ESA Cloud_CCI

Data Set Description
CC4CL cloud properties

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1. Intent of the Document

This document summarizes essential information needed for users of any level who wish to use the ESA Cloud_cci CC4CL cloud properties data set for climate applications. Two product families are produced in Cloud_cci. The first family is an AATSR-MODIS-AVHRR heritage product group (described here), which contains the cloud properties separately derived from AATSR (Advanced Along Track Scanning Radiometer), MODIS (Moderate Resolution Imaging Spectroradiometer) and AVHRR (Advanced Very High Resolution Radiometer). The second product family contains cloud properties derived from AATSR and MERIS using a synergetic retrieval system (see Data set description sheet for FAME-C).
In the first phase (2010 – 2013) of the Cloud_cci project prototype retrieval versions were established leading to preliminary data sets covering 2007 – 2009. In phase 2 (2014 – 2016) both algorithms are further improved and two multi-decadal coherent global data sets of GCOS cloud property ECVs will be generated covering a time period of 33 years from 1982 to 2014 (see Figure 1).

2. Point of Contact

ESA's Cloud_cci: www.esa-cloud-cci.org, email: contact.cloudcci@dwd.de

3. Data Field Description

The AATSR-MODIS-AVHRR heritage product family is based on the cloud parameter retrieval results from ATSR-2 (on-board ERS-2), AATSR (on-board ENVISAT), MODIS (on-board AQUA and TERRA), and AVHRR (on-board NOAA-7, NOAA-9, NOAA-10, NOAA-11, NOAA-12, NOAA-14, NOAA-15, NOAA-16, NOAA-17, NOAA-18, NOAA-19 and MetOp-A).
The inter-sensor retrieval consistency of the data is ensured by the application of one retrieval scheme (see CC4CL description in the Algorithm Theoretical Baseline Document (ATBD, 2013)). This data, which is temporally and spatially defined on the corresponding native data projection of the satellites instrument used (level 2 data), forms a basis of individual datasets for each cloud parameter, which build the core of this product family. In a second processing step these datasets are further processed to create firstly daily composites (level 3u) and monthly mean (level 3c data) representatives for each parameter on a global grid. More details are given in the Product Specification Document (PSD, 2014).

The cloud products processed in each product family are:

- **Cloud cover**: The cloud cover products contain the total cloud fractional coverage and additionally a separation into three vertical classes: the cloud cover for high, mid-level, and low clouds. The levels separating these layers have been chosen to line up with the borders used in ISCCP and in the GEWEX cloud assessment, thus are set to: 440 hPa and 680 hPa, respectively. The parameter cloud cover is dimensionless.
- **Cloud top pressure**: The air pressure at the uppermost cloud layer that could be identified by the retrieval scheme. The unit is [hPa].
- **Cloud top height**: The height of the uppermost cloud layer that could be identified by the retrieval scheme. The height is not directly retrieved, but inferred from cloud-top pressure. The given height is defined to be the vertical distance above sea level. The unit is meters [m].
- **Cloud top temperature**: The temperature of the uppermost cloud layer that could be identified by the retrieval system. The unit is Kelvin [K]
- **Cloud Phase**: The thermodynamic phase of the retrieved cloud. A separation between ice and water will be provided in the level 2 and level3u products. The phase in the level 3c product is represented by the monthly mean of the liquid cloud fraction.

