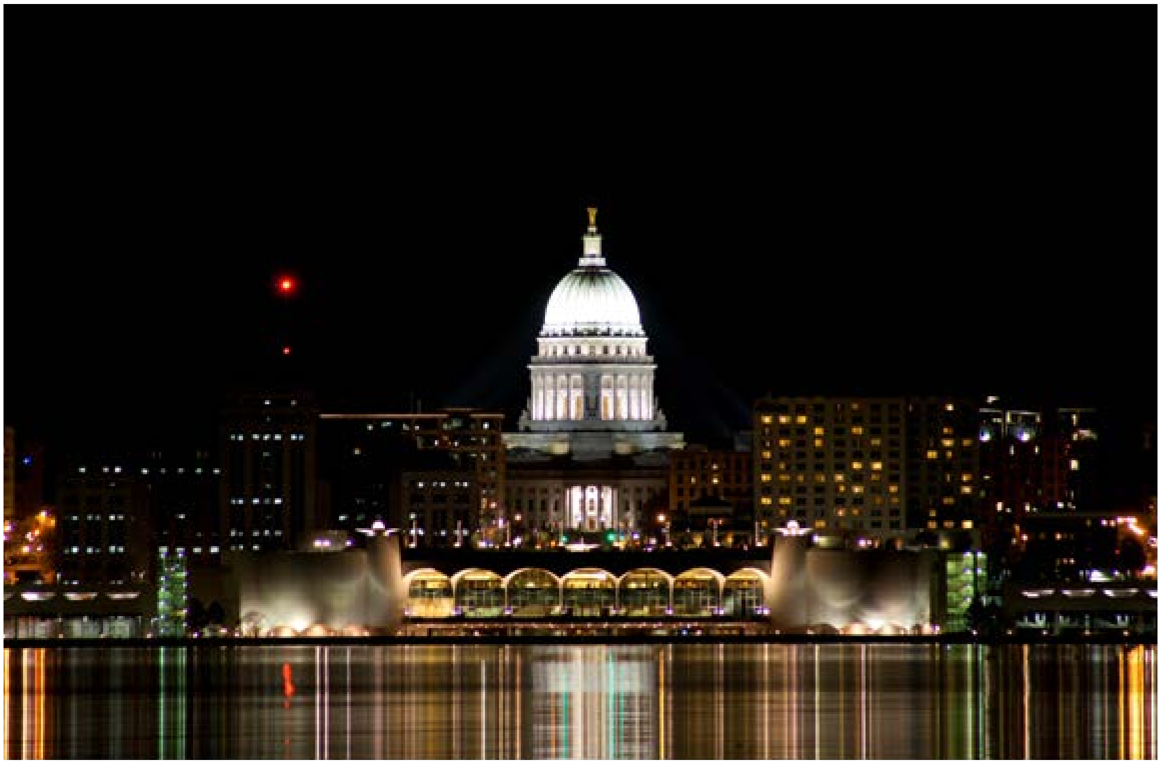
Abstracts

Third Cloud Retrieval Evaluation Workshop



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Organizing Committee

Bryan Baum, Ralf Bennartz, Ulrich Hamann, Andrew Heidinger, Rob Roebeling, Anke Thoss, and Andi Walther

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Cloud liquid water path of warm clouds from passive microwave and visible/near-infrared imagers

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Abstract

Passive microwave (PMW) and visible/near-infrared (VNIR) imagers both provide information about warm cloud macrophysical properties, in particular cloud liquid water path. The synergistic use of PMW and VNIR observations of warm clouds is therefore a promising research avenue not only to cross-validate the two techniques but also to ultimately better characterize warm clouds. However, various caveats and open issues exist. In particular the effects of precipitation contamination, PMW beam filling, and VNIR three-dimensional radiative transfer are currently not well understood and hamper the joint evaluation of PMW and VNIR observations. In this presentation the current state of the art will be summarized and an outlook on potentially important future research paths will be given.

MODIS Collection 6 cloud top height and IR thermodynamic phase

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Abstract

The participants of the CREW-3 workshop may be interested in research that led to improvements in the MODIS operational cloud top pressure/temperature and infrared (IR) thermodynamic phase algorithms for the upcoming MODIS Collection 6 activity. While the cloud top macrophysical parameters were provided through Collection 5 solely at 5-km spatial resolution, these parameters will soon be available at 1-km spatial resolution in Collection 6. The updated algorithms will first be implemented in the forward processing stream and subsequently will be applied to historical data, leading to a consistent, decadal set of cloud products. We will also discuss new parameters that will be provided in Collection 6, including cloud top height and a flag indicating stratospheric cloud detection, i.e., a deep convective cloud that overshoots the tropopause. Additionally, our new approach for determining low-level cloud height will be presented. The refinements to the cloud parameters are due primarily to consideration of two issues: (1) improvement to knowledge of the MODIS spectral response functions for the 15-μm CO_2 bands obtained through intercomparison with AIRS hyperspectral data, and (2) continual intercomparison of global MODIS and CALIPSO instantaneous cloud products throughout the course of algorithm refinement. Analysis of the match-ups of MODIS pixel-level properties and those from CALIPSO Version 3 products are used to quantify and explore the strengths and weaknesses of the MODIS Collection 6 cloud height and IR phase products.

Realistic simulations of MSG/SEVIRI scenes for cloud algorithm validation

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Abstract

Starting from consistent three-dimensional (3D) fields of temperature, pressure, water vapour, as well as of water and ice clouds from the operational numerical weather prediction model COSMO-DE of the German Weather Service, we have performed accurate radiative transfer simulations for MSG/SEVIRI both in three and one dimension. To obtain a spatial resolution suitable for 3D radiative transfer, a downscaling technique has been developed that yields a pixel size of 560\,m. Spectral characteristics of the surface as well as scattering and absorption properties of ice clouds, water clouds and aerosols are taken into account in a consistent way. Such dataset, where both radiation as well as physical properties are known, is extremely useful to develop, test and tune retrieval algorithms. Here we will apply our cloud retrieval algorithm APICS to such dataset and discuss the relevance of 3D radiative effects at the MSG/SEVIRI spatial scale. This is part of the results of a EUMETSAT Fellowship and the simulated radiances could be made available to CREW3 as an additional means to validate the participating cloud retrievals.

Synergistic MERIS-AATSR cloud properties retrievals using optimal estimation technique

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Abstract

The ESA Climate Change Initiative (CCI) has been initiated to respond to the need of reliable long-term satellite-based products for climate by generating Essential Climate Variables (ECVs).The main objective of the ESA Cloud CCI is to provide long-term cloud property data sets exploiting the synergy of different earth observation missions. Amongst the cloud ECVs are cloud cover, cloud top height and temperature, liquid and ice water path. Envisaged are two multi-annual global data sets for the GCOS cloud property ECVs including uncertainty estimates. The first set of cloud products will be developed from the so called heritage combined AATSR-AVHRR-MODIS dataset. The second merged cloud products will be developed from a combined AATSR-MERIS data set.

AATSR and MERIS are both passive instruments mounted on the ENVISAT satellite. They have fully overlapping fields of view, with the smaller nadir swath of AATSR centered in the swath of MERIS. In the reduced resolution mode, the spatial resolution of MERIS is similar to the nadir spatial resolution of AATSR (1 km2). They have slightly different observing geometries. MERIS only observes in the visible and near infrared wavelengths, while AATSR also observes at thermal wavelengths.

The main additional information about clouds provided by MERIS are the radiances measured within and close by the Oxygen-A band, at 754 nm and 762 nm, respectively. Oxygen is constant and well-mixed in the atmosphere and therefore can be used to estimate the average photon path length in the atmosphere. In cloudy situations this average photon path length is mainly determined by the cloud top pressure. The cloud top height can therefore 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 band. From previous sensitivity studies it was found that the cloud top pressure derived from MERIS measurements is highly accurate in cases of low single-layered clouds, but less accurate in cases of semitransparent cirrus or multi-layered clouds. In contrast, the cloud top height retrieval from AATSR is more sensitive to high and optically thin clouds, whereas the sensitivity is reduced for low clouds.

To provide error estimates on a pixel basis, the synergistic retrieval of cloud properties, such as cloud top height, cloud optical thickness and effective radius, from the combined MERIS-AATSR data set will be based on optimal estimation theory. Forward models for MERIS and AATSR measurements are developed using the radiative transfer models MOMO and RTTOV, respectively. Furthermore, a study is employed to investigate the use of the different sensitivities of MERIS and AATSR to different cloudy situations (e.g., multi-layered clouds) and how to introduce this information in an optimal estimation algorithm.

