset for the parameter values;
- A dataset for error values
- Additional datasets for metadata (e.g., quality flags).

Table 5 - Characteristics of the four LSA SAF geographical areas: Each region is defined by the corners position relative to an MSG image of 3712 columns per 3712 lines, starting from North to South and from West to East.

Region Name	Description	Initial Column	Final Column	Initial Line	Final Line	Size in Columns	Size in Lines	Total Number of Pixels
Euro	Europe	1550	3250	50	700	1701	651	1.107.351
NAfr	Northern Africa	1240	3450	700	1850	2211	1151	2.544.861
SAfr	Southern Africa	2140	3350	1850	3040	1211	1191	1.442.301
SAme	Southern America	40	740	1460	2970	701	1511	1.059.211
MSG-Disk	Full earth disk observed by MSG	1	3712	1	3712	3712	3712	13.788.944

3.2 Overview – SEVIRI Climate Data Record LST (MLST-R) Product LSA-050

The LSA SAF SEVIRI/MSG LST Climate Data Record (MLST-R) is processed for the whole disk following the algorithm developed for the NRT product (LSA-001) and covers the 2004-2015 period, i.e., all available SEVIRI level 1.5 data. More specifically, the LSA-050 product is available every 15 minutes, for the following period:

- Start Date: 21/01/2004, nominal time 10:00 UTC
- End Date: 31/12/2015, nominal time 23:45 UTC

From that period onwards, users may consider using the NRT LST product (LSA-001) to complete the dataset, as the same algorithm is used in both cases.

The data are available via the LSA-SAF web site (http://lsa-saf.eumetsat.int) for the full disk – "MSG-Disk" in Table 5. Requests and enquires may be made by email to the LSA-SAF helpdesk, helpdesk.landsaf@ipma.pt.

As in the case of LSA-050 product, users have access to the following data:

- A dataset containing the LST field;
- A quality control information field;
- A dataset containing the LST uncertainty estimates.

The data are coded in HDF5 format. The HDF5 files in LSA SAF system have the following structure:

- A common set of attributes for all kind of data, containing general information about the data (including metadata compliant with U-MARF/EUMETSAT Data Centre requirements);
- A dataset for the parameter values;
- A dataset for error values
- Additional datasets for metadata (e.g., quality flags).

3.3 Geolocation / Rectification

The **LST** SEVIRI-based fields are generated pixel-by-pixel, maintaining the original resolution of SEVIRI level 1.5 data. These correspond to rectified images to 0º longitude, which present a typical geo-reference uncertainty of about 1/3 of a pixel. Data are kept in the native geostationary projection.

Files containing the latitude and longitude of the centre of each pixel may be downloaded from the LSA-SAF website (http://lsa-saf.eumetsat.int; under “Static Data and Tools”):

Longitude

HDF5_LSASAF_MSG_LON_MSG-Disk_.bz2
HDF5_LSASAF_MSG_LON_Euro_200512201600.bz2
HDF5_LSASAF_MSG_LON_NAfr_200505191503.bz2
HDF5_LSASAF_MSG_LON_SAfr_200505191525.bz2
HDF5_LSASAF_MSG_LON_SAme_200505191527.bz2

Latitude

HDF5_LSASAF_MSG_LAT_MSG-Disk_.bz2
HDF5_LSASAF_MSG_LAT_Euro_200512201600.bz2
HDF5_LSASAF_MSG_LAT_NAfr_200505191503.bz2
HDF5_LSASAF_MSG_LAT_SAfr_200505191525.bz2
HDF5_LSASAF_MSG_LAT_SAme_200505191527.bz2

Alternatively, since the data are in the native geostationary projection, centred at 0º longitude and with a sampling distance of 3 km at the sub-satellite point, the latitude and longitude of any pixel may be easily estimated. Given the pixel column number, *ncol* (where *ncol*=1 correspond to the westernmost column of the file), and line number, *nlin* (where *nlin*=1 correspond to the northernmost line), the coordinates of the pixel may be estimated as follows:

$$lon = arctg\left(\frac{s_2}{s_1}\right) + sub\_lon$$ longitude (deg) of pixel centre

$$lat = arctg\left(p_2 \cdot \frac{s_3}{s_{xy}}\right);$$ latitude (deg) of pixel centre

where

sub_lon is the sub-satellite point ($sub\_lon = 0$)

and

$$s_1 = p_1 - s_n \cdot \cos x \cdot \cos y$$

$$s_2 = s_n \cdot \sin x \cdot \cos y$$

$$s_3 = -s_n \cdot \sin y$$

$$s_{xy} = \sqrt{s_1^2 + s_2^2}$$

$$s_d = \sqrt{(p_1 \cdot \cos x \cdot \cos y)^2 - (\cos^2 y + p_2 \cdot \sin^2 y) \cdot p_3}$$

$$s_n = \frac{p_1 \cdot \cos x \cdot \cos y - s_d}{\cos^2 y + p_2 \cdot \sin^2 y}$$

where

$$x = \frac{ncol - COFF}{2^{-16} \cdot CFAC}$$ (in Degrees)

$$y = \frac{nlin - LOFF}{2^{-16} \cdot LFAC}$$ (in Degrees)

$$p_1 = 42164$$

$$p_2 = 1.006803$$

$$p_3 = 1737121856$$

$$CFAC = 13642337$$

$$\mathrm{LFAC} = 13642337$$

The CFAC and LFAC coefficients are column and line scaling factors which depend on the specific segmentation approach of the input SEVIRI data. Finally, COFF and LOFF are coefficients depending on the location of each Land-SAF geographical area within the Meteosat disk. These are included in the file metadata (HDF5 attributes; see document annexes per LST product), and correspond to one set of the values detailed below per SEVIRI/MSG area:

Table 6 Maximum values for number of columns (ncol) and lines (nlin), for each Land-SAF geographical area, and the respective COFF and LOFF coefficients needed to geo-locate the data.

Region Name	**Description**	**Maximum *ncol***	**Maximum *nlin***	**COFF**	**LOFF**
MSG-Disk	Full MSG Disk	3712	3712	1857	1857
Euro	Europe	1701	651	308	1808
NAfr	Northern Africa	2211	1151	618	1158
SAfr	Southern Africa	1211	1191	-282	8
SAme	Southern America	701	1511	1818	398

3.4 File Formats – SEVIRI NRT and CDR LST Products (LSA-001 and LSA-050)

At each time step the LST algorithm generates an external output file according to the following name convention valid for both, the NRT and CDR versions:

HDF5_LSASAF_MSG_LST_<Area>_YYYYMMDDHHMM

where **<Area>**, **YYYY**, **MM**, **DD**, **HH** and **MM** respectively, denote the geographical region (see Table 5), the year, the month, the day, the hour and the minute of data acquisition.

