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Efficient Computation of Turbulent Aerosol Dispersion

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Motivation

Aerosols in turbulence can form clusters of high concentration and voids of low concentration. This phenomenon is known as preferential concentration as a consequence of particle inertia.

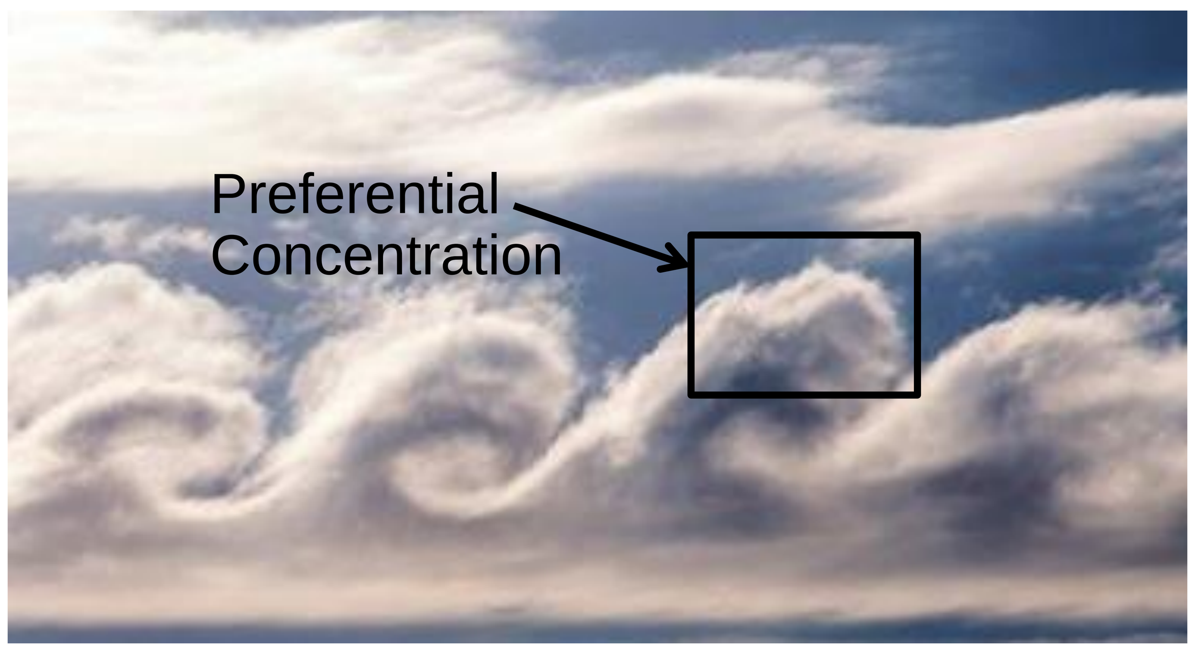

Figure 1. Example of preferential concentration in kelvin-Helmholtz clouds.

Preferential concentration is important for the evolution of the aerosol size distribution which is described by the general aerosol dynamic equation, which is summarised below:

$$total\ collisions \propto local\ concentration^2$$

Therefore local spatial and temporal fluctuations of aerosol concentration can greatly modify the aerosol size distribution and dispersion non-linearly.

Currently, preferential concentration is often neglected in computations, due to computational cost. We aim to reduce the cost by developing an efficient Eulerian formulation.

