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A revised radiation package of G-packed McICA and two-stream approximation

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For more efficient and accurate computation of radiative flux, improvements have been achieved in two aspects, integration of the radiative transfer equation over space and angle. First, the treatment of the Monte Carlo-independent column approximation (MCICA) is modified focusing on efficiency using a reduced number of random samples ("G-packed") within a reconstructed and unified radiation package. The original McICA takes 20% of CPU time of radiation in the Global/Regional Integrated Model systems (GRIMs). The CPU time consumption of McICA is reduced by 70% without compromising accuracy. Second, parameterizations of shortwave two-stream approximations are revised to reduce errors with respect to the 16-stream discrete ordinate method. Delta-scaled two-stream approximation (TSA) is almost unanimously used in Global Circulation Model (GCM) but contains systematic errors which overestimate forward peak scattering as solar elevation decreases. These errors are alleviated by adjusting the parameterizations of each scattering element—aerosol, liquid, ice and snow cloud particles. Parameterizations are determined with 20,129 atmospheric columns of the GRIMs data and tested with 13,422 independent data columns. The result shows that the root-mean-square error (RMSE) over the all atmospheric layers is decreased by 39% on average without significant increase in computational time. Revised TSA developed and validated with a separate one-dimensional model is mounted on GRIMs for mid-term numerical weather forecasting. Monthly averaged global forecast skill scores are unchanged with revised TSA but the temperature at lower levels of the atmosphere (pressure math formula 700 hPa) is slightly increased (< 0.5 K) with corrected atmospheric absorption.