Geostationary Radiative Fluxes Product User Manual

METEOSAT (0°) DLI (OSI-303-a)

METEOSAT (0°) SSI (OSI-304-a)

GOES-E DLI (OSI-305-a)

GOES-E SSI (OSI-306-a)

METEOSAT over Indian Ocean DLI (demo)

METEOSAT over Indian Ocean SSI (demo)

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Document Change record

Document version	Software version	Date	Author	Change description
1.0		10/04/2011		First version.
1.1		14/06/2011		Updated version with Appendix A.4: ncdump of a METEOSAT-9 hourly flux
1.2		28/11/2011		Appendix A.2. and A.3. updated
1.3		15/04/2013		4.5 updated
1.4		16/08/2016		Timeliness correction
1.5	a1.0p1.0	13/07/2017		Addition of the demo products : METEOSAT over Indian Ocean DLI and SSI Addition of information on output formats : GRIB (planned to be stopped at the end of 2017), switch from NetCDF3 to NetCDF4.
1.6	a1.0p1.0	13/12/2017		From 14/12/2017, GOES-16 (new generation) replaces GOES-13 : OSI-305 becomes OSI-305-a OSI-306 becomes OSI-306-a From 14/12/2017, GRIB and NetCDF3 are discontinued. NetCDF4 is the only format available.
1.7	a1.0p1.0	08/02/2018	CH	From 20/02/2018, Meteosat-11 (also Meteosat Second Generation) replaces Meteosat-10: OSI-303 becomes OSI-303-a, OSI-304 becomes OSI-304-a
1.8	a1.0p1.1	26/02/2018	CH	Tuning of coefficient: 0.94 is now applied to the calibrated visible channel (ABI channel 2), which is the main input of the Surface Solar Irradiance (SSI). This factor has been estimated mainly from the comparison between GOES-16 and Meteosat-10 SSI over the area common to both satellites. The tuned algorithm is used since hourly file dated 20180226T10:00:00Z and daily file dated 20180227T12:00:00Z

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1. Introduction

1.1. Overview

The EUMETSAT Ocean and Sea Ice Satellite Application Facility (OSI SAF) is a consortium constituted of Météo-France as leading entity, and MET Norway, DMI, KNMI and Ifremer as co-operating entities.

The OSI SAF is routinely producing on a pre-operational or operational basis a range of air-sea interface products, namely: wind, sea ice characteristics, Sea Surface Temperatures (SST) and radiative fluxes : Downward Longwave Irradiance (DLI) and Surface Solar Irradiance (SSI).

OSI SAF commitments for a 5-years phase are described in the Product Requirement Document (PRD) [AD.1]. Operational and pre-operational OSI SAF products are described in the Service Specification Document (SeSp) [AD.2].

Users are highly recommended to register on the OSI SAF Web Site : http://osi-saf.eumetsat.int, in order to get access to useful information, documentation and links, service messages, and to the helpdesk.

The main content of this manual are a description of the processing methods, an introduction to the algorithms used, some validation results and the product content and format.

The present manual describes the geostationary derived radiative fluxes products.
The OSI SAF is committed to produce hourly and daily DLI and SSI products on distinct 0.05° resolution grids for GOES-E and MSG.
OSI SAF has no commitment on the hourly and daily DLI and SSI products with Meteosat-8 over Indian Ocean data which is available in a demo mode : these data are produced in "best effort" mode, and are not delivered under operational constraints. The production may be temporarily interrupted without any notice.

Table 1 describes the characteristics of the OSI SAF derived geostationary radiative fluxes.

<table>
<tr><th>Name (reference)</th><th>Coverage</th><th>Resolution</th><th>Time characteristics</th><th>Formats**</th><th>Timeliness*</th><th>Volume per unit (NetCDF4)</th></tr>
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</table>

Table 1: Characteristics of the OSI SAF geostationary derived radiative fluxes products

* See timeliness definition in [AD.1]
** **GRIB2 discontinued since 14/12/2017.**

Validation are available in the following reports :

- METEOSAT and GOES-E Radiative fluxes validation report [RD.1]
- Radiative fluxes over Indian Ocean from METEOSAT-8 data, validation report [RD.2]

Validations statistics are also provided in the Half-yearly Operations Reports and on the web site eumetsat.

Until a validation report on GOES-E SST with GOES-16 as input quality is provided in 2018, OSI-305-a and OSI-306-a are distributed with a pre-operational status.

1.2. Ownership and copyright of data

All intellectual property rights of the OSI SAF products belong to EUMETSAT. The use of these products is granted to every interested user, free of charge. If you wish to use these products, EUMETSAT's copyright credit must be shown by displaying the words "Copyright © <YYYY> EUMETSAT" on each of the products used.

User feedback to the OSI SAF project team is highly valued. The comments we get from our users is important argumentation when defining development activities and updates. We welcome anyone to use the data and provide feedback.

