EUMETSAT Satellite Application Facility on Climate Monitoring

Product User Manual
CM SAF Cloud, Albedo, Radiation data record, AVHRR-based, Edition 3 (CLARA-A3)
Top-of-Atmosphere Radiation

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	TCDR	ICDR
TOA Reflected Solar Flux (RSF)	CM-11312	CM-6331
TOA Outgoing Longwave Radiation (OLR)	CM-11342	CM-6321

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Applicable Documents

The following documents, of the exact issue shown, form part of this document to the extent specified herein. Applicable documents are those referenced in the Contract or approved by the Approval Authority. They are referenced in this document in the form [AD X].

Reference	Title	Code, Version, Date
AD 1	CM SAF CDOP3 Project Plan	SAF/CM/DWD/CDOP3_PP_1_7, Version 1.7, 08/12/2021
AD 2	CM SAF CDOP3 Product Requirement Document	SAF/CM/DWD/PRD, Version 4.1

Reference Documents

The reference documents contain useful information related to the subject of the project. These reference documents complement the applicable ones, and can be looked up to enhance the information included in this document if it is desired. They are referenced in this document in the form [RD X].

Reference	Title	Code, Version, Date
RD 1	CM SAF Requirements Review: AVHRR GAC Edition 3 data records (CLARA Ed.3)	SAF/CM/CDOP3/SMHI/RR32, Version 1.2, 08/05/2020
RD 2	ATBD CM SAF Cloud, Albedo, Radiation data record, AVHRR-based, Edition 3 (CLARA-A3): Cloud Products processing chain (level-1 – level-2/2b –level-3).	SAF/CM/DWD/ATBD/GAC v3.3
RD 3	Algorithm Theoretical Basis Document for Cloud Micro Physics of the NWC/PPS	NWC/CDOP3/PPS/SMHI/SCI/ATBD/CMIC, Issue 3.0, 26/04/2021
RD 4	Algorithm Theoretical Basis Document for the Cloud Probability of the NWC/PPS	NWC/CDOP3/PPS/SMHI/SCI/ATBD/CloudProbability, Issue 2.0, 26/04/2021
RD 5	ATBD CM SAF Cloud, Albedo, Radiation data record, AVHRR-based, Edition 3 (CLARA-A3): Surface Radiation	SAF/CM/DWD/ATBD/CLARA/RAD, Issue 3.3

Reference	Title	Code, Version, Date
RD 6	The Data Set Generation Capability Description Document, AVHRR GAC Edition 3 (CLARA-A3)	SAF/CM/DWD/DGCDD/GAC/3, version 3.3
RD 7	Algorithm Theoretical Basis Document CLARA Edition 3: TOA Radiation	SAF/CM/RMIB/ATBD/GAC/TOA
RD 8	Validation Report CLARA Edition 3: TOA Radiation	SAF/CM/RMIB/VAL/GAC/TOA

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1 The EUMETSAT SAF on Climate Monitoring (CM SAF)

The importance of climate monitoring with satellites was recognized in 2000 by EUMETSAT Member States when they amended the EUMETSAT Convention to affirm that the EUMETSAT mandate is also to “contribute to the operational monitoring of the climate and the detection of global climatic changes". Following this, EUMETSAT established within its Satellite Application Facility (SAF) network a dedicated centre, the SAF on Climate Monitoring (CM SAF, http://www.cmsaf.eu).

The consortium of CM SAF currently comprises the Deutscher Wetterdienst (DWD) as host institute, and the partners from the Royal Meteorological Institute of Belgium (RMIB), the Finnish Meteorological Institute (FMI), the Royal Meteorological Institute of the Netherlands (KNMI), the Swedish Meteorological and Hydrological Institute (SMHI), the Meteorological Service of Switzerland (MeteoSwiss), the Meteorological Service of the United Kingdom (UK MetOffice), and the Centre National de la Recherché Scientifique (CNRS). Since the beginning in 1999, the EUMETSAT Satellite Application Facility on Climate Monitoring (CM SAF) has developed and will continue to develop capabilities for a sustained generation and provision of Climate Data Records (CDR’s) derived from operational meteorological satellites.

In particular, the generation of long-term data records is pursued. The ultimate aim is to make the resulting data records suitable for the analysis of climate variability and potentially the detection of climate trends. CM SAF works in close collaboration with the EUMETSAT Central Facility and liaises with other satellite operators to advance the availability, quality and usability of Fundamental Climate Data Records (FCDRs) as defined by the Global Climate Observing System (GCOS). As a major task the CM SAF utilizes FCDRs to produce records of Essential Climate Variables (ECVs) as defined by GCOS. Thematically, the focus of CM SAF is on ECVs associated with the global energy and water cycle.

Another essential task of CM SAF is to produce data records that can serve applications related to the Global Framework of Climate Services initiated by the WMO World Climate Conference-3 in 2009. CM SAF is supporting climate services at national meteorological and hydrological services (NMHSs) with long-term data records but also with data records produced close to real time that can be used to prepare monthly/annual updates of the state of the climate. Both types of products together allow for a consistent description of mean values, anomalies, variability and potential trends for the chosen ECVs. CM SAF ECV data records also serve the improvement of climate models both at global and regional scale.

As an essential partner in the related international frameworks, in particular WMO SCOPE-CM (Sustained COordinated Processing of Environmental satellite data for Climate Monitoring), the CM SAF - together with the EUMETSAT Central Facility, assumes the role as main implementer of EUMETSAT’s commitments in support to global climate monitoring. This is achieved through:

- Application of highest standards and guidelines as lined out by GCOS for the satellite data processing,
- Processing of satellite data within a true international collaboration benefiting from developments at international level and pollinating the partnership with own ideas and standards,
- Intensive validation and improvement of the CM SAF climate data records,

- Taking a major role in data record assessments performed by research organisations such as WCRP (World Climate Research Program). This role provides the CM SAF with deep contacts to research organizations that form a substantial user group for the CM SAF CDRs,
- Maintaining and providing an operational and sustained infrastructure that can serve the community within the transition of mature CDR products from the research community into operational environments.

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

2 Introduction

At the Top-Of-Atmosphere (TOA), the following radiative fluxes are defined: the Incoming Solar Radiation (ISR), the Reflected Solar Flux (RSF) and the Outgoing Longwave Radiation (OLR), as illustrated in Figure 2-1.

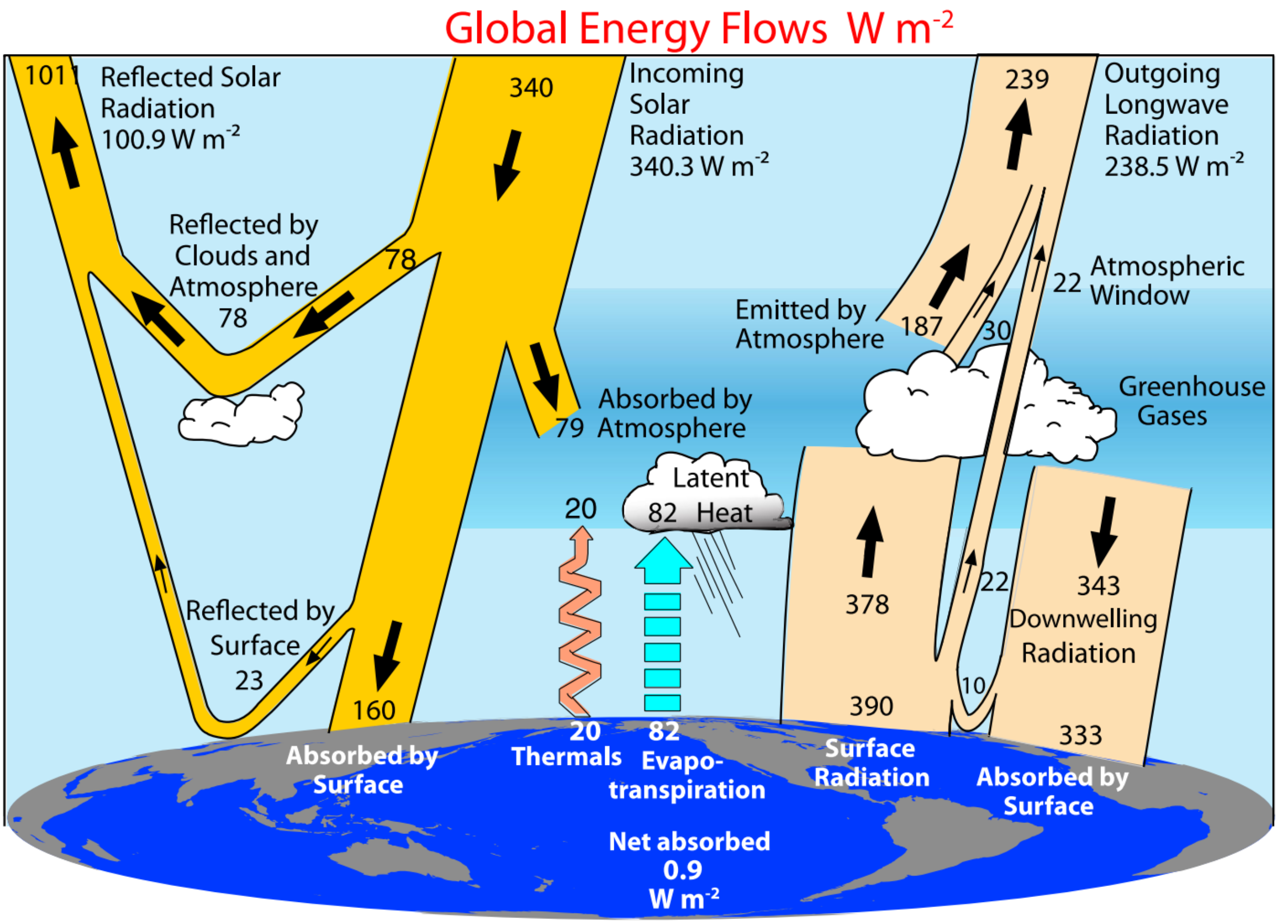

Figure 2-1: An overall schematic of the global annual mean energy flows through the climate system has at the top of atmosphere (TOA) the Incoming and Reflected Solar Radiation, and the Outgoing Longwave Radiation (Trenberth 2020).

These three components of the Earth Radiation Budget (ERB) are the driver of the climate on our planet. In the frame of climate monitoring, the continuous monitoring of these fluxes is of prime importance to understand climate variability and change. The nature of these quantities, which are defined at TOA, makes the use of satellite observations especially useful.

A full global coverage of broadband observations is provided by the Clouds and the Earth's Radiant Energy System (CERES) instruments and derived products (Loeb et al., 2018). Although these are acknowledged to be the golden standard w.r.t. radiative flux data records, two major limitations can be identified: (1) the products are relatively recent, e.g. starting in year 2000 for the EBAF product, and (2) the products have a relatively coarse spatial resolution of 1°x1° (lat-lon equal angle grid). The CLARA-A3 TOA RSF and OLR products developed within CM SAF aim to bridge these gaps, respectively by (1) a prolongation back in time to the late 1970s and (2) by increasing the spatial resolution to 0.25°x0.25°. A third advantage of the new CDRs lies in their synergy and compatibility with the other CDRs from the CM SAF CLARA product family (cloud mask and other cloud parameters, surface radiation, surface albedo, etc.) sharing common algorithms and processing chains.

The two new CLARA-A3 TOA data records are generated with the following CM SAF identifiers:

Content	**CM SAF identifier**	
	TCDR	***ICDR***
TOA Reflected Solar Flux (RSF)	CM-11312	CM-6331
TOA Outgoing Longwave Radiation (OLR)	CM-11342	CM-6321

3 Product Description

3.1 Product definition

RSF and OLR fluxes (*F*) are defined as fluxes per unit area at TOA and are expressed in W/m² units. They are mathematically described as the integral of the directional unfiltered BB radiances (*L*) over all viewing directions defined by the Viewing Zenith Angle (θ) and the Relative Azimuth Angle (φ):

$$F(\theta_0) = \int_{\varphi=0}^{2\pi} \int_{\theta=0}^{\frac{\pi}{2}} (L(\theta_0, \theta, \varphi) \cdot \cos\theta \cdot \sin\theta)\, d\theta\, d\varphi$$

Where θ_0 is the solar zenith angle.

RSF and OLR fluxes are not defined in terms of wavelength but in terms of source: the RSF contains all the incoming solar radiation that is reflected back to space by the Earth (thus the RSF is directly related to the Earth albedo) while the OLR contains all the radiation created by thermal emission in the Earth-atmosphere system which escapes at the TOA (also known as the *TOA Emitted Thermal* flux a.k.a. TET).

As the Earth is an ellipsoid, the TOA fluxes obviously decrease with the altitude at which they are defined/measured as the inverse of the square of the distance to the Earth center. The reference level for the CLARA-A3 TOA flux data record is set to 20 km above the mean sea level, which is consistent with CERES EBAF and should allow a direct comparison with climate models (Loeb et al., 2002).

To compare the CLARA-A3 TOA flux data records with other reference data records, users may be advised to first check if the reference levels are identical. If not, the data records should be rescaled to the same reference level. To scale the fluxes from a reference level h_1 to another reference level h_2, the following multiplicative factor should be used:

$$\frac{(R + h_1)^2}{(R + h_2)^2}$$

where *R* is the radius of the Earth (in the same unit as h_1 and h_2).

3.2 Retrievals

A detailed description of the retrievals was provided in [RD 7], and also published by Clerbaux et al. (2020) for OLR, and by Akkermans and Clerbaux (2021) for RSF. A schematic of the CLARA-A3 TOA fluxes processing chain is given in Figure 3-1.

The panels on the right (bluish colors) describe the RSF retrieval. First, the narrowband reflectances are converted to broadband reflectance using empirical regressions with the Clouds and the Earth's Radiant Energy System (CERES) observations, using a large database of collocated, coangular, and simultaneous AVHRR-CERES observations (i.e. spectral conversion). Second, the anisotropy is corrected by applying Angular Distribution Models (ADMs), which convert directional reflectance into a hemispherical albedo (i.e. directional-hemispherical conversion). Third, the instantaneous albedos are temporally interpolated by a flexible diurnal cycle model, capable of ingesting any number of observations at any time of day, making it suitable for any orbital configuration of NOAA and MetOp satellites. Finally, the twilight conditions (when SZA>84°) prevailing near sunrise and sunset are simulated with an empirical model (not shown in figure). The entire day is then integrated into a single daily mean RSF, and subsequently in monthly mean RSF.

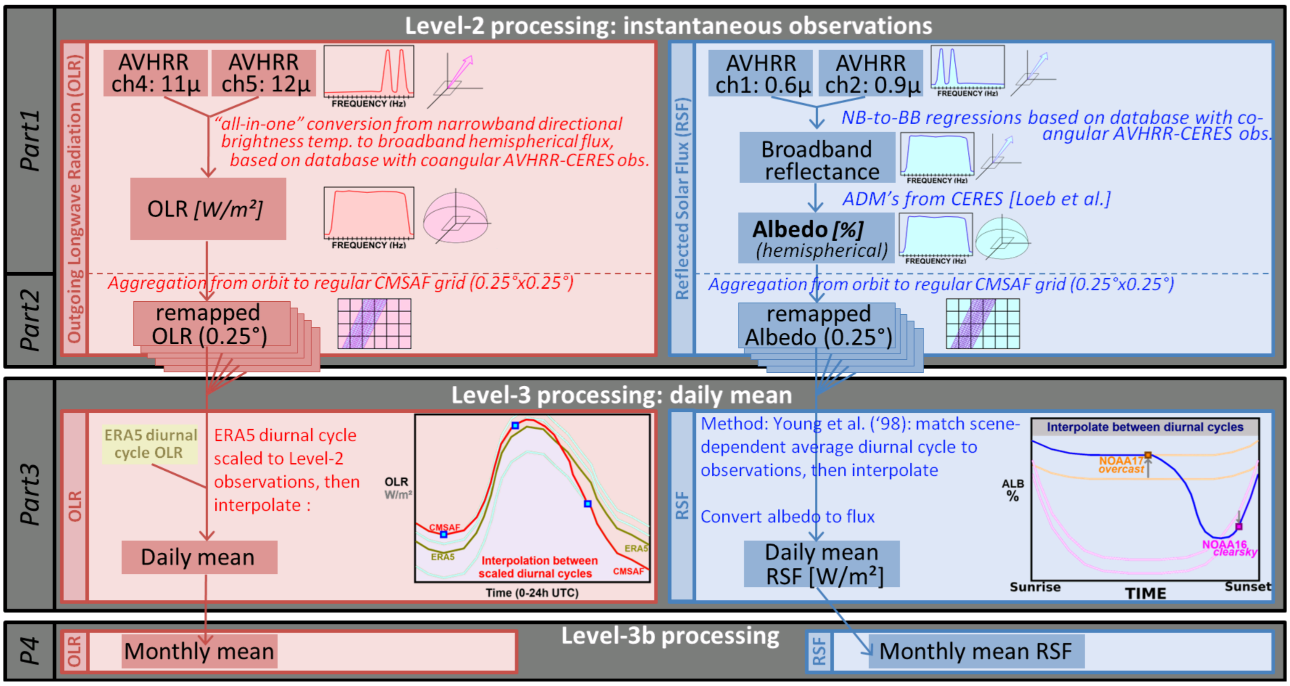

Figure 3-1: Overview of the OLR (left) and RSF (right) processing chain

The panels on the left (reddish colors) describe the OLR retrieval. A first step is the estimation of the instantaneous OLR from the AVHRR observations. This is done by regressions on the same large database of collocated AVHRR-CERES observations (as used for the RSF), but in contrast to RSF, the OLR regressions are an "all-in-one" conversion which combines the spectral and directional conversions. A second step concerns the estimation of daily and monthly OLR from the instantaneous AVHRR overpasses. Over clear sky land, the OLR from ERA5 reanalysis is used to estimate the diurnal variation; otherwise, linear regression is applied.

3.3 Example illustrations of the product

Examples of CLARA-A3 Reflected Solar Flux are provided in Figure 3-2, showing respectively the daily (top) and monthly (bottom) mean RSF in W/m². Similarly, examples of Outgoing Longwave Radiation are provided in Figure 3-3.

