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Low-dimensional model of turbulent Rayleigh-Benard convection in a Cartesian cell with square domain

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A low-dimensional model (LDM) for turbulent Rayleigh-Benard convection in a Cartesian cell with square domain, based on the Galerkin projection of the Boussinesq equations onto a finite set of empirical eigenfunctions, is presented. The empirical eigenfunctions are obtained from a joint Proper Orthogonal Decomposition (POD) of the velocity and temperature fields using the Snapshot Method on the basis of a direct numerical simulation (DNS). The resulting LDM is a quadratic inhomogeneous system of coupled ordinary differential equations which we use to describe the long-time temporal evolution of the large-scale mode amplitudes for a Rayleigh number of 1e5 and a Prandtl number of 0.7. The truncation to a finite number of degrees of freedom, that does not exceed a number of 310 for the present, requires the additional implementation of an eddy viscosity-diffusivity to capture the missing dissipation of the small-scale modes. The magnitude of this additional dissipation mechanism is determined by requiring statistical stationarity and a total dissipation that corresponds with the original DNS data. We compare the performance of two models, a constant so-called Heisenberg viscosity--diffusivity and a mode-dependent or modal one. The latter viscosity--diffusivity model turns out to reproduce the large-scale properties of the turbulent convection qualitatively well, even for a model with only a few hundred POD modes.

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