Abstracts

Cloud Retrieval Evaluation Workshop-4 (CREW-4)

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Program Committee

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Deutscher Wetterdienst
Wetter und Klima aus einer Hand

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ABSTRACTS - ORAL PROGRAMME

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Overview of combined retrievals from active instruments

Robin Hogan

Radar and lidar retrievals of cloud properties are now quite mature, although there remain many new opportunities to explore and uncertainties to resolve. In this talk I will give an overview of methods to retrieve cloud properties from active sensors, focussing particularly on those involving the synergy of two or more instruments, and those that can be applied from space.

I will start by highlighting the variables we need to know for model evaluation and process studies, and how well we need to know them. I will then consider issues surrounding the different cloud types in turn, and the pros and cons of radar-lidar, dual-wavelength radar, active-passive and in one or two cases single-instrument algorithms. A number of the points will be illustrated with examples from the multi-instrument variation retrieval algorithm I am developing for the forthcoming EarthCARE satellite.

In the case of ice clouds, key challenges are to characterize the radar scattering properties of ice particles, the vertical variation of lidar backscatter-to-extinction ratio and the nature of the variation of ice particle density with processes such as riminig. Key new measurements that will come online with the launch of EarthCARE are the radar Doppler velocity and high spectral resolution lidar. Further in the future, high frequency radar (up to 220 GHz) offers interesting advantages to 94 GHz. In the case of liquid clouds, key challenges are to retrieve vertical profiles in the presence of drizzle, and in particular to estimate the height of cloud base from space. Key new measurements to exploit are path-integrated radar attenuation and the information available from the multiply scattered signal in lidars with a field-of-view wider than 50-m, including Calipso. Mixed-phase and convective clouds present further challenges that will be discussed.

The MODIS cloud optical and microphysical property product: Overview of the Collection 6 algorithm and preliminary results

S. Platnick, M. D. King, G. Wind, K. Meyer, N. Amarasinghe, B. Marchant, G. T. Arnold, R. Holz, Z. Zhang, et al.

The latest Collection 6 (C6) processing stream for MODIS retrievals of cloud optical and microphysical properties is expected to begin in November 2013 along with the other MODIS Atmosphere Team products (cloud-top properties, aerosols, and clear sky parameters).

The 1 km daytime-only retrievals (part of the archived products MOD06 and MYD06, for MODIS Terra and Aqua, respectively) are based on well-known solar reflectance techniques. Parameters include cloud optical thickness, effective particle radius, water path, and thermodynamic phase derived from a combination of solar and infrared tests. C6 updates have been extensive, including: (1) effective particle radius retrievals derived separately for various channel combinations, (2) new look-up tables for cloud reflectance and emissivity, (3) retrievals for both liquid water and ice phases, and a subsequent determination of the phase based, in part, on effective radius retrieval outcomes for the two phases, (4) new ice cloud radiative models using roughened particles with a specified habit, (5) separate dataset for lower quality pixels thought to be associated with partly cloud FOVs, and (6) enhanced pixel-level uncertainty calculations incorporating additional radiative error sources including the MODIS L1B uncertainty index for assessing band and scene-dependent radiometric uncertainties.

We will provide an overview of the C6 changes and discuss example retrievals obtained from the archive. Examples will be shown for both pixel-level (Level-2) and gridded (Level-3) products.

The Community Cloud Optimal Estimation Retrieval for Climate (CC4CL): Retrieval System and Application to AVHRR and MODIS sensors

M. Jerg, C. Poulsen, G. Thomas, S. Stapelberg, A. Povey, M. Stengel, R. Hollmann and the ESA Cloud CCI team

An integral part of the ESA Cloud CCI project is the development and further improvement of the optimal estimation (OE) cloud retrieval algorithm ORAC (Optimal Retrieval of Aerosol and Cloud) into the CC4CL retrieval system and its implementation to produce a global multi-sensor cloud climatology.

The retrieval system yields micro- and macro-physical cloud properties like cloud optical thickness, effective radius, cloud top pressure etc. from visible and infrared channel measurements of passive satellite sensors. As a feature of the optimal estimation technique, pixel level retrieval results and uncertainty estimates of the retrieved parameters are calculated simultaneously. Furthermore the OE approach deduces these results coherently and consistently with the radiance measurements and among the retrieved parameters themselves through the rigorous mathematical inversion of the employed physical forward model. These advantages of the approach are not only beneficial for single sensor applications but also lead to a more uniform and general treatment of input data from multiple sensors, facilitate subsequent processing of the data and increase the retrieval's potential applicability to a range of polar orbiting and geostationary sensors. The presentation will introduce the retrieval system, its technical implementation and associated issues to produce a climate dataset from AVHRR and MODIS sensors. Furthermore, the technique applied to generate globally gridded monthly results, daily composites and the treatment of the propagation of the provided pixel level uncertainties into the aforementioned products will be illuminated. Lastly, selected results of the present application of the system will be shown together with planned future work.

Enhancing the PPS cloudmask confidence in the polar night with the VIIRS Day-Night band

Adam Dybbroe and Ronald Scheirer

Cloud detection using passive IR/VIS imagery in the polar night is particularly challenging. State of the art methods using AVHRR, VIIRS and MODIS have documented low confidence and skill over the wintertime polar regions. At night these instruments have limited spectral information, and the cloudy scene has often a low contrast in the IR bands. The commonly used low water cloud feature using the temperature difference between the 3.7 and 11 micron bands often looses its cloud detection ability due to larger than normal cloud droplets and/or due to presence of ice particles in the cloud. Also the ancillary information in form of surface skin temperature and sea ice concentration used e.g. in the NWCSAF PPS cloud mask is uncertain, further negatively impacting the cloud screening algorithm.

Many low clouds go undetected in PPS at night (up to around 20% cloud fraction underestimation in version 2012), often because they have no or little T3.7-T11 information or because the contrast is poor between the cloud top temperature and the forecasted skin temperature.

With the VIIRS Day-Night band (DNB) it is possible to catch some of these missed clouds, in particular over open water, and in general enhance the cloudnmask confidence under favourable moonlight conditions. There is no co-registration of the DNB and the VIIRS M-bands, so blending the M-band data with the DNB refletivity is not straight forward. Here we aim at a post-processing step applied after the current PPS cloudmask. This post-processing step can then be coupled to the cloud composite generator which is a pre-processing step to the Mesoscale analysis model MESAN.

Cloud and Radiation Parameter Retrievals from Satellites Using Updated NASA Langley Algorithms

<u>Patrick Minnis</u>, Rabindra Palikonda, Qing Z. Trepte, Douglas Spangenberg, Benjamin Scarino, Christopher R. Yost, Fu-Lung Chang, Gang Hong, Robert F. Arduini, Sarah T. Bedka, Kristopher M. Bedka, Michele Nordeen, Mandana M. Khaiyer, Szedung Sun-Mack, Yan Chen, Patrick W. Heck, David R. Doelling, William L. Smith Jr., and Ping Yang

Cloud properties have been derived from satellite data at NASA Langley for over 30 years. The cloud algorithms used to retrieve a variety of parameters have evolved from a simple visibleinfrared method to more sophisticated multispectral techniques to facilitate the use of the more capable modern satellite imagers. The latest suite of algorithms is being applied to both low-Earth-orbit (LEOsat) and geostationary satellite (GEOsat) imagers. These include the AVHRR on the NOAA and MetOp satellites, VIIRS on NPP, SEVIRI on MSG, MODIS on Terra and Aqua, and the imagers on the GOES, MTSAT, and FY-2 series of GEOSats. The data are analyzed in near-real time for model assimilation and icing and solar energy forecasts, and for climate projects such as the NOAA CDR and NASA CERES programs. Since CREW-3, a number of changes have been developed including new multi-layer retrieval schemes, new ice crystal models, imager-specific cloud reflectance and emittance models, surface temperature retrievals, improved cloud masks, and background albedos. This paper will review those changes and their effects on the retrieval accuracies of various parameters. The status of the updates for each satellite will also be discussed.

Application of a Spectrally Consistent Multichannel Adiabatic Retrieval to the MODIS Cloud Product

John Rausch, Ralf Bennartz, Vincent Puygrenier and Jean-Louis Brenguier

The aim of this study is to investigate the utility of inferring cloud vertical structure through application of a multispectral adiabatically stratified retrieval method to MODIS observations. The MODIS Cloud Product provides estimates of cloud optical thickness and droplet effective radius for three near infrared absorption wavelengths under a vertically homogeneous plane-parallel assumption. In order to exploit the data quality controls already applied to the MODIS Cloud Product, we invert the existing retrievals into scene reflectances and perform multispectral and bispectral adiabatically stratified retrievals using an optimal estimation framework. Through comparison of the bispectral and multispectral retrievals we attempt to estimate the degree to which a cloud conforms to an adiabatically stratified model near cloud top.

Cloud optical properties of multilayer clouds from solar and thermal SEVIRI channels

Luce Bugliaro

The weighting functions of thermal SEVIRI channels enable the vertical localisation of clouds in the atmosphere and the derivation of cloud optical properties. However, thermal channels are sensitive to a limited range of optical thicknesses. In contrast, solar channels respond to the total column optical thickness of clouds. In this talk we focus on the identification of multilayer cloud situations and on the determination of their optical properties. To this end, we combine the COCS algorithm, which is able to identify thin cirrus clouds even on top of low water clouds using thermal SEVIRI information and to determine their optical thickness, with the APICS algorihtm that exploits solar channels to derive cloud optical thickness and effective particle radius. Preliminary results will be shown.

