The validation of cloud retrieval algorithms using synthetic datasets

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Abstract

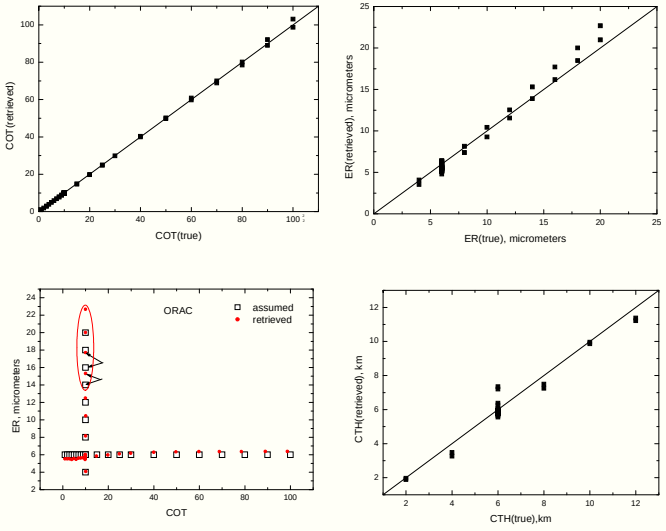
The inter-comparison of various cloud retrieval algorithms using synthetic datasets is of great importance for understanding weak and strong points of various algorithms and also for further improvements of the retrieval techniques. With this in mind, we have performed the inter-comparison study of cloud property retrievals using algorithm initially developed for AATSR (ORAC, RAL-Oxford University), AVHRR(CPP, KNMI), SCIAMACHY/GOME(SACURA, University of Bremen), 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. 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 microns. 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). 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 760nm. In synthetic calculations, the CTH was varied in the range 2-12km, ER was changed from 4 to 20 microns, 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 A-band retrievals with general tendency for the underestimation of CTH.

Algorithms.

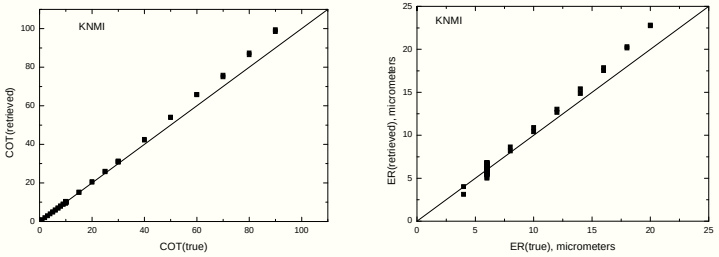
The ORAC algorithm (Poulsen et al. 2011, Watts et al. 1998) is an optimal estimation retrieval that can be used to determine both aerosol and cloud properties from visible/infrared satellite radiometers. In the case of cloud retrievals the algorithm fits radiances computed from LUTs created from DIScrete Ordinates Radiative Transfer (DISORT) (Stamnes et al., 1988) to the TOA signal measured by the satellite by varying the cloud optical thickness (COT), effective radius (ER), cloud top pressure and height, phase and surface temperature simultaneously. The Cloud Property Product (CPP) retrieval scheme, developed at KNMI for AVHRR and SEVIRI, retrieves cloud optical thickness, cloud particle effective radius , cloud thermodynamic phase (CPH), and liquid/ice/total cloud water path (LWP/IWP/CWP). Presently, daily and monthly mean COT, CPH and CWP are produced as official products within EUMETSAT's Satellite Application Facility on Climate Monitoring (CM-SAF), both for geostationary (MSG-SEVIRI) and polar-orbiting (NOAA/METOP-AVHRR) imagers. The retrieval scheme is based on earlier methods that retrieve cloud optical thickness and cloud particle size from satellite radiances at wavelengths in the non-absorbing visible and the moderately absorbing solar infrared part of the spectrum (Nakajima and King, 1990). The principle of the CPP algorithm is that the reflectance of clouds at a non-absorbing wavelength in the visible region is strongly related to cloud optical thickness and has little dependence on the efefctive radius of cloud droplets and crystals, whereas the reflectance of clouds at an absorbing wavelength in the near-infrared region is primarily related to the effective radius of particles. Moreover, differences between the imaginary parts of the refractive indices of water and ice in the NIR allow to retrieve CPH. A Semi-Analytical CloUd Retrieval Algorithm (SACURA) developed at Bremen University is aimed at the determination of cloud liquid water path, effective radius of droplets and cloud optical thickness using spaceborne observations. The algorithm is based on the asymptotical solution of the radiative transfer equation for a special case of cloudy media, having a large optical thickness. Such an approach has already been used in a number of studies (Rozenberg, 1978; King, 1987). The algorithm for the remote sensing of cloud-top pressure from MERIS measurements makes use of the absorption of solar radiation by oxygen at 760nm by relating the strength of absorption to the transmitted airmass: the transmission decreases as the transmitted absorber mass increases. Due to the lack of channels in the shortwave infrared and thermal infrared spectral regions, the measurements of MERIS do not provide enough information for a retrieval of liquid / ice water profiles and path. The cloud optical thickness can be derived from the window reflectance at 754nm, using the MERIS ALBEDOMAP data base for the consideration of the surface reflectance, which is an important influence particularly in cases of optically thin clouds (http://envisat.esa.int/instruments/meris/atbd/).

Results

ORAC AATSR retrievals(RAL-Oxford University)

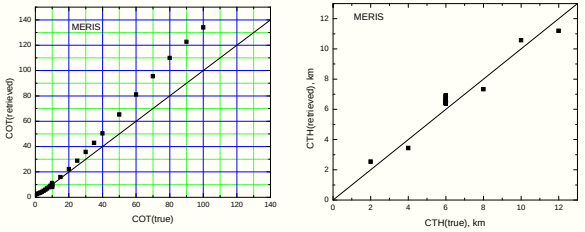


CPP AVHRR retrievals(KNMI)



Results

FUB MERIS retrievals (Free University of Berlin)



SACURA AATSR retrievals (Bremen University)