Using CALIPSO/CloudSat data to evaluate the multilayer cloud properties retrieved from MODIS and SEVIRI data

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Abstract

Passive satellite cloud algorithms generally retrieve single-layered cloud properties from the satellite observed radiances, while day-to-day observations of cloud vertical profiles from active sensing exhibit frequent occurrence of multilayer clouds. Thus, passive satellite retrieved single-layered cloud properties have faced a major challenge when multilayered clouds occurred in the satellite observed fields of view. The task, to be able to retrieve multilayered cloud properties using passive satellite data, is critical in order to have better understanding of the role of clouds on regional and global water and energy cycles. We have developed a multilayer cloud retrieval algorithm that is applicable to the passive satellite sensing data like those from the Moderate-resolution Imaging Spectroradiometer (MODIS), the Spinning Enhanced Visible and InfraRed Imager (SEVIRI) and the Geostationary Operational Environmental Satellite-East (GOES-East). The algorithm uses multi-channel visible-to-IR radiance measurements, including the CO2-absorption channel, to retrieve overlapped upper- and lower-layer cloud properties if a pixel contains multilayered clouds. The algorithm is currently used in the Edition 4 version of the Cloud and Earth's Radiant Energy Systems (CERES) retrieval from the MODIS data to test and explore on the potential multilayered cloud problems. Two objectives of this presentation are 1) to present our multilayered cloud property retrievals from the MODIS and SEVIRI data and 2) to evaluate our MODIS and SEVIRI derived multilayered cloud properties by comparing to two active satellite sensing data retrieved from the Cloud Aerosol Lidar and Infrared Pathfinder Satellite Observation (CALIPSO) and CloudSat radar.

DARDAR: CloudSat and CALIPO synergy product for cloud studies

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Abstract

The aim of the **DARDAR** (ra**DAR**/li**DAR**) project is to retrieve cloud properties by combining the CloudSat radar and the CALIPSO lidar measurements. This project originates from the collaboration between the LATMOS in France and the Cloud Group of the Department of Meteorology, University of Reading. The entire period of CloudSat and CALIPSO is available at the French data Centre **ICARE** in Lille (www.icare.univ-lille1.fr).

- The **DARDAR** project is based on two products: The **DARDAR-MASK** product provides on the same grid CloudSat/CALIPSO/MODIS measurements and their associated errors and an optimized merge mask that any synergistic algorithm could use as inputs. The radar-lidar combination is also very useful for distinguishing cloud phase, for instance the radar is mainly sensitive to ice (larger diameters) while the lidar is more sensitive to liquid water (higher concentration). This is very useful for identifying supercooled layer from ice clouds. The product also incorporates a simplified and a detailed categorization.
- The **DARDAR-CLOUD** product contains the ice cloud properties, such as extinction, ice water content, effective radii and related vertically integrated properties (including their associated errors) retrieved using a synergistic variational algorithm (Delanoe and Hogan 2008 and 2010). We can infer the vertical distribution of detailed cloud properties since the radar and lidar backscatter are proportional to very different powers of particle size, so the combination provides accurate particle size with height and hence more accurate cloud properties than with just one instrument. Furthermore, the radar can penetrate deep ice cloud while lidar cannot but due to its higher sensitivity can identify very thin ice clouds. It is therefore possible to retrieve cloud properties seamlessly between regions of the cloud detected by both radar and lidar, and regions detected by just one of these two instruments.

We will present briefly the **DARDAR** products and illustrate, with a few examples, how they can be used to, carry out cloud climatologies and also evaluate the distribution of IWC and ice cloud fraction in the ECMWF and UK Met Office models.

Cloud analyses with passive satellite imagery viewed from the radiative perspective

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Abstract

Passive satellite imagers provide a unique view on clouds and their role in the climate system. While current and upcoming active satellite sensors offer more direct information about clouds, they cannot yet rival passive observations in terms of spatial and temporal coverage, and availability for climatologically significant time periods. Hence, it is of importance to further to improve and extend current methods to analyse passive satellite imagery, and to gain scientific insights into cloud properties and processes.

Current cloud retrievals are based on the inversion of forward models which contain significant simplifications of reality. In this contribution, we argue that it can be beneficial to adopt a perspective more focused on the observed reflectances and the radiative effects of clouds instead of retrieval results.

In support of this claim, we present an intercomparison of the Cloud Physical Properties retrieval developed within the Satellite Application Facility on Climate Monitoring and the official MODIS cloud products. We argue that by adopting reflectances instead of cloud properties as a metric for the intercomparison, we avoid difficulties in the interpretation caused by non-linearities in the retrieval. Thus the analysis of the origin of differences is facilitated. Additionally, we demonstrate that 2D histograms of satellite-observed reflectances provide a fast and convenient means to capture the climatological effects of clouds over chosen time period. Instead of relying on climatologies of retrieval products, we invoke the retrieval only as a conceptual model for the interpretation of these 2D histograms. From this perspective, the effects of problematic retrieval assumptions become more evident, and are not only excluded as in the case of invalid retrievals. This approach is applied to study the uncertainties introduced by assumptions about ancillary datasets such as surface albedo and cloud masking algorithms.

The calibration of geostationary visible sensors using MODIS as a reference

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Abstract

One important aspect of successful climate monitoring is satellite calibration. There is at least a 25-year of operational geostationary (GEO) record available for climate studies, if properly calibrated. The Global Space-based Inter-Calibration System (GSICS) project is another effort to provide the climate community consistent calibration across multiple platforms. Also, the Clouds and the Earth's Radiant Energy System (CERES) project, provides consistent GEO retrieved cloud properties and derived broadband fluxes across multiple platforms. Both GSICS and CERES visible calibration strategy is to use consistent multiple independent approaches using Aqua-MODIS band 1 as the absolute calibration reference. Using simultaneous nadir overpasses, Terra-MODIS was put on the same radiometric scale as Aqua. The MODIS calibration is transferred to geostationary satellites using coincident ray-matched radiances from both Terra and Aqua. The stability of the transferred calibration is validated using deep convective clouds and desert targets. The channel spectral differences are taken into account using SCIAMACHY hyper-spectral radiances. This CERES project uses this technique to provide seamless cloud retrievals across geostationary domains. The presentation will highlight the SEVIRI calibration of all three visible bands and the calibration application with AVHRR.

SAFNWC / MSG cloud products

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Abstract

Within the SAF in support to Nowcasting and Very Short Range Forecasting (SAF NWC), Météo-France has developed a 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 and second Eumetsat cloud workshop in 2006 and 2009. Since the last Eumetsat cloud workshop in 2009, the cloud algorithms implemented in the SAFNWC/MSG software package have been upgraded: the cloud detection has been improved by the use of the high resolution visible channel (HRV) and by reducing false alarm in night-time over cold snow-covered grounds; the confusion between low and mid-level clouds has been deduced; a cloud phase retrieval has been implemented.

This paper focuses on the new features of the SAFNWC/MSG cloud algorithms that have been implemented since the second Eumetsat cloud workshop in 2009 (v2010 and v2011 of the SAFNWC/MSG software package) and also presents validation results extended over the full MSG disk obtained from SYNOP/SHIP observations and space-borne lidar measurements.

Improved methods for and validation of nighttime cloud property retrievals from SEVIRI, GOES and MODIS

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Abstract

Improvements to the algorithms used at NASA Langley Research Center (LaRC) to retrieve both macrophysical and microphysical nighttime cloud properties will be presented and discussed. Variations of these techniques are applied to nighttime SEVIRI, GOES and MODIS data as well as to simulated nighttime data obtained from daytime thermal channels with any solar contributions removed. The daytime data not only allow for consistency checks across the terminator, but also greatly increase the validation possibilities when used as simulated nighttime datasets, including the ability to compare to other daytime satellite-based retrievals that are normally derived only with the assistance of non-thermal channels, including LaRC's Visible Infrared Solar-infrared Split-window Technique (VISST). Additionally, more deep-dive validation opportunities are available during daytime hours when instruments in field programs and at surface sites are more apt to produce data.

State of the NOAA AWG cloud algorithms

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Abstract

Since the last CREW Workshop, the NOAA AWG Cloud Algorithms have continued to improve. This development has been directed towards the requirements of the GOES-R program and by lessons learned in the PATMOS-x climate processing. This talk will highlight the developments how they impacted the NOAA AWG data submitted to CREW. In particular, the Daytime Cloud Optical and Microphysical Properties (DCOMP) and AWG Cloud Height Algorithm have improved.

