EUMETSAT Satellite Application Facility on Climate Monitoring

Validation Report

SEVIRI cloud mask data set

CM-21012

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Applicable documents

Reference	Title	Code
AD 1	EUMETSAT CM SAF CDOP 2 Product Requirements Document (PRD)	SAF/CM/DWD/PRD/2.4

Reference Documents

Reference	Title	Code
RD 1	Product User Manual SEVIRI Cloud mask data set	SAF/CM/DWD/PUM/SEV/CLM/1.1
RD 2	Data Set Generation Capability Description Document SEVIRI cloud mask data set	SAF/CM/DWD/DGCDD/SEV/CLM/1.1
RD 3	Validation Report SEVIRI Cloud Products Edition 1 (CLAAS)	SAF/CM/DWD/VAL/SEV/CLD/1.2
RD 4	Product User Manual SEVIRI Cloud Products Edition 1 (CLAAS)	SAF/CM/DWD/PUM/SEV/CLD/1.0
RD 5	Algorithm Theoretical Basis Document SEVIRI cloud products edition 1	SAF/CM/DWD/ATBD/SEV/CLD/1.0
RD 6	Algorithm Theoretical Basis Document SAFNWC/MSG "Cloud mask, Cloud Type, Cloud Top Temperature, Pressure, Height"	SAF/NWC/CDOP/MFL/SCI/ATBD/01, Issue 3, Rev. 0
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1. Executive summary

This CM SAF report provides information on the validation of cloud fractional cover derived from measurements taken by the Spinning Enhanced Visible and InfraRed Imager (SEVIRI) onboard the EUMETSAT METEOSAT Second Generation (MSG) satellites. The covered time period ranges from 2004 to 2012, thus includes MSG 1 and MSG 2, for which the transition took place in April 2007. The main new feature is the high temporal resolution of 15 minutes, also the data set is provided on SEVIRI native pixel resolution.

The dataset can be considered as an extension of the dataset CLAAS (DOI: 10.5676/EUMETSAT_SAF_CM/CLAAS/V001 and Stengel et al., 2014) where the validation was extensive including level2 and level3 (i.e. native spatial and temporal resolution as opposed to re-gridded and temporally averaged) product validation. Here ground-based observations (SYNOP and Cloudnet) as well as satellite-based sources (CloudSat, CALIPSO, AMSR-E, SSM/I, MODIS) were used. The new cloud mask derivation is based on the same software and input data sources, also it is provided solely in level2 format. Thus the validation is carried out with CloudSat and CALIPSO.

Table 1: Results from the cloud mask validation based on SEVIRI measurements with CALIOP and CPR, compliance to the target requirement is given. The complete SEVIRI field of view was considered in this study. The covered time span ranged from 2006-2012 where the months January and July were analyzed.

Product	Precision requirement (POD)	Achieved precision
Cloud Mask (CMa)	**0.90**	**0.946 ± 0.008 CALIOP** **0.902 ± 0.011 CPR**

The evaluation scores and their compliance to the target requirements of accuracy and precisions are given in Table 1 and are briefly summarized in the following:

Cloud Mask (CMa)

- The cloud mask product fulfils the target requirements when compared with CALIOP in all cases.
- Optimal requirements are fulfilled when optically thin clouds (cloud optical depth < 0.3) seen by CALIOP are filtered prior to the comparison.

The evaluation results included in this report demonstrate the high quality of the datasets. This builds on the state-of-the-art retrievals system, which was developed at Météo France, on well characterized IR radiances and VIS reflectances and on a carefully implemented reprocessing system and final product generation, which was done at DWD. Further guidance on how to use the product is given in the product user manual [RD 1]. The mentioned accuracy requirements are reported in detail in the product requirements document [AD 1]. The algorithm theoretical basis documents describe the individual parameter algorithms [RD 5 - RD 6].

