Texas Tech University
Friday, 4 April 2014

Transition in Atmospheric Boundary Layer Turbulence Structure from the Neutral to Convective Stability States in Relationship to Wind Turbine Response

James G. Brasseur
Professor of Mechanical Engineering, Biomedical Engineering and Mathematics
Department of Mechanical Engineering
Pennsylvania State University
brasseur@psu.edu

Atmospheric turbulence eddies that pass through wind turbine rotor disks force asymmetric time variations in blade loadings associated with changes in fluctuating wind vector orientation and magnitude. The scales, strengths and vectorial wind structure of atmospheric boundary layer (ABL) turbulence that affect wind turbine performance are strongly dependent on the relative contributions of buoyancy-driven vertical motions from surface heating and shear driven motions from geostrophic winds at the mesoscale, as characterized by the global stability state parameter $–z_i/L$. In the shear-dominant neutral limit, the ABL is characterized by streamwise-elongated coherent eddies of negative fluctuating horizontal velocity As surface heat flux is increased, buoyancy drives vertical fluctuations strongly correlated with shear-driven motions that eventually organize to generate streamwise rolls that couple upper with lower boundary layer. We use large-eddy simulation (LES) to study this transition between "near neutral" and "moderately convective" by quantifying correlations and integral scales as a function of $-z_i/L$. The interactions between outer and the surface layer eddies generate surprising turbulence dynamics that includes a special transitional stability state with unusually enhanced streamwise coherence. The transitional process includes a critical phenomenon with sudden dramatic change in ABL structure, and high sensitivity in horizontal fluctuations to surface heating at a low $–z_i/L$.

Biographical Sketch

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 pursues two research tracts (i) the study of turbulence physics, direct and large-eddy simulation, atmospheric boundary layer dynamics and wind turbines, and (ii) physiology, mechanics and medicine of the gastrointestinal tract and related pharmaceutical issues in drug delivery. Jim is recent Chair of the APS Topical Group on the Physics of Climate (GPC). 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*.