Fellowship report for the CLOUDSTATE fellowship 2013

Ulrich Hamann
CLOUDSTATE fellowship
KNMI, De Bilt, Netherlands
Fellowship supervisors: Rob Roebeling, Anke Thoss, Jan Fokke Meirink

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). Therefore, a cloud retrieval data base was created, to which sixteen scientific institutes from Europe and the USA contributed data, among others the EUMETSAT central facilities, the Nowcasting SAF, and the Climate Monitoring SAF. Retrieval datasets of the passive imagers are inter-compared and validated, deviations among them discussed, and uncertainty estimates investigated in order to understand the potentials and limitations of the cloud retrievals with passive imagers. The findings of this fellowship should help to improve our understanding on the optimal use of cloud products in nowcasting, evaluation of numerical weather prediction and climate models and climate monitoring.

The CLOUDSTATE fellowship is strongly connected to the *Cloud Retrieval Evaluation Workshops* (CREWs) that provide an international forum for satellite-based cloud retrieval teams to share their experience with nowadays cloud parameter retrievals based on observations from passive imaging satellites. Initially the collaboration was established at the EUMETSAT funded Cloud Workshops held in Norrköping, Sweden in 2006 and in Locarno, Switzerland in 2009. Meanwhile a 3rd Cloud Workshop took place in Madison/Wisconsin, USA in 2011. The fellow was strongly involved in the organization of this Cloud Workshop. A 4th CREW is planed for March 2014 in Grainau, Germany.

2. Achievements of CLOUDSTATE fellowship

2.1 Achievements of the 1st year of the fellowship (2011)

During the first year, the fellow installed the project webpage, implemented the validation software being developed for the first two Cloud Workshops at the KNMI and extended it. The cloud detection of the SEVIRI algorithms was inter-compared and challenging situations for cloud detection were identified. Additionally the fellow was strongly involved in the preparation and organization of the 3rd Cloud Retrieval Evaluation Workshop in November 2011. The achievements of the first year of the fellowship are listed in more detail in the following:

Research
A first inter-comparison of the SEVIRI cloud detection retrievals was done. Challenging situations for cloud detection were identified: Thin cirrus, aerosol loaded atmospheres, and broken cloud fields. Comparing the cloud top temperatures, larger deviations among the algorithms were observed in the tropics and for frontal systems. An inter-comparison of the cloud phase (water or

ice) revealed that the algorithms retrieve different cloud phase for the cirrus anvils of the inter-tropical convergence zone and for frontal systems. An analysis of the cloud optical depth revealed that for some algorithms the retrieved cloud optical depth of water clouds depends on the satellite viewing angle. A two algorithm analysis (CM SAF and University of Madison/Wisconsin) for the cloud optical depth was completed. The agreement of these two algorithms is better for water clouds than for ice clouds. For more details, have a look at the CLOUDSTATE fellowship report of the first year (Hamann, 2011).

The CREW database and Vadiation Software

The CREW database was made available for CREW participants at the FTP server of the University of Lille 1. The CREW dataset contains the cloud property retrieval of 15 research institutes using passive imagers as well as validation datasets from independent sensors. For the 3rd CREW in November 2011 the retrieval datasets were updated.

The fellow installed the inter-comparison and validation software, written by Andi Walther for the first two CREWs, and adapted it to the computational environment of the KNMI. The software was developed further, new functions were added and documentation was extended, e.g. the multi algorithm ensemble average and standard deviation were introduced as analysis tools. A version control system (SVN) was created for the CREW inter-comparison and validation software.

CREW webpage

The fellow created the CREW project website www.icare.univ-lille1.fr/crew in order to increase the visibility of the CREW project. The website describes the intention and goals of the CREW project, the datasets and the participating institutes, and the inter-comparison and validation methods. It also gives an overview over the first three CREW meetings, including the workshop program and the participant lists, provides contact information of the scientific board of CREW, and gives access to reports and documents.

Papers and Reports

The first yearly fellowship report for Eumetsat was submitted (Hamann, 2011).

