Title: Large Eddy Simulation Reduced Order Models

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Abstract: Large eddy simulation (LES) is one of the most popular methods for the numerical simulation of turbulent flows. In this talk, we survey our group's efforts over the last decade to develop a large eddy simulation reduced order modeling (LES-ROM) framework for the numerical simulation of turbulent flows.

First, we define ROM spatial filters (e.g., the ROM projection and the ROM differential filter) that allow the definition of the large spatial scales that can be approximated by ROMs in under-resolved numerical simulations (i.e., when the number of ROM modes is not large enough to represent the complex flow dynamics). Then, we describe the ROM closure problem (i.e., modeling the interaction between the large, resolved scales and the small, unresolved scales), which represents one of the main obstacles in the development of ROMs for realistic, turbulent flows. To solve the ROM closure problem, we construct three types of ROM closures: (i) functional ROM closures, which are developed by using physical arguments; (ii) structural ROM closures, which are based on mathematical arguments; and (iii) data-driven ROM closures, which are constructed by using data-driven modeling. We present results for these LES-ROMs in the numerical simulation of under-resolved engineering flows (e.g., flow past a cylinder and turbulent channel flow) and the quasi-geostrophic equations (which model the large scale ocean circulation). Finally, we present numerical analysis results for these LES-ROMs, e.g., stability, convergence, and verifiability.