Eumetsat fellowship report

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1. The CLOUDSTATE fellowship

The aim of the CLOUDSTATE fellowship is to determine the strengths and weaknesses of the state-of-art cloud retrieval algorithms from passive imagers (SEVIRI, AVHRR and MODIS). The retrieval quality of cloud optical, micro- and macro physical properties is evaluated against independent cloud sensors (CPR, CALIOP, POLDER, MISR, and AMSR-E). Therefor a cloud retrieval data base was created, where sixteen scientific institutes from Europe and the USA contributed data among others the EUMETSAT central facilities, the Nowcasting SAF and the Climate Monitoring SAF. Validation results will help to understand the potentials and limitations of the cloud retrievals with passive imagers. Comparing directly several retrieval methods with independent validation datasets allows quantifying the accuracy of the retrieval products. Hence this study will improve our understanding on how to optimally use cloud products in the areas of Nowcasting, evaluation of Numerical Weather Prediction (NWP) and climate models, and climate monitoring.
The CLOUDSTATE fellowship is strongly connected to the *Cloud Retrieval Evaluation Workshops* (CREWs) that provide a forum for international satellite-based cloud retrieval teams to share their experience with nowadays cloud parameter retrievals from passive imaging satellite observations. Initially the collaboration was established at the EUMETSAT funded Cloud Workshops held in Norrköping, Sweden in 2006 and in Locarno, Switzerland in 2009. This fellowship strongly benefits from the preparatory work of *Andrew Walther*, who created the data base for the first two CREWs and wrote the first version of the inter-comparison and validation software.
The fellowship is under the supervision of Rob Roebeling, Anke Thoss, and Jan Fokke Meirink and is located at the Royal Netherlands Meteorological Institute (KNMI), De Bilt in the Netherlands.

2. Archivements of the first year

In the beginning of the fellowship the CREW database of cloud retrievals, which was developed for the first two CREW workshops by Andrew Walther, was taken over. The CREW dataset contains the cloud property retrieval of several research institutes using passive imagers as well as validation datasets from independent sensors. For the third CREW in November 2011 the CREW datasets were updated and made available for the CREW members on the FTP server of the University of Lille. Also the fellow made use of the inter-comparison and validation software of Andrew Walther, and adaped it to the computational environment of the KNMI. The software was developed further,

new functions were added and documentation was extended.
The visibility of the CREW project was increased by the installation of a project website www.icare.univ-lille1.fr/crew. The website descipes the intention and goals of the CREW project, the datasets and scientific methods, and the participating institutes. It also gives a short summary of the CREW meetings, and provides reports, programs, and the participant lists of these meetings.
In 2011 the fellow contributed to the preparation and organization of the 3rd CREW in Madison, Wisconsin, USA, in November 2011, including preparation of the program, selection of chairmen and keynote speakers, and communication with the participants.
As the cloud branch of the ESA Climate Change Initiative pursues similar goals as the CLOUDSTATE fellowship, the fellow attended some of the progress meeting presenting the idea of CREW, advertising the CREW meeting, and recommending the cooperation. The ESA CCI project added one day to their retrieval dataset, which is in common with the CREW dataset. In this way all retrieval algorithms of the ESA CCI project may also be used for the purposes of CREW.

3. Datasets and Methods

The success of CREW can be largely attributed to the inter-comparison strategy of the algorithms. The idea is not only to present the retrievals of the algorithms in individual presentations, but also to have an independent and objective inter-comparison of the algorithm retrievals. To this end all participants provided cloud properties retrievals of their algorithms for five golden days, which were fed into a common database. The cloud parameters of interest are listed in Table 1. The parameters include the cloud mask, the cloud top properties (cloud top temperature, height, pressure, and phase), the optical properties (optical thickness and effective radius), and the macrophysical properties (cloud water path and cloud ice path).

Table 1: List of cloud parameters that are investigated in the CLOUDSTATE fellowship.

Acronym	Property	Units
CMB	Cloud Mask	[%]
CTH	Cloud Top Height	[m]
CTP	Cloud Top Pressure	[hPa]
CTT	Cloud Top Temperature	[K]
CPH	Cloud Phase	[water, ice, mixed]
COD	Cloud Optical Depth	[-]
REF	Particle Effective Radius	[µm]
LWP	Liquid Water Path	[gm^{-2}]
IWP	Ice Water Path	[gm^{-2}]
CTY	Cloud Type	[-]

The CREW focuses on the inter-comparison of passive imagers cloud parameter retrievals, including retrievals from SEVIRI, MODIS, and AVHRR. For validation purposes the data from indipendent sensors like CPR, CALIPSO, and AMSR-E are also included in the common data base. Table 2 lists the organisations that provided passive imager retrievals and reference data for the common database, together with information on the used satellite sensors. We have selected five Golden Days that are listed in table 3. These days were picked based on a good alignment between A-Train sensors on one hand and NOAA-18 overpass on the other hand. During several hours of the selected Golden Days the A-Train satellites are aligned with AVHRR on-board NOAA-18. Our evaluation study will focus on these hours. However, some data providers uploaded their datasets of the five Golden Days for the full 24 hrs.

Table 2: List of organisations that participate in the CREW intercomparison.

Passive Imager Retrievals			
Institute / Group	**Acronym**	**Sensor**	**Contact Persons**
CM-SAF	CMS, KMR	SEVIRI, AVHRR, MODIS	Stengel, Lockhoff, Meirink
DLR	DLR	SEVIRI	Bugliaro, Kox, Gesell
Eumetsat	EUL, EUJ, OCA	SEVIRI	Lutz, Joro, Watts
Free Unverity Berlin	FUB	SEVIRI	Preusker
NASA Goddard	GSF	SEVIRI, MODIS	Platnick, Wind
NASA Langley	LAR	SEVIRI, MODIS	Minnis
NWC-SAF	MFR, SMH	SEVIRI, AVHRR, MODIS	Le Gleau, Dybroe, Thoss
R.Met. Inst. Belgium.	RMB	SEVIRI	Ipe, Dewitte
University of Madison	AWG	SEVIRI	Walther, Heidinger
University of Lille 1	ULI	POLDER/MODIS	Riedi
UK MetOffice	UKM	SEVIRI	Francis, Taylor
Reverence Datasets			
Institute / Group	**Acronym**	**Sensor**	**Contact Persons**
CALIPSO group	CAL	CALIOP	Winker
Cloudsat group	CPR	Cloud Profiling Radar	Stephens
MISR group	MSR	MISR	Horvath
Unversity of Madison	AMS	AMSR-E	Bennartz
CNRS	CNR	AIRS	Stubenrauch, Kahn
CNRS	DAR	CALIOP/CPR	Delanoë, Hogan
University of Madison	HRS	HIRS	Menzel, Olson
NASA JPL	JPL	AIRS	Palikonda, Minnis, Chang
University of Bremen	UBR	SCIAMACHY	Kokhanovsky

Table 3: List of days of the retrieval intercomparison.