- **Cloud optical thickness**: The line integral of the absorption coefficient and the scattering coefficient, along the instruments line of sight in cloudy pixels. This parameter is dimensionless. Additionally a separation between 2 thermodynamic phases will be provided on level 3c basis: liquid - and ice – cloud optical thickness.
- **Cloud effective radius**: The area weighted radius of the cloud drop particles. Additionally a separation between 2 thermodynamic phases will be provided on level 3c basis: liquid - and ice – cloud effective radius.
- **Cloud liquid water path**: This quantity is the vertical integrated liquid water content of existing cloud layers. This quantity is not directly retrieved, but inferred from cloud optical thickness and cloud effective radius in cloudy pixels with liquid cloud phase.
- **Cloud ice water path**: This quantity is the vertical integrated ice water content of existing cloud layers. This quantity is not directly retrieved, but inferred from cloud optical thickness and cloud effective radius in cloudy pixels with ice cloud phase.
- **Joint cloud property histograms**: In level 3c,s products and for daytime only absolute number of occurrences of cloud top pressure and cloud optical thickness values will be provided in a combined cloud property histogram. The binning for each cloud property follows the ISCCP cloud type definition. As a third dimension the information is separated by the cloud phase into liquid + ice and liquid only.

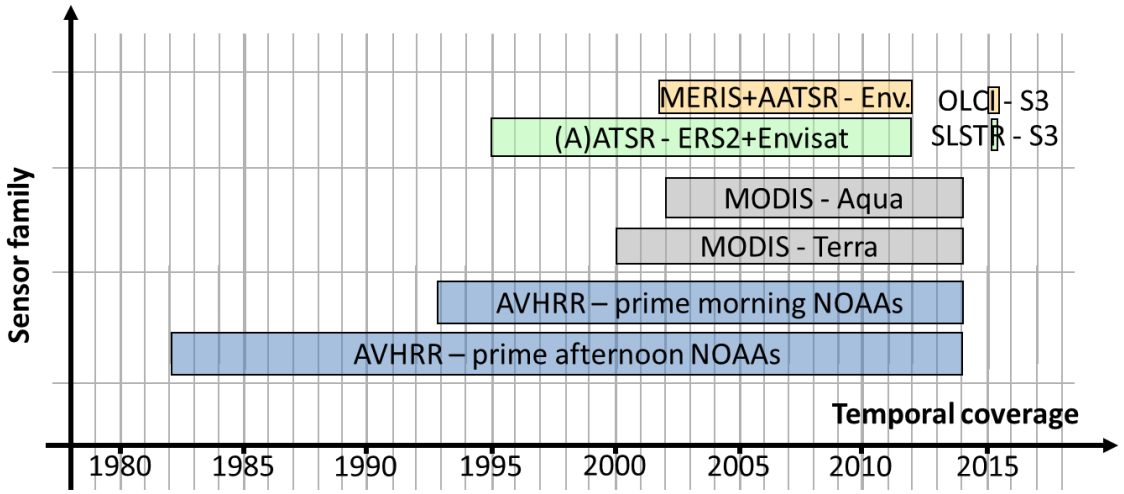

Figure 1: In the ESA Cloud_cci project two long-term coherent global cloud property data sets are produced: (a) AVHRR/MODIS/(A)ATSR time series from 1982 to 2014 and (b) MERIS/AATSR time series from 2002 to 2012. The latter data set will be extended by OLCI/SLSTR on-board Sentinel-3.

4. Data Origin

The AATSR-MODIS-AVHRR dataset spans the time period 1982-2014. The integrated retrieval scheme is based on the optimal estimation approach (Sayer et al., 2011, Rodgers, 2000). The vertical structure of the cloud condensate is retrieved enabling the diagnosis of cloud cover, cloud-top pressure/height/temperature, cloud optical thickness, effective radius and the further derived quantities for cloud liquid and ice water path. A detailed description of the used methodology of the employed algorithms and approaches is provided by the ATBD (2013).

The final outputs are pixel-based L2 and global L3 data projected on an equal-angle grid. The L3 products are provided as daily near-nadir-samples (L3U) with 0.1 degree horizontal resolution as well as monthly averages (L3C) aggregated on a 0.5° latitude-longitude grid.

Table 1: Spectral channels of the Advanced Very High Resolution Radiometer (AVHRR). The three different versions of the instrument are described as well as the corresponding satellites. Notice that channel 3A was only used continuously on NOAA-17 and Metop-A. For the other satellites with AVHRR/3 it was used only for shorter periods.

