Realistic visualization of a cumulus cloud and rainfall based on the cloud formation simulation with the super-droplet method

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This paper reports an attempt to visualize realistically the large-scale data of the cloud formation simulation to combine the super-droplet method, a novel particle-based method for cloud microphysical processes and a non-hydrostatic atmospheric model for cloud dynamical processes. For the realistic visualization, the image synthesis requires optical model computations to include multiple scatterings of sunlights by vast number of the super-droplets. Two kinds of programs for it are developed based on the methodology of the volume photon mapping. One of them is the photon tracing simulation program based on the Monte-Carlo method for the multi-scattering process of lights. Another is the adoptive ray marching program for the final gathering of in-scattered lights onto the view plane. Here, optical characteristics of a super-droplet are defined on several assumptions analogous to the case of real-droplets. For speeding-up, both of these programs are also designed to be executed in parallel, so that the target size of the super-droplet data for the cloud formation simulation is at least of the order of gigabytes per one time-step. Resulting images successfully captures realistic features of the cumulus cloud simulated by the simulation.

1. Introduction

We have developed a novel, particle-based, probabilistic simulation model of cloud microphysics named the super-droplet method (SDM) and the macro-micro interlocked simulation of cloud formation with SDM(1). We have also been developing various types of visualization tools for the cloud formation simulation with SDM. This paper focuses on the visualization methods we developed, mainly the photo-realistic approach based on the optical calculations. To visualize our super-droplet data, we apply techniques of computer graphics fundamentally along the context of a global illumination model of computer graphics, the volume photon mapping in participating media(2). However, we minimize the use of the approximations only for effective appearance frequently applied in the field of computer graphics, in order to extract fully the optical features hidden in the super-droplet data.

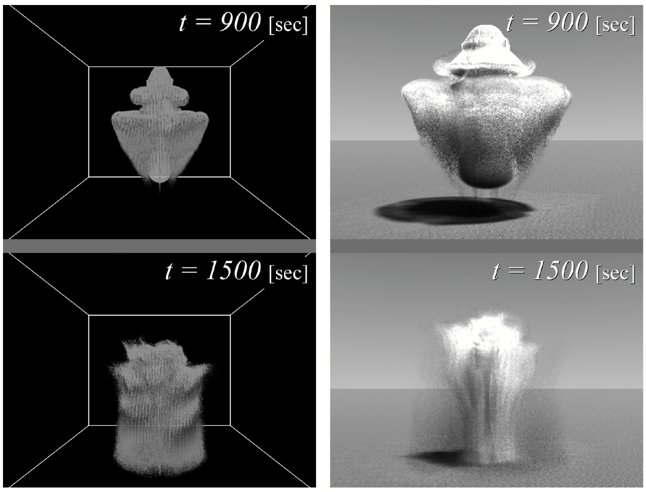

Fig. 1: Results by the photo-realistic approach

2. Cloud microphysics - the super-droplet method

A super-droplet is defined as the conceptual particle representing a multiple number of droplets with the same attributes. The multiplicity of droplets is also added to a member of the attributes of the super-droplet. Processes of motion, condensation/evaporation of super-droplets are defined as same as of droplets. In terms of stochastic coalescence of droplets are also adopted in the unique Monte Carlo scheme(1).

3. Program developments and experiments

We developed of the two types of programs, the photon tracing and the ray marching program, and visualized the sets of super-droplet data obtained by the cloud formation simulation with SDM. Both of the programs are designed for shared memory parallel computers with OpenMP parallelization. The test of the programs for photon tracing and ray marching were performed by using SGI Altix4700 (Intel Itanium2, 256 cores, 256GB memories). We visualized 40 time-steps of the super-droplet data, of which total size is around 53.2GB, and then obtained the sequential images capturing growth and decay of the cumulus cloud (Fig. 1). Several features similar to actual dense clouds are found In these figures, such as complex shape and texture of the surface, shadow of the cloud and rainfall. We can find out the correspondence between the distribution of super-droplet sizes (LHS of Fig. 1) and texture of the cloud surface (RHS of Fig. 1).

References

1. Shima, S. et al., "The super-droplet method for the numerical simulation of clouds and precipitation: A particle-based and probabilistic microphysics model coupled with a non-hydrostatic model", Q. J. R. Meteorol. Soc. Vol. 135 (2009), pp. 1307-1320; arXiv:physics/0701103 [phys-ph] 9 Jan 2007.
2. Jensen, H. W., "Realistic Image Synthesis Using Photon Mapping", AK Peters (2001).