Product User Manual

PUM SC
SNOW COVER

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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 EUMETSAT satellites; Meteosat Second Generation (MSG, launched in August 2002), and the first Meteorological Operational Polar satellite of EUMETSAT (Metop-1, scheduled to December 2005).

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:

- Weather forecasting 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 downwelling shortwave 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 other different 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 satellites systems may also be used such as routine meteorological information. All the products (Figure 1) 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.

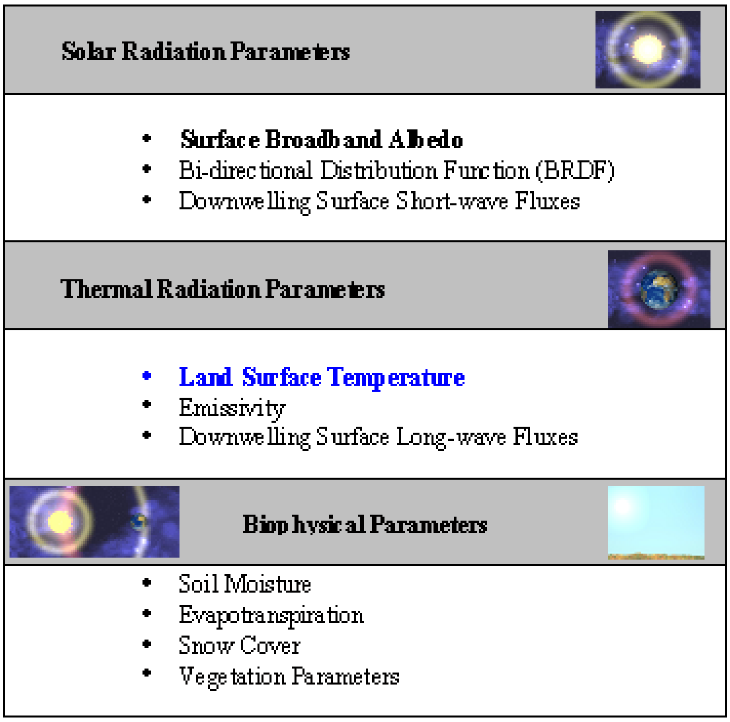

Figure 1 - The LSA SAF products.

The product generation for the MSG disk will be split into 4 different geographical areas (Figure 2), to which different priorities are assigned:

- One region (Euro) covering Europe will be the highest priority geographical area, covering all EUMETSAT member states;
- Two regions (NAfr and SAfr) covering Africa that will be given intermediate priority;
- One region (SAme) over South America that will have the lowest priority.

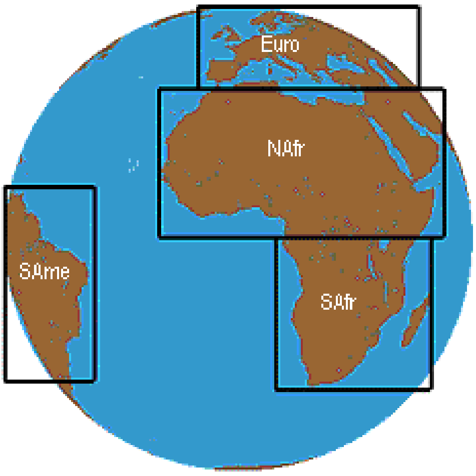

Figure 2 - The LSA SAF geographical areas.

The LSA SAF system is fully centralized at IM and will be able to operationally generate, archive, and disseminate the operational products. The monitoring and quality control of the operational products, also centralized at IM, is performed automatically by the LSA SAF software, which provides quality information to be distributed with the products.

The LSA SAF products are currently available from LSA SAF web-site (www.meteo.pt/landsaf) 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 product users and concerns the Snow Cover. The retrieval of SC is currently based on measurements from the MSG system (MSG SC).

