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Rapid Spatiotemporal Turbulence Modeling with Convolutional Neural ODEs VARUN SHANKAR, Carnegie Mellon University, Pittsburgh, PA 15213, GAVIN PORTWOOD, ARVIND MOHAN, Los Alamos National Laboratory, Los Alamos, NM 87545, PEETAK MITRA, University of Massachusetts, Amherst, MA 01003, VENKAT VISWANATHAN, Carnegie Mellon University, Pittsburgh, PA 15213, DAVID SCHMIDT, University of Massachusetts, Amherst, MA 01003 —

Turbulence modeling has remained a difficult challenge in physics and engineering due to the high complexity of its governing equations. Traditional computational fluid dynamics methods such as DNS and LES have made high-fidelity simulations possible, however these conventional techniques are limited by their sizable computational requirements and are often unsuitable for engineering applications. Much attention has now been turned towards data-driven deep learning approaches, which can capture the underlying nonlinear dynamics at a significantly reduced computational cost. We propose a deep learning architecture to predict a spatiotemporal solution field based on the neural ODE algorithm. We approximate the dynamics of the velocity field with a convolutional network, which captures local spatial variations, and can be evolved through time using existing numerical methods. This approach exploits a principled formulation of the dynamical system and enables vast speed-up. Predictions are evaluated based on a variety of turbulent statistical diagnostics. Network outputs model large scale behavior well, while neglecting some of the smaller scales. Stationarity is observed in the forecasts with minimal kinetic energy losses and predictive capabilities through 2 eddy turnover times.

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