EUMETSAT Satellite Application Facility on Climate Monitoring

Requirements Review

SEVIRI-FCI Edition 4 CDR and ICDR named CLAAS-4

(**CL**oud property and top-of-atmosphere radiation d**A**t**A**set using **S**EVIRI and FCI)

	CDR	ICDR
Fractional Cloud Cover (CFC)	**CM-21016**	**CM-5012**
Joint Cloud property Histogram (JCH)	**CM-21024**	**CM-5022**
Cloud Top level (CTO)	**CM-21034**	**CM-5032**
Cloud Phase (CPH)	**CM-21044**	**CM-5042**
Liquid Water Path (LWP)	**CM-21054**	**CM-5052**
Ice Water Path (IWP)	**CM-21064**	**CM-5062**
Reflected Solar Flux (RSF)	**CM-21302**	**CM-5321**
Outgoing Longwave Radiation (OLR)	**CM-21332**	**CM-5331**

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Applicable documents

Reference	Title	Code
AD 1	CM SAF CDOP4 Project Plan	SAF/CM/DWD/PP/1.0

Reference Documents

Reference	Title	Code
RD 1	CM SAF Product Requirements Document	SAF/CM/DWD/PRD/4.2
RD 2	CM SAF Validation Report SEVIRI cloud products CLAAS Edition 3	SAF/CM/KNMI/VAL/SEV/CLD/3.1
RD 3	NWCSAF Product Requirements Document	NWC/CDOP2/SAF/AEMET/MGT/PRD/1.2 08.07.2013
RD 4	CM SAF Requirements Review TOA Radiation – GERB Edition 2 data sets	SAF/CM/CDOP2/RMIB/GERB/RR 25
RD 5	CM SAF Requirements Review TOA Radiation – TCDR MVIRI/SEVIRI/GERB Edition 1 data sets	SAF/CM/CDOP2/RMIB/GERB/RR 26
RD 6	CM SAF Requirements Review AVHRR GAC Ed3 data records – TOA radiation products	SAF/CM/CDOP3/SMHI/RR32
RD 7	CM SAF / AC SAF Federated Activity: Above-Cloud Aerosol Cases: Improved Assessment from SEVIRI (ACACIAS) – Final Report Part 1: Cloud and Aerosol Properties	CM-AC_FA20_01_REP1

Reference	Title	Code
RD 8	CM SAF / AC SAF Federated Activity: Above-Cloud Aerosol Cases: Improved Assessment from SEVIRI (ACACIAS) – Final Report Part 2: Top-Of-Atmosphere Radiation	CM-AC_FA20_01_REP2

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1 Purpose of the document

This document consolidates the position of the CM SAF project team concerning the product requirements for CDRs CM-21016, CM-21024, CM-21034, CM-21044, CM-21054, CM-21064, CM-21302, CM-21332 and the corresponding ICDRs CM-5012, CM-5022, CM-5032, CM-5042, CM-5052, CM-5062, CM-5321, CM-5331.

2 The Climate Monitoring SAF (CM SAF)

The EUMETSAT Satellite Application Facility on Climate Monitoring (CM SAF, https://www.cmsaf.eu), together with the EUMETSAT Secretariat, holds the role as main implementer of EUMETSAT's commitments in support to climate monitoring.

Since the beginning in 1999, CM SAF has developed and will continue to develop capabilities for a sustained generation and provision of Climate Data Records (CDR's) of Essential Climate Variables (ECVs) as defined by the Global Climate Observing System (GCOS), derived from operational meteorological satellites. In particular, the generation of long-term data records is pursued that are suitable for the analysis of climate variability and potentially the detection of climate trends. Here, the main focus in CM SAF is on those ECVs that describe important components of the Earth's energy budget and its 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. For this, CM SAF is supporting climate services at national meteorological and hydrological services with long-term data records but also with data sets produced in a seamless and coherent way close to real time that can be used to, e.g., prepare monthly/annual updates of the state of the climate. These so-called Interim Climate Data Records (ICDRs) together with the CDRs allow for a consistent description of mean values, anomalies, variability and potential trends for the considered ECVs. CM SAF CDRs also facilitate scientific applications such as for example process studies and evaluation of climate models at regional and global scales.

Furthermore, CM SAF contributes to advancing the availability, quality and usability of Fundamental Climate Data Records (FCDRs) in close collaboration with the EUMETSAT Secretariat and other satellite operators.

CM SAF is connected to the global scientific community ensuring a steady exchange of knowledge to continuously improve the data records and services, among others, through its engagement in international data assessments and through taking over responsibility in various international coordination bodies.

The international consortium of CM SAF currently comprises the Deutscher Wetterdienst (DWD) as host institute, 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), the Meteorological Service of the United Kingdom (UK Met Office) and the Centre National de la Recherche Scientifique (CNRS).

More information, including a complete catalogue of all CM SAF products, can be found at CM SAF's webpage, https://www.cmsaf.eu. Accessing all data products is facilitated through the CM SAF web user interface: https://wui.cmsaf.eu/.

3 Background of products under review

For RR 4.6 the following products as listed in Table 1 from PRD 4.2 (RD 1) are under review:

Table 1: CM SAF products under review.

Product Family	CM SAF Product Identifier		Product Name
	CDR	ICDR	
CLAAS-4	CM-21016	CM-5012	Fractional Cloud Cover
	CM-21024	CM-5022	Joint Cloud property Histogram
	CM-21034	CM-5032	Cloud Top level
	CM-21044	CM-5042	Cloud Phase
	CM-21054	CM-5052	Liquid Water Path
	CM-21064	CM-5062	Ice Water Path
	CM-21302	CM-5321	Reflected Solar Flux
	CM-21332	CM-5331	Outgoing Longwave Radiation

The CLAAS-4 ICDRs extend the associated CLAAS-4 CDRs until present time. To the maximum extent possible the ICDR is based on the same scientific and technical approaches as the CDR. In that sense, the combined CDR and ICDR data records are considered as a unit and consequently they share a common DOI. The CDR itself consists of consistently processed satellite data of a defined period in the past.

3.1 History of products / precursor

In 2012/2013 CM SAF made the first effort to retrieve cloud properties from the full SEVIRI data record, and released the so-called CLAAS data record in September 2013 (Stengel et al., 2013). The second edition of the CLAAS data record (CLAAS-2) was developed in the CDOP2 phase and released in 2016 (Benas et al., 2017). The third edition (CLAAS-3) was released in December 2022 (Benas et al., 2023) and was the first edition for which the CDR and ICDR were seen as one unit being released at the same time, featuring the same product portfolio and optimized consistency in the input data streams. Table 2 provides an overview of the relation of the CM SAF CLAAS-4 products under review in this RR to those in CLAAS-3, including the achieved accuracy for the latter.

One of the new features in CLAAS-4 will be the introduction of top-of-atmosphere (TOA) outgoing longwave radiation (OLR) and reflected solar flux (RSF). Two CM SAF TOA radiation products from Meteosat and GERB imagers have been released in the past, most recently during CDOP-2. Those datasets are named SEVIRI/GERB ed. 2 (CM-21301, CM-21321, CM-21331, CM-21351) and MVIRI/SEVIRI (CM-23311 and CM-23341). These data records were not part of the CLAAS-2 and CLAAS-3 product suites, unlike the current CLAAS-4 TOA products under review.

The SEVIRI/GERB ed 2.0 dataset [RD 4] was based on the instantaneous TOA fluxes from the GERB (Harries et al., 2005) dataset and SEVIRI. All-sky and clear-sky OLR and RSF products were provided over the Meteosat disk at daily, monthly and monthly mean diurnal cycle time-step at a spatial resolution of 0.1 degree (regular grid). This record covered the period 2004-02-01 to 2015-04-30.

Second, the MIVIRI/SEVIRI product (Urbain et al., 2017) [RD 5] was based on observations from the Meteosat Visible and InfraRed Imager (MVIRI) and SEVIRI, onboard the Meteosat First and Second Generation (MFG and MSG), respectively. The all-sky OLR and RSF products were provided over the Meteosat disk at daily, monthly and monthly mean diurnal cycle time-step at a spatial resolution of 0.05 degree (regular grid). This record covered the period 1983-02-01 to 2015-04-30.

Table 2: Relation of CLAAS-4 product identifiers (IDs) with CLAAS-3 product IDs and achieved accuracy and precision as presented in the validation report [RD-2] of CLAAS-3. Accuracy is measured with the bias; precision is measured with Hanssen-Kuipers Skill Score (KSS) and bias-corrected root-mean-square deviation (bc-rmsd) for level-2 (L2) data and with bc-rmsd for level-3 (L3) data. The reference instruments / data records given between brackets are: Cloud-Aerosol Lidar with Orthogonal Polarisation (CALIOP) v4.20, surface synoptic observations (SYNOP), Moderate Resolution Imaging Spectroradiometer (MODIS) Collection 6.1, the microwave-imager-based LWP data record (MAC-LWP), Advanced Microwave Scanning Radiometer 2 (AMSR2), and DARDAR v3.10.

Product Name	CM SAF IDs in CLAAS-4	CLAAS-3	
		CM SAF ID	Achieved accuracy and precision for CDR products
Fractional Cloud Cover	CM-21016 CM-5012	CM-21014 CM-5011	Bias: -2.3% (CALIOP, COT>0), 0.2 (SYNOP), -6.5% (MODIS) L2 KSS: 0.67 (CALIOP, COT>0) L3 bc-rmsd: 8.9% (SYNOP), 9.2% (MODIS) Stability: 0.5%/dec (SYNOP)
Joint Cloud property Histogram	CM-21024 CM-5022	CM-21023 CM-5021	n/a
Cloud top Level	CM-21034 CM-5032	CM-21033 CM-5031	Bias: 230 m / -15 hPa (CALIOP, COT>0.2), 2263 m / -167 hPa (MODIS) L2 bc-rmsd: 2260 m / 119 hPa (CALIOP, COT>0.2) L3 bc-rmsd: 1625 m / 90 hPa (MODIS) Stability: -37m/dec (MODIS)
Cloud Phase	CM-21044 CM-5042	CM-21043 CM-5041	Bias: -5.9% (MODIS) L2 KSS: 0.74 (CALIOP, COT>0.2) L3 bc-rmsd : 13.2% (MODIS) Stability: 2%/dec (MODIS)
Liquid Water Path	CM-21054 CM-5052	CM-21053 CM-5051	Bias: 0.1 g m^{-2} (AMSR2) / -15 g m^{-2} (MODIS) L2 bc-rmsd: 49 g m^{-2} (AMSR2)

			L3 bc-rmsd: 11.4 g m^{-2} (MAC-LWP), 10.8 g m^{-2} (MODIS) Stability: 1.6 g/m²/dec (MAC-LWP)
Ice Water Path	CM-21064 CM-5062	CM-21063 CM-5061	Bias: -29 g m^{-2} (DARDARv3.10), -36 g m^{-2} (MODIS), L2 bc-rmsd: 227 g m^{-2} (DARDARv3.10) L3 bc-rmsd: 17.9 g m^{-2} (MODIS) Stability: 0.1 g/m²/dec (MODIS)
Reflected Solar Flux	CM-21302 CM-5321	n/a	n/a
Outgoing Longwave Radiation	CM-21332 CM-5331	n/a	n/a

3.2 Related open actions from previous meetings and SGs

Open actions from previous reviews and SG meetings are listed in Table 3.

Table 3: Open actions from CDOP-3 CLAAS-3 RR, PCR and DRR/ORR.

Action	Actionee	Description	Due Date	Related RID
PCR 3.7 01	PT	PT to consider for the future CPP retrieval adding (heavy) aerosol flags for a L3 product in order to allow a distinction between high aerosol loads, clouds and aerosol/cloud mixtures.	RR CLAAS-4	**[005]**
PCR 3.7 04	PT	PT to check the potential user needs for the next version of CLAAS (CLAAS-4) for an hourly L3 product.	RR CLAAS-4	**[014]**
PCR 3.7 05	PT	PT to consider for CLAAS-4, using dynamic databases of surface albedo and emissivity (e.g. based on SEVIRI- (and FCI-), SNPP and NOAA20 VIIRS, CAMEL, etc.) as an alternative to MODIS.	RR CLAAS-4	**[024/025]**
PCR 3.7 06	PT	PT to explore some specific cases (e.g. forest fires, dust, snow/ice, etc.) for CLAAS-4 in order to optimize the treatment of problematic pixels in the cloud property retrievals.	RR CLAAS-4	[010]
RR 3.7 002 / **CDOP3_ SG4_A11**	PT	SG tasked the PT to implement the action from RR 3.7 CLAAS-3: - PT to consider to include night-time cloud optical and microphysical products for the CLAAS-4. N.B.: This action is out of control of the CDOP 3 SG. Action does not pre-empt any decision on the portfolio of CDOP 4	RR 4.6 on CLAAS-4	**[002]**

DRR 3.7 / ORR 001	PT	PT to assess that in 2011-2012 and after 2018 (especially in night-time), cloud fraction irregularities are not present in the next version of CLAAS (CLAAS-4).	RR CLAAS-4	**[032]**

3.3 Current Planning

The CM SAF Project Plan [AD 1] provides the CM SAF review schedule. The part relevant for RR 4.6 is recalled in Table 4. The RR 4.6 is followed by the Product Consolidation Review (PCR) and the combined Delivery Readiness Review and Operational Readiness Review (DRR/ORR) in the fourth quarter of 2025.