2. The EUMETSAT SAF on Climate Monitoring (CM SAF)

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

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

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

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

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

- Application of highest standards and guidelines as lined out by GCOS for the satellite data processing,
- Processing of satellite data within a true international collaboration benefiting from developments at international level and pollinating the partnership with own ideas and standards,
- Intensive validation and improvement of the CM SAF climate data records,
- Taking a major role in data set assessments performed by research organisations such as WCRP (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, www.cmsaf.eu. Here, detailed information about product ordering, add-on tools, sample programs and documentation is provided.

3. Satellite data and Methods for comparison with MSG SEVIRI: CloudSat and Calipso from A-Train collocated with AVACS software

3.1 CALIOP on CALYPSO

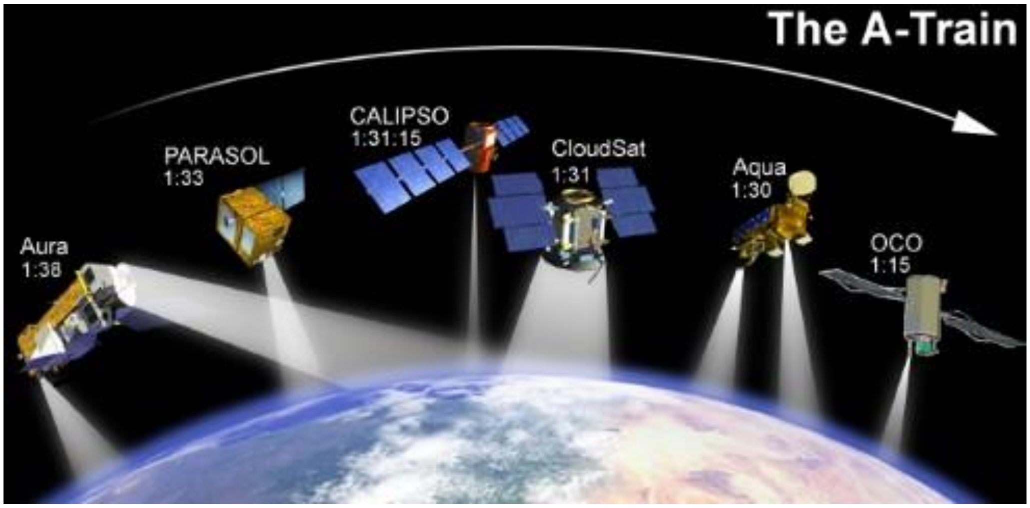

Figure 1 The Aqua-Train satellites. (Image credit: NASA).

Measurements from space-born active instruments (radar + lidar) provide probably the most accurate information that can be derived about cloud presence in the atmosphere. The reason is that the measured reflected radiation comes almost exclusively from cloud and precipitation particles and is therefore not “contaminated” by radiation from other surfaces or atmospheric constituents as is the case for measurements from most passive radiometers. In this validation study it was decided to utilize measurements from the CALIOP lidar instrument carried by the CALIPSO satellite (included in the A-Train series of satellites Figure 1).
The Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observation (CALIPSO) satellite was launched in April 2006 together with CloudSat. The satellite carries the Cloud-Aerosol Lidar with Orthogonal Polarization (CALIOP) and the first data became available in August 2006. CALIOP provides detailed profile information about cloud and aerosol particles and corresponding physical parameters.
CALIOP measures the backscatter intensity at 1064 nm while two other channels measure the orthogonally polarized components of the backscattered signal at 532 nm. The horizontal resolution of each single FOV is 333 m and the vertical resolution is 30-60 m. The used CALIOP cloud product reports observed cloud layers, i.e. all layers observed until the signal becomes too attenuated. In practice the instrument can only

