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

Product User Manual

Down-welling Surface Shortwave Flux (DSSF)

PRODUCTS: LSA-07 (MDSSF) , LSA-08 (EDSSF), LSA-09 (DIDSSF)

Reference Number:	**SAF/LAND/MF/PUM_DSSF/2.6v2**
Issue/Revision Index:	**Issue 2.6v2**
Last Change:	**10/07/2011**

DOCUMENT SIGNATURE TABLE

	Name	Date	Signature
Prepared by :	**Météo-France / CNRM**	**10/07/2011**	
Approved by :	**Land SAF Project Manager**	**10/07/2011**	

DOCUMENTATION CHANGE RECORD

Issue / Revision	Date	Description:
Version 0.0	29/10/2004	Preliminary version
Version 1.0	02/11/2004	Version prepared for SIVVRR 2
Version 1.1	08/03/2005	Version prepared for Check-Point Meeting
Version 1.2	01/06/2005	Version prepared for ORR-1
Version 1.3	20/01/2006	Version prepared for ORR-1 Close-Out
Version 1.4	19/10/2006	Version prepared for OR-1
Version 2.0	15/01/2008	Version prepared for ORR-A EPS
Version 2.6	10/07/2011	Daily cumulative estimates.

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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).

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

	Product	Spatial Coverage	Temporal Resolution
Surface Radiation Budget	**AL – Albedo**	**MSG disk**	**5-day & 30-day**
	LST – Land Surface Temperature	**MSG disk / Global***	**Instantaneous**
	EM – Emissivity	**MSG disk / Global***	**5-day & 30-day**
	DSSF – Down-welling Surface Short-wave Flux	**MSG disk / Global***	**Instantaneous & Daily**
	DSLF – Down-welling Surface Long-wave Flux	**MSG disk / Global***	**Instantaneous & Daily**
Biogeophysical Parameters I	**SC – Snow Cover**	**MSG disk / Global**	**Daily**
	ET – Evapotranspiration	**MSG disk**	**Daily / 30 min**
Biogeophysical Parameters II	**FVC – Fraction of Vegetation Cover**	**MSG disk / Global***	**5-day & 30-day**
	LAI – Leaf Area Index	**MSG disk / Global***	**5-day & 30-day**
	FAPAR – Fraction of Absorbed Photosynthetic Active Radiation	**MSG disk / Global***	**5-day & 30-day**
	RFM – Risk of Fire Mapping	**Europe**	**Daily**
	FD&M – Fire Detection & Monitoring	**MSG disk**	**15-min & Daily**
	FRP – Fire Radiative Power	**MSG disk**	**15-min & hourly**

***Global and 12-hourly products refer to retrievals from AVHRR/EPS.**

****Indirectly, via other LSA SAF components (AL, DSSF, DSLF, FVC, LAI, …)**

*****For cloud identification and classification.**

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.

Most products derived from SEVIRI/Meteosat are generated at full spatial resolution (3km pixel sampling distance at nadir), 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.**

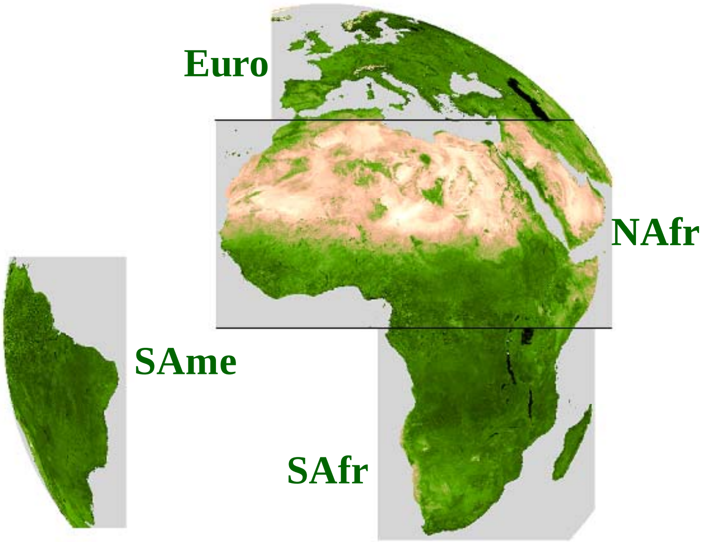

Figure 1 - The LSA SAF geographical areas for SEVIRI-based products.

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 Short-wave radiative Flux (DSSF) generated by the LSA SAF from SEVIRI and AVHRR data system are described in the following sections. The characteristics of AVHRR and SEVIRI based DSSF 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 DSSF, in terms of area coverage, resolution and accuracy.