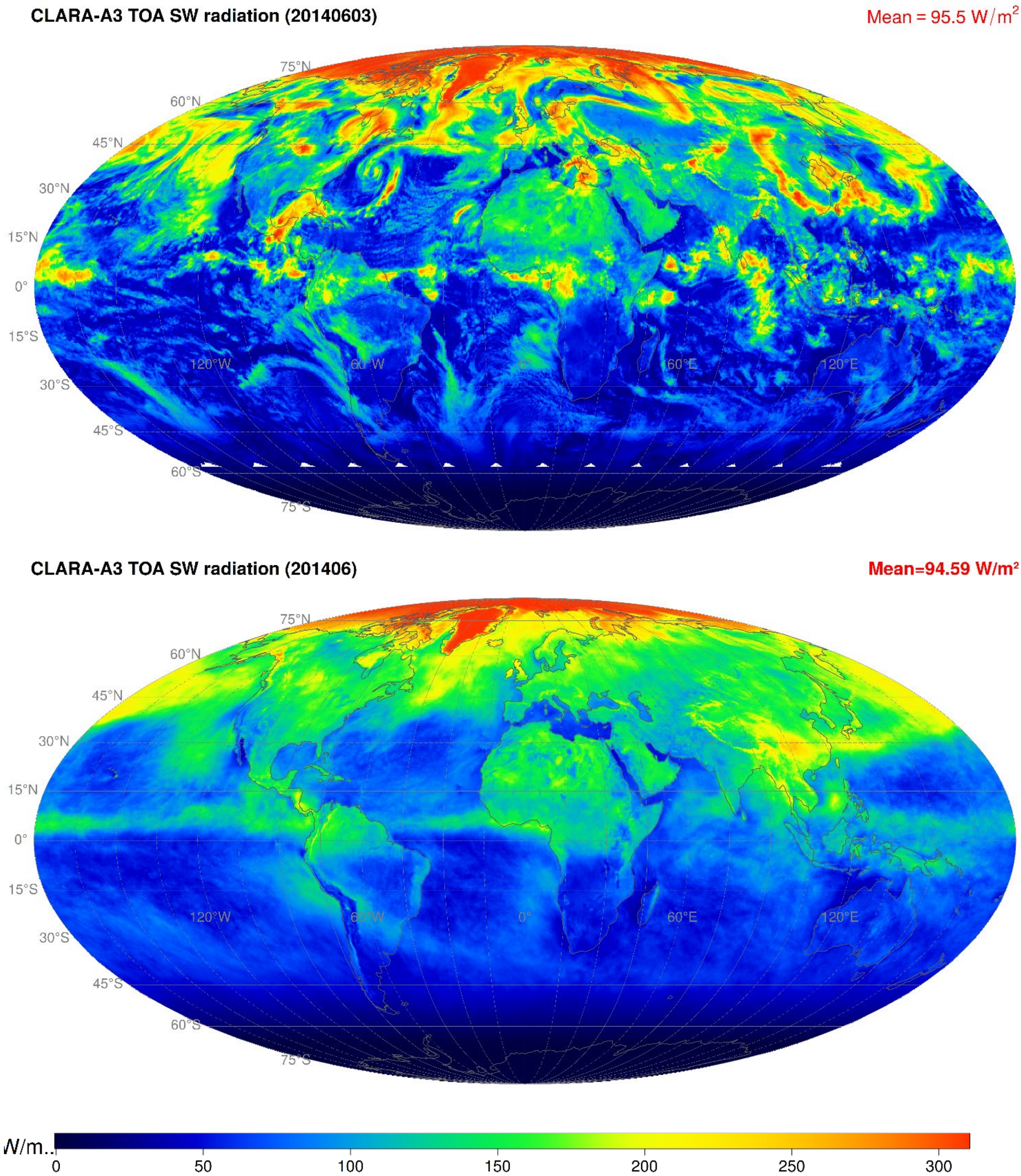

Figure 3-2: Example of daily (03-06-2014) and monthly (06-2014) mean RSF

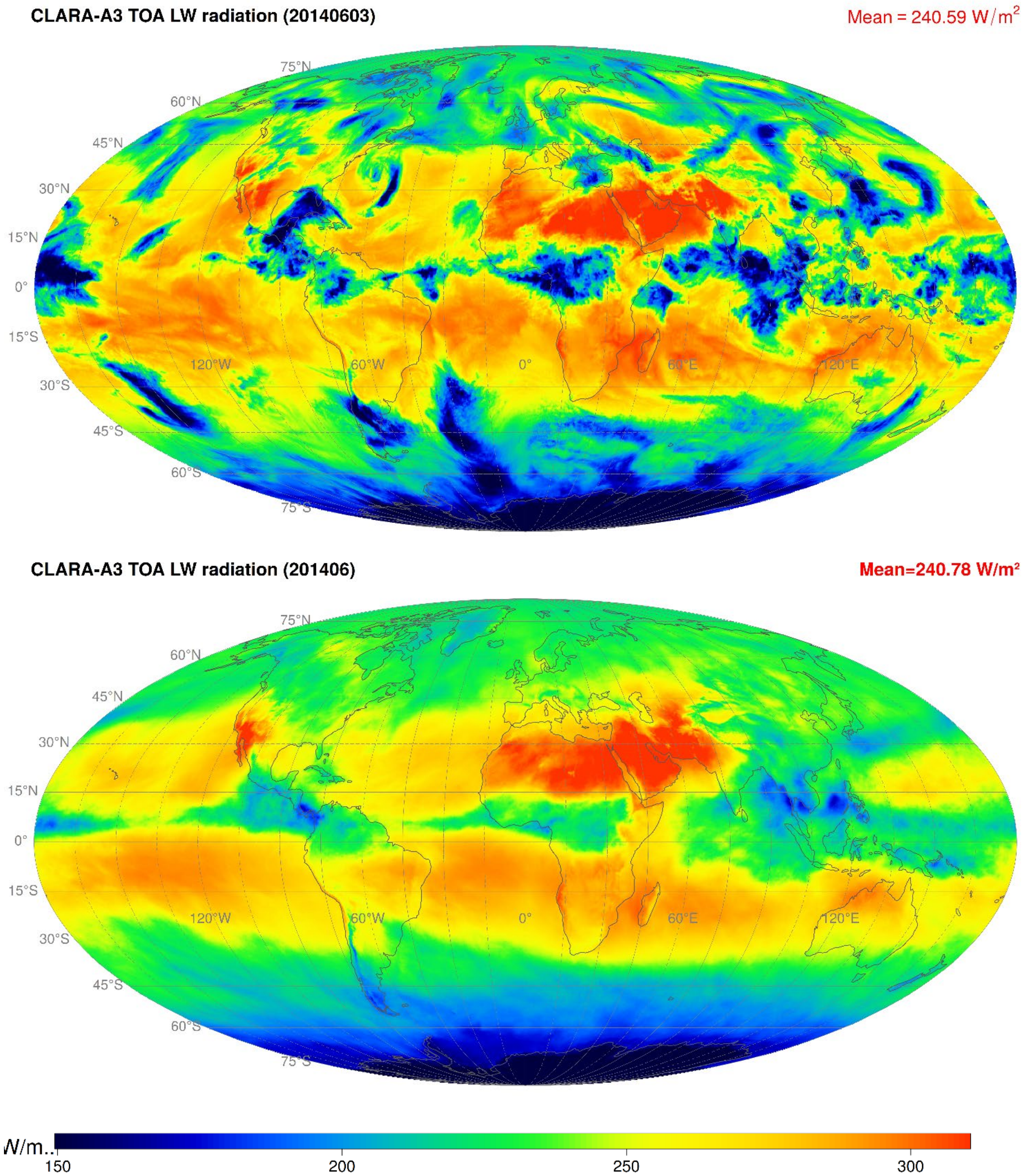

Figure 3-3: Example of daily (03-06-2014) and monthly (06-2014) mean OLR

The level of detail is demonstrated by zooming in on a particular region (Northern Atlantic and Europe) in Figure 3-4, where the CLARA-A3 RSF product (bottom) is compared to the CERES SYN1deg product (top).

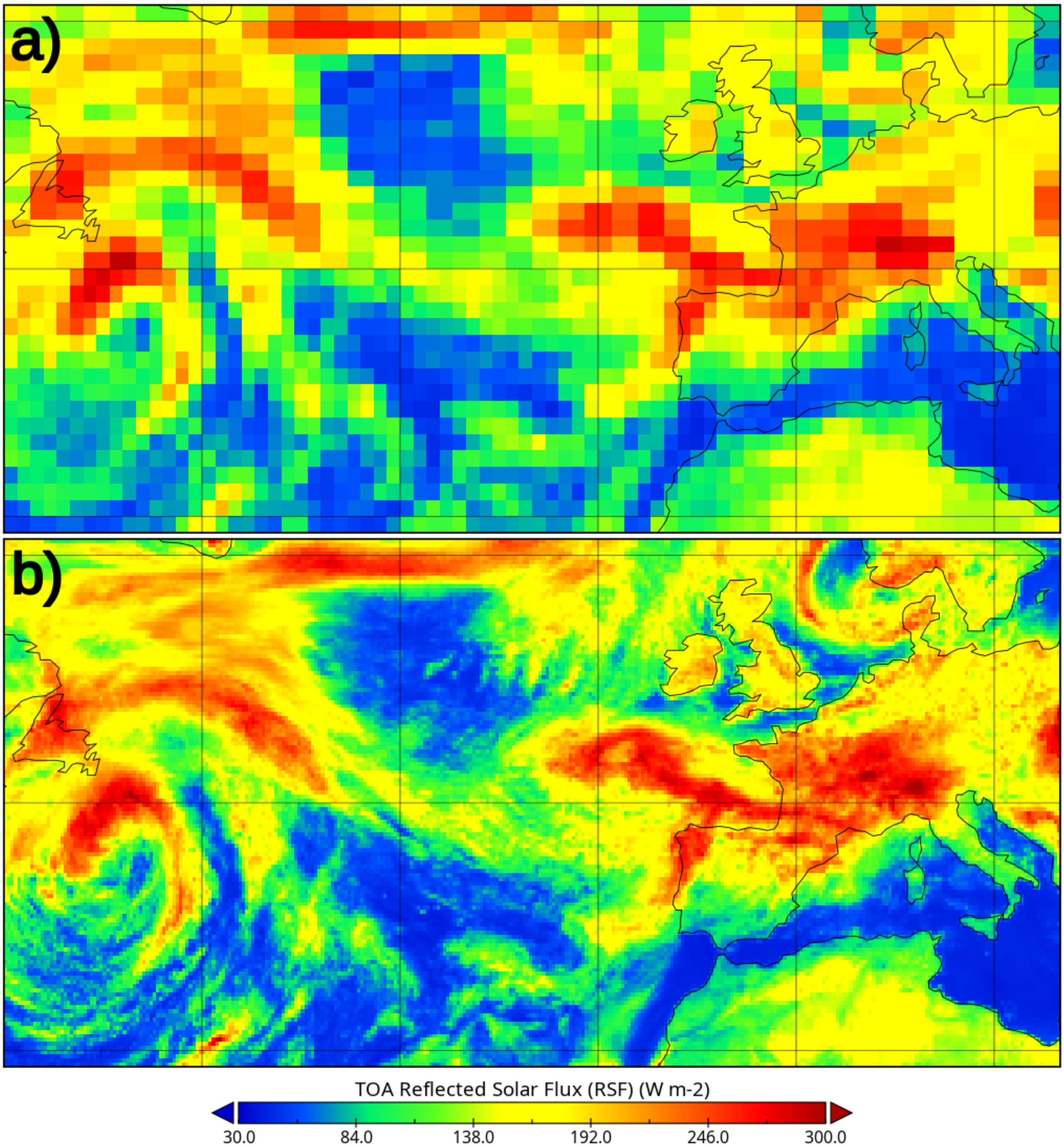

Figure 3-4: Daily mean RSF for 15-06-2008, zoomed in on the Northern Atlantic and Europe, from (a) CERES-SYN1deg, and (b) CLARA-A3

3.4 Summary of validation results

3.4.1 Regional uncertainty (processing error)

As demonstrated in the Validation Report [RD 8] the data record's accuracy is not constant in time due to the temporally varying AVHRR orbital constellation: the number of available satellites and their temporal spread throughout the day has a large impact on the interpolation between instantaneous satellite observations.

When using daily and monthly images of CLARA-A3 mean RSF and OLR, the user should be aware that the regional uncertainty (i.e. processing error) is higher in specific periods of the data record. This is different for the longwave (OLR) compared to the shortwave (RSF) products. Validation results for OLR monthly and daily mean products are provided in Figure 3-5 and Figure 3-6, respectively, and for RSF monthly and daily mean products in Figure 3-7 and Figure 3-8. In these figures, the horizontal dark dotted lines refer to a set of performance requirements determined in the Product Requirement Document (PRD) [AD 2].

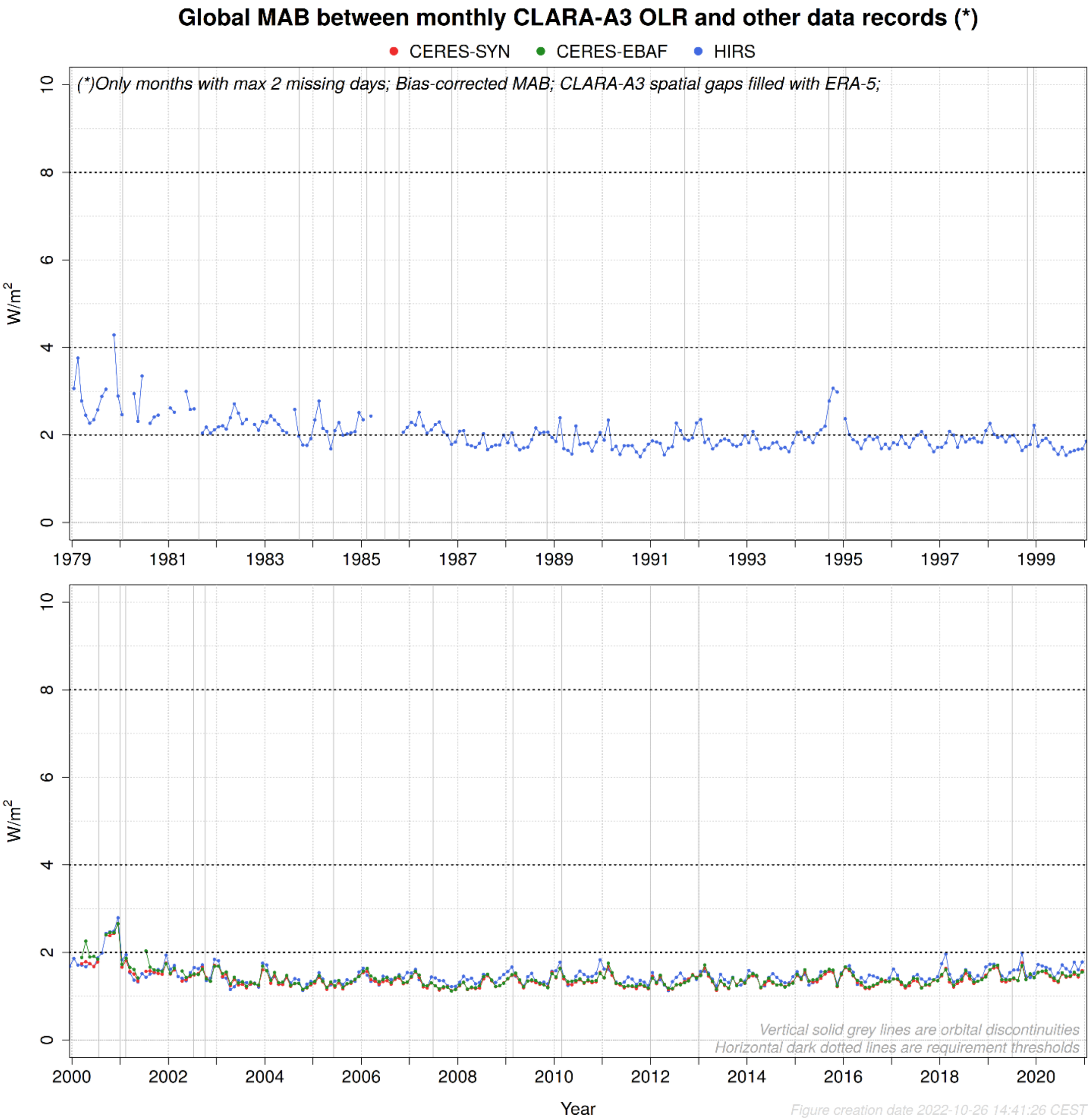

Figure 3-5: Global MAB between monthly CLARA-A3 OLR and other data records

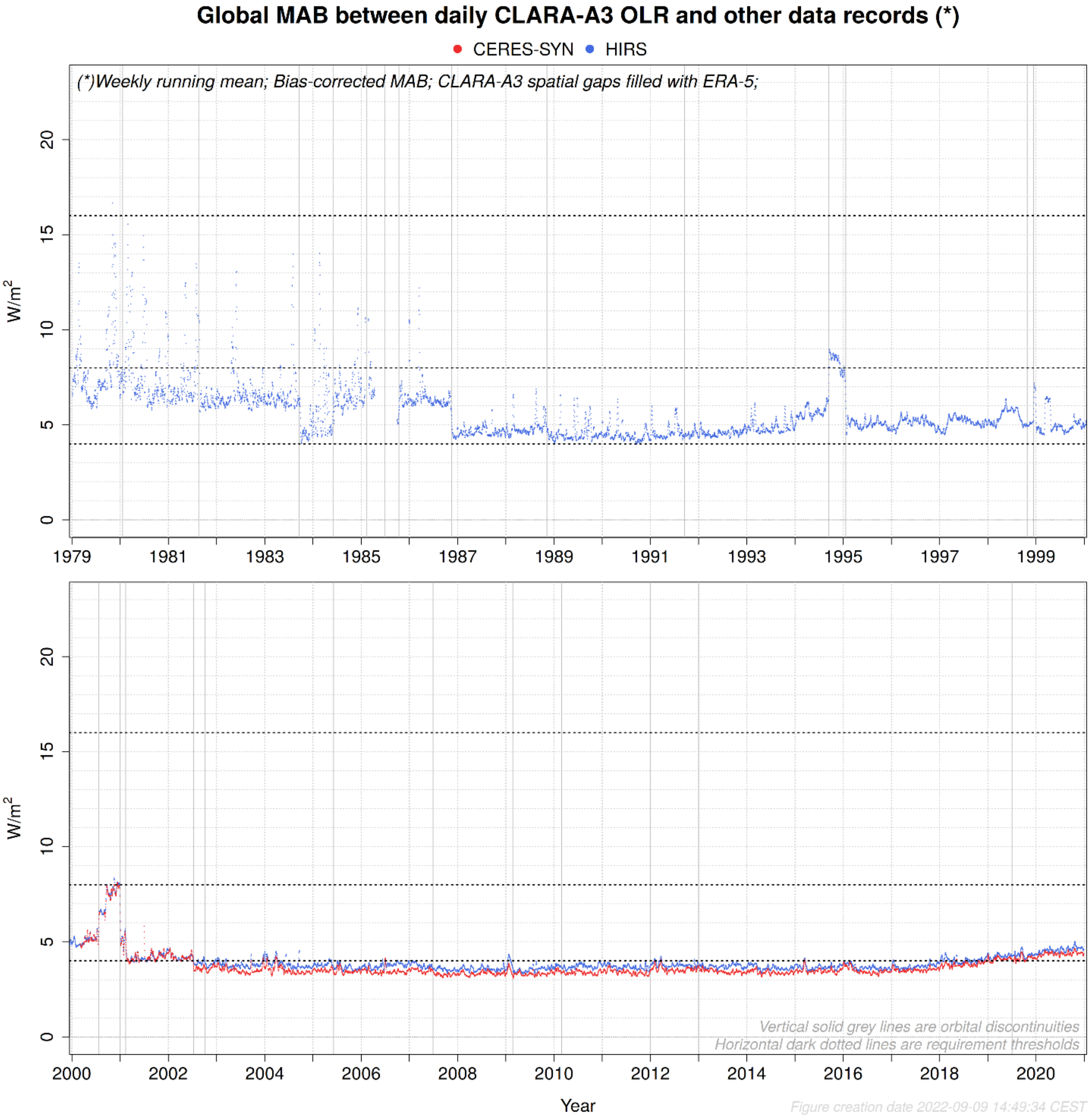

Figure 3-6: Global MAB between daily CLARA-A3 OLR and other data records

For the RSF, there is no reference data record prior to 2000 ("pre-CERES era") that is useful for this kind of validation. Therefore, the Mean Absolute Bias (MAB) of CLARA-A3 RSF w.r.t. CERES RSF during the pre-CERES era is an estimate based on actual CERES-era MAB resulting from equivalent orbital configurations that mimic the pre-CERES constellation (more details in [RD 8]). The resulting estimated MAB is provided as horizontal red lines in Figure 3-7 and Figure 3-8.

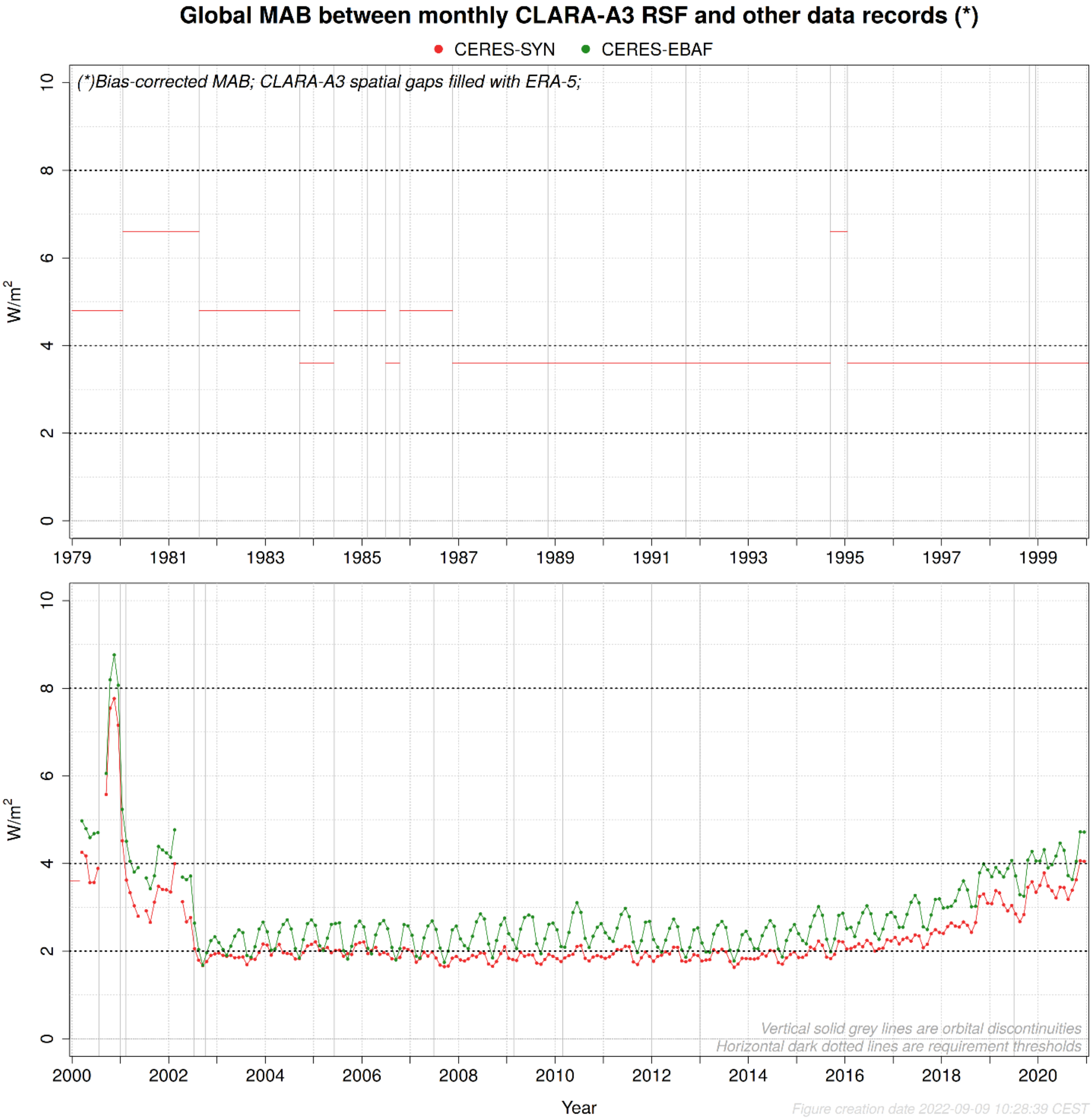

Figure 3-7: Global MAB between monthly CLARA-A3 RSF and other data records; horizontal red lines indicate estimations of MAB during pre-CERES era, based on actual CERES-era MAB using equivalent orbital configurations.

