“Spectral multidomain penalty methods for the simulation of highly nonlinear and non-hydrostatic environmental flows: Progress and challenges”

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Internal gravity waves and localized turbulence are environmental stratified flow phenomena whose computational modeling is faced with significant challenges on account of the strongly nonlinear and non-hydrostatic nature of such phenomena. A promising tool in addressing such challenges are high-order element-based discretization techniques, on account of their high accuracy, spatial adaptivity and weak artificial dissipation and dispersion. Spectral multidomain penalty methods are a variant of these techniques that preserve numerical stability in an under-resolved simulation, an inevitable reality in the study of strongly nonlinear environmental flows, without sacrificing any of the above advantages.

This talk will outline the fundamental components of spectral quadrilateral subdomain method recently developed for the incompressible Navier-Stokes equations. Particular emphasis will be placed on the challenges encountered in the numerical solution of the Poisson-Neumann problem that arises when non-hydrostatic dynamics are of interest. We will discuss strategies for preserving solvability and guaranteeing uniqueness in the iterative solution of the discretized pressure Poisson equation. These strategies rely heavily on a fast computation of the null singular vector of the Poisson matrix. Progress and challenges in the development of efficient preconditioners will also be discussed. We will conclude by showing results for select benchmark cases and summarizing avenues of future study.