Day	Month	Year	Hours with alignment between A-Train and NOAA-18
13	June	2008	12:00-15:30
17	June	2008	22:15-24:00
18	June	2008	00:00-01:45
22	June	2008	10:30-12:15
03	July	2008	10:00-12:00

4. Intercomparsion results

3.1 Cloud mask

Twelve groups provided cloud mask data for the SEVIRI disk. The data was transformed into a binary cloud mask with values 0 for no observation or space, 1 for cloud and 2 for cloudfree. Figure 1 shows cloud masks of the 12 groups for the noon scene of 13th of June 2008. Cloudy pixels are indicated as bright areas, cloud-free areas are blue for ocean and green for land surfaces. The OCA algorithm does not retrieve an own product, but applies the cloud mask obtained by the MPEF algorithm. All algorithms catch the same distribution of cloud on the MSG disk with most cloud in the tropics and in the west wind regions. There is a distinct difference in the total cloud amount for this scene ranging from 41 percent (FUB) to 61 percent (MFR). Most of the retrievals use different thresholds for the detection of clouds. Depending on the complexity of the methods, thresholds are adjusted for illumination, surface, and viewing conditions as well as for trace gases. There are probably differences due to the treatment of partly cloudy pixels depending on the intended use of the product. As an example, the use of the cloud mask in order to reject pixels for the retrieval of ocean parameters requires stricter cloud mask than a general climate estimate of cloud cover. But selective cloud detection influences the statistics of the global clouds making it difficult to compare cloud data set, to merge them, or to use them for the validation of climate models.

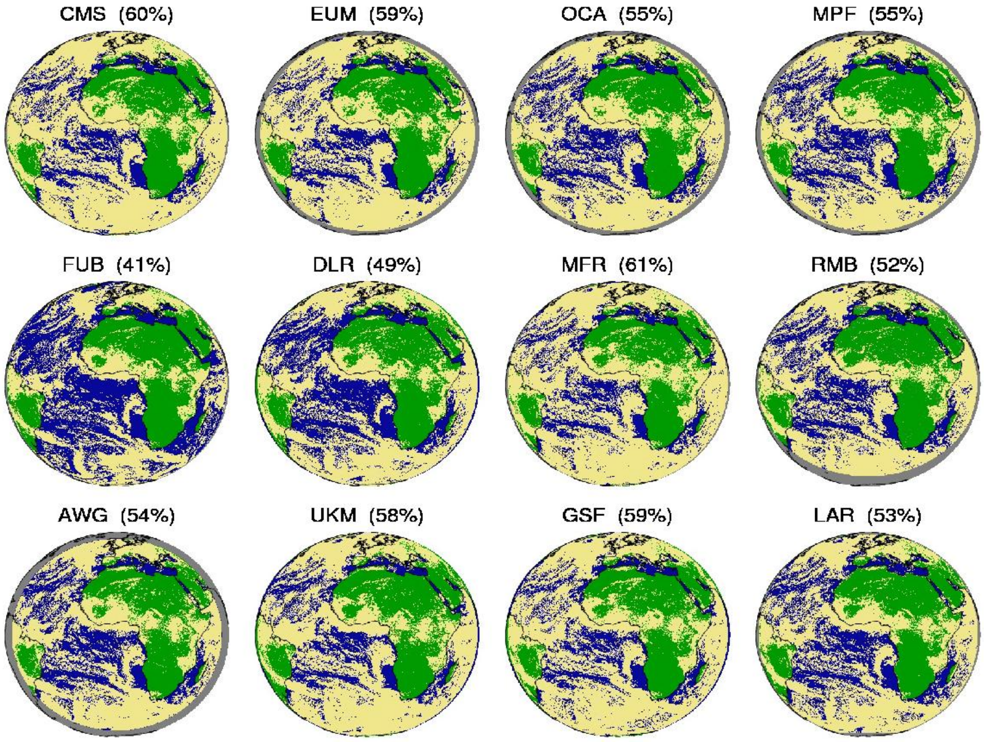

Figure 1: Cloud masks of the 12 CREW algorithms for 13-06-2008 at 12:00UTC.

Figure 2 shows the ‘number of disagreements’, i.e. the number of algorithms for which the cloud mask differs from the majority of algorithms. As 12 data sets were submitted, the maximum number of disagreements is 6. Areas with a high number of disagreements need to be further investigated.
The area marked with a black square is in the vicinity of the ITCZ over Africa. The algorithms detecting clouds in this region derive a thin optical thickness and low cloud top temperatures. So we conclude, that the disagreement of cloud detection in this area is probably caused by the difficult detection of thin and semitransparent cirrus clouds. Especially for semitransparent clouds the knowledge of the surface reflaction properties is essential. As the algorihms use different auxiliary data to discribe the surface, disagreements are expected.
A second area of disagreements - the southern part of the Arabian peninsula and the adjacend sea - is marked with a blue ellipse. The cloud mask of the EUM, MPF, RMB, UWM, and LAR algorithm shows clouds over the Arabian Sea and the Golf of Aden. The EUM, MPF, and UWM also detect clouds over the south-eastern part of Arabia over land. MODIS aerosol retrievals show a higher optical depth over this region at this day. A storm blows dust from the Arabian peninsula over the adjacent sea. The disagreements in the cloud mask is therefor probably caused by the different distinction of cloud and aerosols. It is worth to remark that the area over the Arabian sea where clouds are detected by some algorithms is clearly bounded by the coast. It is possible to argue, that dust are not detected over land, as it is very hard to distinguish from the land surface, whereas over sea the contrast between dust and ocean surface is much better. However the detection of cloud over bright desert surfaces is more difficult, too. The MFR algorithm has a specific test for the distinction of clouds and aerosols. The resulting aerosol flag shows a heavy aerosol load over this area, too.
A third area in the west of Angola is marked by a red rectangle. The aera of higher disagreements surrunds a marine stratucumulus. As the optical thickness of the marine stratucumulus is usually high enough for a reliable cloud detection, a reason for this disagreement is likely the different interpretation of partly cloudy pixels by the different algorithms.