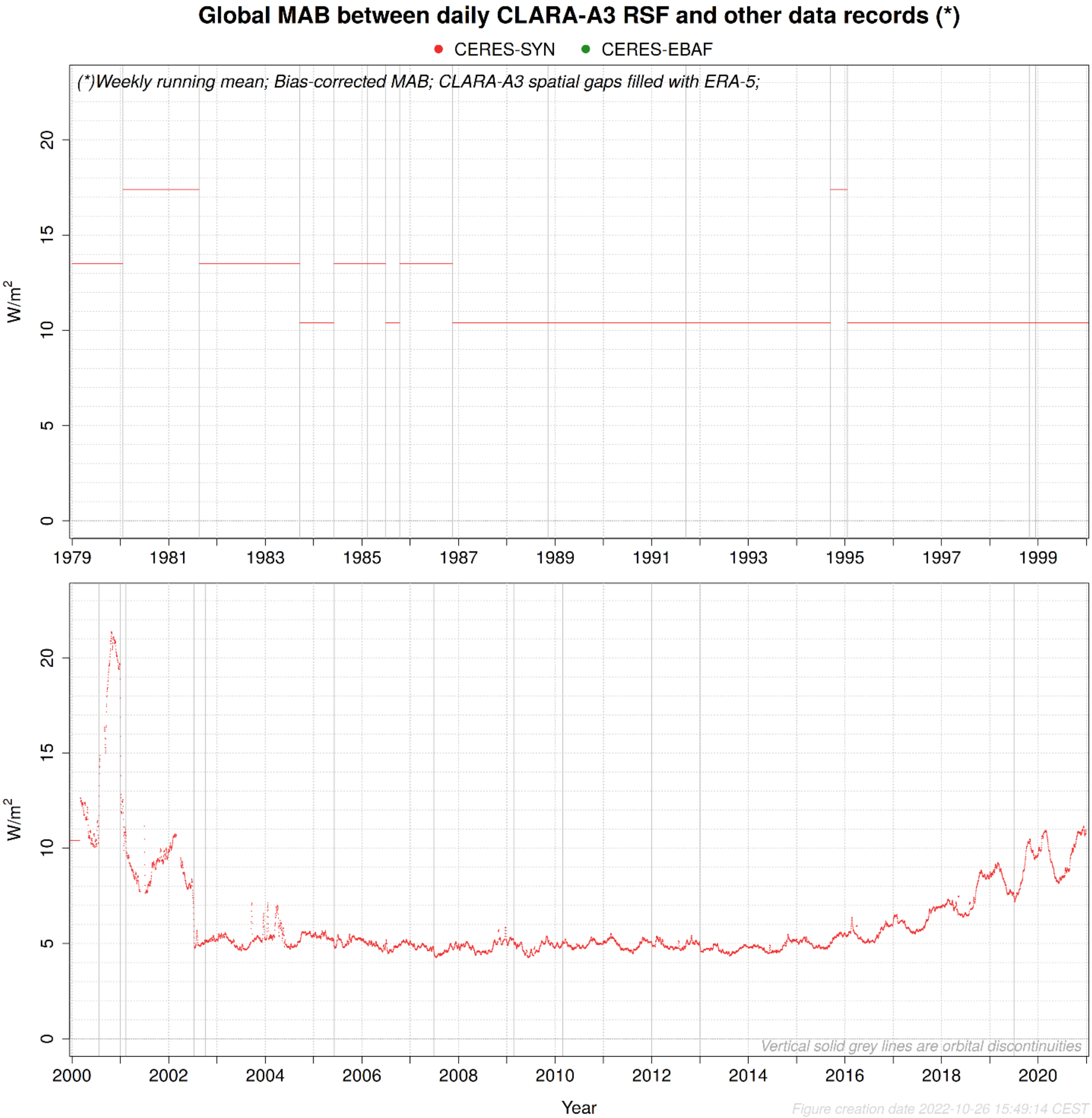

Figure 3-8: Global MAB between daily CLARA-A3 and CERES-SYN RSF; horizontal red lines indicate estimations of MAB during pre-CERES era, based on actual CERES-era MAB using equivalent orbital configurations.

These plots provide a good overview on the temporal variability of the data record's regional uncertainty (capturing both accuracy and precision), also called 'processing error'. It is a guideline for users with specific performance requirements, who are then able to select their period of interest from the data record, based on the performance. Table 3-1 summarizes the validation results in view of the requirements (*threshold, target,* and *optimal*) which were determined in the Product Requirement Document (PRD) [AD 2].

Table 3-1: Requirements and validation results for processing error (regional uncertainty)

CLARA-A3 Parameter		Average MAB (W/m²)	Ref. data record	Threshold requirement W/m² (% met)			Target requirement W/m² (% met)			Optimal requirement W/m² (% met)		
for the entire time series (1979-2020):												
RSF	MM	**3.2***	CERES	**8**	✓	99.3%*	**4**	✓	72.4%*	**2**	✗	24.6%
	DM	**9.0***	CERES	**16**	✓	94.5%*	**8**	✗	44.9%*	**4**	✗	0.0%*
OLR	MM	**1.8**	HIRS	**8**	✓	99.8%	**4**	✓	99.2%	**2**	✓	77.2%
	DM	**4.8**	HIRS	**16**	✓	99.6%	**8**	✓	97.1%	**4**	✗	37.1%
during the CERES era (2000/03-2020/12):												
RSF	MM	**2.3**	CERES	**8**	✓	100%	**4**	✓	96.4%	**2**	✗	49.8%
	DM	**6.2**	CERES	**16**	✓	98.3%	**8**	✓	80.4%	**4**	✗	0.0%
OLR	MM	**1.4**	CERES	**8**	✓	100%	**4**	✓	100%	**2**	✓	98.4%
	DM	**3.7**	CERES	**16**	✓	100%	**8**	✓	99.7%	**4**	✓	81.0%
(*) estimated by mimicking equivalent orbital configurations during CERES era												

3.4.2 Stability

Table 3-2 summarizes the stability validation results in view of the requirements. Note that the *target* and *optimal* requirements are not met: they were based on very strict GCOS requirements (see PRD [AD 2]), which were however not achieved with the CLARA-A3 TOA Radiation products. More information, plots, and documentation are provided in the Validation Report [RD 8]. In general, it can be concluded that the time series' stability generally complies with the threshold requirement as most of the data record (94% for RSF and 99.6% for OLR) is contained within the predetermined 4W/m² *stability envelope* (for more details see [RD 8]). The user is warned that this may not be sufficient for particular purposes a such as climate trend analyses.

Table 3-2: Requirements and validation results for stability

CLARA-A3 Parameter		Reference data record	Threshold requirement W/m² (% met)			Target requirement W/m² (% met)			Optimal requirement W/m² (% met)		
for the entire time series (1979-2020):											
RSF	MM	ERA5	4	94.0%	✓	0.6	30.2%	✗	0.3	14.1%	✗
OLR	MM	HIRS	4	99.6%	✓	0.6	37.3%	✗	0.2	15.3%	✗
OLR	MM	HIRS-MM	4	98.0%	✓	0.6	44.4%	✗	0.2	16.5%	✗
during the CERES era (2000/03-2020/12):											
RSF	MM	CERES	4	99.2%	✓	0.6	52.8%	✗	0.3	24.4%	✗
OLR	MM	CERES	4	100%	✓	0.6	69.6%	✗	0.2	28.4%	✗

3.5 Missing data: treatment and recommendations

For a number of reasons, there are gaps in the data coverage of CLARA-A3 TOA flux products. This section identifies these missing data.

3.5.1 Data gaps in space and time

The occurrence of **temporal data gaps** for the RSF product is shown in Figure 3-9. A day is considered 'missing' if there is no (i.e., zero) Level-2b input data to create the daily mean, which means **no** valid input files (i.e. orbital overpasses) during the preceding, actual, or following day[1]. In that case, there is simply no input data to generate at least 1 valid daily mean grid box. The most common reasons are instrument failure and/or temporal gaps between subsequent satellites (between decommissioning and launch).

[1] At least 1 inputfile in the preceding, actual or following day is sufficient to generate a valid daily mean.

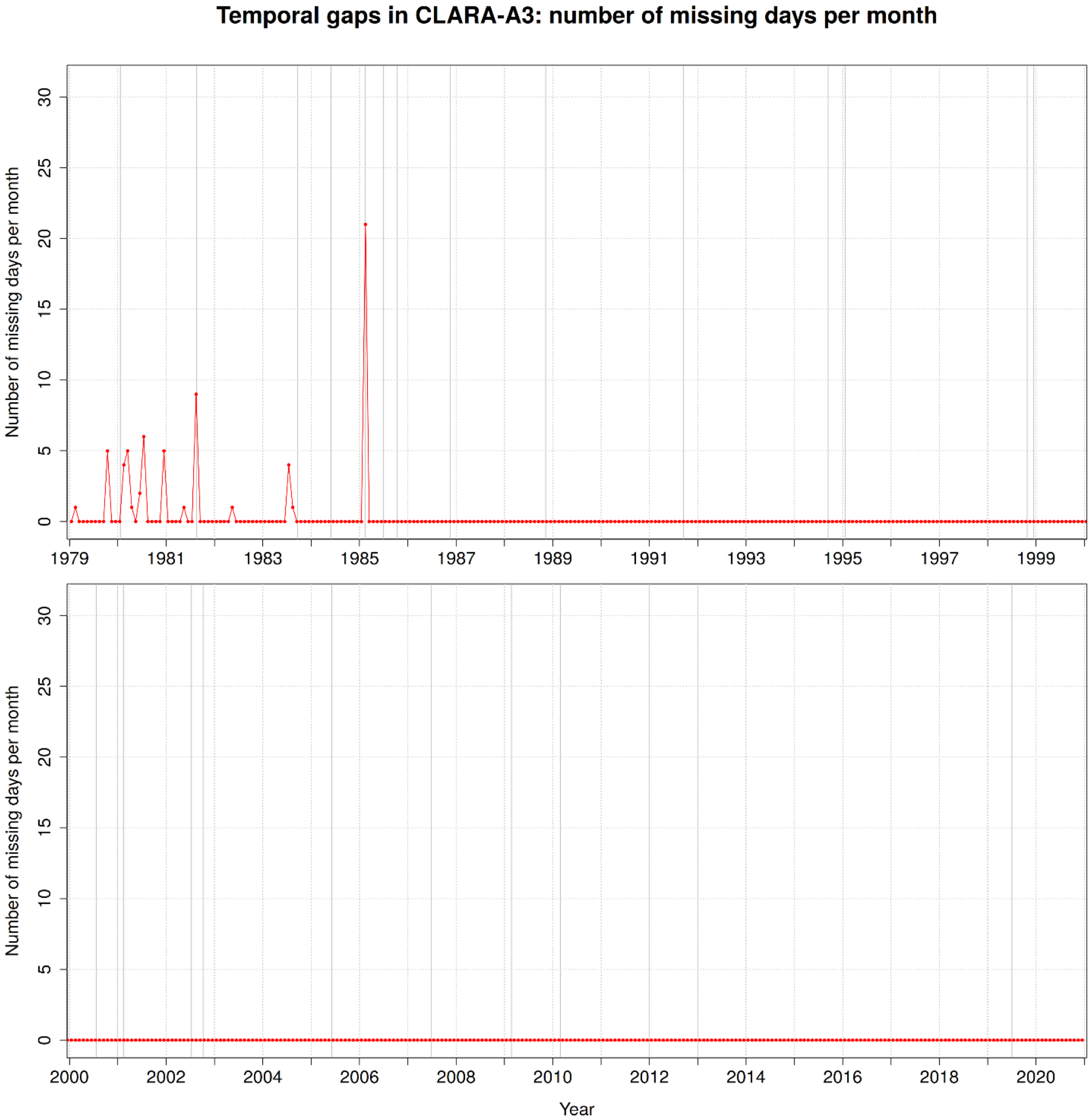

Figure 3-9: Temporal gaps in CLARA-A3

Most important are February 1985 (21 missing days, i.e. only 7 valid days, cfr Figure 3-10) and August 1981 (9 missing days). There is no attempt to perform any gap filling.

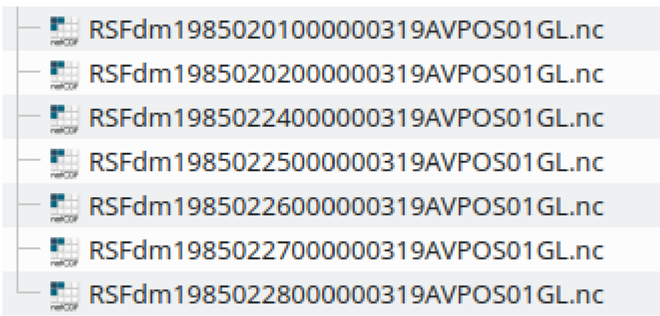

Figure 3-10: Days with valid CLARA-A3 output for February 1985

The occurrence of **spatial data gaps** for the RSF product is shown in Figure 3-11. Missing data are considered “spatial data gaps” if it concerns only parts of the globe, i.e. if not 100% the pixels of a daily mean RSF map are missing. It is acknowledged that the distinction between temporal and spatial data gaps is not really meaningful in some extreme cases (e.g. if almost 100% of pixels are missing).

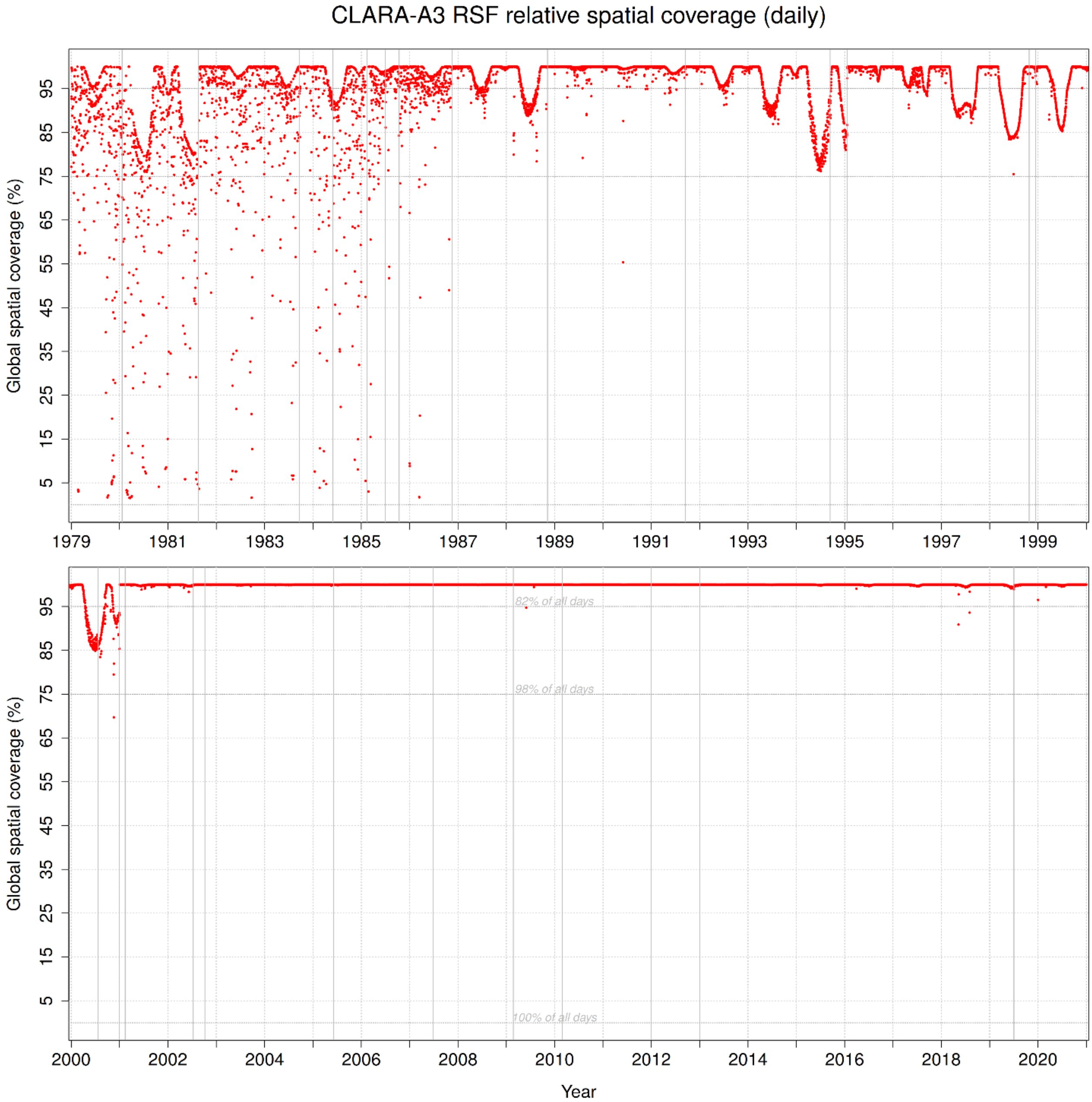

Figure 3-11: Spatial gaps in CLARA-A3 RSF

There are a number of types of spatial data gaps. The most frequent (in terms of time) originates in the fact that for some regions the day length is simply too short to have valid observations between sunrise and sunset. This is quite common during southern wintertime (JJA) in the region where the South Pole “twilight-only regime” borders to the “twilight-and-daylight regime”. Even after implementation of an mitigating exception (extension of the twilight model from 84°<SZA<100° to 80°<SZA<100° on condition that the SZA never decreases below 80°), systematic small pockets of missing values remain common, an example of which is shown in Figure 3-12. Their impact on the global mean is, however, negligible.

