# Multi-modal Combustion Modeling for Turbulent Reacting Flow with Adaptive Scalar Transport

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In the present work, an adaptive scalar transport (AST) model is proposed for the numerical prediction of turbulent reacting flow. In the belief of a significant reduction in the computational cost of flamelet modeling, the primary motivation of this study is to extend its application to a larger stage with a more complex interaction between flow field and chemical reactions. The AST model is designed to address the well-known limitations in predicting species with strong finite-rate chemistry (FRC) properties by integrating detailed chemical reaction modeling. The drift difference, inherited from the PEC [1] framework, is employed as the criterion for evaluating the FRC effect of species. The drift difference quantifies the discrepancy between detailed solutions from scalar transport equations and mapping results from low-manifold representation, thereby determining the species to solve using flamelet tabulation or transport equations. A set of techniques with referential significance in treating sub-model switching in a hybrid model are shown in the article, including the relaxation on species assignment switching between two groups, and the corrections regarding element and mass conservation. To demonstrate the capabilities of AST, simulations are carried out on Sandia flame D which is a typical turbulent flame in model validation with slight extinction and re-ignition characteristics. The sensitive analysis shows that the number of transported species transits smoothly from the monolithic flamelet model to the transported finite-rate chemistry model (FPV and PaSR in this work, specifically) under various demarcation values of the formulated drift-difference parameter. From the results, the computational cost of AST is noticeably reduced as fewer species are transported in detail, yet not linearly. A narrow interval of switching criterion is suggested to preserve the fidelity of AST at FRC level, meanwhile achieving a considerable decrease in the computational cost.

[1] Wu H et al. A Pareto-efficient combustion framework with submodel assignment for predicting complex flame configurations. Combustion and Flame. 2015;162:4208-4230.