probe the full geometrical depth of a cloud if the total optical thickness is not larger than a certain threshold (somewhere in the range 6-10). For optically thicker clouds only the upper portion of the cloud will be sensed.
CALIOP products have been retrieved from the NASA Langley Atmospheric Science Data Centre (ASDC, http://eosweb.larc.nasa.gov/JORDER/ceres.html using the Lidar Level 2 Cloud and Aerosol Layer Information product Version 3.01 and 3.02 (from 2012 onwards). Detailed characteristics are provided here:
http://eosweb.larc.nasa.gov/PRODOCS/calipso/Quality_Summaries/CALIOP_L2LayerProducts_3.01.html
Also the associated information from the Lidar Level 2 Vertical Feature Mask product has been used. The associated details of this product are found here:
http://eosweb.larc.nasa.gov/PRODOCS/calipso/Quality_Summaries/CALIOP_L2VFMProducts_3.01.html
The latter product defines up to 10 cloud layers and each layer is classified into one of 10 cloud types according to Table 2. To be noticed here is that the ISCCP cloud type method has been used in the sense that the vertical separation of Low (categories 0-3), Medium (categories 4-5) and High (categories 6-7) clouds is defined by use of vertical pressure levels of 680 hPa and 440 hPa. However, the separation of thin and thick clouds is made using the information on whether the surface or lower layers below the current layer can be seen by CALIOP.

Table 2: Cloud type categories according to the CALIOP Vertical Feature Mask product.

Cloud type Category	Explanation
Category 0	Low, overcast, thin (transparent St, StCu, and fog)
Category 1:	Low, overcast, thick (opaque St, StCu, and fog)
Category 2	Transition stratocumulus
Category 3	Low, broken (trade Cu and shallow Cu)
Category 4	Altocumulus (transparent)
Category 5	Altostratus (opaque, As, Ns, Ac)
Category 6	Cirrus (transparent)
Category 7	Deep convective (opaque As, Cb, Ns)

The CALIOP products are defined in five different versions with respect to the along-track resolution ranging from 333 m (individual footprint resolution), 1 km, 5 km, 20 km and 80 km. The four latter resolutions are consequently constructed from several original footprints/FOVs. This allows a higher confidence in the correct detection and identification of cloud and aerosol layers compared to when using the original high resolution profiles. For example, the identification of very thin Cirrus clouds is more reliable in the 5 km dataset than in the 1 km dataset since signal-to-noise levels can be raised by using a combined dataset of several original profiles.
We only give a general description of the CALIPSO datasets in this section. The details concerning the actual use of the datasets are elaborated further in the following section 4.1.

Uncertainty and error sources:

It should be emphasized that the CALIOP measurement is probing the atmosphere very efficiently in the along-track direction since it is a nadir pointing instrument. Here, cloud dimensions down to the original FOV resolution (333 m) will be detected. However, it should be made clear that the across-track extension of the observation is still limited to 333 m. Thus, to compare CALIOP-derived results with the results of 3 km SEVIRI pixel data is not entirely consistent (i.e., CALIOP is only capable of covering the SEVIRI pixel properly in one direction and not in the perpendicular direction). However, it is believed that this deficiency is of marginal importance. Most cloud systems on the SEVIRI scale will be detected, e.g., it is very unlikely to imagine elongated clouds with size and shapes below 0.3x4 km that might risk remaining undetected within a SEVIRI pixel that coincides with a CALIOP measurement. Most clouds will have aspect ratios for the two horizontal directions that guarantee detection by CALIOP.
It is important to consider that the CALIOP lidar instrument is much more sensitive to cloud particles than the measurement from a passively imaging instrument. It means that a significant fraction of all CALIOP-detected clouds will not be detected by imagers. Thus, to get reasonable and justified results (i.e., saying something on the performance of the applied cloud detection method for clouds that should be theoretically detectable) one should consider filtering out the contributions from the very thinnest clouds. Therefore this approach has been applied in this validation study.
The cloud detection efficiency with CALIOP is slightly different during day and night because of the additional noise from reflected solar radiation at daytime that can contaminate lidar backscatter measurements. Chepfer et al. (2010) report that this can introduce an artificial difference of not more than 1 % when comparing night time and daytime data. This is also confirmed by Kuehn (2012, personal communication) pointing out that this effect is negligible for optically thick clouds while it may introduce some artificial diurnal variation for optically very thin clouds (of which a large fraction is not detectable by passive imagers).
In the SEVIRI validation context the 5 km CALIOP dataset have been used since this resolution is closest to the nominal SEVIRI resolution. However, we have learnt that the results in different datasets from CALIPSO, related to different horizontal resolutions (with the five options 333 m, 1 km, 5 km, 20 km and 80 km) are unfortunately not entirely consistent (Dave Winker, NASA, personal communication). It means that some of the thick (opaque) boundary layer clouds that are reported in fine resolution (333 m and 1 km) datasets are not reported in the lower resolution (5 km or coarser) datasets. This has to do with the methodology to do averaging at the longer scales (5 km or higher) where contributions from strongly reflecting boundary layer clouds are removed from the original signal to facilitate detection of very thin cloud layers and aerosols. A recent study (Ralph Kuehn, SSEC, Madison, personal communication) estimated the loss of cloudy CALIOP 5 km pixels to between 1-3 % because of this effect based on all orbits in the period1-16 July 2006, when comparing with corresponding results based on 1 km