Table 4: Product to review mapping. Proposed updates are given in red.

Product Family	RR 4.6	PCR 4.6	DRR/ORR 4.6
CLAAS-4	~~Q3 2023~~ Q1 2024	Q3 2024	Q4 2025

4 Definition of products and product requirements

This section details the envisaged products and provides information on the traceability of requirements, validation approach, expected users and application areas, and uniqueness. Specific attention will be given to the planned changes and improvements in CLAAS-4 compared with the current edition.

4.1 Products

The aim of the CLAAS data record is to provide a comprehensive characterization of cloud properties. An important boundary condition is imposed by the instrumentation: the SEVIRI passive VIS-IR imager onboard MSG and the Flexible Combined Imager (FCI) onboard MTG. From these types of instruments information about integrated cloud properties and properties near the tops of clouds can be retrieved. Generally speaking, it is not possible to derive information about the vertical structure of clouds. This determines the range of products that are made available in CLAAS.

The CLAAS-4 data record contains the following cloud and radiation products:

- Fractional cloud cover (CFC). On level-2 this involves the discrimination between cloudy and cloud-free pixels, i.e. a cloud mask. The instantaneous cloud masks are aggregated to level-3 cloud fraction.

- Cloud top level (CTO). This product includes the location of cloud tops expressed in three different ways: as cloud top pressure (CTP) in hPa, cloud top height (CTH) in m and cloud top temperature (CTT) in K.

- Cloud phase (CPH). This provides the dominant thermodynamic phase (liquid or ice) of particles near the top of the cloud.

- Liquid water path (LWP). This is the vertically integrated amount of cloud water in kg m^{-2} for pixels with liquid phase near the cloud top. The product contains the (liquid) cloud optical thickness (COT. dimensionless) and particle effective radius (CER, in μm) as additional layers for two realisations corresponding to using 1.6 μm and 3.9 μm channel information, respectively. Additional product layers are liquid cloud droplet number concentration (CDNC, in cm^{-3}) and cloud geometrical thickness (CGT, in m), based on the 3.9 μm CER along the lines of Bennartz and Rausch (2017).

- Ice water path (IWP). Same as liquid water path but then for pixels with ice phase near the cloud top and without CDNC and CGT products.

- Joint cloud histogram (JCH). This is a combined histogram of CTP, COT and CPH, covering the solution space of these parameters. This gridded three-dimensional histogram (i.e., one histogram for each grid point) gives the absolute numbers of occurrences for specific COT-CTP-CPH combinations within specific bins. Worth to mention is that JCH is one of the key products of the CLAAS simulator that has recently been developed (https://github.com/SatelliteSimulators/AVHRR_based_satellite_simulators), which facilitates a cloud type depend evaluation of models against CLAAS data.

- Reflected Solar Flux (RSF): This provides the reflected solar flux at the top of atmosphere (W m^{-2}).

- Outgoing Longwave Radiation (OLR): This provides the outgoing longwave radiation at the top of atmosphere (W m^{-2}).

The proposed key changes from CLAAS-3 to CLAAS-4 are:

- The time series of the CDR will be extended from 2004–2020 to 2004–2024. The CDR will operationally be extended by the ICDR. The time series will feature the transition from Meteosat-11 SEVIRI to Meteosat-12 FCI. The exact time of transition depends on when SEVIRI is replaced by FCI for the nominal 0° service.

- The input to CLAAS-4 will be a SEVIRI Fundamental Data Record (FDR) made available by EUMETSAT. This FDR will feature (a) a re-calibration of the VIS and NIR1.6 channels, similar to the input for CLAAS-3, and (b) additionally re-calibrated IR measurements. It is expected that the latter improve the stability of the CLAAS-4 record. This also addresses the action listed in Table 3.

- The algorithm choice for CPH is reconsidered. The candidate algorithm is based on an Artificial Neural Network as part of the SEVIRI_ML software package (https://github.com/danielphilipp/seviri_ml) developed in the ESA CCI+ Clouds project (https://climate.esa.int/en/projects/cloud/). Initial tests showed significantly improved performance compared to the CPH scheme used in CLAAS-3.

- The introduction of TOA upwelling shortwave and longwave broadband fluxes that are consistent with the cloud properties derived. Considering older, precursor CM SAF TOA products for SEVIRI (SEVIRI/GERB and MVIRI/SEVIRI, see section 3.1) the main improvements of the new TOA radiation record in CLAAS-4 will be:

  - New narrowband-to-broadband relations (with possible adaptions according to the ACACIAS report [RD 8]).
  - New Angular Distribution Models (ADMs) with implementation of the 4th version of NASA CERES ADMs.
  - Better spatial and temporal resolution with the delivery of the L2 (native MSG grid) 15 min product and the L3 hourly (0.05° grid) product.
  - The full CLAAS-4 CDR period (2004-2024) is covered, and an operational extension is foreseen in the form of an ICDR
  - Better consistency in time (no more discontinuities between GERB and GERB-like)
  - In addition, specifically with respect to MVIRI/SEVIRI, the main improvement of the new TOA radiation record in CLAAS-4 will be the availability of the clear-sky fluxes, allowing the user to quantify the cloud radiative effect.

- Minor updates in the existing PPS and CPP cloud algorithms, including for example retraining of ANNs based on new L1 data or threshold calculations in PPS now also done for larger scan angles (>70°).

Additional notes:

- A specific CPP version for above-cloud absorbing aerosol (ACA) cases, developed in the ACACIAS Federated Activity [RD 7], has been shown to provide improved CER retrievals when using the 1.6 μm NIR channel. However, since CLAAS-4 will (as CLAAS-3) include a CER retrieval based on the 3.9 μm channel, which is much less affected by ACA, and since these ACA situations are rather specific and localized and do therefore not fit well in the general CLAAS framework, the ACACIAS scheme will not be included in CLAAS-4.

- The development of night-time (IR-based) cloud optical and microphysical products (as mentioned in Action CDOP3_SG4_A11 in Table 3) was considered. Such retrievals are feasible and work best for relatively thin clouds (COT smaller than about 7), see for example Wang et al. (2016a) for an optimal estimation retrieval based on MODIS data. The restriction to thin clouds is an important limitation and in addition IR-based retrieval products have different characteristics than VIS/NIR-based products (e.g., Wang et al., 2016b). For these reasons, and in view of the considerable required development effort, it was decided not to add night-time cloud optical and microphysical products to the CLAAS-4 portfolio.

- The 1d histograms for CTO and CWP are removed from the product portfolio due to no user uptake.

4.2.1 Traceability of requirements

The CLAAS records serve various applications (see Section 6), many of which are related to regional climate studies, model evaluation and process studies. Requirements for the use of Essential Climate Variables (ECVs) observations within the climate community have been formulated by the World Meteorological Organization (WMO) in the Global Climate Observing System (GCOS) reports [GCOS-107] and [GCOS-154], and its latest update [GCOS-245]. These reports focus on global applications and give target requirements in terms of horizontal, vertical, and temporal resolution, as well as ‘accuracy’ (in [GCOS-245] now given as ‘uncertainty’) and stability (needed to detect expected long-term trends). [GCOS-245] does not give separate requirements for systematic and random uncertainties. Therefore, different sources of requirements are considered.

While in earlier GCOS reports only target requirements were given, the latest GCOS report ([GCOS-245]) presents the three requirement categories Goal (G), Breakthrough (B) and Threshold (T), which are defined as:

- Goal (G): an ideal requirement above which further improvements are not necessary.

- Breakthrough (B): an intermediate level between threshold and goal which, if achieved, would result in a significant improvement for the targeted application. The breakthrough value may also indicate the level at which specified uses within climate monitoring become possible. It may be appropriate to have different breakthrough values for different uses.

- Threshold (T): the minimum requirement to be met to ensure that data are useful.

Reviewing these definitions, the B requirements seem to be the most appropriate in the context of defining CLAAS-4 requirements. However, some breakthrough requirements are less strict than the target requirements in [GCOS-154].

For cloud properties the target horizontal and temporal resolution requirements in [GCOS-154] were 50 km and 3 hours, respectively, while in [GCOS-245] the B requirements are 100 km and 24 hours. For TOA radiative fluxes the [GCOS-154] target horizontal and temporal resolution requirements were 100 km and 30 days, in contrast to the B requirements of [GCOS-245], which are 50 km and 24 hours.

In climate research and particularly in regional climate studies, however, substantially higher spatial and temporal resolutions are requested. For example, in the World Climate Research Program (WCRP) Europe Coordinated Regional Downscaling Experiment (EURO-CORDEX) initiative (Jacob et al., 2014) regional climate simulations with a horizontal resolution of 12.5 km were presented. Similarly, while CORDEX has so far been limited to 3-hourly resolutions, there is a tendency to go to higher temporal frequencies.

Therefore, the CM SAF aims to provide cloud and radiation products at a spatial resolution of ≈5 km and a temporal resolution of 15 minutes. Such resolutions are enabled by the geostationary MSG-SEVIRI instrument, and allow an excellent description of the diurnal cycle of cloud properties as well as cloud lifetime/tracking applications.

As validation metrics we use the bias and the bias-corrected root-mean-square deviation (bc-rmsd) to reflect systematic and random components of uncertainty, respectively (RD-1, Loew et al., 2017). These metrics are applied over the SEVIRI disk (or a collection of surface stations in the disk) with respect to a certain reference data record. Threshold, target and optimal values of the metrics are defined, which shall not be exceeded for any month in the CLAAS-3 record. It should be noted that, while the requirement for bias of a certain cloud or radiative flux property may be fulfilled, the errors compared to the reference observations can be considerably larger locally (i.e. for subsets of the disk) and in specific conditions (e.g., over bright surfaces, for broken clouds, or for warm clouds during night). Such conditions will be exemplified in the validation report. Furthermore, the requirements must be understood in relation to the measurement sensitivity and spatial resolution of the SEVIRI instrument, and this will be taken into account in the validation process. For example, in the validation of cloud properties with CALIPSO lidar observations the limited sensitivity of SEVIRI to thin clouds and its coarser spatial resolution will be accounted for by filtering out the thinnest portion of CALIPSO-observed clouds and using a CALIPSO aggregated product at a resolution close to that of SEVIRI, respectively.

For level-2 the accuracy requirements are defined with the same metrics, except for the ‘binary’ products, cloud mask and cloud phase. These products distinguish between two events: clear or cloudy and liquid or ice, respectively. For such products a range of quality indicators can be defined based on the 2x2 contingency table (Table 5), of which we discuss in this report:

- Probability of detection (POD) for event 1, 2: $\frac{n_{11}}{n_{11}+n_{21}}$, $\frac{n_{22}}{n_{22}+n_{12}} \in [0,1]$

- False alarm ratio (FAR) for event 1, 2: $\frac{n_{12}}{n_{11}+n_{12}}$, $\frac{n_{21}}{n_{22}+n_{21}} \in [0,1]$

- Hanssen-Kuipers Skill Score (KSS): $\frac{n_{11}n_{22}-n_{21}n_{12}}{(n_{11}+n_{21})(n_{12}+n_{22})} \in [-1,1]$

These scores can be viewed as measures of precision.

Table 5: Contingency table for the 2x2 problem. $\mathbf{n_{ij}}$ is the number of cases where CLAAS reports event i and the reference reports event j. For example, event 1 may be clear and event 2 may be cloudy.

	Reference reports 1	Reference reports 2
CLAAS reports 1	n_{11}	n_{12}
CLAAS reports 2	n_{21}	n_{22}

As for CLAAS-4 binary cloud properties, we will use an evaluation metric that gives a relative complete picture, namely the KSS, with which CM SAF has good experience (e.g. Karlsson and Johansson, 2013). The KSS reflects how well events and no-events can be separated, and it is symmetrical in that respect. It takes values between -1 (complete discrimination failure) and 1 (perfect separation). Negative values imply that the method has no skill. In case of rare events, more suitable skill scores are available (e.g., Ferro and Stephenson, 2011), but cloudiness and cloud phase are typically not rare events, so KSS appears fit for our purpose. For the updated requirements we translated the previous POD and FAR values to corresponding KSS values at typical mean (liquid) cloud fractions.

The CDR part of the CLAAS-4 record will have a length of 21 years. Even if this does not yet approach the ‘climate length’ of ~30 years, it can be sufficient to detect regional trends in cloud properties. Therefore, temporal stability is an important requirement for the data record, and corresponding requirements will be formulated.

The required accuracy for the respective cloud and radiative flux products is detailed below. The focus is on the target requirements. If not specified otherwise, the threshold and optimal requirements are normally set to twice and half the target requirement, respectively. It should be noted that we propose to not change the requirements for CLAAS-4 cloud properties compared to CLAAS-3 due to no major retrieval updates being implemented. The requirements for radiative fluxes will be new in a sense as these properties are new in the CLAAS product portfolio.

