EUMETSAT Satellite Application Facility on Climate Monitoring

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Surface Albedo

Product User Manual

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Applicable Documents

Reference	Title	Code
AD.1.	CM SAF Service Specification Document	SAF/CM/DWD/SeSp/1.9
AD.2.	Validation Report Surface Albedo CLARA-A1	SAF/CM/FMI/VAL/GAC/SAL/1.2
AD.3.	CM SAF Product Requirements Document	SAF/CM/DWD/PRD/1.7
AD.4.	SYSTEMATIC OBSERVATION REQUIREMENTS FOR SATELLITE-BASED DATA PRODUCTS FOR CLIMATE - 2011 Update	GCOS-154

Reference Documents

Reference	Title	Code
RD.1.	Algorithm Theoretical Basis Document Surface Albedo CLARA-A1	SAF/CM/FMI/ATBD/GAC/SAL/1.2

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1 The EUMETSAT SAF on Climate Monitoring (CM SAF)

The importance of climate monitoring with satellites was recognized in 2000 by EUMETSAT Member States when they amended the EUMETSAT Convention to affirm that the EUMETSAT mandate is also to “contribute to the operational monitoring of the climate and the detection of global climatic changes". Following this, EUMETSAT established within its Satellite Application Facility (SAF) network a dedicated centre, the SAF on Climate Monitoring (CM SAF, http://www.cmsaf.eu).
The consortium of CM SAF currently comprises the Deutscher Wetterdienst (DWD) as host institute, and the partners from the Royal Meteorological Institute of Belgium (RMIB), the Finnish Meteorological Institute (FMI), the Royal Meteorological Institute of the Netherlands (KNMI), the Swedish Meteorological and Hydrological Institute (SMHI), the Meteorological Service of Switzerland (MeteoSwiss), and the Meteorological Service of the United Kingdom (UK MetOffice). Since the beginning in 1999, the EUMETSAT Satellite Application Facility on Climate Monitoring (CM SAF) has developed and will continue to develop capabilities for a sustained generation and provision of Climate Data Records (CDR’s) derived from operational meteorological satellites.
In particular the generation of long-term data sets is pursued. The ultimate aim is to make the resulting data sets suitable for the analysis of climate variability and potentially the detection of climate trends. CM SAF works in close collaboration with the EUMETSAT Central Facility and liaises with other satellite operators to advance the availability, quality and usability of Fundamental Climate Data Records (FCDRs) as defined by the Global Climate Observing System (GCOS). As a major task the CM-SAF utilizes FCDRs to produce records of Essential Climate Variables (ECVs) as defined by GCOS. Thematically, the focus of CM SAF is on ECVs associated with the global energy and water cycle.

Another essential task of CM SAF is to produce data sets that can serve applications related to the new Global Framework of Climate Services initiated by the WMO World Climate Conference-3 in 2009. CM SAF is supporting climate services at national meteorological and hydrological services (NMHSs) with long-term data records but also with data sets produced close to real time that can be used to prepare monthly/annual updates of the state of the climate. Both types of products together allow for a consistent description of mean values, anomalies, variability and potential trends for the chosen ECVs. CM SAF ECV data sets also serve the improvement of climate models both at global and regional scale.
As an essential partner in the related international frameworks, in particular WMO SCOPE-CM (Sustained COordinated Processing of Environmental satellite data for Climate Monitoring), the CM SAF - together with the EUMETSAT Central Facility, assumes the role as main implementer of EUMETSAT’s commitments in support to global climate monitoring. This is achieved through:

- Application of highest standards and guidelines as lined out by GCOS for the satellite data processing,
- Processing of satellite data within a true international collaboration benefiting from developments at international level and pollinating the partnership with own ideas and standards,
- Intensive validation and improvement of the CM SAF climate data records,
- Taking a major role in data set assessments performed by research organisations such as WCRP. This role provides the CM SAF with deep contacts to research organizations that form a substantial user group for the CM SAF CDRs,
- Maintaining and providing an operational and sustained infrastructure that can serve the community within the transition of mature CDR products from the research community into operational environments.

A catalogue of all available CM SAF products is accessible via the CM SAF webpage, www.cmsaf.eu/. Here, detailed information about product ordering, add-on tools, sample programs and documentation is provided.

2 Introduction

The purpose of this document is to provide interested users with information on the features, quality and usage of the Global Area Coverage Surface Broadband Albedo (CLARA-SAL) dataset of the Climate-SAF project. The first part of the document introduces the product and its significance. The second part discusses the features and quality of the product in more detail, and the third part describes the end user product format.

Surface albedo is one of the factors governing the Earth's radiation budget, which in turn drives the climate of our planet. (Shortwave) Surface albedo is the dimensionless ratio of the reflected (solar) radiation flux to the incoming (solar) radiation flux. It has been designated as one of the Essential Climate Variables (ECV) of the GCOS, as required by IPCC and UNFCCC (GCOS Secretariat, 2006). Because of surface albedo's significance to the radiation budget, its continuous monitoring is of importance in understanding climate change. Satellites provide the most cost-effective means to achieve global coverage with a relatively short repeat period. All products have been developed and evaluated with respect to requirement goals defined in [AD.3]. The finally achieved product accuracies are described in [AD.2]. Of specific interest here are requirements in [AD.4] as outlined by the Global Climate Observing System (GCOS) community and issued by the United Nations World Meteorological Organisation (WMO) in 2012.

