EUMETSAT Satellite Application Facility on Climate Monitoring

The EUMETSAT Network of Satellite Application Facilities

CM SAF Climate Monitoring

CM SAF Cloud, Albedo, Radiation dataset, AVHRR-based, Edition 1 (CLARA-A1)

Cloud Products

Algorithm Theoretical Basis Document

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Fractional Cloud Cover	**CM-05**
Joint Cloud property histogram	**CM-11**
Cloud Top level	**CM-17**
Cloud Optical Thickness	**CM-34**
Cloud Phase	**CM-38**
Liquid Water Path	**CM-43**
Ice Water Path	**CM-47**

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Reference documents

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RD 3	Algorithm Theoretical Basis Document Cloud physical products AVHRR	SAF/CM/KNMI/ATBD/GAC/CPP/1.1
RD 4	Algorithm Theoretical Basis Document Joint Cloud property Histograms AVHRR/SEVIRI	SAF/CM/SMHI/ATBD/JCH/1.1

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1 The EUMETSAT SAF on Climate Monitoring

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

This CM SAF Algorithm Theoretical Basis Document (ATBD) provides information on the processing chain implemented for the CM SAF AVHRR GAC data set to retrieve geophysical parameters from inter-calibrated measurements of the Advanced Very High Resolution Radiometer (AVHRR). It also provides information on the CM SAF retrieval schemes used to construct the data set employing the measurements of AVHRR instruments onboard the NOAA satellites (NOAA-07, NOAA-09, NOAA-11, NOAA-12, NOAA-13, NOAA-14, NOAA-15, NOAA-16, NOAA-17, NOAA-18, NOAA-19) and the EUMETSAT MetOp-A satellite. The algorithms applied are the PPS (Polar Platform System) cloud processing package (Dybbroe et al., 2005a and Dybbroe et al., 2005b), which is used to determine cloud fraction and cloud top properties, and the CPP (Cloud Physical Properties) algorithm (Roebeling et al. 2006), which retrieves cloud thermodynamic phase, cloud optical thickness, cloud particle effective radius, and liquid/ice water path.

The document seamlessly describes all elements of the production of the final CM SAF AVHRR GAC cloud products which are structured in the following three topics.

1. A description of the data sources and a summary of AVHRR instrument characteristics are given, including a description of the inter-calibration applied to AVHRR GAC measurements.
2. A report on the derivation of the cloud products by applying CPP and PPS algorithms. Note, significant parts of the PPS and CPP algorithms have already been documented in previous ATBDs, which will be referred to in this document when appropriate.
3. The elaboration of the production of the daily and monthly means (Level-3 data) based on the Level-2 products provided by CPP and PPS

Basic accuracy requirements are defined in the product requirements document [AD 1].

The CM SAF AVHRR GAC data set contains multiple cloud parameters derived from AVHRR. The CM SAF release of AVHRR GAC edition 1 contains the following cloud variables:

Fractional Cloud Cover [CM-05, CFC, section 4.1]

Joint Cloud property histogram [CM-11, JCH, section 4.2]

Cloud Top level [CM-17, CTO, section 4.3]

Cloud Optical Thickness [CM-34, COT, section 4.4]

Cloud Phase [CM-38, CPH, section 4.5]

Liquid Water Path [CM-43, LWP, section 4.6]

Ice Water Path [CM-47, IWP, section 4.7]

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3 Processing of measured AVHRR radiances (Level-1)

3.1 Historical overview of the AVHRR GAC dataset

Measurements from the Advanced Very High Resolution Radiometer (AVHRR) radiometer onboard the polar orbiting NOAA satellites and the EUMETSAT METOP satellites have been performed since 1978. Figure 3-1 gives an overview over all satellites carrying the AVHRR instrument until 2009 (the final year covered by the new CM SAF GAC dataset). Notice that also data from NOAA-19 and Metop-A has been used for the last two years in the CM SAF dataset (not included in Figure 3-1). The 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.

