Applying super-droplets as a compact representation of warm-rain microphysics for aerosol-cloud-aerosol interactions

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poster presented at

1. Introduction

Aerosol interacts with clouds by serving as nuclei on which cloud droplets form.
Clouds process aerosol changing size distribution of aerosol by physical and chemical processes occurring in the clouds.

The main challenge of representing aerosol-cloud processing in a numerical cloud model stems from the need to track the properties of cloud drop nuclei throughout the cloud lifecycle. A class of methods allowing such studies is the Lagrangian particle-based simulation technique.

In this study a new implementation a Lagrangian particle-based cloud simulation framework based on the super-droplet method of Shima et al. (2009) is presented. It employs the kappa-Koehler aerosol composition parametrization and features a simple aqueous chemistry representation.

2. Model implementation

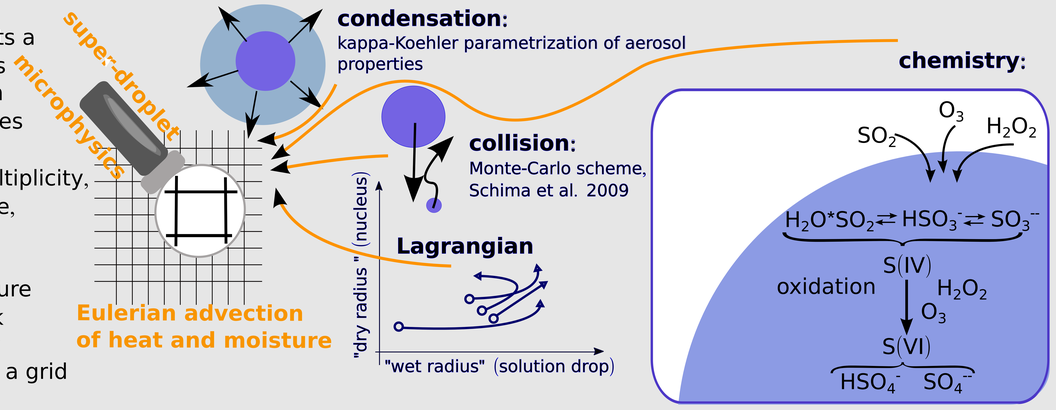
- New object-oriented implementation of the MPDATA Eulerian advection solver (Smolarkiewicz 2006).
- Parallel particle-tracking framework implemented using Nvidia's Thrust library
- open-source, implemented in C++, code repository at: **http://icicle.igf.fuw.edu.pl/**

3. Simulation setup

- based on Stratocumulus case set-up from the 8-th Int Cloud Modeling Workshop (Grabowski, Lebo et al. in preparation)
- 2D prescribed flow field (single eddy)
- constant-with-height initial water vapour and potential temperature profiles (supersaturation in the upper 1/3 of the domain)
- constant with height and in time trace gases (SO_2, O_3, H_2O_2) volume mixing ratios

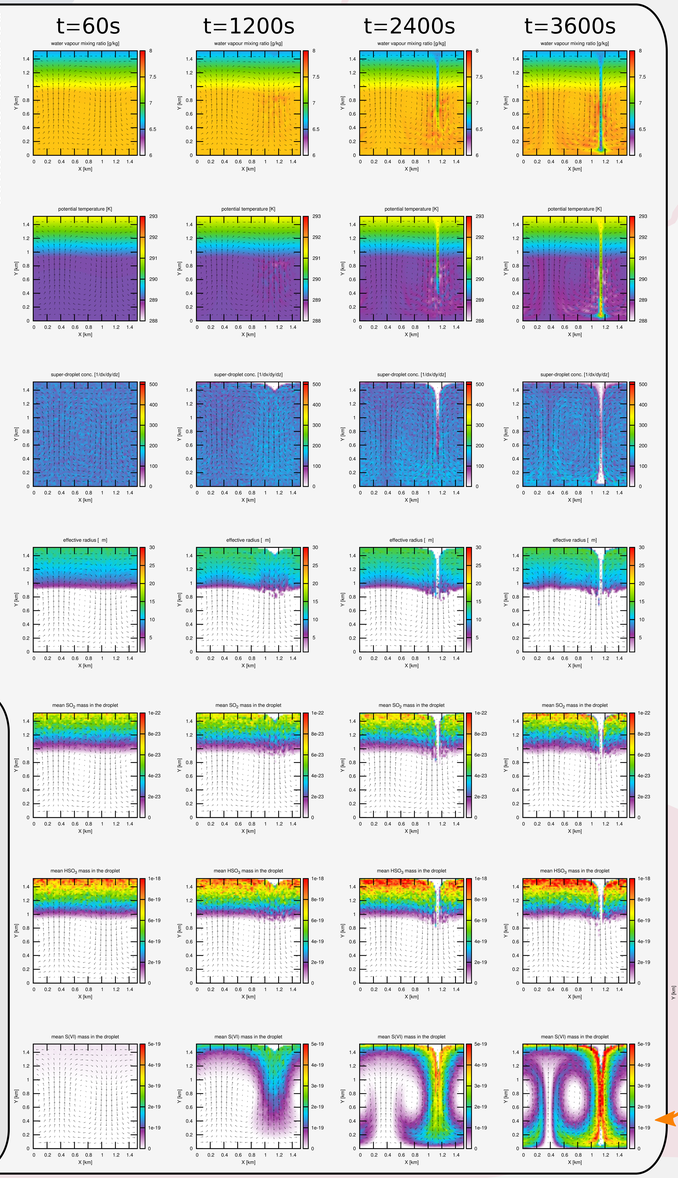
4. The super-droplet method

- each super-droplet represents a multiplicity of solution droplets (aerosol, cloud or precipitation particles) of the same attributes
- super-droplet attributes: multiplicity, dry and wet radii, nucleus type, chemical composition
- coupling with Eulerian moisture and heat advection framework via source terms evaluated by summing over particles within a grid



5. Simulation results

collisions disabled



6. Discussion

- formation of cloud droplets on aerosols
- evaporation of cloud droplets below cloud base (downdraft region)
- advection of the drier air from above the cloud by the downdraft
- formation of dissolved and dissociated chemical compounds (the process is reversed when cloud droplets evaporate below cloud base)
- formation of sulfuric acid ions (HSO_3^- SO_3^{--}) by aqueous phase oxidation (the process is irreversible, formed chemical compounds remain on aerosol nuclei even after drop evaporates)

7. Work in progress

-TO DO: couple the chemistry module with the kappa-Koehler aerosol composition parametrization

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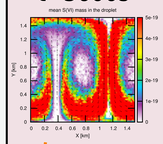

the same simulation setup but with collisions enabled

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2011/01/N/ST10/01483

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