TOWARDS NUMERICAL SIMULATIONS OF THE ULTIMATE STATE OF CONVECTION USING ONE-DIMENSIONAL TURBULENCE MODELING

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Recent laboratory experiments suggest a transition from the classical to the ultimate state of convection across the Rayleigh numbers $2\times10^{13} < Ra < 5\times10^{14}$ for Prandtl number $Pr \approx 1$ [1]. Corresponding Direct Numerical Simulations (DNS) have been conducted up to $Ra = 2\times10^{12}$ which are in the classical state [2]. In order to make simulations for $Ra > 10^{12}$ feasible, we suggest to use a stochastic modeling strategy using the so-called One-Dimensional Turbulence (ODT) model [3, 4]. ODT resolves all scales of the flow, but only along a vertical line (ODT line in Fig. 1). Molecular diffusion is resolved on this line, whereas turbulent advection is modeled by discrete mapping events to save computational cost. These events are selected stochastically in size, position, and time. The acceptance probability is largest where shear and buoyancy yield net extractable energy.
We investigate temperature statistics in high-Ra thermal convection using ODT as stand-alone tool. This is an extension of a previous work [4], but here we use a new and fully-adaptive implementation of ODT [5]. Preliminary results are shown in Fig. 1 together with reference DNS data [2]. These results suggest that the relative modeling error decreases with Ra.

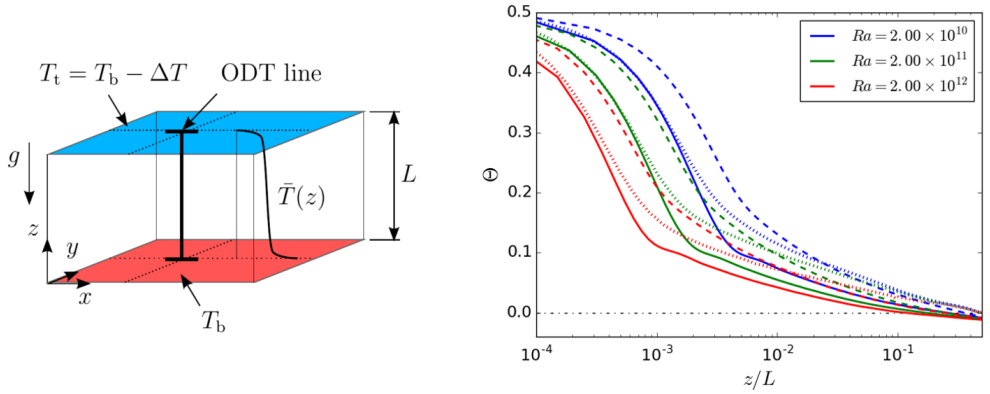

Figure 1: Flow configuration (left). Mean temperature profiles $\Theta(z/L) = \left(\bar{T}(z/L) - T_m\right)/\Delta T$ (where $T_m = (T_b + T_t)/2$) for $2\times10^{10} \leq Ra \leq 2\times10^{12}$ at $Pr = 0.7$ (right). ODT results are shown for two sets of model parameters: $C = 38.7$, $Z = 66.7$ [4] yield the correct Nusselt number (solid), whereas $C = 10.0$ with same Z reproduce the log layer across $10^{-2} < z/L < 10^{-1}$ more accurately (dashed). DNS results are from a cylindrical configuration [2] (dotted).

References

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