Retrieving cloud microphysical properties in a fully 3D environment using active and passive sensors

Mark D. Fielding, Robin J. Hogan, J. Christine Chiu

Despite atmospheric processes acting simultaneously in the vertical and horizontal, very few fully 3D observations of clouds exist. Progress, in the past, has been slow, mostly due to limitations in instrumentation. With the advent of state-of-the-art ground-based scanning cloud radar, expanding retrievals away from just the vertical column is now possible. We will present a pioneering 3D cloud retrieval method (ENCORE) that uses an iterative ensemble Kalman Filter to combine active and passive sensors. As well as being one of the first 3D retrievals for scanning cloud radar, ENCORE uniquely uses 3D radiative transfer as a forward model without the need for its adjoint. The technique provides microphysical properties (effective radius and LWC) along with full error statistics, given measurement uncertainties. We will assess the method's performance in stratocumulus and challenging cumulus cases for both synthetic observations from large eddy simulations and real data from Graciosa Island, Azores, Portugal. We will also discuss the applicability of the algorithm to satellite observations. Detailed, 3D observations of cloud microphysics are vital to act as constraints for the improvement of cloud and radiation parameterizations in climate models.

MODIS Cloud Thermodynamic Phase Discrimination for Collection 6 and Comparisons with CALIOP and POLDER.

<u>Benjamin Marchant</u>, Steven Platnick, George T. Arnold, Jérôme Riedi, Kerry Meyer

For MODIS Collection 6 (C6) the NVSWIR Cloud Thermodynamic Phase discrimination algorithm has been greatly improved thanks to intensive cloud phase product comparisons between Aqua/MODIS and other sensors that compose the A-train mission, such as CALIOP and POLDER. This presentation is intended as a global overview of the C6 NVSWIR Cloud Phase discrimination algorithm. We will briefly introduce the new logic that has been developed to discriminate ice and liquid cloud pixels for MODIS and present global comparisons with CALIOP and POLDER.

A Methodology for Simultaneous Retrieval of Ice and Liquid Water Cloud Properties

O. Sourdeval, L. C.-Labonnote, A. J. Baran, G. Brogniez

The study of clouds have become during the last decades one of the major concerns of the climate research community. A precise knowledge of their properties therefore appears as a necessity in order to supply accurate information to climate models, and a multitude of retrieval methodologies have been developed in this matter. Most of the current methodologies prove to be satisfactory for retrieving the properties of ice or liquid cloud layers, but many of them lack the ability of efficiently taking into account possibilities of overlapping between these two cloud types. This omission can however have strong consequences on the retrievals. In this study, a methodology for retrieving simultaneously the properties of ice and liquid cloud properties is presented. The ice water path of one ice cloud layer, and the optical thickness and droplet effective radius of up to two liquid water cloud layers are retrieved along with precise uncertainties. In order to perform the retrievals, radiometric measurements in five channels ranging form the visible to the thermal infrared are used. The results of a theoretical information content analysis are first presented. This kind of study allows understanding how much information is available in different atmospheric configurations on each parameter to be retrieved, and which set of channels provides this information. The results of statistical analyses of our retrievals are later presented. Good agreements with the products of several A-Train operational algorithms are globally found, even if our study quantitatively show how the latter can be influenced by multi-layer configurations

Overview on cloud retrievals from passive sensors

Ralf Bennartz

Will present overview on passive cloud retrievals with special emphasis on cloud the physical parameters, effective radius, optical thickness, and liquid water path. In addition various issues related to the generation of Level 3 data based on cloud retrievals will be addressed.

Combining vertical resolved ground observations and geostationary satellite observations by use of a forward model approach

Anja Hünerbein, Hartwig Deneke and Andreas Macke

A method is presented to combine the information on the vertical profiles of cloud properties from ground-based observations with information on the spatial variability of cloud products from satellite-based observations. By using the forward model RTTOV and the ground-based Cloudnet products we simulate synthetic satellite observations at the supersites, which are subsequently compared to the actual observations of the Meteosat SEVIRI instrument. We considered different metrics to quantify and interpret the consistency of the synthetic and the observed satellite data: brightness temperatures at the thermal IR channels, the split window channels and tri-spectral combinations of channels, as well as the outgoing longwave radiation. Error bars were computed for the simulated BTs based on the uncertainty estimates of the Cloud net products, and turned out to be very helpful as a consistency check. In this way, the uncertainties of the individual data sets and their scale differences are investigated. This knowledge provides the motivation to combine the cloud products from the satellite with ground measurement to characterize the passing cloud systems over the sites. We studied different cold and warm front systems passing Europe supersites and installed the forward model to the Leipzig site for instantaneous measurement and analysis.

Evaluation of cloud products for Himawari-8/-9

Kazuki SHIMOJI, Ayako TAKEUCHI, Takahito IMAI, Kouki MOURI and Toshiharu IZUMI

Japan Meteorological Agency (JMA) will launch Himawari-8(-9) in 2014(2016) and start its operation in 2015. JMA is developing cloud mask, cloud type/phase and cloud top height as fundamental cloud products for the Himawari-8/-9.

Cloud mask and cloud type/phase will be calculated with threshold tests. Cloud top height will be estimated with interpolation, intercept and radiance ratioing method. These are based on NWC SAF algorithm, partially introduced NOAA/NESDIS algorithm. Preliminary tuning and evaluation of our algorithms are carried out with MSG and CALIPSO data.

The evaluation results of cloud mask, cloud phase, cloud top temperature, cloud top pressure and cloud top height will be discussed in the workshop.

A Simultaneous Cloud-Atmosphere-Surface Retrieval Algorithm Using Hyperspectral Data

Xu Liu, W. Wu, H. Liu, D. Zhou, A. Larar, P. Yang, and B. Baum

We will describe a method of simultaneously retrieving cloud parameters, atmospheric temperature and trace gas profiles, and surface properties using hyperspectral data from CrIS, IASI and AIRS. These hyperspectral data are compressed into EOF domain to effectively using all available spectral channels. A Principal Component-based Radiative Transfer Model (PCRTM) developed at NASA Langley Research Center is used to calculate both the EOF projection coefficients of the observed radiance spectra and their derivatives with respect to atmospheric profiles and other properties. The PCRTM forward model is capable of calculating radiative contributions due to multiple-layer clouds. The multiple scattering effects of the clouds are efficiently parameterized. A physical retrieval algorithm then performs an inversion of atmospheric, cloud, and surface properties in EOF domain directly therefore both reducing the computational need and preserving the information content of hyperspectral data. The inversion algorithm is based on a non-linear Levenberg-Marquardt method with climatology covariance matrices and a priori information as constraints. The retrieved cloud products include, cloud phase, cloud top height, cloud temperature, cloud effective size, and cloud optical depth. We will present results of applying the algorithm to real satellite data such as CrIS and IASI and show validations using collocated data sources.

South Korea's geostationary satellite cloud retrievals: current status and plans for GK-2A in 2017.

Yong-Sang Choi, Hye-Sil Kim, Heeje Cho, Sung-Rae Chung

Cloud algorithm from 5-channel (centered at 0.6, 3.7, 6.7, 10.8, and 12.0 µm) imageries for South Korea's geostationary satellite, COMS, has been operating since July 2010. The current algorithm retrieves cloud mask/fraction, cloud top pressure/temperature/height, cloud optical depth, effective radius, cloud phase, and cloud type. The algorithm has been updated 2 times from its initial version (Choi et al. 2007 IJRS, Choi and Ho 2009 IJRS), and improved in accuracy. Overall validation results based on comparison with MODIS retrievals show moderately good agreement ($r2 > 0.7$ for quantitative parameters). At present, cloud mask and cloud top pressure support operational weather forecasting.

South Korea has just begun developing the cloud algorithm for the Advanced Meteorological Imager (with 15 channels) onboard the succeeding geostationary satellite (GK-2A) operational during 2017-2027. This new algorithm essentially maintains the current cloud parameters for data continuity, but is expected to greatly improve the current accuracy due to some key channels. In particular, the 3.7 µm channel will be replaced with 1.6 or 2.2 µm channel in the sun reflection method for cloud optical depth and effective radius. The CO2 sounding channel at 13.3 µm will be used in the radiance ratioing method for cloud top pressure. The window channel at 8.7 µm will be used for a cloud phase threshold test. As for cloud type, we may follow SEVIRI scene classification. However, we are open to other new approaches that are reported to give better quality of cloud parameters.

Intercomparison of cloud observations from CALIOP and passive sensors

Dave Winker, Anne Garnier, Mark Vaughan, and Jacques Pelon

The CALIOP lidar, flying on the CALIPSO satellite since 2006, has the potential to provide a global reference dataset for cloud distribution and properties. CALIPSO Level 2 products include cloud height and thickness, optical depth, thermodynamic phase, and ice-water content. Early validation comparisons indicated significant discrepancies between cirrus optical depths retrieved by CALIOP and by MODIS, however. Comparisons between 12 um retrievals from the CALIPSO IIR and CALIOP constrained retrievals developed confidence in the accuracy and limits of both retrievals, and led to adjustments in the CALIOP default cirrus lidar ratio to provide improved unconstrained cirrus optical depth retrievals. Increasingly detailed comparisons between retrievals from CALIOP and the IIR have now been performed and are being used to validate retrievals of several different parameters. This work is leading to improvements and refinements in several of the algorithms. Methodologies and findings will be discussed.