The CLARA-SAL dataset spans the period from 1982-2009. The albedo products, distributed as pentad and monthly means at 0.25 degree resolution, are composed from overpass data from the Advanced Very High Resolution Radiometer (AVHRR) instruments on board the National Oceanic and Atmospheric Administration (NOAA) satellites. The characteristics of the time series and its usage are described in the following chapters. The purpose of this document is not to be a detailed guide to the workings of the algorithm itself. Although processing flow is described, readers interested in the nuts and bolts of the SAL algorithm are encouraged to read the CLARA-SAL Algorithm Theoretical Baseline Document (ATBD) [RD.1], available on the CM-SAF project website.

2.1 Suggested usage and limitations

The CLARA-SAL dataset has been validated against a large number of in-situ reference data. Validation criteria have been fulfilled for both vegetated regions and snow/ice-covered areas. Particularly the product accuracy over snow and ice has been shown to be good; therefore we have grounds to recommend using CLARA-SAL for cryospheric studies especially over the Arctic owing to the complete sea ice albedo coverage in CLARA-SAL. The dry, thin atmosphere over the inner parts of Antarctica poses a challenge to the atmospheric correction in CLARA-SAL and may have an effect in product quality there (yet unstudied). Similarly, care needs to be taken when utilizing CLARA-SAL over regions with a high variability in aerosol concentrations in the atmosphere. In general, users are also strongly recommended to examine the number of observations-datafield within each CLARA-SAL product. Cases where the temporal mean albedo of an area is derived from only a few observations are vulnerable to errors in cloud masking, especially over sea ice. Therefore the pentad mean products are generally more vulnerable to retrieval errors than the monthly mean products.

2.2 The EUMETSAT SAF on Climate Monitoring (CM SAF)

The importance of climate monitoring with satellites was recognized in 1999 by EUMETSAT Member States when they amended the EUMETSAT Convention to affirm that the EUMETSAT mandate is also to contribute to the operational monitoring of climate and the detection of global climatic changes". Following this, EUMETSAT established within its

Satellite Application Facility (SAF) network a dedicated centre, the SAF on Climate Monitoring (CM SAF, http://www.cmsaf.eu). Since the start of the CM SAF in 1999 the project went through three phases, i.e., the Development Phase lasting from 1999 to 2004, the Initial Operations Phase (IOP) and the Continued Development and Operations Phase (CDOP). The consortium of CM SAF currently comprises the Deutscher Wetterdienst (DWD) as host institute, and the partners from the Royal Meteorological Institute of Belgium (RMIB), the Finnish Meteorological Institute (FMI), the Royal Meteorological Institute of the Netherlands (KNMI), the Swedish Meteorological and Hydrological Institute (SMHI) and the Meteorological Service of Switzerland (MeteoSwiss).

After focusing on the development of retrieval schemes to derive a subset of Essential Climate Variables (ECVs) in the development phase, CM SAF delivered to its users products based on Meteosat and polar orbiter data for Europe and Northern Africa supporting NMHSs in their provision of climate services in the IOP from 2004 to 2007. During CDOP, lasting from 2007 to 2012, the product validation continued, the time series were expanded and algorithms were further improved, while the study domain was extended from the baseline area to the MSG disk for the geostationary products and to include global and Arctic coverage for the polar orbiter products. In addition, long term climate datasets from polar orbiting and geostationary satellites are being generated for climate monitoring (i.e. HOAPS, METEOSAT and AVHRR-GAC based products).

A catalogue of available CM SAF products is available via the CM SAF webpage, http://www.cmsaf.eu/. Here, detailed information about product ordering, add-on tools, sample programs and documentation are provided.

3 Global Area Coverage Surface Albedo (CLARA-SAL)

3.1 Product Definition

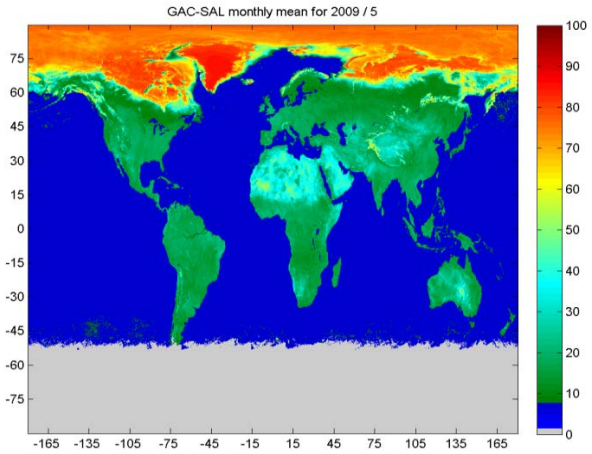
The physical quantity that CLARA-SAL describes is the black-sky surface albedo, mathematically written as (Schaepman-Strub et al., 2006)

$$\alpha(\theta_s,\phi_s)=\int_0^{2\pi}\int_0^{\pi/2} f_r(\theta_s,\phi_s;\theta_r,\phi_r)\cos(\theta_r)\sin(\theta_r)d\theta_r d\phi_r \quad (1)$$

The black-sky surface albedo is the integral of radiation reflected from a single incident direction towards all viewing directions in the zenithal and azimuthal planes. The spectral dependency of albedo is omitted here; a full (black-sky) broadband albedo would be obtained by integrating the spectral directional-hemispherical reflectance over the waveband under investigation. CLARA-SAL is a broadband albedo product, defined with a wavelength range of 0.25 - 2.5 µm for AVHRR.

3.2 Products and availability

The CM SAF SAL products are available as pentad (five-day) and monthly means in a global equally spaced lat/long grid at 0.25 degree spatial resolution. Area shown in Figure 1. A subset of the data spanning either the Arctic or Antarctic region in 25 km resolution with LAEA projection data is also delivered. Please contact the CM SAF User Help Desk for details.



