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

Product User Manual

Snow Cover (SC)

PRODUCTS: H31 (MSG/SEVIRI SC), H32 (METOP/AVHRR SC)

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TABLE OF CONTENTS

List of Figures

List of Tables

1 Introduction

The Satellite Application Facility (SAF) on Land Surface Analysis (LSA) and The EUMETSAT Satellite Application Facility on Support to Operational Hydrology and Water Management (H-SAF) are part of the SAF Network, a set of specialized 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.ipma.pt/).

The main purpose of the H-SAF is to provide satellite-derived products to satisfy the needs of the operational hydrology, although many products can be used for many applications outside the field of hydrology, such as numerical weather prediction.

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 *The former LSA SAF, current HSAF snow extent product. Expected horizontal resolution and spatial coverage, generation frequency, and target accuracy are also indicated. Temporal resolution specifies the time interval to which the product applies.*

Product	Horizontal Resolution & Coverage	Temporal Resolution	Generation Frequency	Target Accuracy
H31 MSG/SEVIRI SC	MSG disk	Daily	Daily	<3% false alarms >75% hit rate forest > 90% for other areas
H32 Metop/AVHRR SC	Global	Daily	Daily	<3% false alarms >75% hit rate forest > 90% for other areas

The LSA SAF snow products (Table 1) are based on level 1.5 MSG/SEVIRI and/or level 1b Metop data. Forecasts provided by the European Centre for Medium-range Weather Forecasts (ECMWF) are also used as ancillary data for atmospheric correction.

The MSG/SEVIRI derived products are generated for full MSG/SEVIRI disk. Metop derived parameters are currently 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. Daily Metop/AVHRR snow product is generated in global 0.01 degree grid. The product H31 and H32 are processed in the LSA SAF system for which the products were originally developed.

The LSA SAF system is fully centralized at IPMA 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 IPMA, 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 website (http://landsaf.ipma.pt) that contains real time examples of the products as well as updated information.

This document is one of the product manuals dedicated to users of the H31 and H32 snow products. The algorithm and the main characteristics of the Snow Cover (SC) generated by the LSA SAF system are described in the following sections. This document describes the snow extent products H31 (MSG/SEVIRI SC) v2.90 and H32 (Metop/AVHRR SC) v1.43.

MSG/SEVIRI snow detection algorithm has not been changed since version 2.50. The main reason for the code changes from v2.50 to v2.90 is the upgrade from HDF5 version 1.6 to v1.8 at the LSA SAF production system. A number of minor bug fixes are also included. These do not change the actual algorithm and the product.

Metop/AVHRR snow detection algorithm has been changed substantially since version 1.00. The detection algorithm in the phase 1 has been rewritten and production of the daily global product has been introduced.

2 Algorithm

The presence of 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 data is also important for hydrological forecasting of river runoff during the melting season. Additionally, remote sensing of other surface parameters require information on whether or not the surface is snow covered. The Algorithm Theoretical Basis Document (ATBD, available from LSA SAF web site) contains the detailed description of the HSAF snow cover algorithms.

The measured radiances at visible (VIS), near infrared (NIR) and infrared (IR) window wavelengths, as obtained by the MSG/SEVIRI and Metop/AVHRR sensors, are essentially determined by the spectral characteristics (e.g., radiances, 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. There are several studies about the use of meteorological satellites for the remote sensing of snow (for example MF-CMS, 2000, Hyvärinen et al, 1999 and Dybbroe 2001).

2.1 General description of the MSG/SEVIRI SC algorithm

The MSG/SEVIRI snow cover (SC) retrieval is based on multispectral threshold technique applied to each pixel of the image. Detailed description of the snow detection algorithm is in Algorithm Theoretical Basis Document (ATBD) and in Siljamo and Hyvärinen, 2011. In the algorithm MSG/SEVIRI radiance and brightness temperatures of several channels are used together with land surface temperature (LST) and solar and satellite angles to classify each pixel of the land areas. For example, snow and ice can be separated from water clouds by their low reflectance at 1.6 µm or at 3.9 µm channels. Cirrus clouds can be separated using the difference between brightness temperatures at 10.8 µm and 12.0 µm channels. A combination of these and similar characteristics are used to separate snow covered and snow free pixels. One example of the different characteristics is in a scatter plot in Figure 1. This and other similar figures have been used for the development of the classification rules of the snow cover algorithm.

The SC algorithm performs the following two tasks: deriving snow cover from the satellite data every 15 minutes and temporal integration of the previous 24 hour satellite scenes. See Figure 2 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 for each satellite scene. This produces a full resolution snow cover map every 15 minutes. 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.

