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Modelling of the joint probability function in turbulent flame-wall interaction of premixed flames using Quadrature-based Moment Methods and tabulated chemistry.

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In technical combustors, the chemical reactions typically take place in combustion chambers confined by walls to allow power generation. Inside the chamber, the flames can interact with the surrounding walls, leading to stagnating reactions caused by enthalpy losses at the (cold) walls. This phenomenon affects combustion efficiency and pollutant formation. The numerical simulation of turbulent flame-wall interactions poses two main challenges. Firstly, the effect of enthalpy loss on the chemical reactions needs to be considered. Secondly, the fluctuations of the reactive scalars caused by turbulence, the so-called turbulence-chemistry interaction, need to be accounted for. This study focuses on the latter. A novel turbulence-chemistry interaction closure, the Conditional Quadrature Method of Moments (CQMOM), is presented that accounts for the unresolved fluctuations of the reactive scalars by their joint probability density function (PDF). In the CQMOM, the integrals of the unknown PDF are approximated by a set of moments that are solved for during runtime. The CQMOM extends the Quadrature Method of Moments to a multidimensional PDF of progress variable and enthalpy and is coupled to a state-of-the-art chemistry manifold for flame-wall interaction. The CQMOM is validated a priori using a direct numerical simulation (DNS) database of a premixed methane-air flame ignited in a fully developed turbulent channel flow. First, the complex multidimensional PDFs that need to be accounted for in the turbulence-chemistry interaction closure are analyzed in both, the context of Reynolds-Averaged Navier Stokes and Large Eddy Simulations. Thereby, the core flow and the near-wall region, which is affected by enthalpy losses, are considered. Furthermore, the CQMOM approach and a presumed PDF approach from the literature are compared using the DNS database as reference. Both models show high accuracy in the core flow. In the near-wall region, however, only the CQMOM is suitable to predict the flame structures.