Projection	Geographic
Ellipsoid	WGS-84
Region (deg)	long: -179.875 -> 179.875, lat: 89.875 -> -89.875
Resolution	0.25 degrees
Size	720 columns, 1440 lines

Figure 1: CLARA-SAL monthly mean lat/long grid example and parameters.

3.3 CLARA-SAL algorithm

AVHRR channels 1 and 2 (0.58-0.68 µm and 0.725-1 µm) are used for the AVHRR-SAL product generation as radiance sources. The overall processing flow of CLARA-SAL is shown in Figure 4. The necessary preprocessing of the satellite data for use with SAL is done by the PPS software package. Details on the AVHRR-PPS package and cloud mask derivation may be found at Dybbroe et al. (2005). The package converts observed satellite radiances to TOA reflectances for CLARA-SAL, and performs the critical cloud masking operation. Sun-satellite geometry data are also provided. Other auxiliary data, such as the water vapour content in the atmosphere or surface pressure, are based on the ERA-Interim model analysis done at ECMWF. Land use information is based on the USGS classification.

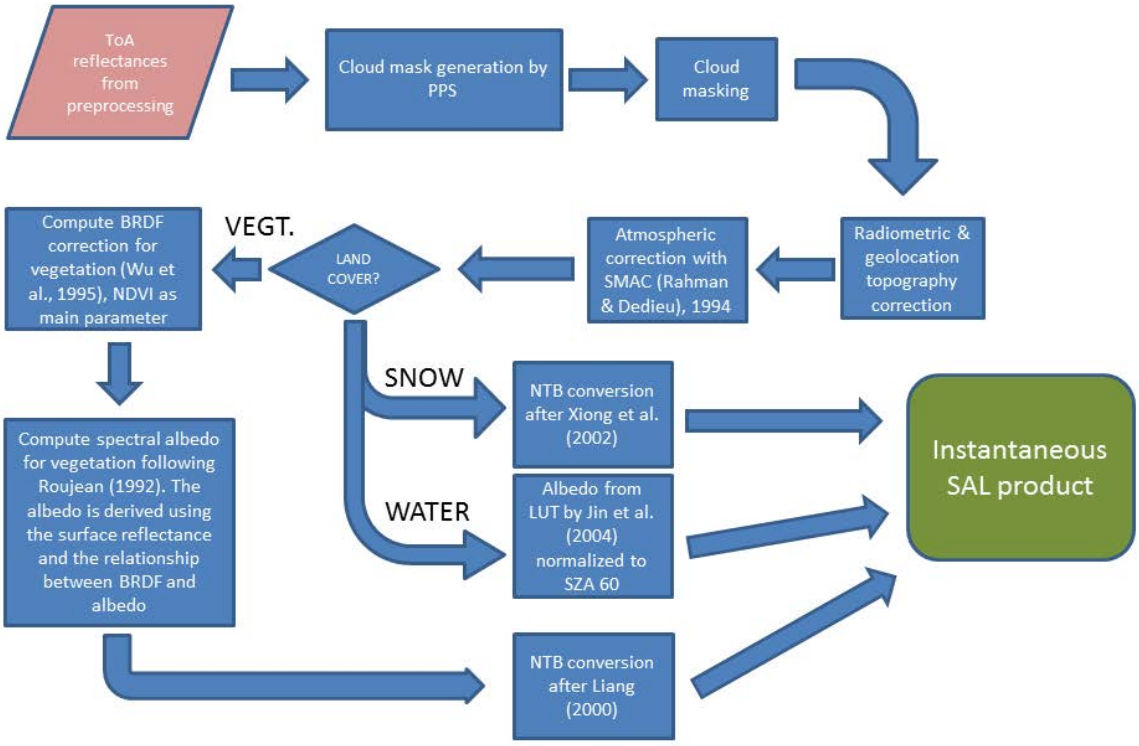


Figure 2: The process flow of the CLARA-SAL product computation.

The product processing proceeds as follows (for details the reader is referred to the SAL ATBD [RD.1]):

- The ToA AVHRR reflectances are provided by the Polar Platform System (PPS) processing software, as discussed above.
- Topography correction for geolocation and radiometry is applied for areas (pixels) with slopes exceeding 5 degrees. For a brief discussion, see below and additionally [RD.1] for details.
    - Motivation: improvement of retrieval accuracy of albedo over mountainous regions.
- SMAC atmospheric correction applied for all observed reflectances.
    - AOD is currently set to 0.1 everywhere, the ozone content of the atmosphere is set to 0.35, surface pressure and water vapour content of the atmosphere are derived from ERA-Interim data.
    - NOAA-18 SMAC coefficients are applied for all NOAA satellites, since the AVHRR radiances are intercalibrated across the AVHRR-GAC FCDR.
- The surface reflectances are expanded into hemispherical spectral albedos by applying a BRDF algorithm based on the work of Roujean et al. (1992) and Wu et al. (1995). The BRDF algorithm is applied to both 0.6 and 0.8 µm channel separately.
- Snow albedo algorithm utilizes empirical sampling of pentad/monthly BRDF. The instantaneous overpasses are kept as directional-directional reflectances, temporal averaging forms desired hemispherical-directional reflectances (black-sky albedo, i.e. CLARA-SAL). Details in [RD.1].
    - Motivation: No robust, universal snow BRDF models available for anisotropy correction. Testing and validation have proven that sufficient sampling of the viewing hemisphere is achieved over most snow-covered regions of the Earth.
- The spectral albedos are processed to a shortwave broadband albedo via a narrow-to-broadband (NTB) conversion. The conversion is both instrument and pixel land cover specific. The land cover information comes from USGS land use classification data.
    - For water pixels, the BB albedo is taken from a LUT after Jin et al. (2004).
    - For snow pixels, the instantaneous BB directional reflectance is computed from the channel-specific spectral directional reflectances (see above) by an NTBC algorithm by Xiong et al. (2002).
    - For other types of land cover, the NTBC conversion takes place based on an algorithm by Liang (2000).
- A normalization of the instantaneous albedo retrievals to a sun zenith angle (SZA) of 60 degrees to better enable averaging for the distributed products was planned but not carried out due to technical reasons. The typical effect on the mean albedo over a pentad or a month is estimated to be 0.01 – 0.02 with respect to a mean albedo normalized to a SZA of 60 degrees.