Extension of the CREW-type Analysis to VIIRS

Andrew Heidinger, Steve Ackerman, Richard Frey, Robert Holz, Patrick Minnis, Steve Platnick, Andi Walter and Gala Wind

The VIIRS sensor replaces the Advanced Very High Resolution Radiometer (AVHRR) as the NOAA polar orbiting meteorological imager. It offers several new solar-reflectance channels, one additional IR window channel and a lunar-reflectance channel. While VIIRS does lack some of the IR channels in H2O and CO2 absorption bands compared to MODIS, it provides improvements in spatial coverage and spatial resolution compared to AVHRR and MODIS.

Several groups now generate VIIRS cloud products operationally. These groups include the official JPSS Program IDPS products, the NOAA JPSS-RR Project, NASA Langley, NASA Goddard and the Swedish Hydrology and Meteorology Institute (SMHI). We propose to conduct a standard analysis of the VIIRS cloud products similar to that done with the SEVIRI data in the previous CREW Workshops. We intend to select scenes that provide nearly simultaneous data with SEVIRI, MODIS, CALIPSO, CLOUDSAT and AVHRR. The focus of this presentation will be cloud height but a complete analysis will be done and available for others to discuss.

CREW: Update on the evaluation of SEVIRI cloud parameter retrievals

<u>Ulrich Hamann</u>, Andi Walther, Ralf Bennartz, Anke Thoss, Jan Fokke Meirink, and Rob Roebeling

Clouds strongly influence the radiation balance and the water cycle of the earth. Hence the detailed monitoring of cloud properties - such as cloud fraction, cloud phase, cloud top temperature, cloud optical depth, cloud particle size, and cloud water path - is important to understand the role of clouds in the weather and the climate system. Measurements of the global distribution of these properties, and their diurnal, seasonal, and inter-annual variations are critical for improving our understanding of the role of clouds in the weather and climate system. To understand the uncertainty characteristics of the retrievals an in depth analysis and validation of the retrieval algorithms and data sets is required.

This presentation focuses on the inter-comparison and validation of the cloud top height retrievals from the Spinning Enhanced Visible and InfraRed Imager (SEVIRI) onboard METEOSAT. For this study we use retrievals from 10 state-of-art algorithms (University of Wisconsin/Madison, Climate Monitoring SAF, DLR, three Eumetsat algorithms, two NASA algorithms, Meteo France, and UK Met Office) that are made available through the common database of CREW (Cloud Retrieval Evaluation Workshop). This database contains five days, during which the satellite constellations are especially suited for validation studies. The accuracy of the cloud top height retrievals is determined by comparisons with CLOUDSAT and CALIPSO measurements. We discuss the uncertainty of the cloud top height retrievals considering their vertical structure. Therefore, we introduce three categories: (i) optically thick single layer clouds, (ii) optically thin single layer clouds, and (iii) multilayered cloud conditions. The difference between the radiatively effective cloud top height and the physical cloud top height is discussed. Additionally, we discuss the cloud top height retrieval in the boundary layer. Here, temperature inversions frequently cause ambiguities converting the observed cloud top temperature to a cloud top height. Approaches to tackle the issues with the multilayered cloud situations and uncertainties of temperature profiles are presented.

We would like to thank Eumetsat for funding of the CREW project including this work. For further information, please have a look at our project website www.icare.univ-lille1.fr/crew.

The inter-comparison of cloud properties retrieved from AVHRR and MODIS using three state-of-the-art retrieval schemes

M. Stengel, S. Mieruch, M. Jerg, K.-G. Karlsson, R. Scheirer, B.Maddux, J.F. Meirink, C. Poulsen, R.Siddans, A.Walther, R. Hollmann

As part of ESA's Climate Change Initiative, the Cloud CCI Project generates long-term cloud property datasets based on ESA and non-European satellite missions. One of the two dataset families is based on AVHRR heritage channel measurements from MODIS, AATSR and AVHRR. As baseline for the retrieval developments made within the Cloud_cci Project, a comprehensive inter-comparison study was carried out using three state-of-the-art schemes: ORAC, CLAVR-x, CM SAF (CPP and PPS). The retrieval schemes were applied to AVHRR and MODIS measurements (AVHRR-heritage channels only) and the retrieved cloud properties were confronted with collocated reference observations of CloudSat, Calipso and AMSR-E, and the individual evaluation results inter-compared. As an additional component of this study the impact of the chosen NIR channel (1.6 vs. 3.7µm) on cloud property retrievals was investigated. This presentation will give an overview on the inter-comparison study carried out and discuss some of the final results and findings in more detail.

Validation of SEVIRI cloud top height retrievals from A-Train data

Chu-Yong Chung, Peter Francis, and Roger Saunders

At the Met Office, cloud parameters, including cloud-top height, cloud-top temperature, effective radius and optical thickness, are being derived operationally from radiances observed by Meteosat geostationary satellite in near-real time, and these parameters are used not only as image interpretation tools for forecasters but also, importantly, as inputs to the numerical weather prediction and automated nowcasting systems.

In this presentation, the Met Office's current operational cloud-top height retrieval algorithm will be briefly demonstrated, some recently performed validation studies comparing cloud-top height with A-Train (mainly Cloudsat CPR) and OCA retrievals using AVAC-S will be shown, and ongoing efforts to improve their accuracy will be described.

Geometric cloud height assignment by Geosynchronous meteorological satellite - simulation and bias analysis

Feng_Lu

In the next decade, the next generation geosynchronous meteorological satellite will be in operational. The new system will provide improved temporal and spatial resolution, based on effective coordinate and careful observation plan arrangement, it is possible to derive cloud top height(CTH) based on stereo view of two geosynchronous satellite.

In this paper, the CTH bias are diagnosed based on the current and future geosynchronous satellite configuration. It shows that the geometric CTHs will be best derived when the two satellites are separated by 60 degrees, further more, the geometric CTH bias for all the operational geosynchronous satellite configuration will be shown. In addition, a case study based on GOES-10/12 images will shown the possibilities of stereo CTH assignments technique.

Retrieval and validation of cloud properties from the AATSR instrument

Caroline Poulsen, Gareth Thomas, Adam Povey, Greg McGarragh, Richard Siddans, Don Grainger, Matthias Jerg, Martin Stengel, Rainer Hollmann

ORAC (Optimal Retrieval of Aerosol and Cloud) is an optimal estimation scheme that retrieves cloud parameters using visible and infrared channels simultaneously the retrieval outputs an uncertainty for each retrieval that is propagated from the uncertainty on the forward model and the uncertainty in the measurements.

I will show results from the application of ORAC to the AATSR instrument including results and validation efforts. In particular I will focus on how vertical sensitivity can be accounted for when validating thermal IR retrieved cloud top height with Calipso and show how the uncertainty can be validated. Finally the correct identification of cloud and aerosol in climate data records is important if we are to accurately identify climate trends in cloud or aerosol properties. As ORAC can also retrieve aerosol properties I will also explain our efforts to harmonise aerosol and cloud retrievals by using Bayesian probability techniques to identify particle type.

A Review of Cloud Property Retrievals over Snow and Sea-ice Surfaces

Andi Walther, Andrew Heidinger

Cloud property retrievals which use visble channels often exhibit limited accuracy over snow and sea-ice surfaces. The main reasons are:

• The high reflectivity of snow and sea-ice surfaces dominates the measured signal in visible channel particularly for thin clouds.

• Retrievals often use snow maps from auxilary data for a background assumption of surface reflectivity. False snow (and non-snow) flags lead to substantial errors in cloud retrievals.

• The a-priori assumption of the surface reflection has a much higher uncertainty than for snow-free surfaces. Snow can have a wide variety of reflection depending on the age of snow (fresh or old), and the type of the area (open fields, forests, urban areas, etc..).

We will present the impacts on cloud property retrievals and their uncertainties for the current PATMOS-x cloud products. Although our focus lies on microphysical properties (optical thickness and effective radius), we will also show the impact on cloud detection and cloud height retrievals.

The polar-orbiting sensors VIIRS/NPP and MODIS have, in contrast to AVHRR or SEVIRI, additional channels (1.2 or 2.2 micron) which may be used for over snow surface retrievals. One example was the bi-spectral approach of 1.6 and 2.2 channels introduced by Platnick 2001. We will outline some of the algorithm approaches and hope this could be discussed during the CREW workshop.

Platnick, S., J.Y.Li, M.D. King, H.Gerber, P.V.Hobbs,2001: A solar reflectance method for retrieving the optical thickness and droplet size of liquid water clouds over snow and ice surfaces, JGR, 106

Towards characterizing the uncertainty of in-situ cloud observations: A case study for the ESA CCI Cloud project validating satellite-based cloud amount in mountain and polar regions

Jędrzej S. Bojanowski and Reto Stöckli

Ground-based cloud observations commonly serve as a validation source for satellite-based cloud parameters. In this study AVHRR- and MODIS-derived cloud amount from the ESA CCI project has been evaluated in the Alps and for polar regions. In situ observations used for the evaluation included SYNOP observations, and automated 10-minute cloud amount based on the long-wave incoming radiation by use of the APCADA algorithm. By assuming a maximum of 1 hour collocation difference yields a heavy reduction in sample size when using SYNOP data (18%) compared to the use of 10-minute APCADA data at Ny-Ålesund (Spitsbergen). We demonstrate that validation statistics are affected by the choice of maximum collocation time difference between the satellite overpasses and in situ observations. For Payerne (Alps) the accuracy (Hanssen-Kuiper's discriminant) of the MODIS-based cloud amount product decreased by 15% when the time shift was changed from 5 to 90 minutes. Therefore, collocation of satellite data with 10-minute cloud amount from APCADA allows for a site-based validation with both a narrow collocation time window and a sufficient number of collocated data pairs. We suggest that validation of cloud properties should not be based on a single dataset of in situ observations, but on a collection of data sources (i.e. SYNOP, APCADA, and active remote sensing). This also provides means to estimate the uncertainty of the validation data which is a key requirement for such validation activities.

