EUMETSAT Satellite Application Facility on Climate Monitoring

The EUMETSAT Network of Satellite Application Facilities

CM SAF Climate Monitoring

Product User Manual

CM SAF Cloud, Albedo, Radiation data record, AVHRR-based, Edition 2 (CLARA-A2)

Cloud Products

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Fractional Cloud Cover	**CM-11011**
Joint Cloud property Histogram	**CM-11021**
Cloud Top level	**CM-11031**
Cloud Phase	**CM-11041**
Liquid Water Path	**CM-11051**
Ice Water Path	**CM-11061**

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Applicable documents

Reference	Title	Code
AD 1	CM SAF Product Requirement Document	SAF/CM/DWD/PRD/2.9
AD 2	SYSTEMATIC OBSERVATION REQUIREMENTS FOR SATELLITE-BASED DATA PRODUCTS FOR CLIMATE 2011 Update	GCOS-154

Reference Documents

Reference	Title	Code
RD 1	Validation Report	SAF/CM/SMHI/VAL/GAC/CLD, 2.2
RD 2	Algorithm Theoretical Basis Document GAC Edition 2 processing chain (level-1 – level-2/2b – level-3).	SAF/CM/DWD/CDOP2/ATBD/CLD, 2.3
RD 3	Algorithm Theoretical Basis Document NWCSAF PPS Cloud Mask Product	NWC/CDOP2/PPS/SMHI/SCI/ATBD/1
RD 4	Algorithm Theoretical Basis Document NWCSAF PPS Cloud Top Product	NWC/CDOP2/PPS/SMHI/SCI/ATBD/3
RD 5	Algorithm Theoretical Basis Document Cloud physical products AVHRR	NWC/CDOP2/PPS/SMHI/SCI/ATBD/5
RD 6	Algorithm Theoretical Basis Document JCH product	SAF/CM/SMHI/ATBD/JCH, 2.2
RD 7	Algorithm Theoretical Basis Document Probabilistic Cloud mask	SAF/CM/SMHI/ATBD/GAC/PBCM, 1.2

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1 Executive summary

This CM SAF Product User Manual provides information on the cloud products of the CLARA-A2 data record (CLARA-A2: CM SAF CLoud, Albedo and Radiation data record – AVHRR-based, Edition 2). The CLARA-A2 record is based on Advanced Very High Resolution Radiometer (AVHRR) observations onboard the NOAA and EUMETSAT MetOp satellites. The covered time period of the data record ranges from January 1982 to December 2015. This report presents user information on the following cloud products:

Fractional Cloud Cover	CM-11011 (CFC)
Joint Cloud property histogram	CM-11021 (JCH)
Cloud Top level	CM-11031 (CTO)
Cloud Phase	CM-11041 (CPH)
Liquid Water Path	CM-11051 (LWP)
Ice Water Path	CM-11061 (IWP)

Some attractive features of the CLARA-A2 data record are:

- More than 3 decades spanning global data record of geophysical variables based on one single satellite sensor family of AVHRR giving homogeneous coverage of conditions along specific latitude bands
- Multiple processing levels of the retrieved cloud properties are available ranging from pixel-based cloud retrievals, which are sampled onto a global 0.05° grid (close to the original sensor resolution), to monthly averages and histograms on a global 0.25° latitude-longitude grid.
- Comprehensive documentation available including a description of the algorithms used, the validation efforts performed, and important aspects for user guidance.
- Freely available data without restrictions. Easy access: (in netcdf format, CF standard) via an interactive download facility (http://wui.cmsaf.eu/)

CLARA-A2 features many improvements and advantages compared to its first edition (CLARA-A1), some of the most important ones being:

- The length of the CLARA-A2 record is 34 years instead of 28 years, now reaching climate time scales.
- The underlying measurements data (level 1) underwent several enhancements, among others: (1) Improved calibration (coefficients were kindly provided by A. Heidinger, University of Wisconsin, USA), (2) Improved footprint geolocation (clock error correction), (3) Extended quality control and data screening procedures, and (4) Application of a AVHRR/2 channel 3b noise reduction method. This effort led to a more mature basis for the generation of CLARA-A2.
- CLARA-A2 features various algorithm improvements for all cloud parameters. Particularly, the CPH algorithm has dramatically improved.
- More cloud parameters are provided as additional layers, which were not provided for CLARA-A1. Two examples are cloud particle effective radius and a probabilistic cloud mask.
- Introduction of level-2b products (un-averaged, pixel-based cloud retrievals, which are sampled onto a global 0.05° grid) in addition to the level-3 products of daily and monthly averages and histograms.

This manual briefly describes the historical development of CM SAF, the CLARA-A2 data record and the CLARA-A2 cloud products. A technical description of the data records including information on the file format as well as on the data access is provided. Furthermore, details on the implementation of the retrieval processing chain, and individual algorithm descriptions are available in the algorithm theoretical basis documents [RD 2] - [RD 7]. Basic accuracy requirements are defined in the product requirements document [AD 1]. A detailed validation of the CLARA-A2 cloud parameters is available in the validation report [RD 1].

2 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 records is pursued. The ultimate aim is to make the resulting data records 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 records that can serve applications related to the 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 records 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 records 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 record assessments performed by research organisations such as WCRP (World Climate Research Program). 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, http:/www.cmsaf.eu/. Here, detailed information about product ordering, add-on tools, sample programs and documentation is provided.

3 Compilation of the CLARA-A2 cloud data record

Measurements made by the Advanced Very High Resolution Radiometer (AVHRR) onboard the polar orbiting NOAA satellites and the EUMETSAT METOP satellites have been performed since 1978. Figure 1-1 gives an overview over all satellites carrying the AVHRR instrument that were used for CLARA-A2 (covering the period 1982-2015). The AVHRR instrument only measured in four spectral bands in the beginning (AVHRR/1) but from 1982 a fifth channel was added (AVHRR/2) and in 1998 even a sixth channel was made available (AVHRR/3), although only accessible if switched with the previous third channel at 3.7 micron. Table 1-1 describes the AVHRR instrument, its various versions and the satellites carrying them. The AVHRR instrument measures at a horizontal resolution close to 1 km at nadir but only data at a reduced resolution of approximately 4 km are permanently archived and available with global coverage since the beginning of measurements. This data record is denoted Global Area Coverage (GAC) AVHRR data.

The retrieval of cloud physical properties (in particular particle effective radius and liquid/ice water path) is sensitive to the shortwave infrared channel being used. Table 1-2 summarizes when either of the channels 3a and 3b have been active on the AVHRR/3 instruments.

Table 1-1 *Spectral channels of the Advanced Very High Resolution Radiometer (AVHRR). The three different versions of the instrument are described as well as the corresponding satellites. Notice that channel 3A was only used continuously on NOAA-17,Metop-A and Metop-B. For the other satellites with AVHRR/3 it was used only for shorter periods*

Channel Number	**Wavelength (µm) AVHRR/1** NOAA-6,8,10	**Wavelength (µm) AVHRR/2** NOAA-7,9,11,12,14	**Wavelength (µm) AVHRR/3** NOAA-15,16,17,18 NOAA-19, Metop-A, Metop-B
1	0.58-0.68	0.58-0.68	0.58-0.68
2	0.725-1.10	0.725-1.10	0.725-1.10
3A	-	-	1.58-1.64
3B	3.55-3.93	3.55-3.93	3.55-3.93
4	10.50-11.50	10.50-11.50	10.50-11.50
5	Channel 4 repeated	11.5-12.5	11.5-12.5

Table 1-2 *Channel 3A and 3B activity for the AVHRR/3 instruments during daytime. Notice that the given time periods show the availability in the CLARA-A2 data record and not the true lifetime of the individual sensor/satellite.*

Satellite	**Channel 3a active**	**Channel 3b active**
NOAA-15		06/1998 – 12/2015
NOAA-16	10/2000 – 04/2003	05/2003 – 12/2011
NOAA-17	07/2002 – 02/2010	
NOAA-18		09/2005 – 12/2015
NOAA-19		06/2009 – 12/2015
Metop-A	09/2007 – 12/2015	
Metop-B	01/2013 – 12/2015	

Figure 1-1 describes the actual coverage of observations in CLARA-A2 from each individual satellite over the entire period. Notice that the limitations to the use of AVHRR/2 and AVHRR/3 instruments lead to poorer time sampling (i.e., only one satellite available for daily observations) between 1982 and 1991. On the other hand, from 2001 and onwards more than two satellites are available for daily observations. The availability of observations peaks at the end of 2009 where as many as six satellites are available (NOAA-15/16/17/18/19 + MetOp-A). In the period 2010-2015 generally 5 satellites are available with the exception of 2012 with only 4 satellites.

