climate change initiative

→ CLOUD NEWSLETTER

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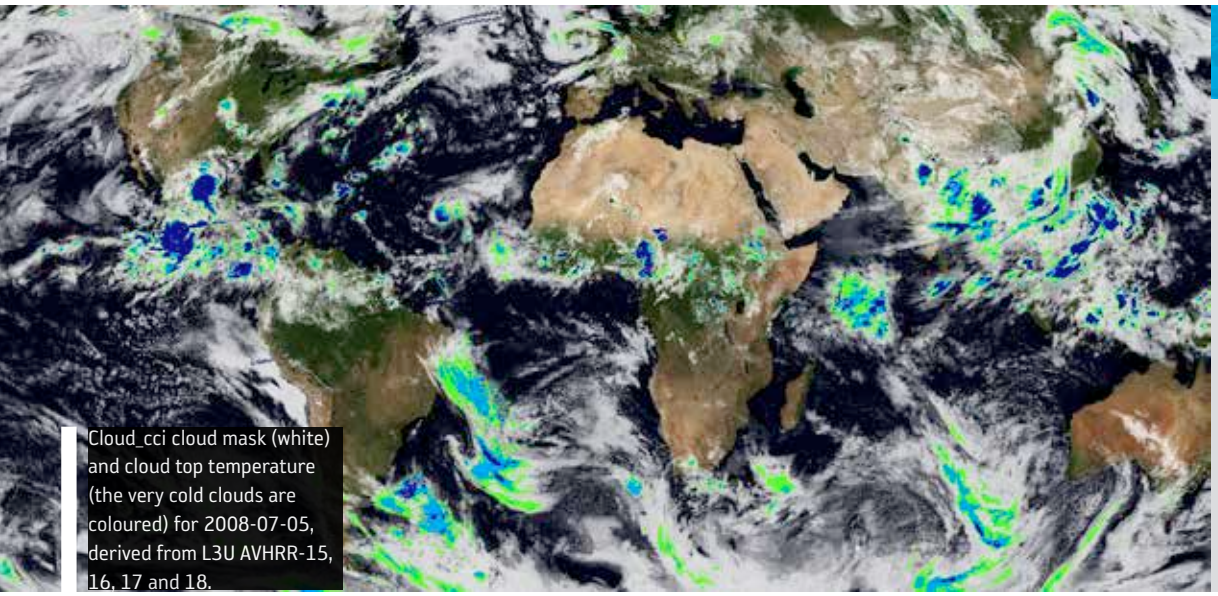

Cloud_cci cloud mask (white) and cloud top temperature (the very cold clouds are coloured) for 2008-07-05, derived from L3U AVHRR-15, 16, 17 and 18.

In this issue:

The ESA Cloud_cci project

The ultimate objective is to provide long-term coherent cloud property data sets exploiting the synergic capabilities of different Earth observation missions allowing for improved accuracies and enhanced temporal and spatial sampling better than those provided by the single sources.

The ESA Cloud_cci project seeks to utilize the increasing potential of the synergic capabilities of past, existing and upcoming European and US satellite missions in order to meet the increasing needs for coherent long-term cloud property datasets required by the scientific community.

The main objectives of this project are:

- Development and application of carefully calibrated and inter-calibrated radiance data sets – so called Fundamental Climate Data Records (FCDRs), for ESA and non ESA instruments in an international collaboration.
- Development of a coherent physical retrieval framework for the Global Climate Observing System (GCOS) cloud property Essential Climate Variables (ECVs), which is publicly available and usable by all interested scientist.
- Development of two multi-annual global data sets for the GCOS cloud property ECVs including uncertainty estimates based on FCDRs.
- Validation and inter-comparison of the multi-decadal cloud property products against ground based and other satellite based measurements taking into account the individual error structures of the individual observations as far as possible.
- Development of a cloud-simulator package to strengthen an application of Cloud_cci products for global and regional climate model analysis.
- Providing a common data base and the necessary assessment of cloud data sets as in the framework of Global Energy and Water Cycle Experiment (GEWEX).
- Development of a complete processing system distributed over Europe that can further strengthen operational production of cloud property data sets after the ESA CCI program is finished.
- Intensify the link with the climate modelling community.