CALIOP data. To our knowledge, this deficiency has not yet been reported in the literature.
In conclusion: Despite the fact that the CALIPSO cloud observations most likely are the best available cloud reference dataset being released so far, there might be still a negative bias in the CALIOP-derived cloud cover visible when using the 5 km dataset. Other errors, e.g. due to misinterpretation of heavy aerosol loads as clouds, are in this respect of minor importance when judging the effect on accumulated results based on a large number of full global orbits. This also concerns problems with reduced signal-to-noise ratios due to solar contamination during daytime.

For the present study, CALIPSO data is used for Level 2 validation of CMa.

3.2 CPR on CloudSat

To complement the picture drawn by the CALIOP lidar also CPR onboard CloudSat is considered. CPR is nadir-looking cloud profiling radar that senses the atmosphere from above with 94 GHz. The instrument's sensitivity is mainly determined by received power and noise level, to optimize this sensitivity a balancing between the limiting factors that are e.g. vertical resolution, cloud backscattering and atmospheric attenuation has to be undertaken. CPR's minimum detectable reflectivity factor is -30 dBZ and the calibration accuracy 1.5 dB. The minimum detectable reflectivity factor requirement was reduced to -26 dBZ when the mission was changed to put CloudSat into a higher orbit for formation flying in A-train. The instrument settings and sensitivity yield the following spatial resolution: 500 m vertical resolution, 1.4 km cross track and 1.7 km along track resolution. The integration time of the individual scans was set to 0.16 s.

Uncertainty and error sources

CPR is not as sensitive to thin cirrus clouds as CALIOP due to the weakness of the backscattered signal in case of high and thin clouds where the noise level will override the signal's strength in some cases. According to Stephens et al. (2002) the limit of cirrus detection by CloudSat lies in the range of optical depth between 0.1 < COT < 0.4. Those clouds will be missed which results in a lower cloud top height compared to CALIOP. In the lower part of the atmosphere, the reflectance of the surface affects the backscattered signal. So the bins in the lower part of the atmosphere are contaminated by the surface's influence, clouds may not be properly detected below 1 km distance to the surface.

In the present study CPR data is also used for Level 2 validation of the cloud mask.

3.3 AVAC-S colocation software

The software package AVAC-S (A-Train Validation of Aerosol and Cloud Properties from SEVIRI) was used for the colocation of SEVIRI data with CALIOP and CPR level 2 measurements. It was created by the Informus GmbH in the framework of a EUMETSAT software development project. AVAC-S (Bennartz et al., 2010) has two main functions:

first it maps all satellite data onto a common grid. The output is stored in hdf5 format for later use. In this validation the common grid is SEVIRI's native resolution and the instruments involved are SEVIRI, CALIOP and CPR, but MODIS and AMSR data can be processed, too. The second capability of AVAC-S is the sub-setting and merging of the input data to facilitate scene-dependent analysis. AVAC-S is written in IDL in object-oriented form.

