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Stable and accurate a posteriori LES of 2D turbulence with convolutional neural networks: Backscatter analysis and generalization via transfer learning

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In large eddy simulations (LES), the subgrid-scale effects are modeled by physics-based or data-driven methods. This work develops a convolutional neural network (CNN) to model the subgrid-scale effects of a two-dimensional turbulent flow. The model is able to capture both the inter-scale forward energy transfer and backscatter in both a priori and a posteriori analyses. The LES-CNN model outperforms the physics-based eddy-viscosity models and the previous proposed local artificial neural network (ANN) models in both short-term prediction and long-term statistics. Transfer learning is implemented to generalize the method for turbulence modeling at higher Reynolds numbers. Encoder-decoder network architecture is proposed to generalize the model to a higher computational grid resolution.