Similar to other renewable energy sources, wind energy is characterized by low power density. Hence, in order for wind energy to make a significant contribution to our overall energy supply, large wind farms (on or off-shore) need to be envisioned. As it turns out, not much is known about the interactions between large wind farms and the atmospheric boundary layer. A case in point, as wind farms are getting larger, operators have begun to complain about the so-called "wind-farm underperformance" problem. This presentation will summarize our results that focus on understanding how wind turbines, when deployed in large arrays, extract kinetic energy from the atmospheric boundary layer. Large Eddy Simulations (LES) are used to improve our understanding of the vertical transport of momentum and kinetic energy across a boundary layer flow with wind turbines. A suite of LES, in which wind turbines are modeled using the classical `actuator
disk' concept, are performed for various wind turbine arrangements, turbine loading factors, and surface roughness values. The results are used to develop improved models for effective roughness length scales and to obtain new optimal spacing distances among wind turbines in a large wind farm. We introduce the notion of generalized transport tubes as a new tool for flow visualization that is particularly useful to analyze the spatial transport of particular physical quantities (e.g. kinetic energy arriving at a particular wind turbine). Finally, we introduce a new engineering model, the Coupled Wake Boundary Layer model that reconciles wake expansion/superposition models currently used in industry with the vertical structure of the atmospheric boundary layer. This work is a collaboration with colleagues, postdocs and students involved in the WINDINSPIRE project and is supported by the US National Science Foundation.

Biography

Charles Meneveau is the Louis M. Sardella Professor in the Department of Mechanical Engineering at Johns Hopkins University. He serves as deputy director of the Institute for Data Intensive Engineering and Science (IDIES) at Johns Hopkins, as Deputy Editor of the Journal of Fluid Mechanics, and as the Editor-in-Chief of the Journal of Turbulence. He received his B.S. degree in Mechanical Engineering from the Universidad Técnica Federico Santa María in Valparaiso, 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 Stanford University/NASA Ames' Center for Turbulence Research.

Professor Meneveau 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. He combines experimental, computational and theoretical tools for his research. At present, he is interested in fluid dynamics of large wind farms, public databases, and subgrid and wall modeling for Large Eddy Simulations and various applications of LES. With his students and co-workers, he has authored over 200 peer-reviewed articles.

Professor Meneveau is a foreign corresponding member of the Chilean Academy of Sciences, and a Fellow of the American Academy of Mechanics,
the U.S. American Physical Society and the American Society of Mechanical Engineers. He received the inaugural Stanley Corrsin Award from the American Physical Society (2011), the 2011 J. Cole Award from AIAA, the 2004 UCAR Outstanding Publication award (with students and other colleagues at JHU and NCAR), the Johns Hopkins University Alumni Association's Excellence in Teaching Award (2003), and the APS' François N. Frenkiel Award for Fluid Mechanics (2001). In the past, he has served as member of the Editorial Committee of the Annual Reviews of Fluid Mechanics and as an Associate Editor for Physics of Fluids.

Note: if you would like to arrange a discussion with Professor Meneveau after the seminar, please email James Brasseur (brasseur@engr.psu.edu), or make arrangements following the seminar.