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On the potential of stochastic multi-scale methods for the simulation of turbulent convection

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Due to its huge complexity, progress in understanding and prediction of turbulence is extremely challenging, yet crucial for scientific advancement in many disciplines. In principle, progress is possible without improved understanding through direct numerical solution (DNS) of the exact governing equations. DNS is widely used and fruitful, but the wide range of scales in atmospheric and other flows of interest often renders it unaffordable, so coarse-grained 3D numerical simulations with subgrid parameterization of the unresolved scales are used. This is especially problematic for multi-physics regimes such as buoyant and reacting flows because much of the complexity is thus relegated to the unresolved small scales. Although 3D coarse-grained methods such as large-eddy simulation (LES) are applied successfully to the atmospheric boundary layer (ABL), they have major shortcomings for multi-physics regimes relevant to, e.g., climate prediction. An alternate strategy, developed initially for combustion research, involves 1D stochastic simulation that affordably resolves all relevant turbulence length and time scales. It preserves the crucial physical distinction between advection and diffusion, which is blurred in filtered approaches. The 1D formulation, imbedded in 3D coarse-grained simulation, yielded performance gains that led atmospheric scientists to introduce 2D-in-3D 'superparameterization' for global-scale circulation modeling. In the talk we will summarize the state of the art in Lagrangian and Eulerian implementations of stochastic multi-scale approaches based on Kerstein's **O**ne-**D**imensional **T**urbulence model. Results for technical and atmospheric buoyant flows will be shown and compared to experiments and DNS.