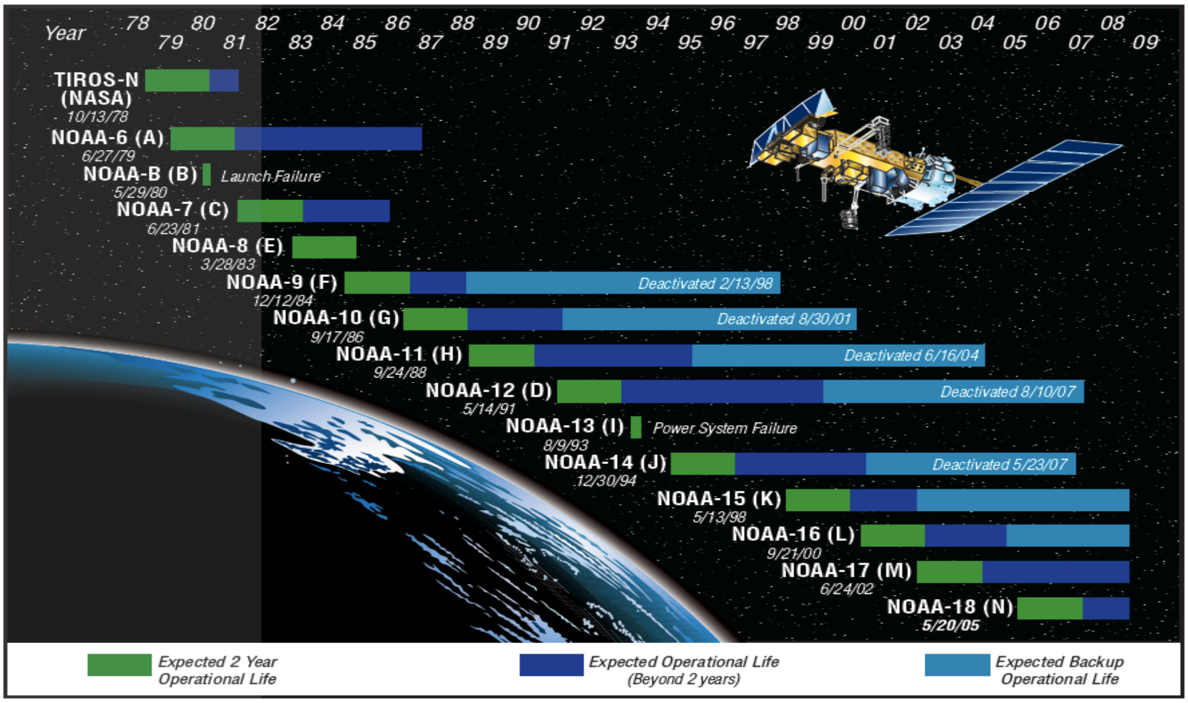

Figure 3-1: *Historic overview of all NOAA satellites available in the covered period until 2009. (Courtesy of Andrew Heidinger, NOAA)*

Table 3-1 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 dataset is denoted Global Area Coverage (GAC) AVHRR data.

Table 3-1: *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 and Metop-1. For the other satellites with AVHRR/3 it was used only for shorter periods.*

Channel Number	Wavelength (micrometers) AVHRR/1 NOAA-6,8,10	Wavelength (micrometers) AVHRR/2 NOAA-7,9,11,12,14	Wavelength (micrometers) AVHRR/3 NOAA-15,16,17,18 NOAA-19, Metop-A
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

3.2 Compilation of the CM SAF GAC cloud dataset

The GAC dataset of global cloud products retrieved by CM SAF cloud retrieval methods spans the time period 1982-2009. 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 (see Table 3-1).

Figure 3-2 describes the coverage of observations from each individual satellite over the entire period. Notice that the limitations to the use of AVHRR/2 and AVHRR/3 instruments leads 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.

