The 8th European Congress on Computational Methods in Applied Sciences and Engineering
ECCOMAS Congress 2022
5-9 June 2022, Oslo, Norway

Structure-preserving POD-based forcing for the two-dimensional Euler equations

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Keywords: *Structure-preservation, Data-driven, Reduced order model, Proper orthogonal decomposition*

Fluid dynamical systems are characterized by a continuous spectrum. Large (resolved) scales are dynamically coupled to small (unresolved) scales resulting in complex behavior. Representing the effect of small-scales on large-scale dynamics, while keeping the computational cost at a reasonable level, remains an open challenge. A promising way to approach this is by means of data-driven forcing, which we pursue here.

In the seminal work [1], a reduced order model is derived for fluid dynamics based on a variational principle. As a result, fundamental conservation laws are maintained under the inclusion of small-scale perturbations. An application of this approach was presented in [2] for the two-dimensional Euler equations, where geometric properties of the solution such as integrated functions of the vorticity are retained. While in [1] the mathematical framework is general, including also stochastic forcing, we focus on deterministic forcing. The deterministic reduced order model is obtained from applying proper orthogonal decomposition (POD) to snapshots of a high-resolution numerical solution in order to compute the unresolved scales. Using the full POD basis, one can reproduce the true solution on a coarse grid without any error [3]. In this work, we will investigate this approach for data-driven structure-preserving forcing in two-dimensional fluid flows, focusing on coarsening and sensitivity of the model to the amount of data provided.

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