SC is derived from the cloud mask generated by the Nowcasting and Very Short Range Forecasting Satellite Application Facility (NWC SAF) software. Section 2 presents a description of the algorithm and section 3 the processing scheme. The data files are described in section 4 that also includes a summary of the product validation.

2 Algorithm

2.1 General description of the SC algorithm

The presence of a snow cover exerts a specific and strong influence on the energy and water budgets of the lower atmosphere. For this reason, large-scale automated snow cover mapping from satellite images is very useful. Snow cover maps can be used as input for numerical weather prediction (NWP) models. Accurate snow cover is also important for hydrological forecasting of river runoff during the melting season. Additionally, remote sensing of other surface parameters requires information on whether or not the surface is snow covered.

The measured radiances at visible (VIS), near infrared (NIR) and infrared (IR) window wavelengths, as produced by the SEVIRI sensors, are determined by the spectral characteristics (e.g., reflectances, emittances, transmittances, temperatures) of land/ocean surfaces and clouds. The snow radiance differs from cloud and snow free land radiances in a characteristic way in the VIS/NIR region.

The MSG snow cover (SC) retrieval is based on the NWC SAF-MSG Cloud Mask. This cloud detection algorithm is based on multispectral threshold technique applied to each pixel of the image. Detailed description of the cloud mask algorithm is in [1] . In that algorithm snow and ice are identified prior to the application of any cloud detection tests. If snow or ice is detected, no further tests to detect cloud are attempted.

Snow and ice are separated from water clouds by their low reflectance at 1.6 µm or at 3.9 µm channels. Cirrus clouds are separated using the difference between brightness temperatures at 10.8 µm and 12.0 µm channels. Some other tests are also applied.

The SC prototype algorithm performs the following tasks: deriving snow cover from the cloud mask (MSG SEVIRI), spatial smoothing (optional) and temporal integration of the previous 24 hour satellite scenes. See Figure 3 for a breakdown of the algorithm processing structure. The implementation of the algorithm consists of two units: unit 1 and unit 2. The first unit handles the deriving of the snow cover and spatial smoothing for each satellite scene. This produces a full resolution snow cover map each 15 minutes with or without spatial smoothing. The second unit produces a daily composite snow cover map by temporal integration of all available snow cover maps (output from unit 1) from the previous 24-hour period. Unit 2 is executed daily at a fixed time.

The resulting snow cover map produced from MSG data contains a classification of each surface pixel or resolution cell into one (and only one) of the following classes:

- totally snow covered
- partially snow covered (for spatially smoothed single scene or daily snow cover)
- no snow
- unclassified
- non-processed

An additional set of quality/processing flags for each pixel indicates the certainty of the classification and integration and also gives information on the processing and conditions.

The algorithm is not intended for use in mountain areas. Pixels in these areas are determined using the elevation data and a flag indicating high terrain is set.

