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ON THE EDDY-DIFFUSIVITY CLOSURE FOR TURBULENT NATURAL CONVECTION

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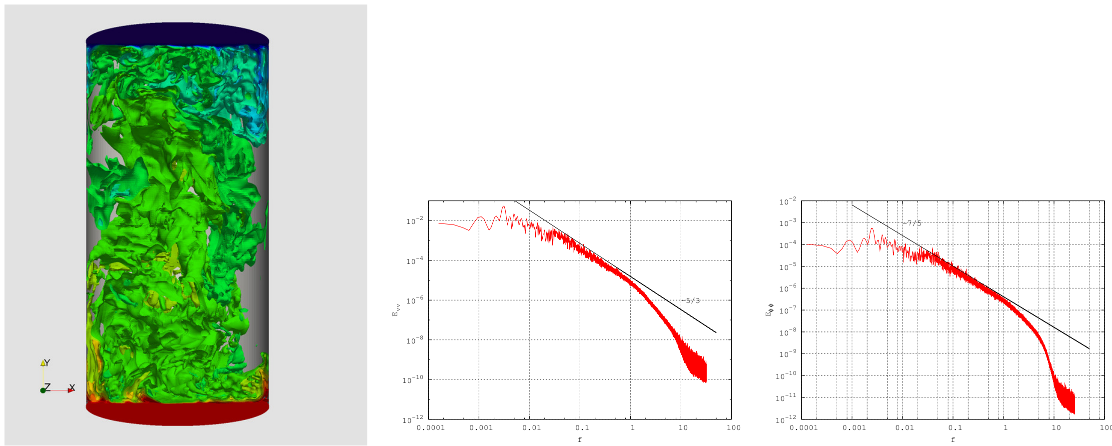
Turbulent natural convection of a fluid inside an enclosure heated from below (Rayleigh-Bénard convection), has been object of many theoretical and experimental investigations [1, 2]. Regarding to numerical simulations, over the past decades they have become a powerful tool for providing extensive data in turbulence structures and flow dynamics, but flow statistics for Direct Numerical Simulations (DNS) at relative high Ra numbers are still limited by an insufficient time integration [3]. In this sense, Large-Eddy Simulations (LES) can be an attractive alternative for the resolution of natural convection problems at high Ra numbers. As LES models the smallest scales of the fluid their results are not only dependent on the grid resolution and the spatial and temporal discretizations but also on the selection of the appropriate subgrid scale stresses (SGS) model for describing the flow behaviour. Therefore, this work aims at testing different subgrid-scale closures for the eddy diffusivity in flows where the scalar transport is relevant. To do this, the different closures will be tested for the Rayleigh-Benard convection. These closures will be compared with the results obtained from DNS for a cavity of aspect ratio $\Gamma = D/H = 0.5$.

The governing equations are discretized by means of second-order conservative schemes [4]. Such discretization preserves the symmetry properties of the continuous differential operators, and ensure both, stability and conservation of the global kinetic-energy balance on any grid. Energy transport is also discretized by means of a conservative scheme. As this formulation preserves the kinetic energy balance, it is a good starting point for the formulation of SGS models, as was pointed out by Verstappen and Veldman [4].

The numerical computations have been performed at a Rayleigh number ($Ra = g\beta\Delta T H^3/\nu\alpha$) $Ra = 2 \times 10^9$ and two Prandlt numbers of $Pr = 0.7$ and $Pr = 10$ in a cylindrical cavity of aspect ratio $\Gamma = 0.5$. In the figure, preliminary results obtained for the DNS at $Pr = 0.7$ are depicted. An important observation is that the temperature spectra decays with a $-7/5$ slope acording with Bolgiano's dynamics, but velocity spectra decays with a



(a) (b) (c)

Figure 1: (a) Instantanous flow configuration, (b) Energy spectra for the velocity fluctuations, (c) energy spectra for temperature fluctuations at r/H=0.25, z/H=0.95

$-5/3$ slope following Kolmogorov theory. According Obukhov-Bolgiano dynamics, inertial ranges with $-7/5$ laws occur when energy transport due to buoyancy forces is more efficient than the ordinary cascade transport, thus kinetic energy behaves as $E_k \sim k^{-11/5}$. On the contrary, if the energy cascade is governed by kinetic-enery dissipation, Kolmogorov $-5/3$ scaling is stablished for both, temperature and velocity fluctuations. This behaviour does not correspond with the energy spectra obtained, but it is in agreement with the calculated spectra by Verzicco and Camussi [5] for $Ra = 2 \times 10^{10}$ and $Ra = 2 \times 10^{11}$. This behaviour of the energy decay should be mimicked by the SGS closure, thus in the final version of the manuscript a thorough comparison of different eddy-diffusivity closures will be presented.

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