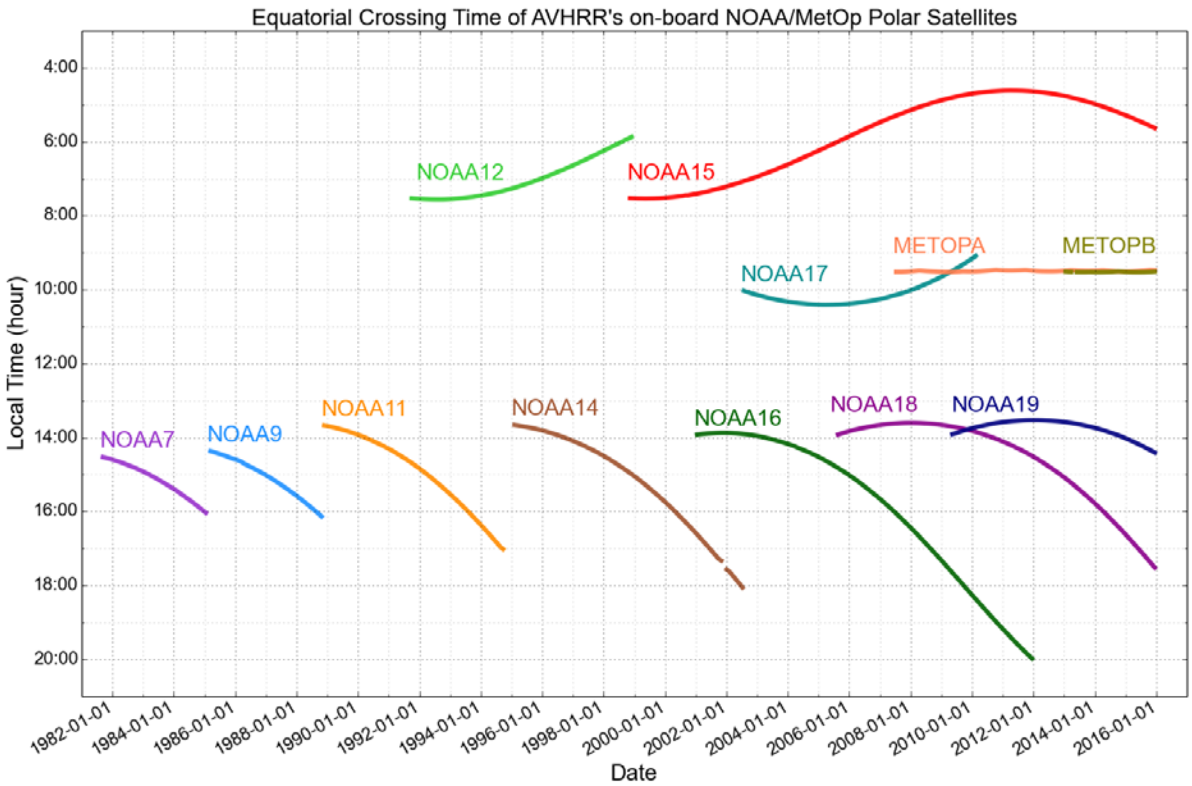

Figure 1-1 *Local solar times at equator observations for all satellites from NOAA-7 to NOAA-19 and METOP A/B. Shown are all data that are used for the processing. The figure shows ascending (northbound) equator crossing times for afternoon satellites (NOAA-7 TO NOAA-19) and descending (southbound) equator crossing times for morning satellites (NOAA-12 to NOAA-17 and METOP A+B). Corresponding night-time observations take place 12 hours earlier/later. Some data gaps are present but only for some isolated dates (Courtesy of Cornelia Schlundt, DWD).*

Observations from polar orbiting sun synchronous satellites are made at the same local solar time at each latitude band. Normally, satellites are classified into observation nodes according to the local solar time when crossing the equator during daytime (illuminated conditions). For the NOAA satellite observations, a system with one morning observation node and one afternoon observation node has been utilised as the fundamental polar orbiting observation system. This guarantees four equally distributed observations per day (if including the complementary observation times at night and in the evening when the satellite passes again 12 hours later). Equator crossing times have varied slightly between satellites.

Morning satellites have generally been confined to the local solar time interval 07:00-08:00 and afternoon satellites to the interval 13:30-14:30. However, a change was introduced for the morning satellites NOAA-17, Metop-A and Metop-B, now being defined in a so-called mid-morning orbit with equator crossing times close to 10:00. A specific problem with the observation nodes for the NOAA satellites has been the difficulty to keep observation times stable for each individual satellite due to orbital drift (Figure 1-1; described in more detail by Ignatov et al., 2004). For example, some satellites (e.g. NOAA-11, NOAA-14 and NOAA-16) were transformed from afternoon to morning observation nodes during their lifetime. For regions exposed to strong diurnal cycles in cloudiness this could cause artificial trends in the achieved monthly mean products. This may also occur due to decreasing cloud detection efficiency at higher solar zenith angles. No compensation for this has been attempted in the CLARA-A2 data record but corrections are considered for future CLARA versions.

This user manual summarizes the CLARA-A2 global cloud products that have been compiled in the CM SAF project based cloud retrieval applied to AVHRR GAC data in the time period 1982-2015. Retrieval methods have been dependent on the access to two infrared (split-window) channels at 11 and 12 microns meaning that only data from satellites carrying the AVHRR/2 or AVHRR/3 instruments have been used.

An important aspect for any product-based climate data record (formally denoted Thematic Climate Data Records – TCDRs) is that retrieved products have been derived from accurately calibrated and homogenized radiances (formally denoted Fundamental Climate Data Records – FCDRs). For the CM SAF CLARA-A2 data record we have generated an AVHRR FCDR (as intermediate, non-official product) for which the calibration of the AVHRR shortwave reflectances is based on work performed by NOAA (updated version of Heidinger et al. (2010)). A similar FCDR is prepared for the compilation of the “NOAA Pathfinder Atmospheres – Extended” (PATMOS-x) data record (for full description, see http://cimss.ssec.wisc.edu/patmosx/overview.html). The updated calibration data, compared to the FCDR used for CLARA-A1 and earlier versions of PATMOS-x, took advantage of the new MODIS Collection 6 data as its main calibration reference (Heidinger et al.; publication currently in preparation). It is important to note, that the used calibration coefficients were calculated for AVHRR measurements until 2014. The extrapolation of the calibration curves into the year 2015 might introduce some additional uncertainties to the CLARA-A2 clouds products of 2015.

The calibration of infrared AVHRR channels is based on the onboard blackbody calibration. This has been found to provide stable and reliable results already. However, future upgrades of the AVHRR FCDR need to address remaining issues here also for the infrared channels (e.g., recognising the work of Mittaz et al., 2009). In addition to the calibration, the used FCDR underwent several quality control and data screening procedures before used in the processing of CLARA-A2.

4 Product definitions

The CLARA-A2 data record based on AVHRR provides global coverage of a number of cloud parameters. Instantaneous, pixel-based cloud retrievals at original AVHRR GAC swath level are used to derive the spatio-temporally sampled (level-2b and level-3 histograms) and averaged (level-3 daily and monthly mean) products. The products are available as daily and monthly composites for each satellite on a regular latitude/longitude grid with a spatial resolution of 0.05° × 0.05° degrees (level-2b), 0.25° × 0.25° (level-3 averages and 1d histograms), and 1.0° × 1.0° (JCH 2d-histograms).

The level-2b format is relatively new and needs some further explanation. It is motivated by the inhomogeneous global coverage of polar sun-synchronous satellite data. Each polar satellite offers 14 observations per day near the pole (evenly distributed over the day) while when passing the equator each location is only observed twice (approximately 12 hours apart). The idea with the introduction of the level-2b data representation is to form a more homogeneous data record having only two observations per day per satellite for each location globally. The alternative to use all observations for level-3 products results in a very skew distribution of the observations because of the inhomogeneous observation frequency (increasing with latitude). By selecting only the observations which are made closest to zenith (the NADIR condition) we ensure that observations are made at almost the same viewing conditions and, most importantly, observations are made at nearly the same local time globally for each level-2b product. In this way, the restricted level-2b products are easier to deal with for certain applications compared to the full set of observations. This concerns in particular the use in COSP simulators aiming at reproducing satellite datasets from Climate Model data.

The level-2b approach means obviously a significant reduction of the amount of used observations. However, the high observation frequency near the poles is undoubtedly very valuable. Therefore, cloud fraction data based on all available observations are also available on two equal-area polar grids at 25 km resolution for the Arctic and Antarctic regions, respectively. These grids are centred at the poles and cover areas of 1000km x 1000km.

All mentioned products exist separately for each satellite. The daily and monthly averages as well as the histograms, however, are also available in aggregated form (i.e., merging all satellites). Acknowledging the different observation capabilities during night and during day and also taking into account existing diurnal variations in cloudiness, a further separation of results into daytime and night-time portions has also been done for some products. Here, all observations made under twilight conditions (solar zenith angles between 75-95 degrees) have been excluded in order to avoid being affected by specific cloud detection problems occurring in the twilight zone.

The temporal coverage of all products ranges from January 1982 to December 2015. Notice again (as visualised in Figure 1-1) that for the first years in the series (1982-1989) only the afternoon satellites are included.

The total set of cloud products are the following (with formal product numbers and abbreviations to the right):

Fractional Cloud Cover	CM-11011 (CFC)
Joint Cloud property histogram	CM-11021 (JCH)
Cloud Top level	CM-11031 (CTO)
Cloud Phase	CM-11041 (CPH)
Liquid Water Path	CM-11051 (LWP)
Ice Water Path	CM-11061 (IWP)

Table 4-1 gives an overview of the CLARA-A2 product suite, containing both daily sampled (level-2b) as well as daily and monthly averaged cloud properties and additionally also monthly histograms.

A complete description of the retrieval methods for each individual product is given in the Algorithm Theoretical Basis Documents [RD 3, RD 4, RD 5, RD 6, RD 7]. The general methods for AVHRR calibration and compilation of level-2b and level-3 products are described in [RD 2].

Regarding level-3 products it should be emphasized that the method for defining level-3 products means that high resolution level-2b data are first averaged into daily means and then all daily means are averaged into monthly means. This follows the GEWEX Cloud Assessment approach (Stubenrauch et al., 2012). Furthermore, for liquid and ice water path (LWP and IWP) the daily mean is calculated as both in-cloud and all-sky values which leads to two different versions of the monthly mean. Since the monthly mean is calculated from the daily means it means that the in-cloud version will give a relatively larger weight to days with low cloud amounts while the all-sky version will give equal weight to all days in a month.

The level-2b approach and the current level-3 definition leads obviously to a significant reduction of the amount of used observations. However, the high observation frequency near the poles is undoubtedly very valuable and consequently there are also some polar products added which use all available observations.

All products have been evaluated with respect to requirement goals defined in [AD 1]. Of specific interest here are requirements in [AD 2] as outlined by the Global Climate Observing System (GCOS) community and issued by the United Nations World Meteorological Organisation (WMO) in 2012. The finally achieved product accuracies are described in [RD 1]. All products in the CLARA-A2 cloud data record fulfil GCOS requirements regarding the horizontal resolution which is mainly explained by the desire to serve also applications in regional climate modelling and in regional climate monitoring. The GCOS requirement on a temporal resolution of 3 hours is not reachable globally for a data record based on polar orbiting satellite data. This resolution is only achieved for high-latitudes and for the Polar Regions. In the tropical region the temporal resolution is close to 6 hours. All GCOS accuracy requirements are generally fulfilled for all cloud products although the requirements on stability have been assessed only to a limited extent since this is inherently difficult without having a true reference data record. Summaries on validation results are given in each parameter subsection in Section 5, and in Section 6 the overall compliance to the requirements is presented.