4. Evaluation of NWC SAF Cloud Mask

4.1 Evaluation against A-train (CALIPSO-CALIOP and CPR on CloudSat): dependence on cloud optical depth

CALIOP is due to the advanced lidar technique more sensitive to high and thin clouds than the passive imager SEVIRI. Therefore, CALIOP is considered as a very good reference. Since cloud mask is a categorical variable, the agreements are reported in terms of hit rates, probability of detection and false alarm rates. It is expectable that more clouds are detected by CALIOP than by SEVIRI.
We analysed on level2 basis, which means that all A-train overpasses of two months (January and June 2009) were remapped onto the SEVIRI grid resolution. For these comparisons a collocation database was composed by matching CALIOP or CPR profiles of the respective time with the closest SEVIRI pixel in June 2009, allowing collocations within the entire SEVIRI disk. The spatially higher resolved CALIOP and CPR cloud mask data were not averaged but only sampled by nearest neighbour whereas the cloud optical depth parameter from CALIOP as well as the cloud top height from CPR were represented by the average value of the respective SEVIRI pixel in order to allow a more realistic approximation of SEVIRI's viewing conditions. The pixel-averaged values have been chosen as the basic variable to detect presence or absence of clouds and restrained with the condition that the cloud mask should have a value indicating "cloud", as opposed to "aerosol" for example.
A winter and a summer month were analyzed; in this case January and June of 2009 were chosen, where there were little gaps in SEVIRI as well as in the validation time-series. Counts denotes all cases with valid measurements in both, SEVIRI and CALIOP or CPR respectively; missing or unprocessed data points were removed from the collocated database, therefore the number of counts can vary from month to month and validation source. The column hit denotes the number of true values in both, SEVIRI and validation source divided by all counts.

The probability of detection POD is defined as

$$POD = \frac{N_{true,detected}}{N_{true}} = \frac{N_{true,detected}}{N_{true,detected} + N_{true,not\ detected}}$$

Where $N_{true,detected}$ is the number of pixels that are cloudy in both, SEVIRI and the validation source (CALIOP or CPR) which is considered as the truth in this statistical analysis. $N_{\text{true,not detected}}$ on the contrary is the number of clear pixel in SEVIRI but cloudy in CALIOP or CPR. The false alarm rate FAR measures the number of falsely detected pixel:

$$FAR = \frac{N_{false,notdetected}}{N_{false}} = \frac{N_{false,not\ detected}}{N_{false,detected} + N_{false,not\ detected}}$$

$N_{\text{false,notdetected}}$ is the number of pixels that were detected as cloudy in SEVIRI but are cloud-free in CALIOP or CPR, respectively. $N_{\text{false,detected}}$ means cloud-free in both cases.

With these settings, the accuracies presented in Table 3 were achieved.

Table 3: Total cloud mask statistics for all matches for January and June 2009. The figures in brackets show the results where CALIOP data were filtered with a cloud optical depth threshold of 0.3. Count denotes the number of all valid collocations, where hit is the number of cloudy pixels in SEVIRI and reference relative to the counts.

Matches vs CPR or CALIOP	**month**	**count**	**hit**	**Probability of detection**	**False alarm rate**
SEV-CPR	January	1012640	0.57	0.91	0.38
	June	960168	0.53	0.89	0.36
SEV-CALIOP	January	789246	0.61	0.94 (0.97)	0.26 (0.37)
	June	732552	0.55	0.94 (0.96)	0.28 (0.37)

The POD of a cloudy pixel is around 90 % in case of CPR, the clouds were slightly better detected in January than in June, FAR is comparably high with 36 – 38 %. Some clouds are also missed by CPR which is not too sensitive for high thin clouds due to the unfavourable signal to noise ratio and also the difficulties with detecting clouds lower that 1 km.

The CALIOP comparison shows a POD of as high as 94% for both months and a clearly lower FAR of 0.26 – 0.28. The POD is well within the target requirement which is 90 % for the complete SEVIRI disc. Since CALIOP is much more sensitive to thin cirrus than SEVIRI, the collocation database is restricted to pixel with an optical depth in CALIOP greater than 0.3. In that case POD rises to 97 % in January and 96 % in June. The detection dependence on cloud optical depth of CALIOP is studied in more detail shown in Figure 2.

