Assessment of 3D cloud radiative transfer effects using observed satellite data

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This study investigates SW and LW broadband radiative fluxes in the 3D cloud-laden atmospheres using a 3D radiative transfer (RT) model, *MCstar*, and satellite-observed cloud data. The 3D extinction coefficient fields are constructed by a newly devised Minimum cloud Information Deviation Profiling Method (MIDPM) that extrapolates CPR radar profiles at nadir into off-nadir regions within MODIS swath based on collocated information of MODIS-derived cloud properties and radar reflectivity profiles. The method is applied to low level maritime water clouds off California, for which the 3D radiative transfer simulations are performed.
The radiative fluxes thus simulated are compared to those obtained from CERES as a way to validate the MIDPM-constructed cloud fields and our 3D radiative transfer simulations. The results show that the simulated SW flux agrees with CERES values within 8 - 50 Wm^{-2}. The large bias is found to occur primarily in the case of large cloud fraction field including a number of thin clouds. A possible reason for the bias is likely to arise from the 1D retrieval error for such thin clouds, which tend to be affected by spatial heterogeneity and to overestimate the cloud optical thickness. Given that the uncertainty of instantaneous CERES TOA flux is around 9Wm^{-2}, the bias of 8-50Wm^{-2} suggests that MIDPM captures a key aspect of the real 3D cloud field, though we need a future study of validation with more data in various conditions.
Such 3D-RT simulations also serve to address another objective of this study, i.e. to characterize the “observed” specific 3D-RT effects by the cloud morphology. The 3D-RT effects are characterized by errors of existing 1D approximations to 3D radiation field. The errors are investigated in terms of their dependence on solar zenith angle (SZA) for the satellite-constructed real cloud cases and are classified to three types corresponding to different simple morphologies, i.e. isolated cloud type, upper cloud-roughened type and lower cloud-roughened type. The error characteristics are further interpreted with the effective cloud fraction (CF_e) profile defined according to average cloud optical thickness and the standard deviation. It is confirmed that the CF_e profile characteristics are consistent with classification of 3D-RT effect into the three types. Such a classification offers a novel insight into 3D-RT effect in a manner that relates to cloud morphology.

Keywords: 3D radiative transfer, cloud radiative effect, observed cloud satellite data