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Autonomic Closure for Large Eddy Simulation of Turbulent Flows and Transport Processes

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February 06 | 11 AM | CSF Darwin 1007

Turbulent flows and the transport of mass, momentum, energy, and scalars within them are central to an enormous range of key applications in science and engineering, including most natural and built engineering processes, devices, and systems. All turbulent transport problems involve wide ranges of time and length scales, which place a tremendous computational burden on direct simulations. Large eddy simulations coarse-grain the governing equations to remove intermediate and small scales, but this creates subgrid-scale terms that must be modeled to achieve a closed set of equations. However, to date, turbulence research has not provided any universal approach for modeling subgrid terms that can reliably provide a level of fidelity approaching that of direct simulation in the resolved scales.

Professor Dahm will present a new and entirely different approach[1] that completely circumvents the need for traditional model-based closure. In “autonomic closure,” subgrid terms are formulated in the resolved primitive variables of the simulation, and a high-dimensional nonlinear nonparametric system identification problem is solved at a test scale for each point and time in the simulation to find the optimal local relation between the subgrid term and the primitive variables. Autonomic closure freely adapts to the varying nonlinear, nonlocal, non-equilibrium, and other characteristics of the turbulence state throughout the simulation. Results from this new approach show exceedingly accurate representations of the detailed space- and time-varying fields for momentum and energy exchange between resolved and subgrid scales. However, the computational cost of this closure methodology exceed than that of traditional prescribed closure models. Professor Dahm also will show there are highly efficient implementations of autonomic closure that retain essentially all of the new approach’s accuracy but at computational costs that are many orders of magnitude smaller. These are efficient enough to make autonomic closure practical for use in large eddy simulations.

[1] *Phys. Rev. E* 93, 031301(R) 2016.

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