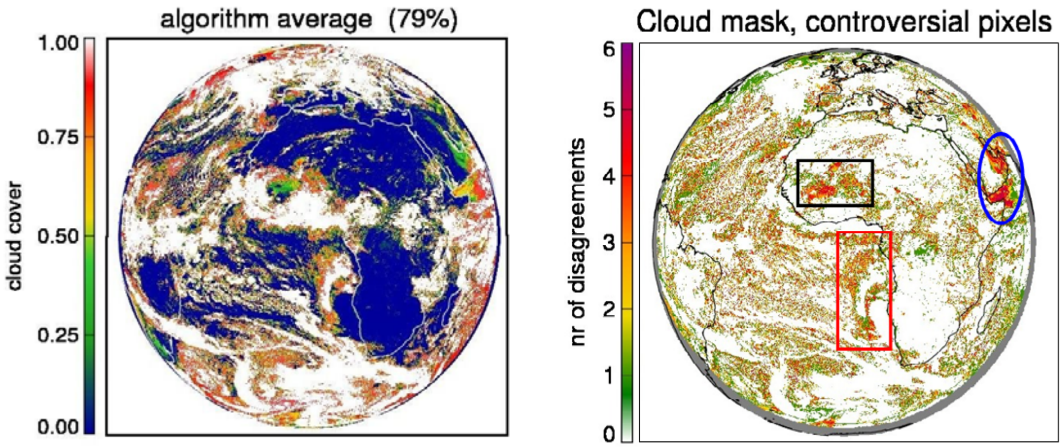

Figure 2: The left figure shows the multi algorithm average of all cloud masks for 13-06-2008 at 12:00UTC. The right figure shows the number of disagreements of the cloud detection. With 12 algorithms participating the inter-comparison, the maximum number of disagreements is 6. The marked areas show specific problems of cloud detection like thin cirrus clouds over land (Sahara), misclassification of dust as cloud (Arabian peninsula), and different classification of partly covered cloud pixels (Southern Atlantic).

3.2 Cloud top temperature

Using the brightness temperatures of the SEVIRI channels, the cloud top temperature is derived by nine of the participating algorithms, shown in figure 3. All results show that the coldest clouds occur over the ITCZ, warmer cloud tops are detected in the trade wind regions and again colder cloud tops occur in frontal systems in the west wind zone.

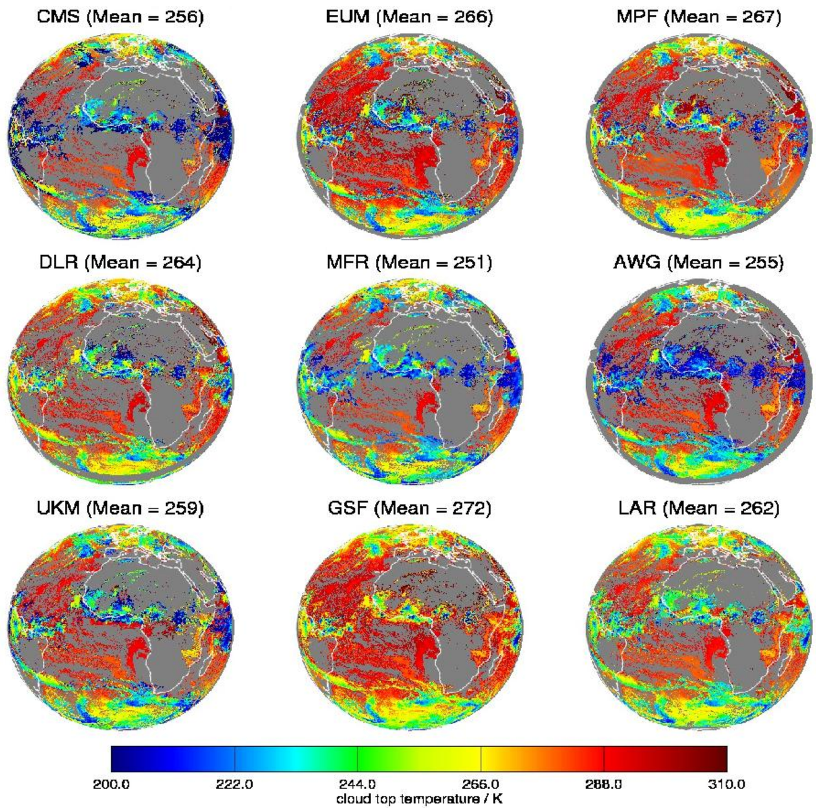

Figure 3: The retrieved cloud top temperature of 9 algorithms for 13-06-2008 12 UTC.

In figure 4 the standard deviation of the multi algorithm ensemble is shown. The right hand side shows the latitudinal average. The GSF algorithm detects cloud top temperature warmer than the multi algorithm average, while the CMS and AWG algorithms derive colder cloud top temperature.

The standard deviation is highest in the tropics. The coldest latitudial average detected by the GSF algorithm is 262K, while CMS detects an latitudial average of cloud top temperatures as low as 220K. One of the most important reasons for the differences is the ability to catch high thin cirrus clouds above other clouds as well as over land and sea. Similarly the standard deviation is high for frontal zones in the west wind region. Here the layered structure of the cloud systems complicates the retrieval, too. The marine stratocumulus region west of Angola has the lowest standard deviation with about 8K. At 15º south the spread of the latidudial average ranges from 277K (AWG) to 284K (DLR). In this region the approximations of horizontal homogeneity are well fullfilled, the vertical extent of the marine stratocumulus is low, and the optical depth is sufficiently high for a precise detection of the cloud top.

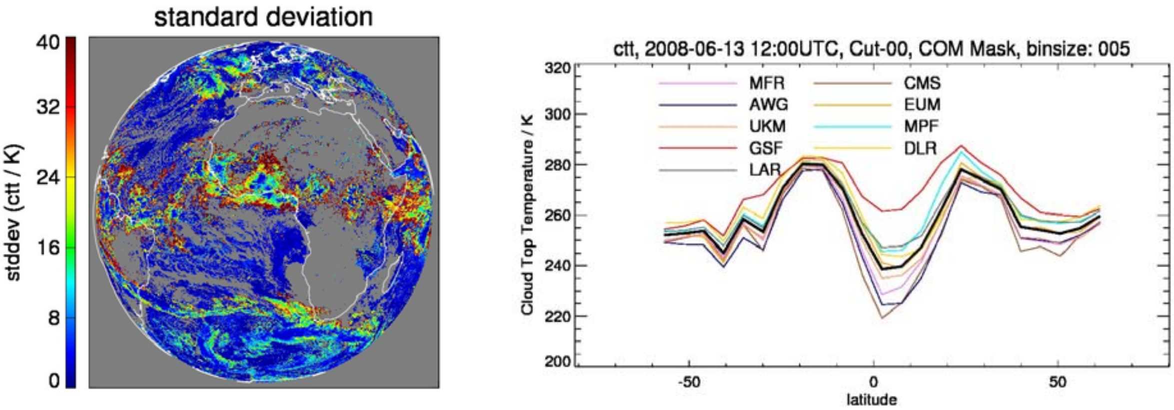

Figure 4: The left hand side shows the multi algorithm standard deviation of the retrieved cloud top temperatures, the right hand side the latitudial average, both for 13-06-2008 12 UTC. The thick black line shows the multi algorithm average.

3.3 Cloud phase

The determination of the cloud phase is an important step in every cloud retrieval algorithm. As cloud ice crystals and water droplets have different spectral characteristics and their phase functions deviate drastically, the retrieval of the cloud optical depth and the effective radius depends cruitially on the cloud phase. The retrieved cloud phases of the participating algorithms are shown in figure 5.