DSSF Product	Coverage	Resolution		Accuracy		
		Temporal	Spatial	Threshold	Target	Optimal
MDSSF (LSA-07) DSSF_SEVIRI	MSG disk	30 min	MSG pixel resolution	20%	DSSF>200 W/m2: 10% DSSF<200 W/m2: 20W/m2	5%
EDSSF (LSA-08) DSSF_AVHRR	Europe & High Latitudes	1/2 day	0.01° x 0.01°	20%	DSSF>200 W/m2: 10% DSSF<200 W/m2: 20W/m2	5%
DIDSSF (LSA-09) DSSF_DAILY	MSG disk	1 day	MSG pixel resolution	20%	DSSF>200 W/m2: 10% DSSF<200 W/m2: 20W/m2	5%

1 ALGORITHM

1.1 Overview

The down-welling surface short-wave radiation flux (DSSF) refers to the radiative energy in the wavelength interval [0.3µm, 4.0µm] reaching the Earth's surface per time and surface unit. It essentially depends on the solar zenith angle, on cloud coverage, and to a lesser extent on atmospheric absorption and surface albedo. The method for the retrieval of DSSF that is implemented in the LSA SAF system largely follows previous developments achieved at Météo-France in the framework of the OSI SAF (Brisson et al., 1999; Ocean & Sea-Ice , 2002). The main differences of the LSA SAF product are the spatial and temporal resolution, the source of ancillary input data, and the use of three short-wave SEVIRI channels (0.6µm, 0.8µm, and 1.6µm).

Figure 2 shows a simplified flow chart of the algorithm. For clear and cloudy pixels quite different parameterisations are applied. The cloud mask therefore represents an important piece of information for the execution of the algorithm. In the presence of clouds the down-welling radiation reaching the ground is considerably reduced. The DSSF is strongly anti-correlated with the observable top-of-atmosphere reflectances: The brighter the clouds appear on the satellite images, the more radiation is reflected by them and the less radiation reaches the ground.

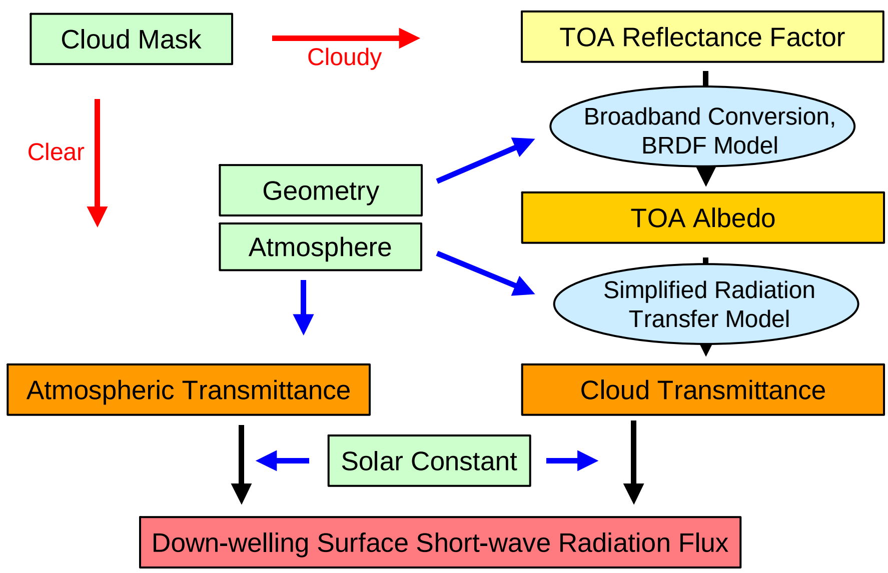

Figure 2: Simplified flow chart of the DSSF algorithm.

1.2 Definition

The down-welling surface short-wave radiation flux $F^{\downarrow}$ is defined as the integral of the spectral irradiance $E(\lambda)$ over the wavelength interval [λ_1=0.3µm, λ_2=4µm]:

$$F^{\downarrow} = \int_{\lambda_1}^{\lambda_2} E(\lambda) d\lambda \ . \tag{1}$$

The spectral irradiance is the hemispherical angular integral of the down-welling spectral radiance $L(\lambda,\theta,\phi)$ weighted by the cosine of the zenith angle:

$$E(\lambda) = \int_0^{2\pi} \int_0^{\pi/2} L(\lambda,\theta,\phi) \cos(\theta) \sin(\theta) d\theta d\phi \tag{2}$$

It includes contributions owing to the direct solar radiation attenuated by the atmosphere as well as diffuse radiation.

In the applied retrieval scheme the DSSF is approximated as

$$F^{\downarrow} = F_0 \, v(t) \cos\theta_s \, T \tag{3}$$

where F_0 is the solar constant (with minor corrections according to the restricted wavelength interval considered), θ_s the solar zenith angle, and T an effective transmittance of the atmosphere or cloud-atmosphere system. The factor

$$v(t) = 1 + 0.033 \cos(2\pi \, t / 365) \tag{4}$$

takes into account the varying distance of the sun as a function of the day t of the year (Iqbal, 1983).

For the effective transmittance T different expressions are used depending on whether a given pixel is marked as clear or cloudy. The information on cloud cover is provided by the cloud mask software, that was developed by the NWC SAF and which is integrated in the LSA SAF operational system.