Channel Number	Wavelength (micrometers) AVHRR/1 NOAA-6, 8, 10	Wavelength (micrometers) AVHRR/2 NOAA-7, 9, 11, 12, 14	Wavelength (micrometers) AVHRR/3 NOAA-15, 16, 17, 18, 19, MetOp-A, MetOp-B
1	0.58 – 0.68	0.58 – 0.68	0.58 – 0.68
2	0.725 – 1.10	0.725 – 1.10	0.725 – 1.10
3a	-	-	1.58 – 1.64
3b	3.55 – 3.93	3.55 – 3.93	3.55 – 3.93
4	10.50 – 11.50	10.50 – 11.50	10.50 – 11.50
5	Channel 4 repeated	11.5 – 12.5	11.5 – 12.5

5. Validation and Uncertainty Estimate

Using a variety of reference data sets, extensive validation studies were conducted to verify and validate the ESA Cloud_cci prototype products (2007-2009) generated within phase I of the project (for details see the Product Validation and Intercomparison Report (PVIR, 2013)). In order to assess the accuracy of the algorithm for instantaneous retrievals, it was compared to simultaneous measurements of MSG-SEVIRI and active sensors, namely CloudSat-CPR and CALIPSO-CALIOP. Moreover, the cloud detection efficiency was analyzed with the help of SYNOP data. To cover the validation of the Cloud_cci level 3 data and compare them to other well-established cloud climatologies, extensive comparisons were made with CM SAF CLARA-A1 and MODIS collection 5 level 3 data. In addition, the liquid water path retrievals were compared to a microwave-derived LWP climatology (University of Wisconsin, UWisc).
Table 2 summarizes the results of the L3 validation of the datasets and puts them into perspective by comparing the derived numbers to the GCOS accuracy requirements. For the interpretation of the numbers given, it is important to bear in mind that none of the validation data sets used can be regarded as a perfect reference. In addition the GCOS requirements are goals for long-time climatologies and in Cloud_cci only three demonstrator data sets have been produced.
To conclude the validation/evaluation of the Cloud_cci phase 1 results demonstrate that the CC4CL AVHRR cloud mask performs similarly well as comparable algorithms (e.g. CALIPSO/CloudSat), except for twilight conditions. Moreover, latitudinal biases were observed, with underestimations of cloud amount for tropical conditions and positive deviations for high latitudes, due to the frequent misclassification of snow and ice surfaces as clouds. The seasonal cycle is well captured and there is a good latitudinal agreement compared to other reference data sets. Using the active sensors for cloud height validation revealed similar results as compared to the validation of comparable algorithms. In general CC4CL underestimates the global cloud cover and does not detect enough high level clouds. In Cloud_cci phase 2 several feedback loops are carried out in order to further improve the algorithms.

Table 2: GCOS requirement compliancy matrix for Cloud_cci cloud property dataset accuracy (URD, 2014)), according to WMO-DOR (2010) (B/T: Breakthrough, Thresh: Threshold). Colors indicate validation results meeting the GCOS goals (green), results lying within the breakthrough range (yellow) and results outside the GCOS thresholds (red).