Evaluation of MISR Stereo cloud-top height retrievals

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Abstract

The Multiangle Imaging SpectroRadiometer (MISR) offers a unique dataset of cloud-top heights derived by locating the same cloud features at different viewing angles. Because the stereo technique is purely geometric, retrievals are insensitive to forecast temperature profiles and absolute radiometric calibration. The MISR cloud-top height algorithm involves two steps. First, mesoscale (70.4-km) cloud-motion vectors, or 'winds,' are estimated by tracking clouds in the nadir and two oblique views (usually 46° and 70°). The current operational processing uses the fast but noisy Nested Maxima feature matcher for wind retrieval. Second, high-resolution (1.1-km) cloud-top heights are calculated by locating clouds in the nadir and near-nadir (26°) views and correcting the retrieved parallaxes for cloud motion using the previously obtained wind vector. This second step employs an area matcher for cloud tracking. Overall, the algorithm requires precise image co-registration and an accurate estimate of the component of the wind in the direction of satellite motion (along-track). The latter requirement arises due to the strong coupling between cloud height and cloud motion in the along-track direction, which yields an average sensitivity of ~90 m height error per 1 m/s along-track wind error.

The MISR TC_STEREO product includes cloud-top heights in two flavors: "BestWinds" and "WithoutWinds". The BestWinds data are only calculated when there exists a good quality wind retrieval for the cloud-top height pixel under consideration, and this wind is used to adjust the retrieved cloud-top height. WithoutWinds cloud-top heights, on the other hand, contain a valid value for every pixel where the stereo matchers produced a result, but assume no wind correction. The current wind retrieval stereo matching algorithm is rather noisy with relatively poor coverage of good quality winds, which results in poor coverage for the BestWind cloud-top heights. Additionally, we discovered that a focal plane distortion that was modeled but not validated with real data leads to a cross-swath bias in the wind retrievals that feeds through to the BestWind heights. The MISR team is working on a new version of the MISR Stereo algorithm that is expected to correct these problems (Kevin Mueller and Veljko Jovanovic, both of JPL, are acknowledged for doing the bulk of the work on the upgrades). We present an analysis of cloud-top heights from both the current operational and the new improved algorithm; however, we only provide validated operational data to the workshop archive.

Synergetic cloud top height retrieval for a passive and an active sensor

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Abstract

The intent of the present study is to combine active and passive measurements to derive a synergetic cloud top height (CTH). The ESA's cloud and aerosol mission EarthCARE is the first satellite mission, which will provide measurements from active sounder and passive imager from one platform. The active backscatter lidar (ATLID) will provide vertical profiles of cloud and aerosol parameters with high spatial resolution. The lidar instrument measures in nadir view, while the passive multi-spectral imager (MSI) has a swath of 150km and a pixel size of 500m. The cloud top height from ATLID will have higher accuracy compared to the cloud top height retrievals from passive instruments. This is true especially for high level cirrus and mid-level altocumulus, which typically stretch over hundreds of square kilometres.

A combined retrieval will be developed which uses the precise cloud top height information from ATLID profiles to adjust the MSI cloud top height product over the entire swath. The stand-alone CTH retrievals from ATLID and MSI are collocated for the nadir pixel and a synergetic product are derived. In a second step, corrections are applied to the whole MSI swath. The synergetic approach is investigated for a large set of cloud data covering a broad variety of atmospheric scenes. We differentiate each cloud observation into a cloud classes based on observations from MSI. With this dataset we will test the calculation of the synergetic cloud top height for the entire MSI swath based on empirical correction.

MODIS on AQUA and CALIPSO built the database for this work. MODIS provides observations similar to MSI. From the CALIOP lidar onboard CALIPSO the 1064-nm elastic backscatter signal is valid as a substitute for the ATLID 355-nm co-polar Mie signal. The 1064-nm signal has a negligible Rayleigh contribution and thus a similar shape in the presence of clouds as the Rayleigh-free filtered ATLID 355-nm co-polar Mie signal.

A MSG/SEVIRI simulator for the validation of climate models

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Abstract

We present a simulator that converts 3-dimensional model cloud fields to 2-dimensional satellite observations. The simulator was used to investigate the retrieval errors in the CPP algorithm in a systematic way, taking into account a large range in cloud optical thickness and surface albedo, as well as variations in cloud cover and multilayer, multiphase clouds. Furthermore we present the application of the simulator to the KNMI regional atmospheric climate model (RACMO), where it was used to derive synthetic satellite images from model scenes to fascilitate a direct comparison of model clouds with observations.

New AIRS Version 6 cloud retrievals: Cloud thermodynamic phase, cirrus cloud optical thickness and effective diameter

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Abstract

We will summarize the development of a new set of cloud products to be produced by the Version 6 AIRS algorithm. These products include (1) cloud thermodynamic phase, (2) cirrus cloud optical thickness, and (3) cirrus cloud effective diameter. The retrieval methodology, error characterization and challenges to operational implementation will be discussed, and some initial results will be presented. We will also make comparisons to collocated Aqua MODIS retrievals and highlight the morphology of geophysical scenes in which agreement and disagreement is found.

Adding uncertainty information to cloud mask products – impact on Level 2 and Level 3 products

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Abstract

Cloud screening in satellite imagery is still a fundamentally important topic for all image-based applications ranging from Nowcasting to environmental and climate monitoring. The efficiency and accuracy of cloud screening is decisive for the quality of individual cloud products as well as for any non-cloud product retrieved down-stream in the processing chain. A particular problem here is that there is no general consensus regarding how to define a cloudy pixel. For example, some applications aim at deriving various surface properties (e.g. Sea Surface Temperatures - SST) and are seriously affected even with the slightest contamination by sub-pixel clouds in a pixel. In contrast, other applications (e.g. cloud property retrievals) need generally completely cloud-filled pixels for being able to make reliable retrievals that are not too contaminated by radiation from other radiation sources within the field of view. This explains why there are still a multitude of different cloud screening algorithms available connected to various applications and user requirements.

There are several ideas on how to make the cloud screening process more generalized so that more than one user requirement can be satisfied and with the side effect that uncertainty information is also made available. This topic will be discussed in a presentation at the EUMETSAT Satellite Conferences in Oslo in September 2011. At the CREW-3 meeting, results will be shown based on the same kind of methods but applied to some of the cases included among the CREW-3 study days. The derived probabilistic information will be evaluated using information from CloudSat and CALIPSO satellite datasets. Furthermore, the methods' potential to facilitate the description of how cloud masking uncertainties affect Level 2 products further downstream in the processing will be discussed as well as the importance for the Level-2 to Level-3 calculation process.

GEWEX cloud assessment: A review

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and GEWEX cloud assessment Team W.B.Rossow, C.Pearl, A Heidinger, A.Walther, A.Guignard, S.Ackerman, S.Platnick, B Maddux, P.Minnis, S Sun-Mack, L.DiGirolamo, A Menzies, P.Menzel, E.Olsen, J.Riedi, S.Zeng, D.Winker, B.Getzewich, H.Chepfer, G.Cesana, C.Poulsen and A.Sayer

Abstract

Clouds play a key role within the weather and climate system of the Earth, controlling the radiation budget and the water cycle. Only satellite observations provide a continuous survey of the state of the atmosphere over the whole globe. Initiated by the GEWEX Radiation Panel, the available global cloud data records have been assessed, and a common data base of cloud property statistics, including monthly averages, variability and distributions, has been created. This data base, together with the description of the twelve participating data sets, should facilitate climate studies and the evaluation of climate models, and will be shortly made available at: http://climserv.ipsl.polytechnique.fr/gewexca/.

GEWEX cloud products are provided by the International Satellite Cloud Climatology Project (ISCCP), using data from a combination of polar orbiting and geostationary imagers. There are two cloud analyses (HIRS-NOAA and TOVS Path-B) using TIROS-N Operational Vertical Sounder Operational (TOVS) observations onboard the NOAA polar orbiting satellites. The relatively high spectral resolution of these instruments provides reliable cirrus identification, day and night. Recently, the NOAA PATMOS-x project has reanalyzed the Advanced Very High Resolution Radiometer (AVHRR) data onboard the same satellites. The NASA Earth Observing System, with the satellites Terra and Aqua, includes the second generation instruments MODIS (Moderate Resolution Imaging Spectro-radiometer) and AIRS (Atmospheric Infrared Sounder). Methods to retrieve cloud properties from MODIS observations have been developed by the MODIS Science Team and by the CERES Science Team. Complementary cloud information is obtained by the active instruments aboard the A-Train: the lidar of the CALIPSO mission and the CloudSat radar, giving for the first time a global insight on cloud layering, and the POLDER (Polarization and Directionality of the Earth's Reflectances) instrument gives insight on the phase of clouds. Whereas passive remote sensing essentially provides information on the uppermost cloud layer, the comparison with cloud amount and top height determined from MISR (Multi-angle Imaging SpectroRadiometer) observations leads to some estimation of the clouds underneath. The recently developed cloud data record of the ATSR (Along-Track-Scanning Radiometer) - GRAPE project has also participated in the assessment.

