Long-term satellite-based cloud property datasets derived within CM SAF

***Martin Stengel*, Frank Kaspar, Maarit Lockhoff, Karl-Göran Karlsson, Jan Fokke Meirink, Anke Kniffka, Rainer Hollmann**

Deutscher Wetterdienst, Frankfurter Str. 135,
63067 Offenbach, Germany
Koninklijk Nederlands Meteorologisch Instituut, Wilhelminalaan 10,
3732 GK De Bilt, Netherlands
Sveriges Meteorologiska och Hydrologiska Institut, Folkborgsvägen 1,
601 76 Norrköping, Sweden

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Abstract

The EUMETSAT Satellite Application Facility on Climate Monitoring (CM SAF) uses space-based observations from both geostationary satellites (Meteosat Second Generation, MSG) and polar orbiting satellites (NOAA, MetOp, DMSP) to provide data sets of geophysical parameters suitable for climate analysis and monitoring.
A substantial part of this initiative is related to clouds and corresponding satellite-derived parameters, such as cloud fractional coverage, cloud top parameters, cloud optical depth, effective radius, cloud phase, and cloud water path. Due to recurring efforts of incorporating revised retrieval schemes and new radiance inter-calibration and homogenization, the processing system is periodically maintained and updated.
Recently, the CM SAF cloud datasets were re-processed using the latest retrieval developments and homogenized radiances. They span time periods of 28 years for AVHRR GAC, and 7 years for SEVIRI, respectively. The latter with very high temporal resolution.
Besides other existing datasets, e.g. Patmos-X (Heidinger et al., 2005), ISCCP (Rossow and Schiffer, 1999), and MODIS- (Platnick et al., 2003), microwave- and IR-sounder-based cloud climatologies, the CM SAF datasets of cloud properties complement the international effort of analysing and understanding clouds and their spatiotemporal variations and long-term variability. The CM SAF datasets allow for investigations of process studies and the general long-term cloud analysis with respect to the time period covered. The reprocessed and homogenized data will support the assessment of possible occurring global or regional trends, and of cyclic variations of cloud parameters at different time scales. Among other applications, these data sets are therefore a proper reference to assess the quality of global climate simulations.
This presentation will give an overview over the cloud products and corresponding datasets, as processed by the CM SAF. Validation results and examples of applications will be shown for the AVHRR GAC dataset. Further, we will give an outlook on future CM SAF activities, which will additionally focus on the generation of cloud properties derived from TOVS and ATOVS, and derived from multiple generations of geostationary instruments.

Introduction

The EUMETSAT Satellite Application Facility on Climate Monitoring (CM SAF) provides medium- and long-term cloud, radiation, water vapour and temperature products and datasets derived from different satellite instruments (Schulz et al., 2009). CM SAF has recently started its new project phase

(since 01 March 2012) now also including UK Met Office as participating institution within the CM SAF consortium (Figure 1).
As complementing part to the creation of operational monitoring products, CM SAF is increasingly focusing on the generation of retrospectively produced long-term datasets taking into account latest retrieval developments as well as inter-calibrated and homogenized satellite measurement records.
For these datasets errors due to orbit changes and inter-satellite biases are minimized. These datasets can be used for monitoring inter-annual variability, and for climate analysis and trend investigation.
With respect to cloud properties, CM SAF is currently generating mid- and long-term datasets, which are comprised of multiple cloud properties derived from the Spinning Enhanced Visible and Infrared Imager (SEVIRI) and Advanced Very High Resolution Radiometer (AVHRR). The SEVIRI dataset cover the available Meteosat Second Generation (MSG) records of MSG-1 and MSG-2 from 2004 until 2010. The AVHRR dataset covers the time period 1982 to 2009, with AVHRR instruments on NOAA 6, 8 and 10 being excluded due to the missing second IR channel. An overview of the individual sensor coverage is given in Figure 2.