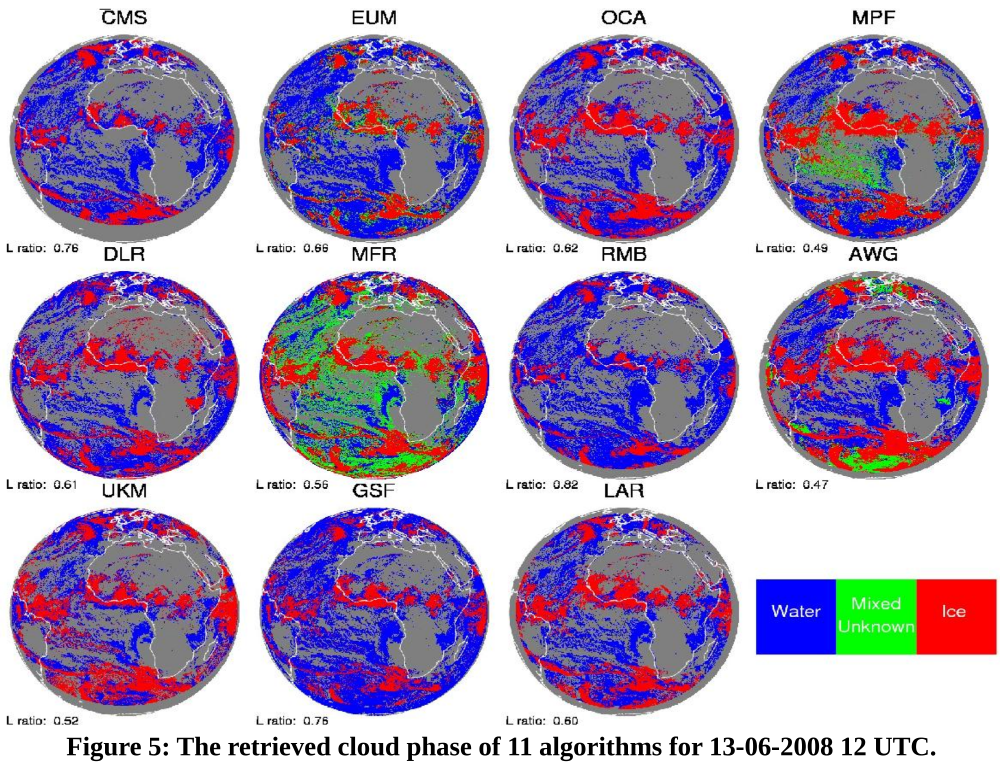

Figure 5: The retrieved cloud phase of 11 algorithms for 13-06-2008 12 UTC.

The general structure is as follows: The cloud tops over the ITCZ consists in most cases of ice. Having a look at the latitudinal average of the individual algorithms in figure 6, the average ice cover of the cloudy pixels in the ITCZ varies drastically from 30% (RMB) to 85% (MPF, MFR, AWG). Probably not all algorithms catch the spreading cirrus anvils having small optical depths. In the trade wind regions most of the cloud are classified as water clouds. Exceptions are the MPF algorithm, that identifies the cloud in the trade wind region of the southern Atlantic as mixed phase, and the MFR algorithm, that identifies the borders of many clouds as mixed. Thus the latitudinal average of MPF and MFR is higher 15-20% higher than the multi algorithm average in those regions. In the west wind regions ice clouds are detected within the frontal systems. Also here the RMB algorithm tend so detect more water cloud than the multi algorithm average, while for the AWG algorithm the ice coverage tend to show larger values than the average, especially for high latitudes.

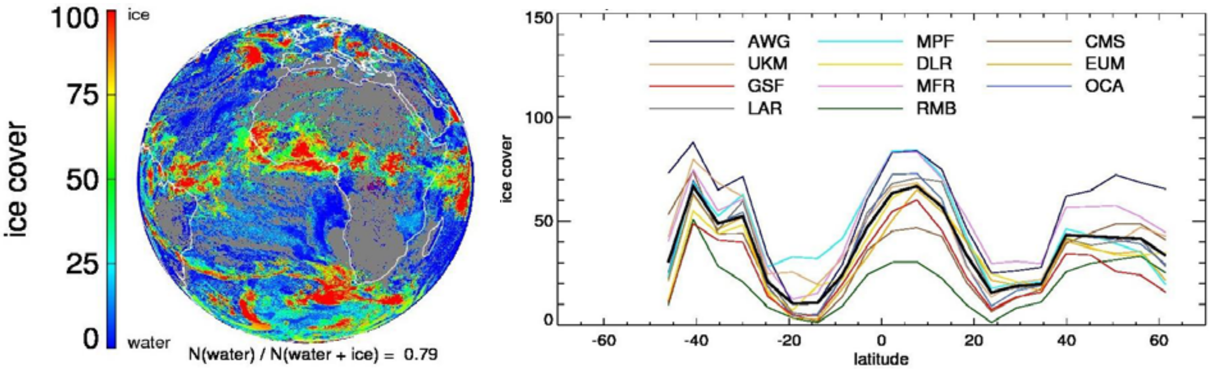

Figure 6: The left hand side shows the multi algorithm average of the cloud phase (water=0, unknown=50, ice=100). Light blue, green and yellow colors mark the areas were the multi algorithm ensemble can not certainly determine one cloud phase. The right hand side shows the zonal average for the individual algorithms, only pixels were every algorithm detected a cloud is taken into account (common cloud mask), both figures for for 13-06-2008 12 UTC.

3.4 Cloud optical depth

Using the Nakajima-King-approach (Nakajima, 1990) or the optimal estimation method, the optical depth and the effective radius are mainly derived from measured visible and near-infrared reflectances. Some algorithms derive use one visible and one infrared channel in an iteration approach (CMS, DLR, RMB, UKM, GSF, and LAR) while others feed all passive imager channels to an optimal estimation method (OCA, and AWG). The results of the single algorithms show similar pattern on the SEVIRI disk, see figure 7. The centers of the deep convective system over Ghana and the Ivory coast are located in the same area for all algorithms. The optical depth of the clouds in the trade wind region agrees well. Larger differences occur for the frontal systems in the west wind region in the northern and southern Atlantic.

The left side of figure 8 shows the multi algorithm average of the optical depth of the same scene. The mean of each pixel is calculated from all algorithms having a sucessful retrieval of the optical depth for this pixel. Algorithms detecting no clouds and algorithms with no convergence of the optical depth retrieval are not included in the mean. The right hand side shows the relative standard deviation of the multi algorithm ensemble. The lowest standard deviations equal or less than 20 are found in the maritime stratocumulus region in the west of Angola and in the west of Morocco. Higher standard deviations up to 50 occur at the border of the disk, clearly suggesting a strong sensitivity of optical depth retrievals to viewing geometry (Roebeling, 2006; Kato 2009). Furthermore a high standard deviations (up to 50) are observed at the edges of meso scale convective systems in the ITCZ, where the anvil of the tropical deep convection spreads out. The signal of these clouds with low optical thickness is mixed with the signiture of the surface. Therefore the retrieval of the cloud optical properties is challenging.