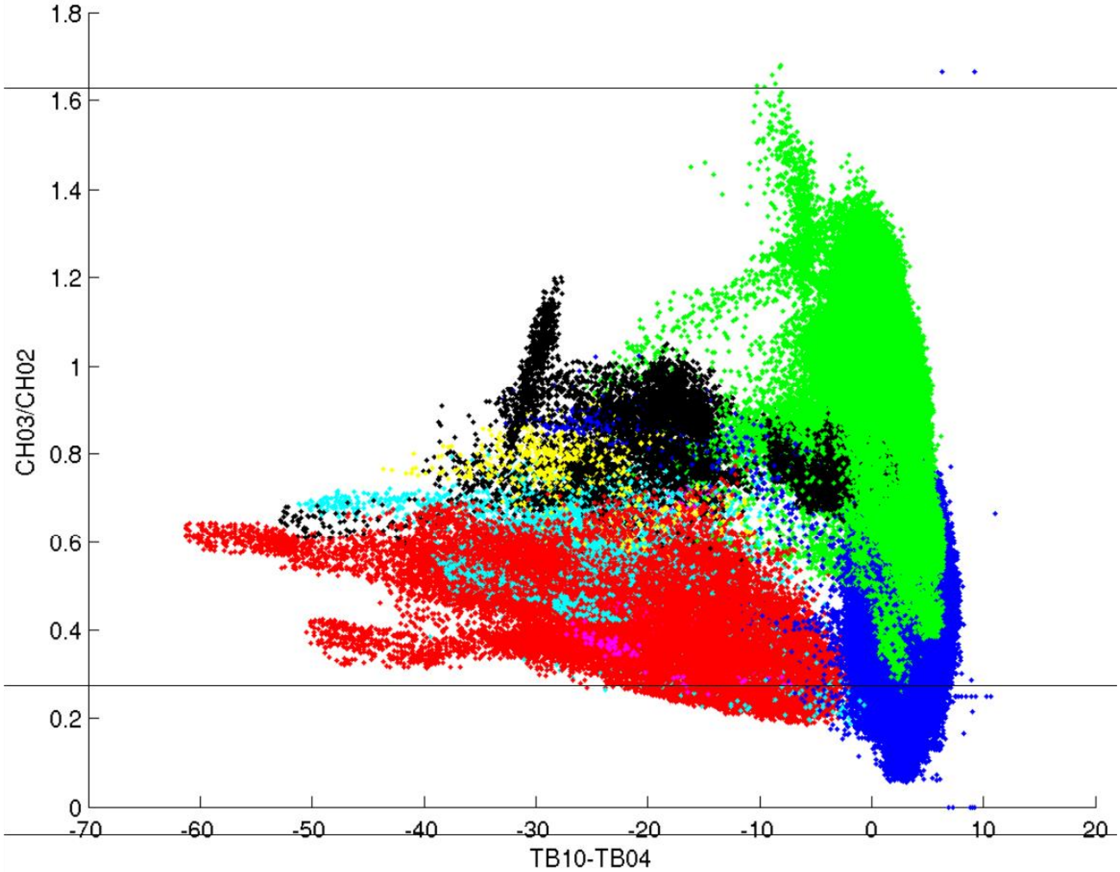

Figure 1 *Radiance ratio of the SEVIRI channels 3 and 2 vs. brightness temperature difference of the channels 10 and 4. Blue (snow) and green (snow free) are quite clearly separated from different cloudy pixel types. Red (ice clouds), black (water clouds) and cyan (mixed clouds) mark the cloud types which are totally opaque. Yellow (snow free) and magenta (snow covered) mark the pixels which are cloud covered, but the clouds are still transparent.*

The resulting snow cover map produced from MSG/SEVIRI 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
- no snow
- unclassified
- non-processed
- water (sea, lake, river etc.)

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 mountainous areas, although the SC product is calculated also for mountain pixels. The highly variable topography of the mountain regions need special attention. Pixels in these areas are determined using the elevation data and a flag indicating high terrain is set. Lakes and other inland waters need also specific attention and currently they are excluded

