University of Colorado at Boulder

AEROSPACE ENGINEERING SCIENCES

Seminar

James G. Brasseur

Professor of Mechanical Engineering,
Biomedical Engineering and Mathematics

Pennsylvania State University

Atmospheric Dynamics and Wind Turbine Response from High Performance Computing

Atmospheric energy-containing turbulent eddies pass through wind turbine rotors at the rotor scale. As they do so, they stimulate temporal and spatial variations in blade surface stress distribution as the blade boundary layers respond to large modulations in velocity magnitude and direction. Consequences include large temporal variations in blade and shaft torque and bending moments with consequent reductions in the efficiency of power extraction and increase in fatigue failures of blades and bearings. My seminar will describe two interrelated programs of research surrounding the above issues.

I will begin with a description of the core Penn State "Cyber Wind Facility (CWF)," a blade-boundary-layer-resolved HPC computational environment designed to capture the dynamic responses of blade boundary layers to the passage of the energy-dominant daytime atmospheric eddies that drive component failures. This multi-year multi-researcher effort has led to current cyber experiments in which a rotating utility-scale wind turbine blade responds to a typical moderately convective daytime atmospheric boundary layer (ABL) "low speed streak" with strong thermal updraft. These simulations show two time scale dynamics underlying >30% temporal variability in blade torque, one associated with the passage of the blade through blade-scale eddy structure and modulation at the eddy passage time scale.

The details of temporal variability in local and integrated blade loadings are directly correlated with the structure of the turbulent eddies embedded within the ABL. These in turn are directly correlated with the stability state of the ABL which itself is driven by mesoscale winds in the free troposphere and surface heat flux, driven during the day by radiant heating of the ground. The second half of my presentation will briefly summarize research programs into the relationship between atmospheric turbulence structure, atmospheric stability, and mesoscale forcing using large-eddy simulation of the atmospheric boundary layer. We find surprising characteristics, two of which will be highlighted: extremely small levels of surface heating can create dramatic changes ABL turbulence structure from the neutral fully shear-driven stability state to a highly coherent state of streamwise rolls, and the transition to convective rolls can be induced without changes in surface heating, by nonequilibrium changes in wind direction at the mesoscale.

Monday, November 10, 2014
3:00 – 4:00 pm
DLC Bechtel Collaboratory

James (Jim) Brasseur is Professor of Mechanical Engineering, Bioengineering and Mathematics at the Pennsylvania State University. He did his graduate work in fundamental fluid dynamics at Stanford University followed by postdoctoral appointments at NASA-Ames Research Center (CFD), the University of Southampton England (aerodynamics), and The Johns Hopkins University (turbulence and biomechanics). He has been at Penn State since 1989. Jim has developed two research tracts (i) fundamental studies of turbulence physics, direct and large-eddy simulation, atmospheric boundary layer dynamics and micro-meteorology, and wind turbine dynamics; and (ii) physiology, mechanics and medicine of the gastrointestinal tract and related pharmaceutical issues in drug delivery. Jim is recent inaugural Chair of the APS Topical Group on the Physics of Climate (GPC) and is on the scientific board of the World Organization for Specialized Studies on Diseases of the Esophagus (OESO). Jim recently completed sabbaticals at the National Center for Atmospheric Research (NCAR) and the NREL National Wind Technology Center (NWTC), where he has strong collaborations. Currently, Jim leads a research team developing a HPC "Cyber Wind Facility" for wind turbine research and is part of an international effort to improve prediction of drug dissolution in vivo vs. in vitro. Jim is Fellow of the American Physical Society and was elected to the Johns Hopkins University Society of Scholars.