The EUMETSAT Satellite Application Facility on Land Surface Analysis (LSA SAF)

Product User Manual

Down-welling Longwave Flux (DSLF)

PRODUCTS: LSA-204 (MDSLF), LSA-206 (DIDSLF)

The EUMETSAT Network of Satellite Application Facilities

LSA SAF
Land Surface Analysis

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Version 3.3	24/09/2010	Includes improved description of daily integration of DSLF (DIDSLF). Description of EPS DSLF (EDSLF) with new algorithm (Prata_modified), already introduced for MDSLF. The definition of nominal, sensing start and sensing end times is now clearer in Annexes B and C. Editorial changes.
Version 3.4	11/11/2015	Change coverage area of MSG products Change acronym IM -> IPMA Change version of applicable documents: PRDv2.8 Update distribution list Removed references to EDSLF

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1 Introduction

The EUMETSAT Satellite Application Facility (SAF) on Land Surface Analysis (LSA; Trigo et al., 2010) 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://landsaf.meteo.pt/).

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 3 km resolution (sampling distance) at nadir (1km for the high-resolution visible channel), and 12 spectral channels (Schmetz et al., 2002).

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 - Summary of LSA SAF operational or under-development products. Temporal resolution specifies the time interval to which the product applies.

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 generated for the full Meteosat disk. However the NRT dissemination via EUMETCast is made by splitting the full disk into 4 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.

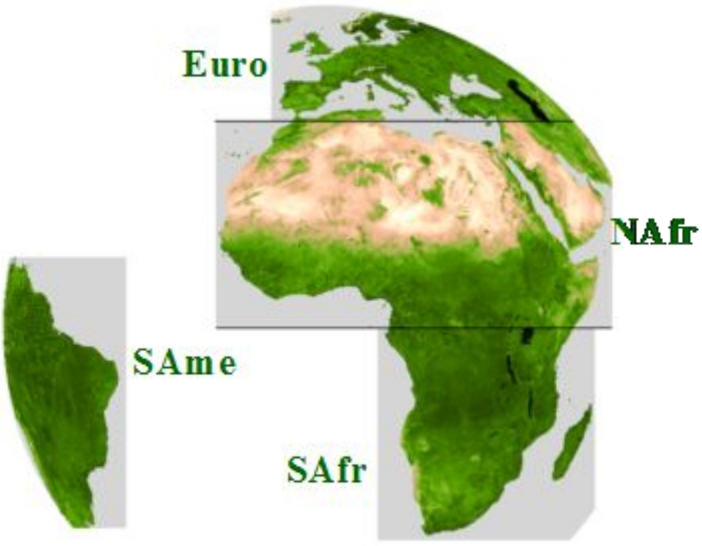

Figure 1 - The LSA SAF geographical areas for SEVIRI-based products.

Metop derived parameters are available at level 1b full spatial resolution and for the processed Product Distribution Units (PDUs), each corresponding to about 3 minutes of instrument-specific observation data. Composite and re-projected products shall also be available.

All LSA SAF products are validated regularly against ground measurements, model outputs, or similar parameters retrieved from other sensors, as appropriate. Furthermore, each retrieved value is distributed with a quality flag and/or error bar providing a qualitative/quantitative measure of the expected accuracy.

The LSA SAF products are currently available from LSA SAF website (http://landsaf.meteo.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 Down-welling Surface Long-wave radiative Flux (DSLF) generated by the LSA SAF from SEVIRI system are described in the following sections. The characteristics of SEVIRI based DSLF 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 (PRD) available at the LSA SAF website http://landsaf.meteo.pt).

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

DSLF Product	Product Identifier	Coverage	Resolution		Accuracy		
			Temporal	Spatial	Threshold	Target	Optimal
MDSLF: DSLF_SEVIRI	LSA-10	MSG disk	30 min	MSG pixel resolution	20%	10%	5%
DIDSLF: DSLF_SEVIRI_day	LSA-12	MSG disk	daily	MSG pixel resolution	20%	10%	5%

2 Algorithm

2.1 Overview

Downwelling Surface Longwave Radiation Flux (**DSLF**) is one of the most important components of the surface energy balance over land and can be defined as the thermal irradiance reaching the surface in the thermal infrared spectrum (4-100µm).

DSLF is directly related to the greenhouse effect and its monitoring has an important role in climate change studies (Philipona et al., 2001). Other applications include meteorology (land applications) and oceanography (air-sea-ice interaction studies).

DSLF is a particularly difficult parameter to retrieve since satellites can only provide an indirect measurement. However Radiative Transfer Models (RTM) may be used to estimate DSLF from atmospheric profiles (temperature and humidity). In the last decade several methods using satellite data have been developed to infer surface radiation budget components (*e.g.* Schmetz, 1989; Sellers, 1990).