The LSA SAF products are provided in HDF5 format developed by the National Center for Supercomputing Applications (NCSA) at the University of Illinois. A comprehensive description and libraries for handling HDF5-files in Fortran and C are available at https://www.hdfgroup.org/.
A user friendly graphical interface to open and view HDF5-files may be downloaded from https://www.hdfgroup.org/products/java/hdfview/index.html.

The HDF5-format allows defining a set of attributes that provide the relevant information. As described in the Appendix A the LST product information includes the general attributes (Table A1), the dataset attributes (Table A2) and the quality flag attributes (Table A 3). Within the HDF5-files the information is organised in the form of separate datasets.

3.5 Product Contents – SEVIRI NRT and CDR LST Products (LSA-001 and LSA-050)

The LST product file contains two datasets containing the values and the respective quality flags. Table 6 and Table 7 show the contents of the LST product file and QC information, respectively. Detailed information is given in Annexes A and E.

Table 7 - Contents of the LST/SEVIRI product file.

Parameter	Dataset Name	Unit	Range	Variable Type	Scale Factor
Land Surface Temperature	LST	ºC	[-80, +70]	2 Byte Signed Integer	100
Quality Flag	Q_FLAGS	1	[0,14238]	2 Byte unsigned Integer	1
Land Surface Temperature Error	errorbar_LST	ºC	≥ 0	2 Byte Signed Integer	100

Table 8 - Description of LST/SEVIRI QC information.

Binary Value	Decimal Value	Description
000	0	Sea Pixel
0100	4	Corrupted Pixel
0001100	12	CMa - pixel non processed
0101100	44	CMa - pixel contaminated by clouds
0111100	60	CMa - Cloud filled
1001100	76	CMa - contaminated by snow/ice
1011100	92	CMa – Undefined
000011100	28	Emissivity Information Missing
0010011100	156	Viewing Angle Out of Range (EM Poor)
0100011100	284	Viewing Angle Out of Range (EM Nominal)
0110011100	412	Viewing Angle Out of Range (EM Excellent)
01010011100	668	cwv information missing
01100011100	796	cwv information missing
01110011100	924	cwv information missing
01011010011110	5790	Below Nominal (+ EM below nominal)
01011100011110	5918	Below Nominal (+ EM nominal)
01011110011110	6046	Below Nominal (+ EM above nominal)
10011100011110	10014	Nominal (EM nominal)
10011110011110	10142	Nominal (EM above nominal)
11011110011110	14238	Above Nominal (EM above nominal)
10111110011110	12190	pixel with GSW-RMSE > 4 k

3.6 Summary of Product Characteristics – SEVIRI NRT and CDR LST Products (LSA-001 and LSA-050)

Product Name: Land Surface Temperature

Product Code: LST

Product Level: Level 2

Description of Product: Land Surface Temperature

Product Parameters:

Coverage: MSG full disk (Land pixels)

Packaging: Euro; NAfr; SAfr; SAme; MSG-Disk

Units: ºC

Range: -80ºC - +70ºC

Sampling: pixel by pixel basis

Resolution:	Temperature: hundreds of ºC
	Spatial: MSG full resolution (3km×3km at nadir)
Accuracy:	<2ºC
Geo-location Requirements:	
Format:	16 bits signed integer
Appended Data:	Quality control information (16 bits integer)
Frequency of generation:	every 15 min
Size of Product:	

Additional Information:

Identification of bands used in algorithm:

MSG IR10.8 (Channel 9)

MSG IR12.0 (Channel 10)

Assumptions on SEVIRI input data:

Calibration

Identification of ancillary and auxiliary data:

SEVIRI viewing angle (from EUMETSAT)
Pixel latitude and longitude (from EUMETSAT)
Cloud Mask (from NWC SAF)
Land-sea mask

4 Data Description – Derived LST Composite Product LSA-003 (DLST)

4.1 Overview – Derived LST Composite (DLST) Product LSA-003

The LSA SAF SEVIRI/MSG chain processes the full MSG/SEVIRI disk area shown in Figure 1. The projection and spatial resolution correspond to the characteristics of Level 1.5 MSG/SEVIRI instrument data. Information on geo-location and data distribution is available at the LSA SAF website: http://landsaf.ipma.pt.
Maximum and median decadal LST composites are generated, together with respective Thermal Surface Parameters (TSP). The LSA-003 product provides the information to users described below.

Maximum LST composites per time-slot (96 files per 10-day compositing period) containing the following data:

- a maximum LST field
- a field with the number of valid LST
- a field with the respective LST error estimate
- a field with the respective LST quality control information

Median LST composites per time-slot (96 files per 10-day compositing period containing the following data:

- a median LST field
- a field with the number of valid LST
- a field with the respective LST error estimate

TSP adjusted to the *Maximum* LST composites (1 file per 10-day compositing period) containing the following data:

- 7 fields containing the TSP (see Table 4)
- a field containing the maximum modelling error estimate
- a field containing the mean modelling error estimate
- a field with quality control information for the model fit

TSP adjusted to the *Median* LST composites (1 file per 10-day compositing period) containing the following data:

- 7 fields containing the TSP (see Table 4)
- a field containing the maximum modelling error estimate
- a field containing the mean modelling error estimate
- a field with quality control information for the model fit

The data are coded in HDF5 format. The HDF5 files in LSA SAF system have the following structure:

- A common set of attributes for all kind of data, containing general information about the data (including metadata compliant with U-MARF requirements)
- A dataset for the parameter values
- A dataset for error values
- Additional datasets for metadata (e.g., quality flags).

4.2 Geolocation / Rectification

The LSA-003 products are available at the SEVIRI geostationary projection – please see section 3.3 of this document.

4.3 File Formats – Derived LST Composite: LSA-003 (DLST)

When the Maximum or Median DLST algorithm is called at the end of the acquisition period (10 days), it generates 96 external output files according to the following name convention:

HDF5_LSASAF_MSG_DLST-<Composite>10D_MSG-Disk_YYYYMMDDHHMM

where **<Composite>**, **YYYY**, **MM**, **DD**, **HH** and **MM** denote the type of composite ("MAX" or "MED"), the year, the month, the day, the hour and the minute of the product. Files following this naming convention correspond to LSA-003A products.

Additionally, or alternatively, users may access the Thermal Surface Parameters adjusted to the maximum and median LST composites (LSA-003A). In this case, the LSA SAF system generates 1 file per compositing period, for each composite type:

HDF5_LSASAF_MSG_DLST-TSP<Composite>10D _MSG-Disk_201701010000

where **<Composite>**, **YYYY**, **MM**, **DD**, **HH** and **MM** denote again the type of composite ("MAX" or "MED"), the year, the month, the day, the hour and the minute of the product. Files following this naming convention correspond to LSA-003B products.