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Cloud_cci Phase 1 and 2

Phase 1: 2010 - 2013

The very first important step in Cloud_cci was to discuss and acquire the user requirements and to define the technical specifications of the final cloud products.

The next stage in the project was the so-called Round Robin (RR) exercise, which assessed and inter-compared the quality of various state-of-the-art cloud retrieval schemes in order to select an appropriate algorithm for climate quality satellite based cloud properties. The satellite radiances (MODIS/AQUA and AVHRR/NOAA18) and auxiliary data (ERA-Interim) for five days in 2008 were prescribed for all participating schemes, which ensured their comparability. The cloud properties were evaluated against reference data provided by CLOUDSAT, CALIOP and AMSR-E, which are instruments within the A-Train constellation.

Finally, two algorithms were selected to form the basis for the community retrieval schemes due to excellent inter-comparison results and the large potential to comply with the project requirements: (1) CC4CL applied to AVHRR, MODIS and AATSR, with ORAC being the core of the retrieval, and (2) FAME-C, which is a novel synergetic retrieval for the ENVISAT instruments AATSR and MERIS. Both algorithms are based on optimal estimation technique, thus they are able to retrieve cloud parameters and uncertainty estimates simultaneously.

In summary, the main achievements in the first phase of the project were the development of two prototype retrieval schemes and the generation of their datasets covering the time period from 2007 until 2009. Finally, the Cloud_cci products were validated and inter-compared with other satellites climatologies as well as with model and reanalysis datasets, which provided a list of further developments and improvements of the algorithms and retrieval systems (see Phase 2).

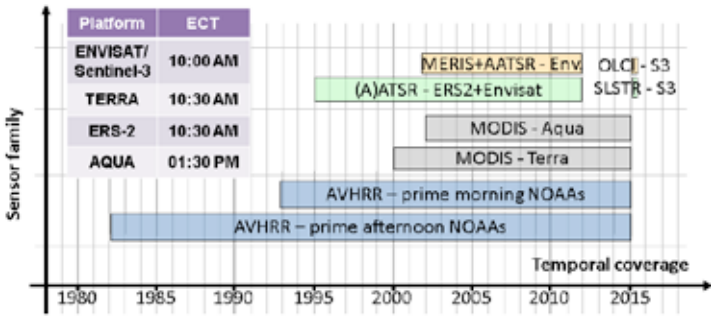

Figure 1: The ESA Cloud_cci project will generate 2 long-term coherent global cloud property data sets: (a) AVHRR-MODIS-(A)ATSR time series from 1982 to 2014 and (b) MERIS+AATSR time series from 2002 to 2012. The latter data set will be extended by OLCI/SLSTR on-board Sentinel-3. Additionally, the equatorial crossing time (ECT) of the satellites shown in this figure are summarized in the table, while ECTs of AVHRR bearing platforms are shown in Figure 2.

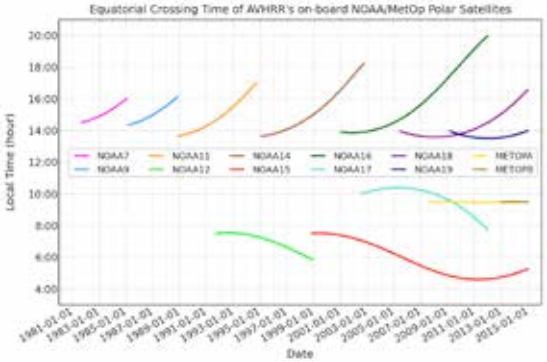

Figure 2: The equatorial crossing time (ECT) of NOAA platforms changes in value over time due to orbit degradation, while the ECT of MetOp satellites remain nearly constant throughout the year because they are in controlled orbits.