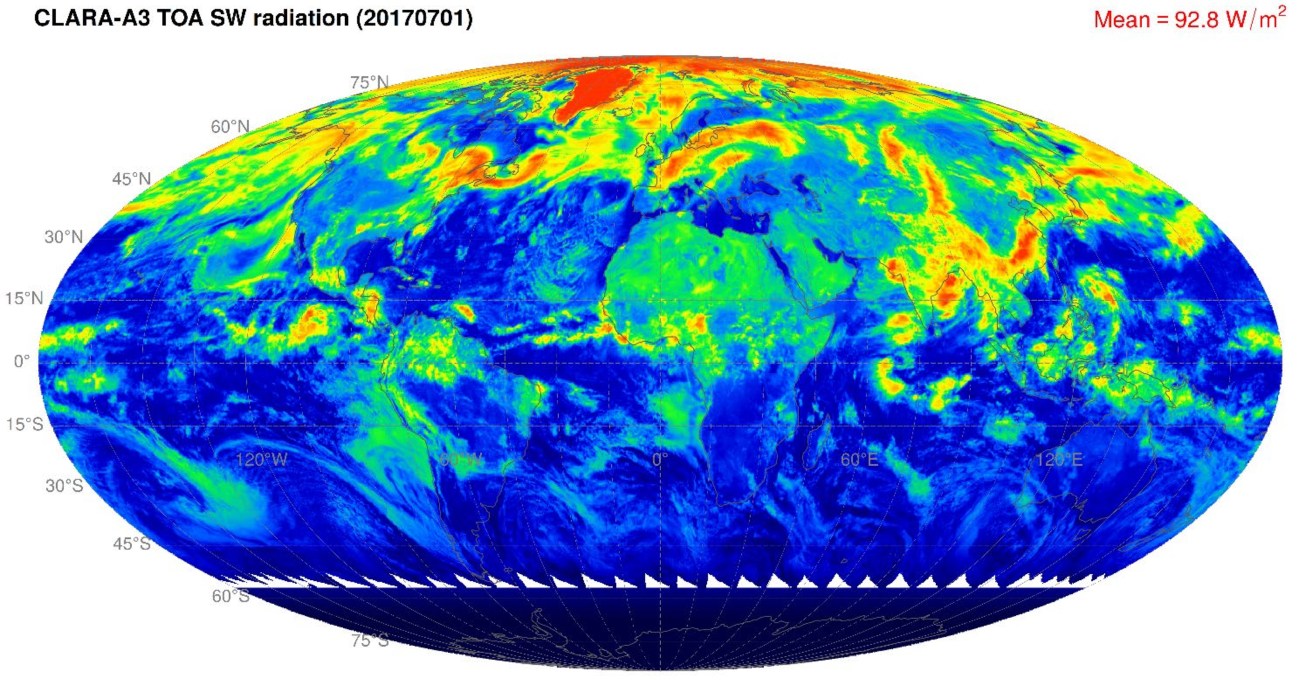

Figure 3-12: Daily CLARA-A3 RSF for 01-07-2017. White area indicates missing spatial data.

A second type consists of missing (parts of) individual orbits, which were filtered out due to insufficient quality, instrument failure, etcetera. An example is given in Figure 3-13.

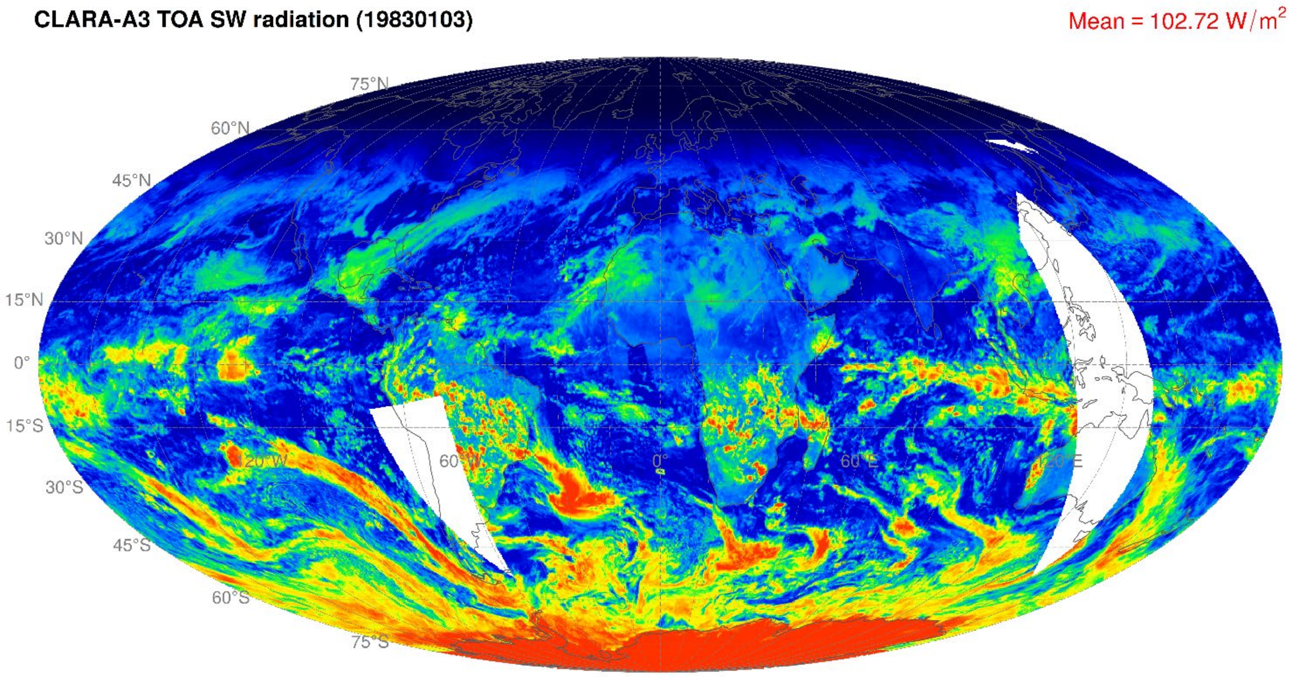

Figure 3-13: Daily CLARA-A3 RSF for 03-01-1983. White area indicates missing spatial data.

The most important type of missing RSF data in terms of spatial extent (of missing area) concerns areas that were flagged as insufficient quality, e.g. due to solar contamination, in the first part of the CLARA-A3 processing chain (i.e. reading the PyGAC output before using the data in PPS, more info in the ATBD [RD 7] Sections 2.1 and 2.2 therein). An example of 13/07/1994 is given below. Almost 25% of the pixels are missing on that day.

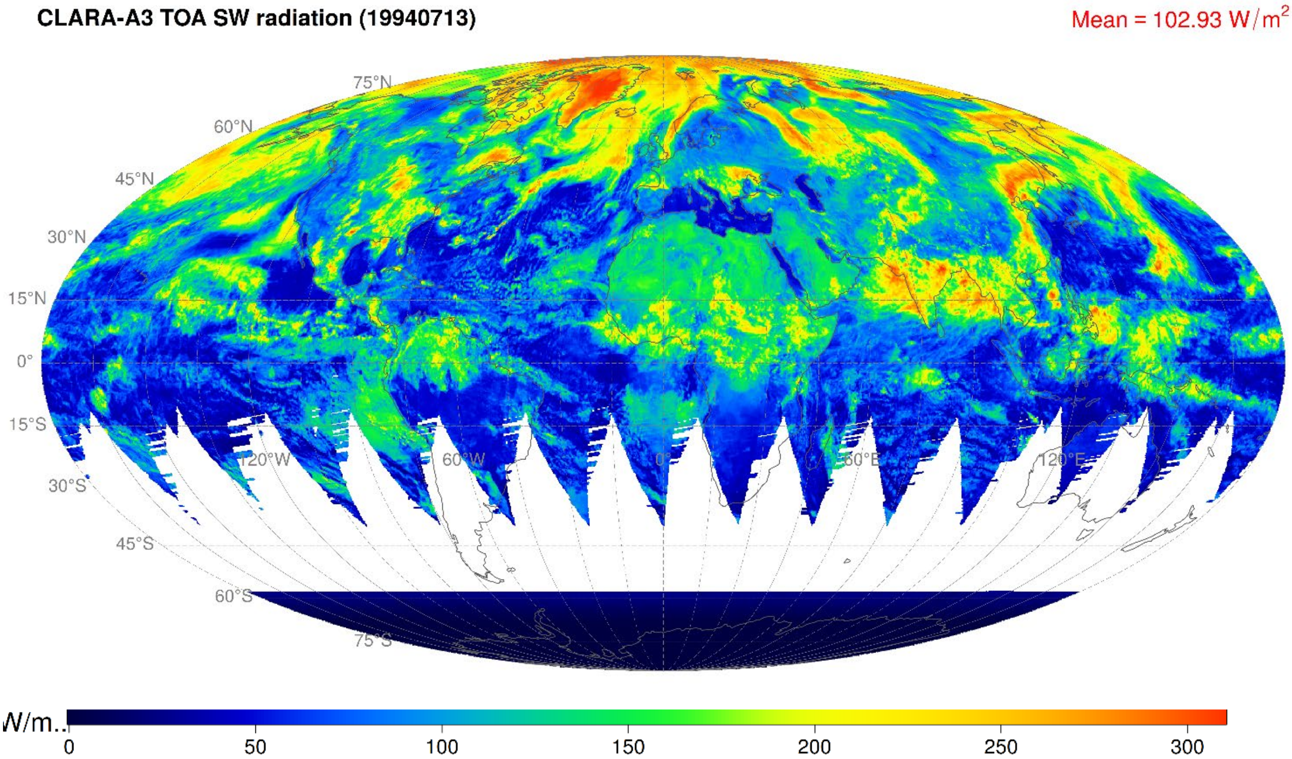

Figure 3-14: Daily CLARA-A3 RSF for 13-07-1994. White area indicates missing spatial data.

The official CLARA-A3 <u>daily</u> mean RSF and OLR products are available without gap filling (i.e., as shown in Figure 3-14). It is clear that **the user should be aware of these gaps when deriving global average fluxes from the daily mean products (or other spatially aggregated statistics)**. This is demonstrated in the Validation Report [RD 8] (Figures 5-8 and 5-9 therein), where the global mean daily CLARA-A3 RSF shows significant anomalies compared to the ERA5 RSF during years with increased spatial data gaps. Without any reference, context, or warning, time series of global mean CLARA-A3 RSF generated by the user could be easily misinterpreted. Therefore, in the validation report [RD 8], the spatial gaps in daily mean RSF and OLR were filled using daily mean ERA5 as '*surrogate data record'*. This method was proven to remove the anomalies due to missing data in CLARA-A3 RSF time series, resulting in a much better alignment of both time series (i.e. a more realistic global mean time series of CLARA-A3).

The official CLARA-A3 <u>monthly</u> mean RSF and OLR products on a given grid box are calculated without considering the number of days with a valid daily mean flux on that pixel during that month.

3.5.2 Recommendations on the use of Daily mean RSF and OLR

The user is strongly advised to check all **daily** mean maps before performing analyses. The daily mean products may be either completely missing, in case all pixels are invalid (i.e. temporal data gaps), or contain certain regions with missing data, in case only part of the globe has valid coverage (i.e. temporal data gaps).

When comparing CLARA-A3 daily mean fluxes with corresponding reference data records, the user should first of all remove the days for which CLARA-A3 does not have any valid output from the reference data record. These temporal data gaps are highly relevant for e.g. February 1985, cf Figure 3-10.

Concerning spatial data gaps, the following approaches are recommended:

- When comparing CLARA-A3 with reference data, the user could “cut out” the same missing regions from the reference data. This makes both products comparable.
- When creating time series of global averages, or when comparing CLARA-A3 with reference data, the user could follow a similar gap-filling approach as performed in [RD 8], i.e. fill the spatial gaps by a third party *‘surrogate’* data record with spatio-temporal continuous coverage (e.g. ERA5, climate model output). This makes both products comparable, and furthermore it has the advantage that realistic global averages are obtained.

Spatial gap-filling is not provided in the official product because the need for gap-filling strongly depends on the specific application of the data (e.g. local vs global scale). Furthermore, the user is left a choice of *surrogate data record* if gap-filling is deemed necessary, without forcing the use of e.g. ERA5 or any other data record.

3.5.3 Recommendations on the use of Monthly mean RSF and OLR

For the **monthly** mean products it is not possible to follow the same recommendations as for the daily mean fluxes (cutting out missing data from reference data, or performing gap-filling), because the products were generated as temporal aggregation from the daily mean fluxes without considering the number of days with a valid daily mean flux on a given pixel. Hence, even if the grid boxes have a “valid” monthly mean flux value, they may be based on only a few days of data and hence not be representative for the real monthly mean flux. In these cases, comparing CLARA-A3 monthly mean flux with a reference data record (also monthly mean flux) may be misleading. Some statistics from the monthly mean validation were found very sensitive to the number of missing days (e.g. the Mean Absolute Bias from CLARA-A3 OLR w.r.t. HIRS OLR).

Therefore, the following approaches are recommended

- Create gap-filled daily mean fluxes and re-create the monthly mean flux product (by temporal aggregation of the newly created gap-filled daily means), i.e. not using the official CLARA-A3 monthly mean products.
- Only using the grid boxes with an acceptable number of missing days.

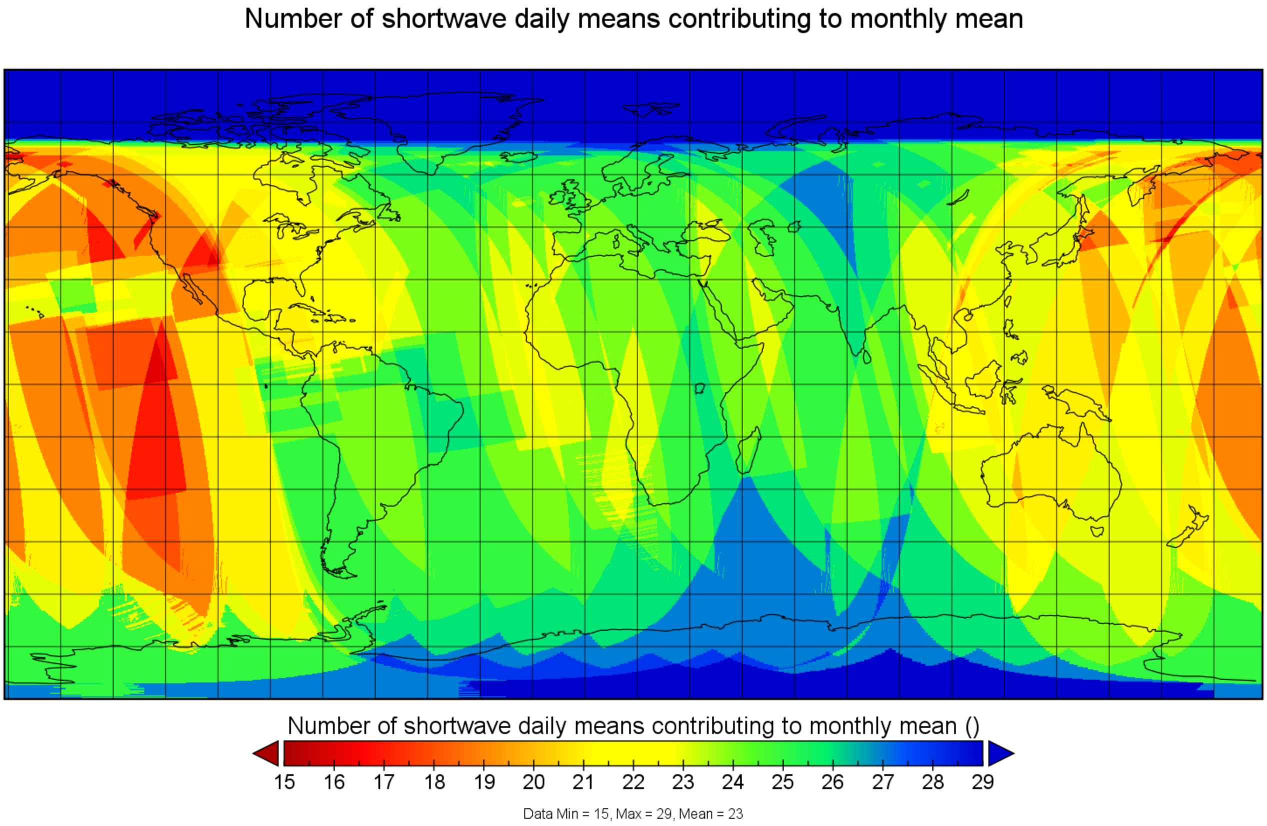

Figure 3-15: Example of monthly RSF ancillary variable "`number_of_sw_daily_means`" in Feb.1984

Additionally, a spatially-explicit flag is also provided in the accompanying ancillary data (variable `bitflags_sw` or `bitflags_lw`), and an example is provided in Figure 3-16. The user is strongly encouraged to verify this auxiliary variable before doing analyses on the main results (i.e. monthly mean fluxes). The bit flags are set for each grid box individually, and contain the following information:

- `bitflags_sw=`**`1`** or `bitflags_lw=`**`1`** (**`MISSINGDAYS_WARNING`**): this flag is set when the temporal coverage is not complete, and the number of missing days ranges between 1-4. The monthly mean RSF is not entirely representative since some days are missing, but can still be used (of course depending on the application or analysis).
- `bitflags_sw=`**`2`** `or bitflags_lw=`**`2`** (**`MISSINGDAYS_INVALID`**): this flag is set when the temporal coverage is not sufficient, with the number of missing days being 5 or more. The monthly mean RSF is considered invalid and the **user is advised not to use it**.

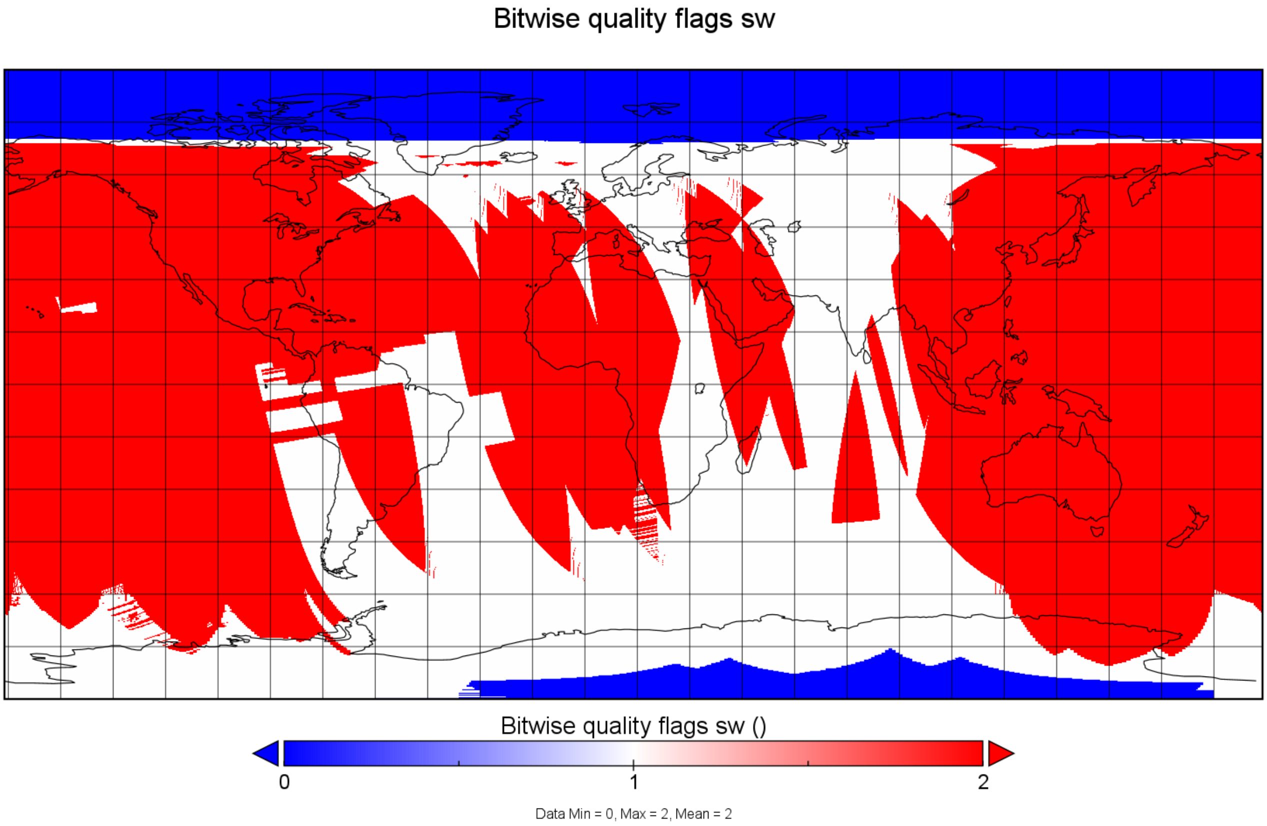

Figure 3-16: Example of monthly RSF ancillary variable "`bitflags_sw`" in February 1984

3.6 General limitations and recommendations

The following points should be considered when using the data.

- Although several quality check processes have been applied, it was not possible to look at each individual AVHRR orbit. Artefacts in the input data may have been missed and could have affected the final products (sometime reduced during the daily/monthly averaging). Should the user suspect problems in some products please report to the CM SAF team through the helpdesk.
- The SW ADM scene type selection is based on a constant surface type map (IGBP). This could introduce flux error in region of seasonally varying vegetation like the Sahel and also in regions that have experienced significant changes during the last decades (e.g. Aral Sea drying).
- The reference level for the CLARA-A3 RSF and OLR data records is set to 20 km above the mean sea level, which is consistent with climate models and CERES EBAF. To compare with other data records, users may be advised to first check if the reference levels are identical. If not, the data records should be rescaled to the same reference level based on the method given in Section 3.1.
- The data records have not been “energy balanced” (see for example Loeb et al., 2009). The overall biases of the data records with respect to CERES EBAF Ed4.1 are -2.0 W/m² for the RSF and -2.2 W/m² for the OLR [RD 8].

