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Enhancing computational efficiency of laminar flames simulations through latent variable transport

E. Muñoz[1,2], M.R. Malik[3], A. Cuoci[4], H.G. Im[3], A. Parente[1,2,5]
*Lead presenter: eva.munoz.salamanca@ulb.be
[1] ATM Laboratory, École polytechnique de Bruxelles, Université Libre de Bruxelles, Belgium
[2] Brussels Institute for Thermal-fluid systems and clean Energy (BRITE), Belgium
[3] Clean Energy Research Platform (CERP), Physical Science and Engineering (PSE) Division, King Abdullah University of Science and Technology (KAUST), Thuwal, Saudi Arabia
[4] Politecnico di Milano, Piazza Leonardo da Vinci 32, 20131 Milano, Italy
[5] WEL Research Institute, Avenue Pasteur 6, 1300 Wavre, Belgium

The multiple scales involved in combustion processes make their numerical simulation highly demanding. In this context, reduced-order models (ROMs) are developed to improve computational efficiency while providing valuable physical insight of the process. This research, in particular, focuses on linear techniques to transform the original state variables into a new set of latent variables (LVs).

We present the LV-transport framework, an extension of PC-transport that improves numerical stability, increases computational efficiency, and allows for direct computation of source terms. PC-transport, originally introduced by Sutherland and Parente[1], formulates transport equations for principal components (PCs) by leveraging the orthogonality and linearity of PCA. Instead of transporting the original state variables, the approaches transport LVs and PCs respectively, allowing the reconstruction of the full state-space from their latent values.

This study evaluates the potential of the method across different fuels and operating conditions. To achieve this, the LV-transport approach is implemented in laminarSMOKE[2], an OpenFOAM-based software designed for solving laminar flames with detailed chemistry. The analysis includes CFD simulations of steady and transient laminar axisymmetric coflow diffusion flames burning mixtures of H2, CH4, or n-heptane with N2 in air [3, 4].

References

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