Methods aiming to estimate surface fluxes from satellite data, with or without use of additional meteorological information, may be separated into different categories: empirical/statistical methods, physical methods and methods relying on a combined use of satellite data and NWP models (hybrid methods). Empirical methods are based on regressions between simultaneously measured radiances from satellite and surface fluxes (Fritz and Rao, 1967; Tarpley, 1979). Physical methods rely upon measured radiances at satellite and related fluxes to optical cloud properties using radiative transfer processes (Moser and Raschke, 1983). Hybrid methods use numerical weather forecast model outputs to obtain the atmospheric parameters as well as cloud parameters as inferred from satellite data (Schmetz, 1989 and Brisson *et al.*, 1994). Concerning the longwave domain, the physical and the hybrid methods, based on physical assumptions, are sensitive to the individual cloud types, their heights and optical thickness, as well as to the temperature and humidity profile in the atmosphere.

2.2 Physics of the Problem

DSLF is the result of atmospheric absorption, emission and scattering within the entire atmospheric column. In clear sky situations DSLF depends on vertical profiles of temperature and gaseous absorbers (primarily the water-vapour followed by CO_2, and others of smaller importance like O_3, CH_4, N_2O and CFCs). However, DSLF is determined by the radiation that originates from a shallow layer close to the surface, about one third being emitted by the lowest 10 meters and 80% by the 500-meter layer (Schmetz, 1989). The cloud contribution mainly occurs in the atmospheric window (8-13µm) and mainly depends on cloud base properties (height, temperature and emissivity).

Clear sky emissivity may be estimated from dew point temperature (Martin and Berdahl, 1984). Cloud sky emissivity may be estimated based on corrections of the clear sky emissivity if the fractional cloud cover and cloudbase temperatures are known. In general, the presence of clouds increases the total sky emissivity.

Clouds have a strong effect on the longwave radiation transfer because they modify the atmospheric emissivity at certain wavelengths. Clouds are almost completely opaque to infrared radiation and prevent the escape of longwave radiation into space. DSLF is greater when clouds are present, especially in the case when low clouds are warmer than the surface. This effect is large enough to influence the surface temperature because of the additional longwave radiation emitted by the clouds. In fact, clouds increase the DSLF because they are optically thick in the wavelengths of the infrared window channels where in turn the atmosphere is optically thin. On the other hand, for most of the thermal spectrum the atmosphere is optically thick and DSLF originates from a layer located only a few meters above the ground. In the thermal window channels the DSLF is dominated by the concentration and temperature of the atmospheric water vapour, but if clouds are present, the DSLF is emitted at cloud bottom. Temperature and height of the optically thick thermal surface may be determined by NWP models or by TOVS.

2.3 Mathematical Description of the Algorithm

The strategy of the LSA SAF DSLF is to make a combined use of satellite and NWP data. The selected algorithm to compute the DSLF for clear sky conditions consists of a modified version of the bulk parameterization first proposed by Prata (1996), for clear sky only. The original formulation was trained with DSLF simulations obtained from MODTRAN-4 (Berk et al., 2000), applied to the TIGR-like database (Chevallier et al., 2000).

$$DSLF = \sigma \, \varepsilon_{sky} \, T_{sky}^4 \qquad (1)$$

where ε_{sky} and T_{sky} are the effective emissivity and temperature of the atmospheric layer above the surface:

$$\varepsilon_{sky} = 1 - \left(1 + \frac{w}{10}\right) \exp\left(-\left(\alpha + \beta \frac{w}{10}\right)^m \right) \qquad (2)$$

$$T_{sky} = T_2 + \left(\gamma \, \Delta T d_2 + \delta\right) \qquad (3)$$

where T_2 is the screen-level air temperature [K] and w the total column water vapour content [kg m^{-2}], and ΔT_2 is the dew point depression at 2m. T_2, ΔT_2 and w are obtained from ECMWF model forecasts.

The parameters in equations (2) and (3), α, β, m, γ, and δ are fitted for clear sky and overcast conditions separately. We assume that for remote sensing retrievals, DSLF at the pixel scale results from the contribution of clear, $F^{\downarrow}_{clear}$, and cloudy, $F^{\downarrow}_{cloudy}$, portions of atmosphere:

$$DSLF = n\,F^{\downarrow}_{cloudy} + (1-n)\,F^{\downarrow}_{clear} \qquad (4)$$

where n is the cloud fraction obtained from visible and infrared imagers. The reasoning behind this approach is the correction of the effects of clouds on the thermal radiation reaching the surface, which still present large deficiencies in NWP models (Meetschen et al., 2004). In the product generated by the LSA SAF, SEVIRI pixels are first classified as clear sky (n=0), cloud filled (n=1), or partially cloudy using the SAF NWC software. When effective cloudiness is not available from the SAF NWC software, n is set to 0.5 in partially cloudy cases.

