Product User Manual

PUM

DOWN-WELLING SURFACE SHORT-WAVE RADIATION FLUX

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1 Introduction

The main purpose of the Satellite Application Facility on Land Surface Analysis (LSA SAF) is to develop techniques to retrieve products related with land, land-atmosphere interactions, and biospheric applications using data from the EUMETSAT satellite systems: Meteosat Second Generation (MSG-1 launched in August 2002 and MSG-2 in December 2005) and the meteorological operational polar satellites (Metop-1 scheduled for June 2006).

Recent studies, namely those involving systematic comparisons of land surface parameterisation schemes, have stressed the role of land surface processes on weather forecasting and climate modelling. Numerical Weather Prediction (NWP) models have incorporated improved land surface representations that require sophisticated assimilation schemes of different types of land surface data that may include remote-sensed information (e.g. on LST, surface albedo, vegetation and soil moisture dynamics). Therefore the NWP community has been identified as having the greatest potential to fully exploit the LSA SAF products and the meteorological users have been assigned the highest priority during the phases of product design and development.

However, the LSA SAF addresses a much broader community, including amongst others:

- Atmospheric reanalyses and climate modelling, which require detailed information on the nature and properties of land.
- Environmental management and land use, which require information on land cover type and land cover changes (e.g. provided by biophysical parameters or thermal characteristics).
- Agricultural and forestry applications, which require information on soil and vegetation properties.
- Renewable energy resources assessment, particularly biomass, which depends on biophysical parameters, and solar energy, which highly depends on down-welling short-wave radiation at the surface.
- Natural hazards management, which requires frequent observations of terrestrial surfaces in both the solar and thermal bands.
- Climatological applications and climate change detection.

Products to be derived by the LSA SAF (Figure 1) will be based on data from satellites combined with data from different other sources. Data from EUMETSAT are extracted from Levels 1.0/1.5 for MSG and Levels 1.a/1.b for Metop. Metop data will be completed with information from other programmes like NOAA. Other sources than EUMETSAT satellite systems may also be used such as routine meteorological information. All the products will be computed within the area covered by the MSG disk or by EPS in the adjacent polar region over specific geographical regions, with the corresponding spatial and temporal resolution.

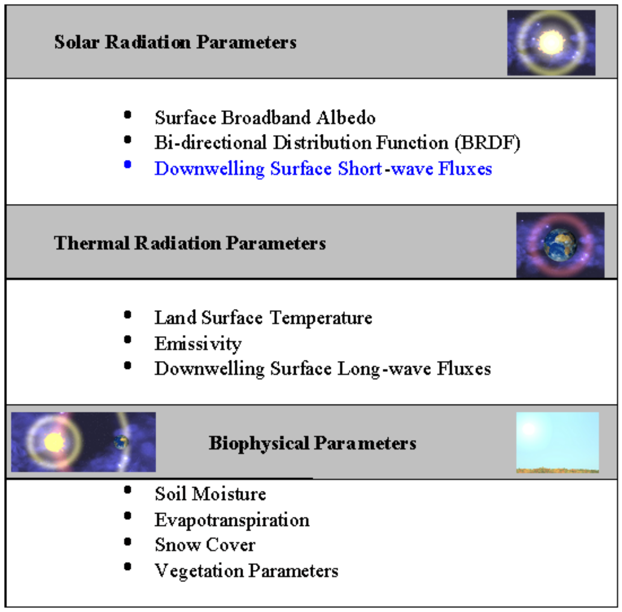

Figure 1: The LSA SAF products.

The product generation for the MSG disk is split into four different geographical areas (Figure 2), to which different priorities are assigned:

- Europe (Euro) is the highest priority geographical area, covering all EUMETSAT member states;
- Africa is split into two geographical regions (NAfr and SAfr) and is given intermediate priority;
- The geographical area including South America (SAme) has the lowest priority.

The LSA SAF system is fully centralised at IM in Lisbon and is able to operationally generate, archive, and disseminate the products. 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 the LSA SAF web-site (http://landsaf.meteo.pt) which 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 and concerns the Down-welling Surface Short-wave Radiation Flux (DSSF) algorithm developed by Météo-France.

