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Optimization strategies for efficient high-resolution volcanic plume simulations with OpenFOAM

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In the last years, the interest in three-dimensional physico-mathematical models for volcanic plumes has grown, motivated by the need of predicting accurately the dispersal patterns of volcanic ash in the atmosphere (to mitigate the risks for civil aviation and for the nearby inhabited regions) and pushed by improved remote sensing techniques and measurements. However, limitations due to the mesh resolution and numerical accuracy as well as the complexity entailed model formulations, have so far prevented a detailed study of turbulence in volcanic plumes at high resolution. Eruptive columns are indeed multiphase gas-particle turbulent flows, in which the largest (integral) scale is in the order of tens or hundreds of kilometers and the smallest scale is of the order of microns. Performing accurate numerical simulations of such phenomena remains therefore a challenging task.

Modern HPC resources and recent model developments enable the study of multiphase turbulent structures of volcanic plumes with an unprecedented level of detail. However, a number of issues of the present model implementation need to be addressed in order to efficiently use the computational resources of modern supercomputing machines. Here we present an overview of an optimization strategy that allows us to perform large parallel simulations of volcanic plumes using ASHEE, a numerical solver based on OpenFOAM and one of the target flagship codes of the project ChEESE (Centre of Excellence for Exascale in Solid Earth). Such optimizations include: mixed precision floating point operations to increase computational speed and reduce memory usage, optimal domain decomposition for better communication load balancing and asynchronous I/O to hide I/O costs. Scaling analysis and volcanic plume simulations are presented to demonstrate the improvement in both computational performances and computing capability.