2.4 Model Calibration/Verification

The calibration of parameters in equations (2) and (3) relies on radiative transfer simulations of downward longwave fluxes at the surface. These simulations are obtained from the MODerate spectral resolution atmospheric TRANSsmittance algorithm (MODTRAN4; Berk et al., 2000) applied to the TIGR-like database (Chevallier et al., 2000). Downward surface radiances at five different zenith angles are then computed for wavelnumbers ranging between 100 and 2500 cm-1 at a resolution of 1 cm-1. Such values are then integrated to provide total downward fluxes within the long-wave domain of the spectrum. The model is configured to use ozone and trace gases climatological data of MODTRAN, and the “Rural” aerosol profile. Temperature and humidity, available at 60 vertical levels between the surface and 10 Pa, are obtained from the TIGR-like dataset. This contains a total of 13495 globally distributed profiles representative of a wide range of atmospheric conditions.

Figure 2 presents scatterplots of different parameterized DSLF values versus MODTRAN simulations. When compared with other parameterization schemes developed by Prata (1996), Dilley and O’Brien (1998), for clear sky conditions, and by Josey et al. (2003), for all sky, the new formulation (equations (2)-(3)) is able to reproduce MODTRAN DSLF, with lower (negligible) bias and root mean square differences (RMSD). Most formulations analysed here for DSLF exhibit conditional biases, i.e., they generally overestimate the lower DSLF values (e.g., Prata96, Dilley&Obrien98, Josey&al03; Figure 2) and/or underestimate those within the higher ranges (Dilley&Obrien98, Josey&al03; Figure 2). Parameterizations of downward long-wave fluxes are often strongly tight to the calibration data. This is clearly the case for the Josey&al03 (Figure 2) scheme, which relied on data collected during oceanographic campaigns. Although these observations were taken over a wide latitudinal range, from the subtropics to the Artic (Josey et al., 2003), the formulation is unable to reproduce the extremes of DSLF distribution. These are likely to correspond either to dry and extremely warm, or very dry and cold conditions only likely to be observed inland.

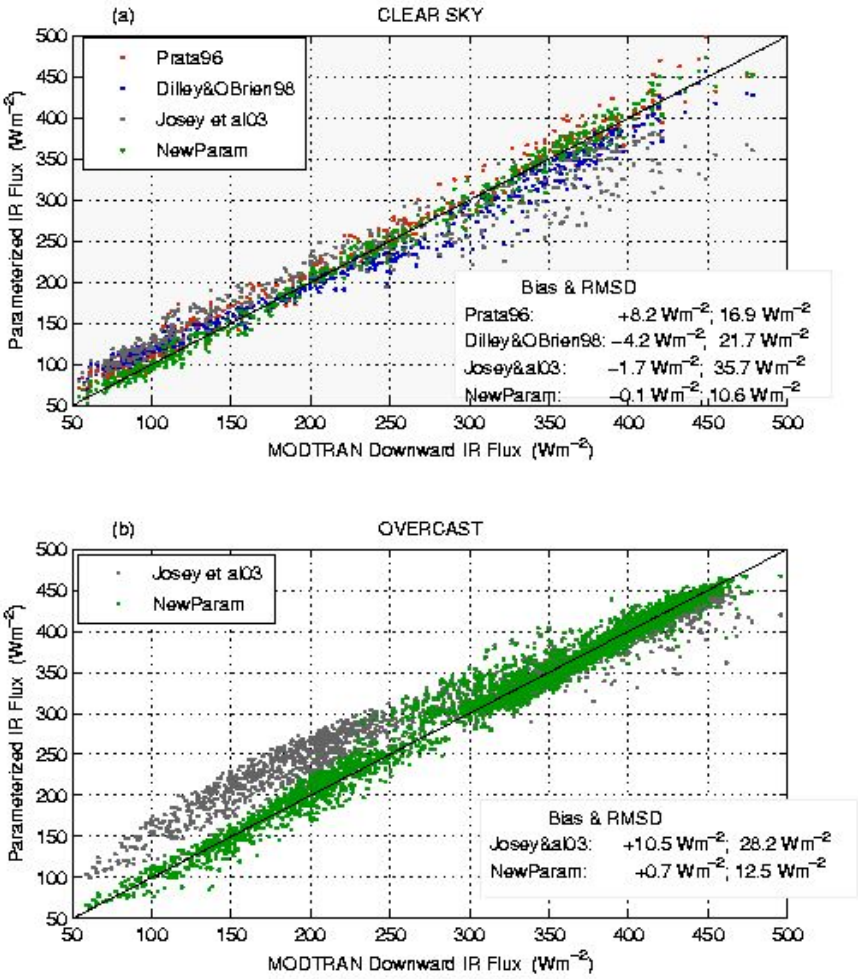

Figure 2 - DSLF estimations obtained with different parameterization schemes (dots coloured according to legend) versus MODTRAN simulations (x-axis), for clear sky (upper panel) and overcast (lower panel) conditions. Systematic differences (parameterizations minus MODTRAN) and root mean square differences are also indicated.