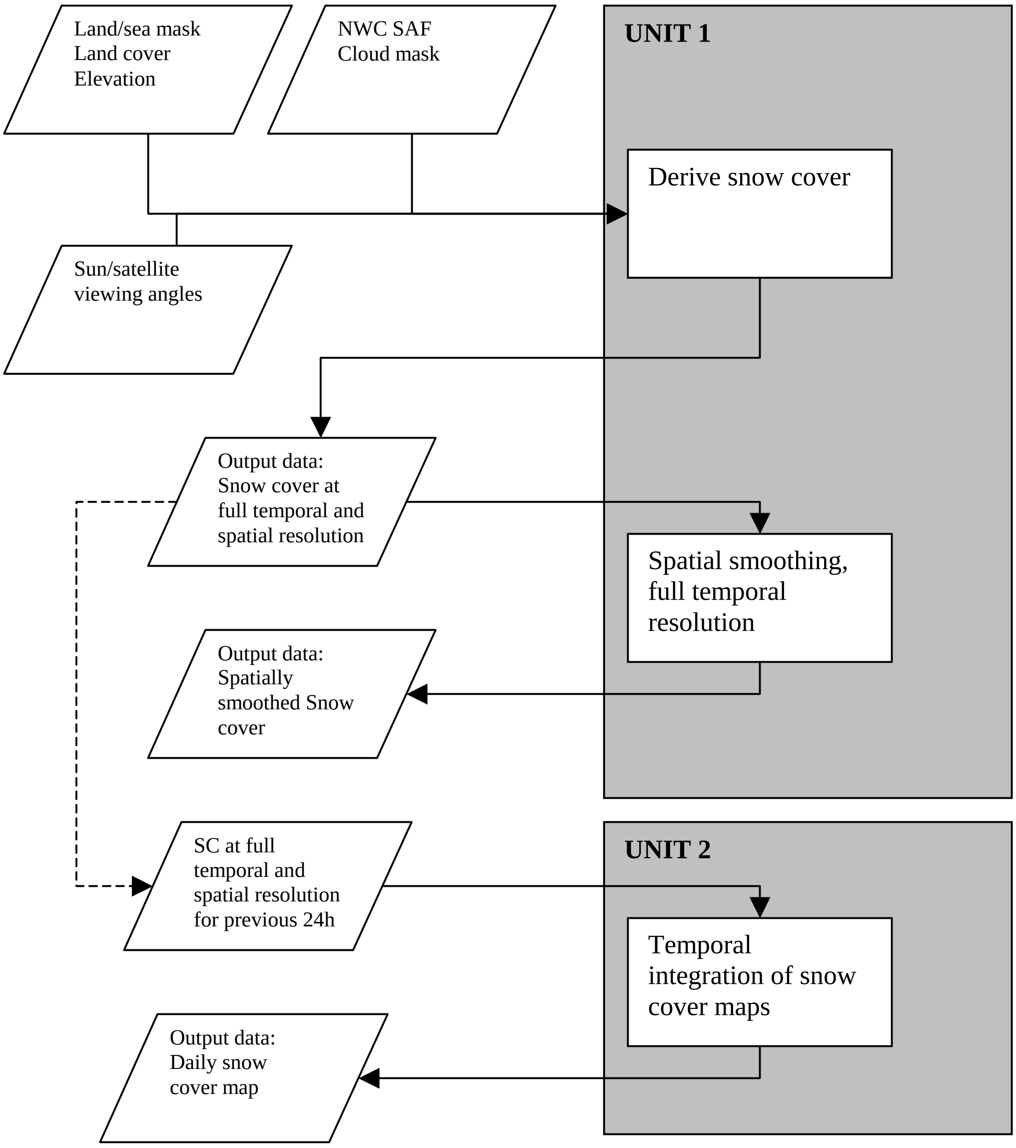

Figure 3 - Flowchart of the Land SAF Snow Cover MSG algorithm

Forests make the detection of snow more difficult. Preliminary product validation shows that the amount of snow pixels is slightly overestimated for non-forest land types, while it is underestimated for forest classes.

2.2 Unit 1: Pre-processing

The information on snow cover is taken from NWC SAF -MSG Cloud Mask which classifies Meteosat pixels into one of the six categories shown in Table 1. Table 1 also shows how we use them for snow cover retrieval.

Table 1 - Relation between Cloud Mask and Snow Cover classes

Cloud Mask category	Snow Cover category	Flags
non-processed	non-processed	-
Cloud free	no snow*	-
cloud contaminated	Unclassified	Obscured by clouds
Cloud filled	Unclassified	Obscured by clouds
snow/ice contaminated	totally snow covered*	-
Undefined	Unclassified	-

* During night, the pixel is set to “unclassified”.

The snow cover category “partially snow covered” is not represented in this table, because that classification is not available in the cloud mask data. Pixels can be classified as partially snow covered either at spatial smoothing or in time integration modules, detailed below.

