A Novel Approach for Introducing 3D Cloud Spatial Structure Into 1D Radiative Transfer

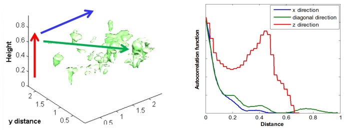
ARM CLIMATE RESEARCH FACILITY

Research Highlight

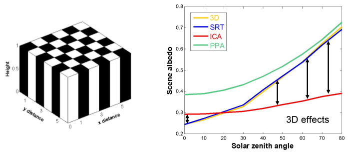
Subgrid-scale variability is one of the main reasons why parameterizations are needed in large-scale models. Similarly, subpixel-scale cloud heterogeneity also plagues satellite retrievals of cloud and aerosol properties. Cloud heterogeneity, to some extent, can be represented by the so-called Independent Column Appoximation, i.e., the gridbox or pixel can be divided into many non-interactive subcolumns and each subcolumn can have its own cloud properties. Neglecting the interaction between subcolumns (i.e., cloud structure) can result in considerable biases in the calculated grid-average quantities.

By using a statistical physics-like concept, we develop a simple 1D statistical transport theory that naturally utilizes a two-point spatial correlation function to describe subgrid-scale cloud-radiation interactions that are traditionally only captured by computationally expensive 3D models. The proposed spatial correlation function encodes the most important information about the spatial arrangement and morphology of clouds and therefore introduces the dependence of radiation field on the 3D structure. Comparison studies of three types of transport media representing checker board, cumulus clouds, and stratocumulus clouds show that the statistical theory is capable of quantitatively capturing the properties of 3D transport models with several orders less computational costs, e.g., enhancement or suppression of reflection by allowing horizontal transport.

The new 1D approach is able to achieve up to one order better accuracy than the Independent Column Approximation method but with several orders less computational cost. This approach therefore provides a novel way to parameterize 3D cloud structure and enables a realistic representation of cloud radiation interactions in large-scale models and satellite remote sensing.



An example of a 3D cloud liquid water content field and the corresponding spatial autocorrelation function along x, z, and diagonal directions. Statistically, the cloud appears to be horizontally isotropic.



The scene albedo calculated using different approaches as a function of solar zenith angle using an idealized checkboard cloud case. The differences between the full 3D approach and ICA approach are the so-called 3D effects. The proposed approach (SRT) is capable of capturing the dependence of 3D effects on the solar angle.

Reference(s)

Huang D and Y Liu. 2015. "A novel approach for introducing cloud spatial structure into cloud radiative transfer parameterizations." Environmental Research Letters, 9(12), 124022.

Contributors

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Working Group(s)

Cloud Life Cycle