Contributions to CREW-3

The fellow was strongly involved in the the preparation and organisation of the 3rd CREW in Madison/Wisconsin, USA, including preparation of the program, selection of chairmen and keynote speakers, and communication with the participants. In total 71 scientists attended the 3rd CREW, 35 oral presentations including 6 keynote lectures were given, and 18 posters were presented.

Meetings and Presentations

The results of the first year of the fellowship were presented at the *3rd Cloud Retrieval Evaluation Workhop* in Madison/Wisconsin, USA, and at the *EUMETSAT Conference* in Oslo. As the cloud branch of the ESA Climate Change Initiative pursues similar goals as the CLOUDSTATE fellowship, the fellow participated the *2nd, 3rd, and 4th progress meeting of the cloud project of the ESA Climate Change Initiative*. He gave an overview of the CREW activities and arranged a common 'golden day' for retrieval inter-comparisons. Finally, the fellow presented his progress at the *EUMETSAT Fellow Day* in Darmstadt.

2.2 Achievements of the 2nd year of the fellowship (2012)

In the second year, new algorithms and products were implemented in the database and validation software of CREW. The validation of the cloud top height retrieval products was extended. The results of the CREW inter-comparison and validation were presented at several conferences. The achievements of the second year of the fellowship are listed in more detail in the following:

Research

An inter-comparison of the SEVIRI cloud top height retrievals started by Andi Walther was extended. A first case study was performed to investigate the performance of the cloud top height retrievals for multi layer, thin cirrus layer, and boundary layer situations. It was found that the approach of the OCA algorithm of retrieving the cloud top height of a possible second layer works well for the investigated case study. A new algorithm for the retrieval of the cloud top height of ice clouds, named COCS, was investigated. It was diagnosed that the cloud top height retrieved by COCS is higher then those of the other algorithms due to the different retrieval approach. Finally a first assessment of the uncertainty estimates of the retrieved cloud product was done.

The CREW database
The fellow included two new SEVIRI datasets, one by the DLR for ice clouds (COCS) and one from the University of Marburg (EIM) for water clouds into the CREW database. The datasets of the CM SAF (CMS) and from Eumetsat (OCA) were updated. The latter includes products for a possible second cloud layer and uncertainty estimates.

The CREW Vadiation Software
The binary representation of the cloud mask and cloud phase was changed to a floating point representation of cloud cover and ice (or water) coverage. In this way a statistical analysis like multi algorithm average and standard deviation were enabled for these properties. The validation software was extended in order to use the additional groups (COCS and EIM) and additional products (second cloud layer products and retrieval uncertainties of OCA). Filtering functions for the cloud phase and for earth surface types were introduced in that way, that an analysis can easily be performed e.g. for clouds over the ocean or ice clouds only.

Papers and Reports
An article was submitted to the proceedings of the International Radiaion Symposium. An article was submitted to the proceedings of the International Radiation Symposium. The second yearly fellowship report for Eumetsat was submitted (Hamann, 2012). The preparation for a publication of the cloud top height validation in Atmos. Meas. Tech. was initialized.

Meetings and Presentations
In 2012, the scientific results of the second year of the fellowship were presented at the *International Radiation Symposium* in Berlin (Germany), at the *Eumetsat Conference* in Sopot (Poland), and at the *American Geophysical Union Fall meeting* in San Francisco (USA). During the conferences, the results of the CLOUDSTATE fellowships were discussed with the international scientific community. The fellow participated a *CREW progress meeting* that was realized during the Eumetsat Conference and a *progress meeting of the ESA Climate Change Initiative cloud project* in Norrkoepping (Sweden). Finally, the fellow presented his progress at the *EUMETSAT Fellow Day* in Darmstadt (Germany).

2.3 Achievements of the 3rd year of the fellowship (2013)

In the 3rd year of the CLOUDSTATE fellowship, the fellow concentrated on publishing the results found so far. The scientific investigation on the cloud top height (CTH) inter-comparison and validation was intensified. The newest version of the AVAC-S software was applied to use additional CALIOP products for this investigation. The work resulted in a submission of a manuscript to the peer reviewed journal Atmospheric Measurement Techniques.

