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Radiative fluxes from active satellite observations and their sensitivity to scale

Jennifer Müller (1), Hartwig Deneke (2), Victor Venema (3), and Clemens Simmer (3)

(1) Free University Berlin, Institute for Space Science, Germany (jenny.mueller.86@gmail.com), (2) Leibniz Institute for Tropospheric Research, Leipzig, Germany, (3) University Bonn, Meteorological Institute, Bonn, Germany

Our knowledge of clouds including their vertical and horizontal structure and their influence on the earth's radiation budget and climate is still limited. Since 2006 the radar and lidar measurements from the CloudSat and CALIPSO satellites provide unprecedented information about both the vertical and the horizontal cloud extent. We used these measurements to analyze the impact of clouds and especially the impact of their small-scale variability on the radiation budget of the earth and on the climate system.

We utilized a combination of products from CloudSat and CALIPSO to calculate profiles of shortwave and longwave radiative fluxes and heating rates of cloudy and clear atmospheric columns and thus quantified the impact of clouds on the radiative budget. The calculations were carried out with the Rapid Radiative Transfer Model for GCM applications (RRTMG), which is based on the two-stream-approximation. Absorption by atmospheric gases is parameterized by the correlated-k-method. RRTMG is numerically very efficient and provides accurate results. It has therefore recently been adopted as radiative scheme in some atmospheric models, e.g. the one of ECMWF. Additionally to clouds the impact of aerosols on radiation can be considered in RRTMG. We combined the aerosol optical depth measured by CALIPSO at a wavelength of 532nm with the spectral dependency of aerosol optical depth given by the aerosol models of the Optical Properties of Aerosols and Clouds (OPAC) library.

The radiative fluxes calculated with RRTMG were initially compared to the official CloudSat flux product 2B-FLXHR to test the reliability of our calculations and to analyze the sensitivity to different assumptions related to model parameterizations and the usage of the input data. These comparisons showed that the largest differences were caused by differing assumptions about the surface albedo and gaseous absorption. The former leads to the largest differences between the radiative fluxes of both data sets.

The main aim of our investigation was to quantify the impact of subscale cloud variability on typical spatial resolutions of climate and atmospheric models. Therefore a lower resolution was simulated by averaging the full resolution satellite data. The averaged data were then used to test and compare different assumptions about the treatment of cloud overlap. These assumptions include simple arithmetic averaging of cloud physical properties and the usage of the Monte Carlo Integration of the Independent Column Approximation (McICA) which was applied with three overlap assumptions: maximum, random and maximum-random overlap. The results showed a large improvement when utilizing McICA. Surprisingly this scheme provided the best correspondence to the fully resolved data when maximum overlap was assumed. Furthermore the statistical variability within McICA was examined by comparing different calculations with McICA of the same orbit. It was found that the mean spread between the different runs exceeds the uncertainties between the highly resolved radiative fluxes and the ones calculated with spatially averaged input. This experiment also yields that a single run with McICA resembles the fully resolved data better than the mean values of ten runs.