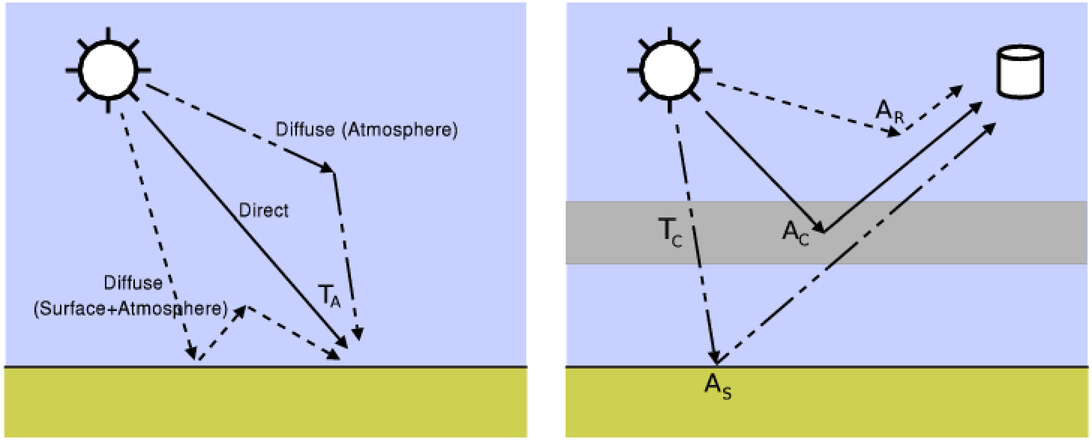

Figure 3: Schematics illustrating some elements of the clear (left) and cloudy sky (right) DSSF estimation methods.

1.3 Clear Sky Method

In the case of clear pixels the factor T is specified as

$$T = T_A + \sum_{n=1}^{\infty} T_A \left(A_S A_A\right)^n = \frac{T_A}{1 - A_S A_A} \ . \qquad \textbf{(5)}$$

T_A represents the transmittance of the atmosphere and quantifies the contribution to the surface flux by the direct radiation as well as the diffuse radiation after scattering by the atmosphere as illustrated in the left diagram of Figure 3. The flux contribution owing to multiple scattering of the light between the surface and the atmosphere is taken into account by the denominator on the right-hand side of equation (5). A_S denotes the surface albedo and A_A the spherical albedo of the atmosphere. As indicated in the equation, the final form of this expression results from a geometric series taking into account an infinite number of scattering orders between surface and atmosphere.

The atmospheric transmittance is calculated after Frouin et al. (1989) as

$$T_A = e^{-\tau_{H2O}} \ e^{-\tau_{O3}} \ e^{-\tau_{Aer+CO2+O2}} \qquad \textbf{(6)}$$

with

$$\tau_{H2O} = a_{H2O}(W / \cos\theta_s)^{b_{H2O}} \ , \ \tau_{O3} = a_{O3}(U_{O3} / \cos\theta_s)^{b_{O3}}$$

$$\text{and } \tau_{Aer+CO2+O2} = \frac{1}{\cos\theta_s}\left(a + \frac{b}{V}\right) \ . \qquad \textbf{(7)}$$

***W* is the water vapour column density in g/cm^2, *U_{O3}* the total ozone amount in atm.cm, and *V* the visibility in km. In the operational system the water vapour estimate is obtained from ECMWF numerical weather model forecasts and the ozone amount is specified according to the TOMS climatology. The visibility is currently kept at a fixed value of 20 km. The values of the parameters a and b were chosen according to the continental aerosol type.**

The spherical albedo of the atmosphere $A_A = a' + b'/V$ is also parameterised as a function of visibility according to Frouin et al. (1989). The numerical values of the various constants are listed in the table below. The value used for F_0 is slightly lower than the solar constant since a restricted wavelength interval is considered in the definition of DSSF and in the radiative transfer calculations which served for setting up the optical thickness parameterisations (7). The surface albedo A_s is taken from the LSA SAF near real time albedo product (Land SAF, 2005). For the time being the bi-hemispherical variant A_{S-bh} is used and the diurnal cycle is approximated by using the functional form suggested by Dickinson (1983) and Briegleb et al. (1986) as

$$A_S = A_{S-bh} \frac{1+d}{1+2d\cos\theta_s} \ \text{ with } d = 0.4 \ . \qquad \textbf{(8)}$$

Table 2: Numerical values of the constants appearing in the parameterisations of Frouin et al. (1989).

F_0	**1358 W/m²**	a_{O3}	**0.041**	b	**0.704**
a_{H2O}	**0.102**	b_{O3}	**0.57**	a'	**0.088**
b_{H2O}	**0.29**	a	**0.066**	b'	**0.456**

1.4 Cloudy Sky Method

For cloudy pixels the DSSF estimate relies on a simplified physical description of the radiation transfer in the cloud-atmosphere-surface system according to Gautier et al. (1980) and Brisson et al. (1999). It is assumed that a homogeneous cloud layer covers the whole image pixel. The effective transmittance factor T is now given by

$$T = \frac{T_A T_C}{1 - A_S T_{bc} A_C} \quad . \tag{9}$$

Compared to the clear-sky case the enumerator additionally includes the cloud transmittance T_C, which is the decisive quantity in this expression. The denominator has a similar significance as in equation (5) and quantifies multiple scattering between the surface and the bottom of the cloud layer. A_C denotes the cloud albedo and T_{bc} represents the atmospheric transmittance between the surface and the cloud.