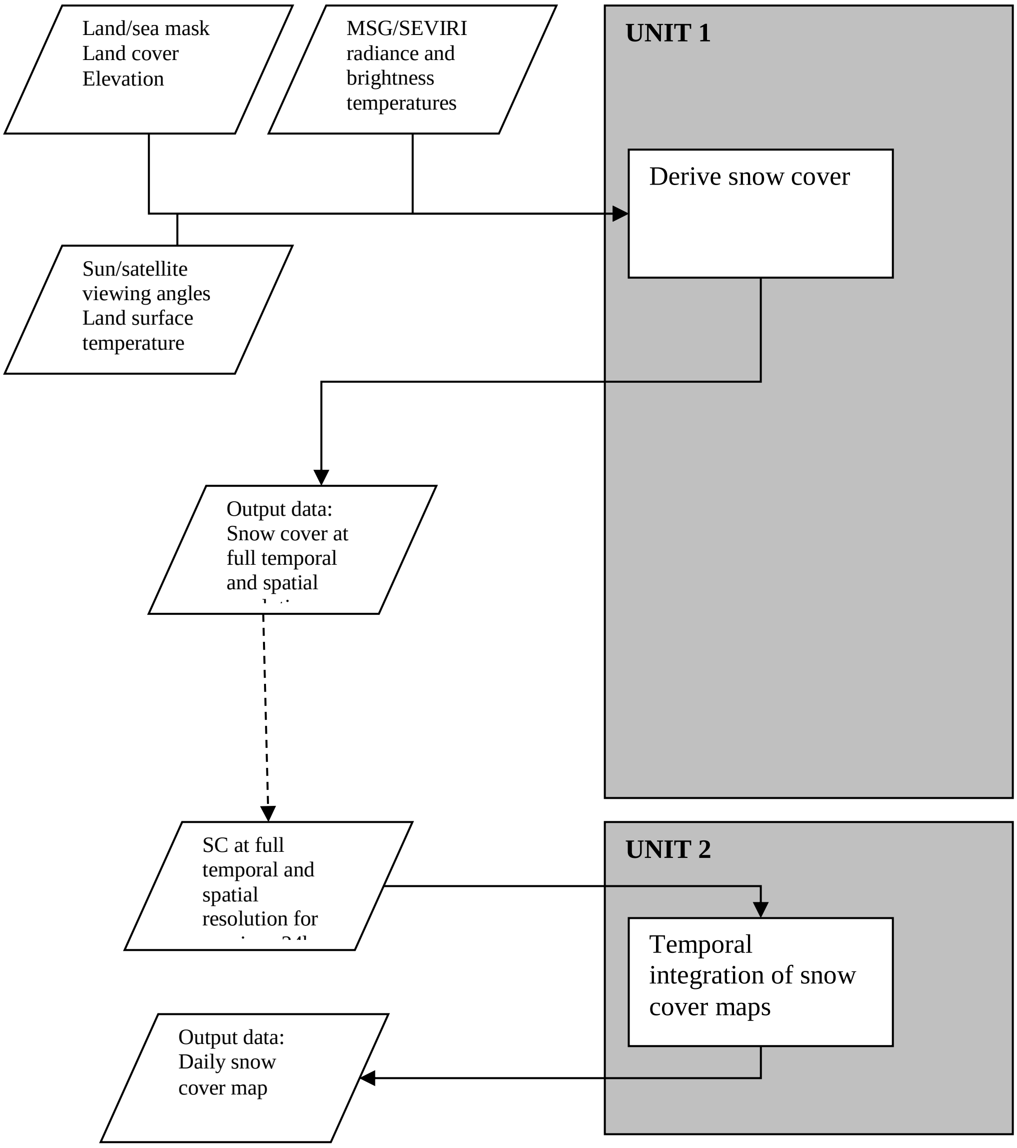

Figure 2 *Flowchart of the Land SAF MSG/SEVIRI Snow Cover algorithm*

In the forest regions snow cover retrieval is quite complicated, because the trees (especially evergreen trees) obstruct the view to the surface, where most of the snow typically is. In certain conditions there can be snow on trees.

This document describes the MSG/SEVIRI SC v2.90. The actual snow detection algorithm is identical to v2.50, but substantial code changes were needed to update the code to use HDF5 v1.8 required by the LSA SAF processing facility.

2.1.1 Unit 1: Generation of single scene snow cover

The information on snow cover is based mainly on MSG/SEVIRI radiances (channels 1, 2 and 3), brightness temperatures (channels 4, 9 and 10). Solar and satellite angles are used as well as LSA SAF LST.

Table 2 *MSG/SEVIRI snow cover classes*

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

The snow cover category “partially snow covered” is not as well defined as snow free or snow covered. Pixels can be classified as partially snow covered in unit 1 or in time integration modules, detailed below. This means that partial snow cover can be partial for many reasons. Usually this class indicates the presence of snow in the area, but only a small percentage of the surface is snow covered. It is also possible that this class indicates probable snow i.e. that it is possible that area is snow covered, but the algorithm can not detect it for certain. Direct observations of the snow coverage on the surface are needed to improve the accuracy of the partial snow cover class. When the product is used as input data for applications this class can be combined with snow covered class or snow free class depending of the application.

The quality flags are set accordingly to the values of the input data flags, light conditions, and inversion. There are also flags for the land mask, the land use data and the elevation data. The quality flags are described in appendix B.

The data retrieval step produces a full resolution snow cover map, with information on the state of each pixel (snow/partial snow/no snow), provided the input data are available, and there is sufficient illumination. Cloudy pixels and also those pixels which were not classified by any of the rules used in the algorithm are set as unclassified.

The algorithm is using also some more or less static input data such as elevation and land use. Currently these are provided by IPMA and are based on United States Geological Survey (USGS) data.

2.1.2 Unit 2: Generation of daily snow cover

The last step in the MSG/SEVIRI 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.