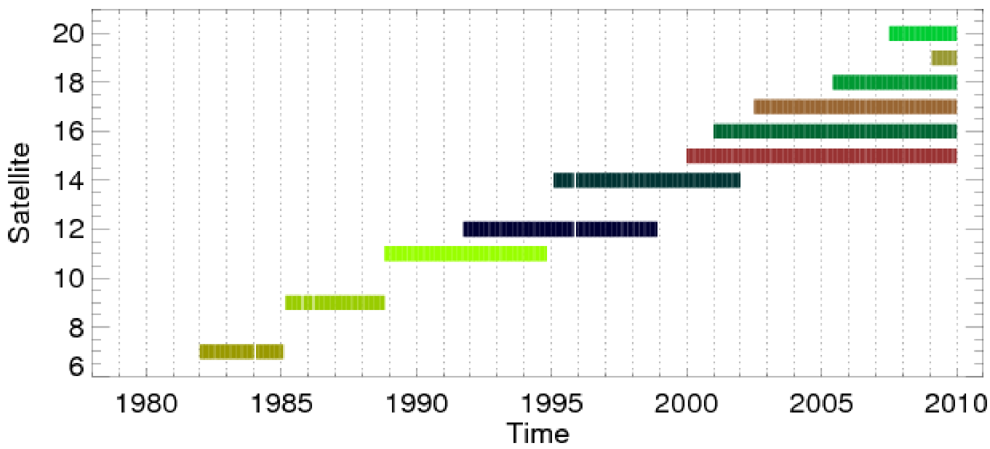

Figure 3-2: *Visualisation of the used NOAA-satellites showing satellite numbers on Y-axis and the length of the observation period for each satellite. Notice that number 20 denotes Metop-A. Some data gaps are present but only for some isolated months for NOAA-7, NOAA-9, NOAA-12 and NOAA-14.*

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 almost 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 and Metop-A, 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 (e.g., as described by Ignatov et al., 2004). This is illustrated further in Figure 3-3 for all NOAA satellites. Some compensation for this has been attempted in the CM SAF dataset but not for all parameters.

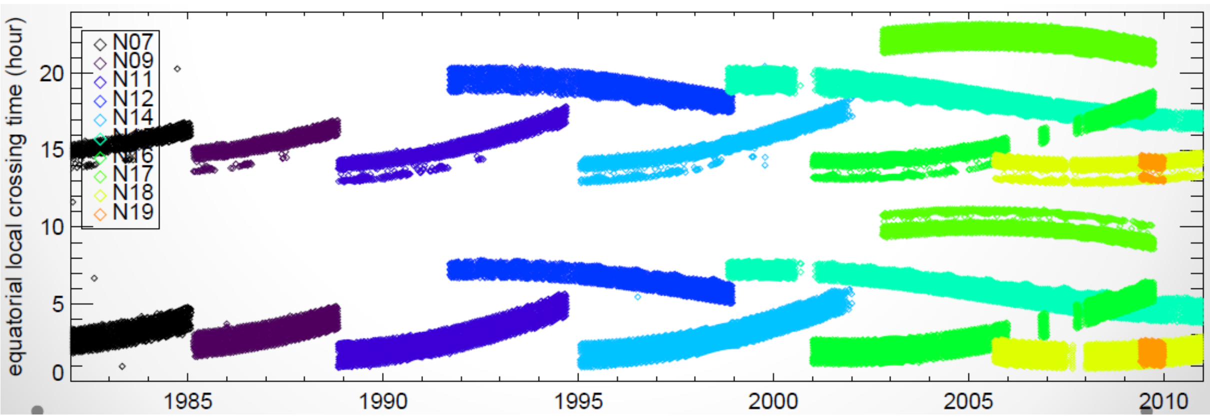

Figure 3-3: *Local solar times at equator observations for all NOAA satellites from NOAA7 to NOAA19. (Courtesy of M. Foster, NOAA). Notice that the figure shows both ascending (northbound) and ascending (southbound) equator crossing times for each satellite separated 12 hours apart.*

3.3 AVHRR radiance intercalibration

An important aspect for any product-based climate dataset (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 dataset we have used an AVHRR FCDR prepared by NOAA (Heidinger et al., 2010). This FCDR was prepared for the compilation of the "NOAA Pathfinder Atmospheres – Extended" (PATMOS-x) dataset (for full description, see http://cimss.ssec.wisc.edu/patmosx/overview.html). This FCDR focussed in particular on homogenization of the AVHRR visible reflectances (now available for download at NOAA's National Climate Data Centre, NCDC - see available datasets at http://www.ncdc.noaa.gov/cdr/operationalcdrs.html). The calibration of infrared AVHRR channels is basically left untouched since the use of onboard blackbody calibration targets have been found to provide stable and reliable results. 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).