The cloud transmittance T_C and albedo A_C may be highly variable on small time scales depending on the daily evolution of the clouds. Their instantaneous values are determined from the satellite measurements with the help of a simple physical model. For this purpose the measured spectral reflectances in the 0.6µm, 0.8µm, and 1.6µm SEVIRI or AVHRR channels are first transformed to broad-band top-of-atmosphere albedo A_{TOA} by applying the spectral conversion relations proposed by Clerbaux et al. (2005) and the angular reflectance model of Manalo-Smith et al. (1998). As illustrated in the right diagram of Figure 3, the signal at the top of the atmosphere comprises contributions owing to Rayleigh scattering by the atmosphere above the cloud (A_R), radiation reflected by the cloud which is attenuated by the atmosphere above ($A_C T_{SunCloudSat}$), and radiation reflected by the surface which is attenuated by the atmosphere and the cloud ($A_S T_{SunSurfaceSat} T_C^2$):

$$A_{TOA} = A_R + A_C T_{SunCloudSat} + \frac{A_S T_{SunSurfaceSat} T_C^2}{1 - A_S T_{bc} A_C} \quad . \tag{10}$$

As before, the significance of the denominator in the third term is to take into account multiple scattering between the surface and the bottom of the cloud layer. Following Brisson et al. (1999) the transmittance factors $T_{SunCloudSat}$, $T_{SunSurfaceSat}$, and T_{bc}, as well as A_R are calculated with parameterisations given by Lacis and Hansen

(1974). The cloud transmittance T_C is expressed in terms of the cloud albedo A_C and the cloud absorption a_C as

$$T_C = 1 - A_C - a_C = 1 - A_C - \alpha \; A_C \; . \qquad (11)$$

The cloud absorption is modelled as a linear function of the cloud albedo by introducing the "cloud absorption factor" α. The currently employed numerical value of $\alpha = 0.11$ was not derived from first principles, but has been adjusted by matching the final flux estimates with the help of a validation database (Ocean & Sea-Ice, 2005). This parameter therefore mainly serves for "absorbing" the methodological approximations and uncertainties, rather than for quantifying the physical cloud properties.

Combining the expressions (10) and (11) allows us to calculate the two unknowns T_C and A_C from the "observable" A_{TOA} by solving a quadratic equation, and finally to obtain the DSSF estimate with equations (9) and (3).

The equation system gives a physical solution for T_C and A_C unless the "observed" value for A_{TOA} is beyond the following limits:

$$A_{TOA}^{\min} = A_R + A_S T_{SunSurfaceSat} \quad \text{corresponding to } T_C\!=\!1 \qquad (12)$$

$$A_{TOA}^{\max} = A_R + \frac{T_{SunCloudSat}}{1+\alpha} \quad \text{corresponding to } T_C\!=\!0 \, . \qquad (13)$$

If the limiting conditions for the top-of-atmosphere albedo are violated, the cloud transmittance is set to the limiting value and a quality flag is set accordingly.

2 PRODUCT DESCRIPTION

2.1 Continental Windows

In the LSA SAF operational system, the four geographical regions of the MSG disk as depicted in Figure 1 are processed separately. The main characteristics of these windows are listed in Table 3. The projection and spatial resolution correspond to the characteristics of the Level 1.5 MSG/SEVIRI instrument data. Information on geo-location and data distribution is available from the LSA SAF website: http://landsaf.meteo.pt. For the EPS/AVHRR instrument data, each product dissemination unit (PDU) is processed separately. A PDU corresponds to 3-minutes scan duration.

Table 3: Characteristics of the four LSA SAF geographical areas
Each region is defined by the corner positions relative to an MSG image of 3712 columns per 3712 lines with indices starting at 1 in the North and West.

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

2.2 Geolocation / Rectification

The DSSF SEVIRI-based (MDSSF) 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 Land-SAF website (http://landsaf.meteo.pt; under "Static Data and Tools"):

Longitude

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_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)**

$p_1 = 42164$

$p_2 = 1.006803$

$p_3 = 1737121856$

$CFAC = 13642337$

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 Land-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 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
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

2.3 File Format

The DSSF algorithm generates a single type of external product output files. The file names for the DSSF products derived from MSG respect the convention

HDF5_LSASAF_MDSSF_Region_YYYYMMDDhhmm

where Region, YYYY, MM, DD, hh, and mm, respectively, denote the region name, year, month, day, hour, and minute of the start of image data acquisition. For products derived from AVHRR, the file names are

HDF5_LSASAF_EDSSF_PDU_YYYYMMDDhhmmss

For distribution via EumetCast the prefix "S-LSA_-" is added to the file names.

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

A user-friendly graphical interface to open and view HDF5-files can be downloaded from http://hdf.ncsa.uiuc.edu/hdf-java-html/hdfview. The HDF5-format permits the definition of a set of attributes for providing relevant information. Each LSA SAF product file includes the general attributes listed in Table 7 of Appendix B. Within the HDF5-files the information is organised in the form of separate datasets. For each dataset a set of additional attributes is available (Table 8 of Appendix B).