A pixel is classified as snow covered if it is snow covered in all single images (unclassified pixels excluded). Similarly the pixel is snow free if all observations show that the pixel is snow free. If the observations disagree slightly (there are both snow free and snow covered observations, but there is a reasonable majority) the more probable alternative is selected. The rules used are described in the ATBD.

The snow cover product derived from MSG/SEVIRI is generated daily for SEVIRI full disk, an example is presented in the Figure 3. In the figure the most obvious limitation of the geostationary product is well presented. Almost all of the snow covered surface is near the edge of disk where low viewing angle makes the snow detection challenging.

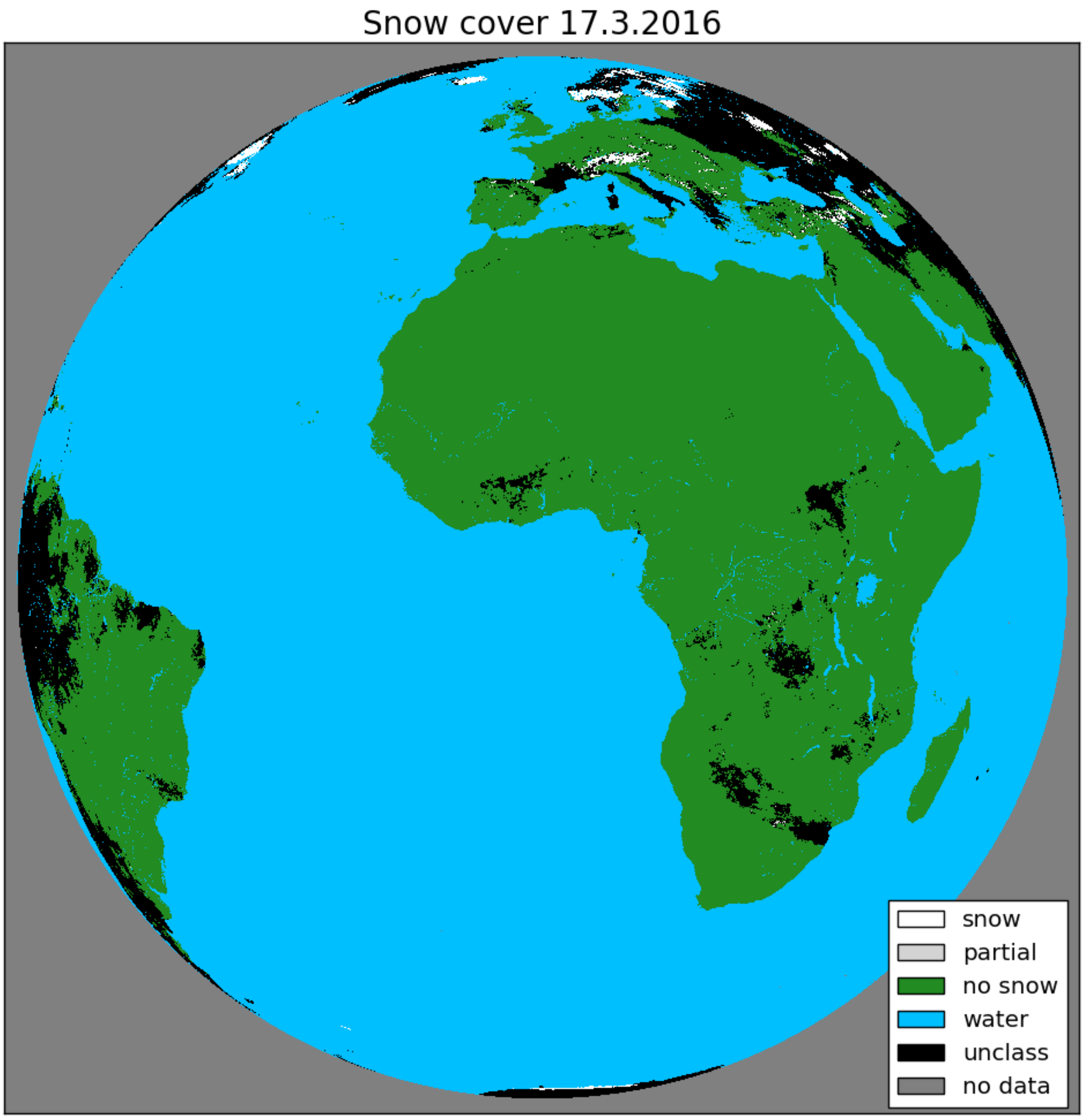

Figure 3 *MSG/SEVIRI snow cover on March 17, 2016.*

Current MSG/SEVIRI snow product is generated daily for full MSG/SEVIRI disk. Previously it was generated daily for the 4 pre-defined areas described in Table 3. These regional products are used in some delivery methods. 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 3 *Characteristics of the four LSA SAF geographical areas.Current product is generated for full MSG/SEVIRI disk, but the product is still available in regional format via some delivery methods.For the full disk product the Region name is Disk.*