4 Retrieval of swath-based cloud properties (Level-2)

This section provides information on the processing of PPS and CPP to retrieve cloud parameters from inter-calibrated AVHRR observations. Each parameter is briefly introduced in the following with the respective detailed ATBD being referred to.

4.1 Fractional Cloud Cover [CM-05, CFC]

This product is derived directly from results of a cloud screening or cloud masking method. 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. The cloud screening and cloud masking is performed using the NWC SAF PPS 2010 algorithm (with modifications), which is described in more detail in [RD-1].

4.2 Joint Cloud property Histogram [CM-11, 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, which can be found in section 5.3.2. More details on this product can be found in [RD-4].

4.3 Cloud Top level [CM-17, 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 semitransparent clouds, and it is applied to all cloudy pixels as identified by the PPS cloud mask product.

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. 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) is retrieved.

Both schemes are part of NWC SAF PPS 2010. Details can be found in [RD-2].

4.4 Cloud Optical Thickness [CM-34, COT]

The Cloud Optical Thickness (COT) is defined at 0.6 µm under the assumption of a plane parallel atmosphere with reference to a vertical transect. COT is retrieved from a comparison of the measured 0.6 µm reflectance to pre-calculated Lookup Table (LUT) values. The LUTs were obtained using radiative transfer calculations from the Doubling Adding KNMI (DAK) model. COT is simultaneously retrieved with cloud particle effective radius in an iterative manner.

During the iteration the retrieval of COT at the 0.6-µm channel is used to update the retrieval of cloud particle effective radius at the 1.6/3.7-µm channel. This iteration process continues until the retrieved cloud physical properties converge to stable values. For more details on the radiative transfer modelling and retrieval scheme details we refer to [RD-3].

4.5 Cloud Phase [CM-38, CPH]

The cloud thermodynamic phase (CPH) is determined as follows. The iterative process described above is first applied using the ice cloud LUT. If convergence is achieved and the cloud-top temperature ($T_{c,}$ obtained from measured 10.8-µm brightness temperatures) is lower than 265 K, the phase ‘ice’ is assigned. If not, the phase ‘water’ is assigned. Details can be found in [RD-3]

4.6 Liquid Water Path [CM-43, LWP]

Liquid water path is computed from the retrieved COT and cloud particle effective radius (r_e) values by (Stephens et al., 1978):

$$LWP = \frac{2}{3} COT \rho_l r_e \,,$$

in which ρ_l represents the density of liquid water (1000 kg m^{-3}). More details can be found in [RD-3].

4.7 Ice Water Path [CM-47, IWP]

The Ice Water Path (IWP) is calculated using the same formula as for LWP using the retrieved effective radius of ice crystals and the density of ice (930 kg m^{-3}). For the ice crystals, volume equivalent effective radii are 6, 12, 26, and 51 µm. These radii are based on 4 types of imperfect hexagonal columns defined by Hess et al. (1998). See [RD-3] for more details.

5 Generation of daily and monthly means (Level-3)

As input for the L2 to L3 processing environment serve pixel level retrieval results of the Level 2 algorithm software of PPS and CPP. The final outputs produced are global fields of daily and monthly averages with specification defined in [AD-1]. These specifications are summarized in section 5.1. Before creation of L3 data, the pixel-based data is re-projected onto a $(0.05°)^2$ latitude-longitude grid which is described in section 5.2. Building on these remapped fields, the Level-3 data (daily and monthly means) are aggregated and averaged on the final $(0.25°)^2$ grid with details given in section 5.3.

