Comparisons of Lagrangian and Eulerian PDF methods in simulations of non-premixed turbulent jet flames with moderate-to-strong turbulence-chemistry interactions

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Transported probability density function (PDF) methods have been applied widely and effectively for modelling turbulent reacting flows. In most applications of PDF methods to date, Lagrangian particle Monte Carlo algorithms have been used to solve a modelled PDF transport equation. However, Lagrangian particle PDF methods are computationally intensive and are not readily integrated into conventional Eulerian computational fluid dynamics (CFD) codes. Eulerian field PDF methods have been proposed as an alternative. Here a systematic comparison is performed among three methods for solving the same underlying modelled composition PDF transport equation: a consistent hybrid Lagrangian particle/Eulerian mesh (LPEM) method, a stochastic Eulerian field (SEF) method and a deterministic Eulerian field method with a direct-quadrature-method-of-moments closure (a multi-environment PDF-MEPDF method). The comparisons have been made in simulations of a series of three non-premixed, piloted methane?air turbulent jet flames that exhibit progressively increasing levels of local extinction and turbulence-chemistry interactions: Sandia/TUD flames D, E and F. The three PDF methods have been implemented using the same underlying CFD solver, and results obtained using the three methods have been compared using (to the extent possible) equivalent physical models and numerical parameters. Reasonably converged mean and rms scalar profiles are obtained using 40 particles per cell for the LPEM method or 40 Eulerian fields for the SEF method. Results from these stochastic methods are compared with results obtained using two- and three-environment MEPDF methods. The relative advantages and disadvantages of each method in terms of accuracy and computational requirements are explored and identified. In general, the results obtained from the two stochastic methods (LPEM and SEF) are very similar, and are in closer agreement with experimental measurements than those obtained using the MEPDF method, while MEPDF is the most computationally efficient of the three methods. These and other findings are discussed in detail.

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