Comparing OCA and DARDAR upper layer COT in multi-layer situations

P. D. Watts

The EUMETSAT Optimal Cloud Analysis (OCA) retrieval algorithm retrieves two-layer properties when multi-layer cloud is detected. The retrieved layer cloud top pressures (CTPs) have been validated using values from the Cloud Profiling Radar (CPR) and Cloud-Aerosol Lidar with Orthogonal Polarization (CALIOP). Until now however, the validation of cloud optical thickness (COT) has been made by comparison to MODIS derived values and therefore restricted to total COT. The availability of DARDAR (raDAR/liDAR) project data has allowed a first validation of the SEVIRI OCA COTs for the upper ice layer in multi-layer clouds.

The validating DARDAR product used here is the visible optical depth, defined as the integral of the ice cloud visible extinction along a vertical path through the entire atmosphere. The results indicate that the OCA scheme generally detects the presence of multi-layer cloud when the overlying cloud layer is of optical thickness < ~4-6 and > ~0.1-0.3 in the tropics and > ~0.5 at high latitudes. The higher sensitivity to thin cirrus in the tropics may be related to the greater thermal contrast found with the higher / colder tropical clouds. The upper limit likely arises because the detection, based on goodness of fit to a single layer cloud model, is highly dependent on the infrared channels for which a cloud with COT > 4-6 is essentially opaque and therefore radiatively equivalent to a single layer.

OCA COTs for the upper layer clouds apparantly compare well with DARDAR values, however the agreement is often outside their respective 3□ error estimates and a OCA bias of minus 20-30% is indicated.

For the single layer clouds (derived from visible and infrared measurements), there is an indication that the OCA COTS are biased high, although from the present examples it is not clear this is a consistent feature.

All results are so far based on relatively few cases and as such are very provisional.

UW-Atmospheric PEATE cloud evaluation capabilities: resolving cirrus optical thickness retrieval differences between solar reflectance, IR, and CALIOP observations

Robert E Holz, Steve Platnick, Steve Ackerman, Gala Wind, Ping Yang, Chenx Wang, Dave Winker, Mark Vaughan, and Ann Garnier

The combination of active and passive measurements provides a truly new capability to better characterize the accuracy of cloud retrievals and better understand the global composition and distribution of clouds including independent retrievals of COT. Despite its importance, significant uncertainties currently exist in COT retrievals due to the lack of independent validation. We will present global comparisons between the MODIS and CALIOP COT for single layer ocean cirrus that reveals an approximate factor of two biases between the v3 CALIOP and MODIS C5 daytime COT. This bias has major implications for using the EOS record to study cirrus cloud radiative processes which motivates our investigation of both the CALIOP and MODIS COT retrievals with the goal of understanding and then resolving the bias.

Both MODIS and the CALIOP (daytime mainly) COT retrievals require a priori information concerning the ice scattering properties that relate the measured reflectance (MODIS), and attenuated backscatter (CALIOP) to the cloud COT. Uncertainties in the ice scattering properties of either CALIOP or MODIS could account for the bias found in the comparison. As will be presented, the infrared (IR) has mostly orthogonal sources of uncertainty compared to the MODIS and CALIOP visible retrievals providing an independent means to access COT. The COT retrievals are evaluated using Top Of Atmosphere (TOA) radiative closure as well as direct comparisons with independent IR cirrus COT retrievals.

Using the SSEC Atmospheric PEATE, various ice single scattering models (Yang et al. 2012) were investigated and used to reprocess a month of collocated observations. For CALIOP changes in the assumed extinction to backscatter ratio were investigated with modified lidar ratios. The new results were re-compared against both the radiatve closure TOA radiances and retrievals of COT with MODIS and CALIOP demonstrating a significantly reduced bias. Based on these findings the MODIS collection 6 ice cloud optical property retrievals will change from the multi-habit aggregation used in Collection 5 to a single habit of roughened aggregated columns (Yang et al. 2012).

Cloud retrievals for severe weather forecasts

Daniel Rosenfeld and *John Mecikalski*

Severe convective storms are manifestations of the updraft speeds that electrify the clouds, support large hail and spawn tornadoes. When the strong updrafts turn back towards the surface with the heavy precipitation they incur downbursts and squalls. The updraft speeds can be detected by the rising rate of the top of convective elements, which turn into overshoots followed by large anvil expansion rate when the towers hit the tropopause. Satellite retrieved microstructure can also reveal the updraft speeds. Larger updrafts at cloud base cause greater supersaturation and nucleate more aerosols into larger number of smaller cloud drops, which is manifested as smaller cloud drop effective radius (re). The effect of updrafts on re becomes much more evident above the height where coalescence dominates the growth rate of re with additional height. In a fast rising cloud parcel the re has little time to grow by coalescence with increasing height. This means that strong updrafts are manifested as slow increase of re with decreasing T (cloud top temperature). Similarly, the development of ice in the fast rising parcel has insufficient time to glaciate the cloud before reaching the homogeneous ice nucleation isotherm of -38°C. The homogenously frozen cloud drops create small ice particles in the anvils, which can also be detected from satellites.

SAFNWC/MSG cloud products

M. Derrien, H. LeGléau and M.-P. Raoul

Within the SAF in support to Nowcasting and Very Short Range Forecasting (SAF NWC, www.nwcsaf.org), Météo-France has developed software to extract cloud parameters (cloud mask and types, cloud top temperature and height) from MSG SEVIRI imagery. These modules are part of the SAFNWC/MSG software package whose first operational version has been available to users since June 2004. The successive versions of the software have been validated over one-year periods by using collocated SYNOP observation, manual nephanalyst reports, radiosondes and lidar measurements and have been inter-compared to other operational schemes during the first, second and third Eumetsat cloud workshop in 2006, 2009 and 2011. Since the last Eumetsat cloud workshop in 2011, the cloud algorithms remained unchanged. Our current efforts aim to the preparation of the next version expected in 2015 that will include a new cloud microphysics product, the use of on-line RTTOV simulations to improve the cloud detection, and the possibility to process all meteorological geostationary satellites.

Cloud properties retrieved from passive imagers and application to the shortwave flux estimation, regarding renewable energy

Takashi Y. NAKAJIMA, Hideaki TAKENAKA, Takashi NAGAO, Husi LETU, Takeshi WATANABE

Cloud properties such as optical thickness, particle size, thermo-dynamical phase, cloud top temperature are primal information for surveying cloud evolution process, establishing climatological database, and so on. One of primal application to use cloud properties is for estimating solar radiation reached to the ground surface through clouds. It is used for estimating potential renewable energy. Geostationary satellites are useful for such objective since they observe the earth for wide area with high temporal frequency and moderately spatial resolution. Actually, recent geostationary satellites, Himawari, Meteosat, GOES cover most parts of the earth every 30 minutes to an hour. These satellites will be replaced by the 3rd generation from 2015, with drastic improvements of observation ability; 16 spectral bands, every 10 minutes or more frequently. Solar radiation at the ground surface can be estimated by a fast radiative transfer calculation with input of cloud properties retrieved from geostationary satellites. The polar orbital earth observing satellites are also needed for improving the data analysis techniques used for the geostationary satellites. For instances, a synergistic use of the multi-spectral imager and the cloud radar aboard polar orbital satellites reveals relationship between multi-spectral reflectances and vertical structure of clouds that contributes to both developing inversion algorithms of cloud properties and estimating solar radiation. This paper presents method to estimate such cloud properties and solar radiation, showing the latest atmospheric science and technology.

New Methods to Infer Aircraft Icing Conditions from Satellite Cloud Retrievals

William L. Smith Jr., Patrick Minnis , Cecilia Fleeger, Douglas Spangenberg, and Rabindra Palikonda

The occurrence of super-cooled liquid water (SLW) in clouds is a significant hazard to aircraft. Accurate diagnoses and forecasts of the meteorological conditions associated with aircraft icing requires identifying the location and vertical distribution of clouds with SLW droplets, as well as characteristics of the droplet size distribution. Thus, identifying icing conditions with the traditional tools available to forecasters is challenging. With the advent of cloud property retrieval methods, additional information from satellite data can be exploited. This paper describes ongoing work to improve the resolution of icing conditions in all cloud conditions using satellite-derived cloud parameters. The algorithms provide near real-time estimates of the icing probability, potential intensity, and the likely altitude range across the globe. Pilot reports over the U.S. are used to validate the methods. For unobscured lower level clouds, the SLW cloud properties can be inferred directly from the satellite data. For ice over water clouds which contain about 40% of the icing reported by pilots, the satellite retrievals are used to constrain climatological information on the vertical distribution of cloud mass and phase partitioning derived from a combination of active sensor data, microwave radiometer data and cloud model simulations. An over-arching goal of this work is to demonstrate a 3-dimensional approach to improve the utility of operational satellite data for constraining cloud properties in weather analyses and decision support systems. A brief algorithm description and results from verification studies, including several case studies highlighting the potential for diagnosing severe icing conditions, will be presented.