1.3. Glossary

AVHRR	Advanced Very High Resolution Radiometer
CERES	Clouds and Earth's Radiant Energy System
CMS	Centre de Météorologie Spatiale (Météo-France)
DAY	Internal OSI SAF products, in space view at full resolution : integration of all the hourly values in the UT day
DLI	Downward Longwave Irradiance
DMI	Danish Meteorological Institute
ECMWF	European Center for Medium range Weather Forecast
GOES	Geostationary Operational Environmental Satellite
GRIB	Gridded Binary format
HL	High Latitudes
Ifremer	Institut Français de Recherche pour l'Exploitation de la Mer
IR	Infrared
LML	Low and Mid Latitudes
MDB	Match up Data Base
MET	(or MET Norway) Norvegian Meteorological Institute
NOAA	National Oceanic and Atmospheric Administration
NWC SAF	Nowcasting SAF
OSI SAF	Ocean and Sea Ice SAF
PRD	Internal OSI SAF products, in space view at full resolution : output of the interpolation at UT rounded hour
SAF	Satellite Application Facility
SAT	Internal OSI SAF products, in space view at full resolution : output of the calculation performed every 30 minutes
SEVIRI	Spinning Enhanced Visible and Infrared Imager
SSI	Surface Solar Irradiance
SST	Sea Surface Temperature
TOA	Top of atmosphere
UT	Universal Time

Tableau 2: Glossary

1.4. Applicable and reference documents

1.4.1. Applicable documents

[AD.1] OSI SAF
CDOP 3 Product Requirement Document (PRD)
SAF/OSI/CDOP3/MF/MGT/PL/2-001, Version 1.1, 20/11/2017

[AD.2] OSI SAF
Service Specification (SeSp)
SAF/OSI/CDOP3/MF/MGT/PL/003, Version 1.2, 20/11/2017

Reference to an Applicable Document within the body of this document is indicated as reference in the list above, e.g. [AD.1].

1.4.2. Reference documents

[RD.1] OSI SAF
METEOSAT and GOES-E Radiative fluxes *validation report*
SAF/OSI/CDOP/M-F/TEC/MA/184
Version 1.2, June 2011

[RD.2] OSI SAF
Radiative fluxes over Indian Ocean from METEOSAT-8 data, validation report
SAF/OSI/CDOP3/MF/SCI/RP/305
Version 1.0, 3 July 2017

Reference to a Reference Document within the body of this document is indicated as reference in the list above, e.g. [RD.1].

2. SSI algorithm

The OSI SAF algorithm is a physical parametrization applied separately to every pixel of a satellite image to derive an instantaneous field of the Solar Surface Irradiance. This section presents the basic equations of the method and those specific to a given satellite. The satellite dependent parameters may evolve during the lifetime of the chain; the values indicated in this section are valid at the time of the present document.

2.1. Equations

The main input for SSI calculation is the satellite visible image and the various steps of the method are the following.

Calibration

This step, which converts the satellite visible count into a bi-directional reflectance, depends on the considered radiometer channel. The formulation of equation (1) depends on the instrument and are presented in the following paragraphs.

$$L_{sc} = L_{sc}(t, C) \quad (1)$$

$$R_{nb} = L_{sc} / [\nu(j) \cos(\theta_0)] \quad (2)$$

$$\nu(j) = 1 + 0.0334 \cos[2\pi(j-2) / 365.25] \quad (3)$$

with

- C : radiometer count
- t : current time (julian day)
- θ_0 : sun zenith angle
- $\nu(j)$: corrective term accounting for the Earth-sun distance seasonal variation, j is the day of year
- L_{sc} : scaled radiance i.e. radiance divided by the “effective solar constant”, which is the solar spectral irradiance convoluted with the radiometer filter
- R_{nb} : narrowband reflectance

Narrow to broadband conversion

The reflectance relative to the narrow band of the radiometer spectral filter is converted into the reflectance relative to the broadband of the solar spectrum. This step depends on the satellite and on the scene type, for instance vegetation, desert, ocean or cloud.

Anisotropy correction

The broadband bi-directional reflectance is converted into the planetary albedo, which is independent of satellite viewing angle. This step is based on the Manalo-Smith et al. 1998 formulas (derived from Earth Radiation Budget Instrument data), where the anisotropic factor is an analytical function of the viewing angles depending on the scene type.

$$A(\theta_0) = R / f_{aniso} \quad (4)$$

with

- A : Top Of Atmosphere (TOA) albedo or planetary albedo
- R : broadband reflectance
- f_{aniso} : anisotropic factor or bi-directional reflectance function (BDRF)

Clear sky parameterization
This step uses the Frouin and Chertock, 1992 parameterization, where the atmospheric transmittance is an analytical formula depending on the satellite and sun zenith angles, the integrated water vapor content of the atmosphere, ozone content, horizontal visibility and surface albedo (for the multiple scattering corrective term).

$E = E_0\ \nu(j)\cos(\theta_0)\ T_a$ in clear case (5)

with

E : surface solar irradiance
E_0 : solar constant
T_a : clear sky atmospheric transmittance (with multiple scattering)

Cloudy sky parametrization
This step uses a physical parametrization of the SSI as a function of the planetary albedo and the basic equations are given below (see Brisson et al., 1999 for more details).