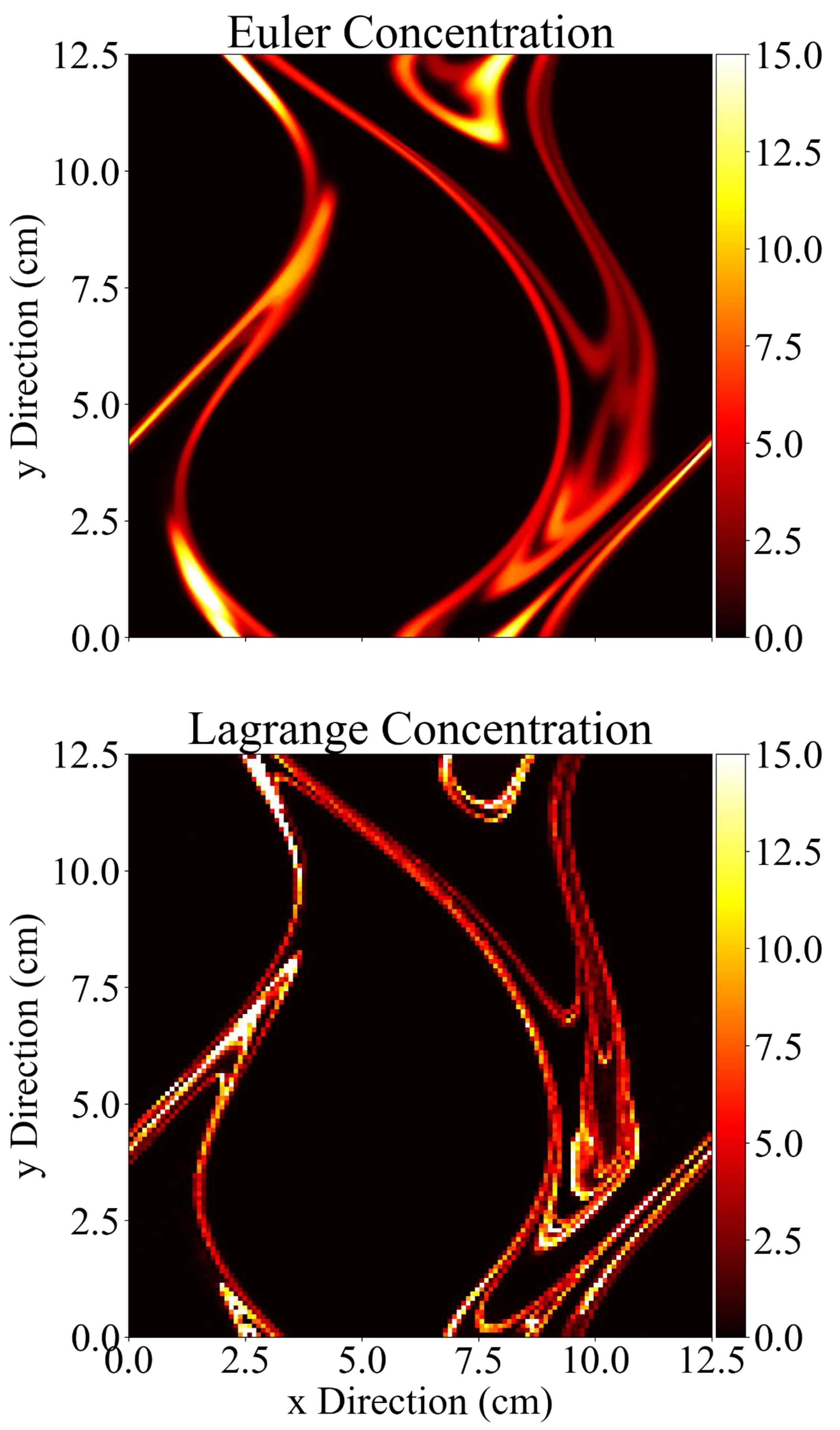

Figure 2. Snapshot of relative concentration of aerosol within a turbulent 2D simulation. Eulerian simulation (top) and Lagrangian simulation (bottom).

Statement of the problem

Commonly aerosols are simulated with Lagrangian tracking through a turbulent flow, where each aerosol particle is followed individually within the fluid flow. This method is close to the physical reality, as we do have individual particles. Although, Lagrangian simulations are closer to the physical reality, they require a large number of particles (typically many millions) to reduce the statistical uncertainty of the results, such as presented in Figure 2.

An Eulerian method for simulating aerosol particles involves simulating the concentration field directly. Therefore, it reduces the computational needs of the Lagrangian method while reducing the statistical uncertainty. Figure 2 shows the concentrations fields from both the Lagrangian and newly developed Eulerian method. The main message from Figure 1 is that the Lagrangian has more detail but also more random noise with more expensive computations.

The newly developed Eulerian method includes adding Reynolds stresses for the aerosol phase, which allows the capture of ballistic trajectories and therefore accurately the preferential concentration for the first time. The Eulerian method was extended to 3D simulations, Figure 3 provides an example for forced homogenous isotropic (HIT) 3D turbulence.