The LSA SAF products are provided in HDF5 format developed by the National Center for Supercomputing Applications (NCSA) at the University of Illinois. A comprehensive description and libraries for handling HDF5-files in Fortran and C are available at https://www.hdfgroup.org/.
A user friendly graphical interface to open and view HDF5-files may be downloaded from https://www.hdfgroup.org/products/java/hdfview/index.html.

The HDF5-format allows defining a set of attributes that provide the relevant information. As described in the Appendix A the LST product information includes the general attributes (Table A1), the dataset attributes (Table A2) and the quality flag attributes (Table A 3). Within the HDF5-files the information is organised in the form of separate datasets.

4.4 Product Contents – Derived LST Composite: LSA-003 (DLST)

The Maximum Decadal LST Composite product file contains two datasets with the values, one dataset with the number of valid LST in the compositing interval, and one dataset with the respective quality flags. Table 9 shows the contents of the Maximum DLST product. The quality flag information is identical to the one associated with the determined maximum MLST and therefore follows the description of LSA-001 product (see Table 8).

Table 9 - Contents of the maximum DLST composite product file.

Parameter	Dataset Name	Unit	Range	Variable Type	Scale Factor
Maximum Land Surface Temperature	LST_MAX	ºC	[-80, +70]	2 Byte Signed Integer	100
Number of Valid MLST values	NUM_VALID	1	[0, 11]	2 Byte Signed Integer	1
Quality Flag	Q_FLAGS	1	[0,14238]	2 Byte unsigned Integer	1
Land Surface Temperature Error	errorbar_LST	ºC	≥ 0	2 Byte Signed Integer	100

The Median Decadal LST Composite product file contains two datasets with the values and one dataset with the number of valid LST in the compositing interval (Table 10). No quality flag information is given since the determined median values may be associated with more than one MLST. Detailed information is given in Annexes B and E.

Table 10 - Contents of the median DLST composite product file.

Parameter	Dataset Name	Unit	Range	Variable Type	Scale Factor
Median Land Surface Temperature	LST_MED	ºC	[-80, +70]	2 Byte Signed Integer	100
Number of Valid MLST values	NUM_VALID	1	[0, 11]	2 Byte Signed Integer	1
Land Surface Temperature Error	errorbar_LST	ºC	≥ 0	2 Byte Signed Integer	100

TSP product files for Maximum and Median composites contain 10 datasets: 7 TSP fields plus the associated mean error, maximum error, and quality flags for the model fit. Table 11 and Table 12 show the contents of TSP product files (LSA-003B) and the meaning of the QC information (dataset 'qual'), respectively. Detailed information is given in Annex C.

Table 11 – Contents of the files with Thermal Surface Parameters (TSP) for Maximum and Median composites.

Parameter	Dataset Name	Unit	Range	Variable Type	Scale Factor
Minimum Temperature	T0	ºC	[-80, +70]	16-bit Integer	100
Temperature Amplitude	Ta	ºC	[+5, +50]	16-bit Integer	100
Attenuation constant	att	15 min , SEVIRI slot	[+0.5, +60]	16-bit Integer	100
Temperature Difference	dT	°C	[-150, +150] Typical: [-10, +10]	16-bit Integer	100
Maximum error	max_err	°C	[0, +70] Typical: [0, +20]	16-bit Integer	100
Mean error	mean_err	°C	[0, +70] Typical: [0, +5]	16-bit Integer	100
Quality Flag	qual	1	[0,192]	16-bit Integer	1
Start time of exponential decay (night)	tdec	15 min , SEVIRI slot	[>= 1] Typical: [50,90]	16-bit Integer	100
Time of maximum temperature	tmax	15 min , SEVIRI slot	[>=1] Typical: [30, 70]	16-bit Integer	100
Total optical thickness	tot	1	[0.01,2.0]	16-bit Integer	10000

Table 12 - Description of DLST TSP (LSA-003B) QC information in field 'qual'.

Binary Value	Decimal Value	Description
00000000	0	Result OK
00000001	1	No result: data unevenly distributed
00000010	2	No result: diurnal LST variation too small
00000100	4	No result: data gap too large
00001000	8	No result: too few data points
01000000	64	Warning: maximum number of iterations (10)
10000000	128	Invalid: singular matrix error

4.5 Summary of Product Characteristics – DLST Product (LSA-003)

Product Name:	Composite Derived Land Surface Temperature
Product Code:	COMDLST
Product Level:	Level 3
Description of Product**:**	Decadal maximum / median composite of MLST

Product Parameters:

Coverage:	MSG full disk (Land pixels)
Packaging:	MSG-Disk
Units:	ºC
Range:	-80ºC - +70ºC (Land Surface Temperature fields only)
Sampling:	pixel by pixel basis
Resolution:	Temperature: hundreds of ºC
	Spatial: MSG full resolution (3km×3km at nadir)
Accuracy:	<2ºC
Geo-location Requirements:	
Format:	16 bits signed integer
Appended Data:	Quality control information (16 bits integer)
Frequency of generation:	every 10 days
Size of Product:	

Product Name:	TSP Derived Land Surface Temperature
Product Code:	TSPDLST
Product Level:	Level 3
Description of Product:	Thermal Surface Parameters of DLST composites

Product Parameters:

Coverage:	MSG full disk (Land pixels)
Packaging:	Disk
Units:	ºC, time, unity
Range:	see Table 11
Sampling:	pixel by pixel basis
Resolution:	Fields with unit temperature: hundreds of ºC
	Fields with unit time: hundreds of a SEVIRI slot
	Total Optical Thickness: one ten thousands
	Spatial: MSG full resolution (3km×3km at nadir)
Accuracy:	Temperatures: <2ºC; Times: < 15 minutes
Geo-location Requirements:	
Format:	16 bits signed integer
Appended Data:	Quality control information (16 bits integer)
Frequency of generation:	every 10 days
Size of Product:	

Additional Information:

DLST are entirely based on (composited) MLST products: therefore, they share the same characteristics.