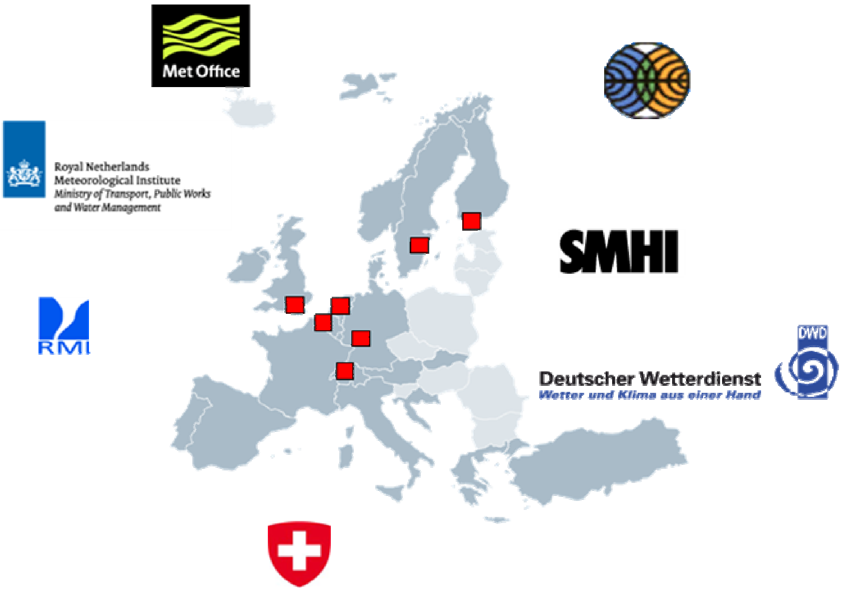

Figure 1 The EUMETSAT CM SAF consortium as of 01 March 2012.

The CM SAF cloud property datasets

Various cloud properties are derived for AVHRR as well as for SEVIRI. For both instruments, two retrieval schemes are applied, one retrieving cloud mask and cloud top parameters, such as temperature, pressure and height, the other one retrieving the cloud top phase and microphysical parameters effective radius and cloud topical thickness, which are used to determine liquid and ice water path. The retrieval schemes used, as well as other dataset specifications are given in Table 1. The following list names the produced cloud properties for SEVIRI and AVHRR:

- Cloud Fractional Coverage (CFC)
- Cloud Top Parameters (CTH, CTP, CTT)
- Cloud Phase (CPH)
- Liquid/Ice Water Path (LWP/IWP)
- Cloud Optical Thickness (COT)
- 1D-Histograms, COT-CTP-2D-Histograms

The AVHRR retrieval systems and the datasets have been generated, comprehensively evaluated and inter-compared and documented. All documents can be found on the CM SAF website:

http://www.cmsaf.eu. The SEVIRI datasets are currently finalized and the respective documentation will soon be available on the website as well.