$E = E_0\ \nu(j)\cos(\theta_0)\ T_1\ T_{cl}$ in cloudy case (6)

$T_{cl} = T_c / (1 - T_{bc} A_s . A_c)$ (7)

$T_c = 1 - A_c - A_c\ m\cos(\theta_0)$ (8)

$A = A_{ray} + T_{2top} A_c + A_s T_2 T_c^2 / (1 - T_{bc} A_s . A_c)$ (9)

with

T_1 : sun-surface atmospheric transmittance, without multiple scattering (consistent with T_a)
T_2 : sun-surface-satellite transmittance
T_{2top} : sun-cloud-satellite transmittance
T_{bc} : transmittance below cloud (to account for multiple scattering)
A_{ray} : Rayleigh albedo
A_s : surface albedo
A_c : cloud albedo
T_c : cloud transmittance
T_{cl} : cloud factor
m : cloud absorption factor

The sea surface albedo can be calculated theoretically, while the land surface albedo is derived from an atlas. Both of them vary with respect to the sun zenith angle. The Briegleb et al., 1986 formulas are used:

land $A_s = A_s(0)\ (1+2d) / (1+2d\,\mu_0)$ $d = 0.4$ (10)

sea with clear sky $A_s = 0.026/(0.065+ \mu_0^{\ 1.7}) + 15.0(\mu_0 -0.1)(\mu_0-0.5)(\mu_0-1.)$ (11)

sea with cloudy sky $A_s = 0.06$ (12)

where $\mu_0 = \cos(\theta_0)$

The method is based on already published parametrizations except for one parameter, the cloud absorption factor (m in equation (8)), which has been tuned on actual satellite data. It should be noted that the tuned value is not fully independent of the satellite calibration.

2.2. METEOSAT specific

Calibration of SEVIRI visible channel

At present, the SSI is derived from the 0.6 µm visible channel of SEVIRI. According to Rogers and Pili, 2001 and to Pili, 2002 (personal communication), the calibration equation, (1), can be written as follows:

$$L_{SC} = (cal\_offset + cal\_slope\ C) / f \qquad (1a)$$

with

C : radiometer count
cal_offset : calibration offset of SEVIRI level 1.5 header, in mW m^{-2} sr^{-1} $(cm^{-1})^{-1}$
cal_slope : calibration slope of SEVIRI level 1.5 header, in mW m^{-2} sr^{-1} $(cm^{-1})^{-1}$
f: radiance to reflectance factor, f= 21.21 mW m^{-2} sr^{-1} $(cm^{-1})^{-1}$ for the 0.6 µm channel (Pili, 2002, personal communication)

The calibration coefficients of SEVIRI level 1.5 data are updated several times per year, as a result of the vicarious calibration method presented in Govaerts and Clerici, 2003. However, the correspondence between the level 1.5 values and those in Govaerts and Clerici, 2003 has not been explicitly presented and is not straightforward (different units, intermediate constants not given and, likely, different offset calculation).
The radiometer drift is taken into account in the level 1.5 calibration coefficients.

Narrow to broadband band conversion

As proposed in Pinker and Lazlo, 1992, this conversion is made with a linear formula :

$$R = M\ R_{nb} + B \qquad (13)$$

where the M and B coefficients depend on the scene type. Instead of one type “cloud” as in Pinker and Lazlo, 1992, several types of clouds have been introduced, since the reflectance of fractional and semi-transparent clouds vary with the underlying surface.

Meteosat coefficients are based on the well-calibrated broadband radiometer CERES (Clouds and Earth’s Radiant Energy System). They have been obtained by regression on Meteosat-8/SEVIRI and CERES co-located data, supplied by Nicolas Clerbaux. They have been applied to Meteosat-8 data (since 8 March 2005), to Meteosat-9, to Meteosat-10 and to Meteosat-11.

	cloud over ocean	cloud over vegetation	cloud over desert
M	0.819	0.774	0.814
B	0.023	0.063	0.030

Table 3: narrow to broadband band coefficients for the 0.6 µm visible channel of SEVIRI

2.3. GOES-E specific

Calibration of visible channel

In the case of GOES-E, the calibration can be written by one of the following equations:

$$Lsc = \alpha\ a\ [\ 1 + b\ (t - t_0)\ ]\ (C - C_0) \qquad (1c)$$

or

$$Lsc = \alpha\ a\ \exp[b\ (t - t_0)\ ]\ (C - C_0) \qquad (1b)$$

with

C	: radiometer count
C_0	: radiometer space count
α	: pre-launch calibration coefficient
a	: calibration correction coefficient valid at t0 (count-1)
b	: radiometer drift (count-1 day-1 or count-1 year-1)
t_0	: reference time
t	: current time

Equation (1b) is the correct formula, which is used at NOAA. Equation (1c) is an approximation, widely used in the past for GOES and METEOSAT series, which could be used for a drift estimation obtained with this formula.

The CMS operational scheme, which ingests and pre-processes GOES-E data, uses the pre-launch calibration coefficients, available in Weinreb and Han, 2009 (they slightly differ for the eight detectors of the visible channel). Then the OSI SAF processing chain applies a calibration correction.

GOES-12 visible channel has been inter-calibrated against METEOSAT-8 at 37.5W, following the method described in Le Borgne et al. 2004, leading to a corrective factor to be applied to the pre-launch calibration coefficients and to a drift estimation.