Research
The fellow intensified the research on the inter-comparison and validation of the cloud top height of the SEVIRI algorithms. The CREW validation software was adapted to work with a new version of the AVAC-S software that was provided in April 2013. The validation software was extended in order to handle several additional CALIOP products, namely the backscattering signals, the number of layers found and the column optical depth. The accuracy of the CTH retrievals was investigated for three cloud categories: optically thin and thick single layer clouds and multi layer clouds. Figure 1 shows the Taylor diagrams for the comparison to CALIOP (left) and CPR (right).

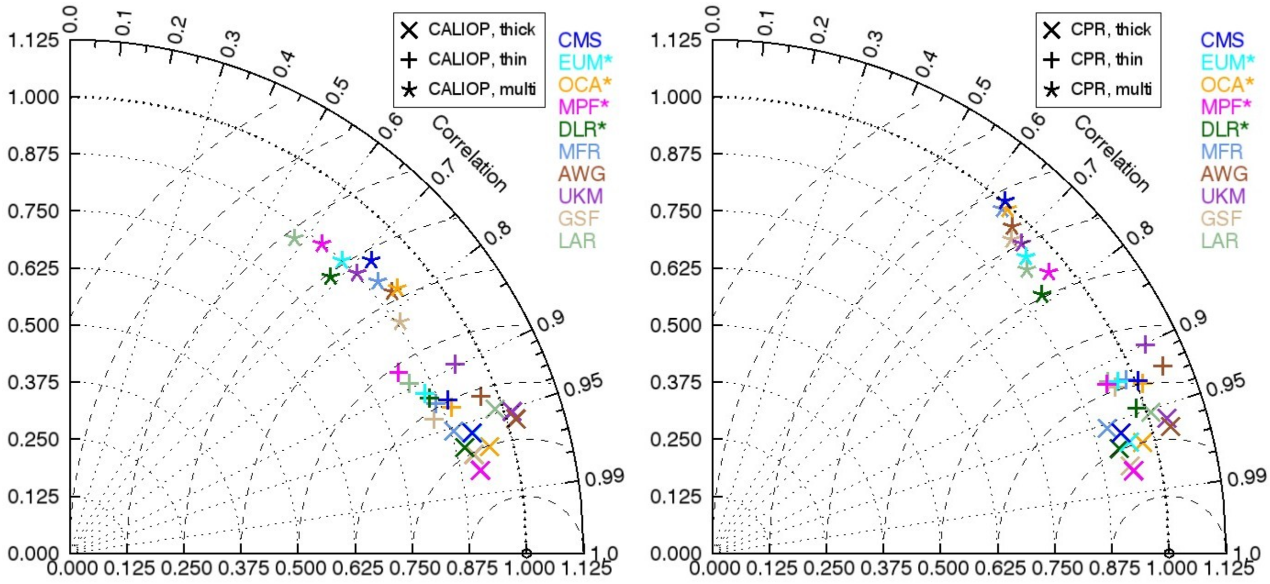


Figure 1: Taylor diagrams illustrating the comparison of the SEVIRI cloud top height retrievals with CALIOP (left) and CPR (right). The Taylor diagrams show the standard deviations of the SEVIRI retrievals divided by that of the reference sensor as radial coordinate and the cosine of the correlation coefficients of these datasets as angle. The statistics are calculated separately for optically thick (CALIOP COD > 3) and thin (CALIOP COD < 3) single layer clouds as well as for multi-layer clouds.

For optically thick single layer clouds the correlation coefficients between the SEVIRI and the reference datasets are generally above 0.95 and the biases are on the order of a few hundred meters. The uncertainty for optically thin clouds is greater than for optically thick clouds, but the correlation coefficients are larger than 0.92. For multi layer clouds they are between 0.59 and 0.83. The CTH standard deviation of the SEVIRI algorithms is smaller than those of CALIOP, as CALIOP is able to detect a larger part of the high thin cirrus clouds. The CTH standard deviation of CPR is comparable to those of the SEVIRI algorithms.