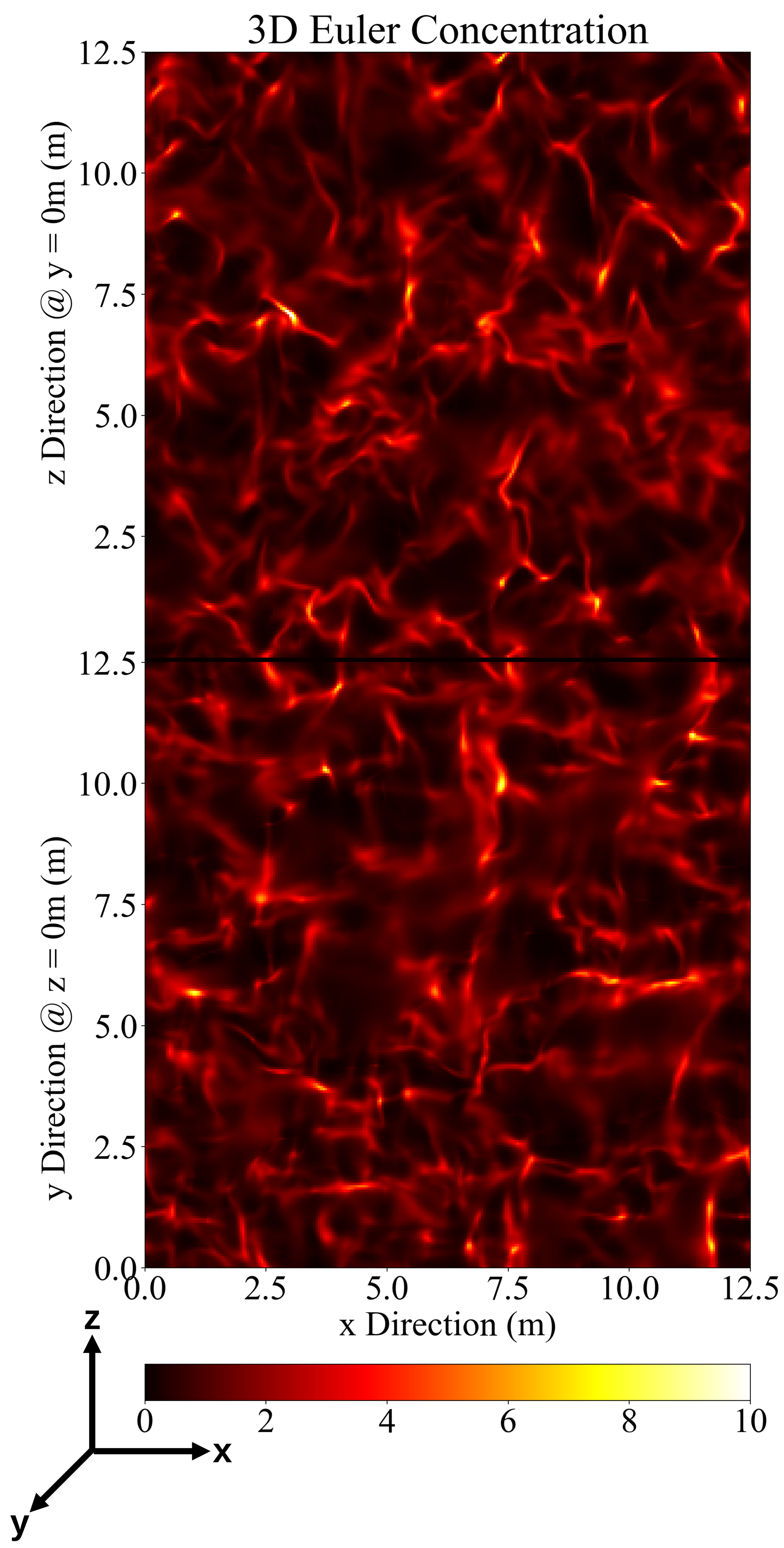

Figure 3. Instantaneous relative concentration of aerosol within 3D HIT across 2 orthogonal slices (z,x) & (y,x).

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