Introduction to Cloud Modeling - report 4

Kamil Kolasa

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The main topic during last few Introduction to cloud modeling tutorials was collision and coalescence of cloud droplets. To describe this phenomenon we used a Monte Carlo scheme, which inter alia involved the Golovin's kernel, super-droplets method and randomly generated pairs sampling proposed by Shima et al. [2009]. First of all, Golovin's kernel is given as:

$$K_{jk} = b(v_j + v_k), \tag{1}$$

where v_j and v_k are droplets' volumes and $b = 1.5{\cdot}10^3\ \mathrm{s}^{-1}$. Then, the probability of coalescence is

$$P_{jk} = K_{jk}\Delta t/V, \tag{2}$$

where Δt is the timestep and V is the cloud volume.

Because of high numerical cost of calculating the probabilities for every droplet, a method of super-droplets was implemented. Each superdroplet (labeled i) represents a number of identical real droplets ξ_i. To reduce the cost even more, probability of coalescence was not calculated for every droplets pair for a timestep. Every timestep droplets were randomly collected into pairs. Both of these operations introduce changed probabilities, namely for super-droplets:

$$P_{jk}^{\mathrm{SD}} = \max(\xi_j, \xi_k)P_{jk} \tag{3}$$

and for super-droplets with linear sampling:

$$P_{jk}^{\mathrm{SD,LS}} = \frac{\mathcal{N}(\mathcal{N}-1)}{2\lfloor \mathcal{N}/2 \rfloor}, \tag{4}$$

where $\mathcal{N}$ is the number of considered pairs.

Figures 1-4 present results of numerical calculations described above. The initial droplet number density was $n_0 = 100\ \mathrm{cm}^{-3}$, the cloud volume was $V = 10^6\ \mathrm{m}^3$, number of super-droplets was $\mathcal{N} = 1000$ and the initial droplet volume distribution was given by equation:

$$f(v) = \frac{1}{\bar{v}}\exp\left(-\frac{v}{\bar{v}}\right) \tag{5}$$

with $\bar{v} = \frac{4}{3}\pi\bar{r}^3$ given by mean radius $\bar{r} = 30.531\ \mu\mathrm{m}$. The Figure 1 shows numerically obtained droplet number density with respect to time and also a theoretical solution to the problem. As one can see, for the first seconds both lines overlap each other, however for greater values of time the cyan line tends to zero faster than the blue one. This might be a numerical artefact, because for the described algorithm it is impossible to all droplets to disappear. The limiting case is when all the super-droplets combine into one. This might be the reason why the numerical data does not cover the theoretical predictions perfectly for smaller concentrations. However, the exponential time-dependence is still present.

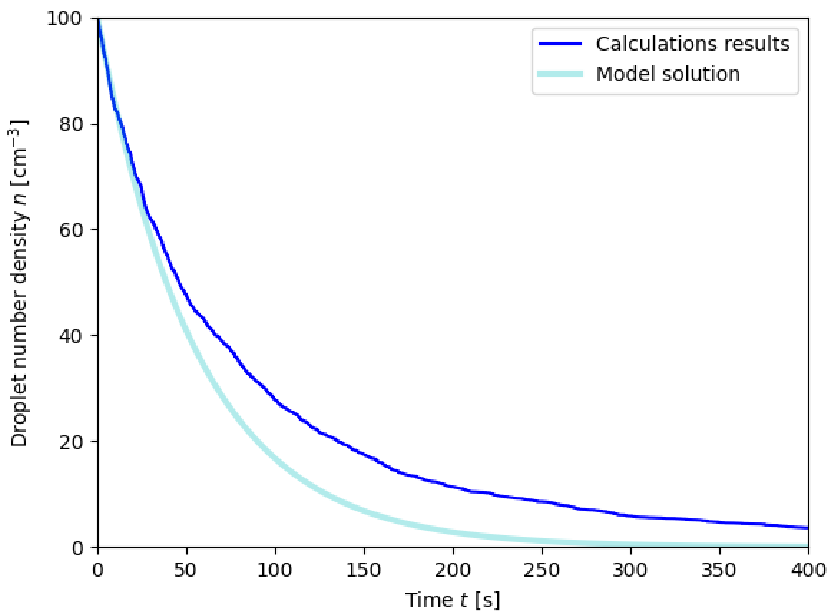

Figure 1: Droplet number density n.