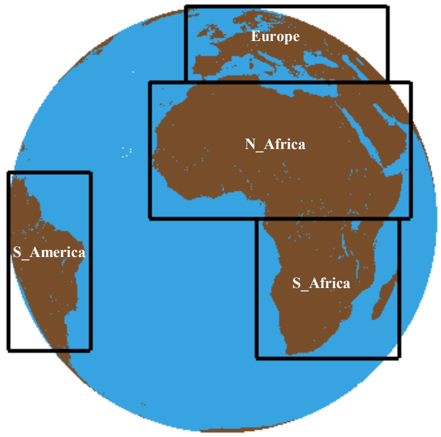

Figure 2: The LSA SAF geographical areas.

2 Algorithm

2.1 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 SAF on Ocean & Sea-Ice (Brisson et al., 1999; OSI SAF, 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 3 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.

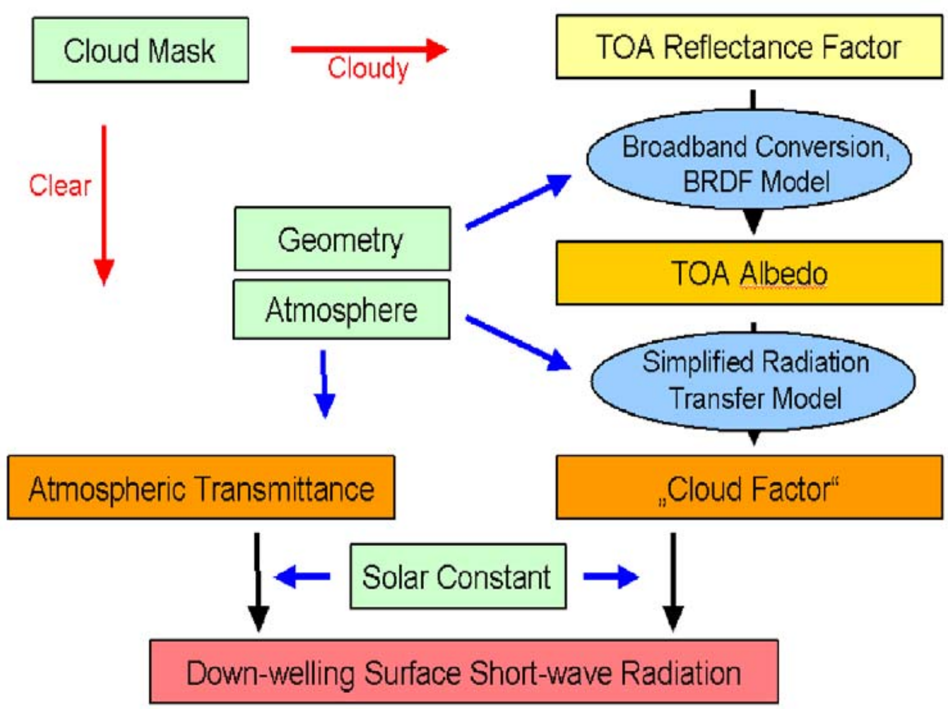

Figure 3: Simplified flow chart of the DSSF algorithm.

2.2 Definition of DSSF

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]:

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

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:

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

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

$$F^{\downarrow} = F_0 \, v(t) \cos\theta_s T_a T_x \quad , \quad (3)$$

where F_0 is the solar constant, $v(t)$ a correction factor to take into account the varying distance of the sun, θ_s the solar zenith angle, and T_a the transmittance of the atmosphere. For the factor T_x 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 Land-SAF operational system. In addition to the static atmospheric constituents, variable water vapour and ozone contents are taken into account for calculating the atmospheric transmittance.

2.3 Clear Sky Method

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

$$T_x = T_d = \frac{1}{1 - A_s (c_1 + \frac{c_2}{V})} \quad , \quad (4)$$

where A_s is the broadband surface albedo, V the visibility, and c_1 and c_2 are constants. The term T_d is larger than one and represents the increase due to multiple scattering between the surface and the atmosphere which contributes to the diffuse component of the down-welling radiation. Currently a static map is used for the surface albedo. The visibility parameter is kept at a fixed value for the time being.