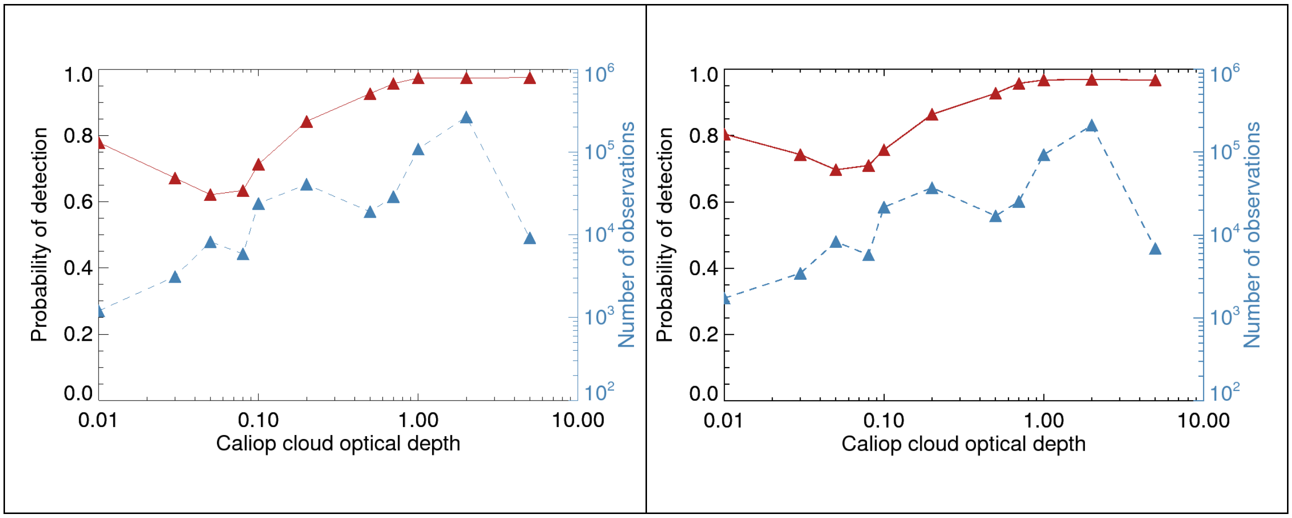

Figure 2: Probability of detecting a cloudy pixel with SEVIRI, dependent on cloud optical depth of CALIOP. On the left hand side the results of January 2009 are shown, while on the right hand side June 2009 is depicted.

Here all matching pixel in score classes are evaluated with thresholds as indicated in Figure 2. As can be seen, POD is smallest for COD about 0.04 and rises continuously with COD. At COD = 0.7 saturation is already reached and the POD does not increase any further. It may be interesting to notice the two dips in the number of observations at COD = 0.08 and COD = 0.5 which are present in both, winter as well as summer data. The POD of a cloudy pixel at these specific CODs is not affected. This effect could be caused by two mechanisms: a physical reason could be that there are not as many clouds with these specific optical thicknesses, second are small gaps in the detection of clouds by the CALIOP algorithm. The investigation of the mechanism is beyond the scope of this document and remains to be elucidated.

