A hybrid method for hydrodynamic-kinetic flow

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In this work we present a non stationary domain decomposition algorithm for multiscale hydrodynamic-kinetic problems, in which the Knudsen number may span from equilibrium to highly rarefied regimes. Our approach is characterized by using the full Boltzmann equation for the kinetic regime, the Compressible Euler equations for equilibrium region, with a buffer zone in which the BGK-ES equation is used to represent the transition between fully kinetic to equilibrium flows.

In this fashion, the Boltzmann solver is used only when the collision integral is non-stiff, and the mean free path is of the same order as the mesh size needed to capture variations in macroscopic quantities. Thus, in principle, the same mesh size and time steps can be used in the whole computation. Moreover, the time step is limited only by convective terms.

This talk will concentrate on the integration of the BGK model and of its ES-BGK extension, and on the preservation of asymptotic properties at the numerical level. Moreover, care will also be given to the preservation of these properties in the enforcement of boundary conditions using the technique of immersed boundaries. This choice permits to treat complex domains, but still using a cartesian structure for the grid, which leads to good scaling properties when the code is parallelized.

Since the Boltzmann solver is applied only in wholly kinetic regimes, we use the reduced noise DSMC scheme we have recently proposed. This ensures a smooth exchange of information across the different domains, with a natural way to construct interface numerical fluxes. Several tests comparing our hybrid scheme with full Boltzmann DSMC computations show the good agreement between the two solutions, on a wide range of Knudsen numbers.

Finally, two dimensional tests show that the boundary conditions proposed here for the BGK model prevent the onset of spurious energy fluxes close to the hydrodynamic regime.

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