2.4 Cloudy Sky Method

For cloudy pixels the DSSF estimate relies on a simplified physical description of the radiative transfer in the cloud-atmosphere-surface system. In this case T_x represents the “cloud factor" T_{cl} which is given by

$$T_x = T_{cl} = \frac{T_c}{1 - T_{bc} A_s A_c} \ . \qquad (5)$$

The denominator has a similar significance as in the clear sky case and quantifies multiple scattering between the surface and the clouds. T_{bc} represents the atmospheric transmittance below the cloud, which is close to one and whose exact quantification is of minor importance. A_c denotes the cloud albedo. The cloud transmittance T_c is the decisive quantity in this expression. T_c and A_c are calculated by solving an equation system which follows from the radiation transfer parameterisation. The top-of-atmosphere broadband albedo turns out to be the most important input quantity for this equation system. It may be highly variable on small time scales depending on the daily evolution of the clouds. It is determined from the observed instantaneous reflectances in the 0.6µm, 0.8µm, and 1.6µm SEVIRI channels. For this purpose the spectral reflectances of an image scene are first transformed to broadband reflectance by applying a pre-defined set of conversion coefficients. Then the bi-directional reflectance model of Manalo-Smith et al. (1998) is used to convert the directional reflectance values into top-of-atmosphere albedo estimates.

3 Validation

As specified in the User Requirements Document the objective for the accuracy of the product is 5%. The validation strategy is documented in the Scientific Validation Plan Document. Preliminary results are given in the Validation Report available on the LSA SAF website. A summary of the validation studies will be included in the Product User Manual when substantial quantitative results are available.

4 Product Description

4.1 Overview

In the LSA SAF operational system the four geographical regions depicted in Figure 2 are processed separately. The main characteristics of these windows are listed in Table 1. 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 are available from the LSA-SAF website: http://landsaf.meteo.pt. The DSSF 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. In Northern Europe the line acquisition time deviates from the slot time by approximately 12 minutes.

Table 1: 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 indeces 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

4.2 File Format

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

HDF5_LSASAF_MSG_DSSF_Region_YYYYMMDDhhmm

where **Region**, **YYYY**, **MM**, **DD**, **hh**, and **mm**, respectively, denote the region name, year, month, day, hour, and minute of data acquisition.

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 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/. 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 4 of Appendix C. 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 5 of Appendix C).

4.3 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 2. Figure 4 and Figure 5, respectively, depict examples for the DSSF estimate and the corresponding quality flag derived from one slot of MSG observations.

Table 2: 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

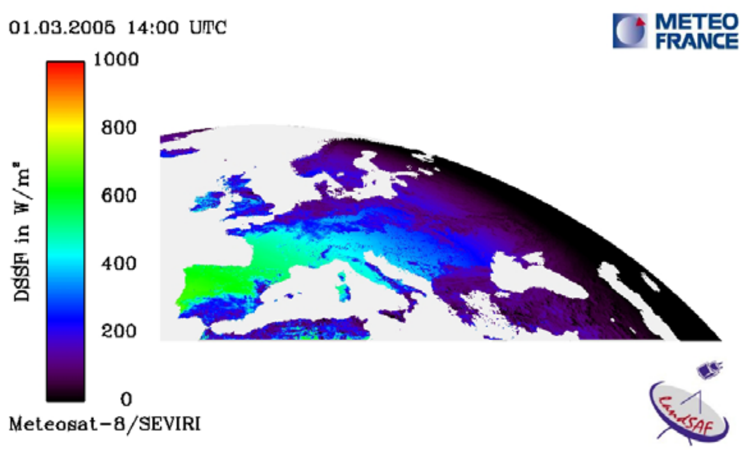

Figure 4: Down-welling surface short-wave radiation flux estimate for the European window on the 1st of March 2005 at 14:00 UTC.