2.4 Temporal Reference

The MDSSF product is calculated for every second slot of MSG input data at intervals of 30 minutes. The estimates are derived for the instantaneous acquisition time of each image line. The SEVIRI image scans are performed from South to North. Hence in Northern Europe the line acquisition time deviates from the slot time by approximately 12 minutes. The difference Δt between the acquisition time and the slot time is a linear function of the line position. It can be approximated as

$$\Delta t = 760 - Y/5 \quad \text{(In seconds)}, \qquad (14)$$

where Y is the line number in the full disk image with indices starting in the North. This relation is depicted in Figure 4, which also shows the dependence of Δt on the latitude (for a longitude of 0°).

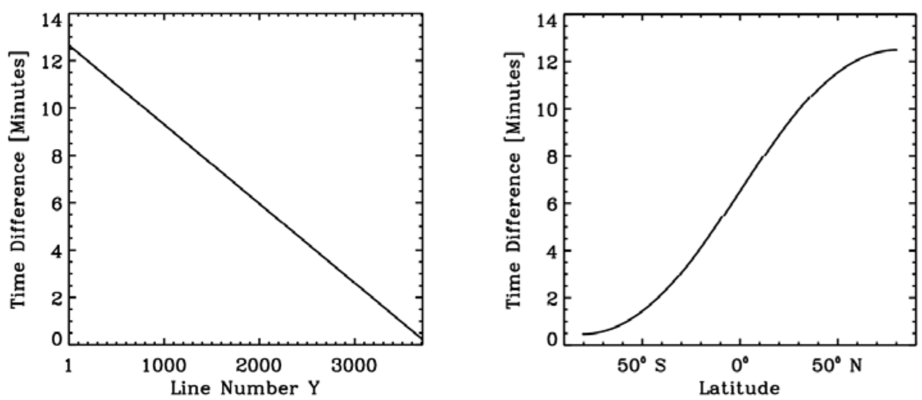

Figure 4: The time difference between the slot and the acquisition time of the image line as a function of the line number (left) and the latitude for a longitude of 0° (right).

For the EDSSF products derived from EPS, the AVHRR image scans are performed from North to South (only the descending part of the orbit is processed). Each PDU corresponds to a 3-minutes scan and represents 1080 data lines. The difference Δt between the acquisition time and the sensing start time is a linear function of the line position too and can be approximated as

$$\Delta t = Y/6 \text{ (In seconds)}, \qquad (15)$$

where Y is the line number in the image.

2.5 Product Content

The DSSF product files comprise two datasets: one for the actual flux estimates and one for the quality flag. The technical properties are summarised in Table 5. Figure 5 and Figure 6, respectively, depict examples for the MDSSF estimate and the corresponding quality flag derived from one slot of MSG observations.

The signification of the numerical values of the quality flag is explained in Table 6. Bits 0 and 1 propagate the land/sea mask information. The bits 2 to 4 include the cloud mask flag as provided by the respective input file (cf. Nowcasting SAF, 2004). Finally bits 5 to 7 contain information about the method applied to calculate the DSSF estimate and possible problems encountered.

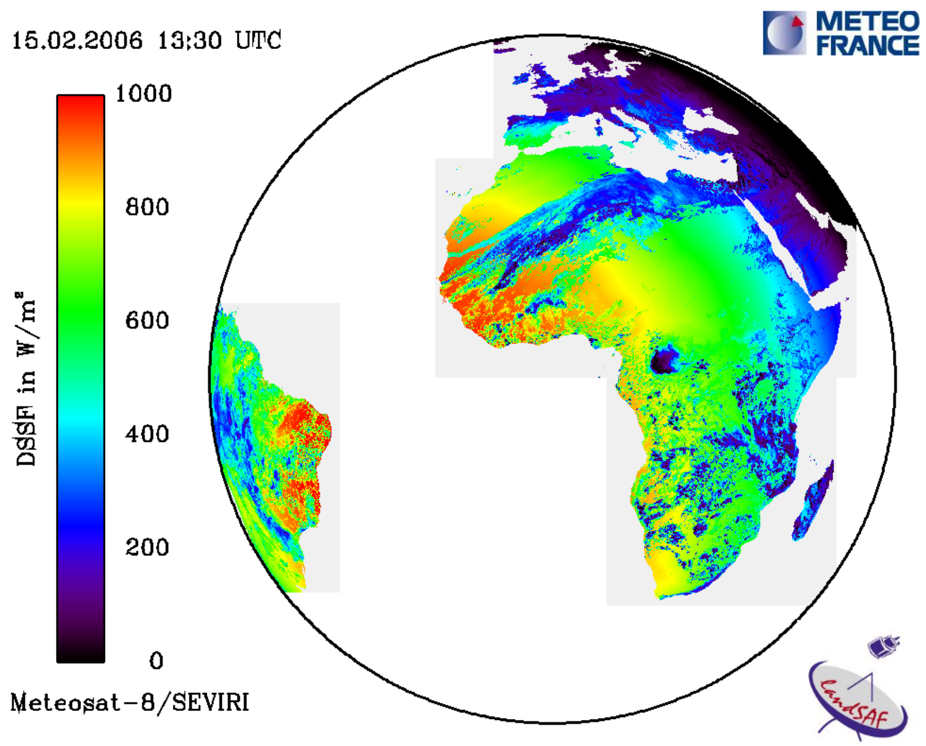

Figure 5: Re-composed full-disk image of the down-welling surface short-wave radiation flux estimate for the European window on the 15th of February 2006 at 13:30 UTC.