Fractional cloud cover (CM-21016)

For level-2 data we propose the same target requirement value of KSS=0.6 as in CLAAS-3, which was derived from combining requirements for POD (target > 90 %) and FAR (target < 15 %) for a typical cloud fraction value of 65% in a Federated Activity (FA_OSI_LSA_CM_13_01) between OSI SAF, LSA SAF and CM SAF. Furthermore, we propose to keep KSS=0.5 and 0.8 as threshold and optimal requirements, respectively.

In [GCOS-154] the accuracy requirement for cloud fraction was defined as a range of 1–5 %, dependent on cloud emissivity. In [GCOS-245] the cloud cover requirements are 3%, 6% and 12% for G, B and T. For CLAAS-3 CFC the target bias requirement was set to 5 %, which we propose to keep for CLAAS-4, because no major retrieval developments have taken place for CLAAS-4.

Typically, we have set the target for the level-3 bc-rmsd, as a measure of precision, to twice that for the bias. For CLAAS-4 CFC daily and monthly means this implies a target bc-rmsd of 10 %.

The temporal stability advised by [GCOS-154] was a range of 0.3–3 %/decade. In [GCOS-245] this was refined to 0.3, 0.6, 1.2 %/decade for G, B and T, respectively, which is stricter on the upper end. For CLAAS-3 the target requirement for stability of the bias was defined to be somewhere in the middle of this range: 2 %/decade. This requirement was met when conducting the validation [RD-2]. For CLAAS-4 a new FDR will become available which ideally should increase stability. Due to the non-negligible uncertainty introduced when using a new input stream, we propose to not further tighten the target requirement but rather leave it at 2%/decade. The corresponding threshold and optimal values remain at 5 %/dec and 0.5 %/dec, respectively.

Joint cloud histogram (CM-21024)

This combination of products was introduced for studying the evolution of various cloud regimes in time and space and stems from some pioneering International Satellite Cloud Climatology Project (ISCCP) work (e.g., by Jakob and Tselioudis, 2003). The main strength of the histograms is that they provide a very condensed and easily interpreted way of analyzing some of the most essential features of cloud appearance. No separate requirements are formulated for the JCH product, since its accuracy depends on that of the underlying products CTP (part of CTO, CM-21034), COT (part of LWP/IWP, CM-21054/CM-21064), and CPH (CM-21044), which have their own requirements.

Cloud top level (CM-21034)

In [GCOS-245] requirements for cloud top pressure were replaced by requirements for cloud top height, for which the accuracy G, B, T requirements were newly defined: 0.3, 0.6 and 1.2 km, respectively. Cloud top pressure, height and temperature are closely related. Therefore, a set of requirements for one of these quantities would be sufficient. With CTH we pick the newly introduced ECV in [GCOS-245] , which is also closest to what is primarily measured with active sensors (e.g., CALIPSO) which we usually use as reference.

For CLAAS-3 the L2 products target requirements for accuracy, precision and stability were set to 800 m, 2400 m and 270 m/dec. For CLAAS-3 L3 products the precision requirements were set 1600 m. The CLAAS-3 evaluation showed that these target requirements are meaningful targets but can't be tightened. Thus, we propose to keep these product requirements for CLAAS-4.

Cloud phase (CM-21044)

For CLAAS-3 level-2 data the target accuracy requirement was set to KSS=0.6, which was derived from requirements for POD and FAR from NWCSAF [RD 3]. This is the same value as obtained for the cloud mask. Therefore, we propose to also set the other requirements identical to those for the cloud mask, implying threshold and optimal requirements of KSS=0.5 and KSS=0.8, respectively.

Since CPH is not a GCOS ECV, no guidelines for target accuracy are available for this parameter. For CPH we propose to follow the cloud mask and define a target bias of 5 % for the fraction of water clouds (relative to the total cloud fraction), a target bc-rmsd of twice this value, i.e. 10 %, and a target stability of 2 %/decade. These numbers and rationale are identical to CLAAS-3.

Liquid water path (CM-21054)

For CLAAS-3 we derived the LWP target requirements of 10 g/m² for accuracy, 50 g/m² for L2 precision, 20 g/m² for L3 precision and 3 g/m²/dec for stability. These values were derived amongst others from the relative target requirements (in %) given in [GCOS-154] and following the rationale above to double the numbers for the target requirements for L3 precision. As the B requirement in [GCOS-245] of 100 g/m² not further tightens these requirements and given the fact that no major updates will be implemented for LWP and IWP retrievals, we propose to keep the same numbers for CLAAS-4 as for CLAAS-3. An exception is made for the L2 precision requirement, which turned out to be challenging in CLAAS-3 and which we propose to weaken to 100 g/m², still very much in line with [GCOS-245].

Note that [GCOS-245] includes separate requirements for cloud optical thickness and effective radius. While these ECVs are included in the CLAAS-3 LWP and IWP products we propose to not introduce formal requirements for them, since it is very hard or impossible to find proper reference measurements for large-scale validation.

Ice water path (CM-21064)

The GCOS accuracy requirement for IWP is identical to LWP in [GCOS-154] and [GCOS-245]. However, from a retrieval point of view the uncertainties in IWP are larger than in LWP, mainly because assumptions on ice crystal habits have to be made. Therefore, we propose to apply relatively less strict CLAAS-4 requirements for IWP than for LWP (increase values by a factor 2, as also done for CLAAS-3). Specifically, we propose to set the target requirements to 20 g/m² for accuracy, 200 g/m² for L2 precision, 40 g/m^2, for L3 precision and 6 g/m²/dec for stability.

Reflected solar flux (CM-21302) and Outgoing longwave radiation (CM-21332)

As these two products are new in CLAAS-4, the requirements discussion is done more comprehensively. The WMO Global Climate Observing System (GCOS) defines the TOA RSF and OLR as Essential Climate Variables (ECVs) together with their associated requirements.

Regarding spatial resolution, the GCOS "goal" requirement of 10km will be achieved since the RSF and OLR products, derived from the SEVIRI instrument (~3km footprint at nadir), will be developed and released on native SEVIRI grid and on a 0.05°x0.05° regular lat-lon grid. Concerning temporal resolution (i.e., sampling frequency), the GCOS "goal" requirement (hourly resolution) will be overcome since the products, derived from the SEVIRI instrument, will be available every 15 minute. In addition, the products will be available with a temporal resolution of monthly, daily, hourly, as well as monthly mean diurnal cycle.

With respect to uncertainty, the requirements from [GCOS-245] are not followed because they are meant for globally averaged fluxes: this is mentioned by Ohring et al. (2005) on which the requirements are based ("*The spatial scale of interest to the workshop is generally that of global averages*"), and it was also explicitly mentioned in [GCOS-200] ("*Earth Radiation Budget parameters: Requirements on global mean: 1 W/m²*"). However, the CLAAS-4 TOA flux products don't have a global FOV, and furthermore the intended use of the products is wider than just calculating global means and global mean trends. Indeed, the spatially-explicit (i.e.,"regional") use of the data is of prime importance, and therefore the requirements will be defined in terms of regional uncertainty: for each hourly/daily/monthly mean, this is quantified by the spatial bc-rmsd (bias corrected RMS of the gridded bias map) between a high-quality state-of-the-art reference data record and the CLAAS-4 TOA flux product. The latter will be regridded to match the coarser grid of the reference data. The implemented requirements are partially adopted from existing CM SAF RSF and OLR products CM-23311 and CM-23341 [RD 5], CM-21301 and CM-21331 [RD 4], CM-11312 and CM-11342 [RD 6], which were defined by taking into account a review of known (typical) usage of the products (i.e., proxy for user needs). An overview of the requirements is given in Table 6. For the newly introduced hourly and L2 products, the requirements will be relaxed by a factor of 4 with respect to the monthly mean requirements (as a combination of the existing factor 2 relaxation between monthly mean and daily mean, and between monthly mean and monthly mean (hourly) diurnal cycle).

Table 6: Uncertainty requirements for CM-21302 and CM-21332.

Products		Threshold requirement (W/m²)	Target requirement (W/m²)	Optimal requirement (W/m²)	Remarks
RSF (all and clear sky)	L3 Monthly Mean (MM)	8	4	2	Requirements refer to: - At 1 standard deviation (RMSD) - At 1°x1° scale - Taking only VZA<60° - Does not include bias due to the absolute calibration (use of bc-RMSD) -for products with a strong diurnal cycle (RSF L2 and L3 hourly and MMDC) the requirement refers to average illumination conditions.
	L3 Daily Mean (DM)	16	8	4	
	L3 MM (hourly) Diurnal Cycle (MMDC)	16	8	4	
	L3 Hourly Mean (HM)	32	16	8	
	L2 (15 min)	32	16	8	
OLR (all and clear sky)	L3 Monthly Mean (MM)	4	2	1	
	L3 Daily Mean (DM)	8	4	2	
	L3 MM (hourly) Diurnal Cycle (MMDC)	8	4	2	
	L3 Hourly (HM)	16	8	4	
	L2 (15 min)	16	8	4	

Those numbers should be understood at “1 standard deviation” which means that, assuming a normal distribution of the error, (only) 68% of the FOV should have accuracy better than the threshold/target/optimal requirements. To get a better idea of the maximum error that could affect the dataset, the user may consider the error at “2 standard deviations” by simply doubling those figures (this accuracy is expected to be fulfilled over 95% of the FOV).

For products with a strong diurnal cycle (RSF L2 and L3 hourly and MMDC) the requirement refers to average illumination conditions. This is done by scaling the sub-daily error according to the ratio of illumination conditions at that time with respect to the daily mean illumination conditions.

The stability requirements (expressed in *W/m²/decade*) refer to the maximum allowed change in systematic error (i.e. mean bias) per decade of the CLAAS-4 TOA flux w.r.t. a reference product. Similar to the uncertainty, we also adopt existing requirements for CM SAF RSF and OLR products (Table 7).

Please note that the expected additional (relative) error expected for clear-sky fluxes, due to the cloud screening process and possible sub-pixel cloud contamination not detected by the cloud mask, should be compensated by lower absolute values of clear-sky fluxes with respect to all-sky fluxes. In addition, to target similar error and stability seems crucial as they are expected to be used together to estimate cloud radiative effect.

Table 7: Stability requirements for CM-21302 and CM-21332.

Products	Threshold requirement (W/m²/decade)	Target requirement (W/m²/decade)	Optimal requirement (W/m²/decade)
RSF (all and clear sky)	2	0.6	0.3
OLR (all and clear sky)	2	0.6	0.3

4.2.2 Validation approach

Validation of cloud products is a complicated task because for many cloud parameters no single data record exists that can serve as a true reference. An exception are data records of cloud cover, cloud-top phase and cloud-top height provided by the spaceborne lidar and radar sensors CALIPSO-CALIOP and Cloudsat-CPR. However, these instruments were not present prior to 2007 and provide data at only two specific overpass times. Similarly, ground-based observations do not provide all cloud parameters and are normally restricted to a small number of surface sites, with limited coverage outside the developed world and over the ocean.

For these reasons, we aim at an evaluation approach, broader than strict validation, which characterizes the data products by comparison with various data records, taking the respective sensitivities into account. These comparisons can then complement each other, giving a more complete picture of the quality of the CLAAS-3 products. Similarly, the evaluation is not restricted to the parameters and scope included in the PRD tables. For example, products will be separately evaluated for daytime and night-time when applicable, because product characteristics typically depend on the availability of shortwave channels. Another example is that in the case of CTO not only the parameters CTH, for which requirements have been formulated, will be covered, but also CTP and CTT. As a final example, the layers in the LWP and IWP products, such as cloud optical thickness and particle effective radius, will be evaluated separately.

In the following, the validation/evaluation approach and data sources are discussed per cloud product. For all products, MODIS and VIIRS will be considered as important reference instruments for evaluation of CLAAS-4. This includes the official MODIS cloud products from the latest available collection (currently 6.1: Platnick et al., 2017). MODIS makes similar measurements as SEVIRI, but it has many more channels and is mounted on the polar orbiters Terra and Aqua. Therefore, it is very well suited not only to evaluate the level 2 and 3 products for the SEVIRI field of view but also to study the dependence of the measurement quality on the viewing zenith angle. Since the MODIS instruments are approaching their end of life and the Terra and Aqua platforms are not kept in stable orbits anymore, the combined Aqua MODIS and SNPP/NOAA-20 VIIRS continuity products (CLDPROP: Frey et al., 2020; Platnick et al., 2021) will also be considered.

Fractional cloud cover (CM-21016)

The main source of validation observations for CFC is the space-based CALIPSO-CALIOP lidar instrument. Cloud observations from this sensor are available from 2007 onwards, and they provide more direct and easily interpreted observations of cloud detection and vertical cloud structure than passive methods. Also, the CALIOP data are available in a format where the point measurements were aggregated to a horizontal resolution of 5 km which is very similar to SEVIRI's pixel size. As demonstrated by Karlsson and Håkansson (2018) the CALIOP cloud optical thickness information can be used to determine the cloud detection sensitivity of passive imagers. This sensitivity will be accounted for in the validation process by filtering out the CALIOP-observed clouds below a certain optical thickness threshold, typically around 0.2. In RD 3 and Benas et al. (2017, 2023) extensive validation of the CLAAS-2 and CLAAS-3 cloud masks with CALIOP was presented, and we intend to continue the same approach for CLAAS-4. This work will likely be extended by including EarthCARE active sensor products when available.