Phase 2: 2014 - 2016

The main objectives in the second phase of the Cloud_cci project are:

Further developments and improvements of both optimal estimation techniques and their processing systems;

Generation of an improved AVHRR GAC L1C dataset using the newly developed inter-calibration tool "pyGAC", which applies updated calibration coefficients for the VIS channels (by courtesy of A. Heidinger, andrew.heidinger@noaa.gov);

Processing of about 100 years of satellite data providing the complete time series (1982 – 2014) for all satellites;

Comprehensive validation of the Cloud_cci products against well established ground- and satellite-based datasets, e. g. ARM, CloudNet, Synoptical stations, PATMOS-x, ISCCP, CLARA-A2, MODIS collection 6;

Development of cloud simulators to ease the usage in the climate modelling community;

The generation of an additional data set based on **IASI sounder instrument data** in order to evaluate and assess the uncertainties of the VIS/IR retrieval results.

Cloud_cci algorithms and products

CC4CL (Community OE Cloud Retrieval for Climate) and FAME-C (Freie Universität Berlin AATSR MERIS Cloud) are optimal estimation based retrieval systems providing GCOS cloud property ECVs.

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For the generation of cloud climatologies, it is important to quantify the macro- and microphysical parameters and the associated uncertainties. In order to achieve this in the project, two OE retrieval schemes have been developed. This method enables rigorous error propagation and the inclusion of all measurements and any a priori information and associated errors in a mathematical framework. The technical description of both algorithms can be found at the project webpage.

The Cloud_cci products generated by CC4CL and FAME-C are listed and described in Table 1. The final outputs are pixel-based level 2 (L2) and global level 3 (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 degree latitude-longitude grid for each individual instrument. Moreover, Cloud_cci provides L3S products, which are globally gridded monthly means derived for each sensor family (i. e. AVHRR, MODIS, AATSR) and derived from all sensors on-board all satellites used (one dataset) for each parameter and month.

Cloud_cci products	Abbreviation	Description
Cloud cover	CC	The total cloud fractional coverage for 3 vertical classes (high, mid-level, low clouds) following ISCCP classification.
Cloud phase	CP	The total cloud fractional coverage for 3 vertical classes (high, mid-level, low clouds) following ISCCP classification.
Cloud optical thickness	COT	The line integral of the absorption coefficient and the scattering coefficient along the instruments line of sight in cloud pixels.
Cloud effective radius	CER	The area weighted radius of the cloud drop and crystal particles, respectively.
Cloud top pressure/height/ temperature	CPT/CTH/CTT	The air pressure [hPa] /height [m] /temperature [K] of the uppermost cloud layer that could be identified by the retrieval system.
Cloud liquid and ice water path	LWP/IWP	This quantity is the vertical integrated liquid/ice water content of existing cloud layers.
Spectral cloud albedo	CALB	The blacksky albedo derived for channel 1 (0.67 µm) and 2 (0.87 µm), respectively.

Table 1: List of generated Cloud_cci properties. CC and CP are derived from the pre-processing step, where each satellite pixel is classified as either clear or cloudy and liquid or ice, respectively. These information are required in the main processing stage (i.e. OE), which provides COT, CER and CTP simultaneously by fitting a physically consistent cloud/atmosphere/surface model to the satellite observations from the visible to the mid-infrared. In the post processing CTH and CTT are inferred from CTP using ECMWF ERA-Interim temperature and pressure profiles. Moreover, LWP and IWP are obtained from COT and CER in cloudy pixels with the corresponding cloud phase. Last but not least, Cloud_cci provides a spectral cloud albedo for two visible channels.

Algorithm improvements and current project status

Example results

Recently, measurements in 2008 provided by:

- AVHRR/NOAA-17 & AVHRR/NOAA-18 (CC4CL),
- MODIS/AQUA (CC4CL),
- AATSR/ENVISAT (CC4CL), and
- AATSR+MERIS/ENVISAT (FAME-C)

were processed (version 1.3) in order to analyse and evaluate the newest implementations in the retrieval schemes improving the data quality.

