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Building a proper tensor-diffusivity model for large-eddy simulation of buoyancy-driven flows

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In this work, we plan to shed light on the following research question: *can we find a nonlinear tensorial subgrid-scale (SGS) heat flux model with good physical and numerical properties, such that we can obtain satisfactory predictions for buoyancy driven turbulent flows?* This is motivated by our recent findings showing that the classical (linear) eddy-diffusivity assumption, $\boldsymbol{q}^{eddy} \propto \nabla \overline{T}$, fails to provide a reasonable approximation for the SGS heat flux, $\boldsymbol{q} = \overline{\boldsymbol{u}T} - \overline{\boldsymbol{u}}\overline{T}$ (see Figure 1, left). This has been shown in our work [1] where SGS features have been studied *a priori* for a Rayleigh-Bénard convection (RBC) (see Figure 1, right). We have also concluded that nonlinear (or tensorial) models can give good approximations of the actual SGS heat flux. The nonlinear Leonard model, $\boldsymbol{q}^{nl} \propto \nabla \overline{\boldsymbol{u}} \nabla \overline{T}$, is an example thereof. However, this model is unstable and therefore it cannot be used as standalone SGS heat flux model. Apart from being numerically stable we also want to have the proper cubic near-wall behavior. Corrections in this regard will be presented together with *a priori/posteriori* studies of nonlinear SGS heat flux models for RBC. Results from LES simulations will be compared with the DNS results obtained in the on-going PRACE project *"Exploring new frontiers in Rayleigh-Bénard convection"*.

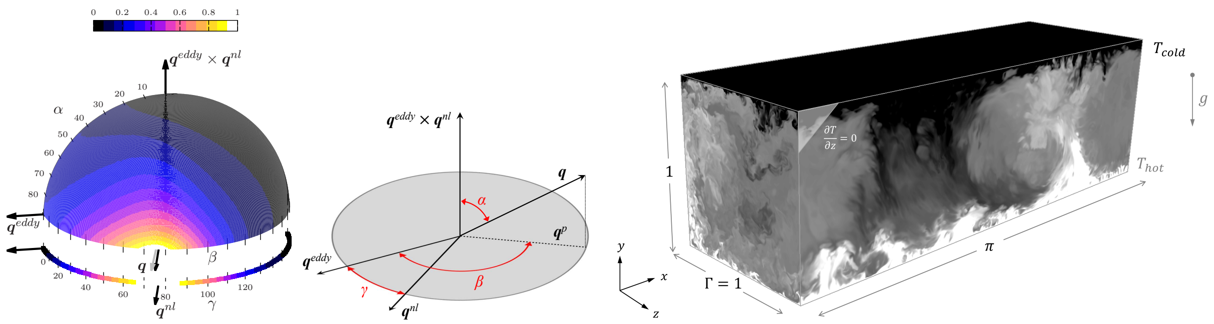

Figure 1: Left: alignment trends of the actual SGS heat flux, $\boldsymbol{q}$. For details the reader is referred to our recent work [1]. Right: schema of the air-filled RBC studied in Ref. [1] displayed together with a developed instantaneous temperature field of the DNS at $Ra = 10^{10}$.

REFERENCES

[1] F. Dabbagh, F. X. Trias, A. Gorobets, and A. Oliva. A priori study of subgrid-scale features in turbulent Rayleigh-Bénard convection. *Physics of Fluids*, 29:105103, 2017.