PhD Opening Position:

Towards data-driven LES subgrid-scale flow modelling with machine learning

Contact:
Guillaume Balarac (LEGI), guillaume.balarac@univ-grenoble-alpes.fr
Julien Le Sommer (IGE), julien.lesommer@univ-grenoble-alpes.fr
Ronan Fablet (LabSTIC), ronan.fablet@imt-atlantique.fr

Context:
Sub-grid scale closures are key ingredients for turbulent flows simulations. Such closures are needed to account for the impact of unresolved fine scale variables over resolved larger scales variables because of the nonlinearity of fluid dynamics (Sagaut et al. 2006). In practice, these models are usually deterministically asserved to large scale resolved quantities and obtained through the combination of theoretical and empirical considerations.
Over recent years, progress have been made in LES and RANS modelling by applying machine learning (ML) techniques for calibrating models on the basis of databases of DNS simulations (Kutz 2017, Vollant et al. 2017). Recent advances in ML algorithms and in their software implementation are therefore expected to yield breakthrough in LES modelling over coming years. Convolutional neural networks (CNN, a particular class of neural networks that rely on local convolution operations) are in particular expected to be well adapted to LES modelling, because they naturally encode the filtering operations involved in designing LES closures (Bolton and Zanna et al. 2018) and can be trained over large databases.

Objective:
In this project, we intend to define a new robust modeling strategy to be able to model a large range of sub-grid scales quantities. The project will first focus on the modeling of scalar quantities as needed for various applications (heat transfer, combustion, oceanography, …). A particular attention will be devoted to environmental fluid flows simulations and to their applications in operational systems, as for instance ocean prediction systems. The ultimate goal will be to take into account the modeling error propagation, and its interaction with numerical errors in the ML techniques to insure the accuracy of the model for long-time evolution.
The proposed work will be coordinated by Guillaume Balarac (LEGI) and Julien Le Sommer (IGE) in order to build upon the existing background knowledge in LES modelling and in applications to oceanic flows. Machine learning algorithms, including CNN architectures, will be based on Keras (https://keras.io) front-end to TensorFlow (https://www.tensorflow.org) backend, under the supervision of Ronan Fablet (LabSTIC).

Expected profile:
- Master of Science in applied mathematics, physics, or mechanical engineering
- Competences in fluid dynamics, statistics, and/ or scientific computing
- Good experience in programming and in data analysis
- Excellent writing skills, fluent in English
- Rigorous, autonomous, creative and motivated by working at the edge between physics (turbulent flows) and applied mathematics (machine learning)

References :
Bolton, T. and Zanna, L. (2018) *Journal of Advances in Modeling Earth Systems*
Kutz, J. N. (2017) *Journal of Fluid Mechanics*,
Sagaut, P. (2006), Large eddy simulation for incompressible flows: an introduction..
Vollant, A., Balarac, G. and Corre, C. (2017) *Journal of Turbulence*