GOES-13 became operational on 14 April 2010. As the method used for GOES-12 does not allow a rapid calibration, an empirical approach has been followed. Firstly, a positive bias was observed on the validation stations with GOES-13 on 15-30 April (compared to a negligible bias with GOES-12 on 1-13 April), secondly the routine SSI comparison GOES-E minus METEOSAT shows a positive difference starting on 15 April with GOES-13. This lead to a calibration correction coefficient a = 1.11 (without drift, i.e. b = 0).
GOES-13 calibration has been updated several times with the NOAA post-launch calibration coefficients of February 2011 (http://www.oso.noaa.gov/goes/goes-calibration/), leading to the following values:

15 March 2011	a= 1.1127	b = 0.0558 year-1	t_0: 14 April 2010
9 October 2013	a= 1.1256	b = 0.0358 year-1	t_0: 14 April 2010

GOES-16 became operational in December 2017. Temporary calibration was used, and it was updated on 26 February 2018:

14 December 2017	a=1.0	b=0 year-1	t_0: 1 September 2017
26 February 2018	a= 0.94	b=0 year-1	t_0: 1 September 2017

Narrow to broadband band conversion
The GOES-12 versus METEOSAT-8 comparison at 37.5W has produced GOES-12 calibration coefficient, as a first step, and narrow to broadband coefficients, as a second step. The results over ocean and over Brazil allow to obtain coefficients, “cloud over ocean” and “cloud over vegetation”, respectively. No data are available close to 37.5W to obtain the “cloud over desert” coefficients, which are taken equal the “cloud over vegetation” values.

Similarly to the METEOSAT satellites, the GOES-12 coefficients are also used for GOES-13 and GOES-16. These coefficients are presented in table 4.

	cloud over ocean	cloud over vegetation	cloud over desert
M	0.838	0.801	0.801
B	0.014	0.032	0.032

Table 4: GOES-E narrow to broadband band coefficients

3. DLI algorithm

3.1. Equations

The OSI SAF algorithm is a bulk parametrization that uses NWP model outputs to calculate a clear sky Downward Longwave Irradiance (DLI), corrected according to satellite derived cloud information. The calculated DLI is considered as instantaneous since the cloud information, cloud types derived from the NWC SAF classification, for nighttime cases, and Surface Solar Irradiance (SSI), for daytime cases, are instantaneous. This section presents the equations of the DLI parametrization, which are rather simple and satellite independent.

$$L = (\mathcal{E}_0 + (1 - \mathcal{E}_0)\, C\,)\, \sigma\, T_a^4 \qquad (14)$$

$$\mathcal{E}_0 = 1-(1+\xi)\exp\{-(1.2 + 3.0\,\xi)^{1/2}\} \;\; -0.05\,(p_0-p) / (p_0-710) \qquad (15)$$

$$\xi = 46.5\,(e / T_a)$$

(16)

$$C = 1 - E / E_{clear} \qquad \text{“SOLAR” method, for daytime cases} \qquad (18)$$

$$C = C_i \qquad \text{“CLASSIF” method, for nighttime cases} \qquad (18)$$

with
- L : downward longwave irradiance at the Earth’s surface (W/m^2)
- $\mathcal{E}_0$: clear sky emissivity
- C : infrared cloud amount
- T_a : near surface air temperature (K)
- σ : Stefan-Boltzmann constant □ = 5.6696 10^{-8} W m^{-2} K^{-4}
- e : near surface surface water vapor pressure (hPa)
- p : surface atmospheric pressure (hPa)
- p_0 : normal atmospheric pressure, 1013.25 hPa
- E : surface solar irradiance (W/m^2)
- E_{clear} : clear sky surface solar irradiance (W/m^2)
- C_i : contribution coefficient of this cloud type

The DLI is calculated as the sum of a clear sky and cloud sky contributions (equation (14)). The clear sky emissivity is derived from the near surface air temperature and water vapor pressure, according to the formulation proposed by Prata, 1996 (equations (15) and (16)). The infrared cloud amount, which gives the cloudy sky contribution, is obtained by two different formulations:

- For daytime cases (equation (17)), the infrared cloud amount is directly deduced from the actual to clear sky SSI ratio, as proposed by Crawford and Duchon, 1999.
- For nighttime cases (equation (18)), the infrared cloud amount is directly the cloud contribution coefficent of the cloud type covering the pixel.

The DLI cloud types correspond to a simplified cloud classification, merging several types of the NWC SAF detailed cloud classification (Derrien and Le Gléau, 2005). The values of the cloud contribution coefficients, presented in table 5, have been adjusted on a 1-year data base (July 97 to June 98) gathering DLI measurements, GOES-8 data and observed air temperature and humidity (Brisson et al., 2000). The NWC SAF detailed cloud types have evolved since 1998 but the METEOSAT and GOES-E cloud types have always been merged into the same simplified cloud types.

DLI cloud type	C_i	DLI cloud type	C_i
clear	0	fractional cloud	0.15
low cloud	0.82	volcanic ash	0
medium cloud	0.78	sand cloud	0.52
high opaque cloud	0.72	unclassified	0
thin cirrus	0.11	clear re-classified	0
thick cirrus	0.49	medium dubious	0.15

Table 5: cloud types and cloud contribution coefficients (Ci)

4. Processing scheme

4.1. Principles

The three satellites, GOES-E and METEOSAT (Meteosat-8 over Indian Ocean and Meteosat-11 in 0°), are processed separately with a similar scheme. The radiative fluxes are calculated in satellite space view at full resolution for hourly and daily products and re-mapped afterwards.