3.3.1 CLARA-SAL topography correction:

The topography affects the satellite image in first order in two ways: 1) the altitude difference with respect to sealevel will cause the geolocation of the pixel to be shifted and 2) the inclination of the slopes of the terrain within a pixel will alter its reflectance value. As the BRDF calculations are based on a horizontal plane assumption, erroneous values will be

obtained for inclined slopes. In addition, the slope distribution of the terrain covered by the pixel may contain slopes that are not seen at all by the sun or the satellite. These kinds of situations will cause even larger errors than small slope inclinations.

The topography correction is calculated in two parts. First, the apparent location of a pixel is computed and pixels are moved to their actual locations on a flat plane (within 1 pixel accuracy). Then, a high-resolution DEM is fitted into the satellite data and viewing/illumination geometry data is applied to compute the number of slopes within the satellite pixel that are illuminated, in shadow or illuminated/viewable but not within the BRDF model validity range. The unseen/shadowed slopes are assumed to have the same physical albedo as the observed slopes. The observed reflectance is corrected for assuming that the slopes that could not contribute to the observed reflectance would contribute to the albedo of the area equally much as the slopes that were visible in the observed satellite image. For more details, the reader is encouraged to see the ATBD [RD.1].

3.4 Validation

The CLARA-SAL dataset has been validated prior to release against ground truth data from the Baseline Surface Radiation Network (BSRN), Greenland Climate Network (GC-Net), and the Arctic Research Center of FMI. The validation was performed at 10 sites worldwide, including Greenland and Antarctica. In addition, the CLARA-SAL performance over sea ice was validated against Tara expedition albedo measurements from Arctic summer 2007.

The **target accuracy** for CLARA-SAL Edition 1 is specified in the Climate-SAF Product Requirements Document (PRD) as **25% relative to the reference** [AD.3]. According to the results in [AD.2], **CLARA-SAL meets the target accuracy at nearly all of the validation sites during the validation period 1994-2009**. The cases where the discrepancy between in situ and CLARA-SAL observations is greater than the requirement typically result from poor comparability between the data owing to heterogeneous land cover around the validation site.

The CLARA-SAL dataset has also been compared to CERES and MODIS black-sky albedo mean products. Differences between the products are generally between 10 and 20% in relative terms. Details of the study may be found in [AD.2].

GCOS requirements for black-sky surface albedo products are to have an accuracy of 5% and a stability of 1%. While these requirements are highly stringent for a coarse-resolution instrument like AVHRR with relatively few measurement wavebands, we are nevertheless working towards improving CLARA-SAL accuracy further in future dataset Editions.

As examples of the achieved accuracy, we show here validation results from the BSRN site of Southern Great Plains (SGP) and the Greenland Climate Network site of Summit station. The SGP site provides the best background for validation of CLARA-SAL, since it is one of the few vegetated validation sites where the land cover is homogeneous enough to remove comparability issues between the coarse CLARA-SAL albedo and the point-like in situ observation data. Summit is a good candidate for evaluating the snow albedo retrieval in CLARA-SAL, since the site is in the central part of the Greenland Ice Sheet, its albedo is very stable during the summer months when retrievals are possible, and there is no vegetation to interfere with the snow albedo retrieval.

