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ADVANCES IN TURBULENCE MODELING USING NONLOCAL DERIVATIVES, IMPLICIT LES AND DEEP LEARNING

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ABSTRACT

Turbulence is a nonlocal and multi-scale phenomenon that presents several computational challenges. Resolving all scales implies nonlocality is addressed implicitly, as it does not require a closure model, but it is computationally prohibitive. Inorder to keep the computational cost feasible, spatially or temporally averaged fields have been considered in the literature in conjunction with modeling the discarded scales explicitly, with an eddy-viscosity closure model. These methods had relatively good success, but non-negligible limitations. Thus, properly addressing and capturing turbulent behaviour still remains an open challenge.

In this mini-symposium we gather experts that have taken non-standard approaches to the simulation of turbulent behaviour, including nonlocal derivatives, implicit large eddy simulations (LES), and deep learning. As an example, paper [1] shows how the classical eddy-viscosity model can be generalized by introducing a nonlocal, fractional stress-strain relationship. In [2] it is shown that physical dissipation can be matched to numerical dissipation when the contributions of discarded scales are small; this approach is known as implicit LES. Finally, paper [3] is an example of a more popular deep learning approach to physics modeling; here a case of separated flow is solved without any turbulence model, via neural networks.

REFERENCES

[1] Mehta PP. Fractional and tempered fractional models for Reynolds-averaged Navier-Stokes equations. arXiv preprint arXiv:2305.00770. 2023 May 1.

[2] Girfoglio M, Quaini A, Rozza G. A POD-Galerkin reduced order model for a LES filtering approach. Journal of Computational Physics. 2021 Jul 1;436:110260.

[3] Eivazi H, Tahani M, Schlatter P and Vinuesa R. Physics-informed neural networks for solving Reynolds-averaged Navier–Stokes equations. Physics of Fluids. 2022 Jul 7;34(7):075117.