For a detailed analysis of the performance of different parameterization schemes to estimate the downward thermal radiation reaching the surface, please the DSLF Algorithm Theoretical Basis Document (ATBD_DSLF), available at http:/landsaf.meteo.pt.

2.5 Daily Down-welling Surface Longwave Flux

The daily down-welling surface longwave fluxes estimated by the LSA SAF corresponds to a daily integration of instantaneous values:

$$F^{\downarrow}_{daily} = \int_{t_0}^{t_{end}} F^{\downarrow}\, dt \qquad (5)$$

Where t_0 and t_{end} correspond to 0 and 24 UTC, respectively. Currently $F^{\downarrow}_{daily}$ is estimated from SEVIRI instantaneous fluxes, computed every 30-min, using the trapezoid rule:

$$DIDSLF = \sum_{i=1}^{N-1} 0.5\left(DSLF_i + DSLF_{i+1}\right)\cdot \Delta t \qquad (6)$$

Since we use 30-minute DSLF values, N=48 (maximum number of time slots per day) and $\Delta t = 30 \cdot 60$ s.

2.6 Quality Control

Automatic Quality Control (QC) is performed on DSLF instantaneous (30-minute) fields and the quality information is provided on a pixel basis. As shown in Annex A, DSLF QC contains general information about input data quality and information about DSLF confidence level. The DSLF confidence level was defined based on the following parameters: screen-level temperature and total column water vapour for clear sky conditions and on total cloud fraction for cloudy sky conditions. The three considered levels of confidence (*i.e.* above nominal, nominal and below nominal) correspond to estimated uncertainties on DSLF values (respectively less than 5%, between 5 and 10% and above 10%).

The quality of the daily accumulated fluxes is strongly dependent on data availability throughout the day. Therefore, DIDSLF datasets are distributed along with (i) a matrix with percent of missing slots within the corresponding 24hour period, evaluated pixel-by-pixel; (ii) the maximum number of consecutive observations missing, also on a pixel basis.

3 Processing Scheme

3.1 SEVIRI/Meteosat DSLF Product: LSA-204 (MDSLF)

The main flow of the processing chain is given in Figure 3. It is worth recalling that the DSLF for clear and cloudy sky conditions are computed by different schemes coded in the same package.

The overall procedure starts with an input section where all necessary input files are read and tested for missing and/or error data. Data Processing consists of two parallel chains according to the Cloud Mask information, since the coefficients in the DSLF formulation depend on the pixel cloud mask classification. A QC is performed for both cases. The output consists of a unique DSLF field and the QC data contains the information about cloud satellite derived information (Cloud Mask and Effective Cloudiness).

Both methods are computationally efficient. The major steps of algorithm execution may be described as follows:

1 outer loop for MSG column

2 Inner loop for MSG line

2.1 search for land pixels, skip and flag sea pixels
2.2 search for for t2m, cwv, td2m, skip and flag missing values
2.3 check cloud pixel information, skip and flag missing values
2.3.1 - Process Clear Sky pixels
2.3.1.1 compute DSLF with clear sky parameters
2.3.1.2 compute DSLF confidence level and perform QC
2.3.2 - Process Cloudy Sky pixels
2.3.2.1 search for effective cloudiness pixel value, skip and flag missing values
2.3.2.2 compute DSLF as weighted average of cloud and clear sky contribution
2.3.2.3compute DSLF confidence level and perform QC

