Weekly CEAFM Seminar: Fall 2015

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Date: **Friday, October 2, 2015**

Time: 11:00 AM

Location: Gilman Hall # 132

Speaker: **Prof. William Anderson** (University of Texas at Dallas)

Title: ***"Large-Eddy Simulation of Rough Wall Turbulence: Effects of Complex Topography, Evidence of Inner-Outer Effects, and the Role of Turbulence in Aeolian Systems"***

Abstract

High Reynolds number rough wall turbulent flows are ubiquitous in engineering and geophysical flows. Turbulent momentum transport influences the aero-/hydro-dynamic signature of bluff bodies and the performance of vapor power systems; in geophysical flows, turbulent mixing impacts urban dispersion, the hydrologic cycle, and sedimentary processes in fluvial/aeolian systems. Recently, it has been shown that spanwise topographic heterogeneity can induce a mean domain-scale (δ) circulation. We demonstrate that these circulations are Prandtl's Secondary Flow of the Second Kind: sustained and driven by spanwise-wall-normal heterogeneity in the Reynolds stresses (all of which vanish in the absence of spanwise topographic heterogeneity). These findings are supported by large-eddy simulation (channel flow: Anderson et al., 2015: J. Fluid Mech.) and experimental measurement (boundary layer: Barros and Christensen, 2014: J. Fluid Mech.) Mejia-Alvarez and Christensen, 2013: Phys. Fluids termed the resulting heterogeneity in spanwise-wall-normal streamwise velocity low-and high-momentum pathways (in order to draw distinction against low- and high-momentum regions – LMR, HMR – which are a spatially meandering, transient feature of wall turbulence). This work has prompted closer inspection on how mean secondary flows alter the structural attributes of LMRs and HMRs. Results have demonstrated that the inclination angle of coherent structures is steepened within high-momentum pathways (i.e., the hairpin packet paradigm is preserved, but altered, due to turbulent secondary flows). We have also investigated how spanwise spacing, s, between topographic heterogeneities influences turbulent secondary flows, finding that $s/\delta > 2$ is a necessary condition for formation of δ-scale mean circulations (i.e., δ-scale circulations can be attenuated by interaction with adjacent circulations). In other work, we have explored the presence of an "amplitude modulation" effect of the roughness sublayer by inertial layer LMRs and HMRs; we have shown that periods of momentum excess (deficit) in the inertial layer precede periods of elevated (depressed) streamwise—wall-normal Reynolds shearing stress in the roughness sublayer. This work is inspired by Marusic et al., 2010: Science, who showed that LMRs and HMRs in the logarithmic region of smooth wall turbulent boundary layers exhibit an amplitude modulation of the viscous wall region. A decoupling procedure presented by Mathis et al., 2009: J. Fluid Mech. is used to illustrate that an amplitude modulation effect is indeed present for rough wall flows. Finally, we present results from LES of neutrally stratified atmospheric boundary layer flow over a sparsely vegetated, arid landscape. On such landscapes, aeolian erosion is induced (and sustained) by kinetic energy fluxes in the aloft surface layer. Conceptual models typically indicate that sediment flux, q (via saltation or drift), scales with imposed aerodynamic stress raised to some exponent, n, where $n > 1$. Since aerodynamic stress (in fully rough, inertia-dominated flows) scales with incoming velocity squared, u2, it follows that q ~ u2n (where u is some relevant component of the flow, u(x,t)). Thus, even small (turbulent) deviations of u from its time-averaged value may play an enormously important role in aeolian activity. In order to illustrate the importance of surface stress intermittency, we have used conditional averaging predicated on aerodynamic surface stress during LES (where threshold selection is guided by probability density functions of local surface stress). This averaging procedure provides an ensemble-mean visualization of flow structures responsible for erosion "events". Preliminary evidence indicates that surface stress peaks are associated with the passage of inclined, high-momentum regions flanked by adjacent low-momentum regions.