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Explore missing flow dynamics by physics-informed deep learning: the parametrised governing system

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Gaining and understanding the flow dynamics have much importance in a wide range of disciplines, e.g. astrophysics, geophysics, biology, mechanical engineering and biomedical engineering. As a reliable way in practice, especially for turbulent flows, regional flow information such as velocity and its statistics, can be measured experimentally. Due to the poor fidelity or experimental limitations, some information may not be resolved in a region of interest. On the other hand, detailed flow features are described by the governing equations, e.g. the Navier-Stokes equations for viscous fluid, and can be resolved numerically, which is heavily dependent on the capability of either computing resources or modelling. Alternatively, we address this problem by employing the physics-informed deep learning, and treat the governing equations as a parameterised constraint to recover the missing flow dynamics. We demonstrate that with limited data, no matter from experiment or others, the flow dynamics in the region where the required data is missing or not measured, can be reconstructed with the parameterised governing equations. Meanwhile, a richer dataset, with spatial distribution of the control parameter (e.g. eddy viscosity of turbulence modellings), can be obtained. The method provided in this paper may shed light on data-driven scale-adaptive turbulent structure recovering and understanding of complex fluid physics, and can be extended to other parameterised governing systems beyond fluid mechanics.