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	1107351
NAfr	Northern Africa	1240	3450	700	1850	2211	1151	2544861
SAfr	Southern Africa	2140	3350	1850	3040	1211	1191	1442301
Same	Southern America	40	740	1460	2970	701	1511	1059211

2.2 General description of the Metop/AVHRR SC algorithm

The Metop/AVHRR snow cover algorithm has been developed using the general principles used in the MSG/SEVIRI SC algorithm. The Metop/AVHRR snow cover (SC) retrieval is based on multispectral threshold technique applied to each pixel of the image. Detailed description of the snow detection algorithm is in Algorithm Theoretical Basis Document (ATBD). In the algorithm Metop/AVHRR radiance and brightness temperatures of several channels are used together with land surface temperature (LST) and solar and satellite angles to classify each pixel of the land areas.

The target of the algorithm is snow detection. The achieve the best results, no cloud detection is employed before the snow detection algorithm. If the pixel can not be classified either as snow covered or snow free (or rarely used partially snow covered class), it is left as unclassified. Usually this means that the pixel is either too dark for classification (night) or it is at least partly cloudy.

The algorithm does not have aerosol corrections, because a simple on/off classification does not require finely tuned aerosol detection. In a more detailed product which tries to detect the percentage of the snow covered area might benefit of aerosol corrections, but the primary challenges are in the vegetation data (tree species, tree density etc).

The SC algorithm derives snow cover from the satellite data for each PDU which cover 3 minutes of the satellite track. See Figure 4 for a breakdown of the algorithm processing structure. The implementation of the algorithm consists of two parts (unit 1 and unit 2). The unit 1 produces a full resolution snow cover map for one PDU. The unit 2 reprojects and merges to a global 0.01 degree grid all available PDU snow cover maps (output from unit 1) to create the daily global snow cover product.