5. Evaluation of the time-series

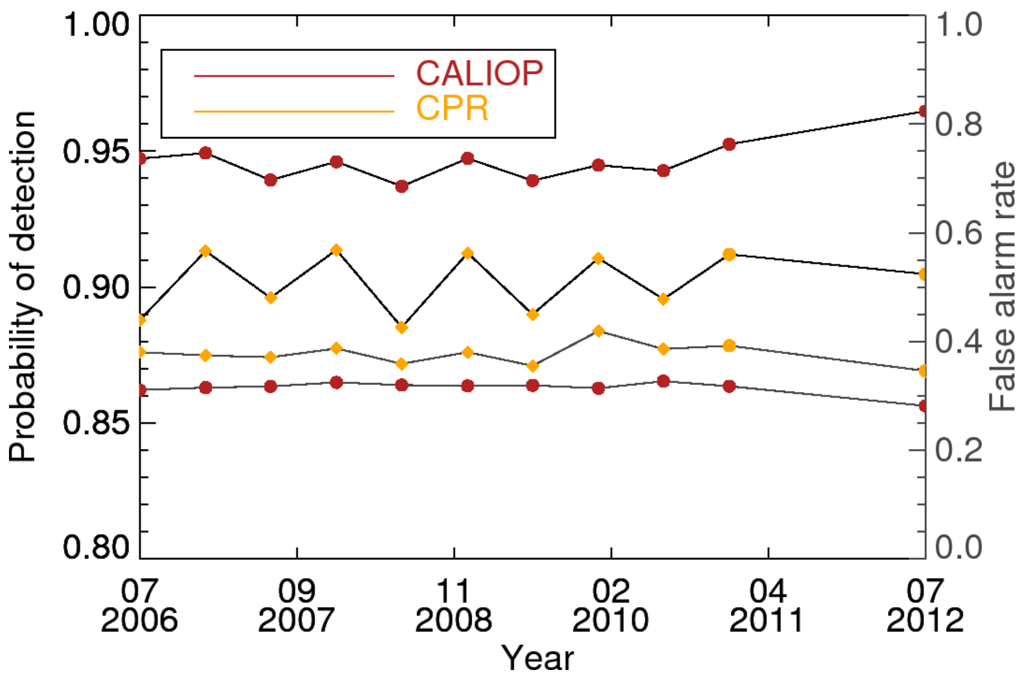

Figure 3: Time-series evaluation of SEVIRI cloud mask with CALIOP and CPR, January and July of each year from 07/2006 to 07/2012. The black line denotes the POD whereas the grey line refers to the FAR.

The evaluation of the cloud mask data set was extended to the complete range of available CALIOP and CPR measurements to demonstrate the average temporal stability of the cloud mask. Here for each year a summer and a winter month with maximum and minimum illumination of each hemisphere were analyzed in order to capture possible periodical effects. The collocation database ranges from July 2006 to July 2012. Note that from January 2012 onwards the CALIOP data set version V3.02 was used instead of V3.01. The analysis was carried out exactly as described before in 4.1; results in form of validation time-series are shown in Figure 3. The results of the probability of detection are stable over time within a range of 0.946 ± 0.008 for CALIOP and 0.902 ± 0.011 in case of CPR, whereas the false alarm rate for the comparison with CALIOP is 0.315 ± 0.012 and for CPR 0.377 ± 0.02. Missing points in the plot denote cases where either CPR or CALIOP data were not present or no collocations could be found with SEVIRI, respectively. Note that in case of missing CPR data the evaluation was omitted for CALIOP too, since CPR profiles are used for parallax correction of

SEVIRI clouds. The probability of detecting a cloud in both, the sensor and the reference is higher if CALIOP is considered as reference.
Thus the cloud mask of SEVIRI compares better to CALIOP than to CPR. A possible reason is the limitation of CPR in case of clouds lower than 1 km or high and optically thin clouds. This could be revealed by an analysis with respect to vertical cloud classes. Since no height information was retrieved for the clouds in the present data set the analysis not possible.

A seasonal cycle can be detected; the POD is generally higher in January than in July for both, CALIOP and CPR. The bias can be caused by the combination of two factors; first the varying illumination conditions of a hemisphere during a winter or summer month respectively which leads to a switch in algorithm from day to night time mode in case of SEVIRI and second the uneven distribution of land mass or rather surface albedo and therefore different capabilities of detecting a cloud.

6. Conclusion and final remarks

With this report the validation of the cloud mask dataset derived from SEVIRI measurements with the NWC SAF software package msgv2012 is presented. The dataset has a temporal resolution of 15 min and spans the time-period 2004-2012. It is provided on SEVIRI pixel resolution. This temporally and spatially high resolved dataset was produced within the Federate Activity FA_OSI_LSA_CM_13_01 which is a combined effort of the CM SAF, OSI SAF and LSA SAF. For the validation reference datasets from independent observation sources are used with have a different measurement strategy. The used reference observation sources were: CALIPSO and CloudSat datasets on level2 basis. For the colocation of all satellite measurements the software package AVACS-S was used.

Summary of results

- Overall very good agreement of SEVIRI cloud mask with CPR and CALIOP is found for January and July (2006 - 2012) as well as June 2009. The probability of detection is as high as 94.6 ± 0.08 % for CALIOP and 90.2 ± 0.11 % for CPR.