An essential point is the calculation of products interpolated at rounded UT hours. A radiative flux calculated on a satellite image is not homogeneous in time. The pixel time varies from north to south, of about 12 minutes for METEOSAT data and about 24 minutes for GOES-E data. This temporal variation cannot be neglected for the SSI, which directly depends on the sun zenith angle. In the previous operational chain, a time information was associated to each pixel. The present chain delivers a pseudo instantaneous product, which is obtained by a pixel dependant temporal interpolation between two consecutive satellite images.

The main steps of the processing scheme are described in the next sections.

4.2. Calculation on the satellite slot

This step is performed every 30 minutes in satellite space view at full resolution; the output is a so-called SAT product. The SSI calculation combines the algorithm presented in section 2 and various auxiliary parameters (atlas, monthly climatology or instantaneous field), briefly described in Appendix 8.1. The DLI is calculated by the algorithm presented in section 3.

4.3. Interpolation at UT rounded hour

The output of this step is a so-called PRD product. The interpolation method has been developed especially for the SSI and is also applied to the DLI. On each pixel, all time dependant parameters (viewing angles, surface albedo, atmospheric absorption) are calculated at the UT rounded hour (H). The cloud albedo (SSI) or the cloud contribution (DLI) is interpolated between the values available before and after H.

The interpolation scheme is designed to cope for eventual missing images and to produce a value in any case (the quality level being decreased accordingly to the problems encountered, as described in 4.5):

- in normal case, the before-and-after values are separated by 30 minutes, but a wider interval is allowed,
- if only one value is available, instead of the before-and-after values, this value is used as of,
- eventually, a default value will be used: 0.22 (as of March 2011) for the cloud albedo and 0.29 (as of March 2011) for the cloud contribution

4.4. Daily calculation

A so-called DAY product is derived from the PRD products. The daily value is the integration of all the hourly values in the UT day. As the PRD products do not have missing values, the DLI daily integration is straightforward. The SSI daily integration is slightly more complicate, since it accounts for the calculated sunrise and sun set times, independently for every pixel. The solar day may be fully included in the UT day or corresponds to two uncompleted solar days: day 1 / night / day 2.

4.5. Quality levels

Similarly to the SST products, each pixel DLI or SSI value, is associated to a quality level expressed on a scale showing 6 values : 0 : unprocessed, 1 : erroneous, 2: bad, 3: acceptable, 4: good, 5 : excellent.

The 0 value corresponds most of the time to space, the 1 value corresponds to an error in the software logic and should not occur. The other value meanings depend on the products and are described below.

<u>SSI SAT</u>

- 5: nominal calculation
- 4: SSI calculation with a minor problem:
  - sunglint
  - TOA albedo too low, case considered as clear
  - TOA albedo too high, maximum cloudiness assumed, SSI=0

<u>DLI SAT</u>

- 5: DLI value calculated with the daytime method (SSI ratio)
- 4: DLI value calculated with the nighttime method (NWC classification)

Values 3 and 2 are not used for the SAT products.

<u>SSI or DLI PRD</u>

The PRD flux value is interpolated between SAT values, as explained in 4.3; its quality level is obtained as follows:

- 5: interpolation between two SAT values both having a quality level of 5
- 4: interpolation between two SAT values with quality levels (4,5) or (4,4)
- 3: interpolation with only one SAT value: sunrise, sunset or missing value
- 2: no SAT value available, using default cloud albedo or contribution

<u>SSI or DLI DAY</u>

The quality level is the rounded mean of the PRD quality levels associated to the fluxes entering into the daily integration; this produces a value from 2 to 5.

The list of pyrgeometer stations used for validating the geostationary DLI or SSI products is available on the OSI SAF Web Site from the following page :
http://osi-saf.eumetsat.int/lml/img/flx_map_stations_2b.gif

4.6. Remapping

The SAT, PRD and DAY products are internal OSI SAF products, in space view at full resolution. The OSI SAF distributed products are obtained by remapping at the nearest neighbour the PRD and DAY products onto a regular 0.05° grid. The remapping is a final step, which simply re-distributes the radiative fluxes and quality level values without changing them.

5. Product description

The final geostationary derived radiative fluxes products characteristics are the following:

Projection:	linear scaling in latitude and longitude	
Resolution:	0.05 degree in latitude and longitude	
Size:	2400 columns, 2400 lines	
Longitude and latitude limits :	GOES-E SST:	60S-60N; 135W- 15W
	MSG SST:	60S-60N; 60 W- 60E
	MSG IO SST :	60S-60N; 19.5W-101.5E
Time:	every rounded TU hour and daily	

There are separate files for each satellite and for each hourly or daily product.
DLI and SSI are in the same file for NetCDF4 output.

Information on the NetCDF4 files volume (per unit) is indicated in Table 1 : Characteristics of the OSI SAF geostationary derived radiative fluxes products.

6. Access to the products

Access to the products is indicated in the following table :

Name (reference)	Format*	Near real time access	Off line access
MET DLI (OSI-303) MET SSI (OSI-304) GOES-E DLI (OSI-305-a) GOES-E SSI (OSI-306-a)	L3 NetCDF4	EUMETCast Ifremer FTP server	Ifremer FTP server EUMETSAT data centre (from 2017)
MET IO DLI (demo) MET IO SSI (demo)	L3 NetCDF4	Ifremer FTP server	Ifremer FTP server

Table 6: Access to the products

*** GRIB2 discontinued since 14/12/2017.**

Ifremer FTP server, ftp://eftp.ifremer.fr/cersat-rt/project/osi-saf/, is accessible to users registered on the OSI SAF web site http://osi-saf.eumetsat.int (Users rights are provided on request in the registration process).

