Friday, April 21 • 11:00 am – UTEB., rm 476

Numerical simulation of stratified turbulence

Georgios Matheou, Ph.D.
Jet Propulsion Laboratory, California Institute of Technology

Abstract: Stratified turbulent flows are prominent in many engineering and geophysical applications. Using direct numerical simulation (DNS), stationary and homogeneous shear driven turbulence is studied in various stratifications. Based on the analysis of the DNS, a large-eddy simulation (LES) subgrid-scale (SGS) model is developed. To attain and maintain a stationary flow in the DNS, the mean shear is throttled such that the net production remains constant for all times. This results in a flow that is characterized solely by its mean shear and its mean buoyancy gradient, independent of initial conditions. A direct acknowledgement of the confining influence of the periodic simulation domain leads to a meaningful physical interpretation of the large scales. Once an appropriate confinement scale is identified, many features of stratified sheared turbulence can be readily understood in terms of the Monin–Obukhov similarity theory. Utilizing elements of the similarity theory, a buoyancy-adjusted extension of the stretched-vortex SGS model is developed. The stability correction accounts for the increasing anisotropy of turbulence as stratification increases. Moreover, the model does not include any flow adjustable parameters. A series of LESs of diverse atmospheric boundary layers is carried out to validate the model extension to stratified flows and assess its performance. The effects of LES model error are studied in simulations of a stratocumulus cloud deck. The representation of stratocumulus clouds is the largest source of uncertainty in climate models and LES modeling is invaluable in gaining insight into the flow physics. To investigate the effects of model error, simulations are carried out with variable grid resolution and physical processes, e.g., with and without radiation. Two main sources of model error are identified: (a) under-prediction of the amount of cloud liquid because of small (< 5%) errors in temperature and humidity in the cloud layer, and (b) a feedback between cloud-top radiative cooling and vertical turbulent fluxes. The sharp inversion at the boundary layer top does not lead to degradation of model performance, with the exception of cloud liquid. Even though cloud-top radiative cooling is not a significant factor in driving the turbulence in the boundary layer, it leads to difficulties in the accurate prediction of the turbulent fluxes.

Biography: Georgios Matheou has been a Research Scientist at the Jet Propulsion Laboratory since 2010. He is also a Visiting Associate in Aerospace at the California Institute of Technology and a Visiting Assistant Researcher at the Joint Institute for Regional Earth System Science and Engineering (JIFREESE) of the University of California, Los Angeles (UCLA). Matheou received his Diploma in Mechanical Engineering (2002) from the National Technical University of Athens and Ph.D. in Aeronautics from Caltech (2008). Matheou's research interests include fluid dynamics and turbulence, modeling of multi-scale multi-physics flows, numerical methods, and high performance computing. His current research centers on a multi-scale approach for the understanding and prediction of the Earth's atmosphere where a Russian Doll approach is applied using different modeling techniques to capture interactions ranging from the global/planetary scale to the smallest turbulent motions. Matheou received the American Physical Society's Milton Van Dyke Award in 2011 and Galley of Fluid Motion Award in 2016, and NASA's Early Career Public Achievement Medal in 2016.

For additional information, please contact Prof Ugur Pasaogullari or
Elizabeth Dracobly at (860) 486-4001