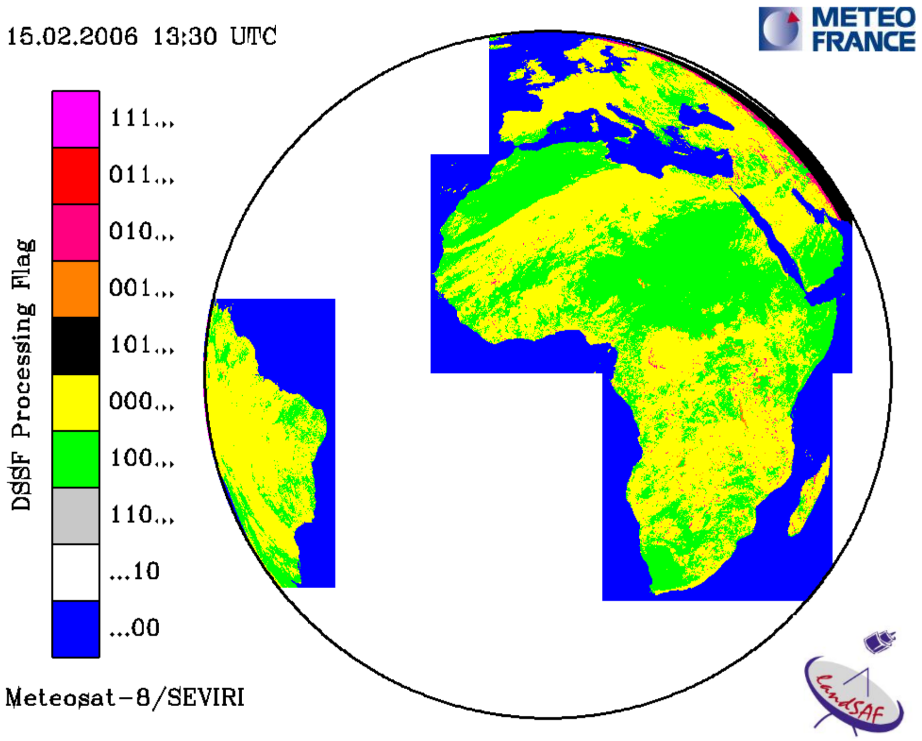

Figure 6: Quality flag corresponding to the DSSF estimate depicted in Figure 5. The signification of the bit codes is given in Table 6. xxx… indicates that the most significant bits 5 to 7 were used for visualisation while …xx represents the least significant bits 0 to 1.

The daily values are determined by averaging all available (day-time) LSA SAF MDSSF estimates for a given day. For such, we first calculate daily synthesis (time integrated) (0 - 23:30 UTC) DSSF values (J / m^2 a scaling factor of 10) as the sum of [0.5*(DSSF_t1 + DSSF_t2)*(t2-t1)], for all pairs of times (t1,t2) with valid data. The product name is DIDSSF and dimension is normally in J/kg/m². For sake of clear understanding, we divide such quantity by 86400s (24h*3600s). Note that the quality flag for DIDSSF is inherited from the MDSSF.

Table 5: Content of the DSSF product files.

Parameter	Dataset Name	Unit	Range	Variable Type	Scale Factor
$F^{\downarrow}$	DSSF	W/m^2	[0, 1500]	2-Byte Signed Integer	10
Quality Flag	DSSF_Q_Flag	na	[0, 255]	1-Byte Unsigned Int.	na

Table 6: DSSF quality flag information.

Bit		Binary Code	Description
Bits 0-1	Land/Sea Mask	00	Ocean++
		01	Land
		10	Space (Outside of MSG disk)++
		11	Continental Water
Bits 2-4	Cloud Mask	000	Unprocessed
		001	Clear
		010	Contaminated
		011	Cloud Filled
		100	Snow/Ice
		101	Undefined
Bit 5-7	DSSF Algorithm	000	Cloudy Sky Method
		001	Cloudy Sky Method, A_{TOA} below lower limit of equation (12)
		010	Cloudy Sky Method, A_{TOA} above upper limit of equation (13)
		011	Algorithm Failed
		100	Clear Sky Method
		101	Night
		110	Beyond specified View Angle Limit
		111	Not Processed (Cloud Mask undefined)

++For ocean and space pixels the values of the bits 2 to 7 are zero.