There are more possible flags than those mentioned in Table 1. The quality flags are set accordingly to the values of the Cloud Mask flags, light conditions, and inversion. There are also flags for the land mask, the land use data and the elevation data.

The data retrieval step produces a full resolution snow cover map, for clear-sky pixels, with binary information on the state of each pixel (snow/no snow), provided the input data are available, and there is sufficient illumination.

The algorithm is using also some more or less static input data such as elevation and land use. Currently these are taken from USGS.

2.3 Unit 1: Spatial smoothing

The snow cover maps keep the original spatial MSG resolution, under the smoothing procedure. The smoothing procedure is used to make the snow cover pattern smoother and reduce variability in partially snow covered areas. Each pixel is influenced by the pixels around it. Number of pixels of different classes are counted on an area of 3x3 (configurable, can also be e.g. 5x5), and the result is set in the pixel in the centre pixel of that area. The pixels on the border keep their original value.

In Figure 4 the pixel F (dark grey) is influenced by the pixels A-C, E-G and I-K (the light-grey pixels as well as F itself). Next we move to pixel G, which is influenced by the pixels B-D, F-H and J-L. We see that F is one of the pixels influencing G and G is one of the pixels influencing F.

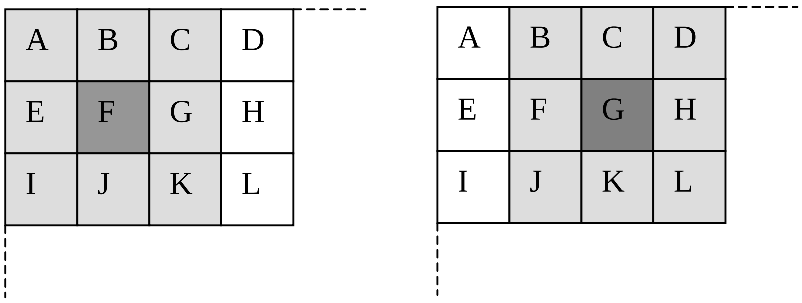

Figure 4 - Influencing area at spatial smoothing

The design of the smoothing algorithm is simple: if all classified pixels within the influencing area are classified as snow covered, the centre pixel is classified as totally covered. For a pixel with only snow free pixels around it, the class is snow free. A mixed snow covered and snow free pixel is classified as partially snow covered.

Smoothing is done for two reasons: to account for possible poor geolocation and to reduce the risk of incorrect classification of a snow covered surface as snow free. Accurate geolocation of satellite ground pixels is very important near coasts, lakes or mountains. If the algorithm uses the land-thresholding scheme for a pixel that is actually at sea or on a mountain, the results will probably be incorrect. For MSG, the geolocation is not likely to be poor. Geolocation problems generally arise for polar satellites, which will be used in future versions of the algorithm.

A certain portion of pixels classified as partially snow covered by the smoothing process or temporal integration might correspond to areas which are fully snow covered in reality. The reason for this wrong classification can be for example an undetected snow covered pixel.

2.4 Unit 2: Temporal integration

The last step in the SC algorithm is to produce a 24-hour composite snow cover map using all available single scene snow cover maps. This reduces the effect of clouds obscuring the surface and further reduces the risk of misclassification.

The Snow Cover product derived from MSG is generated daily, for the 4 pre-defined areas (Figure 2), described in Table 2. Each region is defined by the corners position relative to an MSG image of 3712 columns per 3712 lines, running from North to South and from West to East.

Table 2- Characteristics of the four LSA SAF geographical areas.

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

3 Data Description

3.1 Overview

Data users have access to the following data:

- a Snow Cover field;
- a quality control information field.

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

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

A detailed description of the attributes (general and common) defined for the LSA SAF files is given in Appendix A and B.

The Snow Cover product consists of a HDF5 a file containing two datasets (SC classes and respective QC data). The relevant information concerning the data fields is included in HDF5 attributes.