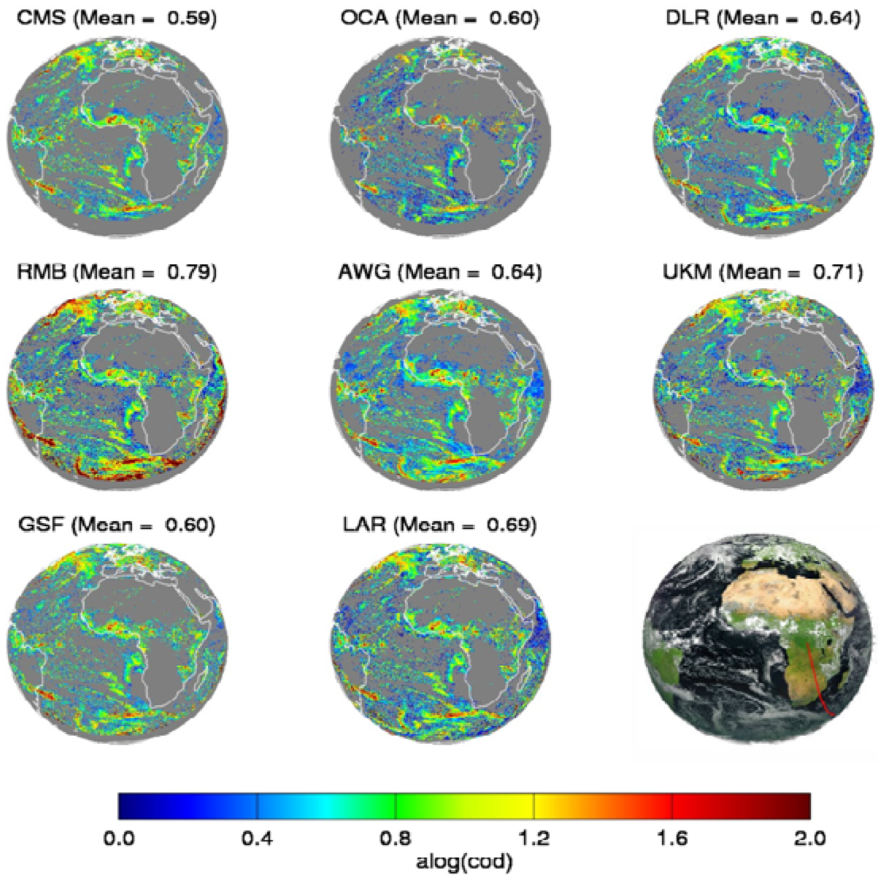

Figure 7: Cloud optical depth of 8 retrieval algorithms for 13-06-2008 12 UTC. The lower right diagram shows a pseudo color composite with the path of the A-train satellite constellation.

In the right site of figure 8 we investigate the dependency of cloud optical depth on the viewing zenith angle for ice and water clouds seperately. For ice clouds the optical depth retrievals of most algorithms are similar independently of the viewing zenith angle. Only the RMB algorithm shows an increase of the cloud optical depth with the viewing zenith angle, and the OCA algorithm retrieves smaller cloud optical depths than the majority of the algorithms. As the OCA algorithm has an advanced scheme for detecting multi layer cloud systems, the differences of the OCA algorithm and the average might be due to the fact, that the optical depth of an underlying water cloud is not added to the total optical depth, as it is done in all the other algorithms.

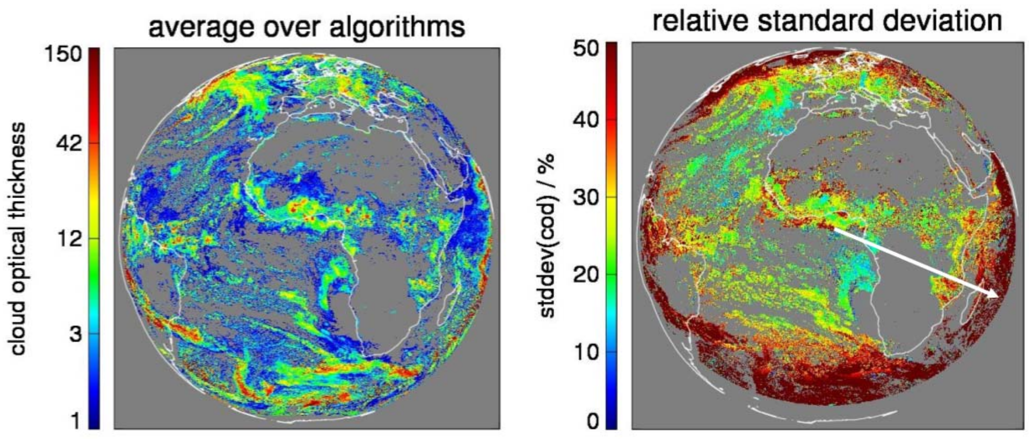

Figure 8: On the left hand side the multi algorithm average for the cloud optical depth is shown. On the right hand side the relative standard deviation of the multi algorithm ensemble for the cloud optical depth in shown. Both figures show the results for 13-06-2008 12 UTC.

The retrieval results for the optical depth of water clouds agree well for low viewing zenith angles, see figure 9. However, for a viewing zenith angle larger than 40º the results start to diverge. The RMB and UKM algorithms retrieve an optical depth higher than agerage, while AWG and CMS are lower than average. The reason for increasing differences in retrieved optical depth values of water cloud at zenith angles larger than 40º might be, that the retrieval for water clouds is stronger influenced by three dimensional effects than for ice clouds. This seems to be plausible, as mostly water clouds form more pronounced cloud top structures than ice clouds (Loeb, 1998; Varnai, 2007).

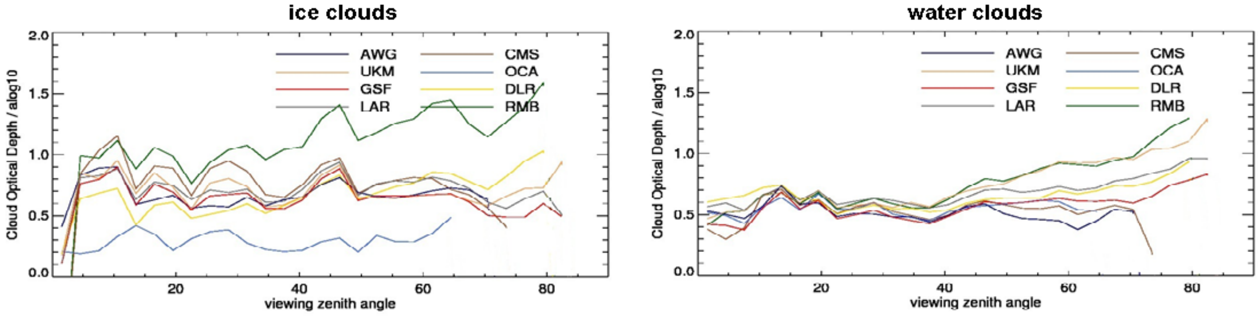

Figure 9: The left diagram shows the cloud opticical depth of ice clouds in dependence of the viewing zenith angle for 13-06-2008, 12 UTC. The right diagram shows the same, but for water clouds.