Impact of Smoke on Ice Cloud Properties in Geostationary Data

Bryan A. Baum and Andrew Heidinger

Sometimes wildfire events become pyroconvective, meaning that plumes quickly grow to incredible heights over the course of hours and become pyroCumulonimbus, or pyroCb. The pyroCb events inject huge amounts of wildfire emissions into the upper troposphere and even into the lower stratosphere (UT/LS). The emissions contain soot, mineral dust, and "brown carbon" (or BC; complex light absorbing organic material). Over the course of 2013, we captured several pyroCb events for which we were able to obtain GOES-14 super rapid scan (1 minute) data. We will show results from PATMOS-x cloud properties derived during these super-rapid-scan episodes. For these pyroCb events, the brightness temperature of the smoke/cloud plume can be colder than -40˚C, but the smoke decreases the visible band reflectivities far below what one would expect from ice clouds. The result of the severe smoke loading can lead to puzzling retrievals. Since the smoke, once lofted to the UT/LS, can travel great distances in a short amount of time, the question is how ice clouds are impacted downstream of the pyroCb event. The study of these three cases will provide some insight that may be of interest to the CREW-4 participants.

What did we learn from the GEWEX Cloud Assessment?

C. Stubenrauch, S. Kinne and GEWEX Cloud Assessment Team

The GEWEX Cloud Assessment, initiated in 2005 by the GEWEX Radiation Panel, provides the first coordinated intercomparison of publicly available, global L3 cloud products (gridded, monthly statistics) retrieved from spaceborne measurements of multi-spectral imagers, IR sounders and lidar. Extending the self-assessments by the different teams, the analyses using the common database (http://climserv.ipsl.polytechnique.fr/gewexca/) have shown how cloud properties are perceived by instruments measuring different parts of the electromagnetic spectrum and how cloud property averages and distributions are affected by instrument choice as well as some methodological decisions. These satellite cloud products are very valuable for climate studies or model evaluation: Even if absolute values, especially those of high-level cloud statistics depend on instrument (or retrieval) capability to detect and/or identify thin cirrus, relative geographical and seasonal variations in the cloud properties agree very well (only a few exceptions like deserts and snow-covered regions). Probability density functions of radiative and bulk microphysical properties also agree well, when one considers retrieval filtering or possible biases due to partly cloudy pixels and due to ice-water misidentification. When comparing to climate models, observation time and view from above as well as retrieval filtering have to be taken into account.

The study of long-term variations with these datasets requires consideration of many factors, which have to be carefully investigated before attributing any detected trends to climate change.

Detailed results and description of the datasets are given in a WCRP report (Nov 2012) and key results are summarized in the Bulletin of American Meteorological Society (July 2013).

Evaluation of cloud optical and microphysical property observations in the CLAAS dataset

Jan Fokke Meirink, Gerd-Jan van Zadelhoff, Rob Roebeling, Martin Stengel, Anke Kniffka, Maarit Lockhoff, Rainer Hollmann, Karl-Goran Karlsson

Clouds play a central role in the Earth's atmosphere, and satellite observations are crucial to monitor clouds and understand their impact on the energy and water cycles.

The CM SAF conducted a reprocessing effort of cloud properties based on MSG-SEVIRI measurements for the time frame 2004 until 2011. The resulting CLAAS (CM SAF cLoud property dAtAset using SEVIRI) dataset is now publicly available and allows for regional cloud property studies with high spatial and temporal resolution.

Here, we present an overview of the CLAAS cloud optical and microphysical property record, including cloud thermodynamic phase, optical thickness and liquid/ice water path. Detailed comparisons with MODIS products have been performed, showing in general very similar spatial distributions and temporal variability. Differences occur particularly towards higher latitudes. Therefore, we analyse the seasonal cycle of cloud properties over the southern Atlantic Ocean in more detail. Finally, passive microwave observations are used to evaluate seasonal and diurnal cycles of liquid water path over marine stratocumulus regions.

Ten Year Time Series of High Cloud Frequencies from HIRS and MODIS

Richard Frey and W. Paul Menzel

Frequency of occurrence of high-altitude tropospheric clouds has been extracted from NOAA/HIRS and NASA/MODIS polar orbiting satellite data using CO2 slicing to infer cloud height and effective emissivity. Data from HIRS sensors on board NOAA-15 through NOAA-19 and METOP-A are compared to that of MODIS Aqua for the years 2000-2009. The HIRS and MODIS CO2-slicing algorithms have been made as consistent as is reasonably possible. Clear vs. cloudy discrimination is accomplished with collocated PATMOS-X (AVHRR) cloud detection data for HIRS FOVs and the 1-km MODIS cloud mask (MOD35) for MODIS 5x5-pixel (5-km) regions. In order to address issues affecting sensor to sensor radiance calibration and calculations of clear sky radiances, high-spectral resolution infrared data from IASI has been used to adjust spectral response functions in the recent HIRS data; Satellite Nadir Overpasses (SNOs) are used to inter-calibrate the HIRS sensors before IASI. Several updates have been made to the MODIS CO2 slicing algorithm (Collection 6) including the use of high-spectral resolution data from the AIRS instrument to refine MODIS spectral response functions in the CO2-absorption bands. Results from the two data sets will be compared and analyzed using consistent Level-2 to Level-3 methods. Similarities and differences in high cloud frequencies and trends will be reported.

ESA Climate Change Initiative: Evaluation of the FAME-C cloud properties for the years 2007-2009

Cintia Carbajal Henken, Rasmus Lindstrot, Rene Preusker and Jürgen Fischer

In the frame of the ESA Climate Change Initiative Cloud the FAME-C (FUB AATSR-MERIS Cloud Retrieval) algorithm has been developed. Cloud products have been retrieved using measurements from the Advanced Along-Track Scanning Radiometer (AATSR) and the MEdium Resolution Imaging Spectrometer (MERIS), both mounted on the polar orbiting satellite ENVISAT.

A daytime cloud climatology for the years 2007-2009 has now been produced in the first phase of the project. Efforts have been taken for evaluation of the FAME-C cloud climatology by comparing to ground-based observations as well as to other satellited-based cloud climatologies, mainly on a level-3 basis. However, to understand differences in the level-3 products also comparisons are performed on a level-2 basis by comparing histograms of cloud properties for certain regions of interest.

The cloud top height can be determined from both thermal emission of the cloud using AATSR measurements in the infrared as well as from the average photon path length using MERIS measurements within and near the Oxygen-A absorption band. In cloudy situations this average photon path length is mainly determined by the cloud top pressure, but also influenced by the cloud vertical profile. The difference in sensitivity of both cloud top height retrievals to cloud vertical extension is demonstrated by comparing the difference in retrieved cloud top heights to ground-based radar observations.

A comparison of NOAA/AVHRR derived cloud amount with MODIS and surface observation data

Liu Jian *Yang Xiaofeng Cuipeng*

The satellite data used in this paper is NOAA daily date covered 1989-2008 that come from National Satellite Meteorological Center. The total cloud amount is calculated using improved cloud detection and radiation calculation method. Based on 2007yr data, NOAA/AVHRR derived total cloud amount is validated using MODIS cloud products and synoptic observations. Taking surface observation as true values, AVHRR derived and MODIS cloud parameters are validated each. The analysis results show that accuracy rate of processed AVHRR cloud detection is higher than MODIS cloud detection. Total cloud amounts estimated from NOAA/AVHRR are smaller than cloud amount reported by surface observers. Using EOF method analyzes the cloud distribution of AVHRR derived cloud amount, MODIS cloud product and surface observations. The results showed that the first EOF eigenvector can represent the distribution of three kinds of cloud amount data. Compared with MODIS, both time coefficient and spatial distribution of AVHRR derived cloud amount are closer to surface observation, especially in winter time. Using SVD method analyzes the relationship between AVHRR derived cloud amount, MODIS cloud product and surface observations. It was found that either AVHRR derived or MODIS cloud amount has good correlation with surface observations. The first five SVD mode correlation coefficients of AVHRR derived are larger than MODIS's. The first SVD mode time correlation coefficient of AVHRR derived is 0.96 that is larger than MODIS's 0.76. Two suit data show that AVHRR derived cloud amount has better match degree with surface observation than MODIS cloud amount.

Aggregation methods and their uncertainties

Nadia Smith, W. Paul Menzel, Bryan Baum, Elisabeth Weisz, Ralf Bennartz, Andi Walther

To overcome the complexities associated with combining or comparing multi-sensor data, a framework was developed to allow the projection of data from their unique instrument domain to a uniform space–time domain. The space-time gridding (STG) framework ingests measurements from any source, thus allowing multi-sensor comparison and fusion. The framework has two components. 1) The spatial gridding phase in which geophysical properties are filtered based on a set of criteria (e.g., time of day, viewing angle, quality control, or based on a secondary characteristic such as cloud phase) and then aggregated into nearest neighbor clusters as defined by equal-angle grid cells. 2) The temporal gridding phase in which daily statistics are calculated per grid cell from which longer time-aggregate statistics are derived. The latter can be any statistical metric (or combination thereof) that helps characterize the parameter at hand. The STG framework has proven to be effective in aggregating data into quality information for a number of different applications and geophysical parameters, e.g., brightness temperature, cloud physical and optical properties as well as temperature and water vapor soundings. We will describe the basic STG framework and how uncertainty can be quantified and minimized at each step of processing. We will then examine different implementations of STG with the goal to demonstrate its value in climate research as well as real-time monitoring applications.

