Boulder Fluid and Thermal Sciences Seminar Series

Thursday, May 2, 2019
9:00am-10:00am (refreshments at 8:45am)
Clark Conference Room ECAD 109 in the Engineering Center
University of Colorado, Boulder

High Resolution Numerical Simulations of Buoyancy-Driven Flows

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Buoyancy-driven flows are commonly found in both nature and engineering, including volcanic plumes, underwater hydrothermal vents, and industrial burners. The study of these flows using computational simulations is, however, made challenging by the large separation of physical scales inherent in these flows, and also by the presence of additional complex phenomena such as combustion. In this thesis, we outline advances in computational modeling of buoyancy-driven flows, as well as describe physical insights obtained from the simulations. First, we discuss the complexities involved in the simulation of these flows, including the challenges imposed by large scale separations and the need to assign physically accurate boundary conditions. After presenting preliminary two-dimensional simulations, we discuss an alternative formulation of the equations of motion involving a low-Mach number approximation. This, along with the use of a fully adaptive grid, allows for high fidelity computations that bridge the large-scale separations found in many real-world buoyancy-driven flows. High resolution simulations of a one-meter diameter helium plume are performed with an emphasis on the physical resolution required to accurately predict dynamics and statistics up to second-order. The highest resolution simulation is then analyzed in an attempt to improve sub-grid scale models for large eddy simulations. Finally, the fundamental puffing instability present in buoyant jets is examined through a series of simulations for a variety of inlet geometries over a range of operating conditions. We present a new, universal scaling law that is able to predict the dominant frequency of pulsation for an arbitrarily shaped buoyant jet. The new scaling law collapses data from the present simulations as well as all available experimental data from three decades of research. Ultimately, the work contained in this thesis represents a substantial step forward in our ability to computationally model and understand buoyancy-driven flows.

Biography: Nick graduated from Dartmouth College's Thayer School of Engineering in 2013 with a B.A. in Engineering Physics (minor in Art History) and a B.E. in Mechanical Engineering. Joining the TESLa team in 2013, Nick enjoyed a year and a half internship at the National Renewable Energy Laboratory in Boulder studying the effects of offshore wind turbines on ocean waves as well as vertical axis wind turbine aerodynamics and performance. Currently he works on turbulent reacting flow problems via LES simulation during the day and dreams of fire tornados at night.