3.2 File Formats

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

HDF5_LSASAF_MSG_SC_<Area>_YYYYMMDDHHMM

where <**Area**>, **YYYY**, **MM**, **DD**, **HH** and **MM** respectively, denote the geographical region (see Table 2), the year, the month, the day, the hour and the minute of data acquisition.

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

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

The HDF5-format allows defining a set of attributes that provide the relevant information about the respective file. As described in the Appendix A the SC product information includes the general attributes (Table A5), the dataset attributes (Table A6) and the quality flag attributes (Table A7). Within the HDF5-files the information is organised in the form of separate datasets.

3.3 Product Contents

The SC product file contains two datasets corresponding to the values and the respective quality flags (Table 3). Table 4 describes possible values of the SC product. Table A6 and Table A7, respectively, show the contents of the SC product dataset and QC information dataset. Detailed information is given in Appendix A and B.

Table 3 - Contents of the SC product file.

Parameter	Dataset Name	Unit	Range	Variable Type
Snow Cover	SC		0-5	
Quality Flag	SC_Q_Flag			

Table 4 - Values of the SC product and respective snow cover category.

Snow Cover Category	SC - Product
non-processed	0
totally snow covered	1
partially snow covered	2
Snow free ground	3
Unclassified	4
Reserved for future use	5

3.4 Summary of Product Characteristics

Product Name:	Snow Cover
Product Code:	SC
Product Level:	Level 3
Description of Product:	Snow Cover

Product Parameters:

Coverage:	MSG full disk (Land pixels)
Packaging:	Europe, N_Africa, S_Africa, S_America
Units:	n.a.
Range:	0-5
Sampling:	pixel by pixel basis
Resolution:	Indata: n.a.
	Spatial: MSG full resolution (3km×3km at nadir)
Accuracy:	n.a.
Geo-location Requirements:	
Format:	8 bits integer
Appended Data:	Quality control information (16 bits integer)
Frequency of generation:	once every day
Size of Product:	

Additional Information:

Identification of bands used in algorithm:

SEVIRI-data is used only indirectly. Input is taken from NWC SAF-Cloud Mask.

Assumptions on input data:

Identification of ancillary and auxiliary data:

SEVIRI viewing angle
Sun angles
Land-sea mask
Land use
Elevation

4 Validation and Quality Control

The adopted strategy for validation of SC product consists of two main steps: 1) comparison with in situ measurements; 2) inter-comparison with other satellite derived SC products.

The Validation Report includes some results from the comparison of MSG SC product with in situ SYNOP snow depth observations.

Automatic Quality Control (QC) is performed on SC data and the quality information is provided on a pixel basis. As shown in Appendix A, SC QC contains general information about input data.

As specified in the User Requirements Document the objective for the accuracy of the snow cover product is less than 3% of false alarms and over 75% hit rate for forest areas and over 90% for other areas. The strategy adopted for confirming the achievement of this goal is documented in the Scientific Validation Plan Document. Preliminary results are given in the Validation Report. A summary of the validation studies will be included in the Product User Manual when substantive quantitative results are available.

5 References

[1] MF-CMS, 2002: User Manual for the PGE01-02-03 of the SAFNWC/MSG: Scientific part. Document code SAF/NWC/IOP/MFL/SCI/SUM/01 issue 1, revision 2, 3 May 2005.

[2] Hyvarinen, O., Karlsson, K-G., Dybbroe, A., 1999: Investigations of NOAA AVHRR/3 1.6 mm imagery for snow, cloud and sunglint discrimination, SAFNWC Visiting Scientist Report, Available at http://www.smhi.se/saf under Documents.

[3] Dybbroe, A., 2001: The retrieval of the SAFNWC cloudmask and cloudtype from AVHRR and SEVIRI at high latitudes, SAFNWC Action PT06-04, Available at http://www.smhi.se/saf under Documents.

