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*Modeling & Learning Fluid Dynamics with the Neural Basis Method*

Fluid flow plays a central role in fields ranging from geophysics to medicine, yet accurate and efficient simulation remains challenging. Classical numerical methods achieve stability and accuracy through operator-consistent approximation spaces, while many neural PDE methods rely on black-box optimization, often leading to poor conditioning, limited interpretability, and fragile generalization.

In this talk, I introduce the Neural Basis Method (NBM), a framework that treats neural networks as physics-conforming solution representations and enforces governing equations through operator-aware projection rather than neural loss minimization. This leads to deterministic, stable formulations with energy-consistent residuals. By incorporating finite element-like locality, NBM also accommodates complex geometries while preserving its projection-based structure.

Building on this foundation, NBM enables a new approach to operator learning by learning parametric maps from problem inputs to neural basis coefficients, offering substantial acceleration without sacrificing accuracy or interpretability. I will present the underlying ideas, theoretical foundations, and numerical results, including incompressible Navier–Stokes flows and coupled flow–transport problems in CO2 storage. These examples demonstrate orders-of-magnitude speedups with solver-level accuracy, highlighting NBM's potential to bridge classical numerical analysis and modern machine learning.