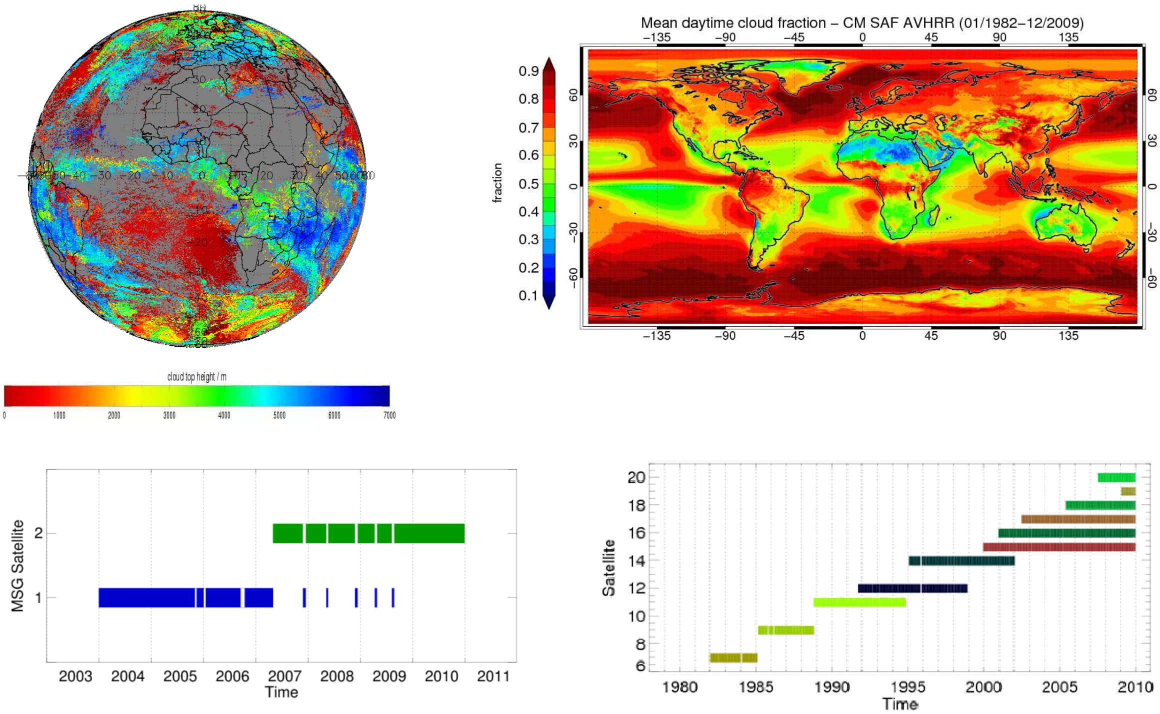

Figure 2 Upper left: spatial coverage of SEVIRI observations. Upper right: example of global coverage of CM SAF AVHRR GAC cloud property datasets. Bottom left: Coverage of SEVIRI data availability for MSG-1 and MSG-2. Maintenance periods of MSG-2 are filled whenever possible with MSG-1 SEVIRI observations. Bottom right: Time of individual AVHRR instruments onboard various NOAA satellites, whose number is given as y-axis (the value 20 here corresponds here to AVHRR onboard MetOp).

Table 1 Specifications of CM SAF cloud property datasets. In the last row the used retrieval schemes are referenced.

	SEVIRI		**AVHRR**
Retrieval software	MSG-NWC package for CFC, CTH, CTP, CTT; CPP software for COT, LWP, IWP, CPH		PPS software package for CFC, CTH, CTP, CTT; CPP software for COT, LWP, IWP, CPH
Auxiliary data	ERA-Interim		ERA-Interim
Instruments/Sensors	SEVIRI on MSG1/2		AVHRR-GAC on NOAA 7,9,11,12,14,15,16,17,18,19 and MetOp
Temporal coverage	2004 – 2010*		1982 – 2009
Spatial coverage	SEVIRI full disk, 0.05° grid, (CTP-COT histograms are defined on 1° grid)		Global coverage on 0.25° (CTP-COT histograms are defined on 1° grid); Polar EASE grid (25km resolution)for North and South Pole areas (CFC only)
Calibration	IR: Reprocessed radiances before May/2008 (recently provided by EUMETSAT) VIS/NIR: calibration (against MODIS, done by KNMI) applied to channels 0.6, 0.8, 1.6		VIS: Recalibrated visible reflectances provided by NOAA (Heidinger et al., 2010). IR: unchanged (only onboard BB calibration)
Products	Daily and monthly means, 1d/2d histograms		Daily and monthly means, 1d/2d histograms

* the temporal coverage of the SEVIRI dataset edition 1 might also cover 2011
CPP: Cloud Physical Properties (Roebeling et al., 2006; SATBD2, 2012)
MSG-NWC: NWC SAF MSG software package (SATBD1, 2009)
PPS: NWC SAF Polar Processing System (Dybbroe et al., 2005a and Dybbroe et al., 2005b)

Validation and inter-comparison results

In this section some validation and inter-comparison results are shown on exemplary basis. The results shown and other validation studies can be found in the validation report of the CM SAF AVHRR GAC edition 1 (http://www.cmsaf.eu). The first example shown here is based on cloud fraction comparisons of SYNOP observations (Figure 3), which had been converted to monthly means and then compared to the CM SAF GAC products. It can be seen, that the mean deviation to the SYNOP observation, considering the entire period, is very close to zero for many regions on the globe. However, a few regions can be found for which the bias exceeds 0.2, meaning that the satellite product is overestimating the cloud fraction with respect to the SYNOP values. These regions are for example found in the Middle East and in Australia.