Table 4-1 *CLARA-A2 product features incl. day and night separation, liquid water and ice as well as histogram representation. Level-2b refers to the non-averaged, pixel-based cloud retrievals sampled onto a global lat/lon grid.[1] CMA is a level-2b binary cloud mask that also contains an additional layer of a (experimental) probabilistic cloud mask . All products listed exist separately for each satellite, but also aggregated as so-called 'allsat' products.*

	level 2b global 0.05° lat/lon grid	**Daily mean global** 0.25° lat/lon grid	**Monthly mean global** 0.25° lat/lon grid	**Monthly histograms global** 0.25° lat/lon grid	**Daily mean Polar** 25 km EASE grid	**Monthly mean Polar** 25 km EASE grid
CFC	✓ as CMA[1]	✓ day/night high/mid/low	✓ day/night high/mid/low	-	✓ day/night high/mid/low	✓ day/night high/mid/low
CTO (CTH, CTP, CTT)	✓	✓	✓	✓	✓	✓
CPH	✓	✓ day/night	✓ day/night	-	✓ day/night	✓ day/night
LWP (+τ, r_e)	✓ as CWP	✓	✓	✓ as CWP	✓	✓
IWP (+τ, r_e)	✓ as CWP	✓	✓	✓ as CWP	✓	✓
JCH	N/A	N/A	N/A	✓ liquid/ice (1.0° grid)	N/A	N/A

5 Product description

In this section, each cloud product is shortly described regarding its definition, retrieval method, information content and limitations. Validation results are also described shortly for each cloud product. A summary statement on the validation results can also be found in Section 6. More details on achieved validation results are given in [RD 1]. At the end of each product description a short statement on recommended applications areas is given.

5.1 Fractional cloud cover – CFC

This product is derived directly from results of a cloud detection method provided as a binary cloud mask in level-2b (daily sampled on a global 0.05° grid) and mean cloud fraction in level-3 (on a global 0.25° lat/lon grid). The cloud fractional cover is defined as the fraction of cloudy pixels per grid square compared to the total number of analysed pixels in the grid square. Fractional cloud cover is expressed in percent. A probabilistic cloud mask is included in the level-2b as an experimental product. The probabilistic version gives cloud probabilities from 0 to 100 % making it possible for a user to flexibly select the confidence level of the cloud mask. The two versions of the cloud mask are not directly compatible since the probabilistic formulation cannot use image features in the same flexible way as the original PPS method. However, the two methods use in principle the same core image features and their associated pre-calculated thresholds (as described in RD 7). This ensures that the overall performance does not differ much (as shown in RD 1). Figure 5-1 shows example maps of level-2b standard cloud mask and level-3 cloud fraction.

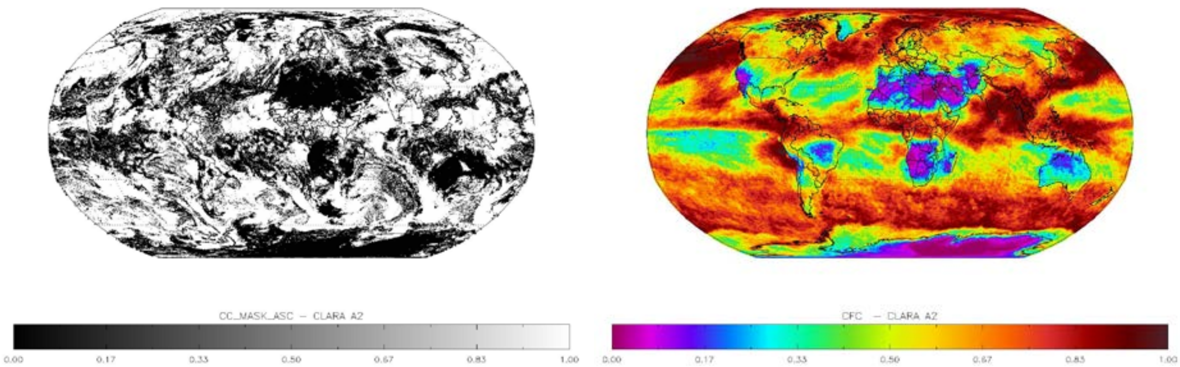

Figure 5-1 *Left: Global map of CLARA-A2 level-2b cloud mask (0: clear; 1: cloudy) for 2008/06/21. Right: Global map of CLARA-A2 monthly mean total cloud fraction for 2008/06.*

Short Algorithm description

This product is calculated using the NWC SAF PPS (Polar Platform System) 2014 (incl. patch 1) cloud mask algorithm (see http://NWC SAF.inm.es/ for details on the NWC-SAF project). The algorithm (detailed by Dybbroe et al., 2005) is based on a multi-spectral thresholding technique applied to every pixel of the satellite scene. Several threshold tests may be applied (and must be passed) before a pixel is assigned to be cloudy or cloud-free.
Thresholds are determined from present viewing and illumination conditions and from the current atmospheric state (prescribed by data assimilation products from numerical weather prediction models – here, the ERA-Interim dataset, see Dee et al, 2011 and http://www.ecmwf.int/research/era/do/get/era-interim). Also ancillary information about surface status (e.g. land use categories and surface emissivities) is taken into account. Thus, thresholds are dynamically defined and therefore unique for each individual pixel.
A detailed description is given in [RD 3].

Highlights

- Cloud screening is based on information from all available AVHRR channels
- Thin Cirrus clouds are identified using split-window infrared channels (not utilised by traditional VIS/IR methods)
- Water clouds with cloud temperatures close to surface temperatures are identified at night using 3.7 micron channel information (often not identified by traditional IR methods)
- Observation frequency is high in polar areas – 14 observations per day per satellite
- Cloud detection in polar summer in the Arctic and Antarctic regions shown to be comparable with MODIS cloud data records (Karlsson and Dybbroe, 2010) - thus, the advantage here is the very long observation period
- Efficient polar summer cloud screening allows high-quality estimations of surface albedo (e.g., at the time of minimum ice extent in the Arctic region)
- Daytime conditions with good illumination (i.e., conditions enabling access to information in all spectral channels) provide best cloud screening results

Limitations

- Not all clouds will be detected due to inherent limitations of the AVHRR imager as being a passive radiometer with a rather coarse field of view (here about 5 km in size). Comparisons with the actively probing lidar instrument CALIOP show that clouds with optical thicknesses below 0.15 are more likely being missed than being detected from AVHRR data.
- Some thin clouds (particularly ice clouds) over cold ground surfaces may remain undetected even if having cloud optical thicknesses higher than the above mentioned detection limit
- Twilight conditions are especially challenging to AVHRR cloud screening methods leading to some systematic underestimation of cloud amounts (especially for morning-evening satellites)
- CFC results over the Arctic and Antarctic regions during the polar winter are very unreliable and generally largely underestimated (-20 % or more in absolute units as shown in comparisons with CALIPSO-CALIOP observations)
- The above deficiencies indicates that overall global mean CFC estimations are slightly negatively biased
- The same deficiencies and the fact that observation density related to the availability of morning-evening and afternoon-night satellites changes over the years (best density in observations the last 10-15 years with some dominance of observations at morning-evening), leads to some artificial (decreasing) trends in global cloud cover over the full CLARA-A2 period.
- Some spurious occurrences of false clouds may occur at night-time over desert surfaces due to problems in estimating surface emissivities.

Validation

Validation studies based on CALIPSO-CALIOP observations shows that for clouds having a vertically integrated cloud optical thickness greater than 0.15 the overall global bias is -3.2 %. The largest underestimation (10-25 %) occurs over the Polar Regions during the Polar winter season whereas some overestimation (up to 10 %) can be found over some oceanic regions (mainly in the Tropics). These results agree very well with corresponding validation studies based on surface stations (SYNOP) showing a global bias of -3.1 %.

Recommended applications

Despite efforts for inter-calibration and homogenisation, the CM SAF CFC data record may still not be of sufficient quality for offering global climate trend analysis. More work is needed before this status can be reached (see also concluding discussion in section 5). However, for most regions except the Polar Regions validation efforts have shown very good results. It concerns in particular mid-latitude and high-latitude regions but also Tropical land regions. For the Polar Regions, the treatment of polar winter conditions still remains as a very big challenge for AVHRR cloud retrievals. Nevertheless, results during the Polar summer appear to be of good quality and studies related to cloud-sea ice interaction in the Polar summer are encouraged.

5.2 Cloud Top level – CTO

Three versions of the CM SAF Cloud Top product exist: 1. Cloud Top Temperature (CTT), expressed in Kelvin; 2. Cloud Top Height (CTH), expressed as altitude over ground topography (m); 3. Cloud Top Pressure (CTP), expressed in pressure co-ordinates (hPa). The CTO product is derived using two approaches, one for opaque and one for fractional and semi-transparent clouds, and it is applied to all cloudy pixels as identified by the PPS cloud mask product. The data is provided as pixel-based values in level-2b (daily sampled on a global 0.05° grid), as daily and monthly averages (on a global 0.25° lat/lon grid), and monthly sampled histograms (on a global 0.25° lat/lon grid). For the daily and monthly averages, the data are averaged arithmetically (linearly) but for the Cloud Top Pressure product also a geometric mean (i.e., average of the logarithm of cloud top pressure) is available. Figure 5-2 shows example maps of level-2b cloud mask and level-3 cloud fraction.
Notice that the cloud altitude given by CTH is defined as the mean cloud altitude relative to the topography (GTOPO30) and not relative to the mean sea level. The used topography data set is available to users as an ancillary dataset.