5 Data Description – AVHRR/Metop LST Product: LSA-002 (ELST)

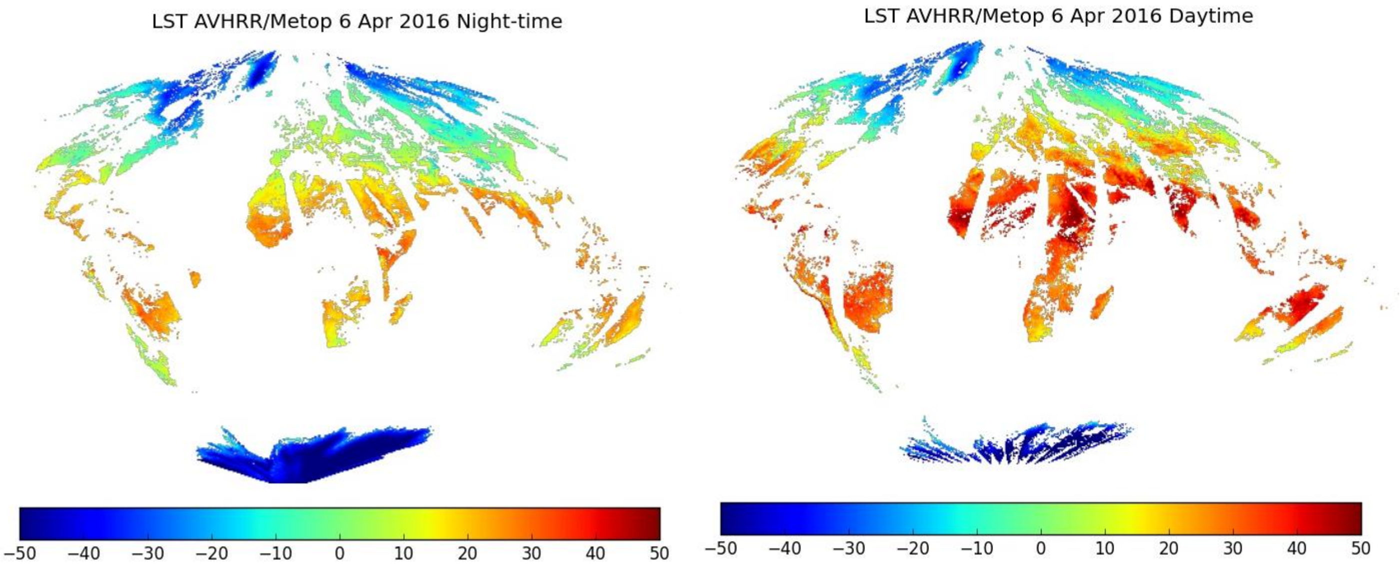

Figure 6 Metop LSA SAF Daily LST Product (ºC): an example of one daytime and night-time composite products estimated for AVHRR/Metop observations gathered on the 6 April 2016.

5.1 Overview – AVHRR LST

The LSA SAF AVHRR/Metop chain processes all Product Distribution Units (PDUs) at the LSA SAF processing centre, which correspond to about 3 minutes of instrument-specific observation data, then aggregate those PDUs in two half day datasets, day and night. The LST product is available in sinusoidal projection, centred at (0ºN,0ºW), with a resolution of 0.01º by 0.01º. Details on data distribution are available at the LSA SAF web-site: http://landsaf.ipma.pt.

Data users have access to the following data:

- LST field;
- quality control information field;
- sensor viewing angle
- Time of aquisition

The data are coded in HDF5 format. The HDF5 files in LSA SAF system have the following structure:

- A common set of attributes for all kind of data, containing general information about the data (including metadata compliant with U-MARF requirements);
- A dataset for the parameter values;
- Additional datasets for metadata (e.g., quality flags).

5.2 File Formats – AVHRR LST

The daily aggregated output files are named according to the following convention:

HDF5_LSASAF_<Satellite_name>-AVHR_EDLST_<Time>-GLOBE_YYYYMMDDhhmmss

where **<Satellite_name>, <Time>, YYYY**, **MM**, **DD**, **hh, mm** and **ss** respectively, denote satellite name (M01 or M02), day or night, the year, the month, the day, the hour, the minute of data acquisition.

The LSA SAF products are provided in HDF5 format developed by the National Center for Supercomputing Applications (NCSA) at the University of Illinois. A comprehensive description is available at http://hdf.ncsa.uiuc.edu/.

Libraries for handling HDF5-files in Fortran and C are available at http://hdf.ncsa.uiuc.edu/products/hdf5/. A user friendly graphical interface to open and view HDF5-files may also be downloaded from http://hdf.ncsa.uiuc.edu/products/hdf5/.

HDF5-format allows defining a set of attributes that provide the relevant information. As described in the Appendix A the LST product information includes the general attributes (Table B 1), the dataset attributes (Table B 2) and the quality flag attributes (Table B 3). Within the HDF5-files the information is organised in the form of separate datasets.

5.3 Product Contents – AVHRR LST

The LST product file contains four datasets containing the values and the respective quality flags. Table 13 and Table 14 show the contents of the LST product file and QC information, respectively. Detailed information is given in Annex D.

Table 13 - Contents of the LST/AVHRR product file.

Parameter	Dataset Name	Unit	Range	Variable Type	Scale Factor
Land Surface Temperature	LST	°C	[-80, +70]	2-Byte Signed Integer	100
Quality Flag	Q_Flag	1	[-4, 4]	1-Byte Signed Integer	1
Sensor viewing angle	VZA	°	[-90,90]	2-Byte Signed Integer	1
Time of aquisition	Aquisition_time	m	[1-1440]	2-Byte Signed Integer	1

Table 14 - Description of LST/AVHRR QC information.

Decimal Value	Description
-5	CMa - contaminated by snow/ice
-4	CMa - Cloud filled
-3	CMa - pixel contaminated by clouds
-2	Viewing Angle Out of Range
-1	Sea Pixel
0	Unprocessed pixel
1	Below Nominal
2	Nominal
3	Above Nominal

5.4 Summary of Product Characteristics – AVHRR LST

Product Name: Daily Land Surface Temperature

Product Code: EDLST

Product Level: Level 3

Description of Product**:** Land Surface Temperature

Product Parameters:

Coverage: Globe
Units: ºC

Range: -80ºC - +70ºC

Sampling: 0.01° by 0.01°

Resolution: Temperature: hundreds of ºC

Spatial: 0.01° by 0.01°

Target accuracy: <2ºC

Geo-location Requirements:

Format: 16 bits signed integer

Appended Data: Quality control information (8 bits integer)
sensor viewing angle (16 bits integer)
Time of acquisition (16 bits integer)

Frequency of generation: 1 day

Size of Product: ~150MB

Additional Information:

Identification of bands used in algorithm:

AVHRR/3 Channel 4

AVHRR/3 Channel 5

Assumptions on AVHRR input data:

Calibration

Identification of ancillary and auxiliary data:

Metop/AVHRR viewing and solar angle (from EUMETSAT)
Pixel latitude and longitude (from EUMETSAT)
Land-sea mask (from USGS-IGBP)
TCWV (from ECMWF)

6 Validation and Quality Control

The spectral capability of MSG-SEVIRI has the potential to provide LST with accuracy comparable to that from polar-orbiters like ENVISAT-AATSR, Terra-MODIS, or NOAA-AVHRR. The adopted strategy for validation of LST product consists in three main steps: 1) inter-comparison with other satellite derived LST products; 2) comparison with in situ measurements; 3) evaluation of errors in the main variables used as input for LST algorithm (e.g. ECMWF forecasts fields for 2m-temperature and total column water vapour). See the Work Plan Document for detailed information (SAF_Land_SVWP_v1.0.doc).

