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COARSE GRAINED SIMULATIONS AND TURBULENT MIXING

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ABSTRACT

Mixing of materials by the small scales of turbulent motion is a critical element of many flow systems of interest in engineering, geophysics and astrophysics. Numerical simulation plays a crucial role and turbulent mixing predictability is a major concern. Small-scale resolution requirements focus typically on those of continuum fluid mechanics described by the Navier-Stokes equations; different requirements are involved depending on the regime considered and on the relative importance of coupled physics such as multi-species diffusion and combustion as determined by Knudsen, Reynolds, Schmidt, Damköhler, and other characteristic non-dimensional numbers. Direct numerical simulation (DNS) resolving all relevant physical space/time scales, is prohibitively expensive in the foreseeable future for most practical flows and regimes of interest at moderate-to-high Re. On the other end of the simulation spectrum are the Reynolds-Averaged Navier-Stokes (RANS) approaches – which focus on statistical moments for an ensemble of realizations and model the turbulent effects. In coarse grained simulation (CGS) large energy containing structures are resolved, smaller structures are spatially filtered out, and unresolved subgrid scale (SGS) effects are modeled; this includes classical LES strategies [1] with explicit closure SGS models, and implicit LES (ILES) [2], relying on SGS modeling implicitly provided by physics capturing numerical algorithms. The CGS strategy of separating resolved / unresolved physics constitutes the viable intermediate approach between DNS and RANS to address practical geometries and multiphysics. Complex turbulent flow applications unavoidably involve under-resolved simulations, and robustness of CGS predictions is a frequently unsettled issue. The validity of the scale separation assumptions in CGS needs to be carefully tested when potentially important SGS flow physics is involved, specifically, for turbulent wall bounded flows, and for turbulent material mixing – the focus area of the proposed mini-symposia. We examine our understanding of coarse-grained turbulent mixing, its theoretical basis, verification, validation, and predictability aspects, and progress addressing difficult open issues in complex non-equilibrium applications involving single- as well as multi-phase turbulent flow.

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