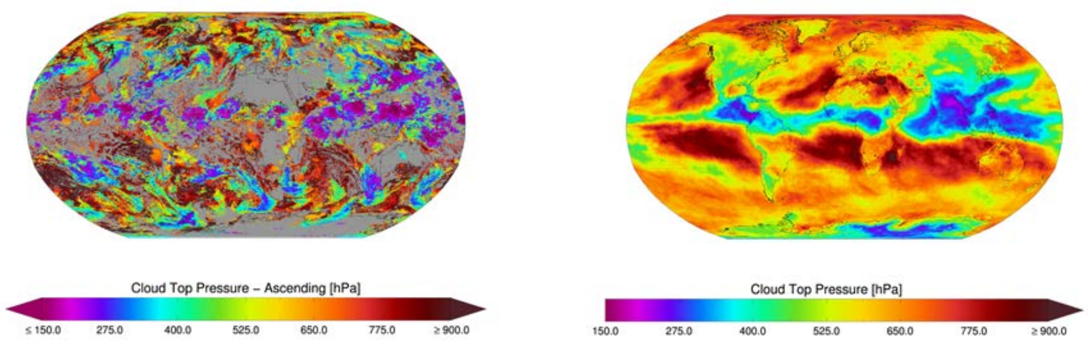

Figure 5-2 *Left: Global map of CLARA-A2 level-2b cloud top pressure for 2008/06/21. Right: Global map of CLARA-A2 monthly mean cloud top pressure for 2008/06.*

Short Algorithm description

For the determination of cloud top information, the CM SAF uses (as for cloud detection) the NWC SAF PPS 2014 (incl. patch 1). The CTO product is derived using two algorithms, one for opaque and one for fractional and semitransparent clouds, and it is applied to all cloudy pixels as identified by the PPS cloud mask product. Semi-transparent or fractional (no distinction between the two is made) clouds are identified as clouds having significant (threshold-based) brightness temperature differences between AVHRR channels 3b, 4 and 5 (i.e., at 3.7 micron, 11 micron and 12 micron).

The opaque algorithm use simulated cloud free and cloudy TOA 11 µm radiances which are compared and matched to measured radiances. Cloudy radiances are simulated assuming "black-body"-clouds at various levels.
The semi-transparent algorithm is applied to all pixels classified as semi-transparent cirrus or fractional water cloud. This classification is based on the analysis of brightness temperature differences of the 11 micron and 12 micron (split window) channels noting that this difference is generally small or negligible for opaque clouds. Also brightness temperatures at 3.7 micron are studied in this process. A histogram technique is applied based on the construction of two dimensional histograms using AVHRR channel 4 and 5 brightness temperatures composed over larger segments. By an iterative procedure a polynomial curve (simulating the arc shape) is fitted to the histogram-plotted values from which the cloud top temperature and pressure (taken from ERA-Interim profiles) are retrieved.

Highlights

- Cloud top heights are determined using the closest reference profiles available from the ERA-Interim dataset
- The semi-transparent correction attempts to find the physically correct cloud top level as opposed to the radiatively efficient cloud top level achieved if only matching brightness temperatures to reference profiles

Limitations

- Both cloud retrieval methods are unreliable in the presence of strong temperature inversions in the troposphere
- The previous circumstance leads to unreliable cloud top estimations in the polar winter near the poles and over cold land surfaces.
- Cloud top level estimations for boundary layer clouds have often a positive bias, sometimes larger than 1000 m, due to problems with resolving boundary layer inversions in reference profiles from ancillary datasets (ERA-Interim)
- As mentioned for the CFC product, optically very thin clouds may not be detected at all. Even if being detected, it is very difficult to assign a correct cloud top level for the thinnest clouds (see next bullet).
- The semi-transparency correction method works only in cases of single-layer clouds meaning that some fraction (up to about 5 % of all clouds) may be left without a valid CTO value (e.g., multi-layer cloud cases)
- Clouds interpreted as being opaque are in reality often diffuse or multi-layered in their upper portions – this often leads to an underestimation of the true cloud top of up to 2000 m

Validation

Validation studies based on CALIPSO-CALIOP show an overall global estimation of the CTH bias of -840 m. However, this figure is partly misleading since we often find large underestimations (several kilometers) for thin high clouds and a pronounced overestimation (up to 1 km) for boundary layer clouds.

Recommended applications

CTO is an important cloud feature for many climate applications since it largely determines the effective height of thermal emission to space from the cloudy portions of the atmosphere. However, it is clear that many cloud tops of boundary layer clouds appear to be overestimated in height in the CLARA-A2 data record, mainly because of problems in having good enough background reference profiles available from NWP reanalysis datasets. This, together with the frequent underestimation of thin high clouds, leads to some excessive amounts of mid-level clouds in the CLARA-A2 data record. This has to be taken into account in potential applications of the CTO product.

5.3 Cloud Phase – CPH

The cloud phase product is meant to represent the thermodynamic phase of the particles near the cloud top. This product is provided as a binary cloud phase information (liquid or ice) in level-2b (daily sampled on a global 0.05° grid) and mean liquid and ice cloud fraction in level-3 (on a global 0.25° lat/lon grid). The liquid cloud fractional cover is defined as the fraction of liquid cloud pixels per grid square compared to the total number of cloudy pixels (for which a phase could be determined) in the grid square. Liquid cloud fraction is expressed in percent. Figure 5-3 shows example maps of level-2b binary cloud phase and level-3 liquid cloud fraction.

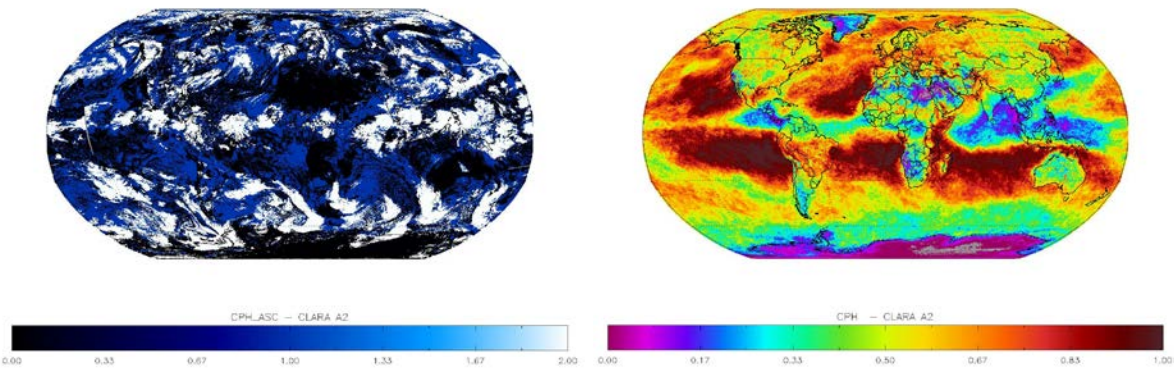

Figure 5-3 *Left: Global map of CLARA-A2 level-2b cloud phase (0: clear; 1: liquid; 2: ice) for 2008/06/21. Right: Global map of CLARA-A2 monthly mean liquid cloud fraction for 2008/06.*

Short Algorithm description

The cloud-top thermodynamic phase (CPH) is determined from a cloud typing approach following Pavolonis and Heidinger (2004) and Pavolonis et al. (2005). This algorithm consists of a series of spectral tests applied to infrared brightness temperatures. It has a night-time branch as well as a daytime branch in which shortwave reflectances are considered in addition. The algorithm initially yields one of the following cloud types: liquid, supercooled, opaque ice, cirrus, overlap, and overshooting. These are then further condensed to liquid (former two) and ice (latter four) phase.

Highlights

- The algorithm provides cloud phase both during daytime and nighttime.
- In addition to liquid/ice discrimination a further breakdown into cloud types is provided.
- The phase discrimination shows good agreement with active CALIOP observations.

Limitations

The main limitations of the CPH retrieval are:

- The identification of thin cirrus over water clouds is challenging.
- Due to the nature of passive satellite observations, the phase near the top of the clouds is retrieved with limited sensitivity to lower cloud layers.

Validation

The CPH product was extensively compared with other VIS-IR imager based data records, showing an overall high degree of consistency with in particular MODIS and PATMOS-x, with a global multi-year mean difference in liquid cloud fraction of 1-5 % (absolute units). Validation was performed against one of the available Cloudsat-CALIPSO based data records: DARDAR (Delanoë and Hogan, 2008. This yielded a hitrate (phase agreement as a fraction of all collocations) of around 0.9.

Recommended applications

The CPH data record is specifically useful for studies of cloud glaciation, e.g. in the life cycle of convective activity characterized by a transition from liquid to ice phase as the clouds grow vertically. In general, wherever multi annual, stable and spatially highly resolved information is needed, CPH data from CLARA-A2 can be applied.
Care should be taken when using the data record for long-term trend analysis. Despite extensive calibration efforts, inter-satellite discontinuities still exist, and trend analysis is further complicated by the orbital drift of the satellites.

5.4 Liquid Water Path – LWP

This product is the vertical mass integral of liquid cloud particles per area. LWP is provided as pixel-based cloud water path (CWP) in level-2b (daily sampled on a global 0.05° grid) grid cells that are assigned a liquid cloud, as daily and monthly averages, and monthly sampled histograms (on a global 0.25° lat/lon grid). The daily and monthly LWP averages are given as so-called in-cloud values (only averaging over the liquid cloud pixels) and as so-called 'allsky' or 'grid-mean' values (for which the non-liquid cloud pixels are accounted for with an LWP of 0). The latter usually correspond to the output from atmospheric models. Figure 5-4 shows example maps of level-2b cloud water path and level-3 monthly mean liquid water path.

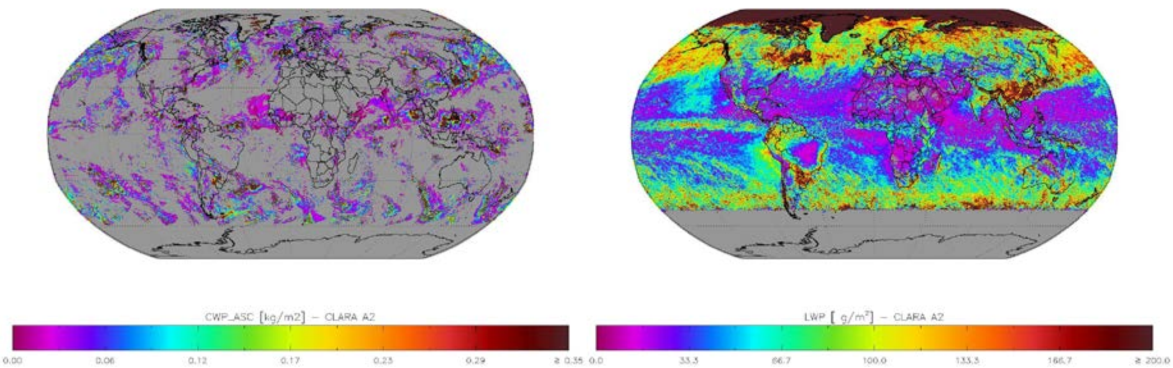

Figure 5-4 *Left: Global map of CLARA-A2 level-2b cloud water path (in all cloud pixels) for 2008/06/21. Right: Global map of CLARA-A2 monthly mean liquid water path for 2008/06.*

Short Algorithm description

The central principle of the method to retrieve cloud optical and microphysical properties is that the reflectance of clouds at a (for cloud particles) non-absorbing wavelength in the visible region (e.g., 0.6 or 0.8 μm) is strongly related to the optical thickness (τ) and has little dependence on particle effective radius (r_e), whereas the reflectance of clouds at an absorbing wavelength in the shortwave-infrared region (e.g., 1.6 or 3.7 μm) is strongly dependent on effective radius (Nakajima and King, 1992).