Extending error characterization of cloud masking: Exploring the validity and usefulness of the Naïve Bayesian probabilistic cloud masking method

Karl-Göran Karlsson

Uncertainties in the basic cloud mask affect the quality of all cloud products retrieved in the subsequent steps after cloud screening. Until today this has often been handled in a rather pragmatic and simple way by applying quality flags to the cloud mask and then excluding low quality cloudy pixels from further cloud parameter retrievals. However, this has the disadvantage of leaving out a significant fraction of all pixels from the retrieval, i.e., those that are not confident clear or cloudy. This in turn means that we might have inconsistencies between retrieved cloud amounts (based on all cloudy pixels) and the retrieved cloud parameters (based on only a sub-set of all cloudy pixels).

A way to more explicitly handle the cloud masking uncertainty would be to express the cloud mask result as a cloud probability. Here, some AVHRR GAC results, based on the Naïve Bayesian probabilistic approach and derived as a postprocessing of the NWC SAF PPS cloudmask, will be shown. Training and validation of the method has been made based on measurements from the CALIPSO-CALIOP sensor. Applications of the probabilistic cloud mask will be discussed with particular focus on the potential use for error characterization of Level 3 products and the reduction of inconsistencies between products.

The cloud cover vertical distribution and its diurnal cycle observed from Multi-Geostationary data

<u>Sèze, G.,</u> C. Stubenrauch, A. Feofilov, J. Pelon, M. Derrien, H. Le Gléau

For the need of the MEGHA-TROPIQUES experiment, a geostationary cloud data set has been developed. This data set consists of cloud classification and cloud top pressure fields obtained from the application of the SAFNWC algorithm to the multi-spectral SEVIRI radiometer data on board the METEOSAT second generation satellite and to the GOES-E, GOES-W and MTSAT satellite data. These four sets of data allow to retrieve cloud parameters with one hour sampling or better over a large part of the tropical belt (35°S-35°N). Here we analyze the cloud cover diurnal cycle for one summer and one winter season of this data set. Ocean and land are studied separately. A special focus is given to the high-level and mid-level cloud cover. To better interpret the geostationary data results, the coincident CALIPSO/CLOUDSAT/AIRS and IASI cloud data are used.

An assessment of cloud liquid water path and droplet number concentration retrievals derived from MODIS-like observations: Comparison with large-eddy simulation and implications for aerosol indirect effect study

Zhibo Zhang, Daniel Miller, Andrew S. Ackerman, Steven Platnick

The cloud liquid water path (LWP) and cloud droplet number concentration (CDNC) are two key parameters in the study of aerosol-cloud interaction. The objective of this research is to identify and understand the uncertainty sources in MODIS-like LWP and CDNC retrievals. First, we use radiative transfer models (both 1D and 3D) to simulate the MODIS observation from large-eddy simulations (LES). Then, LWP and CDNC are retrieved from the simulated observation. Finally, we compare the retrieved and LES cloud fields to identify sources of uncertainties. Three major sources of uncertainty are identified: 1) cloud vertical structure, 2) cloud horizontal inhomogeneity and 3) 3-D radiative transfer effects. An intriguing finding is that in many cases these uncertainties act to cancel one another leading to reduced impacts on the retrieval. The implications for aerosol-cloud interaction study, in particular Twomey effect, will be discussed.

MODIS Collection 6 Clear Sky Restoral: Filtering cloud mask "not clear" pixels

Kerry Meyer, Steve Platnick, Gala Wind, Jerome Riedi

Correctly identifying cloudy pixels appropriate for the MODIS cloud optical and microphysical property retrievals (MOD06) is accomplished in large part using results from the 1km cloud mask tests (MOD35). However, because MOD35 is by design clear sky conservative (i.e., it identifies "not clear" pixels), certain situations exist in which pixels identified by MOD35 as "cloudy" are nevertheless likely to be poor retrieval candidates. For instance, near the edge of clouds or within broken cloud fields, a given 1km MODIS field of view (FOV) may in fact only be partially cloudy. This can be problematic for the MOD06 retrievals because in these cases the assumptions of a completely overcast homogenous cloudy FOV and 1-dimensional plane-parallel radiative transfer no longer hold, and subsequent retrievals will be of lower confidence. Furthermore, some pixels may be identified by MOD35 as "cloudy" for reasons other than the presence of clouds, such as scenes with thick smoke or lofted dust, and should therefore not be retrieved as clouds. With such situations in mind, a Clear Sky Restoral (CSR) algorithm was introduced in Collection 5 MOD06, which attempts to identify pixels expected to be poor retrieval candidates. In Collection 6, the CSR algorithm has a more prominent role, as partially cloudy pixel retrievals are now independently reported in both the level-2 and level-3 products. Here, details and examples are provided of the MOD06 CSR algorithm, including changes introduced for Collection 6.

How to prepare satellite-based cloud information for use by modelers

Robert Pincus

This talk will discuss what is necessary to make a robust comparison of models to satellite estimates of cloud properties, with a main focus on long-term global records. I'll describe the process of developing a "simulator" or forward operator that maps the clouds produced by a model to those observed by a satellite at the pixel level, describe how this effort requires deep understanding of satellite observational biases, and point out some of the features that appear in observations that are lost in the simplified representation available from models. I'll also discuss the generation of observational climatologies and try to make a case that providing distributions of cloud properties, or better yet joint distributions, allows for more robust comparisons with models. Finally, I'll suggest that using global models as a guide to how to produce climatologies can both illuminate and skew the choices made about the aggregation of large data sets.

Traceable and Uniform Climate Data Records

Rob Roebeling and Joerg Schulz

An overview is given of the activities currently going on within European Projects (CORE-CLIMAX, QA4ECV), within ESA-CCI clouds, and at NOAA/NESDIS to assess the transparency and maturity of Essential Climate Variable (ECV) climate data records (CDRs). A general overview is given of approaches defined to assess the capacity for the sustained generation of ECV CDRs with respect to the maturity of the CDR generation system, as well as the steps that can be taken to increase the transparency and evaluate the performance of an ECV CDR with respect to a specific application. Finally, some suggestions are made and discussed to improve the traceability and uniformity of the climate data records in the context of CREW.

ABSTRACTS - POSTER PROGRAMME

Version 12 February 2014

The determination of cloud top height using hyperspectral measurements in the oxygen A-band

A. A. Kokhanovsky, V. V. Rozanov, L. Lelli, M. Vountas, J. P. Burrows

There are several methods to determine the cloud top altitude from a satellite. They are based on the spaceborne lidar, radar, or radiometer measurements. The thermal infrared measurements (at the channels located at 11, 12, and around 14 micrometers) are the most frequently used to get the cloud altitudes. With these techniques, the cloud top height is often underestimated.

The future missions must combine the thermal infrared and optical measurements (e.g., hyperspectral measurements in the gaseous absorption bands) to have more accurate and reliable cloud top height products. The measurements of the degree of polarization of reflected light can be used as well. This is of special importance, when multi-layered cloud systems (say, thin Cirrus clouds overlying thick Stratocumulus cloud fields) are under study. As a matter of fact the multi-layered clouds occur with almost the same frequency as the single-layer clouds do. This fact is not accounted for in modern cloud retrieval algorithms based on the radiative transfer models for single-layered water or ice clouds.

In this work we apply the oxygen A-band spectrometry to get the physical cloud top height from the hyperspectral measurements as performed by SCIAMACHY, GOME, and GOME-2 instruments. The retrievals have been performed for the complete datasets of SCIAMACHY, GOME, and GOME-2 measurements (up till 2012). The retrievals are based on the fact that the high clouds screen the oxygen and make the oxygen absorption line as seen from a satellite in the reflectance spectra less pronounced. The asymptotic radiative transfer theory in the gaseous absorption band (with vertically varying single scattering albedo) valid for optically thick clouds is used in the retrievals. The retrieval method is thoroughly discussed. The results of the retrievals are compared against ground - based radar measurements. The comparisons with the cloud top heights derived from the thermal infrared measurements are also performed.

Multi-layered Cloud Parameter Retrievals: Developments and Improvements Using Passive Satellite Observations

<u>Fu-Lung Chang</u>, Patrick Minnis, Rabindra Palikonda, Sunny Sun-Mack, Yan Chen, Mandana Khaiyer, Douglas Spangenberg, and Christopher Yost

One of the challenges facing passive satellite cloud retrievals was the presence of multi-layered clouds, especially when ice overlapping water clouds occurred within the field of view of a satellite pixel resolution. In this study, we present a number of the multi-layered cloud parameter retrieval schemes that are feasible when applying to the different passive satellite observations. These include the MODIS, VIIRS, and AVHRR from the low-Earth-orbit satellites (LEOsat) and the SEVIRI and GOES series from the geostationary satellites (GEOsat). Work on the developments and improvements of these multi-layered cloud parameter retrievals has been continued and directed towards part of the enhancement of NASA Langley cloud algorithms and products. This presentation will show and discuss the highlights of our findings based on our study and evaluation of these multi-layered cloud products. It will also show and discuss the caveats and future improvements.