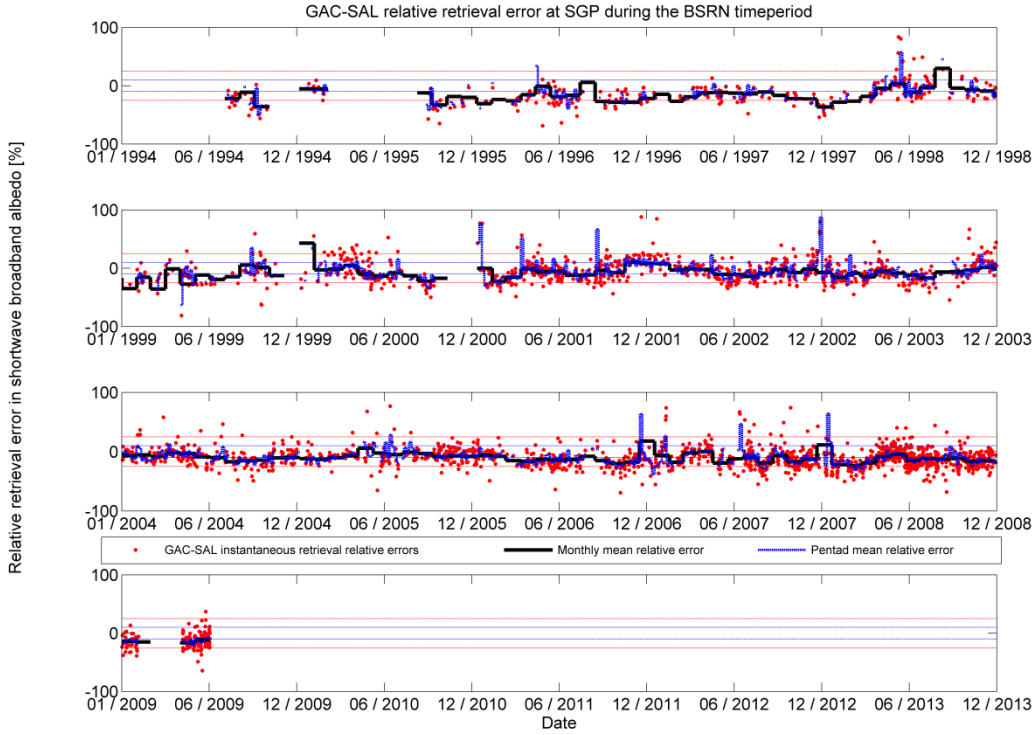


Figure 3: CLARA-SAL relative retrieval error over SGP. Red circles indicate retrieval errors at instantaneous level; the black and blue lines indicate the retrieval error of the monthly and pentad means. Red dashed line shows 25% and the blue dashed line 10% relative error levels.

Figure 3 shows the monthly and pentad albedo retrieval errors at SGP. Apart from a scattered snowfall events, the albedo at SGP remains quite stable. CLARA-SAL tracks the mean in situ albedo well in monthly mean scale and also on pentad mean scales, although there occasional cloud misclassifications or snowfall events may cause larger errors. While the instantaneous CLARA-SAL albedo retrieval errors (red circles) have a larger variability, the mean albedo is tracked correctly. Mean achieved accuracy over the 15-year validation period was ~10%.

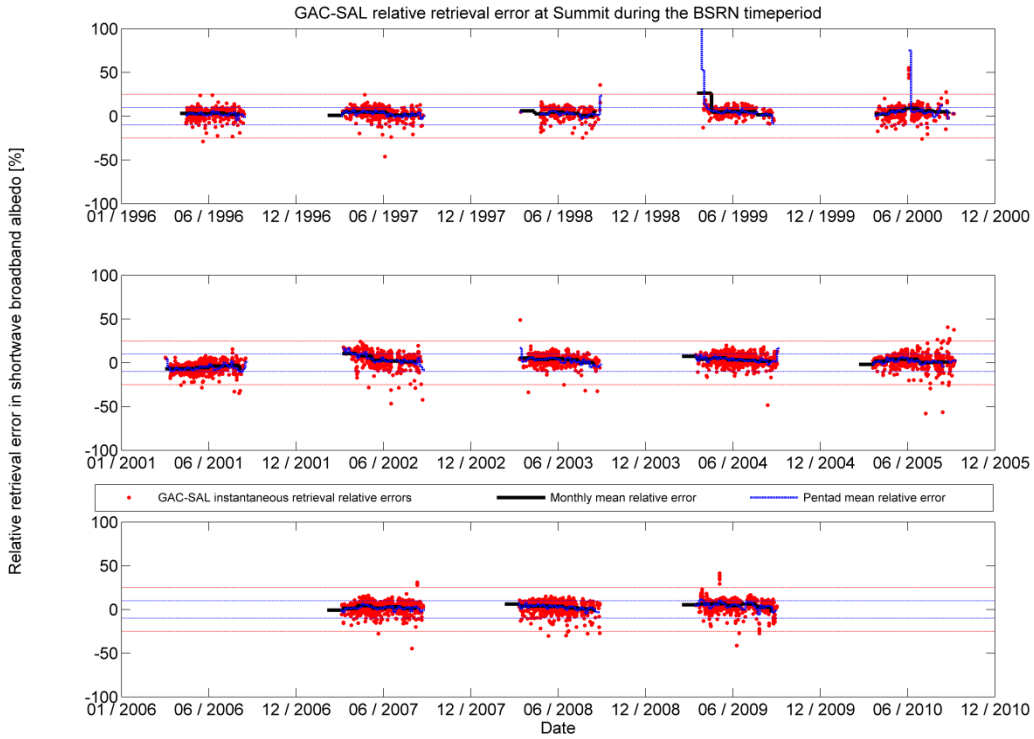


Figure 4: CLARA-SAL relative retrieval error over Summit station. Red circles indicate retrieval errors at instantaneous level; the black and blue lines indicate the retrieval error of the monthly and pentad mean. Red dashed line shows 25% and the blue dashed line 10% relative error levels.

Figure 4 shows similarly the achieved retrieval accuracy at Summit station, Greenland. Both in situ and CLARA-SAL albedo are stable over the 13 years of data that have been analyzed. Again, instantaneous retrievals (which are in fact samples of the on-site bidirectional reflectance) show a range of variability around the mean, yet the mean albedo is stable. The mean relative retrieval error at Summit over the 13 analyzed years was ~3% for monthly means and ~4% for the pentad means.

3.5 Limitations

The computation of surface broadband albedo is a complex task with several possible sources of error. A detailed listing and study of each factor is beyond the scope of this manual, the interested reader may find a detailed analysis in [RD.1]. However, it is important to mention here the most important error sources of the algorithm:

- The accuracy of the cloud mask is critical to the SAL product quality. Cloud overestimation in the mask is not a problem since the weekly and monthly SAL end products generally have sufficient sampling to compensate. However, underestimation of clouds may lead to sporadic instantaneous surface albedo retrieval overestimations of several hundred per cent (relative). Over snow-covered areas, the underestimation of cloud cover typically leads to an underestimation of the instantaneous surface albedo. The end products are resistant to such effects because they are the result of averaging of instantaneous products, leading to mitigation of sporadic errors. The quantification of the robustness of SAL end products to cloud mask errors is yet to be performed.