The figures below show monthly zonal mean of total cloud cover (CC_TOTAL: Figure 3), and cloud top pressure (CTP: Figure 4), obtained from the recent processing (v1.3) in comparison with the prototype (PT) data (v1.0) generated in Phase 1 and NASA MODIS Terra collection 5 results.

It is reasonable to compare the cloud products derived from instruments on board NOAA-17, ENVISAT and TERRA platforms because they have very similar equator crossing times (see Figure 1 and 2), i.e. 10:00 am for ENVISAT and NOAA-17 and 10:30 am for TERRA.

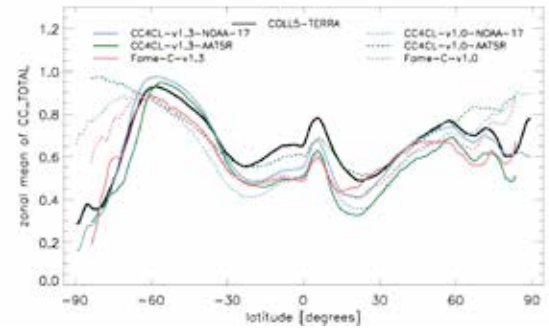

Figure 3: Comparison of monthly zonal mean of total cloud cover (CC_TOTAL) for 2008 obtained from the recent processing (v1.3, solid lines) with the prototype data (v1.0, dotted lines) generated in phase 1 and NASA MODIS Terra collection 5 data (reference data set, black line).

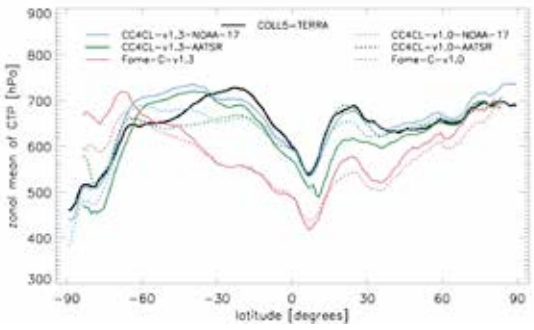

Figure 4: Comparison of monthly zonal mean of total cloud top pressure (CTP) for 2008 obtained from the recent processing (v1.3, solid lines) with the prototype data (v1.0, dotted lines) generated in phase 1 and NASA MODIS Terra collection 5 data (reference data set, black line).

Figure 3 demonstrates that CC_TOTAL-v1.3 significantly improved compared to PT-v1.0 and MODIS data, especially in the high but also mid latitudes. However, in the tropics and subtropics CC_TOTAL is still lower as compared to MODIS/TERRA. Most probably the algorithms miss very high and optical thin clouds, which might be detected by MODIS due to a good deal more of spectral information available.

In Figure 4 one can see that CTP-v1.3 from CC4CL improved overall compared to PT-v1.0 and MODIS zonal mean, mainly due to a boundary layer correction, which results in lower deep stratus cumulus clouds. CTP-v1.3 from FAME-C slightly changed compared to PT-v1.0 still retrieving too high clouds between -45 and +45 latitude. While CC4CL uses IR channels at 11 and 12 microns to retrieve CTP, FAME-C uses the oxygen A-band of MERIS (761 nm). However, the different methods cannot explain the differences. CTP from FAME-C is under investigation and will be further improved.

Figure 5 depicts CC4CL/NOAA-18 global 2D Joint Cloud Properties (JCP) histograms for water and ice clouds, respectively. They show the relative occurrence of cloud types using the combination of the retrieved COT and CTP parameters based on the well-known ISCCP cloud classification. Note that COT is obtained from the visible spectral information and thus, these 2D histograms are only available for the daytime observations. While the JCP histogram for water clouds (see left panel) looks very reasonable, it is currently investigated why there are some ice clouds occurring in the water cloud regime (see right panel).