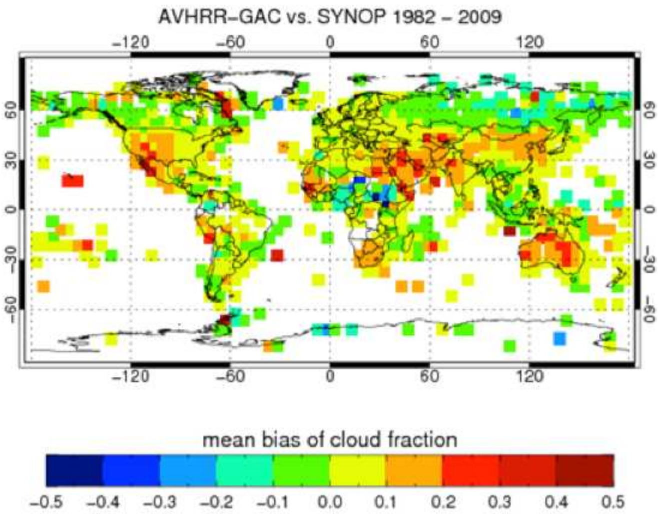

Figure 3 Mean deviation of monthly mean cloud fraction of CM SAF AVHRR GAC products with respect to SYNOP observations. The time period covered in this comparison is 1982 to 2009.

In the next figure (Figure 4) cloud thermodynamic phase, liquid water path and ice water path are inter-compared with other satellite products.

For cloud phase the zonal means of the individual CM SAF products for NOAA17 and NOAA18 were investigated with respect to MODIS/TERRA and MODIS/AQUA. Due to the orbital properties, the AVHRR/NOAA17 vs. MODIS/Terra and the AVHRR/NOAA18 vs. MODIS/AQUA approach should allow to reduce uncertainties in the comparisons caused by sampling issues. Except for higher latitudes, the zonal means of liquid cloud fraction of the CM SAF products of NOAA17 and NOAA18 agree very well with those of MODIS/TERRA and MODIS/AQUA only showing in general a very slight overestimation, which is most pronounced between approximately 30 and 50 degree north. Due to the sun-satellite geometry and possible snow coverage, the agreement is worse for the higher latitude, here showing a strong underestimation compared to MODIS.

The liquid and ice water path of CM SAF NOAA18 were compared to MODIS/AQUA, PATMOS-X and ISCCP. Except from the higher northern latitude, the agreement of CM SAF LWP with MODIS is very encouraging. It seems to be similar to Patmos-X, even being a bit closer to MODIS in northern Mid-Latitudes. However, the deviations among all products increase significantly which is most likely due to snow cover and due to high sun-zenith angles.

The ice water path comparisons show some underestimation of the CM SAF products compared to MODIS. Here the Patmos-X product agrees well with MODIS, while the CM SAF is very similar to ISCCP. Due to thresholds in the derivation of the microphysical properties for ice clouds, these comparisons might be strongly affected by different samplings when creating the monthly means of each product.

Generally speaking, due to the enhanced spectral capabilities of MODIS, one can consider MODIS to be a good reference for satellite-based imagers. However, also MODIS and corresponding cloud products might have weaknesses.
It also needs to be noted that for all products, monthly averages were compared which were generated individually at each data providing centres. This might include varying spatial samplings in the Level 3 aggregations, which could explain some if the deviations found in these comparisons.

In a further comparison the two-dimensional Joint Cloud Property Histograms of CM SAF were compared against MODIS and ISCCP for one particular month (Figure 5). The histograms are shown in the available binning of CTP and COT. While CM SAF AVHRR and MODIS seem to give similar messages, with having the most clouds as low-level clouds with CTP between 680 and 950 hPa and COT between 2 and 20, does ISCCP have another maximum in the distribution for mid-level clouds (440 to 680 hPa) and COT of 10 to 20. Also in the mid and upper troposphere, the CM SAF does not deviate a lot from MODIS with providing COT of 4 to 20 for clouds in these heights. For a better comparison, the binning of the products is suggested to be adjusted.

