Turbulence from an observer perspective

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MAE Seminar Series

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Direct numerical simulations of turbulence provide non-intrusive access to any flow quantity of interest, at all the resolved scales of motion. However, simulations often invoke idealizations that compromise realism, e.g. truncated domains and modeled boundary conditions. Experiments, on the other hand, are free of such idealizations and probe the true flow, although they must contend with limited spatio-temporal sensor resolution and the challenge of interpreting indirect measurements. By assimilating turbulence measurements, no matter how scarce, in simulations, we can leverage the advantages of both experiments and simulations, and mitigate their respective deficiencies. The measurements-infused simulations achieve a high level of fidelity by tracking the evolution of the true flow state, and provide direct access to any flow quantity of interest at higher resolution than the original sensor data. In this context, measurements are no longer mere records of instantaneous, local flow quantities, but rather an encoding of the antecedent flow events that we decode using the governing equations. Turbulence chaos plays a central role in obfuscating the interpretation of the data. Measurements that are infinitesimally close may be due to entirely different earlier conditions—a dual to the famous butterfly effect. We will examine several data-assimilation problems in wall turbulence and establish the minimum resolution of measurements for which we can accurately reconstruct all the missing flow scales. We will highlight the roles of the Taylor microscale and the Lyapunov timescale, and discuss the fundamental difficulties of predicting turbulence from limited observations.

Tamer Zaki **is a professor and the Director of Graduate Studies in the Department of Mechanical Engineering at Johns Hopkins University (JHU). He received his Ph.D. (2005) in Flow Physics and Computational Engineering from Stanford University. In 2006 he joined Imperial College London as an Assistant and subsequently Associate Professor of Mechanical Engineering, and has been a faculty member at Johns Hopkins since 2013. Zaki's research applies high-fidelity simulations to predict transitional and turbulent shear flows, in both Newtonian and complex fluids. He has developed state-of-the-art data assimilation techniques for the interpretation of scarce measurements, and for the optimization of sensor placement in uncertain environments. Zaki is a recipient of the Office of Naval Research Young Investigator Award and the William H. Huggins Excellence in Teaching Award. He is a member of the JHU Center for Environmental & Applied Fluid Mechanics, the Institute for Data Intensive Engineering & Science, and the Hopkins Extreme Materials Institute. Zaki is a fellow of the American Physical Society, serves on the Editorial Advisory Board of** ***Flow, Turbulence and Combustion*****, and is an Associate Editor of the** ***Journal of Fluid Mechanics*****.**

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