In addition, cloud observations made at meteorological surface synoptic stations (SYNOP) will be used as input for the validation of cloud cover. Drawbacks of SYNOP observations are that they are performed in varying ways (e.g., human observers or ceilometers with different sensitivities to high clouds), that their quality is not uniform, and that they have limited coverage outside the developed world and over the ocean. However, especially due to their long-term availability, they remain a useful reference data record suitable for monitoring and validating space-based estimations of cloud coverage. Finally, MODIS and VIIRS are used as references for L3 product evaluation.

Joint cloud histogram (CM-21024)

The Joint Cloud Histogram will be not be validated separately as it consists of the histogram components CTP, COT, and CPH. However, JCH will be inter-compared with similar histogram data from the official MODIS product.

Cloud top level (CM-21034)

The main validation data source for the cloud top level products will be CALIPSO. With the vertically resolved cloud top data from CALIOP it is possible to analyze the effective detection range of a passive instrument such as SEVIRI. In RD-3 and Benas et al. (2017, 2023) extensive validation of the CLAAS-2 and CLAAS-3 cloud top level products with CALIOP was presented, and we intend to continue the same approach for CLAAS-4. Similar to CFC, the limited sensitivity of SEVIRI to the highest thin cloud layers will be accounted for in the validation process. As for Fractional cloud cover (CM-21016), the evaluation will include using EarthCARE data as another reference if and when available.

As additional evaluation, the SEVIRI-derived monthly mean products will be evaluated with MODIS and VIIRS, comparable sensors in terms of measurement technique and footprint.

Cloud phase (CM-21044)

As for CFC and CTO, CALIPSO (and potentially EarthCARE) will also be used as the main reference to validate the CPH product, exploiting the layer optical thickness information in the validation process as for CFC and CTO. This validation will be complemented by comparisons with MODIS/VIIRS data.

Liquid water path (CM-21054)

For LWP, passive microwave (PMW) imagers provide a useful reference. We plan to perform pixel-based comparisons with the Advanced Microwave Scanning Radiometer 2 (AMSR2). Note that this validation will be carried out at the resolution of the PMW pixels, which is coarser than that of SEVIRI. In addition, level-3 LWP will be compared with the MAC-LWP climatology presented in Elsaesser et al., (2017). Although these observations are a very useful reference, some of their limitations have to be acknowledged: PMW LWP observations are characterized by a number of systematic errors (e.g., Seethala and Horvath, 2010), have a considerably coarser resolution than the SEVIRI observations, and are available over ocean only. For all comparisons against PMW LWP, CLAAS-4 all-sky LWP will be used.

MODIS/VIIRS LWP retrievals will be used for additional evaluation, as they constitute an important reference to study longer-term homogeneity, as well as to pinpoint potential algorithm deficiencies.

Ice water path (CM-21064)

For IWP, the DARDAR product (Cazenave et al., 2019; Delanoë and Hogan, 2008) is probably the best reference, as it combines the sensitivities of the CALIPSO lidar to thin ice clouds with that of Cloudsat to thicker clouds. DARDAR will be used for the validation of CLAAS-4 level-2 IWP, while comparisons with MODIS and VIIRS will be used for further evaluation as for the other cloud products.

Reflected solar flux (21302) and Outgoing longwave radiation (21332)

The main validation data source to evaluate TOA RSF and OLR products, both for all-sky and clear-sky conditions, will be CERES (Wielicki et al., 1996; Loeb et al., 2016). The processing error (a.k.a. regional uncertainty) of the newly produced CLAAS-4 gridded Level-3 TOA radiation products (monthly, daily, hourly, monthly mean diurnal cycle) will be assessed by the (spatial) bc-rmsd between gridded CLAAS-4 TOA flux and gridded reference product, defined for each time step (monthly, daily,..). Reference data records include CERES EBAF ed4.2 (Loeb et al., 2018; Kato et al., 2018), CERES SYN-1deg ed4.2 (Doelling et al., 2013; Doelling et al., 2016) and HIRS-OLR v01r02 (Lee, 2014; Lee et al., 2014). In addition, our products will be compared with historical CM SAF SEVIRI/GERB and MVIRI/SEVIRI products. CERES EBAF will only be used for monthly comparison as is it not available at higher temporal resolution. It is worth noting that CERES SYN-1deg data make use of geostationary satellites (among which Meteosat) which are then scaled so that they match the polar orbiting CERES observations. Thus, Meteosat-based CLAAS4 flux products are not fully independent from CERES SYN-1deg. However, CERES SYN-1deg products don't use only Meteosat 0° data but also GOES-East (for longitude < -37.5°E) and Meteosat Indian ocean (for longitude > 20° or 30°W). Therefore, the comparison is still meaningful out of central band of longitude.

In the Product Requirements Document (PRD) [RD 1], this processing error (regional uncertainty) is referred to as 'precision'.

The term 'accuracy' in the PRD [RD 1] conventionally refers to the 'global mean' (i.e. FOV-mean) bias. The absolute radiometric level is important for global Earth imbalance studies, but for process studies, this absolute level is generally a less critical element. Since the CLAAS-4 RSF and OLR products rely on empirical relations with the CERES products (for NB-to-BB, for ADM,..), their radiometric level is considered 'tuned' (not independent) to this reference record. Furthermore, there are significant spatial (i.e., regional) bias variations, leading to large compensation effects. For these reasons, the absolute global/FOV mean bias itself is not considered a meaningful uncertainty metric for the CLAAS-4 TOA flux products, and no attempt is done to set requirements for this metric. However, the CLAAS-4 mean bias w.r.t. other data records, i.e. how CLAAS-4 and these other data records are scaled compared to the absolute level of the CERES reference products, will be analysed.

The stability will be evaluated by analysing the temporal evolution (trends) and discontinuities (jumps) in the time series of deseasonalized 'global' (i.e., FOV) mean bias, calculated w.r.t. products CERES EBAF, CERES SYN-1deg, HIRS-OLR which are known to be stable reference records.

Concerning the Level-2 products (instantaneous with 15min-interval), validation will be performed by comparing with observations from the GERB L2 product and/or the CERES Single Scanner Footprint (SSF) product (Su et al., 2015a and 2015b) that are collocated, simultaneous, and coangular with CLAAS4 TOA flux observations. Possibly also EarthCARE L2 observations will be used to validate in the same manner.

4.2 ICDR

The ICDR regularly extends the associated CDR until present time. To the maximum extent possible the ICDR is based on the same input data, scientific approaches, algorithms and processing system as the CDR. The goal is that output from the ICDR is identical to output from the CDR if run in parallel. The intention is to provide to the users a consistent data record based on CDR and ICDR output.

The quality of the ICDR and how it relates to requirements is assessed in two steps:

1) ORR: the Operational Readiness Review takes place prior to the first release of the ICDR. Usually it is conducted in parallel to the DRR of the associated CDR. If both reviews are successfully passed and approved by SG, the combined CDR and ICDR data record is released. The objective of the ORR is to showcase the level of agreement between CDR and ICDR and a first impression on continuous quality of the ICDR after end of CDR. Thus, the ICDR is compared to the CDR using output over a mutual time period to assess the degree of similarity. Additional validation and/or comparisons to external (reference) data records are carried out for the period after the end of the CDR. The output from ORR does not define the Service Specifications. Requirements defined in this RR document are the baseline for this review and the initial Service Specifications.
2) OR: the Operations Review is carried out annually and assesses the compliance of operational CM SAF products, i.e., ICDRs, with Service Specifications. A key objective is to regularly showcase continuous quality and document it. Baseline for the ORs are the Service Specifications.
   During the ORR the focus is on the similarity between CDR and ICDR. With sufficient temporal coverage of the ICDR validation results presented during an early OR will then be used to fine tune the Service Specifications of the ICDR.

4.2.1 Traceability of requirements

The concept of fully consistent CDR and ICDR processing is not achievable given the latency constraint, availability of input data and efforts needed to guarantee quality of input at the same level as for the CDR. Consequently, differences between output from the ICDR and the CDR are expected. Thus, the threshold requirements of the CDR constitute the target requirements of the ICDR. Threshold and optimal requirements are not defined.

4.2.2 Validation approach

During the ORR output from the ICDR will be compared to output from the CDR for an overlap period of approximately 1 year. This evaluation will document the level of CDR-ICDR consistency at the time of CDR-ICDR transition.

During the subsequent, annual ORs the ICDR will be evaluated by comparisons to available reference data streams. These include NASA's merged MODIS+VIIRS time series and

SYNOP for cloud properties, and CERES-EBAF and CERES-SYN1deg for the TOA radiation products.

5 Expected users and application area

5.1 Cloud properties

The users of the CLAAS cloud data records have been mainly scientists performing climate studies. The previous CLAAS releases have been used in scientific studies for various applications. An overview of peer-reviewed papers in which CLAAS cloud data are used is given in Table 8.

Table 8: Overview of peer-reviewed studies in which CM SAF CLAAS cloud products have been used. The first and second column list the lead author and year of publication, respectively; full references can be found in Section 11. The third column mentions the data record used (1β = CLAAS-1 beta-release, 1 = CLAAS-1, 2 = CLAAS-2, 2.1 = CLAAS-2.1, 3 = CLAAS-3). The remaining columns contain further details on which data was used for what application.

Author	Year	Ed.	Parameter	Level	Region	Period	Application
Greuell	2011	1β	CFC, CTT, LWP, IWP, CER	L2	Africa	July 2006	model evaluation - clouds + radiation
Hanschmann	2012	1β	CPH, COT, CER, LWP	L2	Atlantic Ocean	Nov 2007	estimation cloud radiative effect
Pfeifroth	2012	1β	CFC	L3 mmdc	MSG disk	2004-2007	model evaluation - CFC diurnal cycle
V Weverberg	2012	1β	COT, CTP	L2	Belgium	2006-2008	model evaluation - convective activity
Kniffka	2014	1	CFC, LWP	L2	MSG disk	2009	LWP characterization
Alexandri	2015	1	CFC, COT, CER	L3 dm	Europe	2004-2009	model evaluation - surface radiation
Kotarba	2015	1	CFC	L3 mm	Central Europe	2004-2009	intercomparison satellite cloud cover
Werkmeister	2015	1	CFC	L2	Hannover	July-Sep 2009	comparison with ground-based obs.
Zak	2015	1	CFC	L3 mm	Czech Republic	2004-2011	merging with surface observations
Brisson	2016	1	COT, CTP	L2	Belgium	2004-2010	model evaluation - convective activity
Hill	2016	1	CFC, CTP	L2	southern West Africa	2004-2008	climatology of clouds, precip and radiation
Kotarba	2016	1	CFC	L3 mm	Poland and surrounding areas	2004-2009	Comparison with climatology from MODIS
Martins	2016	1	CFC	L3 mmdc	Iberia	2004-2011	characterization cloudiness diurnal cycle
Nickovic	2016	1	IWP	L3 dm	Mediterranean	May 2010, Sept 2012	model evaluation - cloud ice
Pfeifroth	2016	1	CTT	L3 mmdc	West Africa	2004-2010	characterization precipitation diurnal cycle
Ruiz-Arias	2016	1	CFC	L3 mm	Spain	2004-2011	model evaluation - cloud amount
Alexandri	2017	1	CFC, COT	L3 dm	Mediterranean	2004-2009	climate study - surface radiation
Fuchs	2017	1	CFC, CTO, CPH, COT, CER, LWP	L2	Southeast Atlantic	2004-2010	process studies - stratocumulus

Garcia-Carrera	2017	2	CFC	L3 mm, mmdc	Saudi Arabia	2004-2015	Effect of land irrigation on cloud cover
Salgueiro	2017	1	CPH, COT, CER	L2	Iberia	March-May 2011	intercomparison satellite retrievals
Meyer	2017	1+2	CFC	L2	southern Africa	2004-2012	cloud mask for rainfall retrieval
Knippertz	2017	2	CFC, CTO	L2	West Africa	June-July 2016	meteorological and chemical analyses
Mackie	2017	2	LWP, IWP	L3 dm	Niger, Niamey	2006	Model evaluation with NWP model output
Musial	2017	2	CFC, CTH, COT, CER, LWP, IWP	L3 mmdc	Central Europe	2004-2015	Correction of the diurnal cycle of retrieved cloud climatology
Taylor	2017	2	CTT	L2, L3 mmdc	MSG disk	2004-2015	characterization CTT diurnal cycle
Bobryshev	2018	2	CFC	L2	Lindenberg	2009-2015	cloud filtering for water vapor retrieval
Bojanowski	2018	2	CFC	L3 mm	MSG disk	2004-2015	intercomparison satellite cloud cover
Egli	2018	2	CFC	L2	Europe	2006-2015	cloud mask for fog retrieval
Gristey	2018	2	CTH, CWP	L2	MSG disk	July 2006	model evaluation - outgoing radiation
Seethala	2018	2	CFC, CPH, CTT, COT, CER, LWP	L2	Southeast Atlantic	Dec 2010 - Nov 2012	characterizing Sc cloud diurnal cycle
Drönner	2018	2	CMA	L2	Central Europe	2004-2010	training 2d CNNs for cloud detection
Young	2018	2	CPH, COT, CER	L2	MSG disk	June-Sept 2004-2015	retrieval of warm rain occurrence
Kostov	2018	2	CWP, CPH	L2	St Petersburg	2012-2014	comparison of LWP to ground remote sensing
Rau	2018	1	CMA	L2	Austria	2014	Determination of dispersion categories
Benevides	2019	2	CTO	L2	Lisbon	2011-2015	Training of NN to forecast precipitation
Coopman	2019	2	CMA, CTT, CPH, CER, COT	L2	Europe	May-Sep 2012-2015	Cloud life cycle, process studies
Mallet	2019		LWP, COT, CER	L2	SE Atlantic	2016	model evaluation
Fragkos	2019	2	CFC day	L3	SE Europe	2005-2015	Assessment of the total precipitable water
Meyer	2019	2	CMA	L2	S Africa	2013-2014	deriving air temperatures
Paszkuta	2019	1	CFC	L3 mm	Baltic	2015	Comparison with cloudiness assessment algorithm
Tsikerdekis	2019	2	CFC	L3	N Africa	2004-2009	model evaluation
Turini	2019	2	CMA	L2	Iran	2004-2015	Cloud mask for rainfall retrieval
Sinitsyn	2020	2	CFC	L3	MSG disk	2004-2015	Input to SW fluxes parameterization scheme
Coopman	2020	2	CMA, CTT, CPH, CER, COT	L2	Europe	Jun-Aug 2004-2015	Cloud process studies, cloud glaciation
Kim	2020	2	CMA, CWP	L2	Germany (3 stations)	2011-2015	Model evaluation