Climatological averages of cloud properties, their regional, seasonal and diurnal variations as well as time series of these climatologies will be presented. One outcome of this study was, that the different datasets compared better when high-, mid- and low-level cloud amounts were scaled by total cloud amount. This approach might also be useful for comparisons with climate models. About 40% of all clouds are high clouds (with a cloud pressure smaller than 440 hPa) and about 40% of all clouds are single-layer low-level clouds (with a cloud pressure larger than 680 hPa). Differences can be mostly understood by different instrument sensitivities to thin cirrus: the active lidar CALIPSO is the most sensitive instrument to very thin cirrus (50%). The relatively high spectral resolution of IR sounders (TOVS/HIRS and AIRS) makes them the passive instruments most sensitive to cirrus (40%), but already the use of NIR channels during day can increase the sensibility to thin cirrus, as demonstrated by PATMOS-x and MODIS-CE. Latitudinal variation and seasonal cycle agree very well (except for polar regions).

Retrieval of cloud properties using synthetic datasets

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Abstract

The inter-comparison of various cloud retrieval algorithms using synthetic datasets is of great importance for understanding weak and strong points of various algorithms and also for further improvements of the retrieval techniques. With this in mind, we have performed the inter-comparison study of cloud property retrievals using algorithm initially developed for AATSR (ORAC, RAL-Oxford University), AVHRR(CPP, KNMI), SCIAMACHY(SACURA, University of Bremen), and MERIS(ANNA, Free University of Berlin). The results of retrievals of cloud optical thickness(COT), effective radius(ER) of droplets, and cloud top height(CTH) have been inter-compared in the framework of ESA Cloud CCI Project. Generally, the codes produced similar results. Although they are based on different methods to solve the inverse problem. In particular, ORAC is based on optimal estimation approach using fitting for all AATSR channels simultaneously. CPP uses the iteration approach, where COT is determined from a visible channel for an assumed ER and then ER is retrieved the near IR channel using derived COT. The process is stopped if the convergence is reached. The cloud top height is found using measurements at 11 μm SACURA is based on the asymptotic solutions of the radiative transfer equation and parameterizations of results derived from Mie theory. It makes it possible to derive the cloud optical thickness from the visible channel analytically (for arbitrary surface reflectance). The derived value of COT is used in the analytical expression for the reflectance in the near-infrared to derive the value of ER from the solution of a corresponding transcendent equation using Brent's method. Artificial Neural Network Algorithm (ANNA) developed at Free University of Bremen is aimed at determination of CTH and COT using MERIS observations. Neural networks are able to reduce the size of required database, which is of particular importance for the calculation inside gaseous absorption bands (e.g., in the oxygen A-band as used in ESA MERIS operational cloud retrieval). ER can not be retrieved in this case because MERIS does not measure the solar reflected light in the near infrared. The determination of CTH is based on the fact that high clouds screen larger amounts of tropospheric oxygen as compared to low clouds, leading to shallow absorption bands seen in the reflectance spectra around 760 nm. The same approach is used by SACURA as applied to SCIAMACHY (in the framework of the asymptotic radiative transfer theory).

The synthetic dataset was created using the radiative transfer code SCIATRAN, which is the vector radiative transfer model operating in UV-TIR. The SCIATRAN was checked against calculations using other codes and differences well bellow 1% have been found, which is smaller than the calibration error of respective satellite instrumentation. In synthetic calculations, the CTH was varied in the range 2-12km, ER was changed from 4 to 20 μm, COT was in the range 1-100 for various viewing and illumination conditions and underlying surface albedo. It was found that errors in COT and ER are below 20% in most of cases for all codes except ANNA. The failure of COT retrievals using ANNA in some cases (generally, the overestimation of COT) is due to the absence of near IR channels in MERIS setup. The error of CTH retrieval is in the range 0.5-1.0 both for TIR and O_2 A-band retrievals with general tendency for the underestimation of CTH.

Accuracy assessment of SEVIRI cloud detection and cloud top height retrievals using active remote sensing data from CloudSat and CALIPSO

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Abstract

The Satellite Application Facility on Climate Monitoring (CM-SAF), as part of EUMETSAT's SAF network, provides satellite-derived data sets of energy and water cycle related geophysical parameters and thereby contributes to the operational monitoring of the climate system. The CM-SAF product suite encompasses amongst others several cloud parameters derived from the Spinning Enhanced Visible and Infrared Imager (SEVIRI) radiometer on board the METEOSAT Second Generation (MSG) satellites. The aim of this study is to explore and quantify the accuracy of the SEVIRI cloud mask and cloud top height products as operationally generated by the CM-SAF using algorithms provided by the „SAF in Support to Nowcasting and Very Short-Range Forecasting" (NWC-SAF). To this end coincident profiles of vertical cloud structure from the CloudSat Cloud Profiling Radar (CPR) and the Cloud- Aerosol Lidar with Orthogonal Polarization (CALIOP) on board the CALIPSO (Cloud- Aerosol Lidar and Infrared Pathfinder Satellite Observation) satellite are compared to the SEVIRI cloud products for a four month data set including the months January, April, July and October 2009. Clear sky and cloud frequency statistics are calculated on a monthly basis for the three instruments both for the entire match-up data set and separately for different cloud types in order to assess the strengths and weaknesses of the SEVIRI cloud mask. Furthermore, bias and variability in cloud height differences serve as quality indicators for the SEVIRI cloud top height retrievals. Both indicators are found to depend on cloud height and type as well as on whether CloudSat or CALIPSO is used as reference.

Multi-layer cloud detection within the SCE/CLA algorithm

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Abstract

We report on progress made since CREW II with EUMETSAT's cloud detection and cloud analysis scientific algorithm (SCE/CLA) applied to MSG-SEVIRI observations.
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 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 (see presentation of Phil Watts).

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.

In addition we shall report briefly on the progress in other areas of the SCE/CLA algorithm, i.e.: low-level CTP derivation in situations with inversions, progress in using emissivity information for the cloud detection, detection of volcanic ash.

Optical property cloud phase retrievals for MODIS Collection 6: Assessment from CALIOP/CALIPSO

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Abstract

Moderate Resolution Imaging Spectroradiometer (MODIS) retrieval of cloud thermodynamic phase is an important first step in the MODIS optical retrievals algorithm. Since water and ice particles have very different scattering and absorption properties, an incorrect phase can lead to substantial errors in the retrieved cloud optical thickness and/or effective particle radius. There are currently two inferences of cloud phase in the MODIS Collection 5 cloud products based on: (1) bispectral IR tests, and (2) a ‘decision tree’ that combines the IR bispectral result with shortwave IR (SWIR) reflectance ratios and cloud mask tests. The latter is currently used in processing MODIS cloud optical properties. Theses phase tests present however a number of shortcomings, especially for optically thin cirrus, multilayered clouds (such as thin cirrus over lower-level water clouds), mixed phase clouds, and single layered clouds at supercooled temperatures. So, to improve the cloud phase retrievals for the next MODIS Collection 6, we have replaced the SWIR tests based on thresholds of ratios between SWIR and VIS/NIR reflectances with thresholds based on separate ice and liquid cloud effective size retrievals in different SWIR MODIS spectral bands. In addition, we are also testing use of a new tri-spectral IR test.

We will briefly introduce the MODIS Collection 6 cloud optical phase algorithm improvements and show examples of comparison between cloud optical phase retrievals from MODIS/AQUA and CALIOP/CALIPSO.

Using MSG-SEVIRI for the inter-calibration of visible and near-infrared reflectance from polar imagers

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Abstract

Accurate calibration of passive imagers is prerequisite to the generation of thematic climate data records. For the retrieval of cloud optical and microphysical properties especially the visible and near-infrared channels are of major importance. SEVIRI is the first geostationary satellite instrument with multiple narrow-band channels in the shortwave range. In this study we calibrate the SEVIRI 0.6, 0.8 and 1.6 μm channels towards corresponding MODIS channels. The rationale for this is that MODIS is expected to have a better absolute accuracy because of its onboard calibration system.

