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Examination of Three-Dimensional (3-D) Solar Radiative Transfer Effects on Heating Rate Profiles and Fluxes for Cloudy Atmospheres Using A-Train Satellite Measurements

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A-train satellite measurements, a three-dimensional (3-D) scene construction algorithm, and a 3-D shortwave radiative transfer model are used to improve the estimation of the impact of clouds on Earth's radiation budget (ERB). Passive satellite imagery from the Moderate Resolution Imaging Spectroradiometer (MODIS) and two-dimensional (2-D) nadir profiles from CloudSat and Cloud Aerosol Lidar and Infrared Pathfinder Satellite Observation (CALIPSO) are combined to obtain 2-D cross-sections of cloud and aerosol properties. Atmospheric temperature and humidity profiles are described from Goddard Earth Observing System (GEOS-5) data. A correlated k-distribution model is employed to obtain rapid estimation of gaseous optical depths for 70 solar spectral bands. The resulting profiles of optical properties along the CALIPSO and CloudSat ground track are then extended to the cross track direction using MODIS spectral radiances as a mapping tool (Barker et al. 2011). A 3-D Monte Carlo radiative transfer model is then applied to the constructed atmosphere. One-dimensional (1-D) simulations are performed with the independent column approximation (ICA) using the same constructed atmospheres. ICA biases, defined as the difference between ICA and 3-D fluxes and heating rates, are estimated thereby quantifying 3-D radiative cloud effects. In addition, modeled top-of-atmosphere (TOA) irradiances by the 1-D and 3-D models are compared to Clouds and the Earth's Radiant Energy System (CERES)-derived top-of-atmosphere (TOA) irradiances. Differences between modeled and observed irradiances are analyzed according to cloud type. Furthermore, improvements in model estimated irradiances due to the use of the 3-D constructed cloud fields are assessed by comparing modeled irradiances with and without cloud constriction. These analyses were performed using several months of A-train data.

Reference

Barker, H. W., M. P. Jerg, T. Wehr, S. Kato, D. P. Donovan, and R. J. Hogan, 2011: A 3D cloud-construction algorithm for the EarthCARE mission, Q. J. R. Meteorol. Soc., 137, 1042-1058.