Maranan	2020	2	CPH, CER, COT, CTT	L2	West Africa	2016-2017	stratification of precip. by cloud type.
Mallet	2020	2	LWP, COT, CER	L2	SE Atlantic	2004-2015	model evaluation
Mantsis	2020	2	CFC	L3	NW Africa	2011-2015	Model evaluation
Post	2020	2	CFC	L3	Baltic	2004-2015	Comparison with in situ data
Schwitalla	2020	2	CWP	L2	UAE	July 2017	Validation of WRF simulations
Alexandri	2021	2	CFC	L3 mm, mmdc	Greece	2004-2019	Diurnal cycle correction of cloud radiative effect from MODIS
Coopman	2021	2	CMA, CTT, CPH, CER, COT	L2	Southern Oceans	2010	Cloud process studies, cloud glaciation, Southern Oceans
Kassar	2021	2	CMA	L2	Germany	2017	cloud screening for WV retrieval
Marinou	2021	2	CTT	L2	Greece (Crete)	April 2017	Detection of ice clouds
Meroni	2021	2	CTT	L2	SE Africa	Jan 2017, Mar 2018, May 2018	Validation of WRF simulations
Nickovic	2021	2	CTT	L2	Central and N Africa	June 2009, July 2014	Detection of deep convective clouds
Seelig	2021	2	CMA, COT, CWP, CER, CTH; CTT	L2	Canary Islands and surroundings	Aug 2015	cloud tracking and life cycle analysis
Tornow	2020	2	CER, CPH	L2	inner disk	Jan+Jul 2017	development of ADMs
Rybka	2021	2	IWP	L2	Europe	selected days in 2013, 2015	model evaluation
Pan	2021	2	CPH CTT	L2	Tropics	2004-2013	cloud life cycle and aerosols
Bräuer	2022	2	unknown	L2	Europe	2015	tracking clouds
Kotarba	2022	2	CMA CTH	L2	disk	2005-2016	Assessment of sampling uncertainty for space-based lidar mission
Mabasa	2022	2	CFC	L3 dm	South Africa	2014-2019	cloud masking
Ilić	2022	2	CWP, CPH	L2	Saharan and Middle East	April 2016	Evaluation of dust atmospheric model
Overeem	2023	2	CTY	L2	Europe	2013-2020	Filtering mask for precipitation ddata
Harenda	2022	2	CMA, CTH	L2	vicinity of Rzecin (Poland)	2018	Cloud masking and input to OPAC
Tzallas	2022	2.0	COT, CTP	L2	Europe	2004-2017	composing cloud regime dataset
Amell	2022	2.1	IWP	L2, L3 mmdc	disk	2008-2011	evaluating QRNN retrievals of IWP
Mol (a)	2023	2	CTP, COT	L2	Cabauw area	2014-2016	cloud typing for irradiance variability
Mol (b)	2023	2	CTP, COT	L2	Cabauw area	2014-2016	analysis of irradiance variability

Fons	2023	2.1	CER, LWP	L2	Namibian stratocumulus region	2016-2017	aerosol-cloud interactions
Strada	2023	1	CFC	L3	Euro-Mediterranean region	2004-2015	Evaluation Regional climate–chemistry model RegCM4chem

The applications can be roughly grouped as follows:

- characterization of spatio-temporal distributions of cloud properties
- cloud life cycle analysis and process studies
- (regional) climate model evaluation
- inter-comparison with other satellite data or ground-based observations
- cloud filtering for the retrieval/evaluation of other products

The cloud parameters have been used with varying frequency. Most used are CMA and CFC (48 studies), which is expected because this is the most basic cloud product. The other parameters have been used with the following frequencies: CTO (27), CPH (13), LWP (14), IWP (8), COT (19), CER (17). There is a large number of studies using level-2 data (45 studies) compared to level-3 data (23 studies).

This analysis indicates a diverse group of scientific users with multiple application areas. Apart from this, there are many other users/applications with unpublished results. As an example we mention applications in the solar energy sector, for which not only irradiance measurements but also information about clouds is highly important.

Overall one can conclude that all cloud parameters at both level-2 and level-3 are useful and should thus be continued in the next CLAAS release.

5.2 Radiation properties

The previous CM SAF (CDOP-2) releases of Meteosat-based TOA radiative flux products have been used in scientific studies for various applications. An overview of peer-reviewed papers in which those data are used is given in Table 9: the first and second column list the lead author and year of publication, respectively; full references can be found in Section 12. The third column mentions the data record used: S/G=SEVIRI/GERB (CM-21301, CM-21331) or M/S=MVIRI/SEVIRI (CM-23311, CM-23341). The remaining columns contain further details on which data was used for what application.

Table 9: Overview of peer-reviewed studies in which previous Meteosat-based CM-SAF TOA radiative flux products have been used. Complete list of references can be found in Section 12.

Author	Year	Ed.	Parameter	Level	Region	Period	Application
Hentgen	2019	S/G	OLR, RSF	L3 mm, mmdc	Europe	2004-2008	Model evaluation
Mackie	2019	S/G	OLR RSF	L3 mm	West Africa	2005-2014	Model evaluation
Heim	2023	S/G	OLR	L3 mm	37.5°S - 24.5° N and 54.5°W-28.0° E	2004-2010	Model evaluation
Pfeifroth	2018	M/S	RSF	L3 mm	Europe	1992-2015	Understanding regional climate mechanisms
Song	2018	M/S	RSF	L3 mm	Meteosat FOV	1983-2015	Validation of observational TOA albedo data record
Hentgen	2019	M/S	OLR, RSF	L3 mm, mmdc	Europe	1999-2008	Model evaluation
Zhan	2019	M/S	RSF	L3 mm, L3 dm	Meteosat FOV	1983-2015	Evaluation of TOA albedo data products
Van De Walle	2020	M/S	OLR, RSF	L3 mm, mmdc	Lake Victoria Basin (East-Africa)	2011-2015	Model evaluation
Heim	2021	M/S	OLR, RSF	L3 dm	14.7°W – 10.3°E, 18.4 – 4.8°S	August-September 2016	Model evaluation
Van Lipzig	2023	M/S	OLR, RSF	L3 mm, mmdc	Lake Victoria Basin (East-Africa)	2006-2015	Model evaluation

The CM SAF CDR will be complementary to existing datasets (e.g. HIRS OLR, CERES EBAF, CERES SYN1deg-day, ISCCP-FD, GERB) in particular since the datasets provide the diurnal cycle.

Four main application areas for the TOA radiation CDR have been identified and well described in [RD 5]:

- Understanding regional climate mechanisms.
- Quantification of radiative forcing and studies of atmospheric processes such as cloud feedback mechanisms.
- Evaluation/Improvement of climate and NWP models.
- Use as boundary condition to calculate surface radiative fluxes

In addition, the TOA radiation CDR can be used as boundary condition to calculate surface radiative fluxes. A first step in estimating surface radiation often consists in an accurate estimation of TOA reflected radiation (e.g. the algorithm of Pinker and Laszlo (1992)). This approach is adopted in CM SAF CLARA–A2 and CLARA-A3 [RD 6] and in GEWEX-SRB (Stackhouse et al., 2011).

The above mentioned requirements are suited for those 4 application areas and are supported by the different works cited. It is worth considering that only some applications done with the MVIRI/SEVIRI/GERB observations have been discussed here, and that a significant part of the large body of studies based on CERES data could as well be based on the CM SAF TOA radiation CDR.

6 Uniqueness of products

There are many cloud and radiation data records based on passive VIS-IR imagery. However, most of these rely on polar orbiting sensors, which yield global data records but have very limited temporal resolution. Furthermore, currently there is no other record specifically derived from MSG-SEVIRI holding consistent cloud and radiation properties. The ISCCP data record (Rossow and Schiffer 1999) does use geostationary satellite measurements, including SEVIRI, in combination with polar-orbiting imagers, and recently an update (the H-series) was released (Young et al., 2018b). An important difference is that CLAAS takes full advantage of the many channels of the SEVIRI instrument on board of MSG, while ISCCP only uses the two heritage short- and longwave imager channels. Moreover, CLAAS has higher spatial (3 km vs. 10 km) and temporal (15 minutes vs. 3 hours) resolutions. In addition to adding radiation products, the CDR part of CLAAS-4 will span 4 more years: 2004–2024 instead of 2004–2020, again operationally extended by a ICDR. Another new feature will be the transition from SEVIRI to FCI. On the one hand this will be challenging to implement, but on the other hand will offer L2 products at 10 minutes temporal resolution for the FCI part of the record. Another unique feature is the availability of all-sky and clear-sky fluxes. Combined with the available cloud properties, this facilitates in-depth studies about the cloud radiative effect as well as about its dependence on the time of day and cloud type – and this from temporal and spatial scales of individual cloud objects to annual and decadal scales. This will facilitate further investigating the role of clouds in a changing climate systems.

Another unique aspect is the careful calibration of the L1 data of the SEVIRI instruments. For the shortwave channels inter-calibration will be performed either as previously used and outlined in Meirink et al. (2013) or as currently revised at EUMETSAT using desert targets in the so-called MICMICS framework. EUMETSAT is currently also implementing an approach to intercalibrate SEVIRI's longwave channels. This will likely be available for CLAAS-4 and presumably reduce some of the small but detectable instabilities seen in CLAAS-3 for some variables. These ingredients allow the generation of a cloud and radiation data record that is very stable over time.

7 Summary and Conclusion

In this report the CLAAS product suite has been discussed. Planned changes and improvements in CLAAS-4 compared to CLAAS-3 were presented following user requests, suggestions from previous reviews as well as a comprehensive analysis of the user uptake in peer-reviewed literature.

The product requirements were reviewed and adjusted in a few of cases for cloud properties compared to CLAAS-3, while for the TOA radiation the product requirements were derived more fundamentally as these products are new. Furthermore, approaches to verify whether CLAAS-4 will meet the requirements were outlined for all products. In summary, the CM SAF project team recommends to update the requirements for the CDR products CM-21016, CM-21024, CM-21034, CM-21044, CM-21054, CM-21064, CM-21302, CM-21332 and the corresponding ICDR products CM-5012, CM-5022, CM-5032, CM-5042, CM-5052, CM-5062, CM-5321, CM-5331 as outlined in the Appendix as baseline for the development.