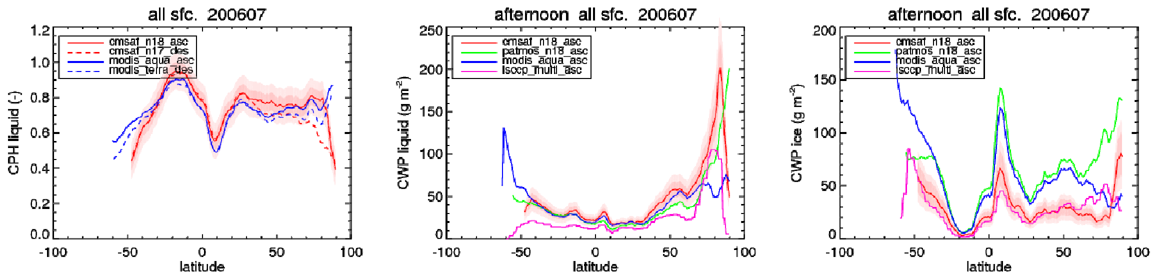

Figure 4 Left: Inter-comparison of CM SAF AVHRR GAC and MODIS zonal mean of the monthly mean fraction of liquid clouds. Compared here are the products for AVHRR17 and 18 and MODIS/AQUA and MODIS/TERRA. Middle: Comparison of zonal mean of monthly mean liquid water path derived from AVHRR18 (CM SAF and Patmos-X), MODIS/AQUA and ISCCP. Right: as middle figure but for ice water path. For all comparison the data was taken from July 2006. The red shaded areas defines the CM SAF product thresholds.

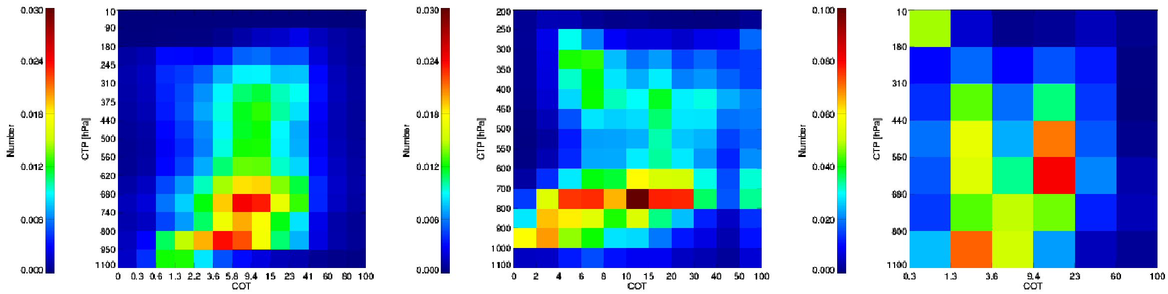

Figure 5 Two-dimensional histograms of the derived cloud physical properties CTP and COT for CM SAF (left), MODIS (middle) and ISCCP (right). The histograms were composed by aggregation of all global cells for one selected month. Note, that the binning is different for all three products. The counts of the histograms are here expressed of relative values with respect to the total number of each histogram.

Known problems/challenges - example

One specific problem (or challenge) shall be mentioned here when generating datasets, which are based on multiple sensors, which may also show sensor degradation. As an example, the CFC parameter of the CM SAF AVHRR is shown by its global and mid-latitude mean as a function of time in Figure 6. Here, it can be clearly seen that there can occur deviations between the AVHRR instruments on different satellites. One can also see that there is instrument degradation or satellite drift driven increasing deviations for some satellites during their lifetime. It is of high interest for the CM SAF team to make this information available to the users of the data, e.g. by a comprehensive description in the validation report. It is also planned to further investigate these features and to find possibilities for improved homogeneity for each parameter of the dataset.

