Numerical methods and models for large-eddy simulations coupled to radiative heat transfer.

Context

The EM2C laboratory has developed a recognized expertise in simulating the interaction between thermal radiation and combustion with large-eddy simulations (LES). An optimized Monte Carlo method [1-2] is used to solve the radiative transfer equation, which provides reference results with a controlled accuracy. Besides, the solver is combined with an accurate description of gases radiative properties, which enables carrying out detailed coupled simulations despite a corresponding significant need in computational resources. Thanks to these advances, the impact of thermal radiation has been studied with high-fidelity in several non-reactive turbulent flows: boundary layers [3-5] and jets [5].

The study of flames in combustion chambers requires the prediction of the wall temperature field in the combustor, which results from different heat transfer mechanisms. In particular, one needs to solve for heat conduction within the solid parts. Several turbulent flames [7-9] have thus been described for the first time in multiphysics large-eddy simulations where radiation is solved with a Monte Carlo approach. Several illustrations of numerical studies combining LES / Solid Heat Transfer / Radiation are presented in figures 1 and 2.

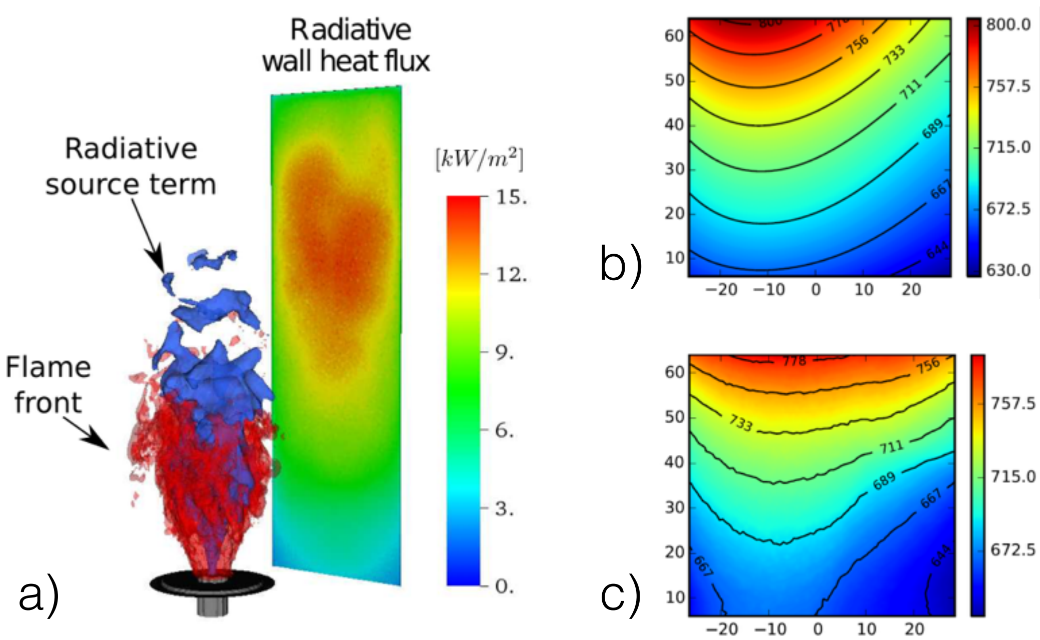

Figure 1 — Confined swirled flame simulated while accounting for radiation. a) Visualization of the turbulent flame in the multiphysics coupled LES. b) Mean wall temperature measurements (in Kelvin). c) Mean wall temperature (in Kelvin) predicted by the coupled simulation LES/Solid Heat Transfer/Radiation.

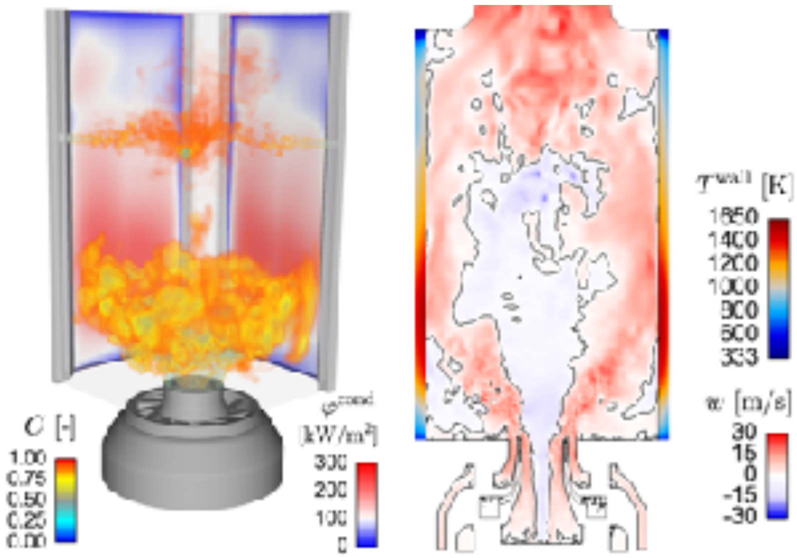

Figure 2 – Sooted swirled flame within a pressurized combustor [9]. Left: Instantaneous volume rendering of the progress variable and 2D contour plot of the wall conductive flux in the DLR FIRST burner. Right : window temperature and field of axial velocity within the combustor.

The achieved coupled simulations allow for determining the wall temperature and fluxes along with their effects on turbulent reactive flows while capturing the associated and very complex physical phenomena. However, several studies remain necessary to i) further improve the used methods and models and ii) increase our understanding of coupled heat transfer in several kinds of applications.

Objectives

The growing maturity of these coupled simulations nowadays demands to increase their robustness and further control their fidelity to achieve an expert balance between accuracy and computational cost. The thesis works will establish reference standards to compute coupled phenomena between turbulent flows (reactive or not) and thermal radiation. The study takes place in the framework of high-fidelity simulations: Monte Carlo methods for radiation; direct numerical simulations (DNS) and large-eddy simulations (LES) for turbulence.

The thesis candidate will hence several aspects of such coupled simulations: choice in the coupling parameters (period, mesh), improvement of models and methods in computations of radiative heat transfer, subgrid-scale models. Several numerical codes will be used during the thesis, such as the Rainier radiation solver developed at EM2C, and codes for LES and DNS of turbulent flows (AVBP, YALES2).

All the developed and implemented methods will be tested in various configurations thanks to the broad set of coupled simulations previously carried out by the team. Furthermore, the candidate will also be able to compare the obtained reference results with other kinds of approaches (DOM, global models for radiative properties) such as those considered in different research groups.

Detailed contents of the thesis

Task 1: Adaptive control of accuracy for coupling methods between DNS and thermal radiation

Task 2: Improvements of methods and models in the Monte Carlo solver to describe radiative heat transfer

Task 3: Reference coupled DNS with massively parallel ressources

Task 4: Subgrid-scale modelling for radiative heat transfer in large-eddy simulations

Extra: Investigate artificial intelligence algorithms for Monte Carlo simulation speedup and subgrid-scale modelling

Profile and skills of the candidate

Master degree in Energetics, Aeronautics or Fluid Mechanics. Previous experience with programming and numerical methods would be appreciated. Good communication and writing skills.

How to apply

Send the following documents to ronan.vicquelin@centralesupelec.fr.

- Copy of passport
- One−page motivation letter.
- Copies of degree and academic transcript (with grades and rankings)
- Your CV with names and contact details of at least two referees
- Reference letters sent separately by the referees

Contact

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