College of Engineering
Department of
Mechanical & Industrial Engineering

The Robert W. Courter Seminar Series

2:30-3:30 pm, Friday, March 22 2019
1263 Patrick F Taylor Hall

Turbulence and Reduced Models for Large Wind Farms

by Charles Meneveau*

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In this presentation we discuss several properties of the flow structure and turbulence in the wind turbine array boundary layer (WTABL). This particular type of shear flow develops when the atmospheric boundary layer interacts with an array of large wind turbines. Based on such understanding, we aim to develop reduced order, analytically tractable models. These are important engineering tools for wind energy, both for design and control purposes. After reviewing some basic tools to predict mean velocities for total power optimization, we will focus on two fluid mechanical themes relevant to wind farm control and inherent variability. We describe a simple (deterministic) dynamic wake model, its use for wind farm control, and its extensions to the case of yawed wind turbines based on a re-interpretation of lifting line theory adapted to the problem of yawed actuator disks. The second part deals with spectral characteristics of the fluctuations in power generated by an array of wind turbines in a wind farm. We show that modeling of the spatio-temporal structure of canonical turbulent boundary layers coupled with variants of the Kraichnan's random sweeping hypothesis can be used to develop analytical predictions of the frequency spectrum of power fluctuations of wind farms. The work to be presented arose from collaborations with Juliaan Bossuyt, Johan Meyers, Richard Stevens, Tony Martinez, Michael Wilczek, Carl Shapiro and Dennice Gayme. We are grateful for National Science Foundation financial support.

* Charles Meneveau is the Louis M. Sardella Professor in the Department of Mechanical Engineering, is Associate Director of the Institute for Data Intensive Engineering and Science (IDIES) and is jointly appointed as Professor in the Department of Physics and Astronomy at Johns Hopkins. He received his B.S. degree in Mechanical Engineering from the Universidad Técnica Federico Santa María in Valparaíso, Chile, in 1985 and M.S, M.Phil. and Ph.D. degrees from Yale University in 1987, 1988 and 1989, respectively. During 1989/90 he was a postdoctoral fellow at the Center for Turbulence Research at Stanford. He has been on the Johns Hopkins faculty since 1990. His area of research is focused on understanding and modeling hydrodynamic turbulence, and complexity in fluid mechanics in general. The insights that have emerged from Professor Meneveau's work have led to new numerical models for Large Eddy Simulations (LES) and applications in engineering and environmental flows, including wind farms. He also focuses on developing methods to share the very large data sets that arise in computational fluid dynamics. He is Deputy Editor of the Journal of Fluid Mechanics and has served as the Editor-in-Chief of the Journal of Turbulence. Professor Meneveau is a member of the US National Academy of Engineering, a foreign corresponding member of the Chilean Academy of Sciences, a Fellow of APS, ASME, AMS and recipient of the Stanley Corrsin Award from the APS, the JHU Alumni Association's Excellence in Teaching Award, and the APS' François N. Frenkiel Award for Fluid Mechanics.