Cloud variable	GCOS requirement Goal, B/T, Thres	Reference data	bias std	CC4CL		
				AVHRR	MODIS	AATSR
Cloud cover	10, 15, 20%	Synop	bias	**-10 to 5%**	**-5 to 10%**	**-5 to 18%**
			std	**10 to 20%**	**10-20%**	**15-30%**
		CLARA-A1	bias	**-5 to 1%**		
			std	**10 to 11%**		
		MODIS coll5 Terra	bias		**9%**	
			std		**9%**	
		MODIS coll5 Aqua	bias		**8%**	
			std		**9%**	
Cloud top height	0.5, 1, 2 km	CLARA-A1	bias	**0 to 0.3 km**		
			std	**0.4 to 0.5 km**		
		MODIS coll 5 Terra, Aqua	bias		**-0.4 km (-40 hPa)**	
			std		**0.7 km (70 hPa)**	
Cloud water path	10,20,50 g/m2	CLARA-A1	bias	**0 to 80 g/m^2**		
			std	**50 to 100 g/m^2**		
		MODIS coll5 Terra	bias		**0 g/m^2**	
			std		**60 g/m^2**	
		MODIS coll5 Aqua	bias		**70 g/m^2**	
			std		**80 g/m^2**	
Cloud water path (liquid only)	10,15,20 g/m2	UWisc	bias	**-40 to 0 g/m^2**		
			std	**8 to 12 g/m^2**		

6. Considerations for climate applications

Due to the short period of generated Cloud_cci data, it is not possible to perform long term data comparisons or to support long term climate analyses.

- However, the cloud cover already showed sufficient result compared to other climatologies and ground based measurements. Nevertheless, underestimations of cloud cover in the tropics have been detected as well as overestimations in the Polar Regions. Best conditions for cloud masking appear to be at daylight with reduced quality during twilight.

- For cloud top height, multilayer clouds appear as single layer mid level clouds resulting in underestimation of high clouds and overestimation of mid level clouds. Here, it is not recommended to use the cloud top height results for climate analysis.
- Retrieval results for cloud optical thickness are problematic over snow or ice covered surfaces.
- During phase 1 the cloud phase scheme was in a non-reliable state and will be replaced by a more sophisticated scheme in phase 2. It is not recommended to use this property in climate analysis studies at the moment.
- In phase 1, a general overestimation of cloud water path was detected, strongly correlated with the cloud phase discrimination. This will be improved in phase 2.

In summary, all products should be treated with care when using the dataset for long-term trend analysis (orbital drifts, inter-satellite discontinuities).

7. Instrument Overview

Measurements from the Advanced Very High Resolution Radiometer (AVHRR) radiometer onboard the polar orbiting NOAA satellites and the EUMETSAT METOP satellites have been performed since 1978. The instrument only measured in four spectral bands in the beginning (AVHRR/1) but from 1982 a fifth channel was added (AVHRR/2) and in 1998 even a sixth channel was made available (AVHRR/3), although only accessible if switched with the previous third channel at 3.7 micron (

Table 1). For the generation of Cloud_cci data set only AVHRR/2 and AVHRR/3 sensors are used.
MODIS onboard Terra (since 2000) and Aqua (since 2002) acquire data in 36 spectral bands ranging in wavelength from 0.4 to 14.4 micron. NASA provided the Cloud_cci team MODIS collection 6 data from both platforms in a reduced version extracting only those 6 channels, which are equivalent to AVHRR/3, and with a spatial resolution of 1 km.
ATSR-2/AATSR onboard ERS-2 (1995-2003) and ENVISAT (2002-2012) respectively, provide 7 channels ranging in wavelength from 0.55 to 12 µm. The instrument has a dual view doubling the number of spectral channels. The heritage channels are extracted to complete the heritage dataset.
The satellite and auxiliary data required for the generation of the ESA Cloud_cci data products is described in detail in the Data Access Requirement Document (DARD, 2014).

8. References

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9. Revision History

08-07-2014 – Version 1.0 – initial draft created by Cornelia Schlundt.
17-07-2014 – Version 1.1 – my two cents (mustard) S. Stapelberg
28-07-2014 – Version 1.2 – small changes, C. Schlundt
28-07-2014 – Version 1.3 – small changes C. Poulsen
30-07-2014 – Version 1.4 – review: R Hollmann
01-08-2014 – Version 1.4 – tables modified, C. Schlundt
12-08-2014 – Version 1.4 – some minor changes, references added, C. Schlundt
09-09-2014 – Version 1.5 – final version, C. Schlundt