The Validation Reports (SAF_Land_IM_VR_LST) include the analysis inter-comparison of LST products derived from different sensor, namely the two LSA SAF products, LST/SEVIRI and LST/AVHRR, MODIS LST and AATSR LST. The validation of LSA SAF LST also includes the comparison with in-situ measurements, although these are relatively scarce within the Meteosat disk. The validation report for LST CDR also include comparisons with MODIS LST and ECMWF Tskin.

Automatic Quality Control (QC) is performed on LST data and the quality information is provided on a pixel basis. As shown in Annex EE LST QC contains general information about input data quality, specific information related with the limits of application and information about LST confidence level. The LST confidence level was defined based on the following parameters: viewing angle; atmospheric characteristics (i.e. surface temperature and column water vapour); EM confidence level. The three considered levels of confidence (i.e. above nominal, nominal and below nominal) correspond to estimated uncertainties on LST values (respectively less than 1K, between 1 and 2K and above 2K). Sensitivity studies have shown that the algorithm errors are larger for large viewing angles and for wet conditions; on the other hand the algorithm shows to be very sensitive to EM uncertainties for dry atmospheric conditions. Results from the validation exercise for LST CDR have shown that a stability requirement of 0.8 K/decade was achieved for all investigated areas (0.75º x 0.75º) considered, for both day and night match-ups and that the observed decadal trends obtained were generally not significant (at 5% significance level). Additional information related with the results obtained from the validation exercise are available in the Validations Reports (SAF_Land_IM_VR_LST).

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9 Glossary

AATSR:	Advanced Along Track Scanning Radiometer
ARM:	NASA Atmospheric Radiation Measurements Program
ASTER:	Advanced Spaceborne Thermal Emission and Reflection Radiometer
AVHRR:	Advanced Very High Resolution Radiometer
cwv:	column water vapour
ECMWF:	European Centre for Medium-Range Weather Forecasts
EM:	Land Surface Emissivity
EMAC:	European Multi-sensor Airborne Campaign
ENVISAT	Environmental Satellite
EOS:	Earth Observing System
EPS:	EUMETSAT Polar System
ESA:	European Space Agency
EUMETSAT:	European Meteorological Satellite Organisation
FIFE:	First ISLSCP Field Experiment
FOV	Field of View
FZK-IMK:	Forschungszentrum Karlsruhe – Insitut für Meteorologie und Klimaforschung (Germany)
GOES:	Geostationary Operational Environmental Satellite
GSW:	Generalized Split-Window
HAPEX:	Hydrological and Atmospheric Pilot Experiment in the Sahel
HDF	Hierarchical Data Format

HIRLAM:	High Resolution Limited Area Model
HIRS:	High Resolution Infrared Radiation Sounder
H-SAF:	Support to Operational Hydrology and Water Management SAF
ICAT:	Instituto de Ciência Aplicada e Tecnologia (Portugal)
IM:	Instituto de Meteorologia (Portugal)
IR:	Infrared Radiation
ISLSCP:	International Satellite Land Surface Climatology Project
LST:	Land Surface Temperature
LUT:	Look-Up Table
MAS:	Modis Airborne Simulator
METEOSAT:	Geostationary Meteorological Satellite
MODIS:	Moderate-Resolution Imaging Spectro-Radiometer
MODTRAN:	Moderate Resolution Transmittance Code
MSG:	Meteosat Second Generation
NASA:	National Air and Space Administration
NDVI:	Normalised Difference Vegetation Index
NE∆T:	Noise Equivalent Temperature
NIR	Near Infrared Radiation
NOAA:	National Oceanic and Atmospheric Administration (USA)
NWC:	NoWCasting SAF
NWP:	Numerical Weather Prediction
PRISM:	Process Research by Imaging Space Mission
QC:	Quality Control
rms:	root mean square
RSS:	Root Sum Square
SAF:	Satellite Application Facility
SEVIRI:	Spinning Enhanced Visible and InfraRed Imager
SPOT	Système Probatoire d'Observation de la Terre
SST:	Sea Surface Temperature
SURFRAD:	Surface Radiation Budget Network
TCWV:	Total Column Water Vapour
TIGR:	TOVS Initial Guess Retrieval
TIR:	Thermal Infrared
TIROS:	Television and Infrared Observation Satellite
TISI:	Temperature Independent Spectral Index
TOVS:	TIROS-N Operational Vertical Sounder
TSP:	Thermal Surface Parameter
TTM:	Two-Temperature Method
U-MARF	Unified Meteorological Archiving and Retrieval Facility
URD:	User Requirements Document
v-a:	viewing angle
VCM:	Vegetation Cover Method
VIS	Visible Radiation

Annex A. Product Metadata – SEVIRI LST

The following Tables describe the metadata distributed with each SEVIRI-based product, in the form of attributes included in the HDF5 format product files.
As for all LSA SAF products, both image acquisition time and slot time, indicated in the attributes of LST files, correspond to the time of observation of the first segment sensed by SEVIRI (or Metop) sensor. Information about the actual sensing time is given by the sensing start and sensing end times, which correspond to the sensing start / end for a given region. Such regions can be one of the four MSG geographical areas (section 3.3), or the global sinusoidal grid in the case of Metop derived parameters.

Table A 1 - General attributes of the files for the SEVIRI LST product.

