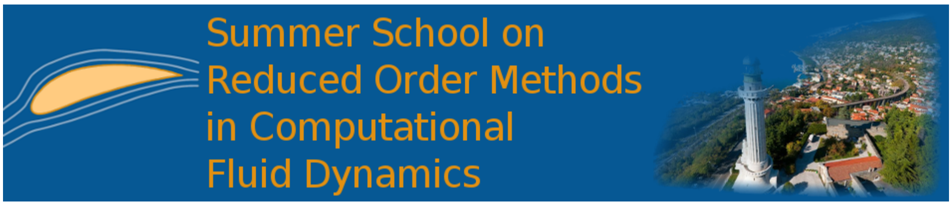

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Finite volume POD-Galerkin Reduced Order Model of the Boussinesq approximation for buoyancy-driven flow

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To model the complex dynamics of buoyancy for nuclear thermal-hydraulic studies and other similar industrial problems, a two-way coupling between the momentum equations and the energy equation is required. To simplify the problem, the Boussinesq approximation is often applied by neglecting the effect of local density differences of the fluid, induced by temperature, except for the density variation in the gravitational body force term.
However, to model buoyancy-driven flows using a full numerical approach is completely unfeasibly for many applications due to the excessive amount of computational time and power needed, especially when a large number of different system configurations are to be tested for control purposes, sensitivity analyses or uncertainty quantification studies.
Therefore, a parametric Reduced Order Model (ROM) of the Boussinesq approximation is developed for which the Full Order Model (FOM) is based on the finite volume approximation. A Proper Orthogonal Decomposition (POD) approach is used for the construction of a reduced basis on which a Galerkin projection of the governing equations is performed to obtain the Reduced Order Model.
The ROM is tested on a simple configuration that consists of a 2D square enclosed cavity with differentially heated walls opposite of each other. The wall temperature boundary conditions are parametrized using a control function method. For this configuration, the control functions are obtained by solving a Laplacian function for temperature. The ROMs are stable, except when the temperature difference between the walls is larger than the case for which the full order solutions, used for the reduced basis construction, are obtained. The accuracy of the reduced order models is assessed against the full order solutions and it is shown that the reduced order model can be used for sensitivity analysis by controlling the non-homogeneous Dirichlet boundary conditions. Finally, the ROM is about 20 times faster than the FOM on a single processor.

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