SEVIRI Cloud Product Collection 6 Updates

Galina Wind, Jerome Riedi, Steven Platnick, Andrew Heidinger

The GSF SEVIRI cloud top, optical and microphysical properties retrieval product has been extensively updated to coincide with MODIS Data Collection 6 operational production. The GSF SEVIRI cloud product shares source code with the MODIS cloud product via the CHIMAERA core, allowing for automated propagation of applicable science updates. We will show updated results, compare with MODIS and discuss operational production and SEVIRI cloud product availability from the ICARE system.

Climate Change in Ethiopia

Habtamu Adugna

Abstract: TBD

Version 12 February 2014

The location of inversion boundary layer clouds

Sauli Joro, Phil Watts, Hans-Joachim Lutz

Significant variations in the cloud top height (CTH) of inversion capped boundary layer clouds have been noted in CREW intercomparison exercises. One major cause is the dual solution allowed by the temperature profile - positions above and below the inversion can provide the same radiating temperature. More subtle effects may arise from the (e.g. forecast) temperature profile used; the height of the inversion or its temperature may be in error and the vertical resolution of the profile data may smooth the inversion location.

Amongst the CREW algorithms there are various approaches to handling these issues and whilst answers to some questions might be clear (e.g. that a boundary layer cloud top should lie within the lower mixed layer), others (e.g. is the cloud top always at the inversion cold point) are currently open. With the investigation here, we hope to clarify some of these issues and provide guidance to the design of algorithmic approaches to boundary layer cloud CTH estimation.

To support the investigation we use CALIPSO data and associated ECMWF profiles to characterise the CTH of boundary layer clouds in relation to characteristic feature points of the boundary layer inversion - the inversion base and top (where the temperature starts to increase and once more decrease, respectively). We use cloud optical thickness estimates derived from collocated SEVIRI data using the EUMETSAT OCA algorithm to investigate any correlation between cloud depth and the CTH - BL feature point relationship.

The CM SAF climate data records of cloud properties

M. Stengel, K.-G. Karlsson, J.F. Meirink

As one of its main objectives, the EUMETSAT Satellite Application Facility on Climate Monitoring (CM SAF) uses space-based observations from meteorological satellites to provide datasets of geophysical parameters suitable for climate analysis and monitoring. For this, recurring reprocessing efforts ensure enhancements in quality and stability of the datasets using latest retrieval developments and (inter-)calibration information. Related to clouds, the CM SAF activities are for the time being focus on datasets derived from passive imager measurements such as the 28-year record of AVHRR and the 8-year record of SEVIRI, as well as on the multi-decadal HIRS measurement record.

This presentation will introduce the cloud property datasets derived in CM SAF. It will further address specific issues associated with the generation of homogeneous and consistent datasets and indicate the validation efforts done to characterize the quality. Another substantial part of the presentation will address the interpretation of the data addressing climate related questions that might be answered using these datasets.

Evaluation results of the optimal estimation based, multi-sensor cloud property data sets derived from AVHRR heritage measurements in the Cloud_cci project.

S. Stapelberg, M. Jerg, M. Stengel, R. Hollmann and the Cloud_cci Team

In 2010 the ESA Climate Change Initiative (CCI) Cloud project was started with the objectives of generating a long-term coherent data set of cloud properties. The cloud properties considered are cloud mask, cloud top estimates, cloud optical thickness, cloud effective radius and post processed parameters such as cloud liquid and ice water path. During the first phase of the project 3 years of data spanning 2007 to 2009 have been produced on a global gridded daily and monthly mean basis. Next to the processing an extended evaluation study was started in order to gain a first understanding of the quality of the retrieved data. The critical discussion of the results of the evaluation holds a key role for the further development and improvement of the dataset's quality.

The presentation will give a short overview of the evaluation study undertaken in the Cloud_cci project. The focus will be on the evaluation of gridded, monthly mean cloud fraction and cloud top data from the Cloud_cci AVHRR-heritage dataset with CLARA-A1, MODIS-Coll5, PATMOS-X and ISCCP data. Exemplary results will be shown. Strengths and shortcomings of the retrieval scheme as well as possible impacts of averaging approaches on the evaluation will be discussed.

Recent improvements to the KNMI Cloud Physical Properties algorithm

<u>Gerd-Jan van Zadelhoff</u>, Jan Fokke Meirink

Within the Satellite Application Facility on Climate Monitoring (CM SAF), KNMI has developed the Cloud Physical Properties (CPP) algorithm. CPP retrieves cloud thermodynamic phase (CPH), cloud optical thickness (τ), cloud particle effective radius (re), and liquid/ice water path (LWP/IWP), and has been used for the generation of two long-term CM SAF datasets: CLARA-A1 (CLoud, Albedo, and RAdiation using AVHRR) and CLAAS (CLoud property dAtAset using SEVIRI). In the coming years new editions of these datasets will be produced with an improved set of algorithms and for extended time periods.

In this work the latest version of the CPP algorithm is discussed, specifically with regards to the updates which have taken place in comparison with the CPP version used for the CLARA and CLAAS datasets. The main topics discussed will be the generation of new look-up-tables and a new version of the cloud phase determination. In addition the effects of new input parameters (cloud top temperature and auxiliary snow and sea-ice fields) and smaller changes in the code will be described.

Update of the SEVIRI scene identification within the GERB processing for Edition 2

A. Ipe, E. Baudrez, N. Clerbaux, I. Decoster, S. Nevens, A. Velzaquez Blazquez

The first Geostationary Earth Radiation Budget (GERB) instrument was launched during the summer 2002 together with the Spinning Enhanced Visible and InfraRed Imager (SEVIRI) on board of the Meteosat-8 satellite. This broadband radiometer aims to deliver near real-time estimates of the top of the atmosphere (TOA) solar and thermal radiative fluxes at high temporal resolution thanks to the geostationary orbit. Such goal is performed at the Royal Meteorological Institute of Belgium by running the L20 GERB processing which generates these fluxes at several spatial resolutions from the directional filtered radiance measurements of the instrument. This processing consists of successive components, one of them being a radiance-to-flux conversion. Such conversion is carried out in the solar region by using information from a scene identification of SEVIRI data and the Earth and Clouds' Radiant Energy System (CERES) solar angular dependency models (ADMs) from the Tropical Rainfall Measuring Mission (TRMM) platform.

As the L20 GERB processing is being finalized for the Edition 2 reprocessing of the whole GERB dataset, we present here the various improvements which are being implemented in the cloud properties retrievals, i.e. cloud thermodynamic phase and cloud optical depth conversion lookup tables (LUTs). Furthermore, we also highlight the reorganization of the scene identification in terms of snow/ice and dust detection prior to any cloud properties retrieval scheme and the improvement of accuracy of the TOA solar fluxes when specific snow/ice and dust ADMs are used for the radiance-to-flux conversion instead of clear desert (for snow/ice) and cloudy (for dust) models.

Improvements in the Optimal Retrieval of Aerosol and Clouds (ORAC) system: Cloud-top correction for infrared measurements

Greg McGarragh, Don Grainger, Caroline Poulsen, Gareth Thomas, Adam Povey

ORAC (Optimal Retrieval of Aerosol and Cloud) is a generalized optimal estimation system that retrieves cloud or aerosol parameters using visible and infrared measurements from any of several satellite instruments. For cloud retrievals, measurements made in the infrared channels are most sensitive not to the cloud-top but to a vertical location within the cloud below the top depending on channel wavelength and the temperature profile. If unaccounted for, this vertical sensitivity will lead to retrieved cloud-top locations that are lower than the actual cloud-top and/or biases in other retrieval parameters such as optical thickness and/or effective radius. Ideally, within an optimal estimation framework, the forward model would be dynamically discretized in the vertical at an appropriate resolution to account for this effect. In the case for a satellite imager, due to the abundance of data and near-real-time processing requirements for NWP applications, a forward model based on an LUT is typically used. We show that in this case, assuming a cloud model and a lapse rate, the thermal infrared measurements may be corrected accounting for their vertical cloud penetration. Using this method, implemented within ORAC, we produce results using AATSR and MODIS measurements. We validate our results against the CALIPSO cloud profile product. Finally, we explore how the vertical sensitivity with wavelength in the infrared may be combined with sensitivity to particle size with wavelength to possibly provide some information on the vertical variation in particle size.

Information content analysis on cloud microphysics parameters from measurements of the future Multi-viewing, Multichannel, Multi-polarisation Instrument (3MI)

Guillaume Merlin, Jérôme Riedi, Laurent Labonnote, Céline Cornet

Cloud feedback remains one of the major source of uncertainties in future climate prediction (IPCC, 2007). In order to reduce this uncertainty, it is fundamental to accurately describe their properties so that their role in global climate models can be correctly understood. For several decades now, a number of different space borne instruments, with their specific observing characteristics, have been used to get this global vision.

The 3MI instrument, developed by ESA for the future EUMETSAT EPS-SG, leverages on previous POLDER missions and will provide multiangle measurements (up to 14 view) of the total and/or polarized light reflected by the Earth atmosphere system in 12 spectral bands (from VIS to SWIR). The 3MI instrument should provide opportunities to observe the links between the cloud structures and the anisotropy of the reflected solar radiation into space. Specific algorithms will be developed in order to take full advantages of these new capabilities.