Attribute	Allowed Values	Data Type
SAF	LSA	String<3>
CENTRE	IM-PT	String<5>
ARCHIVE_FACILITY	IM-PT	String<5>
PRODUCT	LST	String<79>
PARENT_PRODUCT_NAME	Cma, TCWV, Brightness Temperature	Array(4) of string<79>
SPECTRAL_CHANNEL_ID	768	Int
PRODUCT_ALGORITHM_VERSION	X.Y.Z	String<4>
CLOUD_COVERAGE	NWC-CMa,	String<20>
OVERALL_QUALITY_FLAG	OK or NOK	String<3>
ASSOCIATED_QUALITY_INFORMATION	-	String<511>
REGION_NAME	One of: Euro, NAfr, SAfr, Same, Disk	String<4>
COMPRESSION	0	Int
FIELD_TYPE	Product	String<255>
FORECAST_STEP	0	Int
NC	Depend on REGION_NAME	Int
NL	Depend on REGION_NAME	Int
NB_PARAMETERS	2	Int
NOMINAL PRODUCT_TIME	YYYYMMDDhhmmss	String<14>

SATELLITE	MSG*X*	Array[10] of String<9>
INSTRUMENT_ID	SEVI	Array [10] of String<6>
INSTRUMENT_MODE	STATIC_VIEW	String<511>
IMAGE_ACQUISITION_TIME	YYYYMMDDhhmmss	String<14>
ORBIT_TYPE	GEO	String<3>
PROJECTION_NAME	Geos<sub_lon>	String<15>
NOMINAL_LONG	Actual Satellite Nominal Longitude	Real
NOMINAL_LAT	Actual Satellite Nominal Latitude	Real
CFAC	13642337	Int
LFAC	13642337	Int
COFF	Depend on REGION_NAME	Int
LOFF	Depend on REGION_NAME	Int
START_ORBIT_NUMBER	0	Int
END_ORBIT_NUMBER	0	Int
SUB_SATELLITE_POINT_START_LAT	0.0	Real
SUB_SATELLITE_POINT_START_LON	0.0	Real
SUB_SATELLITE_POINT_END_LAT	0.0	Real
SUB_SATELLITE_POINT_END_LON	0.0	Real
SENSING_START_TIME	YYYYMMDDhhmmss	String<14>
SENSING_END_TIME	YYYYMMDDhhmmss	String<14>
PIXEL_SIZE	3.1km	String<10>
GRANULE_TYPE	DP	String<2>
PROCESSING_LEVEL	02	String<2>
PRODUCT_TYPE	LSALST	String<8>
PRODUCT_ACTUAL_SIZE	Depends on the region	Integer > 0, encoded as String<11>
PROCESSING_MODE	N	String<1>
DISPOSITION_FLAG	O	String<1>
TIME_RANGE	15-min	String<20>

STATISTIC_TYPE	-	String<20>
MEAN_SSLAT	Depend on REGION_NAME	Real
MEAN_SSLON	Depend on REGION_NAME	Real
PLANNED_CHAN_PROCESSING	0	Integer
FIRST_LAT	0	Real
FIRST_LON	0	Real

Table A 2 - Attributes of the LST/SEVIRI dataset.

Attribute	Description	Data Type
CLASS	Data	String, length=4
PRODUCT	LST	String, length=3
PRODUCT_ID	235	32-bit integer
N_ COLS	Depend on REGION_NAME	32-bit integer
N_ LINES	Depend on REGION_NAME	32-bit integer
NB_BYTES	2	32-bit integer
SCALING_FACTOR	100.0	64-bit floating-point
OFFSET	0.0	64-bit floating-point
MISS_VALUE	-8000	32-bit integer
UNITS	Degrees Celsius	String, length=15
CAL_SLOPE	999.0	64-bit floating-point
CAL_OFFSET	999.0	64-bit floating-point

Table A 3 - Attributes of the LST/SEVIRI Quality Flag information dataset.

Attribute	Description	Data Type
CLASS	Data	String, length=4
PRODUCT	Q_FLAGS	String, length=7
PRODUCT_ID	999	32-bit integer
N_ COLS	Depend on REGION_NAME	32-bit integer
N_ LINES	Depend on REGION_NAME	32-bit integer
NB_BYTES	2	32-bit integer
SCALING_FACTOR	1.0	64-bit floating-point
OFFSET	0.0	64-bit floating-point
MISS_VALUE	-9999	32-bit integer
UNITS	Dimensionless	String, length=13
CAL_SLOPE	999.0	64-bit floating-point
CAL_OFFSET	999.0	64-bit floating-point

Annex B. Product Metadata – DLST Composites (LSA-003A)

Table B1 - General attributes of the files for the DLST LSA-003A product.

Attribute	Allowed Values	Data Type
SAF	LSA	String<3>
CENTRE	IM-PT	String<5>
ARCHIVE_FACILITY	IM-PT	String<5>
PRODUCT	MXT, MET	String<79>
PARENT_PRODUCT_NAME	LST, Cma,SC,ALB	Array(4) of string<79>
SPECTRAL_CHANNEL_ID	0	Int
PRODUCT_ALGORITHM_VERSION	1.1.0, 2.00	String<4>
CLOUD_COVERAGE	NWC-CMa	String<20>
OVERALL_QUALITY_FLAG	OK or NOK	String<3>
ASSOCIATED_QUALITY_INFORMATION	-	String<511>
REGION_NAME	MSG-Disk	String<4>
COMPRESSION	0	Int
FIELD_TYPE	Product	String<255>
FORECAST_STEP	0	Int
NC	3712	Int
NL	3712	Int
NB_PARAMETERS	4, 3	Int
NOMINAL PRODUCT_TIME	YYYYMMDDhhmmss	String<14>
SATELLITE	MSG*X*	Array[10] of String<9>
INSTRUMENT_ID	SEVI	Array [10] of String<6>
INSTRUMENT_MODE	STATIC_VIEW	String<511>
IMAGE_ACQUISITION_TIME	YYYYMMDDhhmmss	String<14>
ORBIT_TYPE	GEO	String<3>
PROJECTION_NAME	Geos<sub_lon>	String<15>
NOMINAL_LONG	Actual Satellite Nominal Longitude	Real
NOMINAL_LAT	Actual Satellite Nominal Latitude	Real
CFAC	13642337	Int
LFAC	13642337	Int

Attribute	Allowed Values	Data Type
COFF	1857	Int
LOFF	1857	Int
START_ORBIT_NUMBER	0	Int
END_ORBIT_NUMBER	0	Int
SUB_SATELLITE_POINT_START_LAT	0.0	Real
SUB_SATELLITE_POINT_START_LON	0.0	Real
SUB_SATELLITE_POINT_END_LAT	0.0	Real
SUB_SATELLITE_POINT_END_LON	0.0	Real
SENSING_START_TIME	YYYYMMDDhhmmss	String<14>
SENSING_END_TIME	YYYYMMDDhhmmss	String<14>
PIXEL_SIZE	3.1km	String<10>
GRANULE_TYPE	DP	String<2>
PROCESSING_LEVEL	03	String<2>
PRODUCT_TYPE	LSAMXT, LSAMET	String<8>
PRODUCT_ACTUAL_SIZE	Depends on data	Integer > 0, encoded as String<11>
PROCESSING_MODE	N	String<1>
DISPOSITION_FLAG	O	String<1>
TIME_RANGE	10-day	String<20>
STATISTIC_TYPE	-	String<20>
MEAN_SSLAT	0.0	Real
MEAN_SSLON	0.0	Real
PLANNED_CHAN_PROCESSING	0	Integer
FIRST_LAT	0	Real
FIRST_LON	0	Real

Table B 2 - Attributes of the DLST (LSA-003A) maximum temperature, median temperature, and LST errorbar datasets.