2.6 Summary of Product Characteristics

Product Name:	Down-welling Surface Short-wave Radiation Flux
Product Code:	DSSF
Product Level:	02
Product Parameters:	
Coverage:	Continental pixels
Packaging:	Europe, Northern Africa, Southern Africa, South America region for SEVIRI data or PDU (3-mn scan) for AVHRR data
Sampling:	pixel by pixel basis
Spatial Resolution:	full product resolution
Projection:	GEOS (0.00) for SEVIRI, none for AVHRR
Units:	W/m^2
Range:	0 - 1500 (technical upper limit)
Format:	16 bits signed integer (DSSF estimate) 8 bits (quality flag)
Frequency of Generation:	30-min for SEVIRI, irregular for AVHRR
Additional Information:	

Identification of bands used in algorithm: all the bands available in the solar domain

MSG/SEVIRI 006, 008, 016 or
EPS/AVHRR RAD001, RAD002, RAD003

Identification of ancillary and auxiliary data:

Land/Sea mask
Cloud Mask (generated from NWC-SAF)
View Azimuth and Zenith Angles (from LSA SAF System)
Solar Azimuth and Zenith Angles (from LSA SAF System)
Total Column Water Vapour (Forecast data from ECMWF)
Ozone Content (Climatology)
Land Surface Albedo (LSA-SAF Product)

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Development team

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Appendix A. Glossary

AL:	Land Surface Albedo Product
ATBD:	Algorithm Theoretical Basis Document
AVHRR:	Advanced Very High Resolution Radiometer
BRDF:	Bi-directional Reflectance Distribution Function
CNRM:	Centre National de Recherches Météorologiques
cwv:	column water vapour
DSSF:	Down-welling Surface Short-wave Radiation
ECMWF:	European Centre for Medium-Range Weather Forecast
EPS:	EUMETSAT Polar System
EUMETSAT:	European Meteorological Satellite Organisation
GOES:	Geo-stationary Operational Environmental Satellite
HDF:	Hierarchical Data Format
IM:	Instituto de Meteorologia (Portugal)
NIR:	Near Infrared Radiation
METEOSAT:	Geostationary Meteorological Satellite
METOP:	Meteorological Operational polar satellites of EUMETSAT
MISR:	Multi-Angle Imaging Spectra-Radiometer
MF:	Météo-France
MSG:	Meteosat Second Generation
MTR:	Mid Term Review
na:	not applicable
NWC:	NowCasting
NWP:	Numerical Weather Prediction
PAR:	Photosynthetically Active Radiation
OSI:	Ocean and Sea Ice
SAF:	Satellite Application Facility
SEVIRI:	Spinning Enhanced Visible and Infrared Imager
SMAC:	Simplified Method for the Atmospheric Correction
SPR:	Scientific Prototyping Report
SVPD:	Scientific Validation Plan Document
SVVP:	Software Validation & Verification Plan
TOC:	Top of Canopy
TOA:	Top of Atmosphere
TOMS:	Total Ozone Mapping Spectrometer
URD:	User Requirements Document

Appendix B. HDF5-Attributes

The set of general attributes common for all LSA SAF files and their possible values presently assigned for the DSSF product are described in the table below. Mandatory attributes are in bold while non-applicable attributes or values are in italic.

Table 7: General HDF5 attributes.

Attribute	Description	Data Type	MSG SEVIRI	EPS AVHRR
SAF	**SAF package**	**String**	**LSA**	
CENTRE	**Institution (generating/disseminating data)**	**String**	**MF**	
ARCHIVE_FACILITY	**Centre where the data is archived**	**String**	**IM-PT**	
PRODUCT	**Defines the name of the product**	**String**	**DSSF**	
PARENT_PRODUCT_NAME	**Product names upon which the product is based**	**Array[4] of Strings**		
SPECTRAL_CHANNEL_ID	**Channels Identification (1 bit per channel raised if used)**	**Integer**	**7**	**7**
PRODUCT_ALGORITHM_VERSION	**Version of the Algorithm that produced the product**	**String**	**1.12**	
CLOUD_COVERAGE	**Indicator of the cloud coverage in the product**	**String**		
OVERALL_QUALITY_FLAG	**Overall quality flag for the product**	**String**	**OK , NOK**	
ASSOCIATED_QUALITY_INFORMATION	**Several miscellaneous quality indicator for the product**	**String**		
REGION_NAME	**Processed Region Name**	**String**	**Euro, NAfr, SAfr, SAme, Full**	**PDU**
COMPRESSION	**Compression Flag**	**Integer**	**0 – Uncompressed, 1 – Compressed**	
FIELD_TYPE	**Data filed type**	**String**	**Product**	
FORECAST_STEP	***Forecast Step in Hours***	***Integer***	***0***	
NC	**Number of columns**	**Integer**		**2048**
NL	**Number of lines**	**Integer**		**1080**
NB_PARAMETERS	**Number of datasets**	**Integer**	**2**	
NOMINAL_PRODUCT_TIME	**Production Time**	**String**	**YYYYMMDDhhmmss**	
SATELLITE	**Platform identifier (mission and spacecraft the product originated from)**	**Array[10] of Strings**	**MSG1 or MSG2**	**M01**
INSTRUMENT_ID	**Instrument which acquired the product or data used by the product**	**Array[10] of Strings**	**SEVI**	**AVHR**
INSTRUMENT_MODE	**Scanning mode of the instrument at the time of the acquisition.Satellite Identification**	**String**	**STATIC_VIEW**	**NORMAL_VIEW**
IMAGE_ACQUISITION_TIME	**Image Acquisition Time (SEVIRI 1.5 Images)**	**String**	**YYYYMMDDhhmmss**	
ORBIT_TYPE	**Coverage of the product (only for EPS)**	**String**	**GEO**	**LEO**
PROJECTION_NAME	**Projection name and sub-satellite point**	**String**	**GEOS(+000.0)**	***N/A***