The calibration approach is to (i) gather collocated, ray-matched reflectances from both instruments, (ii) correct these for differences in spectral response, and (iii) perform linear regressions to determine calibration slopes. In this presentation we will show that SEVIRI reflectances are quite stable over the period 2004-2010 with respect to MODIS. The differences between the calibrations of Meteosat-8 and Meteosat-9 appeared to be smaller than 2%. However, calibration offsets of up to 7% are found dependent on the channel.

In future research we intend to explore the use SEVIRI for the inter-calibration of polar imagers such as AVHRR and MODIS by a double difference technique. Compared to the traditional simultaneous-nadir-overpasses technique this has the advantage that the calibration analysis is not restricted to high latitudes, where solar zenith angles are high.

Recalibrating and reprocessing the HIRS data to infer global cloud properties and trends

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Abstract

The frequency of occurrence of tropospheric clouds has been extracted from NOAA/HIRS polar orbiting satellite data using CO2 slicing to infer cloud amount and height. The HIRS sensor has been flown on fifteen satellites from TIROS-N through NOAA-19 and METOP-A forming a 30-year record. In order to address issues affecting sensor to sensor radiance calibration and calculation 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 (SNO) are being used to intercalibrate the HIRS sensors before IASI. Thirty year trends in cloud cover and high cloud frequency have been reprocessed.

Updated NASA Langley cloud property retrievals

Patrick Minnis, Rabindra Palikonda, Fu-Lung Chang, William L. Smith, Jr., J. Kirk Ayers, Kris Bedka, Robyn Boeke, Yan Chen, Patrick Heck, Szedung Sun-Mack, Yuhong Yi, and Christopher Yost

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Abstract

An initial set of cloud properties was derived for a limited set of Meteosat data for the Second Cloud Retrieval Workshop in Lucarno, Switzerland using algorithms developed at NASA Langley Research Center (LaRC) for near-real time cloud retrievals. Since then, a number of improvements and advances in the algorithms have been realized. These include more accurate atmospheric corrections, multi-layer cloud properties, cloud base and height estimates, improved cloud retrievals over snow surfaces, and a new cloud ice particle model among others. This paper will present the results for the Meteosat, MODIS, and AVHRR data provided for comparisons with other algorithms. Changes in the algorithms and results will be discussed.

An enhanced cloud classification scheme based on radiative transfer simulations and aggregated ratings

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Abstract

The purpose of this study is to enhance existing cloud masking algorithms dedicated to AVHRR data. A number of schemes utilize a so called “branching approach” which involves a yes/no decision process after each test. This significantly limits the number of possible pixel states to 0 and 1 and hinders the measurement of confidence in acquired classification results. In order to overcome these issues, some algorithms utilize a numerical score function which provides a continuous set of values. This function is constructed in such a way that positive values are assigned to overcast pixels, while negative values correspond to cloud-free pixels. Single scores from each test are then aggregated (summed) into a final rating, which fully reflects the state of a pixel. Nevertheless, for both described approaches, the entire decision process is usually based on predefined threshold values which were empirically determined for certain regions during spectral measurement field campaigns or were defined by means of radiative transfer (RT) simulations. Often these thresholds account for a variety of environmental conditions, which result in incorrect pixel classifications for a particular satellite scene. The spectral response registered on the scene depends on a distinct set of conditions: atmospheric gas and aerosol concentration, illumination conditions, and cloud properties (droplet radius and shape, cloud optical depth, and phase). All of these factors influence the accuracy of cloud discrimination and thus should be accounted for in the thresholds values.

In this study a novel algorithm is proposed that capitalizes on previous “branching approaches” (chiefly on the Cloud and Surface Parameter Retrieval (CASPR) System for Polar AVHRR, Key et al.) and incorporates the aggregated score to allow the end-user to specify the desired level of confidence in a retrieved cloud mask. Moreover, the threshold/parameters of the score function are tuned by means of the “Streamer” radiative transfer code considering current environmental conditions. Tight constraints are put on the parameters which may be derived from auxiliary data (solar/satellite geometry, land cover) and atmospheric models (atmospheric concentration of gases and aerosols). More relaxed constraints are related to unknown cloud properties (droplet radius, shape, phase, optical depth, etc.). The RT simulations are performed for a limited number of boundary conditions in order to create a set of look up tables (LUT). Optionally, the temporal information retrieved from a time series can be incorporated. The final classification results are compared with a cloud mask computed with the CASPR algorithm, as well as cloud cover data retrieved from the CALIPSO satellite. The methodology proposed can be applied to a wide range of satellite sensors by adjusting the radiative transfer model and modifying/adding some spectral tests. This is a prerequisite for a 25-year cloud time series based on NOAA-AVHRR data – the main objective of this study.

LaRC real-time satellite derived products: Overview, applications and limitations

Rabindra Palikonda[1] Patrick Minnis[2] W.L. Smith, Jr.[2], Douglas A. Spangenberg[1], B. Shan[1], Thad Chee[1], J. Kirk Ayers[1], Mandana M. Khaiyer[1], Michele L. Nordeen[1], Louis Nguye[2], C. Fleeger[1], Qing Z. Trepte[1], Fu-Lung Chang[1], and Patrick W. Heck[3]

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Abstract

At NASA Langley, we have been producing real-time satellite derived microphysical properties from geostationary satellite for more than 5 years. The algorithms and the science of understanding clouds have matured over the years resulting in improved cloud products. Satellite derived cloud products are gaining popularity in model assimilation and now-casting applications as these properties improve the model performance. NASA Langley's (LaRC) North American domain cloud products from GOES 11 and GOES-13 are currently assimilated in the operational Rapid Refresh model (RR) from NOAA and the developmental CIP model at NCAR to better forecast icing condition for the aviation community. We recently started including data from the sun-synchronous MODIS data on Terra and Aqua to cover regions beyond 60°N to mitigate the viewing angle limitations of GOES. Similarly, real-time satellite cloud products from the full-disk geostationary satellites, GOES-11, GOES-13, METEOSAT-9, MTSAT-2R, FY2D/E are merged together to derive 3-hourly global products between 60°N to 60°S. A new collaborative project started with NASA Goddard to assimilate the Langley products in the Goddard Earth Observing System Model (GEOS-5) analysis to improve the forecasts. Additionally real-time satellite cloud products are available over multiple regional domains from GOES, Meteosat, and MTSAT at high spatial and temporal resolution centered over ground sites and used to validate our algorithms by comparing with measurements from ground-based instruments. Our products are also used to support field experiments like SPARTICUS, CALNEX, and STORMVEX in daily mission planning operations and post-experiment science analyses. This poster presents an update of our real-time products and their current application in model assimilation and nowcasting. Tools to view our data on the web and download them, in user-friendly formats like netcdf etc. are also shown.

Cloud phase determination using infrared absorption optical depth ratios

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Abstract

Infrared measurements can be used to obtain quantitative information on cloud microphysics, including cloud phase, with the advantage that the measurements are independent of solar zenith angle. As such, infrared brightness temperatures (BT's) and brightness temperature differences (BTD's) have been used extensively in quantitative remote sensing applications for inferring cloud phase. In this study we show that BTD's are fundamentally limited and that a more physically based infrared approach can lead to significant increases in sensitivity to cloud microphysics, especially for optically thin clouds. In lieu of BTD's, we use a derived radiative parameter, β, which is directly related to particle size, habit, and composition. While the concept of effective absorption optical depth ratios (β) has been around since the mid 1980's, this is the first study to explore the use of β for inferring cloud composition in the total absence of cloud vertical boundary information. The results showed that even in the absence of cloud vertical boundary information, one could significantly increase the sensitivity to cloud phase by converting the measured radiances to effective emissivity and constructing effective absorption optical depth ratios from a pair of spectral emissivities in the 8 – 12 μm "window." This increase in sensitivity to cloud phase is relative to brightness temperature differences (BTD's) constructed from the same spectral pairs. In this talk, we will describe the physical concepts (which can be applied to narrow band or hyperspectral infrared measurements) used in constructing the β data space, present results from a β-based cloud phase algorithm that can be applied to SEVIRI or MODIS, and show comparisons to a cloud phase data set derived from spaceborne lidar (CALIOP).