- As addressed with detailed analyses in the Validation Report [RD 8], the overall stability generally complies with the basic (‘*threshold’*) requirements, as most of the data record (94% for RSF and 99.6% for OLR) is contained within the predetermined 4W/m² stability envelope (for more details see [RD 8]). However, the user is warned that this may not be sufficient for particular purposes a such as climate trend analyses, since the very strict GCOS requirements (stability of 0.3-0.6 W/m²) are not achieved. For such applications it is highly recommended to first consult the validation report.
- For clear ocean in the sun glint region (sun glint angle < 25°) the RSF instantaneous flux is not based on the radiance observation but instead on the CERES TRMM diurnal cycle models (Loeb et al., 2003). Those “model” fluxes are used in the interpolation processes to obtain daily mean flux. The effect on the DM and certainly MM products is in general negligible. The ancillary field `relative_share_sunglint` in the RSF files provides, at grid box level, the frequency of the use of those “model” fluxes (relative to the total number of instantaneous observations used in that grid box on that day). An example of this ancillary sun glint information is provided in Figure 3-17, and a comparison with the corresponding daily mean RSF (Figure 3-18) demonstrates the impact of sun glint on RSF (cfr the north-south oriented discontinuities in RSF over clear sky ocean, albeit relatively small in magnitude).
- Another reason for spatial discontinuities is the number of instantaneous observations used to obtain a daily mean flux, which depends on the number of satellites covering that grid box at that time. This in turn depends on the orbital configuration of the AVHRR constellation, which is variable in space and time. The ancillary field `number_of_sw_inst_obs` in the RSF files provides, at grid box level, the total number of instantaneous observations used in that grid box on that day, to obtain the daily mean flux. An example of this ancillary information is provided in Figure 3-19 , and a comparison with the corresponding daily mean RSF (Figure 3-18) demonstrates its impact on RSF, in this case over the Sahara Desert (cfr the north-south oriented discontinuity).

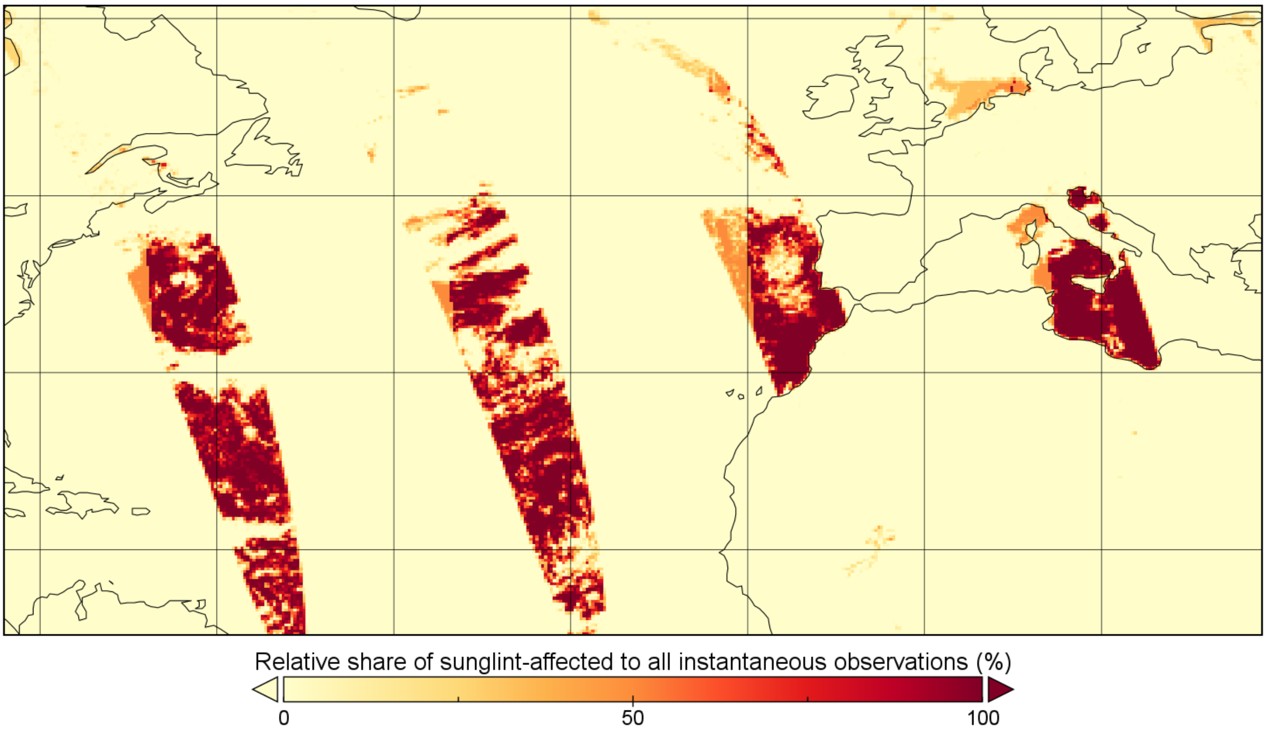

Figure 3-17: Ancillary RSF variable "relative_share_sunlight" on 26/6/1982

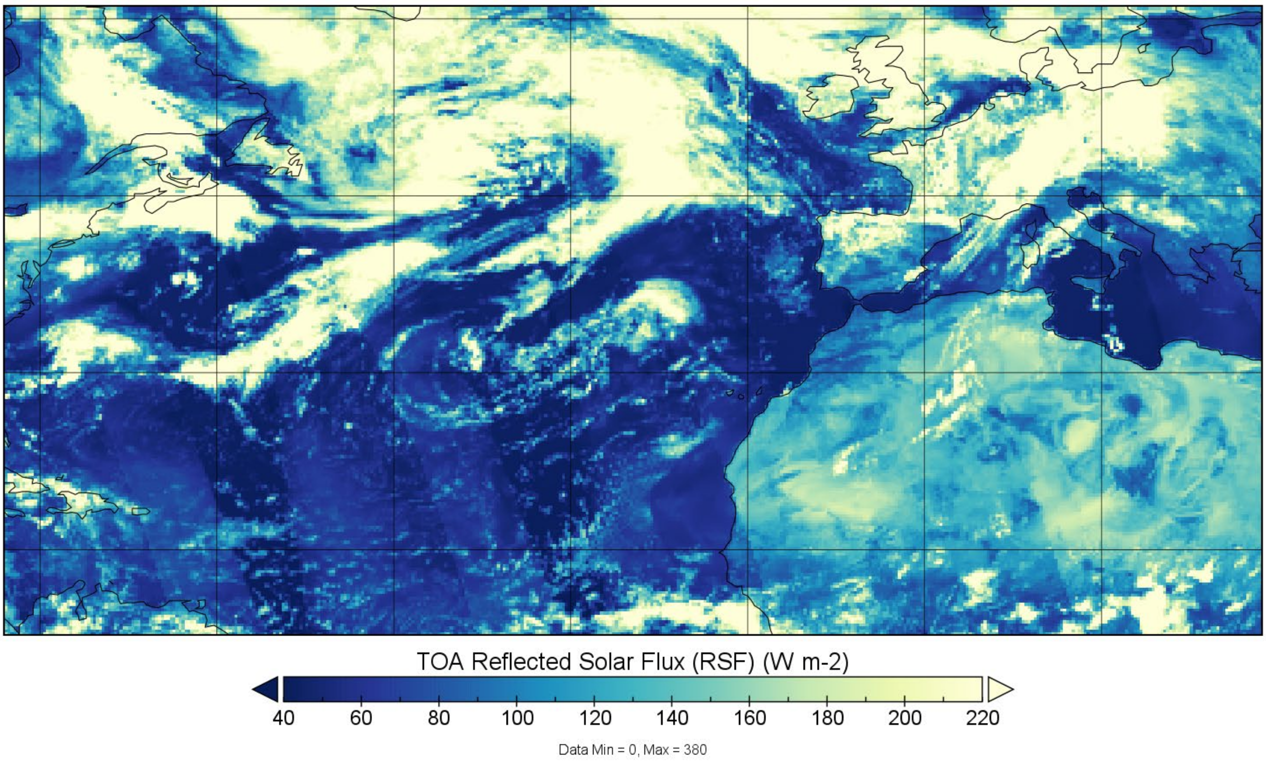

Figure 3-18: Daily mean RSF on 26/6/1982.

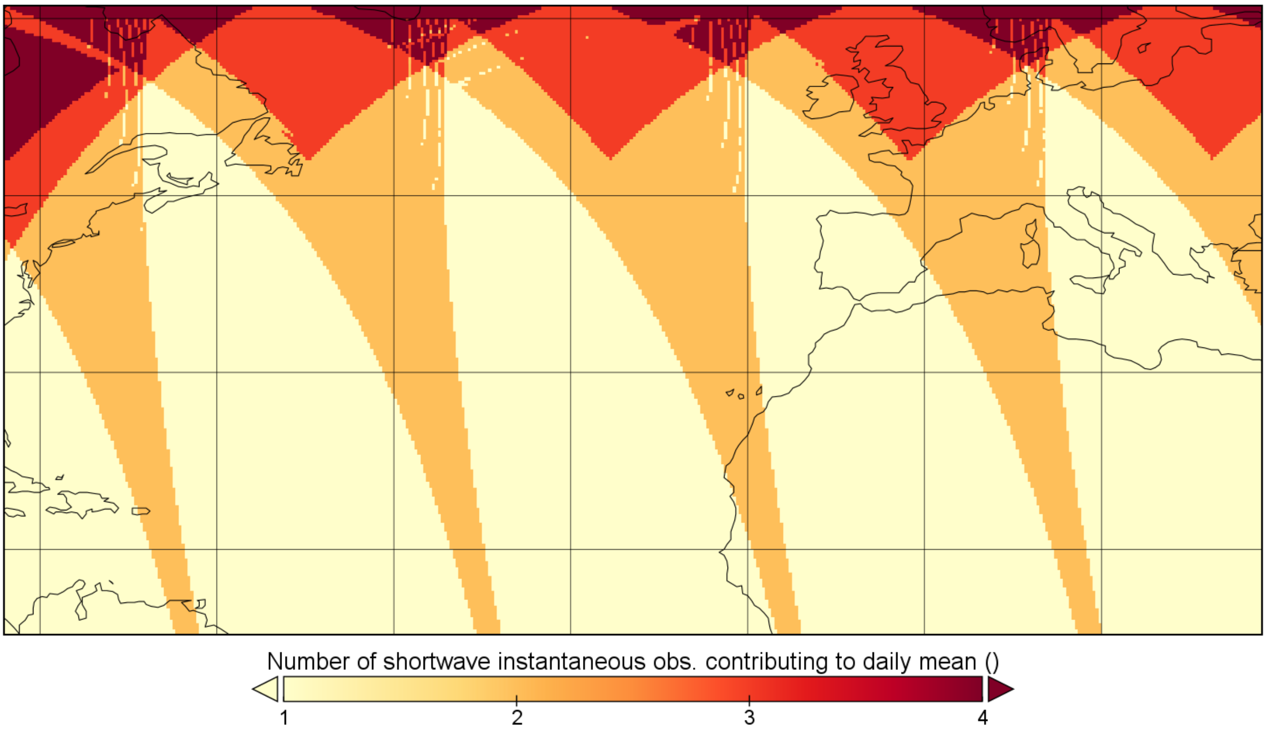

Figure 3-19: Ancillary RSF variable "number_of_sw_inst_obs" on 26/6/1982

3.7 ICDR

Intermediate Climate Data Records (ICDRs) denote regular extensions of Thematic Climate Data Records (TCDRs) with algorithms and processing systems identical to the already generated reference TCDRs, but with shorter time latency. Therefore, the input data used for the CLARA-A3 TCDR require some adaptations when switching to the CLARA-A3 ICDR (see RD 7).

First of all there is the use of ERA5 reanalyses in many parts of the input data (snow depth, 10m wind speed, surface temperature, integrated water vapor,..). This will be replaced by ERA5T data, which provides preliminary data for ERA5 on a daily basis, with a 5-day delay from real time. This enables the retrieval of ERA5 data up to 5 days ago (much improved compared to the 2-3 months delay for the release of validated ERA5 data). Furthermore there is the sea ice concentration, which was for the TCDR provided by a combination of OSI-450 and OSI-430-b products. For the ICDR the sea ice concentration will also be obtained from OSI SAF but now from product OSI-401. Finally, it should be noted that uncertainties in the calibration of visible channels for Metop-C led to that Metop-C products are currently not included in the ICDR dataset. The reason is an anticipated decay with time of the calibration accuracy for the visible radiances for this satellite. The NOAA calibration method is based on a vicarious calibration technique for the visible channels (i.e., no on-board calibration is available) and this requires data from several years to estimate sensor degradation with time and potential biases compared to previous AVHRR instruments. With only 1 ½ years of data available from Metop-C in 2020, the calibration information (more clearly, the time-dependent corrections) was not considered reliable for this satellite for allowing further processing after 2020. Data from Metop-C will therefore be added in 2023 or later to the ICDR as soon as a new calibration update is received.

The algorithms for CLARA-A3 TOA Radiation are identical for TCDR and ICDR. However, the software does make a distinction between both types of data record, by making use of an ICDR-flag which can be enabled in the configuration file. As a result, the alternative ICDR input data is automatically selected instead of the TCDR input data (see Section 2.5), and the output files are generated with some minor differences in terms of filename (cfr CM SAF naming convention) or metadata (global attributes describing the content of the file).

The validation report [RD 8] shows that differences between TCDR and ICDR for OLR and RSF global mean bias and mean absolute bias are relatively minor, without implications for not meeting the requirements. The differences are largely due to the exclusion of Metop-C, and only for specific regions and to a smaller extent also due to changing input data (around sea ice areas, cfr. OSI SAF product change).

Beware that possible changes in the ICDR input data streams and a decay with time of calibration corrections (before the next update) can lead to reduced quality in the CM SAF ICDR products, with partly distinct regional imprints and exceeding the effective ICDR Service Specifications. Please use the data and associated plots with care and check the Service Messages and the Annual Validation Reports (AQARep) of the ICDR (https://www.cmsaf.eu).

4 Data format description

4.1 File naming and Format

The data are provided through the RSF and OLR files:

- RSF: contains the (all-sky) TOA Reflected Solar fluxes (**SW_flux**) and various ancillary/quality fields.
- OLR: contains the (all-sky) TOA Outgoing Longwave Radiation (**LW_flux**) and various ancillary/quality fields.

The products are generated on an equal-angle global grid with a spatial resolution of 0.25°x0.25°. The time resolution is either daily mean (dm) or monthly mean (mm).

All products are delivered as NetCDF (Network Common Data Form) format, version 4 (http://www.unidata.ucar.edu/software/netcdf/) with internal compression using zlib, and follow the CF (Climate and Forecast) Metadata Convention version 1.7 (http://cfconventions.org/). A NetCDF file contains dimensions, variables and attributes, which are all identified by a specific name (and an ID number). These components can be used together to capture the meaning of data and relations among data fields. The specific content of the NetCDF files is described in the following subsections.

The product filenames follow the CM SAF filename convention[2] and are consequently built following the structure:

PROtsyyyymmddhhmmVerGrSourcLvAr.nc

Table **4-1:** File name format

Character	Meaning
PRO	Three-character coding of product type, i.e. "RSF" or "OLR"
t	Time interval of product, i.e. "d" for daily and "m" for monthly
s	Statistics, i.e. "m" for mean and "d" for mean diurnal cycle
yyyymmddhhmm	Date. For the monthly products (mm and md) the first day of the month (01) is used for "dd". The time value ("hhmm") is set to "0000" for all products.
Ver	Version number or release number, i.e. "003"
Gr	Grid, i.e. "19" for the regular lat-lon grid at 0.25° resolution.
Sourc	Data source, i.e. "AVPOS" for AVHRR on polar orbiting satellites
Lv	Processing level, i.e. "01" *(for ICDR, this becomes "I1")*
Ar	Area, i.e. "GL" for Global

Examples:

[2] URL: https://www.cmsaf.eu/EN/Products/NamingConvention/Naming_Convention_node.html

- `RSFdm19850228000000319AVPOS01GL.nc` is a file containing the daily mean RSF product (allsky) for the 28st February 1985
- `OLRmm19850201000000319AVPOS01GL.nc` is a file containing the monthly mean OLR product (allsky) for February 1985

4.2 Content overview

Most variables shown in Table 4-2 are common for daily mean (DM) and monthly mean (MM) products, however, the ones that are unique for only one of them are indicated in color (*red for DM*, *green for MM*).

Table 4-2: Content overview

Prod	Main variables (Section 4.5)	Global variables and attributes (Section 4.4)
RSF	• SW_flux (W/m²) • SW_flux_twilight (W/m²) • relative_share_sunglint (%) • number_of_daylightblocks • relative_share_twilight (%) • relative_share_daylight (%) • bitflags_sw • number_of_sw_inst_obs • *number_of_daylightblocks (DM)* • *satellite_bitflags_sw (DM)* • *number_of_sw_daily_means (MM)*	geospatial_lat_min; geospatial_lat_max; geospatial_lon_min; geospatial_lon_max, title; summary; id; cmsaf_product_id; product_version; creator_name; creator_email; creator_url; institution; project; references; keywords_vocabulary; keywords; Conventions; standard_name_vocabulary; date_created; geospatial_lat_units; geospatial_lat_resolution; geospatial_lon_units; geospatial_lon_resolution; time_coverage_start; time_coverage_end; time_coverage_duration; time_coverage_resolution; platform; platform_vocabulary; instrument; instrument_vocabulary; variable_id; license; source; lineage; CMSAF_L2_processor; CMSAF_L3_processor; *julian_day_12:00UTC (DM); solar_constant_12:00UTC (DM, only for RSF); squared_earthsundistance_12:00UTC (DM, only for RSF)*
OLR	• LW_flux (W/m²) • bitflags_lw • number_of_lw_inst_obs • *satellite_bitflags_lw (DM)* • *number_of_lw_daily_means (MM)*	

A complete technical overview of the file contents is given in Annex 10.1, providing an `ncdump` output of both products (RSF,OLR) on both time scales (daily,monthly). A more user-friendly version is provided in the sections below, discussing respectively the dimensions, global attributes, main variables, and variable attributes.

4.3 Dimensions

The NetCDF file contains the following dimensions as shown in Table 4-3.

Table 4-3: NetCDF dimensions

Name	Description
`lat`	Number of data points along the latitude axis, i.e. lat=720
`lon`	Number of data points along the longitude axis, i.e. lon=1440
`time`	Number of data points along the time axis, i.e. time=1 for both monthly and daily mean products
`bnds`	bnds=2. This dimension is used to define the *lat_bnds, lon_bnds*, and *time_bnds* variables

4.4 Global attributes

Global attributes are common to all products. They feature general information such as the algorithm and version used to generate the product. Global attributes are summarized in Table 4-4. Information that is not fixed but determined by product (*OLR* or *RSF*), temporal resolution (*Daily Mean* or *Monthly Mean*), or data record type (*TCDR* or *ICDR*) are put in a different color.