In addition, results are also prepared on two equal-area polar grids at 25 km resolution for the Arctic and Antarctic regions, respectively. This is done to facilitate usage of results over the poles where the converging longitudes make the use of regular latitude-longitude grids problematic. Here, initial results are defined in a 5 km resolution grid on these regions before averaged into 25 km L3 products. These grids are centred at the poles and cover areas of 1000 km x 1000 km. However, notice that this only concerns the two cloud parameters Fractional Cloud Coverage and Cloud Top Level.

5.1 Definition of product specifications

The CM SAF GAC cloud data set from AVHRR provides global coverage of a number of cloud parameters. Instantaneous AVHRR GAC retrievals at original swath level are used to derive the spatio-temporally averaged data sets. The products are available as daily and monthly composites for each satellite on a regular latitude/longitude grid with a spatial resolution of 0.25° × 0.25° degrees (or, alternatively, 25 km resolution for two Polar Regions for cloud products Cloud Coverage and Cloud Top Level).

The monthly averages 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 (currently only for fractional cloud cover). Here, all observations made under twilight conditions (solar zenith angles between 80-95 degrees) have been excluded in order to avoid being affected by specific cloud detection problems occurring in the twilight zone.

In addition to the daily and monthly means, histograms are provided on monthly time scales. The Joint Cloud property Histograms are two-dimensional histograms of COT and CTP are composed with a spatial resolution of 1° x 1° degrees. (See Section 5.3.2 for more technical details). For CTP, COT, LWP and IWP one-dimensional histograms are constructed on a monthly basis with a spatial resolution of 0.25° × 0.25° degrees (See Sections 5.3.3, 5.3.4, 5.3.6 and 5.3.7 for more technical details.).

The temporal coverage of the data sets ranges from January 1982 to December 2009. Notice again (as mentioned in Section 3 and visualised in Figure 3-1 and Figure 3-2) that for the first years in the series (1982-1989) only the afternoon satellites are included.

5.2 Remapping

As mentioned above, an intermediate remapping step is applied before the final aggregation of the data for the Level-3 production. All Level-2 output cloud properties of PPS and CPP are input to this remapping procedure. These data are on AVHRR GAC pixel level resolution, meaning about 4km by 4km horizontal resolution. The intermediate grid has a resolution of 0.05° in latitude-longitude space (or, alternatively, 5 km for Arctic and Antarctic regions),

which has firstly chosen to be close to the AVHRR GAC resolution and to be a multiple of the final grid resolution to facilitate to the generation of the product fields. The intermediate remapping is implemented to reduce the data amount to be handled, to facilitate the Level-2b composition and to support rapid Level-3 reproductions if necessary.
The remapping is done straight forward by inserting all derived cloud properties and all needed pixel-based auxiliary data of a particular GAC pixel into the closest (0.05° or 5 km)² cell. The entries are overwritten if other pixel were assigned to this grid cell afterwards. Empty cell are not filled with nearest neighbour nor with interpolation, but just left empty.
It is important to note that this remapping is done for each AVHRR orbit of each satellite separately thus creating a remapped fields for each full orbit.

5.3 Calculation of final products

For the daily and monthly averages all data from the remapped fields (see section 5.2) are considered. Aiming at the final spatial product resolution of (0.25° or 25 km)², each valid cloud parameter $x(i, j)$ is aggregated over 5 by 5 cells of the intermediate remapped fields in space, and over all available fields in time and weighted by the number of used, valid cells. Here, all values are considered equally valid, thus no weighting is applied.
It is important to note that different quality checks are applied for filtering valid numbers for each parameter. This is motivated by the fact that not in all cases where a cloud mask is available all cloud retrieval results of CPH, CTO, COT, LWP and IWP are available.
The methods and approaches to generate the final products, as described in this document, are referred to as 'CMSAFGACL3_V1.0' in the data files.

