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Data-driven modeling of high-dimensional geophysical turbulence

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ABSTRACT:

Many geophysical, environmental, and engineering flows are turbulent. Given that simulating turbulent flows by solving the Navier-Stokes equations can be formidable for many practical problems, there is a growing interest in developing reduced-order models (ROMs), which have low computational complexities but retain the key dynamics and essential features of the turbulent flows. Here we introduce two data-driven, model-free methods for computing accurate ROMs for high-dimensional fully turbulent geophysical flows for two purposes: 1) forecasting the short-time spatiotemporal evolution of the system, 2) predicting the long-term response of the system to an external forcing/ actuation. (1) and (2) are essential for many applications such as real-time optimization and control, optimal design, and protection against extreme events. The methods are based on Fluctuation-Dissipation Theorem (FDT) from statistical physics and approximation of the Koopman operator from dynamical systems. The capabilities of the methods are demonstrated using a 3D Rayleigh-Benard convection system at the Rayleigh number of one million, where the flow is fully turbulent.

BIOGRAPHY:

Dr. Hassanzadeh is an assistant professor at the department of mechanical engineering and Earth, environmental and planetary sciences at Rice. He received his B.S. from the University of Tehran (2005), M.S. from the University of Waterloo (2007), and Ph.D. from UC Berkeley (2013), all in Mechanical Engineering. He also holds a M.A. degree in Mathematics from UC Berkeley (2012). He was a Ziff Environmental Fellow at the Harvard University Center for the Environment (2013-2015) and a Postdoctoral Fellow at the Harvard University Department of Earth and Planetary Science (2015-2016). He joined the faculty at Rice in 2016. Dr. Hassanzadeh's honors and awards include an Early-Career Research Fellowship from the National Academy of Sciences Gulf Research Program, Ziff Environmental Fellowship from the Harvard University Center for the Environment, NSERC Postgraduate Scholarship from the Natural Sciences and Engineering Research Council of Canada, Geophysical Fluid Dynamics Fellowship from the Woods Hole Oceanographic Institution, and Outstanding Preliminary Examination Award and Jonathan Laitone Memorial Scholarship from the Department of Mechanical Engineering of UC Berkeley.