Table 4-4: Global NetCDF attributes

Name	Description
`julian_day_12:00UTC`	*(only for DM)* julian day at noon, e.g. “2446125”
`solar_constant_12:00UTC`	*(only for DM RSF)* solar constant at noon [W/m²], e.g. 1362.0306
`squared_earthsundistance_12:00UTC`	*(only for DM RSF)* squared earth-sun distance at noon, e.g. 0.981547969318226
`geospatial_lat_min`	Lowest latitude boundary, i.e. “-90.0”
`geospatial_lat_max`	Highest latitude boundary, i.e. “90.0”
`geospatial_lon_min`	Leftmost longitude boundary, i.e. “-180.0”
`geospatial_lon_max`	Rightmost longitude boundary, i.e. “180.0”
`title`	Data record title, i.e. "CM SAF Cloud, Albedo and Radiation dataset, AVHRR-based edition 3 (CLARA-A3): *Daily*/*Monthly* Mean TOA *Outgoing Longwave Radiation* / *Reflected Solar Flux* (*OLR*/*RSF*)*"*
`summary`	A summary of the data record: " This file contains AVHRR-based *Thematic/intermediate* Climate Data Records (*TCDR*/*ICDR*) produced by the Satellite Application Facility on Climate Monitoring (CM SAF)"
`id`	DOI: "DOI:10.5676/EUM_SAF_CM/CLARA_AVHRR/V003"
`cmsaf_product_id`	CM SAF product identifier, i.e. "CM-11312”(RSF)/“CM-11342”(OLR) (*for TCDR*); or “CM-6331”(RSF)/“CM-6321”(OLR) (*for ICDR*)
`product_version`	"3.0"
`creator_name`	"BE/RMIB"
`creator_email`	"contact.cmsaf@dwd.de"
`creator_url`	"http://www.cmsaf.eu/"
`institution`	"EUMETSAT/CMSAF"
`project`	"Satellite Application Facility on Climate Monitoring (CM SAF)"

`references`	Link to DOI resolver: "https://doi.org/10.5676/EUM_SAF_CM/CLARA_AVHRR/V003"
`keywords_vocabulary`	"GCMD Science Keywords, Version 8.6"
`keywords`	Comma separated list from GCMD Science Keywords: "EARTH SCIENCE > ATMOSPHERE > ATMOSPHERIC RADIATION > RADIATIVE FLUX"
`Conventions`	comma separated list "CF-1.7,ACDD-1.3"
`standard_name_vocabulary`	"Standard Name Table (v57, 11 July 2018)"
`date_created`	ISO 8601:2004 Time when the NetCDF file was generated, as character string YYYY-MM-DDThh:mm:ss<zone> e.g. "2022-03-15T15:46:30Z"
`geospatial_lat_units`	"degrees_north"
`geospatial_lat_resolution`	"0.25 degree"
`geospatial_lon_units`	"degrees_east"
`geospatial_lon_resolution`	"0.25 degree"
`time_coverage_start`	ISO 8601:2004 Start of the time period as character string YYYY-MM-DDThh:mm:ss<zone> e.g. "2014-04-05T00:00:00Z"
`time_coverage_end`	ISO 8601:2004 End of the time period as character string YYYY-MM-DDThh:mm:ss<zone> e.g. "2014-04-06T00:00:00Z"
`time_coverage_duration`	"P1M" for monthly products or "P1D" for daily products.
`time_coverage_resolution`	"P1M" for monthly products or "P1D" for daily products.
`platform`	comma separated list from GCMD Platform List, e.g. "NOAA-7 > National Oceanic & Atmospheric Administration-7,NOAA-9 > National Oceanic & Atmospheric Administration-9"
`platform_vocabulary`	"GCMD Platforms, Version 8.6"
`instrument`	comma separated list from GCMD Platform List, e.g. "AVHRR-2 > Advanced Very High Resolution Radiometer-2"
`instrument_vocabulary`	"GCMD Platforms, Version 8.6"
`variable_id`	Comma separated list of primary variables in the file, e.g. "SW_flux" (*RSF*) or "LW_flux" (*OLR*)
`license`	"The CM SAF data are owned by EUMETSAT and are available to all users free of charge and with no conditions to use. If you wish to use these products, EUMETSAT\'s copyright credit must be shown by displaying the words \"Copyright (c) (2022) EUMETSAT\" under/in each of these SAF Products used in a project or shown in a publication or website.\n\nPlease follow the citation guidelines given at https://doi.org/10.5676/EUM_SAF_CM/CLARA_AVHRR/V003 and also register as a user at http://cm-saf.eumetsat.int/ to receive latest information on CM SAF services and to get access to the CM SAF User Help Desk."
`source`	Colon separated list of Input data: "EUM AVHRR FDR : ERA5 : OSI SAF : USGS : IGBP"
`lineage`	Colon separated list of processing steps applied to input data (ISO Lineage model 19115-2), e.g. "pygac/gac2pps.py :

	NWC/PPS version v2018 : CLARA-A3 TOA toa_flux v2.0 : CLARA-A3 TOA dailymean v2.4"
CMSAF_L2_processor	Software used to generate level-2 products, e.g. "CLARA-A3 TOA toa_flux v2.0"
CMSAF_L3_processor	Software used to generate level-3 products, e.g. "CLARA-A3 TOA dailymean v2.4"

4.5 Main variables

4.5.1 Overview

Main variables are spatially explicit, meaning that they can be viewed as a map with a longitude and latitude dimension. An overview of these variables is given in Table 4-5 (Daily mean RSF), Table 4-6 (monthly mean RSF), Table 4-7 (daily mean OLR), and Table 4-8 (monthly mean OLR).

Table 4-5: Main variables in the Daily Mean RSF products

Name	Description
SW_flux	Reflected Solar Flux (RSF): daily mean value; units: W/m²
SW_flux_twilight	Mean RSF value during twilight conditions (84°>SZA>100°); units: W/m²
relative_share_sunglint	The relative frequency (on a given day and given grid box) of sunglint-affected observations (w.r.t. the total number of instantaneous observations on that day and grid box) which are not used but replaced by a modelled value from the CERES TRMM diurnal cycle model; Units: %; Example: Figure 3-17
satellite_bitflags_sw	A bit flag variable (called 'satellite bit flag') identifying the satellite(s) from which observations are involved in the construction of each pixel's daily mean. The flags simply indicate the presence of each satellite according to Table 4-9. For example, value 61440 can be decomposed in METOP-A, NOAA-19, NOAA-18 and NOAA-17 (values are respectively 32768 & 16384 & 8192 & 4096) Besides the pixel-specific flags, also a single global satellite bit flag is calculated: it contains a bit flag for each satellite that is used for at least 1 grid box (from the 1440x720 grid) and is added as variable attribute "global_value" belonging to the variable "satellite_bitflag_sw".
bitflags_sw	Bitwise quality flags providing either warnings (bits 1-6) or explain why no valid output has been generated (bits 7-9). The bit flag descriptions are provided in Table 4-10; for more in-depth information on these rather technical descriptions, the reader is referred to the ATBD [RD 7].
number_of_daylightblocks	Number of so-called DayLightBlocks (DLB's) contributing to daily mean RSF.
relative_share_daylight	Relative temporal share of daylight model to daily mean; Units: %

`relative_share_twilight`	Relative temporal share of twilight model to daily mean; Units: %
`number_of_sw_inst_obs`	Number of shortwave instantaneous observations contributing to the daily mean flux; Example: Figure 3-19.

In the monthly products, some ancillary fields such as `relative_share_sunglint` are simply temporal averages from all days in that month.

Table 4-6: Main variables in the Monthly Mean RSF products

Name	Description

`SW_flux`
`SW_flux_twilight`
`relative_share_sunglint`
`number_of_sw_inst_obs`
`relative_share_daylight`
`relative_share_twilight`
	Temporal average from the respective ancillary fields in the Daily Mean RSF product files (cfr Table 4-6).

`number_of_sw_daily_means`	Number of shortwave daily means contributing to the monthly mean RSF. More information in Section 3.5.3; Example: Figure 3-15.
`bitflags_sw`	Bitwise quality flag providing information on the representativeness of the monthly mean, i.e. whether it was constructed using sufficient daily mean values. It is discussed in Section 3.5.3; Example: Figure 3-16. The bit flag descriptions are provided in Table 4-11.

Table 4-7: Main variables in the Daily Mean OLR products

Name	Description
`LW_flux`	Outgoing Longwave Radiation (OLR): daily mean value; units: W/m²
`satellite_bitflags_lw`	*(identical to variable `satellite_bitflags_sw` in Table 4-5).*
`bitflags_lw`	*(identical to variable `bitflags_sw` in Table 4-5)*. The bit flag descriptions are provided in Table 4-10; for more in-depth information on these rather technical descriptions, the reader is referred to the ATBD [RD 7].
`number_of_lw_inst_obs`	*(identical to variable `number_of_sw_inst_obs` in Table 4-5)*. Number of shortwave instantaneous observations contributing to the daily mean flux; Example: Figure 3-19.

Table 4-8: Main variables in the Monthly Mean OLR products

Name	**Description**
`LW_flux` `number_of_lw_inst_obs`	Temporal average from the respective ancillary fields in the Daily Mean OLR product files (cfr Table 4-7).
`number_of_lw_daily_means`	*(identical to variable `number_of_sw_daily_means` in Table 4-6).* Number of longwave daily means contributing to the monthly mean OLR.
`bitflags_lw`	*(identical to variable `bitflags_sw` in Table 4-6).* Bitwise quality flag providing information on the representativeness of the monthly mean, i.e. whether it was constructed using sufficient daily mean values. The bit flag descriptions are provided in Table 4-11.

4.5.2 Bit flags

An overview of the **satellite bit flags** for the daily mean products, contained by the variables "`satellite_bitflags_sw`" and "`satellite_bitflags_lw`", is given are given in Table 4-9. The variables are unsigned long integers, meaning that they can contain up to 32 bit flags (max combined value amounts more than 4 billion). Bit numbers (first column) are counted from right to left, so the rightmost digit is "bit number 1", the second digit from the right is "bit number 2", etc.

Table 4-9: Satellite bit flags

Bit nr.	**Binary representation**	**Value**	**Satellite bitflag**	**Sensor**
1	0000000000000000001	1	TIROS-N	AVHRR
2	0000000000000000010	2	NOAA-6	
3	0000000000000000100	4	NOAA-7	
4	0000000000000001000	8	NOAA-8	
5	0000000000000010000	16	NOAA-9	
6	0000000000000100000	32	NOAA-10	
7	0000000000001000000	64	NOAA-11	
8	0000000000010000000	128	NOAA-12	
9	0000000000100000000	256	NOAA-14	
10	0000000001000000000	512	NOAA-15	
11	0000000010000000000	1024	NOAA-16	
12	0000000100000000000	2048	NOAA-17	
13	0000001000000000000	4096	NOAA-18	
14	0000010000000000000	8192	NOAA-19	
15	0000100000000000000	16384	METOP-A	
16	0001000000000000000	32768	METOP-B	
17	0010000000000000000	65536	METOP-C	
18	0100000000000000000	131072	S-NPP	VIIRS
19	1000000000000000000	262144	NOAA-20	

Similarly, an overview of the **quality bit flags** contained by the variables "`bitflags_sw`" and "`bitflags_lw`", is given in Table 4-10 (for the daily mean products), but here the variables are unsigned short integers, meaning that they can contain up to 16 bit flags (max combined value amounts 65535). Bit numbers 1 to 6 are warnings for non-critical issues, such as the quality of the input data or retrieval condition quality. Critical flags indicate non-processed pixels, i.e. situations in which the pixel could not be processed due to a number of reasons and hence has no valid RSF or OLR output (NA, NaN, fill value,..): these are shown in red in Table 4-10; these pixels will be ignored in the temporal aggregation to monthly means. Note that this can be different for RSF and OLR (!). The binary representation is not shown as a separate column in Table 4-10, as this information is identical to Table 4-9. For more information regarding the specific technical flag descriptions, see [RD 8].

Table 4-10: Quality bit flags for Daily mean RSF/OLR.

Bit nr.	Value	Bitflag name	Description
1	1	BITFLAG_NO_DLB	(*RSF only*) No so-called 'daylight-blocks' (DLB's) detected for current day, i.e. all timebins permanently have SZA>84°.
2	2	BITFLAG_INVALID_L2	At least 1 DLB contains at least 1 invalid Level-2 observation (e.g. when Level-1 input data were invalid, or when e.g. effective SZA cutoff is lower than 84°), i.e. an observation that belongs to the timerange of the DLB but are not used due to (counts_level2==0)
3	4	BITFLAG_ALB_ADM4ERR	(*RSF only*) error in Ed.4 ADM: unrealistic (clim.average) albedo value, e.g. negative or too high, so albedo from classic ADMs is used instead
4	8	BITFLAG_ALB_MISMATCH	(*RSF only*) too large mismatch between theoretical albedo curve (from CERES TRMM ADM) and observed albedo, leading to a shift of the theoretical curve outside the physical range [0.0-1.0]; as a "fix", the cloud cover is artificially and iteratively increased (leading to another scene type) until the theoretical albedo curve doesn't shift outside the physical range anymore; if cloudcover increase does not help, the Cloud Optical Thickness is iteratively increased by steps of 5, until the curve fits within physical limits
5	16	BITFLAG_ERA5	(*OLR only*) ERA5 used to model the diurnal cycle
6	32	BITFLAG_TWL_EXT	(*RSF only*) At least 1 *entire* DLB has SZA >= 80° and has no valid observations, and is therefore filled using extrapolated twilight model (in 80°-84° SZA range) [*this overrules BITFLAG_EMPTY_DLB and BITFLAG_INVALID_DLB for the current daylightblock, i.e. at least for this DLB (!) those flags are not activated*]

7*	64	BITFLAG_EMPTY_DLB*	pixel is not processed (*RSF and/or OLR*): At least 1 DLB has no (zero) Level-2 observations, e.g. due to missing inputfiles, or low probability of observations in short-timerange-DLB, when SZA is almost always >84°
8*	128	BITFLAG_INVALID_DLB*	pixel is not processed (*RSF and/or OLR*): At least 1 DLB has all INVALID Level-2 observations (e.g. when input data were invalid, or when e.g. effective SZA cutoff is lower than 84°), i.e. observations that belong to the timerange of the DLB but are not used due to (counts_sw_inst==0), i.e. no Level-2 observation; there are no valid Level-2 pixels (all suffer from counts_sw_inst==0)
9*	256	BITFLAG_INVALID_ALL*	pixel is not processed (*RSF and/or OLR*): There are more than 0 DLB's, and *all of them* have each either no level-2, or all invalid level-2 observations
(*) critical flags indicating why no valid flux output has been generated: no valid RSF and/or OLR			

The flags can be added and the resulting value is a combination of the different bitflags. For instance, a combined value of 9 consists of bit (flag) nr.1 (value 1) and nr.4 (value 8). The flags can be read manually using a bitwise "AND" operation [e.g. checking the existence of `BITFLAG_TWL_EXT` bitflag in C can be done with: `if((BITFLAG_TWL_EXT & bitflag)==BITFLAG_TWL_EXT)`], or with specialized routines.

Table 4-11: Quality bit flags for Monthly mean RSF/OLR.

Bit nr.	Value	Bitflag name	Description
1	1	MISSINGDAYS_WARNING	this flag is set when the temporal coverage is not complete, and the number of missing days ranges between 1-4. The monthly mean RSF is not entirely representative since some days are missing, but can still be used (of course depending on the application or analysis).
2	2	MISSINGDAYS_INVALID	this flag is set when the temporal coverage is not sufficient, with the number of missing days being 5 or more. Even if the monthly mean RSF is generated and available, its value is considered invalid and the **user is advised not to use it**.

4.6 Variable attributes

The variable attributes feature additional information related to the data fields such as the data units or scale factor and offset used to convert compressed data to real data. The variable attributes are summarized in Table 4-12.

Table 4-12: Variable attributes

Name	Description
long_name	Long descriptive name of the data field; Example: "TOA outgoing longwave radiation (OLR)"
standard_name	Standard name that references a description of a variable's content in the CF standard name table (note that some variables do not have a standard name); Example: "toa_outgoing_longwave_flux"
scale_factor	*(if applicable)* Factor by which the data have to be multiplied before their use.
add_offset	*(if applicable)* Number that has to be added to the data before their use and after having multiplied by the scale_factor
units	Physical units of the data. Examples: "W m-2", "%". No units are indicated with "1"
valid_range	Two comma-separated numbers indicating the numeric range to which the valid data is limited (min,max); Example: (0, 15000)
_FillValue	This number represents missing/undefined data. These data needs to be filtered before any processing. Example: -32768

The CF convention mentions the following paragraph about missing data and valid range: "*The missing values of a variable with scale_factor and/or add_offset attributes are interpreted relative to the variable's external values (a.k.a. the packed values, the raw values, the values stored in the netCDF file), not the values that result after the scale and offset are applied. Applications that process variables that have attributes to indicate both a transformation (via a scale and/or offset) and missing values should first check that a data value is valid, and then apply the transformation. Note that values that are identified as missing should not be transformed. Since the missing value is outside the valid range it is possible that applying a transformation to it could result in an invalid operation.*" This approach is followed, and an example is given here: The OLR variable (LW_flux) has as data type 'short integer' and contains the variable attributes scale_factor (0.1) and add_offset (0.0), so it is a single-decimal float value packed (compressed) as short integer. The variable attribute valid_range is defined in terms of packed data and equals (0,15000), so any valid packed data is not allowed below 0 or over 15000, which means in terms of unpacked (transformed/decompressed) data that values are not allowed below 0.0 W/m² or over 1500.0 W/m². Similarly, the variable attribute _FillValue (-32768) is defined in terms of unpacked data, and should be used to exclude missing data *before* applying the unpacking (decompression) using the scale_factor and add_offset attributes.

4.7 ICDR specific adaptations

There are no major ICDR-specific adaptations to the data format. A minor difference is the filename, which is formatted differently, following the CM SAF naming convention (Table 4-1). Other minor differences are some of the global attributes in the metadata, describing the file contents, which were also adapted accordingly (Table 4-4). The ICDR specific changes are indicated in both tables.

5 Data ordering via the Web User Interface (WUI)

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

Further user service including information and documentation about CM SAF and the CM SAF products are available from the CM SAF home page (http://www.cmsaf.eu/).

5.1 Product ordering process

You need to be registered and logged in to order products. A login is provided upon registration, all products are delivered free of charge (Please note the copyright disclaimer given in Section 7). After the selection of the product, the desired way of data transfer can be chosen. This is either via a temporary https account (the default setting), or email. Each order will be confirmed via email, and the user will get another email once the data have been prepared. If the https data transfer was selected, this second email will provide the information on how to access the https server.

5.2 Contact User Help Desk staff

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

5.3 User Problem Report

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

5.4 Service Messages / log of changes

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

6 Feedback

6.1 User feedback

Users of CM SAF products and services are encouraged to provide feedback on the CM SAF product and services to the CM SAF team. We are keen to learn of what use the CM SAF data are. So please feedback your experiences as well as your application area of the CM SAF data.

EUMETSAT CM SAF is a user driven service and is committed to consider the needs and requirements of its users in the planning for product improvements and additions. Please provide your feedback e.g. to our User Help Desk (e-mail address contact.cmsaf@dwd.de).

6.2 Specific requirements for future products

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

6.3 User Workshops

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

7 Copyright and Disclaimer

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

7.1 Copyright

7.2 Acknowledgement and Identification

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

7.3 Re-distribution of CM SAF data

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

8 References

Akkermans, T., & Clerbaux, N. (2021). Retrieval of Daily Mean Top-of-Atmosphere Reflected Solar Flux Using the Advanced Very High Resolution Radiometer (AVHRR) Instruments. Remote Sensing, 13(18), 3695.

Brient, F., Roehrig, R., & Voldoire, A. (2019). Evaluating marine stratocumulus clouds in the CNRM-CM6-1 model using short-term hindcasts. Journal of Advances in Modeling Earth Systems, 11(1), 127-148.

Canty, T., Mascioli, N. R., Smarte, M. D., & Salawitch, R. J. (2013). An empirical model of global climate–Part 1: A critical evaluation of volcanic cooling. Atmospheric Chemistry and Physics, 13(8), 3997-4031.

Clerbaux, N., Akkermans, T., Baudrez, E., Velazquez Blazquez, A., Moutier, W., Moreels, J., & Aebi, C. (2020). The climate monitoring SAF outgoing longwave radiation from AVHRR. Remote Sensing, 12(6), 929.

Dewitte, S., & Clerbaux, N. (2018). Decadal changes of earth's outgoing longwave radiation. Remote Sensing, 10(10), 1539.

Doelling, D. R., Loeb, N. G., Keyes, D. F., Nordeen, M. L., Morstad, D., Nguyen, C., ... & Sun, M. (2013). Geostationary enhanced temporal interpolation for CERES flux products. Journal of Atmospheric and Oceanic Technology, 30(6), 1072-1090.

Eastman, R., & Warren, S. G. (2014). Diurnal cycles of cumulus, cumulonimbus, stratus, stratocumulus, and fog from surface observations over land and ocean. Journal of climate, 27(6), 2386-2404.

Guilbert, S., Parol, F., Cornet, C., Ferlay, N., & Thieuleux F. (2022). Comparison between CERES/AQUA and POLDER/PARASOL shortwave fluxes: analysis of POLDER/PARASOL diurnal extrapolation. Presentation at CERES Science Team Meeting, 28/04/2022. Accessible online at https://ceres.larc.nasa.gov/ceres-science-team-meetings/2022-04/

Gristey, J. J., Chiu, J. C., Gurney, R. J., Morcrette, C. J., Hill, P. G., Russell, J. E., & Brindley, H. E. (2018). Insights into the diurnal cycle of global Earth outgoing radiation using a numerical weather prediction model. Atmospheric Chemistry and Physics, 18(7), 5129-5145.

Hersbach, H., Bell, B., Berrisford, P., Hirahara, S., Horányi, A., Muñoz-Sabater, J., ... & Thépaut, J. N. (2020). The ERA5 global reanalysis. Quarterly Journal of the Royal Meteorological Society, 146(730), 1999-2049.