7. References

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8. Appendices

8.1. SSI and DLI auxiliary parameters

Most of the auxiliary parameters presented here concern the SSI processing

Atlas

Land-sea: It has been derived from the World Vector Shoreline, which includes sea and lake coastlines, accessed through the freeware Global Mapping Tool.

Altitude: contains a mean altitude derived from the global atlas GTOPO30 at 0.00833 degree resolution in latitude and longitude.

Surface type: contains the prevailing land cover type derived from a global atlas at 1/6 degree resolution of the CERES SARB Working Group (which contains 18 types).

Monthly climatologic fields

Surface albedo: contains monthly values over land of broadband surface albedo with sun at zenith, obtained by remapping of a monthly climatology at 0.144 degree resolution by Csizar and Gutman, 1999.

Specific humidity climatology: contains remapped values of the Ort monthly climatology of specific humidity profiles at 2.5 degree latitude and 5 degree longitude resolution.
This climatology is used only if the predicted atmospheric profiles are missing.

Ozone: contains monthly values of ozone content, built from monthly fields of Total Ozone Mapping Spectrometer data on the period January 81 to December 92 at about 1 degree resolution.

Visibility: contains monthly value of the horizontal visibility; at present, they are simply latitude and month dependent according to the figure 5 in Stuhlman et al, 1990.

Instantaneous fields

Predicted water vapor content, air temperature and humidity at 2m, surface pressure: these parameters are derived from Numerical Weather Predicting (NWP) model outputs obtained twice daily from ECMWF. The NWP outputs are 3 to 54-hour range forecasts, every 3 hours on a 0.5-degree resolution grid. A similar scheme is applied to all parameters: each NWP field is first, re-mapped onto the satellite space view, and then temporally interpolated at the image time. The integrated water vapour content is then derived from the air temperature and humidity profiles and from the altitude atlas.

Cloud type

The original cloud type field contains the NWC SAF detailed cloud types in satellite space view at full resolution. They are merged into simplified cloud types.

8.2. Format of the GRIB2 products

The GRIB products are encoded following the rules defined in FM 92 GRIB Edition 2 (version 6).

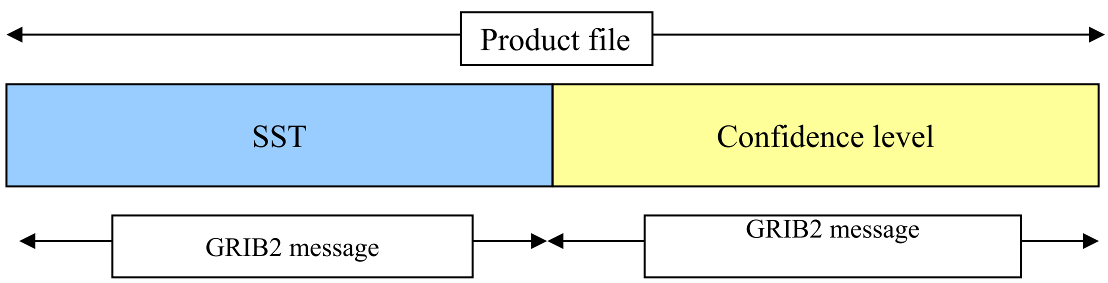
There are four types of GRIB ed. 2 products:

1. hourly SSI products
2. hourly DLI products
3. daily SSI products
4. daily DLI products

File structure

The GRIB ed. 2 products are delivered as a single file in which two GRIB2 messages are concatenated:

The first GRIB2 message provides the fluxes data (DLI or SSI) and the second one provides the confidence level data.



Note : The multi-fields capability of the GRIB2 format has not been used for the sake of the simplicity and also because it would have mixed a standard parameter (SSI or DLI) with a non standard one ("confidence level").

The Appendix A.3 gives some hints to access data by using the ECMWF GRIB API.

Encoding characteristics

Hereafter are described the most relevant and specific information of each section of the GRIB2 messages. Unless otherwise specified the values are given for all types of data (SSI, DLI, confidence level)

Section 0 (Indicator Section)

Octet. No.	Meaning	Value	Notes
7	Discipline	0	Meteorological products (cf. Table 0.0)

All the three messages have the same Indicator Section.

Section 1 (Identification Section)

Octet. No.	Meaning	Value	Notes
6-7	Identification of originating/generating centre	211	Lannion (see Common Code Table C-1)

8-9	Identification of originating/generating sub-centre	0	
12	Significance of Reference Time	3	For hourly products. Observation time (cf. Code Table 1.2)
		192	For daily products. (local use) (cf. Code Table 1.2)
13-19	Reference time of data	variable and product specific	Hourly products: round hour
			Daily products: time stamped 12:00

Both messages (fluxes and confidence level) have the same Identification Section.

Section 2 (Local Use Section)

There is no section 2 in either message.

Section 3 (Grid Identification Section)

Octet. No.	Meaning	Value	Notes
13-14	Grid Definition Template Number	0	Latitude/longitude (see Code Table 3.1)

Data have been organized such as the “scanning mode” flag is 0 (Points of first row scan in the +i direction, points of the first column scan in the –j direction).