In the CPP algorithm (Roebeling et al. 2006), the Doubling-Adding KNMI (DAK) radiative transfer model (De Haan et al. 1987 and Stammes 2001) is used to simulate 0.6- and 1.6-μm top-of-atmosphere reflectances of homogeneous, plane-parallel clouds as a function of viewing geometry, cloud optical thickness, effective radius, and cloud phase. These simulated reflectances are stored in a look-up table (LUT).

τ and r_e are retrieved for cloudy pixels in an iterative manner by matching satellite-observed reflectances to the LUT of RTM-simulated reflectances. From these two properties, the cloud water path (CWP) of water clouds (or liquid water path, LWP) can be computed using the following relation (Stephens, 1978):

$$CWP = 2/3\ \rho_l\ \tau\ r_e,$$

where ρ_l is the density of liquid water. For water clouds effective radii between 3 and 34 μm are retrieved.

Highlights

- Together with LWP, τ and r_e are included as additional layers in the level-2b and level-3 products.
- The careful calibration of the shortwave AVHRR channels has a pronounced effect on the quality of the retrieved τ and r_e, and thus LWP.
- An estimate of the LWP retrieval error is reported.
- The effect of absorption by trace gases in the atmosphere on shortwave narrowband reflectances is taken into account using MODTRAN (Berk et al. 2000) simulations (Meirink et al. 2009).

Limitations

The main limitations of the LWP retrieval are:

- The derivation of cloud physical properties from reflected solar radiation is dependent on the availability of daylight. Thus no retrievals can be done during night time. Even if pixel-level retrievals are performed and reported up to solar zenith angles of 84°, for level-3 aggregation a maximum solar zenith angle of 75° is applied.
- The retrieval is highly problematic over very bright surfaces, particularly ice and snow, as the visible reflectance from clouds is similar to that from the surface.
- Cloud property retrievals are performed assuming that clouds are plane parallel. Two prominent examples of cases for which this assumption is violated are: (1) three-dimensional radiative effects become important if large sub-pixel variations in cloud-top height occur, and particularly if the solar zenith angle is large; (2) retrievals for broken clouds are affected by a reflectance contribution from the surface.
- Aerosols are not considered in the CPP retrieval. This assumption is usually justified because aerosols reside below or within the cloud and their optical thickness is small compared to that of the cloud. However, if the aerosols reside above the cloud and if they are sufficiently absorbing, they can significantly lower the visible reflectance. This leads to underestimations of both τ and r_e, and thus LWP (Haywood et al. 2004).

- Retrievals from passive satellite instruments are limited by the fact that the obtained signal emanates from the integrated profile. Since near-infrared radiation is only penetrating into the cloud to a certain depth (due to absorption by cloud particles), the retrieved effective radius is representative for the upper part of the cloud (Platnick, 2001). The penetration depth depends on the amount of absorption by cloud particles, which is increasing with wavelength. This means that the retrieved r_e depends on which NIR spectral channel is used (1.6 μm or 3.7 μm), creating inhomogeneities in the data record.
- Because the retrieval of effective radius becomes unreliable for thin clouds, weighting with a climatological average r_e is performed for clouds with $\tau < 5$. Although this stabilizes the retrieval results, it does not take away the inherent uncertainty in r_e retrievals for thin clouds.

Validation

The LWP product was extensively compared with other VIS-IR imager based data records, showing an overall high degree of consistency with in particular MODIS and PATMOS-x, with a global multi-year mean difference of about -2 to 4 g m^{-2}. Differences are largest in high-latitude regions. Comparison with the passive microwave based UWisc LWP data record for marine stratocumulus areas yielded a mean difference of -3.5 to -0.5 g m^{-2}. Decadal stability with respect to MODIS was evaluated to be 1 to 2.3 g m^{-2}.

Recommended applications

The LWP data record is most reliable at lower latitudes, or (better said) lower solar zenith angles (below about 65 degrees). In addition, high latitudes are frequently affected by snow and ice cover, giving problems for the retrievals. Care should be taken when using the data record for long-term trend analysis. Despite extensive calibration efforts, inter-satellite discontinuities are observed, and trend analysis is further complicated by the orbital drift of the satellites. Significant differences are observed between the parts of the data record relying on the 1.6-µm and 3.7-µm channels. It is recommended that those parts are not combined but used separately for analyses.

5.5 Ice Water Path – IWP

This product is the vertical mass integral of ice cloud particles per area. IWP is provided as pixel-based cloud water path (CWP) in level-2b (daily sampled on a global 0.05° grid) grid cells that are assigned an ice cloud, as daily and monthly averages, and monthly sampled histograms (on a global 0.25° lat/lon grid). The daily and monthly IWP averages are given as so-called in-cloud values (only averaging over the ice cloud pixels) and as so-called ‘allsky’ or ‘grid-mean’ values (for which the non-ice cloud pixels are accounted for with an IWP of 0). The latter usually correspond to the output of atmospheric models. Figure 5-5 shows example maps of level-2b cloud water path and level-3 monthly mean ice water path.

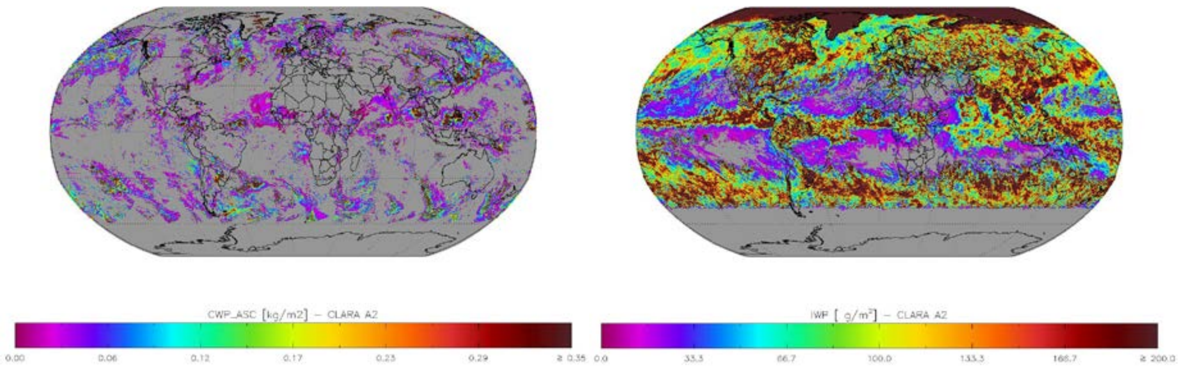

Figure 5-5 *Left: Global map of CLARA-A2 level-2b cloud water path (in all cloud pixels) for 2008/06/21. Right: Global map of CLARA-A2 monthly mean ice water path for 2008/06.*

Short Algorithm description

Ice water path is retrieved in the same way as LWP but with τ and r_e retrievals based on RTM simulations for imperfect hexagonal ice crystals. Homogeneous distributions of ice crystals from the COP library (Hess et al., 1998) are assumed, with effective radii ranging between 5 and 80 μm.

Highlights

- The use of imperfect hexagonal ice crystals gives adequate simulations of total and polarized reflectance of ice clouds (Knap et al. 2005).
- An estimate of the IWP retrieval error is reported.

Limitations

The same limitations as for LWP hold also for IWP. In addition, the r_e retrieval for ice clouds is considerably more uncertain than for water clouds, because particle shapes and roughness vary widely and are not well known. The assumptions on ice crystal habits used to generate the LUTs (in our case imperfect hexagons are assumed) have a profound impact on the retrieved r_e and IWP.

Validation

The IWP product was extensively compared with other VIS-IR imager based data records, showing a global multi-year mean difference of 0.6 to 5.1 g m^{-2} with respect to MODIS. Decadal stability was evaluated to be 2.7 to 3.7 g m^{-2}. Validation with Cloudsat-Calipso based (DARDAR data record) observations showed an overall underestimation of IWP, becoming stronger at high IWP values. This bias was mainly related to differences in effective radius, which, in contrast to optical thickness, was hardly correlated between the data records.

Recommended applications

The IWP data record is just like LWP most reliable at lower latitudes, or lower solar zenith angles below about 65 degrees. In addition, high latitudes are frequently affected by snow and ice cover. In these cases, retrievals are problematic, even if our ancillary database does include snow and ice cover to allow a better estimate of surface albedo. IWP can like LWP be applied where multi annual and spatially highly resolved information is needed. Care should be taken when using the data record for long-term trend analysis because satellite switches and orbital drift compromise its homogeneity.

5.6 Joint Cloud property Histograms – JCH

The JCH product is a combined histogram of CTP and COT covering the solution space of both parameters. This two-dimensional histogram gives the absolute numbers of occurrences for specific COT and CTP combinations defined by specific bins. It is further separated in liquid and ice clouds. An example of JCH is shown in Figure 5-6.