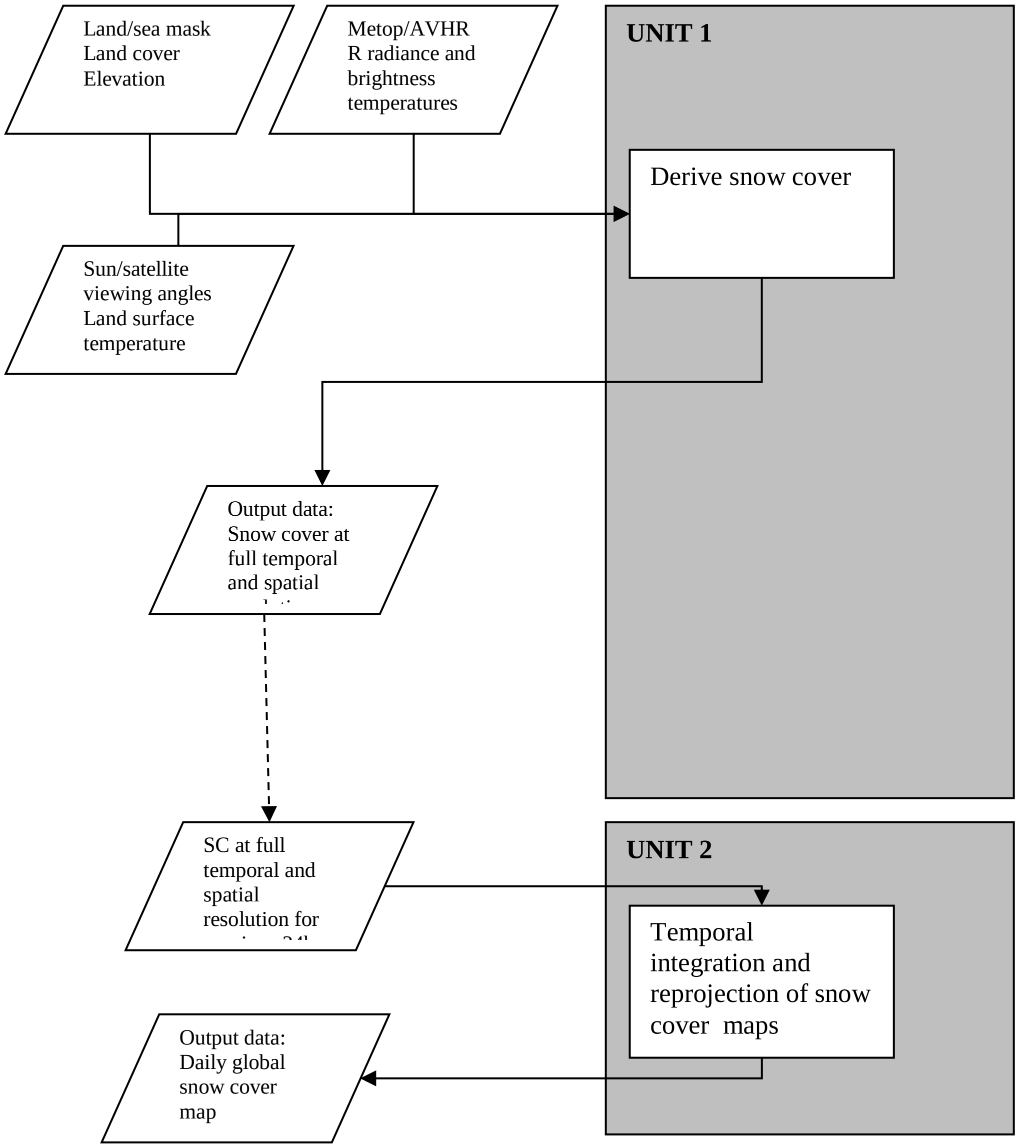

Figure 4 *Flowchart of the Land SAF Metop/AVHRR Snow Cover algorithm.*

2.2.1 Unit 1: Generation of single scene snow cover

The information on snow cover is based mainly on Metop/AVHRR radiances (channels 1, 2 and 3A) and brightness temperatures (channels 4 and 5). Solar and satellite angles are used as well as LSA SAF LST.

Table 4 *Snow cover classes in the product*

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

The snow cover category “partially snow covered” is not as well defined as snow free or snow covered classes. The partial snow cover class can be used for many reasons. Usually this class indicates the presence of snow in the area, but only a small percentage of the surface is snow covered. It is also possible that this class indicates probable snow i.e. that it is possible that area is snow covered, but the algorithm can not detect it for certain. Direct observations of the snow coverage on the surface are needed to improve the accuracy of the partial snow cover class. When the product is used as input data for applications this class can be combined with snow covered class or snow free class depending on the application.

The quality flags are set accordingly to the values of the input data flags, light conditions, and inversion. There are also flags for the land mask, the land use data and the elevation data. The quality flags are described in appendix B.

The data retrieval step produces a full resolution snow cover map, with information on the state of each pixel (snow/partial snow/no snow), provided the input data are available, and there is sufficient illumination. Cloudy pixels and also those pixels which were not classified by any of the rules used in the algorithm are set as unclassified.

The algorithm is using also some more or less static input data such as elevation and land use. Currently these are provided by IPMA and are based on United States Geological Survey (USGS) data.

2.2.2 Unit 2: Generation of global snow cover

When all the daily PDUs are analyzed, the phase 2 (see Figure 4) can be started. In this phase each PDU snow product file and associated coordinates files are loaded in order from the oldest to the newest and the the data is reprojected to 0.01 degree global grid. If the same pixel is classified several times the newest value is used in the merging.

When all data from phase 1 has been read, reprojected and merged, the final product is created by smoothing the data using pixel classification counts in the 3x3 pixels around each pixel.

The rules used for classification and smoothing are described in the Algorithm Theoretical Basis Document (ATBD).

The global snow cover product derived from Metop/AVHRR is generated daily, an example is presented in the Figure 5. In the figure some of the limitations of the polar orbiting satellites are well presented. When compared to a geostationary satellites, there are fewer images of the same location. Some areas near the equator are not covered daily during the daytime which can be seen as black stripes in the image, although this is not a serious limitation on a snow cover product. However, small number of images does limit the snow classification in cloudy areas, which might be cloud free during the day but not at the time of the satellite overpass and, hence, could be classified using e.g. MSG/SEVIRI data.

The most significant challenge, limited capabilities of the AVHRR instrument, can not be seen in the Figure 5. Many channels of the SEVIRI instrument are not available in the older AVHRR instrument and this creates many classification difficulties especially between ice clouds and snow. In some cases not even SEVIRI data provides adequate possibilities for differentiation of snow and ice clouds, but the most modern and future satellites are promising.

