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Large Eddy Simulation of Forced Plumes Using Lattice Boltzmann Method

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Thermal plumes are involved in many aspects of fire safety including wildfires, fire detection, and fire suppression. Such a phenomenon was studied extensively in the literature analytically, experimentally and numerically [1, 2, 3]. The numerical studies in the literature were based on the classical Navier-Stokes equations meanwhile in our study a different approach is used to investigate this phenomenon.

A promising technique for numerical simulations is investigated with a whole different set of equations called the Lattice Boltzmann equations. In this method the fluid is solved on the mesoscopic level instead of the macroscopic level that Navier-Stokes equations are based on [4]. The speed of the LBM makes it attractive nowadays compared to classical Navier-Stokes solvers. The need of such a low cost method rises from the huge computational resources required for LES in large–scale plumes. A pressure-based regularized lattice-Boltzmann method [5] is used to simulate turbulent forced plumes with gravitational forcing term. The solver is based on a $D3Q19$ lattice with a BGK collision model, a regularization procedure is performed before the collision step to enhance numerical stability. Energy equation is solved using the classical finite difference non-conservative enthalpy equation. The coupling is to resolve mass and momentum conservation equations using LBM then to exchange information with the classical enthalpy equation.

Two academic 2D test cases were validated at first; Rayleigh Bénard [6] and Rayleigh Taylor [7] were chosen for model validation, quantitative comparisons with literature are presented. The setup of the 3D forced plume simulation is following the LES of [3]. Quantitative and qualitative comparisons are done with previous analytical, experimental and numerical studies. Axial velocity and temperature profiles are assessed in the far plume-like region, the radial profiles are also examined to check self-similarity, in addition to some over-all quantities of the plume such as: plume width, entrainment coefficient as well as heat and momentum fluxes.

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