TOWARDS A SIMPLE MIXING MODEL FOR PASSIVE SCALAR TRANSPORT USING HIERARCHICAL PARCEL SWAPPING (HIPS)

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The accurate resolution of all scales in turbulent flows with passive scalar transport is a challenging task for most simulation approaches. The wide range of length and time scales and associated high computational costs often allows only simulations at low Schmidt numbers. The Hierarchical Parcel Swapping (HiPS) model [1, 2] is a relatively novel and computationally efficient mixing model that belongs to the family of map-based stochastic models. HiPS uses a binary tree structure, where the state variables associated with fluid parcels reside at the base of the tree, as shown in Fig. 1 (node 7 to 14). Every level of the tree corresponds to a turbulent length and time scale. The turbulent advection is modeled by randomly selected swaps of sub-trees, which are sampled from a Poisson process at rates determined by the corresponding turbulent time scale. Adjacent fluid parcels are mixed either instantaneously or at rates consistent with the prevailing diffusion time scales. In Fig. 1, two swaps and a mixing event are shown. The first swap (blue nodes) is a permutation at node 0. The second swap (red node numbers) changes the proximity of parcel pairs and requires a subsequent mixing event. The simplicity and computational efficiency combined with a high resolution makes HiPS a particularly attractive model for flow simulations [2] and even more for turbulent mixing [1] of multiple scalars. In Lignell et al. [3], an alternative to instantaneous mixing is described and first qualitative results for the application of HiPS to turbulent reactive flows are provided.
In the talk, we present an overview of the HiPS model and discuss its application to mixing and transport of passive scalars. In Fig. 2, the initial distribution for the mixing of one scalar (top) and the temporal evolution of the RMS value (bottom) is shown for Schmidt numbers smaller than one. We provide a new model extension for Schmidt numbers greater than one and compare scalar statistics against existing reference data [4].

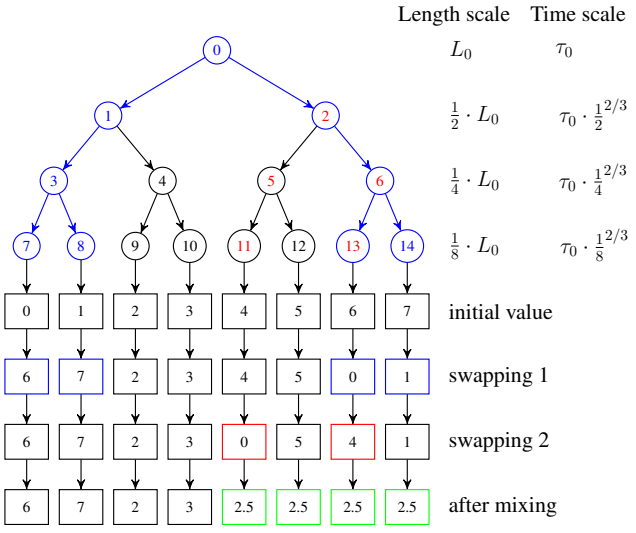

Figure 1: HiPS tree with the illustration of two swaps and one mixing event

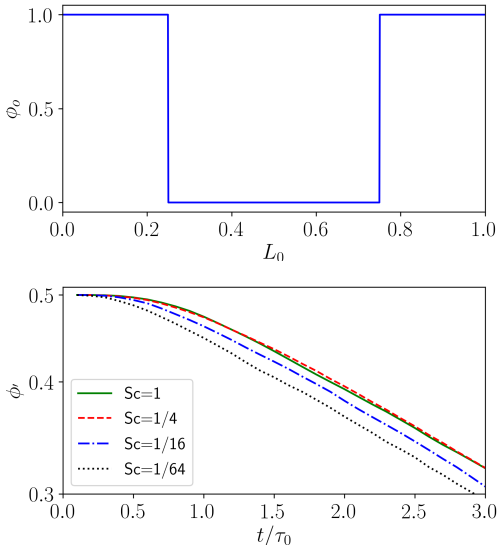

Figure 2: Evolution of scalar RMS for different Schmidt numbers (bottom) and initial scalar distribution (top)

References

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