5.3.1 Fractional Cloud Cover [CFC]

The daily and monthly mean fractional cloud cover is calculated from the aggregation of the instances of the binary cloud mask information as follows:

$$CFC(i,j) = \frac{N(i,j)_{Cloudy}}{N(i,j)_{Cloudy} + N(i,j)_{Clear}} \quad (1)$$

with i and j being the indices of the final field projection, $N(i,j)_{Cloudy}$ the number of cloudy cases and $N(i,j)_{Clear}$ then number of clear cases. Acknowledging the different cloud detection capability during day and night time, an additional separation is done leading to $CFC(i,j)_{Night}$ and $CFC(i,j)_{Day}$, separate day time and night time averages. Here, the solar zenith angle of ≤80° and ≥95° are used to define day and night, respectively. Cases with solar zenith angles between 80° and 95° are excluded due to specific problems occurring in twilight conditions.

5.3.2 Joint Cloud property Histogram [JCH]

Differing from CFC, CPH, COT, LWP and IWP product derivation, the JCH does not include a classical mean of a specific cloud property but covers the solution space for the 2 cloud parameters: COT and CTP. Thus these products are described in four-dimensional fields $JCH(i, j, t, p)$. Indices i and j again refer to location space, while t and p being the indices for specific bins of the range of occurring COT and CTP values.

Each specific field entry contains the absolute number of occurrences of cloud pixel falling into the COT bin t and the CTP bin p being. The following values bordering the bins of COT and CTP (given in hPa) have been defined:

COT: {0, 0.3, 0.6, 1.3, 2.2, 3.6, 5.8, 9.4, 15, 23, 41, 60, 80, 100, 257}
CTP: {0, 37.5, 87.5, 137.5, 187.5, 237.5, 287.5, 337.5, 387.5, 437.5, 487.5, 537.5, 587.5, 637.5, 687.5, 737.5, 787.5, 837.5, 887.5, 937.5, 987.5, 1012.5, 1087.5}

The CTP binning is done in order to properly account for the vertical resolution of the CTP assignment with is 25hPa. In a second step, the histograms are remapped onto ISCCP like binning, but with doubled resolution in CTP and COT. Thus the final and provided binning of the JCH is as follows:

COT:{ 0, 0.3, 0.6, 1.3, 2.2, 3.6, 5.8, 9.4, 15, 23, 41, 60, 80, 100} and
CTP:{ 1, 90, 180, 245, 310, 375, 440, 500, 560, 620, 680, 740, 800, 950, 1100} [hPa].

These histograms are calculated for liquid and ice clouds separately, thus:

$$JCH(i,j,t,p)_{ice} = N(i,j)_{COT \varepsilon COTbin;CTP \varepsilon CTPbin;CPH=ice} \qquad (2)$$

and

$$JCH(i,j,t,p)_{liquid} = N(i,j)_{COT \varepsilon COTbin;CTP \varepsilon CTPbin;CPH=liquid} \qquad (3)$$

5.3.3 Cloud Top Level [CTO]

The CTO product contains daily and monthly means for CTH, CTP, and CTT. For these parameters all valid entries of the remapped fields are aggregated and then weighted by the number of used entries.

$$< x(i,j) >= \frac{1}{N(i,j)_{Cloudy}} \sum_{k=1}^{N(i,j)_{Cloudy}} x_k(i,j) \qquad (4)$$

with $x(i,j)$ being a general expression for CTH, CTP and CTT at a specific grid cell.

For CTP, an alternative way of averaging is followed and additionally calculated and provided as geometrical mean where the variables are averaged in logarithm space:

$$< ctp(i,j) >_{\ln} = \exp(\frac{1}{N(i,j)_{Cloudy}} \sum_{k=1}^{N(i,j)_{Cloudy}} \ln(ctp_k(i,j))) \qquad (5)$$

One-dimensional histograms are generated for CTP on the same spatial resolution, but only on monthly basis. The CTP bin borders for these histograms are:

CTP:{ 1, 90, 180, 245, 310, 375, 440, 500, 560, 620, 680, 740, 800, 950, 1100} [hPa].

5.3.4 Cloud Optical Thickness [COT]

Similar to CTT and CTH and the arithmetical mean of CTP, the daily and monthly mean of COT $< COT(i,j) >$ is calculated following Equation (4). Additional, ice and liquid cloud specific values are calculated: $< COT(i,j) >_{ice}$, $< COT(i,j) >_{liquid}$ using CPH as identifier. As an upper limit for realistic COTs the value of 100 was defined.
One-dimensional histograms are generated for COT on the same spatial resolution, but only on monthly basis. The COT bin borders for these histograms are:

COT:{ 0, 0.3, 0.6, 1.3, 2.2, 3.6, 5.8, 9.4, 15, 23, 41, 60, 80, 100}.

