Geophysical Research Abstracts
Vol. 21, EGU2019-5732-3, 2019
EGU General Assembly 2019

Multi-layer solar radiative transfer considering the vertical variation of inherent optical properties of clouds

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A multi-layer radiative transfer scheme is proposed to deal with the vertical variation of inherent optical properties (IOPs) of clouds in this study. The exponential expressions are used to represent the variation of IOPs and a perturbation method coupled with Eddington approximation is used to solve the single-layer radiative transfer equation. In order to make the reflectance/transmittance of single layer more accuracy, the optical properties are adjusted following delta-scaling in the scheme. A modified adding method based on Chandrasekhar's invariance principle is introduced to resolve multi-layer RT. The accuracy of the proposed scheme is investigated by comparing the reflectance/absorptance to the benchmark in two cases of combination of two layers where IOPs are vertically inhomogeneous. Result shows that the bias related to vertical variation of IOPs reaches 15.8% for reflectance and 33.1% for absorptance while the bias of the proposed scheme is only -1.19% for reflectance and 2.1% for absorptance. By applying the proposed scheme as well as the conventional Eddington approximation to a multi-layer radiative transfer model, we find that the proposed scheme also improve the accuracy in both flux and heating rate calculation by taking the vertical variation of IOPs into account. For computational efficiency, the proposed scheme takes almost triple time of Eddington approximation for pure algorithm and double time of Eddington approximation when being applied to a multi-layer radiative transfer model. In view of its accuracy and efficiency, the proposed scheme is well suited for being applied to a climate model to simulate the radiation effect related to vertical variation of IOPs of clouds.