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ON A PROPER TENSORIAL SUBGRID HEAT FLUX MODEL

F.X. Trias[1], F. Dabbagh[2], D. Santos[1], A. Gorobets[3], A. Oliva[1]

[1] Heat and Mass Transfer Technological Center,
Technical University of Catalonia, C/Colom 11, 08222 Terrassa (Barcelona)
[2] Christian Doppler Laboratory for Multi-Scale Modeling of Multiphase Processes,
Johannes Kepler University, Altenbergerstraße 69, 4040 Linz, Austria
[3] Keldysh Institute of Applied Mathematics, 4A, Miusskaya Sq., Moscow 125047, Russia

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In this work, we aim to shed light to 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 findings showing that the classical (linear) eddy-diffusivity assumption, $q^{eddy} \propto \nabla\overline{T}$, fails to provide a reasonable approximation for the actual SGS heat flux, $q = \overline{uT} - \overline{u}\overline{T}$: namely, *a priori* analysis for air-filled Rayleigh-Bénard convection (RBC) clearly shows a strong misalignment. In the quest for more accurate models, we firstly study and confirm the suitability of the eddy-viscosity assumption for RBC carrying out *a posteriori* tests at very low Prandtl numbers (liquid sodium, $Pr = 0.005$) where no heat flux SGS activity is expected. Then, different (nonlinear) tensor-diffusivity SGS heat flux models are studied *a priori* using DNS data of air-filled ($Pr = 0.7$) RBC at Rayleigh numbers up to 10^{11}. Apart from having good alignment trends with the actual SGS heat flux, we also restrict ourselves to models that are numerically stable *per se* and have the proper cubic near-wall behavior. This analysis leads to a new family of SGS heat flux models based on the symmetric positive semi-definite tensor $\mathsf{G}\mathsf{G}^T$ where $\mathsf{G} \equiv \nabla\overline{u}$, *i.e.* $q \propto \mathsf{G}\mathsf{G}^T\nabla\overline{T}$, and the invariants of the $\mathsf{G}\mathsf{G}^T$ tensor.

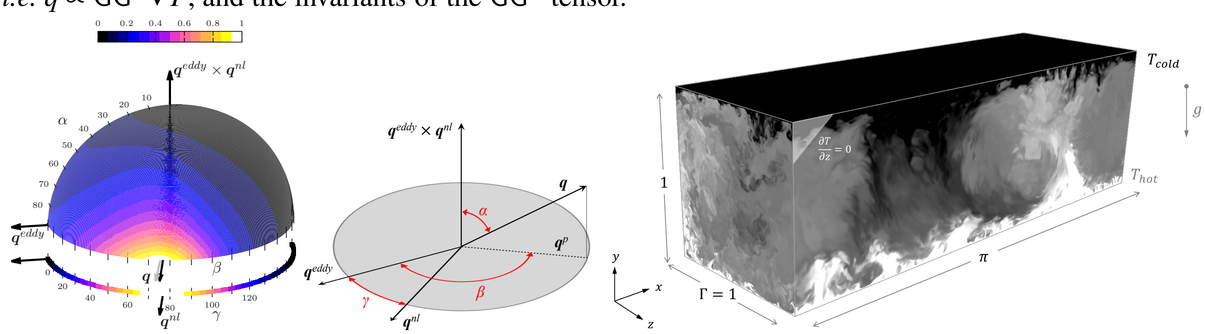

Figure 1: Left: alignment trends of the actual SGS heat flux, q. For details the reader is referred to our work [1]. Right: DNS of the air-filled RBC at $Ra = 10^{10}$ studied in Ref. [1].

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.