Furthermore, the strategies of CTH retrievals for low clouds were studied. It is nessesary to assume a temperature profile to convert the cloud top temperature (CTT) to CTH. Uncertainties of the temperature profile and possible ambiguities in case of temperature inversions make the CTH retrieval in the lower atmosphere challenging. In a small case study the performance of the SEVIRI retrievals was evaluated, see Figure 2. If an inversion is detected and it is reasonable that the CTT matches to a cloud at this height, CM SAF and MPEF shift the cloud top height to the height of the inversion. The algorithm of the Goddard Space Flight Center uses a temperature profile with a constant gradiant to avoid ambiguities. This issue affects many algorithms and is worth to study in more detail in future.

For more information please have a look at Hamann et at. (2013).

Common database and webpage

The dataset of the Goddard Space Flight Center (GSF) was updated for the CTH validation paper. Annoucements of the 4th CREW have been published on the CREW website.

Papers and Reports

A publication of the cloud top height validation was submitted to Atmos. Meas. Tech. and is under review at the moment. The third yearly fellowship report for Eumetsat is submitted with this document.

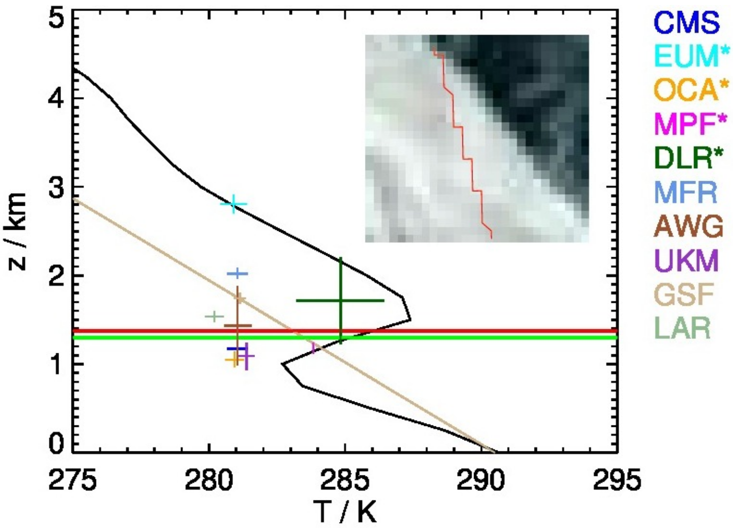


Figure 2: Cloud top height versus temperature for a homogeneous marine stratocumulus region. The crosses mark the results of the different SEVIRI algorithms. The length of the lines mark the standard deviation of these properties. The chosen track is illustrated as RGB in the upper right corner. The green and red line mark the cloud top height of CALIOP and CPR, respectively. The black line shows the tempera ture profile as provided by the ECMWF-AUX product. Groups that did not submit a cloud top height, but a cloud top pressure (that we converted to cloud top height using ECMWF data) are marked with a star *. The temperature profile constructed with a climatological temperature gradient used by the GSF retrieval is shown as brown line.

Contributions to 4th CREW

The Eumetsat fellow provided support for the preparation of the 4th CREW. He will stay involved in the preparation of the 4th CREW by preparing a report giving an overview of the inter-comparison and validation results archived so far.

Meetings and Presentations

The results of the fellowship were presented at the *EUMETSAT Conference* 2013 in Vienna, Austria. The fellow will participate in the 4th CREW in March 2014 in Grainau. If the job situation of the fellow allows, the fellow will participate the *EUMETSAT fellow day* in March 2014.

3. The 4th CREW in March 2014

The Cloud Retrieval Evaluation Workshops are organized regularly in order to discuss to progress of cloud remote sensing and the newest results of the CREW inter-comparison. In 2006, the 1st workshop located in Norrköping, Sweden, had about 19 participants. The 2nd workshop in 2009 located in Locarno, Switzerland had about 42 participants. Finally 71 scientists participated the 3rd CREW. The participants of the 3rd Workshop in Madiason proposed to have a further meeting. **The 4th Cloud Retrieval Evaluation Workshop will be realized 4 – 7 March 2014 in Grainau, southern Germany.** The DWD offered to manage the local organization.