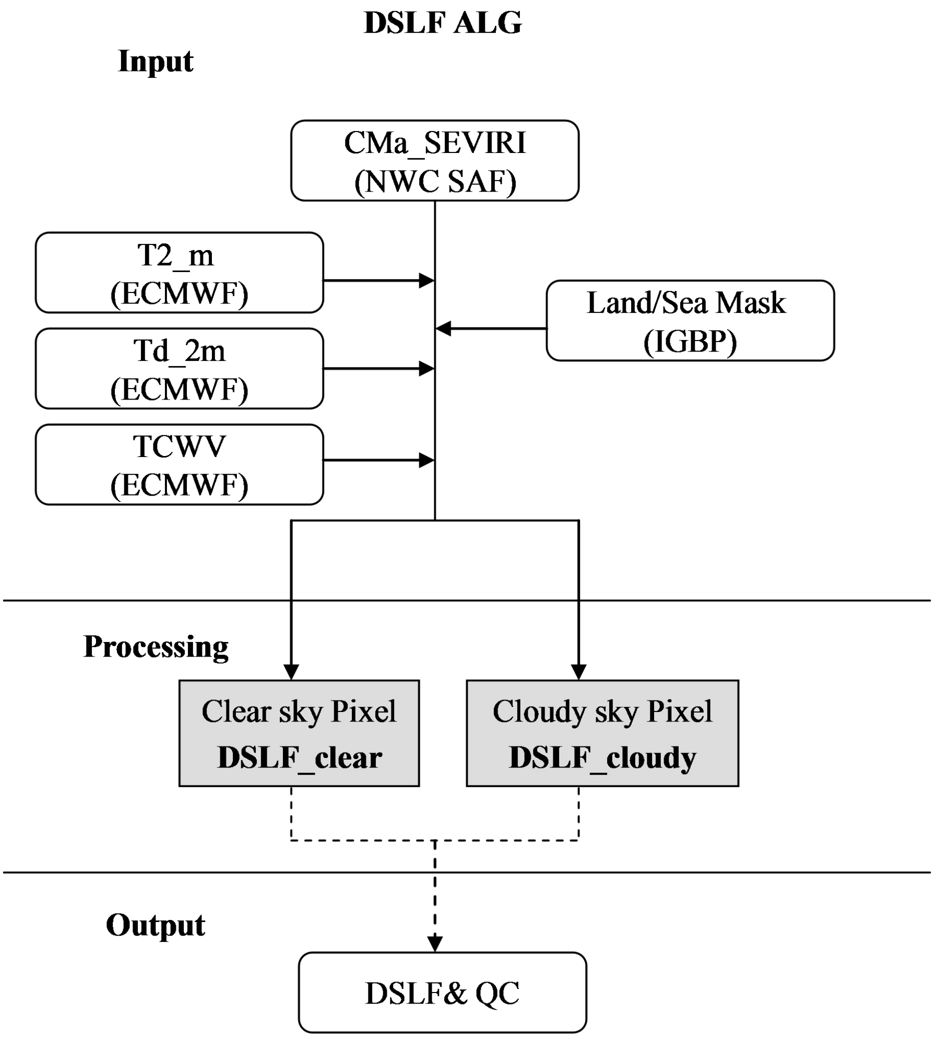

Figure 3 - Diagram of processing chain, for SEVIRI/MSG retrieved DSLF.

3.2 SEVIRI/Meteosat Daily DSLF Product: LSA-206 (DIDSLF)

The major steps of algorithm execution may be described as follows:

1. outer loop over time, for time-slots between 0 and 24 UTC.

2. inner loop for SEVIRI_DSLF pixels
   2.1 read DSLF_SEVIRI quality flags, skip and flag sea pixels
   2.2 search for DSLF_SEVIRI:
      2.2.1 count missing values
      2.2.2 integrate DSLF_SEVIRI over consecutive time-intervals without missing values.

The output corresponds to DSLF integrated over the whole day and the percentage of missing slots.