Small decisions with big impacts: MODIS, ISCCP, and the evaluation of clouds in climate models

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Abstract

The evaluation and diagnosis of clouds produced by climate models has accelerated as it has become clear how important clouds are in controlling model estimates of climate sensitivity. Among the most widely used datasets are ISCCP and MODIS; these datasets share many common elements since they are both based on passive measurements in the visible and infrared. But it turns out that fairly subtle decisions can have a dramatic impact on the cloud climatology inferred from these measurements. In particular, we will show that the different ways in which MODIS and ISCCP treat pixels containing broken clouds (cloud-affected but not fully cloudy) is crucial: MODIS excludes these pixels from daily and monthly means, while ISCCP treats them as the radiative equivalent of homogenous clouds. The result is that MODIS cloud properties are retrieved for about 15% less of the planet's area than are MODIS pixels, but that MODIS observes almost no clouds with optical thickness less than 1.3. Climate models, on the other hand, have no way of reproducing the distribution of cloud sizes and so can not reproduce these sensitivities. We show how this impacts the robustness of model evaluation and, by implication, inter-comparisons of cloud properties among platforms.

A novel technique for validating liquid water cloud properties

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Abstract

Liquid water clouds play an important role in the Earth's energy budget through interactions with Sun radiation. These interactions, over all described as cloud albedo effect, depend on the microphysical and optical properties of the clouds. At regional scale, these cloud properties can be accurately retrieved from a synergistic use of ground-based atmospheric sensors. At larger observation scale, these properties are retrieved by using visible and near-infrared reflectances using passive sensors on geostationary or polar-orbiting satellites. However, the retrieved cloud properties need to be validated before being included in climate and weather models.

In this work, the liquid water cloud properties are retrieved using ground-based cloud radar, ceilometer and microwave radiometer. These properties are then used to generate 3D surrogate cloud fields that serve as input to the EarthCARE SIMulator (ECSIM). The novel approach for the validation of liquid water cloud properties retrieval algorithms makes use of a radiative closure experiment and a radar test to validate the ground-based retrieved cloud properties and of simulated visible and near-infrared reflectances to validate the satellite cloud properties retrievals algorithm. The ECSIM simulated surface irradiances are compared with the independent ground-based Pyranometer measurements in order to assess the accuracy of the ground-based retrievals in reproducing the radiative behavior of the observed cloud (radiation closure experiment). Furthermore, the simulated radar reflectivities are compared with the one observed by the 94 GHz cloud radar to make a further check on the accuracy of the ground-based retrievals in representing the real cloud (radar test).

The KNMI Cloud Physical Properties (CPP) algorithm is applied to the ECSIM-simulated Top-Of-Atmosphere visible and near-infrared reflectances to retrieve the liquid cloud properties. The accuracy of the CPP retrieval algorithm in describing the properties of the cloud field is determined through a comparison of the CPP retrievals against the corresponding cloud properties used as input in the simulator. This new approach can be used for the evaluation and validation of satellite retrieved cloud properties algorithms. In fact, it removes the two main error sources of the satellite product validation from the ground, namely the differences in the observation scales and the parallax effect.

Overview of the MODIS Collection 6 optical property algorithm

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Abstract

The MODIS cloud optical properties algorithm (MOD06/MYD06 for Terra and Aqua MODIS, respectively) has undergone extensive improvements and enhancements since the launch of Terra. These changes have included: improvements in the cloud thermodynamic phase algorithm; substantial changes in the ice cloud light scattering look up tables (LUTs); a clear-sky restoral algorithm for flagging heavy aerosol and sunglint; greatly improved spectral surface albedo maps, including the spectral albedo of snow by ecosystem; inclusion of pixel-level uncertainty estimates for cloud optical thickness, effective radius, and water path derived for three error sources that includes the sensitivity of the retrievals to solar and viewing geometries. To improve overall retrieval quality, we have also implemented cloud edge removal and partly cloudy detection (using MOD35 cloud mask 250m tests), added a supplementary cloud optical thickness and effective radius algorithm over snow and sea ice surfaces and over the ocean, which enables comparison with the "standard" 2.1 µm effective radius retrieval, and added a multi-layer cloud detection algorithm.

We will discuss the status of the Collection 6 MOD06 algorithm and show examples of pixel-level (Level-2) cloud retrievals for selected data granules, as well as gridded (Level-3) statistics.

MODIS optical property pixel-level uncertainty estimates in Collection 6

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Abstract

Moderate Resolution Imaging Spectroradiometer (MODIS) retrievals of optical thickness and effective particle radius for liquid water and ice phase clouds employ a well-known VNIR/SWIR solar reflectance technique. For this type of algorithm, we evaluate the quantitative uncertainty in simultaneous retrievals of these two cloud parameters to pixel-level radiometric calibration estimates and other fundamental (and tractable) error sources.

The technique, first implemented in MOD06 Collection 5 processing, uses sensitivity calculations derived from pre-computed cloud reflectance look-up tables coupled with estimates for the effect of various error sources on cloud-top reflectance. An important error source is instrument radiometric calibration (other tractable sources included in Collection 5 are surface spectral albedo and atmospheric corrections). We will show cloud retrieval uncertainties derived from new MODIS L1B VNIR and SWIR band pixel-level uncertainty estimates that will be used in Collection 6 processing. Because of the nature of the approach, results will deal exclusively with pixel-level uncertainties associated with plane-parallel clouds; real-world radiative departures from a plane-parallel model are an additional consideration. While we demonstrate the uncertainty technique with operational 1 km MODIS retrievals from the Terra and Aqua satellite platforms, the technique is applicable to any reflectance-based satellite or air-borne sensor retrieval using similar spectral channels.

A new spectrally consistent adiabatic method to derive cloud properties from MODIS measurement

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Abstract

The adiabatic assumption is a realistic approximation to describe the vertical stratification of warm clouds as showed by multiple observations carried out in stratocumulus (SC) and trade-cumulus (CU) area. According to this assumption, the effective radius increases with the altitude above cloud base at a power 1/3. At a given effective radius, the absorption efficiency increases with the wavelength in the NIR region. Cloud droplets absorb more radiation at the higher NIR-wavelengths which reduce the penetration of radiative energy into the cloud. Combining several NIR-channels gives information about the effective radius for different cloud depth. The cloud adiabaticity can then be determined since the vertical variations of this parameter follow a known analytical law.

The Spectrally Consistent Adiabatic Method (SCAM) is based on this idea to derive accurate cloud properties (liquid water path and cloud droplet number concentration) of adiabatic plane-parallel clouds such as SC. The principle of Nakajima and King's method (NK90 hereafter) is used for the SCAM. The NK90 method is applied on satellite remote sensing measurements of one reflectance in the VIS and one in the NIR, considering warm clouds as vertically uniform plane-parallel clouds. In the new method, the NK90 method is used assuming that cloud microphysical properties are adiabatically stratified. The presented work will show the consistency of this approach and the accuracy of the retrieved cloud properties.

Estimation of cloud properties though a spectrally consistent adiabatic model

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Abstract

In order to better estimate the microphysical properties of clouds from satellite observations while minimizing computational complexity, MODIS Level 2 retrievals of boundary layer cloud optical thickness and droplet effective radius, calculated under a vertically homogenous cloud assumption are mapped to reflectances for several MODIS Visible-NIR channels though a lookup table derived from RTM simulations of vertically homogenous clouds. The obtained reflectances are then mapped through a lookup table calculated by the RTM under adiabatic assumptions back to optical thickness and droplet effective radius. It is expected that this multispectral method will offer better estimates of cloud microphysical properties and vertical structure than those obtained under a vertically homogeneous framework while being computationally less expensive than applying the adiabatic model directly to raw scene reflectances.

Use of A-Train observations to assess cloud phase retrievals from SEVIRI/MSG

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Abstract

Phase of condensed atmospheric water and its relation with main thermodynamic parameters plays a critical role in the formation and evolution of clouds. Cloud particle microphysics is a first order parameter for computation of radiative exchange. It also governs strongly clouds lifetime through precipitation and sedimentation processes linked with particle size and shape and therefore phase. Not surprisingly, the representation of condensed water thermodynamic phase in models is a major source of uncertainty for the evaluation of clouds and water vapor feedbacks in an evolving climate.

Therefore, there is a critical need to better determine and describe the distribution of condensed water between ice and liquid phase in clouds, and the relations with main thermodynamic parameters that governs this partitioning. As with many other problems, satellite observations especially from operational sensors are of outermost importance for the establishment and validation of relationship that exist between cloud phase and other atmospheric parameters. In addition, determination of cloud phase is usually a first and an always compulsory step in any scheme that is used to derive more advanced cloud properties.

