Anonymous Referee 1

We thank the reviewer for his detailed review and valuable comments. The manuscript has been modified according to the suggestions proposed by the reviewer. The remainder is devoted to the specific response item-by-item of the reviewer's comments

This paper describes a 3DCLOUD algorithm to generate stochastic 3D cloud fields to be used as a tool to understand cloud-radiation interactions. Overall, I found the paper to be a very good and thorough description of the 3DCLOUD algorithm and feel the paper is a nice fit for this journal. It is also wonderful that the authors provide a link to access the code described in this paper. My recommendation is to accept this paper after the minor points mentioned (below) are addressed.

Minor points:

1. **It would be helpful to reader to describe some fundamental differences between this 3DCLOUD generator and LES. While these may appear fairly obvious it would be nice to list them explicitly in the introduction and/or conclusions section for readers who are more familiar with LES and not so much stochastic cloud generators.**

In the introduction of the revised manuscript, we add before the sentence "Nevertheless, LES are very expensive to run in a 3D domain" this paragraph :

The goal of the LES approach is to simulate the three-dimensional atmospheric turbulent flows. There are different scales of turbulent eddies; large eddies (from 100 to 1000 m and more) that are produced directly by the instability of the mean flow and small eddies (from a few centimeters to 100 m) as well as by the energy-cascade process from the larger eddies (Moeng, 1984). LES seeks to capture accurately the larger eddies, while only modeling the smaller ones. Instead of reproducing all the scales of turbulence flow, they can integrate a flow in which small scale details are removed from the solution. The spatial filtered equations can, therefore, be integrated with available resources (Bryan et al., 2003). Nevertheless, they are still very expensive to run in a 3D domain.

Moreover, in section 2.1.1 (The simplification of basic atmospheric equation) we explain differences between LES equations and 3DCLOUD equations. After the presentation of the second law of newton, we add :

The continuity and momentum equations of the atmosphere under the anelastic and Boussinesq approximation, assuming shallow motion, neglecting Coriolis parameter, neglecting frictional forces, and neglecting the molecular viscosity can be written (Holton, 2004, p. 117 ; Houze, 1993, p. 35 ; Emanuel, 1994, p. 11)

$$\begin{cases} \nabla.\boldsymbol{u} = 0 \\ \dfrac{D\boldsymbol{u}}{Dt} = -\dfrac{1}{\rho_0}\nabla p^* + B\boldsymbol{k} \end{cases} \tag{2}$$

where B is the buoyancy acceleration, ρ_0 is the constant mean value of air density and p^* is the pressure perturbations. The above differential operators are valid only in the limit when δt, δx, δy and δz approach 0 (Pielke, 2002, p. 41). Nevertheless, turbulent motions (shear induced eddies, convection eddies) have spatial and temporal variations at scales much smaller than those resolved by LES and 3DCLOUD. If we assume field variables can be separated in slowly varying mean field and rapidly varying turbulent component, and if we apply the Reynolds decomposition, we can rewrite the above equation set as:

$$\begin{cases} \nabla.\boldsymbol{u} = 0 \\ \dfrac{D\boldsymbol{u}}{Dt} = -\dfrac{1}{\rho_0}\nabla p^* + B\boldsymbol{k} + \boldsymbol{\Phi} \end{cases} \qquad (3)$$

where $\boldsymbol{\Phi}$ is the three dimensional convergence of the eddy flux of moment (Houze, 1993, p. 42), the turbulent flux (Holton, 2002, p 119) or the sub-grid correlation term (Pielke, 2002, p. 44). The Reynolds decomposition is not used in LES. The atmospheric equations are derived by spatial filtering, where a special function is applied. Thus, the filtering operation acts on atmospheric quantities and separates them in two categories: the resolved one (large eddy) and unresolved one (subgrid-scale). An unknown term remains in the filtered equations of LES, often called the subgrid-scale stress, which needs to be parameterized or estimated with the help of subgrid-scale modeling. This subgrid-scale stress for LES equations is analogous to the $\boldsymbol{\Phi}$ term for Reynolds decomposition. In 3DCLOUD, the $\boldsymbol{\Phi}$ term is voluntarily neglected. Indeed, the guiding idea of 3DCLOUD is to simulate, in the fastest way, 3D fluctuations of LWC/IWC of a cloud showing turbulent properties (or invariant scale properties).

For example, it would be nice if the authors would state how long it takes to run the matlab code for some of the cases at different spatial resolutions (perhaps in a table). Surely, it is much faster than LES.

This remark of referee 1 is analogous with one of the referee 2: “. What is the computational expense of 3DCloud as compared to LES?