5.3.5 Cloud Phase [CPH]

Similarly to CFC, the daily and monthly from the aggregation over the different instances of the cloud phase retrievals. CPH is expressed as fraction of liquid water clouds by calculating the ratio of number of detected liquid clouds $N(i,j)_{Cloudy}$ with respect to the total number detected clouds $N(i,j)_{Cloudy}$:

$$CPH(i,j) = \frac{N(i,j)_{liquid}}{N(i,j)_{Cloudy}}$$

5.3.6 Liquid and Ice Water Path [LWP]

Daily and monthly mean LWP is calculated for each grid cell $< LWP(i,j) >$ as given in Equation (4). If collocated COT values exceed 100, the LWP is scaled down accordingly.
One-dimensional histograms are generated for LWP on the same spatial resolution, but only on monthly basis. The LWP bin borders for these histograms are:

LWP: {0, 5, 10, 20, 35, 50, 75, 100, 150, 200, 300, 500, 1000, 2000, inf} [g/m²].

5.3.7 Ice Water Path [IWP]

Daily and monthly mean IWP is calculated for each grid cell $< IWP(i,j) >$ as given in Equation (4). If collocated COT values exceed 100, the IWP is scaled down accordingly.
One-dimensional histograms are generated for IWP on the same spatial resolution, but only on monthly basis. The IWP bin borders for these histograms are:

IWP: {0, 5, 10, 20, 35, 50, 75, 100, 150, 200, 300, 500, 1000, 2000, inf} [g/m²].

5.4 Additional statistical parameters

In addition to the daily and monthly mean values, the standard deviations s over all valid and used values is calculated for CTO, COT, LWP and IWP for each grid box with

$$s(x(i,j)) = (< x^2(i,j) > - < x(i,j) >^2)^{0.5}$$

5.5 Requirements on the availability of measurements

The calculation of the final product as mentioned above is done in two varying configurations. While the first configuration only the data of a specific AVHRR on a specific platform/satellite is considered, the second configuration incorporates all available remapped data for a specific time and grid cell of the final products

No specific requirements are applied to create satellite-specific daily means. However, for monthly means at least 20 days of retrieval results of a specific platform have to be present to trigger the production of a monthly mean for this platform. Further, the orbits of the last day of the month have also to be present, which is due to technical reasons.

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7 Glossary

ATBD	Algorithm Theoretical Baseline Document
AVHRR	Advanced Very High Resolution Radiometer
CDOP	Continuous Development and Operations Phase
CM SAF	Satellite Application Facility on Climate Monitoring
CPP	Cloud Physical Properties
DRI	Delivery Readiness Inspection
DWD	Deutscher Wetterdienst (German MetService)
ECMWF	European Centre for Medium Range Forecast
ECV	Essential Climate Variable
EPS	European Polar System
EUMETSAT	European Organisation for the Exploitation of Meteorological Satellites
FOV	Field of view
GCOS	Global Climate Observing System
IOP	Initial Operations Phase
ITCZ	Inter-Tropical Convergence Zone
KNMI	Koninklijk Nederlands Meteorologisch Institut
NASA	National Aeronautics and Space Administration
NDBC	National Data Buoy Center
NESDIS	National Environmental Satellite, Data, and Information System
NOAA	National Oceanic & Atmospheric Administration
NODC	National Oceanographic Data Center
NWP	Numerical Weather Prediction
PPS	Polar Platform System
PRD	Product Requirement Document
PUM	Product User Manual
RMIB	Royal Meteorological Institute of Belgium
RMS	Root Mean Square
RSMAS	Rosenstiel School of Marine and Atmospheric Science
RSS	Remote Sensing Systems
SAF	Satellite Application Facility
SMHI	Swedish Meteorological and Hydrological Institute
SST	Sea Surface Temperature