For more details, see the “Grid characteristics” paragraph below.

Both messages (fluxes and confidence level) have the same Grid Identification Section.

Section 4 (Product Definition Section)

Octet. No.	Meaning	Value	Notes
8-9	Product definition template number	31	Satellite product (see Code Table 4.0)
10	Parameter category	4	SSI data : 4 (Short-wave radiation) (see Code Table 4.1 for Product Discipline 0)
		5	DLI data Long-wave radiation (see Code Table 4.1 for Product Discipline 0)
		192	SSI and DLI confidence level data (local use)

11	Parameter number	7	SSI data Downward short-wave radiation flux (see Code Table 4.2)
		3	SSI Confidence level data (Since confidence level has no entry in the code table, a local category values is to be used)
		3	DLI data Downward long-wave radiation flux (see Code Table 4.2)
		4	DLI Confidence level data (Since confidence level has no entry in the code table, a local category values is to be used)
13	Observation generating processing identifier	220	Product from the operational processing chain
		229	Product from the test processing chain
14	Number of contributing spectral bands	1	

The satellite series, the satellite number and the instrument type codes are specific to the type of satellite.

For METEOSAT satellites:

Octet. No.	Meaning	Value	Notes
15-16	Satellites series	333	Meteosat Second Generation (see BUFR code table 0 02020
26-36	Satellite number	55	METEOSAT08 (see BUFR code table 0 01 007)
		56	METEOSAT09 (see BUFR code table 0 01 007)
37-47	Instrument type	207	SEVIRI (see BUFR code table 0 02 019)

For GOES satellites:

Octet. No.	Meaning	Value	Notes
15-16	Satellites series	241	GOES (see BUFR code table 0 02020
26-36	Satellite number	257	GOES13 (see BUFR code table 0 01 007)
37-47	Instrument type	615	IMAGER (see BUFR code table 0 02 019)

Section 5 (Data Representation Section)

Octet. No.	Meaning	Value	Notes
10-11	Data Representation Template Number	0	Grid point data-simple packing (see Code Table 5.0)

The products are encoded so that:

- the decimal precision (set by the Decimal scale factor) of the fluxes values is 1 decimal digit (0.1 Wm-2).
- the numbers of bits per confidence level value is 3

Octet No.		SSI / DLI	Confidence level
18-19	Decimal scale factor	1	0
20	Number of bits	~12 - 14	3

The reference value (Octet No 12-15) and the Binary scale factor (Octet No 16-17) may vary, though the binary scale factor should be 0 in most cases.

Section 6 (Bit Map Section)

The “Bit-map indicator” (Octet No. 6) is always 0 (a bit-map applies) for. fluxes data. Fluxes data are missing on pixels where fluxes have not been computed.
The “Bit-map indicator” is always 255 (no bit-map applies) for confidence level data. Confidence level are present in every case.

Octet No.		SSI / DLI	Confidence level
6	Bit-map indicator	0	255

Section 7 (Data Section)

The section 7 provides the data according to the Data Representation Template number given in octets 10-11 of Section 5.

The following table gives the meanings of the three types of data :

data	meanings
SSI	Downward short-wave radiation flux (in $W.m^{-2}$)
DLI	Downward long-wave radiation flux (in $W.m^{-2}$)
Confidence level	An index value with the following meanings : 0: unprocessed 1: erroneous 2: bad 3: acceptable 4: good 5 : excellent

Grid characteristics

METEOSAT products

Projection	Equidistant cylindrical
Resolution	0.05 °
Size	2400 columns x 2400 lines
Upper left corner pixel center	59.975 N / 59.975 W

Converting between pixel coordinates (column, line) and geographical ones (longitude, latitude) is straightforward by using the linear relations:

longitude = -59.975 + 0.05 (column – 1)
latitude = 59.975 – 0.05 (line – 1)

where:

- longitude and latitude are in degrees,
- 1 ≤ column ≤ 2400
- 1 ≤ line ≤ 2400

GOES products

Projection	Equidistant cylindrical
Resolution	0.05 °
Size	2400 columns x 2400 lines
Upper left corner pixel center	59.975 N / 134.975 W

Converting between pixel coordinates (column, line) and geographical ones (longitude, latitude) is straightforward by using the linear relations:

longitude = -134.975 + 0.05 (column – 1)
latitude = 59.975 – 0.05 (line – 1)

where:

- longitude and latitude are in degrees,
- 1 ≤ column ≤ 2400
- 1 ≤ line ≤ 2400

8.3. Accessing data by using the ECMWF GRIB API

The ECMWF GRIB API is an application program interface accessible from C and FORTRAN programs developed for encoding and decoding WMO FM-92 GRIB edition 1 and edition 2 messages. A useful set of command line tools is also provided to give quick access to grib messages.

For more details see:
https://software.ecmwf.int/wiki/display/GRIB/Home

Definition of template 4.31

In order to decode properly the product file with the grib_api software a file named template.4.31.def must exist in the GRIB API definition files. This file is provided starting with the version 1.5.0 of the GRIB API. It is recommended to use GRIB API version 1.8.0 or newer.