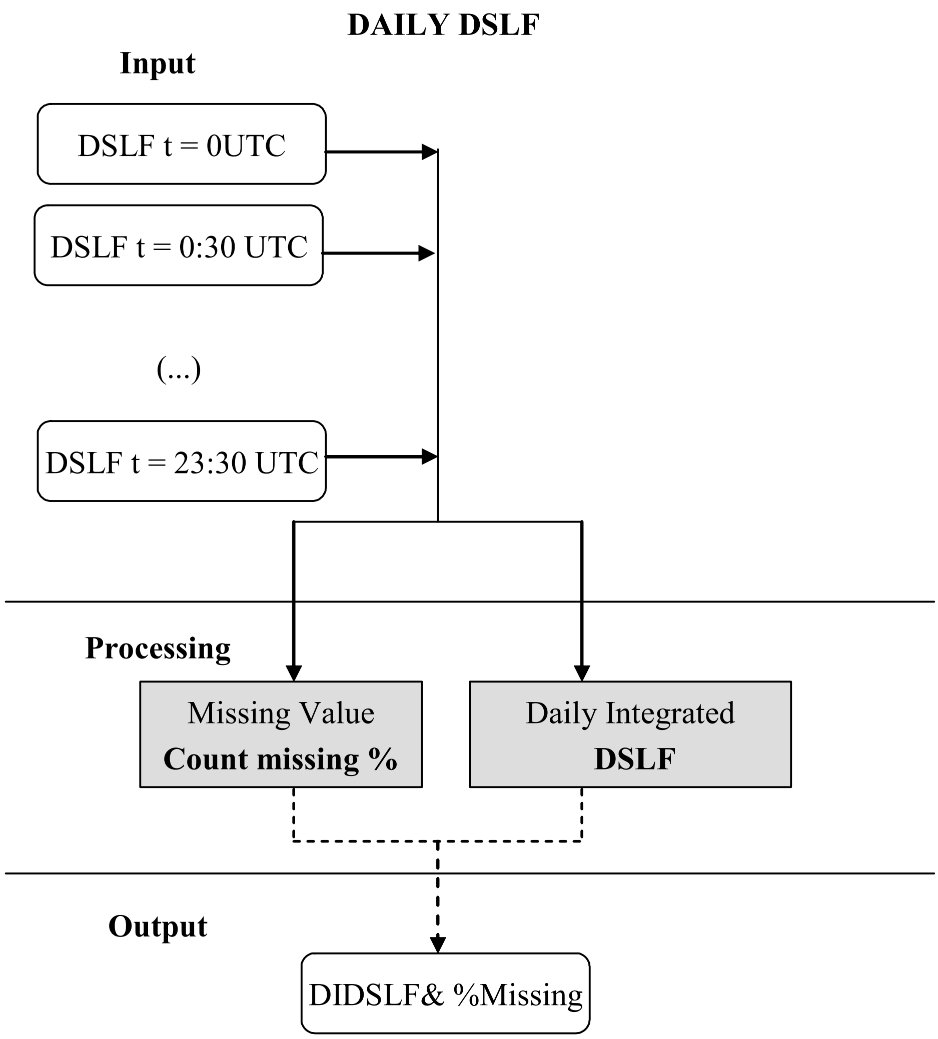

Figure 4 - As in Figure 3, but for DSLF daily (DIDSLF) product.

4 Data Description - SEVIRI/Meteosat DSLF Products

4.1 Overview – SEVIRI DSLF (MDSLF)

The product derived from MSG data consists of instantaneous DSLF fields estimated every 30 minutes for the full MSG disk. However, the EUMETCast users receive subsets of the full disk for the four geographical areas (Figure 1). The main Characteristics of the LSA SAF geographical areas are described in Table 3.

Table 3 - 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

Users have access to the following data:

- DSLF field;
- quality control information field.

The data is 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).

The DSLF product, estimated every 30-minutes, is available in an HDF5 a file containing two datasets (DSLF quantities and respective QC data). The relevant information concerning the data fields is included in HDF5 attributes. A detailed description of the attributes (general and common) defined for the DSLF product is given in Annex B.

4.2 Overview – Daily SEVIRI DSLF (DIDSLF)

The daily product derived from MSG data consists of the integration of instantaneous DSLF fields estimated over the period 0 – 24 UTC, for the full MSG disk (last line in Table 3).
Users have access to the following data:

- DSLF daily field (J m^{-2});
- The percentage of missing slots, per pixel, indicative of the robustness of the daily values (100% corresponds to the best possible estimation).

The data is 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).

The DSLF product, estimated daily, is available in an HDF5 a file containing the two datasets described above. The relevant information concerning the data fields is included in HDF5 attributes. A detailed description of the attributes (general and common) defined for the DSLF product is given in Annex B.

4.3 Geolocation / Rectification

The **DSLF** 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://landsaf.meteo.pt; under "Static Data and Tools"):

Longitude

HDF5_LSASAF_MSG_LON_MSG-Disk_
HDF5_LSASAF_MSG_LON_Euro_.bz2
HDF5_LSASAF_MSG_LON_NAfr_.bz2
HDF5_LSASAF_MSG_LON_SAfr_.bz2
HDF5_LSASAF_MSG_LON_SAme_.bz2

Latitude

HDF5_LSASAF_MSG_LAT_MSG-Disk_
HDF5_LSASAF_MSG_LAT_Euro_.bz2
HDF5_LSASAF_MSG_LAT_NAfr_.bz2
HDF5_LSASAF_MSG_LAT_SAfr_.bz2
HDF5_LSASAF_MSG_LAT_SAme_.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)

$$p_1 = 42164$$

$$p_2 = 1.006803$$

$$p_3 = 1737121856$$

$$CFAC = 13642337$$

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 the each LSA SAF geographical area within the Meteosat disk. These are included in the file metadata (HDF5 attributes; Annex B), and correspond to one set of the values detailed below per SEVIRI/MSG area:

Table 4 - Maximum values for number of columns (ncol) and lines (nlin), for each LSA 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

4.4 File Formats – SEVIRI DSLF

At each time step the DSLF algorithm generates an external output file according to the following name convention:

HDF5_LSASAF_MSG_DSLF_<Area>_YYYYMMDDHHMM

where **<Area>**, **YYYY**, **MM**, **DD**, **HH** and **MM** respectively, denote the geographical region (see Table 4), 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 is available at http://hdf.ncsa.uiuc.edu/.