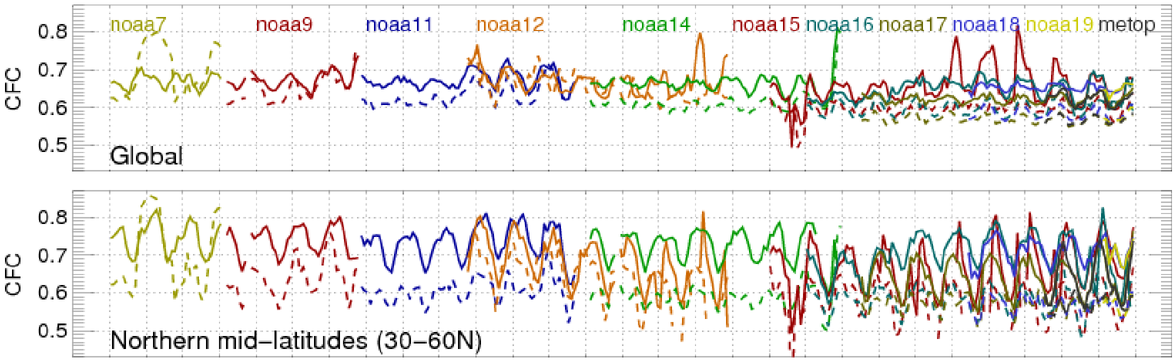

Figure 6 Time series of mean CFC (as in CM SAF AVHRR dataset) for the entire globe and mid-latitudes, separated for the various AVHRR carrying satellites used in the CM SAF AVHRR datasets. Dashed lines are night-time observation, while solid lines represent day-time. (The time series for the mid-latitudes has been corrected, thus deviates from the original conference presentation.)

Future cloud-related activities in CM SAF

The cloud-related activities in the next years will be firstly, to periodically conduct reprocessing events for the various datasets, using improved retrieval schemes and updated inter-calibration information. Secondly, CM SAF will include new cloud property datasets in its portfolio, which are, for example, a merged MVIRI/SEVIRI cloud cover dataset, and a TOVS/ATOVS cloud property dataset with the focus on high clouds. In Figure 7 the reprocessing events and the releases of the new datasets are shown together with the approx. time frame of their release and their temporal coverage. Also shown are the processing of the operational products of AVHRR and SEVIRI cloud properties. The processing of the operational products will be transferred to the EUMETSAT CAF (Central Application Facility), which is planned for 2013.

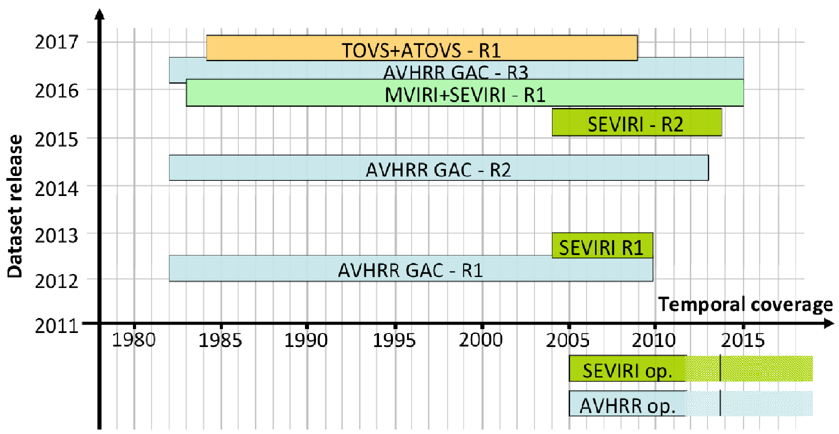

Figure 7 Schematic sketch of CM SAF cloud property datasets to be generated and release between 2012 and 2017. The x-axis shows the temporal coverage of the datasets, while the y-axis gives the release year. The temporal coverage of upcoming editions of the AVHRR GAC datasets might also include earlier AVHRR data before 1982 when found to be useful. Also shown are the CM SAF operational products for AVHRR and SEVIRI, established in 2005, whose processing will be taken over by the EUMETSAT CAF (Central Application Facility) in the timeframe of 2013/2014.