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3.5 Exemplary inter-comparison of two algorithms

Figure 10 shows the cross scatter plot of the cloud optical depth for the AWG and the CMS algorithm. The compared retrieval results split up into to clusters. One cluster agrees well along the one-to-one line. The other one is a factor of $10^{0.2} = 1.6$ above the one-to-one line. Both clusters look S-shaped in this diagram, meaning that for small optical depths the AWG algorithm tends to retrieve large optical depths than the CMS algorithm, and for large optical depths the other way around. Possibly this S-shape is caused by differences in the re-calibration of the satellite observations (Govaerts 2004; Jiang 2009, Minnis 2002a; Minnis 2002b).

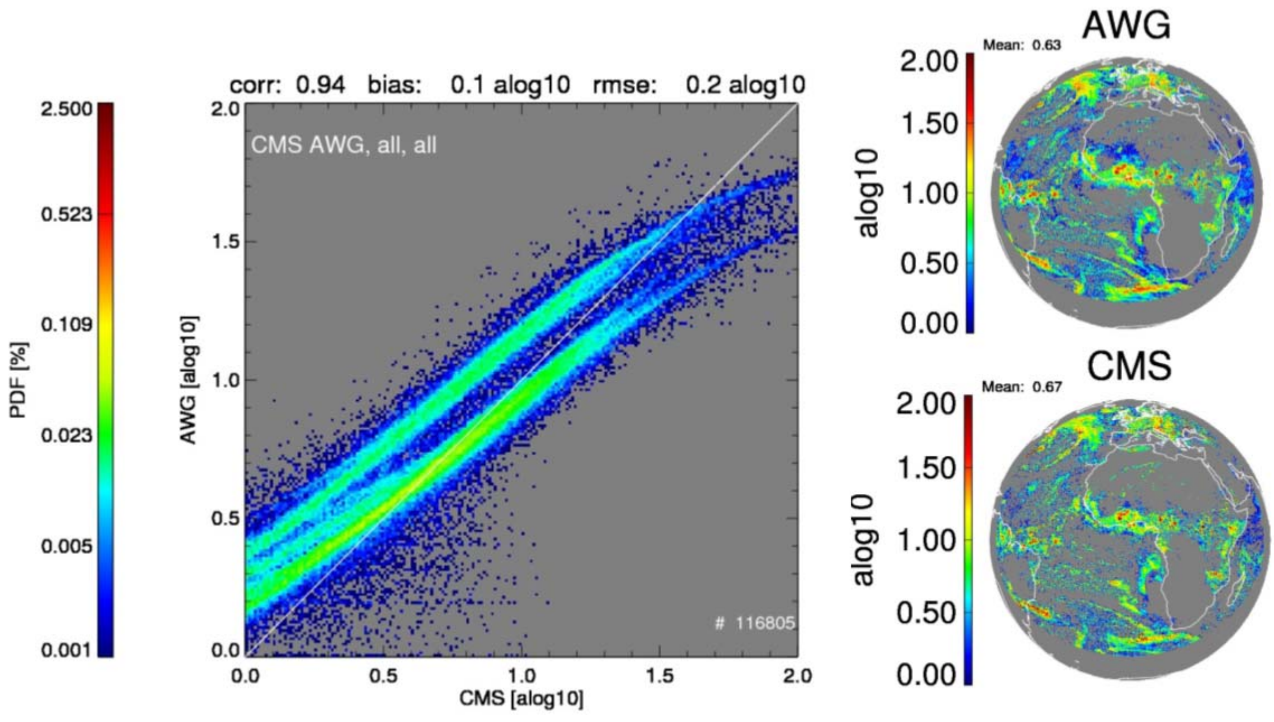


Figure 10: On the left hand side the cross scatter diagram for the cloud optical depth of the CMS and AWG algorithm is shown for 13-06-2008, 12 UTC. The cloud optical depth is on a logarithmic scale. The two diagrams on the right hand side show the results of the individual retrievals.

Figure 11 shows the same analysis as in the last figure, but for ice and water clouds seperately. The clusters fall clearly apart. This analysis reveals that retrieval algorithms for the optical depth of ice clouds differ around the factor of 1.6, while the optical depths of the water clouds agree well.

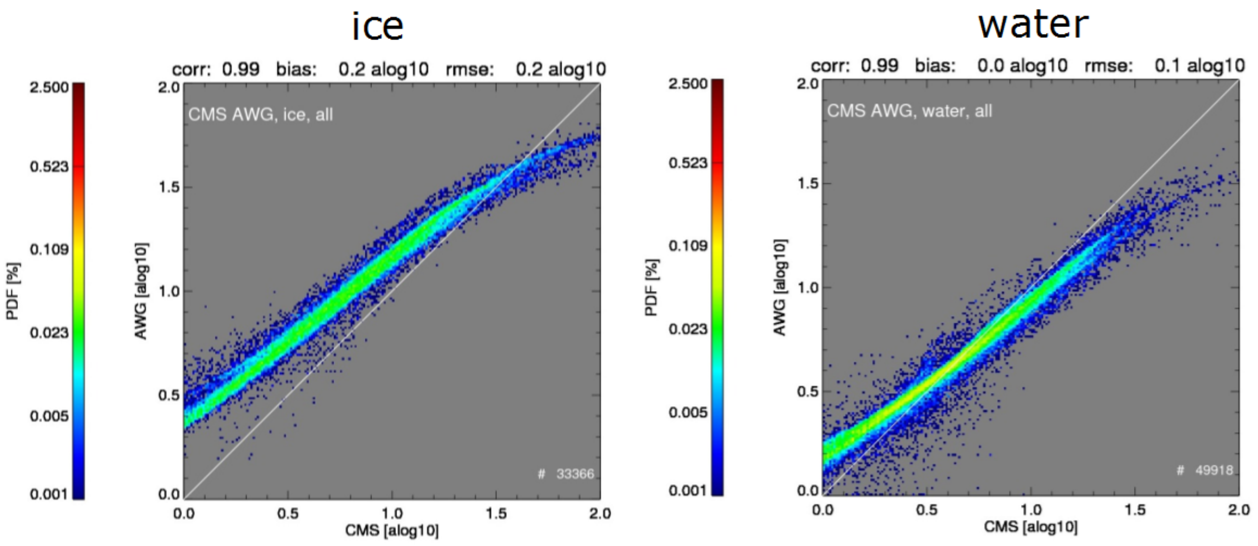


Figure 11: The same as figure 9, but differentiated between ice and water clouds.