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7 Acronyms

AVHRR	Advanced Very High Resolution Radiometer
ECMWF	European Centre for Medium-Range Weather Forecasts
ENVISAT	Environmental Satellite
EOS	Earth Observing System
EPS	EUMETSAT Polar System
ESA	European Space Agency
EUMETSAT	European Organisation for the Exploitation of Meteorological Satellites
FMI	Finnish Meteorological Institute
GOES	Geostationary Operational Environmental Satellite
HDF	Hierarchical Data Format
HIRLAM	High Resolution Limited Area Model
ICAT	Instituto de Ciência Aplicada e Tecnologia (Portugal)
IM	Instituto de Meteorologia (Portugal)
IR	Infrared Radiation
LSA	Land Surface Analysis
LST	Land Surface Temperature
MAS	Modis Airborne Simulator
METEOSAT	Geostationary Meteorological Satellite
MODIS	Moderate-Resolution Imaging Spectro-Radiometer
MODTRAN	Moderate Resolution Transmittance Code
MSG	Meteosat Second Generation
NASA	National Air and Space Administration
NOAA	National Oceanic and Atmospheric Administration (USA)
NWC	NoWCasting (SAF)
NWP	Numerical Weather Prediction
QC	Quality Control
rms	root mean square
RSS	Root Sum Square
SAF	Satellite Application Facility
SC	Snow Cover
SEVIRI	Spinning Enhanced Visible and InfraRed Imager
SMHI	Swedish Meteorological and Hydrological Institute
SPOT	Système Probatoire d'Observation de la Terre
TIR	Thermal Inf rared
TIROS	Television and Infrared Observation Satellite
TOVS	TIROS-N Operational Vertical Sounder
URD	User Requirements Document
USGS	U.S. Geological Survey
v-a	viewing angle

Appendix A: HDF5 Format

Table A5 - General attributes of the SC product file.

Attribute Name	Attribute Value	Type
SAF	LSA	String
CENTRE	IM	String
ARCHIVE_FACILITY	-	String
PRODUCT	SC	String
PARENT_PRODUCT_NAME	Cma	String, array (4)
SPECTRAL_CHANNEL_ID	0	Int
PRODUCT_ALGORITHM_VERSION	V0.0	String
BASE_ALGORITHM_VERSION	-	String
CLOUD_COVERAGE	-	String
OVERALL_QUALITY_FLAG	-	String
ASSOCIATED_QUALITY_INFORMATION	-	String
REGION_NAME	Euro	String
COMPRESSION	0	Int
FIELD_TYPE	Image	String
FORECAST_STEP	0	Int
NC	1701	Int
NL	651	Int
NB_PARAMETERS	2	Int
NOMINAL PRODUCT_TIME	YYMMDDhhmmss	String
SATELLITE_ID	321	Int
IMAGE_ACQUISITION_TIME	YYMMDDhhmmss	String
ORBIT_TYPE	-	String
PROJECTION_NAME	Geos<000.0>	String
NOMINAL_LONG		Real
NOMINAL_LAT		Real
CFAC	40693	Int
LFAC	40693	Int
COFF	307	Int
LOFF	1807	Int
START_ORBIT_NUMBER	0	Int
END_ORBIT_NUMBER	0	Int
SUB_SATELLITE_POINT_START_LAT	0.0	Real

Attribute Name	Attribute Value	Type
SUB_SATELLITE_POINT_START_LON	0.0	Real
SUB_SATELLITE_POINT_END_LAT	0.0	Real
SUB_SATELLITE_POINT_END_LON	0.0	Real
SENSING_START_TIME	-	String
SENSING_END_TIME	-	String
SPATIAL_COVERAGE_MODEL	-	String
PIXEL_SIZE	-	String
GRANULE_TYPE	-	String
PROCESSING_LEVEL	-	String
PRODUCT_TYPE	-	String
PRODUCT_ACTUAL_SIZE	-	String
NATIVE_PRODUCT_FORMAT_TYPE	-	String
NATIVE_PRODUCT_FORMAT_VERSION	-	String
PROCESSING_MODE	-	String
SOURCE_ENVIRONMENT	-	String
DISPOSITION_FLAG	-	String

Table A6- Attributes of the SC dataset.