- Sensitivity studies with respect to the optical thickness of the cloud exhibit that by filtering cases of optically thin clouds (according to CALIOP) the agreement of the SEVIRI cloud mask with CALIOP is significantly increased for optical depth of 0.3 and higher, while the detection probability for optically thinner clouds is reduced significantly.

Table 4: Results from the cloud mask validation based on SEVIRI measurements with CALIOP and CPR, compliance to the target requirement is given.

Product	Precision requirement (POD)	Achieved precision
Cloud Mask (CMa)	**0.90**	**0.946 ± 0.008 CALIOP** **0.902 ± 0.011 CPR**

These figures can be compared to the original software package validation carried out by NWC SAF with comparable conditions. NWC SAF uses SYNOP data for Europe in the time frame 10/12/2010 to 21/03/2011. NWP fields forecasted with the French model ARPEGE four times per day (0h, 6h, 12h and 18h) at 1.5 degree horizontal resolution were used instead of ERA interim as in the present study, details can be found in [RD 7]. The results are expanded for varying illumination conditions where highest PODs and lowest FARs were achieved during daytime, lowest PODs occur in twilight and highest FARs at night-time. The average POD equals 96.5 % and FAR = 4.1 % where the POD is comparable to the figures from the present evaluation with CALIOP and CPR. However, the reported FAR from NWC SAF is higher than the CALIOP and CPR result. This is likely related to several factors primarily field of view, reference period and reference region.

The validation with two independent observation sources is in this case justified since a much more extensive validation effort was carried out on the occasion of processing of the SEVIRI-derived CM SAF dataset CLAAS (CM SAF CLoud property dAtAset using SEVIRI) where the NWC SAF software msgv2012 was employed to derive the cloud mask based on the same SEVIRI level 1b radiances (EUMETSAT, 2007 and 2010, though only in hourly resolution) as were used in this dataset. CLAAS proved to be a dataset of high quality that fulfils all requirements and was released in April 2013. Since the cloud mask dataset presented here has undergone similar production process, the reader may also be interested to consult the validation report RD 3, particularly the dependence of detection quality on SEVIRI's viewing zenith angle could be of interest, a theme that was not touched in the present validation report but is important for the user to decide on the data range appropriate to the user's specific requirements (compare also [RD 1]).

7. References

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8. Glossary

AMSR-E	**9. Advanced Microwave Scanning Radiometer - EOS**
ATBD	Algorithm Theoretical Baseline Document
AVAC-S	A-Train Validation of Aerosol and Cloud Properties from SEVIRI
AVHRR	Advanced Very High Resolution Radiometer
CALIPSO	Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations
CALIOP	Cloud-Aerosol Lidar with Orthogonal Polarisation
CDO	Climate Data Operators
CDOP	Continuous Development and Operations Phase
CFOT	Cloud Feature Optical Depth
CLAAS	CM SAF CLoud property dAtAset using SEVIRI
CM SAF	Satellite Application Facility on Climate Monitoring
CPR	Cloud Profiling Radar
COT	Cloud Optical Thickness
DRI	Delivery Readiness Inspection
DWD	Deutscher Wetterdienst (German Met Service)
ECMWF	European Centre for Medium Range Forecast
ECV	Essential Climate Variable
ERA-Interim	Second ECMWF Re-Analysis dataset
EUMETSAT	European Organisation for the Exploitation of Meteorological Satellites
FCDR	Fundamental Climate Data Record
GCOS	Global Climate Observing System
IDL	Interactive Data Language
ISCCP	International Satellite Cloud Climatology Project
MODIS	Moderate Resolution Imaging Spectroradiometer
MSG	Meteosat Second Generation
NWC SAF	SAF on Nowcasting and Very Short Range Forecasting
NWP	Numerical Weather Prediction
POD	Probability of Detection
PRD	Product Requirement Document
PUM	Product User Manual
SEVIRI	Spinning Enhanced Visible and InfraRed Imager
SAF	Satellite Application Facility
SSMI/S	Special Sensor Microwave Imager / Sounder

SYNOP	Synoptic observations