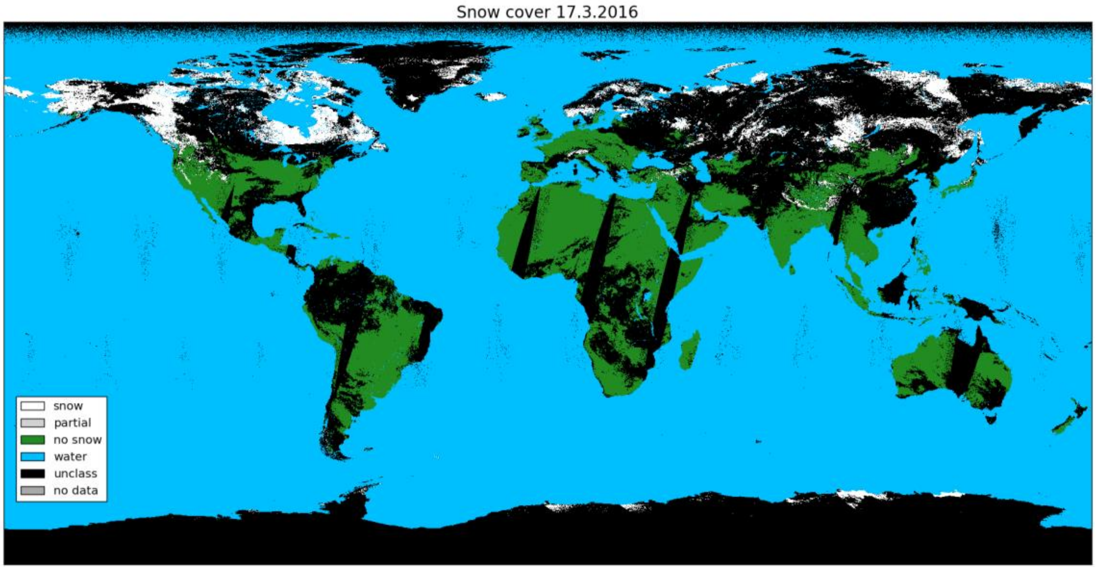

Figure 5 *Global Metop/AVHRR snow cover on March 17, 2016.*

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 SEVIRI Snow Cover: Geolocation / Rectification

The Snow Cover SEVIRI-based fields are generated pixel-by-pixel, maintaining the original resolution of SEVIRI level 1.5 data. These correspond to rectified images to 0º longitude, which present a typical geo-reference uncertainty of about 1/3 of a pixel. Data are kept in the native geostationary projection.

Files containing the latitude and longitude of the centre of each pixel may be downloaded from the Land-SAF website (http://landsaf.ipma.pt; under "Static Data and Tools"):

Longitude

HDF5_LSASAF_MSG_LON_MSG-Disk_.bz2
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_MSG-Disk_.bz2
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 (attributes), and correspond to one set of the values detailed below per SEVIRI/MSG area:

Table 5 *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
MSG-Disk	Full MSG Disk	3712	3712	1857	1857
Euro	Europe	1701	651	308	1808
NAfr	Northern Africa	2211	1151	618	1158
SAfr	Southern Africa	1211	1191	-282	8
SAme	Southern America	701	1511	1818	398

3.3 AVHRR Snow Cover Projection

The AVHRR/Metop Scnow cover product is available in a global sinusoidal projection, centred at (0^{o}N,0^{o}W), with a resolution of 0.01^o by 0.01^o.

3.4 File Formats

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

HDF5_LSASAF_MSG_SC2_<Area>_YYYYMMDDHHMM (for the daily MSG/SEVIRI SC) or
HDF5_LSASAF_M01-AVHR_EDSC_GLOBE_YYYYMMDDHHMM03 (for the EPS/AVHRR SC)

where <**Area**>, **YYYY**, **MM**, **DD**, **HH** and **MM** respectively, denote the geographical region (see Table 3), the year, the month, the day, the hour and the minute of data acquisition.

The LSA SAF products are provided in the HDF5 format. Originally developed at the National Center for Supercomputing Applications, it is currently supported by the non-profit HDF Group, whose mission is to ensure continued development of HDF5 technologies, and the continued accessibility of data currently stored in HDF. Documentation and HDF5 software are available from the http://www.hdfgroup.org/

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 A8), the dataset attributes (Table A9) and the quality flag attributes. Within the HDF5-files the information is organized in the form of separate datasets.

3.5 Product Contents

The SC product file contains two datasets corresponding to the values and the respective quality flags (Table 6). Table 7 describes possible values of the SC product. Table A9 and Appendix B**Error! Reference source not found.**, respectively, show the contents of the SC product dataset and QC information dataset. Detailed information is given in Appendix A and B.

Table 6 *Contents of the LSA SAF SC product file.*

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

Table 7 *Values of the LSA SAF SC products 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

3.6 Summary of MSG/SEVIRI SC Product Characteristics

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

Product Parameters:

Coverage:	MSG/SEVIRI full disk
Packaging:	Full disk
Units:	n.a.
Range:	0-5
Sampling:	pixel by pixel basis
Resolution:	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:	Full disk

Additional Information:

Identification of bands used in algorithm:

Pre-processed MSG radiances (channels 1, 2, 3, 4) and brightness temperatures (channels 4, 9 and 10)

Identification of ancillary and auxiliary data:

SEVIRI viewing angle

Sun angles

Land-sea mask

Land use

Elevation

3.7 Summary of Metop/AVHRR SC Product Characteristics

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

Product Parameters:

Coverage:	Global
Packaging:	Global
Units:	n.a.
Range:	0-5
Sampling:	pixel by pixel basis
Resolution:	0.01 x 0.01 degrees
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:

Pre-processed AVHRR radiances (channels 1, 2 and 3A) and brightness temperatures (channels 4 and 5)

Identification of ancillary and auxiliary data:

AVHRR viewing angle

Sun angles

Land-sea mask

Land use

Elevation

4 Validation and Quality Control

4.1 MSG/SEVIRI

An overview of the validation results of the LSA SAF snow cover product is presented here. A more detailed report of the validation of the LSA SAF SC products is available in the Validation report, available from the LSA SAF web site.