Hogan, R. J., & Bozzo, A. (2018). A flexible and efficient radiation scheme for the ECMWF model. Journal of Advances in Modeling Earth Systems, 10(8), 1990-2008.

Johnson, G. C., Lyman, J. M., & Loeb, N. G. (2016). Improving estimates of Earth's energy imbalance. Nature Climate Change, 6(7), 639-640.

Lee, H.-T. (2014). HIRS Daily OLR Climate Data Record Development and Evaluation, CERES Science Team Meeting, April 22-24, 2014 Hampton, VA.

Lee, H.-T., Schreck, C. J., & Knapp, K. R. (2014). Generation of the Daily OLR Climate Data Record. 2014 EUMETSAT Meteorological Satellite Conference, 22–26 September 2014, Geneva, Switzerland.

Loeb, N. G., Kato, S., & Wielicki, B. A. (2002). Defining top-of-the-atmosphere flux reference level for Earth radiation budget studies. Journal of climate, 15(22), 3301-3309.

Loeb, N. G., Wielicki, B. A., Doelling, D. R., Smith, G. L., Keyes, D. F., Kato, S., ... & Wong, T. (2009). Toward optimal closure of the Earth's top-of-atmosphere radiation budget. Journal of Climate, 22(3), 748-766.

Loeb, N. G., Doelling, D. R., Wang, H., Su, W., Nguyen, C., Corbett, J. G., ... & Kato, S. (2018). Clouds and the earth's radiant energy system (CERES) energy balanced and filled (EBAF) top-of-atmosphere (TOA) edition-4.0 data product. Journal of Climate, 31(2), 895-918.

Loeb, N. G., & Doelling, D. R. (2020). CERES energy balanced and filled (EBAF) from afternoon-only satellite orbits. Remote Sensing, 12(8), 1280.

Stengel, M., Stapelberg, S., Sus, O., Finkensieper, S., Würzler, B., Philipp, D., ... & McGarragh, G. (2020). Cloud_cci Advanced Very High Resolution Radiometer post meridiem (AVHRR-PM) dataset version 3: 35-year climatology of global cloud and radiation properties. Earth System Science Data, 12(1), 41-60.

Trenberth, K. E. (2020). Understanding climate change through Earth's energy flows. Journal of the Royal Society of New Zealand, 50(2), 331-347.

Young, D. F., Minnis, P., Doelling, D. R., Gibson, G. G., & Wong, T. (1998). Temporal interpolation methods for the Clouds and the Earth's Radiant Energy System (CERES) experiment. Journal of Applied Meteorology, 37(6), 572-590.

Young, A. H., Knapp, K. R., Inamdar, A., Hankins, W., & Rossow, W. B. (2018). The international satellite cloud climatology project H-Series climate data record product. Earth System Science Data, 10(1), 583-593.

Zhang, Y., Rossow, W. B., Lacis, A. A., & Oinas, V. (2019). Calculation, evaluation and application of long-term, global radiative flux datasets at ISCCP: past and present. Study of cloud and water processes in weather and climate through satellite observations Submitted for. World Scientific Publishing Company as the second volume in a multi-part series on Earth sciences.

Zhang, Y., Jin, Z., & Sikand, M. (2021). The top-of-atmosphere, surface and atmospheric cloud radiative kernels based on ISCCP-H datasets: method and evaluation. Journal of Geophysical Research: Atmospheres, 126(24), e2021JD035053.

9 Glossary

ADM	Angular Distribution Model *(also: Angular Dependency Model)*
ATBD	Algorithm Theoretical Baseline Document
AVHRR	Advanced Very High Resolution Radiometer
CDR	Climate Data Record *(see also: FCDR)*
CERES	Clouds and the Earth's Radiant Energy System
CLARA-AX	CM SAF cloud, Albedo and Radiation products, AVHRR based, Edition X
CLASS	The Comprehensive Large Array-data Stewardship System (NOAA)
Cloud_CCI	Project covering the cloud component in the European Space Agency's (ESA) Climate Change Initiative (CCI) programme
CDR	Climate Data Record *(see also: FCDR)*
CMAext(ended); CMAprob	Cloud Mask Extended (legacy); Cloud Mask Probabilistic (new)
CM SAF	Climate Monitoring Satellite Application Facility
COT	Cloud Optical Thickness *(also: Cloud Optical Depth)*
DLB	Day Light Block
DM	Daily Mean
ERA5	Fifth generation ECMWF reanalysis
F(C)DR	Fundamental (Climate) Data Record
FIDUCEO	Fidelity and uncertainty in climate data records from Earth Observations (EU FP7 project)
GAC	Global Area Coverage
GAC orbit grid	Irregular grid with each pixel representing an AVHRR/GAC observation on its original location
GEO	Geostationary (satellite)
HIRS	High Resolution Infrared Radiation Sounder
ICDR	Intermediate Climate Data Record
IGBP	International Geosphere Biosphere Program
IWV	Integrated Water Vapor
LW	Longwave
MB	Mean Bias
MM	Monthly Mean
MAB	Mean Absolute Bias
MODIS	Moderate Resolution Imaging Spectroradiometer (on Aqua and Terra satellites)
NOAA	National Oceanic and Atmospheric Administration
NOAA-X	NOAA satellite numbered X
NTB	Narrowband-to-broadband
NWC SAF	Nowcasting Satellite Application Facility
OLR	Outgoing Longwave Radiation (W/m^2)
OSI SAF	Ocean and Sea Ice Satellite Application Facility
PPS	Polar Platform System
RAA (φ)	Relative Azimuth Angle (°)
RMSB	Root Mean Square Bias
RSF	Reflected Solar Flux (W/m^2)
SBAF	Spectral Band Adjustment Factors
SNO	Simultaneous Nadir Observations
SST	Sea Surface Temperatures
SW	Shortwave
SZA (θ_0)	Solar Zenith Angle (°)
TCDR	Thematic Climate Data Record
TIROS-N	Television InfraRed Observation Satellite -N
TOA	Top of Atmosphere
TRMM	Tropical Rainfall Measuring Mission
TWL	Twilight
VIRS	Visible Infrared Scanner
VIIRS	Visible Infrared Imaging Radiometer Suite

VZA (θ)	Viewing Zenith Angle (°)

10 Annex

10.1 Summary of file format and contents (using ncdump)

Here follow the results of "`ncdump -h`" on the four combinations of product (RSF,OLR) and time scale (daily, monthly). The daily products are shown for date 22-01-2019, and the monthly products for January 2019.

10.1.1 Daily mean RSF

```
netcdf RSFdm20190122000000319AVPOS01GL {
dimensions:
	lat = 720 ;
	lon = 1440 ;
	time = 1 ;
	bnds = 2 ;
variables:
	double lon(lon) ;
		lon:standard_name = "longitude" ;
		lon:long_name = "Longitude" ;
		lon:units = "degrees_east" ;
		lon:bounds = "lon_bnds" ;
	double lat(lat) ;
		lat:standard_name = "latitude" ;
		lat:long_name = "Latitude" ;
		lat:units = "degrees_north" ;
		lat:bounds = "lat_bnds" ;
	double time(time) ;
		time:standard_name = "time" ;
		time:long_name = "Time" ;
		time:units = "days since 1970-01-01 00:00" ;
		time:bounds = "time_bnds" ;
		time:calendar = "standard" ;
	double lat_bnds(lat, bnds) ;
		lat_bnds:long_name = "Latitude bounds" ;
	double lon_bnds(lon, bnds) ;
		lon_bnds:long_name = "Longitude bounds" ;
	double time_bnds(time, bnds) ;
		time_bnds:long_name = "Time bounds" ;
	ubyte record_status(time) ;
		record_status:long_name = "Record Status" ;
		record_status:comment = "Overall status of each record (timestamp) in this file. If a record is flagged as not ok, it is recommended not to use it." ;
		record_status:flag_meanings = "ok void bad_quality" ;
		record_status:flag_values = 0UB, 1UB, 2UB ;
	short SW_flux(time, lat, lon) ;
		SW_flux:_FillValue = -32768s ;
		SW_flux:add_offset = 0. ;
		SW_flux:scale_factor = 0.1 ;
		SW_flux:valid_range = 0s, 15000s ;
		SW_flux:standard_name = "toa_outgoing_shortwave_flux" ;
		SW_flux:long_name = "TOA Reflected Solar Flux (RSF)" ;
		SW_flux:units = "W m-2" ;
		SW_flux:coordinates = "time lon lat" ;
		SW_flux:ancillary_variables = "bitflags_sw satellite_bitflags_sw number_of_sw_inst_obs" ;
	short SW_flux_twilight(time, lat, lon) ;
		SW_flux_twilight:_FillValue = -32768s ;
		SW_flux_twilight:add_offset = 0. ;
		SW_flux_twilight:scale_factor = 0.1 ;
		SW_flux_twilight:valid_range = -32767s, 32767s ;
		SW_flux_twilight:long_name = "TOA outgoing shortwave flux from twilight model" ;
		SW_flux_twilight:units = "W m-2" ;
		SW_flux_twilight:coordinates = "time lon lat" ;
	short relative_share_sunglint(time, lat, lon) ;
		relative_share_sunglint:_FillValue = -32768s ;
		relative_share_sunglint:add_offset = 0. ;
```

```
		relative_share_sunglint:scale_factor = 0.01 ;
		relative_share_sunglint:valid_range = 0s, 10000s ;
		relative_share_sunglint:long_name = "Relative share of sunglint-affected to all instantaneous observations" ;
		relative_share_sunglint:units = "%" ;
		relative_share_sunglint:coordinates = "time lon lat" ;
	ushort bitflags_sw(time, lat, lon) ;
		bitflags_sw:_FillValue = 65535US ;
		bitflags_sw:valid_range = 0US, 65534US ;
		bitflags_sw:long_name = "Bitwise quality flags_sw" ;
		bitflags_sw:units = "1" ;
		bitflags_sw:coordinates = "time lon lat" ;
		bitflags_sw:flag_meanings = "NO_DLB INVALID_L2 ALB_ADM4ERR ALB_MISMATCH spare_bit BITFLAG_TWL_EXT EMPTY_DLB INVALID_DLB INVALID_ALL" ;
		bitflags_sw:flag_masks = 1US, 2US, 4US, 8US, 16US, 32US, 64US, 128US, 256US ;
	int satellite_bitflags_sw(time, lat, lon) ;
		satellite_bitflags_sw:_FillValue = -2147483648 ;
		satellite_bitflags_sw:valid_range = -2147483647, 2147483647 ;
		satellite_bitflags_sw:long_name = "flag indicating which satellites were used for SW daily mean" ;
		satellite_bitflags_sw:units = "1" ;
		satellite_bitflags_sw:coordinates = "time lon lat" ;
		satellite_bitflags_sw:flag_meanings = "TIROS-N NOAA-6 NOAA-7 NOAA-8 NOAA-9 NOAA-10 NOAA-11 NOAA-12 NOAA-14 NOAA-15 NOAA-16 NOAA-17 NOAA-18 NOAA-19 METOP-A METOP-B METOP-C S-NPP NOAA-20" ;
		satellite_bitflags_sw:global_value = 61952 ;
		satellite_bitflags_sw:flag_masks = 1, 2, 4, 8, 16, 32, 64, 128, 256, 512, 1024, 2048, 4096, 8192, 16384, 32768, 65536, 131072, 262144 ;
	ubyte number_of_sw_inst_obs(time, lat, lon) ;
		number_of_sw_inst_obs:_FillValue = 255UB ;
		number_of_sw_inst_obs:valid_range = 0UB, 254UB ;
		number_of_sw_inst_obs:long_name = "Number of shortwave instantaneous obs. contributing to daily mean" ;
		number_of_sw_inst_obs:units = "1" ;
		number_of_sw_inst_obs:coordinates = "time lon lat" ;
	ubyte number_of_daylightblocks(time, lat, lon) ;
		number_of_daylightblocks:_FillValue = 255UB ;
		number_of_daylightblocks:valid_range = 0UB, 254UB ;
		number_of_daylightblocks:long_name = "Number of so-called DayLightBlocks (DLB\'s) contributing to daily mean" ;
		number_of_daylightblocks:units = "1" ;
		number_of_daylightblocks:coordinates = "time lon lat" ;
	short relative_share_twilight(time, lat, lon) ;
		relative_share_twilight:_FillValue = -32768s ;
		relative_share_twilight:add_offset = 0. ;
		relative_share_twilight:scale_factor = 0.01 ;
		relative_share_twilight:valid_range = 0s, 10000s ;
		relative_share_twilight:long_name = "Relative temporal share of twilight model to daily mean" ;
		relative_share_twilight:units = "%" ;
		relative_share_twilight:coordinates = "time lon lat" ;
	short relative_share_daylight(time, lat, lon) ;
		relative_share_daylight:_FillValue = -32768s ;
		relative_share_daylight:add_offset = 0. ;
		relative_share_daylight:scale_factor = 0.01 ;
		relative_share_daylight:valid_range = 0s, 10000s ;
		relative_share_daylight:long_name = "Relative temporal share of daylight model to daily mean" ;
		relative_share_daylight:units = "%" ;
		relative_share_daylight:coordinates = "time lon lat" ;

// global attributes:
		:julian_day_12\:00UTC = 2458506 ;
		:solar_constant_12\:00UTC = 1362.0118 ;
		:squared_earthsundistance_12\:00UTC = 0.968498038559939 ;
		:geospatial_lat_min = -90. ;
		:geospatial_lat_max = 90. ;
		:geospatial_lon_min = -180. ;
		:geospatial_lon_max = 180. ;
		:title = "CM SAF Cloud, Albedo and Radiation dataset, AVHRR-based edition 3 (CLARA-A3): Daily Mean TOA Reflected Solar Flux (RSF)" ;
		:summary = "This file contains AVHRR-based Thematic Climate Data Records (TCDR) produced by the Satellite Application Facility on Climate Monitoring (CM SAF)" ;
		:id = "DOI:10.5676/EUM_SAF_CM/CLARA_AVHRR/V003" ;
		:cmsaf_product_id = "CM-11312" ;
		:product_version = "3.0" ;
		:creator_name = "BE/RMIB" ;
		:creator_email = "contact.cmsaf@dwd.de" ;
		:creator_url = "http://www.cmsaf.eu/" ;
		:institution = "EUMETSAT/CMSAF" ;
		:project = "Satellite Application Facility on Climate Monitoring (CM SAF)" ;
		:references = "https://doi.org/10.5676/EUM_SAF_CM/CLARA_AVHRR/V003" ;
```

```
        :keywords_vocabulary = "GCMD Science Keywords, Version 8.6" ;
        :keywords = "EARTH SCIENCE > ATMOSPHERE > ATMOSPHERIC RADIATION > RADIATIVE FLUX" ;
        :Conventions = "CF-1.7,ACDD-1.3" ;
        :standard_name_vocabulary = "Standard Name Table (v57, 11 July 2018)" ;
        :date_created = "2022-04-03T13:44:51Z" ;
        :geospatial_lat_units = "degrees_north" ;
        :geospatial_lat_resolution = "0.25 degree" ;
        :geospatial_lon_units = "degrees_east" ;
        :geospatial_lon_resolution = "0.25 degree" ;
        :time_coverage_start = "2019-01-22T00:00:00Z" ;
        :time_coverage_end = "2019-01-23T00:00:00Z" ;
        :time_coverage_duration = "P1D" ;
        :time_coverage_resolution = "P1D" ;
        :platform = "NOAA-15 > National Oceanic & Atmospheric Administration-15,NOAA-18 > National Oceanic & Atmospheric Administration-18,NOAA-19 > National Oceanic & Atmospheric Administration-19,METOP-A > Meteorological Operational Satellite - A" ;
        :platform_vocabulary = "GCMD Platforms, Version 8.6" ;
        :instrument = "AVHRR-3 > Advanced Very High Resolution Radiometer-3" ;
        :instrument_vocabulary = "GCMD Instruments, Version 8.6" ;
        :variable_id = "SW_flux" ;
        :license = "The CM SAF data are owned by EUMETSAT and are available to all users free of charge and with no conditions to use. If you wish to use these products, EUMETSAT\'s copyright credit must be shown by displaying the words \"Copyright (c) (2022) EUMETSAT\" under/in each of these SAF Products used in a project or shown in a publication or website.\n\nPlease follow the citation guidelines given at https://doi.org/10.5676/EUM_SAF_CM/CLARA_AVHRR/V003 and also register as a user at http://cm-saf.eumetsat.int/ to receive latest information on CM SAF services and to get access to the CM SAF User Help Desk." ;
        :source = "EUM AVHRR FDR : ERA5 : OSI SAF : USGS : IGBP" ;
        :lineage = "pygac/gac2pps.py : PPSv2018-patch5 : CLARA-A3 TOA toa_flux v2.0 : CLARA-A3 TOA dailymean v2.4" ;
        :CMSAF_L2_processor = "CLARA-A3 TOA toa_flux v2.0" ;
        :CMSAF_L3_processor = "CLARA-A3 TOA dailymean v2.4" ;
}
```