- The current atmospheric correction is a compromise between the need to avoid introducing artificial retrieval errors into product and a desire to correctly account for the atmospheric physics affecting the surface albedo retrieval. We currently use an atmospheric model to account for the second-order atmospheric variables that affect surface albedo retrievals, namely columnar water vapour and surface pressure. Ozone content of the atmosphere is kept constant. However, the most important atmospheric variable affecting the surface albedo retrievals is the aerosol optical depth (AOD) in the atmosphere. Variations in AOD are both regional and global; their effect in space-observed surface reflectances is substantial. Yet an accurate derivation of AOD from satellite observations to support surface albedo retrievals requires assumptions on the albedo of the underlying surface. Through making these assumptions, the product contains an internal correlation between the AOD and the albedo of the terrain underneath, which is an undesired combination. To avoid this, we currently choose to use a fixed AOD content in the atmosphere everywhere. Though additional albedo retrieval errors will occasionally occur as a result, we make this choice consciously in order to preserve the trend analysis capabilities of the CLARA-SAL product.

- Errors in the land use classification data are another source of retrieval error that should be considered. The LUC data is not continuously updated, therefore man-made or natural changes in land cover are generally not correctly picked up by CLARA-SAL, which is dependent on LUC data to choose a proper surface albedo subroutine. A known location where errors do occur is the ablation zone in West Greenland for Arctic SAL. There broken terrain, ice flows and progressing snow melt in summer seasons cause the LUC classification to be inaccurate, leading to major retrieval errors. Also, the algorithm does not yet properly delineate between desert areas and other barren terrain, leading to increased retrieval errors for desert. Since the CLARA-SAL dataset also covers 27 years in time, inaccuracies in the USGS classification are unavoidable. Their effect and source is also very difficult to localize in time or space.

3.6 Outlook

The CLARA-SAL dataset will be reprocessed and extended forward in time twice during the years 2012-2017. Improvements for the next dataset Editions are currently being studied. The algorithm improvements will focus on the following areas:

1. Atmospheric correction. We plan to introduce non-static aerosol concentration information into CLARA-SAL processing to improve the atmospheric correction accuracy. This data may come from independent observations, aerosol climatologies, or some combination of them. Furthermore, we plan to also include non-static O3 content data from e.g. TOMS timeseries.
2. Land use classification/BRDF effects. An accurate and temporally variable LUC dataset would minimize BRDF correction errors in CLARA-SAL. Derivation of such a dataset over the CLARA-SAL coverage period is not a trivial task, but we are studying options to either accomplish this or possibly redesign the BRDF correction algorithm to circumvent the issue.
3. Topography correction improvements. CLARA-SAL accuracy in mountainous areas will be a subject of further studies and, if necessary, refinements to the topography correction algorithm currently implemented.

4 Data Description

CM SAF's climate monitoring HOAPS products are provided as NetCDF (Network Common Data Format) files (http://www.unidata.ucar.edu/software/netcdf/). The data files are created following NetCDF Climate and Forecast (CF) Metadata Convention version 1.5 (http://cf-pcmdi.llnl.gov/) and NetCDF Attribute Convention for Dataset Discovery version 1.0.

For data processing and conversion to various graphical packages input format, CM SAF recommends the usage of the climate data operators (CDO), available under GNU Public License (GPL) from MPI-M (http://www.mpimet.mpg.de/~cdo).

4.1 Data file contents

A common NetCDF file consists of dimensions, variables, and attributes. These components can be used together to capture the meaning of data and relations among data. All CLARA-SAL product files are built following the same design principles.

Each data file contains the following coordinate variables:

time start of averaging/composite time period [days counted from 1970-01-01]
time_bnds two-dimensional array defining the averaging/composite time period [days counted from 1970-01-01]
latitude geographical latitude of pixel centre [degree_north]
longitude geographical longitude of pixel centre [degree_east]

Each data file contains the following 2-dimensional variables:

sal contains the CLARA-SAL product data [percent]
sal_nobs contains the numbers of valid satellite observations for each SAL pixel[unitless]
sal_stdv contains the standard deviation of the CLARA-SAL product per pixel [percent]

The monthly mean SAL products additionally contain the following 2-dim data field:

sal_median contains the median of the valid SAL retrievals per pixel [percent]

Table 1: CLARA-SAL variables in a NetCDF file

Variable	Size	Type
time	1 x 1	double
time_bnds	2 x 1	double
latitude	720 x 1	double
longitude	1440 x 1	double
sal	1440 x 720 x 1	single
sal_median (mm only)	1440 x 720 x 1	single
sal_nobs	1440 x 720 x 1	int32
sal_stdv	1440 x 720 x 1	single

The data file also contains an array of global attributes for data documentation and improved usability purposes. These attributes are contained in each CLARA-SAL product, and are listed in Table 2.

