



ME Seminar



Advancing Offshore Wind Energy in India Through Fundamental Fluid Dynamics Research

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ABSTRACT

Offshore wind energy presents a key opportunity for India to achieve the United Nations' Sustainable Development Goal of affordable and clean energy. With a national target of installing 30 GW of offshore wind capacity by 2030, realizing this vision requires a deeper understanding of how wind turbines interact with atmospheric boundary layer (ABL) flows and the underlying progressive sea or ocean surface waves. Modeling these multiscale interactions using high-fidelity large-eddy simulations (LES) is computationally prohibitive for practical wind farm design. Reduced-order models, whether physics-based or machine-learning-assisted, offer cost-effective alternatives, but most models remain oversimplified, as they neglect realistic meteorological and oceanic effects such as wind veer (change in wind direction with height), varying atmospheric thermal stability conditions, and air-sea interactions. This talk presents recent advances in developing physics-based and machine-learning-assisted reduced-order models that enable fast yet accurate predictions of offshore wind farm flows. Specifically, I will discuss: (i) a simplified analytical model for ABL mean wind profiles that incorporates wind veer and thermal stratification effects; (ii) the integration of this ABL model with a wind turbine wake model to predict wake-induced power losses across different thermal stability regimes; and (iii) an ordinary-differential-equation-based model for wind-wave interactions that captures wave-induced airflow perturbations and form drag under various wind-over-wave conditions. I will also highlight ongoing efforts toward machine-learning-assisted modeling of wave-induced turbulence stresses. Together, these modeling developments, rooted in fundamental fluid dynamics, lay the foundation for developing a unified, cost-effective predictive modeling framework for capturing coupled wind-wave-wake interactions in offshore wind farms. Such models can support the optimal design and performance of offshore wind farms across diverse atmospheric conditions, thereby helping reduce India's levelized cost of offshore wind energy.

ABOUT THE SPEAKER

Dr. Ghanesh Narasimhan is a Postdoctoral Associate in the Department of Mechanical Engineering and St. Anthony Falls Laboratory at the University of Minnesota. He earned his Ph.D. and master's (by coursework) degrees in Mechanical Engineering from Johns Hopkins University, a master's (by research) degree in Earth Sciences from the Centre for Earth Sciences, Indian Institute of Science (IISc), and a bachelor's degree in Mechanical Engineering from the National Institute of Technology, Tiruchirappalli. Dr. Narasimhan's research focuses on modeling turbulent flows in geophysical and engineering contexts by integrating theoretical, numerical, machine learning, and experimental approaches. His postdoctoral research involves large-eddy simulations (LES) of wind-over-wave flows and the development of theoretical and machine-learning-assisted models for quantifying wind-wave interactions. His doctoral work focused on LES and theoretical modeling of atmospheric boundary layer (ABL) flows and wind turbine wakes, as well as machine-learning-accelerated LES of transitional channel flows. He also contributed to the development of wind farm flow datasets publicly available through the Johns Hopkins Turbulence Database (JHTDB). At IISc, his master's research investigated the damping characteristics of small-scale magnetohydrodynamic (MHD) waves inside Earth's outer core. He also led the design and construction of a rotating cylindrical annulus experimental setup to simulate convective flows under rapid rotation, representing fluid dynamics within Earth's outer core. Dr. Narasimhan's broader research vision is to address key challenges in fluid dynamics and contribute to advancing India's offshore wind energy and environmental flow modeling capabilities in support of the United Nations' sustainable development goals.



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