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9 List of Abbreviations

AD	Applicable document
ADM	Angular Distribution Model
AMSR	Advanced Microwave Scanning Radiometer
B	Breakthrough
CALIOP	Cloud-Aerosol Lidar with Orthogonal Polarization
CALIPSO	Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations
CDOP	Continuous Development and Operations Phase
CERES	Clouds and the Earth's Radiant Energy System
CDNC	Cloud Droplet Number Concentration
CDR	Climate Data Record
CER	Cloud particle Effective Radius
CFC	Cloud Fractional Coverage
CGMS	Coordination Group for Meteorological Satellites
CGT	Cloud Geometrical Thickness
CLAAS	CLoud property dAtAset using SEVIRI
CMA	Cloud Mask
CM SAF	Satellite Application Facility on Climate Monitoring
CNRS	Centre National de la Recherche Scientifique
COT	Cloud Optical Thickness
CPH	Cloud Phase
CPP	Cloud Physical Properties

CTH/CTP/CTT	Cloud Top Height/Pressure/Temperature
DARDAR	raDAR/liDAR
DFG	Deutsche Forschungsgemeinschaft
DM	Daily Mean
DRR	Delivery Readiness Review
DWD	Deutscher Wetterdienst (German MetService)
DOI	Digital Object Identifier
EBAF	Energy Balanced and Filled
ECV	Essential Climate Variables
ERBE	Earth Radiation Budget Experiment
ERBS	ERBE Satellite
EUMETSAT	European Organisation for the Exploitation of Meteorological Satellites
FAR	False Alarm Rate
FDR	Fundamental Data Record
FCDR	Fundamental Climate Data Record
FCI	Flexible Combined Imager
FOV	Field Of View
FMI	Finnish Meteorological Institute
G	Goal
GCOS	Global Climate Observing System
GEO	Geosynchronous orbit

GERB	Geostationary Earth radiation budget
HM	Hourly Mean
ICDR	Interim Climate Data Record
ICWG	International Clouds Working Group
IR	Infrared
ISCCP	International Satellite Cloud Climatology Project
IWP	Ice Water Path
JCH	Joint Cloud Histogram
KNMI	Royal Netherlands Meteorological Institute
KSS	Hanssen-Kuipers Skill Score
L2	Level 2
L3	Level 3
LSA SAF	Land Surface Analysis
LWP	Liquid Water Path
MeteoSwiss	Meteorological Service of Switzerland
MFG	Meteosat First Generation
MM	Monthly Mean
MMDC	Monthly Mean Diurnal Cycle
MODIS	Moderate Resolution Imaging Spectroradiometer
MSG	Meteosat Second Generation
MVIRI	Meteosat Visible and Infrared Imager
NASA	National Aeronautics and Space Administration

NB	Narrow Band
NIR	Near IR
NOAA	National Oceanic and Atmospheric Administration
NWP	Numerical Weather Prediction
OLR	Outgoing Longwave Radiation
OR	Operations Review
ORR	Operational Readiness Review
OSI SAF	Ocean and Sea Ice SAF
POD	Probability of Detection
PPS	Polar Platform System
PRD	Product Requirement Document
PT	Project Team
Q	Quarter
RD	Reference Document
RMIB	Royal Meteorological Institute of Belgium
RR	Requirements Review
RSF	Reflected Solar Flux
RT	Radiative Transfer
SAF	Satellite Application Facility
SEVIRI	Spinning Enhanced Visible and InfraRed Imager
SMHI	Swedish Meteorological and Hydrological Institute
SSF	Single Scanner Footprint

SYN	Synoptic Radiative Fluxes and Clouds
T	Threshold
TOA	Top Of Atmosphere
UK Met Office	Meteorological Service of the United Kingdom
VIS	Visible
VIIRS	Visible Infrared Imaging Radiometer Suite
WMO	World Meteorological Organization

10 Appendix A: (Updated) Product requirements CM SAF products under review

The following tables present the products requirements for the CDRs CM-21016, CM-21024, CM-21034, CM-21044, CM-21054, CM-21064, CM-21302, CM-21332, each followed by product requirements of the associated ICDRs (i.e. CM-5012, CM-5022, CM-5032, CM-5042, CM-5052, CM-5062, CM-5321, CM-5331).

Changes relative to the PRD v4.2 are marked in red. These changes follow discussions above, provide more concrete details of a specification or correct obvious inconsistencies/errors.

Table 10: Requirements for the CM SAF product **CM-21016 (CFC CDR)**.

CM-21016	CLAAS-4 Fractional Cloud Cover TCDR	CFC_R5_CLAAS_4_TCDR

Type
Dataset

Input Satellite Data
Operational Satellite:FCI
Operational Satellite:SEVIRI

Application Areas
Climate Modelling and Evaluation

Dissemination Information

Distribution format
L2:NetCDF4
L3:NetCDF4

Generation frequency

Generation timeliness

Spatio-temporal Information

Spatial Coverage
L2:METEOSAT full disk (includes Europe, Africa, Atlantic Ocean)
L3:METEOSAT full disk (includes Europe, Africa, Atlantic Ocean)

Spatial Resolution
L2:HORIZONTAL: native satellite pixel resolution ~$(3\ km)^2$
L3 dm and mm: HORIZONTAL: $(0.05)^2$
L3 mmdc: HORIZONTAL: $(0.25)^2$

Temporal Resolution
L2:Instantaneous: 10/15min
L3:Daily:Mean
L3:Monthly:Mean
L3:Monthly:Mean diurnal-cycle

Temporal Coverage
1/1/2004
12/31/2024

Uncertainty Characteristics			Optimum	Target	Threshold
CFC-Instantaneous	ACCURACY	bias	1 %	5 %	10 %
CFC-Instantaneous	PRECISION	KSS	>0.8	>0.6	>0.5
CFC-Instantaneous	STABILITY	decadal	0.5	2 %	5 %
CFC-Daily Mean	ACCURACY	bias	1 %	5 %	10 %
CFC-Daily Mean	PRECISION	bc-RMS	5 %	10 %	20 %
CFC-Daily Mean	STABILITY	decadal	0.50 %	2 %	5 %
CFC-Monthly Mean	ACCURACY	bias	1 %	5 %	10 %
CFC-Monthly Mean	PRECISION	bc-RMS	5 %	10 %	20 %
CFC-Monthly Mean	STABILITY	decadal	0.5 %	2 %	5 %
CFC-Monthly Mean DC	ACCURACY	bias	1%	5 %	10 %
CFC-Monthly Mean DC	PRECISION	bc-RMS	5 %	10 %	20 %
CFC-Monthly Mean DC	STABILITY	decadal	0.5 %	2 %	5 %

Verification:
L2 validation against Calipso / EarthCARE
L3 validation against SYNOP plus evaluation against MODIS

Comment:
Naive Bayesian probablistic cloud masking with statistics depending on surface types
Additional data layers:
L3: CFC for high, middle and low clouds, CFC for daytime and nighttime

Table 11: Product requirements for **CM-5012 (CFC ICDR)**.

CM-5012	SEVIRI-FCI Fractional Cloud Cover ICDR	CFC_METEO_R1_ICDR

Type
Product

Input Satellite Data Operational Satellite:~~SEVIRI~~ FCI	*Application Areas* Cimate Monitoring

Dissemination Information

Distribution format L2:NetCDF4 L3:NetCDF4	*Generation frequency* 1 day , 1 month
	Generation timeliness 10 days (95%) 15 days (100%)

Spatio-temporal Information

Spatial Coverage L2:METEOSAT full disk (includes Europe, Africa, Atlantic Ocean) L3:METEOSAT full disk (includes Europe, Africa, Atlantic Ocean)	*Spatial Resolution* L2:HORIZONTAL: native satellite pixel resolution ~(3 km)[2] L3 dm and mm: HORIZONTAL: $(0.05)^2$ L3 mmdc: HORIZONTAL: $(0.25)^2$
Temporal Resolution L2:Instantaneous: 10min L3:Daily:Mean L3:Monthly:Mean L3:Monthly:Mean diurnal-cycle	*Temporal Coverage* 1/1/2025 onwards

Uncertainty Characteristics			Optimum	Target	Threshold
CFC-Instantaneous	ACCURACY	bias		10 %	
CFC-Instantaneous	PRECISION	KSS		>0.5	
CFC-Daily Mean	ACCURACY	bias		10 %	
CFC-Daily Mean	PRECISION	bc-RMS		20 %	
CFC-Monthly Mean	ACCURACY	bias		10 %	
CFC-Monthly Mean	PRECISION	bc-RMS		20 %	
CFC-Monthly Mean DC	ACCURACY	bias		10 %	
CFC-Monthly Mean DC	PRECISION	bc-RMS		20%	

Verification:
Validation against SYNOP plus comparison against MODIS

Comment:

Table 12: Requirements for the CM SAF product **CM-21024 (JCH CDR)**

CM-21024	CLAAS-4 Joint Cloud Histogram TCDR	JCH_R4_CLAAS_4_TCDR

Type
Dataset

Input Satellite Data
Operational Satellite:FCI
Operational Satellite:SEVIRI

Application Areas
Climate Modelling and Evaluation

Dissemination Information

Distribution format
L3:NetCDF4

Generation frequency

Generation timeliness

Spatio-temporal Information

Spatial Coverage
L3:METEOSAT full disk (includes Europe, Africa, Atlantic Ocean)

Spatial Resolution
L3 mh:HORIZONTAL:(0.25)²

Temporal Resolution
L3:Monthly:Histogram

Temporal Coverage
1/1/2004
12/31/2024

Uncertainty Characteristics			Optimum	Target	Threshold	
JCH-Monthly Histogram	ACCURACY	bias	n/a	n/a	n/a	

Verification:
L3 comparisons with MODIS

Comment:
The JCH product aggregates information from CTO (CM-21034), cloud optical thickness (in CM-21054 and CM-21064), and CPH (CM-21044). Its accuracy depends on the accuracy of these products. JCH is restricted to satellite and solar zenith angle < 84°

Table 13: Requirements for the CM SAF product **CM-5022 (JCH ICDR)**

CM-5022	SEVIRI-FCI Joint Cloud histogram ICDR	JCH_METEO_R1_ICDR

Type
Product

Input Satellite Data Operational Satellite: FCI	*Application Areas* Cimate Monitoring

Dissemination Information

Distribution format L3:NetCDF4	*Generation frequency* 1 month
	Generation timeliness 10 days (95%) 15 days (100%)

Spatio-temporal Information

Spatial Coverage L3:METEOSAT full disk (includes Europe, Africa, Atlantic Ocean)	*Spatial Resolution* L3 mh:HORIZONTAL:$(0.25)^2$
Temporal Resolution L3:Monthly:Histogram	*Temporal Coverage* 1/1/2025 onwards

Uncertainty Characteristics			Optimum	Target	Threshold
JCH-Monthly Histogram	ACCURACY	bias	n/a	n/a	n/a
JCH-Monthly Histogram	PRECISION	bc-RMS	n/a	n/a	n/a
JCH-Monthly Histogram	STABILITY	decadal	n/a	n/a	n/a

Verification:
Comparison against MODIS

Comment:

Table 14: Requirements for the CM SAF product **CM-21034 (CTO CDR)**

CM-21034 | CLAAS-4 Cloud Top Level TCDR | CTO_R4_CLAAS_4_TCDR

Type
Dataset

Input Satellite Data
Operational Satellite:FCI
Operational Satellite:SEVIRI

Application Areas
Climate Modelling and Evaluation

Dissemination Information

Distribution format
L2:NetCDF4
L3:NetCDF4

Generation frequency

Generation timeliness

Spatio-temporal Information

Spatial Coverage
L2:METEOSAT full disk (includes Europe, Africa, Atlantic Ocean)
L3:METEOSAT full disk (includes Europe, Africa, Atlantic Ocean)

Spatial Resolution
L2: HORIZONTAL: native satellite pixel resolution ~$(3\ \mathrm{km})^2$
L3 dm and mm:HORIZONTAL: $(0.05)^2$
L3 mmdc: HORIZONTAL: $(0.25)^2$

Temporal Resolution
L2:Instantaneous: 10/15min
L3:Daily:Mean
L3:Monthly:Mean
L3:Monthly:Mean diurnal-cycle

Temporal Coverage
1/1/2004
12/31/2024

Uncertainty Characteristics			Optimum	Target	Threshold
CTH-Instantaneous	ACCURACY	bias	270 m	800 m	1600 m
CTH-Instantaneous	PRECISION	bc-RMS	800 m	2400 m	4800 m
CTH-Instantaneous	STABILITY	decadal	90 m	270 m	530 m
CTH-Daily Mean	ACCURACY	bias	270 m	800 m	1600 m
CTH-Daily Mean	PRECISION	bc-RMS	530 m	1600 m	3200 m
CTH-Daily Mean	STABILITY	decadal	90 m	270 m	530 m
CTH-Monthly Mean	ACCURACY	bias	270 m	800 m	1600 m
CTH-Monthly Mean	PRECISION	bc-RMS	530 m	1600 m	3200 m
CTH-Monthly Mean	STABILITY	decadal	90 m	270 m	530 m
CTH-Monthly Mean DC	ACCURACY	bias	270 m	800 m	1600 m
CTH-Monthly Mean DC	PRECISION	bc-RMS	530 m	1600 m	3200 m
CTH-Monthly Mean DC	STABILITY	decadal	90 m	270 m	530 m
~~CTP-Daily Mean~~	~~ACCURACY~~	~~bias~~	~~15 hPa~~	~~45 hPa~~	~~90 hPa~~
~~CTP-Daily Mean~~	~~PRECISION~~	~~bc-RMS~~	~~30 hPa~~	~~90 hPa~~	~~180 hPa~~
~~CTP-Daily Mean~~	~~STABILITY~~	~~decadal~~	~~5 hPa~~	~~15 hPa~~	~~30 hPa~~
~~CTP-Instantaneous (none)~~	~~ACCURACY~~	~~bias~~	~~15 hPa~~	~~45 hPa~~	~~90 hPa~~
~~CTP-Instantaneous (none)~~	~~PRECISION~~	~~bc-RMS~~	~~45 hPa~~	~~235 hPa~~	~~270 hPa~~
~~CTP-Instantaneous (none)~~	~~STABILITY~~	~~decadal~~	~~5 hPa~~	~~15 hPa~~	~~30 hPa~~
~~CTP-Monthly Mean~~	~~ACCURACY~~	~~bias~~	~~15 hPa~~	~~45 hPa~~	~~90 hPa~~
~~CTP-Monthly Mean~~	~~PRECISION~~	~~bc-RMS~~	~~30 hPa~~	~~90 hPa~~	~~180 hPa~~
~~CTP-Monthly Mean~~	~~STABILITY~~	~~decadal~~	~~5 hPa~~	~~15 hPa~~	~~30 hPa~~
~~CTP-Monthly Mean DC~~	~~ACCURACY~~	~~bias~~	~~15 hPa~~	~~45 hPa~~	~~90 hPa~~
~~CTP-Monthly Mean DC~~	~~PRECISION~~	~~bc-RMS~~	~~30 hPa~~	~~90 hPa~~	~~180 hPa~~
~~CTP-Monthly Mean DC~~	~~STABILITY~~	~~decadal~~	~~5 hPa~~	~~15 hPa~~	~~30 hPa~~