Summary

In this presentation CM SAF cloud property datasets have been described. The AVHRR GAC dataset was analysed in more depth showing validation and inter-comparison results against ground-based and satellite based products of e.g. SYNOP and MODIS. Most of the shown comparisons strengthened the confidence in the quality of the CM SAF AVHRR GAC dataset by showing good agreements to the reference observations. Only for the ice water path comparisons a slight systematic underestimation was found, which could also be caused by different sampling. The evaluation of the two-dimensional cloud property histograms showed a good agreement with MODIS, while some deviations from ISCCP were found. Based on a time series of cloud fractional coverage (inferred from the AVHRR GAC dataset) challenges with respect to the generation and homogenization of datasets of geophysical parameters were discussed. This issue is of particular importance if multiple instruments and/or satellites are involved, which might be affected by satellite drift or instrument degradation in their lifetime.

Generally speaking, in addition to the operational products, CM SAF is generating more and more climate data records for radiation (e.g. MVIRI, SEVIRI, AVHRR), tropospheric humidity and temperature (SSM/I, ATOVS), and clouds (SEVIRI, AVHRR, (A)TOVS), with periodic reprocessings. Two cloud property datasets have recently been started to generate (SEVIRI and AVHRR GAC based). The AVHRR dataset, its evaluation and comprehensive description is completed. This dataset will be officially released in June 2012. The SEVIRI dataset is currently processed. According validation and characterization steps will be conducted soon leading to an approx. official release date at the end of 2012.
As done for all CM SAF operational products and retrospectively generated datasets, comprehensive characterizations and evaluations are carried out and documentation will be available at the CM SAF website when released (www.cmsaf.eu).

References

Dybbroe, A., A. Thoss and K.-G. Karlsson, 2005a: NWCSAF AVHRR cloud detection and analysis using dynamic thresholds and radiative transfer modeling - Part I: Algorithm description, J. Appl. Meteor, 44, pp. 39-54.

Dybbroe, A., A. Thoss and K.-G. Karlsson, 2005b: NWCSAF AVHRR cloud detection and analysis using dynamic thresholds and radiative transfer modeling - Part II: Tuning and validation, J. Appl. Meteor, 44, 55-71.

Heidinger, A.K., M.D. Goldberg, A. Jelenak and M.J. Pavolonis, 2005: A new AVHRR cloud climatology, Proc. SPIE 5658, 197, doi: 10.1117/12.579047.

Heidinger, A.K., W.C. Straka, C.C. Molling, J.T. Sullivan and X.Q. Wu, 2010: Deriving an inter-sensor consistent calibration for the AVHRR solar reflectance data record. Int. J. Rem. Sens., 31(24), 6493-6517

Mittaz, P.D. and R. Harris, 2009: A Physical Method for the Calibration of the AVHRR/3 Thermal IR Channels 1: The Prelaunch Calibration Data. J. Atmos. Ocean. Tech., 26, 996-1019, doi: 10.1175/2008JTECHO636.1

Roebeling, R.A., A.J. Feijt and P. Stammes, 2006, Cloud property retrievals for climate monitoring: implications of differences between SEVIRI on METEOSAT-8 and AVHRR on NOAA-17, J. Geophys. Res., 111, D20210, doi:10.1029/2005JD006990.

Platnick, S., et al. (2003), The MODIS cloud products: Algorithms and examples From Terra, IEEE Trans. Geosci. Remote Sens., 41, 459-473, doi:10.1109/TGRS.2002.808301.

Rossow, W. B., and R. A. Schiffer, 1999: Advances in understanding clouds fromISCCP, Bull. Amer. Meeorot. Soc., 80, 2261-2287.

SATBD1, 2009: Algorithm Theoretical Basis Document - Cloud Fraction, Cloud Type and Cloud Top Parameter Retrieval from SEVIRI, reference no.: SAF/CM/DWD/ATBD/ CFC_CTH_CTO_SEVIRI, Version: 1.0, 10 September 2009, available at www.cmsaf.eu

SATBD2, 2012: Algorithm Theoretical Basis Document cloud physical products AVHRR, SAF/CM/KNMI/ATBD/GAC/CPP/1.0, available at www.cmsaf.eu

Schulz, J., et al., 2009: Operational climate monitoring from space: the EUMETSAT Satellite Application Facility on Climate Monitoring (CM-SAF), Atmos. Chem. Phys., 9, 1687-1709