The current status of the project can be summarized as follows. After analysing the recent results (v1.3) some issues have been detected, which need to be solved before the complete and final data set can be processed and provided to the community.

However, a longer time series was already processed (see Figure 6) for two reasons: first of all, to test and improve the stability of the processing system and secondly, to have the possibility investigating the stability and homogeneity of the final cloud products.

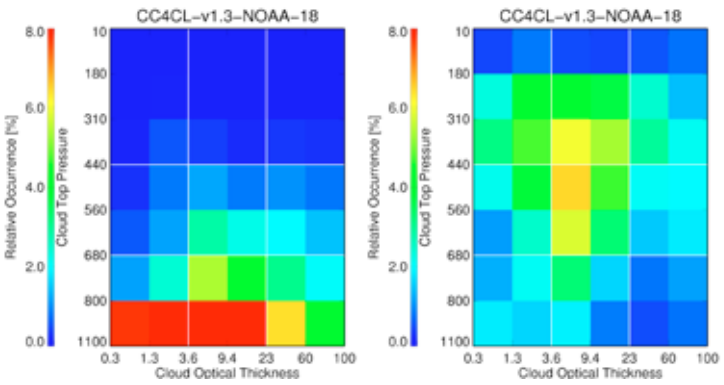

Figure 5: Joint Cloud Property Histograms for AVHRR/NOAA-18 2008 separated for water (left) and ice (right) clouds, respectively, showing the relative occurrence of the cloud types w.r.t. ISCCP COT-CTP classification. This product is only available for daytime retrievals because COT is derived from visible spectral information.

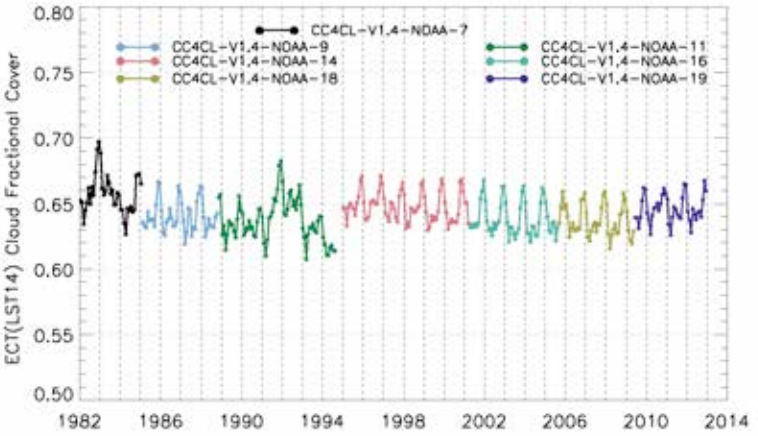

Figure 6: Time series of AVHRR GAC fractional cloud cover (CFC) from 1982 until 2013 using afternoon satellites. The solid lines are latitude-weighted global monthly mean values. Since the orbits of NOAA platforms drift over time (see Figure 2), the global mean has been corrected for the systematic change of illumination conditions and local time of observation (14:00 local time).

Benefit for the user community - Added value of ESA Cloud_cci products

- ◊ **Spectral consistency** of derived parameters, which is achieved by an optimal-estimation approach based on fitting a physically consistent cloud model to satellite observations simultaneously from the visible to the mid-infrared.
- ◊ **Uncertainty characterization**, which will be inferred by the application of the optimal estimation approach as physically consistent single pixel uncertainty estimation and propagated to the final level 3 products.
- ◊ **Increased temporal resolution** by including multiple polar-orbiting satellite instruments, which also allows for mature cloud property histograms on 0.5° resolution due to high increased sampling rate.
- ◊ **Comprehensive assessment and documentation** of the retrieval schemes and the derived cloud property datasets including the exploitation of applicability for evaluation of climate models and reanalyses.

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