M2 Internship proposal: Parametric study of Thermal-Large Eddy Simulation (T-LES) models in turbulent anisothermal channel flow

Context

This internship is part of the SOLAIRE ANR project which includes 2 Ph.D. students. The SOLAIRE project aims to improve the efficiency of converting concentrated solar energy into electricity using artificial intelligence. The key component of these power plants is the solar receiver, which converts concentrated solar energy into thermal energy and transfers it to a heat-carrying fluid, pressured air in our case. The project focuses on maximizing thermal transfers between the gas and the wall of the solar receiver, while minimizing pressure losses. This is done through optimization of thermal transfers and the development of strategies for controlling near-wall turbulence in the solar receiver using machine learning. For more context, see this POLYPHEM project video explaining challenges with solar receiver research. To best assess different types of Thermal-Large Eddy Simulation (T-LES) models in our study case, it is necessary to run simulations with different types of models on different meshes to obtain the most accurate assessment of these models. This type of simulation offers a good perspective as it's comparatively much cheaper than Direct Numerical Simulation (DNS). A visual representation of DNS can be seen here simulation visualisation.

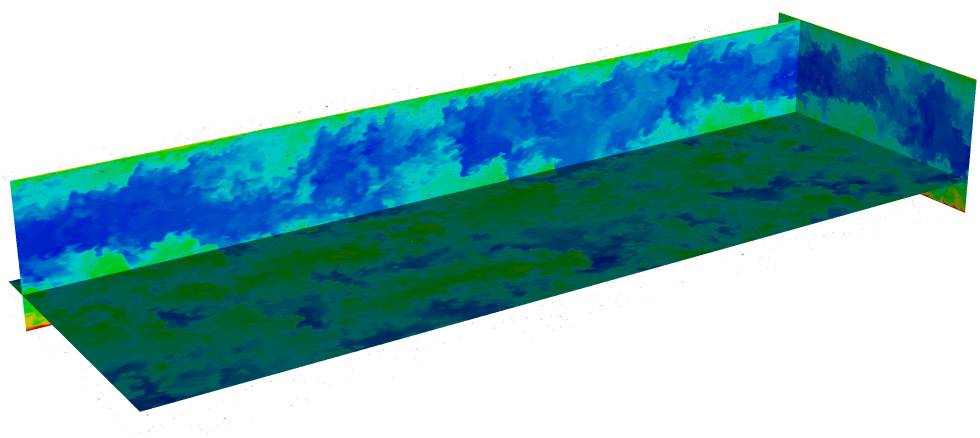

Figure 1: Representation of temperature field, with small structures

Description

As said before, T-LES are a reliable and quick way of simulating flows in different physical settings, but lacks accuracy in some cases, due to the extreme physical conditions. This is because we use a relatively coarse mesh. In a $Re_\tau = 970$ simulation, the DNS data base we have was done on a mesh of $1152 \times 746 \times 768$, 660 million mesh points, which took 2.5 million, 3.8 million and 4.5 million scalar CPU hours respectively for 3 different physical settings. Knowing the cost of computational time, and the cost of such a simulation on the environment, using T-LES is the best alternative. At

$Re_\tau = 970$, a T-LES represents between 0.5% and 0.7% of the computational hours of a DNS, which in this case is only between 12 500 to 17 500 scalar CPU hours, with meshes ranging from 1.4 million points to 3.7 million points. The assessment of performances of different T-LES models on different meshes and with different discretization schemes is essential to best quantify the error done with respect to DNS [3, 5, 4]. On our tests so far, the best models are mixed models, where the closing term is modelled using both a functional and a structural model, weighted by functions of the position in the canal. These models are the Anisotropic Minimum-Dissipation model [6] and the Bardina model [1].

In a first phase, the intern will get familiar with TrioCFD [2], the CFD code we use to run our channel flow simulations, and the post-treatment code we use. In the mean time, they will read the bibliography around this subject and gather information around the numerical effects of different T-LES models in different turbulent flow configurations.

In a second phase, the intern will run Thermal-Large Eddy Simulations (T-LES) for different mixed models, and study their performances with respect to the Direct Numerical Simulations in different physical and numerical settings. These simulations will be done on the TGCC's cluster, called Irene.

Skill requirements

Second year of Master's degree or last year of Engineering School student, with a fluid mechanics background. Programming knowledge and the use of languages like C/C++ Python or Shell is a plus but isn't required. Some understanding of English is appreciated.

Location

PROMES-CNRS Perpignan : Rambla de la thermodynamique, Tecnosud, 66100 Perpignan

Duration

5 to 6 months starting anywhere from February to March 2024

Salary

Current CNRS flat rate gratification (≈ 615 €/month)

Supervisors

- Adrien Toutant (Associate professor, Université de Perpignan Via Domitia - 04 68 68 27 09 adrien.toutant@univ-perp.fr)
- Yanis Zatout (Ph.D. Student, PROMES-CNRS - LISN, yanis.zatout@promes.cnrs.fr)

Application process

Email every supervisor in the same email with:

- Your resume
- Your transcript of Bachelor's and Master's degree grades
- Recommendation letters (optional)

References

[1] J. Bardina, J. Ferziger, and W. Reynolds. Improved subgrid-scale models for large-eddy simulation. In *13th Fluid and PlasmaDynamics Conference*, Fluid Dynamics and Co-Located Conferences. American Institute of Aeronautics and Astronautics, 1980.

[2] Christophe Calvin, Olga Cueto, and Philippe Emonot. An object-oriented approach to the design of fluid mechanics software. *ESAIM: Mathematical Modelling and Numerical Analysis - Modélisation Mathématique et Analyse Numérique*, 36(5):907–921, 2002.

[3] M. David, A. Toutant, and F. Bataille. Direct simulations and subgrid modeling of turbulent channel flows asymmetrically heated from both walls. *Physics of Fluids*, 33(8):085111, 2021.

[4] M. David, A. Toutant, and F. Bataille. Direct simulations and subgrid modeling of turbulent channel flows asymmetrically heated from both walls. *Physics of Fluids*, 33:085111, 08 2021.

[5] M. David, A. Toutant, and F. Bataille. Investigation of thermal large-eddy simulation approaches in a highly turbulent channel flow submitted to strong asymmetric heating. *Physics of Fluids*, 33(4):045104, 2021.

[6] Wybe Rozema, Hyun J. Bae, Parviz Moin, and Roel Verstappen. Minimum-dissipation models for large-eddy simulation. *Physics of Fluids*, 27(8):085107, 2015.