How to split a GRIB2 product file

One simple way to split a SSI (resp. DLI) GRIB2 file into the two GRIB2 messages is to use the grib_copy tool provided in the GRIB API distribution :

```
grib_copy -w parameterCategory=4,parameterNumber=7 product.grb ssi.grb
grib_copy -w parameterCategory=192,parameterNumber=3 product.grb conf_ssi.grb

grib_copy -w parameterCategory=5,parameterNumber=3 product.grb dli.grb
grib_copy -w parameterCategory=192,parameterNumber=4 product.grb conf_ssi.grb
```

These examples have been tested with the 1.9.5 version of the GRIB API.

8.4. ncdump of a METEOSAT-9 hourly flux

```
dimensions:
        lat = 2400 ;
        lon = 2400 ;
variables:
        double time ;
                time:long_name = "reference time" ;
                time:standard_name = "time" ;
                time:units = "seconds since 1981-01-01 00:00:00" ;
                time:_FillValue = -9999999. ;
                time:comment = "" ;
        float lat(lat) ;
                lat:long_name = "latitude" ;
                lat:units = "degrees_north" ;
                lat:valid_min = -90. ;
                lat:valid_max = 90. ;
        float lon(lon) ;
                lon:long_name = "longitude" ;
                lon:units = "degrees_east" ;
                lon:valid_min = -180. ;
                lon:valid_max = 180. ;
        byte landmask(lat, lon) ;
                landmask:long_name = "auxiliary land mask" ;
                landmask:valid_min = 0b ;
                landmask:valid_max = 2b ;
                landmask:_FillValue = -128b ;
                landmask:flag_values = 0b, 1b, 2b ;
                landmask:flag_meanings = "sea land lake" ;
                landmask:comment = "from GMT" ;
                landmask:coordinates = "lon lat" ;
        short ssi(lat, lon) ;
                ssi:long_name = "surface solar irradiance" ;
                ssi:standard_name = "surface_downwelling_shortwave_flux_in_air" ;
                ssi:units = "W m-2" ;
                ssi:add_offset = 0. ;
                ssi:scale_factor = 0.1 ;
                ssi:_FillValue = -32768s ;
                ssi:comment = "" ;
                ssi:coordinates = "lon lat" ;
```

```
        byte ssi_confidence_level(lat, lon) ;
                ssi_confidence_level:long_name = "ssi confidence level" ;
                ssi_confidence_level:valid_min = 0b ;
                ssi_confidence_level:valid_max = 5b ;
                ssi_confidence_level:_FillValue = -128b ;
                ssi_confidence_level:flag_values = 0b, 1b, 2b, 3b, 4b, 5b ;
                ssi_confidence_level:flag_meanings = "unprocessed erroneous bad acceptable good
excellent" ;
                ssi_confidence_level:comment = "" ;
                ssi_confidence_level:coordinates = "lon lat" ;
        short dli(lat, lon) ;
                dli:long_name = "downward longwave irradiance" ;
                dli:standard_name = "surface_downwelling_longwave_flux_in_air" ;
                dli:units = "W m-2" ;
                dli:add_offset = 0. ;
                dli:scale_factor = 0.1 ;
                dli:_FillValue = -32768s ;
                dli:comment = "" ;
                dli:coordinates = "lon lat" ;
        byte dli_confidence_level(lat, lon) ;
                dli_confidence_level:long_name = "dli confidence level" ;
                dli_confidence_level:valid_min = 0b ;
                dli_confidence_level:valid_max = 5b ;
                dli_confidence_level:_FillValue = -128b ;
                dli_confidence_level:flag_values = 0b, 1b, 2b, 3b, 4b, 5b ;
                dli_confidence_level:flag_meanings = "unprocessed erroneous bad acceptable good
excellent" ;
                dli_confidence_level:comment = "" ;
                dli_confidence_level:coordinates = "lon lat" ;

   // global attributes:
                :Conventions = "CF-1.0" ;
                :title = "Surface radiative fluxes" ;
                :institution = "OSISAF" ;
                :history = "METEO-FRANCE/CMS SAFOS processor" ;
                :comment = "PRE-OPERATIONAL DATA FOR BETA TESTING ONLY" ;
                :license = "All intellectual property rights of the Ocean & Sea Ice SAF products
belong to EUMETSAT. The use of these products is granted to every user, free of charge. If users
wish to use these products, EUMETSAT\'s copyright credit must be shown by displaying the
words \'Copyright EUMETSAT\' under each of the products shown. EUMETSAT offers no warranty and ac-
cepts no liability in respect of the Ocean & Sea Ice SAF products. EUMETSAT neither commits to nor
```

```
guarantees the continuity, availability, or quality or suitability for any purpose of, the Ocean & Sea Ice SAF products." ;
                    :acknowledgment = "In case SAF data (pre-operational or operational) has been used for the study described in a paper the following sentence would be an appropriate reference to the funding coming from EUMETSAT: The data from the EUMETSAT Satellite Application Facility on Ocean & Sea Ice  used in this study are accessible through the SAF\'s homepage http://www.osi-saf.org" ;
                    :creator_name = "O&SI SAF" ;
                    :creator_email = "helpdesk@osi-saf.org" ;
                    :creator_url = "http://www.osi-saf.org" ;
                    :platform = "MSG2" ;
                    :file_quality_index = 3 ;
                    :reference_time = "20110524T140000Z" ;
                    :start_time = "20110524T133000Z" ;
                    :stop_time = "20110524T143000Z" ;
```