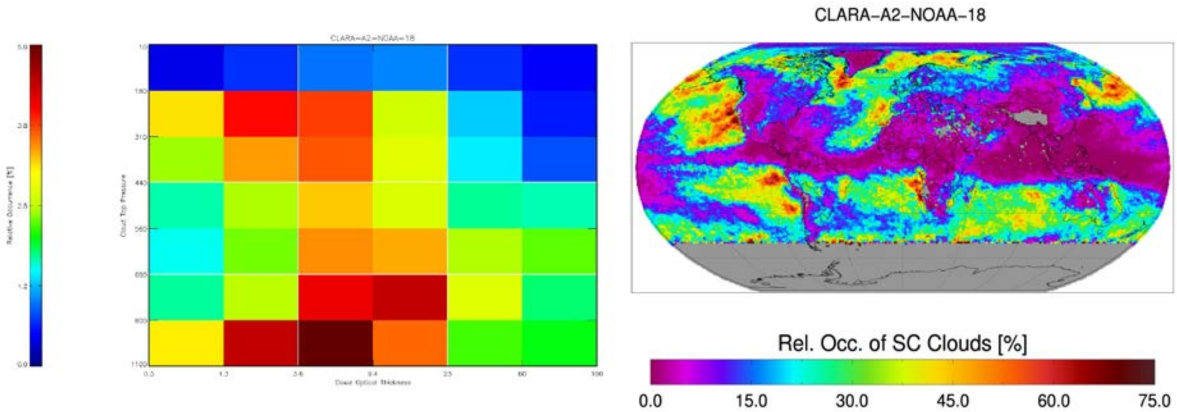

Figure 5-6 *Left: Globally integrated COT-CTP histogram of relative frequency of occurrence 2008/06/21. Right: Global map of relative occurrence of stratocumulus clouds (according to the CTO-CTP classification) for 2008/06.*

Short Algorithm description

No specific retrieval algorithm is needed for this product. It is composed by collecting the COT and CTP retrieval information on pixel level and sorting into pre-defined bins ([RD 2]).

Highlights

- The product adds value to the single standard level-3 products of CTP and COT by showing how the two parameters vary together.
- The histograms are given for each grid point which means that a user can aggregate results over any local or regional domain in order to analyse typical cloud regimes (or types).
- The use of joint histograms is common in applications for evaluating climate models.
- The CLARA-A2 COT and CTP bins for the JCH product have been chosen such that they are a superset of the traditional ISCCP bins. Thus, the CLARA-A2 product can be aggregated to exactly the same bins as used for the ISCCP product.

Limitations

- The product is only available during daytime since the COT is not retrieved at night

Recommended applications

With the JCH diagrams the discrimination between different cloud regimes is supported. COT and CTP information can readily be considered in a more statistical way. Since the CM SAF JCH product is compiled as distributions for each grid point, it is possible to compose cloud distribution statistics for any region size on the globe by simple aggregation of grid point values. Two-dimensional COT-CTP histograms, such as JCH, are nowadays standard outputs of the COSP satellite simulator packages based on climate modelling data. Thus, the evaluation of climate models is suited application of the JCH product.

6 Summary table of validation results regarding product accuracy

Table 6-1 shows the achieved accuracies of the cloud products as discussed in [RD 1]. The acronyms used are: SYNOP = Synoptical surface observations, CALIPSO = Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observation, PATMOS-x = AVHRR Pathfinder Atmospheres – Extended, MODIS = Moderate Resolution Imaging Spectroradiometer, ISCCP = International Satellite Cloud Climatology Project and UWisc = climatology based on passive microwave observations derived at University of Wisconsin. All references are described in detail in [RD 1].

Table 6-1 *Summary table of validation results as given in* [RD 1]*. For CFC and CPH (being defined as percentage values), results are given as absolute values (not relative). In contrast, results for LWP and IWP are given as relative errors.*

Product		Accuracy requirement (Mean error or Bias)	Achieved accuracies
Cloud Fractional Cover	**(CFC)**	**5 % (absolute)**	**-3.2 % (CALIPSO level-2)** **-3.1 % (SYNOP level-3)** **-4.9 % (PATMOS-x level-2b)** **-4 % (PATMOS-x level-3)** **-5.9 % (MODIS)** **-3.4 % (ISCCP)**
Cloud Top Height **Cloud Top Pressure**	**(CTH)** **(CTP)**	**800 m** **50 hPa**	**-840 m (CALIPSO level-2)** **-4.3 hPa (PATMOS-x level-2b)** **-18 hPa (PATMOS-x level-3)** **-88 hPa (MODIS)** **13 hPa (ISCCP)**
Cloud Phase	**(CPH)**	**10 % (absolute)**	**1-2 % (PATMOS-x)** **1-5 % (MODIS)** **1-9 % (ISCCP)**
Liquid Water Path	**(LWP)**	**10 gm^{-2}**	**-3.5 to -0.5 gm^{-2} % (UWisc)** **4.3 gm^{-2} (PATMOS-x)** **2.3 to 3.3 gm^{-2} (MODIS)** **10 to 17 gm^{-2} (ISCCP)**
Ice Water Path	**(IWP)**	**20 gm^{-2}**	**0.6 to 5.1 gm^{-2} (MODIS)** **7.4 to 8.6 gm^{-2} (ISCCP)**
Joint Cloud Histogram	**(JCH)**	**n/a**	**n/a**

Table 6-2 *Summary of validation results compared to target precisions for each cloud product. Consistency checks marked in blue.*

Product		Precision requirement (bc-RMS)	Achieved precisions
Cloud Fractional Cover	**(CFC)**	**20 % (absolute)**	**40 %(CALIPSO level-2)** **6.7 % (SYNOP level-3)** **1.6 % (PATMOS-x level-2b/3)** **10 % (PATMOS-x level-3)** **7.3 % (MODIS)** **8.8 % (ISCCP)**
Cloud Top Height **Cloud Top Pressure**	**(CTH)** **(CTP)**	**1700 m** **100 hPa**	**2380 m (CALIPSO level-2)** **11 hPa (PATMOS-x level-2b/3)** **85 hPa (PATMOS-x level-3)** **58 hPa (MODIS)** **93 hPa (ISCCP)**
Cloud Phase	**(CPH)**	**20 % (absolute)**	**6-7 % (PATMOS-x)** **8-9 % (MODIS)** **13-16 % (ISCCP)**
Liquid Water Path	**(LWP)**	**20 gm^{-2}**	**11-20 gm^{-2} (UWisc)** **17 gm^{-2} (PATMOS-x)** **8-11 gm^{-2} (MODIS)** **14-19 gm^{-2} (ISCCP)**
Ice Water Path	**(IWP)**	**40 gm^{-2}**	**20-24 gm^{-2} (MODIS)** **25-31 gm^{-2} (ISCCP)**
Joint Cloud Histogram	**(JCH)**	**n/a**	**n/a**

7 Outlook

The CM SAF CLARA-A2 is the result of the second reprocessing effort of global AVHRR data in the CM SAF project. Since the processing effort is a major task in itself which requires extensive resources, some specific limitations and shortcomings remain (see limitations section in this document and the validation report ([RD 1).

The generation of the CLARA data records is a sustained effort. In the upcoming CM SAF project phase (CDOP 3) phase, a third release (CLARA-A3) is planned for 2021. All parts of the retrieval and processing components will undergo further enhancements, of which the following shall be listed as a potential subset.

- Acquisition of more level-1 data (satellite measurements) to prolong the data basis back to 1978 (then including the AVHRR/1 sensors as well) and forward to 2019/2020. Also currently existing data gaps (usually only short periods) are to be filled. Potentially considering VIIRS to expand that level-1 data record.
- Further improvement of level-1 quality control and data screening procedures. One example in this context is also the utilization of good data in orbits that have been blacklisted due to scan motor issues introducing error in some parts of the orbits. There exist a significant number of such orbits for NOAA14, NOAA15, and NOAA16.
- Implementation/application of an intercalibration methodology for the IR channel measurements, which have been left untouched so far (only onboard black body calibration used), and inclusion of calibration updates for the shortwave channels.
- Further enhancements to the (probabilistic) cloud mask and the optimization of its utilization for the subsequent retrieval of the cloud properties. This includes adaptation necessary for handling the 4-channel AVHRR/1 sensor onboard NOAA-5, NOAA-6, NOAA-8 and NOAA-10.
- Potential incorporation of HIRS information (measured radiances or retrieved cloud top level) to further improve the cloud top level information in CLARA, especially for high, semi-transparent clouds.
- Improvements in optical property retrievals and phase determination
- Potential further update of the product portfolio (including processing the availability at different processing levels (e.g. level-2b sampling, level-3 averages/histograms). User feedback/requirements on this point are very much appreciated.
- Development and provision of information on accounting for satellite drift and its impact on stability of the CLARA-A2 time series.
- In addition to products on clouds, albedo and surface radiation, CLARA-A3 will feature broadband TOA fluxes for short- and longwave.

8 Data format description

CLARA A2 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 1.6 (http://cf-pcmdi.llnl.gov/) and NetCDF Attribute Convention for Dataset Discovery version 1.3.

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).

8.1 Data format description of non-averaged products

Level-2b data are stored in on a regular lat-lon grid with a spatial resolution of 0.05°. Each variable is stored twice, once for the ascending node and once for the descending node.

8.1.1 General variables

In all product files the same set of general variables are used:

time	definition of the observation time in days since 01.01.1970 00:00:00h
time_bnds	two-dimensional array defining the first and last point in time of the observation
lon	vector containing all 7200 longitudes
lat	vector containing all 3600 latitudes

8.1.2 Attributes

The data fields provide a set of general attributes, which are listed and described in Table 8-1. Only the first 4 attributes are part of each data field. The other are only in some of the data fields, as byte fields for example don't need a scaling factor.

Table 8-1 *Common attributes of each variable in level-2 data.*

Name	Description
_FillValue	*This number represents missing or undefined data. Missing values are to be filtered before scanline*
Valid_min	*Lowest valid value*
Valid_max	*Largest valid value*
Long_name	*Long descriptive name*
Standard_name	*Standard name that references a description of a variable's content in the CF standard name table*
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.*
units	*Physical unit [udunits standards]*
Flag_values, flag_masks, flag_meanings	*Data fields with the data type BYTE are stored as "flags". Each flag has a byte number with an interpretation.*

The absolute value of the respective variable y is composed of the value in the data field x together with scale_factor s and the offset b:

$$Y = s * x + b$$

8.1.3 Product specific data fields

Cloud mask

Scanline_time(time, y, x)
field contains the time of the pixel observation in decimal hours

cc_mask(time, y, x)
field contains the binary cloud mask

CMAprob(time, y, x)
field contains the probability that a cloud is observed in this pixel (experimental product)

Cloud top

Scanline_time(time, y, x)
field contains the time of the pixel observation in decimal hours

ctt(time, y, x)
field contains the cloud top temperature

ctp(time, y, x)
field contains the cloud top pressure

cth(time, y, x)
field contains the cloud top height

Cloud type

Scanline_time(time, y, x)
field contains the time of the pixel observation in decimal hours

cph(time, y, x)
field contains the cloud phase

cph_extended(time, y, x)
field contains the cloud phase and separates between clear, fog, water, super-cooled, opaque, cirrus, and overlap

Cloud physical properties

Scanline_time(time, y, x)
field contains the time of the pixel observation in decimal hours

cwp(time, y, x)
field contains the cloud water path

cwp_uncertainty(time, y, x)
field contains the uncertainty in the retrieval for the cloud water path

cot(time, y, x)
field contains the cloud optical thickness

cot_uncertainty(time, y, x)
field contains the uncertainty in the retrieval for the cloud optical thickness

ref(time, y, x)
field contains the effective droplet radius / effective ice particle size

ref_uncertainty(time, y, x)
field contains the uncertainty in the retrieval error in the effective droplet radius / effective ice particle size

8.1.4 General attributes

Each level-2 netCDF file also possesses general attributes that are valid for all variables contained in this file, the attributes are described in Table 8-2.