In the revised manuscript, we add the Tab 1. We add this paragraph in section 4.1.1 (Effects of numerical spatial resolution):

Table 1 shows the time step, process time for one time step and process time for 2h-simulation with 3DCLOUD model, as a function of the numerical resolution. DYCOMS2-RF01 and BOMEX cases are presented. The process time for 2h-simulation is indicated because 3DCLOUD algorithm convergence is achieved after 2 h (or less) of simulation for stratocumulus, cumulus and cirrus regimes (see Fig. 10 for cumulus case). For both cases, the smaller the spatial resolution, the smaller the step time and the larger the process time. A comparison between 3DCLOUD and BRAMS LES computation time for a specific DYCOMS2-RF01 case is added (see Sect. 3.4). For this specific case, 3DCLOUD simulation is thirty times faster than BRAMS simulation. Note that 3DCLOUD (Matlab code) runs on a personal *computer with Intel Xeon E5520 (2.26 GHz) and BRAMS (Fortran code) runs on a PowerEdge R720 with Intel Xeon E5-2670 (2.60 GHz), both of them having a single-processor configuration.*

Table 1. Time step, process time for one time step and process time for 2h-simulation with 3DCLOUD model, as a function of the numerical resolution. DYCOMS2-RF01 and BOMEX cases are presented. A comparison between 3DCLOUD and BRAMS LES computation time for a specific DYCOMS2-RF01 case is added. 3DCLOUD (Matlab code) runs on a personal computer with Intel Xeon E5520 (2.26 Ghz) and BRAMS (Fortran code) runs on a PowerEdge R720 with Intel Xeon E5-2670 (2.60Ghz), both of them having a single-processor configuration.

Study case	Point mesh $N_x \times N_y \times N_z$	Horizontal numerical resolution Δx [m]	Time step [s]	Process time [s]	Process time for 2h-simulation [s]
DYCOMS2-RF01	$50 \times 50 \times 50$	200	10	0.4	290
	$100 \times 100 \times 50$	100	7	1.3	1340
	$200 \times 200 \times 50$	50	5	5	7200
	$400 \times 400 \times 50$	25	3	18	43200
BOMEX	$50 \times 50 \times 70$	200	30	0.7	170
	$100 \times 100 \times 70$	100	25	2.5	720
	$200 \times 200 \times 70$	50	20	10	3600
	$400 \times 400 \times 70$	25	14	40	20600
DYCOMS2-RF01					
3DCLOUD	$100 \times 100 \times 100$	40	13	2.7	1500
BRAMS	$100 \times 100 \times 100$	40	0.3	2	48600

2. **Figure 6, it is not clear to me which curve represents the 3DCLOUD generator. The figure caption states the bold curve but the color in the legend doesn't quite seem to correspond to the color of the bold curve.**

The legend of Figure 6 is modified in the revised manuscript in order to correspond to the color of the bold curve.

3. **3DCLOUD gen has been compared to time averaged LES profiles, which agree satisfactorily. Have the authors compared the simulated cloud fields (such as those shown in top row of fig. 7) to those produced by LES? If so do they also agree satisfactorily?**

This remark of referee 1 is analogous with one of the referee 2 : "How does the quality of results from 3DCloud compare to LES? Can the authors plot comparable scenes (planform snapshots of cloud or radiative fields) from LES in order to compare differences?".

In the revised manuscript, we add the following paragraph about the 3DCLOUD and LES cloud fields in the new section 3.4 entitled “Comparison between 3DCLOUD and BRAMS LES for DYCOM2-RF01 case”:

In order to underscore differences between 3DCLOUD and LES for comparable scenes, we choose again the well documented DYCOMS2-RF01 case. Snapshots can be found, for example, in Stevens et al. (2005) and in Yamaguchi and Feingold (2012). We performed the 4h simulations of the DYCOMS2-RF01 case with 3DCLOUD and with the Brazilian Regional Atmospheric Modelling System (BRAMS v4) model (Pielke at al., 1992 ; Cotton et al., 2003). BRAMS simulations were provided by G. Penide (Penide et al., 2010). The BRAMS model is constructed around the full set of nonhydrostatic, compressible equations. The cloud microphysics parameterization is based on a two-moment scheme (Meyers et al., 1997). Subgrid scale fluxes are modeled following Deardroff (1980). The base calculations are performed on a $100 \times 100 \times 100$ *point mesh with a step time of 0.3 s.*

