Investigation of turbulent mixing using a stochastic hierarchical parcel swapping mixing model

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Turbulent mixing simulations are challenging since the flow is characterized by a wide range of length and time scales, which yields high resolution requirements. The computational cost of Direct Numerical Simulations (DNS) that resolve all scales rises with at least the cube of the Reynolds number and is therefore not feasible for most engineering applications. Large Eddy Simulations (LES) overcome this limitation by modeling the subgrid scale mixing processes. Hereby, the key challenge is to develop an accurate subgrid mixing model. The Hierarchical Parcel Swapping (HiPS) mixing model represents a computationally efficient approach which was introduced by A.R. Kerstein [1, 2]. HiPS simulates the effects of turbulence on time-evolving, diffusive scalar fields. The interpretation of the diffusive scalar fields or a state space as a binary tree structure is an alternative approach compared to existing mixing models. The characteristic feature of HiPS is that every level of the tree corresponds to a specific length and time scale, which is based on inertial range scaling. The state variables reside only at the base of the tree and are understood as fluid parcels. The effects of turbulent advection are represented by stochastic swaps of sub-trees at rates determined by turbulent time scales associated with the sub-trees. The mixing of adjacent fluid parcels is done at rates consistent with the prevailing diffusion time scales. In the talk, we will detail HiPS as a mixing model and show the generated scalar power spectra with decaying and forced turbulence. Preliminary results for the mean square displacement of passive scalar mixing simulations are given as well. Additionally, the scalar dissipation rate will be presented and compared to existing data [3].

References

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[3] V. Eswaran and S.B. Pope, Direct numerical simulations of the turbulent mixing of a passive scalar. The Physics of Fluids 31 (1988).