An integral part of the CREWs are the discussions on inter-comparison and validation studies done with the data from the common database. In this way knowledge is gained on the behavior of the different retrieval schemes over different cloud conditions.

The main recommendations of the 3rd CREW in Madison for future work were:

- Address the focal points of the GEWEX-Cloud Assessment;
- Address research questions on level-2 cloud retrieval methods:
  - multiple layer cloud detection methods;
  - infrared-only cloud parameter retrieval methods;
  - microphysical properties of ice cloud models;
- Assessment of level-2 cloud properties retrievals and their error estimates;

- Improve on methods to aggregate level-3 cloud products;
- Enhance traceability and uniformity of level-3 cloud products;
- Establish sub-working groups addressing specific research topics;
- Involve other space agencies as well as participants from Asia and Australia;
- Establish CREW as working group under the umbrella of GEWEX and/or CGMS.

As the 4th CREW happens after the end of the CLOUDSTATE fellowship, it would be beneficial that the EUMETSAT fellow may stay involved until the results of the 4th CREW are summarized.

Acknowledgements

We thank EUMETSAT for funding the CLOUDSTATE fellowship and the CREWs as well as for providing the AVAC-S software. Thanks also go to Andi Walther, who created the database for the first two workshops, wrote the first version of the inter-comparison and validation software and supported the work of the fellow.