Attribute	Description	Data Type
CLASS	Data	String
PRODUCT	SC	String
PRODUCT_ID	0	Int
N_ COLS	1701	Int
N_ LINES	651	Int
NB_BYTES	1	Int
SCALING_FACTOR	1.0	Real
OFFSET	0.0	Real
MISS_VALUE	0	Int
UNITS	-	String
CAL_SLOPE		Real
CAL_OFFSET		Real

Table A7- Attributes of the SC Quality Flag information dataset.

Attribute	Description	Data Type
CLASS	Data	String
PRODUCT	Data	String
PRODUCT_ID	0	Int
N_ COLS	1701	Int
N_ LINES	651	Int
NB_BYTES	2	Int
SCALING_FACTOR	1.0	Real
OFFSET	0.0	Real
MISS_VALUE	0	Int
UNITS		String
CAL_SLOPE		Real
CAL_OFFSET		Real

Appendix B: SC Quality Control Information

The table below shows SC QC information.

The quality flags are an array of 16-bit shorts. For each pixel or resolution cell the following flags are set or unset (bitnumber: flag name/flag meaning):

0: LAND/Land mask indicates land
1: COAST/Land mask indicates coast
2: NIGHT/Night illumination conditions
3: TWILIGHT/Twilight conditions
4: SUNGLINT/Sunglint conditions
5: HIGH_TERRAIN/Elevation data indicates high terrain
6: OBSCURED_BY_CLOUDS/Pixel obscured by clouds
7: HIGH_QUAL/High quality at temporal integration
8: LOW_QUAL/Low quality
9: VERYLOW_QUAL/Very low quality at temporal integration
10: FOREST_CONIFER/Landuse indicates coniferous forest
11: FOREST_OTHER/Landuse indicates forest, of other type than coniferous
12: LAKE/Landmask indicates lake/sea
13: INVERSION/Inversion
14: BAD_SAMPLING/Few of the pixels (in up-scaling) where classified

Some examples of values for QC information are described in
Table B8, as well as their meaning. The examples chosen are some of the most common combinations, together with some less common, but illustrative, examples

Table B8 - Examples of SC QC information

Binary Value	Decimal Value	Description
10000000	128	High quality
10000001	129	High quality, Land
1000010000000	4224	High quality, Lake
101000001	321	Low quality, Land, Clouds
1000101000000	4416	Low quality, Lake, Clouds
10010000001	1153	High quality, Land, Forest conif.
100010000001	2177	High quality, Land, Forest other
10100000001	1281	Low quality, Land, Forest conif.
100100000001	2305	Low quality, Land, Forest other
10101000001	1345	Low quality, Land, Forest conif., Clouds
100101000001	2369	Low quality, Land, Forest other, Clouds
100000000	256	Low quality
101000000	320	Low quality, Clouds
100000001	257	Low quality, Land
10000010	130	High quality, Coast
10010000010	1154	High quality, Coast, Forest conif.
10100000010	1282	Low quality, Coast, Forest conif.
10101000010	1346	Low quality, Coast, Forest conif., Clouds
101000010	322	Low quality, Coast, Clouds
1000101001000	4424	Low quality, Lake, Clouds, Twilight
10101001001	1353	Low quality, Land, Forest conif., Clouds, Twilight
100000001	257	Low quality, Land
1000100000000	4097	Low quality, Lake
some examples that are not so common…		
10010010000001	9345	High quality, Land, Forest conif., Inversion
101000100000000	20736	Low quality, Lake, Bad sampling
100000100000001	16641	Low quality, Land, Bad sampling
1000000000	512	Very low quality
1000100010000	4368	Low quality, Lake, Sunglint
100000100	260	Low quality, Night