In this presentation we will briefly describe an algorithm used to retrieve cloud thermodynamic phase from SEVIRI/MSG that has been developed on basis similar to the MODIS Cloud Optical Properties Phase algorithm. We will then present an assessment of this product in view of well characterized cloud phase information derived from POLDER, MODIS and CALIOP for the Golden days selected for the CREW exercise.

Evaluation of the global cloud cover distribution obtained from multi-geostationary data in the frame of the MEGHA-TROPIQUES mission with CALIPSO lidar observations

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Abstract

For the need of the MEGHA-Tropiques space mission, a coherent cloud mask and cloud type classification is required in the latitudinal band between 35°N and 35°S with a good spatial and temporal sampling. The visible and infrared radiance data from the geostationary satellites allowing such an approach are collected and analyzed using the retrieval method developed by the SAFNWC (Legleau and Derrien, 2005; Derrien and Legleau, 2009) for the multi-spectral SEVIRI radiometer on board METEOSAT second generation and adapted to the spectral characteristics and field of view of the GOES-E, GOES-W and MTSAT satellite data. This four set of geostationary data allows to retrieve cloud parameters with a one hour time sampling over a large part of the tropical belt (35 S -35 N). For a four month period in summer 2009, cloud mask, cloud type classification and cloud top pressure products from these four satellite data set have been analyzed. For each geostationary satellite, the mean cloud cover and instantaneous cloud cover properties are compared to cloud layer structure observed with the lidar CALIOP (product layer Version 3). Results of this evaluation study are presented. Day and night, land and ocean are studied separately. The information brings by these results and the remaining work to evaluate the whole diurnal cycle of the geostationary cloud cover properties is discussed.

An equal-angle space-time gridding tool for NPP cloud products

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Abstract

We introduce a method with which to calculate dynamic gridded products from polar-orbiting Level 2 cloud retrievals. The method is instrument independent and derives a time average for each grid cell from statistically significant daily averages. The latter is calculated from a cluster of nearest neighborhood retrievals with a minimum size threshold defined by the mean number of retrievals minus 1.5 times the standard deviation. The value of this approach is illustrated by (i) contrasting it with the traditional nearest neighborhood gridding method, and (ii) comparing global monthly averages of high cloud top pressure retrievals from three instruments on a 1.0 degree equal-angle grid.

Improved methods to resolve the vertical distribution of cloud water from passive satellite data

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Abstract

Cloud parameters derived routinely from passive satellite data have high horizontal resolution but typically lack the vertical resolution needed to adequately resolve clouds for many weather and climate applications. In this study, active sensor data are used to address this shortcoming. A technique to derive cloud water content profiles at the pixel level from passive satellite data is described and demonstrated. This technique constrains climatological information on the vertical distribution of cloud water derived from CloudSat and CALIPSO data with cloud water path and cloud boundary retrievals from passive satellite imagers. Cloud boundaries derived from the active sensor data are used as a baseline to test and empirically improve passive satellite estimates of cloud top and base altitude in a variety of cloud conditions. In addition, cloud water path estimates from active and passive sensors are inter-compared and summarized. Together, these results provide improvements in characterizing the vertical distribution of cloud water from passive satellite data. This study focuses on the cloud retrieval techniques developed at NASA Langley Research Center. Originally developed for application to MODIS for the CERES program, the techniques are also being applied routinely to data taken from GOES, SEVIRI and other operational satellites.

The inter-comparison of retrieved cloud properties within the ESA Cloud CCI project

Martin Stengel (DWD), Sebastian Mieruch (DWD), Matthias Jerg (DWD), Rainer Hollmann (DWD), Alexander Kokhanovsky (University of Bremen), Caroline Poulsen (RAL), Claudia Stubenrauch (LMD), Hermann Mannstein (DLR), Jan Fokke Meirink (KNMI), Karl-Göran Karlsson (SMHI), Rasmus Lindstrot (Freie Universität Berlin), Bojan Boykov (ESA), Gareth Thomas (University of Oxford), and Luis Gomez-Chova (University of Valencia)

As part of ESA's Climate Change Initiative, the Cloud CCI project, which is lead by DWD in cooperation with many international partners, has recently started.

Abstract

The ultimate objective of this project is to provide long-term coherent cloud property data sets exploiting the synergic capabilities of past, existing and upcoming European and American Earth observation missions. The synergy approach allows for improved accuracies and enhanced temporal and spatial sampling of retrieved cloud properties better than those provided by the single sources. Such improvements are required by the scientific community to facilitate further progress in satellite-based climate monitoring, which supports a better understanding of the climate. One objective of the project is the development of a coherent physical retrieval framework for cloud-related essential climate variables.

In support of this, a Round Robin exercise is conducted focusing on the inter-comparison of various cloud property retrieval schemes applied to AVHRR, AATSR and the AVHRR-heritage channel measurements of MODIS-AQUA. In this exercise, the retrieved quantities of various cloud properties are investigated and inter-compared also assessing the quality dependence on specific atmospheric and surface conditions such as different land cover and large scan angles etc. Thus, the Round Robin will reveal the strengths and weaknesses of the different retrieval schemes using reference measurements of the cloud properties from passive and active instruments of the A-Train satellites. Further, the feasibility of an overall quantitative grading of the retrieval schemes is assessed.

The objectives, realization and results of the Round Robin exercise will be presented. The outcome and findings of this exercise can directly support current and future CREW inter-comparison efforts.

Application and evaluation of the Oxford-RAL retrieval of aerosol and cloud algorithm to MODIS data

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Abstract

The Oxford-RAL Retrieval of Aerosol and Cloud (ORAC) algorithm is an optimal estimation retrieval scheme for visible-IR imaging satellite radiometers. As part of the ESA Cloud_CCI project, the ORAC scheme has been applied to MODIS, AVHRR and AATSR data, using a set of "heritage channels" common to all three instruments. As MODIS (Aqua) is part of the A-Train formation of satellites, this has provided a wealth of validation and intercomparison data not previously available for assessing the ORAC algorithm. This poster provides a description ORAC, which is now publicly available as an open-source community algorithm, and presents results of comparisons of ORAC retrievals from all three instruments against CloudSat, CALIPSO and existing MODIS cloud products.

A comparison of cloud detection between CERES Ed4 cloud mask and CALIPSO Version 3 vertical feature mask

Qing Trepte, Patrick Minnis, Sunny Sun-Mack, Ricky Brown, and Charles Trepte

Science Applications International Corporation, Hampton, Virginia

Abstract

In climate and earth energy budget studies, understanding the presence and distribution of various clouds is a very important first step. CERES cloud mask is a global cloud detection algorithm using Terra and Aqua MODIS data as well as other ancillary data sets and it is used operational in NASA's Cloud and Earth's Radiant Energy System (CERES) project.

Comparison between CERES Ed4 cloud mask and CALIPSO Vertical Feature Mask (VFM) provides a powerful tool to validate and improve CERES cloud detection globally as well as to understand the strength and limitation of cloud retrievals between active and passive satellite senses.

In this paper, individual comparison cases will be presented for different types of clouds over various surfaces, including daytime and nighttime conditions and polar and non-polar regions. In addition, the statistics of the global cloud occurrence comparison between CERES Ed4 cloud mask and CALIPSO VFM will be discussed.

Sources of error in satellite derived cloud products

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Abstract

Error analysis of cloud products helps us to estimate how large the uncertainties are, and to reduce them if possible. However, the error estimate of cloud products itself is not often in focus of comparison studies and appears often only as an error bar in scatter plots.

In our presentation we seek to identify the dominant factors of the error budget of the NOAA AWG Cloud Algorithms products according the atmospheric and surface situation. We will show how the uncertainty in the forward model and in the auxiliary data is propagated and how it influences the information content of the retrieval.

We also intend to show comparisons to other groups' cloud product error estimates if available.