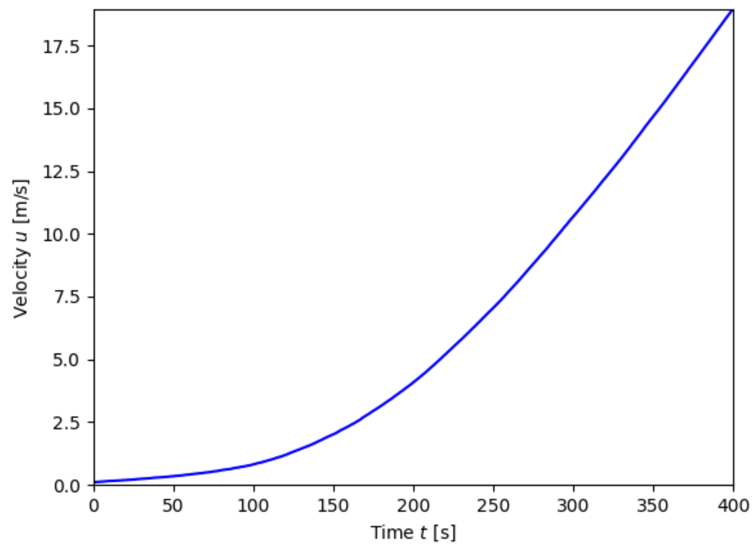

Figure 2: Mean droplets' velocity u.

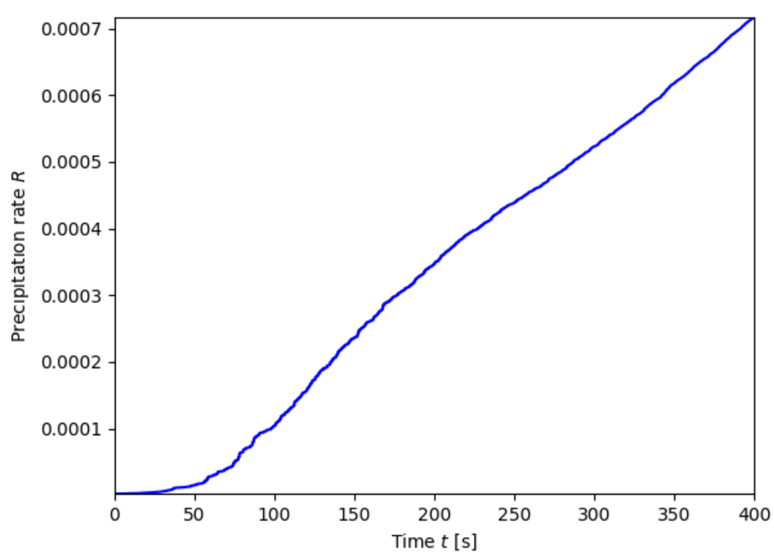

Figure 3: Precipitation rate R.

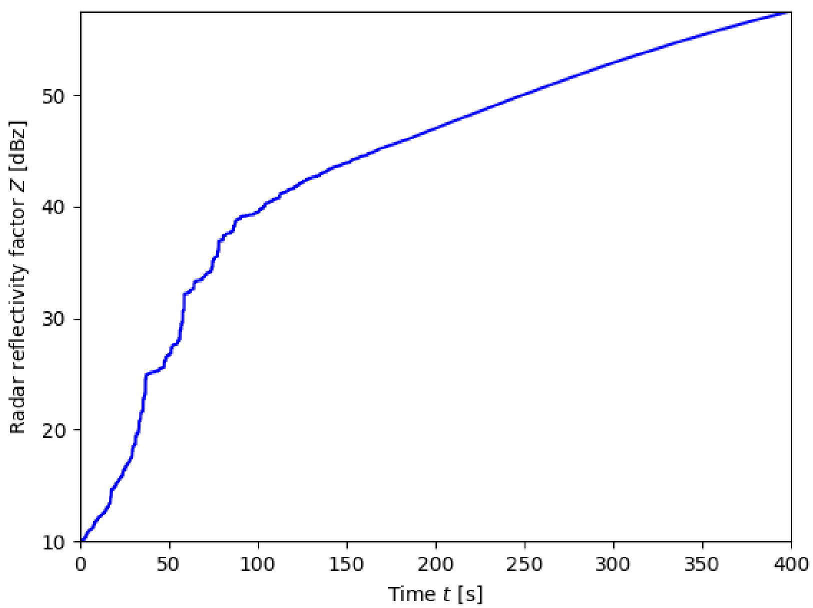

Figure 4: Radar reflectivity factor Z.