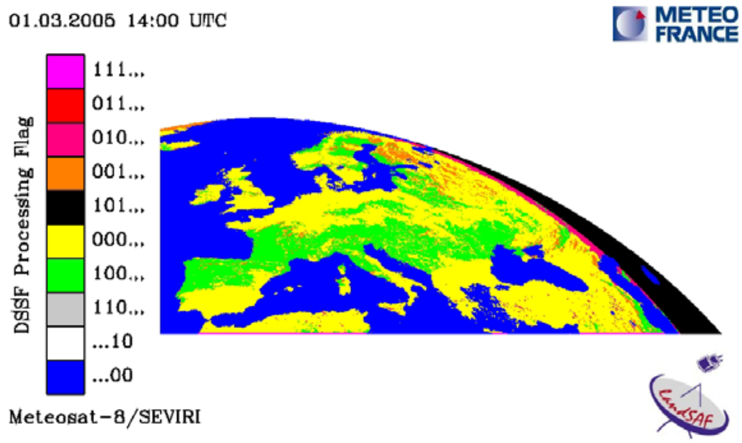

Figure 5: Quality flag corresponding to the DSSF estimate depicted in Figure 4. The signification of the bit codes is given in Table 3. **xxx…** indicates that the most significant bits 5 to 7 were used for visualisation while **…xx** represents the least significant bits 0 to 1.

The signification of the numerical values of the quality flag is explained in Table 3. 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. Finally bits 5 to 7 contain information about the method applied to calculate the DSSF estimate and possible problems encountered.

Table 3: 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
		010	Cloudy Sky Method, A_{TOA} above upper limit
		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.

4.4 Summary of Product Characteristics

Product Name: Down-welling Surface Short-wave Radiation Flux

Product Code: DSSF

Product Level: Level 3

Product Parameters:

Coverage: MSG full disk (Continental pixels)

Packaging: Europe, N_Africa, S_Africa, S_America

Sampling: pixel by pixel basis

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

Projection:	MSG/SEVIRI Level 1.5 data projection
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 minutes
Size of Product Files:	0.7Mb – 1.2Mb (Europe) depending on compression efficiency

Additional Information:

Identification of bands used in algorithm:

MSG VIS 0.6

MSG NIR 0.8

MSG SWIR 1.6

Assumptions on SEVIRI input data:

Radiometric and Geometric Calibration

Identification of ancillary and auxiliary data:

Land/Sea mask
Cloud Mask (from NWC SAF software)
View Azimuth and Zenith Angles (from LSA SAF System)
Solar Azimuth and Zenith Angles (from LSA SAF System)
Total Column Water Vapour (from ECMWF model)
Ozone Content (from TOMS climatology)
Land Surface Albedo (currently a static map)

5 References

Brisson A., LeBorgne P., Marsouin A., 1999, *Development of Algorithms for Surface Solar Irradiance retrieval at O&SI SAF low and Mid Latitude*, Météo-France/CMS, Lannion.

Frouin R, Chertock B., 1992, *A technique for global monitoring of net solar irradiance at the coean surface. Part 1: Model*, J. Appl. Meteor., 31, 1056-1066.

Gautier C., Diak G., Masse S., 1980, A simple physical model to estimate incident solar radiation at the surface from GOES satellite data, J. Climate Appl. Meteor., 19, 1005-1012.

Iqbal M., 1983, *An Introduction to Solar Radiation*, Academic Press, 390pp.

Manalo-Smith N., G.L. Smith, S.N. Tiwari, W. F. Staylor, 1998, *Analytic forms of bi-directional reflectance functions for application to Earth radiation budget studies*, Journal of Geophysical Research, Vol. 103, D16, pp. 19, 733-19, 751.

Ocean & Sea Ice SAF, 2002, *Surface Solar Irradiance Product Manual*, Version 1.2

Appendix A. Developers

The development and implementation have been carried out under the responsibility of the Centre National de Recherches Météorologiques (CNRM) de Météo-France (MF).

Authors: Bernhard Geiger, Dulce Lajas, Laurent Franchistéguy, Dominique Carrer, and Jean-Louis Roujean

Appendix B. 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
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
URD: User Requirements Document

Appendix C. HDF5-Attributes

The set of general attributes to be part of all LSA SAF files and their possible values presently assigned for the DSSF product are described in the table below.

Table 4: General HDF5 attributes.