Progress on optimal estimation cloud property retrieval from SEVIRI observations

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Abstract

We report on progress made since CREW II with EUMETSAT's optimal estimation (OE) method for cloud property retrieval applied to SEVIRI observations. Most significant progress has been guided by availability of high-quality validating data from the A-Train instruments, notably the cloud top pressure estimates and reflectivity profiles from the CPR radar and CALIOP lidar and A-Train MODIS and AMSR-E observations of optical thickness and water path respectively.
Comparisons of CPR reflectivity and MODIS and SEVIRI(OE) CTP estimates have demonstrated that a VIS-IR method like SEVIRI(OE) is more sensitive to multi-layer cloud than an IR-only method (e.g. MODIS); a result of the VIS channels driving the COT retrieval. It is shown that the OE diagnostic solution cost J is very effective at flagging these cases and a suitable threshold on J effectively selects single layer cloud (or cloud where the upper layer is optically thick (~ > 5). In high J (assumed multi-layer) cases the OE scheme is rerun with a simple 2-layer model and the resulting CTPs and COTs are validated using the A-Train data. Upper layer CTPs are almost of the same accuracy as single layer cases but are biased slightly higher than CPR estimates rather than slightly lower. Lower layer CTPs are harder to validate but appear to be useful estimates. Important to note is that successful 2-layer retrievals appear only to be possible if the SEVIRI water vapour channels are fully utilised (assigned low measurement errors in the OE). Whilst the high J discriminator effectively flags most multi-layer cases, it is indiscriminate in that there are other causes of high cost. Thus we test the benefits of using an independent multi-layer flag to help decide which pixels to treat with the 2-layer model.

We will report briefly on other areas of potential interest: a method to avoid 'above inversion' solutions in maritime stratocumulus, experimental use of the HRV channel for sub-pixel fraction information and use of diurnal results to judge the effective variance of marine stratocumulus clouds.

Improvements in night-time low cloud detection and MODIS-style cloud optical properties from MSG SEVIRI

Galina (Gala) Wind[1,2], Steven Platnick[1], and Jérôme Riédi[3]

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Abstract

The MODIS cloud optical properties algorithm (MOD06/MYD06 for Terra and Aqua MODIS, respectively) slated for production in Data Collection 6 has been adapted to execute using available channels on MSG SEVIRI. Available MODIS-style retrievals include IR Window-derived cloud top properties, using the new Collection 6 cloud top properties algorithm, cloud optical thickness from VIS/NIR bands, cloud effective radius from 1.6 and 3.7µm and cloud ice/water path. We also provide pixel-level uncertainty estimate for successful retrievals.

It was found that at nighttime the SEVIRI cloud mask tends to report unnaturally low cloud fraction for marine stratocumulus clouds. A correction algorithm that improves detection of such clouds has been developed.

We will discuss the improvements to nighttime low cloud detection for SEVIRI and show examples and comparisons with MODIS and CALIPSO. We will also show examples of MODIS-style pixel-level (Level-2) cloud retrievals for SEVIRI with comparisons to MODIS.

Cloud measurements, retrievals, and products from CALIPSO

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Abstract

The CALIPSO satellite carries a two-wavelength polarization lidar, operating since June 2006. Over five years of aerosol and cloud profile observations have now been acquired and archived at the NASA Langley Atmospheric Sciences Data Center. CALIPSO Level 2 products include cloud height and thickness, optical depth, thermodynamic phase, and ice-water content. Further, monthly global gridded Level 3 datasets of cloud occurrence have been developed for the GEWEX Cloud Assessment project and for the evaluation of global climate models. This presentation will discuss contents, characteristics, and validation status of CALIPSO cloud data products.

Evaluation of a 30-year NOAA-AVHRR cloud physical property climate data record

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Abstract

Within EUMETSAT's Satellite Application Facility on Climate Monitoring (CM-SAF), a reprocessing effort of 30 years of Global Area Coverage (GAC) Advanced Very High Resolution Radiometer (AVHRR) data, using the Cloud Physical Properties (CPP) retrieval algorithm has recently been completed. Calibrated radiances provided by the National Oceanic and Atmospheric Administration (NOAA) are used to retrieve a range of cloud physical property datasets. These datasets are freely available both at pixel-level and as monthly means.

In this study, we evaluate the 30-year cloud physical property record consisting of cloud thermodynamic phase, cloud optical thickness, particle effective radius, and liquid/ice water path. Comparisons with other cloud property datasets retrieved from visible/near-infrared radiances, such as the AVHRR Pathfinder Atmospheres-Extended (PATMOS-x), the International Satellite Cloud Climatology Project (ISCCP), as well as with the passive microwave based UWisc LWP climatology will be presented. In addition, the suitability of the datasets for detecting regional long-term trends will be explored.

MODIS radiometric calibration and uncertainty assessment

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Abstract

Since launch, Terra and Aqua MODIS have collected more than 11 and 9 years of datasets for comprehensive studies of the Earth's land, ocean, and atmospheric properties. MODIS observations are made in 36 spectral bands: 20 reflective solar bands (RSB) and 16 thermal emissive bands (TEB). Compared to its heritage sensors, MODIS was developed with very stringent calibration and uncertainty requirements. As a result, MODIS was designed and built with a set of state of the art on-board calibrators (OBC), which allow key sensor performance parameters and on-orbit calibration coefficients to be monitored and updated if necessary. In terms of its calibration traceability, MODIS RSB calibration is reflectance based using an on-board solar diffuser (SD) and the TEB calibration is radiance based using an on-board blackbody (BB). In addition to on-orbit calibration coefficients derived from its OBC, calibration parameters determined from sensor pre-launch calibration and characterization are used in both the RSB and TEB calibration and retrieval algorithms. This paper provides a brief description of MODIS calibration methodologies and discusses details of its on-orbit calibration uncertainties. It assesses uncertainty contributions from individual components and differences between Terra and Aqua MODIS due to their design characteristics and on-orbit performance. Also discussed in this paper is the use of MODIS L1B uncertainty index (UI) product.

An assessment of differences between cloud effective particle radius retrievals for marine water clouds from three MODIS spectral bands: Observational and modeling studies

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Abstract

The Moderate Resolution Imaging Spectroradiometer (MODIS) cloud product provides three separate retrievals of cloud particle effective radii (re), derived from 1.6, 2.1 and 3.7 μm band observations. In this study, differences among the three re retrievals for maritime water clouds (designated as re, 1.6 re, 2.1 and re,3.7) were systematically investigated through a series of case studies and global analyses. Substantial differences have been found between the re, 3.7 and re,2.1 retrievals (i.e., Δre,3.7-2.1), and the difference showed a strong dependence on cloud regimes. The Δre, 3.7-2.1 is small, within ±2μm, over the relatively spatially homogeneous costal stratocumulus cloud regions. However, for trade wind cumulus regimes, the re, 3.7 was found to be substantially smaller, sometimes by more than 10 μm, than the re,2.1. The correlations of re differences with key cloud parameters, including the cloud optical thickness (τ), re and a cloud horizontal heterogeneity index (Hσ) derived from 250 m resolution MODIS 0.86 μm band observations, were investigated based on one month of MODIS Terra data. It was found that differences among the three re retrievals for optically thin clouds ($\tau < 5$) are highly variable, ranging from -15μm to 10μm, likely due to the large MODIS retrieval uncertainties when the cloud is thin. The Δre, 3.7-2.1 exhibited a threshold-like dependence on both re,2.1 and Hσ. The re,3.7 is found to agree reasonably well with re,2.1 when re,2.1 is smaller than about 15μm, but becomes increasingly smaller than re,2.1 once re,2.1 exceeds this size. All three re retrievals showed little dependence when $H\sigma < 0.3$. However, for $H\sigma > 0.3$, both re, 1.6 and re,2.1 were seen to increase quickly with increasing Hσ. On the other hand, the re, 3.7 statistics showed little dependence on Hσ and remained relatively stable over the whole range of Hσ values. Potential contributing causes to the substantial re,3.7 and re,2.1 differences are discussed. In particular, based on both 1-D and 3-D radiative transfer simulations, we have elucidated mechanisms by which cloud heterogeneity and 3-D radiative effects can cause large differences between re,3.7 and re,2.1 retrievals for highly inhomogeneous clouds.

Our results suggest that the contrast in observed Δre, 3.7-2.1 between cloud regimes is a result of substantial increases in both cloud re and Hσ. We also speculate that in some highly inhomogeneous, drizzling clouds, cloud vertical structure induced by drizzle and the 3-D radiative effect might operate together to cause dramatic differences between re,3.7 and re,2.1 retrievals.

A MODIS cloud property retrieval simulator is developed to study the effects on Δre,3.7-2.1 of cloud microphysical structure, 3-D radiative transfer and drizzles. This simulator is based on a Large-Eddy Simulation model with bin microphysics and a state-of-the-art 3-D radiative transfer model. Modeling results from this simulator alone with the observational studies based on MODIS products will be presented in this talk.