Attribute	Description	Data Type	MSG SEVIRI	EPS AVHRR
NOMINAL_LONG	Satellite Nominal Longitude	Real	as in Level 1.5 data	*0*
NOMINAL_LAT	Satellite Nominal Latitude	Real	as in Level 1.5 data	*0*
CFAC	Column Scaling Factor (SEVIRI 1.5 Images)	Integer	as in Level 1.5 data	*0*
LFAC	Line Scaling Factor (SEVIRI 1.5 Images)	Integer	as in Level 1.5 data	*0*
COFF	Column Offset (SEVIRI 1.5 Images)	Integer	Depends on Region	*0*
LOFF	Line Offset (SEVIRI 1.5 Images)	Integer	Depends on Region	*0*
START_ORBIT_NUMBER	First of two orbit numbers in the EPS product, valid at the starting of the sensing, i.e, at the beginning of a dump	Integer	*0*	> 0
END_ORBIT_NUMBER	Final of the orbit numbers in the EPS product, valid at the ascending node crossing, i.e. towards the end of a dump	Integer	*0*	> START_ ORBIT_NUMBER
SUB_SATELLITE_POINT_START_LAT	Latitude of sub-satellite at start of acquisition	Real	*0.0*	[-90, 90]
SUB_SATELLITE_POINT_START_LON	Longitude of sub-satellite at start of acquisition	Real	*0.0*	[-180, 180]
SUB_SATELLITE_POINT_END_LAT	Latitude of sub-satellite at end of acquisition	Real	*0.0*	[-90, 90]
SUB_SATELLITE_POINT_END_LON	Longitude of sub-satellite at end of acquisition	Real	*0.0*	[-180, 180]
SENSING_START_TIME	UTC date & time at acquisitions start of the product	String	YYYYMMDDhhmmss	
SENSING_END_TIME	UTC date & time at acquisition end of the product	String	YYYYMMDDhhmmss	
PIXEL_SIZE	For image products, size of pixel at nadir. For meteorological products resolution/accuracy	String	3.1km	1.1km
GRANULE_TYPE	Type description of the item	String	DP	
PROCESSING_LEVEL	Processing Level Applied for generation of the product	String	02	
PRODUCT_TYPE	Abbreviation name for the product type rather product category	String	LSADSSF	
PRODUCT_ACTUAL_SIZE	Actual size of the product	String		
PROCESSING_MODE	Processing mode for generation of the product	String	N – Nominal R – Reprocessed	
DISPOSITION_FLAG	Disposition status indicator of the product, as set by the UMARF operator	String	O – Operational	
TIME_RANGE	Temporal Resolution	String	30-min	Instantaneous
STATISTIC_TYPE	*Statistic Type*	*String*	-	
MEAN_SSLAT	Mean sub-satellite latitude for the coverage area	Real	[-90, 90]	
MEAN_SSLON	Mean sub-satellite longitude for the coverage area	Real	[-180, 180]	

Attribute	Description	Data Type	MSG SEVIRI	EPS AVHRR
PLANNED_CHAN_PROCESSING	*Indicates whether the channel were processed in spectral or effective radiance*	*Integer*	*0 – N/A 1 – spectral radiances 2 – effective radiances*	
FIRST_LAT	*Initial latitude for regular grid projections*	*Real*	*[-90, 90]*	
FIRST_LON	*Initial longitude for regular grid projections*	*Real*	*[-180, 180]*	

The attributes for each dataset of the HDF5-files are described in the following table.

Table 8: Dataset attributes.

Attribute	Description	Data Type	DSSF	DSSF_ Q_Flag
CLASS	**Dataset type**	**String**	**Data**	**Data**
PRODUCT	**Defines the name of the product**	**String**	**DSSF**	**Q_Flag**
PRODUCT_ID	**Product identification accordingly with WMO tables**	**Integer**	**111**	**128**
N_ COLS	**Number of columns**	**Integer**		
N_ LINES	**Number of lines**	**Integer**		
NB_BYTES	**Number of bytes per pixel**	**Integer**	**2**	**1**
SCALING_FACTOR	**Scaling factor for the parameter**	**Real**	**10.0**	***1.0***
OFFSET	**Offset of the scaling factor**	**Real**	**0.0**	***0.0***
MISS_VALUE	**Missing value**	**Integer**	**-1**	***999***
UNITS	**Parameter Units**	**Integer**	**W/m^2**	***N/A***
CAL_SLOPE	***Calibration Constant***	***Real***	***1.0***	***1.0***
CAL_OFFSET	***Calibration Constant***	***Real***	***0.0***	***0.0***