Verification:
L2: validation against CALIOP/EarthCARE

L3: comparisons to MODIS and CALIOP L3

Comment:
Artificial Neural Netwok (ANN) method trained with CALIPSO-CALIOP data
Additional data layers:
L2 and L3: CTO includes cloud top pressure (CTP), cloud top height (CTH) and cloud top temperature (CTT)
L3: logarithmically averaged CTP (in addition to linear average)
L3: CTO for daytime and nighttime, CTO for liquid and ice clouds

Table 15: Requirements for the CM SAF product **CM-5032 (CTO ICDR)**

CM-5032 SEVIRI-FCI Cloud Top Level ICDR CTO_METEO_R1_ICDR

Type
Product

Input Satellite Data
Operational Satellite:-FCI

Application Areas
Cimate Monitoring

Dissemination Information

Distribution format
L2:NetCDF4
L3:NetCDF4

Generation frequency
1 day , 1 month

Generation timeliness
10 days (95%)
15 days (100%)

Spatio-temporal Information

Spatial Coverage
L2:METEOSAT full disk (includes Europe, Africa, Atlantic Ocean)
L3:METEOSAT full disk (includes Europe, Africa, Atlantic Ocean)

Spatial Resolution
L2:HORIZONTAL native satellite pixel resolution ~(3 km)^2
L3 dm and mm:HORIZONTAL: (0.05)²
L3 mmdc: HORIZONTAL: (0.25)²

Temporal Resolution
L2:Instantaneous: 10min
L3:Daily:Mean
L3:Monthly:Mean
L3:Monthly:Mean diurnal-cycle

Temporal Coverage
1/1/2025 onwards

Uncertainty Characteristics			Optimum	Target	Threshold
CTH-Instantaneous	ACCURACY	bias		1600 m	
CTH-Instantaneous	PRECISION	bc-RMS		4000 m	
CTH-Daily Mean	ACCURACY	bias		1600 m	
CTH-Daily Mean	PRECISION	bc-RMS		3200 m	
CTH-Monthly Mean	ACCURACY	bias		1600 m	
CTH-Monthly Mean	PRECISION	bc-RMS		3200 m	
CTH-Monthly Mean DC	ACCURACY	bias		1600 m	
CTH-Monthly Mean DC	PRECISION	bc-RMS		3200 m	
~~CTP-Daily Mean~~	~~ACCURACY~~	~~bias~~		~~90 hPa~~	
~~CTP-Daily Mean~~	~~PRECISION~~	~~bc-RMS~~		~~180 hPa~~	
~~CTP-Instantaneous~~	~~ACCURACY~~	~~bias~~		~~90 hPa~~	
~~CTP-Instantaneous~~	~~PRECISION~~	~~bc-RMS~~		~~270 hPa~~	
~~CTP-Monthly Mean~~	~~ACCURACY~~	~~bias~~		~~90 hPa~~	
~~CTP-Monthly Mean~~	~~PRECISION~~	~~bc-RMS~~		~~180 hPa~~	
~~CTP-Monthly Mean DC~~	~~ACCURACY~~	~~bias~~		~~90 hPa~~	
~~CTP-Monthly Mean DC~~	~~PRECISION~~	~~bc-RMS~~		~~180 hPa~~	

Verification:
Comparison against MODIS

Comment:

Table 16: Requirements for the CM SAF product **CM-21044 (CPH CDR)**

CM-21044 | CLAAS-4 Cloud Phase TCDR | CPH_R4_CLAAS_4_TCDR

Type
Dataset

Input Satellite Data
Operational Satellite:FCI
Operational Satellite:SEVIRI

Application Areas
Climate Modelling and Evaluation

Dissemination Information

Distribution format
L2:NetCDF4
L3:NetCDF4

Generation frequency

Generation timeliness

Spatio-temporal Information

Spatial Coverage
L2:METEOSAT full disk (includes Europe, Africa, Atlantic Ocean)
L3:METEOSAT full disk (includes Europe, Africa, Atlantic Ocean)

Spatial Resolution
L2:HORIZONTAL: native satellite pixel resolution ~(3 km)²
L3 dm and mm:HORIZONTAL: (0.05)²
L3 mmdc: HORIZONTAL: (0.25)²

Temporal Resolution
L2:Instantaneous: 10/15min
L3:Daily:Mean
L3:Monthly:Mean
L3:Monthly:Mean diurnal-cycle

Temporal Coverage
1/1/2004
12/31/2024

Uncertainty Characteristics			Optimum	Target	Threshold
CPH-Instantaneous	ACCURACY	bias	1 %	5 %	10 %
CPH-Instantaneous	PRECISION	KSS	>0.8	>0.6	>0.5
CPH-Instantaneous	STABILITY	decadal	0.5 %	2 %	5 %
CPH-Daily Mean	ACCURACY	bias	1 %	5 %	10 %
CPH-Daily Mean	PRECISION	bc-RMS	5 %	10 %	20 %
CPH-Daily Mean	STABILITY	decadal	0.5 %	2 %	5 %
CPH-Monthly Mean	ACCURACY	bias	1 %	5 %	10 %
CPH-Monthly Mean	PRECISION	bc-RMS	5 %	10 %	20 %
CPH-Monthly Mean	STABILITY	decadal	0.5 %	2 %	5 %
CPH-Monthly Mean DC	ACCURACY	bias	1 %	5 %	10 %
CPH-Monthly Mean DC	PRECISION	bc-RMS	5 %	10 %	20 %
CPH-Monthly Mean DC	STABILITY	decadal	0.5 %	2 %	5 %

Verification:
L2: validation against CALIOP/EarthCARE
L3: comparisons to MODIS and CALIOP L3

Comment:
~~Multispectral thresholding or~~ Artificial Neural Network trained with CALIPSO-CALIOP
Additional data layers:
L2 and L3: extended cloud phase with more categories,
L3: CPH for daytime and nighttime

Table 17: Requirements for the CM SAF product **CM-5042 (CPH ICDR)**

CM-5042	SEVIRI-FCI Cloud Phase ICDR	CPH_METEO_R1_ICDR

Type
Product

Input Satellite Data
Operational Satellite:-FCI

Application Areas
Cimate Monitoring

Dissemination Information

Distribution format
L2:NetCDF4
L3:NetCDF4

Generation frequency
1 day , 1 month

Generation timeliness
10 days (95%)
15 days (100%)

Spatio-temporal Information

Spatial Coverage
L2:METEOSAT full disk (includes Europe, Africa, Atlantic Ocean)
L3:METEOSAT full disk (includes Europe, Africa, Atlantic Ocean)

Spatial Resolution
L2:HORIZONTAL: native satellite pixel resolution ~(3 km)^2
L3 dm and mm:HORIZONTAL: (0.05)²
L3 mmdc: HORIZONTAL: (0.25)²

Temporal Resolution
L2:Instantaneous: 10min
L3:Daily:Mean
L3:Monthly:Mean
L3:Monthly:Mean diurnal-cycle

Temporal Coverage
1/1/2025 onwards

Uncertainty Characteristics			Optimum	Target	Threshold
CPH-Instantaneous	ACCURACY	bias		10 %	
CPH-Instantaneous	PRECISION	KSS		>0.5	
CPH-Daily Mean	ACCURACY	bias		10 %	
CPH-Daily Mean	PRECISION	bc-RMS		20 %	
CPH-Monthly Mean	ACCURACY	bias		10 %	
CPH-Monthly Mean	PRECISION	bc-RMS		20 %	
CPH-Monthly Mean DC	ACCURACY	bias		10 %	
CPH-Monthly Mean DC	PRECISION	bc-RMS		20 %	

Verification:
Comparison against MODIS

Comment:

Table 18: Requirements for the CM SAF product **CM-21054 (LWP CDR)**

CM-21054 CLAAS-4 Liquid Water Path TCDR LWP_R4_CLAAS_4_TCDR

Type
Dataset

Input Satellite Data
Operational Satellite:FCI
Operational Satellite:SEVIRI

Application Areas
Climate Modelling and Evaluation

Dissemination Information

Distribution format
L2:NetCDF4
L3:NetCDF4

Generation frequency

Generation timeliness

Spatio-temporal Information

Spatial Coverage
L2:METEOSAT full disk (includes Europe, Africa, Atlantic Ocean)
L3:METEOSAT full disk (includes Europe, Africa, Atlantic Ocean)

Spatial Resolution
L2:HORIZONTAL: native satellite pixel resolution ~(3 km)²
L3 dm and mm:HORIZONTAL: (0.05)²
L3 mmdc: HORIZONTAL: (0.25)²

Temporal Resolution
L2:Instantaneous: 10/15min
L3:Daily:Mean
~~L3:Monthly norm.:Histogram~~
L3:Monthly:Mean
L3:Monthly:Mean diurnal-cycle

Temporal Coverage
1/1/2004
12/31/2024

Uncertainty Characteristics			Optimum	Target	Threshold
LWP-Instantaneous	ACCURACY	bias	5 g/m²	10 g/m²	20 g/m²
LWP-Instantaneous	PRECISION	bc-RMS	40 g/m²	100 g/m²	200 g/m²
LWP-Instantaneous	STABILITY	decadal	1 g/m²	6 g/m²	3 g/m²
LWP-Daily Mean	ACCURACY	bias	5 g/m²	10 g/m²	20 g/m²
LWP-Daily Mean	PRECISION	bc-RMS	10 g/m²	20 g/m²	40 g/m²
LWP-Daily Mean	STABILITY	decadal	1 g/m²	3 g/m²	6 g/m²
LWP-Monthly Mean	ACCURACY	bias	5 g/m²	10 g/m²	20 g/m²
LWP-Monthly Mean	PRECISION	decadal	10 g/m²	20 g/m²	40 g/m²
LWP-Monthly Mean	STABILITY	decadal	1 g/m²	3 g/m²	6 g/m²
LWP-Monthly Mean DC	ACCURACY	bias	5 g/m²	10 g/m²	20 g/m²
LWP-Monthly Mean DC	PRECISION	bc-RMS	10 g/m²	20 g/m²	40 g/m²
LWP-Monthly Mean DC	STABILITY	decadal	1 g/m²	3 g/m²	6 g/m²

Verification:
L2: validation against passive microwave LWP (e.g. AMSR2)
L3: comparison with passive microwave data records, comparison with MODIS

Comment:
Nakajima-King approach
~~contains separate products for aerosol above cloud scenes~~

Additional data layers:
L2 and L3: cloud optical thickness (COT) and particle effective radius from wavelengths 1.6 and 3.9 µm (CER), cloud droplet number concentration (CDNC) and cloud geometrical thickness (CGT)
L2 and L3: scene heterogeneity (H_σ)
L3: logarithmically averaged COT (in addition to linear average)
L3: LWP averaged over all sky (in addition to cloudy sky average)

Table 19: Requirements for the CM SAF product **CM-5052 (LWP ICDR)**

CM-5052	SEVIRI-FCI Liquid Water Path ICDR	LWP_METEO_R1_ICDR

Type
Product

Input Satellite Data Operational Satellite:-FCI	*Application Areas* Cimate Monitoring
Dissemination Information	
Distribution format L2:NetCDF4 L3:NetCDF4	*Generation frequency* 1 day , 1 month
	Generation timeliness 10 days (95%) 15 days (100%)
Spatio-temporal Information	
Spatial Coverage L2:METEOSAT full disk (includes Europe, Africa, Atlantic Ocean) L3:METEOSAT full disk (includes Europe, Africa, Atlantic Ocean)	*Spatial Resolution* L2:HORIZONTAL: native satellite pixel resolution ~(3 km)^2 L3 dm and mm:HORIZONTAL: (0.05)² L3 mmdc: HORIZONTAL: (0.25)²
Temporal Resolution L2:Instantaneous: 10min L3:Daily:Mean L3:Monthly:Mean L3:Monthly:Mean diurnal-cycle	*Temporal Coverage* 1/1/2025 onwards

Uncertainty Characteristics			Optimum	Target	Threshold
LWP-Instantaneous	ACCURACY	bias		20 g/m²	
LWP-Instantaneous	PRECISION	bc-RMS		200 g/m²	
LWP-Daily Mean	ACCURACY	bias		20 g/m²	
LWP-Daily Mean	PRECISION	bc-RMS		40 g/m²	
LWP-Monthly Mean	ACCURACY	bias		20 g/m²	
LWP-Monthly Mean	PRECISION	bc-RMS		40 g/m²	
LWP-Monthly Mean DC	ACCURACY	bias		20 g/m²	
LWP-Monthly Mean DC	PRECISION	bc-RMS		40 g/m²	

Verification:
Comparison against MODIS

Comment:

Table 20: Requirements for the CM SAF product **CM-21064 (IWP CDR)**

CM-21064 CLAAS-4 Ice Water Path TCDR IWP_R4_CLAAS_4_TCDR

Type
Dataset

Input Satellite Data
Operational Satellite:FCI
Operational Satellite:SEVIRI

Application Areas
Climate Modelling and Evaluation

Dissemination Information

Distribution format
L2:NetCDF4
L3:NetCDF4

Generation frequency

Generation timeliness

Spatio-temporal Information

Spatial Coverage
L2:METEOSAT full disk (includes Europe, Africa, Atlantic Ocean)
L3:METEOSAT disk (CM SAF definition)

Spatial Resolution
L2:HORIZONTAL: native satellite pixel resolution ~(3 km)^2
L3 dm and mm:HORIZONTAL: (0.05)²
L3 mmdc: HORIZONTAL: (0.25)²

Temporal Resolution
L2:Instantaneous: 10/15min
L3:Daily:Mean
~~L3:Monthly:Histogram~~
L3:Monthly:Mean
L3:Monthly:Mean diurnal-cycle

Temporal Coverage
1/1/2004
12/31/2024

Uncertainty Characteristics			Optimum	Target	Threshold
IWP- Instantaneous	ACCURACY	bias	10 g/m²	20 g/m²	40 g/m²
IWP- Instantaneous	PRECISION	bc-RMS	80 g/m²	200 g/m²	400 g/m²
IWP- Instantaneous	STABILITY	decadal	2 g/m²	6 g/m²	12 g/m²
IWP-Daily Mean	ACCURACY	bias	10 g/m²	20 g/m²	40 g/m²
IWP-Daily Mean	PRECISION	bc-RMS	20 g/m²	40 g/m²	80 g/m²
IWP-Daily Mean	STABILITY	decadal	2 g/m²	6 g/m²	12 g/m²
IWP-Monthly Mean	ACCURACY	bias	10 g/m²	20 g/m²	40 g/m²
IWP-Monthly Mean	PRECISION	bc-RMS	20 g/m²	40 g/m²	80 g/m²
IWP-Monthly Mean DC	ACCURACY	bias	10 g/m²	20 g/m²	40 g/m²
IWP-Monthly Mean DC	PRECISION	bc-RMS	20 g/m²	40 g/m²	80 g/m²
IWP-Monthly Mean DC	STABILITY	decadal	2 g/m²	6 g/m²	12 g/m²

Verification:
L2: validation against DARDAR (Cloudsat/CALIPSO)
L3: comparison with MODIS

Comment:
Nakajima-King approach
Additional data layers:

L2 and L3: cloud optical thickness (COT) and particle effective radius from wavelengths 1.6 and 3.9 µm (CER)
L2: scene heterogeneity (Hσ)
L3: logarithmically averaged COT (in addition to linear average)
L3: IWP averaged over all sky (in addition to cloudy sky average)

Table 21: Requirements for the CM SAF product **CM-5062 (IWP ICDR)**

CM-5062 | SEVIRI-FCI Ice Water Path ICDR | IWP_METEO_R1_ICDR

Type
Product

Input Satellite Data
Operational Satellite: FCI

Application Areas
Cimate Monitoring

Dissemination Information

Distribution format
L2:NetCDF4
L3:NetCDF4

Generation frequency
1 day , 1 month

Generation timeliness
10 days (95%)
15 days (100%)

Spatio-temporal Information

Spatial Coverage
L2:METEOSAT full disk (includes Europe, Africa, Atlantic Ocean)
L3:METEOSAT full disk (includes Europe, Africa, Atlantic Ocean)

Spatial Resolution
L2:HORIZONTAL: native satellite pixel resolution ~(3 km)^2
L3 dm and mm:HORIZONTAL: (0.05)²
L3 mmdc: HORIZONTAL: (0.25)²

Temporal Resolution
L2:Instantaneous: 10min
L3:Daily:Mean
L3:Monthly:Mean
L3:Monthly:Mean diurnal-cycle

Temporal Coverage
1/1/2025 onwards

Uncertainty Characteristics			Optimum	Target	Threshold
IWP-Instantaneous	ACCURACY	bias		40 g/m²	
IWP-Instantaneous	PRECISION	bc-RMS		400 g/m²	
IWP-Daily Mean	ACCURACY	bias		40 g/m²	
IWP-Daily Mean	PRECISION	bc-RMS		80 g/m²	
IWP-Monthly Mean	ACCURACY	bias		40 g/m²	
IWP-Monthly Mean	PRECISION	bc-RMS		80 g/m²	
IWP-Monthly Mean DC	ACCURACY	bias		40 g/m²	
IWP-Monthly Mean DC	PRECISION	bc-RMS		80 g/m²	

Verification:
Comparison against MODIS

Comment:

Table 22: Requirements for the CM SAF product **CM-21302 (RSF CDR)**

CM-21302	CLAAS-4 Reflected Solar Flux TCDR	RSF_R1_CLAAS_4_TCDR

Type
Dataset

Input Satellite Data Operational Satellite:FCI Operational Satellite:SEVIRI	*Application Areas* Climate Modelling and Evaluation

Dissemination Information

Distribution format L2:NetCDF4 L3:NetCDF4	*Generation frequency* *Generation timeliness*

Spatio-temporal Information

Spatial Coverage L2:METEOSAT full disk (includes Europe, Africa, Atlantic Ocean) L3:METEOSAT full disk (includes Europe, Africa, Atlantic Ocean)	*Spatial Resolution* L2:HORIZONTAL: native satellite pixel resolution ~(3 km)² L3:HORIZONTAL:(0.05)²
Temporal Resolution L2:Instantaneous:10/15min L3:Hourly:Mean L3:Daily:Mean L3:Monthly:Mean L3:Monthly:Mean diurnal-cycle	*Temporal Coverage* 1/1/2004 12/31/2024

Uncertainty Characteristics			Optimum	Target	Threshold
RSF-Instantaneous	PRECISION	bc-RMS	8 W/m²	16 W/m²	32 W/m²
RSF-Hourly Mean	PRECISION	bc-RMS	8 W/m²	16 W/m²	32 W/m²
RSF-Monthly Mean DC	PRECISION	bc-RMS	4 W/m²	8 W/m²	16 W/m²
RSF-Daily Mean	PRECISION	bc-RMS	4 W/m²	8 W/m²	16 W/m²
RSF-Monthly Mean	PRECISION	bc-RMS	2 W/m²	4 W/m²	8 W/m²
RSF-Monthly Mean	STABILITY	decadal bias	0.3 W/m²/dec	0.6 W/m²/dec	2 W/m²/dec

Verification:
L2: with collocated/simultaneous/coangular observations from CERES-SSF, GERB-L2
L3: with gridded products CERES-EBAF, CERES-SYN1deg

Comment:
Requirements refer to:

- At 1 standard deviation (spatial RMS on gridded bias, i.e. RMSD)
- At 1°x1° scale
- Taking only VZA<60°

-No 'accuracy' requirements are given because the absolute radiometric level (global mean bias) is considered 'tuned' and not independent from our reference datasets (e.g. CERES).
-Additional data layers: clear-sky RSF (for all L2 and L3 products), for which the same requirements are applied
-For products with a strong diurnal cycle (RSF L2 and L3 hourly and MMDC) the requirement refers to average illumination conditions.

-NB-to-BB based on GERB/CERES, Empirical ADMs from CERES

Table 23: Requirements for the CM SAF product **CM-5321 (RSF ICDR)**

CM-5321	SEVIRI-FCI Reflected Solar Flux ICDR	RSF_R1_METEO_ICDR

Type
Product

Input Satellite Data
Operational Satellite: ~~SEVIRI~~ FCI

Application Areas
Cimate Monitoring

Dissemination Information

Distribution format
L2:NetCDF4
L3:NetCDF4

Generation frequency
1 day , 1 month

Generation timeliness
40 days (95% of data)
45 days (100% of data)

Spatio-temporal Information

Spatial Coverage
L2:METEOSAT full disk (includes Europe, Africa, Atlantic Ocean)
L3:METEOSAT full disk (includes Europe, Africa, Atlantic Ocean)

Spatial Resolution
L2:HORIZONTAL: native satellite pixel resolution ~(3 km)^2
L3:HORIZONTAL:(0.05°)^2

Temporal Resolution
L2:Instantaneous:10min
L3:Hourly:Mean
L3:Daily:Mean
L3:Monthly:Mean
L3:Monthly:Mean diurnal-cycle

Temporal Coverage
1/1/2025 onwards

Uncertainty Characteristics			Optimum	Target	Threshold
RSF-Instantaneous	PRECISION	bc-RMS		32 W/m²	
RSF-Hourly Mean	PRECISION	bc-RMS		32 W/m²	
RSF-Monthly Mean DC	PRECISION	bc-RMS		16 W/m²	
RSF-Daily Mean	PRECISION	bc-RMS		16 W/m²	
RSF-Monthly Mean	PRECISION	bc-RMS		8 W/m²	

Verification:
Comparison against CERES-SYN1deg

Comment:
see comments CM-21302 (RSF CDR)

Table 24: Requirements for the CM SAF product **CM-21332 (OLR CDR)**

CM-21332 | CLAAS-4 Outgoing Longwave Radiation TCDR | OLR_R1_CLAAS_4_TCDR

Type
Dataset

Input Satellite Data
Operational Satellite:FCI
Operational Satellite:SEVIRI

Application Areas
Climate Modelling and Evaluation

Dissemination Information

Distribution format
L2:NetCDF4
L3:NetCDF4

Generation frequency

Generation timeliness

Spatio-temporal Information

Spatial Coverage
L2:METEOSAT full disk (includes Europe, Africa, Atlantic Ocean)
L3:METEOSAT full disk (includes Europe, Africa, Atlantic Ocean)

Spatial Resolution
L2:HORIZONTAL: native satellite pixel resolution ~(3 km)²
L3:HORIZONTAL:(0.05)²

Temporal Resolution
L2:Instantaneous:10/15min
L3:Hourly:Mean
L3:Daily:Mean
L3:Monthly:Mean
L3:Monthly:Mean diurnal-cycle

Temporal Coverage
1/1/2004
12/31/2024

Uncertainty Characteristics			Optimum	Target	Threshold
OLR-Instantaneous	PRECISION	bc-RMS	4 W/m²	8 W/m²	16 W/m²
OLR-Hourly Mean	PRECISION	bc-RMS	4 W/m²	8 W/m²	16 W/m²
OLR-Monthly Mean DC	PRECISION	bc-RMS	2 W/m²	4 W/m²	8 W/m²
OLR-Daily Mean	PRECISION	bc-RMS	2 W/m²	4 W/m²	8 W/m²
OLR-Monthly Mean	PRECISION	bc-RMS	1 W/m²	2 W/m²	4 W/m²
OLR-Monthly Mean	STABILITY	decadal bias	0.3 W/m²/dec	0.6 W/m²/dec	2 W/m²/dec

Verification:
L2: with collocated/simultaneous/coangular observations from CERES-SSF, GERB-L2
L3: with gridded products CERES-EBAF, CERES-SYN1deg, HIRS-OLR

Comment:
Requirements refer to:

- At 1 standard deviation (spatial RMS on gridded bias, i.e. RMSD)
- At 1°x1° scale
- Taking only VZA<60°

No ‘accuracy’ requirements are given because the absolute radiometric level (global mean bias) is considered ‘tuned’ and not independent from our reference datasets (e.g. CERES).
Additional data layers: clear-sky RSF (for all L2 and L3 products), for which the same requirements are applied.
NB-to-BB based on GERB/CERES, Theoretical ADMs

Table 25: Requirements for the CM SAF product **CM-5331 (OLR ICDR)**

CM-5331	SEVIRI-FCI Outgoing Longwave Radiation ICDR	OLR_R1_METEO_ICDR

Type
Product

Input Satellite Data
Operational Satellite: ~~SEVIRI~~ FCI

Application Areas
Cimate Monitoring

Dissemination Information

Distribution format
L2:NetCDF4
L3:NetCDF4

Generation frequency
1 day , 1 month

Generation timeliness
40 days (95% of data)
45 days (100% of data)

Spatio-temporal Information

Spatial Coverage
L2:METEOSAT full disk (includes Europe, Africa, Atlantic Ocean)
L3:METEOSAT full disk (includes Europe, Africa, Atlantic Ocean)

Spatial Resolution
L2:HORIZONTAL: native satellite pixel resolution ~$(3\ km)^2$
L3:HORIZONTAL:$(0.05°)^2$

Temporal Resolution
L2:Instantaneous:10min
L3:Hourly:Mean
L3:Daily:Mean
L3:Monthly:Mean
L3:Monthly:Mean diurnal-cycle

Temporal Coverage
1/1/2025 onwards

Uncertainty Characteristics			Optimum	Target	Threshold
OLR-Instantaneous	PRECISION	bc-RMS		16 W/m²	
OLR-Hourly Mean	PRECISION	bc-RMS		16 W/m²	
OLR-Monthly Mean DC	PRECISION	bc-RMS		8 W/m²	
OLR-Daily Mean	PRECISION	bc-RMS		8 W/m²	
OLR-Monthly Mean	PRECISION	bc-RMS		4 W/m²	

Verification:
Comparison against CERES-SYN1deg

Comment:
see comments CM-21332 (OLR CDR)

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