Figure 7 shows the instantaneous cloud-field snapshots of the pseudo albedo (see definition in Sect. 4) at four hours simulated by (a) the UCLA-0 model (picture taken from Stevens et al., 2005), (b) the BRAMS model, both configured following the DYCOMS2-RF01 case (Stevens et al., 2005) and (c) from 3DCLOUD with assimilation of meteorological profiles based on the DYCOMS-RF01 case. Both BRAMS and 3DCLOUD cases are drawn from simulations where $\Delta_x = \Delta_y = 40\ m$ *and* $\Delta_z = 12\ m$*. These three snapshots of cloud fields are characterized by closed cellular convection with large cloud cover, as argued in Yamaguchi and Feingold (2012), who did simulation of DYCOMS-RF01 case with the LES mode of the Advanced Research WRF model. Figure 7 also shows the power spectra computed following the x and y directions and then averaged, for BRAMS and 3DCLOUD optical depth fields. The 3DCLOUD optical depth spectral slope is close to -5/3 in the* $[L_{out}: 1/(2\Delta x)]$ *m^{-1} wavenumber range, as expected, because of the statistical adjustment performed in the second step of the 3DCLOUD algorithm. By contrast, the BRAMS optical depth spectral slope is close to -5/3 only in the* $[2 \times 10^{-3}: 5 \times 10^{-3} \approx 1/(5\Delta x)]$ *m^{-1} wavenumber range. Depending on their degree of sophistication, LES do not always guarantee cloud invariant scale properties at the larger wavenumbers. Indeed, Bryan et al. (2003) have shown, that for the finite-difference model, the vertical wind velocity spectral slope is steeper than -5/3 for scales shorter than* $6\Delta x$*. Table 1 shows the computation performance of 3DCLOUD and BRAMS. For this specific case, 3DCLOUD simulation is thirty times faster than BRAMS simulation.*