Libraries for handling HDF5-files in Fortran and C are available at ftp://ftp.ncsa.uiuc.edu/HDF/HDF5/hdf5-1.6.2/. A user friendly graphical interface to open and view HDF5-files may be downloaded from http://hdf.ncsa.uiuc.edu/hdf-java-html/hdfview/.

The HDF5-format allows defining a set of attributes that provide the relevant information. As described in the Annex B the DSLF 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.

4.5 Summary of Product Characteristics – SEVIRI DSLF

Product Name:	Downwelling Surface Longwave Flux
Product Code:	DSLF
Product Level:	Level 2
Description of Product**:**	Downwelling Surface Longwave Flux

Product Parameters:

Coverage:	MSG full disk (Land pixels)
Packaging:	MSG-Disk, Euro, NAfr, SAfr, SAme
Units:	Wm^{-2}
Range:	0 - 500
Sampling:	pixel by pixel basis
Resolution:	Radiation Flux: Hundredth of Wm^{-2}

Spatial: MSG/SEVIRI full resolution (3km×3km at nadir)

Accuracy: <10%

Geo-location Requirements:

Format: 16 bits signed integer

Appended Data: Quality control information (16 bits integer)

Frequency of generation: every 30 min

Size of Product:

Additional Information:

Identification of bands used in algorithm:

not applicable

Assumptions on SEVIRI input data:

not applicable

Identification of ancillary and auxiliary data:

Pixel latitude and longitude (from EUMETSAT)
Cloud Mask (from NWC SAF)
Effective Cloudiness (from NWC SAF)

Land-sea mask
2-m temperature (from ECMWF)
2-m dew point temperature (from ECMWF)
Total column water vapour (from ECMWF)

4.5.1 Quality Indices – SEVIRI

Each DSLF field is associated with a quality flag index field, coded in 16-bit word as was described in Annex A. The expected values for QC information are described in Table 5 as well as their meaning.

Table 5 - Description of DSLF/SEVIRI QC information.

Binary Value	Decimal Value	Description
0	0	sea/out of disk pixel
100	4	T_{2m} information missing
1100	12	Td_{2m} information missing
11100	28	TCWV information missing
111100	60	CMa information missing
1001111101	637	Below Nominal >10% and Cloud free pixel
10001111101	1149	Nominal and Cloud free pixel
11001111101	1661	Above Nominal <5 % and Cloud free pixel
01100111101	829	Below Nominal >10% and snow/ice pixel (from CMa)
10100111101	1341	Nominal and snow/ice pixel (from CMa)
11100111101	1852	Above Nominal <5 % and snow/ice pixel (from CMa)
1011111101	765	Below Nominal >10% and cloud filled pixel
10011111101	1277	Nominal and cloud filled pixel
11011111101	1789	Above Nominal <5 % and cloud filled pixel
1010111101	701	Below Nominal >10% and cloud contaminated pixel
10010111101	1213	Nominal and cloud contaminated pixel
11010111101	1725	Above Nominal <5 % cloud contaminated pixel
1101111101	893	Below Nominal >10% and undefined cloudy pixel
10101111101	1405	Nominal and undefined cloudy pixel
11101111101	1917	Above Nominal <5 % and undefined cloudy pixel

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7 Glossary

DSLF:	Downwelling Surface Longwave Radiation
ECMWF:	European Centre for Medium-Range Weather Forecasts
EPS:	EUMETSAT Polar System
EUMETSAT:	European Meteorological Satellite Organisation
GOES:	Geostationary Operational Environmental Satellite
HDF	Hierarchical Data Format
IM:	Instituto de Meteorologia (Portugal)
IPMA:	Instituto Português do Mar e da Atmosfera
IR:	Infrared Radiation
METEOSAT:	Geostationary Meteorological Satellite
MODIS:	Moderate-Resolution Imaging Spectro-Radiometer
MODTRAN:	Moderate Resolution Transmittance Code
MSG:	Meteosat Second Generation
NWC SAF:	NoWCasting SAF
NWP:	Numerical Weather Prediction
O&SI SAF:	Ocean & Sea Ice SAF
QC:	Quality Control
RTM:	Radiative Transfer Model
rms:	root mean square
SAF:	Satellite Application Facility
SEVIRI:	Spinning Enhanced Visible and InfraRed Imager
SD:	Standard Deviation
SURFRAD:	Surface Radiation Budget Network
TIGR:	TOVS Initial Guess Retrieval
TOVS:	TIROS-N Operational Vertical Sounder
TPW:	Total Precipitable Water
U-MARF	Unified Meteorological Archiving and Retrieval Facility
URD:	User Requirements Document

ANNEX A – DSLF Quality Control Information

Table A 1 – DSLF QC information.