Table 2: CLARA-SAL product attributes

Name	Description
title	
Conventions	conventions followed, "CF-1.5" for all files
Metadata_Convention	conventions followed, "Unidata Dataset Discovery v1.0" for all files
institution	institution where the data was produced
Digital_Object_Identifier	DOI assigned to this dataset
creator_url	URL contact information for the creator of the data
creator_email	email contact information for the creator of the data
references	references that describe the data or methods used to produce it
source	original data source, “AVHRR GAC edition 1” for gridded products
cdm_data_type	data type, “grid” for gridded products
filename	original filename
time_coverage_start	temporal coverage start of the data [ISO8601 date]
time_coverage_end	temporal coverage end of the data [ISO8601 date]
time_coverage_duration	temporal coverage duration of the data [ISO8601 duration]
time_coverage_resolution	temporal coverage resolution of the data [ISO8601 duration]
geospatial_lat_units	latitude attributes unit [degree_north]
geospatial_lat_resolution	latitude grid resolution
geospatial_lat_min	latitude bounding box minimum
geospatial_lat_max	latitude bounding box maximum
geospatial_lon_units	longitude attributes unit [degree_east]
geospatial_lon_resolution	longitude grid resolution
geospatial_lon_min	longitude bounding box minimum
geospatial_lon_max	longitude bounding box maximum
dataset_version	GAC dataset version
cmsaf_gac_major_version_number	GAC major Edition version
cmsaf_gac_minor_version_number	GAC minor Edition version
cmsaf_gac_parameter_name	GAC parameter name.
cmsaf_parameter_id	GAC parameter ID
processed_satellites	satellite overpasses (id and number) processed for this mean
processed_orbit_nodes	satellite orbit nodes processed for this mean "ascending, descending" for all files
cmsaf_parameter_id	CM SAF product identifier code (60 for CLARA-SAL)
cmsaf_parameter_code	CM SAF product name
L3_processor	Software version of the GAC averaging & reprojection software
L2_processors	Versions of the L2 software used to generate the product [SAL and PPS software versions applied for CLARA-SAL generation]
Level1_intercalibration	intercalibration version applied
reference_documents	Identifier codes and names of the GAC product documents applicable for this data.

In addition to the global attributes, each variable also has attached attributes. The variable-specific attributes are listed with explanations in

Table 3: Attributes assigned to variables

Name	Description
long_name	long descriptive name
standard_name	standard name that references a description of a variable's content in the CF standard name table
units	physical unit [udunits standards]
valid_min	smallest valid value of a variable
valid_max	largest valid value of a variable
scale_factor	The data are to be multiplied by this factor after it is read.
add_offset	This number is to be added to the data after it is read. If scale_factor is present, the data are first scaled before the offset is added.
_FillValue	This number represent missing or undefined data. Missing values are to be filtered before scaling.
missing	same as _FillValue
cell_methods	method used to derive data that represents cell values

5 Data ordering via the Web User Interface (WUI)

The internet address http://wui.cmsaf.eu allows direct access to the CM SAF data ordering interface. On this webpage a detailed description how to use it for product search and ordering is given. We refer the user to this description since it is the central and most up to date documentation. However, some of the key features and services are briefly described in the following sections.
Further user service including information and documentation about CM SAF and the CM SAF products are available from the CM SAF home page (http://www.cmsaf.eu).

5.1 Product ordering process

You need to be registered and logged in to order products. A login is provided upon registration, all products are delivered free of charge (Please not the copyright disclaimer given in section 7.1). After the selection of the product, the desired way of data transfer can be chosen. This is either via a temporary ftp account (the default setting), or by CD/DVD or email. Each order will be confirmed via email, and the user will get another email once the data have been prepared. If the ftp data transfer was selected, this second email will provide the information on how to access the ftp server.

5.2 Contact User Help Desk staff

In case of questions the contact information of the User Help Desk (e-mail address contact.cmsaf@dwd.de) are available via the CM SAF home webpage (www.cmsaf.eu) or the home page of the Web User Interface (http://wui.cmsaf.eu).

5.3 User Problem Report

Users of CM SAF products and services are encouraged to provide feedback on the CM SAF product and services to the CM SAF team. Users can either contact the User Help Desk (see section 5.2.) or use the “User Problem Report” page. A link to the “User Problem Report” is available either from the CM SAF home page (www.cmsaf.eu) or the Web User Interface home page (http://wui.cmsaf.eu).

5.4 Service Messages / log of changes

Service messages and a log of changes are also accessible from the CM SAF home webpage (http://www.cmsaf.eu) and provide useful information on product status, versioning and known deficiencies.

6 Feedback

6.1 User feedback

Users of CM SAF products and services are encouraged to provide feedback on the CM SAF product and services to the CM SAF team. We are keen to learn of what use the CM SAF data are. So please feedback your experiences as well as your application area of the CM SAF data.
EUMETSAT CM SAF is an user driven service and is committed to consider the needs and requirements of its users in the planning for product improvements and additions. Please provide your feedback e.g. to our User Help Desk (e-mail address contact.cmsaf@dwd.de).

6.2 Specific requirements for future products

Beside your general feedback you are cordially invited to provide your specific requirements on future products for your applications. Please provide your requirements e.g. to our staff or via our User Help Desk (e-mail address contact.cmsaf@dwd.de).

6.3 User Workshops

CM SAF is organizing on regular basis training workshops in order to facilitate the use of our data. Furthermore through our regular (approximately every four years) user's workshop we revisit our product baseline. Your participation in any of these workshops is highly appreciated. Please have a look at on the CM SAF home web page (www.cmsaf.eu) to get the latest news on upcoming events.

7 Copyright and Disclaimer

The user of CM SAF data agrees to respect the following regulations:

7.1 Copyright

All intellectual property rights of the CM 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 in publications, presentations, web pages etc., ***EUMETSAT's copyright credit must be shown by displaying the words "copyright (year) EUMETSAT" on each of the products used.***

7.2 Acknowledgement and Identification

When exploiting EUMETSAT/CM SAF data you are kindly requested to acknowledge this contribution accordingly and make reference to the CM SAF, e.g. by stating "The work performed was done (i.a.) by using data from EUMETSAT's Satellite Application Facility on Climate Monitoring (CM SAF)". It is highly recommended to clearly identify the product version used. An effective way to do this is the citation of CM SAF data records via the digital object identifier (doi). All information can be retrieved through (http://www.cmsaf.eu/DOI).
The DOI for this data set is provided on the title page of this document.