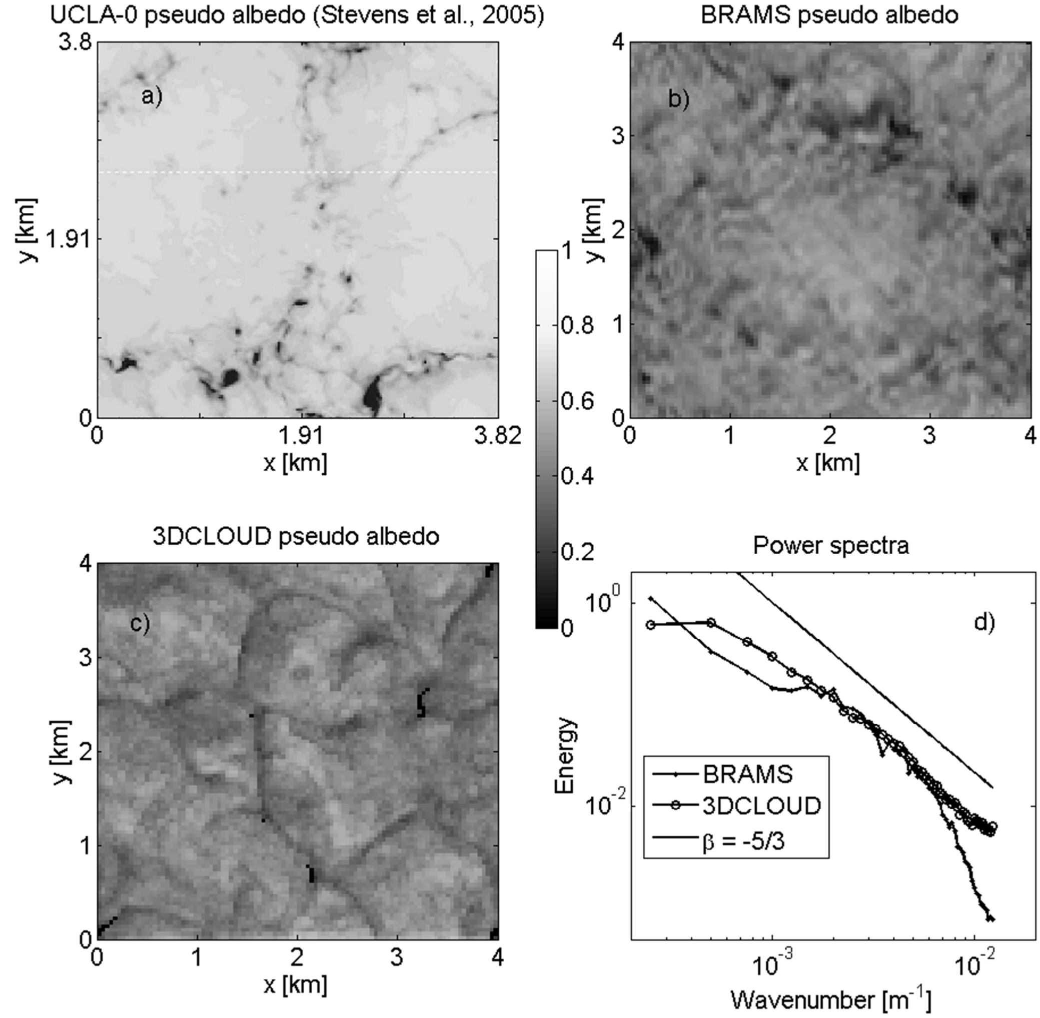

Figure 7. The instantaneous cloud-field snapshots of the pseudo albedo at four hours simulated by (a) the UCLA-0 model (picture taken from Stevens et al., 2005), (b) the BRAMS model, both configured following the DYCOMS2-RF01 case (Stevens et al., 2005) and (c) from 3DCLOUD with assimilation of meteorological profiles based on the DYCOMS-RF01 case. The UCLA-0 field is drawn from simulation where $N_x = N_y = 192$ *and* $\Delta_x = \Delta_y = 20$ *m. Both BRAMS and 3DCLOUD are drawn from simulations where* $N_x = N_y = N_z = 100$, $\Delta_x = \Delta_y = 40$ *m and* $\Delta_z = 12$ *m. Note that the 3DCLOUD field is obtained at the second step of the algorithm, with the inhomogeneity parameter* $\rho_\tau = 0.3$, *mean optical depth* $\bar{\tau} = 10$ *and* $L_{out} = 2$ *km. (d) is the optical depth power spectra computed following the x and the y directions and then averaged, for BRAMS (points) and 3DCLOUD (circles). A theoretical power spectrum with spectral slope* $\beta = -5/3$ *is added (black line).*

4. **Figures 2 through 4, please state which cases are being examined in the figure captions.**

In the revised manuscript, we add in the figure captions of figures 2 and figure 3 the sentence: *“Displayed is The DYCOM2-RF01 case is displayed*”. We add in the figure captions of figure 4 and figure 5 the sentence: “*The BOMEX case is displayed*”.

5. **Throughout the paper there are frequent minor grammatical errors. In addition, some paragraph breaks (or lack of them) are awkwardly chosen.**

The revised manuscript has been proofread by a native English speaker.

6. **At the bottom of page 303 the authors state “This method gives satisfactory results for stratocumulus and cumulus clouds cloud fields but not for cirrus fields”. A short explanation follow this statement of why it wouldn’t work for cirrus fields would be helpful.**

To control the cloud coverage C at the step 1 of 3DLOUD algorithm, we iteratively adjust the value of the vertical profile of vapor mixing ratio until C value reaches the required value within few percent. This method gives satisfactory results for stratocumulus and cumulus clouds fields but not for cirrus cloud fields.

To explain why it is difficult to control the cloud coverage in cirrus regime with the current version of 3DCLOUD, we add in the revised manuscript this paragraph, just after the sentence “This method gives satisfactory results for stratocumulus and cumulus clouds cloud fields but not for cirrus fields”:

This is because condensation/evaporation and dynamic processes are different for stratocumulus/cumulus and cirrus regimes. Indeed, for liquid and warm stratocumulus/cumulus regime, liquid super or sub-saturation regions are not allowed in 3DCLOUD. Therefore, the distinction between cloudy and free cloud voxels is sharp. Moreover, as stratocumulus/cumulus fields are often driven by convection processes in a well-mixed planetary boundary layer, vertical correlation occurs between cloudy voxels (free cloud voxels) and updrafts (downdrafts). Thus, the fractional cloud coverage is easily controlled by adjusting the vertical profile of vapor mixing ratio during the simulation. By contrast, in ice cirrus regimes, (large) ice crystals can survive even if ice relative humidity is less than 100%. Ice super or sub-saturation regions are often observed in cirrus and are taken into account in the Starr and Cox parameterization used in 3DCLOUD. Therefore, many cloudy voxels still exist in our cirrus simulations, even if the ice water content is very small. The distinction between cloudy and free cloud voxels is, thus, very tenuous. Moreover, cirrus dynamics is often driven by wind shear: small fractional cloud coverage can exist at the top of the cirrus field due to convection or radiative cooling coexisting with large fractional cloud coverage and can also exist at the bottom of cirrus field due to wind shear. Finally, the total cloud coverage could be large. If we adjust the vertical profile of vapor mixing ratio during the simulation in the same way as for the stratocumulus/cumulus field, the total cloud *coverage will be difficult to control. Further investigations are thus needed to perfectly control the cloud coverage of cirrus simulated by 3DCLOUD.*