Attribute	Description	Data Type	Value for DSSF Product Files
SAF	SAF package	String	LSA
CENTRE	Institution (generating/disseminating data)	String	MF
ARCHIVE_FACILITY	Centre where the data is archived	String	-
PRODUCT	Defines the name of the product	String	DSSF
PARENT_PRODUCT_NAME	Array of up to 4 product names, upon which the product is based	String Array(4)	CMa, AL,WV, SZA, SAA
SPECTRAL_CHANNEL_ID	Channel Identification (1 bit per channel, where LSB is HRV and MSB is IR13.4; values are 0 if not used, 1 if used.)	Integer	14
PRODUCT_ALGORITHM_VERSION	Version of the Algorithm that produce the product	String	1.11
BASE_ALGORITHM_VERSION	Version of the algorithm, (i) which was used to generate the L1.0 MSG product, or (ii) that produced the L1.0 or L1.5 MSG parent product, upon which the product is based.	String	-
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, or SAme.
COMPRESSION	Compression Flag	Integer	0 – Uncompressed 1 – Compressed
FIELD_TYPE	Data filed type	String	-.
FORECAST_STEP	Forecast Step in Hours	Integer	0
NC	Number of columns	Integer	Depends on Region
NL	Number of lines	Integer	Depends on Region
NB_PARAMETERS	Number of datasets	Integer	2

Attribute	Description	Data Type	Value for DSSF Product Files
NOMINAL PRODUCT_TIME	Production Time	String	YYMMDDhhmmss
SATELLITE_ID	Satellite Identification	Integer	0
IMAGE_ACQUISITION_TIME	Image Acquisition Time (SEVIRI 1.5 Images)	String	YYMMDDhhmm
ORBIT_TYPE	Coverage of the product (only for EPS)	String	-
PROJECTION_NAME	Projection name and sub-satellite point	String	-
NOMINAL_LONG	Satellite Nominal Longitude	Real	0
NOMINAL_LAT	Satellite Nominal Latitude	Real	0
CFAC	Column Scaling Factor (SEVIRI 1.5 Images)	Integer	0
LFAC	Line Scaling Factor (SEVIRI 1.5 Images)	Integer	0
COFF	Column Offset (SEVIRI 1.5 Images)	Integer	0
LOFF	Line Offset (SEVIRI 1.5 Images)	Integer	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
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
SUB_SATELLITE_POINT_START_LAT	Latitude of sub-satellite at start of acquisition	Real	0
SUB_SATELLITE_POINT_START_LON	Longitude of sub-satellite at start of acquisition	Real	0
SUB_SATELLITE_POINT_END_LAT	Latitude of sub-satellite at end of acquisition	Real	0
SUB_SATELLITE_POINT_END_LON	Longitude of sub-satellite at end of acquisition	Real	0
SENSING_START_TIME	UTC date & time at acquisitions start of the product	String	-
SENSING_END_TIME	UTC date & time at acquisition end of the product	String	-
SPATIAL_COVERAGE_MODEL	Model of spatial coverage of the entire product	String	-
PIXEL_SIZE	For image products, size of pixel at nadir. For meteorological products resolution/accuracy	String	-
GRANULE_TYPE	Type description of the item	String	-

Attribute	Description	Data Type	Value for DSSF Product Files
PROCESSING_LEVEL	Processing Level Applied for generation of the product	String	-
PRODUCT_TYPE	Abbreviation name for the product type rather product category	String	-
PRODUCT_ACTUAL_SIZE	Actual size of the product	String	-
NATIVE_PRODUCT_FORMAT_TYPE	Data format of the product	String	-
NATIVE_PRODUCT_FORMAT_VERSION	Concatenation of major and minor version of the product format	String	-
PROCESSING_MODE	Processing mode for generation of the product	String	-
SOURCE_ENVIRONMENT	MSG ground-segment environment (chain) in witch the product has been processed	String	-
DISPOSITION_FLAG	Disposition status indicator of the product, as set by the UMARF operator	String	-

LSB – Lower Significant Bit
MSB – Most Significant Bit
YY - Year; MM-Month; DD – Day; hh – Hour; mm – Minute; ss – Second
String => Character (len=80)
Integer => Integer (kind=4)
Real => Real (kind=8)

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

Table 5: Dataset attributes.

Attribute	Description	Data Type	Value for Dataset DSSF	Value for Dataset 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	Depends on Region	Depends on Region
N_ LINES	Number of lines	Integer	Depends on Region	Depends on Region
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