Attribute	Description	Data Type
CLASS	Data	String, length=4
PRODUCT	MXT, MET, ERL	String, length=3
PRODUCT_ID	999	32-bit integer
N_ COLS	3712	32-bit integer
N_ LINES	3712	32-bit integer
NB_BYTES	2	32-bit integer
SCALING_FACTOR	100.0	64-bit floating-point
OFFSET	0.0	64-bit floating-point
MISS_VALUE	-8000	32-bit integer
UNITS	Deg Celsius	String, length=15
CAL_SLOPE	999.0	64-bit floating-point
CAL_OFFSET	999.0	64-bit floating-point

Table B 3 - Attributes of the DLST (LSA-003A) number of valid LST dataset.

Attribute	Description	Data Type
CLASS	Data	String, length=4
PRODUCT	NUV	String, length=3
PRODUCT_ID	999	32-bit integer
N_ COLS	3712	32-bit integer
N_ LINES	3712	32-bit integer
NB_BYTES	2	32-bit integer
SCALING_FACTOR	1.0	64-bit floating-point
OFFSET	0.0	64-bit floating-point
MISS_VALUE	-8000	32-bit integer
UNITS	Counts	String, length=15
CAL_SLOPE	999.0	64-bit floating-point
CAL_OFFSET	999.0	64-bit floating-point

Table B 4 - Attributes of the DLST (LSA-003A) Quality Flag information dataset.

Attribute	Description	Data Type
CLASS	Data	String, length=4
PRODUCT	QFL	String, length=7
PRODUCT_ID	999	32-bit integer
N_ COLS	3712	32-bit integer
N_ LINES	3712	32-bit integer
NB_BYTES	2	32-bit integer
SCALING_FACTOR	1.0	64-bit floating-point
OFFSET	0.0	64-bit floating-point
MISS_VALUE	-9999	32-bit integer
UNITS	Dimensionless	String, length=13
CAL_SLOPE	999.0	64-bit floating-point
CAL_OFFSET	999.0	64-bit floating-point

Annex C. Product Metadata – DLST TSP (LSA-003B)

Table C 1 - General attributes of the files for the DLST TSP product.

Attribute	Allowed Values	Data Type
SAF	LSA	String<3>
CENTRE	IM-PT	String<5>
ARCHIVE_FACILITY	IM-PT	String<5>
PRODUCT	TSP	String<79>
PARENT_PRODUCT_NAME	LST, Cma, SC, Albedo	Array(4) of string<79>
SPECTRAL_CHANNEL_ID	0	Int
PRODUCT_ALGORITHM_VERSION	1.1.1	String<4>
CLOUD_COVERAGE	NWC-CMa,	String<20>
OVERALL_QUALITY_FLAG	OK or NOK	String<3>
ASSOCIATED_QUALITY_INFORMATION	-	String<511>
REGION_NAME	MSG-Disk	String<4>
COMPRESSION	0	Int
FIELD_TYPE	Product	String<255>
FORECAST_STEP	0	Int
NC	3712	Int
NL	3712	Int
NB_PARAMETERS	2	Int
NOMINAL PRODUCT_TIME	YYYYMMDDhhmmss	String<14>
SATELLITE	MSG*X*	Array[10] of String<9>
INSTRUMENT_ID	SEVI	Array [10] of String<6>
INSTRUMENT_MODE	STATIC_VIEW	String<511>
IMAGE_ACQUISITION_TIME	YYYYMMDDhhmmss	String<14>
ORBIT_TYPE	GEO	String<3>
PROJECTION_NAME	Geos<sub_lon>	String<15>
NOMINAL_LONG	Actual Satellite Nominal Longitude	Real
NOMINAL_LAT	Actual Satellite Nominal Latitude	Real
CFAC	13642337	Int
LFAC	13642337	Int

Attribute	Allowed Values	Data Type
COFF	1857	Int
LOFF	1857	Int
START_ORBIT_NUMBER	0	Int
END_ORBIT_NUMBER	0	Int
SUB_SATELLITE_POINT_START_LAT	0.0	Real
SUB_SATELLITE_POINT_START_LON	0.0	Real
SUB_SATELLITE_POINT_END_LAT	0.0	Real
SUB_SATELLITE_POINT_END_LON	0.0	Real
SENSING_START_TIME	YYYYMMDDhhmmss	String<14>
SENSING_END_TIME	N/A	String<14>
PIXEL_SIZE	3.1km	String<10>
GRANULE_TYPE	DP	String<2>
PROCESSING_LEVEL	03	String<2>
PRODUCT_TYPE	LSATSP	String<8>
PRODUCT_ACTUAL_SIZE	Depends on data	Integer > 0, encoded as String<11>
PROCESSING_MODE	N	String<1>
DISPOSITION_FLAG	O	String<1>
TIME_RANGE	1-day	String<20>
STATISTIC_TYPE	N/A	String<20>
MEAN_SSLAT	0.0	Real
MEAN_SSLON	0.0	Real
PLANNED_CHAN_PROCESSING	0	Integer
FIRST_LAT	0	Real
FIRST_LON	0	Real

Table C 2 - Attributes of the DLST TSP (LSA-003B) and the associated error and quality information datasets.

Attribute	Description	Data Type
CLASS	Data	String, length=4
PRODUCT	TSP	String, length=3
PRODUCT_ID	999	32-bit integer
N_ COLS	3712	32-bit integer
N_ LINES	3712	32-bit integer
NB_BYTES	2	32-bit integer
SCALING_FACTOR	1.0, 100.0, 10000.0	64-bit floating-point
OFFSET	0.0	64-bit floating-point
MISS_VALUE	0	32-bit integer
UNITS	Dimensionless, Degrees Celsius, Time	String, length=15
CAL_SLOPE	999.0	64-bit floating-point
CAL_OFFSET	999.0	64-bit floating-point

Annex D. Product Metadata – AVHRR LST

Table D 1 - General attributes of the files for the AVHRR LST product.