5. The 3rd CREW workshop in November 2011

The CREW workshops are organised regularly in order to discuss to progress of cloud remote sensing and the newest results of the CREW inter-comparison. From 15 -18 November 2011 the 3rd Cloud Retrieval Evaluation Workshop (CREW-3) took place in Madison, Wisconsin, USA.

Figure 12: The skyline of Madison/Wisconsin, the city of the hosting university of the 3rd Cloud Retrieval evaluation workshop.

Figure 13 illustrates the rapidly growing number of participants of the CREW meeting. In 2006, the first workshop held in Norrköping, Sweden, had about 19 participants. The second workshop in 2009 located in Locarno, Switzerland had about 42 participants. Finally 71 scientist participated the CREW 3 workshop. The goal to include more American scientist into the CREW activities was well fullfilled. The number of US american scientist rose from three in 2009 to 36 scientist. They came from the University of Madison-Wisconsin, NASA Langley research center, Nasa Space Goddard flight center, University of California, the Taxas A&M University, and the University of Maryland.

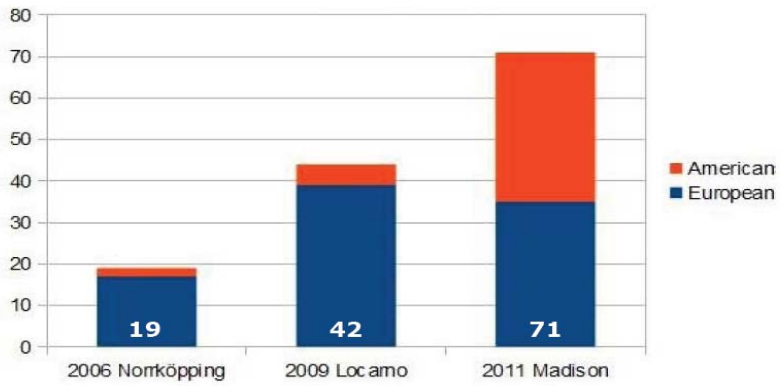


Figure 13: The number of participating scientist of the CREW workshops in 2006, 2009, and 2011. The fraction of American scientist is shown in orange.

The CREW-3 workshop lasted for 4 days. The program covered all steps involved in making cloud properties retrievals from the uncalibrated observations (Level 0) to climatological means (Level 3 data). In the session on *Instrument Calibration*, the need for calibration of satellite radiances and the possible techniques were discussed. The importance of a detailed charaterisation of the sensor before lanch and the montitoring of the temporal changes of the sensitivity were emphasized. The latter may be achived by observation of stable long term targets such as deep convective clouds, deserts, and glaciers. Other studies use water clouds, sun glint, or the moon as targets, too. In order to transfer the calibration advantages from one satellite to another the ray-matching technique is used.

The second session *Cloud Reference Observations* included several presentations on the capabilities for the observation of cloud parameters of recent active satellite instruments, such as CLOUDSAT, CALIPSO, and the passive microwave instrument AMSR as well as for the the MISR intrument. Comparison of passivly and activly observed cloud properties is increasingly important in the framework of CREW. Especially merged products of CALIPSO and CLOUDSAT - like the GEOPROF and the DARDAR datasets - combine the high sensitivity to thin optical depth from CALIPSO and the large penetration depth of CLOUDSAT and are therefor an important source of information for the validation of passive imager retrievals. AMSR was identified to be the most reliable validation dataset for the water content of clouds. Attention has to be given to the effect of precipitation on the microwave signal and to a slight bias for small water pathes. MISR is another valuable data set for validation. The MISR retrieval uses the parallax of clouds observed from three angles to derive the cloud top height.

In the sessions on *Cloud Detection* it was noted that the diverging detection efficiency of thin cirrus clouds and broken clouds causes differences of the derived cloud masks. For thin clouds the detection efficiency rises with larger viewing zenith angle, and an accurate knowledge of the surface BRDF is required for both cases. The benefit of the high resolution visible channel of SEVIRI for the detection of broken clouds and cloud edges was emphasised. Several groups suggested or already derive a propability of cloud presense instead of a binary cloud mask. In that way the cloud mask can be customized to specific applications.

In the sessions *Cloud Properties Retrievals* and *Inter-comparison and Validation* the physical fundamentals of cloud remote sensing were reviewed. Many updates of retrieval data sets using SEVIRI, MODIS, AIRS, or other sensors including many impressive improvements were presented. In these sessions as well as in the workshops the importance of multi layer cloud detections was reported, as the measured radiance from multi layer systems can severely influence the cloud height and cloud optical property retrievals. Several ways for the detection of multi layer systems were suggested, where all strategies make use of the CO_2 and water vapour channels. The ambiguity of cloud height determination for inversions was discussed. Some groups reported that the surface inversions are inadequatly captured by weater models. The usage of a temperature profile based on satellite data instead of modeled temperatures near the surface lead to an improved cloud height retrieval. The cloud phase detection was improved for several algorithms, too. The different absorption of water and ice in the shortwave and infrared as well as the polarized reflection features of spherical and non-sperical particles were used fot this purpose. Furthermore it was reported that the effects of the three dimensional radiative transfer and the assumptions for the ice crystal shape have an important influence on the retrieved optical properties.

Finally, in the session on *Generation of Climate Datasets* presentations were given on conditions and requirements that need to be satisfied for the generation of climatological cloud parameter data records for climate monitoring and climate model evaluation studies. In order to improve the comparability, the model state needs to be reduced to the observable quantities being done by means of observation simulators within the climate models. Level 2 retrieval uncertainties must be well understood and a comprehensive uncertainty propagation from level 2 to level 3 needs to be conducted. The climate community is very interested in possible biases of cloud parameters that can not be catched by uncertainties based on cost functions or standard deviations. Lastly a good consistency of cloud data sets from different sensors, a high absolute accuracy, an accurate reprentation of the climate variability as well as a easy data format and accessability was reported to be desirable for the climate community.

Beside the sessions three parallel breakout sessions were part of the workshop. In this framework a free discussion of cloud retrieval principles and the validation of cloud parameters was encouraged. The topics of these sessions were i) *Cloud Vertical Placement* ii) *Cloud Physical Properties*, and iii) *Generation of Climate Datasets*.