The product H31 (MSG/SEVIRI snow cover) is the flat land part of the HSAF product H10. The product H10 is validated in HSAF and the results for the flat land areas represent the quality of the original H31 product in flat land areas.

Independent validation has been performed for HSAF snow products H10, H12 and H31 (Kilpys, 2016) using Lithuanian snow observations. The results show very high agreement of product H31 and in situ data which is consistent with the HSAF validation reports.

4.2 Metop/AVHRR

The Metop/AVHRR global snow cover product has not been generated operationally before February 2016. Reprocessed data is available since January 2015

Validation results based on reprocessed products between January 2015 and October 2016 global surface observations of snow depth and state of ground show good agreement. See Validation report for further details.

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7 Acronyms

AVHRR	Advanced Very High Resolution Radiometer
CDOP	Continuous Development and Operations Phase
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
HDF	Hierarchical Data Format
HIRLAM	High Resolution Limited Area Model
ICAT	Instituto de Ciência Aplicada e Tecnologia (Portugal)
IPMA	Instituto Português do Mar e da Atmosfera (Portugal)
IMS	Interactive Multisensor Snow and Ice Mapping System
IR	Infrared Radiation
LSA	Land Surface Analysis
LST	Land Surface Temperature
METEOSAT	Geostationary Meteorological Satellite
MODIS	Moderate-Resolution Imaging Spectro-Radiometer
MSG	Meteosat Second Generation
NASA	National Air and Space Administration
NESDIS	National Environmental Satellite, Data and Information Service
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
URD	User Requirements Document
USGS	U.S. Geological Survey
v-a	viewing angle

Appendix A: HDF5 Format

Table A8 - General attributes of the SC product file.

Attribute Name	Attribute Value	Type
ARCHIVE_FACILITY	IM-PT	String
ASSOCIATED_QUALITY_INFORMATION	-	String
CENTRE	IM-PT	String
CFAC		Int
CLOUD_COVERAGE	-	String
COFF		Int
COMPRESSION		Int
DISPOSITION_FLAG	-	String
END_ORBIT_NUMBER	0	Int
FIELD_TYPE	Product	String
FIRST_LAT		Real
FIRST_LONG		Real
FORECAST_STEP	0	Int
GRANULE_TYPE	-	String
IMAGE_ACQUISITION_TIME	YYMMDDhhmmss	String
LFAC		Int
LOFF		Int
NB_PARAMETERS	2	Int
NC		Int
NL		Int
NOMINAL PRODUCT_TIME	YYMMDDhhmm	String
NOMINAL_LAT		Real
NOMINAL_LONG		Real
ORBIT_TYPE	LEO/GEO	String
OVERALL_QUALITY_FLAG	OK	String
PARENT_PRODUCT_NAME	-	String array (4)
PIXEL_SIZE		String
PROCESSING_LEVEL	2	String
PROCESSING_MODE	N	String
PRODUCT	MDSC/EDSC	String
PRODUCT_ACTUAL_SIZE		String
PRODUCT_ALGORITHM_VERSION	1.41.00/2.90.00	String
PRODUCT_TYPE	LSAMDSC/LSAEDSC	String

Attribute Name	Attribute Value	Type
PROJECTION_NAME		String
REGION_NAME	Disk/GLOBE	String
SAF	LSA	String
SATELLITE		Int
SENSING_END_TIME	-	String
SENSING_START_TIME	-	String
SPECTRAL_CHANNEL_ID		Int
START_ORBIT_NUMBER		Int
SUB_SATELLITE_POINT_END_LAT	0.0	Real
SUB_SATELLITE_POINT_END_LON	0.0	Real
SUB_SATELLITE_POINT_START_LAT	0.0	Real
SUB_SATELLITE_POINT_START_LON	0.0	Real
TIME_RANGE	daily	String

Table A9- Attributes of the SC dataset and SC Quality Flag dataset

SC dataset			SC Quality Flag dataset		
Attribute	**Description**	**Type**	**Attribute**	**Description**	**Type**
CLASS	Data	String	CLASS	Data	String
PRODUCT	EDSC/MDSC	String	PRODUCT	SC Flags	String
PRODUCT_ID		Int	PRODUCT_ID	0	Int
N_ COLS		Int	N_ COLS		Int
N_ LINES		Int	N_ LINES		Int
NB_BYTES	1	Int	NB_BYTES	2	Int
SCALING_FACTOR	1.0	Real	SCALING_FACTOR	1.0	Real
OFFSET	0.0	Real	OFFSET	0.0	Real
MISS_VALUE	0	Int	MISS_VALUE	0	Int
UNITS	-	String	UNITS		String

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 B10, as well as their meaning. The examples chosen are some of the most common combinations, together with some less common, but illustrative, examples

Table B10 - 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