International Conference on Numerical Combustion
Rome, Italy, October 14-17, 2025
www.icnc2025.com

Enhancing Turbulent Premixed Flame Predictions in LES Using Deep Learning PDE Models

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Large eddy simulation (LES) turbulence models often fail to account for the effects of heat release and the corresponding changes in flow turbulence in turbulent reacting flows, thus necessitating a generalized turbulence-modeling approach for accurate predictions across all regimes of flame–turbulence interaction. These interactions depend critically on the filter Damköhler number. We develop eddy-viscosity closures that remain accurate across varying filter Damköhler numbers using a data-assimilation technique that optimizes over the LES partial differential equations. The data are assimilated via a neural network and adjoint-based optimization. We evaluate our method on a series of temporally evolving premixed jet flames spanning a broad range of filter scales and Damköhler numbers, comparing its performance against the classical Smagorinsky model. Our results demonstrate that this approach effectively captures the unclosed terms in the LES equations, yielding more accurate predictions of flow and flame properties throughout all regimes of flame–turbulence interaction.