7.3 Re-distribution of CM SAF data

Please do not re-distribute CM SAF data to 3rd parties. The use of the CM SAF products is granted free of charge to every interested user, but we have an essential interest to know how many and what users the CM SAF has. This helps to ensure of the CM SAF operational services as well as its evolution according to users needs and requirements. Each new user shall register at CM SAF in order to retrieve the data.

8 References

Briegleb, B.P. , P. Minnis, V. Ramanathan, and E. Harrison, 1986: Comparison of regional clear-sky albedos inferred from satellite observations and model computations. *Jounal of Climate and Applied Meteorology*, **25**, 214–226.

Derrien, M. and LeGléau, H., 2005: MSG/SEVIRI cloud mask and type from SAFNWC. *International Journal of Remote Sensing*, **26**, 4707–4732.

Dybbroe, A. Thoss, A. and Karlsson, K-G, 2005: SAFNWC AVHRR cloud detection and analysis using dynamic thresholds and radiative transfer modelling part I: Algorithm description. *Journal of Applied Meteorology*, **44**, 39–54.

Jin, Z., Charlock, T.P., Smith, W.L., Jr, and K. Rutledge, 2004: A parameterization of ocean surface albedo. *Geophysical Research Letters*, **31**, 22301.

Liang S., 2000: Narrowband to broadband conversions of land surface albedo: Algorithms. *Remote Sensing of Environment*, **76**, 213–238.

Manalo-Smith, N. G.L. Smith, S.N. Tiwari, S.N. W.F. Staylor, 1998: Analytic forms of bidirectional reflectance functions for application to earth radiation budget studies. Journal of Geophysical Research, 103(D16):19733–19752.

WMO, 2006: Systematic observation requirements for satellite-based products for climate. Technical Report 107, Global Climate Observing System, World Meteorological Organization, 7 bis, Avenue de la Paix P.O. Box No. 2300 CH-1211 Geneva 2, Switzerland.

Rahman H. and G. Dedieu, 1994: Smac: a simplified method for the atmospheric correction of satellite measurements in the solar spectrum. *International Journal of Remote Sensing,* **15**, 1994.

Roujean, J.-L., M. Leroy, and P.-Y. Deschamps, 1992: A bidirectional reflectance model of the earth's surface for the correction of remote sensing data. *Journal of Geophysical Research*, **97**, 20455–20468.

Schaepman-Strub, G., Schaepman, M.E., Painter, T.H., Dangel, S., Martonchik, J.V., 2006: Reflectance quantities in optical remote sensing – definitions and case studies. Remote Sensing of Environment, **103**, 27-42.

Steffen K., J.E. Box and W. Abdalati, 1996; Greenland climate network: Gc-net. CRREL 96-27 Special Report on Glaciers, Ice Sheets and Volcanoes, tribute to M. Meier, pages 98–103.

van Leeuwen W.J.D. and J. L. Roujean, 2002: Land surface albedo from the synergistic use of polar (EPS) and geo-stationary (MSG) observing systems: An assessment of physical uncertainties. *Remote Sensing of Environment*, **81**, 273–289.

Wu, A., Z. Li, and J. Cihlar, 1995: Effects of land cover type and greenness on advanced very high resolution radiometer bidirectional reflectances: Analysis and removal. *Journal of Geophysical Research*, **100(D5)**, 9179–9192, 1995.

Xiong, X., K. Stamnes and D. Lubin, 2002: Surface albedo over the arctic ocean derived from AVHRR and its validation with SHEBA data. *Journal of Applied Meteorology*, **41**, 413–425.

9 Abbreviations

AOD	Aerosol Optical Depth
AVHRR	Advanced Very High Resolution Radiometer (NOAA)
BB	Broadband
BRDF	Bidirectional Reflectance Distribution Function
BSRN	Baseline Surface Radiation Network
CLARA	CM SAF cLouds, Albedo and RAdiation
CM SAF	Satellite Application Facility on Climate Monitoring
DEM	Digital Elevation Model
DWD	Deutscher Wetterdienst
ECMWF	European Center for Medium-Range Weather Forecasts
ECV	Essential Climate Variable
EUMETSAT	European Organisation for the Exploitation of Meteorological Satellites
EPS	Enhanced Polar System
FMI	Finnish Meteorological Institute
GC-Net	Greenland Climate Network
GCOS	Global Climate Observing System
GME	DWD Global Model
IPCC	Intergovernmental Panel on Climate Change
KNMI	Koninklijk Nederlands Meteorologisch Instituut (Royal Netherlands Meteorological Institute)
LUC	Land Use Classification
LUT	Look-Up Table
MODIS	Moderate Resolution Imaging Spectroradiometer
NOAA	National Oceanic and Atmospheric Administration
NTB (C)	Narrow-to-Broadband (Conversion)
NWC-SAF	Nowcasting Satellite Application Facility
NWP	Numerical Weather Prediction
OSI-SAF	Ocean and Sea Ice Satellite Application Facility
PNG	Portable Network Graphics
PPS	Polar Platform System
RMIB	Royal Meteorological Institute of Belgium
SAF	Satellite Application Facility
CLARA-SAL	CM SAF cLouds, Albedo and Radiation - Surface ALbedo product
SEVIRI	Spinning Enhanced Visible and Infra-Red Imager
SGP	Southern Great Plains (a BSRN site in the United States)
SMAC	Simplified method for the atmospheric correction of satellite measurements in the solar spectrum
SMHI	Swedish Meteorological and Hydrological Institute
SZA	Sun Zenith Angle
TOA	Top of Atmosphere
UNFCCC	United Nations Framework Convention on Climate Change
USGS	United States Geological Survey
VZA	Viewing Zenith Angle