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Development of a radiative flux evaluation program with a 3D Monte Carlo radiative transfer code

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In this study, we have developed a 3D Monte-Carlo radiative transfer code that can treat a broadband solar flux calculation, also implemented with k-distribution parameters of Sekiguchi and Nakajima (2008). We used this code for generating the radiative flux profile and heating rate profile in the atmosphere including broken clouds. In order to construct 3D extinction coefficient fields, we tried following three methods:, 1) stochastic clouds generated by randomized extinction coefficient distribution and regularly-distributed tiled clouds, 2) numerical simulations by a non-hydrostatic model with bin cloud microphysics model and 3) Minimum cloud Information Deviation Profiling Method (MIDPM).

The second construction of 3D cloud systems was performed by numerical simulation of Californian summer stratus clouds using a non-hydrostatic atmospheric model with a bin-type cloud microphysics model based on the JMA NHM model (Iguchi et al., 2008; Sato et al., 2009, 2012). The numerical simulations were conducted on horizontal (vertical) grid with a spacing of 100m (20m) and 300m (20m) in a domain of 30 km,30 km,1.5 km with a horizontally periodic lateral boundary condition. Two different cell systems were simulated depending on the cloud condensation nuclei (CCN) concentration. In the case of level scale resolution 100m, a regional averaged cloud optical thickness, <COT>, and standard deviation, standard deviation of COT, are 3.0 and 4.3 for pristine case and 8.5 and 7.4 for polluted case.

In the MIDPM method, we first constructed a library of the pair of observed parameters from CLOUDSAT/CPR and collocated AQUA/MODIS imager products at the footprint of CPR along the CLOUDSAT orbit, i.e. the profile of effective radar reflectivity factor, dBZe(z), spectral MSI radiances, cloud optical thickness (COT), effective particle radius (RE) and cloud top temperature (Tc) for a case of summer stratus cloud off California coast on July 2, 2007. We then selected a best matched radar reflectivity factor profile from the library for each of off nadir pixels of MODIS where CPR profile is not available, by minimizing the deviation between library MODIS parameters and those at the pixel.

Using these constructed 3D cloud systems, we calculated the radiation field by our Monte-Carlo radiative transfer code at wavelengths of 0.5, 1.6 and 2.1 microns. We compared a reflectivity of 3D with plane parallel and a reflectivity of 3D with IPA. Independent Pixel Approximation (IPA) is an approximation calculated as plane parallel

each pixel for radiation. In the case of wavelength 0.5 microns, as expected, all the discrepancy between 3D cloud and equivalent IPA cloud cases are smaller than the discrepancy between 3D cloud and equivalent plane parallel cloud cases. At a maximum the reflectivity difference for the IPA cloud cases for NHM+ACB model and MODSI/CPR result reaches a value up to 0.040, whereas plane parallel show a large reflectivity difference as 0.010. Each values convert to incident radiative flux then the values are 30Wm-2 and 10Wm-2 respectively. We made sure of the high resolution reduce the accuracy of the difference between the 3D clouds case and IPA clouds case. Then we validate the evidence for tiled clouds we found the relativity of solar zenith angles and the relativity solar azimuth angles for the difference between 3D clouds and IPA clouds. For relativity of solar zenith angles the difference is thickness of stratum. For the relativity solar azimuth angles the difference is amount of cloud. We should calculate the radiation field in many cases of clouds both the realistic clouds case as MODIS/CPR and tiled clouds and so on.

Keywords: Monte Carlo, radiative transfer, radiative flux, 3D cloud, satellite observation, model