CENTER FOR THERMO-FLUID MECHANICS

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Large-eddy simulation of environmental turbulence: Langmuir cells in the ocean and aeolian morphodynamics on Mars

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ABSTRACT

The coastal zone represents a spatial nexus for dramatic turbulent mixing in the atmosphere and the ocean. From ocean sequestration of anthropogenic carbon and heat from coastal populations, to transport of agricultural nitrogen affecting biodiversity in aquatic systems, to aeolian morphodynamics sustained by fluxes of momentum from the atmospheric surface layer. In this seminar, three topics of ongoing research within my group will be presented, all of which have direct implications for the coastal zone. First: results from large-eddy simulation of coastal zone Langmuir turbulence are shown. This is accomplished with numerical integration of the grid-filtered Craik-Leibovich equations, wherein the forcing required to sustain the counter-rotating Langmuir cells is prescribed via the curl of vorticity and Stokes drift – an idealized velocity profile representing the aggregate motion due to waves. In contrast to the open ocean, where the mechanism sustaining Langmuir cells eventually vanishes, it is found that the presence of bottom-boundary layer shear results in distinctly different turbulence morphology. The scale of Langmuir cells does not remain constant, and instead cells associated with downwelling occupy the entire column; it is shown that this ostensible "cell thickening" is a product of mechanical shear on the seafloor. This result has implications for benthic zone sequestration of surface quantities, and for sediment erosion and suspension in coastal zones. Second: results from a collaborative experimental and numerical study of turbulent flow over barchan sand dunes are shown. The dunes are arranged such that a relatively small, upflow dune approaches a relatively large, downflow dune from a spanwise offset position, thereby guaranteeing interaction since the smaller dune migrates faster. Using various diagnostic techniques – conditional sampling, wavelet decomposition, Reynolds-averaged vorticity dyamics, and differential helicity – we have been able to elucidate flow processes responsible for the elegant spatial patterns exhibited by the dunes as interaction proceeds. We find, in particular, that the large dune is scoured by a persistent roller in the space between the adjacent dunes, indicating that "interaction" begins long before the dunes experience physical contact. Finally, results of a theoretical effort to define, a priori, the Reynolds-averaged flow above a lower boundary with spanwise-heterogeneous roughness, is presented. Such flows are known to exhibit mean flow heterogeneities far different a canonical rough wall flow, with secondary roll cells that are sustained by spatial heterogeneity in the turbulent stresses. We demonstrate that mean streamwise velocity can be predicted a priori via similarity solution of the mean streamwise vorticity transport equation. A vortex forcing term – inspired by techniques already used to model Langmuir turbulence in the ocean – was used to represent the affects of spanwise topographic heterogeneity within the flow. Efficacy of the vortex forcing term was established with large-eddy simulation cases, wherein vortex forcing model parameters were altered to capture different surface conditions.

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BIO:

William Anderson is the Eugene McDermott Professor and Associate Professor of Mechanical Engineering at the University of Texas at Dallas. He received his doctoral degree in Mechanical Engineering from The Johns Hopkins University in 2011. His research interests are primarily numerical simulation of small-scale geophysical turbulence, and fundamental processes in rough-wall turbulence. He is a 2014 recipient of the Air Force Office of Scientific Research Young Investigator Program award. His work has been supported by the Army Research Office, National Science Foundation, Air Force Office of Scientific Research, and Texas General Land Office.