3DCLOUD, a flexible three-dimensional cloud generator for radiative transfer

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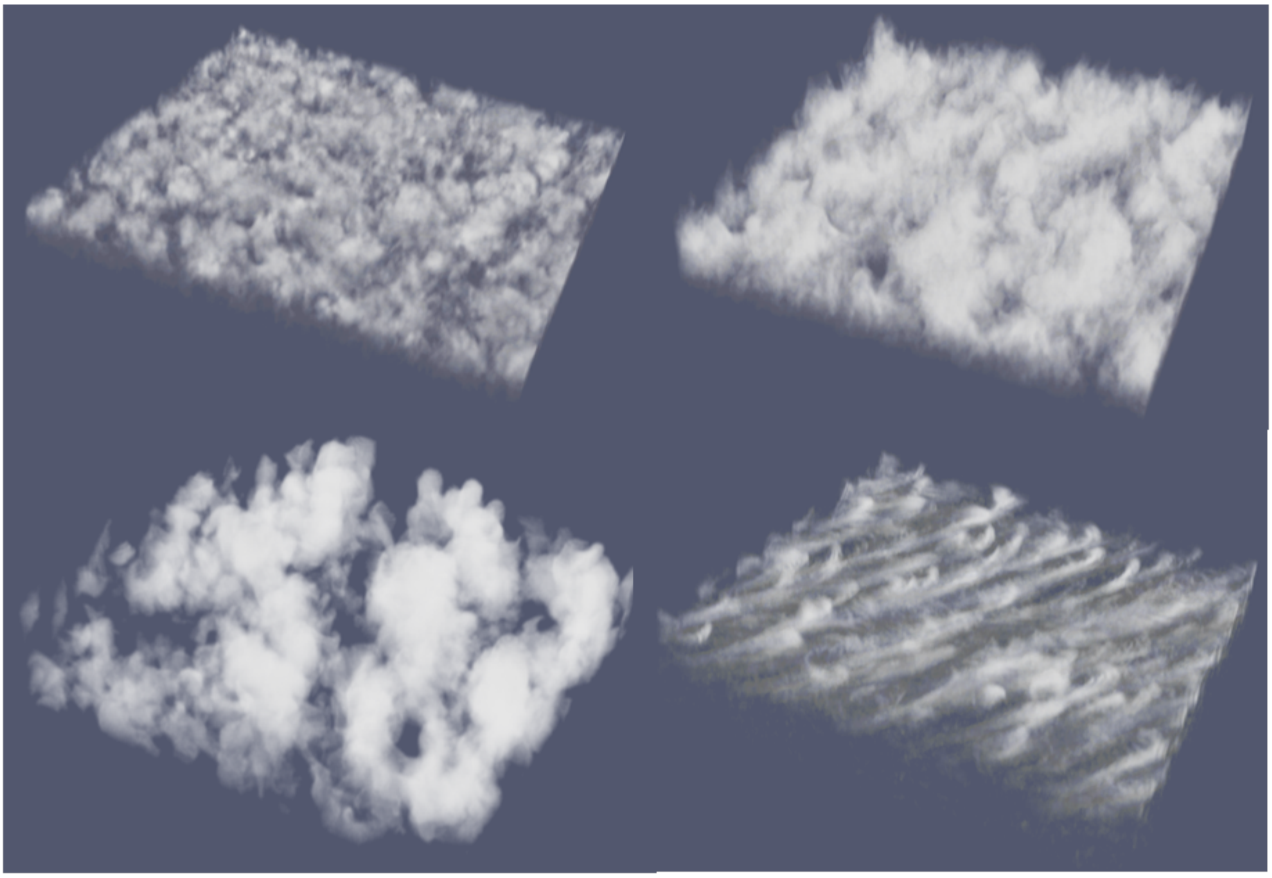
Determining the significance of the tridimensional (3D) inhomogeneity of clouds for climate and remote sensing applications requires the measurement and the simulation of the full range of actual cloud structure. The difficulty is to generate cloud property fields that are statistically representative of cloud fields in nature.

Cloud fields generated by dynamic cloud models, such as the large-eddy simulation model (LES), are very attractive, as they contain the state of the art of physical processes. Nevertheless, they are still very expensive to run in a 3-D domain. Stochastic models have the capability to simulate quickly realistic 2D and 3D cloud structures with just a few parameters. These stochastic models are often based on fractal or Fourier framework. The scale invariant properties observed in real clouds can be controlled. The power spectra of the logarithm of their optical properties typically exhibits a spectral slope of around −5/3 from small scale (a few meters) to the "integral scale" or the outer scale (few tenths of a kilometer to one-hundred kilometers), where the spectrum becomes flat (decorrelation occurs). The disadvantage of such models arises from the fact that effects of meteorological processes are not always considered and dominant scales of organization related to turbulent eddy due, for example, to wind shear, convection, and entrainment are not directly modelled. The aim of the 3DCLOUD (Szczap et al., 2014) is to reconcile these two approaches.

3DCLOUD is designed to generate cloud fields that share some statistical properties observed in real clouds such as the inhomogeneity parameter (standard deviation normalized by the mean of the studied quantity), the Fourier spectral slope (close to −5/3 between the smallest scale of the simulation to the outer scale). Firstly, 3DCLOUD assimilates meteorological profiles (humidity, pressure, temperature and wind velocity). The cloud coverage C, defined by the user, can also be assimilated. 3DCLOUD solves drastically simplified basic atmospheric equations, in order to simulate 3-D cloud structures of liquid or ice water content. Secondly, the Fourier filtering method is used to constrain independently the intensity of inhomogeneity parameter, of spectral slope, of outer scale and of mean of optical depth. Distribution of optical depth is assumed to be gamma.

3DCLOUD model was developed to run on a personal computer under Matlab environment with the Matlab statistics toolbox. 3DCLOUD is thirty times faster than the BRAMS model. We are developing 3DCLOUD_V2 code, an enhanced version of the 3DCLOUD model, where the wavelet framework is used instead of the Fourier framework in the second step. It is well known that wavelets are localized in both space and frequency whereas the standard Fourier transform is localized only in frequency. We show that new iterative wavelet method operating during the second step of 3DCLOUD_v2 algorithm can better control the spectral slope value while keeping spatially the cloud structure simulated during the second step of 3DCLOUD model.

Keywords: 3DCLOUD, radiative transfer, cloud generator



Volume rendering of stratocumulus, cumulus and cirrus fields generated by 3DCLOUD