Prior to these development, it is necessary to understand the limits and advantages of these new measurements for retrieving liquid cloud properties. Through information content analysis based on Shannon's theory, we propose to analyze the amount of information coming from each measurement (especially the SWIR channels) and how this information is spread out on clouds parameters. Two pieces of information will be explored to diagnose this new observing system, e.g. the posterior state vector covariance matrix as well as the total and partial degree of freedom in both measurement and state space.

Retrieval of Cloud Optical Properties and Their Application to Examinations of Cloud Life-Cycles

Jennifer Slobodda, Rene Preusker, Jürgen Fischer

To retrieve cloud optical properties we use the method first described by Nakajima and King (1990). As input data to our retrieval we use measurements from the Spinning Enhanced Visible and InfraRed Imager (SEVIRI) on the geostationary satellite Meteosat Second Generation (MSG). As non-absorbing channel we utilize 0.6µm or 0.8µm and 1.6µm as the absorbing one. The Matrix Operator Model (MOMO; Fell and Fischer, 2001) is used as forward operator. This is a radiative transfer code developed at the Institute for Space Sciences. It is capable of calculating radiative transfer in the shortwave and longwave spectral range. The retrieval provides us with cloud optical depth (COD) and effective radius (Reff). Further the liquid water content (LWC) can be estimated from both properties. First comparisons to data from the retrieval developed at the Royal Netherlands Meteorological Institute (KNMI) and to data from the Moderate Resolution Imaging Spectroradiometer (MODIS) show good agreement. Furthermore we made some comparisons of LWC to ground based measurements which show good agreement for the magnitude of LWC but defer in terms of temporal variations.

We use the retrieved values of COD and Reff to examine the life-cycle of convective cloud systems over Europe. We track a cell through series of SEVIRI images and examine the development of mean values of the cloud properties over time. First case studies show a growth of COD in developing parts of a cloud system while in decaying parts COD decreases and Reff increases.

Inter-comparison of cloud parameters between COMS and MODIS

<u>Haklim Choi</u>, Eunha Son, Eun-Jeong Cha

Through the analysis of satellite cloud is an important factor in severe weather and weather forecasts. Moreover, the inter-comparison of cloud parameter through various satellite is of very importance for understanding weak and strong points of various algorithms and also for further improvements of the retrieval and evaluation.

National Meteorological Satellite Center has started a regular service since April 2011, chollian meteorological satellite(COMS) cloud parameter(cloud phase,cloud type,cloud top height, cloud top temperature)are applicated in the analysis of nowcasting and forecasting. Futhermore, the quality assessment is conducted to the various cloud products within MODIS(AQUA and TERRA) and CALIPSO datasets.

We will briefly show results of examples of inter-comparison cloud parameters against MODIS and CALIPSO during May 2012 to April 2013.

DECADAL CLOUD TRENDS AS MEASURED BY THREE GENERATIONS OF HYPERSPECTRAL INFRARED SOUNDERS, AIRS, IASI and CrIS

Nadia Smith, Elisabeth Weisz, Paul Menzel, Bryan Baum

Hyperspectral infrared sounders have been in low-Earth orbit for more than a decade. They measure temperature, humidity and trace gas profiles, as well as surface and cloud parameters, such as height, optical thickness and emissivity. The University of Wisconsin-Madison hyperspectral retrieval system was developed to retrieve this full suite of parameters from all four operational hyperspectral sounders and aggregate them onto a regular space-time grid. The four sounders are AIRS (Atmospheric Infrared Sounder) on Aqua since 2002, IASI (Infrared Atmospheric Sounding Interferometer) on Metop-A since 2006 and Metop-B since 2012, CrIS (Cross-Track Infrared Scanner) on Suomi-NPP since 2011. In this paper we examine a decade of global trends in cloud height and frequency as measured by these sounders. We highlight the continuity that can be achieved in cloud products from these different instruments to allow a decadal global trend assessment. We then compare hyperspectral trends in cloud height and frequency with those derived from HIRS (High-Resolution Infrared Radiation Sounder) and ISCCP (International Satellite Cloud Climatology Project). This paper demonstrates the quality of information that hyperspectral sounders add to the decadal analysis of clouds.

Evaluation of Level-3 aggregation methods

Theo Steenbergen and Rob Roebeling

In order to assess the differences between level-2 to level-3 aggregation methods one month of MODIS level-2 data have been collected and used to derive level-3 monthly products of Cloud Top Pressure, Cloud Optical Thickness and Cloud Particle Size taking 4 different aggregation methods. The aggregation methods compared are the official MODIS method, the GEWEX Cloud Assessment method, the University of Wisconsin method, and the EUMETSAT prototype method. In the presentation the differences between the methods will be presented. In addition, we will show the effect of using different filtering rules, and different temporal and spatial resolutions.

The results reveal that level-3 products differ considerably, even when the input level-2 products are identical. The differences can be assigned to filtering rules (number of pixels required, cloud screening, quality flag handling, etc), to manned of accounting for the products frequency distributions (gaussian, bimodal, logarithmic, etc), to the resampling method (grid snapping, grid averaging, etc). It will be shown that differences are a function of the spatial location

Detection of multi-layer cloud situations

Hans-Joachim Lutz, Phil Watts, Sauli Joro

A major step in the derivation of the cloud top pressure (CTP) is the identification of multi-layer cloud situations. Within the CLA algorithm different methods to derive the CTP are applied (IR10.8 method, WV rationing method with WV6.2 and WV7.3, CO-2 method with IR13.4). The results of the different methods are analysed and compared. An inconsistency in the estimated heights together with the analysis of the effective cloud amount and the cloud phase implies the presence of multi-layer cloud. From this analysis a multi-layer cloud flag is derived and the final CTP is derived. The CLA multi-layer cloud flag will serve as an input to the Optimal Estimation (OE) retrieval.

The results of the CLA – CTP have been compared to those from the CPR estimates. In addition the multi-layer cloud flag has been compared to the Optimal Estimation (OE) method diagnostic solution cost.

Introduction of the Optimal Cloud Analysis for Himawari-8/-9

Masahiro Hayaschi

The Japan Meteorological Agency (JMA) is introducing the Optimal Cloud Analysis (OCA) developed by EUMETSAT for the next geostationary satellites “Himawari-8/-9”. Advanced Himawari Imager (AHI) on board Himawari-8/-9 will have 16 bands from visible to infrared range (3 near infrared, 3 visible and 10 infrared bands). High-qualified cloud parameters are expected by applying the optimal estimation method to the multiband data from AHI.

Currently, JMA is preliminary running OCA with MSG/SEVIRI data as a proxy of Himawari-8/AHI data. For the validation, outputs of JMA OCA are compared with CALIOP and MODIS products. The results will be discussed in the workshop.

Diurnal cycles of linear contrail coverage, cirrus coverage, and outgoing longwave radiation in the North Atlantic flight corridor derived from MSG and compared with MODIS

Kaspar Graf, Ulrich Schumann, David Duda, Pat Minnis

Linear contrail cover, cirrus cover, and outgoing longwave radiation are derived from the SEVIRI instrument aboard the MSG satellites for a period of eight years. The high temporal resolution of 15 min allows for analysis of the diurnal cycles of these quantities. Assuming functions which describe the mean effect of aviation onto the observed quantity and assumptions of the natural background diurnal cycle allows for an estimate of the aviation induced values of contrail coverage, cirrus coverage and longwave forcing in the flight corridor. Based on these results, global models can be applied in order to scale these observations to the globe.

The diurnal cycles of the abovementioned quantities are compared with linear contrail coverage values derived from MODIS aboard the polar orbiting satellites Terra and Aqua. In combination, Terra and Aqua provide contrail coverage values for four overpass times in the North Atlantic flight corridor which does not allow for resolving the full diurnal cycle. However, combining the LEO satellite results with the geostationary platform of Meteosat allows for check of consistency.

Linear contrail coverage observed by a polar orbiting instrument during a distinct overpass time can over- or underestimate the 24h mean contrail coverage, depending on the ratio of air traffic occurrence in a, e.g., 4h time window before the overpass time and the 24h mean value of air traffic occurrence. In order to analyze this effect, contrail coverage observed by MODIS is compared with predictions of contrail cover forecasted by a Contrail and Cirrus Prediction tool CoCiP.

NWCSAF PPS package v 2014: updates and prelimenary validation results

Anke Thoss, Nina Håkansson, Adam Dybbroe, Ronald Scheirer, Sara Hörnquist, Karl-Göran Karlsson; Jan-Fokke Meirink

The EUMETSAT NWCSAF PPS package is a processing package for cloud and precipitation products from polar orbiting meteorological satellite data. It aims primarily at processing AVHRR and VIIRS data and is used both for Nowcasting and Climate applications. For the 2014 version of the software, substantial updates have been implemented for Cloud Mask, Cloud Top Temperature and Height as well as Cloud Physical Properties Products. Our poster summerizes the updates, and presents level 2 validation results against CALIOP for cloud mask, Cloud Height and Cloud phase. Cloud Liquid water path over sea is validated against AMSR-E data. We aim to release the package to users in June 2014.

How much independent cloud information's could be measured with OLCI's Oxygen A band channels?

André Hollstein and Jürgen Fischer

A dataset of possible future measurements of the OLCI Oxygen A band channels was created using hyper spectral measurements from the instrument TANSO-FTS on board the GOSAT satellite. Using principal component analysis, the total number of independent information within the Oxygen A band at total OLCI spectral resolution was estimated. In addition, it is estimated how much of those information are contained in the data which is transmitted by OLCI.