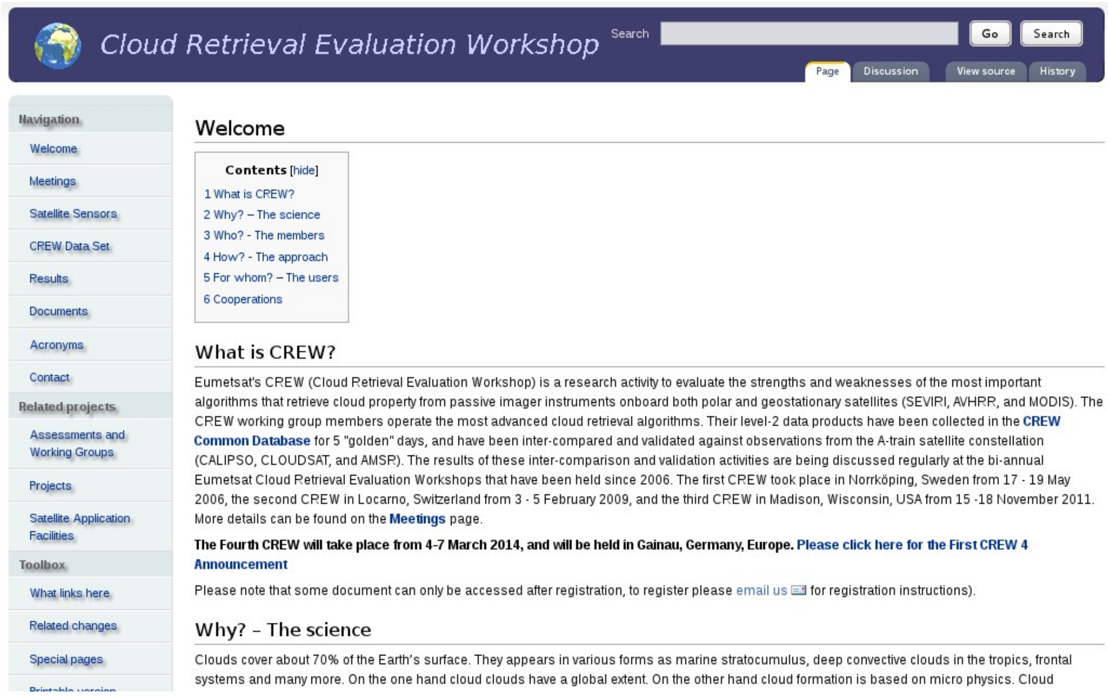
4. Documentation of the CREW project

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

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

Furthermore, the CREW database consisting of 12 SEVIRI algorithms and reference datasets is available for CREW participants 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
AMT	Atmospheric Measurement Techniques (peer reviewed journal)
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
COCS	Cirrus Optical properties derived from CALIOP and SEVIRI
CPP	Cloud Physical Properties algorithm
CPR	Cloud Profiling Radar
CREW	Cloud Retrieval Evaluation Workshop
EUMETSAT	European Organization for the Exploitation of Meteorological Satellites
KNMI	Koninklijk Nederlands Meteorologisch Instituut
METEOSAT	Meteorological satellite
MISR	Multi-angle Imaging SpectroRadiometer
MSG	Meteosat Second Generation
MODIS	Moderate Resolution Imaging Spectroradiometer (NASA/Terra, Aqua)
POLDER	POLarization and Directionality of the Earth's Reflectances
SEVIRI	Spinning Enhanced Visible and Infrared Imager

References

Hamann, U., A. Walther, B. Baum, R. Bennartz, L. Bugliaro, M. Derrien, P. Francis, A. Heidinger, S. Joro, A. Kniffka, H. Le Gléau, M. Lockhoff, H.-J. Lutz, J. F. Meirink, P. Minnis, R. Palikonda, R. Roebeling, A. Thoss, S. Platnick, P. Watts, and G. Wind (2013): Remote sensing of cloud top pressure/height from SEVIRI: Analysis of ten current retrieval algorithms, submitted to Atmos. Meas. Tech.

Bennartz, R., F. Fell, A. Walther (2010): AVAC-S: A-Train Validation of Aerosol and Cloud properties from SEVIRI, EUMETSAT document: EUM-07-839-INF

Karlsson, K.-G. and E. Johansson (2013): On the optimal method for evaluating cloud products from passive satellite imagery using CALIPSO-CALIOP data: Example investigating the CM SAF CLARA-A1 dataset, Atmos. Meas. Tech., 6, 1271-1286, doi:10.5194/amt-6-1271-2013

Kox, S. H. Mannstein, F. Ewald, and B. Mayer, (2010): COCS - Cirrus Optical properties derived from CALIOP and SEVIRI during day and night time. EUMETSAT Conference 2010 Proceedings. EUMETSAT.

Kox, S., A. Ostler, M. Vazquez--Navarro, L. Bugliaro, H. Mannstein (2011): Optical properties of thin cirrus derived from the infrared channels of SEVIRI. EUMETSAT Conference 2011 Proceedings. EUMETSAT.

Kox, S. (2012): Remote sensing of the diurnal cycle of optically thin cirrus clouds. PhD thesis, LMU München, Fakultät für Physik.

Krebs, W., H. Mannstein, L. Bugliaro, and B. Mayer (2007): Technical note: a new day- and night-time Meteosat Second Generation Cirrus Detection Algorithm MeCiDA. Atmos. Chem. Phys., 7(4): 10933–10969. ISSN 1680-7375. doi: 10.5194/acpd-7-10933-2007.

Menzel, W. Paul et al. (2008): MODIS Global Cloud-Top Pressure and Amount Estimation: Algorithm Description and Results. J. Appl. Meteor. Climatol., 47, 1175–1198.
doi: http://dx.doi.org/10.1175/2007JAMC1705.1

Nakajima, T., and K. D. King (1990): Determination of the Optical Thickness and Effective Particle Radius of Clouds from Reflected Solar Radiation Measurements. Part 1: Theory. J. Atmos. Sci ., 47, 1878-1893.

Schmetz, J., P. Pili, S. Tjemkes, D. Just, J. Kerkmann, S. Rota, and A. Ratier (2002): An introduction to Meteosat Second Generation (MSG), B. Am. Meteorol. Soc., pp. 977–992.