10.1.2 Monthly mean RSF

```
netcdf RSFmm20190101000000319AVPOS01GL {
dimensions:
    lat = 720 ;
    lon = 1440 ;
    time = 1 ;
    bnds = 2 ;
variables:
    double lon(lon) ;
        lon:standard_name = "longitude" ;
        lon:long_name = "Longitude" ;
        lon:units = "degrees_east" ;
        lon:bounds = "lon_bnds" ;
    double lat(lat) ;
        lat:standard_name = "latitude" ;
        lat:long_name = "Latitude" ;
        lat:units = "degrees_north" ;
        lat:bounds = "lat_bnds" ;
    double time(time) ;
        time:standard_name = "time" ;
        time:long_name = "Time" ;
        time:units = "days since 1970-01-01 00:00" ;
        time:bounds = "time_bnds" ;
        time:calendar = "standard" ;
    double lat_bnds(lat, bnds) ;
        lat_bnds:long_name = "Latitude bounds" ;
    double lon_bnds(lon, bnds) ;
        lon_bnds:long_name = "Longitude bounds" ;
    double time_bnds(time, bnds) ;
        time_bnds:long_name = "Time bounds" ;
    ubyte record_status(time) ;
        record_status:long_name = "Record Status" ;
        record_status:comment = "Overall status of each record (timestamp) in this file. If a record is flagged as not ok, it is recommended not to use it." ;
        record_status:flag_meanings = "ok void bad_quality" ;
        record_status:flag_values = 0UB, 1UB, 2UB ;
    short SW_flux(time, lat, lon) ;
        SW_flux:_FillValue = -32768s ;
        SW_flux:add_offset = 0. ;
        SW_flux:scale_factor = 0.1 ;
        SW_flux:valid_range = 0s, 15000s ;
        SW_flux:standard_name = "toa_outgoing_shortwave_flux" ;
```

```
                SW_flux:long_name = "TOA Reflected Solar Flux (RSF)" ;
                SW_flux:units = "W m-2" ;
                SW_flux:coordinates = "time lon lat" ;
                SW_flux:ancillary_variables = "bitflags_sw number_of_sw_daily_means" ;
        short SW_flux_twilight(time, lat, lon) ;
                SW_flux_twilight:_FillValue = -32768s ;
                SW_flux_twilight:add_offset = 0. ;
                SW_flux_twilight:scale_factor = 0.1 ;
                SW_flux_twilight:valid_range = -32767s, 32767s ;
                SW_flux_twilight:long_name = "TOA outgoing shortwave flux from twilight model" ;
                SW_flux_twilight:units = "W m-2" ;
                SW_flux_twilight:coordinates = "time lon lat" ;
        ubyte number_of_sw_inst_obs(time, lat, lon) ;
                number_of_sw_inst_obs:_FillValue = 255UB ;
                number_of_sw_inst_obs:valid_range = 0UB, 254UB ;
                number_of_sw_inst_obs:long_name = "Number of shortwave instantaneous obs. contributing to daily mean" ;
                number_of_sw_inst_obs:units = "1" ;
                number_of_sw_inst_obs:coordinates = "time lon lat" ;
        short relative_share_twilight(time, lat, lon) ;
                relative_share_twilight:_FillValue = -32768s ;
                relative_share_twilight:add_offset = 0. ;
                relative_share_twilight:scale_factor = 0.01 ;
                relative_share_twilight:valid_range = 0s, 10000s ;
                relative_share_twilight:long_name = "Relative temporal share of twilight model to daily mean" ;
                relative_share_twilight:units = "%" ;
                relative_share_twilight:coordinates = "time lon lat" ;
        short relative_share_daylight(time, lat, lon) ;
                relative_share_daylight:_FillValue = -32768s ;
                relative_share_daylight:add_offset = 0. ;
                relative_share_daylight:scale_factor = 0.01 ;
                relative_share_daylight:valid_range = 0s, 10000s ;
                relative_share_daylight:long_name = "Relative temporal share of daylight model to daily mean" ;
                relative_share_daylight:units = "%" ;
                relative_share_daylight:coordinates = "time lon lat" ;
        short relative_share_sunglint(time, lat, lon) ;
                relative_share_sunglint:_FillValue = -32768s ;
                relative_share_sunglint:add_offset = 0. ;
                relative_share_sunglint:scale_factor = 0.01 ;
                relative_share_sunglint:valid_range = 0s, 10000s ;
                relative_share_sunglint:long_name = "Relative share of sunglint-affected to all instantaneous observations" ;
                relative_share_sunglint:units = "%" ;
                relative_share_sunglint:coordinates = "time lon lat" ;
        ushort bitflags_sw(time, lat, lon) ;
                bitflags_sw:_FillValue = 65535US ;
                bitflags_sw:valid_range = 0US, 65534US ;
                bitflags_sw:long_name = "Bitwise quality flags_sw" ;
                bitflags_sw:units = "1" ;
                bitflags_sw:coordinates = "time lon lat" ;
                bitflags_sw:flag_meanings = "MISSINGDAYS_WARNING MISSINGDAYS_INVALID" ;
                bitflags_sw:flag_masks = 1US, 2US ;
        ubyte number_of_sw_daily_means(time, lat, lon) ;
                number_of_sw_daily_means:_FillValue = 255UB ;
                number_of_sw_daily_means:valid_range = 0UB, 254UB ;
                number_of_sw_daily_means:long_name = "Number of shortwave daily means contributing to monthly mean" ;
                number_of_sw_daily_means:units = "1" ;
                number_of_sw_daily_means:coordinates = "time lon lat" ;

// global attributes:
                :geospatial_lat_min = -90. ;
                :geospatial_lat_max = 90. ;
                :geospatial_lon_min = -180. ;
                :geospatial_lon_max = 180. ;
                :title = "CM SAF Cloud, Albedo and Radiation dataset, AVHRR-based edition 3 (CLARA-A3): Monthly Mean TOA Reflected Solar Flux (RSF)" ;
                :summary = "This file contains AVHRR-based Thematic Climate Data Records (TCDR) produced by the Satellite Application Facility on Climate Monitoring
(CM SAF)" ;
                :id = "DOI:10.5676/EUM_SAF_CM/CLARA_AVHRR/V003" ;
                :cmsaf_product_id = "CM-11312" ;
                :product_version = "3.0" ;
                :creator_name = "BE/RMIB" ;
                :creator_email = "contact.cmsaf@dwd.de" ;
                :creator_url = "http://www.cmsaf.eu/" ;
                :institution = "EUMETSAT/CMSAF" ;
                :project = "Satellite Application Facility on Climate Monitoring (CM SAF)" ;
```

```
		:references = "https://doi.org/10.5676/EUM_SAF_CM/CLARA_AVHRR/V003" ;
		:keywords_vocabulary = "GCMD Science Keywords, Version 8.6" ;
		:keywords = "EARTH SCIENCE > ATMOSPHERE > ATMOSPHERIC RADIATION > RADIATIVE FLUX" ;
		:Conventions = "CF-1.7,ACDD-1.3" ;
		:standard_name_vocabulary = "Standard Name Table (v57, 11 July 2018)" ;
		:date_created = "2022-04-03T13:53:17Z" ;
		:geospatial_lat_units = "degrees_north" ;
		:geospatial_lat_resolution = "0.25 degree" ;
		:geospatial_lon_units = "degrees_east" ;
		:geospatial_lon_resolution = "0.25 degree" ;
		:time_coverage_start = "2019-01-01T00:00:00Z" ;
		:time_coverage_end = "2019-02-01T00:00:00Z" ;
		:time_coverage_duration = "P1M" ;
		:time_coverage_resolution = "P1M" ;
		:platform = "NOAA-15 > National Oceanic & Atmospheric Administration-15,NOAA-18 > National Oceanic & Atmospheric Administration-18,NOAA-19 > National Oceanic & Atmospheric Administration-19,METOP-A > Meteorological Operational Satellite - A" ;
		:platform_vocabulary = "GCMD Platforms, Version 8.6" ;
		:instrument = "AVHRR-3 > Advanced Very High Resolution Radiometer-3" ;
		:instrument_vocabulary = "GCMD Instruments, Version 8.6" ;
		:variable_id = "SW_flux" ;
		:license = "The CM SAF data are owned by EUMETSAT and are available to all users free of charge and with no conditions to use. If you wish to use these products, EUMETSAT\'s copyright credit must be shown by displaying the words \"Copyright (c) (2022) EUMETSAT\" under/in each of these SAF Products used in a project or shown in a publication or website.\n\nPlease follow the citation guidelines given at https://doi.org/10.5676/EUM_SAF_CM/CLARA_AVHRR/V003 and also register as a user at http://cm-saf.eumetsat.int/ to receive latest information on CM SAF services and to get access to the CM SAF User Help Desk." ;
		:source = "FCDR AVHRR-GAC : ERA-5 : OSISAF : USGS : IGBP" ;
		:lineage = "pygac/gac2pps.py : NWC/PPS version v2018 : CLARA-A3 TOA toa_flux v2.0 : CLARA-A3 TOA dailymean v2.4" ;
		:CMSAF_L2_processor = "CLARA-A3 TOA toa_flux v2.0" ;
		:CMSAF_L3_processor = "CLARA-A3 TOA dailymean v2.4" ;
}
```

10.1.3 Daily mean OLR

```
netcdf OLRdm20190122000000319AVPOS01GL {
dimensions:
	lat = 720 ;
	lon = 1440 ;
	time = 1 ;
	bnds = 2 ;
variables:
	double lon(lon) ;
		lon:standard_name = "longitude" ;
		lon:long_name = "Longitude" ;
		lon:units = "degrees_east" ;
		lon:bounds = "lon_bnds" ;
	double lat(lat) ;
		lat:standard_name = "latitude" ;
		lat:long_name = "Latitude" ;
		lat:units = "degrees_north" ;
		lat:bounds = "lat_bnds" ;
	double time(time) ;
		time:standard_name = "time" ;
		time:long_name = "Time" ;
		time:units = "days since 1970-01-01 00:00" ;
		time:bounds = "time_bnds" ;
		time:calendar = "standard" ;
	double lat_bnds(lat, bnds) ;
		lat_bnds:long_name = "Latitude bounds" ;
	double lon_bnds(lon, bnds) ;
		lon_bnds:long_name = "Longitude bounds" ;
	double time_bnds(time, bnds) ;
		time_bnds:long_name = "Time bounds" ;
	ubyte record_status(time) ;
		record_status:long_name = "Record Status" ;
		record_status:comment = "Overall status of each record (timestamp) in this file. If a record is flagged as not ok, it is recommended not to use it." ;
		record_status:flag_meanings = "ok void bad_quality" ;
		record_status:flag_values = 0UB, 1UB, 2UB ;
	ushort bitflags_lw(time, lat, lon) ;
		bitflags_lw:_FillValue = 65535US ;
		bitflags_lw:valid_range = 0US, 65534US ;
```

```
		bitflags_lw:long_name = "Bitwise quality flags_lw" ;
		bitflags_lw:units = "1" ;
		bitflags_lw:coordinates = "time lon lat" ;
		bitflags_lw:flag_meanings = "NO_DLB INVALID_L2 spare_bit spare_bit BITFLAG_ERA5 spare_bit EMPTY_DLB INVALID_DLB INVALID_ALL" ;
		bitflags_lw:flag_masks = 1US, 2US, 4US, 8US, 16US, 32US, 64US, 128US, 256US ;
	int satellite_bitflags_lw(time, lat, lon) ;
		satellite_bitflags_lw:_FillValue = -2147483648 ;
		satellite_bitflags_lw:valid_range = -2147483647, 2147483647 ;
		satellite_bitflags_lw:long_name = "flag indicating which satellites were used for LW daily mean" ;
		satellite_bitflags_lw:units = "1" ;
		satellite_bitflags_lw:coordinates = "time lon lat" ;
		satellite_bitflags_lw:flag_meanings = "TIROS-N NOAA-6 NOAA-7 NOAA-8 NOAA-9 NOAA-10 NOAA-11 NOAA-12 NOAA-14 NOAA-15 NOAA-16 NOAA-17 NOAA-18 NOAA-19 METOP-A METOP-B METOP-C S-NPP NOAA-20" ;
		satellite_bitflags_lw:global_value = 61952 ;
		satellite_bitflags_lw:flag_masks = 1, 2, 4, 8, 16, 32, 64, 128, 256, 512, 1024, 2048, 4096, 8192, 16384, 32768, 65536, 131072, 262144 ;
	ubyte number_of_lw_inst_obs(time, lat, lon) ;
		number_of_lw_inst_obs:_FillValue = 255UB ;
		number_of_lw_inst_obs:valid_range = 0UB, 254UB ;
		number_of_lw_inst_obs:long_name = "Number of longwave instantaneous obs. contributing to daily mean" ;
		number_of_lw_inst_obs:units = "1" ;
		number_of_lw_inst_obs:coordinates = "time lon lat" ;
	short LW_flux(time, lat, lon) ;
		LW_flux:_FillValue = -32768s ;
		LW_flux:add_offset = 0. ;
		LW_flux:scale_factor = 0.1 ;
		LW_flux:valid_range = 0s, 15000s ;
		LW_flux:standard_name = "toa_outgoing_longwave_flux" ;
		LW_flux:long_name = "TOA outgoing longwave radiation (OLR)" ;
		LW_flux:units = "W m-2" ;
		LW_flux:coordinates = "time lon lat" ;
		LW_flux:ancillary_variables = "bitflags_lw satellite_bitflags_lw number_of_lw_inst_obs" ;

// global attributes:
		:julian_day_12\:00UTC = 2458506 ;
		:geospatial_lat_min = -90. ;
		:geospatial_lat_max = 90. ;
		:geospatial_lon_min = -180. ;
		:geospatial_lon_max = 180. ;
		:title = "CM SAF Cloud, Albedo and Radiation dataset, AVHRR-based edition 3 (CLARA-A3): Daily Mean TOA Outgoing Longwave Radiation (OLR)" ;
		:summary = "This file contains AVHRR-based Thematic Climate Data Records (TCDR) produced by the Satellite Application Facility on Climate Monitoring (CM SAF)" ;
		:id = "DOI:10.5676/EUM_SAF_CM/CLARA_AVHRR/V003" ;
		:cmsaf_product_id = "CM-11342" ;
		:product_version = "3.0" ;
		:creator_name = "BE/RMIB" ;
		:creator_email = "contact.cmsaf@dwd.de" ;
		:creator_url = "http://www.cmsaf.eu/" ;
		:institution = "EUMETSAT/CMSAF" ;
		:project = "Satellite Application Facility on Climate Monitoring (CM SAF)" ;
		:references = "https://doi.org/10.5676/EUM_SAF_CM/CLARA_AVHRR/V003" ;
		:keywords_vocabulary = "GCMD Science Keywords, Version 8.6" ;
		:keywords = "EARTH SCIENCE > ATMOSPHERE > ATMOSPHERIC RADIATION > RADIATIVE FLUX" ;
		:Conventions = "CF-1.7,ACDD-1.3" ;
		:standard_name_vocabulary = "Standard Name Table (v57, 11 July 2018)" ;
		:date_created = "2022-04-03T13:44:44Z" ;
		:geospatial_lat_units = "degrees_north" ;
		:geospatial_lat_resolution = "0.25 degree" ;
		:geospatial_lon_units = "degrees_east" ;
		:geospatial_lon_resolution = "0.25 degree" ;
		:time_coverage_start = "2019-01-22T00:00:00Z" ;
		:time_coverage_end = "2019-01-23T00:00:00Z" ;
		:time_coverage_duration = "P1D" ;
		:time_coverage_resolution = "P1D" ;
		:platform = "NOAA-15 > National Oceanic & Atmospheric Administration-15,NOAA-18 > National Oceanic & Atmospheric Administration-18,NOAA-19 > National Oceanic & Atmospheric Administration-19,METOP-A > Meteorological Operational Satellite - A" ;
		:platform_vocabulary = "GCMD Platforms, Version 8.6" ;
		:instrument = "AVHRR-3 > Advanced Very High Resolution Radiometer-3" ;
		:instrument_vocabulary = "GCMD Instruments, Version 8.6" ;
		:variable_id = "LW_flux" ;
		:license = "The CM SAF data are owned by EUMETSAT and are available to all users free of charge and with no conditions to use. If you wish to use these products, EUMETSAT\'s copyright credit must be shown by displaying the words \"Copyright (c) (2022) EUMETSAT\" under/in each of these SAF Products used in a project or shown in a publication or website.\n\nPlease follow the citation guidelines given at https://doi.org/10.5676/EUM_SAF_CM/CLARA_AVHRR/V003 and also register as a user at http://cm-saf.eumetsat.int/ to receive latest information on CM SAF services and to get access to the CM SAF User Help Desk." ;
```

```
            :source = "EUM AVHRR FDR : ERA5 : OSI SAF : USGS : IGBP" ;
            :lineage = "pygac/gac2pps.py : PPSv2018-patch5 : CLARA-A3 TOA toa_flux v2.0 : CLARA-A3 TOA dailymean v2.4" ;
            :CMSAF_L2_processor = "CLARA-A3 TOA toa_flux v2.0" ;
            :CMSAF_L3_processor = "CLARA-A3 TOA dailymean v2.4" ;
}
```

10.1.4 Monthly mean OLR

```
netcdf OLRmm20190101000000319AVPOS01GL {
dimensions:
        lat = 720 ;
        lon = 1440 ;
        time = 1 ;
        bnds = 2 ;
variables:
        double lon(lon) ;
                lon:standard_name = "longitude" ;
                lon:long_name = "Longitude" ;
                lon:units = "degrees_east" ;
                lon:bounds = "lon_bnds" ;
        double lat(lat) ;
                lat:standard_name = "latitude" ;
                lat:long_name = "Latitude" ;
                lat:units = "degrees_north" ;
                lat:bounds = "lat_bnds" ;
        double time(time) ;
                time:standard_name = "time" ;
                time:long_name = "Time" ;
                time:units = "days since 1970-01-01 00:00" ;
                time:bounds = "time_bnds" ;
                time:calendar = "standard" ;
        double lat_bnds(lat, bnds) ;
                lat_bnds:long_name = "Latitude bounds" ;
        double lon_bnds(lon, bnds) ;
                lon_bnds:long_name = "Longitude bounds" ;
        double time_bnds(time, bnds) ;
                time_bnds:long_name = "Time bounds" ;
        ubyte record_status(time) ;
                record_status:long_name = "Record Status" ;
                record_status:comment = "Overall status of each record (timestamp) in this file. If a record is flagged as not ok, it is recommended not to use it." ;
                record_status:flag_meanings = "ok void bad_quality" ;
                record_status:flag_values = 0UB, 1UB, 2UB ;
        ubyte number_of_lw_daily_means(time, lat, lon) ;
                number_of_lw_daily_means:_FillValue = 255UB ;
                number_of_lw_daily_means:valid_range = 0UB, 254UB ;
                number_of_lw_daily_means:long_name = "Number of longwave daily means contributing to monthly mean" ;
                number_of_lw_daily_means:units = "1" ;
                number_of_lw_daily_means:coordinates = "time lon lat" ;
        short LW_flux(time, lat, lon) ;
                LW_flux:_FillValue = -32768s ;
                LW_flux:add_offset = 0. ;
                LW_flux:scale_factor = 0.1 ;
                LW_flux:valid_range = 0s, 15000s ;
                LW_flux:standard_name = "toa_outgoing_longwave_flux" ;
                LW_flux:long_name = "TOA outgoing longwave radiation (OLR)" ;
                LW_flux:units = "W m-2" ;
                LW_flux:coordinates = "time lon lat" ;
                LW_flux:ancillary_variables = "bitflags_lw number_of_lw_daily_means" ;
        ubyte number_of_lw_inst_obs(time, lat, lon) ;
                number_of_lw_inst_obs:_FillValue = 255UB ;
                number_of_lw_inst_obs:valid_range = 0UB, 254UB ;
                number_of_lw_inst_obs:long_name = "Number of longwave instantaneous obs. contributing to daily mean" ;
                number_of_lw_inst_obs:units = "1" ;
                number_of_lw_inst_obs:coordinates = "time lon lat" ;
        ushort bitflags_lw(time, lat, lon) ;
                bitflags_lw:_FillValue = 65535US ;
                bitflags_lw:valid_range = 0US, 65534US ;
                bitflags_lw:long_name = "Bitwise quality flags_lw" ;
                bitflags_lw:units = "1" ;
```

```
		bitflags_lw:coordinates = "time lon lat" ;
		bitflags_lw:flag_meanings = "MISSINGDAYS_WARNING MISSINGDAYS_INVALID" ;
		bitflags_lw:flag_masks = 1US, 2US ;

// global attributes:
		:geospatial_lat_min = -90. ;
		:geospatial_lat_max = 90. ;
		:geospatial_lon_min = -180. ;
		:geospatial_lon_max = 180. ;
		:title = "CM SAF Cloud, Albedo and Radiation dataset, AVHRR-based edition 3 (CLARA-A3): Monthly Mean TOA Outgoing Longwave Radiation (OLR)" ;
		:summary = "This file contains AVHRR-based Thematic Climate Data Records (TCDR) produced by the Satellite Application Facility on Climate Monitoring (CM SAF)" ;
		:id = "DOI:10.5676/EUM_SAF_CM/CLARA_AVHRR/V003" ;
		:cmsaf_product_id = "CM-11342" ;
		:product_version = "3.0" ;
		:creator_name = "BE/RMIB" ;
		:creator_email = "contact.cmsaf@dwd.de" ;
		:creator_url = "http://www.cmsaf.eu/" ;
		:institution = "EUMETSAT/CMSAF" ;
		:project = "Satellite Application Facility on Climate Monitoring (CM SAF)" ;
		:references = "https://doi.org/10.5676/EUM_SAF_CM/CLARA_AVHRR/V003" ;
		:keywords_vocabulary = "GCMD Science Keywords, Version 8.6" ;
		:keywords = "EARTH SCIENCE > ATMOSPHERE > ATMOSPHERIC RADIATION > RADIATIVE FLUX" ;
		:Conventions = "CF-1.7,ACDD-1.3" ;
		:standard_name_vocabulary = "Standard Name Table (v57, 11 July 2018)" ;
		:date_created = "2022-04-03T13:53:11Z" ;
		:geospatial_lat_units = "degrees_north" ;
		:geospatial_lat_resolution = "0.25 degree" ;
		:geospatial_lon_units = "degrees_east" ;
		:geospatial_lon_resolution = "0.25 degree" ;
		:time_coverage_start = "2019-01-01T00:00:00Z" ;
		:time_coverage_end = "2019-02-01T00:00:00Z" ;
		:time_coverage_duration = "P1M" ;
		:time_coverage_resolution = "P1M" ;
		:platform = "NOAA-15 > National Oceanic & Atmospheric Administration-15,NOAA-18 > National Oceanic & Atmospheric Administration-18,NOAA-19 > National Oceanic & Atmospheric Administration-19,METOP-A > Meteorological Operational Satellite - A" ;
		:platform_vocabulary = "GCMD Platforms, Version 8.6" ;
		:instrument = "AVHRR-3 > Advanced Very High Resolution Radiometer-3" ;
		:instrument_vocabulary = "GCMD Instruments, Version 8.6" ;
		:variable_id = "LW_flux" ;
		:license = "The CM SAF data are owned by EUMETSAT and are available to all users free of charge and with no conditions to use. If you wish to use these products, EUMETSAT\'s copyright credit must be shown by displaying the words \"Copyright (c) (2022) EUMETSAT\" under/in each of these SAF Products used in a project or shown in a publication or website.\n\nPlease follow the citation guidelines given at https://doi.org/10.5676/EUM_SAF_CM/CLARA_AVHRR/V003 and also register as a user at http://cm-saf.eumetsat.int/ to receive latest information on CM SAF services and to get access to the CM SAF User Help Desk." ;
		:source = "FCDR AVHRR-GAC : ERA-5 : OSISAF : USGS : IGBP" ;
		:lineage = "pygac/gac2pps.py : NWC/PPS version v2018 : CLARA-A3 TOA toa_flux v2.0 : CLARA-A3 TOA dailymean v2.4" ;
		:CMSAF_L2_processor = "CLARA-A3 TOA toa_flux v2.0" ;
		:CMSAF_L3_processor = "CLARA-A3 TOA dailymean v2.4" ;
}
```