The first Working Group suggested complementing the cloud height and temperature retrievals with information on the cloud type i.e.: opaque, semi-transparent, or multiple-layer clouds. In addition, this group strongly supported the recent developments towards better detecting multiple-layer clouds in an atmospheric column. The Working Group on *Cloud Physical Properties* discussed in detail the differences between cloud property retrievals from infrared (IR) observations, and the microphysical properties of ice cloud models that should be used to retrieve ice cloud parameters from visible (VIS) and shortwave infrared (SWIR) observations. They concluded that IR-only cloud optical thickness retrievals appear to have better skill than VIS/SWIR techniques for clouds with optical thicknesses smaller than 3. Based on comparisons between retrievals of optical thickness using active sensors (CALIOP/CPR), VIS/SWIR, polarized measurements from PARASOL, and IR-only, the retrievals for ice cloud seem to match best with nature when roughened particles are assumed. Finally, the Working Group on *Generation of Climate Datasets* discussed ways forward to accommodate a common approach for generating global gridded (Level 3) cloud climatologies with respect to methods used for spatial sampling and methods for calculating uncertainty information. Moreover, the need was stressed for uniformity among the cloud parameter datasets.

Error! Reference source not found. summarises the most important challenges for the cloud retrieval from passive sensors identified during the CREW-3 meeting.

Table 4: Main challenges for cloud remote sensing from passive images identified during the CREW-3 meeting.

· Calibration of satellite measurements
· Comparability of cloud masks
· Distinguish clouds and aerosols
· Detection of and retrieval for thin and semitransparent clouds
· Cloud phase determination (mixed phase)
· Cloud top structure and 3D effects (viewing geometry)
· Multi layer systems, broken clouds
· Realistic ice crystal shapes and mixture
· Cloud retrieval over snow and ice
· Consistency of day, night and twilight
· Cloud top height of low clouds within inversions
· Cloud water path retrieval (assumptions for profiles)
· Uncertainty propagation

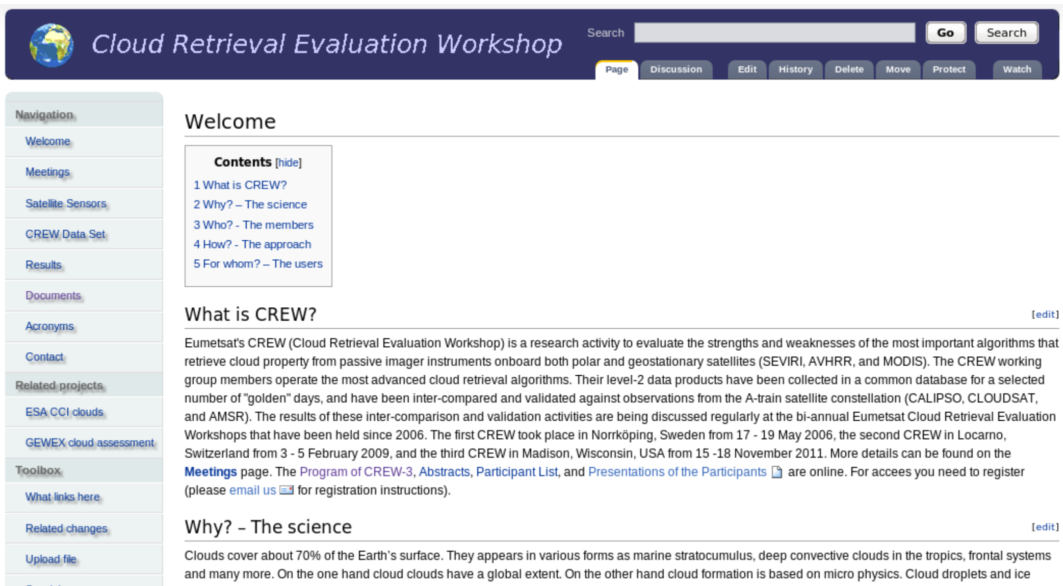
6. Future plans

The participants of CREW made suggestions for further research to be performed in the framwork of the the CLOUDSTATE fellowship. In the next year a paper about the inter-comparison of the cloud detection and cloud height retrievals of the SEVIRI sensors is planed. The prepartation of another inter-comparison paper for the cloud optical properties is aspired. Both papers should be submitted to AMT. In the beginning of the third year of the fellowship the comparison of SEVIRI with polar orbiting satellites is planed. A short investigation of how Level 3 cloud products and their error characteristics are influenced by in-situ errors and uncertainties will be carried out at the end of the fellowship. If time and data availability allow, synthetic cloud reflectances and simulated satellite picture will be used to investigate the behavior of the cloud algorithms.
In 2012 the scientific results will be presented at the IRS in June in Berlin, the Eumetsat Conference in Sopot in September, and at the AGU in San Francisco in December 2012. During the conferences discussions with the scientist providing datasets for CREW are possible.
The participants of the 3rd Workshop in Madiason proposed to have a ***4th Cloud Retrieval Evaluation Workshop***. The DWD offered to realise the local organisation in Grainau, southern Germany. The Workshop will be subject to the funding situation. The first suggestion was to realise the CREW-4 in mid 2013, in order to allow the Eumetsat fellow to update the CREW database before the workshop, present comparison results during and sum up the workshop result until the end of the fellowship in December 2013. Suggestions were made to shift CREW-4 to the end of 2013 or the beginning of 2014 in order to give the data providing institutes to have more time for development of their remote sensing algorithms. If CREW-4 happens at a later stage, it would be beneficial that the Eumetsat fellow may stay involved until the results of CREW-4 are summaried. Possibilities for this are not clear yet.

7. Documentation of CREW

The CREW project - including the objectives, the participating institutions, datasets and methods, reports of the meetings, presentations of the participants - is documented on the CREW project website:

http://www.icare.univ-lille1.fr/crew/



Furthermore the CREW database of 12 SEVIRI algorithms and the reference datasets are available via the CREW website or the ICARE ftp webserver:

ftp://ftpush.icare.univ-lille1.fr/crew/data

Acronyms

AMSR-E	Advanced Microwave Scanning Radiometer for EOS
AVHRR	Advanced Very High Resolution Radiometer
CALIOP	Cloud-Aerosol Lidar with Orthogonal Polarisation
CALIPSO	Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observation
CLOUDSAT	Cloud satellite mission operated by NASA
CM-SAF	Satellite Application Facility on Climate Monitoring
CPP	Cloud Physical Properties algorithm
CPR	Cloud Profiling Radar
CREW	Cloud Retrieval Evaluation Workshop
EUMETSAT	Europe's Meteorological Satellite Organisation
KNMI	Koninklijk Nederlands Meteorologisch Instituut
METEOSAT	Meteorological satellite
MSG	Meteosat Second Generation
MODIS	Moderate Resolution Imaging Spectroradiometer (NASA/Terra, Aqua)
PARASOL	Polarization and Anisotropy of Reflectances for Atmospheric Sciences Coupled with Observations from Lidar
POLDER	POLarization and Directionality of the Earth's Reflectances
SEVIRI	Spinning Enhanced Visible and Infrared Imager

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