Stephens, G. L. et al. (2002): The CloudSat Mission and the A-Train: A New Dimension of Space-Based Observations of Clouds and Precipitation, Bull. Am. Meteor. Soc., 83, pp. 1771-1790.

Watts, P., R. Bennartz, and F. Fell (2011a): Retrieval of two-layer cloud properties from multispectral observation using optimal estimation, Journal of Geophysical Research, Vol. 116, D16203, doi:10.1029/2011JD015883

Watts, P. (2011b): Progress on Optimal Estimation Cloud Retrievals from SEVIRI, Oral presentation at the 3rd CREW meeting, Madison/Wisconsin, USA, 15.-18. November 2011

Winker, D. M., J. Pelon, M. P. McCormck, (2002): The CALIPSO mission: Spaceborne lidar for observation of aerosols and clouds, Proc. Of SPIE – Lidar Remote Sensing for Industry and Environment Monitoring III, Hangzhou, China, Vol. 4893, 24-25 October 2002

Zinner, T. (2005): Fernerkundung inhomogener Bewölkung und deren Einfluss auf die solare Strahlungsbilanz, DLR Forschungsbericht 2005-03

CREW articles in Scientific Newsletters

Roebeling R., B. Baum, R. Bennartz, U. Hamann, A. Heidinger, A. Thoss, and A. Walther, 2012
Third Cloud Retrieval Evaluation Workshop (CREW-3)
GEWEX newletter 2012, February 2012

Roebeling R., B. Baum, R. Bennartz, U. Hamann, A. Heidinger, A. Thoss, and A. Walther, 2012
The Third Cloud Retrieval Evaluation Workshop
BAMS newletter, submitted

CREW conference contributions

Hamann, U., A. Walther, R. Bennartz, A. Thoss, J. F. Meirink, and R. Roebeling, 2013
Towards understanding differences between cloud retrievals from passive imagers
Poster presentation
Eumetsat Conference 2013, Vienna, Austria

Hamann, U., A. Walther, R. Bennartz, A. Thoss, J. F. M. Meirink, and R. Roebeling, 2012
The CREW Inter-comparison of SEVIRI cloud retrievals
Oral presentation
American Geophysical Union Fall Meeting 2012, San Francisco, USA

Hamann U., R. Bennartz, J. F. Meirink, R. Roebeling, and A. Thoss, 2012
Inter-comparison of cloud property retrievals using the CREW data base
Oral presentation
Eumetsat Conference 2012, Oslo, Norway

Hamann, U., R. Bennartz, J. F. Meirink, R. Roebeling, and A. Thoss, 2012
Inter-comparison of cloud detection and cloud top height retrievals using the CREW data base
Poster presentation
International Radiation Symposium 2012, Berlin, Germany

Roebeling R., B. Baum, R. Bennartz, U. Hamann, A. Heidinger, A. Thoss, and A. Walther, 2012
Outcome of the Third Cloud Retrieval Evaluation Workshop
Oral presentation
International Radiation Symposium 2012, Berlin, Germany

Roebeling R., B. Baum, U. Hamann, A. Thoss, A. Heidinger, R. Bennartz, and A. Walther, 2012
Outcome of the Third Cloud Retrieval Evaluation Workshop
Oral presentation
Symposium EGU General Assembly 2012, Vienna, Austria, p.6173

Hamann, U., 2011
Results of the CREW-3 inter-comparison
Oral presenation
Cloud Retrieval Evaluation Workshop 2011, Madison/Wisconsin, USA, November 2011

Hamann, U., A. Walther, A. Thoss, J. F. Meirink, and R. Roebeling, 2011
Validation of present-day cloud retrieval methods
Oral presenation
Eumetsat Conference 2011, Oslo, Norway

CLOUDSTATE Fellowship reports

Hamann, U., 2011, Fellowship report for the CLOUDSTATE fellowship 2011

Hamann, U., 2012, Fellowship report for the CLOUDSTATE fellowship 2012

Hamann, U., 2013, Fellowship report for the CLOUDSTATE fellowship 2013