Binary Value	Decimal Value	Description
000	0	sea/out of disk pixel
100	4	T_{2m} information missing
1100	12	Td_{2m} information missing
11100	28	TCWV information missing
111100	60	CMa information missing
1001111101	637	Below Nominal (CMa - Cloud-free)
10001111101	1149	Nominal (CMa - Cloud-free)
11001111101	1661	Above Nominal (CMa - Cloud-free)
1100111101	829	Below Nominal (CMa - contaminated by snow/ice)
10100111101	1341	Nominal(CMa - contaminated by snow/ice)
11100111101	1852	Above Nominal (CMa - contaminated by snow/ice)
1011111101	765	Below Nominal (CMa - Cloud filled)
10011111101	1277	Nominal (CMa - Cloud filled)
11011111101	1789	Above Nominal (CMa - Cloud filled)
1010111101	701	Below Nominal (CMa - pixel contaminated by clouds)
10010111101	1213	Nominal (CMa - pixel contaminated by clouds)
11010111101	1725	Above Nominal (CMa - pixel contaminated by clouds)
1101111101	893	Below Nominal (CMa - Cloud undifined)
10101111101	1405	Nominal (CMa - Cloud Cloud undifined)
11101111101	1917	Above Nominal (CMa - Cloud Cloud undifined)

ANNEX B – Product Metadata – SEVIRI DSLF

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 DSLF 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 4.1), or a PDU in the case of Metop derived parameters.

Table B 1 - General attributes of the files for the SEVIRI DSLF product.

Attribute	Allowed Values	Data Type
SAF	LSA	String<3>
CENTRE	IM-PT	String<5>
ARCHIVE_FACILITY	IM-PT	String<5>
PRODUCT	DSLF	String<79>
PARENT_PRODUCT_NAME	Cma, 2T, TCWV, 2D	Array(4) of string<79>
SPECTRAL_CHANNEL_ID	0	Int
PRODUCT_ALGORITHM_VERSION	X.Y	String<4>
CLOUD_COVERAGE	-	String<20>
OVERALL_QUALITY_FLAG	OK or NOK	String<3>
ASSOCIATED_QUALITY_INFORMATION	-	String<511>
REGION_NAME	One of: Euro, NAfr, SAfr, SAme	String<4>
COMPRESSION	0	Int
FIELD_TYPE	Product	String<255>
FORECAST_STEP	0	Int
NC	Depend on REGION_NAME (Table 3)	Int
NL	Depend on REGION_NAME (Table 3)	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	Depend on REGION_NAME (Table 3)	Int
LOFF	Depend on REGION_NAME (Table 3)	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	LSADSLF	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	30-min	String<20>
STATISTIC_TYPE	-	String<20>
MEAN_SSLAT	Depend on REGION_NAME (Table 3)	Real
MEAN_SSLON	Depend on REGION_NAME (Table 3)	Real
PLANNED_CHAN_PROCESSING	0	Integer
FIRST_LAT	0	Real
FIRST_LON	0	Real

Table B 2 - Attributes of the DSLF/SEVIRI dataset.

Name	Value	Type
CLASS	Data	String, length=4
PRODUCT	DSLF	String, length=4
PRODUCT_ID	175	32-bit integer
N_ COLS	Depend on REGION_NAME (Table 3)	32-bit integer
N_ LINES	Depend on REGION_NAME (Table 3)	32-bit integer
NB_BYTES	2	32-bit integer t
SCALING_FACTOR	10.0	64-bit floating-point
OFFSET	0.0	64-bit floating-point
MISS_VALUE	0	32-bit integer
UNITS	Wm-2	String, length=15
CAL_SLOPE	999.0	64-bit floating-point
CAL_OFFSET	999.0	64-bit floating-point

Table B 2 - Attributes of the DSLF/SEVIRI Quality Flag information dataset.

Name	Value	Type
CLASS	Data	String, length=4
PRODUCT	Q_FLAGS	String, length=7
PRODUCT_ID	999	32-bit integer
N_ COLS	Depend on REGION_NAME (Table 3)	32-bit integer
N_ LINES	Depend on REGION_NAME (Table 3)	32-bit integer
NB_BYTES	2	32-bit integer t
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