Attribute	Values	Data Type
SAF	LSA	String<3>
CENTRE	IM-PT	String<5>
ARCHIVE_FACILITY	IM-PT	String<5>
PRODUCT	LST	String<79>
PARENT_PRODUCT_NAME	Cma, TCWV, Brightness Temperature	Array(4) of string<79>
SPECTRAL_CHANNEL_ID	24	Int
PRODUCT_ALGORITHM_VERSION	X.Y.Z	String<5>
CLOUD_COVERAGE	NWC-CMa, …	String<20>
OVERALL_QUALITY_FLAG	OK or NOK	String<3>
ASSOCIATED_QUALITY_INFORMATION	-	String<511>
REGION_NAME	GLOBE	String<4>
COMPRESSION	9	Int
FIELD_TYPE	Product	String<255>
FORECAST_STEP	0	Int
NC	36000	Int
NL	18000	Int
NB_PARAMETERS	4	Int
NOMINAL PRODUCT_TIME	YYYYMMDDhhmmss	String<14>
SATELLITE	METOP*X*	Array[10] of String<9>
INSTRUMENT_ID	AVHR	Array [10] of String<6>
INSTRUMENT_MODE	NORMAL_VIEW	String<511>
IMAGE_ACQUISITION_TIME	YYYYMMDDhhmmss	String<14>
ORBIT_TYPE	LEO	String<3>
PROJECTION_NAME	-	String<15>
NOMINAL_LONG	0	Real
NOMINAL_LAT	0	Real
CFAC	0	Int
LFAC	0	Int

Attribute	Values	Data Type
COFF	0	Int
LOFF	0	Int
START_ORBIT_NUMBER	Depend on the orbit	Int
END_ORBIT_NUMBER	Depend on the orbit	Int
SENSING_START_TIME	YYYYMMDDhhmmss	String<14>
SENSING_END_TIME	YYYYMMDDhhmmss	String<14>
PIXEL_SIZE	1.1km	String<10>
GRANULE_TYPE	DP	String<2>
PROCESSING_LEVEL	02	String<2>
PRODUCT_TYPE	LSALST	String<8>
PRODUCT_ACTUAL_SIZE	8847360	Integer > 0, encoded as String<11>
PROCESSING_MODE	N	String<1>
DISPOSITION_FLAG	O	String<1>
TIME_RANGE	1-day	String<20>
STATISTIC_TYPE	-	String<20>
MEAN_SSLAT	0	Real
MEAN_SSLON	0	Real
PLANNED_CHAN_PROCESSING	0	Integer
FIRST_LAT	0	Real
FIRST_LON	0	Real

Table D 2 - Attributes of the LST/AVHRR dataset.

Attribute	Description	Data Type
CLASS	Data	String, length=4
PRODUCT	LST	String, length=3
PRODUCT_ID	235	32-bit integer
N_ COLS	360002048	32-bit integer
N_ LINES	180001080	32-bit integer
NB_BYTES	2	32-bit integer
SCALING_FACTOR	100.0	64-bit floating-point
OFFSET	0.0	64-bit floating-point
MISS_VALUE	-8000	32-bit integer
UNITS	Degrees Celsium	String, length=15
CAL_SLOPE	999.0	64-bit floating-point
CAL_OFFSET	999.0	64-bit floating-point

Table D 3 - Attributes of the LST/AVHRR Quality Flag information dataset.

Attribute	Description	Data Type
CLASS	Data	String, length=4
PRODUCT	Q_FLAGS	String, length=7
PRODUCT_ID	999	32-bit integer
N_ COLS	36000	32-bit integer
N_ LINES	18000	32-bit integer
NB_BYTES	1	32-bit integer
SCALING_FACTOR	1.0	64-bit floating-point
OFFSET	0.0	64-bit floating-point
MISS_VALUE	0	32-bit integer
UNITS	Dimensionless	String, length=13
CAL_SLOPE	999.0	64-bit floating-point
CAL_OFFSET	999.0	64-bit floating-point

Table D 4 - Attributes of the LST/AVHRR Sensor viewing angle dataset.

Attribute	Description	Data Type
CLASS	Data	String, length=4
PRODUCT	VZA	String, length=7
PRODUCT_ID	999	32-bit integer
N_ COLS	36000	32-bit integer
N_ LINES	18000	32-bit integer
NB_BYTES	2	32-bit integer
SCALING_FACTOR	1.0	64-bit floating-point
OFFSET	0.0	64-bit floating-point
MISS_VALUE	0	32-bit integer
UNITS	degrees	String, length=13
CAL_SLOPE	999.0	64-bit floating-point
CAL_OFFSET	999.0	64-bit floating-point

Table D 5 - Attributes of the LST/AVHRR time of acquisition dataset.

The values in the time of acquisition dataset are minutes counting from 00:00 GMT of the day of the product.

Attribute	Description	Data Type
CLASS	Data	String, length=4
PRODUCT	Acquisition_time	String, length=7
PRODUCT_ID	999	32-bit integer
N_ COLS	36000	32-bit integer
N_ LINES	18000	32-bit integer
NB_BYTES	2	32-bit integer
SCALING_FACTOR	1.0	64-bit floating-point

OFFSET	0.0	64-bit floating-point
MISS_VALUE	0	32-bit integer
UNITS	minutes	String, length=13
CAL_SLOPE	999.0	64-bit floating-point
CAL_OFFSET	999.0	64-bit floating-point

Annex E. LST Quality Control Information (SEVIRI LST products only)

Table E 1 – LST QC information.

Bit	Field	Category	Binary code	Description
00-01	Data quality	Unprocessed	00	Sea pixel Satellite Data Corrupted Cloud mask (unprocessed; cloud contaminated; cloud filled; snow/ice contaminated; undefined) Emissivity unprocessed Viewing-Angle out of GSW admissible limit TCWV out of GSW admissible limit
		Suspect	01	Pixel in neighbourhood of clouds
		Good	10	The pixel has no known effects
02-02	Land/Sea	Sea	0	
		Land	1	
03-03	Satellite Image [IR10.8 & IR12.0] or [ch 4 & ch 5]	Corrupted	0	
		Ok	1	
04-06	Cloud /Mask	Unprocessed	000	Pixel non processed
		Clear	001	Cloud free pixel
		Contaminated	010	Pixel contaminated by clouds
		Cloud filled	011	Pixel filled by clouds (covered by thick cloud)
		Snow/Ice	100	Pixel Contaminated by snow or ice
		Undefined	101	Not classified due to known separability problems
07-08	Emissivity	Unprocessed	00	
		>1.2%	01	Below nominal Quality
		0.6-1.2%	10	Nominal Quality
		<0.6%	11	Above nominal Quality
10-10	Total Column Water Vapour (TCWV)	Out of GSW Range	0	TCWV ≥ 6 cm
		Inside	1	0≤ TCWV < 6 cm
11-11	Reserved		0	
			0	
12-13	LST confidence Level	>2.0 C	01	Below Nominal performance
		1.0-2.0 C	10	Nominal Performance
		<1.0 C	11	Above Nominal Performance