Table 8-2 *General attributes of a non-averaged netCDF file.*

Name	Description
title	*CM SAF cLoud, Albedo and RAdiation dataset, AVHRR-based, edition 2 (CLARA-A2)*
summary	*This file contains AVHRR-based Thematic Climate Data Records (TCDR) produced by the Satellite Application Facility on Climate Monitoring (CM SAF)*
id	*DOI:10.5676/EUM_SAF_CM/CLARA_AVHRR/V002*
product_version	*2.0*
creator_name	*DE/DWD*
creator_email	*contact.cmsaf@dwd.de*
creator_url	*http://www.cmsaf.eu*
institution	*EUMETSAT/CMSAF*
project	*Satellite Application Facility on Climate Monitoring (CM SAF)*
references	*http://dx.doi.org/10.5676/EUM_SAF_CM/CLARA_AVHRR/V002*
platform	*Satellite name of the platform where AVHRR operates on*
instrument	*AVHRR>Advanced Very High Resolution Radiometer*
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	*P1D*
Time_coverage_resolution	*P1D*
geospatial_lat_min	*-90*
geospatial_lat_max	*90*
geospatial_lat_units	*degrees_north*
geospatial_lon_min	*-180*
geospatial_lon_max	*180*
geospatial_lon_units	*degrees_east*
geospatial_lat_resolution	*0.05 degree*
geospatial_lon_resolution	*0.05 degree*
keywords	*EARTH SCIENCE>ATMOSPHERE>CLOUDS>"variable group"*
Conventions	*convention tables for metadata and attributes (CF-1.6, ACDD-1.3)*
keywords_vocabulary	*Vocabulary for keywords in the global attributes (GCMD Science Keywords, Version 8.1)*
standard_name_vocabulary	*Vocabulary for standard names in the parameter attributes (Standard Name Table (v28, 07 January 2015))*
instrument_vocabulary	*Vocabulary for the instrument in the global attributes (GCMD Instruments, Version 8.1)*
platform_vocabulary	*Vocabulary for the platform in the global attributes (GCMD Platforms, Version 8.1)*
date_created	*Point in time, when the file was created [ISO8601 date]*
CMSAF_platform_and_orbit	*Satellite name and number of orbits, that are included in this file*
CMSAF_L1_processor	*PyGAC*
CMSAF_L2_processor	*PPS2014 incl. patch 1 and CPP*
CMSAF_L3_processor	*CMSAFGACL3_V2.0*

8.2 Monthly and daily mean 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 A2 product files are built following the same design principles. The averaged data are provided as daily and monthly means. The daily means are based on the L2B data files, averaged in time over the ascending and descending node and in space from the 0.05° grid to the 0.25° grid. The monthly mean is a temporal average of all daily means. The product files contain general variables, which are common for all files, and product specific variables. The latter are three-dimensional, except for the histograms. Dimension of all three-dimensional fields are named *time, lon*, *lat*. For the JCHs, additional two dimensions for COT and CTP bin are included. All other provided histograms have one additional dimension for variable bin. General variables of each file are *time, time_bnds*, *latitude*, and *longitude* (see section 8.2.1). All data fields, which are described in section 8.2.3, also contain specific attributes as given in section 8.2.2. Global attributes of each file are reported in section 8.2.4. Additionally to the global products, polar data are also provided on an equal-area grid with 25km resolution as daily and monthly mean, which are described in section 6.2.5.

8.2.1 General variables

time

start of averaging/composite time period; In case of diurnal cycles, this is vector has 24 elements
[days counted from 1970-01-01]

time_bnds

two-dimensional array defining the averaging/composite time period

lat

geographical latitude of grid-box centre [degree_north]

lon

geographical longitude of grid-box centre [degree_east]

8.2.2 Attributes

Table 8-3 summarizes the attributes which are assigned to each data field in the NetCDF files. Keep in mind that, depending on the parameter, some attributed can be omitted. For example, if no standard name is defined.

Table 8-3: *Attributes assigned to variables in NetCDF.*

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 represents missing or undefined data. Missing values are to be filtered before scaling.*

8.2.3 Product specific data fields

Fractional cloud coverage (CFC)

nobs(time, lon, lat)
field containing the number of observations used to create mean CFC
nobs_day(time, lon, lat)
field containing the number of observations used to create mean daytime CFC
nobs_night(time, lon, lat)
field containing the number of observations used to create mean nighttime CFC
cfc(time, lon, lat)
field containing the mean CFC value given in percentbetween 0 and 100
cfc_std(time, lon, lat)
field containing the standard deviation over all CFC data points
cfc_day(time, lon, lat)
field containing the mean daytime CFC value given in percentbetween 0 and 100
cfc_night(time, lon, lat)
field containing the mean nighttime CFC value given in percentbetween 0 and 100
cfc_low(time, lon, lat)
field containing the mean CFC of all clouds below 680 hPa given in percent
cfc_middle(time, lon, lat)
field containing the mean CFC of all clouds between 440hPa and 680 hPa given in percent
cfc_high(time, lon, lat)
field containing the mean CFC of all clouds above 440 hPa given in percent

Cloud phase (CPH)

nobs(time, lon, lat)
field containing the number of observations used to create mean CPH
nobs_day(time, lon, lat)
field containing the number of observations used to create mean daytime CPH
cph(time, lon, lat)
field containing the mean liquid cloud fraction given in percent between 0 and 100
cph_std(time, lon, lat)
field containing the standard deviation over all CPH data points
cph_day(time, lon, lat)
field containing the mean daytime liquid cloud fraction given in percent between 0 and 100
cph_day_std(time, lon, lat)
field containing the standard deviation over all daytime CPH data points

Cloud top level

nobs(time, lon, lat)
field containing the number of observations used to create mean cloud top products
ctt(time, lon, lat)
field containing the arithmetical mean cloud top temperature (CTT)
ctt_std(time, lon, lat)
field containing the standard deviation over CTT data points
cth(time, lon, lat)
field containing the arithmetical mean cloud top height (CTH)

cth_std(time, lon, lat)
field containing the standard deviation over CTH data points
ctp(time, lon, lat)
field containing the arithmetical mean cloud top pressure (CTP)
ctp_std(time, lon, lat)
field containing the standard deviation over CTP data points
ctp_log(time, lon, lat)
field containing the logarithmic mean CTP

Liquid water path (LWP)

nobs(time, lon, lat)
field containing the number of observations used to create mean LWP
SZA(time, lon, lat)
field containing the mean solar zenith angle of successful retrieval results and liquid phase results
SZA_std(time, lon, lat)
field containing the standard deviation of the solar zenith angle of successful retrieval results and liquid phase results
lwp(time, lon, lat)
field containing the mean LWP
lwp_allsky(time, lon, lat)
field containing the grid box mean LWP, weighted by the grid box cloud fraction
lwp_std(time, lon, lat)
field containing the standard deviation of the LWP
lwp_error(time, lon, lat)
field containing the mean LWP retrieval error
lwp_error_std(time, lon, lat)
field containing the standard deviation of the LWP retrieval error
cot_ liq(time, lon, lat)
field containing the mean liquid cloud optical thickness (COT)
cot_liq_std(time, lon, lat)
field containing the standard deviation of the liquid COT
cot_liq_error(time, lon, lat)
field containing the mean retrieval error of the liquid COT
cot_liq_error_std(time, lon, lat)
field containing the standard deviation of the liquid COT retrieval error
cot_liq_log(time, lon, lat)
field containing the logarithmic mean liquid COT
ref_ liq(time, lon, lat)
field containing the mean effective radius of water droplets
ref_liq_std(time, lon, lat)
field containing the standard deviation of the effective radius of water droplets
ref_liq_error(time, lon, lat)
field containing the mean retrieval error of the effective radius of water droplets
ref_liq_error_std(time, lon, lat)
field containing the standard deviation of the effective radius of water droplets retrieval error

Ice water path (IWP)

nobs(time, lon, lat)
field containing the number of observations used to create mean IWP

SZA(time, lon, lat)
field containing the mean solar zenith angle of successful retrieval results and ice phase results

SZA_std(time, lon, lat)
field containing the standard deviation of the solar zenith angle of successful retrieval results and ice phase results

iwp(time, lon, lat)
field containing the mean IWP

iwp_allsky(time, lon, lat)
field containing the grid box mean IWP, weighted by the grid box cloud fraction

iwp_std(time, lon, lat)
field containing the standard deviation of the IWP

iwp_error(time, lon, lat)
field containing the mean IWP retrieval error

iwp_error_std(time, lon, lat)
field containing the standard deviation of the IWP retrieval error

cot_ice(time, lon, lat)
field containing the mean ice COT

cot_ice_std(time, lon, lat)
field containing the standard deviation of the ice COT

cot_ice_error(time, lon, lat)
field containing the mean retrieval error of the ice COT

cot_ice_error_std(time, lon, lat)
field containing the standard deviation of the ice cloud COT error

cot_ice_log(time, lon, lat)
field containing the logarithmic mean ice COT

ref_ice(time, lon, lat)
field containing the mean effective radius of ice particles

ref_ice_std(time, lon, lat)
field containing the standard deviation of the effective radius of ice particles

ref_ice_error(time, lon, lat)
field containing the mean retrieval error of the effective radius of ice particles

ref_ice_error_std(time, lon, lat)
field containing the standard deviation of the effective radius of ice particles retrieval error

Joint Cloud property Histograms (JCH)

hist_phase(hist_phase)
two-elements vector containing liquid and ice phase

hist2d_cot_bin_border(hist_cot_bin_border)
vector contains outer limits of the COT bins

hist2d_cot_bin_centre(hist_cot_bin_centre)
vector contains centre of the COT bins

hist2d_ctp_bin_border(hist_ctp_bin_border)
vector contains outer limits of the CTP bins

hist2d_ctp_bin_centre(hist_ctp_bin_centre)
vector contains centre of the CTP bins

cfc(time, lat, lon)

field containing the mean fractional cloud cover, used to the JCH

hist2d_cot_ctp(time,hist_phase,hist2d_ctp_bin_centre,hist2d_cot_bin_centre,lat, lon)
field containing the number of occurrences of specific combinations of COT and CTP ranges at given spatial location. The Joint Cloud property Histograms are defined on coarser spatial resolution (1°) compared to all other products.

One-dimensional histograms

Cloud top histograms

hist_phase(hist_phase)
two-elements vector containing liquid and ice phase

hist1d_ctt_bin_border(hist_ctt_bin_border)
vector contains outer limits of the CTT bins

hist1d_ctt_bin_centre(hist_ctt_bin_centre)
vector contains centre of the CTT bins

hist1d_ctp_bin_border(hist_ctp_bin_border)
vector contains outer limits of the CTP bins

hist1d_ctp_bin_centre(hist_ctp_bin_centre)
vector contains centre of the CTP bins

hist1d_ctt(lon, lat, hist1d_ctt_bin_centre,hist_phase,time)
field contains the number of occurrences of specific CTT ranges at given spatial location.

hist1d_ctp(lon, lat, hist1d_ctp_bin_centre,hist_phase,time)
field contains the number of occurrences of specific CTP ranges at given spatial location.

Cloud water path histograms

hist_phase(hist_phase)
two-elements vector containing liquid and ice phase

hist1d_cwp_bin_border(hist_cwp_bin_border)
vector contains outer limits of the cloud water path (CWP) bins

hist1d_cwp_bin_centre(hist_cwp_bin_centre)
vector contains centre of the CWP bins

hist1d_cot_bin_border(hist_cot_bin_border)
vector contains outer limits of the cloud optical thickness (COT) bins

hist1d_cot_bin_centre(hist_cot_bin_centre)
vector contains centre of the COT bins

hist1d_ref_bin_border(hist_ref_bin_border)
vector contains outer limits of the cloud particle effective radius (REF) bins

hist1d_ref_bin_centre(hist_ref_bin_centre)
vector contains centre of the REF bins

hist1d_cwp(lon, lat, hist1d_cwp_bin_centre,hist_phase,time)
field contains the number of occurrences of specific CWP ranges at given spatial location.

hist1d_cot(lon, lat, hist1d_cot_bin_centre,hist_phase,time)
field contains the number of occurrences of specific COT ranges at given spatial location.

hist1d_ref (lon, lat, hist1d_ref_bin_centre,hist_phase,time)
field contains the number of occurrences of specific REF ranges at given spatial location.

8.2.4 Global attributes

Table 8-4 contains the global attributes of averaged CLARA A2 level-3 final product files. Possible values of the attributes are also given as well as explanations.

Table 8-4: *Overview of global attributes of NetCDF files of CLARA A2 products and possible corresponding values.*

Name	Description
title	*CM SAF cLoud, Albedo and RAdiation data record, AVHRR-based, edition 2 (CLARA-A2)"*
summary	*This file contains AVHRR-based Thematic Climate Data Records (TCDR) produced by the Satellite Application Facility on Climate Monitoring (CM SAF)*
id	*DOI:10.5676/EUM_SAF_CM/CLARA_AVHRR/V002*
product_version	*2.0*
creator_name	*DE/DWD*
creator_email	*contact.cmsaf@dwd.de*
creator_url	*http://www.cmsaf.eu*
institution	*EUMETSAT/CMSAF*
project	*Satellite Application Facility on Climate Monitoring (CM SAF)*
references	*http://dx.doi.org/10.5676/EUM_SAF_CM/CLARA_AVHRR /V002*
keywords_vocabulary	*Vocabulary for keywords in the global attributes (GCMD Science Keywords, Version 8.1)*
keywords	*EARTH SCIENCE>ATMOSPHERE>CLOUDS>"variable group"*
Conventions	*convention tables for metadata and attributes (CF-1.6, ACDD-1.3)*
standard_name_vocabulary	*Vocabulary for standard names in the parameter attributes (Standard Name Table (v28, 07 January 2015))*
date_created	*Point in time, when the file was created [ISO8601 date]*
geospatial_lat_max	*90*
geospatial_lat_min	*-90*
geospatial_lat_units	*degrees_north*
geospatial_lon_max	*180*
geospatial_lon_min	*-180*
geospatial_lon_units	*degrees_east*
Geospational_lat_resolution	*0.25 degrees*
Geospational_lon_resolution	*0.25 degrees*

Name	Description
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	*P1M or P1D (period 1 month, day)*
time_coverage_resolution	*P1M or P1D (period 1 month, day)*
platform_vocabulary	*Vocabulary for platform in the global attributes (GCMD Platforms, Version 8.1)*
instrument_vocabulary	*Vocabulary for instrument in the global attributes (GCMD Instruments, Version 8.1)*
instrument	*Earth Remote Sensing Instruments>Passive Remote Sensing >Spectrometers/Radiometers>Imaging Spectrometers/Radiometers>SEVIRI>Spinning Enhanced Visible and Infrared Imager*
CMSAF_included_Daily_Means	*For monthly means, this attribute counts the number of daily means, that are used to build the monthly mean*
CMSAF_L1_processor	*PyGAC*
CMSAF_L2_processor	*PPS2014 incl. patch 1 and CPP*
CMSAF_L3_processor	*CMSAFGACL3_V2.0*
platform	*Satellite name of the platform where AVHRR operates on*

8.2.5 Polar data

Additionally to the global data CLARA A2 also provides the data on two polar grids with a spatial resolution of 25 km. For each daily or monthly mean one file for each polar area, the Arctic and the Antarctic. These data are provided on an equal area ease grid. Therefore, the latitude and longitude variable are changed from vectors to arrays. They show the latitude and longitude for each grid box. Otherwise, the data structure is identical to the global data files described above.

9 Data ordering via the Web User Interface (WUI)

User services are provided through the CM SAF homepage www.cmsaf.eu. The user service includes information and documentation about the CM SAF and the CM SAF products, information on how to contact the user help desk and allows to search the product catalogue and to order products.

On the main webpage, a detailed description how to use the web interface 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.

9.1 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. 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.

9.2 Contact User Help Desk staff

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

9.3 Feedback/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 chapter 9.2) or use the “User Problem Report” page. A link to the “User Problem Report” is available either from the CM SAF main page (www.cmsaf.eu) or the Web User Interface main page.

9.4 Service Messages / log of changes

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

10 Copyright and Disclaimer

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

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). The doi of the data record can be retrieved through (http://www.cmsaf.eu/DOI).

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 user needs and requirements. Each new user shall register at CM SAF in order to retrieve the data.

Feedback

We are keen to learn of what use the CM SAF data are. So please feedback your experiences and your application area of the CM SAF data. EUMETSAT CM SAF is user driven service and is committed to consider the needs and requirements of its users in the planning for product improvements and additions. Users are invited to provide their specific requirements on future products for their applications.

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12 Glossary

AMSR-E	Advanced Microwave Scanning Radiometer for EOS
ATBD	Algorithm Theoretical Baseline Document
AVHRR	Advanced Very High Resolution Radiometer
BC-RMS	Bias-Corrected RMS
CALIPSO	Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations
CALIOP	Cloud-Aerosol Lidar with Orthogonal Polarisation
CDO	Climate Data Operators
CDOP	Continuous Development and Operations Phase
CF	Climate and Forecast Metadata Convention ((http://cf-pcmdi.llnl.gov/))
CFC	Fractional Cloud Cover
CFOT	Cloud Feature Optical Depth
CLARA-A	CM SAF cLoud, Albedo and Radiation products, AVHRR-based
CLAAS	CM SAF cLoud dAtAset using SEVIRI
CM SAF	Satellite Application Facility on Climate Monitoring
COT	Cloud Optical Thickness
CPH	Cloud Phase
CPR	Cloud Profiling Radar
CTH	Cloud Top Height
CTO	Cloud Top product
CTP	Cloud Top Pressure
CTT	Cloud Top Temperature
CPP	Cloud Physical Properties
DAK	Doubling Adding KNMI (radiative transfer model)
DRR	Delivery Readiness Review
DWD	Deutscher Wetterdienst (German MetService)
ECMWF	European Centre for Medium Range Forecast
ECV	Essential Climate Variable
ERA-Interim	Second ECMWF Re-Analysis dataset
EUMETSAT	European Organisation for the Exploitation of Meteorological Satellites
FAR	False Alarm Ratio
FCDR	Fundamental Climate Data Record
FCI	Flexible Combined Imager

GAC	Global Area Coverage (AVHRR)
GCOS	Global Climate Observing System
GSICS	Global Space-Based Inter-Calibration System
ISCCP	International Satellite Cloud Climatology Project
ITCZ	Inter Tropical Convergence Zone
IWP	Ice Water Path
JCH	Joint Cloud properties Histogram
KNMI	Koninklijk Nederlands Meteorologisch Instituut
KSS	Hanssen-Kuiper Skill Score
LWP	Liquid Water Path
MODIS	Moderate Resolution Imaging Spectroradiometer
MSG	Meteosat Second Generation
MTG	Meteosat Third Generation
NOAA	National Oceanic & Atmospheric Administration
NWC SAF	SAF on Nowcasting and Very Short Range Forecasting
NWP	Numerical Weather Prediction
PATMOS-x	Pathfinder Atmospheres-Extended dataset (NOAA)
POD	Probability Of Detection
PPS	Polar Platform System (NWC SAF polar cloud software package)
PRD	Product Requirement Document
PUM	Product User Manual
REFF	Cloud particle effective radius
RMS	Root Mean Square (Error)
RTTOV	Radiative Transfer model for TOVS
SEVIRI	Spinning Enhanced Visible and InfraRed Imager
SAF	Satellite Application Facility
SMHI	Swedish Meteorological and Hydrological Institute
SYNOP	Synoptic observations
SZA	Solar Zenith Angle
UWisc	University of Wisconsin passive microwave based LWP dataset
VZA	Viewing Zenith Angle